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DEPARTMENT OF TRANSPORTATION
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TRANSMITTAL LETTER

PUBLICATION:
Publication 242

DATE:
June 01, 2015

SUBJECT:

Pavement Policy Manual
Publication 242
May 2015 Edition

INFORMATION AND SPECIAL INSTRUCTIONS:

Publication 242 (Pavement Policy Manual) is to be re-issued with this letter. The enclosed May 2015 Edition represents a complete publication. This Edition supersedes the April 2010 Edition and all subsequent changes. The effective date of the May 2015 Edition is June 1, 2015.

These new guidelines should be adopted on all new and existing projects as soon as practical without affecting any letting schedules.

This release incorporated outstanding Strike-off Letters issued through February 28, 2015. Strike-off Letters issued on or after March 1, 2015 are still effective until they are incorporated into this publication via a change to the initial edition.

CANCEL AND DESTROY THE FOLLOWING:

Publication 242 (April 2010 Edition and all associated changes)

SOL 420-00-19 (Apr. 26, 2000)
SOL 465-10-01 (Feb. 3, 2010)
SOL 465-10-04 (May 7, 2010)
SOL 482-13-15 (Jul. 12, 2013)
SOL 495-13-05 (Jul. 16, 2013)
SOL 482-14-07 (Feb. 26, 2014)
SOL 482-15-06 (Feb. 5, 2015)
SOL 495-15-02 (Feb. 27, 2015)

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Publication 242
PAVEMENT POLICY MANUAL

May 2015 Edition

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PUBLICATION 242 - PAVEMENT POLICY MANUAL
LIST OF CHANGES
MAY 2015 EDITION

The major revisions for this new edition are listed below with a cross-reference to the sections in the old edition that it replaces. Since all minor changes are not indicated, it is strongly advised that all recipients thoroughly examine the changes and revisions incorporated into this new edition.

MAY 2015 EDITION:		**PREVIOUS LOCATION:**
GENERAL		
	• Updated references for Central Office Bureaus, Divisions and Sections based upon recent Highway Administration reorganization.	All Sections
	• Updated references to PennDOT publications to include the publication number and the title.	All Sections
	• Updated references to Chapters and Sections for consistency throughout the publication.	All Sections
	• Updated terminology pertaining to designations of concrete pavements.	All Sections
	• Deleted references to Non-Expressway Pavement Preservation (NEPP) Guidelines.	All Sections
FOREWORD		
	• Added the heading "FOREWORD" to group Purpose, Scope, and Background under it.	Purpose, Scope, Background
	• Incorporated SOL 482-14-07, "Pavement Design Review Approval".	
TABLE OF CONTENTS		
	• Updated to incorporate changes	Table of Contents
CHAPTER 1	GENERAL GUIDELINES AND POLICIES	Chapter 2
	Deleted previous Section 2.3, "Interstate Maintenance Program".	2.3
	Deleted previous Section 2.4, "Pavement Preservation Guidelines".	2.4
	Deleted previous Section 2.5, "I-4R Technical Guidelines".	2.5
1.1	Field Inspection	2.1
	• Revised first paragraph, last sentence to indicate the minutes from the Engineering and Environmental Scoping Field View will include the notes from the pavement project scoping team's field inspection.	
	• Added first sentence in second paragraph regarding who should be invited to Scoping Field Views for proposals/projects involving major pavement rehabilitation or reconstruction.	
	• Deleted third paragraph regarding information to be provided prior to a Scoping Field View.	
	• Deleted second sentence in fourth (now third) paragraph regarding how actions from Scoping Field View impacts drainage, guide rail, etc.	
	• Added fourth paragraph regarding pavement warranty information.	
1.2	Pavement Review Teams	2.2
	• Deleted first five sentences in first paragraph pertaining to I-4R Review Teams.	

1.3	Design Criteria • Added/revised discussion pertaining to New Construction and Reconstruction projects, Resurfacing, Restoration, and Rehabilitation (3R) projects, and Pavement Preservation projects.	NEW
1.4	Value Engineering Proposals • Added four sentences in first paragraph to reference Design and Construction VE procedures in other PennDOT Publications (Refer to SOL 482-14-29.). • Added text at the end of the third paragraph that when applicable, the FHWA will have to approve any deviation from the criteria established in this Manual.	2.6
CHAPTER 2	PROJECT CONSIDERATIONS	Chapter 3
	Deleted previous Section 3.1.1, "Public Relations".	3.1.1
2.1.A	Temporary Traffic Control Considerations • Replaced the previous subsection heading, "Detours". • Inserted first sentence in second paragraph to reference Publication 46 regarding advantages and disadvantages relative to detouring traffic or maintaining traffic through the work zone. • Deleted sentence about maintaining four lanes of traffic on multi-lane highways throughout the construction project.	3.1.2
2.1.B	Project Scope of Work • Added references in Item 1 for mechanized bituminous patching. • Added references in Item 2 to Publication 408 Sections for Item c (slabjacking), Item d (slab stabilization), Item g (joints) and Item h (cracks). • Updated Item 2.j (Friction Characteristics) • Added Item 2.k (Cross-Stitching). • Deleted Item 3.a (Joints and Cracks), relabeled all subsequent items, and added Item 3.c (Bituminous Overlay Considerations). • Added two sentences for Item 3.b (Leveling Course). • Updated reference from the Federal-Aid Manual to FHWA's website for The Federal-aid Highway Program Policy Guidance Center (PGC).	3.1.3
2.1.C	Restricted Performance Specification • Added reference to Warm Mix Asphalt in Publication 408, Section 411. • Revised Item 2 to clarify location for minimum surface course thicknesses (Table 9.5) and to use leveling course for surface corrections and cross slope adjustments. • Added four items in second paragraph to identify criteria for Reinforced or Plain Concrete Cement Pavements, RPS specifications.	3.1.4
2.1.D	Recycling Existing Pavement Materials • Added reference to PA DEP recycled asphalt products General Permit with Reference to Publication 611, *Waste Management Guidance Manual*.	3.1.5
2.1.E	Full Depth Reclamation • Added this section about this pavement rehabilitation technique. The full flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized, or blended, resulting in a stabilized base course (Refer to SOL 420-00-19.).	NEW

2.2	Subgrade Soil Evaluation • Moved fourth paragraph with guidance for an additional pavement subgrade evaluation to Section 6.2.F.	3.2
2.3.A	Basic Principles of Drainage • Replaced second sentence in Item 5 for base drain outlets; added Item 6 for lateral underdrains.	3.3.1
2.3.C	Interstates • Inserted fifth sentence to state subgrade drains should also be considered where the existing roadway shows evidence of water damage and in sag areas.	3.3.3
2.3.D	Non-Interstates • Added seventh sentence to state subgrade drains should also be considered where the existing roadway shows evidence of water damage and in sag areas.	3.3.4
2.5	Cross Slopes • Revised entire section, including references to DM-2, Sections 1.2 and 1.3.	3.5
2.7	Brick Pavements • Added third and fourth sentences in first paragraph regarding aesthetics, historical significance, and cultural significance of brick pavements. • Added fifth and sixth sentences in second paragraph pertaining to structural coefficients.	3.7
2.8	Experimental Pavement Construction • Updated discussion regarding the use of items for experimental pavement construction.	3.8
2.8.A	Stress-Absorbing Membrane and Stress-Absorbing Membrane Interlayer • Inserted second sentence in first paragraph regarding placement. • Added Item 5 to state how pavement designs must include sufficient depth of material.	3.8.1
2.8.B	Geosynthetics in Pavement Structures • Deleted third paragraph regarding use of geogrids for experimental projects. • Deleted fourth paragraph regarding questions concerning soil reinforcement design or geosynthetic standards.	3.8.2
CHAPTER 3	PAVEMENT TYPE DETERMINATION • Incorporated SOL 495-15-02, "Chapter 11, Pavement Type Selection".	Chapter 11
3.1.A	Pavement Type Selection Factors • Deleted wording in second paragraph, second sentence after "Form D-4332"; added third sentence to refer to Chapter 6 for additional information regarding submission and approval procedures.	11.1
3.2	Life-Cycle Cost Analysis Guidelines • Inserted separate sentences stating the Discount Rate and the Asphalt Adjustment Multiplier (AAM) can be found in the ECMS File Cabinet.	11.2
---	Stopped Vehicles	DELETED (11.5.2)
---	Example Calculations	DELETED (11.5.3)
---	Added Time	DELETED (11.5.4)
---	Cost Factors	DELETED (11.5.5)

---	Inflation Factor	DELETED (11.5.6)
---	Example Calculations	DELETED (11.5.7)
3.6.A	Alternate Pavement Type Bidding Project Selection	11.6.1
	• Revised Conceptual Bidding Presentation Example for ECMS.	
CHAPTER 4	PORTLAND CEMENT CONCRETE PAVEMENT GUIDELINES AND POLICIES	Chapter 4
General	Changed "spall repair" to "partial-depth repair".	Chapter 4
4.1.B	Sequence of Construction	4.1.2
	• Revised order / added three items for sequence of construction for CPR projects.	
4.2.D	Exemption Criteria: Substitution of Flexible Base Replacement for Jointed Plain Cement Concrete Pavement (PCC) for Full Depth Patching Material	4.2.4
	• Replaced Hot Mix Asphalt (HMA) with Flexible Base Replacement. • Deleted Items 1 and 4; renumbered all remaining items. • Deleted portion of Item 6 referring to FHWA Pavement Policy provisions.	
4.3.A	General Guidelines	4.3.1
	• Deleted third sentence stating full-depth concrete pavement patching should be performed when spall repair exceeds 5 SF at a transverse joint.	
4.3.B	Joint Cleaning and Sealing	4.3.2
	• Deleted second paragraph in Item 4, Transverse Joint Cleaning and Sealing. • Added Item 5, Dowel Retrofit and Item 6, Cross-Stitching.	
4.4	Concrete Pavement Partial-Depth Repair	4.4
	• Updated Section to be consistent with Publication 408, Section 525.	
4.7	Diamond Grinding and Grooving	4.7
	• Inserted fourth sentence in first paragraph to provide a positive cross slope such that the pavement drains including shoulder area as necessary. • Added fifth paragraph for grooving and sixth paragraph for concrete slurry.	
4.8	Widening and Lane Additions	4.8
	• Deleted Item 5; renumbered all subsequent items.	
4.9	Rehabilitation (previously titled Overlays)	4.9
	• Added Item 6 regarding cracking and seating and breaking and seating (Section 4.9.B). • Revised minimum thickness from 3.5 inches to 4 inches for all bituminous overlays on concrete (Section 4.9.C). • Provided additional/ revised guidance for bonded overlays (Section 4.9.D.1) and unbonded overlays (Section 4.9.D.2). • Moved section for cracking/breaking and seating the existing pavement from Section 4.10.B to Section 4.9.E. Provided definitions for cracking and breaking concrete pavements. • Moved section for rubblizing the existing pavement from Section 4.10.C to Section 4.9.F. Clarified that the District Pavement Engineer will determine whether to specify a Type 1 or Type 2 rubblization.	
4.10	Reconstruction	4.10
	• Inserted sentence to reference Chapter 2 for addressing drainage and/or subgrade issues.	

CHAPTER 5	BITUMINOUS CONCRETE PAVEMENT GUIDELINES AND POLICIES	Chapter 5
5.1	Tack Coat/Prime Coat	5.1
	• Added Warm Mix Asphalt (WMA) after Hot Mix Asphalt (HMA).	
5.2	Seal Coats, Slurry Seals and Surface Treatments	5.2
	• Changed "leveling" to "scratch" in second paragraph, first sentence.	
5.4	Polymer-Modified Emulsified Asphalt Paving System (Micro Surfacing)	5.4
	• Labeled first and second paragraphs as Subsection A, General.	
	• Inserted fourth sentence in second paragraph (Subsection A, General) to indicate Micro Surfacing may be used for rut fill when the pavement distress is not related to base failure.	
5.4.B	Project Selection	NEW
5.4.C	Bid Package Considerations	NEW
5.4.D	Estimating Quantities	5.4
	• Moved text for what was third and fourth paragraphs in Subsection A, General and added label to indicate Subsection D, Estimating Quantities.	
Table 5.2	Polymer-Modified Emulsified Paving System Selection Guide	Table 5.2
	• Added WMA after HMA in Note 1.	
	• Added Note 5 to indicate the Current ADT for divided highways is based on one-way counts.	
5.4.E	Surface and Work Preparation	NEW
5.5	High Friction Surface Treatment (HFST)	NEW
	• Added new Section to describe how HFST is applied to short pavement sections that exhibit a need for increased pavement friction demand.	
	• Added reference to new Appendix (Appendix I).	
5.6	Longitudinal Joints	5.5
	• Split apart previous one paragraph for section into first, fifth, and sixth paragraphs.	
	• Incorporated SOL 424-10-02, "HMA Longitudinal Joint Density Incentive Disincentive Specification" (second, third, and fourth paragraphs) pertaining to usage instructions for design-project selection.	
5.7	Providing Friction in Bituminous Wearing Courses	5.6
	• Modified sixth paragraph, second sentence to indicate the design of inappropriately high SRL designations will be prohibited on non-wearing courses, leveling courses, and shoulders. Deleted reference to short duration temporary roadways.	
5.8.D	Permissive Policy for Superpave HMA Paving Courses	NEW
	• Incorporated SOL 495-13-05, "Warm Mix Asphalt (WMA) Policy and Specifications".	
Table 5.5	Selecting PG-Binders for Conventional and Superpave Pavement Courses	Table 5.5
	• Deleted second column (Cross Reference to Old Viscosity Grading System).	
	• Deleted first sentence in note with asterisk regarding the cost of PG 76-22 binder.	
5.11	Overlays	5.10
	• Added two paragraphs similar to Section 4.9 and before Section 5.10.A.	
5.11.A	Pre-Overlay Surface Preparation	5.10.A
	• Inserted first paragraph to place separate scratch or leveling course ahead of resurfacing operations.	
	• Modified second and third paragraphs to clarify how to use leveling courses.	

5.11.B Thin Bituminous Overlays 5.10.B

- Added text in sixth bullet to place thin bituminous overlays per the pavement depth limitations stated in Table 9.5.

5.11.D Safety Edge NEW

5.13 Stone Matrix Asphalt Wearing Course NEW

- Added section, including steps required to obtain a satisfactory SMA mixture, additional guidance and recommendations regarding its use, and construction requirements.

5.14 Full Depth Reclamation Techniques NEW

- Added section, including selection of projects, material design, and quality control.
- Added Table 5.7, Selection of Full Depth Reclamation (FDR).

CHAPTER 6 PAVEMENT DESIGN PROCEDURES Chapter 6

- Incorporated SOL 482-14-07, "Pavement Design Review Approval".
- Incorporated SOL 482-13-15, "Pavement Design Review Approval".

6.1.C What to Submit (SOL 482-13-15) 6.1.3

- Inserted Item 4; added Items 12 and 13.

6.1.D Procedures (SOL 482-13-15) 6.1.4

- Deleted Table 6.1, "Pavement Design Approval Authority". Renumbered all subsequent tables.

6.1.D.1 General 6.1.4

- Added three sentences at end of first paragraph to indicate Form D-4332 is not submitted when a project is scoped as minor and a consultant is performing final design activities.
- Clarified in fourth paragraph, first sentence to submit all pavement design changes following the original pavement design submission to the original approving authority.

6.1.D.2 PennDOT Oversight Projects (SOL 482-13-15 & SOL 482-14-07) 6.1.4

- Inserted fourth paragraph, second sentence stating all projects designated PennDOT Oversight are eligible for QA Review.
- Clarified in fourth paragraph that QA visits, QA reviews, and QA checklists involve PennDOT Oversight.
- Modified fifth paragraph, first sentence to indicate the type determination procedure is not required on PennDOT oversight projects with less than 30,000 square yards of mainline pavement surface work.
- Added sixth paragraph indicating all deviations from Pub. 242 must be submitted as a waiver to BOPD and that BOPD coordination with FHWA is required on all Federal-aid projects.

6.1.D.3 Federal Oversight Projects (SOL 482-13-15 & 482-14-07) 6.1.4

- Revised / added text.

6.1.D.4 Pavement Preservation Projects (SOL 482-13-15 & SOL 482-14-07) 6.1.4

- Deleted Table 6.1, Pavement Design Approval Authority.
- Modified third paragraph to indicate the District PME is to re-verify the scope of work when the Pavement Type Selection approval date exceeds 15 months.
- Inserted fourth paragraph indicating all deviations from Pub. 242 must be submitted as a waiver to BOPD and that BOPD coordination with FHWA is required on all Federal-aid projects.

	• Added Figure 6.1 of flowchart process for PennDOT Pavement Design Approval.	
6.2	Subgrade Soils	6.2
	• Added sentence for designer to refer to Section 2.2 for project considerations when evaluating the condition of the subgrade soil.	
6.2.A	Resilient Modulus	6.2.1
	• Deleted/modified text related to MFC (multiple locations). • Revised paragraph about seasonal resilient modulus values.	
6.2.A.2	Laboratory CBR (SOL 482-15-06)	6.2.1
	• Established updated requirements related to California Bearing Ratio (CBR) evaluation and resilient modulus determination.	
6.2.A.3	Falling Weight Deflectometer (FWD)	6.2.1
	• Inserted second and third paragraphs for determining M_r.	
6.2.A.4	Field Dynamic Cone Penetration (DCP)	6.2.1
	• Inserted first, second, and third sentences to describe a DCP test.	
6.2.B	Frost Design	6.2.2
	• Added sentence at the end of the sixth paragraph about where to find the Frost Heave spreadsheet tool on PennDOT's website.	
6.2.D	Geogrids	NEW
6.2.E	Geotextiles	NEW
6.2.F	Reconstruction Projects	2.2
CHAPTER 7	TRAFFIC ANALYSIS FOR PAVEMENT DESIGN	Chapter 7
	• Incorporation of SOL 465-10-04, "Use of the new FHWA 13 Vehicle Classification Breakdown in RMS".	
7.1	Traffic Analysis for Pavement Design	7.1
	• Added sentence at the end of the first paragraph about where growth rates are available.	
7.1.B	All Functional Classes of Highways	7.1.2
	• Added second sentence to allow 24-hour one-way vehicle counts on a divided highway.	
7.1.E	Percent Trucks in Design Direction	7.1.5
	• Added fourth sentence to specify a directional factor of 100% for one-way ADT counts.	
7.1.F.1	All Functional Classes of Highways	7.1.6
	• Modified first two paragraphs to specify 24-hour portable or 8-hour manual truck classification survey. • Added third, fourth and fifth paragraphs. • Added Table 7.4, Average Initial Truck Factors (ESALs/Truck) by Vehicle Class	
CHAPTER 9	FULL-DEPTH FLEXIBLE PAVEMENT DESIGN	Chapter 9
9.3	Terminal Serviceability	9.3
	• Added sentence at the end of Item 1 about where to find the Frost Heave spreadsheet tool on PennDOT's website.	
Table 9.1	Estimated Average Rate of Heave (Unified Soils Classification System)	Table 9.1

Table 9.2	Estimated Average Rate of Heave (AASHTO Soils Classification System)	Table 9.2
	• Added text in note with one asterisk to clarify how to classify MFC C, MFC D, and MFC E pavement designs.	
Table 9.3	Structural Coefficients for Materials in Flexible Pavements	Table 9.3
	• Added four structural coefficients for Full Depth Reclamation under the pavement component of Existing Materials to be Overlaid.	
Table 9.6	Suitability of Materials for Specific Application Based on Highway ADT	9.3
	• Deleted table; referenced Table 10.3 instead.	
CHAPTER 10	PAVEMENT OVERLAY DESIGN	Chapter 10
	• Revised numbering of subsections.	All Sections
	• Revised numbering and location of Tables.	All Sections
10.1	General	New Heading
	• Added sentence at end of sixth paragraph describing thickness of pavement course and appropriate Superpave mixture size for scratch and leveling.	
	• Added ninth paragraph regarding how to determine thicknesses for bonded concrete overlays of asphalt pavement and bonded concrete overlays of AC/PCC (composite) pavement using the bonded concrete overlay of asphalt mechanistic-empirical design procedure (BCOA-ME).	
Table 10.5	Superpave Scratch and Leveling Course Thicknesses	Table 10.7
	• Revised multiple thicknesses of pavement courses.	
Table 10.10	Minimum and Maximum Thickness for Concrete Overlays	NEW
	• Provided overlay types, minimum and maximum thicknesses, typical joint spacings, and applicable standard specifications.	
10.7	Unbonded PCC Overlay of PCC Pavement	10.6
	• The paragraph explains why the "Concrete Overlay - Unbonded - Crack and Seat" Section has been removed from this Chapter under the discretion of the Department.	
10.8	Unbonded PCC Overlay of AC Pavement	10.7
	• Replaced Ultra-Thin Whitetopping (UTW) with Unbonded or Bonded Concrete Overlays on Asphalt or Composite Pavements.	
CHAPTER 11	PAVEMENT MANAGEMENT	Chapter 12
	• Moved Section 11.2 to Section 12.2. Renumbered all subsequent Sections.	All Sections
	• Moved FHWA Memorandum for Pavement Preservation Definitions to Chapter 12, Appendix A.	
11.1	Introduction	11.1
	• Inserted fifth paragraph from Section 12.1 about Section 119(e) of Title 23 USC.	
CHAPTER 12	PAVEMENT PRESERVATION GUIDELINES	Appendix G
• Revised numbering of subsections.		All Sections
12.1	Pavement Preservation Project Selection Guidelines	I
	• Moved last sentence in first paragraph about Section 119(e) of Title 23 USC to Section 11.1.	
	• Removed reference in first paragraph to Publication 23, *Maintenance Manual*.	
	• Inserted second sentence in second paragraph with reference to Chapters 11 and 13.	

12.2	Pavement Preservation Project Criteria • Added two paragraphs before Section 12.2.A referring to FHWA's definitions for Pavement Preservation and AASHTO's definition for preventive maintenance.	NEW
12.2.A	Typical Pavement Preservation Treatments • Described flexible pavement treatments and rigid pavement treatments.	NEW
12.2.B	General Guidance for Pavement Preservation Projects • Added five bulleted items.	NEW
12.2.B	Technical Guidance for Pavement Preservation Projects • Deleted Item 1 to extend the pavement life for a minimum of 8 years. • Renumbered subsequent Items 2 and 3 to Items 1 and 2. • Deleted Item 4 to incorporate milled shoulder rumble strips. • Renumbered subsequent Item 5 to Item 3. • Deleted Items 6 and 7 about pavement/shoulder cross slopes. • Renumbered subsequent Item 8 to Item 4; revised this item to correct pavement and/or shoulder edge drop-offs greater than 2 inches. Added sentence in Item 4 to refer to the discussion for safety edge in Chapter 5, Section 5.11.D. • Renumbered Item 10 to Item 6; referred to Publication 13M, Design Manual Part 2 (DM-2), *Highway Design* for updating all guide rail systems, barrier systems, end treatments, guide rail to bridge barrier approach transitions, and impact attenuating devices. Deleted subsections a through f. • Added Items 7 through 12. • Renumbered old Items 11 and 15 to Items 13 and 14. • Deleted old Items 12, 13, and 14.	II
12.2.C	Pavement Preservation projects will not do any of the following • Deleted previous Items 2, 3 and 4; renumbered previous Items 5 and 6 as Items 2 and 3.	II
12.3.A	Flexible Pavements • Added Item 4 for cold in-place recycling and Item 5 for Bonded Concrete Overlay of Asphalt.	II
12.3.C	Bridge Preservation • Revised to refer to Publication 15M, Design Manual Part 4, *Structures*, Section PP5.6.1.	II
12.4	Project Scoping Field View • Added sentence to document the Scoping Field View. • Deleted last two sentences to distribute field view minutes and to submit them with the PS&E package.	III
12.5	Pavement Type Selection Submission Requirements • Modified Item 1 to document the Scoping Field View in the CE Expert System. • Added Items 7 and 8. • Added sentence at end of second paragraph with reference to Chapter 6.	IV
12.6	Bridge Submission Requirements • Replaced reference to SOL 430-09-15 with more generic description.	V
12.7	100% State Funded Pavement Preservation Guidelines • Deleted Section II.A.1 (to extend pavement life for a minimum of 5 years). • Removed rows with information for guide rail and barrier and for guide rail bridge end connections. Guidance is intended to be published in a future update for Publication 13M, Design Manual Part 2, *Highway Design*.	Not Labeled

12.8	Non-Expressway Pavement Preservation Guidelines	DELETED (VI)
12.9	NEPP Project Criteria	DELETED (VII)
12.10	Design Guidelines	DELETED (VIII)
12.11	Project Scoping Field View	DELETED (IX)
12.12	Pavement Type Selection Submission Requirements	DELETED (X)
Appendix A	FHWA Pavement Preservation Memorandum	Chapter 11
CHAPTER 13	INTERSTATE MANAGEMENT PROGRAM GUIDELINES	Appendix I
CHAPTER 14	PENNSYLVANIA'S ROADWAY MANAGEMENT SYSTEM	Chapter 1
	• Incorporated SOL 465-10-01, "Roadway Management System (RMS), Pavement History Quality Assurance and Verification Processes".	
14.1	Roadway Management System Overview	1.1
	• Added fifth sentence at the end of the first paragraph. • Deleted reference to 3R and 4R in the third paragraph, eighth sentence.	
14.2	RMS Pavement History Update Policy	1.2
	• Deleted first paragraph regarding the Pavement History Process Update Implementation Team (Refer to SOL 465-10-01.). • Modified what is now the first paragraph to note as PennDOT's Pavement History Update Process. Inserted second sentence noting how the Process establishes the Methods for tracking pavement projects and updating pavement data in RMS. • Deleted paragraph describing implementation of Pavement History Update Process and Project Tracking Sheets. • Added fourth through sixth paragraphs and Figures 14.1 through 14.2 (Refer to SOL 465-10-01.).	
14.3	Pavement Condition Information – STAMPP Program	1.3
	• Deleted sixth paragraph to reference FHWA Memorandum, "Preventive Maintenance Eligibility".	
APPENDIX G	PENNDOT OVERSIGHT PAVEMENT DESIGN QUALITY ASSURANCE REVIEWS POLICY AND PROCEDURE (revisions in SOL 482-14-07)	Appendix H
APPENDIX H	INTERSTATE MANAGEMENT PROGRAM PAVEMENT MATRIX	Appendix J
APPENDIX I	HIGH FRICTION SURFACE TREATMENT USAGE GUIDE	NEW
APPENDIX J	DEVELOPING STANDARDS AND SPECIFICATIONS FOR FULL DEPTH RECLAMATION: A BEST PRACTICES GUIDE	NEW
APPENDIX K	ABBREVIATIONS	Not Labeled as Appendix

APPENDIX L	GLOSSARY	Not Labeled as Appendix

(NOTE: Eliminated the Index. Users can select the search feature in Adobe to locate information.)

TABLES REVISED

TABLE 3.1	Hourly Percentages of Total Vehicles (was Table 11.1)	DELETED
TABLE 3.2	Roadway Capacity (was Table 11.2)	DELETED
TABLE 3.3	Added Time and Vehicle Running Costs Per 1000 Stops, and Idling Costs (was Table 11.3)	DELETED
TABLE 3.1	Standard Production Rates for Maintenance Activities	NEW
TABLE 6.1	Pavement Design Approval Authority	DELETED
TABLE 6.1	Typical Compacted Dry Density and Optimum Moisture Content Range of Soils (Based on FHWA NHI-05-037) (Was Table 6.1A in SOL 482-15-06.).	NEW
TABLE 6.2	Typical CBR Values (Based on NCHRP Project 1-37A) (Was Table 6.1B in SOL 482-15-06.).	NEW
TABLE 6.3	PSI Descriptive Scale	TABLE 6.2
TABLE 6.4	TSI Values for Each MFC	TABLE 6.3
TABLE 6.5	Reliability by Functional Classification	TABLE 6.4
TABLE 7.4	Average Initial Truck Factors (ESALs/Truck) by Vehicle Class	NEW
TABLE 9.6	Suitability of Base Course for Specific Application Based on Highway ADT	DELETED
TABLE 10.1	Suitability of Leveling Course for Specific Applications Based on Highway ADT	TABLE 10.5(a)
TABLE 10.2	Suitability of Wearing Course for Specific Applications Based on Highway ADT	TABLE 10.5(b)
TABLE 10.3	Suitability of Base Course for Specific Applications Based on Highway ADT	TABLE 10.5(c)
TABLE 10.4	Bituminous Material Thicknesses for Overlays	TABLE 10.6
TABLE 10.5	Superpave Scratch and Leveling Course Thicknesses	TABLE 10.7
TABLE 10.6	Methods to Estimate the Existing Structural Capacity	TABLE 10.1
TABLE 10.7	SN for Future Traffic, SN_f	TABLE 10.2
TABLE 10.8	Pavement Thickness for Future Traffic, D_f	TABLE 10.3
TABLE 10.9	Effective Existing Thickness, D_{eff} Condition Survey Method	TABLE 10.4
TABLE 10.10	Minimum and Maximum Thickness for Concrete Overlays on Existing Concrete Pavements (was Table 10.8)	DELETED
TABLE 10.10	Minimum and Maximum Thickness for Concrete Overlays	NEW
TABLE 11.1	High-level Bituminous Roadways (Resurfacing Network)	TABLE 12.1
TABLE 11.2	Low-level Bituminous Roadways (Seal Coat Network)	TABLE 12.2
TABLE 11.3	Concrete Pavements	TABLE 12.3
TABLE 11.4	Unpaved Roads	TABLE 12.4
TABLE 11.5	Surface Improvement Miles State and Federal Dollars in Appropriations 10582	TABLE 12.5
TABLE 11.6	Surface Improvement Categories	TABLE 12.6
TABLE 11.7	Evaluation of Premature Failures	TABLE 12.7

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PAVEMENT POLICY MANUAL

OUR MISSION:

To support Highway Engineers and Practitioners with technological leadership, statewide quality standards, policy and procedural guidelines for the design of safe, cost effective and structurally reliable pavements. Moreover, to provide for the needs of each facility type, while providing a maintenance friendly design in an environmentally sensitive manner.

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PAVEMENT POLICY MANUAL

TABLE OF CONTENTS

CHAPTER 5 BITUMINOUS CONCRETE PAVEMENT GUIDELINES AND POLICIES

CHAPTER 6 PAVEMENT DESIGN PROCEDURES

CHAPTER 7 TRAFFIC ANALYSIS FOR PAVEMENT DESIGN

CHAPTER 8 RIGID PAVEMENT DESIGN

CHAPTER 9 FULL-DEPTH FLEXIBLE PAVEMENT DESIGN

CHAPTER 10 PAVEMENT OVERLAY DESIGN

CHAPTER 11 PAVEMENT MANAGEMENT

CHAPTER 12 PAVEMENT PRESERVATION GUIDELINES

CHAPTER 13 INTERSTATE MANAGEMENT PROGRAM GUIDELINES

CHAPTER 14 PENNSYLVANIA'S ROADWAY MANAGEMENT SYSTEM

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LIST OF FIGURES

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LIST OF TABLES

FOREWORD

PURPOSE

The *Pavement Policy Manual* is the Pennsylvania Department of Transportation's (PennDOT's) working document for all pavement design (pertaining to new construction, reconstruction, rehabilitation, maintenance, and preservation) and associated policy issues. Statewide adherence to this Manual is expected. Although the term "guidelines" is used within the document, it is only with respect to areas where engineering judgment may be exercised as specifically noted in this Manual.

Also all tables, graphs and charts in this Manual are considered policy. Adherence to these policies is not optional.

Furthermore, note that Publication 242 is in accordance with the requirements set forth by the Stewardship and Oversight Agreement. Section V of the agreement states that "PennDOT will develop Federal-Aid projects in accordance with the standards and guides identified in 23 U.S.C. 109, 23 CFR 625 - *Design Standards for Highways* (as well as other FHWA policies identified in the Federal Register, the Federal-Aid Policy Guide and elsewhere) and/or PennDOT standards or manuals approved by FHWA". In accordance with these requirements, any and all deviations or waivers from the policies set forth within Publication 242 must attain Central Office approval before submission to FHWA for review and concurrence.

Furthermore, any and all deviations or waivers from the policies set forth within Publication 242 must attain Central Office approval for all 100% state funded projects.

It is the intent of this Manual to supersede all previous Strike-Off Letters, and any other letter establishing policy pertaining to pavements.

SCOPE

These policies, guidelines and procedures apply to all projects administered by PennDOT regardless of the origin or source of funding, such as Safety, Capital Budget, Maintenance Betterment and Rehabilitation work. This includes work by both PennDOT and contractors. Projects will not be let if concurrence has not been provided for a pavement design. Furthermore, all Federal Oversight pavement designs shall have the concurrence of the Federal Highway Administration (FHWA) prior to advertisement.

Municipalities that have resurfacing projects on local roads utilizing their own tax dollars may continue to use the criteria they deem appropriate for their specific circumstances**;** however, all State funded projects, including Liquid Fuel Funds, regardless of jurisdiction, are required to follow this Manual and other appropriate State policies, specifications and regulations.

BACKGROUND

The pavement design policies, guidelines, and procedures presented in this manual incorporate data from the AASHO Road Test and The Pennsylvania State University (PSU) test track. Other scientific studies, engineering judgment and PennDOT's own experience have been applied to accommodate anticipated conditions in Pennsylvania. Additional research related to pavement structures in Pennsylvania is continually being performed. Modifications to these policies, guidelines and procedures will be made when appropriate.

The expected life of any pavement structure is a function of several parameters. These parameters include such pavement variables as anticipated 18-kip equivalent single-axle load (ESAL) applications, subgrade bearing capacity, drainage, pavement materials, construction specifications, and construction procedures and conditions. They also include such highway characteristics as maintenance operations, the effect of slow-moving traffic, acceleration and deceleration of traffic, grades, curves and the initial serviceability index. Also among these parameters are such environmental characteristics as the number of freeze/thaw cycles, water flow through the pavement structure and soil conditions. However, there may be other parameters, not currently identified, that may also affect the expected life of a pavement.

Due to the extremely complex interrelationship of the various parameters and the absence of effective quantitative measurement of some of the above parameters, a pavement design method was established as a result of the AASHO Road Test conducted in Ottawa, Illinois, from 1956 to 1960. The primary objective of the Road Test was to determine significant relationships between the number of repetitions of specified axle loads of different magnitudes and arrangement and the performance of various pavement structures on a subgrade soil of known characteristics. For this reason, the magnitude and arrangement of axle loads were varied in a controlled manner. Highway Research Board (HRB) Reports 61A through 61G and 73 describe the Road Test thoroughly.

Because additional research was required to more adequately associate AASHO Road Test data with conditions in Pennsylvania, PennDOT contracted PSU to perform Research Project No. 71-7, *An Evaluation of Pennsylvania's Flexible Pavement Design Procedure*. In 1972, the Pennsylvania Transportation Institute (PTI) of PSU constructed a 1-mile test track facility in State College, Pennsylvania. The primary objective of this road test track was to evaluate better the structural coefficients of the treated base courses used by PennDOT. The study was completed in 1974. This document has been updated to reflect the most current AASHTO design procedure. The AASHTO 1993 *Guide for Design of Pavement Structures* which is accompanied by the AASHTOWare® DARWin® 3.01 Pavement Design method is used in this document.

The policies, guidelines and procedures contained in this Manual have been developed to apply to general statewide situations. ***This Manual does not preclude the application of sound engineering judgment for any unusual situations or problems that may be encountered on a specific project.*** All deviations from these policies and procedures MUST be documented. If exceptions to these policies and procedures are required, approval must be received from the Bureau of Project Delivery and, when applicable, the Federal Highway Administration (FHWA), regardless of the size of the project and whether a submission is required or not.

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CHAPTER 1

GENERAL GUIDELINES AND POLICIES

1.1 FIELD INSPECTION AND PAVEMENT WARRANTY REVIEW

The first step of any pavement design analysis must be a field inspection of the proposed project site to collect information on pavement condition and all other pertinent features such as drainage, shoulders and geometry. This inspection should be made by walking the entire project. "Windshield" evaluations are not adequate. The information from the Roadway Management System (RMS) cannot be used to develop quantities for the detailed design of a project (see Chapter 14 for more information on RMS). A pavement project scoping team from design, construction and maintenance units, led by the unit responsible for the project design, should perform this field inspection. The District Pavement Management Engineer/Pavement Manager (PME/PM) shall make a separate field inspection of the project if unable to attend the field inspection with the others. The minutes from the Engineering and Environmental Scoping Field View will include the notes from the pavement project scoping team's field inspection, indicating the date, names of participants, either as a part of the team or independently, and a summary of their findings.

For proposals/projects involving pavement rehabilitation or reconstruction, the District PME/PM and the Bureau of Project Delivery (BOPD), Highway Design and Technology Section (HDTS), Pavement Design and Analysis Unit (PDAU) should be invited to Scoping Field Views. For all projects scoped, the following information should be reviewed and made available to the pavement project scoping team, prior to the Scoping Field View. Providing this information ensures that the most cost effective pavement strategy is selected, that safety is enhanced to the extent practical, and that the Pavement Preservation Guidelines (when applicable) are followed.

- Project limits (segments or mileposts).
- Pavement History data.
- Pavement Condition data, including International Roughness Index (IRI), distress types and severity. Also indicate if pavement distress is premature.
- For concrete pavement projects, estimated patching (in terms of percent of pavement area).
- Suggested treatment strategy defined in the annual State of the Interstate (SOI) report, along with the justification if a different treatment is proposed.
- Crash-cluster information.
- Pavement cross slope information.
- Traffic Data (ADT, % Trucks).

For Engineering and Environmental (E&E) Scoping Field View procedures, refer to Publication 10B, Design Manual Part 1B, *Post-TIP NEPA Procedures* and Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*.

For pavement warranty information, see Publication 448, *Innovative Bidding Toolkit* and Publication 408, *Specifications,* Section 496.

1.2 PAVEMENT REVIEW TEAMS

The Pavement Review Team is responsible for reviewing all projects that are "Federal Oversight" status. PennDOT Oversight or Federal Oversight status refers to the requirement of FHWA reviews of project documentation and plans.

The Pavement Review Team is made up of personnel from PDAU; the District PME/PM; the FHWA Area Engineer; and appropriate staff from the District.

1.3 DESIGN CRITERIA

The scope of work of a project determines which roadway design criteria apply for pavements. Each project must be adequately reviewed to ensure that the programmed costs and current estimated costs are consistent with the described scope of work.

Detailed roadway design criteria for new highway construction projects, along with the improvement of the existing highway system, are presented in Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 1, Section 1.2. The definitions below provide general guidance for when to follow specific roadway design criteria, especially as they pertain to pavement construction and pavement preservation.

A. New Construction and Reconstruction. New construction provides a facility that did not previously exist at that location. Reconstruction rebuilds an existing facility that may include substantial upgrading of major highway features.

Refer to Chapter 2 through Chapter 9 for guidance, with a focus on rigid pavement design in Chapter 8 and full-depth flexible pavement design in Chapter 9.

B. Resurfacing, Restoration, and Rehabilitation (3R). 3R work, which excludes freeways, is the improvement of an existing facility on similar alignment in order to extend the service life of the facility and/or improve the pavement structural and functional capacity. It typically does not contemplate capacity improvements, major realignment or major upgrading of geometric features. It may include selective improvements to highway geometry and other roadway features and safety appurtenances.

Typical 3R roadway projects include resurfacing (such as pavement overlays) which may add structural capacity to the pavement; refer to Chapter 10 for specific guidance.

C. Pavement Preservation. Pavement preservation projects are not intended to add structural capacity to the pavement. Pavement Preservation Guidelines are to be used on all Federal-aid and 100% state funded projects as applicable. Refer to Chapter 12 and Chapter 13 for further guidance.

When roadway design criteria above cannot be met (e.g., lane width, shoulder width, cross slope, superelevation, vertical clearance), a design exception shall be prepared with full justification provided for the retention, limited improvement, or partial mitigation of these features. For more detailed guidance regarding design exceptions, refer to the section on Design Flexibility in Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 3.

For technical guidance to update or replace guide rail systems, barrier systems, end treatments, bridge connections, and impact attenuating devices, refer to Publication 13M, Design Manual Part 2, *Highway Design*.

1.4 VALUE ENGINEERING PROPOSALS

Design Value Engineering (VE) is an important part of the design and construction process. Design VE procedures are outlined in Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix R. In Appendix R, Section R.1, Design Value Engineering Review, describes: (1) when a Design VE study is required and (2) when informal VE Studies are highly recommended on all Most Complex (Major) and Moderately Complex Projects. Construction VE procedures are discussed in Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 5.

The Pavement Type Determination (Section 3.2) may not be changed through the VE proposal. However, changes to the structural layout of the designed pavement type may be made. All proposed changes to the structural layout must be approved by HDTS and, when applicable, FHWA. Pavement type determination may not be changed since an economic analysis for type determination was already performed considering not only initial cost, but also maintenance and user delay costs over the life of that analysis period. The process is outlined and documented in Chapter 3.

Projects where an LCCA was not completed may be Value Engineered on a case by case basis. However, the proposed changes must adhere to this Manual. Therefore, if a pavement structure's cross section is changed from the indicated plans, then an appropriate new pavement design must be performed and approved by the District Executive, prior to the VE submission. Note that any deviation from the criteria established in this Manual will require the approval of HDTS and, when applicable, FHWA.

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CHAPTER 2

PROJECT CONSIDERATIONS

2.1 GENERAL

A. Temporary Traffic Control Considerations. Pavement design considerations for any project may be affected by the Maintenance and Protection of Traffic (MPT). Publication 213, *Temporary Traffic Control Guidelines*, provides guidance for the most common setup requirements for MPT.

FHWA has provided information of the advantages and disadvantages relative to detouring traffic or maintaining traffic through the work zone (refer to Publication 46, *Traffic Engineering Manual*, Chapter 6, Section 6.14). Detours provide the best possible construction environment. Traffic traveling over intermediate pavement layers and cold longitudinal paving joints contributes to poor pavement performance. However, detours are usually costly and not practical on most projects. Coordinate the use of detours, whenever one is possible and practical, with the District Traffic Unit. Required maintenance must be performed on the detour route before detouring traffic.

B. Project Scope of Work. The scope of the selected project should be in accordance with the Federal policy on pavement management and design (see FHWA's website for The Federal-aid Highway Program Policy and Guidance Center (PGC)) and other existing policies included in this Manual.

Each project presents unique conditions and problems that must be thoroughly evaluated and to which engineering judgment must be applied. The discussion presented here is generalized, but the concept should be followed to ensure that individual project conditions are addressed appropriately.

1. Bituminous Concrete Surfaces. Bituminous concrete pavement surfaces include all pavements with a bituminous concrete wearing surface, regardless of the base type. Concrete or brick pavements with mechanized bituminous patches are not considered bituminous concrete surfaces. For more information about mechanized bituminous patching, refer to Appendix L, Glossary and to Publication 23, *Maintenance Manual*, Chapter 7.

The following items should be evaluated when designing a project:

a. Drainage. The need to improve the removal of surface and subsurface water.

b. Base Repair. The need to remove areas of obvious failure and replace them with materials that will provide adequate structural capacity and facilitate drainage.

c. Scratch and Leveling Courses or Milling. The need to correct the existing surface to provide a level and stable platform for construction of the overlay.

d. Binder Course. The need for additional structural layer thickness to increase the structural capacity of the pavement as determined by non-destructive testing (NDT) or other acceptable design procedures.

e. Surface Friction. The need to improve surface friction of the bituminous pavement when additional structure is not needed.

f. Shoulders. The need to improve the shoulder structure condition or performance.

2. Portland Cement Concrete Surfaces. PennDOT's general policy is to maximize the life of Portland Cement Concrete (PCC) pavement surfaces.

The review team shall evaluate PCC pavements for the following items:

a. Drainage. The need to improve the removal of surface and subsurface water.

b. Patching. The need to remove areas of obvious failure including base repair and to patch according to current specifications and standards.

c. Slabjacking. The need to correct faulted or sunken areas of rigid pavement to the grade of the original pavement according to Publication 408, *Specifications*, Section 681.

d. Slab Stabilization. The need to fill voids beneath existing rigid base or pavement courses according to Publication 408, *Specifications*, Section 679.

e. Dowel Bar Retrofit. The need to provide load transfer on working transverse cracks in slabs. (Publication 72M, *Roadway Construction Standards*, RC-26M shows standard drawings for Dowel Bar Retrofit. Also refer to Publication 408, *Specifications*, Section 527.)

f. Diamond Grinding. The need to improve the profile of rigid pavement by correcting such problems as high areas, curled or warped slabs, and minor rutting according to current specifications.

g. Joints. The need for spall repair and joint rehabilitation or joint cleaning and resealing according to Publication 408, *Specifications*, Sections 512, 513, and 521.

h. Cracks. The need for cleaning and sealing cracks according to Publication 408, *Specifications*, Section 590.

i. Shoulders. The need to improve shoulder structure. Concrete shoulders are useful in strengthening existing PCC pavements.

j. Friction Characteristics. The need to improve surface friction of a PCC pavement. Diamond grinding should be performed when the pavement is structurally sound and when wheel ruts are less than 0.5 inch deep. Safety is improved by a temporary increase in skid friction resistance and a reduction in the potential for hydroplaning. Longitudinal grooving provides channels that improve wet weather friction and decrease hydroplaning potential. Other alternatives such as transverse grooving or overlaying should be considered where pavement conditions are more severe. Depending on the characteristics of the aggregates and cement paste, microsurfacing or other type of overlay may be necessary, e.g., Portland Cement pavements containing Vanport limestone.

k. Cross-Stitching. The need to cross-stitch longitudinal cracks or joints in plain cement concrete pavements by placing epoxy coated deformed tie bars, at an angle, across the longitudinal joint or crack. (Refer to Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 528.)

3. Additional Considerations. Consider the following additional items if an existing PCC pavement is no longer serviceable without an overlay or needs correction for friction and no other alternative rehabilitation procedures are feasible:

a. Structural Requirements. The feasibility of some type of PCC overlay, including an unbonded concrete overlay, or the need for total reconstruction.

b. Leveling Course. The need to correct the existing surface to provide a properly shaped platform for construction of asphalt overlays. It is important to not use the asphalt separation layer as a leveling course. All grade corrections, including leveling, should be accomplished with the concrete overlay itself.

c. Bituminous Overlay Considerations. The need for more than minimum asphalt overlay thickness. The need for a layer of open-graded base to facilitate pavement drainage and to retard reflective cracking.

C. Restricted Performance Specification. Selecting projects for use of the Superpave Restricted Performance Specification (RPS), Publication 408, *Specifications*, Sections 409 and 411 must follow specific guidelines. This specification is to be used on Hot Mix Asphalt or Warm Mix Asphalt, where Superpave wearing and binder courses or Superpave wearing courses meet the following criteria:

1. See normal size lot in Publication 408, *Specifications*, Section 409.3(h)2.a.

2. The surface course thicknesses for Superpave wearing and binder courses must meet the minimum requirements as stated in Table 9.5. This specification is intended for relatively uniform layer thicknesses; surface corrections and cross slope adjustments should be made with a leveling course.

3. On asphalt overlays, the existing pavement must be stable (non-movement under the roller) and properly leveled, sealed and patched before the resurfacing course is placed.

4. Plans and proposals must clearly indicate the limits of paving by State Route (SR) for surface courses to be constructed under RPS specifications. The limits of paving shall be designated on the typical sections and in the tabulation sheets.

When selecting projects for use of the Reinforced or Plain Concrete Cement Pavements, RPS specifications, the following criteria must be met:

1. Pavements are to be constructed on a prepared surface.

2. Pavements are to consist of a uniform, nominal depth of not less than 5,600 square yards.

3. Projects must allow for continuous placement operations.

4. Plans and proposals must clearly indicate the limits of paving by State Route (SR) for surface courses to be constructed under RPS specifications. The limits of RPS paving shall be designated on the typical sections and in the tabulation sheets.

D. Recycling Existing Pavement Materials. Recycling of construction materials is becoming an increasingly valuable strategy. The limited national supply of good quality aggregates in conjunction with the costs of liquid asphalt and energy make recycling more attractive than ever from resource, environmental, and cost perspectives. Currently, Reclaimed Asphalt Pavement (RAP) can be used in Hot Mix Asphalt (HMA), Warm Mix Asphalt (WMA), and Cold Recycled Base Course to conserve asphalt binder and aggregates. Recycled Concrete aggregate can only be used for subbase (Publication 408, *Specifications*, Section 703.2(a)7). Activities that recycle asphalt pavement materials are governed by Pennsylvania Department of Environmental Protection General Permit WMGR090. For guidance regarding the environmental regulations pertaining to the recycling of bituminous pavement products, refer to Publication 611, *Waste Management Guidance Manual*.

E. Full Depth Reclamation. Full Depth Reclamation (FDR) is an effective and sustainable way to recycle existing pavement. FDR is a pavement rehabilitation technique in which the full flexible pavement section and a predetermined portion of the underlying materials are uniformly crushed, pulverized, or blended resulting in a stabilized base course. Additional stabilizing material may be added to further improve the integrity of the recycled product. FDR not only conserves the investment in in-situ materials, but also resolves the issues and minimizes the costs associated with their removal and disposal when following conventional pavement reconstruction practices.

The FDR process can include stabilization by mechanical, chemical, asphalt, or other processes. Detailed discussion of each is contained in Appendix J, Developing Standards and Specifications for Full Depth Pavement Reclamation: A Best Practices Guide. Appendix J presents the Best Practices identified and developed for the use of full depth reclamation of flexible roads, as well as a process for developing and constructing FDR projects.

There may be differences in the structural capacity, and consequently the structure layer coefficient, associated with different stabilization materials. Recommended structure layer coefficient values are provided in Table 9.3. These values were collected from industry literature and existing FDR practices in other states. The values were then verified by testing in Pennsylvania. In general, the range of structure layer coefficients vary from values typical of subbase material to values representative of stabilized materials, depending upon the type of stabilization used. For example, basic pulverization will produce a product similar in support characteristics to a standard 2A subbase material. Stabilization with calcium chloride or similar additives will be slightly improved. Asphalt stabilized layers can generally be considered similar to existing layer coefficients for cold recycling. Chemical stabilization using cement, lime, and similar additives will provide support stiffness equivalent to or slightly better than those achieved from asphalt material stabilization.

2.2 SUBGRADE SOIL EVALUATION

The condition of the subgrade soil is very important when reconstructing pavements. Often existing in-place materials have failed to support construction equipment adequately after the pavement has been removed. Large work order adjustments have frequently been required to undercut and suitably stabilize these areas of low subgrade support. Since most of the State contains similar clay and silt subgrade materials, this problem is expected statewide. Therefore, all pavement replacement projects must take steps to address this problem.

PennDOT first addressed this subgrade problem by endorsing the concept of "going-up," i.e., overlaying the pavement instead of replacing it. Overlay design alternatives, both bituminous and concrete, have been proposed for existing concrete pavements that have been patched, cracked and seated, or rubblized. The overlay protects unsuitable subgrade materials from exposure to construction traffic. In addition, this is a sustainable design option since it takes advantage of the existing pavement structure and materials. An overlay of the existing pavement also increases the vertical distance between the pavement grade line and the moisture level within the pavement structure in areas of high moisture content. This procedure should ultimately improve pavement performance.

Unfortunately, the overlay concept may not be the most cost-effective alternative in all situations. Shoulder width adjustments, slope adjustments to maintain embankment width, guide rail adjustments, vertical adjustments at structures, or other items affecting the adjustment of grade line may adversely affect overall project cost.

For all reconstruction projects (including rubblized projects), an additional pavement subgrade evaluation shall be performed. Refer to Section 6.2.F for additional guidance.

2.3 DRAINAGE

Drainage is probably the most important consideration during the field view, design, construction and maintenance of a pavement structure. Most pavement problems can be attributed, at least in part, to excessive water within or beneath the pavement layers. Nearly all weather-associated deterioration of pavement material is related to the presence of water. The success of each project will depend on how well drainage problems are handled. Since each project will be unique with respect to drainage, engineering expertise will determine the proper method for removing water from the pavement structure. The local maintenance representative should be contacted to identify problem drainage areas.

Subsurface drainage serves two primary purposes. First, it increases pavement life. Removing water from beneath the pavement surface reduces loss of subgrade support and thus increases the resistance of the aggregate base to deflections imposed by traffic loading. It also reduces the deterioration of aggregates, the effect of freezing and thawing, and the pumping or rearrangement of fine materials in the base. Second, more uniform pavement performance will result from proper drainage. Frost heave is the result of expansion of the wet soil when it freezes. This is especially detrimental when the heaving is nonuniform in location and magnitude.

The adequate removal of surface runoff is as important as the removal of subgrade water. Ponded surface water will eventually penetrate the pavement structure. As a minimum, cut or clean ditches, outlet low points by positive means, clean inlets and pipes, and remove excess material build-up along shoulders and under guide rails.

Certain types of pavement distress can be identified as being associated with inadequate subsurface drainage. Concrete pavements and bituminous overlays of concrete pavements react to subsurface moisture in a similar manner. Saturated subgrades provide poor support for concrete pavements, which can result in transverse cracks under traffic loads. This problem is particularly critical during the spring thaw when moisture cannot percolate downward into the subsoil because of the frozen layer beneath it. When a joint has deteriorated (below the pavement surface) into particles that are small enough to impede gravity drainage, water is trapped beneath the joint.

In winter, this trapped water may freeze and cause tenting, the upward movement of the joints due to a localized frost heave.

Distress types associated with inadequate subsurface drainage in bituminous pavements are somewhat different. One type of rutting of the surface is a reflection of rutting of the subgrade. Loads transmitted through the pavement surface can rut a softened subgrade. The ruts are visible on the surface but are the result of a poorly drained base and softened subgrade. Lack of support from a fluid base can result in surface roughness. Cracks may occur, but surface undulations alone will cause a noticeable loss of ride quality. Shrinkage cracks caused by temperature variations and brittleness of the bituminous pavement during cold weather are a type of distress that is observed frequently. Adequate drainage does not retard shrinkage or thermal cracking, but it does prevent the moisture-associated damage adjacent to the thermal crack.

A. Basic Principles of Drainage. The design of the subsurface drainage system must consider the following principles:

1. Some of the free water in the base and subbase can be removed by gravity.

2. Some of the water will not be removed by gravity. In fine soils, water is held in the base, and can even be drawn up in some bases that act like wicks. This is called capillary water, and it is drawn into and held in these base materials because of very small (capillary) openings between the soil particles.

3. Water tables that intersect the subbase must be lowered by drains or they may prevent the drainage of the subsurface layers or even contribute to moisture beneath the pavement.

4. Seepage of water from the sides of an excavation or cut slope must be intercepted by drains to ensure long-term pavement performance.

5. Base drain outlets must be protected from crushing or plugging to ensure that the entire drainage system will work properly. All outlets within mowable areas must be protected by using appropriate headwalls as indicated in Publication 72M, *Roadway Construction Standards*.

6. The use of lateral underdrains in appropriate locations is strongly encouraged. These locations should include wet subgrade areas and all transitions from cut to fill cross sections.

The design of subsurface drainage must also consider the base and subbase layers and drainage hardware for the base, subbase, and subgrade drainage. Material type, size, location and shape are all a part of the design of a drainage system. Base and subbase materials should be highly permeable (i.e., readily allow water to flow through) so that gravity-drainable water will be removed rapidly. High permeability also prevents capillarity because the voids between particles are larger and do not draw or wick water upward.

High permeability, however, does not necessarily provide stability for the operation of construction equipment. Some drainability may be sacrificed to provide a more stable work platform while the pavement layers are being built. Also, permeability is not easily measured in the field, so another test is used as an indicator of permeability. PennDOT uses gradation (particle-size distribution) as an indicator test. Base materials of similar gradation can have different degrees of permeability due to factors such as particle shape. The desired drainage is not always obtained through gradation.

Slope of subbase layers should be maximized to increase the rate of gravity drainage within the granular materials. The smaller the spacing between drainage pipes and between outlet pipes, the greater the rate at which water is removed from the base and subbase layers. All of these considerations - permeability, subbase slope and outlet spacing - have an impact on the cost of a drainage system.

Pavement base drain sizing and outlet spacing must be designed according to the method shown in Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 10, Section 10.3.D, Pavement Base Drains.

B. Cost of Investment. Many factors associated with good drainage are costly and oftentimes some compromise is made to reduce costs. Poor ride quality, more frequent maintenance during the life of the pavement and shorter service life are the predictable results of such compromise. These one-time costs should be considered investments in the pavement system. More often than not, these initial costs are more economically feasible than the costs associated with the results of compromise.

C. Interstates. Continuous pavement base drains must be provided along the outside edge of the pavement, as shown on Publication 72M, *Roadway Construction Standards,* RC-30M, and along the low side of superelevated pavement sections. Drains must also be provided on the median side of the pavement in areas where subsurface water is a particular problem. Base drains must be installed on rehabilitation projects where the existing roadway does not already have functioning edge drains located at the edge of pavement and in the locations specified above. Lateral drains must be installed at the transitions from cut to fill and at other needed locations as identified by the local maintenance representative. Subgrade drains should also be considered where the existing roadway shows evidence of water damage and in sag areas. See Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 1 for typical sections and Chapter 10 for additional information on base drains.

D. Non-Interstates. Pavement base drains must be installed on all projects where subsurface water is a problem. Continuous base drains should be installed along the outside edge of the pavement, along the low side of superelevations and on the median side of the pavement in areas where subsurface water is a particular problem. Continuous pavement base drains should be installed where possible on all rehabilitation projects when the existing pavement does not already have functioning edge drains in the locations specified above. Particular emphasis is given to pavements that are cut into hillsides. Longitudinal edge drains must be installed on these highways. Lateral drains must be installed at the transitions from cut to fill and at other critical locations that have been identified by the local maintenance representative. Subgrade drains should also be considered where the existing roadway shows evidence of water damage and in sag areas.

2.4 BASE REPAIR

Each project must be evaluated to determine the cause of existing base failures and the type of repair necessary to correct them. The field inspection team should determine the methods and materials necessary to correct the base failures. Refer to Section 2.2, Subgrade Soil Evaluation, for assistance in making these determinations. Every effort should be made to make repairs with material similar in type and thickness to existing material to provide proper drainage and avoid creating bathtub situations.

2.5 CROSS SLOPES

For new construction, reconstruction, and 3R projects, the finished roadway surface should provide a minimum cross slope as indicated in Publication 13M, Design Manual Part 2, *Highway Design*, Section 1.2. Superelevations in curved sections should be checked and corrected if necessary. The correction of cross slopes may require additional leveling material or even removal of surface material. Any shoulder reconstruction should conform to the cross slope requirements of Publication 13M, Design Manual Part 2, *Highway Design*, Section 1.2 for the type of shoulder being constructed.

When the design criteria for cross slopes cannot be met for new construction, reconstruction, and 3R projects, a design exception request must be prepared. Refer to Publication 13M, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 3.

For pavement preservation projects, refer to guidance in Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 1, Section 1.3.

2.6 BRIDGE DECKS

All projects that will include work on a bridge structure must be coordinated with the District Bridge Engineer. Overlays of the bridge deck will be performed only as a maintenance measure and only after the deck is checked for dead load capacity by the District Bridge Engineer. The minimum thickness values of overlay materials shown in Table 10.4 do not apply to bridge decks.

2.7 BRICK PAVEMENTS

A number of PennDOT's older roadways were constructed of brick. Whenever considering a project on any of these roadways, contact the District Environmental Manager. In some instances, there has been a desire on the part of the community to maintain the aesthetics of the brick pavement. An assessment may be needed of the historical and cultural significance of the brick pavement.

Some brick pavements were constructed of brick on a concrete base, and some on a stone or aggregate base. The base must be considered when designing any overlay. If the brick pavement is on a concrete base the structural analysis shall be done using the structural coefficient for "Brick with Rigid Base" (see Table 9.3). If the brick pavement is on a stone or other flexible base use the structural coefficient for "Brick with Flexible Base" in the structural analysis (see Table 9.3). In either case, the structural coefficient to be used for the brick is only applied to the depth of brick. The base material has a separate structural coefficient applied only to the depth of base material.

2.8 EXPERIMENTAL PAVEMENT CONSTRUCTION

All experimental pavement construction must be conducted through BOPD, Innovation and Support Services Division (ISSD), New Products and Innovations Section.

If experimental pavement construction is to occur, an Experimental Item Work Plan must be developed and approved prior to the PS&E package submittal. The approved Experimental Item Work Plan and approval letter are to be posted in the ECMS Project Development Checklist.

For Federal Oversight projects, approval for experimental pavement construction is to be acquired from the FHWA.

For Non-federal (100% State), PennDOT oversight NHS, and PennDOT Oversight Non-NHS projects, approval for experimental pavement construction is to be obtained from the appropriate Bureau Director. If Federal Funds are used for the experimental construction, then the FHWA must also be notified.

For additional guidance regarding the use of experimental items, refer to Publication 51, *Plans, Specifications and Estimate Package Delivery Process Policies & Preparation Manual*.

A. Stress-Absorbing Membrane and Stress-Absorbing Membrane Interlayer. Stress-absorbing membrane (SAM) and stress-absorbing membrane interlayer (SAMI) applications are considered experimental construction items. While heavy duty membranes are placed over transverse and longitudinal joints and random cracks in existing concrete pavements (see Publication 408, *Specifications*, Section 467), SAM and SAMI applications are for full width. A properly designed seal coat may perform the intended purpose of an asphalt/rubber SAMI or SAM and can be more cost-effective.

SAM or SAMI applications must meet the following criteria and be coordinated through BOPD, ISSD, New Products and Innovations Section:

1. SAMs and SAMIs should be used only on flexible pavements with flexible bases.

2. The pavement surface must not exhibit excessive cracking or extensive alligator cracks (for the use of SAMs).

3. The distance between thermal cracks cannot be more than 15 feet.

4. The SAMI application should be placed directly on the existing pavement surface. All leveling courses or grade adjustments should be made on top of the SAMI.

5. Pavement designs must include sufficient depth of material over the SAM/SAMI to meet manufacturer's recommendations and a minimum of two courses of material.

B. Geosynthetics in Pavement Structures. Geosynthetics are used in a variety of construction practices. Presently PennDOT's uses are limited to geotextiles for drainage, layer separation, erosion control and sediment control and to geogrids for reinforcement of soft subgrade soil and aggregate layers. Other than applications for drainage, layer separation, erosion control and sediment control, and soft subgrade soil and aggregate layers, geotextiles or geogrids are considered experimental construction items when used as soil reinforcement for adding structure to the pavement.

In order to use a geotextile that will function properly as per current Publication 408, *Specifications*, the geotextile design parameters must be determined on a project-by-project basis. For geotextile applications, Publication 408, *Specifications*, FHWA's *Geosynthetic Design and Construction Guidelines* (http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=1), The National Transportation Product Evaluation Program (NTPEP), the geotextile manufacturer's published product data, and other appropriate technical references should be referenced when determining the geotextile properties, design specifications, product selection and construction procedures.

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CHAPTER 3

PAVEMENT TYPE DETERMINATION

3.1 PAVEMENT TYPE SELECTION FACTORS

A highway system designation shall not determine the choice of pavement type. The following factors should be considered when choosing a pavement type:

1. Economics. Pavement type determination can be influenced by the results of an Engineering Economic analysis (e.g., a Life-Cycle Cost Analysis) on the cost of construction and future maintenance.

2. Life Cycle Cost Analysis. LCCA is used to compare the relative long-term costs of different pavement alternatives. LCCA allows the Department to objectively evaluate costs of two or more rehabilitation and/or new/reconstruction alternatives that may have significantly different initial costs and require very different levels of future preventive maintenance expenditures.

3. Alternate Bidding. Pavement type may be determined through Alternate Bidding as described in Section 3.6. Alternate Bidding is a tool that may be used to stimulate competition in the paving market.

4. Performance of Similar Pavement in the Area. Knowing how a particular design type performed in the past is a valuable guide in predicting future performance. However, there must be a good correlation between conditions and service requirements of the reference pavements and the designs under study. Caution is urged against relying on performance records of reference pavements subjected to much lighter loadings for a large portion of their service life. Caution is also urged when considering the performance of pavements containing materials and/or design features that are no longer commonly used or expected to be used. Reference pavements should be re-analyzed periodically.

5. Adjacent Existing Pavements. The choice of pavement type may be influenced by the pavement types of adjacent sections that have similar conditions to the project and that have provided adequate long-term service.

6. Municipal Preference, Participating Local Government Preference. While these considerations seem outside the realm of the highway engineer, the highway administrator cannot ignore them.

7. Construction Considerations. Various construction considerations may influence the pavement type selection:

- Seasonal construction constraints
- Reduction of maintenance and protection of traffic during construction
- Need for reduced future maintenance in highly congested locations
- Economic impact on local businesses due to duration of construction project

8. Grades, Curvature and Unusual Loadings. Slow-moving vehicles starting and stopping on steep grades and unusual loadings may affect the pavement type selection.

The recommended pavement structure, chosen after careful consideration of the above factors, will be designated on Form D-4332. Any supporting documentation for the type selection must be included with the copies of Form D-4332. Refer to Chapter 6 for additional information regarding submission and approval procedures.

3.2 LIFE-CYCLE COST ANALYSIS GUIDELINES

The policies and methodologies outlined in this Chapter define when a Life-Cycle Cost Analysis (LCCA) must be completed and how to perform the analysis. The HDTS shall review and update (if necessary) the policies and processes every two years, in order to keep up with and reflect the latest innovations, technology developments and costs in the fields of pavement design, construction, maintenance and materials. Stakeholders (including industry) should participate in these reviews.

An LCCA must be submitted to the HDTS for all new construction, reconstruction or rehabilitation projects with at least 30,000 square yards of mainline pavement, including shoulders, regardless of roadway network or funding source.

Structural pavement designs are performed for each pavement type alternative. An LCCA is performed to analyze which pavement structure is most cost-effective over an equivalent specified analysis period. Each pavement type alternative is assumed to have an equivalent performing pavement structure throughout the analysis period. It is important that all practical alternatives are considered when performing an LCCA for these projects, from rehabilitation with either a bituminous or concrete structural overlay to total reconstruction with either pavement type. Justification must be provided when an alternate is not practical and is excluded from the LCCA.

The current LCCA Excel spreadsheet can be downloaded from:

http://www.dot.state.pa.us/Internet/Bureaus/pdBOMO.nsf/LCCA?OpenForm

The total Present Worth costs (Initial Construction + Maintenance Activities + User Delay) of all design alternatives are to be compared and all alternates must have the same analysis period.

Perform the LCCA without factoring inflation. A Discount Rate shall be applied to all future maintenance and user delay costs within the analysis period. The Discount Rate is the five-year rolling average of the annual 30-Year Real Interest Rate on Treasury Notes and Bonds posted by Executive Office of the President, Office of Management and Budget (OMB) Circular A-94. HDTS will provide the updated Discount Rate to all District PMEs each January, based on the information posted at:

http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c/

The Discount Rate can be found in the ECMS File Cabinet.

The cost of all bituminous items, adjusted as per Publication 408, *Specifications*, Section 110.04, Price Adjustment of Bituminous Materials, will be factored by the provided Asphalt Adjustment Multiplier (AAM). The AAM is to be applied to bituminous costs for both initial construction and future maintenance in the LCCA so as to more accurately estimate the most current unit price of bituminous materials at the time of project bidding.

The AAM will be calculated semiannually based on the total of bituminous payments made over the preceding twelve months and bituminous price adjustments applied to those payments. To further clarify, the following equation will be used:

$$\text{AAM} = 1 + \text{Adjustments} / \text{Total of Bituminous Payments.}$$

The AAM will be updated and provided to all District Pavement Management Engineers by the HDTS semiannually during the first week of each July and January. The AAM can be found in the ECMS File Cabinet.

A. Construction Items. The pavement items quantity estimates for each alternative will be based on the actual typical cross section used for the project (e.g. wearing, binder, base, and subbase; or Portland Cement Concrete Pavement (PCCP), treated base, and subbase).

