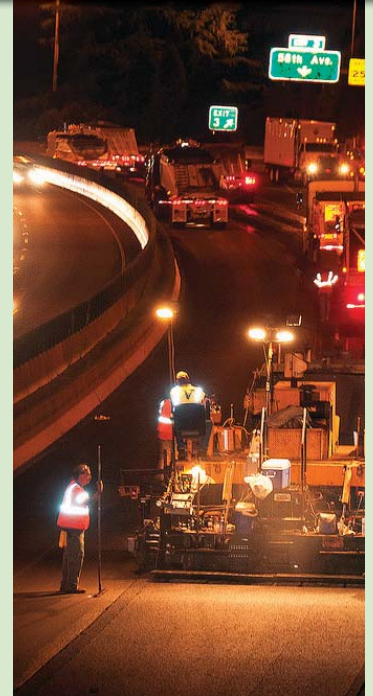


Mechanistic-Empirical Pavement Design Guide

~ *A Manual of Practice* ~

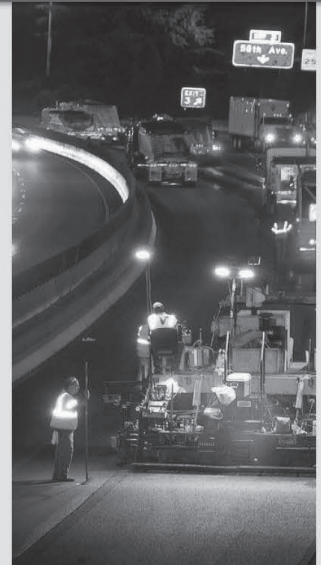


August 2015 • Second Edition



Mechanistic-Empirical Pavement Design Guide

~ A Manual of Practice ~



August 2015 • Second Edition

AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO

© 2015, by American Association of State Highway and Transportation Officials. All rights reserved. This book, or parts thereof, may not be reproduced in any form without written permission of the publisher. Printed in the United States of America.

Publication Code: MEPDG-2

ISBN: 978-1-56051-597-5

**AMERICAN ASSOCIATION OF STATE HIGHWAY
AND TRANSPORTATION OFFICIALS
EXECUTIVE COMMITTEE
2015/2016**

Voting Members

Officers:

President: John Cox, Wyoming

Vice President: Paul Trombino, Iowa

Secretary-Treasurer: Carlos Braceras, Utah

Regional Representatives:

REGION I: Sue Minter, Vermont, One-Year Term
Leslie Richards, Pennsylvania, Two-Year Term

REGION II: John Schroer, Tennessee, One-Year Term
Paul Mattox, West Virginia, Two-Year Term

REGION III: Mike King, Kansas, One-Year Term
Charles A. Zelle, Minnesota, Two-Year Term

REGION IV: Malcom Dougherty, California, One-Year Term
Brian Ness, Idaho, Two-Year Term

Nonvoting Members

Immediate Past President: Mike Hancock, Kentucky

AASHTO Executive Director: Bud Wright, Washington, DC

2015/2016

JOINT TECHNICAL COMMITTEE ON PAVEMENTS

Chair

Judith Corley-Lay
Pavement Analysis Engineer
North Carolina

Vice Chair

John Donahue
Construction and Materials Liaison Engineer
Missouri

MEMBERS:

Bill Farnbach
Chief, Office of Pavement Engineering
California

Zamora Richard
Branch Manager, Project Development
Colorado

Robin Davis
Pavement Design Engineer
Delaware

Chris Brakke
Pavement Design/Management Engineer
Iowa

Greg Schieber
Geotechnical Engineer
Kansas

Paul Looney
Pavement Branch Manager
Kentucky

Jeffery Lambert
Pavement Design Engineer
Louisiana

Richard Bradbury
Director of Materials Testing and Exploration
Maine

Edmund Naras
Pavement Engineer
Massachusetts

Curtis Joel Bleech
Pavement Operations Engineer
Michigan

Curt Turgeon
Pavement Engineer
Minnesota

Thomas Booth
Director, Aeronautics
Mississippi

Wes Yang
Engineering Research Specialist
New York

Aric Morse
Assistant Pavement Engineer
Ohio

Jeff Dean
Pavement Engineer
Oklahoma

Cole Mullis
Pavement Services Engineer
Oregon

Jeff Uhlmeyer
State Pavement Engineer
Washington State

Thomas Medvick
Pavement Engineer, Materials Division
West Virginia

OTHER

American Association of State Highway and Transportation Officials
Vicki Schofield
Project Manager, AASHTOWare

Federal Highway Administration
Gary Crawford
Concrete Pavement Engineer

Transportation Research Board
Amir Hanna, Senior Program Officer
James Bryant

PREFACE

This document describes a pavement design methodology that is based on engineering mechanics and has been validated with extensive road test performance data. This methodology is termed mechanistic-empirical (M-E) pavement design, and it represents a major change from the pavement design methods in practice today.

