


Mechanistic-Empirical Pavement Design Guide

~ A Manual of Practice ~




2020 • Third Edition

American Association of State Highway and Transportation Officials
AASHTO

Preface

This document or manual of practice 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 (ME) pavement design, and it represents a major change from the pavement design methods in practice today.

Interested agencies have already begun implementation activities through staff training, collection of input data (materials library, traffic library, etc.), acquiring of test equipment, and preparation of field sections for local calibration. This manual, referred to as the Mechanistic-Empirical Pavement Design Guide (MEPDG), presents the information necessary for pavement design engineers to start using the ME-based design and analysis method. The software supporting this method is called Pavement ME Design® and is commercially available through AASHTOWare. The software is referred to in this document as PMED.

Multiple enhancements have been made to the AASHTOWare PMED based on completed research projects sponsored by the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Administration (FHWA). In addition, revisions to the software were based on evaluations performed by State Highway Agencies and others in the Community of Practice. The third edition of the MEPDG Manual of Practice was prepared so the manual was consistent with the enhanced features and models included in the software through 2018.

The following table (Table P-1) summarizes the key differences noted between the format and calibration factors used in the MEPDG version 1.1 software, the AASHTOWare Pavement ME Design software version 2.3.1, and version 2.5.3 software.

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

Format, Transfer Functions, and Calibration Coefficients		MEPDG version 1.1	AASHTOWare Pavement ME Design version 2.3.1	AASHTOWare Pavement ME Design version 2.5.3
Output Format		Excel-based	PDF- and Excel-based	PDF- and Excel-based
Climatic Input Data and if Included in Output Summary		Data from Ground-Based Weather Stations; output summary not included	Data from NARR database for rigid and flexible pavements; output summary included	Data from NARR database for rigid pavements and MERRA2 database for flexible and semi-rigid pavements; output summary included
Axle Configuration Data in Output Summary		Not included	Included	Included
Special Axle Load Configuration		Included	Not included	Not included
Reflection Cracking Transfer Function		Empirical regression equation included	ME-based fracture mechanics model included	ME-based fracture mechanics model included
Coefficient of Thermal Expansion (CTE)		CTE for Basalt of 4.6	CTE for Basalt of 5.2	CTE for Basalt of 5.2
PCC Zero Stress Temperature		PCC Zero Stress Temperature (60°–120°F)	PCC Set Temperature (70°–212°F)	PCC Set Temperature (70°–212°F)
Heat Capacity of Asphalt Pavement		Default value of 0.23 BTU/lb-°F	Default value of 0.28 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)	Default value of 1.25 BTU/(ft)(hr)(F)
Surface Shortwave Absorptivity		Default value of 0.95	Default value of 0.85	Default value of 0.85
Global Model Coefficient for Unbound Materials and Soils in Flexible Pavement Subgrade Rutting Model	Aggregate Base	k_{s1} of 1.673	k_{s1} of 2.03	k_{s1} of 0.965
	Coarse-Grained Soil			k_{s1} of 0.965
	Sand Soil			k_{s1} of 0.635
	Fine-Grained Soil	k_{s1} of 1.35	k_{s1} of 1.35	k_{s1} of 0.675

Continued on next page.

Table P-1. Summary of Key Differences in Software Format and Calibration Factors, *continued*

Format, Transfer Functions, and Calibration Coefficients		MEPDG version 1.1	AASHTOWare Pavement ME Design version 2.3.1	AASHTOWare Pavement ME Design version 2.5.3
Global Local Calibration or Field Adjustment Constant for Unbound Materials and Soils in Flexible Pavement Subgrade Rutting Model	Aggregate Base	1.0	1.0	1.0
	Coarse-Grained Soil			1.0
	Sand Soil			1.0
	Fine-Grained Soil			1.0
Global Laboratory-Derived Model Coefficients in the Fatigue Cracking Prediction Model in Flexible Pavement		k_{s1} of 0.007566	k_{s1} of 0.007566	k_{s1} of 3.75
		k_{s2} of -3.9492	k_{s2} of 3.9492	k_{s2} of 2.87
		k_{s3} of -1.281	k_{s3} of 1.281	k_{s3} of 1.46
Global Local Calibration or Field-Adjustment Constants for Fatigue Cracking Prediction Model in Flexible Pavement		β_1 of 1.0	β_1 of 1.0	AC thickness dependent; see Chapter 5
		β_2 of 1.0	β_2 of 1.0	β_2 of 1.38
		β_3 of 1.0	β_3 of 1.0	β_3 of 0.88
Global Bottom-Up Alligator Cracking Transfer Function Coefficients		C_1 of 1.0	C_1 of 1.0	1.31
		C_2 of 1.0	C_2 of 1.0	AC thickness dependent; see Chapter 5
Global Calibration or Field-Adjustment Coefficient in the Transverse Cracking Model for AC		k_t (Level 1) of 5.0	k_t (Level 1) of 1.5	k_s (Level 1) is Mean Annual Air Temperature (MAAT) dependent; see Chapter 5.
		k_t (Level 2) of 1.5	k_t (Level 2) of 0.5	k_s (Level 2) is MAAT dependent; see Chapter 5.
		k_t (Level 3) of 3.0	k_t (Level 3) of 1.5	k_s (Level 3) is MAAT dependent; see Chapter 5.
Global Laboratory Derived Model Coefficients in the Rut Depth Prediction Model		k_1 of -3.35412	k_1 of -3.35412	k_1 of -2.45
		k_{2r} of 0.4791	k_2 of 1.5606	k_2 of 3.01
		k_{3r} of 1.5606	k_3 of 0.4791	k_3 of 0.22

