Guidelines for Completing
the
PAVEMENT INVESTIGATION AND REPORT
(V1 & V2 Activities)

This Supplement lists policy, guidelines, specifications, and references that should be followed for this project. It contains the following sections:

I. Pavement Report
II. Pavement Distress Survey & Assessment
III. Pavement Design Method
IV. Traffic
V. Subgrade Investigation
VI. Pavement and Base Investigation
VII. References

The engineer(s) completing the following activities must be experienced with pavement investigations, pavement design, pavement type selection, pavement rehabilitation methods, and pavement materials.

I. Pavement Report

For a pavement report to reflect the data, analysis, and design decisions made, it is important that the information is accurate and comprehensive, and presented with good formatting techniques and supplemented with tables and charts.

At a minimum, the following information is to be included in the pavement report:

1) Title sheet

2) Approval sheet
    a) The pavement report shall be signed, dated, and stamped by a professional engineer.
    b) The engineer(s) completing QC/QA (review of calculations, assumptions, and recommendations) shall also sign and date as to such.

3) Table of Contents

4) Introduction
    a) General project information such as scope of project, local geology, expected advertisement date, and specific location.
    b) The date and general scope of investigation / data collection.
    c) Unique project issues or circumstances, if applicable.

5) Procedures and Results
   a) Include in tabular or narrative form, pavement distress data, relevant geometric site conditions (pavement and bench width, grades, curves, etc), visual subgrade descriptions, and summary of boring logs, pavement drainage characteristics, and material testing results.
   b) Document any additional/specialized sampling and testing conducted, as applicable (i.e. preliminary mix designs, resilient modulus testing, etc.)
   c) In graphical form, show the existing pavement structural section at the boring/test pit/core locations throughout the project.
   d) Document any test values attained by engineering judgment, assumptions, and / or policy.
   e) Document traffic projections, estimates, and/or counts
   f) Record applicable historical information from project files and / or as-built plans. Record maintenance and project history information.
   g) If applicable, include pavement management system data.
   h) When a part of the scope, include procedures and results from falling-weight deflectometer (FWD) testing, dynamic cone penetrometer (DCP) testing, and / or preliminary mix design testing.
   i) Document project history such as as-built plans and maintenance.

6) Analysis
   a) List the analyses performed on the gathered project data and test results including assumed or calculated variables/parameters
   b) List the results of the analyses.
   c) If applicable, include a life cycle cost analysis (LCCA) of various pavement alternatives. Show results and assumptions.

7) Pavement and Materials Recommendations and Discussion
   a) Provide, compare, and discuss cost effective pavement rehabilitation methods and/or pavement structural sections.
   b) Provide the recommended surfacing type, material quantities for bid estimates (percentage rates), and –as applicable- the asphalt grade, emulsion/cut-back types, stabilizing/recycling agent (cement, foamed asphalt, emulsion, etc.) smoothness requirements, unique gradation requirements, bid items, special contract revisions, and any other information necessary to assure the pavement is built with the appropriate material type and quality.
   c) Provide recommendations on need (including estimated quantities) for subexcavation, patching, underdrains, geogrid, or other design procedures that will resolve problems with soft subgrade, wet subgrade, pavement drainage, poor quality subgrade, or other problems that will significantly impact the performance of the pavement.
   d) As necessary, discuss special construction issues that are related to the construction of the pavement such as, but not limited to: curing, cold temperature issues, traffic control, material haul distance, steep grades (> 8%), sharp curves, local material sources, two season project vs. one season project, need for detours, and lift thickness.

8) Appendices to Include
   a) Site Map (s).
   b) Boring logs, coring logs, test pit logs.
   c) DCP data and/or FWD data with applicable reports and calculations.
   d) Lab and/or mix design test reports.
   e) Pavement design calculations, spreadsheets, and/or computer software output reports. Life cycle costs analysis calculations, reports, and/or software reports.
   f) Pavement distress log.
   g) Photos from throughout the project that represent typical and atypical conditions of the pavement. Photos showing pavement, base, and soil sampling and/or coring. Photos showing existing features that may complicate paving and/or rehabilitation techniques (i.e. walls, curb and gutter).