Interested agencies have already begun implementation activities in terms of staff training, collection of input data (materials library, traffic library, etc.), acquiring of test equipment, and setting up field sections for local calibration. This manual presents the information necessary for pavement design engineers to begin to use the MEPDG design and analysis method.

This manual refers to AASHTOWare Pavement Me Design™, M-E Pavement design software which is commercially available through AASHTOWare, AASHTO's software development program (see <http://www.aashtoware.org/Pavement/Pages/default.aspx>). AASHTOWare Pavement ME Design has been revised from the software described in the previous edition of this manual based upon evaluations performed by state Departments of Transportation and others in the community of practice.

The following table summarizes the key differences noted between the format and calibration factors used in the MEPDG version 1.1 software and the AASHTOWare Pavement ME Design software.

Table i-1. Summary of Key Differences in Software Format and Calibration Factors

Format and Calibration Factors	MEPDG Version 1.1	AASHTOWare Pavement ME Design
Output Format	Excel-based	PDF- and Excel-based
Climatic Data in Output Summary	Not included	Included
Axle Configuration Data in Output Summary	Not included	Included
Special Axle Load Configuration	Included	Not included
Reflection Cracking	Not included	Included
Coefficient of Thermal Expansion (CTE)	CTE for Basalt of 4.6	CTE for Basalt of 5.2
PCC Zero Stress Temperature	PCC Zero Stress Temperature (Range 60° to 120°F)	PCC Set Temperature (Range 70° to 212° F)
Heat Capacity of Asphalt Pavement	Default value of 0.23 BTU/lb-°F	Default value of 0.28 BTU/lb-°F
Thermal Conductivity of Asphalt Pavement	Default value of 0.67 BTU/(ft)(hr)(F)	Default value of 1.25 BTU/(ft)(hr)(F)
Surface Shortwave Absorptivity	Default value of 0.95	Default value of 0.85
Global Calibration Coefficient for Unbound Materials and Soils in Flexible Pavement Subgrade Rutting Model	k_{s1} granular of 1.63	k_{s1} granular of 2.03
Global Field Calibration Coefficients in the Fatigue Cracking Prediction Model in Flexible Pavement	k_p of -3.9492	k_p of 3.9492
	k_f of -1.281	k_f of 1.281
Global Field Calibration Coefficients in the Thermal Cracking Model for HMA	k_t (Level 1) of 5.0	k_t (Level 1) of 1.5
	k_t (Level 2) of 1.5	k_t (Level 2) of 0.5
	k_t (Level 3) of 3.0	k_t (Level 3) of 1.5
Global Field Calibration Coefficients in the Rut Depth Prediction Model	k_{2r} of 0.4791	k_2 of 1.5606
	k_{3r} of 1.5606	k_3 of 0.4791
Calibration Coefficients in the Rigid Pavement Faulting Prediction Model	C_1 of 1.29	C_1 of 1.0184
	C_2 of 1.1	C_2 of 0.91656
	C_3 of 0.001725	C_3 of 0.0021848
	C_4 of 0.0008	C_4 of 0.0008837
	C_7 of 1.2	C_7 of 1.83312
Calibration Coefficient in the Rigid Pavement Punchout Prediction Model	A_{PO} of 195.789	C_3 of 216.8421
	α_{PO} of 19.8947	C_4 of 33.15789
	β_{PO} of -0.526316	C_5 of -0.58947

