GEORGIA DOT RESEARCH PROJECT 17-18

Final Report

Development of Innovative & Effective Training Modules and Methods for Pavement Designers for Rapid Deployment and Continuous Operation of MEPDG

Office of Performance-based Management and Research
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16. Abstract

The American Association of State Highway and Transportation Officials (AASHTO) Joint Task Force on Pavements – in cooperation with the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Association (FHWA) – sponsored the development of an AASHTO Mechanistic-Empirical (ME) pavement design procedure. NCHRP project 1-37A produced rudimentary software that utilized existing ME-based models and databases reflecting current state-of-the-art pavement design procedures. The Mechanistic-Empirical Pavement Design Guide (MEPDG) was completed in 2004 and released to the public for review and evaluation. A formal review was completed by an independent set of consultants under NCHRP Project 1-40A, and version 1.0 of the MEPDG was submitted in 2007 to NCHRP, FHWA, and AASHTO for further consideration as an AASHTO Standard Practice. The MEPDG was formally adopted by AASHTO as an Interim Guide in 2008. Pavement ME Design is a software upgrade to version 1.0 that became available in 2013. AASHTO is distributing and managing the software as an AASHTOWare product.

This User Input Guide is more of an engineering manual for determining the inputs needed for pavement design engineers in Georgia to begin to use Pavement ME Design. Many State Highway Agencies (SHAs) implementing Pavement ME Design conduct a local calibration or verification effort to establish local inputs and determine the calibration factors that result in unbiased predictions. Forensic investigations, including materials testing and pavement performance data, are needed to establish the accuracy and bias of the distress transfer functions and International Roughness Index (IRI) prediction models. GDOT also sponsored a local calibration effort and the results from that effort were used in preparing this User Input Guide.

This manual has been updated from the previous MEPDG training manual with recently measured materials properties, climate data, and traffic inputs.

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DEVELOPMENT OF INNOVATIVE & EFFECTIVE TRAINING MODULES AND METHODS FOR PAVEMENT DESIGNERS FOR RAPID DEPLOYMENT AND CONTINUOUS OPERATION OF MEPDG

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DISCLAIMER STATEMENT

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	Inches	25.4	Millimeters	mm
Ft	Feet	0.305	Meters	m
Yd	Yards	0.914	Meters	m
Mi	Miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
Ac	Acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
Gal	Gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
[NOTE: volumes greater than 1,000 shall be shown in m^3]				
		MASS		
Oz	Ounces	28.35	Grams	g
Lb	Pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (metric tons)	Mg (or t)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit or (F-32)/1.8	5 (F-32)/9	Celsius	°C
		ILLUMINATION		
Fc	foot-candles	10.76	Lux	lx
Fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
Lbf	Pounds	4.45	Newtons	N
lbf/in^2 (psi)	pounds per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
	DENSITY			
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	Millimeters	0.039	Inches	in
M	Meters	3.28	Feet	ft
M	Meters	1.090	Yards	yd
Km	Kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	Hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	Milliliters	0.034	fluid ounces	fl oz
L	Liters	0.264	Gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
G	Grams	0.035	Ounces	oz
Kg	Kilograms	2.202	Pounds	lb
Mg (or t)	megagrams (metric tons)	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	Lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	Pounds	Lbf
kPa	kiloPascals	0.145	pounds per square inch	lbf/in^2 (psi)
Mpa	MegaPascals	0.145	kips per square inch	k/in^2 (ksi)
		DENSITY		
kg/m^3	pounds per cubic foot	0.062	kilograms per cubic meter	lb/ft^3 (pcf)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E 380. (Revised March 2003)

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EXECUTIVE SUMMARY

From the early 1960's through 1993, all versions of the American Association of State Highway and Transportation Officials (AASHTO) Design Guide were based on the empirical performance equations developed from the American Association of State Highway Officials (AASHO) Road Test *(AASHTO 1993)*. The need for and benefits of a mechanistic-based pavement design procedure were recognized at the time when the 1986 Design Guide was adopted *(AASHTO 1986).* To meet that need, the AASHTO Joint Task Force on Pavements – in cooperation with the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Association (FHWA) – sponsored the development of an AASHTO Mechanistic-Empirical (ME) pavement design procedure. NCHRP project 1-37A *(ARA 2004a,b,c,d)* produced rudimentary software that utilized existing ME-based models and databases reflecting current state-of-the-art pavement design procedures.

The Mechanistic-Empirical Pavement Design Guide (MEPDG) was completed in 2004 and released to the public for review and evaluation. A formal review was completed by an independent set of consultants under NCHRP Project 1-40A, and version 1.0 of the MEPDG was submitted in 2007 to NCHRP, FHWA, and AASHTO for further consideration as an AASHTO Standard Practice. The MEPDG was formally adopted by AASHTO as an Interim Guide in 2008 (*AASHTO, 2008*). Pavement ME Design is a software upgrade to version 1.0 that became available in 2013. AASHTO is distributing and managing the software as an AASHTOWare product.

This User Input Guide is more of an engineering manual for determining the inputs needed for pavement design engineers in Georgia to begin to use Pavement ME Design. Many State Highway Agencies (SHAs) implementing Pavement ME Design conduct a local calibration or verification effort to establish local inputs and determine the calibration factors that result in unbiased predictions. Forensic investigations, including materials testing and pavement performance data, are needed to establish the accuracy and bias of the distress transfer functions and International Roughness Index (IRI) prediction models. Georgia Department of Transportation (GDOT) also sponsored a local calibration effort and the results from that effort were used in preparing this User Input Guide.

This manual has been updated from the previous MEPDG training manual (Report No. FHWA/GA-DOT-RD-014-1117) with recently measured materials properties, climate data, and traffic inputs.

GENERAL NOTE:

The final report for this project discusses the recommended default values to be used in design for the primary pavement design and rehabilitation strategies used in Georgia.

CHAPTER 1—INTRODUCTION

The Georgia Department of Transportation (GDOT) currently uses the American Association of State Highway and Transportation Officials (AASHTO) Interim Design Guide for Design of Pavement Structures 1972 Chapter III Revised, 1981 for new pavement and rehabilitation design. As of 2008, however, AASHTO no longer supports this empirical-based pavement design procedure. AASHTO is supporting use of a mechanistic-empirical (ME) based procedure for both new and rehabilitation design of flexible and rigid pavements.

An ME based design method represents a rational engineering approach that has been used by some agencies to replace the empirical AASHTO Guide for Design of Pavement Structures *(AASHTO, 1993)*. The primary advantage of an ME based design system is that it is based on pavement fracture and deformation characteristics of all layers, rather than solely on the pavement's surface condition (ride quality).

The Mechanistic-Empirical Pavement Design Guide (MEPDG), developed under National Cooperative Highway Research Program (NCHRP Project 1-37A, is a ME based method for designing new and rehabilitated flexible and rigid pavements (*ARA, 2004*). The concepts of ME based methods allow the pavement design engineer to quantify the effect of changes in materials, load, climate, age, and construction practices on pavement performance. Such a rational engineering design approach provides a reliable and cost-effective method of diagnosing pavement problems, as well as forecasting maintenance and rehabilitation needs. AASHTO adopted this procedure in 2008 and published the first edition of the Mechanistic-Empirical Pavement Design Guide - A Manual of Practice (MOP) for its use (*AASHTO, 2008*). A second edition of the MOP was published in 2015 and is included with the current version of the design software. A third edition was balloted and approved by AASHTO Committee of Materials and Pavements (COMP) and was published in early 2020.

This Input Guide was prepared for use by GDOT to determine the inputs for the AASHTOWare Pavement ME Design (PMED) software and to provide guidance on the use of PMED.

CHAPTER 2—OVERVIEW OF THE MEPDG DESIGN METHODOLOGY

The MOP is based on ME design concepts, which means that the design procedure calculates pavement responses such as stresses, strains, and deflections, and accumulates the incremental damage from these responses over time. The procedure empirically relates the calculated responses in terms of damage to pavement distresses observed on roadway segments over time. This ME based procedure is shown in flowchart form in Figure 2.1. For a more complete discussion of the ME based concepts, procedure and transfer functions used to predict distress and smoothness, the designer is referred to the MOP, as well as to the “HELP” manual that is included in the PMED software and the NCHRP project 1-37A reports (*ARA, 2004 a,b,c,d*).

This chapter of the Input Guide provides an overview of the transfer functions, design steps, input categories, and hierarchical input approach included in the MOP. The remaining chapters of this Input Guide are focused on determining the inputs to the software for predicting distress and smoothness over the design life of the pavement structure.

2.1 DISTRESS TRANSFER FUNCTIONS INCLUDED IN PMED SOFTWARE

Chapter 5 in the MOP Second Edition includes a summary of the transfer functions for all types of pavements that are included in the MEPDG design and analysis methodology (AASHTO, 2015, 2020). Table 2.1 lists the performance indicators and the type of model or equation used to predict performance for use in design for each family of pavements included in the PMED software. Table 2.1 also lists the transfer functions and regression equations that are recommended for use in Georgia and whether or not they were locally calibrated for current versions of the software. The different pavement types are defined in Chapter 3 and local calibration is outlined in Chapter 9. In Table 2.1, the types pf pavement include flexible pavement and Hot Mix Asphalt (HMA) Overlays, inverted pavement, semi-rigid pavement, and rigid pavement such as Joint Plain

Concrete Pavement (JPCP), Continuous Reinforced Concrete Pavement (CRCP), and Short Joint Plain Concrete Pavement (SJPCP).

Table 2.1—Performance Indicators Predicted by Pavement ME Design

Type of Pavement		**Performance Indicator**		**Type of Model**[3]	**Recommended for Use in Georgia**	**Calibrated PMED Version**[4]
Flexible Pavement and HMA Overlays		HMA Rutting		ME Transfer Function	Yes, locally calibrated	2.3
		Unbound Aggregate Base and Subgrade Rutting		ME Transfer Function	Yes, locally calibrated	2.3
		Fatigue Cracking	Alligator Area Cracking; Bottom-Up Cracking	ME Transfer Function	Yes, locally calibrated	2.3
			Longitudinal Cracking; Top-Down Cracking	ME Transfer Function	***No (see note 1)***	
		Thermal, Low-Temperature Cracking (Transverse)		ME Transfer Function	Yes, locally calibrated	2.3
		International Roughness Index		Regression Equation	Yes, locally calibrated	2.3
		Reflection Cracking; confined to HMA overlays		Regression Equation	Yes, locally calibrated	2.3
Inverted Pavement		Alligator Fatigue Cracking		ME Transfer Function	**Yes, not locally calibrated**	**2.3**
		HMA Rutting		ME Transfer Function	***Yes, not locally calibrated***	**2.3**
		Unbound Aggregate Base and Subgrade Rutting		ME Transfer Function	***Yes, not locally calibrated***	**2.3**
		Thermal, Low-Temperature Cracking (Transverse)		ME Transfer Function	Yes, locally calibrated	2.3
		International Roughness Index		Regression Equation	***Yes, not locally calibrated***	**2.3**
Semi-Rigid Pavement		Fatigue Cracking of Cementitious Layer		ME Transfer Function	***No (see note 2)***	
		HMA Rutting, Fatigue Cracking, and Low-Temperature Cracking; same as for flexible pavements		ME Transfer Functions	Yes, locally calibrated	2.3
		International Roughness Index		Regression Equation	***No (see note 1)***	
Rigid Pavements	JPCP & JPCP Overlays	Faulting		ME Transfer Function	Yes, locally calibrated	2.3
		Fatigue Mid-Slab Cracking		ME Transfer Function	Yes, locally calibrated	2.3
		International Roughness Index		Regression Equation	Yes, locally calibrated	2.3
	CRCP & CRCP Overlays	Punchouts		ME Transfer Function	***Yes, not locally calibrated***	**2.3**
		International Roughness Index		Regression Equation	***Yes, not locally calibrated***	**2.3**

Type of Pavement		Performance Indicator	Type of Model[3]	Recommended for Use in Georgia	Calibrated PMED Version[4]
	SJPCP Overlay of HMA	Longitudinal Cracking	ME Transfer Function	***No (see note 1)***	

NOTES:

1. *The predicted distress or performance indicator should not be used to make design decisions or change the design, until that transfer function has been locally or globally calibrated.*
2. *The current GDOT policy is to allow base alternates in South Georgia. Granular aggregate base (GAB) or soil cement are typical options. In these cases, designs will be done using GAB base and current GDOT policy on thicknesses, until the semi-rigid designs are calibrated.*
3. *"ME Transfer Function" refers to those functions listed in the MOP 2nd/3rd Edition (AASHTO, 2015).*
4. *Transfer functions are verified up to referenced PMED version only. Future validation is necessary for subsequent versions of the software due to changes in model.*

2.2 PAVEMENT DESIGN STEPS USING PAVEMENT ME DESIGN SOFTWARE

Pavement design using the PMED software is an iterative process that can result in multiple acceptable designs. The specific design strategy for a project is selected external to the PMED software and is based on other factors, such as constructability, life cycle costs, and other policies established by GDOT. PMED, however, does include an optimization tool which defines the minimum thickness of an identified layer that satisfies all design criteria or threshold values entered by the user.

The design-analysis process includes the following six steps.

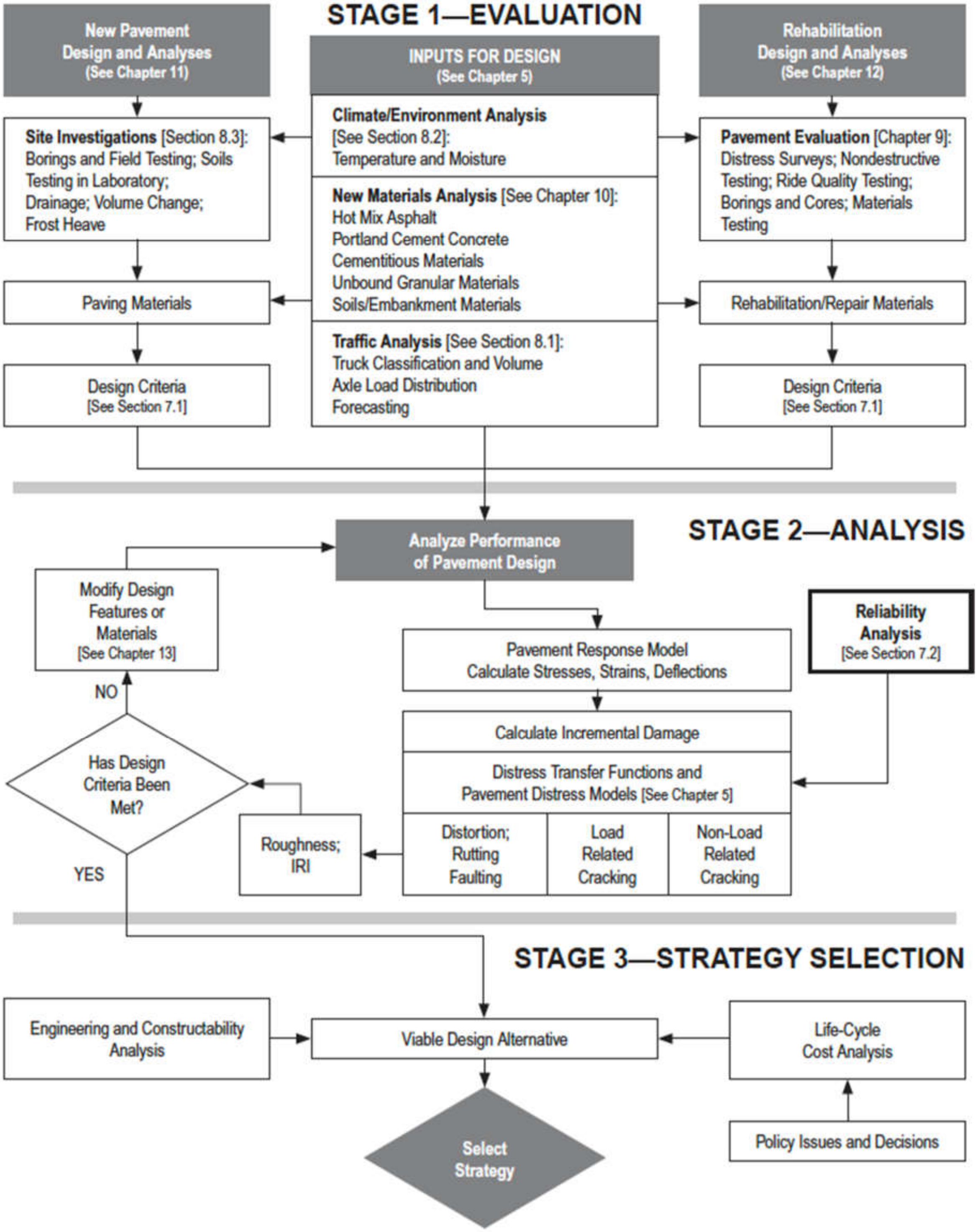


Figure 2.1—Conceptual Flow Chart of the MEPDG Three-Stage Design/Analysis Process for AASHTOWare PMED (*AASHTO, 2015, 2020*)

__Step 1:__ **Select a trial design strategy (new pavement or rehabilitation design)**. The pavement designer can use GDOT's current design procedure (guidelines and catalog) to determine the trial design cross section as a starting point. Establishing the layer structure for all pavements as discussed under Chapters 7 and 8 of this User Input Guide.

For ease of use within the initial implementation of the PMED Software, a set of baseline files was established and included in the GDOT MEPDG library. These files are listed and defined in Chapter 9 of this User Input Guide, because they are specific to the transfer function calibration coefficients to be used in Georgia. One of the appropriate files should be selected in setting up the trial design strategy.

__Step 2:__ **Select the appropriate performance indicator or distress criteria and design reliability level for the project**. Performance criteria can include bottom-up fatigue (alligator) cracking, total rut depth, thermal transverse cracking, and roughness (as estimated using the International Roughness Index [IRI]) for flexible pavement design. Transverse fatigue (mid-slab) cracking, joint faulting, and IRI are the performance criteria for jointed plain concrete pavements (JPCP), while punchouts, crack width, and IRI are the criteria for continuously reinforced concrete pavement (CRCP) design. The performance indicator criteria are obtained from GDOT policies for triggering major rehabilitation or reconstruction and are included in Chapter 4 of this User Input Guide.

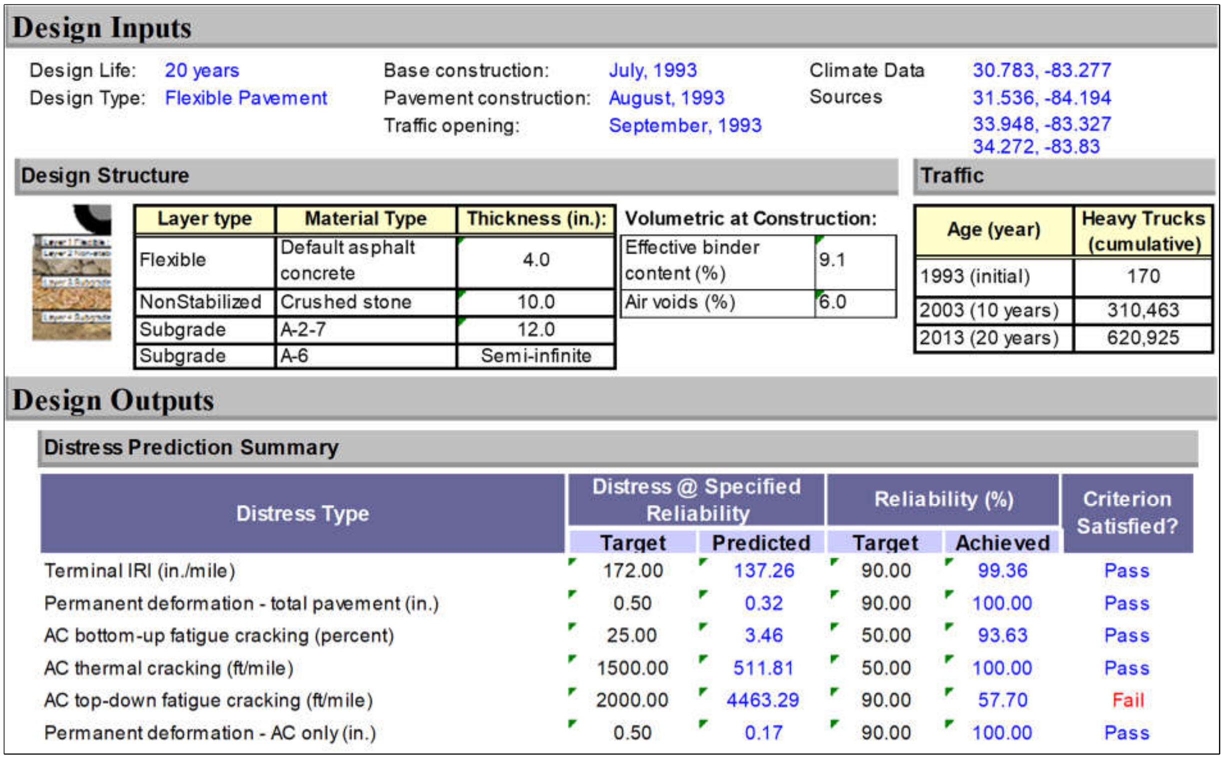
__Step 3:__ **Obtain all inputs for the trial design under consideration**. This step can be a time consuming effort but is necessary for evaluating pavement designs using mechanistic-empirical analysis. The designer must determine the inputs based on their impact on pavement performance. The inputs required to run the software can be obtained using one of three levels of effort. The hierarchical input levels are defined in Section 2.4 of this chapter.

The input categories include general project information, traffic, climate, design features, and pavement structure. The latter chapters of this User Input Guide are focused on determining values for the inputs to the PMED software. Worksheets are included in Chapter 11 for documenting the inputs for a specific design problem. These worksheets are intended to facilitate use of the PMED software.

Step 4: Run PMED software and examine the inputs for engineering reasonableness. The pavement design engineer should examine the input summary to ensure the inputs are correct and what the designer intended. This step should be completed before or after each run.

Step 5: Review and interpret the output in terms of the pavement performance and predicted reliability levels. The PMED software provides a summary of the predicted distresses and IRI of the pavement design as well as the reliability of the prediction for each distress. The user should assess if the trial design has met each of the performance indicator criteria at each of the chosen reliability levels for the project.

Figure 2.2 shows an example of the summary output for a new HMA pavement design. The target distress (performance criteria) and predicted distress at the specified reliability level are listed followed by the target reliability level and achieved reliability level for the target distress. If the “Achieved” reliability is equal to or greater than the “Target” reliability, the pavement structure passes. If the reverse is true, however, the pavement fails. If any key distress fails, the designer must alter the trial design to correct the problem. If further design changes are no longer feasible, available preventative maintenance practices may be considered as alternative solutions at the time of failure.



Design Inputs

Design Life: 20 years
Design Type: Flexible Pavement
Base construction: July, 1993
Pavement construction: August, 1993
Traffic opening: September, 1993
Climate Data Sources: 30.783, -83.277
31.536, -84.194
33.948, -83.327
34.272, -83.83

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	4.0
NonStabilized	Crushed stone	10.0
Subgrade	A-2-7	12.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	9.1
Air voids (%)	6.0

Traffic

Age (year)	Heavy Trucks (cumulative)
1993 (initial)	170
2003 (10 years)	310,463
2013 (20 years)	620,925

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	137.26	90.00	99.36	Pass
Permanent deformation - total pavement (in.)	0.50	0.32	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	25.00	3.46	50.00	93.63	Pass
AC thermal cracking (ft/mile)	1500.00	511.81	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	4463.29	90.00	57.70	Fail
Permanent deformation - AC only (in.)	0.50	0.17	90.00	100.00	Pass

Figure 2.2—MEPDG Output Summary Sheet

The distress and IRI are output by graphs and tables at the end of each month over the design period, so the designer knows the time at which any of the design criteria are exceeded. In addition, materials properties and other factors are output on a month by month basis over the design period. The designer should examine the output material properties, climate summaries, traffic graphs, layer moduli, joint load transfer for JPCP, and other factors to assess their reasonableness. For flexible pavements, the output includes the HMA Dynamic Modulus (E^*) and resilient modulus (M_r) for unbound layers for each month over the design period, while for rigid pavements the slab elastic modulus and flexural strength, the base elastic modulus, and subgrade k-value are also provided for each month throughout the design period.

If the trial design has either input errors, material output anomalies, or has exceeded the performance criteria at the given level of reliability, revise the inputs/trial design and rerun the program. Iterate until the performance criteria have been met or use the optimization tool to determine the minimum layer thickness for the design features selected. When the target reliability level has been achieved, the trial design may be considered a feasible design strategy.

Step 6: **Revise the trial design, as needed**. If any of the criteria has not been met (target reliability not achieved), determine how this deficiency can be remedied by altering the design and rerun the software until all criteria have been met at the target reliability level. While layer thickness is important, many other design factors also affect distress and IRI or smoothness. The designer must examine the performance prediction and determine which design feature to modify to improve performance (e.g., layer thickness, materials properties, layering combinations, geometric features, dowel diameter, and other inputs).

This User Input Guide identifies the design features commonly used in Georgia that should be considered to reduce specific performance indicators. Tables 2.2 through 2.4 provide some general guidelines for revising a design for which the calculated reliability of a specific distress is less than the target value. In addition, the MOP provides general guidance on revising the trial design when the performance criteria have not been met.

This “trial and error” process allows the pavement designer to essentially “build the pavement in his/her computer” prior to building it in the field to see if it will perform. If there is a problem with the design and materials for the given subgrade, climate, and traffic, it can be corrected, and an early failure avoided.

2.3 INPUT CATEGORIES

The inputs are grouped into five categories: (1) General Project Information (including the performance criteria), (2) Traffic, (3) Climate, (4) Design Features, and (5) Structure (including material properties). Each one of these is discussed separately in latter chapters. The GDOT PMED input library contains predefined project elements for traffic, climate, and material inputs. This Guide discusses the various categories of default inputs available in GDOT's PMED input library.

Some of the features listed in Tables 2.2 through 2.4 include layer properties that should not be changed when doing traditional designs. However, there are cases when those features can be revised to achieve an acceptable design—as an example, design-build type projects.

Table 2.2—Example Design Features to Revise for Flexible Pavement and HMA Overlay Designs Not Meeting the Design Criteria or Target Reliability

Distress & IRI	Design Feature Revisions to Minimize or Eliminate Distress
Alligator Cracking (Bottom Initiated)	• Increase thickness of HMA layers. • For thicker HMA layers (> 5-inches), increase dynamic modulus by using stiffer or harder asphalt. • For thinner HMA layers (<3-inches), reduce dynamic modulus by using softer asphalt. • Use a polymer modified asphalt in the lower HMA layer. • Increase density, reduce air void of HMA base layer. • Use an unbound granular aggregate base with a higher resilient modulus. • Increase the thickness of the granular aggregate base layer.
Thermal Transverse Cracking	• Use softer asphalt in the wearing surface or asphalt with a colder lower temperature grade. • Reduce the creep compliance of the HMA surface mixture. • Increase the indirect tensile strength of the HMA surface mixture. • Increase the thickness of the HMA layers. • Increase the asphalt content of the surface mixture.
Rutting in HMA	• Increase the dynamic modulus of the HMA layers by using harder or stiffer asphalt. • Use a polymer modified asphalt in the layers near the surface. • Reduce the asphalt content in the HMA layers Increase the amount of crushed aggregate. • Increase the amount of manufactured fines in the HMA mixtures.
Rutting in Unbound Layers and Subgrade	• Increase the resilient modulus of the aggregate base; increase the density of the aggregate base. • Stabilize the upper foundation layer for weak or collapsible soils. • Use a thicker layer of a granular aggregate base layer. • Place a layer of select embankment material with adequate compaction. • Increase the HMA thickness.
IRI HMA	• Reduce the predicted distresses that deteriorate smoothness. • Require more stringent smoothness criteria and greater incentives (building the pavement smoother at the beginning). • Improve the foundation; use thicker layers of non-frost susceptible materials • Stabilize any expansive soils • Place subsurface drainage system to remove ground water.
Reflection Cracking	• Use an engineered interlayer to mitigate reflective cracks. • Increase HMA overlay thickness. • Increase the modulus of the HMA overlay.

Table 2.3—Example Design Features to Revise for Jointed Plain Concrete Pavement and Overlay Designs Not Meeting the Design Criteria or Target Reliability

Distress & IRI	Modifications to Minimize or Eliminate
Joint Faulting	• Use dowels and increase their diameter as needed. • Do not increase slab thickness to achieve faulting criteria. • Increase erosion resistance of base (specific recommendations for each type of base). • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient (e.g., construct pavement at night, or pave in later afternoon to avoid high solar radiation). • Portland Cement Concrete (PCC) tied shoulder. • Widened slab (by 1 foot maximum to 13 feet). • Reduce joint spacing.
Slab Cracking	• Increase slab thickness. • Use PCC with lower coefficient of thermal expansion. • Increase PCC strength (but not more than 10 percent). • Reduce joint spacing. • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient (e.g., construct pavement at night, or pave in later afternoon to avoid high solar radiation). • PCC tied shoulder (separate placement or monolithic placement better). • Widened slab (by 1 foot maximum to 13 feet).
Joint Crack Width (to reduce joint faulting)	• Decrease joint spacing. • Reduce PCC coefficient of thermal expansion. • Build JPCP to set at lower temperature (cool PCC, place at cooler temperatures). • Reduce drying shrinkage of PCC (increase aggregate size, decrease water-cement ratio, decrease cement content).
Joint Load Transfer Efficiency (LTE) to reduce joint faulting	• Use mechanical load transfer devices (dowels). • Increase diameter of dowels. • Reduce joint crack width (see joint crack width recommendations). • Increase the size of the larger aggregate particles.
IRI JPCP	• Reduce the predicted joint faulting and cracking distresses that will reduce roughness. • Require more stringent smoothness criteria and greater incentives (e.g., reduce the initial as constructed IRI). • Improve the foundation; use thicker layers of non-frost susceptible materials.

Table 2.4—Example Design Features to Revise for Continuously Reinforced Concrete Pavement and Overlay Designs Not Meeting the Design Criteria or Target Reliability

Distress & IRI	Modifications to Minimize or Eliminate
Transverse Crack width	• Build CRCP to set at lower temperature (cool PCC, place during cooler temperatures). • Reduce drying shrinkage of PCC (increase aggregate size, decrease w/c ratio, decrease cement content). • Increase percent longitudinal reinforcement. • Reduce depth of reinforcement (minimum cover over steel: 3.5 in). • Reduce PCC coefficient of thermal expansion (change larger aggregate).
Transverse Crack LTE	• Reduce crack width (see crack width recommendations). • Reduce depth of reinforcement.
Punchouts	• Increase slab thickness. • Increase percent longitudinal reinforcement. • Reduce crack width over analysis period (see crack width recommendations). • Increase PCC strength (maximum of 10 percent). • Increase erosion resistance of base (specific recommendations for each type of base). • Minimize permanent curl/warp through curing procedures that eliminate built-in temperature gradient. • PCC tied shoulder or widened slab.
IRI CRCP	• Reduce the predicted distresses that deteriorate smoothness. • Require more stringent smoothness criteria and greater incentives (e.g., reduce the initial IRI at construction). • Improve the foundation; use thicker layers of non-frost susceptible materials.

2.4 HIERARCHICAL APPROACH FOR DETERMINING INPUTS

The hierarchical input approach provides the designer with a great deal of flexibility to obtain the inputs for a project based on the importance of the parameter and/or project and available resources. The hierarchical approach is employed with regard to traffic, materials, and condition of existing pavement inputs.[1]

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[1] The hierarchical approach for determining the inputs needed by the MEPDG is a feature not found in existing versions of the AASHTO Guide (*AASHTO 1986, 1993*) and other ME-based methods. Currently, input level has no effect other than accuracy of the input parameter (which is important for critical inputs), except for low-temperature thermal cracking of HMA wearing surfaces. For thermal cracking, the standard error of the transfer function is dependent on the input level (see Chapter 9 of this User Input Guide or Section 5 of the MOP Second Edition).

Three levels for most of the inputs are available to the designer. Table 2.5 defines each input level. One of three levels can be used to estimate the values for each input. However, the highest level of input available was used in calibrating the MEPDG transfer functions, both at the global and regional levels. Further discussion on this topic is found in Chapter 9.

For a given design project, inputs can be obtained using a mix of levels, such as dynamic modulus of HMA mixtures from Level 1, traffic load spectra from Level 3, and subgrade resilient modulus from Level 2. It is important to realize that no matter what input design levels are used, the computational algorithm for damage and distress is identical. The same models or transfer functions are used to predict distress and smoothness no matter what input levels are used.

Table 2.5—Hierarchical Input Levels

Input Level	Definition of the Level
1	Input parameter based on site specific data and information. Level 1 represents the case when the user has the greatest knowledge about the input parameter for the specific project. This input level has the highest level of testing (data collection costs) for determining the input value. Input level 1 is recommended for projects having unusual site features and/or considering the use of new materials.
2	Regression equations are used to determine the input value. The data collection and testing for this input level is simpler and less costly. Input level 2 is recommended for use for routine pavement designs and standard materials.
3	Level 3 inputs are based on "best-guessed" (default) values. The Level 3 inputs are based on global or regional default values. This input level requires the minimum amount of testing, and as such, results in the least knowledge about the input parameter for the specific project. Input level 3 is recommended for use when the other input levels are unavailable.

CHAPTER 3—GENERAL PROJECT INFORMATION

This chapter provides **guidance** on determining the input values for the General Project Information parameters for designing new and rehabilitated pavements in Georgia. Example screen shots are included at the end of this chapter for the general project information inputs.

3.1 DESIGN AND PAVEMENT TYPE STRATEGIES

The following sections outline general pavement design strategies for common pavement project types in Georgia. Table 3.1 provides a summary of the recommended calibration factors for each pavement design strategy listed in this section based on their inclusion in the local calibration process.