II. Pavement Distress Survey and Assessment:

Typical pavement distresses along the roadway, their general locations, and their general extent should be documented. The definitions and severity levels of pavement distress should follow the *Distress Identification Manual* (see references). Document pavement conditions by photographs and logging, as necessary. Identify subexcavation and water-problem areas. Identify manholes and other utilities or obstacles that may pose a problem for the pavement design, construction, or rehabilitation. Identify steep grades (> 8%), sharp curves or turnouts (radius < 10 m), stonewalls, low clearance areas, and other obstacles that may affect the type of design or rehabilitation method selected.

III. Pavement Design Method:

The *AASHTO Guide for Design of Pavement Structures* (1986 and 1993 versions), to be referred to as *The AASHTO Guide*, is CFLHD's standard design methodology for new or rehabilitated flexible and rigid pavements. The design life to use on 3R and 4R projects is 20 years. On projects or segments where the scope is complete reconstruction, the minimum pavement section shall be 3" of asphalt pavement over 6" of aggregate base. On a pavement rehabilitation project, the minimum thickness for a structural overlay is 2".

Typical Input Parameters:

1) Design Reliability: Use recommendations from *The AASHTO Guide* per the roadway classification, typically not less than 75% for CFLHD projects.

2) Initial serviceability = 4.2. Terminal serviceability = 2.5 (AADT > 500) and 2.0 (AADT < 500).

3) Design Standard Deviation: Use 0.49 for flexible pavements.

4) Structural Coefficients:

- Bid items 401 & 402: Hot asphalt concrete pavement (HACP), Superpave, Marshall, and Hveem = 0.44
- Bid items 403 & 404: HACP = 0.40
- Bid items 408 & 417: Cold asphalt mix = 0.25 - 0.35 (influenced by strength and quality)
- Bid item 416: Cold in-place recycling (with a recycling train) = 0.28
- Full-depth Reclamation
  - Bid item 418: Foamed asphalt = 0.20-0.25 (influenced by retained strength & other factors)
  - Bid item 304: Cement = 0.15 – 0.22 (figure GG.9, AASHTO '86 Guide)
  - Variant of Bid item 309: Asphalt emulsion = 0.25 (influenced by retained strength & other factors)
  - Bid item 303: Pulverization = 0.12 (existing dense-graded pavement over an aggregate base with a low amount of fines, < 25% passing #200 sieve)
- Bid item 301: Crushed aggregate base = 0.14 (R-value 80+)
- Bid item 301 (or 308): Subbase = 0.10 (R-value 65+)
- Bid item 204: Borrow = 0.08 (R-value 55+)
- Bid item 213: Stabilized subgrade = 0.08 (UCC > 100 psi)

5) Drainage Coefficients: Follow recommendations in *The AASHTO Guide*.

<u>Material type parameters:</u>

1) Asphalt Binder Grade - Reliability: 95% using the LTPP Bind program and the LTPP models. In California, use the equivalent PBA or AR grade. As of the date of this document, California has not converted to the PG-graded system.

2) Design application rates for estimating, material type/grades and other items:

- Asphalt Mix – 145 lbs/ft^3. Use FP-03 section 401 in superpave states and 402 in non-superpave states when the quantities of mix will exceed 4000 tons. If the quantities will be less than 4000 tons, use section 403. Specify an appropriate gradation from Table 703-4 (usually grading E) or Table 703-12 (usually ½ inch designation) in the FP-03. Also designate the smoothness level: Type I for 4R projects and Type II for 3R projects.
- Base – 139 lbs/ft^3. Use FP-03 section 301 when quantities will exceed 5000 tons and section 308 otherwise.
- Anti-Strip Additive (Type 3, Lime) – 1%, by weight of mix. Use on all projects.
- Prime Coat – 0.33 gal/yd^2

  4R projects: First choice (if available and not restricted): Use MC-70 (or MC-30). Second choice: CSS-1, SS-1, CSS-1h, SS-1h.