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Table P-1. Summary of Key Differences in Software Format and Calibration Factors, *continued*

Format, Transfer Functions, and Calibration Coefficients	MEPDG version 1.1	AASHTOWare Pavement ME Design version 2.3.1	AASHTOWare Pavement ME Design version 2.5.3
Global Local Calibration or Field Adjustment Coefficients in the Rut Depth Prediction Model	β_1 of 1.0	β_1 of 1.0	β_1 of 0.40
	β_2 of 1.0	β_2 of 1.0	β_2 of 0.52
	β_3 of 1.0	β_3 of 1.0	β_3 of 1.36
Calibration Coefficients in the Rigid Pavement Cracking Prediction Model	C_4 of 1.0	C_4 of 0.52	C_4 of 0.52
	C_5 of -1.98	C_5 of -2.17	C_5 of -2.17
Calibration Coefficients in the Rigid Pavement Faulting Prediction Model	C_1 of 1.29	C_1 of 1.0184	C_1 of 0.595
	C_2 of 1.1	C_2 of 0.91656	C_2 of 1.636
	C_3 of 0.001725	C_3 of 0.0021848	C_3 of 0.00217
	C_4 of 0.0008	C_4 of 0.0008837	C_4 of 0.00444
	C_6 of 0.4	C_6 of 0.47	C_6 of 0.47
	C_7 of 1.2	C_7 of 1.83312	C_7 of 7.3
Calibration Coefficient in the Rigid Pavement Punchout Prediction Model	APO of 195.789	C_3 of 107.73	C_3 of 107.73
	αPO of 19.8947	C_4 of 2.476	C_4 of 2.475
	βPO of -0.526316	C_5 of -0.785	C_5 of -0.785
Calibration Coefficients in the Short JPCP Overlay Longitudinal Cracking Prediction Model	Excluded	C_4 of 0.4	C_4 of 0.4
		C_5 of -2.21	C_5 of -2.21

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CHAPTER 1

Introduction

The overall objective of the Mechanistic-Empirical Pavement Design Guide (MEPDG) is to provide the highway community with a state-of-the-practice method for the design and analysis of new and rehabilitated pavement structures, based on mechanistic-empirical (ME) principles. This means that the design/analysis procedure calculates pavement responses (stresses, strains, and deflections) and uses those responses to compute incremental damage over time. The procedure empirically relates the cumulative damage to observed pavement distresses. The flowchart in Figure 1-1 illustrates this ME-based procedure. The AASHTOWare Pavement ME Design® is the commercially available software tool. The AASHTOWare software is referred to in this manual as PMED.

The AASHTOWare PMED represents a major change in the way pavement design is performed. AASHTOWare PMED predicts multiple performance indicators (refer to Figure 1-1) and it provides a direct tie between materials, structural design, construction, climate, traffic, and pavement management systems. Figures 1-2 and 1-3 are examples of the interrelationship between these activities for asphalt concrete (AC) and Portland cement concrete (PCC) materials.

1.1 Purpose of Manual

This manual of practice presents information to guide pavement design engineers in making decisions and using AASHTOWare PMED for new pavement and rehabilitation design. The manual does not provide guidance on developing regional or local calibration factors for predicting pavement distress and smoothness. A separate document, *Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide*, provides guidance for determining the local calibration factors for both AC and PCC pavement types (2).

1.2 Overview of the Design Procedure

AASHTOWare PMED is a production-ready design tool to support the day-to-day operations of public and private pavement engineers. When analyzing a pavement design project using

AASHTOWare PMED, whether it is new construction, an overlay, or restoration, utilize the following three-step, basic process:

1. Create a trial design for the project.
2. Run AASHTOWare PMED to predict the key distresses and smoothness for the trial design.
3. Review the predicted performance of the trial design against performance criteria, then modify the trial design as needed in order to produce a feasible design that satisfies the performance criteria at the selected reliability level.

Pavement responses (stresses, strains, and deflections) are combined with other pavement, traffic, climate, and materials parameters to predict the progression of key pavement distresses and smoothness loss over time. These outputs are the basis for checking the adequacy of a trial design. AASHTOWare PMED software also includes an automated process or feature to iterate to an optimized pavement thickness for both flexible and rigid pavements.

