Long Term Pavement Performance Project Laboratory Materials Testing and Handling Guide

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Research, Development, and Technology
Turner-Fairbank Highway Research Center
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LTPP

FOREWORD

The Long Term Pavement Performance (LTPP) program is an ongoing and active program. To obtain current information and access to other technical references, LTPP data users should visit the LTPP Web site at http://www.fhwa.dot.gov/pavement/ltpp. LTPP data requests, technical questions, and data user feedback can be submitted to LTPP customer service via e-mail at ltppinfo@fhwa.dot.gov.

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Technical Report Documentation Page

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16. Abstract

The Long Term Pavement Performance (LTPP) Laboratory Material Testing Guide was originally prepared for laboratory material handling and testing of material specimens and samples of asphalt materials, portland cement concrete, aggregates, and soils under the supervision of the Strategic Highway Research Program. This version of the Guide has been updated to provide a historical reference document for analysts of the LTPP data. It provides the basis for the quality control program used in performing the laboratory testing, the protocols used in testing the material samples, and the guidelines for handling these samples in the laboratory. Additionally, this document provides the guidelines used for identifying the pavement structure based on the material properties of the sampled layers.

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Asphalt cement, asphalt concrete, field sampling, General Pavement Studies, laboratory testing, LTPP, material properties, pavement layering, Pavement Performance Data Base, portland cement concrete, protocol, Specific Pavement Studies, subbase, subgrade, treated base, unbound base	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

AAP	AASHTO Accreditation Program
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ASTM	American Society for Testing and Materials
BBR	bending beam rheometer
COTR	Contracting Officer's Technical Representative
CTB	cement treated base
CTR	coefficient of thermal expansion
DCP	dynamic cone penetrometer
DOT	department of transportation
DSR	dynamic shear rheometer
FHWA	Federal Highway Administration
FWD	Falling Weight Deflectometer
GPS	General Pavement Studies
HCL	hydrochloric acid
HMA	hot mix asphalt
HMAC	hot mix asphalt concrete
ISSA	International Slurry Surfacing Association
L/D	length to diameter ratio
LCB	lean concrete base
LL	liquid limit
LTPP	Long Term Pavement Performance
LVDT	linear voltage displacement transducer
MAP	Materials Action Plan
MRL	Materials Reference Library
NAA	National Aggregate Association
NIST	National Institute of Standards and Technology
PAV	pressure aging vessel
PCC	portland cement concrete
PI	plasticity index
PL	plastic limit
PPDB	Pavement Performance Data Base
PVR	potential vertical rise
QA	quality assurance
QC	quality control
RTFO	rolling thin film oven
SHRP	Strategic Highway Research Program
SPS	Specific Pavement Studies
SSD	Saturated Surface Dry

CHAPTER 1. INTRODUCTION

1.1 HISTORY OF LTPP LABORATORY TESTING

The Long Term Pavement Performance (LTPP) program was a twenty-year study begun in the late 1980s to evaluate pavement performance and the factors that affect it. LTPP's goal was to provide the data necessary to explain how pavements perform and why they perform as they do. To meet this goal, nearly 2,500 pavement test sections were established on in-service highways throughout North America and hence subjected to real traffic loads and a wide range of environmental conditions. At each test section, general inventory, pavement performance monitoring, materials, traffic, climatic, and maintenance and rehabilitation data were collected.

A critical element to the successful accomplishment of the LTPP goal was the collection of accurate and reliable materials data. These data were needed to define the properties of each of the structural pavement layers of the test sections within the program.

Originally, the LTPP materials testing program under the direction of the Strategic Highway Research Program (SHRP) was conducted by one of five laboratory contractors as indicated by Figure 1.1. Testing of all portland cement concrete (PCC) materials was performed by one central contractor under the direct supervision of SHRP. Testing of the asphalt and unbound materials was performed by one of four laboratories under the management of the Regional Engineer assigned by SHRP to each of the four regions. The Regional Engineer was assisted in the contract management by the Regional contractor. The field sampling and laboratory testing for the General Pavement Studies (GPS) test sections was conducted under the contracts identified in Figure 1.1 with the exception of the resilient modulus testing and testing of overlays placed after these contracts ended. At the end of the SHRP oversight of the LTPP program, a five-year report was prepared which provides a complete review of the field sampling and laboratory testing activities performed under SHRP.(1)

The field sampling efforts were performed in accordance with the *SHRP-LTPP Guide for Field Materials Sampling, Testing, and Handling*, Operational Guide No. SHRP-LTPP-OG-006.(2) Each GPS experiment had a sampling plan specific to that experiment. The Field Guide provided each of these individual sampling plans. It also covered the requirements associated with sample naming, labeling, identification, and shipping.

The Specific Pavement Studies (SPS) projects differed from the GPS test sections in that each SPS project incorporated several test sections at a location. Field sampling and laboratory testing plans were developed for each specific SPS project. These sampling and testing plans were based on the general set of sampling and testing plans developed for each SPS experiment and as identified in the experiment specific guidelines. (See references 3–9.) Only the latest version of each of these documents was identified in the reference list. Revisions were made to most of these documents at some point during their use and can be found using the LTPP Guidelines for Data Collection.(10)

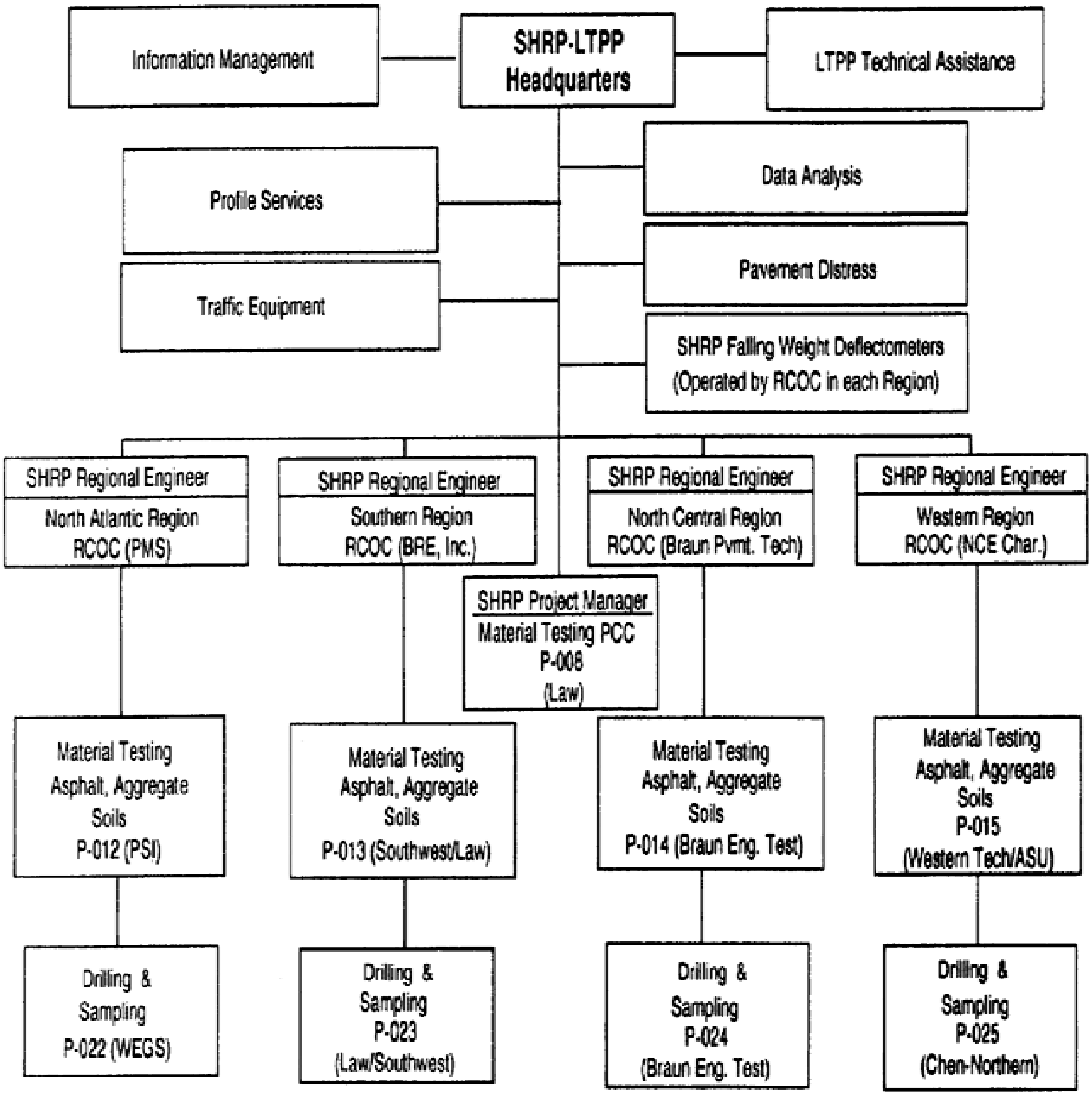


Figure 1.1 Organizational Chart for Laboratory Testing Under Conducted SHRP

Testing for the LTPP program was carried out in accordance with the *SHRP-LTPP Interim Guide for Laboratory Materials Handling and Testing (PCC, Bituminous Materials, Aggregates, and Soils)*, Operational Guide No. SHRP-LTPP-OG-004.[11] The Guide was prepared for the SHRP Laboratory Testing Contractors responsible for laboratory material handling and testing of material specimens and samples of asphalt materials, PCC, aggregates and soils under the supervision of the SHRP Regional Engineers and the SHRP Regional Coordination Office

Contractor staff and SHRP Authorized Representatives. It was first released in November 1989 and served as a contract document providing the required information for sample receipt, testing plans for the GPS experiments, test protocols, sample disposal and invoicing.

Under the Federal Highway Administration (FHWA), testing efforts were consolidated under two contracts. The objective of these two contract laboratories was to perform testing of the SPS projects and complete the resilient modulus testing for the GPS test sections. Additional testing to be performed under these contracts included testing of any overlays constructed on the GPS test sections as time progressed. Due to lack of funding, the testing requirements for these laboratories were reduced to the resilient modulus and supporting tests for the SPS projects and GPS test sections. Because of these funding limitations, the remainder of the testing requirements were taken on by the State departments of transportation (DOTs) constructing the SPS projects and GPS overlays. After approximately one year, one of the FHWA contract laboratories released their contract due to potential conflict of interest with a separate contract held by the same company.

The Laboratory Materials Testing Guide was in a state of constant evolution over the life of the LTPP program and was revised over the years to more fully encompass the needs of the LTPP program. In 1993, updates were made to provide for the SPS project testing and appropriate forms for these projects. Updates were made to various testing procedures to clarify existing procedures. In particular, the protocols for resilient modulus testing for both the asphalt and unbound materials were re-written to provide a more robust means to perform these tests. Revisions to the Guide beginning in 1993 were made by directives from FHWA. The LTPP Customer Support Service Center may be contacted to obtain copies of these directives.

As part of a program assessment conducted in the late 1990s, a review of the available materials data indicated that there were gaps in the available data. An effort was undertaken to fill in these gaps of missing data and improve the overall quality of the available data. As part of this effort, the document *LTPP SPS Materials Data Resolution: Update and Final Action Plan* was developed to fully document the existing gaps and the proposed methods for resolving them.[12] Due to further funding limitations, some of the desired testing originally identified in the Materials Action Plan (MAP) was removed from the plan. The FHWA awarded a laboratory contract to perform the testing identified in the MAP.

The objective of this document is to provide information to analysts regarding the methods used in obtaining research quality laboratory data for the LTPP program.

1.2 DOCUMENT OUTLINE

This version of the laboratory materials testing guide represents a major revision to previous versions of the guide. This version consists of five chapters. The objective of the first chapter is to provide an overview of the history of the guide and the objective of this version. The second chapter provides a summary of the quality control/quality assurance (QC/QA) program used by the LTPP program to assure the quality of the results. Chapter 3 provides the series of forms (L01 to L04) used to alert the FHWA of receipt of data and assign tests to individual samples. Chapter 3 also provides the methods used in splitting samples to obtain the sample used for testing. Chapter 4 provides the protocols, associated forms, and codes used in completion of those forms. Finally, Chapter 5 provides the guidelines for completing the section layering information in the L05 series forms. The last two sections of the document contain a glossary of common terms used throughout the Guide and the references for other relevant LTPP documents.

As the protocols used by the laboratories in performing testing for the LTPP program provide the largest portion of this document, a list of these protocols, test designations, and titles are provided in Table 1.1. Some of the protocols listed in Table 1.1 were developed as new tests to be performed as part of the action plan to provide a more complete set of the materials data in the LTPP Pavement Performance Data Base (PPDB) for the SPS projects. Due to funding issues, these new tests were eliminated from the MAP and no data were collected using these protocols (P27, P28, P29, and P70). Additionally, the protocols beginning with the letter "H" were used for testing materials from the SPS-3 and SPS-4 experiments concerning the effectiveness of maintenance on asphalt concrete pavements and jointed concrete pavements, respectively.

Table 1.1 List of Protocols and QC/QA Checks

Protocol	Designation	Title
P01	AC01	Test Method for Visual Examination and Thickness of Asphaltic Concrete Cores
P02	AC02	Test Method for Bulk Specific Gravity of Asphaltic Concrete
P03	AC03	Test Method for Maximum Specific Gravity of Asphaltic Concrete
P04	AC04	Test Method for Asphalt Content of Asphaltic Concrete
P05	AC05	Test Method for Moisture Susceptibility of Asphaltic Concrete
P07	AC07	Test Method for Determining the Creep Compliance, Resilient Modulus and Strength of Asphalt Materials Using the Indirect Tensile Test Device
P11	AG01	Test Method for Specific Gravity and Absorption of Extracted Coarse Aggregate
P12	AG02	Test Method for Specific Gravity and Absorption of Extracted Fine Aggregate
P14	AG04	Test Method for Gradation of Aggregate Extracted from Asphaltic Concrete
P14A	AG05	Test Method for Fine Aggregate Particle Shape
P21	AE01	Test Method for Recovery of Asphalt from Solution by Abson Method
P22	AE02	Test Method for Penetration of Extracted Asphalt Cement at 77°F (25°C) and 115°F (46°C)
P23	AE03	Test Method for Specific Gravity of Extracted Asphalt Cement
P24#	AE04	Test Method for Viscosity of Asphalt Cement at 77°F (25°C) with Cone and Plate Viscometer
P25	AE05	Test Method for Kinematic and Absolute Viscosity of Extracted Asphalt Cement
P27*	AE07	Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

Protocol	Designation	Title
P28*	AE08	Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
P29*	AE09	Test Method for Determining the Fracture Properties of Asphalt Binder in Direct Tension
P31	TB01	Test Method for Identification and Description of Treated Base and Subbase Materials, and Determination of Type of Treatment
P32	TB02	Test Method for Determination of Compressive Strength of Other than Asphalt Treated Base and Subbase Cores
P41	UG01, UG02	Test Method for Gradation of Unbound Granular Base/Subbase Materials
P42	SS02	Test Method for Hydrometer Analysis of Subgrade Soils
P43	UG04, SS03	Test Method for Determiniation of Atterberg Limits of Unbound Granular Base and Subbase Materials and Subgrade Soils
P44	UG05	Test Method for Moisture-Density Relations of Unbound Granular Base and Subbase Materials
P46	UG07, SS07	Test Method for Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils
P47	UG08	Test Method for Classification and Description of Unbound Granular Base/Subbase Materials
P48	UG09	Test Method for Permeability of Unbound Base and Subbase Materials Under Constant Head Using a Rigid Wall Permeameter
P49	UG10, SS09	Test Method for Determination of Natural Moisture Content
P51	SS01	Test Method for Sieve Analysis of Subgrade Soils
P51A	SS01	Test Method for Dry Sieve Analysis of Subgrade Soils
P52	SS04	Test Method for Classification and Description of Subgrade Soils
P54	SS10	Test Method for Unconfined Compressive Strength of Subgrade Soils
P55	SS05	Test Method for Moisture-Density Relations of Subgrade Soils
P56	SS08	Test Method for Density of Subgrade Soils
P57	SS11	Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
P60	SS12	Test Method for Determining Expansive Soils
P61	PC01	Test Method for Determination of Compressive Strength of PCC Cores/Cylinders
P62	PC02	Test Method for Determination of Splitting Tensile Strength of PCC Cores/Cylinders
P63	PC03	Test Method for Determination of the Coefficient of Thermal Expansion of PCC
P64	PC04	Test Method for Determination of Static Modulus of Elasticity of PCC Cores
P65	PC05	Test Method for Density of PCC
P66	PC06	Test Method for Visual Examination and Thickness of PCC Cores
P67	PC07	Test Method for Determination of the Shear Strength at the Interface of Bonded Layers of Concrete

Protocol	Designation	Title
P68	PC08	Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete Using the Linear Traverse (Rosiwal) Method
P69	PC09	Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
P70*	PC10	Test Method for Petrographic Examination of Hardened Concrete
P71	UG13, SS13	Test Method for Specific Gravity of Unbound Materials
P72	UG14, SS14	Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications
H01L^{+}	AC08	Preparation of Asphalt Cores for Aging Tests
H02L^{+}	AE01S	Recovery of Asphalt from Solution by Abson Method
H03L^{+}	AE02S	Penetration of Bituminous Materials
H04L^{+}	AE06S	Viscosity of Asphalts
H05L^{+}	SC01	Standard Methods of Testing Emulsified Asphalts
H06L^{+}	SC02	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
H07L^{+}	SC03	Testing Crushed Stone, Crushed Slag, and Gravel for Single or Mulstiple Bituminous Surface Treatments
H08L^{+}	SC04	Determination of Flakiness Index of Aggregates
H09L^{+}	SC05	Design, Testing, and Construction of Slurry Seal
H10L^{+}	SC06	Test Method for Measurement of Excess Asphalt in Bituminous Mixtures by Use of a Loaded Wheel Tester and Sand Cohesion
H11L^{+}	SC07	Wet Stripping for Cured Slurry Seal Mixes
H12L^{+}	SC08	Determination of Slurry System Compatibility
H13L^{+}	SC09	Mixing, Setting, and Water Resistance Test to Identify "Quick Set" Emulsified Asphalts
H14L^{+}	SC10	Sieve Analysis of Seal Coat Aggregates
H15L^{+}	SC11	Chip Seal Mix Design
H16L^{+}	CS01	Joint Sealants, Hot-Poured, for Cement and Asphalt Pavements
H17L^{+}	CS02	Joint Sealants, Silicone
H18L^{+}	US01	Compressive Strength of Hydraulic Cement Mortar
H19L^{+}	SC12	Determination of Asphalt Content from Slurry Seal Sample
H20L^{+}	SC13	Accelerated Polishing of Aggregate Using the British Wheel

Notes: # Testing using protocol P24 was cancelled effective December 1997.
* No testing was performed for the LTPP program using this protocol.
+ These tests were used for testing samples from the SPS-3 and SPS-4 projects exclusively.

CHAPTER 2. QUALITY CONTROL/QUALITY ASSURANCE PROCEDURES

2.1 INTRODUCTION

QC of the laboratory test data was divided into four basic sets of procedures. These steps included the following:

- Laboratory QC program to ensure that the laboratory was following a set of prescribed QC guidelines during testing
- Laboratory start-up to ensure that the laboratory was set up for the type of testing to be completed
- Review of the data by an independent party upon completion of testing
- Review of data after entry into the LTPP PPDB using a set of automated checks that evaluated the reasonableness of the data and the consistency of the data with data in other tables in the database.

These QC/QA procedures required input from all parties involved in the LTPP program. The FHWA (and prior to that SHRP) included requirements for the laboratory selected to do the testing as part of the Request for Proposal. The laboratory used an internal quality control procedure in performing the testing. The Regional contractors and the Technical Support contractor both provided data review.

These QC/QA methods evolved over time from those initially implemented under SHRP to improve the overall quality of data in the PPDB. Table 2.1 provides a basic list of these QC/QA procedures along with the group responsible for performing the checks and the year that this portion of the quality program was implemented as well as the year of any major change in that overall procedure.

Table 2.1 Quality Control Responsibilities

QC/QA Procedure	Responsible Party	Year Implemented
Laboratory Accreditation and Requirements	FHWA/SHRP	1988
Laboratory Quality Control Program	Laboratory Contractor	1988
Laboratory Start-Up Procedure performed in addition to Accreditation	Technical Support Services Contractor	1996
Independent Review of Data	Regional Support Contractor	1988
	Technical Support Services Contractor	1996 – Protocol P46 2001 – Protocol P07 2005 – MAP Testing
Automated Quality Assurance Checks	Regional Support Contractor	1988

2.2 LABORATORY IMPLEMENTED QC/QA

The QC/QA procedures implemented by the laboratory were required by contract with FHWA and prior to that SHRP. The laboratory capabilities were reviewed as part of their proposal to perform the work. These capabilities were specified in the Request for Proposals prepared by the contracting agency and included items such as minimum level of experience and education of personnel to supervise and perform the testing.

2.2.1 Laboratory Accreditation

The steps required under the original SHRP contract required that the laboratories be accredited through the AASHTO program.[13] The purpose of the AASHTO Accreditation Program (AAP) was to review the competency of the laboratory to perform specific tests on construction materials. As part of the AAP, the laboratory quality system was assessed for compliance with AASHTO Standard Practice R18.[14] Test procedures on PCC, asphalt materials, and unbound materials are included in the program; however, the AAP did not include every kind of test that could be performed on each of these materials.

Since some of the tests not included in the AAP were considered critical to the LTPP testing plan, a set of proficiency programs were developed and used for these procedures. These programs were initially implemented under SHRP and included the following five areas:

1. Type 1 soil proficiency program – resilient modulus, moisture content, in-situ nuclear moisture/density
2. Type 2 soil proficiency program – resilient modulus, moisture content, in-situ nuclear moisture/density
3. PCC Core sample proficiency program – static modulus of elasticity, Poisson's ratio, splitting tensile strength, and compressive strength
4. Asphalt concrete (AC) Core proficiency program – resilient modulus
5. Laboratory molded AC core proficiency sample program – resilient modulus

The SHRP-P-687 report provides a complete description of these programs and how they were implemented.[1]

2.2.2 Laboratory In-house QC/QA Program

SHRP required that the lab contractors have their own in-house QC/QA programs as well as experienced and capable personnel committed to carrying out these procedures. These QC/QA documents were to include provisions for each of the following facets of a laboratory testing program:

- Qualified personnel, proper equipment, references, adequate facilities
- Project supervision
- Sample identification and receipt, storage, and disposal
- Laboratory handling of samples
- Sample storage and disposal

- Pavement layering and laboratory test assignment
- Adherence to specific laboratory testing protocols
- Accuracy in measurements
- Equipment maintenance and calibration
- Review and checking of data
- Presentation of data and reports

This requirement continued under FHWA. However, the requirement could only be enforced for the laboratories contracted to FHWA that were performing the resilient modulus and associated testing. The State laboratories performing the remaining testing on the SPS projects and GPS overlays were not required to have such a document in place.

2.2.3 Laboratory Start-up

Under FHWA, a laboratory start-up procedure was developed and used prior to allowing any resilient modulus testing of LTPP samples.(15) This program was first initiated in 1996. This procedure reviewed the dynamic performance of the testing system to make sure that the values measured by the system were in fact the loads, displacements, and pressures applied to the sample. Checks were made of the individual system components to ensure that the output met the expected ranges.

The proficiency program was expanded under this procedure to incorporate review of the personnel performing the testing to make sure that they were following the test procedures. Under this portion of the procedure, laboratory personnel were evaluated as they performed each step of the test procedure by a member of the Technical Support contract team. At the same time, the settings within the test system were also reviewed to make sure that they were appropriate and complied with the test protocol.

2.3 ROLE OF THE LAB GUIDE

The Lab Guide was created to provide the first step of the QC/QA process. The Guide provided a uniform set of procedures to be followed by all laboratories participating in the LTPP testing program. The protocols and sample handling procedures included in the Guide were developed to be as specific as possible such that the variation in test results between laboratories would be as small as possible.

Additionally, procedures within the Guide included quality control activities for the assignment of layer numbers to each pavement structure, identification of both samples and layers, performance of lab tests and review of test data, review of layer data, and storage and handling of samples. More information about these procedures is provided in the following chapters.

Quality assurance of the laboratory data was performed in part through timely transmission of information using the standard set of forms provided by the lab guide. A full set of these forms and accompanying descriptions are provided in the following chapters of this version of the Guide.

2.4 INDEPENDENT REVIEW OF THE DATA

2.4.1 Review Prior to Entry

Under SHRP, the Regional Engineer was responsible for providing QA on layering assignments, field data, and laboratory data. Generally, the Regional Engineer utilized Regional contractor staff to provide input on this QA.

This review involved evaluating the consistency of the data with other information that had been obtained from the test section or project. The review also included comparing the tests conducted with those planned and examining the data from a particular test section for variability. Some variation may have existed with the specifics of these reviews between regions, but all of the Regional reviews contained these same general components.

When FHWA took control of the LTPP program, the Regional staff became directly responsible for reviewing data obtained for the State designated laboratories. These laboratories were performing all of the testing on the SPS projects and GPS overlays except the resilient modulus testing. These reviews consisted of the same components as they had under SHRP.

The responsibility for review of the resilient modulus testing under FHWA was placed on the Technical Support contractor. To that end, in 1997, P46CHECK was created to assist in the review of resilient modulus data from unbound (base, subbase, and subgrade) materials.(16) The software provided a way to keep uniformity in the review and ensure that all aspects of the data were evaluated.

The software identified that all 16 data files were present. It also checked that the files were complete and identified the presence of noise in the raw data. Conformance with test method procedures was also verified. Finally, the summary data were reviewed to ensure that the calculations were performed correctly and that the material response followed expected trends.

Similar to P46CHECK, P07CHECK was developed in 2001 and used for evaluating the resilient modulus testing of asphalt materials.(17) The operating characteristics and checks performed by this software were quite similar to those for P46CHECK. Although it was not initially used until 2001, all of the asphalt resilient modulus data contained in the PPDB were evaluated using the P07CHECK software.

Laboratory test data collected under the MAP were also reviewed by the Technical Support contractor. Primarily, this review identified that the data were complete and fell within reasonable ranges. This review did not preclude any review performed by the Regional contractor as well.

2.4.2 Review After Data Entry

Once the data were entered into the PPDB, they were put through a series of data quality checks using several automated QC programs. Specifically, there were three levels of checks to which the data were subjected. The first, or Level-C, checks were to identify any records for which critical data elements were missing. For instance, this check might have identified records in the TST_AC02 table with a missing value for the bulk specific gravity. The Level D checks identified the validity and reasonableness of the data entered in a particular field. For example, an asphalt content entered in table TST_AC04 of 52 percent would have been flagged by this check. Level E checks examined the data for consistency between fields and tables. Among other level E checks performed, these checks made sure that the data entered in tables for asphalt materials corresponded to a layer with an asphalt material code in the TST_L05A table. Additional information about these QC checks was provided in the Data User's Guide.(18)

Once the data were entered into the regional database and checked using the automated QC programs, the data were uploaded on a regular basis to the PPDB. Prior to allowing these data to be released to the general public, the data were reviewed by the Technical Support contractor. In particular, this review evaluated the consistency of the data collected between the regions. The review identified the consistency of the application of procedures and definitions between the varying agencies performing and reviewing the laboratory testing.

2.5 SUMMARY

The QC/QA procedures used within the LTPP program were considered to be a critical element to the laboratory testing program. These procedures extended to all parties involved in the LTPP program. They also extended from the time of proposing on the laboratory contract to after the laboratory data had been uploaded to the PPDB. It was one of the goals of the LTPP program to provide research quality materials characterization for each the test sections under study.

CHAPTER 3. TEST PREPARATION

This chapter covers information regarding forms that were completed prior to testing and preparation of test samples.

3.1 STANDARD FORMS FOR LABORATORY TESTING

This chapter contains LTPP standard forms which were used in the laboratory material handling and testing work. These forms were prepared and submitted prior to laboratory testing. Table 3.1 provides a list of these forms and their purpose.

Table 3.1 Standard L-Series Forms

Form	Title	Purpose
L01	Sample Receipt Report	Identification of the number and types of samples received from the field.
L02	Sample Inspection Report	Identification of the condition in which these samples were received, i.e., samples acceptable for testing or not.
L03	Preliminary Laboratory Test Assignment	Identification of the types of tests to be performed on samples received for each test section.
L04	Laboratory Test Assignment	Assignment of the tests to be performed on each individual sample.

The following entries were made on each of the standard forms in this section: Sheet, Laboratory Performing Test, Laboratory Identification Code, Region, State, Experiment Number, State Code, SHRP ID, Field Set Number, Sampled by, Date Sampled, Submitted by, Date, Checked and Approved, and Date.

SHEET: All data sheets from the laboratory material testing work on a particular project or test section were assigned sequential numbers starting from 1 for the sample receipt report (Form L01) followed by the sample inspection report (Form L02), preliminary laboratory test assignment (Form L03), laboratory test assignments (Form L04) and so on in increasing order through all of the respective L-type laboratory testing forms and continuing through the T-type laboratory testing forms.

If the information was not completely filled out on one sheet for one type of sample/test then multiple sheets were used and numbered accordingly ... 1 of 30, 2 of 30, 3 of 30 ....

LABORATORY PERFORMING TEST: The name of the laboratory where the laboratory materials test was conducted was written on this line.

LTPP LABORATORY IDENTIFICATION CODE: The laboratory identification code number assigned to the laboratory performing the test was recorded. The first two digits of the code indicated the state in which the laboratory was operating.

REGION: Identified the LTPP region in which the project or test section was located:

NA = North Atlantic Region
NC = North Central Region
S = Southern Region
W = Western Region

STATE: Two letter abbreviation (shown in Table 3.2) of the state, District of Columbia, Puerto Rico or the Canadian Province in which the project or test section was located.

EXPERIMENT NO: One of the eight GPS experiments (GPS-1, GPS-2, GPS-3, GPS-4, GPS-5, GPS-6, GPS-7, or GPS-9) or one of the seven SPS experiments (SPS-1, SPS-2, SPS-3, SPS-4, SPS-5, SPS-6, SPS-7, SPS-8, SPS-9P, or SPS-9A) as shown in Table 3.3 of this Guide.

STATE CODE: Two-digit code as shown in Table 3.2 for the state in which the project or test section was located.

SHRP ID: The four-digit code identifying the specific LTPP test section within the state.

FIELD SET NO: The field set number was a sequentially assigned number to indicate the different time periods in which material samples and field testing were conducted on the project. These time periods usually referred to different stages in the pavement life, such as prior to overlay construction, after overlay construction, end of test, etc. A field set number could apply to more than one day since sampling of SPS test sections usually required more than one day. As a general rule, the same field set number was applied to all material samples and field tests conducted in a continuous 30 day period, unless a construction event occurs between the two sampling sessions. The number 1 was used for the first time that material sampling and field testing were conducted on the project.

SAMPLED BY: Identified the Drilling and Sampling Crew who performed the field material sampling and field testing work for this particular project.

DATE (OR DATE SAMPLED): Dates were recorded as mm-dd-yyyy. This date was the date on which the field material sampling and field testing was conducted.

At the bottom of each LTPP Standard Form, the following information was entered:

SUBMITTED BY, DATE: The Laboratory Chief's signature and date of signature was required. Underneath this signature, the corporate affiliation of the Laboratory Chief was identified.

Table 3.2. Table of standard codes for the United States, the District of Columbia, Puerto Rico, and Canadian Provinces.

(Based on Table A.1 of the July 2005 revision of the LTPP Inventory Data Collection Guide, Ref. 17)

State	Abbr.	Code	State	Abbr.	Code
Alabama	AL	01	New Mexico	NM	35
Alaska	AK	02	New York	NY	36
Arizona	AZ	04	North Carolina	NC	37
Arkansas	AR	05	North Dakota	ND	38
California	CA	06	Ohio	OH	39
Colorado	CO	08	Oklahoma	OK	40
Connecticut	CT	09	Oregon	OR	41
Delaware	DE	10	Pennsylvania	PA	42
District of Columbia	DC	11	Rhode Island	RI	44
Florida	FL	12	South Carolina	SC	45
Georgia	GA	13	South Dakota	SD	46
Hawaii	HI	15	Tennessee	TN	47
Idaho	ID	16	Texas	TX	48
Illinois	IL	17	Utah	UT	49
Indiana	IN	18	Vermont	VT	50
Iowa	IA	19	Virginia	VA	51
Kansas	KS	20	Washington	WA	53
Kentucky	KY	21	West Virginia	WV	54
Louisiana	LA	22	Wisconsin	WI	55
Maine	ME	23	Wyoming	WY	56
Maryland	MD	24	Puerto Rico	PR	72
Massachusetts	MA	25	Alberta	AB	81
Michigan	MI	26	British Columbia	BC	82
Minnesota	MN	27	Manitoba	MB	83
Mississippi	MS	28	New Brunswick	NB	84
Missouri	MO	29	Newfoundland	NF	85
Montana	MT	30	Nova Scotia	NS	86
Nebraska	NE	31	Ontario	ON	87
Nevada	NV	32	Prince Edward Island	PE	88
New Hampshire	NH	33	Quebec	PQ	89
New Jersey	NJ	34	Saskatchewan	SK	90

Note: The U.S. Codes are consistent with the Federal Information Processing Standards (FIPS) and Highway Performance Monitoring System.

Table 3.3 Summary of Experiments

Experiment Number	Experiment Title
GPS-1	Asphalt concrete over granular base
GPS-2	Asphalt concrete over bound base
GPS-3	Jointed plain concrete pavement
GPS-4	Jointed reinforced concrete pavement
GPS-5	Continuously reinforced concrete pavement
GPS-6	Asphalt concrete overlay over asphalt concrete pavement
GPS-7	Asphalt concrete overlay over portland cement concrete pavement
GPS-9	Unbonded concrete overlay over portland cement concrete pavement
SPS-1	Strategic study of structural factors for flexible pavements
SPS-2	Strategic study of structural factors for rigid pavements
SPS-3	Preventive maintenance effectiveness for flexible pavements
SPS-4	Preventive maintenance effectiveness for rigid pavements
SPS-5	Rehabilitation of asphalt concrete pavements
SPS-6	Rehabilitation of jointed portland cement concrete pavements
SPS-7	Bonded portland cement concrete overlays
SPS-8	Study of environmental effects in the absence of heavy loads
SPS-9P	Validation of SHRP asphalt specifications and mix design and innovations in asphalt pavements
SPS-9A	SUPERPAVE™ Asphalt Binder Study

3.1.1 Form L01 – Sample Receipt Report

This form was used to record information regarding the samples which were received from the drilling and sampling crew by the participating laboratory. This form provided information about receipt of materials for one GPS section or one SPS project. If sampes were received for more than one GPS section or SPS project at a given time, then the samples were separated and separate Form L01s were completed for each individual GPS test section or SPS project reflected within the shipment. The following information was provided on this form:

NUMBER OF SAMPLE CONTAINERS RECEIVED: The number of cartons, boxes and other types of sample containers was provided.

SAMPLES RECEIVED BY: The name(s) of the laboratory personnel who received the samples was written here along with the date the samples were received.

AUTHORIZED BY: The name of the laboratory personnel who authorized the receipt of the samples and checked the sample shipment for completeness. The date of authorization was also included.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
SAMPLE RECEIPT REPORT
LAB DATA SHEET L01 - PAGE 1

LABORATORY PERFORMING TESTS:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __/__ __/__ __ __ __

NUMBER OF SAMPLE CONTAINERS RECEIVED: ________CARTONS _______BOXES _______OTHER

SAMPLES RECEIVED BY:________________________________ DATE:__ __/__ __/__ __ __ __

AUTHORIZED BY:____________________________________ DATE:__ __/__ __/__ __ __ __

WORK INITIATED BY:_________________________________ DATE:__ __/__ __/__ __ __ __

SAMPLES CHECKED WITH THE MATERIALS SAMPLES INVENTORY RECEIVED WITH THE SHIPMENT:

____

TOTAL NUMBER OF:

1) AC CORES: (a) 4" Diam.________(b) 6" Diam.________(c) 12" Diam.________

NUMBER OF AC CORES TO BE SAWED FROM:

(a) BOUND BASE/SUBBASE________ (b) PCC AND BOUND BASE/SUBBASE_____ (c) PCC ______

NUMBER OF PCC CORES TO BE SAWED FROM BOUND BASE OR SUBBASE: __________

2) BOUND BASE CORES (4" Diam.): ____________

3) BOUND SUBBASE (INCLUDING TREATED SUBGRADE) CORES (4" Diam.) ____________

4) UNBOUND BASE SAMPLES: (a) BAGS (BULK) ___________ (b) JARS (MOISTURE)______________

5) UNBOUND SUBBASE SAMPLES: (a) BAGS (BULK)___________ (b) JARS (MOISTURE)______________

6) SUBGRADE SAMPLES: (a) BAGS (BULK) ___________ (b) JARS (MOISTURE)______________

(c) THIN-WALLED TUBES:___________ (d) SPLITSPOON SAMPLES ________JARS

7) PCC CORES: _______________ 8) PCC BEAMS: _______________

9) AC MIX BULK SAMPLES: _____________ 10) AC-TREATED BASE BULK SAMPLES: _____________

CONTINUED ON PAGE 2 OF FORM L01

LTPP LABORATORY MATERIAL HANDLING AND TESTING
SAMPLE RECEIPT REPORT
LAB DATA SHEET L01 - PAGE 2

11) OTHER:

	MATERIAL	TYPE OF SAMPLE	NO. OF SAMPLES RECEIVED
a)	________________	______________________	________
b)	________________	______________________	________
c)	________________	______________________	________

12) SAMPLES TO BE SHIPPED TO OTHER LABORATORIES:

MATERIAL	NO. OF SAMPLES	LABORATORY
________________	_______	___________________
________________	_______	___________________
________________	_______	___________________

VERBAL REPORT TO: FHWA-LTPP REGION __________ DATE__ __/__ __/__ __ __ __

REPORT DISTRIBUTION: ____ FHWA-LTPP REGION __ __/__ __/__ __ __ __

____ FHWA-LTPP LABORATORY PROJECT MANAGER __ __/__ __/__ __ __ __

____ FHWA-LTPP COTR __ __/__ __/__ __ __ __

SPECIAL INSTRUCTIONS:____

____

____

____

Immediately inform the FHWA-LTPP Region, if any substantial discrepancy is found in the actual samples received, as compared to the Material Samples Inventory (Field Operations Information Form 1 and Form 2) provided by the drilling and sampling crew or the state/province highway agency laboratory.

NOTE: ENCLOSE ATTACHMENTS "A" AND B" (LAB SHEETS: L02 AND L03) WITH THIS SAMPLE RECEIPT REPORT.

SUBMITTED BY, DATE	CHECKED AND APPROVED, DATE
____________________________	____________________________
FHWA-LTPP LABORATORY PROJECT MANAGER	FHWA-LTPP REPRESENTATIVE
Affiliation____________________	Affiliation____________________

TOTAL NUMBER OF:

1) AC CORES: The number of 4-inch (102-mm), 6-inch (152-mm) and 12-inch (305-mm) AC cores, respectively, received by the LTPP participating laboratory.

   Additionally, the form provided the number of AC cores out of the total number of AC cores to be sawed each of the following base/subbase materials:

   a) Bound base/subbase
   b) PCC and bound base/subbase (see LTPP Protocol P31 in Chapter 4 for the definition of bound base and subbase)
   c) PCC

   The total number of PCC cores to be sawed from bound base or subbase material was recorded.

2) BOUND BASE CORES: The total number of 4-inch (102-mm) bound base cores received.

3) BOUND SUBBASE (INCLUDING TREATED SUBGRADE) CORES: The total number of 4-inch (102-mm) bound subbase cores received.

4) UNBOUND BASE SAMPLES: The total number of unbound base samples received.

   a) BAGS (BULK)
   b) JARS (MOISTURE)

5) UNBOUND SUBBASE SAMPLES: The total number of unbound subbase samples received.

   a) BAGS (BULK)
   b) JARS (MOISTURE)

6) SUBGRADE SAMPLES: The total number of granular subgrade samples received.

   a) BAGS (BULK)
   b) JARS (MOISTURE)
   c) THIN-WALLED TUBES
   d) SPLITSPOON SAMPLES

7) PCC CORES: The number of PCC core samples received from the drilling and sampling crew.

8) PCC BEAMS: The number of formed PCC beams received.

9) AC MIX BULK SAMPLES: The number of AC hot mix bulk samples received.

10) AC-TREATED BASE BULK SAMPLES: The number of AC-treated base bulk samples.

11) OTHER: The material type, type of sample and number of samples received for any other types of samples received.

12) SAMPLES TO BE SHIPPED TO OTHER LABORATORIES: This section was used to record the type of material, number of samples and the laboratory where the individual samples were shipped.

VERBAL REPORT TO: A "yes" was indicated here after a verbal report to the Region had been completed concerning the sample shipment. The date of this verbal report was also entered.

REPORT DISTRIBUTION: This was "checked off" whenever the Sample Receipt Report was sent to the LTPP Region or the respective laboratory supervisor.

SPECIAL INSTRUCTIONS: Any special instructions for laboratory handling and laboratory material testing were provided here.

Form L01 was not entered into the PPDB.

3.1.2 Form L02 – Sample Inspection Report

This form was Attachment "A" to the Sample Receipt Report (Form L01) and was submitted for approval to the Region with Form L01 and Form L03 after the samples were received and checked and prior to the commencement of the laboratory material testing.

This form (Form L02) was used to record the condition of material samples that were received by the laboratory. The following information was entered on this form:

SAMPLE LOCATION NUMBER: A three-digit location number obtained from field markings and from Field Operations Information Form 1. This number designated the field location of the sample.

LTPP SAMPLE NUMBER: A four-digit alphanumeric LTPP sample number obtained from field markings and Field Operations Form 1.

SAMPLE SIZE: The size of the material sample. For example, the following terms may have been used for these particular samples:

Core - 4 inch (102 mm) diameter
Moisture - jar
Bulk - bag
Block - 12 inch × 12 inch (305 mm × 305 mm)

LTPP LABORATORY MATERIAL HANDLING AND TESTING
ATTACHMENT "A" TO SAMPLE RECEIPT REPORT
(SAMPLE INSPECTION REPORT)
LAB DATA SHEET L02

LABORATORY PERFORMING TESTS:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __
SAMPLED BY: ____
DATE SAMPLED: __ __/__ __/__ __ __ __ FIELD SET NO __

SAMPLE LOCATION NUMBER	LTPP SAMPLE NUMBER	SAMPLE SIZE	SAMPLE TYPE	SAMPLE MATERIAL	SAMPLE CONDITION	REMARKS

* Sample condition as observed during inspection.
** Remarks should include: (a) any discrepancy found after comparing with the sample data submitted by the Drilling and Sampling Crew on Field Operations Information Form 1; (b) any cores of two materials required to be sawed; (c) approximate weight of bulk samples, and (d) insufficient quantity.

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
FHWA-LTPP LABORATORY PROJECT MANAGER FHWA-LTPP REPRESENTATIVE

Affiliation______________________ Affiliation______________________

SAMPLE TYPE: Type of sample. For example; core, block, piece, chunk, bulk, moisture, splitspoon, etc.

SAMPLE MATERIAL: Type of material in the sample. For example: AC, PCC, base, subbase, subgrade, etc.

SAMPLE CONDITION: This entry provided the sample condition observed during inspection. Possible entries may have been good, cracked, loose, bag torn, spilled, etc.

REMARKS: The remarks included such items as discrepancies found after comparing the samples with Field Operations Information Form 1, identification of cores for which sawing was required to separate layers, approximate weight of bulk samples and a comment if there was an insufficient quantity than that required to complete the laboratory material handling and testing program.

GENERAL REMARKS: Any other pertinent comments were supplied here.

The Sample Inspection Report was made in the following sequence.

1) Samples from locations of C-type cores starting from cores of pavement surface layers.
2) Samples from A-type boreholes.
3) Samples from BA-type boreholes.
4) Samples from the test pit.
5) Any other samples.

Form L02 was not entered into the PPDB.

3.1.3 Form L03 – Preliminary Laboratory Test Assignment

This form (Form L03) was used for the preliminary assignment of laboratory tests to a particular laboratory. It was the second attachment, or Attachment "B", to the Sample Receipt Report (Form L01). Form L03 was submitted for approval to the Region along with Form L01 and Form L02 after the samples were received and checked, and prior to the commencement of the laboratory material testing.

A checkmark was placed in the blank space before the test designation if this test was to be performed in the participating laboratory in which the samples were received. A checkmark (√) was placed in this column beside the appropriate test if the test was being performed in a laboratory separate from the laboratory that completed the form and the laboratory that was performing the test was provided in the appropriate location on the form.

Form L03 was not entered into the PPDB.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
ATTACHMENT "B" TO SAMPLE RECEIPT REPORT
PRELIMINARY LABORATORY TEST ASSIGNMENT
LAB DATA SHEET L03

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____
DATE SAMPLED: __ __/__ __/__ __ __ __ FIELD SET NO. __

*	Test	LABORATORY TESTS	Protocol Designation	*	Test	LABORATORY TESTS	Protocol Designation
		ASPHALTIC CONCRETE				UNBOUND GRANULAR BASE/SUBBASE	
	AC01	Core Examination/Thickness	P01		UG01	Particle Size Analysis	P41
	AC02	Bulk Specific Gravity	P02		UG02	Sieve Analysis (washed)	P41
	AC03	Maximum Specific Gravity	P03		UG04	Atterberg Limits	P43
	AC04	Asphalt Content (Extraction)	P04		UG05	Moisture-density Relations	P44
	AC05	Moisture Susceptibility	P05		UG07	Resilient Modulus	P46
	AC07	Resilient Modulus	P07		UG08	Classification	P47
					UG09	Permeability	P48
		Extracted Aggregate			UG10	Natural Moisture Content	P49
	AG01	Specific Gravity – Coarse Aggregate	P11		UG13	Specific Gravity	P71
	AG02	Specific Gravity – Fine Aggregate	P12		UG14	Dynamic Cone Penetrometer	P72
	AG04	Gradation of Aggregate	P14				
	AG05	Fine Aggregate Particle Shape Test	P14A			SUBGRADE SOIL	
					SS01	Sieve Analysis	P51
		Asphalt Cement			SS02	Hydrometer Analysis	P42
	AE01	Abson Recovery	P21		SS03	Atterberg Limits	P43
	AE02	Penetration at 77°F	P22		SS04	Classification	P52
	AE03	Specific Gravity at 60°F	P23		SS05	Moisture-density Relations	P55
	AE05	Viscosity at 140°F and 275°F	P25		SS07	Resilient Modulus	P46
	AE07	Dynamic Shear Rheometer Test	P27		SS08	Unit Weight	P56
	AE08	Bending Beam Rheometer Test	P28		SS09	Natural Moisture Content	P49
	AE09	Direct Tension Test	P29		SS10	Unconfined Compressive Strength	P54
					SS11	Hydraulic Conductivity	P57
		TREATED BASE/SUBBASE MATERIALS			SS12	Expansion Index	P60
	TB01	Classification of Material/Type of Treatment	P31		SS13	Specific Gravity	P71
					SS14	Dynamic Cone Penetrometer	P72
	TB02	Compressive Strength	P32				
	AC07	Resilient Modulus	P07			PORTLAND CEMENT CONCRETE	
					PC01	Compressive Strength	P61
					PC02	Splitting Tensile Strength	P62
					PC03	Coefficient of Thermal Expansion	P63
					PC04	Static Modulus of Elasticity	P64
					PC05	Density of PCC	P65
					PC06	Core Examination/Thickness	P66
					PC07	Interface Bond Strength	P67
					PC08	Air Content	P68
					PC09	Flexural Strength	P69
					PC10	Petrographic Examination	P70

* If the test is being performed at this laboratory, place a (√) in this column beside the appropriate test.

GENERAL REMARKS:____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_____________________________ _____________________________
LABORATORY PROJECT MANAGER FHWA-LTPP REPRESENTATIVE

Affiliation______________________ Affiliation______________________

3.1.4 Form L04 – Laboratory Test Assignments

The Participating Laboratory was responsible for identifying and assigning a pavement layer number on Form L04, getting approval of the LTPP Region for the test assignments, and correcting Form L04 if required.

The following information was entered on Form L04:

LAYER NUMBER: Column 1 of Form L04 was for the designation of the layer number. The layer number was assigned beginning with layer number 1. Layer number 1 was always assigned for the subgrade and the last layer number was always the pavement surface layer. An example of layer numbers for a five-layer pavement structure was:

Subgrade 1
Subbase 2
Base 3
AC Binder Course 4
AC Surface Course 5

An independent layer identification was completed by the Participating Laboratory and layers identified on Form L04 accordingly. Detailed instructions for layer number assignments are provided in Chapter 5 of this Guide.

LAYER DESCRIPTION: Column 2 of Form L04 was for the description of the layer. The two-digit codes presented in Table 3.4, taken from the LTPP Inventory Data Collection Guide, were to be used for layer description. (19)

Table 3.4 Layer Description Codes Used in Completing Form L04

Layer Type	Description Code
Overlay	01
Seal Coat	02
Original Surface Layer	03
AC Layer Below Surface (Binder Course)	04
Base Layer	05
Subbase Layer	06
Subgrade	07
Interlayer	08
Friction Course	09
Surface Treatment	10
Embankment (Fill)	11

LAYER TYPE: The layer type code was assigned in Column 3 using the codes presented in Table 3.5.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY TEST ASSIGNMENTS
LAB DATA SHEET L04

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE ____________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __/__ __/__ __ __ __

1 LAYER NUMBER	2 LAYER DESCRIPTION CODE	3 LAYER TYPE	4 SAMPLE LOCATION NO.	5 LTPP SAMPLE NO.	6 LAB TEST NO.	7 LAB CONTROL NO.	8 LTPP TEST DESIGNATION	9 LTPP PROTOCOL	10 TEST DATE SCHED
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________
__	__ __	__ __	__ __ __	__ __ __ __	__	________	__ __ __ __	P__ __	________

NOTES: COLUMN 1. Layer number 1 is the subgrade soil, the last layer is the existing pavement surface layer.

GENERAL REMARKS:______________________________

____

SUBMITTED BY, DATE　　　　CHECKED AND APPROVED, DATE

______________________　　　　______________________
FHWA-LTPP LABORATORY PROJECT MANAGER　　　　FHWA-LTPP REPRESENTATIVE

Affiliation______________________　　　　Affiliation______________________

Table 3.5 Layer Type Codes Used in Completing Form L04

Layer Type Code	Description
AC	Asphalt concrete (bituminous concrete) layer
PC	Portland cement concrete layer
TB	Bound (treated) base (See Protocol P31 for definition of bound base)
TS	Bound (treated) subbase (See Protocol P31 for definition of bound subbase)
GB	Unbound (granular) base
GS	Unbound (granular) subbase
SS	Subgrade (untreated)
EF	Engineering Fabric

SAMPLE LOCATION NO.: Column 4 contained the LTPP Sample Number. This was a three-digit alphanumeric code obtained from field markings and Field Operations Information Form 1. This number designated the field location of the sample.

LTPP SAMPLE NO.: Column 5 of Form L04 contained the LTPP Sample Number. This was a four-digit alphanumeric code which was obtained from field markings and Field Operations Information Form 1.

LAB TEST NO.: Column 6 contained the Laboratory Test Number which indicated the general area of the test section from which the sample was taken. The number one (1) was used for samples retrieved from locations at Stations 0-. The number two (2) was used for samples retrieved from locations at Stations 5+... The number three (3) was used for samples retrieved from locations within the test section (Stations 0+00 to 5+00). The number four (4) was for samples obtained by combining material from different areas of the test section. The number five (5) was for samples obtained by combining material from multiple test sections. This combining of samples across test sections was required on some SPS projects.

In some tables within the PPDB, laboratory test numbers higher than 5 were used. In these cases, test numbers 6 and 11 have the same meaning as test number 1. Test numbers 7 and 12 have the same meaning as test number 2. Test numbers 8 and 13 have the same meaning as 3. Test numbers 9 and 14 have the same meaning as 4. Test numbers 10 and 15 have the same meaning as 5.

LAB CONTROL NO.: This number was placed in column 7 and was the control number assigned by the Participating Laboratory in accordance with their own practice.

LTPP TEST DESIGNATION: A four-digit alphanumeric code was provided in column 8 as shown to the left of the laboratory test titles on Form L03.

LTPP PROTOCOL: A three- or four-digit code was completed in column 9 which corresponded to the appropriate LTPP Test Designation as shown to the right of the laboratory test titles on Form L03 or in Table 1.1.

TEST DATE SCHED: Column 10 of this form indicated the test date on which the test was scheduled to be performed.

The layering information on corrected and approved Form L04 was used throughout the laboratory testing. However, Form L04 was not recorded in the PPDB. After completion of all tests, Forms L05, L05A, and L05B were prepared using Form L04 and other test data forms, and recorded in the PPDB.

Proper layering identification and information was critical to the PPDB.

3.2 SAMPLE PREPARATION

3.2.1 Asphalt Concrete

One element identified as vital to the LTPP program was the proper identification of individual layers within AC cores and assignment of AC laboratory tests for these various different layers within an asphalt concrete core. Great effort was expended by the laboratories to properly identify individual layers prior to commencing testing.

The LTPP protocol P01, Visual Examination and Thickness of Asphaltic Concrete cores, (included in Chapter 4 of this Guide) was written to provide detailed procedures for identification and determination of thickness of individual layers within the AC core. The test results were recorded on Form T01A (for the entire AC core) and Form T01B (for the individual layers within the AC core). Based on these test results, designated asphalt concrete laboratory tests may have been required on <u>one</u> or <u>more</u> layers within each AC core.

After completion of the AC01 tests (Visual Examination and Thickness of AC Cores, Protocol P01) on all AC cores, the test results were used by the laboratory to compare the AC01 information with the pavement layering recorded in the laboratory test assignments made on Form L04 for samples from each pavement section. Form L04 was completed by the laboratory following the procedure given in Section 3.1.4.

After obtaining approval of the testing assignments and completing the visual examination of the AC core and measuring layer thicknesses using the P01 protocol, the laboratory separated all individual layers within the AC core or block sample using the following rules.

Rule #1: If the AC core, block, or piece consisted of only one layer, the sample was not sawed. The testing was conducted on the core(s), block or piece using the instructions in the designated protocol.

Rule #2: Two or more layers within an AC sample (core, block, piece) were not combined for any specified tests.

Rule #3: Any 1.5-inch (38-mm) or thicker AC layer was separated from the AC sample by carefully sawing the sample. The AC cores were sawed so as to provide as little disturbance to the sample as possible. The sawing operation was performed on the interface of the layer to be separated so that the AC was not weakened by shock or by heating. The sawed surfaces of cores were required to be smooth, plane, parallel, and free from steps, ridges and grooves. The specimens were dried in air at an approximate room temperature (60–75°F [16–24°C]). Sample identification was assigned and traffic direction marked on the core specimen using an arrow to show the direction of travel. The laboratory was required to saw and separate the bottom layer first, followed by the next layer over the bottom layer in ascending order until reaching the top layer.

Exception to Rule #3: For some 12-inch (305-mm) cores and 12-inch (305-mm) blocks, depending on their resistance to softening, that were used for extraction (LTPP Test AC04) and the subsequent extracted aggregate gradation (LTPP Test AG04), the layers, if present, may have been separated by a heating and curing technique. For the details of this technique, see the Appendix to LTPP Protocol P04, Asphalt Content of Asphalt Concrete.

Rule #4: All specified AC tests as shown on Forms L03 and L04, were performed on every 1.5 inch (38 mm) or thicker AC layer.

Rule #5: If a portion of the AC sample contained one or more layers less than 1.5 inches (38 mm) thick, then no sawing was required for those layers. No further testing of these (less than 1.5 inch [38 mm] thick) layers was required. However, all layers were appropriately marked for sample identification and appropriate layer numbers were also marked on the side of the sample for each layer.

3.2.2 Treated Base and Subbase

Cores and chunks of treated material from one layer of base or subbase were sometimes bonded with AC and/or PCC. This combination of materials was sometimes retrieved in the field and shipped to the laboratory as intact cores and chunks. The AC or PCC layer(s) were required to be removed from the treated base or subbase layers by sawing. Layer thicknesses were measured prior to sawing.

Cores and chunks of treated subgrade were sometimes bonded with other bound layers and shipped to the laboratory as intact cores and chunks. The other bound layers were required to be removed from the treated subgrade by sawing in the laboratory. Layer thicknesses were measured and recorded on Form T31 prior to sawing.

If intact cores of the treated material were available then the laboratory uses two of these cores for preliminary identification and determination of layer thickness as prescribed by Protocol P31.

If there were no intact cores, and only chunks/pieces of the treated materials were available, then the laboratory was not required to determine layer thickness and Protocol P31 was used only for identification and description.

After getting approval of the layering and testing assignment, the laboratory separated all individual treated base and subbase layers within the core, block chunk or piece sample using the following rules.

Rule #1: The laboratory was not required to saw the treated base and subbase core, block, chunk, or piece if the sample consisted of only one layer. The testing was conducted on the full thickness of the core(s), block, chunk, or piece using the instructions in the designated protocol.

Rule #2: Two or more treated layers within a sample (core, block, chunk or piece) were separated if the layers were 3 inches (76 mm) thick or more for treated materials other than asphalt treated base (OTB) materials and 1.5 inches (38 mm) or more thick for asphalt treated base (ATB) materials.

Rule #3: A treated layer of 3 inches (76 mm) or more for OTB materials or 1.5 inches (38 mm) for ATB materials were to be separated by carefully sawing the sample providing the least amount of disturbance. Tests were to be performed using Protocols P31 and P32 or P07 as appropriate. Comment code 93 was used in reporting the tests results for Protocol P31 on Form T31.

Rule #4: If the thickness of a treated layer was less than 3 inches (76 mm) for OTB materials or 1.5 inches (38 mm) for ATB materials, then the laboratory performed only Protocol P31 testing on this thin layer. An appropriate comment code 91 or 92 was used in reporting the test results for Protocol P31 on Form T31. No separation of this layer was done.

Rule #5: The treated layer was separated from the sample according to the criteria given in Rules #3 and #4. Sawing treated base and subbase cores required special care so as to provide minimum disturbance. The sawing operation was performed on the interface of the treated layer to be separated so that the material was not weakened by shock or by heating. The sawed surfaces of cores were required to be smooth, parallel, and free from steps, ridges and grooves. The specimens were dried by air at an approximate room temperature (60–75°F [16–24°C]. Sample identification for core, block, chunk, or piece samples was assigned using the procedure described in the Field Handling Guide.[2]

Some pavement sections contained very thin layers such as leveling courses or bond breaker courses placed on top of the base or subbase layers. These very thin layers were not tested and were removed prior to testing the treated base or subbase core(s). These thin layers were identified on Forms L04 and L05A.

The core of the treated material may have had bonded particles from an unbound layer and/or particles of an asphalt concrete layer. These bonded particles were removed by wedging, or by chisel and hammer with care to prevent damage to the cores. If the core was damaged such that it was unsuitable for thickness measurement, then the laboratory recorded this condition using the appropriate comment code identified within the protocol.

3.2.3 Unbound Granular Base and Subbase Materials

The bag(s) of the bulk sample for that layer sampled near each end of the section were weighed separately. The bulk sample may have been received from the field in one or more bags or containers. The weight of all bags was summed up to calculate the total weight of the bulk sample from that end.

The bulk samples, if contained in more than one bag or container, were then combined.

The combined bulk sample was mixed and then dried in accordance with the procedure described in Section 4.1 of American Association of State Highway and Transportation Officials (AASHTO) test method T87-86, Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

The average moisture content, determined in accordance with protocol P49, was used to determine the total dry weight of the sample.

Table 3.6 shows the test sample weights needed by each respective LTPP Protocol and/or pertinent AASHTO and American Society for Testing and Materials (ASTM) standards. These weights were shown for samples of 1-inch (25-mm), 2-inch (51-mm), and 3-inch (76-mm) maximum size aggregates. The required tests were listed in this table in the sequence in which the tests were performed in the laboratory. The mixed and dried bulk sample was reduced to the appropriate test sizes as shown in Table 3.6 using the procedures described in AASHTO T248-83, Reducing Field Samples of Aggregate to Testing Size. The test samples were representative of the total bulk sample.

If the total bulk sample weight, as received from the field and as determined above, was less than the total required weight shown in Table 3.6 then the test samples were obtained from the bulk sample using the following rules.

Rule #1: For 1-inch (25-mm) maximum size aggregates, separate test samples were obtained if the bulk sample from near one end of the section weighed 80 lbs (36 kg) or more. Separate test samples, in the quantities shown in Table 3.6, as appropriate, were obtained for performing the tests using Protocols P41, P43, P47, P44, and P46.

Also, a representative 30-lb (14-kg) sample was taken and stored for possible future use by LTPP. Any excess material was discarded after completing the designated tests and obtaining approval.

Rule #2: For 2-inch (51-mm) maximum size aggregates separate test samples were obtained if the bulk sample from near one end of the section weighed more than 140 lbs (64 kg). Separate test samples in the quantities shown in Table 3.6, as appropriate, were obtained for performing the tests using Protocols P41, P43, P47, P44, and P46.

A representative 30-lb (14-kg) sample was taken also if the total bulk sample was more than 140 lbs (64 kg) and stored for possible future use by LTPP. Material from P46 testing may have been reused if necessary. Any excess material was discarded after completing the designated tests and obtaining approval.

Table 3.6. Approximate weights of test samples.

Protocols	**Approximate weight of test sample for maximum size aggregate of, lbs (kg)**		
	1-inch (25 mm)	**2-inch (51 mm)**	**3-inch (76 mm)**
(a) Unbound Granular Base or Subbase Material Per Layer			
P41	11 (5.0)	40 (18)	*50 or 40 (23 or 18) (see rule 7)
P43	4 (1.8)	9 (4.1)	11 (5.0)
P47	+4 (+1.8)	18 (8.2)	*50 or 40 (23 or 18) (see Rule 7)
P44	20 (9.1)	30 (14)	30 (14)
P46	10 (4.5)	30 (14)	65 (30)
Total Weight (a)	49 (22)	127 (58)	206 (93)
(b) Subgrade Soils (Weight in lbs.)			
P51	11 (5.0)	40 (18)	*50 or 40 (23 or 18) (see Rule 7)
P42	4 (1.8)	9 (4.1)	11 (5.0)
P43	4 (1.8)	9 (4.1)	11 (5.0)
P52	+4 (+1.8)	18 (8.2)	*50 or 40 (23 or 18) (See Rule 7)
P55	20 (9.1)	30 (14)	30 (14)
P46	10 (4.5)	30 (14)	65 (30)
Total Weight (b)	53 (24)	136 (62)	217 (98)

Notes:

1. Approximate weights were based on the requirements of the pertinent Protocol and/or AASHTO and ASTM standards.
2. * indicates smaller test size was permitted by the pertinent Protocol as compared to the test size requirement by the pertinent AASHTO/ASTM standards.
3. + indicates that the listed weight was a slight increase over the minimum weight required by the pertinent AASHTO/ASTM standards.

Rule #3: For 2-inch (51-mm) maximum size aggregates, separate test samples were not taken for performing the classification test (Protocol P47 for the unbound granular base or subbase), if the bulk sample weight was within a range of 80 to 140 lbs (36 to 64 kg). Approximate 40-lb (18-kg) test samples were taken for the gradation test (Protocol P41). The classification tests were performed on the test samples for gradation as described in Protocol P47. The comment code 82 was used in reporting the test results for P47 on Form T47.

Rule #4: For 2-inch (51-mm) maximum size aggregates, separate test samples were obtained for Protocols P41, P43, P44, and P46 if the bulk sample was 140 lbs (64 kg) or less but more than 95 lbs (43 kg). If the bulk sample weight was within the range of 80 to 95 lbs (36 to 43 kg) then separate test samples were taken for only Protocols P41, P43, and P44. The material from the P44 test then was reused for the P46 test. The comment code 83 was used in reporting the test results for P44 and P46.

Sample for Storage. The sample used for the P46 test was saved and stored after completing the test for possible future use by LTPP. The comment code 84 was used in reporting the test results for P46.

Rule #5: For 3-inch (76-mm) maximum size aggregates, a separate test sample for the classification test (P47) was not obtained from the bulk sample. The classification test was performed based on the test sample for gradation as described in Protocol P47. The comment code 82 was used in reporting the test results for P47.

Rule #6: For 3-inch (76-mm) maximum size aggregates, separate test samples were obtained for Protocols P41, P43, P44 and P46 if the bulk sample was more than 140 lbs (64 kg). Approximate 50-lb (23-kg) test samples were taken for gradation tests (Protocol P41) in accordance with Table 3.6.

Sample for Storage. An additional 65-lb (29-kg) sample was taken and stored for possible future used by LTPP if available in the remaining bulk sample. Otherwise, the sample used for P46 was saved after completing the test for future possible use by LTPP and the comment code 84 was used in reporting the test results for P46.

Rule #7: For 3-inch (76-mm) maximum size aggregates, separate test samples were obtained for performing tests according to Protocols P41, P43, and P44 if the bulk samples weighed 80 to 140 lbs (36 to 64 kg). Only 40-lb (18-kg) test samples were taken for the gradation test (Protocol P41).

Only dry sieving was used in the gradation test (Protocol P41) if the weight of the bulk sample was within a range of 80 to 140 lbs (36 to 64 kg). The gradation test sample was reused for performing the resilient modulus testing

(Protocol P46). The comment code 85 was used in reporting the test results for P41 and P46.

Sample for Storage. The sample used for P46 testing was saved and stored after completing the test for possible future use by LTPP. The comment code 84 was used in reporting the test results for P46.

Rule #8: If the total bulk sample for 2- and 3-inch (51- and 76-mm) maximum size aggregates was 40 lbs (18 kg) or more but less than 80 lbs (36 kg) then, (i) only dry sieving for the gradation test (Protocol P41) was performed on a test sample weighing 40 lbs (18 kg), (ii) the gradation test sample was reused for other tests (Protocols P43, P47, P44, and P46), (iii) the sample from the last test was saved and stored for possible future use by LTPP, and (iv) the comment code 86 was added in reporting each test result to indicate this significant deficiency in the sample size.

Rule #9: If the total bulk sample for 1-inch (25-mm) maximum size aggregate was 40 lbs (18 kg) or more but less than 80 lbs (38 kg) then, (i) the sample from the P44 test was reused for P46 test, (ii) the sample from P46 test was saved and stored for possible future use by LTPP, and (iii) the comment code 86 was added in reporting the test results.

3.2.4 Untreated Subgrade Soils

Table 3.6 shows the test sample weights as required by the respective LTPP Protocol and/or pertinent AASHTO and ASTM standards. These weights are shown for samples of 1-inch (25-mm), 2-inch (51-mm), and 3-inch (76-mm) maximum size aggregates. The required tests are listed in this table in the sequence in which the tests were to be performed in the laboratory. The mixed and dried bulk sample was reduced to the appropriate test sizes as shown in Table 3.6 using the procedures described in AASHTO T248-83, Reducing Field Samples of Aggregate to Testing Size. The test samples were representative of the total bulk sample.

If the total bulk sample weight, as received from the field and as determined above, was less than the total required weight shown in Table 3.6 then the test samples was obtained from the bulk sample using the following rules.

Rule #1: For 1-inch (25-mm) maximum size aggregates, separate test samples were obtained if the bulk sample from near one end of the section weighed 80 lbs (36 kg) or more. Separate test samples, in the quantities shown in Table 3.6, as appropriate, were obtained for performing the tests using Protocols P51, P43, P42, P52, P55 and P46.

Sample for Storage. A representative 30-lb (14-kg) sample was taken and stored for possible future use by LTPP. Any excess material was discarded after completing the designated tests and obtaining approval.

Rule #2: For 2-inch (51-mm) maximum size aggregates separate test samples were obtained if the bulk sample from near one end of the section weighed more than 140 lbs (64 kg). Separate test samples in the quantities shown in Table 3.6, as appropriate, were obtained for performing the tests using Protocols P51, P43, P42, P52, P55, and P46.

Sample for Storage. A representative 30-lb (14-kg) sample was also taken if the total bulk sample was more than 140 lbs (64 kg) or more and stored for possible future use by LTPP.

The laboratory may have reused material from the P46 testing, if necessary. Any excess material was discarded after completing the designated tests and obtaining approval.

Rule #3: For 2-inch (51-mm) maximum size aggregates, separate test samples were not taken for performing the classification test (Protocol P52 for the subgrade), if the bulk sample weight was within a range of 80 to 140 lbs (36 to 64 kg). Approximate 40-lb (18-kg) test samples were taken for the gradation test (Protocol P51). The classification tests were performed on the test samples for gradation as described in Protocol P52. The comment code 82 was used in reporting the test results for P52 on Form T52.

Rule #4: For 2-inch (51-mm) maximum size aggregates, separate test samples were obtained for Protocols P51, P43, P42, P55 and P46 if the bulk sample was 140 lbs (64 kg) or less but more than 95 lbs (43 kg). If the bulk sample weight was within a range of 80 to 95 lbs (36 to 43 kg) then separate test samples were taken for only Protocols P51, P43, P42, and P55. The P55 test sample was reused for the P46 test. The comment code 83 was used in reporting the test results for P55 and P46.

Sample for Storage. The sample used for the P46 test was saved and stored after completing the test for possible future use by LTPP. The comment code 84 was used in reporting the test results for P46.

Rule #5: For 3-inch (76-mm) maximum size aggregates, a separate test sample for the classification test (Protocol P52) was not obtained from the bulk sample. The classification test was performed based on the test sample for gradation as described in Protocol P52. The comment code 82 was used in reporting the test results for P52.

Rule #6: For 3-inch (76-mm) maximum size aggregates, separate test samples were obtained for Protocols P51, P43, P42, P55, and P46 if the bulk sample was more than 140 lbs (64 kg). Approximate 50-lb (23-kg) test samples were taken for gradation test (Protocol P51) in accordance with Table 3.6.

Sample for Storage. An additional 65-lb (29-kg) sample was taken and stored for possible future use by LTPP if available in the remaining bulk sample. Otherwise, the sample used for P46 was saved after completing the test for future possible use by LTPP and the comment code 84 was used in reporting the test results for P46.

Rule #7: For 3-inch (76-mm) maximum size aggregates, separate test samples were obtained for performing tests according to Protocols P51, P43, P42, and P55 if the bulk sample weighs 80 to 140 lbs (36 to 64 kg). Only 40-lb (18-kg) test samples were taken for gradation test (Protocol P51).

Only dry sieving was used in the gradation test (Protocol P51) if the weight of the bulk sample was within a range of 80 to 140 lbs (36 to 64 kg). The gradation test sample was reused for performing the resilient modulus testing (Protocol P46). The comment code 85 was used in reporting the test results for P51 and P46.

Sample for Storage. The sample from the P46 test was saved and stored after completing the test for possible future use by LTPP. The comment code 84 was used in reporting the test results for P46.

Rule #8: If the total bulk sample for 2- and 3-inch (51- and 76-mm) maximum size aggregate was 40 lbs (18 kg) or more but less than 80 lbs (36 kg) then, (i) only dry sieving was performed for the gradation test (Protocol P51) on a test sample weighing 40 lbs (18 kg), (ii) the gradation test sample was reused for other tests (Protocols P43, P42, P52, P55, and P46), (iii) the sample from the last test was saved and stored for possible future use by LTPP, and (iv) the comment code 86 was added in reporting each test result to indicate this significant deficiency in the sample size.

Rule #9: If the total bulk sample for 1-inch (51-mm) maximum size aggregates was 40 lbs (18 kg) or more but less than 80 lbs (36 kg) then (i) the sample from P55 testing was reused for P46 testing, (ii) the sample from P46 testing was saved and stored for possible future use by LTPP, and (iii) comment code 86 was added in reporting the test results.

Resilient modulus testing of the "undisturbed" thin-walled tube sample may have been performed by the laboratory without waiting for the entire sequence of testing shown in Table 3.6, provided that the thin-walled tube sample was suitable for testing. If the thin-walled tubes were available and acceptable for the resilient modulus test then no bulk sample was needed to reconstitute the test sample for Protocol P46. The comment code 87 was used in reporting the test results for P46 in this case.

If the thin-walled tube sample was not acceptable as described in Protocol P46, then all rules described above were followed to reconstitute the test sample for the resilient modulus testing. The comment code 88 was used in reporting the test results for P46.

If the thin-walled tube samples were not available then all rules described above for the resilient modulus test sample (Protocol P46) were applicable. The test sample was reconstituted from a representative portion of the bulk sample. The comment code 89 was used in reporting the test results for P46.

If available, the untested thin-walled tube sample was marked and stored for possible future use by LTPP. The comment code 90 was used in reporting the test results for P46.

3.2.5 Portland Cement Concrete

PCC cores from pavement sections included in GPS-3, GPS-4, and GPS-5, extracted from the PCC pavement surface, were marked with an arrow or symbol to show the direction of traffic. Any underlaying bonded layer of treated base and/or subbase (including asphalt treated base, lean concrete, econocrete, cement treated aggregate layers) were required to be removed from the PCC cores in the field or by sawing in the laboratory.

PCC cores from pavement sections included in the GPS-7 were retrieved with an overlaid AC core. If the AC core was bonded with the PCC core and/or the underlaying layer of treated base/subbase was bonded with the PCC core, then the PCC core was to be separated by sawing from the bonded layers in the laboratory. The laboratory was required to paint the same arrow or other traffic direction symbol on the top of the surface of each PCC core as that marked on the surface of the overlying AC core.

After assigning proper layer numbers for the GPS-9 experiment, PCC cores were used to obtain test specimens of the concrete overlay layer and the original concrete pavement layer from each specified location. The mark of the traffic direction was transferred to the underlying original concrete pavement layer surface.

The individual layers within the PCC core were separated using the following rules.

Rule #1: Sawing of the PCC core was not required if the specimen consisted of only one layer. The testing was conducted on the core(s) using the instructions in the designated protocol.

Rule #2: Two or more layers within a PCC core were not to be combined for any specified tests.

Rule #3: Any 1.5-inch (38-mm) or thicker PCC layer was separated from the PCC sample by carefully sawing the sample (see note 1). The sawing was performed with special care such that minimal disturbance was made on the sample. The sawing operation was performed on the interface of the layer to be separated so that the PCC would not be weakened by shock or by heating. The sawed surface of cores were to be smooth, plane, parallel, and free from steps, ridges and grooves. The specimens were dried in air at approximately room temperature (60–75°F [16–24°C]). Sample identification was assigned and the specimens were marked with the traffic direction using the procedure described above. The bottom layer was sawed and separated first, followed by the next layer over the bottom layer in ascending order until reaching the top layer.

Rule #4: If a portion of the PCC sample contained one or more layers less than 1.5 inches (38 mm) thick, then no sawing was required for those layers. No further testing of these (less than 1.5-inch [38-mm] thick) layers was required. However, all layers were required to be appropriately marked for sample identification as described above and appropriate layer numbers marked on the side of the sample for each layer.

Note 1: If a PCC core sample was received by the laboratory with a bituminous layer attached, the AC layer was removed from the core by sawing after performance of the visual examination and length measurement test (LTPP Protocol P66). If the thickness of the AC layer was less than 1.5 inches (38 mm), the AC layer was disposed of after the approval of the FHWA Contracting Officer's Technical Representative (COTR). If the AC layer was more than 1.5 inches (38 mm) thick, then the bituminous layer was tested as required. Under SHRP supervision of the program, this testing required shipment of the AC material to the appropriate laboratory.

3.2.6 Sample Combination under the MAP

As might have been observed in the previous sections, it was quite common to combine samples from several locations to create the sample that was used in testing. Samples were identified from the field using a location number and a sample number. The location number (as identified under the description of the L04) was an alphanumeric code usually, but not always, consisting of three digits for the sample location obtained from field markings and Field Operations Information Form 1. This number designated the field location of the sample. If samples were combined from several field locations to form a representative sample for testing, an asterisk was placed in the third digit from the right for the location number (e.g., BA*). This specified that the laboratory test was conducted on a combined sample.

The sample number (as identified under the description of the L04 form) was an alphanumeric code usually containing four digits which identified the type of sample/specimen and the sampling location of the material sample. If samples were combined from several field locations to form a representative sample, asterisks were placed in the third and fourth digit of the LTPP Sample Number (e.g., BG**). The asterisk(s) specified that the laboratory test was conducted on a combined sample.

Unfortunately, the use of the asterisk did not allow for identification of the samples from which the combined sample was created. Therefore, for the MAP testing, a new naming convention was used for the location number and sample number of these samples.

The location number for the sample was designated with an 'LCS' for a laboratory combined sample or 'FCS' for a field combined sample. These three letter designations were followed with a number beginning with '01' and increasing for each additional combined sample of that type for the test section.

The sample number designation followed the same criteria previously in place as described in the Field Sampling Guide.[2] However, immediately following the first two letters of the sample number, an 'X' was used to indicate that the sample had been combined from two or more other samples.

Additionally, a table was added to the PPDB to indicate the identity of the original samples that were used in creating the combined sample identified.

CHAPTER 4. TESTING INSTRUCTIONS

This chapter contains the primary information needed to complete the testing of individual samples for the LTPP program. The tables on the following pages provide a list of the protocols included in this chapter and the expected number of tests per layer for each protocol by experiment type. These target levels of testing were not always achieved.

4.1 LABORATORY MATERIALS TESTING PROGRAM

Details of the laboratory material testing program for basic GPS work are provided in Tables 4.1 to 4.6. These tables provide the layer type, test designation, LTPP protocol, and number of tests per layer.

The expected SPS testing for each material are presented by experiment in Tables 4.7 to 4.22. For the experiments involving rehabilitation, there were two rounds of testing performed and these are presented in two separate tables—one for pre-construction and one for post-construction. For the SPS-9A projects, the laboratory testing program was fairly involved. The required tests for these projects are presented across seven tables based on the layers involved and the types of samples being collected.

The MAP provided new target levels for the amount of testing required for some of the tests. The MAP testing program summary is provided in Table 4.23. Initially, the plan identified several new tests to be completed, including the Direct Tension Test, Bending Beam Rheometer (BBR) testing, and Dynamic Shear Test on asphalt cement; petrographic examination of hardened concrete on the PCC layers; and specific gravity and Dynamic Cone Penetrometer (DCP) testing on the unbound materials. Due to budget limitations, only the specific gravity and DCP testing of unbound materials were pursued for additional testing. However, the protocols developed for all of these tests were included in this chapter for informational purposes.

4.2 PROTOCOLS

After these tables, the protocols required for laboratory testing are provided. Most of the protocols were modifications of existing AASHTO and ASTM standards. The protocols provided specific directions for performing the tests when the tests were done for the LTPP program. In a few instances, neither AASHTO nor ASTM provided a suitable procedure and therefore a "stand alone" protocol was developed (for example, P01). The protocol and the corresponding AASHTO or ASTM procedure (if applicable) were to be rigorously followed when testing was to be performed for the LTPP program. The protocols are presented in numerical order with the laboratory test data sheets provided directly behind each respective protocol.

Table 4.1 Testing Program for GPS-1, AC over Granular Base

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	16
AC02. Bulk Specific Gravity	P02	2
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	2
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	2
b. Extracted Aggregate		
AG04. Gradation of Aggregate	P14	2
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	2
II. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus	P46	2
UG08. Classification	P47	2
UG10. Natural Moisture Content	P49	5
III. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Definitions:

NAA – National Aggregate Association

Table 4.2. Testing Program for GPS-2, AC over Bound Base

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	16
AC02. Bulk Specific Gravity	P02	2
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	2
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	2
b. Extracted Aggregate		
AG04. Gradation of Aggregate	P14	2
AG05. NAA Test for Fine Aggregate Particle Shape.	P14A	2
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Type of Treatment	P31	2
TB02. Compressive Strength	P32	2
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus (at in situ density, moisture)	P46	2
UG08. Classification	P47	2
UG10. Natural Moisture Content	P49	5
IV. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Table 4.3. Testing Program for GPS-3, 4, 5 – JPCP, JRCP, CRCP

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Portland Cement Concrete		
PC01. Compressive Strength of In-Place Concrete	P61	2
PC02. Splitting Tensile Strength	P62	2
PC04. Static Modulus of In-Place Concrete	P64	2
PC06. Visual Examination and Length Measurement of Cores	P66	14
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Type of Treatment	P31	2
TB02. Compressive Strength	P32	2
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus (at in situ density, moisture)	P46	2
UG08. Classification	P47	2
UG09. Natural Moisture Content	P49	5
IV. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Definitions:

JPCP - Jointed Plain Concrete Pavement
JRCP - Jointed Reinforced Concrete Pavement
CRCP - Continuously Reinforced Concrete Pavement

Table 4.4. Testing Program for GPS-6, AC Overlay over AC

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	16
AC02. Bulk Specific Gravity	P02	2
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	2
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	2
b. Extracted Aggregate		
AG04. Gradation of Aggregate	P14	2
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	2
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Type of Treatment	P31	2
TB02. Compressive Strength	P32	2
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus (at in situ density, moisture)	P46	2
UG08. Classification	P47	2
UG10. Natural Moisture Content	P49	5
IV. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Table 4.5. Testing Program for GPS-7, AC Overlay over PCC

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	16
AC02. Bulk Specific Gravity	P02	2
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	2
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	2
b. Extracted Aggregate		
AG04. Gradation of Aggregate	P14	2
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	2
II. Portland Cement Concrete		
PC01. Compressive Strength of In-Place Concrete	P61	2
PC02. Splitting Tensile Strength	P62	2
PC04. Static Modulus of In-Place Concrete	P64	2
PC06. Visual Examination and Length Measurement of Cores	P66	14
III. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Type of Treatment	P31	2
TB02. Compressive Strength	P32	2
IV. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus (at in situ density, moisture)	P46	2
UG08. Classification	P47	2
UG10. Natural Moisture Content	P49	5
V. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Table 4.6. Testing Program for GPS-9, PCC Overlay over PCC

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Portland Cement Concrete		
PC01. Compressive Strength of In-Place Concrete	P61	2
PC02. Splitting Tensile Strength	P62	2
PC04. Static Modulus of In-Place Concrete	P64	2
PC06. Visual Examination and Length Measurement of Cores	P66	14
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Type of Treatment	P31	2
TB02. Compressive Strength	P32	2
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	2
UG02. Sieve Analysis (Washed)	P41	2
UG04. Atterberg Limits	P43	2
UG05. Moisture-Density Relations	P44	2
UG07. Resilient Modulus (at in situ density, moisture)	P46	2
UG08. Classification	P47	2
UG10. Natural Moisture Content	P49	5
IV. Subgrade		
SS01. Sieve Analysis	P51	2
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	2
SS03. Atterberg Limits	P43	2
SS04. Classification/Type of Subgrade Soils	P52	2
SS05. Moisture-Density Relations	P44	2
SS07. Resilient Modulus (at in situ density, moisture)	P46	2
SS09. Natural Moisture Content	P49	5

Table 4.7. Testing Program for SPS-1, Strategic Study of Structural Factors for Flexible Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	60
AC02. Bulk Specific Gravity	P02	60
AC03. Maximum Specific Gravity	P03	3
AC04. Asphalt Content (Extraction)	P04	3
AC05. Moisture Susceptibility	P05	3
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	18
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Recovered Asphalt Cement		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
d. Asphalt Cement from Tanker		
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
II. Asphalt Treated Base		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	34
AC02. Bulk Specific Gravity	P02	34
AC03. Maximum Specific Gravity	P03	3
AC04. Asphalt Content (Extraction)	P04	3
AC05. Moisture Susceptibility	P05	3
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	9
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Recovered Asphalt Cement		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
d. Asphalt Cement from Tanker		
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
III. Permeable Asphalt Treated Base		
AC04. Asphalt Content (Extraction)	P04	3
AG04. Gradation of Extracted Aggregate	P14	3
IV. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG05. Moisture-Density Relations	P44	3
UG07. Resilient Modulus (at in situ density, moisture)	P46	3
UG08. Classification	P47	3
UG09. Permeability	P48	3
UG10. Natural Moisture Content	P49	3
V. Subgrade		
SS01. Sieve Analysis	P51	6
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	6
SS03. Atterberg Limits	P43	6
SS04. Classification	P52	6
SS05. Moisture-Density Relations	P55	6
SS07. Resilient Modulus (at in situ density, moisture)	P46	6
SS08. Unit Weight	P56	6
SS09. Natural Moisture Content	P49	6
SS10. Unconfined Compressive Strength (if thin-walled tube was available)	P54	6
SS11. Permeability (if thin-wall tube was available)	P57	3
UG09. Permeability (if thin-wall tube was not available)	P48	6

Table 4.8. Testing Program for SPS-2, Strategic Study of Structural Factors for Rigid Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Portland Cement Concrete		
PC01. Compressive Strength	P61	
14 day – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
14 day – 550 psi (3.8 MPa) PCC, cores		6
14 day – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
14 day – 900 psi (6.2 MPa) PCC, cores		6
28 day – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
28 day – 550 psi (3.8 MPa) PCC, cores		6
28 day – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
28 day – 900 psi (6.2 MPa) PCC, cores		6
1 year – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
1 year – 550 psi (3.8 MPa) PCC, cores		6
1 year – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
1 year – 900 psi (6.2 MPa) PCC, cores		6
PC02. Splitting Tensile Strength	P62	
14 day – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
14 day – 550 psi (3.8 MPa) PCC, cores		6
14 day – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
14 day – 900 psi (6.2 MPa) PCC, cores		6
28 day – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
28 day – 550 psi (3.8 MPa) PCC, cores		6
28 day – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
28 day – 900 psi (6.2 MPa) PCC, cores		6
1 year – 550 psi (3.8 MPa) PCC, cylinders molded from fresh PCC		3
1 year – 550 psi (3.8 MPa) PCC, cores		6
1 year – 900 psi (6.2 MPa) PCC, cylinders molded from fresh PCC		3
1 year – 900 psi (6.2 MPa) PCC, cores		6
PC03. Coefficient of Thermal Expansion	P63	6

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
PC04. Static Modulus of Elasticity	P64	
28 day – 550 psi (3.8 MPa) PCC		6
28 day – 900 psi (6.2 MPa) PCC		6
1 year – 550 psi (3.8 MPa) PCC		6
1 year – 900 psi (6.2 MPa) PCC		6
PC05. PCC Unit Weight	P65	12
PC06. Visual Examination and Length Measurement of Cores	P66	99
PC08. Air Content	P68	2
II. Lean Concrete Base		
PC01. Compressive Strength	P61	
7 day, cylinders molded from fresh PCC		4
14 day, cores		8
28 day, cylinders molded from fresh PCC		4
28 day, cores		8
1 year, cylinders molded from fresh PCC		4
1 year, cores		8
PC06. Visual Examination and Length Measurement of Cores	P66	24
III. Permeable Asphalt Treated Base		
AC04. Asphalt Content (Extraction)	P04	3
AG04. Gradation of Extracted Aggregate	P14	3
IV. Unbound Granular Base		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG05. Moisture-Density Relations	P44	3
UG07. Resilient Modulus (at in situ density, moisture)	P46	3
UG08. Classification	P47	3
UG09. Permeability	P48	3
UG10. Natural Moisture Content	P49	3
V. Subgrade		
SS01. Sieve Analysis	P51	6
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	6
SS03. Atterberg Limits	P43	6
SS04. Classification	P52	6
SS05. Moisture-Density Relations	P55	6
SS07. Resilient Modulus (at in situ density, moisture)	P46	6
SS08. Unit Weight (if thin-walled tube is available)	P56	6
SS09. Natural Moisture Content	P49	6
SS10. Unconfined Compressive Strength (if thin-walled tube is available)	P54	6
SS11. Permeability (if thin-wall tube is available)	P57	3
UG09. Permeability (if thin-wall tube is not available)	P48	6

Table 4.9. Pre-Construction Testing program for SPS-5, Rehabilitation of Asphalt Concrete Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	26
AC02. Bulk Specific Gravity	P02	9
AC03. Maximum Specific Gravity	P03	3
AC04. Asphalt Content (Extraction)	P04	3
AC07. Creep Compliance, Resilient Modulus, Indirect Tensile Strength	P07	3
AC08. Field Moisture Damage	P08	3
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Asphalt Cement		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Treatment	P31	3
TB02. Compressive Strength	P32	3
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG05. Moisture-Density Relations	P44	3
UG07. Resilient Modulus (at in situ density, moisture)	P46	3
UG08. Classification	P47	3
UG09. Permeability	P48	3
UG10. Natural Moisture Content	P49	3
IV. Subgrade		
SS01. Sieve Analysis	P51	3
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	3
SS03. Atterberg Limits	P43	3
SS04. Classification	P52	3
SS05. Moisture-Density Relations	P55	3
SS07. Resilient Modulus (at in situ density, moisture)	P46	3
SS08. Unit Weight	P56	3
SS09. Natural Moisture Content	P49	3

Table 4.10. Post-Construction Testing program for SPS-5, Rehabilitation of Asphalt Concrete Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	40
AC02. Bulk Specific Gravity	P02	40
AC03. Maximum Specific Gravity	P03	6
AC04. Asphalt Content (Extraction)	P04	6
AC05. Moisture Susceptibility	P05	6
AC07. Creep Compliance, Resilient Modulus, Indirect Tensile Strength	P07	6
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Asphalt Cement		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3

Table 4.11. Pre-Construction Testing Program for SPS-6, Rehabilitation of Jointed Concrete Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Portland Cement Concrete		
PC01. Compressive Strength	P61	10
PC02. Splitting Tensile Strength	P62	10
PC03. PCC Coefficient of Thermal Expansion	P63	3
PC04. Static Modulus of Elasticity	P64	6
PC05. PCC Unit Weight	P65	10
PC06. Visual Examination and Length Measurement of Cores	P66	23
II. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Treatment	P31	3
TB02. Compressive Strength	P32	3
III. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG05. Moisture-Density Relations	P44	3
UG07. Resilient Modulus (at in situ density, moisture)	P46	3
UG08. Classification	P47	3
UG09. Permeability	P48	3
UG10. Natural Moisture Content	P49	3
IV. Subgrade		
SS01. Sieve Analysis	P51	3
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	3
SS03. Atterberg Limits	P43	3
SS04. Classification	P52	6
SS05. Moisture-Density Relations	P55	3
SS07. Resilient Modulus (at in situ density, moisture)	P46	3
SS08. Unit Weight	P56	6
SS09. Natural Moisture Content	P49	3

Table 4.12. Post-Construction Testing program for SPS-6, Rehabilitation of Jointed Concrete Pavements

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	20
AC02. Bulk Specific Gravity	P02	20
AC03. Maximum Specific Gravity	P03	3
AC04. Asphalt Content (Extraction)	P04	3
AC05. Moisture Susceptibility	P05	3
AC07. Creep Compliance, Resilient Modulus, Indirect Tensile Strength	P07	3
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Asphalt Cement		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3

Table 4.13. Pre-Construction Testing Program for SPS-7, Bonded Portland Cement Concrete Overlays

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Bound (Treated) Base and Subbase		
TB01. Type and Classification of Material and Treatment	P31	3
TB02. Compressive Strength	P32	3
II. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG05. Moisture-Density Relations	P44	3
UG07. Resilient Modulus (at in situ density, moisture)	P46	3
UG08. Classification	P47	3
UG09. Permeability	P48	3
UG10. Natural Moisture Content	P49	3
III. Subgrade		
SS01. Sieve Analysis	P51	3
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	3
SS03. Atterberg Limits	P43	3
SS04. Classification	P52	6
SS05. Moisture-Density Relations	P55	3
SS07. Resilient Modulus (at in situ density, moisture)	P46	3
SS08. Unit Weight	P56	6
SS09. Natural Moisture Content	P49	3

Table 4.14. Post-Construction Testing Program for SPS-7, Bonded Portland Cement Concrete Overlays

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Portland Cement Concrete Overlay		
PC01. Compressive Strength	P61	
14-day, cylinders molded from fresh PCC		6
14-day, cores		4
28-day, cylinders molded from fresh PCC		6
28-day, cores		4
1-year, cylinders molded from fresh PCC		6
1-year, cores		4
PC02. Splitting Tensile Strength	P62	
14-day, cylinders molded from fresh PCC		6
14-day, cores		4
28-day, cylinders molded from fresh PCC		6
28-day, cores		4
1-year, cylinders molded from fresh PCC		6
1-year, cores		4
PC03. PCC Coefficient of Thermal Expansion	P63	1
PC04. Static Modulus of Elasticity	P64	
28-day, cores		4
1-year, cores		4
PC05. PCC Unit Weight	P65	
14-day, cores		4
28-day, cores		4
1-year, cores		4
PC06. Visual Examination and Length Measurement	P66	99
PC07. Interface Bond Strength	P67	
28-day		32
1-year		32
PC08. Air Content	P68	
14-day		2
PC09. Flexural Strength	P69	
14-day, cylinders molded from fresh PCC		6
28-day, cylinders molded from fresh PCC		6
1-year, cylinders molded from fresh PCC		6
II. Portland Cement Concrete Original Pavement		
PC01. Compressive Strength	P61	9
PC02. Splitting Tensile Strength	P62	9
PC03. PCC Coefficient of Thermal Expansion	P63	1
PC04. Static Modulus of Elasticity	P64	9
PC05. PCC Unit Weight	P65	9
PC06. Visual Examination and Length Measurement	P66	47

Table 4.15. Testing Program for SPS-8, Study of Environmental Effects in the Absence of Heavy Loads

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	16
AC02. Bulk Specific Gravity	P02	16
AC03. Maximum Specific Gravity	P03	3
AC04. Asphalt Content (Extraction)	P04	3
AC05. Moisture Susceptibility	P05	3
AC07. Creep Compliance, Resilient Modulus, Indirect Tensile Strength	P07	3
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3
AG02. Specific Gravity of Fine Aggregate	P12	3
AG04. Gradation of Aggregate	P14	3
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3
c. Asphalt Cement (Recovered from Mix)		
AE01. Abson Recovery	P21	3
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
d. Asphalt Cement (From Tanker)		
AE02. Penetration at 77°F (25°C), 115°F (46°C)	P22	3
AE03. Specific Gravity at 60°F (16°C)	P23	3
AE05. Viscosity at 140°F (60°C), 275°F (135°C)	P25	3
II. Portland Cement Concrete		
PC01. Compressive Strength	P61	
14-day, cylinders molded from fresh PCC		3
14-day, cores		3
28-day, cylinders molded from fresh PCC		3
28-day, cores		3
1-year, cylinders molded from fresh PCC		3
1-year, cores		3
PC02. Splitting Tensile Strength	P62	
14-day, cylinders molded from fresh PCC		3
14-day, cores		3
28-day, cylinders molded from fresh PCC		3
28-day, cores		3
1-year, cylinders molded from fresh PCC		3
1-year, cores		3
PC03. PCC Coefficient of Thermal Expansion	P63	1
PC04. Static Modulus of Elasticity	P64	

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
28-day		3
1-year		3
PC05. PCC Unit Weight	P65	9
PC08. Air Content, 28-day	P68	1
PC09. Flexural Strength	P69	
14-day		3
28-day		3
1-year		3

Table 4.16. Testing Program Subsurface Layers for SPS-9A, SUPERPAVE™ Asphalt Binder Study

Material Type, Test Designation	LTPP Protocol	Tests Per Layer
New/Re-Construction		
I. Bound (Treated) Base and Subbase		
AC01. Core Examination and Thickness	P01	6
II. Unbound Granular Base and Subbase		
UG01. Particle Size Analysis	P41	3
UG02. Sieve Analysis (washed)	P41	3
UG04. Atterberg Limits	P43	3
UG08. Classification	P47	3
III. Subgrade		
SS01. Sieve Analysis	P51	3
SS03. Atterberg Limits	P43	3
SS04. Classification	P52	3
SS09. Natural Moisture Content	P49	3
Existing Pavement (Overlay Construction)		
I. Existing Surface Layers		
AC01/PC06. Core Examination and Thickness	P01/P66	6
II. Base/Subbase		
Field Classification of Unbound Base	Field Guide	3
AC01. Core Examination and Thickness (Bound Base)	P01	6
III. Subgrade		
SS01. Sieve Analysis	P51	3
SS03. Atterberg Limits	P43	3
SS04. Classification	P52	3
SS09. Natural Moisture Content	P49	3

Table 4.17. Testing Program Aggregate and Binder Materials for SPS-9A, SUPERPAVE™ Asphalt Binder Study

Material Type, Test Designation	LTPP Protocol	Tests Per Unique Material
I. Aggregate Tests		
AG04. Aggregate Gradation	P14	1
AG01. Specific Gravity of Coarse Aggregate	P11	1
AG02. Specific Gravity of Fine Aggregate	P12	1
Specific Gravity of – No. 200 (0.075 mm) Material	AASHTO T100	1
Coarse Aggregate Angularity	Penn DOT TM 621	1
Fine Aggregate Angularity	ASTM C1252	1
Toughness	AASHTO T96	1
Soundness	AASHTO T104	1
Deleterious Materials	AASHTO T112	1
Clay Content	AASHTO T176	1
Thin, Elongated Particles	ASTM D4791	1
II. Asphalt Cement		
Penetration at 41°F (5°C)	AASHTO T49	1
AE02. Penetration at 77°F (25°C) and 115°F (46°C)	P22	1
AE05. Viscosity at 140°F (60°C) and 275°F (135°C)	P25	2
AE03. Specific Gravity at 60°F (16°C)	P23	2
Dynamic Shear at 3 temperatures	AASHTO TP5	2
Brookfield Viscosity at 135°C (275°F) and 165°C (329°F)	ASTM D4402	1
Rolling Thin Film Oven (RTFOT)	AASHTO T240	a
Dynamic Shear on RTFOT Residue at 3 temperatures	AASHTO TP5	3
Pressure Aging (PAV) of RTFOT residue	AASHTO PP1	a
Creep Stiffness of RTFOT-PAV residue at 2 temperatures – 24 hour conditioning	AASHTO TP1	2
Creep Stiffness of RTFOT-PAV residue at 2 temperatures	AASHTO TP1	2
Dynamic Shear on RTFOT-PAV residue at 3 temperatures	AASHTO TP5	2
Direct Tension on RTFOT-PAV residue at 2 temperatures	AASHTO TP3	2

Notes:

a Sufficient material should be conditioned for the required tests.

Table 4.18. Testing Program of Mixture Design Tests on the SPS-9A, SUPERPAVE™ Asphalt Binder Study Materials from Sections 01 and 03

Samples were to be obtained by combining the aggregate and binder materials in the laboratory.

Material Type, Test Designation	LTPP Protocol	Tests Per Section
Gyratory Compaction at design asphalt content at N_{max}	AASHTO M-002	3
Gyratory Compaction at 7% Air Voids	AASHTO M-002	6
AC02. Bulk Specific Gravity	P02	3
AC03. Maximum Specific Gravity	P03	1
AC05. Moisture Susceptibility	P05	1 test requiring 6 lab samples
Volume Percent of Air Voids	AASHTO PP19	3
Percent Voids in Mineral Aggregate	AASHTO PP19	3
Voids Filled with Asphalt	AASHTO PP19	3

Table 4.19. Testing Program on Specimens Compacted from Field Obtained Bulk Mix Samples Taken from Sections 01 and 03 from SPS-9A, SUPERPAVE™ Asphalt Binder Study

Material Type, Test Designation	LTPP Protocol	Tests Per Section
Gyratory Compaction at N_{max}	AASHTO M-002	6
AC02. Bulk Specific Gravity	P02	6
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	2
AG04. Gradation of Extracted Aggregate	P14	2
Volume Percent of Air Voids	AASHTO PP19	6
Percent Voids in Mineral Aggregate	AASHTO PP19	6
Voids Filled with Asphalt	AASHTO PP19	6

Table 4.20. Testing Program on Specimens Compacted from Bulk Mix Samples Taken from Section 02 from SPS-9A, SUPERPAVE™ Asphalt Binder Study

Material Type, Test Designation	LTPP Protocol	Number of Tests[a]
Gyratory Compaction at N_{max}	AASHTO M-002	6 lab mixed samples
Gyratory Compaction at 3% Air Voids	AASHTO M-002	2 lab mixed samples
Gyratory Compaction at 7% Air Voids	AASHTO M-002	32 lab mixed samples
Gyratory Compaction at N_{max}	AASHTO M-002	6 field samples
Gyratory Compaction at 3% Air Voids	AASHTO M-002	2 field samples
Gyratory Compaction at 7% Air Voids	AASHTO M-002	26 field samples
AC02. Bulk Specific Gravity	P02	9 lab samples 9 field samples
AC03. Maximum Specific Gravity	P03	1 lab sample 2 field samples
AC04. Asphalt Content (Extraction)	P04	6 field samples
AC05. Moisture Susceptibility	P05	1 test from 6 lab samples
AG04. Gradation of Extracted Aggregate	P14	2 field samples
Volume Percent of Air Voids	AASHTO PP19	6
Percent Voids in Mineral Aggregate	AASHTO PP19	6
Voids Filled with Asphalt	AASHTO PP19	6
AC07. Creep Compliance, Resilient Modulus and Indirect Tensile Strength	P07	1 set lab samples 1 set field samples
Frequency Sweep at Constant Height and Simple Shear at Constant Height	AASHTO M-003, P-005	3 lab samples 3 field samples
Volumetric Test and Uniaxial Strain	AASHTO M-003, P-005	3 lab samples 3 field samples
Repeated Shear at Constant Stress Ratio	AASHTO M-003, P-005	2 lab samples 2 field samples
Indirect Tensile Creep Compliance and Indirect Tensile Strength	AASHTO M-005	9 lab samples 9 field samples

Notes:

a Lab samples were obtained by mixing aggregate stockpile samples with the asphalt cement in accordance with the mix design. Field samples were obtained from bulk samples of the asphalt concrete.

Table 4.21. Testing Program on Cores from Test Sections 01 and 03 from SPS-9A, SUPERPAVE™ Asphalt Binder Study Projects and from Test Section 02 at all Intervals after A[1]

Material Type, Test Designation	LTPP Protocol	Tests Per Section
AC01. Core Examination and Thickness	P01	8
AC02. Bulk Specific Gravity	P02	8
AC04. Asphalt Content (Extraction)	P04	8
AG04. Gradation of Extracted Aggregate	P14	2
Volume Percent of Air Voids	AASHTO PP19	2
Volume Percent of Voids in Mineral Aggregate	AASHTO PP19	2
Voids Filled with Asphalt	AASHTO PP19	2
AE01. Abson Recovery	P21	8
Penetration at 41°F (5°C)	AASHTO T49	1
AE02. Penetration at 77°F (25°C) and 115°F (46°C)	P22	1
AE03. Specific Gravity at 60°F (16°C)	P23	2
AE05. Viscosity at 140°F (60°C) and 275°F (135°C)	P25	2
Dynamic Shear at 3 temperatures	AASHTO TP5	2
Creep Stiffness at 2 temperatures	AASHTO TP1	2
Direct Tension at 2 temperatures	AASHTO TP3	2

Notes:

1. The cores represented by the number of tests in this table were for each test section to be tested at a specific time interval, t, where t represents the sampling time interval after construction as follows:

   t = A at time 0, immediately after construction
   t = B at 6 months after construction
   t = C at 12 months after construction
   t = D at 18 months after construction
   t = E at 24 months after construction
   t = F at 48 months after construction

Table 4.22. Testing Program for Cores from Test Section 02 on SPS-9A, SUPERPAVE™ Asphalt Binder Study Projects Taken Immediately After Construction

Material Type, Test Designation	LTPP Protocol	Number of Tests
AC01. Core Examination and Thickness	P01	8
AC02. Bulk Specific Gravity	P02	8
AC03. Maximum Specific Gravity	P03	2
AC04. Asphalt Content (Extraction)	P04	8
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	1
AG04. Gradation of Extracted Aggregate	P14	2
Volume Percent of Air Voids	AASHTO PP19	2
Percent Voids in Mineral Aggregate	AASHTO PP19	2
Voids Filled with Asphalt	AASHTO PP19	2
AE01. Abson Recovery	P21	8
Penetration at 41°F (5°C)	AASHTO T49	1
AE02. Penetration at 77°F (25°C) and 115°F (46°C)	P22	1
AE03. Specific Gravity at 60°F (16°C)	P23	2
AE05. Viscosity at 140°F (60°C) and 275°F (135°C)	P25	2
Dynamic Shear at 3 temperatures	AASHTO TP5	2
Creep Stiffness at 2 temperatures	AASHTO TP1	2
Direct Tension at 2 temperatures	AASHTO TP3	2
Frequency Sweep at Constant Height and Simple Shear at Constant Height	AASHTO M003, P005	2
Volumetric Test and Uniaxial Strain	AASHTO M003, P005	2
Repeated Shear at Constant Stress Ratio	AASHTO M003, P005	2
Indirect Tensile Creep Compliance and Indirect Tensile Strength	AASHTO M05, M005	10

Table 4.23. Testing Program for SPS Projects based on the Materials Action Plan

Material Type, Test Designation	LTPP Protocol	Tests per Layer
I. Asphalt Concrete		
a. Asphaltic Concrete		
AC01. Core Examination and Thickness	P01	3 per Section
AC02. Bulk Specific Gravity	P02	3 per Section
AC03. Maximum Specific Gravity	P03	3 per Project
AC04. Asphalt Content (Extraction)	P04	3 per Project
AC07. Creep Compliance, Resilient Modulus, and Indirect Tensile Strength	P07	3 per Project
b. Extracted Aggregate		
AG01. Specific Gravity of Coarse Aggregate	P11	3 per Project
AG02. Specific Gravity of Fine Aggregate	P12	3 per Project
AG04. Gradation of Aggregate	P14	3 per Project
AG05. NAA Test for Fine Aggregate Particle Shape	P14A	3 per Project
c. Asphalt Cement		
AE03. Specific Gravity at 60°F (16°C)	P23	3 per Project
AE05. Viscosity at 140°F (60°C) and 275°F (135°C)	P25	3 per Project
II. Portland Cement Concrete		
PC01. Compressive Strength (aging test)	P61	3 per Project
PC02. Splitting Tensile Strength (aging test)	P62	3 per Project
PC03. PCC Coefficient of Thermal Expansion	P63	2 per Project
PC04. Static Modulus of Elasticity (aging test)	P64	3 per Project
PC06. Core Examination and Thickness	P66	3 per Section
PC08. Air Content	P68	3 per Project
III. Treated Base and Subbase		
TB01. Type and Classification of Material and Treatment	P31	3 per Project
IV. Unbound Granular Base and Subbase		
UG01/UG02. Sieve Analysis	P41	3 per Project
UG04. Atterberg Limits	P43	3 per Project
UG07. Resilient Modulus (at in situ density, moisture)	P46	3 per Project
UG13. Specific Gravity	P70	3 per Project
UG14. Dynamic Cone Penetrometer	P72	3 per Project
V. Subgrade Soils		
SS01. Sieve Analysis	P51	3 per Project
SS02. Hydrometer to 0.001 mm (0.04 mils)	P42	3 per Project
SS03. Atterberg Limits	P43	3 per Project
SS07. Resilient Modulus (at in situe density, moisture)	P46	3 per Project
SS13. Specific Gravity	P70	3 per Project
SS14. Dynamic Cone Penetrometer	P72	3 per Project

All protocols were to be adhered to as standard procedures for the laboratory material testing work. Results from laboratory tests were reported on standard LTPP test forms as provided with each protocol. The pertinent test form number was indicated in the REPORT section of each protocol. In addition, space for comment codes also was included as the second to last item in the REPORT section of each protocol.

The following entries were made on each of the forms in this section: Sheet, Laboratory Performing Test, Laboratory Identification Code, Region, State, Experiment Number, State Code, SHRP ID, Field Set Number, Sampled by, Date Sampled, LTPP Test Designation, LTPP Protocol, Layer Number, Sampling Area No., Laboratory Test Number, Location Number, LTPP Sample Number, Submitted by, Date, Checked and Approved, and Date.

SHEET: All data sheets from the laboratory material testing work on a particular project or test section were assigned sequential numbers starting from 1 for the sample receipt report (Form L01) followed by the sample inspection report (Form L02), preliminary laboratory test assignment (Form L03), laboratory test assignments (Form L04) and so on in increasing order through all of the respective L-type laboratory testing forms and continuing through the T-type laboratory testing forms.

If the information could not be completely filled out on one sheet for one type of sample/test then multiple sheets were used and numbered accordingly ... 1 of 30, 2 of 30, 3 of 30 ....

LABORATORY PERFORMING TEST: The name of the laboratory where the laboratory materials test was conducted was written on this line.

LTPP LABORATORY IDENTIFICATION CODE: The laboratory identification code number assigned to the laboratory performing the test was recorded. The first two digits of the code indicate the state in which the laboratory was operating.

REGION: Identifies the LTPP region in which the project or test section was located:

NA = North Atlantic Region
NC = North Central Region
S = Southern Region
W = Western Region

STATE: Two letter abbreviation (shown in Table 3.2) of the state, District of Columbia, Puerto Rico or the Canadian Province in which the project or test section was located.

EXPERIMENT NO: One of the eight GPS experiments (GPS-1, GPS-2, GPS-3, GPS-4, GPS-5, GPS-6, GPS-7, or GPS-9) or one of the seven SPS experiments (SPS-1, SPS-2, SPS-5, SPS-6, SPS-7, SPS-8 or SPS-9) as shown in Table 3.3 of this Guide.

STATE CODE: Two-digit code as shown in Table 3.2 for the state in which the project or test section was located.

SHRP ID: The four-digit code identifying the specific LTPP test section within the state.

FIELD SET NO: The field set number was a sequentially assigned number to indicate the different time periods in which material samples and field testing were conducted on the project. These time periods usually referred to different stages in the pavement life, such as prior to overlay construction, after overlay construction, end of test, etc. A field set number could have applied to more than one day since sampling of SPS test sections usually required more than one day. As a general rule, the same field set number was applied to all material samples and field tests conducted in a continuous 30-day period, unless a construction event occurred between the two sampling sessions. The number "1" was entered to indicate the first time that material sampling and field testing were conducted on the project.

SAMPLED BY: This was used to identify the Drilling and Sampling Crew who performed the field material sampling and field testing work for this particular project or test section.

DATE (OR DATE SAMPLED): All dates were recorded as mm-dd-yyyy. This date was the date on which the field material sampling and field testing was conducted.

LAYER NUMBER: This item represents the pavement layer number which was assigned by the Participating Laboratory and recorded on Forms L054, L05A, L05B, T01B through T72. This information was based on Field Operations Information Form 2 included in the Field Data Packet received from the Drilling and Sampling Crew, observations of samples in the laboratory packet, inventory data and approval by the Region.

SAMPLING AREA NO: The sampling area number was a two-digit number used to reference all of the samples taken from one area of an SPS project. It has the form SA-##. This number was specified in the materials sampling plan for the project as developed by the LTPP Region.

LABORATORY TEST NUMBER: The number one (1) was used for samples retrieved from locations at Stations 0-. The number two (2) was used for samples retrieved from locations at Stations 5+... The number three (3) was used for samples retrieved from locations within the test section (Stations 0+00 to 5+00). The number four (4) was for samples obtained by combining material from different areas of the test section. The number five (5) was for samples obtained by combining material from multiple test sections. This combining of samples across test sections was required on some SPS projects.

In some tables within the PPDB, laboratory test numbers higher than 5 were used. In these cases, test numbers 6 and 11 have the same meaning as test number 1. Test numbers 7 and 12 have the same meaning as test number 2. Test numbers 8 and 13 have the same meaning as 3. Test numbers 9 and 14 have the same meaning as 4. Test numbers 10 and 15 have the same meaning as 5.

LOCATION NUMBER: This was a three-digit alphanumeric code for the sample location obtained from field markings and Field Operations Information Form 1. This number designated the field location of the sample. Bulk samples may have been combined from several field locations to form a representative sample. See Section 3.2.6 for more information about the location number in these instances.

LTPP SAMPLE NUMBER: This was an alphanumeric four-digit code which had two letters on the left side and two Arabic numerals on the right side which identified the type of sample/specimen and the sampling location of the material sample. Bulk samples may have been combined from several samples to form a representative sample used in testing. See Section 3.2.6 for more information about the sample number identified in these instances.

The first digit on the left was a letter that defines the "sample type." One of the following nine letters was used: C (Core sample), K (Block sample), B (Bulk sample), M (Moisture sample), T (thin-walled tube sample), J (Splitspoon sample), P (chunk and/or broken pieces), F (molded beam), G (molded cylinder).

The second digit from the left end had another letter which indicated the sample material. It may have been one of the following eight letters: A (asphalt concrete), P (portland cement concrete), X (portland cement concrete 14-day test specimens), Y (28-day test specimens), Z (365-day test specimens), T (treated or bound base/subbase), G (granular or unbound base/subbase) and S (subgrade soil). Refer to the Field Sampling Guide for examples and a further explanation of the LTPP sample codes and numbers.(2)

Sample numbers for each sample retrieved from the field and sent to the Participating Laboratory were found on Field Operations Information Form 1 from the Field Data Packet received from the Drilling and Sampling Crew.

At the bottom of each LTPP Standard Form, the following information was required:

SUBMITTED BY, DATE: The signature (clearly written) of the Laboratory Chief and the date of this signature. Underneath this signature, the corporate affiliation of the Laboratory Chief was identified.

CHECKED AND APPROVED, DATE: The signature (clearly written) of the LTPP Representative who checked and approved the report and the date of this signature. Underneath this signature, the corporate affiliation of the LTPP Representative was identified.

PROTOCOL P01
Test Method for Visual Examination and Thickness of Asphaltic Concrete Cores (AC01)

This LTPP protocol covers visual examination, determination of thickness (measurement of length) of asphaltic (bituminous) concrete cores, and layer identification and determination of layer thickness within an AC core. This test shall be the <u>first</u> test to be performed on AC cores from a LTPP pavement section.

The test shall be carried out in accordance with the following procedures, on every AC core retrieved from the C-type and A1, A2, locations from a pavement section. The following definitions will be used throughout this protocol.

a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

c) Test Specimen: That part of the layer which is used for the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

In this protocol the use of the term core implies the entire length of the core.

1. SCOPE

1.1 This method covers the visual examination of the entire AC core and the measurement of the length of the entire AC core in the laboratory.

1.2 This method also covers the identification and determination of thickness of the individual layers within the AC core.

2. APPLICABLE DOCUMENT

2.1 AASHTO T148-86, Measuring Length of Drilled Concrete Cores.

3. APPARATUS

3.1 The apparatus shall be a calipering device that will measure length of axial elements of the core.

3.2 The apparatus shall be so designed that the core will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or stubs of hardened steel, and the ends that bear against the surface of the core shall be rounded to a radius of not less than ¼ in. (6.4 mm) and not more than ½ in. (12.7 mm).

3.3 The apparatus shall provide for the accommodation of cores of different nominal lengths over a range of at least 1 to 10 in. (25 to 250 mm).

3.4 The calipering apparatus shall be so designed that it will be possible to make a length measurement at the center of the upper end of the core and at three additional points spaced at equal intervals along the circumference of a circle of measurement whose center point coincides with the center of the core and whose radius is approximately one-half of the radius of the core.

3.5 The measuring rod or other device that makes contact with the end surface of the core for measurement shall be rounded to a radius of ⅛ in. (3.2 mm). The scale on which the length readings are made shall be marked with clear, definite, accurately spaced graduations. The spacing of the graduations shall be 0.1 in. (2.54 mm) or a decimal part thereof.

3.6 The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without distortion or deflection of more than 0.01 in. (0.25 mm) during all normal and measuring operations.

4. CORE PREPARATION

4.1 If the AC pavement surface is bonded with a treated base or subbase layer and/or PCC layer (as shipped to the laboratory) then the AC core shall be carefully removed by sawing. It is important that layer thickness of each bonded layer shall be measured prior to sawing, and recorded on Form T01A, T31, T66 as appropriate.

4.2 The core shall be free of any condition not typical of the pavement surface. If a core is found damaged or shows abnormal defects then it shall not be used for length measurement and its condition shall be recorded during the visual examination described in Section 6.

4.3 If a core drilled from a pavement placed on an aggregate base course or subbase course includes particles of the aggregate bonded to the bottom surface of the core, then the bonded particles shall be removed by wedging, or by chisel and hammer, applied so as to expose the lower surface of the AC core. If during the removal of the bonded aggregate the AC is broken so that the instructions of Section 5.4 can not be followed, the core shall not be used for length measurement and its condition shall be recorded during the visual examination described in Section 6.

4.4 Care shall be exercised in preserving the marked arrow, if present, on the top surface of the core. The arrow indicates the direction of traffic on the pavement.

5. PROCEDURE FOR THICKNESS (LENGTH) MEASUREMENT

5.1 Before any measurements of the core length are made, the apparatus shall be calibrated with suitable gauges so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.01 in. (0.25 mm), suitable corrections shall be applied to the core length measurements.

5.2 The core shall be placed in the measuring apparatus with the smooth end of the core, that is, the end that represents the upper surface of the pavement placed in the down position so as to bear against the three hardened-steel supports. The core shall be placed on the supports so that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the core.

5.3 Four measurements of the length shall be made on each core, one at the central position and one each at three additional positions spaced at equal intervals along the circumference of the circle of measurement described in Section 3.4. Each of these measurements shall be read to the nearest 0.1 in. (2.5 mm) either directly or by estimation.

5.4 If, in the course of the measuring operation, it is discovered that at one or more of the measurement points the surface of the core is not representative of the general plane of the core because of a small projection or depression, the core shall be rotated slightly about its axis and a complete set of four measurements made with the core in the new position.

5.5 The individual measurements shall be recorded to the nearest 0.1 in. (2.5 mm) and the average of four measurements, expressed to the nearest 0.1 in. (2.5 mm), shall be reported as the average thickness of the core.

5.6 Identification and Determination of Thickness of Individual Layers within an AC core: Determination of the appropriate layer number and layer thickness of individual layers of a pavement structure is vital to LTPP and a critical element for the entire LTPP program. The procedure described in Appendix B to Protocol P01 shall be followed for identification and determination of thickness of individual layers within an AC core.

6. PROCEDURE FOR VISUAL EXAMINATION

6.1 Cores are to be visually examined for general condition, distresses and defects such as cracks, voids, layer separation, aggregate distribution, bleeding, general type and shape of aggregate such as rounded gravel, angular crushed stone, etc. and indication of stripping. The field logs describing the cores should also be reviewed prior to the visual examination in order to be aware of and confirm or reject any notations made in the field.

6.2 The bottom surface of the core shall also be examined and any condition affecting the length measurements, such as uneven surface due to removal of underlying bonded aggregates from the aggregate base or subbase course (as described in Section 4.3), shall be recorded.

6.3 Results of visual examination shall be based on LTPP standard codes, as described in Appendix A to LTPP Protocol P01.

7. REPORT

The following information is to be recorded on Form T01A:

7.1 Sample identification about the entire core shall include: Laboratory Identification Code, State Code, SHRP ID Field Layer Number, Field Set Number, Sample Location Number, LTPP Sample Number.

7.2 Test identification shall include: Laboratory Test Number, Test Date, LTPP Test Designation, LTPP Protocol Number.

7.3 Test Results:

(a) Average Thickness of Core (L) to the nearest 0.1 inch.

(b) Comments based on Visual Examination. Use standard visual examination result codes listed in Appendix A to LTPP Protocol P01 and a note, if needed, not exceeding 25 characters.

7.4 Comments shall include: LTPP standard comment code(s), as shown in Section 4.3 of the LTPP Laboratory Material Testing Guide, and any other note as needed.

7.5 Use Form T01A (Test Sheet T01A) to report the above information (Items 7.1 to 7.4).

7.6 Use Form T01B (Test Sheet T01B) to report the layer number and layer thickness of individual layers within AC core as determined using the procedure of Appendix B to LTPP Protocol P01.

APPENDIX A
CODES FOR VISUAL EXAMINATION OF ASPHALTIC CONCRETE CORES

This attachment to LTPP Protocol P01 describes a series of two-digit codes for reporting the results of visual examination of AC cores.

Code	Description
01	Intact core; excellent condition; suitable for testing.
02	Hairline cracks on the surface of the core; suitable for testing.
03	Cracks and/or voids visible along the side of the core; core is suitable for testing.
04	Badly cracked or damaged core; unsuitable for testing except for maximum specific gravity (AC03) or asphalt content (AC04) tests.
05	Ridges on the sides of the core (identify by placing a straight edge along the side of the core when the distance between the straight edge and core face is $^1/_{16}$ inch [1.6 mm] or greater); such a condition should be recorded if the core is used for any other test.
06	Very rough and uneven bottom surface of the core. Place the core on a level surface. Identify with this code when less than 75% of the surface area is in contact with a level surface when the core is perpendicular to the surface.
07	Core extremely damaged from sampling, shipping, or laboratory handling; unsuitable for testing. Core thickness was not measured.
08	Core was sawed in the laboratory to remove the core from the underlying bonded layer of base, subbase, or PCC
09	Core consisted of two or more AC layers. Core to be sawed in the laboratory and appropriate layer numbers to be assigned to each layer.
10	One or more AC layers have become separated due to sampling, shipping or laboratory handling; other layers, if present, to be sawed; and appropriate layer numbers to be assigned to each layer.
11	Segregation of coarse and fine aggregate is observed over 25% or more of the surface area of the core.
12	Voids in the matrix of the AC mixture are observed along the sides of the core.
13	Voids due to loss of coarse and fine aggregate are observed along the sides of the core.

Code	Description
14	Core is missing significant portions and can not be considered a coherent cylindrical core; unsuitable for testing.
15	Coarse aggregate along the face of the core contains 50% or more of crushed materials with fractured faces.
16	Coarse aggregate along the face of the core is a mixture of uncrushed gravel and crushed gravel or stone.
17	More than 10% of the surface area of the core contains soft and deleterious aggregate particles or clay balls. Soft is defined as those aggregates that can be easily scratched with a knife.
18	Slight stripping. Stripping is defined as the displacement of asphalt cement film from the surface of the aggregate. Slight stripping is identified when the asphalt cement film has been displaced from and/or discoloration is observed on less than 25% of the surface area of the aggregate(s), showing signs of stripping.
19	Severe stripping. A loss of coarse and fine aggregate has been noted over 25% or more of the core face and the asphalt film has been displaced from 25% or more of the surface area of the aggregate(s).
20	Slight bleeding. 5% or less of the asphalt matrix portion of the core is in a non-hardened condition and exhibits shiny and sticky surface.
21	Severe bleeding. More than 5% of the asphalt matrix portion of the core is in a non-hardened condition and exhibits shiny and sticky surface.
22	Skewed core. A core is considered skewed when either end of the core departs from perpendicularity to the axis by more than 0.5 degrees or ⅛ inch in 12 inches (3 mm in 305 mm), as tested by placing the core on a level surface.
99	Other comment (describe in a note).

