Pavement Health Track (PHT) RSL Forecasting Models

Technical Information

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16. Abstract

The objective of this study was to develop for the FHWA, using an off-the-shelf engineering analysis software interface tool architecture, the Pavement Health Track (PHT) Analysis Tool.

The PHT Analysis Tool is an engineering software application for determining and reporting the health of pavement networks in terms of the pavement's remaining service life (RSL). The PHT Analysis Tool uses performance models recently developed by FHWA for the Highway Economic Requirements System (HERS) and the National Pavement Cost Model (NAPCOM). These pavement models are based on concepts developed under National Cooperative Highway Research Program (NCHRP) Projects 1-37A and 1-40D and included in the Interim American Association of State Highway and Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (MEPDG), making them a simplified version of the more complex mechanistic-empirical (ME) set of models and procedures used in the Interim AASHTO MEPDG.

This report presents an overview of the simplified MEPDG models incorporated into the PHT Analysis Tool along with a detailed description of PHT Analysis Tool approaches to determining pavement RSL, guidance on setting up the PHT analysis tool input database from HPMS and other databases, and guidance on setting key parameters for determining overall RSL.

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PAVEMENT REMAINING SERVICE LIFE: OVERVIEW

Overview

A cornerstone of highway pavement management is to ensure that a given network of pavements provides a minimum level of service to the user public at all times. One way of ensuring that pavements perform adequately is to (1) monitor their condition using performance measures/indicators and (2) forecast future pavement performance with reasonable accuracy so as to be able to plan future maintenance and rehabilitation needs cost effectively. Knowing the current condition and estimating the future pavement condition allows managers to answer the following:

- What is the current condition of my pavement network?
- How does the current condition compare to the required level of service/performance?
- Which individual pavement sections are critical to sustained performance?
- What are my best “operations and maintenance” and “capital improvement” investment strategies to ensure sustained performance over the short to medium time horizon?
- What is my best long-term funding strategy to ensure sustained performance?

The main performance indicator used in answering the questions posed above is pavement remaining service life (RSL).

Service life of a new pavement is defined as the period over which a pavement section adequately performs its desired function or performs to a desired level of service. For an existing pavement, RSL is simply the amount of service life left.

Pavement RSL has been in use, directly or indirectly, for many years, and it provides engineers and managers with an objective assessment of how many more years (under predefined conditions of traffic, environments, terminal level of service, and other factors) a given highway section or network will continue to be in existence.

Approaches to Determining Pavement RSL

Traditional Approach

Traditionally pavement condition has been defined based on only the structural and functional condition of the pavement—the period of time under specified site conditions during which a pavement’s structural or functional condition is expected to remain within stated limits, provided that appropriate routine and preventive maintenance are carried out. Examples of stated design and site conditions include:

- Demands actually placed on the pavement while in use (e.g., traffic applications)
- Environmental conditions (e.g., harshness of the environment [freeze-thaw or wet-dry])
- Planned routine, preventive, and corrective maintenance and other preservation activities
- End condition level of the pavement.

Figure 1 shows an example of how future pavement performance is forecast and used to estimate pavement RSL. Note that RSL could be significantly different if traffic applications and terminal performance are varied. The ability to forecast future pavement condition both at the project and network levels is the bedrock to a successful determination of pavement RSL. For this traditional definition of pavement RSL, pavement condition is characterized using an overall pavement condition index such as pavement serviceability rating (PSR) or smoothness.

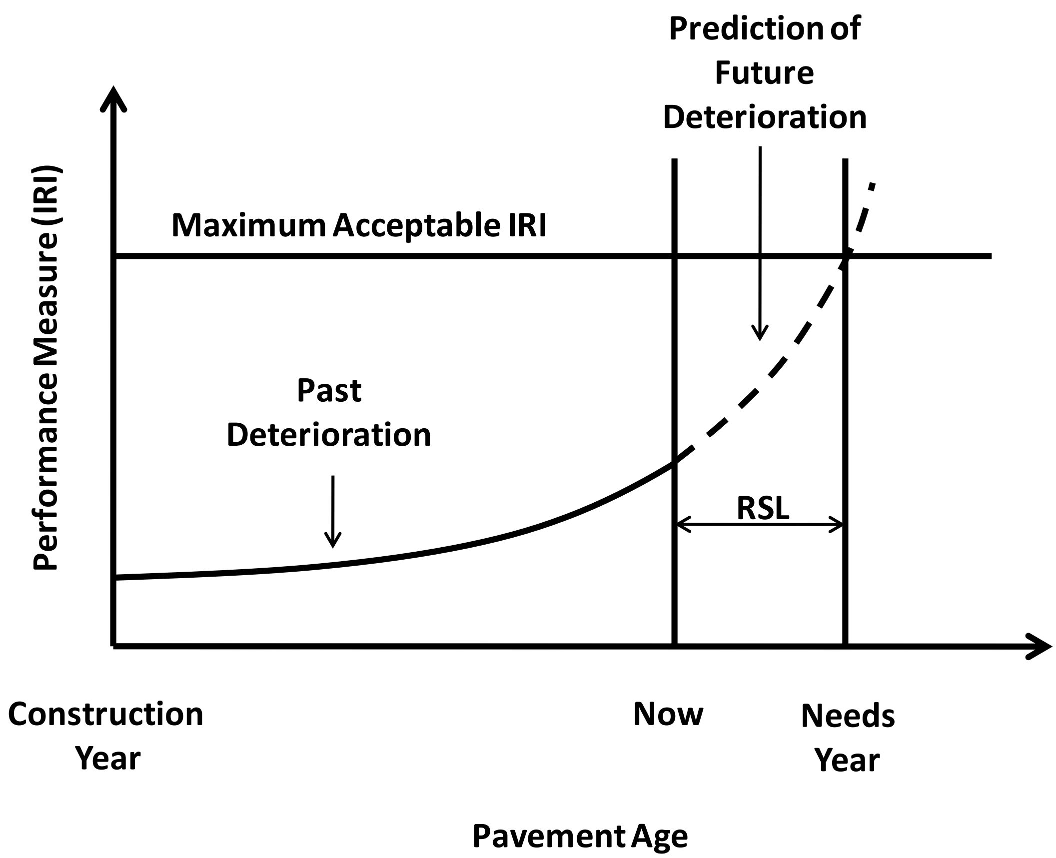

Figure 1. Example of pavement RSL
[based on smoothness (International Roughness Index, or IRI) loss only]

PHT Tool Approach

Current practice is to apply a multi-condition approach for determining pavement RSL. Several publications, including the American Association of State Highway and Transportation Officials (AASHTO) Asset Management Guide and National Cooperative Highway Research Program (NCHRP) Report 551: Performance Measures and Targets for Transportation Asset Management, have described performance measures that can be used in characterizing pavement condition. Commonly used pavement performance measures/indicators used to characterize pavement structural and functional condition are presented in Table 1.

Table 1. Multi-Condition Approach for Determining Pavement RSL

Pavement Performance Measure	Estimate of Pavement RSL
Structural Condition Period until pavement reaches renewal terminal condition level	Time until pavement structural condition deteriorates to renewal intervention level (excessive alligator cracking, transverse cracking, rutting, and faulting)
Functional Condition Period until the pavement no longer provides the required level of service	Time until pavement smoothness deteriorates to renewal intervention level (excessive roughness)

With these performance measures, pavement RSL can be determined to satisfy varying objectives [e.g., remaining functional life, remaining structural life, remaining service life (overall), etc].

Using multiple performance measures, RSL is determined first for each individual pavement performance measure as follows:

$$RSL_{PMX} = AGE_{TD} - AGE_{NOW} \tag{1}$$

Where

RSL_{PMX} = RSL based on performance measure X

AGE_{TD} = forecasted pavement age at threshold value of performance measure X

AGE_{NOW} = current pavement age.

The RSL of a newly constructed pavement is equal to the pavement design life, and any pavement section with a condition worse than the threshold has an RSL of 0.

The PHT Tool allows for overall pavement RSL for a given pavement section to be determined using two methods presented below:

Method 1

Overall pavement section RSL is basically the minimum of all the individually computed RSLs for each performance measure considered. It is defined mathematically as follows:

$$\text{Overall RSL} = \text{Min}\,(RSL_{PM1}, RSL_{PM2}, RSL_{PM3}, \ldots\ldots\ldots\ldots RSL_{PMN}) \tag{2}$$

Method 2

Overall pavement section RSL is basically the weighted average of all the individually computed RSLs for each performance measure considered. It is defined mathematically as follows:

$$\text{Overall RSL} = \frac{\sum_{i=1}^{k} \mathrm{W_i} * \mathrm{RSL}_{\mathrm{PM_i}}}{\sum_{i=1}^{k} \mathrm{W_i}} \qquad (3)$$

Where

Wi	=	weight assigned to a given performance measure i
RSL_{PMi}	=	RSL computed for given performance measure i.

PROCEDURE FOR COMPUTING PAVEMENT RSL

The specific steps that the PHT Tool conducts to determine RSL for a given pavement section are summarized below:

1. Select analysis type and parameters
    a. Analysis type:
        i. Minimum RSL
        ii. Weighted average
    b. Analysis parameters:
        i. Assign weighting factors to each distress/IRI to be used to determine overall RSL.
2. Extract from the Highway Performance Monitoring System (HPMS) program and default databases all relevant data for the given pavement section.
3. Determine current age and condition (distress/IRI).
4. Use relevant pavement condition (distress/IRI) models to forecast future pavement condition (distress/IRI). The predicted future distress/IRI is adjusted using actual distress/IRI data if available in HPMS. This ensures that current pavement condition is projected into the future, minimizing potential errors in future condition predictions.
5. Determine pavement age at which each individual distress/IRI threshold value is attained.
6. Estimate RSL for each individual performance measure (distress/IRI) of interest.
7. Determine overall pavement section RSL (note that computed RSL cannot be greater than the maximum pavement service life)
    a. Minimum RSL
    b. Weighted value.
8. Generate reports and graphs as needed
    a. Histograms
    b. GIS plots.

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PAVEMENT CONDITION FORECASTING MODELS

A summary of performance measures and associated models used to characterize pavement condition is presented in Table 2. Descriptions of each model presented in Table 2 are presented in the following sections.

Table 2. Summary of Performance Measures and Associated Models

Pavement Type	Distress Type/Smoothness	Unit of Measurements
Jointed plain concrete pavement (JPCP)	Transverse “slab” cracking	Percent slabs cracked
	Mean transverse joint faulting	inches
	Transverse joint spalling	percent joints spalled
	Smoothness (IRI)	in/mi
New asphalt pavement	Alligator cracking	Percent lane area
	Rutting	inches
	Transverse cracking	ft/mi
	Smoothness	in/mi
Asphalt concrete (AC) over JPCP	Reflection transverse cracking	percent lane area with reflection cracking

New JPCP Equations

Transverse “Slab” Cracking Model

$$\text{CRK} = \left(\frac{100}{1 + 733085^{-0.00521*(\text{ESALS*LB\_TRF\_FACTOR})^{0.25} + \Delta}} \right) \tag{4}$$

Where

CRK = predicted percent slabs cracked
ESALs = cumulative number of 18-kip equivalent single axle load (see section on estimating equivalent single-axle loads, or ESALs)

$$\text{LB\_TRAF\_FACTOR} = \left(\frac{1}{1 + \left[\frac{\text{AGE}}{\text{LB\_AGE} + 5.41} + 0.0000001 \right]^{-7.89}} \right) \tag{5}$$

AGE = pavement age in years
LB_AGE = age at which the Portland cement concrete (PCC) slab debonds from the base (see PHT Tool default data tables)
LN(Δ) = γ_1 *(EdgeSup) + γ_2*EPCC + γ_3*JTSP + γ_4*PCC_COMP + γ_5*PCCTHK + γ_6*SUBGCOAR + γ_7*CLIMWF (6)

$$+ \gamma_8 * CLIMWNF + \gamma_9 * CLIMDNF$$

A description of the coefficient and input variables used for computing the natural log of Δ is presented in Table 3.

Table 3. JPCP Transverse Cracking Model Coefficients and Input Variables

JPCP Transverse Cracking Model Coefficient	Coefficient Value	Description of Cracking Model Input Variables	Source
γ_1	0.1424	EdgeSup (Edge support), 1 if a tied PCC shoulder or widened slab (slab width > 12 ft) is used, otherwise 0	HPMS program (Lane_Width & Shoulder_Type)
γ_2	- 3.36E-7	EPCC = 28-day PCC slab elastic modulus in psi	PHT Tool default data tables
γ_3	- 0.0571	JTSP = JPCP joint spacing or slab length in feet	HPMS program (Joint_Spacing)
γ_4	0.000188	PCC_COMP = 28-day PCC compressive strength in psi	PHT Tool default data tables
γ_5	0.0598	PCCTHK = PCC slab thickness in inches	HPMS program (Thickness_Rigid)*
γ_6	0.2951	SUBGCOAR = 1 if subgrade soil type is coarse grained, otherwise 0	HPMS program (Soil_Type)
γ_7	0.1323	CLIMWF = 1 if pavement is located in a wet-freeze climate, otherwise 0	HPMS program (Climate_Zone)
γ_8	0.2443	CLIMWNF = 1 if pavement is located in a wet-no-freeze climate, otherwise 0	
γ_9	0.7636	CLIMDNF = 1 if pavement is located in a dry-no-freeze climate, otherwise 0	

*Also available in HPMS Estimates table.

Transverse Joint Faulting Model

$$\begin{aligned} PFAULT = \; & (ESALS^{0.521})*(1 - 0.6413*DowDia)*(-9.01E\text{-}06*ATB \\ & - 9.50E\text{-}06*CTB + 0.000013*(1\text{-}EdgeSup) + 1.44E\text{-}08*FI \\ & + 3.68E\text{-}06*JTSP + 0.000014*WET - 4.91E\text{-}06*PCCTHK \\ & - 9.36E\text{-}06*SubgCoar) \end{aligned} \tag{7}$$

A description of input variables used for faulting is presented in Table 4.