TABLE OF CONTENTS

1. Introduction	1
1.1 Purpose of Manual	1
1.2 Overview of the MEPDG Design Procedure	1
2. Referenced Documents and Standards	11
2.1 Test Protocols and Standards	11
2.2 Material Specifications	13
2.3 Standard Practices and Terminology	13
2.4 Referenced Documents	13
3. Significance and Use of the MEPDG	17
3.1 Performance Indicators Predicted by the AASHTOWare Pavement ME Design	17
3.2 MEPDG General Design Approach	18
3.3 New Flexible Pavement and HMA Overlay Design Strategies Applicable for Use with AASHTOWare Pavement ME Design	20
3.4 New Rigid Pavement, PCC Overlay, and Restoration of Rigid Pavement Design Strategies Applicable for Use with AASHTOWare Pavement ME Design	23
3.5 Design Features and Factors Not Included Within the MEPDG Process	26
4. Terminology and Definition of Terms	29
4.1 General Terms	29
4.2 Hierarchical Input Levels	31
4.3 Truck Traffic Terms	31
4.4 Smoothness	32
4.5 Distress or Performance Indicator Terms—HMA-Surfaced Pavements	32
4.6 Distress or Performance Indicator Terms—PCC-Surfaced Pavements	33
5. Performance Indicator Prediction Methodologies—An Overview	35
5.1 Selecting the Input Levels	35
5.2 Calibration Factors Included in AASHTOWare Pavement ME Design	37
5.3 Distress Prediction Equations for Flexible Pavements and HMA Overlays	37
5.4 Distress Prediction Equations for Rigid Pavements and PCC Overlays	53
6. General Project Information	69
6.1 Design/Analysis Life	69
6.2 Construction and Traffic Opening Dates	69
7. Selecting Design Criteria and Reliability Level	71
7.1 Recommended Design-Performance Criteria	71
7.2 Reliability	72
8. Determining Site Conditions and Factors	75
8.1 Truck Traffic	75
8.2 Climate	81

8.3	Foundation and Subgrade Soils	82
8.4	Existing Pavements	83
9.	Pavement Evaluation for Rehabilitation Design	85
9.1	Overall Condition Assessment and Problem Definition Categories.	85
9.2	Data Collection to Define Condition Assessment.	89
9.3	Analysis of Pavement Evaluation Data for Rehabilitation Design Considerations.	103
10.	Determination of Material Properties for New Paving Materials.	109
10.1	Material Inputs and the Hierarchical Input Concept	109
10.2	HMA Mixtures; Including SMA, Asphalt-Treated or Stabilized Base Layers, and Asphalt Permeable-Treated Base Layers.	109
10.3	PCC Mixtures, Lean Concrete, and Cement-Treated Base Layers	116
10.4	Chemically Stabilized Materials; Including Lean Concrete and Cement-Treated Base Layers	116
10.5	Unbound Aggregate Base Materials and Engineered Embankments	123
11.	Pavement Design Strategies	129
11.1	New Flexible Pavement Design Strategies—Developing the Initial Trial Design	129
11.2	New Rigid Pavement Design Strategies—Developing the Initial Trial Design	136
12.	Rehabilitation Design Strategies	143
12.1	General Overview of Rehabilitation Design Using the AASHTOWare Pavement ME Design	143
12.2	Rehabilitation Design with HMA Overlays	145
12.3	Rehabilitation Design with PCC Overlays.	164
13.	Interpretation and Analysis of the Results of the Trial Design	181
13.1	Summary of Inputs for Trial Design	181
13.2	Reliability of Trial Design.	181
13.3	Supplemental Information (Layer Modulus, Truck Applications, and Other Factors)	183
13.4	Predicted Performance Values	184
13.5	Judging the Acceptability of the Trial Design.	185
 Abbreviations And Terms		
	Abbreviations.	189
	Terms	191
 Index		
	Index	195