Any six codes from the above list can be used to report the results of the visual examination. A note may also be recorded (the note shall not be more than 25 characters long).

APPENDIX B
IDENTIFICATION AND DETERMINATION OF THICKNESS OF INDIVIDUAL LAYERS WITHIN AN ASPHALTIC CONCRETE CORE

This attachment to LTPP Protocol P01 covers the identification and determination of the thickness of individual layers within an AC core. The test shall be carried out on every AC core that has been tested by the Protocol P01 procedure for visual examination and determination of thickness of the entire AC core. Identifying layers, assigning appropriate layer numbers, and determining the layer thickness of individual layers within an AC Core are absolutely essential for proper test assignments and imperative in developing the materials portion of the PPDB. The assigned layer numbers shall be used for identifying and reporting all other AC and associated material tests.

1. SCOPE

1.1 This method covers the identification and determination of thickness of the individual layers within the AC core.

2. APPARATUS

2.1 A steel ruler marked with clear, definite, accurately spaced graduations. The spacing of the graduations shall be 0.1 in. (2.54 mm) or a decimal part thereof.

3. TEST PROCEDURE

3.1 Layer Identification - Individual layers within an AC core shall be identified by examining the entire core along its side. The interface of any two adjacent layers shall be marked by using chalk at four approximate equally spaced positions along the circumference of the core. The relevant inventory information on pavement layers and thickness should be reviewed prior to identifying the layers in the core. The LTPP Inventory Data Collection Guide codes for layer descriptions are shown in the following; however it is unlikely that all of the layers will be present in any one core.[19]

Overlay.................................... 01
Seal Coat................................. 02
Original Surface Layer........... 03
AC Layer Below Surface 04
(Binder Course)
Friction Course 09
Surface Treatment 10

3.2 Layer Number Assignment - Proper assignment of layer number(s) within an AC core is vital to LTPP and a critical element prior to performing other laboratory tests. The following rules shall be used for assigning layer numbers to individual layers.

3.2.1 If the entire AC core retrieved from the pavement is intact and consists of only one layer (no layer interface observed and marked in Section 3.1 of Appendix B to Protocol P01) then this entire core is assigned the <u>same</u> layer number as the field layer number assigned to this layer on Field Operations Form 2 by the Drilling and Sampling Crew. Example: The following field layer numbers are assigned on Field Operations Form 2 to the materials samples retrieved from a pavement section included in a LTPP section.

Field Layer Number	Material/Sample Type
4	AC Cores
3	Cement Treated Base (CTB) Cores
2	Unbound Subbase Samples
1	Subgrade Samples

If the AC core consists of only one layer, then its layer number should be 4 (same as the field layer number assigned in the field).

3.2.2 If two or more layers are identified in Section 3.1 of Appendix B to Protocol P01, then the layer numbers are assigned from the bottom layer to the top layer in the laboratory. The layer number of the bottom layer is required to be the same as the field layer number assigned to the entire AC core on Field Operations Information Form 2. The last layer number shall be assigned to the top layer of the AC core. For example, consider a pavement structure for which four layers were identified in the field (Field Operations Information Form 2), as in the example of Section 3.2.1 of Appendix B to Protocol P01. If four layers are identified by the laboratory within the AC core from this pavement, then the following layer numbers will be assigned to the individual layers.

Field Layer Number (for the entire AC Core)	Layers Identified Within the AC Core	Layer Number (from the bottom of the AC core)
4	Binder Course	4
	Original Surface Course	5
	Overlay	6
	Friction Course	7

(Note: The top of the friction course is the pavement surface in the above examples. This example is correct to the extent that there is no discrepancy in the other three layers below the AC layer.)

3.3 Determination of Layer Thickness - The thickness of the individual layers shall be determined to the nearest 0.1 inch (2.54 mm) by taking the average of four measurements at equal distances along the face of the core, on the positions marked for each layer identified in Section 3.1 of Appendix B to Protocol P01.

4. REPORT

The following information is to be recorded on Form T01B:

4.1 Sample identification shall include: Laboratory Identification Code, State Code, SHRP ID, Field Layer Number, Layer Number (as determined in Section 3.2 of Appendix B to Protocol P01), Field Set Number, Sample Location Number, LTPP Sample Number.

4.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

4.3 Test Results:

(a) Layer Number

(b) Layer Description (use the codes shown in Section 3.1 of Appendix B to Protocol P01 for describing the individual layers within the AC Core).

(c) Layer Thickness for each layer within the AC Core, to the nearest 0.1 inches

4.4 Comments shall include: LTPP standard comment code(s), as shown in Section 4.3 of this Guide, and any other note as needed.

4.5 Use Form T01B (Test Sheet T01B) to report the above information (Items 4.1 to 4.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
AC CORE EXAMINATION AND THICKNESS
LAB DATA SHEET T01A

ASPHALT CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC01/LTPP PROTOCOL P01

(This form is to be used to describe the entire AC core only)
(Treated base/subbase portions of the cores should be described on Form T31)

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. FIELD LAYER NUMBER (FROM FIELD OPERATIONS FORM 2) __

2. SHRP ID	__ __ __ __	__ __ __ __	__ __ __ __
3. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __
4. LABORATORY TEST NO.	__	__	__
5. LOCATION NUMBER	__ __ __	__ __ __	__ __ __
6. SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __
7. AVERAGE THICKNESS* (L) inches	__ __ . __	__ __ . __	__ __ . __
8. VISUAL EXAMINATION			
(a) CODE (Section 7.3(b), Protocol P01)	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___
(b) NOTE	______________ ______________ ______________	______________ ______________ ______________	______________ ______________ ______________
9. COMMENTS			
(a) CODE (Section 7.4, Protocol P01)	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___
(b) NOTE	______________ ______________	______________ ______________	______________ ______________
10. TEST DATE	___ - ___ - ____	___ - ___ - ____	___ - ___ - ____

* Measure AC core thickness prior to sawing from other bonded layers.

GENERAL REMARKS:______________________________

SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

_________________________ | _________________________

LABORATORY CHIEF

Affiliation_________________ | Affiliation__________________

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
AC CORE EXAMINATION AND THICKNESS
LAB DATA SHEET T01B

ASPHALT CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC01/LTPP PROTOCOL P01

(This form is to be used to report detailed information as described in Appendix B to Protocol P01)

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. (FIELD) LAYER NUMBER (FROM FORM T01A) __

2. SHRP ID	__ __ __ __			__ __ __ __			__ __ __ __		
3. SAMPLING AREA NO. (SA-)	__ __			__ __			__ __		
4. LABORATORY TEST NO.	__			__			__		
5. LOCATION NUMBER	__ __ __			__ __ __			__ __ __		
6. SAMPLE NUMBER	__ __ __ __			__ __ __ __			__ __ __ __		
7. LAYER INFORMATION		LAYER			LAYER			LAYER	
(Start layer number from the bottom layer within the AC Core)	NO.	DESC.	THICK (in)	NO.	DESC.	THICK (in)	NO.	DESC.	THICK (in)
	___	__ __	__ __ . __	___	__ __	__ __ . __	___	__ __	__ __ . __
	___	__ __	__ __ . __	___	__ __	__ __ . __	___	__ __	__ __ . __
	___	__ __	__ __ . __	___	__ __	__ __ . __	___	__ __	__ __ . __
	___	__ __	__ __ . __	___	__ __	__ __ . __	___	__ __	__ __ . __
	___	__ __	__ __ . __	___	__ __	__ __ . __	___	__ __	__ __ . __
8. COMMENTS									
(a) CODE	__ __ __ __ __ __			__ __ __ __ __ __			__ __ __ __ __ __		
	__ __ __ __ __ __			__ __ __ __ __ __			__ __ __ __ __ __		
(b) NOTE	______________			______________			______________		
	______________			______________			______________		
9. TEST DATE	__ __ - __ __ - __ __ __ __			__ __ - __ __ - __ __ __ __			__ __ - __ __ - __ __ __ __		

* Same layer number as entered in item 1 (Field layer number) if there is no other discrepancy in layers identified in the field and laboratory.
GENERAL REMARKS:____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_______________________ __________________________
LABORATORY CHIEF

Affiliation________________ Affiliation____________________

PROTOCOL P02
Test Method for Bulk Specific Gravity of Asphaltic Concrete (AC02)

This LTPP protocol covers the determination of the bulk specific gravity of asphaltic (bituminous) concrete cores and this test shall be carried out in accordance with AASHTO T166-88I (Method A) as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard (AASHTO T166-88I, Method A) shall be followed as written. This test shall be performed on cores obtained from test sections included in the LTPP experiments.

1. SCOPE

1.2 This method should not be used with samples that contain open or interconnecting voids and/or absorb more than 2 percent of water by volume, as determined by LTPP Protocol P02.

2. TEST SPECIMENS

2.1 Test specimens will be cores obtained from a bituminous pavement section.

2.2 Size of specimens: The size of the bituminous concrete cores will be as specified in the laboratory test program.

2.4 Care shall be taken to avoid distortion, bending or cracking of specimens during and after the removal from the pavement, and during storage in the laboratory. Specimens shall be stored in a safe, cool place.

2.5 If required, specimens may be separated from other pavement layers by sawing.

4. PROCEDURE

4.1 Follow the guidelines of Note 3, first the immersed mass, then the surface dry mass and finally the dry mass.

5. CALCULATION

5.3 If the percent water absorbed by the first specimen in Section 5.2 exceeds 2 percent, use Appendix A (Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens) to LTPP Protocol P02.

6. APPARATUS (METHOD B)

Delete

7. PROCEDURE (METHOD B)

Delete

8. CALCULATIONS (METHOD B)

Delete

9. PROCEDURE (METHOD C)

Delete

10. CALCULATIONS (METHOD C)

Delete

12. REPORT

12.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

12.2 Test Identification shall include: Laboratory Test Number, Test Date, LTPP Test Designation, LTPP Protocol Number.

12.3 Test Results

(a) Bulk Specific Gravity (BSG) to three decimal places.

(b) Percent Water Absorbed by Volume, percent (to the nearest whole number).

(c) Bulk Specific Gravity (paraffin-coated specimen) to three decimal places.

12.4 Comments shall include LTPP standard comment code(s) listed in Section 4.3 and any other note as needed.

12.5 Use Form T02 (Test Sheet T02) to report the above information (Items 12.1 to 12.4).

APPENDIX A
BULK SPECIFIC GRAVITY OF ASPHALTIC CONCRETE USING PARAFFIN-COATED SPECIMENS.

This appendix to LTPP Protocol P02 covers the determination of bulk specific gravity of paraffin-coated cores of asphaltic (bituminous) concrete and this test shall be carried out in accordance with AASHTO T275-83 (Method A) as modified and described in the following. The test shall be carried out only if more than two percent of water is absorbed by the specimen using LTPP Protocol P02. This test shall be performed on cores obtained from test sections included in the LTPP experiments.

1. SCOPE

1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted bituminous mixtures as defined in AASHTO M 132, Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases.

1.2 This method should be used with samples that contain open or interconnecting voids and/or absorb more than 2 percent of water by volume, as determined by LTPP Protocol P02.

1.3 The bulk specific gravity of the compacted bituminous mixtures may be used in calculating the unit weight of the mixture.

2. TEST SPECIMENS

2.1 Test specimens will be cores obtained from a bituminous pavement section. The mixtures may be surface or wearing course, binder or leveling course, or bituminous base.

2.2 Size of Specimens: The size of the bituminous concrete cores will be as specified in the laboratory test program.

2.3 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement and during storage in the laboratory. Specimens shall be stored in a safe, cool place.

2.4 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

2.5 If required, specimens may be separated from other pavement layers by sawing.

3. APPARATUS

3.1 Balance - Conforming to the requirements of AASHTO M231, for the class of balance required for the sample weight of the sample being tested. The balance shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of balance. (Note 1)

Note 1 - the holder should be immersed to a depth sufficient to cover it and the test sample during weighing. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

3.2 Water Bath - For immersing the specimen in water while suspended under the balance, equipped with an over low outlet for maintaining a constant water level.

4. PROCEDURE

4.1 Mass of Uncoated Specimens - Weight the specimen after it has been dried to a constant mass. Designate this mass as A. (Note 2).

Note 2 - Constant shall be defined as the mass at which further drying as 125 ± 5°F (52 ± 3°C) does not alter the mass 0.05 percent. The sample shall initially be dried overnight at 125 ± 5°F (52 ± 3°C) and then weighed at two hour drying intervals.

4.2 Mass of Coated Specimen in Air - Coat the test specimen on all surfaces with melted paraffin sufficiently thick to seal all voids. Allow the coating to cool in air at room temperature for 30 minutes and then weigh the specimen. Designate this mass as D. (Notes 3 and 4).

Note 3 - The specimen shall be dusted with powdered talc prior to coating in order to utilize the specimen for further tests which require the removal of the paraffin coating.

Note 4 - Application of the paraffin may be accomplished by chilling the specimen in a refrigerating unit to a temperature of approximately 40°F (4.5°C) for 30 minutes and then dipping the specimen in warm paraffin (10°F [5.5°C] above melting point). It may be necessary to brush the surface of the paraffin with added hot paraffin in order to fill any pinpoint holes.

4.3 Mass of Coated Specimen in Water - Weigh the coated specimen in water bath at 77 ± 2°F (25 ± 1°C). Designate the mass as E.

4.4 Specific Gravity of Paraffin - Determine the specific gravity of the paraffin at 77 ± 2°F (25 ± 1°C), if unknown, and designate this as F.

5. CALCULATION

5.1 Calculate the bulk specific gravity of the specimen as follows (report the value to three decimal places):

$$BulkSpecificGravity = \frac{A}{D - E - {(D - A)}/{F}}$$

Where: A = mass of the dry specimen in air, g,
D = mass of the dry specimen plus paraffin coating in air, g,
E = mass of the dry specimen plus paraffin in water, g,
F = specific gravity of the paraffin at 77°F ± 2°F (25 ± 1°C).

6. REPORT

Report the test result in item 12.3(c) of LTPP Protocol P02.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
BULK SPECIFIC GRAVITY
LAB DATA SHEET T02

ASPHALT CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC02/LTPP PROTOCOL P02

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. SHRP ID	__ __ __ __	__ __ __ __	__ __ __ __
3. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __
4. LABORATORY TEST NUMBER	__	__	__
5. LOCATION NUMBER	__ __ __	__ __ __	__ __ __
6. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __
7. BULK SPECIFIC GRAVITY (BSG)	__ . __ __ __	__ . __ __ __	__ . __ __ __
8. WATER ABSORBED, %	__ __	__ __	__ __
9. TEST ON PARAFFIN COATED SPECIMEN (YES/NO)	_____	_____	_____
10. BSG (PARAFFIN COATED SPECIMEN)	__ . __ __ __	__ . __ __ __	__ . __ __ __
11. COMMENTS			
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	______________ ______________	______________ ______________	______________ ______________
12. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

(Do not use the test result with water absorption of more than 2 percent.)

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

Affiliation__________________ Affiliation____________________

PROTOCOL P03
Test Method for Maximum Specific Gravity of Asphaltic Concrete (AC03)

This LTPP protocol covers the determination of the maximum specific gravity of asphaltic (bituminous) concrete and the test shall be carried out in accordance with AASHTO T209-82 (86) as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard will be followed as written. The test shall be performed on AC material obtained from test sections included in the LTPP experiments.

1. SCOPE

1.1 This method covers the determination of the maximum specific gravity of AC samples taken from a pavement.

2. APPLICABLE DOCUMENT

2.1 Delete

3. APPARATUS

3.1 Balance, with ample capacity, and with sufficient sensitivity to enable maximum specific gravities of samples of AC to be calculated to at least four significant figures; that is, to at least three decimal places. It shall be equipped with a suitable suspension apparatus and holder to permit weighing the sample while suspended from the center of the scale pan of the balance.

5. TEST SAMPLES

5.1 The core sample shall be used after performing other nondestructive laboratory tests on the sample. The size of the sample shall conform to the requirement given in 5.2 or the acceptable available sample, whichever is minimum.

5.3 The core sample shall be heated in an oven until it softens so that the coarse aggregate that was cut or sliced during the coring operations can be removed from the sides. The sliced aggregate shall be carefully removed so as not to remove or disturb the unsliced aggregate.

10. REPORT

10.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

10.2 Test Identification shall include: Laboratory Test Number, Test Date, LTPP Test Designation, LTPP Protocol Number.

10.3 Test Results

(a) Maximum Specific Gravity (GMM), to four significant figures; that is, to at least three decimal places.

10.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 and any other note as needed.

10.5 Use Form T03 (Test Sheet T03) to report the above information (Items 10.1 to 10.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
MAXIMUM SPECIFIC GRAVITY
LAB DATA SHEET T03

ASPHALTIC CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC03/LTPP PROTOCOL P03

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. SHRP ID	__ __ __ __	__ __ __ __	__ __ __ __
3. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __
4. LABORATORY TEST NUMBER	__	__	__
5. LOCATION NUMBER	__ __ __	__ __ __	__ __ __
6. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __
7. MAXIMUM SPECIFIC GRAVITY (GMM)	__ . __ __ __	__ . __ __ __	__ . __ __ __
8. COMMENTS			
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	________________ ________________	________________ ________________	________________ ________________
9. TEST DATE	__ __ - __ __ - __ __ __ __	__ __ - __ __ - __ __ __ __	__ __ - __ __ - __ __ __ __

GENERAL REMARKS:____

____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

__________________________ __________________________
LABORATORY CHIEF

Affiliation__________________ Affiliation____________________

PROTOCOL P04
Test Method for Asphalt Content of Asphaltic Concrete (AC04)

This LTPP protocol covers the determination of the asphalt content of asphaltic (bituminous) materials retrieved from the LTPP test sections and this test shall be carried out in accordance with AASHTO T164-05 (Method A) as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard (AASHTO T164-05, Method A) shall be followed as written. The test shall be performed on the samples taken from: (a) 12-in. (305-mm) diameter AC cores, (b) block AC samples taken from the test pit(s), (c) bulk samples of AC retrieved from the test section, or (d) as otherwise directed by LTPP.

1. SCOPE

1.1 This method covers the quantitative extraction of asphalt (bitumen) from AC paving mixtures and pavement samples.

6. REAGENT

Reagent-grade Trichloroethylene, as specified in Section 6.5 of AASHTO T164-05, is required by LTPP as the solvent. (Proper care shall be exercised in the laboratory to ensure all safety procedures associated with this solvent are followed.)

8. SAMPLING

8.1 The samples for the test shall be taken from (a) 12-in. (305-mm) diameter AC core(s) (and separated from any other layer, if necessary), (b) block sample(s) (from the test pit locations), (c) bulk samples of AC or (d) as otherwise directed by LTPP. These locations are shown in the LTPP field material sampling plans. The steps shown in 8.2 shall be followed to prepare the test specimen.

8.2 Preparation of Test Specimens

8.2.2 The test sample shall be taken from the middle of the warmed-up core or block or a representative portion of the AC mix bulk sample. Caution shall be taken to avoid the sliced aggregate from the outer sides of the core or block sample in the test sample. The size of the test sample shall be governed by the nominal maximum aggregate size in the AC mixture and by the requirements shown in Table 1 of AASHTO T164-05. Generally the size of the test sample shall conform to the following guidelines.

Nominal Maximum Aggregate Size	Recommended Test Sample Size
½ inch (12.5 mm)	3.0 – 3.5 lbs. (1.4 – 1.6 kg)
¾ inch (19.0 mm)	4.0 – 4.5 lbs. (1.8 – 2.0 kg)

Nominal Maximum Aggregate Size	Recommended Test Sample Size
1 inch (25.0 mm)	6.5 – 7.0 lbs (2.9 – 3.2 kg)
1 ½ inch (37.5 mm)	8.5 – 9.0 lbs (3.9 – 4.1 kg)

In any event, if the available material does not provide an adequate size test specimen and is 25 percent less than the recommended minimum size, then this size deficiency can be made up by taking more material from one of the other cores from the same sampling area (and same testable layer) after it has been tested using the specified nondestructive test (such as LTPP test AC02).

8.2.3 In addition, a test specimen is required for the determination of moisture (Section 9) in the mixtures. Take this test specimen from the remaining portion of the layer immediately after obtaining the extraction test specimen.

Note 3 - Delete.

11. PROCEDURE (METHOD A)

12. CALCULATION

12.2 Calculate the percent asphalt content (BC) using the following:

$$Asphalt(Bitumen)Content,\% = \frac{(W_1 - W_2) - (W_3 + W_4)}{W_1 - W_2} \times 100$$

Where W_1, W_2, W_3, and W_4 are the same as defined in 12.1 of the AASHTO Standard.

13. APPARATUS (METHOD B)

Delete

14. PREPARATION OF TEST PORTIONS (METHOD B)

Delete

15. PROCEDURE (METHOD B)

Delete

16. CALCULATION OF BITUMEN CONTENT (METHOD B)

Delete

17. APPARATUS (METHOD C)

Delete

18. PREPARATION OF TEST PORTIONS (METHOD C)

Delete

19. PROCEDURE (METHOD C)

Delete

20. CALCULATION OF BITUMEN CONTENT (METHOD C)

Delete

21. APPARATUS (METHOD D)

Delete

22. PREPARATION OF TEST PORTIONS (METHOD D)

Delete

23. PROCEDURE (METHOD D)

Delete

24. CALCULATION OF BITUMEN CONTENT (METHOD D)

Delete

25. APPARATUS (METHOD E)

Delete

26. REAGENTS AND MATERIALS (METHOD E)

Delete

27. PREPARATION OF TEST PORTIONS (METHOD E)

Delete

28. PROCEDURE (METHOD E)

Delete

29. CALCULATION OF BITUMEN CONTENT (METHOD E)

Delete

31. REPORT

31.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

31.2 Test Identification shall include: Laboratory Test Number, Test Date, LTPP Test Designation, LTPP Protocol Number.

31.3 Test Results

Asphalt content, in percentage form, to one decimal place (BC).

31.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 and any other note as needed.

31.5 Use Form T04 (Test Sheet T04) to report the above information (Items 31.1 to 31.4).

SHEET ____ OF ____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
ASPHALT CONTENT (QUANTITATIVE EXTRACTION)
LAB DATA SHEET T04

ASPHALTIC CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC04/LTPP PROTOCOL P04

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2.	SHRP ID	__ __ __ __	__ __ __ __	__ __ __ __
3.	SAMPLING AREA NO. (SA-)	__ __	__ __	__ __
4.	LABORATORY TEST NUMBER	__	__	__
5.	LOCATION NUMBER	__ __ __	__ __ __	__ __ __
6.	LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __
7.	ASPHALT CONTENT (BC)	__ __ . __ %	__ __ . __ %	__ __ . __ %
8.	COMMENTS			
	(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
	(b) NOTE	______________ ______________	______________ ______________	______________ ______________
9.	TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS: ____

____

SUBMITTED BY, DATE

____
LABORATORY CHIEF

Affiliation_______________

CHECKED AND APPROVED, DATE

____

Affiliation_______________

PROTOCOL P05
Test Method for Moisture Susceptibility of Asphaltic Concrete (AC05)

This LTPP Protocol describes a method for determining the moisture susceptibility of asphalt concrete specimens. This test is based primarily on AASHTO T283. The test shall be performed on compacted specimens obtained from projects included within the LTPP experiments.

1. SCOPE

1.1 General

This method involves the evaluation of changes in tensile strength resulting from the effects of saturation and accelerated water conditioning of compacted bituminous mixtures. The results can be used as indicators of the long term stripping susceptibility of bituminous mixtures. In this procedure, stripping is defined as the breaking of the bond between the asphalt cement and the aggregate surfaces resulting in exposed aggregate surfaces with minimal or no asphalt cement coating. The extent of stripping is established on a 102-mm (4-in) core split in indirect tension.

1.2 Summary of Test Method

Eight test specimens are required from each asphalt concrete bulk sample. Two of the cores will be used to establish the vacuum saturation technique outlined in Section 8.3. The remaining six cores shall be divided into two equal subsets of three specimens each. The first subset is tested in the dry condition for indirect tension. The second subset is subjected to vacuum saturation followed by freeze and warm-water soaking cycles and then tested in indirect tension to determine the tensile strength. Numerical indices of tensile strength properties including mean values (Y), standard deviation (S_d) and coefficient of variation (i.e., CV = 100 S_d/Y) are computed from the test data obtained from the two subsets; dry and conditioned.

1.3 Significance and Use

This method involves an evaluation of the effects of saturation and accelerated water conditioning on the tensile strength of bituminous mixtures compacted in the laboratory. In particular, this method will be used to investigate bituminous mixtures produced for use in the LTPP experiments.

Numerical indices of retained indirect tensile properties are obtained by comparing the tensile properties of saturated, accelerated water-conditioned laboratory specimens with similar properties of dry specimens.

1.4 Sample Storage

AC cores should be stored flat side down, fully supported, and between 5°C (40°F) and 21°C (70°F) in an environmentally protected (enclosed area not subject to the natural elements) storeroom.

Each sample shall have a label or tag attached that clearly identifies the material, the project number/test section from which it was recovered and the sample number, as a minimum.

1.5 Units

In this protocol, the International System of Units (SI - The Modernized Metric System) is regarded as the standard. Units are expressed first in their "soft" metric form followed, in parenthesis, by their U.S. Customary unit equivalent.

2. TESTING

2.1 Moisture Susceptibility testing shall be conducted <u>after</u>; (1) approval by the FHWA COTR to begin AC moisture susceptibility testing, (2) approval of Form L04 by the FHWA-LTPP Region, (3) visual examination and thickness of AC cores and thickness determination of layers within AC cores using Protocol P01, and (4) final layer assignment based on the P01 test results (corrected form L04, if needed) have been completed. To attain approval under item (1), the laboratory must; (a) submit and obtain approval of the QC/QA plan for the moisture susceptibility testing, and (b) demonstrate that their testing equipment meets or exceeds the specifications contained in this protocol.

2.2 Test Sample Locations and Assignment of Laboratory Test Numbers

The test shall be performed on recompacted test specimens of asphalt concrete retrieved from LTPP test sections as dictated by the sampling plans for the particular project.

The test results shall be reported separately for test samples obtained from the beginning, middle, and end of a test section as follows:

(a) Beginning of the Section (Stations 0-): samples of each layer that are retrieved from areas in the approach end of the test section (stations preceding 0+00) shall be assigned Laboratory Test Number '1'.

(b) End of the Section (Stations 5+): samples of each layer that are retrieved from areas in the leave end of the test section (stations after 5+00) shall be assigned Laboratory Test Number '2'.

(c) Middle of the Section (Stations 0 to +5): samples of each layer that are retrieved from areas in the middle of the test section (from the paver) shall be assigned Laboratory Test Number '3'.

3. DEFINITIONS

The following definitions are used throughout this protocol:

3.1 Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous.

3.2 Test Specimen: That part of the layer which is used for the specified test.

4. APPLICABLE DOCUMENTS

4.1 AASHTO Standards

T166 Bulk Specific Gravity of Compacted Bituminous Mixtures
T167 Compressive Strength of Bituminous Mixtures
T168 Sampling Bituminous Paving Mixtures
T209 Maximum Specific Gravity of Bituminous Paving Mixtures
T245 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
T246 Resistance to Deformation and Cohesion of Bituminous Mixtures by Means of Hveem Apparatus
T247 Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor
T283 Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

4.2 ASTM Standards

D3387 Test for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)

4.3 LTPP Protocols

Protocol P01 -Visual Examination and Thickness of Asphaltic Concrete Cores
Protocol P02 -Bulk Specific Gravity of Asphaltic Concrete
Protocol P03 -Maximum Specific Gravity of Asphaltic Concrete

5. APPARATUS

5.1 Equipment for preparing and compacting specimens from one of the following AASHTO Methods: T245 and T247, or ASTM Method D3387.

5.2 Vacuum Container from AASHTO T209 and vacuum pump or water aspirator from AASHTO T209 including manometer or vacuum gauge.

5.3 Balance and water bath from AASHTO T166.

5.4 Water bath capable of maintaining a temperature of 60 ± 1°C (140 ± 1.8°F).

5.5 Freezer maintained at -18 ± 3°C (0 ± 5°F).

5.6 A supply of plastic film for wrapping, heavy-duty leak proof plastic bags to enclose the saturated specimens and masking tape.

5.7 10-ml graduated cylinder.

5.8 Aluminum pans having a surface area of 485 to 645 cm^2 (75 to 100 in^2) in the bottom and a depth of approximately 25 mm (1 in).

5.9 Forced air draft oven capable of maintaining a temperature of 60 ± 1°C (140 ± 1.8°F).

5.10 Loading jack and ring dynamometer from AASHTO T245, or a mechanical or hydraulic testing machine from AASHTO T167 to provide a range of accurately controllable rates of vertical deformation including 51 mm per minute (2 inches per minute).

5.11 Loading Strips - Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 102 mm (4 in) in diameter, the loading strips shall be 12.7-mm (0.5-in) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the curved portion of the loading strips shall be rounded by grinding to remove the sharp edge in order to not cut into the sample during testing.

5.12 Recording Device - An X-Y plotter or real time computer generated plot shall be used to record the maximum compressive load applied to each test specimen.

6. PREPARATION OF LABORATORY TEST SPECIMENS

6.1 Specimens with a nominal diameter of 102 mm (4 in) and a height of 63.5 mm (2.5 in) are to be prepared. Aggregate particles larger than 25.4 mm (1 in) should be scalped out prior to specimen preparation. The specimens should represent only <u>one</u> layer of the pavement structure.

6.2 After mixing, the mixture shall be placed in an aluminum pan having a bottom surface area of 485 to 645 cm^2 (75 to 100 in^2) and a depth of approximately 25 mm (1 in) and cooled at room temperature for 2 ± 0.5 hours. The mixture shall then be placed in a 60°C (140°F) oven for a curing period of 16 hours.

6.3 After curing, the mixture shall be placed in an oven at 135°C (275°F) for 2 hours prior to compaction. The mixture shall then be compacted to 7 ± 1.0 percent air voids or a specific void level expected in the field. The level of voids can be obtained by either adjusting the number of blows in AASHTO Method T245; adjusting foot pressure, number of tamps, leveling load, or some combination of these in AASHTO Method T247; or adjusting the number of revolutions in ASTM D3387. The exact procedure must be determined experimentally for each mixture before the eight specimens are prepared. In all cases, ASTM D3387 is the preferred method of compaction. AASHTO T245 or T247 shall only be used if the necessary equipment or expertise is not available to perform ASTM D3387.

6.4 After the specimen is extracted from the mold, it shall be subjected to an adequate cool-down period. A centering device (see Figure 1) shall then be used to scribe diametral lines on the front and back faces of the test specimens. The lines shall be scribed to pass through the center of the test specimen and will represent the axis for indirect tensile testing. It is very important to insure that the diametral marks on the front and back faces of the specimen lie in the same vertical plane. If access is limited at the rear face of the specimen, the alignment of the scribed line on the back face can be checked with the use of a mirror.

Note: Sample Number Convention. When retrieved from the field the bulk sample of asphaltic material will have a Location Number similar to "B##" and a Sample Number similar to "BV##", "BR##", "BA##" or "BT##." After compaction, each individual compacted sample shall be assigned a new Sample Number. This Sample Number should begin with the letter "D" (representing a molded sample), followed by the letter "A" (representing asphaltic material) or "T" (representing asphalt treated material), as appropriate. The last two digits should be a number assigned consecutively from one to the number of samples molded from a given bulk sample. Generally, the Sample Numbers for a given bulk sample of AC will be DA01, DA02, DA03, DA04, DA05, DA06, DA07 and DA08. This Sample Number shall follow the molded sample through all subsequent phases of materials testing. The Location Number shall remain as specified for the bulk sample.

6.5 The test specimens shall be stored for 72 to 96 hours at room temperature.

7. ASSOCIATED TEST REQUIREMENTS

7.1 The theoretical maximum specific gravity of the mixture shall be determined (using a separate uncompacted portion of the AC mixture) using LTPP Protocol P03.

7.2 The specimen thickness shall be obtained in accordance with LTPP Protocol P01.

7.3 The bulk specific gravity of each compacted specimen shall be determined using LTPP Protocol P02.

7.4 The estimated air voids of each specimen shall be calculated using AASHTO T269.

7.5 The specimens shall be sorted into two equal subsets of three samples each. The average air voids of the two subsets shall be approximately equal.

8. PRECONDITIONING OF TEST SPECIMENS

Of the original eight samples, three each are to be tested as dry and conditioned specimens. The remaining two samples are to be used in establishing the proper saturation method in order to avoid damaging any of the three conditioned samples. If an acceptable saturation level cannot be achieved using the two extra samples, then one of the three samples to be conditioned can be used to attempt a third combination of time and vacuum pressure.

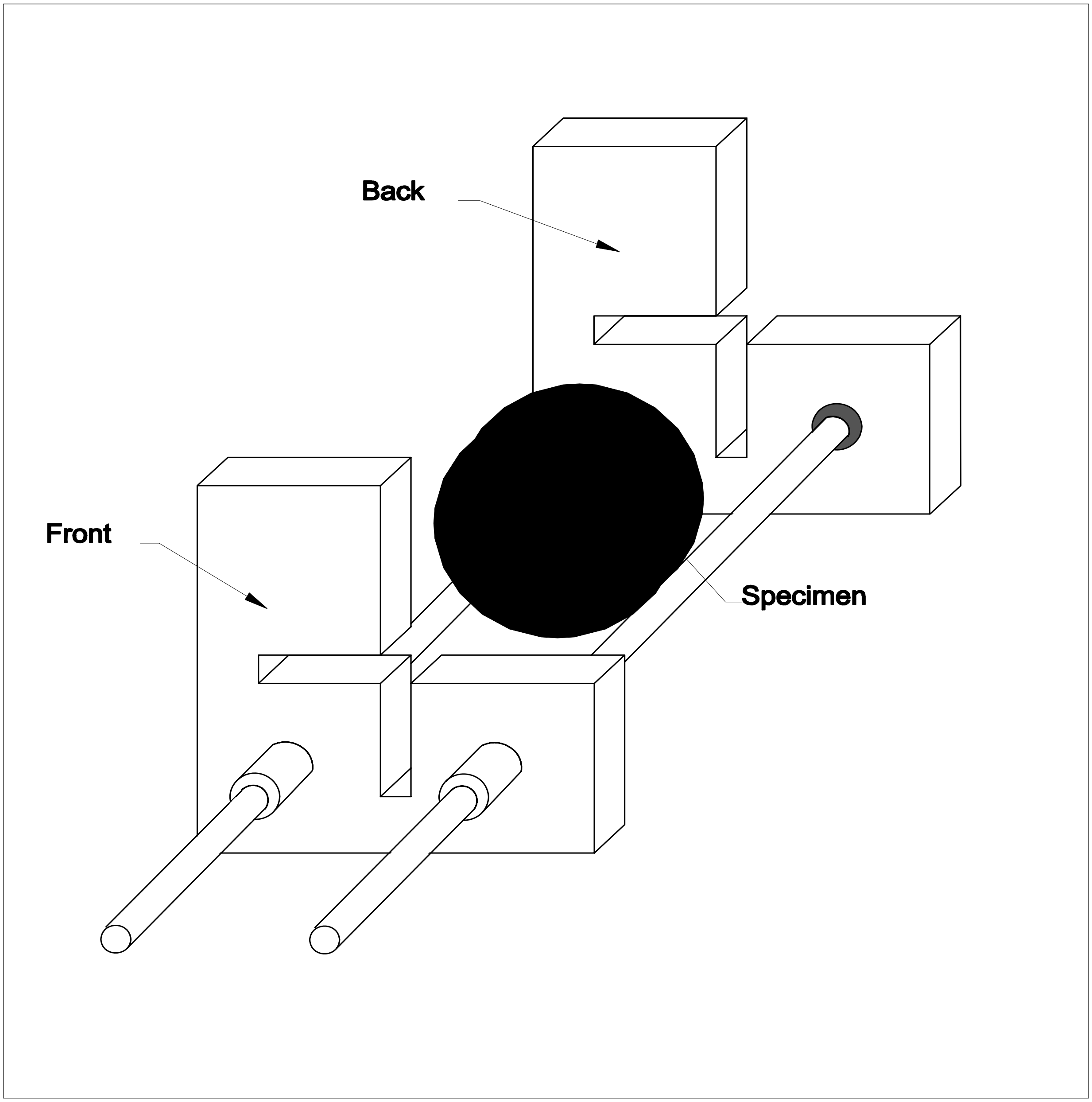


Figure 1. Illustration of suitable specimen marking device

8.1 One subset will be tested dry and the other will be preconditioned before testing.

8.2 The dry subset will be stored at room temperature until testing. When the specimens are ready to be tested, they shall be wrapped with plastic or placed in a heavy-duty leakproof plastic bag. The specimens shall then be placed in a 25°C (77°F) water bath for 2 hours and then tested.

8.3 The other subset shall be conditioned as follows:

8.3.1 The specimen shall be placed in the vacuum container supported above the container bottom by a spacer. The container shall be filled with distilled water at room temperature so that the specimens have at least one inch of water above their surface. A vacuum pressure of 508 mm of Hg (20 in of Hg) shall be applied for five minutes. The vacuum shall be removed but the specimen will remain submerged in water for 30 minutes.

8.3.2 The bulk specific gravity shall be determined by LTPP Protocol P02. Compare the saturated surface-dry weight with the saturated surface-dry weight determined in Section 7.3. The volume of absorbed water shall be calculated.

8.3.3 The degree of saturation shall be determined by comparing the volume of absorbed water with the volume of air voids from Section 7.4. If the volume of water is between 55 and 80 percent of the volume of air, proceed to Section 8.3.4. If volume of water is less than 55 percent, repeat the procedure beginning with Section 8.3.1 using more vacuum and/or time. If the volume of water is more than 80 percent, the specimen has been damaged and shall be discarded. Repeat the procedure beginning with Section 8.3.1 using less vacuum and/or time.

8.3.4 The vacuum saturated specimens shall be tightly covered with a plastic film (saran wrap or equivalent). Each wrapped specimen shall be placed in a plastic bag containing 10 ml of water and the bag shall be sealed.

8.3.5 The plastic bag containing the specimen shall be placed in a freezer at -18 ± 3°C (0 ± 5°F) for 16 hours.

8.3.6 After 16 hours, the specimens shall be placed in a 60 ± 1°C (140 ± 1.8°F) water bath for 24 hours. As soon as possible after placement in the water bath, remove the plastic bag and film from the specimens.

8.3.7 Remove the specimens after 24 hours in the 60°C (140°F) water bath, and place them in a water bath at 25 ± 0.5°C (77 ± 1°F) for 2 hours. It may be necessary to add ice to the water bath to prevent the water temperature from rising above 25°C (77°F). No more than 15 minutes should be required for the water bath to reach 25°C (77°F). The specimens shall then be tested as described in Section 9.

9. TESTING

9.1 Determine the tensile strength of all specimens (dry and conditioned) at 25°C (77°F) in accordance with Section 9.2. The order of specimen testing shall be randomized using an appropriate randomization scheme.

9.2 The specimen shall then be removed from the 25°C (77°F) water bath and placed between the two loading strips in the testing machine using the diametral scribed markings. Care must be taken to insure that the load will be applied along the diametral axis of the specimen as illustrated in Figure 2.

The diametral markings shall be used to insure that the specimen is aligned from top to bottom, front to back. The alignment of the front face of the specimen can be checked by insuring that the diametral marking is centered on the top and bottom loading strips. With the use of a mirror, the back face can be similarly aligned. After specimen placement is assured, a compressive load shall be applied at a controlled deformation rate of 51 mm (2 in) per minute along the diametral axis of the test specimen.

9.3 The maximum compressive load observed during testing shall be recorded but the loading will continue until a vertical crack appears along at least two-thirds of the test specimen. Remove the specimen from the machine and separate into halves at the crack interface. If the specimen cannot be separated (or split) by hand after a crack has developed over at least ⅔ of the length, it should be reinserted in the tensile test machine and the loading continued until the crack increases in length or width to the extent that the specimen can be separated by hand. In no case should any equipment other than the testing machine be used to split the specimen. The interior surface shall be inspected for stripping and the observations recorded. Using a magnifying glass, estimate the amount of coarse aggregate (that material retained on the 6.3-mm [¼-inch] sieve - pieces larger than approximately 6.3 mm [0.25 in]) in the broken face of the sample that has been stripped. Similarly, estimate, (using a stereozoom microscope, if available) the amount of fine aggregate (that material passing the 6.3-mm [¼-inch] sieve - pieces smaller than approximately 6.3 mm [0.25 in]) that has been stripped. Figure 3 shall be used to estimate the relative stripping percentages of the coarse aggregate. For estimating stripping percentages of the fine aggregate, representative areas of the surface may be chosen for making "counts" of coated and uncoated aggregate, which can be used to calculate the percent stripping of fine aggregate.

9.4 The core may be disposed of at the conclusion of the visual examination using appropriate procedures.

10. CALCULATIONS

10.1 Calculate the indirect tensile strength of each specimen as follows:

$$S_t = \left(\frac{50.127 \times P_0}{t}\right) \times \left(\sin\left(\frac{1455.313}{D}\right) - \frac{12.7}{D}\right)$$

where: S_t = Indirect tensile strength, kPa
P_0 = Maximum load sustained by the specimen, N
t = Specimen thickness, mm
D = Specimen diameter, mm

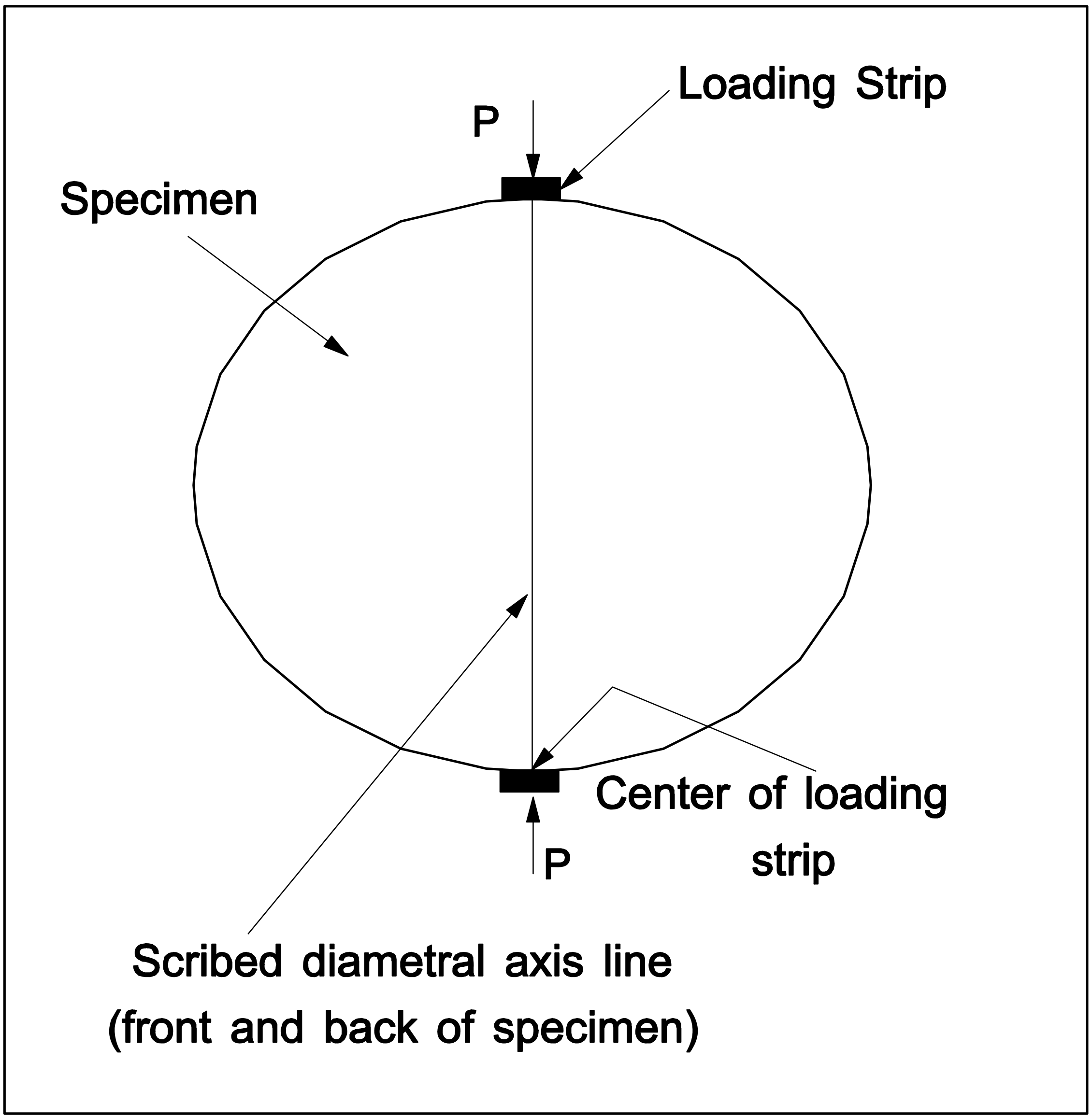


Figure 2. Proper alignment of specimen within the loading strips for the indirect tensile test.

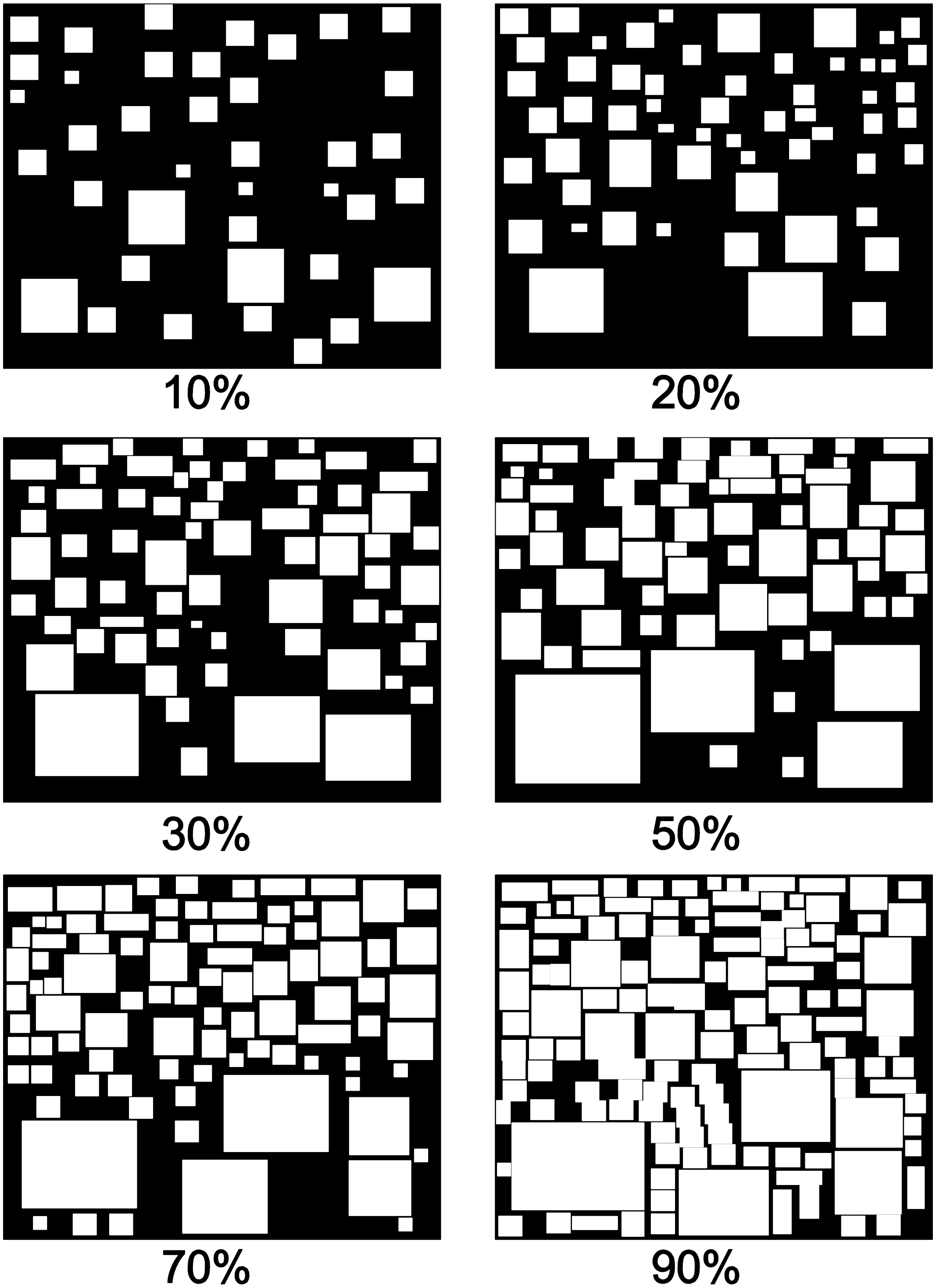


Figure 3. Chart for visual percentage estimation.

10.2 Calculate the numerical index of the asphalt mixture's response to the detrimental effect of water as follows:

$$TensileStrengthRatio(TSR) = \frac{Y_c}{Y_d}$$

where: Y_d = average tensile strength of dry subset
Y_c = average tensile strength of conditioned subset.

TSR values near one are indicative of mixtures which will have very low susceptibility to stripping after exposure to moisture and freeze-thaw conditions.

10.3 Calculate the Relative Variation in Strength (RVS) as follows:

$$RVS = \frac{CV_c}{CV_d}$$

where: CV_c = coefficient of variation for conditioned subset (S_c/Y_c)
CV_d = coefficient of variation for dry subset (S_d/Y_d)

where S_c and S_d are calculated using the following equations:

$$S_c = \sqrt{\frac{(S_{tc1} - Y_c)^2 + (S_{tc2} - Y_c)^2 + (S_{tc3} - Y_c)^2}{2}}$$

where: S_{tc1} = tensile strength of the first conditioned specimen
S_{tc2} = tensile strength of the second conditioned specimen
S_{tc3} = tensile strength of the third conditioned specimen
Y_c = $(S_{tc1} + S_{tc2} + S_{tc3})/3$

and

$$S_d = \sqrt{\frac{(S_{td1} - Y_d)^2 + (S_{td2} - Y_d)^2 + (S_{td3} - Y_d)^2}{2}}$$

where: S_{td1} = tensile strength of first dry specimen
S_{td2} = tensile strength of second dry specimen
S_{td3} = tensile strength of third dry specimen
Y_d = $(S_{td1} + S_{td2} + S_{td3})/3$

11. REPORT

The following information is to be recorded on Form T05:

11.1 Sample identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

11.2 Test identification shall include: LTPP Test designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

11.3 Test Results

Report the following:

11.3.1 Maximum specific gravity of the uncompacted AC mixture.

11.3.2 Average test specimen height to the nearest 2.5 mm.

11.3.3 Average test specimen diameter to the nearest 0.25 mm.

11.3.4 Method of compaction.

11.3.5 Bulk specific gravity of each test specimen after molding and prior to conditioning.

11.3.6 Percent air voids calculated for each specimen.

11.3.7 Bulk specific gravity of each "conditioned" test specimen after vacuum saturation.

11.3.8 Total maximum load sustained by each specimen during the indirect tensile strength test in N to the nearest whole number.

11.3.9 Tensile strength of each specimen to the nearest kPa.

11.3.10 Average tensile strength of the three "control" specimens and the average tensile strength of the three "conditioned" samples (Y_d and Y_c respectively), kPa.

11.3.11 Standard deviation of tensile strength for the "control" and "conditioned" subsets (S_d and S_c, respectively).

11.3.12 Tensile strength ratio calculated for the specimens.

11.3.13 Relative variation in strength for the specimens (RVS).

11.3.14 Record the estimated percent coarse and fine aggregate stripped.

11.3.15 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide and any other note as needed.

11.3.16 Test date.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
MOISTURE SUSCEPTIBILITY
LAB DATA SHEET T05

ASPHALT CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC05/LTPP PROTOCOL P05

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

SHRP REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SAMPLED BY: ___________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER ____
2. LABORATORY TEST NUMBER __
3. SHRP ID __ __ __ __
4. LOCATION NUMBER __ __ __
5. SAMPLING AREA NUMBER (SA-) __ __
6. MAXIMUM SPECIFIC GRAVITY OF MIX __ . __ __ __
7. METHOD OF COMPACTION ________________________

8. TEST RESULTS

DATA ITEM	**UNCONDITIONED (DRY)**			**CONDITIONED**		
LTPP SAMPLE NO.	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _	_ _ _ _
AVG. SPEC. HGT.	_ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _ _._
AVG. SPEC. DIAM.	_ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _ _._
BSG AFTER MOLDING	_._ _ _	_._ _ _	_._ _ _	_._ _ _	_._ _ _	_._ _ _
% AIR VOIDS	_ _._	_ _._	_ _._	_ _._	_ _._	_ _._
BSG AFTER VAC. SAT.				_._ _ _	_._ _ _	_._ _ _
MAX. LOAD	_ _ _ _ _.	_ _ _ _ _.	_ _ _ _ _.	_ _ _ _ _.	_ _ _ _ _.	_ _ _ _ _.

DATA ITEM	**UNCONDITIONED (DRY)**			**CONDITIONED**		
INDIRECT TENS. STR.	_ _ _ _.	_ _ _ _.	_ _ _ _.	_ _ _ _.	_ _ _ _.	_ _ _ _.
AVG. INDIRECT TENS. STR.	_ _ _ _.			_ _ _ _.		
STD. INDIRECT TENS. STR.	_ _ _.			_ _ _.		
TENSILE STRENGTH RATIO	__ . __ __					
RELATIVE VAR. IN STR.	__ __ __					
COARSE AGG. STRIPPED, %				__ __ __.	__ __ __.	__ __ __.
FINE AGG. STRIPPED, %				__ __ __.	__ __ __.	__ __ __.
COMMENT CODES	__ __, __ __, __ __, __ __, __ __, __ __					
NOTE	________________________________					
TEST DATE	___________	___________	___________	___________	___________	___________

GENERAL REMARKS:____

SUBMITTED BY, DATE

CHECKED AND APPROVED, DATE

____

LABORATORY CHIEF

Affiliation_____________________________

____

Affiliation_____________________________

PROTOCOL P07
Test Method for Determining the Creep Compliance, Resilient Modulus and Strength of Asphalt Materials Using the Indirect Tensile Test Device (AC07)

1. SCOPE

1.1 General

This LTPP program protocol describes procedures for determination of Creep Compliance, Resilient Modulus (M_r), and Strength of hot-mix asphalt concrete (HMAC) using indirect tensile test techniques. This protocol is partially based on test standards AASHTO TP9-94 (Edition 1B), ASTM D4123, and the procedures outlined in Section 4.4 (Roque et al.) of this protocol.

This protocol describes three distinct procedures for the determination of (1) creep compliance, (2) resilient modulus, and (3) tensile strength. This procedure requires three test specimens obtained from the same general area of the pavement test section. Each specimen is subject to creep compliance at -10, 5, and 25°C (14, 41, and 77°F), resilient modulus determinations at 5, 25, and 40°C (41, 77, and 104°F) and a strength test at 25°C (77°F). Therefore, three replicate test results are obtained for each specimen set.

The methods described are only applicable to core samples from hot mix asphalt (HMA) pavement layers. For LTPP, samples tested under this procedure are nominally 100-mm (4-in) core samples. It should be noted that this test procedure could be adapted for use with 150-mm (6-in) diameter specimens or laboratory compacted specimens. However for LTPP purposes, testing is restricted to the above criteria.

1.2 Summary of Test Method

1.2.1 Creep Compliance - The tensile creep compliance is determined by applying a static compressive load of fixed magnitude along the diametral axis of a cylindrical specimen. The resulting horizontal and vertical deformations measured near the center of the specimen are used to calculate tensile creep compliance as a function of time. Loads are selected to keep the material's response in the linear viscoelastic (LVE) range. This is accomplished by keeping horizontal deformations below 0.089 mm (0.0035 in).[1] Horizontal and vertical deformations are measured in the central region of the specimen, away from the localized stress concentrations caused by the loading conditions. The creep compliance test is performed on each specimen at temperatures of -10, 5, and 25°C (14, 41, and 77°F).

1.2.2 Resilient Modulus - A cyclic stress of fixed amplitude, with a duration of 0.1 seconds followed by a rest period of 0.9 seconds, is applied to the test specimen. During testing the specimen is subjected to a dynamic cyclic stress and a constant stress (seating load).

[1]For a 100-mm (4-in) specimen.

Loads are selected to keep horizontal deformations between 0.038 and 0.089 mm (0.0015 and 0.0035 in)[2]. The deformation responses of the specimen are measured near the center of the specimen and used to calculate both an instantaneous and total resilient modulus (M_{Ri} and M_{Rt} respectively). Instantaneous resilient modulus is calculated using the recoverable horizontal deformation that occurs during the unloading portion of one load-unload cycle. Total resilient modulus is calculated using the total recoverable deformation, which includes both the instantaneous recoverable and the time-dependent continuing recoverable deformation during the unload or rest-period portion of one cycle. The resilient modulus test is performed on each specimen at temperatures of 5, 25, and 40°C (41, 77 and 104°F).

1.2.3 Tensile Strength - The tensile strength is determined by loading the specimen along its diametral axis at a fixed deformation rate until failure occurs. Failure is defined as the point after which the load no longer increases. The maximum load sustained by the specimen is used to calculate the indirect tensile strength. For LTPP testing, the point at which the first crack develops in the failure plane is also identified and recorded. This portion of the test procedure is performed at 25°C (77°F).

1.2.4 Testing Sequence - Each test specimen is tested in the following sequence:

1. Creep Compliance -10°C (14°F)
2. Resilient Modulus 5°C (41°F)
3. Creep Compliance 5°C (41°F)
4. Resilient Modulus 25°C (77°F)
5. Creep Compliance 25°C (77°F)
6. Resilient Modulus 40°C (104°F)
7. Tensile Strength 25°C (77°F)

1.3 Significance and Use

The values of creep compliance can be used as indicators of the relative quality of asphalt materials, as well as, to generate stiffness estimates for pavement design and evaluation models. The test can also be used to investigate the effects of temperature, load magnitude, and creep loading time on asphalt material properties.

When used in conjunction with other physical properties, the creep compliance can contribute to the overall mixture characterization and could well be a key factor for determining mixture suitability for use as a highway paving material under a variety of loading and environmental conditions.

The value of resilient modulus determined from this protocol procedure is a measure of the elastic modulus of HMA materials recognizing certain non-linear characteristics. Resilient modulus values can be used with structural response analysis models to calculate

[2]For a 100-mm (4-in) specimen.

the pavement structural response to wheel loads, and with pavement design procedures to design pavement structures.

The resilient modulus test provides a means of characterizing pavement construction materials including surface, base, and subbase HMA materials under a variety of temperatures and stress states that simulate the conditions in a pavement subjected to moving wheel loads.

The indirect tensile strength test at 25°C (77°F) is used to determine the tensile strength, failure strain and the fracture energy of the specimens used for creep compliance and resilient modulus testing.

1.4 Sample Storage

Specimens of HMA materials for use in this testing shall be kept in an environmentally protected (enclosed area not subjected to the natural elements) storage area at temperatures between 5 and 24°C (40 and 75°F). Each specimen shall have a label or tag that clearly identifies the material, project number/test section from which it was recovered, and the sample number.

1.5 Units

In this protocol, the International System of Units (SI - The Modernized Metric System) is regarded as the standard. Units are expressed first in their "hard" metric form followed, in parenthesis, by their U.S. Customary unit equivalent.

2. GENERAL SPECIFICATIONS

2.1 Testing Prerequisites

This testing procedure shall be conducted <u>after</u>; (1) approval by the FHWA COTR to begin testing, (2) approval of Form L04 by the FHWA LTPP RCOC, (3) visual examination and thickness determination of AC cores and thickness determination of layers within AC cores using Protocol P01, (4) final layer assignment based on the P01 test results (corrected Form L04, if needed), and (5) bulk specific gravity testing of the specimens to be used for this testing have been completed according to Protocol P02. To attain approval under item (1), the laboratory must: (a) submit and obtain approval of the QC/QA plan for LTPP Protocol P07 testing, (b) demonstrate that their testing equipment meets or exceeds the specifications contained in this protocol, and (c) successfully complete all applicable requirements of the FHWA LTPP P07 Start-up and QC Procedure.

2.2 Sample Size

This testing shall be conducted on 102-mm (4-in) diameter asphalt concrete specimens that are between 25 (minimum) and 51 mm (maximum) (1.0 and 2.0 in) in thickness. The desired thickness for testing is 51 mm (2 in).

2.3 Test Core Locations and Assignment of Laboratory Test Numbers

This test shall be performed on specimens obtained from C-type, 102-mm (4-in) diameter core holes as dictated by the sampling plans for the particular LTPP section. The testing will be performed on asphalt layers with a thickness greater than 25 mm (1.0 in). Generally, samples are retrieved from the approach (stations 0+000m [0+00ft] -) and/or leave (stations 0+152m [5+00ft] +) ends of a test section but it is possible that for forensic or other studies specimens may be retrieved from within the pavement section. Test results shall be reported separately for samples obtained at the approach, within and leave end of the test section as follows:

(a) Beginning of the Section (stations 0+000m [0+00ft] -): Core specimens that are retrieved from areas in the approach end of the test section (stations preceding 0+000m [0+00ft]) shall be assigned Laboratory Test Number "1".

(b) End of the Section (stations 0+152m [5+00ft] +): Core specimens that are retrieved from areas in the leave end of the test section (stations after 0+152m [5+00ft]) shall be assigned Laboratory Test Number "2".

(c) Within the Section (stations 0+000m - 0+152m [0+00ft to 5+00ft]): Core specimens that are retrieved from areas within the test section (stations 0+000m - 0+152m [0+00ft - 5+00ft]) shall be assigned Laboratory Test Number "3".

If any of the test specimens obtained from the specified core locations are damaged or untestable, other cores within the same grouping and same layer that have not been identified for other testing can be substituted for this testing. <u>Test specimens from one area (approach, within or leave) of an LTPP section may not be substituted for test specimens from another area</u>. An appropriate comment code shall be used in reporting the test results and any specimen substitution.

3. DEFINITIONS

The following definitions are used throughout this protocol:

(a) Layer: that part of the pavement produced with similar material and placed with similar equipment and techniques. The layer thickness can be equal to or less than the core thickness or length.

(b) Core: an intact cylindrical specimen of pavement materials which is removed from the pavement by drilling and sampling at the designated core location. A core may consist of, or include, one or more different layers.

(c) Test Specimen: that part of the layer which is used for, or in, the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

(d) Creep: the time-dependent part of strain resulting from stress. A typical load versus deformation graph for creep testing is shown in Figure 1.

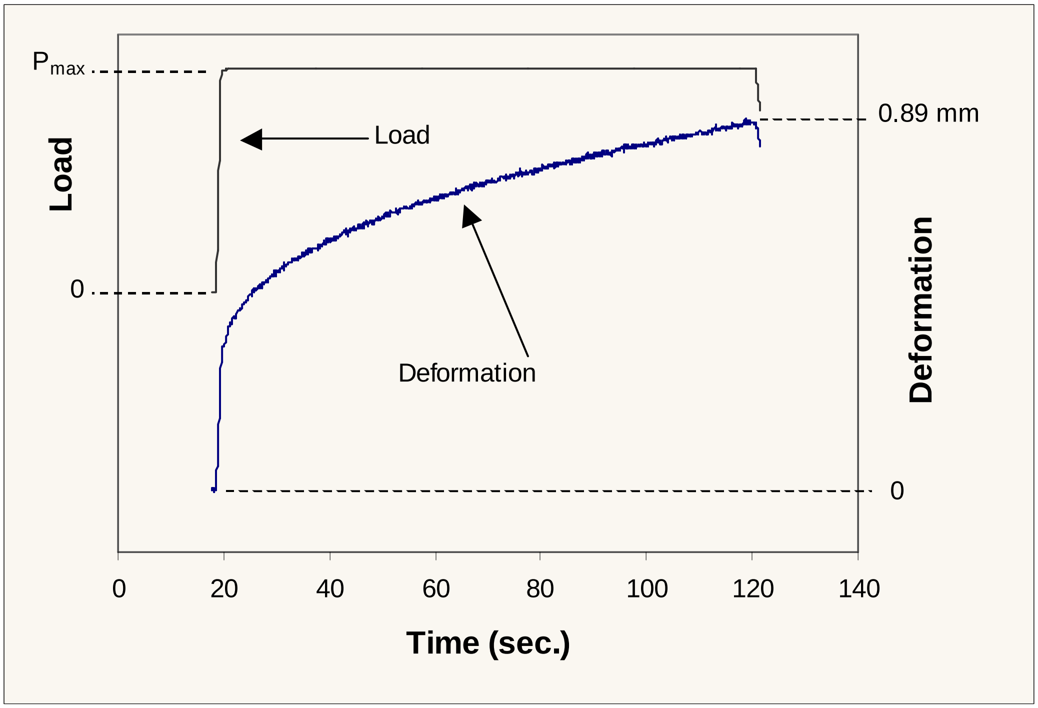


Figure 1. Typical creep test

(e) Creep Compliance: the time-dependent strain divided by the applied stress.

(f) Poisson's Ratio, μ: the absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

(g) Haversine Shaped Load Form: the required load pulse form for the resilient modulus portion of the P07 test. The load pulse is of the form $[(1 - \cos\theta)/2]$, and the cyclic load (P_{cyclic}) is varied from a seating load ($P_{contact}$) to the maximum load (P_{max}), as shown in Figure 2.

(h) Maximum Applied Load (P_{max}): the maximum total load applied to the sample, including the contact and cyclic loads.

$$P_{max} = P_{contact} + P_{cyclic}$$

(i) Contact Load ($P_{contact}$): the vertical load placed on the specimen in order to maintain contact between the loading strip and the specimen.

(j) Cyclic Load (Resilient Load, P_{cyclic}): load applied to a test specimen which is used to calculate the resilient modulus.

$$P_{cyclic} = P_{max} - P_{contact}$$

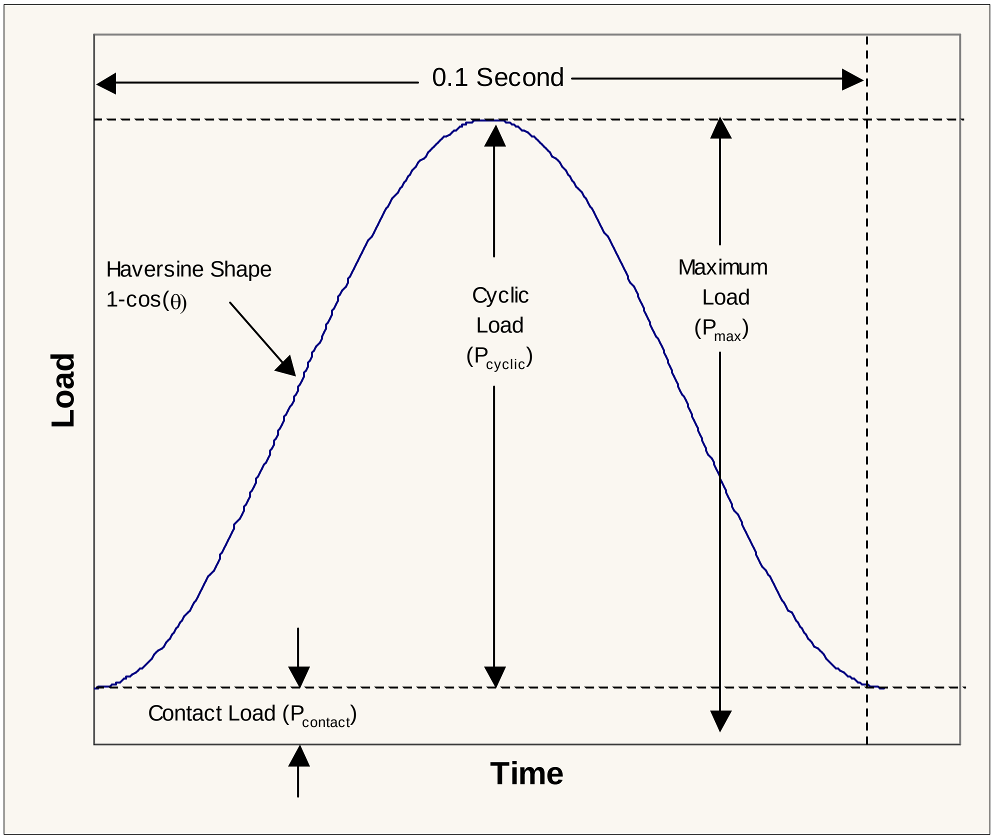


Figure 2. Definition of load pulse terms

(k) Instantaneous Resilient Modulus: determined from the deformation-time plots (both horizontal and vertical) using the instantaneous resilient deformation, obtained in the manner indicated in Figure 3 and described herein. For each cycle, two regression lines are used to determine the instantaneous and total deformations. The range for regression line 1 starts at the 5^{th} point after the maximum deformation value and ends at the 17^{th} point after the maximum deformation (13 points total). The range for regression line 2 includes the last 299 points of the cycle and the first point from the following cycle. For each cycle, the instantaneous deformation is calculated by subtracting the deformation value at the intersection of regression lines 1 and 2 from the maximum deformation. A typical deformation versus time graph for resilient modulus testing is shown in Figure 4.

(l) Total Resilient Modulus: determined from the deformation-time plots using the total resilient deformation, obtained in the manner indicated in Figure 3 and described herein. For each cycle, the total deformation is calculated by the deformation value of regression line 2 at the first point of the next cycle from the maximum deformation. This value includes both the instantaneous recoverable deformation and the time dependent continuing recoverable deformation during the rest-period portion of one cycle.

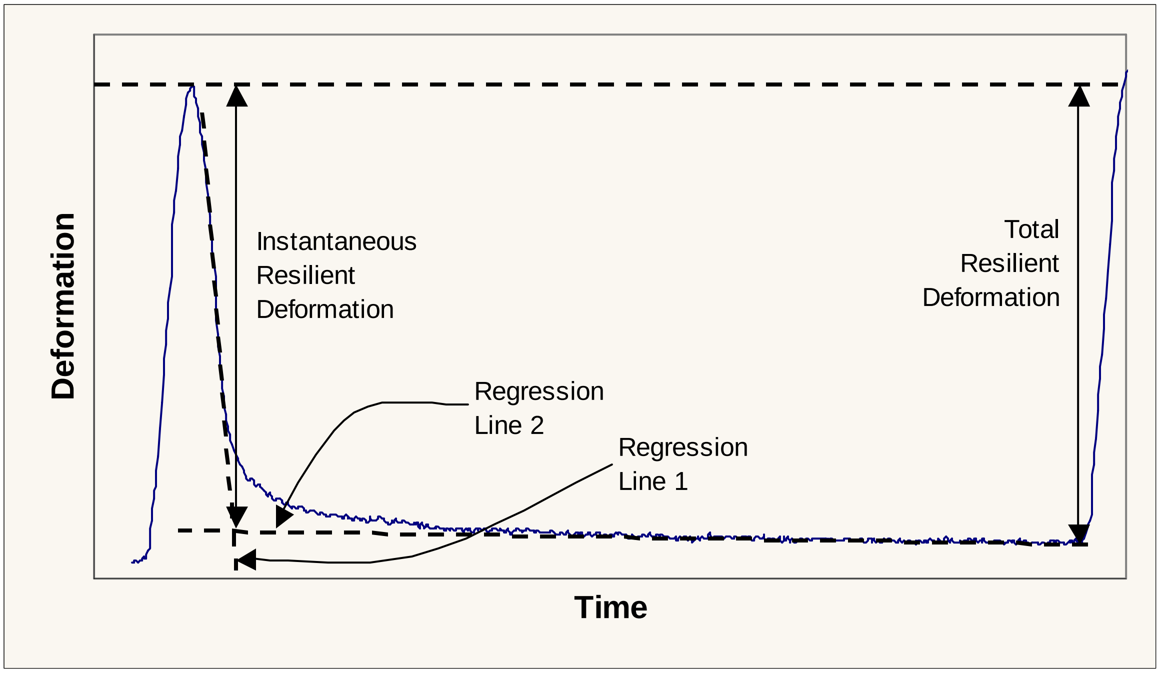


Figure 3. Instantaneous and total resilient deformations

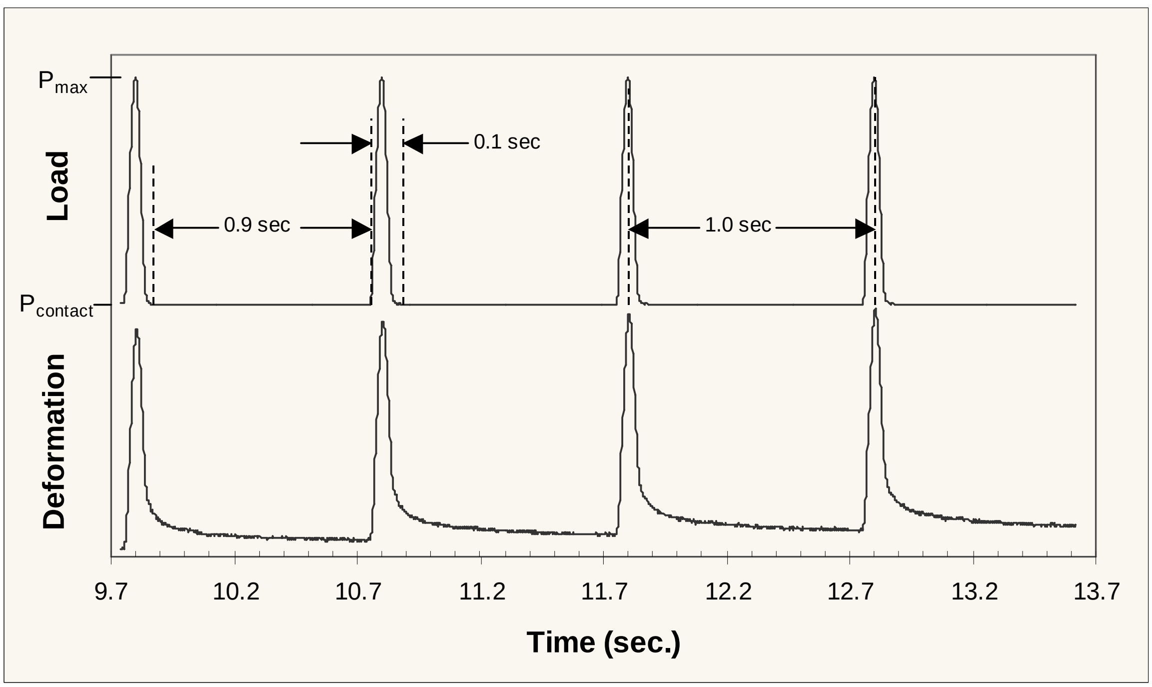


Figure 4. Typical resilient modulus test

(m) Tensile Strength: the strength shown by a specimen subjected to tension, as distinct from torsion, compression, or shear. A typical load versus deformation plot for indirect tensile strength testing is shown in Figure 5.

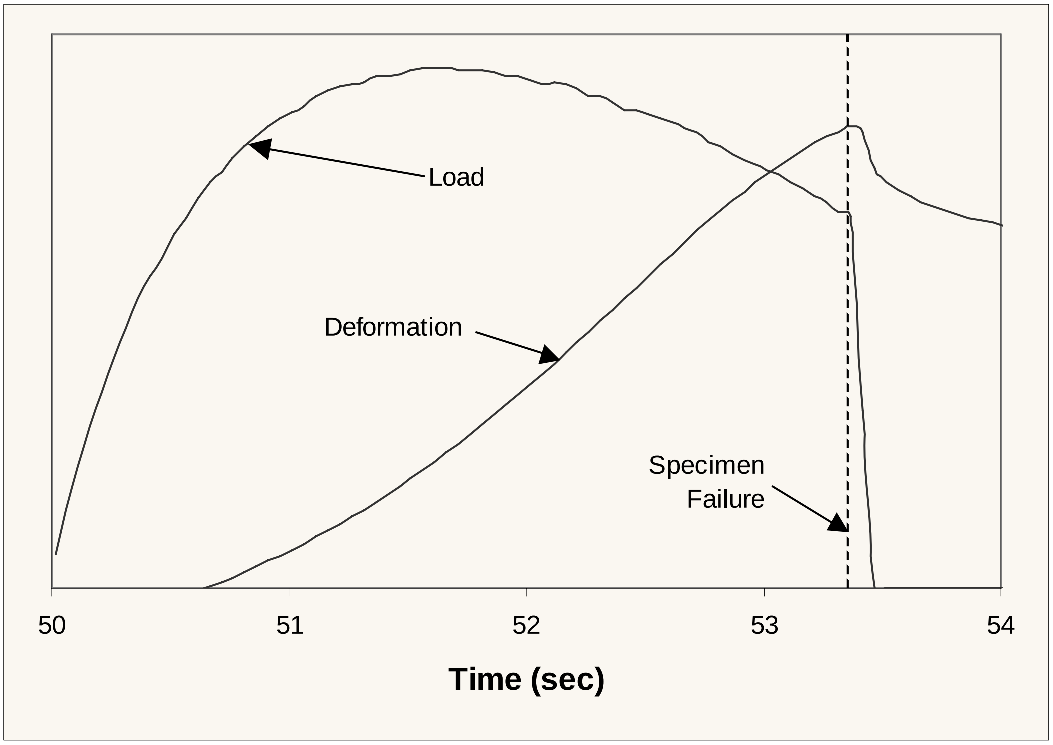


Figure 5. Typical indirect tensile test

4. APPLICABLE DOCUMENTS

4.1 LTPP Protocols

P01 Visual Examination and Thickness of Asphaltic Concrete Cores.
P02 Bulk Specific Gravity of Asphaltic Concrete.

4.2 AASHTO Standards

TP9-94 (Edition 1B) Standard Test Method for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) using the Indirect Tensile Test Device, September 1994.

4.3 ASTM Standards

D4123 Indirect Tension Test for Resilient Modulus of Bituminous Mixtures

4.4 Other

Evaluation of SHRP Indirect Tension Tester to Mitigate Cracking in Asphalt Concrete Pavements and Overlays, Roque, Reynaldo, et al. August 1997.

5. APPARATUS

5.1 Loading Device

The testing machine shall be a top-loading, closed-loop, servo-hydraulic testing machine. The loading device shall be capable of providing a fixed or constant load with a resolution of at least 4.45N (1 lbf) and constant rate of ram displacement between 12 and 75 mm/minute (0.5–3 in/minute). The test machine should also be capable of applying a haversine shaped load pulse over the range of load durations, load levels, and rest periods described in this protocol (nominally 0.1 second in duration followed by a rest period of 0.9 seconds). The load frame should be capable of handling a minimum of 22,240 N (5,000 lbf).

5.2 Diametral Loading Heads and Specimen Restraint System

Diametral loading heads, equipped with concave steel loading strips having a radius of curvature equal to the nominal radius of the test specimen (nominally 102 mm [4 in]) are required to apply load to the specimen. The loading strip shall be 13 mm (0.5 in) wide. For LTPP testing purposes, the diametral loading heads and specimen restraint system is as specified in Appendix A (Test Equipment Specifications) of this protocol. Typical diametral loading heads are shown in Figure 6.

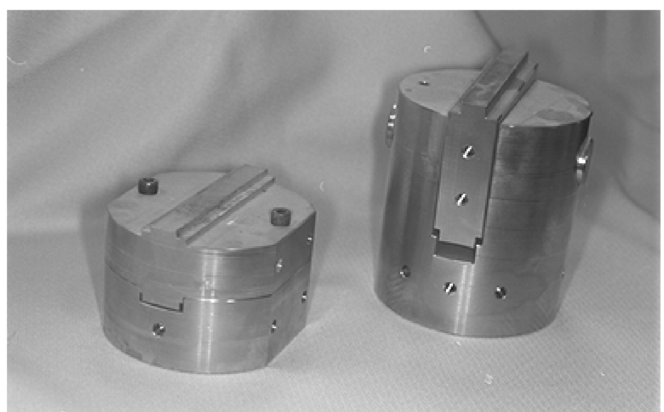


Figure 6. Typical loading heads

NOTE: The loading heads have been designed to be interchangeable so that either 102-mm (4-in) or 152-mm (6-in) diameter samples can be tested. The appropriate loading strip can be used by simply rotating the upper and lower loading platens 180 degrees. The upper loading platen was designed to rotate freely under load to accommodate specimens that are not perfectly cylindrical (e.g., field cores). The vertical plates on the lower loading head serve as a specimen restraint system. When the specimen is broken during the strength test, these plates keep the two halves from falling and reduce the potential for damage of the deformation measurement system. The specimen restraint system is adjustable to accommodate 102-mm (4-in) and 152-mm (6-in) diameter specimens. An aluminum block designed to align the upper and lower loading platens is shown in Appendix A of this protocol. This alignment unit is necessary because, unlike a typical resilient modulus loading frame that has the upper and lower loading platens permanently affixed, the upper and lower loading platens in this system are independent of each other. Therefore, this block was designed to align the upper and lower loading strips during initial installation and periodically to check and adjust the alignment.

5.3 Gauge Points

Eight gauge points are required per specimen. The gauge points must be magnetic (e.g., low carbon steel). Detailed specifications for the gauge points are contained in Appendix A. Typical gauge points are shown in Figure 7.

5.4 Contact Point Template

A template for marking the contact point where the loading heads would be perfectly aligned with the gauge points. Detailed specifications for this device are contained in Appendix A of this protocol with a typical contact point template shown in Figure 8.

5.5 Gauge Point Mounting System

A gauge point mounting system is required. This device is used to mount the gauge points precisely on cylindrical test specimens. Detailed specifications for this device are contained in Appendix A of this protocol. A typical gauge point mounting device is shown in Figure 9.

5.6 Temperature Control System

The temperature-control system should be capable of maintaining temperature control within ± 0.2°C (± 0.4°F) (measured near the center of the chamber), at settings ranging from -10 to 40°C (14 to 104°F). The system shall include a temperature-controlled cabinet large enough to house the diametral loading heads and specimen constraint system as well as three test specimens.

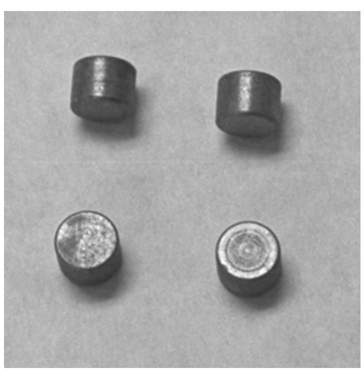


Figure 7. Typical gauge points

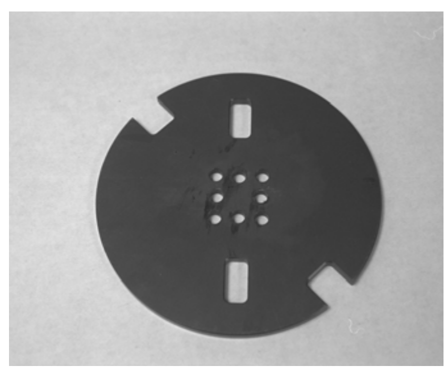


Figure 8. Typical contact point template

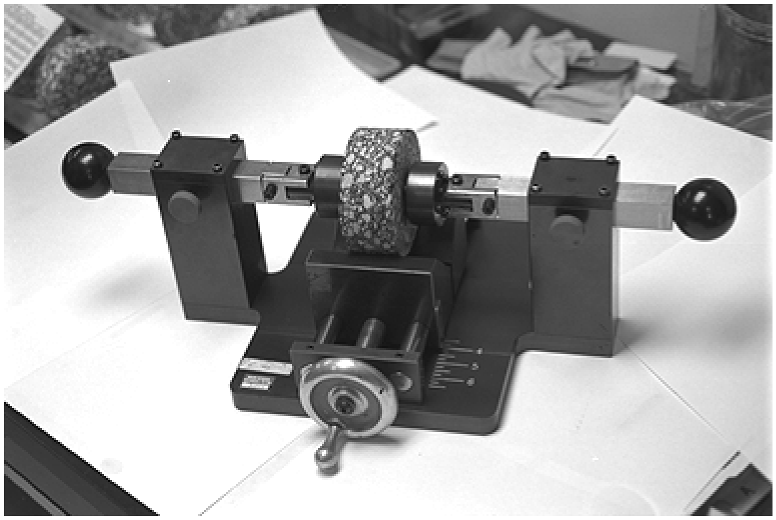


Figure 9. Typical gauge point mounting device

The chambers shall be capable of a minimum temperature change rate of ±15°C/hour (± 27°F/hour). A thermally sealed access port for thermocouple or electrical feed through is also required. In addition, it is preferred that the test chamber or an adjacent preconditioning chamber be large enough to house up to 25 test specimens during production testing operations.

5.7 Measurement and Recording System

The measuring and recording system shall include sensors for measuring and simultaneously recording horizontal and vertical deformations on both faces of the specimen and the load applied to the specimen. The system shall be capable of recording horizontal deformations with a resolution of 0.00025 mm (0.000010 in). The system shall also be capable of recording vertical deformations with a resolution of 0.0005 mm (0.000020 in). Load cells shall be accurately calibrated with a resolution of 5 N (1 lbf) or better. In all cases, the noise in the recording system should be less than the accuracy of the deformation measurement devices being used.

5.7.1 Recorder - The measuring or recording devices must provide real time deformation and load information and should be capable of monitoring readings at a minimum of 500 points/second. These parameters shall be recorded on an analog to digital or digital data acquisition system. The data acquisition system must be able to record time, temperature, load, and four deformation measurement devices.

5.7.2 Deformation Measurement - The values of vertical and horizontal deformation shall be measured with 25 mm (1 in) gauge point mounted extensometers with a full scale travel of 0.5 mm (0.02 in.). The extensometers must be capable of performing within the temperature range prescribed in this test procedure.

Extensometer Response Checks. The extensometers shall be calibrated every two weeks, or after every 50 resilient modulus tests, as per manufacturer specifications.

5.7.3 Load Measurement - The repetitive loads shall be measured with an electronic load cell with a capacity 22,000 N (5,000 lbf) and a sensitivity of ±5 N (± 1 lbf). The capacity of the load cell shall be matched as closely as possible to the expected testing load ranges to allow adequate feedback response, especially for haversine loading conditions.

During periods of resilient modulus testing, the load cell shall be monitored and checked once a month with a calibrated proving ring or independent load cell to assure that it is operating properly.

5.8 Specimen Sawing Apparatus

A specimen sawing device will be used to cut parallel, smooth and plane top and bottom faces for the asphalt cores. A water-cooled masonry saw has been found to perform this function adequately.

5.9 Humidity Cabinet

A chamber that can control to ± 5% relative humidity is necessary to condition specimens. This cabinet or chamber must be large enough to accommodate the number of specimens expected to be tested over 3 days.

5.10 Data Reduction and Analysis System

An automated data reduction and analysis system is necessary to process the data generated by this test procedure. Manual data reduction and analysis is possible but impractical. For LTPP testing, a series of software programs have been developed to process and analyze the data. Appendix B of this procedure outlines the algorithms used in data analysis.

6. TEST SPECIMEN PREREQUISITES

6.1 General Specifications

Cores for test specimen preparation, which may contain one or more testable layers, must have smooth and uniform vertical (curved) surfaces. Cores that are obviously deformed or have any visible cracks must be rejected. Irregular top and bottom surfaces shall be trued up as necessary. Individual layer specimens shall be obtained by cutting with a water-cooled masonry saw.

Each specimen shall represent a single AC layer at one end of the test section. If the field core includes two or more different AC layers, the layers shall be separated at the layer interface by sawing. Any testable layers as identified in the P01 test (Form T01B) shall be separated. Layers that contain more than one lift of the same material placed under the same contract specification may be tested as a single specimen. The traffic direction symbol shall be marked on each layer after cutting to maintain the correct orientation. Layers too thin to test (less than 25 mm [1.0 in]), as well as any thin surface treatments, shall be removed and discarded.

All samples from a single area of the test section (before, within or end) that are candidates for this test shall be assembled, and the bulk specific gravity test results reviewed. Of this group of test candidates, the three specimens with the closest bulk specific gravities should be selected.

6.2 Specimen Thickness

The test specimens designated for M_R testing shall be sawn from the appropriately numbered cores as described above in thickness no greater than 51 mm (2.0 in) in preparation for resilient modulus testing.

The desired thickness for testing is approximately 51 mm (2.0 in). If the thickness of a particular AC layer scheduled for testing is 76 mm (3.0 in) or more, then the 51-mm (2-in) specimen to be used for testing shall be obtained from the middle of the AC layer by sawing the specimen.

The thickness of each test specimen shall be measured to the nearest 0.25 mm (0.01 in) prior to testing. The thickness shall be determined by averaging four measurements located at quarter points around the sample perimeter, and 13 to 25 mm (0.5 to 1 in) in from the specimen edge.

6.3 Specimen Diameter

The diameter of each test specimen shall be determined prior to testing to the nearest 0.25 mm (0.01 in) by averaging diametral measurements. Measure the diameter of the specimen at mid-height along (1) the axis parallel to the direction of traffic and (2) the axis perpendicular (90 degrees) to the axis measured in (1) above. The measurements shall be averaged to determine the diameter of the test specimen. Core diameters shall be no less than 97.8 mm (3.85 in) or more than 105.4 mm (4.15 in).

6.4 Diametral Axis

Marking of the diametral axis to be tested shall be performed using the loading head contact template described in Appendix A. The axis shall be parallel to the traffic direction symbol (arrow) or "T" marked during the field coring operations. This diametral axis location can be rotated slightly, if necessary, to avoid contact of the loading strips with abnormally large aggregate particles or surface voids. Rotation of the test axis is also required if the surfaces to be loaded taper by more than 0.127 mm (0.005 in) from parallel.

6.5 Sample Preparation

Saw at least 6 mm (0.25 in) from both sides of each test specimen to provide smooth, parallel surfaces for mounting the measurement gauges. Measurements taken on cut faces yield more consistent results and gauge points can be attached more firmly. If the sample is too thin (less than 25 mm (1.0 in)) to accommodate the sawing operation, then the sawing operation is not performed.

Determine the bulk specific gravity of the specimen in accordance with LTPP Protocol P02 except that if the water absorbed by the specimen exceeds 2 percent, substitute a thin, adherent, water resistant plastic wrap membrane for the paraffin coating.

Specimens shall be stored in a cabinet at a constant relative humidity of 50 percent for 3 days prior to testing to ensure uniform moisture conditions.

Epoxy four gauge points to each flat face of the specimen (4 per face) using the gauge point mounting system. On each flat face of the specimen, two gauge points shall be placed along the vertical and two along the horizontal axes with a center to center spacing of 25.0 ± 0.2 mm (1.0 ± .1 in). The location of the gauge points on each face shall be identical. The gauge points shall be affixed to the specimen with suitable epoxy (e.g., "Zap-a-gap" has been used successfully). Figure 10 illustrates a specimen with gauge points mounted.

Mount the extensometers onto the test specimen, as shown in Figure 11.

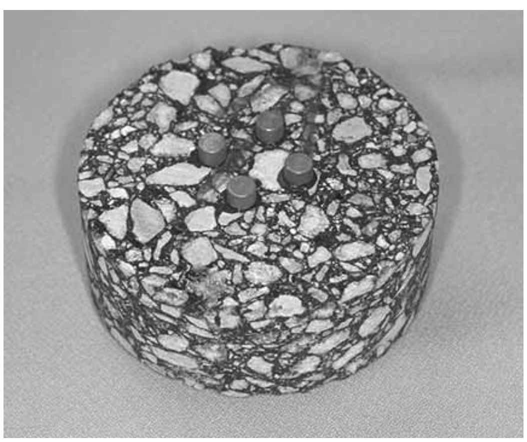


Figure 10. Asphalt specimen with gauge points mounted

Figure 11. Asphalt specimen with extensometers mounted

7. TEST PROCEDURE

7.1 General

The asphalt cores shall be placed in a controlled temperature cabinet/chamber and brought to the specified test temperature. Unless the core specimen temperature is monitored in some manner and the actual temperature is known, the core samples shall remain in the cabinet/chamber for a minimum of 24 hours prior to testing at 5°C (41°F) and 25°C (77°F). Specimens shall be held at 40°C (104°F) for a minimum of three hours, but not exceeding six hours, prior to testing. All specimens should be stored in an environment where the temperature is maintained between 5 and 21°C (40 and 70°F) until they are to be conditioned for testing.

Each specimen is tested in the following sequence:

1. Creep Compliance -10°C (14°F)
2. Resilient Modulus 5°C (41°F)
3. Creep Compliance 5°C (41°F)
4. Resilient Modulus 25°C (77°F)
5. Creep Compliance 25°C (77°F)
6. Resilient Modulus 40°C (104°F)
7. Tensile Strength 25°C (77°F)

Mount and center the deformation devices on the sample and zero or rebalance the electronic measurement system.

7.2 Alignment and Specimen Seating

At each temperature, insert the test specimen into the loading device and position it so that the load strip alignment mark on the test specimen lines up with the loading strips. The alignment of the front face of the specimen can be checked by insuring that the specimen load strip alignment markings are centered on the top and bottom loading strips. If necessary, the rear face of the specimen can be similarly aligned by using a mirror. A specimen mounted in the loading device is shown in Figure 12.

The contact surface between the specimen and each loading strip is critical for proper test results. Any projections or depressions in the specimen-to-strip contact surface which leave the loading strips in a non-contact condition over a length of more than 19 mm (0.75 in) shall be reason for rotating the test axis or rejecting the specimen. In instances where significant non-contact is suspected, machinists dye shall be used to check the specimen-to-strip contact area. If no suitable replacement specimen is available that meets this criteria, the test shall be conducted on the designated specimen. Code 39 shall be used to document this situation. Prior to performing the test procedure at a given temperature, the extensometers shall be stable. For resilient modulus and indirect tensile strength testing, stability is defined as the horizontal extensometers not drifting by more then 50 micro-strain over 100 seconds. Prior to performing creep compliance testing, stability is defined as the horizontal extensometers not drifting by more then 10 micro-strain over 100 seconds. If these tolerances are not met, it is an indication that the specimen has not stabilized at the test temperature.

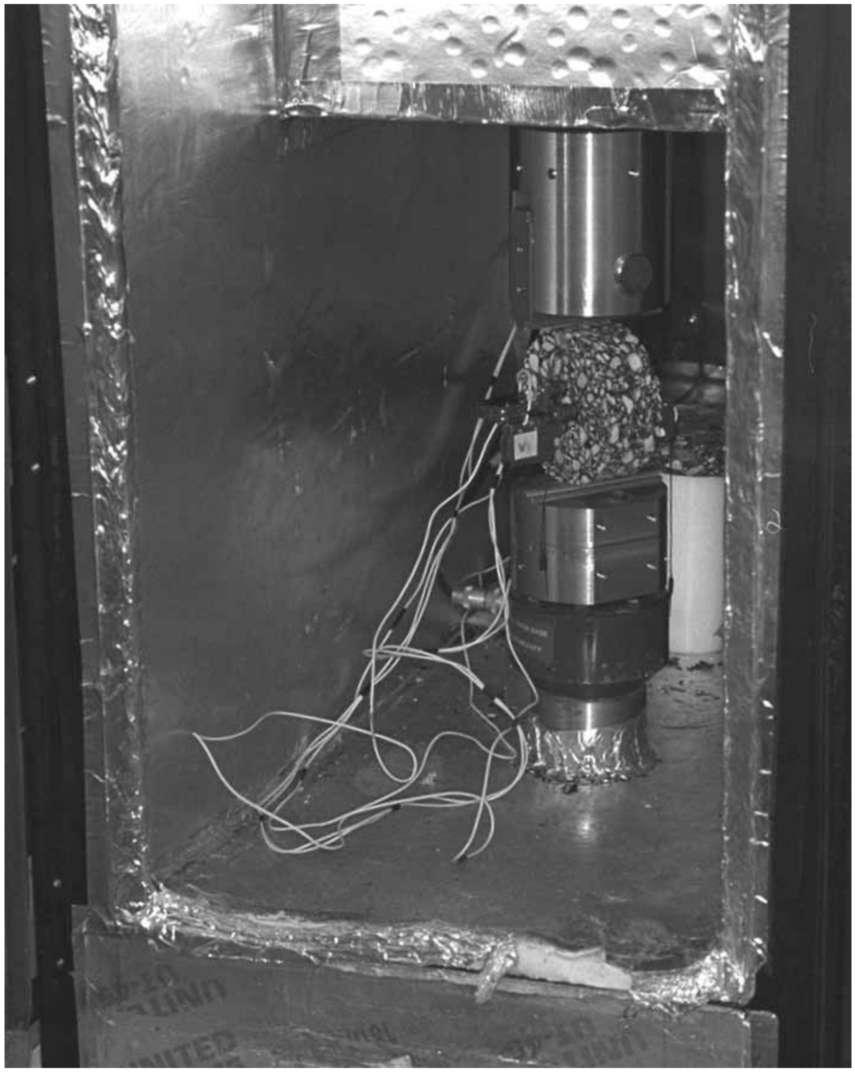


Figure 12. Specimen mounted in loading device

7.3 Creep Compliance Determination

After extensometer stability is achieved, apply a static load of fixed magnitude (± 2 percent), without impact to the specimen, that produces a horizontal deformation of 0.038 to 0.089 mm (0.0015 to 0.035 in) after 100 ± 2 sec. If either deformation limit is exceeded, stop the test and allow a minimum recovery time of 3 minutes before reloading at a different level. These limits prevent both non-linear response, characterized by exceeding the upper limit, and significant problems associated with noise and drift inherent in sensors when violating the lower strain limit. Collect data at 10 Hz. Return to the initial load level.

7.4 Resilient Modulus Determination

After stability is achieved, zero or rebalance the deformation measurement devices and apply a repeated haversine waveform load to the specimen with a period of 0.1 second followed by a rest period of 0.9 seconds. Use a load that produces a peak horizontal deformation between 0.038 and 0.089 mm (0.0015 and 0.0035 in). If the deformations fall outside these limits, stop the test and allow a minimum recovery time of 3 minutes before reloading at a different level. As explained previously, these limits prevent both non-linear response, characterized by exceeding the upper limit and significant problems associated with noise and drift inherent in sensors when violating the lower limit. Collect data at a uniform rate of 500 points per load cycle.

Once the appropriate load is achieved, testing may commence. The specimen shall be cycled (loaded and unloaded) until deformation and load data are obtained for a minimum of three load cycles. The response haversine waveform shall be matched as closely as possible to the command wave form by adjusting the feedback controls of the system.

7.5 Tensile Strength Determination

This test is only performed at 25°C (77°F) after all other testing is complete, as it will destroy the sample. After stability is achieved, zero the deformation measurement devices. Apply a load to the specimen at a constant rate of 50 mm (2 in) of ram displacement per minute. Record the vertical and horizontal displacement of the sample and the load until the load begins to decrease. Stop the test as soon as this occurs in order to prevent damage to the deformation measurement devices from a sudden failure of the specimen. Collect data at a rate of 2 Hz.

8. DATA ANALYSIS AND CALCULATIONS

For the purposes of LTPP testing, data analysis and calculations are performed using software developed by Dr. Reynaldo Roque. The software used to perform these calculations is titled as follows: MRFHWA.EXE - used to calculate resilient modulus test results. ITLTFHWA.EXE - used to calculate creep compliance and indirect tensile test results. Documentation accompanying the software describes its use. In addition, Appendix B outlines the analysis methodology used by the software.

9. REPORT

The report shall consist of a hard copy of Form T07, and electronic copies of all data files referenced on Form T07 submitted on an accompanying diskette.

9.1 Form T07 - Sample Summary Information

Form T07 contains general information about each test specimen. Fill out Form T07 as described below. Items 1 through 6 shall be the same for each specimen. Items 7 through 44 shall be filled out for each of the three specimens undergoing testing.

9.1.1 Item 1 – State Code

9.1.2 Item 2 – SHRP ID

9.1.3 Item 3 – Layer Number

9.1.4 Item 4 – Field Set

9.1.5 Item 5 – Test No (Generally all three specimens will have the same Test No. However space has been left to record the Test No for each specimen independently in case three adequate specimens with the same Test No were not provided to the lab.)

9.1.6 Item 6 - Sample Area (SPS sections only) (As with Test No, the Sample Area should be the same for all three specimens)

9.1.7 Item 7 – Location Number

9.1.8 Item 8 – LTPP Sample Number

9.1.9 Item 9 – Average Specimen Thickness, mm.

9.1.10 Item 10 – Average Specimen Diameter, mm.

9.1.11 Item 11 – Bulk Specific Gravity (from Test AC02).

9.1.12 Item 12 – Comment 1. This comment shall be in accordance with the codes listed in Section 4.3 of this Guide.

9.1.13 Item 13 – Comment 2. This comment shall be in accordance with the codes listed in Section 4.3 of this Guide.

9.1.14 Item 14 – Comment 3. This comment shall be in accordance with the codes listed in Section 4.3 of this Guide.

9.1.15 Item 15 – Other Comments. This field shall be used to document situations for which there is no corresponding code in Section 4.3 of this Guide.

9.1.16 Item 16 – Data Filename, Test 1. This shall be the name of the raw data file generated during resilient modulus testing at the first test temperature.

9.1.17 Item 17 – Test 1 Temp. (°C). This shall be the temperature at which the first resilient modulus test was run.

9.1.18 Item 18 – Data Filename, Test 2. This shall be the name of the raw data file generated during resilient modulus testing at the second test temperature.

9.1.19 Item 19 – Test 2 Temp. (°C). This shall be the temperature at which the second resilient modulus test was run.

9.1.20 Item 20 – Data Filename, Test 3. This shall be the name of the raw data file generated during resilient modulus testing at the second test temperature.

9.1.21 Item 21 – Test 3 Temp. (°C). This shall be the temperature at which the first resilient modulus test was run.

9.1.22 Item 22 – Analysis Filename. This shall be the name of the resilient modulus output file generated by the "MRFHWA" software.

9.1.23 Item 23 – Data Filename, Test 1. This shall be the name of the raw data file generated during creep compliance testing at the first test temperature.

9.1.24 Item 24 – Test 1 Temp. (°C). This shall be the temperature at which the first creep compliance test was run

9.1.25 Item 25 – Data Filename, Test 2. This shall be the name of the raw data file generated during creep compliance testing at the second test temperature.

9.1.26 Item 26 – Test 2 Temp. (°C). This shall be the temperature at which the second creep compliance test was run.

9.1.27 Item 27 – Data Filename, Test 3. This shall be the name of the raw data file generated during creep compliance testing at the third test temperature.

9.1.28 Item 28 – Test 3 Temp. (°C). This shall be the temperature at which the third creep compliance test was run.

9.1.29 Item 29 – Analysis Filename. This shall be the name of the creep compliance output file generated by the "ITLTFHWA" software.

9.1.30 Item 30 – Data Filename. This shall be the name of the raw data file generated during the indirect tensile strength test.

9.1.31 Item 31 – Test Temp (°C). This shall be the temperature at which the indirect tensile strength test was run.

9.1.32 Item 32 – ".OUT" Filename. This shall be the name of the output file containing indirect tensile strength and poisons ratio generated by the "ITLTFHWA" software. By default this file has a ".out" extension.

9.1.33 Item 33 – ".STR" Filename. This shall be the name of the output file containing the stress versus strain information calculated by the "ITLTFHWA" software. By default this file has a ".str" extension. (Currently this data is not used by LTPP.)

9.1.34 Item 34 – ".FAM" Filename. This shall be the name of the output file containing the initial tangent modulus, failure strain and fracture energy calculated by the "ITLTFHWA" software. By default this file has a ".fam" extension. (Currently this data is not used by LTPP.)

9.2 Electronic Data files

The electronic data files shall be located on a clearly labeled diskette accompanying form T07, and the filenames shall be as recorded on form T07. One complete test sequence will generate 26 data files. The breakdown is as follows:

9 Resilient modulus raw data files
(one for each specimen at each temperature)

9 Creep compliance raw data files
(one for each specimen at each temperature)

3 Indirect tensile strength test raw data files
(one for each specimen)

1 Resilient modulus analysis file

1 Creep compliance analysis file

3 Indirect tensile strength test analysis files

9.2.1 File Naming convention

9.2.1.1 Raw Data Files

As a result of testing performed using this procedure, 21 raw data files are generated. Raw data files are files that contain time, load, deformation, and temperature information for each test procedure. The data files are named in the following manner:

12345678.dat

Slots 1, 2, 3, and 4 are used to assign a number to each sample. This number shall be assigned sequentially by the laboratory, and shall be unique to the specimen under test. Slots 5 and 6 of the file are used to designate the test performed; "rm" for resilient modulus, "cp" for creep compliance, or "ts" for indirect tensile strength. Slots 7 and 8 are used to designate the test temperature; "-0" for -10°C (14°F), "05" for 5°C (41°F), "25" for 25°C (77°F), and "40" for 40°C (104°F). All files have a ".dat" extension to designate it is a raw data file. Table 1 contains an example of the number and naming of data files resulting from one test sequence.

Table 1. Example Data File Names

Test	Temperature	Specimen 1	Specimen 2	Specimen 3
Resilient Modulus	5°C (41°F)	6042rm05.dat	6043rm05.dat	6044rm05.dat
	25°C (77°F)	6042rm25.dat	6043rm25.dat	6044rm25.dat
	40°C (104°F)	6042rm40.dat	6043rm40.dat	6044rm40.dat
Creep Compliance	-10°C (14°F)	6042cp-0.dat	6043cp-0.dat	6044cp-0.dat
	5°C (41°F)	6042cp05.dat	6043cp05.dat	6044cp05.dat
	25°C (77°F)	6042cp25.dat	6043cp25.dat	6044cp25.dat
Indirect Tensile Strength	25°C (77°F)	6042ts25.dat	6043ts25.dat	6044ts25.dat

9.2.1.2 Analysis Files

The analysis files are created by running the "MRFHWA" software on the resilient modulus data files, and the "ITLTFHWA" software on the creep compliance and indirect tensile strength data files. The analysis files generated by these programs by default have the same first eight characters as the specimen 1 data file, but a different extension. Table 2 contains example analysis filenames for the set of raw data files contained in Table 1.

Table 2. Example Analysis File Names

Contents	Filename
Resilient Modulus	6042rm05.mro
Creep Compliance	6042cp-0.out
Indirect Tensile Strength	6042ts25.out
Stress vs. Strain	6042ts25.str
Initial tangent modulus, fracture energy and failure strain	6042ts25.fam

9.2.2 File Structure

As these files are to be analyzed and uploaded to the PPDB using automated software, strict adherence to the standard file structures presented here is critical.

9.2.2.1 Raw Data File Structure

Each raw data file shall contain seven tab-delimited columns containing the following information:

Column 1 – horizontal deformation, sample face 1, in.
Column 2 – vertical deformation, sample face 1, in.

Column 3 – horizontal deformation, sample face 2, in.
Column 4 – horizontal deformation, sample face 2, in.
Column 5 – applied load, lb.
Column 6 – time, seconds
Column 7 – environmental chamber temperature, °F

Each raw data file corresponds to an asphalt specimen that has undergone the Resilient Modulus, Creep Compliance, or Indirect Tensile testing; all of the data files follow roughly the same format. Each data file contains a number of rows that contain data for each sampling point taken during the testing process. The specific format for each data file type is as follows:

9.2.2.1.1 Resilient Modulus Data File

For resilient modulus testing, five test cycles are collected at a sampling rate of 500 points per second, resulting in a data file with approximately 2500 rows. The first thirteen rows contain header information that is not essential for the calculations. The fourteenth and fifteenth rows are the data names and units; the data are arranged in columns below the data names and units. The data is organized in columns 1 through 7; there should be exactly 2562 rows of data. The first column (rows 16–2577) contains deformation data collected from the first horizontal extensometer. The second column (rows 16–2577) contains deformation data collected from the first vertical extensometer. The third column (rows 16–2577) contains deformation data collected from the second horizontal extensometer. The fourth column (rows 16–2577) contains deformation data from the second vertical extensometer. The fifth column (rows 16–2577) contains load data obtained throughout the test. The sixth column (rows 16–2577) contains the time at which the corresponding data values are recorded; the total nominal time duration of each test should be 5 seconds. The environmental chamber temperature is shown in the seventh column (rows 16–2577).

9.2.2.1.2 Creep Compliance Raw Data File

Creep compliance testing requires a sampling rate of 10 points per second for 100 seconds, and these data files nominally contain a little over a thousand rows of data (1000 rows of testing data and a few pre-test and post-test data points). Each data file corresponds to an asphalt specimen that has undergone the creep compliance testing. The first 5 rows of each data file contain header information that is not essential for the calculations. Row 6 includes the data labels for each data type and row 7 includes the units for each data type. The data is organized in columns 1 through 7; there should be exactly 1039 rows of data. The first column (rows 8–1046) contains deformation data collected from the first horizontal extensometer. The second column (rows 8–1046) contains deformation data collected from the first vertical extensometer. The third column (rows 8–1046) contains deformation data collected from the second horizontal extensometer. The fourth column (8–1046) contains deformation data from the second vertical extensometer. The fifth column (rows 8–1046) contains load data obtained throughout the test. The sixth column (rows 8–1046) contains the time at which the corresponding data values are recorded; the total nominal duration of each test should be 100 seconds. The environmental chamber temperature is shown in the seventh column (rows 8–1046).

9.2.2.1.3 Indirect Tensile Strength Raw Data File

Indirect tensile strength testing requires data collection at no less than twenty points per second for the duration of the test. The number of rows in these files fluctuates based upon the response (strain to failure) of the test specimen. Each data file corresponds to an asphalt specimen that has undergone the indirect tensile testing. The first 6 rows of each data file contain header information that is not essential for the calculations. Row 7 includes the data labels for each data type and row 8 includes the units for each data type. The data is organized in columns 1 through 7. The first column contains the deformation data collected from the first horizontal extensometer. The second column contains the deformation data collected from the first vertical extensometers. The third column contains the deformation data collected from the second horizontal extensometer. The fourth column contains the deformation data from the second vertical extensometer. The fifth column contains the load data obtained throughout the test. The sixth column contains the time at which the corresponding data values are recorded. The environmental chamber temperature is shown in the seventh column.

9.2.2.2 Analysis File Structure

The analysis files shall be generated by the "MRFHWA" and "ITLTFHWA" programs, and shall be submitted by the lab with no modifications.

Appendix A

Test Equipment Specifications

A1. LOAD HEADS

A1.1 Bottom Load Heads

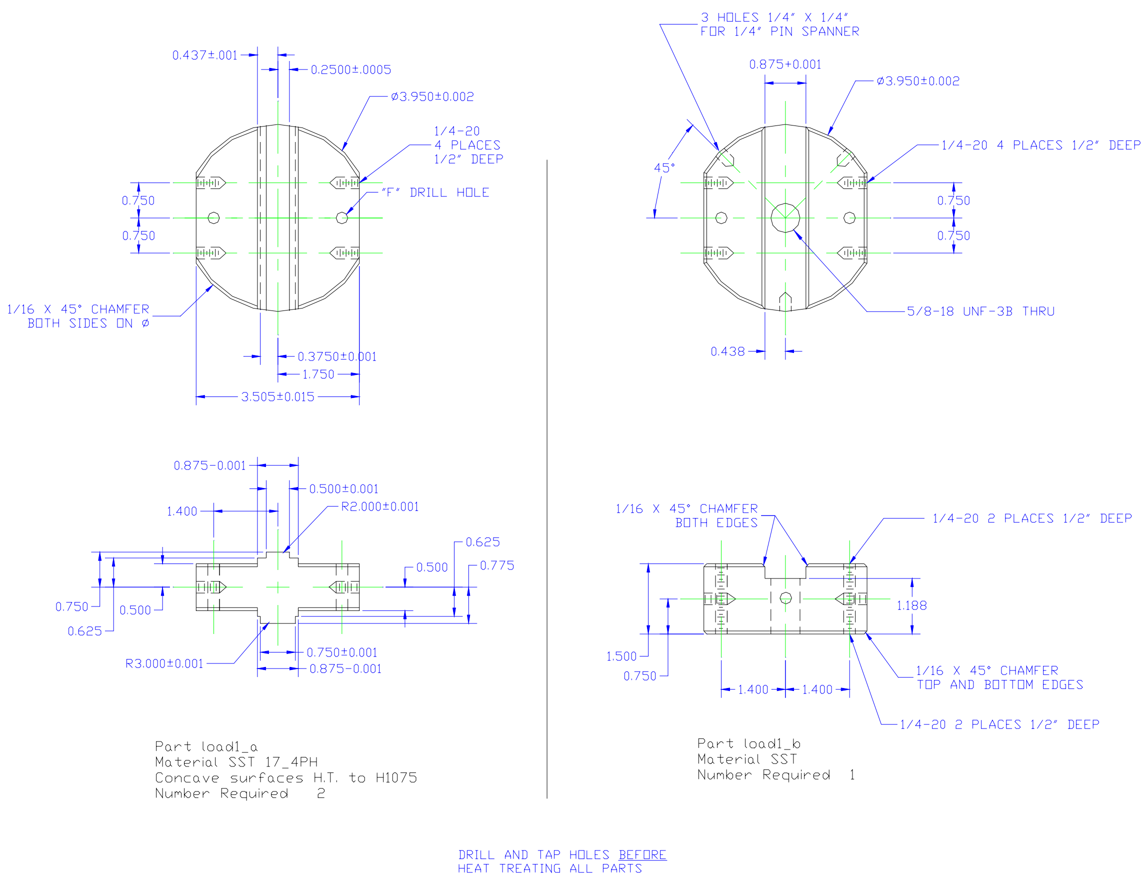


Figure A.1.1. Bottom load heads.

A1.2 Bottom Load Head Subassembly

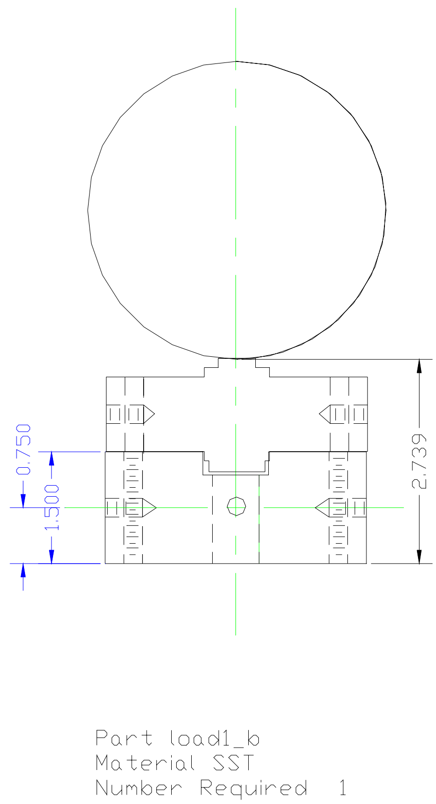


Figure A.1.2. Bottom load head subassembly.

A1.3 Top Load Head

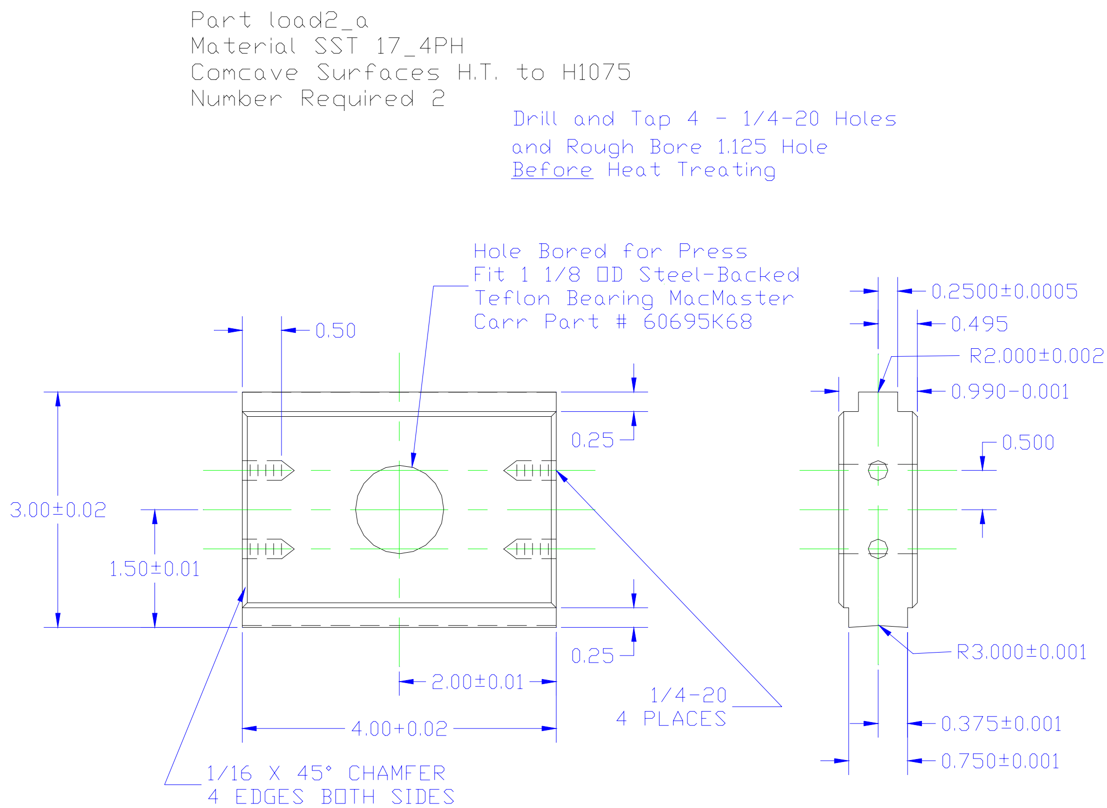


Figure A.1.3. Top load head.

A1.4 Top Load Head Swivel Block

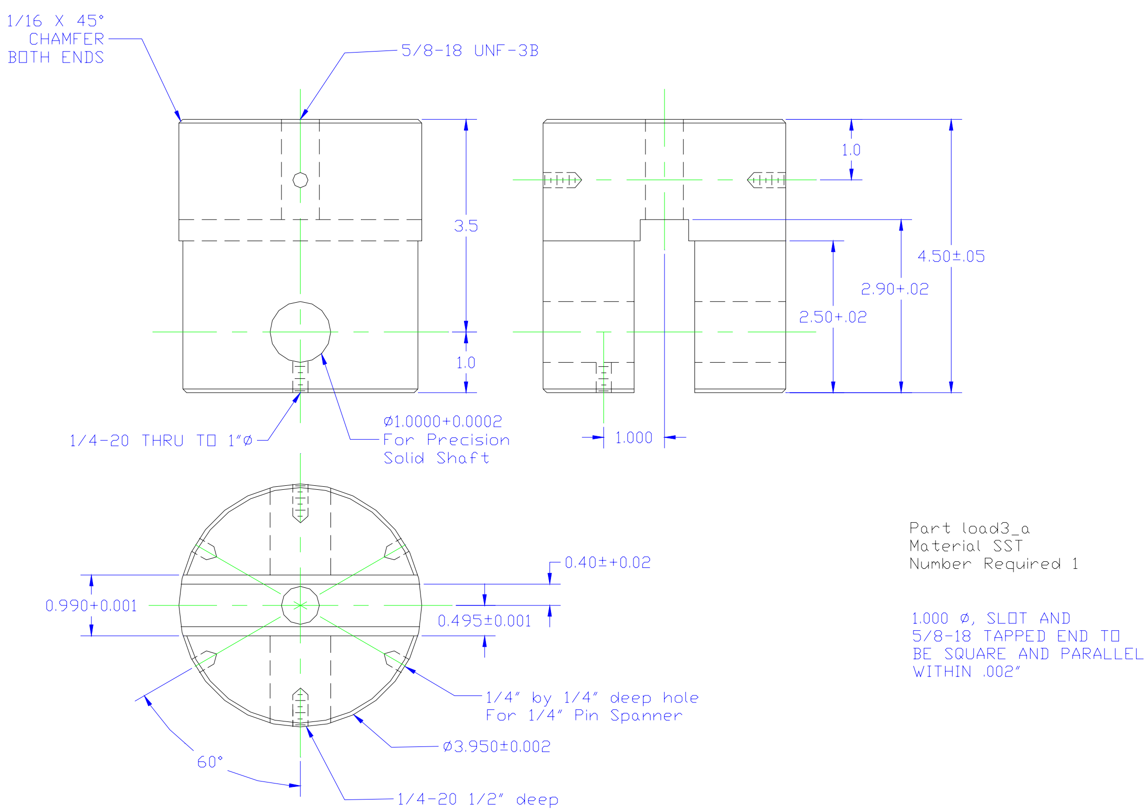


Figure A.1.4. Top load head swivel block.