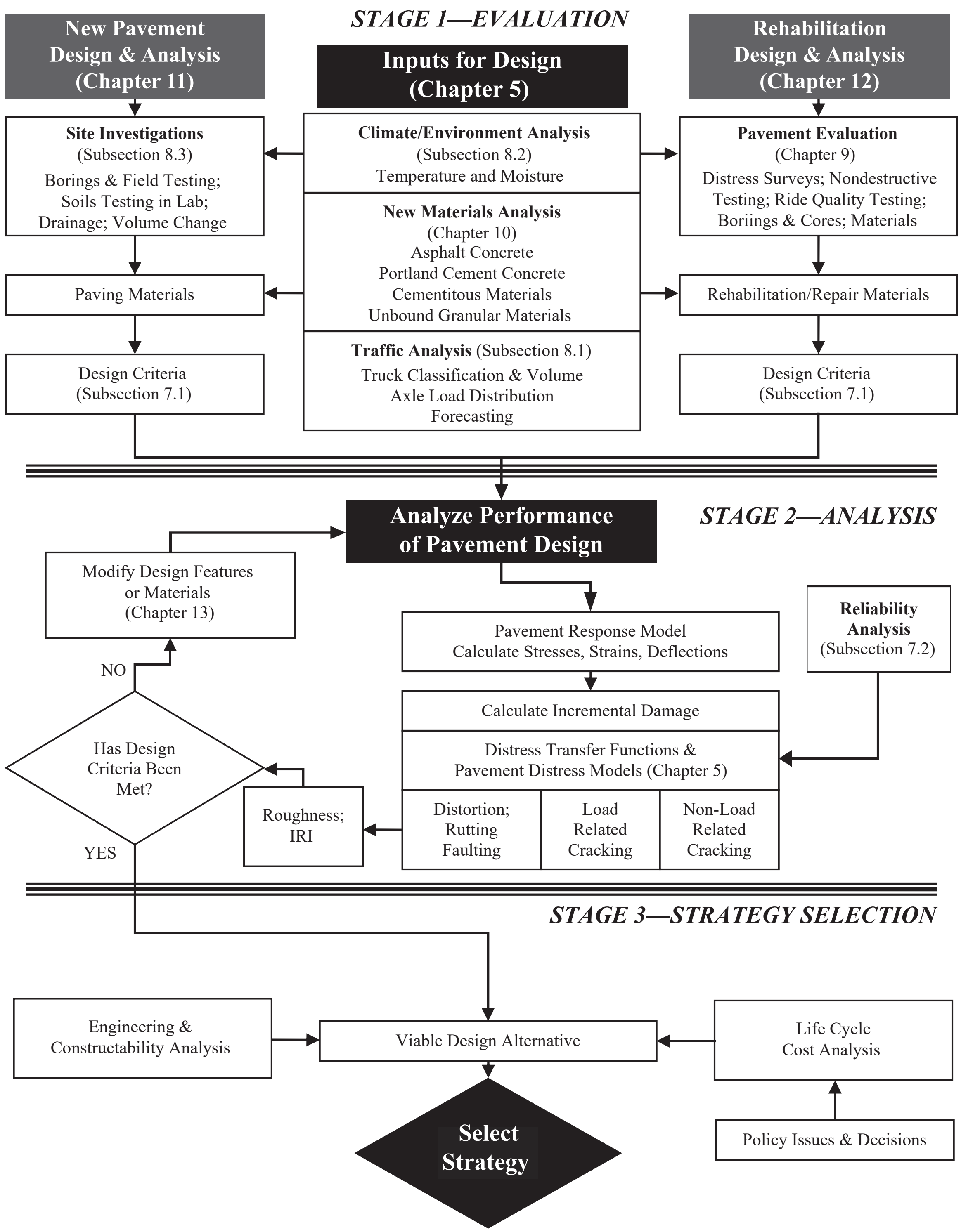

Figure 1-1. Conceptual Flow Chart of the Three-Stage Design/Analysis Process for AASHTOWare PMED

