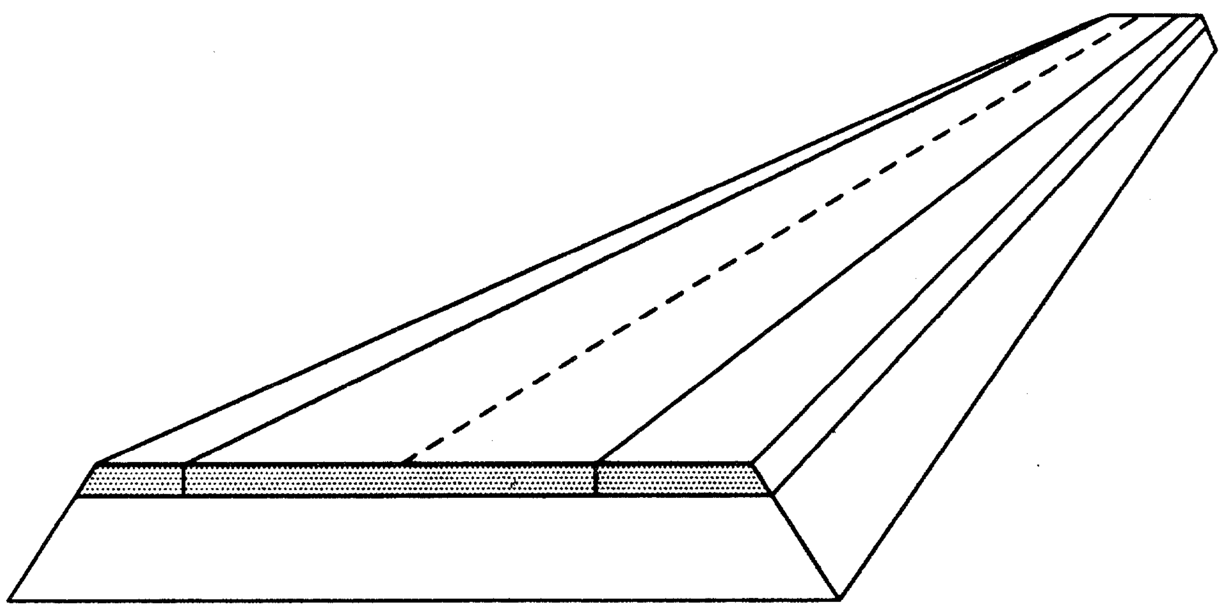
PAVEMENT NOTEBOOK

FOR FHWA ENGINEERS



US Department
of Transportation

Federal Highway
Administration

Office of Engineering
Pavement Division

October 1996

Publication No. FHWA-PD-96-037

Pavement Notebook for FHWA Engineers

Chief, Pavement Division HNG-40

Regional Administrators
Federal Lands Highway Program Administrator
Division Administrators

Attached are copies of the 2nd revision to the *Pavement Notebook for FHWA Engineers*. This notebook serves as a compilation of FHWA policy and guidance on pavement issues. Formal updates and revisions are coordinated through the Pavement Division. The notebook provides space in Chapter 11 for pavement related comments.

Request for additional copies should be addressed to:

Federal Highway Administration
Pavement Division - Attn: Mr. Peter J. Serrano, P.E.
Pavement Design and Rehabilitation Branch (HNG-42)
400 Seventh Street, S.W.
Washington, D.C. 20590

Attachments

INSTRUCTIONS FOR REVISION NO. 2

Table of Contents

1. Remove old introductory information and replace with new introductory information (3 pages).

2. Remove old Table of Contents and replace with new Table of Contents.

Chapter 1 Pavement Policy

1. Remove old Chapter 1 title page and replace with new Chapter 1 title page.

2. Remove Section 1.1 (Pavement Policy - Mr. R.D. Morgan, January 13, 1989) and replace with new Section 1.1 (Pavement Design and Management Requirements, Pavement Management System, 23 CFR 500, Subpart B, April 22, 1994; Non-Regulatory Supplement, General Pavement Design Considerations, October 5, 1995).

3. Remove Section 1.2 (FHPM 6-2-4-1, Pavement Management and Design Policy, March 6, 1989) and replace with new Section 1.2 (ISTEA Pavement Management Systems.

4. Add new Section 1.3 (Cost Comparison of Asphalt vs. Concrete Pavement, OIG Final Report, July 26, 1994).

5. Add new Section 1.4 (Proposed Final Interstate Maintance Fund Transfer Policy, September 21, 1994).
   - Transfer of Interstate Maintance Program Funds, Proposed Final Policy Statement, Federal Register, September 02, 1994).
   - Transfer of Interstate Maintance Program Funds, Interim Policy Statement, Federal Register, March 03, 1993).

Chapter 2 Pavement Issues

1. Remove old Chapter 2 title page and replace with new Chapter 2 title page.

INSTRUCTIONS FOR REVISION NO. 2

Chapter 2 Pavement Issues

2. Remove Section 2.10 (Life Cycle Cost, M
new Section 2.10 (Life Cycle Cost Analysi
Interim Policy Statement, July 11, 1994).

3. Add to Section 2.13 (Preventive Maintena
Information on Interstate Maintenance P

4. Add new Section 2.14 (Computer Softwar
July 1995).

Chapter 3 Rigid Pavement

1. Remove old Chapter 3 title page and repl
page.

2. Add to Section 3.5 (Dowel Bar Inserters,

3. Add new Section 3.10 (TA 5080.17, Port
Design and Field Control, July 14, 1994).

Chapter 4 Flexible Pavement

1. Remove old Chapter 4 title page and replace
page.

2. Add new Section 4.8, Aggregate Gradati
Particle Size Distribution Curve, 1962.
   - Aggregate Gradation: Simplification,
     Uniform Application
   - A New Graphical Chart for Evaluating

Chapter 5 Pavement Drainage

1. Remove old Chapter 5 title page and repl
page.

INSTRUCTIONS FOR REVISION NO. 2

Chapter 5 Pavement Drainage

2. Add new Section 5.6 (Western States Pavement Subdrainage Conference, August 10, 1994).

3. Add new Section 5.7 (Drainable Pavement Systems, Demonstration Project 87, April 06, 1992).

4. Add new Section 5.8 (Effectiveness of Highway Edgedrains, Concrete Pavement Drainage Rehabilitation, State of Practice Report, Experimental Project No. 12, April 14, 1993).

5. Add new Section 5.9 (Maintenance of Pavement Edgedrain Systems, March 21, 1995).

6. Add new Section 5.10 (Pavement Subsurface Drainage Activities, December 16, 1994).

Chapter 7 Pavement Rehabilitation

1. Remove old Chapter 7 title page and replace with new Chapter 7 title page.

2. Add new Section 7.9 (Overview of Surface Rehabilitation Techniques, Report Number FHWA-PD-92-008, April 6, 1992).

3. Add new Section 7.10 (State of the Practice Design, Construction, and Performance of Micro-Surfacing, Report Number FHWA-SA-94-051, July 12, 1994).

4. Add new Section 7.11 (Retrofit Load Transfer, Special Project 204, February 10, 1994).

5. Add new Section 7.13 (Thin Bonded Overlay and Surface Lamination Pavements and Bridges, ISTEA 6005, July 1, 1994).

INSTRUCTIONS FOR
REVISION NO. 2

Chapter 8 Surface and Other Considerations

1. Remove old Chapter 8 title page and replace with new Chapter 8 title page.

2. Add new Section 8.7 (Measurements, Specifications, and Achievement of Smoothness for Pavement Construction, NCHRP No. 167, 1990).

3. Add new Section 8.8 (A Half Century with the California Profilograph, Report Number FHWA-AZ-SP9102, February 1992).

Chapter 9 Pavement Management

1. Remove old Chapter 9 title page and replace with new Chapter 9 title page.

2. Remove Section 9.1 (Pavement Management System, A National Perspective) and replace with new Section 9.1 (A National Perspective on Pavement Management, July 1994).

3. Add new Section 9.5 (Pavement Management System - Federal Register, December 1, 1993).

Chapter 10 Strategic Highway Research Program Product

1. Add new Chapter 10 title page.

2. Add new Section 10.1 (Strategic Highway Research Program Product Implementation Status Report, December 1995 (Published Quarterly)

3. Add new Section 10.2 (Strategic Highway Research Program (SHRP), Information Clearinghouse, July 22, 1994).

INTRODUCTION

This notebook is intended to be a working tool that provides a readily available compilation of current FHWA policy and guidance on pavements. Users are encouraged to add material as they see fit.

The notebook is composed of:

(1) Reference to appropriate Federal-aid Highway Program Manual directives;

(2) Other issuances, such as Technical Advisories and Notices which present short-term instructions or interim policy;

(3) FHWA memorandums clarifying policy or providing technical guidance;

(4) Discussions reflecting current state-of-the-art or philosophy;

(5) Material on developmental and research areas related to pavements.

The material is arranged by subject into chapters and sections. The Table of Contents shows current date for each document.

Any comments, suggested additions, or revisions to the notebook should be directed to the Federal Highway Administration, Attn: Mr. Peter J. Serrano, Pavement Division, HNG-46, 400 Seventh St., S.W., Washington, D.C.; Telephone number 202.366.1341 or email at *Peter.J.Serrano@fhwa.dot.gov.*

Enclosed is the second revision to the *Pavement Notebook For FHWA Engineers*. Please make the changes contained in the attachment. Submit the attached form on the following page so that we can include your name and address on our mailing list. For further information or additional copies of the notebook contact Mr. Peter J. Serrano at 202.366.1341 or *Peter.J.Serrano@fhwa.dot.gov*.

Refer to: HNG-40

Chief, Pavement Division
Federal Highway Administration
400 Seventh Street, SW., Room 3118
Washington, D.C. 20590-0001

Attn: Mr. Peter J. Serrano, P.E.

Dear Sir:

I have received a copy of the *Pavement Notebook for FHWA Engineers* and would like to be on your distribution list for future updates and/or additions to the notebook.

Request for additional copies should be addressed to:

Federal Highway Administration
Pavement Division - Attn: Mr. Peter J. Serrano, P.E.
Pavement Design and Rehabilitation Branch (HNG-42)
400 Seventh Street, S.W.
Washington, D.C 20590

Please mail or fax the form below.

------------------------ cut here ------------------------

Name: ______________________________

Title: ______________________________

Agency: ______________________________

Address: ______________________________

____

Telephone Number: ______________________________

Federal Highway Administration - Pavement Division
Attn: Mr. Peter J. Serrano, P.E. (HNG-42);
Fax number: 202.366.3713

TABLE of CONTENTS

TABLE of CONTENTS

CHAPTER 2 PAVEMENT ISSUES

CHAPTER 3 RIGID PAVEMENT

TABLE of CONTENTS

CHAPTER 4 FLEXIBLE PAVEMENT

CHAPTER 5 PAVEMENT DRAINAGE

TABLE of CONTENTS

TABLE of CONTENTS

TABLE of CONTENTS

Chapter 1

Pavement Policy

CHAPTER 1

PAVEMENT POLICY

1.1 **Pavement Design and Management Requirements**

- Pavement Management System, 23 CFR 500, Subpart B, April 22, 1994.
  - 500.201, Purpose
  - 500.203, PMS definition
  - 500.205, PMS general requirements
  - 500.207, PMS components
  - 500.209, PMS compliance scheduling
- Non-Regulatory Supplement, October 05, 1995.
  - 500.205, General Pavement Design Considerations

1.2 **ISTEA Pavement Management Systems**

- Action: ISTEA Pavement Management Systems, November 4, 1994
  - Technical Guidance

1.3 **Cost Comparison of Asphalt versus Concrete Pavement, OIG Final Report, July 26, 1994.**

1.4 **Proposed Final Interstate Maintance Fund Transfer Policy, September 21, 1994).**

- Transfer of Interstate Maintance Program Funds, Proposed Final Policy Statement, Federal Register, September 02, 1994).
- Transfer of Interstate Maintance Program Funds, Interim Policy Statement, Federal Register, March 03, 1993).

SUBCHAPTER F - TRANSPORTATION INFRASTRUCTURE MANAGEMENT

PART 500 - MANAGEMENT AND MONITORING SYSTEMS

Subpart B - Pavement Management System

Authority: 23 U.S.C. 134, 135, 303 and 315; 49 U.S.C. app. 1607;
23 CFR 1.32; and 49 CFR 1.48 and 1.51.

Source: 58 FR 63475, Dec. 1, 1993 [Effective Jan. 3, 1994]

Sec. 500.201 Purpose.

The purpose of this subpart is to set forth requirements for development, establishment, implementation, and continued operation of a pavement management system (PMS) for Federal-aid highways in each State in accordance with the provisions of 23 U.S.C. 303 and subpart A of this part.

Sec. 500.203 PMS definitions.

Unless otherwise specified in this part, the definitions in 23 U.S.C. 101(a) and Sec. 500.103 are applicable to this subpart. As used in this part:

Pavement design means a project level activity where detailed engineering and economic considerations are given to alternative combinations of subbase, base, and surface materials which will provide adequate load carrying capacity. Factors which are considered include: materials, traffic, climate, maintenance, drainage, and life-cycle costs.

Pavement management system (PMS) means a systematic process that provides, analyzes, and summarizes pavement information for use in selecting and implementing cost-effective pavement construction, rehabilitation, and maintenance programs.

Sec. 500.205 PMS general requirements.

(a) Each State shall have a PMS for Federal-aid highways that meets the requirements of Sec. 500.207 of this subpart.

(b) The State is responsible for assuring that all Federal-aid highways in the State, except those that are federally owned, are covered by a PMS. Coverage of federally owned public roads shall be determined cooperatively by the State, the FHWA, and the agencies that own the roads.

(c) PMSs should be based on the concepts described in the ``AASHTO Guidelines for Pavement Management Systems.'' [AASHTO Guidelines for Pavement Management Systems, July 1990, can be purchased from the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, NW., suite 225, Washington, DC 20001. Available for inspection as prescribed in 49 CFR part 7, appendix D.]

(d) Pavements shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner.

Sec. 500.207 PMS components.

(a) The PMS for the National Highway System (NHS) shall, as a minimum, consist of the following components:

(1) Data collection and management.

(i) An inventory of physical pavement features including the number of lanes, length, width, surface type, functional classification, and shoulder information.

(ii) A history of project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance.

(iii) Condition surveys that include ride, distress, rutting, and surface friction.

(iv) Traffic information including volumes, classification, and load data.

(v) A data base that links all data files related to the PMS. The data base shall be the source of pavement related information reported to the FHWA for the HPMS in accordance with the HPMS Field Manual. [Highway Performance Monitoring System (HPMS) Field Manual for the Continuing Analytical and Statistical Data Base, DOT/FHWA, August 30, 1993, (FHWA Order M5600.1B). Available for inspection and copying as prescribed in 49 CFR part 7, appendix D.]

(2) Analyses, at a frequency established by the State consistent with its PMS objectives.

(i) A pavement condition analysis that includes ride, distress, rutting, and surface friction.

(ii) A pavement performance analysis that includes an estimate of present and predicted performance of specific pavement types and an estimate of the remaining service life of all pavements on the network.

(iii) An investment analysis that includes:

(A) A network-level analysis that estimates total costs for present and projected conditions across the network.

(B) A project level analysis that determines investment strategies including a prioritized list of recommended candidate projects with recommended preservation treatments that span single-year and multi-year periods using life-cycle cost analysis.

(C) Appropriate horizons, as determined by the State, for these investment analyses.

(iv) For appropriate sections, an engineering analysis that includes evaluation of design, construction, rehabilitation, materials, mix designs, and preventive maintenance as they relate to the performance of pavements.

(3) Update. The PMS shall be evaluated annually, based on the agency's current policies, engineering criteria, practices, and experience, and updated as necessary.

(b) The PMS for Federal-aid highways that are not on the NHS shall be modeled on the components described in paragraph (a) of this section, but may be tailored to meet State and local needs. These components shall incorporate the use of the international roughness index or the pavement serviceability rating data as specified in Chapter IV of the HPMS Field Manual.

Sec. 500.209 PMS compliance schedule.

(a) By October 1, 1994, the State shall develop a work plan that identifies major activities and responsibilities and includes a schedule that demonstrates full operation and use of the PMS on the NHS by October 1, 1995, and on non-NHS Federal-aid highways by October 1, 1997.

(b) By October 1, 1995:

(1) The PMS for the NHS shall be fully operational and shall provide projects and programs for consideration in developing metropolitan and statewide transportation plans and improvement programs; and

(2) PMS design for non-NHS Federal-aid highways shall be completed or underway in accordance with the State's work plan.

(c) By October 1, 1997, the PMS for non-NHS Federal-aid highways shall be fully operational and shall provide projects and programs for consideration in developing metropolitan and statewide transportation plans and improvement programs.

Federal-Aid Policy Guide

U. S. Department of Transportation

Federal Highway Administration

Subject

FEDERAL-AID POLICY GUIDE - CHANGE

Date

Transmittal Number

14

1. PURPOSE. To transmit new and revised pages to the Federal-Aid Policy Guide (FAPG).

2. COMMENTS. The FAPG is being updated to include the following items.

   a. Federal-aid regulations previously published in the Federal Register.

      (1) Revised sections: (a) 23 CFR Part 630, Preconstruction Procedures, (b) 23 CFR Part 637, Construction Inspection and Approval, (c) 23 CFR Part 645, Utilities, and (d) 49 CFR Part 18, Grants and Cooperative Agreements to State and Local Governments.

      (2) Removed section: 23 CFR Part 1204, Uniform Guidelines for State Highway Safety Programs.

   b. Supplemental sections NS 23 CFR 140G, NS 23 CFR Part 500, NS 23 CFR Part 635D, NS 23 CFR Part 645A and NS 23 CFR Part 660A have been revised.

   c. Revised pages to the Table of Contents are also included with this transmittal.

3. REGULATORY MATERIAL. The regulatory material contained in this directive has been published in the Federal Register and will be codified in Title 23, Code of Federal Regulations.

4. ACTION. Each recipient office is responsible for filing the attached FAPG pages into the binders provided.

Moore

George S. Moore, Jr.
Associate Administrator
for Administration

DISTRIBUTION:

OPI:

THIS PAGE LEFT BLANK
INTENTIONALLY

NON-REGULATORY SUPPLEMENT

OPI: HNG-42

1. GENERAL PAVEMENT DESIGN CONSIDERATIONS (23 CFR 500.205(d))

Title 23 CFR 500.205(d) establishes the following requirement: "*Pavements shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner.*" The regulations do not specify the procedures to be followed to meet this requirement. Rather each State Highway Agency (SHA) is expected to use a design procedure which is appropriate for their conditions. The SHA may use the design procedures outlined in the AASHTO Guide for Design of Pavement Structures or they may use other pavement design procedures that, based on past performance or research, are expected to produce satisfactory pavement designs.

a. FHWA Evaluation of Pavement Design Procedures

(1) Consistent with FHWA's Operational Philosophy on process review/product evaluation (PR/PE) attached to Executive Director Carlson's November 12, 1991 memorandum, the FHWA field offices will conduct periodic reviews of the SHA's pavement design process. As part of the review, FHWA field offices will sample a sufficient number of projects to determine that the pavement design process is being followed and the process provides reasonable engineering results. If the reviews show that the SHAs have and are following an acceptable pavement design process, routine pavement design reviews of individual projects will not be required.

(2) The FHWA encourages the development of mechanistic pavement design procedures. To promote consistency in application of mechanistic related design procedures,

the Pavement Division will participate with the Region and Division offices in reviewing and discussing these procedures with the State during their development.

b. Factors to Consider in Pavement Design.

Highway agencies should pay particular attention to the following items in designing pavements.

(1) Traffic. Pavement designers should work closely with the SHA component responsible for the development of the Traffic Monitoring System for Highways (TMS/H) required under 23 CFR 500.801. The TMS/H should reflect the accuracy of traffic volume, classification, and truck weight data required for pavement design.

(a) Accurate cumulative load (normally expressed as 18 kip equivalent single axle loads or ESALs) estimates are extremely important to structural pavement design. Load estimates should be based on representative current vehicle classification and truck weight data and anticipated growth in heavy truck volumes and weights. Representative current traffic data should be obtained using statistically valid procedures for obtaining count, classification, and weight data based on the concepts described in the FHWA "Traffic Monitoring Guide" and the "AASHTO Guidelines for Traffic Data Programs."

(b) Accurate vehicle classification data on the number and types of trucks is essential to estimating cumulative loads during the design period and should be given special emphasis. Weight information should be obtained using weigh-inmotion (WIM) equipment since this data is more representative than data obtained using static enforcement scales which are plagued with avoidance problems. States should continue to automate their monitoring program through installation of strategically placed automatic vehicle classification and WIM systems as soon as possible to improve the current base traffic data used to forecast future truck volumes and loads.

(c) The SHA's forecasts of future loadings should, as a minimum, be based on two truck classes: trucks up to 4-axle combination and trucks with 5-axles or more. Changes in load factors should also be monitored and forecasted. The forecasting procedures should consider past trends and future economic activity in the area. A traffic data collection and forecasting program that identifies the most important truck types and the changes in numbers and weights of these truck types during the design period should provide realistic load estimates.

(2) Roadbed Soils. Both the 1986 and 1993 versions of the "AASHTO Guide For Design of Pavement Structures" require the use of the Resilient Modulus (M_R) (a measure of the elastic property of soils) in lieu of soil support value as the basic materials value to characterize roadbed soils for flexible pavements. The AASHTO Guide strongly recommends that SHAs acquire the necessary equipment to measure M_R. SHAs who use M_R values converted from CBR and R-value should conduct correlation studies using a range of soil types, saturation levels, and densities to determine realistic input values. For rigid pavements, the

use of a k-value is required. NCHRP Report 372, Support Under Portland Cement Concrete Pavements, provides improved guidance on selecting appropriate values for this factor. Proper roadbed soil support is needed for longer pavement service lives and more cost-effective pavement design.

(3) Drainage

(a) Drainage is one of the more important factors in pavement design, yet inadequate subsurface drainage continues to be a significant cause of pavement distress, particularly in portland cement concrete pavements. During the last 10 years significant strides have been made in the development of positive drainage systems for new and reconstructed pavements. There have also been major developments in products and materials which can be used for retrofit longitudinal edgedrains.

(b) The developments in permeable base technology and longitudinal edgedrains make positive pavement drainage possible and affordable. Accordingly, pavement design procedures need to consider the effects of moisture on the performance of the pavement. Where the drainage analysis or past performance indicates the potential for reduced service life due to saturated structural layers or pumping, the design needs to include positive measures to minimize that potential.

(4) Shoulder Structure

(a) Recent studies demonstrate that full structural shoulders improve both mainline pavement and shoulder performance. Research results have shown that widening the right pavement lane and placing the edge stripe 0.5 m from the outside pavement edge significantly improves pavement performance.

(b) The SHAs are encouraged to use paved shoulders where conditions warrant. Shoulders should be structurally capable of withstanding wheel loadings from encroaching truck traffic. On urban freeways or expressways, strong consideration should be given to constructing the shoulder to the same structural section as the mainline pavement. This will allow the shoulder to be used as a temporary detour lane during future rehabilitation or reconstruction.

(c) On new and reconstructed pavement projects, the SHAs are encouraged to investigate the advantage of specifying that the shoulder be constructed of the same materials as the mainline, particularly on high-volume roadways. Constructing shoulders of the same materials as the mainline facilitates construction, reduces maintenance costs, improves mainline pavement performance, and provides additional flexibility for future rehabilitation.

(5) Engineering and Economic Analysis.

The design of both new and rehabilitated pavements should include an engineering and economic evaluation of alternative strategies and materials. The project specific analysis should be evaluated in light of the needs of the entire system. Appendix B of the 1993 "AASHTO Guide for Design of Pavement Structures," and the "FHWA Pavement Rehabilitation Manual," provide guidance on engineering considerations. The Engineering evaluation should include consideration of the use of recycled materials or pavement recycling techniques where feasible. Economic considerations include an economic analysis based on Life Cycle Costs (LCC). The FHWA interim policy statement on LCC analysis published in the July 11, 1994 Federal Register provides guidance on LCC Analysis.

(a) Pavements are long term public investments and all the costs (both agency and user) that occur throughout their lives should be considered. LCCA identifies the long term economic efficiency of competing pavement designs. However, the resulting numbers themselves are less important than the logical analysis framework fostered by LCCA in which the consequences of competing alternatives are evaluated. When performing LCCA for pavement design, the variability of input parameters needs to be considered. The results of LCCA should be evaluated to determine whether differences in costs between competing alternatives are statistically significant. This evaluation is particularly important when the LCC analysis reflects relatively small economic differences between alternatives.

(b) The FHWA's policy on alternate bids, which would include bids for alternate pavement types, is addressed in 23 CFR 635.411(b). This section requires the use of alternate bid items "When ... more than one... product... will fulfill the requirements... and these ... products are judged... equally acceptable on the basis of engineering analysis and the anticipated prices... are estimated to be approximately the same.

(1) The FHWA does not encourage the use of alternate bids to determine the mainline pavement type, primarily due to the difficulties in developing truly equivalent pavement designs.

(2) In those rare instances where the use of alternate bids is considered, the SHA's engineering and economic analysis of the pavement type selection process should clearly demonstrate that there is no clear cut choice between two or more alternatives having equivalent designs. Equivalent design implies that each alternative will be designed to perform equally over the same performance period and have similar life-cycle costs.

c. Rehabilitation Pavement Design. It is essential that rehabilitation projects be properly engineered to achieve the best return possible for the money expended. When an existing pavement structure is sound and the cost to restore serviceability is minor when compared to the cost of a new pavement structure or major rehabilitation, an engineering and economic analysis of alternative actions may not be necessary. In general, for all major rehabilitation projects, each of the following steps should be followed to properly analyze and design the project.

(1) Project Evaluation

(a) Obtain the necessary information to evaluate the performance and establish the condition of the in-place pavement with regard to traffic loading, environmental conditions, material strength, and quality. Historical pavement condition data, obtained from the Pavement Management System (PMS), can provide good initial information.

(b) Identify the types of pavement distresses and the factors causing the distresses before developing appropriate rehabilitation alternatives. The tools necessary to analyze pavement failures, such as coring, boring, trenching, and deflection measurements, are well known, and need to be employed more often.

(c) Evaluate the array of feasible alternatives in terms of how well they address the causes of the deterioration, repair the existing distress, and prevent the premature reoccurrence of the distress.

(2) Project Analysis

(a) Perform an engineering and economic analysis of candidate strategies. The engineering analysis should consider the traffic loads, climate, materials, construction practices, and expected performance. The economic analysis should be based on life cycle cost and consider service life, initial cost, maintenance costs, user costs, and future rehabilitation requirements, including maintenance of traffic.

(b) Select the rehabilitation alternative which best satisfies the needs of a particular project considering economics, budget constraints, traffic service, climate, and engineering judgment.

(3) Project Design

(a) Conduct sufficient testing, both destructive and non-destructive, to verify the assumptions made during the alternative evaluation phase. The SHAs should consider a new distress survey if the original condition survey was sample based or if the survey is not current in terms of the time the project is scheduled to go to contract.

(b) Consider and address all factors causing the distress in addition to the surface indicators in the final design. Such factors as structural capacity, subgrade support, surface and subsurface drainage characteristics need to be considered and provided for in the final design.

(c) Once a rehabilitation alternative is selected, design the project using appropriate engineering techniques. A number of publications are available to guide the selection of these engineering techniques. The FHWA's "Pavement Rehabilitation Manual," and training course "Techniques for Pavement Rehabilitation" provide excellent guidelines. There are also a number of excellent guides available from the asphalt and concrete industries.

(4) Project Implementation

(a) Document the intent of the design in the project plans and specifications to provide both the contractor and the construction engineering personnel a clear and concise project proposal. In addition, maintain adequate communication between the design and construction engineers. This will reinforce the intent of the design and provide feedback on project constructability and performance to aid timely evaluation of the selected rehabilitation alternative.

(b) The performance information should also be included as a part of the SHA's PMS. The lack of good performance data on pavement rehabilitation techniques is one of the weaker points in the rehabilitation process. Increased emphasis should be placed on developing basic performance and maintenance cost data on rehabilitation techniques where performance data is not presently available.

2. SAFETY (23 CFR 500.205d)

a. The SHAs should provide skid resistant surfaces on all projects, regardless of funding source. New pavement surfaces constructed with Federal funds must have skid resistant properties suitable for the needs of the traffic. New pavement surfaces on projects where a skid resistant surface was previously constructed with Federal funds must have skid resistant properties suitable for the needs of the traffic even if not now financed with Federal-aid funds.

b. The SHAs should analyze pavement performance histories and existing skid data to ensure that the materials, mix designs, and construction techniques used are capable of providing a satisfactory skid resistant surface over the expected performance period of the pavement. Each SHA's skid accident reduction program should include a systematic process to identify, analyze, and correct hazardous skid locations. The SHA's should use the same construction procedures and quality standards used in constructing new pavements in pavement maintenance operations.

c. Plans and specifications for proposed pavement rehabilitation and reconstruction projects should include items to minimize disruption and ensure adequate protection of the motorists and workers within the construction work zone in accordance with the provisions of 23 CFR 630, subpart J and 23 CFR 635, subpart A.

NOV 04 1994

ACTION: ISTEA Pavement Management Systems

Director, Office of Engineering HNG-41

Regional Administrators

We are approaching the first bench mark in implementing the Pavement Management System (PMS) provisions in ISTEA. By January 1, 1995, each State is required to submit to the division office the certification statement, work plan, and status for implementing its PMS. The division office should review the submission and forward its comments and a copy of the documents to the region. The regional office has the responsibility to review and accept the submission and notify the division office accordingly.

The purpose of this memorandum is twofold. First, we want to provide technical guidance and criteria in order to implement the PMS provisions in ISTEA in a complete and consistent manner. Secondly, we request your cooperation and assistance in providing us with PMS information, so we can continue to monitor the States' progress in developing and implementing their PMS's.

1. During the past months, we have assisted several field offices in reviewing draft work plans and noted some deficiencies and inconsistencies that warrant attention. Presently, we need to focus on four technical items: (1) multi-year prioritization, (2) life-cycle cost analysis, (3) condition survey distresses, and (4) condition survey samples. Attached is technical guidance on these four items for your use. We have reiterated some of the fundamentals of PMS for the benefit of the States and divisions who are experiencing a high turnover and influx of engineers and managers who are new to PMS.

2. For the past 8 years the Pavement Management Branch has maintained a national database on the status of the States' PMS's that is used to assess and guide the national PMS program. With the advent of the ISTEA certification process, the information in the database will continue to play an important role in managing the national program. As you know, the information has always been collected and reported by the FHWA staff. We are requesting your cooperation and assistance to have the division office PMS specialists update this information when they concurrently review the States' PMS certifications and work plans. Please send the completed PMS Survey form (copy attached) to the Pavement Management Branch, HNG-41 by January 17, 1995.

Implementing the PMS provisions in ISTEA is of vital importance to FHWA. The key to success is a strong joint effort between Headquarters and the field offices. We will continue to provide technical guidance and direction as needed to help achieve a comprehensive and consistent PMS program. If you have any questions, or need technical assistance, please contact Mr. Frank Botelho at 202-366-1336.

William A. Weseman

William A. Weseman

TECHNICAL GUIDANCE

1. Multi-Year Prioritization. Multi-year prioritization is the heart of a PMS. It provides a prioritized listing of projects for which rehabilitation/preservation actions are recommended for each year of the planning horizon. The multi-year prioritized list of candidate projects and treatments is a "first cut" list that is normally produced by the Pavement Management Engineer(s) and submitted to the appropriate offices in the Agency to be used as input in developing the statewide pavement preservation program. The prioritization is based on priority factors, predicted performance, and economic analysis relative to the goals set by the State for its network. The candidate projects should have a high benefit cost ratio based on life-cycle cost analysis. The prioritization process must be objective, analytical, formalized, and automated (computerized for State and large local networks) in order to be stable and repeatable with time and changing of personnel. Its established engineering criteria and analytical methodology are the basis and means of producing and documenting an accountable and justifiable pavement preservation program.

   Many States have not yet established or utilized the above criteria for multi-year prioritization. Rather, they are prioritizing projects solely on a subjective, manual, and "worst first" basis. The field offices need to promote and support major efforts by the State highway agencies (SHA's) to satisfy the intent of our regulation on multi-year prioritization.

2. Life-Cycle Cost Analysis. The need and purpose for life-cycle cost analysis is strongly emphasized in ISTEA. The FHWA issued an interim policy statement on life-cycle cost on July 11, 1994. This policy statement should be used by the field when evaluating the States' life-cycle cost analysis procedures. Prioritization and life-cycle cost analysis are the analytical basis for demonstrating that the expenditure of Federal-aid funds are justifiable and cost effective.

   A State PMS must include a life-cycle cost analysis (that is commensurate with the level of investment and types of preservation treatments) for candidate projects in order to compare alternative treatments and strategies to produce a cost effective preservation program that satisfies the goals of the Agency. The life-cycle cost analysis should be based on the performance prediction and economic models used in multi-year prioritization. Life-cycle cost analysis of specific project treatments should consider future treatments required to maintain the pavement until reconstruction. Life-cycle cost analysis of network-level strategies requires an analysis period of at least one complete cycle in the life of the network, which should be at least 35 years.

3. Condition Survey Distresses. Pavement condition data are the foundation for measuring and monitoring: the "health" of the network; the current and predicted performance of pavements; and the remaining service life of the network. A PMS condition survey bridges the "information gap" between general planning data and detailed design data. Condition data are combined with performance data, life-cycle cost analysis, and priority factors to develop the multi-year list of prioritized projects. The type, extent, and severity of the individual distresses are also used to determine viable preservation treatments.

   The types of distresses that are measured in a pavement condition survey should be chosen on the basis that they support the decisions on where, when, and how to preserve the network. A "sufficiency rating" (commonly used for planning purposes) or a single distress survey do not constitute a PMS condition survey. The premise of using either one as a "common denominator" does not provide the engineering detail needed in PMS's.

4. Condition Survey Samples. The reliability of condition data is crucial to the credibility of a PMS. The least amount of error will occur if 100 percent of the pavement is sampled. The viability of sampling 100 percent is only possible when using automated survey equipment, such as the equipment that is currently used to measure roughness, rutting, and faulting. In the absence of automated equipment, SHA's customarily measure distress data using an approximate 10 percent representative sample. That is, a 10 percent sample on each and every mile of the network. This may somewhat increase or decrease depending on the variability in pavement condition.

   Because of the expanded network coverage of ISTEA (i.e., a total of 936,000 centerline miles of Federal-aid highway), some SHA's are exploring cost cutting measures to reduce the added burden of collecting pavement condition data. Generally, reducing the number of distresses or reducing the sample size does not result in real cost savings because of the increased risk of errors in PMS. However, SHA's can achieve real cost savings by reducing the frequency of the condition surveys. Condition surveys can be conducted every 2 years instead of every year. Biennial surveys should be supplemented with annual updates for newly improved sections and when unexpected changes occur caused by either the environment, loading, premature failures, or accelerated deterioration.

While these fundamental criteria apply to all Federal-aid highways, we want t prevent unnecessary data collection and analysis burdens, so please remind PM practitioners that the level of effort needed to do items 1, 2, and 3 is far less for lower order roads than for the proposed National Highway System.

Date______

NHS PMS SURVEY

(Question II(A) applies to both the NHS and Non-NHS)

I. ORGANIZATION

A. State ______________________

B. FHWA Region ____

C. State Staffing Resources

The following staffing information pertains only to the staff at the central office. It does not apply to district staff or field data collection crews.

1. Does the SHA have a person who is designated as the State's PMS Engineer[1]? Yes____ No____ (If no, still provide a name, address, etc. for the point of contact).

Name ____
Address ____
____
____
City ____________________ ST ___ Zipcode______ PlusFour________
Phone ____________________ FAX ______________________

2. Does the PMS Engineer work full time on PMS? Yes____ No____ If part-time, what percentage is spent on PMS? Part-Time Percentage______.

3. Does the PMS Engineer have the full responsibility and authority to lead the development, implementation, and operation of PMS? Yes____ No____.

4. If NO, how is PMS managed?

____
____

5. If the PMS engineer has an assistant(s), staff, or in-house support; indicate each position(person's name), percent time spent on PMS, and a brief description of their primary function(s). This pertains only to the central office and excludes condition survey crews.(Add additional names on separate sheet.)

	Name	Percent Time	Primary Function(s)
a.	________	________	______________________
b.	________	________	______________________
c.	________	________	______________________

____

[1]PMS Engineer is the person who is in charge of leading and working on developing, implementing, and operating the PMS on a day-to-day basis.

Revised 10/20/94

D. Does the State have an active PMS committee(s) or group(s) that guide and update the PMS? Yes _____ No _____. Provide the positions(i.e. pavement design, materials, etc.) of PMS committee(s) members on an attached sheet.

II. PMS DATABASE

A. PMS Coverage

	Federal-aid Highway Mileage (Centerline)				
	Covered		Not Covered		
	NHS	Non NHS	NHS	Non NHS	Total
State					
Local					
Toll Roads					

B. Inventory Data	Yes	Under Development	Considering In Future	No
1. Pavement type	___	___	___	___
2. Pavement width	___	___	___	___
3. Shoulder type	___	___	___	___
4. Shoulder width	___	___	___	___
5. Number of lanes	___	___	___	___
6. Layer thicknesses	___	___	___	___
7. Joint spacing	___	___	___	___
8. Load transfer	___	___	___	___
9. Subgrade classification	___	___	___	___
10. Material properties	___	___	___	___
11. Resilient modulus	___	___	___	___
12. Drainage	___	___	___	___
13. Other (specify) ______________________________				

C. Project History	Yes	Under Development	No
1. Construction	___	___	___
2. Rehabilitation	___	___	___
3. Maintenance[2]	___	___	___

[2]"Maintenance" refers to preventive maintenance not corrective maintenance. Corrective maintenance refers to pot hole repair, etc.

Revised 10/2

D. Condition Survey

	Yes	Under Development	Considering In Future	No	Equipment
1. Ride	___	___	___	___	___
2. Rutting	___	___	___	___	___
3. Faulting	___	___	___	___	___
4. Cracking	___	___	___	___	___
5. Surface Friction	___	___	___	___	___
6. Network-level Deflection	___	___	___	___	___

E. Distress

	Yes	Under Development	Considering In Future	No
1. High speed windshield survey at 30 to 55 mph.	___	___	___	___
2. Low speed survey at 0 to 10 mph.	___	___	___	___
3. Combination of high and low speed.	___	___	___	___
4. 35mm film viewed at a workstation.	___	___	___	___
5. Video tape viewed at a workstation.	___	___	___	___
6. Distress Identification Manual with pictorial references used to calibrate extent and severity.	___	___	___	___
7. Fully automated. Specify equipment: ___	___	___	___	___

F. What is the frequency of condition data collection on the NHS? ______
____

G. How does the State collect their condition data?
In House ______ Contractor(specify) ______________________________

H. Traffic/Load Data

1. Does the PMS database contain

	Yes	Under Development	Considering In Future	No
a. Annual ESAL's	___	___	___	___
b. Forecast ESAL's	___	___	___	___
c. Cumulative ESAL's	___	___	___	___

2. Does the PMS have an ESAL flow map that is route specific?

Yes ___ Under Development ___ Considering in Future ___ No ___

I. Does the PMS provide IRI or PSR(circle one) to FHWA HQ for the HPMS sample sites?

Yes ___ Under Development ___ No ___

Revised 10/20/94

J. Does the PMS have a relational database?

Yes ____ Under Development ____ No ____

K. How much work has been completed in developing the PMS database? Development work would include: establishing data files, collecting data, loading data, writing application programs for analysis, etc..

0-25% ____ 25-50% ____ 50-75% ____ 75-100% ____

III. INVESTMENT ANALYSES

A. Prioritization

1. Does the PMS office/unit produce a multi-year prioritized list of recommended candidate projects(this is considered a "first cut" list)?

Yes ____ Under Development ____ No ____

2. What method does the PMS use to produce the multi-year prioritized list of projects?

	Yes	Under Development	Considering In Future	No
a. Subjective[3]	____	____	____	____
b. Objective[4]				
1. Priority Model	____	____	____	____
2. Incremental Benefit Cost	____	____	____	____
3. Marginal Cost Effectiveness	____	____	____	____
4. Optimization				

	Yes	Under Development	Considering In Future	No
a. Linear Programming	____	____	____	____
b. Non-Linear Programming	____	____	____	____
c. Integer Programming	____	____	____	____
d. Dynamic Programming	____	____	____	____
e. Other (Specify)				

[3]"Subjective" indicates that the projects were prioritized by individuals using only personal knowledge of the roads.

[4]"Objective" means that the projects were prioritized using a repeatable analytical process.

Revised 10/20/94

3. If the answer to question 2(b) is Yes or Under Development, who developed the software? In House ______ Contractor(specify) ______________

4. Check the factors used to prioritize projects:

	Yes	Under Development	Considering In Future	No
a. Distress	___	___	___	___
b. Ride	___	___	___	___
c. Traffic	___	___	___	___
d. Functional class	___	___	___	___
e. Skid	___	___	___	___
f. Structural adequacy	___	___	___	___
g. Other (Specify)				

B. Preservation Treatment

1. Does the PMS assign a preservation treatment to a candidate project?

   Yes ____ Under Development ____ No ___

2. If the answer to question 1 is Yes or Under Development, which groups of treatments does the PMS cover?

	Yes	Under Development	No
a. Reconstruction	_____	_____	_____
b. Rehabilitation	_____	_____	_____
c. Maintenance[5]	_____	_____	_____

3. What method is used to assign a preservation treatment to a candidate project.

	Yes	Under Development	Considering In Future	No
a. Subjective[6]	___	___	___	___
b. Objective[7]				
1. Matrix	___	___	___	___
2. Decision tree	___	___	___	___
3. Cost Benefit	___	___	___	___
4. Optimization Method listed previously	___	___	___	___
5. Other (Specify)				

---

[5]"Maintenance" refers to preventive maintenance not corrective maintenance. Corrective maintenance refers to pothole repair, etc.

[6]"Subjective" indicates that the projects were prioritized by individuals using only personal knowledge of the roads.

[7]"Objective" means that the projects were prioritized using a repeatable analytical process.

4. If the answer to question 3(b) is Yes or Under Development, who developed tr software? In House ____ Contractor(specify) ____________________

5. Does the PMS do a life-cycle cost analysis for the recommended preservation treatments?

Yes ____ Under Development ____ No ___

6. If the answer to question 5 is Yes or Under Development, who developed the software? In House ____ Contractor(specify) ____________________

C. Pavement Performance Monitoring and Projection

1. Does the PMS monitor pavement performance?

Yes ____ Under Development ____ No ___

2. Check all the pavement indices used to monitor pavement performance:

	Yes	Under Development	Considering In Future	No
a. Ride	___	___	___	___
b. Distress	___	___	___	___
c. Combined Index	___	___	___	___
e. Other (Specify)	____________________			

3. Is load data (cumulative ESAL's) used to monitor pavement performance?

Yes ____ Under Development ____ Considering in Future ____ No ___

4. Does the PMS generate pavement performance curves?

Yes ____ Under Development ____ Considering in Future ____ No ___

5. Are the curves developed for?

	Yes	Under Development	Considering In Future	No
Family of pavements	___	___	___	___
Each pavement	___	___	___	___

6. Does the PMS monitor and predict performance using?

	Yes	Under Development	Considering In Future	No
Markov Transition	___	___	___	___
Semi-Markov Transition	___	___	___	___

7. Does the PMS monitor pavement performance using another method? (specify). ____________________

____

Revised 10/20/94

8. Does the PMS compute the Remaining Service Life of the network?

Yes ____ Under Development ____ No ___

9. If the answer to question 8 is Yes or Under Development, who developed the software? In House ___ Contractor(specify)________________

IV. ENGINEERING ANALYSIS

A. Is the performance data in the PMS database used to evaluate either the accuracy, quality, or the cost effectiveness for:

	Yes	Under Development	Considering In Future	No
1. New pavement design procedures	____	____	____	____
2. Overlay design procedures	____	____	____	____
3. Rehabilitation techniques	____	____	____	____
4. Materials	____	____	____	____
5. Construction	____	____	____	____
6. Preventive maintenance	____	____	____	____
7. Mix designs	____	____	____	____
8. Other (Specify) ________________				

V. PRODUCTS

A. Is the PMS's multi-year prioritized list of recommended projects used as input in the development of the State's:

	Yes	Under Development	No
1. Pavement Preservation Program	____	____	____
2. Statewide Transportation Improvement Program(STIP)	____	____	____
3. Transportation Improvement Program(TIP)	____	____	____

B. Is the PMS's multi-year prioritized list(first cut) compared to the final approved list of pavement preservation projects for reasonableness?

Yes ____ Under Development ____ Considering in Future ____ No ___

VI. UPDATE

Does the SHA annually evaluate and update the PMS relative to the agency's policies, engineering criteria, practices, experience, and current information?

Yes ____ Under Development ____ No ___

Revised 10/20/94

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION:** OIG Final Report on the Audit of Cost Comparison of Asphalt Versus Concrete Pavement

Date: July 26, 1994

From: Rodney E. Slater
Administrator

Reply to Attn. of: HMS-11

To: The Honorable A. Mary Schiavo
Inspector General (JA-1)

We have completed our review of the final report on the Audit of Cost Comparison of Asphalt Versus Concrete Pavement in Region 4. Your transmittal memorandum requested that we reconsider our nonconcurrences with your recommendations and provide specific target dates and further clarification where we have agreed to corrective actions.

Our specific comments relative to each recommendation are contained in the attachment to this memorandum. For clarification, we have included our responses to the draft report, as well as a summary of the OIG comments on those responses in the attachment.

Our further review of the report reveals a fundamental philosophical difference in our approach to administering the Federal-aid highway program. This difference is specifically stated in the report's synopsis, alluded to in the report itself, and incorporated into many of the report's recommendations.

The philosophical difference is clearly articulated in the statement on page iv which reads as follows: "**. . .the continuing problem with FHWA's traditional strategy of facilitating, rather than mandating . . . .**" The report suggests that the FHWA needs to alter its operational relationship with State highway agencies (SHA) and adopt, as we interpret it, a strategy that is inconsistent with this Administration's approach toward customer service and minimizing mandates. We find this to be totally unacceptable and continue to nonconcur with that premise and in all recommendations in the report that would lead the FHWA in that direction.

The FHWA's basic philosophy of **"facilitating, rather than mandating"** is based upon the fact that the Federal-aid highway program is a federally assisted State program. The FHWA must administer it in that light. The Federal-aid highway program is fundamentally a formula allocated program. With finite allocations, SHAs are independently under intense fiscal pressure to assure the most efficient use of all highway dollars, whether they are Federal, State, or local dollars.

The FHWA's fostering of a cooperative partnership approach has served FHWA, the States, and the Nation well since its inception. This partnership approach was strengthened by the passage of the Intermodal Surface Transportation Efficiency Act of 1991. The FHWA continues to look toward bettering, not dismantling, this relationship in the future.

In response to the specific recommendations contained in the report, among other things, we have attached specific clarification and timetables for life-cycle cost analysis (LCCA) and pavement design activities as you requested. The FHWA believes that it is important to note that we have made significant progress over the last few years in both of these areas.

In the area of LCCA, we have reviewed the recent 1993 American Association of State Highway and Transportation Officials (AASHTO) survey of SHA applications of LCCA, conducted an FHWA/AASHTO symposium on LCCA in December 1993, and plan to publish an interim policy statement on LCCA. This policy statement will include recommendations on minimum analysis periods to be used and references Office of Management and Budget Circular A-94 for guidance on the selection of appropriate discount rates. The goal of this policy statement is to clearly define the FHWA's position on some of the more important components of LCCA, including analysis period, discount rate, and user costs. We intend to publish this policy statement in early summer.

It is important to note that we are making significant progress in this area and will be in a better position to further determine our course as current efforts evolve.

The same is true in the area of assuring high quality, cost-effective highway pavement design, construction, maintenance, and preservation. The new December 1993 Pavement Management System (PMS) regulation requires SHAs to develop comprehensive coordinated systems to effectively manage pavement to address current and evolving long-term pavement needs. It also broadens the pavement design requirements to include an analysis of the entire pavement structure (subgrade, subbase, base, and pavement). The regulation specifically requires that pavement design analysis consider life-cycle costs.

The FHWA intends to rewrite its Federal-Aid Policy Guide (FAPG) on pavement design to better track with the recently revised PMS regulation by the end of this calendar year. The revised FAPG, in conjunction with the new PMS regulation, will provide significantly more definitive guidance on pavement design. As noted in our earlier response, the FHWA agreed to direct its regional pavement engineers to participate with the divisions in pavement design and management reviews in each State during the next 2 years. Headquarters pavement engineers will participate in at least one of these reviews per region.

Further, we continue to stand by our original position, as stated in our September 2 memorandum, that the audit report does not support a finding of a material internal control weakness.

We appreciate the opportunity to comment on this draft report concerning the Audit of Cost Comparison of Asphalt Versus Concrete Pavement in Region 4.

2 Attachments

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION**: Proposed Final Interstate Maintenance Fund Transfer Policy

Date: SEP 21 1994

From: Director, Office of Engineering

Reply to Attn of: HNG-42

To: Regional Administrators

Attached is a copy of the FHWA's proposed final policy statement on Interstate Maintenance Fund Transfers, which was published in the Federal Register on Friday, September 2. It addresses criteria relating to the decisions on adequate maintenance of the Interstate System for purposes of the Interstate Maintenance Program Transfer provisions of Title 23, United States Code, Section 119(f)(1). It is a proposed replacement for the Interim Maintenance Fund Transfer Policy, published at 58 Federal Register 12229, on March 3, 1993.

The proposed final policy statement would add safety and geometric criteria not originally proposed in the interim policy, and modify the existing criteria for pavements. Modifications to the pavement criteria would change the IRI criteria from 240 cm/km (150 inches/mile) to 200 cm/km (127 inches/mile), modify the faulting criteria to reflect a faulting rate of 525 mm/km (33 inches/mile) for both plain and reinforced jointed concrete pavements, and add a surface friction related criteria.

We have reopened the docket and will be accepting written public comments until November 1, 1994. We would appreciate it if FHWA field offices would adhere to that date in submitting any comments. Please note, that until we publish a final policy statement, the interim Interstate Fund Transfer Policy, published in the Federal Register on March 3, 1993, is still in effect and governs Interstate Maintenance Fund Transfer requests.

The Pavement Division continues to coordinate this effort for the Office of Engineering. Please direct any questions relating to this policy and/or its implementation to Mr. John Hallin. He can be reached at (202) 366-1323.

for William A. Weseman

Attachment

NOTE : The proposed final policy statement proposes changes to agency policy and has been published to gather public comment. Until the statement becomes final the interim policy statement will prevail for transfer of interstate maintenance program funds.

NOTE: The proposed final policy statement proposes changes to agency policy and has been published to gather public comment. Until the statement becomes final the interim policy statement will prevail for transfer of interstate maintenance program funds.

Federal Highway Administration

[FHWA Docket No. 93–10]

Transfer of Interstate Maintenance Program Funds

AGENCY: Federal Highway Administration (FHWA), DOT.

ACTION: Proposed final policy statement; requests for comments.

SUMMARY: This proposed final policy statement sets forth the FHWA's policy for addressing the interstate maintenance program funds transfer provisions of 23 U.S.C. 119(f)(1). The criteria for determining what constitutes adequate maintenance, which are included in this policy, are associated with only the transfer of Interstate Maintenance (IM) funds and are not related to the State's responsibility to properly maintain projects constructed with Federal-aid funds outlined in 23 U.S.C. 116, Maintenance.

DATES: Comments must be received on or before November 1, 1994.

ADDRESSES: Submit written, signed comments concerning this policy statement to FHWA Docket No. 93–10, Federal Highway Administration, Room 4232, HCC–10, Office of the Chief Counsel, 400 Seventh Street, SW., Washington, DC 20590. All comments received will be available for examination at the above address between 8:30 a.m. and 3:30 p.m., e.t., Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Mr. John Hallin, Chief, Pavement Design and Rehabilitation Branch, (202) 366–1323, or Ms. Vivian Philbin, Attorney-Advisor, Office of Chief Counsel, General Law Branch, (202) 366–0780, Federal Highway Administration, 400 Seventh Street SW., Washington, DC 20590.

SUPPLEMENTARY INFORMATION:

Background

On March 3, 1993, the FHWA published an interim policy statement on the transfer of Interstate maintenance program funds at 58 FR 12299, and provided a 60-day public comment period which closed on May 3, 1993. During the intervening period, FHWA has evaluated the comments and reconsidered its initial position. As a result, the FHWA is proposing to modify the pavement roughness and faulting criteria and to add additional criteria that were not proposed in the interim policy.

A total of 18 State highway agencies (SHAs) and the Highway User Federation for Safety and Mobility (HUFSAM), a public interest group, provided written comments to the docket established for the interim policy statement.

The SHA comments ranged from administrative type questions, such as requests for clarification of measurement procedures and use of existing pavement management system data, to fundamental positions on the individual indicators and the specific established criteria. Some SHAs endorsed various portions of the criteria established, while others took exception to part or all of the criteria.

The HUFSAM strongly endorsed the interim policy. It stressed the need to assure that the Interstate System be maintained at a very high level and noted that, from its studies, nationwide, the Interstate maintenance funding levels are inadequate.

After evaluating the comments received, the FHWA continues to believe that transfers of apportioned IM funds specifically earmarked for Interstate maintenance to other designated programs should be permitted only when the Interstate System routes are in a physical, operational, and safe condition and perform at or near the level for which they were designed, and constructed. Because pavement and bridge activities constitute the major cost items of IM eligible activities, the interim policy focused on pavement and bridge condition indicators as the determining factors for eligibility to transfer IM funds. Other essential elements, necessary to maintain the physical and operational integrity of the Interstate, must also be considered in transportation decisions. Responses to the interim policy, however, indicate a concern that other essential elements need not be considered in transfer decisions. This was not the intent of the interim policy statement.

Section 101(a) of Title 23 U.S.C. defines "maintenance" to mean the preservation of the entire highway, including surface, shoulders, roadside, structures, and such traffic control devices as are necessary for its safe and efficient utilization. As the IM program now provides the major resources for rehabilitation, resurfacing, and restoration (3R) work on the Interstate System, extending the service life of all major components and enhancing highway safety on the system should receive first priority for IM fund use. For example, over 25 percent of the projects and approximately 10 percent of funds from the IM program are currently being expended on traffic and safety improvement projects. The FHWA supports a continued strong emphasis on safety.

In a sampling of SHA pavement management systems conducted during the past year, the FHWA found that the pavement condition indicators established in the interim policy are generally collected and used by the States in evaluating the condition of the Interstate for their own management purposes. While the data collection and reporting procedures differ somewhat, the fundamental indicators are consistently used by the SHA's to manage their Interstate pavements.

The proposed final policy includes the original pavement and bridge condition indicators established in the interim policy and adds pavement surface friction as a fourth pavement condition indicator. However, the roughness criteria has been modified and the separate faulting criteria for jointed plain and joint reinforced concrete pavement (JPCP and JRCP) has been replaced with a single criterion of 525 mm/km (33 inches/mile) for both jointed pavement types.

In addition to these interim factors, this proposed final policy statement adds criteria for the additional traffic and safety related indicators of (1) safety appurtenances, (2) traffic control devices, and (3) geometric elements. These indicators are equally critical to the Interstate System which relies heavily on the availability of IM funds for continued adequacy. Maintenance of the Interstate System's operational as well as physical characteristics in a satisfactory manner remains the first priority for the use of these funds.

Comments Received

This section addresses specific SHA comments organized around the criteria established for each of the individual condition indicators.

Pavement Roughness

Three SHAs suggested that the International Roughness Index (IRI), developed at the International Road Roughness Experiment, is not the appropriate measure of rideability. The FHWA recognizes that IRI does have some limitations. It does, however, provide a common quantitative basis with which to reference the different measures of roughness. Further, it is currently collected by SHAs and provided to FHWA under the Highway Performance Monitoring System (HPMS) submission requirements. Although the FHWA is open to use of improved pavement surface rideability measures, until such time that improved measures and equipment to measure them are accepted and readily available to SHA's, the FHWA will continue to rely on IRI as the ride indicator.

Four SHAs commented that the specific IRI criteria of 240 cm/km (150 inches/mile) was too severe. The FHWA disagrees. The selection of the 240 cm/km upper limit criteria on pavement roughness was directly tied to the FHWA's desire to require Interstate pavement to be in fair or better condition. The interim policy noted that initial IRI to pavement serviceability rating [1] (PSR) conversion studies [2] indicated a 240 cm/km IRI is equivalent to a PSR range of 3.0 to 3.5. Pavements within this range are classified as fair in the FHWA's "1992 Highway Statistics" [3] report. Subsequent additional analysis of the IRI/PSR correlation indicates that a 240 cm/km IRI more accurately reflects a much lower PSR range of 2.5 to 2.8 (pavements in this range are classified as being in poor to mediocre condition [4]). Based on this further analysis, the FHWA has established an upper limit of allowable IRI of 200 cm/km (127"/mile). This converts to a PSR of between 2.8 and 3.2 which is more consistent with the FHWA's original objective that pavements be in fair or better condition [5].

Rutting

Rutting comments were limited to data collection difficulties and reflected a degree of uncertainty about what data collection equipment and procedure would be considered acceptable. No comments were received concerning the appropriateness of the rutting indicator or the established criteria. Therefore the FHWA has retained 15 mm (5/8 inch) as the upper allowable limit of rutting. Concerns related to data collection equipment and procedures are addressed under "Pavement Data Collection," later in the preamble.

Faulting

The SHA comments on the faulting criteria were split evenly; five SHAs thought that the faulting criteria were too restrictive, while five SHAs commented that the criteria were acceptable. In addition, the HUFSAM found the criteria acceptable.

One SHA recommended simplifying the policy by replacing the separate faulting criteria for jointed plain and jointed reinforced concrete pavement (JPCP and JRCP) with a single faulting criterion in mm/km (inches/mile) for both pavement types. A mm/km based criteria would eliminate the need to take joint frequency into account, as the average allowable faulting per joint would be directly related to the number of joints/mile. The FHWA recognizes the merit in this recommendation and has replaced the separate faulting criteria of 3 mm on JPCP and 6 mm on JRCP with an equivalent maximum faulting rate of 525 mm/km (33 inches/mile) for both. This faulting rate is equivalent to 3 mm per joint on typical JPCP with 6 meter (20 foot) joint spacing and 6 mm per joint on JRCP with 12 meter (40 foot) joint spacing. Because joint spacing varies between States, the allowable faulting per joint will differ from State to State, even though the faulting rate per km remains constant.

Administrative—Procedural Tolerance Limits

The most common comment, received from seven SHAs, was that the scope of the application of the criteria was too stringent. The crux of the argument was that some tolerance limit should be established to allow a SHA in substantial compliance to transfer funds. A common suggestion was that the FHWA only require that 90 to 95 percent of the Interstate System meet the criteria before allowing transfer.

The FHWA recognizes that there are continually evolving pavement and bridge needs and, at any one point in time, even SHAs with exceptionally good pavements might not meet the criteria on 100 percent of their Interstate system. The FHWA has already provided relief for this situation. The interim policy specifically allows transfer when all criteria are not met on the Interstate if the work necessary to correct any deficient segments is included in the approved State Transportation Improvement Program, required by 23 U.S.C. 135(f). This relief is included in the final policy. The FHWA believes that allowing a 5 to 10 percent exemption or tolerance would be unwise, as it would allow transfer of money necessary to maintain the Interstate highway system.

[1] The PSR concept was developed at the 1956 American Association of State Highway Officials (AASHO) road test to relate the pavement serviceability index (PSI), computed from objectively measured pavement distress, with subjective serviceability ratings by panels of road users.

[2] Bashar Al-Omari and Michael I. Darter, "Relationships between IRI and PSR: A Report of the Findings of Pavement Model Enhancements for the Highway Performance Monitoring System (HPMS)," Transportation Engineering Series No. 69, University of Illinois at Urbana Champaign, Report No. UILU-ENG-92-2013, September 1992. This document is available for inspection in FHWA Docket No. 93-10.

[3] FHWA, "Highway Statistics 1992," FHWA-PL-93-023. A copy of this document is available for inspection in FHWA Docket No. 93-10.

[4] Ibid.

[5] Ibid.

Pavement Data Collection

Several SHAs posed comments and questions on data collection and reporting procedures. The primary concern appeared to be whether FHWA would require a specific data collection effort using some standardized equipment and procedures that would be different from what is currently used by the individual SHAs. Further, the comments included request for flexibility in summarizing the data. Several suggested that FHWA should use whatever SHA PMS data was available to determine the acceptability of a certification accompanying a transfer request.

The FHWA intends to rely primarily on current surface roughness, rutting, and faulting information contained in SHAs PMS database(s) and from information reported in HPMS in evaluating the pavement component of State certifications accompanying Interstate maintenance fund transfer requests.

The FHWA recognizes the uniqueness of each SHA's PMS and the diversity of equipment and procedures used by the SHAs to meet their particular pavement management needs. The FHWA is not prescribing new specific uniform data collection equipment, procedures, sampling, or data reduction techniques to determine compliance with the pavement Interstate maintenance transfer criteria.

Bridges

Only two SHA's commented on the bridge section of the policy. Both endorsed the use of the current National Bridge Inventory (NBI) bridge deck condition rating (Item 58) as an indicator and supported the criteria requirement that bridge decks have a condition rating of 5 or better. This is consistent with the long standing use of a deck rating of less than 5 to determine a structurally deficient bridge.

Both States also recommended that FHWA include the NBI ratings for superstructure and substructure in the policy and delete the load posting requirement contained in the interim policy.

The FHWA originally considered using superstructure and substructure ratings as specific criteria when it initially developed the interim policy. Upon further consideration, FHWA still supports "load posting" criterion which reflects superstructure and substructure condition ratings and is also a measure of potential safety concern.

The need for load posting is an end result of applying superstructure and substructure conditions, along with other factors, in making load carrying capacity calculations. Changes in condition ratings, and therefore, the load posting, are affected by a reduced maintenance effort which eventually leads to continual and long-term deterioration of bridge elements.

One of the SHAs further recommended that the FHWA incorporate failure susceptibility as an indicator. Failure susceptibility is not required nor normally assessed by States in the course of inspecting bridges to meet national bridge inspection standards. As a result, the FHWA believes it would be inappropriate to use failure susceptibility as a nationwide criterion in the IM fund transfer policy, and has not included it.

Finally, one SHA recommended that bridge railing adequacy should be included in the decision factors. The FHWA considered including bridge railing adequacy as indicated by NBI Item 36 in the early development of policy criteria. The NBI Item 36 is a four segment item that rates bridge railings for adequate impact strength, and approach guardrail for adequate vehicle safety and protection.

The adequacy of bridge railings and approach guardrail is a serious safety concern and should be considered in the States' maintenance program as well as in developing highway safety projects.

Bridge Data Collection

The NBI ratings are determined in accordance with the "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (Coding Guide) U.S. DOT/FHWA, December 1988.

Policy

For the purpose of 23 U.S.C. 119(f)(1), which provides for transfer of State apportioned IM funds that are in excess of a State's need to the State's NHS and STP apportionment, the FHWA will accept a State's certification if the State's Interstate routes meet the following criteria:

Pavement:

(1) An IRI of 200 cm per km (127 inches per mile) or less;

(2) Rutting of 15 mm (5/8 inch) or less on flexible pavements;

(3) Cumulative faulting of 525 mm per km (33 inches/mile) or less on jointed rigid pavements; and

(4) Surfaces have adequate surface friction and drainage, based on the State accidents record system not identifying any locations with a high incidence of wet weather accidents.

Bridges:

(1) Bridge decks in "fair condition" or better (Coding Guide item 58 rated 5 or better); and

(2) No load posting required (Coding Guide item 70 rated 5).

Safety Appurtenances:

Guardrail, bridge rails, safety barriers, and other safety features including the upstream ends of all traffic barriers meet (a) the performance criteria of 23 CFR 625, (b) acceptable use warrants, and (c) installation requirements per State standard plans.

Traffic Control Devices:

All major guide, regulatory, and warning signs meet the minimum size, shape, color, format, and message requirements as well as the day and night legibility and visibility requirements of the MUTCD and amendments.