A2. LOAD RODS

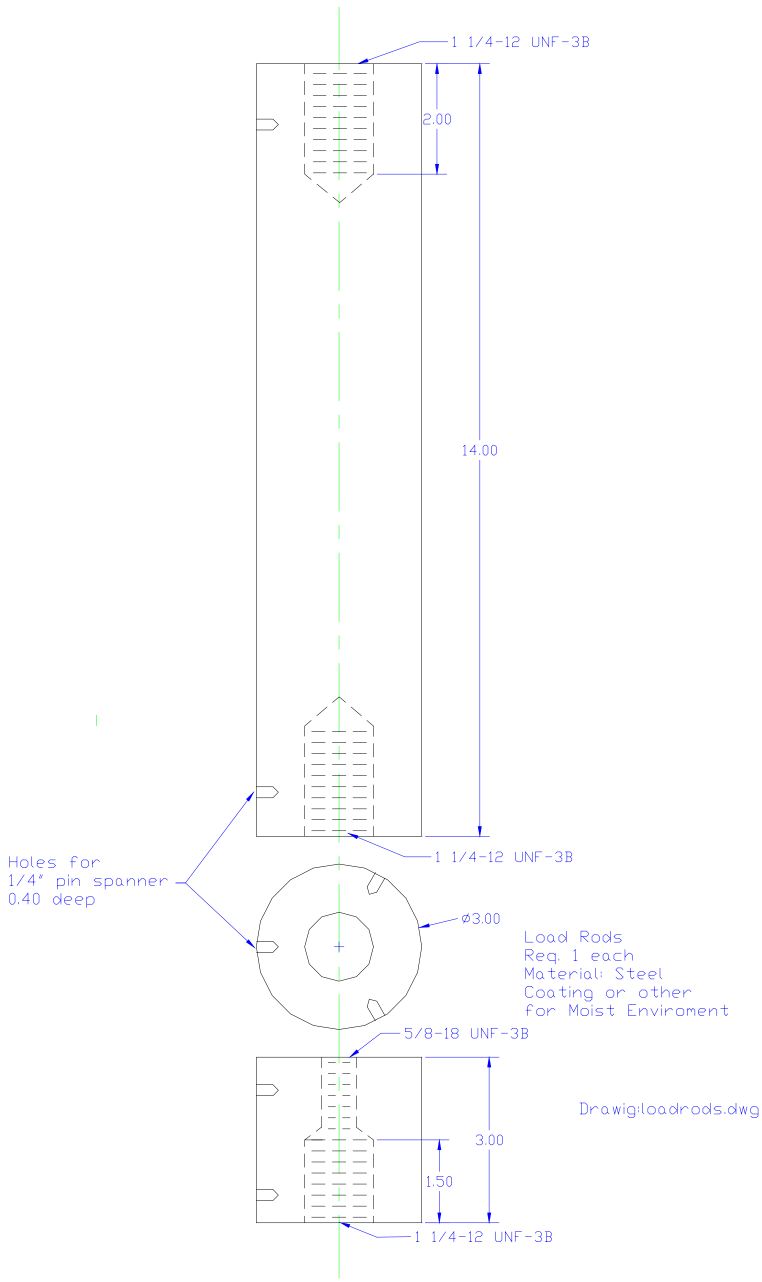


Figure A.2. Load rods.

A3. GAUGE POINT MOUNTING TEMPLATE

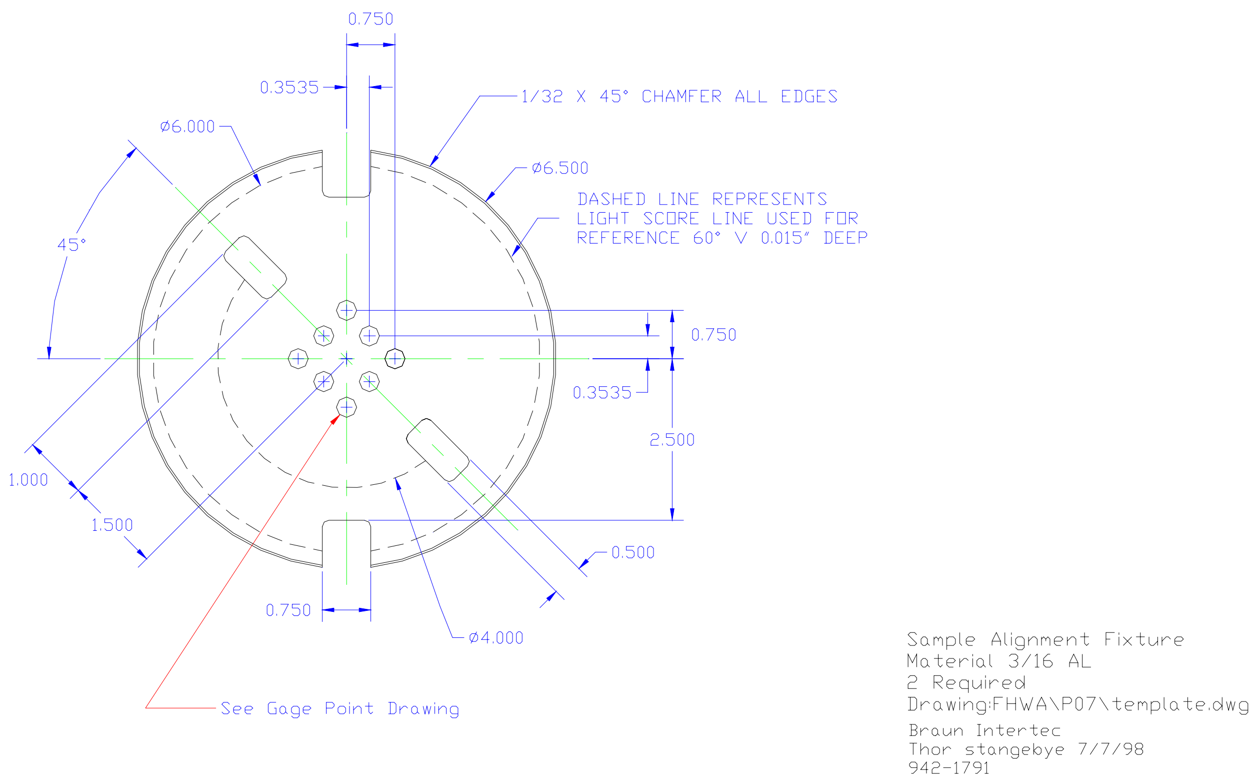
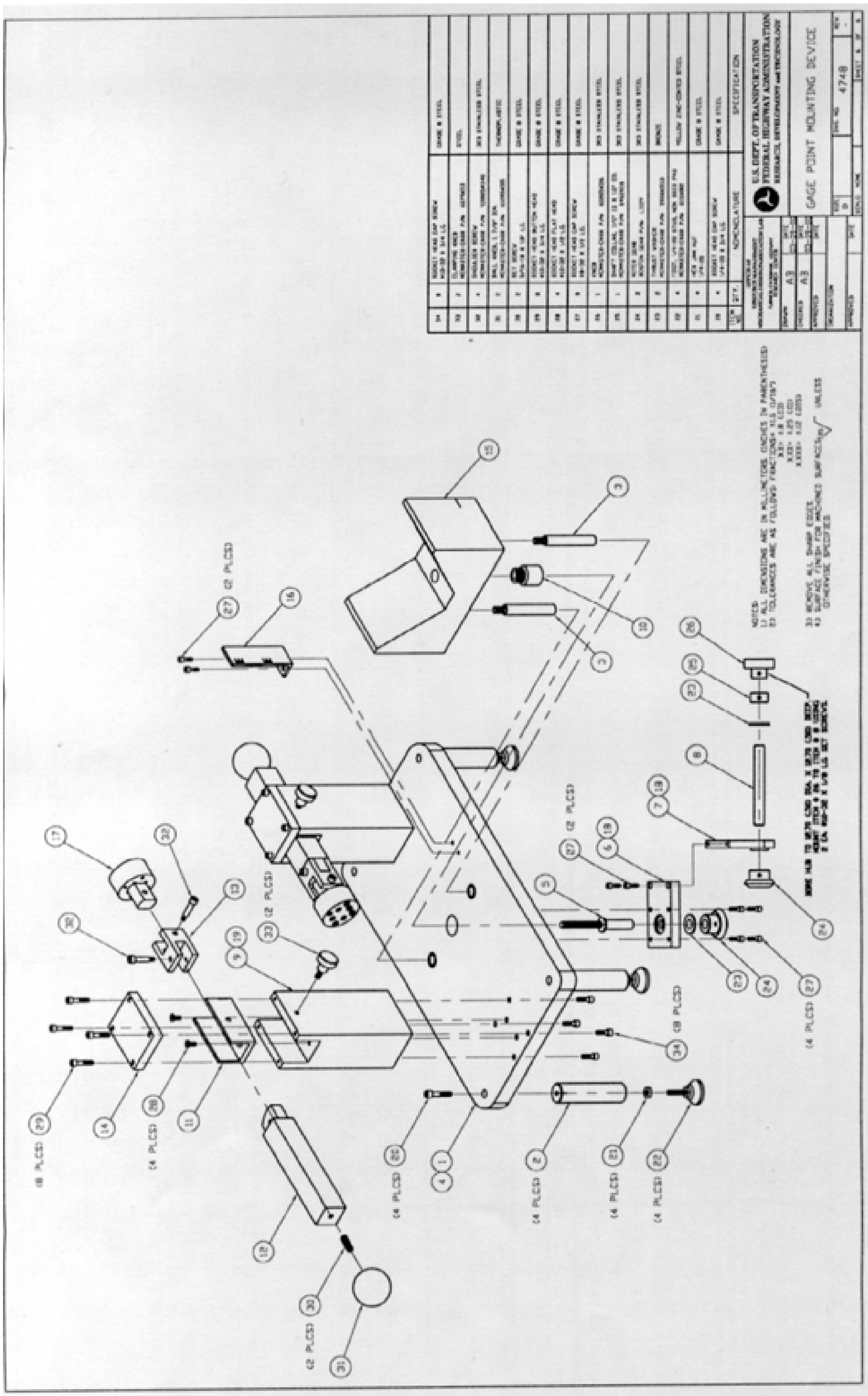


Figure A.3. Gauge point mounting template

A6. GAUGE POINT MOUNTING DEVICE



Appendix B

Data Analysis Algorithms

B1. INTRODUCTION

This appendix contains the algorithms used to determine the resilient modulus, creep compliance and indirect tensile strength for specimens tested using the P07 testing protocol. The algorithms presented herein are based upon the data format, data sampling rates and file structures used for LTPP P07 testing purposes. If formats, sampling rates or file structures used are different than outlined herein, the algorithms should be modified appropriately.

These algorithms are based upon the methods developed by Dr. Reynaldo Roque et al. and documented in the report referenced in Section 4.4 of this protocol. Dr. Roque and his colleagues developed two programs: MRFHWA to reduce and analyze resilient modulus data, and ITLTFHWA to reduce and analyze creep compliance and indirect tensile strength data. The user's guide for the software is available as a separate document. The data analysis methods used in MRFHWA and ITLTFHWA are documented in this appendix.

This appendix is divided into four sections as follows:

B1. Introduction
B2. Resilient Modulus Data Analysis Algorithm
B3. Creep Compliance Data Analysis Algorithm
B4. Indirect Tensile Strength Analysis Algorithm

B2. RESILIENT MODULUS DATA ANALYSIS ALGORITHM

An outline of the resilient modulus data analysis algorithm that is used in the "MRFHWA" software, and described in the report by Roque et al. is presented in section B2.2. The algorithm is described graphically in section B2.3.

B2.1 Subscript Convention

For the purpose of clarity, a subscript convention has been developed. The subscript 'i' represents the specimen number (i = 1, 2, or 3), the subscript 'j' represents the cycle number (j = 1, 2, or 3), and the subscript 'k' represents the specimen face (k = 1 or 2). Thus a variable may have up to three subscripts of the following form: $X_{i,j,k}$.

B2.2 Analysis

<u>A separate analysis must be performed for each of the three temperatures</u>.

B2.2.1 Select Cycles

For each of the three specimens, determine which three cycles of the five recorded in the data file shall be used for analysis. Find the maximum load (Pmax) of the first recorded cycle in the data file. If the maximum occurs at or after 150 points from the start of the file, then the first three cycles recorded in the data file shall be used for subsequent analysis. If the maximum occurs less than 150 points from the start of the file, then the second, third and fourth cycles recorded in the test shall be used. From now on, regardless of which cycles have been selected for analysis, they shall be referred to as cycles 1, 2 and 3, respectively.

B2.2.2 Calculate Contact Load ($Pcontact_i$)

For each of the three specimens calculate the contact load. Only one contact load shall be calculated for each specimen as follows:

(1) Determine the point at which the maximum load (Pmax) occurs for cycle 1.
(2) Select the range of cells from 80 points before Pmax to 30 points before Pmax (50 points total)
(3) Average the load values in the selected range as follows:

Eq. B1: $$Pcontact_i = \frac{\sum_{y=x-80}^{x-30} P_y}{50}$$

where: $Pcontact_i$ = the contact load for specimen i, lbs.
P_y = the load at point y, lbs.
x = the point at which $Pmax_{i,1}$ occurs

B2.2.3 Determine Cycle Start and End Points

For each cycle **j** on each specimen **i**, determine the start and end points as follows. Determine Pmax for cycle **j**

(1) Starting at Pmax, and moving to the left, the start of cycle **j** is defined as the last data point for which the load is <u>greater than</u> $Pcontact_i$ + 6 lbs (2.7 kg). This value shall be referred to as $sp_{i,j}$.

(2) Starting at Pmax and moving to the right, the end point for cycle j is defined as the last data point for which the load is <u>less than</u> $Pcontact_i$ + 6 lbs (2.7 kg). This value shall be referred to as $ep_{i,j}$.

B2.2.4 Determine the Cyclic Load

For each cycle **j** on each specimen **i**, determine the cyclic load ($Pcyclic_{i,j}$) as follows:

Eq. B2: $$Pcyclic_{i,j} = P\max_{i,j} - Pcontact_i$$

where: $Pcyclic_{i,j}$ = the cyclic load for cycle j of specimen i, lbs.

$Pmax_{i,j}$ = the maximum load for cycle j of specimen i, lbs.
$Pcontact_i$ = the contact load of specimen i, lbs

B2.2.5 Calculate the maximum deformations:

On each of the two sawn faces of the sample, deformations are measured in the horizontal and vertical axes. Thus for each sample there will be a total of four deformation vs. time traces. From each of these traces, pick off the maximum deformation for each of the three cycles, within the cycle start and end points defined in section B2.2.3. These deformations will be referred to in the following format:

$$\{\mathbf{H,V}\}max_{\mathbf{i,j,k}}\text{, inches}$$

where {H,V} refers to the axis in which the deformation was measured (horizontal or vertical) and subscripts i, j and k refer to the specimen, cycle and face, as defined in section B2.1.

B2.2.6 Determine minimum deformations:

For $\{\mathbf{H,V}\}max_{\mathbf{i,j,k}}$ calculated in section 4.2.5 there will be two corresponding minimum deformations: Total and Instantaneous, as shown in Figure 3 of the main body of this procedure. To calculate these minimum deformations two regression lines must be developed. These minimum deformations shall be referred to in the following format:

$$\{\mathbf{H,V}\}min\{\mathbf{I,T}\}_{\mathbf{i,j,k}}\text{, inches}$$

where {H,V} refers to the axis in which the deformation was measured (horizontal or vertical), {I,T} refers to the type of deformation (instantaneous or total) and subscripts i, j and k refer to the specimen, cycle and face, as defined in section B2.1.

To calculate $\{\mathbf{H,V}\}min\{\mathbf{I,T}\}_{\mathbf{i,j,k}}$, two regression lines must be developed from the deformation vs. time trace.

B2.2.6.1 Regression Line 1

(1) Starting at $\{\mathbf{H,V}\}max_{\mathbf{i,j,k}}$ and moving to the right, select the 5th through 17th data points (13 data points total).

(2) Perform a least squares linear regression on deformation vs. time for the selected data points. The resulting equation shall be as follows:

Eq. B3
$$Deformation = m_1 \times (Time) + b_1$$

Where: m_1 = the slope of regression line 1, and
b_1 = the Y-intercept of regression line 1

B2.2.6.2 Regression Line 2

(1) Starting at the start point of cycle **j+1** and moving to the left, select first 300 data points (300 data points total).

(2) Perform a least squares linear regression on deformation versus time for the selected data points. The resulting equation shall be as follows:

Eq. B4 $$Deformation = m_2 \times (Time) + b_2$$

Where: m_2 = the slope of regression line 2, and
b_2 = the Y-intercept of regression line 2

B2.2.6.3 Calculate {**H,V**}min$\mathbf{I_{i,j,k}}$

{**H,V**}min$\mathbf{I_{i,j,k}}$ is the deformation at the intersection of regression lines 1 and 2.

Eq. B5 $$\{H,V\}\min I_{i,j,k} = m_2 \times \left(\frac{b_2 - b_1}{m_1 - m_2} \right) + b_1$$

B2.2.6.4 Calculate {**H,V**}min$\mathbf{T_{i,j,k}}$

{**H,V**}min$\mathbf{T_{i,j,k}}$ is the deformation calculated from regression line 1 and the first point of cycle **j+1**

Eq.B6 $$\{H,V\}\min T_{i,j,k} = m_2 \times (sp_{i,j+1}) + b_2$$

B2.2.7 Calculate the total and instantaneous recoverable deformations

The total and instantaneous recoverable deformations shall be referred to as $\Delta\{H,V\}T_{i,j,k}$ and $\Delta\{H,V\}I_{i,j,k}$ respectively.

Eq. B7 $$\Delta\{H,V\}\{I,T\}_{i,j,k} = \{H,V\}\max_{i,j,k} - \{H,V\}\min\{I,T\}_{i,j,k}$$

B2.2.8 Calculate average thickness and diameter

Eq. B8 $$tavg = \frac{\sum_{i=1}^{3} t_i}{3}$$

Eq. B9 $$davg = \frac{\sum_{i=1}^{3} d_i}{3}$$

Where: tavg = the average thickness for all the specimens, inches

t_i = the thickness of specimen i, in
davg = the average thickness for all the specimens, inches
d_i = the diameter of specimen i, in

B2.2.9 Calculate the average cyclic load

Eq. B10
$$Pavg_j = \frac{\sum_{i=1}^{3} Pcyclic_{i,j}}{3}$$

Where: $Pavg_j$ = the average cyclic load for cycle j, lbs.
$Pcyclic_{i,j}$ = the cyclic load for cycle j of specimen i, lbs.

B2.2.10 Calculate the deformation normalization factors

Eq. B11
$$Cnorm_{i,j} = \left(\frac{t_i}{tavg}\right) \times \left(\frac{d_i}{davg}\right) \times \left(\frac{Pcyclic_{i,j}}{Pavg_j}\right)$$

Where: $Cnorm_{i,j}$ = the deformation correction factor for cycle j of specimen i,
t_i = the thickness of specimen i, in.
tavg = the average thickness of the specimens, in.
d_i = the diameter of specimen i, in.
davg = the average diameter of the specimens, in.
$Pcyclic_{i,j}$ = the cyclic load for cycle j of specimen i, lb.
$Pavg_j$ = the average cyclic load for cycle j lb.

B2.2.11 Calculate the normalized deformations

Eq. B12
$$\Delta\{H,V\}\{I,T\}n_{i,j,k} = \left(Cnorm_{i,j,k}\right) \times \left(\Delta\{H,V\}\{I,T\}_{i,j,k}\right)$$

Where: $\Delta\{H,V\}\{I,T\}n_{i,j,k}$ = the normalized deformation for face k and cycle j of specimen i, in.
$Cnorm_{i,j}$ = the deformation correction factor for cycle j of specimen i,
$\Delta\{H,V\}\{I,T\}_{i,j,k}$ = the deformation for face k and cycle j of specimen i, in.

B2.2.12 Average deformation data sets

There are 12 deformation data sets. A deformation data set consists of all the recoverable deformations calculated for a given axis {H,V}, measurement point {I,T} and cycle **j**. Average the deformation data sets by <u>one</u> of the following methods:

B2.2.12.1 Method 1: Normal Analysis

For each deformation data set, remove the highest and lowest deformation and average the remaining four. This average shall be referred to as $\Delta\{H,V\}\{I,T\}navg_j$

B2.2.12.2 Method 2: Variation of Normal Analysis

For each deformation data set, remove the tow highest and the two lowest deformations and average the remaining two. This average shall be referred to as $\Delta\{H,V\}\{I,T\}navg_j$

B2.2.12.3 Method 3: Individual Analysis

For each deformation data set, remove any deformations and average the remaining deformations. This average shall be referred to as $\Delta\{H,V\}\{I,T\}navg_j$

B2.2.13 Calculate Poisson's ratios

Eq. B13 $$v\{I,T\}_j = -0.1 + 1.480 \times \left(\frac{\Delta H\{I,T\}navg_j}{\Delta V\{I,T\}navg_j} \right) - 0.778 \times \left(\frac{\Delta HInavg_j}{\Delta VInavg_j} \right)$$

B2.2.14 Calculate the cycle averaged deformations

Eq. B14 $$\Delta\{H,V\}\{I,T\}ncycleavg = \frac{\sum_{j=1}^{3} \Delta\{H,V\}\{I,T\}navg_j}{3}$$

B2.2.15 Calculate the resilient modulus correction factors

Eq. B15 $$Cmr\{I,T\} = 0.6345 \times \left(\frac{\Delta V\{I,T\}ncycleavg}{\Delta H\{I,T\}ncycleavg} \right) - 0.332$$

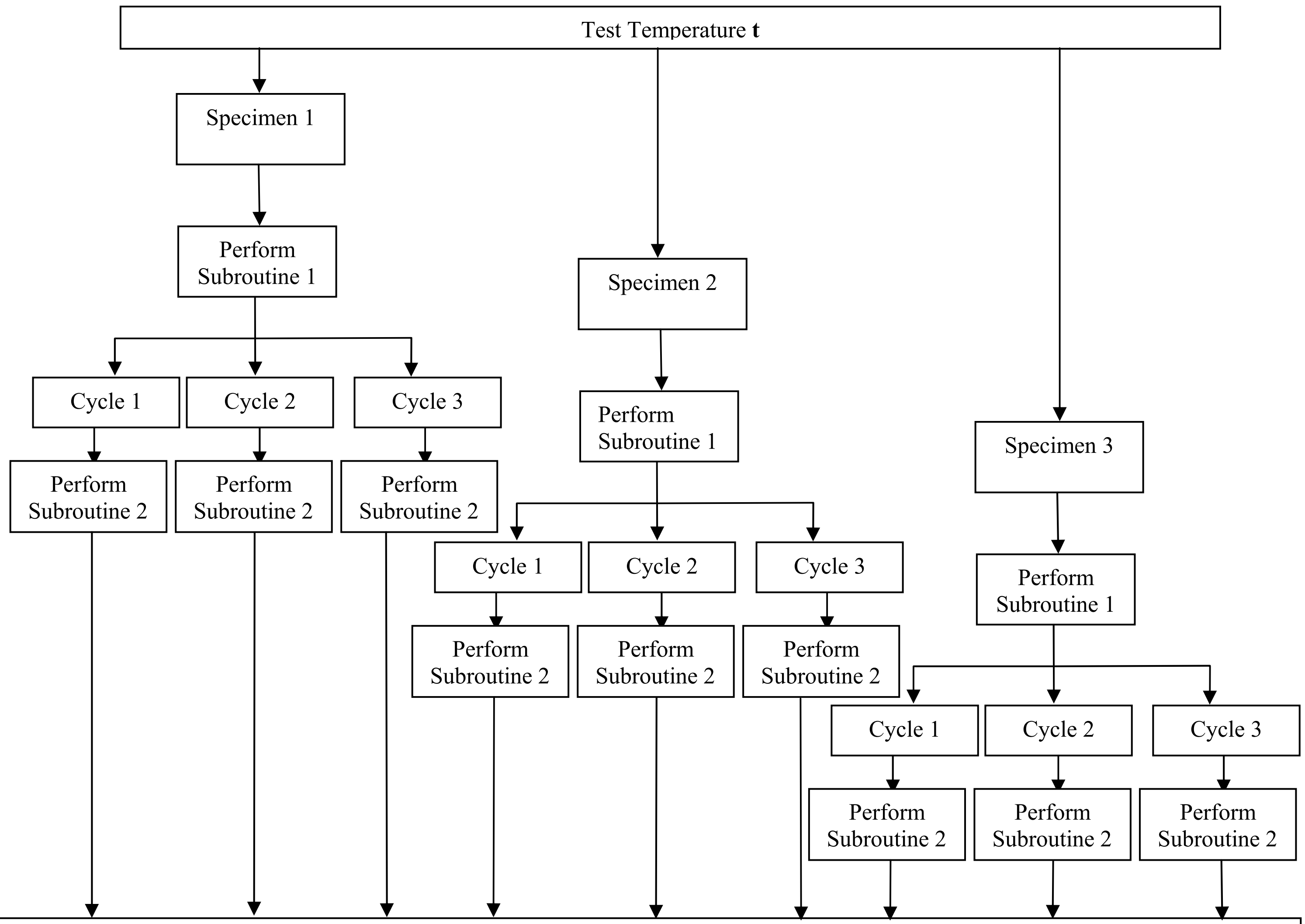
B2.2.16 Calculate resilient modulus

Eq. B16 $$M_r\{I,T\}_j = \frac{l \times Pavg_j}{\Delta H\{I,T\}navg_j \times davg \times tavg \times Cmr\{I,T\}}$$

B2.2.18 Repeat sections B2.2.1 through B2.2.17 for each temperature.

B2.3 Resilient Modulus Data Analysis Algorithm Flowchart

B2.3.1 Main Procedure



Here's what you have calculated so far:

Specimen	Cycle	P_{cyclic}	Face 1 Deformations				Face 2 Deformations			
			Total		Instant.		Total		Instant.	
			Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.
1	1	$Pcyclic_{1,1}$	$\Delta HT_{1,1,1}$	$\Delta VT_{1,1,1}$	$\Delta HI_{1,1,1}$	$\Delta VI_{1,1,1}$	$\Delta HT_{1,1,2}$	$\Delta VT_{1,1,2}$	$\Delta HI_{1,1,2}$	$\Delta VI_{1,1,2}$
	2	$Pcyclic_{1,2}$	$\Delta HT_{1,2,1}$	$\Delta VT_{1,2,1}$	$\Delta HI_{1,2,1}$	$\Delta VI_{1,2,1}$	$\Delta HT_{1,2,2}$	$\Delta VT_{1,2,2}$	$\Delta HI_{1,2,2}$	$\Delta VI_{1,2,2}$
	3	$Pcyclic_{1,3}$	$\Delta HT_{1,3,1}$	$\Delta VT_{1,3,1}$	$\Delta HI_{1,3,1}$	$\Delta VI_{1,3,1}$	$\Delta HT_{1,3,2}$	$\Delta VT_{1,3,2}$	$\Delta HI_{1,3,2}$	$\Delta VI_{1,3,2}$
2	1	$Pcyclic_{2,1}$	$\Delta HT_{2,1,1}$	$\Delta VT_{2,1,1}$	$\Delta HI_{2,1,1}$	$\Delta VI_{2,1,1}$	$\Delta HT_{2,1,2}$	$\Delta VT_{2,1,2}$	$\Delta HI_{2,1,2}$	$\Delta VI_{2,1,2}$
	2	$Pcyclic_{2,2}$	$\Delta HT_{2,2,1}$	$\Delta VT_{2,2,1}$	$\Delta HI_{2,2,1}$	$\Delta VI_{2,2,1}$	$\Delta HT_{2,2,2}$	$\Delta VT_{2,2,2}$	$\Delta HI_{2,2,2}$	$\Delta VI_{2,2,2}$
	3	$Pcyclic_{2,3}$	$\Delta HT_{2,3,1}$	$\Delta VT_{2,3,1}$	$\Delta HI_{2,3,1}$	$\Delta VI_{2,3,1}$	$\Delta HT_{2,3,2}$	$\Delta VT_{2,3,2}$	$\Delta HI_{2,3,2}$	$\Delta VI_{2,3,2}$
3	1	$Pcyclic_{3,1}$	$\Delta HT_{21,1}$	$\Delta VT_{3,1,1}$	$\Delta HI_{3,1,1}$	$\Delta VI_{3,1,1}$	$\Delta HT_{3,1,2}$	$\Delta VT_{3,1,2}$	$\Delta HI_{3,1,2}$	$\Delta VI_{3,1,2}$
	2	$Pcyclic_{3,2}$	$\Delta HT_{2,2,1}$	$\Delta VT_{3,2,1}$	$\Delta HI_{3,2,1}$	$\Delta VI_{3,2,1}$	$\Delta HT_{3, 2,2}$	$\Delta VT_{3,2,2}$	$\Delta HI_{3,2,2}$	$\Delta VI_{3,2,2}$
	3	$Pcyclic_{3,3}$	$\Delta HT_{2,3,1}$	$\Delta VT_{3,3,1}$	$\Delta HI_{3,3,1}$	$\Delta VI_{3,3,1}$	$\Delta HT_{3,3,2}$	$\Delta VT_{3,3,2}$	$\Delta HI_{3,3,2}$	$\Delta VI_{3,3,2}$

1

1

Calculate average thickness (tavg) and diameter (davg) for each specimen:

$tavg = (t_1 + t_2 + t_3)/3$
$davg = (d_1 + d_2 + d_3)/3$

Calculate average cyclic load ($Pavg_j$) for each cycle:

$Pavg_j = Pcyclic_{1,j} + Pcyclic_{2,j} + Pcyclic_{3,j}$

Calculate $Cnorm_{i,j}$ for each specimen and cycle:

$Cnorm_{i,j} = (t_i / tavg) * (d_i / davg) * (Pcyclic_{i,j} / Pavg_j)$

Calculate normalized deformations ($\Delta\{H,V\}\{I,T\}norm_{i,j,k}$):

$\Delta\{H,V\}\{I,T\}n_{i,j,k} = Cnorm_{i,j} * \Delta\{H,V\}\{I,T\}_{i,j,k}$

Here's what you have calculated so far:

Spec-imen	Cycle	Pcyclic	Cnorm	Face 1 Normal.Deformations				Face 2 Normal. Deformations			
				Total		Instant.		Total		Instant.	
				Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.
1	1	$Pcyclic_{1,1}$	$Cnorm_{1,1}$	$\Delta HTn_{1,1,1}$	$\Delta VTn_{1,1,1}$	$\Delta HIn_{1,1,1}$	$\Delta VIn_{1,1,1}$	$\Delta HTn_{1,1,2}$	$\Delta VTn_{1,1,2}$	$\Delta HIn_{1,1,2}$	$\Delta VIn_{1,1,2}$
	2	$Pcyclic_{1,2}$	$Cnorm_{1,2}$	$\Delta HTn_{1,2,1}$	$\Delta VTn_{1,2,1}$	$\Delta HIn_{1,2,1}$	$\Delta VIn_{1,2,1}$	$\Delta HTn_{1,2,2}$	$\Delta VTn_{1,2,2}$	$\Delta HIn_{1,2,2}$	$\Delta VIn_{1,2,2}$
	3	$Pcyclic_{1,3}$	$Cnorm_{1,3}$	$\Delta HTn_{1,3,1}$	$\Delta VTn_{1,3,1}$	$\Delta HIn_{1,3,1}$	$\Delta VIn_{1,3,1}$	$\Delta HTn_{1,3,2}$	$\Delta VTn_{1,3,2}$	$\Delta HIn_{1,3,2}$	$\Delta VIn_{1,3,2}$
2	1	$Pcyclic_{2,1}$	$Cnorm_{2,1}$	$\Delta HTn_{2,1,1}$	$\Delta VTn_{2,1,1}$	$\Delta HIn_{2,1,1}$	$\Delta VIn_{2,1,1}$	$\Delta HTn_{2,1,2}$	$\Delta VTn_{2,1,2}$	$\Delta HIn_{2,1,2}$	$\Delta VIn_{2,1,2}$
	2	$Pcyclic_{2,2}$	$Cnorm_{2,2}$	$\Delta HTn_{2,2,1}$	$\Delta VTn_{2,2,1}$	$\Delta HIn_{2,2,1}$	$\Delta VIn_{2,2,1}$	$\Delta HTn_{2,2,2}$	$\Delta VTn_{2,2,2}$	$\Delta HIn_{2,2,2}$	$\Delta VIn_{2,2,2}$
	3	$Pcyclic_{2,3}$	$Cnorm_{2,3}$	$\Delta HTn_{2,3,1}$	$\Delta VTn_{2,3,1}$	$\Delta HIn_{2,3,1}$	$\Delta VIn_{2,3,1}$	$\Delta HTn_{2,3,2}$	$\Delta VTn_{2,3,2}$	$\Delta HIn_{2,3,2}$	$\Delta VIn_{2,3,2}$
3	1	$Pcyclic_{3,1}$	$Cnorm_{3,1}$	$\Delta HTn_{21,1}$	$\Delta VTn_{3,1,1}$	$\Delta HIn_{3,1,1}$	$\Delta VIn_{3,1,1}$	$\Delta HTn_{3,1,2}$	$\Delta VTn_{3,1,2}$	$\Delta HIn_{3,1,2}$	$\Delta VIn_{3,1,2}$
	2	$Pcyclic_{3,2}$	$Cnorm_{3,2}$	$\Delta HTn_{2,2,1}$	$\Delta VTn_{3,2,1}$	$\Delta HIn_{3,2,1}$	$\Delta VIn_{3,2,1}$	$\Delta HTn_{3, 2,2}$	$\Delta VTn_{3,2,2}$	$\Delta HIn_{3,2,2}$	$\Delta VIn_{3,2,2}$
	3	$Pcyclic_{3,3}$	$Cnorm_{3,3}$	$\Delta HT_{2,3,1}$	$\Delta VTn_{3,3,1}$	$\Delta HIn_{3,3,1}$	$\Delta VIn_{3,3,1}$	$\Delta HTn_{3,3,2}$	$\Delta VTn_{3,3,2}$	$\Delta HIn_{3,3,2}$	$\Delta VIn_{3,3,2}$

2

2

Develop Trim Data Sets ($Trim_{g,h}$)

Trim Data Sets

Set 1: Cycle1, Total Horizontal Deformation

$Trim_{1,1} = \Delta HTn_{1,1,1}$
$Trim_{1,2} = \Delta HTn_{2,1,1}$
$Trim_{1,3} = \Delta HTn_{3,1,1}$
$Trim_{1,4} = \Delta HTn_{1,1,2}$
$Trim_{1,5} = \Delta HTn_{2,1,2}$
$Trim_{1,6} = \Delta HTn_{3,1,2}$

Set 2: Cycle1, Instant Horizontal Deformation

$Trim_{2,1} = \Delta HIn_{1,1,1}$
$Trim_{2,2} = \Delta HIn_{2,1,1}$
$Trim_{2,3} = \Delta HIn_{3,1,1}$
$Trim_{2,4} = \Delta HIn_{1,1,2}$
$Trim_{2,5} = \Delta HIn_{2,1,2}$
$Trim_{2,6} = \Delta HIn_{3,1,2}$

Set 3: Cycle1, Total Vertical Deformation

$Trim_{3,1} = \Delta VTn_{1,1,1}$
$Trim_{3,2} = \Delta VTn_{2,1,1}$
$Trim_{3,3} = \Delta VTn_{3,1,1}$
$Trim_{3,4} = \Delta VTn_{1,1,2}$
$Trim_{3,5} = \Delta VTn_{2,1,2}$
$Trim_{3,6} = \Delta VTn_{3,1,2}$

Set 4: Cycle1, Instant Vertical Deformation

$Trim_{4,1} = \Delta VIn_{1,1,1}$
$Trim_{4,2} = \Delta VIn_{2,1,1}$
$Trim_{4,3} = \Delta VIn_{3,1,1}$
$Trim_{4,4} = \Delta VIn_{1,1,2}$
$Trim_{4,5} = \Delta VIn_{2,1,2}$
$Trim_{4,6} = \Delta VIn_{3,1,2}$

Set 5: Cycle 2, Total Horizontal Deformation

$Trim_{5,1} = \Delta HTn_{1,2,1}$
$Trim_{5,2} = \Delta HTn_{2,2,1}$
$Trim_{5,3} = \Delta HTn_{3,2,1}$
$Trim_{5,4} = \Delta HTn_{1,2,2}$
$Trim_{5,5} = \Delta HTn_{2,2,2}$
$Trim_{5,6} = \Delta HTn_{3,2,2}$

Set 6: Cycle 2, Instant Horizontal Deformation

$Trim_{6,1} = \Delta HIn_{1,2,1}$
$Trim_{6,2} = \Delta HIn_{2,2,1}$
$Trim_{6,3} = \Delta HIn_{3,2,1}$
$Trim_{6,4} = \Delta HIn_{1,2,2}$
$Trim_{6,5} = \Delta HIn_{2,2,2}$
$Trim_{6,6} = \Delta HIn_{3,2,2}$

Set 7: Cycle 2, Total Vertical Deformation

$Trim_{7,1} = \Delta VTn_{1,2,1}$
$Trim_{7,2} = \Delta VTn_{2,2,1}$
$Trim_{7,3} = \Delta VTn_{3,2,1}$
$Trim_{7,4} = \Delta VTn_{1,2,2}$
$Trim_{7,5} = \Delta VTn_{2,2,2}$
$Trim_{7,6} = \Delta VTn_{3,2,2}$

Set 8: Cycle 2, Instant. Vertical Deformation

$Trim_{8,1} = \Delta VIn_{1,2,1}$
$Trim_{8,2} = \Delta VIn_{2,2,1}$
$Trim_{8,3} = \Delta VIn_{3,2,1}$
$Trim_{8,4} = \Delta VIn_{1,2,2}$
$Trim_{8,5} = \Delta VIn_{2,2,2}$
$Trim_{8,6} = \Delta VIn_{3,2,2}$

Set 9: Cycle 3, Total Horizontal Deformation

$Trim_{9,1} = \Delta HTn_{1,3,1}$
$Trim_{9,2} = \Delta HTn_{2,3,1}$
$Trim_{9,3} = \Delta HTn_{3,3,1}$
$Trim_{9,4} = \Delta HTn_{1,3,2}$
$Trim_{9,5} = \Delta HTn_{2,3,2}$
$Trim_{9,6} = \Delta HTn_{3,3,2}$

Set 10: Cycle 3, Instant Horizontal Deformation

$Trim_{10,1} = \Delta HIn_{1,3,1}$
$Trim_{10,2} = \Delta HIn_{2,3,1}$
$Trim_{10,3} = \Delta HIn_{3,3,1}$
$Trim_{10,4} = \Delta HIn_{1,3,2}$
$Trim_{10,5} = \Delta HIn_{2,3,2}$
$Trim_{10,6} = \Delta HIn_{3,3,2}$

Set 11: Cycle 3, Total Vertical Deformation

$Trim_{11,1} = \Delta VTn_{1,3,1}$
$Trim_{11,2} = \Delta VTn_{2,3,1}$
$Trim_{11,3} = \Delta VTn_{3,3,1}$
$Trim_{11,4} = \Delta VTn_{1,3,2}$
$Trim_{11,5} = \Delta VTn_{2,3,2}$
$Trim_{11,6} = \Delta VTn_{3,3,2}$

Set 12: Cycle 3, Instant. Vertical Deformation

$Trim_{12,1} = \Delta VIn_{1,3,1}$
$Trim_{12,2} = \Delta VIn_{2,3,1}$
$Trim_{12,3} = \Delta VIn_{3,3,1}$
$Trim_{12,4} = \Delta VIn_{1,3,2}$
$Trim_{12,5} = \Delta VIn_{2,3,2}$
$Trim_{12,6} = \Delta VIn_{3,3,2}$

3

3

Decision:
Choose an analysis procedure

Normal

Variation of normal analysis

Individual

Calculate $Trimavg_g$ for each trim set **g**:

Remove the highest and lowest deformation, and average the middle four values

Calculate $Trimavg_g$ for each Trim set **g**:

Remove the two highest and two lowest deformations, and average the middle two values

Calculate $Trimavg_g$ for each Trim set **g**:

Choose any deformations from the Trim Set and average them

Calculate the Poisson's ratios for each cycle j and deformation {I,T}

νI_1= -0.100 + 1.480 $(Trimavg_1 / Trimavg_3)^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_1 / Trimavg_3)^2$
νT_1= -0.100 + 1.480 $(Trimavg_2 / Trimavg_4)^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_1 / Trimavg_3)^2$
νI_2= -0.100 + 1.480 $(Trimavg_5 / Trimavg_7)^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_5 / Trimavg_7)^2$
νT_2= -0.100 + 1.480 $(Trimavg_6 / Trimavg_8)^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_5 / Trimavg_7)^2$
νI_3= -0.100 + 1.480 $(Trimavg_9 / Trimavg_{11})^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_9 / Trimavg_{11})^2$
νT_3= -0.100 + 1.480 $(Trimavg_{10} / Trimavg_{12})^2$ – 0.778 $(tavg/davg)^2$ $(Trimavg_9 / Trimavg_{11})^2$

4

4

Calculate the cycle averaged trim deformation (Δ{H,V}{I,T}trimavg) for each orientation {H,V} and deformation {I,T}:

$\Delta HTtrimavg = (Trimavg_1 + Trimavg_5 + Trimavg_9) / 3$
$\Delta HItrimavg = (Trimavg_2 + Trimavg_6 + Trimavg_{10}) / 3$
$\Delta VTtrimavg = (Trimavg_3 + Trimavg_7 + Trimavg_{11}) / 3$
$\Delta VItrimavg = (Trimavg_4 + Trimavg_8 + Trimavg_{12}) / 3$

Calculate resilient modulus correction factors (Cmr{I,T}):

$CmrI = 0.6345 * (\Delta HItrimavg/\Delta VItrimavg)^{-1} – 0.332$
$CmrlT = 0.6345 * (\Delta HTtrimavg/\Delta VTtrimavg)^{-1} – 0.332$

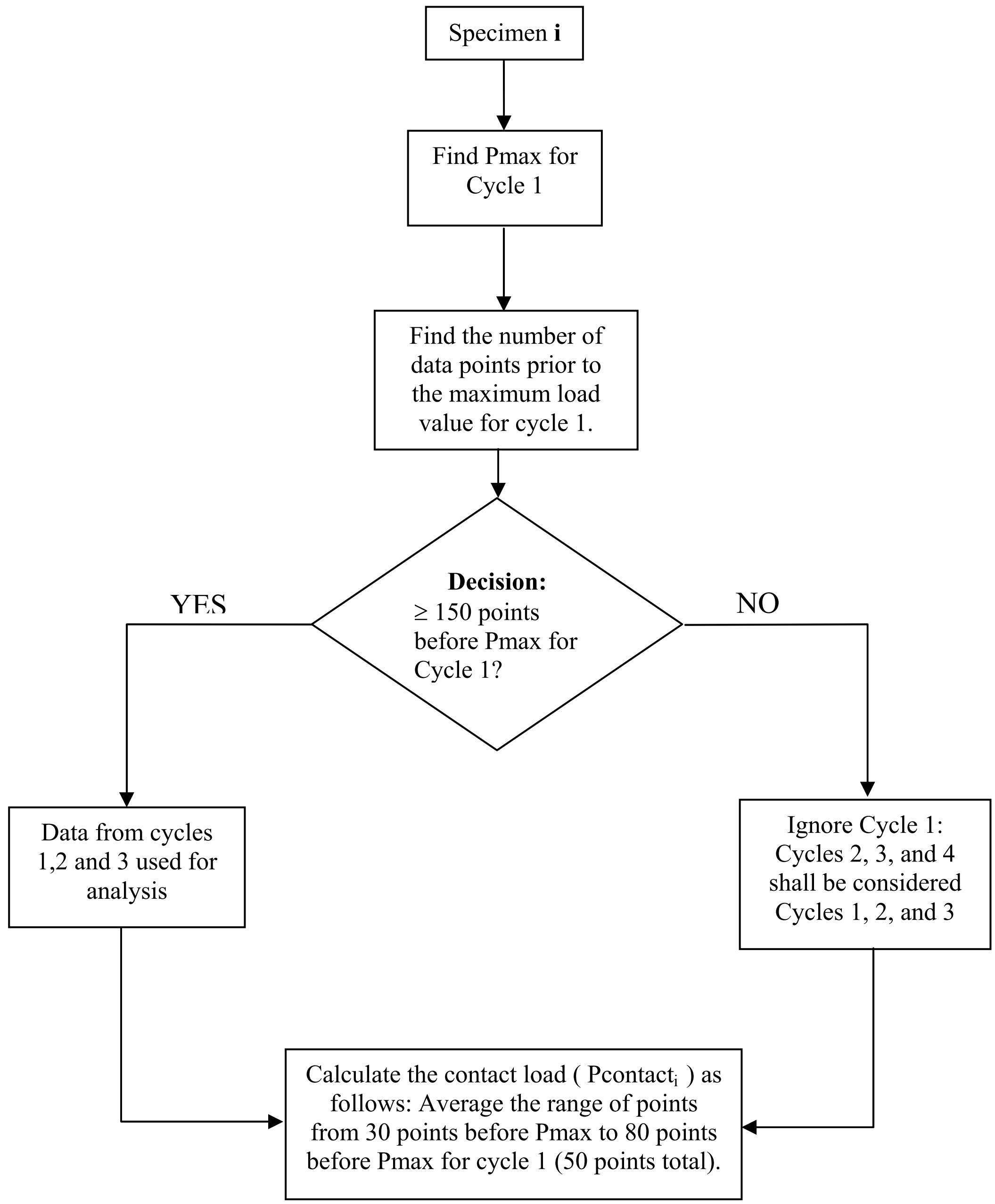
Calculate instantaneous and total resilient modulus ($MR\{I,T\}_j$) for each Cycle **j**

$MRT_1 = (\text{gauge length} * Pavg_1) / (Trimavg_1 * davg * tavg * CcmplT)$
$MRI_1 = (\text{gauge length} * Pavg_1) / (Trimavg_2 * davg * tavg * CcmplI)$
$MRT_2 = (\text{gauge length} * Pavg_2) / (Trimavg_5 * davg * tavg * CcmplT)$
$MRI_2 = (\text{gauge length} * Pavg_2) / (Trimavg_6 * davg * tavg * CcmplI)$
$MRT_3 = (\text{gauge length} * Pavg_3) / (Trimavg_9 * davg * tavg * CcmplT)$
$MRI_3 = (\text{gauge length} * Pavg_3) / (Trimavg_{10} * davg * tavg * CcmplI)$

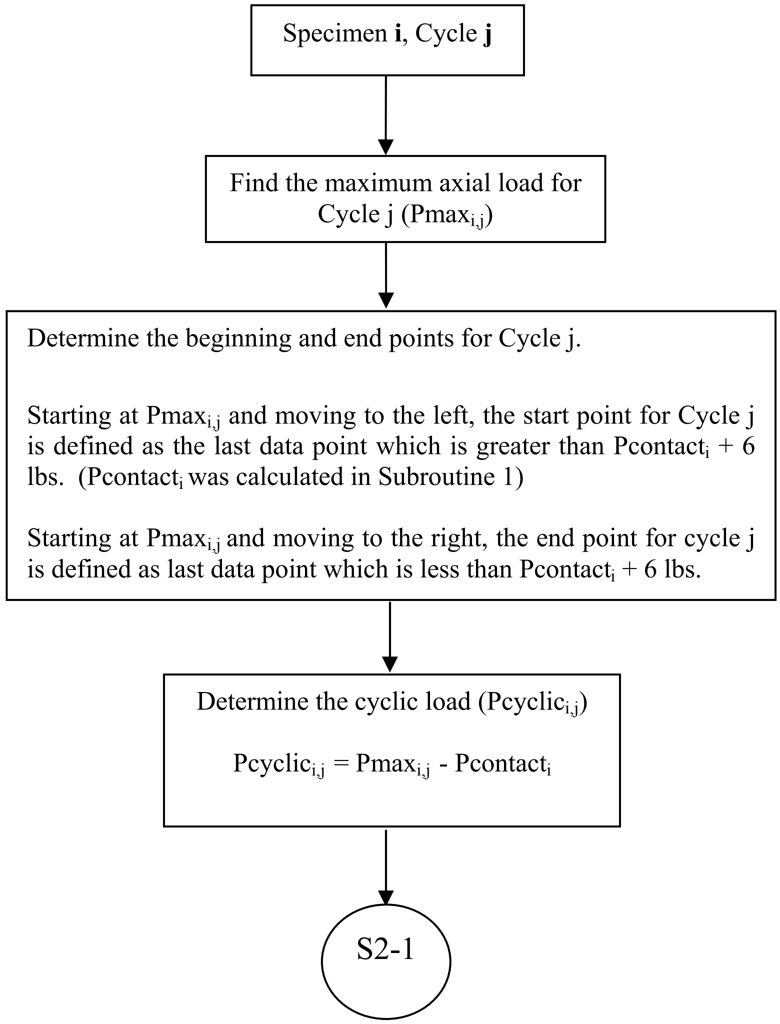
Report the following:

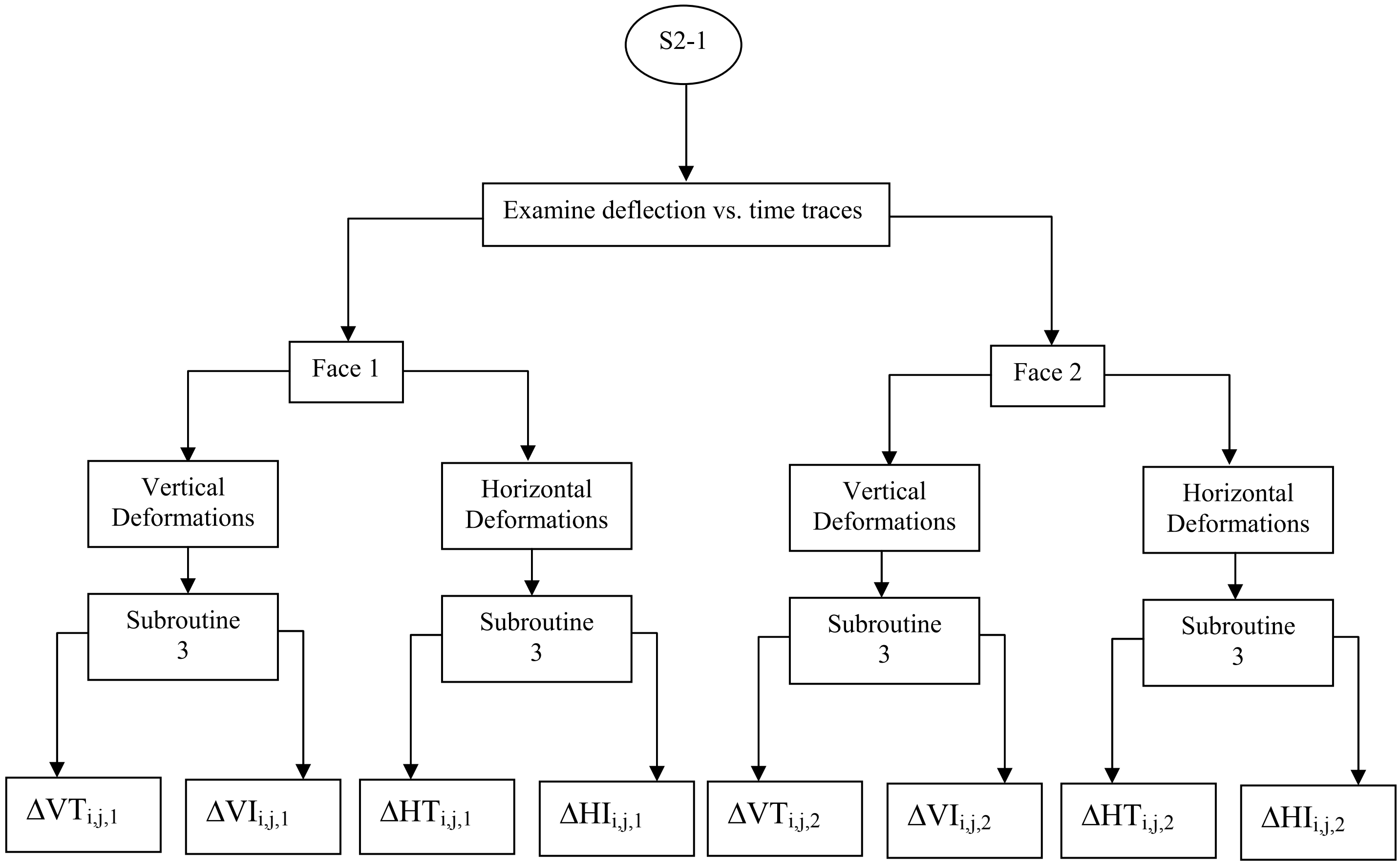
Cycle	νI_j	νT_j	MRI_j	MRT_j
1	νI_1	νT_1	MRI_1	MRT_1
2	νI_2	νT_2	MRI_2	MRT_2
3	νI_3	νT_3	MRI_3	MRT_3

B2.3.2 Subroutine 1

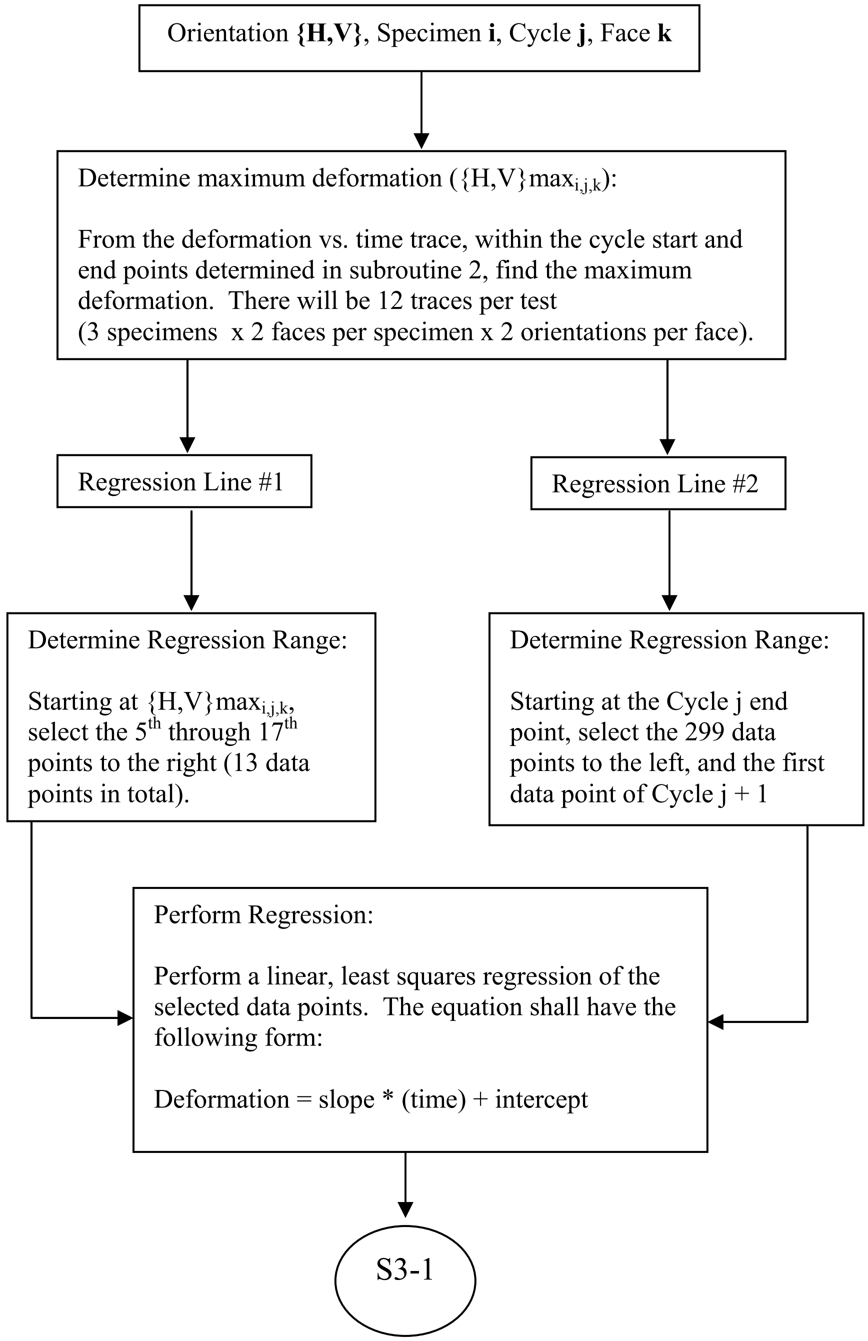


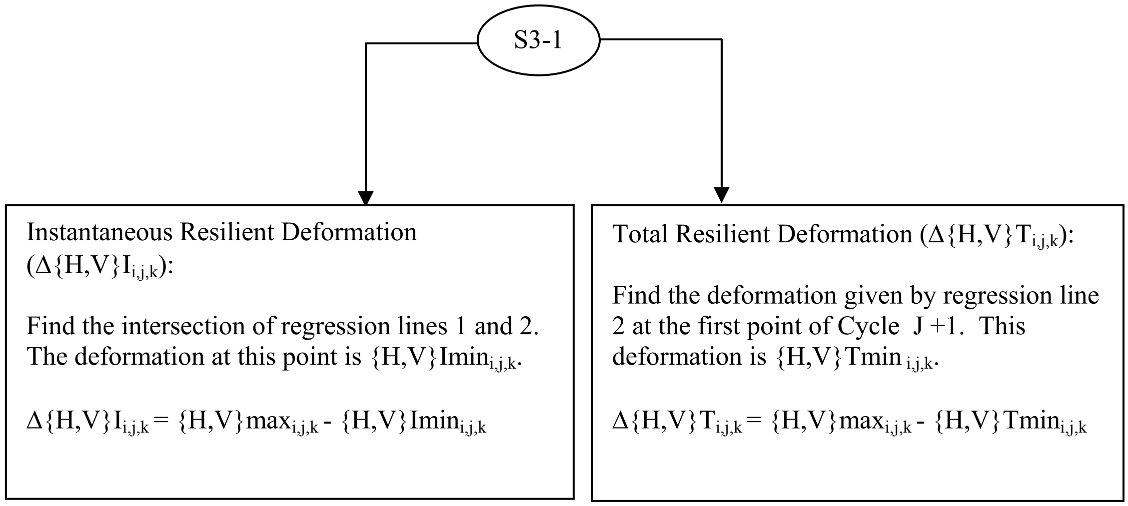
B2.3.3 Subroutine 2




S2-1
Examine deflection vs. time traces
Face 1
Face 2
Vertical Deformations
Horizontal Deformations
Vertical Deformations
Horizontal Deformations
Subroutine 3
Subroutine 3
Subroutine 3
Subroutine 3
$\Delta VT_{i,j,1}$
$\Delta VI_{i,j,1}$
$\Delta HT_{i,j,1}$
$\Delta HI_{i,j,1}$
$\Delta VT_{i,j,2}$
$\Delta VI_{i,j,2}$
$\Delta HT_{i,j,2}$
$\Delta HI_{i,j,2}$

B2.3.4 Subroutine 3





B3. CREEP COMPLIANCE DATA ANALYSIS ALGORITHM

An outline of the creep compliance data analysis algorithm that is used in the "ITLTFHWA" software, and described in the report by Roque et al. is presented in section B3.2. The algorithm is described graphically in section B3.3.

B3.1 Subscript Convention

For the purpose of clarity, a subscript convention has been developed. The subscript 'i' represents the specimen number (i = 1, 2, or 3), the subscript 'j' represents the creep time (j = 1, 2, 5, 10, 20, 50, or 100), and the subscript 'k' represents the specimen face (k = 1 or 2). Thus a variable may have up to three subscripts of the following form: $X_{i,j,k}$.

B3.2 Analysis

A separate analysis must be performed for each of the three temperatures at which creep compliance data is collected.

B3.2.1 Determine the creep test start point

The 10th data point in the file is always assumed to be the starting point of the test. **<u>It is essential that when the test is performed that exactly 10 data points are collected prior to the initial application of the creep load otherwise this analysis algorithm will produce erroneous results. Since the data sampling rate should be constant at 10 Hz, the creep load should be applied exactly 1 second after the data acquisition is initiated.</u>**

B3.2.2 Determine initial extensometer readings

Determine the extensometer reading ($\{H,V\}min_{i,k}$) at the starting point of the creep test for each specimen **i** and face **k**. The starting point was defined in Section B3.2.1.

B3.2.3 Determine the extensometer reading for each creep time **j**

The Table B2 indicates the data point that corresponds to a certain creep time **j** for each face **k** of each specimen **i**.

Table B 2. Extensometer reading data points

Extensometer reading at time **j**	Data Point
$\{H,V\}_{i,1,k}$	20th point in data file
$\{H,V\}_{i,2,k}$	30th point in data file
$\{H,V\}_{i,5,k}$	60th point in data file
$\{H,V\}_{i,10,k}$	110th point in data file
$\{H,V\}_{i,20,k}$	210th point in data file
$\{H,V\}_{i,50,k}$	Average 505th point through 515th point (11 points total)
$\{H,V\}_{i,100,k}$	1010th point in data file

For a 100-second creep test, the deformations at 50 seconds are used to calculate the Poisson's ratio for the experiment. To prevent a spike in the data from influencing the Poisson ratio value, the average of the 505th point through the 515th point (11 points total) is taken as the deformation at 50 seconds.

B3.2.4 Calculate deformations for each creep time **j**, face **k**, and orientation {**H,V**} of each specimen **i**.

Eq. B20 $$\Delta\{H,V\}_{i,j,k} = \{H,V\}_{i,j,k} - \{H,V\}\min_{i,k}$$

Where: $\Delta\{H,V\}_{i,j,k}$ = the deformation for creep time **j** of face **k** of each specimen **i**, in.
$\{H,V\}_{i,j,k}$ = the extensometer reading for creep time **i** of face **k** of each specimen **i**, in.
$\{H,V\}min_{i,k}$ = the extensometer reading at the start of the creep test for each face **k** of each specimen **i**, in.

B3.2.5 Determine the axial load ($P_{i,j}$) for each creep time **j** of each specimen **i**.

Table B 3. Axial load data points

Axial load at time **j**	Data Point
$P_{i,1}$	20th point in data file
$P_{i,2}$	30th point in data file
$P_{i,5}$	60th point in data file
$P_{i,10}$	110th point in data file
$P_{i,20}$	210th point in data file
$P_{i,50}$	510th point in data file
$P_{i,100}$	1010th point in data file

B3.2.6 Determine the average axial load (P_i) on specimen **i**

Eq. B21
$$P_i = \frac{\sum_{t=1,2,5,10,20,50,100} P_{i,t}}{7}$$

where: P_i = the average axial load for specimen **i**, lbs.
$P_{i,t}$ = the axial load for specimen **i** at time = t, lbs.

B3.2.7 Calculate the average specimen thickness (tavg), the average specimen diameter (davg), and the average axial load (Pavg).

Eq. B22
$$tavg = \frac{\sum_{i=1}^{3} t_i}{3} \qquad davg = \frac{\sum_{i=1}^{3} d_i}{3} \qquad Pavg = \frac{\sum_{i=1}^{3} P_i}{3}$$

Where: tavg = the average specimen thickness, in.
davg = the average specimen diameter, in.
Pavg = the average axial load, lbs.
t_i = the thickness of specimen **i**, in.
d_i = the diameter of specimen **i**, in.
P_i = the axial load for specimen **i**, lbs.

B3.2.8 Calculate the deformation normalization factor ($Cnorm_i$) for each specimen **i**.

Eq. B23
$$Cnorm_i = \left(\frac{t_i}{tavg}\right) \times \left(\frac{d_i}{davg}\right) \times \left(\frac{Pavg}{P_i}\right)$$

Where: $Cnorm_i$ = the deformation normalization factor for specimen **i**.
tavg = the average specimen thickness, inches.
davg = the average specimen diameter, inches.
Pavg = the average axial load, lbs.
t_i = the thickness of specimen **i**, inches.
d_i = the diameter of specimen **i**, inches.
P_i = the axial load for specimen **i**, lbs.

B3.2.9 Calculate the normalized deformations ($\Delta\{H,V\}norm_{i,j,k}$) for time **j** and face **k** of each specimen **i**.

Eq. B24
$$\Delta\{H,V\}norm_{i,j,k} = (Cnorm_i) \times \left(\Delta\{H,V\}_{i,j,k}\right)$$

Where: $\Delta\{H,V\}norm_{i,j,k}$ = the normalized deformations for time **j** and face **k** of specimen **i**, inches.
$\Delta\{H,V\}_{i,j,k}$ = the deformation for creep time **j** of face **k** of each specimen **i**, inches.
$Cnorm_i$ = the deformation normalization factor for specimen **i**.

B3.2.10 Average deformation data sets

There are 14 "trim" data sets. A deformation data set consists of all the recoverable deformations calculated for a given orientation {H,V}, and time **j**. Average the deformation data sets by <u>one</u> of the following methods:

B3.2.10.1 Method 1: Normal Analysis

For each trim data set, remove the highest and lowest deformation and average the remaining four. This average shall be referred to as $\Delta\{H,V\}trimavg_j$ for time **j**.

B3.2.10.2 Method 2: Variation of Normal Analysis

For each trim data set, remove the two highest and the two lowest deformations and average the remaining two. This average shall be referred to as $\Delta\{H,V\}trimavg_j$ for time **j**.

B3.2.10.3 Method 3: Individual Analysis

For each trim data set, remove any deformations and average the remaining deformations. This average shall be referred to as $\Delta\{H,V\}trimavg_j$ for time **j**.

B3.2.11 Calculate the Poisson's Ratio at time = 50.

Eq. B25
$$\nu = -0.10 + 1.45\left(\frac{\Delta Htrimavg_{50}}{\Delta Vtrimavg_{50}}\right)^2 - 0.778\left(\frac{\Delta Htrimavg_{50}}{\Delta Vtrimavg_{50}}\right)^2\left(\frac{tavg}{davg}\right)^2$$

Where:
- ν = the Poisson's Ratio
- $\Delta Htrimavg_{50}$ = the average horizontal trimmed deformation at time = 50, in.
- $\Delta Vtrimavg_{50}$ = the average vertical trimmed deformation at time = 50, in.
- tavg = the average specimen thickness, in.
- davg = the average specimen diameter, in.

B3.2.12 Calculate the creep compliance correction factor ($Ccmpl_y$) for each time **j**.

Eq. B26
$$Ccmpl_j = 0.6354\left(\frac{\Delta Htrimavg_j}{\Delta Vtrimavg_j}\right)^{-1} - 0.332$$

Where:
- $Ccmpl_j$ = the creep compliance correction factor at time **j**.
- $\Delta Htrimavg_j$ = the average horizontal trimmed deformation at time **j**, in.
- $\Delta Vtrimavg_j$ = the average vertical trimmed deformation at time **j**, in.

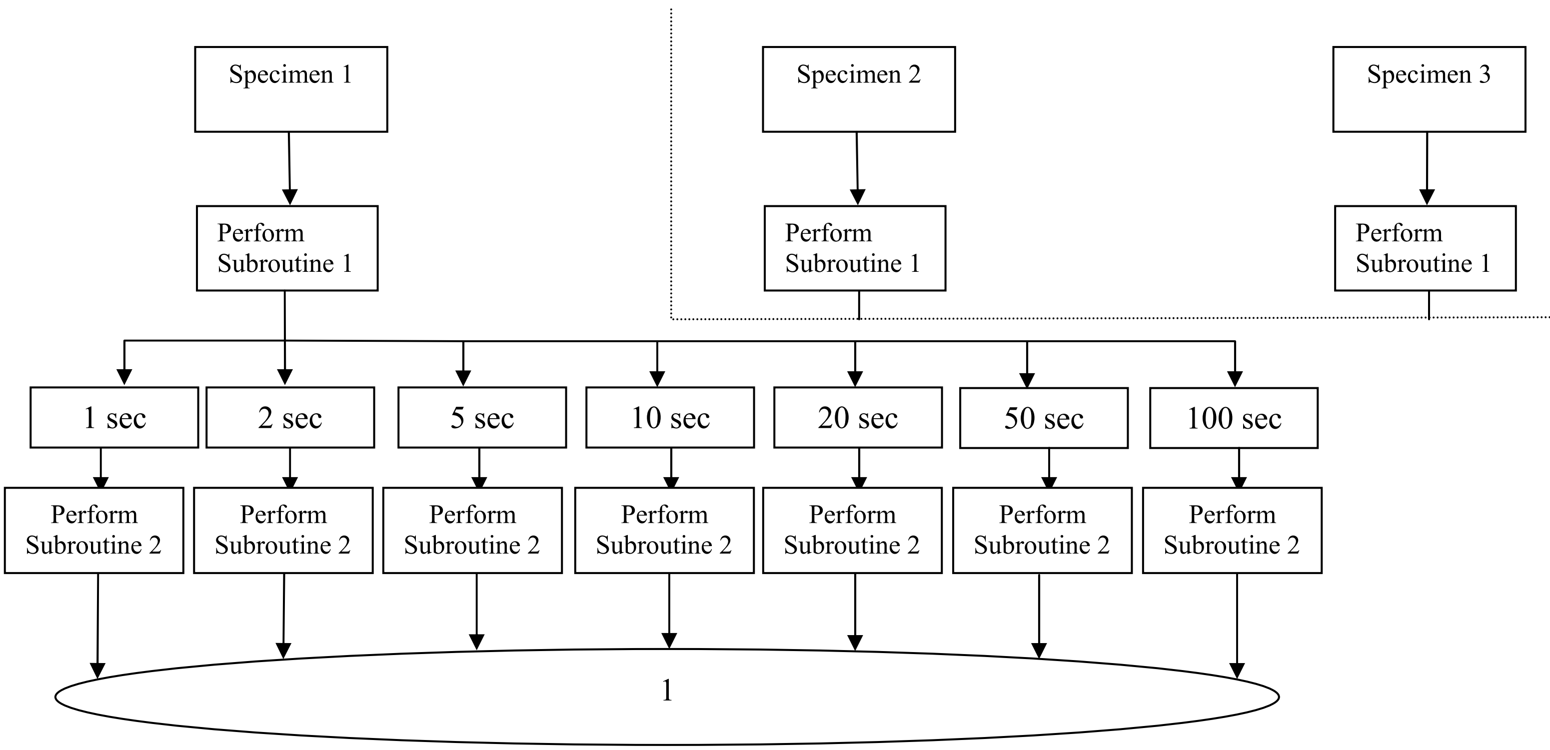
B3.2.13 Calculate the creep compliance for each time **j**.

Eq. B27
$$D_j = \left(\frac{\Delta Htrimavg_j \times davg \times tavg \times Ccmpl_j}{Pavg \times GL}\right)$$

Where:
- D_j = the creep compliance at time **j**, 1/psi
- $\Delta Htrimavg_j$ = the average horizontal trimmed deformation at time **j**, in.
- davg = the average specimen diameter, in.
- tavg = the average specimen thickness, in.
- $Ccmpl_j$ = the creep compliance correction factor at time **j**.
- Pavg = the average axial load, lbs.
- GL = the extensometer gauge length (1 inch [25 mm] for a nominal 4-inch [102-mm] specimen diameter, 1.5 inches [38 mm] for a nominal 6-inch [152-mm] specimen diameter).

B3.3 Creep Compliance Data Analysis Flow Charts

B3.3.1 Main Procedure



1

Here's what you have calculated so far:

Specimen	P	Time (sec)	Face 1		Face 2	
			Horiz.	Vertical	Horiz.	Vertical
1	P_1	1	$\Delta H_{1,1,1}$	$\Delta V_{1,1,1}$	$\Delta H_{1,1,2}$	$\Delta V_{1,1,2}$
		2	$\Delta H_{1,2,1}$	$\Delta V_{1,2,1}$	$\Delta H_{1,2,2}$	$\Delta V_{1,2,2}$
		5	$\Delta H_{1,5,1}$	$\Delta V_{1,5,1}$	$\Delta H_{1,5,2}$	$\Delta V_{1,5,2}$
		10	$\Delta H_{1,10,1}$	$\Delta V_{1,10,1}$	$\Delta H_{1,10,2}$	$\Delta V_{1,10,2}$
		20	$\Delta H_{1,20,1}$	$\Delta V_{1,20,1}$	$\Delta H_{1,20,2}$	$\Delta V_{1,20,2}$
		50	$\Delta H_{1,50,1}$	$\Delta V_{1,50,1}$	$\Delta H_{1,50,2}$	$\Delta V_{1,50,2}$
		100	$\Delta H_{1,100,1}$	$\Delta V_{1,100,1}$	$\Delta H_{1,100,2}$	$\Delta V_{1,100,2}$
2	P_2	1	$\Delta H_{2,1,1}$	$\Delta V_{2,1,1}$	$\Delta H_{2,1,2}$	$\Delta V_{2,1,2}$
		2	$\Delta H_{2,2,1}$	$\Delta V_{2,2,1}$	$\Delta H_{2,2,2}$	$\Delta V_{2,2,2}$
		5	$\Delta H_{2,5,1}$	$\Delta V_{2,5,1}$	$\Delta H_{2,5,2}$	$\Delta V_{2,5,2}$
		10	$\Delta H_{2,10,1}$	$\Delta V_{2,10,1}$	$\Delta H_{2,10,2}$	$\Delta V_{2,10,2}$
		20	$\Delta H_{2,20,1}$	$\Delta V_{2,20,1}$	$\Delta H_{2,20,2}$	$\Delta V_{2,20,2}$
		50	$\Delta H_{2,50,1}$	$\Delta V_{2,50,1}$	$\Delta H_{2,50,2}$	$\Delta V_{2,50,2}$
		100	$\Delta H_{2,100,1}$	$\Delta V_{2,100,1}$	$\Delta H_{2,100,2}$	$\Delta V_{2,100,2}$
3	P_3	1	$\Delta H_{3,1,1}$	$\Delta V_{3,1,1}$	$\Delta H_{3,1,2}$	$\Delta V_{3,1,2}$
		2	$\Delta H_{3,2,1}$	$\Delta V_{3,2,1}$	$\Delta H_{3,2,2}$	$\Delta V_{3,2,2}$
		5	$\Delta H_{3,5,1}$	$\Delta V_{3,5,1}$	$\Delta H_{3,5,2}$	$\Delta V_{3,5,2}$
		10	$\Delta H_{3,10,1}$	$\Delta V_{3,10,1}$	$\Delta H_{3,10,2}$	$\Delta V_{3,10,2}$
		20	$\Delta H_{3,20,1}$	$\Delta V_{3,20,1}$	$\Delta H_{3,20,2}$	$\Delta V_{3,20,2}$
		50	$\Delta H_{3,50,1}$	$\Delta V_{3,50,1}$	$\Delta H_{3,50,2}$	$\Delta V_{3,50,2}$
		100	$\Delta H_{3,100,1}$	$\Delta V_{3,100,1}$	$\Delta H_{3,100,2}$	$\Delta V_{3,100,2}$

Calculate average specimen thickness (Tavg), diameter (Davg) and axial load (Pavg):

Tavg = ($T_1 + T_2 + T_3$) / 3
Davg = ($D_1 + D_2 + D_3$) / 3
Pavg = ($P_1 + P_2 + P_3$) / 3

2

2

Calculate the deformation normalization factors for each specimen **i** (**$Cnorm_i$**)

$Cnorm_i = (T_i / Tavg) * (D_i / Davg) * (Pavg / P_i)$

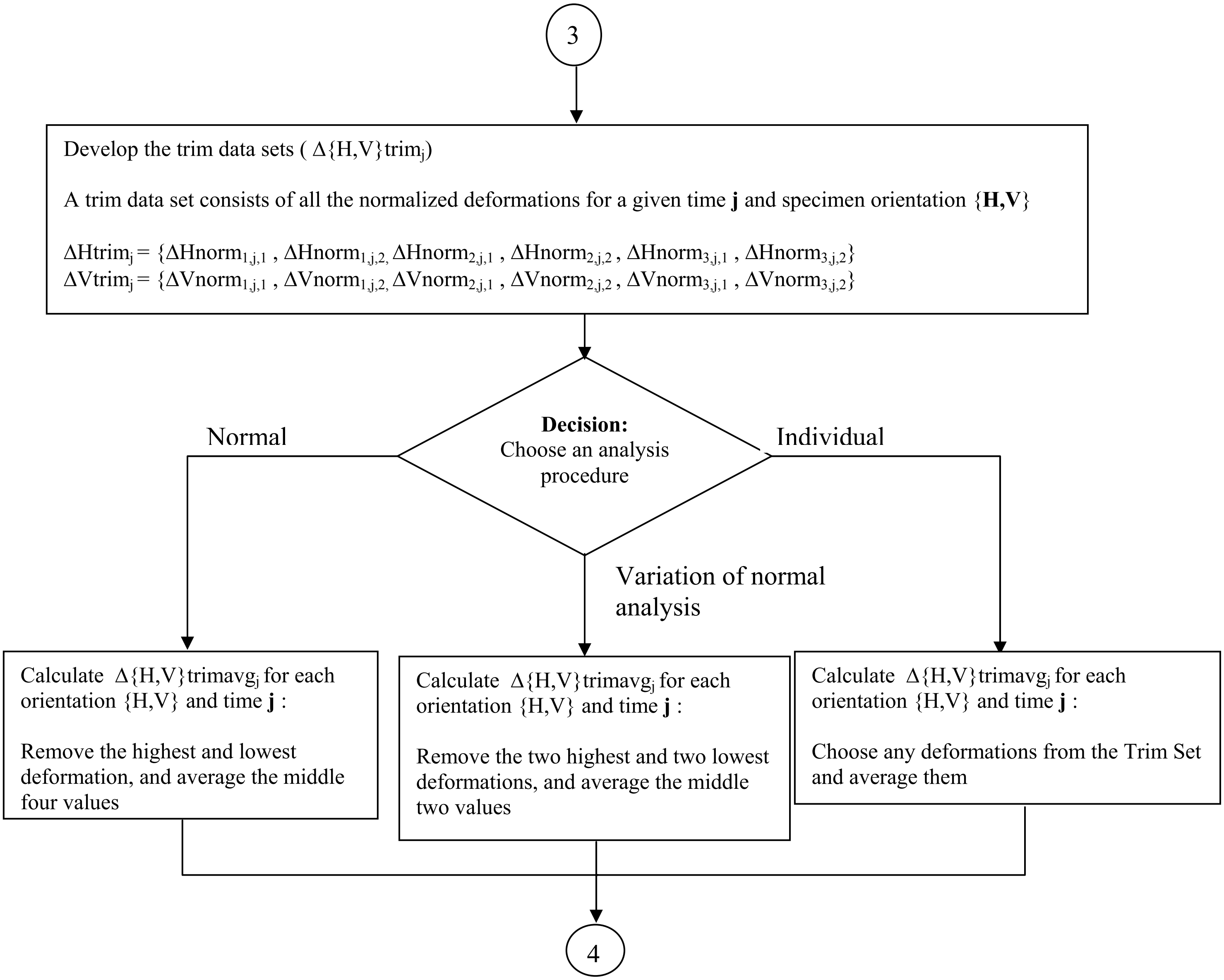
Calculate the normalized deformations for each orientation {H,V}specimen **i**, time **j** and face **k** ($\Delta\{H,V\}norm_{i,j,k}$):

$\Delta\{H,V\}norm_{i,j,k} = Cnorm_i * \Delta\{H,V\}_{i,j,k}$

Here's what you have calculated so far

Specimen	P	Cnorm	Time (sec)	Face 1		Face 2	
				Horiz.	Vertical	Horiz.	Vertical
1	P_1	$Cnorm_1$	1	$\Delta Hnorm_{1,1,1}$	$\Delta Vnorm_{1,1,1}$	$\Delta Hnorm_{1,1,2}$	$\Delta Vnorm_{1,1,2}$
			2	$\Delta Hnorm_{1,2,1}$	$\Delta Vnorm_{1,2,1}$	$\Delta Hnorm_{1,2,2}$	$\Delta Vnorm_{1,2,2}$
			5	$\Delta Hnorm_{1,5,1}$	$\Delta Vnorm_{1,5,1}$	$\Delta Hnorm_{1,5,2}$	$\Delta Vnorm_{1,5,2}$
			10	$\Delta Hnorm_{1,10,1}$	$\Delta Vnorm_{1,10,1}$	$\Delta Hnorm_{1,10,2}$	$\Delta Vnorm_{1,10,2}$
			20	$\Delta Hnorm_{1,20,1}$	$\Delta Vnorm_{1,20,1}$	$\Delta Hnorm_{1,20,2}$	$\Delta Vnorm_{1,20,2}$
			50	$\Delta Hnorm_{1,50,1}$	$\Delta Vnorm_{1,50,1}$	$\Delta Hnorm_{1,50,2}$	$\Delta Vnorm_{1,50,2}$
			100	$\Delta Hnorm_{1,100,1}$	$\Delta Vnorm_{1,100,1}$	$\Delta Hnorm_{1,100,2}$	$\Delta Vnorm_{1,100,2}$
2	P_2	$Cnorm_2$	1	$\Delta Hnorm_{2,1,1}$	$\Delta Vnorm_{2,1,1}$	$\Delta Hnorm_{2,1,2}$	$\Delta Vnorm_{2,1,2}$
			2	$\Delta Hnorm_{2,2,1}$	$\Delta Vnorm_{2,2,1}$	$\Delta Hnorm_{2,2,2}$	$\Delta Vnorm_{2,2,2}$
			5	$\Delta Hnorm_{2,5,1}$	$\Delta Vnorm_{2,5,1}$	$\Delta Hnorm_{2,5,2}$	$\Delta Vnorm_{2,5,2}$
			10	$\Delta Hnorm_{2,10,1}$	$\Delta Vnorm_{2,10,1}$	$\Delta Hnorm_{2,10,2}$	$\Delta Vnorm_{2,10,2}$
			20	$\Delta Hnorm_{2,20,1}$	$\Delta Vnorm_{2,20,1}$	$\Delta Hnorm_{2,20,2}$	$\Delta Vnorm_{2,20,2}$
			50	$\Delta Hnorm_{2,50,1}$	$\Delta Vnorm_{2,50,1}$	$\Delta Hnorm_{2,50,2}$	$\Delta Vnorm_{2,50,2}$
			100	$\Delta Hnorm_{2,100,1}$	$\Delta Vnorm_{2,100,1}$	$\Delta Hnorm_{2,100,2}$	$\Delta Vnorm_{2,100,2}$
3	P_3	$Cnorm_3$	1	$\Delta Hnorm_{3,1,1}$	$\Delta Vnorm_{3,1,1}$	$\Delta Hnorm_{3,1,2}$	$\Delta Vnorm_{3,1,2}$
			2	$\Delta Hnorm_{3,2,1}$	$\Delta Vnorm_{3,2,1}$	$\Delta Hnorm_{3,2,2}$	$\Delta Vnorm_{3,2,2}$
			5	$\Delta Hnorm_{3,5,1}$	$\Delta Vnorm_{3,5,1}$	$\Delta Hnorm_{3,5,2}$	$\Delta Vnorm_{3,5,2}$
			10	$\Delta Hnorm_{3,10,1}$	$\Delta Vnorm_{3,10,1}$	$\Delta Hnorm_{3,10,2}$	$\Delta Vnorm_{3,10,2}$
			20	$\Delta Hnorm_{3,20,1}$	$\Delta Vnorm_{3,20,1}$	$\Delta Hnorm_{3,20,2}$	$\Delta Vnorm_{3,20,2}$
			50	$\Delta Hnorm_{3,50,1}$	$\Delta Vnorm_{3,50,1}$	$\Delta Hnorm_{3,50,2}$	$\Delta Vnorm_{3,50,2}$
			100	$\Delta Hnorm_{3,100,1}$	$\Delta Vnorm_{3,100,1}$	$\Delta Hnorm_{3,100,2}$	$\Delta Vnorm_{3,100,2}$

3


3
Develop the trim data sets ($\Delta\{H,V\}trim_j$)
A trim data set consists of all the normalized deformations for a given time **j** and specimen orientation {**H,V**}
$\Delta Htrim_j = \{\Delta Hnorm_{1,j,1}, \Delta Hnorm_{1,j,2}, \Delta Hnorm_{2,j,1}, \Delta Hnorm_{2,j,2}, \Delta Hnorm_{3,j,1}, \Delta Hnorm_{3,j,2}\}$
$\Delta Vtrim_j = \{\Delta Vnorm_{1,j,1}, \Delta Vnorm_{1,j,2}, \Delta Vnorm_{2,j,1}, \Delta Vnorm_{2,j,2}, \Delta Vnorm_{3,j,1}, \Delta Vnorm_{3,j,2}\}$
Decision: Choose an analysis procedure
Normal
Individual
Variation of normal analysis
Calculate $\Delta\{H,V\}trimavg_j$ for each orientation {H,V} and time **j** :
Remove the highest and lowest deformation, and average the middle four values
Calculate $\Delta\{H,V\}trimavg_j$ for each orientation {H,V} and time **j** :
Remove the two highest and two lowest deformations, and average the middle two values
Calculate $\Delta\{H,V\}trimavg_j$ for each orientation {H,V} and time **j** :
Choose any deformations from the Trim Set and average them
4

4

Calculate Poisson's Ratios at time **50** (ν_{50}):

$$\nu_{50} = -0.10 + (1.48 - 0.778 * (Tavg / Davg)^2) * (\Delta Htrimavg_{50} / \Delta Vtrimavg_{50})^2$$

Calculate the creep compliance correction factors for each time **j** ($Ccmpl_j$):

$$Ccmpl_j = 0.634 * (\Delta Vtrimavg_j / \Delta Htrimavg_j)$$

Calculate creep compliance at each time **j** (D_j):

$$D_j = (\Delta Htrimavg_j) * (Davg) * (Tavg) * (Ccmpl_j) / ((Pavg) * (gauge\ length)$$

Report the following:

Time (sec)	D_j
1	D_1
2	D_2
5	D_5
10	D_{10}
20	D_{20}
50	D_{50}
100	D_{100}

ν_{50}

B3.3.2 Subroutine 1

specimen **i**

Determine the creep test start point:

For a properly formatted data file, the start point is defined as the tenth point from the start of the data file, at time = 1 sec

Determine extensometer reading at the start point ($\{H,V\}min_{i,k}$) for each specimen **i** and face **k**

B3.3.3 Subroutine 2

specimen **i**,

↓

Determine the extensometer reading of specimen **i**, orientation {**H,V**} face **k** at time **j** ($\{H,V\}_{i,j,k}$):
EXCEPT for time **50**

From the deformation vs. time trace select the point at (start point + (j * 10))

↓

Determine the extensometer reading of specimen **i**, orientation {**H,V**} face **k** at time **50** ($\{H,V\}_{i,j,50}$):

From the deformation vs. time trace select the points at (start point + 495) to (start point + 505), and average them

↓

Calculate the deformation of specimen **i**, orientation {**H,V**} face **k** at time **j** ($\Delta\{H,V\}_{i,j,k}$):

$\Delta\{H,V\}_{i,j,k} = \{H,V\}_{i,j,k} - \{H,V\}min_{i,k}$

↓

Determine the axial load on specimen **i**, at time **j** ($P_{i,j}$)

From the load vs. time trace select the point at (start point + (j * 10))

↓

Calculate the average axial load on specimen **i**, ($P_{i,}$)

$P_i = (P_{i,1} + P_{i,2} + P_{i,5} + P_{i,10} + P_{i,20} + P_{i,50} + P_{i,100}) / 7$

B4. INDIRECT TENSILE STRENGTH DATA ANALYSIS ALGORITHIM

An outline of the indirect tensile strength algorithm that is used in the "ITLTFHWA" software, and described in the report by Roque et al. is presented in section B4.2. The algorithm is described graphically in section B4.3.

B4.1 Subscript Convention

For the purpose of clarity, a subscript convention has been developed. The subscript 'i' represents the specimen number (i = 1, 2 or 3), the subscript 'j' represents the specimen face (j =1 or 2) and the subscript 't' represents the time at which a value was measured. Thus a variable may have up to three subscripts of the following form: $X_{i,j,t}$.

B4.2 Analysis

B.4.2.1 Invert Load Values

For each of the three specimens, multiply all load values by –1, so that compression values are positive.

B.4.2.2 Determine Cycle Start Time (ts_i):

For specimen **i**, determine the time at which the load cycle starts. The load cycle start time is defined as the first time **t** that satisfies the following two requirements:

1) The load must continuously increase over the three data points subsequent to ts_i, as shown below:

Eq. B28: $$P_{i,ts_i+1.5} \rangle P_{i,ts_i+1.0} \rangle P_{i,ts_i+0.5} \rangle P_{i,ts_i}$$

2) The load must increase by at least 40 lbs (18 kg) over the three data points subsequent to ts_i, as shown below:

Eq. B29: $$P_{t+1.5} - P_t \rangle 40 lbs.$$

B4.2.3 Zero the Time Values

For each specimen **i**, subtract ts_i from each time value, so that the load cycle starts at t = 0.

B4.2.4 Zero the Load Values

For each specimen **i**, subtract the initial load value, $P_{i,0}$ from each load value, so that the load at the time the cycle starts is 0.

B4.2.5 Calculate the Deformation Zero Value ($\{H,V\}s_{i,j}$)

For each specimen **i**, face **j**, and orientation **{H,V}**, the deformation zero value is equal to the average of the 10 deformation values prior to the load cycle start, as shown below:

Eq. B30: $$\{H,V\}s_{i,j} = \frac{\sum_{t=1}^{10} \{H,V\}_{i,j,\frac{-t}{2}}}{10}$$

B4.2.6 Zero the Deformation Values

For each specimen **i**, face **j**, and orientation **{H,V}**, subtract $\{H,V\}s_{i,j}$ from the respective deformation value.

B4.2.7 Determine the Failure Load ($P_{i,tfi}$)

B4.2.7.1 Determine $tf_{i,j}$

For each specimen **i**, and face **j**, determine the time where $V_{i,j,t} - H_{i,j,t}$ is at a maximum ($tf_{i,j}$).

B4.2.7.2 Determine Time of Specimen Failure (tf_i)

For each specimen **i**, the time of specimen failure (tf_i) is the minimum of $tf_{i,1}$ and $tf_{i,2}$.

B4.2.7.3 Determine the Failure Load ($P_{i,tfi}$)

For each specimen **i**, the failure load is the load **P** corresponding to time tf_i.

B4.2.9 Determine the Deformations at Half the Failure Load ($\Delta\{H,V\}_{i,j}$)

B4.2.9.1 Determine the Time of Half Failure Load (th_i)

For each specimen **i,** th_i is the time that satisfies the following equation:

Eq. B31 $$P_{i,th_i} = \frac{P_{i,tf_i}}{2}$$

B4.2.9.2 Determine Deformations at Time th_i

For each specimen i, face j and orientation {H,V}, select the deformations at time th_i. This value shall be referred to as $\Delta\{H,V\}_{i,j}$.

B4.2.10 Calculate the Average Specimen Thickness and Diameter

Calculate the average specimen thickness (Tavg) and diameter (Davg) as shown below:

Eq. B32 $$Tavg = \frac{T_1 + T_2 + T_3}{3}$$

Eq. B33 $$Davg = \frac{D_1 + D_2 + D_3}{3}$$

B4.2.11 Calculate the Deformation Normalization Factors ($Cnorm_i$)

For each specimen i, calculate the deformation normalization factors as shown below:

Eq. B34 $$Cnorm_i = \frac{T_i}{Tavg} + \frac{D_i}{Davg}$$

B4.2.12 Calculate the Normalized Deformations ($\Delta\{H,V\}norm_{i,j}$)

Eq. B35 $$\Delta\{H,V\}norm_{i,j} = Cnorm_i \times \Delta\{H,V\}norm_{i,j}$$

B4.2.13 Average deformation data sets

There are 2 "trim" data sets. A deformation data set consists of all the normalized deformations calculated for a given orientation {H,V}. Average the deformation data sets by <u>one</u> of the following methods:

B4.2.13.1 Method 1: Normal Analysis

For each trim data set, remove the highest and lowest deformation and average the remaining four. This average shall be referred to as Δ{H,V}trimavg.

B4.2.13.2 Method 2: Variation of Normal Analysis

For each trim data set, remove the two highest and the two lowest deformations and average the remaining two. This average shall be referred to as Δ{H,V}trimavg.

B4.2.13.3 Method 3: Individual Analysis

For each trim data set, remove any deformations and average the remaining deformations. This average shall be referred to as Δ{H,V}trimavg.

B4.2.14 Calculate Poisson's Ratio (ν)

Eq. B36 $$\nu = -0.10 + 1.48\left(\frac{\Delta Htrimavg}{\Delta Vtrimavg}\right)^2 - 0.778\left(\frac{\Delta Htrimavg}{\Delta Vtrimavg}\right)^2 * \left(\frac{Tavg}{Davg}\right)^2$$

B4.2.15 Calculate "Used" Poisson's Ratio (ν_{used})

B4.2.15.1 Case 1: ν > 0.5

If the ν calculated in step B4.2.14 is greater than 0.5, then $\nu_{\text{used}} = 0.5$.

B4.2.15.2 Case 2: ν < 0.05

If the ν calculated in step B4.2.14 is less than 0.05, then $\nu_{\text{used}} = 0.05$.

B4.2.15.3 Case 3: 0.05 < ν < 0.5

If the ν calculated in step B4.2.14 is between 0.05 and 0.5, then $\nu_{\text{used}} = \nu$.

B4.2.16 Calculate the Stress Correction Factors

For each specimen **i**, calculate the stress correction factors as follows:

Eq. B37 $$CSX_i = 0.948 - 0.1114\left(\frac{T_i}{D_i}\right) - 0.2963\nu_{used} + 1.463\left(\frac{T_i}{D_i}\right)\nu_{used}$$

B4.2.17 Calculate the Indirect Tensile Strength

For each specimen **i**, calculate the indirect tensile strength as follows:

Eq. B38 $$ITS_i = \frac{2P_{i,tf_i}CSX_i}{\pi T_i D_i}$$

B4.2.18 Calculate the Average Indirect Tensile Strength

Eq. B39 $$ITSavg = \frac{ITS_1 + ITS_2 + ITS_3}{3}$$

B4.3 Indirect Tensile Strength Analysis Flowcharts

B4.3.1 Main Procedure

Specimen 1 → Perform Subroutine 1

Specimen 2 → Perform Subroutine 1

Specimen 3 → Perform Subroutine 1

Here's what you have calculated so far:

Specimen	Load	Face 1 deformations		Face 2 Deformations	
		Horiz.	Vertical	Horiz.	Vertical
1	$P_{1,f}$	$\Delta H_{1,1,f/2}$	$\Delta V_{1,1,f/2}$	$\Delta H_{1,2,f/2}$	$\Delta V_{1,2,f/2}$
2	$P_{2,f}$	$\Delta H_{2,1,f/2}$	$\Delta V_{2,1,f/2}$	$\Delta H_{2,2,f/2}$	$\Delta V_{2,2,f/2}$
3	$P_{3,f}$	$\Delta H_{3,1,f/2}$	$\Delta V_{3,1,f/2}$	$\Delta H_{3,2,f/2}$	$\Delta V_{3,2,f/2}$

↓

Calculate average specimen thickness (Tavg) and diameter (Davg):

$Tavg = (T_1 + T_2 + T_3) / 3$
$Davg = (D_1 + D_2 + D_3) / 3$

↓

Calculate the deformation normalization factors for each specimen **i** ($Cnorm_i$)

$Cnorm_i = (T_i / Tavg) * (D_i / Davg)$

↓

Calculate the normalized deformations for each orientation **{H,V}**, specimen **i** and face **j** ($\Delta\{H,V\}norm_{i,j,f/2}$):

$\Delta\{H,V\}norm_{i,j,f/2} = Cnorm_i * \Delta\{H,V\}_{i,j,f/2}$

↓

Develop the trim data sets (**Δ{H,V}trim**):

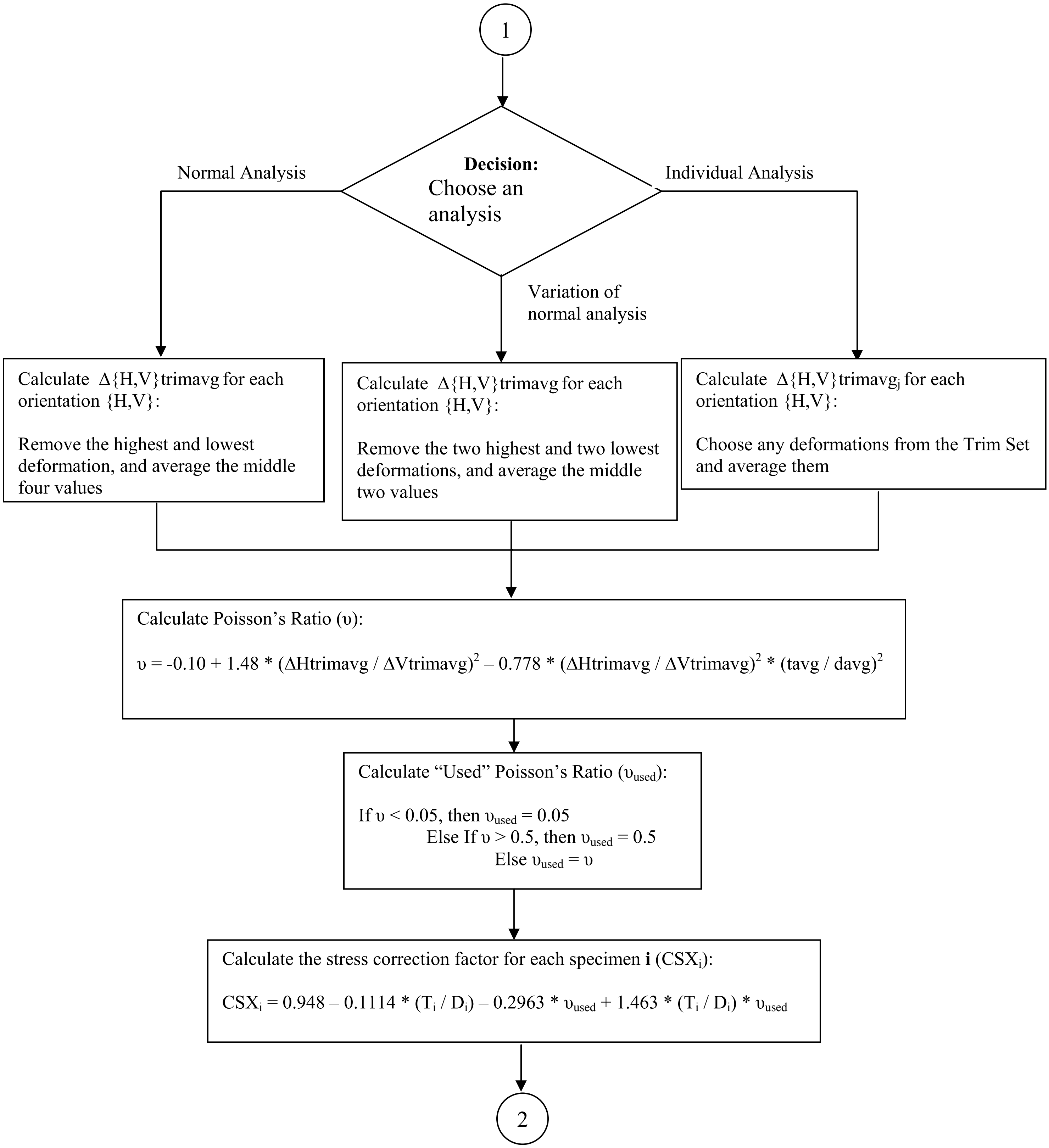
A trim data set contains all of the normalized deformations for a given specimen orientation {H,V}:

$\Delta Htrim = (\Delta Hnorm_{1,1,f/2}, \Delta Hnorm_{1,2,f/2}, \Delta Hnorm_{2,1,f/2}, \Delta Hnorm_{2,2,f/2}, \Delta Hnorm_{3,1,f/2}, \Delta Hnorm_{3,2,f/2})$

$\Delta Vtrim = (\Delta Vnorm_{1,1,f/2}, \Delta Vnorm_{1,2,f/2}, \Delta Vnorm_{2,1,f/2}, \Delta Vnorm_{2,2,f/2}, \Delta Vnorm_{3,1,f/2}, \Delta Vnorm_{3,2,f/2})$

↓

1


1
Decision:
Choose an analysis
Normal Analysis
Variation of normal analysis
Individual Analysis
Calculate Δ{H,V}trimavg for each orientation {H,V}:
Remove the highest and lowest deformation, and average the middle four values
Calculate Δ{H,V}trimavg for each orientation {H,V}:
Remove the two highest and two lowest deformations, and average the middle two values
Calculate $\Delta\{H,V\}trimavg_j$ for each orientation {H,V}:
Choose any deformations from the Trim Set and average them
Calculate Poisson's Ratio (υ):
$\upsilon = -0.10 + 1.48 * (\Delta Htrimavg / \Delta Vtrimavg)^2 - 0.778 * (\Delta Htrimavg / \Delta Vtrimavg)^2 * (tavg / davg)^2$
Calculate "Used" Poisson's Ratio (υ_{used}):
If $\upsilon < 0.05$, then $\upsilon_{used} = 0.05$
Else If $\upsilon > 0.5$, then $\upsilon_{used} = 0.5$
Else $\upsilon_{used} = \upsilon$
Calculate the stress correction factor for each specimen **i** (CSX_i):
$CSX_i = 0.948 - 0.1114 * (T_i / D_i) - 0.2963 * \upsilon_{used} + 1.463 * (T_i / D_i) * \upsilon_{used}$
2

2

Calculate the indirect tensile strength for each specimen **i** (ITS_i):

$$ITS_i = (2 * P_{i,f} * CSX_i) / (\pi * T_i * D_i)$$

Calculate the average indirect tensile strength (ITSavg):

$$ITSavg = (ITS_1 + ITS_2 + ITS_3) / 3$$

Report the following:

ITS_1
ITS_2
ITS_3
ITSavg
υ
υ_{used}

B.4.3.2 Subroutine 1

Specimen i

↓

Multiply all load values by –1 so that compression values are positive.

↓

Determine the time at which the load cycle starts (s):

s is the earliest time **t** (in seconds) that satisfies the following two equations:

$P_{t+1.5} - P_t > 40$ lbs.

$P_{t+1.5} > P_{t+1.0} > P_{t+0.5} > P_t$

↓

Zero the time values for each time **t**:

SET $t = t - s$

↓

Normalize the load values, **P**, for each time **t** (P_t):

SET $P_t = P_t - P_s$

↓

Normalize the deformation values for each orientation **{H,V}**, face **j** and time **t** ($\{H,V\}_{j,t}$):

SET $\{H,V\}_{j,t} = \{H,V\}_{j,t} - (\{H,V\}_{j,s-5.0} + \{H,V\}_{j,s-4.5} + \{H,V\}_{j,s-4.0} + \{H,V\}_{j,s-3.5} + \{H,V\}_{j,s-3.0} + \{H,V\}_{j,s-2.5} + \{H,V\}_{j,s-2.0} + \{H,V\}_{j,s-1.5} + \{H,V\}_{j,s-1.0} + \{H,V\}_{j,s-0.5}) / 10$

↓

S-1

S-1

Find the time at which maximum difference between the vertical and horizontal deformations occurs for each face **j** (f_j):

f_j is the time t where $(V\}_{j,t}$ - $\{H\}_{j,t}$ is at a maximum

Select the minimum of f_1 and f_2 (f). This is the time of the specimen failure.

Select the load **P** at time **f** (P_f). This is the specimen failure load

Find the time at which the load is one-half the failure load (f/2):

f/2 is the time t that satisfies the following equation:

$P_{f/2} = (P_f) / 2$

Select the deformations for each orientation {H,V} and face j ($\Delta\{HV\}_{j,f/2}$)

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
CREEP COMPLIANCE, RESILIENT MODULUS AND INDIRECT TENSILE STRENGTH
LAB DATA SHEET T07 **- SAMPLE SUMMARY INFORMATION**

ASPHALT CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AC07/LTPP PROTOCOL P07

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

1. STATE CODE: ___ ___ 2. SHRP ID: ___ ___ ___ ___

3. LAYER NO: ___ 4. FIELD SET: ___

DATA ITEM	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
5. TEST NO	___	___	___
6. SAMPLE AREA (SA-)	___ ___	___ ___	___ ___
7. LOCATION NO	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___
8. LTPP SAMPLE NO	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___
9. AVG. THICKNESS (mm)	___ ___ . ___	___ ___ . ___	___ ___ . ___
10. AVG. DIAMETER (mm)	___ ___ ___ . ___	___ ___ ___ . ___	___ ___ ___ . ___
11. BULK SPECIFIC GRAVITY	___ . ___ ___ ___	___ . ___ ___ ___	___ . ___ ___ ___
12. COMMENT 1	___ ___	___ ___	___ ___
13. COMMENT 2	___ ___	___ ___	___ ___
14. COMMENT 3	___ ___	___ ___	___ ___
15. Other Comments			

1. STATE CODE: ____ ____
2. SHRP ID: ____ ____ ____ ____

3. LAYER NO: ____
4. FIELD SET: ____

DATA ITEM	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
RESILIENT MODULUS TEST			
16. DATA FILENAME, TEST 1	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
17. TEST 1 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
18. DATA FILENAME, TEST 2	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
19. TEST 2 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
20. DATA FILENAME, TEST 3	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
21. TEST 3 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
22. ANALYSIS FILENAME	_ _ _ _ _ _ _ _ _ . MRO		
CREEP COMPLIANCE TEST			
23. DATA FILENAME, TEST 1	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
24. TEST 1 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
25. DATA FILENAME, TEST 2	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
26. TEST 2 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
27. DATA FILENAME, TEST 3	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
28. TEST 3 TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
29. ANALYSIS FILENAME	_ _ _ _ _ _ _ _ _ . OUT		
INDIRECT TENSILE STRENGTH TEST			
30. DATA FILENAME	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT	_ _ _ _ _ _ _ _ _ . DAT
31. TEST TEMP. (°C)	___ ___ . ___	___ ___ . ___	___ ___ . ___
32. ".OUT" FILENAME	_ _ _ _ _ _ _ _ _ . OUT		
33. ".STR" FILENAME	_ _ _ _ _ _ _ _ _ . STR		
34. ".FAM" FILENAME	_ _ _ _ _ _ _ _ _ . FAM		

GENERAL REMARKS: ____

SUBMITTED BY, DATE

____

LABORATORY CHIEF

Affiliation: ______________________

CHECKED AND APPROVED, DATE

____

Affiliation: ______________________

PROTOCOL P11
Test Method for Specific Gravity and Absorption of Extracted Coarse Aggregate (AG01)

This LTPP Protocol describes the determination of the specific gravity of coarse aggregate extracted from AC. This test shall be conducted after completion of LTPP Test Designation AG04 (LTPP Protocol P14 - Gradation of Extracted Aggregate) and shall be carried out in accordance with AASHTO T85-04 as modified herein. Only sections of the referenced standard which have been modified are included below. In all other sections, the standard (AASHTO T85-04) shall be followed as published. The test shall be performed on aggregate extracted from the test sample used for the asphalt content test (LTPP Test Designation AC04) on samples retrieved from projects included in the LTPP experiments.

1. SCOPE

1.1 This method covers the determination of the bulk specific gravity and absorption of extracted coarse aggregate. The bulk specific gravity and absorption are based on aggregate subjected to 15 hours of soaking in water. This method is not intended for use with lightweight aggregate.

2. APPLICABLE DOCUMENTS

2.3 LTPP Protocols

Protocol P04 - Determination of Asphalt Content (Extraction)
Protocol P12 - Specific Gravity and Absorption of Extracted Fine Aggregate
Protocol P14 - Gradation of Extracted Aggregate

5. SIGNIFICANCE AND USE

5.2 Delete

7. SAMPLING

7.1 Delete

7.2 Retrieve all material retained on the No. 4 (4.75-mm) and larger sieve after completion of LTPP Protocol P04 - Gradation of Extracted Aggregate.

7.3 Add - Note 1a: if minimum sample weights are not obtained, the test shall still be performed, however, comment code "01" shall be used to report this condition.

7.4 Delete

8. PROCEDURE

8.2 Delete

9. CALCULATIONS

9.1.2 Delete

9.1.3 Delete

10. REPORT

Record the following information on Form T11.

10.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

10.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

10.3 Test Results

10.3.1 Weight of test sample, grams.

10.3.2 Weight of oven dry test sample in air (A), grams.

10.3.3 Weight of saturated surface-dry (SSD) test sample in air, (B) grams.

10.3.4 Weight of saturated surface-dry (SSD) test sample in water, (C) grams.

10.3.5 Bulk specific gravity of coarse aggregate (to two decimal places).

10.3.6 Percent absorption (to one decimal place).

10.3.7 Comments shall include LTPP standard comment code(s) as shown Section 4.3 of this Guide and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SPECIFIC GRAVITY AND ABSORPTION OF EXTRACTED COARSE AGGREGATE
LAB DATA SHEET T11

ASPHALT CONCRETE LAYER (EXTRACTED AGGREGATE)
LTPP TEST DESIGNATION: AG01/LTPP PROTOCOL P11

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. LOCATION NUMBER __ __ __

3. LABORATORY TEST NUMBER __

4. LTPP SAMPLE NUMBER __ __ __ __

5. WEIGHT OF TEST SAMPLE, grams __ __ __ __.__

6. WEIGHT OF OVEN DRY TEST SAMPLE IN AIR (A), grams __ __ __ __.__

7. WEIGHT OF SSD TEST SAMPLE IN AIR (B), grams __ __ __ __.__

8. WEIGHT OF SSD TEST SAMPLE IN WATER (C), grams __ __ __ __.__

9. BULK SPECIFIC GRAVITY OF COARSE AGGREGATE __ __.__ __

10. ABSORPTION OF COARSE AGGREGATE __ __.__

11. COMMENTS
 (a) CODE __ __ __ __ __ __ __ __ __ __ __ __

 (b) NOTE ____

12. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

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SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

__________________________ __________________________________
LABORATORY CHIEF

Affiliation:__________________ Affiliation:_______________________

PROTOCOL P12
Test Method for Specific Gravity and Absorption of Extracted Fine Aggregate (AG02)

This LTPP protocol describes the determination of the specific gravity of the fine aggregate extracted from AC. This test shall be conducted after completion of LTPP Test Designation AG04 (LTPP Protocol P14 - Gradation of Extracted Aggregate) and this test shall be carried out in accordance with AASHTO T84-88 as modified herein. Only sections of the referenced standard which have been modified are included below. In all other sections, the standard (AASHTO T84-88) shall be followed as published. The test shall be performed on aggregate extracted from the test sample used for the asphalt content test (LTPP Test Designation AC04) on samples retrieved from projects included in the LTPP experiments.

1. SCOPE

1.1 This method covers the determination of the bulk specific gravity and absorption of extracted fine aggregate at 73.4/73.4°F (23/23°C).

1.2 Delete

1.3 Delete

2. APPLICABLE DOCUMENTS

2.3 LTPP Protocols

Protocol P04 - Determination of Asphalt Content (Extraction)
Protocol P11 - Specific Gravity and Absorption of Extracted Coarse Aggregate
Protocol P14 - Gradation of Extracted Aggregate

3. SIGNIFICANCE AND USE

3.2 Delete

5. SAMPLING

5.1 The sample for test shall be obtained from the fine aggregate (material passing the No. 4 [4.75-mm] sieve) used for LTPP Protocol P14 (Gradation of Extracted Aggregate).

6. PREPARATION OF TEST SPECIMEN

6.1 Obtain approximately 1 kg (2.2 lbs) of fine aggregate from the sample used in LTPP Protocol P14. If this minimum sample weight cannot be obtained, the test shall still be performed, however, comment code "01" from Section 4.3 of the LTPP Laboratory Testing Guide shall be used to report this condition.

6.1.2 Delete

7. PROCEDURE

7.1.1 Delete

7.1.2 Delete

7.2.1 Delete

7.3.1 Delete

8. BULK SPECIFIC GRAVITY

8.1.1 Delete

9. BULK SPECIFIC GRAVITY (SATURATED SURFACE-DRY BASIS)

9.1 Delete

9.1.1 Delete

10. APPARENT SPECIFIC GRAVITY

10.1 Delete

12. REPORT

Record the following information on Form T12.

12.1 Sample identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

12.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

12.3 Test Results

12.3.1 Weight of test sample, grams.

12.3.2 Weight of oven dry test sample in air (A), grams.

12.3.3 Weight of pycnometer filled with water (B), grams.

12.3.4 Weight of pycnometer with specimen and water to calibration mark (C), grams.

12.3.5 Weight of saturated surface-dry (SSD) specimen (S), grams.

12.3.6 Bulk specific gravity of fine extracted aggregate.

12.3.7 Percent absorption.

12.3.8 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SPECIFIC GRAVITY AND ABSORPTION OF EXTRACTED FINE AGGREGATE
LAB DATA SHEET T12

ASPHALT CONCRETE LAYER (EXTRACTED AGGREGATE)
LTPP TEST DESIGNATION: AG02/LTPP PROTOCOL P12

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

LTPP REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ___________________________________ FIELD SET NO. __ __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __
5. WEIGHT OF TEST SAMPLE, grams __ __ __ __.__
6. WEIGHT OF OVEN DRY TEST SAMPLE IN AIR (A), grams __ __ __ __.__
7. WEIGHT OF PYCNOMETER FILLED WITH WATER (B), grams __ __ __ __.__
8. WEIGHT OF PYCNOMETER WITH SPECIMEN AND WATER TO CALIBRATION MARK (C), grams __ __ __ __.__
9. WEIGHT OF SSD SPECIMEN (S), grams __ __ __ __.__
10. BULK SPECIFIC GRAVITY OF FINE EXTRACTED AGGREGATE __ __.__ __
11. PERCENT ABSORPTION OF FINE AGGREGATE __ __.__
12. COMMENTS
    (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
    (b) NOTE ____
13. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

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SUBMITTED BY CHECKED AND APPROVED, DATE

__________________________ __________________________

LABORATORY CHIEF

Affiliation:__________________ Affiliation:______________________

PROTOCOL P14
Gradation of Aggregate Extracted from Asphaltic Concrete (AG04)

This LTPP protocol covers the determination of the gradation of the aggregate extracted from AC after completion of LTPP Test Designation AC04 (LTPP Protocol P04). This test shall be carried out in accordance with AASHTO T30-98 as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard shall be followed as written. The test shall be performed on aggregate extracted from the test sample used for the asphalt content test (LTPP Test Designation AC04).

6. PROCEDURE

6.5 The aggregate shall then be sieved over sieves of the various sizes required (see Section 7.3) including the 0.075-mm (No. 200) sieve. The weight of material passing each sieve and retained on the next and the amount passing the 0.075-mm (No. 200) sieve shall be recorded. The summation of these various weights must check the dried weight after washing within 0.2 percent of the total weight. The weight of dry material passing the 0.075-mm (No. 200) sieve by dry sieving shall be added to the weight of mineral matter in the bitumen and the weight removed by washing in order to obtain the total passing 0.075-mm (No. 200) sieve. If it is desired to check the weight of material washed through the 0.075-mm (No. 200) sieve, the wash water may be evaporated to dryness or filtered through a tarred filter paper which is subsequently dried and weighed. The weights of fractions retained on the various sieves and the total passing the 0.075-mm (No. 200) sieve shall be converted to percentages by dividing each by the total weight of aggregate in the bituminous mixture from Section 6.1.

After sieving, combine the material from the 2.00-mm (No. 10), 0.425-mm (No. 40), 0.180-mm (No. 80), 0.075-mm (No. 200) sieves and the pan and save this sample in <u>double</u> plastic bags. These samples will be used in the future to conduct protocol P14A, Fine Aggregate Particle Shape. Use sturdy double plastic bags and seal or tie each carefully to prevent loss and intermixing. Identify each sample by enclosing a Xerox copy of the T14 laboratory test data sheet which shall be fully completed and approved. This form shall have the complete identification of the layer and sample. Further instructions concerning the disposition of these samples will be issued at a later date.

Table 4.32 of this Guide shall be consulted to assign a material code for geologic classifications.

7. REPORT

7.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

7.2 Test Identification shall include: Laboratory Test Number, Test Date, LTPP Test Designation, LTPP Protocol Number.

7.3 Test Results

The results of the sieve analysis shall be reported as the percent weight of dry aggregate passing each sieve to the appropriate number of significant figures and decimal places as follows:

Sieve Size	Percent Passing
1 ½ in. (37.5-mm)	__ __ __.
1 in. (25.0-mm)	__ __ __.
¾ in. (19.0-mm)	__ __ __.
½ in. (12.5-mm)	__ __ __.
⅜ in (9.5-mm)	__ __ __.
#4 (4.75-mm)	__ __ __.
#10 (2.00-mm)	__ __.
#40 (0.425-mm)	__ __.
#80 (0.180-mm)	__ __.
#200 (0.075-mm)	__ __ . __

Primary Geologic Classification Code __ __
Secondary Geologic Classification Code (A) __ __
Secondary Geologic Classification Code (B) __ __

The secondary geologic classification codes (A) and (B) are not mandatory data entry fields. These codes should only be assigned to the test sample when a secondary constituent geologic classification code shall always be assigned to the major geologic aggregate constituent.

7.4 Comments shall include LTPP Standard comment code(s) as shown in Section 4.3 of this Guide and any other note as needed.

7.5 Use Form T14 (Test Sheet T14) to report the above information (Items 7.1 to 7.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
GRADATION OF AGGREGATE
LAB DATA SHEET T14
ASPHALTIC CONCRETE LAYER (ASPHALTIC CONCRETE PROPERTIES)
LTPP TEST DESIGNATION AG04/LTPP PROTOCOL P14

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION ______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____
SAMPLED BY: ___________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __			
2. SHRP ID	__ __ __ __	__ __ __ __	__ __ __ __
3. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __
4. LABORATORY TEST NUMBER	__	__	__
5. LOCATION NUMBER	__ __ __	__ __ __	__ __ __
6. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __
7. GRADATION, % PASSING EACH SIEVE SIZE			
Standard (mm)			
1 ½ inch (37.5 mm)	__ __ __ .	__ __ __ .	__ __ __ .
1 inch (25.0 mm)	__ __ __ .	__ __ __ .	__ __ __ .
¾ inch (19.0 mm)	__ __ __ .	__ __ __ .	__ __ __ .
½ inch (12.5 mm)	__ __ __ .	__ __ __ .	__ __ __ .
⅜ inch (9.5 mm)	__ __ __ .	__ __ __ .	__ __ __ .
#4 (4.75 mm)	__ __ __ .	__ __ __ .	__ __ __ .
#10 (2.00 mm)	__ __ .	__ __ .	__ __ .
#40 (0.425 mm)	__ __ .	__ __ .	__ __ .
#80 (0.180 mm)	__ __ .	__ __ .	__ __ .
#200 (0.075 mm)	__ __ . __	__ __ . __	__ __ . __
PRIMARY GEOLOGICAL CLASSIFICATION CODE	__ __	__ __	__ __
SECONDARY GEOLOGICAL CLASSIFICATION CODE (A)	__ __	__ __	__ __
SECONDARY GEOLOGICAL CLASSIFICATION CODE (B)	__ __	__ __	__ __
8. COMMENTS			
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	______________ ______________	______________ ______________	______________ ______________
9. TEST DATE	__ __ - __ __ - __ __ __ __	__ __ - __ __ - __ __ __ __	__ __ - __ __ - __ __ __ __

GENERAL REMARKS:____
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SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

_________________________ | _________________________

LABORATORY CHIEF

Affiliation______________________ | Affiliation______________________

PROTOCOL P14A
Test Method for Fine Aggregate Particle Shape (AG05)

This LTPP protocol covers the determination of the void content and specific gravity of fine aggregate (aggregate passing the 2.36-mm [No. 8] sieve) extracted from AC specimens. This test shall be performed after completion of LTPP Test Designation AG04 (LTPP Protocol P14 - Gradation of Aggregate Extracted from Asphaltic Concrete).

1. SCOPE

1.1 General

This method covers the sample identification, preparation, and testing of fine aggregate extracted from AC specimens obtained from the LTPP studies.

Through the performance of this test, the laboratory will determine the loose percent voids, specific gravity and absorption of the fine aggregate.

1.2 Sample Storage

The samples of extracted aggregate materials should be kept in an environmentally protected (enclosed area not subject to the natural elements) storage area at temperatures between 5°C (40°F) and 38°C (100°F).

Each sample shall have a label or tag attached that clearly identifies the material, the project number/test section from which it was recovered and the sample number, as a minimum.

1.3 Units - In this protocol, the International System of Units (SI - The Modernized Metric System) is regarded as the standard. Units are expressed first in their "soft" metric form followed, in parenthesis, by their U.S. Customary unit equivalent.

2. TESTING

2.1 Testing Prerequisites

The testing described in this protocol shall be conducted after; (1) approval by the FHWA COTR to begin testing, (2) initial layer assignment using Form L04, (3) visual examination and thickness of AC cores and thickness of layers within AC cores using Protocol P01, (4) final layer assignment based on the P01 test results (corrected Form L04 if needed), and (5) completion of all other applicable tests. In order to obtain approval under item (1), the laboratory must, at least, (a) submit and obtain approval of the QC/QA plan for FHWA materials testing, and (b) demonstrate that their testing equipment meets or exceeds the specifications contained in this protocol.

2.2 Test Sample Locations and Assignment of Laboratory Test Numbers

The test shall be performed on the test specimens of asphalt concrete retrieved from BA-type, 305-mm (12-inch) diameter coreholes, from the test pit(s), or from other bulk sampling locations as dictated by the sampling plans for the particular LTPP section.

The test results shall be reported separately for test samples obtained from the beginning and end of a test section as follows:

(a) Beginning of the Section (Stations 0-): samples of each layer that are retrieved from areas in the approach end of the test section (stations preceding 0+00) shall be assigned Laboratory Test Number '1'.

(b) End of the Section (Stations 5+): samples of each layer that are retrieved from areas in the leave end of the test section (stations after 5+00) shall be assigned Laboratory Test Number '2'.

(c) Middle of the Section (Stations 0 to +5): samples of each layer that are retrieved from areas in the middle of the test section (from the paver) shall be assigned Laboratory Test Number '3'.

3. DEFINITIONS

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous.

(b) Sample: A representative portion of material from one or more pavement layers received from the field. A sample can be a core, block, chunk, pieces, bulk, thin-walled tube, or jar sample.

(c) Test Sample: That part of the sample of an asphalt concrete layer or which is prepared and used for the specified test. The quantity of the test sample may be the same but will usually be less than the bulk sample.

(d) Test Specimen: For the purpose of this protocol, a test specimen is defined as that part of the extracted aggregate sample used for the testing described in this protocol.

4. APPLICABLE DOCUMENTS

4.1 AASHTO Standards

AASHTO T30-87I Mechanical Analysis of Extracted Aggregate.

4.2 ASTM Standards

ASTM C128-84 Test Method for Specific Gravity and Absorption of Fine Aggregate.

ASTM C117-87 Test Method for Material Finer than 75-µm (No. 200) Sieve in Mineral Aggregate; except in this case, a 150-µm (No. 100) sieve will be used to remove minus 150-µm (No. 100) material.
ASTM C136-84 Sieve Analysis of Fine and Coarse Aggregates.