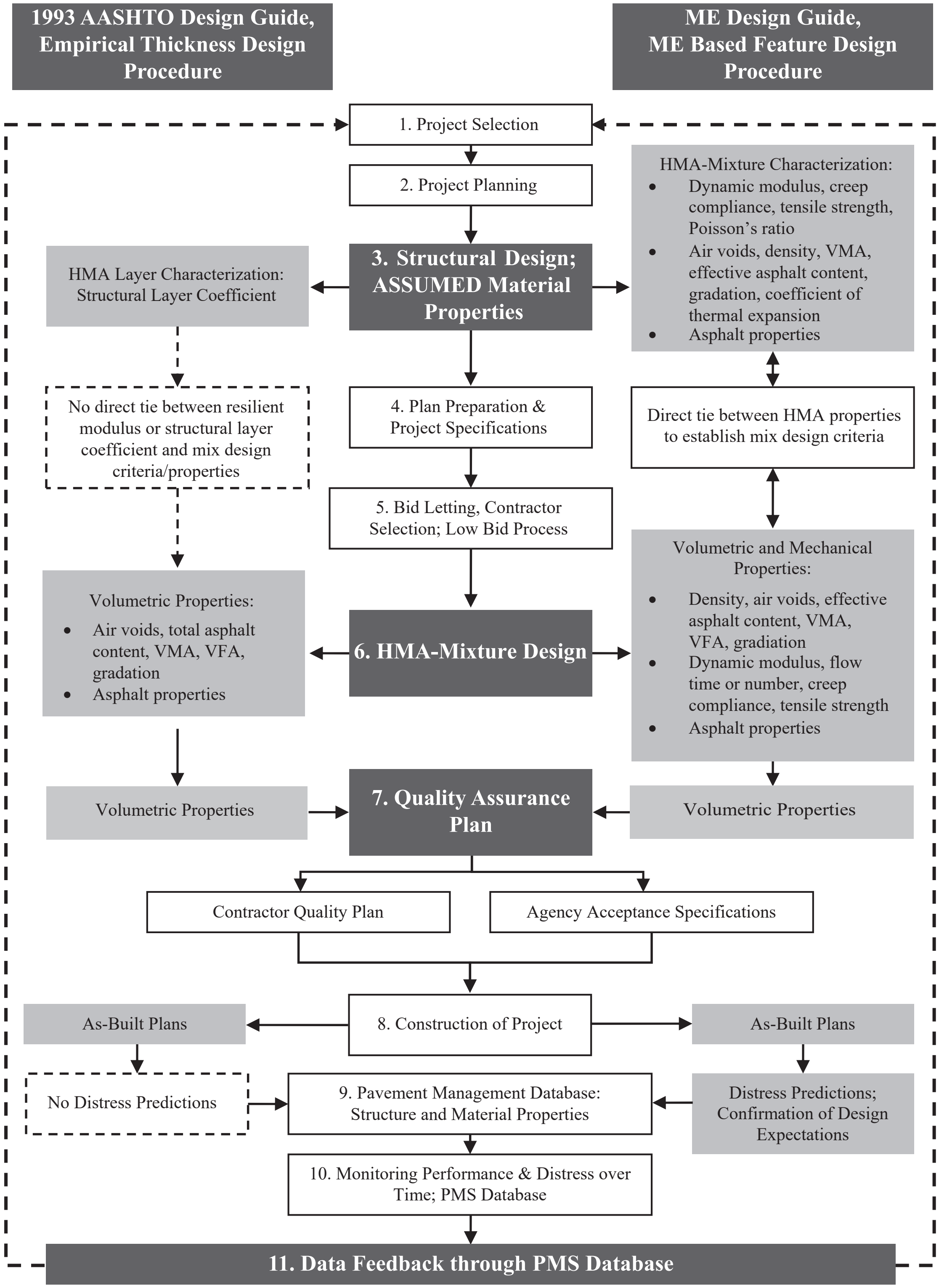

Figure 1-2. Typical Differences between Empirical Design Procedures and an Integrated ME Design System, in Terms of AC Mixture Characterization