Geometric Elements:

(1) The horizontal and vertical alignment, and widths of median, traveled way, and shoulders meet the AASHTO Interstate Standards, as incorporated in 23 CFR 625, in effect either at the time of original construction, major reconstruction, or inclusion into the Interstate system, whichever was the latest; and

(2) Hazardous features (fixed objects, steep sideslopes, etc.) within the clear zone are either eliminated, corrected, or adequately shielded.

In the event that the condition, as reflected by current databases, does not meet the required criteria, for any segment of Interstate, the State's request for funding transfer may not be approved unless the State certifies that the deficient segments have either been subsequently upgraded to meet the required criteria or that the work necessary to correct any such deficient segments is included in the approved State Transportation Improvement Program, required by 23 U.S.C. 135(f).

Section 119(f)(2) of Title 23, U.S.C., allows the States to transfer up to 20 percent of the apportioned IM funds to the NHS and STP apportionment based solely on the request of the States.

(23 U.S.C. 119 and 315; 49 CFR 1.48(b))

Issued on: August 29, 1994.

Rodney E. Slater,

Federal Highway Administrator.

[FR Doc. 94–21757 Filed 9–1–94; 8:45 am]

BILLING CODE 4910–22–P

NOTE : The proposed final policy statement proposes changes to agency policy and has been published to gather public comment. Until the statement becomes final the interim policy statement will prevail for transfer of interstate maintenance program funds.

Federal Highway Administration

[FHWA Docket No. 93–10]

Transfer of Interstate Maintenance Program Funds

AGENCY: Federal Highway Administration (FHEA), DOT.

ACTION: Interim policy statement.

SUMMARY: This interim policy statement establishes the FHWA's policy for addressing the interstate maintenance program funds transfer provisions of section 119(f)(1) of title 23, United States Code (U.S.C.), which was amended by Section 1009 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. By publishing this interim policy statement the FHWA seeks to advise States of the criteria the agency will use in evaluating a State's request to transfer interstate maintenance funds, while providing the opportunity for public comment prior to issuing a final policy statement.

DATES: Comments must be received on or before May 3, 1993.

ADDRESSES: Submit written, signed comments concerning this policy statement to FHWA Docket No. 93–10, Federal Highway Administration, room 4232, HCC–10, Office of the Chief Counsel, 400 Seventh Street, SW., Washington, DC 20590. All comments received will be available for examination at the above address between 8:30 a.m. and 3:30 p.m. e.t., Monday through Friday, except legal Federal holidays.

FOR FURTHER INFORMATION CONTACT: Mr. Louis Papet, Chief, Pavement Division, (202) 366–1324, or Mrs. Vivian Philbin, Attorney Advisor, Office of Chief Counsel, General Law Branch, (202) 366–0780, Federal Highway Administration, 400 Seventh Street SW., Washington DC 20590.

SUPPLEMENTARY INFORMATION:

Background

Section 1009 of the ISTEA amended 23 U.S.C. 119 by replacing "Interstate System resurfacing" with the "Interstate maintenance program" (IM) Public Law 102–240, section 1009, 105 Stat. 1914, 1933. Section 1009 also established additional constraints affecting the States' options for transferring a portion of these funds to the States' apportionments for other Federal-aid programs.

Section 119(f)(1), as amended, allows the transfer of IM funds to other Federal-aid highway programs provided the State certifies to the Secretary that: (1) Any part of the IM funds are in excess of the needs of the State for resurfacing, restoring, or rehabilitating Interstate System routes and (2) that it is adequately maintaining the Interstate System, and the Secretary accepts such certification. Notwithstanding section 119(f)(1), section 119((f)(2), as amended, allows the States to "unconditionally" transfer up to 20 percent of unobligated IM apportioned funds based solely on the request of the States.

Further, section 1009(c)(2) of the ISTEA requires the Secretary to develop and make available to the States criteria for determining what constitutes adequate maintenance of the Interstate System for the purposes of section 119(f)(1) of title 23, United States Code. The criteria for determining what constitutes adequate maintenance, which are included in this policy, are associated with only the transfer of IM funds and are not related to the State's responsibility to properly maintain projects constructed with Federal-aid funds outlined in 23 U.S.C. 116, Maintenance.

In developing the specific criteria, the FHWA believes that transfers of apportioned IM funds specifically earmarked for Interstate maintenance to other designated programs should only be allowed when the Interstate System routes are in a physical condition to perform at or near the level for which they were designed and intended.

Pavement and bridge activities constitute the majority of IM eligible activities. The FHWA has focused on pavement and bridge condition indicators as determining factors for eligibility to transfer IM funds.

The FHWA has selected Interstate pavement condition indicators (surface roughness, rutting, and faulting) and bridge condition indicators (bridge deck condition and the need for load posting) for evaluating State's requests to transfer IM funds under the provisions of 23 U.S.C. 119(f)(1). These indicators are collected and used by the States in evaluating the condition of the Interstate for their own management purposes. They are generally incorporated into State pavement and bridge management systems and the national bridge inventory and highway performance monitoring system.

Pavement Condition Indicators

Roughness

The FHWA will use the International Roughness Index (IRI) to evaluate roadway roughness, and has set an upper IRI limit of 240 cm per km (150 inches per mile) for surface roughness.

The IRI was developed at the International Road Roughness Experiment sponsored by the World Bank and several countries, including the United States, in Brazil in 1982. It is designed to provide a common quantitative basis with which to reference the different measures of roughness. It summarizes the longitudinal surface profile in the wheel track and simulates the response of one wheel of a typical passenger car traveling 80 km per hour (50 miles per hour) to road roughness.

The IRI upper limit of 240 cm per km, selected by the FHWA, is based on consideration of research efforts that relate actual roadways with a known IRI with the public's perception of ride quality. A recent study [1] conducted for the FHWA indicated that objectively developed IRI numbers could be mathematically correlated with subjectively developed pavement serviceability ratings [2] (PSR) generated by panels of road users. This work included mathematical formulas that allow conversions between IRI readings and anticipated road user evaluation of pavement performance (*i.e.*, PSR).

Conversion formulas [3] indicate that an IRI of 240 cm per km correlates to a PSR range of between 3.0 and 3.5, which is slightly greater than the 2.5 to 3.0 PSR range associated with terminal serviceability for Interstate highway pavements.[4]

[1] Bashar Al-Omari and Michael I. Darter, "Relationships between IRI and PSR: A Report of the Findings of Pavement Model Enhancements for the Highway Performance Monitoring System (HPMS)," Transportation Engineering Series No. 69, University of Illinois at Urbana Champaign, Report No. UILU–ENG–92–2013, September 1992. This document is available for inspection in FHWA Docket No. 93–10.

[2] The PSR concept was developed at the 1956 American Association of State highway Officials (AASHO) road test to relate the pavement serviceability index (PSI), computed from objectively measured pavement distress, with subjective serviceability ratings by panels of road users.

[3] Includes conversion formulas developed inhouse by the State of Maine, for the South Carolina pavement management system by PMS Inc. and the previously mentioned Al-Omari and Darter research cited in footnote No. 1.

[4] The "AASHTO Guide for Design of Pavement Structures", AASHTO, 1986 (page I–8) defines terminal serviceability index as the lowest acceptable level before resurfacing or reconstruction becomes necessary for the particular class of highway. The AASHTO Guide goes on to note that

Continued

Rutting

The FHWA has established 15 mm (5/8 inch) as the upper allowable limit of rutting.

The American Association of State Highway and Transportation Officials (AASHTO) Highway Subcommittee on Construction surveyed State highway agencies in 1988 on rutting. The survey revealed that for State maintained roads, 1/2 inch rutting would initiate rehabilitation in about 35 percent of the States. An additional 35 percent of the States indicated that 5/8 inch of rutting would initiate rehabilitation. The "Highway Pavement Distress Identification Manual" (HPDIM)[5] classifies 1/2 to 1 inch of rutting as moderate severity.

The FHWA 15 mm (5/8 inch) criterion is consistent with the performance levels expected on the Interstate System.

Faulting

The FHWA has established two levels of faulting criteria that are related to pavement type. The FHWA has established an upper limit on faulting of 3 mm (1/8 inch) on jointed plain concrete pavements (JPCP), and an upper limit on faulting of 6 mm (1/4 inch) on jointed reinforced concrete pavements (JRCP).

Generally, State highway agencies consider faulting to be objectionable in the 1/8 to 1/2 inch range. The HPDIM classifies faulting between 1/16 and 1/4 inch as moderate severity. The "Pavement and Shoulder Maintenance Performance Guides," August 1984, FHWA publication number TS–84–208, indicates faulting should be repaired at 1/4 inch. A copy of TS–84–208 is available for inspection in FHWA Docket No. 93–10.

The FHWA selected a lower level of faulting for JPCP than for JRCP because JPCP joints occur more frequently. The levels selected are consistent with the higher expectation the traveling public associates with Interstate highways.

Pavement Data

Procedures for developing IRI are currently well defined in the guidance provided in the "Highway Performance Monitoring System (HPMS) Field Manual," Appendix J "Roughness Equipment, Calibration and Data Collection." This document is widely available in planning sections of State highway agencies and the FHWA division offices and a copy of this publication is available for inspection in FHWA Docket No. 93–10. IRI data are collected annually and reported to the FHWA under the HPMS program.

The FHWA pavement policy, (23 CFR part 626) requires each State to have an operational pavement management system (PMS) for principal arterials (which includes the Interstate system) in place by January 13, 1993.

The FHWA envisions that the States will assemble necessary pavement surface roughness, rutting, and faulting information from data currently available in the States' PMS database(s) and from information reported in HPMS.

The FHWA division offices will work with the States in identifying acceptable procedures for measuring and compiling the data available from the States' PMS. Data supporting each State's IM transfer request will be made available for inspection by the FHWA.

Bridge Condition Indicators

The FHWA will use the current national bridge inventory (NBI) bridge deck condition rating (item 58) and the rating indicating whether the bridge requires load posting (item 70) as indicators of Interstate bridge condition for purposes of evaluating States' requests for IM transfer. The NBI ratings are determined in accordance with the "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (Coding Guide) US DOT/FHWA, December 1988. A copy of this publication is available for inspection in FHWA Docket No. 93–10.

Bridge Decks

The FHWA will require that bridge decks have a condition rating (item 58) of 5 or better.

Bridge decks are rated in item 58 on a scale of 0 to 9 with a rating of 9 representing a bridge deck in excellent condition. A Coding Guide deck rating of less than 5 indicates a poor condition with the deck showing deterioration and spalling. In relation to pavement roughness, a deck with a rating less than 5 is considered a rough deck that would not provide a reasonably smooth ride. A deck rating of less than 5 is a long-standing condition rating used to determine a structurally deficient bridge.

Posting

The FHWA will require that NBI item 70, for load posting, must be a rating of 5.

The National Bridge Inspection Standards (23 CFR part 650, subpart C) require the posting of load limits only if the maximum legal load in a State produces stresses in excess of the operating stress levels. The operating stress level will result from the absolute maximum permissible load to which a bridge may be subjected. Coding Guide item 70 of the NBI is the item for bridge posting, and a State's rating of 5 indicates that no posting is required at the operating level.

Load posting of a bridge reduces the level of service of the system of which the bridge is an integral part and can potentially disrupt interstate and intrastate commerce. Heavy vehicles may be required to take long detour routes thereby indirectly adding to the costs the public must bear for goods and services. Load posting of a bridge may also be an indicator of a bridge's superstructure or substructure capacity that may have been affected by continual and long term deterioration of the bridge's elements and which could have been prevented or abated by adequate preventive maintenance.

Policy

For the purpose of 23 U.S.C. 119(f)(1), which provides for transfer of IM funds apportioned to the States, the FHWA will accept a State's certification if the State's Interstate routes meet the following criteria:

Pavement

(1) An IRI of 240 cm per km (150 inches per mile) or less;

(2) Rutting of 15 mm (5/8 inch) or less; and

(3) Faulting of 3 mm (1/8 inch) or less on JPCP and 6 mm (1/4 inch) or less on JRCP.

Bridges

(1) Bridge decks in "fair condition" or better (Coding Guide item 58 rated 5 or better); and

(2) No load posting required (Coding Guide item 70 rated 5).

In the event that the condition, as reflected by current condition data bases, for any segment of Interstate pavement or bridge does not meet the required criteria, the State's request for funding transfer may later be approved only if the State certifies that the deficient segments have been subsequently upgraded to meet the required criteria or that the work necessary to correct any such deficient segments is included in the approved State Transportation Improvement Program, required by 23 U.S.C. 135(f).

Section 119(f)(2) of title 23 U.S.C. allows the States to "unconditionally" transfer up to 20 percent of unobligated IM apportioned funds based solely on the request of the States.

Authority: 23 U.S.C. 119 and 315; 49 CFR 1.48(b).

Issued on: February 24, 1993.

E. Dean Carlson,

Executive Director, Federal Highway Administration.

[FR Doc. 93–4809 Filed 3–2–93; 8:45 am]

BILLING CODE 4910–22–M

a terminal serviceability index of 2.5 to 3.0 is often suggested for use in the design of major highways. A copy of this publication is available for inspection in FHWA Docket No. 93–10.

[5] The "Highway Pavement Distress Identification Manual", US DOT/FHWA, DOT–FH–11–9175/ NCHRP 1–19, March, 1979 reprinted February 1986. This Publication is available for inspection in FHWA Docket No. 93–10.

Chapter 2

Pavement Issues

CHAPTER 2

PAVEMENT ISSUES

2.1 Reserved.

2.2 Reserved.

2.3 Tire Pressure, Technical Paper 89-001, February 15, 1989.

2.4 Reserved.

2.5 A Discussion of Discount Rates for Economic Analysis of Pavements, February 1990.

2.6 Resilient Modulus Testing Equipment, February 24, 1988.

2.7 Longitudinal Joint Construction and Edge Drop-Offs, March 1989.

2.8 Reserved.

2.9 Reserved.

2.10 Life Cycle Cost Analysis, September 15, 1992.
- Interim Policy Statement - FR, July 11, 1994.

2.11 Reserved

2.12 ISTEA Implementation Interstate Maintenance Program, Memorandum, May 21, 1992.

2.13 Preventive Maintenance, July 27, 1992.
- Information on Interstate Maintenance Program, June 14, 1993.

2.14 Computer Software
- McTran's Software, July 1995.

U.S. Department
of Transportation

**Federal Highway
Administration**

Memorandum

Subject **ACTION:** Life-Cycle Cost Analysis

Date SEP 15 1992

From Chairman, PMCG

Reply to
Attn of HNG-42

To PMCG Members (See Attached List)

A Life-Cycle Costing (LCC) Task Force has been formed in response to LCC interest expressed by the FHWA Research and Development Executive Board at its 1991-92 winter meeting. The Task Force consists of representatives from the Associate Administrators for Policy (HPP-12), Research (HNR-20), Program Development (HNG-42), Motor Carrier (HIA-20), and Administration (HCP-22). The Task Force mission is to develop recommendations for the Research and Development Executive Board on appropriate ways to incorporate LCC analysis into the Federal-aid highway program, as well as the necessary LCC research, development, and training needs.

Attached for your review and comments is a draft of the Task Force's preliminary study paper, "Life-Cycle Costing and Life-Cycle Cost Analysis: Applications Within FHWA and The Federal-aid Highway Program." We are scheduling a presentation and discussion period of the Task Force's initial effort at the next PMCG meeting. We are seeking PMCG reaction, input and suggestion for improvement necessary to obtain PMCG endorsement of a course of action prior to presenting the task force findings to the Executive Research Review Board on October 22.

We would appreciate receiving your comments by September 28. Mr. Jim Walls has been designated to coordinate this effort and is available to address any questions you may have or clarify any proposals contained in the preliminary study. Mr. Walls can be reached at 366-1339.

for

Louis M. Papet

PMCG Members:

Lou Papet	HNG-40
Richard Torbik	HEP-10
Tom Pasko	HNR-1
Doug Bernard	HTA-1
Madeline Bloom	HPP-1
Dave McElhaney	HPM-1
John Grimm	HIA-1
W. Mendenhall, Jr.	HRA-06
Byron Lord	HNR-20
Paul Teng	HNR-40
Don Fohs	HNR-30
Ted Ferragut	HTA-20
Dick McComb	HTA-2

Life Cycle Costing and Life Cycle Cost Analysis:

Applications Within

FHWA and The Federal-aid Highway Program

Preliminary Study
August 1992

Task Force Members:

Jim Walls	HNG-42	(Pavements)
Byron Lord	HNR-20	(Research)
Walt Manning	HPP-12	(Policy)
Dennis Miller	HIA-10	(Motor Carrier)
Frank Waltos	HCP-32	(Contracts and Procurement)

Executive Summary

In response to interest expressed by the FHWA Research and Development Executive Board in Life-Cycle Costing (LCC), the Pavement Management Coordinating Group (PMCG) established an internal LCC Task Force consisting of representatives from the major affected Associate Administrators. The Task Force was specifically charged with developing recommendations on appropriate LCC research needs.

Fundamental to accomplishing its primary tasking, the Task Force had to first identify current and potential FHWA LCC applications along with some fundamental policy implications. The Task Force also looked at the LCC implication of the ISTEA. This paper includes the Task Force's preliminary efforts in this area.

In terms of its specific tasking on LCC research needs, this paper identifies relevant LCC issues and limitations. It lays out research approach options and a plan of action.

Based on its initial efforts, the Task Force proposes two separate but concurrent LCC efforts; an internal LCC policy development effort and a two-phase LCC contract research effort. The policy development effort, although internally directed, would most likely require some outside contractor support.

Under Phase I of the contract research effort, FHWA would contract with several companies to provide inter-disciplinary teams to define and clarify LCC issues and necessary research. Phase I work would include development of detailed work plans that address the identified LCC research needs. Under Phase II, FHWA would continue to fund a more limited number of multi-disciplinary research teams to actually conduct the more promising research activities identified in Phase 1.

The results of this proposed multi-phase research effort and the internal policy development effort would eventually be digested into FHWA guidance on LCC. This final step would most likely be done with in-house staff using consultant support.

The Task Force stresses from the onset that the outputs of life-cycle cost analysis (LCCA) are not decisions in themselves; but rather inputs into the decision making process.

A draft copy of this paper was circulated to the PMCG and discussed at the last July 14 PMCG meeting. The draft paper has been revised to incorporate their views and comments.

The Task Force at this point has not made contact with any of FHWA's partners and/or customers. Consistent with FHWA's outreach program, the Task Force suggests that appropriate outside groups be contacted before research funding decisions are made. Groups such as the American Trucking Association and the Association of American Railroads have conducted research in this area and are likely to have a keen interest in FHWA's efforts. Industry groups such as NAPA, AI, PCA, plus ARTBA would also be interested.

Introduction

A Life-Cycle Costing (LCC) Task Force was formed by Mr. Louis Papet, Chairman of the PMCG, in response to LCC interest expressed by the Research and Development Executive Board at its 1991 - 92 winter meeting. The Task Force is composed of representatives from the Associate Administrators for Policy (HPP-12), Research (HNR-20), Program Development (HNG-42), Motor Carrier (HIA-20), and Administration (HCP-22). Specific Task Force members include:

Jim Walls	HNG-42 (Office of Engineering, Pavements Division)
Byron Lord	HNR-20 (Office of Engineering, Highway Operations Research and Development, Pavements Division)
Walt Manning	HPP-12 (Office of Policy Development, Transportation Studies Division)
Dennis Miller	HIA-10 (Motor Carrier)
Frank Waltos	HCP-32 (Office of Contracts and Procurement Research and Special Programs Division)

The Task Force mission is to develop recommendations for the FHWA Research and Development Executive Board on appropriate ways to incorporate LCC analysis into the Federal-aid highway program, as well as the necessary LCC research, development, and training needs.

This study paper first defines LCC, LCC analysis, and cost effectiveness. It then discusses potential LCC applications with their implications. This discussion is followed by a summary of current policies and a look at new LCC mandates. General LCC technical and policy related issues and limitations are then discussed. In the closing sections, the paper discusses potential approaches to determining and conducting needed research and training necessary to implement LCCA, and finally, the last section presents recommendations on the preferred course of action.

Definitions

Current literature loosely defines life-cycle costing/life-cycle cost analysis as a form of economic analysis which focuses attention on determining the longer term economic implications of alternative strategies rather than merely the initial or front end costs of the immediate decision at hand. It is a tool that can be used to assist in making economically prudent long-term expenditure decisions, i.e., cost-effective investment decisions.

The Task Force believes the terms "life-cycle costing" and "life-cycle cost analysis" are synonymous. However, life-cycle cost analysis is more descriptive of the inherent analytical process and, as a result, the remainder of this paper uses the term life-cycle cost analysis (LCCA).

A related term, cost effectiveness, also has bearing in terms of FHWA Policy. Cost effectiveness is an economic related measure (generally a ratio) that describes how well an alternative meets a performance type objective in relation to the cost of achieving that performance. The cost component of cost-effectiveness measures should generally reflect life-cycle cost. The attractiveness of using cost-effectiveness measures is based on its ability to tie cost to performance. For example, a cost-effective measure in the safety area might be cost/accident reduced. In terms of pavements, it could be cost per ESAL carried until terminal serviceability is reached.

As well as defining what LCCA and cost effectiveness are, it is equally important to define what they are not. The Task Force stresses from the onset that the outputs of life-cycle cost analysis are not decisions in themselves; but rather inputs into the decisionmaking process.

LCC Applications

The Task Force sees two distinct areas where LCCA could be applied within FHWA, i.e., internal and external applications. .The FHWA can use internal applications to support decisionmaking at the national level. External applications are those related to the Federal-aid highway program. Within each area there are multiple application possibilities.

In terms of the Federal-aid highway program, there are several potential decision levels where highway agencies could apply LCCA. These decision levels include but are not necessarily limited to:

State Network Analysis - To evaluate total funding needs and to determine resource allocation levels for the various systems, project categories, or improvement types in relation to established system wide performance goals. The LCCA can also be incorporated into the various management systems required by the ISTEA.

Project Prioritization - To Compare the merits of funding one project in lieu of another.

Pavement Design - To assist in pavement type selection and to evaluate the marginal rate of return for providing premium in lieu of standard pavements.

Materials Specifications - To compare the use of imported premium aggregate versus lower quality, but locally available aggregate.

Total Quality Management - To evaluate the long-term impact of increased attention to quality control. For example, increased expenditure for research and testing equipment may quickly pay for itself.

Operational Analysis - To evaluate catch basin clean out policy, the type and application rates of de-icing chemicals, use of cathodic protection, etc.

Current LCC Policy

Internally, the FHWA already incorporates cost-effective considerations in terms of national level policy development and analysis of alternate investment strategies. The Associate Administrator for Policy incorporates many aspects of life-cycle costing analysis during development of the biennial report to Congress, "Status of the Nations Highway and Bridges." Some LCC principles have been and more will be included in cost allocation studies and in developing and evaluating legislative proposals.

Externally, the FHWA does not specifically require State highway agencies (SHA) to conduct life-cycle costing or economic analysis in support of either program or project level decisions as a precondition for federal-aid funding. This is not true for other US DOT Modal Administrations.

The Federal Transit Administration (FTA) requires development of cost-effectiveness measures based on life-cycle cost analysis in support of grant applications for Section 3 discretionary money. This requirement, called an Alternatives Analysis, must be conducted by applicants at the Draft EIS stage, and the results must be included in the Draft EIS. This Alternatives Analysis requirement has been in place for many years, and the FTA has developed and published specific procedural guidelines on how to conduct it.

In contrast, the FHWA has administered a formula based rather than a discretionary program and has encouraged rather than mandated LCCA in the State and local decisionmaking process affecting Federal-aid highway funds. While FHWA will continue to administer a predominately formula based program, FHWA now administers some discretionary programs. The LCC would appear to have a more substantive roll in discretionary programs.

The FHWA, in its pavement policy, requires SHA's to have a pavement management systems (PMS). In that policy, FHWA defines PMS as a set of tools for finding cost-effective strategies.

At its March 8-10 meeting, the Research and Technology Coordinating Committee developed comments on the FHWA R&T program. Among other comments, the committee noted that, ". . . the lack of attention to life-cycle costs and benefits is a major impediment to the utilization of highway related technologies. Particular effort should be made in the research program to develop novel, user-friendly, and robust methods and tools for life-cycle costing"

ISTEA LCC Provisions

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 specifically addresses LCC under sections 134(f)(12) and 135(c)(20). These sections require that the metropolitan and statewide planning processes incorporate consideration of several factors including "the use of life-cycle costs in the design and engineering of bridges, tunnels, or pavement."

Cost effectiveness is referenced in section 119, "Interstate Maintenance Program." Under subsection 4, it establishes eligibility when a "State can demonstrate . . . that such activities are a cost- effective means . . ."

The ISTEA also addresses LCCA in FTA's Section 3(i) program. The revisions both weaken and strengthen the application of LCC in FTA's Alternative Analysis. While the legislation specifically exempts certain metropolitan areas from Alternatives Analysis requirements, it strengthened the Alternative Analysis requirements in non exempted areas.

One aspect of the ISTEA that presents somewhat of a dilemma for LCCA is the requirement to develop and implement several management systems. While current experience reveals that PMS's can be used to foster systematic decisions based on life-cycle costs, few if any, explicitly incorporate user costs or the time value of money. Most focus on maximizing performance based on fixed budgets. Even in those highway agencies that have PMS's in which budget level and performance impact are directly related, the systems have little to do with ultimate budget decisions.

<u>LCC Analysis Issues</u>

Each LCCA application will, to varying degrees, have its own specific LCC issues. However, some of the more obvious fundamental issues include determining:

(a) the appropriate life cycle and analysis periods
(b) the alternatives that should be included
(c) the performance histories of the alternatives
(d) the cost factors to be included
(e) the actual costs of the various cost factors
(f) the appropriate discount rate

Procedural issues are also a concern. It include concerns over how:

(a) inflation is addressed?
(b) sensitive the results are to the discount rate?
(c) performance history variations are addressed?
(d) Agency Costs and User Costs are incorporated?
(e) SHAs can capture and re-invest user cost savings?

<u>Technical, Policy and Procedural Issues and Limitations</u>

<u>Legitimate Subjective Inputs</u>

Being a form of economic analysis, LCCA has all the strengths, weaknesses, and limitations of traditional economic analysis. Foremost among the weaknesses is the fact that LCCA includes many technical assumptions and policy related positions which directly influence the outcome of such analysis. The assumptions and policy inputs necessary to conduct an analysis can be very subjective and highly susceptible to criticism from all parties impacted by the analysis.

Technical assumptions and policy inputs must be clearly identified along with supporting rational. Rational limits or acceptable ranges should be established for technical inputs and policy related assumptions. Sensitivity analysis should be conducted within the acceptable ranges to evaluate the influence of the parameter being considered.

Alternative Development

Another important LCC issue is assuring consideration of a broad range of alternatives. The LCCA cannot be used to evaluate the economic wisdom of a particular alternative in and of itself. It can only evaluate the relative merits between alternatives. As such, incorporating all viable alternatives is essential. This should include promising new approaches and technology. Unfortunately, estimating the performance lives of alternatives, is at best, both an art and a science even when historical data is available. Untried but promising alternatives inherently incorporate greater risk than the tried and true. This additional risk has to be addressed.

Private industry incorporates risk through the selection of appropriate discount rates. Riskier projects (investments) require prospects of greater (generally 3-5% more) return. The SHA efforts in developing PM Systems and SHRP LTPP research will develop a better understanding of pavement performance relationships and should help in reducing risk.

Performance Equivalency

Implicit in economic analysis is the assumption that performance differences between alternatives can be clearly defined, captured, and reflected in the analytical results. While this is true for some aspects, it is not always the case. All alternatives which have the same "useful life," in terms of either years or loadings, do not necessarily provide equivalent performance over that "useful life."

For example, two competing pavement rehabilitation alternatives with the same pavement life, may very well deteriorate differently. If this is the case, then they will provide different levels of service over their useful lives, even if they reach the same terminal serviceability at the same time (see figure 1).

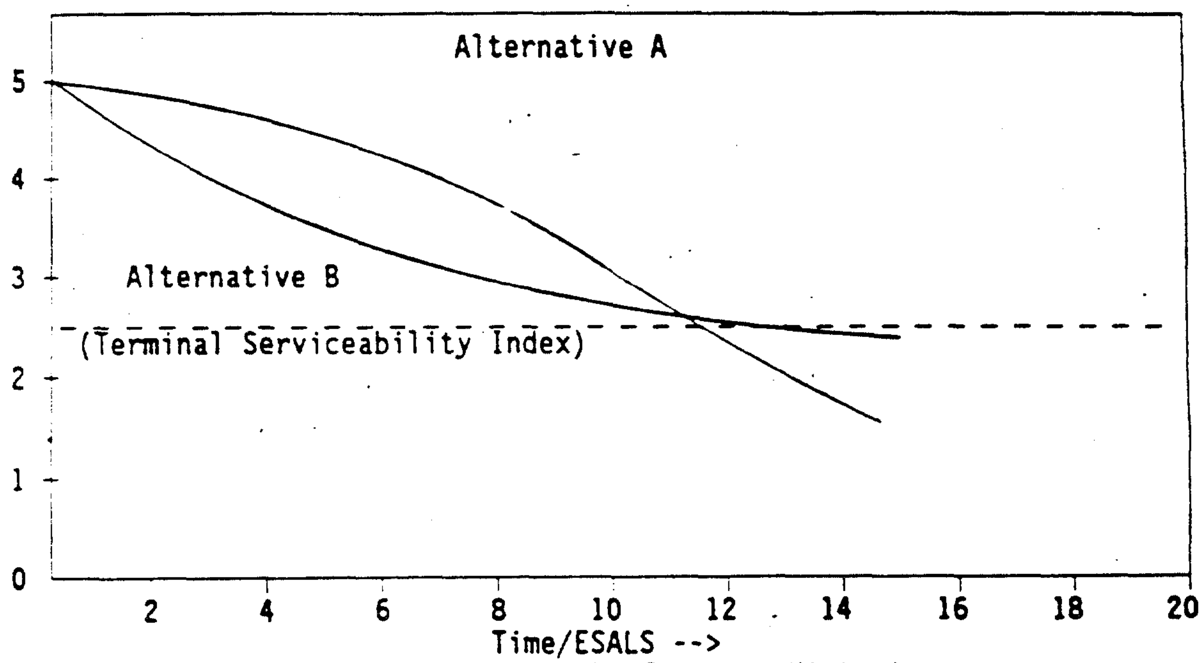


Figure 1 Pavement Performance Histories

Non-costable and Non-quantifiable

In any economic analysis, there are, generally speaking, non- costable and non-quantifiable elements that, none-the-less, need to be considered in the decision making process. The how and the degree to which the non-costable and non-quantifiable elements are addressed is a major issue. While broader scope analysis are more complete, they are not necessarily more accurate.

The degree to which current and future costs and benefits can be accurately estimated severely limit the ability of LCCA to distinguish between of alternatives when LCCA reveals little economic difference. When LCCA results are relatively close (within 10-20% of one another) relative risk and other considerations take on greater significance.

User Costs

Highway user costs, particularly travel time or delay cost, have been controversial. While they may be difficult to quantify and price, construction imposed traffic delays have become, and are likely to continue to be, an ever increasing burden imposed on the public.

Currently, highway agencies have little economic incentive to select alternatives that minimize total (agency plus user) LCC. The alternative with the lowest total life-cycle cost may well be the one that has the lowest user cost but, at the same time, the highest agency cost. Because there are no readily available mechanisms for highway agencies to transform reductions in user costs to additional highway investment capital, the current system encourages highway agencies to minimize agency rather than total costs. This tends to result in significant sub-optimization of total possible benefits.

This issue is addressed to some extent by requiring full maintenance of traffic on heavily traveled routes. Highway agencies are already paying a premium on certain projects for limiting the contractors hours of operation and/or elaborate traffic detours. Highway agencies need to anticipate this trend and incorporate higher future rehabilitation cost in current life-cycle cost analysis.

Marginal Costs

The LCCA is generally used as a means of determining the most economically efficient (some times the cheapest) project from among a set of alternative that adequately meet the minimum performance requirements. This may well be short sighted. Highway agencies need to look at marginal costs, especially when relatively modest total cost increases make significant differences in performance and or service lives. Premium pavements may be economically justified in areas with no alternative routes for maintenance, rehabilitation, and/or reconstruction activities.

Discount Rate

As a minimum, model LCCA procedures should incorporate the time value of money and discount future cost and benefits to a common time. As just noted, such procedures must include internal (highway agency), as well as external (user) costs associated with a highway facility over its intended useful life. Such procedures, however, would have to provide guidance on how to deal with the highway agency's inability to capture user cost saving for future reinvestment.

Procedures

To be practical, LCCA must be conducted using procedures that recognize the policy issues that influence the analysis and explicitly document the policy positions taken in the analysis. The FHWA does not currently have LCCA procedural guidelines. If the FHWA intends to use LCCA internally, it needs to establish procedures governing such applications. If, on the other hand, FHWA expects to encourage consideration of LCCA in State and local highway agency decisions affecting Federal-aid highway funds, FHWA will need to establish LCCA procedural guidelines. From a technical aspect, model procedures should identify and evaluate all viable alternatives and relevant cost factors. They should incorporate techniques for developing accurate cost, performance, and service lives of identified alternatives.

Alternate Approaches

While the Task Force has been able to identify areas where LCCA research would be productive, it believes a more comprehensive look at the entire process as applies to highway investment decisionmaking is warranted. The Task Force further believes that integration of the many debatable positions into a cohesive position on the application of LCC and appropriate guidelines on the conduct of LCCA within the FHWA program would be much more positive contribution.

The Task Force also looked at developing an in-house working group to review the literature and identify and conduct the needed research. The Task force believes FHWA does not have sufficient manpower in the appropriate multi-disciplinary fields available to make a significant contribution to advancing LCC within FHWA. LCC embraces many complex issues; some are readily apparent, others are more subtle. Prior to more active FHWA involvement, endorsement, or technical support of LCC, FHWA sponsored research is necessary to:

(1) more clearly define, explore, and resolve identified LCC issues;
(2) identify and explore other important LCC issues not currently identified; and
(3) develop a comprehensive approach to incorporate the research findings into integrated procedures for the various LCC applications.

Policy Recommendations

The Task Force recommends that FHWA policy explicitly promote the long-term cost-effective use of Federal funds, both in its internal operations and in the Federal-aid highway program.

The FHWA should continue to use LCCA and cost-effectiveness considerations in its internal operations to evaluate the condition and performance trend of the Nation's highways, and to determine whether or not we are using resources to the maximum advantage in achieving the national transportation goals. Other internal applications could include developing and analyzing highway investment policy, developing and evaluating cost allocation studies, and evaluation of competing IVHS technologies and other R&D activities.

The FHWA should increase its efforts to encourage, support, and implement State and local use of life-cycle cost analysis principles at all decision levels. It should develop model LCC guidelines, building on extensive existing LCCA knowledge base including that of State and local highway agencies. The FHWA should make these LCCA guidelines available to highway agencies and require consideration of LCC in the Urban and Statewide Planning processes. The FHWA should also require the development of LCC and cost-effectiveness information as part of each ISTEA mandated management system.

In response to specific ISTEA LCC requirements, FHWA should focus on program rather than project specific requirements. The FHWA should provide guidance on conducting LCCA, require that it be conducted, and ensure that the results are explicitly considered in the decisionmaking process. It should <u>not</u> become involved in conducting or reviewing/approving actual LCCA's conducted by State and local highway agencies, even on Federal-aid highway program funded projects.

<u>Research Recommendations</u>:

In order to move forward with LCCA, FHWA should initiate research and training, necessary to foster improved LCC analysis at all decision levels.

Because of the financial/economic focus, the research should be conducted by a multi-disciplinary team that draws on the strengths of economists, financial analysts, and other appropriate disciplines, as well as the highway engineering community.

Because of the enormity and complexity of LCCA and the pervasiveness of potential application opportunities, it will be difficult to formulate a comprehensive research work plan with existing in-house resources.

The Task force recommends that FHWA pursue a two-phase LCCA contract research effort as follows:

Phase I - an innovative exploratory research effort.

Phase II - a traditional, in depth, detailed research effort into specific LCCA issue areas identified in phase I.

<u>Phase I - Exploratory Research</u>

The exploratory research phase would require that selected contractor(s) develop an inter-disciplinary team acceptable to FHWA that would;

1. Explore policy issues and the implications of various FHWA courses of action.

2. Identify specific LCC research needs associated with the courses of action identified.
3. Develop a detailed work plan and cost proposal that addresses the specific research needs identified.

Because of the complexity of LCCA, and the relatively inexpensive cost anticipated for the exploratory research, the Task Force believes it would be extremely beneficial (i.e., cost effective from a LCC perspective) to fund multiple research teams for this early stage research. The Task Force envisions awarding multiple contracts under one primary exploratory research contract. The exact number of exploratory research contracts to be funded would be based on the responses received to the request for proposals (RFP).

Phase II - Detailed Research

The Phase II research component is basically designed to carry out the specific research that will be proposed in the detailed work plans developed by the inter-disciplinary teams under Phase I. Upon completion of the Phase I exploratory research, FHWA would evaluate the research team(s) findings and proposed work plans. At that point, FHWA would decide whether to fund of all or part of the research activities identified by one or all the exploratory research contractors. The Task Force envisions the Phase II component would be an option included in the Phase I research contract.

On completion of this proposed two-phase research effort, FHWA will still need to consolidate the various research teams efforts, produce LCCA guidelines, and where necessary, develop LCCA policy, technical advisories, and possibly regulations. The Task Force recommends that the final component would be to establish appropriate training program(s).

With the concurrence of the Research and Development Executive Board, the Task Force will establish a LCCA working group to develop an RFP consistent with the preceding recommendations. Preliminary estimates are that an RFP could be ready for early FY 93 Funding. Funding for the second phase would not be necessary until FY 94.

Federal Highway Administration

[FHWA Docket No. 94–15]

Life-Cycle Cost Analysis

AGENCY: Federal Highway Administration (FHWA), DOT.

ACTION: Interim policy statement; request for comments.

SUMMARY: This FHWA policy statement on life-cycle cost analysis (LCCA) helps fulfill Federal management responsibilities for analyzing life-cycle cost aspects of infrastructure investment decisions under Executive Order 12893, "Principles of Federal Infrastructure Investment." The policy statement establishes LCCA principles to be applied by FHWA in infrastructure investment analyses, and in evaluating the adequacy of State highway agency procedures used in conducting required LCCA for investments funded through the Federal-aid highway program. States and local agencies are expected to apply these principles in evaluating program and project level investment decisions involving Federal-aid highway funds as required under applicable FHWA regulations. Comments are solicited on potential problems in implementing provisions of this policy statement and specific needs for training and technical assistance in LCCA.

DATES: This interim policy statement is effective on July 11, 1994. Comments on the interim policy statement must be received on or before October 11, 1994. A final LCCA policy statement will be published that takes into consideration comments received on this interim statement.

ADDRESSES: Submit written, signed comments concerning this interim policy statement to FHWA Docket No. 94–15, Federal Highway Administration, room 4232, HCC–10, Office of the Chief Counsel, 400 Seventh Street, SW., Washington D.C. 20590. In addition to specific comments on this policy statement, comments are requested on training and technical assistance needed to implement LCCA. All comments received will be available for examination at the above address between 8:30 a.m. and 3:30 p.m. e.t. Monday through Friday, except legal Federal holidays.

FOR FURTHER INFORMATION CONTACT: Mr. James W. March, Chief, Systems Analysis Branch, (202) 366–9237, or Mr. Steven M. Rochlis, Legislation and Regulations Division, (202) 366–1395, Federal Highway Administration, 400 Seventh Street SW., Washington D.C. 20590.

SUPPLEMENTARY INFORMATION:

Background

There is an increasing recognition that total life-cycle costs of highway and transportation investments must be given greater consideration in all phases of highway programs. Executive Order 12893, "Principles of Federal Infrastructure Investment," requires that benefits and costs of infrastructure investment be measured and appropriately discounted over the full life cycle of each project. Sections 1024 and 1025 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) (Pub. L. 102–240, 105 Stat. 1914, 1977) also require consideration of "the use of life-cycle cost in the design and engineering of bridges, tunnels, or pavement." Subpart B of the interim final rule on implementation of ISTEA management systems (23 CFR 500.207) requires use of LCCA for pavement management systems (PMS) and Subpart C (23 CFR 500.307) requires use of LCCA or comparable techniques for bridge management systems (BMS).

Life-cycle cost analysis is an economic evaluation of all current and future costs associated with investment alternatives. It is a valuable economic analysis technique for evaluating highway and other transportation programs and projects that require long-term capital and maintenance expenditures over the extended lives of facilities. Future costs are discounted using an appropriate discount rate to compare costs incurred at different points in time.

Life-cycle cost analysis principles and techniques are used in many types of economic analysis to compare benefits and costs arising at different points in time. Benefit-cost analysis and cost effectiveness analysis, for instance, use life-cycle cost analysis principles to discount future benefits and costs of investment alternatives over the lives of alternatives being evaluated.

Life-cycle cost analysis is used to evaluate programs of pavement and bridge improvements as well as individual projects. It is an important input to estimates of future funding requirements and to the development of improvement programs, especially when there are budget constraints.

The use of value engineering is receiving increased attention as a technique for analyzing the functions of a program, project, system, product, or service to identify opportunities to significantly lower costs while still achieving the essential functions. Life-cycle costs are often analyzed to ensure that unnecessary costs are avoided by considering future operations, maintenance, and reconstruction requirements.

Total life-cycle costs of specific facilities may be many times the initial construction costs when user costs are considered. It is essential that a long term perspective be taken in programming improvements, selecting among alternative maintenance, rehabilitation, and reconstruction strategies, and designing pavements, structures, and other highway elements. Longer design lives may have to be considered, and traditional strategies for programming maintenance and rehabilitation activities may have to be reevaluated to determine whether they adequately consider future costs, including user delay-related costs.

Increasing congestion on important highways in urban areas and some rural areas makes it critical to fully consider life-cycle costs of investment decisions. Safety concerns and auxiliary construction costs to maintain, rehabilitate, or reconstruct congested highways and bridges under traffic are very high. User costs and delays around work zones in congested areas may be even higher and represent significant inefficiencies that may adversely affect economic productivity, especially on the National Highway System (NHS). These delays can erode productivity gains realized by the growing number of industries using just-in-time and other advanced logistics strategies that depend on efficient and predictable transportation.

Regardless of whether user costs are included in a formal LCCA, most States already implicitly consider user costs when they choose to pay premiums to maintain traffic through work zones or design more durable pavements in congested urban areas. Including user costs in LCCA makes these implicit considerations explicit, and may help identify other opportunities to reduce overall agency and user costs.

Recognition of the high future costs to maintain and rehabilitate highways, bridges and tunnels, and their associated traffic control, safety, environmental, and hydraulic components has led to increased interest in the potential for LCCA to improve investment productivity and reduce public and private costs of highway and other transportation programs. The FHWA and the American Association of State Highway and Transportation Officials (AASHTO) jointly sponsored a symposium in December 1993 to learn more about LCCA practices among the States and to identify research, training, technical assistance, and policy-related needs to improve LCCA application. An important input to that symposium was an AASHTO survey of State LCCA practices.

Many specific LCCA issues and research needs were identified at the symposium. Key technical issues included how to establish the appropriate analysis period, how to value and properly consider user costs, and how to choose the appropriate discount rate. Participants also identified important research and data needed to predict pavement and bridge performance and forecast future traffic.

An important policy issue raised at the symposium was the recognition that results of LCCA may favor selection of improvements with higher initial costs in order to achieve significant long term savings in overall investment requirements. It may indicate, for instance, that more projects warrant reconstruction rather than rehabilitation strategies, that early intervention with preventive maintenance is cost effective, or that somewhat higher designs or levels of service may be appropriate for some facilities. The FHWA recognizes that LCCA, thus, may result in proposals for greater expenditures up front. At the same time virtually all transportation agencies will continue to face budgetary limitations at least over the short term. Life-cycle cost analysis will help agencies identify and explain the real costs borne by transportation users of inadequate infrastructure funding. Furthermore, LCCA can assist agencies that face fiscal constraints in making the best use of available funds. Several States already use LCCA in developing network improvement programs as part of their pavement and bridge management systems. Eventually it is desirable for all States to have such capabilities.

The following paragraphs highlight key principles of good LCCA practice. Applying these principles generally will allow States and local agencies to identify investment alternatives that will minimize total life-cycle costs. While their use is not mandatory in all instances, States are strongly encouraged to apply these principles in conducting life-cycle cost analyses unless there are unique characteristics of particular programs or projects that require principles to be modified. Life-cycle cost analysis, of course, is only one consideration in many investment decisions, but it certainly is one of the most important for NHS routes and other high volume roads in light of the costs and lost productivity associated with future maintenance and rehabilitation actions.

In general there are no hard and fast rules concerning the appropriate length of the analysis period. The analysis period will vary depending on the type of improvement (bridge, versus tunnel, versus pavement), the location (urban versus rural), the highway system (NHS versus other), and the design lives of all appropriate alternatives. In general, longer design lives should be considered for improvements on the NHS and other high volume urban roadways because future agency and user costs associated with maintenance and rehabilitation activities may be so high. For pavement improvements on the NHS, design lives of 50 years may be reasonable while bridge and tunnel improvements may have design lives of

100 or more years. The consideration of longer design lives will require longer analysis periods in LCCA. Analysis periods for projects involving other modes generally should be long enough to cover the full life-expectancy of the investment—the time until facilities would have to be reconstructed if initially constructed to an optimum design. These lives would vary according to the modal alternative being examined. Analysis periods for all project alternatives should be the same length.

The inclusion of user costs in LCCA is particularly controversial among some States. Part of the controversy over user costs is the fact that they often are many times higher than agency costs and can critically influence decisions. While all motorists do not value costs of delays as highly as do commercial travelers, the costs and lost productivity to businesses of delays around work zones are simply too high to ignore. In fact, such delays arguably have a greater impact on business than delays associated with inadequate capacity because businesses factor normal congestion costs into their plans; but delays around work zones generally cannot be foreseen and thus are more disruptive. Technical advisories to be developed on estimating user operating and delay costs will address this issue in greater detail.

In addition to increased delay and vehicle operating costs, rehabilitation and maintenance activities may result in increased accident costs around work zones. Technical advisories will be developed to assist in estimating increases in accident rates associated with different types of rehabilitation and maintenance activities. The most comprehensive information on the costs of motor vehicle accidents is contained in the National Highway Traffic Safety Administration's publication, "The Economic Cost of Motor Vehicle Crashes, 1990." A copy of this document is available in the public docket for this notice.

The proper use of the discount rate has been an issue for LCCA, cost-benefit analysis and other types of economic analysis as well. Among the issues are the relationship between the discount rate and inflation, factors that affect the choice of rates, and how to establish rates over a long analysis period. Office of Management and Budget (OMB) Circular A–94, "Guidelines and Discount Rate for Benefit-Cost Analysis of Federal Programs," provides guidance on selecting appropriate discount rates for economic analyses. Since the choice of discount rate can affect relative life-cycle costs, sensitivity analysis may be appropriate if two or more alternatives are close in cost, if streams of costs and benefits among alternatives vary significantly over time, or if the discount rate is outside the range of discount rates recommended by OMB.

The FHWA will develop training and technical assistance materials to address issues in LCCA. These materials should supplement guidance on economic analysis techniques contained in AASHTO's 1977 publication, "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements,"[1] the "Red Book," in the forthcoming update to that publication which was developed under National Cooperative Highway Research Program Project 7–12, and in other guidance on LCCA issues. While additional materials are being developed, this interim policy statement provides guidance on LCCA principles applicable to highway and structure design.

The FHWA is reviewing its policy on alternative bridge designs (53 FR 21637, June 9, 1988) for consistency with this interim life-cycle cost analysis policy as well as with Executive Order 12893.

Policy

The following is FHWA's LCCA policy for infrastructure investment analyses. It represents good practice that should be followed by States and local transportation agencies in making program and project investment decisions:

1. Life-cycle costs are an important consideration in all highway investment decisions.

2. The level of detail in LCCA should be commensurate with the level of investment involved and the types of alternatives being analyzed. Investments on the NHS generally warrant more detailed analysis than investments on non-NHS routes. Similarly, evaluation of decisions whether to reconstruct or rehabilitate a facility warrants more detailed analysis than consideration of alternative maintenance strategies.

3. Typical life-cycle cost analysis profiles may be developed and used as the basis for evaluating alternatives for general types of improvements, such as, consideration of alternative pavement designs or different types of bridges on various functional class highways. Major programs and projects, however, often will require consideration of a broad range of alternative rehabilitation and reconstruction options and more detailed analysis of potential alternatives. The potential applicability and use of LCCA profiles will be discussed in greater detail in future technical advisories.

4. Other factors, including budgetary, environmental, and safety considerations, legitimately influence highway investment decisions and should be considered along with the results of LCCA in evaluating investment alternatives. Life-cycle cost analysis principles should be used in conjunction with other appropriate economic analysis techniques in pavement and bridge management systems. Systemwide or network objectives as well as project level concerns should be considered in decisionmaking, and both levels of analysis should consider life-cycle costs.

5. Analysis periods should be for the life of the facility or system of facilities being evaluated and should account for costs of foreseeable future actions. Analysis periods should not be less than 75 years for major bridge, tunnel, or hydraulic system investments, and not less than 35 years for pavement investments. Longer design lives may be appropriate for the NHS or other major routes or corridors.

6. All appropriate agency costs anticipated during the analysis period should be considered in the analysis, including traffic control costs during maintenance and rehabilitation, costs of special construction procedures required to maintain traffic, and agency operating costs for such things as tunnel lighting and ventilation. In those cases where the agency required to operate a facility is not the one making the investment decision, it is important for the funding agency to include operating costs borne by other organizations responsible for operating the facilities.

7. User costs including increased vehicle operating costs, accident costs, and delay-related costs incurred throughout the analysis period should be considered in LCCA. Increased costs due to deteriorated riding surfaces, circuitous routings, and accidents and delays around and through maintenance and construction work zones are all important.

8. Future agency and user costs should be discounted to net present value or converted to equivalent uniform annual costs using appropriate discount rates. Discount rates selected should be consistent with guidance provided in OMB Circular A–94.

[1] This document is available for inspection as prescribed at 49 CFR Part 7, Appendix D. It may be purchased from the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, NW., Suite 225, Washington DC 20001. A copy also will be available in the public docket for this notice.

Technical advisories on these and other technical issues in the application of LCCA will be issued by FHWA in the future.

Issued on: June 30, 1994.

Rodney E. Slater,

Federal Highway Administrator.

[FR Doc. 94-16719 Filed 7-8-94; 8:45 am]

BILLING CODE 4910-22-P

Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: INFORMATION: 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) Implementation Interstate Maintenance Program

Date: MAY 21 1992

From: Associate Administrator for Program Development

Reply to Attn of: HNG-13

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

The purpose of this memorandum is to provide written guidance regarding the provisions in the 1991 ISTEA which created the Interstate maintenance (IM) program.

Authorizations - Section 1003

Section 1003(a)(1) establishes the first annual authorizations for the IM program for FY 1992 through FY 1997, in amounts ranging from $2.431 billion to $2.914 billion.

Apportionments - Section 1009

Section 1009 modified Section 104(b)(5)(B) of Title 23, which previously established the apportionment formula for the I-4R program. The formula remains based on the same factors, lane-mile (55 percent) and vehicular miles of travel (45 percent), for apportioning IM funds, but the formula now includes those Interstate routes designated under Sections 103 and 139(c) of Title 23 plus Interstate routes designated under 23 U.S.C., Section 139(a) before March 9, 1984 (except toll roads not subject to a secretarial agreement as provided in Section 105 of the Federal-Aid Highway Act of 1978). Section 104(b)(5)(B) of Title 23 provides that no State shall receive less than one-half percent of the total IM funds apportioned annually.

The certificate of apportionment of FY 1992 funds was transmitted by the FHWA Notice N 4510.264 dated December 18, 1991.

Availability - Section 1020

Section 1020(a) rewrites 23 U.S.C. 118 and provides that IM funds shall remain available for obligation in a State for a period of 3 years after the last day of the fiscal year for which they are authorized. For example, FY 1992 funds were apportioned on December 18, 1991, and will lapse on September 30, 1995, and FY 1993 funds will be apportioned on October 1, 1992, and will lapse on September 30, 1996.

Federal Share - Section 1021

Section 1021(a) provides that the Federal share on all IM projects shall be 90 percent, except as modified in States with sliding scales.

Eligibility - Section 1009

Section 1009(e)(5) amends 23 U.S.C. 119(a) to permit the Secretary to approve IM funded projects for resurfacing, restoring, and rehabilitating routes on the Interstate System designated under Sections 103 and 139(c) of Title 23, and routes designated prior to March 9, 1984, under Section 139(a) and (b) of Title 23.

Section 1009(e)(3) amends Section 119(c) of Title 23 to establish types of work eligible for IM funding. The section has been interpreted to include as eligible, those work items which provide for 3R work on existing features on the Interstate route and its interchanges and grade separations within normal "touchdown limits." For example, the rehabilitation of existing roadside hardware may include IM funding for work such as bringing old guardrail up to current standards, maintenance of impact attenuators, refurbishing existing traffic control signs, pavement markings, and other devices, etc. However, excluded from eligibility for IM funding are all new work elements, such as new interchanges, new ramps, new rest areas, new noise walls, or other work which does not resurface, restore, or rehabilitate an existing element.

Existing bridges (including over crossing structures) may be replaced with IM funds, provided they meet the structurally deficient criteria of the bridge program. Bridges classified as functionally obsolete may also be replaced with IM funding, except that capacity expansion elements should be subject to the limitations discussed in the following paragraphs.

Section 1009(a) prohibits IM funding for the portion of the cost of any project attributable to the expansion of the capacity of any Interstate highway or bridge, except for the addition of high-occupancy vehicle lanes or auxiliary lanes (such as truck climbing lanes).

In determining what portion of a project is eligible for IM funding and what portion is capacity expansion (and, therefore, not eligible for IM funds), the basic purpose of the project should be considered. If the project is a combination of preservation and capacity expansion, the cost should be split with 3R items eligible for IM funding and capacity expansion items eligible for other funds. In determining the split, it may be helpful to visualize the project without the capacity expansion work (added lanes, bridge widening or extension for example) and allow IM funding for all necessary 3R items.

Section 1009(e)(4) amends 23 U.S.C. 119(e) to allow IM funding for preventative maintenance activities, which a State can demonstrate through its pavement management system, are a cost-effective means of extending Interstate pavement life. Preventative maintenance includes activities such as sealing joints and cracks, patching concrete pavement, shoulder repair, and restoration of drainage systems which are found to be cost-effective projects resulting in extending the service life of pavements.

This provision has been extended administratively to allow IM funding for other preventative maintenance activities. Examples may include structure work such as crack sealing, joint repair, seismic retrofit, scour countermeasures, and painting of steel members which are cost-effective in extending the service life of the structure.

Toll Roads, Bridges and Tunnels - Section 1012

Section 1012(d) provides that existing toll agreements entered into under Section 119(e) or 129 of Title 23 prior to and in effect on the date of enactment of the 1991 ISTEA, shall continue in effect. All new agreements must be executed in accordance with the provisions of the 1991 ISTEA. Guidance on the use of Federal-aid funds on toll roads has been provided by Mr. Kane's memorandum of March 12, 1992.

Discretionary Funds

There is no provision for set aside of funds from the IM program for discretionary purposes. Also there is no provision for reallocation of apportioned IM funds which lapse at the end of the availability period.

Section 1020 does provide for a continuation of the I-4R discretionary fund program that is separate and distinct from the IM program. The source of the I-4R discretionary funds is an annual set aside from National Highway System (NHS) funds. These I-4R discretionary funds may be used for IM-type projects or for other improvements on the Interstate including projects to provide additional Interstate capacity. A memorandum was issued on December 20, 1991, which outlined procedures for applying for FY 1992 I-4R discretionary funds. A similar memorandum will be issued annually.

Transferability - Section 1009

Section 1009(e)(5)(D) and (E) modifies 23 U.S.C. 119(f) to allow a State to unconditionally transfer an amount not to exceed 20 percent of its IM apportionment to its apportionments under 23 U.S.C. 104(b)(1) for the NHS, or 23 U.S.C. 104(b)(3) for the Surface Transportation Program (STP).

Section 1009(b) further amends 23 U.S.C. 119(f) to allow a State to transfer an amount in excess of the 20 percent unconditional IM fund transfer, if the State certifies to the Secretary that (1) the sums to be transferred are in excess of its needs for resurfacing, restoration or rehabilitating its Interstate System routes and (2) the State is adequately maintaining the Interstate System, and if the Secretary accepts the certification.

State requests to transfer IM funds should be submitted to the Division Administrator and may be approved by the Regional Federal Highway Administrator. Funds transferred into the STP will be transferred into the State Flexible Appropriation Code 33D.

Adequate Maintenance of the Interstate System

Requirements for the State to certify that it is adequately maintaining the Interstate System and that the Secretary develop criteria for determining what constitutes "adequate maintenance" were added by Section 1009(c)(2).

We anticipate that formal rulemaking may be necessary to allow input from the States in the development of definitive guidance on what constitutes adequate maintenance. Therefore, for the purpose of evaluating State requests to transfer IM funds, in excess of the 20 percent unconditional amount, and until such time as these criteria are established, the guidance contained in the Federal-Aid Policy Guide, CFR 635E and its supplement (old FHPM 6-4-3-1) should be used for determining whether the State is adequately maintaining the Interstate System.

Headquarters Contacts

This guidance will be updated in the future if further clarifications are found necessary. Questions about what constitutes adequate maintenance of the Interstate System should be directed to the Construction and Maintenance Division (HNG-21). Pavement management systems are coordinated by the Pavement Division (HNG-41). Other questions about the IM program should be directed to the Interstate and Program Support Branch (HNG-13).

Anthony R. Kane

U.S. Department
of Transportation
Federal Highway
Administration

Memorandum

Subject: INFORMATION: Preventive Maintenance

Date: JUL 27 1992

From: Associate Administrator for
Program Development

Reply to Attn of: HNG-10

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

Section 119 of Title 23, United States Code, was amended by the Intermodal Surface Transportation Efficiency Act of 1991 to provide specific Federal-aid fund eligibility for preventive maintenance on Interstate highways.

We consider preventive maintenance to include roadway activities such as joint repair, pavement patching, shoulder repair, and restoration of drainage systems, and bridge activities such as crack sealing, joint repair, seismic retrofit, scour countermeasures, and painting. Such work is eligible for Federal-aid participation where the work is determined to be cost-effective for preserving the pavement and bridge structure and extending the pavement and bridge life to at least achieve the design life of the facility.

Due to the nature of preventive maintenance type work, the Division Administrator may approve a request to advance this type of project on Interstate highways without including safety or geometric enhancements, but with the understanding that appropriate safety and geometric enhancements will be an integral part of future 3R/4R projects. This approach may also be applied to minor work the Division Administrator considers eligible for Federal-aid funding on other Federal-aid highways. Preventive maintenance or minor work items shall not degrade any existing safety or geometric aspects of the facility.

Anthony R. Kane

U.S. Department
of Transportation
Federal Highway
Administration

Memorandum

Subject INFORMATION: Interstate Maintenance Program

Date June 14, 1993

From Executive Director

Reply to Attn of HNG-21

To Regional Federal Highway Administrators
Division Administrators
Federal Lands Highway Program Administrator

Over the last decade, the State highway agencies have carried out necessary resurfacing, restoration, rehabilitation and reconstruction (4R) of Interstate highways in accordance with the provisions of 23 U.S.C. 119 using funds apportioned under 23 U.S.C. 104(b)(5)(B). Since there was no differentiation in eligibility or pro rata funding for the various classes of work, there was not a need to develop strict definitions for determining whether the proposed work was resurfacing, restoration, rehabilitation or reconstruction. General definitions for pavement reconstruction and pavement rehabilitation (3R) are included in the "Pavement Policy" (23 CFR 626) which was established in 1988.

Currently, some questions pertaining to the definitions for rehabilitation and reconstruction have been raised since Section 1009(e) of the ISTEA of 1991 generally eliminated reconstruction on the Interstate System from eligibility under 23 U.S.C. 119, Interstate Maintenance (IM) Program. As revised, this section promotes maintenance of the Interstate System through approval of projects for resurfacing, restoration and rehabilitation, and through preventive maintenance activities.

Preventive maintenance includes restoration or rehabilitation of specific elements of a highway facility when it can be demonstrated that such activities are a cost-effective means of extending the pavement life. The list of specific work elements which are generally accepted as extending the service life of pavements and bridges is extensive. In general, any work which provides additional pavement structural capacity (general overlays or replacement of portions of the pavement structure), or prevents the intrusion of water into the pavement or pavement base (seal coats, joint seals, crack seals, overlays), or provides for removal of water that is in the pavement or pavement base (underdrains, restoration of drainage systems), restores pavement rideability (profiling, milling), or prevents the deterioration of bridges (cleaning and painting, seismic retrofit, scour countermeasures, deck rehabilitation or repair, deck drain cleaning) are considered to be work which extends the service life of the highway. These typical preventive maintenance work items are not intended to be all inclusive but are rather a limited list of examples. The changes made by Section 1009(e) of the ISTEA of 1991 allow considerable flexibility in determining, based on good engineering analysis, the most cost-effective method of extending the service life of the existing Interstate pavements and bridges.

Each of the States either have, or are in the process of developing pavement, bridge and other management systems in response to the ISTEA of 1991 and previous FHWA policies. One of the purposes of a pavement management system is to identify cost-effective strategies for proposed pavement work. In some cases, the most cost-effective pavement strategy may be removal and replacement of all or part of a badly deteriorated pavement structure. However, if a removal and replacement strategy is considered ineligible for IM funding, a less cost-effective strategy may be selected by the State based only on the class of available funding. Forcing any particular strategy based primarily on availability of funds would not provide the public with the best use of Federal-aid funds. Therefore, in order to provide the States with necessary flexibility and still meet the intent of the revised 23 U.S.C. 119, pavement work which is identified by the State's pavement management system as being cost-effective, including removal and replacement strategies, where no additional capacity is provided is eligible as an IM Program funded project.

Reconstruction on the Interstate System may still be approved; however, unless the proposed work meets the eligibility requirements of 23 U.S.C. 119(c), such work must use funds other than those apportioned under 23 U.S.C. 104(b)(5)(B).

Mr. Anthony R. Kane's May 21, 1992, memorandum on "1991 Intermodal Surface Transportation Efficiency Act (ISTEA) Implementation Interstate Maintenance Program" listed, as examples, several types of improvements which were not eligible for IM funding. The example concerning "new ramps" has created some confusion. As a result, further clarification is necessary.

After reviewing the legislation, we have determined that the addition of new ramps at existing interchanges is properly a part of "interchange reconstruction" and does not constitute added capacity under 23 U.S.C. 119(g). Eligible new ramps may include those associated with reconstruction of existing interchanges necessitated by traffic growth or operational problems. Examples might include the addition of one or more loops to an existing diamond interchange, the addition of a directional ramp to relieve Interstate traffic congestion, or the addition of a ramp or ramps to provide a missing traffic movement. These examples are also not intended to be all inclusive. In general, new ramps associated with the reconstruction of an existing interchange are eligible for IM funding and conversely, new ramps on an Interstate route where there is presently no existing interchange are not eligible for IM funding.

In addition to these comments and guidance concerning pavement and interchange eligibility, any proposals for IM funded projects should include considerations for safety or geometric enhancements in accordance with Mr. Kane's July 27, 1992, memorandum on "Preventive Maintenance."

E. Dean Carlson

McTrans

CATALOG

Mc*Trans* (Center for Microcomputers in Transportation), is a software distribution and user support center, originally established by the Federal Highway Administration (FHWA), and now supported by the Federal Transit Administration (FTA). The Mc*Trans* Center provides support to microcomputer users through technical assistance of the software it distributes.

Our goal is to serve as the *nation's primary center for* technical support and distribution of highway transportation and transit software. With a staff of experts in a wide range of specialties, Mc*Trans* fields inquiries on a variety of subjects, such as: *what programs are available for your needs, which computer should be purchased to run your software, and help with specific programs.*

As a support center, we learn about what software others are using and hear about programs that you are looking for. Feel free to call Mc*Trans* with your questions: 1-800-226-1013 (24-hour message hotline); (904) 392-0378; Fax: (904) 392-3224; or logon to McLink, our 24-hour electronic bulletin board, (904) 392-3225.