4.3 LTPP Protocols

P04 Asphalt Content (Extraction)
P14 Gradation of Aggregate Extracted from Asphaltic Concrete and Attachment.

4.4 National Aggregates Association Documents

Proposed NAA Method for Particle Shape and Texture of Fine Aggregate Using Uncompacted Void Content - Appendix A. (A similar test method is in the process of being standardized by ASTM).

5. SAMPLE PREPARATION

5.1 Samples accompanied by a copy of Test Sheet T14 will be identified corresponding to the LTPP identification, which includes: Region, State, State Code, Experiment No., SHRP ID, Field Set Number, Layer Number, Laboratory Test Number, Location Number, and LTPP Sample Number.

5.2 The sample is initially scalped on a 4.75-mm (No. 4) sieve to remove the oversize material. The plus 4.75-mm (No. 4) material will be discarded. The portion passing the 4.75-mm (No. 4) sieve shall be split by the use of a sample splitter or quartering to produce a test portion weighing 500 to 1000 grams (1.1 to 2.2 lbs) and washed over a 150-µm (No. 100) sieve to remove minus 150-µm (No. 100) sizes. Return particles retained on the 150-µm (No. 100) sieve to the test portion and dry to constant weight at 105°C (220°F). This sample is then used to determine specific gravity.

6. TEST PROCEDURE

6.1 Specific Gravity and Absorption. Use ASTM C128 with the following exceptions. Add at least 4 percent moisture, stir, and cover the sample. Allow sample to stand at least overnight. Uncover sample and dry (with the aid of warm flowing air) to approximate saturated surface dry (SSD) condition. This process takes 10 to 15 minutes. When the sample appears to be at SSD, weigh approximately 500 to 600 grams (1.1 to 1.3 lbs) of the SSD sand (SSD weight = D) and then place it in the pycnometer in accordance with ASTM C128. Roll and agitate the pycnometer to eliminate entrapped air bubbles. Allow the sample to stand in a controlled temperature environment for at least 4 hours. Adjust water level and weigh the sample, H_2O and flask (weight = C). Remove sample and H_2O from pycnometer and oven dry the sample. Remove sample from oven, allow to cool and weigh (oven dry weight = A). All weights should be recorded to at least the nearest one-tenth gram.

Note 1: Pre-weighed pans are used to facilitate the weighing/drying process.

6.2 Calculate the Bulk Dry Specific Gravity as follows:

$$BulkDrySpecificGravity = \frac{A}{(B + D - C)}$$

where: A = Oven dry weight of fine aggregate; grams
B = Weight of pycnometer with water only; grams
C = Weight of pycnometer with fine aggregate and water; grams
D = SSD weight of fine aggregate sample; grams

Calculate the bulk specific gravity and report to three decimal places.

6.3 Calculate the percent absorption as follows:

$$Absorption,\% = 100 \times \frac{(D - A)}{A}$$

where: A = Oven dry weight of fine aggregate; grams
D = SSD weight of fine aggregate sample; grams

Report the percent absorption to the nearest two decimal places.

6.4 Sieving. Sieve the dried sample over the nested fine aggregate sieves in a mechanical shaker for 5 minutes. Do not record the weights of each of the size fractions. Maintain the individual size fractions in a dry condition in separate containers for use in the void content test.

6.5 Prepare the void content sample from the individual sieve size fractions as follows:

2.36 mm (No. 8) – 1.18 mm (No. 16)	44 grams (1.6 oz)
1.18 mm (No. 16) – 600 µm (No. 30)	57 grams (2.0 oz)
600 µm (No. 30) – 300 µm (No. 50)	72 grams (2.5 oz)
300 µm (No. 50) – 150 µm (No. 100)	17 grams (0.6 oz)
	190 grams (6.7 oz)

The tolerance on each of these weights is ± 0.2 g (0.01 oz).

If there is not enough in one or more of the size fractions to make up the required sample, additional fine aggregate can be sieved to provide the required sizes. (Fine aggregate left over from the SSD material can be dried and sieved as needed).

If one or more sizes are only very slightly short of the required amount, use a proportionately smaller sample as long as it is adequate to fill the receiving container in the void content test to overflowing. For example, using a 90 percent sample:

2.36 mm (No. 8) – 1.18 mm (No. 16)	39.6 grams (1.4 oz)
1.18 mm (No. 16) – 600 μm (No. 30)	51.3 grams (1.8 oz)
600 μm (No. 30) – 300 μm (No. 50)	64.8 grams (2.3 oz)
300 μm (No. 50) – 150 μm (No. 100)	15.3 grams (0.6 oz)

Note 2: After every ten tests, the tenth test specimen shall be put aside and retested the following day or within a few days of the initial test. This will provide a good indication of the repeatability of the test procedure.

6.6 Save small portions of excess sizes in paper cups for archival purposes. (If enough excess material is not available, the void content sample can be used for this after the void content is run). At least 300 particles randomly sampled from each of the four sieve fractions from the paper cup should be placed on a stiff paper card, held on by double-sided tape, so that each of the four sizes can be viewed conveniently. Insert the card (with sample identification) into an envelope and send the material to the Materials Reference Library (MRL). These samples will serve as a record of the sample and will be saved for archival purposes.

6.7 Uncompacted void content procedure. Run in accordance with <u>Appendix A</u> of this protocol, NAA-JRL Method of Test for Particle Shape and Texture of Fine Aggregate Using Uncompacted Void Content. Calculate and record the uncompacted void content.

7. REPORT

7.1 The test results should be reported in a flat-file spreadsheet format (Excel and ASCII format). The format of the spreadsheet is described in Appendix B. The flat file spreadsheet is intended for use by laboratories that will conduct a high volume of P14A tests. If a laboratory will only conduct a small number of tests (i.e., less than fifteen), then the optional data sheet provided at the end of this protocol may be used to report the data results.

7.2 The following information will be included in the spreadsheet.

7.2.1 The specimen identification shall include: Laboratory Identification Code, State Code, SHRP ID, Layer Number, Field Set Number, Sampling Area No. (SPS-only), Sample Location Number, and LTPP Sample Number.

7.2.2 Report the following:

7.2.2.1 Comment Code and Notes to comments (if any) as described in 7.3 (the note section may contain up to 40 characters).

7.2.2.2 Bulk Dry Specific Gravity (to three decimal places).

7.2.2.3 Absorption, Percent (to two decimal places).

7.2.2.4 Duplicate test determinations and the average Uncompacted Void Content, Percent (to two decimal places).

7.2.2.5 Diff (test 1 - test 2). Difference between duplicate void content tests on the same sample.

Note 3: Cases where the specific gravity is reported and the void content is not reported indicate that the sample was deficient in at least one size fraction to determine the uncompacted void content.

Note 4: If a void content is needed, but the specific gravity is not available, the specific gravity of the next closest sample obtained from the same layer shall be used in the calculation of void content.

7.3 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other notes as needed. Additional codes for special comments associated with this protocol are given below.

Code	Comment
61	Insufficient sample to complete tests.
99	Other comment (describe in a note).

8. Retention/Disposal of Samples

8.1 Obtain, label and save a sample of at least 50 grams (0.1 lb) of the minus 4.75-mm (No. 4) as-received material left over after quartering to obtain the test sample. This sample shall be shipped and stored at the MRL.

8.2 All void content samples (nominal 190-gram [0.4-lb] sample) will be saved in suitable containers. One void content sample from each sample shall be shipped and stored at the MRL.

APPENDIX A - PROTOCOL P14A
NAA-JRL METHOD OF TEST FOR PARTICLE SHAPE AND TEXTURE OF FINE AGGREGATE USING VOID CONTENT

1. SCOPE

1.1 This method covers the determination of the loose uncompacted void content of a fine aggregate for use as a measure of its angularity and texture.

1.2 Procedures are included for the measurement of void content using sand separated into individual sieve fractions and recombined to a standard grading.

2. SUMMARY

2.1 A nominal 100-cm^3 (6.1-in^3) cylinder is filled with fine aggregate of prescribed gradation by allowing the sample to flow through a funnel from a fixed height into the cylindrical container. The cylinder is struck off and weighed. Uncompacted void content is calculated as the difference between the cylinder volume and the absolute volume of the measured weight of fine aggregate collected in the cylindrical container. It is calculated using the bulk dry specific gravity of the sand. <u>Two runs are made on each sample and the results are averaged.</u>

3. SIGNIFICANCE AND USE

3.1 This procedure provides a numerical result in terms of percent void content determined under standardized conditions which correlates with the particle shape and texture properties of a fine aggregate. An increase in void content by this procedure indicates greater angularity and rougher texture. Lower void content results are associated with more rounded smooth sands.

3.2 This test of a regraded sample is most useful as a quick test which indicates the particle shape properties of a graded fine aggregate. Typically, the material used to make up the standard graded sample can be obtained from a single sieve analysis of the fine aggregate.

3.3 Generally, the bulk dry specific gravity of the sand, graded as received, is used for calculating the void content. Occasionally, if the mineralogy of the size fractions varies markedly, it may be necessary to determine the specific gravity of the size fraction used.

3.4 Void content information will be useful as an indicator of properties such as: the mixing water demand of PCC; in AC the effect of the fine aggregate on stability and voids in the mineral aggregate; or the stability of the fine aggregate phase of a base course aggregate.

4. APPLICABLE DOCUMENTS

4.1 ASTM Standards

ASTM C117-87 Test Method for Material Finer than 75-µm (No. 200) Sieve in Mineral Aggregate; except in this case, a 150-µm (No. 100) sieve will be used to remove minus 150-µm (No. 100) material.
ASTM C128-84 Test Method for Specific Gravity and Absorption of Fine Aggregate.
ASTM C136-84 Sieve Analysis of Fine and Coarse Aggregates.

5. APPARATUS

5.1 Funnel -- The lateral surface of the right frustum of a cone sloped 60 ± 4° from the horizontal with an opening of 12.7 ± 0.64 mm (0.50 ± 0.025 in.) in diameter. The funnel shall be smooth on the inside and at least 38 mm (1.5 in.) high. (Pycnometer top C9455 sold by Hogentogler and Co., Inc., 9515 Gerwig, Columbia, Maryland 21045, 301-381-2390 appears to be satisfactory, except that the size of the opening has to be enlarged and any burrs or lips that are apparent should be removed by light filing or sanding.) It shall have a volume of at least 200 cm^3 (12.2 in^3) or shall be provided with a supplemental container to provide the required volume.

5.2 Funnel stand -- A support capable of holding the funnel firmly in position with its axis collinear with the axis of the measure and the funnel opening 114 ± 3 mm (4.5 ± 0.1 in.) above the top of the cylinder. A suitable arrangement is shown in Figure 1 and Figure 2.

5.3 Measure -- A right cylinder of approximately 100 cm^3 (6.1 in^3) capacity having an inside diameter of 38.6 ± 1.3 mm (1.52 ± 0.05 in.) and an inside height of approximately 85.6 mm (3.37 in.) made of drawn copper water pipe meeting ASTM Specification B 88 Type M (Type M copper drain, waste and vent pipe should have outside and inside diameters of approximately 1.63 (41.4 mm) and 1.52 (38.6 mm) inches, respectively) or equally rigid material. The bottom of the measure shall be at least 6.3 mm (0.25 in.) thick, shall be firmly sealed to the tubing, and shall be provided with means for aligning the axis of the cylinder with that of the funnel.

5.4 Pan -- A metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain sand grains that overflow the measure during filling or strike off.

5.5 A metal spatula about 100 mm (4 in.) long with sharp straight edges. The end shall be cut at a right angle to the edges. The straight edge of the spatula is used to strike off the fine aggregate.

5.6 Scale of balance capable of weighing the measure and its content to ± 0.1 grams.

6. CALIBRATION OF MEASURE

6.1 Weigh the dry, empty measure with a flat, glass plate slightly larger than its diameter and with the top edge of the container lightly coated with grease. Fill the measure with water at a temperature of 18 to 24°C (65 to 75°F). Place the glass plate on the measure, being sure that no air bubbles remain. Dry the outer surfaces of the measure and determine the combined weight of measure, glass plate, grease and water.

6.2 Calculate the volume of the measure as follows:

$$V = \frac{W}{0.998}$$

where: V = volume of cylinder in cm^3
W = net weight of water in grams

7. SAMPLING

7.1 The sample(s) used for this test shall be obtained from aggregate extracted from an AC specimen. The sample is washed over a 150-µm (No. 100) sieve and then dried and sieved for 5 minutes into separate size fractions using ASTM C136 procedures. Maintain the necessary size fractions obtained from one (or more) sieve analyses in a dry condition in separate containers for each size.

8. PREPARATION OF TEST SAMPLES

8.1 Graded Sample -- weigh out and combine the following quantities of dry sand from each of the sizes:

Individual Size Fraction	Weight, grams
2.36 mm (No. 8) – 1.18 mm (No. 16)	44 grams (1.5 oz.)
1.18 mm (No. 16) – 600 µm (No. 30)	57 grams (2.0 oz.)
600 µm (No. 30) – 300 µm (No. 50)	72 grams (2.5 oz.)
300 µm (No. 50) – 150 µm (No. 100)	17 grams (0.6 oz.)
	190 grams (6.7 oz.)

The tolerance on each of these weights is ± 0.2 grams. Mix the test sample until it appears homogeneous.

9. PROCEDURE

9.1 If the sand has become moist, dry the sand to the constant weight in accordance with Method C136 and cool to room temperature. Tare out the weight of the cylindrical measure, and then center the measure under the funnel.

9.2 Mix the test sample until it appears homogeneous. Using a finger to block the opening, pour the test sample into the funnel. Remove the finger, and allow the sample to fall freely into the measure.

9.3 After the funnel empties, remove excess sand from the measure by a single pass of the spatula with the blade vertical using the straight part of its edge in light contact with the top of the measure. Until this operation is complete, exercise care to avoid vibration or disturbance that could cause compaction of the fine aggregate in the measure. Brush adhering grains from the outside of the measure and weigh the contents to the nearest 0.1 grams (0.004 oz). Retain all sand grains.

Note 1: After strike-off, the measure may be tapped lightly to compact the sample to make it easier to transfer the measure to scale or balance without spilling any of the sample.

9.4 Collect the sample from the retaining pan and measure, and repeat the procedure again.

9.5 For each run, record the weight of the sand in the measure.

10. CALCULATION

10.1 Calculate the uncompacted voids for each determination as follows:

$$U = \frac{V - \left(\frac{W}{G}\right)}{V} \times 100$$

where: V = volume of measure in cm^3.
W = net weight of fine aggregate in measure.
G = bulk dry specific gravity of fine aggregate measured in accordance with Method C128, Test for Specific Gravity and Absorption of Fine Aggregate.
U = uncompacted voids, percent.

Note 2: For most aggregate sources, the fine aggregate specific gravity does not vary much from sample to sample or from size to size in the minus 2.36-mm (No. 8) fraction. Therefore, unless there is reason to believe that the specific gravity of individual sizes is appreciably different, it is intended that the value used in this calculation may be from a routine specific gravity test of an as-received grading of the fine aggregate. If significant variation between different samples is expected, then specific gravity should be determined on material from the same field sample from which the uncompacted void content sample was derived. Normally, the as-received gradation can be tested for specific gravity, particularly if the 2.36-mm (No. 8) to 150-µm (No. 100) size fraction represents more than 50 percent of the as-received grading.

10.2 For the Graded Sample, calculate the average uncompacted voids for the two determinations and report the result as U_G.

11. REPORT

11.1 For the <u>Graded Sample</u> report:

11.1.1 The Uncompacted Voids (U_G), percent (to two decimal places).

11.1.2 The Specific Gravity value used in the calculation.

12. PRECISION

12.1 Within Laboratory -- Analyses of within laboratory data from sixteen laboratories which made void content tests on independent samples of three similar sources of rounded sands, graded in accordance with the graded standard sand in C778, resulted in a within laboratory standard deviation (1S) of 0.13 percent voids for repeat determinations on the same sample.

Differences greater than 0.37 percent voids between duplicate tests on the same sample by the same operator should occur by chance less than 5 percent of the time (D2S limit).

12.2 Multi-Laboratory -- Analyses of data from sixteen laboratories which made void content tests on independent samples of three similar sources of rounded sands, graded in accordance with the graded standard sand in C778, resulted in a multi-laboratory standard deviation (1S) of 0.33 percent voids. Since this value includes random variance due to the difference in samples, the standard deviation for multi-laboratory tests on the same sample should be lower. Differences greater than 0.93 percent voids between tests in two different laboratories should occur by chance less than 5 percent of the time (D2S limit) for these rounded sands.

12.3 Additional precision data is needed for tests of sands having different levels of angularity and texture tested in accordance with both procedures included in this Method.

13. REFERENCES:

1. Rex, H.M., and Peck, R.A., "A Laboratory Test to Evaluate the Shape and Surface Texture of Fine Aggregate Particles," Public Roads, V. 29, No. 5, Dec. 1956, pp 118-120.

2. Bloem, Delmar L., and Gaynor, Richard D., "Effects of Aggregate Properties on Strength of Concrete," ACI Journal, Proceedings, V.60, No. 10, Oct. 1963, pp 1429-1456.

3. Kalcheff, Ignat V., "Portland Cement Concrete with Stone Sand," Special Engineering Report, National Crushed Stone Association, Washington, D.C., July 1977, 20 pp.

4. Kandhal, P.S., Motter, J.B., and Khatri, M.A., "Evaluation of Particle Shape and Texture: Manufactured Versus Natural Sands," Transportation Research Record, No. 1301.

APPENDIX B - PROTOCOL P14A
NAA FINE AGGREGATE AND TEXTURE DATABASE

1. GENERAL

The data resulting from this test procedure shall be entered in a computer spreadsheet format as provided to the laboratory. The database shall be provided to the FHWA COTR in printed form and as a Microsoft Excel file and as an ASCII file. The spreadsheet file to be used will be provided to the laboratory by the FHWA COTR.

2. DESCRIPTION OF DATABASE

Data shall be split in columns as follows:

<u>Columns 1-10 – Laboratory Material Test Data</u>

Column 1	- Sequential numbers to facilitate sorting
Column 2	- Region
Column 3	- State Abbreviation
Column 4	- State Code
Column 5	- LTPP Experiment Code
Column 6	- SHRP Test Section Identification
Column 7	- Field Set Number
Column 9	- Organization that obtained the samples
Column 10	- Organization that sent samples to NAA (completed P14)

<u>Columns 11-15 - SHRP Sample Identification Codes</u>

Column 11	- Layer Number (From T14)
Column 12	- Laboratory Test Number
Column 13	- Location Number
Column 14	- LTPP Sample Number
Column 15	- Lot Number (Designation assigned to the sample by the laboratory – optional)

<u>Columns 16-25 - Void Content Data</u>

Column 16	- Bulk Dry Specific Gravity
Column 17	- Absorption, in percent
Column 18	- Void Content – Average of Tests 1 & 2
Column 19	- Void Content – Test 1
Column 20	- Void Content – Test 2 on same sample

Column 21	- Difference between void test 1 and 2 on same sample
Column 22	- Comment Code
Column 23	- Note to Comment Code (optional)
Column 24	- Laboratory Identification Code
Column 25	- Test Date

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
NAA TEST FOR FINE AGGREGATE PARTICLE SHAPE
LAB DATA SHEET T14A

ASPHALT CONCRETE LAYER (EXTRACTED AGGREGATE)
LTPP TEST DESIGNATION: AG05/LTPP PROTOCOL P14A

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __
5. BULK DRY SPECIFIC GRAVITY OF FINE AGGREGATE __.__ __ __
6. ABSORPTION OF FINE AGGREGATE __.__ __
7. UNCOMPACTED VOID CONTENT 1, (U_{G1}), % __ __.__ __
8. UNCOMPACTED VOID CONTENT 2, (U_{G2}), % __ __.__ __
9. UNCOMPACTED VOID CONTENT AVG, (U_{Gavg}), % __ __.__ __
10. DIFFERENCE IN UNCOMPACTED VOID CONTENT, (V_1-V_2), % __.__ __ __
11. COMMENTS
    (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
    (b) NOTE ____________________________________
12. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
____
____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_________________________ _________________________
LABORATORY CHIEF

Affiliation:________________ Affiliation:____________________

PROTOCOL P21
Test Method for Recovery of Asphalt From Solution by Abson Method (AE01)

This LTPP protocol describes the Abson recovery method of asphalt cement binder from solutions previously obtained by extracting asphalt mixtures with reagent-grade trichloroethylene.

This test shall be carried out in accordance with AASHTO T170-00 with the exception of some of the sections of the reference standard which have been modified as presented here. In all other sections, the test standard AASHTO T170-00 shall be followed as published.

This test shall be carried out on drilled cores and block specimens as well as uncompacted samples of both virgin and recycled asphalt-aggregate mixtures obtained from test sections included in the LTPP experiments.

1. SCOPE

1.2 This protocol may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use of this protocol.

2. APPLICABLE DOCUMENTS

2.4 LTPP Protocol

Protocol P04 - Determination of Asphalt Content (Extraction)

(Protocol P04 may be found in the LTPP Laboratory Testing Guide.)

4. SIGNIFICANCE AND USE

4.1 The asphalt should be extracted from the asphalt-aggregate mixture in accordance with Protocol P04 "Determination of Asphalt Content" utilizing reagent-grade trichloroethylene as the solvent.

Note 2 – Delete

9. PROCEDURE

9.4 If the residue in the flask is highly viscous at 325°F (163°C) so that dispersion of the carbon dioxide in the residue is restricted and the recovered asphalt is expected to have a penetration at 77°F (25°C) of less than 30, maintain the carbon dioxide gas flow and temperature for 20 to 22 minutes.

9.5 The recovered asphalt cement shall be heated to reliquify the sample and portions shall be obtained for penetration, specific gravity and viscosity determinations.

9.6 Ash content determinations shall be conducted on all recovered bitumens in accordance with ASTM Method D2939 and reported with other test data on the recovered asphalt. Ash contents of recovered asphalt greater than 1% may affect the accuracy of the penetration, specific gravity or viscosity tests.

11. REPORT

Record the following information on Form T21.

11.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

11.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

11.3 Test Results

11.3.1 Mass of bitumen recovered.

11.3.2 Ash content of bitumen.

11.3.3 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
RECOVERY OF ASPHALT FROM SOLUTION BY ABSON METHOD
LAB DATA SHEET T21

ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION: AE01/LTPP PROTOCOL P21

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA-__ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. LOCATION NUMBER __ __ __

3. LABORATORY TEST NUMBER __

4. LTPP SAMPLE NUMBER __ __ __ __

5. MASS OF RECOVERED BITUMEN (grams) __ __ __.__

6. ASH CONTENT OF BITUMEN (percent) __.__

7. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
   (b) NOTE ____

8. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_______________________ _______________________
LABORATORY CHIEF

Affiliation:_________________ Affiliation:______________________

PROTOCOL P22
Test Method for Penetration of Extracted Asphalt Cement at 77°F and 115°F (AE02)

This LTPP protocol covers the determination of the penetration of extracted asphalt cements at 77°F (25°C) and 115°F (46°C).

This test shall be carried out in accordance with AASHTO T49-89 with the exception of some of the sections of the reference standard which have been modified as presented below. In all other remaining sections, AASHTO T49-89 shall be followed as written. The test will be carried out on asphalt cement specimens extracted from AC core and block samples, as well as uncompacted samples of both virgin and recycled aggregate mixtures recovered from test sections included in the LTPP experiments. The asphalt cement shall be recovered from the AC cores and asphalt-aggregate mixtures by the Abson method specified in LTPP Protocol P21.

1. SCOPE

1.1 This method describes a procedure for determining the penetration of extracted asphalt cement at two temperatures (77°F [25°C] and 115°F [46°C]).

2. REFERENCED DOCUMENTS

2.5 LTPP Protocol

Protocol P21 - Recovery of Asphalt from Solution by the Abson Method.

6. APPARATUS

6.3 Delete

6.7.2 Delete

7. PREPARATION OF SAMPLE

7.1 Heat the extracted asphalt cement sample with care to prevent local overheating until it has become fluid. Then with constant stirring, raise the temperature of the asphalt cement sample to not more than 180°F (100°C) above its estimated or expected softening point. Avoid the inclusion of air bubbles. To reach the pouring temperature, do not heat the softened sample more than 30 minutes. Then, pour it into the sample container to a depth, that when cooled to the temperature of test, is at least 10 mm (0.4 in.) greater than the depth to which the needle is expected to penetrate. Pour separate samples for each of the test temperatures (77°F [25°C] and 115°F [46°C]).

8. TEST CONDITIONS

8.1 The conditions of the test (i.e., temperature, load, and time) for this protocol shall consist of (1) 77°F (25°C), 100 g (0.2 lb) and 5 s and (2) 115°F (46°C), 100 g (0.2 lb) and 5 s.

9. PROCEDURE

In accordance with Section 9 of AASHTO T49-87 for two separate specimens from the same asphalt cement sample at 77°F (25°C) and 115°F (46°C) (i.e., one at 77°F [25°C] and one at 115°F [46°C]).

9.4 Calculate the Penetration Index using the following formula:

$$PI = \frac{20 - 500A}{1 + 50A}$$

where: PI = Penetration Index and

$$A = \frac{LogPen@115°F - LogPen@77°F}{21.1}$$

Pens in millimeters @ 100 gm., 5 sec.

10. REPORT

Report the following information on Form T22.

10.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

10.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

10.3 Test Results

10.3.1 Report, to the nearest whole unit, the average of at least three penetrations on the same sample, whose values do not differ by more than the amount shown below for each test temperature:

Penetration	Max Difference Between Highest and Lowest PEN
$P \leq 49$	2
$50 \leq P \leq 149$	4
$150 \leq P \leq 249$	6
$250 \leq P$	8

10.3.2 If the differences are exceeded, repeat the test using a second sample from the same batch of asphalt cement.

10.3.3 If the appropriate tolerance is again exceeded, ignore all results and repeat the test completely.

10.3.4 Penetration index to the nearest decimal place.

10.3.5 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION OF EXTRACTED ASPHALT CEMENT AT 77 AND 115°F
TEST DATA SHEET T22

ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION: AE02/LTPP PROTOCOL P22

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __ __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA NO. SA-____

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __
5. PENETRATION @ 77°F (millimeters) __ __ __.
6. PENETRATION @ 115°F (millimeters) __ __ __.
7. PENETRATION INDEX __.__
8. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
   (b) NOTE ______________________________
9. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:______________________________

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SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

Affiliation:_________________ Affiliation:______________________

PROTOCOL P23
Test Method for Specific Gravity of Extracted Asphalt Cement (AE03)

This LTPP protocol covers the determination of the specific gravity of asphalt cements by use of a pycnometer.

This test shall be carried out in accordance with AASHTO T228-90 with the exception of some of the sections of the reference standard which have been modified as presented below. In all other sections, the test standard (AASHTO T228-90) shall be followed as written. The test shall be carried out on asphalt cement extracted from AC core and block specimens as well as uncompacted mixtures of both virgin and recycled asphalt-aggregate mixtures obtained from test sections included in the LTPP experiments.

1. SCOPE

This method covers the determination of the specific gravity of extracted asphalt cement by use of a pycnometer.

2. SPECIFIC GRAVITY

The specific gravity of extracted asphalt cements shall be expressed as the ratio of the mass of a given volume of the material at 60°F (15.6°C) to that of an equal amount of water at the same temperature.

9. REPORT

Record the following information on Form T23.

9.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

9.3 Test Results

9.3.1 Record the specific gravity of the test sample to the nearest third decimal place.

9.3.2 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SPECIFIC GRAVITY OF EXTRACTED ASPHALT CEMENT
TEST DATA SHEET T23

ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION: AE03/LTPP PROTOCOL P23

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. LOCATION NUMBER __ __ __

3. LABORATORY TEST NUMBER __

4. LTPP SAMPLE NUMBER __ __ __ __

5. SPECIFIC GRAVITY __. __ __ __

6. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __

   (b) NOTE ____

7. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
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____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

__________________________ __________________________________
LABORATORY CHIEF

Affiliation:_________________ Affiliation:_______________________

PROTOCOL P24
Test Method for Viscosity of Asphalt Cement at 77°F with Cone and Plate Viscometer

This LTPP protocol covers the determination of the viscosity of asphalt cement at 77°F (25°C) by means of a cone-plate viscometer.

This test shall be carried out in accordance with ASTM D3205-86 with the exception of some of the sections of the reference standard which have been modified as presented herein. In all other sections the test standard (ASTM D3205-86) shall be followed as written. The test will be carried out on asphalt cement samples extracted from AC core and block specimens as well as uncompacted samples of both virgin and recycled asphalt-aggregate mixtures obtained from test sections included in the LTPP SPS experiments.

1. SCOPE

1.1 This test method covers the determination of the viscosity of asphalt cement by means of a cone-plate viscometer. It is applicable to materials exhibitin viscosities in the range from 10^3 to 10^{10} Poises (10^2 to 10^9 PaS) and is therefore suitable for use at 77°F (25°C) for asphalt cements. The shear rate may vary between approximately 10^{-3} to 10^{-2} s^{-1} and the method is suitable for determination on materials having either Newtonian or non-Newtonian flow properties.

9. PREPARATION OF APPARATUS

9.1 Maintain the bath at 77 ± 0.02°F (25 ± 0.01°C). Apply the necessary corrections, if any, to all thermometer readings.

10. PROCEDURE

10.5 Measure the angular velocity for increasing loads using 100-, 300-, 1,000-, 3,000- and 10,000-gram (0.2-, 0.7-, 2.2-, 6.6- and 22-lb) loads starting with the smallest and applying them successively at no more than 10-minute intervals between each application.

10.6 DELETE

11. CALCULATION

11.1 Select the calibration factors corresponding to the cone and cord used. For each load and angular velocity, calculate the shear stress, S, in dynes per square centimeter, the shear rate, D, in reciprocal seconds, and the viscosity, η, in megapoise as follows:

$$S = K_s(L - F)$$

$$D = K_D(\theta / t)$$

$$\eta = \frac{(S / D)}{1 \times 10^6}$$

12. REPORT

Record the following on Form T24:

12.1 Sample identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number and LTPP Sample Number.

12.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

12.3 Test Results

12.3.1 Record the test temperature in degrees fahrenheit.

12.3.2 Viscosity in megapoise for each load.

12.3.3 Shear rate in reciprocal seconds for each load.

12.3.4 If fracture occurs, record the shear stress resulting in the fracture in dynes per square centimeter.

12.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of the LTPP Laboratory Testing Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
VISCOSITY OF ASPHALT CEMENT AT 77°F
TEST DATA SHEET T24

ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION: AE04/LTPP PROTOCOL P24

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATIO CODE: : __ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __
5. TEST TEMPERATURE, °F __ __.__ __
6. LOAD: 100 GRAMS
   (a) VISCOSITY, megapoise __ __.__ __ __
   (b) SHEAR RATE, s^{-1} __.__ __
7. LOAD: 300 GRAMS
   (a) VISCOSITY, meagpoise __ __.__ __ __
   (b) SHEAR RATE, s^{-1} __.__ __
8. LOAD: 1000 GRAMS
   (a) VISCOSITY, meagpoise __ __.__ __ __
   (b) SHEAR RATE, s^{-1} __.__ __
9. LOAD: 3000 GRAMS
   (a) VISCOSITY, meagpoise __ __.__ __ __
   (b) SHEAR RATE, s^{-1} __.__ __
10. LOAD 10000 GRAMS
   (a) VISCOSITY, meagpoise __ __.__ __ __
   (b) SHEAR RATE, s^{-1} __.__ __
11. FRACTURE (only to be completed if fracture of specimen occurs)
   (a) LOAD, grams __ __ __ __ __.
   (b) SHEAR STRESS, dynes/cm^2 __ __.__ __ __ __ __
12. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
   (b) NOTE ______________________________________
13. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_____________________ _________________________
LABORATORY CHIEF

Affiliation:_________________ Affiliation:_________________

PROTOCOL P25
Test Method for Kinematic and Absolute Viscosity of Extracted Asphalt Cement (AE05)

This LTPP protocol describes the method for the determination of the absolute and kinematic viscosities of extracted asphalt cements.

This test shall be carried out in accordance with AASHTO T201-90 (Kinematic Viscosity - 275°F [135°C]) and AASHTO T202-90 (Absolute Viscosity - 145°F [63°C]) as presented below. The test will be carried out on asphalt cement samples extracted from AC core and block specimens as well as uncompacted samples of both virgin and recycled asphalt-aggregate mixtures obtained from test sections included in the LTPP experiments.

1. SCOPE

This method covers procedures for the determination of the absolute (140°F [63°C]) and kinematic viscosity (275°F [135°C]) of asphalt cement.

2. APPLICABLE DOCUMENTS

In accordance with Section 2 of AASHTO T201-86.

3. SUMMARY OF METHOD

3.1. For the kinematic viscosity, the time is measured for a fixed volume of the liquid to flow through the capillary of a calibrated glass capillary viscometer under an accurately reproducible head and at a closely controlled temperature (275°F [135°C]). The kinematic viscosity is then calculated by multiplying the efflux time in seconds by the viscometer calibration factor.

3.2. For the absolute viscosity, the time is measured for a fixed volume of the liquid to be drawn up through a capillary tube by means of a vacuum, under closely controlled conditions of vacuum and temperature (140°F [63°C]). The absolute viscosity, in poise, is then calculated by multiplying flow time in seconds by the viscometer calibration factor.

4. DEFINITIONS

In accordance with Section 4 of AASHTO T201-86.

5. APPARATUS

5.1 Viscometer, capillary-type, made of borosilicate glass, annealed, suitable for the kinematic viscosity test as described in Annex A2, figure A2 (Zeitfuchs Cross-Arm Viscometer) of AASHTO T201-86. Details regarding calibration of the viscometer are given in Annex A3 of AASHTO T201-86.

5.2 Viscometer, capillary-type, made of borosilicate glass, annealed, suitable for the absolute viscosity test as described in Annex A2.1 and A2.2 (Asphalt Institute Vacuum Capillary Viscometer) of AASHTO T202-84. Details regarding the calibration of the viscometer are given in Appendix A4 of AASHTO T202-84.

5.3 Thermometers - In accordance with Section 5.3, 5.3.1 and 5.3.2 of AASHTO T201-86.

5.4 Bath - In accordance with Section 5.4 of AASHTO T201-86.

5.5 Timer - In accordance with Section 5.5 of AASHTO T201-86.

5.6 Vacuum System - In accordance with Section 6.4 of AASHTO T202-84.

6. PREPARATION OF SAMPLE

6.1 Heat 30–40 ml (1.8–2.4 in^3) of the extracted asphalt cement sample with care to prevent local overheating, until it has become sufficiently fluid to pour, occasionally stirring the sample to aid heat transfer and to assure uniformity.

6.2 Transfer a minimum of 20 ml (1.2 in^3) into a suitable container and heat to 275 ± 10°F (135 ± 5.6°C) stirring constantly and taking care to avoid the entrapment of air.

7. PROCEDURE

7.1 *Kinematic Viscosity* - In accordance with sections 7.1 through 7.8 of AASHTO T201-86 utilizing the Zeitfuchs Cross-Arm Viscometer.

7.2 After step 7.1, recombine the sample from step 6.1 and that recovered after step 7.1 and reheat the test sample with care to prevent local overheating until it has become sufficiently fluid to pour, occasionally stirring the sample to aid heat transfer and to assure uniformity. The maximum temperature shall not exceed 180°F (82°C) above the expected softening point.

7.3 Transfer a minimum of 20 ml (0.67 oz) into a suitable container and heat to 275 ± 10°F (135 ± 5.6°C) stirring occasionally and taking care to avoid the entrapment of air.

7.4 *Absolute Viscosity* - perform in accordance with Sections 8.1 through 8.2 of AASHTO T202-84 utilizing an Asphalt Institute Vacuum Capillary Viscometer.

8. CALCULATIONS

8.1 *Kinematic Viscosity* - In accordance with Section 8 of AASHTO T201-86.

8.2 *Absolute Viscosity* - In accordance with Section 9 of AASHTO T202-84.

9. REPORT

Record the following on Form T25.

9.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sample Area Number, Layer Number, Location Number and LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

9.3 Test Results:

Kinematic Viscosity

9.3.1 Calibration constant of the viscometer (c) in centistokes per second.

9.3.2 Efflux time (s) in seconds.

9.3.3 Kinematic viscosity at 275°F (135°C) in centistokes.

Absolute Viscosity

9.3.4 Selected calibration factor (K) in poises per second.

9.3.5 The flow time (S) in seconds.

9.3.6 Vacuum pressure in inches of mercury.

9.3.7 Absolute viscosity in poise.

9.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this LTPP Laboratory Materials Testing Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
KINEMATIC AND ABSOLUTE VISCOSITY
TEST DATA SHEET T25

ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION AE05/SHRP PROTOCOL P25

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __ __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __

2. LOCATION NUMBER __ __ __

3. LABORATORY TEST NUMBER __

4. LTPP SAMPLE NUMBER __ __ __ __

5. KINEMATIC VISCOSITY
   (a) CALIBRATION CONSTANT (C), centistokes/sec __ __ __.__
   (b) EFFLUX TIME (s), seconds __ __ __ __.__
   (c) KINEMATIC VISCOSITY @ 275 °F, centistokes __ __ __ __ __ __.

6. ABSOLUTE VISCOSITY
   (a) CALIBRATION FACTOR (K), poises/sec __ __ __ __ __.__
   (b) FLOW TIME, seconds __ __ __ __. __
   (c) VACUUM PRESSURE, In. of Hg __ __ __. __
   (d) ABSOLUTE VISCOSITY @ 140 °F, poises __ __ __ __ __ __ __.

7. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
   (b) NOTE ____

8. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
____
____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

Affiliation: ______________________ Affiliation:______________________

PROTOCOL P27
Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR) (AE07)

This LTPP Protocol covers the procedures for determining the dynamic shear modulus and phase angle of asphalt binder. The test shall be carried out in accordance with AASHTO T315-02 as described by the following.

4. SUMMARY AND TEST METHOD

4.5 The oscillatory loading frequency should be 10 rad/s using a sinusoidal waveform. The complex modulus (G*) and phase angle (δ) are calculated automatically as part of the operation of the rheometer using proprietary computer software supplied by the equipment manufacturer.

8. PREPARATION OF APPARATUS

8.3 Select the test temperature based upon the laboratory testing plan designed for the individual SPS project. Allow the DSR to reach a stabilized temperature within ± 0.1ºC (± 0.2°F) of test temperature.

13. REPORT

Following information shall be recorded for each test temperature:

13.3 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

13.4 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

13.5 General test and sample information:

13.5.1 Material type should be stated as Original, Rolling Thin Film Oven (RTFO), Pressure Aging Vessel (PAV), or Field Aged.

13.5.2 For field aged specify time since construction, in months.

13.5.3 Test control mode should be indicated as Stress or Strain.

13.5.4 Test plate diameter, in millimeters.

13.5.5 Test gap, in micrometers.

13.5.6 Test temperature, in degree Celsius.

13.5.7 Number of conditioning cycles.

13.5.8 Conditioning frequency, in radians per second.

13.5.9 Test frequency, in radians per second.

13.5.10 Strain amplitude, in percent.

13.5.11 Torque amplitude, in millinewton meter.

13.5.12 AC performance grade.

13.6 Complex modulus and phase angle:

The different complex modulus and phase angle values obtained per cycle shall be reported, as well as their average and standard deviation.

13.7 Comments shall include LTPP standard comment code (s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
RHEOLOGICAL PROPERTIES OF ASPHALT BINDER
USING A DYNAMIC SHEAR RHEOMETER (DSR)
LAB DATA SHEET T27
ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION AE07/LTPP PROTOCOL P27

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __
REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____
LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __ LABORATORY TEST NUMBER __
LOCATION NUMBER __ __ __ LTPP SAMPLE NUMBER __ __ __ __
TEST DATE: __ __-__ __-__ __ __ __

1. MATERIAL TYPE (ORIGINAL = 1, RTFO = 2, PAV = 3, FIELD AGED = 4) __
2. FOR FIELD AGED, TIME SINCE CONSTRUCTION, months __ __ __.__
3. TEST CONTROL MODE (STRESS = 1, STRAIN= 2) __
4. TEST PLATE DIAMETER, mm __ __.__
5. TEST GAP, µm __ __ __ __
6. NUMBER OF CONDITIONING CYCLES __ __
7. TEST TEMPERATURE, ºC __ __.__
8. CONDITIONING FREQUENCY, rad/s __ __.__
9. TEST FREQUENCY, rad/s __ __.__
10. STRAIN AMPLITUDE, percent __ __.__ __
11. TORQUE AMPLITUDE, mN·m __ __ __ __
12. AC PERFORMANCE GRADE PG __ __ - __ __

COMPLEX MODULUS AND PHASE ANGLE (See section 13.4 of Protocol P27)

Cycle No.	**Complex Modulus G* (kPa)**	**Phase Angle δ(°)**	**Cycle No.**	**Complex Modulus G* (kPa)**	**Phase Angle δ(°)**
1	__ __ __ __ __.__	__ __.__	**6**	__ __ __ __ __.__	__ __.__
2	__ __ __ __ __.__	__ __.__	**7**	__ __ __ __ __.__	__ __.__
3	__ __ __ __ __.__	__ __.__	**8**	__ __ __ __ __.__	__ __.__
4	__ __ __ __ __.__	__ __.__	**9**	__ __ __ __ __.__	__ __.__
5	__ __ __ __ __.__	__ __.__	**10**	__ __ __ __ __.__	__ __.__

13. AVERAGE COMPLEX MODULUS (G*), kPa __ __ __ __ __.__
14. AVERAGE PHASE ANGLE (δ), ° __ __.__
15. STANDARD DEVIATION OF COMPLEX MODULUS, kPa __ __ __ __ __.__
16. STANDARD DEVIATION OF PHASE ANGLE (δ), ° __ __.__
17. COMMENTS
    (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
    (b) NOTE ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
LABORATORY CHIEF

Affiliation: ______________________ Affiliation:______________________

PROTOCOL P28
Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR) (AE08)

This LTPP Protocol covers the procedures for determining the flexural creep stiffness of asphalt binders using a bending beam rheometer (BBR). The test shall be carried out in accordance with AASHTO T313-02 as described by the following.

12. PROCEDURE

12.1 Select the test temperature based upon the laboratory testing plan designed for the individual SPS project. After demolding, immediately place the test specimen in the testing bath and condition it at the testing temperature for 60 ± 5 minutes.

14. REPORT

Sample Identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

General test and sample information:

14.3.1 Material type should be stated as Original, RTFO, PAV, or Field Aged.

14.3.2 In case of field aged, specify the time the sample has aged since construction, in months.

14.3.3 Minimum and maximum test temperature, in degree Celsius.

14.3.4 Soak time, in minutes.

14.3.5 Beam width, in millimeters.

14.3.6 Beam thickness, in millimeters.

14.3.7 Preload, in millinewtons.

14.3.8 Seating load, in millinewtons.

14.3.9 Seating load time, in seconds.

14.3.10 Recovery time, in seconds.

14.3.11 AC performance grade.

Summary of results

For every loading time (8, 15, 30, 60, 120, and 240 seconds), report:

14.4.1 Time, in seconds.

14.4.2 Force, in newtons (record force at 0 and 5 seconds also).

14.4.3 Deflection, in millimeters (record deflection at 0 and 5 seconds also).

14.4.4 Stiffness, measured and estimated, in megapascals.

14.4.5 Percent of difference between measured and estimated stiffness values.

14.4.6 Estimated m value. (See section 3.2.4 of AASHTO TP1-98 for definition)

14.4.7 Regression coefficients:

Regression constant A
Regression constant B
Regression constant C
Correlation coefficient, R^2

14.5 Comments shall include LTPP standard comment code (s) as shown in Section 4.3 of this Guide, and any other note as needed.

Raw data from the BBR device should be included.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
FLEXURAL CREEP STIFFNESS OF ASPHALT BINDER
USING THE BENDING BEAM RHEOMETER
LAB DATA SHEET T28
ASPHALT CONCRETE LAYER (ASPHALT CEMENT PROPERTIES)
LTPP TEST DESIGNATION: AE08/LTPP PROTOCOL P28

LABORATORY PERFORMING TEST:________________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION:_______________ STATE:_______________ STATE CODE: __ __
EXPERIMENT NO:_____ SHRP ID: __ __
SAMPLED BY:______________________________ SAMPLE AREA No: SA-__ __
DATE SAMPLED:__ __-__ __-__ __ __ __ FIELD SET NO.: __
LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B)__

SAMPLE LOCATION NUMBER__ __ __ LTPP SAMPLE NUMBER__ __ __ __

LABORATORY TEST NUMBER:__ TEST DATE:__ __-__ __-__ __ __ __

1. MATERIAL TYPE (ORIGINAL = 1, RTFO = 2, PAV = 3, FIELD AGED = 4) __
2. FOR FIELD AGED, TIME SINCE CONSTRUCTION, months __ __ __.__
3. MAX TEST TEMPERATURE, °C __ __.__
4. MIN TEST TEMPERATURE, °C __ __.__
5. SOAK TIME, s __ __ __ __.__
6. BEAM WIDTH, mm __ __.__ __
7. BEAM THICKNESS, mm __ __.__ __
8. PRELOAD, mN __ __
9. SEATING LOAD, mN __ __ __ __
10. SEATING LOAD TIME, s __ __
11. RECOVERY TIME, s __ __
12. AC PERFORMANCE GRADE PG __ __-__ __
13. SUMMARY OF RESULTS

Time (s)	Actual Time (s)	Force (N)	Deflection (mm)	Stiffness (MPa)			m-value
				Measured	Estimated	Difference (%)	
0	_._	__ __.__ __ __ __	__.__ __ __ __				
5	_._	__ __.__ __ __ __	__.__ __ __ __				
8	_._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __
15	_ _._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __
30	_ _._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __
60	_ _._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __
120	_ _ _._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __
240	_ _ _._	__ __.__ __ __ __	__.__ __ __ __	__ __ __ __	__ __ __ __	__.__ __ __ __	__.__ __ __

14. REGRESSION COEFFICIENTS
A = __ __.__ __ __ B = __ __.__ __ __ C = __ __.__ __ __ R^2 = __.__ __ __
15. COMMENT CODES __ __ __ __ __ __ __ __ __ __ __ __
16. NOTE: PLEASE ATTACH THE RAW DATA FROM BENDING BEAM RHEOMETER DEVICE

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF
Affiliation: ______________________ Affiliation:______________________

PROTOCOL P29
Test Method for Determining the Fracture Properties of Asphalt Binder in Direct Tension (AE09)

This LTPP Protocol covers the procedures for determining the failure strain and failure stress of asphalt binders by means of a direct tension test. The test shall be carried out in accordance with AASHTO T314-02 as described by the following.

18. REPORT

18.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

18.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

18.3 General test and sample information:

18.3.1 Material type should be stated as Original, RTFP, PAV, or Field Aged.

18.3.2 For field aged specify time since construction, months.

18.3.3 Specimen cross-sectional area, mm^2.

18.3.4 Gauge length of specimen, mm.

18.3.5 Specimen conditioning time, minutes (it is assumed that all specimens will be conditioned at the same time).

18.3.6 AC performance grade.

For each test specimen, record the following information:

18.3.7 Test temperature, ºC.

18.3.8 Rate of elongation, mm/min.

18.3.9 Percent failure strain, mm/mm x 100.

18.3.10 Failure Stress, MPa.

18.3.11 Peak load, N.

18.3.12 Fracture, yes or no.

18.4 Comments shall include LTPP standard comment code (s) as shown Section 4.3 of this Guide, and any other note as needed.

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
FRACTURE PROPERTIES OF ASPHALT BINDER
IN DIRECT TENSION
LAB DATA SHEET T29

ASPHALT CONCRETE LAYER
LTPP TEST DESIGNATION: AE09/LTPP PROTOCOL P29

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION:_______________ STATE:________________ STATE CODE: __ __
EXPERIMENT NO:_____ SHRP ID: __ __ __ __
SAMPLED BY:_______________________________________ SAMPLE AREA No: SA-__ __
DATE SAMPLED:__ __-__ __-__ __ __ __ FIELD SET NO.: __

SAMPLE LOCATION NUMBER__ __ __ LTPP SAMPLE NUMBER __ __ __ __
LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B)__

LTPP LABORATORY TEST NUMBER:__ TEST DATE:__ __-__ __-__ __ __ __

1. MATERIAL TYPE (ORIGINAL = 1, RTFO = 2, PAV = 3, FIELD AGED = 4) __
2. FOR FIELD AGED, TIME SINCE CONSTRUCTION, months __ __ __.__
3. SPECIMEN CROSS-SECTIONAL AREA (mm^2) __.__
4. GAUGE LENGTH (mm) __ __.__
5. CONDITIONING TIME (minutes) __ __ __
6. AC PERFORMANCE GRADE PG __ __ - __ __

Test No.	Test Temp. °C	Rate of Elongation (mm/min)	Percent Failure Strain (mm/mm)x100	Failure Stress (MPa)	Peak Load (N)	Fracture
1	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	Yes/No
2	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	Yes/No
3	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	Yes/No
4	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	Yes/No
Avg.	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	
SD	_ _._	_. _ _	_._ _	_ _ _._ _	_ _ _.	

Note 1: Out of six specimens tested, discard the lowest two values of failure stress, strain, and energy. Report the remaining four specimen's data here.

Note 2: Please attach raw data from direct tension device.

7. COMMENTS
   (a) CODE __ __ __ __ __ __ __ __ __ __ __ __
   (b) NOTE ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

Affiliation: ____________________ Affiliation:____________________

PROTOCOL P31
Test Method for Identification and Description of Treated Base and Subbase Materials, and Determination of Type of Treatment (TB01)

This LTPP protocol covers the procedures for identification and description of treated base and subbase materials; including lean concrete, econocrete, cement aggregate, soil cement, lime-treated soil, and asphalt treated materials as well as the determination of the type of treatment given to the base and/or subbase material to be tested. This protocol also covers the procedures for identification and description of treated subgrade. This protocol is based on the standard ASTM D2488-00. The test shall be carried out in accordance with this standard (ASTM D2488-00) as modified herein. Those sections of the ASTM standard included in this protocol by reference and without modifications shall be followed. All other sections of this protocol shall be followed as herein written. This test shall be the first test to be performed on 4-inch (102-mm) diameter cores and/or chunks and pieces of any kind of treated base/subbase layers and treated subgrade from a pavement section.

The following definitions will be used throughout this protocol:

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(b) Treated Base or Subbase Materials: Treated base or subbase materials are bound or stabilized layers of base or subbase. The terms (treated, bond, stabilized) are used interchangeably in reference to base and subbase layers containing a cementing or binding type of agent. For LTPP terminology and codes, see Table 4.29 of the LTPP Laboratory Material Testing Guide.

(c) Asphalt Treated Base (ATB) or Subbase: Asphalt treated base and subbase materials (ATB, also known as bituminous treated materials) include soils, aggregate and soil-aggregate mixtures bound by asphalt or bitumen. Examples are asphalt treated aggregate base, soil-asphalt, and sand-asphalt. Typically these materials are produced by cold mix and mixed-in-place procedures. Samples of ATB type materials shall be tested using Protocols P31 and P07 procedures only.

(d) Other than Asphalt Treated Base or Subbase (OTB): Other than asphalt treated base and subbase materials include all types of treated materials for which asphalt or bitumen was not used as a binding agent. Typical OTB materials range from very strong and durable to weak and less durable treated materials. Examples of very strong materials are lean concrete, econocrete, and cement-aggregate. The following materials may range from strong to weak; soil cement, lime-treated materials, and flyash-treated soils. Materials stabilized with chemicals, industrial wastes, and different kinds of proprietary products are also included in the category of OTB materials. Samples of OTB materials shall be tested using Protocols P31 and P32 procedures only.

(e) Treated Subgrade: Treated subgrade materials are bound or stabilized layers of subgrade. The terms (treated, bound, stabilized) are used interchangeably in reference to the treated subgrade containing a cementing or binding type of agent. Table 4.26 and Table 4.29 of the LTPP Laboratory Material Testing Guide should be consulted to assign appropriate LTPP terminology and codes for the description of treated subgrade material and type of treatment respectively. The treated subgrade may be asphalt treated material (for example, ATB) or other than asphalt treated (OTB) material (for example, lime, cement, lime- and cement-flyash, polymer and chemical treated subgrade; but not lean concrete and econocrete).

(f) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(g) Chunks: Chunks (large pieces) of treated base, subbase or subgrade may be extracted from the full thickness of each layer in the test pit area and/or the 12-inch (305-mm) diameter BA... type borehole(s). An undisturbed block sample (12-inch [305-mm] square) may also be taken from the field in certain cases. A chunk is always smaller than a block sample. If chunks or block samples of the treated material can not be recovered, then smaller pieces of the treated material are collected in the field for shipment to the laboratory.

(h) Sample: A representative portion of material from one or more pavement layers received from the field. A sample can be a core, block, chunk, pieces, bulk, thin-walled tube or jar sample.

(i) Test Specimen: That part of the layer which is used for, or in, the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

Preliminary identification and detailed description using Protocol P31 shall be carried out on samples of each layer of treated base and subbase materials and treated subgrade suitable for testing after assigning the appropriate layer number.

Locations for Chunks and Pieces of Treated Layer

If intact cores from the treated layer have not been recovered then chunks and pieces of each treated layer may be retrieved from the following sample locations:

(a) From BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes.

(b) Test pits.

These chunks and pieces are then used for the P31 test.

Assignment of Laboratory Test Numbers

(a) The results of each test determined from the specified cores and/or chunks of the treated layer shall be assigned Laboratory Test Number "1", if these samples were retrieved from near the beginning of a test section (Stations 0-).

(b) The results of each test determined from the specified cores and/or chunks of the treated layer shall be assigned Laboratory Test Number "2", if these samples were retrieved from near the end of a test section (Stations 5+).

(c) The results of each test determined from the specified cores and/or chunks of the treated layer shall be assigned Laboratory Test Number "3", if these samples were retrieved from within the test section (Stations 0+00 to 5+00).

Selection of Protocols P31 and P32 Test Methods

The following sections are applicable to each layer of treated base, treated subbase and treated subgrade.

(1) Cores retrieved from lean concrete, econocrete, cement aggregate or lime, lime-flyash treated, chemical-stabilized and any other non-asphalt treated OTB layers should be tested for compressive strength using LTPP Protocol P32 procedures only if the core thickness is 3 inches (76 mm) or more.

(2) All ATB materials from each layer of treated base or subbase and treated subgrade shall be tested for resilient modulus using LTPP Protocol P07 procedures only if the core thickness is 3 inches (76 mm) or more.

(3) If all the available samples are unsuitable for P32 or P07 testing (broken cores, chunks or pieces of layer material, for example), then only the test results from LTPP Protocol P31 shall be reported on Form T31. The compressive strength or resilient modulus tests (Protocols P32 or P07) shall not be performed. Comment code 92 shall be used to record this condition in reporting the test results on Form T31.

(4) Compressive strength tests (Protocol P32) shall not be performed if the thickness of the treated layer is less than 3 inches (76 mm). Resilient modulus tests (Protocol P07) shall not be performed if the thickness of the treated layer is less than 1 inch (25 mm). This rule shall be applied irrespective of the availability of intact cores and/or only chunks and pieces. The treated layer samples shall be tested using Protocol P31 only.

Testing Sequence for Each Layer of Treated Material

Prior to testing, assign layer numbers using lab sheet L04. The testing sequence to be followed for treated base/subbase materials and treated subgrade is as defined below:

Step 1: Determine layer number (lab sheet L04); mark layer number on sample identification labels for every sample.

Step 2: Conduct preliminary identification of the treated material and measure thickness of cores using Section 9 of LTPP Protocol P31.

Step 3: (a) DO NOT PERFORM THE P32 OR P07 TESTS if suitable cores for the P32 or P07 are not available or the thickness of the treated layer is less than 3 inches (76 mm) or 1 inch (25 mm) respectively.

(b) Go to step 4 if the thickness of the treated layer is acceptable and intact cores suitable for the P32 or P07 tests are available.

Step 4: Select cores for LTPP Protocol P32 - Method A or B (for OTB materials) or LTPP Protocol P07 (for ATB materials), following preliminary identification procedures described in Sections 9 and 11 of LTPP Protocol P31.

Step 5: Depending on the outcome of Step 4 above, apply LTPP Protocol P32 - Method A or Method B for OTB materials or Protocol P07 for ATB materials.

Step 6: Save remnants and broken pieces of the cores tested in Step 5 above for detailed description as defined in Sections 10 and 11 of LTPP Protocol P31.

1. SCOPE

1.1 This protocol covers the preliminary identification of treated base and subbase materials and type of treatment of these pavement layers. Material codes used in this description should be according to the LTPP terminology for pavement materials and soils as described in Table 4.29 of the LTPP Laboratory Material Testing Guide.

1.2 This protocol also covers the detailed description of treated base and subbase materials and type of treatment using LTPP terminology and material codes of Tables 4.27, 4.29, 4.30 and 4.31 of the LTPP Laboratory Material Testing Guide.

1.3 This protocol also covers; (a) the preliminary identification of treated subgrade and type of treatment as described in Section 1.1 of this protocol, and (b) the detailed description of treated subgrade and type of treatment as described in Section 1.2 of this protocol.

1.4 As required in Section 1.5 of ASTM D2488-00.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards: As listed in ASTM D2488-00

ASTM D2488-00 Description and Identification of Soils (Visual- Manual Procedure)

2.2 LTPP Protocols:

P32 Test Method for Determination of Compressive Strength of Other Than Asphalt Treated Base and Subbase Cores
P07 Test Method for Determination of Creep Compliance, Resilient Modulus and Strength of Asphalt Materials Using the Indirect Tensile Test Device

2.3 Other LTPP Documents: LTPP Laboratory Material Testing Guide, Section 4.3

3. SUMMARY OF METHOD

3.1 Using visual examination and simple manual tests as appropriate, this procedure gives standardized methodology for <u>preliminary</u> <u>identification</u> of treated base and subbase materials and treated subgrade.

3.2 This procedure also provides standardized methodology based on visual examination and appropriate simple manual tests described in ASTM D2488-00 for <u>detailed description</u> of treated base and subbase materials and treated subgrade.

4. SIGNIFICANCE AND USE

4.1 This protocol is used to establish a comprehensive standardized, description and identification of treated base and subbase materials and treated subgrade for coded entry in the PPDB.

4.2 This protocol is used to select appropriate cores for use with LTPP Protocols P32 and P07.

4.3 This protocol is also used for selecting the appropriate test Method "A" or "B" of Protocol P32 for testing cores of other than asphalt treated materials.

5. APPARATUS

5.1 As required in Section 6 of ASTM D2488-00.

6. REAGENTS

6.1 As listed in Section 7 of ASTM D2488-00.

7. SAFETY PRECAUTIONS

7.1 As required in Section 8 of ASTM D2488-00.

8. TEST SAMPLES

8.1 The test samples of treated base and subbase materials for <u>preliminary identification</u> will come from the specified locations as described in this protocol. If intact cores are not available then chunks or pieces retrieved from the specified locations shall be used.

8.2 The test samples for <u>detailed description</u> shall be the remnants of the treated base/subbase cores that have been tested using LTPP Protocols P32 or P07, and chunks and pieces of the treated material if available. If these remnants, chunks and pieces are not available, then use the samples specified for the <u>preliminary identification</u> as described in Section 8.1 above.

8.3 Test samples of the treated subgrade shall be obtained following the instructions of (a) Section 8.1 of this protocol for preliminary identification and (b) Section 8.2 of this protocol for detailed description.

8.4 The following LTPP rules shall be followed to prepare cores for testing.

(a) Some pavement sections may contain very thin layers such as leveling courses or bond breaker courses placed on top of the base or subbase layers. These very thin layers are not to be tested and are removed prior to testing the treated base or subbase core(s).

(b) The core of the treated material may have bonded particles from an unbounded layer and/or particles of an AC layer. These bonded particles shall be removed by wedging, or by chisel and hammer, applied to expose the surface of the core. Care shall be exercised so that the cores are not damaged in this process. If the core is damaged so that it is unsuitable for thickness measurement, then this condition shall be recorded using the appropriate comment code, 57, as described in Attachment "A" to Protocol P31 for ATB materials. The comment code 07 shall be used to record this condition for the OTB materials. The comment code 07 is described in Attachment "B" to Protocol P31.

(c) The LTPP rules for core preparation, described in Section 8.4 (a) and (b) of this protocol shall also apply to the cores of treated subgrade.

8.5 Separate all individual treated base and subbase layers within the core, chunk or piece sample using the following LTPP rules.

(a) Rule #1: Sawing of the treated base and subbase core, block, chunk or piece is not required if the sample consists of only one layer. The testing can be conducted on the core(s), chunk, or piece using the instructions provided in the designated protocol.

(b) Rule #2: Two or more treated layers within a sample (core, block, chunk or piece) shall not be combined for any specified tests.

(c) Rule #3: A treated layer of 3 inches (76 mm) or more shall be separated by carefully sawing the sample prior to testing. The comment code 93 shall be used in reporting the test results for Protocol P31 on Form T31.

(d) Rule #4: If the thickness of a treated layer is less than 3 inches (76 mm) then only the Protocol P31 test shall be performed on this thin layer. Comment code 91 or 92 shall be used in reporting the test results for Protocol P31 on Form T31.

(e) Rule #5: Separate the treated layer from the sample according to the criteria given in Rules #3 and #4. Special care shall be taken for sawing treated base and subbase cores so as to provide minimum disturbance. Perform the sawing operation on the interface of the treated layer to be separated so that the material will not be weakened by shock or by heating. The sawed surfaces of cores shall be smooth, plane, parallel, and free from steps, ridges and grooves. Take care in handling the sawed specimens to avoid chipping or cracking. Dry the specimens by air at approximately room temperature (60°F [16°C] to 75°F [24°C]). Assign the appropriate layer number and sample identification for core, chunk or piece samples.

9. PROCEDURE FOR PRELIMINARY IDENTIFICATION AND THICKNESS DETERMINATION

9.1 Use Table 4.29 of Section 4.3 of the LTPP Laboratory Material Testing Guide for preliminary identification of the treated material and type of treatment.

9.2 Select Protocol P32 or P33 test method as described below:

(a) After visual and manual examinations of the treated layer cores, the material shall be designated for use in resilient modulus testing (LTPP Protocol P07) <u>if</u> ATB.

(b) The OTB material (other than asphalt-treated material, such as lean concrete, econocrete, soil cement, lime treated soils), shall be tested for compressive strength following LTPP Protocol P32. Method A of LTPP Protocol P32 shall be used for strong durable material such as lean concrete, econocrete and cement aggregate. Method B of LTPP Protocol P32 shall be used for weak, crumbly, cracked, soft and nondurable specimens of the OTB materials.

9.3 The thickness of each treated layer of base and subbase and treated subgrade shall be determined in the participating laboratory. Layer thicknesses and layer material codes recorded on the field exploration logs such as corehole, borehole and/or test pit at the treated material sampling locations should be reviewed by the Material Testing laboratory prior to assigning thicknesses. Use the following alternatives for thickness determination:

(a) The treated layer thickness should be determined from <u>intact</u> cores using the instructions of Sections 8 and 9.4 of this protocol. Comment code 91 or 93 (as appropriate) shall be used to indicate this thickness determination procedure in reporting the test results for Protocol P31 on Form T31.

(b) If there is no intact core and <u>only</u> chunks and pieces of the treated layer were retrieved in the field, the thickness should be averaged from the information available on field exploration logs. Comment code 92 shall be used to indicate this thickness determination procedure in reporting the test results for Protocol P31 on Form T31.

9.4 Determination of treated layer thickness from intact cores:

(a) The thickness of the individual treated layer shall be determined for each designated intact core identified in Section 9.3 (a) of this protocol. The thickness shall be determined to the nearest (0.1 inch) 3 mm by taking the average of four measurements at equal distances along the face of the core.

(b) **The thickness shall be measured prior to sawing off other bonded layers.**

9.5 Use the visual examination codes from Attachment A (for OTB materials) and Attachment B (for ATB material) of Protocol P31 to describe the condition of the P31 test samples. Up to six codes and a note not exceeding 25 characters are allowed.

10. PROCEDURE FOR DETAILED DESCRIPTION

10.1 Use Section 10 of ASTM D2488-00 for the descriptive information to be assigned to the test samples of treated base and subbase materials and treated subgrade. Use description codes provided in Table 4.27 of the LTPP Laboratory Material Testing Guide. There are 13 sections in Table 4.27 which provide description codes. Only <u>one</u> code from each of these sections is allowed to describe the material <u>except</u> Section 7 from which more than one code is allowed.

10.2 Use description codes provided in Table 4.29 of the LTPP Laboratory Material Testing Guide. Only <u>one</u> code is permitted for reporting the test results on material type and <u>one</u> code is permitted for indicating the type of treatment. A note not exceeding 25 characters is also permitted with each code.

10.3 Use <u>one</u> of the description codes provided in Table 4.30 of the LTPP Laboratory Material Testing Guide for aggregate type description. A note not exceeding 25 characters is also permitted.

10.4 Use <u>one</u> of the description codes provided in Table 4.31 of the LTPP Laboratory Material Testing Guide for geologic classification of soil and soil-aggregate portion of the treated material. A note not exceeding 25 characters is also permitted.

11. REPORT

The following information is to be recorded on Form T31.

11.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

11.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

11.3 Test Results

Report the following:

11.3.1 Results of Preliminary Identification.

(a) Description codes for treated material and type of treatment based on Table 4.29 of the LTPP Laboratory Material Testing Guide, as required in Section 9.1 of this protocol. One code for the type of treated material and one code for the type of treatment are permitted.

(b) Based on the guidelines provided in Section 9.2 of this protocol, designate the cores of the treated layer for testing by either LTPP Protocol P07 or LTPP Protocol P32 (Method A or B).

(c) Layer thickness (to the nearest 0.1 inches [3 mm]) and thickness code (according to Sections 9.3 and 9.4 of this protocol) for each treated layer.

(d) Up to six visual examination codes using Attachment A or Attachment B of this protocol and a note not exceeding 25 characters, as described in Section 9.5 of this protocol.

11.3.2 Results of Detailed Description.

(a) Description codes according to Table 4.27 of the LTPP Laboratory Material Testing Guide as described in Section 10.1 of this protocol. At least five four-digit codes are desirable and up to 10 four-digit codes are allowed.

(b) Color description (as required in Section 10.3 of ASTM D2488-00 and Section 14 of Table 4.27 of the LTPP Laboratory Testing Guide).

(c) One description code for treated material type and one code for the type of treatment from Table 4.29 of the LTPP Laboratory Material Testing Guide, as described in Section 10.2 of this protocol. A note not exceeding 25 characters is also permitted with each code.

(d) One description code from Table 4.30 of the LTPP Laboratory Material Testing Guide for aggregate type description and a note not exceeding 25 characters, as described in Section 10.3 of this protocol.

(e) One description code from Table 4.31 of the LTPP Laboratory Material Testing Guide for geologic classification and a note not exceeding 25 characters, as described in Section 10.4 of this protocol.

11.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments associated with this protocol are given below.

Code	Comment
91	The thickness of the treated layer was determined in the laboratory using the intact cores and the Protocol P31 procedure. Compressive strength test (Protocol P32 for OTB materials) or resilient modulus test (Protocol P07 for ATB materials) shall not be performed on the cores from the designated locations, because the thickness is less than 3 inches (76 mm) or 1 inch (25 mm), respectively.
92	Intact cores were not available. The thickness of the treated layer was averaged from the information available on field exploration logs and used as is in reporting the test results of Protocol P31 on Form T31. Only the Protocol P31 test was conducted on chunks and pieces. Compressive strength test on OTB materials

Code	Comment
	(Protocol P32) or resilient modulus test on ATB materials (Protocol P07) shall <u>not be performed</u>.
93	The thickness of the treated layer was 3 inches (76 mm) (Protocol P32) or 1 inch (25 mm) (Protocol P07) or more as determined from the intact cores. Protocol P31 test was performed. Other tests were or will be performed on <u>intact cores</u> using Protocol P32 (compressive strength for other than asphalt treated materials, ATB).

11.5 Use Form T31 (Test Sheet T31) to report the above information (Items 11.1 to 11.4).

APPENDIX "A" TO LTPP PROTOCOL P31 VISUAL EXAMINATION CODES FOR OTHER THAN ASPHALT TREATED BASE AND SUBBASE (OTB) MATERIALS AND TREATED SUBGRADE

This attachment to LTPP Protocol P31 describes a series of two-digit codes for reporting the results of visual examination of OTB base and subbase materials and treated subgrade such as lean concrete, econocrete, cement-aggregate, lime-treated soil and soil cement.

Code	Description
51	Intact core; excellent condition; suitable for testing
52	Hairline cracks on the surface of the core; suitable for testing
53	Cracks and/or voids visible along the side of the core; core is suitable for testing.
54	Badly cracked or damaged core; unsuitable for testing; suitable for thickness measurements.
55	Ridges on the sides of the cores; (Identify by placing a straightedge along the side of the core when the distance between the straightedge and core face is $^{1}/_{16}$ inch [2 mm] or greater); such a condition should be recorded for P31 and for any other test, if the core is designated for such a purpose.
56	Very rough and uneven bottom surface of the core. Place the core on a level surface. Identify with this code when less than 75% of the surface area is in contact with a level surface when the core is perpendicular to the surface.
57	Core extremely damaged from sampling, shipping, or laboratory handling; unsuitable for testing. Core thickness cannot be measured.
58	Treated base core was sawed in the laboratory to remove the core from the underlying bonded layer of subbase.
59	Core consisted of two or more layers of treated material. Core was sawed in the laboratory and appropriate layer numbers were assigned to each layer.
60	One or more treated material layers have become separated. Appropriate layer numbers were assigned to each layer.
61	Segregation of coarse and fine aggregate is observed over 25% or more of the surface area of the core.
62	Voids in the matrix of the treated base/subbase mixture.
63	Voids due to loss of coarse and fine aggregate are observed along the sides of the core.
64	Core is missing significant portions and cannot be considered a coherent cylindrical core; unsuitable for testing. Do not test for LTPP Protocols P32 or P07.

Code	Description
65	Coarse aggregate along the face of the core contains 50% or more of crushed materials with fractured faces.
66	Coarse aggregate along the face of the core is a mixture of uncrushed gravel and crushed gravel or stone.
67	The exposed aggregates along the face of the core are lightweight aggregate.
68	More than 10% of the surface area of the core contains soft and deleterious aggregate particles or clay balls. Soft aggregates are defined as those aggregates that can be easily scratched with a knife.
69	Cracks are generally <u>across</u> or <u>through</u> the coarse aggregate.
70	Cracks are generally <u>around</u> the periphery of the coarse aggregate.
72	Rims are observed on aggregate.
73	Fine aggregate is natural sand.
74	Fine aggregate is manufactured sand.
75	Fine aggregate is a mixture of natural and manufactured sand.
79	Core indicates deterioration that may be due to freeze-thaw cycles of the pavement layers.
80	Core indicates sulfate attack. Concrete or cement treated material is deteriorated because of volume change caused by chemical and physical reaction or both with sulfates sometimes found in groundwater or soils.
81	Core indicates alkali silica reactivity. It is shown by the expansion of reactive aggregates. As an expansion occurs, the cement matrix is disrupted and cracks. It appears as a map cracked area.
82	Skewed core. A core, after being placed on a level, horizontal surface, is considered skewed when either end of the core departs from perpendicularity to the axis by more than 0.5 degrees or ⅛ inch (3 mm) in 12 inches (305 mm).
99	Other comment (describe in a note).

Any six codes from the above list can be used to report the results of the visual examination. A note may also be recorded (the note shall not be more than 25 characters long).

APPENDIX "B" TO LTPP PROTOCOL P31
VISUAL EXAMINATION CODES FOR
ASPHALT TREATED BASE AND SUBBASE
MATERIALS AND TREATED SUBGRADE

This attachment to LTPP Protocol P31 describes a series of two-digit codes for reporting the results of visual examination of asphalt treated base and subbase (ATB) materials and treated subgrade such as soil-asphalt and sand-asphalt.

Code	Description
01	Intact core; excellent condition; suitable for testing
02	Hairline cracks on the surface of the core; suitable for testing
03	Cracks and/or voids visible along the side of the core; core is suitable for testing.
04	Badly cracked or damaged core; unsuitable for testing; suitable for thickness measurements.
05	Ridges on the sides of the cores (identify by placing a straightedge along the side of the core when the distance between the straightedge and core face is $^{1}/_{16}$ inch (2 mm) or greater); such a condition should be recorded for P31 and for any other test if the core is designated for such purpose.
06	Very rough and uneven bottom surface of the core. Place the core on a level surface. Identify with this code when less than 75% of the surface area is in contact with a level surface when the core is perpendicular to the surface.
07	Core extremely damaged from sampling, shipping, or laboratory handling; unsuitable for testing. Core thickness cannot be measured.
08	Core was sawed in the laboratory to remove the core from the underlying bonded layer of subbase.
09	Core consisted of two or more asphalt treated layers. Core was sawed in the laboratory and appropriate layer numbers to be assigned to each layer.
10	One or more asphaltic treated layers have become separated due to sampling, shipping or laboratory handling; other layers, if present, to be sawed; and appropriate layer numbers to be assigned to each layer.
11	Segregation of coarse and fine aggregate is observed over 25% or more of the surface area of the core.
12	Voids in the matrix of the asphalt treated material are observed along the sides of the core.
13	Voids due to loss of coarse and fine aggregate are observed along the sides of the core.
14	Core is missing significant portions and cannot be considered a coherent cylindrical core; unsuitable for testing using Protocol P33.

Code	Description
15	Coarse aggregate along the face of the core contains 50% or more of crushed materials with fractured faces.
16	Coarse aggregate along the face of the core is a mixture of uncrushed gravel and crushed gravel or stone.
17	More than 10% of the surface area of the core contains soft and deleterious aggregate particles or clay balls. Soft is defined as those aggregates that can be easily scratched with a knife.
18	Slight stripping. Stripping is defined as the displacement of asphalt cement film from the surface of the aggregate. Slight stripping is identified when the asphalt cement film has been displaced from and/or discoloration is observed on less than 25% of the surface area of the aggregate(s), showing signs of stripping.
19	Severe stripping. A loss of coarse and fine aggregate has been noted over 25% or more of the core face and the asphalt film has been displaced from 25% or more of the surface area of the aggregate(s).
20	Slight bleeding. 5% or less of the asphalt matrix portion of the core is in a non-hardened condition and exhibits shiny and sticky surface.
21	Severe bleeding. More than 5% of the asphalt matrix portion of the core is in a non-hardened condition and exhibits shiny and sticky surface.
22	Skewed core. A core, after being placed on a level, horizontal surface, is considered skewed when either end of the core departs from perpendicularity to the axis by more than 0.5° or ⅛ inch in 12 inches (3 mm in 305 mm).
99	Other comment (describe in a note).

Any six codes from the above list can be used to report the results of the visual examination. A note may also be recorded (the note shall not be more than 25 characters long).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DESCRIPTION OF MATERIAL AND TYPE OF TREATMENT
LAB DATA SHEET T31
TREATED BASE/SUBBASE AND SUBGRADE LAYERS
LTPP TEST DESIGNATION TB01/LTPP PROTOCOL P31

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION _______________ STATE _______________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __
TREATED LAYER MATERIAL TYPE: (CIRCLE ONE) TREATED BASE/TREATED SUBBASE/TREATED SUBGRADE

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	_ _	_ _
3. LABORATORY TEST NUMBER	_	_
4. LOCATION NUMBER	_ _ _	_ _ _
5. LTPP SAMPLE NUMBER	_ _ _ _	_ _ _ _
6. PRELIMINARY IDENTIFICATION (SECTION 11.3.1 OF PROTOCOL P31)		
(a) TREATED MATERIAL TYPE (TABLE 4.29, CHAPTER 4, LTPP LAB GUIDE)		
(a.1) TREATED MATERIAL CODE	_ _ _	_ _ _
(a.2) TREATMENT TYPE CODE	_ _ _	_ _ _
(b) PROTOCOL DESIGNATION FOR CORES		
(b.1) DESIGNATED CORES	_ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
(b.2) DESIGNATED PROTOCOL (P32 Method A, P32 Method B or P33)	____________	____________
(c) TREATED LAYER INFORMATION		
*(c.1) AVERAGE THICKNESS, INCHES	_ _._	_ _._
(c.2) THICKNESS CODE	_ _	_ _
(d) VISUAL EXAMINATION		
(d.1) CODE	_ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
(d.2) NOTE	____________	____________
7. DETAILED DESCRIPTION (SECTION 11.3.2 OF PROTOCOL P31)		
(a) CODES (TABLE 4.27, CHAPTER 4, DESCRIPTION LTPP LAB GUIDE)	_ _	_ _
(b) COLOR DESCRIPTION	____________	____________
(c) TREATED MATERIAL TYPE (TABLE 4.29, CHAPTER 4, LTPP LAB GUIDE)		
(c.1) CODE	_ _ _	_ _ _
(c.2) NOTE	____________	____________
TREATMENT TYPE		
(c.3) CODE	_ _ _	_ _ _
(c.4) NOTE	____________	____________
(d) AGGREGATE TYPE DESCRIPTION (TABLE 4.30, CHAPTER 4, LTPP LAB GUIDE)		
(d.1) CODE	_ _ _	_ _ _
(d.2) NOTE	____________	____________
(e) GEOLOGICAL CLASSIFICATION CODE (TABLE 4.31, CHAPTER 4, LTPP LAB GUIDE)		
(e.1) CODE	_ _	_ _
(e.2) NOTE	____________	____________
8. COMMENTS (SECTION 11.3.3 OF PROTOCOL P31)		
(a) CODE	_ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
(b) NOTE	____________	____________
9. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

* Layer thickness should be measured prior to sawing from other bonded cores.

GENERAL REMARKS:______________________________

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________

LABORATORY CHIEF

Affiliation________________ Affiliation____________________

PROTOCOL P32
Test Method for Determination of Compressive Strength of Other than Asphalt Treated Base and Subbase Cores (TB02)

This LTPP Protocol covers the determination of the compressive strength of other than asphalt treated (OTB) base and subbase cores. This protocol also covers the determination of the compressive strength of treated subgrade cores. The OTB materials include lean concrete, econocrete, soil cement, lime-treated soils, and chemical stabilized soils. The selection of the test method (Methods "A" and "B" described later in this protocol) to be used should be based on the condition and quality of the specimen to be tested as determined using Sections 9 and 11 of LTPP Protocol P31.

<u>Selection of Test Methods</u>

(1) Strong, and durable OTB treated materials include lean concrete, econocrete, cement-aggregate and soils treated with cement, lime, cement- or lime-flyash, and chemical products. For these treated materials the test shall be carried out in accordance with ASTM C39-04a as modified by the following (LTPP Protocol P32 - <u>Method "A"</u>). Only sections of the referenced ASTM standard which have been modified are included below. In all other sections the standard ASTM C39-04a shall be followed as written.

(2) For weak, crumbly, cracked, soft and nondurable specimens of cement, lime and/or flyash treated and other OTB materials the test shall be carried out in accordance with ASTM D2166-00, as modified by the following (LTPP Protocol P32 - <u>Method "B"</u>). Only sections of the referenced ASTM standards which have been modified are included below. In all other sections the standard ASTM D2166-00 shall be followed as written.

(3) Cores retrieved from asphalt or bituminous treated pavement layers shall be tested using procedures described in LTPP Protocol P07.

<u>Testing Sequence for Each Layer of Treated Material</u>

Prior to testing, assign layer numbers using lab sheet L04. The testing sequence to be followed is as described below:

Step 1: Determine layer number (lab sheet L04); mark layer number on sample identification labels for every sample.

Step 2: Conduct preliminary identification of the treated material and measure thickness using Section 9 of LTPP Protocol P31.

Step 3: (a) DO NOT PERFORM THE P32 TESTS if suitable cores for the P32 tests are <u>not</u> available <u>or</u> the thickness of the treated layer is less than 3 inches (76 mm). (b) Go to step 4 if the thickness of the treated material is 3 inches (76 mm) or more and intact cores suitable for the P32 are available.

Step 4: Select cores for LTPP Protocol P32 - Method A or B (for OTB materials) following preliminary identification procedures described in Sections 9 and 11 of LTPP Protocol P31.

Step 5: Depending on the outcome of Step 4 above, apply LTPP Protocol P32 - Method A or B for OTB materials.

Step 6: Save remnants and broken pieces of the core tested in Step 5 above for detailed description as defined in Sections 10 and 11 of LTPP Protocol P31.

Definitions

The following definitions will be used throughout this protocol:

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(b) Treated Base or Subbase Materials: Treated base or subbase materials are bound or stabilized layers of base or subbase. The terms (treated, bound, stabilized) are used interchangeably in reference to base and subbase layers containing a cementing or binding type of agent. For LTPP terminology and codes, see Table 4.29 of this Guide.

(c) Asphalt Treated Base (ATB) or Subbase: Asphalt treated base and subbase materials (ATB, also known as bituminous treated materials) include soils, aggregate and soil-aggregate mixtures bound by asphalt or bitumen. Examples are asphalt treated aggregate base, soil-asphalt, and sand-asphalt. Typically these materials are produced by cold- mix and mixed-in-place procedures. Samples of ATB type materials shall be tested using Protocols P31 and P07 procedures only.

(d) Other than Asphalt Treated Base or Subbase (OTB): Other than asphalt treated base and subbase materials include all types of treated materials for which asphalt or bitumen was not used as a binding agent. Typical OTB materials range from very strong and durable to weak and less durable treated materials. Examples of very strong materials are lean concrete, econocrete, and cement- aggregate. The following materials may range from strong to weak; soil cement, lime-treated soils, flyash-treated soils. Materials stabilized with chemicals, industrial wastes, and different kinds of proprietary products are also included in the category of OTB materials. Samples of OTB materials shall be tested using Protocols P31 and P32 procedures only.

(e) Treated Subgrade: Treated subgrade materials are bound or stabilized layers of subgrade. The terms (treated, bound, stabilized) are used interchangeably in reference to the treated subgrade containing a cementing or binding type of agent. Table 4.26 and Table 4.29 of this Guide should be consulted to assign appropriate LTPP terminology and codes for the description of treated subgrade material and type of treatment respectively. The treated subgrade may be asphalt treated material (for example, ATB) or other than asphalt treated

(OTB) material (for example, lime, cement, lime- and cement- flyash, polymer and chemical treated subgrade; <u>but not</u> lean concrete and econocrete).

(f) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(g) Chunks: Chunks (large pieces) of treated base, subbase or subgrade are extracted from the full thickness of each layer in the test pit area and/or the 12-inch (305-mm) diameter BA... type borehole(s). An undisturbed block sample (12-inch [305-mm] square) may also be taken from the field in certain cases. A chunk is always smaller than a block sample. If chunks or block samples of the treated material cannot be recovered, then smaller pieces of the treated material are collected in the field for shipment to the laboratory.

(h) Sample: A representative portion of material from one or more pavement layers received from the field. A sample can be a core, block, chunk, pieces, bulk, thin-walled tube or jar sample.

(i) Test Specimen: That part of the layer which is used for or in the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

<u>Test Core Locations:</u>

The locations for P32 testing are shown on the laboratory testing plans developed for each project.

<u>Assignment of Laboratory Test Numbers</u>

(a) The results of each test determined from the specified cores of the treated layer shall be assigned Laboratory Test Number "1", if these samples were retrieved from near the beginning of the test section (Station 0-).

(b) The results of each test determined from the specified cores of the treated layer shall be assigned Laboratory Test Number "2", if these samples were retrieved from near the end of the test section (Station 5+).

(c) The results of each test determined from the specified cores of the treated layer shall be assigned Laboratory Test Number "3", if these samples were retrieved from within the test section (Stations 0+00 to 5+00).

LTPP PROTOCOL P32 - METHOD A

The test shall be carried out in accordance with **ASTM C39-04a** as modified herein. Those sections of the ASTM standard included in the following by reference and without modifications shall be followed as written in the ASTM standard. All other sections of this protocol shall be followed as herein written.

1. SCOPE

1.1 This test covers the determination of the compressive strength of strong and durable cores of other than asphalt treated (OTB) base and subbase materials. The test is performed on 4-inch (102-mm) diameter cores taken from a pavement section. Examples of strong and durable OTB materials are lean concrete, econocrete and cement-aggregate.

1.2 This protocol also applies to the determination of the compressive strength of strong and durable 4-inch (102-mm) diameter cores of treated subgrade of other than asphalt treated materials.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards: As listed in ASTM C39-04a.

2.2 AASHTO Standards: As listed in AASHTO T22-88I.

AASHTO T22-88I Compressive Strength of Cylindrical Concrete Specimens

2.3 LTPP Protocol:

P31 Test Method for Identification and Description of Treated Base and Subbase Materials, and Determination of Type of Treatment.
P07 Test Method for Determining the Creep Compliance, Resilient Modulus and Strength of Asphalt Materials Using the Indirect Tensile Test Device

2.4 Other LTPP Documents: LTPP Laboratory Material Testing Guide.

3. SUMMARY OF METHOD

3.1 This method consists of applying a compressive axial load to test specimens at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. SIGNIFICANCE AND USE

4.1 As described in Section 4.1 of ASTM C39-04a.

4.2 This test method may be used to determine the compressive strength of cores prepared in accordance with Section 6.2 of ASTM C39-04a.

4.3 Delete Section 4.3 of ASTM C39-04a.

5. APPARATUS

As listed in Section 5 of ASTM C39-04a.

6. TEST SPECIMENS

6.1 The following LTPP rules shall be followed to prepare cores for testing.

(a) Some pavement sections may contain <u>very thin</u> layers such as leveling courses or bond breaker courses placed on top of the base or subbase layers. These very thin layers are not to be tested and are to be removed prior to testing the treated base or subbase core(s).

(b) The core of the treated material may have bonded particles from an unbounded layer and/or particles of an AC layer. These bonded particles shall be removed by wedging, or by chisel and hammer. Care shall be exercised so that the cores are not damaged in this process. If the core is damaged so that it is unsuitable for thickness measurement, then comment code 07 shall be used to record this damaged condition for the OTB materials. The comment code 07 is described in Attachment "A" to Protocol P32.

(c) The LTPP rules for core preparation, described in Section 6.1 (a) and (b) of this protocol shall also apply to the cores of treated subgrade.

6.2 Separate all individual treated base and subbase layers within the core, chunk or piece sample using the following LTPP rules.

(a) Rule #1: Sawing of the treated base and subbase core is <u>not</u> required if the sample consists of only <u>one layer</u>.

(b) Rule #2: Two or more treated layers within a core shall be separated if the layers are 3 inches (76 mm) thick or more.

(c) Rule #3: A treated layer of 3 inches (76 mm) or more shall be separated by carefully sawing the sample prior to testing so as to have the least amount of disturbance. Comment code 93 shall be used in reporting the test results on Form T32.

(d) Rule #4: If the thickness of a treated layer is less than 3 inches (76 mm) then <u>only</u> the Protocol P31 test shall be performed on this thin layer. Appropriate comment code 91 or 92 shall be used in reporting the test results on Form T32. No separation of this layer is to be done.

(e) Rule #5: Separate the treated layer from the sample according to the criteria given in Rules #3 and 4. Special care shall be taken for sawing treated base and subbase <u>cores</u> so as to provide minimum disturbance. Perform the sawing operation on the interface of the treated layer to be separated so that the material will not be weakened by shock or by heating. The sawed surfaces of cores shall be smooth, parallel, and free from steps, ridges and grooves. Take care in handling the sawed specimens to avoid chipping or cracking.

Dry the specimens by air at an approximate room temperature (60°F [16°C] to 75°F [24°C]). Assign the appropriate layer number and sample identification for core, chunk or piece samples.

6.3 (a) The P32 test shall be performed on 4-inch (102-mm) diameter cores taken from a 3-inch (76-mm) or thicker treated layer. Comment code 93 shall be used to record this condition on Form T32. The thickness of the treated layer as determined by the P31 test procedure shall also be recorded on Form T32.

(b) The P32 test shall not be performed if the thickness of the treated layer as determined by the P31 test procedure is less than 3 inches (76 mm). Appropriate comment code 91 or 92 shall be used to record this condition on Form T32.

(c) The P32 test shall not be performed if intact cores suitable for testing are not available. Comment code 92 shall be used to record this condition on Form T32.

(d) Visual examination code(s) from Attachment A to Protocol P32 shall be used to record the condition of the test specimen on Form T32.

6.4 The length of the specimen when capped shall be as nearly as practicable twice its diameter. Follow Section 6.2 of ASTM C39-04a for specimen end preparation. The test specimen shall be prepared to achieve a desired length to diameter (L/D) ratio of approximately 2.0 by sawing and/or grinding the bottom and top ends of the core of a treated base/subbase layer. Moisture conditioning of the specimens is not required.

6.5 Neither end of the test specimens when tested shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to ⅛ inch in 12 inches [3 mm in 305 mm]). The test specimens shall always be capped at both ends by following AASHTO T231-87I procedures for capping hardened concrete specimens.

6.6 The diameter (D) used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.01 inch (0.25 mm) by averaging two diameters measured by a caliper at right angles to each other at about the mid-height of the specimen.

6.7 Measure the length of the specimen before capping (LO) and measure the length of the capped specimen (L) prior to testing to the nearest 0.1 inch (2.5 mm). The length shall be determined by averaging four measurements equally spaced around the specimen.

6.8 Use the length of the capped specimen to compute the L/D ratio. This ratio is required to be reported. If the ratio exceeds 2.10, the specimen shall be further reduced in length. Specimens within the ratio of 1.80 to 2.10 require no correction in the measured compressive strength.

6.9 If the L/D ratio is less than 1.80, apply the correction factor shown below. Values not given in the table shall be determined by interpolation.

L/D Ratio	Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

6.10 Care shall be exercised during sample preparation so that the length of a specimen is not reduced to the extent that L/D ratio becomes less than 1.0. However, if for any reason the L/D ratio is less than 1.0 the test shall be performed, the actual L/D ratio reported and special comment code 95 (see Section 9.4) included in the report on Form T32 that explains the reason for the low value of the L/D ratio. Apply a correction factor of 0.87 to the specimen with the L/D ratio less than 1.0.

7. PROCEDURE

7.1 Delete Section 7.1 of ASTM C39-04a.

7.2 Delete Section 7.2 of ASTM C39-04a.

7.3 Delete Section 7.3 of ASTM C39-04a.

7.4 As described in Section 7.4 of ASTM C39-04a.

7.5 As described in Section 7.5 of ASTM C39-04a.

7.6 As described in Section 7.6 of ASTM C39-04a.

8. CALCULATION

As described in Section 8 of ASTM C39-04a.

9. REPORT

The following information is to be recorded on Form T32:

9.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

9.3 Test Results

Report the following:

(a) Thickness of the treated layer to the nearest 0.1 inch, and thickness code as determined by the P31 test (Section 11.3.1 (c) of Protocol P31).

(b) Visual examination code(s) and a note not exceeding 25 characters according to Attachment A of Protocol P32.

(c) Diameter (D) to nearest 0.01 inch.

(d) Length before capping (LO), Length after capping (L), to the nearest 0.1 inch.

(e) Length to diameter (L/D) ratio, and correction factor.

(f) Cross-sectional area, in square inches to the nearest 0.01 inch^2.

(g) Maximum load, in pounds-force.

(h) Compressive strength (CS), calculated to the nearest 10 psi after applying the appropriate correction factor.

(i) Type of fracture (see Fig. 2 of AASHTO T22-88I and as described below:).

Fracture Type	Code
(a) Cone	11
(b) Cone and split	12
(c) Cone and shear	13
(d) Shear	14
(e) Columnar	15
(f) Other type (explain in a note not exceeding 25 characters	16

9.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note, as needed. Additional codes for special comments associated with Protocol P32 - Method A are given below.

Code	Comment
91	The thickness of the treated layer was determined in the laboratory using the intact cores and the Protocol P31 procedure. Compressive strength test (Protocol P32 for OTB materials) or resilient modulus test (Protocol P07 for ATB materials) was not performed on the cores from the designated locations, because the thickness is less than 3 inches (76 mm).
92	Intact cores were not available. The thickness of the treated layer was averaged from the information available on field exploration logs and <u>used as is</u> in reporting the test results of Protocol P31 on Form T31. The Protocol P31 test was conducted on chunks and

Code	Comment
	pieces. Compressive strength test on OTB materials (Protocol P32) or resilient modulus test on ATB materials (Protocol P07) <u>not performed</u>.
93	The thickness of the treated layer was 3 inches (76 mm) or more as determined from the intact cores. Protocol P31 test was performed. Other tests were or will be performed on <u>intact cores</u> using Protocol P32 (compressive strength for other than asphalt treated materials, OTB) or P07 (resilient modulus for asphalt treated materials, ATB).
95	Length to diameter ratio was less than 1.0 because the layer thickness was less than the diameter of the specimen. A correction factor of 0.87 was applied to calculate the compressive strength.

9.5 Use Form T32 (Test Sheet T32) to report the above information (Items 9.1 to 9.4).

LTPP PROTOCOL P32 - METHOD "B"

The test shall be carried out in accordance with **ASTM D2166-85** as modified herein. Those sections of the ASTM standard included in the following by reference and without modifications shall be followed as written in the ASTM standards. All other sections of this protocol shall be followed as herein written.

10. SCOPE

10.1 This test covers the determination of the compressive strength of weak, soft and/or cracked and nondurable 4-inch (102-mm) diameter cores of other than asphalt treated (OTB) base and/or subbase materials, taken from a pavement section. Examples of treated materials are soil cement and lime treated soil.

10.2 This protocol also applies to the determination of the compressive strength of weak and nondurable 4-inch (102-mm) diameter cores of treated subgrade of other than asphalt treated materials.

10.3 Delete Section 1 of ASTM D2166-00 except:

Section 1.6 of ASTM D2166-00 the values stated in inch-pound units are to be regarded as the standard.

11. APPLICABLE DOCUMENTS

11.1 ASTM Standards: As listed in ASTM D2166-00, Section 2.

11.2 LTPP Protocols:

P31 Test Method for Identification and Description of Treated Base and Subbase Materials, and Determination of Type of Treatment.
P07 Test Method for Determining the Creep Compliance, Resilient Modulus and Strength of Asphalt Materials Using the Indirect Tensile Test Device

11.3 Other LTPP Documents: LTPP Laboratory Material Testing Guide, Section 4.3

12. TERMINOLOGY

Same as defined in Section 3 of ASTM D2166-00.

13. APPARATUS

As required in Section 5 of ASTM D2166-00

14. PREPARATION OF TEST SPECIMENS

Change Section 6 of ASTM D2166-00 to Section 6 of LTPP Protocol P32 - Method A.

15. PROCEDURE

Delete Section 7 of ASTM D2166-00 except for Section 7.1 as modified below:

7.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator. Apply the load so as to produce an axial strain at a rate of ½ to 2%/min. Softer material should be tested at a higher rate of strain. Conversely stiff and brittle material shall be tested at a lower rate of strain. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about 15 minutes. Continue loading until the load values decrease with increasing strain, or until 15% is reached.

16. CALCULATIONS

16.1 Perform calculations as defined in Sections 8.1 through 8.4 of ASTM D2166-00.

16.2 Use the procedure described in Section 8.4 of ASTM D2166-00 to calculate unconfined compressive strength. Include the graph of the stress-strain data with Form T32.

16.3 Delete Section 8.5 of ASTM D2166-00.

17. REPORT

The following information is to be recorded on Form T32:

17.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

17.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

17.3 Test Results

Report the following:

(a) Thickness of treated layer to the nearest 0.1 inch and thickness code as determined by the P31 test (Section 11.3.1 (c) of Protocol P31).

(b) Visual Examination code(s) and a note not exceeding 25 characters according to Attachment A of Protocol P32.

(c) Diameter (D) to nearest 0.01 inch.

(d) Length before capping (LO), Length after capping (L), to the nearest 0.1 inch.

(e) Length to diameter (L/D) ratio, and correction factor.

(f) Cross-sectional area, in square inches to the nearest 0.01 inch^2.

(g) Maximum load, in pounds-force.

(h) Compressive strength (CS), calculated to the nearest 10 psi after applying the appropriate correction factor.

(i) Type of fracture (see description below).

Fracture Type	Code
(a) Cone	11
(b) Cone and split	12
(c) Cone and shear	13
(d) Shear	14
(e) Columnar	15
(f) Other type (explain in a note not exceeding 25 characters)	26

(j) Include the graph of the stress-strain data with Form T32.

17.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note, as needed. Additional codes for special comments associated with Protocol P32 - Method B are given below.

Code	Comment
91	The thickness of the treated layer was determined in the laboratory using the intact cores and the Protocol P31 procedure. Compressive strength test (Protocol P32 for OTB materials) or resilient modulus test (Protocol P07 for ATB materials) was not performed on the cores from the designated locations, because the thickness is less than 3 inches (76 mm).
92	Intact cores were not available. The thickness of the treated layer was averaged from the information available on field exploration logs and used as is in reporting the test results of Protocol P31 on Form T31. The Protocol P31 test was conducted on chunks and pieces. Compressive strength test on OTB materials (Protocol P32) or resilient modulus test on ATB materials (Protocol P07) was not performed.
93	The thickness of the treated layer was 3 inches (76 mm) or more as determined from the intact cores. Protocol P31 test was performed. Other tests were or will be performed on intact cores using Protocol P32 (compressive strength for other than asphalt treated materials, OTB) or P07 (resilient modulus for asphalt treated materials, ATB).
95	Length to diameter ratio was less than 1.0 because the layer thickness was less than the diameter of the specimen. A correction factor of 0.87 was applied to calculate the compressive strength.

17.5 Use Form T32 (Test Sheet T32) to report the above information (Items 17.1 to 17.4).

APPENDIX "A" TO LTPP PROTOCOL P32
CODES FOR VISUAL EXAMINATION OF OTHER THAN ASPHALT TREATED BASE AND SUBBASE (OTB) MATERIALS AND TREATED SUBGRADE

This attachment to LTPP Protocol P32 describes a series of two-digit codes for reporting the results of visual examination of OTB, subbase, and subgrade cores such as lean concrete, econocrete, cement-aggregate, lime-treated soils and soil cement.

Code	Description
51	Intact core; excellent condition; suitable for testing.
52	Hairline cracks on the surface of the core; suitable for testing.
53	Cracks and/or voids visible along the side of the core; core is suitable for testing.
54	Badly cracked or damaged core; unsuitable for testing; suitable for thickness measurements.
55	Ridges on the sides of the cores; (Identify by placing a straightedge along the side of the core when the distance between the straightedge and core face is $^{1}/_{16}$ inch [2 mm] or greater); such a condition should be recorded for P32 and for any other test if the core is designated for such a purpose.
56	Very rough and uneven bottom surface of the core. Place the core on a level surface. Identify with this code when less than 75% of the surface area is in contact with a level surface when the core is perpendicular to the surface.
57	Core extremely damaged from sampling, shipping, or laboratory handling; unsuitable for testing. Core thickness cannot be measured.
58	Treated base core was sawed in the laboratory to remove the core from the underlying bonded layer of subbase.
59	Core consisted of two or more layers of treated material. Core was sawed in the laboratory and appropriate layer numbers were assigned to each layer.
60	One or more treated material layers have become separated, appropriate layer numbers were assigned to each layer.
61	Segregation of coarse and fine aggregate is observed over 25% or more of the surface area of the core.
62	Voids in the matrix of the treated base/subbase mixture are observed along the sides of the core.
63	Voids due to loss of coarse and fine aggregate are observed along the sides of the core.

Code	Description
64	Core is missing significant portions and cannot be considered a coherent cylindrical core; unsuitable for testing. Do not test for LTPP Protocols P32 or P07.
65	Coarse aggregate along the face of the core contains 50% or more of crushed materials with fractured faces.
66	Coarse aggregate along the face of the core is a mixture of uncrushed gravel and crushed gravel or stone.
67	The exposed aggregates along the face of the core are lightweight aggregate.
68	More than 10% of the surface area of the core contains soft and deleterious aggregate particles or clay balls. Soft aggregates are defined as those aggregates that can be easily scratched with a knife.
69	Cracks are generally <u>across</u> or <u>through</u> the coarse aggregate.
70	Cracks are generally <u>around</u> the periphery of the coarse aggregate.
72	Rims are observed on aggregate.
73	Fine aggregate is natural sand.
74	Fine aggregate is manufactured sand.
75	Fine aggregate is a mixture of natural and manufactured sand.
79	Core indicates deterioration that may be due to freeze-thaw cycles of the pavement layers.
80	Core indicates sulfate attack. Concrete or cement treated material is deteriorated because of volume change caused by chemical and physical reaction or both with sulfates sometimes found in groundwater or soils.
81	Core indicates alkali silica reactivity. It is shown by the expansion of reactive aggregates. As expansion occurs, the cement matrix is disrupted and cracks. It appears as a map cracked area.
82	Skewed core. A core, after being placed on a level, horizontal surface, is considered skewed when either end of the core departs from perpendicularity to the axis by more than 0.5° or ⅛ inch in 12 inches (3 mm in 305 mm).
99	Other comment (describe in a note).

Any six codes from the above list can be used to report the results of the visual examination. A note may also be recorded (the note shall not be more than 25 characters long).

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
COMPRESSIVE STRENGTH OF TREATED BASE/SUBBASE AND SUBGRADE CORES
LAB DATA SHEET T32

TREATED BASE/SUBBASE AND SUBGRADE LAYERS
LTPP TEST DESIGNATION TB02/LTPP PROTOCOL P32

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __
TREATED LAYER MATERIAL TYPE: CIRCLE ONE TREATED BASE/TREATED SUBBASE/TREATED SUBGRADE

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	_ _	_ _
4. LABORATORY TEST NUMBER	_	_
5. LOCATION NUMBER	_ _ _	_ _ _
6. LTPP SAMPLE NUMBER	_ _ _ _	_ _ _ _
7. LTPP PROTOCOL P32, METHOD (A OR B)	_	_
8. TEST RESULTS (SECTION 9.3 OR 17.3 OF PROTOCOL P32)		
(a) TREATED LAYER INFORMATION (FROM FORM T31)		
THICKNESS, INCHES	_ _._	_ _._
THICKNESS, CODE	_ _	_ _
(b) VISUAL EXAMINATION CODE	_ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
NOTE	____________	____________
(c) DIAMETER (D), INCHES	_._ _	_._ _
(d) SPECIMEN LENGTH, INCHES		
BEFORE CAPPING, (LO)	_ _._	_ _._
AFTER CAPPING, (L)	_ _._	_ _._
(e) L/D RATIO	_._ _	_._ _
(f) CROSS-SECTIONAL AREA (A), SQ. IN.	_ _._ _	_ _._ _
(g) MAXIMUM LOAD, LBF	_ _ _ _ _ _.	_ _ _ _ _ _.
(h) COMPRESSIVE STRENGTH (CS), PSI (AFTER APPLYING CORRECTION FACTOR)	_ _ _ _ _.	_ _ _ _ _.
(i) TYPE OF FRACTURE (FR), (a) CODE	_ _	_ _
(b) NOTE	____________	____________
(j) GRAPH OF STRESS-STRAIN DATA (METHOD B) ATTACHED (YES OR NO)	____	____
9. COMMENTS (SECTION 9.4 OR 17.4 OF SHRP PROTOCOL P32)		
(a) CODE	_ _ _ _ _ _ _ _ _ _ _ _	_ _ _ _ _ _ _ _ _ _ _ _
(b) NOTE	____________ ____________	____________ ____________
10. TEST DATE	_ _-_ _-_ _ _ _	_ _-_ _-_ _ _ _

GENERAL REMARKS:____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

__________________________ ______________________________

LABORATORY CHIEF

Affiliation___________________ Affiliation______________________

PROTOCOL P41
Test Method for Gradation of Unbound Granular Base/Subbase Materials (UG01, UG02)

This LTPP protocol covers the determination of the gradation of unbound granular base and subbase materials. This protocol is based on: (1) the test standard AASHTO T27-88I (LTPP Test Designation UG01, "Sieve Analysis of Unbound Granular Base and Subbase Materials"), and (2) the test standard AASHTO T11-85 (LTPP Test Designation UG02, "Washed Sieve Analysis of Unbound Granular Base and Subbase Materials"). The tests shall be carried out in accordance with these standards (AASHTO T27-88I and AASHTO T11-85), as modified herein. Those sections of the AASHTO standards included in this protocol by reference and without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Determination of gradation using Protocol P41 shall be the <u>first</u> test to be performed on the bulk samples of each layer of unbound granular base and subbase materials, after, (1) assigning the appropriate layer number and (2) determining the natural moisture content (Protocol P49) from jar samples for each layer. In addition, the combined bulk sample of a layer from an end of a pavement section shall be observed during the bulk sample handling in the laboratory and test sample preparation for the gradation (Protocol P41) and Atterberg Limits (Protocol P43) tests. These observations shall be later used for the classification and description of the sample (Protocol P47).

The locations and sample numbers for P41 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of each unbound layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined, prepared in accordance with AASHTO T87-86 and reduced to a representative test size in accordance with AASHTO T248-83. Because the bulk samples are combined from several locations, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. For unbound granular materials, layer thickness is determined from field exploration logs (bore hole logs and/or test pit logs).

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should <u>never</u> be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample size.

1. SCOPE

1.1 This method covers the determination of the particle size distribution in the test sample of fine and coarse aggregates by <u>dry sieving</u> the test sample according to the standard AASHTO T27-88I, and as described in this protocol.

1.2 This method also covers the determination of the amount of material finer than a No. 200 (0.075-mm) sieve in the test sample by <u>washing</u> according to AASHTO T11-85, and as described in this protocol. Clay particles that are dispersed by the wash water, as well as water soluble materials, will be removed from the aggregate during the test.

1.3 As stated in Section 1.4 of AASHTO T27-88I.

2. APPLICABLE DOCUMENTS

2.1 AASHTO standards: As listed in Sections 2.1 of AASHTO T27-88I and AASHTO T11-85.

AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

2.2 ASTM Standards: As listed in Sections 2.2 of AASHTO T27-88I and AASHTO T11-85.

ASTM D2487-85 Classification of Soils For Engineering Purposes.

2.3 LTPP Protocols:

P43 Determination of Atterberg Limits.
P47 Classification and Description of Unbound Granular Base/Subbase Materials.
P49 Determination of Natural Moisture Content.

3. SUMMARY OF METHOD

3.1 As stated in Section 3.1 of AASHTO T11-85.

3.2 After completing the test according to Section 3.1 above, the test sample of dry aggregate is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

4. SIGNIFICANCE AND USE

4.1 Material finer than the No. 200 (0.075-mm) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving.

Therefore, when accurate determinations of material finer than the No. 200 (0.075-mm) sieve in fine or coarse aggregate are desired, the AASHTO T11-85 method is used on the sample prior to dry sieving in accordance with AASHTO T27-88I. The results of the AASHTO T11-85 test are included in the calculations of AASHTO T27-88I. The total amount of material finer than the No. 200 (0.075-mm) sieve by washing from AASHTO T11-85 procedure, plus that obtained from AASHTO T27-88I method by dry sieving the same sample is reported with the results of AASHTO T27-88I. Usually the additional amount of material finer than the No. 200 (0.075-mm) sieve obtained in the dry sieving process is relatively small amount. If it is large, the efficiency of the washing operation should be checked. It could, also, be an indication of degradation of the aggregate.

4.2 The gradation results obtained by following the test procedures of this protocol (P41) and the Atterberg Limits results (P43) shall be used for classification and description of unbound granular base and subbase (P47).

5. APPARATUS

5.1 Balance - As required in Sections 5.1 of AASHTO T27-88I and AASHTO T11-85.

5.2 Sieves - As required in Section 5.1 of AASHTO T27-88I with the exception that the sieve sizes shall conform to Section 9.3.2 of Protocol P41.

5.3 Mechanical Sieve Shake - As required in Section 5.3 of AASHTO T27-88I.

5.4 Oven - As required in Section 5.4 of AASHTO T11-85.

5.5 Container - As required in Section 5.3 of AASHTO T11-85.

6. TEST SAMPLE

6.1 Assign the appropriate layer number to the bulk sample of the unbound granular base or subbase layer that is being tested. Weigh the total bulk sample received from the field for that layer. Combine the bulk samples from the same sampling area if contained in more than one bag(s). Thoroughly mix the combined bulk sample and dry according to the procedure described in Section 4.1 of AASHTO T87-86.

6.2 Obtain the representative test sample according to the procedure described in Section 6.2 of AASHTO T27-88I.

6.3 Use the natural moisture content determined from the jar samples of the unbound granular layer earlier on Form T49 according to Protocol P49 for the respective bulk sample location(s) to estimate the weight of the test sample when dry.

6.4 The approximate weight of the test sample shall conform to the weight requirement shown in Section 6.4 of AASHTO T27-88I for aggregates with nominal maximum size of 2 inches (51 mm) or less and for the total bulk sample weighing 150 lbs (68 kg) or more. The approximate weight of the test sample shall not exceed 50 lbs (23 kg) for larger nominal maximum size aggregates. The approximate weight of the test sample shall not exceed 40 lbs (18 kg) if the total bulk sample weighs 100 lbs (45 kg) or more, but less than 150 lbs (68 kg).

NOTE: The nominal maximum aggregate size is defined as the smallest sieve opening through which at least <u>95 percent</u> of the aggregate passes. Delete Section 6.5 of AASHTO T27-88I.

6.5 Even if the weight of the test sample is less than the required minimum weight, the test shall be performed; however, this violation of the test standard AASHTO T27-88I shall be recorded as a standard comment code.

7. PROCEDURE

7.1 First test the sample by AASHTO T11-85 in conformity with Sections 7.1 to 7.5 of this protocol to determine the amount of material finer than the No. 200 (0.075-mm) sieve by <u>washed sieving</u>.

7.2 Dry the test sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F) and weigh to the nearest 0.1% of the weight of the sample. Designate this weight as "B".

7.3 As required in Section 7.3 of AASHTO T11-85, using the sieves listed in Section 9.3 of this protocol.

7.4 As required in Section 7.4 of AASHTO T11-85.

7.5 As required in Section 7.5 of AASHTO T11-85. Designate the dry weight of the washed sample to be "C". Weight of material finer than No. 200 (0.075-mm) sieve ("D") is calculated as the difference between "B" and "C". This completes the procedure using AASHTO T11-85.

7.6 Rest of the procedure involves AASHTO T27-88I. Commence <u>dry</u> <u>sieving</u> by using the AASHTO T27-88I procedure in conformity with Sections 7.6 to 7.13 of this protocol.

7.7 Nest the sieves in order of decreasing size of opening from top to bottom and place the dried test sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 7.9 of this protocol.

7.8 As required in Section 7.3 of AASHTO T27-88I.

7.9 As required in Section 7.4 of AASHTO T27-88I.

7.10 The portion of the sample finer than the No. 4 (4.75-mm) sieve may require distribution on two or more sets of sieves to prevent overloading of individual sieves.

Follow Section 7.5 of AASHTO T27-88I.

7.11 As required in Section 7.6 of AASHTO T27-88I.

7.12 As required in Section 7.7 of AASHTO T27-88I.

7.13 Add the weight finer than the No 200 (0.075-mm) sieve determined by the AASHTO T11-85 procedures (according to Section 7.5 of this protocol) to the weight passing the No. 200 (0.075-mm) sieve determined by AASHTO T27-88I by dry sieving of the same sample performed according to Sections 7.6 to 7.12 of this protocol.

8. CALCULATION

8.1 Calculate the amount of material passing the No. 200 (0.075-mm) sieve <u>by washing</u> as follows:

$$A = [(B - C)/B] \times 100$$

where: A = percentage of material finer than a No. 200 (0.075-mm) sieve by washing,
B = original dry weight of test sample, as determined in Section 7.2 of this protocol,
C = dry weight of test sample after washing, as determined in Section 7.5 of this protocol.

8.2 Calculate percentages passing to the nearest 1% (for sieve sizes 3-in. [76-mm] to No. 80 [0.180-mm]), and to the nearest 0.1% for the No. 200 (0.075-mm) sieve on the basis of the total weight of the initial dry test sample (B) prior to the washed sieve analysis.

8.3 Include the weight (D) of material finer than the No. 200 (0.075-mm) sieve, as determined in Section 7.5 of this protocol in the sieve analysis calculation of Section 8.2 of this protocol.

9. REPORT

The following information is to be recorded on Form T41.

9.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

9.3 Test Results

Report the following:

9.3.1 Percent passing the No. 200 (0.075-mm) sieve by washing to the nearest 0.1 percent, as calculated in Section 8.1 of this protocol.

9.3.2 Gradation results based on Sections 8.2 and 8.3 of this protocol to the appropriate number of significant digits as follows:

Sieve Size Standard (mm)	% Passing
3 in. (75.0)	__ __ __.
2 in. (50.0)	__ __ __.
1 ½ in. (37.5)	__ __ __.
1 in. (25.0)	__ __ __.
¾ in. (19.0)	__ __ __.
½ in. (12.5)	__ __ __.
⅜ in. (9.5)	__ __ __.
#4 (4.75)	__ __ __.
#10 (2.00)	__ __ __.
#40 (0.425)	__ __.
#80 (0.180)	__ __.
#200 (0.075)	__ __.__

9.3.3 Attach a cumulative particle size gradation curve such as shown in Figure 4 of ASTM D2487-85 with Form T41.

9.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments that may be associated with the testing of bulk samples are:

Code	Comment
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic material in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3 in. [76-mm] size sieve). The cobbles or large size aggregates were not included in the test samples.

Code	Comment
65	The test sample included shale chunks, claystone, mudstone, siltstone, and sandstone which convert into soils after field and/or laboratory processing (crushing, slaking, etc.).

In addition, record the weight of the test sample to the nearest 1 lb (0.45 kg) as per Section 7.1 of AASHTO T11-85 and the moisture content (Section 6.3 of Protocol P41) to the nearest 1%.

9.5 Use Form T41 (Test Sheet T41) to report the above information (Items 9.1 to 9.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
GRADATION
LAB DATA SHEET T41

UNBOUND GRANULAR BASE/SUBBASE LAYERS
LTPP TEST DESIGNATION UG01, UG02/LTPP PROTOCOL P41

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __

	LAYER MATERIAL (CIRCLE ONE): BASE	SUBBASE
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as the third and fourth digit)	__ __ __ __	__ __ __ __
6. % PASSING #200 SIEVE BY WASHING (Section 9.3.1 of Protocol P41)	__ __.__	__ __.__
7. GRADATION (Section 9.3.2 of Protocol P41)		
% PASSING SIEVE SIZE STANDARD (mm)		
3 in. (75.0)	__ __ __.	__ __ __.
2 in. (50.0)	__ __ __.	__ __ __.
1 ½ in. (37.5)	__ __ __.	__ __ __.
1 in. (25.0)	__ __ __.	__ __ __.
¾ in. (19.0)	__ __ __.	__ __ __.
½ in. (12.5)	__ __ __.	__ __ __.
⅜ in. (9.5)	__ __ __.	__ __ __.
#4 (4.75)	__ __ __.	__ __ __.
#10 (2.00)	__ __ __.	__ __ __.
#40 (0.425)	__ __.	__ __.
#80 (0.180)	__ __.	__ __.
#200 (0.075)	__ __.__	__ __.__
8. COMMENTS (Section 9.4 of Protocol P41)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	________________ ________________	________________ ________________
(c) WEIGHT OF TEST SAMPLE	__ __ __. lbs	__ __ __. lbs
MOISTURE CONTENT	__ __. %	__ __. %
9. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEETS T41 AND T43 ARE USED FOR CLASSIFICATION AND DESCRIPTION ON TEST SHEET T47.
2. ATTACH A CUMULATIVE PARTICLE SIZE GRADATION CURVE WITH FORM T41 (SECTION 9.3.3 OF PROTOCOL P41).

GENERAL REMARKS:______________________________

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

________________________ ________________________
LABORATORY CHIEF

Affiliation________________ Affiliation____________________

PROTOCOL P42
Test Method for Hydrometer Analysis of Subgrade Soils (SS02)

This LTPP protocol covers the determination of the particle size analysis of subgrade soils by the hydrometer analysis. This protocol is based on the test standard AASHTO T88-00 (Particle Size Analysis of Soils). The test shall be carried out in accordance with this standard (AASHTO T88-00), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Determination of particle size analysis using Protocol P42 shall be performed on the bulk samples of the subgrade layer, after, (1) assigning the appropriate layer number, (2) determining the natural moisture content (Protocol P49) from jar samples for the subgrade layer, (3) performing the gradation test (Protocol P51) and (4) determining the Atterberg Limits (Protocol P43). The test sample for the hydrometer analysis (Protocol P42) shall be prepared at the same time as the test samples for gradation (Protocol P51) and Atterberg Limits (Protocol P43) are prepared.

The locations and sample numbers for P42 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of the subgrade layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined and prepared in accordance with AASHTO T87-86 and reduced to a representative test size in accordance with AASHTO T248-83. Because the bulk samples are combined from several locations, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol:

> a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. However, the subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the SPS material sampling and testing program, the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on field exploration logs (bore hole logs and/or test pit logs).
>
> b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should <u>never</u> be mixed with the material from another layer even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample.

1. SCOPE

1.1 This method describes the quantitative determination of the particle size distribution of material finer than a No. 200 (0.075-mm) sieve by hydrometer analysis according to AASHTO T88-86, and as described in this protocol.

1.2 As stated in Section 1.2 of AASHTO T88-86.

2. APPLICABLE DOCUMENTS

2.1 AASHTO standards:

AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.
AASHTO R-11 Recommended Practice for Indicating Which Places Are To Be Considered Significant In Specified Limiting Values.

2.2 LTPP Protocols:

P51 Sieve Analysis of Subgrade Soils.
P43 Determination of Atterberg Limits.
P52 Classification and Description of Subgrade Soils.
P49 Determination of Natural Moisture Content.

3. APPARATUS

The apparatus for the hydrometer analysis shall be the same as required in Section 2.1 of AASHTO T88-00.

4. DISPERSING AGENT

As required in Section 3.1 of AASHTO T88-00.

5. GENERAL REQUIREMENTS FOR WEIGHING

As stated in Section 4.1 of AASHTO T88-00.

6. TEST SAMPLES

6.1 Assign the appropriate layer number to the bulk sample of the subgrade soil that is being tested. The bulk samples are handled in the laboratory as described in Section 6.1 of Protocol P51. The following sections of this protocol refer to the combined bulk sample from one sampling area only.

6.2 A representative portion of the bulk sample for the particle size analysis shall be prepared according to the procedure described in Sections 4.1, 4.2 and 4.2.1 of AASHTO T87-86, for Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

6.3 The required weight of the test sample shall be selected from Section 5.1.2 of AASHTO T88-00 based on the classification of the subgrade soil as determined from Protocol P52.

6.4 A test sample shall be taken from the portion passing the No. 10 (2.00-mm) sieve. The test sample shall be weighed. The approximate weight of the test sample shall conform to the weight requirement described in Section 5.1.2 of AASHTO T88-00.

6.5 The portion of the test sample retained on the No. 10 sieve (2.00-mm) shall be discarded and the procedure described in Section 6 of AASHTO T88-00 shall not be used.

6.6 The test sample (passing the No. 10 [2.00-mm] sieve) selected in Sections 6.3 and 6.4 of this protocol shall be processed by the method described in Section 5.2 of AASHTO T87-86. Samples for hygroscopic moisture and hydrometer analysis shall be weighed immediately.

7. HYDROMETER AND SIEVE ANALYSIS OF FRACTION PASSING THE NO. 10 (2.00-mm) SIEVE

7.1 Determination of Composite Correction for hydrometer readings shall be carried out as described in Sections 7.1 to 7.3 of AASHTO T88-00.

7.2 Determination of hygroscopic moisture shall be made as described in Section 8.1 of AASHTO T88-00.

7.3 Dispersion of soil sample shall be done as required in Sections 9 or 10 of AASHTO T88-00.

7.4 Perform the hydrometer test according to Section 11 of AASHTO T88-00. The last required reading for the hydrometer test will occur at <u>1440 minutes</u> (24 hours). No further readings need be obtained. If during this time frame, the percent smaller than 0.001 mm (0.04 mils) cannot be obtained, <u>do not</u> record an entry for the percent smaller than 0.001 mm (0.04 mils) on Form T42. Leave the data field for percent smaller than 0.001 mm (0.04 mils) blank and record a code "48" in the comments data entry field of the data sheet. The definition of code "48" is given in Section 9.4 of this protocol.

7.5 Sieve Analysis shall be conducted as described in Section 12.1 of AASHTO T88-00 except: Use the No. 40 (0.425-mm) and No. 200 (0.075-mm) sieves for the sieve analysis.

8. CALCULATIONS

8.1 Percentage of hygroscopic moisture shall be calculated as required in Sections 13.1 and 13.2 of AASHTO T88-00.

8.2 Coarse Material.

8.2.1 The portion of the test sample (retained on the No. 10 [2.00-mm] sieve), as determined in Section 6.5 of this protocol is assumed to be free of hygroscopic moisture. See Note 9 of AASHTO T88-00.

8.2.2 Correct the mass of the fraction passing the No. 10 (2.00-mm) sieve for hygroscopic moisture, determined in Section 8.1 of this protocol (Section 13 of AASHTO T88-00).

8.3 Percentage of Soil in Suspension

8.3.1 As required in Sections 15.1, 15.2, 15.2.1 of AASHTO T88-00.

8.3.2 Assume a specific gravity (G) value of 2.65 if a better estimate is not available for the specific classification of the soil type determined according to Protocol P52.

8.3.3 Convert the percentage of soil in suspension to percentage of the total sample (representative portion of the bulk sample), as determined in the sieve analysis test (Protocol P51, Form T51). This shall be accomplished by multiplying the percentage of originally dispersed soil remaining in suspension by the expression:

(Cumulative percent passing the No. 10 [2.00-mm] sieve)/100

where cumulative percentage passing the No. 10 (2.00-mm) sieve is taken from the sieve analysis test results on Form T51.

Example: 35% passing the No. 10 (2.00-mm) sieve was recorded from sieve analysis (Protocol P51) on Form T51.

The percentage of soil in suspension as determined in Section 8.3 of this protocol (Section 15.1 and 15.2 of AASHTO T88-00) should be corrected by multiplying it with 35/100 or 0.35.