Table 3.1—Calibration Factors Recommended for New/Reconstructed Pavement Designs

Pavement Type	Pavement Design Strategy	Recommended Calibration Factors
Flexible and HMA Overlays	Conventional	Local GDOT
	Deep Strength & Full depth	Local GDOT
	Semi-rigid	Local GDOT
	HMA Overlays of Conventional, Deep-strength, and Full-depth Flexible Pavements, and JPCP	Global
	HMA Overlays of CRCP, Fractured JPCP and CRCP	Global
	HMA with soil cement	Global
	Inverted Pavements	Global
Rigid and PCC Overlays	JPCP	Local GDOT
	CRCP	Global
	PCC Overlays (All Types)	Global

NOTE: Local GDOT calibration factors values are located in Chapter 9.

3.1.1 New/Reconstructed Flexible Pavements and HMA Overlays

New and reconstructed HMA surfaced pavements, as well as HMA overlays, included in the PMED software are listed below in two groups: those verified using the Long Term Pavement Performance (LTPP) sites and non-LTPP pavement management sections and those not included in the verification-calibration process. If pavement design strategies are used that were not included in the local calibration process, the global calibration factors have to be used.[2] More detailed discussions on the types of pavement included in the local calibration and verification process are found in Chapter 9 and the final research report for this project (RP 11-17).

1. **Flexible pavements included in verification-local calibration process:** GDOT calibration coefficients of the transfer functions are provided for all of the following flexible pavement types (see Chapter 9):

    1) Conventional flexible pavements: Thin HMA layers (total HMA thickness less than 7 inches) and thick aggregate base layers (crushed gravel and soil-aggregate mixtures), greater than 10 inches in thickness with and without stabilized subgrades.

    2) Deep strength and full-depth flexible pavements: Full-depth and deep-strength were combined into one type of flexible pavement for the GDOT calibration study. Full-depth is defined as HMA layers placed directly on the prepared embankment or on a stabilized subgrade. Deep-strength is defined as a thick HMA (a wearing surface, a binder layer, and a base layer exceeding 7 inches in thickness) placed over a granular aggregate base (GAB) material with or without a stabilized subgrade.

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[2] Fourteen baseline files (6 for new pavement designs and 8 for rehabilitation designs) are included in the GDOT database library, which can be used as a starting point in setting up the trial design structure. These baseline files contain the appropriate GDOT calibration coefficients for each transfer function, even for the design strategies used on an infrequent basis in Georgia. The ten baseline files are listed and defined in Chapter 9 of this User Input Guide.

3) Semi-rigid pavements: HMA mixtures placed over Cement Treated Base (CTB), Cement Aggregate Mixtures (CAM), or lime-fly ash stabilized base layers without an unbound aggregate layer. Semi-rigid pavements were excluded in the original calibration completed under NCHRP Projects 1-37A *(ARA 2004 a,b,c,d)* and 1-40D *(NCHRP 2006)*. More recently, semi-rigid pavements were included during the 2018 global recalibration efforts. The global calibration factors should not be used for semi-rigid pavements until they have been verified using the GDOT semi-rigid pavement sections. Six semi-rigid pavement test sections were included in the local calibration study for GDOT. Most of the six projects had little alligator area cracking. Calibration factors are provided from these sections in Chapter 9 of this User Input Guide, but additional sections need to be included over time to confirm these calibration coefficients.

4) HMA overlays of all conventional, deep-strength, and full-depth flexible pavements, and JPCP.

2. **Flexible pavements not Included in verification-local calibration process:** Calibration coefficients of the transfer functions and layer inputs were established and recommended from other agency studies for the following pavement types (see Chapter 9):

   1) HMA overlays of CRC pavements, as well as HMA overlays of fractured JPCP and CRCP.

   2) Inverted pavements which include an HMA surface over a GAB layer over a CTB or soil cement layer.

3.1.2 New/Reconstructed Rigid Pavements and PCC Overlays

New and reconstructed PCC surfaced pavements, as well as PCC overlays, that were included or excluded from the local calibration refinement process are listed below.[3]

1. **Rigid pavements included in verification-local calibration process:** GDOT calibration coefficients of the transfer functions are provided for the following rigid pavement types (see Chapter 9):
    1) Jointed Plain Concrete pavements (JPCP) include transverse joints spaced to accommodate temperature gradient and drying shrinkage stresses to minimize cracking. The joints include dowels to complement the aggregate interlock in providing load transfer. GDOT JPCP sections used in the calibration had a thickness range of 8 to 12 inches and were placed on HMA, cement stabilized, and granular aggregate bases. Joint spacing ranged from 15 to 30 feet.
2. **Rigid pavements not included in verification-local calibration process:** Calibration coefficients of the transfer functions and layer inputs were established and recommended from other agency studies (see Chapter 9):
    1) CRC pavement includes PCC slab cast without transverse joints and containing longitudinal steel typically in the range of 0.5 – 0.8 percent of the cross-sectional area. The PCC surface develops transverse cracks and the design should ensure that the cracks remain tight and provide good load transfer during the service life of the pavement. A few CRCP sections were included in the verification-calibration process for GDOT, but the design features were generally confined to specific values.

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[3] Footnote 2 also applies to rigid pavements.

Calibration factors are provided from these sections, but additional sections need to be included over time to confirm the GDOT calibration coefficients (see Chapter 9).

2) PCC Overlays of all types of rigid and flexible pavements, including bonded PCC overlay of rigid pavements, unbonded PCC overlay of rigid pavements, and PCC overlay of flexible pavements. The same calibration factors used for new JPCP or CRCP can be used for these designs.

3.1.3 Pavement Preservation and Preventive Maintenance

Pavement preservation treatments have shown to impact the structural performance and regional calibration factors when applied to the HMA surface early in the pavement's life (*Von Quintus and Moulthrop, 2007a and 2007b*). Most of the roadway segments included within the local calibration process for GDOT included the use of pavement preservation and/or preventive maintenance strategies, with the exception of the LTPP SPS projects. Thus, the local calibration values presented in Chapter 9 account for the effects of pavement preservation and preventive maintenance activities commonly used by GDOT.

If GDOT's preservation/maintenance policies change over time, the local calibration factors should be checked to validate whether there is a further reduction in the structural related distresses (bias between the predicted and observed values).

3.2 PROJECT FILE/NAME

The designer should use a simple but descriptive name for the analysis that can be easily identified in the projects files created by the PMED software. The designer should enter appropriate information to identify the project for pavement design purposes and future reference.

The amount of detail is up to the designer.[4] The information for this category of inputs has no impact on the analyses or distress predictions.

3.3 DESIGN LIFE

The design life of a newly reconstructed pavement is the time from opening to traffic until the pavement has structurally deteriorated to the point when significant rehabilitation/reconstruction is needed – exceeding one of the threshold values or design criteria (refer to step #8 of Section 4 in the Pavement ME Design software manual). The design life for all new pavement and rehabilitation designs is 20 years.

The software can handle design lives from 1 year (e.g., detour) to over 50 years. In fact, the software program has the ability to analyze 100-year designs. The design life for "long-life" pavements is defined as 35 to 50 years. However, the distress models have not been calibrated using sections with 35+ year service lives and therefore the user needs to exercise caution while interpreting results using design lives greater than 35 years.

3.4 BASE AND PAVEMENT CONSTRUCTION & TRAFFIC OPENING DATES

3.4.1 New Construction

Construction completion and traffic opening dates are site construction features. These dates are keyed to the monthly traffic loadings and monthly climatic inputs which affect all layer moduli, including the subgrade modulus. The time reference is keyed to the first day of the month.

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[4] The name of the baseline files included in the GDOT database library can be used as an example (see Chapter 9).

In the case of rigid pavements, the construction month also determines the PCC set (or zero-stress) temperature, strength, and elastic modulus. The set temperature provides the temperature baseline for the calculation of joint openings during the design life. The strength and elastic modulus vary monthly over the entire design life and are used in fatigue cracking and joint faulting predictions.

Different construction months can affect performance due to climatic conditions for that month. For larger projects, these dates are difficult to accurately define during design. The designer should select the most likely month for construction and opening the roadway to traffic. These dates are more important for rigid pavements than for flexible pavements, and more importantly, distresses are less sensitive to these dates than for other inputs except for designing temporary pavement structures for detours.

Table 3.2 provides the recommended months when the roadway is periodically opened to traffic as different segments of the project are completed or if the dates are unknown because construction scheduling and phasing have yet to be defined. Specifying any month is defined as the first day of that month. For large projects that extend into different paving seasons, each paving season can be evaluated separately.

Table 3.2—Construction and Traffic Opening Dates

Design	Pavement Type	Base Construction Month	Pavement Construction Month	Traffic Opening Month
New Construction	Flexible	May	June	July
	Rigid	NA	June	August
Rehabilitation	HMA Overlay	NA	June	June
	PCC Overlay	NA	June	August

NOTE: NA – Not applicable.

3.4.2 Rehabilitation

The construction completion date of the existing pavement is required for all rehabilitation designs. This date should represent the time when pavement construction was completed. The predicted distresses and performance indicators are less sensitive to this date than for the construction and opening to traffic date for the overlay. Table 3.2 lists the recommended overlay and traffic opening months for rehabilitation projects when they are unknown.

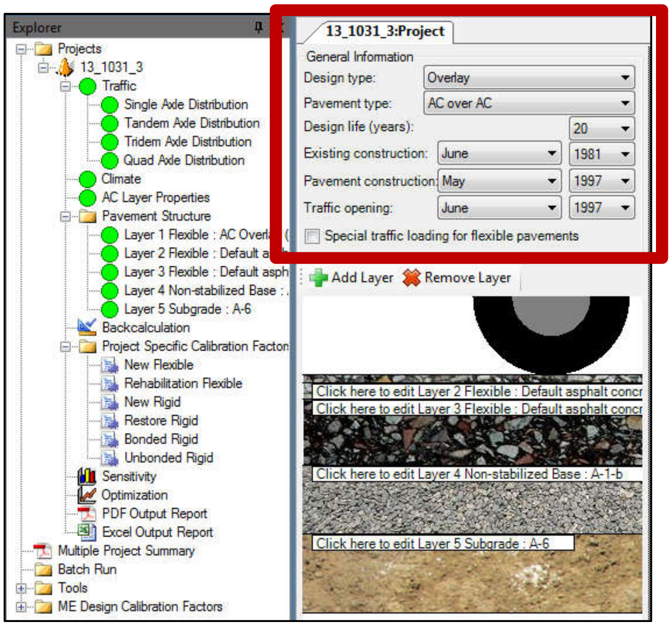
Another issue related to rehabilitation design is when an overlay is being designed for an existing pavement that already has one or more overlays, because only one overlay can be simulated in the program. The following provides some guidance on determining the date of original construction.

1. If the existing overlay is thin or most of it is being milled as part of the rehabilitation strategy, the year the original pavement was opened to traffic should be entered.
2. If a thick structural overlay exists (relative to the existing original pavement surface) and most of that overlay is left in place, the year the structural overlay was opened to traffic should be entered for the original pavement construction.
3. If the user is unsure what date to use, enter the date the original pavement was built or constructed, or just assume the pavement is 30 years old.

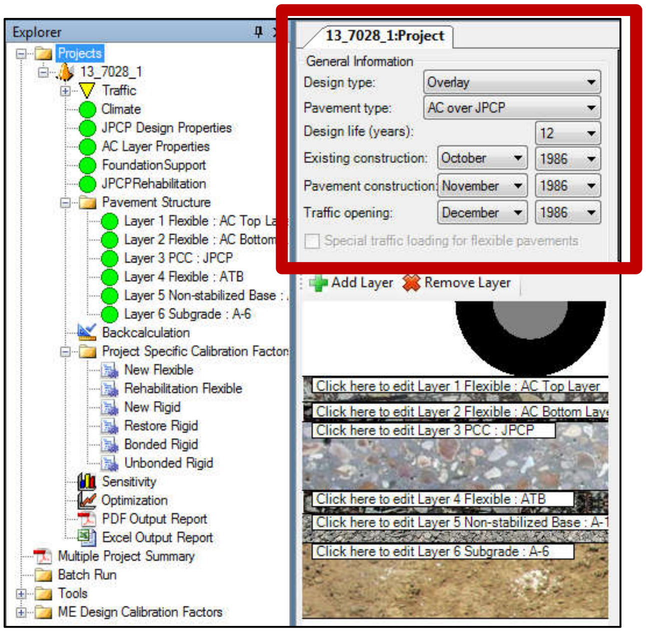
3.5 SCREEN SHOTS FOR GENERAL INFORMATION

The following are screen shot examples that show the General Information for the rehabilitation of flexible such as Asphalt Concrete (AC) over AC and rigid pavements (AC over JPCP). The drop-down arrows are used to access or select different design and pavement types and other information for a specific project.

AC over AC and AC over JPCP



General Information
Design type: Overlay
Pavement type: AC over AC
Design life (years): 20
Existing construction: June 1981
Pavement construction: May 1997
Traffic opening: June 1997
☐ Special traffic loading for flexible pavements



General Information
Design type: Overlay
Pavement type: AC over JPCP
Design life (years): 12
Existing construction: October 1986
Pavement construction: November 1986
Traffic opening: December 1986
☐ Special traffic loading for flexible pavements

CHAPTER 4—PERFORMANCE CRITERIA

Performance criteria are used to ensure a new pavement or rehabilitation design strategy performs satisfactorily over its design life. Performance of a pavement is measured in terms of the key distresses and smoothness, as measured by the IRI (refer to Table 2.1 in Chapter 2 of this User Input Guide and Section 5 of the Pavement ME Design software manual). The designer selects performance criteria or threshold limits that relate directly to the need for rehabilitation. Example screen shots showing the performance criteria are included at the end of this chapter.

4.1 INITIAL INTERNATIONAL ROUGHNESS INDEX (IRI)

The initial IRI is the average IRI value measured after construction and is entered into the input screen for the performance criteria (refer to step #10 of Section 5 in the GDOT Pavement ME Design software manual). This initial value should be determined from construction records of previously placed HMA or PCC surfaces under comparable conditions—previous year construction records.

The IRI reported by GDOT is based on a half car simulation of the longitudinal profile data, while the IRI reported by LTPP and used in the development of the global IRI regression equation was based on a quarter car simulation. The values resulting from a quarter car simulation will be consistently higher in comparison to a half car simulation. As such, the GDOT initial IRI values cannot be entered directly in the PMED.

If this value is unknown for some conditions and/or pavement type, the values in Table 4.1 are recommended for use for different pavement types.

Table 4.1—Initial IRI Values

Type of Pavement	Type of Wearing Surface	GDOT HRI Rating, mm/km	Initial IRI Rating, in./mi.
Flexible & HMA Overlays	Open-Graded Friction Course/Porous European Mix (PEM)	750	53
	Stone Matrix Asphalt (SMA) Mixture	825	59
	Dense-Graded HMA – State Routes	900	64
	Dense-Graded HMA – Urban Routes	1175	84
Rigid	JPCP	900	64
	CRCP	700	50

NOTE: GDOT HRI Rating is based on an analysis of the longitudinal profile data using a half car simulation, while the IRI Rating above is based on an analysis of the longitudinal profile data using a quarter car simulation.

4.2 DISTRESS CRITERIA OR THRESHOLD VALUES

Performance criteria (or Analysis Parameters on the software window) are used to ensure that a pavement design will perform satisfactorily over its design life. Critical limits are selected and used by the designer to judge the adequacy of a design, which represent the condition of pavements that trigger some type of major rehabilitation or reconstruction activity. These criteria are similar in concept to the current AASHTO Design Guide *(AASHTO, 1993)* with the use of only the terminal serviceability index levels. These design criteria should not represent levels of distress or surface conditions that trigger some type of maintenance or non-structural repair.

Distress specific design criteria are a policy decision of GDOT and determined from information included in GDOT pavement management database (Pavement Condition Evaluation System [PACES] for flexible pavements and Concrete Pavement Condition Evaluation System [CPACES] for rigid pavements). The consequence of a project exceeding a performance criterion is requiring earlier than programmed major rehabilitation.

The distress or performance indicator values recommended for design at the design reliability are listed in Tables 4.2 to 4.5 by type of pavement, which are defined and measured in accordance with the Distress Identification Manual (*FHWA, 2003*). The following paragraphs provide more discussion on the MEPDG design criteria relative to the GDOT values and policy decisions.

Table 4.2— Flexible Pavement and HMA Overlay Design Criteria or Threshold Values

Roadway Type (number of lanes are in both directions)		Performance Indicator				
		Fatigue (Load) Cracking		Thermal Cracking, ft./mi.	Permanent Deformation (Rutting)	
		AC Top-Down Fatigue Cracking[A], ft/mile	AC Bottom-Up Fatigue Cracking, %		Total Pavement, in.	AC Only, in.
Non-Interstate	2-Lane State Route	5,000	25	1,500	0.40	0.35
	4-Lane Roadway	5,000	15	1,500	0.40	0.35
Interstate	Rural and Urban	5,000	10	1,000	0.35	0.30

Note A: A value of 5,000 ft./mi. is recommended so the program does not iterate on this value when using the optimization tool. The MOP does not recommend using the AC Top-down fatigue cracking model for design purposes. Future versions of PMED (v2.6+) has a new top-down cracking model.

Table 4.3— Jointed Plain Concrete Pavement Design Criteria or Threshold Values

Roadway Type (number of lanes are in both directions)		Performance Indicator	
		Mean Joint Faulting, in.	Transverse Cracking, % slabs
Non-Interstate	2-Lane, State Route	0.20	10.0
	4-Lane Roadway	0.20	10.0
Interstate	Rural and Urban	0.125	10.0

Table 4.4— Continuously Reinforced Concrete Pavement Design Criteria or Threshold Values

Roadway Type (number of lanes are in both directions)		Performance Indicator
		Punchouts, 1/mile
Non-Interstate	2-Lane, State Route	10
	4-Lane Roadway	10
Interstate	Rural and Urban	5

Table 4.5— Composite and/or Semi-Rigid Pavement Design Criteria or Threshold Values

Roadway Type (number of lanes are in both directions)		Performance Indicator							
		Fatigue (Load) Cracking		Thermal Cracking, ft./mi.	Fatigue Fracture of Chem. Stabilized Layer[B], %	Permanent Deformation (Rutting)		AC Total Cracking	
		AC Top-Down Fatigue Cracking[A], ft/mile	AC Bottom-Up Fatigue Cracking, %			Total Pavement, in.	AC Only, in.	Fatigue Cracking (Bottom-Up & Reflective), %	Transverse Cracking (Thermal & Reflective)[A], ft/mile
Non-Interstate	2-Lane State Route	5000	25	1,500	25	0.40	0.35	25	5000
	4-Lane Roadway	5000	15	1,500	25	0.40	0.35	15	500
Interstate	Rural and Urban	5000	10	1,000	25	0.40	0.35	10	5000

Note A: A value of 5,000 ft./mi. is recommended so the program does not iterate on this value when using the optimization tool

Note B: No information is available to provide recommendation for this value. 25% is currently the default value in PMED

4.2.1 Terminal IRI Criterion

The terminal IRI for which the pavement is considered too rough and requires some type of rehabilitation is a required input. The IRI is predicted over time from the initial IRI and other predicted distresses and a site factor, which is explained in Chapter 5 of the MOP Second and Third Editions (AASHTO, 2015, 2020). Table 4.6 lists the terminal IRI ratings considered to be too rough, and the corresponding GDOT HRI Ratings for these criteria.

4.2.2 Fatigue (Load-Related) Cracking Criterion—Flexible Pavements

Two types of load-related cracking in flexible pavement are included in the PMED Design software: alligator or bottom-up fatigue cracking in terms of percent of total lane area and longitudinal or top-down fatigue cracking in terms of feet per mile (refer to Table 2.1).

In the MEPDG design methodology, bottom-up fatigue (alligator) cracking is assumed to initiate at the bottom of all HMA layers, while top-down (longitudinal) fatigue cracking is assumed to initiate at the surface of the HMA wearing surface (top-down cracking). Alligator or bottom-up fatigue cracking should be used as the design criteria. The surface initiated—longitudinal cracking is not recommended for use as a design criterion at this time. GDOT should consider top down cracking model when the model is fully implemented in the PMED software. The designer should review the predicted longitudinal cracking values but not make any design changes based on the predicted length of longitudinal cracks.

Bottom-up fatigue cracking is the input for new construction design problems, while asphalt concrete (AC) total cracking (bottom-up plus reflective cracks) are the inputs for a rehabilitation design problem – HMA overlays. Reflective cracking calculated by the PMED software is the percentage of cracks in the existing wearing surface that reflect through the HMA overlay. Total cracking is the combined area of new bottom-up fatigue cracks in the HMA overlay plus any cracks in the existing HMA wearing surface that have reflected through the HMA overlay.

Table 4.6—Terminal IRI and Corresponding GDOT HRI Ratings or Values

Roadway Type (number of lanes are in both directions)		Pavement Type							
		Flexible Pavements & HMA Overlays		Semi-Rigid		JPCP		CRCP	
		GDOT HRI Rating; mm/km	IRI Rating; in/mi	GDOT HRI Rating; mm/km	IRI Rating; in/mi	GDOT HRI Rating; mm/km	IRI Rating; in/mi	GDOT HRI Rating; mm/km	IRI Rating; in/mi
Non-Interstate Route	2-Lane, State	3090	220	3230	230	3090	220	2460	175
	4-Lane Roadway	2460	175	2460	175	2460	175	2460	175
Interstate Route	Rural & Urban	2460	175	2460	175	2460	175	2460	175

4.2.3 Permanent Deformation (Rut Depth) Criterion—Flexible Pavements

The PMED software requires the entry of two rut depth (permanent deformation) design criteria for flexible pavements: HMA rutting and total rutting (refer to step #11 of Section 5 in the GDOT Pavement ME Design software manual). The design criteria should be the same for both the HMA rutting and total rutting (refer to Table 4.2).

4.3 DESIGN RELIABILITY

The design reliability included in the MEPDG design methodology is similar, in concept only, to that in the AASHTO Design Guide *(AASHTO, 1993)*. In PMED, a design may specify the desired level of reliability for each distress type and smoothness. Selected design reliability levels may vary by distress type and IRI or may remain constant for each. The level could be decided by weighing the consequence of reaching the terminal condition earlier than the desired design life. Since reliability can significantly impact the pavement predictions, engineering judgement and experience should always be used when selecting a particular value.

Design reliability is defined as the probability that the predicted distress will be less than the critical level over the design period. For example, if 10 projects were designed and constructed using PMED and the design reliability for rutting was set to 90 percent for each project, one of those projects, on average, would show more rutting than the threshold value at the end of the design period. In other words, the reliability level of 90 percent represents the probability (9 out of 10 projects) that the mean rutting for the project will not exceed the total rut depth criterion.

As a result, design reliability should be selected in balance with the desired performance criteria. The selection of a high design reliability level (e.g., 99 percent) and a very low performance criterion (3 percent alligator cracking) might make it almost impossible to build. At the present time, the selection of a very high level of design reliability (e.g., greater than 96 percent) is not recommended because this may significantly increase construction costs.

Table 4.7 lists the reliability levels recommended for different types of roadways, except for reflection and thermal or transverse cracks. The design reliability for reflection and thermal cracks is 50 percent. The design reliability for reflection cracks is hard-coded in the PMED software as 50 percent and cannot be changed. The design reliability for thermal cracking is not hard-coded and needs to be entered by the user as 50 percent. If GDOT uses PMED software Version 2.5.5 or newer, Table 4.7 should be updated as total cracking (reflected and new) has its own reliability input.

The reason 50 percent reliability is recommended for thermal cracks is the mechanism for these cracks in Georgia is different from the mechanism included in the PMED software – thermal cracks caused by one or more cold temperature events. The PMED software does not predict any thermal cracks (caused by cold temperature events) for typical mixtures and climates in Georgia. Many roadway segments used in the calibration process, however, exhibited significant lengths of block cracking that are interpreted in the software as transverse cracking. Therefore, thermal cracks predicted in PMED are not believed to be a result of a low temperature event and instead are indications of block or transverse cracking in the roadway section. Bias was removed between the predicted thermal cracks and observed transverse cracks, but the standard error of the transfer function is large because the mechanisms for the predicted thermal cracks and observed transverse cracks are different. As such, the predicted mean amount of thermal cracks is suggested for use in determining the design features and binder grade of the HMA wearing surface. It should be noted that the PMED software V2.5.5 and newer version adjust the calibration factor for transverse cracking based on Mean Annual Air Temperature (MAAT). Therefore, the predicted amount of transverse cracks will be increased in warm climates.

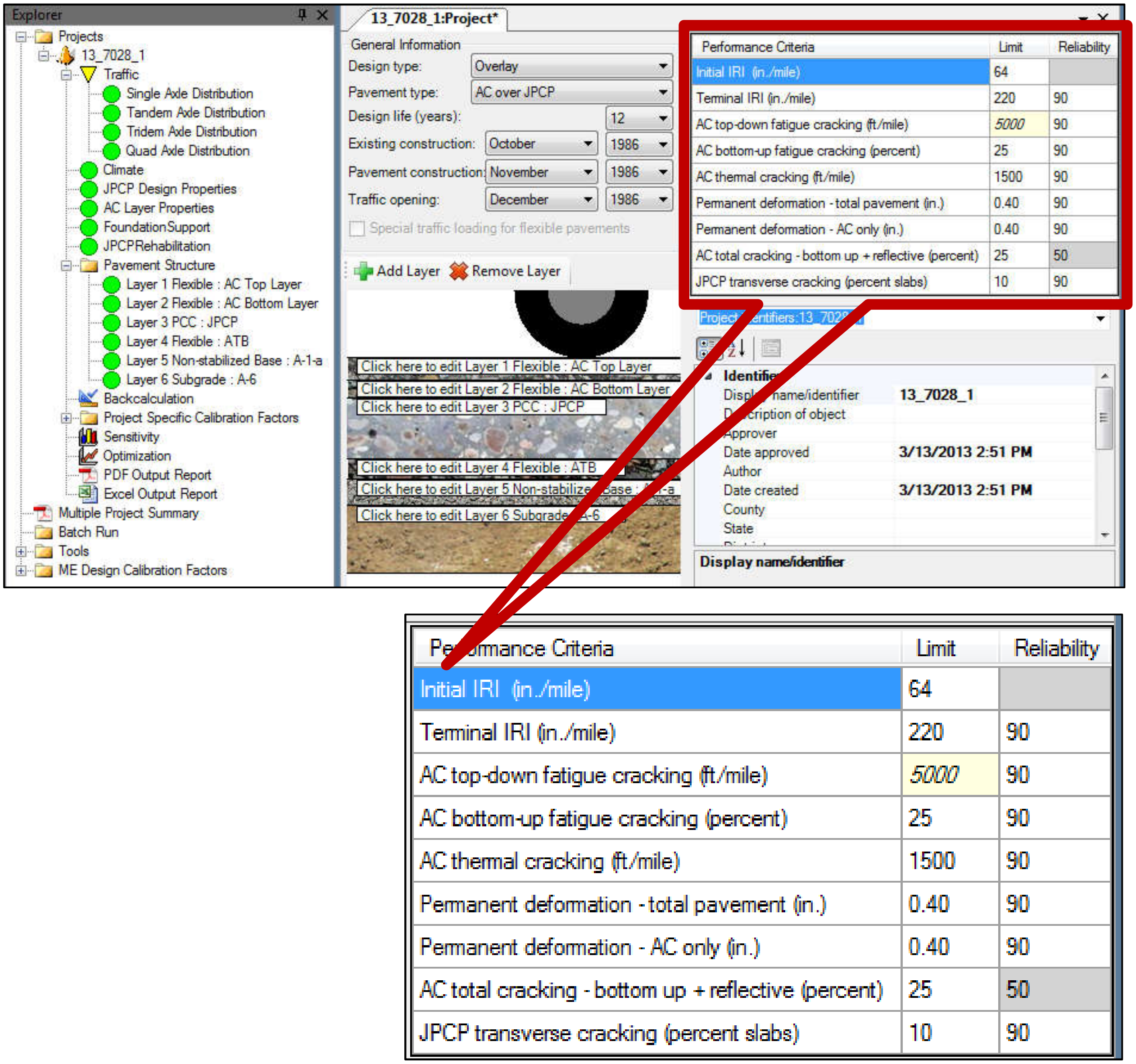
Table 4.7—Reliability Level Recommended for Use with Pavement ME Design

Type of Roadway	**Recommended Reliability Level, %**	
	All Performance Indicators, except for AC Permanent Deformation (Total Pavement) & Thermal Cracking	**AC Permanent Deformation (Total Pavement) & Thermal Cracking**
Interstate & Primary Arterials	95	50
Minor Arterials & Major Collectors	90	50
Low Volume (less than 500 trucks per day in both directions) & Local Roadways	75	50

4.4 SCREEN SHOTS FOR THE PERFORMANCE CRITERIA

This section of Chapter 4 includes screen shot examples that show the Performance Criteria inputs discussed within this chapter for the rehabilitation of flexible and rigid pavements. The same distresses are used for new flexible and rigid pavement designs, with the exception of reflection cracking. The specific pavement distresses are dependent on the pavement type selected for a specific project. The following are screen shots for the major pavement types (AC, JPCP, and CRCP).