LIST OF FIGURES

1-1	Conceptual Flow Chart of the Three-Stage Design/Analysis Process for the AASHTOWare Pavement ME Design	3
1-2	Typical Differences Between Empirical Design Procedures and an Integrated M-E Design System, in Terms of HMA-Mixture Characterization	4
1-3	Typical Differences Between Empirical Design Procedures and an Integrated M-E Design System, in Terms of PCC-Mixture Characterization	5
1-4	Flow Chart of the Steps That Are More Policy Decision-Related and Are Needed to Complete an Analysis of a Trial Design Strategy	7
1-5	Flow Chart of the Steps Needed to Complete an Analysis of a Trial Design Strategy	8
3-1	New (Including Lane Reconstruction) Flexible Pavement Design Strategies That Can Be Simulated with AASHTOWare Pavement ME Design (Refer to Section 11.1); Layer Thickness Not to Scale	21
3-2	HMA Overlay Design Strategies of Flexible, Semi-Rigid, and Rigid Pavements That Can Be Simulated with AASHTOWare Pavement ME Design (Refer to Section 12.2); Layer Thickness Not to Scale	22
3-3	New (Including Lane Reconstruction) Rigid Pavement Design Strategies That Can Be Simulated with AASHTOWare Pavement ME Design (Refer to Section 11.2); Layer Thickness Not to Scale	24
3-4	PCC Overlay Design Strategies of Flexible, Semi-Rigid, and Rigid Pavements That Can Be Simulated with AASHTOWare Pavement ME Design (Refer to Section 12.3); Layer Thickness Not to Scale	25
5-1	Graphical Illustration of the Five Temperature Quintiles Used in AASHTOWare Pavement ME Design to Determine HMA-Mixture Properties for Load-Related Distresses . .	38
5-2	Comparison of Measured and Predicted Total Rutting Resulting from Global Calibration Process	41
5-3	Comparison of Cumulative Fatigue Damage and Measured Alligator Cracking Resulting from Global Calibration Process	44
5-4	Comparison of Measured and Predicted Lengths of Longitudinal Cracking (Top-Down Cracking) Resulting from Global Calibration Process	45
5-5	Comparison of Measured and Predicted Transverse Cracking Resulting from Global Calibration Process	49
5-6	Comparison of Measured and Predicted IRI Values Resulting from Global Calibration Process of Flexible Pavements and HMA Overlays of Flexible Pavements	52
5-7	Comparison of Measured and Predicted IRI Values Resulting from Global Calibration Process of HMA Overlays of PCC Pavements	52
5-8	Comparison of Measured and Predicted Percentage JPCP Slabs Cracked Resulting from Global Calibration Process	55
5-9	Comparison of Measured and Predicted Transverse Cracking of Unbounded JPCP Overlays Resulting from Global Calibration Process	55
5-10	Comparison of Measured and Predicted Transverse Cracking for Restored JPCP Resulting from Global Calibration Process	56

5-11	Comparison of Measured and Predicted Transverse Joint Faulting for New JPCP Resulting from Global Calibration Process	61
5-12	Comparison of Measured and Predicted Transverse Joint Faulting for Unbound JPCP Overlays Resulting from Global Calibration Process	62
5-13	Comparison of Measured and Predicted Transverse Joint Faulting for Restored (Diamond Grinding) JPCP Resulting from Global Calibration Process	62
5-14	Comparison of Measured and Predicted Punchouts for New CRCP Resulting from Global Calibration Process	65
5-15	Comparison of Measured and Predicted IRI Values for New JPCP Resulting from Global Calibration Process	67
5-16	Comparison of Measured and Predicted IRI Values for New CRCP Resulting from Global Calibration Process	68
7-1	Design Reliability Concept for Smoothness (IRI)	73
9-1	Steps and Activities for Assessing the Condition of Existing Pavements for Rehabilitation Design (Refer to Table 9-2)	89
11-1	Flow Chart for Selecting Some Options to Minimize the Effect of Problem Soils on Pavement Performance	131
11-2	Limiting Modulus Criteria of Unbound Aggregate Base and Subbase Layers	135
12-1	Steps for Determining a Preferred Rehabilitation Strategy	144
12-2	Flow Chart of Rehabilitation Design Options Using HMA Overlays	145
12-3	Site Features Conducive to the Selection of the Rubblization Process for Rehabilitating PCC Pavements	160
12-4	Recommendations for a Detailed Investigation of the PCC Pavement to Estimate Remaining Life and Identifying Site Features and Conditions Conducive to the Rubblization Process	161
12-5	Evaluate Surface Condition and Distress Severities on Selection of Rubblization Option	162
12-6	Foundation Support Conditions Related to the Selection of the Rubblization Process	163
12-7	Overall Design Process for Major PCC Rehabilitation Strategies of All Pavement Types	166