8.4 Diameter of Soil Particles in Suspension - As described in Section 16 of AASHTO T88-00.

8.5 Fine sieve analysis.

8.5.1 Calculate percent particles larger than the No. 10 (2.00-mm) sieve by subtracting the percent passing the No. 10 (2.00-mm) sieve (from Form T51) from 100.

8.5.2 As described in Section 17.1 of AASHTO T88-86 using the sieves listed in Section 7.5 of Protocol P42.

8.5.3 The percent retained on each sieve (calculated in 8.5.2 of this protocol) shall be converted to the percentages of the total test sample by multiplying these values by the expression:

(Cumulative percent passing the No. 10 [2.00-mm] sieve)/100

8.6 Plotting - As described in Section 18.1 of AASHTO T88-00.

8.7 Precision - As described in Section 20 of AASHTO T88-00.

9. REPORT

The following information is to be recorded on Form T42.

9.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

9.3 Test Results

Report the following:

9.3.1 The result from the accumulation curve (Section 19.1 of AASHTO T88-00) shall be reported as follows.

(a) Particles larger than 2 mm (No. 10 sieve)............................percent
(b) Coarse sand, 2.0 to 0.42 mm (No. 10 to No. 40 sieve)........percent
(c) Fine sand, 0.42 to 0.074 mm (No. 40 to No. 200 sieve)......percent
(d) Silt, 0.074 to 0.002 mm (No. 200 sieve to 0.08 mils) ....percent
(e) Clay, smaller than 0.002 mm (0.08 mils to 0.04 mils) ....percent
(f) Colloids, smaller than 0.001 mm (0.04 mils) ....percent

In these results: (a) shall be the same as calculated in Section 8.5.1 of this Protocol; (b) and (c) shall be the same as calculated according to Section 8.5.3 of this protocol; and (d), (e) and (f) shall be the same as obtained from the hydrometer analysis as calculated in Sections 8.3 and 8.4 of this protocol. Report (f) only if the percent smaller than 0.001 mm (0.04 mils) could be determined during the 1440 minute (24 hour) hydrometer analysis. If this item could not be determined in 1440 minutes (24 hours), do not record an entry for percent smaller than 0.001 mm (0.04 mils) on Form T42 and record a code "48" in the comments data entry field of Form T42. The definition of code "48" is given in Section 9.4 of this protocol.

9.3.2 The results of the complete mechanical analysis furnished by the combined sieve (Protocol P51) and hydrometer analysis (Protocol P42) shall be reported as follows:

(a) Gradation results based on Sections 9.3.2 of Protocol P51 (Form T51) to the appropriate number of significant digits as follows:

Sieve Sizes Standard (mm)	% Passing
3 in. (75.0)	__ __ __.
2 in. (50.0)	__ __ __.
1 ½ in. (37.5)	__ __ __.
1 in. (25.0)	__ __ __.
¾ in. (19.0)	__ __ __.
½ in. (12.5)	__ __ __.
⅜ in. (9.5)	__ __ __.
#4 (4.75)	__ __ __.
#10 (2.00)	__ __ __.
#40 (0.425)	__ __.
#80 (0.180)	__ __.
#200 (0.075)	__ __.__

(b) Hydrometer analysis results:

Smaller Than	Percent
0.02 mm (0.8 mils)	__ __.__
0.002 mm (0.08 mils)	__ __.__
0.001 mm (0.04 mils)	__ __.__

9.3.3 Attach a cumulative particle size gradation curve such as shown in Figure 8 of AASHTO T88-86 with Form T42.

9.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Record percentage of hygroscopic moisture content as calculated in Section 8.1 of this Protocol.

An additional code for a special comment associated with this protocol is given below.

Code	Comment
48	Percent smaller than 0.001 mm (0.04 mils) could not be determined in 1440 minutes (24 hours).

9.5 Use Form T42 (Test Sheet T42) to report the above information (Items 9.1 to 9.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
HYDROMETER ANALYSIS
LAB DATA SHEET T42
SUBGRADE LAYER
LTPP TEST DESIGNATION SS02/LTPP PROTOCOL P42

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as the third and fourth digit)	__ __ __ __	__ __ __ __
6. PARTICLE SIZE DISTRIBUTION (Section 9.3.1 of Protocol P42)		
(a) LARGER THAN 2 mm, %	__ __ __.	__ __ __.
(b) COARSE SAND, 2 TO 0.42 mm, %	__ __ __.	__ __ __.
(c) FINE SAND, 0.42 TO 0.074 mm, %	__ __.	__ __.
(d) SILT, 0.074 TO 0.002 mm, %	__ __.__	__ __.__
(e) CLAY, SMALLER THAN 0.002 mm, %	__ __.__	__ __.__
(f) COLLOIDS, SMALLER THAN 0.001 mm, %	__ __.__	__ __.__
7. GRADATION (Section 9.3.2 (a) of Protocol P42, Test Sheet T51; See Note 1)		
% PASSING SIEVE SIZES STANDARD (mm)		
3 in (75.0)	__ __ __.	__ __ __.
2 in. (50.0)	__ __ __.	__ __ __.
1 ½ in. (37.5)	__ __ __.	__ __ __.
1 in. (25.0)	__ __ __.	__ __ __.
¾ in. (19.0)	__ __ __.	__ __ __.
½ in. (12.5)	__ __ __.	__ __ __.
⅜ in. (9.5)	__ __ __.	__ __ __.
#4 (4.75)	__ __ __.	__ __ __.
#10 (2.00)	__ __ __.	__ __ __.
#40 (0.425)	__ __.	__ __.
#80 (0.180)	__ __.	__ __.
#200 (0.075)	__ __.__	__ __.__
8. HYDROMETER ANALYSIS (Section 9.3.2 (b) of Protocol P42; See Note 2)		
% SMALLER THAN		
0.02 mm	__ __.__	__ __.__
0.002 mm	__ __.__	__ __.__
0.001 mm	__ __.__	__ __.__
9. COMMENTS (Section 9.4 of Protocol P42)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	________________	________________
(c) HYGROSCOPIC MOISTURE CONTENT	__ __.%	__ __.%
10. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEET T51 ARE ALSO REPORTED ON TEST SHEET T42 (ITEM NO. 6 OF FORM T42).
2. ATTACH A CUMULATIVE PARTICLE SIZE GRADATION CURVE OF COMBINED SIEVE AND HYDROMETER ANALYSIS (SECTION 9.3.3 OF PROTOCOL P42).

GENERAL REMARKS:______________________________

SUBMITTED BY, DATE ______________________ CHECKED AND APPROVED, DATE ______________________

LABORATORY CHIEF
Affiliation______________________ Affiliation______________________

PROTOCOL P43
Test Method for Determination of Atterberg Limits of Unbound Granular Base and Subbase Materials and Subgrade Soils (UG04, SS03)

This LTPP Protocol covers the determination of the liquid limit (LL), plastic limit (PL) and plasticity index (PI) of unbound granular base and subbase materials and subgrade soils. This protocol is based on the test standards AASHTO T89-87I ("Determining the Liquid Limit of Soils - Method B") and AASHTO T90-87I ("Determining the Plastic Limit and Plasticity Index of Soils"). The protocol encompasses LTPP Test Designation UG04 for unbound granular base/subbase and LTPP Test Designation SS03 for subgrade soils. The test shall be carried out in accordance with these standards (AASHTO T89-87I - Method B and AASHTO T90-87I), as modified herein. Those sections of the AASHTO standards included in this protocol by reference and without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

The test shall be performed on a representative test sample weighing approximately 150 grams (0.33 lb) obtained from the bulk samples of each layer of unbound granular base, subbase and subgrade. The sample shall be prepared for testing by following the instructions in Sections 4.1, 4.2.1, 5.2 and 6.1 of AASHTO T87-86, Dry Preparation of Disturbed Soils and Soil Aggregate Samples for Test. The test results shall be reported separately for the test samples obtained from each designated sampling area.

The locations and sample numbers for P43 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of each layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined and then a representative test sample is obtained in accordance with AASHTO T87-86. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. For unbound granular materials, layer thickness is determined from field exploration logs (bore hole logs and/or test pit logs). The subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the LTPP material sampling and testing program the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on the field exploration logs.

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should never be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample size.

1. SCOPE

This test covers the determination of the LL, PL and PI of unbound granular base and subbase materials and subgrade soils. This test is to be conducted in accordance with AASHTO T89-87I (Method B) and AASHTO T90-87I.

2. PROCEDURE FOR LIQUID LIMIT TEST

As required in Section 10 of AASHTO T89-87I.

3. PROCEDURE FOR DETERMINING PLASTIC LIMIT AND PLASTICITY INDEX

As required in Section 4 of AASHTO T90-87I.

4. CALCULATIONS

4.1 Liquid Limit:

4.1.1 Calculate the moisture content as required in Section 11 of AASHTO T89-87I.

4.1.2 Delete Section 7 of AASHTO T89-87I.

4.1.3 Delete Section 8 of AASHTO T89-87I.

4.1.4 Calculate the LL as required in Section 12.1, 12.2, or 12.4 of AASHTO T90-87I.

4.1.5 Delete Section 12.3 of AASHTO T89-87I.

4.2 PL: Calculate the PL as required in Section 5.1 of AASHTO T90-87I.

4.3 PI: Calculate the PI of the test sample according to Section 5.2 and 5.3 of AASHTO T90-87I.

5. REPORT

The following information is to be recorded on Form T43.

5.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

5.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

5.3 Test Result

Report the following:

5.3.1 LTPP Test Designation (UG04 or SS03)

5.3.2 Liquid Limit (LL) of the sample, expressed as a percent to the nearest whole number.

5.3.3 Plastic Limit (PL) of the sample, expressed as a percent to the nearest whole number.

5.3.4 Plasticity Index (PI) of the sample, expressed to the nearest whole number, with the following exception:

Report L as 'NP' when (a) LL and/or PL cannot be determined, or (b) PL is equal to or greater than LL.

5.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments associated with this testing are given below.

Code	Comment
67	PI reported as 'NP' because the LL and/or PL cannot be determined.
68	PI is reported as 'NP' because the PL is equal to or greater than the LL.
69	The test specimen slipped in the cup of the LL device.

5.5 Use Form T43 (Test Sheet T43) to report the above information (Items 5.1 to 5.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
ATTERBERG LIMITS
LAB DATA SHEET T43

UNBOUND GRANULAR BASE/SUBBASE LAYERS AND SUBGRADE SOILS
LTPP TEST DESIGNATION UG04, SS03/LTPP PROTOCOL P43

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __

LAYER MATERIAL (CIRCLE ONE): BASE/SUBBASE/SUBGRADE

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
6. TEST RESULTS (Section 5.3 of Protocol P43)		
(LTPP TEST DESIGNATION: __ __ __ __)		
(a) LIQUID LIMIT (LL), %	__ __ __.	__ __ __.
(b) PLASTIC LIMIT (PL), %	__ __.	__ __.
(c) PLASTICITY INDEX (PI)	__ __	__ __
7. COMMENTS (Section 5.4 of Protocol P43)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	_________________ _________________	_________________ _________________
8. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEETS T41 AND T43 ARE USED FOR CLASSIFICATION AND DESCRIPTION ON TEST SHEET T47.

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________

LABORATORY CHIEF

Affiliation______________________ Affiliation______________________

PROTOCOL P44
Test Method for Moisture-Density Relations of Unbound Granular Base and Subbase Materials (UG05)

This LTPP Protocol covers the determination of the moisture-density relations of unbound granular base and subbase materials. This protocol is based on AASHTO T180-86 ("Moisture-Density Relations of Soils Using a 10-lb [4.54 kg.] Rammer and an 18-in. [457 mm] Drop"). The test shall be carried out in accordance with this standard (AASHTO T180-86), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Determination of moisture-density relations using Protocol P55 shall be performed on the bulk samples of the unbound granular base or subbase layer, <u>after</u>; (1) assigning the appropriate layer number, (2) determining the natural moisture content (Protocol P49) from jar samples of the layer, (3) performing the sieve analysis test (Protocol P41), (4) determining the Atterberg Limits (Protocol P43), and (5) completing the classification and description test (Protocol P47). The results of the moisture-density test (Protocol P44) will be recorded in the PPDB and are also used to ascertain molding water content and density values. These parameters will be used to reconstitute test specimens from the bulk samples of the unbound granular layer for the resilient modulus testing (Protocol P46).

The test shall be performed on a representative test sample obtained from the bulk samples of each layer of unbound granular base and subbase. The test results shall be reported separately for the test samples obtained from each designated sampling area.

The locations and sample numbers for P44 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of each unbound granular base and subbase layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, the bulk samples are combined, prepared and reduced to a representative test size in accordance with AASHTO T87-86 and AASHTO T248-83. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol:

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. For unbound granular materials, layer thickness is determined from field exploration logs (bore hole logs and/or test pit logs).

(b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should never be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

(c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same but will usually be less than the bulk sample.

1. SCOPE

1.1 This method of test covers the determination of the relationship between the moisture content and density of unbound granular base and subbase materials when compacted in a 6-in. (152-mm) diameter mold with a 10-lb (4.54-kg) rammer dropped from a height of 18 in. (457 mm). Two alternate procedures are provided as follows:

Method B - A 6-in. (152-mm) mold: Soil material passing a No. 4 (4.75-mm) sieve.
Method D - A 6-in. (152-mm) mold: Soil material passing a ¾-in. (19-m) sieve.

1.2 Select Method "B" or "D" as appropriate based on the results of the gradation test (Protocol P41).

1.3 As stated in Section 1.3 of AASHTO T180-86.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards

ASTM D653 Terms and Symbols Relating to Soil and Rock.

2.2 AASHTO Standards

AASHTO T180-86 Moisture-Density Relations of Soils Using a 10 lb [4.54 kg.] Rammer and 18 in. [457 mm] Drop.
AASHTO R-11 Recommended Practice For Indicating Which Places of Figures Are To Be Considered Significant In Specified Limiting Values.
AASHTO T19-88I Unit Weight and Voids of Aggregate.
AASHTO M231-87I Weighing Devices Used in the Testing of Materials.
AASHTO M92-85 Wire-Cloth Sieves for Testing Purposes.
AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.
AASHTO T248-83 Reducing Field Samples of Aggregates to Testing Size.

2.3 LTPP Protocols

P41 Gradation of Unbound Granular Base and Subbase Materials.
P47 Classification and Description of Unbound Granular Base/Subbase Materials.
P49 Determination of Natural Moisture Content.
P55 Moisture-Density Relations of Subgrade Soils.

P46 Resilient Modulus of Unbound Granular Base and Subbase Materials and Subgrade Soils.

3. APPARATUS

The apparatus for moisture-density relations testing shall conform to the requirements of Section 2 of AASHTO T180-86 with the following exceptions:

3.1 Molds - As required in Sections 2.1, 2.1.2 and 2.1.3 of AASHTO T180-86. DELETE Section 2.1.1 and Note 1 of AASHTO T180.86.

LTPP PROTOCOL P44 - METHOD "A"

Note – 4-inch (102-mm) molds will not be used in this test, therefore Method A of AASHTO T180-86 will not be used as is. However, Method A is not deleted from this protocol because part of the procedure contained in Method A (Sections 3 and 4) of AASHTO T180-86 is used in Method B.

LTPP PROTOCOL P44 - METHOD "B"

4. SAMPLE

4.1 Prepare the test sample in accordance with Sections 4.1 and 7 of AASHTO T87-86 (Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test).

4.2 The weight of the sample should approximately be 20 lbs (8 kg). Check the gradation test results (Protocol P41) for percentage of coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve. If this percentage is up to 5% then Method B of Protocol P44 shall be used. Include this coarse fraction in the test sample for the moisture-density test. Record this deviation from the AASHTO T180-86 standard by using a special comment code 74 (See Section 10.4 of Protocol P44) on Form T44.

4.3 If there is more than 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve, then use Method D of Protocol P44 to perform the moisture-density test. Use special comment code 75 (See Section 10.4 of Protocol P44) to record this condition on Form T44.

4.4 Discard any coarse material larger than the 1 ½-in. (38-mm) sieve size and do not use this material for the moisture-density test. Use special comment code 76 (See Section 10.4 of Protocol P44) to record this condition on Form T44.

5. PROCEDURE

5.1 Follow the same procedure as described in Section 6 of Method B and Section 4 of Method A of AASHTO T180-86, as appropriate.

5.2 The point at which the wet unit mass either decreases or does not change should be achieved within 3 to 5 water addition increments for this test. If the optimum moisture cannot be found by the fifth increment, note this using a special comment code on Form T44.

LTPP PROTOCOL P44 - METHOD "C"

Note – 4-inch (102-mm) molds will not be used in this test, therefore Method C of AASHTO T180-86 will not be used as is. However, Method C is not deleted from this protocol because part of the procedure contained in Method C (Section 7 and 8) of AASHTO T180-86 is used in Method D.

LTPP PROTOCOL P44 - METHOD "D"

6. SAMPLE

6.1 Prepare the test sample in accordance with Sections 4.1 and 7 of AASHTO T87-86 (Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test).

6.2 The weight of the sample should approximately be 30 lbs (12 kg). Check the gradation test results (Protocol P41) for percentage of coarse aggregate material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve. If this percentage is up to 5% then Method D of Protocol P44 shall be used. <u>Include</u> this coarse fraction in the test sample for the moisture-density test. Record this deviation from the AASHTO T180-86 standard by using special comment code 77 (See Section 10.4 of Protocol P44) on Form T44.

6.3 If there is more than 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve then the test sample for the moisture-density testing shall be sieved using a ¾-in. (19-mm) sieve to separate the coarse fraction retained on the ¾-in. (19-mm) sieve. <u>Discard</u> this coarse fraction from the test sample for the moisture-density testing. Use a special comment code 78 (See Section 10.4 of Protocol P44) to record this condition on Form T44.

6.4 Discard any coarse material larger than the 1 ½-in. (38-mm) sieve size and do not use this material for the moisture-density test. Use a special comment code 76 (See Section 10.4 of Protocol P44) to record this condition on Form T44.

7. PROCEDURE

7.1 Same as described in Section 10.1 of Method D and Section 8 of Method C of AASHTO T180-86.

7.2 The point at which the wet unit mass either decreases or does not change should be achieved within 3 to 5 water addition increments for this test. If the optimum moisture content cannot be found by the fifth increment, note this using a special comment code on Form T44.

8. CALCULATION

8.1 Same as described in Section 11.1 of AASHTO T180-86.

9. MOISTURE - DENSITY RELATIONSHIP

9.1 Same as described in Section 12.1 of AASHTO T180-86 except: DELETE "or kilograms per cubic meter".

9.2 Optimum Moisture Content - As required in Section 12.2 of AASHTO T180-86 except: DELETE "or kilograms per cubic meter".

9.3 Maximum Dry Density - As required in Section 12.3 of AASHTO T180-86.

10. REPORT

The following information is to be recorded on Form T44.

10.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

10.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

10.3 Test Results

Report the following:

10.3.1 The method used (Method B or Method D).

10.3.2 The optimum moisture content (OMC), as a percentage, to the nearest whole number.

10.3.3 The maximum density (MD), in lb/ft^3 (pcf), to the nearest whole number.

10.3.4 Attach optimum moisture content curve plot, prepared in accordance with Section 12 of AASHTO T180-86, with Form T44.

10.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments associated with the moisture-density testing of bulk samples of the unbound granular base or subbase layer are given below.

Code	Comment
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic matter in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-in. [76-mm] size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.).
70	Test could not be completed within five water addition increments. Additional increments were made.
71	Degradation of the test sample was observed during the moisture-density test.
72	The quantity of the test sample was inadequate to complete the moisture-density test. Additional quantity was taken from the other test samples or extra material to complete the moisture-density test.
73	Free water appeared at the bottom of the mold (i.e., seeped onto the plate).
74	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve. This coarse fraction was included in the test sample for the moisture-density test.
75	The coarse fraction passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve was more than 5%. Method D was used to perform the moisture-density test.
76	The test sample contained coarse materials larger than the 1 ½ in. (38-mm) sieve. This coarse material was removed and not used for the moisture-density test.

Code	Comment
77	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve. This coarse material was included in the test sample for the moisture-density test.
78	The coarse fraction passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve was more than 5%. The test sample for the moisture-density testing was sieved using a ¾-in. (19-mm) sieve to separate the coarse fraction from the test sample. This coarse fraction was discarded from the test sample and not used in the moisture-density test. <u>The test sample was, therefore, not truly representative of the bulk sample.</u>
83	Due to insufficient size of the bulk sample, the test sample for the moisture-density test (Protocol P44 or P55) was saved after the test and re-used for the resilient modulus test (Protocol P46).
84	Due to insufficient size of the bulk sample, the sample for the moisture-density test (Protocol P44 or P55) was obtained from the gradation test sample. The gradation test (Protocol P41 or P51) was performed by <u>dry sieving only</u>.

10.5 If the type of face of the rammer is other than 2-in. (51-mm) circular face described herein, please describe the rammer that was used on Form T44.

10.6 Use Form T44 (Test Sheet T44) to report the above information (Items 10.1 to 10.5).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
MOISTURE-DENSITY RELATIONS
LAB DATA SHEET T44

UNBOUND GRANULAR BASE/SUBBASE LAYERS
LTPP TEST DESIGNATION UG05/LTPP PROTOCOL P44

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __
LAYER MATERIAL (CIRCLE ONE): BASE/SUBBASE

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
6. TEST RESULTS (Section 10.3 of Protocol P44)		
(a) METHOD USED (B OR D)	___	___
(b) OPTIMUM MOISTURE CONTENT (OMC), %	__ __.	__ __.
(c) MAXIMUM DENSITY (MD), PCF	__ __ __.	__ __ __.
7. COMMENTS (Section 10.4 of Protocol P44)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	__________________ __________________	__________________ __________________
8. TYPE OF RAMMER FACE (If other than that described in Section 10.5 of Protocol P44)	__________________	__________________
9. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. INCLUDE THE OPTIMUM MOISTURE CONTENT CURVE WITH TEST SHEET T44 (SECTION 10.3.6 OF PROTOCOL P44).

GENERAL REMARKS:____

SUBMITTED BY, DATE

____
LABORATORY CHIEF

Affiliation______________________

CHECKED AND APPROVED, DATE

____

Affiliation______________________

PROTOCOL P46
Test Method for Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils (UG07, SS07)

1. SCOPE

1.1 General

This LTPP program protocol describes the laboratory preparation and testing procedures for the determination of the Resilient Modulus (M_r) of unbound granular base and subbase materials and subgrade soils under specified conditions representing stress states beneath flexible and rigid pavements subjected to moving wheel loads. This protocol is based partially on the test standard AASHTO T292-91I, Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials. The test shall be carried out in accordance with the following protocol procedure.

The methods described are applicable to: undisturbed samples of natural and compacted subgrade soils, and to disturbed samples of unbound base and subbase and subgrade soils prepared for testing by compaction in the laboratory.

In this protocol, stress levels used for testing specimens for resilient modulus will be based upon the location of the specimen within the pavement structure. Samples located within the base and subbase will be subjected to different stress levels as compared to those specimens that are from the subgrade. Generally, specimen size for testing depends upon the type of material based upon the gradation and the PL of the material as described in a later section.

The value of M_r determined from this protocol procedure is a measure of the elastic modulus of unbound base and subbase materials and subgrade soils recognizing certain nonlinear characteristics.

M_r values can be used with structural response analysis models to calculate the pavement structural response to wheel loads, and with pavement design procedures to design pavement structures.

1.2 Summary of Test Method

A repeated axial cyclic stress of fixed magnitude, load duration (0.1 second), and cycle duration (1 second) is applied to a cylindrical test specimen. During testing, the specimen is subjected to a dynamic cyclic stress and a static confining stress provided by means of a triaxial pressure chamber. The total resilient (recoverable) axial deformation response of the specimen is measured and used to calculate the resilient modulus.

1.3 Significance and Use

The resilient modulus test provides a basic constitutive relationship between stress and deformation of pavement construction materials for use in structural analysis of layered pavement systems.

The resilient modulus test provides a means of characterizing pavement construction materials, including subgrade soils under a variety of conditions (i.e., moisture, density, etc.) and stress states that simulate the conditions in a pavement subjected to moving wheel loads.

1.4 Sample Storage

Thin-walled tube samples of the subgrade for use in resilient modulus testing shall be kept in an environmentally protected (enclosed area not subjected to the natural elements) storage area at temperatures between 5°C (41°F) and 21°C (70°F). They shall be stored on their ends in the same orientation as retrieved in the field.

Bulk samples of base/subbase and subgrade materials should be kept in an environmentally protected storage area at temperatures between 5°C (41°F) and 38°C (100°F).

Each sample shall have a label or tag attached that clearly identifies the material, the project number/test section from which it was recovered and the sample number, as a minimum. Bulk granular samples shall be marked with two tags. One shall be placed inside the bag and one attached to the outside.

1.5 Units

In this protocol, the International System of Units (SI - The Modernized Metric System) is regarded as the standard. Units are expressed first in their "soft" metric form followed, in parenthesis, by their U.S. Customary unit equivalent.

2. TESTING

2.1 Testing Prerequisites

Resilient modulus testing shall be conducted after; (1) approval by the FHWA COTR to begin unbound material resilient modulus testing, (2) approval of Form L04 by the FHWA-LTPP Region, (3) appropriate material classification tests are completed and (4) final layer assignments (corrected form L04, if needed) have been completed. To attain approval under item (1), the laboratory must; (a) submit and obtain approval of the QC/QA plan for the unbound materials resilient modulus testing, (b) demonstrate that their testing equipment meets or exceeds the specifications contained in this protocol, and (c) successfully complete all applicable requirements of the Start-up and QC Procedure for LTPP P46 Resilient Modulus Testing.

2.2 Test Sample Locations and Assignment of Laboratory Test Numbers

The test shall be performed on the test specimens prepared from bulk samples of the unbound granular base and subbase materials retrieved from BA-type, 305-mm (12-inch) diameter, boreholes from the test pit(s) or from other bulk sampling locations as dictated by the sampling plans for the particular LTPP section.

For the subgrade soils, the test shall be carried out on undisturbed thin-walled tube samples retrieved from A-type, 152-mm (6-inch) diameter, boreholes and other sampling areas; if available. If the thin-walled tube samples are unavailable or unsuitable for testing, or if directed by the FHWA COTR, then bulk samples of subgrade soils shall be used to remold test specimens for resilient modulus tests. Bulk samples of subgrade soils are retrieved from BA-type, 305-mm (12-inch) diameter boreholes, test pit(s) or from other bulk sampling locations as dictated by the sampling plans for the particular LTPP test section.

The test results shall be reported separately for test samples obtained from the bulk samples collected at the beginning and end of the test section as follows:

(a) Beginning of the Section (Stations 0-): Bulk and thin-wall tube samples of each layer that are retrieved from areas in the approach end of the test section (stations preceding 0+00) shall be assigned Laboratory Test Number '1'.

(b) End of the Section (Stations 5+): Bulk and thin-wall tube samples of each layer that are retrieved from areas in the leave end of the test section (stations after 5+00) shall be assigned Laboratory Test Number '2'.

(c) Within the Section (Stations 0+00 - 5+00): Bulk and thin-wall tube samples of each layer that are retrieved from areas within the test section shall be assigned Laboratory Test Number '3'.

3. DEFINITIONS

The following definitions are used throughout this protocol:

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness of unbound granular base and subbase materials is determined from field exploration logs (borehole logs and/or test pit log).

(b) Sample: A representative portion of material from one or more pavement layers received from the field. A sample can be a core, block, chunk, pieces, bulk, thin-walled tube or jar sample.

(c) Bulk Sample: That part of the pavement material that is removed from an unbound base or subbase layer or from the subgrade. Bulk samples are retrieved from the borehole(s) or a test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the Laboratory Material Testing Contractor. The material from one layer should never be mixed with the material from another layer—even if there is less than the desired amount to perform the specified tests.

(d) Test Sample: That part of the bulk sample of an unbound base or subbase layer or subgrade which is prepared and used for the specified test. The quantity of the test sample may be the same but will usually be less than the bulk sample.

(e) Test Specimen: For the purpose of this protocol, a test specimen is defined as, (i) that part of the thin-walled tube sample of the subgrade which is used for the specified tests and (ii) that part of the test sample of unbound granular base or subbase materials or untreated subgrade soils which is remolded to the specified moisture and density condition by recompaction in the laboratory.

(f) Unbound Granular Base and Subbase Materials: These include soil-aggregate mixtures and naturally occurring materials used in each layer of base or subbase. No binding or stabilizing agent is used to prepare unbound granular base or subbase layers. These materials may be classified as either Type 1 or Type 2 as subsequently defined in articles (h) and (i).

(g) Subgrade: Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. These materials may be classified as either Type 1 or Type 2 as subsequently defined in articles (h) and (i).

> (i) A treated subgrade layer (for example cement- or lime- treated soils) is considered a treated subbase layer in the LTPP program. Treated subgrade materials and bound or stabilized layers of subgrade soils are considered treated subbase materials and should be tested using Protocol P31.
>
> (ii) Untreated subgrade soils include all cohesive and non-cohesive (granular) soils present in the sampling zone.
>
> For the LTPP material sampling and testing program: the thin-walled tube sample of the subgrade is considered to be representative of the subgrade soils within the top 1.5 meters (five feet) of the subgrade; and the bulk sample of the subgrade retrieved from 305-mm (12-inch) diameter boreholes or the test pit is considered to be representative of the subgrade soils within 305 mm (12 inches) below the top of the subgrade, unless otherwise indicated on field exploration logs (borehole logs and/or test pit logs).

(h) Material Type 1: For the purposes of this protocol (resilient modulus tests), Material Type 1 includes all unbound granular base and subbase material and all untreated subgrade soils which meet the criteria of less than 70% passing the 2.00-mm (No. 10) sieve and less than 20% passing the 75-µm (No. 200) sieve, and which have a PI ≤ 10. **Soils classified as Type 1 will be molded in a 152-mm (6-inch) diameter mold.**

NOTE 1: If 10 percent or less of a Type 1 sample is retained on the 37.5-mm (1.5-inch) sieve, the material greater than the 37.5-mm (1.5-inch) sieve shall be scalped off prior to testing. If more than 10 percent of the sample is retained on the 37.5 mm (1.5 inch) sieve, the material shall not be tested and the material shall be stored until further notice and the COTR shall be notified. Instructions concerning the testing of these materials will be issued at a later date.

(i) Material Type 2: For the purpose of this protocol (resilient modulus tests), Material Type 2 includes all unbound granular base/subbase and untreated subgrade soils not meeting the criteria for material Type 1 given above in (h). Generally, thin-walled tube samples of untreated subgrade soils fall in this Type 2 category. **Remolded Type 2 specimens will be compacted in a 71-mm (2.8-inch) diameter mold.**

NOTE 2: If 10 percent or less of a Type 2 sample is retained on the 12.5-mm (½-inch) sieve, the material greater than the 12.5-mm (½-inch) shall be scalped off prior to testing. If more than 10 percent of the sample is retained on the 12.5-mm (½-inch) sieve, the material shall not be tested and the material shall be stored until further notice and the COTR shall be notified. Instructions concerning the testing of these materials will be issued at a later date.

(j) Resilient Modulus of Unbound Materials: The modulus of an unbound material is determined by repeated load triaxial compression tests on test specimens of the unbound material samples. M_r is the ratio of the amplitude of the repeated axial stress to the amplitude of the resultant recoverable axial strain. Figure 1 illustrates a typical load (stress) and deformation (strain) versus time relationship for P46 testing.

The necessary input values for the calculation of resilient modulus are determined from the load-time and deformation-time plots as illustrated in Figure 2 and described herein. The loads/deformations are established by using the maximum load/deformation value minus the minimum load/deformation value for a given cycle. The minimum load/deformation value is determined by taking the average load/deformation values from the last 75 percent (nominally 0.75 second) of the cycle. The average value is used to negate the impact of possible "overshooting" of the load on the rest period cycle. Otherwise, if a strict maximum minus minimum algorithm is used, the overshoot values would become the minimum value and thus this would bias the resulting load/deformation value.

(k) Haversine Shaped Load Form - the required load pulse form for the P46 test. The load pulse is of the form (1-COSθ)/2 and the cyclic load (P_{cyclic}) is varied from 10 to 100 percent of the maximum load (P_{max}) as shown in Figure 3.

(l) Maximum Applied Axial Load (P_{max}) - the total load applied to the sample including the contact and cyclic (resilient) loads.

$$P_{max} = P_{contact} + P_{cyclic}$$

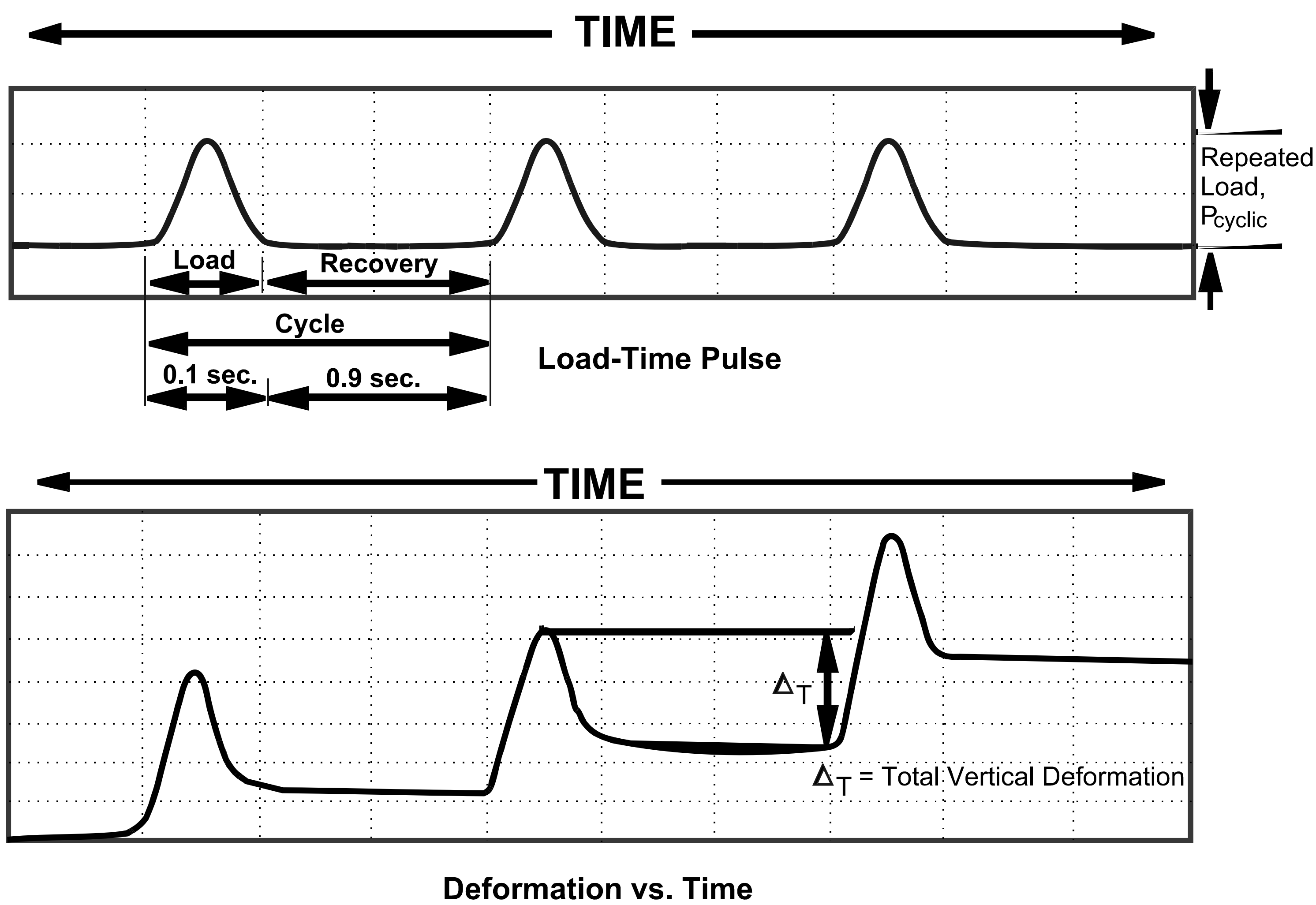


Figure 1. Typical load and deformation versus time relationships

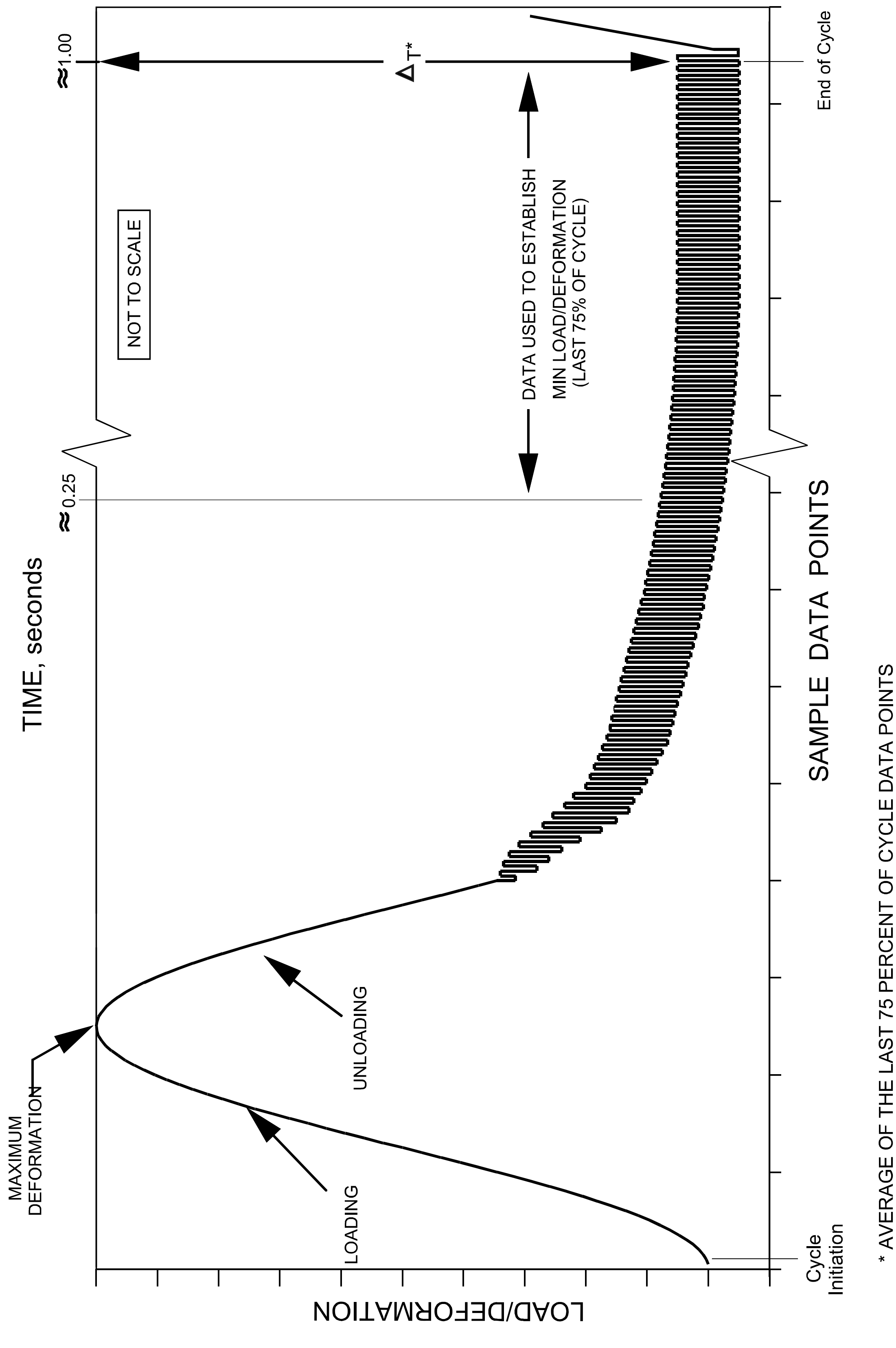


Figure 2. Theoretical determination of maximum/minimum load and deformation

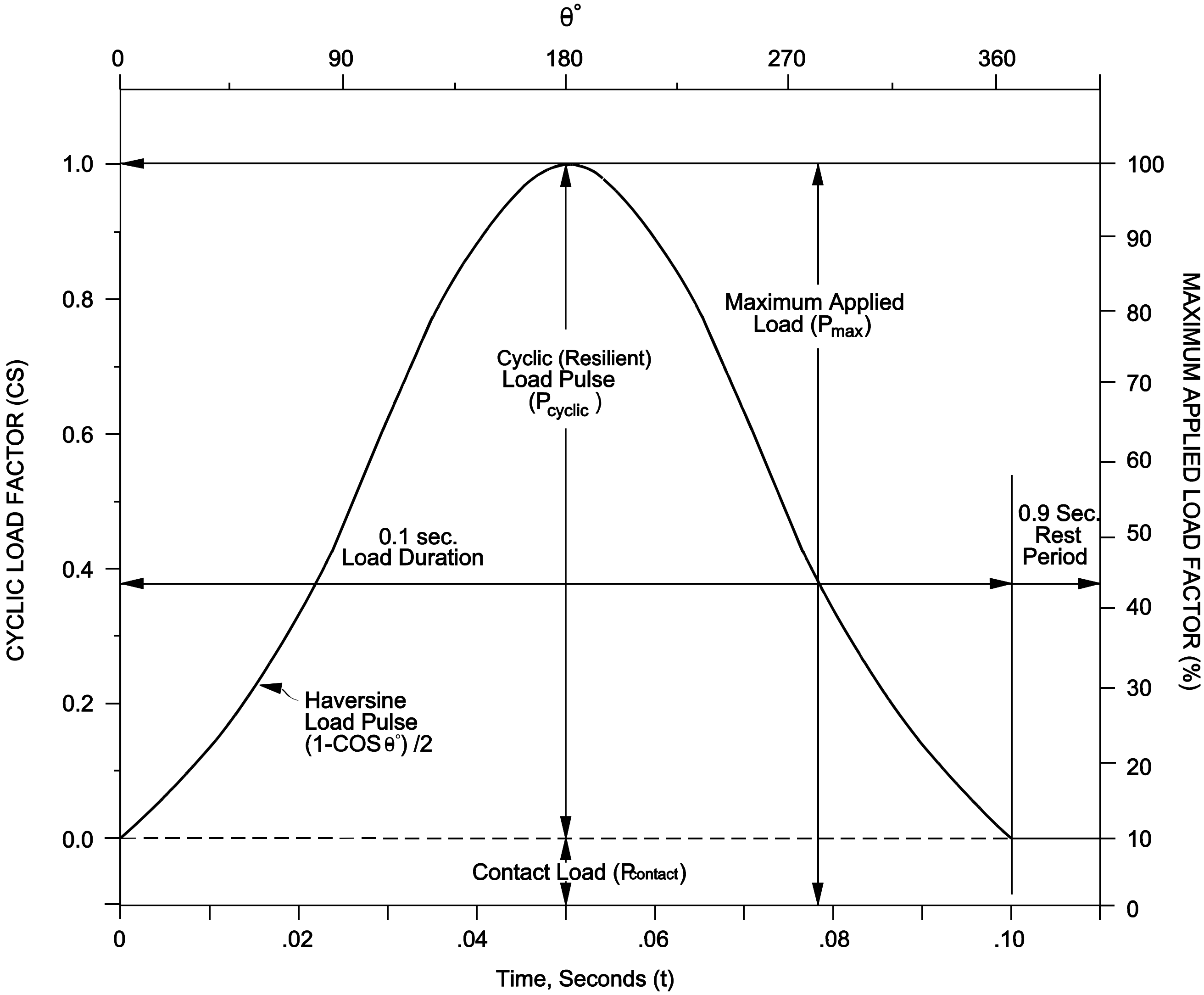


Figure 3. Definition of resilient modulus terms

(m) Contact Load ($P_{contact}$) - vertical load placed on the specimen to maintain a positive contact between the specimen cap and the specimen.

$$P_{contact} = 0.1P_{max}$$

(n) Cyclic Axial Load (Resilient Vertical Load, P_{cyclic}) - repetitive load applied to a test specimen which is used to calculate resilient modulus.

$$P_{cyclic} = P_{max} - P_{contact}$$

(o) Maximum Applied Axial Stress (S_{max}) - the total stress applied to the sample including the contact stress and the cyclic (resilient) stress.

$$S_{max} = P_{max}/A$$

where: A = cross sectional area of the sample.

(p) Cyclic Axial Stress (Resilient Stress, S_{cyclic}) - cyclic (resilient) applied axial stress.

$$S_{cyclic} = P_{cyclic}/A$$

where: A = original cross sectional area of the sample (using the caliper measured diameter prior to testing).

(q) Contact Stress ($S_{contact}$) - axial stress applied to a test specimen to maintain a positive contact between the specimen cap and the specimen.

$$S_{contact} = P_{contact}/A$$

where: A = cross sectional area of the sample (using the caliper measured diameter prior to testing).

Also:

$$S_{contact} = 0.1S_{max}$$

(r) S_3 is the total radial stress; that is, the applied confining pressure in the triaxial chamber (minor principal stress).

(s) e_r is the resilient (recovered) axial deformation due to S_{cyclic}.

(t) ε_r is the resilient (recovered) axial strain due to S_{cyclic}.

$$\varepsilon_r = e_r/L$$

where: L = original specimen length (using caliper measured length prior to testing).

NOTE 3: "L" is considered to be the <u>original</u> test specimen length. This calculation of strain is only valid for testing equipment with linear voltage displacement transducers (LVDTs) positioned outside of the triaxial chamber. If measurement devices are mounted on the specimen, then the value of "L" in the strain calculation becomes equal to the gauge length of the transducers.

(u) Resilient Modulus (M_r) is defined as S_{cyclic}/ε_r.

(v) Load duration is the time interval the specimen is subjected to a cyclic stress (nominally 0.1 sec.).

(w) Cycle duration is the time interval between the successive applications of a cyclic stress (nominally 1.0 sec.).

4. APPLICABLE DOCUMENTS

4.1 AASHTO Standards

T88	Particle Size Analysis of Soils
T99	The Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and 12-Inch (305-mm) Drop
T100	Specific Gravity of Soils
T233	Density of Soil-in-Place by Block, Chunk or Core Sampling
T234	Strength parameters of soils by Triaxial Compression
T265	Laboratory Determination of Moisture Content of Soils
T292	Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials
T238	Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
T239	Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

4.2 LTPP Protocols

P41	Gradation of Unbound Granular Base and Subbase Materials
P42	Hydrometer Analysis of Subgrade Soils
P43	Determination of Atterberg Limits of Unbound Granular Base and Subbase Materials and Subgrade Soils
P44	Moisture-Density Relations of Unbound Granular Base and Subbase Materials
P47	Classification and Description of Unbound Granular Base and Subbase Materials
P49	Determination of Natural Moisture Content
P51	Sieve Analysis of Subgrade Soils
P52	Classification and Description of Subgrade Soils
P55	Moisture-Density Relations of Subgrade Soils

4.3 ASTM Standards

E380	Standard Practice for Use of the International System of Units (SI) (The Modernized Metric System)

5. UNBOUND MATERIALS TESTING PREREQUISITES

5.1 Laboratory Testing Prerequisites for Unbound Granular Base/Subbase Materials

For testing unbound granular base/subbase materials, the following tests shall be performed <u>prior</u> to resilient modulus testing:

- Natural Moisture Content (LTPP Test Designation UG10, Protocol P49)
- Particle Size Analysis (LTPP Test Designations UG01 and UG02, Protocol P41)
- Atterberg Limits (LTPP Test Designation UG04, Protocol P43)
- Classification and Description (LTPP Test Designation UG08, Protocol P47)

- Moisture-Density Relations (LTPP Test Designation UG05, Protocol P44)

For the GPS testing program, in addition to this testing of unbound granular base/subbase materials, the following information shall be available from the field sampling and testing data sheets:

- In situ moisture content (AASHTO T238). If the nuclear moisture information is not available, the optimum moisture content (LTPP Protocol P44) data will be used.
- In situ density (AASHTO T239). If nuclear density information is not available, then moisture-density relationship data (LTPP Protocol P44) will be used.

If the available bulk sample is insufficient in size and a sample from one test is reused for other test(s) and/or the resilient modulus, then the appropriate comment code shall be used in reporting the test results for P46.

5.2 Laboratory Testing Prerequisites for Untreated Subgrade Soils

(a) For testing subgrade materials obtained from bulk samples, the following tests shall be performed <u>prior</u> to resilient modulus testing:

- Natural Moisture Content (LTPP Test Designation SS09, Protocol P49)
- Sieve Analysis (LTPP Test Designation SS01, Protocol P51)
- Hydrometer Analysis (LTPP Test Designation SS02, Protocol P42)
- Atterberg Limits (LTPP Test Designation SS03, Protocol P43)
- Classification and Description (LTPP Test Designation SS04, Protocol P52)
- Moisture-Density Relations (LTPP Test Designation SS05, Protocol P55)

For the GPS testing program, in addition to this testing of subgrade materials, the following information shall be available from the field sampling and testing data sheets:

- In situ moisture content (AASHTO T238). If the nuclear moisture information is not available, the optimum moisture content (LTPP Protocol P55) data will be used.
- In situ density (AASHTO T239). If nuclear density information is not available, then moisture-density relationship data (LTPP Protocol P55) will be used.

If the available bulk sample is insufficient in size and a sample from one test is reused for other test(s) and/or the resilient modulus, then the appropriate comment code shall be used in reporting the test results for P46.

(b) Instructions for undisturbed thin-walled tube samples of subgrade soils:
If the thin-walled tubes are available and acceptable for the resilient modulus test the "undisturbed" thin-walled tube sample shall be used in the resilient modulus testing. The comment code 87 shall be used in reporting the test results for P46.

(c) If a thin-walled tube sample is not available or acceptable for testing then use bulk samples to reconstitute the test specimen for the resilient modulus testing. The comment code 88 shall be used in reporting the test results for P46. Additional comment codes, if applicable, shall be used to identify the manner of reconstitution for the material.

6. APPARATUS

6.1 Triaxial Pressure Chamber

The pressure chamber is used to contain the test specimen and the confining fluid during the test. A typical triaxial chamber suitable for use in resilient testing of soils is shown in Figure 4. The deformation is measured <u>externally</u> with two spring-loaded LVDTs as shown in Figure 4.

6.1.1 Air shall be used in the triaxial chamber as the confining fluid for all LTPP testing.

6.1.2 The chamber shall be made of Lexan, Acrylic or other suitable "see-through" material to facilitate the observation of the specimen during testing.

6.2 Loading Device

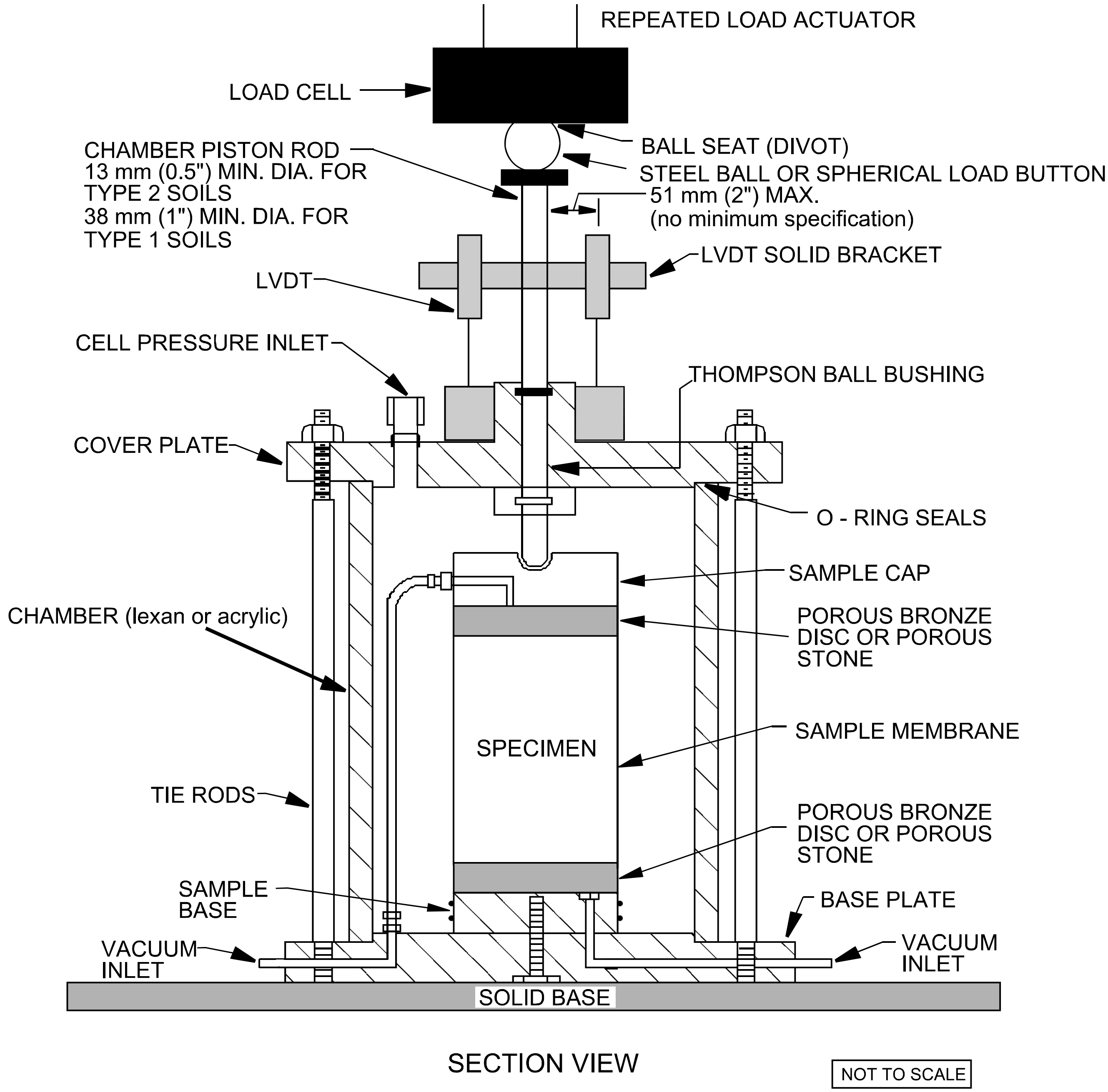
The loading device shall be a top loading, closed loop electrohydraulic testing machine with a function generator which is capable of applying repeated cycles of a haversine-shaped load pulse nominally 0.1 second in duration; followed by rest periods of nominally 0.9 second duration.

The haversine shaped load pulse shall conform to definition (k), Section 3 of this protocol. All preconditioning and testing shall be conducted using a haversine-shaped load pulse. The system generated haversine waveform and the response waveform shall be displayed to allow the operator to adjust the gains to ensure that they coincide during preconditioning and testing.

6.3 Load and Specimen Response Measuring Equipment

6.3.1 The axial load measuring device should be an electronic load cell located between the actuator and the chamber piston rod as shown in Figure 4. The following load cell capacities are required:

Sample Diameter mm (inches)	Maximum Load Capacity kN (lbs)	Required Accuracy N (lbs)
71 (2.8)	2.2 (500)	± 4.5 (± 1)
152 (6.0)	22.24 (5000)	± 22.24 (± 5)



Note 1:
LVDT
tips
shall
rest on
the
triaxial

Figure 4. Typical triaxial chamber with external LVDTs and load cell.

NOTE 4: During periods of resilient modulus testing, the load cell shall be monitored and checked once every two weeks or after every 50 resilient modulus tests with a calibrated proving ring to assure that the load cell is operating properly. An alternative to using a proving ring is to insert an additional calibrated load cell and independently measure the load applied by the original load cell to ensure accurate loadings. Additionally, the load cell shall be checked at any time that the laboratory's in-house QC/QA testing indicates non-compliance or there is a suspicion of a load cell problem. Resilient modulus testing shall not be conducted if the testing system is found to be out of calibration or if the load cell does not meet the manufacturer's tolerance requirements or the tolerance requirements stated above for accuracy, whichever of the two is of the higher accuracy. In addition, all requirements regarding the load cell contained in the Start-up and QC Procedure for LTPP P46 Resilient Modulus Testing must be adhered to at all times.

6.3.2 Test chamber pressures shall be monitored with conventional pressure gauges, manometers or pressure transducers accurate to 0.7 kPa (0.1 psi).

6.3.3 Axial Deformation - Measuring equipment for all materials shall consist of 2 LVDTs fixed to opposite sides of the piston rod outside the test chamber as shown in Figure 4. These two transducers shall be located equidistant, and as close as possible to, the piston rod and shall bear on hard, fixed surfaces which are perpendicular to the LVDT axis. Spring-loaded LVDTs are required. The following LVDT ranges are required:

Sample Diameter, inches (mm)	Range
2.8 (71 mm)	± 0.05 inch (1.3 mm)
6.0 (152 mm)	± 0.25 inch (6.4 mm)

Both LVDT's shall meet the following specifications:

Linearity	± 25% of full scale
Repeatability	± 1% of full scale
Minimum Sensitivity	2 mv/v(AC) or 5 mv/v(DC)

A positive contact between the vertical LVDTs and the surface on which the tips of the transducers rest shall always be maintained during the test procedure. In addition, the two LVDTs shall be wired so that each transducer can be read and reviewed independently and the results averaged for calculation purposes.

NOTE 5: Misalignment, or dirt on the shaft of the transducer can cause the "sticking" of the shafts of the LVDT. The laboratory technician shall depress and release each LVDT prior to each test to assure that there is no sticking. An acceptable cleaner/lubricant (as specified by the manufacturer) shall be applied to the transducer shafts on a regular basis.

NOTE 6: The response of the LVDTs shall be checked daily with the laboratory's in-house QC/QA program. Additionally, the LVDT's shall be calibrated every two weeks, or after every 50 resilient modulus tests, whichever comes first, using a micrometer with compatible resolution or a set of specially machined gauge blocks. Resilient modulus testing shall not be conducted if the LVDTs do not meet the manufacturer's tolerance requirements for accuracy.

6.3.4 Suitable signal excitation, conditioning, and recording equipment are required for simultaneous recording of axial load and deformations. The signal shall be clean and free of noise (use shielded cables for connections). If a filter is used, it should have a frequency which cannot attenuate the signal. The LVDTs shall be wired separately so each LVDT signal can be monitored independently. A <u>minimum</u> of 500 data points from each LVDT shall be recorded per load cycle.

6.4 Specimen Preparation Equipment

A variety of equipment is required to prepare undisturbed samples for testing and to obtain compacted specimens that are representative of field conditions. Use of different materials and different methods of compaction in the field requires the use of varying compaction techniques in the laboratory. See the appendices (A, B and C) to this procedure for specimen preparation (Appendix A), specimen compaction equipment and compaction procedures for Type 1 (Appendix B) and Type 2 materials (Appendix C), respectively.

6.5 Thin-walled Tube Trimming Equipment

Equipment for trimming test specimens from undisturbed thin-walled tube samples of subgrade soils shall be as described in AASHTO T234-85, Strength Parameters of Soils by Triaxial Compression.

6.6 Miscellaneous Apparatus

This includes calipers, micrometer gauge, steel rule (calibrated to 0.5 mm [0.02 inch]), rubber membranes from 0.25 to 0.79 mm (0.01 to 0.031 inch) thickness, rubber O-rings, vacuum source with bubble chamber and regulator, membrane expander, porous stones (subgrade), porous bronze discs (base/subbase), scales, moisture content cans and data sheets, as required.

6.7 System Calibration and Periodic Checks

The entire system (transducer, conditioning and recording devices) shall be calibrated every two weeks or after every fifty resilient modulus tests using the laboratory's in-house QC/QA program. Daily and other periodic checks of the system may also be performed as per the laboratory's in-house QC/QA program.

Documentation of these calibrations and all other QC/QA activities shall be maintained for review by the FHWA COTR. No resilient modulus testing will be conducted unless the entire system meets the established calibration requirements of the approved QC/QA program and the laboratory meets all applicable requirements of the Start-up and QC Procedure for LTPP P46 Resilient Modulus Testing.

7. PREPARATION OF TEST SPECIMENS

7.1 GPS Materials Characterization Program - General

Unless otherwise directed by the FHWA COTR, the following preparation steps shall be followed for the GPS materials characterization program, based on the sieve analysis test results (See Form T41 or T51 as appropriate).

7.1.1 Use the 71-mm (2.8-inch) diameter undisturbed specimen from the thin-walled tube samples for cohesive subgrade soils (Material Type 2). The specimen length shall be at least two times the diameter (minimum length of 142 mm [5.6 inches]) and the specimen shall be prepared as described in Section 7.2. If undisturbed subgrade samples are unavailable or unsuitable for testing, then 71-mm (2.8-inch) diameter molds shall be used to reconstitute Type 2 test specimens.

NOTE 7: If 10 percent or less of a Type 2 sample is retained on the 12.5-mm (0.5-inch) sieve, the material greater than the 12.5-mm (0.5-inch) sieve shall be scalped off prior to testing. If <u>more</u> than 10 percent of the sample is retained on the 12.5-mm (0.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

7.1.2 Use 152-mm (6.0-inch) diameter split molds to prepare 305-mm (12-inch) high test specimens for all Type 1 materials with nominal particle sizes less than or equal to 37.5 mm (1.5 inches).

NOTE 8: If 10 percent or less of a Type 1 sample is retained on the 37.5-mm (1.5-inch) sieve, the material greater than the 37.5-mm (1.5-inch) sieve shall be scalped off prior to testing. If <u>more</u> than 10 percent of the sample is retained on the 37.5-mm (1.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

7.2 GPS - Undisturbed Subgrade Soil Specimens

Undisturbed subgrade soil specimens are trimmed and prepared as described in AASHTO T234-85, Strength Parameters of Soils by Triaxial Compression, using the thin-walled tube samples of the subgrade soil. The natural moisture content (w) of the tube sample shall be determined after triaxial M_r testing, following the procedure outlined in LTPP Protocol P49 (AASHTO T265-86), and recorded in the test report.

The following procedure shall be followed for the thin-walled tube samples:

7.2.1 Examine the thin-walled tube samples obtained from the same sampling location separately. Select the sample most suitable for testing (see NOTE 9) giving priority to samples extracted near the surface of the subgrade. That is, the sample should be taken from the top of the first tube pushed, if it is suitable for testing. If not, examine samples from increasing depths in the subgrade, selecting the first sample suitable for testing. In any case, the depth in relation to the top of the subgrade that the sample is obtained from should be noted on Laboratory Test Data Sheet T46.

NOTE 9: To be suitable for testing, a specimen of sufficient length (at least twice the diameter of the specimen after preparation) must be cut from the tube sample, and must be free from defects that would result in unacceptable or biased test results. Such defects include cracks in the specimen, corners broken off that cannot be repaired during preparation, presence of particles much larger than that typical for the material (example, +19.0-mm (+¾-inch) stones in a fine-grained soil), presence of "foreign objects" such as large roots, wood particles, organic material and gouges due to gravel hanging on the edge of the tube. If the gradation and PI tests indicate that the material (from a bulk sample) corresponding to a thin-wall tube is actually a Type 1 material, the thin-walled tube shall not be used and a specimen must be recompacted (as a Type 1 material) using the bulk sample. If the gradation test indicates that more than 10 percent of a Type 2 sample is retained on the 12.5-mm (0.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

7.2.2 If a good undisturbed subgrade sample is unavailable from a particular location, a reconstituted specimen shall be prepared from the bulk sample from the same end of the test section and same layer. Select a sample for reconstitution, again giving priority to samples extracted near the surface of the subgrade.

7.3 GPS - Laboratory Compacted Specimens

Reconstituted test specimens of both Type 1 and Type 2 materials shall be prepared to approximate the in situ wet density (γ_w) and moisture content (w). These laboratory compacted specimens shall be prepared for all unbound granular base and subbase material and for all subgrade soils for which undisturbed tube specimens could not be obtained.

This protocol states that reconstituted test specimens should be compacted to in-situ moisture and density conditions as measured in the field using nuclear methods (AASHTO T239) whenever these data are available. This requirement was instituted in the protocol in an attempt to better correlate laboratory test results and those from the analysis of deflection measurements performed immediately prior to sampling. It is important to recognize that correlating the laboratory determined resilient modulus values of soils and unbound aggregate at in-situ moisture and density with that obtained from analysis of pavement deflection measurements is an important objective of the LTPP GPS materials characterization program.

However, for some samples, it may be virtually impossible to compact specimens to the measured in-situ moisture and density. In this case, the sample shall be compacted using the alternative compaction requirements of P46—compact at optimum moisture content and 95 percent of the maximum dry density of the material (section 7.3.3). The decision to use the alternate compaction procedure is at the discretion of the laboratory Supervisory

Engineer and should be made on a case-by-case basis. <u>However, every effort shall be made to compact the samples to in-situ conditions prior to electing the alternative sample compaction procedure.</u>

In those cases where the measured in-situ properties at the time of sampling are not available, the sample should also be prepared following the alternative compaction procedure. However, the unavailability of this data must be verified with the corresponding LTPP Region prior to sample preparation. This caveat only applies to the GPS materials characterization program. For the SPS materials characterization program all samples shall be compacted to optimum moisture and 95 percent maximum dry density as described in Section 7.4 of this protocol.

7.3.1 Moisture Content - The moisture content of the laboratory compacted specimen shall be the in-situ moisture content obtained in the field using AASHTO T238 (nuclear method) for that layer. If data is not available on in-situ moisture content, then refer to Section 7.3.3.

The moisture content of the laboratory compacted specimen should not vary by more than ± 1.0 percent for Type 1 materials or ± 0.5 percent for Type 2 materials from the in situ moisture content obtained for that layer.

7.3.2 Compacted Density - The density of the compacted specimen shall be the in-place wet density obtained in the field using AASHTO T239 (nuclear method) for that layer. If this data is not available on in-situ density, then refer to Section 7.3.3.

The wet density of the laboratory compacted specimen should not vary more than ± 3 percent of the in-place wet density for that layer.

7.3.3 If either the in-situ moisture content or the in-place density data is not available, then use the optimum moisture content and 95 percent of the maximum dry density (previously determined using LTPP Protocol P44 (Base/Subbase) or LTPP Protocol P55 (Subgrade) for preparing the reconstituted specimen.

The moisture content of the laboratory compacted specimen should not vary by more than ± 1.0 percent for Type 1 materials or ± 0.5 percent for Type 2 materials from the target moisture content. Also, the wet density of the laboratory compacted specimen should not vary more than ± 3 percent of the target wet density.

7.3.4 Sample Reconstitution - Reconstitute the specimen for Type 1 and Type 2 materials in accordance with the provisions given in Appendix A. The target moisture content and density to be used in determining needed material quantities are as established in Section 7.3. Appendix A provides guidelines for reconstituting the material to obtain a sufficient amount of material to prepare the appropriate specimen type at the designated moisture content and density. After this step is completed, specimen compaction can begin.

7.4 SPS Materials Characterization Program

Unless otherwise directed by the FHWA COTR, the following preparation steps shall be followed for the SPS materials characterization program.

7.4.1 Undisturbed Subgrade Soil Specimens - Undisturbed subgrade soil specimens are trimmed and prepared as described in AASHTO T234-85, Strength Parameters of Soils by Triaxial Compression, using the thin-walled tube samples of the subgrade soil. The specimen length shall be at least two times the diameter (minimum length of 142 mm [5.6 inch]). The natural moisture content (w) of the tube sample shall be determined after triaxial M_r testing, following the procedure outlined in LTPP Protocol P49 (AASHTO T265-86), and recorded in the test report.

The following procedure shall be followed for the thin-walled tube samples:

Examine the thin-walled tube samples obtained from the same sampling location separately. Select the sample most suitable for testing (see NOTE 10) giving priority to samples extracted near the surface of the subgrade. That is, the sample should be taken from the top of the first tube pushed, if it is suitable for testing. If not, examine samples from increasing depths in the subgrade, selecting the first sample suitable for testing. In any case, the depth in relation to the top of the subgrade that the sample is obtained from should be noted on Laboratory Test Data Sheet T46.

NOTE 10: To be suitable for testing, a specimen of sufficient length (at least twice the diameter of the specimen after preparation) must be cut from the tube sample, and must be free from defects that would result in unacceptable or biased test results. Such defects include cracks in the specimen, corners broken off that cannot be repaired during preparation, presence of particles much larger than that typical for the material (example, +19.0-mm [+¾-inch] stones in a fine-grained soil), presence of "foreign objects" such as large roots, wood particles, organic material and gouges due to gravel hanging on the edge of the tube. If the gradation and PI tests indicate that the material (from a bulk sample) corresponding to a thin-wall tube is actually a Type 1 material, the thin-walled tube shall not be used.

7.4.2 Laboratory Compacted Specimens - Reconstituted test specimens of both Type 1 and Type 2 materials shall be prepared to the optimum moisture content and 95 percent of the maximum dry density (previously determined using LTPP Protocol P44 (Base/Subbase) or LTPP Protocol P55 (Subgrade)). Use 71-mm (2.8-inch) diameter molds to reconstitute Type 2 test specimens and 152-mm (6.0-inch) diameter split molds to reconstitute Type 1 materials.

NOTE 11: If 10 percent or less of a Type 2 sample is retained on the 12.5-mm (0.5-inch) sieve, the material greater than the 12.5-mm (0.5-inch) sieve shall be scalped off prior to testing. If <u>more</u> than 10 percent of the sample is retained on the 12.5-mm (0.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

NOTE 12: If 10 percent or less of a Type 1 sample is retained on the 37.5-mm (1.5-inch) sieve, the material greater than the 37.5-mm (1.5-inch) sieve shall be scalped off prior to testing. If more than 10 percent of the sample is retained on the 37.5-mm (1.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

The moisture content of the laboratory compacted specimen should not vary by more than ± 1.0 percent for Type 1 materials or ± 0.5 percent for Type 2 materials from the target moisture content. Also, the wet density of the laboratory compacted specimen should not vary more than ± 3 percent of the target wet density.

7.4.3 Sample Reconstitution - Reconstitute the specimen for Type 1 and Type 2 materials in accordance with the provisions given in Appendix A. The target moisture content and density to be used in determining needed material quantities are as established in this section. Appendix A provides guidelines for reconstituting the material to obtain a sufficient amount of material to prepare the appropriate specimen type at the designated moisture content and density. After this step is completed, specimen compaction can begin.

7.5 GPS and SPS - Compaction Methods and Equipment for Reconstituting Specimens

7.5.1 Compacting Specimens for Type 1 Materials - The general method of compaction for Type 1 materials will be that of Appendix B of this protocol.

7.5.2 Compacting Specimens for Type 2 Materials - The general method of compaction for Type 2 materials will be that of Appendix C of this protocol.

7.5.3 The prepared specimens should be protected from moisture change by applying the triaxial membrane and tested within 5 days of completion. Prior to storage and directly after removal from storage, the specimen shall be weighed to determine if there was any moisture loss. If moisture loss exceeds 1 percent for Type 1 material or 0.5 percent for Type 2 materials, then the prepared specimens will not be tested. However, a new specimen will need to be prepared for testing. Material from the specimens not tested may be reused.

8. TEST PROCEDURE

8.1 Resilient Modulus Test for Subgrade Soils

The procedure described in this section is used for undisturbed or laboratory compacted specimens of subgrade soils. This can include specimens classified as Type 1 (152-mm [6-inch] diameter specimens) or Type 2 (71-mm [2.8-inch] diameter specimens) material.

8.1.1 Assembly of Triaxial Chamber - Specimens trimmed from undisturbed samples and laboratory compacted specimens are placed in the triaxial chamber and loading apparatus in the following steps.

8.1.1.1 Place a dry porous stone on the top of the sample base of the triaxial chamber as shown in Figure 4. Paper filters should be placed between the porous stone and the sample.

8.1.1.2 Carefully place the specimen on the porous stone. Place the membrane on a membrane expander, apply vacuum to the membrane expander, then carefully place the membrane on the sample and remove the vacuum and the membrane expander. Seal the membrane to the pedestal (or bottom plate) with an O-ring or other pressure seals.

8.1.1.3 Place the dry porous stone and the top platen on the specimen, fold up the membrane, and seal it to the top platen with an O-ring or some other pressure seal. Paper filters should be placed between the porous stone and the sample.

After the "specimen assembly" is in-place, the top platen shall be checked to ensure that it is level. A "cross-check" level, or similar, may be used for this determination.

8.1.1.4 If the specimen has been compacted or stored inside a rubber membrane and the porous stones and sample are already attached to the rubber membrane in place, steps 8.1.1.1, 8.1.1.2, and 8.1.1.3 are omitted. Instead, the "specimen assembly" is placed on the base plate of the triaxial chamber.

8.1.1.5 Connect the specimen's bottom drainage line to the vacuum source through the medium of a bubble chamber. Apply a vacuum of 7 kPa (1 psi). If bubbles are present, check for leakage caused by poor connections, holes in the membrane, or imperfect seals at the cap and base. The existence of an airtight seal ensures that the membrane will remain firmly in contact with the specimen. Leakage through holes in the membrane can frequently be eliminated by coating the surface of the membrane with liquid rubber latex or by using a second membrane.

8.1.1.6 When leakage has been eliminated, disconnect the vacuum supply and place the chamber on the base plate, and the cover plate on the chamber. Insert the loading piston and obtain a firm connection with the load cell. Tighten the chamber tie rods firmly. The cover plate of the triaxial chamber shall be checked to ensure that it is level after tightening the tie rods. A "cross-check" level, or similar, may be used for this determination.

8.1.1.7 Slide the assembly apparatus into position under the axial loading device. Positioning of the chamber is extremely critical in eliminating all possible side forces on the piston rod. Couple the loading device to the triaxial chamber piston rod.

Bolt or firmly fasten the triaxial chamber to the bottom loading platen of the test device. For Type 1 samples, a minimum of 4 bolts or fasteners should be used, for Type 2 samples a minimum of 3 bolts should be used. After fastening the triaxial chamber to the bottom platen, the top of the chamber shall be checked to ensure that it is level.

8.1.2 Conduct the Resilient Modulus Test - The following steps are required to conduct the resilient modulus test on a subgrade specimen which has been installed in the triaxial chamber and placed under the loading frame.

8.1.2.1 Open all drainage valves leading into the specimen to atmospheric pressure.

8.1.2.2 If it is not already connected, connect the air pressure supply line to the triaxial chamber and apply the specified pre-conditioning confining pressure of 41.4 kPa (6 psi) to the test specimen. A contact stress of 10 percent ± 0.7 kPa (± 0.1 psi) of the maximum applied axial stress during each sequence number shall be maintained.

8.1.2.3 Conditioning - Begin the test by applying a minimum of 500 repetitions of a load equivalent to a maximum axial stress of 27.6 kPa (4 psi) and corresponding cyclic stress of 24.8 kPa (3.6 psi) using a haversine shaped load pulse consisting of a 0.1 second load followed by a 0.9 second rest period. If the sample is still decreasing in height at the end of the conditioning period, stress cycling shall be continued up to 1,000 repetitions prior to testing.

The foregoing stress sequence constitutes sample conditioning, that is, the elimination of the effects of the interval between compaction and loading and the elimination of initial loading versus reloading. This conditioning also aids in minimizing the effects of initially imperfect contact between the sample cap and the test specimen.

If the total vertical permanent strain reaches 5 percent during conditioning, the conditioning process shall be terminated. For recompacted samples, a review shall be conducted of the compaction process to identify any reason(s) why the sample did not attain adequate compaction. If this review does not provide an explanation, the material shall be re-fabricated and tested a second time. If the sample again reaches 5 percent total vertical permanent strain during preconditioning, then the test shall be terminated and the appropriate item on the data sheet shall be completed. No further testing of this material is necessary.

If the sample is a thin-wall tube, sample handling procedures shall be reviewed to determine if the sample was damaged. If this review does not provide an explanation, another thin-wall tube sample shall be used for the testing. If the sample from the second thin-wall tube also reaches 5 percent total vertical permanent strain during preconditioning, then the test shall be terminated and the appropriate item on the data sheet shall be completed. No further testing of this material is necessary.

NOTE 13: The operator/technician shall conduct appropriate QC/QA comparative checks of the individual deformation output from the two vertical transducers during the conditioning phase of each M_r test in order to recognize specimen misplacement and misalignment. During the preconditioning phase, the two vertical deformation curves should be viewed to ensure that acceptable vertical deformation ratios are being measured. Desired vertical deformation ratios (R_v) are defined as $R_v = Y_{max}/Y_{min} \leq 1.10$, where Y_{max} equals the larger of the two vertical deformations and Y_{min} equals the smaller of the two vertical deformations. Unacceptable vertical deformations are obtained when $R_v > 1.30$. In this case, the test should be discontinued and specimen placement/alignment difficulties alleviated. Once acceptable vertical deformation values are obtained, ($R_v < 1.30$) then the test should be continued to completion. It is emphasized that specimen alignment is critical for proper M_r results.

8.1.2.4 Testing Specimen - The testing is performed following the loading sequence shown in Table 1. Begin by decreasing the maximum axial stress to 13.8 kPa (2 psi) (Sequence No. 1, Table 1) and set the confining pressure to 41.4 kPa (6 psi).

Table 1. Testing sequence for subgrade soils.

Sequence No.	Confining Pressure, S_3		Max. Axial Stress S_{max}		Cyclic Stress S_{cyclic}		Contact Stress $0.1S_{max}$		No. of Load Applications
	kPa	psi	kPa	psi	kPa	psi	kPa	psi	
0	41.4	6	27.6	4	24.8	3.6	2.8	.4	500-1000
1	41.4	6	13.8	2	12.4	1.8	1.4	.2	100
2	41.4	6	27.6	4	24.8	3.6	2.8	.4	100
3	41.4	6	41.4	6	37.3	5.4	4.1	.6	100
4	41.4	6	55.2	8	49.7	7.2	5.5	.8	100
5	41.4	6	68.9	10	62.0	9.0	6.9	1.0	100
6	27.6	4	13.8	2	12.4	1.8	1.4	.2	100
7	27.6	4	27.6	4	24.8	3.6	2.8	.4	100
8	27.6	4	41.4	6	37.3	5.4	4.1	.6	100
9	27.6	4	55.2	8	49.7	7.2	5.5	.8	100
10	27.6	4	68.9	10	62.0	9.0	6.9	1.0	100
11	13.8	2	13.8	2	12.4	1.8	1.4	.2	100
12	13.8	2	27.6	4	24.8	3.6	2.8	.4	100
13	13.8	2	41.4	6	37.3	5.4	4.1	.6	100
14	13.8	2	55.2	8	49.7	7.2	5.5	.8	100
15	13.8	2	68.9	10	62.0	9.0	6.9	1.0	100

NOTE: Load sequences 14 and 15 are not to be used for materials designated as Type 1.

NOTE 14: The contact stresses shown in Table 1 should be adjusted to compensate for the resultant force created by the chamber pressure (upward force) and the weight of the chamber piston rod, including the LVDT holder, (downward force). Instructions for adjusting the contact load are given in Appendix D of this procedure.

8.1.2.5 Apply 100 repetitions of the corresponding cyclic axial stress using a haversine shaped load pulse consisting of a 0.1 second load followed by a 0.9 second rest period. Record the average recovered deformations for each LVDT separately for the last five cycles on Worksheet T46.

8.1.2.6 Increase the maximum axial stress to 27.6 kPa (4 psi) (Sequence No. 3) and repeat step 8.1.2.5 at this new stress level.

8.1.2.7 Increase the cyclic stress to 6 psi (Sequence No. 3) and repeat step 8.1.2.4 at this new stress level.

8.1.2.8 Continue the test for the remaining load sequences in Table 1 (4 to 15) recording the vertical recovered deformation. If at any time the total vertical permanent strain (after preconditioning) exceeds 5 percent, stop the test and report the results on Worksheet T46.

8.1.2.9 After completion of the resilient modulus test procedure, check the total vertical permanent strain that the specimen was subjected to during the resilient modulus (after preconditioning) portion of the test procedure. If the total vertical permanent strain did not exceed 5 percent, continue with the quick shear test procedure (Section 8.1.2.10). If the total vertical permanent strain exceeds 5 percent, the test is completed. No additional testing is to be conducted on the specimen.

8.1.2.10 Apply a confining pressure of 27.6 kPa (4 psi) to the specimen. Apply a load so as to produce an axial strain at a rate of 1 percent per minute under a strain controlled loading procedure. Continue loading until either (1) the load values decrease with increasing strain, (2) 5 percent strain is reached (from the initiation of the quick shear test) or (3) the capacity of the load cell is reached. Data from the internally mounted deformation transducer in the actuator shaft and from the load cell shall be used to record specimen deformation and loads at a maximum of 3 second intervals.

NOTE 15: It has been noted that even though some samples visually bulge and appear to have failed, they do not achieve the above definition of failure at the maximum strain value (5 percent). In some cases, the stress-strain curves "level out" and the load values remain at, or near, constant and do not decrease with increasing strain. If a sample appears to fail without achieving the aforementioned criteria, a comment note should be added to the test data reporting sheet to document this occurrence.

8.1.2.11 At the completion of the triaxial shear test, reduce the confining pressure to zero and remove the sample from the triaxial chamber.

8.1.2.12 Remove the membrane from the specimen and use the entire specimen to determine moisture content in accordance with LTPP Protocol P49. Record this value on Form T46.

8.1.2.13 Plot the stress-strain curve for the specimen for the triaxial shear test procedure.

8.2 Resilient Modulus Test for Base/Subbase Materials

The procedure described in this section applies to all unbound granular base and subbase materials. This can include specimens classified as Type 1 (152-mm [6-inch] diameter specimens) or Type 2 (71-mm [2.8-inch] diameter specimens) material.

8.2.1 Assembly of the Triaxial Chamber - Follow Steps 8.1.1.1 through 8.1.1.7. When compaction is completed, place the paper filter, dry porous bronze disc and sample cap on the top surface of the specimen. Roll the rubber membrane off the rim of the mold and over the sample cap. If the sample cap projects above the rim of the mold, the membrane should be sealed tightly against the cap with the O-ring seal. If it does not, the seal can be applied later. Install the sample in the triaxial chamber as in steps 8.1.1.1 through 8.1.1.7.

8.2.1.1 Connect the chamber pressure supply line and apply a confining pressure of 103.4 kPa (15 psi).

8.2.1.2 Remove the vacuum supply from the vacuum saturation inlet and open the top and bottom head drainage ports to atmospheric pressure.

8.2.2 Conduct the Resilient Modulus Test - After the test specimen has been prepared and placed in the loading device as described in 8.2.1, the following steps are necessary to conduct the resilient modulus testing:

8.2.2.1 If not already done, adjust the position of the axial loading device or triaxial chamber base support as necessary to couple the load-generation device piston and the triaxial chamber piston. The triaxial chamber piston should bear firmly on the load cell. A contact stress of 10 percent ± 0.7 kPa (± 0.1 psi) of the maximum applied axial stress during each sequence number shall be maintained.

8.2.2.2 Adjust the recording devices for the LVDTs and load cell as needed.

8.2.2.3 Conditioning - Set the confining pressure to 103.4 kPa (15 psi) and apply a minimum of 500 repetitions of a load equivalent to a maximum axial stress of 103.4 kPa (15 psi) and corresponding cyclic axial stress of 93.1 kPa (13.5 psi) using a haversine shaped load pulse consisting of a 0.1 second load followed by a 0.9 second rest period. If the sample is still decreasing in height at the end of the conditioning period, stress cycling shall be continued up to 1000 repetitions prior to testing.

The foregoing stress sequence constitutes sample conditioning, that is, the elimination of the effects of the interval between compaction and loading and the elimination of initial loading versus reloading. This conditioning also aids in minimizing the effects of initially imperfect contact between the sample cap and base plate and the test specimen. The drainage valves should be open throughout the resilient testing.

If the total vertical permanent strain reaches 5 percent during conditioning, the conditioning process shall be terminated. A review shall be conducted of the compaction process to identify any reason(s) why the sample did not attain adequate compaction. If this review does not provide an explanation, the material shall be re-fabricated and tested a second time. If the sample again reaches 5 percent total vertical permanent strain during preconditioning, then the test shall be terminated and the appropriate item on the data sheet shall be completed. No further testing of this material is necessary.

NOTE 16: The operator/technician shall conduct appropriate QC/QA comparative checks of the individual deformation output from the two vertical transducers during the conditioning phase of each M_r test in order to recognize specimen misplacement and misalignment. During the preconditioning phase, the two vertical deformation curves should be viewed to ensure that acceptable vertical deformation ratios are being measured. Desired vertical deformation ratios (R_v) are defined as $R_v = Y_{max}/Y_{min} \leq 1.10$, where Y_{max} equals the larger of the two vertical deformations and Y_{min} equals the smaller of the two vertical deformations. Unacceptable vertical deformations are obtained when $R_v > 1.30$. In this case, the test should be discontinued and specimen placement/alignment difficulties alleviated. Once acceptable vertical deformation values are obtained, ($R_v < 1.30$) then the test should be continued to completion. It is emphasized that specimen alignment is critical for proper M_r results.

8.2.2.4 Testing Specimen - The testing is performed following the loading sequences in Table 2 using a haversine shaped load pulse as described above. Decrease the maximum axial stress to 21.0 kPa (3 psi) and set the confining pressure to 21.0 kPa (3 psi) (Sequence No. 1, Table 2).

8.2.2.5 Apply 100 repetitions of the corresponding cyclic stress using a haversine shaped load pulse consisting of a 0.1 second load followed by a 0.9 second rest period. Record the average recovered deformations for each LVDT separately for the last five cycles on Worksheet T46.

NOTE 17: The contact stresses shown in Table 2 should be adjusted to compensate for the resultant force created by the chamber pressure (upward force) and the weight of the chamber piston rod, including the LVDT holder, (downward force). Instructions for adjusting the contact load are given in Appendix D of this procedure.

8.2.2.6 Continue with Sequence No. 2 increasing the maximum axial stress to 41.0 kPa (6 psi) and repeat 8.2.2.5 at this new stress level.

8.2.2.7 Continue the test for the remaining load sequences in Table 2 (sequences 3 to 15) recording the vertical recovered deformation. If, at any time the total vertical permanent strain (after preconditioning) exceeds 5 percent, stop the test and report the results on Worksheet T46.

8.2.2.8 After completion of the resilient modulus test procedure, check the total vertical permanent strain that the specimen was subjected to during the resilient modulus (after preconditioning) portion of the test procedure. If the total vertical permanent strain did not exceed 5 percent, continue with the quick shear test procedure (Section 8.2.2.10). If the total vertical permanent strain exceeds 5 percent, the test is completed. No additional testing is to be conducted on the specimen.

Table 2. Testing sequence for base/subbase materials.

Sequence No.	Confining Pressure, S_3		Max. Axial Stress S_{max}		Cyclic Stress S_{cyclic}		Contact Stress $0.1S_{max}$		No. of Load Applications
	kPa	psi	kPa	psi	kPa	psi	kPa	psi	
0	103.4	15	103.4	15	93.1	13.5	10.3	1.5	500-1000
1	20.7	3	20.7	3	18.6	2.7	2.1	.3	100
2	20.7	3	41.4	6	37.3	5.4	4.1	.6	100
3	20.7	3	62.1	9	55.9	8.1	6.2	.9	100
4	34.5	5	34.5	5	31.0	4.5	3.5	.5	100
5	34.5	5	68.9	10	62.0	9.0	6.9	1.0	100
6	34.5	5	103.4	15	93.1	13.5	10.3	1.5	100
7	68.9	10	68.9	10	62.0	9.0	6.9	1.0	100
8	68.9	10	137.9	20	124.1	18.0	13.8	2.0	100
9	68.9	10	206.8	30	186.1	27.0	20.7	3.0	100
10	103.4	15	68.9	10	62.0	9.0	6.9	1.0	100
11	103.4	15	103.4	15	93.1	13.5	10.3	1.5	100
12	103.4	15	206.8	30	186.1	27.0	20.7	3.0	100
13	137.9	20	103.4	15	93.1	13.5	10.3	1.5	100
14	137.9	20	137.9	20	124.1	18.0	13.8	2.0	100
15	137.9	20	275.8	40	248.2	36.0	27.6	4.0	100

8.2.2.10 Apply a confining pressure of 34.5 kPa (5 psi) to the specimen. Apply a load so as to produce an axial strain at a rate of 1 percent per minute under a strain controlled loading procedure. Continue loading until either (1) the load values decrease with increasing strain, (2) 5 percent strain is reached (from the initiation of the quick shear test) or (3) the capacity of the load cell is reached. Data from the internally mounted deformation transducer in the actuator shaft and from the load cell shall be used to record specimen deformation and loads at a maximum of 3 second intervals.

NOTE 18: It has been noted that even though some samples visually bulge and appear to have failed, they do not achieve the above definition of failure at the maximum strain value (5 percent). In some cases, the stress-strain curves "level out" and the load values remain at, or near, constant and do not decrease with increasing strain. If a sample appears to fail without achieving the aforementioned criteria, a comment note should be added to the test data reporting sheet to document this occurrence.

8.2.2.11 At the completion of the triaxial shear test, reduce the confining pressure to zero and remove the sample from the triaxial cell.

8.2.2.12 Remove the membrane from the specimen and use the entire sample to determine the moisture content in accordance with LTPP Protocol P49. Record this value on the appropriate form (See Worksheet T46).

8.2.2.13 Plot the stress-strain curve for the specimen for the triaxial shear test procedure.

9. CALCULATIONS

Perform the calculations to obtain resilient modulus values using the tabular arrangement shown on Worksheet T46. The resilient modulus value is computed for each of the last 5 cycles of each load sequence. These values are subsequently averaged on the data sheet.

10. REPORT

The report shall consist of the following:

1. hard copy of Form T46A (recompacted specimens) or Form T46B (thin-wall tube specimens),
2. hard copy of Worksheet T46, and
3. computer diskette containing all of the information shown on Form T46A or Form T46B and Worksheet T46 in ASCII file format.

The following general information is to be recorded on all of the Laboratory Data Sheets.

10.1 Specimen Identification

The specimen identification shall include: Laboratory Identification Code, State Code, SHRP ID, Layer Number, Field Set Number, Layer Type (1 = subgrade, 2 = base/subbase), Sampling Area No. (SPS-only), Sample Location Number, LTPP Sample Number, and Material Type (Type 1 or Type 2).

NOTE 19: When bulk samples are retrieved from the same general area from several BA-type 12-inch (305-mm) diameter boreholes, these bulk samples are combined, prepared and reduced to a representative test size in accordance with AASHTO T87 and AASHTO T248. Because the bulk samples are combined from several locations, the Location Number of the sample shall have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

10.2 Test Identification

The test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

10.3 Data Reporting

Report the following information on the appropriate data sheet:

10.3.1 Form T46A shall be used to record general information concerning the specimen and layer being tested. This form shall be completed only for those specimens that are recompacted from bulk samples. This form shall <u>not</u> be used to record information for thin-wall tube samples.

10.3.1.1 <u>Item 8</u> - Record a "Y" (Yes) or "N" (No) to denote whether the sample reached 5% total vertical permanent strain during the preconditioning stage of the test procedure (Sections 8.1.2.3 and 8.2.2.3). Also, note with a "Y" (Yes) or "N" (No) whether or not the sample reached 5% total vertical permanent strain during the testing sequence. Record the number of test sequences completed, either partially or completely, for the given sample.

10.3.1.2 <u>Item 9</u> - Record the specimen dimensions and perform the area and volume calculations.

10.3.1.3 <u>Item 10</u> - Record the compaction weights as per Appendix B (Type 1) or Appendix C (Type 2).

10.3.1.4 <u>Item 11</u> - Record the in situ moisture content/density values used as the basis for compaction of the specimen as per sections 7.3.1 and 7.3.2. These values were obtained from nuclear methods in the field (GPS test sections). If these values are not available (or not used), record the optimum moisture content, maximum dry density and 95% maximum dry density values used as the basis for compaction of the specimen as per section 7.3.3.

10.3.1.5 <u>Item 12</u> - Record the moisture content of the compacted material as per section 3.16 of Appendix B (Type 1) or section 3.12 of Appendix C (Type 2). Record the moisture content of the material after the resilient modulus test as per section 8.1.2.12 (Subgrade) or section 8.2.2.12 (Base/subbase). Also, record the target density used for specimen recompaction.

10.3.1.6 <u>Item 13</u> - Record the results and accompanying information for the quick-shear test procedure as per section 8.1.2.10 (Subgrade) or 8.2.2.10 (Base/Subbase).

10.3.2 Form T46B shall be used to record general information concerning the specimen and layer being tested. This form shall be completed only for thin-wall tube specimens. This form shall not be used to record information for recompacted samples.

10.3.2.1 Item 8 - Record the approximate distance from the top of the subgrade to the top of the specimen. This information can be found on the field data sheets for the test section in question.

10.3.2.2 Item 9 - Record a "Y" (Yes) or "N" (No) to denote whether the sample reached 5% total vertical permanent strain during the preconditioning stage of the test procedure (Sections 8.1.2.3 and 8.2.2.3). Also, note with a "Y" (Yes) or "N" (No) whether or not the sample reached 5% total vertical permanent strain during the testing sequence. Record the number of test sequences completed, either partially or completely, for the given sample.

10.3.2.3 Item 10 - Record the specimen dimensions and perform the area and volume calculations. Record the weight of the specimen.

10.3.2.4 Item 11 - Record the moisture content (in situ) prior to resilient modulus testing. For thin-wall tube samples, this value shall be the moisture content of the layer being tested as per the nuclear methods in the field, or in the absence of this information, the jar moisture sample results. Record the moisture content at the completion of resilient modulus testing as per section 8.1.2.12. Record the wet and dry density of the thin-wall tube sample.

10.3.2.5 Item 12 - Record the results and accompanying information for the quick-shear test procedure as per section 8.1.2.10 (Subgrade).

10.3.3 Record the test data for each specimen in a format similar to Worksheet T46 and attach with Laboratory Data Form T46A or Form T46B. The testing data for all test sequences shall be submitted to the FHWA COTR. Table 3 illustrates the completion of Worksheet T46 for one testing sequence. The following information shall be recorded on Worksheet T46:

10.3.3.1 Column 1 - Record the chamber confining pressure for the testing sequence. Only one entry need be made for the last five load cycles. This entry should correspond exactly with the confining pressure levels shown in Table 1 (Subgrade) or Table 2 (Base/subbase).

10.3.3.2 Column 2 - Record the nominal axial cyclic stress for the testing sequence. Only one entry need be made for the last five load cycles. This entry should correspond exactly with the nominal axial cyclic stress required in Table 1 (Subgrade) or Table 2 (Base/subbase).

10.3.3.3 Columns 4 through 9 - Record the actual applied loads and stresses for each of the last five load cycles as shown on the worksheet.

1. ***LABORATORY IDENTIFICATION CODE*** 1111
2. ***STATE CODE*** 91
3. ***SHRP SECTION ID*** 910101
4. ***FIELD SET NO.*** 1
5. ***LAYER NUMBER*** 1
6. ***LAYER TYPE*** (1 = subgrade, 2 = base/subbase) 1
7. ***SAMPLING AREA NO.*** (SA-)11
8. ***SHRP LABORATORY TEST NUMBER*** 1
9. ***LOCATION NUMBER*** A1
10. ***SHRP SAMPLE NUMBER*** TS01
11. ***MATERIAL TYPE*** 2
12. ***TEST DATE*** 01-02-93
13. ***RESILIENT MODULUS TESTING***

Initial length = 141.7 mm
Initial area = 4168 mm^2

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PARAMETER	***Chamber Confining Pressure***	***Nominal Maximum Axial Stress***	***Cycle No.***	***Actual Applied Max. Axial Load***	***Actual Applied Cyclic Load***	***Actual Applied Contact Load***	***Actual Applied Max. Axial Stress***	***Actual Applied Cyclic Stress***	***Actual Applied Contact Stress***	***Recov Def. LVDT #1 Reading***	***Recov Def. LVDT #2 Reading***	***Average Recov Def. LVDT 1 and 2***	***Resilient Strain***	***Resilient Modulus***
DESIGNATION	S_3	S_{cyclic}	c_i	P_{max}	P_{cyclic}	$P_{contact}$	S_{max}	S_{cyclic}	$S_{contact}$	H_1	H_2	H_{avg}	ε_r	M_r
UNIT	kPa	kPa	---	N	N	N	kPa	kPa	kPa	mm	mm	mm	mm/mm	MPa
DATA FORMAT	_ _ _ . _	_ _ _ . _	-	_ _ _ _._	_ _ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _._	_._ _ _ _ _	_._ _ _ _ _	_._ _ _ _ _	_._ _ _ _ _	_ _ _.
LAST 5 LOAD CYCLES	41.4	13.8	1	57.5	51.8	5.7	13.8	12.4	1.4	.01118	.01120	.01119	.000079	157.0
			2	57.0	51.3	5.7	13.7	12.3	1.4	.01120	.01123	.01122	.000079	155.4
			3	58.0	52.2	5.8	13.9	12.5	1.4	.01118	.01122	.01120	.000079	158.1
			4	57.5	51.8	5.7	13.8	12.4	1.4	.01116	.01119	.01118	.000079	157.2
			5	57.7	51.9	5.8	13.8	12.4	1.4	.01119	.01119	.01119	.000079	157.0
	COLUMN AVERAGE			57.5	51.8	5.7	13.8	12.4	1.4	.01118	.01121	.01119	.000079	157.0
	STANDARD DEV.			0.4	0.3	0.1	0.1	0.1	0 0	.00001	.00002	.00001	.000000	1.0

SUBMITTED BY, DATE

____
LABORATORY CHIEF
Affiliation ____________________

CHECKED AND APPROVED, DATE

Affiliation

Worksheet T46, January 2006 (Partial)

10.3.3.4 Columns 10 through 12 - Record the recoverable axial deformation of the sample for each LVDT independently for each of the last five load cycles. Average the response from the two LVDTs and record this value in column 12. This value will be used to calculate the axial strain of the material.

10.3.3.5 Column 13 – Compute the axial strain for each of the last five load cycles. This value is computed by dividing column 12 by the original length of the specimen, L_0, which was recorded on Laboratory Test Data Form T46A (recompacted specimens) or Form T46B (thin-wall tube specimens).

10.3.3.6 Column 14 – Compute the resilient modulus for each of the last five load cycles. This value is computed by dividing column 8 by column 13.

10.3.3.7 Average – Compute the average of the last five load cycles for each column.

10.3.3.8 Standard Deviation – Compute the standard deviation of the values for each column for the last five load cycles using the equation:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{\sum x_i^2 - \frac{(\sum x_i)^2}{n}}{n-1}}$$

10.4 Comments on Laboratory Data Form T46A (recompacted specimens) or Form T46B (thin-walled tube specimens) shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes associated with resilient modulus testing are:

Codes	Comment
80	Due to insufficient size of the bulk sample, the test sample was used for the last test (Protocol P46, if the sample was reconstituted was saved and stored for possible future use by the LTPP program.
81	A seperate test sample was used for classification and description tests (Protocols P46 or P52)
82	Due to the insufficient size of the bulk sample, the test sample for the gradation test (Protocol P41 or P51) was also used to complete the classification and description tests. (Protocol P47 or P52)
83	Due to the insufficient size of the bulk sample, the test sample for the moisture-density test (Protocol P44 or P55) was saved after the test and reused for the resilient modulus testing (Protocol P46).

Codes	Comment
85	Due to the insufficient size of the bulk sample, only dry sieving was used for the gradation test (Protocol P41 or P51). The test sample after the gradation test was saved and reused to reconstitute the test sample of the resilient modulus testing (Protocol P46).
86	Due to the insufficient size of the bulk sample, only dry sieving was used for the gradation test (Protocol P41 or P51). The test sample was reused for other designated tests and the remnant of the sample was saved and stored for possible future use by the LTPP program.
87	The "undisturbed" thin-wall tube sample was used for the resilient modulus testing (Protocol P46).
88	The thin-wall tube sample was not suitable, therefore a reconstituted sample from the bulk samples was used for the resilient modulus testing.
89	The thin-wall tube sample was not available. The test sample for the resilient modulus testing (Protocol P46) was reconstituted from the bulk sample.
90	An excess portion of the thin-wall tube sample was saved and stored for possible future use by the LTPP program.
94	The test was not performed because of the oversize aggregate; sample was stored until further instruction from the FHWA-LTPP division.

APPENDIX A
SAMPLE PREPARATION

The following provides guidelines for reconstituting the material to be tested so as to produce a sufficient amount of material needed to prepare the appropriate sample type (Type 1 or Type 2 sample) at the designated moisture content and density.

1. SAMPLE CONDITIONING

If the sample is damp when received from the field, dry it until it becomes friable. Drying may be in air or by use of a drying apparatus such that the temperature does not exceed 60°C (140°F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles. Moderate pressure and a 4.75-mm (No. 4) sieve have been found to be adequate to break down clay lumps.

2. SAMPLE PREPARATION

2.1 Determine the moisture content (w_1) of the sample as per LTPP Protocol P49. The sample moisture content shall weigh not less than 200 g (0.44 lb) for samples with a maximum particle size smaller than the 4.75-mm (No. 4) sieve and not less than 500 g (1.1 lbs) for samples with a maximum particle size greater than the 4.75-mm (No. 4) sieve.

2.2 Determine the appropriate total volume (V) of the compacted specimen to be prepared. The total volume must be based on a height of the compacted specimen slightly greater than that required for resilient testing to allow for trimming of the specimen ends if necessary. Compacting to a height/diameter ratio of 2.1 to 2.2 will provide adequate material for this purpose.

2.3 Determine the weight of oven-dry soil solids (W_s) and water (W_w) required to obtain the desired dry density (γ_d) and moisture content (w) as follows:

$$W_s \text{ (pounds)} = \gamma_d \text{ (pounds per cubic foot)} \times V \text{ (cubic feet)}$$
$$W_s \text{ (grams)} = W_s \text{ (pounds)} \times 454$$
$$W_w \text{ (pounds)} = W_s \text{ (pounds)} \times w \text{ (\%/100)}$$
$$W_{wo} \text{ (grams)} = W_w \text{ (pounds)} \times 454$$

2.4 Determine the total weight of the prepared material sample (W_t) required to obtain W_s to produce the desired specimen volume V at dry density γd and moisture content w.

$$W_t \text{ (grams)} = W_s \times (1 + w/100)$$

2.5 Determine the weight of the dried sample (W_{ad}), with the moisture content (w_1), required to obtain W_s, including an additional amount W_{as} of at least 500 grams (1.1 lbs) to provide material for the determination of moisture content at the time of compaction.

$$W_{ad} \text{ (grams)} = (W_s + W_{as}) \times (1 + w_1/100)$$

2.6 Determine the weight of water (W_{aw}) required to increase the weight from the existing dried weight of water (W_1) to the weight of water (W_w) corresponding to the desired compaction moisture content (w).

$$W_1 \text{ (grams)} = (W_s + W_{as}) \times (w_1/100)$$
$$W_2 \text{ (grams)} = (W_s + W_{as}) \times (w/100)$$
$$W_{aw} \text{ (grams)} = W_2 - W_1$$

2.7 Place the sample (W_{ad}) determined in 7.3.7 into a mixing pan.

2.8 Add the water (W_{aw}) to the sample in small amounts and mix thoroughly after each addition.

2.9 Place the mixture in a plastic bag. Seal the bag and place it in a second bag and seal it.

2.10 After mixing and storage at a minimum of overnight and a maximum of two days, weigh the wet soil and container to the nearest gram and record this value on the appropriate form (see Worksheet T46).

2.11 The material is now ready for compaction.

APPENDIX B
COMPACTION OF TYPE 1 SOILS

Type 1 soils will be recompacted using a 152-mm (6.0-inch) split mold and vibratory compaction. Split molds with an inside diameter of 152 mm (6 inches) shall be used to prepare 305-mm (12-inch) high test samples for all Type 1 materials with nominal particle sizes less than or equal to 37.5 mm (1.5 inches). If 10 percent or less of a Type 1 sample is retained on the 37.5-mm (1.5-inch) sieve, the material greater than the 37.5-mm (1.5-inch) sieve shall be scalped off prior to testing. If <u>more</u> than 10 percent of the sample is retained on the 37.5-mm (1.5-inch) sieve, the material shall not be tested and the material shall be stored until further notice. Instructions concerning the testing of these materials will be issued at a later date.

Cohesionless soils shall be compacted in 6 lifts in a split mold mounted on the base of the triaxial cell as shown in Figure 5. Compaction forces are generated by a vibratory impact hammer without kneading action powered by air or electricity and of sufficient size to provide the required laboratory densities while minimizing damage to the sample membrane.

1. SCOPE

This method covers the compaction of Type 1 soils for use in resilient modulus testing.

2. APPARATUS

2.1 A split mold, with an inside diameter of 152 mm (6 inches) having a minimum height of 381 mm (15 inches) (or sufficient height to allow guidance of the compaction head for the final lift).

2.2 Vibratory Compaction Device

Vibratory compaction shall be provided using electric rotary or demolition hammers. The specifications for the hammers are listed below:

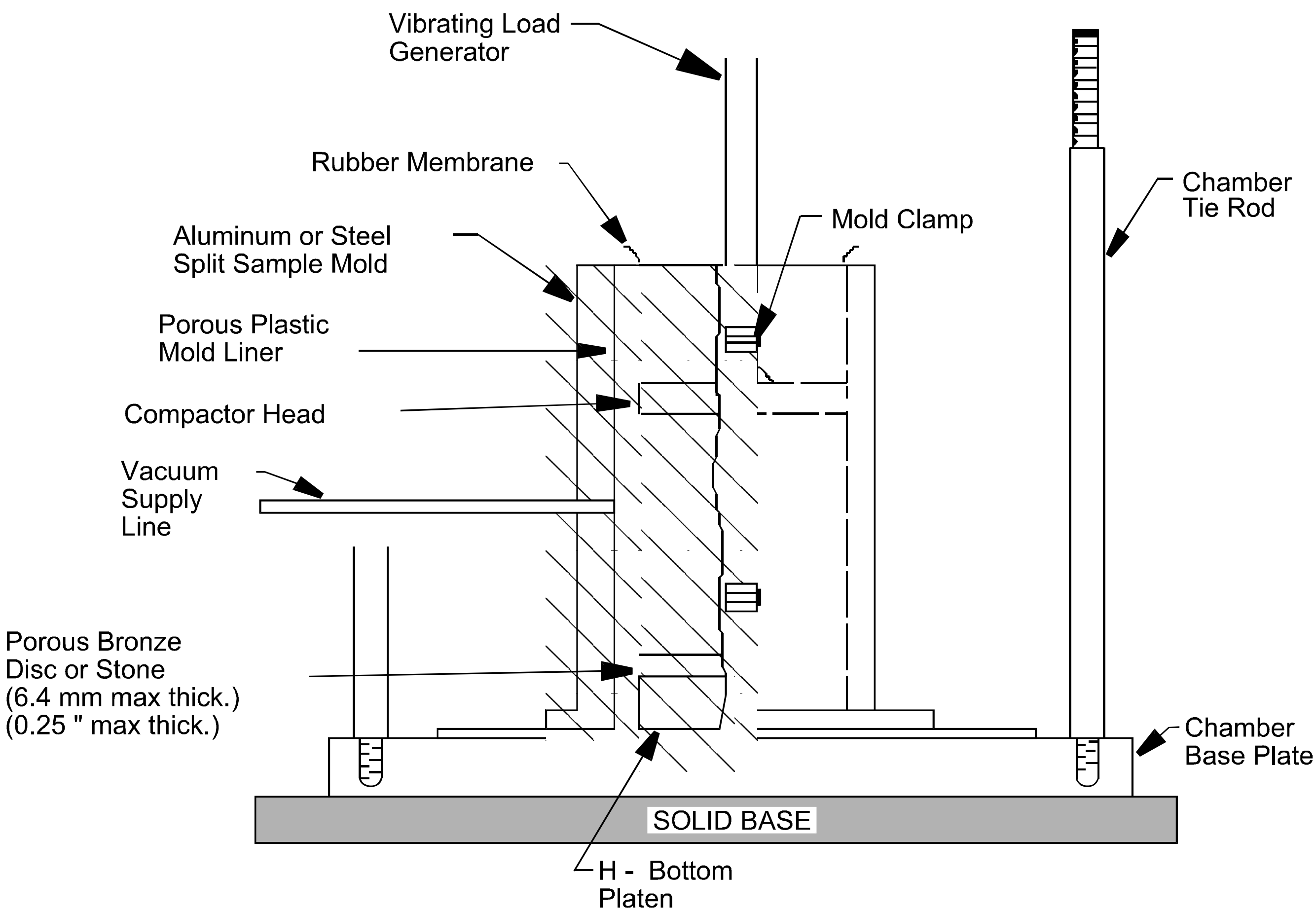
Rated watts input:	750 – 1,250 watts
Blows per minute:	1,800 – 3,000

The compactor head shall be at least 13-mm (0.5-inch) thick and have a diameter of not less than 146 mm (5.75 in.).

NOTE 20: The vibratory compaction device shall be approved by the FHWA COTR prior to the initiation of the testing program.

3. PROCEDURE

3.1 For removable platens, tighten the bottom platen into place on the triaxial cell base. It is essential that an airtight seal is obtained and that the bottom platen interface constitutes a rigid body since calculations of strain assume zero movement of the bottom platen under load.



Note: Compactor head should be 6.35 ± 0.5 mm (0.25 ± 0.02") smaller than specimen diameter.

Figure 5. Typical apparatus for vibratory compaction of Type 1 unbound materials.

3.2 Place the paper filters, two bronze discs/porous stones and the top platen on the bottom platen. Determine the total height of the top and bottom platens and stones to the nearest 0.25 mm (0.1 inch).

3.3 Remove the top platen and bronze disc/porous stone. Measure the thickness of the rubber membrane with a micrometer.

3.4 Place the rubber membrane over the bottom platen, lower bronze disc/porous stone and paper filters. Secure the membrane to the bottom platen using an O-ring or other means to obtain an airtight seal.

3.5 Place the split mold around the bottom platen and draw the membrane up through the mold. Tighten the split mold firmly in place. Exercise care to avoid pinching the membrane.

3.6 Stretch the membrane tightly over the rim of the mold. Apply a vacuum to the mold sufficient to draw the membrane on contact. If wrinkles are present in the membrane, release the vacuum, adjust the membrane, and reapply the vacuum. The use of a porous plastic forming jacket liner helps to ensure that the membrane fits smoothly inside the mold. The vacuum is maintained throughout the compaction procedure.

3.7 Measure, to the nearest 0.25 mm (0.1 inch), the inside diameter of the membrane lined mold and the distance between the top of the lower porous stone and the top of the mold.

3.8 Determine the volume, V, of the specimen to be prepared using the diameter determined in step 3.7 and a value of height between 305 and 318 mm (12 and 12.5 inches).

3.9 Determine the weight of material, at the prepared water content, to be compacted into the volume, V, to obtain the desired density.

3.10 For 152-mm (6-inch) diameter specimens (specimen height of 305 mm (12 inches)) 6 layers of 2 inches (51 mm) per layer are required for the compaction process. Determine the weight of wet soil, W_L, required for each layer.

$$W_L = W_t/N$$

Where: W_t = total weight of test specimen to produce appropriate density,
N = number of layers to be compacted.

3.11 Place the total required weight of soil for all lifts, W_{ad}, into a mixing pan. Add the required amount of water, W_{aw}, and mix thoroughly.

3.12 Determine the weight of wet soil and the mixing pan.

3.13 Place the amount of wet soil, W_L, into the mold. Avoid spillage. Using a spatula, draw soil away from the inside edge of the mold to form a small mound at the center.

3.14 Insert the vibrator head and vibrate the soil until the distance from the surface of the compacted layer to the rim of the mold is equal to the distance measured up in step 3.7 minus the thickness of the layer selected in step 3.10. This may require removal and reinsertion of the vibrator several times until experience is gained in gaging the vibration time which is required.

3.15 Repeat steps 3.13 and 3.14 for each new layer after first scarifying the top surface of the previous layer to a depth of 6.4 mm (¼ inch). The measured distance from the surface of the compacted layer to the rim of the mold is successively reduced by the layer thickness selected in step 3.10. The final surface shall be a smooth horizontal plane. As a recommended final step where porous bronze discs are used, the top plate shall be placed on the sample and seated with the vibrator head. If necessary, due to degradation of the first membrane, a second membrane can be applied to the sample at the conclusion of the compaction process.

3.16 When the compaction process is completed, weight the mixing pan and the excess soil. This weight subtracted from the weight determined in step 3.12 is the weight of the wet soil used (weight of specimen). Verify the compaction water content, W_c, of the excess soil using care in covering the pan of the wetted soil during compaction to avoid drying and loss of moisture. The moisture content of this sample shall be conducted using LTPP Protocol P49.

Proceed with section 8.2 of this protocol.

APPENDIX C
COMPACTION OF TYPE 2 SOILS

The general method of compaction of Type 2 soils will be that of static loading (a modified version of the double plunger method). If testable thin-walled tubes are available, specimens shall not be recompacted.

Specimens shall be recompacted in a 71-mm (2.8-inch) diameter mold. The process is one of compacting a known weight of soil to a volume that is fixed by the dimensions of the mold assembly (mold shall be of a sufficient size to produce specimens 71 mm (2.8 inches) in diameter and 152 mm (6 inches) in height). A typical mold assembly is shown in Figure 6. As an alternative for soils lacking in cohesion, a mold with the membrane installed and held by vacuum, as in Appendix B, may be used. Several steps are required for static compaction as follows in the Procedures section of this appendix and as illustrated in Figures 7–11.

NOTE 21: Alternatively, the sample can be molded to 165 mm (6.5 inches) rather than 152 mm (6.0 inches) and then a miter box can be used to square the ends of the sample and reach the final testable length of 142 mm (5.6 inches). This tends to produce more consistently shaped (level) specimens.

1. SCOPE

   This method covers the compaction of Type 2 soils for use in resilient modulus testing.

2. APPARATUS

   As shown in Figure 6.

   NOTE 22: As an alternative for soils lacking in cohesion, a mold with the membrane installed and held by vacuum, as in Appendix B, may be used.

3. PROCEDURE

3.1 Five layers of equal weight shall be used to compact the specimens using this procedure. Determine the weight of wet soil, W_L, to be used per layer where $W_L = W_t/5$.

3.2 Place one of the spacer plugs into the specimen mold.

3.3 Place the weight of soil, W_L, determined in step 3.1 into the specimen mold. Using a spatula, draw the soil away from the edge of the mold to form a slight mound in the center.

3.4 Insert the second plug and place the assembly in the static loading machine. Apply a small load. Adjust the position of the mold with respect to the soil weight, so that the distances from the mold ends to the respective spacer plug are equal. Soil pressure developed by the initial loading will serve to hold the mold in place. By having both spacer plugs reach the zero volume change simultaneously, more uniform layer densities are obtained.

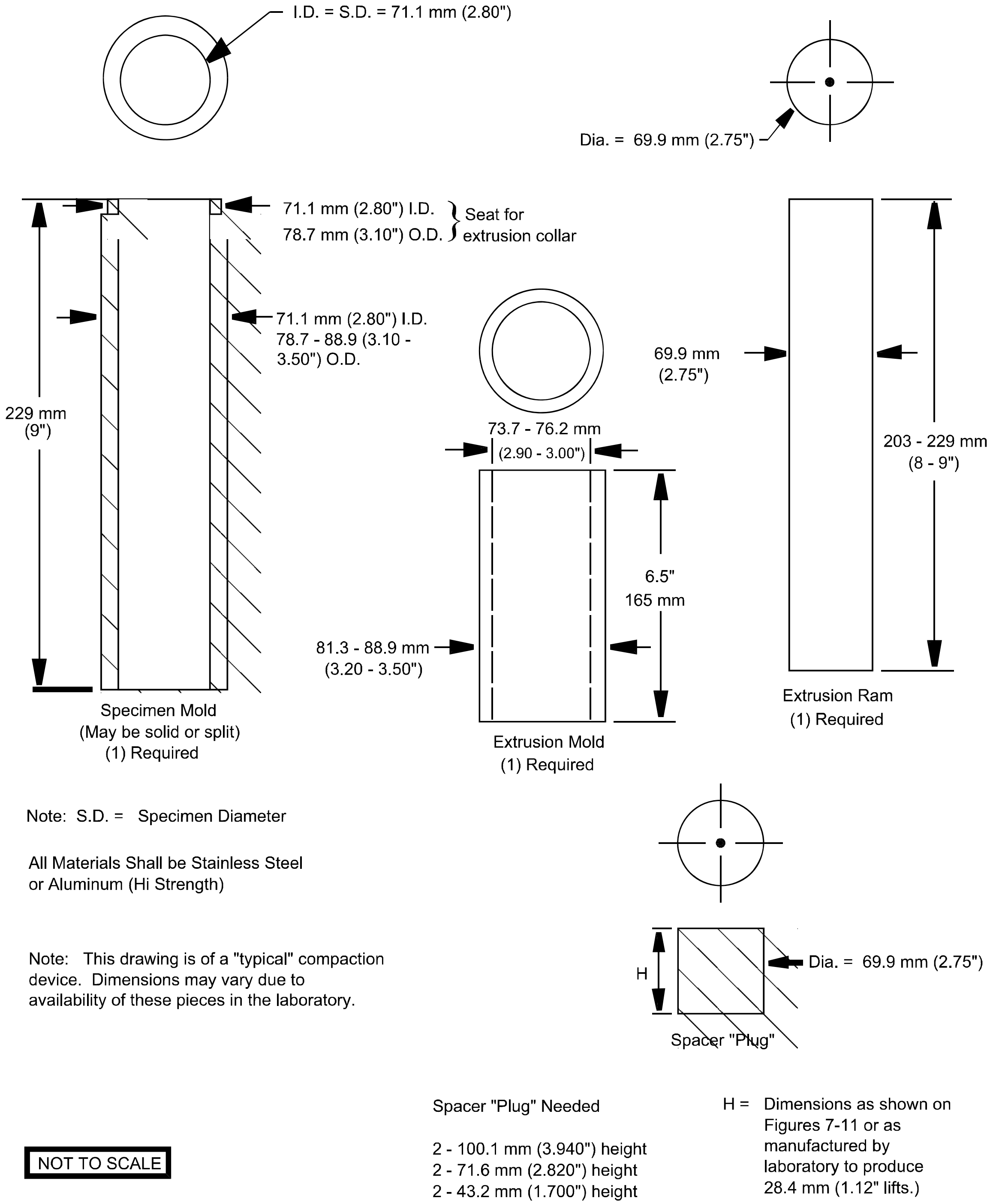


Figure 6. Typical apparatus for static compaction of Type 2 materials.

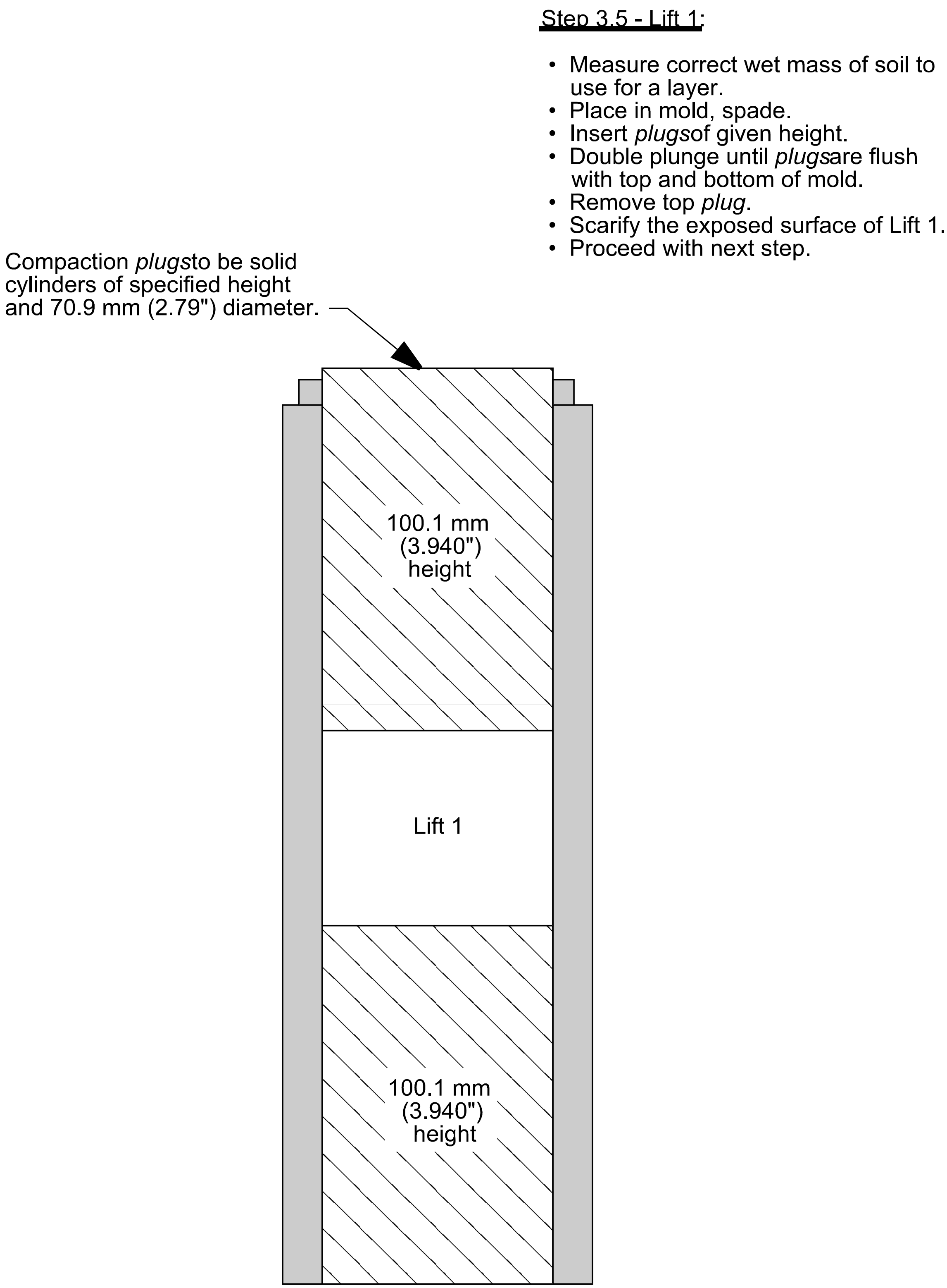


Figure 7. Compaction of Type 2 soil, lift 1.