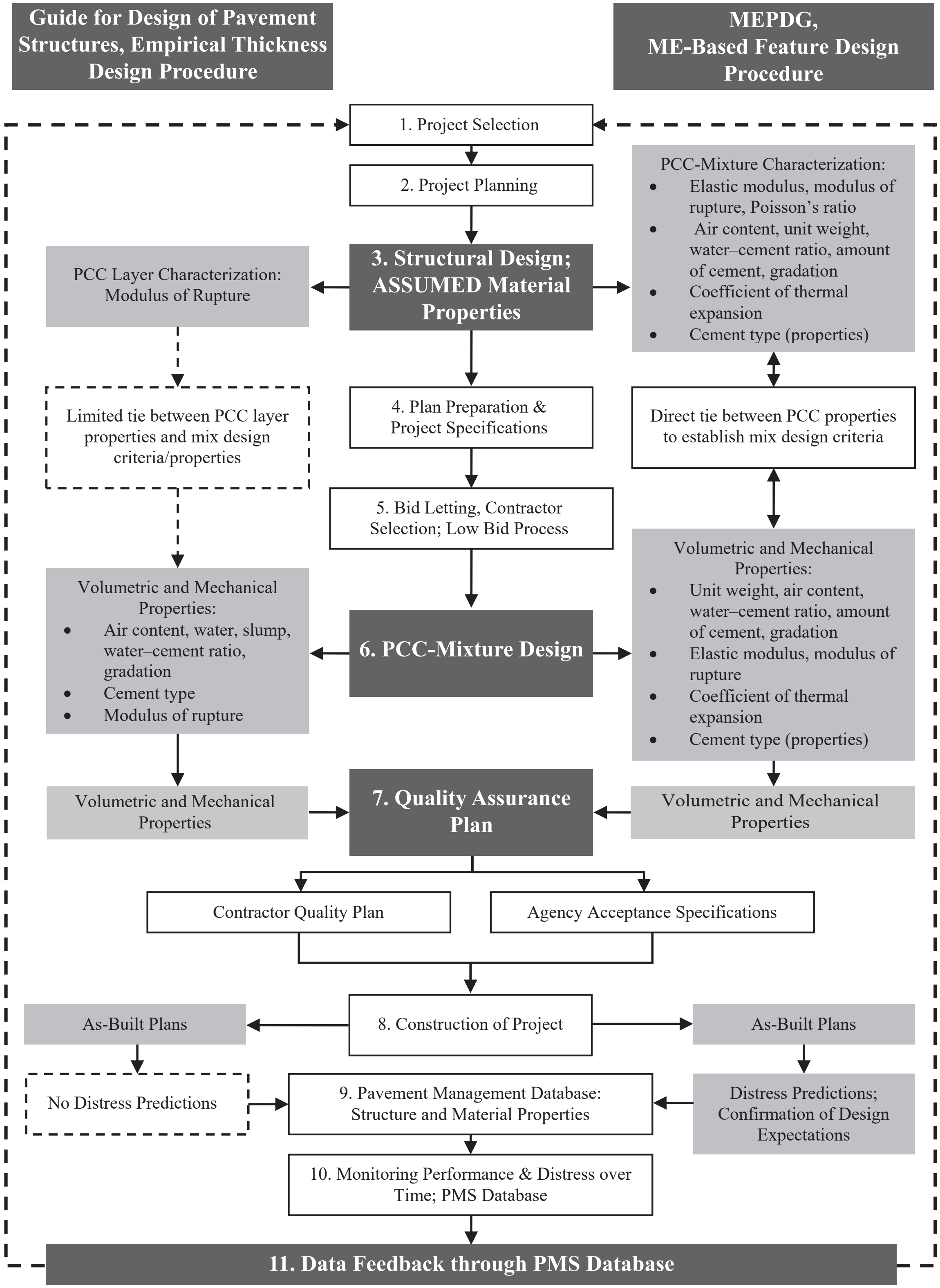

Figure 1-3. Typical Differences between Empirical Design Procedures and an Integrated ME Design System, in Terms of PCC-Mixture Characterization

The ME approach makes it possible to optimize the design and to fully verify that specific distress types will be limited to values less than the failure criteria within the design life of the pavement structure. The basic steps included in the MEPDG are listed below and presented as flow charts in Figures 1-4 and 1-5. The steps shown in Figures 1-4 and 1-5 are referenced to the appropriate sections within this manual of practice.

1. **Select a trial design strategy.** The pavement designer may use an agency-specific procedure to determine the trial design cross section.
2. **Select the appropriate performance indicator criteria (threshold value) and design reliability level for the project.** Design or performance indicator criteria include magnitudes of key pavement distresses and smoothness that may trigger major rehabilitation or reconstruction. These criteria could be a part of an agency's policies for deciding when to rehabilitate or reconstruct. AASHTOWare PMED allows the user to select the performance indicator criteria to be considered. The user can uncheck the box next to the criteria that do not need to be considered. (See Chapter 4.1 for definitions.)
3. **Obtain all inputs for the pavement trial design under consideration.** This step may be a time-consuming effort, but it is what separates the MEPDG from other design procedures. The MEPDG allows the designer to determine inputs using a hierarchical structure in which the effort to quantify a given input is selected based on the importance of the project, importance of the input, and available resources. The required inputs to run the software are obtained using one of three levels of effort that need not be consistent for all of the inputs for a given design. This permits the user to use the "best available" data for all inputs. The hierarchical input levels are defined in Chapters 4 and 5, and are grouped under six broad topics: (1) general project information, (2) design criteria, (3) traffic, (4) climate, (5) structure layering, and (6) material properties (including the design features).
4. **Run AASHTOWare PMED and examine the inputs and outputs for engineering reasonableness.** The software calculates changes in layer properties, damage, key distresses, and the International Roughness Index (IRI) over the design life. The substeps for step 4 include:
    a. Examine the input summary to verify the inputs are correct. This step should be completed after each run, until the designer becomes more familiar with the program and its inputs.
    b. Examine the outputs that comprise the intermediate process—specific parameters (such as climate values), monthly load transfer efficiency (LTE) values for rigid pavement analysis, monthly layer modulus values for flexible and rigid pavement analysis to determine their reasonableness, and calculated performance indicators (pavement distresses and IRI). This step may be completed after each run or until the designer becomes more familiar with the program. Review of important intermediate processes and steps is presented in Chapter 13.

c. Assess whether the trial design has met each of the performance indicator criteria at the design reliability level chosen for the project. As noted above, IRI is an output parameter predicted over time and a measure of surface smoothness. IRI is calculated from other distress predictions (refer to Figure 1-1), site factors, and initial IRI.
d. If any of the criteria are not met, determine how this deficiency can be remedied by altering the materials used, the layering of materials, layer thickness, or other design features.