The differences in costs for pavement-related items (e.g., pavement relief joints, and approach slabs) must be included in the LCCA when calculating initial costs. Only the differences in these items quantities between alternatives shall be included in the LCCA; do not include the total item quantity for each alternative.

The differences in costs for earthwork items must be included in the LCCA when calculating initial costs. To determine the subgrade and excavation quantities, the estimated percentage of the project in total cut, total fill, and cut and fill shall be determined for each alternative. Only the differences in earthwork quantities between alternatives shall be included in the LCCA; do not include the total earthwork quantity for each alternative.

B. Resurfacing. When calculating the total cost for resurfacing alternatives, include the cost of pavement resurfacing, shoulder modifications, necessary pavement patching, drainage and guide rail adjustments, maintenance and protection of traffic, etc.

For LCCA purposes, the first bituminous overlay for rigid pavements (not including scratch or leveling courses) shall be 4 inches thick when 9.5 mm Wearing Course mix is used or 4.5 inches thick when 12.5 mm Wearing Course mix is used. All resurfacing of flexible pavements shall be 1.5 inches thick when 9.5 mm Wearing Course mix is used or 2 inches thick when 12.5 mm Wearing Course mix is used.

C. Shoulders. The LCCA must account for shoulder construction and maintenance. The shoulder type must match the mainline pavement type.

D. Miscellaneous. Engineering and mobilization costs must not be included in the LCCA.

Regarding initial costs for non-pavement items, such as drainage, guiderail, utility relocations, etc., only the differences between alternatives for these items shall be included in the LCCA. Do not include the total item quantity in each alternative.

E. Type Determination. Any of the following will be sufficient to conclusively determine the pavement type although Alternate Pavement Type Bidding (Section 3.6) is still permissible:

1. A difference of 10% or more in life-cycle cost, excluding user delay costs (to compare agency costs only).

2. A difference of 20% or more in life-cycle cost, including user delay costs (to account for impacts to the roadway user).

3. The District Pavement Type Selection Committee may provide justification for a single pavement type selection after consideration of regional factors such as: engineering judgment*, adjacent pavement types and performance, subgrade composition and condition, local materials, right-of-way constraints, maintenance and protection of traffic or utility impacts. The FHWA Technical Advisory, *Use of Alternate Bidding for Pavement Type Selection* and NCHRP Report 703, *Guide for Pavement-Type Selection* shall be used as guides to the District Pavement Type Selection Committee. Projects with substantial non-pavement items may not be good candidates for alternate pavement type bidding. The LCCA, meeting minutes, and conclusions shall be recorded and included in the pavement design package to be submitted for HDTS approval. The composition of the District Pavement Type Selection Committee is at the discretion of the District Executive.

*Engineering judgment should not be an opinion or preference. It must be a unique, extraordinary circumstance that would compel the Department and FHWA to support a more costly alternative. It must be fact-based and defendable to the public and both industries.

If an LCCA is performed more than 3 years prior to project letting, it must be updated to reflect current prices, traffic data, Discount Rate, Construction Cost Index and any changes to the pavement design. For Alternate Pavement Type Bidding, the LCCA must be performed, or updated, within six months prior to project advertisement. Updated LCCA documents must be submitted to HDTS with changes indicated in red font, even if the previous LCCA has been approved by HDTS. Documentation supporting the changes must also be submitted.

Upon approval of an LCCA and pavement type selection, pavement type shall not be changed, whether the project is in design or construction status, unless approved by the HDTS.

3.3 GUIDELINES FOR DEVELOPING INITIAL COSTS

The following guidelines shall be used to develop initial costs for each particular rehabilitation strategy. Adjust these guidelines to include any items that may occur on a particular project that would affect the initial cost of a particular rehabilitation strategy.

A. Bituminous Rehabilitation Strategies.

1. Bituminous Overlay.

- **a.** Design according to Chapter 10.
- **b.** Patching based on actual field measurements. The quantity shall anticipate additional deterioration that will occur between the time of the design field view and the actual construction of the project. Replace concrete pavement with concrete (as per Section 4.2) and bituminous pavement with matching depths of like bituminous courses.
- **c.** Slab stabilization where necessary to restore support to the existing concrete pavement.
- **d.** Bituminous tack coat, if necessary.
- **e.** Continuous pavement base drain. Replace as appropriate.
- **f.** Longitudinal and transverse joint cleaning and sealing of concrete pavements. Asphalt joint and crack sealing on bituminous pavements. Use of heavy-duty membranes, as necessary. Sawing and sealing of bituminous overlays on concrete or on existing sawed and sealed bituminous.
- **g.** Type 6 or Type 7 paved shoulders as applicable.
- **h.** Sawing and sealing the overlay over existing transverse and patch joints.
- **i.** Adjusting or replacing existing guide rail and drainage structures as necessary.

2. Bituminous Overlay on Crack and Seated Concrete.

- **a.** Cracking and seating the existing concrete pavement.
- **b.** Base repair with Base Course/Superpave Base Course.
- **c.** Continuous pavement base drain.
- **d.** Leveling course (1 inch minimum), includes cross-slope correction.
- **e.** Bituminous overlay (thickness as required by design).
- **f.** Full-depth bituminous shoulders.
- **g.** Resetting and/or replacing guide rail and drainage structures, as necessary.

3. Bituminous Overlay on Rubblization.

- **a.** Rubblizing and seating the existing concrete pavement.
- **b.** Base repair with AASHTO #1 aggregate, as necessary.
- **c.** Continuous pavement base drain.
- **a.** Leveling course (1 inch minimum), includes cross-slope correction.

e. Bituminous thickness, as required by design.

f. Full-depth bituminous shoulders.

g. Resetting and/or replacing guide rail and drainage structures, as necessary.

4. Bituminous Reconstruction - Remove and Replace.

a. Design according to Chapter 9.

b. Undercutting and replacement of subgrade, if necessary.

c. Continuous pavement base drain.

B. Concrete Rehabilitation Strategies.

1. Concrete Pavement Rehabilitation.

a. Patching and spall repair based on actual field measurements and/or deflection tests. The quantity shall anticipate additional deterioration that will occur between the time of the design field view and the actual construction of the project.

b. Slab stabilization, as required, to restore full support to the pavement around patches and at other locations.

c. Slabjacking as required.

d. Diamond grinding to improve ride quality as per Publication 408, *Specifications*, Section 514, with the exception of concrete pavements constructed with Vanport Limestone aggregate. An ultra-thin friction course may be used on concrete pavements constructed with any aggregate susceptible to rapid polishing. (Data has shown that grinding a concrete surface removes the effective mortar layer on the pavement and the skid resistance of the exposed Vanport Limestone is susceptible to rapid decline.)

e. Continuous pavement base drain.

f. Rehabilitation of all failed transverse joints, if not previously performed. Otherwise, cleaning and resealing of all joints.

g. Cleaning and sealing all longitudinal joints and pavement/shoulder joints.

h. Adjusting or replacing guide rail and drainage structures, as necessary.

i. Dowel bar retrofit at mid-panel cracks and transverse joints.

2. Concrete Overlays - Bonded and Unbonded.

a. Design in accordance with Chapter 10.

b. Rehabilitation of all failed transverse joints.

c. Concrete pavement patching based on actual field measurements.

d. Slab stabilization around patches and where necessary to restore uniform support.

e. Cleaning and sealing all existing joints, if unbonded overlay.

f. Continuous pavement base drain.

g. Concrete shoulders required if existing shoulders are concrete, otherwise, may match existing shoulder type.

h. Leveling course, if needed, and bond breaker to be included, if unbonded design.

i. Adjusting or replacing all guide rail and drainage structures, as necessary.

j. Fill widening to retain proper shoulder widths, and checking bridge underclearances.

3. Concrete Overlay - Unbonded - Crack and Seat.

a. Cracking and seating existing concrete pavement.

b. Base repair with HMA Base Course/Superpave Base Course, as necessary.

c. Continuous pavement base drain.

d. Leveling course and bond breaker includes cross-slope correction.

e. Unbonded concrete overlay, as designed using the procedure in Chapter 10.

f. Concrete shoulders required if existing shoulders are concrete, otherwise, may match existing shoulder type.

g. Resetting and/or replacing guide rail and drainage structures, as necessary.

h. Fill widening to retain proper shoulder widths, and checking bridge underclearances.

4. Concrete Reconstruction on Rubblization.

a. Rubblizing and seating existing concrete pavement.

b. Base repair with AASHTO #1 aggregate, as necessary.

c. Continuous pavement base drain.

d. Leveling course and bond breaker includes cross-slope correction.

e. Concrete thickness, as required by design.

f. Concrete shoulders.

g. Resetting and/or replacing guide rail and drainage structures, as necessary.

h. Fill widening to retain proper shoulder widths, and checking bridge underclearances.

5. Concrete Reconstruction - Remove and Replace.

a. Design according to Chapter 8.

b. Undercutting and replacement of subgrade, if necessary.

c. Continuous pavement base drain.

3.4 MAINTENANCE STRATEGIES FOR LIFE-CYCLE COST ANALYSIS (LCCA)

A. Bituminous New Construction or Reconstruction (including construction on fractured concrete pavement) - 50 Year Pavement Life (Analysis Period).

5 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders, if Type 1, 1S, 3, 4, 6 or 6S
Maintenance and Protection of Traffic
User Delay

10 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

15 years Full Depth Patching, 2% of pavement area
Mill wearing course
Bituminous Inlay, 1.5 inches or 2.0 inches
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

20 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

25 years Full Depth Patching, 4% of pavement area
Mill wearing course
Bituminous Inlay, 1.5 inches or 2.0 inches
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

30 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

35 years Full Depth Patching, 4% of pavement area
Scratch Course, 60 pounds per square yard
Bituminous Overlay, 1.5 inches or 2.0 inches
Type 7 Paved Shoulders
Adjust guide rail and drainage structures, if necessary
Maintenance and Protection of Traffic
User Delay

40 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

45 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface roadway and shoulders
Partial Depth Asphalt Surface Patching, 2% of pavement area
Maintenance and Protection of Traffic
User Delay

B. Concrete New Construction, Reconstruction (including construction on fractured concrete pavement), Unbonded Concrete Overlay - 50 Year Pavement Life (Analysis Period).

10 years Clean and Seal, 25% of longitudinal joints including shoulders
Clean and Seal, 25% of transverse joints
Maintenance and Protection of Traffic
User Delay

15 years Concrete Patching, 2% of pavement area
Diamond Grinding, 50% of pavement area
Clean and Seal, all longitudinal joints including shoulders
Clean and Seal, all transverse joints
Maintenance and Protection of Traffic
User Delay

25 years Concrete Patching, 4% of pavement area
Diamond Grinding, 100% of pavement area (full width)
Clean and Seal, all longitudinal joints including shoulders
Clean and Seal, all transverse joints
Maintenance and Protection of Traffic
User Delay

35 years Concrete Patching, 6% of pavement area
Clean and Seal, all longitudinal joints including shoulders
Clean and Seal, all transverse joints
Scratch Course, 60 pounds per square yard
Bituminous Overlay, 4 inches or 4.5 inches
Saw and Seal, all transverse joints
Type 7 Paved Shoulders
Adjust guide rail and drainage structures, if necessary
Maintenance and Protection of Traffic
User Delay

40 years Clean and Seal, 25% of longitudinal joints
Clean and Seal, 25% of transverse joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

45 years Crack Seal, 500 lineal feet per mile
Partial Depth Asphalt Surface Patching, 2% of pavement area
Clean and Seal, 25% of all longitudinal joints, including shoulders
Clean and Seal, 25% of all transverse joints
Micro Surface roadway
Maintenance and Protection of Traffic
User Delay

C. Bonded Concrete Overlay - 30 Year Pavement Life (Analysis Period).

5 years	Clean and Seal, 25% of longitudinal joints including shoulders Clean and Seal, 25% of transverse joints Seal Coat or Micro Surface shoulders, if bituminous Maintenance and Protection of Traffic User Delay
10 years	Concrete Patching, 5% of pavement area Diamond Grinding, 50% of pavement area Clean and Seal, 25% of longitudinal joints including shoulders Clean & Seal, 25% of transverse joints Seal Coat or Micro Surface shoulders, if bituminous Maintenance and Protection of Traffic User Delay
15 years	Clean and Seal, 25% of longitudinal joints including shoulders Clean and Seal, 25% of transverse joints Seal Coat or Micro Surface shoulders, if bituminous Maintenance and Protection of Traffic User Delay
20 years	Concrete Patching, 8% of pavement area Clean and Seal, all longitudinal joints including shoulders Clean and Seal, all transverse joints Scratch Course, 60 pounds per square yard Bituminous Overlay, 4 inches or 4.5 inches Saw and Seal, all transverse joints Type 7 Paved Shoulders Adjust guide rail and drainage structures, if necessary Maintenance and Protection of Traffic User Delay
25 years	Clean and Seal, 25% of sawed and sealed joints Crack Seal, 500 lineal feet per mile Seal Coat or Micro Surface shoulders Maintenance and Protection of Traffic User Delay

D. Concrete Pavement Rehabilitation (CPR) & Bituminous Overlay - 30 Year Pavement Life (Analysis Period).

10 years	Mill Wearing Course Bituminous Inlay, 1.5 inches or 2.0 inches Saw & Seal, all transverse joints Seal Coat or Micro Surface shoulders, if Type 1, 1S, 3, 4, 6 or 6S Maintenance and Protection of Traffic User Delay
15 years	Clean & Seal, 25% of sawed & sealed joints Crack Seal, 500 lineal feet per mile Seal Coat or Micro Surface shoulders, if Type 1, 1S, 3, 4, 6 or 6S Maintenance and Protection of Traffic User Delay

20 years Concrete Patching, 2% of pavement area
Scratch Course, 60 pounds per square yard
Bituminous Overlay, 1.5 inches or 2.0 inches
Saw & Seal, all transverse joints
Type 7 Paved Shoulders
Adjust guide rail and drainage structures, if necessary
Maintenance and Protection of Traffic
User Delay

25 years Clean & Seal, 25% of longitudinal and transverse joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

E. Bituminous Overlay on Bituminous Pavement - 10 Year Pavement Life.

5 years Clean and Seal, 25% of longitudinal joints
Crack Seal, 500 lineal feet per mile
Seal Coat or Micro Surface shoulders, if Type 1, 1S, 3, 4, 6 or 6S
Maintenance and Protection of Traffic
User Delay

F. Ultra-Thin Whitetopping on Bituminous Pavements - 10 Year Pavement Life.

5 years Clean and Seal, 25% of longitudinal joints including shoulders
Clean and Seal, 25% of transverse joints
Seal Coat or Micro Surface shoulders
Maintenance and Protection of Traffic
User Delay

3.5 USER DELAY COSTS

Roadway users incur User Delay Costs while roads are being maintained, repaired or reconstructed. User Delay Costs must be accounted for in the life-cycle cost analysis for each alternate to be compared. These costs must be determined, and included in the LCCA, for each year of each alternate that user delays are incurred, including the year of Initial Construction if the User Delay Costs vary for the alternates due to differences in traffic control and/or project phasing. User Delay Costs are divided into three categories:

1. Idling Cost (or Speed Reduction Cost)
2. Time Value Costs (for Idling and Stopping)
3. Stopping Cost

If any of these types of user delays are incurred, the number of vehicles affected by the delay must be calculated. The following sections provide an overview of the items that User Delay Costs entail.

A. Delayed Vehicles. In order to calculate the number of delayed vehicles during an activity in a specific year, the following traffic information is required:

1. Initial ADT, Design Year, and Design Year ADT
2. Composition of the traffic mix by vehicle class (i.e., cars, single unit trucks, combination trucks)
3. Directional Factor
4. Total Days of the Activity

From this information, the following items must then be calculated:

- Traffic Growth Factor
- ADT in each Activity Year
- ADT in each Direction
- ADT Delayed in each Direction
- Total Number of Vehicles Delayed During the Activity
- Total Number of Vehicles Delayed in each vehicle class

See Publication 448, *Innovative Bidding Toolkit*, Chapter 5, Section 5.2.5 for further discussion and explanation of traffic terms.

B. Days of Construction. The total daily User Delay Cost is multiplied by the total number of Days of Construction that the roadway will be under repair. The total number of Days of Construction is determined by applying daily production rates to the specific work activities to be performed, accounting for concurrent activities, and summing the days of controlling operations. Production rates will vary depending on whether the Maintenance and Protection of Traffic is a short-term (partial-day) or long-term (full-day) closure. Standard values to be used in LCCAs are provided in Table 3.1; these values are based on typical production rates provided by industry.

Concurrent activities are indicated and accounted for in the LCCA Excel spreadsheet, so that the total days for each maintenance year reflect the total required time of closure and not the sum of each activity's duration in that year.

TABLE 3.1
STANDARD PRODUCTION RATES FOR MAINTENANCE ACTIVITIES

	PRODUCTION RATE PER SHIFT	
ACTIVITY	**SHORT TERM CLOSURE**	**LONG TERM CLOSURE**
Adjust Drainage Structures	8 inlets	10 inlets
Bituminous Inlay or Overlay	1,800 tons	2,400 tons
Clean & Seal Transverse Joints - concrete surface	3,200 LF	4,200 LF
Clean & Seal Joints - bituminous surface	6,000 LF	8,000 LF
Clean & Seal Longitudinal Joints - concrete surface	6,500 LF	8,500 LF
Concrete Patching	300 SY	400 SY
Crack Seal	6,000 LF	8,000 LF
Diamond Grinding	1,500 SY	2,000 SY
Full-Depth (Bituminous) Patching	300 SY	600 SY
Scratch Course, 60 PSY	1,800 tons	2,400 tons
Mill Wearing Course	16,400 SY	21,900 SY
Reinstall Guide Rail	1,500 LF	2,000 LF
Remove Existing Guide Rail	2,250 LF	3,000 LF
Saw & Seal Transverse Joints	6,400 LF	8,500 LF
Seal Coat or Micro Surface Shoulders	16,000 SY	18,000 SY
Type 7 Paved Shoulders	1,800 tons	2,400 tons

3.6 ALTERNATE PAVEMENT TYPE BIDDING

The following guidelines on Alternate Pavement Type Bidding have been developed to facilitate competition in the paving industry, and to allow PennDOT to realize bid savings for construction projects and take advantage of fluctuating material costs without compromising sound engineering principles and practices. The Department met with the industries and developed the following requirements for alternate pavement type bidding. It should be acknowledged that the outcome of these meetings and compromises produced the process as stated herein. Ongoing efforts with the industries will continue to further refine the process, as necessary.

It is in the best interest of PennDOT to apply Alternate Pavement Type Bidding whenever appropriate so that both industries are competitive and lower costs can be realized. Rather than a predetermined pavement type selection based on an LCCA and historical cost information, there may be motivation to determine pavement type based on low bid. For projects that apply Alternate Pavement Type Bidding, within 6 months following Design Field View (DFV), when the alternate pavement designs are completed, the District shall submit the pavement designs and LCCA to HDTS for review, regardless of whether the project is Federal Oversight or PennDOT Oversight. After HDTS has preliminarily approved the pavement designs, the District will then post the pavement design package in ECMS as an unofficial plans set for a 3-week review and comment period. If the Department chooses to make any corrections or changes, then HDTS will make the final approval of PennDOT Oversight projects or submit to FHWA for Federal Oversight final approval. Alternate Pavement Type Bidding projects will be identified in ECMS on the "Planned 6-Month Letting Schedule" which will be updated monthly.

Alternate Pavement Type Bidding that requires an LCCA includes the determination of C-Factors which account for future maintenance costs, but excludes User Delay Costs, and are added to the construction cost so that the low bid is based on life-cycle costs. Additional requirements for Alternate Pavement Type Bidding are as follows:

- Alternates must be "equivalent," meaning they provide comparable levels of service and performance over the same analysis period.
- The bid package will indicate the appropriate C-Factors for each alternative, determined by PennDOT based on LCCA methodology for the project.
- Typical sections for all alternatives must meet RC standards, DM-2 and Publication 242 requirements.
- Lane width, shoulder width, cross-slope and all other geometric features unrelated to pavement type, shown on the Typical Sections must remain as per the plans.
- The impact of constructability/phasing issues and/or maintenance and protection of traffic constraints should be reflected by varying Initial Construction Costs, User Delay Costs, and/or Maintenance and Protection of Traffic Costs, and not considered separately.

A. Alternate Pavement Type Bidding Project Selection. Alternate Pavement Type Bidding shall be considered for any new construction, reconstruction or rehabilitation project. Alternate pavement type bidding stimulates competition in the paving market, resulting in the potential for considerable savings in construction costs. Enhanced competition in the paving market also spurs innovation and improved pavement quality. Alternate pavement type bidding also takes advantage of fluctuating material costs that cannot be predicted during the preconstruction phase of a project. The FHWA Technical Advisory, *Use of Alternate Bidding for Pavement Type Selection* and NCHRP Report 703, *Guide for Pavement-Type Selection* shall be used as guides. Projects with substantial non-pavement items may not be good candidates for alternate pavement type bidding. The HDTS is responsible for monitoring and tracking Alternate Pavement Type Bidding projects and results.

When an LCCA is not required for a project, as per Section 3.2, pavement type selection is based on initial costs or other factors. Alternate Pavement Type Bidding may still be considered in these cases, with no C-Factor calculation, using alternate designs that have the same scope of treatment, service lives and expected performance. Notify HDTS for tracking purposes.

For Alternate Pavement Type Bidding projects, pavement type shall not be changed after the project is awarded to a contractor unless approved by the HDTS. The pavement type selection was the basis of the contract award and post-award change orders for pavement type negate the purpose of the alternate bidding process.

Alternate Pavement Type Bidding projects may be advertised in one of three ways:

1. The project is identified as a Design/Build project. Publication 448, Innovative Bidding Toolkit is followed for project development. The District develops the LCCA and C-factor for the various alternates in the bid package.

2. Plans, Cross Sections, and Drainage Excavation shall be developed for the deepest pavement type alternative. The intention is to reduce the design effort on the part of the District while designing drainage to accommodate all alternate pavement types in the bid package. This is also intended to reduce any additional design effort needed on the part of the contractor developing a bid on a pavement alternate. Typical Sections are provided for all pavement alternatives in the bid package. Item Numbers and quantities for all alternate pavement materials in the bid package are provided in ECMS.

Traffic Control Plans (TCPs) shall be developed as per the normal project development processes. TCPs shall be fully developed for the worst case scenario in terms of the area of any necessary Temporary Construction Easements.

Conceptual Bidding Presentation Example for ECMS:

Either Concrete Pavement
And Asphalt Treated Permeable Base Course
And Subbase
And Class 1 Excavation - Concrete Pavement

Or Concrete Pavement
And Cement Treated Permeable Base Course
And Subbase
And Class 1 Excavation - Concrete Pavement

Or Superpave Wearing Course
And Superpave Binder
And Superpave Base Course
And Subbase
And Class 1 Excavation - Asphalt Pavement

3. Plans, cross-sections, typical sections, item numbers, quantities, and traffic control plans are fully developed for all pavement alternates in the bid package. This option should only be utilized if it can be done in a cost-effective manner.

B. C-Factor Calculation. The C-Factor is determined by summing the Present Worth (PW) value of the future maintenance costs:

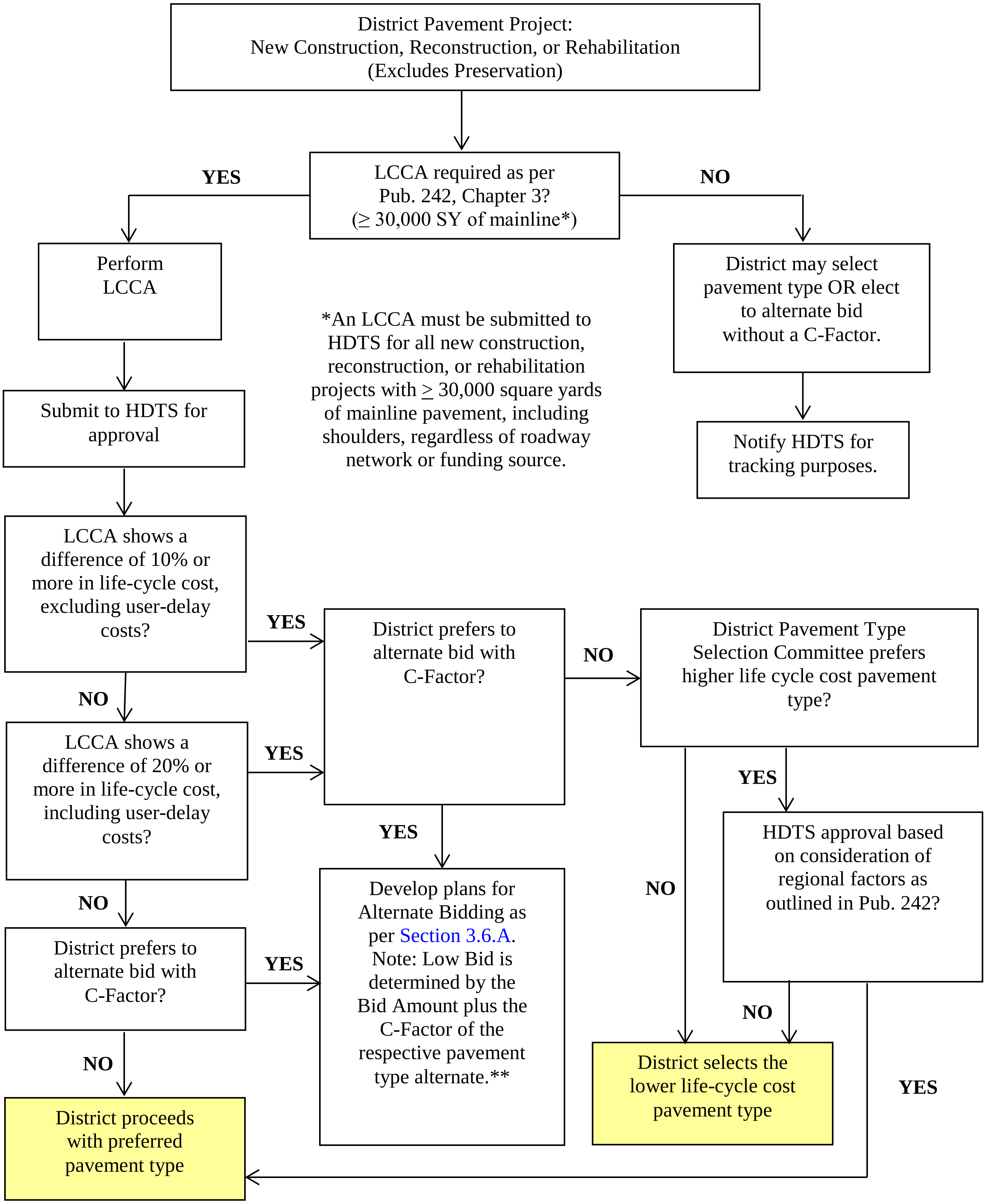
$$C = (PW_{maint})$$

where:

C = C-Factor
PW_{maint} = PW of future maintenance costs, excluding User Delay Costs

Low Bid is determined by the Bid Amount plus the C-Factor of the respective pavement type alternate.

C. LCCA/Alternate Pavement Type Bidding Flow Chart.



*An LCCA must be submitted to HDTS for all new construction, reconstruction, or rehabilitation projects with ≥ 30,000 square yards of mainline pavement, including shoulders, regardless of roadway network or funding source.

** See Section 3.6.B for C-Factor Calculation

CHAPTER 4

PORTLAND CEMENT CONCRETE PAVEMENT (PCCP) GUIDELINES AND POLICIES

4.1 CONCRETE PAVEMENT RESTORATION (CPR)

A. Preliminary Engineering. The major considerations in the design of a rehabilitation project are:

1. The condition of the existing pavement
2. The existing pavement's ability to be rehabilitated
3. The causes of the pavement's distresses
4. Feasible alternatives

When determining the condition of the existing pavement, the exact quantities of the visible distresses should be measured and tabulated. Cores should be taken near deteriorated joints and at random locations to determine the extent of deterioration below the pavement surface. Deflection tests, faulting measurements or other non-destructive techniques should be used to identify which joints to replace and to determine where slab stabilization should be performed.

When determining the existing pavement's ability to be rehabilitated, consider the following factors:

1. Condition of the concrete (percent patching)
2. Compressive strength of the concrete
3. Air content of the concrete
4. Visual observation of durability problems (including aggregate problems and frost damage)
5. Condition of the subgrade and/or subbase
6. Friction adequacy
7. Ride quality
8. Hardness of aggregate (for diamond grinding)

These items can be determined using various methods of destructive and non-destructive testing: coring, deflection tests, ground-penetrating radar, friction tests, roughness measurements, etc.

The total percent patching is important to the overall performance of a pavement. If the percent patching needed on the current project exceeds 10%, not including existing concrete patches in good condition, then the project may not be a viable CPR candidate.

The causes of the existing pavement distresses must be determined. If they are not corrected at the time of the restoration work, then the time and money spent on that work will be wasted by permitting the same problems to recur. Pavement distress generally falls into two primary categories: load-related distresses and climate/materials related distresses. Table 4.1 presents a general categorization of concrete pavement distress according to cause.

If the distresses are primarily load related, then the restoration work may need to include structural improvement as well as the correction of any climate/materials problems. However, if the primary cause is climate/materials durability, then the work should be selected either to reduce the climatic effect or to remove and replace the material.

For a rehabilitation project, the following alternatives should be considered:

1. Restoration (CPR)
2. Concrete overlay(s)
3. Bituminous overlay(s)
4. Concrete reconstruction
5. Bituminous reconstruction

TABLE 4.1
GENERAL CATEGORIZATION OF JOINTED CONCRETE PAVEMENT DISTRESS

DISTRESS TYPE	LOAD RELATED	CLIMATE/MATERIALS RELATED
Blow up		X
Broken slab	X	X
Corner break	X	
Depression		X
Durability "D" cracking		X
Faulting of transverse joints and cracks	X	
Joint load transfer system associated deterioration	X	X
Joint seal damage of transverse joints		X
Lane/shoulder drop-off or heave		X
Lane/shoulder joint separation		X
Longitudinal cracks		X
Longitudinal joint faulting	X	X
Patch deterioration	X	X
Patch adjacent slab deterioration	X	X
Popouts		X
Pumping and water bleeding	X	X
Reactive aggregate durability distress		X
Rutting		X
Scaling, map cracking, and crazing		X
Spalling (transverse and longitudinal joints)	X	X
Spalling (corner)		X
Swell		X
Transverse and diagonal cracks	X	X

The life-cycle cost analysis guidelines presented in Chapter 3 may be used in determining the best alternative.

B. Sequence of Construction. For CPR projects, this sequence of construction should be followed. Furthermore, see also Chapter 12:

1. Slab stabilization and slabjacking
2. Partial-depth repair
3. Load-transfer restoration (dowel retrofits)
4. Cross-stitching
5. Full depth concrete pavement patching
6. Installation of pavement base drains
7. Diamond grinding
8. Shoulder rehabilitation or reconstruction
9. Joint rehabilitation and/or joint cleaning and sealing

Concrete pavement patching and partial-depth repair can take place concurrently with slab stabilization and slabjacking. Joint cleaning and sealing and/or rehabilitation must be performed after diamond grinding to obtain the proper shape factor for the sealant reservoir and to prevent damage to the sealant. Each restoration activity included in CPR is detailed in the following sections.

4.2 CONCRETE PAVEMENT PATCHING

A. General Guidelines. Badly deteriorated pavement and broken slabs can best be repaired with full-depth concrete pavement patching. In this procedure, the deteriorated pavement is removed and replaced with new concrete. These concrete pavement patches must be properly designed and constructed to achieve adequate long-term performance. Load transfer at the joints is essential to proper patch design. Load transfer is achieved by dowelling all patch joints and securely anchoring the dowels to the existing pavement with such anchoring materials as epoxy, polyester binders or vinylester binders. In order for the dowels to be properly secured to the existing pavement, they must be bonded throughout their entire embedded length.

The Engineer should determine appropriate patch boundaries so that the entire deteriorated pavement is removed. The deterioration near joints and cracks is often greater at the slab bottom than near the surface. To minimize future problems, all patching of concrete pavements with or without a bituminous overlay must be made with concrete pavement patches in accordance with Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 516.

If a significant length of roadway (±500 feet) requires intermittent patches with 10 feet or less of original pavement to remain between patches, the pavement section should be removed and reconstructed for its entire length.

When replacement of more than 500 feet of pavement is required (one lane or all lanes), a pavement design analysis should be performed to determine if a thicker slab depth is required.

When reconstructing all adjacent traffic lanes for 500 feet or more with Portland cement concrete (PCC), the pavement must be reconstructed according to Publication 72M, *Roadway Construction Standards*, RC-21M for jointed reinforced concrete pavement (JRCP) or RC-27M for jointed plain concrete pavement (JPCP). RC-21M requires 30-foot joint spacing, perpendicular joints, coated dowel bars and appropriate seals. RC-27M requires 15-foot joint spacing, perpendicular joints, coated dowel bars and appropriate seals. The District may choose either a JPCP or JRCP pavement, but it should be noted that the reinforcement in JRCP does not add any additional strength. The contract proposal or drawings should clearly identify all areas of this design since a separate pay item is required for this construction. Therefore, these areas must be identified during the preliminary engineering phase of the project. A special provision, designated Class 1B Excavation Special, shall be written for the excavation of the original pavement when reconstructing all adjacent lanes.

When reconstructing only one lane for 500 feet or more, the new joints should be placed in line with the existing joints. An intermediate joint may be placed in the new lane, in order to meet current joint spacing requirements as detailed in RC-27M, if no tie bars are used in the area of the intermediate joint. See Publication 72M, *Roadway Construction Standards*, RC-25M, Sheet 3, for shoulders adjacent to jointed concrete as an example. A special provision must be written for these situations and should include the same requirements for reinforcing steel as for concrete pavement patching.

Longitudinal tie bars or tie bolts are only required in concrete patches more than 65 feet long. Tie bar/bolt movements in the partially set patch concrete, due to traffic using the adjacent lane, can be more detrimental to the performance of short patches than the benefits derived from tying the patch to the existing lane. Tie bars or bolts may be installed if traffic will be maintained away from the pavement.

The use of high early strength (HES) concrete should be avoided due to its potential for excessive shrinkage cracking. In certain cases, such as high traffic situations, the use of accelerated concrete should be considered.

There are three separate types of patching operations: concrete pavement restoration (CPR); patching under a bituminous overlay, and patching under an unbonded concrete overlay.

PennDOT has developed detailed guidelines and specifications regarding CPR work. Although PennDOT continues to refine its policies and specifications for CPR, it is important that the best available knowledge be employed in the design and construction of these projects. The standards and specifications for CPR, including modifications, should be followed carefully.

For full-depth patching, all major working cracks should be removed and replaced with new concrete patches. All crushed or deteriorated joints should also be removed. Joint partial-depth repairs should only be made where spalling is not caused by severe joint problems, such as loss of load transfer. These problems can only be corrected by full-depth patching. Extensive surface spalling may also justify pavement replacement or the construction of a thin bonded concrete inlay.

When patching in preparation for a bituminous overlay, the use of all CPR items is not required. Those portions of the standards and policies that deal with the patching operation are required. However, the philosophy used to determine the areas that require patching is different than the one used for CPR work. It is only necessary to remove those portions of the pavement that will not provide a stable uniform base to support the overlay. It is still necessary to replace such nonuniform areas as joints that have lost load transfer or are crushed. Other working joints and cracks may be stabilized in lieu of replacing them. In this case, the old pavement must provide a uniform level of structural support to the overlay. A higher level of support will require a smaller overlay thickness.

On unbonded concrete overlays, stabilization is an important part of the preparation work. Since the existing pavement will be leveled and the new rigid pavement is less susceptible to deflections than the flexible leveling course, uniform support must be provided to the overlay. Cracked areas may be stabilized instead of removed. Major deficiencies in the pavement, however, must be removed and replaced to provide a uniformly supporting pavement layer.

For both types of overlays, it is not necessary to apply such CPR operations as partial-depth repair, joint rehabilitation and diamond grinding to the old pavement. Existing joints and cracks should be filled prior to placing an overlay, but it is not necessary to reconstruct joint reservoirs with proper shape factor or to use high type rubberized joint sealing materials. Spalled concrete pavements can be cleaned and filled with bituminous materials. Leveling courses can correct deficiencies in profile. However, poor workmanship in the placement of concrete patches should not be accepted. Such practices do not provide the uniform support needed and are costly in terms of leveling material required.

B. Accelerated Concrete Pavement Patching. The specification for accelerated concrete pavement patching addresses the use of rapid setting concrete materials in a pavement repair application. It is intended to be used when project circumstances, including business and industrial settings, warrant the use of concrete patch material which will allow an early opening to traffic. It should only be utilized where opening a project to traffic is controlled by the concrete patching operation.

In general, accelerated concrete pavement patching provides a concrete patch that can be opened to traffic as early as 4 to 7 hours after placement. A minimum concrete compressive strength of 1200 pounds per square inch is required at the time of opening to traffic. However, acceptance will be based upon 28-day strengths. The mix design includes high range water reducers and compatible retarding admixtures as required by the operational logistics of the placement. Accelerating admixtures typically do not take effect until after the opening to traffic time period is well past, and do little, if anything, to aid in meeting the specification requirements. The high range water reducer will aid in appropriate reduction of the water/cement ratio to comply with strength requirements at the time of opening to traffic. The use of a well graded aggregate will also aid in achieving early concrete strength.

Another critical factor involved in meeting the specified strength requirements is the control of hydration of heat development. Temperature should typically range from 100°F to 120°F to achieve the required strength within the required time period. This is affected by ambient temperatures, concrete delivery temperature, and curing conditions. Insulated curing materials may be required to achieve the necessary hydration temperature under less than optimum conditions. In addition, it is critical to monitor and control the rate of change in temperature, both increasing and decreasing, during the hydration process. This will protect against thermal shock of the concrete, and improve the ultimate performance of the material.

The use of accelerated concrete pavement patching warrants the use of liquidated damages. The dollar amount of liquidated damages should be determined by user delay calculations. Road Users Liquidated Damages should be imposed on the Contractor for each hour that the lane/roadway is not opened to traffic after the established time, while trying to attain the minimum specified compressive strength. It will be each District's option, not the Contractor's, to determine whether the Contractor must open the lane/roadway at the established compressive strength, or to allow the lane/roadway to remain closed for an agreed upon extended period. Expected traffic congestion should be considered when making this decision. Liquidated damages will be assessed during any time extension. If the expected traffic volume warrants the lane/roadway must be opened at the established time, and strength has not been reached, the work will be considered defective.

The Contractor is responsible for the control and quality of the material and construction. Testing of the last load of concrete should be performed to ensure a test result representing the last patch, since the last patch placed is the most critical for strength gain at the time of opening to traffic since it will have been in place the least amount of time.

C. Concrete Pavement Patching Policy. The Federal Highway Administration's (FHWA's) Division Office has mandated a policy on the repair of rigid pavements requiring full-depth patching. All full-depth slab patching must be performed with PCC in accordance with Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 516. This mandate applies to initial overlays of concrete pavements and to any full-depth repair of previously overlaid rigid pavements of uniform dimensions.

Any pavement maintenance repairs must follow this policy, unless exempted. This policy must be made available to municipalities for their information and use on Federal-aid projects.

The actual application of this policy is governed by the following:

1. This policy applies to all uniform-depth rigid pavements built since 1945, whether or not they have been overlaid. (Note: Air-entrainment began in 1945.)

2. Pavements that have been overlaid and already have bituminous base repair areas will require rigid base repairs to replace any failed bituminous patches and any failed concrete areas.

3. Two-lane facilities must comply with this policy. However, where it is not feasible to maintain traffic safely and where detours are not practically available, exceptions may be made. Exemption requests must be submitted to HDTS for approval before plan preparation. A detailed explanation of the circumstances for requesting the exemption should accompany the request. Along with project data, include: SR; segment; ADT; percent trucks; number, size and purpose of patches; availability of detour routes; and any other information pertinent to the request.

4. Projects not covered under the first item, which may have various materials included in cross section, should be designed using sound engineering practices.

5. This policy is not applicable to crack-and-seat or rubblize projects. AASHTO No. 1 coarse aggregate must be used on rubblize projects when base repair is necessary. Bituminous material may be used on crack-and-seat projects.

6. A 500 foot full-width pavement reconstruction (minimum) is exempt from this policy. These areas include changes in roadway alignment or geometry and reconstruction of pavement superelevations. Reconstruction areas must be designed in accordance with the pavement design procedures found in Chapters 6, 8 and 9.

7. This policy does not apply to brick-surfaced pavements.

8. Pavements originally constructed with PCC base and bituminous overlays should have base repair performed with PCC. Load transfer devices will not be required at the patch joints in this instance.

D. Exemption Criteria: Substitution of Flexible Base Replacement for Jointed Plain Concrete Pavement (JPCP) for Full Depth Patching Material. Patching an existing rigid pavement with a flexible material compromises the long-term life of the pavement. A designer should consider the short- and long-term loss of ride quality before considering the use of flexible base replacement in concrete pavement.

United States Code, Title 23, Section 116(d) states: "A preventive maintenance activity shall be eligible for Federal assistance…if the State demonstrates to the satisfaction of the Secretary that the activity is a cost-effective means of extending the useful life of a Federal-aid highway." PennDOT has successfully extended concrete pavement life by conducting full-depth repairs with concrete, restoring joints and overlaying. A waiver may be submitted to HDTS to use flexible base replacement in lieu of Accelerated Concrete Pavement Patching. A detailed justification must be provided within the waiver request, along with any supporting documentation.

Regardless of the approval process, the following practices should be followed to ensure a sound product, when substituting flexible base replacement for PCC removed on a project:

1. Each project will require the provisions of Publication 408, *Specifications*, Section 409 to be met, including density acceptance sampling and testing.

2. The minimum length of patch shall be 6 feet.

3. The flexible base replacement shall be placed in maximum compacted lifts as specified in Publication 408, *Specifications*, Section 409, and special provisions shall require that each completed lift be allowed to sufficiently cool prior to placing subsequent lifts. This is needed to avoid potential rutting.

4. A minimum overlay shall be placed over the entire project.

4.3 JOINTS

A. General Guidelines. Concrete joint partial-depth repair, joint rehabilitation and longitudinal joint repair should be considered in an effort to preserve or extend the life of an existing PCC pavement when it is not going to be overlaid. These items of work should be performed on pavements that are just beginning to show distress at the joints, even though the pavement's serviceability may still be satisfactory. In addition, if joint performance is a problem (e.g., faulting or poor load transfer), then the joint should be replaced with full-depth concrete pavement patching regardless of the amount of spall repair required.

B. Joint Cleaning and Sealing. Clean and seal all joints and cracks when a PCC pavement is going to be patched and overlaid with either bituminous concrete or unbonded PCC. Seal the joints and cracks with rubberized joint sealing material according to Publication 408, *Specifications*, Section 521. Badly spalled joints and slabs that have interior spalls should be cleaned and filled with FJ-1 bituminous wearing course material (or equivalent) according to Publication 408, *Specifications*, Section 469 prior to placing the overlay. Cleaning and sealing should be paid for as a separate bid item.

For a CPR project to be effective, the future infiltration of water, chlorides and incompressible materials into the pavement structure must be prevented. Methods currently employed to ensure this are as follows:

1. Joint Rehabilitation. Joint rehabilitation is a technique that revitalizes transverse contraction, construction or expansion joints in existing concrete pavements by constructing new sealant reservoirs and resealing the joints. Pavement performance can be greatly improved by providing effective joint seals.

There are two types of joint rehabilitation: Type 1, for rehabilitating existing sawcut joints; and Type 2, for rehabilitating existing metal plate joints (see Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 513). Joint rehabilitation is only applicable when restoring (not overlaying) existing concrete pavements. Joint rehabilitation is the most cost-effective when performed on pavements that are just beginning to exhibit minor joint distresses.

2. Longitudinal Joint Cleaning and Sealing. Cleaning and sealing of the longitudinal joint between traffic lanes and the longitudinal joint between the traffic lane and a concrete shoulder should be performed as part of every CPR project. See Publication 408, *Specifications*, Section 512. When the longitudinal joint has extensive spalls, the joint shall be repaired.

3. Pavement/Shoulder Joint Sealing. Because many concrete pavements have bituminous shoulders, it is essential that the pavement/shoulder joint is cleaned and sealed during every CPR project. Pavement/shoulder joint cleaning and sealing includes constructing a 0.75 inch by 0.75 inch sealant reservoir and sealing the joint with rubberized/asphalt joint sealing material. This work should be performed whether or not the bituminous shoulder will be reconstructed.

4. Transverse Joint Cleaning and Sealing. Transverse joint cleaning and sealing should be performed as part of a CPR project when the sealant reservoir has the proper shape factor (1:1). Transverse joints should also be cleaned and sealed on older roadways where joint rehabilitation is not economically justified but continued service is expected. See Publication 408, *Specifications*, Section 521.

5. Dowel Retrofit. Dowel retrofits are primarily used on roadways that receive heavily channeled loadings where transverse joints or cracks would benefit from improved load transfer. Dowel retrofits involve the installation of epoxy-coated, smooth dowel bars into the wheel paths of existing concrete pavement across cracks or transverse joints without dowels (see Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 527). A power-driven, self-propelled saw is used to make two parallel cuts per dowel bar slot for a minimum of four slots simultaneously, with saw cuts parallel to the roadway centerline. After the slots have been prepared and cleaned, the dowels are prepared and placed into the slots. The slots are then filled with concrete patching material and cured. Measurement and payment includes eight dowel bars per joint or crack.

6. Cross-Stitching. Cross-stitching is a repair technique intended to provide nearly 100% load transfer across a longitudinal crack or joint that is in reasonably good condition. This work consists of cross-stitching longitudinal cracks and may include cross-stitching longitudinal joints in plain cement concrete pavement by placing epoxy coated deformed tie bars, at an angle, across the longitudinal joint or crack (see Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 528). Cross-stitching is applicable for a number of situations where strengthening cracks or joints is required. Among these are:

- Strengthening longitudinal cracks in slabs to prevent slab migration and to maintain aggregate interlock.
- Mitigating the issue of tiebars being omitted from longitudinal contraction joints (due to construction error).
- Tying roadway lanes or shoulder that are separating and causing a maintenance problem.
- Tying centerline longitudinal joints that are starting to fault.

4.4 CONCRETE PAVEMENT PARTIAL-DEPTH REPAIR

Partial-depth repair is a technique that extends the service life of concrete pavements by restoring rideability with partial-depth patches of concrete slabs, as specified in Publication 408, *Specifications*, Section 525. These repairs can last the remaining life of the pavement if properly placed with a durable patch material. Partial-depth repair should only be performed on pavements as part of a CPR project or as maintenance.

Partial-depth repair is suitable for use on transverse or longitudinal joints, cracks, and interior slab spalls when the depth of the repair is no greater than half the slab thickness. Areas that require repair depths that are greater than half the slab thickness are to be repaired with full-depth concrete pavement patches, as specified in Publication 408, *Specifications* Section 516. If spalling at a transverse joint is caused by poor joint performance, then replace the joint with a full-depth concrete patch, regardless of the amount of spalling.

PennDOT classifies concrete pavement partial-depth repair by two types:

1. Type 1 - Spot repairs of transverse or longitudinal joints, cracks, and interior slab surface spalling between 15 inches and 6 feet in length.

2. Type 2 - Extended length repairs of transverse or longitudinal joints, cracks, and interior slab surface spalling in lengths greater than 6 feet.

The material used on any given project will depend on the time available before opening to traffic, expected ambient temperature, cost, size, depth and location of the partial-depth repairs. When a project contains regular concrete pavement patching, use Class AA Cement Concrete Modified since the time before opening to traffic will be controlled by the cure time of the patches. This material performs well since it is more compatible with the original material than the other repair materials.

Follow construction repair area preparation, concrete removal, partial-depth repair, and curing procedures as indicated in Publication 408, *Specifications*, Section 525.3.

Compression is a major cause of partial-depth repair failures. Point-loading failure is also a concern and can occur when the crack below the sawed joint breaks toward the patch area instead of vertically. Both modes of failure can be eliminated by installing a rigid polystyrene board, equal in width to the existing joint, between the patch and the adjacent slab. The patch should not be in contact with the adjacent slabs, and this temporary insert will provide sufficient space for the adjacent slabs to expand.

Expansion/contraction cycles become critical in partial-depth repair at those times of the year when nights are cool and daytime temperatures are high. Partial-depth repairs placed when pavement slabs are contracted should have adequate space between the patch and the adjacent slab to prevent compression failure by point loading of the patch area.

4.5 SLAB STABILIZATION

Pumping action and subgrade consolidation and settlement may create small voids beneath the slab. Most of the voids develop near transverse joints and cracks - particularly at outside slab corners. The loss of slab support results in excessive slab deflections and stresses and causes joint faulting, corner breaks, diagonal cracking and, finally, the complete breakup of the slab.

The following conditions indicate a loss of slab support:

1. Transverse joint faulting
2. Fines near joints or cracks on the traffic lane or shoulder
3. Small depressions (blow holes) in the shoulder at the transverse joint or crack
4. Corner breaks

Slab stabilization is a technique that attempts to stabilize the slab by filling voids at the slab/subbase interface with a cement/pozzolan grout. When voids are filled sufficiently, full support is restored. Slab stabilization shall be done according to Publication 72M, *Roadway Construction Standards*, RC-26M and Publication 408, *Specifications*, Section 679. Slab stabilization does not correct pavement surface depressions, increase the pavement's design structural capacity, or eliminate faulting. However, the pavement's structural integrity can be restored by filling voids to reduce deflections, which then reduces the potential for future pumping, faulting and slab cracking.

To reduce the amount of water that enters the pavement and contributes to pumping, joint and crack sealing must be performed in conjunction with slab stabilization. Also, subsurface drains should be kept in good condition.

For estimating purposes, at least 25 percent of the transverse joints and all patch joints should be stabilized if no preliminary testing has been performed. Estimate 1 cubic foot of grout per hole (0.25 bag of cement per hole). Refer to Publication 72M, *Roadway Construction Standards*, RC-26M for the number and pattern of holes to use at a joint or crack. To improve the effectiveness of full-depth patching, grout the patch with a two-hole pattern (the holes are drilled into the concrete adjacent to the patch). For the passing lane, grout the downslope side of the superelevation.

To economize the use of Maintenance and Protection of Traffic (MPT), drill the pavement just prior to stabilization; both crews (drilling and stabilizing) can be protected by the same traffic control devices. Refer to Publication 213, *Temporary Traffic Control Guidelines*, for MPT setup requirements. For the same reasons, confine drilling and stabilizing to a single lane at any one time.

4.6 SLABJACKING

Slabjacking is a technique that restores the structural integrity and rideability of the pavement by filling the voids beneath the pavement structure and raising the slabs to an acceptable profile. If done correctly, slabjacking can be more economical than slab replacement and is usually completed in less time with minimal interference to traffic. Slabjacking should be used with care because it can cause additional damage if performed improperly. Perform slabjacking according to this Manual and Publication 408, *Specifications*, Section 681.

An arrangement of string lines and blocks is used to determine the desired profile of the slab. The string line is usually positioned about 1 inch above the desired grade. Gauge blocks placed on the slab indicate the profile of the slab during lifting. As the blocks approach the string line, the rate of lifting is slowed. Pumping is stopped completely when the blocks touch the string line.

It is usually impractical, if not impossible, to perform slabjacking when the temperature is high because the pavement slabs will have expanded and the joints will be in compression. However, when correcting an extensive profile deficiency, such as an embankment settlement, slabjacking will more likely be successful if the slab is in compression.

During slabjacking operations, pumping will begin at the lowest point in a depression and work outward in both directions. However, when correcting a profile deficiency, grouting may start at the edge of a depression and work in from both directions. Slab lifting should be done in increments to minimize slab stresses and to avoid cracking. If grout starts to extrude from joints, cracks, or the pavement edge before the target elevation is reached, further slabjacking and grouting in of new drill holes are necessary.

For grout-estimating purposes, use 0.40 bag of cement per hole. Hole patterns must be determined in the field taking the following factors into consideration:

1. The size or length of the depressed area
2. The amount of correction required
3. Subgrade and drainage conditions
4. The location of joints and cracks

Drilling should be done just prior to slabjacking and both operations should be confined to the same traffic lane so they can be protected by the same MPT setup. Refer to Publication 213, *Temporary Traffic Control Guidelines*, for MPT setup details.

4.7 DIAMOND GRINDING AND GROOVING

Diamond grinding is a technique that re-profiles concrete pavements, eliminates wheel ruts, restores transverse drainage, increases pavement friction, and restores pavement surface texture. Total grinding of the pavement surface is preferred. When an isolated low spot is encountered, grinding to meet the low spot is not necessary if it requires excessive grinding of the surrounding pavement. Provide a positive cross slope such that the pavement drains including shoulder area as necessary. See Publication 408, *Specifications*, Section 514.

The cost of grinding depends primarily on the amount of material to be removed and the hardness of the coarse aggregate. If the type of coarse aggregate used in the original pavement is known, the following special provision should be used to aid the contractor in developing a realistic unit price for diamond grinding:

"The existing pavement is reinforced cement concrete constructed in _____ (insert year) using a _____ (insert type of) coarse aggregate and natural sand."

Diamond grinding costs are also influenced by the quantity of diamond grinding on the project, traffic control procedures, work hours, slurry disposal and the degree of pavement smoothness specified. The grinding limits should be clearly shown on the plans and must include the transition or stop lines at bridges and ramps.

Grooving consists of cutting deeper channels into the concrete pavement to provide more drainage of water between the tires and the pavement surface and thus reducing the chances of skidding and hydroplaning. The grooving limits should be clearly shown on the plans and must include the transition or stop lines at bridge decks. Transverse grooving is cut into new concrete pavements; see Publication 408, *Specifications*, Section 501. Longitudinal grooving and transverse grooving may be cut into existing cement concrete pavements after the original texture has been lost; see Publication 408, *Specifications*, Sections 510 and 517.

Concrete slurry impacts surface water by raising pH up to 10 or 11, and creating turbidity. Publication 408, *Specifications*, Sections 510, 514, and 517 specify the removal of slurry or residue resulting from the diamond grinding or grooving as the work progresses. Concrete slurry management shall include measures to prevent slurry from polluting drainage structures (or stormwater control structures), wetlands or waterways. Slurry is not to be wasted within the Department's right-of-way. Slurry is to be disposed of as specified in Publication 408, *Specifications*, Section 105.14.

4.8 WIDENING AND LANE ADDITIONS

Widening or lane additions for rigid pavements should be designed using Class AA cement concrete unless otherwise allowed in the following criteria or unless HDTS grants an exemption for the project. When designing widening or lane additions for existing rigid pavements, these criteria shall be followed:

1. This policy applies to all uniform-depth rigid pavements built since 1945, whether or not they have been overlaid. (Note: Air-entrainment began in 1945.)

2. Full lane additions (≥ 10 feet) shall be designed to the same thickness as the original pavement unless circumstances dictate heavier traffic loadings for the additional lane; then design for actual traffic.

3. Partial lane widening (< 10 feet) shall match existing pavement type and depth.

4. Widening of JPCP shall be constructed with plain cement concrete. JRCP may be widened with either reinforced or plain cement concrete.

5. Transverse joints on the widening or lane addition shall be aligned to match with those on the original pavement. When original transverse joint spacing is 20 feet or less, construct widening with slabs of same length as on the original pavement. When original transverse joint spacing exceeds 20 feet, widen with either JPCP with joint spacing not to exceed 16 feet or JRCP with joint spacing not to exceed 32 feet, and incorporate intermediate joints as necessary so that the slab lengths in the widened section are approximately equal.

6. Lane additions and widening should be tied to the existing pavement.

Sound engineering judgment must be exercised when applying the above criteria. When engineering judgment is contrary to these criteria, an exemption must be requested with supporting documentation submitted with the pavement design (see Section 5.10 for Bituminous Concrete Pavement Widening).

4.9 REHABILITATION

A. Overlays. Overlays are used to correct structural deficiencies, surface deterioration, and/or rideability on existing pavements. The type of overlay that is required for a pavement depends on the condition of the existing pavement.

Overlays are constructed either of PCC (rigid overlays) or bituminous concrete (flexible overlays). Rigid overlays are either unbonded or bonded. Unbonded concrete overlays and bituminous overlays are acceptable for all existing pavement conditions. Bonded concrete overlays of concrete are generally suitable for pavements in fair to excellent condition. Refer to Chapter 10 for guidance on the use of concrete overlays.

B. Surface Preparation. The following items are required for a successful overlay:

1. FWD Testing is required and should be conducted on existing PCCP, prior to designing an overlay for that PCCP.

2. Full-depth patching of the original pavement with PCC or bituminous concrete base course when approved.

3. Slab stabilization when slab movement or faulting is present.

4. Adequate subdrainage where subsurface drainage problems exist.

5. Cleaning and sealing of all existing joints prior to overlaying.

6. Cracking and seating is applicable for JPCP; breaking and seating applies to JRCP and CRCP where efforts are required to break the concrete from the reinforcing steel.

C. Bituminous Overlays. The required thickness of a bituminous overlay is the amount of additional pavement needed to provide the required structural strength as determined using the procedure in Chapter 10, which is based on the AASHTO Design Method. However, all bituminous overlays on concrete must be a minimum of 4 inches thick unless an exemption is granted by HDTS. Exceptions will not be approved for an overlay thickness of less than 1 inch on concrete.

When constructing a bituminous overlay over a concrete pavement, be sure to saw and seal the overlay directly over all underlying transverse joints and patch joints.

D. Concrete Overlays. PCC overlays on existing PCCP can consist of JPCP or JRCP. PCC overlays can be bonded or unbonded, while JRCP overlays must be unbonded.

Slabs that are rocking, pumping, and/or faulted should be stabilized prior to overlaying.

1. Bonded Overlays. The purpose of bonded overlays is to add structural capacity to and eliminate surface distresses on existing concrete pavements that are in good to fair structural condition. On asphalt pavements, bonded overlays generally provide resurfacing solutions for routine or preventive pavement maintenance or for minor rehabilitation on asphalt pavements or composite pavements.

Bonding between the overlay and the existing pavement is essential. The bond ensures that the overlay and existing pavement perform as one structure, with the original pavement continuing to carry a significant portion of the load.

Only use bonded JPCP overlays when the existing pavement is in relatively good condition and added slab thickness is needed to carry anticipated traffic. If extensive surface spalling exists, bonded JPCP overlays can be used to correct this problem also. If additional slab thickness is not needed and if there are restrictions on raising the roadway grade, a bonded JRCP inlay should be considered.

To achieve a bonded overlay, the surface of the existing pavement must be carefully prepared before placing the overlay. See Publication 408, *Specifications*, Section 524. This preparation must include the removal of all oil, grease, surface contaminants, paint and unsound concrete. This can be accomplished by cold milling, shotblasting, sandblasting, waterblasting, or a combination of these. If a cement/water grout is not specified, the existing concrete surface should be saturated. However if a cement/water grout is specified, it should be placed just in front of the paver on the clean, dry pavement surface. The grout must not be allowed to dry or set prior to placement of the concrete overlay.

The temperature of the existing pavement surface is of particular concern with bonded overlays. The rapid cooling of an existing surface may result in shrinkage stresses in the overlay. Conversely, a hot surface will cause curling and warping of the overlay during the initial cure period. This can be especially detrimental to the overlay's ability to bond to the existing pavement.

On the bonded overlay saw all joints to match the transverse and longitudinal joints in the existing pavement. All existing joints should be functioning properly before the concrete overlay is placed. All transverse contraction and expansion joints must be sawed the full depth of the overlay. The longitudinal joints can be sawed 1 inch deep. If the joint in the overlay is narrower than the existing joint, high stresses will develop during slab expansion and cause debonding and spalling. Therefore, the transverse joints in the overlay must be at least as wide as the transverse joints in the original pavement. Before overlaying, a backer rod can be placed at the top of an existing joint to prevent concrete from filling the reservoir. When concrete is placed over a properly functioning expansion joint, two cuts should be made in the plastic concrete and the thin center section of concrete removed. Otherwise, it should be treated as a construction joint in the overlay.

2. Unbonded Overlays. The purpose of unbonded overlays is to restore structural capacity to existing pavements that are moderately to significantly deteriorated. Unbonded overlays are minor or major rehabilitation strategies.

Unbonded overlays are basically new pavements constructed on an existing, stable platform (the existing pavement). The term "unbonded" simply means that bonding between the overlay and the underlying pavement is not needed to achieve the desired performance.

Unbonded concrete overlays can be used to correct a range of pavement deficiencies, from minor structural deficiencies to completely failed pavements. Separating (unbonding) the old concrete pavement from the concrete overlay is achieved by placing a 1 inch minimum bituminous separation layer covered by a bond breaker on the concrete pavement. A leveling course can also act as a separation layer. Polyethylene sheeting or a double application of wax-based white-pigmented curing compound can perform as a successful bond breaker. The use of other materials in lieu of a bituminous separation layer and bond breakers (e.g., geotextile fabric) must be approved in advance by HDTS.

Joints in unbonded concrete overlays are constructed in the same manner as joints in new concrete pavements (see Publication 72M, *Roadway Construction Standards*, RC-20M). It is not necessary to match the transverse joints in the overlay with the transverse joints in the existing pavement. No attempt should be made to do so. Joint spacing for the overlay will depend on the type of pavement being constructed (see Publication 72M, *Roadway Construction Standards*, RC-21M or RC-27M).

E. Cracking/Breaking and Seating the Existing Pavement. Cracking/breaking and seating an existing pavement attempts to achieve a stable, uniform level of support from a concrete pavement that is distressed to such an extent that it is no longer economical to patch the pavement. Cracking an existing JPCP, or breaking the bond between reinforcing steel and concrete on an existing JRCP, attempts to reduce the size of "free-moving" slabs to minimize differential movement at existing cracks, joints, and punchouts. This will, in turn, reduce the occurrence and severity of reflective cracking through the newly applied bituminous surface. These methods afford an intermediate level of support to the pavement overlay. To address drainage and/or subgrade issues, see Chapter 2.

The cracking/breaking and seating process reduces the pavement to 18 inch pieces (approximate) and rolls them into the base or subbase courses to seat them before applying an overlay. When patching a crack-and-seat project before overlaying, use flexible base course replacement instead of concrete patches.

F. Rubblizing the Existing Pavement. This method is applicable to badly distressed pavements, particularly where poor subgrade conditions and/or a high level of moisture is present in the subgrade/subbase. It affords the lowest level of support to the overlay and, thus, requires the thickest overlay. However, it is the most positive method for addressing the problem conditions mentioned above and for ensuring good pavement performance from the overlay in the future. To address drainage and/or subgrade issues, see Chapter 2.

There are two types of rubblizing in Pennsylvania (see Publication 408, *Specifications*, Section 526). The Type 1 rubblize process reduces the pavement to 12 inch pieces (maximum) and Type 2 rubblize process reduces the pavement to 8 inch pieces (maximum). The rubblized concrete pieces are then rolled into the base or subbase courses before placing an overlay. When replacing unsuitable material after the rubblization process, prior to overlaying, use AASHTO No. 1 coarse aggregate instead of flexible base course replacement or concrete patches. The determination to specify a Type 1 or Type 2 rubblization is based on project conditions and is at the discretion of the District Pavement Engineer.

4.10 RECONSTRUCTION

There are several cases where complete removal of the existing pavement section down to the subgrade may be warranted. Complete removal and replacement is needed if the pavement is badly deteriorated, the subgrade is good enough that undercutting will be minimal, and grade restrictions prevent raising the pavement surface with an overlay. Or a poor subgrade may be contributing to the poor pavement performance such that correction by undercutting and backfill is required. To address drainage and/or subgrade issues, see Chapter 2. Whatever the reason, complete removal and replacement provides the most uniform and stable pavement section while keeping grade adjustments to a minimum. However, it is usually a costly method of reconstruction.

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CHAPTER 5

BITUMINOUS CONCRETE PAVEMENT GUIDELINES AND POLICIES

5.1 TACK COAT/PRIME COAT

All contracts with Superpave Hot Mix Asphalt (HMA) and Warm Mix Asphalt (WMA) material should specify either a bituminous tack coat conforming to Publication 408, *Specifications*, Section 460 or bituminous prime coat conforming to Publication 408, *Specifications*, Section 461. Application rates are specified in each section. However, the Project Engineer must select an appropriate application rate within the specifications based on the porosity of the existing surface being overlaid. A lower application rate is intended for very smooth nonporous surfaces. A higher application rate is desirable for more porous surfaces. Note that on concrete pavement surfaces, an excess application of tack material can create a slip plane within the pavement structure that contributes to rutting and shoving in the bituminous overlay.

Evaluate the need for a tack coat/prime coat with FB surface courses on a project-by-project basis. Typically, the FB-1 mix does not require a tack coat. FB-2 mixes using PG 64-22 asphalt cement sometimes require a tack coat.

5.2 SEAL COATS, SLURRY SEALS AND SURFACE TREATMENTS

Seal coats, slurry seals, and surface treatments must not be used on the Interstate system. Use of these on other roads must be determined in accordance with Table 5.1.

A bituminous surface treatment or a scratch course/seal coat combination will correct deficiencies such as minor rutting, minor cracking, and loss of fine aggregate. However these treatments shall not be placed on a pavement in need of structural upgrading.

5.3 FB SURFACE COURSES

FB-1 wearing and binder materials are "cold" mixes. They are usually mixed and placed by a mobile plant, but may also be mixed in a stationary plant. FB-1 mixes are considered to be highly flexible because the mix has a high void content and because most of the bituminous materials used are softer than PG 64-22 asphalt cement. Because of its flexibility, FB-1 is recommended for use on low-volume roads that have highly flexible existing pavement structures.

The FB-2 specifications are very similar to the FB-1 specifications with only two significant differences: mixing must be done at a stationary mixing plant, and the use of PG 58-28 or PG 64-22 asphalt cement is permitted in the mix design. The use of PG 64-22 is the more commonly used asphalt cement for FB-2 mixes. The use of PG 64-22 or PG 58-28 requires that the material be mixed hot and placed hot.

FB Modified may be used either as binder or wearing courses. Use an appropriate Standard Special Provision (SSP). FB Modified may not be permitted on Federal-aid Projects.

Because of the high void content in the FB-1 and FB-2 surfaces, a seal coat or surface treatment must be placed on the FB surface. A minimum of 3 months of warm weather traffic densification of the FB surface is recommended before the application of either a seal coat or surface treatment. When the underlying pavement is structurally sound and the FB surface is in satisfactory condition, it is possible to postpone these applications up to 3 years. A seal coat or surface treatment may not be required on an FB Modified surface for at least 4 years.

When a deflection-based design program is used for design with FB surfaces, the depth of the FB overlay must be adjusted since the program assumes the overlay material is HMA. A structural coefficient of 0.20 must be used for FB courses when designing FB overlays. See Chapter 9 for the structural coefficients for paving materials.

TABLE 5.1
SEAL COAT, SLURRY SEAL AND SURFACE TREATMENT SELECTION GUIDE

CURRENT ADT	SEAL COAT	SLURRY SEAL	SURFACE TREATMENT
0 - 800	Yes	Yes	Yes
801 - 1,500	Yes	Yes	Yes
1,501 - 3,000	2	Yes	2
3,001 - 5,000	2	Yes	2
5,001 - 12,000	2	1	2
12,001 - 20,000	3	1	2
Over 20,000	No	No	No

The numbers in the Table refer to the following:

1 - Use only if base is good and existing surface is a HMA surface, WMA surface, or FJ-1.
2 - Use only if traffic is controlled during and after construction and aggregate is precoated or held to 1.0% passing #200 sieve.
3 - Use only if traffic is detoured or lane is closed for 24 hours and aggregate is precoated or held to 1.0% passing #200 sieve.

FB wearing courses may be used independently on roadways having an ADT of 1,500 or less. For roadways having ADT greater than 1,500, a combination of binder and wearing courses must be used.

Bid FB-1, FB-2 and FB Modified courses as equivalent alternatives in the contract proposal (i.e., FB-1 wearing or FB-2 wearing or FB Modified and FB-1 binder or FB-2 binder or FB Modified). FB courses must not be bid as alternatives to Superpave courses.