3R projects: Do not specify a prime coat on 3R projects, unless the rehabilitation entails the use of section 303, FDR-pulverization. Use the second choice above for projects involving pulverization.

- Tack Coat – 0.10 gal/yd^2, CSS-1, SS-1, CSS-1h, SS-1h.
  4R projects: Tack coat is placed between asphalt lifts.
  3R projects: Tack coat is placed on the existing asphalt surface or the reclaimed/recycled material as well as between asphalt lifts.
- Fog Seal - 0.10 gal/yd^2, CSS-1, SS-1, CSS-1h, SS-1h.
  Include fog seal on all projects. It is used at the discretion of the CO to seal the surface of the completed asphalt pavement when the surface appears coarse, open, and permeable.
- Cold In-place Recycling – Specify an emulsion that is optimum for the project conditions. Communication between the local suppliers and the designer is important. CFLHD typically uses asphalt emulsion grades HFMS-2 or HFMS-2s and their polymer modified versions (Note: some agencies have successfully used a CSS-1-special as well as MS and CMS grades). Application rates are almost always between 1% and 2% by weight of recycled material. For estimating purposes, use an application rate based on the project conditions, but not less than 1.5%. If the road will be open to traffic prior to placement of a wearing surface, include a fog seal bid item and list under FP-03 section 416. In areas where early strength gain is important or to increase resistance to water damage, specify quicklime or cement as additives.
- Full-Depth Reclamation (with a stabilizing agent):
  Cement – A preliminary mix design should be completed on materials gathered from test pit sampling. This material should be pulverized and tested in the lab according to PCA's Soil-Cement Laboratory Handbook (see references). In addition to providing general feasibility and effectiveness information, the mix design will provide an optimum cement application rate, an optimum base to RAP ratio, a lab optimum moisture content and maximum density. The cement application rate is highly dependent upon the properties of the in-situ material and can range from 3% to 9% (and even higher). Ideally, the 7-day UCC test results should be around 400 psi (but less than 800 psi).
  Foamed Asphalt - A preliminary mix design should be completed on materials gathered from test pit sampling. This material should be pulverized and tested in the lab according to CFLHD mix design procedures. In addition to providing general feasibility and effectiveness information, the mix design will provide an optimum foaming rate, an optimum base to RAP ratio, a cement additive rate, and moisture-density relationships. For foamed asphalt to be effective, a minimum of 5% of the blended material must pass the #200 sieve. Foaming rates generally range from 2% to 5%. Typically the required asphalt binder grade is an AC-10.

Asphalt emulsion – A preliminary mix design should be completed on materials gathered from test pit sampling. This material should be pulverized and tested in the lab according to standard industry practice for FDR mix designs with emulsion. The results of the mix design should convey effectiveness, optimum asphalt emulsion grade, need for additives such as lime or cement, and optimum asphalt emulsion application rate.

- Chemical or Mechanical Soil Stabilization – In areas of weak soils, the use of geosynthetics, lime stabilization, cement stabilization, or other such methods should be considered. If such stabilization methods are cost effective, they should be analyzed according to standard engineering / industry practice. For lime stabilization, it is suggested to use AASHTO M 216, ASTM C 977, and D 5102 (UCC strengths of 100 psi is desired). For cement stabilization follow the guidance in PCA's Soil-Cement Laboratory Handbook (see references). For geosynthetics, standardized methods are limited. AASHTO PP-46-1 and M 288 provide some guidance and additional references. The recommended geosynthetic type or stabilizing agent with an application rate should be documented and justified.

