October 2023 ERRATA for *Mechanistic–Empirical Pavement Design Guide,* 3rd Edition, 2021 Supplement (MEPDG-3S)

October 2023

Dear Customer:

AASHTO has issued an erratum, which includes technical revisions, for the *Mechanistic–Empirical Pavement Design Guide,* 3rd Edition, 2021 Supplement (MEPDG-3S).

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https://downloads.transportation.org/MEPDG-3S-Errata.pdf

The changes are detailed in the table under the "October 2023" heading and are displayed in **bold** on the pages within the text. Pages with the new changes have a gray box in the page header reading as follows:

October 2023 Errata

AASHTO staff sincerely apologizes for any inconvenience.

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List of Errata for *AASHTO Mechanistic–Empirical Pavement Design Guide*, 3rd Edition, 2021 Supplement (MEPDG-3S)

Original Page	Section	Existing Text	Corrected Text
October 2023			
v	Table of Contents	Chapter 12 sections are not listed.	Chapter 12 Sections 12.12, 12.12.4, and 12.12.8 are listed.
5–11	5.3.3	The “Asphalt Layers” subsection has several errors and omissions, detailed below:	
		• The subheader title is incorrect.	The correct subheader title is “Asphalt Concrete Layers”.
		• The first paragraph under “Asphalt Concrete Layers” is incorrect.	The first paragraph has been revised as follows: Two types of load-related cracks are predicted by the MEPDG: alligator cracking and longitudinal cracking. The MEPDG assumes that alligator, or area cracks, initiate at the bottom of the AC layers and propagate to the surface with continued truck traffic, while longitudinal cracks are assumed to initiate at the surface.
		• Equations 5-4f through 5-4h and their callouts are numbered incorrectly.	The correct equation numbers are 5-8a through 5-8c.
		• Equation 5-5 and its callout are numbered incorrectly.	The correct equation number is 5-9.
		• Figure 5-3 and its callout are numbered incorrectly.	The correct figure number is 5-4.
		• Equations 5-6a through 5-6d and their callouts are numbered incorrectly.	The correct numbers are 5-10a through 5-10d.
		• Equations 5-7a through 5-7d and their callouts are numbered incorrectly.	The correct equation numbers are 5-11a through 5-11d.
		• Figures 5-4a and 5-4b and their callouts are numbered incorrectly.	The correct figure numbers are 5-5a and 5-5b.
		• Tables 5-1.1 and 5-1.2 and their callouts are numbered incorrectly.	The correct table numbers are 5-2 and 5-3.

List of Errata for *AASHTO Mechanistic–Empirical Pavement Design Guide*, 3rd Edition, 2021 Supplement (MEPDG-3S)

Original Page	Section	Existing Text	Corrected Text
October 2023			
14	Table 7-1	Table note is missing.	Table note reads as follows: * Performance criteria levels need review by agency for adequacy.
14	7.1	Equation callouts are incorrect due to renumbering in Chapter 5.	The first sentence reads as follows: Two parameters are predicted by the top-down cracking model as discussed in Chapter 5: percent total lane area with top-down cracking (see Equation 5-11a) and the average crack depth (see Equation 5-8c). The fourth sentence reads as follows: The reliability is only calculated for the percent total lane area with top-down cracks, because the standard deviation of the residual errors between the measured and predicted top-down cracks is only applicable to the percent total lane area and not crack depth.
24.1	12.12	Chapter 12 content affected by the Chapter 5 revisions is missing.	Parts of Section 12.12 are added to update callouts to tables in Chapter 5.

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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

CHAPTER 5

Performance Indicator Prediction Methodologies

5.3 Distress Prediction Model for Flexible Pavements and HMA Overlays

5.3.3 *Load-Related Cracking*

Asphalt Concrete Layers

Two types of load-related cracks are predicted by the MEPDG: alligator cracking and longitudinal cracking. The MEPDG assumes that alligator, or area cracks, initiate at the bottom of the AC layers and propagate to the surface with continued truck traffic, while longitudinal cracks are assumed to initiate at the surface.