AC over JPCP



General Information

Design type: Overlay

Pavement type: AC over JPCP

Design life (years): 12

Existing construction: October 1986

Pavement construction: November 1986

Traffic opening: December 1986

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	64	
Terminal IRI (in./mile)	220	90
AC top-down fatigue cracking (ft/mile)	*5000*	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal cracking (ft/mile)	1500	90
Permanent deformation - total pavement (in.)	0.40	90
Permanent deformation - AC only (in.)	0.40	90
AC total cracking - bottom up + reflective (percent)	25	50
JPCP transverse cracking (percent slabs)	10	90

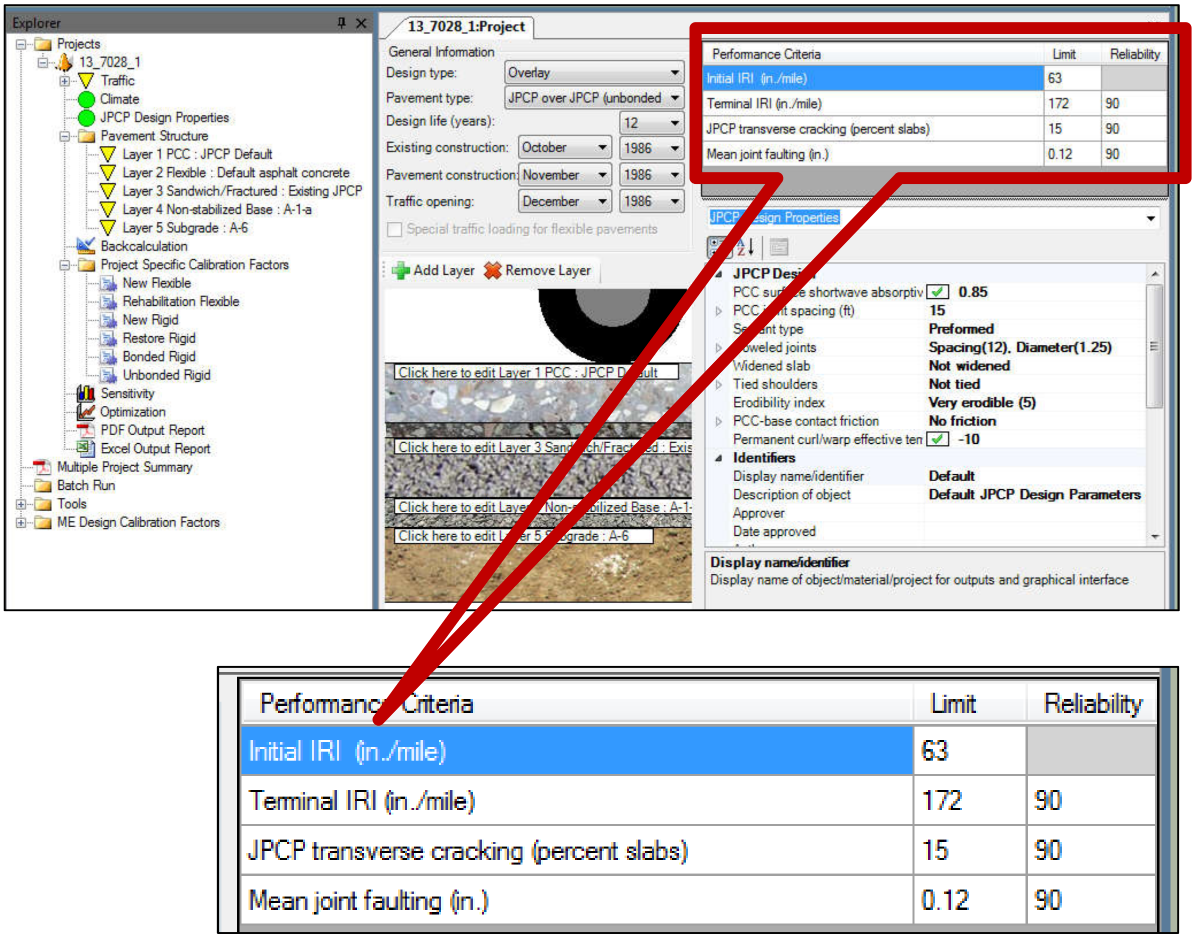
Project Identifiers:13_7028_1

Identifiers

Display name/identifier	13_7028_1
Description of object	
Approver	
Date approved	3/13/2013 2:51 PM
Author	
Date created	3/13/2013 2:51 PM
County	
State	

Display name/identifier

JPCP over JPCP (Unbonded)



General Information

Design type: Overlay

Pavement type: JPCP over JPCP (unbonded)

Design life (years): 12

Existing construction: October 1986

Pavement construction: November 1986

Traffic opening: December 1986

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
JPCP transverse cracking (percent slabs)	15	90
Mean joint faulting (in.)	0.12	90

JPCP Design

PCC surface shortwave absorptiv	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Widened slab	Not widened
Tied shoulders	Not tied
Erodibility index	Very erodible (5)
PCC-base contact friction	No friction
Permanent curl/warp effective ten	☑ -10

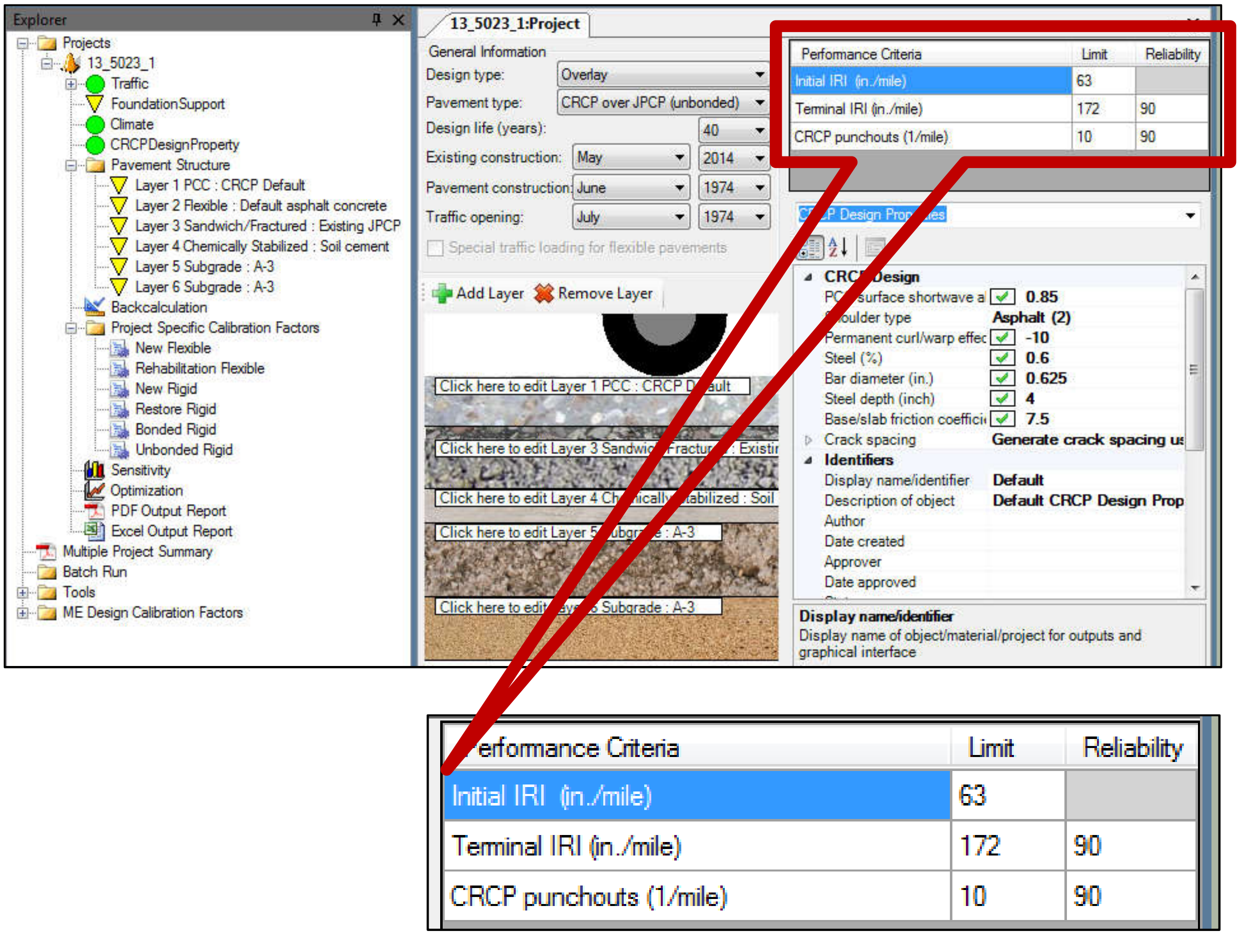
Identifiers

Display name/identifier	Default
Description of object	Default JPCP Design Parameters
Approver	
Date approved	

Display name/identifier
Display name of object/material/project for outputs and graphical interface

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
JPCP transverse cracking (percent slabs)	15	90
Mean joint faulting (in.)	0.12	90

CRCP over JPCP (Unbonded)



General Information

Design type: Overlay

Pavement type: CRCP over JPCP (unbonded)

Design life (years): 40

Existing construction: May 2014

Pavement construction: June 1974

Traffic opening: July 1974

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
CRCP punchouts (1/mile)	10	90

CRC Design

PC surface shortwave a ☑ 0.85

oulder type Asphalt (2)

Permanent curl/warp effec ☑ -10

Steel (%) ☑ 0.6

Bar diameter (in.) ☑ 0.625

Steel depth (inch) ☑ 4

Base/slab friction coeffici ☑ 7.5

Crack spacing Generate crack spacing us

Identifiers

Display name/identifier Default

Description of object Default CRCP Design Prop

Author

Date created

Approver

Date approved

Display name/identifier

Display name of object/material/project for outputs and graphical interface

CHAPTER 5—TRAFFIC INPUTS

This chapter summarizes the truck traffic inputs used for evaluating the adequacy of a design strategy. Example screen shots showing the traffic inputs are included at the end of this chapter.

The Traffic Analysis Branch of the Office of Planning can generate most of the traffic inputs for a specific project. For roadway segments where project specific traffic data are unavailable, the traffic weigh in motion (WIM) study determined and recommended traffic default values to be used for design (*Selezneva and Von Quintus, 2014*). The traffic default values are included in the GDOT ME Design Database. These traffic input libraries were established to save time in entering the traffic data.

Many other truck traffic input parameters are required for predicting the distresses of flexible and rigid pavements. Some of these inputs are difficult to determine and are unavailable within the GDOT truck traffic input library. Thus, the global default values are recommended for use in design and are defined and discussed within the NCHRP Project 1-37A reports (*ARA, 2004a*). These values were used in the regional validation/calibration refinement performed for Georgia, which are required for predicting distresses in both flexible and rigid pavements.

5.1 AVERAGE ANNUAL DAILY TRUCK TRAFFIC (TRAFFIC VOLUME INPUTS)

The following traffic input parameters relate to traffic volume and are considered site specific and should be obtained from the Traffic Analysis Branch of the Office of Planning or the Office of Transportation Data within GDOT. If this information is unavailable, the following subsections provide the recommended default values (input level 3) to be used.

1. Two-way average annual daily truck traffic (AADTT): A project specific AADTT at the beginning of the design period is required for every design. AADTT is a weighted average

between weekday and weekend truck traffic. The designer should enter two-way and not one-way AADTT values. The Traffic Analysis Branch of the Office of Planning typically provides one-way traffic volumes, so those values need to be multiplied by 2 as an input in PMED.

2. Number of lanes: The number of lanes in the design direction.

3. Percent trucks in the design direction or directional distribution factor (DDF): The percentage of trucks in the design direction or directional distribution factor (DDF) is defined by the primary truck class for the roadway; usually vehicle class #9. If sufficient truck volume data is unavailable, a DDF value of 50 percent should be used.

4. Percent trucks in the design lane or lane distribution factor (LDF): The percentage of trucks in the design lane is defined by the primary truck class for the roadway; usually vehicle class #9. If sufficient truck volume data is unavailable, the values listed in Table 5.1 should be used.

Table 5.1—Lane Distribution Factor Recommended for Use with Pavement ME Design

Number of Lanes (Two-Directions)	Lane Distribution Factor, %
4	90
6	80
8	70
10	60

5. Operational speed: This input parameter is taken as the posted speed limit or the average truck speed of the heavier or larger trucks through the project segment. Lower speeds result in higher incremental damage values calculated by the MEPDG design methodology.

5.2 TRAFFIC CAPACITY

This input factor (traffic capacity cap) does not have any impact on the predictions of the performance indicators. Thus, it is recommended that it not be enforced. This input is used to determine if the growth in traffic over time will exceed the capacity of the roadway.

5.3 AXLE CONFIGURATION

1. Average axle width: The average distance between the outside edge of the tires of an axle; 8.5 feet, the PMED default value.
2. Dual tire spacing: The average distance between the center of the two tires; 12 inches, the PMED default value.
3. Tire pressure (hot inflation pressure): The average hot tire pressure; 120 psi, assumed for both single and dual tires, the PMED default value.
4. Tandem axle spacing: The average distance between the two axles of a tandem axle; 51.6 inches, the PMED default value.
5. Tridem axle spacing: The average distance between the three axles of a tridem axle; 49.2 inches, the PMED default value.
6. Quad axle spacing: The average distance between the four axles of a quad axle; 49.2 inches, the PMED default value.

5.4 LATERAL WANDER

1. Mean wheel location: The average distance from the outer edge of the wheel to the pavement edge marking; 18 inches, the PMED default value. This input is only required for a rigid pavement design analysis.

2. Truck traffic wander standard deviation: The standard deviation of lateral distribution of trucks traveling down the roadway; 10 inches, the PMED default value.

3. Design lane width: The width of the lane between the pavement lane designation markings and not the slab width. This input is a design feature and not a traffic input. It is included with the other traffic inputs because it has a significant impact on the stresses in the PCC slab based on the location of the wheel load relative to the edge of the pavement. The value is selected by the designer for the specific project. This input is only required for a rigid pavement design analysis.

5.5 WHEEL BASE

The average axle spacing and percentage of trucks within each spacing are only required for a rigid pavement design analysis. The following are the Georgia default values recommended for use:

1. Average axle spacing:

    1) 12 ft. for short axle spacing.

    2) 15 ft. for medium axle spacing.

    3) 18 ft. for long axle spacing.

2. Average percentage of trucks within each axle spacing:
    1) 17 percent for short axle spacing.
    2) 22 percent for medium axle spacing.
    3) 61 percent for long axle spacing.

5.6 VEHICLE CLASS DISTRIBUTION AND GROWTH

1. **Distribution Factors: Normalized vehicle (truck) class volume distribution:** Determine the percentage of each vehicle or truck class within the mixed traffic (vehicle class 4 through 13 as defined by FHWA). These percentages represent the normalized truck volumes or truck volume distribution and are provided by the Traffic Analysis Branch of the Office of Planning.

    Vehicle class volume data are readily available on just about all roadways in Georgia so the normalized vehicle class distribution can be obtained from the Traffic Analysis Branch of the Office of Planning for most pavement designs. In the few cases, where vehicle class volume data are unavailable or for a new roadway (new alignment), the following paragraphs can be used to estimate the normalized vehicle class volume distribution factors.

    1) Three truck class categories can be used to select one of the seventeen truck traffic classification (TTC) groups included in the PMED software for a specific roadway segment: single unit trucks (vehicle class [VC] 5 to 7), combination trucks or single trailers (VC 8 to 10), and multi-trailer trucks (VC 11 to 13). Estimate the amount of trucks expected within these three truck class categories.

2) Table 5.2 summarizes the TTC groups for those roadways that were used in the local calibration process for Georgia. These TTC groups represent the median groups or values for the LTPP and non-LTPP sites used in the Georgia local calibration study, as well as from the traffic WIM study to identify the common TTC groups found on Georgia's roadways (Selezneva and Von Quintus, 2014).

As noted above, these TTC groups are recommended for use when actual truck traffic data are unavailable for use in design (refer to step #15.2 of Section 6 in the GDOT Pavement ME Design software manual).

Table 5.2—Median Truck Traffic Classification Groups Common to Georgia Roadways

Roadway Description		Type of Truck	Percentage of Trucks	Applicable TTC Group
Freight Routes	Rural Interstate Highways, 4-Lane Divided Highways	Single Units	19.2	TTC-5
		Single Trailers	65.9	
		Multi-Trailers	14.9	
	Urban Interstate Highways, 4-Lane Divided Highways	Single Units	42.9	TTC-6
		Single Trailers	56.4	
		Multi-Trailers	1.7	
	Principal Roadways, 4-Lane Divided Highways	Single Units	32.2	TTC 4
		Single Trailers	65.0	
		Multi-Trailers	2.8	
Non-Freight Routes	Minor Arterials and Major Collector Routes (more than 1,000 AADTT in both directions)	Single Units	57.9	TTC 12
		Single Trailers	39.9	
		Multi-Trailers	2.2	
	Local Two-Lane Routes with Low Truck Volumes (less than 1,000 AADTT in both directions)	Single Units	73.9	TTC-14
		Single Trailers	25.1	
		Multi-Trailers	1.0	

NOTE: Single units include vehicle classes 4 to 7; single trailers include vehicle classes 8 to 10; and multi-trailers include vehicle classes 11 to 13.

2. **Growth rate of truck traffic:** Estimate the increase in truck traffic over time. The growth of truck traffic is difficult to accurately estimate because there are many site and social-economic factors that cannot be predicted 20+ years into the future. In most cases, the growth rate for each vehicle class will be provided by the Traffic Analysis Branch of the Office of Planning for a particular roadway segment. The type and

magnitude of the growth rate can be entered in the PMED software for each truck class (refer to step #15 in Section 6 of the Pavement ME Design software manual).

The user has three options in choosing a traffic growth function, as listed below:

1) No growth: Truck volume for a specific truck class remains the same throughout the design life.

2) Linear growth: Truck volume increases by a constant percentage of the base year traffic for the specific truck class.

3) Compound growth: Truck volume increases by a constant percentage of the preceding year traffic for the specific truck class.

Negative Growth should not be used. If truck traffic is expected to decrease within the design life, use the average truck volume throughout the design life for that truck class and assume no growth.

5.7 MONTHLY ADJUSTMENT

The monthly distribution factors (MDF) represent the relative amount of trucks traveling on the roadway segment during any month within a typical year. The MDF can be provided by the Traffic Analysis Branch of the Office of Planning.

Two sets of MDF were determined from the roadway segments with sufficient data and are defined as seasonally dependent and seasonally independent. Both sets of values are listed in Tables 5.3 and 5.4 and should be used when sufficient truck volume data are unavailable. The default MDF can be imported into the PMED software from the truck traffic data library established for GDOT. The values in Tables 5.3 and 5.4 are provided in this User Input Guide for checking the values imported into the software. Table 5.3 includes the seasonally dependent values to be used for the non-freight routes, while Table 5.4 includes the seasonally independent values to be used for the freight routes. The Georgia freight routes are shown in Figure 5.1. All freight routes are generally along the interstate roadways, while the non-freight routes are along the non-interstate roadways. For any questions regarding freight routes, contact the Traffic Analysis Branch of the Office of Planning.

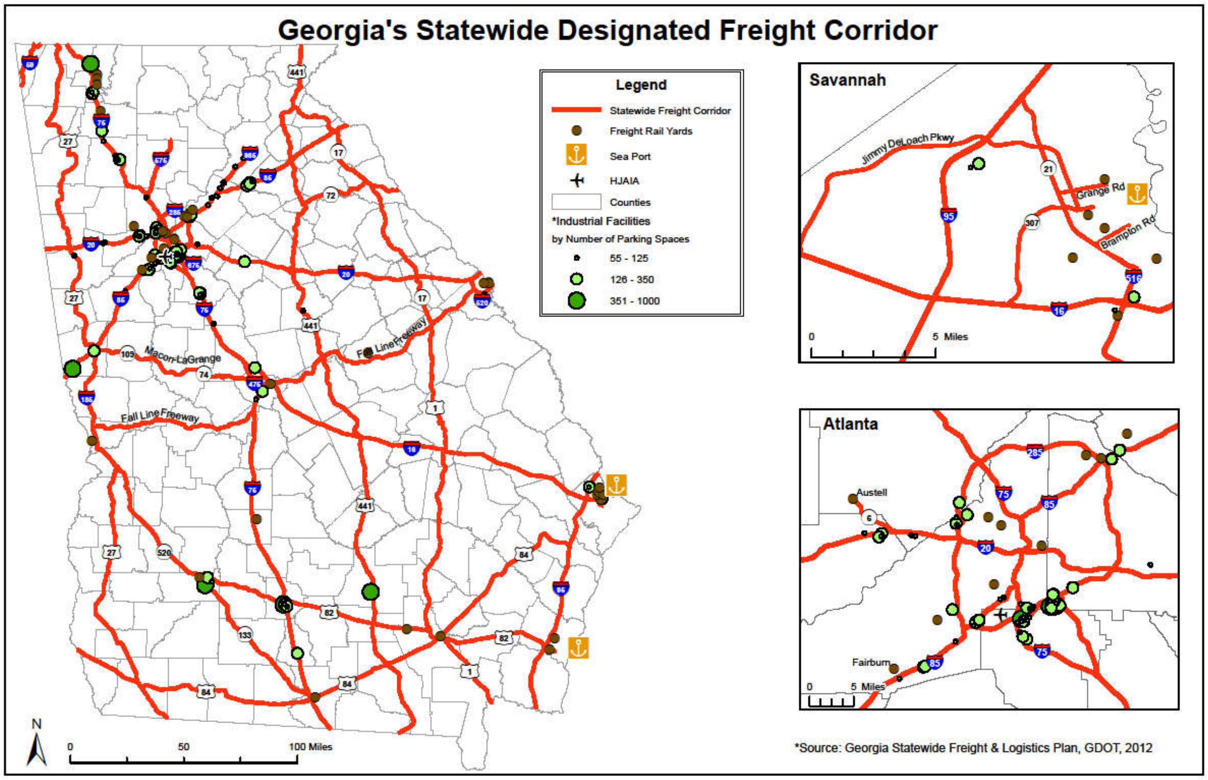
Table 5.3—Monthly Adjustment Factors for Non-Freight Routes; Seasonally Dependent

	Truck Classification									
Month	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
January	0.17	0.11	0.79	1.6	0.22	0.22	1.94	0.16	0.51	1.12
February	0.23	0.06	0.74	1.53	0.28	0.39	2.06	0.39	0.67	0.65
March	0.74	0.56	0.91	0.89	0.91	0.84	1.42	0.74	0.86	0.74
April	1.41	1.26	1.08	0.6	1.29	1.34	0.65	1.28	1.07	0.81
May	1.71	1.65	1.08	0.12	1.51	1.45	0.36	1.61	1.26	0.57
June	1.54	1.97	1.08	0.12	1.53	1.5	0.24	1.72	1.32	0.57
July	1.49	2.14	1.02	0.12	1.4	1.4	0.19	1.46	1.07	0.65
August	1.41	1.95	1.19	0.12	1.52	1.63	0.25	1.63	1.3	0.96
September	1.46	1.2	1.03	0.56	1.54	1.55	0.42	1.61	1.56	1.11
October	1.29	0.78	1.15	1.19	1.18	1.17	1	1.01	1.13	2.18
November	0.33	0.16	1.08	2.87	0.39	0.34	1.93	0.28	0.79	1.28
December	0.22	0.16	0.85	2.28	0.23	0.17	1.54	0.11	0.46	1.36

Table 5.4—Monthly Adjustment Factors for Freight Routes; Seasonally Independent

Month	Truck Classification									
	4	5	6	7	8	9	10	11	12	13
January	0.6	0.84	1.56	0.96	0.96	1.06	1.32	0.96	1.08	1.32
February	0.72	0.96	1.2	0.96	1.08	1.06	1.2	0.96	1.14	0.96
March	0.96	1.08	0.96	0.6	1.08	1.06	0.96	0.96	1.14	0.96
April	1.44	1.2	0.96	0.48	1.08	0.96	0.96	0.96	1.08	0.84
May	1.08	0.96	0.84	0.48	1.08	0.96	0.96	0.96	0.84	0.48
June	1.08	1.08	0.72	0.6	1.08	0.96	0.96	1.08	0.96	0.6
July	0.72	0.84	1.08	1.08	0.96	0.84	0.84	0.96	0.84	0.6
August	0.84	0.72	0.96	1.32	1.08	0.96	0.84	1.08	0.96	0.84
September	0.84	0.84	0.84	1.32	0.84	0.96	0.96	1.08	0.96	0.84
October	1.44	1.32	0.96	1.44	0.96	1.06	0.96	1.08	1.08	1.32
November	1.32	1.2	0.96	1.44	0.96	1.06	0.96	0.96	1.08	1.44
December	0.96	0.96	0.96	1.32	0.84	1.06	1.08	0.96	0.84	1.8

NOTE: Freight routes are along the interstate roadways, while non-freight routes are for the non-interstate routes. Contact the Traffic Analysis Branch of the Office of Planning to confirm input.



*Source: Georgia Statewide Freight & Logistics Plan, GDOT, 2012

Figure 5.1—Freight Routes Identified in Georgia

5.8 HOURLY ADJUSTMENT

Hourly distribution factors (HDF) are only required for rigid pavement analyses; they are not used for predicting distresses of flexible pavements and HMA overlays of flexible pavements. The global default values included in the PMED software were found to be appropriate for Georgia interstates and principle arterials. Insufficient truck traffic volume data were unavailable to determine the HDF for the other roadway functional classification. Thus, it is recommended that the global default HDF be used for all roadways. Table 5.5 lists the global HDF for verifying the inputs. [NOTE: The hourly distribution factors input fields in the PMED software are only visible for rigid pavement designs.]

Table 5.5—Hourly Distribution Factors Recommended for Georgia

Time of Day	Hourly Distribution of Truck Traffic, %
Midnight to 6 a.m.	2.3
6 a.m. to 10 a.m.	5.0
10 a.m. to 4 p.m.	5.9
4 p.m. to 8 p.m.	4.6
8 p.m. to Midnight	3.1

5.9 AXLES PER TRUCK CLASS

The average number of axles per truck class was determined from an analysis of the GDOT's WIM data as part of the traffic WIM study (*Selezneva and Von Quintus, 2014*). The default number of axles per truck class is listed in Table 5.6. These values are also included in the traffic library as part of the GDOT database. Table 5.6 is provided for checking the values imported into the PMED software for a specific project.

Table 5.6—Default Values for the Number of Axles per Truck Class

Truck Class	Number of Axles per Truck Class			
	Single Axles	Tandem Axles	Tridem Axles	Quad Axles
4	1.3	0.7	0	0
5	2.0	0	0	0
6	1.0	1.0	0	0
7	1.0	0.26	0.83	0
8	2.4	0.6	0	0
9	1.2	1.6	0	0
10	1.3	1.3	0.5	0.02
11	4.7	0.1	0.01	0
12	3.9	1.0	0.01	0
13	2.0	2.0	0.20	0.06

5.10 AXLE LOAD DISTRIBUTION FACTORS

Table 5.7 lists the files with the normalized axle load spectra (NALS) or distribution factors included in the GDOT database library. The default NALS were determined from the traffic WIM project (*Selezneva and Von Quintus, 2014*) for use in design to save time in entering the axle load distribution data. In addition, the Traffic Analysis Branch of the Office of Planning can provide these values from the permanent WIM sites as more sites are installed on Georgia's roadways.

Table 5.8 includes the tandem axle NALS factors for the heavier axle weights of vehicle class 9 to verify the values imported into the PMED software.

The three NALS classifications or files were derived from a limited number of WIM sites with relatively few over loaded trucks. If the designer is concerned with overloaded trucks along the route in question, the global NALS developed under NCHRP Project 1-37A should be selected for use. For roadways where the designer wants more accurate weight data, the portable weigh in motion (WIM) equipment can be used to measure the NALS over a short time period (minimum of 3 weeks) for the specific roadway in question.

Table 5.7—Normalized Axle Load Distribution Files included in the GDOT Database Library

Axle Loading Classification	Description of Normalized Axle Load Distribution
Default	Global default axle load distributions developed under NCHRP 1-37A; not specific to GDOT roadways and includes higher percentages of overloaded trucks.
GDOT_M	Non-Freight urban and rural routes with an AADTT less than 1,000 in both directions (minor arterials, collectors and state routes).
GDOT_H1	Non-Freight urban and rural routes with an AADTT greater than 1,000 in both directions (principle and non-interstate routes).
GDOT_H2	Freight routes and rural and urban interstate roadways with an AADTT greater than 2,000 in both directions.

Table 5.8—Normalized Axle Load Distribution Factors for Vehicle Class 9 Tandem Axles

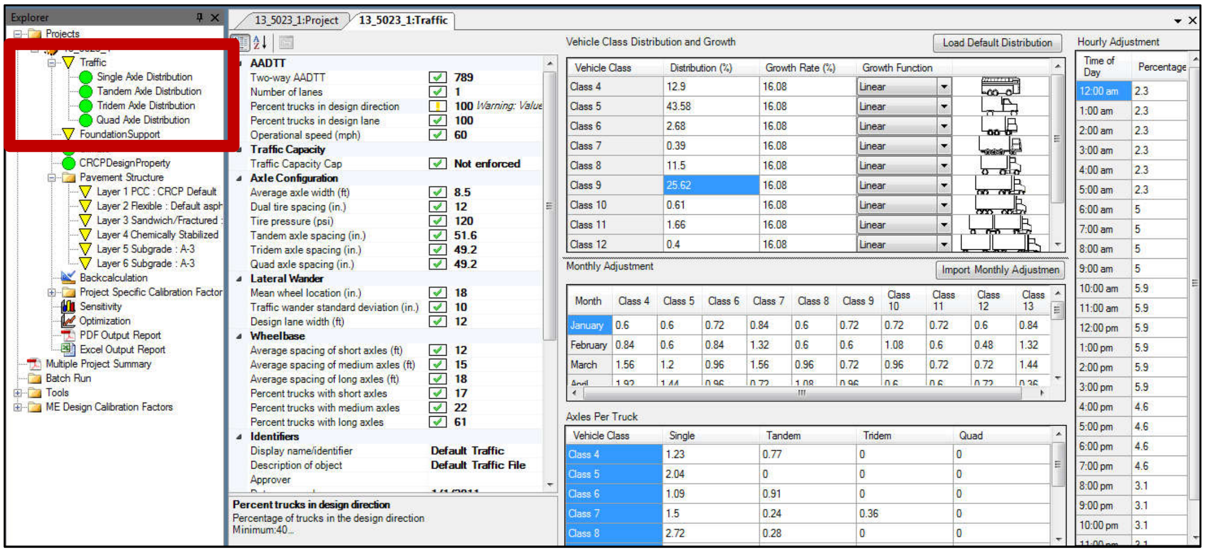
Axle Loading Classification	Tandem Axle Weight for Class 9 Trucks, lbs.						
	30,000	32,000	34,000	36,000	38,000	40,000	42,000
Global Default, NALS	6.13	6.28	5.67	4.46	3.16	2.13	1.41
GDOT_M, NALS	5.43	8.15	7.68	3.86	1.48	0.55	0.21
GDOT_H1, NALS	6.38	9.51	10.94	5.19	1.21	0.34	0.11
GDOT_H2, NALS	7.82	11.10	12.79	7.51	2.44	0.83	0.37

NALS – Normalized Axle Load Spectra (values in percentages).

5.11 SCREEN SHOTS FOR THE TRAFFIC INPUTS

This section of Chapter 5 includes screen shot examples for the different traffic inputs discussed within this chapter. The drop-down arrows are used to access or select specific information for the project.

Overall Screen Shot for Traffic



AADTT
- Two-way AADTT ☑ 789
- Number of lanes ☑ 1
- Percent trucks in design direction ! 100 *Warning: Value*
- Percent trucks in design lane ☑ 100
- Operational speed (mph) ☑ 60

Traffic Capacity
- Traffic Capacity Cap ☑ Not enforced

Axle Configuration
- Average axle width (ft) ☑ 8.5
- Dual tire spacing (in.) ☑ 12
- Tire pressure (psi) ☑ 120
- Tandem axle spacing (in.) ☑ 51.6
- Tridem axle spacing (in.) ☑ 49.2
- Quad axle spacing (in.) ☑ 49.2

Lateral Wander
- Mean wheel location (in.) ☑ 18
- Traffic wander standard deviation (in.) ☑ 10
- Design lane width (ft) ☑ 12

Wheelbase
- Average spacing of short axles (ft) ☑ 12
- Average spacing of medium axles (ft) ☑ 15
- Average spacing of long axles (ft) ☑ 18
- Percent trucks with short axles ☑ 17
- Percent trucks with medium axles ☑ 22
- Percent trucks with long axles ☑ 61

Identifiers
- Display name/identifier **Default Traffic**
- Description of object **Default Traffic File**
- Approver

Percent trucks in design direction
Percentage of trucks in the design direction
Minimum:40...

Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	12.9	16.08	Linear
Class 5	43.58	16.08	Linear
Class 6	2.68	16.08	Linear
Class 7	0.39	16.08	Linear
Class 8	11.5	16.08	Linear
Class 9	25.62	16.08	Linear
Class 10	0.61	16.08	Linear
Class 11	1.66	16.08	Linear
Class 12	0.4	16.08	Linear

Monthly Adjustment

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.6	0.6	0.72	0.84	0.6	0.72	0.72	0.72	0.6	0.84
February	0.84	0.6	0.84	1.32	0.6	0.6	1.08	0.6	0.48	1.32
March	1.56	1.2	0.96	1.56	0.96	0.72	0.96	0.72	0.72	1.44

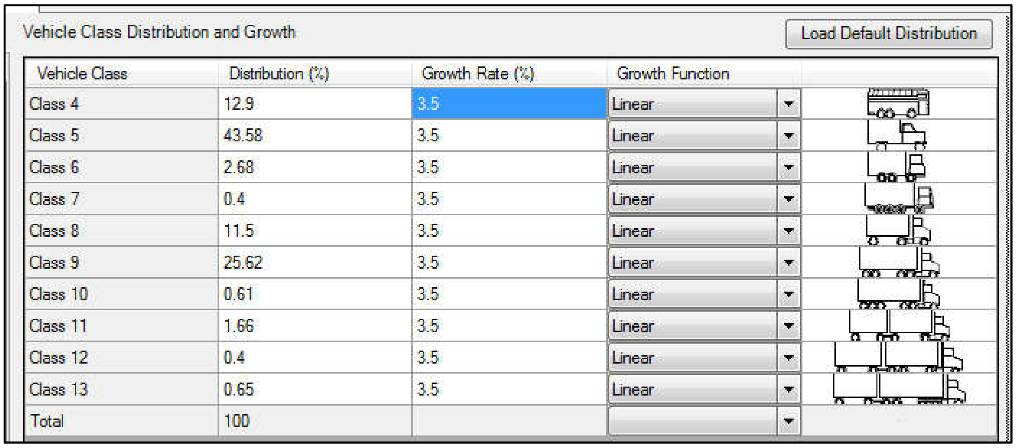
Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.23	0.77	0	0
Class 5	2.04	0	0	0
Class 6	1.09	0.91	0	0
Class 7	1.5	0.24	0.36	0
Class 8	2.72	0.28	0	0

Hourly Adjustment

Time of Day	Percentage
12:00 am	2.3
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5
7:00 am	5
8:00 am	5
9:00 am	5
10:00 am	5.9
11:00 am	5.9
12:00 pm	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1
10:00 pm	3.1

Vehicle Class Distribution and Growth



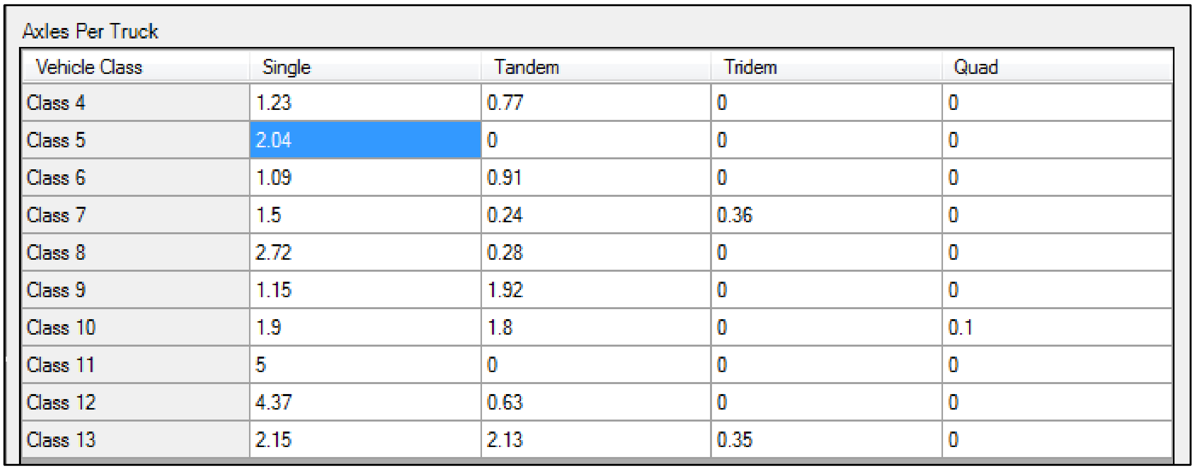
Vehicle Class Distribution and Growth

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	12.9	3.5	Linear
Class 5	43.58	3.5	Linear
Class 6	2.68	3.5	Linear
Class 7	0.4	3.5	Linear
Class 8	11.5	3.5	Linear
Class 9	25.62	3.5	Linear
Class 10	0.61	3.5	Linear
Class 11	1.66	3.5	Linear
Class 12	0.4	3.5	Linear
Class 13	0.65	3.5	Linear
Total	100		