McFinder, the Mc*Trans* catalog-on-disk, is updated quarterly. This catalog is updated annually, with quarterly updates in the Mc*Trans* Newsletter. Both can be obtained free on request.

N **NEW PRODUCTS** since June 94

U **UPDATES** since June 94

Carson City PMS

The Carson City Pavement Management System was developed under an FHWA Rural Technical Assistance Program (RTAP) project. Road inventory data include street name, segment limits and location, subgrade strengths, lengths, widths and surrounding land uses. Structural information includes presence of curb and gutter, shoulder width, surface and base type, thickness and deflection. The condition survey includes information on ride quality, alligator cracking, ravelling and longitudinal plus traverse cracking as the recorded forms of distress; and acceptable, tolerable and unacceptable listed as the three degrees of severity. The total quantity of each distress and severity combination is recorded for each street segment and deduct values assigned. Traffic survey information includes volumes and classification.

The type and extent of distress determine the rehabilitation strategy alternative. The ride quality, alligator cracking and status of surface ravelling are checked. Then, depending on the traffic index (a measure of truck volume and weights), a maintenance and rehabilitation treatment is recommended. Priorities are assigned based on a cost-benefit ratio determined as a function of cost-per-vehicle-mile. Cost estimates are then applied and listed with the expected life cycle before new treatments are required.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.1+ (384K and Hard Disk)

Supporting Software: dBASE III+

Product#	Description	Price
CCPMS	Carson City PMS, 7/89	$50
CCPMS.D	Documentation	$10

ELSYM 5

ELSYM 5 is a computerized procedure which models a three-dimensional idealized elastic layered pavement system. It computes the various component stresses, strains, and displacements along with principal values at locations specified by the user, within the layered pavement. This program was developed for the Federal Highway Administration.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.1+

Product#	Description	Price
ELSYM	ELSYM5, 12/86	$40
ELSYM.D	Documentation	$5

EXPEAR

EXPEAR (EXpert system for Pavements Evaluation And Rehabilitation) is a comprehensive computerized system to assist engineers in evaluating concrete highway pavements, developing feasible rehabilitation alternatives, and predicting the performance and cost effectiveness of the alternatives. In its current state of development it is considered an excellent training tool. Some modifications would be required to make this program suitable for routine use.

A computer program has been developed for each of the three pavement types: Jointed Plain Concrete Pavement (JPCP), Jointed Reinforced Concrete Pavements (JRCP), and Continuously Reinforced Concrete Pavement (CRCP). The current version is EXPEAR 1.4 which possesses the capability to do life-cycle cost analysis and to delay rehabilitation up to five years.

EXPEAR was developed by the University of Illinois at Urbana-Champaign under FHWA administrative funded or Highway Planning and Research funded contracts. Further work to enhance the capabilities of EXPEAR is proposed. A hard disk is recommended both for speed of execution and storage of data files.

EXPEAR comes from Kathleen T. Hall of the University of Illinois. A supplemental document describing the Concrete Pavement Evaluation and Rehabilitation System is also available.

LOS: 3

Operating System: IBM PC/MS-DOS 3.0+

Product#	Description	Price
EXPEAR	EXPEAR, Ver.1.4	$45
EXPEAR.D	Documentation	$20
EXPEAR.DS	Supplemental Document	$25

HDM-III and HDM-PC

HDM-III and HDM-PC (Highway Design and Maintenance Standards Model) is designed to make comparative cost estimates and economic evaluations of different construction and maintenance options, including different time staging strategies, either for a given road section or an entire network. The concept can simply be outlined as: determining costs, adding the set of costs over time and comparing the total cost streams for various maintenance and construction alternatives.

HD-PC includes the core HDM-III model, a facility to input data, a mechanism to use the outputs with Lotus 1-2-3, and a constrained version of the Expenditure Budgeting Model (EBM). If HDM is used with the EBM, it is capable of comparing options under year-to-year budget constraints.

The basic data requirements are the network description, construction options, maintenance standards and unit costs, vehicle characteristics and unit costs, traffic volumes and projections, exogenous benefits and costs, and analysis period and discount rates. The program is distributed exclusively by **McTrans** under license from the World Bank in Washington, DC.

The HDM-PC comes in two versions: 1) fully supported, which includes free technical assistance and updates and 2) unsupported, which has no support services. Both include the HDM-PC User's Manual and the EBM. The EBM may also be purchased separately (PC only). The mainframe version is only available as fully supported. The main HDM-III documentation (HDM.DV1 and .DV2 below), which describe the model in detail, must be purchased separately.

A French version of HDM III is available from PENDC of Paris or through **McTrans**. Call for details.

LOS: 1 (Copyright 1988, the World Bank)

Operating System: IBM PC/MS-DOS 2.2+ (640K and Hard Disk) and Mainframe

Product#	Description	Price
HDM	Fully supported HDM-PC, Ver.2.0 (incl. EBM, User's Manual, Volumes 1, 2 and HDM Manager)	$400
EBM	Fully supported version of EBM (incl. User's Manual)	$60
HDM.UPG	Upgrade to supported	$300
HDM.UN	Unsupported HDM-PC (incl. EBM and User's Manual)	$100
EBM.UN	Unsupported version of EBM (incl. User's Manual)	$30
HDM.D	Extra copies of HDM-PC User's Manual	$15
HDM.DV1	HDM model documentation Vol. 1: Description of HDM-III	$20
HDM.DV2	HDM model documentation Vol. 2: User's Manual for HDM-III	$25

HDM Manager

HDM Manager is a user-friendly shell environment for specific customized applications of HDM-III. It stores the input data in an efficient manner, creates all the required HDM-III input files, runs the HDM-III program, collects the results and presents the results in a practical way. It provides a simple but powerful package for learning and using the major concepts of HDM-III.

HDM Manager is designed to be used with the full HDM-III package and documentation, which must be obtained separately. HDM Manager comes from the World Bank and *is included with the fully-supported HDM-III.*

LOS: 3 (Copyright 1993, The World Bank)

Operating System: IBM PC/MS-DOS 3.1+

Product#	Description	Price
HDM.MGR	HDM Manager, Ver.2.0	$15

ILLI-BACK

ILLI-BACK is a closed-form backcalculation procedure for rigid pavements. It is a computerized adaptation of a rigorous, theoretically sound and efficient backcalculation procedure, applicable to two-layer, rigid pavement systems. This method simplifies considerably the effort required in interpreting nondestructive testing (NDT) data. A unique feature of this approach is that in addition to yielding the required backcalculated parameters, it also allows an evaluation of the degree to which the in situ system behaves as idealized by theory, and provides an indication of possible equipment shortcomings when these arise in the field.

The ILLI-BACK backcalculation procedure considers a two-layer system, consisting of a rigid pavement slab resting on an elastic solid (ES) or a dense liquid (DL) foundation. The backcalculation process requires four sensor deflections and utilizes the concept for determining the Area of the deflecting basin.

When ILLI-BACK is executed on a personal computer, execution time per deflection basin permits the interpretation of a vast amount of NDT data in a very reasonable time. The method makes it feasible for the first time to have a practical backcalculation procedure attached to the testing device in the field, providing instant checks on the accuracy of the deflection results generated, while there is still time and opportunity for remedial action. The program supports English and Metric units and runs interactively or in batch mode and is distributed in Copy-Protected format.

LOS: 7 (Copyright 1988, A.M. Ioannides)

Operating System: IBM PC/MS-DOS 2.1+ and math coprocessor

Product#	Description	Price
ILBACK	ILLI-BACK, Ver.2.0	$225

ILLI-PAVE Algorithms

ILLI-PAVE Algorithms is a program based on a set of algorithms that were assembled from ILLI-PAVE, a very large complex finite element program. The algorithms are contained in the program called ILLIALGR in the form of a series of spreadsheets selected from the menus. ILLI-PAVE Algorithms can be used for preliminary design and analysis of flexible pavements. This program was developed for the Federal Highway Administration.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.1+

Product#	Description	Price
ILLI	ILLI-PAVE, 12/86	$40
ILLI.D	Documentation	$5

JCP-1

JCP-1 (Jointed Concrete Pavement) determines the serviceability and fatigue data for use in rigid pavement design. The design process is an iterative process in which a designer specifies trial structural designs, determines the required inputs, executes the program, analyzes the resulting fatigue and serviceability data, modifies the design, and repeats the procedure. The program will analyze any number of slab thicknesses and provide outputs for each thickness, while holding all other inputs constant.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.0+

Product#	Description	Price
JCP	Jointed Concrete Pavement-1, 12/86	$45
JCP.D	Documentation	$5

Long Beach PMS

The Long Beach Pavement Management System was also developed under the FHWA Rural Technical Assistance Program (RTAP) project.

The system uses data files for physical information on the sections to be included in the analysis; pavement survey data detailing the condition of the surface; and information on the scoring, treatment and cost estimates for each road segment. Traffic data are incorporated into the analysis in the form of a Traffic Index based on ESAL's. An evaluation system is utilized which rates the sections from the pavement surveys and applies a decision tree to determine initial proposed treatments and their estimated costs. LBPMS analyzes both flexible (asphalt concrete) and rigid (Portland cement concrete) pavement types and produces several intermediate and final reports.

LOS: 3 (From FHWA)

Operating System: IBM PC/MS-DOS 2.1+ (384K and Hard Disk)

Supporting Software: dBASE III+

Product#	Description	Price
LBPMS	Long Beach PMS, 6/89	$40
LBPMS.D	Documentation	$10

MAPCON

MAPCON (Methods for Analyzing Pavement CONdition data) is a comprehensive, but user friendly package for pavement safety, roughness, structural capacity and surface condition analysis. MAPCON includes ELSYM5 and the California FPMS and RPMS (which also are distributed separately) and others. MAPCON provides "paths" to all the individual programs, enabling the user to better analyze the pavement conditions, which can then be made part of a pavement management system.

MAPCON was developed by Pennsylvania State University and ARE, Inc., under contract to FHWA. A hard disk is highly desirable, but not required.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.0+ (512K)

Product#	Description	Price
MAPCON	MAPCON, 4/87	$100
MAPCON.D	Documentation	$65

MIX

MIX is a menu driven, BASIC program which calculates the specific gravities of aggregates for the design of the asphalt mix and the proportions of each aggregate in the mix. The program is based on the methodology described in the MS-2 Report published by the Asphalt I[n]stitute. No formal documentation is availabl[e]

LOS: 5 (from University of Puerto Rico)

Operating System: IBM PC/MS-DOS 2.0+

Supporting Software: BASIC

Product#	Description	P
MIX	MIX, 1/80	

MODULUS and PASELS

MODULUS and PASELS are two programs assess the current condition of the moduli o various structural layers of existing asphalt pavement. The moduli values are often obtained through nondestructive testing with use of falling weight deflectometers. The h: volume data collection capabilities of mode nondestructive testing equipment require a analysis method which is capable of rapid backcalculation of pavement layer moduli production mode of data reduction. A laye elastic method, MODULUS, was develope microcomputer use which is very fast in op tion and provides consistently reliable resu Random errors in the measurements and sy tematic errors in the backcalculation proce may be reduced–the former by repeating t measurements and the latter by using a mi computer expert system, PASELS, to provi consistently acceptable layer moduli value

These programs were developed under a tional Cooperative Highway Research Pro gram project, the results of which are pub lished as NCHRP Report 327, "Determini Asphaltic Concrete Pavement Structural P erties by Nondestructive Testing." This r which contains user's manuals for both p grams, may be obtained through the Tran tation Research Board, Washington, D.C.

LOS: 3

Operating System: IBM PC/MS-DOS 2.0+

Product#	Description
MODUL	MODULUS, Ver.4.0
PASEL	PASELS, Ver.1.0

NULOAD

NULOAD is a computerized procedure th evaluates the effect of legal load limit cha on the (set of 12) life cycle costs of flexibl rigid, and/or composite pavements. Data i are interactively input through NULDIN, user-friendly processor for NULOAD. Co erable input data is required.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.0+

Product#	Description
NULOAD	NULOAD, 12/86
NULOAD.D	Documentation

PAVECHEK

Pavechek is a software package for designing interlocking concrete pavements. The structural design of flexible interlocking concrete pavements can be accomplished quickly on this menu-driven, PC computer based program. Pavement cross section designs can be generated for both new or overlay interlocking concrete pavements with unbound or bound base materials. Various levels of sophistication can be used in the program depending on the level of detail of input data available. The design rationale is based on the widely used 1986 AASHTO "Guide for the Design of Pavement Structures".

LOS: 7

Operating System: IBM PC/MS-DOS 2.1+ (Graphics)

Product#	Description	Price
PAVECHEK	Pavechek, Ver.1.0	$55

Pavement Management Forecasting Model

Pavement Management Forecasting Model (PMF) is a Lotus 1-2-3 template for use in planning roadway maintenance and strategies. It runs in a Lotus, Release 2 environment and is completely menu driven. Data on road maintenance and construction unit costs, pavement deterioration rates, future funding estimates and current road conditions are required. Based upon three repair strategies, output is generated in tabular summaries and graphic plots. It allows changes at any level to iterate to desired results.

Agencies responsible for roadway maintenance related funding decisions will find it useful to compare various alternatives. The Lotus design is included in the appendix for users who might modify the algorithms to customized applications. PMF was donated by Mr. William Massicott of the Metropolitan Area Planning Council, Boston.

LOS: 3

Operating System: IBM PC/MS-DOS 2.0+

Supporting Software: Lotus 1-2-3

Product #	Description	Price
PMF	PMF, Ver. 1.0	$40
PMF.D	Documentation	$15

Pavement Management System

Pavement Management System (PMS) is a decision support tool used to assist management responsible for allocating pavement maintenance resources. In a simple view, PMS is a process where information about the pavement system is collected, stored, analyzed and reported.

This third generation, Version 3.0, combines a life cycle approach to pavement maintenance with a user-friendly, mouse or keyboard driven graphical user interface. This standard system includes five modules for analyzing inventory, history, pavement condition, cost and budget, and a knowledge-based ranking system. It uses a maintenance priority ranking system based upon the data collected and stored in the other four modules. In addition, the system's modular design allows the integration with other software to provide enhanced graphical reports and system performance feedback.

LOS: 7 (Copyright 1992, Resource International, Inc.)

Operation System:IBM PC/MS-DOS 3.0+

Product#	Description	Price
PMS	PMS	$695
PMS.GIS	PMS GIS version	$2,500

PMSPro

PMSPro is a pavement management program written in the Microsoft Windows environment using FoxPro for Windows. The program allows the user to completely customize the program by defining decision trees, rehabilitation strategies, deterioration curves, deduct curves, and costs for different pavement types, functional classes, and traffic classes. PMSPro also contains other methods of calculating condition scores such as: WADOT PSC, FAA PCI, PAVER PCI.

PMSPro evaluates a street network both at the project level and the network level. At the Project Level, condition scores are used to prioritize streets. Decision trees evaluate the type and amount of distress to select an appropriate rehabilitation strategy. PMSPro can evaluate all street segments or only those that have changed since the last analysis.

A complete cost accounting package allows costs to be adjusted according to the type and amount of distress as well as other costs such as flagging and engineering.

At the Network Level, a simplified decision process uses future calculated condition scores to select an appropriate rehabilitation strategy and cost. The analysis period can range from 5 to 80 years. Evaluate by functional class or traffic class. Carry unspent funds forward. Prioritize by Worst First or Last.

PMSPro also can handle condition surveys or ditches, sidewalks, street signs and other street accessories. A maintenance module allows the tracking of past maintenance and costs.

Compatible with most GIS programs, including MapInfo from MapInfo, Inc. A GIS program can display pavement condition, recommended rehabilitation strategies, pavement types, sign inventory, etc. by connecting the databases to a map.

LOS: 7 (Copyright 1992©1994, Pavement Engineers, Inc.)

Operating Software: IBM PC/MS-DOS 3.0+

Product #	Description	Price
PMSPRO	PMSPRO Pavement Management Program Ver. 5.2	$1,000

Road Manager™

The Road Manager™ is a modular roadway management system. Its unique features are the ability to include ALL roadway features in the evaluation of a road section, a modular design, user defined parameters allowing extensive customization to fit local conditions and policies, and a modern software design using light bar menus, a complete help system and pick lists for easy data entry.

The General Roadway module serves as the "control center" for all other modules, recording road lengths, widths, classifications, etc., as well as overall condition indices for eight different types of roadway features. The General Roadway module can also be used as a stand alone system, suitable for "windshield survey" evaluation of a road network. *The General Roadway module is required for all other modules.*

The Asphalt Pavement, Roadway Drainage and Roadway Utility modules allow the detailed inventory and evaluation of roadway distresses, drainage needs and utility related features. These modules include a user definable decision table that determines recommended repairs or maintenance. All calculations related to determining a condition index, recommended repairs and estimated costs can be modified by the user.

The Improvement Plan module uses information generated in the Asphalt Pavement, Roadway Drainage and Roadway Utility modules to develop lists of recommended improvements as well as required budgets to attain a given network condition level. The computer-generated plan for improvements can be overridden by the user. The estimated deterioration curves used by the system in projecting future pavement and utility patch condition can also be modified.

The Repair History module serves as an electronic file cabinet, recording all work performed on a road section as it is completed. The Street Diagram module graphically displays and prints all Drainage and Utility features that have been inventoried through their respective modules.

LOS: 7 (Copyright 1989, The Info Center, Inc.)

Operating System: IBM PC/MS-DOS 3.0+ (640K and Hard Disk)

Product#	Description	Price
RMRD	General Roadway, Ver. 1.51	$495
RMAS	Asphalt Pavement, Ver. 1.51	$995
RMGR	Gravel Road, Ver. 1.51	$495

Chapter 3

Rigid Pavement

CHAPTER 3

RIGID PAVEMENT

3.1 TA 5040.30, Concrete Pavement Joints, November 30, 1990.

3.2 The Benefits of Using Dowel Bars, Technical Paper 89-03, May 17, 1989.

3.3 Preformed Compression Seals, Technical Paper 89-04, September 11, 1989.

3.4 Reinforcing Steel for JRCP (Cores form Kansas I-70), July 25, 1989.

3.5 Dowel Bar Inserters, February 23, 1996.
- Dowel Bar Inserters, March 6, 1990.
- Dowel Bar Placement: Mechanical Insertion versus Basket Assemblies, February 1989.

3.6 TA 5080.14, Continuously Reinforced Concrete Pavement, June 5, 1990.
- Modification to TA 5080.14, August 29, 1990.

3.7 Case Study, CRCP, June 22, 1987.

3.8 Lateral Load Distribution and Use of PCC Extended Pavement Slabs for Reduced Fatigue, June 16, 1989.

3.9 Longitudinal Cracking at Transverse Joints of New Jointed Portland Cement Concrete (PCC) Pavement with PCC Shoulders, November 30, 1988.

3.10 TA 5080.17, Portland Concrete Cement Mix Design and Field Control, July 14, 1994.

3.11 Summary of State Highway Practices on Rigid Pavement Joints and their Performance, May 19, 1987.

3.12 Bondbreakers for Portland Cement Concrete Pavement with Lean Concrete Bases, June 13, 1988.

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: Dowel Bar Inserters

Date: February 23, 1996

From: Chief, Pavement Division

Reply to Attn. of: HNG-40

To: Regional Administrators
Federal Lands Highway Program Administrator
Attention: Regional Pavement Engineers

By a March 6, 1990, memorandum, Mr. Louis Papet provided a copy of a Wisconsin Department of Transportation report on "Dowel Bar Placement: Mechanical Insertion Versus Basket Assemblies." Since that time, there appears to have been poor acceptance of the use of dowel bar inserters. A recent draft NCHRP report noted that 8 States allow the use of inserters, 13 States allow it as an acceptable option, and 20 States do not allow their use.

This technique has been used exclusively in some European countries for over 20 years with satisfactory dowel placement results. We believe all States should be encouraged to make this an allowable option in their specifications. We continue to encourage checking of dowel tolerances by probing through the fresh concrete early during the project and periodically as the work progresses. We also continue to recommend that when either baskets or inserters are used, the location of the dowels in the completed pavement be verified using metal detectors, pachometers, and cores.

If you have any comments or questions, please contact Mr. John Hallin at (202) 366-1323 or Mr. Roger Larson at (202) 366-1326

T. Paul Teng

T. Paul Teng, P.E.

U.S. Department of Transportation

Federal Highway Administration

Technical Advisory

Subject

PORTLAND CEMENT CONCRETE MIX DESIGN AND FIELD CONTROL

Classification Code: T 5080.17

Date: July 14, 1994

1. PURPOSE. To set forth guidance and recommendations relating to portland cement concrete materials, covering the areas of material selection, mixture design, mixing, placement, and quality control.

2. BACKGROUND

a. Each year approximately 46 million cubic meters of concrete are used in all highway construction. The vast majority of States use a prescription type specification for portland cement concrete, often specifying minimum cement content, maximum water cement ratio, slump range, air content, and many times aggregate proportions. Admixtures such as fly ash are incorporated into mixes as a part of the prescription.

b. This system has worked fairly well in the past but may change as emphasis is placed on performance based specifications. States have begun to reduce or eliminate the amount of inspection at concrete plants as automation has increased productivity.

3. MATERIALS

a. Portland Cement. The proper type of portland cement should be specified for the conditions which exist.

OPI: HNG-23

(1) Types I, II, III, IP, and IS are typically used in highway construction. Type I is used when no special circumstances exist. Type II is used when sulfate exposure conditions are present. Type III is used when high early strengths are required. The use of Types IP and IS result in lower early strength gains and can be substituted for Type I cement when early strength is not a concern. In addition to the above mentioned types, Types IV and V are sometimes used in highway applications to meet special conditions. Further information about these cements can be found in the book <u>Design and Control of Concrete Mixtures</u> published by the Portland Cement Association (PCA).

(2) It is recommended that the acceptance of portland cement be based on certification by the supplier. The certification should contain the lot number of the cement. The supplier's test results should accompany the certification or be available to the State. Verification samples should be taken and used as part of the acceptance system.

(3) If alkali aggregate reactivity (AAR) is a concern, a maximum alkali content of 0.6 percent should be specified. Some State highway agencies consider this amount too high and recommend smaller amounts. If AAR is a problem in the State, a review of a States' Materials Manual is suggested. See Concrete Distress Conditions Section for other remedies.

b. Aggregates. Aggregates make up 60 to 70 percent of the volume of concrete mixes. A significant portion of poorly performing highway concrete can be traced to aggregate quality problems.

(1) The fine aggregate should meet the requirements of the American Association of State Highway and Transportation Officials (AASHTO) M 6.

(2) The range for the gradation of fine aggregate is quite broad. The fineness modulus (FM), calculated using AASHTO T 27, can be used as a tool for assessing the variability of the fine aggregate gradation. The specifications should limit the range of the FM between 2.3 and 3.1 according to AASHTO M6 and the variation of the FM should not be more than 0.20 from the value of the aggregate source.

(3) The FM is a means to control the influence that fine aggregate has on workability and the air content of the mix and is sometimes specified in the mix design. Further information regarding FM can be found in the Federal Highway Administration's manual FHWA-ED-89-006 (Portland Cement Concrete Materials Manual).

(4) It should also be noted that to provide good skid resistance, the PCA recommends that the siliceous particle content of the fine aggregate should be at least 25 percent. Consideration should be given, however, to the possibility of alkali-silica reactions when this is done.

(5) The coarse aggregate should meet the requirements stated in AASHTO M 80. For most parts of the country the severe exposure requirements should be used which means the use of class A aggregate for structural concrete and class B aggregate for pavements. The following table contains some of the more common information provided by Table 1 in AASHTO M 80.

	Class A Aggregate	Class B Aggregate
Clay lumps and friable particles	2%	3%
Chert	3%	3%
Sum of clay lumps, friable particles and chert	3%	5%
Material finer than No. 200	1%	1%
Coal and Lignite	0.5%	0.5%
Abrasion	50%	50%
Sodium Sulfate Soundness	12%	12%

c. Water

(1) The water serves as a key material in the hydration of the cement. In general, potable water is recommended although some non-potable water may also be acceptable for making concrete. Water of questionable quality should be examined since this can effect the strength and setting time. The following criteria is contained in Table 1 in AASHTO M 157 and is based on control tests made with distilled water:

Test	Limits
Compressive strength percent of control tests at 7 days	90
Time of set deviation from control	1 hour earlier to 1.5 hour later

(2) Wash water can be used to make concrete providing the resulting concrete mix water meets the following criteria in Table 2 in AASHTO M 157:

Chemical	Limits
Chloride as percent of weight of cement for the following uses:	
prestressed concrete	0.06
reinforced concrete in moist environment exposed to chlorides	0.10
reinforced concrete in moist environment not exposed to chlorides	0.15
sulfates	3000 ppm
alkalis	600 ppm
total solids	50,000 ppm

(3) If there is any question about the water, it should be tested using AASHTO T 26.

(4) It should be noted that the American Concrete Institute (ACI) provides more stringent tolerances for total chlorides in the mix. The chloride content for wash water in AASHTO M 157 is recommended for total chloride content in ACI 201.2R 22.

d. Admixtures. Admixtures are typically placed in mixes to improve the quality or performance. They can affect several properties and can have a adverse impact on the mix if not used properly. To avoid possible problems, it is suggested that trial batches be made to evaluate the mix.

(1) Air entraining admixtures should be specified when concrete will be exposed to freeze/thaw conditions, deicing salt applications, or sulfate attack. Recommendations for air content are contained in paragraph 4d.

(a) A vinsol resin type admixture should be added when fly ash having a variable loss on ignition (LOI) content (between 3 percent and 6 percent) is present. This is because of the effect that fly ash's fineness and carbon content has on the air entrainment system. Fly ashes not having a variable LOI do not have an adverse impact on entraining agents and therefore vinsol resin type admixtures may not be necessary.

(b) The specifications for air entraining admixtures are contained in AASHTO M 154.

(2) Chemical admixtures include water reducers, retarders, accelerators, high range water reducers (superplasticizers), corrosion inhibitors and combinations of the above. The specifications for chemical admixtures are contained in AASHTO M 194.

(a) Mixes containing admixtures are permitted an increase in shrinkage and a decrease in freeze thaw durability (as indicated in Table 1 AASHTO M 194) in comparison with mixes having no admixtures.

(b) Admixtures are usually accepted based on preapproval of the material and supplier certification. Verification tests should be performed on liquid admixtures to confirm that the material is the same as that which was approved. The identifying tests include chloride and solids content, pH, and infrared spectrometry.

(c) Water reducers and retarders may be used in bridge deck concrete to extend the time of set. This is especially important when the length of placement may result in flexural cracks created by dead load deflections during placement.

Often water reducers and retarders may increase the potential for shrinkage cracks and bleeding. Because of these concerns, increased attention needs to be placed on curing and protection.

(d) High range water reducers can be used to make high slump concretes at normal water cement (w/c) ratios or normal range slumps at low w/c ratios. The primary concern with the use of these admixtures is the loss of slump which occurs in 30 to 60 minutes. Redosing twice with additional admixture is allowed by ACI 212.4R; however, redosing typically reduces air entrainment. Type F and G high range water reducers may also be used. Type G has the added advantage of containing a retarding agent.

<u>1</u> If transit mix trucks are used to mix high slump concrete, it is recommended that a 75mm slump concrete be used at a full mixing capacity to ensure uniform concrete properties. If transit mix trucks are used to mix low w/c ratio concrete, it is recommended that the load size be reduced to 1/2 to 2/3 the mixing capacity to ensure uniform concrete properties. Admixture companies are recommending additional mixing time with low w/c mixtures instead of decreasing the size of the load. This may have detrimental effects on some properties of the concrete such as the degradation of the aggregate resulting from over mixing.

<u>2</u> High range water reducers may also affect the size and spacing of entrained air. If Freeze-Thaw

testing as described by ASTM C 666 indicates this to be a problem, it is recommended that the air content be increased by 1½ percent.

(e) Calcium chloride, the most commonly used accelerator, has been associated with corrosion of reinforcing steel and should not be used where reinforcing steel is present. In addition to the corrosion problem calcium chloride also reduces sulfate resistance, increases alkali-aggregate reaction, and increases shrinkage. Calcium chloride should not be used in hot weather conditions, prestressed concrete, or steam cured concrete. In applications using calcium chloride, the dosage rate should be limited to 2 percent by weight of cement.

(f) Non-Calcium Chloride accelerators are available and can be used where reinforcing steel is present. However, care must be taken in selecting these since some may be soluble salts which can also aggravate corrosion.

(g) Calcium Nitrate, which can be used as a corrosion inhibitor, also can function as an accelerator. There are no consensus standards available for the use of this material. Manufacturer specification sheets should be consulted for proper use.

(3) Mineral admixtures include fly ash, ground granulated blast furnace slag, natural pozzolans, lime, and microsilica (microsilica is also known as silica fume). Currently all of these materials are being used as additives or to reduce cement contents. Mineral admixtures are accepted based on approved sources with certifications and verification samples.

(a) According to the American Society of Testing and Materials (ASTM) C 618 and AASHTO M 295 there are two classes of fly ash, class C and class F. Since variability in fineness and carbon content can affect air content, the optional uniformity specifications in AASHTO M 295 should be specified when air entrained concrete is used. Fly ashes with LOI values less than 3 percent will typically not affect air content. Vinsol resin air entrainment admixtures should be specified when fly ash with LOI higher than 3 percent is used.

1. Fly ash may be used as a supplement or a replacement and is typically limited to 15 to 25 percent. If it is used as a replacement, it replaces cement on a 1.0 to 1.2:1 basis by weight.

2. Fly ash can be used to increase workability, reduce permeability, and mitigate alkali silica reaction (ASR); some Class C can make it worse. Class F fly ash with a calcium oxide content less than 10 percent can be used to mitigate ASR and sulfate attack. Fly ash with a calcium oxide content greater than 10 percent should be used in concrete which will be subjected to sulfate attack only with verification testing. This percentage and fly ash classification should only be used as a guide; further qualification should be based on ASTM C 452.

3. The cementing action with fly ash is pozzolanic in nature. The pozzolanic reaction with fly ash stops at approximately 4° Celsius.

Precautions need to be taken when using fly ash in concrete at lower temperatures. It should also be noted that fly ash can reduce early strength development and, therefore, should be monitored closely.

(b) Ground granulated blast furnace slag specifications are contained in AASHTO M 302.

1 Ground granulated blast furnace slag (GGBFS) is a cementitious material and can be substituted for cement on a 1:1 basis by weight for up to 50 percent of the cement in the mix.

2 For fresh concrete using GGBFS, the air entrainment agent dosage may need to be increased. The workability and finishability typically are improved but in mixes having high cementitious material content, mixes can be sticky and difficult to finish. Bleeding may be reduced and setting time may be longer.

3 Ground granulated blast furnace slag can reduce sulfate attack, alkali-aggregate reactions, and permeability. The rate of strength gain is usually decreased and sensitive to low temperature.

(c) Microsilica specifications are contained in AASHTO M 307. Microsilica can be used as an admixture or as a replacement for an equivalent amount of cement to produce high strength concrete. Microsilica will reduce permeability and help reduce alkali-aggregate reactions.

1 Microsilica has been used as an addition to concrete up to 15 percent by weight of cement, although the normal proportion is 10 percent. With an addition of 15 percent, the potential exists for very strong, brittle concrete. It increases the water demand in a concrete mix; however, dosage rates of less than 5 percent will not typically require a water reducer. High replacement rates will require the use of a high range water reducer.

2 Microsilica greatly increases the cohesion of a mix, virtually eliminating the potential for segregation. However, the cohesion may cause mixes to be sticky and difficult to finish. It may be necessary to specify a higher slump than normal to offset the increased cohesion and maintain workability. In addition, microsilica in the mix greatly reduces bleeding; therefore, mixes which contain microsilica tend to have a greater potential for plastic shrinkage cracking. It is imperative to use the proper curing methods to prevent the surface water from evaporating too quickly.

4. PROPORTIONING. Most of the concrete placed in highway facilities in the United States are under severe exposure conditions. State highway agencies specify a recipe for concrete mixes which includes minimum cement content, maximum water-cement ratio, air content range, and minimum strength. These requirements are necessary to achieve durability, as well as strength.

a. The maximum aggregate size should be as large as possible. This reduces total aggregate surface area and results in lower cement demand. The maximum aggregate size should be limited to 20 percent of the narrowest dimension of a concrete member, 75 percent of the clear spacing between reinforcing steel, or 33 percent of the depth of a slab for unreinforced concrete.

b. The minimum cement content refers to all cementitious and pozzolanic material in the concrete, including cement and any mineral admixtures that are being added to or substituted for cement. Replacement rates should be based on those contained in paragraph 3d(3).

(1) The PCA recommends a minimum cement content of 335 kg/m^3 for concrete placed in severe exposure conditions and ACI 316R recommends a minimum cement content of 335 kg/m^3 for concrete pavements in all locations unless local experience indicates satisfactory performance with lower cement contents. Even if strength requirements can be met with a lower cement content, a minimum cement content of 335 kg/m^3 should be used unless it can be demonstrated that the concrete will be durable.

(2) In cases where local experience allows a reduction in cement content below 335 kg/m^3 the cement content should not be reduced below the following minimum cement contents recommended by ACI 302.1R Table 5.2.4 for concrete slab and floor construction. The minimum cement contents listed below are based on the nominal maximum size of the aggregate. The cement content decreases as the nominal maximum aggregate size increases due to the decrease in aggregate surface area.

Nominal maximum size aggregate, mm	Cement content kg/m^3
37.5mm	280kg/m^3
25mm	310kg/m^3
19mm	320kg/m^3
12.5mm	350kg/m^3
9.5mm	365kg/m^3

(3) Low strength concrete in the field should not be addressed by arbitrarily increasing the cement content since an increase in cement content will increase the water demand leading to higher shrinkage and permeability. All changes in mix proportions should be evaluated with a trial batch.

c. The water-cement ratio in all cases should be as low as possible while maintaining workability. For freeze thaw resistance the following maximum water cement ratios are recommended in ACI 201.2R.

Thin sections (bridge decks, pavements and curbs) and sections with less than 25 mm cover and concrete exposed to deicing salts	0.45
all other structures	0.50

The water-cement ratio should include the weight of all cement, pozzolan, and other cementitious material.

d. The air content in the mortar fraction of the mix should contain approximately 9 percent air for concrete mixes exposed to severe conditions.

(1) The following recommendations are from ACI 201.2R Table 1.4.3.

Nominal maximum size aggregate, mm	Air content Percent
37.5mm	5-1/2
25mm	6
19mm	6
12.5mm	7
9.5mm	7-1/2

(2) The specified tolerance for air content should be ± 1½ percent.

5. PROPERTIES OF CONCRETE. Trial batches should be performed on all mixes at the expected placement temperatures. This is especially true for mixes containing multiple admixtures.

a. Workability. A concrete mix must be workable to ensure proper consolidation and finishing. The workability of a mix is a function of the gradation of the aggregate, amount and type of admixtures, water content, concrete temperature, and time. Once a workable mix is established during the trial batch process, slump can be used to monitor the consistency and uniformity of the mix. Slump, by itself, is not a measure of workability.

b. Durability

(1) Freeze-thaw durability depends on durable aggregates, proper air entrainment, low permeability, and a low water-cement ratio.

(2) D-cracking is strictly a pavement durability problem and is associated with aggregates. It should be addressed with the source approval of the aggregates.

(3) Alkali aggregate reactions are mostly the result of the alkali content of the cement in the concrete. The most common alkali aggregate reaction is associated with silicious aggregates although reactions have occurred with carbonate materials. If a reactive aggregate is encountered, several options are available: not using the source of aggregate, using a low alkali cement, using fly ash, or using microsilica. If alkali reactive aggregates are used, testing should be performed with the mix prior to its use to ensure a durable concrete.

(4) Resistance to or susceptibility to sulfate attack depends on the chemical composition of the cementitious portion of the concrete. Sulfate attack can occur from ground water, deicing salts, or sea water. Type II or Type V cement or some fly ashes, may be used to mitigate the problem.

c. Strength. The strength requirement is the compressive strength, f'_c, at 28 days. This must be equal to or exceed the average of any set of three consecutive strength tests. No individual test (average of two cylinders) can be more than 3.5 MPa below the strength requirements in the specification.

6. MIXING, AGITATION, AND TRANSPORTATION

a. In order to ensure proper operation, a concrete plant must be calibrated and inspected. Plant approval should include all the items covered in the Checklist for Portland Cement Concrete Plant Inspection (Attachment 1). This same checklist also discusses the inspection of truck mixers. The plant certification program operated by the National Ready Mix Concrete Association covers the same information contained in the attachment.

b. The mixing time for central mixers and approval of truck mixers should be determined by the uniformity test discussed in AASHTO M 157, Ready Mixed Concrete. The test is based on the comparison of tests on samples taken at the first and last 15 percent of the load. The following are maximum permissible differences to consider the mix properly mixed.

Test	Maximum Difference
Unit weight (air free basis)	15 kg/m^3,
Air content	1 percent
Slump	
less than 100mm	25mm
100 to 150mm	37.5mm
Coarse aggregate content	6.0 percent
Unit weight of air free mortar	1.6 percent
Compressive strength (7 day)	7.5 percent

c. Water added at the job site must be measured accurately. A water meter is the most accurate method for determining the amount of water added to the mix.

d. The recommendations for testing appear in paragraph 11, Quality Control and Testing, of this document.

e. The haul time should be limited to 90 minutes for truck mixers that agitate the mix and 30 minutes for trucks that do not agitate the mix. The maximum number of revolutions for truck mixers should be limited to 300.

f. No admixtures or water should be permitted to be added to the mix after the mixer has started unloading.

7. <u>PLACEMENT AND CONSOLIDATION</u>

a. Prior to placement of the concrete an inspection should occur covering the items in either the checklist for the placement of structural concrete (Attachment 2) or the checklist for the placement of concrete paving (Attachment 3).

b. Acceptance testing for pumped concrete should occur at the discharge end of the pump.

c. Aluminum pipe and chutes should not be used in concrete pumping operations.

d. Concrete can be conveyed to the location of placement by several commonly used methods including pumps, belt conveyors, buckets, chutes, and dropchutes. Care should be taken to ensure that there is no debris or blockages that will hinder or influence the properties or flow of the material. Concrete should not be allowed to free fall from distances greater than 1.2 meters to avoid segregation.

e. All concrete should be accompanied to the project with a delivery ticket. A sample delivery ticket appears as Attachment 4.

f. The proper consolidation of concrete is a significant factor in the ultimate performance of the concrete and it is achieved through vibration.

(1) The following are recommended frequencies for vibrators from ACI 309.

Diameter of head, mm	Frequency vibrations per minute
20 to 40 mm	10,000 - 15,000
30 to 65 mm	9,000 - 13,500
50 to 90 mm	8,000 - 12,000

8. CURING AND PROTECTION

a. Curing

(1) Curing is performed to maintain the presence of water in concrete and to provide a favorable temperature for cement hydration. Methods of curing include ponding, spraying, and fogging with water, wet covers such as burlap, plastic sheets, membranes, and the use of steam, electric forms, or insulation.

(2) The application rate of a particular curing compound should be based on the rate established during the approval process of the curing compound. The AASHTO M 148 indicates that a rate of application of $5m^2$/liter should be used for testing the material if no other rate is specified.

b. Protection

(1) Cold weather protection should be required when it is expected that the daily mean temperature for three consecutive days will fall below 4° Celsius. The following recommendations are for the minimum temperatures for delivered concrete as they appear in AASHTO M 157.

Air	Minimum Concrete Temperature	
Temperature	Thin	Thick
-1 to 7°C	16°C	10°C
-18° to -1°C	18°C	13°C
Below -18°C	21°C	16°C

Thin sections are defined as those less than 300 mm.

(2) Concrete should never be placed on a frozen subgrade. Care should be taken to assure that the subgrade is free from frost.

(3) Hot weather conditions can be defined as a condition of high temperature, low humidity, and high winds. The existence of these conditions can be determined by finding the evaporation rate described in ACI 305 and included in Attachment 5. An evaporation rate exceeding 1 $kg/m^2/hr$ has the potential of causing plastic shrinkage cracks. The evaporation rate is a function of concrete temperature, ambient temperature, relative humidity, and wind velocity. This chart has been incorporated into several State specifications. It may not completely apply in all cases, especially in mixes containing admixtures which reduce the amount of bleeding.

(4) In addition to the plastic shrinkage cracking problem, ultimate strength will decrease with higher temperatures. The ACI has not recommended a maximum concrete temperature since strength loss can be compensated for by other means.

However, significant strength loss occurs above 32°C. Due to the strength loss and increase in potential for plastic shrinkage cracking, many States have set a maximum ambient placement temperature of 32°C. In all cases, trial batches should be performed at the highest expected temperature to ensure that the concrete will have the desired properties.

9. CONCRETE DISTRESS CONDITIONS

a. Alkali aggregate reactivity can be one of two types, alkali-silica and alkali-carbonate. The most prominent problem is cracking of the concrete due to the alkali-silica reaction (ASR).

(1) A widely used test to determine ASR is ASTM C 227. The current test criteria allow a maximum expansion of 0.05 percent at 3 months and 0.1 percent at 6 months. Research by PCA indicates that the critical criteria is 0.1 percent ultimate expansion. Since some reactions take longer than others, testing should continue as long as expansion is occurring. Some aggregates may take several years to show expansion.

(a) Recently the Strategic Highway Research Program developed a test which can be used for rapid determination of ASR. It is called the Gel Fluorescence Test and can be performed easily and inexpensively by field personnel. With this test, a 5 percent solution of uranyl acetate is applied on the concrete surface. Ultraviolet light is then used to illuminate the surface and if ASR exists, a yellow-green fluorescent glow will appear. Some safety concerns may be associated with this test so proper precautions are recommended. It should also be noted that the test is limited to preexisting concrete and not to fresh concrete.

(b) Alkali-silica reaction can be mitigated by limiting the alkali content of portland cement to 0.6 percent, by using class F fly ash or microsilica admixtures, or by reducing the water to cement ratio. The success of this approach may be limited; therefore, laboratory testing should be conducted. Protecting the final structure from moisture also reduces ASR.

(c) Although PCA recommends 25 percent of the fine aggregate be siliceous material to improve skid resistance, the use of some siliceous material can promote the ASR reaction and requires care to ensure this will not occur.

(2) Alkali-carbonate reaction (ACR) may occur with dolomitic limestones which contain large amounts of calcite, clay, or silts. ASTM C 586 is used to screen dolomitic materials for alkali-carbonate reactions.

b. D-cracking occurs when freeze-thaw conditions combine with saturated concrete made from susceptible coarse aggregates. The problem is only associated with pavements. Some dolomites and limestones are susceptible due to their pore structure.

(1) The most common test for predicting D-cracking susceptible aggregates is AASHTO T 161. There are two methods contained in the procedure. In method A the specimens are immersed in water for freezing and thawing. In method B the specimens are frozen in air and thawed in water. The number of freeze thaw cycles varies between 300 to 350. The minimum durability factor specified by the States range between 80 and 95. Some States have also specified a maximum expansion criteria range between 0.025 percent and 0.06 percent. It should be noted that the test method allows a significant range of time for freezing and thawing cycles. This can account for the variation in the criteria used by the States. Care needs to be taken when establishing criteria so that it will correspond to the test equipment and the history of performance of the aggregates.

(2) The hydraulic fracture test developed under SHRP may be able to provide a determination of the D-cracking susceptibility of aggregates in only about 1 week compared with the 8 weeks for T 161. In this test, dry aggregates are submerged in a pressure chamber and the pressure is increased to force water into the pores. After releasing the pressure, D-cracking susceptible aggregate will fracture as the water is forced out of the pores.

10. MANUFACTURED CONCRETE PRODUCTS Concrete products consist of structural elements constructed at a plant and trucked to the jobsite. These precast products typically consist of beams, pipes, barriers, poles and other special elements. The criteria outlined within this document apply to these products as well. Additional information about prestressed products are contained in the Checklist for Prestressed Concrete Products in Attachment 6.

11. QUALITY CONTROL AND TESTING

a. All testing should be performed by certified technicians. The ACI and the National Institute for Certification in Engineering Technologies (NICET) administer a concrete technician certification program. Guidance for establishing a certification program for testing personnel appears in a FHWA paper titled "Laboratory Accreditation and Certification of Testing Personnel."

b. Process control testing should be performed on aggregate moisture content, aggregate gradation, air content, unit weight, and slump at the plant.

(1) The specifications should require that the contractor provide a process control plan. The State should also provide guidance on the minimum requirements for a process control plan. As a minimum, the process control plan should include the information contained in Attachment 7.

(2) All process control tests should be plotted on control charts. Control charts are a good visual tool for discovering trends quickly before major problems occur.

c. The acceptance procedures should include monitoring of the process control activities including aggregate gradation testing. In addition, acceptance testing at placement would include slump, strength, and air content. Close monitoring of the water-cement ratio is also required since this will ultimately affect the durability and strength of the concrete.

Additional information on acceptance procedures is provided in the Technical Advisory on Acceptance of Materials T 5080.11.

d. It is recommended that compressive strength be accepted using statistical criteria (based on average strength and standard deviation) to ensure that the strength, f'_c, at 28 days, is equal or exceeded by the average of any set of three consecutive strength tests. No individual test (average of two cylinders) can be more than 3.5 MPa below the specified strength. There are two strengths to be considered. One is the minimum specified strength (f'_c) which is a function of the structural requirements. The second is the average strength for mix design (f'_{cr}). The f'_{cr} must be higher than f'_c to ensure that the concrete will exceed the minimum specified strength. The following recommendations for f'_{cr} are from ACI 318.

(1) Unknown Standard Deviation

Specified compressive strength, MPa	Required average compressive. strength, MPa
f'_c	f'_{cr}
Less than 20MPa	$f'_c + 6.9$
20MPa to 35MPa	$f'_c + 8.3$
Over 35MPa	$f'_c + 9.6$

(2) Known Standard Deviation

For greater than 30 test results (one test result is the average of two cylinder breaks) f'_{cr} is the greater of the two values from the following equations.

MPa

$$f'_{cr} = f'_c + 1.4s$$
$$f'_{cr} = f'_c + 2.4s - 3.5$$

s = Standard deviation

(3) For 15 to 30 test results the standard deviation in the above formulas can be modified by the following factors.

No. of Tests	Modification factor for standard deviation
Less than 15	use table for unknown s
15	1.16
20	1.08
25	1.03
30	1.00

e. Air content and slump should be accepted based on an attribute system, i.e., pass/fail. The following is a recommended criteria.

Acceptance criteria	Air content deviation, %	Slump deviation, mm
Acceptable	< 1.5	< 25mm
Acceptable for trucks on the road	1.5 to 2	25 to 31.5mm
Reject	> 2	> 31.5mm

f. Testing procedures for resistance to freeze-thaw damage, deicing salt attack, and abrasion resistance are long and involved and do not lend themselves to testing on a routine basis. These tests are usually conducted to determine the durability of the concrete. It should also be noted that high strength concrete does not always insure durable concrete.

Anthony R. Kane
Associate Administrator
for Program Development

Attachments

THIS PAGE LEFT BLANK
INTENTIONALLY

CHECKLIST FOR PORTLAND CEMENT CONCRETE PLANT INSPECTION

1. <u>Materials</u>

A. Cements and Mineral Admixtures (cement, fly ash, etc.)

(1) Is evidence of cement or fly ash acceptability present (certification, test results)?

(2) Are bins or silos tight and provide for free movement to discharge opening?

(3) Are bins or silos periodically emptied to check for caking?

(4) Plants should provide separate storage for each type of cement or mineral admixture being used. Are the materials being isolated to prevent intermingling or contamination?

B. Aggregates

(1) Does the plant display evidence of source approval?

(2) Are aggregates stockpiled to prevent segregation and degradation? The preferred method of stockpiling is in layers. Cone shaped stockpiles will segregate.

(3) Are stockpiles adequately separated to prevent intermingling?

(4) Does the plant maintain separate storage bins or compartments for each size or type of aggregate? Are the aggregates tested for gradation and moisture content?

(5) What is the surface underneath stockpiles? Soil or paved? Are the stockpiles covered?

C. Water

(1) Does the plant have an adequate water supply with pressure sufficient to prevent interference with accuracy of measurement?

(2) Is there any evidence or history of contaminants in supply?

D. Liquid Admixtures

(1) Is there evidence of source approval?

(2) Is the admixture and dispensing equipment protected from freezing, contamination, or dilution?

(3) How often are the admixture metering and dispensing equipment periodically cleaned?

2. <u>Batching Equipment</u>

A. Scales

(1) Scales should indicate weight by means of a beam with balance indicator, full range dial, or digital display.

(2) For all types of batching systems the weighing devices must be readable by the batchman and the inspector from their normal stations.

(3) Scales should be certified or should be calibrated with a certified scale.

(4) Ten 25 kilogram test weights should be available at the plant at all times.

(5) Scale accuracy should generally be within plus or minus .4 percent of the scale capacity.

(6) Water meters will need to be calibrated to 1 percent of total added amount.

B. Batchers

(1) Cementitious material should be weighed on a scale that is separate and distinct from other materials.

(2) Bins with adequate separation should be provided for fine aggregate and each size coarse aggregate.

(3) Weigh hoppers should not allow the accumulation of tare materials and should fully discharge into the mixer.

(4) Batchers should be capable of completely stopping the flow of material and water batchers should be capable of leak free cut off.

(5) Separate dispensers will be provided for each admixture.

(6) Each volumetric admixture dispenser should be an accurately calibrated container that is visible to the batchman from his normal position.

(7) Aggregate should be measured to plus or minus 2 percent of the desired weight, cement to 1 percent, water to 1 percent and admixtures to 3 percent.

(8) Semi-automatic and automatic control mechanisms should be appropriately interlocked.

3. <u>Mixing</u>

A. Stationary Mixers

(1) Mixers should be equipped with a metal plate that indicates mixing speed and capacity.

(2) Mixers should be equipped with an acceptable timing device that will not permit discharge until the specified mixing time has elapsed.

(3) Mixers are to be examined periodically to detect changes in condition due to accumulation of hardened concrete or blade wear. A copy of the manufacturer's design, showing dimensions and arrangements of blades, should be available at the plant at all times.

B. Truck Mixers

(1) Mixers should be equipped with a metal plate that indicates mixing speed, capacity, mixing revolutions, agitating speed and agitating capacity.

(2) Mixers should be equipped with a revolution counter.

(3) Mixers are to be examined to determine satisfactory interior condition, that is, no appreciable accumulation of hardened concrete and no excessive blade wear. A copy of the manufacturer's design, showing dimensions and arrangements of blades, should be available at the plant at all times.

(4) Charging and discharge openings and chutes should be in good condition.

4. <u>Weather</u>

A. Hot Weather

(1) When concreting during hot weather, is plant equipped to cool ingredients? Is equipment available to produce acceptable ice?

(2) How are aggregates cooled? If by sprinkling, is provision made to account for excessive water?

B. Cold Weather

(1) When concreting during cold weather, is plant equipped to heat ingredients to produce concrete of applicable minimum temperature.

CHECKLIST FOR STRUCTURAL CONCRETE

1. <u>TREATMENT OF FOUNDATION MATERIAL</u>

   Has special care been taken not to disturb the bottom of any foundation excavation?

2. <u>CURING</u>

   Is the concrete being cured for 7 days, by one of the following methods?

   (a) Waterproof paper method

   (b) Polyethylene sheeting method

   (c) Wetted burlap method

   (d) Membrane curing method

3. <u>REINFORCEMENT BAR STORAGE</u>

   Are all delivered rebars being stored above the ground upon skids, platform, or other supports? A light coating of rust will not be considered objectionable.

   Are epoxy coated bars being stored on padded supports and handled to prevent damage to the bar coating?

4. <u>FORMS</u>

   Are the forms clean, braced, tight, and sufficiently rigid to prevent distortion?

   When wooden forms are used, are they dressed lumber or plywood and oiled <u>prior</u> to rebar placement?

   Are all sharp corners in forms being filleted with 20 millimeters molding, unless otherwise specified?

5. <u>REINFORCEMENT BAR PLACEMENT</u>

   Are all reinforcement bars tied securely in place? Are epoxy coated bars being tied with plastic or epoxy coated tie wire?

When epoxy coated bars are cut in the field, are they being sawed, sheared, or cut with a torch? Cutting with a torch is not acceptable. If cut in the field, the bars should be repainted at the cut ends with a similar type of epoxy paint.

Are at least 50 percent of the bar intersections being tied?

Are all rebar laps of the specified length?

Are all portions of metal bar supports in contact with any concrete surface galvanized or plastic coated? Are epoxy coated bars being supported with plastic, plastic coated, or epoxy wire chairs?

Are the reinforcement bar support in sufficient quantity and adequately spaced to rigidly support the reinforcement bars?

After epoxy coated bars are in place, are the bars inspected for damage to the coating and is the contractor repairing all scars and minor defects using the specified repair materials?

Is the finishing machine being used to detect high bars by making a "dry run" over the length of the deck prior to concrete placement? Is the proper coverage being maintained between the bars and any form work or surface, top, side, and bottom?

6. <u>PRE-POUR INSPECTION</u>

Prior to the placement of the concrete have the reinforcement bars, construction joints, and forms been cleaned of mortar, dirt, and debris?

Are the strike-off screeds set to crown, and other equipment on the job-site (such as vibrators) in good working condition?

7. <u>USE OF RETARDING ADMIXTURE (BRIDGE DECK)</u>

If the specified temperature is reached, is a retarding admixture being used in the bridge deck concrete?

8. TEMPERATURE CONTROL

Are proper precautions being taken for hot and cold weather concrete?

If outside temperatures warrant it, are temperature checks of the plastic concrete being taken?

9. TIME OF HAUL

Is all concrete that is being hauled in truck mixers being deposited within 90 minutes from the time stamped on the tickets?

If central-mixed concrete is hauled in nonagitor trucks, is the concrete being deposited within 30 minutes?

10. REVOLUTIONS

Have 70 to 100 mixing revolutions at mixing speed been put on the truck at the required speed (6-18 RPM)?

Have 30 mixing revolutions been placed on the truck at the required speed (6-18 RPM) after water has been added at the site?

Is the agitating speed between 2-6 RPM?

Are total number of revolutions being limited to 300?

11. CONCRETE DELIVERY TICKET

Are all truck tickets being properly completed, collected, and retained?

12. WATER CONTROL

Is all water that is being added to the mix accounted for and checked to ensure the w/c ratio is not exceeded?

13. AIR CONTENT DETERMINATION

Are air content tests being performed according to the required frequency?

14. SLUMP TEST

Are slump tests bring performed according to the required frequency?

15. STRENGTH TEST

Are concrete test specimens being cast at the site of work as per the required frequency?

16. PLACING CONCRETE

Is the concrete being deposited as near its final position as possible? (Moving concrete horizontally with vibrators is not permitted.)

Is the concrete being bucketed, belt conveyed, pumped, or otherwise placed in such a manner as to avoid segregation and is not being allowed to drop more than 1.2 meters?

17. CONSOLIDATION

Is all the concrete being consolidated with hand operated spud vibrators while it is being placed?

18. FINISHING (DECKS)

Is a finishing machine (having at least one reciprocating, nonvibratory screed operating on rails or other supports) being used to strike off and screed the bridge deck?

19. STRAIGHTEDGE TESTING AND SURFACE CORRECTION (DECK)

Is the plastic concrete being tested for trueness with a 3 meter straightedge held in contact with the slab in successive positions parallel to the centerline?

Are all depressions being immediately filled and all high areas being cut down and refinished?

20. SURFACE TEXTURING

Is the deck surface being textured with either a burlap drag or an artificial turf drag followed by tining with a flexible metal comb?

CHECKLIST FOR PORTLAND CEMENT CONCRETE PAVING

1. SUBBASE TRIMMING

   Has the subbase been trimmed prior to paving?

2. PAVING FORMS (IF USED)

   Are the forms: metal, not less than 3 meters in length, equipped with both pin locks and joint locks, within 2 millimeters along the length of its upper edge, within 7.5 millimeters along the length of its front face, and in sufficient supply.

   Is the height of form face at least the edge thickness of proposed pavement, the base width equal to or greater than the height, and are three steel pins being used to secure each section?

   Are the forms being set on a hard and true grade, built up in 12.5 millimeters maximum lifts of granular material in low areas (without using wooden shims) and oiled prior to the placing of concrete?

   When wooden forms are allowed, are they full depth, smooth, free of warp, not less than 50 millimeters thick when used on tangent, and securely fastened to line and grade?

   Are curved form of metal or wood being used on curves of 30 meters radius or less?

3. FORM ALIGNMENT

   Is the contractor checking the forms for line and grade and making necessary adjustments prior to concrete placement?

4. TEMPLATE

   Is the surface of the subbase being tested for crown and elevation by means of a template?

5. SUBBASE THICKNESS TEST

After trimming, is the thickness of the subbase being checked?

6. DRAINAGE

Is the subgrade being kept drained during all operations? Are all berms of earth deposited adjacent to the grade being kept drained by cutting lateral ditches through the berms?

7. LUG SYSTEMS (CONTINUOUSLY REINFORCED)

If concrete lug end anchorages are specified, are they staked and checked for dimensions and re-bar placement as shown in the plans?

Are they constructed of Structural Concrete at least 24 hours prior to pavement construction?

8. LONGITUDINAL JOINT KEYWAY AND BARS

Are the beginning and ending stations marked where adjacent curb, median, or pavement will necessitate the placement of keyway and/or bars in the edge of the proposed pavement?

9. SUPERELEVATION STAKING

Are the plan curb data examined for all curves to determine where to stake the beginning and ending stations for all superelevation transitions?

10. TEMPERATURE LIMITATIONS

Does the outside air temperature in the shade meet State specifications?

Does the temperature of the concrete meet State specifications at the time of placement?

11. REINFORCEMENT LAPPING

Are the locations and lengths of lap for bar or fabric reinforcement in conformance with the specifications.

Are all bar and fabric laps being tied?

12. TRUCK REQUIREMENTS

Is all concrete in a stationary mixer being deposited within 30 minutes when hauled in non-agitating trucks and within 90 minutes when hauled in agitator trucks?

Is transit mixed concrete being delivered and deposited within 90 minutes from the time stamped on the ticket?

If the contractor plans to use previously placed pavement as a haul road, are the truck weights checked to assure compliance with maximum weights permitted by State Law?

13. REINFORCEMENT PLACEMENT

Is the reinforcement being placed in accordance with one of the following methods?

Method A - After the full depth concrete is struck off the reinforcement should be placed into the concrete to the required depth by mechanical means.

Method B - The reinforcement should be supported on the prepared subbase by approved chairs having sand plates.

Method C - When the concrete is being placed in two layers the reinforcement should be laid full length on the struck-off bottom layer of concrete in its final position without further manipulation. (Cover within 30 minutes.) The depth of the first lift is 2/3 the depth of the pavement.

Method D - The reinforcement may be placed in the pavement using a method which does not require transverse steel or support chairs for support of the longitudinal steel. Tie bars at longitudinal joints are still required.

14. SEQUENCES OF FORM TYPE PAVING

Is all of the required concrete finishing equipment on the job and in acceptable working condition? Are the following sequences for form type paving being properly followed:

(a) Placing concrete. As little rehandling as possible. If equipment used can cause segregation, is the concrete being unloaded into an approved spreading device?

(b) Strike-off. Is the concrete being struck full width to the approximate cross section of the pavement?

(c) Consolidation. Is one pass of an approved surface vibrator or internal vibrator being made?

(d) Screeding. Are at least two passes with a machine having two oscillating screeds, and a finisher float being made?

(e) Straightedging - Are at least two 3 meter long shoulder operated or surface operated surface trueness testers (straightedges) being used?

(f) Surfacing Texturing - Are State specifications for texturing and tining being followed?

15. <u>SEQUENCES OF SLIPFORM PAVING</u>

When the contractor uses this optional method for the construction of the pavement are the following sequences being properly followed:

(a) Is the formless paver capable of spreading, consolidating internally, screeding and float finishing the newly placed concrete in one pass to the required line and grade?

(b) Is the pavement being straightedged, edged, and textured as required in the previous question 14?

(c) Does the contractor have available at all times metal or wooden sideforms and burlap or curing paper for the protection of the pavement in case of rain?

(d) Is the contractor immediately repairing all slumping edges in excess of 12.5 millimeters?

16. THICKNESS TEST

Is the thickness of the pavement being checked?

17. AIR CONTENT

Is the air content being tested as required by the frequency chart?

18. SLUMP

Is the slump being checked as required by the frequency chart?

19. REINFORCEMENT, DOWEL, AND TIE BAR DEPTH CHECKS

Is the concrete being probed to check the vertical and horizontal positioning of the pavement reinforcement, dowels, and tie bars?

20. STRENGTH

Are test specimens being cast at the site of work at the required frequency:

(a) at least one set per day
(b) one set for every 150 meters of two lane pavement (300 meters of one lane pavement)

21. LONGITUDINAL JOINT

(a) Are tie bars placed properly?

(b) Are the joints sawed at the same time as the transverse joints with pavement widths greater than 7.3 meters? Are they cleaned and immediately filled with sealer?

22. TRANSVERSE JOINTS

(a) Are the smooth dowel bars positioned parallel to the grade at a depth of ½ t.

Are the dowel bars coated with a thin bond breaker?

Are the capped ends of the bar coated with a debonding agent? (Expansion joints)

(b) Is a 1/3T deep groove being sawed over each assembly as soon as possible after concrete placement? Cleaned immediately?

(c) Are all joints being sealed after the curing period and before opening to traffic?

23. <u>TRANSVERSE CONSTRUCTION JOINTS (CONTINUOUSLY REINFORCED CONCRETE)</u>

(a) Are construction joints being placed at the end of each day's operation or after an interruption in the concreting operation of 30 minutes or more?

(b) Are construction joints being placed at least 1 meter from nearest bar lap?

(c) Are construction joints strengthened by supplementary 1.8 meter long bars of the same nominal diameter as the longitudinal steel so that the area of steel through the joint is increased by at least 1/3?

(d) Are construction joints formed by means of a clean (not oiled) split header board conforming to the cross section of the pavement?

(e) Is the concrete at construction joints being given supplemental internal vibration along the length of the joint both at the end of the day's operation and once again at the resumption on the next day? This is critical.

24. <u>TRANSVERSE CONSTRUCTION JOINTS (JOINTED PAVEMENT)</u>

(a) Are construction joints being placed at the end of each day's operation or after an interruption in the concreting operation of 30 minutes or more?

(b) Are construction joints being placed at least 3 meters from any transverse joint?

(c) Are construction joints being strengthened by epoxy coated dowel bars of the same size and positioning as specified for contraction joints?

Is a thin coating of bonding breaking agent applied to the dowels?

(d) Are construction joints being formed by means of a suitable header board conforming to the cross-section of the pavement?

25. SURPLUS - DEFICIENCY DETERMINATION

Is a daily check being made on the yield of produced concrete?

26. CURING

Are the pavement surface and edges being cured by one of the following methods:

(a) Waterproof Paper Method. Are the surfaces being covered as soon as possible with blankets or tear-free reinforced kraft paper, with 300 millimeter laps, properly weighted? Has the pavement been wetted with a fine spray first?

(b) Polyethylene Sheeting Method. Are surfaces covered as soon as possible with 30 meter long sheets of white polyethylene, with 300 millimeter laps, properly weighted? Has the pavement been wetted with a fine spray first?

(c) Wetted Burlap Method. Are surfaces covered as soon as possible with two layers of wet burlap, with 150 millimeter laps? Kept saturated by means of a mechanically operated sprinkling system or an impermeable covering? (Alternate: one burlap and one burlene blanket)

(d) Membrane Curing Method. Are surfaces covered as soon as the water sheen has disappeared, with two separate applications of agitated white curing compound being uniformly applied at a rate of $5m^2/l$? (Note that each application should be separated by at least 1 minute).

Do the curing compounds meet specification requirements?

27. <u>PROTECTION</u>

Is the contractor providing protection of the pavement from low temperatures?

Does the contractor have adequate protection on hand in case of rain?

28. <u>SURFACE VARIATIONS</u>

At the end of curing period, is the pavement being profilographed or straightedged in each wheel lane for surface variations?

(a) Are all bumps being marked, ground down or pavement replaced?