The section titled "For top-down or longitudinal cracks" is removed and replaced with the following paragraphs, ending just before the "CTB Layers" discussion.

For top-down cracking:

The fracture mechanics model incorporated into Pavement ME uses the Paris' law of crack propagation to characterize crack growth due to repeated application of traffic loads.

$$\frac{dc}{dN} = A\left(\Delta K\right)^n \qquad \textbf{(5-8a)}$$

$$\frac{dc}{dT} = A\left(\Delta K\right)^n \qquad \textbf{(5-8b)}$$

where:

dc = Change or growth in crack length, where c = Crack length

dN = Increase in loading cycles during a time increment, where N = Number of loading cycles

dT = Increase in thermal cycles during a time increment, where T = Temperature

ΔK = Stress intensity amplitude that depends on the stress level, the geometry of the pavement structure, the fracture model, crack length, and load transfer efficiency across the crack or joint
A, n = Fracture properties of asphalt concrete mixture

The NCHRP 1-52 study found that transverse thermal stress does not contribute significantly to the growth of top-down cracking. Therefore, stress intensity at the crack tip due to traffic loading is used to calculate crack length increments. The formation of micro-cracks and subsequent failure of asphalt concrete is modeled using the modified Paris' law shown below in Equation 5-8c.

$$\frac{dc}{dN} = A'\left(J_R\right)^{n'} \tag{5-8c}$$

where:
A', n' = Fracture properties of asphalt concrete mixture
J_R = Pseudo J-integral

The pseudo J-integral used in the modified Paris' law is defined as the increment in dissipated pseudo work per unit crack surface area. The J-integral is related to the stress intensity factors (K, as defined in Equation 5-8c) as shown in Equation 5-9.

$$J_R = \frac{1-\nu^2}{E_R}(K_I^2 + K_{II}^2) + \frac{1+\nu}{E_R}K_{III}^2 \tag{5-9}$$

where:
ν = Poisson's ratio of asphalt concrete
E_R = Representative elastic modulus
K_I = Stress intensity factor in Mode I (opening)
K_{II} = Stress intensity factor in Mode II (in-plane shear)
K_{III} = Stress intensity factor in Mode III (out-of-plane share)

The J-integral is computed from stress intensity factors in all three modes of fracture, which are shown below in Figure 5-4.

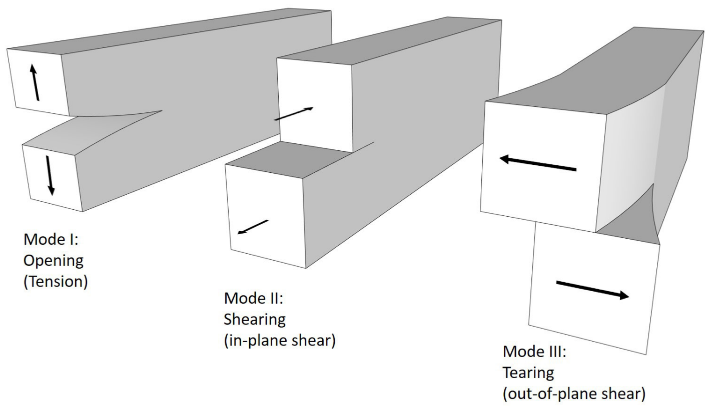

Figure 5-4. Mechanisms of Thermally Induced Reflective Cracks of Asphalt Overlays

The fracture parameter n' is calculated from asphalt mixture volumetrics and the asphalt's relaxation modulus Power law function parameters (E_1 and m), as shown below in Equation 5-10a. The parameter A' was found to be strongly correlated to n' and is calculated directly using a regression equation, as shown in Equation 5-10b.

$$n' = -9.00498 + 1.0627\psi + \frac{2.8713}{m} - 40.8788\left(\frac{1}{E_1}\right)^m + 18.868\frac{P_b}{V_a + P_b} \quad \textbf{(5-10a)}$$

$$A' = 10^{-1\times(1.2752n+1.713)} \quad \textbf{(5-10b)}$$

where:

Ψ = Shape parameter of the aggregate power law function
m, E_1 = Relaxation modulus Power law function parameters, aged asphalt
P_b = Percent asphalt binder by weight of mix, %
V_a = Air voids in the asphalt layer, %

The pseudo J-integrals were calculated using finite element analysis in ABAQUS using different pavement structures, layer thicknesses, material properties (layer moduli), and crack depths. The analyses were performed by inserting a longitudinal crack of length 39.4 in. in the middle of the pavement lane in the longitudinal direction (along the direction of traffic). Artificial neural networks were developed to compute J-integrals at runtime for each set of inputs, i.e., aged asphalt modulus and crack depth at each monthly interval.

Crack growth is modeled using the modified Paris' law over the pavement's design life as described above. The time to crack initiation, defined as the time to reach a crack length of 0.3 in., is calculated using a regression equation, as shown in Equation 5-10c. The longitudinal and alligator cracking data from the LTPP database was used for calibrating the t_0 and crack area transfer functions.

$$t_0 = \frac{K_{L1}}{1 + e^{K_{L2} \times 100 \times \frac{a_0}{2A_0} + K_{L3} \times HT + K_{L4} \times LT + K_{L5} \times \log_{10} \text{AADTT}}} \quad \textbf{(5-10c)}$$

where:
t_0= Time to crack initiation, days
$K_{L1 \text{ through } L5}$ = Calibration coefficients for time to crack initiation
$a_0/2A_0$ = Energy parameter, calculated using Equation 5-10d
HT = Annual number of days above 89.6°F
LT = Annual number of days below 32°F
AADTT = Annual average daily truck traffic (initial year)

$$\frac{a_0}{2A_0} = 0.1796 + 1.5 \times 10^{-5} E_1 - 0.69m - 7.169 \times 10^{-4} H_a \quad \textbf{(5-10d)}$$

where:
H_a = total asphalt thickness
K_{L1} through K_{L5} = calibration coefficients
K_{L1} = 64271618
K_{L2} = 0.2855
K_{L3} = 0.011
K_{L4} = 0.0149
K_{L5} = 3.266

The total percentage lane area of top-down cracks is calculated as a function of the number of months to failure and the maximum allowable area of cracking, L_{MAX}. A value of 58 percent is assumed for L_{MAX} and represents the total area of two wheel paths. According to the NCHRP 1-52 study, the definitions of terms related to crack length prediction are:

- Crack initiation: Crack length (depth of the crack from surface) is equal to 0.3 in.
- Failure: Crack length is equal to 1.575 in.
- Months to failure, Month: Number of months required for crack (after initiation) to reach the failure criterion of 1.575 in.

The predicted top-down cracking versus time is an S-shaped curve, and is calculated using the model shown in Equation 5-11a.

$$L(t) = L_{MAX} e^{-\left(\frac{C_1 \rho}{t - C_3 t_0}\right)^{C_2 \beta}} \quad \textbf{(5-11a)}$$

where:
$L(t)$ = Top-down cracking total lane area (%)
L_{MAX} = Maximum area of top-down cracking (%)
$C_{1,}$ $C_{2,}$ C_3 = Calibration coeficcients
ρ = Scale parameter of the top-down cracking curve
t = Analysis month in days
t_0 = Time to crack initiation, days
β = Shape parameter of the top-down cracking curve

The scale and shape parameters ρ and β are calculated as a function of number of months to failure, Month using Equations 5-11b and 5-11c, respectively.

$$\rho = \alpha_1 + \alpha_2 \times \text{Month} \quad \textbf{(5-11b)}$$

$$\beta = 0.7319 \times \left(\log_{10} \text{Month}\right)^{-1.2801} \quad \textbf{(5-11c)}$$

α_1 and α_2 are calibration parameters whose values depend on whether the pavement is located in a wet (WF or WNF) or dry (DF or DNF) climatic zone.

The calibration of the top-down cracking model applies to both the cracking prediction model shown in Equation 5-11a as well as the number of days to crack initiation, t_0, as shown in Equation 5-10c. Figure 5-5a includes a comparison of the measured and predicted number of days, t_0, from the LTPP sites included in the study. Figure 5-5b includes a comparison between the measured and predicted area of top-down cracking.