Monthly Adjustments

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	0.6	0.6	0.72	0.84	0.6	0.72	0.72	0.72	0.6	0.84
February	0.84	0.6	0.84	1.32	0.6	0.6	1.08	0.6	0.48	1.32
March	1.56	1.2	0.96	1.56	0.96	0.72	0.96	0.72	0.72	1.44
April	1.92	1.44	0.96	0.72	1.08	0.96	0.6	0.6	0.72	0.36
May	1.68	1.08	0.84	0.6	0.96	0.96	0.6	0.84	0.6	0.24
June	0.96	0.72	0.84	1.2	0.72	0.72	0.84	0.72	0.72	0.84
July	0.84	1.2	1.56	2.28	0.96	0.72	2.04	0.84	0.84	3
August	0.6	1.08	1.2	0.96	1.32	1.32	1.2	1.32	1.56	1.2
September	0.36	0.96	1.08	0.72	1.32	1.44	1.2	1.44	1.68	0.84
October	0.6	0.84	1.08	0.84	1.2	1.32	1.08	1.44	1.56	0.96
November	1.08	1.08	0.84	0.24	1.08	1.2	0.6	1.32	1.2	0.24
December	0.96	1.2	1.08	0.72	1.2	1.32	1.08	1.44	1.32	0.72

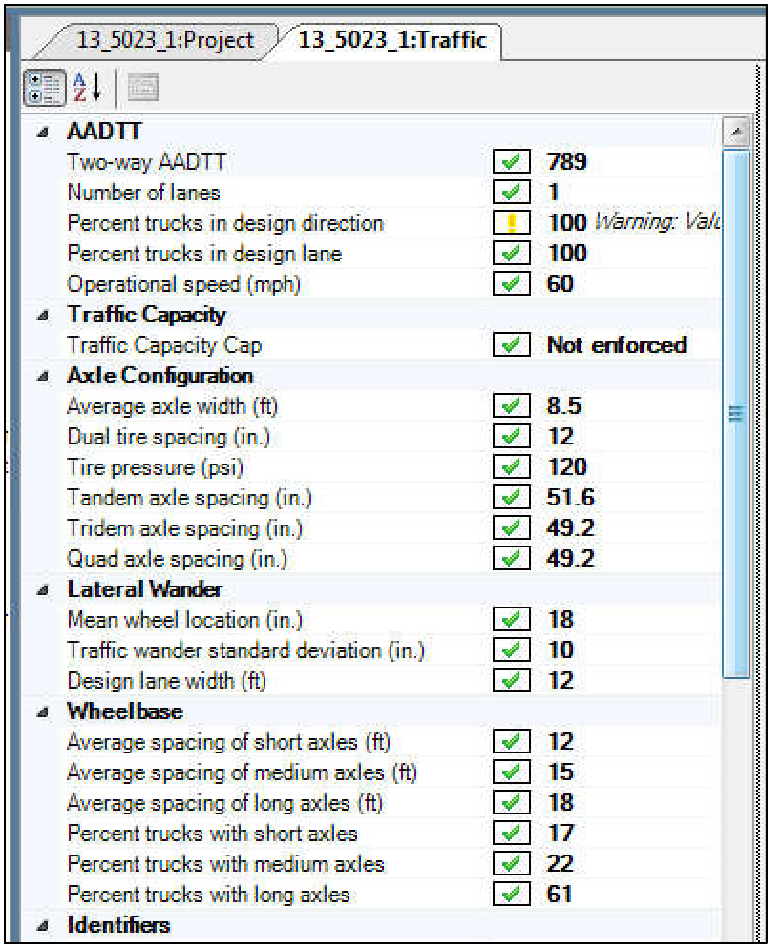
Number of Axles Per Vehicle (Truck) Class



Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.23	0.77	0	0
Class 5	2.04	0	0	0
Class 6	1.09	0.91	0	0
Class 7	1.5	0.24	0.36	0
Class 8	2.72	0.28	0	0
Class 9	1.15	1.92	0	0
Class 10	1.9	1.8	0	0.1
Class 11	5	0	0	0
Class 12	4.37	0.63	0	0
Class 13	2.15	2.13	0.35	0

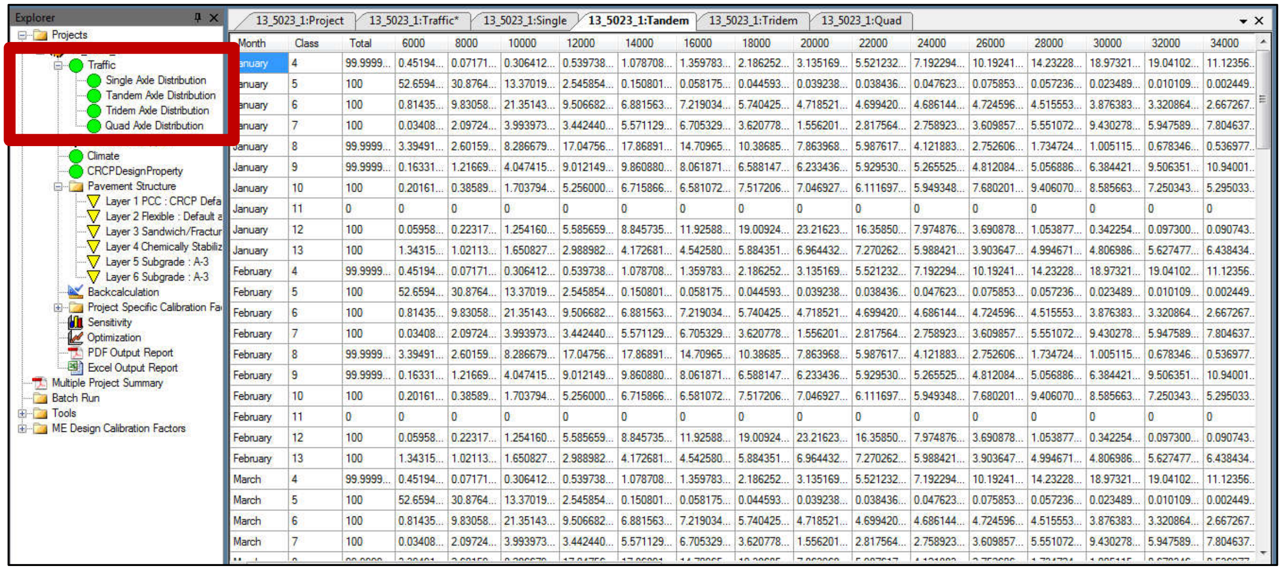
AADTT, Traffic Capacity, Axle Configuration, Lateral Wander, and Wheelbase

Note: As stated previously, average axle width, mean wheel location, design lane width, and all wheelbase inputs are only used for the rigid pavement analyses. These inputs parameters are not used in the flexible pavement analyses.



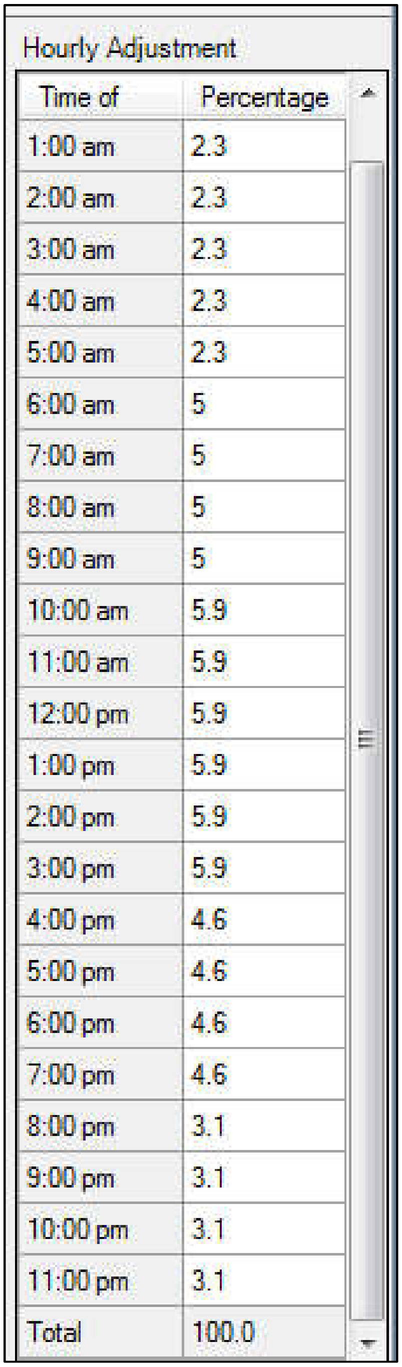
AADTT		
Two-way AADTT	✓	789
Number of lanes	✓	1
Percent trucks in design direction	!	100 *Warning: Val*
Percent trucks in design lane	✓	100
Operational speed (mph)	✓	60
Traffic Capacity		
Traffic Capacity Cap	✓	Not enforced
Axle Configuration		
Average axle width (ft)	✓	8.5
Dual tire spacing (in.)	✓	12
Tire pressure (psi)	✓	120
Tandem axle spacing (in.)	✓	51.6
Tridem axle spacing (in.)	✓	49.2
Quad axle spacing (in.)	✓	49.2
Lateral Wander		
Mean wheel location (in.)	✓	18
Traffic wander standard deviation (in.)	✓	10
Design lane width (ft)	✓	12
Wheelbase		
Average spacing of short axles (ft)	✓	12
Average spacing of medium axles (ft)	✓	15
Average spacing of long axles (ft)	✓	18
Percent trucks with short axles	✓	17
Percent trucks with medium axles	✓	22
Percent trucks with long axles	✓	61
Identifiers		

Normalized Axle Load Distribution



Month	Class	Total	6000	8000	10000	12000	14000	16000	18000	20000	22000	24000	26000	28000	30000	32000	34000
anuary	4	99.9999...	0.45194...	0.07171...	0.306412...	0.539738...	1.078708...	1.359783...	2.186252...	3.135169...	5.521232...	7.192294...	10.19241...	14.23228...	18.97321...	19.04102...	11.12356...
anuary	5	100	52.6594...	30.8764...	13.37019...	2.545854...	0.150801...	0.058175...	0.044593...	0.039238...	0.038436...	0.047623...	0.075853...	0.057236...	0.023489...	0.010109...	0.002449...
anuary	6	100	0.81435...	9.83058...	21.35143...	9.506682...	6.881563...	7.219034...	5.740425...	4.718521...	4.699420...	4.686144...	4.724596...	4.515553...	3.876383...	3.320864...	2.667267...
anuary	7	100	0.03408...	2.09724...	3.993973...	3.442440...	5.571129...	6.705329...	3.620778...	1.556201...	2.817564...	2.758923...	3.609857...	5.551072...	9.430278...	5.947589...	7.804637...
January	8	99.9999...	3.39491...	2.60159...	8.286679...	17.04756...	17.86891...	14.70965...	10.38685...	7.863968...	5.987617...	4.121883...	2.752606...	1.734724...	1.005115...	0.678346...	0.536977...
January	9	99.9999...	0.16331...	1.21669...	4.047415...	9.012149...	9.860880...	8.061871...	6.588147...	6.233436...	5.929530...	5.265525...	4.812084...	5.056886...	6.384421...	9.506351...	10.94001...
January	10	100	0.20161...	0.38589...	1.703794...	5.256000...	6.715866...	6.581072...	7.517206...	7.046927...	6.111697...	5.949348...	7.680201...	9.406070...	8.585663...	7.250343...	5.295033...
January	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	12	100	0.05958...	0.22317...	1.254160...	5.585659...	8.845735...	11.92588...	19.00924...	23.21623...	16.35850...	7.974876...	3.690878...	1.053877...	0.342254...	0.097300...	0.090743...
January	13	100	1.34315...	1.02113...	1.650827...	2.988982...	4.172681...	4.542580...	5.884351...	6.964432...	7.270262...	5.988421...	3.903647...	4.994671...	4.806986...	5.627477...	6.438434...
February	4	99.9999...	0.45194...	0.07171...	0.306412...	0.539738...	1.078708...	1.359783...	2.186252...	3.135169...	5.521232...	7.192294...	10.19241...	14.23228...	18.97321...	19.04102...	11.12356...
February	5	100	52.6594...	30.8764...	13.37019...	2.545854...	0.150801...	0.058175...	0.044593...	0.039238...	0.038436...	0.047623...	0.075853...	0.057236...	0.023489...	0.010109...	0.002449...
February	6	100	0.81435...	9.83058...	21.35143...	9.506682...	6.881563...	7.219034...	5.740425...	4.718521...	4.699420...	4.686144...	4.724596...	4.515553...	3.876383...	3.320864...	2.667267...
February	7	100	0.03408...	2.09724...	3.993973...	3.442440...	5.571129...	6.705329...	3.620778...	1.556201...	2.817564...	2.758923...	3.609857...	5.551072...	9.430278...	5.947589...	7.804637...
February	8	99.9999...	3.39491...	2.60159...	8.286679...	17.04756...	17.86891...	14.70965...	10.38685...	7.863968...	5.987617...	4.121883...	2.752606...	1.734724...	1.005115...	0.678346...	0.536977...
February	9	99.9999...	0.16331...	1.21669...	4.047415...	9.012149...	9.860880...	8.061871...	6.588147...	6.233436...	5.929530...	5.265525...	4.812084...	5.056886...	6.384421...	9.506351...	10.94001...
February	10	100	0.20161...	0.38589...	1.703794...	5.256000...	6.715866...	6.581072...	7.517206...	7.046927...	6.111697...	5.949348...	7.680201...	9.406070...	8.585663...	7.250343...	5.295033...
February	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	12	100	0.05958...	0.22317...	1.254160...	5.585659...	8.845735...	11.92588...	19.00924...	23.21623...	16.35850...	7.974876...	3.690878...	1.053877...	0.342254...	0.097300...	0.090743...
February	13	100	1.34315...	1.02113...	1.650827...	2.988982...	4.172681...	4.542580...	5.884351...	6.964432...	7.270262...	5.988421...	3.903647...	4.994671...	4.806986...	5.627477...	6.438434...
March	4	99.9999...	0.45194...	0.07171...	0.306412...	0.539738...	1.078708...	1.359783...	2.186252...	3.135169...	5.521232...	7.192294...	10.19241...	14.23228...	18.97321...	19.04102...	11.12356...
March	5	100	52.6594...	30.8764...	13.37019...	2.545854...	0.150801...	0.058175...	0.044593...	0.039238...	0.038436...	0.047623...	0.075853...	0.057236...	0.023489...	0.010109...	0.002449...
March	6	100	0.81435...	9.83058...	21.35143...	9.506682...	6.881563...	7.219034...	5.740425...	4.718521...	4.699420...	4.686144...	4.724596...	4.515553...	3.876383...	3.320864...	2.667267...
March	7	100	0.03408...	2.09724...	3.993973...	3.442440...	5.571129...	6.705329...	3.620778...	1.556201...	2.817564...	2.758923...	3.609857...	5.551072...	9.430278...	5.947589...	7.804637...

Hourly Adjustment
Note: as previously stated, hourly adjustments are only used in the rigid pavement analyses and are not used in the flexible pavement analyses.



Time of	Percentage
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5
7:00 am	5
8:00 am	5
9:00 am	5
10:00 am	5.9
11:00 am	5.9
12:00 pm	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1
10:00 pm	3.1
11:00 pm	3.1
Total	100.0

CHAPTER 6—CLIMATE INPUTS

Detailed climatic data are required for predicting pavement distresses in PMED and include hourly temperature, precipitation, wind speed, relative humidity, and cloud cover. These data are used to predict the temperature and moisture distribution in each of the pavement layers and provide inputs to the JPCP joint opening/closing and faulting as well as the site factors for the IRI regression equations for all pavement types. The climate files that are included with the PMED software were updated in 2016. The new hourly climate data is an assimilated dataset which is based on various ground-based observations. The North American Regional Reanalysis (NARR) climate data is the default for rigid pavements while the Modern Era Retrospective-analysis for Research and Applications-2 (MERRA-2) is the default for flexible pavement designs.

6.1 PROJECT LOCATION INFORMATION

The average **latitude, longitude, elevation** of the project location should be determined and entered in the software. The latitude and longitude are included on the cover sheet for the plans of a specific roadway project. The mid-point of the project can be selected for the location information. In PMED versions 2.5 or later, the location and elevation may be input by selecting the mid-point of the project using the map function in the climate input window.

The PMED software climate module uses a map based selection and will identify nine weather locations that are closest to the project location based on similar elevation. The designer can select a single weather grid node or multiple locations that are applicable to the project location to create a virtual weather station for the project location. The virtual weather station hourly data is calculated using the inverse squared distance interpolation method. (refer to subsections 6.3 and 6.4 of this chapter).

6.2 DEPTH TO WATER TABLE

The depth to the water table is a parameter that gets entered on the climate screen. The depth to the water table or “free” water is the average distance between the pavement surface and the depth at which free water is encountered. This depth should be representative of cuts and fills along the project location.

The depth to a water table is measured from borings taken along the project location. The depth to the water table has an effect on the moisture content of the unbound layers above the water table. The water table depth entered in the PMED software is the shallower depth to: free water, perched water, or the lateral flow of water. The following provides some guidance in determining the depth to the water table or free water.

1. The depth of borings usually does not exceed 10-feet for pavement design purposes, while the depth to the water table exceeds 10 feet in many locations. In addition, the borings are usually not monitored or left open over a sufficient amount of time to measure the depth to water. If seasonal or perched water table depths are known to exist along the project site, these seasonal values should be entered into the software.
2. The depth to the water table should be based on local experience and/or from a geotechnical engineer knowledgeable of the local conditions along the specific project. For example, the water depth from historical borings for bridges and other similar structures can be used to estimate that depth.
3. Georgia water table data for various locations and counties can be found at the U.S. Geological Survey web site: http://ga.water.usgs.gov/.
4. If borings are unavailable and no information can be obtained from other sources adjacent to the project, Table 6.1 can be used as a guide in selecting the annual values to be used.

Table 6.1—Annual Depth to Water Table Recommended for Use

Location	Annual Depth to Water Table, ft.
Coastal Areas or Counties	6
Southern Counties: South of the Fall Line	10
Northern Counties: North of the Fall Line	15
Mountainous Areas or Higher Elevation Counties	20

6.3 CLIMATE STATIONS

The PMED software has a number of national weather stations embedded in the software for ease of use (Figure 6.1). Table 6.2 lists the Georgia weather stations that are currently available in the Pavement ME Design software national database and those stations in adjacent states which are close to the state line. Any one of these weather stations can be selected for a project within the nearby area. The climate data for that station, however, will be used for the distress prediction computations rather than the specific project location. In selecting a climate station, pay attention to the elevation of the station. A climate station should be selected with a similar elevation as it can have a significant effect on air temperature.

The AASHTOWare PMED procedure recommends two or more of these climate stations be selected as close to the project as possible to provide hourly temperature, precipitation, wind speed, relative humidity, and cloud cover information. This allows the user to create a virtual climate station (refer to Section 6.4) at the project location. Since moving to assimilated datasets, the amount of missing hourly climate data has reduced significantly and even eliminated completely.

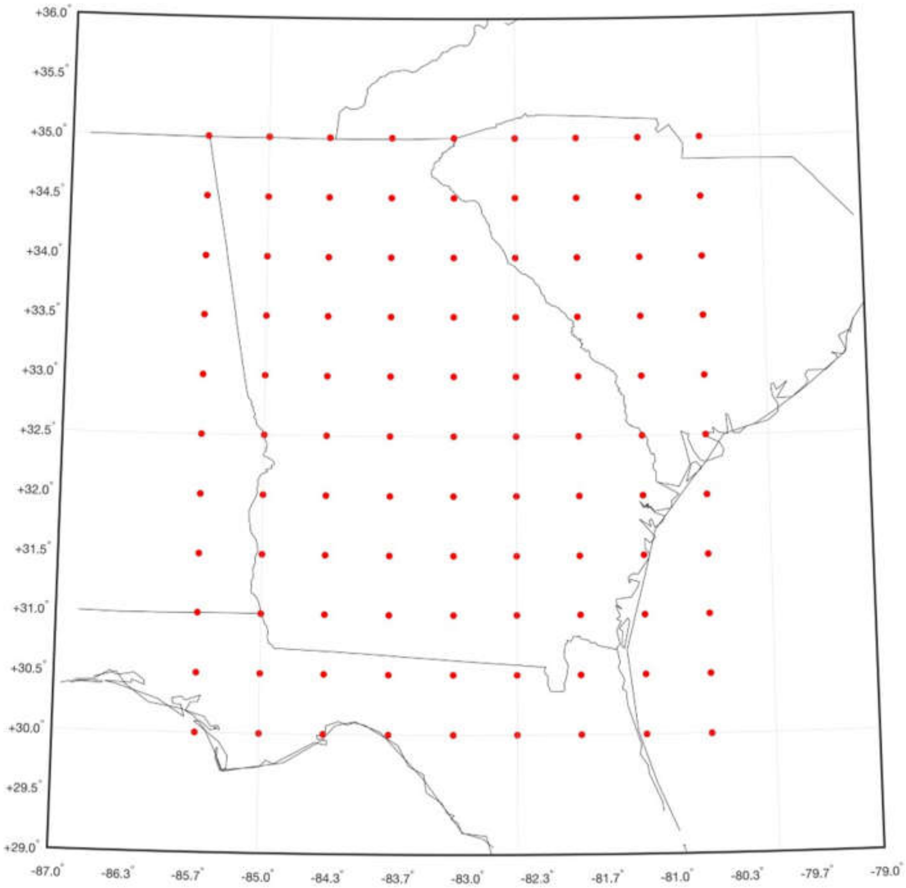


Figure 6.1—MERRA-2 Grid Cell Locations

6.4 CREATION OF SIMULATED CLIMATE STATION

After selecting the appropriate climate stations in the vicinity of the project and providing the depth to the water table, the user can select one station or simulate a weather station that is most representative of the project location. These simulated climate stations are typically referred to as virtual climate stations.

The simulated or virtual climate station is saved by the software so that it can be used for all future trial designs or sensitivity studies relevant to a specific location. This can be done by simply selecting the import option and picking the simulated climate station file created for the specific project.

Table 6.2—Climate Stations Available from AASHTOWare for Georgia (North American Regional Reanalysis, NARR)

City		Climate Station Number	Longitude (Degrees. Minutes)	Latitude (Degrees. Minutes)	Elevation, ft.
Albany, GA		13869	-84.194	31.536	190
Alma, GA		13870	-82.507	31.536	193
Athens, GA		13873	-83.327	33.948	800
Atlanta, GA	Fulton Co. Brown Field	03888	-84.521	33.779	801
	Peachtree City Falcon Field	53819	-84.567	33.355	798
	Dekalb Peachtree Airport	53863	-84.302	33.875	977
	Hartsfield International	13874	-84.427	33.640	998
Augusta, GA	Regional Bush Field	03820	-81.965	33.370	132
	Daniel Field	13837	-82.039	33.467	412
Brunswick, GA		13878	-81.391	31.252	19
Cartersville, GA		53873	-84.849	34.123	754
Columbus, GA		93842	-84.942	32.516	392
Gainesville, GA		53838	-83.830	34.272	1266
Macon, GA		03813	-83.654	32.688	342
Rome, GA		93801	-85.161	34.348	692
Savannah, GA		03822	-81.202	32.119	25
Valdosta. GA		93845	-83.277	30.783	198
Troy, AL		03878	-86.012	31.861	385
Jacksonville, FL;	International Airport	13889	-81.693	30.494	26
	Craig Municipal Airport	53860	-81.515	30.336	46
Charleston, SC		13880	-80.041	32.899	39
Columbia, SC	Downtown	53867	-80.996	33.971	180
	Metropolitan Airport	13883	-81.118	33.942	225
Greenville, SC		13886	-82.346	34.846	1006
Greenwood, SC		53874	-82.159	34.249	631
Orangeburg, SC		53854	-80.858	33.462	196
Chattanooga, TN		13882	-85.200	35.033	671

6.5 USE OF CUSTOM CLIMATE FILES

PMED allows for the establishment and use of custom climate files (*.hcd format) in the design process. Custom climate .hcd files developed through GDOT research projects 16-10 (Durham et al, 2019) and 19-16 using MERRA-2 climate data have been created for use as climate inputs in GDOT designs. The custom .hcd files include corrected percent sunshine values based on the surface shortwave radiation values reported in the MERRA-2 climate files.

Custom climate stations should be used for all GDOT pavement designs. Default stations using the hcd files provided through the Pavement ME Design software national database are recommended only when custom stations are not available. To access the custom climate station database, users must select the “Use custom hcd folder and station file” function in the Options dropdown of the Climate window. Table 6.3 lists the Georgia weather stations that have been developed using the custom Georgia climate database.

It should be noted that the custom option might not even be needed other than for rigid pavements because the default is NARR. The only difference between the non-custom and custom selection is to tell the software where to look for the hcd files.

If the custom climate station numbers match the original MERRA-2 station numbers then they can be used directly in the hcd folder instead of the “custom hcd folder”.

Table 6.3—Climate Stations Available from Custom Database for Georgia

City	Climate Station Number	Latitude (Degrees. Minutes)	Longitude (Degrees. Minutes)	Elevation, ft.
Panama City, FL	132632	30.000	-85.625	65.60
Eastpoint, FL	132633	30.000	-85.000	26.24
Panacea, FL	132634	30.000	-84.375	0.00
Perry. FL	132635	30.000	-83.750	3.28
Mayo, FL	132636	30.000	-83.125	82.00
Lake Butler, FL	132637	30.000	-82.500	137.76
Middleburg, FL	132638	30.000	-81.875	98.40
Chipley, FL	133208	30.500	-85.625	52.48
Blountstown, FL	133209	30.500	-85.000	45.92
Tallahassee, FL	133210	30.500	-84.375	101.68
Monticello, FL	133211	30.500	-83.750	78.72

City	Climate Station Number	Latitude (Degrees. Minutes)	Longitude (Degrees. Minutes)	Elevation, ft.
Jennings, FL	133212	30.500	-83.125	114.80
Lake City, FL	133213	30.500	-82.500	137.76
Callahan, FL	133214	30.500	-81.875	85.28
Slocomb, AL	133784	31.000	-85.625	206.64
Donalsonville, GA	133785	31.000	-85.000	88.56
Whigham, GA	133786	31.000	-84.375	154.16
Pavo, GA	133787	31.000	-83.750	249.28
Lakeland, GA	133788	31.000	-83.125	206.64
Manor, GA	133789	31.000	-82.500	141.04
White Oak, GA	133790	31.000	-81.875	101.68
Ozark, AL	134360	31.500	-85.625	423.12
Fort Gaines, GA	134361	31.500	-85.000	278.80
Albany, GA	134362	31.500	-84.375	262.40
Sumner, GA	134363	31.500	-83.750	419.84
Ocilla, GA	134364	31.500	-83.125	311.60
Alma, GA	134365	31.500	-82.500	180.40
Jesup, GA	134366	31.500	-81.875	59.04
Crescent, GA	134367	31.500	-81.250	16.40
Union Springs, AL	134936	32.000	-85.625	492.00
Lumpkin, GA	134937	32.000	-85.000	505.12
Plains, GA	134938	32.000	-84.375	501.84
Cordele, GA	134939	32.000	-83.750	308.32
Milan, GA	134940	32.000	-83.125	324.72
Uvalda, GA	134941	32.000	-82.500	196.80
Glennville, GA	134942	32.000	-81.875	173.84
Savannah, GA	134943	32.000	-81.250	13.12
Notasulga, AL	135512	32.500	-85.625	337.84
Phenix City, AL	135513	32.500	-85.000	377.20
Mauk, GA	135514	32.500	-84.375	695.36
Perry, GA	135515	32.500	-83.750	416.56
Dudley, GA	135516	32.500	-83.125	341.12
Adrian, GA	135517	32.500	-82.500	203.36
Statesboro, GA	135518	32.500	-81.875	255.84
Clyo, GA	135519	32.500	-81.250	88.56
Beaufort, SC	135520	32.500	-80.625	0.00
Daviston, AL	136088	33.000	-85.625	669.12

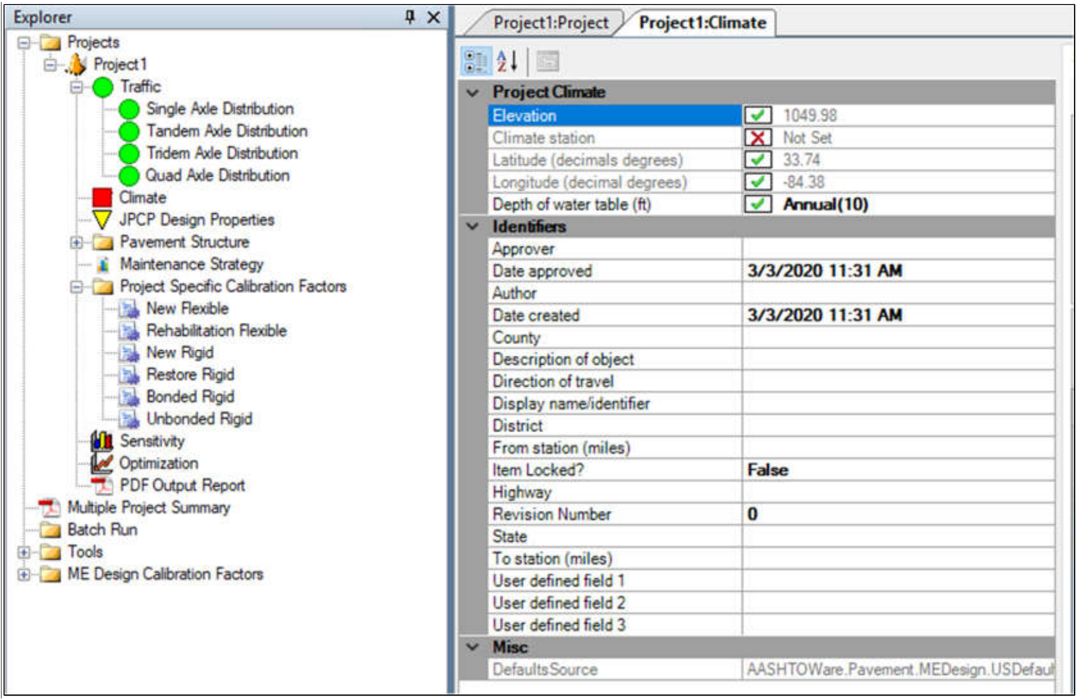
City	Climate Station Number	Latitude (Degrees. Minutes)	Longitude (Degrees. Minutes)	Elevation, ft.
Lagrange, GA	136089	33.000	-85.000	675.68
Meansville, GA	136090	33.000	-84.375	1151.28
Juliette, GA	136091	33.000	-83.750	482.16
Milledgeville, GA	136092	33.000	-83.125	232.88
Bartow, GA	136093	33.000	-82.500	252.56
Sardis, GA	136094	33.000	-81.875	295.20
Allendale, SC	136095	33.000	-81.250	154.16
Walterboro, SC	136096	33.000	-80.625	88.56
Heflin, AL	136664	33.500	-85.625	885.60
Carrollton, GA	136665	33.500	-85.000	974.16
Jonesboro, GA	136666	33.500	-84.375	869.20
Mansfield, GA	136667	33.500	-83.750	701.92
Greensboro, GA	136668	33.500	-83.125	610.08
Thomson, GA	136669	33.500	-82.500	495.28
Burnettown, SC	136670	33.500	-81.875	183.68
Springfield, SC	136671	33.500	-81.250	236.16
Elloree, SC	136672	33.500	-80.625	164.00
Piedmont, AL	137240	34.000	-85.625	754.40
Rockmart, GA	137241	34.000	-85.000	970.88
Sandy Springs, GA	137242	34.000	-84.375	852.80
Winder, GA	137243	34.000	-83.750	1006.96
Comer, GA	137244	34.000	-83.125	669.12
Mount Carmel, SC	137245	34.000	-82.500	498.56
Saluda, SC	137246	34.000	-81.875	554.32
Lexington, SC	137247	34.000	-81.250	390.32
Rembert, SC	137248	34.000	-80.625	137.76
Fort Payne, AL	137816	34.500	-85.625	1590.80
Calhoun, GA	137817	34.500	-85.000	659.28
Jasper, GA	137818	34.500	-84.375	1931.92
Clermont, GA	137819	34.500	-83.750	1413.68
Gumlog, GA	137820	34.500	-83.125	688.80
Belton, SC	137821	34.500	-82.500	800.32
Clinton, SC	137822	34.500	-81.875	587.12
Blackstock, SC	137823	34.500	-81.250	498.56
Kershaw, SC	137824	34.500	-80.625	518.24
New Hope, TN	138392	35.000	-85.625	783.92

City	Climate Station Number	Latitude (Degrees. Minutes)	Longitude (Degrees. Minutes)	Elevation, ft.
Apison, TN	138393	35.000	-85.000	954.48
Copperhill, TN	138394	35.000	-84.375	1610.48
Hayesville, NC	138395	35.000	-83.750	2063.12
Clayton, GA	138396	35.000	-83.125	2915.92
Travelers Rest, SC	138397	35.000	-82.500	1105.36
Spartanburg, SC	138398	35.000	-81.875	751.12
York, SC	138399	35.000	-81.250	718.32
Monroe, NC	138400	35.000	-80.625	652.72

6.6 SCREEN SHOTS FOR THE CLIMATE INPUTS

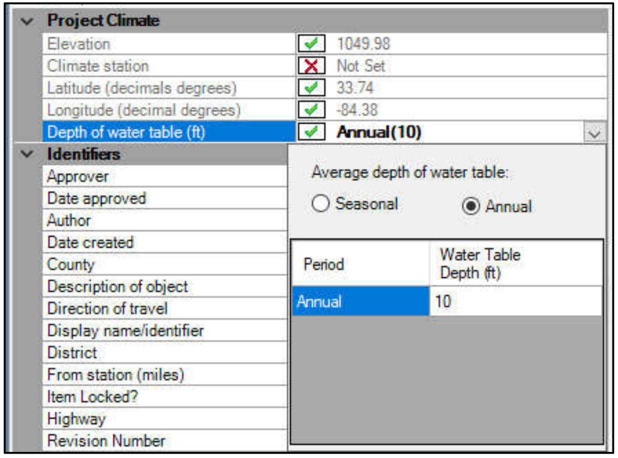
The following are screen shot examples that show the climate inputs discussed within this chapter. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for Climate



Project Climate	
Elevation	✓ 1049.98
Climate station	☒ Not Set
Latitude (decimals degrees)	✓ 33.74
Longitude (decimal degrees)	✓ -84.38
Depth of water table (ft)	✓ Annual(10)
Identifiers	
Approver	
Date approved	3/3/2020 11:31 AM
Author	
Date created	3/3/2020 11:31 AM
County	
Description of object	
Direction of travel	
Display name/identifier	
District	
From station (miles)	
Item Locked?	False
Highway	
Revision Number	0
State	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Misc	
DefaultsSource	AASHTOWare.Pavement.MEDesign.USDefaul

Depth to Water Table



Project Climate

Elevation	✓	1049.98
Climate station	☒	Not Set
Latitude (decimals degrees)	✓	33.74
Longitude (decimal degrees)	✓	-84.38
Depth of water table (ft)	✓	Annual(10)

Identifiers

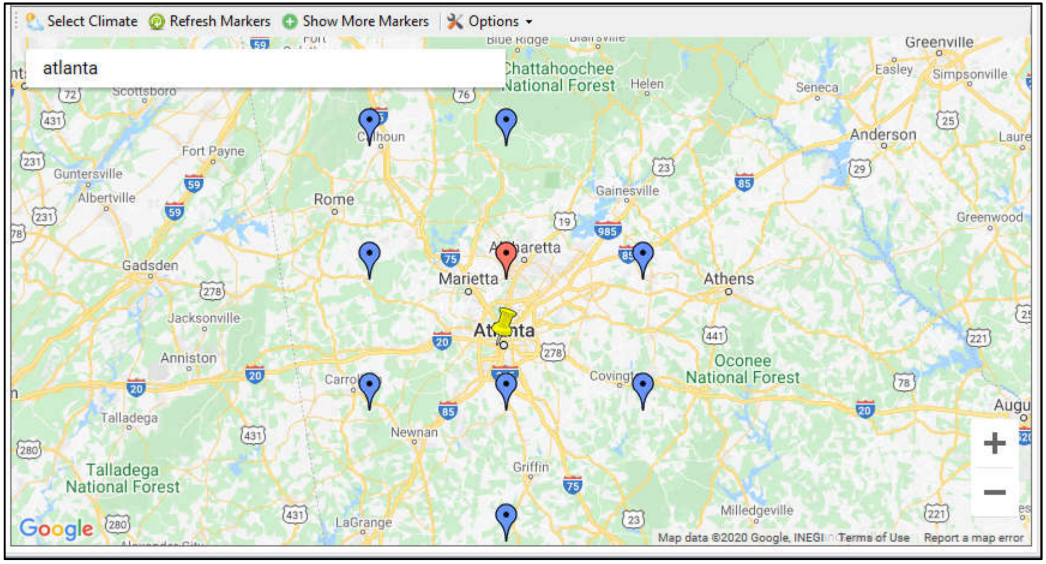
- Approver
- Date approved
- Author
- Date created
- County
- Description of object
- Direction of travel
- Display name/identifier
- District
- From station (miles)
- Item Locked?
- Highway
- Revision Number

Average depth of water table:

○ Seasonal ● Annual

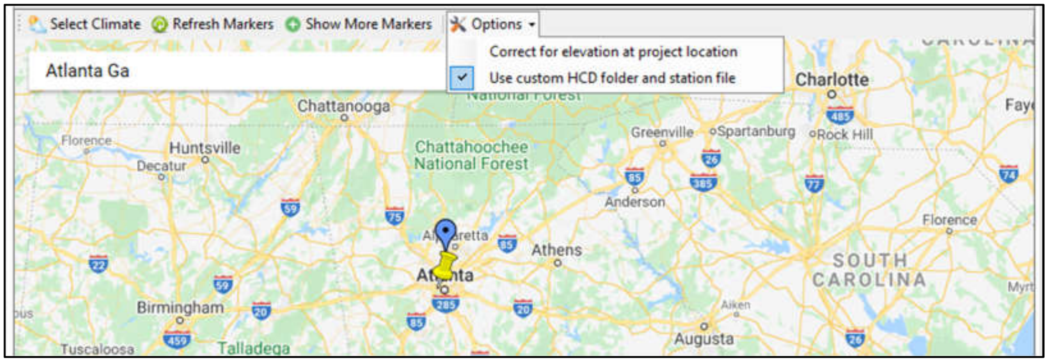
Period	Water Table Depth (ft)
Annual	10

Climate Station Map



atlanta

Custom Climate Station Selection



Atlanta Ga

Correct for elevation at project location

☑ Use custom HCD folder and station file

CHAPTER 7—DESIGN FEATURES AND LAYER PROPERTY INPUTS

Different features and properties are required by the PMED software for different pavement types or materials. The layer structure should be set up prior to entering any of the layer features and properties. This chapter discusses the features and properties required for specific pavement types. Example screen shots showing the design features and layer property inputs are included at the end of each section within this chapter.