29. <u>OPENING TO TRAFFIC</u>

Is the pavement being closed to traffic until:

(a) The curing and protection period has elapsed?

(b) All joints have been sealed?

(c) The required strength has been achieved by test specimen?

(d) If the contractor wishes to open the pavement to traffic prior to the date of your first routine strength test, are additional specimens being cast and then allowed to cure out in the open the same as the pavement?

HAUL TICKET FOR TRUCK MIX CONCRETE

PROJECT NO. ______________
BATCHED FROM (PLANT) ______________
NO. CUBIC METERS ______________
CONCRETE ______________

DATE: ______________
TRUCK NO. ______________
CLASS OF ______________

BATCH WEIGHTS

CEMENT BRAND ______________
kg ______________
FINE AGGR. SOURCE ______________
kg ______________
COARSE AGGR. SOURCE ______________
kg ______________
FLY ASH SOURCE ______________
kg ______________

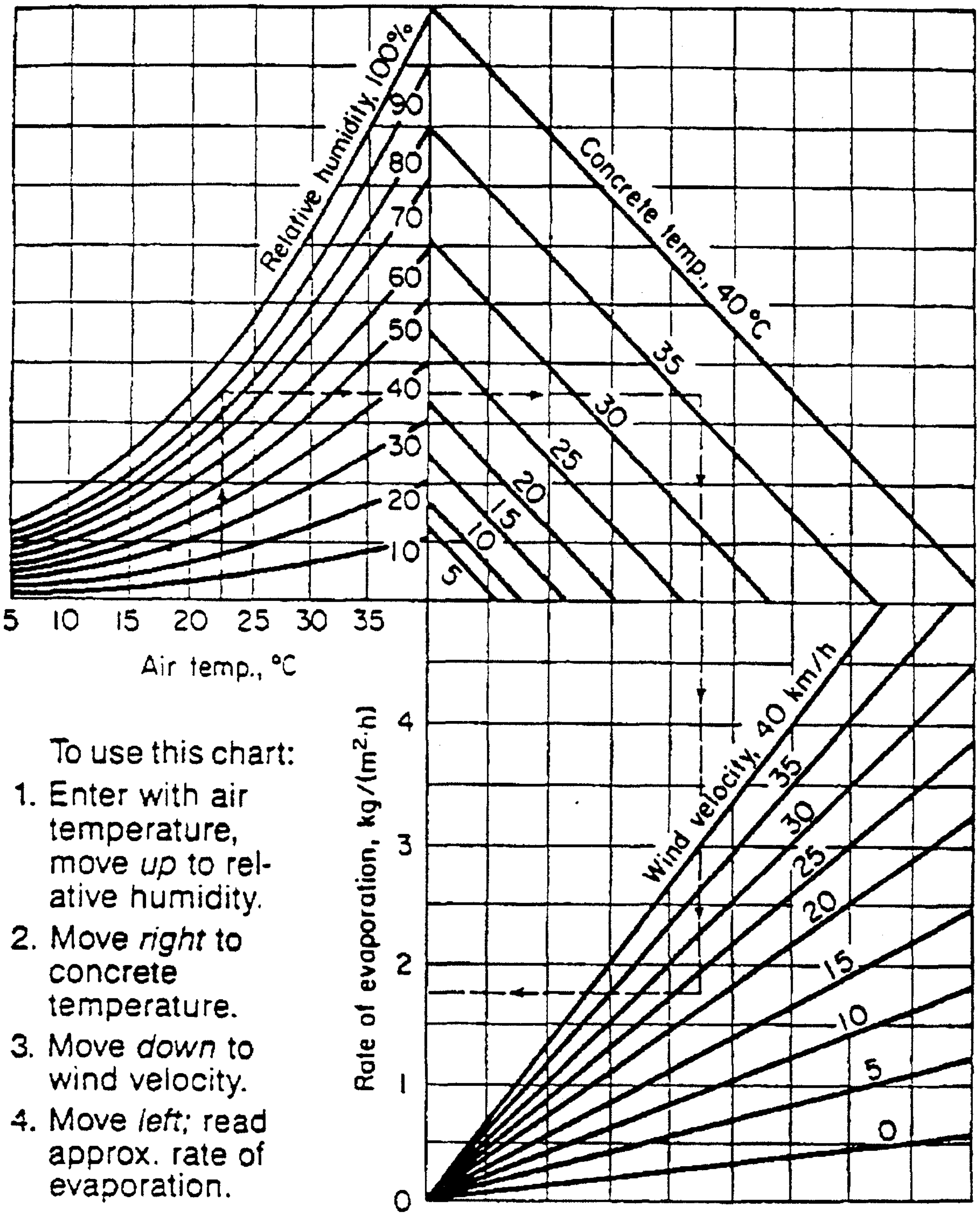
AIR ENTRAINMENT BRAND ______________
grams ______________
RETARDER BRAND ______________
grams ______________
WATER REDUCER BRAND ______________
ml ______________

WATER
MAXIMUM WATER ALLOWED, Liter ______________
FREE MOISTURE
CA Liters ______________
FA Liters ______________
WATER ADDED AT PLANT Liters ______________
MAXIMUM WATER THAT CAN BE ADDED AT THE SITE Liters ______________

PLANT	SITE
TIME WATER ADDED TO MIX ______ AM / PM	TIME DISCHARED COMPLETED ______ AM / PM
	WATER ADDED AT JOBSITE Liters ______
	TOTAL WATER IN BATCH Liters ______
NUMBER OF MIXING	MIXING REVOLUTIONS AT SITE ______
	TOTAL NO. OF REVOLUTIONS ______
	SLUMP ______ AIR ______
	UNIT WEIGHT ______
	CONC. TEMP ______
	AIR TEMP ______
Signature ______________	Signature ______________

THIS PAGE LEFT BLANK
INTENTIONALLY

NOMOGRAPH USED TO
DETERMINE EVAPORATION RATE



To use this chart:

1. Enter with air temperature, move *up* to relative humidity.
2. Move *right* to concrete temperature.
3. Move *down* to wind velocity.
4. Move *left;* read approx. rate of evaporation.

THIS PAGE LEFT BLANK
INTENTIONALLY

CHECKLIST FOR QUALIFICATION OF FACILITIES FOR PRESTRESSED CONCRETE PRODUCTION

1. Items which require written approval: (check applicable blanks)

   (a) Plans and computations of facilities ________

   (b) Concrete mix design (should include curves for 28-day strength) vs W/C Ratio: ________

   (c) Curing method ________

   (d) Epoxy-sand mortar, if used ________

   (e) Coal tar epoxy, if used ________

   (f) Water reducer-retarder ________

   (g) Design Engineer should be approved by State DOT ________

   (h) Gauge calibration should be certified ________

   (i) Computations regarding beam tests (2 weeks prior to testing) ________

2. What is length and capacity of stressing bed(s)

   Bed No. ________ Length ________ Capacity ________
   Bed No. ________ Length ________ Capacity ________
   Bed No. ________ Length ________ Capacity ________

3. Procedure of prestressing (pretensioning) and stress release:

   (a) Jacks, carriages, and struts are adequate to attain and maintain design stress.
   Yes ________ No ________
   Comments:
   ____
   ____

(b) Stressing of straight strands: (check applicable blanks)
Single strand method ___________
Multiple strand method ___________

Comments:

____

____

(c) Stressing of draped strands (check applicable blanks)
Single strand method ______
Multiple strand method ______
Final draped position ______ both ends ______
Partial draped position ______ one end ______

Comments:

____

____

(d) Single strand jack available.
Yes ___________ No___________

(e) Is an accurate dynamometer available for use in applying initial tension to the strands?
Yes ___________ No ___________

(f) What is proposed initial load to be applied ___________ lbs.

(g) Is there a permanent, accurate linear gauge with which to measure elongation?
Yes ___________ No ___________

4. Forms: (Make comments in spaces provided)

(a) Metal

____

____

(b) True to shape and dimensions

____

____

(c) Adequate in number

____

____

(d) Condition and composition of bulkheads

____

____

(e) Type of hold-down device to be used

____

____

(f) Is provision being made to maintain 25 millimeter concrete cover over hold-down device?

____

____

(g) Are bulkheads and hold-down devices adequate to maintain dimensions of strand centers as shown on the plans?

____

____

5. Are facilities adequate for proper storage and handling of bridge members?
Yes __________ No __________

(a) Approximate available storage area ______________________

(b) Condition of storage area ______________________

6. Are facilities available for properly testing a member of the design type to be fabricated?
Yes __________ No__________ (if No explain)

____

____

7. Are adequate lighting facilities available in the event that placing of concrete at night is necessary?
Yes __________ No __________

8. Vibrating equipment:

(a) Condition ______________________________

(b) Number to be used in placing __________________

(c) Two spaces available ______________

9. Source of Materials:

(a) Steel Wire and Strand (manufacturer)

____

(b) Cement (type and brand name)

____

(c) Coarse Aggregate (producer and location)

____

(d) Sand (producer and location)

____

(e) Retarder (brand name)

____

(f) Form Oil (type and name)

____

(g) Reinforcing Steel (producer)

____

10. Type of concrete mixing facilities: mixed at plant ______________
Ready Mix concrete ______________

(a) Are concrete batching facilities adequate to ensure good quality and sufficient quantity to avoid delays under all working conditions?
Yes __________ No __________

11. Testing equipment available: (check applicable blanks)

(a) Plastic cylinder molds ______________
No. Available ______________

(b) Slump Cone ______________

(c) Air content device ______________
(pressure __________ volumetric __________)

(d) Facilities for testing cylinders available at (proposed location)

____

12. Requirements for steam cure method:

(a) Three (3) recording thermometers available

___

(b) Temperature record charts

___

(c) Adequate temperature control valves

___

(1) What are the increments of spacing of control valves?

___

13. Are facilities available for proper protection and handling of component materials in storage? (Rate "S" if satisfactory, "U" if unsatisfactory, and "NA" if not applicable)

(a) Wire and/or strand ______
(b) Reinforcing steel ______
(c) Structural steel ______
(d) Cement ______
(e) Coarse Aggregate ______
(f) Sand ______

14. Is there a suitable shelter (at least 14 square meters floor space, facilities for lights, heat, desk(s), etc.) available for the inspector's use?

___

15. Personnel present during inspection of plants:

Producers/Contractors	Highway Department

THIS PAGE LEFT BLANK
INTENTIONALLY

GUIDE FOR QUALITY CONTROL PLAN FOR PORTLAND CEMENT CONCRETE

REQUIREMENTS

1. General Requirements:

The contractor should provide and maintain a quality control system that will provide reasonable assurance that all materials and products submitted to the State for acceptance will conform to the contract requirements whether manufactured or processed by the contractor or procured from suppliers or subcontractors or vendors. The contractor should perform or have performed the inspections and tests required to substantiate product conformance to contract document requirements and should also perform or have performed all inspections and tests otherwise required by the contract. The quality control inspections and tests should be documented and should be available for review by the engineer throughout the life of the contract.

2. Quality Control Plan:

The contractor should prepare a Quality Control Plan detailing the type and frequency of inspection, sampling and testing deemed necessary to measure, and control the various properties of materials and construction governed by the Specifications. As a minimum, the sampling and testing plan should detail sampling location and techniques, and test frequency to be utilized. The Quality Control Plan should be submitted in writing to the engineer at the preconstruction conference.

The Plan should identify the personnel responsible for the contractor's quality control. This should include the company official who will act as liaison with State personnel, as well as the Certified Portland Cement Concrete Technician who will direct the inspection program.

The class or classes of concrete involved will be listed separately. If existing mix designs are to be utilized, the Mix Design Numbers should be listed.

Quality control sampling, testing, and inspection should be an integral part of the contractor's quality control system. In addition to the above requirements, the contractor's quality control system should document the quality control requirements shown in Table 1. The quality control activities shown in Table 1 are considered to be normal activities necessary to control the production and placing of a given product or material at an acceptable quality level. To facilitate the States' activities, all completed gradation samples should be retained by the contractor until further disposition is designated by the State.

It is intended that sampling and testing be in accordance with standard methods and procedures, and that measuring and testing equipment be properly calibrated. If alternative sampling methods, procedures and inspection equipment are to be used, they should be detailed in the Quality Control Plan.

3. Documentation:

The contractor should maintain adequate records of all inspections and tests. The records should indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the nature of corrective action taken as appropriate. The contractor's documentation procedures will be subject to the review and approval of the State prior to the start of the work and to compliance checks during the progress of the work.

4. Charts and Forms:

All conforming and non-conforming inspections and tests results should be kept complete and should be available at all times to the State during the performance of the work. Batch tickets and gradation data will be submitted to the State as the work progresses. All test data will be plotted on control charts. It is normally expected that testing and charting will be completed within 48 hours after sampling.

All charts and records documenting the contractor's quality control inspections and tests should become property of the State upon completion of the work.

5. Corrective Action:

The contractor should take prompt action to correct conditions which have resulted, or could result, in the submission to the State of materials and products which do not conform to the requirements of the Contract documents.

6. Non-Conforming Materials:

The contractor should establish and maintain an effective and positive system for controlling non-conforming material, including procedures for its identification, isolation, and disposition. Reclaiming or reworking of non-conforming materials should be in accordance with procedures acceptable to the State.

All non-conforming materials and products should be positively identified to prevent use, shipment, and intermingling with conforming materials and products. Holding areas, mutually agreeable to the State and the contractor, should be provided by the contractor.

7. Acceptance:

The State will monitor the performance of the contractor's quality control plan and will perform verification testing to ensure that proper sampling and testing procedures are used by the contractor. The State may shut down the contractors operations for failing to follow the approved process control plan. All acceptance testing will be performed by State personnel.

TABLE 1

CONTRACTOR'S QUALITY CONTROL REQUIREMENTS

Minimum Quality Control Requirement	Frequency
A. PLANT AND TRUCKS	
1. Mixer Blades	Prior to Start of Job and weekly
2. Scales	Prior to Start of Job and weekly
a. Tared	Daily
b. Calibrate	Prior to Start of Job
c. Check Calibration	Weekly
3. Gauges and Meters - Plant and Truck	
a. Calibrate	Yearly
b. Check Calibration	Weekly
4. Admixture Dispenser	
a. Calibrate	Prior to Start of Job
b. Check Operation and Calibration	Daily
B. AGGREGATES	
1. Fine Aggregate	
a. Gradation	21 Days
b. Deleterious Substances	Daily
c. Moisture	Daily
2. Coarse Aggregates	
a. Gradation	21 Days
b. Percent Passing No. 200 Sieve	Daily
c. Moisture	Daily
C. PLASTIC CONCRETE	
1. Entrained Air Content	One Per 1/2 Day Operation
2. Consistency	One Per 1/2 Day of Operation
3. Temperature	One Per 1/2 Day of Operation
4. Yield	One Per 1/2 Day of Operation

Chapter 4

Flexible Pavement

CHAPTER 4

FLEXIBLE PAVEMENT

4.1 TA 5040.27, Asphalt Concrete Mix Design and Field Control, February 16, 1988.

4.2 Prevention of Premature Distress in Asphalt Concrete Pavements, Technical Paper 88-02, April 18, 1988.

4.3 Guidelines on the Use of Bag-House Fines, April 7, 1988.

4.4 Reserved.

4.5 State of the Practice on the Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier, Report Number FHWA-SA-92-022, June 9, 1992.

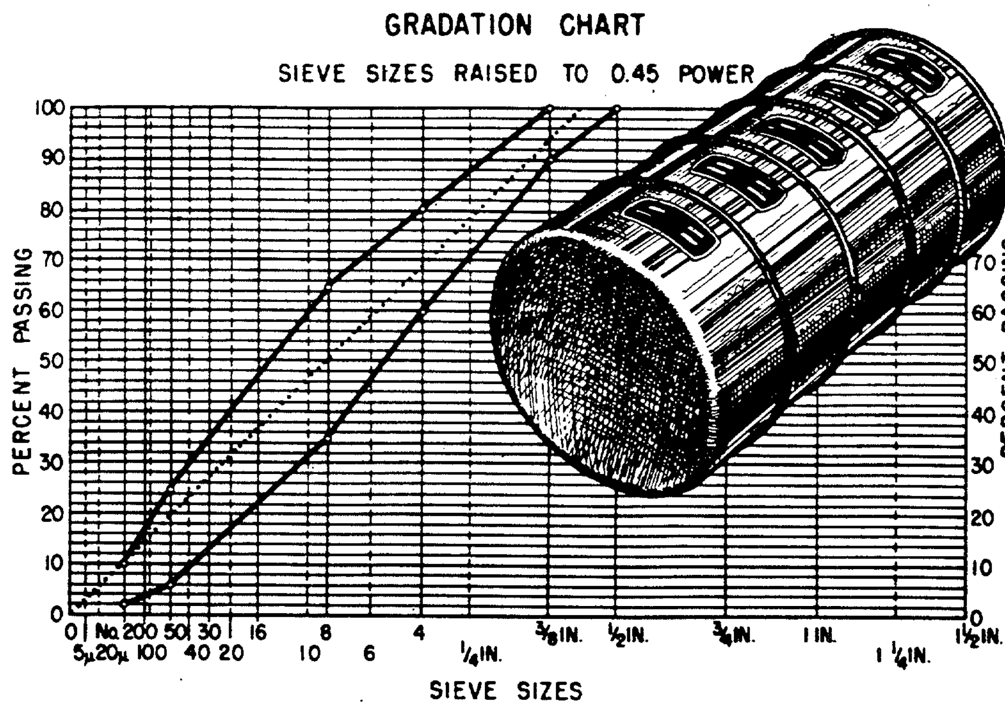
4.6 Reserved.

4.7 Processed Used-Oil and Heavy Fuel Oils for Use in Hot Mix Asphalt Production, June 21, 1990.

4.8 Aggregate Gradation for Highways - 0.45 Particle Size Distribution Curve, 1962.

- Aggregate Gradation: Simplification, Standardization, and Uniform Application
- A New Graphical Chart for Evaluating Aggregate Gradation

AGGREGATE GRADATION FOR HIGHWAYS



Simplification, Standardization, and Uniform Application

and

A New Graphical Evaluation Chart

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

WASHINGTON : 1962

THIS PAGE LEFT BLANK
INTENTIONALLY

AGGREGATE GRADATION FOR HIGHWAYS

Aggregate Gradation: Simplification, Standardization, and Uniform Application

and

A New Graphical Chart for Evaluating Aggregate Gradation

By the Bureau of Public Roads

U.S. DEPARTMENT OF COMMERCE

Luther H. Hodges, *Secretary*

BUREAU OF PUBLIC ROADS

Rex M. Whitton, *Administrator*

United States Government Printing Office, Washington, D.C. : May 1962

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. - - - - - - - - - - - - - - Price 25 cents

AGGREGATE GRADATION: SIMPLIFICATION, STANDARDIZATION, AND UNIFORM APPLICATION

BY THE BUREAU OF PUBLIC ROADS

This report was prepared by a special committee appointed by Assistant Federal Highway Administrator and Chief Engineer Francis C. Turner and representing the Bureau of Public Roads Offices of Engineering, Operations, and Research. The committee included Ardery R. Rankin, chairman, Office of the Assistant Administrator; Carl A. Carpenter and Russell H. Brink, Physical Research Division; Morley B. Christensen, Construction and Maintenance Division; and William B. Huffine and Norman J. Cohen, Equipment and Methods Division

The Need for Simplification

Because of the magnitude of the nationwide highway construction program and the enormous amount of public funds required to finance it, every effort must be made to develop and apply ways and means of reducing construction costs while at the same time assuring the production of only high quality work. In its continuing mission of contributing toward the accomplishment of that objective, the Bureau of Public Roads has made a study of the possibility of effecting economies through simplification, standardization, and uniform application of aggregate gradations.

In performing this study, analyses were made of the current standard specifications of the highway departments of the 50 States, the Commonwealth of Puerto Rico, and the District of Columbia. The analyses disclosed a wide diversity in the requirements pertaining to aggregate gradations. Some 215 dissimilar gradations are specified for coarse aggregates for portland cement concrete. Of these gradations 88 are for both structures and pavement, 91 are for structures only, and 36 are solely for pavements. In contrast, Part I of the *Standard Specifications for Highway Materials* of the American Association of State Highway Officials includes only 19 gradations of coarse aggregates for all highway construction (see AASHO Designation M 43–49), with only 7 designed for use in concrete pavements or bases, bridges, and incidental structures (see AASHO Designation M 80–51). Similarly, the 52 highway departments specify a total of 58 fine aggregate gradations for both pavement and structural concrete whereas AASHO specifies only 1 (see AASHO Designation M 6–51).

In addition, there is considerable lack of consistency among the States in the number and sizes of sieves used to determine the gradations; furthermore, there is no uniform method in actual use by the States for designating aggregate gradation sizes. Only two States refer to the size designations used in AASHO Designation M 80–51. Some States have their own systems of size designations and other States use no designations at all.

Obviously, a greater degree of simplicity, standardization, and uniformity of usage for aggregate gradations would be highly desirable. For example, a commercial supplier who presently furnishes aggregates under numerous varying specification requirements for several Federal, State, county, and municipal highway organizations for identical construction purposes, would certainly find it much simpler and less costly if the same few gradations with identical specification requirements were used by all these agencies. Similarly, construction contractors bidding in more than one jurisdiction could prepare their bids much more intelligently and probably at lower prices if the specification requirements and the materials designations were the same for all jurisdictions.

For reasons of economy and because of the growing scarcity of high-quality aggregates in some areas, it is essential to make as much use as possible of aggregates that are locally available. This frequently necessitates tailoring the specification requirements to fit the characteristics of such local aggregates to whatever extent may be compatible with producing high-quality construction at economical prices. Nevertheless, a much greater degree of standardization and uniform use of aggregate gradations can undoubtedly be achieved. The problem has long been recognized and has here been approached with three specific objectives:

1. To develop a minimum number of standard aggregate gradations that can be uniformly adopted nationwide for general usage, while at the same time recognizing the need for some variations by special provisions to fit locally available materials.
2. To achieve uniformity in the number and sizes of sieves to be used in specifying the aggregate gradations.
3. To develop and adopt a simple and uniform system for identification of the standard aggregate gradations.

The Simplified Practice Recommendation

A major step toward accomplishing these objectives was taken on June 30, 1948, when the Department of Commerce approved and issued Simplified Practice Recommendations R 163–48 [1] for coarse aggregates, including crushed stone, gravel, and slag. A predecessor recommendation had originally been approved for promulgation in June 1936 and issued as R 163–36. It was proposed by the Joint Technical Committee of the Mineral Aggregates Association, composed of representatives of the National Sand and Gravel Association, the National Crushed Stone Association, and the National Slag Association. Producers, distributors, and users of mineral aggregate all cooperated in developing the simplified practice recommendation. An intermediate revision was approved and published in 1939 and some additional revisions subsequent to 1939 resulted in the publication of the current issue of 1948. Table 1 shows the SPR gradings that are currently in effect.

As will shortly be described, the SPR system has been essentially adopted by both the American Association of State Highway Officials and the American Society for Testing and Materials.

Value of the SPR system

The simplified practice recommendation R 163–48 embodies a number of highly logical and useful features:

1. *Standard sieves.*—The SPR gradings employ a simple and convenient, square-opening, sieve-size series based primarily on the logarithmic principle.

The basic logarithmic sieve series employed begins with a sieve having clear openings of 3 inches and each smaller sieve has clear openings the diameter of which is one-half that of the next larger one. Thus the basic series is 3-inch, 1½-inch, ¾-inch, ⅜-inch, No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200. Because some consumer interests consider that the logarithmic series does not provide enough control in the larger sizes while others desire greater freedom in selecting maximum sizes, the gaps have been reduced in the SPR series by superimposing upon the logarithmic series, the arbitrary sizes 4-inch, 3½-inch, 2½-inch, 2-inch, 1-inch, and ½-inch. Also, two of the logarithmic sizes were left out of the SPR series—the No. 30 because it was felt that it serves no useful purpose in grading control of coarse commercial aggregates, and the No. 200 because material of this size (soil fines and commercial mineral filler for bituminous paving mixtures) is not and should not be considered an ingredient of commercial coarse aggregates. Both the No. 30 and the No. 200 sieves are required in specifying sands and fillers, as in the ASTM and AASHO standards, and both fit in the logarithmic series.

2. *Simple system.*—The SPR gradings embody a simple and readily understandable system of individual size and grading designations consisting basically of single-digit numbers.

The single-digit numbering series starts with No. 1 for the standard commercial aggregate having the largest top-size particles and progresses from No. 1 through No. 9 as the individual standard coarse aggregates decrease in size, as shown in table 2.

Because of consistent demands for certain longer gradings than the relatively short ones represented by the basic series, shown in the first column of table 2, a secondary

[1] *Coarse Aggregates (Crushed Stone, Gravel, and Slag), Simplified Practice Recommendation R 163–48*, approved June 30, 1948, National Bureau of Standards, U.S. Department of Commerce, 1948.

Table 1.—Sizes of coarse aggregate (crushed stone, gravel, and slag) from Simplified Practice Recommendation, R 163–48 [1]

SPR size number	Nominal size,[2] square openings	Amounts finer than each laboratory sieve (square openings), percentage by weight														
		4-in.	3½-in.	3-in.	2½-in.	2-in.	1½-in.	1-in.	¾-in.	½-in.	⅜-in.	No. 4	No. 8	No. 16	No. 50	No. 100
1	3½-1½	100	90-100		25-60		0-15		0-5							
1F [3]	3½-2	100	90-100			0-10	0-2									
2F [3]	3-1½		100	90-100			0-10	0-2								
2	2½-1½			100	90-100	35-70	0-15		0-5							
24	2½-¾			100	90-100		25-60		0-10	0-5						
3	2-1				100	90-100	35-70	0-15		0-5						
357	2-No. 4				100	95-100		35-70		10-30		0-5				
4	1½-¾					100	90-100	20-55	0-15		0-5					
467	1½-No. 4					100	95-100		35-70		10-30	0-5				
5	1-½						100	90-100	20-55	0-10	0-5					
56	1-⅜						100	90-100	40-75	15-35	0-15	0-5				
57	1-No. 4						100	95-100		25-60		0-10	0-5			
6	¾-⅜							100	90-100	20-55	0-15	0-5				
67	¾-No. 4							100	90-100		20-55	0-10	0-5			
68	¾-No. 8							100	90-100		30-65	5-25	0-10	0-5		
7	½-No. 4								100	90-100	40-70	0-15	0-5			
78	½-No. 8								100	90-100	40-75	5-25	0-10	0-5		
8	⅜-No. 8									100	85-100	10-30	0-10	0-5		
89	⅜-No. 16									100	90-100	20-55	5-30	0-10	0-5	
9	No. 4-No. 16										100	85-100	10-40	0-10	0-5	
10	No. 4-0 [4]										100	85-100				10-30
G1 [5]	1½-No. 50						100	80-100		50-85		20-40	15-35	5-25	0-10	0-2
G2 [5]	1½-No. 8						100	65-100		35-75		10-25	0-10	0-5		
G3 [5]	1½-No. 4						100	60-95		25-60		0-15	0-5			

[1] *Coarse Aggregates (Crushed Stone, Gravel and Slag), Simplified Practice Recommendation R 163–48*, Approved June 30, 1948, National Bureau of Standards, U.S. Department of Commerce, p. 2.

[2] In inches, except where otherwise indicated. Numbered sieves are those of the United States Standard Sieve series.

[3] Special sizes for sewage trickling filter media.

[4] Screenings.

[5] The requirements for grading depend upon percentage of crushed particles in gravel. Size G1 is for gravel containing 20 percent or less of crushed particles; G2 is for gravel containing more than 20 percent and not more than 40 percent of crushed particles; G3 is for gravel containing crushed particles in excess of 40 percent. (Designated as railroad ballast, gravel.)

Table 2.—Basic Simplified Practice Recommendations numbering system

Basic SPR designations	Combinations of basic designations	Nominal size: Maximum	Nominal size: Minimum	Size limits: Maximum	Size limits: Minimum
1		3½-in	1½-in	4-in	¾-in.
2		2½-in	1½-in	3-in	¾-in.
3		2-in	1-in	2½-in	½-in.
	357				
4		1½-in	¾-in	2-in	⅜-in.
	467				
5		1-in	½-in	1½-in	⅜-in.
	56				
	57				
6		¾-in	⅜-in	1-in	No. 4.
	67				
	68				
7		½-in	No. 4	¾-in	No. 8.
	78				
8		⅜-in	No. 8	½-in	No. 16.
9		No. 4	No. 16	⅜-in	No. 50.

grading series was developed by combining the basic gradings. These combinations of the basic gradings are identified by corresponding combinations of the single digit numbers. Thus, standard aggregate No. 357, shown in the second column of table 2, which immediately follows No. 3 in the SPR table of gradings (table 1), is a combination of standard sizes Nos. 3, 5, and 7 in such proportions as to conform to the grading-band limits that were assigned to it. Similarly, standard aggregate No. 56, following No. 5, is a combination of standard sizes Nos. 5 and 6 in such proportions as to conform to the grading-band limits assigned to it.

Gradings Nos. 1F, 2F, G1, G2, and G3, listed in table 1, do not apply to highway work and are not included in the abridged version of table 1 that has been published in the AASHO and ASTM Standards. Item 10 (table 1) represents screenings and may be considered more or less a residual material from aggregate crushing and processing. It is not generally subject to close control, as indicated by the wide limits on the amount passing the No. 100 sieve, and is not considered pertinent to this discussion.

3. *Flexibility.*—The SPR gradings permit a high degree of flexibility.

The standard, stock aggregates can be combined to produce any reasonable total grading for roadbuilding purposes when further combined with suitable sands or mineral filler.

Adoption by AASHO and ASTM

The original SPR issuance, R 163–36, was adopted, essentially as promulgated, by the American Society for Testing and Materials in 1937 as Tentative Specification D 448–37T. It was carried as a Tentative Standard, with revisions in 1941 and 1942, until 1947, when it was advanced to Standard. The Standard was revised in 1949 and in 1954 and now appears in ASTM publications as Standard Specification D 448–54.

The simplified practice recommendation, including its numbering system, was adopted to cover standard sizes of coarse aggregate for highway construction by the American Association of State Highway Officials in 1942 and was designated AASHO Specification M 43–42. With some exceptions the SPR gradings were also adopted that year for crushed stone and crushed slag, for various specific purposes as in AASHO Designation M 75–42, base course; M 76–42, bituminous concrete base course and others; and also M 80–42, coarse aggregate for portland cement concrete: but in these individual applications the SPR numbering system was not used by AASHO until 1949. Since that year, all features of the SPR scheme have, with minor deviations,[2] been generally included in AASHO specifications for specific items as well as in the general group specification for coarse aggregates for highway construction. Some slight revisions of M 43–42 were made in 1949 and the designation was changed to M 43–49 which is still carried.

The present SPR system does not provide complete gradings for portland cement concrete or bituminous paving mixtures because it does not cover sands or mineral fillers. For both of these, however, there are AASHO and ASTM standards.

Aggregates for Portland Cement Concrete

The adoption by AASHO and ASTM of the SPR system for coarse aggregates for portland cement concrete has just been described. With regard to sand for portland cement concrete, the need for standardization is now met by AASHO Specification M 6–51 and ASTM Specification C 33–59, which are very similar to each other, as shown in table 3, and both of which have proved satisfactory in use. Both gradings utilize the logarithmic sieve sizes and are therefore compatible with the SPR system.

Aggregates for Bituminous Paving Mixtures

Coarse aggregates

AASHO has two specifications for coarse aggregates for bituminous paving mixtures: one for bituminous concrete base course, M 76–51, and one for bituminous concrete surface course, M 79–51. However, each of these is somewhat lacking in desirable flexibility in that only two SPR aggregate sizes are provided in each case.

[2] These deviations are as follows:

Size designation No. 3 (2 in. to 1 in.): Percentage passing the 2-in. sieve: 95–100 (SPR 163–48); 95–100 (AASHO M 43–49); 90–100 (ASTM D 448–54).

Size designation No. 67 (¾-in. to No. 4): Percentage passing the ¾-in. sieve: 90–100 (SPR 163–48); 90–100 (ASTM D 448–54); 95–100 (AASHO M 80–51); 90–100 (AASHO M 43–49).

Table 3.—AASHO and ASTM sand gradings for portland cement concrete

Sieve size	Percentage passing sieve: AASHO M 6–51	Percentage passing sieve: ASTM C 33–59
⅜-in	100	100
No. 4	95–100	95–100
No. 8		80–100
No. 16	45–80	[1] 50–85
No. 30		25–60
No. 50	[2] 10–30	[2] 10–30
No. 100	[3] 2–10	[3] 2–10

[1] Prior to 1962 these requirements were 45–80.
[2] These requirements may be changed to 5–30; see referenced specifications.
[3] These requirements may be changed to 0–10; see referenced specifications.

Table 4.—Grading requirements for coarse aggregate for bituminous paving mixtures, from ASTM Designation D 692–59T

SPR size No.	Nominal size (sieves with square openings)	Amounts finer than each laboratory sieve (square openings), percentage by weight									
		2½-in.	2-in.	1½-in.	1-in.	¾-in.	½-in.	⅜-in.	No. 4 [1]	No. 8 [2]	No. 16 [3]
3	2-in. to 1-in.	100	90–100	35–70	0–15		0–5				
357	2-in. to No. 4	100	95–100		35–70		10–30		0–5		
4	1½-in. to ¾-in.		100	90–100	20–55	0–15		0–5			
467	1½-in. to No. 4		100	95–100		35–70		10–30	0–5		
5	1-in. to ½-in.			100	90–100	20–55	0–10	0–5			
57	1-in. to No. 4			100	95–100		25–60		0–10	0–5	
6	¾-in. to ⅜-in.				100	90–100	20–55	0–15	0–5		
67	¾-in. to No. 4				100	90–100		20–55	0–10	0–5	
68	¾-in. to No. 8				100	90–100		30–65	5–25	0–10	0–5
7	½-in. to No. 4					100	90–100	40–70	0–15	0–5	
78	½-in. to No. 8					100	90–100	40–75	5–25	0–10	0–5
8	⅜-in. to No. 8						100	85–100	10–30	0–10	0–5

[1] 4,760-micron. [2] 2,380-micron. [3] 1,190-micron.

ASTM has had for some years a specification for coarse aggregates for bituminous paving mixtures, D 692, covering 9 standard SPR sizes. In 1959 the then current version, D 692-54, was amended by adding SPR aggregates Nos. 5, 6, and 68, and the specification now carries the designation D 692-59T. It has much greater flexibility, therefore, than the current AASHO specifications. The current ASTM requirements are shown in table 4.

Sands

In the case of sands for bituminous paving mixtures, ASTM has recently completed a committee study of current practices with the participation of representatives of the AASHO Materials Committee, the Highway Research Board, the Asphalt Institute, the National Slag Association, the National Sand and Gravel Association, the National Ready Mixed Concrete Association, and the National Crushed Stone Association. The Bureau of Public Roads was actively represented in all of this ASTM committee work. Following this study and with the participation of the same representatives, ASTM has revised its previous specifications for fine aggregates for sheet asphalt and bituminous concrete pavements, and now provides for three sand types under Specification D 1073-59T, fine aggregates for bituminous paving mixtures, as shown in table 5. These gradings also utilize the logarithmic sieve series and are therefore compatible with the SPR system.

Table 5.—Grading requirements [1] for fine aggregate for bituminous pavements, from ASTM Designation D 1073–59T

Sieve size	Amounts finer than each laboratory sieve (square openings), percentage by weight		
	Grading No. 1	Grading No. 2	Grading No. 3
⅜-in.	100		100
No. 4	95–100	100	80–100
No. 8	70–100	95–100	65–100
No. 16	40–80	85–100	40–80
No. 30	20–65	65–90	20–65
No. 50	7–40	30–60	7–40
No. 100	2–20	5–25	2–20
No. 200	0–10	0–5	0–10

[1] It is recognized that for certain purposes satisfactory results may be obtained with materials not conforming to these specifications. In such cases the use of fine aggregate not conforming to the grading requirements of these specifications may be authorized only under special provisions based on field experience or laboratory studies of the possibility of designing a mixture of materials to be used on the job that will yield bituminous paving mixtures equivalent to the job-mix requirements.

Table 6.—ASTM mineral filler grading, from ASTM Designation D 242–57T [1]

Sieve size	Percentage passing
No. 30	100
No. 50	95–100
No. 100	90–100
No. 200	70–100

[1] "The mineral filler shall consist of limestone dust, portland cement, or other suitable mineral matter . . ."

Mineral filler

The current ASTM specification for mineral filler, Designation D 242-57T, was last revised in 1957 and is generally representative of present thinking. It fails to restrict the types of mineral that could be approved for use as fillers but, in controlling the grading, it utilizes the logarithmic sieve series and is therefore compatible with the SPR system. The grading requirements are shown in table 6. Control below the No. 200 sieve is under study.

Combined Gradings

Bituminous paving mixtures

In general, current design practice for bituminous paving mixtures differs from that for portland cement concrete. As step one in bituminous mix design, it is almost a universal practice to set up definite grading patterns for bituminous paving mixtures wherein the coarse aggregate, the fine aggregate or sand, and the mineral filler are combined to produce gradings that will fall within specified bands delineated by minimum and maximum limits for each sieve. In some cases the gradings have been established mainly through experience, but more frequently they have been established through laboratory and field research which has shown, among other things, that high density within certain limits promotes stability, and that high density without limits promotes resistance to weathering of the bituminous binder. While the factor of density is not, by any means, the only design factor for the grading bands for bituminous paving mixtures, it has had a predominating influence.

The second design step for bituminous paving mixtures consists of either determining or estimating the appropriate amount of bituminous binder to use. Here again practice has been established on the basis of experience and judgment in some cases while well established laboratory procedures, based on laboratory and field research, are used in others. In the latter case, the predominating factor determining ~~suitable bitumen~~ content is related to density or specifically to the void spaces available for binder in the compacted aggregate and the effect of overfilling or underfilling these voids on the stability and weather resistance of the plastic paving mixture.

Portland cement concrete

The situation with regard to portland cement concrete design is quite different. The design controls for concrete in present-day practice are fineness modulus, cement factor, and water-cement ratio with the cement factor and water-cement ratio being the primary variables used in designing for a specific strength range. The cement factor and water-cement ratio may also be varied to some extent to affect workability as measured by the slump test, with plasticizers being used occasionally to improve workability and strength. From the practical standpoint of field control, no one factor so adversely affects the strength and uniformity of the concrete as lack of control of water content. The proportions are set up on the basis of laboratory trial mixtures, utilizing the aggregates for the specific job and taking into consideration such factors as particle shape and surface texture, absorption, and others. Little or no use is made of total grading bands that might be set up on the basis of density or other possible design factors related to overall grading.

The practice of setting up the mixture for each job on the basis of laboratory tests is followed for reasons of practicality even though, for many years, research was conducted to develop the relations between the density of the aggregate, as influenced by the grading, and the quality of concrete.[3]

[3] Reference is made to this research and to the relations so established in *A Treatise on Concrete, Plain and Reinforced*, by F. W. Taylor and S. E. Thompson, 3d edition, 1916.

Table 7.— Composition of asphalt paving mixtures (from table III, ASTM specification for hot-mixed, hot-laid asphalt paving, Designation D 1663–59T)

Sieve size	Nominal maximum size of aggregates							
	2-in.	1½-in.	1-in.	¾-in.	½-in.	⅜-in.	No. 4	No. 8
	Asphalt concrete						Sand asphalt	Sheet asphalt
GRADING OF TOTAL AGGREGATE (COARSE PLUS FINE, PLUS FILLER IF REQUIRED): AMOUNTS FINER THAN EACH LABORATORY SIEVE (SQUARE OPENING), PERCENTAGE BY WEIGHT								
2½-in.	100							
2-in.	90-100	100						
1½-in.		90–100	100					
1-in.	60–80		90–100	100				
¾-in.		60–80		90–100	100			
½-in.	35–65		60–80		90–100	100		
⅜-in.				60–80		90–100	100	
No. 4	15–50	20–55	25–60	35–65	45–70	60–80	80–100	100
No. 8 [1]	10–40	10–40	15–45	20–50	25–55	35–65	65–100	95–100
No. 16							40–80	85-100
No. 30							20–65	70–95
No. 50	2–15	2–16	3–18	3–20	5–20	6–25	7–40	45–75
No. 100							3–20	20–40
No. 200 [2]	0–4	0–5	1–7	2–8	2–9	2–10	2–10	9–20
ASPHALT CEMENT, PERCENTAGE BY WEIGHT OF TOTAL MIXTURE [3]								
	3½–7½	3½–8	4–8½	4–9	4½–9½	5–10	7–12	8½–12
SUGGESTED COARSE AGGREGATES, SPR SIZES								
	3 and 57	4 and 67	5 and 7 or 57.	67 or 68 or 6 and 8.	7 or 78	8		

[1] In considering the total grading characteristics of an asphalt paving mixture the amount passing the No. 8 sieve is a significant and convenient field control point between fine and coarse aggregate. Gradings approaching the maximum amount permitted to pass the No. 8 sieve will result in pavement surfaces having comparatively fine texture, while coarse gradings approaching the minimum amount passing the No. 8 sieve will result in surfaces with comparatively coarse texture.

[2] The material passing the No. 200 sieve may consist of fine particles of the aggregates or mineral filler, or both. It shall be free from organic matter and clay particles and shall be nonplastic when tested by the method of test for liquid limit of soils (ASTM Designation D 423), and the method of test for plastic limit and plasticity index of soils (ASTM Designation D 424).

[3] The quantity of asphalt cement is given in terms of percentage by weight of the total mixture. The wide difference in the specific gravity of various aggregates, as well as a considerable difference in absorption, results in a comparatively wide range in the limiting amount of asphalt cement specified. The amount of asphalt required for a given mixture should be determined by appropriate laboratory testing or on the basis of past experience with similar mixtures, or by a combination of both.

ASTM Grading Bands for Hot-Mix Asphaltic Paving Mixtures

As already indicated, density has been generally discarded as a direct design factor for portland cement concrete but not for bituminous paving mixtures. Concurrently with the work done recently in developing a set of three sand gradings for bituminous work, ASTM has also developed a system of grading bands for combined coarse, fine, and filler aggregates for sand asphalt, sheet asphalt, and asphaltic concrete. These gradings are presented as table III in ASTM Standard Specification D 1663–59T. They are reproduced here in table 7.

The same industry and consumer representatives that

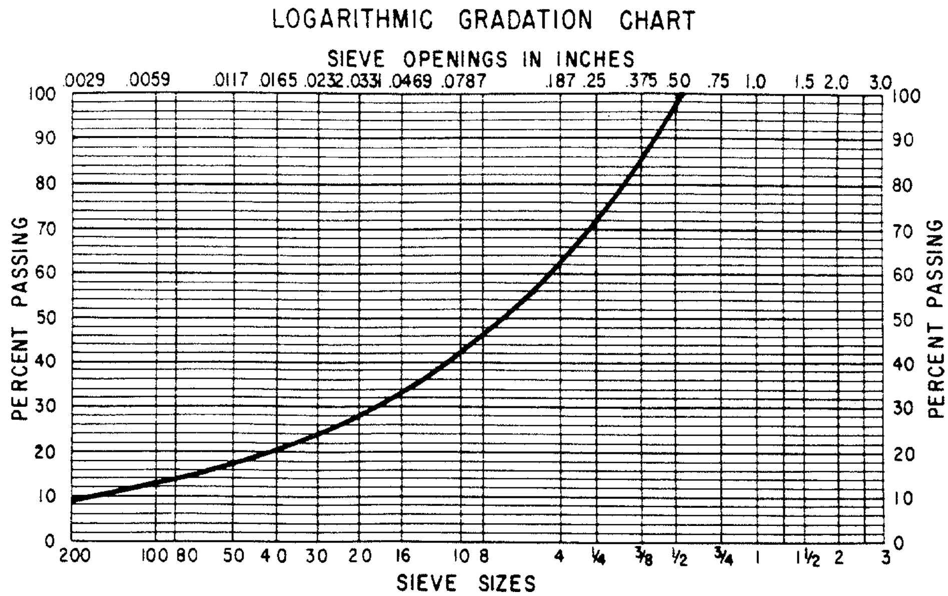


Figure 1.—A dense, stable grading plotted on the logarithmic gradation chart.

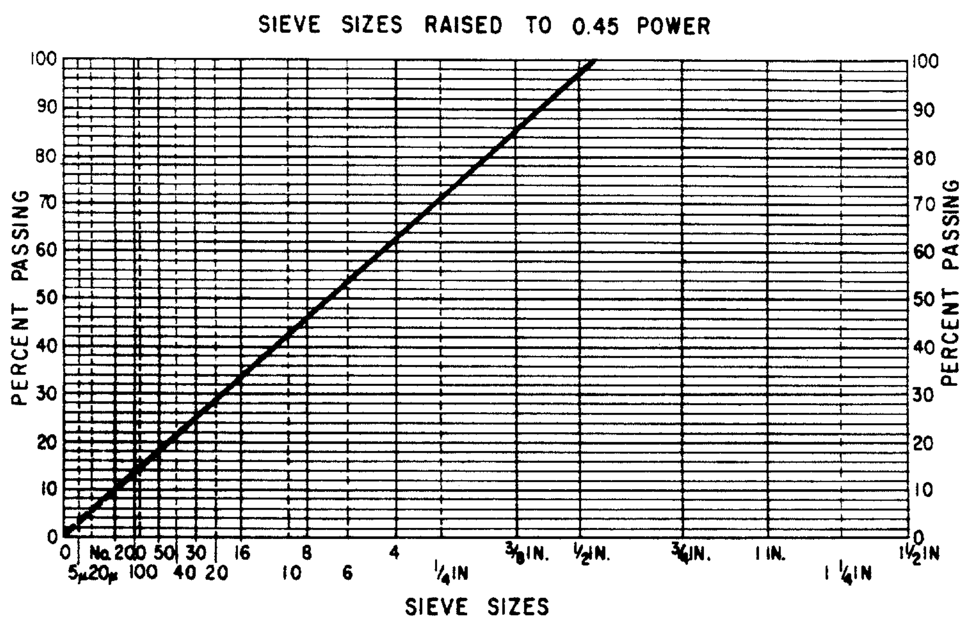


Figure 2.—Grading shown in figure 1 replotted on the 0.45-power gradation chart.

were previously named, also participated in this development. The ASTM composite gradings of table 7 are made up from SPR coarse aggregates and the ASTM sands and filler previously described. They are thus fully compatible with the SPR system. They have existed as ASTM Tentative Standards for only 2 years and were set up with the full realization that they might require some revision in the light of experience.

New gradation chart developed

In presenting the graphical material that is to follow, use is made of a new gradation chart devised by the Bureau of Public Roads, based on relations established by L. W. Nijboer of the Netherlands. Development of the chart is described in detail in the companion article in this bulletin.

In the plotting method now generally used, gradings that have proved to be highly compactible, and hence desirable as conducive to stability and resistance to moisture and weathering in bituminous paving mixtures, have a downward curving shape which is generally agreed to approximate the curve shown in figure 1. Here, the vertical scale is arithmetic and shows total percentage passing the various sieves, while the horizontal scale represents the logarithms of the sieve openings.

The simple expedient of using, for the horizontal scale, the sieve openings (inches or millimeters) raised to the 0.45 power, converts this particular curve to a straight line passing at its lower left extremity through zero percent for an imaginary sieve having zero-size openings, as shown in figure 2. Of course, grading curves having either greater or less curvature could be similarly straightened by using different exponents. It is believed, however, that the curve of figure 1 and its corresponding straight-line equivalent, figure 2, represents very nearly an ideal grading from the standpoint of density. Both research and experience indicate that the maximum particle size of the graded aggregate does not affect the shape of the maximum-density curve so that the straight-line principle using the exponent 0.45, or other basic curves and corresponding exponents, applies regardless of maximum size. The convenience of this device is readily apparent since it relieves those concerned with asphalt technology of the need to remember the exact shape of a specific curved line.

Problem mixtures

In recent years several State highway departments have reported one or more instances of difficulty with bituminous concretes produced under their own current specifications: the mixtures were hard to compact and remained "tender" for some time after rolling—that is, they were slow in developing stability. Others have reported instances of splotchy pavement surfaces where moisture was present in the aggregate. Some of these States have supplied information to the Bureau of Public Roads as to the aggregate gradings that produced these unsatisfactory mixtures.

It has been noted that, in nearly all cases, these gradings were characterized by a rise or hump in the grading curve, when plotted by the new method, because of disproportionately large quantities of finer sand fractions. It was further noted that the unsatisfactory mixtures did not contain what would be considered excessive amounts of filler, the fraction passing the No. 200 sieve.

In 1961 the Bureau of Public Roads conducted a

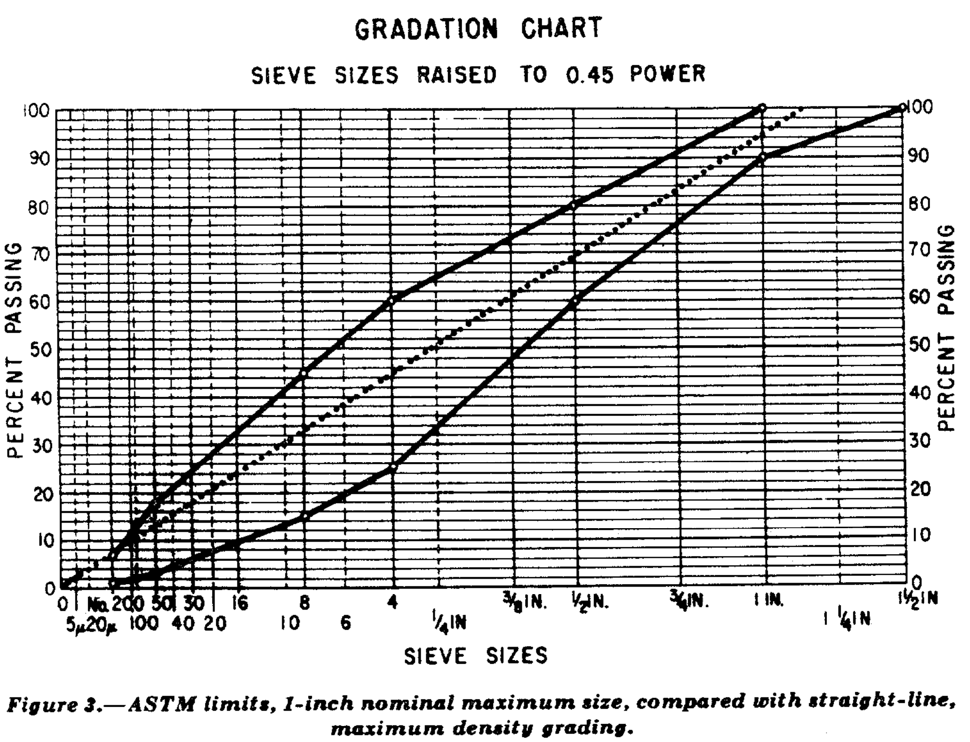


Figure 3.—ASTM limits, 1-inch nominal maximum size, compared with straight-line, maximum density grading.

laboratory study of this specific problem and utilized, for the first time, the new method of plotting gradings to facilitate interpretation of the results. Some of the results of that study are shown graphically here because they bear directly on the problem of grading control as treated in this report. They are fully reported and discussed in the companion article in this bulletin.

Among other things, the study showed that the laboratory test results were consistent with the unsatisfactory experience reported by the States on the problem mixtures described.

ASTM gradings need further study

The ASTM grading band for 1-inch maximum size asphaltic concrete is shown in figure 3 as illustrative of the eight sizes covered by ASTM Specification D 1663-59T and presented in table 7. Also shown in figure 3 is the straight (dotted) line that would represent the maximum-density grading if it can be assumed for this purpose that the maximum size for each grading may be arbitrarily established by passing the straight line midway between the upper and lower band limits for the largest sieve having both values shown.

Figures 4–6 show the aggregate gradings for the problem mixtures previously mentioned and the relation of their gradings to corresponding ASTM grading bands. These mixtures, which proved tender in the field or were splotchy when laid, were found to be low in stability when duplicated and tested in the laboratory. The two mixtures shown in figures 4 and 5 are representative of several cases in which the States reported the mixtures to be tender during construction and for considerable periods after rolling. The mixture shown in figure 6 represents several cases where splotchy pavements have been noted.

Since two of these typically humped gradings fall within the upper band limits of the corresponding ASTM gradings, even in the critical, fine sand zone, there is a strong indication that the upper band limits of the ASTM grading specifications for asphaltic concrete need some downward adjustment, at least at the No. 30 and No. 50 sieves, to further restrict the fine sand. However, a definite recommendation in this specific matter must await further study.

Basic Purpose of SPR System

The line of argument most frequently used by those opposing changes in grading control is that they are familiar and satisfied with what they are using and that they do not need or want new gradings. This points up the need for a clearer understanding of the basic purpose of the SPR scheme and of the ease with which any desired grading curve or band can be converted from one sieve-size system to another. The well established and fully validated graphical conversion method is illustrated in figure 7, which has a logarithmic horizontal scale. The equivalent straight line chart, exponent 0.45, is shown in figure 8.

In these two illustrations, an aggregate gradation band regularly specified by one of the State highway depart-

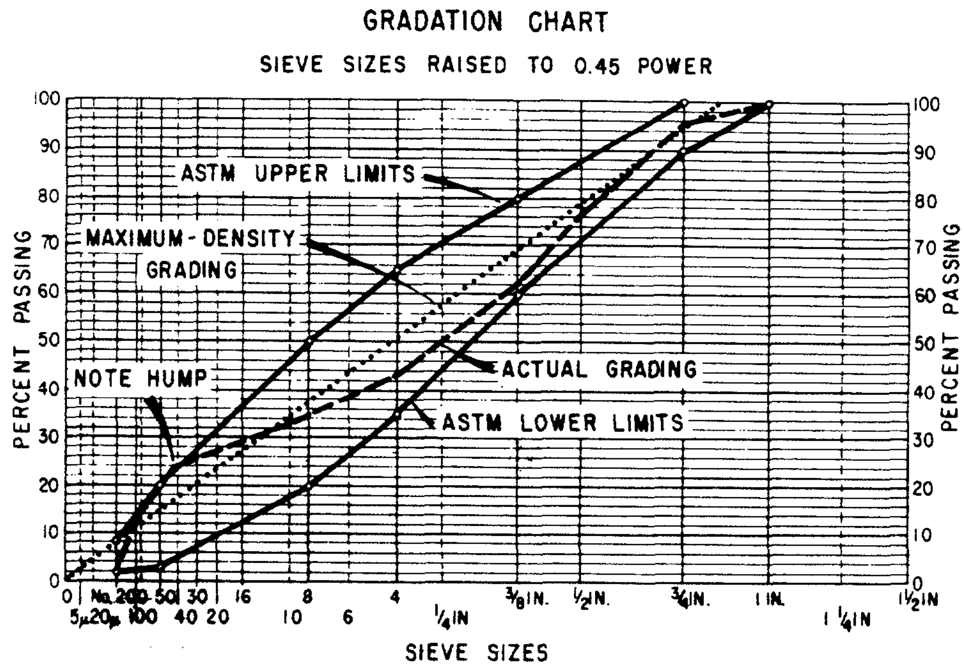


Figure 4.—Aggregate grading for a 3/4-inch nominal maximum size mixture identified as a "tender" mix.

4.8.11

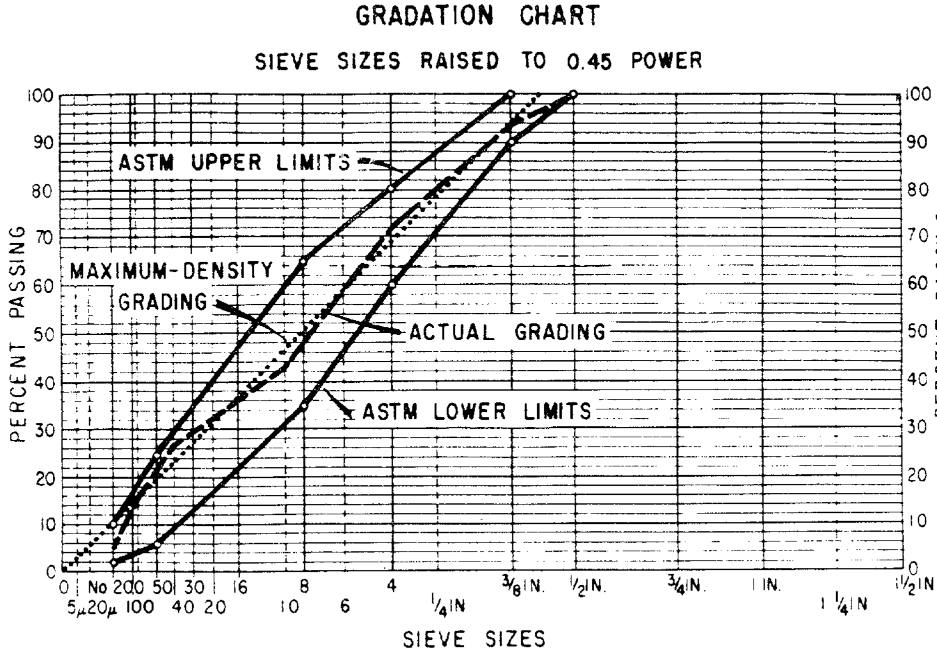


Figure 5.—Aggregate grading for a 3/8-inch nominal maximum size mixture identified as a "tender" mix.

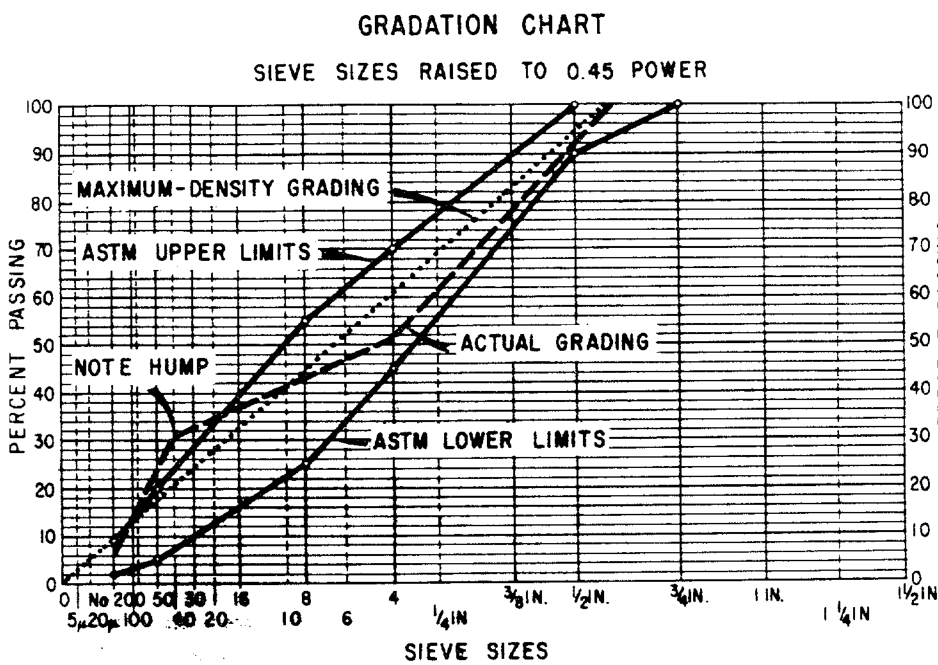


Figure 6.—Typical grading for a 1/2-inch maximum size mixture where a small amount of moisture in the aggregate has resulted in a splotchy pavement surface.

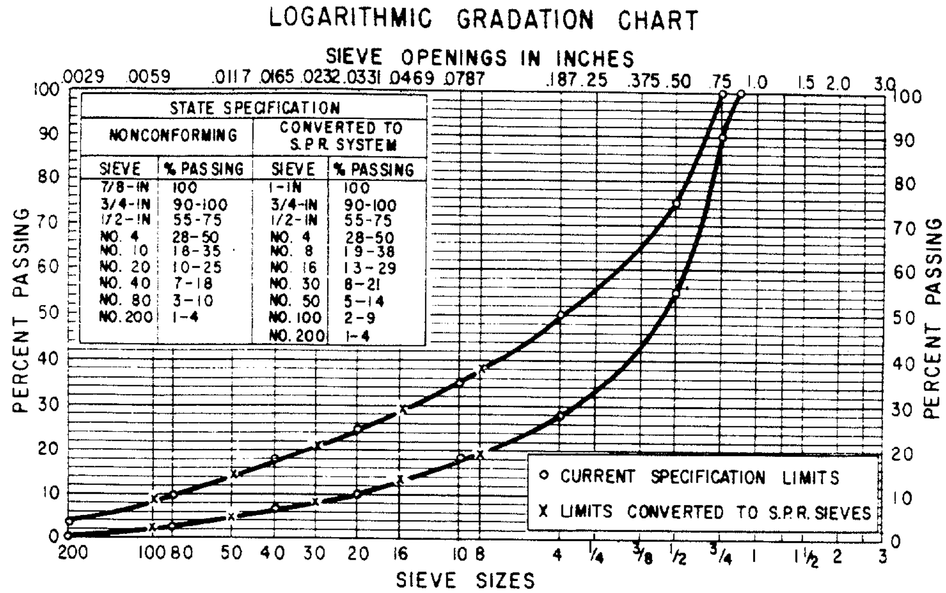
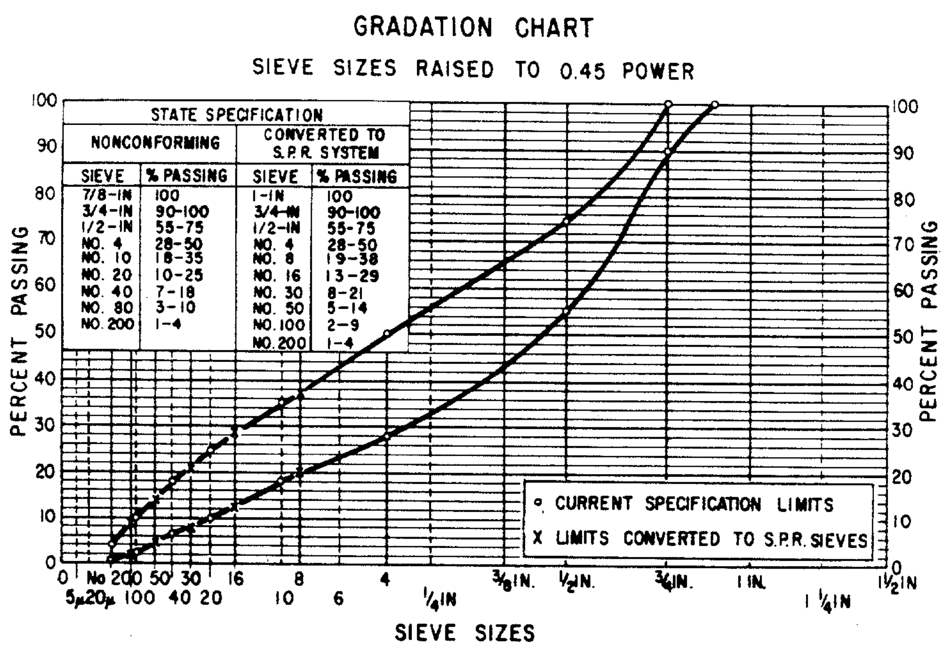


Figure 7.—Conversion of a current State specification to SPR sieve sizes, using the logarithmic gradation chart.



igure 8.—Conversion of a current State specification to SPR sieve sizes, using the Public Roads gradation chart.

ments is converted from the sieve-size system traditionally used by the State to the SPR sieve-size system. The corresponding tabular gradings are shown on the charts. In making the conversion, no change is introduced in the shape or placement of the band limits and it can be stated with confidence that an aggregate produced to conform with either, will conform to the other.

Not only do these illustrations demonstrate the ease and convenience of converting other grading systems to the SPR system, or common language, but additionally, they demonstrate that the conversion does not involve changing the particle distribution of a specific, designed, or desired aggregate.

It should be pointed out in this connection that the use of the SPR sieve series to express total gradations, as for example, $1\frac{1}{2}$-inch maximum size to No. 200, does not assure that specific desired gradings can always be made up from combinations of standard SPR numbered aggregate fractions with ASTM sand and filler, although in normal practice such situations should be comparatively rare.