<u>Step 3.7 - Lift 2:</u>

- Measure correct wet mass of soil to use for a layer.
- Place in mold, spade.
- Insert 71.6 mm (2.820") *plug.*
- Plunge until *plugs*are flush with top and bottom of mold.
- Flip mold over and remove 100.1 mm (3.940") *plug*, keeping the 71.6 mm (2.820") *plug*in place.
- Scarify the exposed surface of Lift 1.
- Proceed with next step.

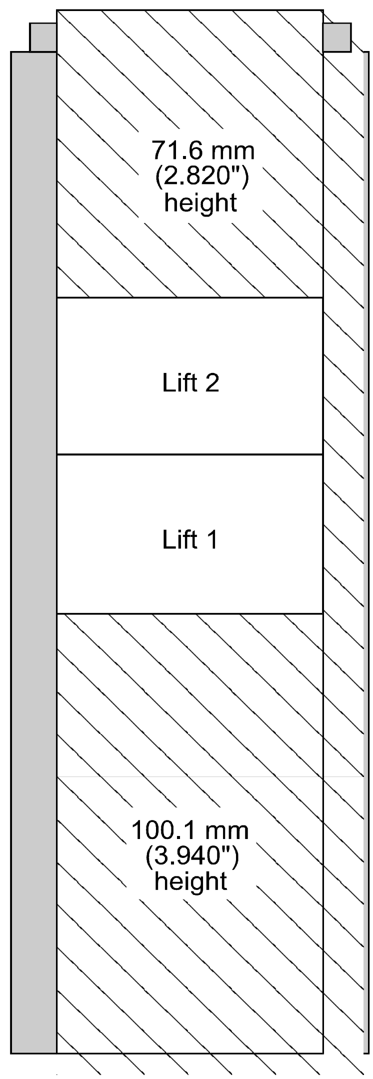


Figure 8. Compaction of Type 2 soil, lift 2.

<u>Step 3.9 - Lift 3:</u>

- Measure correct wet weight of soil to use for a layer.
- Place in mold, spade.
- Insert 71.6 mm (2.820") *plug*.
- Plunge until *plugs* are flush with top and bottom of mold.
- Flip mold over and remove 71.6 mm (2.820") *plug*, from the top of Lift 2, keeping the 71.6 mm (2.820") *plug* (on Lift 3) in place.
- Scarify the exposed surface of Lift 2.
- Proceed with next step.

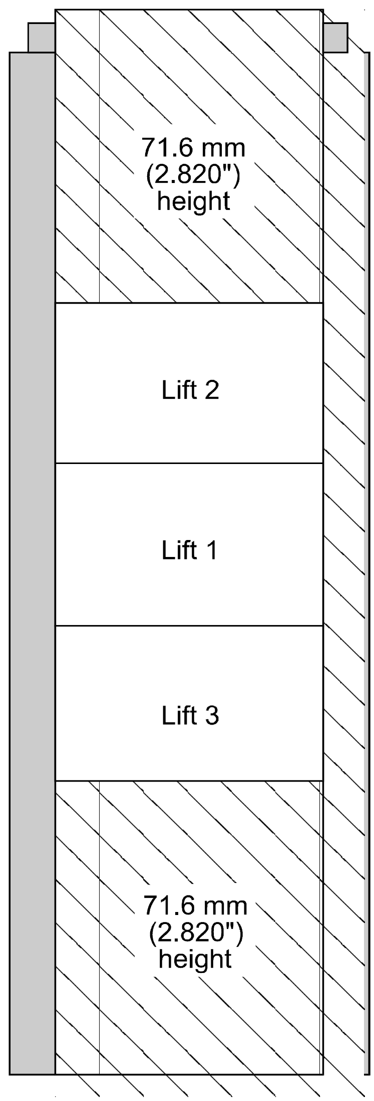


Figure 9. Compaction of Type 2 soil, lift 3.

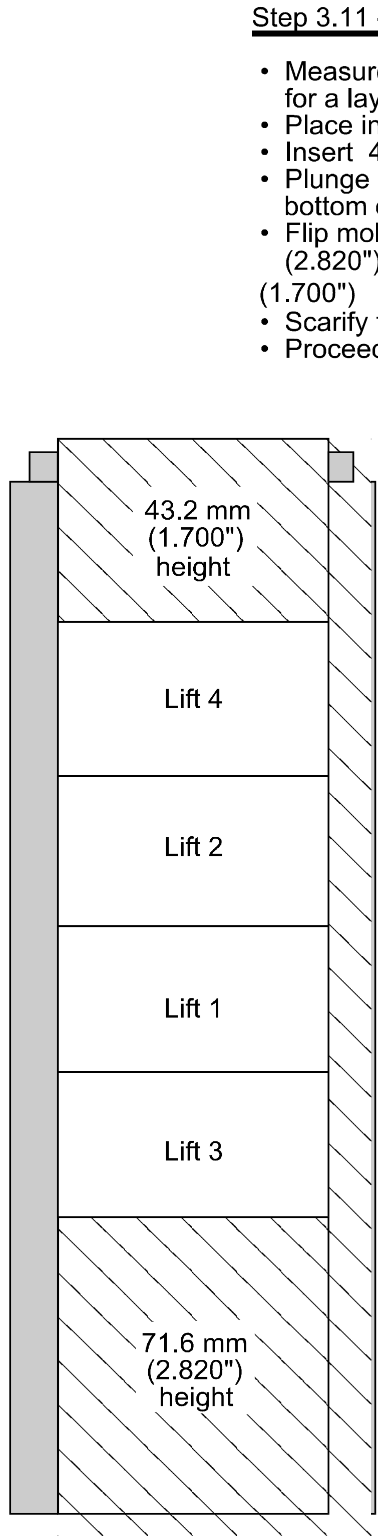


Figure 10. Compaction of Type 2 soil, lift 4.

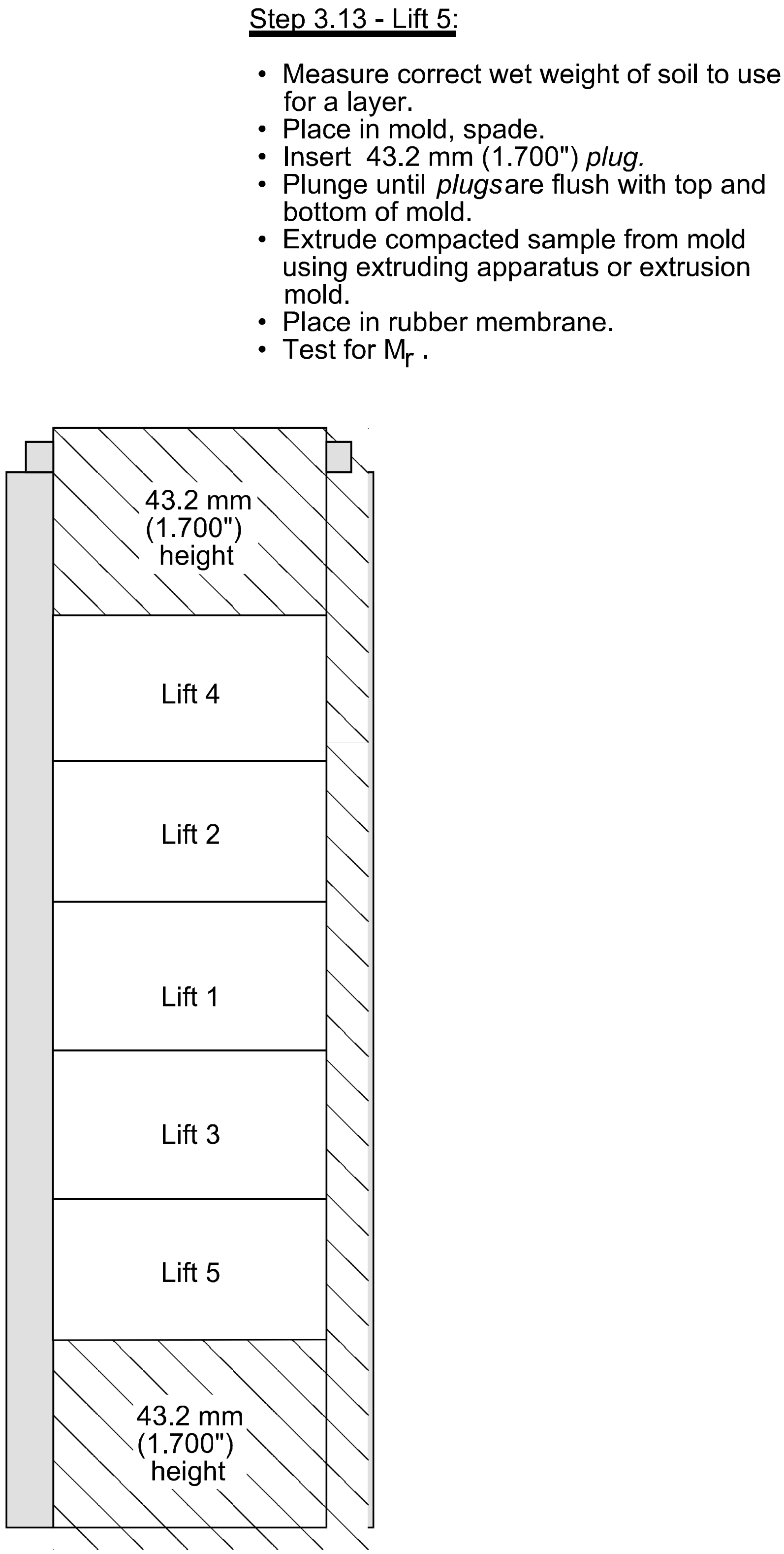


Figure 11. Compaction of Type 2 soil, lift 5.

3.5 Slowly increase the load until the plugs rest firmly against the mold ends. Maintain this load for a period of not less than one minute. The amount of soil rebound depends on the rate of loading and load duration. The slower the rate of loading and the longer the load is maintained, the less the rebound (see Figure 7).

NOTE 23: To obtain uniform densities, extreme care must be taken to center the first soil layer exactly between the ends of the specimen mold. Checks and any necessary adjustments should be made after completion of steps 4 and 5.

NOTE 24: Use of compaction by measuring the plunge movements to determine that the desired volume has been reached for each layer is an acceptable alternative to the user of spacer plugs.

3.6 Decrease the load to zero and remove the assembly from the loading machine.

3.7 Remove the loading ram. Scarify the top surface of the compacted layer to a depth of 3.2 mm (⅛ inch) and put the weight of wet soil, W_L, for the second layer in place and form a mound. Add a spacer plug of height shown in Figure 8.

3.8 Slowly increase the load until the plugs rest firmly against the top of the mold end. Maintain load for a period of not less than one minute (see Figure 8).

3.9 Remove the load and flip the mold over and remove the bottom plug keeping the top plug in place. Scarify the bottom surface of layer 1 and put the weight of wet soil, W_L, for the third layer in place and form a mound. Add a spacer ring of height shown in Figure 9.

3.10 Place the assembly in the loading machine. Increase the load slowly until the spacer plugs firmly contact the ends of the specimen mold. Maintain this load for a period of not less than one minute.

3.11 Follow the steps presented in Figure 10 and 11 to compact the remaining two layers.

3.12 After compaction is completed, determine the moisture content of the remaining soil using LTPP Protocol P49. Record this value on LTPP Laboratory Data Form T46A.

3.13 Using the extrusion ram, press the compacted soil out of the specimen mold and into the extrusion mold. Extrusion should be done slowly to avoid impact loading the specimen.

3.14 Using the extrusion mold, carefully slide the specimen off the ram, onto a solid end platen. The platen should be circular with a diameter equal to that of the specimen and have a minimum thickness of 13 mm (0.5 in.). Platens shall be of a material which will not absorb soil moisture.

3.15 Determine the weight of the compacted specimen to the nearest gram. Measure the height and diameter to the nearest 0.25 mm (0.01 inch). Record these values on Worksheet T46.

3.16 Place a platen similar to the one used in step 3.13 on top of the specimen.

3.17 Using a vacuum membrane expander, place the membrane over the specimen. Carefully pull the ends of the membrane over the end platens. Secure the membrane to each platen using O-rings or other means to provide an airtight seal.

Proceed with Section 8.1 of this protocol.

APPENDIX D
DETERMINATION OF APPLIED CONTACT LOAD

Prior to conduct of the resilient modulus test procedure, the contact load levels must be adjusted to compensate for the resultant force created by the chamber pressure (upward force) and the weight of the chamber piston rod, including the LVDT holder (downward force). This appendix provides guidelines and an example as to the proper method with which to establish the contact load levels.

1. PROCEDURE

Using the confining pressure in kPa (A), the area of the rod in m^2 (B) and the weight of the rod in kN (C), the following equation can be used to determine the resultant force (F) from the downward force of the chamber piston rod assembly and the uplift force of the confining pressure on the chamber piston rod assembly:

$$F\ (\text{kN}) = (A \times B) - C$$

For this equation, the force is positive if the resultant force is upward and negative if the resultant force is in the downward direction. This result is then added to the contact load placed on the specimen (the sign of "F", positive or negative, will determine the direction of the adjustment). Therefore:

$$P_{contact\text{-}adjusted} = P_{contact} + F$$

NOTE 25: For very low loads (primarily Type 2 subgrade samples), this may result in an adjusted load that is less than 5 N (1.1 lbf). In this case, a minimum of 5 N (1.1lbf) (or the lowest sensitivity rating of the load cell) is always used as the absolute minimum contact load to stay within the load cell sensitivity range.

After establishing $P_{contact\text{-}adjusted}$, the maximum load must also be adjusted to produce the correct cyclic load on the specimen. This is a straightforward procedure governed by the following equation:

$$P_{max\text{-}adjusted} = P_{contact\text{-}adjusted} + P_{cyclic}$$

Where P_{max} and P_{cyclic} are as defined in Section 3 of the main body of this protocol.

2. EXAMPLE

An example follows for a Type 1 sample. The following test setup is given:

Specimen Diameter = 152 mm (6 inch)
Chamber Piston Rod Diam. = 25.4 mm (1 inch)
Chamber Piston Rod Assembly Weight = 0.01588 kN (3.66 lbf)

Using this information, the following values can be calculated:

Area of Sample: 0.01815 m^2 (0.1954 ft^2)
Area of Chamber Piston Rod: 0.00051 m^2 (0.0055 ft^2)

For Type 1 testing of base/subbase materials, confining pressures of 21, 35, 69, 103, and 138 kPa (3, 5, 10, 15, and 20 psi) are used. Therefore, using all of the above values and the equations in section 1 of this appendix, the adjusted contact force ($P_{contact\text{-}adjusted}$) can be determined as shown in table 4.

Using $P_{contact\text{-}adjusted}$, the adjusted maximum loading parameters can be determined using the equation:

$$P_{max\text{-}adjusted} = P_{cyclic} + P_{contact\text{-}adjusted}$$

These calculations need to be made and the contact and maximum loads adjusted for each combination of pavement layer and material type (base/subbase – Type 1 and Type 2, subgrade – Type 1 and Type 2) and for each triaxial cell (since each triaxial cell may have a different resultant force, "F") that is used for resilient modulus testing.

Table 4. Example calculation matrix for $P_{contact\text{-}mod}$

Sequence Number	Confining Press., kPa (psi)	Required Contact Load, kN[1] (lbf) ($P_{contact}$)	Resultant Force, kN[2] (lbf) (F)	Adjusted Contact Load, kN[3] (lbf) ($P_{contact\text{-}adjusted}$)
0	103 (15)	0.188 (42)	0.037 (8.3)	0.224 (50)
1	21 (3)	0.0375 (8)	-0.00517 (-1.2)	0.0324 (7)
2	21 (3)	0.0751 (17)	-0.00517 (-1.2)	0.0699 (16)
3	21 (3)	0.113 (25)	-0.00517 (-1.2)	0.107 (24)
4	35 (5)	0.0626 (14)	0.00197 (0.4)	0.0645 (15)
5	35 (5)	0.125 (28)	0.00197 (0.4)	0.127 (29)
6	35 (5)	0.188 (42)	0.00197 (0.4)	0.190 (43)
7	69 (10)	0.125 (28)	0.01931 (4.3)	0.144 (32)
8	69 (10)	0.250 (56)	0.01931 (4.3)	0.270 (61)
9	69 (10)	0.375 (84)	0.01931 (4.3)	0.395 (89)
10	103 (15)	0.125 (28)	0.0367 (8.3)	0.162 (36)
11	103 (15)	0.188 (42)	0.0367 (8.3)	0.224 (50)
12	103 (15)	0.375 (84)	0.0367 (8.3)	0.412 (93)
13	138 (20)	0.188 (42)	0.0545 (12.3)	0.242 (54)
14	138 (20)	0.250 (56)	0.0545 (12.3)	0.305 (69)
15	138 (20)	0.501 (113)	0.0545 (12.3)	0.555 (125)

1. From Table 2.
2. Use equation from Section 1 of this appendix.
3. $P_{contact\text{-}adjusted} = P_{contact} + F$.

Table 5. Example calculation matrix for modified Type 1 loadings

Sequence Number	$P_{contact-adjusted}$, kN[1] (lbf)	P_{cyclic}, kN[2] (lbf)	$P_{max-mod}$, kN[3] (lbf)
0	0.224 (50)	1.690 (380)	1.91 (429)
1	0.0324 (7)	0.338 (76)	0.370 (83)
2	0.0699 (16)	0.677 (152)	0.747 (168)
3	0.107 (24)	1.02 (229)	1.12 (252)
4	0.0645 (15)	0.563 (127)	0.627 (141)
5	0.127 (29)	1.13 (254)	1.252 (281)
6	0.190 (43)	1.69 (380)	1.88 (423)
7	0.144 (32)	1.13 (254)	1.27 (286)
8	0.270 (61)	2.25 (506)	2.52 (567)
9	0.395 (89)	3.38 (760)	3.77 (848)
10	0.162 (36)	1.13 (254)	1.29 (290)
11	0.224 (50)	1.69 (380)	1.91 (429)
12	0.412 (93)	3.38 (760)	3.79 (852)
13	0.242 (54)	1.69 (380)	1.93 (434)
14	0.305 (69)	2.25 (506)	2.56 (576)
15	0.555 (125)	4.51 (1014)	5.06 (1138)

1. From Table 4.
2. From Table 2.
3. $P_{max-adjusted} = P_{cyclic} + P_{contact-adjusted}$

LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
RESILIENT MODULUS OF UNBOUND GRANULAR BASE/SUBBASE MATERIALS AND SUBGRADE SOILS
***LABORATORY DATA SHEET T46A* - RECOMPACTED SAMPLES**

UNBOUND GRANULAR BASE/SUBBASE LAYERS AND SUBGRADE SOILS
SHRP TEST DESIGNATION UG07, SS07/SHRP PROTOCOL P46

LABORATORY PERFORMING TEST:________________________________
LABORATORY IDENTIFICATION CODE: __ __ __ __
SAMPLES FROM: SHRP REGION______________ STATE________ STATE CODE: __ __
EXPT. NO.: ______________ SHRP SECTION ID.:__ __ __ __ __ __
SAMPLED BY: ____________________________ FIELD SET NO.: ___
DRILLING AND SAMPLING CONTRACTOR/AGENCY
SAMPLING DATE: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __
2. LAYER TYPE (1 = subgrade, 2 = base/subbase) __
3. SAMPLING AREA NO. (SA-)__ __
4. SHRP LABORATORY TEST NUMBER __
5. LOCATION NUMBER __ __ __
6. SHRP SAMPLE NUMBER __ __ __ __
7. MATERIAL TYPE (Type 1 or Type 2) __
8. TEST INFORMATION
   PRECONDITIONING - GREATER THAN 5% PERM. STRAIN? (Y = YES OR N = NO) __
   TESTING - GREATER THAN 5% PERM. STRAIN? (Y = YES OR N = NO) __
   TESTING - NUMBER OF LOAD SEQUENCES COMPLETED (0 - 15) __ __
9. SPECIMEN INFO.:

SPEC. DIAM., mm
- TOP __ __ __ . __
- MIDDLE __ __ __ . __
- BOTTOM __ __ __ . __
- AVERAGE __ __ __ . __
- MEMBRANE THICKNESS(1), mm __ . __ __
- MEMBRANE THICKNESS(2), mm __ . __ __

NET DIAM, mm __ __ __ . __

HEIGHT OF SPECIMEN, CAP AND BASE, mm __ __ __ . __
HEIGHT OF CAP AND BASE, mm __ __ __ . __
INITIAL LENGTH L_o, mm __ __ __ . __
INITIAL AREA, A_o, mm^2 __ __ __ __ __ .
INITIAL VOLUME, A_oL_o, mm^3 __ __ __ __ __ __ __ .

10. SOIL SPECIMEN WEIGHT:
   INITIAL WEIGHT OF CONTAINER AND WET SOIL, grams __ __ __ __ __ . __ __
   FINAL WEIGHT OF CONTAINER AND WET SOIL, grams __ __ __ __ __ . __ __
   WEIGHT OF WET SOIL USED, grams __ __ __ __ __ . __ __
11. SOIL PROPERTIES:

IN SITUE MOISTURE CONTENT (NUCLEAR), % __ __ __ . __
IN SITU WET DENSITY (NUCLEAR), kg/m^3 __ __ __ __ . __

or
OPTIMUM MOISTURE CONTENT, % __ __ . __
MAX. DRY DENSITY, kg/m^3 __ __ __ __ . __
95% MAX. DRY DENSITY, kg/m^3 __ __ __ __ . __

12. SPECIMEN PROPERTIES:
   COMPACTION MOISTURE CONTENT, % __ __ . __
   MOISTURE CONTENT AFTER RESILIENT MODULUS TESTING, % __ __ . __
   COMPACTION DRY DENSITY, γ_d, kg/m^3 __ __ __ __ . __
13. QUICK SHEAR TEST
   STRESS-STRAIN PLOT ATTACHED (Y = YES OR N = NO) __
   TRIAXIAL SHEAR MAXIMUM STRENGTH (MAX. LOAD/X-SECTION AREA), kPa __ __ __ __.
   SPECIMEN FAIL DURING TRIAXIAL SHEAR? (Y = YES, N = NO) __
14. COMMENTS (Section 10.4 of Protocol P46)
   (a) CODE __ __, __ __, __ __, __ __, __ __, __ __
   (b) NOTE ________________________________
15. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS:________________________________
SUBMITTED BY, DATE

____
LABORATORY CHIEF
Affiliation________________

CHECKED AND APPROVED, DATE

____
Affiliation________________

LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
RESILIENT MODULUS OF UNBOUND GRANULAR BASE/SUBBASE MATERIALS AND SUBGRADE SOILS
***LABORATORY DATA SHEET T46B* - THINWALL TUBE SAMPLES**

UNBOUND GRANULAR BASE/SUBBASE LAYERS AND SUBGRADE SOILS
SHRP TEST DESIGNATION UG07, SS07/SHRP PROTOCOL P46

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
SAMPLES FROM: SHRP REGION______________ STATE________ STATE CODE: __ __
EXPT. NO.: ______________ SHRP SECTION ID.:__ __ __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO.: ___
DRILLING AND SAMPLING CONTRACTOR/AGENCY
SAMPLING DATE: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __
2. LAYER TYPE (1 = subgrade, 2 = base/subbase) __
3. SAMPLING AREA NO. (SA-) __ __
4. SHRP LABORATORY TEST NUMBER __
5. LOCATION NUMBER __ __ __
6. SHRP SAMPLE NUMBER __ __ __ __
7. MATERIAL TYPE (Type 1 or Type 2) __
8. APPROX. DISTANCE FROM TOP OF SUBGRADE TO SAMPLE, m __ . __ __
9. TEST INFORMATION
   PRECONDITIONING - GREATER THAN 5% PERM. STRAIN? (Y = YES OR N = NO) __
   TESTING - GREATER THAN 5% PERM. STRAIN? (Y = YES OR N = NO) __
   TESTING - NUMBER OF LOAD SEQUENCES COMPLETED (0 - 15) __ __
10. SPECIMEN INFO.:
    SPEC. DIAM., mm
        TOP __ __ __ . __
        MIDDLE __ __ __ . __
        BOTTOM __ __ __ . __
        AVERAGE __ __ __ . __
        MEMBRANE THICKNESS(1), mm __ . __ __
        MEMBRANE THICKNESS(2), mm __ . __ __
    NET DIAM, mm __ __ __ . __
    INITIAL LENGTH L_o, mm __ __ __ . __
    INITIAL AREA, A_o, mm^2 __ __ __ __ __ .
    INITIAL VOLUME, A_oL_o, mm^3 __ __ __ __ __ __ __ .
    INITIAL WEIGHT, grams __ __ __ __ __ . __
11. SOIL PROPERTIES:
    IN SITU MOISTURE CONTENT, % __ __ . __
    MOISTURE CONTENT AFTER RESILIENT MODULUS TESTING, % __ __ . __
    WET DENSITY, γ_w, kg/m^3 __ __ __ __ . __
    DRY DENSITY, γ_d, kg/m^3 __ __ __ __ . __
12. QUICK SHEAR TEST
    STRESS-STRAIN PLOT ATTACHED (Y = YES OR N = NO) __
    TRIAXIAL SHEAR MAXIMUM STRENGTH (MAX. LOAD/X-SECTION AREA), kPa __ __ __ __.
    SPECIMEN FAIL DURING TRIAXIAL SHEAR? (Y = YES, N = NO) __
13. COMMENTS (Section 10.4 of Protocol P46)
    (a) CODE __ __, __ __, __ __, __ __, __ __, __ __
    (b) NOTE ____
14. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS:____

SUBMITTED BY, DATE   CHECKED AND APPROVED, DATE

__________________________   __________________________
LABORATORY CHIEF
Affiliation__________________   Affiliation__________________

LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
RESILIENT MODULUS OF UNBOUND GRANULAR BASE/SUBBASE MATERIALS AND SUBGRADE SOILS
LABORATORY DATA SHEET T46 WORKSHEET
UNBOUND GRANULAR BASE/SUBBASE LAYERS AND SUBGRADE SOILS
SHRP TEST DESIGNATION UG07, SS07/SHRP PROTOCOL P46

1. LABORATORY IDENTIFICATION CODE __ __ __ __
2. STATE CODE __ __
3. SHRP SECTION ID __ __ __ __ __ __
4. FIELD SET NO. __
5. LAYER NUMBER __
6. LAYER TYPE (1 = subgrade, 2 = base/subbase) __
7. SAMPLING AREA NO. (SA-) __ __
8. LABORATORY TEST NUMBER __
9. LOCATION NUMBER __ __ __
10. LTPP SAMPLE NUMBER __ __ __ __
11. MATERIAL TYPE __
12. TEST DATE __ __ - __ __ - __ __ __ __
13. RESILIENT MODULUS TESTING

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PARAMETER	***Chamber Confining Pressure***	***Nominal Maximum Axial Stress***	***Cycle No.***	***Actual Applied Max. Axial Load***	***Actual Applied Cyclic Load***	***Actual Applied Contact Load***	***Actual Applied Max. Axial Stress***	***Actual Applied Cyclic Stress***	***Actual Applied Contact Stress***	***Recov Def. LVDT #1 Reading***	***Recov Def. LVDT #2 Reading***	***Average Recov Def. LVDT 1 and 2***	***Resilient Strain***	***Resilient Modulus***
DESIGNATION	S_3	S_{cyclic}	c_i	P_{max}	P_{cyclic}	$P_{contact}$	S_{max}	S_{cyclic}	$S_{contact}$	H_1	H_2	H_{avg}	ε_r	M_r
UNIT	kPa	kPa	---	N	N	N	kPa	kPa	kPa	mm	mm	mm	mm/mm	MPa
PRECISION	_ _ _ . _	_ _ _ . _	_	_ _ _ _._	_ _ _ _._	_ _ _._	_ _ _._	_ _ _._	_ _._	_._ _ _ _ _	_._ _ _ _ _	_._ _ _ _ _	_._ _ _ _ _	_ _ _.
SEQUENCE 1			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

SHEET _____ OF _____

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 2			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 3			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 4			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 5			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 6			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 7			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 8			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 9			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 10			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 11			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 12			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 13			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 14			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

COLUMN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEQUENCE 15			1											
			2											
			3											
			4											
			5											
	COLUMN AVERAGE													
	STANDARD DEV.													

SUBMITTED BY, DATE

____
LABORATORY CHIEF
Affiliation ____________________

CHECKED AND APPROVED, DATE

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Affiliation________________________

PROTOCOL P47
Test Method for Classification and Description of Unbound Granular Base/Subbase Materials (UG08)

This LTPP Protocol covers the procedures for classification and description of unbound granular base and subbase materials. The test shall be carried out in accordance with ASTM D2488-00 as modified by the following. The sections of the referenced standard included in this protocol without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Classification and description using Protocol P47 shall be carried out on the bulk samples of each layer of unbound granular base and subbase materials after; (1) assigning the appropriate layer number, (2) determining the natural moisture content in accordance with Protocol P49, (3) performing gradation tests in accordance with Protocol P41, and (4) carrying out the Atterberg Limits test in accordance with Protocol P43.

The observations made during the bulk sample handling and test sample preparation in the laboratory shall be used in determining the description in accordance with this protocol (P47). The test results shall be reported separately for the test samples obtained form each designated sampling area.

The locations and sample numbers for P47 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples for each layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined and prepared in accordance with AASHTO T87-86. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. For unbound granular materials, layer thickness is determined from field exploration logs (bore hole logs and/or test pit logs).

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the bore hole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should never be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample size.

1. SCOPE

1.1 This protocol covers ASTM D2488-00, visual-manual procedures for the classification and description of unbound granular base and subbase materials, and for assigning material codes according to the LTPP terminology for pavement materials as described in Table 4.29 of Chapter 4 of this Guide.

1.2 Standard values are in inch-pound units.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards: As listed in ASTM D2488-00.

2.2 AASHTO Standards:

AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

2.3 LTPP Protocols:

P41 Test Method for Gradation of Unbound Granular Base and Subbase Materials.
P43 Test Method for Determination of Atterberg Limits of Unbound Granular Base and Subbase Materials and Subgrade Soils.
P46 Test Method for Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils.

2.4 Other LTPP Documents: LTPP Laboratory Material Testing Guide.

3. DEFINITIONS

As listed in Section 3 of ASTM D2488-00.

4. SUMMARY OF METHOD

4.1 As described in Section 4.1 of ASTM D2488-00. This method yields a standardized criteria and procedures for describing and identifying soils based on a visual examination and simple manual tests.

4.2 As described in Section 4.2 of ASTM D2488-00. The material is classified using Table 4.29 of the LTPP Laboratory Testing Guide based on ASTM D2488-00 using <u>visual-manual procedures only</u>.

4.3 Material designations and codes are used to report the description.

5. SIGNIFICANCE AND USE

5.1 As described in Section 5 of ASTM D2488-00 for unbound granular base and subbase materials.

5.2 This protocol is also used to assign "M_r Material Type" (Type 1 or Type 2) for the resilient modulus testing (Protocol P46).

6. APPARATUS

As required in Section 6 of ASTM D2488-00.

7. REAGENTS

As listed in Section 7 of ASTM D2488-00.

8. SAFETY PRECAUTIONS

As required in Section 8 of ASTM D2488-00.

9. SAMPLING

9.1 The bulk sample shall be considered to be representative of the layer from which it was obtained from the field. If the bulk sample is contained in more than one bag, then these bulk samples shall be combined as described in Protocol P41 and considered as the test sample for this protocol.

9.2 If the test sample being examined is smaller than the minimum recommended amount listed in Section 9.3 of ASTM D2488-00, the report shall include an appropriate comment code.

10. DESCRIPTIVE INFORMATION AND CLASSIFICATION FOR TEST SAMPLES

10.1 Use Sections 10 to 15 of ASTM D2488-00 for the descriptive/visual-manual classification information to be assigned to the test samples. In addition, the descriptions and visual-manual classification shall be reported by using the material codes provided in Table 4.29 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

10.2 The material shall also be assigned M_r Material Type "1" or "2" for use in the resilient modulus testing (Protocol P46). According to Protocol P46, all unbound granular base and subbase materials and subgrade soils are categorized as Type 1 or Type 2 according to the following rules:

a) All unbound granular base and subbase materials are categorized as "Type 1" materials.

b) All unbound subgrade soils which meet the criteria of 70 percent maximum passing the No. 10 (2.00-mm) sieve and 20 percent maximum passing the No. 200 (0.075-mm) sieve with a PI ≤ 10 are also categorized as "Type 1" materials.

c) All unbound subgrade soils not meeting the criteria given in (b) above with a PI > 10 are categorized as "Type 2" materials.

d) All thin-walled tube samples of the subgrade soils are also categorized as "Type 2" materials.

11. REPORT

The following information is to be recorded on Form T47.

11.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

11.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

11.3 Test Results

Report the following:

11.3.1 Visual-manual Description based on ASTM D2488-00.

(a) Range of particle size (as described in Section 10.10 of ASTM D2488-00).

(b) Maximum particle size (as described in Section 10.11 of ASTM D2488-00).

(c) Color description (as required in Section 10.3 of ASTM D2488-00).

(d) Codes for other properties according to Table 4.27 of the LTPP Laboratory Material Testing Guide. Up to 10 four-digit codes are allowed.

11.3.2 A visual-manual classification using a three-digit code from Table 4.29 (Base and Subbase Material Description) of the LTPP Laboratory Material Testing Guide.

11.3.3 "M_r Material Type" based on the guidelines provided in Section 10.2 of this protocol. Assign "1" to all unbound granular base and subbase materials.

11.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Use codes 61 to 65 as given below for additional comments.

Code	Comment
61	Insufficient size of the test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic material in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-inch (305-mm) sieve and retained on the 3-inch (76-mm) size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.)

11.5 Use Form T47 (Test Sheet T47) to report the above information (Items 11.1 to 11.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
CLASSIFICATION AND DESCRIPTION
LAB DATA SHEET T47

UNBOUND GRANULAR BASE/SUBBASE LAYERS
LTPP TEST DESIGNATION UG08/LTPP PROTOCOL P47

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __
LAYER MATERIAL (CIRCLE ONE): BASE/SUBBASE

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as the third and fourth digit)	__ __ __ __	__ __ __ __
6. VISUAL-MANUAL DESCRIPTION (Section 11.3.1 of Protocol P47)		
(a) RANGE OF PARTICLE SIZE	____________	____________
(b) MAXIMUM PARTICLE SIZE	____________	____________
(c) COLOR DESCRIPTION	____________	____________
(d) CODES-OTHER PROPERTIES	__ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __
(Table 4.27 of LTPP LAB GUIDE)	__ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __
	__ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __
	__ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __
7. VISUAL-MANUAL CLASSIFICATION (Section 11.3.2 of Protocol P47)	__ __ __	__ __ __
8. Mr MATERIAL TYPE (Section 11.3.3 of Protocol P47)	___	___
9. COMMENTS (Section 11.4 of Protocol P47)		
(a) CODE	__ __ __ __ __ __	__ __ __ __ __ __
	__ __ __ __ __ __	__ __ __ __ __ __
(b) NOTE	____________	____________
10. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS:____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF
Affiliation____________________ Affiliation____________________

PROTOCOL P48
Test Method for Permeability of Unbound Base and Subbase Materials Under Constant Head Using a Rigid Wall Permeameter (UG09)

This protocol covers the determination of the coefficient of permeability by a constant-head method for the laminar flow of water through unbound base and subbase materials. This protocol is based on AASHTO T 215-70 (Permeability of Granular Soils (Constant Head)). The test shall be performed in accordance with this standard (AASHTO T 215-70), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as written herein.

The referenced test method shall be performed on representative base and/or subbase samples obtained at designated LTPP sampling locations.

1. SCOPE

Add the following:

1.2 The term "coefficient of permeability" is often used to describe the coefficient, k, in Darcy's Law. However, in this standard the terms "hydraulic gradient" and "coefficient of permeability" are used interchangeably.

4. SAMPLE

4.2 Delete Note 2.

5. PREPARATION OF SPECIMENS

5.5.1 Compact each layer of soil thoroughly with the vibratory tamper, uniformly distributing the light tamping action over the surface of the layer in a regular pattern. The pressure of contact and the length of time of the vibrating action at each spot should not cause soil to escape from beneath the edges of the tamping foot, thus tending to loosen the layer. A sufficient number of coverages shall be completed to produce the required density. The specimens shall be compacted to within ± 3 percent of the in situ density measured for the layer in the field using the nuclear density gauge. If this density measurement is not available, use 95 percent of the maximum dry density previously determined for the layer (LTPP Protocol P44) as the compaction density.

5.5.2 Delete

5.5.2.1 Delete

5.5.2.2 Delete

5.5.2.3 Delete

5.5.3 Delete

8. REPORT

Record the following on Form T48:

8.1 Sample identification shall include: Laboratory Identification Code, Region, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, and Location Number.

8.2 Test identification shall include: Laboratory Test Number, LTPP Test Designation, LTPP Protocol Number, and the Test Date.

8.3 Test Results:

8.3.1 The initial moisture content of the specimen (W_i), as a percentage, to the nearest whole number.

8.3.2 The final moisture content of the specimen (W_f), as a percentage, to the nearest whole number.

8.3.3 The initial dry density of the specimen (DD_i), in lb/ft^3 (pcf), to the nearest whole number.

8.3.4 The final dry density of the specimen (DD_f), in lb/ft^3 (pcf), to the nearest whole number.

8.3.5 The hydraulic gradient (H/L) used in the test, to the nearest 0.01.

8.3.6 The average measured hydraulic conductivity (k), in cm/sec (cps) of the specimen, reported with two significant figures in scientific notation, for example 7.1E-6.

8.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any notes as required.

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PERMEABILITY
LAB DATA SHEET T48

UNBOUND GRANULAR BASE/SUBBASE LAYERS
LTPP TEST DESIGNATION UG09/LTPP PROTOCOL P48

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

LAYER MATERIAL (CIRCLE ONE): BASE/SUBBASE

1. LAYER NUMBER (FROM LAB SHEET L04) ___
2. SAMPLING AREA NO. (SA-) __ __
3. LABORATORY TEST NUMBER __
4. LOCATION NUMBER __ __ __
5. LTPP SAMPLE NUMBER __ __ __ __
6. TEST RESULTS
   (a) INITIAL MOISTURE CONTENT (W_i), % __ __.
   (b) FINAL MOISTURE CONTENT (W_f), % __ __.
   (c) INITIAL DRY DENSITY (DD_i), pcf __ __ __.
   (d) FINAL DRY DENSITY (DD_f), pcf __ __ __.
   (e) HYDRAULIC GRADIENT (H/L) __ __ __.
   (f) AVERAGE HYDRAULIC CONDUCTIVITY (R), cm/sec __.__E- ___
7. COMMENTS
   (a) CODE __ __ __ __ __ __
   __ __ __ __ __ __
   (b) NOTE ____________
8. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

SUBMITTED BY, DATE

____
LABORATORY CHIEF

Affiliation______________________

CHECKED AND APPROVED, DATE

____

Affiliation______________________

PROTOCOL P49
Test Method for Determination of Natural Moisture Content (UG10, SS09)

This LTPP protocol covers the determination of the natural moisture content of the unbound granular base and subbase materials and subgrade soils. The test shall be carried out in accordance with AASHTO T265-93 as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard shall be followed as written. The test shall be performed on samples of each layer of unbound granular base, subbase and subgrade collected from the specified locations on the pavement sections and marked for moisture content testing, unless otherwise directed by LTPP.

1. SCOPE

1.1 This method covers the laboratory determination of the moisture content of unbound granular base and subbase materials and subgrade soils.

7. REPORT

The following information is to be recorded on Form T49.

7.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

7.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

7.3 Test Results

(a) Moisture content (w) of the sample to the nearest 0.1 percent.

7.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed.

7.5 Use Form T49 (Test Sheet T49) to report the above information (Items 7.1 to 7.5).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
NATURAL MOISTURE CONTENT
LAB DATA SHEET T49

UNBOUND GRANULAR BASE/SUBBASE LAYERS AND SUBGRADE SOILS
LTPP TEST DESIGNATION UG10, SS09/LTPP PROTOCOL P49

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

(CIRCLE SS09 FOR SUBGRADE AND UG10 FOR UNBOUND BASE/SUBBASE) UG10/SS09

LAYER MATERIAL (CHECK ONE): BASE/SUBBASE/SUBGRADE

1. LAYER NUMBER (FROM LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __	__ __	__ __	__ __
3. LABORATORY TEST NUMBER	__	__	__	__	__	__
4. LOCATION NUMBER	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __
6. MOISTURE CONTENT (w)%	__ __.__%	__ __.__%	__ __.__%	__ __.__%	__ __.__%	__ __.__%
7. COMMENTS						
(a) CODE	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
(b) NOTE	_________	_________	_________	_________	_________	_________
	_________	_________	_________	_________	_________	_________
9. TEST DATE	__-__-___	__-__-___	__-__-___	__-__-___	__-__-___	__-__-___

GENERAL REMARKS:____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
LABORATORY CHIEF

Affiliation______________________ Affiliation______________________

PROTOCOL P51
Test Method for Sieve Analysis of Subgrade Soils (SS01)

This LTPP protocol covers the determination of the gradation of subgrade soils by washed and dry sieve analyses. This protocol is based on: (1) the test standard AASHTO T27-88I (Sieve Analysis of Fine and Coarse Aggregates), and (2) the test standard AASHTO T11-85 (Amount of Material Finer Than 0.075 mm (No. 200 sieve) in Aggregate) collectively known as LTPP Test Designation SS01 for subgrade soils. The tests shall be carried out in accordance with these standards (AASHTO T27-88I and AASHTO T11-85), as modified herein. Those sections of the AASHTO standards included in this protocol by reference and without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Determination of gradation using Protocol P51 shall be the <u>first</u> test to be performed on the bulk samples of the subgrade layer, after, (1) assigning the appropriate layer number and (2) determining the natural moisture content (Protocol P49) from jar samples for the subgrade layer. In addition, the combined bulk sample of the subgrade from each designated sampling area shall be described during the bulk sample handling in the laboratory and test sample preparation for the gradation (P51) and Atterberg Limits (Protocol P43) tests. These descriptions shall be later used for the classification and description of the sample (Protocol P52). The test results shall be reported separately for the test samples obtained from each designated sampling area.

The locations and sample numbers for P51 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of the subgrade layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined, prepared in accordance with AASHTO T87-86 and reduced to a representative test size in accordance with AASHTO T248-83. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the SPS material sampling and testing program, the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on field exploration logs (bore hole logs and/or test pit logs).

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should <u>never</u> be mixed with the material from another layer even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample.

1. SCOPE

1.1 This method covers the determination of the particle size distribution in the test sample of fine and coarse aggregates by <u>dry sieving</u> the test sample of the subgrade soil according to AASHTO T27-88I, and as described in this protocol.

1.2 This method also covers the determination of the amount of material finer than a No. 200 (0.075-mm) sieve in the test sample of the subgrade soil by <u>washing</u> according to AASHTO T11-85, and as described in this protocol. Clay particles that are dispersed by the wash water, as well as water soluble materials, will be removed from the aggregate during the test.

1.3 As stated in Section 1.4 of AASHTO T27-88I.

2. APPLICABLE DOCUMENTS

2.1 AASHTO standards: As listed in Sections 2.1 of AASHTO T27-88I and AASHTO T11-85.

AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

2.2 ASTM Standards: As listed in Sections 2.2 of AASHTO T27-88I and AASHTO T11-85.

ASTM D2487-85 Classification of Soils for Engineering Purposes.

2.3 LTPP Protocols:

P43 Determination of Atterberg Limits.
P52 Classification and Description of Subgrade Soils.
P49 Determination of Natural Moisture Content.

3. SUMMARY OF METHOD

3.1 As stated in Section 3.1 of AASHTO T11-85.

3.2 After completing the test according to Section 3.1 above, the test sample of dry aggregate is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

4. SIGNIFICANCE AND USE

4.1 Material finer than the No. 200 (0.075-mm) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than the No. 200 (0.075-mm) sieve in fine or coarse aggregate are desired, the AASHTO T11-85 method is used on the sample prior to dry sieving in accordance with AASHTO T27-88I. The results of the AASHTO T11-85 test are included in the calculations of AASHTO T27-88I. The total amount of material finer than the No. 200 (0.075-mm) sieve by washing from AASHTO T11-85 procedure plus that obtained from AASHTO T27-88I method by dry sieving the same sample is reported with the results of AASHTO T27-88I. Usually the amount of material finer than the No. 200 (0.075-mm) sieve obtained in the dry sieving process is a relatively small amount. If it is large, the efficiency of the washing operation should be checked. It could, also, be an indication of degradation of the aggregate.

4.2 The gradation results obtained by following the test procedures of this protocol (P51) and the Atterberg limits results (P43) shall be used for classification and description of subgrade soils (P52).

5. APPARATUS

5.1 Balance - As required in Sections 5.1 of AASHTO T27-88I and AASHTO T11-85.

5.2 Sieves - As required in Section 5.1 of AASHTO T27-88I with the exception that the sieve sizes shall conform to Section 9.3.2 of Protocol P51.

5.3 Mechanical Sieve Shake - As required in Section 5.3 of AASHTO T27-88I.

5.4 Oven - As required in Section 5.4 of AASHTO T11-85.

5.5 Container - As required in Section 5.3 of AASHTO T11-85.

6. TEST SAMPLE

6.1 Assign the appropriate layer number to the bulk sample of the subgrade soil that is being tested. Weigh the total bulk sample received from the field for that layer. The bulk samples from different sampling areas shall be weighed separately. The following sections of this protocol refer to the combined bulk sample from <u>one</u> sampling area only. Combine the bulk samples if contained in more than one bag(s). Thoroughly mix the combined bulk sample and dry according to the procedure described in Section 4.1 of AASHTO T87-86.

6.2 Obtain the representative test sample according to the procedure described in Section 6.2 of AASHTO T27-88I.

6.3 Use the natural moisture content determined from the jar samples of the subgrade soil earlier on Form T49 according to Protocol P49 for the respective bulk sample location(s) to estimate the weight of the test sample when dry.

6.4 The approximate weight of the test sample shall conform to the weight requirement described in Section 6.4 of AASHTO T27-88I for aggregates with nominal maximum size of 2 inches (51 mm) or less for the total bulk sample weighing 150 lbs (68 kg) or more. The approximate weight of the test sample shall not exceed 50 lbs (23 kg) for larger nominal maximum size aggregates. The approximate weight of the test sample shall not exceed 40 lbs (18 kg) if the total bulk sample weighs 100 lbs (45 kg) or more, but less than 150 lbs (68 kg).

NOTE: The nominal maximum aggregate size is defined as the smallest sieve opening through which at least <u>95 percent</u> of the aggregate passes. Delete Section 6.5 of AASHTO T27-88I.

6.5 Even if the weight of the test sample is less than the required minimum weight, the test shall be performed; however, this violation of the test standard AASHTO T27-88I shall be recorded as a standard comment code.

7. PROCEDURE

7.1 First test the sample by AASHTO T11-85 in conformity with Sections 7.1 to 7.5 of this protocol to determine the amount of material finer than the No. 200 (0.075-mm) sieve by <u>washed sieving</u>.

7.2 Dry the test sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F) and weigh to the nearest 0.1% of the weight of the sample. Designate this weight as "B".

7.3 As required in Section 7.3 of AASHTO T11-85, using the sieves listed in Section 9.3 of this protocol.

7.4 As required in Section 7.4 of AASHTO T11-85.

7.5 As required in Section 7.5 of AASHTO T11-85. Designate the dry weight of the washed sample to be "C". Weight of material finer than No. 200 (0.075-mm) sieve ("D") is calculated as the difference between "B" and "C". This completes the procedure using AASHTO T11-85.

7.6 Rest of the procedure involves AASHTO T27-88I. Commence <u>dry sieving</u> by using the AASHTO T27-88I procedure in conformity with Sections 7.6 to 7.13 of this protocol.

7.7 Nest the sieves in order of decreasing size of opening from top to bottom and place the dried test sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 7.9 of this protocol.

7.8 As required in Section 7.3 of AASHTO T27-88I.

7.9 As required in Section 7.4 of AASHTO T27-88I.

7.10 The portion of the sample finer than the No. 4 (4.75-mm) sieve may require distribution on two or more sets of sieves to prevent overloading of individual sieves.

Follow Section 7.5 of AASHTO T27-88I.

7.11 As required in Section 7.6 of AASHTO T27-88I.

7.12 As required in Section 7.7 of AASHTO T27-88I.

7.13 Add the weight finer than the No 200 (0.075-mm) sieve determined by the AASHTO T11-85 procedures (according to Section 7.5 of this protocol) to the weight passing the No. 200 (0.075-mm) sieve determined by AASHTO T27-88I by dry sieving of the same sample performed according to Sections 7.6 to 7.12 of this protocol.

8. CALCULATION

8.1 Calculate the amount of material passing the No. 200 (0.075-mm) sieve <u>by washing</u> as follows:

$$A = [(B - C)/B] \times 100$$

where: A = percentage of material finer than a No. 200 (0.075-mm) sieve by washing,
B = original dry weight of test sample, as determined in Section 7.2 of this protocol,
C = dry weight of test sample after washing, as determined in Section 7.5 of this protocol.

8.2 Calculate percentages passing to the nearest 1% (for sieve sizes 3-in. [76-mm] to No. 80 [0.180-mm]), and to the nearest 0.1% for the No. 200 (0.075-mm) sieve on the basis of the total weight of the initial dry test sample (B) prior to the washed sieve analysis.

8.3 Include the weight (D) of material finer than the No. 200 (0.075-mm) sieve, as determined in Section 7.5 of this protocol in the sieve analysis calculation of Section 8.2 of this protocol.

9. REPORT

The following information is to be recorded on Form T51.

9.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

9.3 Test Results

Report the following:

9.3.1 Percent passing the No. 200 (0.075-mm) sieve by washing to the nearest 0.1 percent, as calculated in Section 8.1 of this protocol.

9.3.2 Gradation results based on Sections 8.2 and 8.3 of this protocol to the appropriate number of significant digits as follows:

Sieve Sizes Standard (mm)	% Passing
3 in. (75.0)	__ __ __.
2 in. (50.0)	__ __ __.
1 ½ in. (37.5)	__ __ __.
1 in. (25.0)	__ __ __.
¾ in. (19.0)	__ __ __.
½ in. (12.5)	__ __ __.
⅜ in. (9.5)	__ __ __.
#4 (4.75)	__ __ __.
#10 (2.00)	__ __ __.
#40 (0.425)	__ __.
#80 (0.180)	__ __.
#200 (0.075)	__ __.__

9.3.3 Attach a cumulative particle size gradation curve such as shown in Figure 4 of ASTM D2487-85 with Form T51.

9.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments that may be associated with the testing of bulk samples are:

Code	Comment
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic material in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-in. [76-mm] size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone, and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.)

In addition, record the weight of the test sample to the nearest 1 lb (0.45 kg) as per Section 7.1 of AASHTO T11-85 and the moisture content (Section 6.3 of Protocol P51) to the nearest 1%.

9.5 Use Form T51 (Test Sheet T51) to report the above information (Items 9.1 to 9.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SIEVE ANALYSIS OF SUBGRADE SOILS
LAB DATA SHEET T51

SUBGRADE SOILS
LTPP TEST DESIGNATION SS01/LTPP PROTOCOL P51

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1.	LAYER NUMBER (FROM LAB SHEET L04) __		
2.	SAMPLING AREA NO. (SA-)	__ __	__ __
3.	LABORATOY TEST NUMBER	__	__
4.	LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5.	LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
6.	% PASSING #200 SIEVE BY WASHING (Section 9.3.1 of Protocol P51)	__ __.__	__ __.__
7.	GRADATION (Section 9.3.2 of Protocol P51)		
	% PASSING SIEVE SIZE STANDARD (mm)		
	3 in. (75.0)	__ __ __.	__ __ __.
	2 in. (50.0)	__ __ __.	__ __ __.
	1 ½ in. (37.5)	__ __ __.	__ __ __.
	1 in. (25.0)	__ __ __.	__ __ __.
	¾ in. (19.0)	__ __ __.	__ __ __.
	½ in. (12.5)	__ __ __.	__ __ __.
	⅜ in. (9.5)	__ __ __.	__ __ __.
	#4 (4.75)	__ __ __.	__ __ __.
	#10 (2.00)	__ __ __.	__ __ __.
	#40 (0.425)	__ __.	__ __.
	#80 (0.180)	__ __.	__ __.
	#200 (0.075)	__ __.__	__ __.__
8.	COMMENTS (Section 9.4 of Protocol P51)		
	(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
	(b) NOTE	____________ ____________	____________ ____________
	(c) WEIGHT OF TEST SAMPLE,	__ __ __.__ lb	__ __ __.__ lb
	MOISTURES CONTENT	__ __.%	__ __.%
9.	TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEETS T51 AND T43 ARE USED FOR CLASSIFICATION AND DESCRIPTION ON TEST SHEET T52.
2. ATTACH A CUMULATIVE PARTICLE SIZE GRADATION CURVE WITH FORM T51 (SECTION 9.3.3 OF PROTOCOL P51).

GENERAL REMARKS:____

SUBMITTED BY, DATE

____

LABORATORY CHIEF

Affiliation______________

CHECKED AND APPROVED, DATE

____

Affiliation______________

PROTOCOL P51A
Test Method for Dry Sieve Analysis of Subgrade Soils (SS01)

This LTPP protocol covers the determination of the gradation of subgrade soils by dry sieve analysis. This protocol is based on test standard AASHTO T27-88I (Sieve Analysis of Fine and Coarse Aggregates) and is designated as LTPP Test SS01 for subgrade soils. The tests shall be carried out in accordance with AASHTO T27-88I), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

The purpose of LTPP P51A is to allow, at the Laboratory Manager's discretion, a dry sieving (in place of a wet and dry sieving—i.e., Protocol P51) procedure to be conducted on very "clean" subgrade soils. The general definition of "clean" for Protocol P51A is outlined below. Generally, Protocol P51A shall only be used on subgrade soils with estimated classifications of A-1, A-2 or A-3 by the AASHTO classification system and which meet certain specified conditions with respect to coatings on the coarse aggregate and clay lumps contained in the sample. The specific requirements are as follows:

WHEN TO USE PROTOCOL P51A
Protocol P51A is a dry sieving procedure for subgrade soils. Two requirements must be met in order to used Protocol P51A: Requirement 1 – <u>less than</u> twenty five percent of the surface area of the coarse grained soil fraction (i.e., + No. 4 [4.75-mm] material) is coated with soil fines (i.e., – No. 200 [0.075-mm] material). Requirement 2 – a "significant" (i.e., as defined in the following table) amount of clay lumps or hard balls of fine materials <u>are not</u> present in the bulk sample of subgrade soil. <u>Both Requirement 1 and Requirement 2 must be met</u> in order to use Protocol P51A. To determine if these requirements are met, the laboratory manager (or his/her designee) shall conduct a visual examination of the subgrade soil bulk sample. Approximately 22 lbs (10 kg) shall be split from the bulk sample. Requirement 1 The coarse aggregate portion of this sample shall be examined to estimate the percent clay coating, if any. If twenty-five percent or less of the surface area is coated, then Requirement 1 is satisfied. If Requirement 1 <u>is not</u> satisfied, then the visual examination shall cease and a wet and dry sieving process shall be used (Protocol P51). If Requirement 1 <u>is met</u>, then the sample shall be examined for clay lumps.

Requirement 2

If no clay lumps are apparent, then Requirement 2 is satisfied and dry sieving should be initiated in accordance with this protocol. However, if clay lumps are present then the size and number of the clay lumps in the sample should be estimated. The following table shall then be used to determine if Requirement 2 is met.

Note: The table below is based on a 22-lb (10-kg) sample. If the representative sample is smaller than 22 lbs (10 kg), appropriate reductions in the allowable number of clay lumps shown in this table shall be used.

APPROXIMATE CLAY LUMP SIZE	ESTIMATED AASHTO CLASSIFICATION	
	A1, A2, A3	A4, A5, A6, A7
¼ inch (6.3 mm)	70 clay lumps	Use Protocol P51
⅜ inch (9.5 mm)	20 clay lumps	
½ inch (12.5 mm)	7 clay lumps	
¾ inch (19.0 mm)	2 clay lumps	
1 inch (25.0 mm)	1 clay lump	

If clay lumps are present in sizes and amounts <u>less than</u> those shown in the above table for the appropriate estimated AASHTO classification, Requirement 2 is satisfied. If clay lumps are present in numbers <u>greater than</u> those specified above, the wet and dry sieving process (Protocol P51) shall be used.

<u>If both or either Requirement 1 and Requirement 2 are violated</u>, then Protocol P51 shall be used.

Determination of gradation using Protocol P51A shall be the <u>first</u> test to be performed on the bulk samples of the subgrade layer, after, (1) assigning the appropriate layer number and (2) determining the natural moisture content (Protocol P49) from jar samples for the subgrade layer, (3) estimating the AASHTO classification and (4) determining the applicability of Protocol P51 or P51A. In addition, the combined bulk sample of the subgrade shall be described during the bulk sample handling in the laboratory and test sample preparation for the gradation (P51A) and Atterberg Limits (Protocol P43) tests. These descriptions shall be later used for the classification and description of the sample (Protocol P52).

When bulk samples of the subgrade layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined, prepared in accordance with AASHTO T87-86 and reduced to a representative test size in accordance with AASHTO T248-83. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the LTPP material sampling and testing program, the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on field exploration logs (bore hole logs and/or test pit logs).

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the Participating Laboratory. The material from one layer should never be mixed with the material from another layer even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample.

1. SCOPE

This method covers the determination of the particle size distribution in the test sample of fine and coarse aggregates by dry sieving the test sample of the subgrade soil according to AASHTO T27-88I, and as described in this protocol.

2. APPLICABLE DOCUMENTS

2.1 AASHTO standards: As listed in Section 2.1 of AASHTO T27-88I.

AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

2.2 ASTM Standards: As listed in Section 2.2 of AASHTO T27-88I.

ASTM D2487-85 Classification of Soils for Engineering Purposes.

2.3 LTPP Protocols:

P43 Determination of Atterberg Limits.
P52 Classification and Description of Subgrade Soils.
P49 Determination of Natural Moisture Content.

3. SIGNIFICANCE AND USE

The gradation results obtained by following the test procedures of this protocol (P51A) and the Atterberg limits results (P43) shall be used for laboratory classification and description of subgrade soils (P52).

4. APPARATUS

As required in Section 5 of AASHTO T27-88I with the exception that the sieve sizes shall conform to Section 8.3.1 of Protocol P51A.

5. TEST SAMPLE

5.1 Assign the appropriate layer number to the bulk sample of the subgrade soil that is being tested. Weigh the total bulk sample received from the field for that layer. The bulk samples from the different sampling areas shall be weighed separately. The following sections of this protocol refer to the combined bulk sample from near <u>one sampling area only</u>. Combine the bulk samples if contained in more than one bag(s). Thoroughly mix the combined bulk sample and dry according to the procedure described in Section 4.1 of AASHTO T87-86.

5.2 Obtain the representative test sample according to the procedure described in Section 6.2 of AASHTO T27-88I.

5.3 Use the natural moisture content determined from the jar samples of the subgrade soil earlier on Form T49 according to Protocol P49 for the respective bulk sample location(s) to estimate the weight of the test sample when dry.

5.4 The approximate weight of the test sample shall conform to the weight requirement described in Section 6.4 of AASHTO T27-88I for aggregates with nominal maximum size of 2 inches (51 mm) or less for the total bulk sample weighing 150 lbs (68 kg) or more. The approximate weight of the test sample shall not exceed 50 lbs (23 kg) for larger nominal maximum size aggregates. The approximate weight of the test sample shall not exceed 40 lbs (18 kg) if the total bulk sample weighs 100 lbs (45 kg) or more, but less than 150 lbs (68 kg).

Note: The nominal maximum aggregate size is defined as the smallest sieve size opening through which at least <u>95 percent</u> of the aggregate passes. Delete Section 6.5 of AASHTO T27-88I.

5.5 Even if the weight of the test sample is less than the required minimum weight, the test shall be performed; however, this violation of the test standard AASHTO T27-88I shall be recorded as a standard comment code.

6. PROCEDURE

6.1 Dry the test sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F) and weigh to the nearest 0.1% of the weight of the sample.

6.2 Commence <u>dry sieving</u> by using the AASHTO T27-88I procedure in conformity with Sections 6.2 to 6.4 of this protocol.

6.3 Nest the sieves in order of decreasing size of opening from top to bottom and place the dried test sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy or sieving described in Section 7.4 of AASHTO T27-88I.

6.4 As required in Sections 7.3-7.7 of AASHTO T27-88I.

7. CALCULATION

Calculate percentages passing to the nearest 1% (for sieve sizes 3-in. [76-mm] to No. 80 [0.180-mm]), and to the nearest 0.1% for the No. 200 (0.075-mm) sieve on the basis of the total weight of the initial dry test sample.

8. REPORT

The following information is to be recorded on Form T51A.

8.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

8.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

8.3 Test Results

Report the following:

Gradation results based on Section 7 of this protocol to the appropriate number of significant digits as follows:

Sieve Sizes Standard (mm)	% Passing
3 in. (75.0)	__ __ __.
2 in. (50.0)	__ __ __.
1 ½ in. (37.5)	__ __ __.
1 in. (25.0)	__ __ __.
¾ in. (19.0)	__ __ __.
½ in. (12.5)	__ __ __.
⅜ in. (9.5)	__ __ __.
#4 (4.75)	__ __ __.
#10 (2.00)	__ __ __.
#40 (0.425)	__ __.
#80 (0.180)	__ __.
#200 (0.075)	__ __.__

8.4 Attach a cumulative particle size gradation curve such as shown in Figure 4 of ASTM D2487-85 with Form T51A.

8.5 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments that may be associated with the testing of bulk samples are:

Code	Comment
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic material in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-inch [76-mm] size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.).

In addition, record the weight of the test sample to the nearest 1 lb (0.5 kg) and the moisture content (Section 5.3 of Protocol P51A) to the nearest 1%.

8.6 Use Form T51A (Test Sheet T51A) to report the above information (Items 8.1 to 8.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DRY SIEVE ANALYSIS OF SUBGRADE SOILS
LAB DATA SHEET T51A

SUBGRADE SOILS
LTPP TEST DESIGNATION SS01/LTPP PROTOCOL P51A

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
7. GRADATION (Section 8.3.1 of Protocol P51A)		
% PASSING SIEVE SIZE STANDARD (mm)		
3 in. (75.0)	__ __ __.	__ __ __.
2 in. (50.0)	__ __ __.	__ __ __.
1 ½ in. (37.5)	__ __ __.	__ __ __.
1 in. (25.0)	__ __ __.	__ __ __.
¾ in. (19.0)	__ __ __.	__ __ __.
½ in. (12.5)	__ __ __.	__ __ __.
⅜ in. (9.5)	__ __ __.	__ __ __.
#4 (4.75)	__ __ __.	__ __ __.
#10 (2.00)	__ __ __.	__ __ __.
#40 (0.425)	__ __.	__ __.
#80 (0.180)	__ __.	__ __.
#200 (0.075)	__ __.__	__ __.__
8. COMMENTS (Section 8.4 of Protocol P51A)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	________________ ________________	________________ ________________
(c) WEIGHT OF TEST SAMPLE	__ __ __.__ lb.	__ __ __.__ lb.
MOISTURE CONTENT	__ __.%	__ __.%
9. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEETS T51A AND T43 ARE USED FOR CLASSIFICATION AND DESCRIPTION ON TEST SHEET T52.
2. ATTACH A CUMULATIVE PARTICLE SIZE GRADATION CURVE WITH FORM T51A (SECTION 8.3.2 OF PROTOCOL P51A).

GENERAL REMARKS:____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

Affiliation_____________________ Affiliation_____________________

PROTOCOL P52
Test Method for Classification and Description of Subgrade Soils (SS04)

This LTPP Protocol covers the procedures for classification and description of subgrade soils. The test shall be carried out in accordance with ASTM D2488-00 and AASHTO M145-87I as modified by the following. The sections of the reference standards included in this protocol without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

Classification and description using Protocol P52 shall be carried out on the bulk samples of the subgrade layer after; (1) assigning the appropriate layer number, (2) determining the natural moisture content in accordance with Protocol P49, (3) performing gradation tests in accordance with Protocol P51, and (4) carrying out the Atterberg Limits tests in accordance with Protocol P43.

The observations made during the bulk sample handling in the laboratory and test sample preparation, and the results of the gradation and Atterberg Limits tests (Protocols P51 and P43) shall be used in determining the classification in accordance with this protocol (P52). The test results shall be reported separately for the test samples obtained from each designated sampling area.

The locations and sample numbers for P52 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of the subgrade layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined and prepared in accordance with AASHTO T87-86. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol.

a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the LTPP material sampling and testing program, the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on field exploration logs (bore hole logs and/or test pit logs).

b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should never be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same, but will usually be less than the bulk sample size.

1. SCOPE

1.1 This protocol covers ASTM D2488-00, visual-manual procedures for the classification and description of subgrade soils, and for assigning material codes according to the LTPP terminology for pavement materials and soils as described in Table 4.26 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

1.2 This protocol also requires the use of AASHTO classification (AASHTO M145-87I standard) and the respective material codes according to the LTPP terminology for pavement materials and soils as described in Table 4.26 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

1.3 Standard values shall be inch-pound units.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards: As listed in ASTM D2488-00.

2.2 AASHTO Standards:

AASHTO M145-87I The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.
AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.

2.3 LTPP Protocols:

P51 Sieve Analysis of Subgrade Soils.
P42 Hydrometer Analysis.
P43 Determination of Atterberg Limits of Unbound Granular Base and Subbase Materials and Subgrade Soils.
P46 Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils.

2.4 Other LTPP Documents: LTPP Laboratory Material Testing Guide.

3. DEFINITIONS

As listed in Section 3 of ASTM D2488-00.

4. SUMMARY OF METHOD

4.1 As described in Section 4.1 of ASTM D2488-00. This method yields standardized criteria and procedures for describing and identifying soils based on a visual examination and simple manual tests.

4.2 As described in Section 4.2 of ASTM D2488-00. The soil is classified using Table 4.26 of the LTPP Laboratory Material Testing Guide based on ASTM D2488-00 using <u>visual-manual procedures only</u>.

4.3 Material classification designations and codes are used to report the classification and description.

5. SIGNIFICANCE AND USE

5.1 As described in Section 5 of ASTM D2488-00 for subgrade soils.

5.2 This protocol is also used to assign "M_r Material Type" (Type 1 or Type 2) for the resilient modulus testing (Protocol P46).

6. APPARATUS

As required in Section 6 of ASTM D2488-00.

7. REAGENTS

As listed in Section 7 of ASTM D2488-00.

8. SAFETY PRECAUTIONS

As required in Section 8 of ASTM D2488-00.

9. SAMPLING

9.1 The bulk sample shall be considered to be <u>representative</u> of the subgrade layer from which it was obtained from the field. If the bulk sample is contained in more than one bag then these bulk samples shall be combined as described in Protocol P51 and considered as the test sample for this protocol.

9.2 If the test sample being examined is smaller than the minimum recommended amount listed in Section 9.3 of ASTM D2488-00, the report shall include an appropriate comment.

10. DESCRIPTIVE INFORMATION AND CLASSIFICATION FOR TEST SAMPLES

10.1 Use Sections 10 to 15 of ASTM D2488-00 for the descriptive/visual-manual classification information to be assigned to the test samples. In addition, the descriptions and visual-manual classification shall be reported by using the material codes provided in Table 4.26 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

10.2 Use the AASHTO classification system (AASHTO M145-87I) for assigning the AASHTO classification using material codes provided in Table 4.27 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

10.3 The material shall also be assigned M_r Material Type "1" or "2" for use in the resilient modulus testing (Protocol P46). According to Protocol P46, all unbound granular base and subbase materials and subgrade soils are categorized as Type 1 or Type 2 according to the following rules:

a) All unbound granular base and subbase materials are categorized as "Type 1" materials.

b) All unbound subgrade soils which meet the criteria of 70 percent maximum passing the No. 10 (2.00-mm) sieve and 20 percent maximum passing the No. 200 (0.075-mm) sieve are also categorized as "Type 1" materials.

c) All unbound subgrade soils not meeting the criteria given in (b) above are categorized as "Type 2" materials.

d) All thin-walled tube samples of the subgrade soils are also categorized as "Type 2" materials.

11. REPORT

The following information is to be recorded on Form T52.

11.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

11.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

11.3 Test Results

Report the following:

11.3.1 Visual-Manual Description based on ASTM D2488-00

(a) Range of particle size (as described in Section 10.10 of ASTM D2488-00).

(b) Maximum particle size (as described in Section 10.11 of ASTM D2488-00).

(c) Color description (as required in Section 10.3 of ASTM D2488-00).

(d) Material Codes for other properties according to Table 4.27 of the LTPP Laboratory Material Testing Guide. Up to 10 four-digit codes are allowed.

11.3.2 Visual-manual classification using a three-digit code from Table 4.27 of Chapter 4 of the LTPP Laboratory Material Testing Guide as required in Sections 14 and 15 of ASTM D2488-00.

11.3.3 AASHTO Classification Code using a three-digit code according to Table 4.28 of Chapter 4 of the LTPP Laboratory Material Testing Guide.

11.3.4 "M_r Material Type" based on the guidelines provided in Section 10.3 of this protocol. The subgrade bulk sample can be assigned either "1" or "2" for M_r Material Type designation depending on the criteria (a) and (b) stated in Section 10.3 of this protocol. However, the subgrade bulk sample shall be assigned M_r Material Type "2" if a thin-walled tube sample of the subgrade was retrieved from the same area.

11.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Use codes 61 to 65 as given below for additional comments.

Code	Comment
61	Insufficient size of the test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic material in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-in. [76-mm] size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone, and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.).

12.5 Use Form T52 (Test Sheet T52) to report the above information (Items 11.1 to 11.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
CLASSIFICATION AND DESCRIPTION
LAB DATA SHEET T52

SUBGRADE SOILS
LTPP TEST DESIGNATION SS04/LTPP PROTOCOL P52

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __
REGION ________________ STATE ________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __		
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
6. VISUAL-MANUAL DESCRIPTION (Section 11.3.1 of Protocol P52)		
(a) RANGE OF PARTICLE SIZE	________________	________________
(b) MAXIMUM PARTICLE SIZE	________________	________________
(c) COLOR DESCRIPTION	________________	________________
(d) CODES – OTHER PROPERTIES (Table 4.27 of LTPP Lab Guide)	__ __	__ __
7. VISUAL-MANUAL CLASSIFICATION (Section 11.3.2 of Protocol P52)	__ __ __	__ __ __
8. AASHTO CLASSIFICATION CODE (Section 11.3.3 of Protocol P52)	__ __ __	__ __ __
9. Mr MATERIAL TYPE (Section 11.3.4 of Protocol P52)	___	___
10. COMMENTS (Section 11.4 of Protocol P52)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	________________	________________
11. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. RESULTS OF TEST SHEETS T51 AND T43 ARE USED FOR CLASSIFICATION AND DESCRIPTION ON TEST SHEET T52.

GENERAL REMARKS:______________________________

SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

Affiliation______________________ Affiliation______________________

PROTOCOL P54
Test Method for Unconfined Compressive Strength of Subgrade Soils

This protocol describes the test method for determining the unconfined compressive strength of cohesive subgrade soil samples. This protocol is based on AASHTO T208-90 (Unconfined Compressive Strength of Cohesive Soil). The test shall be performed in accordance with this standard (AASHTO T208-90), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as herein written.

The referenced test method shall be performed on a representative subgrade sample obtained from one of the thin-walled tube samples obtained at designated A-Type sampling locations.

1. SCOPE

1.1 This test method covers the determination of the unconfined compressive strength of soils in the undisturbed condition using the strain-controlled application of the axial load.

2. REFERENCED DOCUMENTS

2.3 LTPP Protocols

P49 Determination of the Natural Moisture Content
P56 Unit Weight of Subgrade Soils

4. SIGNIFICANCE AND USE

4.3 Delete

6. PREPARATION OF TEST SPECIMENS

6.1 Add: For LTPP SPS materials testing, 2.8-inch (71-mm) diameter samples shall be obtained from the thin-walled tube samples.

6.2 Delete the last two sentences of Section 6.2.

Add: Secure a representative sample of cuttings for use in determining the specimen's moisture content.

6.3 Delete

6.4 Delete

7. PROCEDURE

7.3 Record all required data on Form T54.

8. CALCULATIONS

8.2 Add: Calculate the cross-sectional area to two decimal places.

8.4 Add: For LTPP materials testing purposes include the graph of the stress-strain curve with Form T54.

8.5 Calculate the dry density of the specimen in accordance with LTPP Protocol P56.

9. REPORT

Record the following on Form T54:

9.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Layer Number and Location Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and Test Date.

9.3 Test Results

9.3.1 Specimen height, in inches, to two decimal places.

9.3.2 Specimen diameter, in inches, to two decimal places.

9.3.3 Average cross-sectional area, in square inches (in^2), to two decimal places.

9.3.4 Length-to-diameter ratio (L/D) to one decimal place.

9.3.5 Moisture content, in percent, to one decimal place.

9.3.6 Dry density, in lb/ft^3 (pcf), to the nearest whole number.

9.3.7 The unconfined compressive strength (q_u) in lb/in^2 (psi) to the nearest whole number.

9.3.8 The average strain at failure, as a percentage, to the nearest 0.1 percent.

9.3.9 The average rate of strain to failure, as a percentage per minute, to the nearest 0.1 percent.

9.4 Comments shall include: LTPP standard comment code(s), as shown in Section 4.3 of the LTPP Laboratory Material Testing Guide, and any other note as needed.

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
UNCONFINED COMPRESSIVE STRENGTH OF SUBGRADE SOIL
LAB DATA SHEET T54

SUBGRADE SOILS
LTPP TEST DESIGNATION SS10/LTPP PROTOCOL P54

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA NO.: SA-______

1. LAYER NUMBER ______

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS

(a) SPECIMEN HEIGHT, inches __ __.__ __
(b) SPECIMEN DIAMETER, inches __ __.__ __
(c) AVERAGE CROSS-SECTIONAL AREA, in^2 __ __.__ __
(d) MOISTURE CONTENT, % __ __.__
(e) DRY DENSITY, pcf __ __ __.
(f) UNCONFINED COMPRESSED STRENGTH (q_u), psi __ __ __.
(g) LENGTH-TO-DIAMETER RATIO (L/D) __.__
(h) AVERAGE STRAIN AT FAILURE, % __ __.__
(i) AVERAGE RATE OF STRAIN TO FAILURE, %/min __.__

6. COMMENTS
(a) CODE __ __ __ __ __ __
__ __ __ __ __ __
(b) NOTE ______________

7. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

__________________________ __________________________
LABORATORY CHIEF

Affiliation____________________ Affiliation____________________

PROTOCOL P55
Test Method for Moisture-Density Relations of Subgrade Soils (SS05)

This LTPP Protocol covers the determination of the moisture-density relations of subgrade soils. This protocol is based on AASHTO T 99-86 ("The Moisture-Density Relations of Soils Using a 5.5-lb [2.5 kg] Rammer and a 12-in. [305-mm] Drop"). The test shall be carried out in accordance with this standard (AASHTO T99-86), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as herein written.

The determination of the moisture-density relations using Protocol P55 shall be performed on the bulk samples of the subgrade layer, after; (1) assigning the appropriate layer number, (2) determining the natural moisture content (Protocol P49) from jar samples of the subgrade layer, (3) performing the sieve analysis test (Protocol P51), (4) determining the Atterberg Limits (Protocol P43), and (5) completing the classification and description test (Protocol P52). The results of the moisture-density test (Protocol P55) will be recorded in the PPDB and are also used to ascertain molding water content and density values. These parameters will be later used to reconstitute test specimens from the bulk samples of the subgrade layer for the resilient modulus testing (Protocol P46).

The test shall be performed on a representative test sample obtained from the bulk samples of subgrade soils. The test results shall be reported separately for the test samples obtained from each designated sampling area.

The locations and sample numbers for P55 testing are as shown on the laboratory testing plans developed for each project.

When bulk samples of the subgrade layer are retrieved from BA1, BA2, BA3... type 12-inch (305-mm) diameter boreholes, these bulk samples are combined, prepared and reduced to a representative test size in accordance with AASHTO T87-86 and AASHTO T248-83. Because the bulk samples are combined, the Location Number of the sample should have an asterisk placed as the third digit. Similarly, the LTPP Sample Number should have an asterisk placed as the third and fourth digits.

The following definitions will be used throughout this protocol:

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The subgrade layer may not conform to the above definition. Subgrade soils are prepared and compacted before the placement of subbase and/or base layers. For the LTPP materials sampling and testing program, the subgrade layer is considered to be representative of the subgrade soils within 12 inches (305 mm) below the top of the subgrade, unless otherwise indicated on field exploration logs (bore hole logs and/or test pit logs).

(b) Bulk Sample: That part of the pavement material that is removed from an unbound layer from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the participating laboratory. The material from one layer should <u>never</u> be mixed with the material from another layer—even if there is less than the desired amount to perform the specified test.

(c) Test Sample: That part of the bulk sample of an unbound layer which is prepared and used for the specified test. The quantity of the test sample may be the same but will usually be less than the bulk sample.

1. SCOPE

1.1 This method of test covers the determination of the relationship between the moisture content and density of subgrade soils when compacted in a 6-inch (152-mm) diameter mold with a 5.5-lb (2.5-kg) rammer dropped from a height of 12 in. (305 mm). Two alternate procedures are provided as follows:

Method B - A 6-in. (152-mm) diameter mold: soil material passing a No. 4 (4.75-mm) sieve.

Method D - A 6-in. (152-mm) diameter mold: soil material passing a ¾-in. (19-mm) sieve.

1.2 Select method "B" or "D" as appropriate based on the results of the sieve analysis (Protocol P51).

1.3 As stated in Section 1.3 of AASHTO T99-86.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards

ASTM D653 Terms and Symbols Relating to Soil and Rock.

2.2 AASHTO Standards

AASHTO T99-86 The Moisture-Density Relation of Soils Using a 5.5-lb [2.5-kg] Rammer and a 12-in. [305-mm] Drop.
AASHTO R-11 Recommended Practice for Indicating Which Places of Figures Are To Be Considered Significant in Specified Limiting Values.
AASHTO T19-88I Unit Weight and Voids in Aggregate.
AASHTO M231-87I Weighing Devices Used in the Testing of Materials.
AASHTO M92-85 Wire-Cloth Sieves for Testing Purposes.
AASHTO T87-86 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test.
AASHTO T248-83 Reducing Field Samples of Aggregates to Testing Size.

2.3 LTPP Protocols

P51 Sieve Analysis of Subgrade Soils.
P52 Classification and Description of subgrade soils.
P49 Determination of Natural Moisture Content.
P44 Moisture-Density Relations of Unbound Granular Base/Subbase Materials.
P46 Resilient Modulus of Unbound Granular Base and Subbase Materials and Subgrade Soils.

3. APPARATUS

The apparatus for moisture-density relations testing shall conform to the requirements of Section 2 of AASHTO T99-86 with the following exceptions:

3.1 Molds - As required in Section 2.1, 2.1.2 and 2.1.3 of AASHTO T99-86. Delete Section 2.1.1 and Note 1 of AASHTO T99-86.

LTPP PROTOCOL P55 - METHOD "A"

Note – 4-inch (102-mm) molds will not be used in this test, therefore Method A of AASHTO T99-86 will not be used as is. However, Method A is not deleted from this protocol as part of the procedure contained in Method A (Sections 3 and 4) of AASHTO T99-86 is used in Method B.

LTPP PROTOCOL P55 - METHOD "B"

4. SAMPLE

4.1 Prepare the subgrade soil sample in accordance with Sections 4.1 and 7 of AASHTO T87-86 (Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test).

4.2 The weight of the test sample should approximately be 20 lb (9 kg). Check the gradation test results (Protocol P51) for percentage of coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve. If this percentage is up to 5% then Method B of Protocol P55 shall be used. Include this coarse fraction in the test sample for moisture-density test and record this deviation from the AASHTO T99-86 standard by using special comment code 74 (See Section 10.4 of Protocol P55) on Form T55.

4.3 If there is more than 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve, then use Method D of Protocol P55 to perform the moisture-density test. Use special comment code 75 (See Section 10.4 of Protocol P55) to record this condition on Form T55.

4.4 Discard any coarse material larger than the 1 ½-in. (38-mm) sieve size and do not use this material for the moisture-density test. Use special comment code 76 (See Section 10.4 of Protocol P55) to record this condition on Form T55.

5. PROCEDURE

5.1 Follow the same procedure as described in Section 6 of Method B and Section 4 of Method A of AASHTO T99-86, as appropriate.

5.2 The point at which the wet unit mass either decreases or does not change should be achieved within 3 to 5 water addition increments for this test. If the optimum moisture cannot be found by the fifth increment, note this using a special comment code on Form T55.

LTPP PROTOCOL P55 - METHOD "C"

Note – 4-inch (102-mm) molds will not be used in this test, therefore Method C of AASHTO T99-86 will not be used as is. However, Method C is not deleted from this protocol as part of the procedure contained in Method C (Sections 7 and 8) of AASHTO T99-86 is used in Method D.

LTPP PROTOCOL P55 - METHOD "D"

6. SAMPLE

6.1 Prepare the subgrade soil sample in accordance with Sections 4.1 and 7 of AASHTO T87-86 (Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test).

6.2 The weight of the sample should approximately be 30 lbs (14 kg). Check the gradation test results (Protocol P51) for percentage of coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve. If this percentage is up to 5% then Method D of Protocol P55 shall be used. <u>Include</u> this coarse fraction in the test sample for the moisture-density test. Record this deviation from the AASHTO T99-86 standard by using special comment code 77 (See Section 10.4 of Protocol P55) on Form T55.

6.3 If there is more than 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve, then the test sample for the moisture-density testing shall be sieved using a ¾-in. (19-mm) sieve to separate the coarse fraction retained on the ¾-in. (19-mm) sieve. <u>Discard</u> this coarse fraction from the test sample for the moisture-density. Use special comment code 78 (See Section 10.4 of Protocol P55) to record this condition on Form T55.

6.4 Discard any coarse material larger than the 1 ½-in. (38-mm) sieve and do not use this material for moisture-density test. Use special comment code 76 (See Section 10.4 of Protocol P55) to record this condition on Form T55.

7. PROCEDURE

7.1 Same as described in Section 10.1 of Method D and Section 8 of Method C of AASHTO T99-86.

7.2 The point at which the wet unit mass either decreases or does not change should be achieved within 3 to 5 water addition increments for this test. If the optimum moisture content cannot be found by the fifth increment, note this using a special comment code on Form T55.

8. CALCULATIONS

8.1 As required in Section 11.1 of AASHTO T99-86.

9. MOISTURE - DENSITY RELATIONSHIP

9.1 Same as described in Section 12.1 of AASHTO T99-86 except: Delete "or kilograms per cubic meter".

9.2 Optimum Moisture Content - As required in Section 12.2 of AASHTO T99-86 except: Delete "or kilograms per cubic meter".

9.3 Maximum Density - As required in Section 12.3 of AASHTO T99-86.

10. REPORT

The following information is to be recorded on Form T55.

10.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

10.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

10.3 Test Results

Report the following:

10.3.1 The method used (Method B or Method D).

10.3.2 The optimum moisture content (OMC), as a percentage, to the nearest whole number.

10.3.3 The maximum density (MD),in lb/ft^3 (pcf), to the nearest whole number.

10.3.4 Attach optimum moisture content curve plot, prepared in accordance with Section 12 of AASHTO T99-86, with Form T55.

10.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note as needed. Additional codes for special comments associated with the moisture-density testing of bulk samples of the subgrade soils are given below.

Code	Comment
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.
62	Presence of roots and other organic matter in the bulk sample retrieved from the field.
63	Presence of mica in the bulk sample retrieved from the field.
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-in. [76-mm] size sieve).
65	The test sample included shale chunks, claystone, mudstone, siltstone, and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.).
70	Test could not be completed within five water addition increments. Additional increments were made.
71	Degradation of the test sample was observed during the moisture-density test.
72	The quantity of the test sample was inadequate to complete the moisture-density test. Additional quantity was taken from other test samples or extra material to complete the moisture-density test.
73	Free water appeared at the bottom of the mold (i.e., seeped onto the place).
74	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve. This coarse fraction was included in the test sample for the moisture-density test.
75	The coarse fraction passing the 1 ½ in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve was more than 5%. Method D was used to perform the moisture-density test.
76	The test sample contained coarse material larger than the 1 ½ in. (38-mm) sieve. This coarse material was removed and not used for the moisture-density test.

Code	Comment
77	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve. This coarse material was included in the test sample for the moisture-density test.
78	The coarse fraction passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve was more than 5%. The test sample for the moisture-density testing was sieved using a ¾-in. (19-mm) sieve to separate the coarse fraction from the test sample. This coarse fraction was discarded from the test sample and not used in the moisture-density test. <u>The test sample was, therefore, not truly representative of the bulk sample.</u>
83	Due to insufficient size of the bulk sample, the test sample for the moisture-density test (Protocol P44 or P55) was saved after the test and re-used for the resilient modulus test (Protocol P46).
84	Due to insufficient size of the bulk sample; the sample for the moisture-density testing was obtained from the gradation test sample. The gradation test (Protocol P41 or P51) was performed by <u>dry sieving only</u>.

10.5 If the type of face of the rammer is other than 2-in. (50.8-mm) circular face described herein, please describe the rammer that was used on Form T55.

10.6 Use Form T55 (Test Sheet T55) to report the above information (Items 10.1 to 10.5).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
MOISTURE-DENSITY RELATIONS
LAB DATA SHEET T55

SUBGRADE SOILS
LTPP TEST DESIGNATION SS05/LTPP PROTOCOL P55

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER (Enter an asterisk as the third digit)	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER (Enter an asterisk as third and fourth digit)	__ __ __ __	__ __ __ __
6. TEST RESULTS (Section 10.3 of Protocol P55)		
(a) METHOD USED (B or D)	___	___
(b) OPTIMUM MOISTURE CONTENT (OMC), %	__ __.	__ __.
(c) MAXIMUM DENSITY (MD), PCF	__ __ __.	__ __ __.
7. COMMENTS (Section 10.4 of Protocol P55)		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	____________________ ____________________	____________________ ____________________
8. TYPE OF RAMMER FACE (If other than that described in Section 10.5 of Protocol P55)	____________________	____________________
9. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

NOTE: 1. INCLUDE THE OPTIMUM MOISTURE CONTENT CURVE WITH TEST SHEET T55 (SECTION 10.3.6 OF PROTOCOL P55).
GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

Affiliation____________________ Affiliation____________________

PROTOCOL P56
Test Method for Density of Subgrade Soils (SS08)

This protocol covers the test method for determining the in-place density of cohesive subgrade soils. This protocol is based upon the sample extrusion and preparation procedures described in AASHTO T208-90 (Unconfined Compressive Strength of Cohesive Soil). The test shall be performed in accordance with the following procedures on a representative subgrade sample from one of the thin-walled tube samples obtained at designated A-Type sampling locations.

1. SCOPE

1.1 This protocol covers the procedures for determining the in-place density and moisture content of cohesive subgrade soils. The test procedure utilizes subgrade samples which have been carefully extruded from thinwalled tubes, trimmed, and measured.

1.2 This test method is suitable only for non-organic soils which can retain a stable, undisturbed state when extruded and unconfined.

2. REFERENCED DOCUMENTS

2.1 AASHTO Documents:

AASHTO T208-90, Unconfined Compressive Strength of Cohesive Soil

2.2 LTPP Protocols:

P49 Determination of Natural Moisture Content.

3. SIGNIFICANCE AND USE

This procedure is used to determine the density of the in-place subgrade soils.

4. APPARATUS

4.1 Sample Extruder - The sample extruder shall be capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, at a uniform rate, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to keep the degree of disturbance negligible.

4.2 Dial Comparator - The dial comparator, or other suitable device, shall be used to measure the physical dimensions of the extruded specimen to within 0.1% of the measured dimension.

Note 1 - Vernier calipers are not recommended for soft specimens, which will deform as the calipers are set on the specimen.

4.3 Balance - The balance used to weigh specimens shall determine the mass of the specimen to within 0.1% of its total mass.

4.4 Equipment - Equipment as specified in LTPP Protocol P49.

4.5 Miscellaneous Apparatus - Miscellaneous apparatus includes specimen trimming and carving tools and moisture content cans, as required.

5. PREPARATION OF TEST SPECIMENS

5.1 Specimen Size - The specimen height-to-diameter ratio shall be between 2 and 2.5.

5.2 Sample Extrusion - Handle the specimens carefully to prevent disturbance, changes in cross section, or loss of moisture content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut in small sections to facilitate removal of the specimen without disturbance. The tube specimens may be tested without trimming except for squaring off the ends. When trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings.

6. TEST PROCEDURE

6.1 Determine the mass, M_1, of the moist specimen.

6.2 Determine the dimensions of the entire specimen. Determine the average height and diameter of the test specimen using the apparatus specified in 4.2. Take a minimum of three height measurements (120° apart), and at least three diameter measurements at the quarter points of the height. The dimensions shall be used to calculate the volume of the soil sample.

6.3 Determine the moisture content of the specimen in accordance with LTPP Protocol P49. The entire specimen, or a representative specimen sample, shall be used in determining the moisture content.

7. CALCULATIONS

7.1 If the <u>entire</u> specimen is used to determine the moisture content, the in-place dry density of the soil is expressed as the mass of the oven-dry soil divided by the total volume of soil, and is reported in pounds per cubic foot. The following equation may be used for the calculation of the density:

$$DD = (M_2 / V) \times 3.810$$

Where: M_2 = oven-dry mass of the entire specimen, grams, and
V = volume of the specimen in cubic inches (to nearest 0.1 cubic inch).
(note: 3.810 is a factor transforming gm/in^3 to pcf.)

7.2 If a representative specimen is used to determine the moisture content, calculate the oven-dry mass of the entire specimen, M_2, in grams as follows:

$$M_2 = [M_1 / (100 + w)] \times 100$$

Where: M_1 = mass of entire moist specimen, g
w = moisture content of representative specimen, %, oven-dry mass basis

Then calculate the dry density, DD, of the entire specimen in pounds per cubic foot as follows:

$$DD = (M_2 / V) \times 3.810$$

Where: M_2 = oven-dry mass of the entire specimen, grams, and
V = volume of the entire specimen in cubic inches (to nearest 0.1 cubic inch)
(note: 3.810 is a factor transforming gm/in$_3$ to pcf.)

8. REPORT

Record the following on Form T56

8.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, and Location Number.

8.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

8.3 Test Results

8.3.1 The height and diameter of the specimen, in inches, to two decimal places.

8.3.2 The mass of the moist specimen, in grams, to one decimal place.

8.3.3 The mass of the oven-dry specimen, in grams, to one decimal place.

8.3.4 The dry density of the specimen (DD), in lb/ft^3 (pcf), to the nearest whole number.

8.3.5 The moisture content of the entire specimen, or representative specimen (w), as a percentage, to the nearest whole number.

8.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other notes as required.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DENSITY OF SUBGRADE SOIL
LAB DATA SHEET T56

SUBGRADE SOILS
LTPP TEST DESIGNATION SS08/LTPP PROTOCOL P56

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: _______________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA NO.: SA-______

1. LAYER NUMBER ______

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS

   (a) SPECIMEN HEIGHT, inches __ __.__ __

   (b) SPECIMEN DIAMETER, inches __ __.__ __

   (c) SPECIMEN MASS (moist), grams __ __ __ . __

   (d) SPECIMEN MASS (oven-dry), grams __ __ __ __ . __

   (e) MOISTURE CONTENT (w), % __ __.__

   (f) DRY DENSITY (DD), pcf __ __ __.

7. COMMENTS

   (a) CODE __ __ __ __ __ __
   __ __ __ __ __ __

   (b) NOTE _________________

8. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
LABORATORY CHIEF

Affiliation______________________ Affiliation______________________

PROTOCOL P57
Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter (SS11)

This protocol covers the laboratory measurement of the hydraulic conductivity (also referred to as "coefficient of permeability") of water-saturated porous materials with a flexible wall permeameter. This protocol is based on ASTM D5084-90 (Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter). The test shall be performed in accordance with this standard (ASTM D5084-90), as modified herein. Those sections of the ASTM standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as written herein.

The referenced test method shall be performed on representative subgrade samples from one of the thin-walled tube samples obtained at designated LTPP sampling locations.

1. SCOPE

1.2 This test method shall be utilized with undisturbed thin-walled tube samples that have hydraulic conductivity less than or equal to 1×10^{-5} m/s (1×10^{-3} cm/s [2.54×10^{-3} in/s]).

1.3 The hydraulic conductivity of materials with hydraulic conductivities greater than 1×10^{-5} m/s may be determined by LTPP Protocol P48.

2. REFERENCE DOCUMENTS

2.2 LTPP Protocols

P48 Permeability of Unbound Base and Subbase Materials Under Constant Head Using a Rigid Wall Permeameter.
P49 Determination of the Natural Moisture Content of Unbound Base/Subbase and Subgrade.

5. APPARATUS

5.1 Hydraulic System - Method B (Falling Head Test) shall be utilized for this testing.

5.1.1 Delete

5.1.2 Add: For the purposes of this protocol, the falling head test shall be performed using a constant tailwater elevation.

5.1.3 Delete

5.9 Delete

6. REAGENTS

6.1.2 The permeant liquid shall be 0.005N $CaSO_4$, which can be obtained for example, by dissolving 6.8 grams (0.24 oz.) of nonhydrated reagent grade $CaSO_4$ in 10 liters (2.6 gallons) of de-aired distilled water.

7. TEST SPECIMENS

7.1 The specimens shall have a minimum height equal to the diameter.

7.2 The specimens shall be extruded from the tubes and tested without trimming except for cutting the end surfaces plane and perpendicular to the longitudinal axis of the specimen. Where the sampling operations have caused disturbance of the soil, the disturbed material shall be trimmed.

7.2 Delete the last sentence of Section 7.2. Add: The water content of the trimmings shall be determined in accordance with LTPP Protocol P49.

7.3 Delete

7.4 Delete

8. PROCEDURE

8.3.3 Saturation of the specimen shall be verified by measuring the B coefficient as indicated in 8.3.3.1.

8.3.3.2 Delete

8.3.3.3 Delete

8.4 Consolidate the specimen to the effective vertical stress of 10 psi (69 kPa).

8.5 Use the falling-head test with constant tail water level (Method B).

8.5.1 Utilize published relationships between soil type and hydraulic conductivity and the table shown in 8.5.1 to obtain an estimate of the specimens's hydraulic conductivity and establish a hydraulic gradient to be used during testing.

8.5.3 Delete

8.5.4.2 Delete

8.5.5 Delete

8.6 Delete the last two sentences of Section 8.6. Add: The final moisture content of the specimen shall be determined using LTPP Protocol P49. The final mass, height and diameter shall be measured to the appropriate number of digits as shown in Section 10.3.

9. CALCULATION

9.1 Delete

9.2.2 Delete

10. REPORT

Record the following on Form T57.

10.1 Sample identification shall include: LTPP Laboratory Identification Code, Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, and Location Number.

10.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

10.3 Test Results

10.3.1 Initial mass of soil, in grams, to one decimal place.

10.3.2 Initial specimen height, in inches, to two decimal places.

10.3.3 Initial specimen diameter, in inches, to two decimal places.

10.3.4 Final mass of soil, in grams, to one decimal place.

10.3.5 Final specimen height, in inches, to two decimal places.

10.3.6 Final specimen diameter, in inches, to two decimal places.

10.3.7 The initial water content of the specimen (W_i), as a percentage, to the nearest whole number.

10.3.8 The final water content of the specimen (W_f), as a percentage, to the nearest whole number.

10.3.9 The initial dry density of the specimen (DD_i) in lb/ft^3 (pcf), to the nearest whole number.

10.3.10 The final dry density of the specimen (DD_f), in lb/ft^3 (pcf), to the nearest whole number.

10.3.11 The magnitude of the total back pressure (BP), in lb/in^2 (psi), to the nearest whole number.

10.3.12 The maximum effective consolidation stress, in lb/in^2 (psi), to the nearest whole number. The maximum effective stress exists at the effluent end of the test specimen.

10.3.13 The minimum effective consolidation stress, in lb/in^2 (psi), to the nearest whole number. The minimum effective stress exists at the influent end of the test specimen.

10.3.14 The maximum hydraulic gradient $(H/L)_{max}$ used in the test, to the nearest whole number.

10.3.15 The minimum hydraulic gradient $(H/L)_{min}$ used in the test, to the nearest whole number.

10.3.16 The final degree of saturation of the specimen (S_r), as a percentage, to the nearest whole number.

10.3.17 The average hydraulic conductivity (k) for the last four determinations of hydraulic conductivity (obtained as described in 8.5.4), reported with two significant figures, for example, 7.1×10^{-6} cm/s (1.8×10^{-5} in/s), and reported in units of cm/s.

10.4 Comments shall include LTPP standard code(s), as shown in Section 4.3 of this Guide and any other notes as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PERMEABILITY
LAB DATA SHEET T57

SUBGRADE SOILS
LTPP TEST DESIGNATION: SS11/LTPP PROTOCOL P57

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION: ________ STATE: ____________________________ STATE CODE: __ __
EXPERIMENT NO.: _____ SHRP ID: __ __ __ __
SAMPLED BY: ___________________________________ FIELD SET NO.: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO.: SA- _____

1. LAYER NUMBER ___
2. LABORATORY TEST NUMBER ___
3. LOCATION NUMBER __ __ __
4. LTPP SAMPLE NUMBER __ __ __ __
5. SPECIMEN PARAMETERS (INITIAL)
   (a) MASS, grams __ __ __.__
   (b) HEIGHT, inches __ __.__ __
   (c) DIAMETER, inches __ __.__ __
6. TEST RESULTS
   (a) INITIAL WATER CONTENT (W_i), % __ __.
   (b) FINAL WATER CONTENT (W_f), % __ __.
   (c) INITIAL DRY DENSITY (DD_i), pcf __ __ __.
   (d) FINAL DRY DENSITY (DD_f), pcf __ __ __.
   (e) TOTAL BACK PRESSURE (BP), % __ __ __.
   (f) MAXIMUM EFFECTIVE STRESS, psi __ __.
   (g) MINIMUM EFFECTIVE STRESS, psi __ __.
   (h) MAXIMUM HYDRAULIC GRADIENT (H/L) max __ __.
   (i) MINIMUM HYDRAULIC GRADIENT (H/L) min __ __.
   (j) FINAL DEGREE OF SATURATION (S_r), % __ __.
   (k) AVERAGE HYDRAULIC CONDUCTIVITY (R), cm/s __ __ E - _____
7. SPECIMEN PARAMETERS (FINAL)
   (a) MASS, grams __ __ __.__
   (b) HEIGHT, inches __ __.__ __
   (c) DIAMETER, inches __ __.__ __
9. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ______________________________________
10. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_____________________________ _____________________________
LABORATORY CHIEF

Affiliation_____________________ Affiliation_____________________

PROTOCOL P60
Test Method for Determining Expansive Soils (SS12)

This protocol describes a method to determine if a soil is expansive and a method to predict the amount of swell. This protocol is based on AASHTO Designation T 258-81 (1996), Determining Expansive Soils. The test shall be performed in accordance with this standard (AASHTO T 258), as modified herein. Those sections of the AASHTO standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as modified herein.

The referenced test method shall be performed on representative subgrade samples obtained at designated LTPP sampling locations.

1. SCOPE

This test covers a method to determine if a soil is expansive and a method to predict the amount of swell in the soil. This test is to be conducted in accordance with AASHTO T258-81 (1996), Method II.

2. REFERENCED DOCUMENTS

2.2 LTPP Protocols

P43 Determination of Atterberg Limits
P49 Determination of the Natural Moisture Content
P51 Sieve Analysis of Subgrade Soils

3. DETECTING EXPANSIVE SOILS

3.1 The potential expansiveness of a soil may be determined by using the Atterberg Limits of the soil. The Atterberg Limits shall be determined in accordance with LTPP Protocol P43, Determination of Atterberg Limits.

3.2 The soil's potential for expansion may be determined based on Table 1.

Table 1. Potential for Expansion

Degree of Expansion	Liquid Limit	Plasticity Index
High	> 60	> 35
Marginal	50-60	25-35
Low	< 50	< 25

4. DETERMINING THE AMOUNT OF SWELL

4.1 The amount of swell to be expected in a stratum is determined by an empirical procedure called the Potential Vertical Rise (PVR) Method. The method requires knowledge of the depth of the expansive subgrade.

4.2 Delete

4.3 PVR Test and Prediction Procedure

4.3.1 The moisture content of the subgrade soils will be determined using samples obtained at intervals of 2 feet (0.6 m) to a total depth of 20 feet (6.1 m) below top of subgrade. Test in accordance with LTPP Protocol P49, Determination of the Natural Moisture Content.

4.3.3 For each sample determine the LL and PI in accordance with LTPP Protocol P43. In addition, determine the percent binder (minus No. 40 [0.425-mm] sieve) in the soil layers in accordance with LTPP Protocol P51, Sieve Analysis of Subgrade Soils.

Note: For SPS-8 projects, a maximum depth of sampling is 20 feet (6.1 m). It is assumed that even if expansive soils exist below the 20-foot (6.1-m) depth, the influence on total PVR will not be significant. Also, if the amount of material retained on the No. 40 (0.425-mm) sieve is less than 25% by weight, then Atterberg Limits will not determined for that sample.

4.3.13 Record the following on Form T60:

Sample identification shall include: Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, and Location Number.

Test identification shall include: LTPP Test Designation, LTPP Protocol Number, and Test Date.

Test results shall include: percent passing the No. 40 (0.425-mm) sieve; natural moisture content; LL; PL; the PVR in inches for each 2-ft (0.6-m) layer, as calculated according to Section 4.3 of AASHTO T 258-81 (1990), and the total PVR for the location.

Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note, as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINING EXPANSIVE SOILS
LAB DATA SHEET T60

SUBGRADE SOILS
TEST DESIGNATION SS12/PROTOCOL P60

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP_ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. __ __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L05B) __ __
2. LABORATORY TEST NUMBER __
3. LOCATION NUMBER __ __ __ __ __
4. TEST RESULTS

Sample Depth, ft.	p_{40}, %	mc, %	LL	PL	PVR, in.
0-2	__ __.__	__ __.__	__ __	__ __	__.__ __
2-4	__ __.__	__ __.__	__ __	__ __	__.__ __
4-6	__ __.__	__ __.__	__ __	__ __	__.__ __
6-8	__ __.__	__ __.__	__ __	__ __	__.__ __
8-10	__ __.__	__ __.__	__ __	__ __	__.__ __
10-12	__ __.__	__ __.__	__ __	__ __	__.__ __
12-14	__ __.__	__ __.__	__ __	__ __	__.__ __
14-16	__ __.__	__ __.__	__ __	__ __	__.__ __
16-18	__ __.__	__ __.__	__ __	__ __	__.__ __
18-20	__ __.__	__ __.__	__ __	__ __	__.__ __

5. TOTAL PVR, inches __ __.__ __
6. COMMENTS
 (a) CODE: __ __ __ __ __ __ __ __ __ __ __ __
 (b) NOTE: ____
7. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____

____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_____________________________ _____________________________
LABORATORY CHIEF

Affiliation_____________________ Affiliation_____________________

PROTOCOL P61
Test Method for Determination of Compressive Strength of PCC Cores/Cylinders (PC01)

This LTPP protocol covers the determination of the compressive strength of PCC cores and molded cylinders. The test shall be carried out in accordance with AASHTO T22-88I, as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard (AASHTO T22-88I) shall be followed as written. The test shall be performed on PCC cores obtained from LTPP projects. The specimens to be tested are as shown on the materials testing plans developed for each project.

For PCC pavement cores consisting of multiple layers, the test shall be conducted separately on the core specimens consisting of each of the concrete overlay layers and the original concrete pavement layer from each specified location after assigning proper layer numbers. Layer numbers shall be assigned using the field layer number information from Field Operations Information Form 2 of the field data packet or lab sheet L04. The following definitions will be used throughout this protocol.

a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

c) Test Specimen: That part of the layer which is used for the specified test. The thickness of test specimens cored from the pavement can be equal to or less than the layer thickness.

1. SCOPE

1.1 This test covers the determination of the compressive strength of concrete cores or molded cylinders obtained from a SPS or GPS pavement project.

2. APPLICABLE DOCUMENTS

2.1 AASHTO Standards: As listed in AASHTO T22-88I.

2.2 ASTM Standards: As listed in AASHTO T22-88I.

2.3 LTPP Protocols: P66 - Visual Examination and Thickness of Portland Cement Concrete Cores.

3. SUMMARY OF METHOD

3.1 This method consists of applying a compressive axial load to test specimens at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. SIGNIFICANCE AND USE

4.3 Delete

6. TEST SPECIMENS

6.1 The length of the specimen when capped, shall be as nearly as practicable twice its diameter. Follow Section 6.2 of AASHTO T24-86 for specimen end preparation. The test specimen shall be prepared to achieve the desired length to diameter (L/D) ratio of 1.94 to 2.10 by sawing and/or grinding the bottom and top ends of the core of a PCC layer. Exceptions are: (a) thin PCC overlay layers and (b) the need for reduction in length because of sawing off concrete with embedded steel.

6.2 Neither end of test specimens when tested shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to ⅛ inch in 12 inches [3 mm in 305 mm]). The test specimens shall always be capped at both ends by following AASHTO T231-87I procedures for capping hardened concrete specimens.

6.3 The diameter (D) used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.01 inch (0.25 mm) by averaging two diameters measured by a caliper at right angles to each other at about the mid-height of the specimen.

6.4 Measure the length of the specimen before capping (L_O) and measure the length of the capped specimen (L) prior to testing to the nearest 0.1 inch (2.5 mm). The length shall be determined by averaging four measurements equally spaced around the specimen.

6.5 Use the length of the capped specimen to compute the L/D ratio. This ratio is required to be reported. If the ratio exceeds 2.10, the specimen shall be further reduced in length. Specimens within the ratio of 1.80 to 2.10 require no correction in the measured compressive strength.

6.6 If the L/D ratio is less than 1.80, apply the correction factor shown in the following:

L/D Ratio	Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

Values not given in the table shall be determined by interpolation.

6.7 Care shall be exercised during sample preparation so that the length of a specimen is not reduced to the extent that L/D ratio becomes less than 1.0. However, if for any reason the L/D ratio is less than 1.0 the test shall be performed, the actual L/D ratio reported and a special comment (see Section 9.4) included in the report that explains the reason for the low value of the L/D ratio. Apply a correction factor of 0.87 to a specimen with a L/D ratio less than 1.0.

6.8 PCC cores (obtained from the pavement) shall be stored flat side down, fully supported and at between 5°C (40°F) and 38°C (100°F) in an environmentally protected storeroom.

PCC cylinders (molded in the field) shall be moist cured during storage prior to testing at 23 ± 1.7°C (73.4 ± 3°F). As applied to the treatment of demolded specimens, moist curing means that the test specimens shall have free water maintained on the entire surface at all times. The moist room shall meet the requirements of AASHTO Specification M201. Specimens shall not be exposed to dripping or running water.

Prior to performing the test, the cores or cylinders shall be submerged in lime-saturated water at 23 ± 1.7°C (73.4 ± 3°F) for at least 40 hours immediately prior to performing the test.

9. REPORT

The following information is to be recorded on Form T61:

9.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

9.3 Test Results

Report the following:

(a) Diameter (D) to nearest 0.01 inch.

(b) Length before capping (LO), Length after capping (L), to the nearest 0.1 inch.

(c) Length to diameter (L/D) ratio.

(d) Cross-sectional area, in square inches to the nearest 0.01 inch.

(e) Maximum load, in pounds-force.

(f) Compressive strength (CS), calculated to the nearest 10 psi after applying the appropriate correction factor.

(g) Type of fracture (see Fig. 2 of AASHTO T22-88I and described as follows).

Fracture Type	Code
(a) Cone	11
(b) Cone and split	12
(c) Cone and shear	13
(d) Shear	14
(e) Columnar	15
(f) Other type (explain in a note)	16

9.4 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other note, as needed. Additional codes for special comments associated with the testing are given below.

Code	Comments
21	Length to diameter ratio was less than 1.0 because the layer thickness was less than the diameter of the specimen.
22	Length to diameter ratio was equal to or less than 1.0 because the specimen was sawed in order to remove concrete with embedded steel.
23	Embedded steel was noted in the specimen near the middle of the diametral plane.
24	Embedded steel was noted at or near the side of the test specimen.
25	The specimen was skewed (either end of the specimen departed from perpendicularity to the axis by more than 0.5° or ⅛ inch in 12 inches (3 mm in 305 mm), as tested by placing the specimen on a level surface).

9.5 Use Form T61 (Test Sheet T61) to report the above information (Items 9.1 to 9.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
COMPRESSIVE STRENGTH OF PCC CORES
LAB DATA SHEET T61

PORTLAND CEMENT CONCRETE
TEST DESIGNATION PC01/PROTOCOL P61

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM FIELD OPERATIONS FORM 2 AND/OR LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __
6. DIAMETER (D), INCHES	__.__ __	__.__ __
7. LENGTH BEFORE CAPPING (LO), INCHES	__ __.__	__ __.__
8. LENGTH OF CAPPED SPECIMEN (L),	__ __.__	__ __.__
9. L/D RATIO	__.__ __	__.__ __
10. CROSS-SECTIONAL AREA (A), SQ. IN.	__ __.__ __	__ __.__ __
11. MAXIMUM LOAD, LBF	__ __ __ __ __ __.	__ __ __ __ __ __.
12. COMPRESSIVE STRENGTH (CS), PSI (AFTER APPLYING CORRECTION FACTOR)	__ __ __ __ __.	__ __ __ __ __.
13. TYPE OF FRACTURE (FR)		
(a) CODE	__ __	__ __
(b) NOTE	____________________	____________________
14. COMMENTS		
(a) CODE	__ __ __ __ __ __ __ __ __ __ __ __	__ __ __ __ __ __ __ __ __ __ __ __
(b) NOTE	____________________ ____________________	____________________ ____________________
15. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS:____

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SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

______________________________ | ______________________________
LABORATORY CHIEF

Affiliation____________________ | Affiliation__________________

PROTOCOL P62
Test Method for Determination of Splitting Tensile Strength of PCC Cores/Cylinders (PC02)

This LTPP protocol covers the determination of the splitting tensile strength of PCC cores and molded cylinders. The test shall be carried out in accordance with AASHTO T198-88I as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard (AASHTO T198-88I) shall be followed as written. The test shall be performed on cores or molded cylinders obtained from LTPP projects. The specimens to be tested are as shown on the materials testing plans developed for each project.

For PCC pavement cores consisting of multiple layers, the test shall be conducted separately on the core specimens consisting of each of the concrete overlay layers and the original concrete pavement layer from each specified location after assigning proper layer numbers. Layer numbers shall be assigned using the field layer number information from Field Operations Information Form 2 of the field data packet or lab sheet L04. The following definitions will be used throughout this protocol.

(a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(c) Test Specimen: That part of the layer which is used for the specified test. The thickness of test specimens cored from the pavement can be equal to or less than the layer thickness.

1. SCOPE

1.1 This test covers the determination of the splitting tensile strength of cores or molded cylinders obtained from a GPS or SPS pavement project.

2. APPLICABLE DOCUMENTS

2.1 AASHTO Standards: AASHTO T22-88I, AASHTO T24-86, AASHTO T67-85

2.2 LTPP Protocol: P66 - Visual Examination and Thickness of Portland Cement Concrete Cores/Cylinders.

4. TEST SPECIMENS

4.1 The test specimen shall be prepared following the procedure of Sections 7.1–7.3 of AASHTO T24-86.

4.2 The test specimen shall be sawed and/or ground to achieve a uniform length, and the end surfaces shall conform to Section 6.2 of AASHTO T24-86. The length to diameter ratio shall be as nearly as practicable between 1 and 2; in any case the length to diameter ratio shall not exceed 2.5. In order to comply with these requirements, the test specimen is required to be trimmed as not to exceed one inch at the bottom of the specimen and up to ½ inch (13 mm) at the top of the specimen. The finished ends are not to be capped.

4.3 PCC cores, retrieved from the pavement, are marked with an arrow or other symbol to show the direction of traffic. It is important that this orientation mark be transferred to the trimmed surface of the PCC core if the core is trimmed to comply with the requirements of Section 4.2. After trimming, the PCC specimen that will be used for testing will no longer contain the arrow or other symbol that was marked during the drilling operations. Therefore, the participating laboratory is required to adhere to the following rule:

If any PCC core requires trimming at the top, then the laboratory technician shall paint the same arrow or other traffic direction symbol on the trimmed surface that is marked on the surface of the core. The arrow or other symbol shall be placed along the same axis to designate the direction of traffic on the pavement surface. The face to be marked shall be the one closest to the pavement surface.

4.4 Measure the average diameter (D) of the test specimen to the nearest 0.01 inch (0.25 mm) following Section 5.2 of AASHTO T198-88I.

4.5 Determine the length (L) of the test specimen to the nearest 0.1 inch (2.5 mm) in accordance with Section 5.2 of AASHTO T198-88I.

4.6 PCC <u>cores</u> (obtained from the pavement) shall be stored flat side down, fully supported and at between 5°C (40°F) and 38°C (100°F) in an environmentally protected storeroom.

PCC <u>cylinders</u> (molded in the field) shall be moist cured during storage prior to testing at 23 ± 1.7°C (73.4 ± 3°F). As applied to the treatment of demolded specimens, moist curing means that the test specimens shall have free water maintained on the entire surface at all times. The moist room shall meet the requirements of AASHTO Specification M201. Specimens shall not be exposed to dripping or running water.

Prior to performing the test, the cores or cylinders shall be submerged in lime-saturated water at 23 ± 1.7°C (73.4 ± 3°F) for at least 40 hours immediately prior to performing the test.

7. REPORT

The following information is to be recorded on Form T62:

7.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

7.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

7.3 Test Results

Report the following:

(a) Diameter (D) to the nearest 0.01 inches.

(b) Length (L) to the nearest 0.1 inches.

(c) Maximum load, in pounds-force.

(d) Splitting tensile strength (STS) calculated to the nearest 1 psi.

(e) Type of fracture, as described with a code and note in Section 9.3(g) of LTPP Protocol P61.

(f) Length to diameter (L/D) ratio.

7.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide and any other note, as needed. Additional codes for special comments associated with the testing are given below.

Code	Comments
31	Length to diameter ratio was equal to or less than 1.0 because the layer thickness was less than the diameter of the specimen.
32	The specimen was trimmed only at the bottom end.
33	The specimen was trimmed only at the top end.
34	The specimen was trimmed at the bottom and top ends.
35	The line of contact between the specimen and each bearing strip was straight and free from any projections or depressions higher or deeper than 0.01 inches (0.25 mm).
36	The line of contact described in code 35 above was made possible by grinding.
37	The line of contact described in code 35 above was made possible by capping, or by grinding and capping.
38	The line of contact between the specimen and each bearing strip had more than 0.01-inch (0.25-mm) tolerance as described in Code 35 but less than 0.1-inch (2.5-mm) tolerance. The specimen was tested.

Code	Comments
39	The projections/depressions on the test surface (as described in Code 35) were higher or deeper than 0.1 inch (2.5 mm). The specimen was tested because there was no other replacement specimen.
40	The PCC core retrieved from the field did not have any arrow or "T" to show the direction of traffic.

7.5 Use form T62 (Test Sheet T62) to report the above information (Items 7.1 to 7.4).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SPLITTING TENSILE STRENGTH OF PCC CORES
LAB DATA SHEET T62

PORTLAND CEMENT CONCRETE
TEST DESIGNATION PC02/PROTOCOL P62

LABORATORY PERFORMING TEST:______________________________
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM FIELD OPERATIONS FORM 2 AND/OR LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __
6. DIAMETER (D), INCHES	__.__ __	__.__ __
7. SPECIMEN LENGTH (L), INCHES	__ __.__	__ __.__
8. MAXIMUM LOAD, LBF	__ __ __ __ __ __.	__ __ __ __ __ __.
9. SPLITTING TENSILE STRENTH (STS), PSI	__ __ __ __.	__ __ __ __.
10. TYPE OF FRACTURE (FR)		
(a) CODE	__ __	__ __
(b) NOTE	________________	________________
11. L/D RATIO	__.__ __	__.__ __
12. COMMENTS		
(a) CODE	__ __ __ __ __ __	__ __ __ __ __ __
	__ __ __ __ __ __	__ __ __ __ __ __
(b) NOTE	________________	________________
	________________	________________
13. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS:______________________________

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SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

Affiliation______________________ Affiliation______________________

PROTOCOL P63
Test Method for the Determination of the Coefficient of Thermal Expansion of PCC (PC03)

This LTPP protocol covers the test method for determination of the coefficient of thermal expansion (CTE) of hardened PCC. This protocol is based on a test method and apparatus developed by the FHWA at the Turner-Fairbank Highway Research Center.

The test described herein may be performed on concrete cylinders or cores drilled from field structures.

The following definitions will be used throughout this protocol:

(a) Core: An intact cylindrical specimen of a concrete structure which is removed from the structure by drilling in accordance with AASHTO T24 (ASTM C42).

(b) Cylinder: An intact cylindrical specimen of concrete fabricated in accordance with AASHTO T23 or AASHTO T126 (ASTM C31 or ASTM C192).

(c) Test Specimen: That portion of a core or cylinder which is used in this test. Test specimens should be 175-mm (7-inches) long with a nominal diameter of 100 mm (4 inches).

NOTE: The apparatus used in this test will allow use of specimens 175 to 200 mm (7 to 8 inches) long with nominal diameters of 100 to 150 mm (4 to 6 inches); however, for ease of testing and for consistency it is recommended that a consistent specimen length and diameter be used whenever possible. Use of different lengths and/or diameters will require adjustment of the apparatus and recalibration.

1. SCOPE

1.1 This test method covers determination of the CTE of hydraulic cement concrete cores or cylinders. Since it is known that the degree of saturation of concrete influences its measured CTE, the moisture condition of the concrete specimens must be controlled. For this test procedure, the specimens must be in a saturated condition.

1.2 The values stated in SI units shall be regarded as the standard.

2. APPLICABLE DOCUMENTS

2.1 AASHTO Standards:

T23 Making and Curing Concrete Test Specimens in the Field.
T24 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T126 Making and Curing Concrete Test Specimens in the Laboratory.

2.2 ASTM Standards:

C31 Making and Curing Concrete Test Specimens in the Field.
C42 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.
C192 Making and Curing Concrete Test Specimens in the Laboratory.

2.3 LTPP Protocols:

P66 Visual Examination and Thickness of PCC Cores

3. SUMMARY OF TEST METHOD

3.1 This method determines the CTE of a cylindrical concrete specimen, maintained in a saturated condition, by measuring the length change of the specimen due to a specified temperature change. The measured length change is corrected for any change in length of the measuring apparatus (previously determined), and the CTE is then calculated by dividing the corrected length change by the temperature change and then the specimen length, as described in the section on calculations.

4. SIGNIFICANCE AND USE

4.1 Measurement of the CTE permits assessment of the potential for length/volume change of concrete due to a uniform temperature change, and the potential deformation of a concrete structure due to a temperature gradient through the concrete. As an example, for pavement slabs on grade, uniform temperature change will affect the openings at joints, and a temperature gradient through the thickness of these same slabs will produce curling of the slabs. Using the results of this test, better estimates of slab movement and stress development due to temperature change can be obtained.

5. EQUIPMENT

5.1 Concrete saw, capable of sawing the ends of a cylindrical specimen perpendicular to the axis and parallel to each other.

5.2 A scale or balance having a capacity of 20 kg (44 lb), and accurate to 0.1% over its range.

5.3 Caliper, comparator or other suitable device to measure the specimen length to the nearest 0.1 mm (0.004 in).

5.4 A controlled temperature water bath with a temperature range of 10 to 50°C (50 to 122°F), capable of controlling the temperature to 0.1°C (0.2°F).

5.5 A rigid support frame for the specimen to be used during length change measurement. The frame should be designed to have minimal influence on the length change measurements obtained during the test, and support the specimen such that the specimen is allowed to freely adjust to any change in temperature. A suitable support frame is described in detail in Appendix A.

5.6 Four submersible temperature measuring devices with a resolution of 0.1°C (0.2°F) and accurate to 0.2°C (0.4°F).

5.7 A submersible LVDT gauge head with excitation source and digital readout, with a minimum resolution of 0.00025 mm (0.00001 in), and a range suitable for the test (for ease in setting up the apparatus, a range of ± 3 mm (0.1 in) has been found practical).

NOTE: LVDT with the appropriate associated electronic actuating and indicating apparatus appear to give the best results with respect to stability, sensitivity, and reliability. Multichannel recording of outputs has been found to be practical and efficient. As an alternate, a data logger can be used to excite the LVDT and record the LVDT and both temperature and time outputs. The data can be stored directly in a personal computer for graphing of test results.

5.8 A micrometer, or other suitable device for calibrating the LVDT over the range to be used in the test, and with a minimum resolution of 0.00025 mm (0.00001 in).

6. TEST SPECIMENS

6.1 Test specimens shall consist of drilled 100-mm (4-in) nominal diameter cores sampled from the concrete structure being evaluated, or 100-mm (4-in) nominal diameter cylinders. Cores shall be obtained in accordance with AASHTO T24. Cylinders shall be cast in accordance with AASHTO T23 or T126. The specimens shall be sawed perpendicular to the axis at a suitable length. A length of 180 ± 2 mm (7.0 ± 0.1 in) has been found acceptable. The standard reference material used for calibration (see Appendix) shall be the same length as the test specimen so that the frame does not have to be adjusted between calibration and testing. The sawed ends shall be flat and parallel.

7. PROCEDURE

7.1 Specimen conditioning

The specimens shall be conditioned by submersion in saturated limewater at 23 ± 2°C (73 ± 4°F) for not less than 48 hours and until two successive weighings of the surface-dried sample at intervals of 24 hours show an increase in weight of less than 0.5%. A surface dried sample is obtained by removing the surface moisture with a towel.