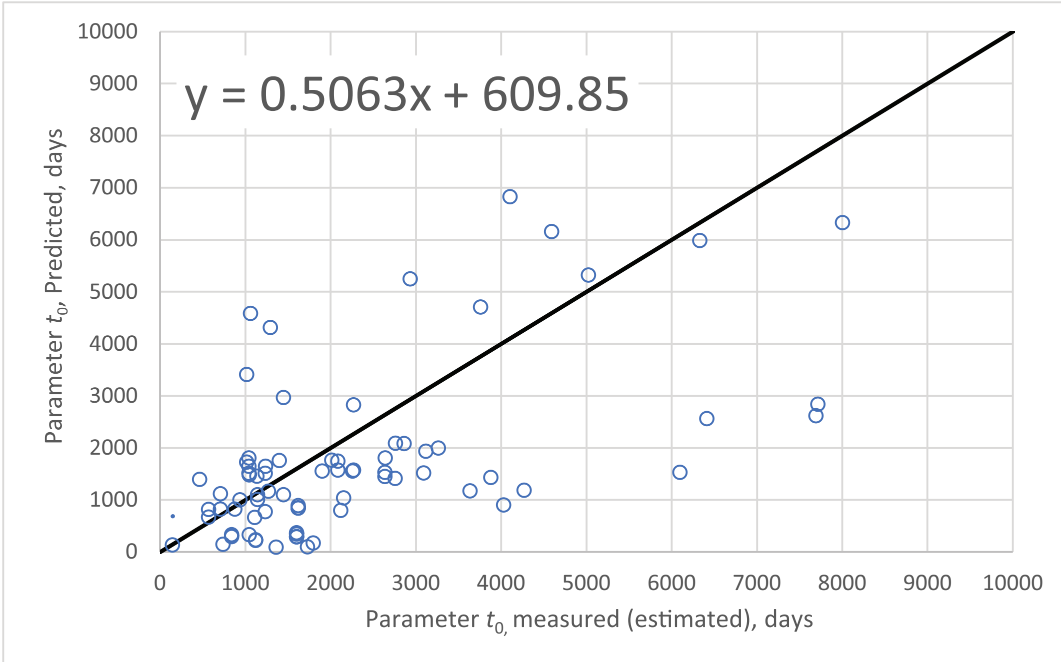

Figure 5-5a. Measured versus Predicted Number of Days to Crack Initiation

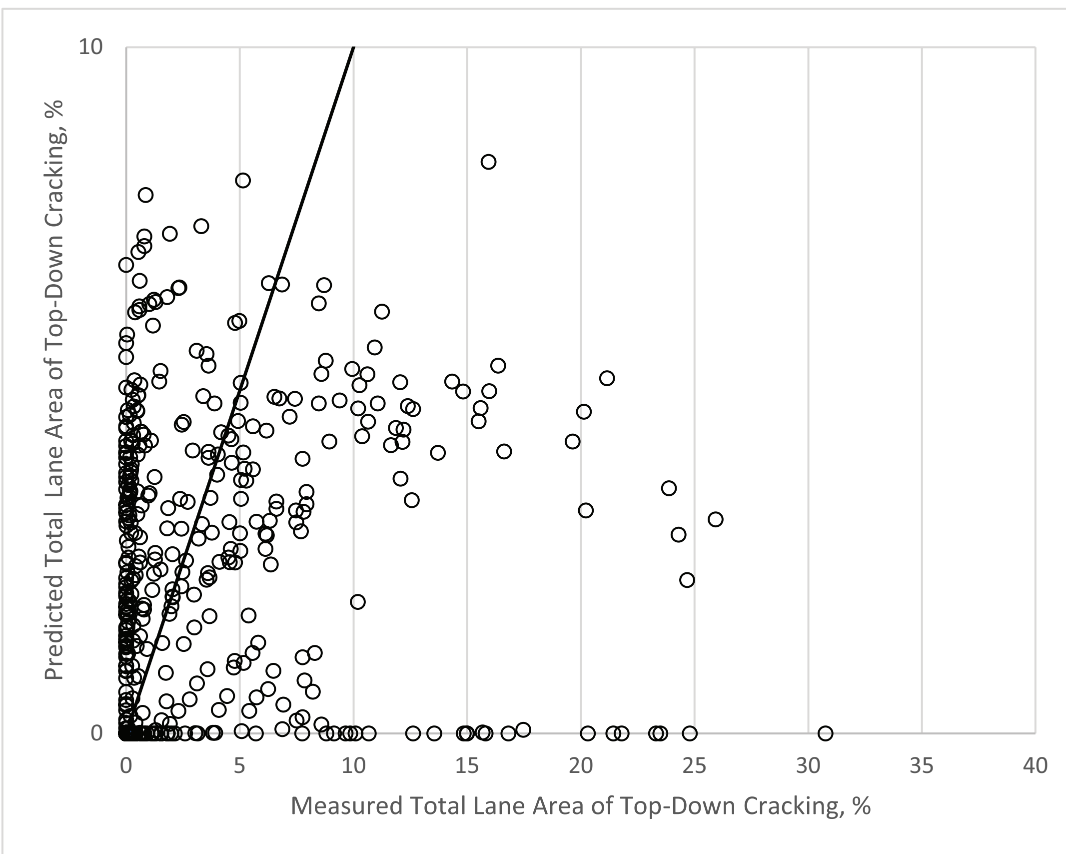

Figure 5-5b. Measured versus Predicted Area of Top-Down Cracking

Table 5-2 shows the values of α_1 and α_2 for the four climatic zones. The calibration parameters for the t_0 values are shown in Table 5-3. Equation 5-11d is the standard deviation of residual errors, σ_{RE}, for determining the reliability of a specific design strategy.

$$\sigma_{RE} = 0.3657\left(TDC_{Mean}\right) + 3.6563 \tag{5-11d}$$

where:

TDC_{Mean} = predicted top-down cracking (% total lane area) based on average inputs

Table 5-2. Calibration Parameters α_1 and α_2: Global Coefficients

Climatic Zone	α_1	α_2
Wet Freeze (WF)	631.04	2269.8
Wet Non-Freeze (WNF)	631.04	2269.8
Dry Freeze (DF)	1617.6	–1705.3
Dry Non-Freeze (DNF)	1617.6	–1705.3

Table 5-3. Calibration Parameters for Crack Initiation Time, t_0: Global Coefficients

Calibration Parameter	New Flexible
K_{L1}	64271618
K_{L2}	0.2855
K_{L3}	0.011
K_{L4}	0.0149
K_{L5}	3.266

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CHAPTER 7

Selecting Design Criteria and Reliability Level

7.1 Recommended Design-Performance Criteria