IV. Traffic:

Baseline traffic data should be average annual daily traffic (AADT) and include the percentages of the 13 FHWA vehicle classifications. The mixed traffic should be converted into equivalent single axle loads (ESAL) using the procedures of *The AASHTO Guide.* The Park, County, or State, as applicable, will usually have current traffic data. If vehicle axle weights are not available, the following ESAL per vehicle values can be used:

Vehicle Classification (description)	Typical ESAL/unit
1 (motorcycles)	N/A
2 (passenger cars)	**0.0004**
3 (other 2-axle, 4-tire single unit vehicle)	0.0004
4 (buses)	**0.88**
5 (two-axle, six-tire single unit truck; RV)	**0.50**
6 (three-axle single unit trucks)	**1.50**
7 (four or more axle single unit truck)	1.50
8 (four or less axle single trailer trucks)	2.00
9 (five axle semi-trailer, logging truck)	**2.20**
10 (six or more axle semi-trailer truck)	2.20
11 (five or less axle multi-trailer trucks)	3.00
12 (six axle multi-trailer truck)	3.50
13 (seven or more axle multi-trailer truck)	3.50

If traffic loading is calculated to be less than 50,000 ESALs, use 50,000 ESALs for design purposes. Use a directional split of traffic of 0.60, unless a traffic study indicates some other value. If traffic growth studies are not available, use 2% for volume and 0% for loads, or engineering judgment. It is realized that specific vehicle classification data may not always be available. Every effort should be made to at least get estimates of traffic from the bolded vehicle classifications above. The performance period for 3R and 4R projects is 20 years (unless otherwise indicated).

V. Subgrade Soil Investigation:

It is preferable to characterize the strength of the subgrade by determining its resilient modulus values, either by direct sampling and testing or by FWD testing and back calculation. However, in lieu of resilient modulus evaluation, R-value or CBR testing is acceptable. The R-values or CBR values must be correlated to a resilient modulus value. To determine the correlation, it is best to use the local state DOT's correlation method. If the local state does not have a correlation method, use a trusted method from another state or the process outlined in *The AASHTO Guide*. In addition to strength testing, soil samples must be tested for classification (AASHTO, USCS) and moisture content. When included in the scope of work, soils should also be evaluated for resistivity, pH, and/or salt contents. If the soil has the potential for expanding (swelling), additional tests such as specific gravity and moisture-density relations may be needed to determine the potential expansiveness of the soil (see AASHTO T 258). <u>Remember: For all site investigations, obtain necessary permits and utility clearances, and arrange for traffic control.</u>

Summary of Typical Soil Testing*			
Strength	**Soil Classification and Properties**	**Resistivity, pH, Salts**	**Moisture Content**
Resilient Modulus – AASHTO T 307 R-Value – AASHTO T 190 CBR – AASHTO T 193 FWD – AASHTO T 256	AASHTO M 145 (report results of all testing) ASTM D 2487	Soil Resistivity – AASHTO T 288 pH – AASHTO T 289 Sulfate content – AASHTO T 290 Chloride content – AASHTO T 291	AASHTO T 255 or T 265

*Note: Testing must be completed by a laboratory accredited by AASHTO (AMRL) for the type of testing performed.

<u>Typical Boring Requirements</u>:

1) Evaluate the subgrade at least every 0.5-mile by logging and completing 5-foot borings. Record the pavement layers depths, material types, and visual moisture conditions. Asphalt layer depth shall be recorded to the nearest 0.25 inch. Base and/or subbase depths shall be recorded to the nearest 0.50-inch. Pronounced differences in subgrade material shall be recorded to the nearest 0.5-foot.
2) Collect a 3 lb. sample of subgrade soil placed in an air tight baggy for in-situ moisture content testing
3) Collect a 65 lb. sample of subgrade soil for strength testing and classification testing.

4) Complete the number of strength and classification tests (i.e. R-values, resilient modulus, or CBRs) to properly characterize all the different soil types encountered. The number of tests completed is at the discretion of an engineer experienced in field investigations, but typically in-situ moisture content, strength testing, and classifications (USCS & AASHTO) should be completed on a sample every mile (for very consistent material this can be reduced).

In lieu of (or to help support) the boring data, FWD testing and/or DCP testing can be completed to characterize the strength of the soil. In most cases economy and improved data can be achieved by using these tests.