5. **Revise the trial design, as needed.** If the trial design has input errors, material output anomalies, or has exceeded the failure criteria at the given level of reliability, revise the inputs/trial design and rerun the program. An automated process to iterate to an optimized thickness is done by AASHTOWare PMED to produce a feasible design.

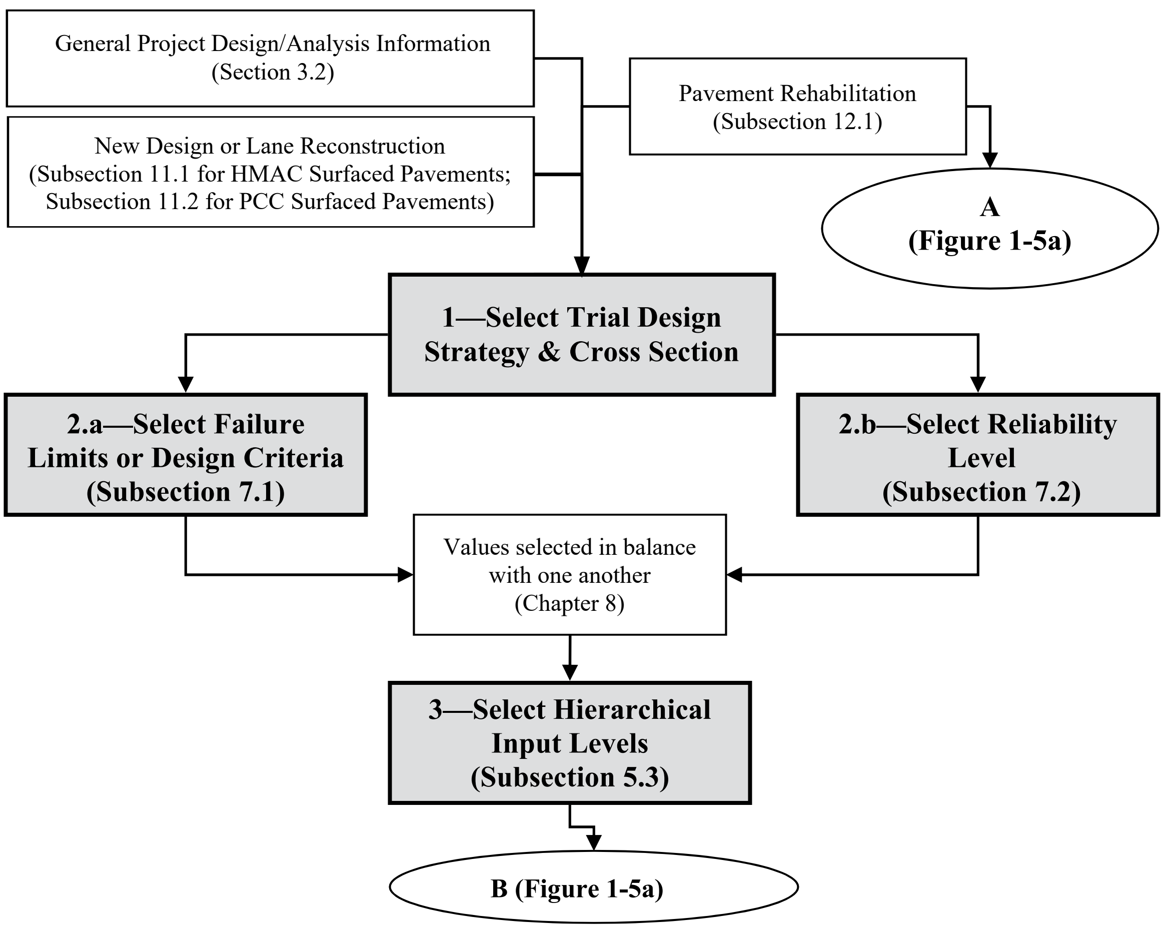

Figure 1-4. Flow Chart of the Steps That Are More Policy Decision Related and Needed to Complete an Analysis of a Trial Design Strategy