Generally, the same freedom to modify grading band control limits to exploit field experience or the findings of research is inherent in the standardized scheme presented here as exists in the multiplicity of State specifications now in use. The need for some degree of freedom in this respect is fully recognized.

However, this philosophy cannot legitimately be used to justify the kind of trivial differences that account for a large proportion of the hundreds of aggregate gradations appearing in State specifications.

Recommended Course of Action

The study which is the subject of this report was undertaken for the purpose of furthering the three objectives mentioned—drastic reduction of "standard" gradations, agreement on sieve sizes, and agreement on a uniform system of identification of standard gradations. Because of the inherent flexibility of the SPR scheme, coupled with compatible sand and filler specifications now available as AASHO and ASTM standards, it is believed that a large proportion of the many special gradings now appearing in State specifications could be eliminated, thereby achieving important economies in highway construction. In many cases, it would only be necessary to convert to the SPR standard sieve sizes, as illustrated in figures 7 and 8, and to use SPR grading designations.

A desirable course of action and one that is strongly recommended for implementation by the American Association of State Highway Officials is essentially as follows:

1. Elimination from individual State specifications of all sieve sizes that are at variance with those officially adopted by AASHO and substitution therefor of conforming sieve sizes. This could be done easily by utilizing the method illustrated in figures 7 and 8. The new grading tables would provide the same gradations as those previously specified.

2. Elimination from individual State specifications of other gradation requirements not conforming to AASHO or related ASTM standards to the maximum practicable extent.

3. Retention for use, as special provisions or supplemental specifications, of such nonconforming gradation requirements as may be justified.

Standards Now Recommended

The following AASHO and ASTM standards are recommended for general use by all highway departments:

1. AASHO M 43–49, standard sizes of coarse aggregate for highway construction.

2. AASHO M 80–51, coarse aggregate for portland cement concrete.

3. AASHO M 6–51, fine aggregate for portland cement concrete.

4. ASTM D 692–59T, coarse aggregate for bituminous paving mixtures.[4]

5. ASTM D 1073–59T, fine aggregate for bituminous paving mixtures.

6. ASTM D 242–57T, mineral filler for sheet asphalt and bituminous concrete pavements.

In addition to the above six standards, the following tentative standard is recommended for study, possible revision, and general use:

7. ASTM D 1663–59T, hot mixed, hot laid asphalt paving mixtures.

[4] Requires one revision for adoption by AASHO to conform to AASHO M 43–49, namely for aggregate No. 3 the percentages passing the 2-in. sieve would have to be changed from 90–100 (ASTM) to 95–100, as now required in AASHO M 43–49.

A NEW GRAPHICAL CHART FOR EVALUATING AGGREGATE GRADATION

By the Physical Research Division
Bureau of Public Roads

Reported [1] by Joseph F. Goode, Highway Research Engineer
and Lawrence A. Lufsey, Highway Engineering Technician

The Problem of Diverse Gradations

As forcefully brought home in the companion article in this bulletin, there is a wide diversity in the requirements pertaining to aggregate gradations in the current standard specifications of the State highway departments, and the multiplicity would be increased many fold if the specifications of county, city, and other government jurisdictions responsible for highway construction were taken into account. It is obviously questionable that so many variants are necessary, or that they all are as good as they might be.

Engineers are becoming increasingly aware of the importance of the proper design of bituminous paving mixtures to provide pavements that will meet the demands of modern traffic. They generally agree that gradation of the aggregate is one of the factors that must be carefully considered, especially for heavy duty highways. But they disagree as to what gradations are the more satisfactory. This can be verified by examining the gradation requirements of specifications used by the various State highway departments and other agencies. They differ widely.

Some specifications are so broad that they permit the use of paving mixtures ranging from those that result in open and coarse surface textured pavements to those that are tight and fine grained. They also permit the use of paving mixtures of either low or high stability. Within these gradation limits the engineer often has considerable leeway in selecting pavement type to his liking, and whether the most satisfactory gradation is selected will depend on his judgment or experience.

Other specifications are narrow enough to permit little variation in pavement type and characteristics. But these tighter specifications differ enough among themselves to result in a wide range in types and characteristics of pavement.

A review of the many different gradation requirements will also show that engineers do not agree as to method for specifying gradations. They employ at least four different methods:

1. Percentages by weight of total aggregate passing each of several specified sieves (total percent passing basis).
2. Percentages by weight of total aggregate retained on each of several specified sieves (total percent retained basis).
3. Percentages by weight of total aggregate between consecutive sizes of specified sieves (passing and retained, total aggregate basis).
4. Percentages of aggregate, by weight of bituminous mixture, between consecutive sizes of specified sieves (passing and retained, mix basis).

To complicate matters further, different combinations of sieve sizes are specified to control specific grading ranges and a few agencies even specify round opening screens for coarse aggregate grading control.

Such nonuniformity in methods of expressing gradations adds to the difficulty of studying and evaluating aggregate gradations in terms of construction characteristics and pavement performance. In some instances it also tends to add unnecessarily to the construction costs. Standardization of sieve sizes and aggregate gradations and the conscientious use of such standards would almost certainly result in fewer, more uniform, and probably better specifications, and in more economical construction.

Development of a New Gradation Chart

The primary purpose of this article is to present and illustrate the use of a new aggregate gradation chart that will be especially valuable in developing more realistic specifications and in evaluating individual gradations.

Those accustomed to expressing gradations as percentages passing the various sieves are thoroughly familiar with the common gradation chart in which percentages passing are shown arithmetically on the vertical scale and the logarithmic scale is used for the horizontal spacing

[1] Presented at the annual meeting of the Association of Asphalt Paving Technologists, New Orleans, La., Jan. 30, 1962.

of sieve sizes (see fig. 7 in the preceding article, p. 10). This chart, which will be referred to hereafter as the logarithmic gradation chart, has had wide use for some 30 years and has proven valuable in illustrating individual gradations and determining their position relative to specification limits. This type of chart, however, has one significant disadvantage in that it shows a maximum density gradation as a deeply sagging curve, the shape of which is hard to define.

To provide a better means of relating actual aggregate gradation to maximum density gradation, a new chart has been devised by the Bureau of Public Roads. The horizontal scale for the several sieve sizes of this chart is a power function rather than the logarithm of the sieve opening in microns. The vertical scale is arithmetical, the same as for the logarithmic chart. An important feature of the new chart is that it provides for a zero theoretical sieve size. Thus, for practical purposes, all straight lines plotted from the lower left corner of the chart, at zero percent passing zero theoretical sieve size, upward and toward the right to any specific maximum size, represent maximum density gradations. The exponent of the power function is 0.45, i.e., the horizontal scale represents the various sieve openings in microns raised to the 0.45 power.

Background of development

The selection of the 0.45 exponent was based on research performed by L. W. Nijboer of the Netherlands and first published in 1948.[2] Nijboer used a double logarithmic gradation chart in a study of the influence of aggregate gradation on mineral voids. All gradations used in his study were represented by straight lines, with various slopes, when plotted on his chart; the variation in slope resulting from his use of several different gradations of the same maximum (¾-inch) size. Nijboer made two series of tests on compacted bituminous mixtures, using rounded gravel for the coarse aggregate in one series of tests and an angular crushed stone in the other. Mineral voids were determined for all of the mixtures and were plotted

[2] *Plasticity as a Factor in the Design of Dense Bituminous Road Carpets*, by L. W. Nijboer, Elsevier Publishing Co., 1948.

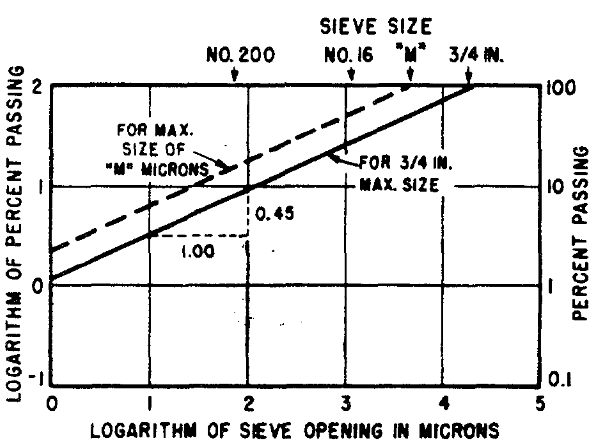


Figure 1.—Maximum density gradation plotted on a double log chart.

against the slopes of the straight line gradation curves. For both types of coarse aggregate, the minimum mineral voids, or maximum aggregate density, occurred for a gradation having a slope of 0.45 on the double log chart.

Figure 1 shows this maximum density gradation for a ¾-inch maximum size aggregate plotted on a double log chart. The figure also illustrates a maximum density curve for a gradation with a maximum size designated as M microns, for the following discussion in which it is assumed that all maximum density curves have a slope of 0.45 on the double log chart regardless of maximum size.

In developing the equation for a maximum density curve let:

M = maximum size of aggregate in microns.

S = size of opening for a particular sieve.

P = percentage passing the particular sieve.

$\log B$ = intercept on vertical axis of the chart.

The general equation of the curve is:

$$\log P = \log B + 0.45 \log S \qquad (1)$$

Other equations are:

$$\log 100 - \log B = 0.45 (\log M - \log 1); \text{ or}$$

$$2 - \log B = 0.45 (\log M); \text{ or}$$

$$\log B = 2 - 0.45 \log M \qquad (2)$$

Substituting equation (2) in equation (1) we have:

$$\log P = 2 - 0.45 \log M + 0.45 \log S; \text{ or}$$

$$\log P = 2 + 0.45 (\log S - \log M); \text{ or}$$

$$P = 100 \left(\frac{S}{M}\right)^{0.45} \qquad (3)$$

The exponent in equation (3) is the one used in designing the new gradation chart. By the use of logarithms, the sizes of sieve openings in microns were raised to the 0.45 power. These values were then employed with a suitable arithmetical scale for establishing the horizontal position of each sieve. The procedure is illustrated for a few of the sieve sizes on figure 2.

Figure 2 also illustrates how maximum density gradation is indicated for a gradation having a maximum size of M microns: simply by plotting a straight line from the origin, at the lower left corner of the chart, to the selected maximum size at the top of the chart. As can be seen from the information on the left side of the chart, the equation for such a line is that shown above as equation (3). Thus, any gradation that will plot as a straight line through the origin of the new chart will also plot as a straight line on the double log chart of Nijboer and will have a slope of 0.45.

The new gradation chart described in this article, and hereafter referred to as the Public Roads gradation chart, is not, strictly speaking, an entirely new type. The National Crushed Stone Association, in its *Crushed Stone Journal*, has been using a square-root gradation chart for several years to illustrate gradations. The only difference between the Association's chart and the new one presented here is that the former is based on an exponent of 0.50 for the power function instead of 0.45. The research of Nijboer and data to be presented later in this article show that 0.45 is a more realistic value for indicating maximum density.

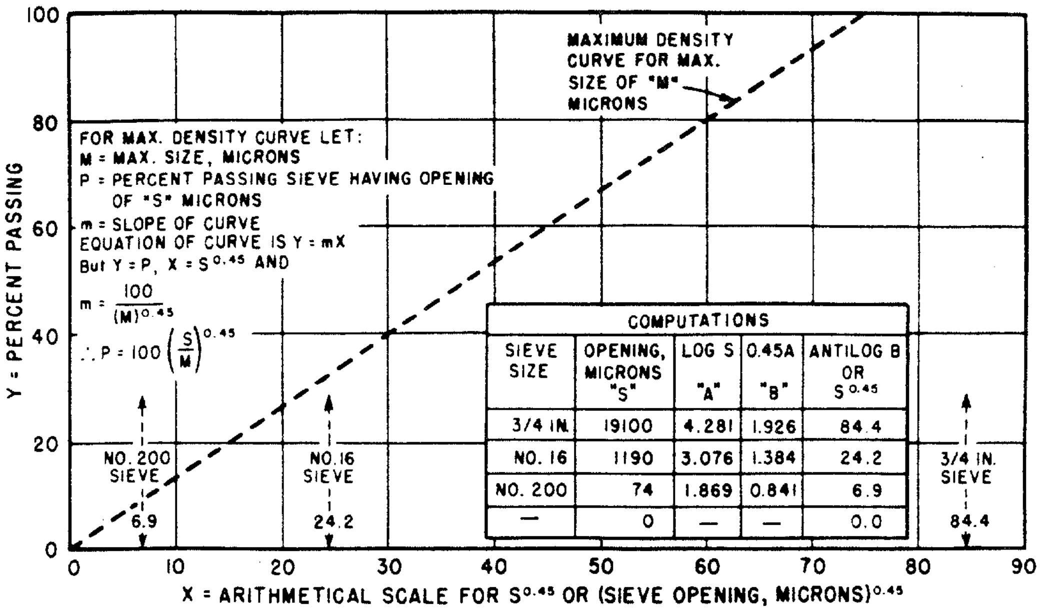


Figure 2.—Illustration of computations and method of positioning sieve sizes in setting up the Public Roads gradation chart.

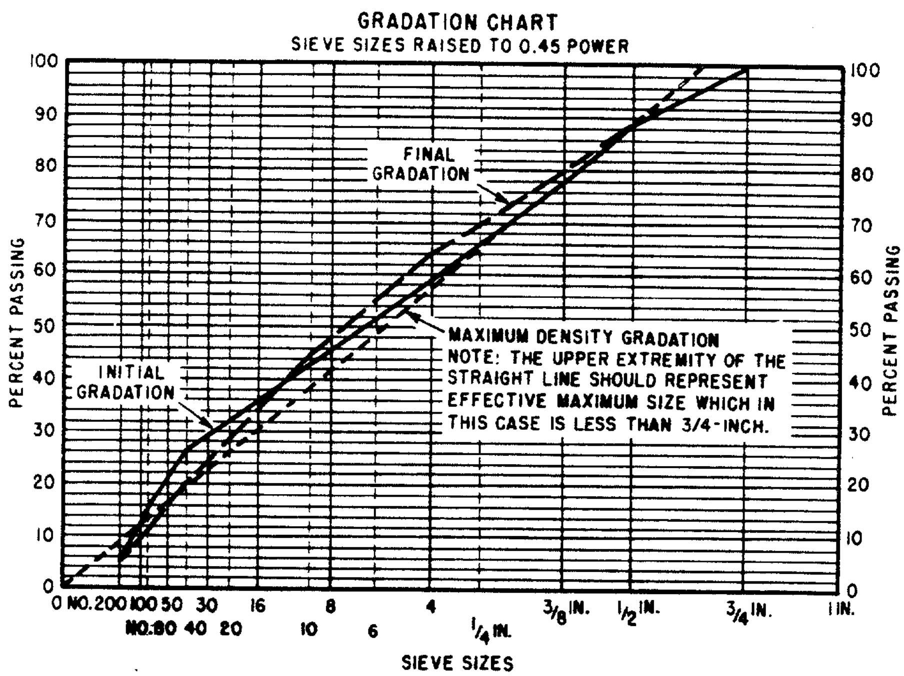


Figure 3.—Gradations of problem mixture (project A) compared with maximum density gradation.

Using Chart in Study of Tender Mixes

Soon after the Public Roads gradation chart was developed it was used to study gradations of aggregate from several bituminous mixtures that had been reported as having unsatisfactory compaction characteristics. During the past 4 or 5 years, engineers have reported several instances of hot asphaltic concrete mixtures that conformed to their specifications but could not be compacted in the normal manner because they were slow in developing sufficient stability to withstand the weight of rolling equipment. Such mixtures are usually called "tender" mixes.

Those having experience with such mixtures have tended to place most of the blame on the particular asphalt used. Occasionally it was recognized that such factors as high temperatures of the mixture, the air, and the underlying structure, excessively heavy rolling equipment, or the presence of moisture in the mixture might contribute to the unsatisfactory condition. The possibility was very seldom considered that aggregate gradation could be an equally important factor and that the grading requirements used could be contributing to this problem.

To illustrate the type of aggregate gradation that seems to be rather consistently associated with tender mixtures, some specific examples from three different parts of the country are discussed in the paragraphs that follow.

On a 1958 construction project, identified as project A, the engineers were careful to select cold feed materials and proportions for the wearing course mixture that would provide a median gradation within the specification limits. Despite these precautions, the resulting mixture had the characteristics of a tender mix. It was described as a critical mixture which did not compact satisfactorily at any asphalt content within the specification limits. At asphalt contents only slightly below the one that was most nearly satisfactory, the mixture was friable and developed cracks behind the finishing machine. At only slightly higher asphalt contents the mixture was too unstable to compact.

Although the engineers suspected the asphalt was at fault they decided to try a modified gradation, which resulted in a less critical mixture with greatly improved compaction characteristics. The initial and final gradations and the corresponding maximum density gradation are shown plotted on the Public Roads gradation chart in figure 3. Attention is called to the hump in the curve above the maximum density line at the Nos. 50, 40, and 30 sieve sizes for the initial gradation used in the unsatisfactory mixture and to the absence of a hump at these sieve sizes for the final gradation which produced the more satisfactory mixture.

Figure 4 shows gradations used on three other projects, each having a hump above the maximum density line at about the No. 30 sieve when plotted on the Public Roads chart. Two of these, for projects B and D, built in 1958 in a different State than project A, are gradations of mixtures containing gravel and sand that were described

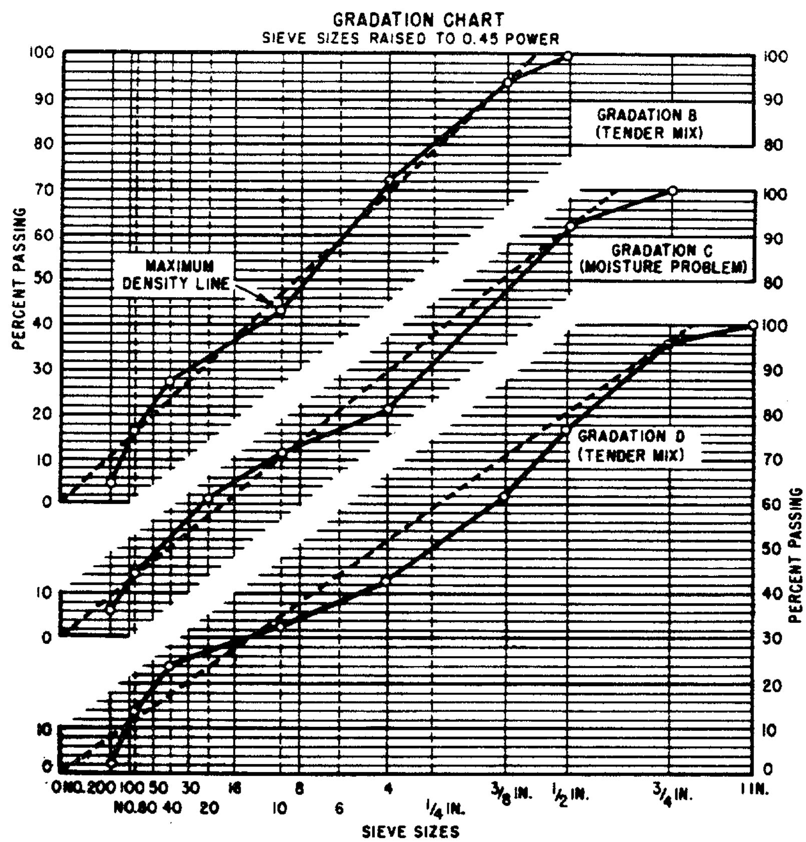


Figure 4.—Gradations of problem mixtures (projects B, C, and D) compared with maximum density gradations.

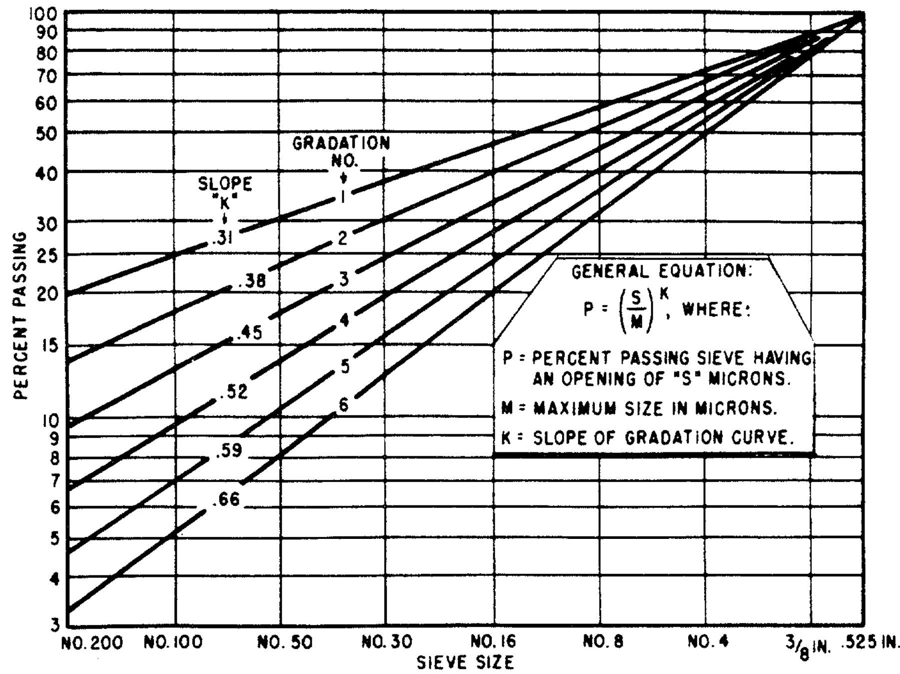
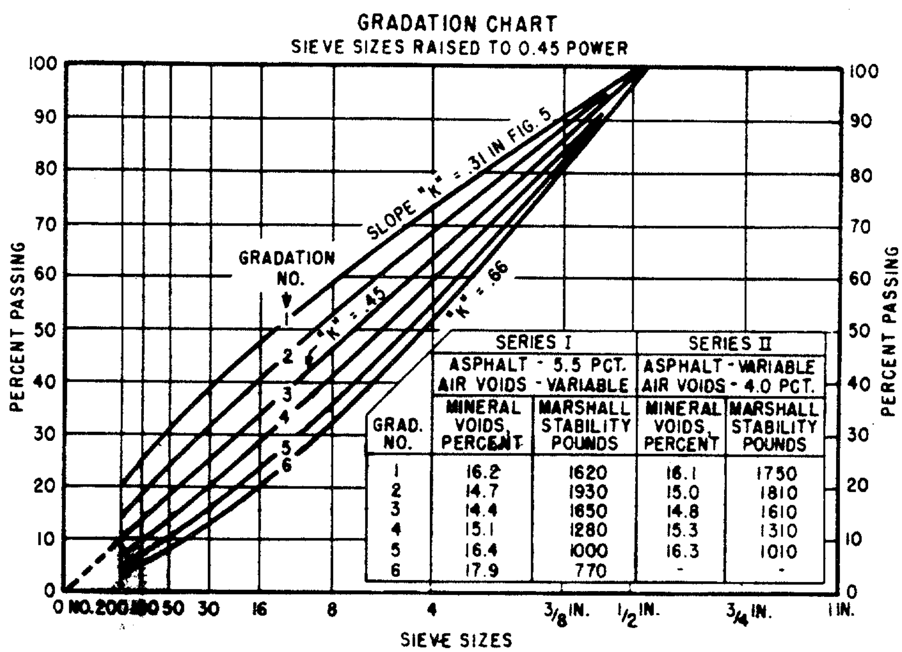


Figure 5.—Gradations Nos. 1–6 plotted on double log chart.



GRAD. NO.	SERIES I: ASPHALT - 5.5 PCT. AIR VOIDS - VARIABLE: MINERAL VOIDS, PERCENT	SERIES I: MARSHALL STABILITY POUNDS	SERIES II: ASPHALT - VARIABLE AIR VOIDS - 4.0 PCT.: MINERAL VOIDS, PERCENT	SERIES II: MARSHALL STABILITY POUNDS
1	16.2	1620	16.1	1750
2	14.7	1930	15.0	1810
3	14.4	1650	14.8	1610
4	15.1	1280	15.3	1310
5	16.4	1000	16.3	1010
6	17.9	770	-	-

Figure 6.**—**Gradations Nos. 1–6** (**straight-line gradations in fig. 5**) **plotted on the Public Roads gradation chart.

as tender mixes. The third gradation, for project C, is typical of those used in a State which has had considerable difficulty with moisture problems in laying bituminous pavements containing certain coarse aggregates. A very small amount of moisture in such mixtures often results in a splotchy pavement surface.

There have been exceptions, but nearly all gradation curves of problem mixtures studied by the research laboratories of the Bureau of Public Roads have been characterized by a hump above the maximum density line at or near the No. 30 sieve. Such mixtures have an excess of fine sand in relation to total sand. This excess not only results in lower compacted densities but tends to float the larger particles and destroy stability that might otherwise result from coarse aggregate interlock. In addition, fine sand is inherently less stable than coarse sand.

Thus, improper aggregate gradation is identified as an important contributing factor to the unsatisfactory behavior of some bituminous mixtures. Other factors, such as asphalt characteristics, high temperatures, and moisture vapor cannot be ruled out; but unsatisfactory grading, particularly oversanding in the fine sizes, must not be overlooked as a possible source of trouble.

Laboratory Evaluation of Gradation Chart

To evaluate further the usefulness of the new Public Roads gradation chart, a laboratory study was undertaken with two main objectives: To substantiate Nijboer's findings, and to determine more precisely the effect of "hump" gradations on mineral voids and stability of compacted asphaltic concrete. The study employed the gyratory method of molding and the Marshall stability test.

The investigation was limited to 24 different gradations of gravel, sand, and limestone dust aggregate having a maximum size of 0.525 inch. These gradations are shown in table 1 of the appendix (p. 24), together with values for effective specific gravity values which were used in computing voids.

Verification of 0.45 exponent

In order to verify Nijboer's findings, the first six gradations were made up so that they would plot as straight lines with varying slopes K on the double log chart, as shown in figure 5. When plotted on the New Public Roads

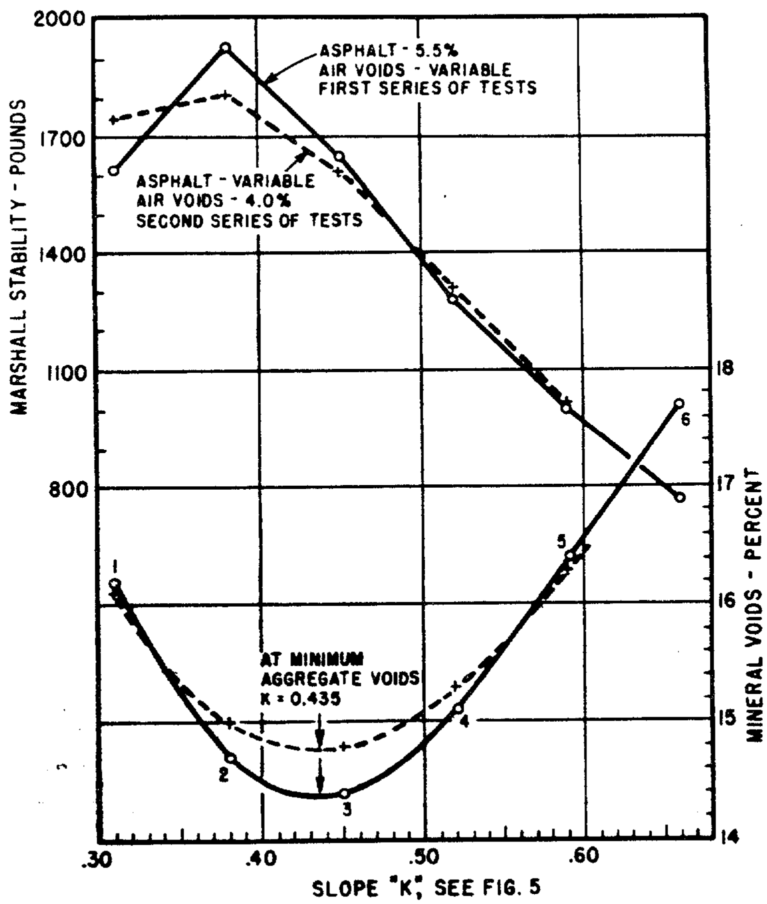


Figure 7.—Mineral voids and Marshall stabilities of gradations Nos. 1–6.

gradation chart, figure 6, five of these gradings plotted as curves because of the variations in the exponent K. Only gradation No. 3, which had a slope (or exponent K) of 0.45 in figure 5, plotted as a straight line in figure 6. Figure 6 also contains, for ready reference, data on mineral voids and Marshall stability extracted from table 4 of the appendix. It will be noted that the aggregates were combined with asphalt in two series of mixtures, one with constant asphalt content of 5.5 percent and the other with variable asphalt content to produce constant air voids of 4.0 percent.

Figure 7 shows the Marshall stability and mineral void values in graphical form. In the upper part of this figure, Marshall stability (see tabulation, fig. 6) is plotted against K or slope from the double log chart (see fig. 5). The solid-line curve represents test results for a constant percentage of asphalt, the first series of tests; the dashed line represents results for a constant percentage of air voids, the second series of tests. Corresponding curves for mineral voids are shown in the lower part of the figure.

It will be noted in figure 7 that minimum aggregate voids, or maximum aggregate densities, occur at the point where K equals 0.435. This is slightly lower than Nijboer's value of 0.45 on which the new Public Roads gradation chart is based, but the slight difference is not considered significant. Figure 7 also shows that the value of K had a pronounced effect on Marshall stability for both series of tests. For the coarsest grained aggregate (grading No. 6, for which $K=0.66$), stability was less than 800 pounds. For the finest grained aggregate of the study (grading No. 1, for which $K=0.31$), stability was between 1,600 and 1,750 pounds for the two series. The maximum values for the two series were between 1,800 and 1,950 pounds.

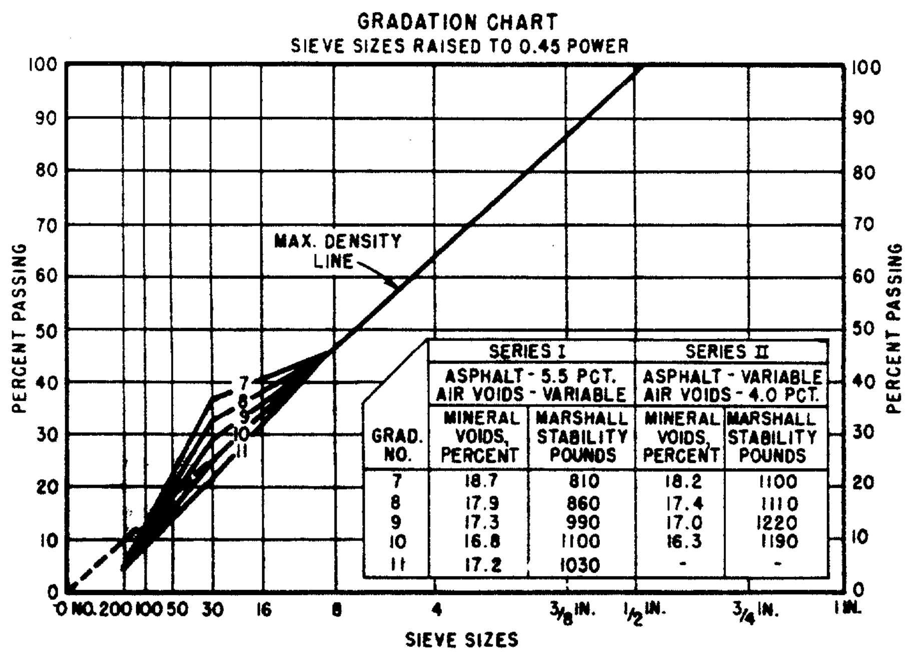
Study of "hump" gradations

Figures 8–10 use the Public Roads gradation chart to illustrate gradations that plotted with a hump at the No. 30 sieve size and to compare them with a maximum density curve (gradations Nos. 7–11 and 13–21, shown in table 1 of the appendix). Each of these figures also includes a tabulation (extracted from table 4 of the appendix) showing mineral voids and stability for mixtures with constant asphalt content and with a constant volume of air voids.

Figure 8 shows the gradation curves and test results for gradations Nos. 7–11, each of which had 46.0 percent passing the No. 8 sieve, the same as that for the maximum density curve. These gradations are considered optimum in the amount of total sand.

As will be seen in figure 8, the curve for gradation No. 11 plotted as a straight line from the No. 8 sieve to the No. 200 sieve and this portion of the curve is below the maximum density line. The curve for gradation No. 10 is on the maximum density line from maximum size to the No. 30 sieve but then drops below the maximum density line to the No. 200 sieve; it therefore has a slight hump at the No. 30 sieve but the fact that this hump is not above the maximum density line is considered significant since gradation No. 10 had the lowest mineral voids of this group of gradations for both series of tests, and also had the highest stability for the series in which asphalt content was maintained constant. Its stability was only 30 pounds lower than the highest value in the second test series, where air voids were maintained constant.

The humps at the No. 30 sieve size for gradations Nos. 9, 8, and 7 are progressively larger than that for gradation No. 10 and are all above the maximum density line. As the humps become more pronounced the gradations show increasing void contents and decreasing stabilities.



	SERIES I: ASPHALT - 5.5 PCT. AIR VOIDS - VARIABLE		SERIES II: ASPHALT - VARIABLE AIR VOIDS - 4.0 PCT.	
GRAD. NO.	MINERAL VOIDS, PERCENT	MARSHALL STABILITY POUNDS	MINERAL VOIDS, PERCENT	MARSHALL STABILITY POUNDS
7	18.7	810	18.2	1100
8	17.9	860	17.4	1110
9	17.3	990	17.0	1220
10	16.8	1100	16.3	1190
11	17.2	1030	-	-

Figure 8.—Hump gradations of gravel mixtures, medium in total sand.

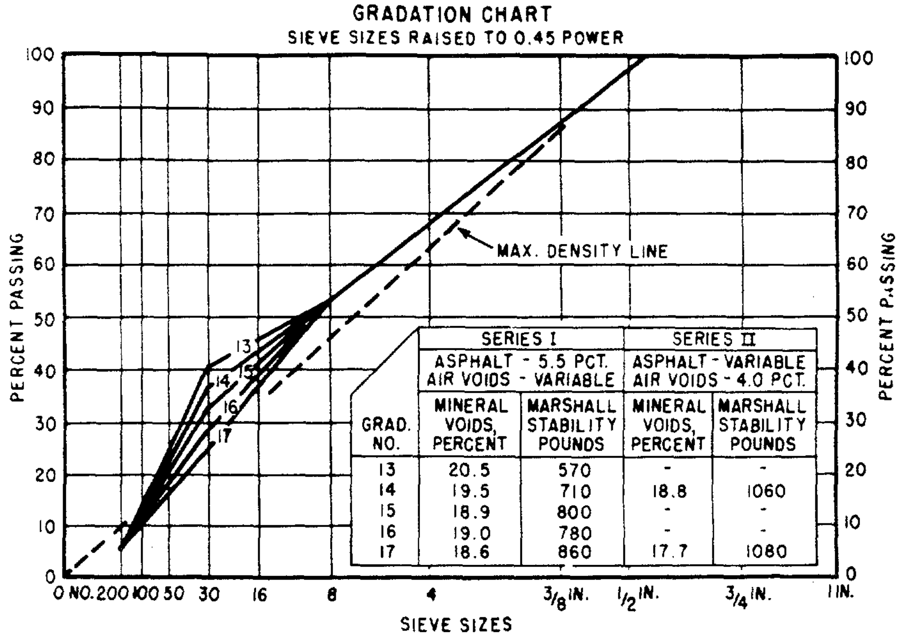


Figure 9.—Hump gradations of gravel mixtures, high in total sand.

Figure 9 shows the gradation curves and test results for gradations Nos. 13–17, all of which had 53.3 percent passing the No. 8 sieve and are considered high in total sand when compared to the gradations shown in figure 8.

The curve for gradation No. 17 does not have a hump at the No. 30 sieve size; it is a straight line from the No. 8 to the No. 200 sieve and intersects the maximum density curve at the No. 30 sieve. This gradation showed the lowest value of mineral voids for the group. The curve for gradation No. 16 has a slight hump above the maximum density curve at the No. 30 sieve size, and gradation curves Nos. 15, 14, and 13 have increasingly larger humps. Allowing for experimental error, it will be noted that, in general, increasing magnitude of the hump corresponded with increasing mineral voids and decreasing stability for the series of tests where the asphalt was maintained constant. Where the air voids were maintained constant, in the two instances shown, there was a slight increase in mineral voids but no significant change in stability.

Figure 10 shows the curves for gradations Nos. 18–21, which had 38.9 percent passing the No. 8 sieve and are considered low in total sand when compared to the gradations shown in figure 8.

The entire curve for gradation No. 21 plotted below the maximum density line and has a very slight hump at the No. 30 sieve size. The curve for gradation No. 20 has a slight hump and touches the maximum density line at the No. 30 sieve size; otherwise it is completely below the maximum density line. This is considered significant since gradation No. 20 had the lowest mineral voids and the highest stability of this group of gradations in both series of tests.

Gradation No. 19 had a considerable hump at the No. 30 sieve size, above the maximum density curve. This gradation had greater mineral voids and less stability than those of gradation No. 20. Gradation No. 18 had the largest hump of the group and it also had the highest percentage of mineral voids and the lowest stabilities.

Conclusions on hump gradations

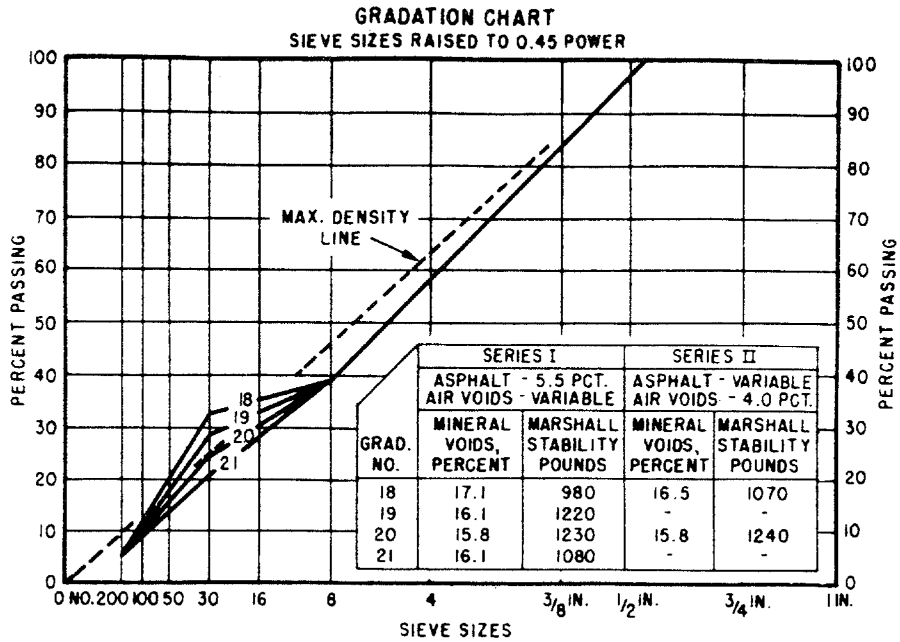
The above discussions, based on figures 8–10, of humps in gradation curves at the No. 30 sieve size, may be summarized as follows:

1. A hump above the maximum density line in all cases was associated with a lower aggregate density (higher mineral voids) than a hump that just touches the maximum density line.

2. In nearly all cases the hump also was associated with a lower Marshall stability value. The reduction in stability was more pronounced for the series of tests in which the asphalt content was maintained constant than for the series in which the asphalt content was varied to provide a constant volume of air voids.

3. The greater the magnitude of the hump above the maximum density line, the lower was the aggregate density (in all cases) and the stability (in nearly all cases).

Thus, based on results of laboratory tests of gravel mixtures, the presence of a hump in the aggregate gradation curve at about the No. 30 sieve and above the maximum density line is indicative of an undesirable gradation. The extent to which differences in laboratory density and stability can be related to field compaction and performance characteristics is not now known. However, the results of these laboratory tests and studies of known field examples discussed earlier do show that "hump" gradations may be a contributing factor toward the unsatisfactory behavior of mixtures. Further verification of their effect should be determined by controlled field studies.



	SERIES I		SERIES II	
	ASPHALT - 5.5 PCT. AIR VOIDS - VARIABLE		ASPHALT - VARIABLE AIR VOIDS - 4.0 PCT.	
GRAD. NO.	MINERAL VOIDS, PERCENT	MARSHALL STABILITY POUNDS	MINERAL VOIDS, PERCENT	MARSHALL STABILITY POUNDS
18	17.1	980	16.5	1070
19	16.1	1220	-	-
20	15.8	1230	15.8	1240
21	16.1	1080	-	-

Figure 10.—Hump gradations of gravel mixtures, low in total sand.

Use of chart in improving gradations

One of the advantageous uses of the Public Roads gradation chart is in revising gradations to obtain greater or lesser mineral voids. Often it is desirable to decrease the mineral voids to provide a more stable mixture. At other times it is desirable to increase the mineral voids to allow room for more asphalt in the mixture and thereby improve its durability; for example, McLeod [3] prefers to maintain a minimum of 15-percent mineral voids in the compacted mixture.

Based on this 15-percent voids criterion the maximum density gradation used in these tests, No. 3, would not be satisfactory since it had mineral voids of 14.4 and 14.8 percent, respectively, for the first and second series of tests. Gradation No. 10, which is similar to gradation No. 3 except for a lower dust content, would be satisfactory because its respective mineral voids were 16.8 and 16.3 percent, appreciably greater than the 15-percent criterion. Thus, one effective way of modifying a gradation to provide greater or lesser mineral voids is to change its dust content. However, this may not be practical or it may be more economical to modify the gradation at other sieve sizes.

If the modification is to be made by varying the gradation of the sand portion, figures 8–10 suggest that it might be done by increasing or decreasing the percentage passing the No. 30 sieve for the entire aggregate while maintaining constant the percentages passing the No. 8 and No. 200 sieves. In figure 10, for example, if gradation No. 19 should prove too dense it could be modified to a less dense gradation by increasing the percentage of aggregate passing the No. 30 sieve and thereby moving the gradation curve away from the maximum density line; or it could be made denser by reducing the percentage passing the No. 30 sieve to bring the curve closer to the maximum density line.

If, however, the modification is to be made by adjusting the percentage of sand or by varying the gradation of the coarse aggregate, another factor must be taken into account. An allowance must be made for the fact that skip gradations can promote higher density.

Skip gradations

Figure 11 shows curves and data for three skip gradations, Nos. 22–24. The slope of these curves between the No. 4 and No. 8 sieve sizes is appreciably less than the slopes of the remaining portions. They might be referred to as gradations that plot with a hump at the No. 8 sieve size. Figure 11 also shows curves and data for the maximum density gradation, No. 3, and for gradation No. 12 which plots as a straight line from the maximum size to the same percentage passing the No. 200 sieve as that of the other curves.

Comparing the curves in figure 11 with respect to their positions relative to the maximum density line is complicated by the fact that some of them cross it. For example, gradation No. 12 plotted closer to the maximum density line than gradation No. 22 at the No. 4 and larger sieve sizes, but further from the line at the No. 16 and smaller sieve sizes. On the average, however, gradation No. 12 plotted closer to the maximum density line than gradation No. 22, and it showed the higher density (lower mineral voids).

Similarly, skip gradation No. 22 plotted closer to the maximum density line than skip gradation No. 23 at the

[3] *Relationships between Density, Bitumen Content, and Voids Properties of Compacted Bituminous Paving Mixtures*, by N. W. McLeod, Proceedings of the 35th annual meeting of the Highway Research Board, vol. 35, 1956, pp. 327–404.

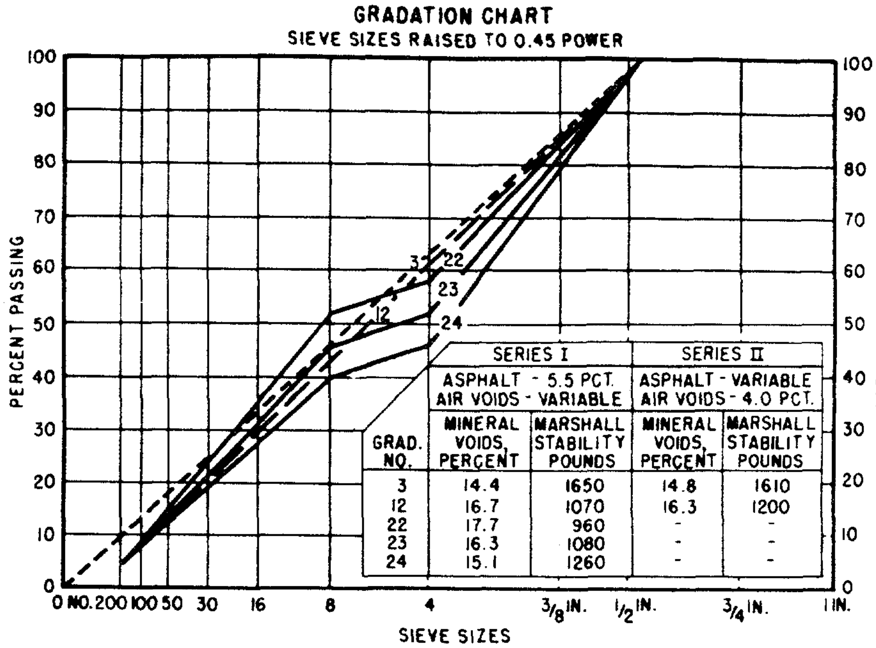


Figure 11.—Skip gradations compared with gradations Nos. 3 and 12.

No. 4 and larger sieve sizes, further from the line at the No. 8 sieve size, and again closer to the line at the No. 30 and smaller sieves. Which gradation plotted closer to the maximum density line on the average is questionable, but gradation No. 23 had the higher density.

There is no doubt that gradation No. 24 plotted the furthest from the maximum density line and it showed the highest density of the three skip gradations. Its density, however, was not as great as that of gradation No. 3, the one that is used to represent maximum density on

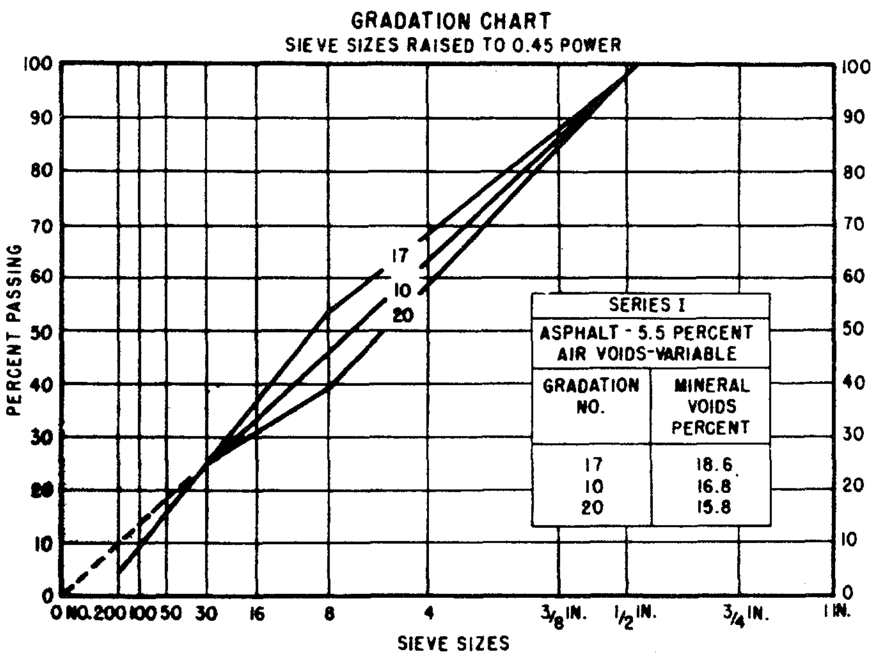


Figure 12.—Gradations varying in percentage passing No. 8 sieve, with medium percentage passing No. 30 sieve.

4.8.24

the gradation chart. But this does not preclude the possibility that there may be other skip gradations of the same maximum size that will exceed the density of gradation No. 3.

Figures 12 and 13 compare data for gradations that vary in the percentage passing the No. 8 sieve. These were selected from previous figures used to illustrate "hump" gradations. They provide the same indications as figure 11. For example, in figure 12, gradation No. 20 plotted further from the maximum density line than gradation No. 10 but had the higher density. The same relationship held for gradations Nos. 18 and 8 in figure 13. Incidentally, gradation No. 20 in figure 12 and gradations Nos. 8 and 18 in figure 13 can be classified as skip gradations as well as "hump" gradations because they plot with slopes flatter between the No. 8 and the No. 30 sieve size than elsewhere.

In reference to the higher density skip gradations in figures 11-13, it is considered important to note that in all cases the right-hand portion of the gradation curve was below the maximum density line. This fact must be taken into account when using the maximum density line as a reference for adjusting skip gradations to provide a lower or a higher density.

Conclusions

The laboratory study covered by this article was limited to data representing 24 different gradations of aggregate of a single maximum size. Only one asphalt and one type of aggregate were used in the mixtures. Based on these limited conditions, the following conclusions are warranted:

1. The new Public Roads gradation chart provides a much more convenient means of studying aggregate gradations than the logarithmic chart now commonly used. The greater convenience results from the fact that maximum density gradations can be represented on the chart by a straight line from a theoretical zero percent passing zero sieve size to 100 percent passing the effective maximum size.

2. This maximum density line constitutes a new design tool, in that it serves as an easily remembered line in comparing different gradations or in adjusting gradations to provide desired voids and stability characteristics.

3. For gradations of the same type of aggregate which plot as smooth curves entirely above or below the maximum density line, those closest to the line will usually represent gradations yielding the lowest voids in the compacted mixture.

4. For gradations of the same type of aggregate which plot as identical curves except for the portion between the No. 8 and the No. 200 sieves, those that show appreciable humps above the maximum density line at about the No. 30 sieve will have higher mineral voids and lower Marshall stabilities than those plotting with lesser humps. Analysis of several problem mixtures from field projects has clearly confirmed this finding and points up the detrimental effect of gradation humps in the finer aggregate sizes.

5. For skip gradations, low mineral voids are associated with curves that stay appreciably below the maximum density line in the right-hand or coarse aggregate zone of the chart.

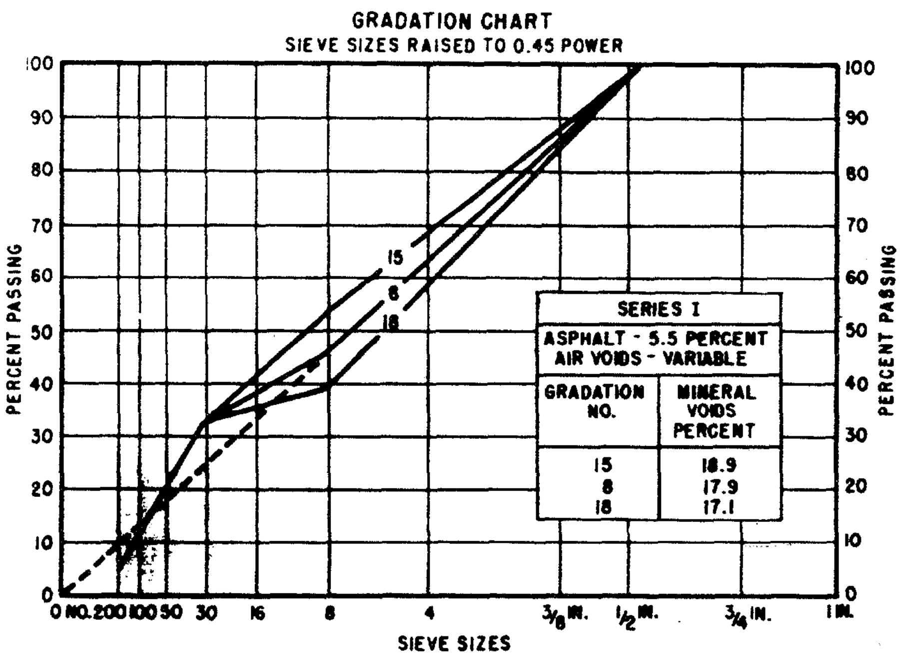


Figure 13.—Gradations varying in percentage passing No. 8 sieve, with high percentage passing No. 30 sieve.

APPENDIX: PROCEDURE AND DETAILS OF PROJECT

Processing aggregate

Table 1 shows the aggregate gradations used in the study and includes values of effective specific gravity which were used in computing voids. The effective specific gravities are rational values determined directly on several of the mixtures by the Rice vacuum saturation procedure.[4]

The aggregate larger than the No. 4 sieve and a portion of that passing the No. 4 sieve and retained on the No. 8 sieve was an uncrushed river gravel. The remainder of the aggregate consisted of sand from the same source and a commercial limestone mineral filler. The amount of mineral filler used varied with the gradation. In all cases 60 percent of the total aggregate passing the No. 200 sieve consisted of limestone dust.

Table 2 gives the apparent and bulk specific gravities of the three stock aggregates. Rational values of apparent and bulk specific gravity of the combined aggregate representing different gradations were not determined.

In preparing the aggregate to be combined to meet the several gradations, the gravel and the sand larger than the No. 8 sieve were accurately separated into 0.525-inch to ⅜-inch, ⅜-inch to No. 4, and No. 4 to No. 8 sieve size fractions. Since it is very difficult to obtain clean separations for fine size aggregate in large quantities, no attempt was made to separate the sand into exact sieve size fractions. Instead, it was separated into approximate sizes by a relatively rapid sieving process, and the gradations of the several fractions were then accurately determined and used in computing the correct proportions to provide the desired combined gradations.

Preparing mixtures and test specimens

An 85–100 penetration grade asphalt was used in all mixtures. Table 3 gives its test properties.

The mixtures were prepared in a laboratory mixer from aggregate heated to 325° F. and asphalt heated to 300° F. Each batch was just sufficient for one test specimen, which, immediately after being mixed, was compacted in a gyratory mold heated to 200° F. Figure 14 (p. 26) shows the gyratory compactor used in molding the specimens.

The test specimens, 4 inches in diameter and 2½ inches in height, were molded by applying 30 gyrations at a 1-degree angle and under a foot pressure of 100 p.s.i. Previous work by McRae and McDaniel[5] indicated that this procedure produced densities corresponding to those of the 50-blow, hand-compacted Marshall specimen.

Tests performed

The specimens were tested for bulk specific gravity, Marshall stability, and Marshall flow value. Bulk specific gravity was determined by the procedure described in Section 4(a) of AASHO Method T-165. Air and mineral voids, based on effective specific gravity of the aggregate, were computed from the bulk specific gravities.

[4] *Maximum Specific Gravity of Bituminous Mixtures by Vacuum Saturation Procedure*, by J. M. Rice, in *Symposium on Specific Gravity of Bituminous Coated Aggregates*, Special Technical Publication No. 191, American Society for Testing Materials, June 1956, pp. 43–61.

[5] *Progress Report on the Corps of Engineers' Kneading Compactor for Bituminous Mixtures*, by J. L. McRae and A. R. McDaniel, Proceedings of the Association of Asphalt Paving Technologists, vol. 27, 1958, pp. 357–382.

Table 1.—Gradation and effective specific gravity of aggregate blends

Gradation No.	Percentage passing indicated sieve										Effective specific gravity [1]
	0.525 in.	½-in.	⅜-in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	
1	100	99	90	73	58.6	47.3	38.0	30.8	24.8	20.0	2.651
2	100	98	88	68	52.0	39.9	30.6	23.6	18.1	13.9	2.650
3	100	98	86	63	46.0	33.7	24.6	18.0	13.2	9.7	2.649
4	100	98	84	59	40.8	28.5	19.8	13.8	9.7	6.7	2.648
5	100	97	82	55	36.2	24.0	15.9	10.6	7.1	4.7	2.646
6	100	97	80	51	32.1	20.3	12.8	8.1	5.2	3.2	2.643
7	100	98	86	63	46.0	40.6	36.6	22.6	12.3	4.7	2.665
8	100	98	86	63	46.0	38.3	32.6	20.4	11.4	4.7	2.661
9	100	98	86	63	46.0	36.0	28.6	18.1	10.4	4.7	2.658
10	100	98	86	63	46.0	33.7	24.6	15.9	9.4	4.7	2.655
11	100	98	86	63	46.0	32.0	21.6	14.2	8.7	4.7	2.653
12	100	98	85	61	43.1	30.1	20.4	13.5	8.4	4.7	2.651
13	100	98	88	68	53.3	46.0	40.6	24.9	13.3	4.7	2.670
14	100	98	88	68	53.3	43.7	36.6	22.6	12.3	4.7	2.667
15	100	98	88	68	53.3	41.4	32.6	20.4	11.4	4.7	2.663
16	100	98	88	68	53.3	39.1	28.6	18.1	10.4	4.7	2.660
17	100	98	88	68	53.3	36.8	24.6	15.9	9.4	4.7	2.657
18	100	98	84	58	38.9	35.3	32.6	20.4	11.4	4.7	2.659
19	100	98	84	58	38.9	33.0	28.6	18.1	10.4	4.7	2.656
20	100	98	84	58	38.9	30.7	24.6	15.9	9.5	4.7	2.653
21	100	98	84	58	38.9	28.4	20.6	13.6	8.5	4.7	2.650
22	100	98	84	58	52.0	36.0	24.1	15.6	9.3	4.7	2.657
23	100	97	82	52	46.0	32.0	21.6	14.2	8.7	4.7	2.653
24	100	97	80	46	40.0	28.1	19.2	12.8	8.1	4.7	2.649

[1] Rational values allowing for gradation and based on the results of several tests by the Rice vacuum saturation procedure.

Table 2.—Physical properties of aggregates [1]

	Gravel		Sand	Limestone mineral filler
	¼-in. to ⅜-in.	¾-in. to No. 4		
Apparent specific gravity	2.66	2.66	2.67	2.71
Bulk specific gravity	2.59	2.62	2.58	
Water absorption, percent	1.0	.6	1.4	

[1] AASHO methods T 84 and T 85.

Table 3.—Physical properties of asphalt

Property	Value
Original asphalt:	
Specific gravity, 77°/77° F	1.016
Flash point, C.O.C. °F	540
Softening point °F	117
Penetration, 77° F, 100 g., 5 sec.	93
Ductility, 77° F cm.	230
Bitumen percent	99.8
After oven loss test (AASHO T 47):	
Loss percent	0.06
Penetration	80
Retained penetration percent	86
After thin-film oven test (AASHO T 179):	
Loss percent	0.20
Softening point °F	132
Penetration	54
Retained penetration percent	58
Ductility cm.	196

Two series of tests were conducted, the results of which are summarized in table 4. The first series was performed on all 24 gradations shown in table 1. All 24 mixtures contained 5.5 percent of asphalt by weight of the aggregate. A total of 72 test specimens, 3 for each of the 24 gradations, was made. The work was done in three rounds, one round of 24 specimens being prepared on each of three different days. The test results for each group of three corresponding specimens from the three rounds were averaged.

The second series of tests was performed on 14 of the 24 gradations. Asphalt contents were computed from the results of the first series of tests to produce air voids in pairs of compacted specimens slightly greater and slightly less than 4 percent so that test results for this second test series could be interpolated for exactly 4-percent air voids. A total of 84 specimens, 3 pairs for each of the 14 gradations, was made. The work was done in 3 rounds, 1 round of 28 specimens for the 14 gradations being prepared on each of 3 different days. The test results for each group of corresponding specimens were averaged.

Table 4.—Physical properties of gyratory compacted gravel mixtures

Gradation No.	1st series of tests: [1] Asphalt, 5.5 percent; [2] air voids, variable					2d series of tests: [1] [4] Asphalt, variable: air voids, 4.0 percent [2]				
	Bulk specific gravity	Mineral voids [3]	Air voids [3]	Marshall stability	Marshall flow	Asphalt content [2]	Bulk specific gravity	Mineral voids [3]	Marshall stability	Marshall flow
		Percent	*Percent*	*Pounds*		*Percent*		*Percent*	*Pounds*	
1	2.344	16.2	4.2	1,620	9	5.52	2.347	16.1	1,750	8
2	2.384	14.7	2.5	1,980	10	4.96	2.364	15.0	1,810	8
3	2.392	14.4	2.1	1,680	10	4.88	2.367	14.8	1,610	8
4	2.373	15.1	2.9	1,280	9	5.12	2.357	15.3	1,310	9
5	2.334	16.4	4.4	1,000	9	5.62	2.340	16.3	1,010	8
6	2.290	17.9	6.2	770	9					
7	2.286	18.7	7.0	810	7	6.64	2.304	18.2	1,100	7
8	2.304	17.9	6.1	880	8	6.22	2.323	17.4	1,110	7
9	2.320	17.3	5.4	980	8	5.97	2.339	17.0	1,220	8
10	2.331	16.8	4.8	1,100	9	5.64	2.347	16.3	1,190	7
11	2.318	17.2	5.3	1,090	8					
12	2.330	16.7	4.7	1,070	9	5.65	2.344	16.3	1,200	9
13	2.240	20.5	9.0	570	7					
14	2.265	19.5	7.9	710	7	6.93	2.317	18.8	1,060	8
15	2.277	18.9	7.2	800	7					
16	2.274	19.0	7.3	780	8					
17	2.282	18.6	6.9	860	8	6.38	2.325	17.7	1,080	8
18	2.326	17.1	5.2	980	7	5.70	2.348	16.5	1,070	7
19	2.350	16.1	4.1	1,220	8					
20	2.355	15.8	3.8	1,230	9	5.34	2.355	15.8	1,240	8
21	2.346	16.1	4.1	1,080	8					
22	2.308	17.7	5.9	980	8					
23	2.343	16.3	4.3	1,080	8					
24	2.374	15.1	2.9	1,260	8					

[1] Averages of 3 values, 1 per round for 3 rounds of tests.
[2] By weight of aggregate.
[3] Based on effective specific gravity of the aggregate.
[4] Interpolated values from results at 2 asphalt contents.

THIS PAGE LEFT BLANK
INTENTIONALLY

Chapter 5

Pavement Drainage

CHAPTER 5

PAVEMENT DRAINAGE

5.1 Pavement Design Acceptance, Consideration of Drainage, Memorandum, T. D. Larson, February 6, 1992.

- Technical Guide Paper, 90-01, Subsurface Pavement Drainage, 1990.

5.2 Longitudinal Edgedrains, Concrete Pavement Drainage Rehabilitation, State of Practice Report, Experimental Project No. 12, April 1989.

5.3 Permeable Base Design and Construction, January 1989.

5.4 Case Study, Pavement Edgedrain, TA 5040.14, June 8, 1989.

5.5 Subsurface Drainage of Portland Cement Concrete Pavements; Where Are We? December 1991.

5.6 Western States Pavement Subdrainage Conference, August 10, 1994.

5.7 Drainable Pavement Systems, Demonstration Project 87, April 06, 1992.

5.8 Effectiveness of Highway Edgedrains, Concrete Pavement Drainage Rehabilitation, State of Practice Report, Experimental Project No. 12, April 14, 1993.

5.9 Maintenance of Pavement Edgedrain Systems, March 21, 1995.

5.10 Pavement Subsurface Drainage Activities, December 16, 1994.

U.S. Department
of Transportation

**Federal Highway
Administration**

Memorandum

Subject INFORMATION: Distribution of Proceedings Western States Drainable PCC Pavement Workshop

Date AUG 10 1994

From Director, Office of Engineering
For: Director, Office of Technology Applications

Reply to Attn of HNG-42

To Regional Administrators
Federal Lands Highway Program Administrator
ATTENTION: Technology Transfer Coordinators

The Federal Highway Administration, in cooperation with the California Department of Transportation along with the Southwest Concrete Pavement Association, sponsored the subject conference in Sacramento, California, during July 21-22, 1993. This memorandum transmits copies of the proceedings (Publication No. FHWA-SA-94-045) and provides you with an update on our pavement drainage efforts.

Presentations describing the design and construction procedures used in the construction of permeable bases were made by the various western State highway agencies (Arizona, California, Nevada, Oregon, Washington, and Wyoming). The proceedings were compiled by Mr. James H. Woodstrom of the Southwest Concrete Pavement Association.

Currently, we have completed presentations of Demonstration Project No. 87 (DP 87), "Drainable Pavement Systems" in 42 States, Puerto Rico, and the District of Columbia. This demonstration project primarily covered drainage of Portland Cement Concrete (PCC) pavements. Unfortunately, one of the reoccurring comments during the presentation was that it did not cover drainage of flexible pavements or retrofit longitudinal edgedrains.