Typical Requirements for FWD testing**:**

1) The AASHTO T 256 testing procedure and calibration protocols are to be followed. Provide date of last reference load cell and deflection sensor calibration (must be within the last year). Relative calibration of the deflection sensors should have been done within the last month or on site before testing. Quality control procedures as recommended by the FWD manufacturer should be followed.

2) FWD Survey:

   a) Testing should be completed in each lane along the outside wheel path. The spacing between tests is to be no greater than 100 m (328') with a 50 m (164') offset between the lanes.
   b) The drop sequence should be as follows (or the contractor may provide justification for a different sequence): At each test location complete 3 measured drops including a seeding drop before each measured drop. The target loads should be 27 kN (6000 lbs.), 40 kN (9000 lbs.) and 53 kN (12,000 lbs.) respectively for the 3 drops.
   c) The FWD should automatically record pavement and air temperature at each test location, and this data should be used, as necessary, during the evaluation phase.
   d) The FWD output file format must be compatible with DARWin™ 3.0. The output file format should also support PDDX file format so other back calculation programs can be used for analysis. Provide the test data on standard floppy disks or CD-ROMS. A description of the quality assurance procedures that will be completed on the FWD data to assure that it is good quality data should be provided.
   e) Follow-up or closely spaced testing to delineate particularly low strength areas may be needed. The engineer on site should make this determination.
   f) Coring (or GPR) must be completed throughout the project to accurately establish the pavement and base thickness in order to determine the back calculated moduli for the pavement, base, and subgrade layers.

3) Analysis of Data: An acceptable back calculation and analysis program should be used (MODULUS, ELMOD MODCOMP5, EVERCALC, DAPS, etc).

4) Other Recommended Specifications: 300 mm (11.8 in.) Load plate diameter. Seven sensors spaced at 0 mm, 203 mm, 305 mm, 457 mm, 610 mm, 914 mm, and 1524 mm (0, 8, 12, 18, 24, 36, and 60 inches).

Typical Requirements for DCP Testing:

The DCP measures the penetration per blow into a pavement through each of the different pavement layers. This penetration is a function of the in-situ shear strength of the material. Good correlations exist between DCP measurements and the well-known CBR test.

DCP measurements can be taken in test pits, at the bottom of core holes, and along the shoulder to determine the in-situ strength of the base and subgrade, and the ability of this material to support a heavy in-place recycling train.

1) The locations and quantity of DCP tests to perform depends upon the existing roadway conditions and the scope of the project. It is important to use good engineering judgment when determining locations and quantity of tests. Generally, a DCP test should be performed at each core and test pit site. Additionally, DCP tests can be performed along the shoulder, if roadway widening is expected.

2) Operational guidelines provided in the DCP users manual should be followed.

3) The Corps of Engineers (COE) correlation equation should be used for the analysis. In general, and a DCP index (mm/blow) of 10 or less indicates good subgrade support, a DCP index of 10 to 20 indicates marginal support, and an index greater than 20 indicates poor subgrade support.

VI. Pavement and Base Investigation (3R projects only):

If an overlay or a mill and overlay are determined to be the best rehabilitation alternative, FWD testing should be completed as indicated above to determine layer moduli values and the required overlay thickness. If the pavement condition has deteriorated to a level where an overlay will not provide long-term performance, other rehabilitation alternatives such as partial and full-depth recycling/reclamation should be evaluated for effectiveness and feasibility. The evaluation should include coring/augering the pavement structure along the route to determine pavement and base thickness and where changes in pavement thickness/type occur. Test pits should also be excavated to collect bulk pavement and base samples for preliminary mix designs and testing of base material. Variability of pavement/base thickness, quality, and type will have a significant influence on the recommended pavement rehabilitation method and is important bid information.

Typical Requirements for Coring:

Dry-core or auger the pavement at least every 0.25 mile (or in between every 0.50 mile boring) in the outside wheel path or center of lane. Alternate lanes between samples. Depending upon consistency of structural section, coring frequency may have to be increased –especially to delineate the start and end point of atypical thick or thin sections. If depth variation is suspected transversely, coring at the centerline and/or edge of pavement may also be necessary. Record pavement thickness (nearest 0.25-inch) and quality (i.e. solid core, stripping, etc.). Record presence, thickness (nearest 0.50-inch), and visual quality of base. Record location (milepost or station) at each core site. As appropriate, complete DCP testing into the base and subgrade. Patch core holes with cold mix as acceptable to the agency and COTR.