… Table 7-1 provides the performance values for consideration by highway agencies, realizing that these values may vary among agencies, based on their specific conditions.

Table 7-1. Design Criteria or Threshold Values Recommended for Use in Judging the Acceptability of a Trial Design

Pavement Type	Performance Criteria	Threshold Value at End of Design Life
AC pavement and overlays	AC bottom-up cracking; longitudinal/alligator cracks	Interstate: 10% lane area Primary: 20% lane area Secondary: 35% lane area
	AC top-down cracking; longitudinal/alligator cracks in the wheel paths	Interstate: 10% lane area Primary: 20% lane area Secondary: 35% lane area
	Total rut depth (permanent deformation in wheel paths)	Interstate: 0.40 in. Primary: 0.50 in. Others (<45 mph): 0.65 in.
	Transverse cracking length (thermal cracks)	Interstate: 500 ft/mi Primary: 700 ft/mi Secondary: 700 ft/mi
	IRI (smoothness)	Interstate: 160 in./mi Primary: 200 in./mi Secondary: 200 in./mi
JPCP new, CPR, and overlays	Mean joint faulting	Interstate: 0.15 in. Primary: 0.20 in. Secondary: 0.25 in.
	Percent transverse slab cracking	Interstate: 10% Primary: 15% Secondary: 20%
	IRI (smoothness)	Interstate: 160 in./mi Primary: 200 in./mi Secondary: 200 in./mi