5.4 POLYMER-MODIFIED EMULSIFIED ASPHALT PAVING SYSTEM (MICRO SURFACING)

A. General. Polymer-Modified Emulsified Asphalt Paving System (Micro Surfacing) is appropriate for restoring or resurfacing a pavement that is structurally sound and does not require a significant amount of base repair. It cures quickly and performs well under traffic when proper controls have been maintained. Micro Surfacing may be considered for standard usage as an alternative to slurry seal, seal coats and surface treatment. Type A and Type B materials may be considered as alternatives to FJ-1 scratch courses. If Micro Surfacing is selected for use, it is imperative that the specifications are followed exactly. Table 5.2 provides a selection guide for when to use Micro Surfacing.

Micro Surfacing is very cost-effective on four-lane roadways where only the travel lane is rutted. Also, for special cases such as fill-in over trolley tracks and granite blocks, it may be specified without an alternative. When a structural overlay is not needed, Micro Surfacing may be used for rut filling to re-profile the bituminous pavement without any additional resurfacing. Micro Surfacing may be used for rut fill when the pavement distress is not related to base failure. It may also be considered for restoring rutted, but sound, jointed plain or reinforced concrete pavements since shoulders and inlet reconstruction can be greatly reduced or eliminated. On Jointed Plain Concrete Pavement (JPCP) and Jointed Reinforced Concrete Pavement (JRCP), do not place Superpave HMA/WMA scratch and/or leveling course prior to application of Micro Surfacing. In addition, Micro Surfacing can be effectively used to restore skid resistance to otherwise structurally sound pavements.

B. Project Selection.

1. When selecting a roadway project for Micro Surfacing, the road surface will have the following conditions: low severity cracking; low to medium severity raveling/weathering; friction loss; and moisture infiltration. Micro Surfacing can also be used to fill minor surface irregularities.

2. It is recommended that a double application be used unless the road surface is in excellent condition.

3. If the Micro Surfacing Project is on an Interstate, it is recommended to use a double application of Type A SRL-E (Publication 408, *Specifications*, Section 483), even if the road surface is in excellent condition.

4. The Skid Resistance Level (SRL) is selected from Table 5.4, the same table utilized for asphalt wearing surfaces.

5. Micro Surfacing material is classified into three mix types and will be used as follows:

a. Type A. Will be used to seal cracks, fill voids, and shallow (less than 1/2 inch) ruts; and provide a scratch course or surface treatment.

b. Type B. Will be used to fill moderate (1/2 inch to 1 1/4 inch) ruts; and provide a scratch course, a leveling course, surface treatment or seal coat.

c. Type RF. Will be used to fill deep (up to 2 inch) ruts in a single pass.

6. A table to create Item Numbers for each Type of Micro Surfacing and a list of those items is provided in Publication 408, *Specifications*, Appendix D and P:\penndot shared\Bureau of Maintenance and Operations\Roadway Management Division\Pavement Management\Micro Surfacing.

C. Bid Package Considerations.

1. Districts should group projects together in 20 to 40 lane mile sections to get the best pricing.

2. Bid Packages should be sent out to the contractor for bid before March 31st for optimal competition.

3. For nighttime activities, the work is to be scheduled between June 1st and August 31st.

4. For work during daylight, the work is to be scheduled between May 1st and September 30th.

5. Prepare bid/design package using sample templates that are located in the Design Template file at the below location. A sample of commonly used items can also be found at the same location. P:\penndot shared\Bureau of Maintenance and Operations\Roadway Management Division\Pavement Management\Micro Surfacing.

6. District Traffic Engineer or representative develops Traffic Control Plan, and plan should be included in the Design Package.

7. Attach the Micro Surfacing Mix Design and Materials Analysis form TR-483 located at: P:\penndot shared\Bureau of Maintenance and Operations\Roadway Management Division\Pavement Management\Micro Surfacing. (The Mix Design and Analysis form will be added to the Project Office Manual.).

8. Additional Directions for creating a bid/design package can be found at the following location:
ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%2051.pdf

D. Estimating Quantities. For estimating quantities of scratch and leveling course, use the following guidelines:

1. Micro Surfacing scratch or leveling courses require approximately 30% of Superpave leveling quantity. For example: 90 pounds per square yard of Superpave would require 27 pounds per square yard of Micro Surfacing.

2. Micro Surfacing scratch and surface courses used as an alternative to Superpave scratch and surface courses require a Type A or Type B scratch course plus the required square yards of Type A or Type B surface course as guided in Tables 5.2 and 5.3 and Section 5.4.C.5.

Table 5.3 provides application rates for Micro Surfacing used as a rut-filler. Application rates are provided for non-surface leveling course (rut-filling when an overlay will be placed) and for a re-profiling course (rut-filling as a surface course).

TABLE 5.2

POLYMER-MODIFIED EMULSIFIED PAVING SYSTEM SELECTION GUIDE

CURRENT ADT[5]	NON-SURFACE LEVELING COURSE			RE-PROFILE COURSE, RUT FILL USED AS SURFACE COURSE			WEARING COURSE, FULL WIDTH	
	TYPE A	TYPE B	TYPE RF	TYPE A	TYPE B	TYPE RF	TYPE A	TYPE B
0 - 5,000	2	3	4	2	3	4	Yes	Yes
5,000 - 10,000	2	3	4	2	3	4	Yes	Yes
10,001 - 20,000	2	3	4	2	3	4	Yes	Yes
Over 20,000	2	3	4	No	3	4	Yes	No

Numbers in Table refer to the following notes:
1 - Use only if existing surface is HMA/WMA or FJ bituminous concrete
2 - Use only if wheel ruts or depressions average 0.5 inch or less
3 - Use only if wheel ruts or depressions average more than 0.5 inch and less than 1.5 inches
4 - Use only if wheel ruts or depressions average 1.5 inches or more
5 - For divided highways the Current ADT is based on one-way counts.

TABLE 5.3

POLYMER-MODIFIED EMULSIFIED PAVING SYSTEM-RUT-FILL APPLICATION RATE GUIDE

(Rut-Filling Yield* Estimates for Design Based on Rut Depth)

AVERAGE RUT DEPTH (in)	TYPE OF MIXTURE	NON-SURFACE LEVELING COURSE (lb/sy)	RE-PROFILE COURSE (lb/sy)
1/4	A	10	15
3/8	A	12	16
7/16	A	15	25
1/2	B	23	28
9/16	B	27	32
5/8	B	31	36
11/16	B	35	40
3/4	B	39	44
7/8	RF	44	49
1	RF	49	54
1-1/8	RF	53	58
1-1/4	RF	57	62
1-1/2	RF	61	66

*****Yield is application of total mixture for Rut Fill in pounds per square yards. For heavier applications, a second application should be applied. However, proper and complete curing of the first application is necessary prior to additional application. Item Description in Schedule of Quantities should indicate a double application quantity when such is planned.

E. Surface and Work Preparation. See Publication 408, *Specifications*, Section 483.

5.5 HIGH FRICTION SURFACE TREATMENT

A High Friction Surface Treatment (HFST) is a thin layer of specially engineered binder resin that is topped with a durable, high friction aggregate (Bauxite). A HFST has exceptional skid-resistance properties, with Skid Numbers of 70 and above, which are not typically acquired by conventional materials. A HFST may be used on both Asphalt and Portland Cement concrete surfaces, and has an anticipated service life of 6 to 8 years.

A HFST is applied to short pavement sections, usually 1,500 feet or less, that exhibit a need for increased pavement friction demand. The HFST can help decrease highway fatalities and serious injuries related to wet pavement crashes at select locations such as curves, intersection approaches, or downgrades where increased vehicle braking is required. A safety evaluation will need to be completed to determine if an HFST is an appropriate treatment.

A HFST can be applied by machine at a similar speed to other paving surface treatments, or applied with hand tools. Mechanized application is the preferred method where possible, as it provides a more consistent distribution of resin and aggregate, leading to a more durable final product. Manual applications should only be used on small sections (less than 300 square yards), where it is not practical to use mechanized equipment. A combination of mechanized or semi-mechanized equipment should be used in most applications with handwork allowed in difficult to reach or with irregular shaped areas.

Refer to and utilize the Department's HFST specification (Publication 408, *Specifications*, Section 659) for all HFST work that is implemented.

For additional guidance, refer to the High Friction Surface Treatment (HFST) Usage Guide in Appendix I.

5.6 LONGITUDINAL JOINTS

During the proposal preparation stage of a project, consideration shall be given to specifying construction procedures that would provide for the best possible bituminous pavement in the area around the longitudinal joint.

Any project that meets all of the following criteria must include a bid item in the bid package in conjunction with Publication 408, *Specifications*, Section 405 (Evaluation of Bituminous Pavement Longitudinal Joint Density and Payment of Incentive/Disincentive). The criteria are:

1. All RPS pavements, regardless of network, or standard pavements on the National Highway System.
2. Pavement density acceptance via pavement cores.
3. Length of testable longitudinal joint meeting item #1 > 12,500 feet

Do not include the joint density incentive/disincentive item on projects that do not meet the above criteria.

For projects with multiple routes, where the incentive/disincentive does not apply to all of the routes, the contract/plans should stipulate which routes are included and which routes are not included in the item.

For those pavements where the District requires special construction procedures, a provision must be included requiring full-width paving, dual pavers or another system that would accomplish the desired result.

Also, include appropriate provisions in the special provision for the maintenance and protection of traffic (MPT) during construction to coordinate the paving method with traffic protection and/or detour operations. Refer to Publication 213, *Temporary Traffic Control Guidelines*, for MPT setup requirements.

5.7 PROVIDING FRICTION IN BITUMINOUS WEARING COURSES

The pavement surface of a highway should have an adequate level of friction throughout its life to ensure safe driving conditions. From a safety standpoint, a desirable surface:

- Develops an adequate amount of friction between the tire and pavement
- Has sufficient surface texture (i.e., low-speed gradient) to prevent build-up of water pressure at the tire/pavement interface at the posted speed limit
- Is capable of retaining these properties under traffic and environmental conditions throughout the life of the surface.

Studies of bituminous pavement surfaces during their normal service life indicate that material properties, mix design and construction techniques are all criteria in the development of a surface with good friction values. The most significant material property affecting the surface friction is the polishing resistance of the coarse aggregate. In 1975, PennDOT adopted a system of rating aggregates for friction.

The rating system was developed from a comprehensive test strip research program. It was determined that friction values go through an annual cycle in Pennsylvania roughly approximating a sine curve. Low values usually occur in late summer and fall with the amplitude depending on coarse aggregate characteristics and traffic volume. Initial friction measurements were nearly all adequate and not indicative of future performance. Coarse aggregate properties have the major effect, and the petrographic properties of a particular source can be related to its friction value.

Each of the approved sources of coarse aggregate listed in Publication 34, *Aggregate Producers* (Bulletin 14), are assigned a Skid Resistance Level (SRL) designation based on the particular aggregate properties. The SRL designation for an aggregate is based on performance in properly designed and produced dense-graded bituminous surfaces. Friction test results determined by PennDOT, using AASHTO-T242 Test Method, are used in reevaluating SRL designations.

When planning all new construction, overlays and resurfacing work, use the guidelines in Table 5.4 to determine the appropriate SRL designation for the coarse aggregate used in bituminous wearing course or the fine aggregate in FJ-1 wearing course. Determine the SRL designation by the anticipated initial ADT on new facilities or the current ADT for resurfacing. Exceptions to this may be made on a project-by-project basis.

Whenever a bituminous wearing course will be used, the SRL designation shall be indicated on pavement design approval forms, on typical sections and in the contract proposal. ***The design of inappropriately high SRL designations will be prohibited on non-wearing courses, leveling courses, and shoulders.*** However, a contractor is given the option of providing an aggregate with that SRL or better or an equivalent blend of aggregates.

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TABLE 5.4
SRL CRITERIA

INITIAL OR CURRENT ONE-WAY ADT	INITIAL OR CURRENT TWO-WAY ADT	SRL DESIGNATION
Above 10,000	Above 20,000	E
2,501 - 10,000	5,001 - 20,000	H; Blend of E and M; Blend of E and G
1,501 - 2,500	3,001 - 5,000	G; Blend of H and M; Blend of E and L
501 - 1,500	1,001 - 3,000	M; Blend of H and L; Blend of G and L; Blend of E and L
0 - 500	0 - 1,000	L

*E = Excellent, H = High, G = Good, M = Medium, L = Low

5.8 SUPERPAVE PAVING COURSES

A. General. Superpave provides a system for designing HMA and WMA paving courses to resist the climatic and traffic conditions for a specific project location. The full Superpave Asphalt Mixture Design System includes a volumetric asphalt mixture design procedure and additional mixture analysis. The Superpave volumetric asphalt mixture design procedure is a basic mixture design procedure that replaced the Marshall method of asphalt mixture design. The additional mixture analysis is based on advanced performance testing and performance prediction models that predict the performance of mixtures under the specific climatic and traffic conditions of a project.

Because Superpave is tailored to individual projects, PennDOT Pavement Management Engineers/Pavement Managers (PME/PM) and Project Designers will need to specify Superpave paving courses based on selection of a PG-Binder and the number of equivalent 18-kip single axle loads (ESALs). From the PG-Binder and the number of ESALs specified on a project, the Contractor and Producer of the Superpave paving course is able to properly design the mixture to resist permanent deformation (rutting) and thermal cracking (low temperature cracking).

Although projects will result in multiple mix designs, designers should attempt to minimize the number of total mixes per project. Most projects should have no more than three individual mix designs per project, while major projects should not exceed five individual mix designs. Numerous mix designs within a project are confusing and also result in higher cost.

B. Specifying PG-Binders for Superpave Paving Courses. Specify PG-Binders as detailed in Section 5.9 and Table 5.5.

C. Calculating Design Life ESAL's for Superpave Paving Courses. Design ESALs to be specified and described in the Item Numbers and in the Item Descriptions for Superpave HMA and WMA paving courses are to be calculated using a 20-year design life. The 20-year design life ESALs are to be used for all projects including Pavement Preservation projects. Use the 20-year design life ESALs even if the project's service life is intended or expected to be less than 20 years. Design ESALs calculated using a 20-year design life is very important in the Superpave volumetric asphalt mixture design procedure. The 20-year design life ESALs establish the rate of loading expected by the paving course. The 20-year design life ESALs will be used by the Producer of the HMA and WMA to properly design a HMA and WMA mixture.

After calculating the design ESALs of a particular State Route (SR) using a 20-year design life, determine what ESAL range the 20-year design life ESALs fall between. Superpave volumetric mixture design has five ESAL ranges for mixture design. The five ranges are as follows:

- < 0.3 million ESALs
- 0.3 to < 3.0 million ESALs
- 3.0 to < 10.0 million ESALs
- 10.0 to < 30.0 million ESALs
- 30.0 million ESALs and greater

Select the ESAL range that corresponds to the 20-year design life ESALs calculated for a specific SR. Specify that range in the Item Numbers and Item Descriptions for Superpave HMA and WMA paving courses.

When the top of a design layer is ≥ 4 inches from the pavement surface (primarily base courses) and the estimated ESAL range is ≥ 0.3 million ESALs, decrease the design ESAL range by one, unless the mixture will be exposed to significant mainline and construction traffic prior to being overlaid. If less than 25% of the layer is within 4 inches of the surface, the layer may be considered to be below 4 inches for mixture design purposes.

For mix design quantities less than 250 tons or less than 1000 square yards at 1 1/2 inches, the ESAL range may be changed up or down by one range to minimize the number of mix designs per project. Permission from PDAU is required for all other ESAL range changes, i.e. larger quantities, small quantities by more than one range, etc.

D. Permissive Policy for Superpave Paving Courses. For projects that are to include the placement of one or more Superpave asphalt paving courses, the Project Designer may either specify the placement of Superpave HMA paving courses and include, as alternates, bid items for the equivalent WMA paving courses; or directly specify the placement of Superpave WMA paving courses.

In order to maintain a neutral presentation in the bid proposal when both HMA and WMA paving courses are to be specified as alternates, references to material type that appear in typical sections, details, and all other information in the plans should not specify WMA or HMA. Only the bid items, as shown in the Schedule of Prices and on tabulation and summary sheets, should include the HMA or WMA designation within the description of an individual bid item, so that the bidder's intent with regard to the type of bituminous pavement it has elected to construct can be clearly indicated.

5.9 SPECIFYING PG-BINDERS FOR SUPERPAVE PAVEMENT COURSES

A. Standard Grades of PG-Binders. Only three (3) standard PG-Binders (PG 58-28, 64-22 and 76-22) are to be specified in Conventional Pavement Courses and Superpave Pavement Courses. Standard Binders have been selected to limit the proliferation of PG-Binders, so that asphalt binder suppliers can adequately plan, produce, and supply a set number of asphalt binder grades at an economical price to PennDOT. Table 5.5 lists the three standard PG-Binders and the project types and pavement courses for which they are to be used.

B. "Bumping" Practice for PG-Binders. Under the Superpave Mixture Design System, there exists a practice of "bumping" the high-temperature grade of the PG-Binder (example: "bumping" one grade from a PG 58-28 to a PG 64-28). This practice is intended to provide a stiffer asphalt binder at high pavement temperatures that typically occur during the summer months, to resist pavement rutting better. Use the PG-Binders identified in Table 5.5 that will best fit the project type.

C. Nonstandard Grades of PG-Binders. Nonstandard grades of PG-Binders are defined as those grades of PG-Binders not shown in Table 5.5, such as PG 64-28, PG 70-28, PG 76-28, PG 70-22, or any other PG-Binder. Nonstandard grades of PG-Binders may only be used with prior approval from BOPD, Innovative and Support Services Division (ISSD), Laboratory Testing Section. If a District desires to use a nonstandard grade of PG-Binder, a Superpave Special Study Project will be required including additional work as described in Section 5.9.E.

TABLE 5.5
SELECTING PG-BINDERS FOR CONVENTIONAL AND SUPERPAVE PAVEMENT COURSES

PG-BINDER	**PROJECT TYPES**	**ELIGIBLE PAVEMENT COURSES**	**COST (STANDARD OR PREMIUM)**
PG 58-28	To be used in the northern half of the State {Districts 1-0, 2-0, 3-0, 4-0, 9-0, 10-0, 11-0, 12-0 and 5-0 (Monroe, Carbon, & Schuylkill Counties only)} under light traffic conditions and level or rolling terrain. Do not use in heavily trafficked intersections. Do not use on steep downgrades where traffic is under moderate to heavy braking. Do not use on steep upgrades where truck traffic slows considerably. Use in situations where AC-10 was specified in the past.	Wearing Binder Base	Standard
PG 64-22	To be used in any part of the State under most traffic conditions. Use in situations where AC-20 was specified in the past.	Wearing Binder Base Leveling Scratch	Standard
PG 76-22	To be used in any part of the State under heavy traffic situations, at intersections, or at locations where rutting has occurred in the past. Use is recommended for projects that have $\geq$ 2,500 ESALs per day. Use in situations where polymer-modified asphalt cement (PMAC) was specified in the past. Note: PG 76-22 can result in Superpave mixtures which may be difficult to work with by hand during certain construction operations such as; driveway adjustments, paving around drainage inlets & manholes.	Wearing Binder *	Premium

*Under extreme heavy traffic situations, or locations where rutting has been a problem in the past, the District should specify the PG 76-22 in both the Wearing Course and Binder Course.

D. Approved PG 76-22 Asphalt Binders. Approved PG 76-22 asphalt binder Suppliers are listed in Publication 35, *Approved Construction Materials* (Bulletin 15). The approved PG 76-22 asphalt binders are those asphalt binders that are polymer modified by adding styrene block copolymers (SB or SBS formulations). Publication 35, *Approved Construction Materials* (Bulletin 15) may also list Provisionally Approved PG 76-22 that is an asphalt binder that is modified by adding other polymer formulations such as natural latex (SBR formulation) or other modifiers. Provisionally approved PG 76-22 asphalt binder can be used on any project requiring PG 76-22. For the list of provisionally approved modifiers and their use, refer to Publication 35, *Approved Construction Materials* (Bulletin 15).

E. Superpave Special Study Projects. All projects dealing with nonstandard grades of PG-Binders or unapproved PG 76-22 asphalt binders must be submitted to the ISSD for approval. Approval will be granted subject to the District agreeing to specify one or more of the standard grades of PG-Binders (when nonstandard grades are desired), or one or more of the currently approved PG 76-22 asphalt binders (when unapproved PG 76-22 asphalt binders are desired) to serve as control sections for comparison. These comparisons are necessary and will help identify other grades of PG-Binders, different polymer modifiers, and/or asphalt binder blending techniques that are viable and will perform well under the various climate, traffic and structural conditions in Pennsylvania.

The three standard grades of PG-Binders and the approved PG 76-22 asphalt binders polymer modified with SB and SBS formulations have been used in the past on PennDOT projects and PennDOT experimental projects. Their performance both in the short-term (construction) and long-term (5 to 10 years) has been well documented. The documentation indicates good performance under actual Pennsylvania climatic conditions, various traffic conditions, and various project types.

Superpave Special Study projects will require the District to coordinate with the ISSD and to perform additional work that may include the following:

- Detailed pre-construction manual pavement distress surveys
- Additional asphalt binder sampling for ISSD and the Northeast Center of Excellence for Pavement Technology (NECEPT)
- Additional loose box sampling for ISSD and NECEPT
- Additional core sampling for ISSD and NECEPT
- Post-construction manual pavement distress surveys and core sampling for a period of 3 to 5 years after construction.

ISSD and NECEPT will provide the District the necessary sampling plan to follow during construction of these Superpave Special Study Projects. If required, ISSD and NECEPT will also supply the necessary technical support and coordination in helping the District to construct these needed projects.

5.10 WIDENING

Partial lane widening (< 10 feet) of bituminous pavements must match the existing pavement structure (i.e., bituminous layers will be matched with equal depth of bituminous material, and concrete layers will be matched with an equal thickness of concrete). As much as possible, keep drainage layers consistent with those of the existing pavement.

Full width lane additions (≥ 10 feet) should match the existing pavement structure also, unless circumstances dictate heavier or lighter traffic loadings for the additional lane. In those cases, design for the actual traffic. It is important when changing the pavement layer thicknesses to check that drainage is adequately provided throughout the pavement cross section (see Section 4.8 for PCC Pavement Widening).

5.11 OVERLAYS

Overlays are used to correct structural deficiencies, surface deterioration, and/or rideability on existing pavements. The type of overlay that is required for a pavement depends on the condition of the existing pavement.

Overlays are constructed either of Portland cement concrete (rigid overlays) or bituminous concrete (flexible overlays). Rigid overlays are subdivided as follows: are either unbonded or bonded. Unbonded concrete overlays and bituminous overlays are acceptable for all existing pavement conditions. Refer to Chapter 10 for guidance on the use of concrete overlays over flexible or AC/PCC (composite) pavements.

A. Pre-Overlay Surface Preparation. Where indicated, place a separate scratch or leveling course ahead of resurfacing operations. Use a scratch course to fill wheel ruts and other local small depressions even with the surrounding pavement.

A leveling course, minimum of 1 inch thickness, is placed to provide a uniform working platform on which the binder and/or wearing course is placed. A leveling course is also used to correct an erratic longitudinal profile of the existing pavement. However, when a leveling course is used, it may be included in the pavement's structural calculations as a 1 inch thick paving course.

Only a leveling course can be used to correct profile or to re-establish the proper cross section of the roadway. It is not recommended to combine a binder course with a leveling course since it is difficult to maintain adequate quality control of either the leveling course or the binder layer. The leveling course (wearing or binder) tonnage item establishes the cross slope, while the wearing and/or binder courses are to be placed at a uniform depth. Superpave 25.0 mm, 19.0 mm, 12.5 mm and 9.5 mm mix may be used, at the appropriate minimum depths, to attain the required cross section.

Refer to Table 10.5 for minimum and maximum thicknesses.

Alternative methods for improving the transverse or longitudinal profile of the pavement include heater planing and milling. These alternatives shall only be considered when the pavement base is in stable condition and removal of the material would not affect the pavement performance or when curb reveal, shoulders, guide rail or drainage structure adjustments are major considerations.

When milling a portion of a bituminous layer over a cement concrete or brick base pavement the entire bituminous layer may be removed. However, it is preferred that a minimum of 1 1/2 inches of existing bituminous material be left in place, in order for the material to retain its structural integrity and be adequately bonded to the underlying base. Coring must be performed during the design phase of the project to determine if an adequate bond exists between the concrete or brick base and the existing bituminous material. Debonding of the existing bituminous overlay from the concrete or brick base will require removing the entire depth of existing bituminous overlay. Allow for debonding areas not discovered by coring with a surface replacement item in the contract.

B. Thin Bituminous Overlays. On Interstates do not place Superpave Wearing Course overlays with a thickness less than 1 1/2 inches without prior approval from PDAU. On non-Interstates do not place Superpave Wearing Course overlays with a thickness less than 1 1/2 inches without meeting the following conditions:

- The existing pavement surface is bituminous.
- The existing pavement is structurally sound; less than 2% of the pavement requires patching.
- Surface drainage is good, or will be upgraded to good, with this project.
- Subsurface drainage is good, or will be upgraded to good, with this project.
- No structural upgrade of the pavement is required.
- Thin bituminous overlays will only be placed per the pavement depth limitations stated in Table 9.5 and in accordance with the weather limitations stated in Publication 408, *Specifications*, Section 409.3(b).

C. Guidelines for Superpave HMA, 9.5 mm Fine Grade (FG). Since PennDOT implemented 100% use of Superpave HMA mixes in 2000, the need for a material for thin functional overlays became apparent. Due to the financial limitations, PennDOT, counties and many municipal surface improvement programs would be adversely impacted if the minimum overlay thickness was 1 1/2 inches in depth.

In order to meet this need, PennDOT developed the Superpave HMA Wearing Course, 9.5 mm Fine Grade (FG) to allow applications less than the typical 1 1/2 inch wearing course required by a standard Superpave HMA, 9.5 mm Wearing Course. Use of Superpave HMA 9.5 FG as a scratch and or leveling course is permissible within the limitations stated in Table 10.4.

The following are limitations and guidelines for the proper application of Superpave HMA Wearing Course, 9.5 mm FG:

1. Use Tables 9.5, 10.4, and 10.5 for Structural Coefficient number, minimum and maximum placement depths, and Scratch and Leveling Course Thicknesses.

2. Use Table 10.1, and/or 10.2 for ADT limits for proper application.

3. Only use Superpave HMA, 9.5 mm FG Wearing Course on sound pavement surfaces.

4. Do not use Superpave HMA, 9.5 mm FG Scratch or Leveling Course as a pavement surface course.

5. Superpave HMA, 9.5 mm FG Scratch or Leveling Course may be used in conjunction with a Seal Coat or other surface treatment.

6. Use of Superpave HMA, 9.5 mm FG Wearing Course as a tonnage item on Maintenance Contract work or a Group Project must state the minimum and maximum allowable depths within the contract.

7. Do not use PG Binder 76-22 for Superpave HMA, 9.5 mm FG Wearing Courses.

D. Safety Edge$_{\mathbf{SM}}$. The Safety Edge allows drivers who drift off highways to return to the road. Instead of a vertical drop-off, the Safety Edge consolidates the edge of the pavement to a 30° taper (with a 26° to 40° construction tolerance). The Safety Edge provides a strong, durable transition for all vehicles. Even at higher speeds, vehicles can return to the paved road. By including the Safety Edge detail while paving, this countermeasure can be implemented system-wide at a very low cost.

The Safety Edge shall be used as a standard pavement edge treatment on the outside edge of bituminous pavements and shoulders. It should be used for both wearing and binder courses with a depth of 1 1/2 inches and greater. The total depth of the Safety Edge should not be more than 5 inches.

The Safety Edge is considered incidental to the paving course being placed when the standard special provision is included in the contract. The Safety Edge will result in an approximate 1% increase in the HMA/WMA material quantity. For tonnage items the 1% increase must be added to the project quantities.

For additional information and guidance about the Safety Edge, including when it is to be used and how it is to be built, refer to Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 12, Section 12.8.

5.12 COLD RECYCLED BITUMINOUS BASE COURSES

A. Introduction. Cold recycling of asphalt pavements can be an advantageous pavement rehabilitation alternative. Cold recycling is an environmentally acceptable method of rehabilitating asphalt pavements that offers significant economic savings. The Department's standard specification is provided in Publication 408, *Specifications*, Section 341.

B. General. Cold recycled base course is existing asphalt pavement that is processed and treated without additional heating to produce a restored pavement layer to serve as a new base course. Typically this involves milling to a specified depth, adding and mixing emulsified asphalt, placing to a specified grade and compacting. Normally a HMA overlay is placed over the base course; however a cold-mix asphalt overlay or an asphalt surface treatment is adequate if traffic is light.

C. Characteristics of Cold Recycled Mixtures.

1. The structural strength of these mixtures is lower when first constructed and it increases as the mixture cures over several weeks. A minimum of one week curing under favorable weather conditions (low humidity-high temperature) is required for these mixtures before placing the wearing course.

2. Unlike hot asphalt mixes, these mixes are less resistant to abrasion by the traffic. These mixtures are not suitable for high ADT roads unless detours can be established until adequate structural strength is obtained.

3. Due to the higher void content of these mixes, a wearing surface is imperative.

4. The minimum compacted depth is 3 inches and the maximum is 5 inches.

5. If the recycled asphalt pavement (RAP) consists of wearing course or fine graded mix, incorporate virgin coarse aggregate (No. 8, 57, or 67) into the recycled mixture to meet the requirements of Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27).

D. Selection of Projects. Project selection is an important factor in assuring the success of a cold recycling project. The selection process includes an assessment of existing pavement conditions, sampling and testing of pavement, base, subbase and subgrade materials, and a study of the pavement's construction and maintenance history and traffic. The assessment process includes an evaluation of the potential risk involved if the pavement does not support the cold recycling equipment and traffic through construction.

Most types of pavement distress can be rehabilitated by cold recycling. However, cracked pavements with structurally sound, well drained bases and subgrades are the best candidates.

Asphalt pavements with fatigue cracks, transverse thermal cracks, reflection cracks and raveling can be successfully recycled. The cold recycling process destroys the existing crack pattern and produces a crack free layer for a new surface course.

Cold recycling can be economical and effective for reconstruction or widening of collector and local access highways, and for reconstruction or construction of shoulders. Since the underlying untreated base material can also be recycled with the bituminous layer, a higher strength and uniform base course is obtained. In-place cold recycling can be more economical and effective than central plant mixing for projects located in areas far from the central mix plant. Central plant mixing can be used where surplus millings are available or the existing bituminous pavement is removed to allow for stabilization, grade adjustment or some other treatment of underlying materials.

The following guidelines are recommended in selecting a candidate project for cold recycling:

1. ADT Criteria:

TABLE 5.6
ADT CRITERIA

ADT VOLUME	COLD RECYCLING OPTION
1,000 and less	Provide a surface treatment (double application) as a minimum for wearing course.
1,001 to 3,000	Provide a Superpave wearing course or cold mix wearing course (FB modified, FB-2 or FB-1).
3,001 to 10,000	Provide a Superpave wearing course.
10,001 to 15,000	If daily ESALs are less than 200, provide a Superpave wearing course and binder course.
More than 15,000	Do not use.

Projects carrying significantly heavy truck traffic (i.e., 200 or more daily ESALs) should not be selected for cold recycling.

2. The existing road must have at least 2 inches of bituminous material. Use 1 inch of underlying untreated reclaimed aggregate material (RAM) or add 1 inch of virgin aggregate during the recycling process to achieve the 3 inch minimum thickness. Do not specify the milling cut depth below the bottom of the existing bituminous pavement unless the underlying material is recyclable. If the RAM consists of aggregates larger than 2 inches (such as, some native stone bases) or excessive soils, it cannot be appropriately recycled using these specifications and procedures. Department guidelines and specifications for Full Depth Reclamation are provided in Section 5.14; Publication 408, *Specifications*, Section 344; and Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27), Chapter 2, Section 7: Full Depth Reclamation (Using Bituminous Stabilization Process).

3. If the existing road has deteriorated due to poor drainage conditions, do not attempt cold recycling.

4. Only select projects where traffic can be controlled or detoured during base construction and curing period.

E. Materials Design and Control. The mix design process for cold recycled base course is outlined in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27), Chapter 2. The design method lists applicable test procedures and the type of emulsified asphalts permitted for use on Department cold recycled base course projects. The design procedure listed in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27) must be utilized by any contractor or consultant who has been awarded the contract for Department Cold Recycled Base Course projects.

Polymer modified emulsions provide improved initial strength of the recycled mix. Use of polymer modified emulsions is recommended where the following are encountered:

- Traffic volumes over 3,000 two-lane AADT.
- High percentage of truck traffic.
- Early or late season recycling where initial curing may be impaired.
- Any areas where quick stabilities may be desired.

5.13 STONE MATRIX ASPHALT WEARING COURSE

Stone Matrix Asphalt (SMA) is a tough, stable, rut-resistant mixture that relies on stone-to-stone contact to provide strength and rich mortar binder to provide durability. These objectives are usually achieved with a gap graded aggregate coupled with a fiber or polymer modified, high asphalt content matrix.

The five steps required to obtain a satisfactory SMA mixture are:

- Select proper aggregate materials;

- Determine an aggregate gradation yielding stone-on-stone contact;

- Ensure the chosen gradation meets or exceeds minimum requirements for voids in the mineral aggregate (VMA) or allows the minimum binder content to be used;

- Choose an asphalt content that provides the desired air void level; and

- Evaluate the moisture susceptibility and asphalt cement draindown sensitivity.

SMA is generally more expensive than a typical dense-graded Superpave because it requires more durable aggregates, higher asphalt content and, typically, a modified asphalt binder and stabilizer. In the right situations, it should be cost-effective because of its increased rut resistance and improved durability.

The following list provides additional guidance and recommendations regarding the use of SMA:

- Consider specifying SMA when there is a minimum quantity of 50,000 square yards. Quantities closer to 100,000 or more square yards makes SMA a good option. SMA requires a special mix design, a fiber machine to be purchased/leased, a 100 ton test strip performed off site, high amount of mineral filler added in a different manner than usual, and often special aggregate production. With all of these factors, SMA would be cost prohibitive for the Department to put out in small quantities.

- Consider specifying SMA for Interstates, Interstate look-alike highways, and high-speed freeways.

- Consider recommending SMA as the wearing course on current roadways with greater than 30 million ESALs.

- Avoid specifying SMA in areas where a lot of handwork or many changes to the paver configuration will be required such as intersections, etc.

- Avoid using SMA in areas where there are any issues with the underlying pavements. SMA is a premium mix for a premium price; it should not be used as a stopgap approach for a problem area thinking that superior performance will be obtained.

Construction requirements for SMA are found in Publication 408, *Specifications*, Section 419, Stone Matrix Asphalt Mixture Design, RPS Construction of Plant-Mixed HMA Wearing Courses.

For additional information about Stone Matrix Asphalt, refer to the publication, *Designing and Constructing SMA Mixtures---State-of-the-Practice, Quality Improvement Series 122* by the National Asphalt Pavement Association.

5.14 FULL DEPTH RECLAMATION TECHNIQUES

A. Introduction. Full Depth Reclamation (FDR) is an effective method for rehabilitating distressed roads. A road reclaimer pulverizes the existing asphalt layer, incorporating underlying aggregate base and/or subgrade materials, stabilizes the material using one or a combination of several methods, and places it back on the roadway grade. The FDR material is then shaped using motor graders, and compacted. After compaction, traffic may drive on the newly reclaimed pavement base layer. This process adds strength and flexibility to the existing pavement materials and eliminates existing distresses to provide a renewed pavement base. FDR is an effective tool for highway agencies to reduce rehabilitation costs and achieve sustainability of their road system. The Department's standard specification is provided in Publication 408, *Specifications*, Section 344.

FDR is distinguished from other rehabilitation techniques like Cold In-Place Recycling or Hot In-Place Recycling in that the pulverizing machine always penetrates completely through the asphalt layers into the underlying base layers, thereby eliminating the potential for reflective cracking or pavement failure resulting from a weak base layer. The following benefits can be achieved from the FDR process:

- Existing bases can be reclaimed for upgrading existing roads.

- Pavements experiencing severe distress can be reclaimed.

- Using materials in-place minimizes disposal and the use of virgin materials.

- Drainage and cross slopes can be re-established.

- The existing road material is completely recycled.

- The process builds structure within the pavement cross section, minimizing the need for surface elevation adjustments.

- Reclamation can be used as a first step in stage construction, adding more structure as needed to meet increasing traffic demands over time.

The quality of the reclaimed material can generally be improved by the introduction of a stabilizing material. Typical stabilization materials are chemical, asphalt, or some others such as calcium chloride. Chemical stabilization involves mixing and reacting some stabilization material or materials such as cement, fly ash, or lime kiln dust.

B. Selection of Projects.

1. Evaluation and Assessment of the Roadway. As with other pavement treatments, it is important that sufficient information about the existing pavement be gathered when attempting to determine if FDR is a suitable rehabilitation strategy, or to design a successful FDR project. The initial evaluation and assessment of the existing pavement will require the following information:

- Determination of Traffic Level
- Survey of the Existing Pavement Condition
- In-Situ Testing
- Sampling

a. Traffic Level. It is important to obtain a reliable estimate of future traffic loading on the road before the road is constructed. While FDR may be applicable over a range of traffic levels, the overall pavement design must be consistent with standard pavement design traffic analysis procedures.

b. Pavement Condition Survey. Having a recent pavement condition survey is important. For PennDOT projects, this is typically performed in accordance with the criteria provided in Publication 336, *Automated Pavement Condition Survey Field Manual* or Publication 343, *Continuously Reinforced Concrete and Unpaved Roads Condition Survey Field Manual*, depending on existing road surface type. Alternatively, other distress procedures such as those defined in MicroPaver™ or a similar distress evaluation procedure may be used for municipal projects.

The distress survey not only provides information about the condition of the pavement at the time of survey, but also provides insight into the causes of the visible distresses. It is always important to understand the mechanisms responsible for existing pavement damage, in order to prevent the same damage mechanisms from causing failure of the rehabilitated pavement.

Upon completion of the distress survey, a summary report should be provided to document the level of distresses and corresponding observations. The severity of rutting, cracking, raveling, potholes, and drainage issues should be specifically considered in the rehabilitation strategy performed to assure each is appropriately addressed.

c. In-Situ Testing. Beyond a visual survey of the pavement condition, it is important to assess the in-situ strength of the subgrade material which will support the rehabilitated pavement structure. Falling Weight Deflectometer (FWD) testing before rehabilitation provides valuable information about the stiffness of the existing pavement materials. Testing after construction is useful for determining the stiffness of the new pavement. Appendix J, Section J.2.C.1 presents additional details about the use of this test. Two other tests are also useful for testing the subgrade; the dynamic cone penetrometer (DCP), and the light weight deflectometer (LWD). Details about DCP testing are presented in Appendix J, Section J.2.C.2, and details about LWD testing are presented in Appendix J, Section J.2.C.3.

d. Sampling. Proper sampling plays a vital role in the successful design and construction of FDR. The following criteria must be considered when obtaining samples from the FDR candidate roadway. Details for properly collecting and handling samples are presented in Appendix J, Section J.2.D. The subsections for each category in Appendix J are shown below:

- Section J.2.D.1 Number of samples and locations of sampling
- Section J.2.D.2 Material sample size
- Section J.2.D.3 Sampling techniques

- Section J.2.D.4 Depth of sampling and identification of layers
- Section J.2.D.5 Handling and evaluation

2. Determine Layer Thicknesses and Drainage Conditions. The determination of an appropriate layer thickness is critical to the success of FDR, as with any other well-designed pavement alternative. There are two considerations in selecting a FDR layer thickness. One is the composition of the existing pavement and subgrade materials that could be incorporated into the reclaimed layer. The second is the structural requirement for the pavement based on the anticipated traffic and environmental conditions, and the role of the reclaimed layer within the total required pavement structure. The practicality of using FDR is to some degree determined from the thickness of the existing pavement and the type and amount of subgrade material which will be incorporated into the reclaimed layer.

The construction of a well-drained pavement system is vital to the successful performance of all pavements. The presence of excess water within a pavement structure, including the subgrade, is detrimental to any pavement. Excess moisture can result in the loss of pavement material integrity and weakening of the pavement structural capacity. Therefore, it is important that any existing drainage problems be identified and corrected prior to constructing the reclaimed pavement layer. Wet subgrade locations should be identified and effective drainage installed before FDR is undertaken. Other water-related damage within the existing pavement layers should be evaluated to determine the source of water, and a solution for correcting the problem before reclamation.

3. Evaluate the Applicability of FDR. Table 5.7 provides an indication of when FDR is a suitable rehabilitation strategy, based on pavement surface distresses present. This procedure is the first step in the FDR decision making process. In general, FDR is indicated for use in situations where improvement of the support layers is required. Other strategies are likely to be more effective for surface-related distresses.

C. Material Design and Quality Control. FDR can be performed using one of several stabilization mechanisms including pulverization stabilization, mechanical stabilization, chemical stabilization, calcium chloride stabilization, and emulsified asphalt stabilization.

1. Pulverization Stabilization. This method of stabilization uses only the reclaimed, in-place materials, without additives other than moisture to aid compaction. As such, the strength potential of these materials in their re-compacted condition must be considered. Pulverization is also the foundational step for all FDR methods using additives for stabilization. A detailed description of the pulverization process is presented in Appendix J, Section J.3.A. Construction details for pulverization stabilization are presented in Appendix J, Section J.4.A.

2. Mechanical Stabilization. Mechanical stabilization is accomplished by pulverizing the existing pavement, reshaping, and re-compacting the reclaimed material as with pulverization stabilization, but also adding aggregate material, or RAP material, to improve gradation. This imported granular material is introduced to the recomposed base layer during the pulverization process. This method of stabilization may improve the structural integrity of the existing materials, or may be used to increase the volume of material for raising the surface elevation or widening without reducing layer thickness. A detailed description of the mechanical stabilization process is presented in Appendix J, Section J.3.B. Construction details for mechanical stabilization are presented in Appendix J, Section J.4.B.

3. Chemical Stabilization. Chemical stabilization is a process by which wet or dry chemical additives are used to stabilize the reclaimed material. The most common additives include Portland cement, lime, and fly ash, which may be used individually or in combination. Lime kiln dust and fly ash material from the fluidized bed combustion process have seen limited use and are potentially available for FDR use.

Generally, increasing the amount of chemical stabilizer increases strength, but excessive amounts of stabilizing agent may result in brittleness. The type and content of stabilizer used should be determined by laboratory testing. Stabilizing agents may be applied dry or as a slurry ahead of the reclaimer, or may be introduced as a slurry the mixing chamber of the reclaimer through a spray bar. Details about chemical stabilization, including mix design, mix design development, and strength requirements are presented in Appendix J, Section J.3.C. Construction details for chemical stabilization are presented in Appendix J, Section J.4.C.

TABLE 5.7
SELECTION OF FULL DEPTH RECLAMATION (FDR)

PAVEMENT DISTRESS	FDR
Surface Defects	
Raveling	
Flushing	
Low skid resistance	
Deformation	
Corrugations	
Ruts-shallow	
Rutting Deep[1]	X[2,3]
Cracking (Load Associated)	
Alligator	X
Longitudinal	
Wheel Path	X
Pavement Edge	X
Slippage	
Cracking (Non-Load Associated)	
Block (Shrinkage)	X
Longitudinal (Joint)	
Transverse (Thermal)	X
Reflection	X
Maintenance Patching	
Spray	X[4]
Skin	X[4]
Pothole	X
Deep Hot Mix	
Weak Base or Subgrade	X
Ride Quality/Roughness	
General Unevenness	
Depressions (Settlement)	X[5]
High Spots (Heaving)	X[6]

[1] Rutting originating from the lower portion of the pavement (below surface course and including base and subgrade).

[2] The addition of new aggregate may be required for unstable mixes.

[3] The chemical stabilization of the subgrade may be required if the soil is soft, or wet.

[4] In some instances, spray and skin patches may be removed by cold planing prior to these treatments (considered if very asphalt rich, bleeding).

[5] Used if depressions are due to a poor subgrade condition.

[6] Used if high spots caused by frost heave or swelling of an expansive subgrade soil exist.

4. Stabilization Using Chlorides. Calcium chloride and magnesium chloride additives result in some gain in strength due to particle cementing. These chemicals will also lower the freezing temperature of the reclaimed material improving resistance to the effects of the freeze-thaw cycle. Generally, calcium chloride is applied using a minimum 35% solution at a rate of 0.1 to 0.15 gallons per square yard for each 1 inch of depth reclaimed. Details about stabilization using chlorides, including mix design, mix design development, and strength requirements are presented in Appendix J, Section J.3.D. Construction details for stabilization using chlorides are available in Appendix J, Section J.4.D.

5. Emulsified Asphalt Stabilization. Asphalt stabilization typically includes emulsified asphalt. Asphalt stabilization offers several advantages including improving resistance to water-related damage and improved fatigue resistance to loading. Asphalt stabilized FDR also works well with other additives such as granular materials, cement, and lime.

The selection of an appropriate amount and type of stabilizing material is part of the mix design process. The mix design process for FDR is outlined in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27), Chapter 2. The design method lists applicable test procedures and the types of emulsified asphalts for use on PennDOT system FDR projects. The design procedure and quality control listed in Bulletin 27 must be utilized for PennDOT FDR projects. Additional details about mix design, mix design development, apparatus, and procedures for emulsified asphalt stabilization can be found in Appendix J, Section J.3.E. Construction details for emulsified asphalt stabilization are available in Appendix J, Section J.4.E.

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CHAPTER 6

PAVEMENT DESIGN PROCEDURES

6.1 PAVEMENT DESIGN ANALYSIS/SUBMITTAL

All pavement designs for the Pennsylvania Department of Transportation shall be completed according to the 1993 AASHTO Pavement Design Procedures as amended by the Department. Use of the AASHTOWare® DARWin® 3.01 software is required. Chapters 6 through 10 describe the basics regarding the 1993 AASHTO Pavement Design method and provide guidance on input values that are to be used for all Department projects. Note that Chapters 6 through 10 assume that the DARWin® software will be used.

From herein, the "AASHTOWare® DARWin® 3.01 software" will be referred to as DARWin.

A. When to Do Analysis. All new construction, reconstruction and rehabilitation projects require a DARWin pavement design analysis for all projects when the total pavement length is more than 500 continuous feet on divided roadways and 1,000 continuous feet on undivided roadways and for bridge approach work where the total paving of both sides of the structure is greater than 1,000 feet. Refer to Figure 6.1 for a flowchart of the PennDOT pavement design approval process.

For PennDOT Oversight projects, considering one rigid and one flexible design alternative is suggested. The design alternatives to be considered for Federal Oversight projects will be determined during the Scoping Field View.

Furthermore, if the letting date is more than 3 years after the approved pavement design and Life-Cycle Cost Analysis (LCCA), a new design and LCCA (if required) shall be performed.

For all short pavement section projects not requiring a DARWin pavement design analysis as described above in the first paragraph of this Section, the proposed pavement may match the existing pavement structure where it meets minimum thickness requirements as described in Tables 8.3 and 9.4. Where the existing pavement structure is less than the minimum thicknesses, the new pavement must meet minimum thickness criteria. Where the existing pavement is a composite pavement that well-exceeds the minimum pavement thickness or contains elements not reasonable to replicate such as crack-and-seat, a DARWin pavement design analysis may be performed in order to achieve a structurally sufficient pavement in a cost-effective manner.

B. When to Submit. The proposed pavement structures for all short pavement section projects as described in Section 6.1.A above shall have the District Executive's approval recorded on the project file and are not required to be submitted to PDAU.

The submission requirements for PennDOT Oversight and Federal Oversight projects can be found in Section 6.1.D under "PennDOT Oversight Projects" and "Federal Oversight Projects."

If a new project field view is required because the pavement condition has changed, new updated traffic data for the project shall be obtained and a new pavement design shall be performed to verify that the designed pavement section is structurally adequate. Furthermore, for projects requiring an LCCA, a new LCCA will be required for the project using new (updated) pavement sections for the various alternatives.

C. What to Submit. All pavement design submissions shall include the following supporting documentation (in the order shown, 2 copies required for Federal Oversight projects, 1 copy for PennDOT Oversight projects):

1. Cover Letter with the following minimum information:

- MPMS Project Number
- County, SR and Section Number, Segments/Offsets
- PennDOT Oversight or Federal Oversight Status
- Anticipated Central Office PS&E Date and Estimated Let Date
- Estimated project cost, pavement length and total length

- Brief project description along with highlighting special circumstances
- Identification and justification for all exceptions to this Manual.

2. Form D-4332

3. Typical Section Drawing for each design showing all edge drains, widening, etc. This can be on 8 1/2 inch × 11 inch paper, with appropriate Segment/Offset and equivalent stationing. Project Pavement Design files should also contain sealed plan sheets.

4. Location map of the project showing the beginning and ending segments and any intersecting roadways.

5. DARWin printouts: Include entire printout for each design.

6. Provide all structural design calculations and supporting information. Printouts of the DARWin screens used should be included.

7. Traffic: Include summary table of ADT and truck percentage for each design followed by all the traffic information and breakdowns for the project. Also provide source and date of the traffic data.

8. Geotechnical Report: Include summary table of CBR for each design, as needed, followed by all supporting Falling Weight Deflectometer (FWD) data and/or soils testing results described in Section 2.2. Note that the District Geotechnical Engineer's signature must be provided with the geotechnical data.

9. Pavement sections that will be used to accommodate traffic for construction sequencing (i.e., crossovers, shoulders, etc.). Designs for temporary crossovers need not be submitted for approval. However, it will be considered best practice to give consideration to seasonal factors, required length of service, and percentage of truck traffic when specifying temporary pavement sections.

10. LCCA printouts and supporting calculations of quantity and unit costs. Also, include supporting documentation for unit costs. If adjacent sections are being submitted with the same pavement design, only one LCCA is required using quantities combined from the adjacent sections.

11. For Pavement Preservation Projects (Chapter 12) submit patching percentage from FWD testing and a visual survey.

12. Provide the existing pavement history (for the project limits) from RMS for pavement preservation, widening, structural overlay and other rehabilitation projects. Roadway segments with the same pavement structure/layers can be presented on a single RMS print-out with the matching roadway segments listed.

13. For all projects with unique or experimental pavement and/or materials, provide all pavement related special provisions for the project.

D. Procedures.

1. General. The pavement design analysis shall be performed using DARWin and the type determination shall be performed as described in Chapter 3. Completed forms shall be submitted to the District Executive (DE) for approval. Upon approval by the DE, the pavement design package shall be completed and sent to BOPD. If the approved pavement structure includes a bituminous wearing course, the appropriate Skid Resistance Level (SRL) designation (see Table 5.4) shall be submitted on Form D-4332. The exception to this is when a project is scoped as minor and a consultant is performing final design activities. Then please refer to Publication 10X, Design Manual Part 1X, *Appendices to Design Manual 1, 1A, 1B, and 1C*, Appendix AB, Minor Projects Design Process. The appendix indicates that final design phase approvals will not be submitted to Department for signature or approval.

A single pavement design analysis and type determination may be used for two or more adjacent projects on the same route if the following conditions do not change substantially on any of the construction sections:

- **a.** Total 18-kip ESALs
- **b.** Effective Modulus of Subgrade Reaction and/or Roadbed Soil Resilient Modulus
- **c.** Initial and Terminal Serviceability
- **d.** Reliability Level
- **e.** Estimated contract unit costs of the pavement materials
- **f.** Existing pavement section (for rehabilitation)

For adjacent projects meeting the requirements above, submission of the pavement design for the project shall be required to designate appropriate identifiers such as outlined earlier in this section for each Project Section involved.

All pavement design changes made following the original pavement design submission shall be submitted to the original approving authority (FHWA, BOPD, or the District). The authority will evaluate the design for concurrence. This policy includes changes made during construction as work order adjustments. These changes must have concurrence from BOPD, and FHWA approval when required, prior to submission of the work order.

The District Pavement Management Engineer/Pavement Manager (PME/PM) shall be consulted at the time the pavement design changes are contemplated. The PME/PM is responsible for ensuring that appropriate documentation is submitted to BOPD. Any supporting project cost data, particularly on active construction contracts, shall be provided to the PME/PM so that it can be included as a part of the evaluation package. No approved pavement designs (PME/PM, CO and/or FHWA) may be changed or modified in any manner, during the design process or during construction, without the prior consent in writing by the approving authority. As always the submission shall be clear to facilitate the review and reduce the response time.

Pavement Type Definitions:

- Reconstruction - Pavement reconstruction is the replacement or reestablishment of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure. Reconstruction may utilize either new or recycled materials incorporated into the materials used for the reconstruction of the complete pavement section. Reconstruction is required when a pavement has either failed or has become functionally obsolete.

- Rehabilitation - Pavement rehabilitation shall be defined as resurfacing, restoration, and rehabilitation (3R) work consisting of structural enhancements that extend the service life of an existing pavement and/or improve its structural and functional capacity. This may include partial recycling of the existing pavement, placement of additional surface materials, and/or other work necessary to return an existing pavement to a condition of structural or functional adequacy. Rehabilitation techniques and treatments include crack and seat with structural overlays, rubblization with structural overlays, structural bituminous overlays, concrete overlays, etc.

- Pavement Preservation - Pavement Preservation is a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations. Preservation treatments include micro surfacing, bituminous overlays, mill and overlay, Concrete Pavement Restoration (CPR), thin bonded concrete on asphalt (BCOA), etc.

2. PennDOT Oversight Projects. PennDOT Oversight project pavement designs must be submitted for review and approval to BOPD for all projects requiring an LCCA as described in Chapter 3.

All other PennDOT Oversight pavement design reviews (including Pavement Preservation projects) are handled on a certification basis. To obtain certification, individual PME/PMs must perform and submit five pavement designs (PennDOT Oversight or Federal Oversight) to PDAU. The five pavement designs must be performed using DARWin and must include at least one design of each surface type (bituminous and concrete). BOPD will certify PME/PMs in writing once the five submitted pavement designs are approved. PME/PMs are encouraged to participate in pavement related training sessions as they are offered by the Department.

Certified PME/PMs will recommend approval of Federal Oversight or PennDOT Oversight pavement designs using Form D-4332 to the DE based on sound engineering principles and conformance to Publication 242, *Pavement Policy Manual*. The DE's approval of PennDOT Oversight pavement designs will be final. PennDOT Oversight Designs prepared by the current certified PME/PM will not require PDAU approval except as noted in the first paragraph of this section. The District must maintain an approved copy of Form D-4332 for a minimum period of 7 years.

A QA review team, generally consisting of two PDAU staff, will perform a PennDOT Oversight QA visit to each District annually regardless of the PME/PM certification status. All projects designated PennDOT Oversight are eligible for the PennDOT Oversight QA Review. A detailed report of the findings for each visit will be issued from the Director BOPD to the DE. A copy of the report will also be issued to the following entities: FHWA, Deputy Secretary for Highway Administration, Director Bureau of Maintenance and Operations, Pavement Testing and Asset Management Section Chief and the PME/PM. Please refer to Appendix G for PennDOT Oversight Pavement Design Quality Assurance Reviews Policy and Procedure, for a more detailed discussion and the PennDOT Oversight QA Checklist.

The type determination procedure as discussed in Chapter 3 is not required on PennDOT Oversight projects with less than 30,000 square yards of mainline pavement surface work (including pavement and shoulders); however, sufficient justification for type selection and proposed work must be documented in the project file. Justification may include engineering judgment, experience, existing conditions, and adjacent pavement type. All reconstruction projects need detailed soils reports as outlined in Section 2.2.

All deviations from this Manual must be submitted as a waiver to BOPD for review and approval. BOPD coordination with FHWA is required on all Federal-aid projects.

3. Federal Oversight Projects. Pavement designs (including Pavement Preservation) for all Federal Oversight projects must have FHWA approval. Upon completion of the District's pavement design, the certified District PME/PMs must complete a Quality Control Check. The Quality Control Checklist portion of the Quality Control/Quality Assurance Checklist and Score Sheet in Appendix H, must be completed, signed and included in the pavement design submission. The District will prepare two copies of the completed pavement design package for submission; one copy of the complete pavement design package shall be submitted to FHWA for review and one copy shall be forwarded to BOPD (since it is required that BOPD is copied on all FHWA correspondence). BOPD will perform a Quality Assurance Review on selected pavement design projects.

An uncertified PME/PM must submit one copy of the complete design package to BOPD for review and approval. Upon BOPD's approval, the District submits the pavement design package to FHWA for review and approval. It is required that BOPD is copied on all FHWA correspondence.

FHWA will review and approve the District submitted pavement design. If comments and/or revisions result, then FHWA will coordinate subsequent pavement design corrections and/or revisions with the District PME/PM until FHWA approval is acquired. It is required that BOPD is copied on all correspondence.

Refer to Appendix H, Federal Oversight Pavement Design Quality Assurance Reviews Policy and Procedure for more details and the Federal Oversight QA Checklist.

Pavement designs shall be completed and approved immediately after the Design Field View Submission. FHWA and Central Office should be notified of all Scoping Field Views on projects with Central Office or FHWA approval authority. Assistance from Central Office is available upon request prior to any submission to FHWA.

All deviations from this Manual must be submitted as a waiver to BOPD for review and approval prior to Pavement Design Submission to FHWA. BOPD coordination with FHWA is required on all Federal Oversight projects.

4. Pavement Preservation Projects. The Pavement Preservation Guidelines (see Chapter 12) are to be used on all Federal-aid and 100% State funded pavement preservation projects as applicable.

The pavement preservation activities were shown to be cost effective based upon data from the PennDOT's Roadway Management System (RMS) and thus do not require a pavement design analysis. For exceptions to these guidelines that involve geometric and bridge issues, reference the Design Flexibility section in Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 3 for design exception documentation and approval procedures. Pavement design related exceptions should be directed to PDAU.

Pavement Preservation projects must be let within 15 months of the Pavement Type Selection approval date. Projects exceeding this limit will be required to undergo a review by the District PME/PM to re-verify the scope of work.

All deviations from the Pavement Preservation Guidelines within this Manual must be submitted as a waiver to BOPD for review and approval. BOPD coordination with FHWA is required on all Federal-aid projects. BOPD must be copied on all waivers approved by the DE.

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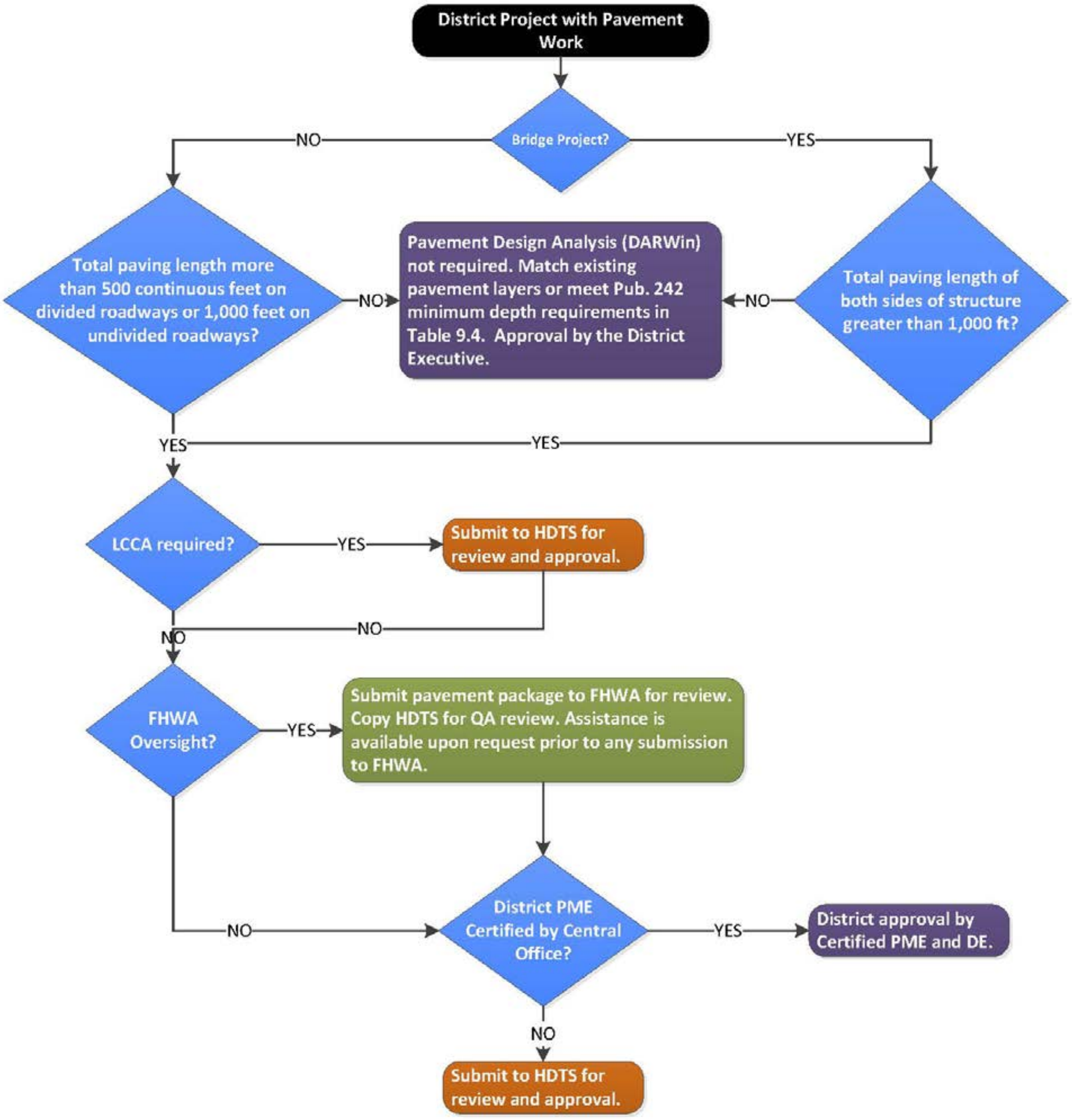
PennDOT Pavement Design Approval
Figure 6.1



6.2 SUBGRADE SOILS

For project considerations when evaluating the condition of the subgrade soil, including for all pavement reconstruction projects (including rubblized projects), refer to Section 2.2, Subgrade Soil Evaluation. Additional design considerations for subgrade soils are found below.

A. Resilient Modulus. Designer shall consult with the District Geotechnical Engineer in the determination of the soil resilient modulus, as per Publication 293, *Geotechnical Engineering Manual.*

The AASHTO Design process uses the resilient modulus, M_r, to characterize roadbed soils in pavement design. The resilient modulus is a measure of the elastic property of soil acknowledging certain nonlinear characteristics. M_r is used directly in flexible pavement design but must be converted to an Effective Modulus of Subgrade Reaction, k, for rigid pavement design. Soils testing must be completed prior to the pavement design process and the results must be provided to the PME/PM.

To obtain seasonal resilient modulus values, testing should be performed on representative soil samples in stress and moisture conditions simulating seasons with significantly different moisture conditions. Typically, spring modulus values are 10% to 20% lower than normal/summer modulus values. Frozen subgrade modulus values are typically two times greater than the normal/summer modulus values.

M_r may be estimated using the following equation from Heukelom and Klomp, for all roadways:

$$M_r \text{ (psi)} = 1500 \times \text{CBR}$$

Discussion of various methods of determining the design value of M_r follows:

1. Laboratory M_r. Direct laboratory determination of M_r is not currently permitted in the pavement design process. Recent experience has uncovered inconsistencies in the measured values and until procedural and equipment variables can be resolved, this method of obtaining M_r will not be acceptable for use in pavement designs.

2. Laboratory CBR. Laboratory CBR values should be used at all times for interstate and expressways. The laboratory testing should be performed on soaked samples. CBR test results are used in the following equation from Heukelom and Klomp to estimate M_r:

$$M_r \text{ (psi)} = 1{,}500 \times \text{CBR}$$

If CBR values are unattainable, designers should consult with the Highway Design and Technology Section (HDTS) of the Bureau of Project Delivery for other possible options. Designers should also consult with their District Geotechnical Engineer.

Although a thorough evaluation of the laboratory test data should be performed and documented regardless of the CBR value, a higher level of analysis is required when project subgrade CBR values are greater than 10. This is to ensure unrealistically high M_r values are not used in the pavement design. The same is true for CBR values less than 5 to ensure that recommendations for significant undercutting and/or other methods of subgrade improvement are necessary and justified.

It is imperative that the project CBR values are verified through a detailed evaluation of other laboratory tested soil properties to validate that the subgrade soils are capable of achieving the estimated M_r for the project. These soil properties include soil classification, gradation, percent material passing the #200 sieve, soil index properties (Atterberg limits), maximum dry density, optimum moisture content, and AASHTO Soil Classification Group Index. Additionally, consideration must be given to where a sample was taken (i.e., cut, fill, or at-grade areas of the project site). Note that the soil samples collected throughout the site should account for all conditions present so that a thorough evaluation of the variability of the CBR along the entire roadway alignment can be performed. Specific discussion regarding the evaluation of soil parameters is presented below.

a. Soil Classification. The soil classification of the samples collected shall be evaluated to determine the general distribution of soil types throughout the project area. This will allow the designer to quantify the total area of the project represented by each soil type. The classification results should be used to determine if lower CBR values are isolated to a local area(s), or wide-spread across the project site. In general, coarse-grained soils typically provide higher CBR values than fine-grained soils.

b. Gradation. The gradation curve for a particular soil type provides insight to the behavior of the soil during compaction and under applied loading. Well graded soils (i.e., soils with evenly distributed large, medium, and small particle sizes) tend to compact more densely than soils that are poorly graded (i.e., an over-abundance of one particle size) or gap graded (i.e., a lack of one or more particle sizes). Therefore, higher dry unit weights, and consequently higher CBR values, can be expected for soils with gradation curves that have a relatively smooth shape than for gradation curves that include near-vertical and/or near horizontal segments. Two indicators of the shape of a soil's gradation curve are the coefficient of uniformity, C_u, and the coefficient of curvature, C_c. The following equations from ASTM D2487 are used to determine C_u and C_c:

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{(D_{30})^2}{(D_{10})\,(D_{60})}$$

where:

D_{10}, D_{30}, & D_{60} = percent passing the #10, #30, and #60 sieves, respectively

In the Unified Soil Classification System, the following criteria must be met for gravels and sands to be considered well graded:

Gravel: $C_u \geq 4$ and $1 \leq C_c \leq 3$

Sand: $C_u \geq 6$ and $1 \leq C_c \leq 3$

If both of these criteria are not met, the soil is described as poorly graded.

c. Percent Passing #200 Sieve. The percent of material passing the #200 sieve (fines content) can have a significant effect on the behavior of soil. The fines can be separated into silt and clay sized particles. Soils with high fines content are usually more moisture sensitive than soils with less fines, and can be more difficult to compact. Additionally, soils with increasing fines content typically result in decreasing CBR values and a higher susceptibility to frost heave.

d. Soil Index Properties. Soil index properties (Atterberg limits) consist of the liquid limit (LL), plastic limit (PL), and plasticity index (PI). The PI is defined as the LL minus the PL. Soils with increasing PI and LL values have higher compressibility and elasticity than non-plastic soils, tend to be more difficult to compact, and have greater potential to lose strength under increased loading and/or with increased moisture. Soils with high LL and PI typically have low CBR values.

e. AASHTO Group Index (GI). The Group Index is an indicator of the suitability of a particular soil as subgrade material in the AASHTO Classification System. Soils with low GI values tend to have higher CBR values than soils with high GI values. The GI for a soil sample is a function of the percent of soil passing the #200 sieve and the Atterberg limits. The GI is calculated as follows:

$$GI = (\%\ \text{Passing}\ \#200 - 35)[0.2 + 0.005(LL - 40)] + 0.01(\%\ \text{Passing}\ \#200 - 15)(PI - 10)$$

For Group A-2-6 and Group A-2-7, only the second term of the equation is used. This reduces the equation to the following:

$$GI = 0.01(\% \text{ Passing } \#200 - 15)(PI - 10)$$

The GI for soil types A-1-a, A-1-b, A-2-4, A-2-5, and A-3 is always zero.

f. Maximum Dry Density. The maximum dry density (also known as maximum dry unit weight) is a measure of the maximum soil density that can be achieved at the optimum water content for a given compactive effort. Well graded soils with a broad range of particle sizes will usually achieve higher maximum dry densities than soils which are poorly graded because well graded soils allow less void space between the soil particles. Coarse-grained soils typically provide greater maximum dry densities and higher CBR values than fine-grained soils.

g. Optimum Moisture Content. The optimum moisture content is the amount of water required for a soil to achieve its maximum dry density. The optimum moisture content normally increases with increasing fines content of the soil. The relationship between maximum dry density and optimum moisture content provides insight to the behavior of the soil during compaction and the sensitivity of the soil to varying water content.