Typical Requirements for Test Pits:

Excavate enough test pits in order to adequately represent the different conditions and materials of the roadway. Typically 2 to 5 test pits will be excavated depending upon project length and material variability. Data from the above core sampling should be used to strategically choose test pit locations (i.e. significant changes in pavement thickness or type, areas of soft subgrade, differing base or asphalt material, etc.). Excavate test pits to the full-depth of the pavement structure and into the subgrade. Excavate the test pits along the outside wheel path if significant rutting is present (in order to determine origin of rutting), otherwise excavate in the center of the lane or near the pavement edge. At each test pit, record the location, thickness of the pavement layers (asphalt layer depth to the nearest 0.25 inch; base and/or subbase depths to the nearest 0.50 inch), a visual description of the pavement, soil, and base, and their moisture conditions. Additionally, at each test pit, gather and retain the following materials for completing a preliminary recycling/reclamation mix design.

Typical quantities of materials to gather:

- 3 lbs. sample of subgrade soil placed in an air tight baggy for in-situ moisture content testing
- 150 lbs of asphalt (in 5-gallon buckets)
- 160 lbs. of base (in 5-gallon buckets)
- 120 lbs. of subgrade (in 5-gallon buckets)

Replace and compact the excess material in the test pit. Place and compact 4 inches of cold mix or the equivalent thickness of the existing pavement, whichever is greater.

The preliminary mix design(s) should confirm the feasibility of in-place recycling/reclamation, structural coefficient, and determine the optimum stabilizing agent(s) and optimum percentage rate of stabilizer(s) to use. The CFLHD Pavement Section can be contacted for mix design requirements and methods. Reference 4, 6, 8, and 9 below also contain guidelines for mix design requirements. If a stabilizing additive is not being proposed, classification (AASHTO & USCS) and gradation of the existing base material is typically all the testing that is necessary.

VII. References:

1. 1996 Federal Lands Highway Project Development and Design Manual (FLH PDDM) available via CFLHD Project Development Home Page. http://www.wfl.fhwa.dot.gov/design/manual/

2. AASHTO Guide for the Design of Pavement Structures (1993 edition)

3. Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects, FP-96 or FP-03.

4. Basic Asphalt Recycling Manual, 2001 edition, Federal Highway Administration, publication NHI01-22.

5. Distress Identification Manual for the Long-Term Pavement Performance Project, Federal Highway Administration, Turner-Fairbanks Highway Research Center, Publication No.FHWA-RD-03-031, June 2003. Available online at http://www.tfhrc.gov/pavement/ltpp/reports.htm

6. Wirtgen Cold Recycling Manual, 2nd Revision, September 2001, Windhagen, Germany, ISBN 3-936215-00-6.

7. Techniques for Pavement Rehabilitation, Reference Manual, Federal Highway Administration, National Highway Institute, Publication No. FHWA HI-98-033.

8. "Full Depth Reclamation – A Century of Advancement for the New Millennium". Guidance brochure available at www.arra.org or by calling (410) 267-0023.

9. Soil-Cement Laboratory Handbook. Portland Cement Association. Copyright 1992. Available at www.portcement.org.

10. Concrete Engineering of Streets and Local Roads – A Reference Manual. ACPA TB200P. Available at www.pavement.com.

U.S. Government references can be obtained from the National Technical Information Service (NTIS), Springfield, VA 22161, (703) 487-4650, http://www.ntis.gov/. FHWA references are available from the FHWA Reports Center, 9701 Philadelphia Ct., Unit Q, Lanham, MD 20706, (301) 577-0818, FAX (301) 577-1421. All other references must be obtained from their respective sources. AASHTO publications can be ordered by calling 1-(800)-736-9014.