Transverse Joint Spalling

$$SPALL = \left[\frac{AGE}{AGE + 0.01}\right]\left[\frac{100}{1 + 1.005^{(-12*AGE+SCF)}}\right] \quad (8)$$

Where

SPALL = predicted percentage joints spalled (medium- and high-severities)

AGE = pavement age since construction or reconstruction, years

SCF = scaling factor based on site-, design-, and climate-related variables:

SCF = –1400 + 350 * AIR% * (0.5 + PREFORM) + 43.4 f'c ^ 0.4 – 0.2 (FTCYC * AGE) + 43 hPCC – 536 WC_Ratio (9)

A description of input variables used for computing SCF is presented in Table 5.

Table 4. Description of JPCP Transverse Joint Faulting Model Input Variables

Description of Faulting Model Input Variables	Source
PFAULT = predicted mean transverse joint faulting, in	—
ESALs = cumulative number of 18-kip equivalent single axle load	see Section on estimating ESALs
DowDia = dowel diameter, in	HPMS program (Dowel_Bar) & PHT Tool default data tables
ATB = 1 if base type is asphalt treated material, otherwise 0	HPMS program (Base_Type)*
CTB = 1 if base type is cement treated material, otherwise 0, for CTB = 1	HPMS program (Base_Type)*
EdgeSup (Edge support) = 1 if a tied PCC shoulder or widened slab (slab width > 12 ft) is used, otherwise 0	HPMS program (Lane_Width & Shoulder_Type)
FI = freezing index, deg F days	PHT Tool default data tables
JTSP = JPCP joint spacing or slab length in feet	HPMS program (Joint_Spacing)
WET= 1 if climate is “Wet-Freeze” or “Wet-Nofreeze,” otherwise 0	HPMS program (Climate_Zone)
PCCTHK = PCC slab thickness in inches	HPMS program (Thickness_Rigid)*
SUBGCOAR = 1 if subgrade soil type is coarse grained, otherwise 0	HPMS program (Soil_Type)

* Also available in HPMS Estimates table.

Table 5. Description o f JPCP Transverse Joint Spalling Model Input Variables

Description of Spalling Model Input Variables	Source
AIR% =PCC air content, percent	PHT Tool default data tables
AGE = time since last construction or reconstruction, years	HPMS program (Year_Last_Improvement OR Year_Last_Construction)
PREFORM =1 if preformed sealant is present; 0 if not	PHT Tool default data tables
f'c =PCC 28-day compressive strength, psi	PHT Tool default data tables
FTCYC = average annual number of air freeze-thaw cycles	PHT Tool default data tables
hPCC = PCC slab thickness, in	HPMS program (Thickness_Rigid)*
WC_Ratio = PCC water/cement ratio (by weight)	PHT Tool default data tables

* Also available in HPMS Estimates table.

Smoothness (IRI)

$$IRI = IRI_I + 0.8203*CRK + 0.4417*SPALL + 0.4929*TFAULT + 25.24*SF \qquad (10)$$

Where

SF = Site factor = AGE (1+0.5556*FI) (1+P_{200})*10^{-6}

A description of input variables used for computing IRI is presented in Table 6.

Table 6. Description of JPCP IRI Model Input Variables

Description of IRI Model Input Variables	Source
IRI = predicted IRI, in/mi	
IRII = initial IRI, in/mi	Assume MEPDG default of 63.4 in/mi OR assume HPMS program IRI corresponding to Year_Last_Improvement OR Year_Last_Construction
CRK = percent slabs with transverse cracks	See equation 4
SPALL = percentage of joints with spalling (medium and high severities)	See equation 8
TFAULT= Total joint faulting cumulated per mi, in	See equation 7
AGE = pavement age since construction or reconstruction, years	HPMS program (Year_Last_Improvement OR Year_Last_Construction)
FI = mean annual freezing index, °F-days	PHT Tool default data tables
P200 = percent subgrade material passing No. 200 sieve	PHT Tool default data tables

*Also available in HPMS Estimates table.

New Flexible Pavement Equations

The first step in computing flexible pavement distress and IRI is to estimate critical strains within the hot mix asphalt (HMA), base, and subgrade layers as described in the following sections.

Input 1: HMA Dynamic Modulus (Witzak Model)

$$\begin{aligned}\log E^{*} &= -1.249937 + 0.02932\rho_{200} - 0.001767(\rho_{200})^{2} - 0.002841\rho_{4} - 0.058097V_{a} \\ &- 0.802208\left(\frac{V_{beff}}{V_{beff}+V_{a}}\right) + \frac{3.871977 - 0.0021\rho_{4} + 0.003958\rho_{38} - 0.000017(\rho_{38})^{2} + 0.005470\rho_{34}}{1+e^{(-0.603313-0.313351\log(f)-0.393532\log(\eta_{t,z}))}}\end{aligned} \tag{11}$$

Table 7 describes the input variables used for computing HMA Dynamic Modulus. The input variables and the steps involved in estimating aged HMA binder viscosity and loading frequency of loading are presented below.

Table 7. Description of HMA Dynamic Modulus Equation Input Variables

Description of HMA Dynamic Modulus Equation Input Variables	Source
E^{*}= HMA dynamic modulus, psi	See equation 11
$\eta_{t,z}$ = aged HMA binder viscosity at time t, and depth z, MPoise	See equation 18
f = pavement layer loading frequency, Hz	See equation 13
V_a = as-constructed HMA mix air void content, percent	PHT Tool default data tables
V_{beff} = effective as-constructed HMA mix bitumen content, percent by volume	PHT Tool default data tables
ρ_{34} = cumulative percent retained on the ¾ in sieve for the HMA mix	PHT Tool default data tables
ρ_{38} = cumulative percent retained on the 3/8 in sieve for the HMA mix	PHT Tool default data tables
ρ_{4} = cumulative percent retained on the No. 4 sieve for the HMA mix	PHT Tool default data tables
ρ_{200} = percent passing the No. 200 sieve for the HMA mix	PHT Tool default data tables

A. Input variables for estimating aged HMA binder viscosity (at time t and depth z) (input to HMA dynamic modulus model)

<u>Step 1</u>: Compute unaged HMA binder viscosity (at a reference temperature of 77 ^{o}F) using the American Society for Testing and Materials (ASTM) viscosity temperature relationship below:

$$\log\log\eta_{orig} = A + VTS\log T_{R} \tag{12}$$

A description of the input variables used for computing unaged HMA binder viscosity is presented in Table 8.

Table 8. Input Variables for the Unaged HMA Binder Viscosity Equation

Description of Unaged HMA Binder Viscosity Equation Input Variables	Source
η_{orig} = unaged HMA binder viscosity (at reference temperature 77 oF), cP	See equation 12
T_R = temperature, Rankine (reference temperature is 77 ^{o}F, convert to Rankine)	—
A = regression intercept *	PHT Tool default data tables
VTS = regression slope of viscosity temperature susceptibility	PHT Tool default data tables

* See Tables 51 and 52 in "Guidelines for Implementing the new MEPDG Pavement Equations." Battelle and ARA. Draft Final report submitted to FHWA Office of Policy. May 2010.

Step 2: Compute HMA binder viscosity at placement as follows:

$$\begin{aligned} \log\log(\eta_{t=0}) &= a_0 + a_1 \log\log(\eta_{orig}) \\ a_0 &= 0.054405 + 0.004082 \times code \\ a_1 &= 0.972035 + 0.010886 \times code \end{aligned} \tag{13}$$

A description of input variables used for computing HMA binder viscosity at placements presented in Table 9.

Table 9. Input Variables for the HMA Binder Viscosity at Placement Equation

<table>
<tr><th>Description of HMA Binder Viscosity at Placement Equation Input Variables</th><th>Source</th></tr>
<tr><td>$\eta_{t=0}$ = HMA binder viscosity at placement, cP</td><td>—</td></tr>
<tr><td>η_{orig} = unaged HMA binder viscosity, cP</td><td>See equation 10</td></tr>
<tr><td>code = hardening ratio (0, representing average conditions is recommended)</td><td>
<table>
<tr><th>Placement Hardening Resistance</th><th>Expected Hardening Ratio Values</th><th>Code Value</th></tr>
<tr><td>Excellent to Good</td><td>HR ≤ 1.030</td><td>-1</td></tr>
<tr><td>Average</td><td>1.030 < HR ≤ 1.075</td><td>0</td></tr>
<tr><td>Fair</td><td>1.075 < HR ≤ 1.100</td><td>1</td></tr>
<tr><td>Poor</td><td>HR > 1.100</td><td>2</td></tr>
</table>
</td></tr>
</table>

Step 3: Compute HMA binder viscosity at any given pavement age (at the HMA surface) described as follows:

$$\log\log(\eta_{aged}) = \frac{\log\log(\eta_{t=0}) + At}{1 + Bt} \tag{14}$$

where

A = $-0.004166+1.41213(C)+(C)\log(MAAT)+(D)\log\log$□$\eta_{t=0})$

B = $0.197725+0.068384\log(C)$

C = $10^{(274.4946-193.831\log(T_R)+33.9366\log(T_R)^2)}$

D = $-14.5521+10.47662\log(T_R)-1.88161\log(T_R)^2$

A description of input variables used for computing HMA binder viscosity at any given pavement age (at the HMA surface) is presented in Table 10.

Table 10. Input Variables for the HMA Binder Viscosity Equation (at the HMA surface, for any given age)

Description of HMA Binder Viscosity at Any Age Equation Input Variables	Source
η_{aged} = aged viscosity at HMA surface, cP	See equation 14
$\eta_{t=0}$ = HMA binder viscosity at placement, cP	See equation 13
MAAT = mean annual air temperature, °F	PHT Tool default data tables
T_R = pavement surface temperature in Rankine	PHT Tool default data tables
t = time in months (pavement age in months)	HPMS program (Year_Last_Improvement OR Year_Last_Construction)

Step 4: Adjust aged viscosity at HMA surface (η_{aged}) for changes in HMA air voids as follows:

$$\log\log(\eta_{aged})' = F_v \log\log(\eta_{aged}) \tag{15}$$

$$F_v = \frac{1 + 1.0367\times10^{-4}(VA)(t)}{1 + 6.1798\times10^{-4}(t)} \tag{16}$$

$$VA = \frac{VA_{orig} + 0.011(t) - 2}{1 + 4.24\times10^{-4}(t)(Maat) + 1.169\times10^{-3}\left(\dfrac{t}{\eta_{orig,77}}\right)} + 2 \tag{17}$$

A description of input variables used for adjusting aged viscosity at HMA surface (η_{aged}) for changes in HMA air voids is presented in Table 11.

Table 11. Input Variables for Adjusting Aged Viscosity for Changes in HMA Air Voids (at the HMA surface)

Description of Input Variables for Adjusting Aged Viscosity at HMA Surface (η_{Aged}) for Changes in HMA Air Voids Input Variables	Source
VA_{orig} = HMA air voids at placement HMA, percent	PHT Tool default data tables
MAAT = mean annual air temperature, °F	PHT Tool default data tables
η_{orig} = unaged HMA binder viscosity (at reference temperature 77 oF), cP	See equation 10
t = time in months (pavement age in months)	HPMS program (Year_Last_Improvement OR Year_Last_Construction)

Step 5: Compute HMA viscosity at a given age and depth within the HMA layer as follows:

$$\eta_{t,z} = \frac{\eta_t(4+E) - E(\eta_{t=0})(1-4z)}{4(1+Ez)} \tag{18}$$

A description of input variables used for computing HMA viscosity at a given age and depth within the HMA layer is presented in Table 12.

Table 12. Input Variables for Computing HMA Viscosity (at a given age and depth)

Description of Input Variables for Computing HMA Viscosity at a Given Age and Depth Within the HMA Layer Input Variables	Source
$\eta_{t,z}$ = HMA binder viscosity at time t, and depth z, MPoise	See equation 18
$(\eta_{aged})'$ = HMA binder viscosity (aged viscosity at HMA surface adjusted for changes in HMA air voids), MPoise	See equation 15
z = depth within HMA layer of interest, in	Determined based on critical response location (see Table 13)
$E = 23.83e^{(-0.0308\ MAAT)}$	—
MAAT = mean annual air temperature, °F	PHT Tool default data tables

Table 13. Locations for Computing Critical Flexible Pavement Responses

New Equation	Critical Location (Depth)
Rutting	Middle of the HMA layer
Transverse cracking	0.5-in
Alligator cracking	Bottom of HMA layer

B. Input variables for estimating frequency of loading (input to HMA dynamic modulus model)

Frequency of loading is determined as follows:

$$f = \frac{17.6 * V_S}{L_{eff}} \tag{19}$$

A description of the variables used for computing frequency of loading is presented in Table 14.

Table 14. Input Variables for Computing Frequency of Loading

Description of Input Variables for Frequency of Loading	Source
V_s = travel speed	HPMS program (Speed_Limit)
L_{eff} = effective length, ft = $2(a_c + Z_{eff})$	—
a_c = radius of tire contact area	Assume 6-in
Z_{eff} = effective depth, in = $d_i * \sqrt[3]{\frac{E_{HMA}}{M_r}}$	—
d_i = critical location (depth) within HMA layer for which frequency is being calculated	See Table 13
E_{HMA} = HMA modulus, psi	Assume typical value of 1,000,000 psi
Mr = subgrade resilient modulus, psi	PHT Tool default data tables

Input 2: Critical Strains Equation Inputs

A description of input variables required by the equations for computing critical strains is presented in Table 15.

Table 15. Input Variables Required for Computing Critical Strains

Description of Input Variables Required by the Equations for Computing Critical Strains	Source
hAC = HMA thickness, in	HPMS program (Thickness_Flexible)**
E* = HMA dynamic modulus, psi ()	See Equation 9
hB = base layer thickness	HPMS program (Base_Thickness)**
EB = base layer modulus, psi	HPMS program (Base_Type) and PHT Tool default data tables**
ESUBG = subgrade layer modulus	HPMS program (Soil_Type) and PHT Tool default data tables**

**Also available in HPMS Estimates table.

Use the inputs assembled to compute critical strain within the pavement structure as needed using the closed-form equations presented in Table 16.