On June 6-8, a Technical Working Group (TWG) on Flexible Pavement Drainage Design was convened to develop input for the design and construction of permeable bases for flexible pavements. Discussions and input from the TWG are being reviewed by the Pavement Division and a design consensus will be formulated. This guidance will be provided to the field.

The National Highway Institute will also incorporate this new guidance on flexible pavement drainage design in its new NHI Course No. 13126, "Pavement Subsurface Drainage Design." This training course will be a complete drainage package covering PCC and flexible pavements and retrofit longitudinal edgedrains. A Request for Proposal for the course has been developed and has been forwarded to the Office of Contracts and Procurement. The development time will be approximately 2 years.

Sufficient copies of the publication have been distributed to provide one copy to each regional office, and two copies to each division office. Direct distribution has been made to the division offices, which are asked to forward one copy to the State. If additional copies of the proceedings are desired, or if you have any questions regarding DP 87, the western States report, or pavement drainage, please contact Project Manager Bob Baumgardner at 202-366-4612.

Ray S. Griffith for

William A. Weseman

Attachment

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: ACTION: Demonstration Project No. 87 "Drainable Pavement Systems"

Date: APR 6 1992

From: Director, Office of Engineering
Director, Office of Technology Applications

Reply to Attn. of: HNG-42

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator
ATTN: Technology Transfer Coordinators
Regional Pavement Engineers

We are pleased to announce that the subject demonstration project is available to State highway agencies (SHA's).

The pavement structural section is the single most costly element of a highway system. Water in the pavement section has been determined to be a factor in premature pavement deterioration. Inadequate base drainage has been identified as a nationwide problem, particularly in concrete pavements. A number of SHA's have developed innovative pavement designs and construction practices that have been successful in draining the pavement section. Application of these innovative techniques can reduce premature pavement failures and extend the useful life and investment in the Nation's roadways.

To demonstrate these newer pavement drainage techniques and other concepts, the Federal Highway Administration's (FHWA) Office of Technology Applications and Office of Engineering have developed Demonstration Project No. 87, "Drainable Pavement Systems." The project centers around classroom discussions that provide current state-of-the-art guidance for designing, constructing, and maintaining permeable base drainage systems. Detailed guidance will be provided for the design and construction of both unstabilized and stabilized permeable bases. The staff will also demonstrate the permeability of different base course materials.

Forwarded under separate cover are additional copies of the attached project flyer. These flyers are for distribution to the State agencies in your region. Interested agencies should submit requests for the demonstration project through the local FHWA office.

Please call Project Manager Robert Baumgardner at (202) 366-4612, should you have any questions.

Douglas A. Bernard

T. A. Stam for Thomas O. Willett

Attachments

THIS PAGE LEFT BLANK
INTENTIONALLY

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION**: "Effectiveness of Highway Edgedrains," Experimental Project No. 12, Concrete Pavement Drainage Rehabilitation

Date: APR 14 1993

From: Chief, Pavement Division
Chief, Engineering Applications Division

Reply to Attn. of: HNG-40
HTA-20

To: Federal Regional Highway Administrators
Division Administrators
Federal Lands Highway Program Administrator

Transmitted under separate cover are sufficient copies of the subject report for use by you and your States. This study measured concurrent rainfall and edgedrain discharges, piezometric water levels and soil moisture under the pavement and shoulders in 10 States (Alabama, Arkansas, California, Illinois, Minnesota, New York, North Carolina, Oregon, West Virginia, and Wyoming). This report should be of interest to State pavement design and research engineers in your region. We would like to take this opportunity to thank you and the participating State and division staffs for making this project a success.

We believe that a principal contribution that this report makes is that it provides an excellent guide to any State interested in developing a pavement drainage study. The pavement instrumentation necessary for drainage is well documented.

Your attention is particularly directed to the CONCLUSION, Effectiveness of Edgedrains, section on page 78 of the subject report. We feel that the following three statements have considerable impact on the national pavement subsurface drainage effort to reduce damage to the pavement structure caused by surface infiltration through joints and cracks:

- "Retrofitting longitudinal edgedrains to an existing highway provides a sink to collect water draining laterally off pavement surfaces, as well as water reaching the edgedrain through subgrade voids and channels."
- "Tight, low permeability subgrade material precludes ready, lateral drainage with or without edgedrains."
- "If highway restoration, as well as construction, includes provisions for a permeable subgrade (base), as well as edgedrains, the two together should prove the most efficient in restoring the highway."

We would like to direct your attention to Column (8) of Table 3 on page 64. The wide range of the percent of rainfall that shows up in the edgedrain discharges indicates how difficult it is to design edgedrain systems. Therefore, this study fully supports the "Time-to-Drain" concepts presented in Demonstration Project No. 87, "Drainable Pavement Systems" (Demo 87).

We would like to take this opportunity to update you on our pavement drainage efforts. Currently, we are making presentations of Demo 87. Attached is a map showing the progress of the project. It should be noted that this project only covers drainage of new or reconstructed portland cement concrete (PCC) pavements with permeable bases, a separator layer and edgedrains. Drainage of asphalt concrete (AC) pavements or retrofit longitudinal edgedrains is not covered in the demonstration project.

The next generation of our pavement drainage activities will include the development of the National Highway Institute Course No. 13126, "Pavement Subsurface Drainage Design." Drainage of pavement infiltration for both PCC and AC pavements, along with retrofit longitudinal edgedrains, will be covered. This project is in the conceptual stage with a National Highway Institute proposal under development.

A limited number of additional copies of the attached report are available from our Report Center, or by purchase from the Geological Survey (Report No. WRRI 92-4147, cost - $13.00, and telephone number (303) 236-7476):

U.S. Geological Survey
Books and Open-File Reports Section
Box 25286, Federal Center
Denver, Colorado 80225

If you have any additional questions, please contact Mr. Robert Baumgardner (202) 366-4612 in the Pavement Division.

Theodore R. Ferragut

Louis M. Papet

Attachments

Memorandum

U.S. Department
of Transportation

Federal Highway
Administration

Subject: **ACTION**: Maintenance of Pavement Edgedrain Systems

Date: MAR 21 1995

From: Associate Administrator for Program Development

Reply to Attn. of: HNG-42

To: Regional Administrators
Federal Lands Highway Program Administrator
ATTENTION: Regional Pavement Engineers

The purpose of this memorandum is to strongly reiterate the need for maintenance of edgedrain systems. We have become increasingly concerned about the lack of maintenance of the edgedrain systems that we have observed around the country. Recently, one of our division offices made an extensive review of the maintenance of pavement edgedrain systems and prepared an excellent report documenting their findings. Attached is a copy of their report "Maintenance of Pavement Underdrain System." The reference to the identity of the division office and the State highway agency has been removed at their request. We recommend that the division offices in your region conduct similar field evaluations of existing edgedrain systems.

Sufficient copies of the publication are attached to provide one copy to each regional office, and two copies to each division office. We ask that this report be forwarded to the State. If additional copies of the report are needed, please contact Mr. Robert Baumgardner at (202) 366-4612.

We cannot over emphasize the importance of proper construction and maintenance of pavement edgedrain systems. If water is not rapidly removed from these systems, they will serve as reservoirs saturating pavement bases and causing rather than preventing accelerated pavement deterioration.

Currently, we are finalizing a service contract for the video inspection of highway edgedrains. This service will assist you and the State in evaluating pavement drainage systems. The video inspection will provide a qualitative picture of edgedrain conditions in the State.

For Thomas J. Ptak

FEDERAL HIGHWAY ADMINISTRATION 1893 1993

Form DOT F 1320.65A (Rev. 5/83)

THIS PAGE LEFT BLANK
INTENTIONALLY

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION**: Pavement Subsurface Drainage Activities

Date: DEC 16 1994

From: Chief, Pavement Divison

Reply to Attn. of: HNG-42

To: Regional Administrators
Federal Lands Highway Program Administrator

The purpose of this memorandum is to update you on our pavement drainage activities and transmit a copy of the **Demonstration Project No. 87, (Demo 87) "Drainable Pavement Systems Instructor's Guide"**. This publication provides a capsulized picture of pavement subsurface drainage design. Demo 87 was presented in over 40 States, Puerto Rico and the District of Columbia. Attached is a map showing participation.

With the successful completion of the first phase of Demo 87, we are moving into Phase II of Demo 87, which consists of three activities:

First, a Technical Working Group (TWG) on **Flexible Pavement Drainage Design** consisting of participants from FHWA, State highway agencies (SHA's), universities, and industries was convened in June of this year. The participants provided input as a TWG by drawing on their experience and expertise. Wide ranging discussions on the design and construction of flexible pavements revealed that there was no clear definition of the role of drainage in flexible pavements. One point of consensus was that, if a permeable base was provided in a flexible pavement, it would primarily combat pavement infiltration water; it would not solve ground water problems. A summary of the TWG workshop's notes was transmitted to each regional office by memorandum dated November 21, 1994.

Second, we have developed a Proposal (RFP) entitled **"Video Inspection of Highway Edgedrains,"** which is now being considered for contract award. This will provide SHA's with a qualitative video picture of edgedrain conditions. Upon request of the SHA, the video contractor will be available to the SHA for up to a week to investigate the edgedrain in-situ conditions. Both existing edgedrains and new construction could be viewed on both AC and PCC pavements. After the inspection, the Contractor will provide the SHA with a copy of video tapes and 35 mm slides taken during the inspection. Also available will be Graphic Information System (GIS) output documenting both the vertical and horizontal alinement of the edgedrain system. We expect this activity to be available about March 1, 1995.

Third, we are interested in continuing to develop expertise and provide technical support in the construction of permeable base and drainage systems for both flexible and concrete pavements. We would appreciate feedback from your office to identify upcoming construction projects, so that we can assess developing construction techniques and practices and provide technical support as appropriate. We encourage studies to evaluate the effect of drainable systems on pavement performance (particularly AC pavements) which includes a non-drained control section. Please keep us informed of any studies underway or planned.

Attached is a brief one-page description of our current drainage activities that you may want to disseminate to your division offices and SHA's.

for T. Paul Teng

2 Attachments

SUMMARY OF FHWA'S CURRENT PAVEMENT SUBSURFACE DRAINAGE ACTIVITIES

December 1994

Demonstration Project No. 87, "Drainable Pavement Systems" (Demo 87) provided detailed design and construction guidance for drainage systems under Portland Cement Concrete (PCC) pavements. Established drainage design procedures were combined with the state-of-the-art in practical permeable base construction to provide a well balanced approach for the drainage of PCC pavements. Detail design and construction guidance was provided for permeable bases, separator layers and edgedrains. Demo 87 was presented in over 40 States, Puerto Rico and the District of Columbia. With the successful completion of the first phase of Demo 87, we are moving into Phase II of Demo 87 which consists of athree activities.

First, a Technical Working Group on **Flexible Pavement Drainage Design** (TWG) consisting of participants from FHWA, State highway agencies (SHA's), Universities, and Industry was convened in June of this year. The participants provided input as a TWG by drawing on their experience and expertise. Wide ranging discussions on the design and construction of flexible pavements revealed that there was no clear definition of the role of drainage in flexible pavements. The only point of consensus was that, if a permeable base was provided in a flexible pavement, it would primarily combat pavement infiltration water; it would not solve ground water problems. A summary of the TWG workshop is available.

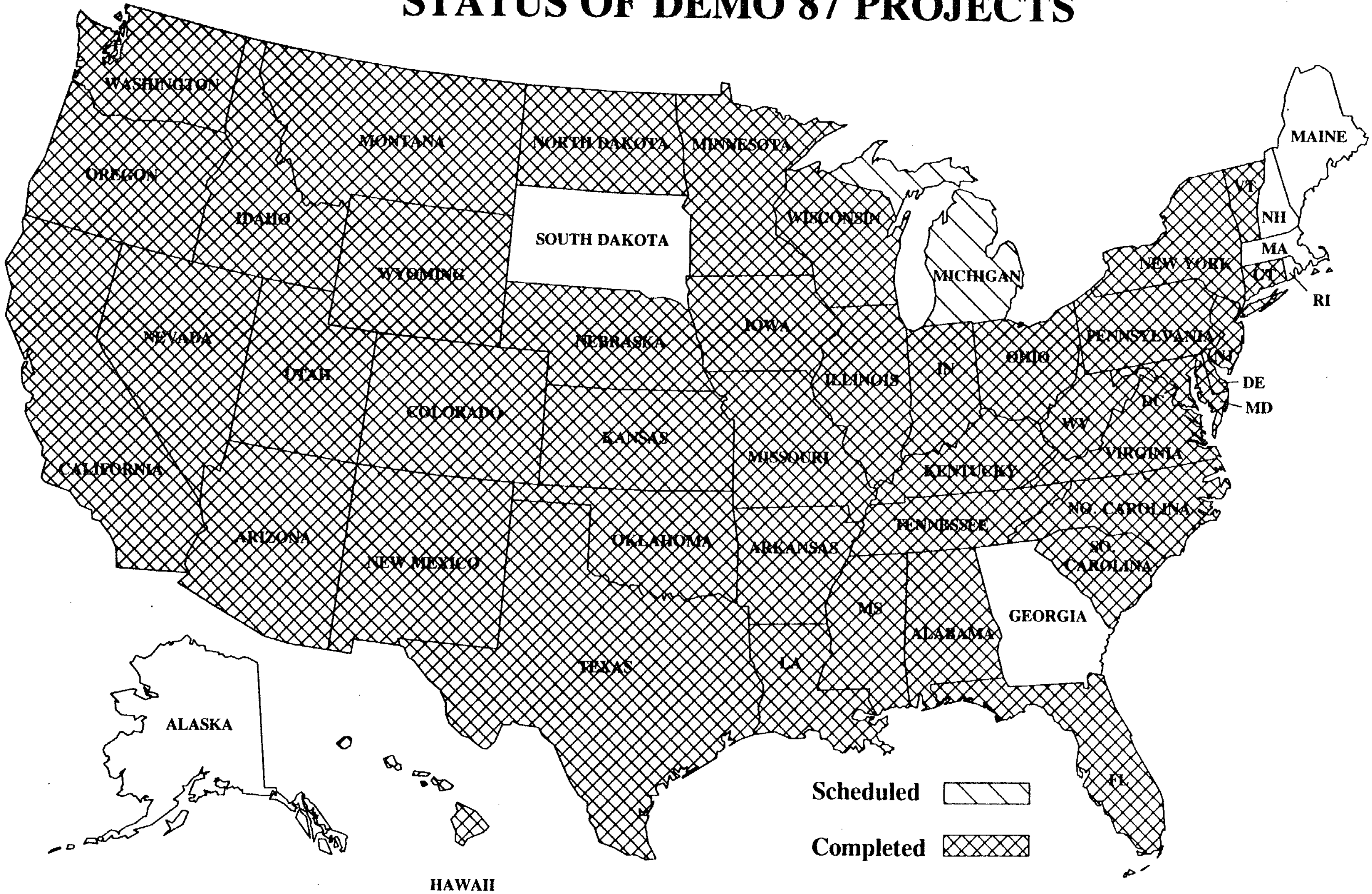
Second, we are preparing to award a contract in response to a Request for Proposal (RFP) entitled **"Video Inspection of Highway Edgedrains"** contract. This will provide State highway agencies (SHA's) with a qualitative video picture of edgedrain conditions. Upon request of the SHA, the Contractor will be available to the SHA's for up the a week to investigate the edgedrain in situ conditions. Both existing edgedrains and new construction for AC and PCC pavements could be viewed. The equipment cannot inspect "fin" drains or round pipe less than 100 mm diameter. After the inspection, the Contractor will provide the SHA with a copy of video tapes and 35 mm slides taken during the inspection. Also, Graphic Information Systems (GIS) information on edgedrain vertical and horizontal alinement will be provided. We expect this activity to be available by March 1, 1995.

Third, we are interested in continuing to develop expertise and provide technical support in the construction of permeable base and drainage systems for both flexible and concrete pavements. To accomplish this activity, field trips will be made to view construction and provide technical support for placing permeable bases in both rigid and flexible pavements. We are also interested in studies evaluating the effect of these systems on pavement performance.

We are now finalizing a RFP entitled **"Pavement Subsurface Drainage Microcomputer Program."** This microcomputer program will replicate the design procedures contained in the Demo 87 Participant Notebook. This will provide engineers with a useful tool for drainage design.

The National Highway Institute (NHI) has advertised a RFP for developing a training course entitled **NHI Course No. 13126 "Pavement Subsurface Drainage Design."** Drainage guidance for PCC and flexible pavements, along with retrofit edgedrains, will be compiled into a comprehensive pavement drainage training course. The length of the course will be about 3 days and will follow a slide-lecture format. This training course will be available to all SHA's and Industry though NHI.

STATUS OF DEMO 87 PROJECTS



THIS PAGE LEFT BLANK
INTENTIONALLY

Chapter 6

Shoulder

CHAPTER 6

SHOULDER

6.1 TA 5040.29, Paved Shoulders, February 2, 1990.

Chapter 7

Pavement Rehabilitation

CHAPTER 7

PAVEMENT REHABILITATION

7.1 Concrete Pavement Restoration Performance Review, May 22, 1997.
- Concrete Pavement Restoration Performance Review, April 1987.

7.2 Crack and Seat Performance Review Report, April 1987.

7.3 Saw and Seal Pavement Rehabilitation Technique, February 22, 1988.
- Saw and Seal Pavement Rehabilitation Technique, Technical Paper 88-01.

7.4 Reserved

7.5 FHWA Notice N5080.93, Hot and Cold Recycling of Asphalt Pavements, October 6, 1981.

7.6 Reserved.

7.7 Use of Recycled Concrete in Portland Cement Concrete Pavement, July 25, 1989.

7.8 Use of Recycled PCC as Aggregates in PCC Pavements, February 1985.

7.9 Overview of Surface Rehabilitation Techniques for Asphalt Pavements, Report Number FHWA-PD-92-008, April 6, 1992.

7.10 State of the Practice Design, Construction, and Performance of Micro-Surfacing, Report Number FHWA-SA-94-051, July 12, 1994.

7.11 Retrofit Load Transfer, Special Project 204, February 10, 1994.

7.12 Reserved.

7.13 Thin Bonded Overlay and Surface Lamination Pavements and Bridges, ISTEA 6005, July 1, 1994.

U.S. Department
of Transportation
**Federal Highway
Administration**

Memorandum

Subject: Technical Paper - An Overview of Surface Rehabilitation Techniques for Asphalt Pavements

Date: APR 6 1992

From: Chief, Pavement Division

Reply to Attn. of: HNG-42

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

During the past year, the Pavement Division, in conjunction with the Office of Technology Applications, has been involved in a comprehensive effort to develop an information base on existing and emerging surface rehabilitation techniques for asphalt pavements. Examples of techniques we are evaluating include: (1) cold mixtures such as slurry seals and micro-surfacing; (2) single and multiple chip seals; and (3) open and dense graded thin hot-mix overlays. The use of modified binders and fibers in these applications will also be examined. This project will provide information on the usage, design, construction, cost, and anticipated performance of these techniques when applied as a functional improvement to a structurally sound higher volume roadway pavement. Further, this project will complement and expand on the information gained from the Strategic Highway Research Program's specific pavement studies (SPS-3) experiment.

Attached are copies of the technical paper entitled, "An Overview of Surface Rehabilitation Techniques for Asphalt Pavements," (FHWA-PD-92-008). You may wish to provide copies of this paper to your division offices. This paper summarizes known preventative maintenance and surface rehabilitation techniques based on our literature search and some limited field work. During the coming months, we will be visiting several existing and new projects to gather additional related information on various applications. Your staff assistance in this regard will be appreciated.

If you have any questions on our effort or like to arrange for a presentation on this subject, please call Messrs. Hassan Raza at FTS 366-1338 or James Sorenson at FTS 366-1333.

Louis M. Papet

Attachments

THIS PAGE LEFT BLANK
INTENTIONALLY

Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: ACTION: Distribution of Publication

Date: July 12, 1994

From: Director, Office of Engineering
Director, Office of Technology Applications

Reply to Attn of: HNG-42

To: Regional Administrators
Federal Lands Highway Program Administrator

The attached publication, State of the Practice Design, Construction, and Performance of Micro-surfacing (FHWA-SA-94-051) provides a comprehensive discussion on an emerging surface rehabilitation technology. Sufficient copies of this publication are attached for your use and further distribution to the division offices and States within your region. Copies have also been distributed to each of the LTAP Technology Transfer Centers. Additional copies are available in limited supply from the Research and Technology Report Center, HRD-11, 6300 Georgetown Pike, McLean, Virginia 22101-2296 (telephone 703-285-2144).

Micro-surfacing consists of polymer-modified asphalt emulsion, crushed aggregate, mineral filler, water, and field-controlled additives as needed. Micro-surfacing is primarily used to seal existing surfaces, improve surface friction, and fill wheel ruts on both moderate and high volume roads. When properly designed and constructed, micro-surfacing has shown promising results with several years of service life. This surface rehabilitation technique has also been used effectively on portland cement concrete pavements to improve surface friction or address mechanical wear in the wheel paths.

This state-of-the-practice paper is a result of a joint effort by the offices of Engineering and Technology Applications, and the industry to develop information on existing and emerging surface rehabilitation techniques for asphalt pavements. The first product of this effort, An Overview of Surface Rehabilitation Techniques for Asphalt Pavements (FHWA-PD-92-008) was developed and distributed in April 1992. Presentation slides for both of the above papers will be available later this fall.

In a related effort, an Office of Engineering memorandum dated June 24 announced the availability of warranty guide specifications for micro-surfacing projects on the National Highway System under Experimental Project 14. If you have any questions or would like to request technical support in the surface rehabilitation area, please call Hassan Raza at 202-366-1338.

William A. Weseman

Ray G. Griffith
FOR: Director, Office of
Technology Applications

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: INFORMATION: SP204 - Retrofit Load Transfer

Date: FEB 10 1994

From: Chief, Pavement Division
Chief, Engineering Applications Division

Reply to Attn of: HNG-42
HTA-21

To: Regional Federal Highway Administrators
Division Federal Highway Administrators
Federal Lands Highway Program Administrator

Attached are the following documents for your use and information:

1. Current status report - **SPECIAL PROJECT 204** - Retrofit Load Transfer and December 27, 1993 report Retrofit Load Transfer in Jointed Concrete Pavements
2. TRB Preprint 940247, Linda M. Pierce, PCCP Rehabilitation in Washington State (A Case Study)
3. Inspection report by Lynn Porter and Cathy Nicolas on Washington State Load Transfer Retrofit Project
4. Report by Roger Larson of load transfer restrofit field visits in Puerto and Indiana

Until recently, load transfer retrofit had been used only experimentally in the continental United States. In the last ten years, an estimated 300 lane Km of faulted or cracked undoweled jointed plain concrete pavement (JPCP) has been successfully rehabilitated in Puerto Rico. Based on the generally good performance of previously constructed load transfer retrofit experimental sections in the U.S. and the outstanding performance in Puerto Rico, SP-204 was initiated to encourage the development of equipment to construct multiple slots in each wheelpath to increase the production rate for this technique and to reduce the construction cost and road user delays.

Attachment 1 describes the current status and background of this effort. Attachment 2 describes the preliminary engineering and experimental test section construction that led to the 53 km project now underway in Washington State. Attachment 3 describes the major Washington State project currently underway involving 53 km (about 24 km now complete) of retrofit load transfer on eastbound I-90. Attachment 4 describes field visits to Puerto Rico to observe the long term performance of retrofit load transfer projects and to Indiana to observe a demonstration of the feasibility of using carbide milling technology to construct multiple slots in jointed reinforced concrete pavement (JRCP).

FEDERAL HIGHWAY ADMINISTRATION 1893 1993

Based upon the recent construction of 24 lane km of retrofit dowels (JPCP) in the project currently underway in Washington State and the successful demonstration of milling three slots per wheelpath in one pass on working cracks in a JRCP ramp in Indiana, equipment is now available to economically construct retrofit load transfer at joints or cracks in existing jointed concrete pavements. The bid price to construct retrofit load transfer devices in Washington State was $34.50 per dowel installed (62,000 38 mm dowels in 64 mm wide slots). The average bid price in Puerto Rico is $20 per dowel installed (25 mm dowel in 40 mm wide slots) where this has been done routinely for ten years (slots sawed individually).

This technique should be used with other concrete pavement restoration techniques to rehabilitate existing jointed concrete pavement <u>before</u> serious deterioration is present. Perhaps the most cost-effective initial application of this technique would be to restore load transfer at working cracks developing in under-reinforced JRCP in other wise good condition. If performed early, it would also provide a cost-effective extension of the service life at the joints on undoweled JPCP and at transverse cracks without serious deterioration in either doweled or undoweled JPCP. If serious deterioration is present, full depth patching and/or selective slab replacements should be performed instead.

When properly applied, this technique will result in a cost-effective extension of the service life of existing jointed concrete pavements in good to fair condition. This technique would also be a very effective routine and preventive maintenance technique to reduce the cost and user delays during repairs of working cracks shortly after they develop and before full depth patches or slab replacements become necessary.

If you have comments or questions, please contact Mr. Roger Larson, the project manager of SP 204, at (202) 366-1326. A Technical Working Group will be formed shortly to update guidance reflecting the new equipment developments and other critical technical issues to help ensure success of this promising technique.

Theodore R. Ferragut

Louis M. Papet

4 Attachments

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: ACTION: ISTEA Section 6005
Thin Bonded Overlay and Surface Lamination
Pavements and Bridges
Reply due: October 31, 1994

Date: July 1, 1994

From: Director, Office of Engineering

Reply to Attn. of: HNG-32
HNG-42

To: Regional Federal Highway Administrators

We are requesting applications for additional projects for the Thin Bonded Overlay and Surface Lamination (TBO) Program, which is part of the Applied Research and Technology (ART) Program established by Section 6005 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. A summary of the TBO program and the application procedures are described in Attachment A. The application form is included as Attachment B. A summary of information on technologies is included in Attachment C. A listing of bridge deck and pavement overlay projects and TBO technologies previously approved is included in Attachment D and the evaluation plans developed for these projects are included in Attachment E.

Additional projects are being sought for available fiscal year (FY) 1994 and 1995 funding. Projects proposed for construction in FY 1996 and 1997 are also encouraged. There may be no future solicitations for ISTEA TBO projects if enough candidate projects are available for selection from responses to this request. Please contact the States in your region for candidate projects for the TBO program. Candidate projects proposed by the State highway agencies must be submitted on the application form (Attachment B) and sent with any supporting information to the appropriate Federal Highway Administration Division Office by October 14, 1994, for forwarding to this office by October 31. The Section 6005 funding provided (100 percent for reporting and evaluation and 80 percent for construction and an equal amount of obligation authority for projects approved as a part of this solicitation) is in addition to the individual State's regular Federal-aid. Please also note that priority for funding will be given to the technologies listed in the *New Projects Sought* section of Attachment A.

Your cooperation and attention are greatly appreciated. If you have any questions or comments, please contact Mr. Vasant Mistry, HNG-32, (202) 366-4599 or Mr. Roger Larson, HNG-42, (202) 366-1326. General questions on the ART Program should be addressed to Mr. Richard A. McComb, HTA-2, (202) 366-2792.

for William A. Weseman

5 Attachments

THIS PAGE LEFT BLANK
INTENTIONALLY

Chapter 8

Surface and Other Considerations

CHAPTER 8

SURFACE AND OTHER CONSIDERATIONS

8.1 Rideability Specifications, December 17, 1987.

8.2 A Selection of Measuring Equipment Used to Monitor and Enforce Rideability Specifications, Technical Paper 88-03, May 24, 1988.

8.3 TA 5040.17, Skid Accident Reduction Programs, December 23, 1980.

8.4 TA 5140.10, Texturing and Skid Resistance of Concrete Pavement and Bridge Decks, September 18, 1979.

8.5 TA 5040.31, Open-Graded Asphalt Friction Course, December 26, 1990.

8.6 Automatic Profile Index Computation, February 21, 1991.
- Analysis and Recommendations Concerning Profilograph Measurements in South Dakota, November 1990.

8.7 Measurements, Specifications, and Achievement of Smoothness for Pavement Construction, NCHRP No. 167, 1990.

8.8 A Half Century with the California Profilograph, Report Number FHWA-AZ-SP9102, February 1992.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **167**

MEASUREMENTS, SPECIFICATIONS, AND ACHIEVEMENT OF SMOOTHNESS FOR PAVEMENT CONSTRUCTION

JAMES H. WOODSTROM
Carmichael, California

Topic Panel

DAVID O. COX, *Federal Highway Administration*
ALFRED DONOFRIO, *Delaware Department of Transportation*
RUDOLPH R. HEGMON, *Federal Highway Administration*
WILLIAM D. O. PATERSON, *World Bank*
GEORGE W. RING, *Transportation Research Board*
ROLANDS L. RIZENBERGS, *Kentucky Transportation Cabinet*
JAMES C. WAMBOLD, *Pennsylvania Transportation Institute*
JOHN C. WASLEY, *Federal Highway Administration*

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. NOVEMBER 1990

8.7.01

THIS PAGE LEFT BLANK
INTENTIONALLY

MEASUREMENTS, SPECIFICATIONS, AND ACHIEVEMENT OF SMOOTHNESS FOR PAVEMENT CONSTRUCTION

SUMMARY

The concern about the smoothness of highway surfaces precedes the development of motorized vehicles. In the early days, the simple straightedge was used as the sole indicator of smoothness. But even before the turn of the century, efforts were directed at developing improved devices for smoothness evaluation. From 1900 to near midcentury, numerous devices of increasing complexity were invented. These were primarily mechanical devices with elaborate multi-wheeled support systems. Advances in several technological fields have now been applied to smoothness-measuring equipment, resulting in the incorporation of electrical circuitry, electronics, ultrasonics, lasers, and computerization.

Although the early devices were primarily of concern to the practicing engineer, the advent of test road construction brought the research engineer onto the scene. Many devices were developed in connection with specific research efforts. The automotive industry became interested because of the effect that certain types of pavement had on motor vehicles. In recent years highway managers have recognized that the public rates a highway primarily on its riding characteristic. Thus it is necessary to program an increasing amount of highway funds to address the issue of pavement smoothness on a system-wide basis.

As a consequence, several smoothness-measuring devices have been developed and are in current use. The fundamentals of operation, cost, and appropriateness to address a specific need vary considerably. Certain devices are far better suited than others to the purpose of controlling the smoothness of newly constructed pavements. Therefore, it is important for those concerned with obtaining smoothness in construction to be aware of the equipment best suited for that purpose and the relation of that equipment to the entire spectrum of smoothness-measuring devices.

Smoothness-measuring equipment currently used in new pavement construction includes straightedges (static and rolling), profilographs, response-type road-roughness-measuring systems, and inertial profilometers. All agencies use a straightedge—a few as the sole approach to smoothness control, but most as an adjunct to other equipment. The type of instrument receiving increased application is the profilograph, either the California or Rainhart type. These devices are similar in that they portray graphically certain characteristics of pavement smoothness, are relatively simple mechanical devices, can be used on new concrete pavement surfaces soon after construction, are low-cost/low-maintenance devices, and provide information that is readily acceptable by specifying agencies and the construction industry. Profilographs provide an analog trace to which specification tolerances are applied. The traces can be used to locate specific pavement features in the field. The primary disadvantages with this type of instrument are the slow speed of operation (3 mph) and the time required for evaluating the profiles, although the latter item has been addressed by computerized models that are now available. Other disadvantages include the exaggeration and suppression of parts of the surface wavelength spectrum, the occasional

exclusion by the blanking band of surface irregularities that may be of importance, and a mediocre correlation to other reference roughness standards.

Other devices being used in evaluating smoothness of new construction, including response-type road-roughness-measuring systems and inertial profilometers, are used considerably less often than profilographs for a variety of reasons. They are not able to be used on concrete pavements for a considerable time after paving (i.e., until the concrete gains sufficient strength), they don't allow ready identification or location of pavement surface aberrations, and, in some cases, they are very costly items. However, they can operate at high speeds; thus a considerable amount of data can be obtained at a lower cost. Also, the smoothness statistic is achieved with little or no manual processing. High-speed equipment has its greatest application in entire highway system assessment, research applications, and for calibration purposes.

Numerous research efforts as well as symposia and workshops have been directed toward providing information on the use of smoothness-measuring equipment. Although there are vast differences in equipment types and their ultimate application, the relationships of several smoothness indexes have been compared and are reasonably well defined.

A survey of practices in use in the United States and Canada revealed that there is a wide diversity in the use of smoothness specifications and equipment. However, emphasis on smoothness by specifying agencies, together with strong support from the construction industry, has led to the attainment of increasingly smoother pavements.

1. Report No. FHWA-AZ-SP9102	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
A HALF CENTURY WITH THE CALIFORNIA PROFILOGRAPH
Phase I Experiment

5. Report Date
February,1992

6. Performing Organization Code

7. Author(s)
Larry A. Scofield, Sylvester Kalevela, Mary Anderson, Asm Hossain

8. Performing Organization Report No.

9. Performing Organization Name and Address
Arizona Transportation Research Center
College of Engineering, ERC, Rm 405
Arizona State University

10. Work Unit No.

11. Contract or Grant No
HPR-PL-1(41) ITEM 114

12. Sponsoring Agency Name and Address
ARIZONA DEPARTMENT OF TRANSPORTATION
206 S. 17TH AVENUE
PHOENIX, ARIZONA 85007

13. Type of Report & Period Covered
Final-Sept. 1990 - June 1991

14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This study was performed to establish equipment and operator variability for mechanical and computerized California profilographs. Future work, based on testing conducted during this study, should develop precision and bias statements for profilographs.

The research consists of two phases. Phase I, reported herein, provided a literature review, performed the field testing and conducted the statistical anlysis. The historical development of the profilograph and California test procedures and specifications were evaluated in relationship to todays incentive/disincentive specifications. Additionally, equipment parameters which influence test variability were reviewed.

Two field experiments were conducted. The first experiment, designed to evaluate variability, consisted of a 4x4x2 randomized block design with replication. Two levels of pavement roughness, four operators, and four profilogrphs were utilized. The second experiment, designed to evaluate the effects of data filter settings on profile index obtained with computerized profiliographs, consisted of a 3x2x2x2 randomized block design with replication. Two levels of pavement roughness, two computerized profilographs, two operataors, and three data filter settings were used.

The results of the study indicated that the average repeatability was 0.75 inches/mile and 0.56 inches/mile for the rough and smooth track conditions, respectfully.

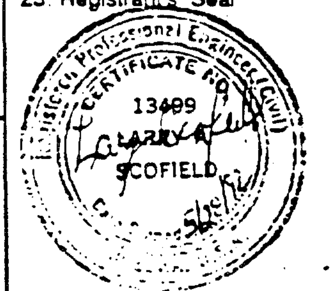
The average repeatability for an operator performing trace reduction was 0.94 inches/mile for one device and 1.72 inches/mile for a second device.

The data filter setting used on computerized profilographs has a significant affect on the resulting profilo index. For each 1000 unit change in the data filter setting, a 7% reduction in the profile index was obtained when compared to the manufacturers recommended value of 8000.

17. Key Words
Profilograph, Pavement Roughness, Pavement Smoothness, California Profilograph, Profile, Specifications, Incentive, Disincentive

18. Distribution Statement
Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

23. Registrant's Seal



19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	58	

THIS PAGE LEFT BLANK
INTENTIONALLY

Chapter 9

Pavement Management

CHAPTER 9

PAVEMENT MANAGEMENT

9.1 A National Perspective on Pavement Management, July 1994.

9.2 Automated Pavement Condition Data Collection Equipment, July 1989.

9.3 Addressing Institutional Barriers to Implementing a PMS, August 19, 1991.

9.4 FHWA Order 5080.3, Pavement Management Coordination, April 13, 1992.

9.5 Pavement Management System - Federal Register, December 1, 1993.

National Perspective on Pavement Management

FRANK BOTELHO

The nation's highway network represents a multibillion dollar investment that allows for the essential movement of people and goods.

Sound decisions on preventive maintenance, rehabilitation, and reconstruction of highway pavements are crucial to protecting that investment. For this reason, Pavement Management Systems (PMS) have become increasingly important and are now federally mandated on all Federal-aid highways. PMS provide valuable assistance to decision makers in determining cost-effective strategies for providing and maintaining pavements in serviceable condition.

History of PMS

Unlike other management systems that have begun in recent years, PMS were started two decades ago. Although they have made steady progress since that time, they are still new compared with other institutional functions such as planning, design, construction, maintenance, and research.

By the mid-1980s PMS were proving themselves and the benefits were being documented. By the end of the 1980s more than half the states were developing or implementing PMS. In 1989 the Federal Highway Administration (FHWA) issued a policy requiring all states to have a PMS that would cover principal arterials under the states' jurisdiction. It was therefore apparent to FHWA that a PMS was needed by all to ensure the cost-effective expenditure of Federal-aid funds.

The scope of federal and state involvement in PMS expanded when Congress passed the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and required all states to have a PMS that covers all Federal-aid highways. The most significant aspect of this law was the expanded network coverage. FHWA's 1989 policy covered 313,700 centerline miles and ISTEA approximately tripled that coverage, increasing it to 916,200 centerline miles. This expanded coverage translates into a need for significant coordination among state and local governments. For example, of the total of 916,200 miles covered, 365,200 are under local jurisdiction.

In December 1993, FHWA issued a regulation covering all management systems. Section 500, Subpart B, of the regulation describes the ISTEA requirements for PMS. The following items are noteworthy:

1. The regulation is nonprescriptive;
2. Federal-aid funds are eligible for the development, implementation, and annual operation of a PMS;
3. States must develop their work plan by October 1994, designed to meet the implementation requirements;
4. Standards are included for the National Highway System (NHS);
5. The PMS for the NHS must be fully operational by October 1995;
6. The states have full flexibility to develop the standards for the PMS that cover the non-NHS routes;
7. The PMS for non-NHS routes must be fully operational by October 1997; and
8. PMS information must be used as input into the development of the metropolitan and statewide transportation plans and improvement programs.

Section 500.207, PMS Components, contains the components of a PMS for highways on NHS. There are three primary components: data collection, analyses, and update. The components under data collection include

1. *Inventory:* physical pavement features including the number of lanes, length, width, surface type, functional classification, and shoulder information;
2. *History:* project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance;
3. *Condition survey:* roughness or ride, pavement distress, rutting, and surface friction;
4. *Traffic:* volume, vehicle type, and load data; and
5. *Data base:* compilation of all data files used in the PMS.

The components under analyses include

Frank Botelho is Chief, Pavement Management Branch, Federal Highway Administration.

1. *Condition analysis:* ride, distress, rutting, and surface friction;

2. *Performance analysis:* pavement performance analysis and an estimate of remaining service life;

3. *Investment analysis:* an estimate of network and project level investment strategies. These include single- and multi-year period analyses and should consider life-cycle cost evaluation;

4. *Engineering analysis:* evaluation of design, construction, rehabilitation, materials, mix designs, and maintenance; and

5. *Feedback analysis:* evaluation and updating of procedures and calibration of relationships using PMS performance data and current engineering criteria.

Advantages of PMS

A PMS involves a systematic approach that supplies quantifiable engineering information to help highway engineers and administrators manage highway pavements. The total decision-making process is based on information from PMS coupled with engineering experience, budget constraints, scheduling parameters, management prerogatives, public input, political considerations, and planning and programming factors.

The purpose of a PMS is to enhance the way an agency manages and engineers the preservation of its pavement network. A PMS brings to the table "condition data," the past, present, and predicted future condition of the pavement network. Coupled with inventory, project history, and cost data, a PMS can perform a myriad of engineering, management, and investment analyses.

A PMS helps provide the engineering justification for a multiyear network-level pavement preservation program. It can be used to measure the cost-effectiveness of the preservation program and in doing so it can determine the value added to the assets. When all the information in a PMS is analyzed (including key items such as the remaining service life), an agency can determine if it is meeting its own goals. Some basic questions a PMS should answer are

- Is the network in acceptable condition according to the agency's policy?
- Is the trend in condition staying the same, improving, or declining?
- Is there a backlog, and if so, how large is it?

A PMS should explore and seize opportunities to extend the service life of pavements—a major investment in the future of the nation's infrastructure. This goal can be accomplished by using the information in a PMS data base (i.e., performance data) to evaluate how well pavements are designed, constructed, and maintained. The quality of engineering and the materials used are of the utmost importance because these factors determine the rate at which pavements deteriorate. In general terms, a PMS should help accomplish work more efficiently and provide a way to measure how well it is carried out.

ISTEA requires that states have pavement management systems covering all Federal-aid highways, many of which are under local jurisdiction.

PMS Perspective

The following is an item-by-item perspective on current practices, future trends, and common hurdles in PMS.

Inventory

Most, if not all, states have an inventory of the physical features that are on the surface of the pavement (i.e., number of lanes, length, width, surface type, functional classification, and shoulder information). A number of states are lacking information on features that lie below the surface because of the time and expense involved in coring the pavement. The newest proven technology being used by the states to measure pavement layer thicknesses is ground-penetrating radar. When calibrated and using computer analysis, ground-penetrating radar can measure pavement layer thickness within plus or minus 5 percent for materials that have different dielectric constants. State-of-the-art equipment operates at highway speeds that makes it fast, safe, and cost-effective.

Project History

Most states do not have a complete project history (i.e., preventive maintenance, rehabilitation, and reconstruction data) for the NHS. Maintenance information is the weakest link. Most states have recently developed, or are in the process of developing, a PMS file for preventive maintenance activities. In cases for which it is impractical to resurrect the pavement history because of time, labor, and cost, agencies are now beginning to track the project history.

Roughness

The technology for measuring pavement roughness at the network level generally began with response-type devices, followed by ultrasonic and visible optical devices. The future trend is toward infrared optical and laser profile devices.

Rutting

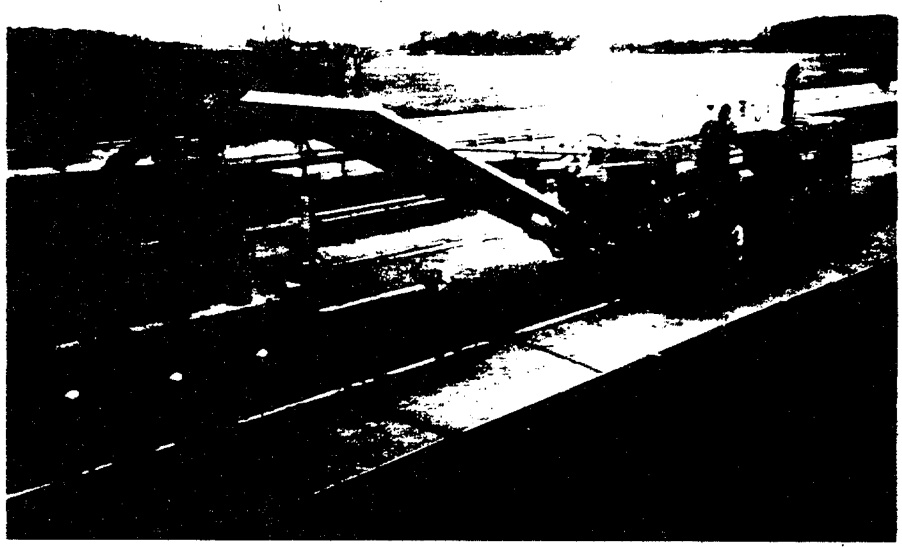
When PMS was first introduced 15 to 20 years ago, rutting was measured using straight edges and string lines. During the past 10 years, most state highway agencies (SHA) have acquired automated devices that measure rutting at highway speeds. These are typically ultrasonic devices with either three or five sensors. There are two other devices: one has 19 ultrasonic sensors and another has 11 lasers.

Cracking

In general, cracking is the distress that "drives" most PMS. For many years, cracks were measured using trained survey crews who walked or drove on the pavement. There are two types of driven surveys: slow and highway speeds (typically 40 to 50 mph). Currently, various SHAs use 35-mm film and super VHS video to photograph the surface of the pavement. The film and videos are then viewed on a monitor at an office workstation by a trained observer who performs the distress survey.

Viewing a film or video at an office workstation is safer and more convenient than conducting a walking field survey. However, pavement management engineers using walking surveys are able to detect more low-severity distresses than they can by watching a film or video survey because of its limited resolution.

A number of PMS engineers believe the optimum system is a fully automated approach that uses the science of pattern recognition. This type of system videotapes the pavement surface, enhances the images using gray scales and pattern recognition, and counts the cracks using computer software and algorithms. The obvious advantages of this type of system are high-speed data processing, safety, labor savings, and consistent data. Fully automated systems have now been developed, including one by the Texas Department of Transportation.



CMI CORPORATION

Pavement management systems provide valuable help in determining cost-effective strategies for providing and maintaining pavements in serviceable condition.

Structural Carrying Capacity

Only a handful of states are currently measuring the structural carrying capacity of their pavements at the network level using deflection measurements. Network-level measurements are not intended to have the same degree of accuracy as project design measurements. States that collect network-level data have shown them to be good general indicators of the overall carrying capacity of the network. These types of data and analysis can flag attention to special situations; for example when certain roads appear to have less carrying capacity than needed. Stationary deflection-measuring devices do not lend themselves to network-level PMS because the process is slow and costly. In the future, PMS will need a deflection-measuring device that operates at or near highway speeds. The deflection measurements obtained from a "rolling deflectometer," as it is known, and the pavement layer thicknesses obtained from the ground-penetrating radar, are used to compute the structural carrying capacity of the pavement.

Performance

Most states have the raw data needed to monitor and predict pavement performance, which is typically measured as condition or serviceability over a period of time. Currently half the states have performance curves, one-quarter are in the process of developing performance, and the remainder are not yet active. Excellent off-the-shelf software packages that PMS engineers can use for regression analysis are available. In the future, these software packages, coupled with today's high-speed and ever-more-powerful PCs, will enable PMS engineers to track and predict performance on a "route-specific" basis. This capability has already been proven and put into operation in at least some SHAs.

Traffic and Load Data

PMS need average daily traffic flow maps and equivalent single-axle load (ESAL) flow maps on a route-specific basis. Currently all SHAs have traffic flow maps. However, few SHAs have or can produce ESAL flow maps. Most traffic-collection procedures are geared toward collecting traffic volumes, which are primarily used by highway engineers and planners for capacity analysis. Until PMS came along, there was no need to collect traffic data for load analysis on a route-specific basis. Unfortunately for PMS engineers, collecting load data on a route-specific basis is more expensive than the existing traffic-collection process and it is not known if the additional expense (which has not been calculated for each state) is justifiable. More study is needed on this topic. Many PMS engineers and planners believe that better traffic- and load-prediction models are needed.

Ranking Projects

The backbone and heart of a PMS is its ability to rank in priority order pavement preservation projects that are justifiable and cost-effective. The most important phrase in the new (December 1993) FHWA regulation on management systems is the requirement that PMS for NHS produce "a prioritized list of recommended candidate projects with recommended preservation treatments that span single-year and multi-year periods using life-cycle cost analysis." Currently most state PMS do not produce a multiyear ranked list of projects with recommended treatments using life-cycle cost analysis, but are expected to have this capability in the future.

Remaining Service Life

Determining "remaining service life" is a requirement in the new regulation for NHS. Currently only 10 SHAs perform this analysis, but in the future it is anticipated that most will find this an unencumbered task. It is important to monitor the long-range health of a network and this analysis enables managers and programmers to maintain a "steady state" in their multiyear workload and budget.

Relational Data Base

A PMS cannot automatically, systematically, consistently, and efficiently function without a "relational data base" because the amount and complexity of data cannot be computed manually for a typical state PMS. Currently half the SHAs have relational data bases, one-quarter are developing them, and the remainder are not active at the present time. Given the state-of-the-art capabilities in relational data-base management systems, it is anticipated that most SHAs will have relational data bases in the near future.

Uniformity

Currently there is little-to-no uniformity among the states in the way they measure, collect, and report PMS condition data. The reason is that all states developed their PMS independently. This independence, of course, has many advantages for designing a PMS to meet the needs and objectives of any agency. But states are at a disadvantage when communicating with each other about basic condition information such as roughness, rutting, and cracking. They will find a lack of uniformity, which means that they cannot communicate or help each other to enhance this area of PMS. Efforts are under way and accomplishments have been made by ASTM and the Road Profiler Users Group (RPUG) that deserve commendation. The other management systems such as bridge and safety already have national standards for data collection and reporting.

PMS will benefit if the 50 states, Puerto Rico, and the District of Columbia agree to adopt more uniform methods to collect and report condition data. Future efforts by ASTM; RPUG; Strategic Highway Research Program, Long-Term Pavement Performance; FHWA; and the American Association of State Highway and Transportation Officials' Task Force on Pavements are aimed in that direction.

In-House and Outside Resources

Pavement management is a procedure that includes a wide variety of technical components. Some of these require a high degree of technical skill to develop and implement, whereas others require a high concentration of effort to establish. Each agency should carefully and objectively weigh its in-house capabilities, and if it does not have the resources, it should seriously consider seeking assistance from a consultant or a university. In the long run, it will save a lot of time and money and result in a better final product.

Staffing

The biggest problem the states face in developing, implementing, updating, and operating a PMS is staffing. There is a significant shortage of people who understand PMS. Once employees are trained and gain some experience, they are often promoted or transferred to other jobs. For the past five years, the annual turnover rate of state PMS engineers has been approximately 25 percent. The state incentives for early retirements have fueled that rate in the past two years. Generally, most SHAs have only one person who oversees the management and daily operation of the complete PMS program, and when that person leaves, most often the PMS shuts down. This situation occurs quite frequently and because of the current budget constraints and staffing ceilings in most highway agencies, it is not likely to improve. Unfortunately there is no quick fix to this problem.

Future Implementation of PMS

In gauging the future success of implementing PMS as called for in ISTEA, organizations must first decide whether they are serious about PMS. If so, and the commitment is made to do the work, supply the resources, and use the system, then PMS use is likely to be successful.

Students in the nation's colleges and universities will provide the life blood for PMS in the future. Currently 24 such institutions offer courses on PMS, but more are needed. FHWA and SHAs should support academia in providing more education about PMS and other management systems.

The largest institutional obstacle facing PMS today is acceptance by all managers and engineers in all agencies (including federal, state, and local). The reasons for this are many. The future holds more hard work for those who are serious about pavement management.

The NHS Designation Act of 1995, Section 205(a) - Suspension of Management Systems, made PMS a State option and no longer required by federal law. The interim management systems regulation is being revaluated.

SUBCHAPTER F—TRANSPORTATION INFRASTRUCTURE MANAGEMENT

PART 500—MANAGEMENT AND MONITORING SYSTEMS

Subpart A—General

Sec.
500.101 Purpose.
500.103 Definitions.
500.105 Development, establishment, and implementation of the systems.
500.107 Compliance.
500.109 Sanctions.
500.111 Funds for development, establishment, and implementation of the systems.
500.113 Acceptance of existing management systems.

Subpart B—Pavement Management System

500.201 Purpose.
500.203 PMS definitions.
500.205 PMS general requirements.
500.207 PMS components.
500.209 PMS compliance schedule.

Subpart C—Bridge Management System

500.301 Purpose.
500.303 BMS definitions.
500.305 BMS general requirements.
500.307 BMS components.
500.309 BMS compliance schedule.

Subpart D—Highway Safety Management System

500.401 Purpose.
500.403 SMS definitions.
500.405 SMS general requirements.
500.407 SMS components.
500.409 SMS compliance schedule.

Subpart E—Traffic Congestion Management System

500.501 Purpose.
500.503 CMS definitions.
500.505 CMS general requirements.
500.507 CMS components.
500.509 CMS compliance schedule.

Subpart F—Public Transportation Facilities and Equipment Management System

500.601 Purpose.
500.603 PTMS definitions.
500.605 PTMS general requirements.
500.607 PTMS components.
500.609 PTMS compliance schedule.

Subpart G—Intermodal Facilities and Systems Management System

500.701 Purpose.
500.703 IMS definitions.
500.705 IMS general requirements.
500.707 IMS components.
500.709 IMS compliance schedule.

Subpart H—Traffic Monitoring System for Highways

500.801 Purpose.
500.803 TMS/H definitions.
500.805 TMS/H general requirements.
500.807 TMS/H components.
500.809 TMS/H compliance schedule.

Authority: 23 U.S.C. 134, 135, 303 and 315; 49 U.S.C. app. 1607; 23 CFR 1.32; and 49 CFR 1.48 and 1.51.

Subpart A—General

§ 500.101 Purpose.

The purpose of this part is to implement the requirements of 23 U.S.C. 303, Management Systems, which requires State development, establishment, and implementation of systems for managing highway pavement of Federal-aid highways (PMS), bridges on and off Federal-aid highways (BMS), highway safety (SMS), traffic congestion (CMS), public transportation facilities and equipment (PTMS), and intermodal transportation facilities and systems (IMS). Section 303 also requires State development, establishment, and implementation of a traffic monitoring system for highways and public transportation facilities and equipment. This subpart includes definitions and general requirements that are applicable to all of these systems. Additional requirements applicable to a specific system are included in subparts B through H of this part.

§ 500.103 Definitions.

Unless otherwise specified in this part, the definitions in 23 U.S.C. 101(a) are applicable to this part. As used in this part:

Certifying official(s) means the position(s) designated by the Governor of a State or the Commonwealth of Puerto Rico or the Mayor of the District of Columbia to certify that the management system(s) is/are being implemented in the State.

Cooperation means working together to achieve a common goal or objective.

Federal agency(ies) means for the PMS and BMS, the Federal Highway Administration (FHWA); for the SMS, the FHWA and the National Highway Traffic Safety Administration; for the CMS, PTMS, and IMS, the FHWA and the Federal Transit Administration (FTA).

Federal-aid highways means those highways eligible for assistance under title 23, U.S.C., except those functionally classified as local or rural minor collectors.

Highway Performance Monitoring System (HPMS) means the State/Federal system used by the FHWA to provide information on the extent and physical condition of the nation's highway system, its use, performance, and needs. The system includes an inventory of the nation's highways including traffic volumes.

Life-cycle cost analysis means a procedure for evaluating the economic worth of one or more projects or investments by discounting future costs over the life of the project or investment.

Management system means a systematic process, designed to assist decisionmakers in selecting cost-effective strategies/actions to improve the efficiency and safety of, and protect the investment in, the nation's transportation infrastructure. A management system includes: Identification of performance measures; data collection and analysis; determination of needs; evaluation and selection of appropriate strategies/actions to address the needs; and evaluation of the effectiveness of the implemented strategies/actions.

Metropolitan planning area means the geographic area in which the metropolitan transportation planning process required by 23 U.S.C. 134 and section 8 of the Federal Transit Act (49 U.S.C. app. 1607) must be carried out.

Metropolitan planning organization (MPO) means the forum for cooperative transportation decisionmaking for a metropolitan planning area.

National highway system (NHS) means the system of highways designated and approved in accordance with the provisions of 23 U.S.C. 103(b).

Performance measures means operational characteristic, physical condition, or other appropriate parameters used as a benchmark to evaluate the adequacy of transportation facilities and estimate needed improvements.

State means any one of the fifty States, the District of Columbia, or Puerto Rico.

Transportation Management Area (TMA) means an urbanized area with a population over 200,000 (as determined by the latest decennial census) or other area when TMA designation is requested by the Governor and the MPO (or affected local officials), and officially designated by the Administrators of the FHWA and the FTA. The TMA designation applies to the entire metropolitan planning area(s).

Work plan means a written description of major activities necessary to develop, establish, and implement a management or monitoring system, including identification of responsibilities, resources, and target dates for completion of the major activities.

§ 500.106 Development, establishment, and implementation of the systems.

(a) Each State shall develop, establish, and implement the systems identified in § 500.101. Each State shall tailor the systems to meet State, regional, or local goals, policies, and resources, but the systems must meet the requirements as specified in subparts B through H of this part. Documentation that describes each management system shall be maintained by the States for the Federal agencies to determine, on a periodic basis, whether the systems meet the requirements in this subpart and subparts B through H of this part, as applicable.

(b) Each State shall have procedures, within the State's organization, for coordination of the development, establishment, implementation and operation of the management systems. The procedures must include:

(1) An oversight process to assure that adequate resources are available for implementation and that target dates in the work plan(s) are met;

(2) The use of data bases with a common or coordinated reference systems and methods for data sharing; and

(3) A mechanism to address issues related to the purposes of more than one management system.

(c) In developing and implementing each management system, the State shall cooperate with MPOs in metropolitan areas, local officials in non-metropolitan areas, affected agencies receiving assistance under the Federal Transit Act and other agencies (including private owners and operators) that have responsibility for operation of the affected transportation systems or facilities.

(d) In accordance with the provisions of 23 U.S.C. 134(i)(3) and 49 U.S.C. app. 1607(i)(3) and the requirements of 23 CFR part 450, the CMS shall be part of the metropolitan planning process in TMAs.

(e) Within metropolitan planning areas, the CMS, PTMS, and IMS shall, to the extent appropriate, be part of the metropolitan transportation planning process required under the provisions of 23 U.S.C. 134 and 49 U.S.C. app. 1607.

(f) In metropolitan planning areas that have more than one MPO and/or that include more than one State, the establishment, development, and implementation of the CMS, PTMS, and IMS shall be coordinated among the State(s) and MPO(s) to ensure compatibility of the systems and their results.

(g) The results (e.g., policies, programs, projects, etc.) of the individual management systems shall be considered in the development of metropolitan and statewide transportation plans and improvement programs and in making project selection decisions under title 23, U.S.C., and under the Federal Transit Act.

(h) The roles and responsibilities of the State, MPO(s), recipients of assistance under the Federal Transit Act, and other agencies involved in the development, establishment, and implementation of each system shall be mutually determined by the parties involved. A State may enter into agreements with local governments, regional agencies (such as MPOs), recipients of funds under the Federal Transit Act, or other entities to develop, establish, and implement appropriate parts of any or all of the systems, but the State shall be responsible for overseeing and coordinating such activities.

(i) Section 204(a) of title 23, U.S.C., requires the Secretary in cooperation with the Secretaries of the Interior and Agriculture to develop the safety, bridge and pavement management systems for Federal lands highways, as defined in 23 U.S.C. 101(a). To avoid duplication of effort, the management systems required under this part should be used to the extent appropriate to fulfill the requirement in 23 U.S.C. 204(a) regarding establishment and implementation of pavement, bridge, and safety management systems for Federal lands highways. The State, the Federal agencies, and the agencies that own the roads shall cooperatively determine responsibility for coverage of Federal lands highways under their respective jurisdictional control and shall ensure that the results of the PMS, BMS, and SMS for Federal lands highways are available, as appropriate, for consideration in developing metropolitan and statewide transportation plans and improvement programs and are provided to the FHWA for use in developing Federal lands highway programs.

(j) Each management system must include appropriate means to evaluate the effectiveness of implemented actions developed through use of that system. The effectiveness of the management systems in enhancing transportation investment decisions and improving the overall efficiency of the State's transportation systems and facilities shall be evaluated periodically, preferably as part of the metropolitan and statewide planning processes.

§ 500.107 Compliance.

(a) States must be implementing the management systems specified in subparts B through G of this part beginning in Federal fiscal year 1995 (October 1, 1994 to September 30, 1995) and must certify annually to the Secretary of Transportation that they are implementing each of the management systems. A State shall be considered to be implementing a management system if the system is under development or in use in accordance with the compliance schedule for that system as specified in subparts B through G of this part.

(b) The Governor of the State or the Commonwealth of Puerto Rico or the Mayor of the District of Columbia shall notify the FHWA Division Administrator in writing by September 30, 1994, of the title(s) of the certifying official(s) for each management system. If there is a change in designated position(s), the State shall provide documentation of the revised designation with, or prior to, the next annual certification. In those States where responsibility for all of the management systems is within a single agency (e.g., State DOT), designation of one certifying official for all of the management systems is recommended.

(c) The certification statement(s) shall be submitted by the certifying official(s) to the FHWA Division Administrator by January 1 of each year, beginning January 1, 1995. To the extent possible, one certification statement should cover all six management systems. If more than one certification statement will be submitted by a State, the statements should be coordinated at the State level and submitted simultaneously. The first certification statement shall include a copy of the workplan(s), required in accordance with the compliance schedule for each management system, and a summary of the status of implementation of the management system(s). Subsequent certification statement(s) shall include a summary of the status of implementation of each management system and a discussion of planned corrective actions for any management system(s) or subsystem(s) that are not under development or fully operational in accordance with the compliance schedule and work plan for the management system.

(d) The FHWA Division Administrator will provide copies of the certification statement(s) and any relevant supporting documentation and correspondence to other Federal agencies identified for the specific system(s) in § 500.103. Within 90 days of receipt, the Federal agencies will review the certification and the FHWA Division Administrator will notify the State whether the certification is acceptable or if sanctions may be imposed in accordance with the provisions of § 500.109.

(e) A State shall be considered to be implementing the traffic monitoring system for highways (TMS/H), specified in subpart H of this part, if the system is under development or in use in accordance with the compliance schedule in § 500.809. The State shall submit the work plan for the TMS/H to the FHWA Division Administrator by January 1, 1995.

(The information collection requirements in paragraphs (c) and (e) of § 500.107 have been approved by the Office of Management and Budget under control number 2125–0555.)

§ 500.109 Sanctions.

(a) Beginning January 1, 1995, if a State fails to certify annually as required by this regulation, or if the Federal agencies determine that any management system or subsystem, specified in subparts B through G of this part, is not being adequately implemented, notwithstanding the State's certification(s), the Secretary may withhold up to 10 percent of the funds apportioned to the State under title 23, U.S.C., and to any recipient of assistance under the Federal Transit Act for any fiscal year beginning after September 30, 1995. Sanctions may be imposed on a statewide basis, on a subarea of a State, for specific categories of funds or types of projects, or for specific recipients or subrecipients of funds under title 23, U.S.C., or under the Federal Transit Act depending on the adequacy of implementation of the management systems.

(b) While a State may enter into agreements with local governments or other agencies to develop, establish, and implement all or parts of the management systems, in accordance with § 500.105(g), the State shall be responsible for ensuring that the systems are being implemented statewide and for taking any necessary corrective action, including implementing the systems at the regional and local levels if necessary.

(c) Prior to imposing a sanction, a State will be notified in writing by the FHWA of the sanction(s) to be imposed, the reasons for the sanctions, and the actions necessary to correct the deficiencies. After 60 days from the date of notification to the State, the Federal agencies will consider any corrective actions proposed by the State and the FHWA will notify the State if such actions are acceptable or if sanctions are to be applied.

(d) In instances where a State, or responsible sub-unit of a State or recipient of funds under the Federal Transit Act, has not fully implemented all of the management systems, consideration shall be given by the Federal agencies to efforts underway or planned to make the systems fully operational within a reasonable time period.

(e) To the extent that they have not lapsed, funds withheld pursuant to this subpart shall be made available to the State or recipient under the Federal Transit Act upon a determination by the Federal agencies that the management systems are being adequately implemented.

§ 500.111 Funds for development, establishment, and implementation of the systems.

(a) The following categories of funds may be used for development, establishment, and implementation of any of the management and monitoring systems: National Highway System, Surface Transportation Program, FHWA State planning and research and metropolitan planning funds (including the optional use of minimum allocation funds authorized under 23 U.S.C. 157(c) for carrying out the provisions of 23 U.S.C. 307(c)(1) and 23 U.S.C. 134(a)), Federal Transit Act Section 8 (49 U.S.C. app. 1607), Federal Transit Act Section 9 (49 U.S.C. app. 1607a), Federal Transit Act Section 26(a)(2) (49 U.S.C. app. 1622(a)(2)), and Federal Transit Act Section 26(b)(1) (49 U.S.C. app. 1626(b)(1)). Congestion Mitigation and Air Quality Improvement Program funds (23 U.S.C. 104(b)(2)) may be used for those management systems that can be shown to contribute to the attainment of a national ambient air quality standard. Apportioned bridge funds (23 U.S.C. 144(e)) may be used for development and establishment of the bridge management system.

(b) Federal funds identified in paragraph (a) of this section used for development, establishment, or implementation of the management and monitoring systems shall be administered in accordance with the procedures and requirements applicable to the category of funds.

§ 500.113 Acceptance of existing management systems.