7.1 AC (HMA) LAYER PROPERTIES: NEW AND EXISTING LAYERS

7.1.1 Multi-Layer Rutting Calibration Parameters

The PMED version 2.1 and later permits the user to input layer specific plastic deformation parameters of the rut depth transfer function. This feature was unavailable when the local calibration work was completed for GDOT. As such, the same plastic deformation parameters should be used for all HMA layers (refer to Chapter 9 for the local calibration permanent deformation factors). The multi-layer rutting option in the PMED software should be false which is also the PMED default value.

7.1.2 HMA/AC Surface Shortwave Absorptivity

Use the default value for the HMA surface shortwave absorptivity for all new pavement and rehabilitation designs; a value of 0.85. This value should not be changed without revising the local calibration parameters.

7.1.3 Endurance Limit

The PMED software permits the user to enter an endurance limit for HMA layers or mixtures. The endurance limit represents the tensile strain at which no fatigue cracking damage accumulates within that layer.

The global calibration of the fatigue cracking transfer function did not include the endurance limit as a mixture property or design feature. Similarly, the GDOT local calibration of the bottom-up fatigue cracking transfer function did not include the endurance limit as a mixture property or design feature. Thus, it is recommended that the endurance limit not be used in design.

7.1.4 Layer Interface Friction

All global and regional calibration studies have been completed assuming full friction between each layer, because there is no standardized test for measuring this value. An interface friction value of 1.0 represents full friction. Thus, a value of 1.0 should be used for design.

An interface friction value of 0 represents no friction between two adjacent layers (e.g., not including a tack coat between an existing HMA surface and HMA overlay). No friction should only be used for forensic investigations to answer “what if” questions. Interface friction values less than 1.0 will increase HMA rutting and fatigue cracking. All pavement designs should be completed with full interlayer friction.

7.1.5 Rehabilitation: Condition of Existing Flexible Pavement

The condition of the existing flexible pavement surface is estimated from the distress measurements (condition surveys [input levels 2 or 3]) or determined from backcalculated elastic modulus (input level 1). Rehabilitation input level 1 should be used when deflection basin data are available. For input levels 2 or 3, the distresses on the existing pavement can be obtained from current condition surveys or extracted from PACES or the computerized PACES (COPACES). The following summarizes the use of different input levels for rehabilitation designs. It is worth noting that the rehabilitation input option is not included for new flexible pavement designs.

1. Rehabilitation input level 1

   Deflection basins provide valuable information and are believed to result in more reliable rehabilitation designs. Measured deflection basins are used to estimate the in place elastic modulus values for each structural layer and subgrade of the existing pavement. Backcalculation of the elastic layer modulus values are determined or calculated external to the PMED software. The average backcalculated values for a specific design section should be entered for each pavement layer and subgrade soil. These elastic modulus values for each pavement layer and subgrade are discussed in the next chapter of the User Input Guide.

   The other input required for rehabilitation input level 1 is the average rut depth within each pavement layer and subgrade. Table 7.1 lists the percentages to be used in distributing the total rut depth measured at the surface to each pavement layer and subgrade.

Table 7.1—Ratios to Distribute Total Rut Depth to Individual Layers

Flexible Pavement Layer	Ratio of Total Rut Depth Distributed to Each Layer
HMA/AC	0.75
Granular Aggregate Base	0.10
Subgrade	0.15

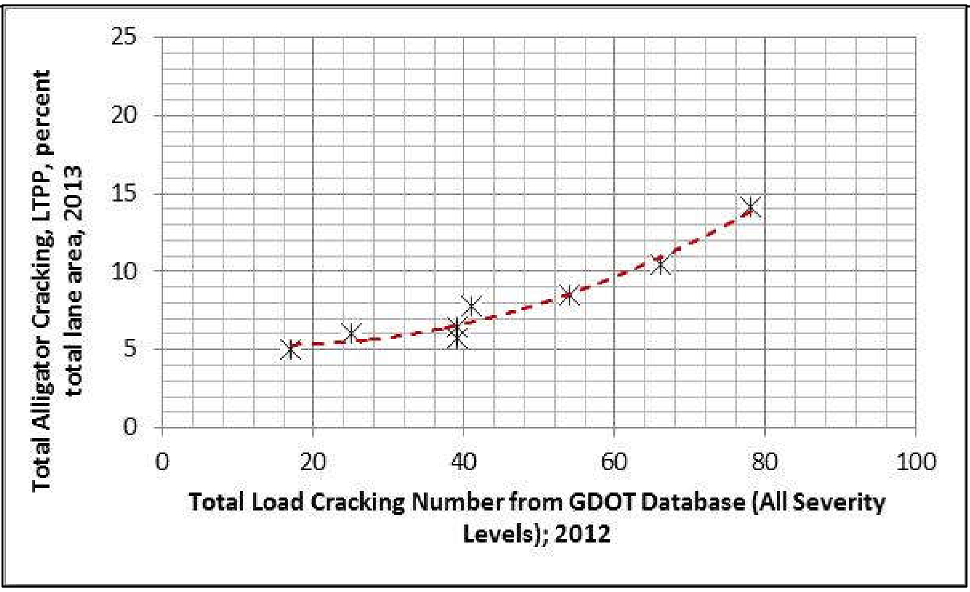
These percentages were determined through the global calibration process under NCHRP projects 1-37A and 1-40D, and based on a limited number of studies at the global and local levels (Colorado, Montana, etc.). The values were verified based on the local calibration study for GDOT using the LTPP and non-LTPP roadway segments by determining the values that result in the lowest standard error of the rut depth transfer function.

2. Rehabilitation input level 2

   If deflection data are unavailable to estimate the in-place condition of the HMA layers, the use of input level 2 is reasonable without significantly increasing the cost of the pavement evaluation costs. For input level 2, two inputs are required to determine the condition of the existing pavement layers. These inputs are listed and defined below:

   1) The average total amount of fatigue cracking (load cracking per GDOT's PACES/COPACES) within the wheel path area in terms of percent of total lane area should be entered for each design section. The designer can also use the distress data and information included in GDOT's pavement management database. In this case, Figure 7.1 should be used to transform the historical information or data into the cracking values predicted by the MEPDG software. The designer simply enters the GDOT total amount of load cracking in Figure 7.1 to estimate the amount or area of bottom-up alligator fatigue cracking.

   2) The average rut depth within each pavement layer and subgrade, which is the same as for rehabilitation input level 1, as defined above.



EXAMPLE: Enter the total load cracking number on the x-axis and project up to the intersection of the dashed line. At the intersection with the dashed line, project horizontally to the y-axis to determine the estimated total alligator cracking that would be measured in accordance with LTPP.

NOTE: If the GDOT load cracking number is composed entirely of severity level 1, the total alligator cracking should be limited to a maximum value of 16 percent. If the GDOT load cracking number is composed of entirely severity levels 1 and 2, the total alligator cracking should be limited to a maximum value of 20 percent. For all other combinations of the GDOT load cracking number, the total alligator cracking should be limited to a maximum value of 30 percent.

Figure 7.1—Relationship between GDOT's Load Cracking Number (All Severity Levels) included in PACES and the Total Area of Alligator Fatigue Cracking

3. Rehabilitation input level 3

   Five subjective pavement ratings are used to describe the condition of the pavement surface, which are defined in the MOP and considered appropriate for GDOT. Table 7.2 relates the subjective condition survey ratings included in the PMED software to GDOT PACES rating reported for each roadway segment for planning purposes.

   The other input required for input level 3 is the average total rut depth measured at the surface of the HMA. The PMED software distributes that total rut depth measured at the surface to the different layers using the layer percentages determined under the NCHRP Project 1-37A project.

Table 7.2—MEPDG Condition Ratings for the GDOT PACES Rating or Composite Pavement Condition Index

GDOT PACES and COPACES Rating Index	MEPDG Subjective Condition Ratings; Input Level 3
> 90	Excellent
80 to 90	Good
70 to 80	Fair
60 to 70	Poor
<60	Very Poor

7.1.6 Milled Thickness of Existing HMA Layers

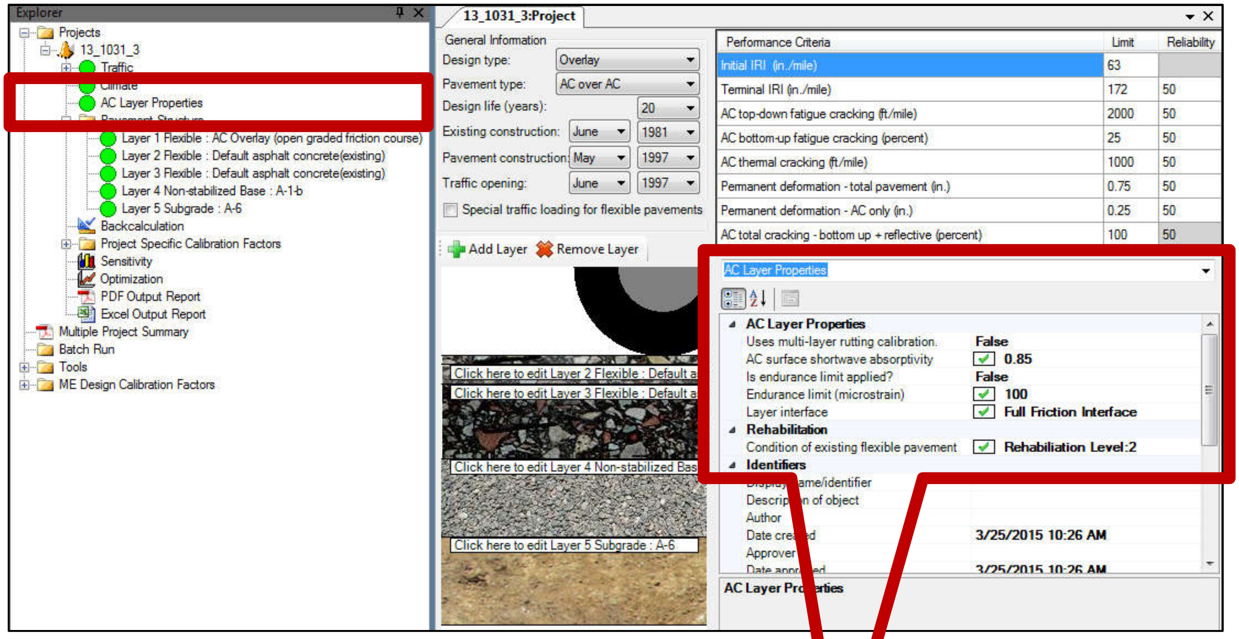
Milling a portion of the existing HMA is a common rehabilitation activity prior to placing the HMA overlay. The planned milled thickness is entered in the AC Layer Properties screen under Rehabilitation.

The thickness of the combined existing HMA layers should be the thickness “after” milling. The milled-thickness is used for damage computations based on the dynamic modulus and is not subtracted from the existing HMA layer thickness. Additional discussion is provided under Section 8.1 on entering the thickness of the existing HMA layers when one or more overlays have already been placed on the original flexible pavement and/or when more than three HMA layers are placed.

7.1.7 Screen Shots for the AC (HMA) Layer Properties: New and Existing Layers

The following are screen shot examples that show the AC Layer Property inputs discussed within this section of Chapter 7. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the AC Layer Properties



General Information

Design type: Overlay

Pavement type: AC over AC

Design life (years): 20

Existing construction: June 1981

Pavement construction: May 1997

Traffic opening: June 1997

☐ Special traffic loading for flexible pavements

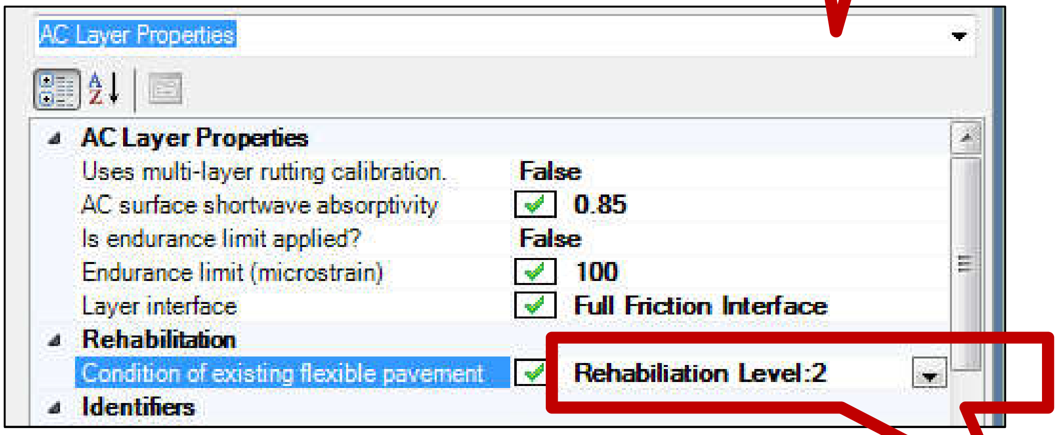
Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50
AC total cracking - bottom up + reflective (percent)	100	50

AC Layer Properties

AC Layer Properties	
Uses multi-layer rutting calibration.	**False**
AC surface shortwave absorptivity	☑ **0.85**
Is endurance limit applied?	**False**
Endurance limit (microstrain)	☑ **100**
Layer interface	☑ **Full Friction Interface**
Rehabilitation	
Condition of existing flexible pavement	☑ **Rehabiliation Level:2**
Identifiers	
Display name/identifier	
Description of object	
Author	
Date created	**3/25/2015 10:26 AM**
Approver	
Date approved	**3/25/2015 10:26 AM**

AC Layer Properties

AC Layer Properties Screen

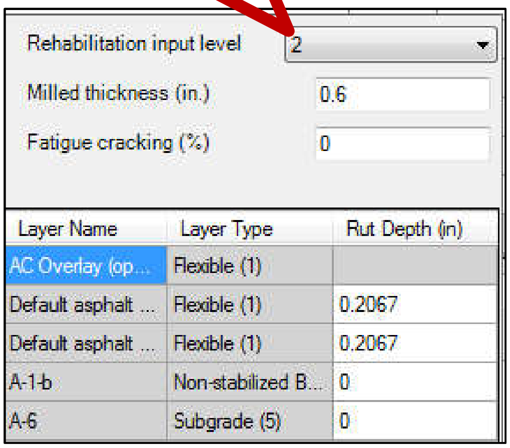


AC Layer Properties

AC Layer Properties	
Uses multi-layer rutting calibration.	**False**
AC surface shortwave absorptivity	☑ **0.85**
Is endurance limit applied?	**False**
Endurance limit (microstrain)	☑ **100**
Layer interface	☑ **Full Friction Interface**
Rehabilitation	
Condition of existing flexible pavement	☑ **Rehabiliation Level:2**
Identifiers	

Rehabilitation Screen

Note: this drop down screen is only applicable for rehabilitation or overlay projects of flexible pavements.



Rehabilitation input level: 2

Milled thickness (in.): 0.6

Fatigue cracking (%): 0

Layer Name	Layer Type	Rut Depth (in)
AC Overlay (op...	Flexible (1)	
Default asphalt ...	Flexible (1)	0.2067
Default asphalt ...	Flexible (1)	0.2067
A-1-b	Non-stabilized B...	0
A-6	Subgrade (5)	0

7.2 JPCP: NEW AND EXISTING LAYERS

7.2.1 PCC Surface Shortwave Absorptivity

Use the default value for the PCC surface shortwave absorptivity for all new pavement and rehabilitation designs; a value of 0.85.

7.2.2 Joint Spacing

PMED allows two options for the joint spacing of JPCP: a constant or random joint spacing. GDOT only permits the use of a constant joint spacing. However, a random joint spacing has been used or allowed by GDOT in the past. The joint spacing used on most projects in Georgia is 15 to 20 feet. The recommended joint spacing for most jointed plain concrete pavements (JPCP) is 15 feet. This spacing provides a good balance between minimization of transverse cracking and joint costs.

7.2.3 Sealant Type

PMED allows two options for the type of sealant used in the transverse joints: preformed and other sealants. The other sealants listed in the PMED software include liquid (hot and cold poured) sealants, silicone, and/or no sealant. Georgia currently seals the joint with silicone, so the 'other sealant' option should be used.

7.2.4 Dowels

GDOT typically uses dowels in all transverse joints of JPCP because appropriately sized dowels control joint faulting. The trial diameter and spacing of the dowels are inputs to PMED. GDOT typically uses 1.5 inch dowels for pavements 10 inches or thicker, but the Georgia Standard

5046H should be referenced to determine appropriate diameter for the design. The spacing of the dowels is typically 12 inches.

The program outputs joint faulting predictions which must meet the faulting criteria at the designated reliability level.

7.2.5 Widened Slab

Widened slabs are used to reduce the edge stresses from wheel loads. The user enters the width of the widened slab for the specific project. A maximum of 1-ft widening of the slab should be used. Thus, the paint strip is placed at 12 feet, but the slab placement width is 13 feet.

7.2.6 Tied Shoulders

Tied shoulders are used to reduce the edge stresses from the wheel loads. The user simply identifies whether the shoulders will be tied to the JPCP for the specific project. A longitudinal joint load transfer efficiency of 40 percent should be used.

7.2.7 Erodibility Index

The erodibility index for JPCP is defined by the type of base material for the specific project, and is classified in five categories, which are listed in Table 7.3. More erosion resistant base material results in lower predicted joint faulting and a thinner PCC layer.

7.2.8 PCC-Base Contact or Interface Friction for JPCP

JPCP design should be based on full friction between the slab and base course, and nothing should be done in construction to break the bond between layers. Some base types, however, are prone to debond after a few years and this increases stress in the slab that leads to cracking.

The following lengths of time for full contract friction between the PCC slab and base course are recommended (means and range obtained from the national or global calibration). This is one of the reasons GDOT uses either HMA (or asphalt stabilized base) or GAB for the base layer under the PCC slabs.

1. Asphalt Stabilized Base: Use full design analysis period.

2. Cement Stabilized Base: Use up to 120 months as there is a good chance of deboning after this stage.

3. Lime Treated Base: Use up to 150 months

4. Lean Concrete Base: Use zero (0) months if base is finished smooth and cured with wax based curing compound.

5. Unbound Granular Aggregate Base: Use full design analysis period.

Table 7.3—Erodibility Category Index Recommended for Different Base Materials

Erodibility Category		**Recommendation Based on Type of Base Material**
1	Extremely Erosion Resistant	Asphalt Stabilized Layer or HMA.
2	Very Erosion Resistant	Cement Treated or Lean Concrete Base Layer.
3	Erosion Resistant	Dense-graded crushed stone or granular aggregate base (GAB) materials with less than 10 percent fines.
4	Fairly Erodible	Dense-graded or granular aggregate base materials with more than 10 percent fines; *typical GDOT GAB*.
5	Very Erodible	Silts and other non-cohesive fine-grained soils and cohesive soils.

7.2.9 Pavement Curl/Warp Effective Temperature Difference

Use the default value for the PCC pavement curl/warp effective temperature difference for all new pavement and rehabilitation designs; a value of -10 degree Fahrenheit (°F).

7.2.10 Foundation Support for Rehabilitation of Rigid Pavements

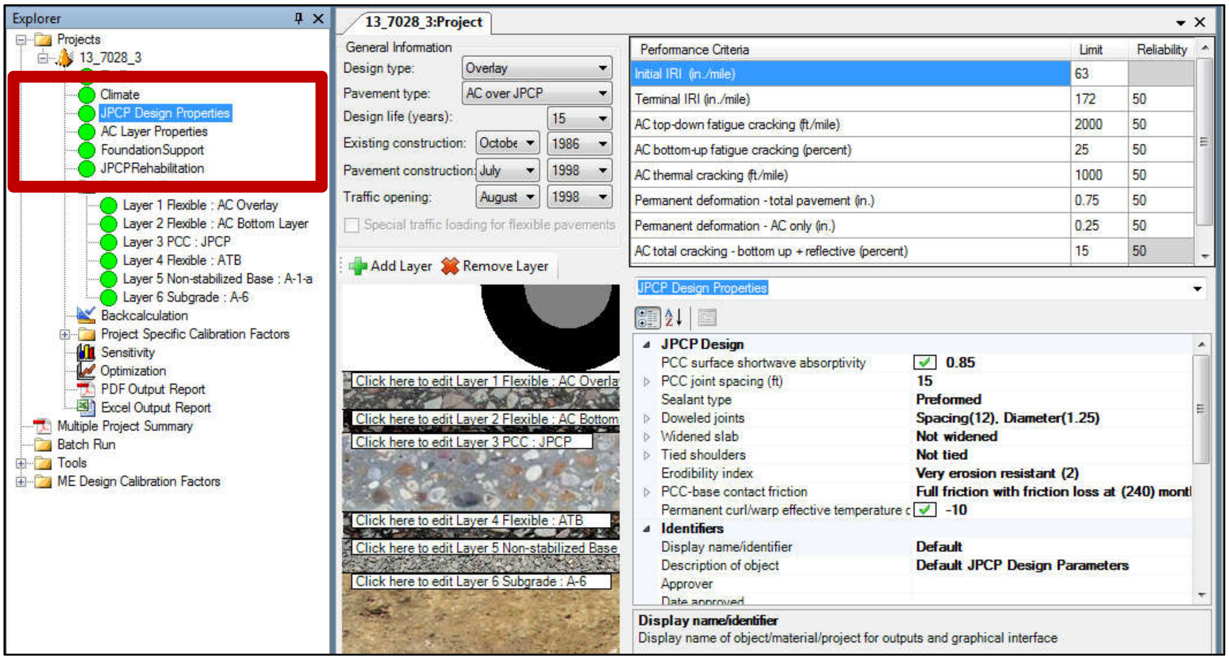
The foundation support (subgrade) **resilient modulus at optimum moisture and maximum dry unit weight** can be estimated based on soil class or California Bearing Ratio (CBR) and entered similar to the design of new rigid pavements. [See section 8.6.2 of this Guide for a more detailed discussion on Resilient Modulus.] If Falling Weight Deflectometer (FWD) testing is available, however, the **K-value can be obtained from backcalculation** and entered directly into the PMED software for the month tested. K-value can be calculated in accordance with the procedure documented in the 1993 AASHTO Design Guide or with other software programs (*Von Quintus and Rao, 2015*). This process is by far the most accurate approach that gives subgrade support along the project.

7.2.11 Condition of Existing PCC Surface for JPCP Rehabilitation Design

The inputs to describe the condition of the existing PCC surface and any repairs made to the surface are listed below and discussed in the next chapter of the User Input Guide under rehabilitation of rigid pavements.

Two inputs are required for the existing PCC layer when designing an HMA overlay of an existing JPCP or diamond grinding: (1) the user determines the **percentage of slabs that are transversely cracked or have been replaced prior to rehabilitation or restoration**, and (2) the **percentage of slabs that will be replaced as part of the rehabilitation project after restoration**. These two inputs are important because they define the in-place damage of the JPCP for predicting future damage and cracking of the PCC slabs.

7.2.12 Screen Shots for the JPCP Layer Properties: New and Existing Layers



General Information

Design type: Overlay

Pavement type: AC over JPCP

Design life (years): 15

Existing construction: Octobe 1986

Pavement construction: July 1998

Traffic opening: August 1998

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50
AC total cracking - bottom up + reflective (percent)	15	50

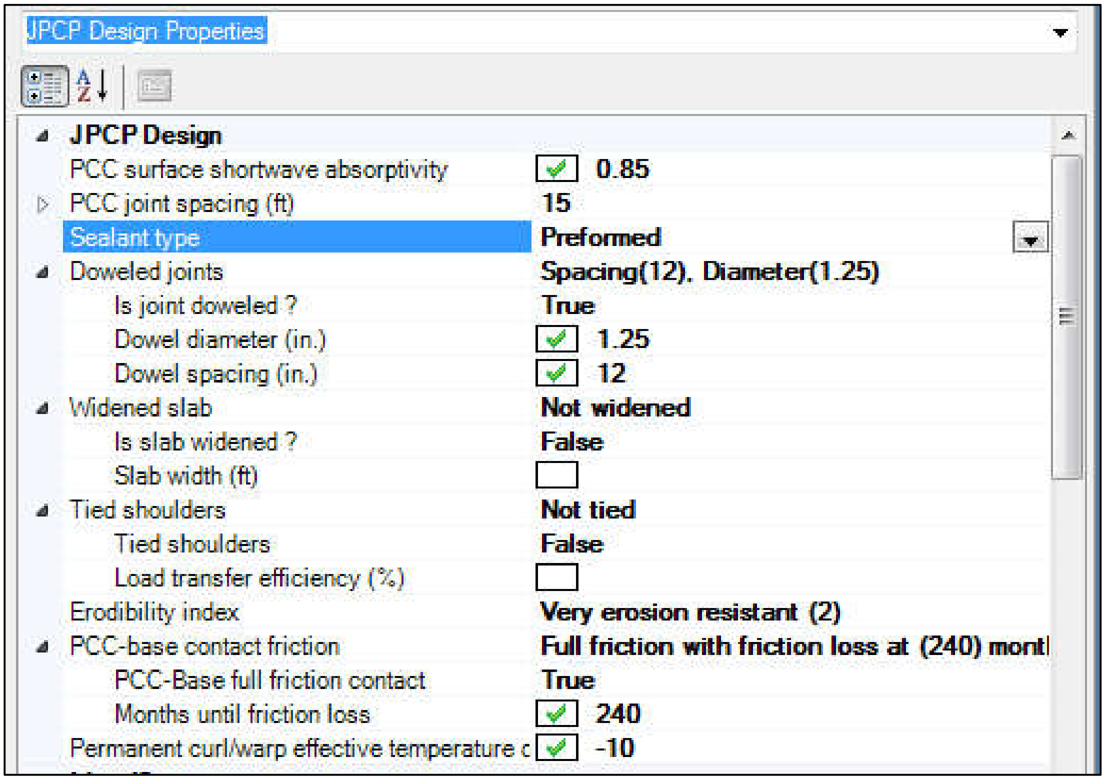
JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Widened slab	Not widened
Tied shoulders	Not tied
Erodibility index	Very erosion resistant (2)
PCC-base contact friction	Full friction with friction loss at (240) montl
Permanent curl/warp effective temperature c	☑ -10
Identifiers	
Display name/identifier	Default
Description of object	Default JPCP Design Parameters
Approver	
Date approved	

Display name/identifier
Display name of object/material/project for outputs and graphical interface

The following are screen shot examples that show the JPCP Design Property and other inputs discussed within this section of Chapter 7. The drop-down arrows are used to access or select specific information and other input values for the project.