Table 16. Equations for Estimating Critical Strains within HMA Pavement

Model Input Variables/Clusters	Model Coefficients			
	Equation 20	Equation 21	Equation 22	Equation 23
	Horizontal Tensile Strain at the Bottom of HMA Layer	Vertical Strain at the Middle of HMA Layer	Vertical Strain at the Middle of Base Layer	Vertical Strain at the Top of Subgrade Layer
Intercept	0.007706079	-0.010539965	-0.013753501	-0.005714644
hAC	-0.000875072	0.000580293	0.001795503	0.000670647
E*	-0.000371346	0.001475217	0.000590472	0.000206993
hB	-0.000160482	-8.95177E-05	0.000696071	0.000481929
EB	-0.000541586	-3.38384E-05	0.001059805	3.15126E-05
ESUBG	-5.93918E-05	-8.15273E-05	-3.35863E-05	0.000518046
hAC* hAC	0.00001224	3.81811E-05	-4.18585E-05	-9.8384E-06
hAC *E*	1.64491E-05	-5.76145E-05	-0.000026373	-5.7542E-06
(E*)*(E*)	8.595E-07	-5.06666E-05	-2.9108E-06	-1.0728E-06
hAC *hB	8.3575E-06	7.7843E-06	-6.06075E-05	-4.32508E-05
hB *E*	2.5259E-06	6.1704E-06	-2.25257E-05	-1.30924E-05
hB*hB	6.1914E-06	-7.451E-07	1.6373E-06	-1.4025E-06
hAC *EB	4.17036E-05	2.4867E-06	-8.40397E-05	-6.8449E-06
EB*E*	2.34109E-05	3.4547E-06	-3.06634E-05	-1.8974E-06
hB*EB	1.5431E-06	-2.6824E-06	-1.68535E-05	3.5859E-06
EB*EB	2.8965E-06	-5.528E-07	-1.74637E-05	1.4018E-06
hAC *ESUBG	1.1711E-06	0.000005491	7.128E-07	-3.41892E-05
ESUBG*E*	-3.461E-07	4.4916E-06	5.702E-07	-1.04126E-05
hB*ESUBG	5.5404E-06	0.000002114	-1.8562E-06	-2.26448E-05
EB*ESUBG	3.2144E-06	-1.213E-07	5.3833E-06	-3.1661E-06
ESUBG*ESUBG	3.526E-07	9.21E-08	-2.1207E-06	-0.000009591

NOTES:

For Equation 18, if the estimated tensile strain is less than 0, set tensile strain to 0.000001.

For Equations 19, 20 and 21, if the vertical compressive strain is greater than 0, set vertical compressive strain to 0.000001, otherwise vertical compressive strain = estimated value * -1.

Compute Distress and IRI for Flexible Pavements

Alligator Cracking

$$ACRK = \frac{89.644}{0.1331 + 7.6199 \sum_{n=1}^{n=k} FDAM^{-0.8361}} \tag{24}$$

A description of the variables required by the alligator cracking model is presented in Table 17.

Table 17. Input Variables Required by the Alligator Cracking Model

Description of Input Variables Required by the Alligator Cracking Model	Source
ACRK = alligator cracking, percent lane area	—
k = total number of months in analysis period	—
FDAM = fatigue at the bottom of the HMA layer $= \frac{MESAL}{N_f}$	—
MESAL = total 18-kip ESALs for each given month	See section on estimating traffic
N_f = allowable number of 18-kip ESALs applications $= 1.2347 * 0.00432 * k_1 * C * \left(\frac{1}{E^*}\right)^{1.281*\beta_1} * \left(\frac{1}{\varepsilon_t}\right)^{3.9492*\beta_2}$	—
$k_1 = \frac{1}{0.000398 + \frac{0.003602}{1 + e^{(11.02 - 3.49 \times h_{AC})}}}$	—
hAC = HMA thickness, in	HPMS program (Thickness_Flexible)**
$C = 10^M$	—
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	—
V_a = HMA mix as-constructed air voids, percent	PHT Tool default data tables
V_b = HMA mix effective as-constructed placed volumetric binder content	PHT Tool default data tables
β_1 = 1.2	—
β_2 = 1.0672	—
E* = HMA dynamic modulus, psi ()	See Equation 11
ε_t = tensile strain at the bottom of the HMA layer	See Equation 20

**Also available in HPMS Estimates table.

Rutting

$$\text{TRUT} = \text{ACRUT} + \text{BASERUT} + \text{SUBGRUT} \tag{25}$$

Where

TRUT = total pavement rutting, in

ACRUT = rutting in the HMA layer, in

$$= 0.000493 \times MAAT^{1.5606} \times \sum_{n=1}^{k} \left(\varepsilon_{vHMA} \times MESAL^{0.4791} \right) \tag{26}$$

BASERUT = rutting in the base layer, in

$$= 4.4833 * \varepsilon_{\text{vBASE}} * \text{h}_\text{B} * \text{CESAL}^{0.1307} \tag{27}$$

SUBGRUT = rutting in the subgrade layer, in

$$= (0.0025 PRECIP + 0.000080 FI) \left(\frac{\varepsilon_o}{\varepsilon_r} \right)^{0.9692} e^{-\left(\frac{\rho}{CESAL}\right)^{\beta}} \left(\varepsilon_{vSUBG} \right)^{0.1116} \tag{28}$$

A description of input variables required by the rutting model is presented in Table 18.

Table 18. Input Variables Required by the Rutting Model

Description of Input Variables Required by the Rutting Model	Source
MAAT = mean annual air temperature, °F	PHT Tool default data tables
k = total number of months in analysis period	—
MESAL = total 18-kip ESALs for each given month	See section on estimating traffic
$\varepsilon_{\text{vHMA}}$ = vertical strain in the middle of the HMA layer	See Equation 21
$\varepsilon_{\text{vBASE}}$ = vertical strain in the middle of the BASE layer	See Equation 22 (use representative $\varepsilon_{\text{vBASE}}$ for the entire analysis period)
hB = base layer thickness	HPMS program (Base_Thickness)**
CESAL = total 18-kip ESALs for entire analysis period	See section on estimating traffic
$\varepsilon_{\text{vSUBG}}$ = vertical strain in the top 12 in. of the subgrade	See Equation 22 (use representative $\varepsilon_{\text{vSUBG}}$ for the entire analysis period)
PRECIP = mean annual precipitation or rainfall	PHT Tool default data tables
FI = mean annual freezing index, °F days	PHT Tool default data tables
$\beta = 0.7*10^{(-0.61119-0.017638\text{Wc})}$	—
$\rho = 10^{(0.622685 + 0.541524\text{Wc})}$	—
$\left(\frac{\varepsilon_o}{\varepsilon_r}\right) = 10^{(0.74168 + 0.08109\text{Wc} - 0.000012157*\text{Mr})}$	—
W_c = soil moisture content $= 51.712 * CBR_{SUBG}^{-0.3586 \times GWT^{0.1192}}$	—
GWT = depth to ground water table $\text{CBR}_{\text{SUBG}} = \left(\frac{M_r}{2555}\right)^{1.5625}$	PHT Tool default data tables (typical range is 5 to 40 ft
Mr = subgrade resilient modulus at optimum moisture content, psi	PHT Tool default data tables

**Also available in HPMS Estimates table.

Transverse Cracking

$$TCRK = \left(\frac{AGE}{AGE+1}\right) \times \frac{6000}{1+1.03^{(-5.9033*AGE+FACTOR)}} \quad (29)$$

Where

TCRK = number of transverse cracks per mile

AGE = pavement age in years

FACTOR = 1472.2 + 3.167*H_{HMA} - 879.8*loglogη - 16.98*Va - 3.385*PCT¾ - 0.25*FTCYC (30)

A description of input variables required to compute FACTOR is presented in Table 19.

Table 19. Input Variables Required to Compute FACTOR

Description of Input Variables Required to Compute Factor	Source
hAC = HMA thickness, in	HPMS program (Thickness_Flexible)**
η_{aged} = aged viscosity at HMA surface, cP	See equation 12
V_a = HMA mix as-constructed air voids, percent	PHT Tool default data tables
PCT3/4 = percent passing ¾ in sieve for the HMA mix	PHT Tool default data tables
FTCYC = mean annual air freeze-thaw cycles	PHT Tool default data tables

**Also available in HPMS Estimates table.

Smoothness (IRI)

IRI = INI_IRI + 40.0*MRUT + 0.4*CRACK + 0.008*TRANS_CK + 0.015*SF (31)

Where

INI_IRI = initial IRI, in/mi (use MEPDG default of 63.4 in/mi)

MRUT = total rutting, in (see Equation 25)

CRACK = alligator cracking, percent lane area (see Equation 18)

TRANS_CK = transverse cracking, ft/mile (see Equation 29)

SF = FROSTH + SWELLP*$AGE^{1.5}$

FROSTH = LN([PRECIP+1]*FINES*[FI+1])

SWELLP = LN([PRECIP+1]*CLAY*[PI+1])

A description of the variables to compute FROSTH and SWELLP are presented in Table 20.

Table 20. Input Variables Required to Compute FROSTH and SWELLP

Description of Input Variables Required to Compute FROSTH and SWELLP	Source
FINES = FSAND + SILT	
AGE = pavement age since construction or reconstruction, years	HPMS program (Year_Last_Improvement OR Year_Last_Construction)
PI = subgrade soil plasticity index	
PRECIP = mean annual precipitation or rainfall	PHT Tool default data tables
FI = mean annual freezing index, ^{o}F days	PHT Tool default data tables
FSAND = amount of fine sand particles in subgrade (percent of particles with sizes between 0.074 and 0.42 mm)	PHT Tool default data tables
SILT= amount of silt particles in subgrade (percent of particles with sizes between 0.074 and 0.002 mm)	PHT Tool default data tables
CLAY = amount of clay size particles in subgrade (percent of particles less than 0.002 mm)	PHT Tool default data tables

* Also available in HPMS Estimates table.

Compute Distress and IRI for Composite (HMA/JPCP) Pavement

Reflection Transverse Cracking

$$RCRK = \frac{100}{1 + 2.718^{a(c)+b(AGE)(d)}} \tag{32}$$

Where

RCRK = percent of cracks reflected, percent area of reflection cracking assumes a reflected crack width of 1ft.

AGE = pavement age (years after asphalt overlay placement, see HPMS program)

a = $3.5+0.75*H_{eff}$

b = $-0.688 – 3.373*H_{eff} - 0.9154$

c = 1.0

H_{eff} = $H_{HMA} – 1$ (for JPCP with good joint load transfer efficiency, i.e., faulting < 0.03 in)

H_{eff} = $H_{HMA} – 3$ (for JPCP with poor joint load transfer efficiency, i.e., faulting $\geq$ 0.03 in)

H_{HMA} = asphalt layer thickness (see PHT Tool default data tables)

The values of the reflective cracking model parameters d are presented in Table 21.

Table 21. Values of the Reflective Cracking Model Parameter d

Effective Asphalt Overlay Thickness, in	Delay Cracking by 2 yrs (Recommended for High Type Pavements)	Accelerate Cracking by 2 yrs (Recommended for Other Pavements Types)
< 4	0.6	3.0
4 to 6	0.7	1.7
> 6	0.8	1.4

* The following functional classed are classified as high-type: Interstates and principal arterials (e.g., U.S. highways, expressways, and freeways). Local routes and state highways (e.g., minor arterial, minor and major collectors, and local roadways are mostly classified as other.

Smoothness (IRI)

The IRI prediction model adopted from the MEPDG is as follows:

$$IRI = INI\_IRI + 40.8*MRUT + 0.575*CRACK + 0.0014*TRANS\_CK + 0.00825*SF \qquad (33)$$

All variables are as already defined. Note that TRANS_CK includes all reflection cracking (transverse joints & transverse cracks) from the existing jointed concrete pavement and HMA transverse cracking.

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PROCEDURE FOR ESTIMATING ESAL

Step 1: Assemble Relevant Data from the HPMS 2010+ Program

Traffic data required from HPMS are presented in Table 22.

Table 22. Traffic Data Required from HPMS for Computing ESALs

Data Item	Source	Description
AADT	HPMS program	Annual average daily traffic (count or factored) value to represent the current data year. For two-way facilities, provide the AADT for both directions; provide the directional AADT if part of a one-way couplet or for one-way streets
AADT_Single	HPMS program	AADT for single unit trucks (classes 4-7). All single-unit truck activity over all days of the week and seasons of the year in terms of annual average daily traffic
AADT_Combination	HPMS program	AADT for combination trucks (classes 8-13)
Future_AADT	HPMS program	Forecasted two-way AADT
Future_AADT_Year		Four-digit year for which FUTURE_AADT has been forecasted in. This cannot be for less than 18 years or more than 25 years from the data year

Step 2: Estimate Future AADT Growth Rate

A linear growth in traffic is assumed for estimating future AADT growth, which is computed as follows using data from the HPMS program (see Table 22):

$$GR = \frac{AADT_F - AADT_C}{FYR - CYR} \tag{34}$$

Where

GR = AADT growth rate
$AADT_F$ = future AAD
$AADT_C$ = current AADT
FYR = future year
CYR = current year.