Verify that the CBR test results are supported by the companion laboratory test results, as discussed above. Confirm that the CBR test results are within the typical range of values for the soil types present. Typical values for various soil properties are included in Table 6.1 and Table 6.2. Note that the tabulated values are provided as a guide, and actual values could vary.

TABLE 6.1
TYPICAL COMPACTED DRY DENSITY AND OPTIMUM MOISTURE CONTENT RANGES OF SOILS
(BASED ON FHWA NHI-05-037)

AASHTO SOIL CLASSIFICATION	COMPACTED DRY UNIT WEIGHT (lb/ft^3)	OPTIMUM MOISTURE CONTENT (%)
A-1	115-134	5-15
A-2	109-134	9-18
A-3	100-119	5-12
A-4	94-125	10-20
A-5	84-100	20-35
A-6	94-119	10-30
A-7	81-115	15-35

TABLE 6.2
TYPICAL CBR VALUES
(BASED ON NCHRP PROJECT 1-37A)

AASHTO SOIL CLASSIFICATION	TYPICAL CBR RANGE**
A-1-a	60-80
A-1-b	35-60
A-2-4	20-40
A-2-5	15-30
A-2-6	10-25
A-2-7	10-20
A-3	15-35
A-4	10-20
A-5*	8-16
A-6	5-15
A-7-5*	2-8
A-7-6	1-5

* Material unsuitable as new embankment or subgrade as per Publication 408
** Typical CBR Range values are provided only as a guideline for comparison with laboratory tested CBR values. In no case shall values from the table be directly used in performing pavement designs. See limitations on CBR design values below.

If the lowest CBR values are located in isolated areas of the project, consider improving the subgrade in those areas to achieve CBR values that are representative of the overall project conditions. Discuss subgrade improvement options with the District Geotechnical Engineer and select an improvement strategy suitable for the soil type present. Coordinate the limits, details, quantities, and specifications and/or special provisions for the required subgrade improvement with the project team to ensure that the requirements are adequately detailed in the PS&E. Include all necessary special provisions for subgrade improvement in the pavement design submission.

If the laboratory test results for CBR include a high or low value that does not appear to be representative of the soil type tested and of other samples tested, disregard the value in determining the CBR for pavement design. When the CBR laboratory test results for the project indicate a wide range of values or when lower values are wide-spread across the project site, select a value for design that is based on the soil type that will control the design (i.e., the soil type with the lowest CBR values) so that the designed pavement section is adequate for all areas of the project.

When large areas of a project have significantly different soil types and CBR values, it may be permissible to divide the project into a limited number of subsections with different pavement design sections in order to make better use of construction materials. This provision may be considered where there is a distinct break point that delineates the transition between pavement designs, and the drainage beneath newly constructed pavements with different thicknesses can be effectively accommodated. It is not the intent of this provision to create short lengths within the project having differing pavement thicknesses, which would be burdensome to the contractor and inspection forces. Discuss with the project team early in the design process to solicit feedback and determine if more than one pavement design section is feasible for the project.

When determining design CBR values for rehabilitation projects, such as overlays, where the existing pavement will not be removed to expose the subgrade and the subgrade will not be reworked, consider the in-situ density of the subgrade soil in relation to the laboratory CBR value. If the in-situ density is significantly less than the maximum dry density, the in-situ CBR value will likely be less than the laboratory value. In cases such as this, multiply the CBR by 1,000 instead of 1,500 when using the Heukelom and Klomp equation to convert a CBR value to M_r. A more conservative equation is necessary to assure that artificially high values are not used.

All CBR values greater than 10 for use in pavement designs shall be approved by the Chief Geotechnical Engineer.

In no case will a CBR value greater than 20 be allowed to be used in the Heukelom and Klomp correlation (i.e., 1,500 × 20 = 30,000 psi maximum). Note that the occurrence of a M_r value greater than 20,000 psi for subgrade soils is rare in Pennsylvania. M_r values between 20,000 to 30,000 psi should be used with extreme caution. The unjustified use of high M_r values in the pavement design may result in inadequate pavement thickness and premature failure of the pavement.

If considerable uncertainty exists with regard to the validity of the laboratory tested CBR value, perform additional laboratory and/or field testing to support the value selected for design. Field testing may consist of FWD and/or DCP testing, where appropriate, to back calculate M_r for validation purposes.

Document and submit the complete evaluation of the laboratory testing results, CBR selection, and resulting M_r with the pavement design submission.

3. Falling Weight Deflectometer (FWD). M_r value back calculated from FWD data is only permissible in the following situations:

- Full depth bituminous pavement sections
- Existing bituminous overlays on thin concrete pavements (original concrete pavements less than 8 inches in depth or any parabolic sections)
- Existing bituminous overlays on concrete pavements which suffer from severe Alkali-Silica Reaction (ASR) degradation
- Asphalt overlays on concrete pavements built before 1945
- Prior to AC Overlay of Fractured PCC
- Directly on subgrade and subbase (this situation is rare)

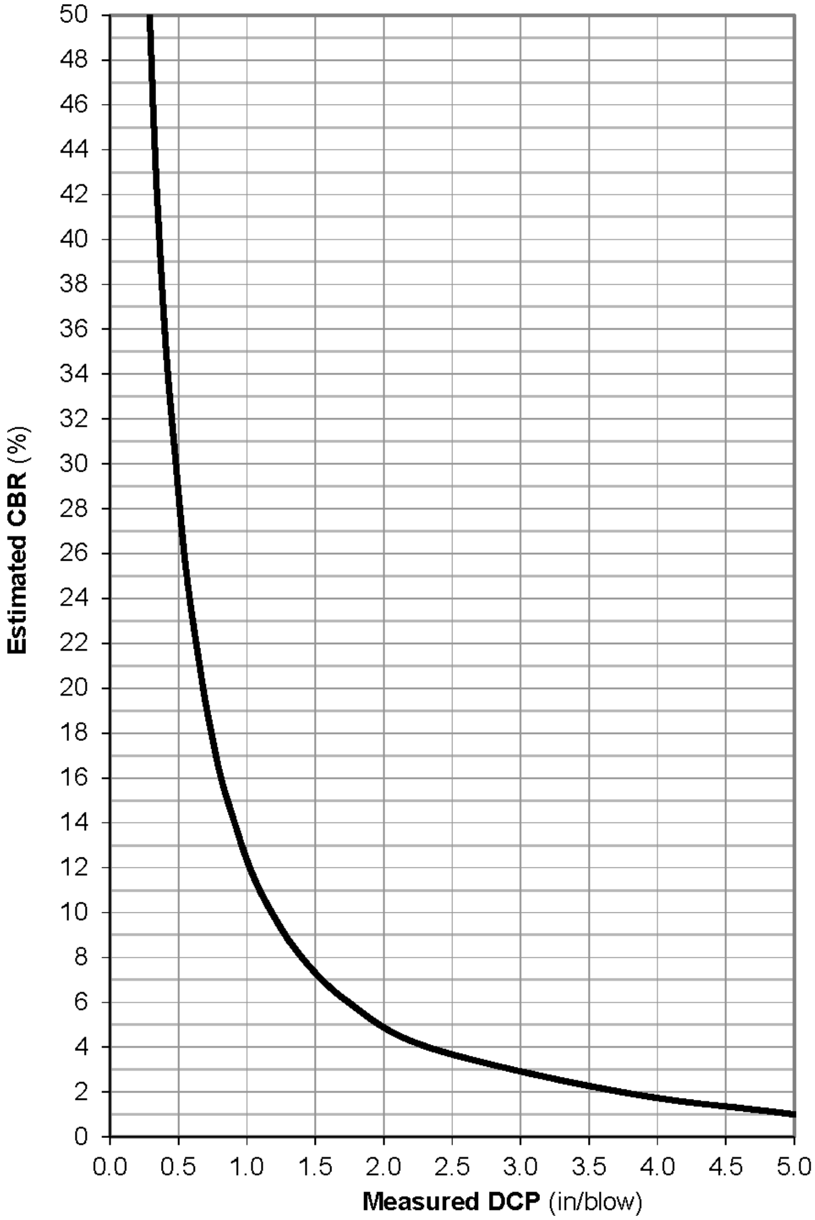
The 1993 AASHTO Guide for Design of Pavement Structures, Part III, Chapter 5.5 (AC Overlay of Fractured PCC Slab Pavement) describes the necessary testing to determine M_r. Deflection measurements are obtained at midslab locations that are not cracked with FWD at 9,000 pounds following ASTM D 4694 and D 4695. A deflection measurement is needed at a distance of approximately 4 feet from the center of the load. Follow Chapter 5.5.5, Step 4 to use measured deflection to calculate M_r.

The backcalculated M_r value must be adjusted to make it consistent with the laboratory-measured value used in the development of the flexible pavement design equation. Use a correction factor of C = 0.25. An adjustment may also be needed to account for seasonal effects. See Chapter 5.5.5, Step 6. The presence of a very stiff layer (e.g., bedrock) within about 15 feet of the top of the subgrade may cause the backcalculated M_r to be high. When such a condition exists, a value less than 0.25 for C may be warranted. When k is back calculated using FWD data, it must be converted to a static k value by dividing the dynamic k value obtained from back calculation by two.

Back calculation of a subgrade resilient modulus from FWD data is not an exact science, and erroneous values may result given certain conditions. Back calculation of the subgrade resilient modulus from FWD data may be unreliable if accurate pavement layer information is unknown, if the pavement section changes frequently over the deflection tested section, and/or if the current pavement exhibits a fair amount of distress (especially cracking). Superficially high modulus values may result. Therefore, if back calculation of M_r yields a value above 15,000 pounds per square inch, it must be verified by another form of testing prior to its use in the pavement design process. (M_r values around 4,000 pounds per square inch are considered poor, 8,000 pounds per square inch is considered fair, and 16,000 pounds per square inch is considered high.)

4. Field Dynamic Cone Penetration (DCP). A DCP test provides a measure of a material's in-situ resistance to penetration. The test is performed by driving a metal cone into the ground by repeatedly striking it with a 17.6 pound hammer dropped from a distance of 2.26 feet. The penetration of the cone is measured after each blow and is recorded to provide a continuous measure of shearing resistance up to 5 feet below the ground surface. DCP test results may be used and converted to M_r values via the CBR conversion. Use Figure 6.2 to facilitate the conversion. The use of DCP is limited to roadways with MFC = B, C, D & E.

FIGURE 6.2
DCP - CBR CORRELATION



DCP in/blow	CBR %
5.00	1
3.73	2
2.32	4
1.74	6
1.40	8
1.18	10
1.02	12
0.91	14
0.81	16
0.74	18
0.68	20
0.56	25
0.48	30
0.41	35
0.36	40
0.32	45
0.29	50

-log (CBR) = 2.20 - 0.71 (log(DCP))^1.5 + 0.75

Transportation Research Institute
Technion Institute of Technology
Publication No. 87-065, Moshe Livneh (1987)

However, proper CBR (California Bearing Ratio) testing must be performed to substantiate the CBR value used in design calculations. Conversions from Standard Penetration Tests (SPTs) to CBR values, for use in the above equation, will not be permitted. Furthermore, use of the Heukelom and Klomp equation for estimating M_r may be disallowed in the future after more familiarity and experience are gained regarding M_r.

Soil representative of subgrade conditions existing on the project should be used in the design analysis. Once the pavement is designed, the plans must specify the minimum acceptable roadbed soil resilient modulus to ensure that it meets the assumptions used in the pavement design. All borrow materials must conform to the minimum specified resilient modulus.

For collector or local road projects, the District Geotechnical Engineer may use judgment based on such sources as County Soil Surveys, existing conditions, and experience to estimate the roadbed soil resilient modulus value. For all projects other than collectors or local roads, the roadbed soil resilient modulus must be based on laboratory or on-site test results. Refer to Section 2.2 for further discussion on the types of tests to be performed.

Documentation regarding the resilient modulus value testing/determination must be submitted with Forms D-4332 and the type determination.

For all projects, the District Geotechnical Engineer shall verify, by signature, the appropriate roadbed soil resilient modulus value for use in the pavement design.

B. Frost Design. The effects of frost action on the pavement structure are major concerns when designing pavements that are intended to provide a high degree of serviceability for extended periods of time. Pavement damage from frost action is the result of differential heaving of the pavement, loss of bearing support capacity during the spring-thaw period or warm winter periods induced by an excess of moisture, and freeze/thaw damage to the materials themselves. Detrimental frost action occurs in the presence of frost-susceptible soils, freezing temperatures, and a supply of water. Any solution to the problem of frost action must reduce or eliminate these factors.

It is recommended that soils highly susceptible to frost heave be removed and replaced with a layer of non-frost-susceptible material thick enough to insulate the roadbed soil from frost penetration. This should also significantly reduce or eliminate the thaw-weakening that normally occurs in the roadbed soil in early spring.

The basic approach used in the design procedure to accommodate a frost susceptible subgrade is to provide a stronger base course able to withstand the effects of lower bearing support. However, even when frost heave is addressed in the pavement design, other measures to minimize the effect of differential heaving should also be taken. One example is the installation of pavement base drains and any other appropriate drains. These considerations may not affect the pavement structure thickness, but they will have a marked effect on the performance and maintenance requirements of that pavement.

Differential heaving is the result of abrupt changes in subgrade conditions due to changes in soil type, varying groundwater conditions, cross-trenches backfilled with different materials, shallow bedrock, the presence of large underlying stones and boulders, a change from fill to cut, etc. Whenever possible, these conditions should be identified in the Soil Survey Report. Selective grading, blending and mixing of subgrade soils and boulder removal are all effective methods for providing uniform subgrade conditions. Another method is to provide gradual subgrade transitions at discontinuities of subgrade support, such as cut-fill intersections, junctions of sharply differing types of subgrade soils, and intersections of rock and earth subgrades. These transitions may be made of embankment material or granular, non-frost-susceptible material such as subbase. Granular transitions should be used where a new pavement structure will abut an existing pavement of a different total depth. Refer to NCHRP Synthesis 26, *Roadway Design for Seasonal Frost Areas*.

Typically, frost heave is not a problem when an adequate granular foundation course is used, particularly for rigid pavements. Therefore, treatment for frost heave in the pavement design of rigid pavements should only be included if there is significant justification.

Although AASHTO recommends removing and replacing all frost susceptible material instead of increasing the pavement structure, the Department has not found this policy to always be feasible. Therefore, treatment for frost heave should always be included in full-depth flexible pavement design. Since AASHTO does not promote increasing pavement depth to accommodate for frost heave, DARWin does not include a module to calculate the loss of serviceability due to frost heave. The procedure outlined in the 1993 AASHTO *Guide for Design of Pavement Structures*, Appendix G should be used to calculate the loss of serviceability due to frost heave. This is discussed in further detail in Section 9.3. A Frost Heave spreadsheet tool is available online for use under the PDAU page of the PennDOT website.

C. Rock Cuts. When the proposed grade line requires excavation of rock, the conditions of the rock shall be evaluated in the Soil Survey Report. A recommended depth of subbase or other treatment for each specific rock cut shall be included in the report. Lateral benches, as determined in the Soil Survey Report, shall be retained in rock/soil transition areas.

D. Geogrids. Geogrids may be used at the interface between subgrade and aggregate layers to stabilize weak pavement subgrades. A geogrid is a net-like geosynthetic with apertures of sufficient size to allow interlocking with surrounding unbound materials such as soil, rock, and aggregate, and functions primarily as reinforcement. Factors favoring the use of geogrids include simple and quick installation; increase in types, brands, and quality of geogrids; and the decrease in cost of purchasing the material due to high competitiveness among manufacturers.

Publication 408, *Specifications*, Section 221 and Section 738 and Publication 35, *Approved Construction Materials* (Bulletin 15), along with manufacturer's published product data and other appropriate technical references, should be used when determining the geogrid properties, design specifications, product selection and construction procedures.

Questions concerning geogrids should be directed to BOPD, ISSD, Geotechnical Section.

E. Geotextiles. Geotextiles are permeable fabrics that may be used to separate subgrade and subbase layers. Geotextiles are fabrics consisting of long chain polymeric filaments or yarns formed into a stable network so that the filaments or yarns retain their relative position to each other.

Three geotextiles may be specified in conjunction with pavement designs:

1. Class 4---Layer Separation (Type A). Fabric that separates two dissimilar materials (e.g., subbase and subgrade) so that the integrity and functionality of each material remains intact or is improved.

2. Class 4---Stabilization (Type B). Fabric utilized in a dual function: to separate two dissimilar materials (e.g., subbase and subgrade) and to strengthen subgrade that is low in tension.

3. Class 4---Reinforcement (Type C). Fabric similar to Class 4, Type B, except overlaps must be stitched for a subgrade with a CBR value of 0.5 or lower.

Publication 408, *Specifications*, Section 212 and Section 735 and Publication 35, *Approved Construction Materials* (Bulletin 15), along with manufacturer's published product data and other appropriate technical references, should be used when determining the geotextile properties, design specifications, product selection and construction procedures.

F. Reconstruction Projects. For all reconstruction projects (including rubblized projects), an additional pavement subgrade evaluation shall be performed. This evaluation must include, at a minimum:

1. Gradation. Gradation tests are performed to determine the percent of given particle sizes of the different soil types on the project. Gradation is needed for proper soil classification and determining engineering properties of the soil. Gradation is also required for the CBR test.

2. In-place Moisture Content. The ratio of the weight of water in the soil to the weight of the solids. This ratio multiplied by 100 is the percentage of water content (moisture content).

3. In-place Density. The weight of soil solids and water divided by the total volume.

4. California Bearing Ratio (CBR). This test is intended to evaluate the potential strength of cohesive materials having maximum particle size less than 3/4 inch. This is used on subgrade, subbase and base course. The CBR is used to develop the resilient modulus and the k values for the pavement design.

These tests shall be performed on the existing subgrade or subbase material upon which the project will be built. Borrow materials placed as part of the roadway construction must be tested prior to placement of pavement. Undercutting and/or stabilizing may be required if CBR values are less than 5; refer to Section 6.2.A.2, Laboratory CBR, for additional guidance.

If extra-depth undercut or stabilization procedures are recommended from the evaluation of the above tests or other applicable tests, then the amount and cost of these items must be included in the project design. Realistic project evaluation must be conducted to determine the extent of the undesirable subgrade and the treatment necessary to correct the situation.

6.3 SERVICEABILITY INDICES AND MAINTENANCE FUNCTIONAL CLASSIFICATIONS

"Present Serviceability" is the ability of a specific section of pavement to service traffic in its existing condition. The term was developed at the AASHO Road Test, where the serviceabilities of numerous pavements were subjectively rated by a panel of people selected from representative groups of highway users.

Through multiple regression analysis, mathematical formulas were derived and validated through which pavement indices (or ratings) could be satisfactorily estimated from objective measurements taken on the pavements. Serviceability indices (or direct ratings) always reflect the conditions existing at the time the measurements are made.

A Present Serviceability Index (PSI) formula was developed based on measurements of pavement roughness, cracks, patches and rut depth. PSI values range from 0 to 5. The descriptive scale developed at the AASHO Road Test is shown in Table 6.3.

TABLE 6.3
PSI DESCRIPTIVE SCALE

RATING SCALE	DESCRIPTIVE SCALE
5 – 4	Very Good
4 – 3	Good
3 – 2	Fair
2 – 1	Poor
1 – 0	Very Poor

The initial serviceability level used in the AASHTO 93 Pavement Design method is an estimate of what the PSI will be immediately after construction.

Similar to the PSI system, PennDOT has incorporated a Present Serviceability Rating (PSR) system. The PSR Number is also a number between 0 and 5, and the value reflects a descriptive scale that corresponds to the PSI system. Prior to 1995, PSR was calculated based on the roughness index and the Systematic Technique to Analyze and Manage Pennsylvania Pavements (STAMPP) condition data for each segment. In 1995, the adjustment based on condition data was eliminated and PSR became strictly a function of the roughness index. PSR numbers can be found in the RMS.

Resurfacing or reconstruction can improve pavement serviceability, but it is not the only reason for taking these actions. Other reasons, such as inadequate friction, geometric upgrades or insufficient capacity, may dictate pavement resurfacing or reconstruction. Surface treatments may be required to retain surface durability rather than to improve PSR.

Non-destructive Testing of a pavement can be used as an engineering tool to assist in selecting rehabilitation alternatives. This Non-destructive Testing information includes friction values, riding quality and structural capacity. The Non-destructive Testing equipment currently used by PennDOT is: the Single Locked Wheel Skid Tester for friction values; the High Speed Profilers with laser sensors for riding quality; and the FWD.

The Terminal Serviceability Index (TSI) is the level of performance or condition at which a pavement is no longer considered adequate to serve the needs of the users. In order to determine the TSI value for a particular roadway, the Maintenance Functional Classification (MFC) must be known. MFCs can be found in the RMS. The average ride quality of highways in each MFC category will be different just as the functions of highways in each category are different. TSI values were chosen as the minimum riding condition acceptable for each MFC category.

For example, pavements on Interstates and other limited access freeways should provide a high level of serviceability for an extended period of time and be as maintenance-free as possible. Furthermore, these roadways are designed for higher maximum speed, higher volumes and longer durations of travel than local access freeways, and are expected to have better average riding quality. Therefore, a higher TSI value is established for these facilities than for those with a lesser functional classification.

In Table 6.4, definitions of the MFCs are provided along with the appropriate initial serviceability value and terminal serviceability value to be used in the AASHTO pavement design process for each. New pavement, reconstructed pavement and overlay designs shall be performed using at least the terminal serviceability value given in this table; the next higher TSI value may be used when the traffic volume is significantly high for the functional classification of the highway.

TABLE 6.4
TSI VALUES FOR EACH MFC

MAINTENANCE FUNCTIONAL CODE	DESCRIPTION	INITIAL SERVICEABILITY LEVEL			TERMINAL SERVICEABILITY LEVEL
		RIGID	COMPOSITE	FLEXIBLE	
A	Interstate highways	4.5	4.5	4.2	3.0
B	Limited Access and Major Arterial highways	4.5	4.5	4.2	3.0
C	Minor Arterial highways	4.5	4.5	4.2	2.5
D	Collector highways	4.5	4.5	4.2	2.5
E	Local Access highways	4.5	4.5	4.2	2.0

*Note: The terminal serviceability level to be used in flexible pavement design is the value listed in Table 6.2 PLUS the estimated loss of serviceability due to frost heave. Frost Heave is to be considered in Asphalt Overlays of fractured PCC and full depth asphalt pavements; see Section 9.3 for further details.

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6.4 RELIABILITY

The reliability percentage used in the AASHTO design accounts for the variability and degree of uncertainty associated with pavement design to ensure that the design will last through the analysis period. It accounts for both variation in traffic prediction and performance prediction. Table 6.5 provides the reliability ranges by Functional Classification for use in all Department pavements. Note that the ranges in Table 6.5 are more restrictive than those provided in the 1993 AASHTO Guide for Design of Pavement Structures.

TABLE 6.5
RELIABILITY BY FUNCTIONAL CLASSIFICATION

FUNCTIONAL CLASSIFICATION	RANGE (%)
Interstates and Other Expressways	95
Arterials	90 - 95
Collectors	85 - 90
Locals	70 - 85

6.5 OVERALL STANDARD DEVIATION

An Overall Standard Deviation, S_o, is required in the AASHTO Pavement design process to account for all error and/or variability associated with design and construction inputs. For rigid pavement design, a value of 0.35 should be used. Flexible pavement, asphalt overlays of fractured PCC pavement and flexible overlays over flexible pavements should use a value of 0.45. Use a value of 0.40 for flexible pavement over rigid pavement.

6.6 RAMP PAVEMENT DESIGN

A pavement design must be performed for any proposed or existing ramps on a limited access highway. The pavement type, concrete or bituminous, for the ramps shall be the same type as the higher traffic volume roadway in the interchange. The acceleration and deceleration portions of the ramps must have the same pavement type and thickness as the roadway they are being merged with. In addition, ramps should be designed using the same roadway classification as higher traffic volume roadway in the interchange.

The design of all ramp pavement structures within an interchange will be based on the ramp with the highest traffic loadings. Minimum depths appropriate to higher traffic volume roadway in the interchange shall apply. When the ramp pavements are being designed, careful consideration shall be given to the potential for development around an interchange. If the potential for generating heavy truck traffic exists, then the ramp shall be designed accordingly.

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CHAPTER 7

TRAFFIC ANALYSIS FOR PAVEMENT DESIGN

7.1 TRAFFIC ANALYSIS FOR PAVEMENT DESIGN

Traffic data for pavement design will be supplied by the Bureau of Planning and Research (BPR) or other regional authority upon request by the District Executive, and will include initial ADT, annual percentage growth, average daily truck percentage and breakdown by classification, and average daily directional factor (D). Most of this information is also available on the traffic count data screen of the Roadway Management System (RMS). Growth rates are available on PennDOT’s intranet, under BPR.

To calculate the total 18-kip ESALs for a project's performance period, use the Rigorous ESAL Calculation method of DARWin. The items necessary for the calculation of the total 18-kip ESALs are as follows:

A. Performance Period. The performance period is the period of time that an initial, or rehabilitated, pavement structure will last before reaching its terminal serviceability. This is more commonly referred to as the design period.

B. Two-Way Daily Traffic (ADT). The average daily traffic (ADT) needed for the total 18-kip ESAL calculation is a 24-hour, two-directional vehicle count for the subject project at the time it is first opened to traffic (i.e., in the year it is to be constructed). In addition, 24-hour, one-way vehicle counts on a divided highway (where segments run in both directions) may be used as well.

C. Number of Lanes in Design Direction. Since the ADT is a two directional count, the number of lanes in each direction needs to be identified, because only one direction of traveling traffic is used in the design procedure.

D. Percent of All Trucks in Design Lane. This is the percent of all trucks in the most heavily used lane, commonly referred to as the "driving lane" or the design lane. The percent of all trucks in the design lane has previously been referred to as the lane distribution factor. For a two-lane highway, there is only one lane in each direction and the percent of all trucks in the design lane is 100%. For four-lane highways, the percent of all trucks in the design lane is 90%. For highways with six or more lanes, the percent of all trucks in the design lane is 80%.

E. Percent Trucks in Design Direction. The percent of trucks in the design direction is commonly referred to as the directional distribution factor. The percent of trucks in the design direction is multiplied by the two-way ADT to account for differences in truck traffic by direction. Use a directional factor of 50% unless the BPR directs otherwise or traffic data shows this not to be the case. Use a directional factor of 100% for one-way ADT counts.

F. Rigorous ESAL Calculation. Once the Rigorous Method of 18-kip ESAL calculation is chosen, the following inputs will be required:

- Percent of ADT. The percent of the ADT corresponding to each vehicle classification shown in Table 7.1. Note that the percent of passenger cars is equal to 100% minus the total truck percentage. To obtain the correct percentages for the different truck classification breakdowns when using RMS data, multiply the total truck percentage by the classification percentage.

- Annual % Growth. The percent growth per year of truck traffic volume. All vehicle classes should use the same growth rate unless historical evidence and/or traffic studies justify otherwise.

- Average Initial Truck Factor (ESALs/Truck). The ESAL factors given in Table 7.1 should be used for the corresponding vehicle classes.

TABLE 7.1
AVERAGE INITIAL TRUCK FACTORS (ESALs/TRUCK) BY VEHICLE CLASS

VEHICLE CLASSIFICATION			**ESALs**	
LINE # IN DARWIN® 3.01	**FHWA CLASS**	**CORRESPONDING DEPARTMENT DESCRIPTION**	**RIGID**	**FLEXIBLE**
1	1	Motorcycle	0*	0*
2	2	Passenger Cars	0*	0*
3	3	SUV/Pick-up	0*	0*
4	4	BUS Factor	0.24	0.24
5	5	2-axle, 6-tire	0.24	0.24
6	6	3-axle, single unit	1.15	0.82
7	7	4-axle, single unit	7.00	4.50
8	8	3-axle, single trailer	0.60	0.44
9	9	3-axle, multiple axle trailer	1.59	1.00
10	10	6-axle, single trailer	1.42	0.75
11	11	5-axle, multiple trailer	2.40	2.33
12	12	6-axle, multiple trailer	1.42	1.28
13	13	7-axle, multiple trailer	1.42	1.28

*Note: Because motorcycles, passenger cars, and SUV/Pick-up trucks do not significantly contribute to the 18-kip ESALs they are considered negligible and an ESAL/truck factor of 0 is assigned. However, the percent of the ADT in this class must be input into DARWin because the Total Percentage must equal 100.00%. If there are any vehicles that are not large enough to be classified in any of the above classes, they should be grouped with the motorcycle percentage.

- Annual % Growth in Truck Factor. A 0% growth should be used for the annual percent growth in truck factor, unless historical evidence or loading studies justify otherwise.

- Growth Rate Calculation Type. The compound growth rate calculation method in DARWin must be used.

1. All Functional Classifications of Highways. The truck classification information can be obtained from the RMS Traffic Count Data Screen. If the information is not there, or it seems to be outdated, then a truck classification survey (24-hour portable or 8-hour manual) must be performed for the proposed improvement. The District will be responsible for the selection of site(s). However, the BPR will aid in site selection if any problems arise. A written request to the BPR together with a location map indicating the proposed new facility is required.

The manual classification count will be recorded on Form PS-121 according to the instructions presented in Appendix B. The manual count will then be sent to the BPR for expansion and refinement. In addition to the manual classification count, the District will also include a location map that shows where the manual classification count was conducted and the proposed improvement.

The classification data for the new FHWA 13 Vehicle Classification Breakdown in RMS Traffic Counts has not yet been fully updated for all roads. The BPR is in the process of collecting and updating this information. With approximately 29,000 traffic counts throughout the state, 7,000 are taken each year in which 30% of those are taken as classification counts. Having begun this process in 2008, the estimated completion year is 2018.

When the breakdown was updated to the 13 classes in RMS, default values needed to be used for each of the 10 Traffic Pattern Groups (TPG). If any volume count is taken before a classification count is taken, the default values are used. Only when a classification count is taken mechanically will the percentages and the rigid and flexible ESALs listed at the bottom of the RMS 466 screen be accurate.

In the RMS 461 screen, open and check each year after 01/01/2008, beginning with the most current date and working back until the "TYPE" shows "MACHINE" or "MANUAL" in the top right-hand corner of the RMS 466 screen. This denotes that the classification counts have been updated and the individual truck percents are accurate for Table 7.1 in the most current Traffic Count year. If the "TYPE" shows "ADJUSTED", "AXLE VOL" or "LOOP VOL" and one of the previous years, after 01/01/2008, does not show the "TYPE" as "MACHINE" or "MANUAL" then a valid classification count has not yet been collected using the new classifications and the individual classification breakdown has not yet been updated. If none of the years after 01/01/2008 show the "TYPE" as "MACHINE" or "MANUAL", then use the previous year's classification count before 2008 for pavement design purposes utilizing the ESAL factors given in Table 7.4.

2. Collectors and Local Roads (Short Method / Simple Method). For areas of new construction, the Simple Method may be used, provided that the pavement layer thicknesses determined using the Simple Method does not exceed the minimum layer thicknesses for the appropriate type of roadway (see Table 9.4). If these limits are exceeded for new construction, then the daily 18-kip ESALs must be evaluated using the Rigorous Method. The actual structural requirements for new construction shall then be determined using the results.

The Simple Method may be used on rehabilitation projects if the structural requirements do not exceed the structural capacity of the existing pavement. If the above limit is exceeded for rehabilitation projects, then the 18-kip ESALs must be evaluated according to the Rigorous Method to determine if the existing pavement is indeed deficient.

When the Simple Method is used, the Annual Truck Factor Growth Rate Percentage should be inputted as 0%. The Annual Truck Volume Growth Rate is the percent growth expected annually over the design life. For the Average Initial Truck Factor, use values from Table 7.2.

TABLE 7.2
18-KIP ESALs/TRUCK FACTORS FOR COLLECTORS AND LOCAL ROADS (SIMPLE METHOD)

ESALs	
RIGID	**FLEXIBLE**
0.80	0.59

<u>The Simple Method must not be used on any roadways other than collectors and local roads</u>. Using this method on other types of roads can lead to premature failure of the pavement or excessive costs.

3. Cross Routes that Interchange with Limited Access Freeways. An accurate estimate of the future truck traffic on cross routes that are provided with direct access to limited access freeways is difficult. Possible future development around an interchange area could radically affect the truck traffic on the cross route. Furthermore, the slow-moving, accelerating, decelerating, and turning movements of trucks are considered more detrimental to pavement structures than trucks moving uniformly on a tangent section. The values presented in Table 7.3 are the minimum design daily 18-kip ESALs used for cross routes that are provided with direct access to limited access freeways. If the design year ADT (the projected traffic volume occurring at the end of the project's structural design life when measured from the estimated year of completed construction) of the cross route exceeds 8,000, then the Rigorous Method must be used to calculate the daily 18-kip ESALs. Table 7.3 should not be used indiscriminately or in place of a truck distribution count otherwise required. A truck distribution count is required when the area around the proposed or existing interchange is essentially completely developed or when traffic volumes on the cross routes are expected to decrease instead of increase.

TABLE 7.3
18-KIP ESALs FOR CROSS ROUTES THAT INTERCHANGE WITH LIMITED ACCESS FREEWAYS

DESIGN YEAR ADT (CROSS ROUTE)	ESALs	
	RIGID	FLEXIBLE
0 - 1,000	20	10
1,001 - 2,000	80	60
2,001 - 3,000	140	100
3,001 - 5,000	220	150
5,001 - 8,000	360	250

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TABLE 7.4
AVERAGE INITIAL TRUCK FACTORS (ESALs/TRUCK) BY VEHICLE CLASS

VEHICLE CLASSIFICATION			ESALs	
LINE # IN DARWin 3.01	**FHWA CLASS**	**CORRESPONDING DEPARTMENT DESCRIPTION**	**RIGID**	**FLEXIBLE**
1	2	Passenger Cars	0*	0*
2	5	2-axle, 6-tire	0.24	0.24
3	6	3-axle, single unit	1.15	0.82
4	7	4-axle, single unit	7.00	4.50
5	8	3-axle, single trailer	0.43	0.44
6	8	4-axle, single trailer	0.90	0.76
7	9	5+-axle, single trailer	1.59	1.00
8	11	5+-axle, twin trailer	2.40	2.33
9	12	6-axle, twin trailer	1.42	1.28

*Note: Because passenger cars do not significantly contribute to the 18-kip ESALs they are considered negligible and an ESAL/truck factor of 0 is assigned. However, the percent of the ADT in this class must be inputted into DARWin because the Total Percentage must equal 100.00%. If there are any vehicles that are not large enough to be classified in any of the above classes, such as motorcycles, they should be grouped with the passenger car percentage.

4. Localized Routes Carrying Heavy Truck Traffic. In special cases, the 18-kip ESAL factor for each vehicle type will be incorrect. These cases will often involve localized routes and industrial complex connections. For such cases, Appendix C presents the 18-kip ESAL by axle load and type. Appendix C also gives a general format to substitute for Item 4 in determining the daily 18-kip ESALs.

The Districts are responsible for identifying the routes that require special attention. They will also be responsible for obtaining, from the industry involved, the type of truck traffic, axle load weight, distribution and type, current truck volume, and anticipated truck volume growth percentage. This may require coordination with the BPR. Care must be taken to evaluate the daily 18-kip ESALs since trucks entering and leaving will be counted twice. The axle load equivalents, however, will be different if a portion of these trucks return empty.

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CHAPTER 8

RIGID PAVEMENT DESIGN

In general the components of a pavement structure include subgrade, subbase, base, and surface. The subgrade is the prepared earth surface on which the pavement will be constructed. The subbase is an aggregate layer placed on the subgrade to provide drainage and a platform for the subsequent layers. The base provides support for the pavement surface and is typically constructed of bituminous or cement concrete material.

This Chapter discusses the 1993 AASHTO Pavement Design Procedures for rigid pavements. The following inputs are necessary to design a rigid pavement structure according to the 1993 AASHTO Pavement Design Procedures using the AASHTOWare® DARWin® 3.01 (DARWin) software.

- 18-kip ESALs Over Initial Performance Period
- Initial Serviceability
- Terminal Serviceability
- 28-day Mean PCC Modulus of Rupture
- 28-day Mean Elastic Modulus of Slab
- Mean Effective k-value
- Reliability Level
- Overall Standard Deviation
- Load Transfer Coefficient, J
- Overall Drainage Coefficient, C_d

Sections 8.1 through 8.10 provide guidance on the variables used in rigid pavement design. Note that the acronym PCC for Portland Cement Concrete is used in this Chapter to be consistent with the terminology used in DARWin®.

8.1 18-KIP ESALS OVER INITIAL PERFORMANCE PERIOD

Calculate the 18-kip ESALs over the initial performance period, or design life, according to Chapter 7, Traffic Analysis for Pavement Design.

8.2 INITIAL SERVICEABILITY

Use an Initial Serviceability of 4.5, as per Table 6.3.

8.3 TERMINAL SERVICEABILITY

Use the Terminal Serviceability value corresponding to the appropriate roadway classification provided in Table 6.3.

8.4 28-DAY MEAN PCC MODULUS OF RUPTURE

Concrete Modulus of Rupture, S'_c (pounds per square inch)

The concrete modulus of rupture is a measure of the extreme fiber tensile stress under a breaking bond. It is calculated as follows:

$$S'_c = K(f_c')^{0.5}$$

where: K = 9 (constant)

Using the average compressive strength for Class AA concrete in Pennsylvania of 4,925 pounds per square inch, and a standard deviation of 432 pounds per square inch, results in S'_c = 631 pounds per square inch.

Use S'_c = 631 pounds per square inch in all rigid pavement designs unless District experience and data indicates otherwise.

8.5 28-DAY MEAN ELASTIC MODULUS OF SLAB

Concrete Elastic Modulus, E_c (pounds per square inch)

The Concrete Elastic Modulus is a measure of stiffness or rigidity of concrete. The following correlation is recommended by the American Concrete Institute for normal weight Portland Cement Concrete:

$$E_c = 57{,}000\,(f_c')^{0.5}$$

where: f_c' = PCC compressive strength (pounds per square inch).

If the 28-day structural design compressive strength of 3500 pounds per square inch, for Class AA concrete (paving), is used in the above equation, $E_c = 3.4 \times 10^6$ pounds per square inch. However, the 1993 AASHTO Pavement Design Procedures were developed using mean input values. The mean concrete elastic modulus for Class AA concrete is 4,000,000 pounds per square inch. This corresponds with a mean compressive strength of 4,925 pounds per square inch. Unless District historical data shows mean compressive strengths significantly different than 4,925 pounds per square inch, use an E_c value of 4×10^6 pounds per square inch in all rigid pavement designs.

8.6 MEAN EFFECTIVE K-VALUE

Effective Modulus of Subgrade Reaction, k (pounds per square inch)

Rigid pavement design involves the use of a modulus of subgrade reaction (k). The k-value is directly proportional to the roadbed soil resilient modulus, M_r. The roadbed soil resilient modulus is required to calculate the effective k-value. It may be seasonally adjusted if seasonal values are known or estimated according to Section 6.2. For information regarding testing to obtain the roadbed soil resilient modulus refer to Section 6.2.

For use within DARWin, subbase is considered to be both the subbase and base course. When calculating the effective k-value, combine the base and subbase. Use the respective depths to calculate a weighted average loss of support.

The effective modulus of subgrade reaction is dependent upon several factors besides the roadbed soil resilient modulus. These factors are listed below:

- Subbase Type - different subbase types have different strengths or modulus values.
- Subbase Thickness (inches) - different subbase thicknesses can be evaluated to determine the effect on the design thickness and thus determine the most economical design.
- Loss of Support, LS - The loss of support factor is used to correct the effective k-value for potential erosion or pumping of the subbase material. See Table 8.1 for recommended loss of support factors for Pennsylvania's pavements and materials.
- Depth to Rigid Foundation (feet) - If bedrock lies within 10 feet of the surface of the subgrade for a significant length of the project, its effect should be considered in the determination of the k-value.

TABLE 8.1
LOSS OF SUPPORT FACTORS

TYPE OF MATERIAL	LOSS OF SUPPORT FACTOR
OGS	1.0
2A Subbase	1.0
HMA Base Course/Superpave Base Course	0.5
Rubblized PCC Base Course	0.5
Cracked and Seated PCC Base Course	0.5
Treated Permeable Base Course (ATPBC or CTPBC)	0.5

A different effective k-value should be calculated for each different subbase type and depth to be analyzed. All Interstate and Expressway rigid pavement designs should have a subbase consisting of a Treated Permeable Base Course **(**TPBC) layer on a 2A Subbase layer. Asphalt Treated Permeable Base Course (ATPBC) and Cement Treated Permeable Base Course (CTPBC) must be bid as alternates.

When calculating the effective k-value, use a Base Elastic Modulus (E_{SB}) of:

15,000 pounds per square inch for "spring thaw" conditions (spring)
30,000 pounds per square inch for "normal" conditions (summer and fall)
50,000 pounds per square inch for "frozen" conditions (winter)

However, these values should be adjusted if necessary so that the ratio of the subbase to the roadbed soil resilient modulus does not exceed 4. This will prevent designing for an artificial condition. Note that if two different types of subbase materials are to be used, such as a layer of Treated Permeable Base Course (TPBC), on a layer of 2A Subbase, the thickness of the two layers should be added and the total used to determine the effective modulus of subgrade reaction.

The use of OGS in all new construction or reconstruction of Interstates and Expressways is prohibited. The use of OGS is prohibited in plain cement concrete projects requiring pavement designs. Only treated permeable base may be used for plain cement concrete projects. OGS may be considered for 3R projects and other minor projects such as CPR, widening projects, or improvements to existing pavement constructed on OGS and 2A Subbase. In all such cases, OGS should only be used when appropriate outlet drainage can be achieved. OGS should not be used in areas where positive drainage cannot be achieved.

8.7 RELIABILITY LEVEL

See Section 6.4 for the appropriate reliability level to use.

8.8 OVERALL STANDARD DEVIATION

Use an overall standard deviation of 0.35 for rigid pavement design, as per Section 6.5.

8.9 LOAD TRANSFER COEFFICIENT, J

The load transfer coefficient, J, used in the AASHTO Rigid Pavement Design Procedures, is to account for the lateral support provided to the pavement at the slab corners. Corner stress is reduced when transverse joints are doweled, and also when tied concrete shoulders are present. When poor lateral support is estimated, the J value will increase. Table 8.2 provides the ranges for use in all Department designs. Note that the ranges are different than the ones provided in the 1993 AASHTO Guide for Design of Pavement Structures. If past deflection testing to find the load transfer efficiencies of transverse joints in in-service rigid pavements within the District indicated good to normal load transfer efficiencies, use a value towards the lower end of the ranges provided in Table 8.2. However, if past deflection testing for load transfer efficiency of transverse joints indicated low load transfer efficiencies, values towards the upper end of the ranges may be more appropriate.

TABLE 8.2
LOAD TRANSFER COEFFICIENT VALUES, J

DESCRIPTION	VALUE
Tied Concrete Shoulders	2.7 - 3.1
Curb	3.2

8.10 OVERALL DRAINAGE COEFFICIENT, C_d

The drainage coefficient, C_d, incorporates the impact of drainage quality on rigid pavement life. Until further study can be completed by PennDOT regarding the proper procedure for determining a drainage coefficient, use $C_d = 1.0$. This gives no benefit or disadvantage to rigid pavement designs based on drainage. As an additional note, the drainage coefficient value for conditions at the AASHO Road Test was 1.0, which corresponds to a rating of fair for the quality of drainage present.

8.11 CALCULATED DESIGN THICKNESS

After all the input values have been determined and entered, clicking the "Calculate Button" in DARWin will yield the calculated design thickness. Note that unlike PennDOT's previous concrete pavement design process, the required slab thickness may not be reduced by 1 inch if tied concrete shoulders are used, because the effect of the tied concrete shoulders is accounted for in the load transfer coefficient, J. However, once the required slab thickness is determined, round up or down to the nearest whole inch (e.g., 10.4 inches becomes 10.0 inches and 10.5 inches becomes 11.0 inches). Assure that the recommended pavement depths are within the minimum and maximum depths provided in Table 8.3.

When higher strength cement concrete is required, a special provision will be required in the bid to ensure that the required strength is used in construction. (Also assure that corresponding appropriate values for the concrete elastic modulus and the concrete modulus of rupture are used in the pavement design.) This includes revising the price adjustment table when Restricted Performance Specifications (RPS) is used on the project.

When a treated permeable base course is used, it should extend a minimum of 3 feet beyond each pavement edge to provide a stable, uniform platform for operation of paving equipment. This will aid in obtaining a smoother pavement surface.

There are no specific frost design requirements in the design of rigid pavements. Rigid pavements designed on the basis of saturated subgrade strength tests have ample reserve structural capacity to withstand the periods of reduced support during spring thaws. However, if differential frost heave is expected, refer to Section 6.2.B, Frost Design. Generally, the mitigation of differential frost heave through the increased structural strength design (thickness of pavement) has a limited success rate for rigid pavements.

TABLE 8.3
MINIMUM AND MAXIMUM DEPTHS FOR CONCRETE PAVEMENTS

	MINIMUM DEPTHS					MAXIMUM DEPTHS
	INTERSTATES AND OTHER LIMITED ACCESS FREEWAYS					
	ALTERNATIVE					
COURSES	A*	B*	ARTERIALS	COLLECTORS	LOCAL ROADS	
JPCP	9 in	9 in	9 in	8 in	7 in	20 in
TPBC	4 in	3 in	4 in	4 in	4 in**	4 in
2A	4 in	6 in	4 in	4 in	4 in	6 in
JRCP	8 in	8 in	6 in	6 in	6 in	--
TPBC	4 in	3 in	4 in	4 in	4 in**	4 in
2A	4 in	6 in	4 in	4 in	4 in	6 in

* Either Alternative A or B is acceptable.
** TPBC may be eliminated on low-volume/local roads, but the depth of 2A will be 6 inches.

The designer must determine the combination of design variables that will result in the most economical rigid pavement design while maintaining the required durability and rideability qualities. Contact the District Pavement Management Engineer/Pavement Manager for assistance in developing this design.

8.12 CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

The structural design of continuously reinforced concrete pavement (CRCP) should be performed according to the 1993 AASHTO *Guide for Design of Pavement Structures* using DARWin. The base course must be extended 3 feet beyond each pavement edge, the same as for conventional rigid pavement. CRCP should only be used in special cases. For assistance in determining when to use CRCP, contact PDAU. Since details and specifications for construction of CRCP are deleted from both Publication 72M, *Roadway Construction Standards*, and Publication 408, *Specifications*, the use of CRCP requires that special provisions are included in the contract document. CRCP can only be used with the approval of the Director, BOPD.

8.13 WIDER LANES FOR CONCRETE PAVEMENT

A wider concrete slab provides a combination of concrete roadways with a partial bituminous right shoulder. The wider 14-foot concrete slab will be striped at 12 feet. The remaining 2 feet will provide an effective 10-foot shoulder, when combined with an 8 foot Type 1 asphalt shoulder. Wider slabs are for consideration on low-volume rural Interstates and Expressways with two-way ADTs less than 10,000, where the need for an incident management lane is low.

The passing lane design will remain as conventional design with 12-foot lanes and tied 4-foot concrete shoulder.

For purposes of design, use Load Transfer Coefficient (J) for "Tied Concrete Shoulders" in Table 8.2.

8.14 SHOULDERS FOR JOINTED PLAIN CONCRETE PAVEMENT

The use of plain cement concrete shoulders tied to a cement concrete pavement of any type has several advantages. The primary reason for requiring concrete shoulders adjacent to concrete pavements is that concrete shoulders provide greater stiffness to a pavement structure. Greater stiffness in a rigid pavement reduces the magnitude of deflections and prolongs the service life of the pavement structure. In addition, tied concrete shoulders prevent differential heaving or settlement between pavement and shoulder. Thus, maintenance requirements are reduced and safety is increased with respect to other shoulder types adjacent to cement concrete pavements.

Full Depth Cement Concrete Shoulder must be considered where a high probability exists for incident management activity on high volume corridors and/or future work zone traffic control needs, as deemed necessary by the District. For urban Interstates/Expressways, where the need is identified, dowel transverse shoulder joints as shown in Publication 72M, *Roadway Construction Standards*, RC-25M. However, full depth shoulders on rural Interstates/Expressways will not require use of dowel bars on transverse shoulder joints provided the District determines there is no anticipated need to use the shoulders for supporting traffic during work zone traffic control operations or incident management activities on a high volume corridor. Where applicable, use the following specifications and standards.

1. For dowelled shoulders, use Publication 408, *Specifications,* Sections 501 or 506 - Reinforced or Plain Cement Concrete Pavements.

2. For non-dowelled shoulders, use Publication 408, *Specifications,* Section 658 - Concrete Shoulders.

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CHAPTER 9

FULL-DEPTH FLEXIBLE PAVEMENT DESIGN

This Chapter describes the procedures and the input values necessary to design a full-depth flexible pavement using the procedures in the 1993 AASHTO *Guide for Design of Pavement Structures*.

- 18-kip ESALs Over Initial Performance Period
- Initial Serviceability
- Terminal Serviceability
- Reliability Level
- Overall Standard Deviation
- Roadbed Soil Resilient Modulus
- Number of Construction Stages

9.1 18-KIP ESALS OVER INITIAL PERFORMANCE PERIOD

Calculate the 18-kip ESALs over the initial performance period, or design life, according to Chapter 7, Traffic Analysis for Pavement Design.

9.2 INITIAL SERVICEABILITY

Use an initial serviceability of 4.2, as per Table 6.3.

9.3 TERMINAL SERVICEABILITY

For full-depth flexible pavement design, use the Terminal Serviceability value listed in Table 6.3 PLUS the calculated loss of serviceability due to frost heave. For example, if a full-depth flexible pavement was being designed for an Interstate and the estimated loss of serviceability due to frost heave was found to be 0.75, a value of 3.75 (3.0 + 0.75) would be used for the terminal serviceability index.

Because DARWin does not calculate the loss of serviceability due to frost heave, it must be found using Appendix G of the 1993 AASHTO *Guide for Design of Pavement Structures*, Section G.2, Frost Heave. Three factors are needed to determine the loss of serviceability from Figure G.8, Chart for Estimating Serviceability Loss Due to Frost Heave, which are as follows:

1. Frost Heave Rate
2. Maximum Potential Serviceability Loss Due to Frost Heave
3. Frost Heave Probability

Once the three factors listed above are determined (see below for discussion on each), use Figure G.8 of the 1993 AASHTO *Guide for Design of Pavement Structures* to determine the serviceability loss due to frost heave. To use the chart, begin by drawing a vertical line corresponding to the time, *t*, which should equal the design life in years. Next, draw a horizontal line through the point where that vertical line meets the curve for the frost heave rate for the project. Now, it is necessary to draw a vertical line through the point where the horizontal line meets the curve for 100% frost heave probability. Finally, draw a horizontal line through the point where the last vertical line drawn meets the maximum serviceability loss due to frost heave obtained from Figure G.7. The serviceability loss due to frost heave is found where the horizontal line crosses the ΔPSI_{FH} axis.

1. Frost Heave Rate. The frost heave rate should be determined from Table 9.1 or Table 9.2, according to the subgrade soil type. If more than one type of subgrade soil is encountered on the project and the corresponding rates are relatively close, the average may be used. However, if drastically different soil types and thus frost heave rates are encountered, the loss of serviceability corresponding to each should be

determined and a separate pavement design performed for each. A Frost Heave spreadsheet tool is available online for use under the PDAU page of the PennDOT website.

2. Maximum Potential Serviceability Loss Due to Frost Heave. To determine the maximum potential serviceability loss due to frost heave, first find the depth of frost penetration, in feet, that the project area will encounter. The frost penetration depth is determined using the Design Freezing Index, found in Appendix D, for the weather station located nearest the project being designed. Where appropriate, the index numbers may be averaged to best depict conditions at a specific location. The depth of frost penetration is determined by entering the abscissa of Figure 9.1 with the appropriate Design Freezing Index and reading the depth of frost penetration on the left. Divide the depth from Figure 9.1 by 12 to get the depth in feet and use this in Figure G.7, Graph for Estimating Maximum Serviceability Loss Due to Frost Heave, of the 1993 AASHTO *Guide for Design of Pavement Structures*. To use this figure, draw a vertical line corresponding to the correct depth of frost penetration. Draw a horizontal line through the point where the vertical line crosses the line for the FAIR drainage quality. Read the corresponding Maximum Serviceability Loss Due to Frost Heave.

3. Frost Heave Probability. The last variable required to use Figure G.8 of the 1993 AASHTO *Guide for Design of Pavement Structures* is the estimated frost heave probability. This is an estimate of the percent area of the project that will experience frost heave. Use a recommended range for frost heave probability (P_f) of 25% - 75% in all flexible designs. Values outside these ranges must be verified through a soils report.

9.4 RELIABILITY LEVEL

See Section 6.4 for the appropriate reliability level to use.

9.5 OVERALL STANDARD DEVIATION

Use an overall standard deviation of 0.45 for flexible pavement design, as per Section 6.5.

9.6 EFFECTIVE ROADBED SOIL RESILIENT MODULUS

The Roadbed Soil Resilient Modulus, M_r, is used to represent the subgrade support characteristics in the design of flexible pavements. The M_r value used in the AASHTO design process should be the average of the tests taken for the project. If significantly different values are obtained within the same project, then separate pavement designs shall be performed for the different sections. It is important to test samples at the same density and moisture content they will develop in service. Since the procedures in the 1993 AASHTO *Guide for Design of Pavement Structures* were created to use average M_r values, it is not necessary to purposely input low modulus values to represent possible worst case scenarios.

If seasonal values of the roadbed soil resilient modulus are known or estimated according to typical behavior, as discussed in Section 6.2, input the values in the roadbed soil resilient modulus secondary dialog box and calculate the effective roadbed soil resilient modulus. Note that all seasons entered are automatically set-up for equal time lengths. Therefore, if six seasons are entered, each season will be equivalent to two months.

See Section 6.2 for more information regarding the roadbed soil resilient modulus.

TABLE 9.1
ESTIMATED AVERAGE RATE OF HEAVE
(UNIFIED SOILS CLASSIFICATION SYSTEM)

CLASSIFICATION OF SUBGRADE SOIL*	**ESTIMATED AVERAGE RATE OF HEAVE (mm/day)**
GW	2
GP	3
GM	4
GC	4
GW – GM	4
GW – GC	3
GP – GM	4
GP – GC	4
GM – GC	5
SW	3
SP	1
SM	7
SC	5
SW – SM	7
SW – SC	4
SP – SM	7
SP – SC	3
SM – SC	5
ML	15 - 20
CL	8
OL	**
MH	**
CH	1
OH	**
ML – OL	** 15 -20

*For MFC A and MFC B pavement designs, this chart is to be used with laboratory classification of subgrade soils. For MFC C, MFC D, and MFC E pavement designs, laboratory classifications are not required (i.e., field classifications are acceptable).

**OL, MH, and OH soils do not meet minimum specifications for subgrade material. ML-OL are marginal and may or may not meet minimum specifications for subgrade.

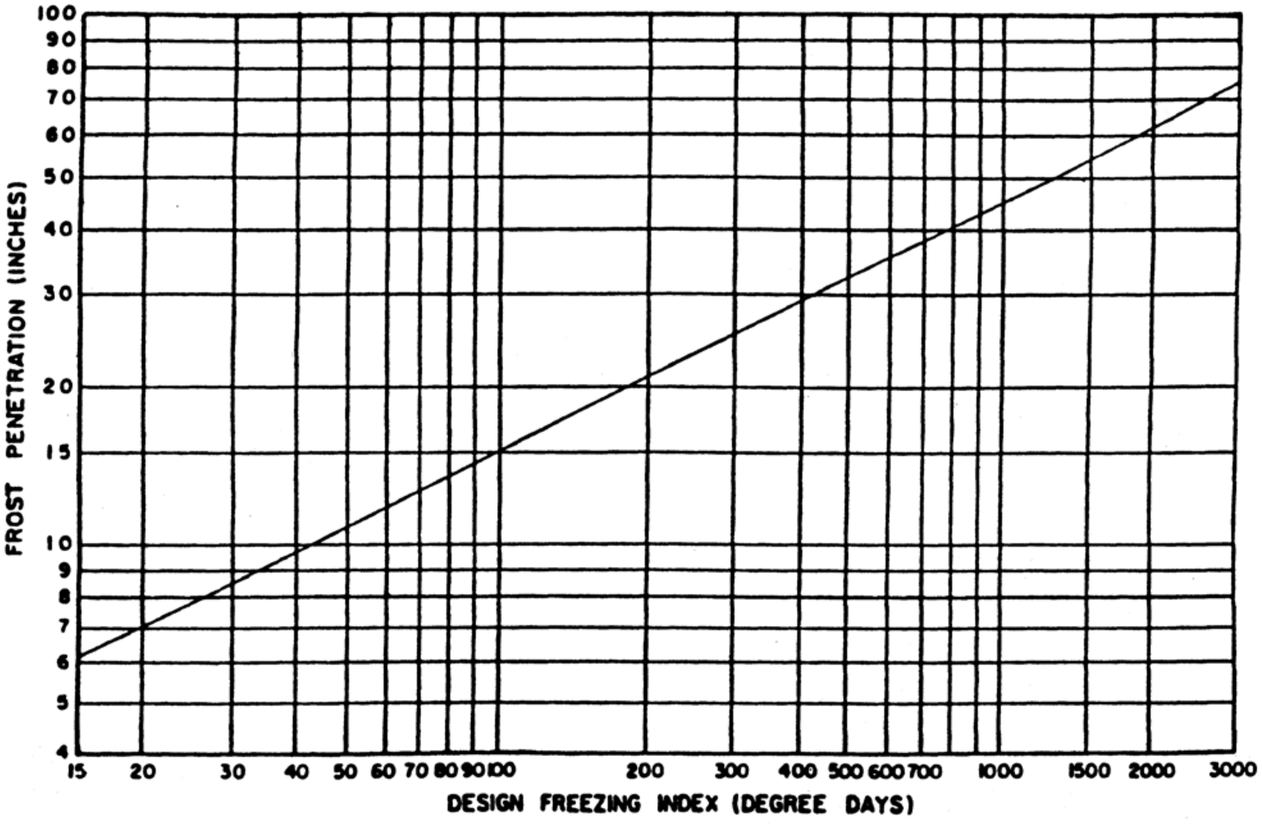
TABLE 9.2
ESTIMATED AVERAGE RATE OF HEAVE (AASHTO SOILS CLASSIFICATION SYSTEM)

CLASSIFICATION OF SUBGRADE SOIL*	**ESTIMATED AVERAGE RATE OF HEAVE (mm/day)**
A-1-a	3
A-1-b	5
A-2-4	6
A-2-5	6
A-2-6	5
A-2-7	5
A-3	1
A-4	15-20
A-5	**
A-6	8
A-7-5	**
A-7-6	6

*For MFC A and MFC B pavement designs, this chart is to be used with laboratory classification of subgrade soils. For MFC C, MFC D, and MFC E pavement designs, laboratory classifications are not required (i.e., field classifications are acceptable).

**A-5 and A-7-5 soils do not meet minimum specifications for subgrade material.

FIGURE 9.1
DESIGN CHART FOR DETERMINATION OF FROST PENETRATION



9.7 NUMBER OF CONSTRUCTION STAGES

Staged construction is not to be considered. Therefore, the Number of Construction Stages shall always be set to one.

9.8 DESIGN STRUCTURAL NUMBER

Once the variables necessary for full-depth flexible design are entered, calculate the design structural number by clicking the "Calculate Button".

The resulting Design Structural Number depicts the required strength the proposed pavement will need to provide. This structural number must be converted to individual layer thicknesses of the pavement through the following equation.

$$SN = a_1d_1 + a_2d_2m_2 + a_3d_3m_3 + ...a_nd_nm_n$$

where: SN = Structural Number
a_i = Structural Coefficient for layer I
d_i = Thickness of layer I
m_i = Drainage Coefficient for layer I

The Calculated SN from the thickness design must be greater than the Design SN to be structurally adequate. Use either the Specified Thickness Design method or Optimized Thickness Design method available in DARWin to determine structurally adequate pavement layer thicknesses. Do not use the Layered Analysis Thickness Design method. Obtain the structural coefficients, a_i, for each layer from Table 9.3. All layer drainage coefficients, m_i, shall be set to 1.0.

The determination of the pavement design is restricted by the minimum and maximum course depths from Tables 9.4 and 9.5. Pavement course adjustments should be made so that the least total pavement cost is incurred. Surface, base and subbase cost (per inch), minimum and maximum lift depths, and structural coefficients should be considered in the development of a pavement design. When the approved pavement structure is a flexible pavement with either an aggregate/cement or aggregate/lime/pozzolan base course, these two base materials must be included in the project bid proposal as alternatives.

Table 10.3 shows the suitability of bituminous materials for use in specific applications, based on the ADT of the highway.

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TABLE 9.3
STRUCTURAL COEFFICIENTS FOR MATERIALS IN FLEXIBLE PAVEMENTS

PAVEMENT COMPONENT	STRUCTURAL COEFFICIENT
Surface Course; New Construction, Reconstruction, or Overlay:	
Superpave 9.5 mm, 12.5 mm, 19.0 mm, 25.0 mm (Wearing and Binder Courses)	0.44
FB-1, FB-2 (Wearing and Binder Courses)	0.20
FJ-1, FJ-1C, FJ-4 (Wearing Courses)	0.35
Base Course; New Construction, or Reconstruction:	
Plain Cement Concrete (PCBC)	0.50
Lean Cement Concrete (LCBC)	0.40
Superpave 25.0 mm Base Course	0.40
Superpave 37.5 mm Base Course	0.40
Crushed Aggregate (CABC)	0.14
Crushed Aggregate, Type DG (CABCDG)	0.18
Aggregate - Bituminous (ABBC)	0.30
Aggregate - Cement (ACBC)	0.40
Aggregate - Lime - Pozzolan (ALPBC)	0.40
Existing Materials to be Overlaid:	
Cement Concrete (Good condition, < 5% patching)	0.40
Cement Concrete (Fair condition, < 10% patching)	0.30
Cement Concrete (Failed - no patching or > 10% patching)	0.25
Cracked/Break and Seated Cement Concrete	0.25
Bituminous Concrete	0.30
Cold Recycled Bituminous Concrete	0.30
Full Depth Reclamation	
Pulverization	0.11
Calcium Chloride and similar additives	0.14
Asphalt Stabilization	0.25 - 0.30
Chemical Stabilization	0.32 - 0.35
Scarified Bituminous Concrete	0.14
Brick with Rigid Base	0.40
Brick with Flexible Base	0.20
Crushed Aggregate Base Course	0.14
Crushed Aggregate Base Course, Type DG	0.18
Miscellaneous Existing Materials (CP-2, AT-1, HEs, Oil Bond Stone, Bit. Road Mixes)	0.20
Subbase; New Construction, Reconstruction, or Existing to be Overlaid*:	
Open Graded Subbase	0.11
No. 2A Subbase	0.11
Asphalt Treated Permeable Base Course (ATPBC)	0.20
Cement Treated Permeable Base Course (CTPBC)	0.20
Rubblized Cement Concrete	0.20

* See Section 10.2 for guidance regarding subbase inclusion in overlay designs.

TABLE 9.4
MINIMUM AND MAXIMUM THICKNESS OF SURFACE, BASE, AND SUBBASE MATERIALS FOR SUPERPAVE MIXES

COURSES	MAXIMUM THICKNESS	MINIMUM THICKNESS		
	ALL HIGHWAY CLASSIFICATIONS	MFC A & B	MFC C & D	MFC E
Surface	4 in	N/A	3.5 in* – 4 in	3.5 in* – 4 in
CABC, CABC-DG	16 in	N/A	8 in	6 in
Subbase	As Required	N/A	6 in	6 in
Surface	4 in	N/A	3.5 in* – 4 in	3.5 in* – 4 in
Agg./Cement Base Courses	12 in	N/A	5 in	5 in
Subbase	As Required	N/A	6 in	6 in
Surface	4.5 in	4 in	3.5 in* – 4 in	1 in** – 2 in
Superpave Base Course	15 in	3 in	3 in	4 in
Subbase	As Required	8 in	6 in	6 in
Surface	4.5 in	N/A	3.5 in* – 4 in	1 in** – 2 in
Agg./Bituminous Base Course	12 in	N/A	5 in	5 in
Subbase	As Required	N/A	6 in	6 in
Surface	4 in	4 in	3.5 in* – 4 in	3.5 in* – 4 in
Plain Cement Concrete Base Course	12 in	7 in	5 in	5 in
Subbase	As Required	8 in	6 in	6 in

*3.5 inches may only be used if 1 inch SP 9.5 mm FG Wearing Course is used with 2.5 inches SP 19.0 mm Binder Course.

**1 inch may only be used if 1 inch SP 9.5 mm FG Wearing Course is used.

TABLE 9.5
SUPERPAVE MATERIAL THICKNESSES

SUPERPAVE MATERIAL	MINIMUM DESIGN THICKNESS	MAXIMUM DESIGN THICKNESS
9.5 mm Fine Grade Wearing Course*	1 in	< 1.5 in
9.5 mm Wearing Course*	1.5 in	2 in
12.5 mm Wearing Course*	2 in	3 in
19.0 mm Binder Course	2.5 in	4.5 in
25.0 mm Binder Course	3 in	5.5 in
25.0 mm Base Course	3 in	As required by design
37.5 mm Base Course**	4.5 in	As required by design

*When used as a wearing course, not for scratch or leveling. Reference Table 10.5 when using as a scratch or leveling course.

**Use only when material quantity requirement is greater than 5,000 tons. For Superpave Maximum Construction Lift Thicknesses reference Publication 408, *Specifications*, Section 309.3(h)1.b.

CHAPTER 10

PAVEMENT OVERLAY DESIGN

10.1 GENERAL

A pavement overlay design is required for all projects that are being designed to improve ride or are otherwise suspected to be structurally inadequate. A pavement overlay design is also required for projects being designed due to low friction values. All overlay designs will be designed for a minimum 8-year structural design life and a maximum of 20 years.

To accomplish any overlay design, adequate and accurate traffic information must be used as the basis for design. Use the best information available. The minimum information needed is current Average Daily Traffic (ADT), projected traffic growth, and the truck percentage. A truck distribution is also required, unless the roadway is a collector or local road and the simple method may be used to calculate the 18-kip ESALs for the project (see Chapter 7). This data should be acquired as early in the design stage as possible.

If the required traffic information is not available in the District, it shall be requested from the Bureau of Planning and Research (BPR). If the BPR is unable to supply complete or updated data, the District may be requested to perform traffic counts. The truck classification count shall be performed in accordance with instructions given in Appendix B. The collected data must be submitted to the BPR for refinement and for development of truck distributions to be used in the design.

The determination of the design daily 18-kip ESALs must be in accordance with Chapter 7.

Form D-4332 shall be completed for each resurfacing or overlay design and submitted to PDAU for concurrence and FHWA approval, when necessary, as detailed in Section 6.1.B.