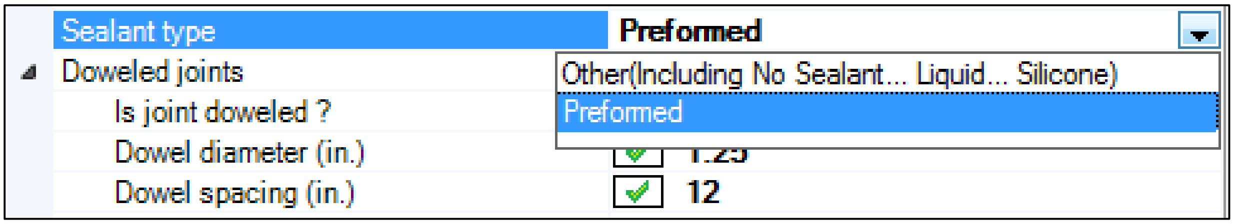
Overall Screen Shot for the JPCP Design Properties, Foundation Support, and JPCP Rehabilitation

JPCP Design Properties Screen



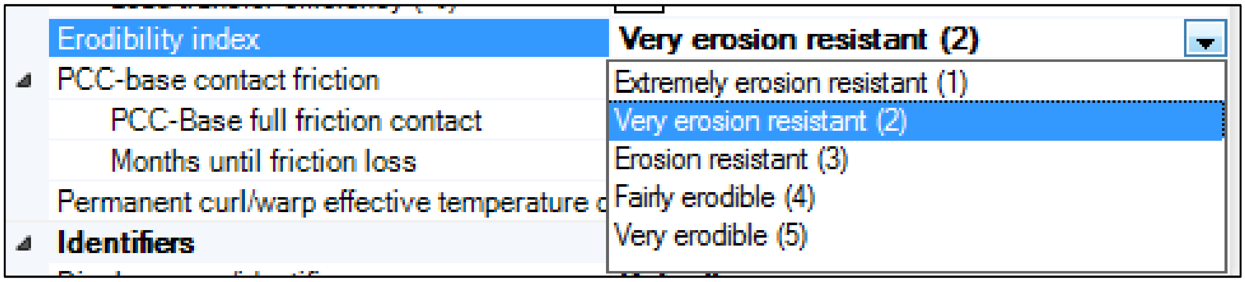
JPCP Design	
PCC surface shortwave absorptivity	☑ 0.85
PCC joint spacing (ft)	15
Sealant type	Preformed
Doweled joints	Spacing(12), Diameter(1.25)
Is joint doweled ?	True
Dowel diameter (in.)	☑ 1.25
Dowel spacing (in.)	☑ 12
Widened slab	Not widened
Is slab widened ?	False
Slab width (ft)	☐
Tied shoulders	Not tied
Tied shoulders	False
Load transfer efficiency (%)	☐
Erodibility index	Very erosion resistant (2)
PCC-base contact friction	Full friction with friction loss at (240) mont
PCC-Base full friction contact	True
Months until friction loss	☑ 240
Permanent curl/warp effective temperature c	☑ -10

Sealant Type Screen Shot



Sealant type	Preformed
Doweled joints	
Is joint doweled ?	
Dowel diameter (in.)	☑ 1.25
Dowel spacing (in.)	☑ 12

Erodibility Index Screen Shot

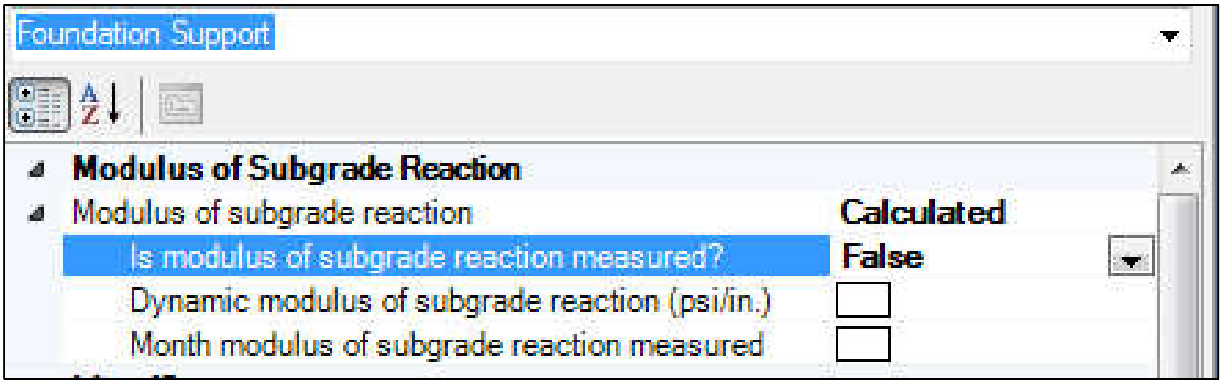


Erodibility index: Very erosion resistant (2)

- Extremely erosion resistant (1)
- Very erosion resistant (2)
- Erosion resistant (3)
- Fairly erodible (4)
- Very erodible (5)

PCC-base contact friction
PCC-Base full friction contact
Months until friction loss
Permanent curl/warp effective temperature d
Identifiers

Foundation Support



Foundation Support

Modulus of Subgrade Reaction
Modulus of subgrade reaction: **Calculated**
Is modulus of subgrade reaction measured?: **False**
Dynamic modulus of subgrade reaction (psi/in.): ☐
Month modulus of subgrade reaction measured: ☐

JPCP Rehabilitation

Existing JPCP Condition

JPCP Rehabilitation
Slabs distressed/replaced before restoration (%): ☑ **0**
Slabs repaired/replaced after restoration (%): ☑ **0**

7.3 CRCP: NEW AND EXISTING LAYERS

7.3.1 Inputs

The inputs for the PCC layer of CRCP are the same as for JPCP listed above, except as summarized below:

1. Shoulder type: The type of shoulder is determined by the user. Four shoulder types are available for consideration: (1) tied PCC, separate; (2) tied PCC, monolithic, (3) asphalt, and (4) gravel or an unbound granular aggregate base material. A roller compacted concrete can be assumed as an asphalt shoulder since it is not tied into the PCC slab. If alternates are allowed, use an asphalt shoulder for the design.
2. Percent longitudinal steel included in the PCC slab is a project specific design input and varies between 0.65 and 0.80 percent area of slab. This is a critical input to the design.
3. Bar diameter of the longitudinal steel reinforcement is a project specific design input.
4. Depth of the longitudinal steel reinforcement is a project specific design input. The longitudinal steel is usually placed at the mid-depth or higher in the PCC slab. Placement just above mid-depth (3.5 inches of concrete cover minimum), however, will result in tighter cracks and improved performance.
5. Base/Slab friction coefficient or the coefficient of friction at the interface of the CRCP and layer supporting the CRCP. There is no test method for measuring the coefficient of friction between two pavement layers. Table 7.4 summarizes the default values recommended for design which are included in the most recent MOP Edition (AASHTO, 2020).

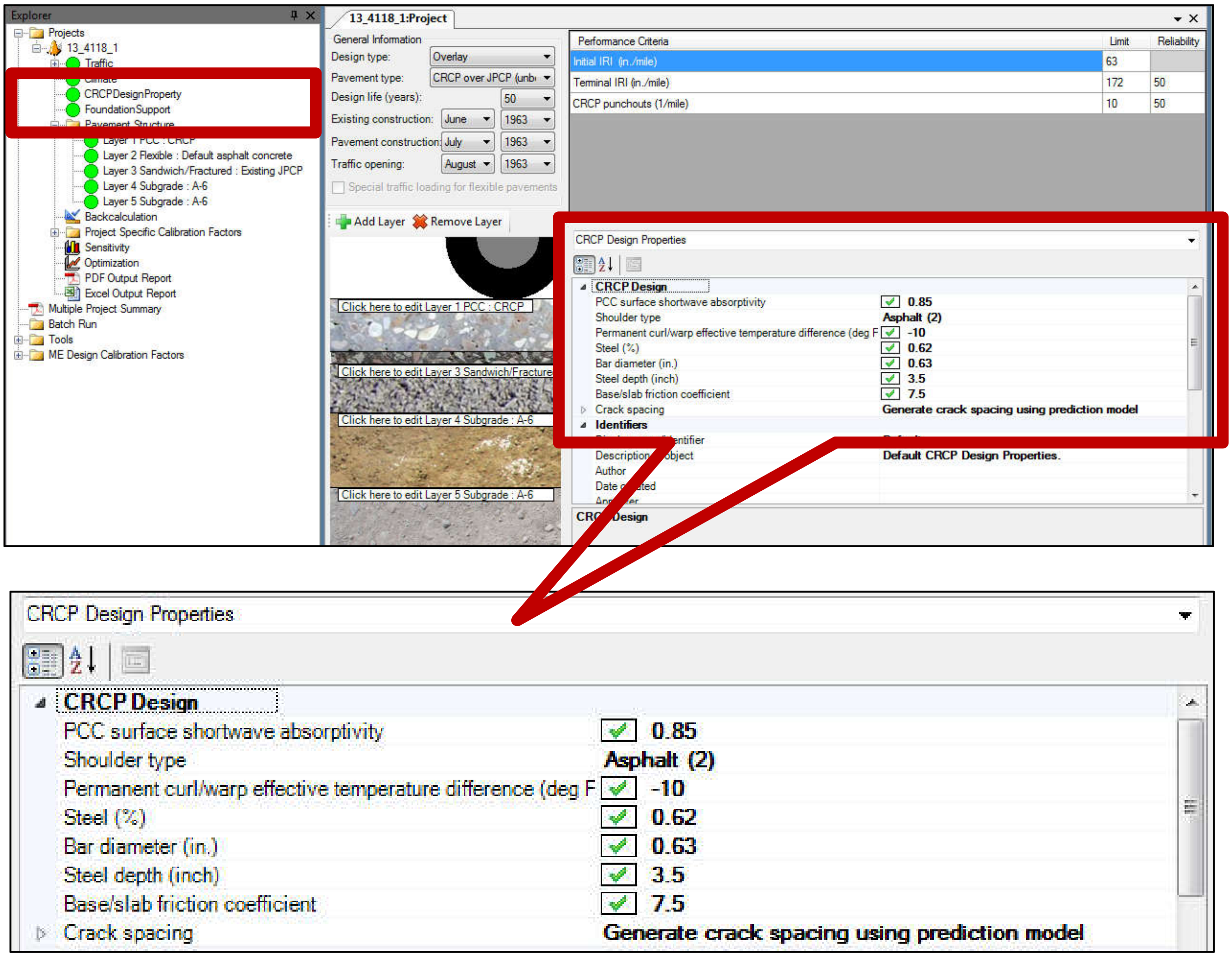
Table 7.4—Base/Slab Friction Coefficient Recommended based on Different Layers below CRCP (AASHTO, 2020)

Base Type	Friction Coefficient (mean)
Asphalt treated base	8.5
Cement treated base	9.6
Lime treated base	10.7
Granular aggregate base	2.7

7.3.2 Screen Shots for the CRCP Layer Properties: New and Existing Layers

The following are screen shot examples that show the CRCP Design Property and other inputs discussed within this section of Chapter 7. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the CRCP Design Properties, Foundation Support, and JPCP Rehabilitation



General Information

Design type: Overlay

Pavement type: CRCP over JPCP (unb

Design life (years): 50

Existing construction: June 1963

Pavement construction: July 1963

Traffic opening: August 1963

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
CRCP punchouts (1/mile)	10	50

CRCP Design Properties

CRCP Design	
PCC surface shortwave absorptivity	☑ 0.85
Shoulder type	Asphalt (2)
Permanent curl/warp effective temperature difference (deg F	☑ -10
Steel (%)	☑ 0.62
Bar diameter (in.)	☑ 0.63
Steel depth (inch)	☑ 3.5
Base/slab friction coefficient	☑ 7.5
Crack spacing	Generate crack spacing using prediction model

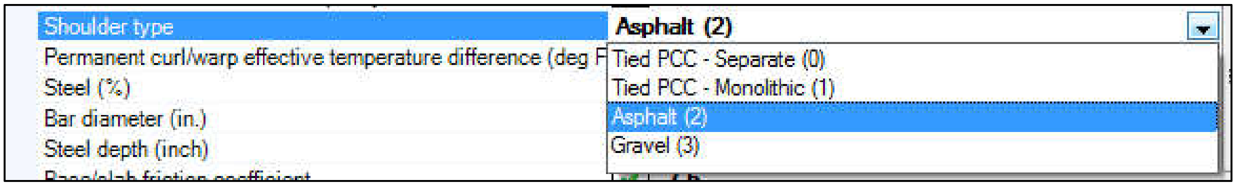
Identifiers

Description of object: Default CRCP Design Properties.

Author

Date created

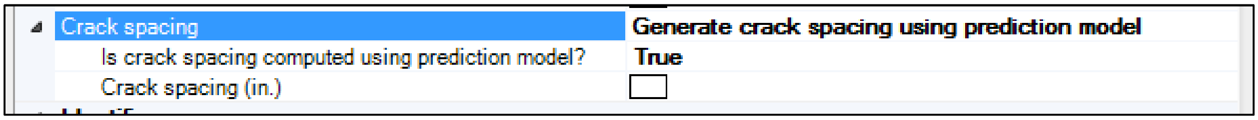
Shoulder Type



Shoulder type	Asphalt (2)
Permanent curl/warp effective temperature difference (deg F	
Steel (%)	
Bar diameter (in.)	
Steel depth (inch)	
Base/slab friction coefficient	

Tied PCC - Separate (0)
Tied PCC - Monolithic (1)
Asphalt (2)
Gravel (3)

Crack Spacing



Crack spacing	Generate crack spacing using prediction model
Is crack spacing computed using prediction model?	True
Crack spacing (in.)	☐

CHAPTER 8—LAYER/MATERIAL PROPERTY INPUTS

The inputs to define the structure are straightforward and include the material type and thickness of each layer included in the design strategy. Figure 8.1 shows the pavement layer structure typically required by GDOT, and Table 8.1 lists the minimum and maximum layer thicknesses appropriate for input in the PMED software. The values found in Table 8.1 do not reflect current GDOT design recommendations but instead provide the range of thickness values recorded for each material during the local calibration process. The GDOT Pavement Design Manual or Policy Design Manual should be referenced for design thicknesses from official design standards such as the 2018 guidelines for Superpave and other mix type selection Guidelines and the Geotechnical QA/QC Manual.[5]

8.1 PAVEMENT LAYERS FOR FLEXIBLE PAVEMENT DESIGN

The following provides a recommendation for creating the pavement structure used in a new or rehabilitated flexible pavement analysis (see Figure 8.1).

8.1.1 HMA and Asphalt Stabilized Base Layers

For both new construction and rehabilitation designs, thin HMA layers (less than 1.0 inch in thickness) should be combined with an adjacent structural layer. As an example, open graded or porous friction courses, PEM, 4.75 mm mixture, and other thin layers should be combined with the lower or adjacent dense-graded HMA/AC Superpave mixture or layer.

1. For new construction or reconstruction problems, limit the number of HMA layers to three (maximum number allowed). The lower layer controls bottom-up or alligator

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[5] The number of layers used in an analysis has an effect on the PMED run time—using more layers, increases the run time.

cracking, while the upper layers have more control on the predictions of rut depth and longitudinal or top-down cracking. For flexible pavements & HMA/AC overlays, the designer should iterate on the lower HMA/AC overlay layer for determining the required total thickness. When combining thin surface layers with a lower dense-graded HMA/AC layer for new construction, the layer thickness ratios in Table 8.2 should be used in determining the equivalent thickness of the lower dense graded HMA/AC layer in accordance with equation 1 to be entered in the PMED software.

$$D_{equivalent} = D_{Dense-Graded} + \left(R\left[D_{Thin-Layer}\right]\right) \tag{1}$$

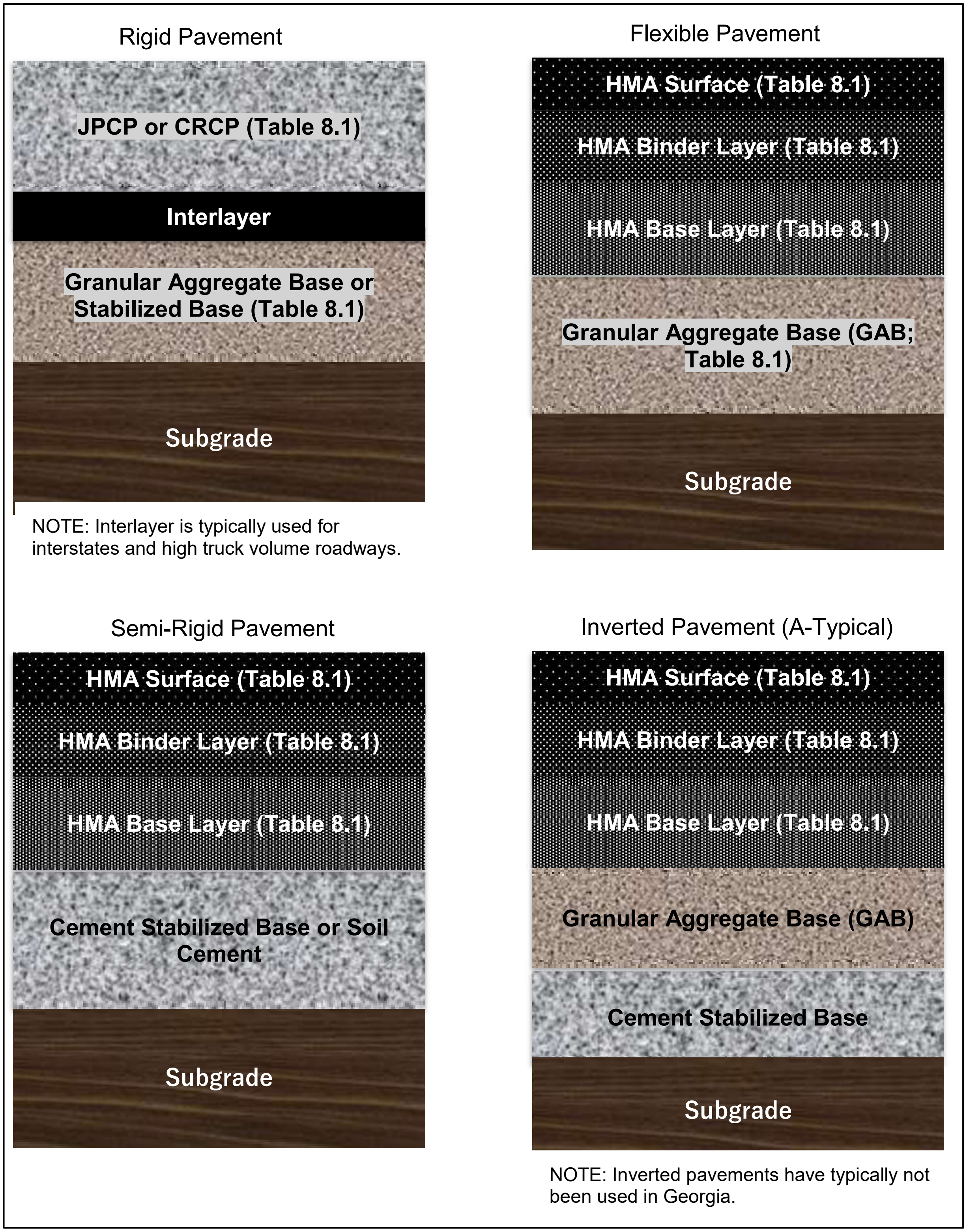
Where:

$D_{equivalent}$ - Thickness of the equivalent dense-graded mix.

$D_{Dense\text{-}Graded}$ - Use thickness of the lower dense-graded mix, see Table 8.1.

R - Equivalent thickness ratio of the thin layer to the dense-graded layer; provided in Table 8.2.

$D_{Thin\text{-}Layer}$ - Thickness of the thin layer which is identified in Tables 8.1 and 8.2.



NOTE: Interlayer is typically used for interstates and high truck volume roadways.

NOTE: Inverted pavements have typically not been used in Georgia.

Figure 8.1—New Pavement Structures Typically Required by GDOT

Table 8.1—Minimum and Maximum Layer Thicknesses

Layer/Material Designation		Layer Thickness, in.		
		Use	Min.	Max.
PCC	JPCP	Design^A	6.0	15.0
	CRCP	Design^A	7.0	15.0
	HMA Interlayer	Manual^B	NA*	
HMA/AC	Surface Layer	Manual^B	0.75	2.5
	Binder Layer	Manual^B	1.75	3.0
	Base Layer	Manual^B	3.0	12.0
Unbound Layers	GAB	Manual^B	7.5	16.0
	Asphalt Base	Manual^B	3.0	12.0
	Subgrade	Design^A	NA*	
	Stabilized Soil	Design^A	7.5	12.0

**NA - Not Applicable.*

Note A: "Design" in the Use Column means the thickness is to be design for the specific project

Note B: "Manual" in the Use Column means the thickness is to be designed in accordance with the GDOT Pavement Design Manual or Policy Design Manual

Table 8.2—HMA/AC Layer Thickness Ratios (R) to be Used in Combining Thin Layers with Lower Dense-Graded HMA/AC Layers

Thin Layers	Ratio to a Dense-Graded Layer
Open-Graded or Porous Friction Course	0.75
PEM	0.75
4.75 mm Mix	1.0

The above ratios were determined based on the equivalent stiffness method.

2. For rehabilitation, the existing HMA/AC and overlay layers are restricted to four total AC layers. When three layers are entered to represent the existing HMA, only one overlay layer can be used. For this case, the thickness entered into the software for the existing upper layer is defined as the existing layer thickness (prior to milling) minus the milled thickness (see Section 7.1.6). Conversely, if three overlay layers are entered, only one layer can be used to represent the existing HMA layers. For this case, the thickness entered into the software for the existing layer is defined as the total existing AC thickness (prior to milling) minus the milled thickness. For rehabilitation, it is recommended that the existing HMA/AC layers be combined as one

layer, unless there is a specific reason why two layers should be simulated. Results from deflection basin testing and the backcalculation of elastic layer modulus values should be used to determine whether the existing HMA layers are confined to one or two layers.

8.1.2. Base Layers

GDOT typically uses one type of base layer along a project, which include additional asphalt base (25 mm HMA), soil cement, and granular aggregate base (GAB). Asphalt stabilized base layers were noted above, while the others are discussed in the bullets below.

1. Unbound Granular Aggregate Base (GAB) Layers: Limit the compacted GAB layers to two for both new and rehabilitation design; most of the designs will include only one GAB layer that is placed in two lifts. If more than two layers are being considered within the design strategy combine similar materials, especially any layer that is relatively thin (less than 6 inches). The number of unbound GAB layers of the existing pavement structure for rehabilitation design should coincide with the pavement structure used to backcalculate elastic layer modulus values from deflection basin data.
2. Cement Treated Base or Cementitious Layers: No more than one layer of cement, lime, or lime-fly ash stabilized base layer should be used in the analysis. This does not include stabilized subgrade soils, which is covered under the next major bullet item. When the cementitious layer is placed directly below the HMA layer, even if this layer is a stabilized subgrade, the pavement structure is defined as a semi-rigid pavement (see Figure 8.1). Semi-rigid pavements were calibrated nationally in 2018.

There were limited semi-rigid pavements with sufficient materials data for use in the local calibration process for GDOT (see Table 2.1).

3. Asphalt Base (25mm HMA): A layer of 25mm HMA may be used as replacement for a typical GAB layer in certain projects where GAB applications are less feasible. Only three total asphalt layers are permitted in the software for new design. Using asphalt base as a base layer substitute will limit the maximum number of asphalt surface layers to two.

8.1.3. Stabilized Subgrade

No more than one layer of a stabilized subgrade should be used in the analysis. It is permissible to include a stabilized aggregate base layer and stabilized subgrade within the same run. In the past, GDOT has treated this layer as an equal thickness of GAB. Stabilized subgrades simulated in the PMED software, however, are treated separately and should be simulated as such in accordance with the following guidance.

1. If the stabilized subgrade is used as a construction platform with only minimum additive for improving the strength, the layer should be combined with the subgrade layer and not treated as a separate layer.
2. Conversely, a stabilized subgrade for improving the structural strength of the pavement is entered as a separate layer with a constant elastic or resilient modulus value for that layer. The inputs for these stabilized soils are included in Section 8.7 of the User Input Guide.

8.1.4. Embankment/Foundation Layers or Subgrade

The subgrade should be limited to two layers; a compacted embankment layer and the natural or undisturbed soil. The exception to this recommendation is when a water table is located near the surface (less than 10 ft.) and the type of soil changes significantly between the water table and lower pavement layer because the properties of the soils can have a significant effect on the amount of water being moved through the subgrade—lowering the resilient modulus of the upper soil strata.

8.1.5. Bedrock

For some projects, bedrock or a very stiff layer may be encountered. The maximum thickness of the subgrade above a rigid layer, however, is 100 inches. For depths greater than 10 feet, the bedrock has little impact on the predicted distresses. When bedrock is encountered within 10 feet of the surface, the designer can enter it as a separate layer.

The material properties needed for each layer are discussed in separate sections of this chapter.

8.2 PAVEMENT LAYERS FOR RIGID PAVEMENT DESIGN

Inputs in this category primarily define the structural layers of the PCC pavement including the material types and thicknesses (see Figure 8.1). Similar to the process defined in Section 8.1 for flexible pavements, each layer of the trial section is inserted by selecting the material type, the actual material classification, and the thickness. The following provides guidance for setting up the pavement structure used in a rigid pavement analysis.

8.2.1. JPCP or CRCP Layers

For new construction, the rigid pavement is limited to one PCC layer and two PCC layers for rehabilitation designs of rigid pavements (PCC overlay and existing PCC layer).

8.2.2. Base Layers

GDOT typically uses one type of base layer along a project, which include asphalt stabilized base (25 mm HMA), cement stabilized or treated base, and GAB.

1. HMA or Asphalt Stabilized Base Layers: For new construction or reconstruction problems, HMA or stabilized base layers are placed below the PCC slabs and are limited to one layer. The inputs for the asphalt stabilized base layer are the same as for flexible pavements.

2. Unbound Granular Aggregate Base Layers: Limit the compacted unbound GAB layers to one for both new and rehabilitation design of rigid pavements. If more than one layer is used within the design strategy combine similar materials, especially any layer that is relatively thin (less than 6 inches). The number of GAB layers of the existing pavement structure for rehabilitation design should coincide with the pavement structure used to backcalculate elastic layer modulus values from deflection basin data.

3. Cement Treated Base or Cementitious Layers: No more than one layer of cement, lime, or lime-fly ash stabilized base layer should be used in the analysis. This does not include stabilized subgrade soils, which is covered under the next bullet item.

8.2.3. Stabilized Subgrade

No more than one layer of a stabilized subgrade should be considered in the analysis. It is permissible to consider or simulate a stabilized base layer and stabilized subgrade within the same run.

8.2.4. Embankment/Foundation Layers or Subgrade

The subgrade should be limited to no more than two layers; a compacted embankment layer and the natural or undisturbed soil. The exception to this recommendation is when a water table is located near the surface (less than 10 ft.) and the type of soil changes significantly between the water table and lower pavement layer because the properties of the soils can have a significant effect on the amount of water being moved through the subgrade—lowering the resilient modulus of the upper soil strata.

The material properties needed for each layer are discussed in separate sections of this chapter.

8.3 ASPHALT CONCRETE (AC)

The layer or material properties for the AC or HMA layers are grouped into three categories: volumetric, mechanical, and thermal properties. Example screen shots showing the AC material property inputs are included at the end of this section.

8.3.1 Asphalt Layer, Thickness

The thickness for different AC layers needs to be entered into the software. A maximum of three AC layers can be included in the pavement structure simulation, so some AC layers may need to be combined for a specific trial design. Section 8.1 provides discussion on combining different AC layers, while Table 8.1 listed the minimum and maximum AC layer thickness.

8.3.2 Mixture Volumetric Properties

The volumetric properties include air voids, effective asphalt binder content by volume, aggregate gradation, mix unit weight, and asphalt grade. Gradation is included under the mechanical properties because it is only used to calculate the dynamic modulus of the mix for input levels 2 and 3. The volumetric properties should represent the mixture after compaction at the completion of construction. Obviously, the project specific values will be unavailable to the designer because the project is yet to be built. These parameters should be available from previous construction records. The following summarizes the recommended input parameters and values for the HMA mixtures.

1. Air voids, effective asphalt content by volume, and unit weight: Use the average values from historical construction records for a particular type of HMA mixture. Table 8.3 includes the volumetric properties based on the target values for common HMA mixtures used in Georgia for the time period of 2012-2014. For higher design level inputs, The University of Georgia (UGA) developed an asphalt volumetric properties databased for 16 different Georgia asphalt mixtures (Kim et al., 2019). The properties are included in the material testing library and can be imported into the PMED software from the material library. The following volumetric equations can be used to estimate the input parameters.

Table 8.3—Volumetric Properties for Georgia's Dense-Graded Mixtures

Volumetric Property	Superpave Mixture					SMA Mix	
	Surface Mixtures			Binder	Base		
	9.5 mm, Type I	9.5 mm, Type II	12.5 mm	19 mm	25 mm	12.5 mm	19 mm
Average Air Voids, %	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Effective Asphalt Content by Volume, %	10.5	10.5	10.6	9.6	9.2	12.0	11.5
Density, pcf	148	148	148	148	148	152	152

Air Voids, V_a:

$$V_a = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \times 100 \tag{2}$$

Void In Mineral Aggregate, *VMA*:

$$VMA = 100 - \left(\frac{G_{mb}(P_s)}{G_{se}}\right) \tag{3}$$

Effective Asphalt Content by Volume, V_{be}:

$$V_{be} = VMA - V_a \tag{4}$$

Where:

V_a = Air voids.

VMA = Voids in mineral aggregate.

V_{be} = Effective asphalt content by volume.

G_{mb} = Bulk specific gravity of the HMA mixture.

G_{mm} = Maximum theoretical specific gravity of the HMA mixture.

G_{se} = Effective specific gravity of the combined aggregate blend.

P_s = Percentage of aggregate in mix by weight, % (P_s=100-P_b).

Poisson's Ratio: Use the temperature calculated values from the regression equation included in PMED.

8.3.3 Mechanical Properties

Kim (2013) conducted dynamic modulus test on multiple HMA mixtures. UGA later updated this database with 18 additional mixtures (Kim et al., 2019). Table 8.4 depicts the mixtures whose time-temperature dependent dynamic modulus values were acquired for Level 1 design. If data is not available for the project location, Figure 8.2 may be used along with Table 8.4 for regional approximations. The detailed results of both studies are included in the material testing library and can be imported into the PMED software via the material library. For those mixtures and binder grades not relevant to the GDOT materials library, input level 3 values must be entered into the PMED software.

Table 8.4—HMA Mixtures with Level 1 Dynamic Modulus

Region	Binder Grade	NMAS (mm)	Binder Location	Material File Name
1	64-22	19	Dalton (Whitefield)	L*_PG64_19_A_R1
		25	Dalton (Whitefield)	L*_PG64_25_A_R1
2	64-22	19	Athens (Clarke)	L*_PG64_19_A_R2
	67-22	12.5	Toccoa (Stephens)	L*_PG67_12.5_A_R2
	76-22	12.5	Kennesaw (Cobb)	L*_PG76_12.5_A_R2
3	64-22	9.5	Albany (Dougherty)	L*_PG64_9.5_B_R3-A
			Vienna (Dooly)	L*_PG64_9.5_B_R3-V
		12.5	Forrest Park (Clayton)	L*_PG64_12.5_A_R3-FP
			LaGrange (Troup)	L*_PG64_12.5_A_R3-LG
			Albany (Dougherty)	L*_PG64_12.5_B_R3
		19	Vienna (Dooly)	L*_PG64_19_B_R3
		25	Vienna (Dooly)	L*_PG64_25_B_R3
	67-22	9.5	Columbus (Muscogee)	L*_PG67_9.5_C_R3
	76-22	12.5	Columbus (Muscogee)	L*_PG76_12.5_C_R3
4	67-22	9.5	Statesboro (Bulloch)	L*_PG67_9.5_B_R4
		12.5	Statesboro (Bulloch)	L*_PG67_12.5_B_R4

Note: The material file name indicates the mixture is included in the GDOT materials library. The exact dynamic modulus values for each temperature and frequency for every mixture are included in Appendix A.

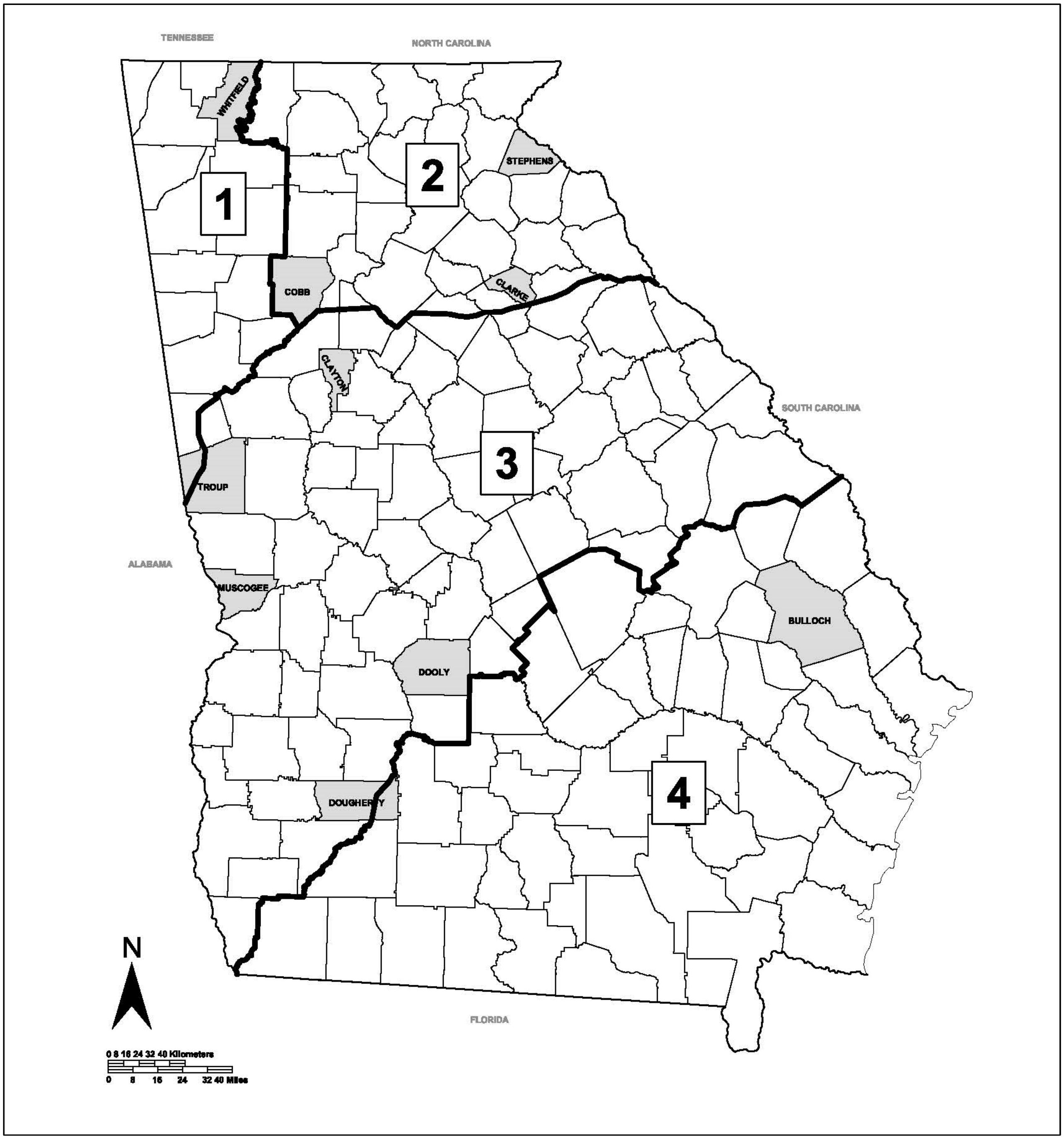


Figure 8.2—HMA Database Collection Regions

Table 8.5 is a matrix of the HMA dense-graded mixtures that are included in the GDOT materials library in relation to the typical binder grades used in Georgia. For those mixtures and binder grades not included in the GDOT materials library, input level 3 values need to be entered into the PMED software.