Note that for two-way facilities, HPMS provides AADT for both directions while directional AADT if provided for one-way couplet or one-way streets. Thus, a 50 percent directional factor is assumed for two-way facilities and 100 percent directional factor for one-way couplet or one-way streets. The lane distribution factors shown in Table 23 are assumed:

Table 23. Lane Distribution Factors

No. of Lanes	Lane Distribution Factors
1	1
2	0.9
3	0.6
4 and > 4	0.45

Step 3: Estimate AADT for Any Given Year X

$$AADT_x = AADT_c + GR * AGE \tag{35}$$

Where

$AADT_X$	=	$AADT_X$ (for any given age X)
GR	=	AADT growth rate
$AADT_C$	=	current AADT
AGE	=	age in years

Step 4: Estimate Number of Single Unit and Combination Trucks

$$TRKS\_SU = AADT\_Single*AADTX/AADT_C \tag{36}$$

$$TRKS\_COMB = AADT\_Combination*AADTX/AADTC \tag{37}$$

Step 5: Estimate Number of FHWA Class 4 through 13 Trucks

Use the appropriate distribution (see Table 24) (select based on pavement location and functional class) to determine FHWA vehicle class 4 through 13 distribution.

Table 24. Distribution of Single Unit and Combination Trucks (Percent)

Location	Functional Class	HPMS FCLASS Code	Distribution of SU Trucks				Distribution of Combination Trucks					
			4	5	6	7	8	9	10	11	12	13
Rural	Interstate	1	10.2	66.8	20.2	2.8	8.8	76.8	4.4	3.7	1.5	5.0
	Principal Arterial – Other*	2	—	—	—	—	—	—	—	—	—	—
	Principal Arterial – Other	3	6.8	70.9	20.0	2.4	14.3	69.3	7.1	2.1	1.3	6.0
	Minor Arterial	4	8.0	68.8	19.4	3.8	19.5	62.4	6.5	1.7	1.7	8.2
	Major Collector	5	7.4	71.2	18.8	2.6	17.9	52.7	6.2	0.6	1.2	21.5
	Minor Collector	6	18.8	46.4	23.2	11.7	23.7	68.1	2.4	0.2	0.5	5.1
	Local	7	9.7	66.1	21.8	2.4	21.0	60.6	9.2	1.0	1.4	6.9
Urban	Interstate	1	9.6	64.1	23.6	2.8	14.4	76.4	3.0	3.6	1.0	1.5
	Principal Arterial – Other*	2	9.5	61.3	24.1	5.1	19.2	70.8	4.0	2.8	1.1	2.2
	Principal Arterial – Other	3	7.8	70.7	18.0	3.5	15.2	67.1	7.0	2.6	1.4	6.7
	Minor Arterial	4	10.6	68.1	18.5	2.7	12.9	47.5	17.7	1.7	2.2	18.0
	Major Collector	5	—	—	—	—	—	—	—	—	—	—
	Minor Collector	6	—	—	—	—	—	—	—	—	—	—
	Local	7	—	—	—	—	—	—	—	—	—	—

* Freeways or Expressways

Step 6: Estimate Number of Axle per FHWA Class 4 through 13 Trucks

For each truck class, use the factors in Table 25 to estimate the number of single, tandem, tridem, and quad axles (i.e., multiply the number of trucks in each class by the factor).

Table 25. Average Number of Single, Tandem, Tridem, and Quad axles per Vehicle Class

FHWA Vehicle Class	Number of Single Axles	Number of Tandem Axles	Number of Tridem Axles	Number of Quad Axles
4	1.43	0.71	0	0
5	2.12	0.07	0	0
6	0.91	0.87	0.02	0
7	2.18	0.63	0.7	0.04
8	2.39	0.71	0.01	0.01
9	0.95	1.85	0	0
10	0.86	0.94	0.7	0.04
11	3.52	0.58	0.15	0.04
12	2.63	1.25	0.25	0.01
13	1.27	1.56	0.52	0.03

Step 7: Determine the Number of Single, Tandem, Tridem, and Quad Axles for Each Load Class

For each truck class, use the information in Table 26 through Table 29 to estimate number of single, tandem, tridem, and quad axles.

Step 8: Use Appropriate AASHTO Load Equivalency Factors (LEFs) to Estimate ESALs

For each axle type and load range, estimate ESALs by multiplying the number of axles in each cell by the appropriate LEF. See Table 30 through Table 33.

Step 9: Estimate Cumulative ESALs

Total or cumulative ESALs is the sum of all ESALs for each load range and axle type.

Table 26. Single-Axle Load Distribution Values for each Vehicle/Truck Class (Percentages)

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	5	6	7	8	9	10	11	12	13
3000	1.80	10.03	2.47	2.14	11.62	1.74	3.64	3.55	6.68	8.88
4000	0.96	13.19	1.78	0.55	5.36	1.37	1.24	2.91	2.29	2.67
5000	2.91	16.40	3.45	2.42	7.82	2.84	2.36	5.19	4.87	3.81
6000	3.99	10.69	3.95	2.70	6.98	3.53	3.38	5.27	5.86	5.23
7000	6.80	9.21	6.70	3.21	7.98	4.93	5.18	6.32	5.97	6.03
8000	11.45	8.26	8.44	5.81	9.69	8.43	8.34	6.97	8.85	8.10
9000	11.28	7.11	11.93	5.26	9.98	13.66	13.84	8.07	9.57	8.35
10000	11.04	5.84	13.55	7.38	8.49	17.66	17.33	9.70	9.95	10.69
11000	9.86	4.53	12.12	6.85	6.46	16.69	16.19	8.54	8.59	10.69
12000	8.53	3.46	9.47	7.41	5.18	11.63	10.30	7.28	7.09	11.11
13000	7.32	2.56	6.81	8.99	4.00	6.09	6.52	7.16	5.86	7.34
14000	5.55	1.92	5.05	8.15	3.38	3.52	3.94	5.65	6.58	3.78
15000	4.23	1.54	2.74	7.77	2.73	1.91	2.33	4.77	4.55	3.10
16000	3.11	1.19	2.66	6.84	2.19	1.55	1.57	4.35	3.63	2.58
17000	2.54	0.90	1.92	5.67	1.83	1.10	1.07	3.56	2.56	1.52
18000	1.98	0.68	1.43	4.63	1.53	0.88	0.71	3.02	2.00	1.32
19000	1.53	0.52	1.07	3.50	1.16	0.73	0.53	2.06	1.54	1.00
20000	1.19	0.40	0.82	2.64	0.97	0.53	0.32	1.63	0.98	0.83
21000	1.16	0.31	0.64	1.90	0.61	0.38	0.29	1.27	0.71	0.64
22000	0.66	0.31	0.49	1.31	0.55	0.25	0.19	0.76	0.51	0.38
23000	0.56	0.18	0.38	0.97	0.36	0.17	0.15	0.59	0.29	0.52
24000	0.37	0.14	0.26	0.67	0.26	0.13	0.17	0.41	0.27	0.22
25000	0.31	0.15	0.24	0.43	0.19	0.08	0.09	0.25	0.19	0.13
26000	0.18	0.12	0.13	1.18	0.16	0.06	0.05	0.14	0.15	0.26
27000	0.18	0.08	0.13	0.26	0.11	0.04	0.03	0.21	0.12	0.28
28000	0.14	0.05	0.08	0.17	0.08	0.03	0.02	0.07	0.08	0.12
29000	0.08	0.05	0.08	0.17	0.05	0.02	0.03	0.09	0.09	0.13
30000	0.05	0.02	0.05	0.08	0.04	0.01	0.02	0.06	0.02	0.05
31000	0.04	0.02	0.03	0.72	0.04	0.01	0.03	0.03	0.03	0.05
32000	0.04	0.02	0.03	0.06	0.12	0.01	0.01	0.04	0.01	0.08
33000	0.04	0.02	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.06
34000	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.02
35000	0.02	0.02	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.01
36000	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
37000	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
38000	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01
39000	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01
40000	0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.02	0.00	0.00
41000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 27. Tandem-Axle Load Distribution Values for each Vehicle/Truck Class (Percentages)

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	5	6	7	8	9	10	11	12	13
6000	5.88	7.06	5.28	13.74	18.95	2.78	2.45	7.93	5.23	6.41
8000	1.44	35.42	8.42	6.71	8.05	3.92	2.19	3.15	1.75	3.85
10000	1.94	13.23	10.81	6.49	11.15	6.51	3.65	5.21	3.35	5.58
12000	2.73	6.32	8.99	3.46	11.92	7.61	5.40	8.24	5.89	5.66
14000	3.63	4.33	7.71	7.06	10.51	7.74	6.90	8.88	8.72	5.73
16000	4.96	5.09	7.50	4.83	8.25	7.00	7.51	8.45	8.37	5.53
18000	7.95	5.05	6.76	4.97	6.77	5.82	6.99	7.08	9.76	4.90
20000	11.58	4.39	6.06	4.58	5.32	5.59	6.61	5.49	10.85	4.54
22000	14.20	2.31	5.71	4.26	4.13	5.16	6.26	5.14	10.78	6.45
24000	13.14	2.28	5.17	3.85	3.12	5.05	5.95	5.99	7.24	4.77
26000	10.75	1.53	4.52	3.44	2.34	5.28	6.16	5.73	6.14	4.34
28000	7.47	1.96	3.96	6.06	1.82	5.53	6.54	4.37	4.93	5.63
30000	5.08	1.89	3.21	3.68	1.58	6.13	6.24	6.57	3.93	7.24
32000	3.12	2.19	3.91	2.98	1.20	6.34	5.92	4.61	3.09	4.69
34000	1.87	1.74	2.12	2.89	1.05	5.67	4.99	4.48	2.74	4.51
36000	1.30	1.78	1.74	2.54	0.94	4.46	3.63	2.91	1.73	3.93
38000	0.76	1.67	1.44	2.66	0.56	3.16	2.79	1.83	1.32	4.20
40000	0.53	0.38	1.26	2.50	0.64	2.13	2.24	1.12	1.07	3.22
42000	0.52	0.36	1.01	1.57	0.28	1.41	1.69	0.84	0.58	2.28
44000	0.30	0.19	0.83	1.53	0.28	0.91	1.26	0.68	0.51	1.77
46000	0.21	0.13	0.71	2.13	0.41	0.59	1.54	0.32	0.43	1.23
48000	0.18	0.13	0.63	1.89	0.20	0.39	0.73	0.21	0.22	0.85
50000	0.11	0.14	0.49	1.17	0.14	0.26	0.57	0.21	0.22	0.64
52000	0.06	0.20	0.39	1.07	0.11	0.17	0.40	0.07	0.23	0.39
54000	0.04	0.06	0.32	0.87	0.06	0.11	0.38	0.13	0.20	0.60
56000	0.08	0.06	0.26	0.81	0.05	0.08	0.25	0.15	0.12	0.26
58000	0.01	0.02	0.19	0.47	0.03	0.05	0.16	0.09	0.07	0.18
60000	0.02	0.02	0.17	0.49	0.02	0.03	0.15	0.03	0.19	0.08
62000	0.10	0.01	0.13	0.38	0.06	0.02	0.09	0.06	0.09	0.14
64000	0.01	0.01	0.08	0.24	0.02	0.02	0.08	0.01	0.04	0.07
66000	0.02	0.01	0.06	0.15	0.02	0.02	0.06	0.01	0.02	0.08
68000	0.01	0.00	0.07	0.16	0.00	0.02	0.05	0.01	0.04	0.03
70000	0.01	0.02	0.04	0.06	0.00	0.01	0.11	0.00	0.12	0.01
72000	0.00	0.01	0.04	0.13	0.00	0.01	0.04	0.00	0.01	0.04
74000	0.00	0.00	0.02	0.06	0.00	0.01	0.01	0.00	0.01	0.02
76000	0.00	0.00	0.01	0.06	0.00	0.00	0.01	0.00	0.01	0.04
78000	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.02
80000	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.08
82000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 28. Tridem-Axle Load Distribution Values for each Vehicle/Truck Class (Percentages)

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	5	6	7	8	9	10	11	12	13
12000	66.67	48.28	29.51	5.89	20.89	59.19	16.21	23.31	13.28	10.86
15000	0.00	1.08	9.20	2.18	2.33	13.03	9.51	20.89	6.38	4.40
18000	0.00	0.43	7.60	3.32	3.34	7.89	7.30	15.88	6.74	4.75
21000	0.00	0.15	10.35	2.98	4.26	6.51	5.83	12.00	6.00	4.04
24000	0.00	0.73	4.73	3.27	3.71	2.78	5.82	5.80	4.37	3.02
27000	0.00	3.13	3.55	4.26	4.32	1.87	5.03	2.61	4.53	4.46
30000	0.00	3.83	6.27	4.48	5.24	2.51	4.99	2.08	8.01	4.99
33000	0.00	0.70	4.18	5.11	4.89	1.02	5.79	2.06	5.61	3.82
36000	0.00	15.59	2.11	7.01	3.91	0.66	6.71	2.94	6.25	6.51
39000	0.00	0.70	2.22	6.77	5.00	0.55	7.41	1.10	8.04	5.49
42000	26.66	3.48	1.79	7.21	3.99	0.59	6.41	2.98	6.70	6.53
45000	6.67	2.93	1.70	7.18	4.53	0.84	4.93	1.95	6.08	5.19
48000	0.00	3.33	1.19	6.63	4.96	0.36	4.54	1.87	3.48	6.32
51000	0.00	1.78	3.12	5.84	4.98	0.46	2.82	0.72	5.81	5.20
54000	0.00	4.48	0.96	6.20	5.98	0.27	1.79	1.27	2.22	5.47
57000	0.00	0.00	0.00	6.91	5.00	0.23	1.34	0.41	0.98	4.68
60000	0.00	0.00	0.10	4.34	3.10	0.32	0.98	0.40	0.89	2.39
63000	0.00	0.00	2.09	2.94	1.51	0.12	0.60	0.16	0.96	2.33
66000	0.00	0.00	1.96	2.13	1.40	0.10	0.52	0.99	1.39	2.71
69000	0.00	6.25	1.47	1.42	1.59	0.25	0.34	0.20	0.38	1.22
72000	0.00	0.00	2.94	1.96	1.16	0.12	0.35	0.38	0.11	1.10
75000	0.00	0.00	0.02	0.63	0.99	0.09	0.22	0.00	0.08	1.17
78000	0.00	0.00	0.00	0.46	1.12	0.07	0.17	0.00	0.23	1.13
81000	0.00	0.00	1.47	0.28	1.42	0.05	0.13	0.00	0.20	0.55
84000	0.00	3.13	0.00	0.24	0.06	0.02	0.07	0.00	0.41	0.68
87000	0.00	0.00	0.45	0.12	0.05	0.04	0.07	0.00	0.07	0.17
90000	0.00	0.00	0.00	0.09	0.10	0.02	0.04	0.00	0.09	0.22
93000	0.00	0.00	0.04	0.08	0.01	0.02	0.03	0.00	0.35	0.30
96000	0.00	0.00	0.00	0.02	0.00	0.02	0.03	0.00	0.03	0.07
99000	0.00	0.00	0.98	0.02	0.10	0.00	0.01	0.00	0.10	0.11
102000	0.00	0.00	0.00	0.03	0.06	0.00	0.01	0.00	0.23	0.12