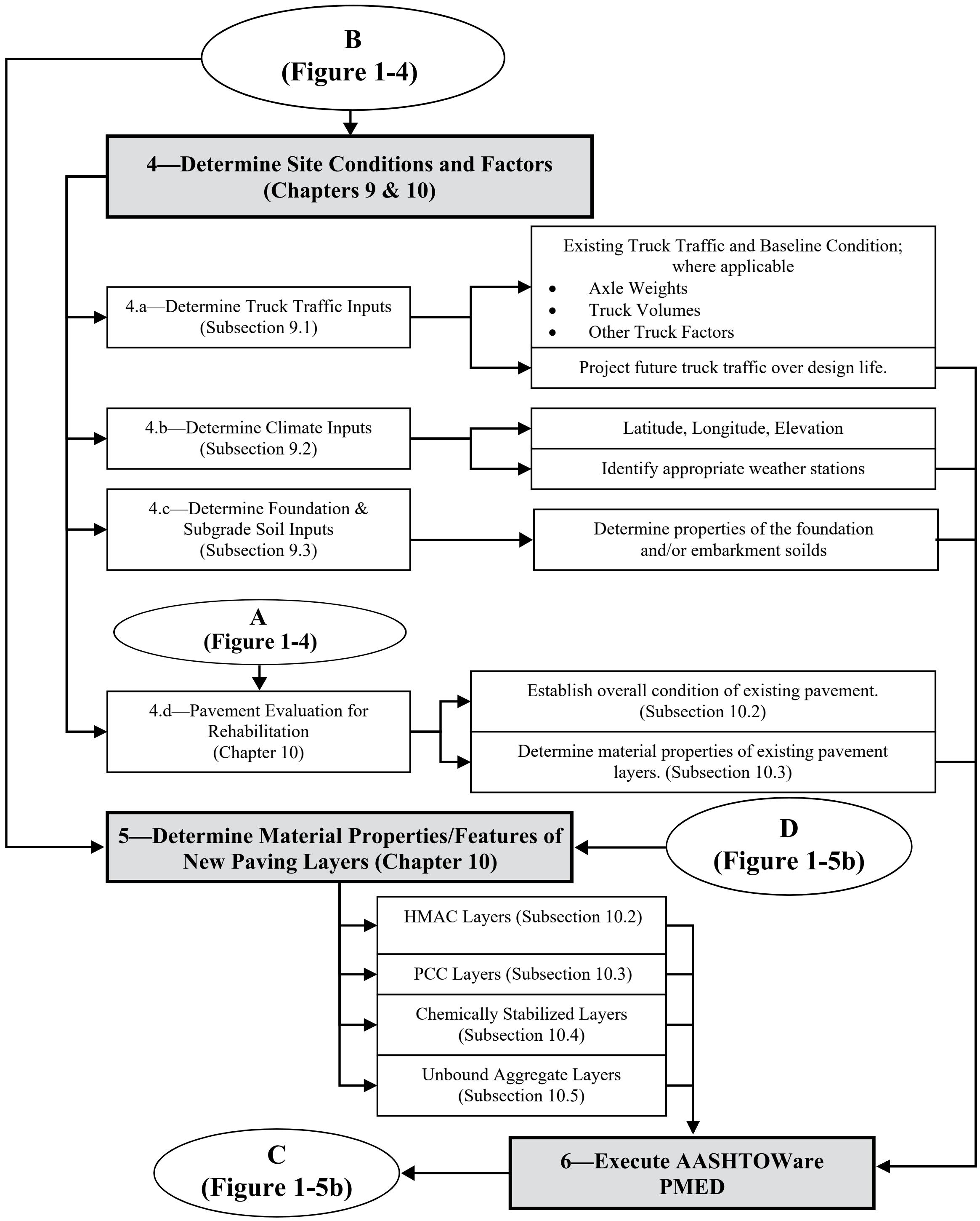

Figure 1-5a. Flow Chart of the Steps Needed to Complete an Analysis of a Trial Design Strategy