Table 10.1, Table 10.2, and Table 10.3 show the suitability of various bituminous materials (leveling, wearing, and base courses) for use in specific applications, based on the ADT of the highway. Table 10.4 provides the minimum and maximum layer thicknesses that may be used for pavement resurfacing or overlays using bituminous materials. When overlaying cement concrete or brick pavements for the first time with bituminous materials or when previous bituminous overlays are totally removed from these same surfaces, a minimum of 2 1/2 inches of binder material is required. The wearing course shall have the minimum thickness indicated for the material to be used. Table 10.5 shows the thickness of pavement course and the appropriate Superpave mixture size for both scratch and leveling types of pavement courses.

There may be an exception to these minimum thicknesses where there is a parking lane and where curb reveal is critical. In these cases, the wearing course may be tapered to a 1 inch depth at the curb (only within the parking lane). Careful attention must be given to the compaction in this area and to sealing the pavement/curb joint. Minimum thicknesses will still be required in the travel lanes. The District Pavement Management Engineer/Pavement Manager (PME/PM) shall be consulted when particular circumstances and minimum thickness requirements seem incompatible.

There are seven types of overlays can be designed using DARWin, according to the 1993 AASHTO Pavement Design Procedures. Note that the acronym PCC, for Portland Cement Concrete, is used in this Chapter to be consistent with the terminology used in DARWin®. They are as follows:

- AC overlay of AC pavement
- AC overlay of fractured PCC slab
- AC overlay of PCC slab
- AC overlay of AC/PCC (composite) pavement
- Bonded PCC overlay of PCC pavement
- Unbonded PCC overlay of PCC or AC/PCC (composite) pavement
- Unbonded PCC overlay of AC pavement

Bonded concrete overlays of asphalt pavement and bonded concrete overlays of AC/PCC (composite) pavement requires a different design procedure because the 1993 AASHTO Pavement Design Procedures do not account for bonding between the concrete overlay and the existing asphalt pavement. Thicknesses for these type overlays shall be determined using the bonded concrete overlay of asphalt mechanistic-empirical design procedure (BCOA-ME). This procedure was developed at the University of Pittsburgh under the FHWA Pooled Fund Study TPF 5-165. For more information, go to http://www.engineering.pitt.edu/Vandenbossche/BCOA-ME/.

TABLE 10.1
SUITABILITY OF LEVELING COURSE FOR SPECIFIC APPLICATIONS BASED ON HIGHWAY ADT

LEVELING COURSE							
CURRENT ADT	**FB-1**	**FB-2**	**FJ-1 FJ-1C**	**SP 9.5 mm FG**	**SP 9.5 mm**	**SP 12.5 mm**	**SP 19.0 mm**
0 - 800	Yes	Yes	Yes	Yes	Yes	Yes	Yes
801 - 1,500	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1,501 - 3,000	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3,001 - 5,000	No	No	Yes	Yes	Yes	Yes	Yes
5,001 - 12,000	No	No	*2	Yes	Yes	Yes	Yes
12,001 - 20,000	No	No	*2	Yes	Yes	Yes	Yes
Above 20,000	No	No	No	Yes	Yes	Yes	Yes

TABLE 10.2
SUITABILITY OF WEARING COURSE FOR SPECIFIC APPLICATIONS BASED ON HIGHWAY ADT

WEARING COURSE							
CURRENT ADT	**FB-1 *4**	**FB-2 *4**	**FJ-1,FJ-1C *1 *2**	**SP 9.5 mm FG *2**	**SP 9.5 mm**	**SP 12.5 mm**	**SP 19.0 mm**
0 - 800	Yes	Yes	Yes	Yes	Yes	Yes	Yes
801 - 1,500	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1,501 - 3,000	*3	*3	Yes	Yes	Yes	Yes	Yes
3,001 - 5,000	No	No	Yes	Yes	Yes	Yes	Yes
5,001 - 12,000	No	No	No	*5	Yes	Yes	Yes
12,001 - 20,000	No	No	No	*5	Yes	Yes	Yes
Above 20,000	No	No	No	*5	Yes	Yes	Yes

*1 Use only if speed limit is 40 mph or less.
*2 Use only if base is good and existing surface is sound.
*3 Combination of binder course and wearing course shall be used with ADT over 1,500.
*4 Seal Coat within 3 years.
*5 Use only if minimum thickness is 1.5 inches

TABLE 10.3
SUITABILITY OF BASE COURSE FOR SPECIFIC APPLICATIONS BASED ON HIGHWAY ADT

	BASE COURSE	
CURRENT ADT	**SP 25.0 mm**	**SP 37.5 mm**
0 - 800	Yes	No
801 - 1,500	Yes	No
1,501 - 3,000	Yes	No
3,001 - 5,000	Yes	No
5,001 - 12,000	Yes	*6
12,001 - 20,000	Yes	*6
Above 20,000	Yes	*6

*6 Use only if project construction item quantity is greater than 5,000 tons and application is for full lane width and full depth base course.

TABLE 10.4
BITUMINOUS MATERIAL THICKNESSES FOR OVERLAYS

MATERIAL	MINIMUM THICKNESS	MAXIMUM THICKNESS
Superpave 9.5 mm Fine Grade Wearing Course	1 in	< 1.5 in
Superpave 9.5 mm Wearing Course	1.5 in	2 in
Superpave 12.5 mm Wearing Course	2 in	3 in
Superpave 19.0 mm Binder Course	2.5 in	4.5 in
Superpave 25.0 mm Binder Course	3 in	5.5 in
FJ-1 Course[1], FJ-4 Wearing Course	1 in	1.25 in
FB-1 Wearing Course [1,2,3,4]	1 in	1.5 in
FB-1 Binder Course [4]	2 in	2.5 in
FB-2 Wearing Course [1,2,3,4]	1 in	1.5 in
FB-2 Binder Course [4]	2 in	2.5 in
Superpave 25.0 mm Base Course [5]	3 in	As required by design
Superpave 37.5 mm Base Course [5,8]	4.5 in	As required by design
Asphalt Treated Permeable Material (ATPBC)	3 in[7]	4 in

[1] When used as a wearing course.
[2] A combination of binder course and wearing course shall be used with ADT >1,500, total minimum 3 inches.
[3] Requires a seal coat after a minimum of 3 months from date of construction to a maximum of 3 years.
[4] FB-Modified will use the same values as FB-1 & FB-2.
[5] For Superpave Maximum Construction Lift Thicknesses reference Publication 408, *Specifications*, Section 309.3(h)1.b.
[7] May only be placed on 6 inches of 2A subbase material.
[8] Use only when material quantity requirement is greater than 5,000 tons.

TABLE 10.5
SUPERPAVE SCRATCH AND LEVELING COURSE THICKNESSES

TYPE OF PAVEMENT COURSE	THICKNESS OF PAVEMENT COURSE	APPROPRIATE SUPERPAVE MIXTURE SIZE
Scratch	60 lb/sy to 110 lb/sy or ≤ 1 in depth	Superpave 9.5 mm FG or 9.5 mm Wearing
Leveling (Buildup)	≥ 1 in to 2.5 in	Superpave 9.5 mm Wearing
	≥ 1.5 in to 3 in	Superpave 12.5 mm Wearing
	≥ 2 in to ≤ 4.5 in	Superpave 19.0 mm Binder
	≥ 3 in to ≤ 6 in	Superpave 25.0 mm Binder
	≥ 6 in [*1]	Any combination of 2 or more Superpave Mixture Sizes and Thickness to meet the project requirements for buildup

[*1] Place leveling course as per construction lift thickness maximums in Table 10.4.

This Chapter provides a brief overview of each overlay type. Selection of the appropriate type of overlay is dependent primarily on the existing pavement type and condition. For example, it would be inappropriate to place a bonded PCC overlay on an existing concrete roadway that is severely cracked and/or faulted.

There are two basic variables required to be calculated in all overlay designs (except PCC Overlay of AC Pavement, which is discussed in further detail later), the existing effective structural capacity of the pavement and the structural capacity required for future traffic. For rigid and composite pavements the effective structural capacity is denoted by D_{eff}, and the structural capacity required to support future traffic is denoted by D_f. For flexible pavements the effective structural capacity is denoted by SN_{eff}, and the structural capacity required to support future traffic is denoted by SN_f.

There are three basic evaluation methods for evaluating the effective structural capacity of an existing pavement. They are as follows:

1. Condition Survey or Component Analysis. These methods take into account pavement distress and/or layer analysis.

2. Non-Destructive Deflection Testing. This method relies on Falling Weight Deflectometer (FWD) data to evaluate the in situ subgrade and pavement stiffness.

3. Remaining Life. This method uses past traffic data and the pavement's current condition to estimate the pavement's remaining service life. This method is NOT to be used for Department pavement designs due to the lack of accurate historical traffic data.

Table 10.6 details the available methods of evaluating the effective structural capacity of each overlay type.

TABLE 10.6
METHODS TO ESTIMATE THE EXISTING STRUCTURAL CAPACITY

OVERLAY TYPE	METHOD(S) AVAILABLE TO ESTIMATE THE EFFECTIVE EXISTING STRUCTURAL CAPACITY, D_{eff} OR SN_{eff} (EXCLUDES REMAINING LIFE METHOD)	D_{eff} or SN_{eff}	D_f or SN_f
AC Overlay of AC Pavement	Component Analysis Non-Destructive Testing	SN_{eff}	SN_f
AC Overlay of Fractured PCC Slab	Component Analysis	SN_{eff}	SN_f
AC Overlay of PCC Pavement	Condition Survey	D_{eff}	D_f
AC Overlay of AC/PCC Pavement	Condition Survey	D_{eff}	D_f
Bonded PCC Overlay of PCC Pavement	Condition Survey	D_{eff}	D_f
Unbonded PCC Overlay of PCC Pavement	Condition Survey	D_{eff}	D_f
PCC Overlay of AC Pavement	Not Applicable	N/A	D_f

10.2 AC OVERLAY OF AC PAVEMENT

In a design of an AC overlay for an existing AC pavement, the Structural Number (SN) for Future Traffic and the Effective Existing SN need to be calculated. (DARWin has secondary dialog boxes to calculate both.) The overlay design must accommodate the difference between the SN for Future Traffic and the Effective Existing SN.

Reference Table 10.7 for direction on appropriate input values when calculating the SN for Future Traffic.

Use flexible pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

There are three methods available in DARWin to calculate the effective SN of the existing pavement; the Component Method, Remaining Life Method, and the Non-Destructive Testing Method. The Component Method or Non-Destructive Testing Method should be used for AC Overlay of AC Pavement design. Obtain existing pavement structure data from pavement cores from the project. If for some reason cores are not available, use Pavement History data from the Roadway Management System (RMS).

For the Component Method, the depths of all pavement layers and their corresponding structural coefficients found in Table 9.3 are entered into DARWin so the SN_{eff} can be calculated based on the structural number equation detailed in Section 9.8 (all drainage coefficients should equal to 1.0). Because the existing subbase may be in poor condition, do not include it in the structural evaluation of the existing pavement for overlay design on Interstates. Subbase may be missing completely on Non-Interstates; therefore, do not include subbase when the design 18-kip ESALs exceed 5,000,000 on all other roadways, unless subbase investigation has been performed to verify its quality and drainability.

Once the SN for Future Traffic and the Existing Effective SN are determined, the Overlay Structural Number can be calculated (click the "Calculate Button" in DARWin). Next, perform a thickness design. In DARWin, use either the specified or optimized thickness design methods (these can be found by pulling down the Design tab in DARWin). The Calculated SN must be greater than the Overlay (Design) SN for the overlay to be structurally adequate.

10.3 AC OVERLAY OF FRACTURED PCC SLAB

The AC Overlay of Fractured PCC Slab method of overlay design may be used to design an AC overlay for either a cracked and seated or rubblized Jointed Plain Concrete Pavement (JPCP) or Jointed Reinforced Concrete Pavement (JRCP). The design method is similar to that listed in Section 10.2. First the SN for Future Traffic is calculated, and then the Existing Effective SN is calculated. Follow the guidance provided in Section 10.2, regarding subbase inclusion, when determining the Existing Effective SN using the Component Method. Once the SN for Future

Traffic and the Existing Effective SN are determined, the Overlay SN can be calculated. After the Overlay SN is found, perform a thickness design. Reference Table 10.7 and Section 10.2 for further guidance.

Use flexible pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

10.4 AC OVERLAY OF JOINTED PLAIN CONCRETE PAVEMENT (JPCP)

The AC Overlay of JPCP method of overlay design may be used to design an AC overlay on JPCP, JRCP, or CRCP rigid pavement types. This method should also be used if the existing pavement is concrete with a bituminous overlay but the bituminous overlay will be removed prior to the new AC overlay.

Use rigid pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

The first step in designing an AC overlay of JPCP is to calculate the pavement thickness for future traffic. This is done using a secondary screen in DARWin that resembles the rigid pavement design process. When calculating the Pavement Thickness for Future Traffic, reference Table 10.8 for direction on appropriate input values.

TABLE 10.7
SN FOR FUTURE TRAFFIC, SN_f

REQUIRED INPUT	REFERENCE
Future 18-kips ESALs Over Design Period	Chapter 7
Initial Serviceability	Table 6.3
Terminal Serviceability	Table 6.3 (Frost Heave is to be considered in AC Overlay of fractured JPCP and HMA pavements. See Section 6.2.B.)
Reliability Level	Table 6.4
Overall Standard Deviation	Section 6.5
Design Resilient Modulus	Section 6.2 - Note that for FWD Backcalculation data a correction factor, C, of 0.25 is needed. This is necessary to obtain M_r values from backcalculated deflection data that are consistent with values from laboratory tests. In addition, caution should be used not to use a value in design that is too high. When using the equation presented in Chapter 6 to convert a CBR value to M_r, multiply the CBR by 1,000 instead of 1,500. A more conservative equation is necessary to assure that artificially high values are not used. If a M_r value greater than 3,000 psi is used, the project is being designed on a soil stiffer than the silty-clay A-6 soil used at the AASHO Road Test site. Thus, a thinner overlay will result due to the increased soil support conditions being designed.

TABLE 10.8
PAVEMENT THICKNESS FOR FUTURE TRAFFIC, D_f

REQUIRED INPUT	REFERENCE
Future 18-kip ESALs Over Design Period	Chapter 7
Initial Serviceability	Table 6.3
Terminal Serviceability	Table 6.3 (Frost Heave is not to be considered in PCC or Composite Designs.)
PCC Modulus of Rupture	Section 8.4 (Typically 631 psi)
PCC Elastic Modulus	Section 8.5 (Typically 4,000,000 psi)
Static k-value	This is a measure of the support provided to the concrete pavement by all the underlying layers, the subbase and subgrade. The dynamic k-value may be found through backcalculation of deflection data. Divide by two to convert the dynamic k-value to a static k-value.
Reliability Level	Table 6.4
Overall Standard Deviation	Section 6.5
Load Transfer Coefficient	Section 8.9
Overall Drainage Coefficient	Use $C_d = 1.0$

Once the Pavement Thickness for Future Traffic is determined, the Effective Existing Thickness must be calculated. Two existing pavement evaluation methods are available in DARWin, the Condition Survey Method and the Remaining Life Method. Use the Condition Survey Method. To use this method, STAMPP condition data from the Roadway Management System must be obtained. A field view by the District PME/PM may also be necessary to determine accurate input values for some of the existing condition input variables. Refer to Table 10.9 for further guidance on appropriate inputs. Include with the pavement design submission documentation of where and how the input values used in the Condition Survey were obtained.

After the Effective Existing Thickness is determined, select the "Calculate Button" and the necessary overlay thickness will be calculated and displayed. Note that unlike the other overlay design processes discussed up to this point, this is the actual overlay thickness required, not the required structural number.

10.5 AC OVERLAY OF AC/PCC (COMPOSITE) PAVEMENT

The AC Overlay of an AC/PCC (composite) method of overlay design shall be utilized when a previously overlaid concrete roadway will be overlaid with bituminous material without removing an existing bituminous overlay. Note that if the existing bituminous overlay is suspected of possessing material problems or deficiencies, cores of the pavement shall be obtained and analyzed. If material deficiencies exist, the existing bituminous overlay must be completely removed prior to the application of a new bituminous overlay, and a design for an "AC Overlay of PCC Pavement" should be performed (instead of the "AC Overlay of AC/PCC Pavement" method).

The first step in the AC Overlay of AC/PCC Pavement design procedure is to determine the Pavement Thickness for Future Traffic. Reference Table 10.8 for guidance. After the Pavement Thickness for Future Traffic is determined, the Effective Existing Thickness must be calculated using the Condition Survey Method. Reference Table 10.9 for guidance regarding pavement condition data inputs. As in the "AC Overlay of PCC Pavement" overlay design method, the end result calculated in DARWin is the actual thickness of the bituminous overlay required, not the required SN.

Use rigid pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

10.6 BONDED PCC OVERLAY OF PCC PAVEMENT

PennDOT currently designs two types of concrete overlays of existing concrete pavements, bonded and unbonded. Table 10.10 contains the minimum and maximum thicknesses for concrete overlays. Bonded overlays are directly bonded to the existing concrete pavement in such a manner that the overlay and the existing concrete pavement act as a single monolithic slab. Bonded PCC overlays should only be utilized where the existing concrete pavement does not exhibit a great extent of cracking and/or faulting. If there is a significant amount of distress in the existing concrete pavement, it will be reflected up through the bonded PCC overlay if it is not repaired or corrected.

Use rigid pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

To design a Bonded PCC Overlay, begin by calculating the Pavement Thickness for Future Traffic in DARWin. (Reference Table 10.8 for guidance.) Continue by computing the Effective Existing Thickness using the Condition Survey evaluation method in DARWin. (Reference Table 10.9 for guidance.) After both variables have been calculated, selecting the "Calculate Button" will yield the required concrete thickness for the bonded PCC overlay. This number should be rounded up to the nearest half-inch. Assure that the recommended bonded PCC overlay depth is within the minimum and maximum depths specified in Table 10.10.

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TABLE 10.9
EFFECTIVE EXISTING THICKNESS, D_{eff}
CONDITION SURVEY METHOD

REQUIRED INPUT	REFERENCE
Existing PCC Thickness	Pavement Cores RMS - Pavement History
Existing AC Thickness	Pavement Cores (Preferred) RMS - Pavement History
AC Milling Thickness	Design Information
Rut Depth	Field Measurement RMS - STAMPP Condition Data
Durability Adjustment Factor	Dependent on Overlay Design Method. Use applicable table of 1993 AASHTO *Guide for Design of Pavement Structures* (Table 5.8, 5.10, or 5.12)
Fatigue Damage Adjustment Factor	Dependent on Overlay Design Method. Use applicable table of 1993 AASHTO *Guide for Design of Pavement Structures* (Table 5.8 or 5.12)
AC Quality Adjustment Factor	Table 5.10 of 1993 AASHTO *Guide for Design of Pavement Structures*
Number of Deteriorated Joints per mile (Medium and High Severity Joint Spalling or Faulting)*	This is the number (per mile) of medium and high severity deteriorated joints that will not be patched prior to overlay.
Number of Deteriorated Cracks per mile (Medium and High Severity Cracking)*	This is the number (per mile) of medium and high severity cracks that will not be patched prior to overlay.
Number of Unrepaired Punchouts per mile (CRC Pavements Only)*	This is the number (per mile) of punchouts that will not be repaired prior to overlay.
Number of Expansion Joints, Exceptionally Wide Joints, or AC Full Depth Patches	This is the number of expansion joints, exceptionally wide joints, or full depth bituminous patches that will remain.
Joints and Cracks Adjustment Factor	This adjustment factor will automatically be calculated by DARWin. Note that STAMPP data and/or a project field view will aid in determining the number of existing distresses that should be patched or repaired prior to overlay. If all deteriorated joints, cracks, punchouts, and patches will be patched with PCC or repaired prior to overlay, as required, a factor of 1.0 may be used.

* For distress and severity definitions reference Publication 336, *Automated Pavement Condition Survey Field Manual*.

** Provide documentation with the pavement design regarding where and how the input values for the Condition Survey Method were obtained/determined.

TABLE 10.10
MINIMUM AND MAXIMUM THICKNESS FOR CONCRETE OVERLAYS

OVERLAY TYPE	MINUMUM THICKNESS	MAXIMUM THICKNESS	TYPICAL JOINT SPACING*	APPLICABLE STANDARD SPECIFICATION
Bonded Concrete Over Concrete	2.0 in	5.0 in	Match existing pavement	524
Ultra-Thin Bonded Concrete Over Asphalt or AC/PCC (composite)	2.5 in	4.0 in	3 ft × 3 ft	523
Bonded Concrete Over Asphalt or AC/PCC (composite)	4.0 in	8.0 in	6 ft × 6 ft	540**
Unbonded Concrete Over Concrete, Asphalt, or AC/PCC (composite)	5.0 in	13.0 in	6 ft × 6 ft for pavements thinner than 8 in, 12 ft × 12 ft for all others***	501/506

Notes:
*Joint spacing of 4 feet by 4 feet will result in longitudinal joints in the wheel path and is not recommended.

** The Bonded Concrete Over Asphalt or AC/PCC (composite) specification is currently in the Clearance Transmittal process. Contact PDAU for assistance.

*** This joint spacing is not included in the current standards. Use of this will require a special provision for the project.

10.7 UNBONDED PCC OVERLAY OF PCC PAVEMENT

The "Concrete Overlay – Unbonded – Crack and Seat" section has been removed from this Chapter under the discretion of the Department. The Department does not agree with the current methodology available by the DARWin software to produce an accurate Unbonded Concrete Overlay pavement structure over a Crack and Seated concrete pavement. The previous direction was to treat the Crack and Seated pavement as a subbase layer and utilize the Rigid pavement design module to design the Unbonded Concrete Pavement slab thickness. The Department encourages the use of Unbonded Concrete Overlays where appropriate, but does not recommend the Crack and Seat method prior to this work. It is recommended to utilize the Unbonded Concrete Overlay module over an existing concrete pavement with a thicker asphalt interlayer in lieu of cracking the concrete pavement. However, if Crack and Seating the existing concrete pavement is preferred, then it is recommended to only overlay with asphalt and use the "AC over Fractured PCC" module for the design thickness.

10.8 UNBONDED PCC OVERLAY OF AC PAVEMENT

The PCC Overlay of AC Pavement design method available in DARWin considers the bituminous pavement as a supporting layer for the PCC overlay, but does not account for any direct structural contribution. Therefore, the required PCC overlay thickness is equal to the calculated Pavement Thickness for Future Traffic. Reference Table 10.8 for guidance in determining the Pavement Thickness for Future Traffic.

Use rigid pavement Average Initial Truck Factors from Table 7.1 for ESAL calculations.

The PCC Overlay of AC Pavement method of overlay design referenced above is designed to provide structural strength and is therefore considered a structural overlay.

If a significant amount of additional structural strength is not needed, however the surface course of the pavement is rutted and/or pushed and shoved, consider an Unbonded Concrete Overlay or Bonded Concrete Overlay on Asphalt or Composite pavements, unless the rutting problem is due to fatigue failure such as a poor base, subbase, or subgrade. Then an ultra-thin cement concrete overlay should not be used until the underlying base problem is corrected.

Bonded Concrete Overlay on Asphalt (BCOA) is a thin Portland cement concrete overlay reinforced with polypropylene fibers placed on an existing bituminous pavement after milling. The minimum depth of concrete for a BCOA is 2.5 inches, and the maximum allowed is 4 inches. The recommended bituminous material thickness on which to place the Portland cement concrete overlay is 3 inches, after milling.

BCOA is considered a non-structural wearing course and may be used as an alternative to traditional milling and overlaying with bituminous concrete. Accelerated cement concrete mixes are recommended in high traffic areas due to constraints in the Maintenance and Protection of Traffic.

Appropriate applications for BCOA are at intersections or access ramps on interchanges where bituminous pavements have shoved and rutted. All BCOA projects from an Engineering District must have concurrence from BOPD prior to the Design Field View. PDAU will provide the necessary assistance.

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CHAPTER 11

PAVEMENT MANAGEMENT

11.1 INTRODUCTION

Pavement management is a standardized process to institute goals, establish policy, perform long-range planning, allocate resources, develop programs, deliver projects, and employ a systematic approach for maintaining roadways, forecasting needs, and performing cost/benefit analysis at both the project level and network level. Pavement management allows for programming maintenance and rehabilitation strategies at the optimum time and to quantify needs over any projected time. Project-level pavement management supports decisions about the best treatment to apply to a selected section of pavement.

The benefits of pavement management include:

- The ability to show impact of funding decisions.
- The ability to provide recommendations for effective maintenance, preservation and rehabilitation strategies.
- The ability to forecast the future condition of the system, the impact of delaying treatments, and/or various funding scenarios.
- The ability to track the performance of selected treatments (life-cycle analysis for treatments).
- The ability to establish performance measures, perform statistical analysis and research, and generate reports.
- The optimization of feasible solutions by user defined budgets, resources or restrictions.
- The ability to objectively document, measure, and evaluate parameters that affect performance.
- The increase of credibility and accountability of infrastructure investment decisions.
- An emphasis on performance-based investment decisions, based on objective measures of system condition and performance.

An asset management system in general, and specifically a Pavement Asset Management System (PAMS), provides tools and a methodology for synthesizing design, materials, construction, maintenance, and rehabilitation activities to maximize pavement life and benefits. Pavement management allows for programming maintenance and rehabilitation strategies at the optimum time and to quantify needs over any projected time. One of the most important functions of a PAMS is its ability to show the impact of alternative funding levels and strategies. Pavement Management typically consists of three major components: (1) regular collection of highway condition data; (2) a computer database to sort and store the condition data along with construction, traffic, inventory, and maintenance data; and (3) an analysis program to determine the most cost-effective strategies to maintain and preserve the highway system.

Pavement management can be used at two levels: network and project level. The network-level PAMS supports general planning, programming, policy decisions, and is normally related to the budget process and establishing agency priorities. The project-level PAMS supports decisions about the best treatment to apply to a selected section of pavement; detailed consideration is given to defining the strategy for a particular section which will provide the desired service levels at the least total cost over the analysis period.

Section 119(e) of Title 23 USC requires a State to develop a risk-based asset management plan for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system.

The success of Pavement Management hinges on the tools, data, and performance measures that drive decision making. This Chapter consolidates various programs and initiatives currently in place or underway in order to provide background and direction for the foundation of PennDOT's Pavement Management efforts.

11.2 PAVEMENT TREATMENT CYCLES

The plan and strategy for PennDOT's Pavement Management was defined through the Maintenance Efficiency and Cost Effectiveness (MECE) initiative. The MECE Pavement Management Subgroup defined pavement cycle charts to be the basis for selecting appropriate treatments, based on several references, including the PennDOT 1988-92 Cycle Task Force recommendations, this Manual, and Publication No. FHWA-SA-96-027, *Pavement Maintenance Effectiveness Preventive Maintenance Treatments*. The cycles are in Tables 11.1 through 11.4.

TABLE 11.1
HIGH-LEVEL BITUMINOUS ROADWAYS (RESURFACING NETWORK)

ACTIVITY	FREQUENCY
Crack sealing	Years 5, 15, 25, 35 and 45
Clean and Seal longitudinal joints	Years 5, 15, 25, 35 and 45
Micro Surfacing (optional)	5 to 10 years
Resurfacing	10 years (with no interim surface seal)
	13 to 17 years (with an interim surface seal)
Seal Coat or Micro Surface paved shoulders	Years 5, 10, 15, 30 and 45

TABLE 11.2
LOW-LEVEL BITUMINOUS ROADWAYS (SEAL COAT NETWORK)

ACTIVITY	FREQUENCY
Crack sealing	3 to 5 years
Seal coat (rural) or Micro Surface	8 to 10 years
Micro Surface or level (urban)	5 to 6 years
Resurface or level	15 to 20 years

TABLE 11.3
CONCRETE PAVEMENTS

ACTIVITY	FREQUENCY
Clean and Seal joints	Years 8, 15, 25, 30, 35, 40 and 45
Concrete patching	Years 15, 25, 35 and 45
Diamond Grinding	15 years
Overlay	Years 25, 35 and 45
Seal Coat (if bituminous) or Micro Surface Shoulders	30 years

TABLE 11.4
UNPAVED ROADS

ACTIVITY	FREQUENCY
Shaping	Yearly

Maintaining roadways according to these cycles will extend pavement life and increase the time before major rehabilitation or reconstruction is necessary. These defined cycles also provide the methodology to assess the backlog of roadways that are "out of cycle"; that is, those that have not been treated according to the defined timeframes.

Pavements not maintained properly obviously cannot be expected to provide the same life as those that are properly maintained. The maintenance cycles and the reconstruction cycles must both be evaluated when selecting the project type.

11.3 SURFACE IMPROVEMENT PROGRAM REPORTING

The reporting of annual surface improvement is vital to pavement management in order to document how funds are to be expended, and to determine the number of miles improved over time. Surface Improvement Miles and Dollars information is requested annually in the business plan guidelines. Since the business plan guidelines have been separated from the budget instructions, Surface Improvement Miles and Dollars information is also required from each District in support of the budget request to the Governor.

For reporting, include surface improvements completed with Highway Maintenance (10582) funds (do not include Turnbacks). Districts must provide a table for each county in the District, as well as a District summary table each year.

It is important that mileage is captured accurately in order to assess the amount of the network treated annually. Mileages and costs must be reported according to the Fiscal Year that the projects are open to traffic.

Surface improvement programs are to be defined, as planned, in Plant Maintenance M-213. Progress reports will be run throughout the year to measure performance. At a minimum, the following activities must be included in Plant Maintenance:

- 711-7123-01 Mixer Paver
- 711-7124-01 Seal Coat
- 711-7125-01 Paver Finisher 1 inch
- 711-7131-01 & 02 Level and Scratch
- 711-7133-01 Recycling
- 711-7134-01 Slurry Seal, Micro Surfacing, Ultrathin Friction Course
- 711-7135-01 Paver Finisher over 1 inch
- 711-7136-01 Widening BCBC
- 711-7137-01 Widening Recycled
- 711-7141-01 Concrete Patching
- 711-7216-01 Shoulder Upgrading
- 711-7222-02 Shoulder Paving
- 711-7224-01 Shoulder Seal Coat
- 711-7233-01 Shoulder Recycling
- 711-7128-01 Crack Sealing-Bituminous Surface
- 711-7147-01 Joint Sealing Concrete Roads

Crack Sealing and Joint Sealing were recently added to the required M-213 activity listing. Reporting these activities is needed for Pavement Management and cycle assessments. Crack sealing on the resurfacing network is to be completed on a 3 to 5 year cycle. There will be a close review of the resurfacing network that is 5 years and greater in age with no crack sealing completed or planned. The concrete network is to be joint sealed on a 5-year cycle.

Table 11.5 is an example of the table that must be provided. This example specifies the years to be reported as part of the fiscal year 2007-2008 budget request and business plans.

A. Definitions for Mileage Reports based on MECE Subgroup 1B Final Report. Surface improvements will be reported within the categories identified below. <u>All mileage will be reported in segment miles, which is the total length of all improved roadway segments</u>.

1. Betterments. Typically programmed as 381 (100% state), or 383 (federal funds with or without matching state from the maintenance allocation).

a. Resurfacing – Pavement design is required and 3R criteria is followed (refer to Publication 13M, Design Manual Part 2, *Highway Design*, for 3R criteria).

b. Widening – capacity is increased or the roadway width is increased 10 feet or greater.

c. Intersection improvements (turning lanes).

d. Reconstruction.

e. Concrete Rehabilitation – CPR and overlay (excludes PM criteria – overlay of 4 inches or greater).

Note that the program (as defined in MPMS, i.e., 381, 383) should not alone dictate how mileage is reported, because pavement preservation can be funded as a 383 project. In those cases, that work should be reported in one of the Pavement Preservation categories identified below.

In addition to defining the Betterment mileages in the "XX-0 Surface Improvement Miles FY XX-XX.xls" file (for the current fiscal year), Betterment projects are also to be entered in a template, named "XX-0 Betterment Projects FY XX-XX.xls", located in the following folder:

P:\PENNDOT Shared\Bureau of Maintenance and Operations\Roadway Management Division\Surface Improvement

TABLE 11.5
SURFACE IMPROVEMENT MILES
STATE AND FEDERAL DOLLARS IN APPROPRIATIONS 10582

APPROPRIATIONS 10582 ACTIVITY	ACTUAL 2008-2009		PLANNED							
			2009-2010		2010-2011		2011-2012		2012-2013	
	MILES	$	MILES	$	MILES	$	MILES	$	MILES	$
BETTERMENT	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
RESURFACING & CPR	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Resurfacing	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
CPR	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Recycling/Seal Coat	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Recycle only	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
WIDENING	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Included in Betterment or Resurfacing project	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Widening only	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
LEVELING & SEALING	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Micro Surfacing	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Leveling with seal coat	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Seal coat only	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Leveling only	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
SURFACE REPAIR	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Mechanized Patch	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Skin Patch	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
PAVEMENT TOTAL	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
SHOULDER	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00

Please copy this template for the appropriate fiscal year, rename for the appropriate District and save to the same location. Insert rows as necessary to define each project for each year. For group projects, define limits of improvement for each SR separately.

Separate versions of this table must also be provided for each of the three Highway Maintenance (10582) funding scenarios. In addition to the District number, also indicate "scenario 1", "scenario 2", and "scenario 3" in the filename.

Betterment projects defined in the aforementioned spreadsheet will be monitored in MPMS. Throughout the year, completed Betterment mileage will be determined for these projects when "open to traffic" is indicated in MPMS.

2. Pavement Preservation. Pavement preservation items are to be reported according to the following categories:

a. Resurfacing & CPR.

(1) Resurfacing – Thin Overlays. Overlay of 1 inch to 1.5 inches with or without leveling (7123, 7125, 7135), or overlay of 2 inches or greater when 3R criterion is not followed.

(2) CPR

(a) Concrete patching, without diamond grinding (7141) with 2% or greater patching of the total area full mileage credit will be provided; dowel bar retrofits will be included.

(b) Concrete patching, without diamond grinding (7141) with less than 2% of concrete patching; 280 square yards concrete patching is equal to 1 mile of surface improvement.

(c) CPR with diamond grinding (7141) would receive full mileage credit.

(3) Recycling/Seal Coat. Cold in-place or pug mill method (7133). If seal or resurfacing is done in the same fiscal year count mileage once, in this category, and report cost for both operations. If seal or resurfacing is done in different fiscal years, report appropriate mileage in this category and also in the seal coat category for the appropriate years.

(4) Recycling Only. Cold in-place or pug mill method (7133).

b. Widening (7136, 7137). Full mileage is counted when the width meets the Publication 23, *Maintenance Manual* criteria. Depth of widening will be based on existing pavement structure and ESALs. It is recommended that the depth of the widening does not exceed the depth of the existing pavement structure.

(1) Widening as part of a Betterment or Resurfacing Project. If betterment or resurfacing is done in the same fiscal year, report appropriate mileage in this category and also in the betterment or resurfacing category.

(2) Widening Only. If betterment or resurfacing is done in different years, report appropriate mileage in this category and also in the betterment or resurfacing category for the appropriate years.

c. Leveling & Sealing.

(1) Micro Surfacing (7134)

(2) Leveling (7131) with seal coat (7124) – Mileage will be counted once, not separately, when both treatments are done in the same Fiscal Year. Count mileage separately if leveling is done in a different Fiscal Year than a surface treatment.

(3) Seal coat only (7124)

(4) Leveling only (7131) – Count mileage separately if leveling is done in a different Fiscal Year than a surface treatment.

d. Surface Repair.

(1) Mechanized patching (7122) (900 tons per mile)

(2) Skin patching (7127) (3,696 gallons per mile)

3. Shoulder Improvements. Shoulder improvements are counted for widths 2 feet and greater. These mileages will be recorded separate from items identified in Group 2.

a. Shoulder upgrades (7216, 7233). Require a minimum depth of 4 inches of HMA Base Course or recycled equivalent.

b. Shoulder resurfacing (7222-02).

c. Shoulder seal coat (7224).

B. Definitions for Governor's Budget (Program Performance) Measures. Surface improvement mileages are reported each year to the Governor's Office of Budget. Table 11.6 defines the measure, and the surface improvement category that comprise each measure.

TABLE 11.6
SURFACE IMPROVEMENT CATEGORIES

MEASURE	DESCRIPTION	SURFACE IMPROVEMENT CATEGORY
Structural Restoration	Rehabilitation projects - minimum 3.0 in of pavement with associated base repair, drainage, bridge structure, shoulder, guide rail, and other work.	Betterment
Maintenance Resurfacing	Bituminous overlay - typically 1.5 in to 3.0 in of pavement and shoulder work.	Resurfacing, CPR, Recycling and Widening
Surface Repairs	Light resurfacing, spot patching and oil & chip treatment - typically 1 in to 1.25 in or less.	Leveling & Sealing plus Surface Repair

11.4 INTERNATIONAL ROUGHNESS INDEX TESTING FOR NEW PAVEMENT SURFACES

The Bureau of Maintenance and Operations (BOMO), Asset Management Division, Pavement Testing and Asset Management Section is responsible for system-wide International Roughness Index (IRI) data collection, quality assurance, storage and retrieval, and reporting. Data is collected and analyzed by the Pavement Testing and Asset Management staff and/or by the Videologging contractor. IRI for the entire National Highway System (NHS), including Interstates, is collected each year. IRI data for non-NHS routes are collected on a two-year cycle.

In addition to the normal annual testing program, the plan that has been implemented calls for Pavement Testing and Asset Management staff to collect new IRI data on all pavements that have been resurfaced, reconstructed, etc. Pavement History data, stored in the Roadway Management System (RMS), will be the source of information from which testing schedules are set. The Districts are responsible for the prompt entry of Pavement History data for all maintenance and construction projects. Data for Department force projects should be entered within 4 weeks of the project's reopening to traffic, and data for contractor projects should be entered within 6 weeks. Pavement Testing and Asset Management runs weekly programs that search Pavement History data for new entries, and is committed to perform IRI testing on the "new" pavements within 3 months of data entry. If the Videologging contractor is scheduled to test the new pavement surface within this same period, that data will be used.

Timely and complete Pavement History data makes IRI data more valuable and more usable, particularly from an asset management and pavement preservation perspective. Attempting to analyze new pavement IRI values, trends, anomalies, or deterioration rates is very difficult without knowing how or when a pavement was constructed, reconstructed, resurfaced, etc. Likewise, determining the effectiveness of construction, or predicting pavement life cannot be done without measuring and reporting initial condition data, such as rideability. Hence, the proposed tie between Pavement History data entry and new pavement IRI testing.

With PennDOT's focus on ride quality improvements, there has been an increased emphasis on IRI in recent years. The Districts, in particular, want to see current IRI values that reflect the improvements they are making. There has been concern that, at the end of any given year, construction and/or maintenance projects completed by the Districts may not be reflected in the IRI data for that year. In the past, this may have occurred several ways: no data may have been collected due to traffic control setups during construction, the data may have been collected before the project began, or the construction may have taken place on non-NHS routes that were not scheduled to be tested during that year. Any of these instances resulted in data that did not represent the current pavement smoothness. The new pavement testing program eliminates all of these instances, because new pavements are tested after they are reopened to traffic.

11.5 CONDITION SURVEYOR QUALIFICATION

As part of the Systematic Techniques to Analyze and Management Pennsylvania's Pavements (STAMPP) program, all employees hired for the Shoulder and Guide Rail Condition Surveys, must attend a centralized training program and pass a written test in order to work as a STAMPP Surveyor.

Training is offered each May/June to all personnel hired for the purpose of surveying shoulders and guide rail for the STAMPP program. A written test is given at the end of the training. All surveyors must achieve a passing grade on the test in order to qualify for working in the STAMPP program. This criterion should be made known to all potential STAMPP surveyors. Wording to this effect must be written into contracts let for hiring STAMPP surveyors.

The following criterion applies to all potential STAMPP surveyors:

1. Anyone who fails the first written test will be required to take additional training provided by the District, and be given a retest within two calendar weeks of the first test. The surveyor(s) who fail the first test may not perform STAMPP surveys in the interim.

2. Anyone who fails the second test will be assigned a subject matter mentor by the District. The mentor shall provide additional training in preparation for a third test. A third test, administered at the District by someone other than the mentor, will be taken within one week of the second test. The surveyor(s) who fail the second test may not perform STAMPP surveys in the interim.

3. Anyone who fails the third written test will be eliminated from working in the STAMPP program that survey season.

11.6 SKID RESISTANCE TESTING PROGRAMS

The BOMO, Asset Management Division, Pavement Testing and Asset Management Section manages four different skid testing programs: Wet Pavement Accident Cluster (WPAC) requests, "special requests", Skid Resistance Level (SRL) Evaluation, and research.

A. WPAC Requests. Wet pavement crashes may be an indicator that a section of roadway has reduced skid resistance properties in the pavement surface. Appropriate sites that are identified on the wet crash cluster list should be skid tested to determine if the friction characteristics of the pavement surface are adequate. The WPAC list consists of sites with eight or more wet pavement crashes in 3,000 feet (in 5 years), and a wet/total crash ratio equal to or exceeding 0.30. Also, appropriate sites where frequent new wet pavement crashes have been identified, whether the site is on a wet cluster list or not, should be skid tested as well.

WPAC test sites are to be determined by District Safety Engineers based on reports available through the Crash Data Analysis and Retrieval (CDART) application. Skid testing for the requested WPAC sites will be prioritized and conducted by the BOMO with the goal to complete all testing by the end of the calendar year.

To assist with the BOMO's planning of the statewide testing program, it is requested that each District submit their skid testing program needs by May 15 of each year. Adherence to this date will allow for better planning of the majority of the year's testing needs; however, additional requests for unforeseen needs will be accepted after May 15.

The District Safety Engineer is responsible for coordinating the District's annual skid testing program and for obtaining the wet cluster list from CDART by analyzing an appropriate five year period. Note that crash data for the most current calendar year is not fully available until April/May of the following year. Also, account for identified sites that were recently skid tested, so as not to inadvertently retest the same sites if not required.

B. Special Requests. A special request for testing is generally in response to a specific and immediate need. The BOMO's goal is to provide the requesting District with test results within 2 weeks of the request. It is important that special requests are limited to those with truly an immediate need for results within 2 weeks, and WPAC requests are submitted separately.

C. SRL Evaluations. Requests are made through BOPD to test for the SRL of in place aggregate. These requests are often initiated by the aggregate supplier seeking to have a stockpile approved and included in Publication 35, *Approved Construction Materials*, (Bulletin 15), or by BOPD to verify the SRL of an aggregate. The timeframe for the test is requested with the test request, and is usually 3 months.

D. Research. Requests can be made by the Districts to test for the friction characteristics of new in place material when evaluating the performance of the material for recommended future use. The timeframe for the test is requested with the test request, and is usually 3 months.

11.7 FALLING WEIGHT DEFLECTOMETER (FWD) TESTING PROGRAMS

FWD data is required whenever a structural pavement overlay design is required, and California Bearing Ratio (CBR) or Resilient Modulus data are not available. Furthermore, FWD data are required for Concrete Pavement Restoration (CPR) projects, to determine the amount of required patching. The District Pavement Management Engineer/Pavement Manager obtains FWD data by submitting a testing request to the BOMO. It is desirable for the District project design staff to have this data prior to Final Design.

Note that testing concrete pavement joints for CPR projects can only be performed when the air temperature does not exceed 70°F, and no FWD testing can be performed if the subgrade is frozen. Also, testing should not be done more than two years prior to construction, since conditions may worsen and design requirements may change over that period of time.

Provide the Design Field View date for the project with each testing request to help determine the date that results are needed. Note that since FWD testing is a slow moving operation, the BOMO will coordinate traffic control with the appropriate County forces. Their cooperation will be necessary to maintain testing schedules.

11.8 TRACKING NEW MAINTENANCE TECHNIQUES, PROCESSES AND MATERIALS

There are many new roadway maintenance techniques, processes and materials being introduced by the Districts and Counties for use by Maintenance forces (contract or Department). When a new product, technique or process is tried in one District or County, it is important that the construction and performance results are shared with other Districts and Counties. Sharing information will not only prevent duplication of effort, but will enable others to more expeditiously use those products and techniques that prove valuable to PennDOT's maintenance of state owned roadways, or, conversely, avoid using those materials and techniques that prove otherwise.

To this end, the following plan for tracking projects utilizing new maintenance techniques, processes and/or materials shall be followed:

Project information should be sent to the BOMO a minimum of 1 month prior to construction. This information should include a description of the new maintenance technique, process and/or material being used and where it will be used. Complete the Project Information Form provided in Appendix F, Tracking New Maintenance Techniques, Processes and Materials Evaluation Plan Forms, and send it to the address on the form.

BOMO will review the project information and determine which of the following two procedures shall be used:

- If the project involves a new technique or material, BOMO will forward the project information to BOPD, ISSD, New Products and Innovations Section for inclusion in the New Products Evaluation program.
- If the project involves a new process or revision to an existing process, then either BOMO, the District, or County proposing the project (at their discretion) will monitor the construction and subsequent performance using one of the following methods:

A. **Method 1.** BOMO monitors construction and performance:

BOMO will monitor and report on the construction and conduct and report on periodic performance reviews.

B. **Method 2.** District/County monitors construction and performance:

1. Step 1 – Construction. Use the Construction Report form provided in Appendix F, Tracking New Maintenance Techniques, Processes and Materials Evaluation Plan Forms, to report on the construction technique used or the placement of material/product. Include digital photos of the construction procedure. Place copies of the form and photos on the shared drive at the location specified below and notify BOMO that the construction information is available.

P:\PennDOT Shared\Bureau of Maintenance and Operations\Roadway Management Division\Roadway Inventory & Testing\Shared Data\Evaluation of New Materials and Techniques

2. Step 2 – Performance Reviews. Performance reviews, including digital photos to support the performance review, should be conducted at least twice a year - end of summer and after winter season - for a minimum of three years or for the life of the material placed (whichever is less). Complete the Performance Review form provided in Appendix F, Tracking New Maintenance Techniques, Processes and Materials Evaluation Plan Forms, and place the form, along with digital photos taken, on the shared drive at the location referenced above. Notify BOMO that the performance review information is available.

C. **Method 1 and 2.** BOMO will distribute construction and performance summaries of new or revised maintenance processes to the Districts and Counties once information is available.

Details of this procedure are in the attachment. Separate forms are also provided to: (1) notify BOMO of upcoming projects; (2) record construction procedures; and (3) record periodic performance.

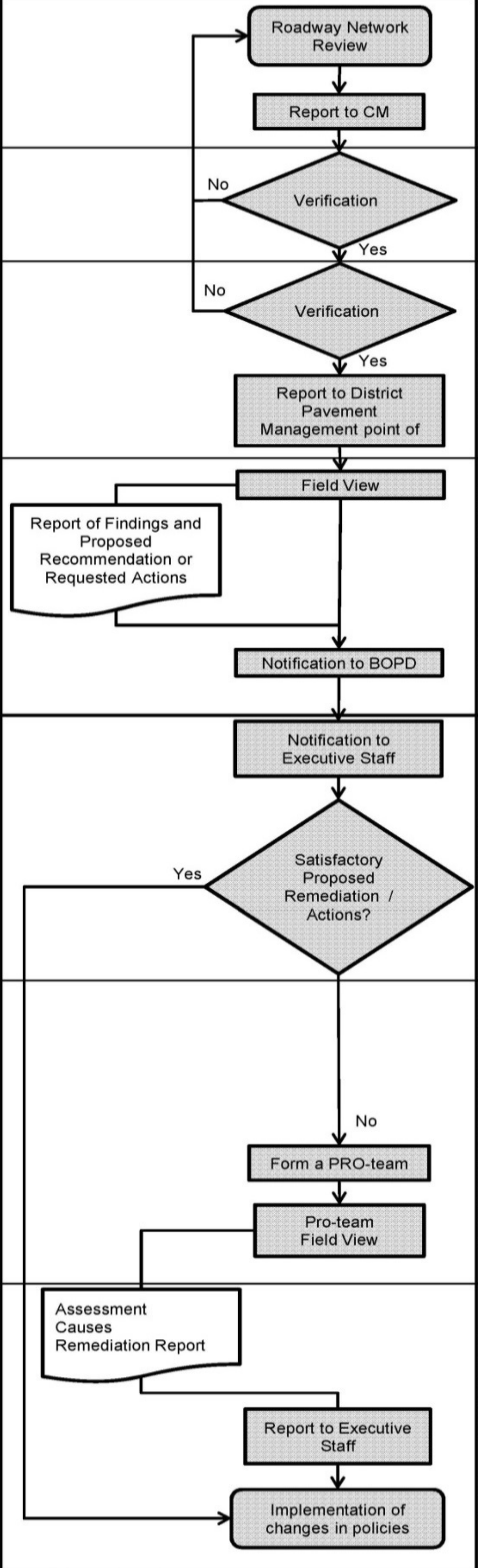
11.9 EVALUATION OF PREMATURE FAILURES

Premature failure is defined as any non-localized failure which potentially warrants the immediate development of a project and allocation of funding beyond the current program development process.

As part of PennDOT's efforts to define a unified pavement management strategy, and determine the end-state components of such a strategy, development of "premature pavement failure response" procedures are proposed. In light of several recent pavement failures it has been determined that the procedures are needed.

Timely reporting, appropriate evaluation to determine strategy and proper remediation of premature pavement failure is critical to the success of preventing extensive roadway damage. In order to react in a timely manner, the proposed general steps are outlined in Table 11.7, defining when each step is warranted, and timeliness of response.

TABLE 11.7
EVALUATION OF PREMATURE FAILURES



	Working Days	Activity	Activity Detail	Responsible
DISTRICT	1 day		1. Reviews roadway network as defined in Publication 23, *Maintenance Manual* , Sections 3.2 and 3.5. 2. Identification of premature Pavement Failures are reported by ACM to the County Manager (CM).	Assistant County Manager (ACM)
	1 day		3. Upon verification the CM reports the premature failure to the Assistant District Executive for Maintenance (ADEM).	County Manager (CM)
	1 day		4. Upon verification, the ADEM will notify the District's Pavement Management point of contact, who will field view the section. The point of contact is defined as the member of each District's Pavement Management team who coordinates the District efforts as well as liaison with Central Office.	ADEM
	2 days		5. The findings of this assessment will be reported to the Highway Design and Technology Section (HDTS), Highway Delivery Division, Bureau of Project Delivery, along with the urgency and promptness for remediation. Validated premature failures should be reported to HDTS within one week of first detection. The report should include project length, project pavement history data, project construction data, assessment of the condition, and a recommendation regarding the urgency and promptness for remediation.	District Pavement Management Point of contact
CENTRAL OFFICE	1 week		6. HDTS will immediately notify Executive staff of the issue. 6B. HDTS will determine if the proposed Remediations / actions proposed by the District are satisfactory.	HDTS HDTS
	1 week		7. A PRO-team of specified personnel including staff from HDTS will be formed to field view and evaluate the pavement, determine remediation, and define necessary research, testing and follow-up evaluation. The field view will occur within two weeks of HDTS notification*. The team may also include personnel from the Laboratory Testing Section of the Innovation and Support Services Division, Bureau of Project Delivery, Federal Highway Administration, industry, and District staff familiar with the design, materials, construction, and/or maintenance of the failed pavement.	HDTS & Pro-team
	1 week		8. Assessment and causes of the failure, recommended remediation and costs, and necessary follow-up actions, with due dates, will be documented and reported to Executive staff by BOPD within one week of the PRO-team field view. 9. Upon completion of evaluation, necessary changes to specifications, policies, and/or design procedures will be determined and implemented.	HDTS

*In the event of poor weather in winter, the field view may need to be scheduled at a later time, but no more than six weeks after HDTS notification.

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CHAPTER 12

PAVEMENT PRESERVATION GUIDELINES

12.1 PAVEMENT PRESERVATION PROJECT SELECTION GUIDELINES

The Pavement Preservation Guidelines herein are to be used for Federal-aid and 100% state-funded projects as applicable.

Preservation strategies for interstate/freeway sections should be developed to incorporate Pavement Preservation work at appropriate intervals to maintain the pavement throughout the design life of the roadway. See Chapters 11 and 13 for plan requirements. Districts must have an overall interstate/freeway plan developed for each year of their four-year program. This plan should be developed and formally documented using the Roadway Management System (RMS). Programmed and executed Pavement Preservation work, including work such as Maintenance Contracts, must also be included in the District's overall interstate/freeway program. Formal documentation of the work completed on the subject highway systems in the RMS's Pavement History database is essential to the planning and programming effort.

12.2 PAVEMENT PRESERVATION PROJECT CRITERIA

Refer to the memo in Chapter 12, Appendix A, FHWA Pavement Preservation Memorandum from FHWA dated September 12, 2005 for Pavement Preservation definitions. Also defined are the components of Pavement Preservation.

AASHTO's Standing Committee on Highways defines preventive maintenance as the planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing structural capacity).

A. Typical Pavement Preservation Treatments.

1. Flexible Pavement Treatments:

- **a.** Asphalt Rejuvenators
- **b.** Asphalt Sealers
- **c.** Crack Sealing
- **d.** Crack Filling
- **e.** Scrub Seals
- **f.** Sand Seals
- **g.** Chip Seals
- **h.** Cape Seals
- **i.** Slurry Seals
- **j.** Micro Surfacing
- **k.** Profile Milling
- **l.** Ultra-Thin Friction Course (generally ≤ 3/4 inch)
- **m.** Thin Overlays (non-structural, generally ≤ 2 inches)
- **n.** Mill & Resurface (non-structural, generally ≤ 2 inches)
- **o.** Ultra-Thin Bonded Concrete Overlay of Asphalt (as a non-structural wearing course)
- **p.** Hot In-place Recycling
- **q.** Cold In-place Recycling

2. Rigid Pavement Treatments:

- **a.** Crack Sealing

- **b.** Joint Resealing
- **c.** Spall Repair
- **d.** Dowel Bar Retrofit
- **e.** Cross Stitching (longitudinal cracks and joints)
- **f.** Partial Depth Repair
- **g.** Full Depth Repair (< 10% of repairs)
- **h.** Ultra-Thin Friction Course (generally ≤ 3/4 inch)
- **i.** Slab Stabilization
- **j.** Slab Jacking
- **k.** Diamond Grooving
- **l.** Diamond Grinding

B. The following general guidance shall apply for Pavement Preservation projects:

- All Pavement Preservation projects should consider appropriate ways to maintain or enhance the current level of safety and accessibility.

- Isolated or obvious deficiencies must always be evaluated and addressed if cost effective.

- Safety enhancements are encouraged and included in projects where they are determined to be a cost-effective way to improve safety.

- Safety enhancements can be deferred and included within an operative safety management system or included in a future project in the STIP.

- In no way shall Pavement Preservation type projects adversely impact the safety of the traveled way or its users.

The following technical guidance shall apply for Pavement Preservation projects:

1. Use the appropriate Ride Specification on all applicable Pavement Preservation projects.

2. Achieve a minimum ride quality as applicable, per Publication 408, *Specifications*, Section 404.4 or Section 507.4.

3. Meet all Pavement Preservation geometric criteria per Publication 13M, Design Manual Part 2, *Highway Design*, Section 1.3.

4. Correct pavement and/or shoulder edge drop-offs greater than 2 inches. See Section 5.11.D for additional information regarding Safety Edge.

5. Provide pavement markings that are considered durable when conditions exist as described in Publication 46, *Traffic Engineering Manual*, Section 3.2, Pavement Markings.

6. Update or replace all guide rail systems, barrier systems, end treatments, guide rail to bridge barrier approach transitions, and impact attenuating devices to be in working order and in compliance with current Department policy as described in Publication 13M, Design Manual Part 2, *Highway Design*.

7. Replace any damaged signs in compliance with current Department policy.

8. Address railroad crossings as per Publication 371, *Grade Crossing Manual*, Chapter 3, The Highway-Railroad Crossing Safety Project Process.

9. Address Americans with Disabilities Act compliance in accordance with current Department policy as stated in Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 6.

10. As applicable, address bicycle and pedestrian traffic in accordance with guidance provided in Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*.

11. As applicable, restore existing or add centerline, edge line, or shoulder rumble strips in compliance with current Department policy (refer to Publication 72M, *Roadway Construction Standards* and Publication 638, *District Highway Safety Guidance Manual*).

12. Address other appropriate safety-related items to the extent practical (e.g., pipe headwalls, non-breakaway signs, remove/relocate/shield/delineate vulnerable fixed objects within the clear zone, etc.). Refer to Publication 13M, Design Manual Part 2, *Highway Design*, Chapter 12 and AASHTO's current edition of the *Roadside Design Guide*.

13. Evaluate crash history within the project limits to identify and address highway safety concerns.

14. Projects must comply with FHWA's current edition of the *Manual on Uniform Traffic Control Devices* (MUTCD).

C. Pavement Preservation projects will not do any of the following:

1. Degrade existing safety features (e.g., reduction of guide rail height below minimum acceptable criteria).

2. Increase the structural depth of the existing pavement to increase pavement life. First time overlay of concrete pavements must conform to appropriate minimum depths as outlined in Table 9.5 and Table 10.4 for the materials selected.

3. Provide new capacity consisting of new travel lanes. However, essential operational improvements such as auxiliary lanes and extensions to acceleration and deceleration lanes may be considered where safety can be enhanced and congestion reduced at a reasonable cost. Such improvements must be submitted for approval at the Design Field View submission. Preservation projects may include operational enhancements for weaving/auxiliary lanes 3,000 feet or less provided the travel lanes adjacent to weaving/auxiliary lanes are being preserved and the travel lanes are being preserved for 10,000 contiguous feet (excluding bridges).

12.3 DESIGN GUIDELINES

The Pavement Preservation activities listed below are shown to be cost-effective based upon data from PennDOT's Pavement Management System and thus do not require a pavement design. For exceptions to these guidelines that involve geometric and bridge issues, reference Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 3, Section 3.4.C, Design Flexibility for design exception documentation and approval procedures. Pavement design related exceptions should be directed to HDTS. Thickness limitations do not include material required for slope correction.

A. Flexible Pavements. Note: Overlay Projects on existing flexible pavements that exceed 2 inches will not be eligible for consideration as Pavement Preservation except as noted below.

1. 1 1/2 inches Superpave 9.5 mm mix or 2 inches Superpave 12.5 mm mix design overlay with maximum 1 inch scratch course as per Section 5.11.B. Apply leveling course as required to meet design cross section.

2. Mill and Overlay to eliminate rutting or problematic materials; milling and overlay depths of 1 1/2 inches or 2 inches may be exceeded to remove and replace existing pavement to a depth necessary to correct a rutting problem or other identifiable material problems. Coring of existing pavement is required to determine required milling depth. Cores should be inspected to determine depth and integrity of existing pavement.

3. Micro Surfacing or Ultra-Thin Friction Course to improve skid resistance, ride quality, and/or rut filling. Such treatments must occur early in the maintenance cycle before advanced distresses emerge.

4. Cold In-Place Recycling of base to a maximum depth of 4 inches, with a 1 1/2 inch (maximum) asphalt overlay with 60 pounds per square yard of scratch course.

5. Ultra-Thin Bonded Concrete Overlay of Asphalt depth of 2 inches as a non-structural wearing course.

B. Rigid Pavements. Note: Overlays with scratch (not including leveling) on existing concrete surfaces that exceed 4 1/2 inches when Superpave 9.5 mm Wearing Course mix is used or 5 inches when Superpave 12.5 mm Wearing Course mix is used are not eligible for consideration as Pavement Preservation and must follow 3R criteria. Leveling courses as required to meet minimum cross slope requirements will be permitted and will not be considered in the depth calculation. Projects requiring concrete patching exceeding 10% of the total pavement area will not be eligible as Pavement Preservation unless it can be shown that exceeding 10% is cost effective. All patching quantities will be determined prior to the Final Design Office Meeting and PS&E Submission. Patching quantities must include but are not limited to areas such as faulted joints, cracks, existing bituminous patches, failed concrete patches, and transverse/longitudinal spalls and cracks. The guidelines below also apply to mill and overlay projects.

1. Concrete full depth patching and joint rehabilitation. Patching must include repair of all failed joints (Verified by Falling Weight Deflectometer (FWD) testing). Concrete pavement patching may be performed up to, but not exceeding, 10%, unless the cost effectiveness of exceeding 10% can be shown. If no bituminous overlay is proposed, the concrete patching project may require diamond grinding in order to achieve the intended smooth ride.

2. Diamond grinding, or Micro Surfacing, or Ultra-Thin Friction Course with slab stabilization, or slab jacking, or patching as allowed within this criteria to improve skid resistance and/or ride quality.

3. 1 1/2 inches of Superpave 9.5 mm mix design or 2 inches Superpave 12.5 mm mix design on 2 1/2 inches of Superpave 19.0 mm mix design overlay on an optional 1/2 inch maximum Superpave 9.5 mm mix design scratch course on concrete pavements.

4. 1 1/2 inches of Superpave 9.5 mm mix design or 2 inches Superpave 12.5 mm mix design on Polymer-modified emulsified paving system (Micro Surfacing). This only applies for structurally sound pavements, as verified by FWD testing which indicate total patching percentages of less than 10%.

5. Dowel Bar Retrofit or a combination of various Concrete Pavement Restoration (CPR) techniques.

C. Bridge Preservation. Whenever possible, include both bridge and roadway items on the project to minimize multiple impacts on the motoring public (refer to Publication 15M, Design Manual Part 4, *Structures*, Section PP5.6.1, Bridge Preservation for a list of eligible activities).

12.4 PROJECT SCOPING FIELD VIEW

A Scoping Field View will be held to review the project and discuss specific issues concerning safety and pavement design alternatives. The minutes will be recorded and formalized by the District and will include a RMS pavement condition report and Pavement Type Selection submission. For more information on the Scoping Field View see Publication 10C, Design Manual Part 1C, *Transportation Engineering Procedures*, Chapter 2 and Publication 10B, Design Manual Part 1B, *Post-TIP NEPA Procedures*, Chapter 3.

12.5 PAVEMENT TYPE SELECTION SUBMISSION REQUIREMENTS

The following items will be required as a minimum for Pavement Type Approval on Pavement Preservation projects. The intent of the requirements is to provide justification for the proposed work on a particular project. Provide:

1. Scoping Field View documentation will be completed in the CE Expert System as per Publication 10B, Design Manual Part 1B, *Post-TIP NEPA Procedures*, Chapter 3.

2. Existing pavement data including all maintenance surface treatments.

3. International Roughness Index (IRI) and friction data.

4. Description of all work to be performed on the project, such as extent and type of patching, depth of milling, extent of joint repairs, extent of joint sealing, type of shoulder work (if any), subsurface drainage, etc.

5. Falling Weight Deflectometer (FWD) test data (where appropriate).

6. Geotechnical data may be required to support the appropriateness of slab stabilization as a Pavement Preservation treatment.

7. A copy of Form D-4332.

8. Any unique pavement/materials-related special provisions should also be included in the submission.

Submit all of the above information from the District Executive or the Assistant District Executive of Design with a formal PennDOT Pavement Type Selection Memo to HDTS requesting approval. See Chapter 6 for additional information regarding pavement design submission and approval requirements.

12.6 BRIDGE SUBMISSION REQUIREMENTS

The following items are required in a submission to provide sufficient justification for the chosen treatments:

1. A copy of the "IM" screen from BMS2. Provide the proposed maintenance activities associated with each bridge. Also provide completed maintenance activities that were eligible preservation activities per Publication 15M, Design Manual Part 4, *Structures*, Section PP5.6.1 in the last 10 years.

2. A brief scope of work describing the eligible preservation activities that will be performed. Eligible preservation activities are listed in Publication 15M, Design Manual Part 4, *Structures*, Section PP5.6.1. Also, clarify if the preservation activity improves a structurally deficient bridge to be classified as non-structurally deficient. The scope of work should be consistent with the Department's long range plan that is utilized for a Risk Assessment for PennDOT-Owned Bridges and Culverts, and Local Bridges and Culverts.

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12.7 100% STATE FUNDED PAVEMENT PRESERVATION GUIDELINES

For 100% State funded projects, follow the Federal-aid Guidelines, with the following exceptions:

Federal-aid Section	Additions and Modifications Applicable to 100% State Funded Projects
12.1	For certain projects, it may be necessary to deviate from some of these Pavement Preservation Guidelines with proper coordination with HDTS. When hazardous or rapidly deteriorating conditions necessitate a project as an interim measure, some of these criteria may be waived, including the requirement indicated in Section 12.2.B.6. Pavement type submissions for these interim measures, when conditions warrant, should include the program year, estimated project cost, and section number if they are available for the future rehabilitation or reconstruction project.
12.2.B.2	The IRI < 95 criteria may be waived for overlays of hazardous sections, as described above.
12.3.B	The 4-inch depth minimum requirement for overlays on rigid pavements may be waived for overlays of hazardous sections, as described above. However, no overlay less than 1 1/2 inches may be placed directly on the rigid pavements.

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CHAPTER 12, APPENDIX A

FHWA PAVEMENT PRESERVATION MEMORANDUM

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U.S. Department
of Transportation
**Federal Highway
Administration**

Memorandum

Subject: **ACTION**: Pavement Preservation Definitions

Date: September 12, 2005

(Original Signed by David R. Geiger, P.E.)

From: David R. Geiger, P.E.
Director, Office of Asset Management

Reply to
Attn. of: HIAM-20

To: Associate Administrators
Directors of Field Services
Resource Center Director and Operations Manager
Division Administrators
Federal Lands Highway Division Engineers

As a follow-up to our Preventive Maintenance memorandum of October 8, 2004, it has come to our attention that there are differences about how pavement preservation terminology is being interpreted among local and State transportation agencies (STAs). This can cause inconsistency relating to how the preservation programs are applied and their effectiveness measured. Based on those questions and a review of literature, we are issuing this guidance to provide clarification to pavement preservation definitions.

Pavement preservation represents a proactive approach in maintaining our existing highways. It enables STAs to reduce costly, time consuming rehabilitation and reconstruction projects and the associated traffic disruptions. With timely preservation we can provide the traveling public with improved safety and mobility, reduced congestion, and smoother, longer lasting pavements. This is the true goal of pavement preservation, a goal in which the FHWA, through its partnership with States, local agencies, industry organizations, and other interested stakeholders, is committed to achieve.

A Pavement Preservation program consists primarily of three components: preventive maintenance, minor rehabilitation (non structural), and some routine maintenance activities as seen in figure 1.

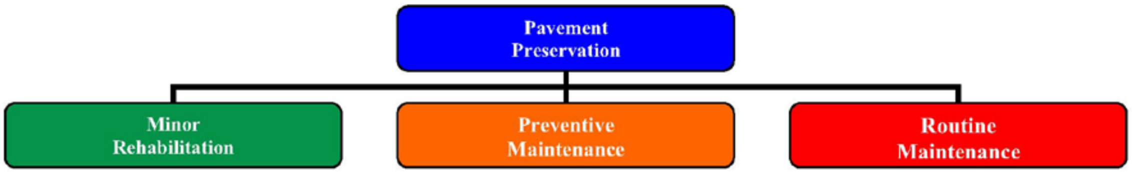


Figure 1: Components of Pavement Preservation

An effective pavement preservation program can benefit STAs by preserving investment on the NHS and other Federal-aid roadways, enhancing pavement performance, ensuring cost-effectiveness, extending pavement life, reducing user delays, and providing improved safety and mobility.

It is FHWA's goal to support the development and conduct of effective pavement preservation programs. As indicated above, pavement preservation is a combination of different strategies which, when taken together, achieve a single goal. It is useful to clarify the distinctions between the various types of maintenance activities, especially in the sense of why they would or would not be considered preservation.

For a treatment to be considered pavement preservation, one must consider its intended purpose. As shown in Table 1 below, the distinctive characteristics of pavement preservation activities are that they restore the function of the existing system and extend its service life, not increase its capacity or strength.