Table 29. Quad-Axle Load Distribution Values for each Vehicle/Truck Class (Percentages)

Mean Axle Load, lbs.	Vehicle/Truck Class									
	4	5	6	7	8	9	10	11	12	13
12000	66.66	48.31	29.50	5.89	20.89	59.19	16.21	23.31	13.28	10.87
15000	0.00	1.07	9.20	2.18	2.33	13.03	9.51	20.89	6.38	4.40
18000	0.00	0.43	7.60	3.32	3.34	7.89	7.29	15.88	6.74	4.75
21000	0.00	0.15	10.36	2.98	4.26	6.51	5.83	12.00	6.00	4.04
24000	0.00	0.73	4.73	3.27	3.71	2.78	5.82	5.80	4.37	3.02
27000	0.00	3.12	3.55	4.26	4.32	1.87	5.04	2.61	4.53	4.46
30000	0.00	3.83	6.27	4.48	5.24	2.51	4.99	2.08	8.01	4.99
33000	0.00	0.70	4.18	5.11	4.89	1.02	5.79	2.06	5.61	3.82
36000	0.00	15.61	2.11	7.01	3.91	0.66	6.71	2.94	6.25	6.51
39000	0.00	0.70	2.22	6.77	5.00	0.55	7.41	1.10	8.04	5.49
42000	26.67	3.47	1.79	7.21	3.99	0.59	6.41	2.98	6.70	6.52
45000	6.67	2.93	1.70	7.18	4.53	0.84	4.93	1.95	6.08	5.19
48000	0.00	3.33	1.19	6.63	4.96	0.36	4.54	1.87	3.48	6.32
51000	0.00	1.78	3.12	5.84	4.98	0.46	2.82	0.72	5.81	5.20
54000	0.00	4.47	0.96	6.20	5.98	0.27	1.79	1.27	2.22	5.47
57000	0.00	0.00	0.00	6.91	5.00	0.23	1.34	0.41	0.98	4.68
60000	0.00	0.00	0.10	4.34	3.10	0.32	0.98	0.40	0.89	2.39
63000	0.00	0.00	2.09	2.94	1.51	0.12	0.60	0.16	0.96	2.33
66000	0.00	0.00	1.96	2.13	1.40	0.10	0.52	0.99	1.39	2.71
69000	0.00	6.24	1.47	1.42	1.59	0.25	0.34	0.20	0.38	1.22
72000	0.00	0.00	2.94	1.96	1.16	0.12	0.35	0.38	0.11	1.10
75000	0.00	0.00	0.02	0.63	0.99	0.09	0.22	0.00	0.08	1.17
78000	0.00	0.00	0.00	0.46	1.12	0.07	0.17	0.00	0.23	1.13
81000	0.00	0.00	1.47	0.28	1.42	0.05	0.13	0.00	0.20	0.55
84000	0.00	3.13	0.00	0.24	0.06	0.02	0.07	0.00	0.41	0.68
87000	0.00	0.00	0.45	0.12	0.05	0.04	0.07	0.00	0.07	0.17
90000	0.00	0.00	0.00	0.09	0.10	0.02	0.04	0.00	0.09	0.22
93000	0.00	0.00	0.04	0.08	0.01	0.02	0.03	0.00	0.35	0.30
96000	0.00	0.00	0.00	0.02	0.00	0.02	0.03	0.00	0.03	0.07
99000	0.00	0.00	0.98	0.02	0.10	0.00	0.01	0.00	0.10	0.11
102000	0.00	0.00	0.00	0.03	0.06	0.00	0.01	0.00	0.23	0.12

Table 30. Example of AASHTO Load Equivalent Factors for Computing ESALs

Axle Type	Mean Axle Load, lbs.	Load Equivalency Factor (LEF)	
		Flexible	Rigid
Single	3000	0.0011	0.00072
	4000	0.002	0.00209
	5000	0.006	0.005
	6000	0.01	0.01043
	7000	0.021	0.0196
	8000	0.032	0.0343
	9000	0.057	0.0562
	10000	0.082	0.0877
	11000	0.129	0.1311
	12000	0.176	0.189
	13000	0.2585	0.264
	14000	0.341	0.36
	15000	0.4725	0.478
	16000	0.604	0.623
	17000	0.802	0.796
	18000	1	1
	19000	1.285	1.24
	20000	1.57	1.51
	21000	1.955	1.83
	22000	2.34	2.18
	23000	2.85	2.58
	24000	3.36	3.03
	25000	4.015	3.53
	26000	4.67	4.09
	27000	5.48	4.71
	28000	6.29	5.39
	29000	7.285	6.14
	30000	8.28	6.97
	31000	9.49	7.88
	32000	10.7	8.88
	33000	12.15	9.98
	34000	13.6	11.18
	35000	15.35	12.5
	36000	17.1	13.93
	37000	19.2	15.5
	38000	21.3	17.2
	39000	23.8	19.06
	40000	26.3	21.08
	41000	29.25	23.27

Table 31. Example of AASHTO Load Equivalent Factors for Computing ESALs

Axle Type	Mean Axle Load, lbs.	Load Equivalency Factor (LEF)	
		Flexible	Rigid
Tandem	6000	0.002	0
	8000	0.005	0
	10000	0.013	0.00688
	12000	0.026	0.0144
	14000	0.048	0.027
	16000	0.082	0.0472
	18000	0.133	0.0773
	20000	0.206	0.1206
	22000	0.308	0.18
	24000	0.444	0.26
	26000	0.622	0.364
	28000	0.85	0.495
	30000	1.14	0.658
	32000	1.49	0.857
	34000	1.92	1.095
	36000	2.43	1.38
	38000	3.03	1.7
	40000	3.74	2.08
	42000	4.55	2.51
	44000	5.48	3
	46000	6.53	3.55
	48000	7.73	4.17
	50000	9.07	4.86
	52000	10.6	5.63
	54000	12.3	6.47
	56000	14.2	7.41
	58000	16.3	8.45
	60000	18.7	9.59
	62000	21.4	10.84
	64000	24.4	12.22
	66000	27.6	13.73
	68000	31.3	15.38
	70000	35.3	17.19
	72000	39.8	19.16
	74000	44.7	21.32
	76000	50.1	23.66
	78000	56.1	26.22
	80000	62.5	28.99
	82000	69.6	31.76

Table 32. Example of AASHTO Load Equivalent Factors for Computing ESALs

Axle Type	Mean Axle Load, lbs.	Load Equivalency Factor (LEF)	
		Flexible	Rigid
Tridem	12000	0.009	0.003
	15000	0.0225	0.008
	18000	0.044	0.017
	21000	0.083	0.033
	24000	0.141	0.057
	27000	0.23	0.093
	30000	0.354	0.145
	33000	0.5295	0.217
	36000	0.757	0.313
	39000	1.059	0.438
	42000	1.44	0.597
	45000	1.915	0.793
	48000	2.49	1.033
	51000	3.19	1.32
	54000	4	1.66
	57000	4.975	2.05
	60000	6.08	2.51
	63000	7.365	3.03
	66000	8.83	3.62
	69000	10.5	4.28
	72000	12.4	5.03
	75000	14.6	5.86
	78000	17.1	6.78
	81000	19.9	8.577
	84000	23.1	9.965
	87000	26.65	11.518
	90000	30.7	13.246
	93000	30.7	15.165
	96000	30.7	17.287
	99000	30.7	19.627
	102000	30.7	22.199

Table 33. Example of AASHTO Load Equivalent Factors for Computing ESALs

Axle Type	Mean Axle Load, lbs.	Load Equivalency Factor (LEF)	
		Flexible	Rigid
Quad	12000	0.009	0.003
	15000	0.0225	0.008
	18000	0.044	0.017
	21000	0.083	0.033
	24000	0.141	0.057
	27000	0.23	0.093
	30000	0.354	0.145
	33000	0.5295	0.217
	36000	0.757	0.313
	39000	1.059	0.438
	42000	1.44	0.597
	45000	1.915	0.793
	48000	2.49	1.033
	51000	3.19	1.32
	54000	4	1.66
	57000	4.975	2.05
	60000	6.08	2.51
	63000	7.365	3.03
	66000	8.83	3.62
	69000	10.5	4.28
	72000	12.4	5.03
	75000	14.6	5.86
	78000	17.1	6.78
	81000	19.9	8.577
	84000	23.1	9.965
	87000	26.65	11.518
	90000	30.7	13.246
	93000	30.7	15.165
	96000	30.7	17.287
	99000	30.7	19.627
	102000	30.7	22.199

GUIDANCE ON SETTING UP THE INPUT DATABASE

Data Sources for Running the New Pavement Equations

Data for running the PHT Tool will be obtained from two primary sources: (a) the HPMS program and (b) default data tables (developed mostly using Long Term Pavement Performance, or LTPP data and MEPDG default data tables). Descriptions of all sources of data for running the new pavement equations in HERS are presented in the following sections.

Data from the HPMS Program

The 2010+ version of the HPMS program would be the primary source of data for running the new equations in HERS. The majority of the individual data items required will be from the HPMS Programs Sections and Estimates data tables. A detailed description of the HPMS 2010+ Program is presented in the *HPMS Reassessment 2010+ Final Report* (FHWA 2008). A listing and detailed description of the data items of interest for running the new pavement equations is presented in Table 31 along with a description of the data.

Non-HPMS Data Requirements

Data items (state or material type defaults) not provided by the HPMS program but required by the new pavement equations are provided as default data tables. Information in these default tables was obtained primarily from the LTPP database and MEPDG. Default data items provided included:

- HMA
  - Gradation
  - A & VTS (MEPDG asphalt binder prediction model coefficients)
- PCC (materials and design)
  - Compressive strength
  - Elastic modulus
  - Dowel diameter
  - PCC/base interface zero friction age
- Climate
  - Precipitation
  - Freezing index
  - Air freeze-thaw cycles
  - Monthly mean air temperature
- Subgrade
  - Gradation
  - Resilient modulus (AASHTO 1997, LTPP 2009).

The default data items are presented in Table 34 through Table 43. The Traffic default inputs along with HPMS traffic data were used to compute ESALs (the traffic input for most of the new equations).

Table 34. HPMS Data Items Required for Pavement Equations

Reference Number	Data Item (from HPMS Sections, Reference, and Summaries Catalog)	Description
3.2.1.1.3	Route_ID	Up to 32 alpha-numeric digits that identify the route
3.2.2.1.1	Year_Record	The calendar year for which the data apply
3.2.2.1.2	State_Code	The State FIPS code
3.4.1.1.3	County_Code	Census defined County FIPS codes
3.2.2.1.6	Sample_ID	A unique Identifier for the Sample
3.2.2.1.4	Begin_Point	Beginning of a section. The Route_ID, Begin_Point, and End_Point utilize the Linear Reference Method (LRM) that is native to the State DOT
3.2.2.1.5	End_Point	End of a section. The Route_ID, Begin_Point, and End_Point utilize the Linear Reference Method (LRM) that is native to the State DOT
3.3.1.1.7	Section_Length	The true length of the section that is used to determine the certified mileage
	Volume_Group	
3.2.1.2.1	F_System	1. Interstate 2. Principal Arterial – Other Freeways and Expressways 3. Principal Arterial – Other 4. Minor Arterial 5. Major Collector 6. Minor Collector 7. Local
3.2.1.2.2	Urban_Code	• 99999 Rural • 99998 Small urban area (population < 50000) • Others Urban
3.2.1.2.3	Facility_Type	1. One-Way Roadway 2. Two-Way Roadway 3. Couplet 4. Ramp 5. Non-Mainline
3.2.1.2.7	Through_Lanes	Code the number of through lanes according to the striping, if present, on multilane facilities, or according to traffic use or State/local design guidelines if no striping or only centerline striping is present. Enter the prevailing number of through lanes in both directions carrying through traffic in the off-peak period. Exclude what are defined as auxiliary lanes, such as collector-distributor lanes, weaving lanes, frontage road lanes, parking and turning lanes, acceleration/deceleration lanes, toll collection lanes and truck climbing lanes
3.2.1.2.21	AADT	AADT (Count or Factored) value to represent the current data year. For two-way facilities, provide the AADT for both directions; provide the directional AADT if part of a one-way couplet or for one-way streets
3.2.1.2.22	AADT_Single	AADT for single unit trucks (classes 4-7). All single-unit truck activity over all days of the week and seasons of the year in terms of annual average daily traffic
3.2.1.2.24	AADT_Combination	AADT for Combination Trucks (classes 8-13)
3.2.1.2.28	Future_AADT	Forecasted two-way AADT