(a) Existing State laws, rules, or procedures that the Federal agencies determine fulfill the purposes of a management system, or portion thereof, as specified in this part may be accepted by the Federal agencies in lieu of development and implementation of a new system.

(b) If a State has existing laws, rules, or procedures that it wants to use to meet the requirements of this part, it shall submit a written request to the FHWA Division Administrator that the Federal agencies accept the existing management system in lieu of development of a new system. The request shall include a discussion, and any necessary supporting documentation, that shows how the existing system meets the requirements of this part. The documentation shall reflect the views of the MPOs, transit operators, and other affected agencies, as appropriate, and the actions to be taken to assure that the cooperation required under § 500.105(c) is established.

(c) Upon receipt of a request, the FHWA Division Administrator will coordinate review of the request with the other Federal agencies specified in § 500.103 and with appropriate FHWA offices. Within 90 days of receipt of the State's request, the FHWA will notify the State that the existing system is either fully acceptable, acceptable subject to specific modifications, or unacceptable and that a new system must be developed.

(d) To meet the compliance schedule for a system, the State must submit any requests under paragraph (a) of this section no later than June 1, 1994.

Subpart B—Pavement Management System

§ 500.201 Purpose.

The purpose of this subpart is to set forth requirements for development, establishment, implementation, and continued operation of a pavement management system (PMS) for Federal-aid highways in each State in accordance with the provisions of 23 U.S.C. 303 and subpart A of this part.

§ 500.203 PMS definitions.

Unless otherwise specified in this part, the definitions in 23 U.S.C. 101(a) and § 500.103 are applicable to this subpart. As used in this part:

Pavement design means a project level activity where detailed engineering and economic considerations are given to alternative combinations of subbase, base, and surface materials which will provide adequate load carrying capacity. Factors which are considered include: materials, traffic, climate, maintenance, drainage, and life-cycle costs.

Pavement management system (PMS) means a systematic process that provides, analyzes, and summarizes pavement information for use in selecting and implementing cost-effective pavement construction, rehabilitation, and maintenance programs.

§ 500.205 PMS general requirements.

(a) Each State shall have a PMS for Federal-aid highways that meets the requirements of § 500.207 of this subpart.

(b) The State is responsible for assuring that all Federal-aid highways in the State, except those that are federally owned, are covered by a PMS. Coverage of federally owned public roads shall be determined cooperatively by the State, the FHWA, and the agencies that own the roads.

(c) PMSs should be based on the concepts described in the "AASHTO Guidelines for Pavement Management Systems."[1]

(d) Pavements shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner.

§ 500.207 PMS components.

(a) The PMS for the National Highway System (NHS) shall, as a minimum, consist of the following components:

(1) Data collection and management.

(i) An inventory of physical pavement features including the number of lanes, length, width, surface type, functional classification, and shoulder information.

(ii) A history of project dates and types of construction, reconstruction, rehabilitation, and preventive maintenance.

(iii) Condition surveys that include ride, distress, rutting, and surface friction.

(iv) Traffic information including volumes, classification, and load data.

(v) A data base that links all data files related to the PMS. The data base shall be the source of pavement related information reported to the FHWA for the HPMS in accordance with the HPMS Field Manual.[2]

(2) Analyses, at a frequency established by the State consistent with its PMS objectives.

(i) A pavement condition analysis that includes ride, distress, rutting, and surface friction.

(ii) A pavement performance analysis that includes an estimate of present and predicted performance of specific pavement types and an estimate of the remaining service life of all pavements on the network.

(iii) An investment analysis that includes:

(A) A network-level analysis that estimates total costs for present and projected conditions across the network.

(B) A project level analysis that determines investment strategies including a prioritized list of recommended candidate projects with recommended preservation treatments that span single-year and multi-year periods using life-cycle cost analysis.

(C) Appropriate horizons, as determined by the State, for these investment analyses.

(iv) For appropriate sections, an engineering analysis that includes the evaluation of design, construction, rehabilitation, materials, mix designs, and preventive maintenance as they relate to the performance of pavements.

(3) Update. The PMS shall be evaluated annually, based on the agency's current policies, engineering criteria, practices, and experience, and updated as necessary.

(b) The PMS for Federal-aid highways that are not on the NHS shall be modeled on the components described in paragraph (a) of this section, but may be tailored to meet State and local needs. These components shall incorporate the use of the international roughness index or the pavement serviceability rating data as specified in Chapter IV of the HPMS Field Manual.

§ 500.209 PMS compliance schedule.

(a) By October 1, 1994, the State shall develop a work plan that identifies major activities and responsibilities and includes a schedule that demonstrates full operation and use of the PMS on the NHS by October 1, 1995, and on non-NHS Federal-aid highways by October 1, 1997.

(b) By October 1, 1995:

(1) The PMS for the NHS shall be fully operational and shall provide projects and programs for consideration in developing metropolitan and statewide transportation plans and improvement programs; and

(2) PMS design for non-NHS Federal-aid highways shall be completed or underway in accordance with the State's work plan.

(c) By October 1, 1997, the PMS for non-NHS Federal-aid highways shall be fully operational and shall provide projects and programs for consideration in developing metropolitan and statewide transportation plans and improvement programs.

---

[1] AASHTO Guidelines for Pavement Management Systems, July 1990, can be purchased from the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, NW., suite 225, Washington, DC 20001. Available for inspection as prescribed in 49 CFR part 7, appendix D.

[2] Highway Performance Monitoring System (HPMS) Field Manual for the Continuing Analytical and Statistical Data Base, DOT/FHWA, August 30, 1993, (FHWA Order M5600.1B). Available for inspection and copying as prescribed in 49 CFR part 7, appendix D.

Chapter 10

Strategic Highway Research Program Product

CHAPTER 10

STRATEGIC HIGHWAY RESEARCH PROGRAM

10.1 **Strategic Highway Research Program Product Implementation Status Report, December 1995 (Published Quarterly)**

10.2 Strategic Highway Research Program (SHRP), Information Clearinghouse, July 22, 1994.

10.3 Strategic Highway Research Program (SHRP)
- Implementation Plan for SHRP Products, June 3, 1993.
- SHRP Products Implementation Plan, November 22, 1993.
- Asphalt Research Output and Implementation Program, September 1993.

10.4 Reserved

10.5 Office of Technology Applications,
- SHRP Technology Applications Programs - April 1994 (Published Semi-annually)

DEMONSTRATION PROJECTS

DP-75	Mobile Concrete Laboratory (SHRP)
DP-84	Corrosion Survey Techniques
DP-87	Drainable Pavements
DP-87	Drainable Pavement Systems (Phase II)
DP-89	Quality Management
DP-90	Mobile Asphalt Laboratories
DP-108	Pavement Management Analysis

APPLICATION PROJECTS

AP-21	Geotechnical Microcomputer Programs
AP-102	SHRP Distress Identification Manual
AP-118	Falling Weight Deflectometer Quality Assurance Software

TESTING AND EVALUATION PROJECTS

TE-14	Innovative Contracting Practices
TE-18	Stone Matrix Asphalt
TE-21	Pavement Condition Measurement (SHRP)
TE-25	Strategic Highway Research Program Work-Zone Safety Devices
TE-27	Innovative Pavement Materials & Treatments
TE-28	SHRP Snow and Ice Technology
TE-30	High Performance Rigid Pavements (HPRP)

CHAPTER 10

STRATEGIC HIGHWAY RESEARCH PROGRAM

10.5 Office of Technology Applications,

TESTING AND EVALUATION PROJECTS

TE-34	SHRP Concrete Showcase Contracts - Concrete Mix Design and Construction Aids - Concrete Durability - Alkali-Silica Reactivity and Florescent Microscopy
TE-36	High-Performance Concrete
TE-39	SHRP Asphalt Support Projects - Pool Funded Equipment Study Support - SHRP Asphalt Equipment Loan Program - Field Implementation Asphalt - SuperPave Models - Georgia Loaded Wheel Tester
TE-44	Electrochemical Chloride Extraction from Reinforced Concrete Structures

STATUS REPORT

Strategic Highway Research Program Product Implementation

December 1995

U.S. Department
of Transportation
Federal Highway
Administration

Table of Contents

FOREWORD

The Strategic Highway Research Program (SHRP) was conceived and funded by State highway departments as a means of developing new technologies for designing and maintaining longer-lasting, safer roadways. During the 5-year program, experts in materials, construction, maintenance, traffic operations, and other areas focused on developing better ways of building and maintaining roads and bridges.

The research program ended in 1993. Since then, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB) have been working with highway agencies and industry on the implementation of SHRP products. This Status Report, which is published periodically, summarizes the activities and projects currently under way for implementing the products of the Strategic Highway Research Program.

If you are familiar with the SHRP technologies and have followed the development of the implementation activities, the information in the Status Report gets right to the heart of the subject. However, if you are not quite so familiar with the subject, the Status Report may actually generate more questions. In those cases where the "bridge" is not complete, we encourage you to pick up the telephone and contact the chairman or secretary of the appropriate technical working group for additional information.

The strategic plan for SHRP implementation is described in the *Implementation Plan—SHRP Products* (June 1993, FHWA-SA-93-054). The plan describes the internal and external organizational structure, partners and partnerships, purposes, roles, and the implementation mechanisms and support functions that are used to accomplish the program. The plan provides the framework under which the partnerships function in developing the detailed product implementation plans.

FHWA provides several sources of information and assistance with SHRP products, including the following:

- Pooled-fund purchases of new test equipment.
- Test and evaluation projects.
- Training, equipment demonstrations, workshops, and exhibits.
- SHRP Information Clearinghouse, a computerized, on-line source of information on FHWA's SHRP implementation activities.
- *Focus*, a monthly newsletter reporting on State, Federal, and industry initiatives for implementing SHRP products.

Technical Working Group Contacts

Asphalt

Chairman: Gerry Eller, Office of Engineering, 202-366-4853 (fax: 202-366-9981; email: geller@ intergate.dot.gov).

Secretary: John D'Angelo, Office of Technology Applications, 202-366-0121 (fax: 202-366-7909; email: jdangelo@intergate.dot.gov).

Highway Operations

Co-Chairmen:

Joe Lasek (Work Zone Safety), Office of Highway Safety, 202-366-2174 (fax: 202-366-2249; email: jlasek@intergate.dot.gov).

Jesse Story (Pavement and Winter Maintenance), Office of Engineering, 202-366-1552 (fax: 202-366-9981; email: jstory@intergate.dot.gov).

Co-Secretaries:

Mike Burk (Work Zone Safety), Office of Technology Applications, 202-366-8033 (fax: 202-366-7909; email: mburk@intergate.dot.gov).

Gary Henderson (Pavement and Winter Maintenance), Office of Technology Applications, 202-366-1283 (fax: 202-366-7909; email: ghenderson@intergate.dot.gov).

Concrete and Structures

Chairman: Suneel Vanikar, Office of Technology Applications, 202-366-0120 (fax 202-366-7909; email: svanikar@intergate.dot.gov).

Secretary: Donald Jackson, Office of Technology Applications, 202-366-6770 (fax: 202-366-7909; email: djackson @intergate.dot.gov).

Continued, page 4

Assisting in the development of the overall strategy for SHRP implementation is the Transportation Research Board's SHRP Committee. The committee, composed of top-level managers from industry, State highway agencies, academia, and FHWA, provides oversight to the long-term pavement performance studies and serves as a sounding board for ideas for overcoming institutional barriers to SHRP implementation.

Each State and FHWA regional and division office has designated a SHRP implementation coordinator. So that these coordinators can benefit from each others' experiences, FHWA holds a coordinators meeting each January in Washington, D.C.

The technical working groups and their subgroups, known as expert task groups, are key players in shaping the scope, structure, and content of the SHRP implementation program.

The AASHTO Task Force on SHRP Implementation, chaired by Bobbie Templeton of the Texas Department of Transportation, provides coordination and guidance to States in implementing SHRP products.

With local governments responsible for more than 70 percent of our Nation's roads and streets, local highway organizations are prime candidates for implementing SHRP products. FHWA has contracted with Hibbs Highway Engineering Services to assist the Local Technical Assistance Program (LTAP) centers with the delivery of SHRP products to local governments. Toward that end, Hibbs provides the LTAP centers with news articles, technical materials, product exhibits, loaner equipment, and training packages geared to the needs of local highway agencies.

Continued from page 3

Long-Term Pavement Performance

Chairman: John Hallin, Office of Engineering, 202-366-1323 (fax: 202-366-9981; email: jhallin @intergate.dot.gov).

Overall Coordination

Tommy Beatty, Office of Technology Applications, 202-366-8028 (fax: 202-366-7909; email: tbeatty@intergate. dot.gov).

To obtain a copy of the software program needed to access the SHRP Information Clearinghouse, contact Mark Bradley at Tonya (telephone: 202-289-8108; fax: 202-289-8107).

To be added to the *Focus* mailing list, contact Lisa Pope at Harrington-Hughes & Associates (telephone: 202-347-1448; fax 202-347-6938).

Asphalt *UPDATE*

FHWA continues its outreach program to inform the highway community about the Superpave system, which was the primary product of the SHRP asphalt research program.

A new **brochure**, "The Superpave System: New Tools for Designing and Building More Durable Asphalt Pavements," provides an overview of the Superpave system and a list of resources for additional information. The brochure (Publication Number FHWA-SA-96-010) is available from FHWA's Reports Distribution Center (telephone: 703-285-2144, fax: 703-285-2919).

The Superpave system was also the theme of the October 1995 issue of the *Asphalt Contractor*. FHWA provided several articles for the issue:

- User-Producer Groups Set the Stage for Superpave
- Team Refining Superpave Software
- States Move Forward on Superpave
- Superpave Straight Talk
- Superpave Travels a Rocky Road to Implementation

A new **videotape** on the Superpave volumetric mix design procedures, produced jointly by FHWA and the National Asphalt Pavement Association, will be available in January 1996.

Superpave was very much on the agenda of the recent annual meeting of the American Association of State Highway and Transportation Officials. Augmenting the many presentations and committee meetings on Superpave was FHWA's mobile Superpave laboratory, which was parked outside the meeting site to allow participants a hands-on look at the new test devices.

Binder Test Equipment

Testing asphalt binders for conformance with the Superpave binder specification requires five principal pieces of equipment:

- Pressure aging vessel, to simulate in-service aging of the binder;
- Rotational viscometer, to determine the flow characteristics of the binder;
- Bending beam rheometer, to measure the binder's low-temperature stiffness;

Superpave

The Superpave (Superior Performing Asphalt Pavements) mix design and analysis system is a significant advancement in hot-mix asphalt pavement design. By taking into account climatic conditions and projected traffic loads, the system allows highway departments and contractors to create pavements that will better resist rutting and cracking and that will last longer.

State highway agencies, roadbuilders, suppliers, and others in the highway industry are in the process of acquiring and learning how to use the battery of new test equipment required for Superpave mixes. This section highlights the progress made by both States and industry in reaching the two target dates for Superpave implementation: adoption of the Superpave binder specification by 1997, and full-scale use of Superpave volumetric mix design by 2000.

Since 1992, FHWA has been providing technical assistance, support, and training in the use of the Superpave system. Those activities are expected to continue until 2000.

- Dynamic shear rheometer, to measure the binder's stiffness and phase angle at intermediate and high temperatures;
- Direct tension tester, to measure the low-temperature tensile and fracture properties.

All **States now have** the pressure aging vessel, rotational viscometer, bending beam rheometer, and dynamic shear rheometer. These devices were obtained through a pooled-fund purchase coordinated by FHWA.

In addition, FHWA has **loaned a full set** of the binder test equipment to each of the five regional asphalt user-producer groups. This equipment will be used both for training engineers and technicians and for testing asphalt binder samples provided by State departments of transportation and others.

The prototype for the third generation of the **direct tension tester**, the final piece of necessary binder equipment, is currently undergoing testing and evaluation at FHWA's Turner-Fairbank Highway Research Center (TFHRC). Once this evaluation is complete and necessary changes have been made, FHWA will purchase up to five additional units and loan them to the regional user-producer groups (UPGs) for ruggedness testing. The pooled-fund procurement for the States is expected to begin in late 1996.

Contacts at FHWA

Superpave Training and Field Assistance:
John Bukowski
Telephone: 202-366-1287
Fax: 202-366-7909
email:
jbukowski@intergate.dot.gov

Mobile Asphalt Laboratories:
Tom Harman
Telephone: 202-366-0859
Fax: 202-366-7909
email:
tharman@intergate.dot.gov

Superpave Regional Centers:
John Bukowski
Telephone: 202-366-1287
Fax: 202-366-7909
email:
jbukowski@intergate.dot.gov

Superpave Models and Software Management:
Joe Maestas
Telephone: 202-366-2084
Fax: 202-366-3713
email:
jmaestas@intergate.dot.gov

Asphalt Technical Working Group:
Gerry Eller
Telephone: 202-366-4853
Fax: 202-366-9981
email:
geller@intergate.dot.gov

Superpave Volumetric Mix Design

The Superpave mix design system is based on volumetric proportioning of the asphalt and aggregate materials and laboratory compaction of trial mixes using the **Superpave gyratory compactor**. All 50 States, as well as Puerto Rico and the District of Columbia, have received the Superpave gyratory compactor as part of the pooled-fund purchase.

The Superpave system also includes mix analysis procedures for predicting how well a mix will perform in the field. These procedures are intended for mixes that will be placed in pavements with very high traffic volumes and loads. Two new, sophisticated pieces of laboratory equipment—the Superpave shear tester and the indirect tensile tester—provide the data needed for the performance models.

A prototype of the **Superpave shear tester** is currently being evaluated at the TFHRC and by the five Superpave regional centers (Alabama, Indiana, Pennsylvania, Nevada, and Texas). Because of the high cost and complexity of the device, highway agencies and contractors have expressed interest in a simplified version that would perform only the shear test (no ancillary tests) and would not require a pressure chamber. Once the evaluation of the full-scale Superpave shear tester is complete, FHWA will look into developing a simplified, less costly version.

The first-article **indirect tensile tester** was delivered to the TFHRC in July 1995. It is now undergoing testing and evaluation.

Training Programs

Since 1993, the **Asphalt Institute** has, under contract with FHWA, offered Superpave training courses and technical assistance to State departments of transportation, paving contractors, asphalt suppliers, and others. The Institute's National Asphalt Training Center, located in Lexington, Kentucky, has held sixteen 1-week courses in **binder testing**, drawing 290 participants. The center has also taught fourteen 1-week courses in mix design to 275 engineers and technicians.

FHWA recently awarded the Asphalt Institute a contract for the second phase of Superpave training. Over the next 3 years, the National Asphalt Training Center will provide additional laboratory training in the areas of **mix design and pavement performance prediction**. The center will also work with the Superpave regional centers to provide local on-site training, technical assistance, and workshops.

Two **training manuals** developed for the courses, *Superpave Performance-Graded Asphalt Binder Specification and Testing* (Publication No. SP-1) and *Superpave Level 1 Mix Design* (Publication No. SP-2), are available from the Asphalt Institute.

Mobile Asphalt Laboratories

FHWA now has two mobile asphalt laboratories. The laboratories are staffed with skilled technicians who provide assistance and training in Superpave **volumetric mix design and quality control/quality assurance** at construction sites across the country. The mobile laboratories are each equipped with a Superpave gyratory compactor and are used to demonstrate the principles of Superpave volumetric mix design.

This year, the labs have provided assistance at a dozen job sites, including an extended evaluation at FHWA's new test track, WesTrack.

Superpave Software

The Superpave software and performance models are currently being refined in response to evaluations by FHWA and its contractors, as well as a select group of field testers.

The **first version** of the software will be demonstrated at

For more information on training programs, contact the Asphalt Institute's National Asphalt Training Center:
Telephone: 606-288-4964
Fax: 606-288-4999

FHWA's technology fair of SHRP products, which will be held in conjunction with the Transportation Research Board annual meeting in Washington, D.C., in January 1996.

FHWA has contracted with the University of Maryland to **refine and manage the software**, particularly the performance models.

Test Tracks

The Superpave system is currently being tested and validated through a variety of experimental projects. These include the new **WesTrack** facility, located at the Nevada Automotive Test Center. The track features 26 hot-mix asphalt pavement test sections. The performance of the various test sections will be evaluated against the Superpave performance prediction models.

FHWA is also collecting performance data, using **two accelerated loading** facility machines at the TFHRC, to validate the Superpave asphalt binder and mixture specifications.

Regional Coordination and Training

The asphalt user-producer groups continue to play a key role in developing and facilitating the implementation of the Superpave system. They have outlined a sensible, well-planned strategy for **adopting the Superpave system on a regional basis.**

Superpave centers have been established in each of the five asphalt user-producer group regions. The centers, operated jointly by universities and State departments of transportation, will conduct a thorough and coordinated shakedown of the procedures used with the Superpave shear test and indirect tensile test. They will also provide training on a regional basis.

New Logo Emphasizes Partnerships

To emphasize the partnerships involved in implementing the Superpave system, FHWA recently introduced a new Superpave logo. The logo shows the principal partners in the Superpave implementation program—namely, the American Association of State Highway and Transportation Officials, the highway industry, and FHWA. "Superpave 2000" signifies the target date for nationwide implementation of the Superpave mix design procedures.

Asphalt User-Producer Groups

Northeast Asphalt User-Producer Group
Frank Fee
Telephone: 609-428-8808
Fax: 609-963-0111

Southeast Asphalt User-Producer Group
Paul Krugler
Telephone: 512-465-7632
Fax: 512-302-2215

North Central Asphalt User-Producer Group
Dick Ingberg
Telephone: 612-942-3066
Fax: 612-942-3059

Rocky Mountain User-Producer Group
Bob Rask
Telephone: 303-798-2972
Fax: 303-794-5205

Pacific Coast User-Producer Group
Rick Holmgreen
Telephone: 713-544-8257
Fax: 713-544-8150

Concrete and Structures *UPDATE*

Showcase workshops, conducted on a regional basis, are one of the principal means of conveying information about the SHRP products for improving construction and maintenance practices for concrete pavements and structures. Each workshop features hands-on training and classroom learning on a group of related SHRP products. In some cases, technical assistance and loaner equipment are available to State highway agencies. After each workshop, participants from State highway agencies, industry, and FHWA meet to discuss how the technologies can be implemented on a regional basis.

Showcase workshops are available or planned in the following six topic areas:

- Alkali-Silica Reactivity (ASR)
- Concrete Durability
- Assessment of the Physical Condition of Reinforced Concrete Structures
- Methodologies for Reinforced Concrete Removal, Repair, Protection, and Rehabilitation
- Electrochemical Chloride Extraction
- High-Performance Concrete for Bridges and High-Performance Rigid Pavements

The pilot **concrete durability** showcase workshop was held June 27-28, 1995, in Arlington, Virginia. Presented by Construction Technologies Laboratories (CTL), the course introduced participants to a number of devices and procedures for evaluating the durability of concrete. The workshop covered five main topics:

- Permeability
- Freeze-thaw resistance
- Quality control
- Nondestructive testing
- Expert systems

Techniques discussed included the impact-echo method for measuring concrete thickness and locating defects, the microwave oven drying method for determining water content, and the hydraulic fracture test. FHWA will begin holding concrete durability workshops on a regional basis in April 1996.

Eight **ASR showcase workshops** were held in 1995. These

More than 40 products were developed under SHRP's concrete and structures program. These products can be classified under the broad categories of bridge condition assessment, bridge protection and rehabilitation, concrete durability, high-performance concrete, and alkali-silica reactivity. Many of these products can be applied to both pavements and bridges. The focus now is on refining the products and, through such means as showcase workshops, introducing them to the State highway departments and highway contractors.

Showcase Workshops

Alkali-Silica Reactivity

The 3-day workshop features several SHRP products for detecting alkali-silica reactivity (ASR) in concrete in the field and in the laboratory. Includes hands-on training in identifying ASR. Target audience: materials engineers in highway departments and industry.

Next workshop: Montreal, Quebec, April 16-18, 1996.

Contact: Roger Surdahl, 202-366-1563 (fax: 202-366-9981; e-mail: rsurdahl @intergate.dot.gov).

Concrete Durability

Covers freeze-thaw durability, concrete permeability, and nondestructive testing of concrete. Target audience: materials and research engineers and technicians.

Schedule: Workshops will commence in April 1996.

Contact: Gary Crawford, 202-366-1286 (fax: 202-366-7909; e-mail: gcrawford @intergate.dot.gov).

Assessment of the Physical Condition of Reinforced Concrete Structures

Features corrosion detection devices, radar units, and rapid chloride test kits and emphasizes using these devices to evaluate bare and covered bridges. Target audience: bridge and construction engineers and technicians.

Schedule: The pilot showcase is tentatively scheduled for March 1996.

Contact: Donald Jackson, 202-366-6770 (fax: 202-366-7909; e-mail: djackson @intergate.dot.gov).

workshops are designed to give participants hands-on training in identifying and mitigating the effects of ASR-induced deterioration in portland cement concrete. The next workshop is scheduled for April 1996 in Montreal, Quebec.

Pilot workshops for the showcases on assessing the **physical condition of concrete structures and repairing, protecting, and rehabilitating concrete structures** will be held in spring 1996. The two showcases will run back-to-back during the same week, to make it possible for more engineers and technicians to attend.

Two ground-penetrating radar units for bridge deck evaluations have been ordered for use in both the workshops and field corrosion activities. The equipment is due to be delivered in the spring of 1996.

Three pilot **electrochemical chloride extraction** (ECE) projects have been installed: a bridge deck in Arlington, Virginia, and bridge columns and piers in Charlottesville, Virginia, and Sioux City, South Dakota. ECE is a promising technique for removing chloride ions from reinforced concrete structures, thus slowing deterioration. The pilot projects are designed to provide more information on the results of the ECE process, including how long a treatment can be expected to last and under what conditions ECE treatment is advised.

Open houses held at the pilot projects attracted a diverse group of attendees from State and Federal governments, private industry, and academia.

The pilot workshop on ECE was held in Arlington, Virginia, in July 1995. A field trip to the Arlington bridge project was included as part of the workshop.

Equipment Evaluations

Field evaluations of the **impact-echo device** are under way. The devices have been loaned to the highway departments in Wisconsin, New York, Iowa, California, South Dakota, Missouri, Virginia, Texas, Mississippi, West Virginia, New Jersey, Nevada, North Carolina, Massachusetts, and Pennsylvania, as well as the University of Washington and the University of Texas. In addition, Kansas, South Dakota, Indiana, and the University of Louisville have each purchased the equipment.

Initial evaluation reports of the device have been turned in by Missouri, Wisconsin, West Virginia, and Virginia. Users have reported difficulties in taking measurements and interpreting data with the device and have recommended additional research and development. The biggest problem they encountered was measuring the pavement thickness within the desired accuracy of ±5 mm; results to date have been in the range of ±13 mm. To address this problem, FHWA has begun testing a new production unit that allows users to measure pavement thickness more accurately (±4 mm).

Five small **hydraulic fracture test chambers** have been purchased for round-robin testing. The units have been sent to Kentucky, Iowa, Missouri, North Dakota, and Maryland.

Additional **air permeability test devices** have also been purchased, bringing the total available for loans to five. To date, the equipment has been loaned to Florida, New Jersey, Nevada, Arkansas, Missouri, the University of Nebraska, the Virginia Transportation Research Council, and South Dakota.

High-Performance Concrete

Officials from FHWA and the American Association of State Highway and Transportation Officials, together with representatives from private contractors and consulting agencies, recently toured the Northumberland Strait Crossing Project in Prince Edward Island, Canada. They met with Canadian officials and had an opportunity for a first-hand look at the bridge that is being built with high-performance concrete (HPC).

The first **HPC for bridges showcase workshop** will be held March 25-27, 1996, in Houston, Texas. It will cover the advantages and disadvantages of high-performance concrete, mix proportioning, structural design considerations, and evaluation of bridge component performance.

There are currently five **HPC bridge projects** being constructed in four States: Texas (2 bridges), Virginia, Nebraska, and New Hampshire. The projects are funded jointly by the Office of Technology Applications, the Office of Engineering R&D, the Office of Advanced Research, and the participating States. In addition, 10 States (California, Georgia, Iowa, Massachusetts, Minnesota, New York, Ohio, Pennsylvania, Texas, and Washington) have pooled a portion of their research funds to help finance two of the projects. projects. Seven more HPC for bridges projects have been proposed by Georgia, Colorado, Ohio, Washington, North Carolina, Nevada, and Indiana.

FHWA is making arrangements to host an **international HPC conference** in 1997.

Members of the expert task group (ETG) on **high-performance rigid pavements** (HPRP) held their first meeting in April 1995. As a result of their discussions, FHWA, through its regional offices, has invited State highway agencies to submit proposals for modifying or developing concrete paving projects to incorporate high-performance features.

Methodologies for Reinforced Concrete Removal, Repair, Protection, and Rehabilitation

The workshop features a variety of SHRP and non-SHRP products (including software, specifications, test procedures, and reference documents). Target audience: bridge and construction engineers and technicians.

Schedule: The pilot workshop is tentatively scheduled for March 1996.

Contact: Donald Jackson, 202-366-6770 (fax: 202-366-7909; e-mail: djackson @intergate.dot.gov).

Electrochemical Chloride Extraction

Demonstration projects in Delaware and Maryland will provide the basis for discussion in the workshops. Target audience: bridge and construction engineers and technicians.

Scheduled for Wilmington, Delaware, summer 1996, and Baltimore, Maryland, fall 1996.

Contact: Donald Jackson, 202-366-6770 (fax: 202-366-7909; e-mail: djackson @intergate.dot.gov).

High-Performance Concrete for Bridges

This workshop covers mix proportioning, structural design considerations, and advantages and disadvantages of high-performance concrete (HPC). Target audience: materials, bridge, and design engineers, as well as concrete inspectors.

Contact: Terry Halkyard, 202-366-6765 (fax: 202-366-7909; email: thalkyard@intergate.dot.gov).

Highway Operations UPDATE

The SHRP highway operations program developed a wide range of test methods, design guides, and products addressing such areas as pavement repair, preventive pavement maintenance, snow and ice control, and work zone safety. Some of these products are undergoing further evaluation and refinement. Others, such as most of the work zone safety devices, have been readily adopted by State highway agencies.

Showcase workshops will be used to introduce many of these products on a regional basis.

Workshop Contacts

Snow and Ice Control
Contact: Salim Nassif, 202-366-1557 (fax: 202-366-9981; email: snassif @intergate.dot.gov).

Pavement Preventive Maintenance
Contact: Michael Smith, 202-366-4057 (fax: 202-366-9981; email: mrsmith@intergate.dot.gov).

Innovative Pavement Maintenance
Contact: Patrick Bauer, 202-366-1554 (fax: 202-366-998); email: pbauer @intergate.dot.gov).

Pavement Preventive Maintenance

More than 100 persons attended the May 1995 pilot **showcase workshop** on pavement preventive maintenance, held in Denver, Colorado. Designed for pavement, construction, and maintenance engineers, the workshop covered preventive treatments for both hot-mix asphalt and portland cement concrete pavements.

Regional workshops are tentatively scheduled to begin in early 1996. Workshop leaders will explain and demonstrate promising treatments that have been found to extend pavement service life. Test and evaluation plans for preventive maintenance treatments will be developed, and technical assistance will be provided to those State highway agencies participating in the evaluations.

Innovative Pavement Maintenance

The pilot showcase workshop on innovative pavement effectiveness was held in August 1995 in Washington, D.C. The workshop covered the **four maintenance areas** studied under SHRP:

- pothole repair in asphalt concrete pavements,
- crack sealing and filling in asphalt concrete pavements,
- spall repair in portland cement concrete pavements, and
- joint resealing in portland cement concrete pavements.

The workshop was divided into six sessions. The first two sessions were aimed at upper management and emphasized the importance of pavement maintenance to a sound pavement management strategy. The other sessions were geared for maintenance engineers and provided more detailed information.

Regional workshops are scheduled to begin early in 1996.

Snow and Ice Technology

FHWA recently wrapped up its 2-year **anti-icing test and evaluation project** (T&E Project 28). The study, which consisted of extensive field testing of various anti-icing technologies, culminated in a symposium in Estes Park, Colorado, in October

1995. The symposium drew more than 200 maintenance engineers and managers from State and local highway agencies, academia, consultants, suppliers, and manufacturers. The 15 State highway agencies that participated in the study reported the strategies they used and the benefits they gained. The contractor for the project, the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL), summarized the overall findings and described the methodologies used in the study.

Based on data collected in the study, CRREL has developed a **guidance manual** for anti-icing operations under a variety of storm conditions. Highway agencies will be able to use the manual to develop their own localized anti-icing strategies. A draft of the manual was distributed at the Colorado symposium, and a final version is expected in early 1996.

Beginning in 1996, FHWA will conduct a series of 2-day **regional workshops** to showcase the snow and ice technologies. In addition to anti-icing strategies and technologies, the workshops will cover

- methods for evaluating chemical deicers,
- ice disbonding,
- road weather information systems,
- customized weather prediction,
- snow drift control,
- snowplow cutting edge,
- snowplow design, and
- snowplow scoop.

FHWA is currently seeking participants for five **test and evaluation projects:**

- Anti-icing—to evaluate how well spreader equipment distributes a finely graded salt prewetted with a liquid chemical.
- Road weather information systems—to determine the integration and interoperability between systems from different vendors and to establish a standard protocol.
- Road weather information systems—to test and evaluate snow and ice control management systems that are based on road weather information systems.
- Cutting edge—to evaluate a plow blade coated with a high cobalt grade of tungsten carbide to resist wear from shock.
- Plow design—to evaluate a plow that combines the SHRP-developed cutting edge, snowplow scoop, and moldboard design.

Snow and Ice Test and Evaluation Project

To solicit interest in the snow and ice test and evaluation projects, FHWA has distributed a brochure, *Better Snow and Ice Control Using State-of-the-Art Technologies: An Invitation to Test and Evaluation and Winter Workshops.*

For a copy of the brochure, which includes a response card to indicate interest, contact Salim Nassif at FHWA (telephone: 202-366-1557; fax: 202-366-9981; email: snassif@intergate dot.gov).

Work Zone Safety Devices

Since 1992, the SHRP work zone safety devices have been **displayed at 41 major events**, including such recent ones as the Texas Municipal League 1995 Convention and the 1995 annual meeting of the American Association of State Highway and Transportation Officials. Each FHWA region and most Local Technical Assistance Program (LTAP) centers have received a full set of the safety devices, allowing the devices to be shown at many regional and local events. To make it easier for the regions and LTAP centers to demonstrate the SHRP products to local and State highway agencies, FHWA has provided utility trailers that can easily store and transport the entire complement of work zone safety devices.

FHWA is encouraging highway agencies to try out the products in actual field applications. Technical assistance and funding support have been provided to participating States.

Availability of Devices

Seven work zone safety devices are now commercially available.*

Five companies currently manufacture **intrusion alarms**. The Safety Line Infrared Alarm (ASTI Transportation Systems, Newark, Delaware) consists of an infrared transmission unit housed in a traffic cone; the alarm unit is housed in a second cone. It provides both longitudinal and transverse detection.

The Safety Sentinel Microwave Alarm (Traffic Management Systems Corporation, St. Louis, Missouri) is a two-unit system housed in plastic drums. Solar cells are mounted on top of the drums to recharge the batteries as needed. The system uses a microwave beam to provide longitudinal detection. It also includes a drone radar transmitter that sets off radar detectors in vehicles within 600 meters of the unit, helping to slow approaching traffic.

The Model 10 two-unit intrusion alarm (Safe Lite System, Newtown, Pennsylvania) runs on rechargeable batteries and uses a radio communications linkage between the units. A pneumatic tube laid on the pavement is used to detect intruding vehicles and provides transverse detection at the lane closure.

The intrusion alarm manufactured by the Columbia Safety Sign Company (Woodland, Washington) also uses a pneumatic tube to detect intruding vehicles.

The Watchdog (Kenco International, Ligonier, Pennsylvania) consists of a series of pneumatic hoses hard-wired to the alarm unit.

*The U.S. Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Work Zone Safety Brochure

Highway work zones are dangerous places. The need to perform critical road repairs often conflicts with the need to maintain traffic flow, leading to increased potential for work zone accidents. The SHRP work zone safety devices were designed to address these opposing needs.

The SHRP work zone safety devices are described and portrayed in an FHWA brochure, *Innovative Devices for Safer Work Zones*. The brochure covers the flashing stop/slow paddle, portable rumble strip, portable all-terrain sign and stand, direction indicator barricade, opposing traffic lane divider, intrusion alarm, remotely driven vehicle, portable crash cushion, truck-mounted attenuator for salt-spreaders, and queue detector.

The brochure also includes a listing of the SHRP work zone safety device contacts in each of the FHWA regions.

To request a copy of the brochure, contact Jacques Jenkins at 202-366-8025 (fax 202-366-7909; email: jjenkins@intergate.dot.gov).

Impact Recovery Systems (San Antonio, Texas), Flexstake, Inc. (Ft. Meyers, Florida), and Flasher Handling Corporation (Depew, New York) currently manufacture the **opposing traffic lane divider.** All three products feature a similar two-arrow face design, with the main difference between the three being the support systems for returning the divider to an upright position when hit.

Three companies currently manufacture devices that meet the basic criteria for SHRP's **direction indicator barricade.** The product from WLI Industries, Inc., (Villa Park, Illinois) has a horizontal arrow on a type II barricade, while Flasher Handling Corporation (Depew, New York) and Carsonite, Inc. (Carson City, Nevada) place the sign panels on a support with a weighted base. The device's primary objective is to provide guidance during lane closures. Currently, the barricade is still considered experimental and thus requires permission from FHWA for use.

Poly Enterprise (Monrovia, California) has produced a molded version of the **portable rumble strip** using virgin and recycled plastic in place of the neoprene laminated version developed by SHRP. The rumble strip works best under low speed traffic conditions; under high traffic speeds or heavy truck volume, the strip is subject to rotation and movement.

The original SHRP-designed **flashing stop/slow paddle** is currently being produced by a Canadian firm, Detronics, and distributed by Graham-Migletz, Inc. (Independence, Missouri). In addition, Columbia Safety Sign Corporation (Woodland, Washington), Action West (Kelso, Washington), A/C Enterprise (Vancouver, Washington), Medifax, Inc. (La Center, Washington), and Brittney Safety Sign (Copper Country Safety Sales, Phoenix, Arizona) are each manufacturing a paddle that is based on the SHRP concept but that uses strobe lights or bulbs rather than high-intensity halogen bulbs.

Napoleon Fabricators, Inc. (Napoleon, Ohio) and AdraCorp. (Huntsville, Alabama) both manufacture the **portable all-terrain sign and stand.** AdraCorp's product is a tripod version that weighs just over 3 kilograms (7 pounds).

The **queue detector,** which consists of a transmitter, receiver, and electronics module, is available from ASTI Transportation Systems (New Castle, Delaware). The detector alerts drivers to stopped or slow traffic ahead, giving them more time to react and prevent accidents.

Still Under Development

The portable crash cushion is currently being modified so that it uses a small trailer for more maneuverability in loading and unloading. Three trailer units are currently being manufactured for testing and evaluation by State highway agencies.

MUTCD Approval

The revised Part VI of the *Manual on Uniform Traffic Control Devices* includes three of SHRP's work zone safety devices.

Section 6E-4 includes a discussion of stop/slow paddles and approves the use of SHRP's flashing stop/slow paddle.

SHRP's portable rumble strip meets the specifications set forth in Section 6F-8d, which describes allowable types of rumble strips and their proper application.

Section 6F-8g covers opposing traffic lane dividers, which are used as center lane dividers to separate opposing traffic on a two-lane, two-way operation.

Long-Term Pavement Performance *UPDATE*

Designed to give States the information and products they need to build and maintain longer lasting pavements, the 20-year long-term pavement performance (LTPP) program is almost at its midpoint. The program is, however, already delivering products, such as the modified Georgia faultmeter and the falling weight deflectometer calibration procedures.

Some of the products now available relate to materials testing, pavement performance monitoring, and equipment standards and calibration procedures. Still under development are products directed at the selection and effectiveness of maintenance strategies, performance of various rehabilitation techniques and materials, and the selection of design features for new construction or total reconstruction.

Strategic Plan Published

In September 1995, the LTPP program published ***The Long-Term Pavement Performance Roadmap: A Strategic Plan.*** The plan was developed with input from State and provincial highway agencies, the American Association of State Highway and Transportation Officials (AASHTO), the Transportation Research Board (TRB), industry, academia, and FHWA.

The *Roadmap* contains a data analysis plan for developing LTPP products, and it identifies critical issues facing the LTPP program. The *Roadmap* also provides a brief history of the LTPP program, its partners, and their roles. It charts a course to the program's near-term and longer term destinations.

The *Roadmap* is being widely distributed to help inform the highway community about the projects and products of the LTPP program. AASHTO has sent copies of the *Roadmap* to each State.

Just as the LTPP program is a dynamic process, so too is the *Roadmap*; the report will be updated periodically to reflect changing needs and priorities.

A new pocket-sized brochure describing the LTPP program was published by FHWA in October 1995. The brochure, titled *Improving Pavement Technology: A 20-Year Journey*, consists of a series of commonly asked questions and answers about the LTPP program.

National Conference To Be Held in March

To provide an update on the LTPP program's accomplishments and the products being developed by the program, FHWA will convene a conference in Irvine, California, in March 1996. The conference, "Improving Pavements with LTPP: Products for Today and Tomorrow," will be held March 26-28 at the Arnold & Mabel Beckman Center of the National Academies of Science and Engineering.

The conference will focus upon LTPP products that contribute to increased pavement life; early products available from the LTPP program, and the path to developing additional anticipated products.

The conference is intended primarily for State, Federal, and industry engineers and managers with responsibilities for delivering pavement programs. The conference will also be of interest to engineers involved in the conduct of the LTPP studies or other pavement research programs.

The conference is cosponsored by:

- American Association of State Highway and Transportation Officials
- American Concrete Pavement Association
- American Trucking Associations
- Canadian Strategic Highway Research Program
- National Asphalt Pavement Association
- National Stone Association
- Transportation Research Board

LTPP Product Preview

In January 1996, FHWA will distribute a new brochure containing a list of the available and planned LTPP products. The *LTPP Product Preview* will include a description of each product, its status, and a name of the person to contact for more information.

Products will be grouped in four categories: materials testing, design guidelines, pavement monitoring procedures, and equipment standards and calibration. The Product Preview will be used to develop implementation plans for the products. Engineers and managers who desire to be among the earlier users of the products will also find the brochure helpful.

SPS-3/4 1995 Field Evaluations Completed

Expert teams of engineers from State highway agencies, industry, and FHWA have completed their evaluations of the performance of various preventive maintenance treatments constructed in 1990 as part of SHRP. Regional teams conducted on-site field evaluations of the specific pavement studies (SPS) experiments (flexible pavements, SPS-3, and rigid pavements, SPS-4) during August, September, and October 1995. Each field review was 6 to 10 days in length. More than 81 experimental sites and 405 test sections were visited.

The review teams' subjective evaluations will be used to complement the LTPP data analysis now under way on the 5 years of performance data collected at the sites. The objective of this analysis effort is the formulation of sound conclusions

Publication Requests

To request a copy of

- *The Long-Term Pavement Performance Roadmap: A Strategic Plan* (FHWA-RD-95-200)
- *LTPP Product Preview*
- *LTPP Conference Brochure*

contact the Pavement Performance Division, Office of Engineering R&D, at 703-285-2355 (fax: 703-285-2767).

and recommendations on the performance and use of these preventive maintenance treatments—that is, what works, and what doesn't. A national summary report detailing the observations, conclusions, and recommendations of the review teams is being developed by an FHWA contractor, Nichols Consulting Engineers, and should be available in early 1996. A final report on the entire SPS 3&4 project is also being prepared. Technology transfer materials and manuals of practice will be developed to assist highway agencies in implementing the study findings.

Monitored Traffic Data Now Included in National Information Management System

The LTPP National Information Management System now includes actual traffic data collected at monitored general pavement studies (GPS) sites. State and provincial highway agencies have been collecting the data since 1990, but access to the data was delayed until standardized processing procedures could be developed.

The newly available traffic data covers the 1990-1993 period and contains information on

- traffic and truck volumes,
- weight distributions of axle groups by vehicle type, and
- equivalent single-axle load estimates.

The information is based on vehicle counts collected at more than 470 GPS sites and vehicle weights measured at nearly 400 GPS sites in 48 States and provinces.

LTPP Activities at the 1996 TRB Annual Meeting

The LTPP program will be very visible at the 1996 Transportation Research Board Annual Meeting in Washington, D.C. The activities start on January 6 with the Data Analysis Working Group meeting. At the SHRP Coordinators meeting on January 7, highlights of the LTPP program will be presented in the plenary session. An LTPP exhibit will be set up at the technology fair that follows the coordinators meeting.

The international LTPP coordinators will meet on January 7. Participants will share the status of their LTPP activities and explore opportunities for further cooperative efforts.

On January 8, Session 42 will feature a series of presentations on the *Roadmap*, related AASHTO activities, and LTPP products.

Data Sampler Software

To obtain a copy of the Data Sampler and Data Request software program, contact Barbara Ostrom at 703-285-2514 (fax: 703-285-2767; email: bkostrom@intergate.dot.gov).

The program is furnished on a single 90-mm (3.5-inch) disk. It requires a computer running under Windows version 3.0 or higher, 2 megabytes of hard disk space, and 4 megabytes of RAM.

Asphalt *Technical Working Group*

Andrewski, Dave
Materials Engineer
Indiana DOT
100 North Senate Avenue
Indianapolis IN 45204-2249
Phone: 317-232-5280
Fax: 317-356-9351

Collins, Ronald
State Materials & Research Engineer
Georgia DOT
Office of Materials & Research Lab
15 Kennedy Drive
Forest Park GA 30050
Phone: 404-363-7510
Fax: 404-363-7684

D'Angelo, John
Highway Engineer
Federal Highway Administration
400 7th Street, S.W., HTA-21
Washington DC 20590
Phone: 202-366-0121
Fax: 202-366-7909

Decker, Dale
Director of Engineering
National Asphalt Pavement Association
5100 Forbes Boulevard
Lanham MD 20706-4413
Phone: 301-731-4748
Fax: 301-731-4621

Eller, Gerald
Director, Office of Engineering
Federal Highway Administration
400 7th Street, S.W., HNG-20
Washington DC 20590
Phone: 202-366-4853
Fax: 202-366-9981

Epps, Jon A.
Professor of Civil Engineering
University of Nevada-Reno
College of Engineering
Mail Stop 256
Reno NV 89557-0901
Phone: 702-784-6873
Fax: 702-784-1429

Fee, Francis
Manager, Technical Services
Elf Asphalt, Incorporated
36th and River Road
P.O. Box 638
Pennsaukan NJ 08110
Phone: 609-428-8808
Fax: 609-963-0011

Fehsenfeld, Fred
Executive Committee Chairman
Asphalt Refining Company
5400 W. 86th Street
Indianapolis IN 46268-0123
Phone: 317-872-6010
Fax: 317-879-8145

Fevre, M. Claude
Directeur
Groupement Professionnel des Bitumes
4, avenue Hoche
Paris 75008
FRANCE
Phone: 33-1-40537000
Fax: 33-1-40537049

Finkle, Rodney
Materials Engineer
Washington DOT
Transportation Building, KF-01
Jefferson Street at Maple Park
Olympia WA 98504-7300
Phone: 206-753-7103
Fax: 206-705-6808

Hallin, John P.
Pavement Design and Rehabilitation
Federal Highway Administration
400 7th Street, S.W., HNG-42
Washington DC 20590
Phone: 202-366-1323
Fax: 202-366-3713

Holt, Dave
Executive Vice President
Minnesota Asphalt Pavement Association
900 Long Lake Road, Suite 202
New Brighton MN 55112
Phone: 612-636-4666
Fax: 612-636-4790

Asphalt Technical Working Group (continued)

Kidner, Everett
Materials Supervisor
Idaho DOT
3311 West State Street
P.O. Box 7129
Boise ID 83707
Phone: 208-334-8439
Fax: 208-334-3858

Kline, Charles
Chief of Materials & Testing
Pennsylvania DOT
Transportation & Safety Building
Commonwealth & Forster Streets
Harrisburg PA 17120
Phone: 717-787-4720
Fax: 717-787-5491

Lord, Byron N.
Chief, Engineering Applications
Federal Highway Administration
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-0131
Fax: 202-366-7909

McCarthy, Bernard
Director of Technical Services
The Asphalt Institute
6917 Arlington Road
Bethesda MD 20814
Phone: 301-656-5824
Fax: 301-656-5825

Page, Gale
Bit. Materials & Research Eng.
Florida DOT
State Materials Office
605 Suwannee Street
Tallahassee FL 32399-0450
Phone: 904-372-5304
Fax: 904-277-3403

Potts, Charles F.
President
APAC, Incorporated
900 Ashwood Parkway,
Suite 700
Atlanta GA 30338-4780
Phone: 404-392-5462
Fax: 404-392-5593

Rafalowski, Mike
Highway Engineer
Federal Highway Administration
HNG-23
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-1571
Fax: 202-360-9981

Telford, Jack
Division Engineer-Materials
Oklahoma DOT
200 N.E. 21st Street
Oklahoma City OK 73105-3204
Phone: 405-521-2677
Fax: 405-521-2524

Trent, Roy
Chief, Engrg. & Special
Projects
Office of Engineering R&D
Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, VA 22101
Telephone: 703-285-2062
Fax: 703-285-3105

Concrete and Structures *Technical Working Group*

Brown, Bernard C.
State Materials Engineer
Iowa DOT
Office of Materials
800 Lincoln Way
Ames IA 50010
Phone: 515-239-1452
Fax: 515-239-1309

Bushman, James
President
Bushman Associates
P.O. Box 425
Medina OH 44258
Phone: 216-769-3694
Fax: 216-769-2197

Clemena, Geraldo
Senior Research Scientist
Virginia Highway & Transportation Research Council
530 Edgemont Road
Charlottesville VA 22903-2454
Phone: 804-293-1949
Fax: 804-293-1990

Cole, Lawrence W.
Vice President, Engineering & Research
American Concrete Pavement Association
5420 Old Orchard Road
Skokie IL 60077-1083
Phone: 708-966-6200
Fax: 708-966-9781

Fiorato, Tony
Vice President
Portland Cement Association
5420 Old Orchard Road
Skokie IL 60077-1083
Phone 708-966-6200
Fax: 708-988-9781

Gaynor, Richard D.
Executive Vice President
NAA-NRMCA
900 Spring Street
Silver Spring MD 20910
Phone: 301-587-1400
Fax: 301-585-4219

Gehler, James C.
Chief Materials & Phy. Research
Illinois DOT
2300 South Dirksen Parkway
Springfield IL 62764
Phone: 217-782-7200
Fax: 217-782-6828

Girard, Robert J.
Materials Research Director
Missouri Highway and Transportation Department
Highway and Transportation Building
1511 Missouri Boulevard, Dock "A"
P.O. Box 270
Jefferson City MO 65102
Phone: 314-751-1040
Fax: 314-751-8682

Hoblitzell, James
Structural Engineer
Federal Highway Administration
HNG-32
400 7th Street, S.W., Room 3203
Washington DC 20590
Phone: 202-366-4598
Fax: 202-366-9981

Holland, Terrence
Director of Engineering
Master Builders
23700 Chagrin Boulevard
Cleveland OH 44122-5554
Phone: 216-831-5500
Fax: 216-831-3470

Hover, Kenneth C.
Director, Department of Structural Engineering
Cornell University
Hollister Hall
Ithaca NY 14653-3501
Phone: 607-255-3406
Fax: 607-255-9004

Jackson, Donald
Highway Engineer
Federal Highway Administration
400 7th Street, S.W., HTA-22
Washington DC 20570
Phone: 202-366-6770
Fax: 202-366-7909

Concrete and Structures Technical Working Group (continued)

Larson, Roger M.
Highway Research Engineer
Federal Highway Administration
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-1326
Fax: 202-366-9981

Naret, Frank
Structures Engineer
New York DOT
Building 5, State Office Campus
Albany NY 12232
Phone: 518-485-1386
Fax: 515-485-4021

Pasko, Jr., Thomas J.
Office of Advanced Research Ctr.
Federal Highway Administration
6300 Georgetown Pike, HAR-1
McLean VA 22101-2296
Phone: 703-285-2034
Fax: 703-285-2379

Roberts, James E.
Chief, Division of Structures
California DOT
1120 N Street
P.O. Box 942673
Sacramento CA 94273-0001
Phone: 916-445-3810
Fax: 916-654-6608

Smith, Lawrence L.
State Materials & Research Engineer
Florida DOT
Bureau of Materials & Research
605 Suwannee Street
Tallahassee FL 32399-0450
Phone: 904-372-5304
Fax: 904-277-3403

Vanikar, Suneel
Highway Engineer
Federal Highway Administration
HTA-21
400 7th Street, S.W.
Washington DC 20590
Phone: 202-368-0120
Fax: 202-366-7909

Virmani, Paul
Highway Research Engineer
Federal Highway Administration
6300 Georgetown Pike, HNR-10
McLean VA 22101
Phone: 703-285-2439
Fax: 703-285-2439

Weil, Thomas
Group Product Manager
W.R. Grace & Company
62 Whittmore Avenue
Cambridge MA 02140-1692
Phone: 617-876-1400
Fax: 617-876-1400

Younger, Carey
Research Engineer
New Jersey State DOT
1035 Parkway Avenue, CN 600
Trenton NJ 08625
Phone: 609-530-2001
Fax: 609-530-8294

Highway Operations *Technical Working Group*

Amsler, Sr., Duane E.
Civil Engineer III
New York DOT
Building 5, State Office Campus
Albany NY 12232-0001
Phone: 515-457-9501
Fax: 518-457-4021

Burk, Mike
Safety & Design Applications Branch
Federal Highway Administration
400 7th Street, S.W., HTA-31
Washington DC 20590
Phone: 202-366-8033
Fax: 202-366-8518

Cumberledge, Gaylord
Chief, Roadway Management Systems
Pennsylvania DOT
Transportation & Safety Building
Commonwealth & Forster Streets
Harrisburg PA 17120
Phone: 717-783-6145
Fax: 717-787-7839

Dudeck, Conrad L.
Professor of Civil Engineering
Texas A&M University
TTI-CE Tower, Suite 310
Texas Transportation Institute
College Station TX 77843-3135
Phone: 409-845-1727
Fax: 409-845-6254

Garrett, Robert M.
Executive Director
American Traffic Service Association
ATSSA Building
5440 Jefferson Davis Highway
Fredericksburg VA 22407
Phone: 703-898-5400
Fax: 703-598-5510

Hanneman, Richard L.
President
Salt Institute
700 North Fairfax Street, Suite 600
Alexandria VA 22314-3040
Phone: 703-549-4648
Fax: 703-548-2194

Henderson, Gary
Chief, Roadway Applications Branch
Federal Highway Administration
Nassif Building, HTA-21
400 7th Street, S.W., Room 6319
Washington DC 20590
Phone: 202-366-1283
Fax: 202-366-7909

Humphrey, Norman
Maintenance Engineer
South Dakota DOT
Transportation Building
700 East Broadway Avenue
Pierre SD 57501-2586
Phone: 605-773-3571
Fax: 605-773-3921

Joseph, Charles
President
Charles Joseph Traffic Services
514 S. Church Street
Rockford IL 61101
Phone: 815-964-9640
Fax: 815-964-5318

Kuemmel, David A.
Assistant Professor of Civil Engineering
Marquette University
1515 West Wisconsin Avenue
P.O. Box 65
Milwaukee WI 53233
Phone: 414-288-3528
Fax: 414-288-7082

Lasek, Joseph
Chief, Technical Development
Federal Highway Administration
HHS-11
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-2174
Fax: 202-366-8518

Law, Charles
District Engineer
Georgia DOT
15 Kennedy Drive
Cartersville GA 30120
Phone: 404-387-3602
Fax: 404-363-7684

Highway Operations Technical Working Group (continued)

Lord, Byron N.
Chief, Engineering Applications
Federal Highway Administration
400 7th Street, S.W.
Washington DC 20590
Phone: 202-355-0131
Fax: 202-366-7909

MacMullen, John
Membership Services
Representative
American Public Works
Association
105 West 11th Street,
Suite 1600
Kansas City MO 64105-1805
Phone: 816-472-5100
Fax: 816-472-1510

McCarthy, Bernard
Director of Technical Services
The Asphalt Institute
6917 Arlington Road
Bethesda MD 20814
Phone: 301-656-5824
Fax: 301-656-5825

Pletan, Rodney A.
State Maintenance Engineer
Minnesota DOT
Transportation Building
395 John Ireland Boulevard
Saint Paul MN 55155
Phone: 512-297-3590
Fax: 612-297-3150

Smithson, Leland
Director, Office of Maintenance
Iowa DOT
800 Lincoln Way
Ames IA 50010
Phone 515-239-1519
Fax: 515-239-1539

Story, Jesse
Chief, Program Management
Federal Highway Administration
C&M Division, HNG-21
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-1552
Fax: 202-366-9981

Swenson, Arlen T.
Manager, Rental Marketing
John Deere National Sales
Division
400 19th Street
Moline IL 61265
Phone: 309-765-3170
Fax: 309-765-3123

Tignor, Samuel
Information & Behavorial
Systems Division
Federal Highway Administration
TFHRC, Room T-210
400 7th Street, S.W.
Washington DC 20590
Phone: 703-285-2031
Fax: 703-285-2113

Toth, Stephen A.
Chief, Bureau of Equipment
New Jersey State DOT
1035 Parkway Avenue, CN 600
Trenton NJ 08625
Phone: 609-530-2200
Fax: 509-530-8294

Long-Term Pavement Performance *Technical Working Group*

Christory, Jean-Pierre
Laboratorie reg. de l'Ouest Parisien
12, rue Teissereno de Bort
78190 Trappes
France
Phone: 33-1-24821234
Fax: 33-1-30508369

Churilla, Charles J.
Chief, Pavement Performance Division
Federal Highway Administration
Turner-Fairbanks Highway Research Center
6300 Georgetown Pike (HNR-40)
McLean VA 22101
Phone: 703-285-2355
Fax: 703-285-2767

Dougan, Ph.D., Charles E.
Director of Research & Materials
Connecticut DOT
24 Wolcott Hill Road
Wethersfield CT 06109
Phone: 203-258-0372
Fax: 203-566-4904

Ertman Larsen, Hans Jorgen
Head of Road Research Division
Danish Road Institute
Elisagaardsvej 5
P.O. Box 235
Roskilde DK 4000
DENMARK
Phone: 45-46300100
Fax: 45-46300105

Hallin, John P.
Pavement Design and Rehabilitation
Federal Highway Administration
400 7th Street, S.W., HNG-42
Washington DC 20590
Phone: 202-366-1323
Fax: 202-366-3713

Henderson, Gary
Chief, Roadway Applications Branch
Federal Highway Administration
Nassif Building, HTA-21
400 7th Street, S.W., Room 6319
Washington DC 20590
Phone: 202-366-1283
Fax: 202-366-7909

Knutson, Marlin J.
President
American Concrete Pavement Association
3800 N. Wilke Road, Suite 490
Arlington Heights IL 60004
Phone: 708-394-5577
Fax: 708-394-5610

Lord, Byron N.
Chief, Engineering Applications
Federal Highway Administration
400 7th Street, S.W.
Washington DC 20590
Phone: 202-366-0131
Fax: 202-366-7909

Mathews, Jack R.
Executive Director
Alabama Asphalt Pavement Association
P.O. Box 70396
Montgomery AL 36107-0396
Phone: 205-835-5314
Fax: 205-265-4931

Staggs, William
Pavement Management Engineer
Arkansas State Highway & Transportation Department
P.O. Box 2261
10324 Interstate 30
Little Rock AR 72203
Phone: 501-569-2265
Fax: 501-569-2623

McWaters, Brian
Pavement Engineer
Iowa DOT
800 Lincoln Way
Ames IA 50010
Phone: 515-239-1510
Fax: 515-239-1873

Pryor, Charles A.
Vice President Engineering
National Stone Association
1415 Elliot Place, N.W.
Washington DC 20007-2599
Phone: 202-342-1100
Fax: 202-342-0702

Long-Term Pavement Performance Technical Working Group (continued)

Shaffer, Douglas L.
Senior Program Officer
Transportation Research Board
GR 326
2101 Constitution Avenue, N.W.
Washington DC 20418
Phone 202-334-1430
Fax: 202-334-2003

Sullivan, Richard H.
Director
Minnesota DOT
Transportation Building
395 John Ireland Boulevard
Saint Paul MN 55155
Phone: 612-296-5509
Fax: 612-297-3160

Tahir, A. Haleem
SHRP Product Implementation Coordinator
American Association of State Highway and Transportation Officials
Building 226, Room A365
Gaithersburg MD 20899
Phone: 301-975-6704
Fax: 301-330-1956

Teng, Paul
Chief, Pavement Division
Federal Highway Administration
400 7th Street, S.W., HNG-40
Washington DC 20590
Phone: 202-366-1324
Fax: 202-366-9981

Way, George
Pavement & Design Section Engineer
Arizona DOT
206 S. 17th Avenue, Room 102A
Phoenix AZ 85007
Phone: 602-255-8085
Fax: 602-255-8138

Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: SHRP Information Clearinghouse

Date: July 22, 1994

From: Associate Administrator for Safety and System Applications
Washington, D.C. 20590

Reply to Attn of: HTA-3

To: Regional Administrators

One of the challenges in conducting the SHRP implementation program is communication, within FHWA, and with all of our partners regarding the structure and status of the program, and about the numerous opportunities to participate. One communication tool is the FHWA's SHRP Product Implementation Status Report. Prepared quarterly, the Status Report captures the highlights of the SHRP implementation program. Attached is the June issue. To date, the FHWA has utilized its traditional communication mechanisms supplemented by extensive use of E-mail directly to the FHWA SHRP coordinators in the regions and divisions. The Status Report is one example of the information that is distributed via E-mail to our field offices. National and regional meetings have also been used to tell the story. The FHWA also publishes the SHRP FOCUS monthly newsletter which is sent to 8,500 individuals nationally and internationally.

One of the recommendations which the FHWA received regarding SHRP implementation communication was to establish a computer based information system. One that would allow any interested party to learn what is planned, who is doing it, and when it will happen. The SHRP Information Clearinghouse contains: (1) Status Report, (2) Product Information, (3) Calendar, (4) Directories, and (5) SHRP Report Abstracts.

The Clearinghouse, which is operated by the Office of Technology Applications is currently accessible to all users via a modem and an 800 telephone line. The only requirement for operation of the system is that a user execute a series of computer commands on his or her initial entry. These instructions have been E-mailed directly to the region and division SHRP Coordinators. We are currently exploring options to access the Clearinghouse on the FHWA WAN and AASHTO VAN.

As the principal potential users of the SHRP products, the State highway agencies need to be introduced to the Clearinghouse and provided the computer instructions. To strengthen the SHRP implementation partnership, we are

Federal Highway Administration 1893 1993

requesting that the division offices inform the State highway agencies about the Clearinghouse. To assist the divisions, attached are:

A suggested letter from the division office to the State introducing the Clearinghouse - **please modify the letter to suit local conditions,**

Sufficient quantity to provide two computer diskettes to each State, and

An information page describing the Clearinghouse.

The letter to the State should also go to the Local Technical Assistance Program (LTAP) Technology Transfer Centers in each State and in Puerto Rico. A limited number of SHRP products are of interest to small and local governments. The FHWA is funding a contract to promote SHRP products to local governments through the LTAP technology transfer centers. Information on the implementation efforts for local governments is also contained in the Clearinghouse data bases and each center is being sent directly a copy of the diskette. A separate distribution will be made to the four technology transfer centers for American Indian tribal governments.

Industry, national associations and trade publications, academia, and international users will be informed about the Clearinghouse through magazine articles in FOCUS, PUBLIC ROADS, other magazines, and general advertisements. Please feel free to inform regional and local industry and publications regarding the availability and access to the Clearinghouse.

The regions, divisions, and States have all cooperated enthusiastically and significant progress has been made toward the adoption of the SHRP products. However, a lot remains to be accomplished and your continued support and participation is critical to the overall success of the implementation effort. The Headquarters SHRP implementation team is available to assist you. Please do not hesitate to contact any of the individuals identified in the Status Report for assistance.