7.2 Test Procedure

7.2.1 Place the measuring apparatus, with LVDT attached, in the water bath and fill the bath with cold tap water. Place the four temperature sensors in the bath at locations that will provide an average temperature for the bath as a whole. To avoid any sticking at the points of contact with the specimen, put a VERY THIN film of silicon grease on the end of the support buttons and LVDT tip.

7.2.2 Remove the specimen from the saturation tank and measure its length at room temperature to the nearest 0.1 mm (0.004 in). After measuring the length, place the specimen in the measuring apparatus located in the controlled temperature bath, making sure that the lower end of the specimen is firmly seated against the support buttons, and that the LVDT tip is seated against the upper end of the specimen.

NOTE: The desired range of travel is the linear range of the LVDT over which it has been calibrated. The LVDT travel during the test should remain well within this range to insure accurate results.

7.2.3 Set the temperature of the water bath to 10 ± 1°C (50 ± 2°F). When the bath reaches this temperature, allow the bath to remain at this temperature until thermal equilibrium of the specimen has been reached, as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in) taken every ten minutes over a one-half hour time period. Also at this time, check that the specimen is firmly seated against the support buttons, as confirmed by the LVDT reading.

7.2.4 Record the temperature readings from the four sensors to the nearest 0.1°C (0.2°F). Record the LVDT reading to the nearest 0.00025 mm (0.00001 in). These are the initial readings.

7.2.5 Set the temperature of the water bath to 50 ± 1°C (122 ± 2°F). Once the bath has reached 50 ± 1°C (122 ± 2°F), allow the bath to remain at this temperature until thermal equilibrium of the specimen has been reached, as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in) taken every ten minutes over a one-half hour time period.

7.2.6 Record the temperature readings from the four sensors to the nearest 0.1°C (0.2°F). Record the LVDT reading to the nearest 0.00025 mm (0.00001 in). These are the second readings.

7.2.7 Set the temperature of the water bath to 10 ± 1°C (50 ± 2°F). When the bath reaches this temperature, allow the bath to remain at this temperature until thermal equilibrium of the specimen has been reached, as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in) taken every ten minutes over a one-half hour time period.

7.2.8 Record the temperature readings from the four sensors to the nearest 0.1°C (0.2°F). Record the LVDT reading to the nearest 0.00025 mm (0.00001 in). These are the final readings.

8. CALCULATIONS

8.1 Coefficient of Thermal Expansion - Calculate the CTE of one expansion or contraction test-segment of a concrete specimen as follows (reported in micro strains/°C):

$$CTE = (\Delta L_a / L_o) / \Delta T \qquad (1)$$

where: ΔL_a= actual length change of specimen during temperature change, mm (see equation 2)
L_o = measured length of specimen at room temperature, mm
ΔT = measured temperature change (average of the 4 sensors),°C (increase is positive, decrease is negative)

$$\Delta L_a = \Delta L_m + \Delta L_f \qquad (2)$$

where: ΔL_m = measured length change of specimen during temperature change, mm (increase = positive, decrease = negative)
ΔL_f = length change of the measuring apparatus during temperature change, mm (see equation 3)

$$\Delta L_f = C_f \times L_o \times \Delta T \qquad (3)$$

where: C_f = correction factor accounting for the change in length of the measurement apparatus with temperature, in^{-6}/in/°C (see appendix A.2)

8.2 For the expansion test segment, the initial and second readings are used in the calculations. For the contraction test segment, the second and final readings are used in the calculations.

8.3 The test result is the average of the two CTE values obtained from the two test segments provided the two values are within 0.3 microstrain/°C (0.2 microstrain/°F) of each other. If the two values are not within 0.3 microstrain/°C (0.2 microstrain/°F) of each other, one or more additional test segments are completed until two successive test segments yield CTE values within 0.3 microstrain/°C (0.2 microstrain/°F) of each other. The test result is the average of these two CTE values.

$$CTE = (CTE_1 + CTE_2) / 2 \qquad (4)$$

NOTE: Differences in successive CTEs greater than the required value sometimes occur during the first few cycles of temperature change due to minor misalignment, or lack of proper initial seating of the specimen. This is usually self-correcting during the first few temperature cycles. However, it does point out the importance of carefully positioning the specimen at the start of the test.

9. REPORT

The following information is to be recorded on Form T63:

9.1 Sample identification shall include: SHRP ID, Laboratory Identification Code, State Code, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, LTPP Laboratory Test Number, Test Date.

9.3 Correction Factor Measurements

9.3.1 Description of material type calibration specimen.

9.3.2 Length of calibration specimen in millimeters (to the nearest millimeter).

9.3.3 Diameter of calibration specimen in millimeters (to the nearest millimeter).

9.3.4 CTE, α_c, of calibration specimen, mm/°C.

9.3.5 Average C_f, average correction factor, mm/°C (from the results of three tests).

9.4 Test Results

9.4.1 Description of specimen, including type of specimen, diameter, coarse aggregate type, age.

9.4.2 Length of specimen (L) in millimeters (to the nearest 0.1 mm).

9.4.3 Initial temperature (T_i), in °C, to the nearest 0.1°C.

9.4.4 Initial LVDT reading, in volts, to the nearest 0.001 volts.

NOTE: Some LVDT signal conditioning equipment gives output directly in units of length rather than in volts. Such equipment is also acceptable and would eliminate the need to convert a voltage reading to units of length.

9.4.5 Final temperature (T_f), in °C, to the nearest 0.1°C.

9.4.6 Final LVDT reading, in volts, to the nearest 0.001 volts.

9.4.7 LVDT calibration factor, in volts/mm.

9.4.8 CTE, α_c, of PCC specimen, mm.

9.5 Comments shall include LTPP standard comment codes, as shown in Section 4.3 of this Guide and any other notes as needed.

APPENDIX A
STANDARD TESTING EQUIPMENT

A.1 Specimen Measuring Apparatus

The measuring apparatus consists of two primary components: a frame and a length change measuring device.

A.1.1 Frame

Figure A.1 shows a schematic of a suitable measuring frame. Any specimen measuring frame should be constructed with the following features in mind:

Because the frame will be submerged in water throughout the test, components should be made of a non-corroding material. In so far as possible, the portions of the frame which directly affect measurement over a change in temperature, should be constructed of invar and protected from corrosion as necessary.

The frame may be designed to be adjustable to accommodate different sample lengths; however, calibrations will be required after each adjustment.

A.1.2 Length Change Measurement Devices

The sample length change may be measured using any suitable apparatus which can be submerged in water, has sufficient resolution, and gives reproducible results. The FHWA apparatus uses a submersible spring-loaded LVDT gauge head for length change measurement.

Appropriate signal conditioning equipment will be required if an LVDT or other electronic transducer is used for length change measurements. A voltmeter or a computer and data acquisition software may also be required if the signal conditioning equipment does not have a digital readout. The LVDT will require calibration using a micrometer to relate the digital readout output (which may be in volts or arbitrary units) to actual length changes.

The contact tip (at the point of contact between the measuring device and the specimen) must be attached to the length change measuring device with a suitable adhesive to prevent loosening during a test.

A.2. Reference Test for Determination of Correction Factor

The test procedure described in Section 7.2 is used to determine a correction factor to account for expansion of the measuring apparatus during the test. A specimen with a known CTE is used. The specimen should be composed of a material which is essentially linearly-elastic, non-corroding, non-oxidizing, and non-magnetic and have a thermal coefficient as close as possible to that of concrete (304 stainless steel, which has a CTE of 17.3×10^{-6}/°C (9.6×10^{-6}/°F), is a suitable material). The reference material sample should also be of the same nominal dimensions as the test samples, so that no adjustment of the frame and/or the LVDT is necessary between calibration and testing.

A.2.1 Calculation of the correction factor

Assuming that the length change of the apparatus varies linearly with temperature, the correction factor C_f is defined as:

$$C_f = \Delta L_f / L_{cs} / \Delta T \tag{A.1}$$

where: ΔL_f = length change of the measuring apparatus during temperature change, mm (see equation A.2)

L_{cs} = measured length of calibration specimen at room temperature, mm

ΔT = measured temperature change, °C (increase = positive, decrease = negative)

$$\Delta L_f = \Delta L_a - \Delta L_m \tag{A.2}$$

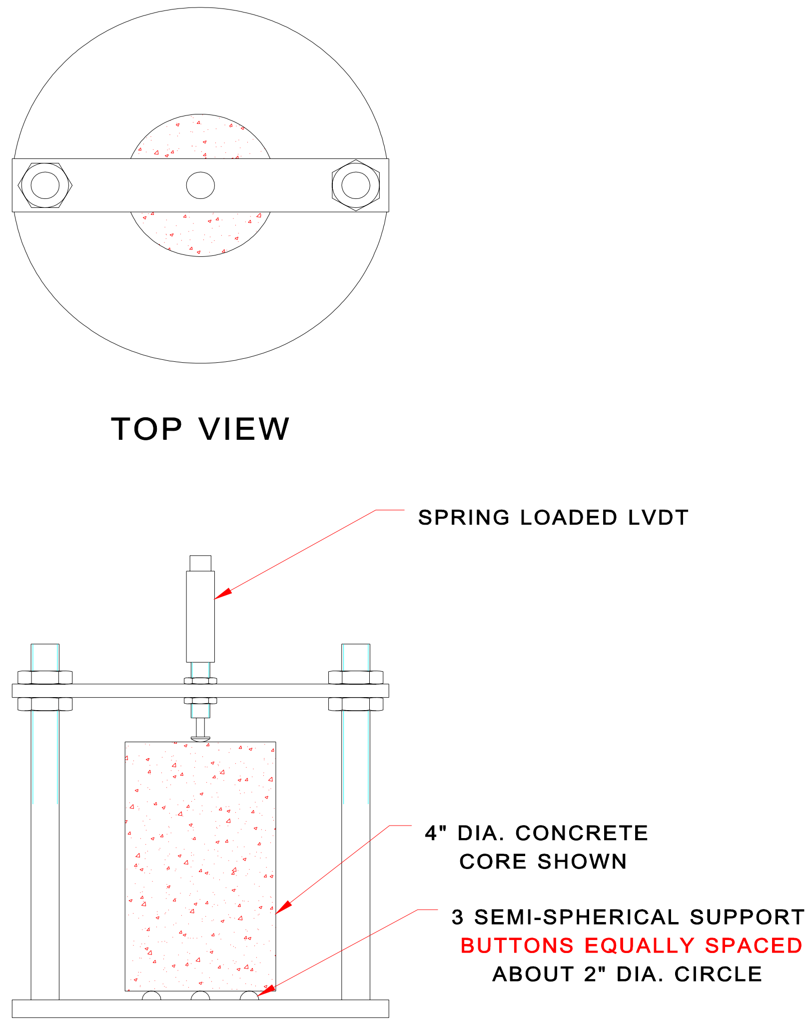
where: ΔL_a = actual length change of calibration specimen during temperature change, mm (see equation A.3)

ΔL_m = measured length change of calibration specimen during temperature change, mm (increase = positive, decrease = negative)

$$\Delta L_a = L_{cs} \times \alpha_c \times \Delta T \tag{A.3}$$

where: α_c = CTE of calibration specimen, /°C (known)

NOTE: It is recommended that at least 3 calibration tests be performed, and that the average of the correction factors calculated for each test be used for calculations on actual concrete test.



BASEPLATE DIA. ≅ 10"

FRAME HEIGTH ≅ 10"

Figure A.1 Schematic of Suitable Measuring Frame.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINATION OF THE COEFFICIENT OF THERMAL EXPANSION
LAB DATA SHEET T63-A

PORTLAND CEMENT CONCRETE
TEST DESIGNATION PC03/PROTOCOL P63

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER		__
2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __
6. DIAMETER (D), mm	__ __ __	__ __ __
7. SPECIMENT LENGTH (L), mm	__ __ __	__ __ __
8. INITIAL TEMPERATURE, °C	__ __.__	__ __.__
9. INITIAL LVDT READING, VOLTS	__.__ __ __	__.__ __ __
10. FINAL TEMPERATURE, °C	__ __.__	__ __.__
11. FINAL LVDT READING, VOLTS	__.__ __ __	__.__ __ __
12. LVDT CALIBRATION FACTOR, VOLTS/mm	__ __ __ __	__ __ __ __
13. C_f OF MEASUREMENT APPARATUS, (mm^{-6}/mm/°C) (SEE T63-B)	__ __ __ __	__ __ __ __
14. CTE	__ __ __	__ __ __
15. COMMENTS		
(a) CODE	__ __ __ __ __ __	__ __ __ __ __ __
	__ __ __ __ __ __	__ __ __ __ __ __
(b) NOTE	____________________	____________________
	____________________	____________________
16. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS:____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
LABORATORY CHIEF LTPP REPRESENTATIVE

Affiliation____________________ Affiliation____________________

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINATION OF THE COEFFICIENT OF THERMAL EXPANSION APPARATURS CORRECTION FACTOR
LAB DATA SHEET T63-B

PORTLAND CEMENT CONCRETE
TEST DESIGNATION PC03/PROTOCOL P63

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ________________ STATE __________________ STATE CODE __ __

1. CALIBRATION SPECIMEN MATERIAL ________________________________

2. CALIBRATION SPECIMEN LENGTH (L), mm	__ __ __	__ __ __	__ __ __
3. CALIBRATION SPECIMEN DIAMETER	__ __ __	__ __ __	__ __ __
4. CTE OF CALIBRATION SPECIMEN, mm/°c	__ __ __	__ __ __	__ __ __
5. AVERAGE C_f, $mm^{-6}/mm/°C$			__ __ __ __
6. COMMENTS			
(a) CODE	__ __ __ __ __ __	__ __ __ __ __ __	__ __ __ __ __ __
	__ __ __ __ __ __	__ __ __ __ __ __	__ __ __ __ __ __
(b) NOTE	________________	________________	________________
	________________	________________	________________
7. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __

GENERAL REMARKS:____

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SUBMITTED BY, DATE

____
LABORATORY CHIEF

Affiliation____________________

CHECKED AND APPROVED, DATE

____
LTPP REPRESENTATIVE

Affiliation__________________

PROTOCOL P64
Test Method for Determination of Static Modulus of Elasticity of PCC Cores (PC04)

This LTPP protocol covers the determination of the static modulus of elasticity and Poisson's ratio of PCC cores under longitudinal compressive stress. The test shall be carried out in accordance with ASTM C469-02 as modified by the following. Only sections of the referenced standard which have been modified are included below. In all other sections the standard (ASTM C469-02) shall be followed as written. The test shall be performed on cores obtained from LTPP projects. The specimens to be tested are as shown on the materials testing plans developed for each project.

For PCC pavement cores consisting of multiple layers, the test shall be conducted separately on the test specimens consisting of each of the concrete overlay layers and the original concrete pavement layer from each specified location after assigning proper layer numbers. Layer numbers shall be assigned using the field layer number information from Field Operations Information Form 2 of the field data packet or lab sheet L04. The following definitions will be used throughout this protocol.

(a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(c) Test Specimen: That part of the layer which is used for the specified test. The thickness of test specimens cored from the pavement can be equal to or less than the layer thickness.

1. SCOPE

1.1 This test covers the determination of chord modulus of elasticity (Young's) and Poisson's ratio for PCC cores when the test specimen has been placed under longitudinal compressive stress. Chord modulus of elasticity and Poisson's ratio are defined in ASTM E-6.

2. REFERENCE DOCUMENTS

2.1 ASTM Standards: As listed in ASTM C469-02.

2.2 AASHTO Standards:

AASHTO T22-88I Compressive Strength of Cylindrical Concrete Specimens
AASHTO T24-86 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
AASHTO T67 Load Verification of Testing Machines
AASHTO T231-87I Capping Cylindrical Concrete Specimens

2.3 LTPP Protocols

P61 Test Method for Determination of Compressive Strength of In-Place Concrete
P66 Test Method for Visual Examination and Thickness of Portland Cement Concrete Cores

3. SIGNIFICANCE AND USE

3.1 This test method provides a stress to strain ratio value and a ratio of lateral to longitudinal strain for hardened concrete.

3.2 The modulus of elasticity and Poisson's ratio values, applicable within the customary working stress range of 0 to 40 percent of ultimate concrete strength, may be used in computing stresses for observed strains.

4. APPARATUS

4.1 Add: The requirements of Section 5.1 of AASHTO T22-88I shall also be applied.

4.2 Compressometer - As described in ASTM C469-02

5. TEST SPECIMENS

5.2 Drilled Core Specimens - The test specimen shall be prepared to achieve the desired length to diameter (L/D) ratio of 1.5 or greater by sawing or grinding the bottom (not to exceed 1 inch [25 mm]) and top (up to ½ inch [13 mm]) of the core of a PCC layer. If L/D ratio is less than 1.5 because of being a thin PCC layer, then this condition shall be recorded in the report.

PCC <u>cores</u> (obtained from the pavement) shall be stored flat side down, fully supported and at between 40°F (5°C) and 100°F (38°C) in an environmentally protected storeroom.

Prior to performing the test, the cores or cylinders shall be submerged in lime-saturated water at 73.4 ± 3°F (23 ± 1.7°C) for at least 40 hours immediately prior to performing the test.

5.3 Add: Capping of both ends of the test specimen can be accomplished by using the procedures of AASHTO T231-87I.

5.4 The length (L) of the test specimen can also be determined to the nearest 0.1 inch (3 mm) by averaging four measurements equally spaced around the specimen. The diameter (D) of the test specimen shall be measured to the nearest 0.01 inch (0.3 mm) by averaging two diameters measured by a caliper at right angles to each other near the mid-height of the specimen. The average diameter (D) shall be used to calculate the cross sectional area of the test specimen.

5.5 The test specimen shall be weighed immediately prior to the test and the weight recorded to the nearest 0.1 lb (0.05 kg). The unit weight shall be determined using LTPP Protocol P65.

6. PROCEDURE

6.2 Determine the compressive strength of the companion cores (as described in LTPP protocol P61) prior to the test for static modulus of elasticity).

6.5 The ultimate load is determined from the compressive strength tests performed on companion specimens.

6.6 Delete

6.8 After the test, the specimen shall be properly marked and placed into storage.

7. CALCULATIONS

7.3 Calculate the modulus of elasticity (E_c) and Poisson's ratio (μ) by following Sections 7.1 and 7.2 of the standard (ASTM C469-02).

Select the value of S_1 stress level that corresponds to a longitudinal strain specified in Section 7.1 of ASTM C469-02.

Select the value of S_2 stress level corresponding to 40 percent of ultimate load (maximum load at failure) determined during the compressive strength test conducted earlier on the companion test specimen taken from the same or near the same sampling area.

8. REPORT

The following information is to be recorded on Form T64.

8.1 Sample Identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

8.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

8.3 Test Results

Report the following:

(a) Diameter (D) to the nearest 0.01 inch.

(b) Length (L) to the nearest 0.1 inch.

(c) Length to Diameter (L/D) ratio.

(d) Unit weight (C_W) of the concrete to the nearest 1 lb/ft^3. (pcf)

(e) Modulus of elasticity (E_c) to the nearest 50,000 psi.

(f) Poisson's ratio (μ) to the nearest 0.01.

(g) Plots of stress-strain curves (include the compressive strength and ultimate load of the companion specimen on the plot).

8.4 Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide and any other note, as needed. Additional codes for special comments associated with testing are given below.

Code	Comments
41	Length to diameter ratio was less than 1.5 because the layer was equal to or less than the diameter of the specimen.
42	Length to diameter ratio was equal to or less than 1.5 because the specimen was sawed in order to remove concrete with embedded steel.
43	Embedded steel was noted in the specimen near the middle of the diametral plane.
44	Embedded steel was noted at or near the side of the test specimen.
45	The specimen was trimmed only at the bottom end.
46	The specimen was trimmed only at the top end.
47	The specimen was trimmed at the top and bottom ends.

8.5 Use Form T64 (Test Sheet T64) to report the above information (Items 8.1 to 8.4).

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
STATIC MODULUS OF ELASTICITY OF PCC CORES
LAB DATA SHEET T64

PORTLAND CEMENT CONCRETE
TEST DESIGNATION PC04/PROTOCOL P64

LABORATORY PERFORMING TEST:____________________
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION ____________ STATE ____________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ____________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM FIELD OPERATIONS FORM 2 AND/OR LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __
3. LABORATORY TEST NUMBER	__	__
4. LOCATION NUMBER	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __
6. DIAMETER (D), INCHES	__.__ __	__.__ __
7. SPECIMENT LENGTH (L), INCHES	__ __.__	__ __.__
8. L/D RATIO	__.__ __	__.__ __
9. UNIT WEIGHT (CW), PCF	__ __ __.	__ __ __.
10. MODULUS OF ELASTICITY (Ec), PSI	__ __ __ __ __ __ __.	__ __ __ __ __ __ __.
11. POISSON'S RATIO (μ)	0.__ __	0.__ __
12. COMMENTS		
(a) CODE	__ __ __ __ __ __	__ __ __ __ __ __
	__ __ __ __ __ __	__ __ __ __ __ __
(b) NOTE	____________	____________
	____________	____________
13. TEST DATE	__ __-__ __-__ __ __ __	__ __-__ __-__ __ __ __
NOTE: STRESS STRAIN PLOTS MADE AND ATTACHED (CHECK YES OR NO)	YES NO	YES NO

GENERAL REMARKS:____________________

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________ ____________________
LABORATORY CHIEF

Affiliation____________ Affiliation____________

PROTOCOL P65
Test Method for Density of PCC (PC05)

This protocol covers the determination of the specific gravity, density, percent absorption and percent voids in PCC. The test shall be conducted in accordance with ASTM C642-97 as modified herein. Sections of the referenced standard which have been modified are included below. In all other sections, the standard (ASTM C642-97) shall be followed as written. The test shall be performed on PCC cores or portions of PCC cores extracted from test sections included in the LTPP experiments. The following definitions will be used throughout this protocol:

(a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(c) Test Specimen: That part of the layer which is used for the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

1. SCOPE

1.1 This test method covers the determinations of specific gravity, density, percent absorption and percent voids in PCC core specimens or portions thereof.

4. TEST SPECIMENS

4.1 The specimens shall be PCC cores or portions thereof. These cores or pieces shall be of one layer of the PCC pavement and shall be free from observable cracks, fissures or shattered edges.

6. CALCULATION

6.2 Calculate the density of the concrete using the following equation:

$$Density = 62.36g_1$$

where: g_1 = Bulk specific gravity, dry.

8. REPORT

Record the following information on Form T65:

8.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number, and LTPP Sample Number.

8.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

8.3 Test Results

8.3.1 Weight of oven-dried specimen in air (A), grams.

8.3.2 Weight of surface-dry specimen in air after immersion (B), grams.

8.3.3 Weight of surface-dry sample in air after immersion and boiling (C), grams.

8.3.4 Weight of sample in water after immersion and boiling (D), grams.

8.3.5 Percent absorption after immersion (to one decimal place).

8.3.6 Bulk specific gravity, dry (g_1) (to two decimal places).

8.3.7 Apparent specific gravity (g_2) (to two decimal places).

8.3.8 Density (to one decimal place).

8.3.9 Percent voids in PCC (to one decimal place).

8.3.10 Comments shall include: LTPP standard comment code(s), as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DENSITY OF PORTLAND CEMENT CONCRETE
LAB DATA SHEET T65

PORTLAND CEMENT CONCRETE
LTPP TEST DESIGNATION PC05/LTPP PROTOCOL P65

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION______________ STATE______________________ STATE CODE __ __
EXPERIMENT NO ________ SHRP ID __ __ __ __
SAMPLED BY: ____ FIELD SET NO. ___
REGIONAL DRILLING AND SAMPLING CONTRACTOR SAMPLING AREA NO SA-__ __
SAMPLING DATE: __ __-__ __-__ __ __ __

1. LAYER NUMBER ___
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER ___
4. LTPP SAMPLE NUMBER __ __ __ __
5. WEIGHT OF OVEN-DRIED SPECIMEN IN AIR (A), grams __ __ __ __ __.__
6. WEIGHT OF SURFACE-DRY SPECIMEN IN AIR AFTER IMMERSION (B), grams __ __ __ __ __.__
7. WEIGHT OF SURFACE-DRY SPECIMEN IN AIR AFTER IMMERSION AND BOILING (C), grams __ __ __ __ __.__
8. WEIGHT OF TEST SPECIMEN IN WATER AFTER IMMERSION AND BOILING (D), grams __ __ __ __ __.__
9. PERCENT ABSORPTION AFTER IMMERSION, % __.__
10. BULK SPECIFIC GRAVITY, DRY __ __.__ __
11. APPARENT SPECIFIC GRAVITY __ __.__ __
12. DENSITY OF PCC, lb/ft^3 __ __ __.__
13. PERCENT VOIDS IN PCC, % __.__
14. COMMENTS
    (a) CODE __ __ __ __ __ __
    __ __ __ __ __ __
    (b) NOTE ____
15. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS:____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

_____________________________ _____________________________
LABORATORY CHIEF

Affiliation_____________________ Affiliation_____________________

PROTOCOL P66
Test Method for Visual Examination and Thickness of PCC Cores (PC06)

This LTPP protocol covers the visual examination and determination of thickness (measurement of length) of PCC cores. The visual examination shall be performed prior to the conduct of other designated tests. The test shall be carried out in accordance with the following procedure, unless otherwise directed by LTPP.

If an AC core is bonded with the PCC core and/or the underlying layer of treated base/subbase is bonded with the PCC core, then the PCC portion will be sawed off from other bonded layers in the laboratory. The participating laboratory is required to paint the same arrow or other traffic direction symbol on the top of the surface of each PCC core as that marked on the surface of the overlying AC core after sawing.

PCC cores from pavement sections are marked with an arrow or other symbol to show the direction of traffic. Any underlying bonded layer of treated base and/or subbase (including asphaltic treated base, lean concrete, econocrete, or cement treated aggregate layers) are required to be removed from the PCC cores in the field or in the participating laboratory by sawing. Layer thicknesses shall be measured prior to sawing.

For PCC pavements cores consisting of multiple PCC layers, the test shall be conducted separately on the test specimens from the concrete overlay layer and the original concrete pavement layer from each specified location after assigning proper layer numbers. The traffic direction symbol marking shall be transferred to the underlying bonded original concrete pavement layer surface by the Laboratory Contractor following the procedure in paragraph 2. This rule does not apply to specimens designated for LTPP Protocol P67, Interface Bond Strength Test. The following definitions will be used throughout this protocol.

(a) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two or more different layers.

(b) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.

(c) Test Specimen: That part of the layer which is used for the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.

In this protocol the use of the term core implies the entire length of the core.

When assigning the layer number in the laboratory to the PCC cores, the field layer number information provided on Field Operations Information Form 2 of the field data packet and/or lab sheet L04, should be carefully examined and the following rules shall be followed.

RULE #1: If only one field layer number is assigned to the overlay concrete layer and the original concrete pavement layer of the PCC core, then this field layer number shall be assigned to the underlying original concrete pavement core, and the next layer number shall be assigned to the overlay. These layer numbers shall be used on Form T66 and included on the sample tags/labels.

RULE #2: If two different field layer numbers from Field Operations Information Form 2 or two different layer numbers from lab sheet L04 have been assigned to the two bonded concrete layers within the PCC core or to the two separated PCC cores from the same location on the pavement, then these layer numbers shall be retained for use on Form T66 and included on the sample tags/labels.

RULE #3: In all other cases when a PCC core consists of only one PCC layer from a given location from the PCC pavement, then the field layer number from Field Operations Information Form 2 (or the layer number assigned on lab sheet L04, if different from the field layer number) shall be retained by the participating laboratory on Form T66 and on the sample tags/labels.

1. SCOPE

1.1 This method covers the visual examination of the entire PCC core and measurement of the length of the entire PCC core in the laboratory.

2. APPLICABLE DOCUMENT

2.1 AASHTO T148-86, Measuring Length of Drilled Concrete Cores.

2.2 ASTM C856-83, Petrographic Examination of Hardened Concrete.

3. APPARATUS

3.1 The apparatus shall be a calipering device that will measure the length of axial elements of the core.

3.2 The apparatus shall be so designed that the core will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or stubs of hardened steel, and the ends that bear against the surface of the core shall be rounded to a radius of not less than 6.4 mm (¼ in.) and not more than 12.7 mm (½ in.).

3.3 The apparatus shall provide for the accommodation of cores of different nominal lengths over a range of at least 25 to 250 mm (1 to 10 in.).

3.4 The calipering apparatus shall be so designed that it will be possible to make a length measurement at the center of the upper end of the core and at three additional points spaced at equal intervals along the circumference of a circle of measurement whose center point coincides with the center of the core and whose radius is approximately one-half of the radius of the core.

3.5 The measuring rod or other device that makes contact with the end surface of the core for measurement shall be rounded to a radius of 3.2 mm (⅛ in.). The scale on which the length readings are made shall be marked with clear, definite, accurately spaced graduations. The spacing of the graduations shall be 2.54 mm (0.1 in.) or a decimal part thereof.

3.6 The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without distortion or deflection of more than 0.25 mm (0.01 in.) during all normal measuring operations.

4. CORE PREPARATION

4.1 If the PCC pavement core is bonded with a treated base or subbase layer and/or AC layer (as shipped to the laboratory) then the PCC portion of the core shall be carefully removed by sawing <u>after</u> measuring layer thicknesses. If two PCC layers are bonded within the PCC core then these should be separated by sawing <u>after</u> measuring layer thickness. In all cases, the arrow or other traffic direction symbol marking on the top surface shall be transferred to the top of the sawed surface of the core as explained in the beginning (paragraph 3) of this protocol.

4.2 The core shall be free of any conditions not typical of the pavement surface. If a core is found damaged or shows abnormal defects then it shall not be used for length measurement and its condition shall be recorded during the visual examination described in Section 6.

4.3 If a core drilled from a pavement includes particles of the aggregate material bonded to the bottom surface of the core, then the bonded particles shall be removed by wedging, or by chisel and hammer, so as to expose the lower surface of the PCC core. If during the removal of the bonded aggregate the concrete is broken so that the instructions of Section 5.4 cannot be followed, the core shall not be used for length measurement and its condition shall be recorded during the visual examination described in Section 6.

4.4 Care shall be exercised in preserving the marked arrow or other symbol, if present on the top surface of the core. The arrow or the other symbol marking indicates the direction of traffic on the pavement.

5. PROCEDURE FOR THICKNESS (LENGTH) MEASUREMENT

5.1 Before any measurements of the core length are made, the apparatus shall be calibrated with suitable gauges so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.25 mm (0.01 in.), suitable corrections shall be applied to the core length measurements.

5.2 The core shall be placed in the measuring apparatus with the smooth end of the core, that is, the end that represents the upper surface of the pavement placed in the down position so as to bear against the three hardened-steel supports. The core shall be placed on the supports so that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the core.

5.3 Four measurements of the length shall be made on each core, one at the central position and one each at three additional positions spaced at equal intervals along the circumference of the circle of measurement described in Section 3.4. Each of these measurements shall be read to the nearest 2.5 mm (0.1 in.) either directly or by interpolation.

5.4 If, in the course of the measuring operation, it is discovered that at one or more of the measurement points the surface of the core is not representative of the general plane of the core because of a small projection or depression, the core shall be rotated slightly about it axis and a complete set of four measurements made with the core in the new position.

5.5 The individual measurements shall be recorded to the nearest 2.5 mm (0.1 in.) and the average of four measurements, expressed to the nearest 2.5 mm (0.1 in.), shall be reported as the average thickness of the core.

6. PROCEDURE FOR VISUAL EXAMINATION

6.1 Cores are to be visually examined for general condition, deterioration distresses and defects such as cracks, voids, staining, honeycombing, layer separation, aggregate distribution, general type and shape of aggregate such as rounded gravel, angular crushed stone, etc. The field logs should be reviewed prior to the visual examination in order to be aware of and confirm or reject any notations made in the field.

6.2 The bottom surface of the core shall also be examined and any condition affecting the length measurements such as uneven surface due to removal of underlying bonded aggregates from the aggregate base or subbase course (as described in Section 4.3) , shall be recorded.

6.3 Follow the instructions provided in Section 4.2 (especially 4.2.1, 4.2.2, 4.2.3, 4.2.5, 4.2.6, 4.2.7, 4.2.10, 4.2.11), Section 10.2 and Table 1 of ASTM C856-83 standard for further visual examination. Petrographic and stereo microscopic examinations are not required.

6.4 Results of visual examination shall be based on LTPP standard codes, as described in Appendix "A" to LTPP Protocol P66.

7. REPORT

The following information is to be recorded on Form T66.

7.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, LTPP Sample Number.

7.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, Test Date.

7.3 Test Results:

(a) Average Thickness of Core (L) to the nearest 0.1 inches.

(b) Comments based on Visual Examination. Use standard visual examination result codes listed in Appendix A to LTPP Protocol P66 and a note, if needed, not exceeding 25 characters.

7.4 Comments shall include: LTPP standard comment code(s) in Section 4.3 of this Guide and any other note as needed.

7.5 Use Form T66 (Test Sheet T66) to report the above information (Items 7.1 to 7.4).

7.6 Test results of PCC cores from <u>only one</u> PCC layer (with the same layer number) shall be reported on the same test sheet (Form T66). Test results of the PCC cores from the second PCC layer, if present, shall be reported on a separate test sheet (Form T66).

APPENDIX "A" TO LTPP PROTOCOL P66
CODES FOR VISUAL EXAMINATION OF
PORTLAND CEMENT CONCRETE CORES

This attachment to LTPP Protocol P66 describes a series of two-digit codes for reporting the results of visual examination of PCC cores.

Code	Description
51	Intact core; excellent condition; suitable for testing.
52	Hairline cracks on the surface of the core; suitable for testing.
53	Cracks and/or voids visible along the side of the core; core is suitable for testing.
54	Badly cracked or damaged core; unsuitable for testing.
55	Ridges on the sides of the cores; (Identify by placing a straightedge along the side of the core when the distance between the straightedge and core face is $^{1}/_{16}$ inch [1.6 mm] or greater); such a condition should be recorded if the core is used for any other test.
56	Very rough and uneven bottom surface of the core. Place the core on a level surface. Identify with this code when less than 75% of the surface area is in contact with a level surface when the core is perpendicular to the surface.
57	Core extremely damaged from sampling, shipping, or laboratory handling; unsuitable for testing. Core thickness cannot be measured.
58	Core was sawed in the laboratory to remove the core from the underlying bonded layer of base, subbase, or AC.
59	Core consisted of two or more PCC layers. Core was sawed in the laboratory and appropriate layer numbers were assigned to each PCC layer.
60	One or more PCC layers have become separated, appropriate layer numbers were assigned to each PCC layer.
61	Segregation of coarse and fine aggregate is observed over 25% or more of the surface area of the core.
62	Voids in the matrix of the PCC mixture are observed along the sides of the core.
63	Voids due to loss of coarse and fine aggregate are observed along the sides of the core.
64	Core is missing significant portions and cannot be considered a coherent cylindrical core; unsuitable for testing.
65	Coarse aggregate along the face of the core contains 50% or more of crushed materials with fractured faces.

Code	Description
66	Coarse aggregate along the face of the core is a mixture of uncrushed gravel and crushed gravel or stone.
67	The exposed aggregates along the face of the core are lightweight aggregate.
68	More than 10% of the surface area of the core contains soft and deleterious aggregate particles or clay balls. Soft aggregates are defined as those aggregates that can be easily scratched with a knife.
69	Cracks are generally <u>across</u> or <u>through</u> the coarse aggregate.
70	Cracks are generally <u>around</u> the periphery of the coarse aggregate.
71	Cracks are associated with embedded steel.
72	Rims are observed on aggregate.
73	Fine aggregate is natural sand.
74	Fine aggregate is manufactured sand.
75	Fine aggregate is a mixture of natural and manufactured sand.
76	Steel is present in the core (give type size and location of steel in a separate note).
77	Steel is corroded.
78	Core indicates D-crack – cracking is defined as a series of closely spaced crescent-shaped hairline cracks that appear at a PCC pavement surface and often curve around the intersection of longitudinal joints/cracks and transverse joints/cracks.
79	Core indicates deterioration due to freeze-thaw cycles.
80	Core indicates sulfate attack.
81	Core indicates alkali silica reactivity. It is shown by the expansion of reactive aggregates. As expansion occurs, the cement matrix is disrupted and cracks. It appears as a map cracked area.
82	Skewed core. A core is considered skewed when either end of the core departs from perpendicularity to the axis by more than 0.5° or ⅛ inch in 12 inches (3 mm in 305 mm), as tested by placing the core on a level surface.
99	Other comment (describe in a note).

Any six codes from the above list can be used to report the results of the visual examination. A note may also be recorded (the note shall not be more than 25 characters long).

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PCC CORE EXAMINATION AND THICKNESS
LAB DATA SHEET T66

PORTLAND CEMENT CONCRETE
LTPP TEST DESIGNATION PC06/LTPP PROTOCOL P66

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE:__ __ __ __

REGION _______________ STATE ________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM FIELD OPERATIONS FORM 2 AND/OR LAB SHEET L04) __

2. SAMPLING AREA NO. (SA-)	__ __	__ __	__ __	__ __	__ __	__ __
3. LABORATORY TEST NUMBER	__	__	__	__	__	__
4. LOCATION NUMBER	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
5. LTPP SAMPLE NUMBER	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __	__ __ __ __
6. AVERAGE THICKNESS (L), INCHES	__ __.__	__ __.__	__ __.__	__ __.__	__ __.__	__ __.__
7. VISUAL EXAMINATION						
(a) CODE	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
(Section 7.3(b), Protocol P66)	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
(b) NOTE	__________	__________	__________	__________	__________	__________
	__________	__________	__________	__________	__________	__________
	__________	__________	__________	__________	__________	__________
8. COMMENTS						
(a) CODE	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
(Section 7.4, Protocol P66)	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
(b) NOTE	__________	__________	__________	__________	__________	__________
	__________	__________	__________	__________	__________	__________
9. TEST DATE	___-___-___	___-___-___	___-___-___	___-___-___	___-___-___	___-___-___

GENERAL REMARKS:____

SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

LABORATORY CHIEF

Affiliation____________________ Affiliation____________________

PROTOCOL P67
Test Method for Determination of the Shear Strength at the Interface of Bonded Layers of Concrete (PC07)

This protocol covers the test method for the determination of the shear strength at the interface of bonded layers of concrete. This protocol is based on the Iowa DOT Test Method No. IOWA 406-B (September 1984). The test described herein shall be performed on drilled concrete cores obtained from LTPP test sections as shown on the materials testing plans developed for each project.

1. SCOPE

1.1 General

This test method covers the determination of the interface shear strength of a drilled concrete core sampled from a bonded concrete overlay pavement.

1.2 Summary of Test Method

This method consists of applying a continuous load to the vertical diametral plane of the test specimen along the bonded interface between the overlay concrete and existing concrete (see Figure 1). The load is applied until a shear failure occurs at the bonded interface. The bond shear strength is calculated by dividing the maximum load attained during the test by the cross-sectional area of the test specimen.

1.3 Significance and Use

The bond shear strength may be used to assess the integrity of the bond between bonded concrete overlay and the underlying concrete pavement.

1.4 Sample Storage

PCC cores shall be stored flat side down, fully supported and at between 5°C (40°F) and 38°C (100°F) in an environmentally protected (enclosed area not subject to the natural elements) storeroom.

Each specimen shall have a label or tag attached that clearly identifies the material, the project number/test section from which it was recovered, and the sample number, as a minimum.

1.5 Units

In this protocol, the International System of Units (SI - The Modernized Metric System) is regarded as the standard. Units are expressed first in their "soft" metric form followed, in parenthesis, by their U.S. Customary unit equivalent.

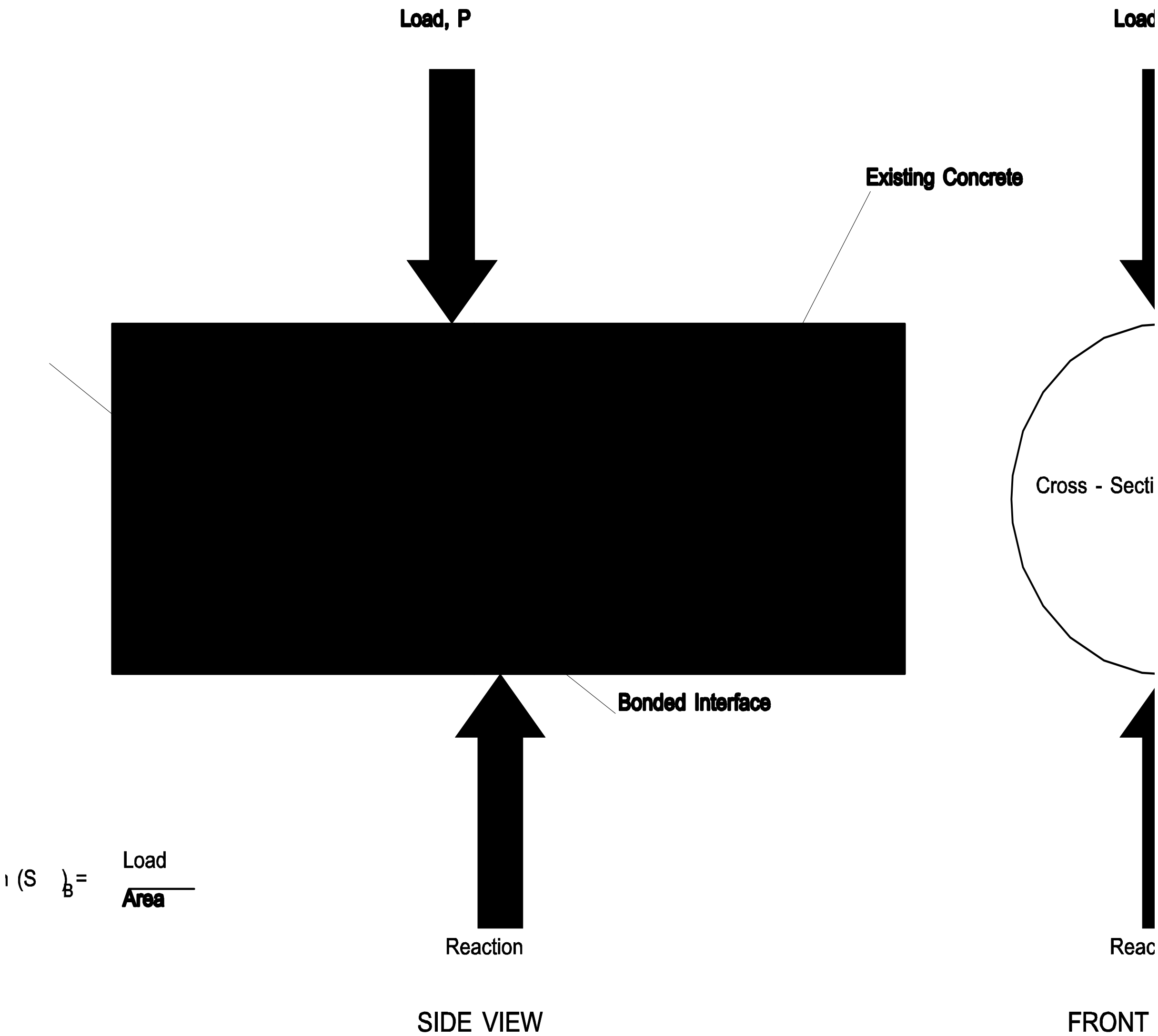

Figure 1. Loading scheme used for the shear strength test.

2. TESTING

2.1 Testing Prerequisites

The testing described in this protocol shall be conducted after; (1) approval by the FHWA COTR to begin testing, (2) initial layer assignment using Form L04, (3) visual examination and thickness of PCC cores and thickness of layers within PCC cores using Protocol P66, (4) final layer assignment based on the P66 test results (corrected Form L04 if needed), and (5) completion of all other applicable tests. In order to obtain approval under item (1), the laboratory must, at least, (a) submit and obtain approval of the QC/QA plan for FHWA materials testing, and (b) demonstrate that their testing equipment meets or exceeds the specifications contained in this protocol.

2.2 Test Sample Locations and Assignment of Laboratory Test Numbers

The test shall be performed on the test specimens of PCC retrieved from C-type, 102-mm (4-inch) diameter coreholes or from other sampling locations as dictated by the sampling plans for the particular LTPP section.

The test results shall be reported separately for test specimens obtained from the beginning and end of a test section as follows:

(a)Beginning of the Section (Stations 0-): specimens of the overlay and original layer that are retrieved from areas in the approach end of the test section (stations preceding 0+00) shall be assigned Laboratory Test Number '1'.

(b)End of the Section (Stations 5+): specimens of the original and overlay layer that are retrieved from areas in the leave end of the test section (stations after 5+00) shall be assigned Laboratory Test Number '2'.

3. DEFINITIONS

The following definitions will be used throughout this protocol.

(a) Layer: That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogenous.

(b) Core: An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two, or more layers of concrete.

(c) Test Specimen: That portion of the core which is used for the specified test. For this protocol, the test specimen shall include a representative portion of the existing concrete and overlay concrete.

4. APPLICABLE DOCUMENTS

4.1 ASTM Standards

C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
C42 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
E4 Standard Practices for Load Verification of Testing Machines
E74 Standard Practices for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

4.2 AASHTO Standards

T24 Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T67 Standard Methods of Load Verification of Testing Machines

4.3 LTPP Protocols

P66 Visual Examination and Thickness of Portland Cement Concrete Cores

4.4 Other Documents:

Iowa Test Method No. 406-B, Method of Test for Determining the Shearing Strength of Bonded Concrete, Iowa DOT, 1984

5. APPARATUS

5.1 Loading Block

The loading block used for the bond shear test shall be designed to accommodate a 102-mm (4-in.) diameter test specimen. A typical loading block is illustrated in Figure 2.

5.2 Loading Head

A metal loading head with a concave surface having a 51-mm (2-in.) radius of curvature is required to apply load to the specimen. The loading head shall be 13 mm (0.5 in) wide. Edges should be rounded by grinding to remove sharp edges. A typical loading head is illustrated in Figure 2.

5.3 Testing Machine

The testing machine shall conform to the requirements of the ASTM Test Method C 39 possessing sufficient capacity that will provide the rate of loading described in Section 7.

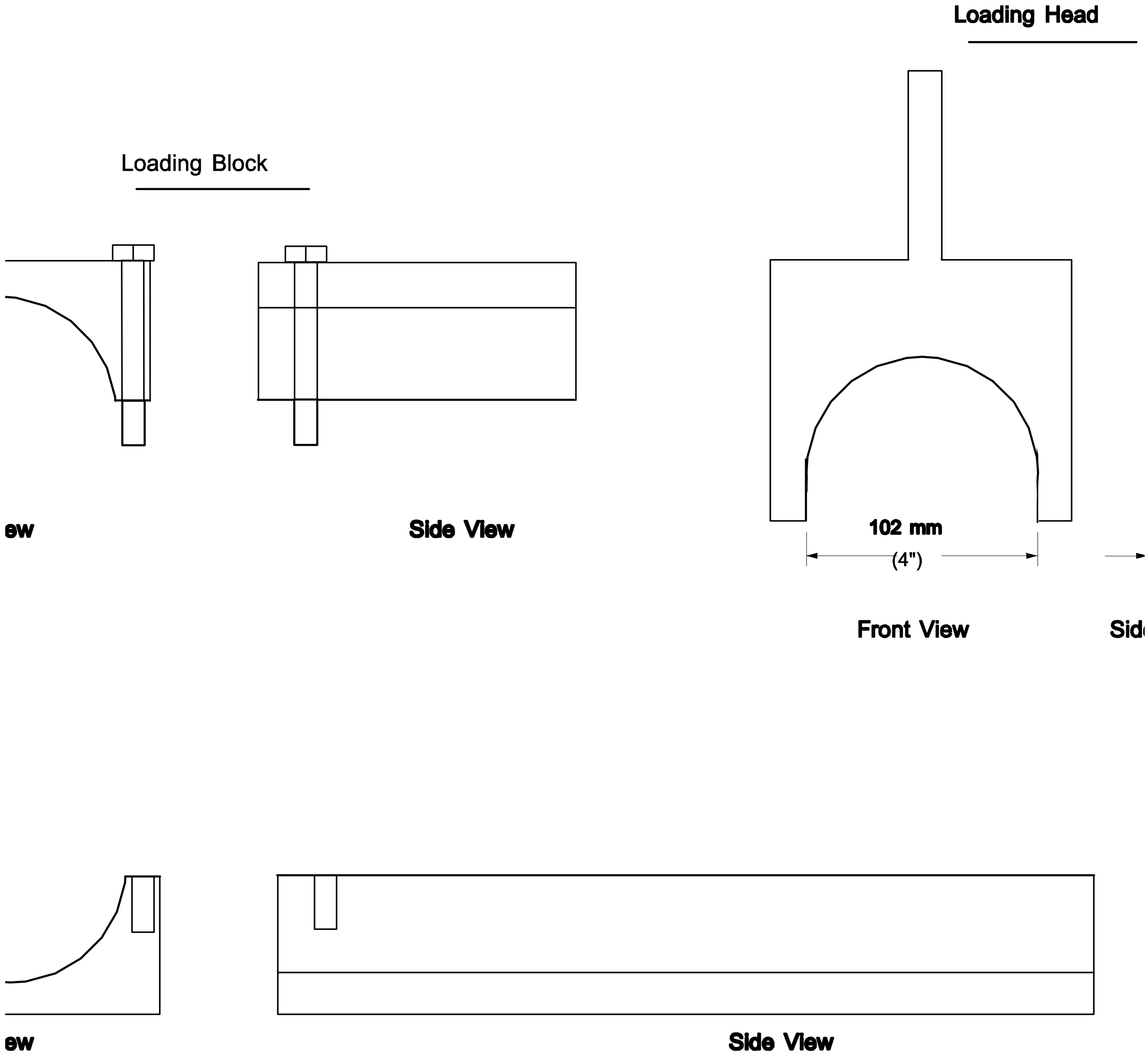

Figure 2. Typical loading block and loading head.

6. TEST SPECIMENS

6.1 Test specimens shall consist of drilled, 102-mm (4-in) diameter cores sampled from the test section. The cores shall be drilled in accordance with the procedures set forth in the LTPP Guide for Field Materials Sampling Testing and Handling. The length of the drilled cores shall include both the existing and the overlay concrete layers.

7. PROCEDURE

7.1 Specimen Positioning

7.1.1 Secure the specimen in the loading block. The bonded interface shall be centered between the edge of the loading block and the edge of the loading head.

7.1.2 Align the loading head adjacent to the bonded interface. The loading head shall rest parallel to the bonded interface on the overlay concrete portion of the specimen.

NOTE 1: Sample positioning and loading is shown in Figure 3.

7.2 Rate of loading

7.2.1 Apply the load continuously and without shock, at a constant rate within the range of 2760 to 3450 kPa (400 to 500 psi) per minute until failure occurs. Record the maximum applied load, P_{MAX}, carried by the specimen during the test.

8. CALCULATIONS

8.1 Calculate the bond shear strength, S_B, as follows:

$$S_B = \frac{P_{MAX} \times 10^3}{A}$$

where: S_B = bond shear strength, kPa
P_{MAX} = maximum load applied to specimen, N
A = cross-sectional area of test specimen, mm^2

and:

$$A = \frac{\pi D^2}{4}$$

where: A = cross-sectional area of test specimen, mm^2
D = diameter of test specimen, mm

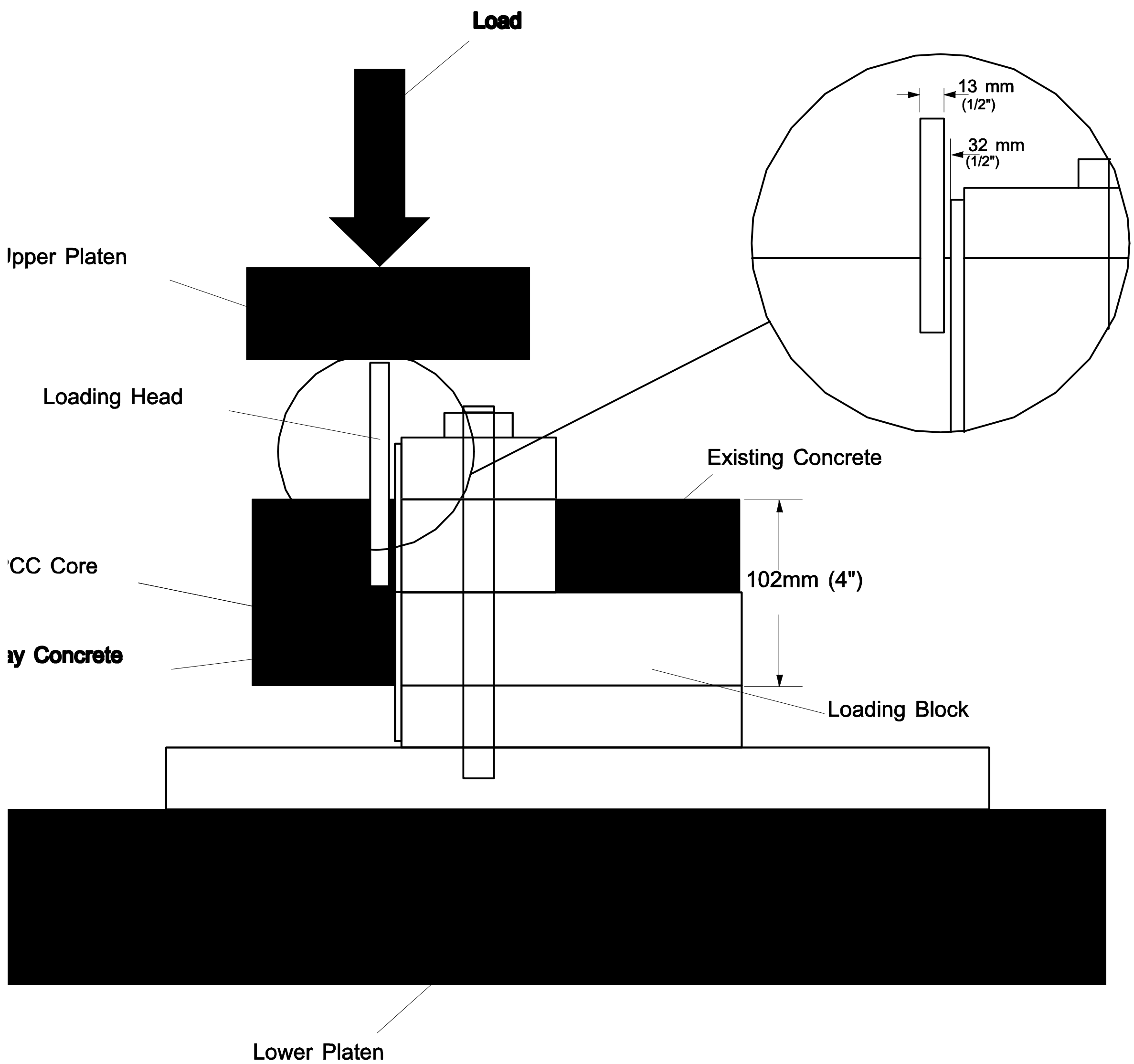

Figure 3. Illustration of sample positioning and loading.

9. REPORT

The following information shall be recorded on Form T67.

9.1 Sample identification shall include: Laboratory Identification Code, State Code, SHRP ID, Layer Number, Field Set Number, Sampling Area No., Sample Location Number, and LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

9.3 Failure Plane. Identify if failure occurred at the interface, in the existing concrete layer, or in the overlay concrete.

9.4 Test Results

9.4.1 Specimen dimensions including thickness of the overlay concrete, thickness of existing concrete, diameter and cross-sectional area.

9.4.2 Maximum load applied in N.

9.4.3 Bond shear strength in kPa.

9.5 Comments shall include LTPP standard comment codes, as shown in Section 4.3 of this Guide and any other notes as needed. Additional codes for special comments associated with the shear bond strength test are given below:

Code	Comment
53	Irregular interface between existing and overlay concrete.
54	Failure plane in overlay concrete.
55	Failure plane in existing concrete.
56	Failure plane in interface between existing and overlay concrete.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINATION OF THE SHEAR STRENGTH
AT THE INTERFACE OF BONDED LAYERS OF CONCRETE
LAB DATA SHEET T67

PORTLAND CEMENT CONCRETE
LTPP TEST DESIGNATION PC07/LTPP PROTOCOL P67

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ______________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: __________________________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER (OVERLAY LAYER) __
2. LAYER NUMBER (ORIGINAL SURFACE LAYER) __
3. LOCATION NUMBER __ __ __
4. LABORATORY TEST NUMBER __
5. LTPP SAMPLE NUMBER __ __ __ __
6. DIAMETER, mm __ __ __ .
7. LENGTH OF SPECIMEN, mm __ __ __ .
8. THICKNESS OF OVERLAY LAYER, mm __ __ __ .
9. THICKNESS OF ORIGINAL SURFACE LAYER, mm __ __ __ .
10. CROSS-SECTIONAL AREA, mm^2 __ __ __ __ __ __ .
11. MAXIMUM LOAD, N __ __ __ __ __ __ __.
12. SHEAR BOND STRENGTH, kPa __ __ __ __ __.
13. COMMENTS
    (a) CODE
    (b) NOTE

TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____
SUBMITTED BY:

____
LABORATORY CHIEF

Affiliation: ____________________

CHECKED AND APPROVED, DATE:

____

Affiliation: ____________________

PROTOCOL P68
Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete Using the Linear Traverse (Rosiwal) Method (PC08)

This protocol covers the test method for determining the air-void content and parameters of the air-void system in hardened concrete using the linear traverse (Procedure A) method. This protocol is based on ASTM C457-98 (Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete). The test shall be performed in accordance with this standard (ASTM C457-98), as modified herein. Those sections of the ASTM standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as written herein.

1. SCOPE

1.1 Only the linear traverse method shall be used.

4. SAMPLING

4.2 Delete

4.3 Delete

12. DELETE

13. DELETE

14. DELETE

15. REPORT

The following information shall be recorded on Form T68.

15.1 Sample identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Location Number, Layer Number, and Sample Number.

15.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number and the Test Date.

15.3 Test Results

15.3.1 Record all calculation parameters as required on Form T68.

15.3.2 Report the values for A, α, and L to the nearest two significant digits.

15.4 Comments shall include LTPP standard comment codes, as shown in Section 4.3 of this Guide and any other notes as needed.

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
AIR CONTENT OF HARDENED CONCRETE
LAB DATA SHEET T68

PORTLAND CEMENT CONCRETE
LTPP TEST DESIGNATION PC08/LTPP PROTOCOL P68

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION: ________________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER __ __
2. LOCATION NUMBER __ __ __ __ __
3. LABORATORY TEST NUMBER __ __
4. LTPP SAMPLE NUMBER __ __ __ __ __ __
5. TRAVERSE DIMENSIONS
   a. TRAVERSE LENGTH THROUGH AIR (T_a), inches __ __.__ __ __
   b. TRAVERSE LENGTH THROUGH PASTE (T_p), inches __ __.__ __ __
   c. TOTAL LENGTH OF TRAVERSE (T_t), inches __ __ __
6. NUMBER OF AIR VOIDS INTERSECTED, N __ __ __ __ __
7. AIR CONTENT (A), percent __ __.__
8. AVERAGE CHORD LENGTH (l), inches 0.__ __ __
9. SPECIFIC SURFACE (α), inches^{-1} __ __ __ __
10. SPACING FACTOR (L), inches 0.__ __ __
11. PASTE-AIR RATIO (p/A) __ __.__ __ __
12. COMMENTS
   (a) CODE ____ ____ ____ ____ ____ ____
   (b) NOTE ____
13. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS: ____

____

SUBMITTED BY, DATE

CHECKED AND APPROVED, DATE

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LABORATORY CHIEF

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Affiliation_____________________

Affiliation_____________________

PROTOCOL P69
Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) (PC09)

This protocol covers the test method for determining the flexural strength of concrete by the use of a simple beam with third-point loading. This protocol is based on ASTM C78-02 (Flexural Strength of Concrete Using Simple Beam with Third-Point Loading). The test shall be performed in accordance with this standard (ASTM C78-02), as modified herein. Those sections of the ASTM standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as written herein.

9. REPORT

Record the following on Form T69.

9.1 Sample identification shall include: Laboratory Identification Code, Region, State, State Code, Experiment Number, SHRP ID, Field Set Number, Sampling Area Number, Layer Number, Location Number, LTPP Sample Number.

9.2 Test identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and the Test Date.

9.3 Specimen dimensions including the average width, average depth and span length. All dimensions measured to the nearest 0.05 inches.

9.4 Details of curing history (25 characters or less).

9.5 Moisture condition.

9.6 Specimen age, days.

9.7 Maximum applied load in pounds-force.

9.8 Modulus of rupture calculated to the nearest 5 psi.

9.9 Comments shall include LTPP standard comment code(s), as shown in Section 4.3 of this Guide and any other notes as required. Additional codes for special comments associated with the test method for determining the flexural strength of concrete are given below:

Code	Comment
50	Specimen capped
51	Specimen ground
52	Leather shims used

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
FLEXURAL STRENGTH
LAB DATA SHEET T69

PORTLAND CEMENT CONCRETE
LTPP TEST DESIGNATION PC09/LTPP PROTOCOL P69

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION: ______________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____________________________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER __ __
2. LOCATION NUMBER __ __ __ __ __
3. LABORATORY TEST NUMBER __ __
4. LTPP SAMPLE NUMBER __ __ __ __ __ __
5. SPECIMEN DIMENSIONS
   (a) AVERAGE WIDTH, inches __ __.__ __
   (b) AVERAGE DEPTH, inches __ __.__ __
   (c) SPAN LENGTH, inches __ __.__ __
6. DETAILS OF CURING HISTORY ______________________________
7. MOISTURE CONDITION ______________________________
8. SPECIMEN AGE, days __ __ __ __
9. MAXIMUM APPLIED LOAD, LBF __ __ __ __ __
10. MODULUS OF RUPTURE __ __ __ __
11. COMMENTS
   (a) CODE ____ ____ ____ ____ ____ ____
   (b) NOTE ____
12. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

CHECKED AND APPROVED, DATE

____
LABORATORY CHIEF

____

Affiliation_____________________

Affiliation_____________________

PROTOCOL P70
Test Method for Petrographic Examination of Hardened Concrete (PC10)

This LTPP Protocol covers the procedures for the petrographic examination of samples of hardened concrete. The test shall be carried out in accordance with ASTM C856-04 as described by the following.

1. SCOPE

1.1 Samples examined as part of this procedure will be concrete cores obtained from in-service pavement sections. Reference in the protocol to "concrete constructions" refers only to these samples for the purposes of LTPP testing.

1.3 Annex A1 for identifying locations where alkali-silica gel may be present will not be performed as part of this test procedure.

3. QUALIFICATONS OF PETROGRAPHERS AND USE OF TECHNICIANS

3.1 The qualifications outlined in the standard are not part of this test method per se. However, these qualifications may be used in the selection of a laboratory to perform the testing.

4. PURPOSES OF EXAMINATION

4.2.8 Delete

4.2.9 Delete

4.2.12 Delete

4.4 Delete

4.5 Delete

5. APPARATUS

5.2 For Specimen Preparation:

5.2.1 *Diamond Saw* – Slabbing saw with an automatic feed and blade large enough to make at least a 175-mm (6.9-inch) cut in one pass.

5.2.3 *Horizontal Lap Wheel or Wheels*, steel, cast iron, or other metal lap, at least 400 mm (15.7 inches) in diameter and large enough to grain a 100 by 150-mm (4 by 6-inch) area.

5.2.5 *Polishing Wheel*, at least 200 mm (7.9 inches) in diameter and two-speed

5.2.8 *Abrasives* – Silicon carbide grits, 150-µm (5.9 mils), 63-µm (2.5 mils), 31-µm (1.2 mils), 16-µm (0.6 mils), and 12-µm (0.5 mils); optical finishing powders such as M-303, M-204, M-309; polishing powders as needed.

5.2.10 *Canada balsam or Lakeside 70 cement* for impregnating concrete and mounting thin sections plus appropriate solvent.

7. SAMPLES

7.1 The minimum sample size will be a 150-mm (6-inch) diameter core and the full depth of the pavement.

7.2 Samples from Constructions

7.2.3 The information provided with the samples should include:

7.2.3.1 The location and original orientation of each specimen

7.2.3.2 Delete

7.2.3.3 Delete

7.2.3.4 Delete

7.2.3.5 Age of the structure

7.2.3.6 Delete

7.2.3.7 Delete

7.2.3.8 Prevalent distresses on the pavement section

7.2.3.9 Delete

7.3 Delete

13. REPORT

13.1 Following information shall be recorded for each test:

13.1.1 Sample Identification shall include: Laboratory Identification Code, LTPP Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

13.1.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

13.2 All photographs will be taken with a digital camera with a minimum level of resolution of 1280 x 960 pixels.

13.3 Each picture will be stored in an electronic file using the following naming convention:

SSSHRPFSLLOC_NN.jpg

Where:	SS =	State code
	SHRP =	SHRP ID for site
	FS =	field set
	L =	layer number
	LOC =	location number
	NN =	image number

13.4 Comments shall include LTPP standard comment code (s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE
TEST DATA SHEET T70

PORTLAND CEMENT CONCRETE LAYER
LTPP TEST DESIGNATION PC10/LTPP PROTOCOL P70

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION _________________ STATE ___________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ______________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____
TEST DATE: __ __-__ __-__ __ __ __

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __

COARSE AGGREGATE INFORMATION

5. MINERALOGY, AS PERCEPTIBLE ______________________________
6. MAXIMUM GRAIN SIZE DIMENSION, mm __ __ __
7. MINIMUM GRAIN SIZE DIMENSION, mm __ __
4. TYPE (1 = GRAVEL, 2 = CRUSHED STONE, 3 = MIXED (1 AND 2), 4 = OTHER) __
   IF TYPE = OTHER: ______________________________
5. PERCENTAGE OF COARSE AGGREGATE, % __ __
6. SHAPE ______________________________
7. PACKING ______________________________
8. GRADING (1 = EVEN, 2 = UNEVEN, 3 = EXCESS, 4 = DEFICIENCY OF SIZE(S)) __
9. PARALLELISM OF LONG AXES OF EXPOSED SECTIONS
   (1 = NORMAL TO DIRECTION OR PLACEMENT, 2 = PARALLEL TO FINISHED SURFACE) __
10. SURFACE TEXTURE ______________________________
11. INTERANGULAR BOND ______________________________
12. PERCENTAGE OF CONCRETE BREAKING THROUGH AGGREGATE, % __ __ __
13. IS BREAKING OCCURING THROUGH ONE PREDOMINANT TYPE OF AGGREGATE (Y/N) __
    IF Y, WHAT KIND? ______________________________
14. PERCENTAGE OF AGGREGATE WITH BOUNDARY VOIDS __ __ __
15. IS BREAKING OCCURING THROUGH ONE PREDOMINANT TYPE OF AGGREGATE (Y/N) __
    IF Y, WHAT KIND? ______________________________
16. ADDITIONAL INFORMATION:____

____

FINE AGGREGATE INFORMATION

17. MINERALOGY, AS PERCEPTIBLE ______________________________
18. TYPE (1 = NATURAL SAND, 2 = MANUFACTURED SAND, 3 = MIXED, 4 = OTHER) __
    IF TYPE = OTHER : ______________________________
19. DISTRIBUTION ______________________________
20. PARTICLE SHAPE ______________________________
21. GRADING ______________________________

22. PERFERRED ORIENTATION ____
23. SURFACE TEXTURE ____
24. ADDITIONAL INFORMATION: ____

____

MATRIX

25. COLOR ____
26. COLOR DISTRIBUTION (1 = MOTTLED, 2 = EVEN, 3 = GRADATIONAL CHANGES) __
27. FRACTURES PRESENT:
   (1 = THROUGH AGGREGATE, 2 = AROUND AGGREGATE, 3 = NO FRACTURING OBSERVED) __
28. CONTACT OF MATRIX WITH AGGREGATE: (1 = CLOSE, 3 = AGGREGATE NOT DISLODGED WITH FINGERS OR PROBE, 4 = BOUNDARY OPENINGS FREQUENT, 5 = BROUNDARY OPENINGS RARE) __
   IF BOUNDARY OPENINGS PRESENT: WIDTH __ __ mm, EMPTY (Y/N) __
29. CRACKS PRESENT BEFORE SPECIMEN PREPARATION (Y/N) __
30. CRACKS PRESENT AFTER SPECIMEN PREPARATION (Y/N) __
31. MINERAL ADMIXTURES (Y/N) __
   IF YES, THEN TYPE: ____
32. CONTAMINATION: ____
33. BLEEDING: ____
34. ADDITIONAL INFORMATION: ____

____

VOIDS

35. PERCENTAGE OF VOIDS, % __
36. PREDOMINANT VOID SHAPE (1 = SPHERICAL, 2 = ELLIPSOIDAL, 3 = IRREGULAR, 4 = DISK-SHAPED, 5 = OTHER) __
   IF OTHER, DESCRIPTION : ____
37. PROPOROTION OF SPHERICAL TO NONSPHERICAL VOIDS, % __ __ __
38. DISTRIBUTION ____
39. GRADING ____
40. PARALLELISM OF LONG AXES OF IRREGULAR VOIDS
   VOIDS PARALLEL TO EACH OTHER (Y/N) __
   VOIDS PARALLEL TO LONG AXES OF COARSE AGGREGATE (Y/N) __
41. COLOR CHANGE BETWEEN VOIDS AND MATRIX (Y/N) __
42. VOID CONDITION (1 = EMPTY, 2 = FILLED, 3 = LINED, 4 = PARTLY LINED) __
   (1 = THROUGH AGGREGATE, 2 = AROUND AGGREGATE, 3 = NO FRACTURING OBSERVED) __
43. INTERIOR SURFACE OF VOIDS (1 = LIKE REST OF MATRIX, 2 = DULL, 3 = SHINING) __
44. LININGS IN VOIDS (1 = ABSENT, 2 = RARE, 3 = COMMON IN MOST) __
45. CONDITION OF LININGS (1 = ABSENT, 2 = COMPLETE, 3 = PARTIAL) __
46. LINING COLOR (1 = NO LININGS, 2 = COLORLESS, 3 = COLORED) __
47. LINING SHAPES (1 = NO LININGS, 2 = SILKY TUFTS, 3 = HEXAGONAL TABLETS, 4 = GEL) __
48. ADDITIONAL INFORMATION ON LININGS: ____

____

49. UNDERSIDE VOIDES OR SHEETS OF VOIDS ARE: 1= UNCOMMON, 2 = SMALL, 3 = COMMON,
   4 = ABUNDANT __
50. ADDITIONAL INFORMATION ON VOIDS: ____

____

GENERAL INFORMATION AND COMMENTS

51. PHOTOGRAPHS TAKEN (Y/N) __
52. NUMBER OF PHOTOGRAPHS __
53. COMMENT CODES __ __ __ __ __ __ __ __ __ __ __ __
54. ADDITIONAL COMMENT :

SUBMITTED BY, DATE

CHECKED AND APPROVED, DATE

LABORATORY CHIEF

Affiliation: ______________________

Affiliation: ______________________

PROTOCOL P71
Test Method for Specific Gravity of Unbound Materials (UG13, SS13)

This LTPP Protocol covers the procedures for determining the Specific Gravity of Unbound Materials. The test shall be carried out in accordance with AASHTO T100-95 and AASHTO T85-91 (1996) as described by the following.

This protocol has been developed utilizing portions of each referenced test method and should be followed as written herein.

1. SCOPE

1.1 This test method covers determination of the specific gravity of unbound materials. When the test sample is composed of particles both larger and smaller than the 4.75-mm (No. 4) sieve, the sample shall be separated on the 4.75-mm (No. 4) sieve and the appropriate procedures of this test method shall be used on each portion. The specific gravity value for the soil shall be the weighted average of the two values (See Note 1 of AASHTO T-85). If a test sample only contains material retained on the 4.75-mm (No. 4) sieve, then only those pertinent sections of this protocol apply. If a test sample only contains material passing the 4.75-mm (No. 4) sieve, then only those pertinent sections of this protocol apply.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards

2.1.1 See section 2.1 of AASHTO T-85.

2.1.2 See section 2.1 of AASHTO T-100.

2.2 ASTM Standards

2.2.1 See section 2.2 of AASHTO T-85.

2.2.2 See section 2.2 of AASHTO T-100.

3. TERMINOLOGY

3.1 See section 3 of AASTHO T-85.

3.2 See section 3 of AASHTO T-100.

4. SIGNIFICANCE AND USE

4.1 See section 5 of AASTHO T-85.

4.2 See section 4 of AASHTO T-100.

5. APPARATUS

5.1 See section 6 of AASTHO T-85.

5.2 See section 5 of AASHTO T-100.

6. SAMPLING

6.1 Thoroughly mix the sample of unbound material and reduce it to the approximate quantity needed using the applicable procedures in AASHTO T-248.

6.2 Split the test sample on the 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface.

6.3 The test sample passing the 4.75-mm (No. 4) sieve will be tested in accordance with section 7 of this protocol. If a sufficient amount of material is not present to perform the test (as per section 8.1 of AASHTO T100) then this part of the test is not conducted.

6.4 The test sample retained on the 4.75-mm (No. 4) sieve will be tested in accordance with section 8 of this protocol. If a sufficient amount of material is not present to perform the test (as per section 7.3 of AASHTO T85) then this part of the test is not conducted.

7. TEST SAMPLE PASSING 4.75-mm (No. 4) SIEVE

7.1 *Calibration of pycnometer* — This procedure shall be conducted as per section 7 of AASHTO T100.

7.2 *Sample* — This procedure shall be conducted as per section 8 of AASHTO T100.

7.3 *Procedure* — This procedure shall be conducted as per section 9 of AASHTO T100.

8. TEST SAMPLE RETAINED ON 4.75-mm (No. 4) SIEVE

8.1 *Procedure* — This procedure shall be conducted as per section 8 of AASHTO T85. However, section 8.2 of AASHTO T85 is to be deleted, as it does not apply to LTPP testing.

9. CALCULATIONS

9.1 Calculations for test sample passing the 4.75-mm (No. 4) sieve shall be performed as per section 10 of AASHTO T100.

9.2 Calculations for test sample retained on the 4.75-mm (No. 4) sieve shall be performed as per section 9 of AASHTO T85.

9.3 If a test sample contains particles both larger and smaller than the 4.75-mm (No. 4) sieve, an average of specific gravity shall be computed as per note 1 of AASHTO T100.

10. REPORT

10.1 Sample Identification shall include: Laboratory Identification Code, Region, State, State Code, SHRP ID, Layer Number, Field Set Number, Sample Area Number, Sample Location Number, and LTPP Sample Number.

10.2 Test Identification shall include: LTPP Test Designation, LTPP Protocol Number, Laboratory Test Number, and Test Date.

10.3 General sample information

10.3.1 Percent of soil particles retained on the 4.75-mm (No. 4) sieve, R_1, in percent.

10.3.2 Percent of soil particles passing the 4.75-mm (No. 4) sieve, P_1, in percent.

10.4 Test sample passing the 4.75-mm (No. 4) sieve

10.4.1 Mass of oven-dried soil, W_0, in grams.

10.4.2 Mass of pycnometer filled with water at temperature T_x, W_a, in grams.

10.4.3 Mass of pycnometer filled with water and soil at temperature T_x, W_b, in grams.

10.4.4 Temperature of the contents of the pycnometer when mass W_b was determined, T_x, in degrees Celsius.

10.4.5 Specific gravity of test sample passing the 4.75-mm (No. 4) sieve, G_2.

10.5 Test sample retained on the 4.75-mm (No. 4) sieve

10.5.1 Mass of oven dry test sample in air, A, in grams.

10.5.2 Mass of saturated surface-dry (SSD) test sample in air, B, in grams.

10.5.3 Mass of saturated test sample in water, C, in grams.

10.5.4 Bulk specific gravity of test sample retained on the 4.75-mm (No. 4) sieve.

10.5.5 Bulk specific gravity of test sample (saturated-surface-dry) retained on the 4.75-mm (No. 4) sieve.

10.5.6 Apparent specific gravity of test sample retained on the 4.75-mm (No. 4) sieve, G_1.

10.5.7 Percentage of absorption.

10.6 Average specific gravity

10.6.1 Weighted average specific gravity of test samples composed of particles larger and smaller than the 4.75-mm (No. 4) sieve, G_{avg}. (Use the results from 10.4.5, G_2, and 10.5.7, G_1, for this calculation)

10.7 Comments shall include LTPP standard comment code (s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SPECIFIC GRAVITY OF UNBOUND MATERIALS
TEST DATA SHEET T71

BASE/SUBBASE/SUBGRADE
LTPP TEST DESIGNATION UG13, SS13/LTPP PROTOCOL P71

LABORATORY PERFORMING TEST:____
LABORATORY IDENTIFICATION CODE: __ __ __ __
REGION _______________ STATE _________________ STATE CODE __ __
EXPERIMENT NO _____ SHRP ID __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO. __
DATE SAMPLED: __ __-__ __-__ __ __ __ SAMPLING AREA No: SA- _____

1. LAYER NUMBER (FROM LAB SHEET L04 AND FORM T01B) __
2. SAMPLE LOCATION NUMBER __ __ __
3. LABORATORY TEST NUMBER __
4. LTPP SAMPLE NUMBER __ __ __ __
5. PERCENT OF SOILS RETAINED ON THE 4.75-mm SIEVE (R_1), percent __ __ __.__
6. PERCENT OF SOILS PASSING THE 4.75-mm SIEVE (P_1), percent __ __ __.__
7. MASS OF OVEN-DRIED SOIL (W_0), g __ __ __.__ __ __
8. MASS OF PYCNOMETER FILLED WITH WATER AT TEMPERATURE T_x (W_a), g __ __ __.__ __ __
9. MASS OF PYCNOMETER FILLED WITH WATER AND SOIL AT T_x (W_b), g __ __ __.__ __ __
10. TEMPERATURE (T_x), °C __ __.__
11. SPECIFIC GRAVITY, G_2 __ __.__ __ __
12. MASS OF OVEN DRY TEST SAMPLE IN AIR (A), g __ __ __ __ __ __.__
13. MASS OF SATURATED SURFACE-DRY TEST SAMPLE IN AIR (B), g __ __ __ __ __ __.__
14. MASS OF SATURATED TEST SAMPLE IN WATER (C), g __ __ __ __ __ __.__
15. BULK SPECIFIC GRAVITY __ __.__ __ __
16. BULK SPECIFIC GRAVITY (SSD CONDITION) __ __.__ __ __
17. APPARENT SPECIFIC GRAVITY (G_1) __ __.__ __ __
18. PERCENT ABSORPTION __ __.__
19. WEIGHTED AVERAGE SPECIFIC GRAVITY (G_{avg}) __ __.__ __ __
20. COMMENTS
    (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
    (b) NOTE ____
21. TEST DATE __ __-__ __-__ __ __ __

GENERAL REMARKS:____
____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

Affiliation: ________________ Affiliation: ________________

PROTOCOL P72
Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications (UG14, SS14)

This LTPP Protocol covers the procedures to assess *in situ* strength of undisturbed soil and/or compacted material using the DCP with an 8-kg (17.6-lb) hammer. The test shall be carried out in accordance with ASTM D6951-03 as modified by the following. The sections of the reference standard included in this protocol without modifications shall be strictly followed. All other sections of this protocol shall be followed as herein written.

8. REPORT

8.1 LTPP Region, State, State Code, Experiment Number, SHRP ID, Route/Highway Name, Lane, Direction (North = N, South = S, East = E, West = W), Sample/Test Location, Operator, Hammer Weight, Test Date, Location Station, Depth of Zero Point Below Surface, Lateral Location, Layer Tested.

8.2 Results:

8.2.1 Number of hammer blows between test readings.

8.2.2 Cumulative penetration after each set of hammer blows, in millimeters.

8.2.3 Difference in cumulative penetration between readings, in millimeters.

8.2.4 Penetration per blow, in millimeters. It is calculated by dividing the cumulative penetration by the number of blows between test readings.

8.2.5 Hammer factor. For 8-kg (17.6-lb) hammer, enter 1. For 4.6-kg (10.1-lb) hammer, enter 2.

8.2.6 DCP index, in millimeters per blow. This index is the result of multiplying the penetration per blow by the hammer factor.

8.2.7 CBR, in percent. It is taken from CBR versus DCP index correlation.

8.2.8 Moisture content, in percent, when available.

8.4 Comments shall include LTPP standard comment code (s) as shown in Section 4.3 of this Guide, and any other note as needed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION RATE OF THE DYNAMIC CONE PENETROMETER
LAB DATA SHEET T72

BASE/SUBGRADE SOILS
LTPP TEST DESIGNATION: UG14, SS14/LTPP PROTOCOL P72

LTPP REGION:_________________ STATE CODE: __ __
STATE:__________________ SHRP ID: __ __ __ __
OPERATOR:_______________ FIELD SET NO.: __
TEST DATE:__ __-__ __-__ __ __ __ LOC NO.: __ __ __ __ __ __
HAMMER WEIGHT: □ 8-Kg □ 4.6-Kg
LOCATION STATION:________________ DEPTH OF ZERO POINT BELOW SURFACE: _____________ mm
LATERAL LOCATION (Distance from outside lane marker): __ __.__ m

Number of blows	Cumulative penetration (mm)	Penetration between readings (mm)	Penetration per blow (mm)	Hammer Factor	DCP Index (mm/blow)	CBR (%)	Moisture (%)
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
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__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __
__ __	__ __ __	__ __ __	__ __ __	__	__ __	__ __ __	__ __ __

Note: If additional rows needed, please use another data sheet.

COMMENTS

(a) CODE __ __ __ __ __ __ __ __ __ __ __ __

(b) NOTE ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________

LABORATORY CHIEF

Affiliation:__________________ Affiliation:________________________

PROTOCOL H01L
Preparation of Asphalt Cores for Aging Tests (AC08)

This procedure will be used to prepare asphalt cores for testing to determine how the asphalt material ages. It will be conducted after core examination in accordance with LTPP Method AC01. It will be completed prior to extracting asphalt for the aging tests.

After the treatments have been placed, the HMAC overlay, chip seal, or slurry seal will be removed from the remainder of the core using a diamond blade saw as necessary. Then the top 1 in. (25 mm) of the core will be removed using an air-cooled diamond blade saw. The aging tests will be conducted on the asphalt cement extracted from the top 1 in (25 mm) of the core. Abson recovery, penetration and viscosity will be tested in accordance with LTPP H02L, H03L, and H04L protocols. The next 1-in (25-mm) layer will also be removed using an air-cooled diamond blade saw for moisture content analysis.

PROTOCOL H02L
Recovery of Asphalt from Solution by Abson Method (AE01S)

This LTPP protocol covers the recovery of asphalt cement from cores recovered from pavements as a part of the SPS-3 studies. The recovery shall be performed in accordance with AASHTO T170-89I, Standard Method of Test for Recovery of Asphalt from Solution by Abson Method.

The extraction shall be performed in accordance with Method A of AASHTO T164-89I, Standard Method of Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures, except as designated below. Reagent-grade trichloroethylene (TCE) should be used as the reagent required in paragraph 4, however, at the discretion of the COTR, the use of technical-grade TCE (type 1) may be allowed under the following circumstances:

1. The laboratory has passed the AMRL certification to perform AASHTO T164 within the last five years. A copy of the certification shall be sent to the COTR.

2. The laboratory engages an independent laboratory to analyze and verify that its stores of technical-grade TCE meet Federal Specification O-T-634. A copy of the results of this independent verification shall be sent to the COTR.

The moisture in the sample shall be tested in accordance with AASHTO T110-88I, Standard Method of Test for Moisture or Volatile Distillates in Bituminous Mixtures, except as designated below. Xylene will be used as the solvent required by paragraph 2.4. Tests listed in Paragraph 6 will be omitted. Instead of the requirements of Paragraph 3, the following shall be used. The top one inch of each core will be removed in accordance with LTPP Protocol H01L and used in the extraction and subsequent test. The moisture content will be determined from the next 1-inch (25-mm) layer, which must also be removed using an air-cooled diamond blade saw.

This protocol includes no testing of the extracted material. All tests on the extracted material are required by Protocols H03L and H04L.

The results will be recorded on LTPP Test Form H01. Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed. Additional codes for special comments associated with the testing are given below.

Code	Comment
18	Insufficient material to perform test. Test was not performed.
19	Insufficient material to perform the moisture content test. Test was not performed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
ABSON RECOVERY
LAB DATA SHEET H01

ASPHALT CONCRETE
LTPP TEST DESIGNATION AE01S/LTPP PROTOCOL H02L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: __________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) MOISTURE IN MIXTURE, % __ __.__
   (b) ASPHALT CONTENT, % __ __.__
   (c) ASH CONTENT, % __.__

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

LABORATORY CHIEF

Affiliation Affiliation

PROTOCOL H03L
Penetration of Bituminous Materials (AE02S)

This LTPP protocol covers the determination of the penetration of asphalt cements at 25°C (77°F). It is intended to be used on asphalt cements extracted from cores recovered from pavements as a part of the SPS-3 studies. The test shall be performed in accordance with AASHTO T49-89I, Standard Method of Test for Penetration of Bituminous Materials, except as designated below. The test shall be conducted at 25°C (77°F). The 50-gram (0.11-lb) weight will be placed on the needle providing a 100-gram (0.22-lb) weight total. Use this test in place of ASTM D5 when necessary. When performing the test in accordance with ASTM D3407-78, use a penetration cone in place of the needle, meeting the requirements established in paragraph 5 of ASTM D3407-78.

The results will be recorded on LTPP Form H02 for SPS-3. The results will be recorded on LTPP Form H15 for SPS-4. Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed. Additional codes for special comments associated with the testing are given below.

Code	Comment
18	Insufficient material to perform test. Test was not performed.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
PENETRATION OF BITUMINOUS MATERIALS
LAB DATA SHEET H02

ASPHALT CONCRETE
LTPP TEST DESIGNATION AE02S/LTPP PROTOCOL H03L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: _________________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) AVERAGE PENETRATION, 0.1 mm __ __ __

   (b) TEST TEMPERATURE, °C __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

LABORATORY CHIEF

Affiliation

CHECKED AND APPROVED, DATE

Affiliation

PROTOCOL H04L
Viscosity of Asphalts (AE06S)

This LTPP protocol covers the determination of absolute viscosity. It is intended to be used on asphalt cements extracted from cores taken as a part of the SPS-3 studies.

The absolute viscosity of asphalt cements shall be determined by vacuum capillary viscometers at 60°C (140°F). The test shall be performed in accordance with AASHTO T202-89I, Standard Method of Test for Viscosity of Asphalts by Vacuum Capillary Viscometer, except as designated below. Asphalt Institute viscometers shall be used.

The results will be recorded on LTPP Test Sheet H03. Comments shall include LTPP standard comment code(s) as shown in Section 4.3 of this Guide, and any other note as needed. An additional code for special comments associated with the testing is given below.

Code	Comment
18	Insufficient material to perform test. Test was not performed.
20	Insufficient asphalt cement to perform Protocol H03L (penetration and H04L (viscosity) on separate samples. The penetration sample was reused for the viscosity test.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
VISCOSITY OF BITUMINOUS MATERIALS
LAB DATA SHEET H03

ASPHALT CONCRETE
LTPP TEST DESIGNATION AE06S/LTPP PROTOCOL H04L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: __ __ __ __

REGION: ______________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____________________________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) VACUUM CAPILLARY (ABSOLUTE) VISCOSITY, poise __ __ __ __
   (b) TEST TEMPERATURE, °C __ __ __
   (c) VACUUM, mm Hg __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

____
SUBMITTED BY, DATE | CHECKED AND APPROVED, DATE

______________________________ | ______________________________
LABORATORY CHIEF

______________________________ | ______________________________
Affiliation | Affiliation

PROTOCOL H05L
Standard Methods of Testing Emulsified Asphalts (SC01)

This LTPP protocol covers the tests performed on an emulsified asphalt. These tests are intended to be used on the emulsions used in the slurry and chip seals as part of the SPS-3 studies. The tests are to be run in accordance with AASHTO T59-89I, Standard Methods of Test for Testing Emulsified Asphalts, except Procedure B of Residue by Evaporation will be used to determine the quantity of residual asphalt and to recover the base asphalt for further testing. The following tests are not required: Identification of Residue by Evaporation, Oil Distillate by micro-Distillation, Settlement, Coating, Freezing, and Coating Ability and Water Resistance. Testing will begin within five days of the sample date.

The results will be recorded on LTPP Test Sheets H04A, H04B, H04C, and H05. The following table was prepared to define the specific tests to be applied to the samples of materials sent to the laboratory. Only those tests identified with an "X" are required. Separate sets of columns show the tests for the rapid setting emulsions used with the chip seals (Sample Material Code AECS) and for the slow setting emulsions used with the slurry seals (Sample Material Code AESL). Each of these has two columns identified as SO01 and Other. All of the tests shown under the column SO01 will be completed on the respective emulsion when the sample location code is SO01, SO02, etc. In addition, every fourth sample with other location codes will receive the testing shown under the respective column identified as SO01. The remaining samples will receive only the tests shown under the respective columns identified as Other.

Table of Tests for Chip Seal and Slurry Seal Emulsions

	Chip Seal Emulsion		Slurry Seal Emulsion	
Sample Material Code	AECS		AESL	
Sample Location Code	SO01	Other	SO01	Other
Residue by Distillation	X	X	X	X
Particle Charge	X	X	X	X
Viscosity (Saybolt Furol)	X	X	X	X
Demulsibility	X			
Cement Mixing			X	X
Sieve Test	X	X	X	X
Miscibility with Water	X		X	
Storage Stability	X	X	X	X
Classification Test for Rapid Setting	X	X		
Field Coating	X			
Weight per Gallon		X	X	
Examination of Residue				
Specific Gravity	X		X	
Solubility in Trichl.	X	X	X	X
Penetration	X	X	X	X
Ductility	X	X	X	X

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTS ON EMULSION
LAB DATA SHEET H04A

EMULSIFIED ASPHALT
LTPP TEST DESIGNATION SC01/LTPP PROTOCOL H05L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: _________________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) RESIDUE AND OIL DISTILLATE BY DISTILLATION
       PRESENT RESIDUE BY DISTILLATION, % __ __.__
       OIL DISTILLATE, % __ __.__

   (b) DUCTILITY OF RESIDUE, cm/min __ __ __

   (c) PENETRATION OF RESIDUE, 0.1 mm __ __ __

   (d) SOLUBILITY OF RESIDUE, % __ __.__

   (e) CEMENT MIXING, % mass __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

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LABORATORY CHIEF

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Affiliation

CHECKED AND APPROVED, DATE

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Affiliation

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTS ON EMULSION
LAB DATA SHEET H04B

EMULSIFIED ASPHALT
LTPP TEST DESIGNATION SC01/LTPP PROTOCOL H05L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: _________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) CONSISTENCY (SAYBOLT VISCOSITY)
       VISCOSITY AT 25°C, seconds __ __ __
       VISCOSITY AT 50°C, seconds __ __ __

   (b) PARTICLE CHARGE OF EMULSIFIED ASPHALTS POLARITY ______________
       (positive or negative)

   (c) SIEVE TEST, % mass __ __

   (d) STORAGE STABILITY OF ASPHALT EMULSION, % __ __

   (e) CLASSIFICATION TEST FOR RAPID SETTING CATIONIC EMULSIFIED ASPHALT
       Aggregate surface coated by emulsion less than uncoated aggregate surface area (yes or no) _____

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

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LABORATORY CHIEF

______________________________ ______________________________
Affiliation Affiliation

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTS ON EMULSION
LAB DATA SHEET H04C

EMULSIFIED ASPHALT
LTPP TEST DESIGNATION SC01/LTPP PROTOCOL H05L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) FIELD-COATING TEST ON EMULSIFIED ASPHALT
       COATING OF STONE (good, fair, or poor) ____________
       FREE WATER PRESENT (yes or no) ____________

   (b) DEMULSIBILITY, % mass __ __

   (c) MISCIBILITY WITH WATER
       COAGULATION OF ASPHALT CEMENT (yes or no) ___________

   (d) SPECIFIC GRAVITY OF RESIDUE __.__ __ __

   (e) WEIGHT PER GALLON OF EMULSIFIED ASPHALT
       UNIT WEIGHT OF EMULSION, lb/gal __ __.__ __
       TEMEPRATURE OF TEST, °C __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

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______________________________ ______________________________
Affiliation Affiliation

PROTOCOL H06L
Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test (SC02)

This LTPP protocol covers the test to indicate the proportions of clay-like or plastic fines and dusts in granular soils and fine aggregates. This test is intended to be used on the aggregates used in the slurry seals as part of the SPS-3 studies. The test will be performed in accordance with AASHTO T176-86, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test, with the exception that the Mechanical Shaker Method (Referee Method) must be used.

Test results will be recorded on LTPP Test Sheet H06.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SAND EQUIVALENT TEST
LAB DATA SHEET H06

AGGREGATE PROPERTIES
LTPP TEST DESIGNATION SC02/LTPP PROTOCOL H06L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. SAND EQUIVALENCY, % __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

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LABORATORY CHIEF

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Affiliation

CHECKED AND APPROVED, DATE

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Affiliation

PROTOCOL H07L
Testing Crushed Stone, Crushed Slag, and Gravel for Single or Multiple Bituminous Surface Treatments (SC03)

This LTPP protocol covers the testing for the quality and size of crushed aggregate to be used in single or multiple bituminous surface treatments. All tests required by ASTM D1139-83, Standard Specifications for Crushed Stone, Crushed Slag, and Gravel for Single or Multiple Bituminous Surface Treatments will be completed in accordance with ASTM D1139 with the following exceptions:

1. Resistance to Degradation will be determined in accordance with AASHTO T96-87I.
2. Unit weight will be determined in accordance with AASHTO T19-88I, using the rodding procedure described in paragraph 7.
3. Sulfate Soundness will be determined in accordance with AASHTO T104-86I using Sodium Sulfate.
4. Sieve Analysis will be determined in accordance with LTPP Test SC10, H14L.
5. Clay Lumps and Friable Particles will be determined in accordance with AASHTO T112-87I.
6. Lightweight pieces will be determined in accordance with AASHTO T113-86. The liquid will be a zinc chloride solution with a specific gravity of 2.0.
7. No measure of flat or elongated pieces is required.

The results will be recorded on LTPP Test Sheet H07.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTING CRUSHED STONE
LAB DATA SHEET H07

AGGREGATE PROPERTIES
LTPP TEST DESIGNATION SC03/LTPP PROTOCOL H07L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________	STATE: _____	STATE CODE:	__ __
EXPERIMENT NO: _____		SHRP ID:	__ __ __ __
SAMPLED BY: ______________________		FIELD SET NO:	___
DATE SAMPLED: __ __ - __ __ - __ __ __ __		SAMPLING AREA NO:	SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) RESISTANCE TO DEGRADATION BY LOS ANGELES MACHINE, PERCENTAGE OF WEAR, % __ __

   (b) UNIT WEIGHT, lb/ft^3 __ __ __

   (c) SOUNDNESS, total % loss __ __

   (d) CLAY LUMPS AND FRIABLE PARTICLES, % weight __ __

   (e) MATERIAL FLOATING ON A LIQUID WITH A SPECIFIC GRAVITY OF 2.0 PERCENTAGE OF LIGHTWEIGHT MATERIAL, % __ __

6. COMMENTS
   (a) CODE ___ ___   ___ ___   ___ ___   ___ ___   ___ ___   ___ ___

   (b) NOTE ______________________________________

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE	CHECKED AND APPROVED, DATE
______________________	______________________
LABORATORY CHIEF	
______________________	______________________
Affiliation	Affiliation

PROTOCOL H08L
Determination of Flakiness Index of Aggregates (SC04)

This LTPP protocol covers the procedure of determining the percentage by weight of particles whose thickness is less than three-fifths of their mean dimension. This test is to be performed on the aggregate to be used in the chip seal as part of the SPS-3 studies. This test will be performed in accordance with the Determination of Flakiness Index of Aggregates as described in "Asphalt Surface Treatments" (MS-13) dated January 1975 and "A Basic Asphalt Emulsion Manual" (MS-19) dated March 1979, by the Asphalt Institute.

The results will be recorded on LTPP Test Sheet H08.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTING CRUSHED STONE
LAB DATA SHEET H08

AGGREGATE PROPERTIES
LTPP TEST DESIGNATION SC04/LTPP PROTOCOL H08L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ____________________	STATE: _____	STATE CODE:	__ __
EXPERIMENT NO: _____		SHRP ID:	__ __ __ __
SAMPLED BY: ______________________________		FIELD SET NO:	___
DATE SAMPLED: __ __ - __ __ - __ __ __ __		SAMPLING AREA NO:	SA- ____

1. LAYER NUMBER	___
2. LABORATORY TEST NUMBER	__
3. LOCATION NUMBER	__ __ __
4. LTPP SAMPLE NUMBER	__ __ __ __
5. FLAKINESS INDEX, %	__ __
6. COMMENTS	
(a) CODE	___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
(b) NOTE	______________________________
7. TEST DATE	__ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE	CHECKED AND APPROVED, DATE
____________________	____________________
LABORATORY CHIEF	
____________________	____________________
Affiliation	Affiliation

PROTOCOL H09L
Design, Testing, and Construction of Slurry Seal (SC05)

This LTPP protocol covers the design, testing, and construction of slurry seal mixtures. It is intended that the tests be performed on the slurry seals to be used as part of the SPS-3 studies. All tests required by ASTM D3910-84 are to be performed in accordance with ASTM D3910-84, Standard Practices for Design, Testing, and Construction of Slurry Seals. Set Time, Cure, Time, Traffic Time and System Classification will be conducted in accordance with the International Slurry Surfacing Association (ISSA) test method TB-139, 1982 – Revised 1990. Consistency is measured in accordance with paragraph 6.1 as modified by ISSA TB 106, 1976 – Revised 1990.

The results will be recorded on LTPP Test Sheet H09.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
TESTING OF SLURRY SEALS
LAB DATA SHEET H09

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC05/LTPP PROTOCOL H09L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) CONSISTENCY (FLOW), cm __.__

   (b) SET TIME, hr __ __.__ __

   (c) CURE TIME, hr __ __.__ __

   (d) TRAFFIC TIME, hr __ __.__ __

   (e) SYSTEM CLASSIFICATION __ __ - __ __ __

   (f) WET TRACK ABRASION (LOSS), gm/ft^2 __ __ __.__

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

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LABORATORY CHIEF

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Affiliation Affiliation

PROTOCOL H10L
Test Method for Measurement of Excess Asphalt in Bituminous Mixtures by Use of a Loaded Wheel Tester and Sand Cohesion (SC06)

This LTPP protocol covers the loaded wheel test which is used to compact fine aggregate bituminous mixtures. This test is to be performed on the slurry seals to be used in the SPS-3 studies. It is to be performed in accordance with ISSA technical bulletin TB-109, 1976 – Revised 1978. The testing will be completed using 125 lb (57 kg) applied load at 77°F ± 2°F (25°C ± 1°C). The number of cycles required in paragraph 6.5 will be 1000.

The results will be recorded on LTPP Test Sheet H10.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
LOADED WHEEL TEST
LAB DATA SHEET H10

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC06/LTPP PROTOCOL H10L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___
REGION: _________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) WEIGHT BEFORE TESTING, gm __ __ __

   (b) SPECIMEN THICKNESS, in __.__ __

   (c) TACK POINT, cycles __ __ __ __

   (d) WEIGHT ON TEST WHEEL, lbs __ __ __ __

   (e) TEMPERATURE OF TEST, °F __ __ __

   (f) WEIGHT AFTER TESTING, gm __ __ __

   (e) SAND ADHESION, gm __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ________________________________
LABORATORY CHIEF

______________________________ ________________________________
Affiliation Affiliation

PROTOCOL H11L
Wet Stripping for Cured Slurry Seal Mixes (SC07)

This LTPP protocol aids in selecting a compatible slurry seal system with a given aggregate. It is intended for use on the slurry seals as part of the SPS-3 studies. The test is to be performed in accordance with ISSA TB-114 – Revised 1990.

The results will be recorded on LTPP Test Sheet H11.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
WET-STRIPPING TEST FOR CURRED SLURRY SEAL MIXES
LAB DATA SHEET H11

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC07/LTPP PROTOCOL H11L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ______________________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. AGGREGATE SURFACE RETAINING COATING, % __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ______________________________________

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

____
LABORATORY CHIEF

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Affiliation

CHECKED AND APPROVED, DATE

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Affiliation

PROTOCOL H12L
Determination of Slurry System Compatibility (SC08)

This LTPP protocol covers the compatibility of a slurry seal system. It is intended for use on the slurry seal to be used as part of the SPS-3 studies. The test is to be performed in accordance with ISSA TB-115 – Revised January 1990. The Mix and Workability Test is not required. The Wet Stripping Test is performed in LTPP Test Designation SC07 and need not be repeated as a part of this test.

The results will be recorded on LTPP Test Sheet H12.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINATION OF SLURRY SYSTEM COMPATIBILITY
LAB DATA SHEET H12

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC08/LTPP PROTOCOL H12L

LABORATORY PERFORMING TEST: ______________________________
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____________________ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) CONSISTENCY __ TACKY __ SATISFACTORY

   (b) SPLIT CONSISTENCY
       ASPHALT AND AGGREGATE DISTRIBUTION __ UNIFORM __ NONUNIFORM

       SURFACE OF SPECIMEN __ TACKY __ SATISFACTORY

   (c) REFEREE CUP, % AC Difference __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ______________________________

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ______________________________

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________ ______________________
LABORATORY CHIEF

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Affiliation Affiliation

PROTOCOL H13L
Mixing, Setting and Water Resistance Test to Identify "Quick Set" Emulsified Asphalts (SC09)

This LTPP protocol covers the procedures used to identify a quick set emulsified asphalt. The test is to be performed in accordance with ISSA TB-102, 1978 – Revised 1990, Mixing, Setting and Water Resistance Test to Identify "Quick Set" Emulsified Asphalts.

The results will be recorded on LTPP Test Sheet H13.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
MIXING, SETTING AND WATER RESISTANCE TEST TO IDENTIFY QUICK SET EMULSIFIED ASPHALTS
LAB DATA SHEET H13

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC09/LTPP PROTOCOL H13L

LABORATORY PERFORMING TEST: ______________________________
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: __________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ______________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) MIXING TIME, seconds __ __ __

   (b) PAPER TOWEL STAINED __ YES __ NO

   (c) WATER DISCOLORATION __ NONE __ SLIGHT __ MORE THAN SLIGHT

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ______________________________

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ______________________________

SUBMITTED BY, DATE

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LABORATORY CHIEF

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Affiliation

CHECKED AND APPROVED, DATE

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Affiliation

PROTOCOL H14L
Sieve Analysis of Seal Coat Aggregates (SC10)

This LTPP protocol covers the procedures used to determine the size distribution of aggregates for chip seals and slurry seals for use in the H-101 SPS-3 study. The test is to be performed in accordance with AASHTO T27-82 as modified herein. The sieve sizes shall conform to the following:

Chip Seal	Slurry Seal
½ in (12.5 mm)	
⅜ in (9.50 mm)	$^{5}/_{16}$ in (8.00 mm)
No. 4 (4.75 mm)	No. 4 (4.75 mm)
No. 8 (2.36 mm)	No. 8 (2.36 mm)
No. 10 (2.00 mm)	
	No. 16 (1.18 mm)
	No. 30 (0.600 mm)
	No. 50 (0.300 mm)
	No. 100 (0.150 mm)
No. 200 (0.075 mm)	No. 200 (0.075 mm)

The results of testing on chip seal aggregates (AGCS) will be recorded on LTPP Test Sheet H16. The results of testing on slurry seal aggregates (AGSL) will be recorded on LTPP Test Sheet H17.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
AGGREGATE GRADATION
LAB DATA SHEET H16A

CHIP SEAL PROPERTIES
LTPP TEST DESIGNATION SC10/LTPP PROTOCOL H14L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ______________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ____________________________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. GRADATION, % PASSING EACH SIEVE

Standard	
½ in. (12.5 mm)	__ __.__
⅜ in. (9.50 mm)	__ __.__
#4 (4.75 mm)	__ __.__
#8 (2.36 mm)	__ __.__
#10 (2.00 mm)	__ __.__
#200 (0.075 mm)	__ __.__

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

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LABORATORY CHIEF

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Affiliation

CHECKED AND APPROVED, DATE

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Affiliation

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
AGGREGATE GRADATION
LAB DATA SHEET H16B

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC10/LTPP PROTOCOL H14L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________ STATE: _____	STATE CODE: __ __
EXPERIMENT NO: _____	SHRP ID: __ __ __ __
SAMPLED BY: ______________________	FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __	SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. GRADATION, % PASSING EACH SIEVE

Standard	
5/16 in. (8.00 mm)	__ __.__
#4 (4.75 mm)	__ __.__
#8 (2.36 mm)	__ __.__
#16 (1.18 mm)	__ __.__
#30 (0.600 mm)	__ __.__
#50 (0.300 mm)	__ __.__
#100 (0.150 mm)	__ __.__
#200 (0.075 mm)	__ __.__

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE	CHECKED AND APPROVED, DATE
______________________	______________________
LABORATORY CHIEF	
______________________	______________________
Affiliation	Affiliation

PROTOCOL H15L
Chip Seal Mix Design (SC11)

This LTPP protocol covers the procedures for determining the chip seal design to be used as part of the SPS-3 studies. The design procedure will be performed in accordance with Appendix C, Design of Surface Treatments, Procedure B, of the Asphalt Surface Treatments (MS-13) Handbook, published by the Asphalt Institute. Use AASHTO T85-88I for determining the bulk specific gravity of the aggregates. Allow for 10% aggregate waste (E). Assume a traffic factor (T) of 0.65 and a surface adjustment variable (V) of 0.00. These latter two will be adjusted in the field to modify the residual asphalt spread rate as needed for site specific conditions. The asphalt spread rate will be used to determine the emulsified asphalt spread rate.

The results will be recorded on LTPP Test Sheet H14.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
CHIP SEAL MIX DESIGN
LAB DATA SHEET H14

CHIP SEAL PROPERTIES
LTPP TEST DESIGNATION SC11/LTPP PROTOCOL H15L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___
REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) BULK SPECIFIC GRAVITY OF AGGREGATE __.__ __

   (b) AVERAGE LEAST DIMENSION, in __.__ __

   (c) AGGREGATE WASTAGE FACTOR (E) __.__ __

   (d) AGGREGATE SPREAD RATE, lb/yd^2 __ __.__

   (e) TRAFFIC FACTOR (T) __.__ __

   (f) SURFACE CONDITION VARIABLE (V), gal/yd^2 __.__ __

   (g) RESIDUAL ASPHALT SPREAD RATE, gal/yd^2 __.__ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____
SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

____________________________ ____________________________
Affiliation Affiliation

PROTOCOL H16L
Joint Sealants, Hot-Poured, for Cement and Asphalt Pavements (CS01)

This LTPP protocol covers the test for bituminous hot-poured types of joint sealants for PCC and AC pavements. These tests are intended to be used on materials which are hot-poured, joint or crack sealants. The tests will be performed in accordance with ASTM D3407-78, Standard Method of Testing Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements. Alternate Procedure 7.4.1, may not be used, and Preparation of Specimens under 9.1.1 must be completed in accordance with AASHTO T245-89I. Penetration tests required in paragraph 5 shall be completed in accordance with LTPP Protocol H03L.

The results will be recorded on LTPP Test Sheet H15.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
HOT-POURED JOINT SEALANT
LAB DATA SHEET H15

HOT-POURED JOINT SEALANT PROPERTIES
LTPP TEST DESIGNATION CS01/LTPP PROTOCOL H16L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___
REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS

	Initial	After Prolonged Heating
(a) AVERAGE PENETRATION, 0.1 mm	__ __ __	__ __ __
TEMPERATURE, °C	__ __	__ __
(b) FLOW (CHANGE IN LENGTH), mm	__ __.__	__ __.__
(c) BOND (ALL THREE SAMPLES)	__ PASS __ FAIL	__ PASS __ FAIL
(d) RESILIENCE (AVERAGE RECOVERY), %	__ __	__ __
(e) ASPHALT COMPATIBILITY RESULTS	__ PASS __ FAIL	__ PASS __ FAIL
	APPROVED	REJECTED

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE

____
LABORATORY CHIEF

____
Affiliation

CHECKED AND APPROVED, DATE

____

____
Affiliation

PROTOCOL H17L
Joint Sealants, Silicone (CS02)

This LTPP protocol covers the tests for silicone joint sealants for PCC pavements. The tests will be performed in accordance with Georgia DOT Standards Specifications, GA DOT 833.06, Silicone Sealants and Bond Breakers (Modification). A copy of the specification and test methods are given in SPS-4 Attachment G of the Manual for the SHRP Maintenance Effectiveness Study of Rigid Pavements (SPS-4).

The results will be recorded on LTPP Test Sheet H19.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
SILICONE JOINT SEALANTS
LAB DATA SHEET H19
SILICONE JOINT SEALANT PROPERTIES
LTPP TEST DESIGNATION CS02/LTPP PROTOCOL H17L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___
REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ____ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) TENSILE STRESS AT 150% STRAIN, psi ________________

   (b) DUROMETER HARDNESS (SHORE A) ________________

   (c) BONDING STRENGTH ON CONCRETE MORTAR, psi ________________
   (AVERAGE OF 5 TESTED)

   (d) TACK FREE TIME, min ________________

   (e) EXTRUSION RATE, g/min ________________

   (f) NONVOLATILE, % ________________

   (g) SPECIFIC GRAVITY ________________

   (h) MOVEMENT CAPABILITY AND ADHESION __ SATISFACTORY __ UNSATISFACTORY

   (i) OZONE AND U.V. RESISITANCE __ SATISFACTORY __ UNSATISFACTORY

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

______________________________ ______________________________
LABORATORY CHIEF

______________________________ ______________________________
Affiliation Affiliation

PROTOCOL H18L
Compressive Strength of Hydraulic Cement Mortar (US01)

This LTPP protocol covers the tests for compressive strength of hydraulic cement mortars for testing undersealing materials as a part of SPS-4. The tests will be performed in accordance with AASHTO T106-88I.

PROTOCOL H19L
Determination of Asphalt Content from Slurry Seal Sample (SC12)

This LTPP protocol covers the determination of asphalt cement content from slurry seal samples taken in the field as a part of the SPS-3 studies. The extraction shall be performed in accordance with AASHTO T164-89I, Standard Method of Test for Quantitative Extraction of Bitumen from Bituminous Paving mixtures, except as designated below. Reagent-grade trichloroethylene shall be used as the reagent required in paragraph 4. Method A shall be followed. The sample shall be taken from the slurry seal sample taken in the field. A 3- to 3.5-lb (1.4- to 1.6-kg) representative sample shall be taken from the sample submitted for testing.

The moisture in the sample shall be tested in accordance with AASHTO T110-88I, Standard Method of Test for Moisture or Volatile Distillates in Bituminous Mixtures, except as designated below. Xylene will be used as the solvent required by paragraph 2.4. Tests listed in Paragraph 6 will be omitted.

The results will be recorded on LTPP Test Sheet H17.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
DETERMINATION OF ASPHALT CONTENT FROM SLURRY SEAL SAMPLE
LAB DATA SHEET H17

SLURRY SEAL PROPERTIES
LTPP TEST DESIGNATION SC12/LTPP PROTOCOL H19L

LABORATORY PERFORMING TEST: ______________________________
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___

REGION: ________________ STATE: _____
EXPERIMENT NO: _____
SAMPLED BY: ______________________
DATE SAMPLED: __ __ - __ __ - __ __ __ __

STATE CODE: __ __
SHRP ID: __ __ __ __
FIELD SET NO: ___
SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) MOISTURE IN MIXTURE, % __ __.__
   (b) ASPHALT CONTENT, % __ __.__

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
   (b) NOTE ______________________________

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ______________________________

SUBMITTED BY, DATE

____
LABORATORY CHIEF

____
Affiliation

CHECKED AND APPROVED, DATE

____

____
Affiliation

PROTOCOL H20L
Accelerated Polishing of Aggregate Using the British Wheel (SC13)

This LTPP protocol covers the procedures for determining the polish value of aggregates used for the chip seals used as part of the SPS-3 studies. The tests will be performed in accordance with AASHTO T279-83, Accelerated Polishing of Aggregate Using the British Wheel.

The results will be recorded on LTPP Test Sheet H18.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
LABORATORY MATERIAL TEST DATA
POLISH VALUE
LAB DATA SHEET H18

CHIP SEAL PROPERTIES
LTPP TEST DESIGNATION CS13/LTPP PROTOCOL H20L

LABORATORY PERFORMING TEST: ____
LABORATORY IDENTIFICATION CODE: ___ ___ ___ ___
REGION: ________________________ STATE: _____ STATE CODE: __ __
EXPERIMENT NO: _____ SHRP ID: __ __ __ __
SAMPLED BY: ________________________________ FIELD SET NO: ___
DATE SAMPLED: __ __ - __ __ - __ __ __ __ SAMPLING AREA NO: SA- ____

1. LAYER NUMBER ___

2. LABORATORY TEST NUMBER __

3. LOCATION NUMBER __ __ __

4. LTPP SAMPLE NUMBER __ __ __ __

5. TEST RESULTS
   (a) Gradation, % Passing Each Sieve
   Standard
   ½ in. (12.5 mm) __ __.__
   ⅜ in. (9.50 mm) __ __.__
   #4 (4.75 mm) __ __.__
   #8 (2.36 mm) __ __.__
   #10 (2.00 mm) __ __.__
   #200 (0.075 mm) __ __.__

   (b) INITIAL FRICTION VALUE __ __ __.__

   (c) POLISH VALUE __ __ __

6. COMMENTS
   (a) CODE ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

   (b) NOTE ____

7. TEST DATE __ __ - __ __ - __ __ __ __

GENERAL REMARKS: ____

SUBMITTED BY, DATE CHECKED AND APPROVED, DATE

____________________________ ____________________________
LABORATORY CHIEF

____________________________ ____________________________
Affiliation Affiliation

4.3 STANDARD CODES

This last section of Chapter 4 contains the detail information on the codes used in completing the laboratory test data sheets. These include the comment codes used at the bottom of the test data sheets. One or more of the LTPP standard comments presented in Table 4.24 may have been used on the test form. Some of the comments presented in Table 4.24 are specific to particular protocols. The relevant protocols for each comment are provided within the table.

Table 4.24 LTPP Standard Comments

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
01	Test is performed on insufficient size sample according to the test standard/protocol.	All
02	The test specimen is flawed, not ideal, still tested.	All
03	Procedural mistake is made by the laboratory or the laboratory suspects that some test parts were not in strict conformance to the protocol.	All
04	Test results (partially) do not seem reasonable; no explanation is provided.	All
05	Test results (partially) do not seem reasonable; explanation is provided in the following note.	All
06	Test is suspect, sample was misnumbered.	All
07	Test is suspect, sample was not correctly identified.	All
08	Equipment was not in calibration (found after inspection).	All
09	L/D (specimen length to diameter) ratio is not according to the requirement of the test for layer thickness.	All
10	L/D ratio is not according to the requirement for maximum size aggregate.	All
11	The technician's results are not consistent with the previous technician's results.	All
12	This test is a replacement for the previous test.	All
13	LTPP has directed a deviation in the test procedure.	All
14	Substantial update in the LTPP protocol.	All
15	Very thin, untestable, layer.	All
16	Layer thickness <u>was</u> measured in the laboratory prior to sawing from other bonded layers.	All
17	Layer thickness was <u>not</u> measured in the laboratory prior to sawing from other bonded layers.	All
18	Insufficient material to perform the test. Test was not performed.	All
19	Insufficient material to perform the moisture content test. Test was not performed.	All
20	Not enough AC for H03L/H04L on separate samples. H03L sample reused for the H04L test.	All

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
21	Length to diameter ratio was less than 1.0 because the layer thickness was less than the diameter of the specimen.	P61
22	Length to diameter ratio was equal to or less than 1.0 because the specimen was sawed in order to remove concrete with embedded steel.	P61
23	Embedded steel was noted in the specimen near the middle of the diametral plane.	P61
24	Embedded steel was noted at or near the side of the test specimen.	P61
25	The specimen was skewed (either end of the specimen departed from perpendicularity to the axis by more than 0.5° or ⅛ inch in 12 inches (3 mm in 305 mm), as tested by placing the specimen on a level surface).	P61
26	M_r determinations generally done within four minutes.	All
27	M_r determinations were generally not done within four minutes.	All
28	Test performed in a temperature controlled cabinet.	All
29	Dummy specimen used to monitor temperature.	All
30	Specimen damaged and not tested. Replacement was used.	All
31	Length to diameter ratio was equal to or less than 1.0 because the layer thickness was less than the diameter of the specimen.	P62
32	The specimen was trimmed only at the bottom end.	P62
33	The specimen was trimmed only at the top end.	P62
34	The specimen was trimmed at the bottom and top ends.	P62
35	The line of contact between the specimen and each bearing strip was straight and free from any projections or depressions higher or deeper than 0.01 inches (0.25 mm).	P62
36	The line of contact described in code 35 above was made possible by grinding.	P62
37	The line of contact described in code 35 above was made possible by capping, or by grinding and capping.	P62
38	The line of contact between the specimen and each bearing strip had more than 0.01-inch (0.25-mm) tolerance as described in Code 35 but less than 0.1-inch (2.5-mm) tolerance. The specimen was tested.	P62

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
39	The projections/depressions on the test surface (as described in Code 35) were higher or deeper than 0.1 inch (2.5 mm). The specimen was tested because there was no other replacement specimen.	P62
40	The PCC core retrieved from the field did not have any arrow or "T" to show the direction of traffic.	P62
41	Length to diameter ratio was less than 1.5 because the layer was equal to or less than the diameter of the specimen.	P64
42	Length to diameter ratio was equal to or less than 1.5 because the specimen was sawed in order to remove concrete with embedded steel.	P64
43	Embedded steel was noted in the specimen near the middle of the diametral plane.	P64
44	Embedded steel was noted at or near the side of the test specimen.	P64
45	The specimen was trimmed only at the bottom end.	P64
46	The specimen was trimmed only at the top end.	P64
47	The specimen was trimmed at the top and bottom ends.	P64
48	Percent smaller than 0.001 mm (0.04 mils) could not be determined in 1440 minutes (24 hours).	P42
50	Specimen capped	P69
51	Specimen ground	P69
52	Leather shims used	P69
53	Irregular interface between existing and overlay concrete.	P67
54	Failure plane in overlay concrete.	P67
55	Failure plane in existing concrete.	P67
56	Failure plane in interface between existing and overlay concrete.	P67
61	Insufficient size of test sample because the quantity of the bulk sample was significantly less than that required for the tests.	P14A, P41, P44, P47, P51, P51A, P52, P55
62	Presence of roots and other organic matter in the bulk sample retrieved from the field.	P41, P44, P47, P51, P51A, P52, P55
63	Presence of mica in the bulk sample retrieved from the field.	P41, P44, P47, P51, P51A, P52, P55

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
64	The bulk sample contained cobbles or large size aggregates (stone fragments passing the 12-in. [305-mm] sieve and retained on the 3-in. [76-mm] size sieve).	P41, P44, P47, P51, P51A, P52, P55
65	The test sample included shale chunks, claystone, mudstone, siltstone, and sandstone which convert into soils after field and/or laboratory processing (crushing, slacking, etc.).	P41, P44, P47, P51, P51A, P52, P55
67	PI reported as 'NP' because the LL and/or PL cannot be determined.	P43
68	PI is reported as 'NP' because the PL is equal to or greater than the LL.	P43
69	The test specimen slipped in the cup of the LL device.	P43
70	Test could not be completed within five water addition increments. Additional increments were made.	P44, P55
71	Degradation of the test sample was observed during the moisture-density test.	P44, P55
72	The quantity of the test sample was inadequate to complete the moisture-density test. Additional quantity was taken from other test samples or extra material to complete the moisture-density test.	P44, P55
73	Free water appeared at the bottom of the mold (i.e., seeped onto the place).	P44, P55
74	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve. This coarse fraction was included in the test sample for the moisture-density test.	P44, P55
75	The coarse fraction passing the 1 ½ in. (38-mm) sieve and retained on the No. 4 (4.75-mm) sieve was more than 5%. Method D was used to perform the moisture-density test.	P44, P55
76	The test sample contained coarse material larger than the 1 ½ in. (38-mm) sieve. This coarse material was removed and not used for the moisture-density test.	P44, P55
77	The gradation test results (Protocol P41 and Form T41 <u>or</u> Protocol P51 and Form T51, as appropriate) indicate up to 5% coarse material passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve. This coarse material was included in the test sample for the moisture-density test.	P44, P55

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
78	The coarse fraction passing the 1 ½-in. (38-mm) sieve and retained on the ¾-in. (19-mm) sieve was more than 5%. The test sample for the moisture-density testing was sieved using a ¾-in. (19-mm) sieve to separate the coarse fraction from the test sample. This coarse fraction was discarded from the test sample and not used in the moisture-density test. The test sample was, therefore, not truly representative of the bulk sample.	P44, P55
80	Due to insufficient size of the bulk sample, the test sample was used for the last test (Protocol P46, if the sample was reconstituted was saved and stored for possible future use by the LTPP program.	P46
81	A seperate test sample was used for classification and description tests (Protocols P46 or P52)	P46
82	Due to the insufficient size of the bulk sample, the test sample for the gradation test (Protocol P41 or P51) was also used to complete the classification and description tests. (Protocol P47 or P52)	P46
83	Due to the insufficient size of the bulk sample, the test sample for the moisture-density test (Protocol P44 or P55) was saved after the test and reused for the resilient modulus testing (Protocol P46).	P44, P46, P55
84	Due to insufficient size of the bulk sample; the sample for the moisture-density testing was obtained from the gradation test sample. The gradation test (Protocol P41 or P51) was performed by dry sieving only.	P44, P55
85	Due to the insufficient size of the bulk sample, only dry sieving was used for the gradation test (Protocol P41 or P51). The test sample after the gradation test was saved and reused to reconstitute the test sample of the resilient modulus testing (Protocol P46).	P46
86	Due to the insufficient size of the bulk sample, only dry sieving was used for the gradation test (Protocol P41 or P51). The test sample was reused for other designated tests and the remnant of the sample was saved and stored for possible future use by the LTPP program.	P46
87	The "undisturbed" thin-wall tube sample was used for the resilient modulus testing (Protocol P46).	P46
88	The thin-wall tube sample was not suitable, therefore a reconstituted sample from the bulk samples was used for the resilient modulus testing.	P46

COMMENT CODE	LTPP STANDARD COMMENT	RELEVANT TO PROTOCOL
89	The thin-wall tube sample was not available. The test sample for the resilient modulus testing (Protocol P46) was reconstituted from the bulk sample.	P46
90	An excess portion of the thin-wall tube sample was saved and stored for possible future use by the LTPP program.	P46
91	The thickness of the treated layer was determined in the laboratory using the intact cores and the Protocol P31 procedure. Compressive strength test (Protocol P32 for OTB materials) or resilient modulus test (Protocol P07 for ATB materials) shall not be performed on the cores from the designated locations, because the thickness is less than 3 inches (76 mm) or 1 inch (25 mm), respectively.	P31, P32
92	Intact cores were not available. The thickness of the treated layer was averaged from the information available on field exploration logs and used as is in reporting the test results of Protocol P31 on Form T31. Only the Protocol P31 test was conducted on chunks and pieces. Compressive strength test on OTB materials (Protocol P32) or resilient modulus test on ATB materials (Protocol P07) shall not be performed.	P31, P32
93	The thickness of the treated layer was 3 inches (76 mm) (Protocol P32) or 1 inch (25 mm) (Protocol P07) or more as determined from the intact cores. Protocol P31 test was performed. Other tests were or will be performed on intact cores using Protocol P32 (compressive strength for other than asphalt treated materials, ATB).	P31, P32
94	The test was not performed because of the oversize aggregate; sample was stored until further instruction from the FHWA-LTPP division.	P46
95	Length to diameter ratio was less than 1.0 because the layer thickness was less than the diameter of the specimen. A correction factor of 0.87 was applied to calculate the compressive strength.	P32
99	Other comment (see the following note).	All

On the test data form, the LTPP standard comment code(s) may have been followed by an explanatory note of up to 25 characters in length.