Reference Number	Data Item (from HPMS Sections, Reference, and Summaries Catalog)	Description
	Future_AADT_Year	Four-digit year for which FUTURE_AADT has been forecasted in. This cannot be for less than 18 years nor more than 25years from the data year
3.2.1.2.34	Lane_Width	The measure of existing lane width
3.2.1.2.37	Shoulder_Type	1. None 2. Surfaced shoulder exists - bituminous concrete (AC) 3. Surfaced shoulder exists - Portland Cement Concrete surface (PCC) 4. Stabilized shoulder exists (stabilized gravel or other granular material with or without admixture) 5. Combination shoulder exists (shoulder width has two or more surface types; e.g., part of the shoulder width is surfaced and a part of the width is earth) 6. Earth shoulder exists 7. Barrier curb exists; no shoulder in front of curb
3.2.1.2.14	Speed_Limit	Posted speed limit
3.2.1.2.61	Climate_Zone*	Climate zone as defined by the 4 LTPP climate zone descriptions 1. Wet-Freeze 2. Wet-Nonfreeze 3. Dry-Freeze 4. Dry-Nonfreeze
3.2.1.2.49	Surface_Type	1. Unpaved 2. Bituminous 3. JPCP – Jointed Plain Concrete Pavement 4. JRCP – Jointed Reinforced Concrete Pavement 5. CRCP – Continuously Reinforced Concrete Pavement 6. Asphalt-Concrete (AC) Overlay over Existing AC Pavement 7. AC Overlay over Existing Jointed Concrete Pavement 8. AC (Bi Overlay over Existing CRCP) 9. Unbonded Jointed Concrete Overlay on PCC Pavements 10. Unbonded CRCP Overlay on PCC Pavements 11. Bonded PCC Overlays on PCC Pavements 12. Other
3.2.1.2.54	Year_Last_Improvement	The year in which the roadway surface was improved
3.2.1.2.55	Year_Last_Construction	The year the section was last improved (the year the section was constructed or reconstructed)
3.2.1.2.56	Last_Overlay_Thickness	Thickness of the most recent pavement overlay
3.2.1.2.57	Thickness_Rigid	Thickness of the rigid pavement
3.2.1.2.58	Thickness_Flexible	Thickness of the flexible pavement
3.2.1.2.59	Base_Type	1. No base 2. Aggregate 3. Asphalt or cement stabilized 4. Asphalt or cement stabilized with granular subbase 5. Hot mix AC (Bituminous) 6. Lean concrete 7. Stabilized open-graded permeable 8. Fractured PCC
3.2.1.2.60	Base_Thickness	The thickness of the base pavement

<table>
<tr><th>Reference Number</th><th>Data Item (from HPMS Sections, Reference, and Summaries Catalog)</th><th>Description</th></tr>
<tr><td>3.2.1.2.62</td><td>Soil_Type</td><td>Soil type as defined by AASHTO soil classes
<table>
<tr><td>1</td><td>Granular (35% or less passing the 0.075 mm sieve) (AASHTO Soil Class A0 through A-3)</td></tr>
<tr><td>2</td><td>Fine (Silt-Clay) Materials (>35% passing the 0.075 mm sieve) (AASHTO Soil Class A-4 through A-7)</td></tr>
</table></td></tr>
<tr><td>3.2.1.2.47</td><td>IRI</td><td>International Roughness Index</td></tr>
<tr><td>3.2.1.2.52</td><td>Fatigue_Cracking</td><td>Estimate of total area with fatigue type cracking for AC pavements and total percent of slabs with cracking for PCC pavements</td></tr>
<tr><td>3.2.1.2.53</td><td>Transverse_Cracking</td><td>Estimate of total ft/mi or m/km of transverse cracking</td></tr>
<tr><td>3.2.1.2.50</td><td>Rutting</td><td>Average Rutting</td></tr>
<tr><td>3.2.1.2.51</td><td>Faulting</td><td>The average vertical displacement between adjacent jointed concrete panels</td></tr>
<tr><td>3.2.1.2.48</td><td>PSR</td><td>
<table>
<tr><th>PSR</th><th>Description</th></tr>
<tr><td>4.0 – 5.0</td><td>Only new (or nearly new) superior pavements are likely to be smooth enough and distress free (sufficiently free of cracks and patches) to qualify for this category. Most pavements constructed or resurfaced during the data year would normally be rated in this category.</td></tr>
<tr><td>3.0 – 4.0</td><td>Pavements in this category, although not quite as smooth as those described above, give a first class ride and exhibit few, if any, visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration, such as minor cracks and spalling.</td></tr>
<tr><td>2.0 – 3.0</td><td>The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and extensive patching. Rigid pavements in this group may have a few joint failures, faulting and/or cracking, and some pumping.</td></tr>
<tr><td>1.0 – 2.0</td><td>Pavements in this category have deteriorated to such an Extent that they affect the speed of free-flow traffic. Flexible pavement may have large potholes and deep cracks. Distress includes raveling, cracking, rutting and occurs over 50 percent of the surface. Rigid pavement distress includes joint spalling, patching, cracking, scaling, and may include pumping and faulting.</td></tr>
<tr><td>0.0 – 1.0</td><td>Pavements in this category are in an extremely deteriorated condition. The facility is passable only at reduced speeds, and with considerable ride discomfort. Large potholes and deep cracks exist. Distress occurs over 75 percent or more of the surface.</td></tr>
</table></td></tr>
<tr><td>3.5.1.1.6</td><td>Is_State_Owned</td><td>0. Off-State System
1. On-State System</td></tr>
<tr><td>3.5.1.2.1</td><td>Last_Overlay_Thickness</td><td>Typical design or construction last overlay thickness</td></tr>
<tr><td>3.5.1.2.2</td><td>Thickness_Rigid</td><td>Typical design or construction thickness of rigid pavement</td></tr>
<tr><td>3.5.1.2.3</td><td>Thickness_Flexible</td><td>Typical design or construction thickness of Flexible Pavement</td></tr>
<tr><td>3.5.1.2.4</td><td>Base_Type</td><td>1. Crushed Gravel
2. Crushed Stone
3. Granular
4. Asphalt Stabilized
5. High Stabilized
6. Weakly Stabilized
7. Drainable Material</td></tr>
<tr><td>3.5.1.2.5</td><td>Base_Thickness</td><td>Typical design or construction thickness</td></tr>
</table>

<table>
<tr><th>Reference Number</th><th>Data Item (from HPMS Sections, Reference, and Summaries Catalog)</th><th>Description</th></tr>
<tr><td>3.5.1.2.6</td><td>Binder_Type</td><td>
<u>Viscosity Graded Binders</u>

Less than AC-2.5
AC-2.5 to AC-4
AC-5 to AC-9
AC-10 to AC-19
AC-20 to AC-29
AC-30 to AC-39
AC-40 to AC-49
AC-50 or more

<u>Codes for Super Pave Binders</u>
<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="9">Low Temperature Grade</th></tr>
<tr><th>Less than -4</th><th>-4 to -9</th><th>-10 to -15</th><th>-16 to -21</th><th>-22 to -27</th><th>-28 to -33</th><th>-34 to -39</th><th>-40 to -45</th><th>-46 or more</th></tr>
<tr><th rowspan="10">High Temp Grade</th><th>Less than 40</th><td>10</td><td>20</td><td>30</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td></tr>
<tr><th>40 to 45</th><td>11</td><td>21</td><td>31</td><td>41</td><td>51</td><td>61</td><td>71</td><td>81</td><td>91</td></tr>
<tr><th>46 to 51</th><td>12</td><td>22</td><td>32</td><td>42</td><td>52</td><td>62</td><td>72</td><td>82</td><td>92</td></tr>
<tr><th>52 to 57</th><td>13</td><td>23</td><td>33</td><td>43</td><td>53</td><td>63</td><td>73</td><td>83</td><td>93</td></tr>
<tr><th>58 to 63</th><td>14</td><td>24</td><td>34</td><td>44</td><td>54</td><td>64</td><td>74</td><td>84</td><td>94</td></tr>
<tr><th>63 to 69</th><td>15</td><td>25</td><td>35</td><td>45</td><td>55</td><td>65</td><td>75</td><td>85</td><td>95</td></tr>
<tr><th>70 to 75</th><td>16</td><td>26</td><td>36</td><td>46</td><td>56</td><td>66</td><td>76</td><td>86</td><td>96</td></tr>
<tr><th>76 to 81</th><td>17</td><td>27</td><td>37</td><td>47</td><td>57</td><td>67</td><td>77</td><td>87</td><td>97</td></tr>
<tr><th>82 to 87</th><td>18</td><td>28</td><td>38</td><td>48</td><td>58</td><td>68</td><td>78</td><td>88</td><td>98</td></tr>
<tr><th>88 or more</th><td>19</td><td>29</td><td>39</td><td>49</td><td>59</td><td>69</td><td>79</td><td>89</td><td>99</td></tr>
</table>
</td></tr>
<tr><td>3.5.1.2.7</td><td>Dowel_Bar</td><td>

No – Dowel Bars not typically used
Yes – Dowel Bars are typically used

</td></tr>
<tr><td>3.5.1.2.8</td><td>Joint_Spacing</td><td>Typical joint spacing</td></tr>
</table>

Table 35. Default Soil Properties Information (Computed using LTPP data)

State FIPS Code	HPMS Soil Type	Subgrade Soil Sand Fraction, percent	Subgrade Soil Silt Fraction, percent	Subgrade Soil Clay Fraction, percent	Subgrade Soil Plasticity Index, percent
1	1	59.6	13.5	14.3	5.3
1	2	32.1	32.4	22.4	13.9
2	1	25.4	6.2	2.2	2.8
4	1	42.4	14.2	6.1	8.7
4	2	34.6	31.4	10.3	12.7
5	1	54.9	13.3	4.8	3.0
5	2	25.5	46.6	21.9	12.9
6	1	58.5	14.0	4.4	3.5
6	2	32.6	32.4	18.3	17.0
8	1	52.0	15.0	10.9	7.2
8	2	30.3	39.1	25.6	16.8
9	1	47.9	13.6	7.4	0.0
10	1	69.2	17.1	9.9	3.2
10	2	36.6	44.4	15.3	1.8
11	1	36.5	5.9	10.1	17.5
12	1	77.7	6.4	6.0	8.5
13	1	61.9	15.4	15.2	6.6
13	2	47.4	21.2	22.1	9.9
15	1	25.0	4.7	0.3	0.0
15	2	28.8	30.0	23.3	17.0
16	1	35.0	12.5	3.9	3.7
16	2	29.3	39.0	7.3	8.3
17	1	76.5	6.0	3.6	0.0
17	2	15.3	57.8	21.4	12.2
18	1	64.4	17.5	6.6	2.9
18	2	23.9	45.9	22.6	10.4
19	1	60.8	20.2	10.6	3.5
19	2	33.8	39.9	22.1	16.1
20	1	75.2	14.4	10.0	2.0
20	2	23.6	50.5	25.9	17.7
21	1	24.0	20.8	4.8	4.5
21	2	13.9	41.9	36.2	21.3
22	1	81.0	15.2	1.9	0.0
22	2	13.8	57.2	28.3	21.9
23	1	60.7	7.7	1.9	0.0
24	1	44.2	49.4	6.4	32.8
24	2	5.2	66.0	14.5	2.5
25	1	39.5	17.1	3.4	0.0
26	1	79.8	7.7	5.0	1.3
26	2	31.7	36.9	25.4	10.3
27	1	72.9	10.1	4.5	1.5
27	2	33.9	38.3	19.9	14.9

State FIPS Code	HPMS Soil Type	Subgrade Soil Sand Fraction, percent	Subgrade Soil Silt Fraction, percent	Subgrade Soil Clay Fraction, percent	Subgrade Soil Plasticity Index, percent
29	1	25.6	18.8	19.0	27.1
29	2	16.5	37.7	30.4	27.4
30	1	45.7	14.9	7.8	11.8
30	2	34.1	31.1	17.9	16.3
31	1	71.1	13.6	3.8	0.5
31	2	11.8	59.9	27.2	17.1
32	1	47.8	15.2	5.3	5.9
32	2	38.4	46.1	9.3	15.6
33	1	82.5	7.7	3.7	0.0
34	1	69.4	8.2	5.3	0.9
35	1	52.1	16.4	11.1	9.2
35	2	29.0	31.5	26.8	24.9
36	1	57.8	15.6	6.2	2.1
36	2	31.5	29.0	11.6	5.0
37	1	67.9	17.3	8.0	5.1
37	2	33.0	40.1	18.3	15.2
38	2	11.8	50.7	36.1	28.3
39	1	15.0	13.9	4.6	4.5
39	2	17.9	44.4	28.6	15.4
40	1	55.5	15.5	9.8	10.1
40	2	31.2	38.2	24.4	16.8
41	1	27.9	16.2	6.4	10.3
41	2	20.6	32.8	15.9	19.3
42	1	25.7	18.7	11.2	7.4
42	2	24.6	26.5	16.4	9.3
44	1	36.5	2.2	2.0	0.0
45	1	67.9	10.9	13.4	9.3
45	2	45.1	27.5	20.7	5.7
46	1	37.1	16.5	6.3	5.5
46	2	22.0	48.2	21.6	17.8
47	1	34.2	34.0	17.8	19.3
47	2	22.7	35.6	25.7	16.2
48	1	65.4	14.8	9.1	9.6
48	2	27.9	34.7	31.0	20.5
49	1	40.1	19.2	7.4	4.2
49	2	26.9	31.0	11.5	9.8
50	1	36.9	15.3	9.6	3.9
50	2	31.2	26.7	28.5	12.3
51	1	40.3	24.4	12.4	5.3
51	2	25.9	46.2	13.4	8.1
53	1	38.7	17.5	3.7	4.1
53	2	23.9	52.2	8.6	10.0
54	1	24.3	16.0	10.4	9.2
54	2	22.0	38.6	14.0	7.8