Dennis C. Judycki

Dennis C. Judycki

Attachments

U.S. Department of Transportation
Federal Highway Administration

SHRP Information Clearinghouse

As part of its SHRP implementation program, FHWA has initiated numerous activities, including workshops, exhibits, technical assistance, and test and evaluation projects. Keeping track of all that information is a formidable task.

FHWA created the SHRP Information Clearinghouse to make it easier for State departments of transportation, industry, academia, the international community, and others to check the status of the SHRP products and to get information about FHWA's implementation activities.

The Clearinghouse is actually a set of five databases, housed in an IBM-compatible computer. A customized software program links the databases and provides a graphical user interface. FHWA regularly reviews and updates the data.

The Clearinghouse includes:

- The full text of the most recent version of FHWA's SHRP Implementation Status Report

- Product Information
  - -Historical and current information
  - -Information on the showcase workshops and contracts
  - -Information on the States participating in test and evaluation projects for SHRP products

- Calendar of SHRP-related exhibits, workshops, training programs, and meetings

- A directory of FHWA contractors, technical working group and expert task group members, technical assistance sources, SHRP coordinators, and others involved in SHRP implementation activities

- Abstracts of all SHRP reports - as well as information on ordering the reports

The Clearinghouse runs in a user-friendly Windows environment. It is easy to navigate; the user selects from a series of menus. There are no special computer hardware or software requirements, but a mouse is recommended.

The SHRP Information Clearinghouse became operational in July 1994. You can reach the Clearinghouse through FHWA's local-area network or by using a high-speed (9600 baud or faster) modem to dial directly into the host computer. To request a copy of the self-installing software (which you will need to dial in to the Clearinghouse), contact Tonya Inc. at 202-289-8108. For more information about the SHRP Information Clearinghouse, contact FHWA's Office of Technology Applications (fax 202-366-7909).

THIS PAGE LEFT BLANK
INTENTIONALLY

Memorandum

U.S. Department of Transportation

Federal Highway Administration

Subject: Implementation Plan for the Strategic Highway Research Program (SHRP) Products

Date: June 3, 1993

From: Executive Director

Reply to Attn of: HTA-3

To: Associate Administrators
Regional Administrators
Federal Lands Highway Program Administrator

The Federal Highway Administration (FHWA) continues to put a priority on the implementation program for the SHRP products. Most recently, the attached plan on SHRP products implementation was developed under the direction of the FHWA SHRP Implementation Coordination Group (SICG). The plan describes the overall approach, the partnerships that are considered essential to the successful implementation of the SHRP products and the roles of the involved organizations, including our field offices. Also, attached is a companion document that lists the organizational memberships of the various committees and task forces associated with this program.

The plan was developed with the understanding that it is a living document that would grow and change in response to the needs of the users of the SHRP products. It provides the framework by which the specific individual product(s) implementation plans, both national, regional and State, will be developed. To be successful, the specific product implementation plans must be tailored to meet regional and State conditions. It is strongly recommended that the regions and divisions be active participants with the States and industry in the development of these implementation plans.

During the coming months, FHWA will continue to put in place the SHRP products implementation mechanisms and activities such as the four technical working groups, the development of specific national plans and the showcase contracts referred to in the plan. However, within the framework described in the plan you are encouraged to begin planning the development of regional strategies and possible organizational structures that include our partners. I strongly encourage you to become actively involved in this process and in the subsequent implementation activities.

The Office of Technology Applications (OTA) is available to provide additional information regarding the SHRP implementation plan and to assist your staff in the development of regional and State plans. During this summer and fall visits by OTA staff to your Region, meetings will be held to discuss the program with your staff.

E. Dean Carlson

Attachments

Federal Highway Administration
HTA-3:CChurilla:ljp:366-6626:5/26/93
cc: HOA-1
HOA-2
HOA-3
HOAES
HST-1 3401
HTA-1
HTA-3 Official File

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject SHRP Products Implementation

Date November 22, 1993

From Executive Director

Reply to Attn of HTA-3

To Associate Administrators
Regional Administrators
Federal Lands Highway Program Administrator

The Federal Highway Administration (FHWA) has made significant progress in the SHRP implementation activities at the national level. The four Technical Working Groups (TWGs) have been formed and are addressing the development of product-specific implementation plans, contracts for various SHRP implementation support functions are in place, and the first of the showcase contracts has been awarded. Attached for your information is the SHRP Implementation Status Report that describes the FHWA activities. This report is routinely distributed on E-mail to the region and division office SHRP coordinators.

One of the SHRP support activities is a Speakers Bureau that provides FHWA a mechanism to respond to the many requests for presentations on SHRP products. When FHWA staff is unable to respond to a request for a SHRP presentation, the Speakers Bureau can provide a knowledgeable individual from the private sector. The FHWA also has other means available when we wish to utilize an individual from a State highway agency as a SHRP products speaker. Please contact Charlie Churilla (202-366-6626) in the Office of Technology Applications if we can help in this regard.

One of the field office SHRP implementation activities that is extremely important is working with the State highway agencies to establish or foster the operation of SHRP implementation activities. A number of States have established SHRP implementation committees as a means to coordinate the evaluation and adoption of SHRP products. In those States that have such a committee, the region and division offices can play valuable roles as an information source on the products and a champion for the many implementation activities being offered by FHWA. I am requesting that you encourage the Division Administrators to discuss SHRP implementation with their State counterparts. In those instances where an implementation process does not exist, the importance of taking action now should be stressed.

Federal Highway Administration 1893 1993

In the many instances where such a committee or process already exists, the discussion should focus on the strengthening of the State-FHWA implementation partnership. To assist you in this effort, attached are copies of a SHRP Implementation videotape prepared by FHWA.

During the life of the SHRP, an annual State Coordinators' meeting was held in conjunction with the Transportation Research Board (TRB) Annual Meeting. The SHRP meeting is being continued by FHWA, with the support of TRB, and will focus on the implementation activities and the continuation of the Long Term Pavement Performance program. In the past, this meeting has been extremely well attended with representatives from 70+ percent of the States. Attendance by a regional office representative, and at your discretion from one of your division offices, is recommended. Washington Office Directed Travel has been approved for the SHRP Coordinators' meeting.

Also, during the fall, representatives from the Headquarters offices involved in the SHRP implementation efforts have visited most of the regional offices to provide firsthand information on the SHRP implementation activities and to discuss the region and division offices' roles in these activities. One of the items specifically addressed during several of these meetings was the funding for the SHRP implementation activities at the regional and State levels. As the national implementation plans are developed by the TWGs, each region will have the opportunity to develop regional plans for specific products or showcase group of products. Activities in the regional plans may include test and evaluations, regional equipment purchases, and associated administrative costs for the regional technical committees. The Office of Technology Applications is available to assist your office in the development of these regional plans and to provide the funding for these field-led implementation activities. Detailed information regarding the funding of the regional plans will be forthcoming.

For the SHRP implementation to be a success, it requires the active participation by all the partners. At the national level, TRB, AASHTO, and FHWA have taken a number of significant steps towards this goal. However, to ultimately reach the goal, the States in cooperation with the FHWA field offices and local industry must act. I, again, want to strongly encourage you and your staff to continue to be active participants in the implementation process.

E Dean Carlson

E. Dean Carlson

2 Attachments

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-SA-94-025		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
STRATEGIC HIGHWAY RESEARCH PROGRAM ASPHALT RESEARCH OUTPUT AND IMPLEMENTATION PROGRAM	5. Report Date: September 1993 6. Performing Organization Code:
7. Author(s) Theodore R. Ferragut, P.E.	8. Performing Organization Report No.
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Technology Applications Federal Highway Administration 400 Seventh Street, S.W. Washington, D.C. 20590	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Intermodal Surface Transportation Efficiency Act of 1991 fully supported the implementation of research results from the $150 million Strategic Highway Research Program (SHRP). Successful implementation of SHRP by and large will be measured by successful implementation of the asphalt research.

In a unique cooperative spirit, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the SHRP Project Management Office have worked together to develop a plan that ensures the research will indeed be implemented. This paper describes important aspects of this partnership and focuses on key elements of the plan. These elements include:

- The large scale procurement and evaluation of new equipment.
- Integration of equipment procurement with national training agenda.
- Use of mobile laboratory support.
- Integrated activities with standards setting functions of AASHTO.
- Integrated use of other funding sources for followup research and implementation - National Cooperative Highway Research Program (NCHRP), FHWA Administrative Funds, and Federal-aid Planning and Research Funds.
- The unique role of users-producer groups and technical working groups that represent public and private interests.

Finally, the paper discusses the very critical function of Specific Pavement Study 9 (SPS-9), Validation of the SHRP Superpave™ and Innovations in Asphalt Pavements, in the continuing refinement of the Superpave™ performance models and design methods.

17. Key Words	18. Distribution Statement
Strategic Highway Research Program, asphalt concrete pavement, asphalt, asphalt binder, asphalt mixture	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	

Form DOT F 1700.7 (12-92) Reprodu[illegible]ated page authorized

THIS PAGE LEFT BLANK
INTENTIONALLY

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: INFORMATION: Distribution of Publication

Date: March 23, 1994

From: Associate Administrator for Safety and System Applications

Reply to Attn of: HTA-13

To: Regional Administrators
Federal Lands Highway Program Administrator

Distributed with this memorandum is Federal Highway Administration Technology Applications Program, April 1994, Publication No. FHWA-SA-94-028, an update of the July 1993 publication (FHWA-SA-93-075). This provides a current listing of all technology transfer projects and an up-to-date status on the activities within the project. The Office of Technology Applications (OTA) will continue to update and distribute this publication periodically in order to keep the field offices, States, and Technology Transfer Centers up to date on the technology transfer activities underway.

Sufficient copies of this publication are being distributed to provide 6 copies to each regional office and 10 to each division office. Direct distribution is being made to the division offices; copies for State highway agencies are included with the copies for the division offices. Two copies are also being sent to each Local Technical Assistance Program Technology Transfer Center.

A limited number of additional copies are available from the FHWA Research and Technology Report Center, HRD-11, Room A-200, 6300 Georgetown Pike, McLean, Virginia 22101-2296.

Dennis C. Judycki
Dennis C. Judycki

Attachment

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-75 Mobile Concrete Laboratory (SHRP)

DESCRIPTION : The project's goals include demonstration of state-of-the-art concrete technology in materials selection, mix designs, laboratory testing, and field testing. Project activities include guidance for updating specifications and use of computer technology for design, testing, and data storage. A partnership with manufacturers, contractors, industry associations, and academia is maintained in all of the project's activities.

This project demonstrates the use of innovative laboratory and in situ testing equipment, and promotes high-performance concrete and the use of chemical admixtures. This project also supports the activities of SP-201, "Accelerated Rigid Paving Techniques."

BACKGROUND : With today's construction heavily involved in rehabilitation and reconstruction, highway engineers place ever greater demands on Portland cement concrete. These demands include lower permeability, higher and earlier strength, and improved workability. Many concrete admixtures are available today that specifically address these demands. However, to understand and effectively use these admixtures, innovative mix designs, testing equipment, and techniques are a prerequisite.

With the use of a mobile concrete laboratory, 26 field demonstrations have been performed in the last 5 years. Two-day workshops on state-of-the-art concrete technology have been conducted in 44 States. Twenty 1-day seminars on "Concrete Admixtures" have been conducted. Many presentations, including the mobile concrete laboratory, have been given at national, regional, and local FHWA and industry meetings. More than 2,500 State DOT and FHWA engineers have attended workshops, seminars, and field demonstrations. Under the equipment loan program, in situ testing equipment has been loaned to 20 States.

PROJECT MANAGERS : Suneel Vanikar, HTA-21, (202) 366-0120 and Gary Crawford, HTA-21, (202) 366-1286

STATUS : In 1995, mobile laboratory field demonstrations were conducted in Texas, Ohio, and Virginia. One-day nondestructive testing (NDT) workshops were held in Missouri and Iowa. This NDT workshop will be presented in several States over the next few years. This workshop includes some SHRP-developed products. A Concrete admixtures seminar was presented in Hawaii.

The remaining States will be visited over the next several years, with many States asking for repeat visits as the SHRP-developed products are included in the laboratory. The 1-day admixture seminars will continue for a few more years. Additionally, this mobile laboratory will support efforts related to implementing SHRP-developed concrete technology. The major emphasis for the next several years will be on field demonstrations of the SHRP-developed products and implementation of Performance Related Specification for Concrete Pavements.

TECHNOLOGY TRANSFER AIDS : Mobile laboratory, telephone and on-site assistance, speakers, specialized workshops and seminars, and nondestructive equipment loan program. A new mobile concrete laboratory was acquired in 1995.

PUBLICATIONS : FHWA reports on several field studies available through the Office of Technology Applications.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-84 Corrosion Survey Techniques

DESCRIPTION : The objective of this project is to demonstrate and document the latest concepts and test procedures for corrosion surveys on reinforced concrete structures. A secondary objective is to work in conjunction with States to collect data on structures that already have protective systems and to determine their effectiveness. The project is divided into three distinct modules:

- Executive Presentation Slide presentation and some equipment demonstration.
- Equipment Demonstration Slide presentation on bridge evaluation techniques and 1- to 2-day equipment demonstrations.
- Hands-on Training and Testing. Three to four days of hands-on experience with equipment.
- A loan program for States that are interested in a particular piece of equipment.

Several products developed under the Strategic Highway Research Program (SHRP) are being demonstrated as part of this project.

BACKGROUND : Deterioration of reinforced concrete by corrosion of the reinforcing steel is the most frequent cause for needing maintenance, rehabilitation, or replacement of concrete structural elements. The ability to identify an active corrosion process in the early stages is the most important factor in minimizing the cost of corrosion-related repairs.

Today's equipment is lighter, stronger, more durable, and is capable of interfacing with microcomputers through CADD-like software. Additionally, with the growing attention paid to concrete substructure corrosion, this equipment solves some of the difficulties of surveying vertical surfaces over rivers, coastal waters, and freeways. Some tests that will be performed are half-cell potential survey, delamination mapping, rapid field measuring, chloride content, concrete cover survey, rebar corrosion rates, and crack measurement.

PROJECT MANAGER : Donald Jackson, HTA-22 (202) 366-6770

STATUS : This project was announced late in 1991. DP-84 has been presented 36 times since then. Interested States may request demonstrations from the project manager.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-87 Drainable Pavements

DESCRIPTION : This project was developed to help State highway agencies and industry partners become more familiar with new techniques in permeable base and edgedrain system design and construction. This project concentrates on the use of permeable bases with concrete pavements and consists of a workshop that features a slide presentation, design manual, and field construction technical assistance. It also incorporates a hydraulic demonstration model that presents the drainage rate of various aggregate materials used in road building, including permeable bases.

BACKGROUND : Water in the pavement section is recognized as a major factor in pavement deterioration and early loss of pavement service life. In recent years, highway engineers have recognized the cost benefits of providing permeable bases to drain the pavement section. New aggregate gradations and stabilizing materials for base courses have been used to provide a balance between drainability and stability. Construction engineers also have developed new techniques for placing and compacting permeable base material.

PROJECT MANAGER : Robert Baumgardner, HNG-42, (202) 366-4612

STATUS : More than 40 workshops have been completed to date. Scheduled presentations concluded in March 1994. The scope of the workshop portion of this project will be expanded in a future NHI course to include retrofit edgedrains and drainage of flexible pavement. (See DP-87 Phase II, page under Asphalt Pavement Design and Construction.)

TECHNOLOGY TRANSFER AIDS : Workshop available on request (subject to long-range planning), specifications from Wisconsin, technical assistance, construction evaluation monies (limited), computer software available from PCTrans, University of Kansas, and McTrans, University of Florida.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-87 Drainable Pavement Systems (Phase II)

DESCRIPTION : This project was developed to help State highway agencies and industry partners become more familiar with new techniques in permeable base and edgedrain system design and construction for concrete pavements. This phase of the project will concentrate on the use of permeable bases with asphalt pavements and, as with concrete pavements under Phase I, consists of a workshop that features a slide presentation, design manual, and field construction technical assistance.

BACKGROUND : Water in the pavement section is recognized as a major factor in pavement deterioration and early loss of pavement service life. In recent years, highway engineers have recognized the cost benefits of providing permeable bases to drain the pavement section. New aggregate gradations and stabilizing materials for base courses have been used to provide a balance between drainability and stability. Construction engineers also have developed new techniques for placing and compacting permeable base material.

PROJECT MANAGER : Robert Baumgardner, HNG-42, (202) 366-4612

STATUS : This project is being expanded in an NHI course to include retrofit edgedrains and drainage of flexible pavement. In addition, a contract has been awarded to Applied Research Associates to develop a microcomputer program to calculate pavement subsurface drainage.

TECHNOLOGY TRANSFER AIDS : Workshop available on request (subject to long-range planning), equipment demonstration.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-89 Quality Management

DESCRIPTION : The goal of this project is to build top-level support and awareness of quality management and to provide training to State highway agencies in statistical quality control techniques. It is part of the National Quality Initiative. This project involves four quality management activities.

- Participate on a joint FHWA/AASHTO/industry steering committee to guide and help focus efforts on the quality of construction, performance, and quality management with emphasis on a partnership effort.

- Develop (jointly) and issue broadly based national policy/goals.

- Hold high level seminars for upper management of Federal, State, industry, and others to educate and gain support.

- Provide technical training, guidance, and tools to others responsible for implementation.

BACKGROUND : There has been a conscious effort within the United States during the past decade to promote a correlation between American products and quality. In general, this effort has been focused in the manufacturing industry. The United States has begun to promote the concept of American quality because quality is an important factor in maintaining global competitiveness.

With the emphasis on quality again moving toward national significance, this project will provide direction and address a broader role of quality in the highway environment.

PROJECT MANAGER : Don Tuggle, HNG-21, (202) 366-1553

PROJECT COORDINATOR : Gary Henderson, HTA-22, (202) 366-1283

STATUS : In an effort to widely disseminate the principles and ideals begun at the National Quality Initiative Seminar in Dallas/Ft. Worth, Texas on November 10, 1992, four AASHTO Regional NQI Seminars involving well over 10,000 people nationwide have been conducted. Additional support of state-level NQI activities has been provided.

An "NQI National Conference" will be held in Alexandria, VA on November 14 and 15, 1995. The first-ever NQI Achievement Award will be presented for the best highway project at this conference.

A 5-day training course (*Materials Control and Acceptance: Quality Assurance*) and a 2-day workshop (*Quality Management for Managers*) is being co-sponsored with the National Highway Institute. Approximately 38 of the 50 available five-day courses and 41 of the 56 available two-day workshops have been presented. Several statistical quality assurance computer programs have been developed by the New Jersey DOT. A technical review of the user manual has been completed, and distribution of the manuals and programs is expected by the end of 1995. In addition a number of workshops and seminars have been supported such as a technician training and certification workshop in Platteville, Wisconsin and a quality assurance specifications development workshop in Little Rock, Arkansas.

TECHNOLOGY TRANSFER AIDS : One-week course, two-day workshops, technical assistance, speakers, and computer programs.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-90 Mobile Asphalt Laboratories

DESCRIPTION : This project is a major Office of Technology Applications initiative to promote Strategic Highway Research Program (SHRP) findings in the asphalt area. This project uses two mobile laboratories to provide State highway agencies with a hands-on demonstration of the SHRP SUPERPAVE design system and field management techniques.

The major objective of the project is to promote the Super Pave Mix design system and mix verification / volumetric quality control in the field.

The typical project centers on transplanting a mobile lab to an active paving project at the invitation of the State. Once it is on site, State, contractor, and Federal engineers can witness, compare, and critique the test procedures and sequences.

PROJECT MANAGERS : Thomas Harman, HTA-21, (202) 366-0859; John D'Angelo, HTA-21, (202) 366-0121; and John Bukowski, HTA-21, (202) 366-1287.

STATUS : The use of mobile laboratories for asphalt mix is ongoing. The concepts of Mix Verification and Voids Acceptance have been demonstrated and field simulated in more than 38 States in the last 8 years. As an additional service, more than 50 Federal and State contractors, engineers, and technicians have spent 2 to 5 days in a mobile laboratory learning and strengthening their skills in the asphalt mix area. In 1991, a formal 2-day workshop was added to the demonstration. In 1993, key elements of the SHRP SUPERPAVE mix design system were also added to the workshop. During 1994 and 1995 the laboratory provided field control on several projects using SUPERPAVE designed mixes.

A report detailing the results of the field simulation was voted the "Best Paper of the Year 1991" by the Association of Asphalt Paving Technologists. This report, *Summary of Simulation Studies*, is available from the project managers.

The remaining States will be visited over the next several years. With the addition of the SUPERPAVE system, many States are expected to request repeat visits as they explore the adoption of the new techniques. The mobile laboratory has supported other OTA activities, such as stone matrix asphalt (SMA), and is expected to perform this support activity more frequently in the next few years.

TECHNOLOGY TRANSFER AIDS : Mobile laboratory (subject to scheduling), telephone and on-site assistance, speakers, and specialized workshops and seminars.

PUBLICATIONS : *Summary of Simulation Studies*, by J. D'Angelo and T. Ferragut, 1991.

THIS PAGE LEFT BLANK
INTENTIONALLY

DP-108 Pavement Management Analysis

PURPOSE : To demonstrate how various PMS prioritization methods are used to identify justifiable and cost-effective pavement preservation strategies for various funding levels and develop multi-year prioritized list of pavement preservation projects.

To demonstrate how PMS pavement performance data is used to perform engineering analyses that could evaluate pavement design, construction, materials and maintenance procedures as they relate to performance of pavements.

BACKGROUND : The ISTEA Interim Final Rule for management systems requires each State Highway Agency to develop a PMS for the National Highway System capable of performing various pavement analyses.

These analyses included pavement performance analysis to analyze the current and predicted performance of specific pavement types, investment analyses to estimate total cost for present and projected conditions across the network, and investment strategies to prioritized pavement preservation projects with recommended preservation treatments that span single and multi-year periods using life-cycle cost analysis.

The regulation also requires the PMS to be capable of performing engineering analyses for appropriate network sections that could evaluate pavement design, construction, rehabilitation, materials, mix designs, and preventive maintenance as they relate to performance of pavements.

State examples of pavement performance, multi-year prioritization methods, cost analyses and engineering analyses will be used to develop two to three-day demonstration sessions. The project consists of two demonstration activities.

- The first activity consists of a series of PMS outreach sessions to provide one-on-one discussions and technical assistance to States that are developing the analyses required to perform **multi-year prioritization of pavement preservation projects.**

- The second project consists a demonstration of the **use of PMS performance data in engineering applications.**

The main topics to be demonstrated in the multi-year prioritization demonstration activity are:

- Pavement Performance Analysis
- Selection of Pavement Preservation Strategies and Treatments
- Cost Analyses
- Effects of Budget Constraints
- Project Selection Process

The main topics to be demonstrated in the use of PMS performance data in engineering applications demonstration activity are:

- Historical Performance Data

- Evaluation of Pavement Design Procedure
- Evaluation of Pavement Construction Practices
- Materials Performance Analysis
- Pavement Preservation Analysis

PROJECT MANAGER : Luis Rodriguez, HNG-41, (202) 366-1335.

STATUS : A contract has been awarded for the multi-year prioritization demonstrations. Demonstration sessions are expected to begin in the first quarter of 1996.

Bids are currently being evaluated for a contract to perform PMS engineering analysis demonstrations. The contract should be awarded by the end of 1995 and sessions are expected to begin in early 1997.

Bridge Design and Construction

Bridge design, as many other segments of civil engineering, has evolved from early art forms to a sophisticated science. A hundred years of experience have been assimilated into the engineering practice, and modern research and development findings have been re-examined, tested, proven in service, and codified into bridge specifications and practice. The traditional design philosophies and methods, such as Working Stress Design (WSD) and Ultimate Strength Design (USD), are still used in bridge design. However, recent developments in bridge design specifications have departed from the traditional approaches to incorporate more rational methods.

Load Factor Design (LFD) was a first step toward implementing a bridge design code based on statistical factors accounting for variability of loads, lack of accuracy in the analysis, and the probability of simultaneous occurrence of different loads. Load and Resistance Factor Design (LRFD) extended the philosophy to include resistance factors that account for the variability of material properties, structural dimensions and workmanship, and the uncertainty in the prediction of resistance. The LRFD code, properly applied, is expected to lead to more rational bridge designs that will produce more economical and durable highway bridges. A concerted effort to train bridge designers in the concept of load and resistance factors, as well as the application to bridge design, is crucial to the successful implementation of the new codes.

The LRFD specifications are ideal for assimilating new developments in bridge materials and construction methods, such as electroslag welding and high performance concretes, since resistance factors can be modified as necessary to represent uncertainties in material properties. Part of this project will involve promoting new bridge materials and construction methods and also implementing the LRFD code in bridge design software.

Recent innovative developments in bridge design codes, bridge materials, and construction methods have led to the establishment of 10 milestones.

1. Develop and initiate formal training sessions for the design of bridge superstructures and bridge foundations using the LRFD code.

2. Develop and initiate formal training sessions for the use of nondestructive load testing to determine load ratings of bridges.

3. Develop and initiate a demonstration project on electroslag welding for steel bridges.

4. Approve the LRFD specifications as the sole AASHTO code for design of highway bridges.

5. Upgrade major bridge design, analysis, and rating software with LRFD code: BRASS, AASHTO BDS.

6. Use High-Performance Concrete in a prestressed concrete bridge in Virginia.

7. Prepare Technology Transfer material and conduct a regional seminar on the use of High-Performance Concrete in a prestressed concrete bridge in Texas.

8. Use High-Performance Concrete in parallel structures conventional concrete in one, HPC in the other.

9. Establish an equipment loan program for SHRP-developed High-Performance Concrete test equipment.

10. Establish design and construction guidelines for High-Performance Concrete.

THIS PAGE LEFT BLANK
INTENTIONALLY

AP-21 Geotechnical Microcomputer Programs

DESCRIPTION : This project has involved the development of several geotechnical programs under contract with geotechnical microcomputer programming firms. These programs have been made available to the States by the OTA.

BACKGROUND : The microcomputer industry has undergone rapid changes in recent years. New developments in hardware and software make the use of the microcomputer in civil engineering applications more feasible, practical, and almost indispensable.

The microcomputer can be used to solve many geotechnical problems that need repetitive and yet complicated calculations, such as analyzing embankment and foundation deformations, estimating pile behavior under static and dynamic forces, and calculating foundation settlements. Five of the microcomputer programs developed or under development are:

COM624P: Analyzes the behavior of piles or drilled shafts, subjected to lateral loads using the p-y method.

EMBANK: Determines one-dimensional compression settlement because of embankment loads.

SPILE: Calculates the ultimate static pile capacity in cohesive and cohesionless soils.

RSS: Analyzes stability of slopes that contain soil reinforcement. The analysis is performed using a two-dimensional limiting equilibrium method.

MSEW: Designs and/or analyzes required reinforcement for mechanically stabilized retaining walls, which does not consider specific facing configurations.

DRIVEN: This program is the updated version of the SPILE Program.

PILE FOUNDATION : This program will be developed based on the University of Florida program - LPGSTAN which is capable of analyzing bridge foundations subject to extreme events (hurricanes, ship and ice imports). The program will extend its capabilities to include the analysis and design of sound walls, retaining walls, signs and high mast lighting structures.

PROJECT MANAGER : Chien-Tan Chang, HTA-22, (202) 366-6749

STATUS : The SPILE Program has been upgraded, the new program is called Driven. This program is estimated to be completed by the end of 1995. RSS Program has been completed. It will be tested for about 2 months and will be distributed early December 1995. Contracts are being negotiated to develop a new version of MSEW program and a multiple faceted program called Pile Foundations.

THIS PAGE LEFT BLANK
INTENTIONALLY

AP-102 SHRP Distress Identification Manual

DESCRIPTION : The *Distress Identification Manual* is a pictorial rating manual for distress identification on highway pavements. The manual's photographs, descriptions, and illustrations provide a reference for the consistent identification and quantification of the severity and extent of pavement distress. It also provides a common language for describing cracks, potholes, rutting, spalling, and other pavement distresses. As a "distress dictionary," the manual has the potential to improve inter- and intra-agency communication while leading to more uniform evaluations of pavement performance.

The manual is divided into three sections that focus on particular types of pavement: (1) asphalt concrete surfaced, (2) jointed Portland cement concrete, and (3) continuously reinforced Portland cement concrete. Each distress is clearly labeled, described, and illustrated.

BACKGROUND : In 1987, the Strategic Highway Research Program (SHRP) began its largest and most comprehensive pavement performance the Long-Term Pavement Performance (LTPP) program. The *Distress Identification Manual* was developed as a tool for the LTPP program. It allows States and others to provide accurate, uniform, and comparable information on the condition of LTPP test sections. Moreover, it enables individuals and agencies to interpret LTPP data or to correlate LTPP findings with their own research efforts.

PROJECT MANAGER : James Walls, HNG-42, (202) 366-1339

STATUS : The SHRP distributed multiple copies of the latest color version of the *Distress Identification Manual* in July 1993. NHI will offer several training courses on the Manual to State and local highway agencies starting in the Fall of 1995.

Copies of the training materials will be made available to academia and the Technology Transfer Centers.

TECHNOLOGY TRANSFER AIDS : The project manager will continue to provide technical advice and participate in conferences, seminars, workshops, and user training sessions. Test and evaluation by a limited number of States is also anticipated.

PUBLICATIONS : *The Distress Identification Manual for the Long-Term Pavement Performance Project* can be purchased from the Transportation Research Board. Telephone: (202) 334-3214; Fax: (202) 334-2519. Cost: $20.

THIS PAGE LEFT BLANK
INTENTIONALLY

AP-118 Falling Weight Deflectometer Quality Assurance Software (SHRP)

DESCRIPTION : This project develops, markets, and distributes generic versions of the Strategic Highway Research Program's (SHRP's) Falling Weight Deflectometer (FWD) Quality Assurance software for use by State highway agencies. The generic versions accommodate various FWDs, sensor numbers, sensor spacings, and test protocols.

BACKGROUND : The SHRP FWD Quality Assurance Software is a spinoff product of SHRP's Long-Term Pavement Performance (LTPP) studies. It is one of four spinoff products SHRP recommended for FHWA implementation activities in 1992.

Falling Weight Deflectometers are used widely by highway agencies to collect pavement response data used in pavement rehabilitation, design, pavement management systems, and forensic examinations of failed pavements. The overall goal of the SHRP FWD Quality Assurance Software is to ensure the consistent collection of high-quality pavement deflection data.

To provide quality assurance for FWD data collection, SHRP developed four software programs and established reference calibration centers at several State highway agencies to provide for quality measurement and data collection.

Since many of the State highway agencies either own or contract for deflection testing services by an FWD, the use of this quality assurance software should provide improved testing data. Unfortunately, all of this software was written specifically for SHRP and its methods. As an example, the programs are written to read data files from Dynatest FWD with seven sensors at the prescribed SHRP sensor spacing.

PROJECT MANAGER : Max Grogg, (518)431-4224.

STATUS : A Technical Working Group was established in 1993. During 1994 the LTPP Division continued to revise these software packages based upon their need, experience, and input from the Technical Working Group. These modifications should be completed by October 1995. In 1996 a consultant contract will be executed to perform the software modification. Additional funding will provide for training on the software and the calibration centers. Limited field testing by the SHAs will be conducted, and modified generic software will be marketed.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-14 Innovative Contracting Practices

DESCRIPTION : The objective of this project is to identify innovative contracting practices for evaluation and documentation that have the potential to reduce life-cycle costs to State highway agencies, while maintaining product quality and an acceptable level of contractor profitability. Practices tested under this contract include design/build, warranties, guarantees, lane rental, cost plus time bidding, and incentives/disincentives.

BACKGROUND : This project resulted from the work of a 1988 Transportation Research Board (TRB) task force that spent 3 years exploring innovative practices in the U.S. and abroad. Its findings were released as Transportation Research Circular Number 386, titled "Innovative Contracting Practices" (1991).

Another initiative relative to innovative contracting practices resulted from an asphalt pavement study group's 1990 European tour. The group was impressed with what it saw and recommended three innovative practices that could be pursued through a test and evaluation effort:

- Functional contracts (design/build),
- Warranties of riding surfaces, and
- Lane rental.

In addition, a fourth practice, cost-plus-time bidding, has gained widespread acceptance from State highway agencies.

PROJECT MANAGER : Wady Williams, HNG-22, (202) 366-0606

STATUS : This project has been operational for over 5 years and approximately 65 percent of the SHA's have participated at least once.

By far, the most popular technique used has been cost-plus-time bidding. Twenty-six States and the District of Columbia have used this method thus far. Six SHA's have either completed design/build contracts or have initiated such contracts. Contacts have been completed in Arizona and Colorado with favorable results. Total project time was substantially less than would have been expected for conventional design-bid-build projects, there was no significant change in design costs, and claims were essentially eliminated. Six SHA's have undertaken projects using the lane rental concept to reduce road-user impacts and, eight SHA's have chosen to use and evaluate warranty provisions.

In 1995 FHWA published *Rebuilding America: Partnership For Investment*, FHWA publication No. FHWA-PD-95-028, which contains descriptions of innovative practices and a list of projects using these practices.

TECHNOLOGY TRANSFER AIDS : Lane rental specifications, background information on warranties and guarantees (from the Transportation Research Board), and telephone and speaker assistance.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-18 Stone Matrix Asphalt

DESCRIPTION : The goal of this project is to test and evaluate the use of Stone Matrix Asphalt (SMA) on several test sections of U.S. highways to determine its construction feasibility and cost-effective performance. DP-90's mobile asphalt laboratories, its staff, and the Turner-Fairbank Highway Research Center staff are available to assist other States with SMA mix design information. The mobile asphalt laboratories provide materials analysis on-site while supporting quality control and compliance.

BACKGROUND : In 1990, a team of State, industry, and Federal engineers from the U.S. participated in a European Asphalt Study Tour. Their mission was to identify promising asphalt technologies. Of the asphalt mixture technologies studied, SMA had great promise for use in this country.

SMA is an asphalt mixture developed in the 1980's in Germany to provide a rut-resistant pavement surface layer. SMA's proven performance is attributed to a "gap graded" aggregate gradation that provides a stone-to-stone structure held together by a durable asphalt cement, mineral filler, and fiber matrix. SMA is routinely used in many parts of Europe.

PROJECT MANAGER : John Bukowski, HTA-21, (202) 366-1287

STATUS : Interest in SMA remains strong. To date, project presentations have been made at nearly 100 locations to thousands of government and industry individuals interested in the various aspects of material selection, design, construction, and performance. Continuing interest in SMA is evident by the increasing number of States that participate and the tonnage of SMA used in projects.

Year	Number of States	Tons of SMA
1991	4	less than 50,000
1992	12	100,000
1993	15	200,000
1994	23	300,000
1995	27	400,000

Extensive monitoring is under way on more than 50 separate test sites constructed in Maryland, Georgia, Virginia, Texas, California, Alaska, Arkansas, New Jersey, Kansas, Illinois, Ohio, Michigan, Wisconsin, Indiana, and Missouri. Data from these projects are being analyzed and model specifications have been disseminated. Further evaluation is targeting mixture design, cost reduction, quality control, and predictive performance of the SMA pavements. SMA sites are being visited and evaluated by a contractor, which should lead to a greater understanding and more systematic evaluation approach. A mix design research effort funded by the NCHRP 9-8 is underway at the National Center for Asphalt Technology and Auburn University. Efforts are also underway to use some of the Superpave mix technologies in designing SMA.

TECHNOLOGY TRANSFER AIDS : Telephone and on-site assistance, speakers, mix design assistance (based on laboratory availability), and mobile laboratory (subject to long-range planning).

PUBLICATIONS : SMA Model Materials Selection and Construction Guidelines are available through the Office of Technology Applications and are also being distributed by the industry. Copies of material on European SMA Synthesis also are available upon request.

TE-21 Pavement Condition Measurement (SHRP)

DESCRIPTION : This project evaluates and promotes state-of-the-art pavement condition evaluation equipment and consolidates previous ongoing activities with SHRP implementation efforts related to pavement condition measurement. The project will be expanded to include new technology as it becomes available.

Three kinds of equipment have been evaluated through field test and evaluation:

- SHRP Ground Penetrating Radar
- SHRP Seismic Pavement Analyzer
- Fully Automated Pavement Distress Measuring Equipment

PROJECT MANAGERS : Luis Rodriquez, HNG-41, (202) 366-1335 and George Jones, HNG-41, (202) 366-1338.

STATUS : The final report on the fully automated pavement distress measuring equipment has been completed and distributed to all State highway agencies. Reports on additional equipment analysis will be issued upon completion of field test and evaluation. A follow-up test was conducted in North Carolina during December 1994. North Carolina DOT is currently completing the data analysis from that test.

The Technical Working Group met and decided not to fund any additional testing of either the ground penetrating radar or the seismic pavement analyzer. The developers of both pieces of equipment are continuing with the equipments' development. Commercial development through the private sector is encouraged.

TECHNOLOGY TRANSFER AIDS : Test and evaluation in selected States through work orders and equipment loan. A follow-up program of workshops, seminars, and literature is envisioned.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-25 Strategic Highway Research Program Work-Zone Safety Devices

DESCRIPTION : To improve safety and efficiency of day-to-day maintenance and operations of work zones, the Strategic Highway Research Program (SHRP) produced 12 devices that are applicable in work zones, especially for maintenance activities.

1. Salt Spreader Truck Mounted Attenuator (TMA)
2. Portable Crash Cushion **
3. Ultrasonic Detection Alarm
4. Infrared Intrusion Alarm **
5. Queue-Length Detector **
6. Portable Rumble Strip **
7. Direction Indicator Barricade **
8. Opposing Traffic Lane Divider **
9. Diverging Lights
10. Flashing STOP/SlOW Paddle **
11. All-Terrain Sign & Stand
12. Remotely Driven Vehicle

** Interest indicated by commercial fabricators.

The Salt Spreader Truck Mounted Attenuator is commercially produced and marketed exclusively by private industry. Six of the other devices, representing the basic SHRP developed concepts, are commercially available and are ready for trial field use. These include the Opposing Traffic Lane Dividers, Portable Rumble Strip, Flashing STOP/SLOW Paddle, Direction Indicator Barricades, Work Zone Intrusion Alarms, and the All-Terrain Sign Stand with Signs. The Portable Crash Cushion and the Remotely Driven Vehicle are being modified to improve their performance. The Queue-Length Detector and Diverging Lights have had technical problems that remain unsolved and also appear to have a limited market demand. Further work on these two devices is on hold.

PROJECT MANAGER : Joe Lasek, HHS-11, (202) 366 2174

PROJECT COORDINATOR : Peter Hatzi, HTA-31, (202) 366 8036

STATUS : Most of the devices have been exhibited by the FHWA and SHRP staff at many national and regional conferences and technical shows. The purpose of showcasing the devices during fiscal years 1992 through 1994 is to acquaint potential users with these new devices and to develop interest in their use.

FHWA supports activities to provide the various devices to State highway agencies for trial use and evaluation. A solicitation of interest was made to the State DOTs through FHWA division offices. Based upon responses, funds were provided to the States to acquire limited numbers of the devices for trial use under actual work conditions. In return information on the overall performance of the devices will be provided to FHWA.

Some additional funding will be made available in FY 1994 for acquiring Intrusion Alarms and other devices that may become available for trial use and evaluation. The funding will be provided under normal Federal aid procedures. Through this evaluation method, FHWA will accumulate an information base on the in-service performance of the various devices, while allowing the States to gain experience with them.

TE-27 Innovative Pavement Materials & Treatments

DESCRIPTION : This project provides States an opportunity to evaluate SHRP pavement maintenance products and techniques by introducing preventive maintenance technology and principles. Technical assistance will be provided on surface treatments and guidance will be available in the use of innovative materials. SHRP technology in two areas is included:

- Effectiveness of pavement preventive maintenance: management concepts, optimum timing of various surface treatment applications, guide specifications for preventive maintenance, and a 1-day workshop.

- Innovative materials: pothole patching, crack sealing, joint sealing, spall repair and other materials and surface repair guidelines, introduction of objective data collection techniques for joint seal effectiveness, and a 1-day workshop.

PROJECT MANAGER : Patrick Bauer, HNG-21, (202) 366-1554 and Michael Smith, HNG-42, (202) 366-4057.

PROJECT COORDINATORS : Jim Sorenson, HNG-42, (202) 366-1333 and Gary Henderson, HTA-21, (202) 366-1283.

STATUS : Showcase contracts have been awarded for Preventive Maintenance and Innovative Materials, and pilot workshops have been conducted. Test and Evaluation programs are under development. The first pilot workshop was held in May, 1995, in Colorado. The second pilot is being held in September, 1995, in Arizona. It is anticipated that workshops for both technologies will be available in the late Fall of 1995.

TECHNOLOGY TRANSFER AIDS : Seminars, technical assistance, and field test and evaluation work orders.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-28 SHRP Snow and Ice Technology

DESCRIPTION : This project tests and evaluates SHRP snow and ice technology products in five major areas: snowplow cutting edges, snow fences, roadway weather information systems, anti-icing technologies, and de-icing chemicals. The project will provide an opportunity for States to test and evaluate better designed snowplows and snow fences, improved storm forecasting and communication methods, and more efficient and effective snow removal and ice control methods.

The primary products emerging from this SHRP technology area are design guides, manual of practice for anti-icing operations, research reports, handbooks, evaluation methodologies, and improved snow removal equipment. Guidelines have been developed for evaluating equipment, materials, and methods for utilizing anti-icing technology. FHWA's implementation effort of the SHRP technology has three parts:

- Anti-icing Technology through a technical services support agreement with U.S. Army Corp of Engineers (Cold Regions Research and Engineering Laboratory CRREL).

- Showcasing contract incorporating workshops, field test and evaluation, and equipment loans.

- Field Test and Evaluations through work orders with State highway agencies.

PROJECT MANAGERS : Salim Nassif, HNG-21, (202) 366-1557;Chung Eng, HNG-21, (202) 366-1555.

PROJECT COORDINATOR : Gary Henderson, HTA-21, (202) 366-1283

STATUS : Product/technologies currently being evaluated include weather information systems for highway operations, anti-icing operations, innovative snow fence design and construction, and snow scoops. Additional products/technologies and participants will be added through the showcasing contract. Work orders were established with 15 State highway agencies to evaluate the effectiveness of SHRP anti-icing techniques over the 1993/94 and 1994/95 winter period. Work orders were also established with an additional seven State highway agencies; four to evaluate the Wels portable interactive weather prediction system, and several other weather services in terms of usefulness and accuracy for highway operations; two to evaluate snow fences designed in accordance with SHRP guidelines; and one to evaluate the effectiveness of the snow scoop retrofitted to their existing plows.

A showcase contract has been executed to package the various technologies and develop a series of workshops and seminars focusing on snow and ice technologies. Additional field trials will be initiated with selected States to further evaluate various products by winter 1995/96. Workshops will begin during the first quarter of 1996.

TECHNOLOGY TRANSFER AIDS : Workshops on snow and ice technology will be available in the near future. Following standard work order procedures, States may participate in field tests and evaluations of selected products. Technical assistance will be available to guide participants on proper application and evaluation of products/technology. Limited funding is available.

Pavement Management Technology : This technology group focuses on those technologies related to identification, evaluation, and testing for pavement distress and collection of pavement performance data. It includes a Distress Identification Manual and several pieces of equipment developed under the Strategic Highway Research Program's Long Term Pavement Performance (LTPP) program. Programs under this group will establish a continuing effort to test and evaluate emerging equipment and technology and will provide comprehensive reports of testing results to the industry. This effort will result eventually in more accurate and consistent distress identification and performance data.

TE-30 High Performance Rigid Pavements (HPRP)

DESCRIPTION : The immediate goal of the HPRP Program is to construct some selected highway projects to explore the applicability of other innovative concrete pavement design and construction concepts in the United States. The long range goal is further improvement of cement concrete pavement design, materials, and construction technology and equipment through innovation, research, training, and following pavement technology developments in other nations.

BACKGROUND : In 1992 a team of State, industry, and Federal engineers participated in the U.S. Tour of European Concrete Highways. Their mission was to review European concrete pavement experiences and obtain information relating to finance, research, design, construction, maintenance, and performance to assist with development of appropriate actions for enhancing the U.S. highway system. The follow-up visits to Germany and Austria obtained sufficient information to construct experimental sections using German design and Austrian exposed aggregate surface treatment technique to reduce tire/pavement noise..

PROJECT MANAGER : John M. Becker, HNG-40, (202) 366-1340

PROJECT COORDINATOR : Suneel Vanikar, HTA-21, (202) 366-0120

STATUS : In 1993 a 1-mile test section was constructed on I-75 (Chrysler Freeway) in downtown Detroit, Michigan. The design and construction procedures of the experimental pavement section were similar to those used in Germany and Austria. The project will be monitored for 3 years and evaluation reports have and will be prepared. An open house was organized during construction to demonstrate the European design and construction technology. FHWA plans to participate in additional projects incorporating some of the European and other innovative design features.

State Highway Agencies have been asked to submit proposals for HPRP projects by October 10, 1995. Expert Working Groups will be formed to select projects for FY 1996 funding, to evaluate HPRP performance and to oversee open house activities and to develop T^2 workshops.

TECHNOLOGY TRANSFER AIDS : Telephone and on-site assistance, speakers, and mobile laboratory.

PUBLICATIONS : *Report on the 1992 U.S. Tour of European Concrete Highways,* 1992, and *Summary Report of Follow-up Tour of Germany and Austria,* 1993. Both reports are available through the Office of Technology Applications. A video-tape on the Michigan project is available from the Office of Technology Applications.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-34 SHRP Concrete Showcase Contracts

CONCRETE MIX DESIGN AND CONSTRUCTION AIDS (SHRP)

DESCRIPTION : This project provides State DOTs and industry with SHRP-developed information on concrete mix design and curing tables along with providing technical assistance for implementation. Curing tables will aid resident engineers and contractors in their decision process.

BACKGROUND : Packing diagrams have been developed by SHRP to get dense concrete. The diagrams are used as mix design techniques. Properly used, the mix design may improve tensile strength and durability. Curing tables have been developed and include temperature, cement content, and critical dimensions to aid proper curing. The goal of these efforts is to obtain dense, impermeable, and durable concrete with minimum cracks.

PROJECT MANAGER : Suneel Vanikar, HTA-21, (202) 366-0120

STATUS : A Work Order was provided to the Indiana DOT in 1992 to perform field verification of packing diagrams, and field testing and evaluation are complete. A work order was provided to the University of Louisville for additional testing and evaluation in 1994 and is underway. Minnesota DOT conducted their own packing handbook evaluation in 1994. In 1994, the Missouri HTD examined the packing handbook for possible use in mix design.

In 1994, these products were promoted through presentations, and they will be incorporated into other SHRP-related implementation efforts for concrete durability and high performance concrete.

In 1995, the draft Packing Handbook evaluation report and the Curing Tables evaluation report were sent to AASHTO and distributed to members of the Technical Working Group.

TECHNOLOGY TRANSFER AIDS : Presentations are available upon request from the Office of Technology Applications.

CONCRETE DURABILITY (SHRP)

DESCRIPTION : This project will showcase SHRP-developed products and provide education and technical assistance to State DOTs and the industry by developing and presenting workshops and providing testing equipment to State DOTs through an equipment loan program.

This implementation effort includes new test procedures for D-Cracking potential of aggregates, a revised test procedure for freeze-thaw durability, and specifications for aggregates. It will also include an expert system for rehabilitation strategy. The durability of concrete structures and pavements is a key issue in rebuilding infrastructure.

PROJECT MANAGER : Gary Crawford, HTA-21, (202) 366-1286

PROJECT COORDINATOR : Suneel Vanikar, HTA-21, (202) 366-0120

STATUS : Five impact echo devices, five in situ surface air flow permeameters and five hydraulic fracture devices have been purchased and are available through an equipment loan program. The impact-echo device has been loaned to ten agencies, the surface air flow permeameter has been loaned to eight agencies, and the hydraulic fracture device has been loaned to five interested highway agencies. The products are being promoted through a manual, workshops, equipment loans, and technical assistance. Consultant services were obtained in 1994 to develop and present workshops, showcase products, manage the equipment loan program, and provide technical assistance. A pilot workshop was held in Virginia in June 1995. Regional workshops will start in late 1995 and continue through 1996. Some products will also be demonstrated in the FHWA mobile concrete laboratory.

TECHNOLOGY TRANSFER AIDS : Workshops, equipment loans, and technical assistance through consultant services. A manual will be developed for the workshops.

ALKALI-SILICA REACTIVITY (ASR) AND FLORESCENT MICROSCOPY (SHRP)

DESCRIPTION : This project will provide education and technical assistance to State DOTs and the industry while showcasing SHRP-developed products relating to alkali-silica reactivity (ASR) and florescent microscopy.

ASR is a problem for many States, particularly those with concrete pavements. This implementation effort includes identification of ASR, field and laboratory tests, mitigation of ASR in existing structures, and mix design procedures to reduce potential for ASR.

The project will develop and present workshops, provide testing equipment to State DOTs through an equipment loan program, and provide technical assistance.

PROJECT MANAGE : Roger Surdahl, HNG-23, (202) 366-1563

PROJECT COORDINATOR : Suneel Vanikar, HTA-21, (202) 366-0120

STATUS : Six ASR field detection test kits have been purchased. The consultant contract to develop a 3-day workshop and other showcase activities was awarded in 1993. A pilot workshop was held in Pennsylvania in late 1994. Workshop presentations started in 1995, and workshops were presented in Nebraska, New Jersey, North Carolina, Wyoming, Nevada, Oregon, Minnesota, and New Mexico. An equipment loan program has been established, and technical assistance is provided under the contract. Equipment loan and technical assistance were provided to Pennsylvania, Nevada, Idaho, Delaware, Oregon, and Indiana DOT's. Field testing of lithium compounds to minimize ASR is underway in New Mexico, Nevada, New Hampshire, and Pennsylvania.

In 1996, the products will be promoted through a manual, additional workshops, product showcasing, and technical assistance. Some products will continue to be demonstrated in the FHWA mobile concrete laboratory.

TECHNOLOGY TRANSFER AIDS : Workshops, equipment loans, and technical assistance through consultant services.

Concrete Pavement Design and Construction

The concrete pavement design and construction technology group focuses on innovative designs and construction techniques that provide immediate solutions to specific Portland cement concrete pavement problems. The range of technologies addresses water in pavements, faulting joints and cracks, paving under limited time restrictions, pavement durability and economy, and methods of achieving improved overall performance through performance-related specifications.

Several projects incorporating emerging technologies for design and construction are in development stages. These include high-performance rigid pavement design and construction methods, various concrete pavement texturing techniques to minimize noise and enhance safety, and evaluation and implementation of performance-related specifications for concrete pavements.

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-36 High-Performance Concrete

DESCRIPTION : This national effort will include seminars, workshops, equipment loan programs, demonstration bridges, and technical assistance to evaluate, showcase, and promote high performance concrete and SHRP research products in high performance concrete. The initial goals are to obtain all equipment, specifications, test procedures, and reference documents related to the subject; organize the materials; develop seminar and workshop technology transfer materials; and plan an equipment loan program. The secondary goals are to present seminars and workshops, implement the equipment loan program, provide technical assistance, and construct Demonstration Bridges.

BACKGROUND : The Strategic Highway Research Program (SHRP) supported considerable research into high performance concrete. As a result of this research, new testing methods have been developed and some existing testing methods have been modified to 1) determine the validity of existing test methods; 2) give greater uniformity to test results; and 3) give engineers greater confidence in the material properties of high performance concrete.

A major goal of SHRP was to develop improved criteria and testing methods for the mechanical properties and behavior of high-performance concrete. The training and dissemination of information to personnel (governmental and industry) required to perform tests and mixture design is an essential step for the effective use of new field identification procedures, test procedures, and mixture design methods.

PROJECT MANAGER : Terry D. Halkyard, HTA-22, (202) 366-6765

PROJECT COORDINATOR : John M. Hooks, HTA-22, (202) 366-6643

STATUS : A national multi-year effort is planned that would target a maximum number of interested government and private industry engineers and technicians. This effort will promote the use of high performance concrete and the thorough evaluation of SHRP-developed products to transfer technology to a wide audience throughout the United States. High performance concrete is being used in bridges under construction in Nebraska, Texas and Virginia, and plans are being made for its use in bridges in New Hampshire, Ohio, Colorado, Georgia and Washington. A workshop on the use of high performance concrete in the Texas bridge is planned for early 1996.

TECHNOLOGY TRANSFER AIDS : Workshops on High Performance Concrete, technical assistance, speakers, and presentation materials.

Bridge Inspection and Bridge Management

More than 40 percent of the Nation's 575,000 highway bridges are functionally obsolete or structurally deficient. These deficient structures represent significant impediments to the safe, economical use of the highway system and result in safety hazards, high user costs, and huge outlays for preservation and replacement. Balanced against this backlog of bridge needs is a generally inadequate level of funding by public agencies for infrastructure needs.

The collapse of the Silver Bridge in 1967 was the immediate catalyst for what became a comprehensive bridge safety inspection program mandated by the National Bridge Inspection Standards (NBIS). Every bridge on a public road must be inspected at least every 2 years and highway agencies across the Nation have inspection staffs and programs that collect and update critical bridge inventory and inspection data. After almost 20 years, there is still a manifest need to more effectively analyze this data, to better define bridge needs, and to find effective solutions.

The complexities and costs associated with preserving the Nation's bridge infrastructure demand innovative approaches to collection and analysis of data and prediction of current and future bridge preservation actions. These needs, coupled with the availability of modern analytical methods and high-speed computers, are leading to the development of comprehensive bridge management systems. Prior to the late 1980s, there were no existing management systems adaptable to the management of bridge programs nor was there any clear definition of key bridge management principles or objectives. Therefore, in cooperation with AASHTO, California DOT, and a specially formulated technical working group (TWG) representing several State DOT's, OTA was able to establish the following primary requirements of a comprehensive Bridge Management System (BMS):

General Procedures

1. Identify and establish responsibility for data collection and management and for bridge decision making based on a comprehensive BMS.

2. Coordinate program and project-level decisions and coordinate bridge maintenance and improvement actions and a process of priority programming.

3. Ensure a clear method of communicating needs and programs to outside audiences.

Functional Needs

1. Automated database of bridge inventory, condition data, and a historical data file.

2. Deterioration models for projecting future condition of bridge elements with or without intervening actions.

3. Identify costs related to feasible actions, user costs associated with a deficient bridge condition, and budget and other key constraints.

4. Develop multi-period procedures and reporting capabilities.

Efforts to define modern bridge management led to a cooperative effort with California DOT and the TWG to be develop the PONTIS BMS. With Pontis under development, and with the added incentive of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, six milestones were established:

1. Publish Version 2.0 of PONTIS, the BMS jointly developed by FHWA, California DOT and the TWG (complete); accomplish transfer of PONTIS support to the AASHTOWare software system (complete).

2. Develop and begin formal BMS training sessions for bridge inspectors and bridge managers (sessions to be underway beginning in October 1995).

3. Establish an FHWA network of BMS specialists and regional TWGs to provide BMS training and support to SHA and local agency bridge managers (underway).

4. Implement a Commonly Recognized (CoRe) Element system to define standard bridge elements

(complete); establish uniform method of converting core element condition data to NBI format (ready for adoption).

5. Each State implement a comprehensive BMS (underway).

6. Organize a new demonstration project to promote innovative computer hardware and software to improve efficiency and quality of bridge data collection and management (scheduled to begin in FY 1997).

THIS PAGE LEFT BLANK
INTENTIONALLY

TE-39 SHRP Asphalt Support Projects

This project supports a multitude of activities to promote the SHRP asphalt program.

PROJECT MANAGERS : The managers for all TE-39 projects are: John D'Angelo, HTA-21, (202) 366-0121; Thomas Harman, HTA-21, (202) 366-0859; and John Bukowski, HTA21, (202) 366-1287.

POOLED FUND EQUIPMENT STUDY SUPPORT (SHRP)

DESCRIPTION : FHWA, in cooperation with AASHTO and SHRP, initiated a pooled fund study that gives the participating States the opportunity to acquire SUPERPAVE asphalt binder and mix test equipment. Since the pooled fund announcement on January 10, 1992, States have committed at least a portion of the estimated $335,000 to purchase the equipment. The pooled fund study allows each State to use its Federal SP&R monies without matching funds.

STATUS : Procurement of the equipment is scheduled for a 4-year period. All participating States have received the SUPERPAVE binder equipment. The mix design equipment must go through further development with a series of first article testing. This process should allow for a more rigid analysis of the equipment prior to the purchase. The States have received the gyratory compaction equipment to begin work on the SUPERPAVE mix design system.

Procurement of the mixture analysis equipment and the SUPERPAVE Shear Tester and Indirect Tensile Tester will initially be limited to six units. These will be evaluated at SUPERPAVE Centers established in PA, AL, TX, NV, and IN as well as at the FHWA TFHRC. Equipment procurement for all State DOTs of these devices is scheduled for 1996.

TECHNOLOGY TRANSFER AIDS : Equipment on loan (subject to availability), State reports available through the Office of Technology Applications (subject to availability), and telephone assistance.

SHRP ASPHALT EQUIPMENT LOAN PROGRAM

DESCRIPTION : This project evaluates asphalt binder equipment developed to support the binder specification under the Strategic Highway Research Program (SHRP). The Office of Technology Applications (OTA) has five sets of asphalt cement testing equipment, plus one set for OTA and one set for FHWA's Research and Development. This equipment includes:

- Bending beam rheometer with computer
- Dynamic shear rheometer with computer
- Pressure aging vessel
- Direct tension tester with computer
- Brookfield viscometer

Ruggedness and precision/bias data are being collected for the final specifications (a secondary but very important purpose of this project). OTA is working closely with the AASHTO Subcommittee on Materials to accomplish this expeditiously.

STATUS : All equipment has been delivered and will continue to be loaned to States within each user-producer group. Funding also involves workshops (that include the user-producer group concept) and evaluation monies, as required.

TECHNOLOGY TRANSFER AIDS : Equipment specifications, vendor list, and provisional test procedures. Binder technicians are available for on-site training, three-day workshops, and telephone assistance.

SHRP FIELD IMPLEMENTATION ASPHALT

DESCRIPTION : This project will provide technical assistance to the States in the local use of Superpave equipment provided under the pooled fund buy. A competitive contract was awarded to the Asphalt Institute for field engineers and technicians to assist the States. Assistance will include equipment setup, testing, test interpretation, local workshops, training in the design and construction of mixes, and guidance for the construction of Special Pavement Section (SPS) 9 design and construction. This project will be closely integrated with LTPP.

STATUS : The contract was be let in FY 1995 and will last for 3 to 5 years.

TECHNOLOGY TRANSFER AIDS : On site training, field and telephone technical assistance.

SHRP SUPERPAVE MODELS

DESCRIPTION : This project will assist in completing the SHRP work on the model ~ that underpin SUPERPAVE. The effort will be completed through a competitive bid contract. The work will include software support, model documentation, and further refinement and documentation. The contract for technical assistance win be let in 1993 and operate for 3 to 4 years.

STATUS : Procurement is on hold until the SHRP reports on the models are made available to include in procurement documents.

GEORGIA LOADED WHEEL TESTER (LWT)

DESCRIPTION : This project supports SHRP asphalt implementation efforts by evaluating innovative asphalt testing equipment. Products under consideration include the nuclear asphalt content gauge, indirect tensile test, moisture sensitivity tests, and most significantly, the Georgia Loaded Wheel Tester (LWT). While not directly associated with SHRP, this project will finance additional evaluations of SHRP-developed products not specifically identified in the pooled fund buy.

BACKGROUND : The Georgia LWT was developed by Dr. Jim Lai at Georgia Tech, in cooperation with the Georgia DOT. It is a quick, efficient, and inexpensive method for determining rut susceptibility of surface mixes. Georgia DOT has developed a specification that is used on all high-traffic roadway projects and other projects where rutting susceptibility is a concern.

FHWA sponsored a round-robin test program with six State DOTs to evaluate the Georgia device, which was found to be repeatable and reproducible. A Work Order with Georgia DOT was issued by FHWA to modify the device to make it semiautomatic and controlled electronically. The modified device is capable of testing multiple samples at one time and handling 75 by 125 by 375 mm samples. The temperature and the hose pressure also are adjustable.

A second round-robin test program is planned to evaluate the modified device.

STATUS : Five States have evaluated the Georgia LWT and will report their findings during the next several years. Georgia Tech has upgraded several features of the LWT to make it semiautomatic and electronically controlled. This modified device is being tested currently. An Expert Task Group was assembled in late 1993 as States completed their evaluations. Funding for this project considers additional State evaluations of this and as yet undefined equipment and techniques that show promise.

TECHNOLOGY TRANSFER AIDS : Equipment loans, field and telephone technical assistance.

Asphalt Pavement Design and Construction

The asphalt pavement design and construction technology group focuses on innovative techniques for design and construction of high performance asphalt pavements used in new construction, reconstruction, rehabilitation, restoration, or resurfacing.

Since 1987, the Federal Highway Administration (FHWA) has supported the "Development of Performance-Related Specifications for Highway Construction" as one of its high priority research areas. Performance-related specifications (PRS) require materials and construction tests, the results of which correlate to a known degree with the performance of the completed product. A series of FHWA, National Cooperative Highway Research Program (NCHRP), and State Planning and Research (SP&R) studies have produced the initial framework and at least a partial system of PRS for hot mix asphalt pavement construction.

The focus in the PRS is on quality control of construction selecting the best available materials and establishing the mix and pavement designs. PRS addresses three questions:

- What quality control tests need to be run *during* construction to minimize premature fatigue cracking or rutting?

- What is the impact on the subsequent performance of deviations from the target values of properties such as density or asphalt content, or both?

- What payment adjustments are appropriate when such deviations are encountered?

The focus of other projects under this technology group is to evaluate these specific technologies to determine the optimum procedure to achieve quality construction and high performance asphalt pavements.

Publication No. FHWA-PD-96-037
HNG-40/8-96(250)QE

TE-44 Electrochemical Chloride Extraction from Reinforced Concrete Structures

DESCRIPTION : The objective of this project is to demonstrate and document the results established under the SHRP Study. A secondary objective is to work in conjunction with States, private sector, and academia to collect data on new structures protected using the chloride extraction method. Pilot projects will include installations on both the decks and substructures.

BACKGROUND : Corrosion of reinforcing steel is recognized as one of the major contributors to the deterioration of reinforced concrete structures, and the chloride ions that penetrate to the level of the reinforcing bars are a critical element in the corrosion process. One technique for dealing with this problem is chloride extraction. The electrochemical extraction of chloride from concrete structures is accomplished by applying an anode and an electrolyte to the concrete surface and passing direct current (DC) between the anode and the reinforcing steel, which acts as a cathode. Since anions (negatively charged ions) migrate toward the anode, it is possible to cause the negatively charged chloride ions to migrate toward the anode and away from the steel. Chloride extraction is similar in principle to cathodic protection (CP). The major difference is in the magnitude of the current, which is about 100 to 500 times that used for cathodic protection. The total amount of charge (current time) applied for chloride extraction is about the same as a CP system would deliver over a period of about 10 years. The other important difference is that chloride extraction is a short-term treatment, whereas cathodic protection is normally intended to remain in operation for the life of the structure.

PROJECT MANAGER : Donald R. Jackson, HTA-22, (202) 366-6770

STATUS : A work order with Virginia and South Dakota Departments of Transportation to install and evaluate the electrochemical chloride extraction procedure was approved for a bridge carrying 34th Street over I-395 into Arlington, Virginia, and a bridge in Sioux City, South Dakota. The procedure was installed on three sections of the Virginia deck and three piers of the South Dakota bridge in the early spring of 1995. The procedure was also installed on three substructure piers on a structure in Charlottesville, Virginia, in the Spring of 1995.

Open houses were held for the Virginia and South Dakota installations in August 1995. The Open Houses were well attended. Ten States were represented at the Virginia Open House, and five at the South Dakota Open House. The South Dakota Open House took place on August 9, 1995 in Sioux City. Fifty guests, representing Federal, State, academic and private sector organizations, attended each Open House.

THIS PAGE LEFT BLANK
INTENTIONALLY

Chapter 11

Regional / Divisional Items

CHAPTER 11
REGION / DIVISION ITEMS

Publication No. FHWA-PD-96-037
HNG-40/8-96(250)QE