LIST OF TABLES

5-1	Typical Input Levels Used in Recalibration Effort of AASHTOWare Pavement ME Design Models	36
5-2	Reflection Cracking Model Regression Fitting Parameters	50
5-3	Assumed Effective Base LTE for Different Base Types	59
7-1	AASHTOWare Pavement ME Design—Design Criteria or Threshold Values Recommended for Use in Judging the Acceptability of a Trial Design	72
7-2	Suggested Minimum Levels of Reliability for Different Functional Classifications of the Roadway	74
8-1	Minimum Sample Size (Number of Days per Year) to Estimate the Normalized Axle- Load Distribution—WIM Data	76
8-2	Minimum Sample Size (Number of Days per Season) to Estimate the Normalized Truck Traffic Distribution—Automated Vehicle Classifiers (AVC) Data	76
8-3	TTC Group Description and Corresponding Truck Class Distribution Default Values Included in AASHTOWare Pavement ME Design Software	79
8-4	Definitions and Descriptions for the TTC Groups	80
8-5	Summary of Soil Characteristics as a Pavement Material	84
9-1	Checklist of Factors for Overall Pavement Condition Assessment and Problem Definition ...	87
9-2	Hierarchical Input Levels for a Pavement Evaluation Program to Determine Inputs for Existing Pavement Layers for Rehabilitation Design Using AASHTOWare Pavement ME Design	90
9-3	Field Data Collection and Evaluation Plan	93
9-4	Guidelines for Obtaining Non-Materials Input Data for Pavement Rehabilitation	94
9-5	Use of Deflection Basin Test Results for Selecting Rehabilitation Strategies and in Estimating Inputs for Rehabilitation Design with AASHTOWare Pavement ME Design	96
9-6	Summary of Destructive Tests, Procedures, and Inputs for the AASHTOWare Pavement ME Design	98
9-7	Models/Relationships Used for Determining Level 2 E or M_r	99
9-8	Models Relating Material Index and Strength Properties to M_r	101
9-9	Distress Types and Severity Levels Recommended for Assessing Rigid Pavement Structural Adequacy	104
9-10	Distress Types and Levels Recommended for Assessing Current Flexible Pavement Structural Adequacy	105
10-1	Major Material Types for AASHTOWare Pavement ME Design	110
10-2	Asphalt Materials and the Test Protocols for Measuring the Material Property Inputs for New and Existing HMA Layers	111
10-3	Recommended Input Parameters and Values; Limited or No Testing Capabilities for HMA (Input Levels 2 or 3)	114
10-4	PCC Material Input Level 1 Parameters and Test Protocols for New and Existing PCC	117
10-5	Recommended Input Parameters and Values; Limited or No Test Capabilities for PCC Materials (Input Levels 2 or 3)	118

10-6	Chemically Stabilized Materials Input Requirements and Test Protocols for New and Existing Chemically Stabilized Materials	121
10-7	Recommended Input Levels 2 and 3 Parameters and Values for Chemically Stabilized Materials Properties.	122
10-8	C-Values to Convert the Calculated Layer Modulus Values to an Equivalent Resilient Modulus Measured in the Laboratory.	123
10-9	Unbound Aggregate Base, Subbase, Embankment, and Subgrade Soil Material Requirements and Test Protocols for New and Existing Materials	124
10-10	Recommended Input Levels 2 and 3 Input Parameters and Values for Unbound Aggregate Base, Subbase, Embankment, and Subgrade Soil Material Properties	125
11-1	General IRI Recommendations	136
11-2	Range and Median Slab/Base Friction Coefficients by Base Type	140
12-1	Definitions of the Surface Condition for Input Level 3 Pavement Condition Ratings and Suggested Rehabilitation Options	147
12-2	Candidate Repair and Preventive Treatments for Flexible, Rigid, and Composite Pavements	149
12-3	Summary of Major Rehabilitation Strategies and Treatments Prior to Overlay Placement for Existing HMA and HMA/PCC Pavements	150
12-4	Data Required for Characterizing Existing PCC Slab Static Elastic Modulus for HMA Overlay Design	156
12-5	Recommendations for Performance Criteria for HMA Overlays of JPCP and CRCP	157
12-6	Recommendations for Modifying Trial Design to Reduce Distress/Smoothness for HMA Overlays of JPCP and CRCP	158
12-7	PCC Rehabilitation Options—Strategies to Correct Surface and Structural Deficiencies of All Type of Existing Pavements	165
12-8	Summary of Key Aspects of Joint Design and Interlayer Friction for JPCP Overlays	168
12-9	Data Required for Characterizing Existing PCC Slab	169
12-10	Description of Existing Pavement Condition.	169
12-11	Summary of Factors That Influence Rehabilitated JPCP Distress	172
12-12	Guidance on How to Select the Appropriate Design Features for Rehabilitated JPCP Design.	174
12-13	Recommendations for Modifying Trial Design to Reduce Distress/Smoothness for JPCP Rehabilitation Design	175
12-14	Summary of Factors That Influence Rehabilitated CRCP Distress and Smoothness	177
12-15	Guidance on How to Select the Appropriate Design Features for Rehabilitated CRCP Design	178
13-1	Reliability Summary for Flexible Pavement Trial Design Example	182
13-2	Reliability Summary for JPCP Trial Design Example	182
13-3	Guidance for Modifying HMA Trial Designs to Satisfy Performance Criteria	187
13-4	Guidance on Modifying JPCP Trial Designs to Satisfy Performance Criteria	188
13-5	Guidance on Modifying CRCP Trial Designs to Satisfy Performance Criteria	188