The following tables provide additional codes used in the description of the materials both in the field and in the laboratory.

4.3.1 LTPP Terminology for Describing Pavements, Pavement Materials and Soils in the Field (field use)

Table 4.25 provides codes used for describing pavement materials in the field. This table was provided within this document to allow laboratory personnel to easily identify the definitions of these codes. This table was reproduced from Appendix C, Table C.2 of the LTPP Field Material Sampling Guide and contains unique three-digit material codes.

Field Use

Table 4.25 was prepared to record material descriptions and codes in the field. The drilling and sampling personnel were required to use these codes to complete borehole, shoulder auger probe and test pit exploration logs.

Table 4.25 contains generic terminology based on the material classifications and codes given in Tables 4.26, 4.29 and 4.32 of this section. For use in the field, Table 4.25 was condensed from the detailed LTPP terminology for pavements, pavement materials and soils described in Tables 4.26, 4.29 and 4.32. Table 4.25 contains: (a) codes for pavement surface material types, (b) codes for unbound granular base and subbase material types, (c) codes for bound base and subbase material types, and (d) codes for subgrade soil types.

General categories for subgrade soils and selected soil types in some of these categories were provided in (d). For example, the code used for the general category of treated soil (treated or stabilized subgrade) was 180. If the field technician/driller was reasonably sure that he had encountered bituminous treated soil then he would use code 183 instead of 180. Similarly the overall code used for clay was 101. In addition, five more detailed codes were included in this category. The driller recorded code 101 on the borehole log for a clay soil. However, if the crew was reasonably certain that the soil could be classified in more detail, such as silty clay (code 131), or sandy clay (code 113), then these codes were used in place of code 101.

Laboratory Use

Table 4.25 was consulted by the materials testing laboratories only for information. Detailed material classification descriptions and codes for pavement materials and soils were to be furnished by the materials testing laboratories using Tables 4.26 to 4.29 in conjunction with appropriate laboratory tests and detailed observations.

Table 4.25. LTPP Terminology for Describing Pavements, Pavement Materials and Soils in the Field.

DESCRIPTION	CODE
(a) Pavement Surface Material Type	
Asphaltic Concrete (AC)	700*
Portland Cement Concrete (PCC)	730+
(b) Unbound Base/Subbase Material Type	

DESCRIPTION	CODE
Gravel (Uncrushed)	302
Crushed Stone	303
Crushed Gravel	304
Soil-Aggregate Mixture (Predominantly Fine-Grained)	307
Soil-Aggregate Mixture (Predominantly Coarse-Grained)	308
Other (specify if possible or use the term unknown)	310
(c) Bound Base/Subbase Material Type	
Asphalt Treated Mixture	321
Cement Aggregate Mixture	331
Econocrete	332
Lean Concrete	334
Sand-shell Mixture	336
Lime Treated Soil	338
Soil Cement	339
Other (specify if possible or use the term unknown)	350
(d) Subgrade Soil Type	
Clay (C)	101
Clay with Gravel	104
Clay with Sand	107
Gravelly Clay	110
Sandy Clay	113
Silty Clay (CL-ML)	131
Silt (ML)	141
Silt with Gravel	142
Silt with Sand	143
Gravelly Silt	144
Sandy Silt	145
Clayey Silt	148
Peat	151
Treated Soil	180
Lime-Treated Soil	181
Cement-Treated Soil	182
Bituminous-Treated Soil	183
Sand (S)	201

DESCRIPTION	CODE
Poorly Graded Sand (SP)	202
Silty Sand (SM)	214
Clayey Sand (SC)	216
Gravel (G)	251
Poorly Graded Gravel (GP)	252
Silty Gravel (GM)	264
Clayey Gravel (GC)	266
Shale	281
Rock	282
Cobbles	283
Boulder	284

Notes: See Tables 4.26, 4.29, 4.32, and 4.35 for detailed description of LTPP terminology and codes.

(a) See Table 4.32 for details of pavement surface type terminology.

*Code 700 was to be used for all AC layers (sand asphalt and other types of surface, wearing, binder or bituminous base course) in the field.

+Code 730 was to be used for all PCC surface types in the field.

(b) and (c) See Table 4.29 for detailed description of base and subbase material terminology.

(d) See Table 4.26 for details of subgrade soil terminology.

4.3.2 Detailed Classification and Description of Soils (laboratory use)

Table 4.26 contains a detailed classification and description of soils based on ASTM D2487-85. Materials codes are also provided in the table for the Unified Soil Classification System.

Laboratory Use

The materials testing laboratories were required to use Table 4.26 for classification and description of subgrade soils (LTPP Protocol P52). Unique three-digit material codes were provided in this table.

The materials testing laboratories used Table 4.26 in conjunction with; (a) the laboratory gradation test results (LTPP Protocol P51 for the subgrade soils), and (b) the laboratory test results of Atterberg Limits (LTPP Protocol P43 for subgrade soils).

The materials testing laboratories also used the Table 4.26 codes for recording subgrade material type on Form L05 (Summary of Pavement Layers) of the LTPP Laboratory Material Testing Guide.

Field Use

Table 4.26 was not used by the drilling and sampling personnel.

Table 4.26. Detailed Classification and Description of Soils.

DESCRIPTION	CODE
I. Fine-Grained Soils: Fine-grained soils are those having 50 percent or more by dry weight passing the No. 200 (0.075-mm) sieve.	100
(1) Clay (C): (ASTM D2488-84) Soil passing a No. 200 (0.075-mm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, clay is a fine-grained soil, or the fine-grained portion of a soil, with a PI equal to or greater than 4, and the plot of PI versus LL falls on or above the "A" line of Figure 3 of ASTM D2487.	101
(2) Inorganic clay (in which the organic matter does not influence the LL) is classified as:	
Lean Clay (CL), if the LL is less than 50	102
Fat Clay (CH), if the LL is 50 or greater	103
(3) Further classification of predominantly clay soils is done if less than 30% but 15% or more of the test sample is retained on the No. 200 (0.075-mm) sieve. Add the words "with gravel" or "with sand," whichever is predominant. (ASTM D2488-84)	
Clay with Gravel	104
Lean Clay with Gravel	105
Fat Clay with Gravel	106
Clay with Sand	107
Lean Clay with Sand	108
Fat Clay with Sand	109
(Note: Codes 107, 108, and 109 will also apply, if the percent of sand is equal to the percent of gravel.)	
(4) For predominantly clay soils the following classification applies, if 30% or more of the test sample is retained on the No. 200 (0.075-mm) sieve. Add the word "gravelly" or "sandy," whichever is predominant to the group symbol. (ASTM D2488-84)	
Gravelly Clay	110

DESCRIPTION	CODE
Gravelly Lean Clay	111
Gravelly Fat Clay	112
Sandy Clay	113
Sandy Lean Clay	114
Sandy Fat Clay	115
(Note: Codes 113, 114, and 115 will also apply, if the percent of sand is equal to the percent of gravel.	
Further division is done by adding the word "with sand" if more than 15% sand is present; or the word "with gravel" if more than 15% gravel is present.	
Gravelly Clay with Sand	116
Gravelly Lean Clay with Sand	117
Gravelly Fat Clay with Sand	118
Sandy Clay with Gravel	119
Sandy Lean Clay with Gravel	120
Sandy Fat Clay with Gravel	121
(5) Silty Clay (CL-ML) Combined silt and clay. For material passing 85% or more on the No. 200 (0.075-mm) sieve if the position of the PI versus LL plot falls on or about the A-line and PI is in the range of 4 to 7. (ASTM D2487-85) Silty Clay is further classified according to the percent of sand and/or gravel in the test sample	131
Silty Clay with Gravel (Less than 30% but more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly gravel.)	132
Silty Clay with Sand (Less than 30% but equal to or more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly sand.)	133
Gravelly Silty Clay (Gravel is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.	134
Sandy Silty Clay (Sand is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	135

DESCRIPTION	CODE
Gravelly Silty Clay with Sand (Equal to or more than 15% sand is present in the predominantly gravel fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	136
Sandy Silty Clay with Gravel (More than 15% gravel is present in the predominantly sand fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	137
(6) Silt (ML) Soil passing the No. 200 (0.075-mm) sieve that is non-plastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, silt is a fine-grained soil, or the fine-grained portion of a soil, with LL less than 50 and a PI less than 4, or the plot of PI versus LL falls below the "A" line of Figure 3 of ASTM D2487. (ASTM D2488-84) Silt is further classified according to the percent of sand and/or gravel in the test sample	141
Silt with Gravel (Less than 30% but more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly gravel.)	142
Silt with Sand (Less than 30% but equal to or more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly sand.)	143
Gravelly Silt (Gravel is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	144
Sandy Silt (Sand is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	145
Gravelly Silt with Sand (15% or more sand is present in the predominantly gravel fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	146
Sandy Silt with Gravel (A silt soil containing a predominantly sand fraction at 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve, if which 15% or more is gravel.)	147
Clayey Silt A silt soil containing some clay material with slight plasticity. (ASTM D2488-84)	148

DESCRIPTION	CODE
(7) Peat A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat. (ASTM D2488-84)	151
(8) Organic Soil (OL/OH) The soil is identified as an organic soil (OL/OH), if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often organic soils will change color, for example, black to brown, when exposed to the air. Some organic soil will lighten in color significantly when air dried. Organic soil normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy. (ASTM D2488-84) For organic soils, the LL after oven drying is less than 75% of the LL of the original specimen determined before oven drying. Organic soil is further classified according to the percent of sand and/or gravel in the test sample.	160
Organic Soil with Gravel (Less than 30% but equal to or more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly gravel.)	161
Organic Soil with Sand (Less than 30% but equal to or more than 15% retained on the No. 200 [0.075-mm] sieve is predominantly sand.)	162
Gravelly Organic Soil (Gravel is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	163
Sandy Organic Soil (Sand is predominant in the fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	164
Gravelly Organic Soil with Sand (15% or more sand is present in the predominantly gravel fraction of 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve.)	165
Sandy Organic Soil with Gravel (An organic soil containing predominantly sand fraction at 30% or more of the test sample retained on the No. 200 [0.075-mm] sieve, of which 15% or more is gravel.)	166
(9) In some cases through practice and experience it may be possible to further identify the organic soils as organic silt or organic clay.	

DESCRIPTION	CODE
(a) Organic Clay Clay with sufficient organic content to influence the soil properties. For classification, organic clay is a soil that would be classified as clay, except that its LL value after oven drying is less than 75% of its LL value before oven drying. (ASTM D2487-85) Further classification is based on LL and PI.	171
Organic Clay (OL) If the LL (not oven dried) is less than 50%; the PI is 4 or greater and the PI versus LL plot falls on or above the "A" line.	172
Organic Clay (OH) If the LL (not oven dried) is 50% or greater; and the PI versus LL plot falls on or above the "A" line.	173
(b) Organic Silt Silt with sufficient organic content to influence the soil properties. For classification, organic silt is a soil that would be classified as silt except that its LL value after oven drying is less than 75% of its LL value before oven drying. (ASTM D2487-85) Further classification is based on LL and PI.	176
Organic Silt (OL) If the LL (not oven dried) is less than 50%; the PI is less than 4 or the position of the PI versus LL plot falls below the "A" line.	177
Organic Silt (OH) If the LL (not oven dried) is 50% or greater and the position of the PI versus LL plot falls below the "A" line.	178
(10) Treated Soil (Material codes 180 through 183 are also included in Table 4.29 to indicate treated subgrade soil type)	180
(a) Lime-Treated Soil The addition of lime to the soil which results in decreased soil density, changes in the plasticity properties of the soil and increased soil strength.	181
(b) Cement-Treated Soil The addition of portland cement to the soil that produces a hardened soil-cement which increases the stability of the soil.	182
(c) Bituminous-Treated Soil	183
II. Coarse-Grained Soils The coarse-grained soils are those having 50 percent or less passing the No. 200 (0.075-mm) sieve.	200

DESCRIPTION	CODE
(1) Sand (S) Granular material resulting from the disintegration, grinding, or crushing of rock which will pass the No. 10 (2.00-mm) sieve and be retained on the No. 200 (0.075-mm) sieve. Coarse sand is sand passing the No. 10 (2.00-mm) sieve and retained on the No. 40 (0.425-mm) sieve. Fine sand is sand passing the No. 40 (0.425-mm) sieve and retained on the No. 200 (0.075-mm) sieve. (AASHTO M146-70, 1980)	201
Poorly Graded Sand (SP) Predominantly one size or a range of sizes of sand with some intermediate sizes missing and 5% or less fines.	202
Poorly graded sand is further classified according to the plasticity and type of fine fraction and percent of gravel in the test sample.	
Poorly Graded Sand with Gravel (With 5% or less fines and 15% or more gravel)	203
Poorly Graded Sand with Silt (SP-SM) (With 10% fines or ML or MH type and less than 15% gravel.)	204
Poorly Graded Sand with Silt and Gravel (With 10% fines of ML or MH type and 15% or more gravel.)	205
Poorly Graded Sand with Clay (SP-SC) (With 10% fines of CL or CH type and less than 15% gravel.)	206
Poorly Graded Sand with Clay and Gravel (With 10% fines of CL or CH type and 15% or more gravel.)	207
Well-Graded Sand (SW) A wide range of particle and substantial amounts of the intermediate particle sizes with 5% or less fines. Well-graded sand is further classified according to the plasticity and type of fine fraction and percent of gravel in the test sample.	208
Well-Graded Sand with Gravel (With 5% or less fines and 15% or more gravel.)	209
Well-Graded Sand with Silt (SW-SM) (With 10% fines of ML or MH type and less than 15% gravel.)	210
Well-Graded Sand with Silt and Gravel (With 10% fines of ML or MH type and 15% or more gravel.)	211
Well-Graded Sand with Clay (SW-SC) (With 10% fines of CL or CH type and less than 15% gravel.)	212
Well-Graded Sand with Clay and Gravel (With 10% fines of CL or CH type and 15% or more gravel.)	213

DESCRIPTION	CODE
Silty Sand (SM) Sands with 15% or more fines passing the No. 200 (0.075-mm) sieve having low or no plasticity and less than 15% gravel. The LL and PI based on minus No. 40 (0.425-mm) sieve fraction should plot below the "A" line on the plasticity chart.	214
Silty Sand with Gravel Silty sand with 15% or more fines and 15% or more gravel.	215
Clayey Sand (SC) Sands with less than 15% gravel and 15% or more fines passing the No. 200 (0.075-mm) sieve that are more clay-like and that range in plasticity from low to high. The LLs and PI of soils in this group should plot above the "A" line on the plasticity chart.	216
Clayey Sand with Gravel Clayey sand with 15% or more fines and 15% or more gravel.	217
(2) Gravel (G) Rounded particles of rock which will pass a 3-inch (75-mm) sieve and be retained on a No. 10 (2.00-mm) sieve. Coarse gravel, passing the 3-inch (75-mm) sieve and retained on the 1-inch (25-mm) sieve. Medium gravel, passing the 1-inch (25-mm) sieve and retained on the ⅜-inch (9.5-mm) sieve. Fine gravel, passing the ⅜-inch (9.5-mm) sieve and retained on the No. 10 (2.00-mm) sieve. (AASHTO M146-70, 1980)	251
Poorly Graded Gravel (GP) Poorly graded gravels, gravel-sand mixtures, little or no fines. Predominantly one size or a range of sizes with some intermediate sizes missing. Poorly graded gravel is further classified according to the plasticity and type of fine fraction and percent of sand in the test sample.	252
Poorly Graded Gravel with Sand (With 5% or less fines and 15% or more sand.)	253
Poorly Graded Gravel with Silt (GP-GM) (With 10% fines of ML or MH type and less than 15% sand.)	254
Poorly Graded Gravel with Silt and Sand (With 10% fines of ML or MH type and 15% or more sand.)	255
Poorly Graded Gravel with Clay (GP-GC) (With 10% fines of CL or CH type and less than 15% sand.)	256
Poorly Graded Gravel with Clay and Sand (With 10% fines of CL or CH type and 15% or more sand.)	257

DESCRIPTION	CODE
Well-Graded Gravel (GW) It has a wide range of particle sizes and substantial amounts of the intermediate particle sizes. (ASTM D2488-84) Well-graded gravel is further classified according to the plasticity and type of fine fraction and percent of sand in the test sample.	258
Well-Graded Gravel with Sand (With 5% or less fines and 15% or more sand.)	259
Well-Graded Gravel with Silt (GW-GM) (With 10% fines of ML or MH type and less than 15% sand.)	260
Well-Graded Gravel with Silt and Sand (With 10% fines of ML or MH type and 15% or more sand.)	261
Well-Graded Gravel with Clay (GW-GC) (With 10% fines of CL or CH type and less than 15% sand.)	262
Well-Graded Gravel with Clay and Sand (With 10% fines of CL or CH type and 15% or more sand.)	263
Silty Gravel (GM) (With 15% or more fines having low or no plasticity and less than 15% sand.)	264
Silty Gravel with Sand (With 15% or more fines and 15% or more sand.)	265
Clayey Gravel (GC) Gravelly soils with 15% or more fines passing the No. 200 (0.075-mm) sieve that are more clay-like and that range in plasticity from low to high and less than 15% sand. The LLs and PIs of soils in this group should plot above the "A" line on the plasticity chart.	266
Clayey Gravel with Sand (With 15% or more fines and 15% or more sand.)	267
III. Rock and Stone This category includes naturally formed solid mineral matter occurring in large masses, and naturally or crushed angular particles of rock.	280
(1) Shale Gray, black, reddish, or green rock which is fine-grained and composed of, or derived by erosion of sedimentary silts or clays, or of any type of rock that contains clay. The cleavage surfaces of shales are generally dull and earthy. Shale converts to soil after field and/or laboratory processing (crushing, slaking, etc.)	281

DESCRIPTION	CODE
(2) Rock Natural solid mineral matter occurring in large masses of fragments. (ASTM D653-85, AASHTO M146-70, 1980). The same code may be used for materials used in rock fill.	282
(3) Cobbles Particles of rock that will pass a 12-inch (305-mm) square opening and be retained on a 3-inch (75-mm) sieve. (ASTM D2488-84)	283
(4) Boulder Particles of rock that will not pass a 12-inch (305-mm) square opening. (ASTM D2488-84)	284
(5) Claystone/Mudstone Claystone and mudstone convert to soil after field and/or laboratory processing (crushing, slaking, etc.)	285
(6) Siltstone Siltstone converts to soil after field and/or laboratory processing (crushing, slaking, etc.)	286
(7) Sandstone Sandstone converts to soil after field and/or laboratory processing (crushing, slaking, etc.)	287
(8) Slag Large fragments of the non-metallic product developed simultaneously with iron in a blast furnace that essentially consists of alumino-silicates of lime and other bases.	288
(9) Shale Chunk Retrieved as 2- to 4-inch (50- to 100-mm) pieces of shale from field. Example of laboratory description: dry, brown, no reaction with hydrochloric acid (HCL). After laboratory processing by slaking in water for 24 hours, material identified as "Sandy Lean Clay (CL)" – 61% of clayey fines, LL = 37, PI = 16, 33% fine to medium sand; 6% gravel-size pieces of shale.	289
(10) Crushed Sandstone Product of commercial crushing operation. Example of laboratory description: "Poorly Graded Sand with Silt (SP-SM)" – 91% fine to medium sand; 9% silty (estimated) fines; dry, reddish-brown, strong reaction with HCL.	290
(11) Crushed Limestone Product of commercial crushing operation on limestone rock pieces.	291

DESCRIPTION	CODE
(12) Crushed Rock Processed gravel and cobbles from a pit. Example of laboratory description: "Poorly Graded Gravel (GP)" – 89% fine, hard, angular gravel-size particles; 11% coarse, hard, angular sand-size particles, dry, tan; no reaction with HCL; coefficient of curvature 2.4, and uniformity coefficient 0.9.	292
(13) Broken Shells Example of laboratory description: 62% gravel-size, broken shells; 31% sand and sand-size shell pieces; 7% fines; would be identified as "Poorly Graded Gravel with Sand (GP)."	293
(14) Other (specify if possible or use the term unknown)	294

4.3.3 Soil Descriptions and Material Codes Based on Visual Methods (laboratory use)

The classification and description of soils based on the visual-manual methods of ASTM D2488-84 and associated material codes were included in Table 4.27. The tables, numbered (1) to (14) included in Table 4.27 were taken from ASTM D2488-84.

Laboratory Use

The materials testing laboratories were required to use Table 4.27 for classification and description of unbound granular base and subbase materials (LTPP Protocol P47) and subgrade soils (LTPP Protocol P52). Table 4.27 was also used for description of treated base and subbase materials and treated subgrade. Unique four-digit material codes were defined in this table.

The materials testing laboratories used Table 4.27 in conjunction with: (a) the visual-manual procedures described in ASTM D2488-84, (b) the laboratory test results obtained from the gradation and Atterberg Limits tests as appropriate (LTPP Protocols P41, P43, P51).

Field Use

Table 4.27 was not used by the drilling and sampling personnel.

Table 4.27. Soils Descriptions and Material Codes Based on Visual Methods.

DESCRIPTION	CRITERIA	CODE
(1) Criteria for Describing Angularity of Coarse-Grained Particles (See Figure 3 of ASTM D2488-84)		
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces	2101
Subangular	Particles are similar to angular description but have rounded edges	2102

DESCRIPTION	CRITERIA	CODE
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges	2103
Rounded	Particles have smoothly curved sides and no edges	2104
(2) Criteria for Describing Particle Shape (See Figure 4 of ASTM D2488-84) The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.		
Flat	Particles with width/thickness > 3	2201
Elongated	Particles with length/width > 3	2202
Flat and elongated	Particles meet criteria for both flat and elongated	2203
(3) Criteria for Describing Moisture Condition		
Dry	Absence of moisture, dusty, dry to the touch	1301
Moist	Damp but no visible water	1302
Wet	Visible free water, usually soil is below water table	1303
(4) Criteria for Describing the Reaction with HCL		
None	No visible reaction	2301
Weak	Some reaction, with bubbles forming slowly	2302
Strong	Violent reaction, with bubbles forming immediately	2303
(5) Criteria for Describing Consistency		
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)	1401
Soft	Thumb will penetrate soil about 1 in. (25 mm)	1402
Firm	Thumb will indent soil about ¼ in. (6 mm)	1403
Hard	Thumb will not indent soil but readily indented with thumbnail	1404
Very hard	Thumbnail will not indent soil	1405
(6) Criteria for Describing Cementation		
Weak	Crumbles or breaks with handling or little finger pressure	1501
Moderate	Crumbles or breaks with considerable finger pressure	1502
Strong	Will not crumble or break with finger pressure	1503
(7) Criteria for Describing Structure		
Stratified	Alternating layers of varying material or color with layers at least ¼-inch (6-mm) thick; note thickness	1601
Laminated	Alternating layers of varying material or color with the layers less than ¼-inch (6-mm) thick; note thickness	1602
Fissured	Breaks along definite planes of fracture with little resistance to fracturing	1603
Slickensided	Fracture planes appear polished or glossy sometimes striated	1604
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown	1605
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness	1606
Homogenous	Same color and appearance throughout	1607
(8) Criteria for Describing Dry Strength		
None	The dry specimen crumbles into powder with mere pressure of handling	1701

DESCRIPTION	CRITERIA	CODE
Low	The dry specimen crumbles into powder with some finger pressure	1702
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure	1703
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface	1704
Very high	The dry specimen cannot be broken between the thumb and a hard surface	1705
(9) Criteria for Describing Dilatancy		
None	No visible change in the specimen	1801
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing	1802
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing	1803
(10) Criteria for Describing Toughness		
Low	Only slight pressure is required to roll the thread near the PL. The thread and the lump are weak and soft	1901
Medium	Medium pressure is required to roll the thread to near the PL. The thread and the lump have medium stiffness	1902
High	Considerable pressure is required to roll the thread to near the PL. The thread and the lump have very high stiffness.	1903
(11) Criteria for Describing Plasticity		
Nonplastic	A ⅛-inch (3-mm) thread cannot be rolled at any water content	1201
Low	The thread can barely be rolled and the lump cannot be formed when drier than the PL	1202
Medium	The thread is easy to roll and not much time is required to reach the PL. The thread cannot be rerolled after reaching PL. The lump crumbles when drier than the PL.	1203
High	It takes considerable time rolling and kneading to reach the PL. The thread can be rerolled several times after reaching the PL. The lump can be formed without crumbling when drier than the PL.	1204
(12) Criteria for Describing Color		
Colors of soils should be reported on field exploration logs and laboratory test reports with other material description information as appropriate. There is no material code for this purpose.		

(13) Identification of Inorganic Fine-Grained Soils from Manual Tests

SOIL SYMBOL	DRY STRENGTH	DILATANCY	TOUGHNESS	CODE
ML	None to low	Slow to rapid	Low or thread cannot be formed	1101
CL	Medium to high	None to slow	Medium	1102
MH	Low to medium	None to slow	Low to medium	1103
CH	High to very high	None	High	1104

(14) *Criteria for Relative Density of Coarse-grained Soils*			
PENETRATION RESISTANCE*, Blows/Foot	**DESCRIPTIVE TERM**	**RELATIVE DENSITY**	**CODE**
0 to 4	Very Loose	0 to 20%	2001
4 to 10	Loose	20% to 40%	2002
10 to 30	Medium Dense	40% to 70%	2003
30 to 50	Dense	70% to 90%	2004
Over 50	Very Dense	90% to 100%	2005
Includes (1) clean, fine gravels and sands, depending on distribution of grain sizes and (2) silty or clayey fine gravels and sands. Condition was rated according to relative density, as determined by laboratory tests or estimated from resistance to sampler penetration.			
*Penetration resistance was recorded on borehole logs at locations A1 and A2 on the pavement section by the Drilling and Sampling Contractor.			

4.3.4 AASHTO Classification for Soil and Soil-Aggregate Materials (laboratory use)

Material codes for the AASHTO classification of soils and soil-aggregate materials based on AASHTO M145-87I were included in Table 4.28.

Laboratory Use

The materials testing laboratories used Table 4.28 for classification and description of subgrade soils (LTPP Protocol P52). Unique three-digit material codes were defined in this table.

The materials testing laboratories used Table 4.28 in conjunction with; (a) the procedures described in AASHTO M145-87I, (b) the laboratory gradation test results (LTPP Protocol P51 for the subgrade soils), and (c) the laboratory test results of Atterberg Limits (LTPP Protocol P43 for subgrade soils). The materials testing laboratories report a specific classification in the A-1 group; for example, a soil should be classified either A-1-a (material code 502) or A-1-b (material code 503).

Field Use

Table 4.28 was not used by the drilling and sampling personnel.

Table 4.28. AASHTO Classification for Soil and Soil-Aggregate Material Types.

MATERIAL TYPE	DESCRIPTION	CODE
A-1	The typical material of this group is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand, and a non-plastic or feebly plastic soil binder. However, this group includes also stone fragments, gravel, coarse sand, volcanic cinders, etc. without soil binder. (AASHTO M145-82)	501

MATERIAL TYPE	DESCRIPTION	CODE
A-1-a	Subgroup A-1-a includes those materials consisting predominantly of stone fragments or gravel, either with or without a well-graded binder of fine material. (AASHTO M145-82)	502
A-1-b	Subgroup A-1-b includes those materials consisting predominantly of coarse sand either with or without a well-graded soil binder. (AASHTO M145-82)	503
A-2	This group includes a wide variety of "granular" materials which are border-line between the materials falling in Groups A-1 and A-3 and silt-clay materials of Group A-4, A-5, A-6, and A-7. It includes all materials containing 35 percent or less passing the No. 200 (0.075-mm) sieve which cannot be classified as A-1 or A-3, due to fines content or plasticity or both, in excess of the limitations for those groups. (AASHTO M145-82)	505
A-2-4 A-2-5	Subgroups A-2-4 and A-2-5 include various granular materials containing 35 percent or less passing the No. 200 (0.075-mm) sieve and with a minus No. 40 (0.425-mm) portion having the characteristics of the A-4 and A-5 groups. These groups include such materials as gravel and coarse sand with silt contents or PIs in excess of the limitations of Group A-1, and fine sand with non-plastic silt content in excess of the limitations of Group A-3. (AASHTO M145-82)	506 507
A-2-6 A-2-7	Subgroups A-2-6 and A-2-7 include materials similar to those described under Subgroups A-2-4 and A-2-5 except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group. (AASHTO M145-82)	508 509
A-3	The typical material of this group is fine beach sand or fine desert blow sand without silty or clay fines or with a very small amount of non-plastic silt. The group includes also stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel. (AASHTO M145-82)	504
A-4	The typical material of this group is a non-plastic or moderately plastic silty soil having 75 percent or more passing the No. 200 (0.075-mm) sieve. The group includes also mixtures of fine silty soil and up to 64 percent of sand and gravel retained on the No. 200 (0.075-mm) sieve. (AASHTO M145-82)	510
A-5	The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaceous character and may be highly elastic as indicated by the high LL. (AASHTO M145-82)	511

MATERIAL TYPE	DESCRIPTION	CODE
A-6	The typical material of this group is a plastic clay soil usually having 75 percent or more passing the No. 200 (0.075-mm) sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the No. 200 (0.075-mm) sieve. Materials of this group usually have high volume change between wet and dry states. (AASHTO M145-82)	512
A-7	The typical material of this group is similar to that described under Group A-6, except that it has the high LLs characteristic of the A-5 group and may be elastic as well as subject to high volume change. (AASHTO M145-82)	513
A-7-5	Subgroup A-7-5 includes those materials with moderate PIs in relation to LL and which may be highly elastic as well as subject to considerable volume change. (AASHTO M145-82)	514
A-7-6	Subgroup A-7-6 includes those materials with high PIs in relation to LL and which are subject to extremely high volume change. (AASHTO M145-82)	515

Notes: 1. Follow AASHTO M145-82 (1986) procedures to classify the material according to these AASHTO classification groups and then assign appropriate material codes. Use specific classification in A-1 group; for example a soil should be classified either A-1-a (material code 502) or A-1-b (material code 503)
2. According to Tables 1 and 2 of AASHTO M145-82 (1986):

Granular Material Groups (35% or less Passing No. 200 [0.075-mm])	Silt-Clay Material Groups (More than 35% Passing No. 200 [0.075-mm] Sieve)
A-1 (Stone fragments, gravel and sand) A-3 (Non-plastic fine sand) A-2 (Silty or clayey gravel and sand)	A-4 (Silty soils) A-5 (Silty soils) A-6 (Clayey soils) A-7 (Clayey soils)

4.3.5 Base and Subbase Materials Description (laboratory use)

Table 4.29 contains description and material codes of all types of base and subbase materials based on material processing and construction methods.

Laboratory Use

The materials testing laboratories used Table 4.29 for description of all types of treated base and subbase materials (LTPP Protocol P31) and all types of untreated unbound granular base and subbase materials (LTPP Protocol P47). Unique three-digit material codes were defined in this table.

The materials testing laboratories used Table 4.29 in conjunction with; (a) detailed descriptions made during bulk sample handling, (b) test preparation for gradation and other laboratory tests,

(c) the laboratory gradation test results (LTPP Protocol P41 for the unbound granular base and subbase material) and (d) description and type of treatment for treated base and subbase materials and treated subgrade (LTPP Protocol P31).

The materials testing laboratories used Table 4.29 codes for recording base and subbase layer material information on Form L05 (Summary of Pavement Layers).

Field Use

Some major categories of description and associated material codes of all types of base and subbase materials from Table 4.29 were also used in Table 4.25 (included in this Chapter). Table 4.25 was used by the drilling and sampling personnel to complete the borehole, shoulder auger probe and test pit exploration logs.

Table 4.29. Base and Subbase Materials Description.

MATERIAL TYPE	DESCRIPTION	CODE
1. Detailed Description of Unbound Granular Base/Subbase Material Unbound Granular Base: Unbound granular base layer material includes material codes 302 through 308, 310. Unbound Granular Subbase: Unbound granular subbase layer material includes material codes 302 through 308, 310.		
Gravel (Uncrushed)	The product resulting from screening blending of material from the deposit, consisting of particles with a shape and texture largely dependent on the nature of the deposit. The product may include some particles with fracture faces resulting from crushing oversize material. (ASTM D1139-83)	302
Crushed Stone	The product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation. (ASTM D1139-83)	303
Crushed Gravel	The product resulting from the crushing of gravel, with a requirement that at least a prescribed percentage of the resulting particles have fracture faces. Some uncrushed particles may be included. (ASTM D1139-82)	304
Crushed Slag	The nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and of other bases, that is developed simultaneously with iron in a blast furnace. The product resulting from the crushing of air-cooled iron blast-furnace slag. (ASTM D1139-83)	305
Sand	Fine aggregate resulting from natural disintegration and abrasion of rock or processing of completely friable sandstone.	306

MATERIAL TYPE	DESCRIPTION	CODE
Soil-Aggregate Mixture (Predominantly Fine-Grained Soil)	Natural or prepared mixture of fine-grained soil with a percentage of aggregates included in the mixture. This material meets the criteria of less than 70 percent passing the No. 10 (2.00-mm) sieve and more than 35 percent passing the No. 200 (0.075-mm) sieve. Typically this material includes all those materials which do not meet the criteria given below for the predominantly coarse-grained soil aggregate mixture. Note: If greater than 70 percent passes the No. 10 (2.00-mm) sieve, then the material is considered a soil. If less than 70 percent passes the No. 10 (2.00-mm) sieve, the material should be considered a soil-aggregate mixture.	307
Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)	Natural or prepared mixtures of coarse-grained soil with a percentage of aggregates included in the mixture. Typically this material meets the criteria of less than 70 percent passing the No. 10 (2.00-mm) sieve and less than 35 percent passing the No. 200 (0.075-mm) sieve.	308
Fine-Grained Soil	This material meets the criteria of more than 70 percent passing the No. 10 (2.00-mm) sieve and more than 50 percent passing the No. 200 (0.075-mm) sieve.	309
Other (Specify if possible or use the term unknown)		310
2. Detailed Description of Treated Base/Subbase Material		
Treated Base/Subbase	Treated base/subbase material includes material codes 319 through 341, 350. The asphalt treated material (ATB) consists of material codes 319 through 330. Other than asphalt treated material (OTB) consists of material codes 331 through 341.	
HMAC	HMAC (hot-mix, hot-laid asphaltic concrete) is a mixture of heated coarse and fine aggregate or fine aggregate alone, with or without mineral filler, uniformly mixed with asphalt cement. Typically HMAC material is produced in an asphalt plant or drum mixer and laid hot at the paving site for AC surface, wearing, binder, and bituminous base courses.	319
Sand Asphalt	A mixture of sand and asphalt cement or cutback or emulsified asphalt. It may be prepared with or without special control of aggregate grading and may or may not contain mineral filler. Either mixed-in-place or plant-mix construction may be employed. Sand-asphalt is used in construction of both base and surface courses.	320
Asphalt-Treated Mixture	(Also called Asphalt-Treated Base, ATB, Black Base) General term used for all types of bituminous treated material. With the	321

MATERIAL TYPE	DESCRIPTION	CODE
	exception of HMAC material (material codes 700, 319) and Sand Asphalt (material codes 02, 320).	
Dense Graded Hot Laid Central Plant Mix	A mixture of asphalt cement and mineral aggregate prepared in a central bituminous mixing plant and spread and compacted at the job site at a temperature above ambient temperature, and containing an aggregate that has a particle size distribution such that when it is compacted, the resulting voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, are relatively small.	322
Dense-Graded, Cold-Laid, Central Plant Mix	A mixture of cut-back asphalt, bituminous emulsion or tar and mineral aggregate prepared in a central bituminous mixing plant and spread and compacted at the job site when the mixture is at or near ambient temperature containing an aggregate that has a particle size distribution such that when it is compacted, the resulting voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, are relatively small.	323
Dense-Graded, Cold-Laid, Mixed In-Place	A bituminous surface or base course produced by mixing mineral aggregate and cut-back asphalt, bituminous emulsion, or tar at the job-site by means of travel plants, motor graders, drags, or special road-mixing equipment designed to be laid either shortly after mixing or when the mixture is at or near ambient temperature, and containing an aggregate that has a particle size distribution such that when it is compacted, the resulting voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, are relatively small.	324
Open-Graded, Hot-Laid, Central Plant Mix	A mixture of emulsion and heated mineral aggregate usually prepared in a conventional asphalt plant or drum mixer and spread and compacted at the job site at a temperature above ambient containing an aggregate that has a particle size distribution such that when it is compacted, the voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, remain relatively large.	325
Open-Graded, Cold-Laid, Central Plant Mix	A mixture of cut-back asphalt, bituminous emulsion, or tar and mineral aggregate prepared in a central bituminous mixing plant and spread and compacted at the job-site when the mixture is at or near ambient temperature containing an aggregate that has a particle size distribution such that when it is compacted, the voids between the aggregate particles, expressed as a percentage of the total space occupied by the material, remain relatively large.	326

MATERIAL TYPE	DESCRIPTION	CODE
Open-Graded, Cold-Laid, Mixed-in-Place	A bituminous base or subbase course produced by mixing mineral aggregate and cut-back asphalt, bituminous emulsion, or tar at the job-site by means of travel plants, motor graders, drags, or special road-mixing equipment designed to be laid either shortly after missing or when the mixture is at or near ambient temperature, and containing an aggregate that has a particle size distribution such that when it is compacted, the voids between the aggregate particles, expressed as a percentage of total space occupied by the material, remain relatively large.	327
Recycled Asphalt Concrete, Plant Mix, Hot Laid	HMAC containing reclaimed AC which is mixed at the plant, transported to the job site and laid at a temperature substantially higher than ambient temperature.	328
Recycled Asphalt Concrete, Plant Mix, Cold Laid	A cold laid bituminous mixture containing reclaimed asphalt concrete which is batch mixed at the plant, transported to the job site and laid at ambient temperature.	329
Recycled Asphalt Concrete, Mixed-In-Place	A bituminous concrete layer containing reclaimed asphalt concrete which is mixed in-place and laid at the job site at ambient temperature.	330
Cement Aggregate Mixture	(Also called cement-treated base, CTB) A mixture of aggregate and soil binder treated with portland cement and used as base or subbase to increase the stability of the pavement structure. Typically 4 to 8 percent portland cement is used to achieve a specified minimum value of compressive strength. The materials may have been mixed in-place or produced at a batch or a continuous mixing plant.	331
Lean Concrete	(Also called lean-concrete base, LCB) A PCC mixture with a relatively low cement content.	334
Econocrete	A PCC mixture made with marginal aggregate and a relatively low cement content.	332
Cement-Treated Soil	The addition of cement to the soil to improve the plasticity characteristics of the soil and its load bearing capacity.	333
Recycled Portland Cement Concrete	Waste concrete which has been crushed which will have at least three-quarters of the compressive strength, good workability and durability and two-thirds of the modulus of elasticity of regular, new concrete. Recycled PCC mixture is produced using crushed and processed PCC for more than 50 percent of the total aggregate.	335
Sand-Shell Mixture	A mixture of sandy material and shell fragment or material used in the subbase or base course or a mixture of processed shell blended with predominantly coarse-grained soil.	336

MATERIAL TYPE	DESCRIPTION	CODE
Limerock, Caliche	Soft Carbonate Rock. Caliche is a granular material consisting of at least 70 percent calcium carbonate, obtained from the processing of a soft carbonate rock (lime rock) or calcium carbonate deposits precipitated underground in arid environments. The granular material will pass a 3-inch (76-mm) sieve and will typically contain a relatively high percentage passing the No. 40 (0.425-mm) sieve.	337
Lime-Treated Soil	The addition of lime to soil (usually fine-grained) which results in decreased soil density, changes in the plasticity properties of the soil and increased soil strength (also called lump-modified soil).	338
Soil Cement	Soil (generally granular soil) bound by portland cement to produce a hardened soil-cement mixture with a requirement for minimum compressive strength. Soil cement generally has a higher cement content than that used in cement-treated soil.	339
Pozzolanic-Aggregate Mixture	A mixture of natural pozzolanic aggregate or soil or flyash material that produces a stiff bound material with cementitious properties.	340
Cracked and Seated PCC Layer	The original cracked PCC surface layer has been broken or cracked and seated by rolling this material. May not be salvageable from core sampling.	341
Other (Specify if possible or use the term unknown)		350
3. <u>Detailed Description of Treated Subgrade Soil</u>		
Treated Subgrade Soil	For the LTPP-GPS study, a treated subgrade soil is considered a treated subbase layer. Material code 180 indicates a general term for treated subgrade soils. Material codes 180 through 183 are also included in Table 4.26 of this Guide.	180
Lime-Treated Soil	The addition of lime to the soil which results in decreased soil density, changes in plasticity properties of the soil and increased soil strength.	181
Cement-Treated Subgrade Soil	The addition of cement to the soil to improved the plasticity properties of the soil and its load carrying capacity.	182
Bituminous Treated Subgrade Soil	The soil treated with bituminous materials to improve the soil strength.	183
4. <u>Type of Treatment in Treated Base/Subbase/Subgrade Material</u>		
Lime – includes all classes of quick lime and hydrated lime		351
Lime-flyash		352

MATERIAL TYPE	DESCRIPTION	CODE
Lime- and cement-flyash		353
Cement – portland cement		354
Bitumen – includes all classes of bituminous and asphalt treatments		355
Calcium Chloride		356
Sodium Chloride		357
Other Chemical Treatment – includes polymer stabilization		358
Other (specify if possible or use the term unknown)		360

4.3.6 Aggregate Type Description (laboratory use)

Description and material codes for coarse and fine aggregate types were listed in Table 4.30.

Laboratory Use

The materials testing laboratories used Table 4.30 for describing the coarse aggregate type for treated base and subbase materials (LTPP Protocol P31). The aggregate type description was reported with the results of LTPP Protocol P31 by the materials testing laboratories. Unique three-digit codes were defined in this table.

Field Use

Table 4.30 was not used by the drilling and sampling personnel.

Table 4.30. Aggregate Type Description

TYPE AND DESCRIPTION	CODE
1. Coarse Aggregate: Aggregate predominantly retained on the No. 4 (4.75-mm) sieve; or that portion of an aggregate retained on the No. 4 (4.75-mm) sieve. (ASTM C125-85)	
Gravel: (See Table 4.29 for definition, same as Code 302)	401
Crushed Stone: (See Table 4.29 for definition, same as Code 303)	402
Crushed Gravel: (See Table 4.29 for definition, same as Code 304)	403
Crushed Slag; (See Table 4.29 for definition, same as Code 305)	404
Blend: The combination of several sizes of coarse aggregate to form a uniformly graded composition of materials.	405

TYPE AND DESCRIPTION	CODE
Manufactured: Coarse aggregate produced by crushing rock, gravel iron blast furnace slag, or hydraulic-cement concrete.	406
Light Weight: Aggregate of low density used to produce lightweight concrete, included; pumice, scoria, volcanic cinders, tuff and diatomite; expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculate, or slag; and end products of coal or coke combustion. (ASTM C125-85)	407
Other: (Specify if possible or use the term unknown)	408
2. Fine Aggregate: Aggregate passing the ⅜-inch (9.5-mm) sieve and almost entirely passing the No. 4 (4.75-mm) sieve and predominantly retained on the No. 200 (0.075-mm) sieve; or that portion of an aggregate passing the No. 4 (4.75-mm) sieve and retained on the No. 200 (0.075-mm) sieve. (ASTM C125-85)	
Natural Sand: (See Table 4.26, Code 201 for definition)	409
Manufactured Sand: Fine aggregate produced by crushing rock, gravel, iron blast furnace slag, or hydraulic-cement concrete. (ASTM C125-85)	410
Blend: The combination of several differently sized fine aggregates to produce a uniformly graded mixture of materials.	411
Other: (Specify if possible or use the term unknown)	412

4.3.7 Geologic Classification Codes (laboratory use)

Geologic classification codes for coarse aggregates are listed in Table 4.31.

Laboratory Use

The materials testing laboratories used Table 4.31 for recording the geologic description of aggregate for: (a) treated base and subbase materials using LTPP Protocol P31 and (b) extracted aggregate from AC using LTPP Protocol P14. Unique two-digit codes were defined in this table.

Field Use

Table 4.31 was not used by the drilling and sampling personnel.

Table 4.31. Geologic Classification Codes.

(Same codes as used for inventory data collection, Table A.9 of the July 2005 revision of the LTPP Inventory Data Collection Guide (19))

DESCRIPTION	CODE
Igneous Rock:	

DESCRIPTION	CODE
Granite	01
Syenite	02
Diroite	03
Gabbro	04
Peridotite	05
Felsite	06
Basalt	07
Diabase	08
Sedimentary Rock:	
Limestone	09
Dolomite	10
Shale	11
Sandstone	12
Chert	13
Conglomerate	14
Breccia	15
Metamorphic Rock:	
Gneiss	16
Schist	17
Amphibolite	18
Slate	19
Quartzite	20
Marble	21
Serpentine	22
Other Rock Type: (Specify if possible or use the term unknown)	30
Geological Classification of Soils	
Glacial Soils	31
Boulder Clay	32
Glacial Sands and Gravels	33
Laminated Silts and Laminated Clays	34
Varved Clays	35
Ground Moraine	36

DESCRIPTION	CODE
Fluvio-Glacial Sands and Gravels	37
Other Glacial Soils	38
Plateau Gravels	40
River Gravels	41
Alluvium	42
Alluvial Clays and/or Peat	43
Alluvial Silt	44
Other Alluvial Soils	45
Coastal Shingle and Beach Deposits	46
Wind-Blown Sand	47
Loess (collapsible soil)	48
Shale, Siltstone, Mudstone, Claystone	49
Expansive Soils	50
Residual Soils	51
Residual Soils Derived from Granites, Gneisses, and Schists (maybe highly micaceous and sandy)	52
Residual Soils Developed from Limestone, Sandstone, and Shale (generally highly plastic)	53
Other Residual Soils	54
Coquina	55
Shell	56
Marl	58
Caliche	59
Other (specify if possible or use the term unknown)	60

4.3.8. Pavement Surface Material Type Description (laboratory use)

The pavement surface material type was identified by using the unique two- and three-digit codes listed in Table 4.32.

In this table, AC code 700 represents the general category of AC or bituminous concrete pavements. Codes 01, 02, 03, and 09 through 16 were used for detailed descriptions of AC pavement surface material.

Code 730 was used to define the general category of PCC pavements. Codes 04 through 08 and 17 through 19 were used for detailed descriptions of PCC pavement surface materials.

Laboratory Use

The materials testing laboratories used detailed material descriptions and associated codes if they could make a positive identification. Otherwise, they retained code 700 for AC and code 730 for PCC, as described in the field exploration logs. These codes were to be recorded on Form L05 (Summary of Pavement Layers).

Field Use

Codes 700 (AC pavement) and 730 (PCC pavement) were required to be used on field coreholes, boreholes, shoulder auger probe and test pit exploration logs by the drilling and sampling personnel. These two codes were included in Table 4.25.

Table 4.32. Pavement Surface Material Type Description.

(Same Codes 01 through 20 and 71, 72, 73 as used for inventory data collection, Table A.5 of the current revision of the LTPP Inventory Data Collection Guide (19))

MATERIAL TYPE	CODE
Asphaltic Concrete (AC)	700[1]
Hot Mixed, Hot Laid Asphalt Concrete, Dense Graded	01
Hot Mixed, Hot Laid Asphalt Concrete, Open Graded (Porous Friction Course)	02
Sand Asphalt	03
Plant Mix (Emulsified Asphalt) Material, Cold Laid	09
Plant Mix (Cutback Asphalt) Material, Cold Laid	10
Chip Seal	71
Slurry Seal	72
Fog Seal	73
Single Surface Treatment	11
Double Surface Treatment	12
Recycled Asphalt Concrete, Hot Laid, Central Plant Mix	13
Recycled Asphalt Concrete, Cold Laid, Central Plant Mix	14
Recycled Asphalt Concrete, Cold Laid, Mixed-In-Place	15
Recycled Asphalt Concrete, Heater Scarification/Recompaction	16
Portland Cement Concrete (JPCP)	04
Portland Cement Concrete (JRCP)	05

MATERIAL TYPE	CODE
Portland Cement Concrete (CRCP)	06
Portland Cement Concrete (Prestressed)	07
Portland Cement Concrete (Fiber Reinforced)	08
Plain Portland Cement Concrete (only used for SPS-7 overlays of CRCP)	90
Recycled Portland Cement Concrete, JPCP	17
Recycled Portland Cement Concrete, JRCP	18
Recycled Portland Cement Concrete, CRCP	19
Other (Specify if possible or use the term unknown)	20
Portland Cement Concrete (PCC)	730[2]

[1]AC - A general term (Code 700) that describes AC layer(s). Code 700 was used for all AC layers (AC, sand asphalt, and other types of surface, wearing and binder courses) in the field data packet received by the laboratory. The laboratory was to provide, if at all possible, a more detailed description using codes 01, 02, 03 and 09 to 16.

[2]PCC - A general term (Code 730) that describes portland cement concrete layer(s). Code 730 was used for all PCC surface types in the field data packet received by the laboratory. The laboratory was to provide, if at all possible, a more detailed description using codes 04 to 08, 17 and 19.

4.3.9 Portland Cement Types Description (for information only)

Table 4.33 includes codes for portland cement types and descriptions which were used for inventory data collection and site verification.

Table 4.33 was not used by the drilling and sampling personnel in the field, or by the materials testing laboratories.

Table 4.33 was included here for information only.

Table 4.33. Portland Cement Types Description.

(Same codes as used for inventory data collection, Table A.11 of the July 2005 revision of the LTPP Inventory Data Collection Guide (FHWA-HRT-06-066).)

TYPE	DESCRIPTION	CODE
Type I	For use when the special properties specified for any other type are not required. (AASHTO M85-84)	41
Type II	For general use, more especially when moderate sulfate resistance or moderate heat of hydration is desired. (AASHTO M85-84)	42

TYPE	DESCRIPTION	CODE
Type III	For use when high early strength is desired. (AASHTO M85-84)	43
Type IV	For use when low heat of hydration is desired. (AASHTO M85-84)	44
Type V	For use when high sulfate resistance is desired. (AASHTO M240-85)	45
Type IS	Portland blast-furnace slag cement for use in general concrete construction. (AASHTO M240-85)	46
Type ISA	Portland blast-furnace slag cement for use in general concrete construction with air-entrainment. (AASHTO M240-85)	47
Type IA	Air-entraining cement for the same use as Type I, where air-entrainment is desired. (AASHTO M85-84)	48
Type IIA	Air-entraining cement for the same uses as Type II, where air-entraining is desired. (AASHTO M85-84)	49
Type IIIA	Air-entraining cement for the same use as Type III, where air-entraining is desired. (AASHTO M85-84)	50
Type IP	Portland-pozzolan cement for use in general construction. (AASHTO M240-85)	51
Type IPA	Portland-pozzolan cement for use in general concrete construction with air-entrainment. (AASHTO M240-85)	52
Type N	Normal hydrated lime portland cement used for masonary purposes.	53
Type NA	Normal hydrated lime portland cement used for masonary purposes with 7 – 14% air-entrainment.	54
Other (Specify if possible or use the term unknown)		55

Note: This table is included for information only.

4.3.10. Pavement Type Descriptions (for information only)

Pavement type descriptions and codes included in Table 4.34 were used for inventory data collection and site verification.

Table 4.34 was not used by the drilling and sampling personnel in the field, or by the materials testing laboratories.

Table 4.34 was included here for information only.

Table 4.34. Pavement Type Descriptions.

(Same codes as used for inventory data collection, Table A.4 of the July 2005 revision of the LTPP Inventory Data Collection Guide [19].)

TYPE OF PAVEMENT	CODE
Asphalt Concrete (AC) Surfaced Pavements:	
AC with Granular Base	01
AC with Bituminous Treated Base	02
AC with Non-Bituminous Treated Base	07
AC Overlay on AC Pavement	03
AC Overlay on JPCP Pavement	28
AC Overlay on JRCP Pavement	29
AC Overlay on CRCP Pavement	30
Other (Specify if possible or use the term unknown)	10
Portland Cement Concrete Surfaced Pavements:	
JPCP – Placed Directly on Untreated Subgrade	11
JRCP – Placed Directly on Untreated Subgrade	12
CRCP – Placed Directly on Untreated Subgrade	13
JPCP – Placed Directly on Treated Subgrade	14
JRCP – Placed Directly on Treated Subgrade	15
CRCP – Placed Directly on Treated Subgrade	16
JPCP – Over Unbound Base	17
JRCP – Over Unbound Base	18
CRCP – Over Unbound Base	19
JPCP Over Bituminous Treated Base	20
JRCP Over Bituminous Treated Base	21
CRCP Over Bituminous Treated Base	22
JPCP Over Non-Bituminous Treated Base	23
JRCP Over Non-Bituminous Treated Base	24
CRCP Over Non-Bituminous Treated Base	25
JPCP Overlay on JPCP Pavement	31
JPCP Overlay on JRCP Pavement	33
JPCP Overlay on CRCP Pavement	35
JRCP Overlay on JPCP Pavement	32

TYPE OF PAVEMENT	CODE
JRCP Overlay on JRCP Pavement	34
JRCP Overlay on CRCP Pavement	36
CRCP Overlay on JPCP Pavement	38
CRCP Overlay on JRCP Pavement	39
CRCP Overlay on CRCP Pavement	37
JPCP Overlay on AC Pavement	04
JRCP Overlay on AC Pavement	05
CRCP Overlay on AC Pavement	06
Prestressed Concrete Pavement	40
Other (Specify if possible or use the term unknown)	49
*Composite Pavements (Wearing Surface Included in Initial Construction:	
JPCP With Asphalt Concrete Wearing Surface	51
JRCP With Asphalt Concrete Wearing Surface	52
CRCP With Asphalt Concrete Wearing Surface	53
Other (Specify if possible or use the term unknown)	59

Definitions:
JPCP - Jointed Plain Concrete Pavement
JRCP - Jointed Reinforced Concrete Pavement
CRCP - Continuously Reinforced Concrete Pavement
* "Composite Pavements" are pavements originally constructed with an asphalt concrete wearing surface over a PCC slab (1986 "AASHTO Guide for Design of Pavement Structures").
Note: This table is included for information only.

4.3.11. Material Codes Used for Interlayers (laboratory use)

The pavement interlayer material type was identified by using the unique two-digit codes listed in Table 4.35.

Laboratory Use

The materials testing laboratories used detailed material descriptions and associated codes if they could make a positive identification. Otherwise, they retain code 700 for AC and code 730 for PCC, as described in the field exploration logs. These codes were recorded on Form L05 (Summary of Pavement Layers).

Field Use

Codes 700 (AC pavement) and 730 (PCC pavement) were used on field coreholes, boreholes, shoulder auger probe and test pit exploration logs by the drilling and sampling personnel. These two codes were included in Table 4.25.

Table 4.35. Material Codes Used for Interlayers.

(Same codes as used for inventory data collection, Table A.8 of the July 2005 revision of the LTPP Inventory Data Collection Guide (19).)

MATERIAL TYPE	CODE
Grout	70
Chip Seal	71
Slurry Seal	72
Fog Seal	73
Woven Geotextile	74
Nonwoven Geotextile	75
Stress Absorbing Membrane Interlayer	77
Dense Graded Asphalt Concrete Interlayer	78
Aggregate Interlayer	79
Open Graded Asphalt Concrete Interlayer	80
Chip Seal with Modified Binder (Does not include crumb rubber)	81
Sand Seal	82
Asphalt-Rubber Seal Coat	83
Sand Asphalt	84
Other	85

4.3.12 Use of LTPP Terminology and Material Codes in Field Sampling Work

The exploration logs (LTPP field forms S01, S01A, S02A, S02B, S03, and S05) for the field sampling work were filled out using the material terminology and codes described in Table 4.25.

Pavement surface material types were described in the pavement inventory data sheets using the terminology of Table 4.32. On field exploration logs, the general terms 'AC' (asphaltic concrete, material code 700) and 'PCC' (portland cement concrete, material code 730) were used to describe pavement surface materials. AC (material code 700) materials included all HMAC and other types of asphalt surface materials for the purpose of field reports.

The LTPP terminology and codes shown in Table 4.25 were used for the description of base and subbase materials on exploration logs.

Table 4.25 also contained material codes and soils terminology for describing subgrade soils on field exploration logs. These codes were taken from Table 4.26 and used for describing both coarse- and fine-grained subgrade soils.

4.3.13 Use of LTPP Terminology and Material Codes in Laboratory Material Testing Work

The information provided in the above section for pavement surface material type was also applicable in the laboratory material testing work. Form L05 (Summary of Pavement Layer) of the LTPP Laboratory Material Testing Guide required the use of Table 4.32. Tables 4.26 (Subgrade Soils), 4.29 (Base and Subbase Materials), and 4.35 (Interlayer Materials) were also used to complete Form L05.

For treated base and subbase description tests (LTPP Laboratory Protocol P31) the LTPP terminology codes shown in Tables 4.27, 4.29, 4.30 and 4.31 were used.

For unbound granular base and subbase description classification tests (LTPP Laboratory Protocol P47), the LTPP terminology and codes shown in Table 4.29 (based on processing methods), and Table 4.27 (based on ASTM D2488-84) were used. The geologic classification codes of Table 4.31 were also used for the coarse aggregate description of the extracted aggregates from the asphalt extraction test (LTPP Protocol P14).

The LTPP terminology and codes included in Tables 4.26, 4.27 and 4.38 were used to record the laboratory classification test (LTPP Protocol P52) on subgrade soils.

CHAPTER 5. SECTION LAYERING

In the analysis of comparison of different pavement structures, the performance of these structures depends upon many factors. A primary factor is the pavement structure or pavement layering. Information must be readily available to determine the type of layers present (pavement surface and underlying supporting layers), the thickness of these layers, and their material properties.

This chapter provides the steps involved in the process for the determining the pavement structure at each test section. This detailed layering information was considered critical for relating laboratory tests to appropriate layers and for the future access to the laboratory test results in the LTPP PPDB. It should also be noted that this process involved extensive cooperation and coordination between all parties involved in the field sampling and laboratory testing process.

Unlike the GPS, SPS projects consisted of multiple test sections. As illustrated in Chapter 4, all tests were not performed on every layer of every test section of an SPS project due to limitations on budget. Hence, the section layering information was used to provide the analyst with a means of relating test results on similar materials in separate test sections. Therefore, portions of these procedures were specific only to SPS projects and these will be identified in the following sections.

5.1 GENERAL PAVEMENT LAYERING METHODOLOGY

Instructions for three forms were provided within this section. These forms were identified in Table 5.1.

Table 5.1 Identification of L05 Forms

Form Number	Description	Relevant To:
L05	Summary of Pavement Layers: Project Level	SPS ONLY
L05A	Summary of Pavement Layers: Section Level – Measured Data	GPS & SPS
L05B	Summary of Pavement Layers: Section Level – Analysis Section	GPS & SPS

Since SPS projects consist of multiple test sections, a "Project Level Layering Structure" was developed to keep track of pavement layering and test results from various test sections. The ultimate purpose of the project level layering was to set up an accounting system to be used to link material tests for a given pavement layer in a particular section to other similar materials, throughout the project.

As the name suggests, in order to complete Form L05, every pavement layer within a SPS project will be listed and assigned a "Project Level Layer Code." This project level layer code was used to extract layer information from the PPDB. Form L05 was input into the PPDB prior to entry of any other materials data (except field material sampling and field testing data). Form L05A was used on a test section basis for both GPS and SPS test sections to record the field or laboratory determined material classification and measured thicknesses for a given pavement layer. Since testing plans were developed to address specific needs, portions of the form may have been left blank for some layers within the test section. This form was used in concert with other information to develop the "Analysis Section" (Form L05B) for each test section.

Form L05B (Analysis Section) was used to establish the final pavement layer structure for each test section. All information available for the test section was used to derive this layer structure. Therefore, this form may have used data actually derived from the section itself, or if information was not available, data from other test sections in close proximity to the section. The purpose and process for completing this form was identical between SPS and GPS test sections.

The following sections outline the process used in completing the above referenced forms. These directions provide the methods used to define an appropriate project and section level layer structure. Prior to completion of the L05s, the personnel evaluating the test section were required to have at their disposal the following resources:

- Inventory data, if available (Inventory data were not required on new construction SPS projects),
- Field material sampling and testing data, including photographs of cores, test pits, etc. that were taken in the field,
- Materials testing data packet, including any photographs which were taken during core examinations, etc.,
- Construction plans or typical cross sections, when available,
- Appropriate state supplemental documents,
- Any other useful information which the evaluation personnel deem relevant, including falling weight deflectometer (FWD) information and profilometer (i.e., roughness) data.

For SPS projects the following additional information was required as well:

- For SPS test sections, the appropriate SPS Experimental Designs (used to establish the expected layer structure for new construction),
- Project specific material sampling and testing plan,
- Construction data sheets for the experiment including rod and level survey data, if available,
- A draft version of Form L05 Summary of Pavement Layers: Project Level (completed prior to field material sampling and testing).

After the appropriate materials were gathered, the evaluation personnel made an informed decision concerning the final pavement layer structure for each project and/or test section.

5.2 COMPLETION OF FORM L05 – SPS ONLY

Within the SPS experiments, two main classes of experimental pavements were investigated. Within the first class were the three experiments of newly constructed pavements consisting of:

- SPS-1 Strategic Study of Structural Factors for Flexible Pavements
- SPS-2 Strategic Study of Structural Factors for Rigid Pavements
- SPS-8 Study of Environmental Effects in the Absence of Heavy Loads

Within the second class, a study of the effectiveness of various maintenance and rehabilitation strategies was investigated. These five studies included:

- SPS-3 Preventive Maintenance Effectiveness of Flexible Pavements
- SPS-4 Preventive Maintenance Effectiveness of Rigid Pavements
- SPS-5 Rehabilitation of Asphalt Concrete Pavements
- SPS-6 Rehabilitation of Jointed Portland Cement Concrete Pavements
- SPS-7 Bonded Portland Cement Concrete Overlays

These two classes of experiment inherently had different strategies for pavement layering due to the greater opportunity for sampling and measuring pavement layers for the new construction class of experiment. SPS-9P and SPS-9A projects could fall into either category with some projects consisting of new construction and others involving rehabilitation.

The destructive sampling and testing of an existing pavement to determine its structure and material properties was limited due to both the potential damage that may have occurred and the related costs of sampling. The following instructions present the set of guidelines used to summarize material properties and thicknesses of the various layers for each SPS experiment and test section.

Within the original design of the PPDB, the layer number was designated as a key field from which data could be easily referenced. Form L05 "Summary of Pavement Layers: Project Level" was designed to define the pavement layering throughout the project, to assist in initializing other tables within the PPDB and to provide a key index for the laboratory testing of the sampled materials. This form was completed primarily using the field sampling and laboratory testing data and the following supplemental sources of information:

- SPS experimental designs,
- Project specific material sampling and testing plan,
- All pertinent construction documents,
- Inventory data,
- State supplemental documents,
- Other related documents as available.

This detailed and distinct project layering information was considered <u>critical</u> for relating laboratory tests to appropriate layers for future access to the laboratory test results in the PPDB. The following is an explanation of the data entry items needed to complete Form L05.

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
SUMMARY OF PAVEMENT LAYERS: PROJECT LEVEL
LAB DATA SHEET L05

STATE CODE ___ ___

SECTION ID ___ ___ 0 0

1	2	3	4	5
Project Layer Code	Material Code	Inventory Layer Number 1	Inventory Layer Number 2	Comments (Use 50 Characters or less) (Use an extra sheet if necessary)
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________
___	__ __ __	__ __	__ __	______________________________

GENERAL REMARKS: ____

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CHECKED AND APPROVED, DATE

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Affiliation:_____________________

5.2.1 Header Information

The L05 form has three general areas for input data. The first area is the project definition information. This area required the following information:

- Sheet ___ of ___ to identify the order within a data packet. This was primarily used as a bookkeeping tool by the Region. All data sheets from the laboratory materials testing work on a particular SPS project were to be assigned sequential numbers starting from 1 for the sample receipt report (Form L01) followed by the sample inspection report (Form L02); preliminary laboratory test assignment (Form L03); laboratory test assignments (Form L04) and so on in increasing order through all of the respective L-type laboratory testing forms and continuing through the T-type laboratory testing forms.

  Note: All laboratory testing data forms used the <u>test section specific</u> layer number in reporting data results. The Project Level Layer Code was used only on Forms L05, L05A, and L05B as described in this document. In addition, the final version of Forms L05, L05A, and L05B was completed only after all appropriate laboratory characterization tests had been performed.

- State Code: The State Code was assigned using a two-digit code as shown in Table 3.1 of this Guide.

- SHRP Section ID: The first digit (from the left) of this code should either be a 0 (zero), for the first project conducted in a state (except for the SPS-3 and SPS-4 projects that start with the letter A for the first project in a state) or a letter starting with A, B, etc for the second, third, etc. projects of the same SPS experiment constructed in the same state. The second digit corresponds to the SPS experiment number. <u>The last two digits (third and fourth digits) of the SHRP Section ID were always denoted as 00 to indicate "Project Level" information.</u> This was pre-printed on the form for convenience.

5.2.2 Layer Information

The second area of the form defines the Project Level pavement layers. Five data fields were defined. These are:

- Column 1. Project Layer Code
- Column 2. Material Code
- Column 3. Inventory Layer 1
- Column 4. Inventory Layer 2
- Column 5. Comment Field

Project Layer Code

The Project Layer Code was a single character field identifying a unique material layer existing within the Project. The Project Layer Code always started with the subgrade being labeled Layer A. Each subsequent distinct layer was assigned a Project Layer Code in ascending alphabetical order (B, C, etc.) corresponding to its location or placement within the pavement structure. A Project Layer Code was assigned for all possible distinct pavement layers present on the SPS project (including supplemental sections).

Material Code

The Material Code designations were based on the standard LTPP terminology for pavement materials and soils and these three-digit codes were entered in Column 2 on Form L05. This information was obtained from the test results for all pavement layers. The LTPP standard terminology was provided in Chapter 4 of this Guide. Table 5.2 identifies the tables from Chapter 4 that were used for this purpose and should be derived from the laboratory materials testing of the layer.

Table 5.2 Chapter 4 Tables Providing Standard LTPP Terminology for L05

Layer Type and Material	Table Number and Title
Subgrade Soils	Table 4.26 – Soil Classification and Description
Subbase and Base	Table 4.29 – Base and Subbase Materials Description
Pavement Surface (AC, PCC)	Table 4.32 – Pavement Surface Material Type Description
Interlayers	Table 4.35 – Material Codes for Interlayers

All treated base and subbase layers were to be described by series 300 material codes.

Inventory Layer Numbers

These columns (3 and 4) addressed the compatibility of Inventory Layer Structures and Project Level Layer Codes identified above. As part of Form L05, a correlation between the layer structure from the laboratory materials testing data and the layer structure from Inventory data was provided. This correlation was necessary to provide analysts with a means to extract data from the inventory portion of the PPDB and match that data to specific layers within the pavement layer structure. This was especially true for thin (≤ 1.5 inches [38 mm]) asphalt concrete layers which could not be tested under LTPP procedures. This correlation between the inventory layer data and the laboratory/field sampling determined layer data provided the analyst with the missing information. Two columns were used for this cross reference. The first column (3) was intended to list the primary or most likely Inventory Layer Number for a cross reference. An additional column (4) was included if more than one Inventory Layer was associated with a Project Layer. (It should be noted that these fields did not apply to the newly constructed pavements within SPS-1, SPS-2, and SPS-8). If there were no corresponding inventory layers, then both Inventory Layer Numbers were left blank. If there was only one corresponding inventory layer, then only Inventory Layer Number 1 was completed. If two or more corresponding inventory layers were identified, the Inventory Layer 1 was set to the lowest corresponding layer number and Inventory Layer 2 was set to the highest corresponding layer number.

In <u>no</u> case was the inventory layer data changed to conform to Form L05 results. If an error was detected in the inventory data, then this error was revised accordingly. However, inventory layer data and Form L05 data may not have been in exact accordance. If layers were missing or additional layers were identified, then the "Inventory Layer No. 1 and 2" on Form L05 may have been left blank as appropriate. The purpose of these fields on Form L05 was to provide the <u>best estimate</u> of the link between inventory data and Form L05. It was not mandatory that each layer on Form L05 contain a corresponding inventory layer number if no layer in the inventory layer structure matched the material properties of those layers in Form L05.

Comment

This comment field (Column 5) was included to record additional clarifications in the PPDB. Data within this field was not mandatory. A comment of up to 50 characters may have been entered in this field.

5.2.3 Signatory Section

This section was provided to list general remarks relating to the specific project that were considered helpful to either the database managers and/or the analyst. In addition to general remarks, signatory blocks were included for submitting and reviewing personnel.

5.2.4 Completion of Form L05

The proper layering for Form L05 was considered critical to the ability of researchers to extract and effectively utilize material characterization data for each SPS project. In general, the layering system or scheme satisfied the following requirements:

- All project layering started at the subgrade. If the laboratory testing revealed that the Material Code at one location in the project was 145 (Sandy Silt) while at another location the Material Code was 214 (Silty Sand), two distinct layers (for example "A" and "B") must be used as Subgrade Layer Codes.

- Each distinct layer in the pavement structure must have a unique Pavement Layer Code. This coding system included <u>all distinct layers</u> within the SPS project. (Please note that this form initiated the pavement layer structure in the PPDB and it provided an index for the testing program. It was intended to be a concise, all-inclusive list of layers within the experimental project including supplemental sections.)

- Prior to entering data from a project, the engineer compiled a list of all the materials present within the project. Both the primary SPS materials and any additional materials involved within the supplemental sections were compiled.

5.3 FORM L05A SUMMARY OF PAVEMENT LAYERS: MEASUREMENT DATA – GPS & SPS

Similar to the L05 form, this form has three areas for input. The intent of this form was to identify the various pavement layers within the test section that had layer thickness measurements and material characterization data. One form was to be completed for each construction event on each test section. Layer Thicknesses from cores, borings, test pits or survey data and material descriptions (Material Code) from laboratory testing were to be completed where applicable.

After completion of the specified material characterization tests for each layer (excluding resilient modulus testing), the pavement layering information for each section was summarized for each test location within the pavement section containing measurement data using Form L05A.

An independent evaluation of measured pavement information was one of the vital pieces of information needed for the PPDB. The Form L05A (Summary of Pavement Layers – Measurement Data) was completed using the information on Form T01B, Form T31, Form T47, Form T52, Form T66, Form L04, the Construction Data Sheets (as applicable), and the field exploration logs contained in the field data packet provided by drilling and sampling personnel. For SPS projects, a sketch of the test locations for the project may have been compiled prior to starting this form. This sketch served as a quick reference to identify locations of material thickness measurement and characterization testing.

5.3.1 L05A Header Information

The L05A form has three general areas for input data. The first area or header was the project definition information. This area required the following information.

- Sheet ____ of ____ to identify the order within a data packet.
- State Code
- SHRP Section ID: For SPS test sections the last two digits of this field were related to the test section number, i.e. 01, 02, etc, unlike the L05 form. For GPS test sections this was the four-digit code assigned to distinguish that test section from the others in the state.
- Construction Number: The construction number was referenced to the **EXPERIMENT_SECTION** table of the PPDB. The Construction Number shown on Form L05A matched the status of the project at that point in time. This number started at 1 for the original pavement construction and was raised by 1 for <u>each change</u> in the pavement layer structure (including maintenance treatments). For the SPS maintenance and rehabilitation experiments (SPS-3, SPS-4, SPS-5, SPS-6, and SPS-7), the Construction Number generally was a "1" prior to the maintenance treatment or rehabilitation and a "2" after the maintenance treatment or rehabilitation was performed. Form L05A was completed for each change in Construction Number.

This header information was used to identify the experiment and the appropriate test section.

LTPP LABORATORY MATERIAL HANDLING AND TESTING
SUMMARY OF PAVEMENT LAYERS – MEASUREMENT DATA
LAB DATA SHEET L05A

STATE CODE ___ ___
SECTION ID ___ ___ ___ ___
CONSTRUCTION NUMBER ___ ___

1	2	3	4	5	6	7	8	9	10	11	12	13
LAYER NUMBER	PROJECT LAYER CODE	LAYER DESC.	LAYER TYPE	BEFORE SECTION			WITHIN SECTION			AFTER SECTION		
				LAYER THICKNESS (INCHES)	MATERIAL CODE	MEAS. TYPE	LAYER THICKNESS (INCHES)	MATERIAL CODE	MEAS. TYPE	LAYER THICKNESS (INCHES)	MATERIAL CODE	MEAS. TYPE
1	___	__ __	__ __	UNK/___ ft*	__ __ __	__ __ __	UNK/___ ft*	__ __ __	__ __ __	UNK/___ ft*	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __
__ __	___	__ __	__ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __	__ __ __.	__ __ __	__ __ __

* See the shoulder auger probe logs (Form S05); circle "UNK" if no refusal was found within 20 feet; enter depth to refusal in feet if found within 20 feet and cross out "UNK".

GENERAL REMARKS: ____
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CHECKED AND APPROVED, DATE

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Affiliation:______________________

5.3.2 Layer Information

The second section of Form L05A contains the following information:

- Column 1. Layer Number
- Column 2. Project Layer Code
- Column 3. Layer Description
- Column 4. Layer Type
- Column 5. Layer Thickness (Before Section)
- Column 6. Material Code (Before Section)
- Column 7. Measurement Type (Before Section)
- Column 8. Layer Thickness (Within Section)
- Column 9. Material Code (Within Section)
- Column 10. Measurement Type (Within Section)
- Column 11. Layer Thickness (After Section)
- Column 12. Material Code (After Section)
- Column 13. Measurement Type (After Section)

Layer Number

The Layer Number (Column 1) was a sequential set of two-digit numbers identifying the pavement layers present within a specific test section. The Layer Number (Column 1) was assigned starting with Layer Number 1. Layer Number 1 was always assigned for the subgrade and the highest Layer Number was always the top pavement layer. In general, the overall structure for the test sections was defined prior to completion of the Form L05A by material sampling and laboratory testing procedures. For SPS projects, all of the pavement layers defined within the Project Layering may not have existed within every test section; however, the Layer Numbers were an all-inclusive sequential set. The Layer Number started at 1 and continued without skipping numbers until the largest Layer Number (surface layer) was entered. Please note that even if a layer(s) was not measured or tested, it was included on Form L05A.

Project Layer Code

The Project Layer Code was required for test sections included in SPS projects. On L05A forms completed for GPS test sections, the project layer code was left blank.

The Project Layer Code (Column 2) was a unique single character code identifying each possible layer within the SPS project. These codes were generated and entered within Form L05. This code provided a critical cross reference between the layers within one test section and the layers throughout the project. Correct identification of this code was considered critical to the efficient operation of the PPDB.

The definition of "layer" is as follows: That part of the pavement produced or comprised of uniform materials and placed with similar equipment and techniques. The material within a particular layer was assumed to be homogeneous. In the case of subgrade layers, small variances in the gradation of the material may have changed its material code slightly. This type of difference was acceptable and the most representative material code was used on Form L05. If significant changes in gradation (i.e., fine versus coarse) occurred in a material, the subgrade was considered two different layers and numbered accordingly. Also engineering fabrics were considered layers in the pavement structure and these materials were shown on the L05, L05A and L05B forms. However, tack coats were not to be considered layers in the pavement structure.

Layer Description

The Layer Description Code (column 3) was provided using the codes shown in Table 5.3.

Table 5.3 Layer Description Codes Used in Completing L05 Forms

Layer Type	Description Code
Overlay	01
Seal Coat	02
Original Surface Layer	03
AC Layer Below Surface (Binder Course)	04
Base Layer	05
Subbase Layer	06
Subgrade	07
Interlayer	08
Friction Course	09
Surface Treatment	10
Embankment (Fill)	11

Layer Description Code "11" was used only for SPS-1, SPS-2, and SPS-8 projects (e.g., "new construction"). Apparent embankment materials used in test sections for other experiments were coded using Layer Description Code 6 (Subbase).

Layer Description Code "8" (Interlayer) applied to Stress Absorbing Membrane Interlayers (SAMIs), all types of engineering fabrics and any other type of distinct layer that was used for providing a separation between two "structural" layers. An interlayer was generally a "non-structural" component of the pavement layer system.

Table 5.4 provides a list of valid material codes for each Layer Description Code.

Layer Type

The Layer Type Code (Column 4) was assigned using the two character codes provided in Table 5.5.

Table 5.6 provides a list of valid Layer Type Codes for each Layer Description Code.

Table 5.4 Valid Material Codes for Each Layer Description

Layer Description Code	Valid Material Code
01	01-08, 13, 16-20
02	71, 72, 73
03	01-08, 17-20
04	01, 03, 13, 20
05	302-310, 319-350
06	302-310, 319-350
07	100-178, 200-294
08	71-80, 85
09	02, 20
10	11, 12, 20
11	100-178, 200-294

Table 5.5 Layer Type Codes for Use in L05 Forms

Layer Type Code	Description
AC	Asphalt concrete (bituminous concrete) layer
PC	Portland cement concrete layer
TB	Bound (treated) base layer
TS	Bound (treated) subbase layer
GB	Unbound (granular) base layer
GS	Unbound (granular) subbase layer
SS	Subgrade (untreated)
EF	Engineering fabrics

Table 5.6 Valid Layer Type Codes for Each Layer Description

Layer Description Code	Layer Type Code
01	AC, PC
02	AC
03	AC, PC
04	AC
05	TB, GB
06	TS, GS
07	SS
08	AC, EF
09	AC
10	AC
11	GS

Layer Thickness

The Layer Thicknesses (Column 5 – Before Section, Column 8 – Within Section, and Column 11 – After Section) were based on information available from field logs of boreholes, the test pit log, the shoulder auger probe, field survey data, laboratory determination using Protocol P01 and Form T01B for AC layer thicknesses from AC cores (as available) and Form T66 for PCC layer thicknesses, respectively. The layer thickness was recorded in inches for all layers with the exception of the subgrade layer which was to be recorded to the nearest foot based on information obtained from Form S05, "Log of Shoulder Auger Probe," for each test section. The layer thickness (i.e., depth to refusal of the shoulder auger probe) for the subgrade layer (layer number 1) and underlying strata was recorded only on Form L05A for each test section adjacent to the shoulder boring. For the test sections without a corresponding shoulder boring, this field was left blank.

The thicknesses obtained from field survey data (rod and level) on SPS projects were to be used for unbound or potentially unbound base layers on new construction projects. Field determinations of the layer thickness of the Permeable Asphalt Treated Base layers on SPS-1 and SPS-2 projects may have been included in the determination of layer thicknesses, since laboratory testing of these cores (if available) was minimal.

Material Code

The Material Code designation was based on the LTPP standard terminology for pavement materials and soils and these codes were entered in Column 6 (Before Section), Column 9 (Within Section) and/or Column 12 (After Section) on Form L05A. This field was completed in a similar manner as explained for Form L05.

Similar to layer thickness, the laboratory only completed the Material Code of the underlying structure for test section locations that had material characterization tests performed.

Measurement Type

The measurement type was entered in Column 7 (Before Section), Column 10 (Within Section) and Column 13 (After Section) and was used to enter the code(s) on which the thickness measurements were based. Space was provided for up to three one-digit codes in each corresponding column on Form L05A. The codes are presented in Table 5.7.

5.3.3 Signatory Section

This section was provided to list general remarks relating to the specific project that were considered helpful to either the database manager(s) and/or the analyst. In addition to general remarks, signatory blocks were included for submitting and reviewing personnel.

Table 5.7 Measurement Type Codes for Use on Form L05A

Description	Code
Pavement Core (laboratory measurement)	1
Pavement Core (field core logs)	2
Cores of Bound Base/Subbase (field core logs)	3
Bore hole logs for B1, B2, B3, and A1, A2 type sampling areas	4
Field Survey Data	5
Test Pit Log	6
Other	7
No measurements conducted on this layer	8
Ground Penetrating Radar	9

5.3.4 Completion of Form L05A

In addition to the above explanation, the following general guidelines were used to check Form L05A after completion.

- For an original surface (Layer Description = 3), the layer type (Column 4), AC or PC in Form L05A, was expected to correspond to the original surface as listed in the inventory layer data (This does not apply to new construction SPS experiments).

- For an overlay (Layer Description = 1), the layer type (Column 4), AC or PC in Form L05A, was expected to correspond to the overlay surface as listed in the inventory layer data (if the overlay surface was present in the inventory data).

- A comparison was made between Form T01B (AC Core Examination and Thickness) and Form L05A. For a given layer number, the Layer Description on Form T01B was required to equal the Layer Description on Form L05A. Additionally, the layer thickness on Form L05A was required to be close to the average of all of the cores tested on Form T01B for a given end of the test section.

- Layer thickness values on Form L05A were compared with the field data sheets as a check to ensure that the proper layer thickness was assigned, and to resolve significant differences.

- Layer thickness values on Form L05A were checked for reasonableness. A list of suggested checks for reasonableness is presented in Table 5.8.

- If the values were out of range, then a check was made of the field and laboratory data, as appropriate, to determine if the layer thickness reported on Form L05A was valid.

- Each layer was to be included on the Form even if no measurements or testing was conducted on the layer. Measurement Type number 8 (no measurements conducted on this layer) was to be used to document this case. All fields, except Measurement Type were to be left blank if Measurement Type 8 was used.

Table 5.8 Reasonable Thickness Ranges for Each Layer Description

Layer Description	Range, inches (mm)
1 – Overlay	0.5 – 9.0 (13 – 229)
2 – Seal Coat	0.1 – 1.5 (2.5 – 38)
3 – Original Surface	0.5 – 13.0 (13 – 330)
4 – AC Layer Below Surface	0.5 – 10.0 (13 – 254)
5 – Base	1.0 – 24.0 (25 – 610)
6 – Subbase	3.0 – 47.9 (76 – 1217)
8 – Interlayer	0.1 – 6.0 (2.5 – 152)
9 – Friction Course	0.1 – 2.5 (2.5 – 64)
10 – Surface Treatment	0.1 – 1.5 (2.5 – 38)
11 – Embankment	3.0 – 47.9 (76 – 1217)

- For base/subbase layers, the Material Code descriptions as entered in columns 6 and 9 or 12 of Form L05A were the "Classification and Description of Unbound Granular Base and Subbase" codes as obtained from Table 4.29. These codes were based on laboratory test data and on visual examinations.

- For subgrade and embankment layers, the Material Code descriptions as entered in Columns 6, 9, and 12 of Form L05A were the "Soil Classification and Description" codes as obtained from Table 4.26 of Chapter 4, based on the laboratory test data and on visual examinations.

After the rudimentary QC/QA checks were completed and all discrepancies resolved, Form L05B, Analysis Section was completed. This form defined a single set of layer material codes and layer thicknesses which best represented that pavement structure layering beneath each LTPP pavement study section.

5.4 FORM L05B SUMMARY OF PAVEMENT LAYERS: ANALYSIS SECTION – GPS & SPS

Form L05B was used to establish the final "analysis section" for each construction event on each pavement test section. The most representative pavement structure and material characterization for the pavement structure of <u>each test section</u> was determined from the field, laboratory and measured project layering information (Form L05A).

5.4.1 L05B Header Information

The L05B form has three general areas for input data. The first area or header was the project definition information. This area required the following information:

SHEET _____ OF _____

LTPP LABORATORY MATERIAL HANDLING AND TESTING
SUMMARY OF PAVEMENT LAYERS – ANALYSIS
LAB DATA SHEET L05B

STATE CODE ___ ___
SECTION ID ___ ___ ___ ___
CONSTRUCTION NUMBER ___ ___

1	2	3	4	5	6	7			8
LAYER NUMBER	PROJECT LAYER CODE	LAYER DESC.	LAYER TYPE	LAYER THICKNESS (INCHES)	MATERIAL CODE	COMMENT CODE			COMMENT NOTE (50 characters or less) (Use an extra sheet if necessary)
1	___	07	__ __	(UNK/ ___ ft)*	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________
__ __	___	__ __	__ __	__ __ __.	__ __ __	___	___	___	________

*See the shoulder auger probe logs (Form S05); circle "UNK" if no refusal was found within 20 feet at the nearest adjacent probe; enter depth to refusal in feet if found within 20 feet and cross out "UNK".

GENERAL REMARKS: ____
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CHECKED AND APPROVED, DATE

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Affiliation:______________________

- Sheet ___ of ___ to identify the order within a data packet.
- State Code
- SHRP Section ID: For SPS test sections the last two digits of this field were related to the test section number, i.e. 01, 02, etc, unlike the L05 form. For GPS test sections this was the four-digit code assigned to distinguish that test section from the others in the state.
- Construction Number: The construction number was referenced to the **EXPERIMENT_SECTION** table of the PPDB. The construction number shown on Form L05B matched the status of the project at the point in time represented by the L05B. This number started at 1 for the original pavement construction and was raised by 1 for <u>each change</u> in the pavement layer structure (including maintenance treatments). For the SPS maintenance and rehabilitation experiments (SPS-3, SPS-4, SPS-5, SPS-6, and SPS-7), the Construction Number generally was a "1" prior to the maintenance treatment or rehabilitation and a "2" after the maintenance treatment or rehabilitation was performed. Form L05B was completed for each change in Construction Number.

This header information was used to identify the experiment and the appropriate test section.

5.4.2 Layer Information

The second section of Form L05B contains the following information:

- Column 1. Layer Number
- Column 2. Project Layer Code
- Column 3. Layer Description
- Column 4. Layer Type
- Column 5. Layer Thickness
- Column 6. Material Code
- Column 7. Comment Code
- Column 8. Comment Note

Layer Number

The Layer Number (Column 1) was a sequential set of two-digit numbers identifying the pavement layers present within a specific test section. The Layer Number (Column 1) was assigned starting with Layer Number 1. Layer Number 1 was <u>always</u> assigned for the subgrade and the highest Layer Number was always the pavement surface layer. The overall structure for the test sections was generally defined by material sampling and laboratory testing procedures. It is important to note that all of the pavement layers defined within the Project Layering may not have existed within each test section; however, the Layer Numbers were required to be an all-inclusive sequential set. The Layer Number started at 1 and continued <u>without</u> skipping numbers until the largest Layer Number (top layer) was entered.

NOTE: The correspondence of the Section Layer Number (Form L05B) with the Project Layer code (Form L05) was required to accurately identify the appropriate materials data for a given SPS project in the PPDB. Columns 1 and 2 were completed with care for the proper link between all of the forms to be identified.

Project Layer Code

The Project Layer Code was only required for test sections included in SPS projects. This field was left blank for L05B forms on GPS test sections.

The Project Layer Code (Column 2) was a unique single character code identifying each possible layer within the project. These codes were generated and entered within Form L05. This code provided a critical cross reference from the layers within one test section to the layers throughout the project. Correct identification of this code was considered critical to the efficient operation of the PPDB.

Layer Description

The Layer Description Code (Column 3) was provided using the same procedures and codes as used for Form L05A.

Layer Type

The Layer Type Code (Column 4) was assigned using the same procedures and codes as used for Form L05A.

Layer Thickness

The depth to the rigid layer of the subgrade was determined using Form S05, Log of Shoulder Auger Probe, for the nearest adjacent test probe. The thickness for the subsequent layers was determined from Form L05A, Construction Data Sheets or field boring logs for the nearest adjacent test boring or measurement location. In the event of two locations being equidistant to the test section, selection of layer thickness was based upon the most "reasonable" measurement. Similarly, if a layer was milled or decreased in thickness by some means, the survey data was used to determine this reduction. This reduction was then subtracted from the original thickness of the layer and recorded in Column 5.

Material Code

The Material Code designation was based on the LTPP standard terminology for pavement materials and soils and these codes were entered in Column 6 on Form L05B. This field was completed in a similar manner as explained for Form L05 and the material code shown on Form L05B was the same code as used for Form L05.

Comment Code

This code provides a clarification of the selected thickness and material codes selected. Column 7 is completed by including any pertinent comment codes (A-Z) associated with the determination of layer structure, layer thickness determination, etc. Comment codes used for column 7 are presented in Table 5.9.

Table 5.9 Comment Codes to be Used in Completing Form L05B

Code	Comment
A	FWD data on section agree best with approach end sample location.
B	FWD data agree best with leave end sample location.
C	Profile and condition data agree best with approach end sample location.
D	Profile and condition data agree best with leave end sample location.
E	Gradations similar at section ends and averaged to determine materials code.
F	Gradations different at section ends, material code from approach end used.
G	Gradations different at section ends, material code from the leave end used.
H	Atterberg Limits similar at both section ends. Material code from approach end used.
I	Atterberg Limits different at both section ends. Material code from approach end used.
J	Atterberg Limits different at both section ends. Material code from leave end used.
K	This layer absent at approach end.
L	This layer absent at leave end.
M	Layer inadvertently not sampled during drilling and sampling, but the layer does exist. (For example, an unbound base and subbase sampled as one layer.)
N	Information from the state DOT indicates that the beginning end is more representative.
O	Information from the state DOT indicates that the leave end is more representative.
P	The material code for this layer was derived from laboratory testing of similar material from an adjacent test section. A note should be added to the Comment Note field to indicate the test section from which the material code was derived.
Q	The layer thickness for this layer was derived from thickness measurements of the same material from an adjacent test section. A note should be added to the Comment Note field to indicate the test section from which the layer thickness was derived.
R	Layer was partially removed by milling.
S	Layer was completely removed by milling.
T	Sampling only occurred at approach end.
U	Sampling only occurred at leave end.
Z	Other (use column 8 to describe the action taken).

A total of three comment codes may have been entered in Column 7 of Form L05B to describe the decisions made to determine the analysis layer structure.

Comment Note

Comment Note (Column 8) was completed if code Z, "other", was used to describe the decision made in defining a layer. This note also may have been used to record any other pertinent information concerning the definition of the test section layer structure. Up to 50 characters may have been entered into this column.

5.4.3 Signatory Section

This section was provided to list general remarks relating to the specific project that were considered helpful to either the database managers and/or the analyst. In addition to general remarks, signatory blocks have been included for submitting and reviewing personnel.

5.4.4 Completion of Form L05B

The Form L05B was completed in the following order:

1. Establish the layer structure,
2. Establish layer thicknesses, and
3. Establish material codes for each layer.

The complete layer structure for the test section was established by analyzing Form L05A, inventory data and construction records and determining the appropriate layer structure. For many of the GPS test sections and SPS projects, this procedure was relatively straightforward for bound pavement layers (AC, PCC, ATB, LCB) since these layers were generally measured for thickness at each test section. The main difficulty in the completion of Form L05B was that of classifying and determining the thickness of unbound layers for each test section in a given SPS project. Generally, the unbound layers were not classified nor did they have thickness measurements performed at each test section.

This process involved a substantial amount of engineering judgment by the Regions. The following discussion relating to the completion of the L05B form and guidelines for the engineering judgement used by the Regions was separated into four distinct sections according to type of experiment as follows:

1. GPS Experiments
2. New Construction SPS Experiments: SPS-1, SPS-2, and SPS-8
3. Rehabilitation Experiments: SPS-5, SPS-6, and SPS-7
4. Maintenance Effectiveness Experiments: SPS-3 and SPS-4

Each type of experiment had its own special circumstances that are discussed in detail in the following sections. Since SPS-9P and SPS-9A projects may have been either new construction or rehabilitation experiments, the section pertaining to new construction SPS experiments or the section pertaining to rehabilitation experiments were used as appropriate to the construction of the individual project.

GPS Experiments

The complete layer structure for the test section was established by first analyzing Form L05A and determining the appropriate layer structure. In most cases, this was a fairly straightforward procedure. In some cases, layers may have been missing from one end of the test section when compared with the other, and in others the subgrade materials may have been considerably different from end to end.

In the event of a missing layer at one end, it was up to the Region to devise a layering scheme that accommodated both "within section" layering under one layer structure. This case may have involved any number of circumstances, and resolution of this case was completed using a consistent procedure. The following guidelines were followed when assigning layer structures to LTPP pavement test sections.

<u>Layers Consistent Between Ends of the Test Section</u>: The pavement layer structure on Form L05B was assigned using the layer structure as shown on Form L05A.

<u>Layer(s) Missing from One End to Another</u>: For unbound base or subbase layers, the inventory and construction records and typical cross-sections were to be consulted to determine if the layer was planned as part of the layer structure. If the layer was in the original design, then serious consideration was given to using this layer in the analysis pavement section. If the layer was not part of the original design, the as-built construction records and other state records were reviewed to determine if there was some special circumstance associated with the test section. For example, the LTPP sampling area may have been located in a transition area between two older construction projects and/or pavement designs, or two different materials sources may have been used to construct portions of a single specified layer. FWD and profilometer data may also have been used to determine test section homogeneity.

Additionally, the laboratory materials testing data for a layer present only at one end (gradation, Atterberg limits, description and classification, etc.) were reviewed to assure that the layer was not part of another layer either above or below the sampled layer. If for example, the layer structure provided in Table 5.10 was encountered. The material properties of layer 2 (GS – granular subbase) were examined to determine if these were similar to the material properties of layer 3 (GB – unbound base) of the approach end. In this case, the field personnel may have inadvertently sampled this layer (layer 3, approach end) as two independent layers instead of one homogeneous layer. The solution was to combine layer 2 with layer 3 on the approach end for thickness averaging, and to average the lab test data to obtain the properties of the combined layers.

Table 5.10 Example Layer Structure Review

Layer	Approach End	Leave End	Inventory
4	AC	AC	AC
3	GB	GB	GB
2	GS	--	--
1	SS	SS	SS

If none of the previous solutions were effective in providing an obvious choice, the layering from the test pit location may have been used as the representative structure for this section, and an appropriate comment provided to document this decision. If a test pit was not conducted on the section, the Region was expected to choose between the available sampling locations in resolving this layering situation, and again document the basis of the decision in the comments. For bound layers of base/subbase or surface courses, a similar process as that discussed for the unbound layers was followed in the following priority:

1. Inventory, construction records and other state records were checked to identify the intended layer structure or the presence of special circumstances in the sampling location.

2. Laboratory materials testing data were checked to verify measured material properties which may have provided some indication of the appropriate layering.

If the pavement was found to have distinctly different layer/material configurations at each end, additional field drilling and sampling on the section or a more detailed analysis may have been required. As a final resort, if none of these options was viable, the test section may have been discarded. Discarding a test section was considered to be a very serious and expensive decision because of the considerable time and effort spent on each section. On the other hand, this decision may have resulted in the avoidance of future expenses and erroneous interpretations.

After establishing the layer structure, the appropriate layer thicknesses for each layer were determined using the following methods.

<u>Layer Thickness Consistency Between Both Ends</u>. If the thickness of a particular layer was consistent between both ends of the pavement section, then an average pavement layer thickness was established by taking an average layer thickness using the information from both ends. Table 5.11 was used as a guide to determine whether a layer thickness was consistent between section ends and the appropriate action to be taken in each circumstance.

For example, Table 5.12 provides information from Form L05A for a given pavement section that may have been encountered. This test section could be considered consistent between ends (i.e., layer thickness ratios were within tolerable limits). Therefore, the layer thickness from one end to another could be averaged and summarized on Form L05B as presented in Table 5.13.

This example represents the simplest case for determination of layer thicknesses. In some cases, layer thickness ratios between ends of a pavement section were less than the tolerable limits. In these cases, a more detailed investigation of pavement layer thickness was warranted.

<u>Layer Thickness Inconsistent Between Both Ends</u>: If the layer thickness was not consistent between section ends or a layer had a zero thickness on one end, then the section was more closely evaluated to determine the appropriate layer thickness in the following priority:

1. Inventory, construction records and other state records were checked to identify the intended layer structure or the presence of special circumstances in the sampling location. Also the FWD, pavement condition, and profilometer data were checked to ascertain

section homogeneity. Through this review, the sampling site at one end of a section was found to be more representative than the other, then the data from the more representative end of the section was used on Form L05B.

Table 5.11 Guide for Consistency Check on Layer Thickness

Type of Layer Materials	Codes	Greatest Layer Thickness[1], inches (mm) A	Difference in Layer Thickness Between Ends[2], inches (mm)	Appropriate Action[3]
PCC	4, 5, 6	≤8 (203)	≤1.5 (38)	Average
			> 1.5 (38)	Investigate
		> 8 (203)	≤ 2.0 (51)	Average
			> 2.0 (51)	Investigate
Bituminous	1, 2, 319-330	≤ 2 (51)	≤ 0.5A	Average
			> 0.5A	Investigate
		> 2 (51)	≤ 0.3A	Average
			> 0.3A	Investigate
Bound Base or Subbase	331 – 335, 339	Any	≤ 0.3A	Average
			> 0.3A	Investigate
Unbound Base or Subbase	302 – 309, 337	Any	≤ 0.5A	Average
			> 0.5A	Investigate

Note: [1]For layer of interest, the absolute value of the difference between thicknesses at station 0- and 5+.
[2]For layer of interest, the greatest thickness for either end appearing on form L05A, designated as "A".
[3]A thickness of 999.9 was only used after a complete investigation of the layer thickness discrepancy and as a last resort when everything else, including engineering judgment, failed to produce a compromise.

Table 5.12 Example of Thickness Consistency Review

Layer No.	Desc	Type	Before Thickness, inches (mm)	Before Material Code	After Thickness, inches (mm)	After Material Code	Layer Thick. Difference, inches (mm)
1	7	SS	--	265	--	265	---
2	6	GS	8.0 (203)	308	8.4 (213)	308	0.5A = 4.2 (107) ok
3	5	GB	12.6 (320)	304	12.0 (305)	304	0.5A = 6.3 (160) ok
4	3	AC	3.6 (91)	1	3.8 (97)	1	0.3A = 1.14 (29) ok
5	2	AC	0.2 (5.1)	71	0.2 (5.1)	71	0.5A = 0.1 (2.5) ok

Table 5.13 L05B Information Based on Table 5.12 Evaluation

Layer No.	Description	Type	Thickness, inches (mm)	Material Code
1	7	SS	--	265
2	6	GS	8.2 (208)	308
3	5	GB	12.3 (312)	304
4	3	AC	3.7 (94)	1
5	2	AC	0.2 (5.1)	71

2. Laboratory materials testing data and field material sampling data were checked to verify the measured material properties which may have provided some indication of the appropriate layer thickness or establishe if a layer thickness entry was errant. Also, the shoulder auger probe log (Form S05) was examined to see if this yields additional information on the layer structure. This was especially prudent for subgrade layers.

3. If the above examinations failed to yield an adequate solution and to provide an obvious choice where a layer was present at both ends, but the layer thickness varied by more than the tolerable limits, between section ends, the situation was reviewed with the SHA. If this also failed to resolve the question, additional sampling of the pavement structure may have been considered. As an interim measure to complete form L05B's for pavement and treated base layers, a thickness of 999.9 was used on Form L05B column 4 along with a comment which indicated that the thickness variation was excessive for analysis purposes. A thickness of 999.9 was only to be used as a last resort when everything else, including engineering judgment, had failed to produce a compromise. To resolve thickness differences on untreated base and subbase layers where no obvious choice existed, the two end thicknesses may have been averaged and an appropriate comment added in column 6 to make the data analyst aware that differences existed.

4. For cases where a layer was not found at one end of the section, leading to a zero thickness entry on Form L05A, and again the above mentioned examinations of FWD, profile and pavement condition data provided no obvious solutions; additional sampling was considered for resolving the structure question. In lieu of added sampling, the weaker of the two pavement structures, as judged by calculating the pavement Structural Number using the AASHTO Guide method and data from Form L05A for both ends of the section, may have been chosen for insertion on Form L05B as the representative pavement structure.

After establishing the layer thicknesses, the appropriate material code for each layer was established using the following method. This may already have been established during the QC/QA of Form L05A.

<u>Material Codes were Consistent from One End to Another</u>: If the material codes were consistent between ends of the test section, then the material code was assigned to the layer in Form L05B.

Material Codes Differed from One End to Another: For subgrade and also for subbase soils, due to the large number of codes available with which to identify the material, there was a greater possibility for discrepancies between the two ends of a test section. The following procedure was used to evaluate and resolve these coding conflicts:

1. The laboratory materials testing data (Form T52, Table 4.27) were checked to ensure that the appropriate materials code was assigned to the layer for the end of the test section. Finally, the soil gradation test data on the critical sieves (No. 10 [2.00-mm], No. 40 [0.425-mm], No. 200 [0.075-mm]) and the Atterberg limit test data for the two opposing samples from each layer were examined. Because a change of only 1% on a critical sieve can change a sample from one material code to another, this examination served to eliminate some apparent code conflicts. Where differences in test data were minor the most appropriate code was chosen, and an appropriate comment inserted in column 6.

2. The gradation data were checked: if ratios between individual sieve sizes or Atterberg limits for the two samples of a given layer taken from the opposite ends of the section were higher than 0.7 (lower percentage/higher percentage), the gradation and Atterberg results were averaged and Table 4.26 was used to assign the subgrade material code.

   For example, if the percent passing the No. 200 (0.075-mm) sieve has the following values: Lab Test No. 1 = 14.2% and Lab Test No. 2 = 12.1%, the ratio (12.1/14.2) = 0.85; therefore, it was acceptable to average these two sieve sizes to determine an "average" material classification code.

3. The shoulder borehole log was reviewed to determine if it provided useful information on the soil types beneath the study section and agreed with sample data from one end or the other.

4. Inventory, construction records and other state records were checked to identify the in situ subgrade soil or embankment soil placed at this location of the project. Using the construction plans (if available), sampling area locations were evaluated to determine areas of cut and fill in or around the test section. The state highway department may also have been consulted during this process which was highly recommended. The material code which appeared to be more logical was assigned.

5. If nothing could be established from the review of pertinent records, then the FWDCHECK plots were reviewed. FWDCHECK data from the outermost sensors (6 & 7) were used to establish if there were consistent results between ends. If the results from within the test section were more similar to the FWD readings at one of the ends, then this was used as the representative layer for material codes. If the FWDCHECK data were not consistent with either end of the test section, then the reviewer used a special material code designation (code 999) to indicate to the analyst that two different subgrade types may underlie the section. A code of 999 was only used as a last resort when everything else, including engineering judgment, had failed to produce a compromise.

For unbound base and subbase layers, the following procedure was followed:

1. The laboratory materials testing data (Form T47, Table 4.29) were checked to assure that the appropriate materials code had been assigned to the layer on Form L05A for each end of the test section.

2. The gradation and Atterberg Limit test data were checked as noted in comment 2 above, and the test data was averaged if test results differed by no more than the 0.7:1 ratio as noted for the subgrade layers. Then the material code for the averaged test data was used.

3. Inventory, construction records and other state records were checked to identify the unbound base and/or subbase layers specified for the pavement. This information was evaluated and the pavement material code was used which was most logical for Form L05B.

4. If the above review did not yield an appropriate resolution to this discrepancy, then the Code 999 was used as the material code for this layer, which was to indicate the significant materials differences to the analyst. <u>A code of 999 was only used as a last resort when everything else, including engineering judgment, had failed to produce a compromise</u>.

For bound base and subbase layers, the following procedure was used:

1. The field materials sampling and laboratory materials testing data were checked to ensure that the appropriate materials code had been assigned to the layers for both ends of the test section. This check involved an extensive review of Form T31, Table 4.29, and a review of the photographs and field logs taken during the field drilling and sampling operations.

2. If this review did not reveal a single logical code, the inventory, construction records and other SHA records were checked to identify the type of bound base and/or subbase layers specified for the pavement. This information was evaluated and the pavement material code was used which was most logical for Form L05B.

For surface layers, the following procedure was followed to resolve discrepancies between material codes:

1. The field materials sampling and laboratory materials testing data were checked to ensure that the appropriate materials testing code had been assigned to the layer. A check was made of Forms T01A, T01B, T02, T03, T04, and T14 forms to determine the appropriate material code. Special care was taken to ensure that different lifts of the same material were not designated as separate layers. Layers were combined where there was no clear reason to list them separately. Cases where a single layer was described, sampled, and tested as two layers at only one end of the section were to be resolved by combining the thicknesses and averaging the test data for the two layers.

2. If this did not resolve the discrepancy, then the inventory, construction records and other state records were checked to identify the surface layer specified for the pavement. This

information was evaluated and the pavement material code was used which was most logical.

3. If the layer retained an obvious difference at the opposite section ends in spite of the above checks, the material code 999 was entered to indicate this fact to the analyst. A code of 999 was only used as a last resort when everything else, including engineering judgment, failed to produce a compromise.

Compatibility of Inventory Layer Structures and Laboratory Materials Testing Layer Structures (column 8 – Form L05B): During the completion of Form L05B, it was necessary to provide a correlation between the layer structure from the laboratory materials testing data and layer structure from inventory data. This correlation was needed to provide analysts with a means to extract data from the inventory portion of the PPDB which were not determined in the LTPP contract laboratory. This was especially true for thin (≤ 1.5 inches [38 mm]) asphalt concrete layers which could not be tested under LTPP procedures. This correlation between the inventory layer data and the laboratory/field sampling determined layer data provided a means of providing the analyst with the missing information.

As an example, "Analysis Section" (Form L05B) contained the information provided in Table 5.14 and inventory layer information contained the data provided in Table 5.15.

Table 5.14 Example Consistency Check L05B Information

Layer No.	Layer Description	Layer Type	Layer Thickness, inches (mm)	Material Code	Material Description
1	07	SS	--	114	Sandy Lean Clay
2	06	GS	9.5 (241)	306	Sand
3	05	GB	2.0 (51)	303	Crushed Stone
4	03	PC	7.8 (198)	730	PCC
5	04	AC	2.8 (71)	01	HMAC
6	01	AC	0.8 (20)	01	HMAC

Table 5.15 Example Consistency Check Inventory Data

Layer No.	Layer Description	Layer Material		Material Description
		Thickness, inches (mm)	Code	
1	07	--	53	Silty Clay
2	06	12.0 (305)	24	Sand
3	05	2.0 (51)	23	Crushed Stone, Gravel or Slag
4	03	7.0 (178)	04	PCC
5	04	3.5 (89)	28	HMAC
6	01	0.8 (20)	01	HMAC

Using these data, it was very easy to make the correlation between the inventory data and the Analysis Section (L05B) data. It was also obvious from these data, that layer 6, (HMAC overlay, 0.8 inches [20 mm]) would not contain laboratory materials testing data since it did not meet the minimum thickness of 1.5 inch (38 mm) criteria. However, the analyst would be able to extract the inventory layer data for layer 6 using the Form L05B layer data and the inventory correlated layer data. This correlation provided a critical link between laboratory materials testing data and inventory data which was useful to researchers.

As another example, the L05B form contained the structure provided in Table 5.16. The inventory layer data are provided in Table 5.17 for another section that may have been encountered. In this example, layers 1, 2, and 3 from Form L05B correlate well with layers 1, 2, and 3, respectively, from the inventory data. However, layers 4, 5, and 6 (HMAC layers) did not correlate exactly. The analysis section contains 3 HMAC layers while the inventory contains 2 HMAC layers. In this case, the laboratory materials testing data and the construction records were reviewed to determine if layers 4 and 5 shown on Form L05B were indeed two distinct AC layers and not lifts of similar material placed under the same construction contract and specifications. If they were lifts of the same asphalt layer then both layer 4 and layer 5 were correlated with layer 4 of the inventory data. If they (layers 4 and 5) were indeed different layers of AC, then a decision was made on which L05B layer to use to correlate with the inventory data. In this case, it was recommended that both layer 4 and layer 5 be correlated with layer 4 of the inventory data even though from the laboratory testing data they appear as different layers. From the thickness given in the inventory data for layer 4 (3.0 inches) and a review of the combined thickness for layer 4 and 5 (2.8 inches [71 mm]) for Form L05B, it was assumed that layers 4 and 5 were specified and placed as one layer and some other factor, such as differing aggregate color or particle sizes, influenced their designation as two separate layers. Thus, the final L05B was completed as shown in Table 5.18.

Table 5.16 L05B Data for Second Example Consistency Check

Layer No.	Layer Description	Layer Type	Layer Thickness, inches (mm)	Material Code	Material Description
1	07	SS	--	204	Poorly Graded Sand w/ Silt
2	06	GS	13.8 (351)	306	Sand
3	05	GB	12.4 (315)	302	Gravel (uncrushed)
4	04	AC	2.0 (51)	01	HMAC
5	03	AC	0.8 (20)	01	HMAC
6	01	AC	1.8 (46)	01	HMAC

Table 5.17 Inventory Data for Second Example Consistency Check

Layer No.	Layer Description	Layer Material Thickness, inches (mm)	Layer Material Code	Material Description
1	07	--	57	Sand
2	06	25.0 (635)	24	Sand
3	05	12.0 (305)	22	Gravel
4	03	3.0 (76)	01	HMAC
5	01	1.5 (38)	01	HMAC

Table 5.18 Final L05B Data for Second Example Consistency Check

Layer No.	Layer Description	Layer Type	Layer Thickness, inches (mm)	Material Code	Inventory Layer No.
1	07	SS	--	204	1
2	06	GS	13.8 (351)	306	2
3	05	GB	12.4 (315)	302	3
4	04	AC	2.0 (51)	01	4
5	03	AC	0.8 (20)	01	4
6	01	AC	1.8 (46)	01	5

In no case were the inventory layer data changed to conform to Form L05B results. If an error was detected in the inventory data, then this error was revised accordingly. However, inventory layer data and Form L05B data were not expected to be in exact accordance. If layers were missing or additional layers were identified, then the Inventory Layer No. on Form L05B may have been left blank for certain layers. The purpose of this field on Form L05B was to provide the best estimate between the inventory data and Form L05B. It was not mandatory that each Form L05B layer contain a corresponding inventory layer number if no layer in the inventory layer structure could adequately be estimated to have the same material properties as those layers in Form L05B.

New Construction Experiments

Establishing the layer structure for the SPS-1, SPS-2, and SPS-8 experiments was a relatively straightforward process. For each test section, a review was conducted of Form L05A. For these projects, every test section had an entry on Form L05A along with thickness measurements from either field survey measurements (rod and level) or core examination and thickness measurements. The layer structure on Form L05A was used to establish the layer structure for each test section. Also, the layer thickness measurements could be obtained from Form L05A as well.

For test sections that had material characterization tests performed on the unbound layers (including subgrade), the material classification code derived from this testing on Form L05A could be used directly on Form L05B. For those test sections that did not have material characterization tests performed from areas within or near the test section, the material classification for the same material from an adjacent section was used. Engineering judgment was required in this case based on the notes from the field during construction and other information that the personnel may have possessed. An underlying assumption in this discussion is that a particular material placed on the project (e.g., Dense Graded Aggregate Base) remained fairly homogeneous throughout the project unless the material was obtained from more than one source. Therefore, material placed on one test section was the same material as placed on an adjacent test section. The appropriate code was placed in the Comment Code section of Form L05B to indicate that a material classification from another test section was used for the test section under evaluation.

Rehabilitation Experiments

The procedures for completion of Form L05B for the SPS-5, SPS-6, and SPS-7 experiments are very similar to that of the GPS program. However, similar to the rest of the SPS experiments, the process was complicated due to limited amount of sampling and testing performed on each test section.

Generally, the thickness measurements and layer material codes recorded on Form L05A could be used directly to complete the L05B. The remaining missing layer thickness and material code (classification data) was to be interpreted from other test sections using engineering judgment. Like the new construction experiments, a critical assumption in this process was that the SPS project as a whole was comprised of homogeneous layers with a relatively constant layer thickness. Therefore, layer thickness and classification information for one section could be used for adjacent test sections.

The complete layer structure for each test section was established first on Form L05B by analyzing Form L05A and determining the appropriate layer structure. During this evaluation, the inventory, construction records and typical cross-sections were consulted to determine if the layers sampled matched consistently with those that were originally planned for the project. If they did not match, the as-built construction records and other state records were reviewed to determine if there was some special circumstance associated with the test section or SPS project. For example, the SPS project could be located between two construction projects and/or pavement designs or two different material sources may have been used to construct portions of a single specified layer. FWD data and possibly profilometer data could be used to obtain some sense of project homogeneity. Overall, however, it was expected that the as-sampled layers match fairly consistently with those proposed for the project.

After establishing the layer structure, the appropriate layer thicknesses for each layer were determined. For bound pavement layers, the layer thickness values were extracted directly from Form L05A. Because layer thickness measurements for bound layers were usually established from opposite ends of the pavement test section, an average thickness from these measurements was reported on Form L05B. This was only performed however, if the layer thicknesses were considered consistent between the ends of the test section. Table 5.11 was used as a guide to determine if a layer thickness was consistent between section ends and the appropriate action to be taken in each circumstance. This table applies to both bound and unbound layers when layer thickness measurements were taken at opposite ends of a particular test section.

If thickness measurements were taken within the test section by rod and level survey, etc., for the overlay layers, the laboratory measurements from cores were compared with the rod and level survey data using the same criteria as shown in Table 5.11 (i.e., the difference between the rod and level data and the laboratory measured thicknesses) to determine the homogeneity of the overlay surface throughout the test section.

If the layer thickness was not consistent between section ends or a layer had a zero thickness on one end, then the section was more closely evaluated to determine the appropriate layer thickness using the same steps outlined for the GPS experiments.

After establishing the layer thicknesses, the appropriate material code for each layer was established using Form L05A and all other available information.

For test sections that had material characterization tests performed on the unbound layers including subgrade (i.e., test pit locations, BA-type locations, etc.), the material classification code derived from this could be used directly on Form L05B. For those test sections that did not have material characterization tests performed from areas within or near the test section, the material classification for the same material from an adjacent section was used. Engineering judgment was required in this case based on the notes from the field during construction and other information that the personnel may possess. An underlying assumption in this discussion was that a particular material placed on the project (e.g., Dense Graded Aggregate Base) will remain fairly homogenous throughout the project unless the material was obtained from more than one source. Therefore, material placed on one test section was the same material as placed on an adjacent test section. The appropriate code was placed in the Comment Code section of Form L05B to indicate that a material classification from another test section was used for the test section under evaluation.

In the (probably rare) case where the test section had testing performed on both ends of the section or in sampling areas equally adjacent to the test section, the procedure outlined for the GPS experiments was followed.

Maintenance Effectiveness Experiments

The SPS-3 and SPS-4 experiments also required a significant amount of engineering judgment in order to establish the pavement analysis section. Generally, it was expected that the only detailed layer information available would be from the associated GPS test section located adjacent to the SPS-3 or SPS-4 project. Also, it was generally expected that one 6-inch (152-mm) borehole was retrieved from each test section. The materials were supposed to be characterized (visually) for this six-inch corehole for all layers through to the subgrade. For the purposes of the completion of the L05B form, the information obtained from this six inch core and auger was of limited value. Therefore, for each section included in the SPS-3 and SPS-4 program, the layer structure for the GPS test section was used to complete the layer structure. The layer thicknesses and material types for each SPS-3 and SPS-4 section obtained from the 6-

inch (152-mm) core and auger were compared to the GPS test section structure to ensure that the layer structures were fairly consistent. The thickness of the maintenance treatment was generally fairly easy to establish from construction records.

If significant variations existed between the GPS test section layering and the 6-inch (152-mm) core and auger location, the as-built construction records and other state records were reviewed to determine if there was some special circumstance associated with the test section or SPS project. For example, the SPS project may have been located between two construction projects and/or pavement designs or two different material sources may have been used to construct portions of a single specified layer. FWD data and possibly profilometer data were used to obtain some sense of project homogeneity.

Prior to completing the layer structure for the SPS-3 and SPS-4 projects, the GPS test section layering and all QC/QA associated with the GPS Form L05B were to have been completed.

GLOSSARY

Layer:	That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous. The layer thickness can be equal to or less than the core thickness or length.
Sample:	A representative portion of material from one or more pavement layers received from the field. A sample can be a core, block, chunk, piece(s), bulk, thin-walled tube or jar sample.
Test Specimen:	That part of the layer which is used for or in the specified test. The thickness of the test specimen can be equal to or less than the layer thickness.
Core:	An intact cylindrical specimen of the pavement material that is removed from the pavement by drilling at the designated location. A core can consist of, or include, one, two, or more different layers.
Block:	A block sample of the pavement material is removed by sawing at the test pit area through the full depth of the pavement. A block sample can consist of, or include, one, two, or more different layers. Chunks and/or pieces are retrieved from the field if a block sample cannot be recovered. Chunks and pieces are always smaller than a block sample.
Chunks:	Chunks (large pieces) of material extracted from the full thickness of each layer in the test pit area and/or the 12-inch (305-mm) diameter BA… type borehole(s). An undisturbed block sample (12 inch [305 mm] square) may also be taken from the field in certain cases. A chunk is always smaller than a block sample. If chunks or block samples of the designated material cannot be recovered, then smaller pieces of the material are collected in the field for shipment to the laboratory.
Pieces:	Very small chunks of material extracted from the full thickness of each layer in the test pit area and/or the 12-inch (305-mm) diameter BA… type borehole(s). An undisturbed block sample (12-inch [305-mm] square), or a chunk sample may also be taken from the field in certain cases. A chunk is always smaller than a block sample and a piece is always smaller than a chunk sample. Pieces are recovered only if block or chunk samples could not be recovered in the field.
Bulk Samples:	That part of the pavement material that is removed from an unbound base or subbase layer or from the subgrade. Bulk samples are retrieved from the borehole(s) and the test pit at the designated locations. The bulk sample of each layer is shipped in one or more bag(s) to the laboratory. The material from one layer should <u>never</u> be mixed with the material from another layer even if there is less than the desired amount to perform the specified tests.

Test Sample: That part of the bulk sample of an unbound base or subbase layer or subgrade which is prepared and used for the specified test. The quantity of the test sample may be the same but will usually be less than the bulk sample.

Asphaltic Concrete (AC): Thoroughly controlled paving mixtures coarse and fine aggregates or fine aggregate above, with or without mineral filler, uniformly mixed with asphalt, and compacted into a uniform dense mass. For purposes of this Guide, AC material generally consists of hot-laid, hot-mixed AC (HMAC) paving mixtures used in bituminous surface, wearing and binder courses, and other HMAC layers beneath the AC surface.

Portland Cement Concrete (PCC): A combination of portland cement, water, and aggregates bound together into a uniform, dense mass. For purposes of this Guide, the material consists of pavement quality portland cement concrete used in the PCC surface layer of PCC pavements.

Treated Base or Subbase Material: Treated base or subbase materials are bound or stabilized base or subbase layers. These terms (treated, bound, stabilized) are used interchangeably in reference to base and subbase layers containing a cementing or binding type of agent. For allowable LTPP terminology and codes, see Table 4.30 of this Guide.

Asphalt Treated Base or Subbase (ATB): Asphalt treated base and subbase materials (also known as bituminous treated materials) include soils, aggregate and soil-aggregate mixtures bound by asphalt cement, emulsified asphalt, cutback asphalt, tar, or bitumen. Examples are asphalt treated aggregate base, soil-asphalt, and sand-asphalt. Typically these materials are produced by cold-mix and mixed-in-place procedures. For the purposes of this Guide, the ATB materials do not include AC materials described in (j) above with the exception of HMAC layers beneath AC surfaces.

Other than Asphalt Treated Base or Subbase (OTB): Other than asphalt treated base and subbase materials include all types of treated materials for which asphalt cement, emulsified asphalt, cutback asphalt, tar or bitumen were not used as a binding agent. Typical OTB materials range from very strong and durable to weak and less durable treated materials. Examples of very strong material are lean concrete, econocrete, and CTB. The following materials may range from strong to weak; soil cement, lime stabilized materials, lime-, flyash-treated soils. Materials stabilized with chemicals, industrial wastes, and different kinds of proprietary products are also included in the category of OTB materials.

Treated Subgrade: Treated subgrade materials are bound or stabilized layers of subgrade soils. The terms (treated, bound, stabilized) are used interchangeably in reference to the treated subgrade containing a cementing or binding type of agent. Table 4.27 and Table 4.30 should be consulted to assign appropriate LTPP terminology and codes for the description of treated subgrade material and type of treatment respectively.

The treated subgrade may be asphalt treated material (for example, ATB) or other than asphalt treated material (for example, OTB, lime, cement, lime-, and cement-flyash, polymer, and chemical treated subgrade; but not lean concrete and econocrete).

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