State FIPS Code	HPMS Soil Type	Subgrade Soil Sand Fraction, percent	Subgrade Soil Silt Fraction, percent	Subgrade Soil Clay Fraction, percent	Subgrade Soil Plasticity Index, percent
55	1	62.2	10.7	4.1	0.3
55	2	32.9	32.7	22.5	10.1
56	1	30.1	14.4	8.3	8.3
56	2	42.3	29.6	15.7	6.4
72	1	35.6	18.9	11.3	5.8
72	2	22.3	22.0	13.3	8.5
81	1	25.7	22.9	11.2	9.5
81	2	23.8	34.8	21.1	14.0
82	1	41.4	13.8	2.9	0.0
83	1	81.8	9.2	5.5	0.0
83	2	28.6	34.5	26.9	41.5
84	1	55.1	9.0	8.0	1.1
84	2	29.0	12.7	9.5	4.5
85	1	20.3	5.5	1.8	0.0
86	1	13.0	8.1	4.4	10.0
87	1	87.2	10.7	2.0	0.0
87	2	25.8	49.5	21.7	4.5
88	1	61.0	20.5	13.0	0.0
88	2	49.8	27.8	13.3	1.2
89	1	56.2	11.9	5.3	0.2
89	2	32.5	28.8	11.6	0.0
90	1	67.7	19.0	7.5	0.8
90	2	54.0	27.2	13.4	4.8

Table 36. Default PCC Properties Information (Computed using LTPP data)

State FIPS Code	PCC Elastic Modulus	PCC Compressive Strength, psi	PCC Air Content, percent	PCC Water to Cement Ratio
1	4,954,918	5,293	4	0.4
4	3,422,131	4,285	4	0.4
5	3,622,951	5,104	4	0.4
6	3,226,321	4,720	4	0.4
8	3,181,352	4,939	4	0.4
9	4,351,093	6,260	4	0.4
10	2,735,656	4,263	4	0.4
12	3,009,368	4,545	4	0.4
13	3,111,190	4,768	4	0.4
16	3,504,098	5,408	4	0.4
17	4,089,578	5,781	4	0.4
18	4,016,393	5,439	4	0.4
19	3,702,186	5,448	4	0.4
20	3,454,577	4,822	4	0.4
21	4,016,393	5,740	4	0.4
22	4,487,705	7,948	4	0.4
23	3,073,770	5,087	4	0.4
24	3,643,443	4,104	4	0.4
26	3,863,843	5,359	4	0.4
27	3,762,059	4,972	4	0.4
28	4,081,284	6,451	4	0.4
29	3,571,162	5,198	4	0.4
31	3,598,019	4,900	4	0.4
32	3,476,776	5,510	4	0.4
34	4,282,787	7,181	4	0.4
35	5,163,934	6,781	4	0.4
36	3,094,262	5,014	4	0.4
37	3,068,648	5,049	4	0.4
38	4,006,148	4,938	4	0.4
39	3,850,507	6,040	4	0.4
40	3,911,885	4,917	4	0.4
41	3,147,996	4,883	4	0.4
42	3,900,675	5,148	4	0.4
44	2,500,000	4,868	4	0.4
45	2,881,148	5,045	4	0.4
46	3,855,020	5,557	4	0.4
48	4,137,660	5,080	4	0.4
49	3,562,646	5,026	4	0.4
50	3,934,426	6,233	4	0.4
51	3,190,867	4,686	4	0.4
53	4,089,578	5,994	4	0.4
54	3,632,172	5,815	4	0.4
55	4,460,383	5,740	4	0.4

State FIPS Code	PCC Elastic Modulus	PCC Compressive Strength, psi	PCC Air Content, percent	PCC Water to Cement Ratio
56	3,709,016	5,243	4	0.4
72	3,606,557	4,780	4	0.4
83	3,862,705	5,369	4	0.4
84	3,893,443	7,128	4	0.4
87	4,887,295	6,681	4	0.4
89	3,746,585	5,536	4	0.4

Table 37. Default JPCP Design Information

<table>
<tr><th>State FIPS Code</th><th>JPCP Design Feature</th><th>Value</th></tr>
<tr><td rowspan="5">All</td><td>Sealant Type</td><td>Preformed = 1, Other or None = 0 (0 is recommended)</td></tr>
<tr><td>Tied shoulder?</td><td>Assumed tied PCC shoulder if the shoulder type is PCC. Shoulder type information is presented in Table 43 (HPMS ref # 3.2.1.2.37)</td></tr>
<tr><td>Dowel diameter, in</td><td><table>
<tr><th>PCC Thickness, in</th><th>Dowel Diameter, in</th></tr>
<tr><td>< 8</td><td>1</td></tr>
<tr><td>8</td><td>1</td></tr>
<tr><td>9</td><td>1.125</td></tr>
<tr><td>10</td><td>1.25</td></tr>
<tr><td>11</td><td>1.375</td></tr>
<tr><td>12</td><td>1.5</td></tr>
<tr><td>> 12</td><td>1.5</td></tr>
</table></td></tr>
<tr><td>PCC/Base interface loss of friction age (debonding) (Ref # 3.2.1.2.59)</td><td><table>
<tr><th>Base Type</th><th>Debonding Age, yr</th></tr>
<tr><td>No base</td><td>0.0</td></tr>
<tr><td>Aggregate</td><td>15.0</td></tr>
<tr><td>Asphalt or cement stabilized</td><td>23</td></tr>
<tr><td>Asphalt or cement stabilized with granular subbase</td><td>23</td></tr>
<tr><td>Hot mix AC (bituminous)</td><td>26.7</td></tr>
<tr><td>Lean concrete</td><td>18.8</td></tr>
<tr><td>Stabilized open-graded permeable</td><td>23</td></tr>
<tr><td>Fractured PCC</td><td>0.0</td></tr>
</table></td></tr>
<tr><td>PCC/Base interface loss of friction age (debonding) (Ref # 3.5.1.2.4)</td><td><table>
<tr><th>Base Type</th><th>Debonding Age, yr</th></tr>
<tr><td>Crushed gravel</td><td>15.0</td></tr>
<tr><td>Crushed stone</td><td>15.0</td></tr>
<tr><td>Granular</td><td>15.0</td></tr>
<tr><td>Asphalt stabilized</td><td>26.7</td></tr>
<tr><td>High stabilized</td><td>18.8</td></tr>
<tr><td>Weakly stabilized</td><td>15.0</td></tr>
<tr><td>Drainable material</td><td>15.0</td></tr>
</table></td></tr>
</table>

Table 38. Default Base Material Modulus (Computed using LTPP Data and MEPDG Defaults)

Base Type	Base Material Description	Elastic or Resilent Modulus, psi
HPMS Ref # 3.2.1.2.59	No base	Not applicable
	Aggregate	24,000
	Asphalt or cement stabilized	500,000
	Asphalt or cement stabilized with granular subbase	500,000
	Hot mix AC (bituminous)	200,000
	Lean concrete	1,000,000
	Stabilized open-graded permeable**	40,000
	Fractured PCC	100,000
HPMS Ref # 3.5.1.2.4	Crushed gravel	40,000
	Crushed stone	40,000
	Granular	24,000
	Asphalt stabilized	200,000
	High stabilized	1,000,000
	Weakly stabilized*	40,000
	Drainable material**	40,000

* Soil cement or lime treated aggregate and soils.

** Treated and untreated permeable materials.

Table 39. Default Climate Data

State FIPS Code	Rainfall, in	Freezing Index, °F-days	Freeze-Thaw Cycles	Mean Monthly Temperature, °F												Depth of Ground Water, ft
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	56.3	46.9	50.4	43.5	47.5	54.5	62.2	70.0	76.7	80.0	79.2	73.8	63.1	53.6	46.0	10
2	33.3	2378.0	98.1	13.5	16.6	24.5	35.3	46.5	55.0	58.5	55.6	46.9	32.5	20.1	14.9	25
4	11.3	53.9	51.7	47.4	51.0	55.5	62.4	71.0	80.2	85.3	83.6	77.7	66.6	54.8	47.4	40
5	50.0	104.0	54.0	39.0	43.9	52.1	61.6	69.6	77.4	81.4	79.9	73.0	62.1	51.1	42.3	10
6	21.7	11.1	24.0	48.5	51.8	54.6	59.2	65.1	71.3	76.0	75.7	72.0	64.3	54.7	48.5	25
8	14.5	638.8	145.8	27.1	32.1	39.6	48.2	57.5	67.2	73.0	71.0	62.3	50.5	37.3	28.7	40
9	46.5	585.8	105.6	26.0	28.5	36.5	47.5	57.7	66.5	71.6	70.1	62.3	51.6	42.0	30.8	10
10	45.5	189.8	71.6	34.4	36.6	44.4	53.9	63.2	72.2	76.7	75.3	68.7	57.7	48.1	38.9	10
11	41.6	157.1	72.4	34.6	37.4	45.6	55.6	65.0	73.9	78.4	76.9	69.8	58.0	48.1	39.0	10
12	55.6	1.5	7.9	58.8	61.0	65.7	70.3	75.9	80.3	81.9	81.7	79.8	73.7	66.9	61.1	10
13	51.1	34.1	41.9	44.9	48.6	55.5	62.9	70.3	76.9	80.1	79.0	74.0	64.0	55.3	47.6	10
15	28.4			71.7	71.8	72.5	73.5	74.9	76.3	77.3	78.0	77.9	77.2	75.4	73.0	25
16	16.6	731.3	127.4	24.8	29.6	37.9	46.1	54.4	62.3	69.4	68.4	59.1	47.5	35.0	26.0	25
17	38.2	741.8	83.8	24.1	29.3	39.7	51.9	62.5	71.7	75.5	73.3	66.0	54.2	41.3	29.4	10
18	41.2	583.7	80.8	26.8	31.1	40.7	52.2	62.5	71.6	75.3	73.3	66.5	54.8	43.0	31.8	10
19	34.8	1155.5	87.3	18.6	24.3	35.7	49.3	60.8	70.2	74.2	71.8	63.6	51.8	37.1	23.9	25
20	32.5	469.4	91.2	29.2	34.6	44.0	54.9	64.8	74.2	79.7	77.8	69.0	57.1	43.4	32.5	25
21	48.3	273.3	81.1	33.6	37.7	46.0	55.6	64.2	72.3	76.3	75.0	68.2	56.8	46.5	37.4	10
22	62.0	7.3	17.7	49.9	53.4	60.1	67.2	74.5	80.0	82.1	81.8	77.6	68.2	59.4	52.5	10
23	44.6	1165.4	103.5	19.0	21.7	31.0	42.4	53.7	62.8	68.2	66.8	58.2	47.3	37.0	24.7	10
24	43.1	194.0	75.4	34.0	36.9	44.8	54.8	64.1	72.8	77.2	75.6	68.8	57.3	47.5	38.2	10
25	46.1	559.9	97.3	26.8	28.8	36.7	47.5	57.9	67.1	72.4	70.9	63.0	52.3	42.4	31.3	10
26	32.2	1012.0	94.4	21.2	23.5	32.6	45.1	56.7	66.0	70.4	68.4	60.6	49.2	37.8	26.6	25
27	28.3	2007.2	86.0	10.1	16.6	28.5	44.2	57.2	66.3	70.8	68.6	58.9	46.7	30.4	16.2	25
28	58.1	70.0	51.2	42.3	46.4	54.0	62.5	70.3	77.3	80.5	79.5	73.9	63.1	53.4	45.4	10
29	41.4	472.1	84.7	29.1	34.4	43.9	55.3	64.6	73.4	78.2	76.3	68.3	56.8	44.3	33.4	10
30	14.9	1059.2	133.6	23.8	28.0	34.8	44.3	53.5	61.8	68.6	67.5	57.4	46.3	33.7	25.2	40
31	26.8	889.1	104.6	22.9	28.3	37.9	50.5	61.3	71.3	76.3	74.0	64.9	52.8	37.9	26.9	25
32	7.3	383.6	121.8	32.0	37.2	44.2	51.1	59.8	68.9	76.1	74.3	65.3	53.1	40.6	32.3	40
33	37.7	959.5	119.0	21.2	24.6	33.3	45.0	56.0	64.9	70.0	68.5	59.8	48.0	38.0	26.6	10