Pavement Preservation Guidelines

	Type of Activity	Increase Capacity	Increase Strength	Reduce Aging	Restore Serviceability
	New Construction	X	X	X	X
	Reconstruction	X	X	X	X
	Major (Heavy) Rehabilitation		X	X	X
	Structural Overlay		X	X	X
Pavement Preservation	Minor (Light) Rehabilitation			X	X
	Preventive Maintenance			X	X
	Routine Maintenance				X
	Corrective (Reactive) Maintenance				X
	Catastrophic Maintenance				X

Table 1- *Pavement Preservation Guidelines*

Definitions for Pavement Maintenance Terminology

Pavement Preservation is "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations."
Source: FHWA Pavement Preservation Expert Task Group

An effective pavement preservation program will address pavements while they are still in good condition and before the onset of serious damage. By applying a cost-effective treatment at the right time, the pavement is restored almost to its original condition. The cumulative effect of systematic, successive preservation treatments is to postpone costly rehabilitation and reconstruction. During the life of a pavement, the cumulative discount value of the series of pavement preservation treatments is substantially less than the discounted value of the more extensive, higher cost of reconstruction and generally more economical than the cost of major rehabilitation. Additionally, performing a series of successive pavement preservation treatments during the life of a pavement is less disruptive to uniform traffic flow than the long closures normally associated with reconstruction projects.

Preventive Maintenance is "a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity)." *Source: AASHTO Standing Committee on Highways, 1997*

Preventive maintenance is typically applied to pavements in good condition having significant remaining service life. As a major component of pavement preservation, preventive maintenance is a strategy of extending the service life by applying cost-effective treatments to the surface or near-surface of structurally sound pavements. Examples of preventive treatments include asphalt crack sealing, chip sealing, slurry or micro-surfacing, thin and ultra-thin hot-mix asphalt overlay, concrete joint sealing, diamond grinding, dowel-bar retrofit, and isolated, partial and/or full-depth concrete repairs to restore functionality of the slab; e.g., edge spalls, or corner breaks.

Pavement Rehabilitation consists of "structural enhancements that extend the service life of an existing pavement and/or improve its load carrying capacity. Rehabilitation techniques include restoration treatments and structural overlays." *Source: AASHTO Highway Subcommittee on Maintenance*

Rehabilitation projects extend the life of existing pavement structures either by restoring existing structural capacity through the elimination of age-related, environmental cracking of embrittled pavement surface or by increasing pavement thickness to strengthen existing pavement sections to accommodate existing or projected traffic loading conditions. Two sub-categories result from these distinctions, which are directly related to the restoration or increase of structural capacity.

> *Minor rehabilitation* consists of non-structural enhancements made to the existing pavement sections to eliminate age-related, top-down surface cracking that develop in flexible pavements due to environmental exposure. Because of the non-structural nature of minor rehabilitation techniques, these types of rehabilitation techniques are placed in the category of pavement preservation.
>
> *Major rehabilitation* "consists of structural enhancements that both extend the service life of an existing pavement and/or improve its load-carrying capability." *Source: AASHTO Highway Subcommittee on Maintenance Definition*

Routine Maintenance "consists of work that is planned and performed on a routine basis to maintain and preserve the condition of the highway system or to respond to specific conditions and events that restore the highway system to an adequate level of service." *Source: AASHTO Highway Subcommittee on Maintenance*

Routine maintenance consists of day-to-day activities that are scheduled by maintenance personnel to maintain and preserve the condition of the highway system at a satisfactory level of service. Examples of pavement-related routine maintenance activities include cleaning of roadside ditches and structures, maintenance of pavement markings and crack filling, pothole patching and isolated overlays. Crack filling is another routine maintenance activity which consists of placing a generally, bituminous material into “non-working” cracks to substantially reduce water infiltration and reinforce adjacent top-down cracks. Depending on the timing of application, the nature of the distress, and the type of activity, certain routine maintenance activities may be classified as preservation. Routine Maintenance activities are often “in-house” or agency-performed and are not normally eligible for Federal-aid funding.

Other activities in pavement repair are an important aspect of a STA’s construction and maintenance program, although they are outside the realm of pavement preservation:

> **Corrective Maintenance** activities are performed in response to the development of a deficiency or deficiencies that negatively impact the safe, efficient operations of the facility and future integrity of the pavement section. Corrective maintenance activities are generally reactive, not proactive, and performed to restore a pavement to an acceptable level of service due to unforeseen conditions. Activities such as pothole repair, patching of localized pavement deterioration, e.g. edge failures and/or grade separations along the shoulders, are considered examples of corrective maintenance of flexible pavements. Examples for rigid pavements might consist of joint replacement or full width and depth slab replacement at isolated locations.
>
> **Catastrophic Maintenance** describes work activities generally necessary to return a roadway facility back to a minimum level of service while a permanent restoration is being designed and scheduled. Examples of situations requiring catastrophic pavement maintenance activities include concrete pavement blow-ups, road washouts, avalanches, or rockslides.
>
> **Pavement Reconstruction** is the replacement of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure. Reconstruction may utilize either new or recycled materials incorporated into the materials used for the reconstruction of the complete pavement section. Reconstruction is required when a pavement has either failed or has become functionally obsolete.

If you need technical support or further guidance in the pavement preservation area, please contact Christopher Newman in the FHWA Office of Asset Management at (202) 366-2023 or via e-mail at Christopher.Newman@fhwa.dot.gov.

CHAPTER 13

INTERSTATE MANAGEMENT PROGRAM GUIDELINES

13.1 PURPOSE

Centralized Interstate Management allows for a consistent Statewide approach to managing and maintaining PennDOT's Interstate network, which consists of 1,300 linear miles and 2,661 bridges (with a total deck area of 34.7 million square feet). While Pennsylvania's Interstate system is the fourth largest in the country, it is not too large to perform a uniform, rigorous analysis and apply a common management approach in order to achieve equitable performance and condition Statewide. The Interstate system is PennDOT's most analyzed and scrutinized roadway network, both within Pennsylvania and nationally. This network serves as the "trunk of the tree" with relation to PennDOT's infrastructure, and the functionality of our remaining roadways is a product of that for our Interstates. Furthermore, due to heavy usage and traffic loading, a poorly managed Interstate system would exhaust resources and dramatically reduce our ability to manage and maintain the remaining 39,000 linear miles and 25,333 bridges on the state-owned highway system.

PennDOT has been collecting and maintaining inventory and condition data on its roadways and bridges for over 20 years, and this data, along with establishing and monitoring performance measures, will be key in the centralized Interstate Management (IM) program. However, PennDOT Districts will continue project management responsibility for Interstate projects. Continued coordination with Metropolitan Planning Organizations (MPOs), Regional Planning Organizations (RPOs), the Federal Highway Administration (FHWA), and Districts will be an integral part of the IM program's success.

13.2 BACKGROUND

As an outgrowth of developing financial guidance for the 2007 Program update, the financial guidance committee, consisting of members from PennDOT, the FHWA and the Commonwealth's MPOs and RPOs, recommended the formation of a Statewide IM program to function as a separate programming entity. This programming concept is also consistent with PennDOT's philosophy of managing the Interstate System within Pennsylvania as a single, Statewide asset.

Approximately $370 million annually has been identified for funding Interstate roadway and bridge projects on a Statewide basis. Interstate preservation, rehabilitation, or reconstruction projects will be the only projects funded under this program. Capacity adding projects, and capacity adding portions of maintenance projects will only be advanced through a collaborative process with MPOs and RPOs whereby regional resources are used to fund the capacity portion of the project. Capacity adding projects are not permitted under the IM program.

Approximately 5% of the annual IM fund will be reserved for program adjustments including cost increases, scope changes, project additions, and emergencies. These adjustments are subject to review by PennDOT's Executive staff.

The following guidance is provided in order that all party's responsibilities and functions in the development of the program are identified. Data elements and factors that are considered significant in the development of a program are provided in order for District and Central Office to evaluate condition, needs, and projects in a coordinated and uniform fashion.

13.3 DATA AND INFORMATION

All IM related data files and information are stored at the following shared folder:

P:\PENNDOT Shared\Bureau of Maintenance and Operations\Roadway Management Division\Interstate Management

13.4 DISTRICT LONG-RANGE PLANNING

Each District will develop a 10-year plan for their Interstate network. Updates are to be made every 2 years in advance of the IM Program Transportation Improvement Program (TIP). The plan will be based on roadway condition data and needs provided in each year's State Of the Interstate (SOI) by BOMO, bridge condition information provided by BOPD, and other information maintained by each District.

The District plan will distinguish IM candidate projects; however, all projects and planned maintenance to be performed on Interstate bridges and roadways are to be detailed, whether they are to be funded via the IM program, Smoother Roads Initiative, Federal-aid Betterment program, County maintenance funds, or other sources. Each District will coordinate their planning efforts with all affected MPOs and RPOs, so that projects within their regions that are candidates to be funded via the IM program or via the local TIP are endorsed by all parties.

Roadway and bridge projects are to be coordinated to maximize maintenance and protection of traffic cost savings. Also, ramp needs are to be addressed as part of proposed mainline projects.

As part of each District's 10-year plan, proposed roadway and bridge projects must be defined in the "Interstate Roadway Plan - Project Data Sheet" and "Interstate Bridge Plan - Project Data Sheet" spreadsheets located at the aforementioned shared location. Add rows for projects and years as necessary. The following information must be provided on the "Interstate Roadway Plan - Project Data Sheet":

- District Priority – each roadway project for each year must be prioritized. Note that if a pre-construction phase is made top priority, then the construction phase should also be made top priority for the appropriate year.
- County
- MPMS Number – if the project is programmed
- SR
- Section
- Limits Of Surface Improvement – beginning and ending segment and offset values. If the project spans both directions, limits for each direction must be defined. Define the limits of surface of improvement, which may be different than the project limits.
- Planned Segment Miles – the total project length, in terms of segment miles. If the project spans both directions, the length in each direction must be accounted.
- Type Of Project – identify if Pavement Preservation (PP) or Major Rehabilitation/Reconstruction, and scope. For example: PP – Mill & Overlay.
- BMS Number – identify all structures planned for work.
- Funding Source – identify source: Interstate Management (IM), Bridge On System/Off System (BOO), Congressional Earmarks (SXF), State Highway match (581), State Bridge match (581), National Highway System (NHS), Surface Transportation Program (STP), Spike funds, County Maintenance (582).
- Current TIP/Program indicator – indicate whether project is currently on the program defined in item #10 (enter "Y" for "yes"), or is a candidate (enter "N" for "no").
- Phase – define the year and costs for each phase.
- Phase Year
- Estimated Phase Costs ($000) (Federal and State)
- Estimated Let Date
- Estimated Completion Date (Open to Traffic)
- Remarks

Bridge Projects must be defined in the "Interstate Bridge Project Data Sheet" spreadsheet located at the aforementioned shared location. The following information must be provided:

- MPMS Number
- BMS Number – identify all structures planned for work.
- BMS Reference Number – identify all structures planned for work.
- District Priority – each bridge project for each year must be prioritized. Note that if a pre-construction phase is made top priority, then the construction phase should also be made top priority for the appropriate year.
- Bridge Work Part of a Roadway Project – Indicator to select whether project is part of roadway project, Yes or No.
- Proposed Deck Area
- Estimated Let Date
- Condition Need – Select appropriate description: overhead bridge with clearance restriction, SD, weak link, on deck or none.
- Type Of Work – Select from list, new, rehabilitation, replacement or preservation
- Work Scope Description
- Funding Source – identify source: Interstate Management (IM), Bridge On System/Off System (BOO), Congressional Earmarks (SXF), State Highway match (581), State Bridge match (581), National Highway System (NHS), Surface Transportation Program (STP), Spike funds, County Maintenance (582)
- Phase – define the year and costs for each phase
- Phase Year
- Estimated Phase Costs ($000) (Federal and State)
- Remarks

In addition to the project spreadsheets, all programmed projects must also be defined in the Multimodal Program Management System (MPMS). In the future, reports based on MPMS data will allow for automated Interstate project reporting, and MPMS data entry standards will be defined to enable reporting.

It is also recommended that the Districts develop "strip maps" for their Interstate routes, denoting 10-year plan projects. Information on the maps should correspond to that provided on the spreadsheets. Figure 13.1 provides an example.

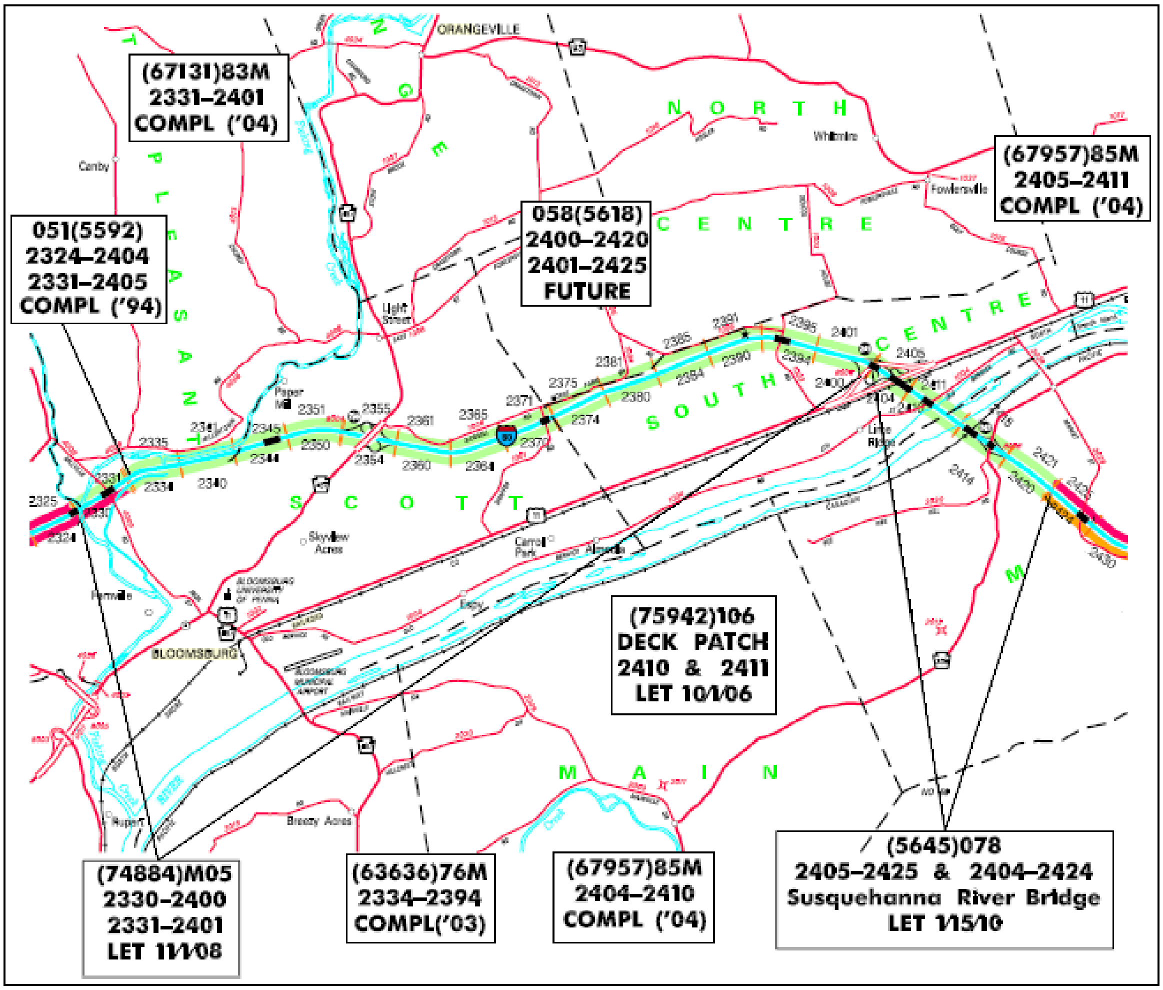
In addition to long-range planning, project delivery and management is to be achieved for each programmed IM project via utilization of Deltek's Open Plan® application. Usage of this application should follow the guidelines in Publication 615, *Scheduling Manual*.

13.5 BASELINE ASSESSMENT

The following roadway and bridge data will be the basis for the District Interstate plan, and also the subsequent evaluation by BOMO, BOPD and the Center for Program Development and Management (CPDM).

A. Pavement. Several performance measures have been defined to monitor the condition of the Interstate system. 2005 data was established as the baseline and the measures will be updated each year by BOMO in order to monitor improvement and the impact of the centralized IM program. Data is summarized by Interstate route per District, by District, and Statewide. The baseline indicators are:

FIGURE 13.1
SAMPLE MAP OF INTERSTATE PLAN



1. Cycle. An assessment of the mileage that is "out of cycle", according to the Interstate treatment cycles defined in this document. Each pavement type is defined individually:

- **a.** Full depth Bituminous pavement.
- **b.** Composite (Portland Cement Concrete base with Bituminous surface).
- **c.** Portland Cement Concrete pavement.

2. Ramp Cycle. An assessment of interchange ramps that are "out of cycle," according to the Interstate treatment cycles defined in this document.

3. International Roughness Index (IRI). A measurement of pavement ride quality, subdivided as follows:

- **a.** The percent of mileage that has Excellent or Good ride quality (< 100 inches per mile).
- **b.** The percent of mileage with Poor ride quality (> 150 inches per mile).

4. Remaining Service Life. An assessment of the remaining service life of the Interstate system, calculated by multiplying remaining life for each roadway segment by its length.

5. Overall Pavement Index (OPI). A summary measurement of pavement condition, subdivided as follows:

- **a.** The percent of mileage in Excellent or Good condition (> 85).
- **b.** The percent of mileage in Poor condition (< 75).

6. Rutting Data. A measurement of surface deformation in the wheel tracks, as follows:

- **a.** The mileage with medium severity rutting (depths > 0.5 inch, but < 1.0 inch).
- **b.** The mileage with high severity rutting (depths > 1.0 inch).

7. Concrete Pavement Preservation. A measurement of the mileage of concrete pavement with a surface age not exceeding 15 years that is programmed. The "programmed" miles are according to MPMS data.

B. Bridge. To keep Pennsylvania's Interstate bridges at a high level of service, which means no weight restricted bridges, sufficient reserve capacity to carry permitted heavy trucks and to safely carry traffic at higher speeds, two critical functions must be provided:

1. Reduce the deck area and number of Structurally Deficient (SD) bridges through bridge improvements (replacements and rehabilitations).

2. Keep good bridges good through effective bridge preservation.

To effectively manage and improve bridge conditions, PennDOT developed a Risk Assessment for PennDOT-Owned Bridges and Structures Report (Risk Assessment) that prioritizes bridge needs in alignment with PennDOT's Asset Management strategy.

The Risk Assessment uses data from the Bridge Management System 2 (BMS2) to prioritize and provide general scopes of work for bridges for both improvement and preservation projects. The Risk Assessment also has cost estimating, programming, and planning functions to facilitate creating a realistic long-range bridge program within fiscal constraints.

Several performance measures have been defined to monitor the bridge conditions of the Interstate system. The 2007 data from BMS2 was established as the baseline. The measures will be updated each year by BOPD to monitor the improvement and impact of the centralized Interstate Management Program. Data is summarized by Interstate route per District, by District, and Statewide. The baseline indicators are:

1. Bridge Statistics. Baseline data on the count of bridges, of deck area, and of the average Sufficiency Rating.

2. Bridge Deficiencies. A measurement of bridge deficiencies from the bridge safety inspection program that is used on a national basis:

- **a.** SD Deck Area. The deck area in square feet of a bridge categorized as SD. An SD bridge may also be Functionally Obsolete (FO).

- **b.** FO Deck Area. The deck area in square feet of a bridge categorized as FO only and not also SD.

- **c.** SD/FO Deck Area. The deck area in square feet of a bridge categorized as SD and/or FO.

- **d.** # SD On/Off. Given a specified timeframe, the # bridges that became SD (On) and the # bridges that are no longer SD (Off) because of intervention (rehabilitation or replacement) when comparing the last two routine inspections.

3. Load Challenged Bridges. A set of leading indicators with respect to the potential for load restrictions and/or restrictions for heavy hauling permits.

a. Weak Link Bridge Deck Area. The bridge deck area that has an Operating load capacity that is between the legal load limit and 110% of legal load; or stated differently, bridges that have a load carrying capacity that is within 10% of requiring posting.

b. On Deck Bridge Deck Area. The bridge deck area that has an Operating load capacity that is between 110% of legal load limit and 120% of legal load.

c. Other High Risk Bridge Deck Area. The deck area of bridges that have Operating Ratings for the H, HS, and ML-80 vehicles as follows:

(1) H Vehicle Operating Rating between 24 to 30 Tons.
(2) HS Vehicle Operating Rating between 43 to 50 Tons.
(3) ML-80 Vehicle Operating Rating between 44 to 57 Tons.

For comparison purposes, a newly constructed bridge has the following operating ratings:

(1) H Vehicle Operating Rating 33 Tons.
(2) HS Vehicle Operating Rating 75 Tons.
(3) ML-80 Vehicle Operating Rating 61 Tons.

4. Other. A set of data for critical components or conditions that affect the structural safety or safety to motorists. Through effective programming, rehabilitation, or replacement, the goal is to improve the safety of the Interstate bridge system.

a. # of Scour Critical Bridges. The number of bridges classified as Scour Critical.

b. # of FCM Bridges. The number of bridges that contain Fracture Critical Members (FCM), as defined by AASHTO.

c. Deck Area of Bridge with Deck Rating ≤ 4. The bridge deck area for structures that are Structurally Deficient solely due to the condition of the deck and also not FO. The other primary structural components, superstructure and substructure, have condition ratings classified fair or above. The deck condition is a safety concern for motorists due to the potential for poor/uneven riding surface.

d. # of maintenance items w/ priority 0 or 1. The number of bridge maintenance items with a priority coding of 0 or 1. 0 priority requires prompt action and 1 priority is a high priority requiring repair as soon as work can be scheduled.

5. Functionality. Data regarding the functionality of the system with respect to movement of over-height vehicles on the Interstate. This includes mainline Interstate bridges and non-Interstate bridges over the Interstate.

a. # of Overpass Bridges w/ Vertical Clearance < 15 Feet. The number of overpass bridges that have a field measured vertical clearance less than 15 feet over the Interstate.

b. # of Overpass Bridges w/ Vertical Clearance < 16 Feet. The number of overpass bridges that have a field measured vertical clearance less than 16 feet over the Interstate.

6. Leaking Deck Joints. The number of bridges that have leaking deck joints determined by the type of joint and the type of recommended maintenance activity.

a. # Interstate Bridges with Leaking Deck Joints. The number of bridges that have leaking deck joints.

b. # Bridges over the Interstate with Leaking Deck Joints. The number of overpass bridges that have leaking deck joints.

13.6 STATE OF THE INTERSTATE REPORT

Each year, BOMO will provide the "State of the Interstate" (SOI) report which will provide analysis of pavement condition data to define the existing pavement condition on a project level, assign the appropriate treatment, and estimate the necessary costs. BOPD will use the Risk Assessment to provide analysis of the bridge condition data on a project level for project scope and cost estimates. A comparison of needs to the current Statewide Interstate program will also be made and is contained in the Interstate Management Needs Assessment report.

As in previous editions of the SOI report, the Interstate system will be divided into projects that are based on the work that has most previously been performed. The limits of a project are based on the extent of the last resurfacing, rehabilitation, or reconstruction that has been performed on that specific portion of the roadway, thereby ensuring relative similarity of pavement type and condition within the "project." At the completion of the most recent construction, the pavement was at its optimum condition. Deterioration of the pavement increases through time, and this deterioration is assumed to be uniform over the limits of the last construction.

Based on these project limits, appropriate pavement and bridge treatments based on condition will be determined and considered for the roadway in order to address the deficiencies and distresses. Further, the results can be used to make a system-wide analysis of the condition of the Interstate system, as well as project what type of efforts and funds are necessary to improve it.

Project prioritization criteria defined in these guidelines will then be used to prioritize the project needs, required timeframes, and establish a data based Interstate program. District Interstate plans should address the SOI project recommendations, proposed changes, and provide supplemental information in order to develop the final Statewide Interstate program.

Note that the information to be provided in this report will serve as a starting point and a tool for program development, but in no way should be used in lieu of in-depth field views of potential projects before determining the actual scope of work.

13.7 FIELD VIEWS

A. General. District staff from design, construction, and maintenance, along with appropriate County personnel, should perform field views of their Interstate network in order to develop and/or verify their 10-year plan. During the year prior to each IM program TIP update, Interstate routes are to be field viewed by representatives from BOPD, BOMO, CPDM, and all pertinent District staff in order to determine appropriate IM project candidates. Representatives from the FHWA may also participate. Supplemental field views may be scheduled to assess changing conditions and priorities. Safety concerns and solutions should be identified during field views as justification for the proposed project scope. Crash data or other supporting data should be presented.

Project Prioritization forms, as shown in Figure 13.2 and Figure 13.3, will be completed for each candidate roadway project in order to verify need and priority. These forms will provide a point-based assessment of each IM candidate based on defined various project and condition information. The criteria defined on these forms provide flexibility to account for other issues or factors that may generate needs.

During the field view, candidate bridge improvement projects determined from the Risk Assessment will be verified for priority and work scope. For both improvement and preservation projects verify the need for scour protection, leaking joints, deck treatments, beam end and bearing area repairs.

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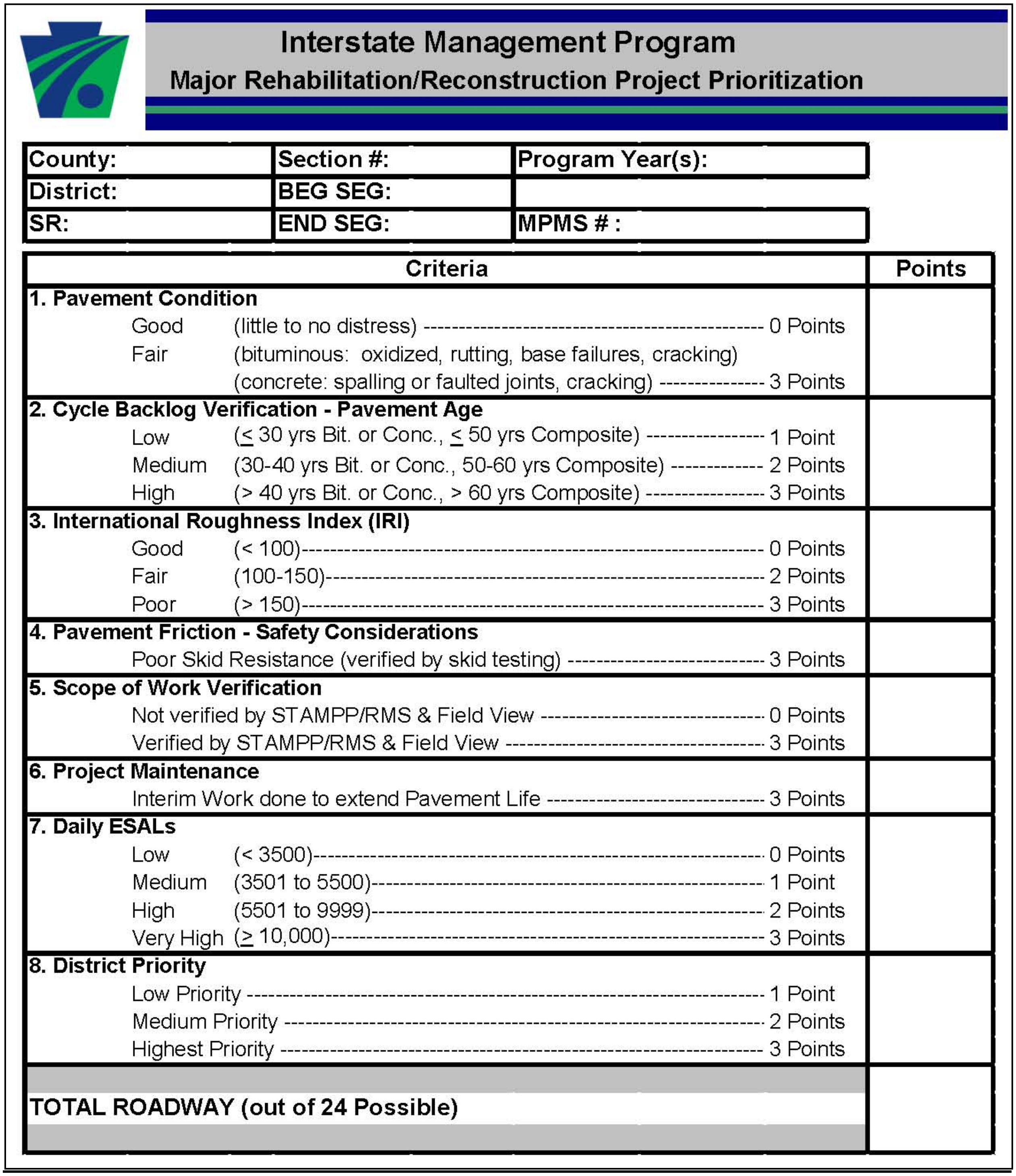
FIGURE 13.2
MAJOR REHABILITATION/RECONSTRUCTION PROJECT FORM



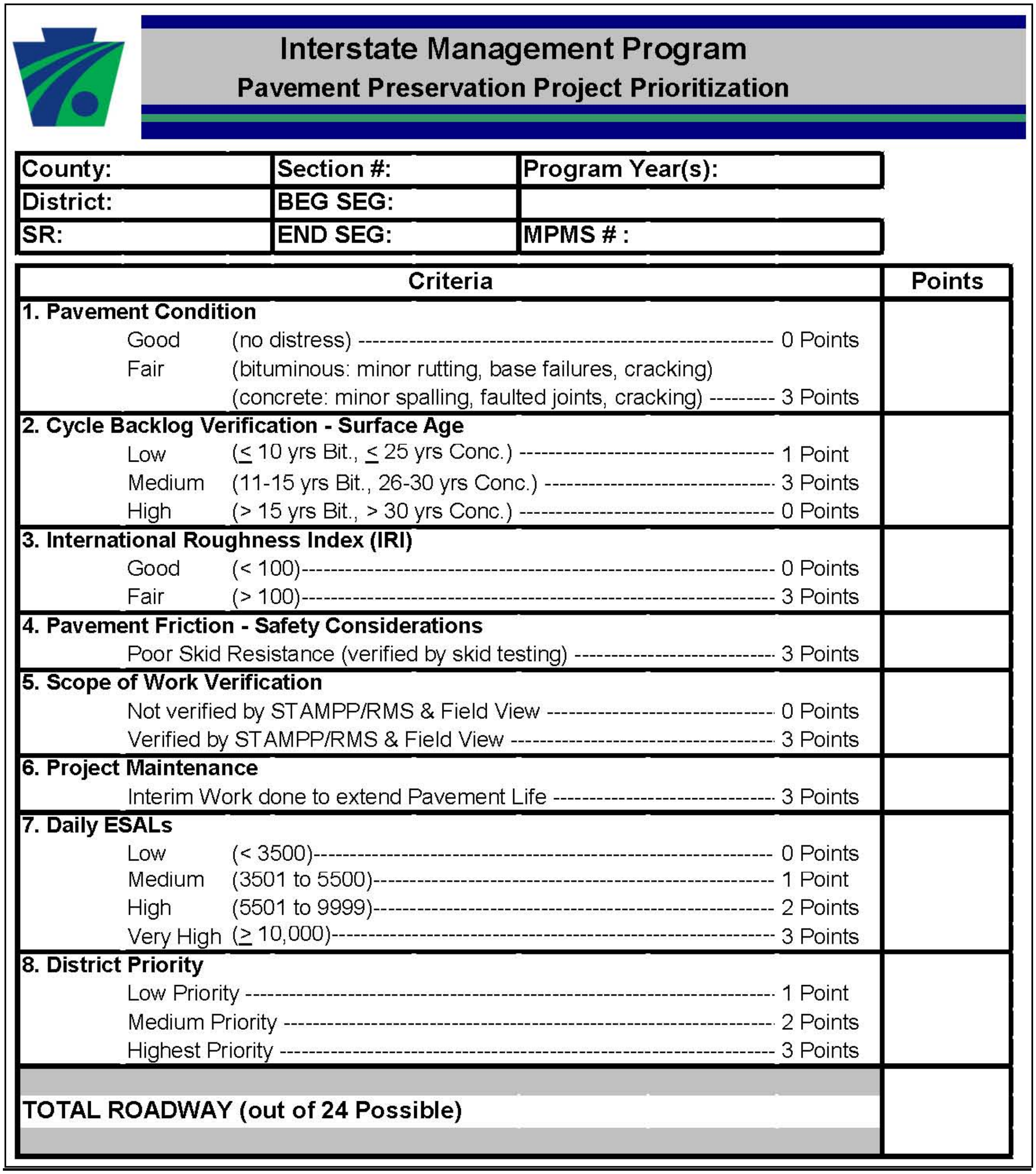
Interstate Management Program

Major Rehabilitation/Reconstruction Project Prioritization

County:	**Section #:**	**Program Year(s):**
District:	**BEG SEG:**	
SR:	**END SEG:**	**MPMS # :**

Criteria	**Points**
1. Pavement Condition	
Good (little to no distress) -- 0 Points	
Fair (bituminous: oxidized, rutting, base failures, cracking) (concrete: spalling or faulted joints, cracking) --------------- 3 Points	
2. Cycle Backlog Verification - Pavement Age	
Low (≤ 30 yrs Bit. or Conc., ≤ 50 yrs Composite) ----------------- 1 Point	
Medium (30-40 yrs Bit. or Conc., 50-60 yrs Composite) ------------- 2 Points	
High (> 40 yrs Bit. or Conc., > 60 yrs Composite) ----------------- 3 Points	
3. International Roughness Index (IRI)	
Good (< 100)--- 0 Points	
Fair (100-150)--- 2 Points	
Poor (> 150)--- 3 Points	
4. Pavement Friction - Safety Considerations	
Poor Skid Resistance (verified by skid testing) --------------------------- 3 Points	
5. Scope of Work Verification	
Not verified by STAMPP/RMS & Field View -------------------------------- 0 Points	
Verified by STAMPP/RMS & Field View ------------------------------------ 3 Points	
6. Project Maintenance	
Interim Work done to extend Pavement Life ------------------------------- 3 Points	
7. Daily ESALs	
Low (< 3500)--- 0 Points	
Medium (3501 to 5500)-- 1 Point	
High (5501 to 9999)-- 2 Points	
Very High (≥ 10,000)--- 3 Points	
8. District Priority	
Low Priority -- 1 Point	
Medium Priority --- 2 Points	
Highest Priority -- 3 Points	
TOTAL ROADWAY (out of 24 Possible)	

FIGURE 13.3
PAVEMENT PRESERVATION PROJECT FORM



Interstate Management Program

Pavement Preservation Project Prioritization

County:	**Section #:**	**Program Year(s):**
District:	**BEG SEG:**	
SR:	**END SEG:**	**MPMS # :**

Criteria	Points
1. Pavement Condition	
Good (no distress) ------------------------------ 0 Points	
Fair (bituminous: minor rutting, base failures, cracking) (concrete: minor spalling, faulted joints, cracking) --------- 3 Points	
2. Cycle Backlog Verification - Surface Age	
Low (≤ 10 yrs Bit., ≤ 25 yrs Conc.) ------------------------------ 1 Point	
Medium (11-15 yrs Bit., 26-30 yrs Conc.) ------------------------------ 3 Points	
High (> 15 yrs Bit., > 30 yrs Conc.) ------------------------------ 0 Points	
3. International Roughness Index (IRI)	
Good (< 100)------------------------------ 0 Points	
Fair (> 100)------------------------------ 3 Points	
4. Pavement Friction - Safety Considerations	
Poor Skid Resistance (verified by skid testing) ------------------------------ 3 Points	
5. Scope of Work Verification	
Not verified by STAMPP/RMS & Field View ------------------------------ 0 Points	
Verified by STAMPP/RMS & Field View ------------------------------ 3 Points	
6. Project Maintenance	
Interim Work done to extend Pavement Life ------------------------------ 3 Points	
7. Daily ESALs	
Low (< 3500)------------------------------ 0 Points	
Medium (3501 to 5500)------------------------------ 1 Point	
High (5501 to 9999)------------------------------ 2 Points	
Very High (≥ 10,000)------------------------------ 3 Points	
8. District Priority	
Low Priority ------------------------------ 1 Point	
Medium Priority ------------------------------ 2 Points	
Highest Priority ------------------------------ 3 Points	
TOTAL ROADWAY (out of 24 Possible)	

B. Instructions for IM Project Prioritization Forms. A separate "Interstate Management Project Prioritization Criteria" form has been established for Major Rehabilitation/Reconstruction projects and Pavement Preservation projects. For each IM candidate project, BOMO will complete the appropriate form and define the following information:

- County – to be provided by the District.
- District – to be provided by the District.
- State Route (SR) – to be provided by the District.
- Section # – to be provided by the District.
- Beginning Segment – to be provided by the District.
- Ending Segment – to be provided by the District.
- Program Year(s) for Construction – to be provided by the District.
- MPMS # – to be provided by the District.
- Pavement Condition – to be assessed by the District, and verified by BOMO, based on an assessment of the pavement condition for the project during the field view. Note that an assessment of what the condition will be at the time for which the project is proposed is necessary; the field view determination may override current STAMPP condition data.
- Cycle Backlog Verification – based on RMS Pavement History data. The Districts should verify this data, and make Pavement History updates as necessary. Pavement age will be assessed for Major Rehabilitation/Reconstruction projects, and surface age will be assessed for Pavement Preservation projects, in accordance with the treatment cycle charts defined in this document. Note that an assessment of what the pavement and/or surface age will be at the time for which the project is proposed is necessary. Points are assessed as follows:

  Major Rehabilitation/Reconstruction:
    1 point: Pavement Age ≤ 30 years for full depth Bituminous, or Concrete pavements, ≤ 50 years for Composite
    2 points: Pavement Age 30-40 years for full depth Bituminous, or Concrete pavements, 50-60 years for Composite
    3 points: Pavement Age > 40 years for full depth Bituminous, or Concrete pavements, > 60 years for Composite

  Pavement Preservation:
    1 point: Pavement Age ≤ 10 years for Bituminous, ≤ 25 years for Concrete
    3 points: Pavement Age 11-15 years for Bituminous, 26-30 years for Concrete

1. International Roughness Index (IRI). To be determined by BOMO, based on RMS data. Fair IRI results in 3 points.

2. Pavement Friction - Safety Considerations. To be provided by the District. Projects with a verified skid resistance problem, based on Skid Friction testing performed by BOMO, will be assessed 3 points.

3. Scope of Work Verification. Scope of work will be determined by the District, but will be verified by BOMO. If the project's scope of work is supported by and verified with the results of the modified STAMPP Treatment Matrix and a field view, 3 points will be assessed. Note that an assessment of what the condition will be at the time for which the project is proposed is necessary; the field view determination may override the matrix result. Capacity-adding projects, or portions of projects related to adding capacity, are not eligible for IM funds.

4. Project Maintenance. The District must define interim maintenance work and/or prior preservation projects which improved surface condition, but not the underlying issues that warrant the proposed project. Since these projects may not be assessed available points in the Scope of Work Verification or Pavement Condition categories, an additional 3 points may be assessed if interim maintenance work was performed.

5. Daily Equivalent Single Axle Loads (ESALs). To be determined by BOMO, based on RMS data. Points are assessed as follows:

1 point:	3501 to 5500 ESALs
2 points:	5501 to 9999 ESALs
3 points:	$\geq$ 10,000 ESALs

6. District Priority. To be determined by the District. The highest priority Rehabilitation/Reconstruction project and the highest priority Pavement Preservation project for each District will be assessed 3 points. Only one project of each type will be assessed the highest priority. Medium priority projects, of each type, will be assessed 2 points, and low priorities will be given 1 point.

13.8 ROADWAY PROJECT CRITERIA

A. Cycle Assessment. Pavement Surface Age is an indicator of preservation needs, and Pavement Structure Age is one of several factors that trigger rehabilitation or reconstruction. An assessment of mileage that is "out of cycle," or forecasted to become out of cycle in upcoming years, is necessary to determine needs and priorities. District Interstate plans must account for how these miles will be addressed. The treatment cycles used to determine needs are as follows:

Bituminous Pavements

Activity	Frequency
Crack sealing	3 to 5 years (5 years used in calculations)
Micro Surfacing (optional)	5 to 10 years
Resurfacing	8 to 12 years (with no interim Micro Surfacing) (10 years used in calculations) 13 to 17 years (with an interim Micro Surfacing)
Reconstruction	> 50 years for full depth bituminous pavement

Concrete Pavements

Activity	Frequency
Joint sealing	8 years (8 years used in calculations)
Concrete patching	Year 15, and 25
Diamond Grinding	15 to 20 years
Bituminous Overlay	25 to 30 years (25 years used in calculations)
Reconstruction	> 55 years for full depth concrete pavement

These treatment cycle thresholds are used to determine appropriate pavement treatments, in conjunction with the "Treatment Matrix" which is detailed in Appendix H. Updated segment level pavement and surface age data will be provided to the Districts each year.

B. International Roughness Data. International Roughness Index (IRI) is a measure of vehicle response to surface texture, faulted or uneven roadway surfaces and pavement surface irregularities. High IRI values indicate poorly performing roadways, while low IRI values indicate good or sound pavement surfaces. For Interstate roadways, ride quality thresholds are defined as follows:

Excellent	Less than or equal to 70 inches per mile
Good	71 to 100 inches per mile
Fair	101 to 150 inches per mile
Poor	Greater than 150 inches per mile

In the data analysis, all Interstate roadway segments with Fair or Poor IRI values are candidates for at least preservation type treatments. Districts must also account for pavements forecasted to become Fair or Poor in upcoming years. Updated IRI data will be provided to the Districts each year, and is to be addressed in District Interstate plans.

C. Interim Maintenance. District Interstate plans must detail interim maintenance work and/or prior preservation projects. This type of work generally improves surface condition, and may result in a lesser treatment being triggered by the matrix – creating an incorrect assessment of need. All past projects that have improved the surface but the condition driving the proposed project type was not addressed, should be detailed. Even if this prior work is properly recorded in the Roadway Management System, it must be noted in the District Interstate plan to account for potential differences in treatment determination.

D. Project Delivery. District Interstate plans must address delivery timelines and issues for each project. Each phase for programmed projects must be detailed and scheduled via entry in Deltek's Open Plan® application. Usage of this application should follow the guidelines identified in Publication 615, *Scheduling Manual*.

E. Pavement Testing.

1. Skid Resistance Testing. All sections of roadway with a verified skid resistance problem, based on Skid Friction testing performed by BOMO, will be assessed additional points on the Project Prioritization forms. If skid friction issues are suspected, requests for testing must be submitted to BOMO. Necessary corrective actions, based on the test results, must be addressed in the District Interstate plan.

2. Falling Weight Deflectometer (FWD) Testing. FWD data is used to determine pavement and subgrade characteristics necessary to perform structural design. Also, FWD data indicates concrete pavement joint efficiency, as well as locations and quantities of required concrete pavement patching. Patching quantities may indicate project type in that patching greater than 10% of the pavement area is generally not cost-effective or permitted for Pavement Preservation projects. FWD test results do not need to be addressed in the District Interstate plans, per se, but may be required to verify project scope.

F. Traffic Loading. Equivalent Single Axle Load (ESAL) data will be considered to determine priorities. This data does not need to be addressed in the District Interstate plans, per se, but may be considered to determine District priorities.

G. Treatment Matrix. Roadway condition assessments are performed annually via the Videologging project. Examples of condition data are: cracking, rutting, edge deterioration, raveling/weathering, joint spalling, and joint faulting.

The Systematic Technique to Analyze and Manage Pennsylvania Pavements (STAMPP) treatment matrices determine appropriate treatments for each segment of roadway given its condition. A modified matrix, provided in Appendix H, will be used for Interstate management and planning. The modified matrix, in conjunction with the treatment cycle charts defined previously, determines whether Routine Maintenance, Pavement Preservation, or Major Rehabilitation/Reconstruction is warranted.

1. Routine Maintenance (RM). Activities that repair and/or retard existing distress. These activities include crack sealing, joint sealing, spall repair, mechanized patch, spray patch, and minimal base repair.

Cyclic crack sealing and joint sealing will be points of emphasis on the Interstate system, as these activities are necessary to maintain the system. As indicated previously, crack sealing of bituminous surfaced pavements, and joint sealing of concrete pavements should be done every 3 to 5 years.

2. Pavement Preservation (PP). A planned strategy of cost effective treatments to retard future deterioration, and maintain or improve the functional condition of the section of highway. Preservation includes Micro Surfacing, bituminous resurfacing with leveling and/or milling, diamond grinding, base repair, and concrete patching.

The Interstate/Expressway Pavement Preservation Guidelines can be found in Chapter 12. It is crucial that Pavement Preservation projects be selected prior to extensive deterioration and in accordance with the appropriate cycle.

3. Major Rehabilitation/Reconstruction. These strategies provide complete replacement of, or increased structural capacity of the pavement. Reconstruction is necessary when the functional pavement life has been exceeded. Major Rehabilitation may involve the same activities as pavement preservation, but base repair and/or patching is more extensive and overlays are placed in order to improve or increase pavement structure.

It may be necessary for the District Interstate plans to address how major rehabilitation/reconstruction needs will be distributed over a range of years in order to lessen the funding requirements in any given year and to assure that all of this mileage does not continue to require treatment at the same time.

STAMPP condition data, and the corresponding treatment matrices, do not always properly account for specific conditions that may be present. Repair of these conditions may be required prior to the point that distress is detected and a treatment is triggered through the matrix. The following are examples:

1. Premature mid-slab cracking of jointed concrete pavements, which may be caused by inadequate subbase material.

2. Faulting of concrete pavement joints is not always properly measured and reported.

3. Aggregate related issues, such as Vanport Limestone concerns and Alkali Silica Reaction (ASR), may not be detectable with STAMPP data. Note that concrete pavements comprised of Vanport Limestone may present skid resistance issues, which can be exacerbated with diamond grinding. These pavements should be monitored and prompt skid resistance testing by BOMO as necessary. The initial bituminous overlay on these pavements may be warranted earlier than indicated on the concrete pavement cycle chart.

4. Ramp pavement condition is not assessed via the STAMPP program.

BOMO is continuously performing quality assurance on condition data, so that data reliability and accuracy can be improved. However, it is important to note that limitations and imperfections in existing data may be present so that Interstate plans account for the true pavement conditions and are not based solely on programmatic results. Specific conditions not identified by STAMPP data should be presented during the field views.

The treatment matrix used to generate the data provided herein has had several revisions related to Jointed Concrete Pavements from that defined in the previous version of the IM Guidelines. Transverse Cracking, Longitudinal Cracking, and Broken Slabs now trigger patching, CPR & overlay, and reconstruction at "earlier" stages than the previous version. The updated trigger points are defined in Appendix H.

The pavement preservation and major rehabilitation/reconstruction needs provided in this document are based on a roadway segment level analysis. As described previously, the SOI report will analyze project level data, as defined by similar pavement type and age. The resultant required mileages of the various pavement treatments may vary to some degree as a result.

13.9 BRIDGE PROJECT CRITERIA

A. General. PennDOT's bridge management philosophy is a holistic approach including timely inspection, load rating analysis, on-demand structural repairs, preservation, and routine maintenance to maximize the life of a bridge. For bridge improvements, PennDOT is incorporating a design approach and details that will result in a 100-year service life. Strategies for bridge rehabilitation and replacement are outlined in Publication 15M, Design Manual Part 4, *Structures*.

Inspection and appraisal data for bridges is also collected by PennDOT and stored in BMS2 for all state-owned bridges greater than or equal to eight feet in length. PennDOT collects and stores all inspection data as required by the FHWA's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (December 1995). All bridges are inspected at a maximum frequency of every two years. Bridge inspections are to be performed in accordance with Publication 238, *Bridge Safety Inspection Manual*.

The development of an effective bridge program includes two main components:

1. Bridge Improvements. The main focus of this portion of the bridge program is to reduce the number and deck area of SD bridges through rehabilitations and replacements.

2. Bridge Preservation. The main focus of this portion of the bridge program is to perform repairs and preventative maintenance to extend the life of good bridges.

The bridge program must be developed by prioritizing bridge projects using the ranking calculated by the Risk Assessment. Adjustments to this ranking are permitted with justification and are to follow the guidelines below.

Balance Bridge Improvement and Bridge Preservation spending to achieve optimum SD reduction and reduce new SD bridge growth rate (suggested mix is 80% - 85% of total spending for Bridge Improvement projects, 10% - 15% of total spending for Bridge Preservation projects and 5% - 10% for Overhead Vertical Clearance Improvements).

1. Bridge Improvement Projects (80% - 85% of Total Bridge Spending). The following considerations are to be used for prioritizing these projects:

a. 85% - 100% of Bridge Improvement spending directed toward SD bridges.

b. Optimize improvement purchasing power with mix of rehabilitations versus replacements, bridges with large deck areas versus small deck areas.

c. Direct a portion of the Bridge Improvement spending to redecking SD bridges that are SD due solely to poor decks.

d. Direct a portion of the Bridge Improvement spending to improving load capacity on permit corridors for Weak Link (100% Legal Load ≤ and < 110% Legal Load) or On Deck (110% Legal Load ≤ and < 120% Legal Load) bridges.

e. Other factors are:

- Age of structure
- Importance of structure
- ADT
- Detour length
- Businesses affected
- Sufficiency Rating
- Project scope (quick strike vs. complex scope).

f. Miscellaneous. Bridge pre-cast parapet replacements/retrofits.

g. Look for bridge improvement work opportunities within limits of planned highway work to optimize other costs.

2. Bridge Preservation Projects (10% - 15% of Total Bridge Spending). The following considerations are to be used for prioritizing these projects:

a. As a number 1 priority, repair scour problems that jeopardize the integrity of a bridge.

b. Eliminate leaking deck joints.

c. Repair beam ends, beam seats, fatigue prone details, and bearings.

d. Fix maintenance priority 0 & 1 items that are critical to the structural integrity of the bridge and can be corrected by a preservation activity.

e. Spot/zone paint portions of steel structures as determined by condition and criticality of the member to the integrity of the structure.

f. Repair bridge decks and provide waterproofing membranes or overlays.

g. Fully repaint steel structures that are not planned for replacement within 20+ years. (Larger bridge assets such as bridge spans > 300 feet have higher priority.) This activity generally has a lower priority than the above items, but may be elevated where significant long-term cost savings may be realized.

h. Look for bridge preservation work opportunities within limits of planned highway work to optimize other costs.

3. Overhead Vertical Clearance Improvements (5% - 10% of Total Bridge Spending):

a. Vertical clearance restrictions < 16 feet over the Interstate mainline impedes the movement of oversize loads, at times forcing the use of secondary roads with bridges of lesser capacity. The older portions of the Interstates, especially I-83, I-78, I-70, I-80 and I-90 contain the majority of these low vertical clearance bridges.

b. The following considerations are to be used for prioritizing these projects:

- Give priority to improving vertical clearances that are ≤ 15 feet.
- Number of overheight vehicle impacts.
- Is structural integrity of overhead bridge compromised?
- Detour length for overheight permits - Diamond interchange?
- Scope of work (lowering highway, replacing entire bridge, or jacking just the superstructure, etc.).

c. Look for overhead vertical clearance improvement work opportunities within limits of planned highway work to optimize other costs.

B. Other Factors. A complete Interstate Management program cannot focus solely on mainline pavements and bridges. Other items, including ramps, shoulders, guide rail, drainage, signing, Intelligent Transportation System (ITS) devices, roadside rests, weigh-in-motion installations, and lighting must be accounted for, maintained, and managed. The level of completeness of data for these assets vary, but must be enhanced and considered as part of the IM program, and must be addressed in District plans. Additionally, other factors must be considered such as functionality and safety issues.

C. Program Development. Based on the data and criteria defined in this document, field views, and District priorities, a priority ranking is assigned to each project. From that, a prioritized list of preservation projects and major rehabilitation/reconstruction projects is established. Other issues will then be considered, such as project phasing, whether design phases are already funded, and other information provided through the Business Plan presentations.

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CHAPTER 14

PENNSYLVANIA'S ROADWAY MANAGEMENT SYSTEM

14.1 ROADWAY MANAGEMENT SYSTEM OVERVIEW

Pennsylvania's Roadway Management System (RMS) is one of the leading computerized roadway management systems in the world. It contains copious data for each segment of Pennsylvania's State-owned highway system. Many of these data elements pertain to the pavement. These data elements include pavement history, pavement condition, roughness, traffic counts and classifications, friction characteristics, divider type, number of lanes and urban/rural codes. The accuracy and completeness of pavement history data is essential to a successful pavement management system.

The information contained in RMS can be very useful for designing a pavement rehabilitation or replacement project. For example, the pavement condition data can be helpful in determining what projects to build, based on needs, and the minimum treatment required; pavement history and traffic data can be used to analyze the existing pavement's structural capacity; and the Maintenance Functional Codes (MFC) can be used to determine the appropriate design criteria.

Unfortunately, as with any data system, RMS has limitations on the availability, detail and timeliness of its data. For example, the pavement condition data found in the Systematic Technique to Analyze and Manage Pennsylvania Pavements (STAMPP) represents a snapshot of the segment on the day it is surveyed. This snapshot does not change when maintenance or rehabilitation work is done after the survey until the segment is resurveyed in subsequent years. Also, traffic data may be several years old. Significant changes may have occurred since the last traffic count. Another limitation concerns pavement history. A layer could have been missed in the pavement history if the layer was a build-up of surface treatments or other maintenance work. Further, there may have been a lapse in recording pavement history information for projects. As useful as the information in RMS is, field viewing and testing of the existing pavement is still essential.

14.2 RMS PAVEMENT HISTORY UPDATE POLICY

PennDOT's Pavement History Update Process provides a means to ensure that pavement related data for construction, maintenance, and Highway Occupancy Permits (HOP) are provided to the District RMS Coordinators for entry in the RMS. The Pavement History Update Process also establishes the methods for tracking pavement projects and updating pavement data in RMS. Using the link below, three separate processes, one for each project type, are to be followed.

Pavement Data forms were developed to facilitate recording pavement layer data from paving projects to be provided to the RMS Coordinator for entry in the RMS. The forms are in the MS Excel two workbooks found using the link below. Instructions for the use of the forms are included. These forms are to be used with the Pavement History Update Process. Districts that already have their own Pavement Data forms in use may continue to use those forms.

Project Tracking sheets provide a means for the RMS Coordinator to track pavement projects, whether construction, maintenance, or HOP, from planning stage through completion. These Project Tracking sheets, in a MS Excel workbook with a separate tab for each project type, found using the link below, will enable the RMS Coordinator to know for which projects pavement history data have or have not been submitted though the Pavement History Update Process.

P:\penndot shared\Bureau of Maintenance and Operations\Roadway Management Division\Roadway Inventory & Testing\Shared Data\Pavement Project Tracking

As shown in Figure 14.1 and Figure 14.2, PennDOT's Pavement History Data Quality Assurance (QA) and Verification Processes establish the methodology for determining the effectiveness of tracking projects and updating pavement history in RMS.

FIGURE 14.1
PAVEMENT HISTORY QA PROCESS

January/February

1. Districts will maintain Project tracking sheets on the shared drive year-round. All construction, maintenance and HOP-related pavement projects will be included. All possible updates for projects completed the previous year shall be made by January 31 of each year.

2. QA Teams comprised of two people are identified:

- Year 1. A representative from Bureau of Maintenance and Operations (BOMO) and a District RMS representative are on each team: BOMO will QA each District. The District RMS representatives will not QA their own District.
- Subsequent Years. BOMO will QA a minimum of three Districts, but not all. When BOMO is not part of a QA Team, RMS representatives from two different Districts will be on a Team. Once again, the District RMS representatives will not QA their own District.

3. BOMO works with each District to create a Pavement History QA schedule based on the projects listed as completed on the Project Tracking sheet.

4. BOMO randomly selects 10% of the surface improvement projects from the previous year for QA. At least one construction, one maintenance, and one HOP-related project will be included, even if that puts the total over 10%. Every offset range within each project will be checked.

5. BOMO, or the Pavement History QA Team when BOMO is not involved, notifies the Districts of which projects are scheduled for a QA review two weeks prior to the review.

March/April

1. Districts collect documentation in the two weeks prior to the scheduled review. The documentation should include any information necessary for the QA reviewers to perform the QA, such as as-built plans and pavement history forms, EDMS records, etc.

2. Shoulders are to be QA reviewed along with the pavement data; however, shoulder results are not included in the QA score.

3. The QA Teams perform the reviews using the QA data forms. Results are provided to BOMO within two weeks of QA.

4. The RMS Coordinator of the District being QA reviewed shall be present during the QA and shall have a network computer available.

June - October

1. BOMO compiles and analyzes QA results from each District.
2. BOMO prepares a report of the QA results with recommended follow-up action where needed.
3. BOMO distributes the Pavement History QA report annually by September 15.

October - December

1. Districts review Pavement History QA report. Implement corrective action where needed by December 31 each year.

2. Districts notify BOMO of completion of corrective action by December 31 each year.

FIGURE 14.2
PAVEMENT HISTORY VERIFICATION PROCESS

January/February

1. BOMO creates Verification Status report of segments/offsets that need verified. Prior to the start of the Verification Process, BOMO had all segments with a reconstruction year of 2004 to 2009 set to Verification Complete in RMS. The initial Verification Status report included all segments/offsets with surface year less than 2004 in RMS. As segments are verified, they will be removed from the list.

2. BOMO provides the lists to Districts for planning yearly verifications.

March - December

1. Districts prepare a list of which segments/offsets will be verified using the following guidelines to complete verifications in 4 years (~25% per year).

- In Year 1, verify all surface improvement projects plus all Interstates and other NHS routes so total verified equals 25%.
- In Years 2-4, verify all surface improvement projects plus additional segments required so total verified equals 25%.

2. Districts verify Pavements History data in RMS. Data is Verified Complete (VC) or Verified Incomplete (VI) in RMS, along with the date of the verification and the User ID of the person completing the verification.

- Verified Complete - data in pavement history are accurate according to sources available.
- Verified Incomplete - data in pavement history are reviewed, but accuracy cannot be determined because supporting documentation is unavailable.
- If data are determined to be inaccurate, the District shall make every effort to correct the data according to the supporting documentation. Once data are corrected, the segment/offset can be marked as Verified Complete.

3. The data to be verified include: pavement layer type, year and order; pavement layer width and depth; and project limits.

4. Districts shall maintain a list of sources used in the verification. These sources may include items such as as-built plans, electronic records on CD or in EDMS, etc. This list will provide the documentation that can be QA reviewed, should that project be selected for QA.

5. BOMO updates the Verification Status report and provides the report to the Districts on a monthly basis once the verification process begins and until 100% verification is completed.

6. All segments reconstructed after being verified, either complete or incomplete, shall be re-verified so to maintain 100% verification of the data.

Pavement History Data QA measures the accuracy of the new pavement data entered into RMS. Figure 14.1 describes the procedure for performing the annual QA. The QA results will be summarized, scored, and reported for each District annually.

Pavement History Data Verification determines the accuracy of pavement data already in RMS. Figure 14.2 provides the procedure. The miles of pavement history data verification (i.e., Verification Measure) will be tracked and reported for each District annually in the Pavement History QA Report.

14.3 PAVEMENT CONDITION INFORMATION - STAMPP PROGRAM

In 1983, PennDOT developed and implemented a pavement management program known as STAMPP. This program consists of an annual pavement condition survey of 100% of the National Highway System (NHS) roadways and 50% of the non-NHS roadways. One hundred percent of the non-NHS is completed every 2 years. The data are input into PennDOT's mainframe database, which has become the core of the RMS.

Publication 336, *Automated Pavement Condition Surveying Field Manual*, contains all necessary information to conduct the field surveys. The distresses to be collected for bituminous and jointed concrete pavements (plain or reinforced) are listed. There is also a detailed section on Pennsylvania's Location Reference System that describes how each roadway segment is identified in the RMS. Publication 343, *Continuously Reinforced Concrete & Unpaved Roads Condition Survey Field Manual* and Publication 33, *Shoulder and Guide Rail Condition Survey Field Manual*, can be downloaded at PennDOT's website.

The STAMPP program includes the development of recommended treatments for each roadway segment. These treatments are based on anticipated maintenance activities. They are not appropriate for use as the basis of developing design projects. They do provide a means for analyzing the pavement distresses and overall pavement condition. It is reasonable to assume that the treatment recommended by the STAMPP program will be somewhat less than the design strategy that will be developed for contract rehabilitation work. For example, a STAMPP Treatment recommendation for surface treatment is normally a good indication that a pavement section needs surfacing. When a rehabilitation design is developed, this surfacing will normally be in the form of a bituminous overlay. All Federal Oversight pavement design submissions must include a copy of the STAMPP Treatment Summary with each copy of Form D-4332.

Further capability has been developed using the RMS database in combination with Statistical Analysis System (SAS) programming. A series of SAS programs have been placed in the SAS Library that provide summaries for items of particular concern, such as shoulder drop-off, potholes and excess asphalt. These items can be used by county maintenance personnel to identify potential high-risk tort liability problems that need to be addressed.

Similar information is available in RMS for guide rail and drainage features. An inventory of all guide rail and drainage features is available, along with condition data. The guide rail data are useful for identifying areas that need to be reviewed by knowledgeable PennDOT personnel, since the survey is performed by nonprofessional, temporary staff. The drainage inventory includes all features less than 8 feet in clear span, which are not included in the BMS2 Inventory. Information can be extracted from the database to identify drainage features requiring maintenance.

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APPENDIX A

SAMPLE FORM D-4332

D-4332 (8-08)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

PAVEMENT TYPE APPROVAL

(Additional pages attached)

Date:
County:
SR:
Section:
Agreement #:
Project #:
MPMS #:

TO:

FROM:

Traffic Route: ______________________________ Township: ________________________________

City: __________________________________ Borough: ____________________________________

Limiting Segment/Offset:

ADT of ____ for Design Year _________

ADT of ____ for Current Year _________

Truck Percentage: ____

Depth and description of all courses above finished subgrade for all pavement designs are described on the attached pages numbered __3__ through _____.

Recommended By: ____

____ , *Pavement Management Engineer/ Pavement Manager*

Approved By: ____

____ , *District Executive*

Copy To:

D-4332 (8-08)

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PAVEMENT TYPE APPROVAL

Pavement Design Project Information

Page# 2 of ___

SR: ______________________

Section: ______________________

County: ______________________ Township: ______________________

City: ______________________ Borough: ______________________

Traffic Route: ______________________

Limiting Segment/Offset:

Limiting Construction Stations: ______________________

Project Length: ______________ Feet ______________ Miles

Pavement Length: ______________ Feet ______________ Miles

System: ☐ FAI ☐ FAP ☐ FAS ☐ State ☐ Other: ______________

FAI: Federal Aid Interstate FAP: Federal Aid Primary FAS: Federal Aid Secondary

Status: ☐ PENNDOT Oversight ☐ Federal Oversight

Financing: Funding Code __________ % Federal Funds ______ % State Funds ______

Work to be done by: Contract ______________ Department Force __________

Project No. ______________ MPMS No. ______________

Project Cost $______________

Current Pavement (Depth, Type, and Width, Year Built, and Condition) or attach RMS Pavement history and condition screen shots.

Current Shoulder Width ___________ Current Curb Section ___________

Adjacent Pavement (Depth, Type, Width, and Condition)

At Beginning (SR ____ / SEG ______) At End (SR ____/SEG _______)

D-4332 (8-08)

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PAVEMENT TYPE APPROVAL

Pavement Structural Section(s)

Page# ___ of ___

SR: ______________________________

Section: _________________________

(List depth and description of all courses above finished subgrade for all pavement designs within the project.)

D-4332 (8-08)

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PAVEMENT TYPE APPROVAL

Pavement Structural Section(s)

Page# ___ of ___

SR: ____________________________

Section: ____________________________

(List depth and description of all courses above finished subgrade for all pavement designs within the project.)

D-4332 (8-08)

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PAVEMENT TYPE APPROVAL

Pavement Structural Section(s)

Page# ___ of ___

SR: ____________________

Section: ____________________

(List depth and description of all courses above finished subgrade for all pavement designs within the project.)

D-4332 (8-08)

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PAVEMENT TYPE APPROVAL

Pavement Structural Section(s)

Page# ___ of ___

SR: ________________________

Section: ________________________

(List depth and description of all courses above finished subgrade for all pavement designs within the project.)

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APPENDIX B

TRUCK COMPOSITION COUNTS FOR DESIGN

B.1 GENERAL INFORMATION

The truck composition count for design purposes should be taken on a day when normal traffic flow can be expected, preferably on a Tuesday, a Wednesday, or a Thursday. This count should be obtained hour by hour for 8 hours. Where it is possible to maintain the counting continuously, nothing less than an 8-hour peak hour shift (6 am to 2 pm or 10 am to 6 pm) on a Tuesday, Wednesday, or Thursday should be attempted.

Form PS-121, Manual Traffic Classification, will be completed for each direction of traffic flow for each 8-hour period of the count. A map that shows the exact location of the count should accompany each submission of the PS-121 form.

Since accuracy in counting is imperative, it is suggested that the operation be checked by a field supervisor for quality control. Explicit instructions should be given for personnel to continue counting at the end of a period until members of the succeeding work shift have arrived and are prepared to begin counting.

It is advisable that the local and State Police are aware of the time and location of the counting operation at least one day before the counting is to begin.

B.2 THE SUPERVISOR

The supervisor shall see that the recorders are on duty at their proper assignments at the appointed time and remain there during the work hours unless relieved. The supervisor will arrange relief for lunch and other times when temporary absence from the station is necessary.

During operation of the station, the supervisor shall make frequent visits to the recorders, spending sufficient time to observe the work, correct any errors observed, and see that the work is being done properly. Arrangements will be made for the work to be collected at the end of each day.

B.3 THE TRAFFIC RECORDERS

The traffic recorders shall be at their assigned station prepared to start counting traffic at the beginning of each operation and shall remain at their assignments continuously until the end of the operation except when officially relieved. The recorders shall synchronize their watch with the supervisor's.

All motor vehicles, including military, fire-fighting, and emergency equipment, passing the station shall be recorded in the proper space on form PS-121 for each hour period.

Traffic in each direction shall be kept separate and recorded on one Form PS-121 for each direction.

B.4 EQUIPMENT

The traffic recorder shall be supplied with pencils, forms, and a board to hold the forms. The classification count boards are available to simplify classification counting. At the top of the board, there will be mounted tally counters to be used in tallying those classifications of most common vehicles, while other vehicles of less common classifications will be hand-tallied in the appropriate spaces on Form PS-121.

B.5 INSTRUCTIONS FOR USE OF TRAFFIC CLASSIFICATION FORM PS-121

The station description at the top of each Form PS-121 must be accurately and completely recorded.

County refers to the name of the county in which the count is being recorded.

Twp. City or Bor. refers to the name of the Township, City, or Borough in which the count is being recorded.

Weather refers to the Clear, Overcast, Rain, Sleet, or Snow condition existing at the station during counting operations.

Pavement Design, Loadometer Survey, Special Project, and HPMS # refer to the purpose for which these counts were recorded. In the case of Pavement Design, Loadometer Survey, or Special Project, a check mark in the appropriate box will be sufficient. HPMS refers to Highway Performance Monitoring System, and the appropriate location number should be included.

Day refers to the day of the week on which the count is being recorded. Date refers to the month, day, and year in which the count is being recorded.

S.R. & T.R. refers to the State Route and Traffic Route numbers of the roadway being studied. Use the segment and offset for the location being classified.

Location, ____________mi. N.S.E. or W. of refers to the distance to the nearest 0.1 mile the counting location is North, South, East, or West of the nearest intersection of the road that is being classified. Circle the appropriate direction.

Hour Period - Left Margin. Use one line for each hour and indicate the hour period in following manner:

8A - 9A	for the hour period between 8 am and 9 am
2P - 3P	for the hour period between 2 pm and 3 pm
11A - 12N	for the hour period between 11 am and noon
11P - 12M	for the hour period between 11 pm and midnight

Passenger Cars - Column 1. All automobiles regardless of registration or size shall be classified to Column 1.