Table 7-1. Design Criteria or Threshold Values Recommended for Use in Judging the Acceptability of a Trial Design *(cont'd)*

Pavement Type	Performance Criteria	Threshold Value at End of Design Life
SJPCP overlays of flexible pavements	Percent longitudinal slab cracking	Interstate: 10% slabs* Primary: 15% slabs* Secondary: 20% slabs*
CRCP new and overlays	Punchouts	Interstate: 10 Primary: 15 Secondary: 20
	IRI	Interstate: 160 in./mi Primary: 200 in./mi Secondary: 200 in./mi

* Performance criteria levels need review by agency for adequacy.

***The following paragraph is to be added*:**

Two parameters are predicted by the top-down cracking model as discussed in Chapter 5: percent total lane area with top-down cracking (see Equation 5-11a) and the average crack depth (see Equation 5-8c). Both percent total lane area and crack depth are included as graphs in the output report. The percent lane area with top-down cracks is a design criterion; however, crack depth is not considered a design criterion. The reliability is only calculated for the percent total lane area with top-down cracks, because the standard deviation of the residual errors between the measured and predicted top-down cracks is only applicable to the percent total lane area and not crack depth. The average crack depth with age graph, however, can be used by the designer to determine when a rehabilitation or repair strategy should be considered to prevent the top-down cracks from reaching a lower asphalt layer.

Table 8-3.2. Axle Load Groups for Single and Dual Tires

FHWA Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
4	Group 1	Group 3	Group 5	Group 7
5	Group 1	Group 3	Group 5	Group 7
6	Group 1	Group 4	Group 6	Group 8
7	Group 1	Group 4	Group 6	Group 8
8	Group 2	Group 4	Group 6	Group 8
9	Group 2	Group 4	Group 6	Group 8
10	Group 2	Group 4	Group 6	Group 8
11	Group 2	Group 4	Group 6	Group 8
12	Group 2	Group 4	Group 6	Group 8
13	Group 2	Group 4	Group 6	Group 8

- …
- **Tire Pressure:** The AASHTOWare PMED software assumes a constant tire pressure for all loading conditions that represents operating conditions (hot inflation tire pressure) for calculating all pavement distresses, except for top-down fatigue cracks in asphalt wearing surfaces. A median value of 120 psi was used in all calibration efforts. It is recommended that this value be used, unless hot inflation pressures are known from previous studies or a special loading condition is simulated.

  For top-down cracking, a constant tire pressure of 120 psi is assumed for all dual tires and single tires with the higher axle loads. However, 40 psi is assumed and used for single tires with the lower axle loads (see Table 8-3.1).
- …

8.2 Climate

…The most important climatic input to the top-down cracking model is the pavement temperature at the crack tip, which is calculated from the pavement nodal temperatures from EICM outputs. Aging models for asphalt mixture wearing surface require the climatic zone (wet/dry, freeze/non-freeze) as an input, which is also calculated by the software from EICM outputs. Equation 5-11a includes the climate parameters defined from the climate that are used to calculate the total percent lane area with top-down cracking.

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CHAPTER 12

Rehabilitation Design Strategies

12.12 Rehabilitation Design with AC Overlays

Table callouts are updated to reflect Chapter 5 revisions as detailed below.

12.12.4 Decide on Pre-Overlay Treatment
In the fourth paragraph after Table 12-3:

The fitting and user-defined cracking calibration parameters in the MEPDG reflection crack prediction equation are provided only for the AC overlay with paving fabrics (refer to **Table 5-4** in Subsection 5.3.5).

12.12.8 AC Overlays of Existing Intact PCC Pavements, Including Composite Pavements (One or More AC overlays of Existing JPCP and CRCP)
In the first paragraph:

The transfer function has been globally calibrated. The global calibration model coefficients are included in **Tables 5-4 and 5-5**.

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