Table 8.5—Binder Grades Typically Used in Georgia's Dense-Graded Mixtures

Mix Size Designation	Asphalt Binder Designation		
	PG64-22	PG67-22	PG76-22
9.5 mm	√	√	
12.5 mm	√	√	√
19 mm	√	√	
25 mm	√	√	

Note: A check mark in the above columns indicates the mixture is included in the GDOT materials library. The average values for the different mixtures are included in Appendix A.

2. New HMA mixtures: If an HMA mixture is included in a design strategy that is not included within the materials library, it is recommended that input level 3 inputs be used to estimate the dynamic modulus values. Two options are provided for estimating dynamic modulus using input levels 2 and 3: (1) NCHRP 1-37A (viscosity-based model), and (2) NCHRP 1-40D (dynamic shear rheometer [DSR] based model). Either one can be used but the DSR model was derived from the viscosity-based model. It is recommended that the NCHRP 1-37A viscosity-based model be used for all current designs as the global calibration factors for all HMA predictive equations were determined using this model.
3. Existing HMA mixtures: For rehabilitation design of flexible pavements, the dynamic modulus of the existing HMA layers is needed. Rehabilitation input levels 2 and 3 are the same as for new HMA mixtures discussed above. For rehabilitation input level 1, the dynamic modulus values represent the backcalculated elastic modulus values.

Deflection basins should be measured over a range of temperatures, even if the deflection testing is completed within the same day so that the backcalculated elastic layer modulus values can be determined for at least two temperatures: one representing the morning hours and one representing the late afternoon hours. If there is no significant difference between the backcalculated elastic modulus values, one average value can be used.

Two other inputs that are needed include: (1) the frequency of deflection testing—a default value of 20 Hz is recommended; and (2) the temperature representative of the average backcalculated elastic modulus value—the mid-depth temperature of the layer used in the backcalculation process measured during deflection testing.

4. Aggregate gradation: It is needed when input levels 2 or 3 are used for dynamic modulus. Use either the values that are near the mid-range of the project specifications or the average values from previous construction records for a particular type of mix. Table 8.6 includes the gradation or percent passing for the common mixtures used in Georgia. It should be noted that all input levels will require aggregate gradation for the PMED software v2.6.

Table 8.6—Gradation for Georgia's Dense-Graded Mixtures

Sieve Size	Superpave Mixtures					SMA Mixtures	
	Surface Mixes			Binder Mix	Base Mix	Surface	Binder
	9.5 mm, Type I	9.5 mm, Type II	12.5 mm	19 mm	25 mm	12.5 mm	19 mm
1.5 in (37.5 mm)	100	100	100	100	100	100	100
1 in. (25.0 mm)	100	100	100	100	95	100	100
0.75 in. (19 mm)	100	100	99	95	85	100	95
0.5 in. (12.5 mm)	99	99	95	82	65	92	60
3/8 in. (9.5 mm)	95	95	85	70	52	65	52
No. 4 (4.75 mm)	75	65	58	49	45	24	24
No. 8 (2.36 mm)	51	45	43	33	33	20	20
No. 200 (75 µm)	6	6	5.8	5	4.8	10	9

5. Reference temperature: Use 70°F. All of the GDOT calibration factors are tied to this default value.
6. Creep compliance and indirect tensile strength: Creep compliance and the indirect tensile strength may be determined in the software using other asphalt material properties such as gradation and binder-related inputs. Therefore, it is recommended that input level 3 be used to estimate these properties until a library of laboratory test results become available. Both the creep compliance and the indirect tensile strength inputs are used for the low temperature cracking transfer function. Because transverse cracking from low temperature events is not that prevalent on Georgia’s roadways, GDOT has not yet expended the resources to measure these properties in the laboratory. Recent efforts have been made to acquire this data for appropriate characterization of the load related distresses in future designs.

8.3.4 Thermal Properties

1. Thermal conductivity of asphalt: Use default value set in program of 0.67 BTU/ft*h*°F. All of the GDOT calibration factors are tied to this default value.

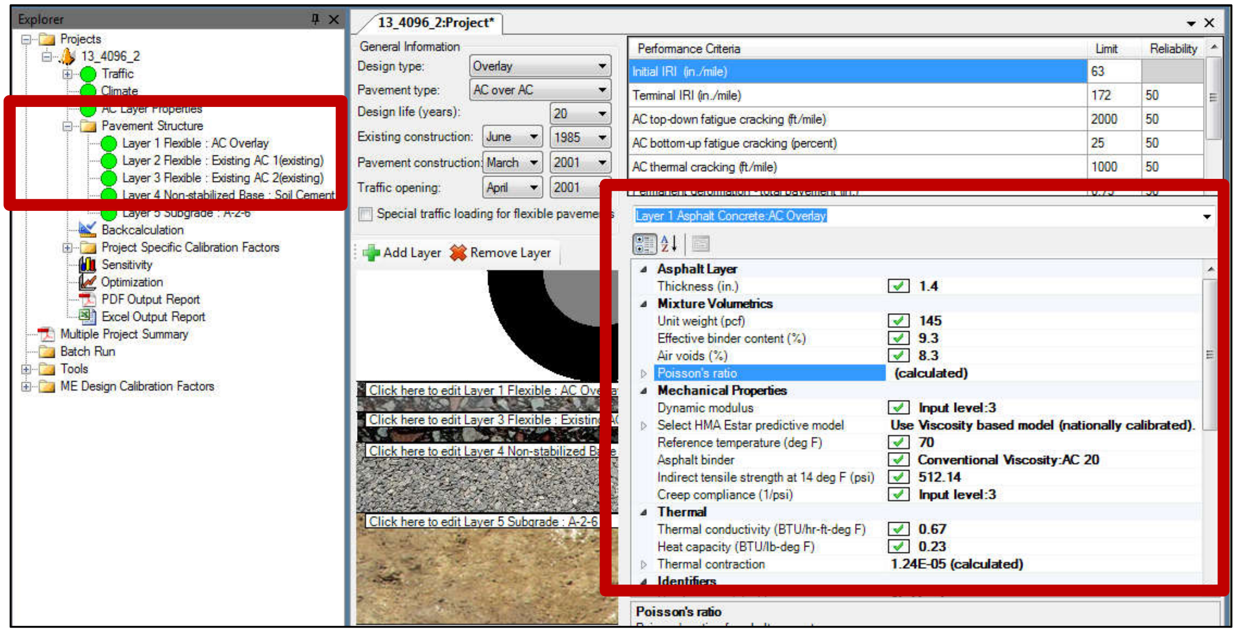
2. Heat capacity of asphalt: Use default value set in program of 0.23 BTU/lb*°F. All of the GDOT calibration factors are tied to this default value.

3. Coefficient of thermal contraction of the mix: Use default values set in the MOP for different mixtures and aggregates. The PMED software will calculate this value. All of the GDOT calibration factors are tied to the global default values calculated by the software.

8.3.5 Screen Shots for the AC Properties: New and Existing Layers

The following are screen shot examples that show the AC material property inputs discussed within this section of Chapter 8. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the Asphalt Concrete Material Properties



General Information

Design type: Overlay

Pavement type: AC over AC

Design life (years): 20

Existing construction: June 1985

Pavement construction: March 2001

Traffic opening: April 2001

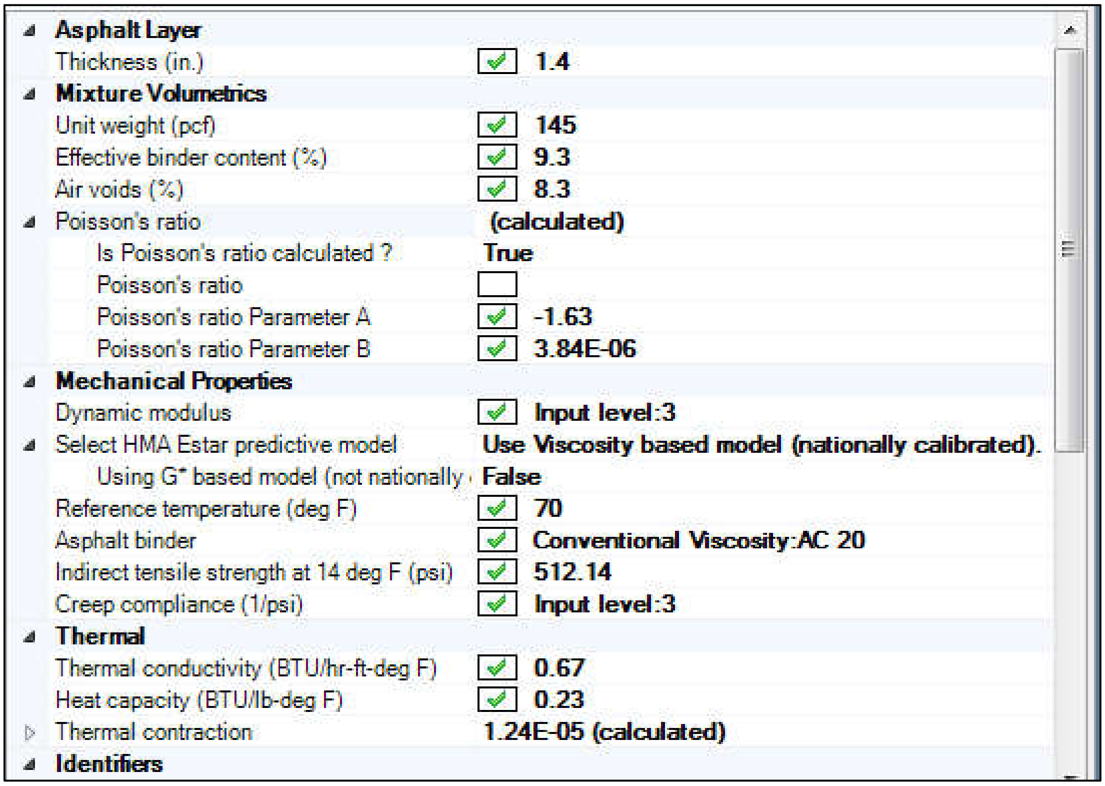
☐ Special traffic loading for flexible paveme

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50

Layer 1 Asphalt Concrete:AC Overlay

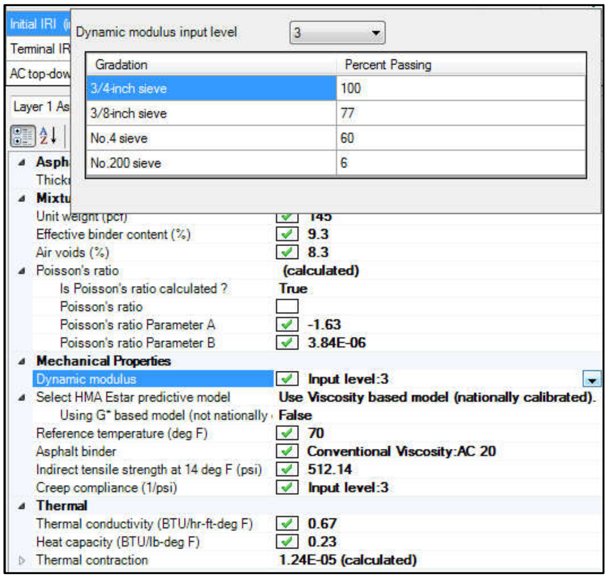
Asphalt Layer	
Thickness (in.)	☑ 1.4
Mixture Volumetrics	
Unit weight (pcf)	☑ 145
Effective binder content (%)	☑ 9.3
Air voids (%)	☑ 8.3
Poisson's ratio	(calculated)
Mechanical Properties	
Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ Conventional Viscosity:AC 20
Indirect tensile strength at 14 deg F (psi)	☑ 512.14
Creep compliance (1/psi)	☑ Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.24E-05 (calculated)
Identifiers	

Asphalt Concrete



Asphalt Layer	
Thickness (in.)	☑ 1.4
Mixture Volumetrics	
Unit weight (pcf)	☑ 145
Effective binder content (%)	☑ 9.3
Air voids (%)	☑ 8.3
Poisson's ratio	**(calculated)**
Is Poisson's ratio calculated ?	**True**
Poisson's ratio	☐
Poisson's ratio Parameter A	☑ -1.63
Poisson's ratio Parameter B	☑ 3.84E-06
Mechanical Properties	
Dynamic modulus	☑ **Input level:3**
Select HMA Estar predictive model	**Use Viscosity based model (nationally calibrated).**
Using G* based model (not nationally	**False**
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ **Conventional Viscosity:AC 20**
Indirect tensile strength at 14 deg F (psi)	☑ 512.14
Creep compliance (1/psi)	☑ **Input level:3**
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.24E-05 (calculated)
Identifiers	

Dynamic Modulus; New AC Layer

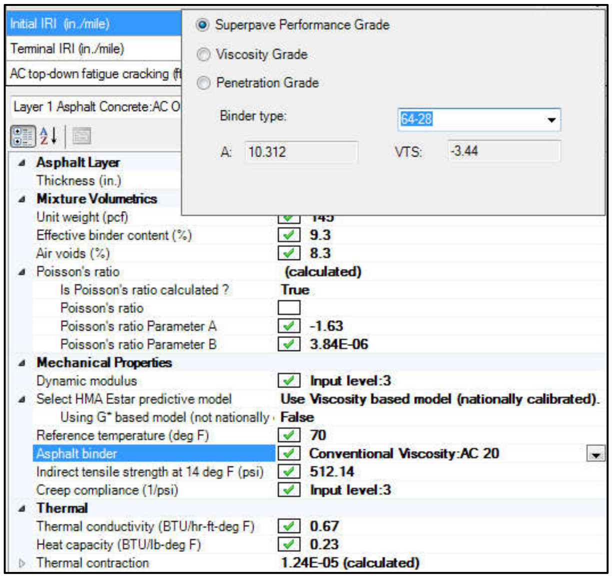


Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Unit weight (pcf)	☑ 145
Effective binder content (%)	☑ 9.3
Air voids (%)	☑ 8.3
Poisson's ratio	**(calculated)**
Is Poisson's ratio calculated ?	**True**
Poisson's ratio	☐
Poisson's ratio Parameter A	☑ -1.63
Poisson's ratio Parameter B	☑ 3.84E-06
Mechanical Properties	
Dynamic modulus	☑ **Input level:3**
Select HMA Estar predictive model	**Use Viscosity based model (nationally calibrated).**
Using G* based model (not nationally	**False**
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ **Conventional Viscosity:AC 20**
Indirect tensile strength at 14 deg F (psi)	☑ 512.14
Creep compliance (1/psi)	☑ **Input level:3**
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.24E-05 (calculated)

Asphalt Binder; Superpave Performance Grade



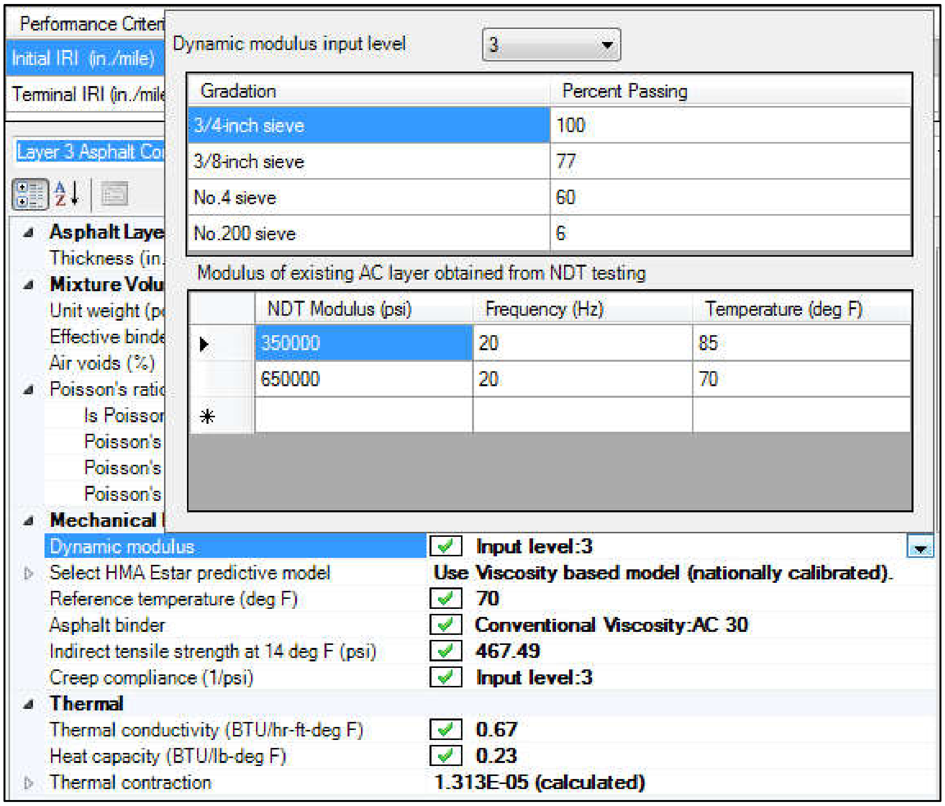
● Superpave Performance Grade
○ Viscosity Grade
○ Penetration Grade

Binder type: 64-28

A: 10.312 VTS: -3.44

Asphalt Layer	
Thickness (in.)	
Mixture Volumetrics	
Unit weight (pcf)	☑ 145
Effective binder content (%)	☑ 9.3
Air voids (%)	☑ 8.3
Poisson's ratio	**(calculated)**
Is Poisson's ratio calculated ?	**True**
Poisson's ratio	☐
Poisson's ratio Parameter A	☑ -1.63
Poisson's ratio Parameter B	☑ 3.84E-06
Mechanical Properties	
Dynamic modulus	☑ **Input level:3**
Select HMA Estar predictive model	**Use Viscosity based model (nationally calibrated).**
Using G* based model (not nationally	**False**
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ **Conventional Viscosity:AC 20**
Indirect tensile strength at 14 deg F (psi)	☑ 512.14
Creep compliance (1/psi)	☑ **Input level:3**
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.24E-05 (calculated)

Rehabilitation: Existing Asphalt Concrete Layer



Dynamic modulus input level: 3

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	77
No.4 sieve	60
No.200 sieve	6

Modulus of existing AC layer obtained from NDT testing

NDT Modulus (psi)	Frequency (Hz)	Temperature (deg F)
350000	20	85
650000	20	70

Dynamic modulus	☑ Input level:3
Select HMA Estar predictive model	Use Viscosity based model (nationally calibrated).
Reference temperature (deg F)	☑ 70
Asphalt binder	☑ Conventional Viscosity:AC 30
Indirect tensile strength at 14 deg F (psi)	☑ 467.49
Creep compliance (1/psi)	☑ Input level:3
Thermal	
Thermal conductivity (BTU/hr-ft-deg F)	☑ 0.67
Heat capacity (BTU/lb-deg F)	☑ 0.23
Thermal contraction	1.313E-05 (calculated)

8.4 PORTLAND CEMENT CONCRETE (PCC) – NEW MIXES

The layer or material properties for the PCC layers are grouped into four categories: general, thermal, mix, and strength properties. Example screen shots showing the PCC material property inputs are included at the end of this section.

A recent study at UGA conducted under RP 18-03 established a database for 12 approved concrete mixtures based on previous projects with similar design characteristics. Table 8.7 provides a summary of the mixture characteristics along with mixture numbers that are referenced throughout this section. The layer or material properties for the PCC mixtures below are recommended for relevant PCC layer designs.

Table 8.7—Georgia Concrete Mixture Properties

Mixture No.	Cementitious Content	Fly Ash (%)	Water / Cement ratio	Coarse Aggregate Type	Coarse Aggregate Fraction	GDOT Project Number
1	541	0	0.431	Granite	11.91	IM-185-1(326)01
2	541	0	0.524	Granite	12.75	NH-IM-20-2(145)01
3	595	0	0.430	Granite	11.40	EDS00-0072-00(039)
4	600	0	0.470	Granite	11.62	NHS00-0005-00(320)
5	580	12.20	0.493	Granite	12.54	NH-IM-20-2(145)01
6	579	19.69	0.446	Granite	11.67	CSNHS-M002-00(965)01
7	622	26.00	0.422	Granite	12.14	NHS-M002-00(434)01
8	605	20.66	0.430	Dolomite	12.09	NHSTP-0075-03(203)
9	590	18.64	0.438	Granite	10.87	CSSTP-0007-00(239)01
10	590	18.64	0.430	Dolomite	10.87	CSSTP-0007-00(239)01
11	600	20.16	0.470	Granite	11.42	IMNH0-0075-01(227)
12	600	20.16	0.470	Granite	11.42	IMNH0-0075-01(227)

8.4.1 General Properties

1. Thickness: The trial layer thickness needs to be entered for the PCC layer. Table 8.1 listed the minimum and maximum layer PCC thickness.

2. Unit weight of PCC: Use the average value from historical construction records for a particular type of PCC mixture or those provided in Table 8.8. In cases where the unit weight is not readily available for the PCC mixes, use a default value of 150 pcf.

3. Poisson’s ratio: All of the GDOT calibration factors are tied to a default Poisson’s ratio of 0.20 because it was unavailable for the PCC mixes included in the LTPP program or for the non-LTPP sections. Ongoing research under RP 18-03 led to the development of Table 8.9, in which Poisson’s ratio was recorded for several Georgia concrete mixtures. The below values were not included in the most recent calibration but have not shown to have significant influence on the transfer functions in PMED as they are within the

expected range. As a result, the use of the average value (0.22) versus the default recommendation (0.20) is at the discretion of the designer.

Table 8.8—Georgia Concrete Fresh Mixture Properties

Mixture No.	Temperature (◦F)	Slump (in)	Air (%)	Unit Weight (lb/ft3)
1	82.4	0.50	4.9	147.2
2	83.4	2.25	4.0	147.4
3	73.7	3.00	6.2	144.4
4	79.3	8.50	6.1	143.0
5	62.1	7.00	4.5	143.4
6	74.1	6.50	5.5	141.6
7	58.6	4.25	3.1	145.2
8	64.4	5.00	5.0	148.8
9	66.2	0.50	4.9	145.8
10	75.4	2.50	5.9	147.2
11	70.5	2.75	3.6	146.6
12	85.8	2.75	4.7	146.4

Table 8.9—Poisson's Ratio for Georgia Concrete Mixtures

		Age of Specimen (days)				
		7	**14**	**28**	**90**	**AVG**
Mixture Number	**Mixture ID**	**Poisson's Ratio**				
1	541/0FA/0.431/11.91G/4.9	0.21	0.22	0.22	0.23	0.22
2	541/0FA/0.524/12.75G/4.0	0.22	0.22	0.22	0.23	0.22
3	595/0FA/0.43/11.4G/6.2	0.21	0.21	0.23	0.24	0.22
4	600/0FA/0.47/11.62G/6.1	0.22	0.21	0.22	0.23	0.22
5	580/12.2FA/0.493/12.54G/4.5	0.17	0.21	0.21	0.26	0.21
6	579/19.69FA/0.446/11.67G/5.5	0.18	0.21	0.20	0.24	0.21
7	622/26FA/0.422/12.14G/3.1	0.19	0.18	0.20	0.25	0.21
8	605/20.66FA/0.43/12.09D/5.0	0.25	0.25	0.26	0.27	0.26
9	590/18.64FA/0.438/10.87G/4.9	0.17	0.20	0.20	0.20	0.19
10	590/18.64FA/0.439/10.87D/5.9	0.20	0.24	0.25	0.27	0.24
11	600/20.16FA/0.47/11.42G/3.6	0.20	0.22	0.21	0.23	0.22
12	600/20.16FA/0.47/11.42G/4.7	0.22	0.21	0.22	0.23	0.22
Average (AVG)		0.20	0.22	0.22	0.24	**0.22**

NOTE: Mixture IDs signify: Cement Content/Fly Ash %/Water-Cement Ratio/CA Fraction/Air Content

8.4.2 Thermal Properties

PCC Coefficient of Thermal Expansion (CTE) is a very critical design input that will affect the pavement design. A CTE database was developed using the same 12 concrete mixtures found in the GDOT material library. The average tested CTE values for these mixes are listed in Table 8.10 and may be used for design Level 1. Default Level 2 CTE values are determined based on PCC coarse aggregate geological class. Designers must determine the source of PCC coarse aggregate and thus, the predominant geological class. With this information, select the most appropriate CTE value from the recommendations presented in Table 8.11 and Table 8.12. If the source of coarse aggregate is unknown, assume granite with the CTE selected from Table 8.11.

Table 8.10—CTE for Georgia Concrete Mixtures

Mixture Number	Mixture ID	Average CTE (10^{-6}/°F)
1	541/0FA/0.431/11.91G/4.9	4.91
2	541/0FA/0.524/12.75G/4.0	4.66
3	595/0FA/0.43/11.4G/6.2	5.25
4	600/0FA/0.47/11.62G/6.1	5.09
5	580/12.2FA/0.493/12.54G/4.5	5.13
6	579/19.69FA/0.446/11.67G/5.5	5.17
7	622/26FA/0.422/12.14G/3.1	5.31
8	605/20.66FA/0.43/12.09D/5.0	5.35
9	590/18.64FA/0.438/10.87G/4.9	5.31
10	590/18.64FA/0.439/10.87D/5.9	5.45
11	600/20.16FA/0.47/11.42G/3.6	4.97
12	600/20.16FA/0.47/11.42G/4.7	4.99
Average		5.13

NOTE: Mixture IDs signify: Cement Content/Fly Ash %/Water-Cement Ratio /CA Fraction/Air Content

Table 8.11—Recommended CTE Values for PCC Mixtures in Georgia that Contain Type I Portland Cement and Natural Sand (Kim, 2012)

Coarse Aggregate Type	CTE (10^{-6}/°F)
Granite	5.1
Dolomite	5.1

1. Thermal conductivity of PCC: Use default value set in program of 1.25 BTU/ft*hr*°F. All of the GDOT calibration factors are tied to this default value.
2. Heat capacity of PCC: Use default value set in program of 0.28 BTU/lb*°F. All of the GDOT calibration factors are tied to this default value.

8.4.3 Mix Physical Properties: New and Intact Existing PCC Slabs

The PMED software requires several inputs for the PCC mix physical properties, which are listed below. The default values for these mix properties recommended for use represent the average value from the mixes included in the GDOT calibration.

1. Cement type: Most of the GDOT PCC mixtures are produced with Type I Portland cement. Type I should be used, unless Type II or III is specified for a specific design. Type I/II Portland cement was used for all of the PCC mixtures included in the calibration.

2. Cement content: The cement content (plus fly ash content) should be available from historical construction records or provided in Table 8.7 for the different PCC mixtures used in Georgia. A local default value of 660 lb./yd.^{3} total cementitious material should be used if information is unavailable to the user.

3. Water/Cement ratio: The water-cement ratio is available from historical construction records or Table 8.7 for the different PCC mixtures. A local default value of 0.45 should be used if information is unavailable to the user.

4. Coarse aggregate type: The common type of coarse aggregates used in the PCC mixes are listed in Table 8.11. The recommended input for most designs is Granite but Dolomite may be assumed for those counties listed in Table 8.12.

Table 8.12—Recommended PCC Aggregate by Source

Location or County	Coarse Aggregate Type
Dade	Dolomite
Catoosa	
Whitfield	
Floyd	
Polk	
Bartow	
Cherokee	
All Remaining Counties	Granite

5. Zero-stress temperature (new and existing intact PCC): Zero stress temperature (Tz) occurs after placement concrete has cured and hardened sufficiently that the temperature begins to drop, resulting in tensile stress. It can be input directly or calculated by the PMED software from monthly ambient temperature and cement content using the equation 5. It is recommended that the user allow the PMED software to calculate this input parameter.

$$Tz = (CC*0.59328*H*0.5*1000*1.8/(1.1*2400) + MMT) \qquad (5)$$

Where:

Tz = Zero stress temperature (allowable range: 60 to 120 degrees Fahrenheit).

CC = Cementitious content, lb/yd^3.

H = -0.0787+0.007*MMT-0.00003*MMT^2.

MMT = Mean monthly temperature for month of construction, degrees Fahrenheit.

6. Ultimate shrinkage: The ultimate shrinkage can be entered manually or calculated by the software. It is recommended the ultimate shrinkage be calculated by the software, because this value was unavailable for the PCC mixes used in Georgia. All of the GDOT

calibration factors were determined based on the software calculating the ultimate shrinkage.

7. Reversible shrinkage: Use default value set in program of 50 percent. All of the GDOT calibration factors are tied to this default value.
8. Time to develop 50 percent of ultimate shrinkage: Use default value set in program of 35 days. All of the GDOT calibration factors are tied to this default value.
9. Curing method: Two options are available within the software: wet curing or curing compound. Curing compound is typically used for GDOT PCC construction. Thus, it is recommended that curing compound be selected unless the designer knows that wet curing will be used for some reason.

8.4.4 Strength Properties

Two mix strength properties are required for using the PMED software: flexural (modulus of rupture) or compressive strength and elastic modulus. Input levels 1 and 2 require time dependent flexural and compressive strengths, respectively, while input level 3 only requires 28-day strength values. Time dependent flexural or compressive strengths were developed by the University of Georgia under RP 18-03 and are provided in the following sections. In cases where these mixtures are irrelevant, input level 3 is recommended for use: 28-day strength and elastic modulus.

1. 28-Day compressive strength: The median value from historical construction records for the 28-day compressive strength is 6,097 psi. It is recommended this value be used in Level 3 designs. The values provided in Table 8.13 are preferred for Level 1 and 2 designs. The mean flexural strength from the PCC calibration test sections was 705 psi.

Table 8.13—Time Dependent Compressive Strength for Georgia Concrete Mixtures

		Age of Specimen (days)				
		7	14	28	90	20-yr/28 day
Mix Number	Mixture ID	Compressive Strength (psi)				
1	541/0FA/0.431/11.91G/4.9	4,680	5,420	6,370	6,240	1.20
2	541/0FA/0.524/12.75G/4.0	4,810	5,440	6,300	6,680	
3	595/0FA/0.43/11.4G/6.2	4,410	4,870	5,350	5,780	
4	600/0FA/0.47/11.62G/6.1	3,130	3,820	4,280	4,490	
5	580/12.2FA/0.493/12.54G/4.5	3,190	3,700	4,390	5,340	
6	579/19.69FA/0.446/11.67G/5.5	3,090	3,580	4,140	5,420	
7	622/26FA/0.422/12.14G/3.1	4,080	4,610	5,420	6,650	
8	605/20.66FA/0.43/12.09D/5.0	4,240	4,920	5,700	7,450	
9	590/18.64FA/0.438/10.87G/4.9	4,980	5,980	6,650	7,940	
10	590/18.64FA/0.439/10.87D/5.9	4,150	4,450	5,220	6,570	
11	600/20.16FA/0.47/11.42G/3.6	4,930	5,640	6,020	8,130	
12	600/20.16FA/0.47/11.42G/4.7	3,820	4,520	5,190	6,950	

NOTE: Mixture IDs signify: Cement Content/Fly Ash %/Water-Cement Ratio/CA Fraction/Air Content

2. 28-Day Modulus of elasticity: The modulus of elasticity (MOE) can be entered manually or calculated by the program based on the 28-day flexural or compressive strength value. Elastic moduli were acquired through RP 18-03 and presented in Table 8.14. For routine designs, it is recommended that the value be calculated by the software. The average elastic modulus from the PCC calibration test sections was 4,500,000 psi.

Table 8.14—Time Dependent Elastic Modulus for Georgia Concrete Mixtures

		Age of Specimen (days)				
		7	14	28	90	**20-yr/28 day**
Mixture Number	**Mixture ID**	**Static MOE (ksi)**				
1	541/0FA/0.431/11.91G/4.9	5,100	5,150	5,350	5,650	1.20
2	541/0FA/0.524/12.75G/4.0	4,750	5,100	5,600	5,850	
3	595/0FA/0.43/11.4G/6.2	4,350	4,450	4,600	5,100	
4	600/0FA/0.47/11.62G/6.1	3,650	3,850	4,100	4,400	
5	580/12.2FA/0.493/12.54G/4.5	2,650	2,950	3,150	3,700	
6	579/19.69FA/0.446/11.67G/5.5	2,900	2,950	3,200	3,650	
7	622/26FA/0.422/12.14G/3.1	3,150	3,350	3,550	4,250	
8	605/20.66FA/0.43/12.09D/5.0	5,500	5,950	6,400	6,600	
9	590/18.64FA/0.438/10.87G/4.9	3,550	3,900	4,150	4,600	
10	590/18.64FA/0.439/10.87D/5.9	5,400	5,550	6,050	7,150	
11	600/20.16FA/0.47/11.42G/3.6	4,950	5,050	5,350	5,950	
12	600/20.16FA/0.47/11.42G/4.7	4,350	4,850	5,250	5,650	

NOTE: Mixture IDs signify: Cement Content/Fly Ash %/Water-Cement Ratio/CA Fraction/Air Content

3. 28-Day modulus of rupture: The modulus of rupture (MOR) is only required for input level 1 and must be entered manually alongside elastic modulus values. Modulus of rupture values were acquired through RP 18-03 and are presented in Table 8.15. However, MOR specimens were tested using 3x4x16 inch beam sizes and may produce greater MOR values as a result.