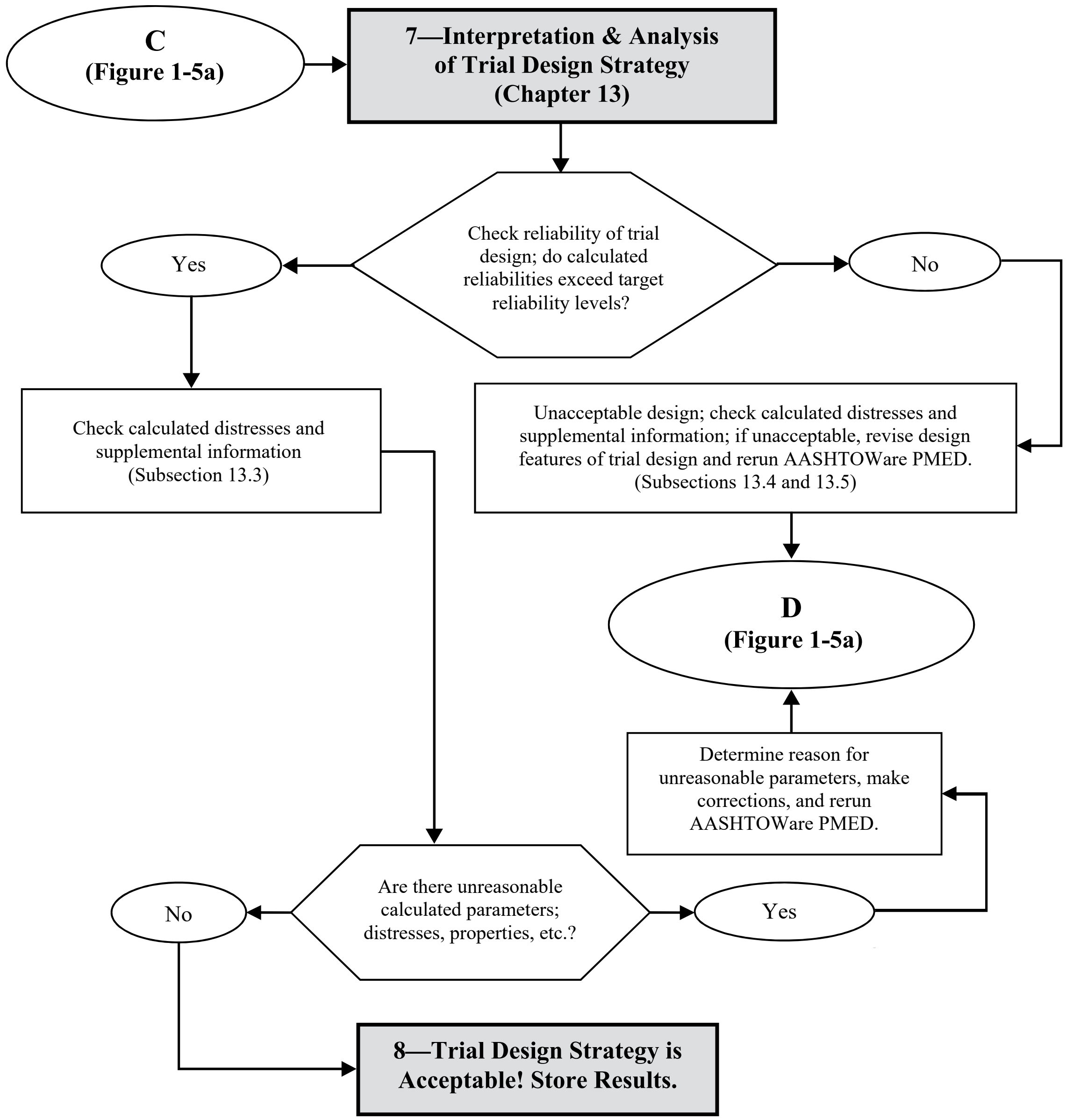

Figure 1-5b. Flow Chart of the Steps Needed to Complete an Analysis of a Trial Design Strategy

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Disclaimer

General jurisdiction over the American Association of State Highway and Transportation Officials (referred to herein as the Association) design standards is a function of the Committee on Materials and Pavements, which has members representing each of the 50 states, the Commonwealth of Puerto Rico, and the Northern Mariana Islands, the District of Columbia, the U.S. Department of Transportation, the New Jersey Turnpike Authority, the Massachusetts Metropolitan District Commission, the Port Authority of New York and New Jersey, six Canadian Provinces, and two Territories. Revisions to the design standards are voted on by the Association Member Departments prior to the publication of each new edition and, if approved by at least two thirds of the members, they are included in the new edition as a design standard of the Association.

This document provides supplemental information to the 3rd Edition of the AASHTO *Mechanistic-Empirical Pavement Design Guide—A Manual of Practice*. The information also supports features integrated in the Association's AASHTOWare Pavement ME Design software package. References are provided for informational purposes only and do not constitute endorsement of any websites or other sources.

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Background

Top-down cracking is a load-related distress in asphalt pavements and overlays, where the crack initiates at the pavement surface and propagates downward through the asphalt layer. Top-down cracks were predicted using a transfer function similar to bottom-up (alligator) cracking in the earlier versions of the Pavement ME Design software (version 2.5.5 and earlier). Top-down cracks were calculated using a transfer function where the crack length is a function of damage. The overall damage accumulated in the asphalt layer is the sum of incremental damage due to traffic loads during a specific duration of time, which was calculated using Miner's law, similar to bottom-up alligator cracks. Top-down cracks were reported as longitudinal crack length in feet per mile in version 2.5.5 and earlier versions.

The study conducted as part of NCHRP project 1-42A evaluated two models for prediction of top-down cracking: (a) a viscoelastic continuum damage (VECD)-based model to predict crack initiation at damage zones and effect on pavement response, and (b) a fracture mechanics-based model to predict crack propagation in the presence of macro-cracks. The NCHRP 1-42A study concluded that both VECD- and fracture mechanics-based models can form the basis for a top-down cracking model suitable for use in the Pavement ME Design software.

The fracture mechanics-based cracking model was developed under NCHRP Project 1-52 and added to the Pavement ME design software. The top-down cracking model from NCHRP 1-52 replaces the older bending beam-based model in the Pavement ME software and output. In addition, longitudinal cracks in the wheel paths and/or alligator cracks have been confirmed through the use of cores to initiate at the surface and propagate down through the asphalt layers. The top-down cracking transfer function was modified to include both longitudinal cracks in the wheel paths and alligator cracks in terms of percent total lane area cracked. This addendum provides the additions and revisions to the 3rd Edition of the MEPDG *Manual of Practice* regarding the methodology and inputs to the fracture-based top-down cracking model.