Passenger Cars pulling trailers shall be classified in Column 1 without any regard for the trailers they may be pulling. However, in the case of one car towing another, then list both vehicles. An automobile towing a truck should be recorded with one count in column 1 and the truck counted once in the appropriate truck Column depending on the wheel and axle configuration. A truck pulling a house trailer, boat trailer, or small utility trailer shall be classified in the appropriate column under TRUCK - SINGLE UNIT, without any reference to the trailer.

Motorcycle - Column 2. All motorized 2-wheel vehicles with operator seated on but not straddling the motor.

B.6 TRUCK - SINGLE UNITS

Pick-up or Panel Trucks - Column 3. This class includes the small utility telephone and gas trucks and residential dry cleaning and milk delivery trucks. Also all pick-ups, panels, and small home delivery trucks with single rear tires are included.

Two-axle Trucks - Columns 4 and 5. These classes include all two-axle trucks other than the pick-up or panel group. Identify these trucks as single (Column 4) or dual (Column 5) rear tire vehicles.

Three-axle - Column 6. This class includes all three-axle single-unit trucks.

Four Axles or More - Column 7. This class includes all trailer and semi-trailer combinations with two axles on the pulling vehicle and one axle on the trailer.

B.7 TRUCKS - COMBINATIONS

Three-Axle Single Trailer - Column 8. This class includes all trailer and semi-trailer combinations with two axles on the pulling vehicle and one axle on the trailer.

Four- Axle Single Trailers - Column 9. This class includes all trailer and semi-trailer combinations with a total of four axles.

Five-Axle Single Trailers - Column 10. This class includes all trailer and semi-trailer combinations with a total of five axles.

Six or More Axles - Column 11. This class includes all trailer and semi-trailer combinations with a total of six or more axles.

Five-Axle-Double Trailer - Column 12. This class includes all truck or truck tractors in combination with two towed units having a total of five axles.

Six-Axle - Double Trailers - Column 13. This class includes truck or truck tractors in combination with two towed units having a total of six axles.

Seven or More Axles - Double Trailers - Column 14. This class includes truck or truck tractors in combination with two towed units having a total of seven or more axles.

B.8 BUSES

Commercial - Column 15. This class includes all commercial buses that are not school buses.

School - Column 16. This class includes all school buses regardless of use during or after school hours.

Total Vehicles - Column 17. This column shall be the total of all classes of vehicles counted in one direction for each hour period. The actual addition of each line and column shall be competed in the office.

Recreational vehicles (R/Vs) are to be included with the TRUCKS - SINGLE UNITS under the appropriate type and number or axles (Column 4 through 7).

The form shall be signed by the recorder and given to the supervisor at the end of the assigned counting period.

B.9 FORM PS-121, MANUAL TRAFFIC CLASSIFICATION

PS 121 (1-96)

COUNTY: ____________

TWP., City OR BORO.: ____________

PENNSYLVANIA DEPARTMENT OF TRANSPORTATON:
BUREAU OF PLANNING AND RESEARCH
MANUAL TRAFFIC CLASSIFICATION

COUNT #: ________ SPEED LIMIT: ________
S.R. ________ T.R. ________
SEGMENT: ________ OFFSET: ________
LOCATION: ________
________ mi. N.S.E. or W. of ________

DAY ________ DATE ____________ , 20____

PAVEMENT DESIGN ☐ LOADOMETER SURVEY ☐ SPECIAL PROJECT ☐ HPMS # ________

HOUR PERIOD	Passenger Cars	Motorcycle/ Motorscooter	TRUCKS-SINGLE UNITS					TRUCKS-COMBINATIONS							BUSES		Total Vehicles
				2 AXLES				SINGLE TRAILERS				DOUBLE TRAILERS					
			Pickup or Panel	Single Rear Tires	Dual Rear Tires	3 Axles	4 Axles or More	Three Axles	Four Axles	Five Axles	Six or More Axles	Five Axles	Six Axles	Seven or More Axles	Commercial	School	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TOTAL																	

NOTE:Classify R/V by axle type.

Remarks: ____________________

Observer: ____________________

APPENDIX C

18-KIP DAILY SINGLE-AXLE LOAD EQUIVALENTS – SPECIAL CASES

On certain localized routes carrying heavy truck traffic, such as industrial complex connections, and coal haul routes, the equivalency values by truck type indicated in page 2 of Form D-4332, as obtained from Tables 6.2, 6.3 and 6.4, may be incorrect. A procedure to determine the 18-kip daily ESALs for such projects is as follows:

- First, identify the basic truck type that will utilize the proposed project. Determine the current average daily volume in one direction and the estimated 20-year projected daily volume of each truck type. Determine the average of the current and 20-year projected daily volume for each truck type in one direction. It is not necessary to consider all truck types. If a negligible number is specified in specific truck categories, those categories and the calculations that accompany them may be eliminated. A method to estimate this ESAL value is presented in Table C.1.

- After the estimated average daily volume has been determined for each truck type, the axle load weight distribution must be determined for each truck type. The District Executive or his representative will be responsible for determining the axle distribution and weights of each type through coordination with the industry involved and possibly the Bureau of Planning and Research.

- The 18-kip daily ESALs may be computed for rigid pavements as shown in Table C.2 and for flexible pavements as shown in Table C.3.

TABLE C.1
METHOD TO ESTIMATE 18-KIP DAILY ESALS FOR SPECIAL PROJECTS

TRUCK TYPE*	**ESTIMATED CURRENT DAILY VOLUME**	**ESTIMATED 20-YEAR PROJECTED DAILY VOLUME**	**ESTIMATED AVERAGE DAILY VOLUME**
2-Axle - 6 Tire			
3-Axle - Single Tire			
3-Axle - Single Trailer			
4-Axle - Single Trailer			
5-Axle - Single Trailer			
Other			

* Other truck types may be included in the table if their volume is sufficient. Specified truck types of negligible volume may be eliminated.

TABLE C.2
METHOD TO COMPUTE 18-KIP ESALS FOR RIGID PAVEMENT FOR SPECIAL PROJECTS

WEIGHT INTERVAL	**18 KIP AXLE EQUIVALENT FACTOR**	**2 AXLE 6 TIRE**	**3 AXLE SINGLE UNIT**	**3 AXLE SINGLE TRAILER**	**4 AXLE SINGLE TRAILER**	**5 AXLE SINGLE TRAILER**	**OTHER**	**OTHER**	**18 KIP EQUIVALENT**
Single Axle	(A)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(B)*
Under - 3,000	0.0002								
3,000 - 6,999	0.0050								
7,000 - 7,999	0.0260								
8,000 - 11,999	0.0820								
12,000 - 15,999	0.3410								
16,000 - 17,999	0.7830								
18,000 - 19,999	1.2600								
20,000 - 21,999	1.9300								
22,000 - 22,400	2.4360								
22,401 - 24,400	3.0360								
24,401 - 28,000	4.8220								

* (B) = (A)[(1) + (2) + (3) + (4) + (5) + (6) + (7)] = Total (Single)^

TANDEM AXLE	**(A)**		**(2)**		**(4)**	**(5)**	**(6)**	**(7)**	**(B)****
Under 6,000	0.010								
6,000 - 11,999	0.010								
12,000 - 17,999	0.063								
18,000 - 23,999	0.253								
24,000 - 29,999	0.729								
30,000 - 31,999	1.305								
32,000 - 33,999	1.700								
34,000 - 36,000	2.165								
36,001 - 38,000	2.721								
38,001 - 40,000	3.373								
40,001 - 45,000	4.475								
45,001 - 50,000	7.420								

****** (B) = (A) [(2) + (4) + (5) + (6) + (7)] = Total (Tandem)^

^ The 18 Kip Daily Single-Axle Load Equivalent is equal to the total of the 18 kip axle equivalent for the single axles plus the total of the 18 kip axle equivalents for the tandem axles.

TABLE C.3
METHOD TO COMPUTE 18-KIP ESALS FOR FLEXIBLE PAVEMENT FOR SPECIAL PROJECTS

WEIGHT INTERVAL	**18 KIP AXLE EQUIVALENT FACTOR**	**2 AXLE 6 TIRE**	**3 AXLE SINGLE UNIT**	**3 AXLE SINGLE TRAILER**	**4 AXLE SINGLE TRAILER**	**5 AXLE SINGLE TRAILER**	**OTHER**	**OTHER**	**18 KIP EQUIVALENT**
Single Axle	(A)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(B)*
Under - 3,000	0.0002								
3,000 - 6,999	0.0050								
7,000 - 7,999	0.0320								
8,000 - 11,999	0.0880								
12,000 - 15,999	0.3600								
16,000 - 17,999	0.7960								
18,000 - 19,999	1.2400								
20,000 - 21,999	1.8300								
22,000 - 22,400	2.2600								
22,401 - 24,400	2.7600								
24,401 - 28,000	4.2140								

* (B) = (A) [(1) + (2) + (3) + (4) + (5) + (6) + (7)] = Total (Single)^

TANDEM AXLE	**(A)**		**(2)**		**(4)**	**(5)**	**(6)**	**(7)**	**(B)****
Under 3,000	0.010								
6,000 - 11,999	0.010								
12,000 - 17,999	0.044								
18,000 - 23,999	0.148								
24,000 - 29,999	0.426								
30,000 - 31,999	0.753								
32,000 - 33,999	0.971								
34,000 - 36,000	1.230								
36,001 - 38,000	1.533								
38,001 - 40,000	1.890								
40,001 - 45,000	2.735								
45,001 - 50,000	4.010								

** (B) = (A) [(2) + (4) + (5) + (6) + (7)] = Total (Tandem)^

^ The 18 Kip Daily Single-Axle Load Equivalent is equal to the total of the 18 kip axle equivalent for the single axles plus the total of the 18 kip axle equivalents for the tandem axles.

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APPENDIX D

DESIGN FREEZING INDEX AND FROST HEAVE WORKSHEET

DISTRICT 1			
Location	**Elevation**	**Index**	**Winter**
Crawford County			
Conneautville	930	1233	62-63
Jamestown	1050	1303	62-63
Meadville	1065	1282	62-63
Titusville Water Works	1220	1585	62-63
Erie County			
Erie Airport	742	1002	62-63
Corry	1440	1203	62-63
Forest County			
Tionesta Dam	1220	1362	62-63
Mercer County			
Farrell-Sharon	855	640*	62-63
Greenville	1026	955	62-63
Mercer 2 mi. NNE	1160	990*	62-63
Venango County			
Franklin	987	1057	62-63
Warren County			
Warren	1280	1012	62-63

DISTRICT 2			
Location	**Elevation**	**Index**	**Winter**
Centre County			
Bellefonte 4 mi. S	1110	971	62-63
Phillipsburg Airport	1918	1243	62-63
State College	1175	983*	62-63
Cameron County			
Emporium	1560	1475	62-63
Clearfield County			
DuBois 7 mi. E	1670	1149*	62-63
Madera	1460	1325	62-63
Clinton County			
Lock Haven	680	1016*	62-63
Renovo	660	1072	62-63
Elk County			
Ridgway	1420	1304*	62-63
Juniata County			
McKean County			
Bradford Airport	2121	1444	62-63
Bradford Reservoir	1680	1369	62-63
Clermont	2104	1281	62-63
Kane	1750	1504	62-63
Mifflin County			
Lewistown	1750	634*	62-63
Potter County			
Coudersport 3 mi. NW	2020	1496	62-63

DISTRICT 3			
Location	**Elevation**	**Index**	**Winter**
Bradford County			
Canton 1 mi. NW		1231	62-63
Towanda	1520	915	62-63
Columbia County			
Berwick	570	982	62-63
Millville 2 mi. SW	860	1179	62-63
Lycoming County			
English Center	880	1167	62-63
Williamsport Airport	527	886	62-63
Montour County			
Northumberland County			
Sunbury	480	925	62-63
Snyder County			
Sullivan County			
Eagles Mere	2020	1167	62-63
Tioga County			
Lawrenceville 2 mi. S	1000	1009	62-63
Wellsboro	1920	1329	62-63
Union County			

DISTRICT 4			
Location	**Elevation**	**Index**	**Winter**
Luzerne County			
Bear Ck. Dam	1700	1381	62-63
Freeland		1029	62-63
Scranton Wilkes-Barre (Airport WB)	940	921	62-63
Lackawanna County			
Scranton	746	930	62-63
Pike County			
Hawley	880	1225	62-63
Susquehanna County			
Montrose	1560	1380*	62-63
Wayne County			
Pleasant Mt. 1 mi. W	1800	1502*	62-63
Wyoming County			
Dixon	750	1101	62-63

DISTRICT 5			
Location	**Elevation**	**Index**	**Winter**
Berks County			
Reading WB	266	436	62-63
Morgantown	595	664	62-63
Carbon County			
Palmerton	435	749*	62-63
Lehigh County			
Allentown WB	376	752	62-63
Allentown Gas	254	621	62-63
Monroe County			
Mt. Pocono 2 mi. N	1915	1194	62-63
Stroudsburg	480	987	62-63
Tobyhanna	1950	1216	62-63
Schuylkill County			
Port Clinton	450	971*	62-63
Northhampton County			
Bethlehem (Lehigh U)	411	752	62-63

DISTRICT 6			
Location	**Elevation**	**Index**	**Winter**
Bucks County			
George School	135	685*	60-61
Quakertown	490	669*	60-61
Chester County			
Coatesville 1 mi. SW	342	592*	60-61
Devault 1 mi. W	360	629	60-61
Phoenixville	105	473	60-61
Delaware County			
Marcus Hook	12	228	60-61
Montgomery County			
Graterford 1 mi. E	240	718	60-61
Norristown	75	355	62-63
Philadelphia County			
Phila. Airport WB	7	506	60-61
Drexel University	30	309	62-63
Pt. Breeze	32	184	62-63

DISTRICT 8			
Location	**Elevation**	**Index**	**Winter**
Adams County			
Arendtsville	710	736	62-63
Gettysburg	540	631*	62-63
Cumberland County			
Bloserville 1 mi. N	640	691	62-63
Carlisle	465	644*	60-61
Shippensburg	709	543	62-63
Dauphin County			
Harrisburg Airport WB	355	558	60-61
Tower City	835	1014	62-63
Franklin County			
Chambersburg	640	681*	60-61
Mercersburg	615	667	62-63
Lancaster County			
Ephrata	465	523	62-63
Holtwood	187	383	62-63
Lancaster 2 mi. NE	255	644*	60-61
Landisville 2 mi. NW	360	819	62-63
Mt. Gretna 2 mi. SE	670	707	62-63
Lebanon County			
Lebanon 4 mi. WNW	590	839	60-61
Perry County			
Newport	400	790*	60-61
York County			
Hanover	600	561	62-63
York 3 mi. SSW	390	620	60-61

DISTRICT 9			
Location	**Elevation**	**Index**	**Winter**
Bedford County			
Everett 1 mi. SW	1029	808*	62-63
Kegg	1280	774	60-61
Blair County			
Altoona HC (PRR)	1500	840	62-63
Martinsburg	1463	746	62-63
Cambria County			
Ebensburg	2090	983	62-63
Johnstown	1214	755*	62-63
Fulton County			
Huntington County			
Huntington	640	755*	62-63
Somerset County			
Confluence 1 SW Dam	1490	919	62-63
Stoystown	1800	1074	62-63

DISTRICT 10			
Location	**Elevation**	**Index**	**Winter**
Armstrong County			
East Brady	820	950	62-63
Ford City 4 mid. Dam	950	1042	62-63
Putneyville 2 mi. SE Dam	1270	1149	62-63
Butler County			
Butler	1101	1085	62-63
Slippery Rock	1345	913	62-63
Clarion County			
Clarion	1114	1126	61-62
Indiana County			
Blairsville 6 ENE	2048	988	62-63
Indiana 3 mi. SE	1102	875	62-63
Marion Center 2 SE	1610	1083	62-63
Jefferson County			

DISTRICT 11			
Location	**Elevation**	**Index**	**Winter**
Allegheny County			
Bakerstown 3 mi. WNW	1230	832	62-63
Pittsburgh AP WB	1151	978	62-63
Pittsburgh WB	749	514	62-63
Beaver County			
Montgomery Lock and Dam	692	662	62-63
Lawrence County			
New Castle	825	843*	62-63

DISTRICT 12			
Location	**Elevation**	**Index**	**Winter**
Fayette County			
Newell	805	564	62-63
Uniontown	1040	455	62-63
Greene County			
Waynesburg 1 mi. E	940	898	62-63
Washington County			
Burgettstown 2 mi. W	980	1108	62-63
Claysville 3 mi. W	1000	745*	62-63
Donora	900	476	62-63
Westmoreland County			
Donegal	1746	1049*	58-59
New Stanton	980	726	62-63
Salina 3 mi. W	1109	878	62-63

* Denotes calculation by the former U.S. Weather Bureau, now known as National Weather Service.

FROST HEAVE WORKSHEET

To determine the Change in Serviceability Loss Due to Frost Heave, ΔPSI_{FH}, you will need 1993 AASHTO Guide for Design of Pavement Structures.

The effects of Frost Heave must be accounted for in all **full-depth flexible** pavement designs and bituminous over rubblized concrete designs. To do this, follow the given steps below.

STEP #1: **Determine the Frost Heave Rate, ϕ (mm/day)**

1. Obtain the soil classification of the future subgrade at the project site.
2. Using the soil classification, determine the Average Rate of Heave from Table 9.1 or 9.2.

(Soil Classification: ________)
FROST HEAVE RATE: ________mm/day

STEP #2: **Select the Frost Heave Probability, P_F**

1. Estimate the percent area of the project that is subject to frost heave. Consider the extent of frost-susceptible subgrade material, moisture availability, drainage quality, number of freeze-thaw cycles per year, depth of frost penetration, and past experience. (Recommended Range: 25% - 75%)

FROST HEAVE PROBABILITY: ________%

STEP #3: **Determine the Maximum Potential Serviceability Loss, ΔPSI_{MAX}**

1. Use Appendix D to find the Design Freezing Index for the project site.

   Design Freezing Index ________
2. Use Figure 9.1 to determine the Frost Penetration from the design freezing index.

   Frost Penetration ________inches = ________feet
3. Use Figure G.7 (pg. G-10) of the 1993 AASHTO Guide to determine the Max. Serviceability Loss Due to Frost Heave. Use a Drainage Quality of FAIR.

MAXIMUM POTENTIAL SERVICEABILITY LOSS: ________

STEP #4: **Determine the Change in Serviceability Loss Due to Frost Heave, ΔPSI_{FH}**

1. Use the results obtained in the first three steps to navigate through Figure G.8 (pg. G-11) of the 1993 AASHTO Guide.

CHANGE IN SERVICEABILITY LOSS DUE TO FROST HEAVE: ______

Once the Change in Serviceability Loss due to Frost Heave is determined (Step #4), add it to the appropriate Terminal Serviceability Index listed in Table 6.2. Use the result as the terminal serviceability input required in DARWin for full-depth flexible pavement designs.

APPENDIX E

PERFORMING LIFE-CYCLE COST ANALYSIS

To be released at a later date.

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APPENDIX F

TRACKING NEW MAINTENANCE TECHNIQUES, PROCESSES AND MATERIALS EVALUATION PLAN FORMS

PROJECT INFORMATION FORM FOR NEW MAINTENANCE TECHNIQUE, PROCESS OR MATERIAL

Technique, Process or Material:
Dates of Construction:
Location: Co: SR Segment (to/from)
Offset (to/from)
Contact Person: Ph #: Email:

Describe the maintenance technique or material to be used:

Describe the problem/issue that this technique or material addresses:

Unit Cost of New Technique or Material:
Comparable Standard:
Unit Cost of Comparable Standard:

Other Comments:

Submit to: Pavement Testing and Asset Management Section Chief
Asset Management Division, BOMO
7th Floor Commonwealth Keystone Building
Harrisburg, PA 17120
Ph (717) 787-6899

CONSTRUCTION REPORT
FOR
NEW MAINTENANCE PROCESS

Maintenance Process:								
Location:	Co:		SR:		Segment (to/from)			
					Offset (to/from)			
Date(s):		Time Begin:		Time End:				
Weather/Temperature:		/						

Describe the process and material used^: (use a separate sheet if more space is needed)

Were there any deviations from the proposed process? (use a separate sheet if more space is needed)

Unit Cost of New Technique or Material:	Comparable Standard:		
	Unit Cost of Comparable Standard:		

Other Comments:

Contact Person:		Ph #		Email:	

Note: Include digital photos of the procedure and material, including finished product.

^If patching operation, provide area of each patch and reference location by offset

Submit to:
Pavement Testing and Asset Management Section Chief
Asset Management Division, BOMO
7th Floor Commonwealth Keystone Building
Harrisburg, PA 17120
Ph (717) 787-6899

PERFORMANCE REVIEW
FOR
NEW MAINTENANCE PROCESS

Date of Review:					Date Constructed:	
Location:	Co.		SR		Segment (to/from)	
					Offset (to/from)	
Reviewer:				Ph #		
				Email		

Maintenance Technique or Material being reviewed:

Conditions Observed: (Complete all conditions that apply; N/A all others)

Bituminous

Cracking (#/Length)			Raveling/Weathering	Delaminations/Potholes
Transverse	Longitudinal	Fatigue *	(sq.ft.)	(sq.ft.)
/	/	/	/	/
(# / ft)	(# / ft)	(# / ft)	(# locations/total area)	# / total area

If Patch^:

Area (sq.ft.)	Length of patch edge not sealed (ft):	
	Secondary Compaction (depth- in.):	

Comments

Concrete

# Joints:		# Slabs:		(total in treatment area)

Cracking (#slabs)		Joint Spalling (# jts)		Spalling - >1sf each	Faulted Joints
Transverse	Longitudinal	Transverse	Longitudinal	(# slabs)	(# joints)

Bituminous Patch^		
Area	Secondary Compaction	Edge not Sealed
(sq.ft.)	(inch)	(ft)

Comments

* # of occasions and cumulative length of each
^ If patching operation, complete one form for each patch; reference location by offset
Note: Include digital photos of the process/material being evaluated

Submit to:
Pavement Testing and Asset Management Section Chief
Asset Management Division, BOMO
7th Floor Commonwealth Keystone Building
Harrisburg, PA 17120
Ph (717) 787-6899

APPENDIX G

QUALITY ASSURANCE POLICY

PennDOT Oversight Pavement Design Quality Assurance Reviews Policy and Procedure

The purpose of the PennDOT Oversight (PO) Pavement Design Quality Assurance Reviews is to satisfy the Stewardship and Oversight Agreement with the Federal Highway Administration (FHWA) dated August 2012 (Refer to Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C,* Appendix C, FHWA/PennDOT Stewardship & Oversight Agreement). Oversight status is provided with the understanding that PennDOT will provide stewardship over the process to assure compliance with Publication 242, *Pavement Policy Manual*.

After the Pavement Management Engineer (PME) is certified, the District approves PO pavement designs locally without submission to Central Office for review or concurrence. As stated in Publication 242, *Pavement Policy Manual*, "Certified PME/PM's will recommend approval of Federal Oversight or PennDOT Oversight pavement designs using Form D-4332 to the District Executive (DE) based on sound engineering principles and conformance to Publication 242, *Pavement Policy Manual*." The empowerment granted to the District is based on the premise that all approvals conform to the requirements of Publication 242, *Pavement Policy Manual*. The District does not approve exemptions to Publication 242, *Pavement Policy Manual*. Exemptions are the purview of the Central Office and FHWA.

Important items mandated by this letter are:

- Implementation of checklist.
- Implementation of 95 point requirement for technical items.
- Continuation of project selection based on letting date, requiring Districts to 'clean up' older designs.
- Penalty for missing or expired pavement designs.
- Enforcement of existing policy requiring signature of the District Geotechnical Engineer.
- Evaluation of Typical Sections from the Final Design Plans. Typicals in file will not be reviewed unless they are copies from the Final Design Plans.

Each QA review is an audit of the PO pavement design process and the documentation procedures used in the District during a 1-year period. In addition to satisfying the Oversight Agreement, the QA review is an opportunity to assess the District's performance during the year so that management might learn of areas for improvement.

The QA review tests the District's ability to maintain the proper records throughout the year as part of day to day business practices. A one-time audit provides a good indication of how well the District has followed policies, procedures and guidelines and how these items have been incorporated into daily routine. The only recognizable way of validating District competence is through documentation. Without complete and thorough documentation, there is nothing of any relevance to base a judgment upon.

The following actions are recommended to the District:

- Develop and implement an internal QA/QC process at the District.

- Use the attached checklist to evaluate pavement designs.

- Include the PME in the Final Design Plans check to verify that the Typical Sections match Form D-4332.

PennDOT Oversight Pavement Design Quality Assurance Reviews Policy and Procedure

- PME should keep spreadsheet of projects designed. Include date of Final Design Plans check and date of letting. This can be used to track designs that may expire before letting.

- Project pavement design files should be kept in an orderly fashion. It is good practice to sort through the file upon approval. Keep all final versions together in the front of the folder. Maintain all reference materials together in the back of the folder and remove all miscellaneous extra papers.

A QA review team, generally consisting of two Pavement Design and Analysis Unit (PDAU) staff from the Bureau of Project Delivery (BOPD), will perform a QA review of each District's PennDOT Oversight (PO) pavement designs annually based on a calendar year regardless of the PME's certification status. Adequate notice of the date of the QA review will be provided to the PME.

The PME will provide all requested pavement designs and typical sections. The District will provide an area for review with a networked computer for each QA team member. The PME will be available to answer questions during the course of the review.

A total of five designs will be checked at each QA review. Five projects will be selected from a list of projects that were let after the previous annual QA. For projects that contain multiple pavement designs only one design per project will be selected for review. The QA review team will not provide a list of the five projects prior to the QA. It is expected that the PME be able to locate all projects on the day of the QA. This includes the typical sections from the set of Final Design Plans. If there are not five eligible projects on the letting list, additional projects will be selected from a list of projects that were let after the initiation of the QA (October 10, 2001).

Each design will be scored on two separate criteria: procedural and technical. Each design will be given a base value of 100 points for each criterion. If the design is not available for review it will receive a score of 0 points. Each design will be scored using the attached checklist. If more than one of the five designs receives a procedural score less than 70 points the District will not pass the QA. If more than one of the five designs receives a technical score of less than 95 points the District will not pass the QA.

The QA review team will provide an exit briefing to the Assistant District Executive (ADE) for Design or designee before departure. The scores given at the briefing are final and cannot be affected by after-the-fact information gathering.

A memo of the findings for each review will be issued from the Director Bureau of Project Delivery (BOPD) to the District Executive. A copy of the memo will also be issued to the following: FHWA, Deputy Secretary for Highway Administration, Director Bureau of Maintenance and Operations, Director Bureau of Project Delivery, ADE Design, Pavement Testing and Asset Management Chief, and District PME/PM. Annually, the QA team will produce and distribute a report of the findings from the QA reviews for that calendar year. It is intended that this report be used by the Districts to compare and examine their processes and to investigate the items that have had the most deviations and work to improve those items.

If the District does not pass the annual QA, corrective actions will be prescribed during the exit briefing and in the memo. If the District does not pass the annual QA, a follow-up QA will be scheduled within 6 months of the annual QA. The procedures for the follow-up QA will be the same as the procedures for the annual QA.

If the District does not pass the follow-up QA, the District will be notified immediately and re-certification is required. The re-certification process will consist of a half day training for the PME by PDAU staff and submission of all PO pavement designs to BOPD until three projects including at least one design of each surface type (bituminous and concrete) are approved. BOPD will notify the District of re-certification in writing once the three submitted pavement designs are approved.

PennDOT Oversight Pavement Design QA Reviews
Checklist and Score Sheet

Date ______________Reviewer __________________________ Procedural Score _______ Technical Score _______

District __________ County ______________________ SR ________ Section _______ ECMS/MPMS __________

Instructions: Check the box if the item is found. If the item is missing or a deviation is found enter the deduction amount in the space provided. If the item is not applicable, enter N/A in the space provided. Procedural and Technical Review each start with 100 points.

Procedural Items [70 points and above is passing]

Found/Actual Points Deducted [Item Value] Item Name and Description. (*Pavement Policy Manual* Reference*)

______ [100] Pavement Design File.
  - Subtract 100 if the pavement design file is not available for review

______ [100] Typical Sections match Form D-4332. Pavement Type, Depth, SRL, and ESALs.
  - Subtract 100 if any inconsistencies are present

______ [50] Skid Resistance Level (SRL) is not below minimum for ADT (Section 5.7 Providing Friction in Bituminous Wearing Courses; & Table 5.4 SRL Criteria)
  - Subtract 50 if incorrect SRL is utilized

______ [20] Form D-4332.
  - Subtract 20 if Form D-4332 not present

______ [20] DARWin Printout.
  - Subtract 20 if all DARWin Printouts are not present

______ [20] Typical Sections from Final Design Plans.
  - Subtract 20 if Typical Sections are not from the Final Design Plans

______ [20] Signature of DE and PME on Form D-4332. (Section 6.1.D Procedures: General)
  - Subtract 20 if signature is not present

______ [20] Project letting before pavement design expiration.
  - Subtract 20 if pavement design is greater than 3 years old

______ [20] Signature of District Geotechnical Engineer on Geotechnical recommendation. (Section 6.2.A Resilient Modulus)
  - Subtract 20 if signature is not present

______ Required Waivers: ____

______
  - Subtract 20 for each waiver that was required and not present

______ [5] Pavement Design File organized.
  - Subtract 5 if all final versions are not located in the front of the folder, all reference materials together in the back of the folder, and all miscellaneous extra papers are not removed. All previous versions must be removed or labeled & fixed together in the back of the folder.

______ [2 each] Correct information in items listed above. ____

____
  - Subtract 2 for every other discrepancy noted but not listed in the above criteria.

Technical Items [95 points and above is passing]

________ [100] Pavement Depths on Form D-4332 structurally adequate.

- Subtract 100 if the pavement depths are not structurally adequate.

________ [5] Frost Heave Calculations. (Section 6.2.B Frost Design; & Table 10.7 SN for Future Traffic)

- Subtract 5 if any erroneous inputs exist.

________ [5] Traffic Data.

- Subtract 5 if the incorrect traffic data was utilized (refer to Chapter 7)

________ [5] Geotechnical recommendation and supporting data.

- Subtract 5 if not present

________ [2 each] Correct DARWin inputs. (Chapters 8, 9, & 10 and supporting info in *Pavement Policy Manual*)

____

____

- Subtract 2 for each erroneous input

Comments:

____

____

____

____

*Items are in reference to Publication 242, *Pavement Policy Manual*, Chapter 6, Sections 6.1.A, When to Do Analysis and 6.1.C, What to Submit. Additional references in Publication 242, *Pavement Policy Manual* are given in parentheses if applicable.

Federal Oversight Pavement Design Quality Assurance Reviews Policy and Procedure

The purpose of the Federal Oversight (FO) Pavement Design Quality Assurance Reviews is to satisfy the Stewardship and Oversight Agreement with the Federal Highway Administration (FHWA) dated August 2012 (Refer to Publication 10X, Design Manual Part 1X, *Appendices to Design Manuals 1, 1A, 1B, and 1C*, Appendix C, FHWA/PennDOT Stewardship & Oversight Agreement). Oversight status is provided with the understanding that PennDOT will provide stewardship over the process to assure compliance with Publication 242, *Pavement Policy Manual*.

After the PME is certified, the District approves FO pavement designs locally and submits directly to FHWA with a concurrent submission to Central Office for Quality Assurance Review. As stated in the PPM, "Certified PME/PM's will recommend approval of Federal Oversight or PennDOT Oversight pavement designs using Form D-4332 to the District Executive (DE) based on sound engineering principles and conformance to Publication 242, *Pavement Policy Manual*." The empowerment granted to the District is based on the premise that all approvals conform to the requirements of Publication 242, *Pavement Policy Manual*. The District does not approve exemptions to Publication 242, *Pavement Policy Manual* on Federal Oversight Projects. Exemptions are the purview of the Central Office and FHWA.

Important items mandated by this letter are:

- Implementation of checklist.
- Implementation of 95 point requirement for technical items.

Each QA review is an audit of the FO pavement design process and the documentation procedures used in the District. In addition to satisfying the Oversight Agreement, the QA review is an opportunity to assess the District's performance and identify areas for improvement.

The QA review tests the District's ability to maintain the proper records throughout the project as part of day to day business practices. A one-time audit provides a good indication of how well the District has followed policies, procedures and guidelines and how these items have been incorporated into daily routine. The only recognizable way of validating District competence is through documentation. Without complete and thorough documentation, there is nothing of any relevance to base a judgment upon.

The following actions are recommended to the District:

- Develop and implement an internal QC process at the District.

- Use the attached checklist to evaluate pavement designs.

- Include the PME in the Final Design Plans check to verify that the Typical Sections match Form D-4332.

- PME should keep spreadsheet of projects designed. Include date of Final Design Plans check and date of letting. This can be used to track designs that may expire before letting.

- Project pavement design files should be kept in an orderly fashion. It is good practice to sort through the file upon approval. Keep all final versions together in the front of the folder. Maintain all reference materials together in the back of the folder and remove all miscellaneous extra papers.

Federal Oversight Pavement Design Quality Assurance Reviews Policy and Procedure

As per Chapter 6, Section 6.1.D.3, the District has previously submitted two copies of the completed pavement design package; one copy was submitted to FHWA for review and one copy was forwarded to BOPD for the Quality Assurance Review (It is required that BOPD is copied on all FHWA correspondence.). BOPD will perform a Quality Assurance Review on selected pavement design projects.

Central Office will contact the PME with questions during the course of the review.

Each design will be scored on two separate criteria: procedural and technical. Each design will be given a base value of 100 points for each criterion. Each design will be scored using the attached checklist. If the design receives a procedural score less than 70 points, the District will not pass the QA. If the District receives a technical score of less than 95 points, the District will not pass the QA.

A memo of the findings for each project review will be issued from the Director Bureau of Project Delivery (BOPD) to the District Executive. A copy of the memo will also be issued to the following: FHWA, ADE Design, Pavement Testing and Asset Management Section Chief and District PME/PM. Annually, the QA team will produce and distribute a report of the findings from all the projects QA reviews throughout the state for that calendar year. It is intended that this report be used by the Districts to compare and examine their processes and to investigate the items that have had the most deviations and work to improve those items. The scores given in the memorandum are final and cannot be affected by after-the-fact information gathering.

If the District does not pass the annual QA, corrective actions will be prescribed in the memo, and a follow-up QA will be scheduled within 6 months. The procedures for the follow-up QA will be the same as the procedures for the project QA.

If the District does not pass the follow-up QA, the District will be notified immediately and re-certification is required. The re-certification process will consist of a half day training for the PME by PDAU staff and submission of all FO pavement designs to BOPD until three projects including at least one design of each surface type (bituminous and concrete) are approved. BOPD will notify the District of re-certification in writing once the three submitted pavement designs are approved.

Pavement Design Quality Assurance/Quality Control Checklist and Score Sheet

Quality Control Checklist:

PME/PM:___________
District: ____________
County: _____________

SR: ___________
Section: _______
ECMS/MPMS #: ______

Date: ________
Project Type:
Pav't Preserv / Rehab / Recon

Instructions: Check the box if the item is provided for review. If the item is not applicable, enter N/A in the space provided.

____ Cover Letter
____ Form D-4332
____ Typical Sections
____ Geotechnical Data with District Geotechnical Engineer's signature
____ LCCA spreadsheet with supporting documentation
____ Special Provisions for unique or experimental pavement and/or materials
____ DARWin Printouts
____ Traffic Data
____ Pavement History

Comments: ____
____
____
____

___________________________________ (Pavement Management Engineer/Project Manager) certifies that the Pavement Design was completed in accordance to Publication 242, and was reviewed for completeness and accuracy. This project is ready to be reviewed by BOPD for Quality Assurance.

TO BE COMPLETED BY PME/PM

--

TO COMPLETE BY BOPD REVIEWER

Quality Assurance Checklist:

Reviewer:___________Date: ______________

Instructions: Check the box if the item is found. If the item is missing or a deviation is found enter the deduction amount in the space provided. If the item is not applicable, enter N/A in the space provided. Procedural and Technical Review each start with 100 points.

Procedural Items [70 points and above is passing]
Found/Actual Points Deducted [Item Value] Item Name and Description. (*Pavement Policy Manual* Reference*)

______ [100] Pavement Design File.
- Subtract 100 if the pavement design file is not available for review

______ [100] Typical Sections match Form D-4332. Pavement Type, Depth, SRL, and ESALs.
- Subtract 100 if any inconsistencies are present

______ [50] Skid Resistance Level (SRL) is not below minimum for ADT (Section 5.7 Providing Friction in Bituminous Wearing Courses & Table 5.4 SRL Criteria)

- Subtract 50 if incorrect SRL is utilized

______ [20] Form D-4332.

- Subtract 20 if Form D-4332 not present

______ [20] DARWin Printout.

- Subtract 20 if all DARWin Printouts are not present

______ [20] Signature of DE and PME on Form D-4332. (Section 6.1.D Procedures: General)

- Subtract 20 if signatures are not present

______ [20] Signature of District Geotechnical Engineer on Geotechnical recommendation. (Section 6.2.A Resilient Modulus)

- Subtract 20 if signature is not present

______ Required Waivers: ________________________________

______

- Subtract 20 for each waiver that was required and not present

______ [5] Pavement Design File organized.

- Subtract 5 if all final versions are not present and all miscellaneous extra papers are not removed. All previous versions must be removed from submission.

______ [2 each] Correct information in items listed above. ________________________________

____

- Subtract 2 for every other discrepancy noted but not listed in the above criteria.

Technical Items [95 points and above is passing]

________ [100] Pavement Depths on Form D-4332 structurally adequate.

- Subtract 100 if the pavement depths are not structurally adequate.

________ [5] Frost Heave Calculations. (Section 6.2.B Frost Design & Table 10.2 SN for Future Traffic)

- Subtract 5 if any erroneous inputs exist.

________ [5] Traffic Data.

- Subtract 5 if the incorrect traffic data was utilized (refer to Chapter 7)

________ [5] Geotechnical recommendation and supporting data.

- Subtract 5 if not present

________ [2 each] Correct DARWin inputs. (Chapters 8, 9, & 10 and supporting info in *Pavement Policy Manual*)

- Subtract 2 for each erroneous input

Comments:

____

____

____

____

*Items are in reference to Publication 242, *Pavement Policy Manual*, Chapter 6, Sections 6.1.A When to Do Analysis and 6.1.C What to Submit. Additional references in Publication 242, *Pavement Policy Manual* are given in parentheses if applicable.

Publication 242 Pavement Design
Quick Reference Guide

DESCRIPTION		RIGID	FLEXIBLE	COMPOSITE	PUB. 242	NOTES
			AC/AC	AC/PCC		
			AC/Fractured PCC	AC/AC/PCC		
Initial Serviceability	MFC **A,B,C,D,E**	4.5	4.2	4.5	Table 6.4, page 6-16	
Terminal Serviceability	MFC **A,B**	3.0	3.0*	3.0	Table 6.4, page 6-16	*flexible - check frost heave Section 9.3
	MFC **C,D**	2.5	2.5*	2.5		
	MFC **E**	2.0	2.0*	2.0		
Reliability	Interstates and Expressways	95			Table 6.5, page 6-17	
	Arterials	90 - 95				
	Collectors	85 - 90				
	Locals	70 - 85				
Overall Standard Deviation		0.35	0.45	0.4	Section 6.5, page 6-17	
SRL	> 20,000 ADT		**E**		Table 5.4, page 5-7	
	5,001-20,000		**H**;E&M;E&G			E&M, etc. = blends
	3,001-5,000		**G**;H&M;E&L			
	1,001-3,000		**M**;H&L;G&L;E&L			
	0-1,000		**L**			
Load Transfer	Tied PCC	2.7-3.1	n/a	2.7-3.1	Table 8.2, page 8-4	
	Curb	3.2	n/a	3.2		
Frost Heave Probability		n/a	25-75%	n/a	Section 9.3, page 9-1	

Highway Design and Technology Section

Last Modified: 5/1/2015

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APPENDIX H

INTERSTATE MANAGEMENT PROGRAM PAVEMENT TREATMENT MATRICES

H.1 DISTRESS EXTENT CALCULATIONS

Extent is defined as the percentage of the segment in which a given distress is present. When the entire segment cannot be surveyed, extent is based on the length, area or the number of slabs/joints that are surveyed.

The surveyed length is less than the segment length when there is a bridge structure, lane closure due to construction, the survey vehicle deviates from the travel lane, or some other reason that disallows a complete segment survey. In these cases, the surveyed length will be reported along with the condition data. The surveyed area is computed by multiplying the surveyed length by the segment width. When any or all of these instances cause the survey length to be less than half of the segment length, then no distress condition data will be reported. When none of these instances occur, survey length equals segment length, and survey area equals segment area.

H.2 TREATMENT MATRICES

The following pages define the treatment matrix for each pavement distress. A separate matrix is defined for each necessary distress severity, and extent limits are defined along the left edge of each matrix.

By entering each treatment matrix with the extent, the appropriate treatment can be determined. As defined above, extent is determined based on either the segment or survey length or area, or the number of slabs or joints for jointed concrete pavement.

For the purposes of Interstate Management, individual treatment types are shown in the matrices, but only the resultant treatment group is used in the assessment of needs and appropriate project type. Each distress is assessed individually, but the "highest" treatment group, based on that determined for each distress is the resultant treatment group. Information shown in "***bold italics***" is revisions from the treatment matrices used in the annual allocation of highway maintenance funds.

H.3 BITUMINOUS PAVEMENT TREATMENT

A. Strategies. The following are the treatments that are required to repair the distresses that are surveyed. Depending on the distresses that are present, multiple treatments may be necessary.

0	Do Nothing
1	Crack Seal
2	Skin Patch
3	Manual Patch
4	Manual Patch, Crack Seal
5	Manual Patch, Skin Patch
6	Mechanized Patch
7	Base Repair, Manual Patch
8	Base Repair, Mechanized Patch
9	Micro Surface/Thin Overlay
10	Resurface
11	Level, Resurface
12	Level, Resurface, Base Repair
13	Mill, Level, Resurface
14	Mill, Level, Resurface, Base Repair
15	Major Rehabilitation/Reconstruction

B. Groups. A treatment group is assigned based on the treatments that have been triggered. If treatments pertaining to different treatment groups are triggered, the highest resulting treatment group is assigned.

Treatment Group:		**Treatment:**
1	Routine Maintenance	1,2,3,4,5,6,7,8
2	Pavement Preservation	9,10,11,12,13,14
3	Major Rehabilitation/Reconstruction	15

INTENTIONALLY BLANK

FATIGUE CRACKING

Extent (% Length)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	***6***	***14***
6 - 10%	0	***6***	***14***
11 - 15%	0	6	***15***
16 - 20%	0	6	***15***
21 - 30%	0	***14***	***15***
31 - 40%	0	***14***	***15***
41 - 50%	0	***14***	***15***
> 50%	0	***14***	***15***

0 – Do Nothing
6 – Mechanized Patch
14 – Mill, Level, Resurface, Base Repair
15 – Major Rehabilitation/Reconstruction

TRANSVERSE CRACKING

Extent (# of Cracks/ ½ mile)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 25	0	0	1
26 - ***44***	0	0	***14***
45 - 50	0	0	***15***
51 - 100	0	***13***	***15***
101 - 150	0	***13***	***15***
151 - 250	0	***13***	***15***
> 250	0	***13***	***15***

0 – Do Nothing
1 – Crack Seal
13 – Mill, Level, Resurface
14 – Mill, Level, Resurface, Base Repair
15 – Major Rehabilitation/Reconstruction

MISCELLANEOUS CRACKING

Extent (% Length)	Treatment		
	Low Severity	Medium Severity	High Severity
0 - 5%	0	0	0
6 - 10%	0	0	***6***
11 - 15%	0	1	***6***
16 - 20%	0	1	***6***
21 - 30%	6	***13***	***13***
31 - 40%	10	***13***	13
41 - 50%	10	***13***	13
> 50%	10	***13***	15

0 – Do Nothing
1 – Crack Seal
6 – Mechanized Patch
10 – Resurface
13 – Mill, Level, Resurface
15 – Major Rehabilitation/Reconstruction

EDGE DETERIORATION

Extent (% Length)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	0	1
6 - 10%	0	0	1
11 - 15%	0	0	7
16 - 20%	0	4	7
21 - 30%	0	4	7
31 - 40%	0	4	7
41 - 50%	0	4	7
> 50%	0	4	7

0 – Do Nothing
1 – Crack Seal
4 – Manual Patch, Crack Seal
7 – Base Repair, Manual Patch

RAVELING/WEATHERING

Extent (% Length)	Treatment	
	Medium Severity	High Severity
0	0	0
>0 - 5%	0	0
6 - 10%	0	6
11 - 15%	0	6
16 - 20%	0	6
21 - 30%	9	13
31 - 40%	9	13
41 - 50%	9	13
> 50%	9	13

0 – Do Nothing
6 – Mechanized Patch
9 – Micro Surfacing/ Thin Overlay
13 – Mill, Level, Resurface

RUT DEPTH

Extent (% Length)	Treatment		
	Low Severity	Medium Severity	High Severity
0		0	0
>0 - 20 %	0	***6***	13
21 - 40 %	0	***13***	13
41 - 60 %	0	***13***	13
> 60%	0	***13***	13

0 – Do Nothing
6 – Mechanized Patch
13 – Mill, Level, Resurface

ROUGHNESS

IRI	Treatment
≤ 100	0
101 - 150	11
151 - 180	11
181 - 210	11
211 - 250	11
251 - 500	11
> 500	11

0 – Do Nothing
11 – Level, Resurface

H.4 JOINTED CONCRETE PAVEMENT TREATMENT

A. Strategies. The following are the treatments that are required to repair the distresses that are surveyed. Depending on the distresses that are present, multiple treatments may be necessary.

0	Do Nothing
1	Joint Seal
2	Crack Seal
3	Spray Patch
4	Mechanized Patch
5	Concrete Patch (Full Depth)
6	Slab Stabilization
7	Slab Stabilization, Diamond Grind
8	Concrete Patch, Diamond Grind
9	Diamond Grind
10	Micro Surface
11	CPR and Overlay
12	Major Rehabilitation/Reconstruction

B. Groups. A treatment group is assigned based on the treatments that have been triggered. If treatments pertaining to different treatment groups are triggered, the highest resulting treatment group is assigned.

Treatment Group:		**Treatment:**
1	Routine Maintenance	1,2,3,4
2	Pavement Preservation	5,6,7,8,9,10,11
3	Major Rehabilitation/Reconstruction	12

Note that composite pavements, with a total bituminous overlay thickness of 2 1/2 inches or less are automatically triggered for Major Rehabilitation/Reconstruction. It is assumed that thin overlays were done as interim measures that did not address the existing concrete pavement condition.

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FAULTED JOINTS

Extent (% Joints)	Treatment	
	Medium Severity	High Severity
0	0	0
>0 - 5%	0	***5***
6 - 10%	0	***8***
11 - 15%	0	***8***
16 - 20%	0	***11***
21 - 30%	***9***	***11***
31 - 40%	***9***	***12***
41 - 50%	***9***	12
> 50%	***9***	12

0 – Do Nothing
5 – Concrete Patch
8 – Concrete Patch, Diamond Grind
9 – Diamond Grind
11 – CPR and Overlay
12 – Major Rehabilitation/Reconstruction

BROKEN SLAB

Extent (% of Slabs)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	***5***	***5***
6 - 10%	0	***11***	***11***
11 - 15%	0	***11***	***12***
16 - 20%	0	11	***12***
21 - 30%	0	12	12
31 - 40%	0	12	12
41 - 50%	0	12	12
> 50%	0	12	12

0 – Do Nothing
5 – Concrete Patch
11 – CPR & Overlay
12 – Major Rehabilitation/Reconstruction

TRANSVERSE JOINT SPALLING

Extent (% of Joints)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	***3***	8
6 - 10%	1	***3***	8
11 - 15%	1	***3***	8
16 - 20%	1	***3***	***11***
21 - 30%	1	***11***	***11***
31 - 40%	1	***11***	***12***
41 - 50%	1	***11***	***12***
> 50%	1	***11***	***12***

0 – Do Nothing
1 – Joint Seal
3 – Spray Patch
8 – Concrete Patch, Diamond Grind
11 – CPR & Overlay
12 – Major Rehabilitation/Reconstruction

TRANSVERSE CRACKING

Extent (% of Slabs)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	***5***	***5***
6 - 10%	0	***11***	***11***
11 - 15%	0	***11***	***12***
16 - 20%	0	***11***	***12***
21 - 30%	0	*12*	12
31 - 40%	0	*12*	12
41 - 50%	0	*12*	12
> 50%	0	*12*	12

0 – Do Nothing
5 – Concrete Patch
11 – CPR & Overlay
12 – Major Rehabilitation/Reconstruction

LONGITUDINAL CRACKING

Extent (% of Slabs)	Treatment		
	Low Severity	Medium Severity	High Severity
0	0	0	0
>0 - 5%	0	***5***	***5***
6 - 10%	0	***11***	***11***
11 - 15%	0	***11***	***12***
16 - 20%	0	***11***	***12***
21 - 30%	0	*12*	***12***
31 - 40%	0	*12*	***12***
41 - 50%	0	*12*	***12***
> 50%	0	*12*	***12***

0 – Do Nothing
2 – Crack Seal

LONGITUDINAL JOINT SPALLING

Extent (% Joints)	Treatment	
	Medium Severity	High Severity
0	0	0
>0 - 5%	3	3
6 - 10%	3	3
11 - 15%	3	3
16 - 20%	3	3
21 - 30%	3	3
31 - 40%	3	3
41 - 50%	3	12
> 50%	3	12

3 – Spray Patch
12 – Major Rehabilitation/Reconstruction

RUT DEPTH

Extent (% Length)	Treatment		
	Low Severity	Medium Severity	High Severity
0		0	0
>0 - 20 %	0	0	10
21 - 40 %	0	0	10
41 - 60 %	0	10	10
> 60%	0	10	10

0 – Do Nothing
10 – Micro Surface

ROUGHNESS

IRI	Treatment
≤ 100	0
101 - 150	9
151 - 180	9
181 - 210	9
211 - 250	9
251 - 500	9
> 500	9

0 – Do Nothing
9 – Diamond Grind

H.5 CONTINUOUSLY REINFORCED CONCRETE (CRC) PAVEMENT TREATMENT STRATEGIES

A. Strategies. Through 2005, there were 8.33 segment miles of pavement with a CRC surface remaining on the Interstate system; 5.12 segment miles on I-180 in Lycoming County, 2.0 miles on I-99 in Blair County, 0.73 segment miles on I-79 in Allegheny County, and 0.48 segment miles on I-476 in Montgomery County. The Interstate Management treatment matrix accounts for CRC Pavements, even though the distress definitions and treatment strategies have not changed since the late 1980's. The revisions developed in the late 1990's and implemented for the 2000-2001 distribution of highway maintenance appropriation funds did not affect CRC Pavements.

The following are the treatments that are required to repair the distresses that are surveyed. Depending on the distresses that are present, multiple treatments may be necessary.

0 Do Nothing
1 Spot Joint Seal
2 Joint Seal
3 Crack Seal
4 Spall Repair
5 Longitudinal Joint Repair
6 CRC Patch
7 Concrete Pavement Patch
8 Replace Terminal Joint
9 Rut Filling
10 Major Rehabilitation

B. Groups. A treatment group is assigned based on the treatments that have been triggered. If treatments pertaining to different treatment groups are triggered, the highest resulting treatment group is assigned.

Treatment Group:		**Treatment:**
1	Routine Maintenance	1,2,3
2	CRC Patching	4,5,6,7,8,9
3	Major Rehabilitation	10

CRC Pavement conditions are defined as values from 0 to 9. 0 represents no distress. The values 1 through 9 define the severity and extent of the distress, as follows:

Severity	Extent			
	None	Low	Medium	High
High		7	8	9
Medium		4	5	6
Low	0	1	2	3

By entering the treatment matrix, shown below, with the distress condition value, the appropriate treatment can be determined. In RMS, an "X" is used to identify all treatments that are triggered by the distress. The distresses are defined along the left edge of the matrix, and the condition values are defined across the top. Some distresses do not have three severity levels; the valid values are shown on the matrix accordingly.

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C. Treatment Matrix.

		Condition Survey Values									
		0	1	2	3	4	5	6	7	8	9
No.	Distress Condition	Recommended Treatment Strategy									
1	Longitudinal Joint Spalling	0	1	2	2	4	4	5	4	5	***10***
2	CRC Transverse Cracking	0	3	3	3	6	***10***	***10***			
3	Punchout	0	3	3	3	6	***10***	***10***	***10***	***10***	***10***
4	Bridge Approaches	0	0	0	0	0	7	7	7	7	7
5	Damaged Terminal Joints	0	0	8	8						
6	Rutting	0	9								

0 – Do Nothing
1 – Spot Joint Seal
2 – Joint Seal
3 – Crack Seal
4 – Spall Repair
5 – Longitudinal Joint Repair
6 – CRC Patch
7 – Concrete Pavement Patch
8 – Replace Terminal Joint
9 – Rut Filling

D. Combined Base Repair/Concrete Patching. The treatment matrices for the various bituminous, jointed concrete, and continuously reinforced concrete (CRC) pavements determine the treatment for each condition individually, not cumulatively. An additional step was added to the matrix to account for the total amount of base repair for bituminous pavements, and patching of concrete pavements that is required to address all of the condition present. The following conditions apply:

1. The following bituminous pavement conditions may trigger base repair:

- **a.** Fatigue Cracking
- **b.** Transverse Cracking

2. The following jointed concrete pavement conditions may trigger patching:

- **a.** Faulted Joints
- **b.** Broken Slabs
- **c.** Transverse Cracking
- **d.** Transverse Joint Spalling

3. The following CRC pavement conditions may trigger patching:

- **a.** Transverse Cracking
- **b.** Punchout

If the sum of all base repair/concrete patching required to address the individual conditions is greater than 10% of the total pavement area, then Major Rehabilitation/ Reconstruction is triggered for the segment. Patching greater than 10% of the pavement area is generally not cost effective or permitted for Pavement Preservation projects. Additionally, if the total required patching plus the total existing patching exceeds 15% of the total pavement area, then Major Rehabilitation/Reconstruction is triggered for the segment.

APPENDIX I

HIGH FRICTION SURFACE TREATMENT USAGE GUIDE

I.1 INTRODUCTION

A High Friction Surface Treatment (HFST) is a thin layer of specially engineered binder resin that is topped with a durable, high friction aggregate (Bauxite). A HFST has exceptional skid-resistance properties, with Skid Numbers of 70 and above, which are not typically acquired by conventional materials. A HFST may be used on both Asphalt and Portland Cement concrete surfaces, and has an anticipated service life of 6 to 8 years.

A HFST is applied to short pavement sections, usually 1,500 feet or less, that exhibit a need for increased pavement friction demand. The HFST can help decrease highway fatalities and serious injuries related to wet pavement crashes at select locations such as curves, intersection approaches, or downgrades where increased vehicle braking is required. A safety evaluation will need to be completed to determine if an HFST is an appropriate treatment.

A HFST can be applied by machine at a similar speed to other paving surface treatments, or applied with hand tools. Mechanized application is the preferred method where possible, as it provides a more consistent distribution of resin and aggregate, leading to a more durable final product. Manual applications should only be used on small sections (less than 300 square yards), where it is not practical to use mechanized equipment. A combination of mechanized or semi-mechanized equipment should be used in most applications with handwork allowed in difficult to reach or with irregular shaped areas.

Refer to and utilize the Department's HFST specification for all HFST work that is implemented.

I.2 SAFETY EVALUATION

When determined (through a safety assessment of roadway crash experience, friction testing, and engineering judgment) that loss of pavement friction is contributing to a higher frequency of wet road crashes, remedial actions should be taken to restore or increase the pavement friction. A HFST is one method used to increase the friction of the pavement surface, and may be utilized on short pavement sections where friction demand is especially critical to motorist performance under wet or icy conditions. Examples of sites where motorists may benefit from a HFST include:

- Curves (and curved ramps) with a history of wet road crashes, where changes to roadway geometry/ superelevation are not possible or too costly. (Note: A HFST should not be used to prevent or remedy heavy truck (high-center of gravity) vehicle overturning.)

- Intersection approaches with a history of wet road crashes, especially at the bottom of downgrades, or where heavy queuing has led to a pattern of intersection crashes.

A HSFT is a medium-cost countermeasure and should be utilized in areas of higher crash occurrence, or where lower-cost countermeasures have proven ineffective.

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I.3 EXISTING PAVEMENT CONDITIONS

A HFST should never be used directly over a structurally inadequate pavement. Pavement distresses should be addressed before applying a HFST, refer to Table I.1, HFST Usage for Asphalt Pavements and Table I.2, HFST Usage for Concrete Pavements for guidance on HFST use for various existing pavement conditions.

Generally, a HFST may be considered for existing pavements where major repairs, overlay, or removal are not anticipated for at least 6 years.

A HFST is not intended as a repair for rutting and will not level pavements.

A HFST is not suitable for placement over the following existing surfaces: slurry surfacing, micro-surfacing, fatted-up & multilayer surface treatments, and surface treatments over soft or unsound bases.

For HFST use on open-graded pavements, a double layer HFST application is necessary.

TABLE I.1
HFST USAGE FOR ASPHALT PAVEMENTS

EXISTING ASPHALT PAVEMENT CONDITION	HFST ALLOWABLE USAGE
Project Length ≤ 1,500 feet	YES
Project Length > 1,500 feet	MAYBE
Low Severity Rutting (1/8 inch or less)	YES
Medium Severity Rutting	NO
High Severity Rutting	NO
Low Severity Fatigue Cracking (hairline or smaller)	YES
Fatigue Cracking	NO
Low Severity Edge Deterioration	YES
Permanent Bituminous Patching (Less than 1%)	YES
Non-Permanent Bituminous Patching	NO
Bleeding	NO
Raveling	NO
Raveling or Weathering	NO

TABLE I.2
HFST USAGE FOR CONCRETE PAVEMENTS

EXISTING CONCRETE PAVEMENT CONDITION	HFST ALLOWABLE USAGE
Project Length ≤ 1,500 feet	YES
Project Length > 1,500 feet	MAYBE
Permanent Concrete Patching	YES
Non-permanent Concrete Patching	NO
Low Severity Cracking (hairline or smaller)	YES
Low Severity Joint Spalling (1 inch or less)	YES
Permanent Concrete Patching	YES
Joint Spalling	NO
Broken Slabs	NO
Faulted Joints	NO

APPENDIX J

DEVELOPING STANDARDS AND SPECIFICATIONS FOR FULL DEPTH RECLAMATION: A BEST PRACTICES GUIDE

EXECUTIVE SUMMARY

This document represents the Best Practices identified and developed for the use of full-depth reclamation of flexible roads. Full Depth Reclamation (FDR) is among the most cost-effective and popular methods of reconstructing deteriorated flexible pavements and unpaved roads. The method is well-suited for low-volume roads, and the best results are obtained if a sound engineering approach is utilized in designing and constructing FDR projects. FDR refers to a specific type of construction in which existing material is pulverized to a specific depth (typically 5 inches to 16 inches), followed by grading and compacting the material to provide a smooth, strong base. Most often the reclaimed material includes base, subbase, or subgrade material requiring mechanical or chemical stabilization of the reclaimed pavement before compaction. The reclaimed material serves as a strong base upon which a hot-mix asphalt overlay or a surface treatment is applied.

J.1 INTRODUCTION

A. The Overall Process. The document provides guidelines for the individual activities that must be accomplished including:

- Determination of the suitability of a road as an FDR candidate;
- Sampling and testing;
- Determination of appropriate FDR techniques and materials;
- FDR mix design development;
- Project planning;
- Project construction and quality control measures; and
- Final surfacing.

The specific details to be followed for each of these steps are discussed so that PennDOT and other users might advance projects using the information provided.

B. Overview of the Categories of FDR. FDR includes the following construction processes. The existing pavement layer materials are pulverized to a 2-inch-minus size by a road reclaimer. Moisture and/or specific stabilizing additives may be added, depending upon the category of FDR employed, to enhance the characteristics of the reclaimed materials, and compacted.

The general categories of FDR available are:

- Pulverization;
- Mechanical Stabilization;
- Asphalt Stabilization;
- Chemical Stabilization; and
- Other Stabilization Methods.

Each of these categories of FDR is discussed in greater detail in Section J.3, Design. The final product is a renewed stabilized pavement base layer with uniform characteristics.

J.2 EVALUATION AND ASSESSMENT OF THE ROADWAY

As with other pavement treatments, it is important that sufficient information about the existing road or pavement materials be in hand when attempting to determine if FDR is a suitable rehabilitation strategy and/or to design a successful FDR project. Initial evaluation and assessment of the existing pavement condition requires conducting the following steps:

- Determination of traffic level;
- Survey of pavement condition;
- In-situ testing; and
- Sampling.

A. Traffic Level. Generally, traffic loading is a significant contributor to most pavement distress. Therefore, it is important to obtain a reliable estimate of traffic projected to use the road during the planned design life. FDR may be applicable for a variety of traffic levels. However, the overall pavement design, including FDR, must be consistent with standard pavement design traffic analysis procedures as described in Publication 242, *Pavement Policy Manual*.

B. Pavement Condition Survey. Having a recent pavement condition survey is important. This is typically carried out by following the procedures provided in Publication 336, *Automated Pavement Condition Survey Field Manual* and in Publication 343, *Continuously Reinforced Concrete and Unpaved Roads Condition Survey Field Manual*. Alternatively, other distress procedures such as those defined in MicroPaver™ or a similar distress evaluation procedure may be used for municipal projects.

The distress survey provides not only information about the present condition of the pavement at the time of survey, but also insight into the causes of visible distresses. Understanding the mechanisms responsible for existing pavement damage is useful for preventing the same damage mechanisms from causing failure of the rehabilitated pavement.

Upon completion of the distress survey, a summary report should be written to document the level of distresses and corresponding observations. The severity of rutting, cracking, raveling, pot holes, and drainage issues should be specifically noted.

C. In-Situ Testing. Beyond visual survey of pavement condition, assessing the in-situ strength of the unbound material, specifically the subgrade upon which the rehabilitated pavement will be residing is important. Two tests are suitable for this purpose: the dynamic cone penetrometer (DCP) and the light weight deflectometer (LWD). In addition, a falling weight deflectometer (FWD) could be used before and after construction to determine pavement strength and uniformity.

1. Falling Weight Deflectometer. Pavement deflection testing provides additional insight into the load-carrying response of a pavement layer system. First, the magnitude of deflection responses provides a relative indication of the strength of the total pavement system. In addition, FWD testing is a quick way to obtain useful information about the uniformity of support, or lack thereof, along the length or across the cross section of a roadway. An understanding of the uniformity of the existing pavement is vital to successfully designing a FDR project.

The pavement deflection response data also provides a useful means of determining in-situ material properties of the various layers within the pavement system. This information is important for design, particularly when mechanistic design methods are used.

One significant benefit of FWD testing is the portability and speed of testing. While some form of traffic control is usually needed when testing an active roadway, the operation can usually be set up as a moving one, minimizing the impact on the traveling public.

2. Dynamic Cone Penetrometer (DCP). The DCP is a simple device for rapid measurement of the in-situ strength of unbound materials. The reference mark is first established once the cone is set to rest on the level flat soil. The DCP is held vertically at the test point and the 17.6-pound hammer is repeatedly raised and then dropped onto the coupling for a drop distance of 22.6 inches. As the 0.75-inch wide, 60° angled cone penetrates into the soil, the number of blows and the penetration depth are recorded. The number of DCP blows per inch (i.e., Penetration Rate) or the rate of penetration DCPI (inches per blow) are correlated with other strength parameters such as California Bearing Ratio (CBR) or resilient modulus.

3. Light Weight Deflectometer (LWD). The LWD is another simple tool for determining in-situ characteristics of the unbound material, specifically the subgrade soil. The 22-pound drop hammer delivers energy to deflect the subgrade under the load plate. Drop weight can be extended to 66 pounds and the drop height could be as high as 33.5 inches. The load plate is flat and circular, and may have diameters of approximately 4 inches or approximately 12 inches. The induced deflection is used by the built-in software to determine the material stiffness or modulus. The resulting modulus is correlated with other strength parameters such as CBR or DCP. The unique advantage of LWD is that it provides an engineering characteristic (material stiffness for design purposes) of the in-situ material through a simple, fast test.

D. Sampling. Proper sampling plays a vital role in the design and construction of FDR. The following criteria must be considered when obtaining samples from the FDR candidate roadway:

- Number of samples and locations of sampling;
- Amount of material to be sampled at each location;
- Techniques of sampling;
- Depth of sampling and identification of layer thicknesses; and
- Handling and evaluation.

1. Number of Samples and Locations of Sampling. The number of samples to be obtained for the project depends on the project size (the project length and the number of lanes in the road section to be reconstructed), the level of subgrade/subbase non-uniformity, and the amount of material needed for laboratory testing. Longer project lengths and high within-project variability require a larger number of road samples. In general, samples should be obtained at 500-foot intervals per lane but under no circumstances should fewer than three samples per lane be obtained for a project. For FDR projects extending longer than 1 mile, sampling could be reduced to one per mile if uniform conditions are observed.

It is best that the sampling locations be selected randomly and without bias, in order to achieve a representative composition of the road section under consideration. If a fixed interval sampling plan is proposed, the reasoning supporting that choice must be justified. An example of fixed interval sampling is establishing the first location, and from there sampling every 1000 feet, or divide the total length by the number of samples and fix the distance between sampling locations. Samples from highly distressed localized areas may not be representative of the whole road section and should be kept separate from other samples. Follow the guidance in PTM No. 1 to determine random sample locations. The location of samples needs to be carefully recorded. Specifically, it should be noted whether the samples are from wheelpath or from non-wheelpath areas.

2. Material Sample Size. Sufficient material must be obtained to conduct the necessary laboratory tests. The amount of material needed must be estimated based on the testing required for initial laboratory work, as well as the follow-up mix design stage. Typically, a test pit provides a large portion of the material needed, but caution should be taken to ensure this material properly represents the job site material. It is desirable to obtain a minimum of 100 pounds of material from each sample location to conduct the lab tests needed for evaluation and design.

3. Sampling Techniques. The objective of the sampling plan is to ensure that the sampled materials are, as nearly as possible, representative of the material which will be later pulverized during construction. Hence, the reclaimed material should be pulverized in the laboratory to get as close as possible to what will be produced through the reclamation process.

If sampling through field pulverization is not possible, standard borings and test pits should be utilized. The asphalt layer can be cored, saw-cut, or removed using hand tools such as picks and shovels. This material is later broken down to finer sizes through laboratory oven heating and hand manipulation, or broken down using a laboratory jaw crusher. The subbase/subgrade material can be sampled through a 4-inch auger drill.

At least one sample should be taken from a test pit. The test pit could be excavated at the shoulder or on the road. The pit should be at least 3 feet by 3 feet - 3 feet by 5 feet being optimal - with the depth of excavation established as noted below in Section J.2.D.4. As material is excavated, it should be maintained in an orderly fashion to facilitate logging of the material. Photographs of test pits can also be very helpful to document findings, and should be used as necessary.

All borings and test pit excavations shall be properly backfilled upon completion.

4. Depth of Sampling and Identification of Layers. Samples should be obtained from all layers expected to be reclaimed (asphalt, base, and possibly subgrade). The depth of sampling for both standard borings and test pits should be 1.5 times the estimated depth of pulverization. The actual depth of pulverization will likely not be known, so 1.5 times the estimated depth should assure excavation of the material needed for the sample. Several testing iterations may be necessary to determine the required sampling depth. It is best if the material from different layers is kept separate, with the expectation that they will be proportionally blended in the lab, especially if the depth of reclamation is not known.

5. Handling and Evaluation. Each sample shall be identified with a tag showing: 1) project name, 2) project number, 3) sample type and number, 4) the location or boring from which the sample was obtained, and 5) the depth interval of the sample.