State FIPS Code	Rainfall, in	Freezing Index, °F-days	Freeze-Thaw Cycles	Mean Monthly Temperature, °F												Depth of Ground Water, ft
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
34	44.8	320.5	85.5	31.0	33.2	41.0	51.2	61.1	70.2	75.0	73.5	66.3	55.2	45.4	35.3	10
35	12.6	159.0	119.2	36.3	41.0	47.1	54.9	63.8	72.8	76.2	74.1	67.6	56.7	44.7	36.9	40
36	40.2	1044.1	100.1	21.4	23.6	32.3	44.8	56.2	64.7	69.2	67.7	59.7	48.5	38.1	26.9	10
37	47.2	92.4	72.6	38.9	42.2	49.5	58.1	65.8	73.2	77.0	75.6	69.6	58.9	49.9	41.8	10
38	20.5	2511.3	85.2	6.4	13.2	25.3	42.1	56.0	64.9	69.4	67.8	57.2	43.6	26.1	11.8	25
39	38.8	577.9	89.9	26.9	30.3	39.4	50.5	60.6	69.5	73.4	71.7	64.9	53.3	42.3	32.0	10
40	36.9	162.0	68.2	37.2	42.3	50.7	60.6	69.1	77.4	82.7	81.7	73.5	62.2	49.7	39.9	10
41	34.8	108.5	59.0	37.3	41.1	45.1	49.7	56.0	62.2	68.0	67.8	62.1	52.5	43.6	38.0	25
42	41.2	572.7	99.6	26.8	29.3	37.8	48.9	58.9	67.5	71.7	70.3	63.0	51.7	41.7	31.4	10
44	46.5	616.4	114.2	25.8	27.8	35.8	46.7	56.9	66.1	71.4	69.8	61.7	51.2	41.4	30.4	10
45	48.2	26.9	48.6	43.6	47.4	54.2	62.2	70.0	76.9	80.5	79.0	73.2	62.9	54.1	46.1	10
46	21.6	1429.2	107.9	17.9	23.2	32.3	45.3	56.9	66.5	72.6	70.8	60.7	47.8	32.5	21.6	25
47	55.0	170.6	79.5	36.1	40.2	48.4	57.3	65.5	73.3	77.2	76.0	69.6	58.2	48.3	39.6	10
48	35.0	55.0	40.6	45.9	50.1	57.1	65.3	72.8	79.4	82.8	82.2	76.3	66.7	56.0	48.1	10
49	13.7	532.4	143.8	27.3	32.3	40.4	47.7	56.4	65.6	72.6	71.1	62.0	50.0	37.4	28.2	40
50	34.8	1344.6	91.7	17.6	19.5	30.1	43.0	55.4	64.7	69.5	67.4	58.9	47.7	36.8	24.0	25
51	44.6	153.7	80.4	36.2	39.4	46.8	56.1	64.4	72.5	76.6	75.0	68.7	57.5	48.4	39.7	10
53	22.8	283.9	73.8	32.7	37.5	43.3	49.6	56.8	63.2	69.4	69.0	61.6	50.7	40.4	33.5	25
54	43.9	336.4	93.5	31.7	35.0	43.2	53.3	62.0	70.1	74.1	72.8	66.2	54.7	44.8	35.8	10
55	33.6	1394.9	93.1	16.7	21.7	31.8	44.9	56.5	65.8	70.7	68.8	60.2	48.2	34.7	21.8	25
56	12.6	1249.2	150.8	21.0	24.7	33.7	42.5	51.7	61.1	68.2	66.9	56.8	44.5	31.0	21.5	40
72	55.8			75.1	74.7	75.5	76.9	78.6	80.1	80.4	80.5	80.3	79.9	78.1	76.0	10
81	18.3	2139.6	120.8	12.9	18.0	26.4	39.5	49.6	56.6	60.9	59.6	50.8	40.7	24.9	15.6	25
82	39.7	535.3	88.5	29.8	34.2	39.6	45.7	52.6	58.0	62.6	62.6	56.1	46.6	36.6	29.7	10
83	21.0	3267.2	79.2	0.1	6.9	20.2	38.8	52.8	61.9	66.4	64.5	54.0	41.3	23.1	6.5	25
84	43.9	1571.4	95.2	15.3	17.5	27.1	38.4	50.5	60.2	66.3	65.2	56.4	45.4	34.7	21.9	10
85	56.4	1207.0	98.7	20.8	19.7	25.9	35.7	44.6	52.7	60.3	60.6	53.5	44.0	35.5	26.9	10
86	56.4	1031.9	97.6	21.7	22.0	29.6	39.2	49.6	59.0	65.3	65.3	57.6	47.1	37.8	27.4	10
87	37.2	1335.3	84.5	17.9	20.2	29.4	42.8	54.7	63.5	68.3	66.6	58.7	47.1	35.9	23.9	10
88	43.2	1296.5	80.5	18.4	18.9	26.9	37.5	48.6	58.1	65.3	65.0	57.4	46.8	36.9	25.5	10
89	40.6	1978.0	76.1	10.0	13.6	24.8	39.7	53.5	62.4	67.0	65.0	55.7	44.3	32.1	17.4	10
90	16.4	3160.6	81.6	1.9	8.7	20.3	38.4	51.9	60.2	64.7	62.9	52.2	39.9	21.8	7.2	25

Table 40. Default Soil Resilient Modulus (Adapted from MEPDG)

HPMS Surface Type Code	HPMS Soil Type Code	Subgrade Soil Resilient Modulus, psi
2	1	22,929
2	2	14,100
3	1	16,643
3	2	12,000
4	1	16,643
4	2	12,000
5	1	16,643
5	2	12,000
6	1	22,929
6	2	14,100
7	1	16,643
7	2	12,000
8	1	16,643
8	2	12,000
9	1	16,643
9	2	12,000
10	1	16,643
10	2	12,000
11	1	16,643
11	2	12,000

Table 41. Default HMA/Asphalt Layer Properties (MEPDG defaults or computed using LTPP)

State FIPS Code	HMA Gradation (Percent Passing Sieve Size)					HMA Air Voids, percent	HMA Binder Content by Volume, percent
	¾-in	⅜-in	No. 4	No. 80	No. 200		
1	91.7	67.5	49.2	8.3	4.9	5.13	9.87
2	99.0	79.7	56.2	11.6	8.6	4.51	10.49
4	93.0	63.2	47.5	16.0	4.9	5.14	9.86
5	91.9	69.4	51.8	10.5	6.1	4.97	10.03
6	98.4	76.5	56.1	10.4	6.0	4.68	10.32
8	99.9	83.7	62.4	12.1	7.3	4.40	10.60
9	93.7	72.0	49.7	10.6	4.4	5.19	9.81
10	93.0	71.9	48.4	9.6	4.9	5.09	9.91
11	97.3	77.6	59.1	10.2	6.8	4.85	10.15
12	99.5	90.4	67.0	12.2	4.5	3.57	11.65
13	87.8	59.6	47.2	13.0	5.4	5.00	10.00
15	98.4	87.0	61.7	13.4	11.6	3.71	11.29
16	99.8	87.9	63.0	13.0	7.4	3.19	11.81
17	98.1	73.6	48.6	12.6	5.9	4.16	10.84
18	86.7	54.1	40.1	4.5	3.1	4.88	10.12
19	99.6	84.4	65.3	10.1	7.8	5.01	9.99
20	99.8	85.2	67.1	12.0	8.9	3.98	11.02
21	91.8	69.8	52.1	18.2	8.8	5.09	9.91
22	97.7	77.6	53.8	12.5	8.3	4.85	10.15
23	91.6	65.8	47.3	10.2	5.3	4.98	10.02
24	97.5	83.7	58.4	9.7	6.2	4.38	10.62
25	90.5	61.9	43.0	12.6	4.4	5.25	9.75
26	97.0	80.4	63.9	9.3	5.7	5.00	10.00
27	99.1	83.0	66.9	13.4	5.0	4.06	11.15
28	96.7	79.7	57.7	13.1	7.0	3.72	11.28
29	97.6	74.5	52.2	13.3	7.9	4.75	10.26
30	99.9	77.7	58.2	11.6	7.1	4.79	10.21
31	98.5	85.7	71.6	13.2	8.7	3.86	11.14
32	97.1	76.7	57.8	14.2	7.1	4.85	10.15
33	76.3	51.8	35.6	6.1	3.3	6.04	8.96
34	94.3	73.7	51.4	9.9	5.6	4.65	10.35
35	97.8	74.9	55.1	12.4	7.2	4.72	10.28
36	91.0	75.5	55.5	10.9	6.6	4.54	10.46
37	95.8	77.4	59.0	11.6	4.8	4.40	10.60
38	100.0	82.5	68.0	8.5	5.3	4.01	10.99
39	98.2	75.0	54.5	9.1	6.2	5.31	9.70
40	93.1	72.7	57.6	11.5	6.3	4.63	10.37
41	97.3	74.2	49.0	9.6	6.7	4.28	10.72
42	94.0	74.7	52.7	8.8	5.4	4.77	10.23
44	100.0	87.5	62.0	16.0	8.5	4.01	10.99
45	99.7	81.3	58.6	12.8	5.0	3.12	11.88
46	99.9	82.9	65.2	13.6	8.0	4.26	10.74

State FIPS Code	HMA Gradation (Percent Passing Sieve Size)					HMA Air Voids, percent	HMA Binder Content by Volume, percent
	¾-in	⅜-in	No. 4	No. 80	No. 200		
47	80.1	63.0	46.0	9.0	6.6	5.18	9.82
48	91.5	76.5	54.5	13.7	6.6	4.19	10.81
49	100.0	80.6	56.5	14.0	8.5	3.74	11.26
50	90.7	68.7	51.5	9.2	4.0	5.33	9.67
51	90.3	69.1	50.9	9.4	5.4	5.30	9.70
53	99.1	81.9	54.9	10.0	6.6	4.52	10.48
54	90.9	78.7	51.6	8.1	3.7	4.01	11.00
55	96.7	74.4	55.6	7.2	3.8	4.49	10.51
56	99.4	82.9	55.8	12.4	7.7	4.05	10.95
72	88.2	69.3	51.7	13.0	7.7	4.85	10.15
81	98.3	80.1	56.8	16.0	11.7	4.53	10.47
82	89.3	65.4	49.3	8.7	7.1	4.85	10.15
83	99.9	82.8	62.3	10.2	5.6	4.09	10.91
84	96.3	78.8	57.7	10.3	5.3	4.29	10.71
85	100.0	81.0	55.9	10.1	5.6	4.01	10.99
86	98.0	78.5	57.8	10.3	6.9	4.85	10.15
87	99.6	79.9	55.8	9.1	3.8	4.15	10.85
88	97.9	77.0	59.0	9.3	5.1	3.61	11.39
89	98.7	75.6	55.0	10.4	4.9	4.32	10.68
90	99.9	76.8	57.9	10.0	6.4	4.47	10.53

Table 42. MEPDG Default A and VTS Parameters Based on Asphalt PG Grade (AASHTO 2007)

High Temp Grade	Low Temperature Grade													
	-10		-16		-22		-28		-34		-40		-46	
	VTS	A	VTS	A	VTS	A	VTS	A	VTS	A	VTS	A	VTS	A
46									-3.901	11.504	-3.393	10.101	-2.905	8.755
52	-4.570	13.386	-4.541	13.305	-4.342	12.755	-4.012	11.840	-3.602	10.707	-3.164	9.496	-2.736	8.310
58	-4.172	12.316	-4.147	12.248	-3.981	11.787	-3.701	11.010	-3.350	10.035	-2.968	8.976		
64	-3.842	11.432	-3.822	11.375	-3.680	10.980	-3.440	10.312	-3.134	9.461	-2.798	8.524		
70	-3.566	10.690	-3.548	10.641	-3.426	10.299	-3.217	9.715	-2.948	8.965	-2.648	8.129		
76	-3.331	10.059	-3.315	10.015	-3.208	9.715	-3.024	9.200	-2.785	8.532				
82	-3.128	9.514	-3.114	9.475	-3.019	9.209	-2.856	8.750	-2.642	8.151				

Table 43. MEPDG Default A and VTS Parameters Based on Asphalt Viscosity Grade (AASHTO 2007)

Asphalt Binder Grade	*A*	*VTS*
AC-2.5	11.5167	-3.8900
AC-5	11.2614	-3.7914
AC-10	11.0134	-3.6954
AC-20	10.7709	-3.6017
AC-30	10.6316	-3.5480
AC-40	10.5338	-3.5104

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GUIDANCE ON SETTING KEY PARAMETERS

Performance Indicators Thresholds

Pavement RSL is determined for a given pavement type based on forecasted condition (characterized using individual distress and IRI). Recommended terminal threshold distress/IRI values that define end of service life are presented in Table 44 and Table 45 for new asphalt and asphalt overlaid asphalt pavements and new JPCP and bonded and unbonded JPCP overlays, respectively. Information presented was obtained from review of current highway agency practices and published literature on the subject matter.

Table 44. Recommended Terminal Threshold Distress and IRI (For new asphalt and asphalt overlaid asphalt pavements)

HPMS Surface Type Code	Pavement Type	Distress Type and IRI							
		Alligator Cracking, percent lane area		Rutting, in		Transverse Cracking, ft/mi		IRI, in/mi	
		High Type	Others	High Type	Others	High Type	Others	High Type	Others
2, 6, & 7	(2) Bituminous (6) Asphalt overlay over existing asphalt pavement (7) Asphalt overlay over existing jointed concrete pavement	23	40	0.5	0.9	1000	2000	177	3000

Table 45. Recommended Terminal Threshold Distress and IRI (for new JPCP and bonded and unbonded JPCP overlays)

HPMS Surface Type Code	Pavement Type	Applicability of New Pavement Equations					
		Transverse Cracking, percent slabs cracked		Transverse Joint Faulting, in		IRI	
		High Type	Others	High Type	Others	High Type	Others
3, 9	(3) JPCP	12	20	0.17	0.3	177	300

Assigning Weights for Estimating Overall RSL

The PHT Tool determines overall RSL in two ways:

1. Minimum of all estimated RSLs for all the individually computed RSLs computed for different performance measures used in analysis
2. Weighted average of all individual RSLs computed.

Using a weighted average requires assignments of weights to the individual performance measures. Typically, weights are assigned in order to satisfy analysis objectives. Analysis objectives typically fall into the following categories:

- Determine structural RSL
- Determine functional RSL
- Determine RSL that reflects both functional and structural condition (most common).

For the first case, RSL due to pavement smoothness is assigned a weight of zero, while all the other structural distresses are assigned weights that add up to 100.

For the second case, RSL due to pavement smoothness is assumed as the pavement RSL. The third and most common method assigned a weight to both functional (IRI) and structural (cracking, rutting, faulting) distresses based on the importance the agency attaches to them. An example of weights applied by Iowa DOT to transform flexible pavement distress data into pavement condition ratings (determined using expert opinion) is presented in Table 46.

Table 46. Automated Condition Rating Calculations

Pavement Distress	Weights	Revised Weights for PHT Tool Performance Measures Only
IRI	35	40
Rutting	20	25
Alligator “fatigue” cracking*	10	25
Transverse cracking	10	10
Longitudinal cracking (non wheelpath)	5	
Longitudinal “fatigue” cracking (wheelpath)*	10	
Block cracking	10	
Total	**100**	**100**

* Both are considered wheelpath fatigue cracking in the PHT Tool.

* Adapted after Resler, J. and O. Smadi. HWYNEEDS: A Sensitivity Analysis. Proceedings: Mid-Continent Transportation Symposium, Ames, Iowa, 2000)

Maximum Service Life

The PHT Tool assigns maximum service life based on pavement type. Computed RSL is replaced by maximum pavement service life if RSL is greater than the maximum service life of the given pavement. Typical maximum service life utilized by the PHT Tool is presented in Table 47.

Table 47. Recommended Maximum Pavement Service Life

Pavement Type	Recommended Maximum Service Life, years
New flexible	20
New JPCP	30
Thick AC overlaid AC	10
Thin AC overlaid AC	6
Thick AC overlaid JPCP	10
Unbonded JPCP over rigid pavement	25
Bond PCC over JPCP	15

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