Moisture content samples shall be a minimum of 8 ounces, and shall be stored in airtight containers made of either glass or plastic. Each sample shall be identified with a tag stating: 1) project name, 2) project number, 3) sample type and number, 4) the location or boring from which the sample was obtained, and 5) the depth of the sample. These samples are to be subjected to classification and moisture-density determination.

Description of soil shall include the following, as a minimum:

- Textural classification (such as clayey sand, lean clay, silt, etc.);
- Color;
- Moisture content at the time of testing;
- Relative-density for coarse-grained soils;
- Characteristics of fine-grained soils (liquid limit, plastic limit, shrinkage limit);
- Other descriptive terms relative to identification of the soil and its composition; and
- AASHTO soil classification.

E. Determine Layer Thicknesses and Drainage Conditions. The determination of layer thicknesses and needed drainage improvements are critical to the success of FDR, as with any other well-designed pavement alternative. There are three considerations in selecting a FDR layer thickness. One is the composition of the existing pavement and subgrade materials which could be incorporated into the reclaimed layer. The second is the structural requirement for the pavement based on the traffic projected to use the road during the planned design life and environmental conditions, and the role of the reclaimed layer within the total required pavement cross-section. The practicality of using FDR is, to some degree, determined based upon the thickness of the existing pavement and the character and amount of subgrade material that will be incorporated into the reclaimed layer. The third factor is the structural contribution of the reclaimed layer to the new pavement structure. This can be significantly influenced by the type of FDR process, and the resulting material stiffness achieved. The stiffness contribution of the FDR layer can be characterized for design purposes in several forms including: structural layer coefficient, resilient modulus, elastic modulus, and California Bearing Ratio (CBR).

The construction of a well-drained pavement system is vital to the successful performance of all pavements. The presence of excess water within a pavement structure, including the subgrade material, is one of the most damaging conditions for any pavement. Excess moisture can result in several accelerated damage mechanisms which result in the loss of pavement material integrity and weakening of the pavement structural capacity. Therefore, it is important that any existing drainage problems be identified and corrected prior to constructing the reclaimed pavement layer. Wet subgrade locations should be identified and effective drainage installed before FDR is undertaken. Other water-related damage within the existing pavement layers should be evaluated to determine the source of water, and the problem should be corrected before reclaiming.

F. Evaluate Applicability of FDR. This section discusses the evaluation steps to determine the suitability of FDR for use on a road. Table J.1 provides an indication of when FDR is a suitable rehabilitation strategy, based on pavement surface distresses present. This procedure is the first step in the FDR decision making process. In general, FDR is indicated for use in situations where improvement of the support layers is required. Other strategies are likely to be more effective for surface-related distresses.

TABLE J.1
SELECTION OF FULL DEPTH RECLAMATION (FDR)

PAVEMENT DISTRESS	FDR
Surface Defects	
Raveling	
Flushing	
Low skid resistance	
Deformation	
Corrugations	
Ruts-shallow	
Rutting Deep[1]	X[2,3]
Cracking (Load Associated)	
Alligator	X
Longitudinal	
Wheel Path	X
Pavement Edge	X
Slippage	
Cracking (Non-Load Associated)	
Block (Shrinkage)	X
Longitudinal (Joint)	
Transverse (Thermal)	X
Reflection	X
Maintenance Patching	
Spray	X[4]
Skin	X[4]
Pothole	X
Deep Hot Mix	
Weak Base or Subgrade	X
Ride Quality/Roughness	
General Unevenness	
Depressions (Settlement)	X[5]
High Spots (Heaving)	X[6]

[1] Rutting originating from the lower portion of the pavement (below surface course and including base and subgrade).

[2] The addition of new aggregate may be required for unstable mixes.

[3] The chemical stabilization of the subgrade may be required if the soil is soft, or wet.

[4] In some instances, spray and skin patches may be removed by cold planing prior to these treatments (considered if very asphalt rich, bleeding).

[5] Used if depressions are due to a poor subgrade condition.

[6] Used if high spots caused by frost heave or swelling of an expansive subgrade soil exist.

1. Characterization of the Composition of the Roadway and Selection of the Stabilization Technique. Using the samples collected from the roadway prism; characterize the samples for the physical and mechanical characteristics referenced in Table J.2.

TABLE J.2
MINIMUM SOIL TESTING METHODS

Moisture Content	AASHTO T 265
Sieve Analysis	PTM No. 616
Mechanical and Hydrometer Particle Size Analysis of Soils	AASHTO T 88
Liquid Limit	AASHTO T 89
Plastic Limit	AASHTO T 90
Moisture-Density Relationship	PTM No. 106
Unconfined Compressive Strength	AASHTO T 208
Materials Finer Than No. 200 Sieve	PTM No. 100

The results of these characterization methods should be used in conjunction with Table J.3 to select the appropriate stabilization approach based on material classification type, along with the percent of material passing the No. 200 sieve, plasticity index, and liquid limit.

TABLE J.3
CORRELATION OF STABILIZATION ADDITIVE AS A FUNCTION OF MATERIAL TYPE, PERCENT PASSING NO. 200 SIEVE, AND PLASTIC INDEX

Percent Passing No. 200	Plastic Index	Stabilizer	Soil Type												
			Granular Material								Silt-Clay Material				
											LL < 50			LL ≥ 50	
			Well-graded gravel	Poorly graded gravel	Silty Gravel	Clayey gravel	Well-graded sand	Poorly graded sand	Silty sand	Clayey sand	Silt, Silt with sand	Lean clay	Organic silt/Organic lean clay	Elastic silt	Fat clay, fat clay with sand
			GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	CL	MH	CH
			A-1-a	A-1-a	A-1-b	A-1-b or A-2-6	A-1-b	A-3 or A-1-b	A-2-4 or A-2-5	A-2-6 or A-2-7	A-4 or A-6	A-6	A-4	A-5 or A-7-5	A-7-6
< 12	< 6	Calcium Chloride	☒	☒		☒	☒								
< 25	< 6	Bituminous	☒	☒	☒	☒	☒								
	< 10	Cement	☒	☒	☒	☒	☒	☒	☒	☒					
	> 10	Lime								☒					
> 25	< 10	Cement				☒			☒	☒	☒				
	10-30	Lime								☒		☒		☒	☒
	> 30	Lime + Cement					☒			☒		☒		☒	☒

Combinations of stabilization additives may also be cost-effective under some circumstances. For example, partial replacement of Portland cement with a fly ash material could result in a better material at a lower cost. If Portland cement content is too high, shrinkage cracking may develop. Partial Portland cement replacement with fly ash can mitigate this problem. If Class F fly ash is used, a small amount of activator, typically hydrated lime or calcium chloride, must be combined with the fly ash. Fluidized bed combustion fly ash not meeting AASHTO M 295 has been found to produce a useful blend with Portland cement.

Small contents of hydrated lime or Portland cement, typically 1.5% and 1.0% by weight, respectively, can produce higher early strength and resistance to moisture damage when added to asphalt stabilization.

Hydrated lime or quicklime can be slaked by spreading the material and spraying it with water prior to mixing, or special mixing trucks can be used to prepare a hydrated lime slurry for use in reclamation.

The use of calcium chloride as the stabilizing additive can facilitate compaction and improve strength relative to untreated aggregate.

2. Laboratory Evaluation. Laboratory evaluation should be conducted by an AASHTO Materials Reference Laboratory (AMRL) or Cement and Concrete Reference Laboratory (CCRL) accredited laboratory, depending upon the material being tested and its intended usage. The laboratory evaluation of the existing road materials must include the combined gradation of the material planned for inclusion in the reclaimed layer. During the mix design development, trial configurations of the combined FDR materials will be reviewed for further mix testing. Specific trial batch testing of the proposed FDR materials is, to some degree, dependent upon the stabilization process being considered.

3. Select Appropriate FDR Based on Findings. Based upon the results of work conducted in the previous sections, a determination of the specific FDR processes that may be suitable for the specific roadway should be made. If more than one possible solution is available, other factors such as the desirability of individual processes for the project and potential cost/benefit of the entire roadway treatment, including surfacing, should be considered.

J.3 DESIGN

A formal design protocol should be followed to optimize the performance of the pavement section. The design requirements for FDR are somewhat unique to the stabilization process selected for use. Therefore, each is discussed below with attention to specific related details. The general procedure for all types of FDR involves a determination of the strength potential of the reclaimed material. This is typically measured using unconfined compressive strength, or indirect tensile strength in the case of asphalt stabilization. Strengths are typically measured following 7 days of curing. For all types of reclamation except pulverization stabilization, the gradation of the combined materials of the final mix must be evaluated, as well as the additive types and contents at the optimum moisture content to achieve the required strength. Specific procedures and strength requirements for the various reclamation types are discussed in the following sections. The following standard test procedures apply to this general procedure.

TEST DESIGNATION	TITLE
PTM No. 100	Standard Method of Test for Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
PTM No 616	Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates
AASHTO T 176	Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
PTM No. 106 (AASHTO T 180)	The Moisture-Density Relations of Soils (using a 5.5-pound Rammer and a 12-inch Drop)

A. Pulverization Stabilization. Since only the in-place materials are being reclaimed, the mix design process should assess the strength potential of these materials when re-compacted at optimum moisture content.

The first step in the process is pulverization, which provides the basic operation for all FDR stabilization types. It consists of pulverizing the in-situ pavement layers and blending the predetermined level of underlying material. The layers and materials affected are determined as part of the structure and mix design processes. A specific gradation of the materials being pulverized is accomplished by the reclaimer by controlling the combination of cutting rotor speed, forward machine travel, gradation control beam position, and mixing chamber front and rear door positions. After initial pulverization, the pulverized material is shaped and graded to within 1/2 inch of the lines and grades of the proposed roadway.

After the material is properly sized by pulverization and shaped, moisture may be added to enable the material to be properly compacted. This is best accomplished by adding a predetermined amount of water through the machine's fluid injection system during the blending process. Alternatively, moisture can be applied to the surface at a calibrated rate prior to the first stage of pulverization, but this relies on the pulverization process to uniformly blend the moisture throughout the pulverized material. The use of the fluid injection method provides much better assurance that the well distributed moisture content required to achieve proper compaction exists in the material.

Breakdown compaction takes place immediately behind the reclaimer to achieve a more consistent density throughout the mat. Requirements for compaction equipment may vary with the depth of pulverized material and other characteristics of the pulverized layer because it must provide sufficient energy to achieve compaction. Typical compaction equipment includes a 20-ton vibratory padfoot roller, a pneumatic 20-ton roller, and a padfoot roller for depths 8 inches or greater.

Subsequent to the breakdown compaction, a motor grader is used to establish the final and proper roadway grade and cross slope. The grading process may result in loss of moisture from drying, so water may be added in front of the roller, or by some other approved method. This rolling stage is typically performed using a pneumatic or heavy smooth drum vibratory compactor which can reseat aggregates loosened during grading. Finish rolling follows using a 12- to 14-ton single or tandem static drum roller.

Once compaction has been completed, a fog seal of emulsified asphalt or other sealer may be applied, if needed, to bond particles to the surface and protect the reclaimed layer from traffic and adverse climatic conditions until a new wearing surface is applied.

B. Mechanical Stabilization. This process includes the integration of aggregate material, or RAP material, to improve the gradation of pulverized road materials. In this instance the mix design process will evaluate the incorporation of the appropriate amount and size of aggregate material to achieve the desired gradation and reclaimed strength.

Mechanical stabilization incorporates imported granular materials into the recomposed FDR base layer during the pulverization process. The need for granular material is determined from a gradation analysis of the combined materials of the existing layers. The process can improve the structural integrity of the existing materials by improving the total grading, or can be used to improve the structural stability of in-place material with excess asphalt content.

The introduction of additional granular material during mechanical stabilization can also be used to improve vertical curves, raise the pavement surface elevation, or accomplish widening without reducing layer thickness. Several materials can be used for mechanical stabilization such as crushed aggregate, reclaimed asphalt pavement, or reclaimed concrete pavement. These materials may be introduced into the reclaimed layer by spreading ahead of the pulverization process, or as a blending pass after initial pulverization and shaping. The stabilization material can be uniformly spread by a motor grader or more consistently by mechanical spreaders or paving equipment.

Mechanical stabilization may be used alone or in combination with other asphalt or chemical stabilizing additives.

C. Chemical Stabilization. This type of FDR addresses the addition of wet or dry chemical additives to stabilize the reclaimed material. The predominant chemical stabilizing additives used for FDR include Portland cement (AASHTO M85) or blended cement (AASHTO M240), lime, and fly ash, as well as blends of these materials. Lime kiln dust and other available reactive materials such as fly ash material from the fluidized bed combustion process have been used on a limited basis and are potentially available for use as FDR stabilizing materials. Chemical stabilizing additives may be applied in either dry or slurry form ahead of the reclaimer. The stabilizing additive may also be introduced into the mixing chamber of the reclaimer through a spray bar, when applied in a slurry form.

The strength gain resulting from the addition of chemical additives is largely dependent upon the type of reclaimed material and the type and amount of stabilizers used. The stabilizer type and content should be determined through laboratory testing. In general, an increase in the amount of chemical stabilizer increases strength. However, an excessive amount of stabilizer could result in brittleness and crack susceptibility of the final product. If the reclaimed layer is too brittle, the fatigue life of the pavement will be reduced.

1. Mix Design. Develop appropriate trial mix designs incorporating the in-situ materials, any aggregate for gradation adjustment, and appropriate chemical stabilization materials.

Remove samples of RAP and RAM to the specified depth and perform appropriate testing to establish mix design. Submit mix design and work plan to the District Materials Engineer/District Materials Manager (DME/DMM) for approval 2 weeks before the planned start of work. Provide an approved mix design and work plan to the Department Representative 5 working days before the planned start of work. Approval of the mix design by the DME/DMM is solely for monitoring quality control and in no way releases the Contractor from his responsibilities.

2. Mix Design Development. Samples must be obtained inclusive of the depth to be recycled. Sampled materials must be properly processed and prepared to closely simulate field conditions. The Representative will oversee the analysis of the samples and the following information will be provided to the DME/DMM as part of the mix design.

3. Strength Requirements.

- Portland cement (AASHTO M85) or Blended cement (AASHTO M240) - Make, cure, and test three unconfined compressive strength specimens of FDR material and Portland cement in accordance with ASTM 1633, method A.
    - Wrap the specimens in plastic wrap, seal in an airtight, moisture-proof bag and cure the test specimens for a period of 7 days.
    - The final mix design will use the amount of Portland cement that provides an unconfined compressive strength that meets these criteria: a minimum unconfined compressive strength value of 200 pounds per square inch in 7 days; and a maximum unconfined compressive strength value of 500 pounds per square inch in 7 days for roads that are designed with a minimum of 3 inch pavement overlay.
    - A minimum unconfined value of 300 pounds per square inch in 7 days and a maximum unconfined compressive strength value of 500 pounds per square inch in 7 days are required for roads that are to be surface treated or overlaid with less than 3 inches of pavement. The mix design chemical application rate may be determined by interpolation between compressive strength test results.
- Lime/Fly Ash (L/FA), Lime Pozzolan and combinations thereof - Make, cure, and test three unconfined compressive strength specimens of FDR material and L/FA or Lime Pozzolan in accordance with ASTM 5203, procedure B.
    - Wrap the specimens in plastic wrap, seal in an airtight, moisture-proof bag and cure the test specimens for a period of 7 days at 104°F before testing.

  - For the final mix design, the required amount of L/FA or Lime Pozzolan will be that which provides an unconfined compressive strength that meets these criteria: a minimum unconfined compressive strength value of 200 pounds per square inch in 7 days; and a maximum unconfined compressive strength value of 500 pounds per square inch in 7 days for roads that are designed with a minimum of 3 inch pavement overlay.

  - A minimum unconfined value of 300 pounds per square inch in 7 days and a maximum unconfined compressive strength value of 500 pounds per square inch in 7 days are required for roads that are to be surface treated or overlaid with less than 3 inches of pavement. The mix design chemical application rate may be determined by interpolation between compressive strength test results.

- Mixture - Combine the reclaimed material, aggregates (if necessary), stabilizing additive(s), and water according to the mix design and at the mix design recommended moisture content. If in-place materials are significantly wetter or drier than measured in the mix design, make field adjustments as recommended in the design under the guidance of the Representative and Qualified Technical Representative to obtain a satisfactory stabilized base course.

D. Stabilization Using Chlorides. Similar to pulverization or mechanical stabilization, this process includes evaluation of the addition of calcium or magnesium chloride to the material.

Additional stabilizing additives include calcium chloride and magnesium chloride, resulting in some strength gain from particle cementing. The introduction of calcium or magnesium chloride has the effect of lowering the freezing temperature of the reclaimed material, helping to reduce the damaging effects of cyclic freeze-thaw. Stabilization using calcium chloride has two advantages over pulverization: compactability and resistance to frost damage are improved. Both of these materials use the same construction techniques previously described.

Calcium chloride should generally be applied using a minimum 35% solution at a rate of 0.1 to 0.15 gallon per square yard for each 1 inch of depth reclaimed followed by a fog seal at the rate of 0.25 gallon per square yard.

Magnesium chloride is available in a 30% concentration for FDR applications. The typical amount of magnesium chloride to be used for a 6 inch FDR application is 1.0 gallon per square yard, with the first application at 0.75 gallon per square yard and then a second application at the rate of 0.25 gallon per square yard, followed by a fog seal at the rate of 0.25 gallon per square yard. If a supplier is not listed in Publication 35, *Approved Construction Materials* (Bulletin 15), the use of magnesium chloride may be permissible on a project approval basis.

E. Emulsified Asphalt Stabilization. The addition of asphalt stabilizing additives to the FDR process is identified by the term asphalt stabilization. The addition of asphalt stabilizing materials to the pulverized layer can increase the stiffness of the layer, and improve resistance to water-related damage. This product could, depending upon the design details, provide improved fatigue resistance to loading as compared with other stabilizing materials. These guidelines are also available in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27).

Two separate processes can be classified as asphalt stabilization: conventional stabilization using emulsified asphalt material, and foamed asphalt processes. More study is required before foamed asphalt processes are implemented, so the focus here is conventional stabilization using emulsified asphalt material. In the conventional FDR with emulsified asphalt process, the asphalt additives can be blended into the reclaimed material through the liquid additive injection system. The asphalt material can be added either in a single pass during the pulverization process, or in a multiple-pass operation, which is more suitable for projects where grade and cross-slope adjustments are needed. This is followed by intermediate shaping, and then a pass for blending the stabilizing additives into the pulverized mat. The multiple-step process is useful for achieving a more uniform final reclaimed layer.

Over the years several methods have been developed for disbursing the emulsified asphalt stabilizing material into a moist reclaimed material layer. Most emulsified asphalt used in stabilization consists of approximately 57% to 65% residual asphalt. Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27) specifies several different emulsions approved for reclamation. Publication 37, *Specifications for Bituminous Materials* (Bulletin 25) specifies the percentage of asphalt residue for those particular emulsions. When the water dissipates the emulsified asphalt is said to have broken, at which point the residual asphalt particles revert to a continuous film that coats the reclaimed material particles. The time required for the emulsified asphalt to break is influenced by the following factors:

- Climatic conditions;
- The internal chemical composition and characteristics of the emulsified asphalt;
- Water dissipation by evaporation or absorption by the reclaimed material;
- External pressures from the mixing and compaction processes; and
- The addition of chemical catalyst such as Portland cement or lime can accelerate the breaking process.

Asphalt-stabilized FDR works well with other additives, including granular material and/or Portland cement or lime. The mix design process should evaluate whether the moisture from slurry is feasible for construction. Any water content which is part of a slurry medium must be considered as a part of the total water in the mixtures. In keeping with this concept, it may be necessary to make a field adjustment to the amount of water added in the field if the in-situ moisture condition of the materials to be reclaimed is significantly different from that used during the mix design process. If more or less water is present at the time of reclaiming, the water added during the process should be adjusted to account for this change from the original mix design.

Either bulk tankers or distributor trucks containing emulsified asphalt material can be coupled to the reclaimer using an interlocking push bar and liquid delivery hose connected to the integrated liquid injection system. The pulverizing machine must be equipped with a computerized integral liquid proportioning system capable of regulating and monitoring the liquid application rate relative to depth of cut, width of injection, advance speed, and material density. A less effective alternative is to uniformly spray the emulsified asphalt onto the pulverized material surface and blend it with the reclaimer. Once the liquid emulsified asphalt breaks, breakdown compaction should occur using a padfoot roller, for depths greater than 8 inches, or pneumatic roller, followed by shaping with a motor grader. Intermediate rolling with a pneumatic roller is then carried out. If surface drying is evident, additional surface moisture may be needed during this step. This could be achieved with rollers equipped with a wetting device, or by the direct application of water. Finish rolling should be accomplished using a single- or double-drum vibratory steel wheel roller to eliminate pneumatic tire marks.

Other additives can be used with the asphalt stabilization process to modify existing reclaimed material to make asphalt stabilization a suitable option. The addition of lime or Portland cement can also be used to decrease the cure time, mitigate stripping damage, and improve the retained strength characteristics of the reclaimed material.

1. Mix Design. Remove samples of RAP and RAM to the specified depth and perform appropriate testing to establish mix design. To determine the appropriate or Optimum Moisture Content (OMC) and corresponding Maximum Dry Density (MDD) use ASTM D698. Submit the mix design to the District Materials Engineer/District Materials Manager (DME/DMM) for approval 3 weeks before the planned start of work. Provide an approved mix design and work plan to the Department Representative 5 working days before the planned start of work. Approval of the mix design by the DME/DMM is solely for monitoring quality control and in no way releases the Contractor from his responsibilities.

2. Mix Design Development. Core samples will be obtained inclusive of the depth to be recycled. Sampled materials must be properly processed and prepared to closely simulate field conditions. A Qualified Technical Representative shall analyze the samples and provide the following information as required by the appropriate documents listed in Section J.3.E.3, below, as part of the mix design to the DME/DMM.

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3. Referenced Documents.

TEST DESIGNATION	TITLE
AASHTO T 59	Standard Method of Test for Emulsified Asphalts
AASHTO M 320	Standard Specification for Performance-Graded Asphalt Binder
PTM No. 100	Standard Method of Test for Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
PTM No. 616	Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates
AASHTO T 176	Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
AASHTO T 209	Standard Method of Test for Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt (HMA)
AASHTO T 166	Standard Method of Test for Bulk Specific Gravity of Compacted Hot-Mix Asphalt (HMA) Using Saturated Surface - Dry Specimens
AASHTO T 283	Standard Method of Test for Resistance of Compacted Hot-Mix Asphalt (HMA) to Moisture-Induced Damage
PTM No. 106	The Moisture-Density Relations of Soils (using a 5.5 pound Rammer and a 12-inch Drop)
ASTM D558-04	Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures
ASTM D698	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lb/ft^3)

4. Apparatus. In the design process, use a calibrated gyratory compactor, indirect tensile testing device, balance, oven, and other equipment.

5. Procedure.

a. Check Suitability of FDR Design Using Emulsified Asphalt. Design using emulsified asphalt is applicable for cases where reclaimed material is not excessively fine-grained. Specifically, the amount of material passing the No. 200 sieve must not exceed 25% and plasticity index must not exceed 6. Design suitability should be checked based on the guidance provided in Table J.3.

b. Emulsified Asphalt Selection. Select emulsified asphalt as approved in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27). Publication 37, *Specifications for Bituminous Materials* (Bulletin 25) specifies the percentage of asphalt residue for those particular emulsions. These emulsions are specified with a minimum residue of between 57% and 65% when tested according to AASHTO T 59. The residue should meet AASHTO M 320 requirements for PG 58-22 or PG 58-28, and PG 64-22 or PG 64-28.

c. Requirements of the Reclaimed Material. The existing pavement or any reclaimed asphalt pavement (RAP) material shall be crushed to meet the maximum size requirement. All materials larger than 2 inches in size shall be removed before further processing. The materials shall be blended in the proportions that are representative of the project depth and cross section. The gradation of the composite (blended) reclaimed material shall be determined in accordance with AASHTO T 11 and T 27. If the gradation is deficient, mechanical stabilization should be applied before emulsified asphalt application. Mechanical stabilization includes the incorporation of virgin aggregate to the extent needed to satisfy gradation requirements. The final gradation shall meet the gradation criteria presented in Table J.4.

TABLE J.4
GRADATION REQUIREMENTS

SIEVE SIZE	PERCENT PASSING
2 inches	95
1 3/4 inches	90-95
3/4 inches	80-90
No. 4	30-60
No. 200	0-20

The sand equivalent (SE) test shall be performed and reported in accordance with AASHTO T 176. SE is from the combined materials. SE should not be less than 30%.

d. Selection of Water Content for Design. A modified Proctor compaction shall be conducted in accordance with PTM No. 106 (AASHTO T 180, ASTM D558) to determine the optimum moisture content (OMC) at peak dry density. Matseeerial containing 20% or more passing the No. 200 sieve shall be mixed with target moisture, sealed, and set aside a minimum of 12 hours. All other material shall be set aside a minimum of 3 hours. If a material contains a significant amount of RAP or coarse material and does not produce a well-defined moisture-density curve, then the moisture content shall be fixed at 3%. If a material contains less than 4% passing the No. 200 sieve or if no peak develops with the OMC curve, then fix the moisture content between 2% and 3%.

e. Preparation of Test Specimens. Sufficient samples shall be taken before the addition of water and emulsified asphalt to produce at least 95 ± 5 mm height and 150 mm diameter compacted specimens. Specimens shall be mixed with the required amount of water for 60 seconds before addition of the emulsified asphalt. These specimens shall be allowed to sit sealed as specified in Section J.3.E.5.d. Four emulsified asphalt contents shall be selected. Note: Four emulsified asphalt contents of 3%, 4%, 5% and 6% by weight of total mix are typically used, but other ranges or narrower bands (0.5%) can be selected. Number of specimens shall be produced for each test method in the laboratory at each emulsified asphalt content according to Table J.5.

TABLE J.5
REQUIRED NUMBER OF LABORATORY PREPARED SPECIMENS

TEST	NO. OF SPECIMENS PER EMULSIFIED ASPHALT CONTENT	SPECIMEN STATUS
Maximum Theoretical Specific Gravity	2	Loose
Indirect Tensile Strength, AASHTO T 283	6	Compacted

- Mixing - Aggregate material and emulsified asphalt shall be mixed in a mechanical mixer at a temperature of 68°F to 79°F for 60 seconds.
- Curing - Specimens after mixing shall be cured individually at 104°F for 27 to 33 minutes.
- Other Additives - If other materials are added, such as lime or Portland cement, then they shall be introduced in a similar manner as they will be on the project. For example, if lime is incorporated a day or more before emulsified asphalt addition, then it shall be added to the wet aggregate a day or more before mixing with emulsified asphalt. If lime is incorporated as slurry, then it shall be incorporated as slurry in the laboratory.

Note: In some cases, adding 1% lime or Portland cement would be desirable before adding emulsified asphalt. Whether lime or Portland cement should be added depends on plasticity index and percent material passing the No. 200 sieve.

f. Compaction. Specimens shall be compacted in a gyratory compactor satisfying requirements outlined in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27), Chapter 2, Section 7. Fifty gyrations shall be applied at a temperature of 68°F to 79°F. After the last gyration, 600 kPa pressure shall be applied for 10 seconds. The mold shall not be heated. After compaction, allow 5 minutes for the compacted mix to stabilize before removing from the mold.

- Curing - Specimens shall be cured at 104°F for 72 hours.

g. Volumetric Measurements.

- Gmm - Determine the Maximum Specific Gravity at each emulsified asphalt content in accordance with AASHTO T 209 and modified requirements outlined in Publication 27, *Bituminous Concrete Mixtures, Design Procedures, and Specifications for Special Bituminous Mixtures* (Bulletin 27).

- Gmb - Determine the Bulk Specific Gravity of all compacted specimens at each emulsified asphalt content using AASHTO T 166.

h. Indirect Tensile Strength and Moisture Susceptibility. The six prepared specimens at each emulsified asphalt content shall be tested according to AASHTO T 283, Section 11.

i. Selection of Emulsified Asphalt Content. A design emulsified asphalt content shall be selected to produce a FDR mixture that meets the design criteria in Table J.6. If more than one emulsified asphalt content produces mixtures which meet the criteria, then select the emulsified asphalt content that produces a mixture with the highest indirect tensile strength. The moisture damage resistance of the selected mix must be checked using AASHTO T 283.

TABLE J.6
DESIGN CRITERIA

PROPERTIES	CRITERIA
Indirect Tensile Strength of Control Specimens, min.	45-50 psi at 50 gyrations
Indirect Tensile Strength Ratio, min.	0.7

6. Report. The report for the Job Mix Formula (JMF) shall provide the following information:

- Physical address of the road and project information;
- Performance Grade of the emulsified asphalt residue used in the mix design;
- General description of the materials received, their locations, and sampling procedure;
- Average thickness of hot-mix asphalt;
- Thickness of different layers to be reclaimed;
- Density and optimum moisture content from Proctor compaction;
- Moisture content used in mix design;
- Indirect tensile strength; and
- Level of saturation and conditioned indirect tensile strength.

F. Foamed Asphalt Stabilization. A future research project will be performed to develop use guidelines.

J.4 CONSTRUCTION

The general construction sequence for FDR is similar for all processes. The generic description of work is included under the Pulverization Stabilization category. It is not repeated for each individual process. However, details specific to each individual process are included in the section addressing that specific process.

A. Pulverization Stabilization.

1. Description. This work consists of the in-place pulverization and uniform blending of existing roadway surface materials and a predetermined thickness of underlying material creating a homogenous mixture of reclaimed base material. The work also consists of shaping, finishing, fine grading, and compaction of the reclaimed base material.

2. Material.

a. Reclaimed Material. 95% of the pulverized surface material is required to pass through a 2 inch sieve. Incorporate all reclaimed material into the base.

- Reclaimed Aggregate Material (RAM) - In-situ aggregate material which is incorporated in the base.

- Reclaimed Asphalt Pavement (RAP) - Processed paving material containing asphalt, cement, and aggregates.

b. Composition of Mixture. Remove samples of RAP and RAM to the specified depth and perform the appropriate testing to determine the appropriate or Optimum Moisture Content (OMC) and corresponding Maximum Dry Density (MDD) according to ASTM D698. Submit the results to the District Materials Engineer/District Materials Manager (DME/DMM) for approval at least 3 weeks before commencement of work on the project. Provide the work plan to the Department Representative 5 working days before the start of work. Approval of the results by the DME/DMM is solely for monitoring and quality control and in no way releases the Contractor from his responsibilities.

3. Construction. Use equipment that produces the completed reclaimed base as follows:

a. Equipment.

- Maintain all equipment in a satisfactory operating condition as specified in Publication 408, *Specifications*, Section 108.05(c).

- Reclaimer - Use a self-propelled rotary reclaimer or equivalent machine capable of cutting through existing roadway materials to depths of up to 16 inches, or as required by the design, with one pass. Provide equipment capable of pulverizing the existing pavement, base, and subgrade at a minimum width of 8 feet. The cutting drum must have the ability to operate at various speeds (rpm), independent of the machine's forward travel speed, in order to control oversized material and gradation. Use a machine equipped with a computerized integral liquid proportioning system capable of regulating and monitoring the water application rate relative to the depth of cut, width of cut, and travel speed. Have the water pump on the machine connected by a hose to the supply tanker/distributor, and mechanically or electronically interlocked with the forward movement/ground speed of the machine. Mount the spray bar to allow the water to be injected directly into the cutting drum/mixing chamber. Provide equipment capable of mixing water and the pulverized pavement materials into a homogenous mixture. Keep the cutting drum fully maintained and in good condition at all times throughout the project. Equipment such as road planers or cold-milling machines designed to mill or shred the existing roadway materials rather than crush or fracture them is not permitted.

- Placement Equipment - Motor grader or by another method approved by the Representative.
- Compaction Equipment - Vibratory padfoot roller 40,000-pounds centrifugal force, particularly for depths 8 inches or greater, or Pneumatic Tire Roller 20 ton for breakdown compaction. Single or Tandem steel drum (static) roller 12-14 ton for finish rolling.

b. Weather Limitations. Do not place paving mixtures from November 1 to March 31 unless approved in writing by the District Executive. Do not place mixtures when surfaces are wet or when the air or surface temperature fall, or is anticipated to fall below 40°F within the subsequent required 7-day cure period. Do not perform reclamation in rain, or if rain is anticipated within 2 hours of completion of the work.

TYPE OF STABILIZER	CLIMATIC LIMITATION FOR CONSTRUCTION
Lime, Fly Ash or Lime-Fly Ash	Do not perform work when reclaimed material could be frozen. Air temperature in the shade should be no less than 40ºF and rising. Complete stabilization at least one month before the first forecast temperature drop below freezing. Two weeks minimum of warm to hot weather is desirable after completing the stabilization work.
Portland Cement or Portland Cement with Fly Ash	Do not perform work when reclaimed material could be frozen. Air temperature in shade should be no less than 40ºF and rising. Complete stabilization should be at least one month before the first forecast temperature drop below freezing.
Calcium Chloride	Do not perform work when reclaimed material could be frozen. Air temperature in shade should be no less than 40ºF and rising. Complete stabilization should be at least one month before the first forecast temperature drop below freezing.
Emulsified Asphalt	Do not perform work when reclaimed material could be frozen. Air temperature in the shade should be no less than 59ºF and rising. The curing process for emulsified asphalt stabilization can be affected by very high humidity. Defer work when rain is imminent or when humidity is greater than 80%. Warm to hot, dry weather is preferred for all types of asphalt stabilization involving cold mixtures because of improved binder dispersion and curing.

c. General. FDR consists of a series of steps of reclaiming which includes subgrade material, with typical depths ranging from 5 inches to 16 inches in depth, or as required by the design, with the aggregate base. The motor grader is used to move and place the reclaimed material to the desired longitudinal grade and cross-slope.

d. Compaction. Shape, grade, and compact to the lines, grades, and depth shown on the plans and cross sections. Commence rolling at the low side of the course. Leave 3 to 6 inches from any unsupported edge(s) unrolled initially to prevent distortion. When material is too coarse (more than 20% retained on the 3/4 inch sieve and less than 35% passing the No. 200 sieve, or more than 30% retained on the 3/4 inch sieve) to use these methods, compaction shall be determined based upon non-movement of material under compaction equipment specified in Publication 408, *Specifications*, Section 210.3(a). Compact until pulverized material does not rut under a loaded tri-axle (GVW 75,000 pounds).

e. Finishing. Complete all portions of the pulverization during daylight hours, unless otherwise allowed.

f. Protection. Protect any finished portion of the reclaimed base upon which any construction equipment is required to travel to prevent marring, distortion, or damage of any kind. Immediately and satisfactorily correct any such damage.

g. Surface Tolerance. When directed by the Representative, test the completed base for smoothness and accuracy of grade, both transversely and longitudinally, using suitable templates and straightedges. Satisfactorily correct any 3000-square yard area where the average surface irregularity exceeds 0.5 inch under a template or straightedge, based on a minimum of at least three measurements.

B. Mechanical Stabilization.

1. Description. This work consists of the incorporation of imported granular materials during the pulverization or mixing pass of a FDR project. Provide reclaimed base course manufactured by in-place pulverizing and uniform blending of the existing roadway surface material and any underlying granular material, thus creating a homogenous mixture of reclaimed base material. The work also consists of shaping, finishing, fine grading, and compaction of the reclaimed base material.

2. Material.

a. Aggregate. Publication 408, *Specifications*, Section 703.2 (Type A, B, or C). Add the gradation and quantity to the mix as required to achieve a dense gradation as characterized by the Fuller Power Curve. If required, add Type A or Type B aggregate, based upon Publication 408, *Specifications*, Section 703, to the mix to meet the target gradation.

3. Construction.

a. General. FDR consists of a series of steps that include pulverization and mixing of the existing roadway surface between 5 inches and 16 inches in depth with the aggregate base. Mechanical stabilizers can be spread either ahead of the pulverization pass or incorporated into a blending pass after pre-pulverization and shaping. The motor grader is used to move and place the reclaimed material to the desired longitudinal grade and cross-slope.

b. Compaction. Shape, grade, and compact to the lines, grades, and depth shown on the plans and cross sections after the material has been processed. Maintain material to within ±3% of the optimum moisture content at the time of compaction. Commence rolling at the low side of the course. Leave 3 to 6 inches from any unsupported edge(s) unrolled initially to prevent distortion. Determine in-place density requirements by the construction of at least one control strip under the guidance of a nuclear gauge operator. After each pass of the compaction equipment take a nuclear density reading in accordance with PTM No. 402. Continue compaction with each piece of equipment until no appreciable increase in density is obtained by additional passes. Upon completion of compaction, make a minimum of ten tests at random locations to determine the average in-place density of the control strip. Record and provide the results to the Department Representative.

Compact the mechanically stabilized base to a target density of at least 98% of the density requirements of the control strip. Determine the in-place density in accordance with PTM No. 402 for each 3000 square yard area. If the density of an area is less than the minimum density, but the base course is uniform in texture, stable and otherwise acceptable, try additional compaction. If additional compaction does not achieve the minimum density, complete an additional control strip in order to verify that proper density is being obtained. Take a minimum of five tests at random locations to determine the average in- place density of the control strip. The new minimum density is 98% of the average in-place density from the control strip.

C. Chemical Stabilization.

1. Description. This work consists of pulverizing and mixing a combination of virgin aggregate (if/where specified), reclaimed asphalt pavement, reclaimed aggregate material, and subgrade material to the specified length, width, and depth. Once pulverized, add the chemical stabilizing additives as per Project Mix Design, and mix the materials together to create a chemically stabilized base course. This work also consists of shaping, finishing, fine grading, and compaction of the reclaimed base material.

2. Material.

a. Stabilizing Agent.

- Portland Cement - Publication 408, *Specifications*, Section 701 (3 to 8% by weight)
- Hydrated Lime* - Publication 408, *Specifications*, Section 723 (2 to 6% by weight)
- Fly Ash* - Publication 408, *Specifications*, Section 724.2(a) (6 to 14% by weight)
- Lime Pozzolan - Publication 408, *Specifications*, Section 725 (6 to 8% by weight)

*Hydrated Lime or Fly Ash will not be used as a singular additive but will be used as a combination of the two. This combination shall be referred to as Lime/Fly Ash (L/FA). There are extensive safety concerns about quicklime. Its use may be approved on a project basis, so long as appropriate safety measures are in place.

3. Construction.

a. Equipment. Use equipment that will produce the completed chemical stabilized base as follows:

- Use equipment capable of automatically metering liquids with a variation of not more than ±2% by weight of liquids. Calibrate before use.

b. Pulverization / Shaping. Before the application of any stabilizing additives, pulverize the roadway materials to the depth specified by the project mix design. Adjacent passes of the reclaimer shall overlap by a minimum of 1 foot to ensure that there are no areas of untreated material left in place. Also, adjacent passes of the reclaimer shall occur within 4 hours so that the longitudinal joint does not adjoin material that has set. Follow up with good compaction. Shape to within 3/4 inch of irregularity to the lines, grades, and/or cross-slope of the proposed roadway and compact until no further densification is achieved. Water may be added to the pulverized material to adjust the moisture content to at least Optimum Moisture Content (OMC), but no more than +3% over OMC. Addition of this water can be done through the machine's liquid additive system and/or through top watering. After acceptance by the DME/DMM the additive spreading and mixing will be done as described below.

Additive Application:

- Portland Cement, Lime/Fly Ash (L/FA), Lime Pozzolan and combinations thereof - Upon completion of the pulverization pass the stabilizing additives previously outlined will be applied at the rate established by the DME/DMM approved project mix design. The additive will be accurately and uniformly spread on the pulverized pavement by using an adjustable rate auger/vane type dry additive distributor. The contractor will provide a canvas, 4 square feet or greater as approved for the specific project, and scale to check the application rate of the spreader. Control the application of dry materials to the roadway to prevent an objectionable level of fugitive dust. Dry additive will not be applied when the wind conditions, in the opinion of the Representative, are such that blowing additives become objectionable to traffic or adjacent property owners. Manual and/or gravity (tail gate) spreading of the additives is unacceptable. For heavy applications of Portland cement, such as when the design requires more than 90 pounds per square yard, a two lift system of application may be applied with PennDOT approval on a project basis. If a two lift system is used, the applications should be equally divided. Such an approach may give more control over fugitive dust.

- Lime or Portland Cement Slurry - If slurries are to be used, the distributor and tanker trucks will be equipped with a recirculating pump and/or agitation system to prevent settling of the materials before application.

- Compaction - Shape, grade, and compact to the lines, grades, and depth shown on the plans and cross sections after the material has been processed. The moisture content before compaction must be at or no more than 3% over OMC. Allow the emulsion to break, based upon field observation, before rolling. The emulsion will likely break during a time window of 30 minutes minimum and 90 minutes maximum. Also, the color may change from brown to black. The condition necessary for rolling may be compared to the initial set of a concrete mixture; it will be influenced by field and ambient conditions and assessed on site. Obvious damage to the FDR material will be observed if a roller is placed on it prematurely. Commence rolling at the low side of the course. Leave 3 to 6 inches from any unsupported edge(s) unrolled initially to prevent distortion. Determine the in-place density requirements by the construction of at least one control strip under the guidance of a nuclear gauge operator. After each pass of the compaction equipment take a nuclear density reading in accordance with PTM No. 402. Continue compaction with each piece of equipment until no appreciable increase in density is obtained by additional passes.

  Upon completion of compaction, make a minimum of ten tests at random locations to determine the average in-place density of the control strip. Record and provide results to the Department Representative. Compact the chemically stabilized base to a target density of at least 98% of the average in-place density of the control strip. Determine the in-place density in accordance with PTM No. 402 for each 3000-square yard area. If the density of an area is less than the minimum density, complete an additional control strip in order to verify that proper density is being obtained. Take a minimum of five tests at random locations to determine the average in-place density of the control strip. The new minimum density is 98% of the average in-place density. If it is determined that the contractor is achieving the minimum density with minimum compactive effort, the Representative may require a new control strip to verify or establish a new minimum density. If the completed chemically stabilized base is unacceptable for any reason, do not continue construction until the cause of the deficiency(ies) is determined and corrected. Final compaction must be completed within 4 hours or less of exposure of cement to water.

- Protection of Surface - Protect the surface from drying and apply an asphalt prime coat, or DME/DMM approved equivalent over the entire surface within 24 hours of final compaction of stabilized base. Apply at a rate of 0.4 gallon per square yard. Use emulsified asphalt meeting the requirements of Publication 408, *Specifications*, Section 461.2(a). If using CSS-1H, apply at between 0.06 gallon per square yard and 0.09 gallon per square yard. Where the surface is utilized for maintaining traffic the application of the asphalt material shall be immediately followed by the application of an approved cover aggregate. Moist curing using suitable equipment is also acceptable. Documentation of the work should be maintained.

- Curing - Allow the chemically stabilized base to cure for at least 5 days after final compaction has been completed.

D. Stabilization Using Chlorides.

1. Description. This work consists of the pulverizing and mixing of a combination of virgin aggregate (if/where specified), reclaimed asphalt pavement, reclaimed aggregate material, and calcium chloride to the specified length, width, and depth. This work also consists of shaping, finishing, fine grading, and compaction of the stabilized base material.

2. Material.

a. Stabilizing Additive. Calcium Chloride - Publication 408, *Specifications*, Section 721. Use a minimum of 35% solution at a rate of 0.10 to 0.15 gallon per square yard for every inch of depth.

b. Aggregate. Publication 408, *Specifications*, Section 703.2 (Type A), No. 8, 10, 57, and 67 - Add the gradation and quantity to the mix as required. If required, add Type A or Type B aggregate, based upon Publication 408, *Specifications*, Section 703, to the mix to meet the target gradation.

c. Mixture. Combine the reclaimed material, aggregates (if necessary), and calcium chloride, and water according to the mix design and at the mix design recommended moisture content. If conditions change, make field adjustments as recommended in the mix design under the guidance of the Representative or Qualified Technical Representative to obtain a satisfactory stabilized base course.

3. Construction.

a. Pulverization/Stabilization/Mixing. Pulverize and mix the roadway material to the design specified treatment depth. Thoroughly mix the existing roadway materials together at the design specified treatment depth while surface adding or injecting the design specified amount of calcium chloride to create a homogenous stabilized mixture. Rough grade to desired cross slope and profile. Apply the designed quantity of calcium chloride and liquid to assure proper compaction.

b. Compaction. Shape, grade, and compact to the lines, grades, and depth shown on the plans and cross sections after the material has been processed. The moisture content before compaction should be not less than the OMC and no more than +3% over Optimum Moisture Content (OMC). Allow the mixture to cure as necessary before rolling. Commence rolling at the low side of the course. Leave 3 to 6 inches from any unsupported edge(s) unrolled initially to prevent distortion. Determine the in-place density requirements by the construction of at least one control strip under the guidance of a nuclear gauge operator. After each pass of the compaction equipment take a nuclear gauge density reading in accordance with PTM No. 402.

Continue compaction with each piece of equipment until no appreciable increase in density is obtained by additional passes. Upon completion of compaction, make a minimum of ten tests at random locations to determine the average in-place density of the control strip. Record and provide the results to the Department Representative. Compact the calcium chloride stabilized base to a target density of at least 98% of the average in-place density of the control strip. Determine the in-place density in accordance with PTM No. 402 for each 3,000 square yard area. If the density of an area is less than the minimum density but the base course is uniform in texture, stable, and otherwise acceptable, try additional compaction. If additional compaction does not achieve the minimum density complete an additional control strip in order to verify that proper density is being obtained.

Take a minimum of five tests at random locations to determine the average in-place density of the control strip. The new minimum density is 98% of the average in-place density. If it is determined that the contractor is achieving the minimum density with minimum compactive effort, the Representative may require a new control strip to verify or establish a new minimum density. If the completed calcium chloride stabilized base is unacceptable for any reason do not continue construction until the cause of the deficiency(ies) is determined and corrected.

c. Curing. Allow the calcium chloride stabilized base to cure for at least 5 days after final compaction has been completed. Only light, local vehicular traffic should be permitted during the curing period. Protect the surface from drying. The selection of the most appropriate approach is site specific, depending upon traffic and the planned surface material applications. Options for consideration include the application of a curing membrane, which in the case of an anticipated overlay would be an emulsion, which can include a fog seal, or the daily distribution of water to the surface during the curing period, although the application of water during high humidity may be unnecessary. If water is applied to the surface, be sure to control the runoff of that water.

E. Emulsified Asphalt Stabilization. This work consists of pulverizing and mixing a combination of virgin aggregate (if/where specified), reclaimed asphalt pavement, reclaimed aggregate material, and subgrade material to the specified length, width, and depth. Full depth reclamation will consist of pulverization of the existing pavement layers to the specified depth, treatment with an approved stabilizing material and/or approved other materials, and compaction.

1. Description. Stabilization may be accomplished using a mixture of emulsified asphalt, imported mineral aggregate, and existing roadway material, mixed and proportioned consistent with recommendations of the FDR Best Practices, and approved in the project mix design.

a. Equipment. Provide the necessary equipment to pulverize, blend, shape, and compact the full depth reclamation materials.

- Reclaimer - Provide a self-propelled, traveling rotary reclaimer or equivalent machine capable of cutting through existing roadway material to depths of up to 16 inches with one pass. The equipment will be capable of pulverizing "In-place" the existing pavement, base and subgrade at a minimum width of 8 feet, and mixing any added materials to the specified depth. The cutting drum must have the ability to operate at various speeds (revolutions per minute), independent of the machines forward speed, in order to control oversized material and gradation.
    - Use a machine equipped with a computerized integral liquid proportioning system capable of regulating and monitoring the water application rate relative to depth of cut, width of cut, and speed. Have the water pump on the machine connected by a hose to the supply tanker/distributor, and mechanically or electronically interlocked with the forward movement/ground speed of the machine. Mount the spray bar to allow the water to be injected directly into the cutting drum/mixing chamber. Provide equipment capable of mixing water, dry additives, emulsified asphalt, and the pulverized pavement materials into a homogenous mixture. Keep the cutting drum fully maintained and in good condition at all times throughout the project. Equipment such as road planers or cold-milling machines designed to mill or shred the existing roadway materials rather than crush or fracture it is not allowed.
    - Use equipment capable of automatically metering liquids in the mixture to ensure thorough mixing of the reclaimed materials.
    - Maintain all equipment as specified in Publication 408, *Specifications*, Section 108.05(c).
- Placement Equipment - Motor Grader or by another method approved by the Engineer.
- Compaction Equipment – Vibratory pad-foot roller 40,000-pounds centrifugal force or Pneumatic Tire Roller 20 ton for breakdown compaction. Use single or tandem steel drum (static) roller 12-14 ton for finish rolling.

b. Reclamation.

- Pulverization - Before the application of any stabilizing additives pulverize the roadway materials to the depth specified by the project mix design. Adding Calcium Chloride during pulverization is acceptable.
- Mixing - Combine the reclaimed material, aggregates (if necessary), stabilizing additive(s), and water according to the mix design and at the mix design recommended moisture content. Maintain adequate liquids in the mixture to ensure thorough mixing of the reclaimed material, aggregates, and stabilizing materials. If conditions change, make field adjustments to obtain a satisfactory FDR material.

If calcium chloride is used as an additive, the chemical may be applied during pulverization.

If slurries are to be used, the distributor and tanker trucks will be equipped with a recirculating pump and/or agitation system to prevent settling of the materials before application.

- Finishing - Shape the reclaimed material surface to within 3/4 inch of irregularity to the lines, grades and/or cross-slope of the proposed roadway. Avoid excessively working the chemically stabilized FDR material, which may detrimentally affect the ultimate strength of the stabilized layer.

- Compaction - The moisture content before compaction must be at or no more than 3% over OMC. Allow the mixture to cure as necessary before rolling. Commence rolling at the low side of the course. Leave 3 to 6 inches from any unsupported edge(s) unrolled initially to prevent distortion. Determine the in-place density requirements by the construction of at least one control strip under the guidance of a nuclear gauge operator. After each pass of the compaction equipment take a nuclear density reading in accordance with PTM No. 402. Continue compaction with each piece of equipment until no appreciable increase in density is obtained by additional passes. Upon completion of compaction, make a minimum of ten tests at random locations to determine the average in-place density of the control strip. Record and provide results to the District.

  Compact the reclaimed material to a target density of at least 95% of the average in-place density of the control strip. Determine the in-place density in accordance with PTM No. 402 for each 3000-square yard area. If the density of an area is less than the minimum density, but the base course is uniform in texture, stable and otherwise acceptable, try additional compaction. If additional compaction does not achieve the minimum density, complete an additional control strip in order to verify that proper density is being obtained. Take a minimum of ten tests at random locations to determine the average in-place density of the control strip. The new minimum density is 98% of the average in-place density.

- Curing - The emulsified asphalt stabilized base must undergo curing before application of the chip seal or overlay. The risk of rutting or moisture damage is increased if the overlay is applied prematurely; curing of the base must be complete. If the overlay is applied prematurely, moisture is retained in the base for a prolonged time and the rate of strength gain is reduced. The rate of curing depends on many factors. In favorable weather conditions (no rain, sunshine, low humidity, high temperature), curing can take place at a considerably faster rate. Sufficient curing and strength gain could take from 2 or 3 days to at least 2 weeks depending on the type and amount of materials used and the climatic conditions. Verify by coring or test pit that curing has occurred throughout the full depth of the FDR before the application of an overlay or wearing course.

- FDR should be proof rolled with a vehicle similar to the heaviest vehicle expected in traffic, or base opening on a strength measurement of the FDR, prior to opening to traffic. Same day return to traffic at posted safe speeds is possible. Roadway should be at 50% of the design optimum moisture content or 3% total moisture content, whichever is reached first, prior to overlay. No damage should be apparent at slow speed, less than 10 miles per hour. Otherwise verify strength by testing.

- Protection - Protect completed portions of the reclaimed work from damage by construction equipment. Immediately correct any such damage to the satisfaction of the Engineer.

- Surface Tolerance - When directed by the Representative, test the stabilized base for smoothness and accuracy of grade, both transversely and longitudinally using suitable templates and straightedges. Satisfactorily correct any 3000 square yard area where the average surface irregularity exceeds 0.5 inch under a template or straightedge, based on a minimum of at least three measurements. Provide a minimum surface cross slope of 0.5 inch per foot, or as required by the design.

- Opening to Traffic - In general, the constructed base could be opened to light traffic (vehicles under 5 tons) 2 hours after completion of the base construction, with proof rolling. Limit heavy load traffic to 7 days later. Appropriate traffic signs must be posted to prevent heavy traffic on the constructed base until completion of base curing and application of the overlay, as described above in the discussion of curing.

F. Foamed Asphalt Stabilization. A future research project will be performed to develop use guidelines.

J.5 QUALITY ASSURANCE / PERFORMANCE MEASUREMENT

Quality assurance and acceptance testing should be included in any controlled pavement rehabilitation process. Thorough documentation of all construction activities, application rates, and work progress are important to verifying control of the reclamation process. Documentation should include test strip as well as final project work. Specific quality assurance and acceptance guidelines to be used in conjunction with FDR pavement rehabilitation are discussed in this section.

A. Preliminary Activities.

1. Preconstruction Meeting. A preconstruction meeting should be required for every FDR project undertaken. Participation by everyone involved in the project is important to insure that all activities are identified and responsibilities clearly defined for each.

2. Preconstruction Equipment Check. Prior to starting actual construction work it is important to conduct an operational examination of all equipment to be used on the project, to insure everything is in proper working order. Most importantly, the calibration of the equipment to be used for distribution of the stabilizer material and water to be mixed in during the reclaiming process must be verified.

3. Test Strip Construction. The construction of a preliminary test strip having a minimum length of 300 feet is recommended. The test strip may be part of the final project, or at an alternative site designated beforehand. This test strip construction should be used to perform the following activities:

- Verify application rates for both the stabilization material and water. Use a 4 square foot tarp or greater, as approved, to check the application rate of the stabilization material by spreading on the ground before application and weighing the material collected on the tarp after application.
- Establish a rolling pattern for compaction of the FDR material.
- Verify the density achieved using a nuclear density gage (PTM No. 402).
- Verify the in-situ moisture content of the reclaimed material using the nuclear gage (PTM No. 402) and by drying field samples with a portable burner and weighing on a portable scale. In-situ moisture of the pulverized material should be checked prior to reclamation to determine any deviation of the moisture content from the mix design condition. The water added during reclamation must be adjusted accordingly.

4. Quality Control Measures. Develop a testing plan that includes coring locations and the number of cores needed for testing. Select at least three cores for every 500 feet of application. The testing plan should include the following measures:

- Calibration of stabilizer metering equipment and spreading units
- Verification of stabilizer application rates
- Sampling to ensure proper Portland cement content
- Sampling to ensure proper moisture content
- Measure thickness of pulverization

- Sample pulverized material right before compaction
- Check adequate density is achieved through Nuclear Gauge
- Check adequate curing is achieved
- Coring - Unconfined Compressive Strength

If test results fall outside limits, the District Executive may accept the product to accommodate project conditions.

B. Acceptance Criteria. Full-depth reclamation work will be accepted on the basis of roadway width, depth, smoothness, and seven day unconfined compressive strength for chemical reclamation according to Method B of ASTM D 1633, except using a recommended aspect ratio being 1:1.5 (specimen with diameter of 6 inches and height of 9 inches). For chemical stabilization processes the minimum acceptance strength varies from 200-500 pounds per square inch as specified by the project mix design. Consideration of specimen aspect ratio is very important in determining compliance with these criteria. If a different aspect ratio is used results must be adjusted to reflect consistent strength values. For a test at the aspect ratio of 2, the strength could be increased by 5% and for a test at aspect ratio of 1 or 1.15, strength should be decreased by 5%.

For asphalt stabilization the specimen must achieve minimum indirect tensile test strength of 50 pounds per square inch for acceptance.

The average surface tolerance must be 1/2 inch or less when measured at a minimum of three locations using a 10-foot straightedge. Surface cross slope must comply with the design requirement, or 0.5 inch per foot at a minimum.

Measurement and Payment:

Once the project meets the acceptance criteria, payment may be made on the area, in square yards, of the whole.

J.6 SURFACING

Full-depth reclamation results in the development of a renewed base course layer. The need for additional pavement structure can be determined from the procedures for structural design analysis provided in Publication 242, *Pavement Policy Manual*. Within the PennDOT pavement surface strategies the surfaces most likely to be used following FDR are primarily hot-mix asphalt or seal coat in cases of low truck traffic. The latter could also be an asphalt surface treatment. Factors which should be considered in selecting a surface type following FDR include:

- Character of the road and surrounding development
- Traffic volume
- Heavy truck traffic distribution
- Anticipated design life of the road and the surface prior to the next surfacing
- Additional structural requirements

In general, surface treatments or seal coats are used for lower-volume roads. Either of these can be used following FDR reclamation. It is recommended that for a hot-mix surface a polymer-modified asphalt binder material is applied to the FDR surface prior to paving, but is not required. This will improve the flexibility of the bond response to climatic and traffic loads. For seal coats and surface treatments it is important to determine the absorption characteristics of the FDR surface when designing the emulsified asphalt application rate. If potential surface absorption is not considered it could result in insufficient binder thickness, and consequently inadequate aggregate adhesion. This situation would result in the loss of surface aggregate under traffic. It is also important to determine the absorption level of the aggregate used in seal coat or chip seal application. The emulsified asphalt application rate should take aggregate absorption level into consideration to ensure sufficient coating will be present. These recommendations are intended to result in satisfactory performance of the final road renewal project.

APPENDIX K

ABBREVIATIONS

3R	Restoration, Rehabilitation, and Resurfacing
AASHO	American Association of State Highway Officials, so-named until 1972,when it was changed to AASHTO
AASHTO	American Association of State Highway and Transportation Officials
AASHTOWare®	AASHTO Software
AC	asphaltic concrete, also known as flexible pavement
AC/PCC	asphalt concrete over Portland cement concrete, also known as composite pavement
ADA	Americans with Disabilities Act
ADE	Assistant District Executive
ADT	average daily traffic
ADTT	average daily truck traffic
AHT	average hourly traffic
ATPBC	asphalt treated permeable base course
BCOA	Bonded Concrete Overlay on Asphalt Pavement
BCOA-ME	Bonded Concrete Overlay of Asphalt Mechanistic-Empirical Design Procedure
BC Standards	Bridge Construction Standards
BOPD	Bureau of Project Delivery
BOMO	Bureau of Maintenance and Operations
BPR	Bureau of Planning and Research
bor.	borough
CABC	cement aggregate base course
CBR	California Bearing Ratio
CDART	Crash Data Access Retrieval Tool
CN	construction number
CO, C.O.	Central Office
Coeff.	coefficient
CPR	concrete pavement restoration
CRC(P)	Continuously Reinforced Concrete (Pavement)
CTPBC	cement treated permeable base course

DARWin®	Pavement Design, Analysis, and Rehabilitation for Windows Software
DCP	Dynamic Cone Penetration
DE	District Executive
DEP	Department of Environmental Protection
DFV	Design Field View
DG	dense-graded
DGE	District Geotechnical Engineer
DME	District Materials Engineer
DPN	Defense Priority Network
ENR	*Engineering News-Record*
ESALs	equivalent single-axle loads
EUAC	equivalent uniform annual cost
FAI	Federal-Aid Interstate
FAP	Federal-Aid Primary
FAS	Federal-Aid Secondary
FCB	Federal Critical Bridge
FDR	Full Depth Reclamation
FG	Fine Grade
FHWA	Federal Highway Administration
FO	Federal Oversight/Functionally Obsolete
ft	foot, feet
FWD	Falling Weight Deflectometer
HES	high early strength
HMA	Hot Mix Asphalt
HOP	Highway Occupancy Permit
HPMS	Highway Performance Monitoring System
HSE	Highway Safety Engineer
IM	Interstate Maintenance/Interstate Management
in.	inch(es)
IRI	International Roughness Index
ITS	Intelligent Transportation System
J	Joint load transfer coefficient

JPCP	jointed plain concrete pavement
JRCP	jointed reinforced concrete pavement
kip	unit of force that equals 1,000 pounds-force
LCCA	Life-Cycle Cost Analysis
M_r	resilient modulus
MPT	Maintenance and Protection of Traffic
MECE	Maintenance Efficiency and Cost Effectiveness
MFC	Maintenance Functional Code
MPMS	Multimodal Project Management System
MPO	Metropolitan Planning Organization
NCHRP	National Cooperative Highway Research Program
NECEPT	Northeast Center of Excellence for Pavement Technology
NEPP	Non-Expressway Pavement Preservation
NTPEP	National Transportation Product Evaluation Program
NHS	National Highway System
OPI	Overall Performance Index
PCC	Portland cement concrete
PTCP	prestressed, post-tensioned concrete pavement
PDAU	Pavement Design Analysis Unit
PennDOT	Pennsylvania Department of Transportation
PG	Performance Grade
PM	Preventive Maintenance or Pavement Manager
PME	Pavement Management Engineer
PMS	Pavement Management System
PMAC	Polymer Modified Asphalt Cement
PPG	Pavement Preservation Guidelines
PPM	Pavement Policy Manual
PO	PennDOT Oversight
PS&E	Plans, Specifications, & Estimate
psi	pounds per square inch
PSI	Present Serviceability Index
PSR	Present Serviceability Rating

PSU	Pennsylvania State University
PSY, psy	pounds per square yard
PTC	Pennsylvania Turnpike Commission
PTI	Pennsylvania Transportation Institute
PTM	Pennsylvania Test Method
PW	Present Worth
QA	Quality Assurance
RAP	Recycled Asphalt Pavement
RAS	Recycled Asphalt Shingles
RCC	Roller Compacted Concrete
RC Standards	Roadway Construction Standards
RMS	Roadway Management System
RPO	Rural Planning Organization
RPS	Restricted Performance Specifications
SAM	Stress-Absorbing Membrane
SAMI	Stress-Absorbing Membrane Interlayer
SAS	Statistical Analysis Software
SEG	segment
SF	square foot, square feet
SN	structural number
SOI	State Of the Interstate
SOL	Strike-off letter
SR	state route
SRI	Smooth Roads Initiative
SRL	Skid Resistance Level
ST	semi-trailer, single trailer
STAMPP	Systematic Technique to Analyze and Manage Pennsylvania's Pavements
SU, S.U.	single unit
SY, sy	square yard(s)
TIP	Transportation Improvement Program
TPBC	Treated Permeable Base Course
TPG	traffic pattern group

T.R.	traffic route
TRB	Transportation Research Board
TSI	Terminal Serviceability Index
twp.	Township
UTFC	Ultra-thin Friction Course
VE	Value Engineering
WMA	Warm Mix Asphalt
WPAC	Wet Pavement Accident Cluster
WZTC	Work Zone Traffic Control

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APPENDIX L

GLOSSARY

18-kip Equivalent Single-Axle Loads - The axles of all vehicles in the ADT converted to an equivalent number of 18-kip (18,000 pound) single-axle loads.

18-kip Single-Axle Load Equivalent - The AASHO Road Test measured performance of a pavement section subjected to axle-load repetitions of a specific type and weight. Thus, the direct application of data from the AASHO Road Test for use in the design of normal highway pavements was impossible due to the diversified axle types (single, tandem) that occur on highways. A mixed traffic flow theory was developed that related the effects on pavement performance of various axle weights to a single axle weight.

The procedure used in this manual to convert a mixed traffic stream of different axle loads and configurations into a design traffic number is to convert each expected axle load into an equivalent number of 18-kip single-axle loads. The load equivalency factors are based on records obtained from Truck Weight Stations throughout the State.

Bearing Capacity - The maximum average load per unit area that will not produce failure by rupture of the supporting soil, or produce excessive settlement.

California Bearing Ratio (CBR) - The percentage of the penetration resistance of material as related to the standard value of crushed stone. These values will be determined in accordance with Pennsylvania Test Method 113.

Compressive Strength (F'_c) - The maximum load per unit area in compression.

Construction Number (CN) - An evaluation of the relative strength of a flexible pavement structure expressed as a relationship between the thickness of a component layer and the type of material used in constructing the layer. The construction number shall be equal to or greater than the structural number obtained from the design procedure. The general equation for this relationship is $CN = a_1D_1+a_2 D_2+a_3D_3$, where a_1, a_2, and a_3 are coefficients of relative strength and D_1 is thickness of bituminous surface course (inches), D_2 is thickness of base course (inches), and D_3 is thickness of subbase course (inches).

Continuously Reinforced Concrete Pavement (CRCP) - A cement concrete pavement in which the longitudinal reinforcing steel is continuous for its length, and no transverse joints, other than construction joints, are installed. The pavement develops seemingly uncontrolled and random transverse cracks. The principle of design for this pavement type is to provide sufficient reinforcement to keep the cracks tightly closed, maintaining the aggregate interlock for load transfer.

Design Freezing Index - The freezing index that represent the coldest freezing season in 10 years or the average of the three coldest seasons in 30 years.

Equivalent Uniform Annual Cost - Distributes all cost associated with a particular rehabilitation strategy uniformly over the analysis period.

Flexible Pavement Structure - A layered system designed to distribute concentrated traffic loads through the component layers without excessive deformation of the subgrade. It usually consists of a bituminous surface course, one or more base courses, and a subbase course.

Flexural Strength - The maximum bending or flexure stress.

Freezing Index - A measure of the combined duration and magnitude of below-freezing temperatures during a freezing season, and a measure of the depth of frost penetration.

Geosynthetics - Materials, such as geotextiles and geogrids, not subject to biological and chemical degradation, used in construction.

Geotextiles - Geosynthetic support and filter fabrics that are placed in contact with the soil to stabilize and retain it. (e.g., filter cloth, reinforcing fabric, and support membranes)

Heavy Duty Membrane - Material placed over transverse and longitudinal joints and random cracks in existing concrete pavements (refer to Publication 408, *Specifications*, Section 467).

Jointed Plain Concrete Pavement (JPCP) - A rigid pavement that uses contraction joints to control cracking and does not use any reinforcing steel. Transverse joint spacing is typically 15 feet so that temperature and moisture stresses do not produce intermediate cracking between joints.

Jointed Reinforced Concrete Pavement (JRCP) - A rigid pavement that uses contraction joints and reinforcing steel to control intermediate cracking. Transverse joint spacing is typically 30 feet or longer. This rigid pavement design option is generally only used when matching existing pavements on widening projects.

Mechanized Bituminous Patches - Mechanized patching intended to repair small areas of severe weathering or raveling, block cracking and multiple shallow potholed areas. Refer to Publication 23, *Maintenance Manual*, Chapter 7 for additional information.

Modulus of Rupture (S_c) - The maximum tensile or bending stress at the instant of failure. For use in rigid design, the Modulus of Rupture for concrete has been determined to be a percentage of the flexural strength.

Nondestructive Testing - Tests performed on the pavement to measure such things as friction, ride, and deflection. These tests do not damage the pavement when they are performed.

Performance - The overall appraisal of the serviceability history of a pavement. It is the trend of serviceability with repetitive load applications.

Present Serviceability Index (PSI) - A number derived by a formula for estimating the serviceability rating of a pavement. It is an indication of the overall serviceability measured at a given time. The values range from 0 to 5.

Present-Worth Cost - The equivalent lump sum value now of all costs over a selected analysis period associated with a particular rehabilitation strategy.

Resilient Modulus (M_r) - The resilient modulus is a measure of the elastic property of soil recognizing certain nonlinear characteristics.

Rigid Pavement Structure - A PCC pavement. Since the modulus of elasticity of the concrete slab is much greater than that of the foundation material, a major portion of the load-carrying capacity is derived from the slab itself; this has been referred to as beam action. A subbase course is usually provided beneath the PCC layer to provide frost protection and to facilitate drainage of subsurface water.

Roller Compacted Concrete - A well graded aggregate cementitious material that combined with water can be placed with asphalt-type pavers equipped with a standard or high density screed.

Serviceability - The ability of a pavement to serve traffic at any given time.

Single-Axle Load - The total load transmitted by all wheels whose centers are 40 inches apart or less.

Structural Number (SN) - A design index number derived from the analysis of traffic and subgrade soil conditions.

Terminal Serviceability Index (TSI) - The level of performance or condition at which a pavement is no longer considered adequate to serve the needs of its users.