Table 8.15—Time Dependent Modulus of Rupture for Georgia Concrete Mixtures

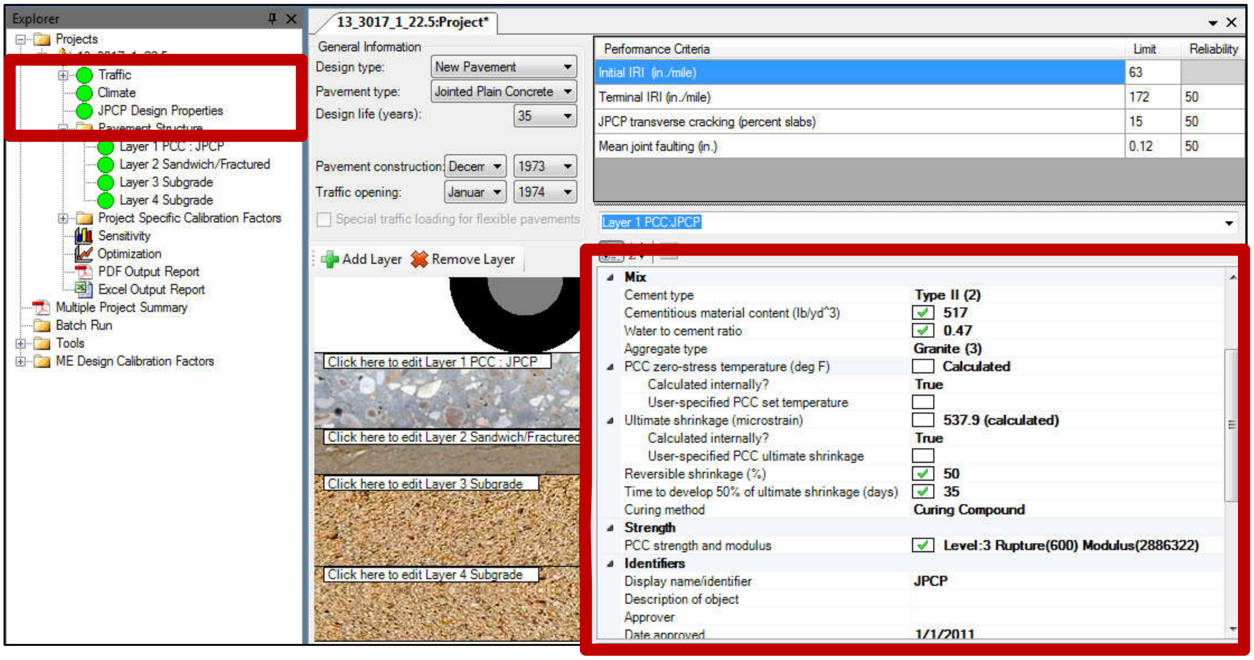
		Age of Specimen (days)				
		7	14	28	90	20-yr/28 day
Mixture Number	**Mixture ID**	**MOR (psi)**				
1	541/0FA/0.431/11.91G/4.9	685	705	710	730	1.20
2	541/0FA/0.524/12.75G/4.0	640	695	725	730	
3	595/0FA/0.43/11.4G/6.2	670	665	805	690	
4	600/0FA/0.47/11.62G/6.1	630	630	665	665	
5	580/12.2FA/0.493/12.54G/4.5	595	640	650	720	
6	579/19.69FA/0.446/11.67G/5.5	615	600	620	730	
7	622/26FA/0.422/12.14G/3.1	600	640	670	720	
8	605/20.66FA/0.43/12.09D/5.0	615	630	660	765	
9	590/18.64FA/0.438/10.87G/4.9	700	700	700	755	
10	590/18.64FA/0.439/10.87D/5.9	615	645	635	765	
11	600/20.16FA/0.47/11.42G/3.6	620	730	785	755	
12	600/20.16FA/0.47/11.42G/4.7	650	640	715	740	

NOTE: Mixture IDs signify: Cement Content/Fly Ash %/Water-Cement Ratio/CA Fraction/Air Content

8.4.5 Screen Shots for the PCC Properties: New Layers

The following are screen shot examples that show the PCC material property inputs discussed within this section of Chapter 8. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the PCC Material Properties



General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete

Design life (years): 35

Pavement construction: Decem 1973

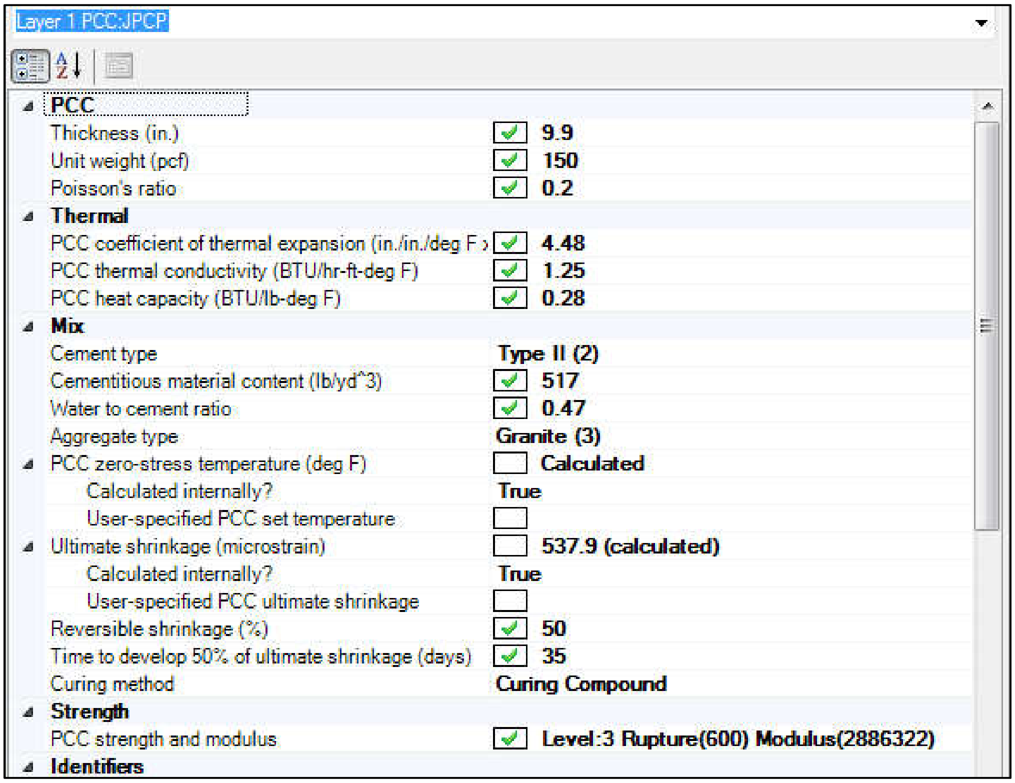
Traffic opening: Januar 1974

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
JPCP transverse cracking (percent slabs)	15	50
Mean joint faulting (in.)	0.12	50

Mix	
Cement type	**Type II (2)**
Cementitious material content (lb/yd^3)	☑ **517**
Water to cement ratio	☑ **0.47**
Aggregate type	**Granite (3)**
PCC zero-stress temperature (deg F)	☐ **Calculated**
Calculated internally?	**True**
User-specified PCC set temperature	☐
Ultimate shrinkage (microstrain)	☐ **537.9 (calculated)**
Calculated internally?	**True**
User-specified PCC ultimate shrinkage	☐
Reversible shrinkage (%)	☑ **50**
Time to develop 50% of ultimate shrinkage (days)	☑ **35**
Curing method	**Curing Compound**
Strength	
PCC strength and modulus	☑ **Level:3 Rupture(600) Modulus(2886322)**
Identifiers	
Display name/identifier	**JPCP**
Description of object	
Approver	
Date approved	1/1/2011

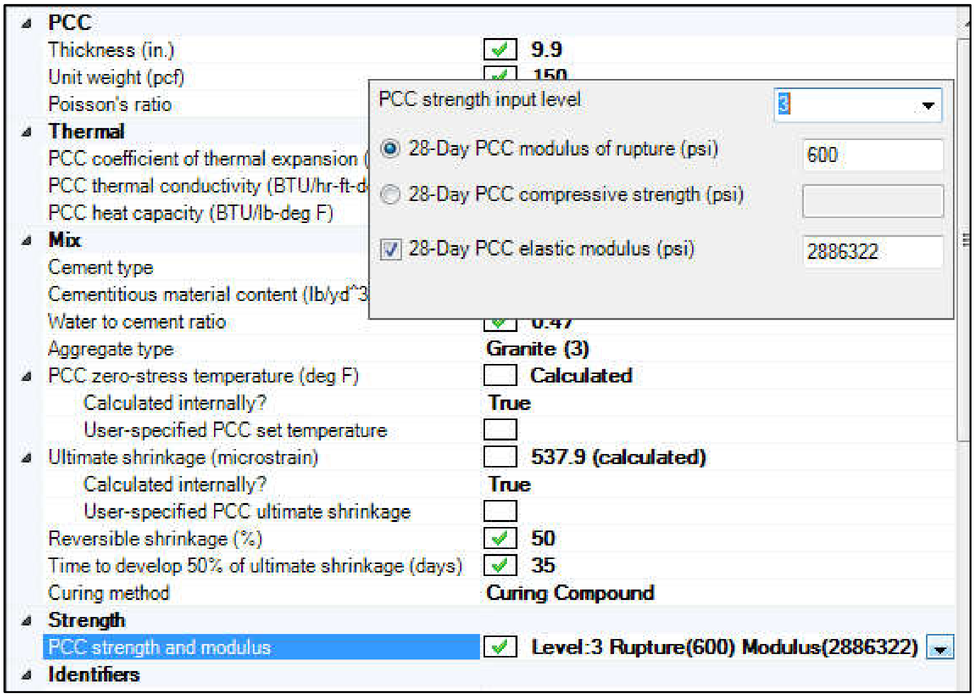
PCC Material Properties



Layer 1 PCC:JPCP

PCC	
Thickness (in.)	☑ 9.9
Unit weight (pcf)	☑ 150
Poisson's ratio	☑ 0.2
Thermal	
PCC coefficient of thermal expansion (in./in./deg F ›	☑ 4.48
PCC thermal conductivity (BTU/hr-ft-deg F)	☑ 1.25
PCC heat capacity (BTU/lb-deg F)	☑ 0.28
Mix	
Cement type	Type II (2)
Cementitious material content (lb/yd^3)	☑ 517
Water to cement ratio	☑ 0.47
Aggregate type	Granite (3)
PCC zero-stress temperature (deg F)	☐ Calculated
Calculated internally?	True
User-specified PCC set temperature	☐
Ultimate shrinkage (microstrain)	☐ 537.9 (calculated)
Calculated internally?	True
User-specified PCC ultimate shrinkage	☐
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	☑ Level:3 Rupture(600) Modulus(2886322)
Identifiers	

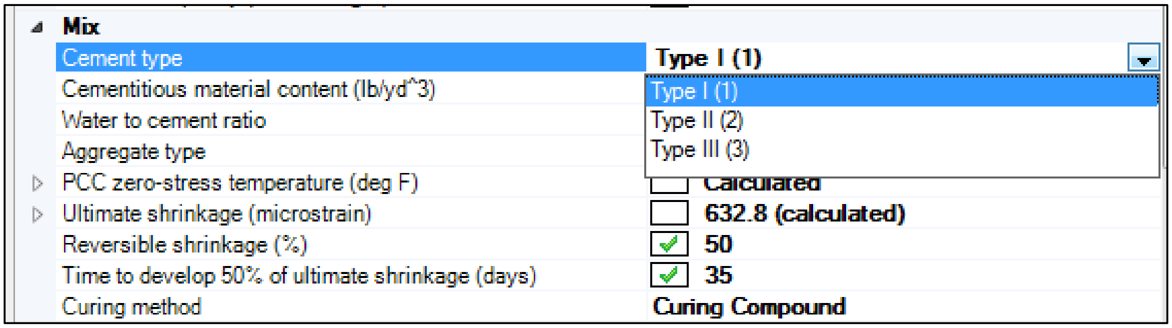
PCC Strength and Modulus



PCC	
Thickness (in.)	☑ 9.9
Unit weight (pcf)	☑ 150
Poisson's ratio	
Thermal	
PCC coefficient of thermal expansion (	
PCC thermal conductivity (BTU/hr-ft-d	
PCC heat capacity (BTU/lb-deg F)	
Mix	
Cement type	
Cementitious material content (lb/yd^3	
Water to cement ratio	☑ 0.47
Aggregate type	Granite (3)
PCC zero-stress temperature (deg F)	☐ Calculated
Calculated internally?	True
User-specified PCC set temperature	☐
Ultimate shrinkage (microstrain)	☐ 537.9 (calculated)
Calculated internally?	True
User-specified PCC ultimate shrinkage	☐
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	
PCC strength and modulus	☑ Level:3 Rupture(600) Modulus(2886322)
Identifiers	

PCC strength input level	3
● 28-Day PCC modulus of rupture (psi)	600
○ 28-Day PCC compressive strength (psi)	
☑ 28-Day PCC elastic modulus (psi)	2886322

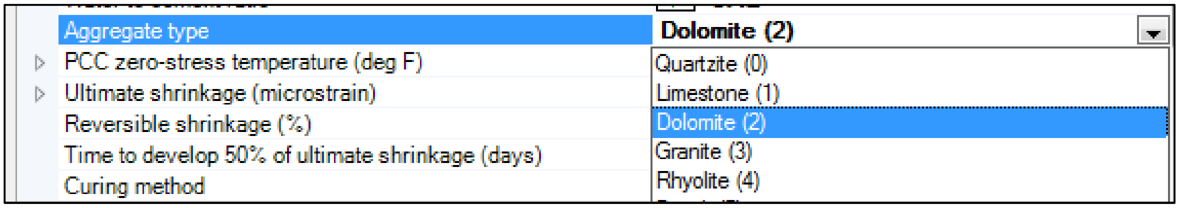
Cement Type



Mix

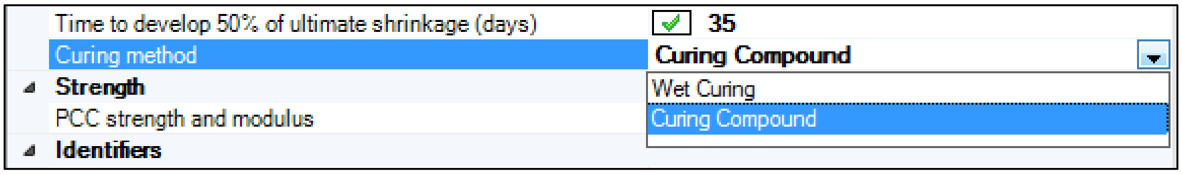
Cement type	Type I (1)
Cementitious material content (lb/yd^3)	Type I (1) Type II (2) Type III (3)
Water to cement ratio	
Aggregate type	
PCC zero-stress temperature (deg F)	☐ Calculated
Ultimate shrinkage (microstrain)	☐ 632.8 (calculated)
Reversible shrinkage (%)	☑ 50
Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound

Aggregate Type



Aggregate type	Dolomite (2)
PCC zero-stress temperature (deg F)	Quartzite (0)
Ultimate shrinkage (microstrain)	Limestone (1)
Reversible shrinkage (%)	Dolomite (2)
Time to develop 50% of ultimate shrinkage (days)	Granite (3)
Curing method	Rhyolite (4)

Curing Method



Time to develop 50% of ultimate shrinkage (days)	☑ 35
Curing method	Curing Compound
Strength	Wet Curing
PCC strength and modulus	Curing Compound
Identifiers	

8.5 PORTLAND CEMENT CONCRETE (PCC) – EXISTING FOR REHABILITATION DESIGNS

8.5.1 Existing Intact PCC Slabs

Existing intact PCC properties are required for HMA overlay, unbonded PCC overlay and for concrete pavement restoration. Example screen shots showing the PCC material property inputs are included at the end of this section, primarily for the fractured slab condition. The PCC properties are the same as for new PCC mixes with the following exceptions.

The designer must assess the overall condition of the existing pavement PCC. Select typical modulus of elasticity values from the range of values given in Table 8.16 based on the amount of cracking (all types including longitudinal, transverse, corner, diagonal) of the existing PCC slabs.

Table 8.16—Recommended Effective Modulus Values for Existing Intact PCC Slabs

Qualitative Description of Pavement Condition	Typical Modulus Ranges, psi	Mean Modulus, psi
Good/Adequate: (10 to 20 percent cracked slabs)	2 to 4 x 10^6	3.0 x 10^6
Marginal: (20 to 50 percent cracked slabs)	1 to 2 x 10^6	1.6 x 10^6
Poor/inadequate: (>50 percent cracked slabs)	0.2 to 1 x 10^6	0.65 x 10^6

NOTE: For backcalculation of PCC slab elastic modulus for uncracked slabs, the resulting modulus value is essentially a dynamic value that must be reduced by multiplying by 0.8 to obtain a static value to input into the Pavement ME.

8.5.2 Fractured PCC Slabs

Existing fractured PCC properties are required for HMA or PCC overlays over fractured PCC pavements. GDOT does not routinely consider fracturing PCC slabs as part of their rehabilitation strategies. Guidance and the recommended input values for fractured PCC slabs are provided for future considerations. The two common methods of fracturing JPCP slabs include: crack and seat and rubblization.

Of the two, the most effective to minimize reflection cracking is rubblization where the PCC slabs are broken into aggregate-sized pieces (less than 6 inches in diameter) that behave similar to a high-quality crushed aggregate layer. The PMED software can be used directly to design an HMA overlay of rubblized concrete similar to a flexible pavement design.

Crack and seat involves cracking the slab into larger pieces (e.g., 3 to 6 ft. pieces) where the key design approach is to provide adequate HMA thickness to reduce deflections in the cracked JPCP to prevent the pieces from becoming loose and rocking which leads to reflection cracking. The PMED software cannot be used to directly design a crack and seat project because HMA over a cracked and seated slab behaves totally different than a flexible pavement. Only the selection of a very conservative modulus of the cracked slab can obtain a reasonable design (the program does not model reflection cracking originating from crack and seated PCC pieces). Thus, it is recommended to assume conservative reflection cracking values to predicted transverse cracking values. The elastic modulus of the fractured PCC slabs should be selected in accordance with the values in Table 8.17.

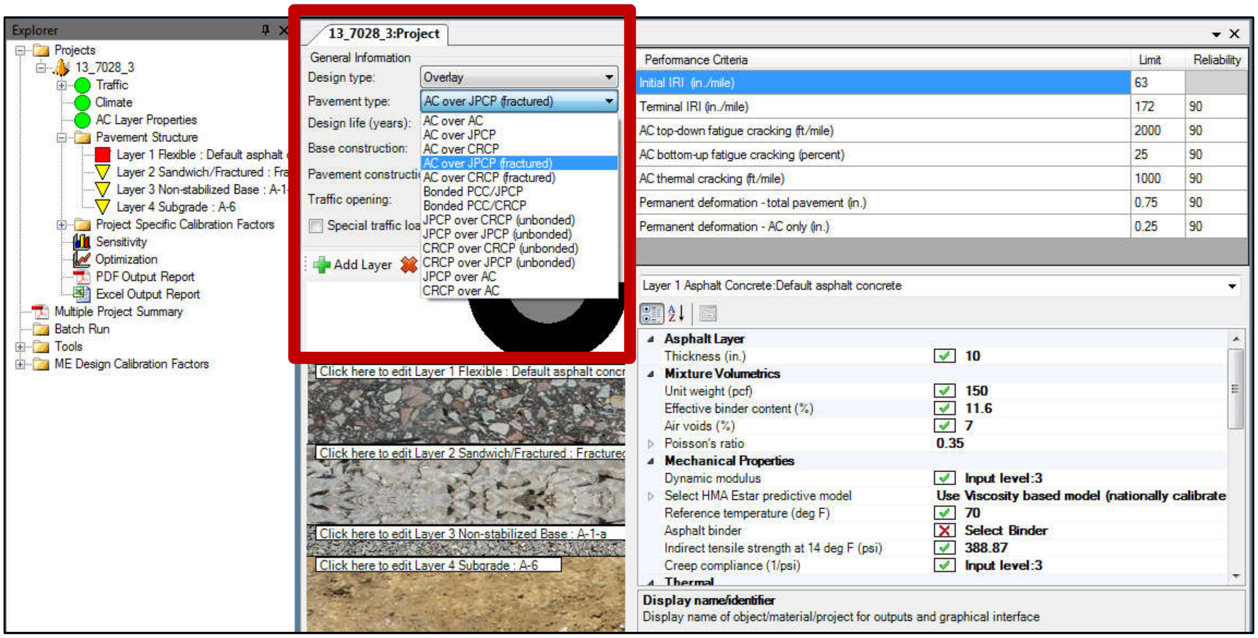
Table 8.17—Recommended Modulus Values for Fractured and Rubblized PCC Slabs

Fractured PCC Type	Elastic Modulus, psi
Rubblized (into crushed granular like material)	50,000
Crack and seat	100,000

8.5.3 Screen Shots for the Fractured PCC Properties

The following are screen shot examples that show the PCC material property inputs for the fractured slabs, as discussed within this section of Chapter 8. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the JPCP Fractured Slabs



General Information
Design type: Overlay
Pavement type: AC over JPCP (fractured)
Design life (years):
Base construction:
Pavement constructi
Traffic opening:
☐ Special traffic loa

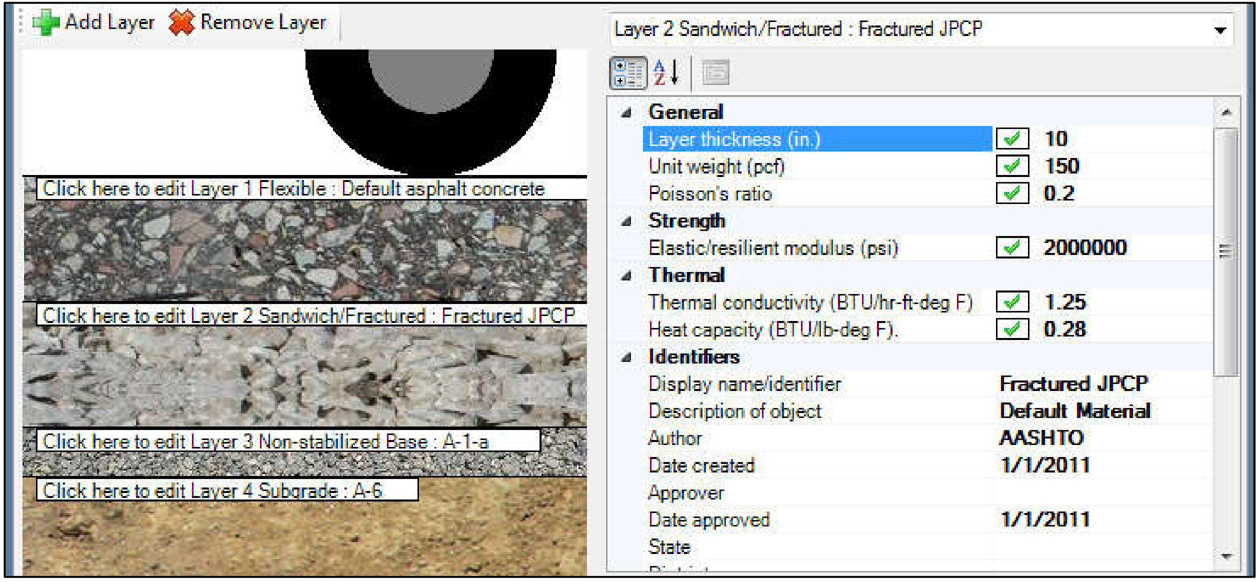
Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal cracking (ft/mile)	1000	90
Permanent deformation - total pavement (in.)	0.75	90
Permanent deformation - AC only (in.)	0.25	90

Layer 1 Asphalt Concrete:Default asphalt concrete

Asphalt Layer		
Thickness (in.)	☑	10
Mixture Volumetrics		
Unit weight (pcf)	☑	150
Effective binder content (%)	☑	11.6
Air voids (%)	☑	7
Poisson's ratio		0.35
Mechanical Properties		
Dynamic modulus	☑	Input level:3
Select HMA Estar predictive model		Use Viscosity based model (nationally calibrate
Reference temperature (deg F)	☑	70
Asphalt binder	☒	Select Binder
Indirect tensile strength at 14 deg F (psi)	☑	388.87
Creep compliance (1/psi)	☑	Input level:3
Thermal		

Display name/identifier
Display name of object/material/project for outputs and graphical interface

Fractured JPCP Layer Properties



Layer 2 Sandwich/Fractured : Fractured JPCP

General		
Layer thickness (in.)	☑	10
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Strength		
Elastic/resilient modulus (psi)	☑	2000000
Thermal		
Thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
Heat capacity (BTU/lb-deg F)	☑	0.28
Identifiers		
Display name/identifier		Fractured JPCP
Description of object		Default Material
Author		AASHTO
Date created		1/1/2011
Approver		
Date approved		1/1/2011
State		

8.6 UNBOUND AGGREGATE BASE MATERIALS AND SOILS

The material properties needed for the unbound aggregate base or subbase layer and embankment or subgrade soils are the same in the PMED software for flexible and rigid pavement designs. Example screen shots showing the unbound aggregate base and subgrade soil or embankment material property inputs are included at the end of this section.

The GDOT materials library includes one file for each of the different unbound base materials typically used in construction and one file for each of the major GDOT soil classifications found in Georgia. The following subsections simply describe the properties included in these files.

8.6.1 General Physical and Volumetric Properties

The following unbound layer and embankment soil properties are site specific and easily determined from laboratory tests. Table 8.18 depicts the typical material properties for standard GDOT soil classifications.

1. Gradation of the material.
2. Atterberg limits tests.
3. Specific gravity.
4. Maximum dry density or the in-place density at the time of construction.
5. Optimum water content or the in-place water content at the time of construction.

Table 8.18—Material Library Subgrade Properties

Material Name	Input Properties								
	Percent Passing, %					Liquid Limit	Plastic Limit	Maximum Dry Density, pcf	Optimum Water Content, %
	No. 4	No. 10	No. 40	No. 60	No. 200				
IA1	100	99.5	70.1	46.2	13.1	25	9	118	10.7
IA2	100	99.7	70.7	48.0	14.7	23	7	116	12.6
IA3	100	99.5	75.4	55.5	12.7	25	9	106	14.5
IIB1	100	100	73.9	52.2	23.9	25	9	122	9.9
IIB2	100	99.3	72.8	55.0	29.0	28	9	118	11.5
IIB3	100	98.8	75.9	59.9	34.6	23	7	112	14.4
IIB4	100	99.1	80.2	66.8	41.4	39	13	100	19.1

For the GAB layers, all default layer properties included in the PMED software for a Crushed Stone Base should be assumed, except for resilient modulus, optimum water content, and maximum dry density. Predefined GAB material files have been developed for the GDOT library using the information found in Table 8.18 and Appendix C. These values represent the recommended values for different GAB materials used in Georgia.

A subsurface investigation or soil survey should be planned to determine the above inputs for the project. If a soil survey and/or pavement investigation is not completed prior to design, the geotechnical engineer can provide values for these inputs based on historical information. The geotechnical engineer should be consulted to determine representative values for each design segment along the project.

- For the soils that are not disturbed during construction, the in-place moisture content and dry density should be entered.

- For the crushed gravel and other aggregate base materials used in Georgia or the embankment soils that are compacted, the mid-range of the specifications or construction data from previous projects can be used to determine the input values. The expected moisture content and dry density after compaction should be entered.

8.6.2 Resilient Modulus

Kim (2013) conducted repeated load resilient modulus tests on typical aggregate base materials used in Georgia and on the more common soils encountered in Georgia through RP 12-07. Resilient modulus tests can also be determined from Dynamic Cone Penetrometer (DCP) tests and physical properties of the material/soil, which is input level 2.

For new alignments or new designs, as well as rehabilitation designs, Tables 8.19 and 8.20 provide the suggested mean value and the range of those values for the different unbound materials that were used in the calibration refinement for Georgia and derived from the repeated load resilient modulus tests for the granular aggregate base and subgrade soils, respectively.

Table 8.19—Resilient Modulus Values for Granular Aggregate Base Materials in Georgia

Type of Material or Soil			Optimum Water Content, %	Maximum Dry Density, pcf	Typical Mean Resilient Modulus, psi
Group	Source	Type			
II	NA*	Recycled Concrete	11.2	121.0	25,000
II	Lithonia	Granite Gneiss	5.7	133.9	25,000
II	Stockbridge	Granite Gneiss	5.9	134.2	21,000
II	Columbus	Granite Gneiss	6.0	137.6	20,000
II	Dahlonega	Granite Gneiss	5.6	135.2	17,000
II	Gainesville	Mylonitic Gneiss	6.0	136.6	20,000
II	Hitchcock	Mylonitic Gneiss	6.2	141.2	22,000
II	Walton County	Biotite Gneiss	6.4	135.0	22,000
	Default Values	All Gneiss GAB	6.0	136.5	23,000
I	Dalton	Limestone	6.6	142.5	22,000
II	Demorest	Meta Sandstone	5.3	137.4	18,000
I	Mayo Mine	Limerock	13.6	112.6	25,000

** Not Applicable.*

Table 8.20—Resilient Modulus Values Derived for Selected Subgrade Soils in Georgia

Type of Material or Soil			Optimum Water Content, %	Maximum Dry Density, pcf	Typical Mean Resilient Modulus, psi
Location or County	GA Soil Class	AASHTO Class			
Default		A-1-a	7.4	127.2	18,000
Toombs	IA1	A-1-b	11.9	119.3	13,000
Default		A-1-b	9.1	123.7	18,000
Lowndes	IIB2	A-2-4	4.7	113.1	17,000
Washington	IIB2	A-2-4	11.0	117.8	18,000
Default		A-2-4	9.0	124.0	16,500
Franklin	IIB3	A-2-4	22.6	105.1	5,000
Default		A-2-5	10.1	121.9	16,000
Default		A-2-6	10.0	121.9	16,000
Coweta	IIB3	A-2-7	16.7	105.3	9,000
Chatham	IIB4	A-2-4	12.7	97.4	15,000
Default		A-2-7	10.6	120.8	16,000
Default		A-3	7.3	120.0	16,000
Default		A-4	11.8	118.4	15,000
Lincoln	IIB4	A-4	23.5	93.4	8,000
Default		A-5	11.4	119.2	8,000
Default		A-6	17.1	107.9	14,000
Default		A-7-5	20.0	102.0	10,000
Walton	IIB4	A-7-6	16.8	104.8	10,000
Default		A-7-6	22.2	97.7	9,000

NOTE: The optimum water content and maximum dry density listed in this table were determined using the Modified Proctor compaction effort.

Where Table 8.20 is not applicable, Figure 8.3 may be used to determine an appropriate subgrade classification to use for input level 2 and 3 designs based on your project location. Subgrade material files of the same name in the GDOT library include a typical resilient modulus value for that region along with the particle size distribution, maximum dry density, and optimum moisture content. The properties for each material classification are summarized in Table 8.18.

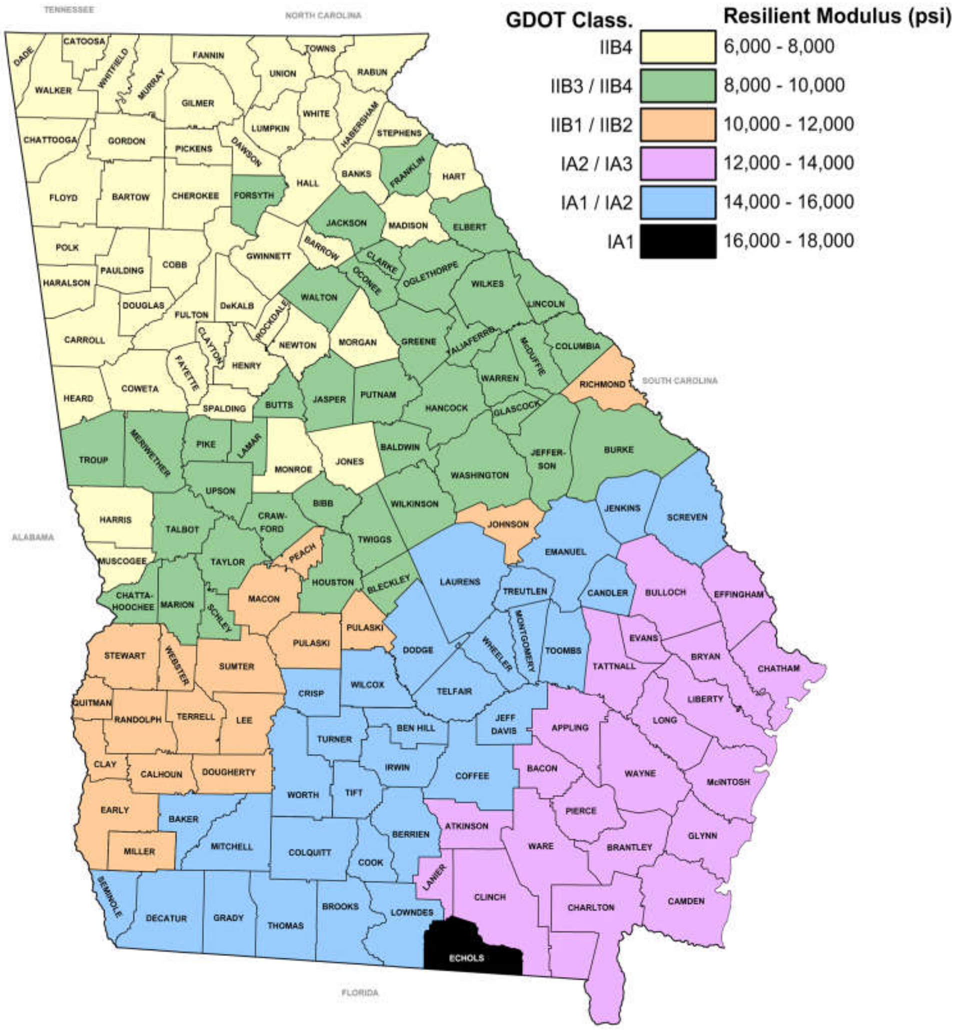


Figure 8.3—Subgrade Classification and Modulus Inputs by County

For rehabilitation/reconstruction designs, the resilient modulus of each unbound layer and embankment can be backcalculated from deflection basin data (input level 1) or estimated from DCP and other physical properties of the soil (input level 2). If the resilient modulus values are determined by backcalculating elastic layer modulus values from deflection basin tests, those values need to be adjusted to laboratory conditions. Table 8.21 lists the adjustment ratios that should be applied to the unbound layers for use in design. More importantly, the in-place water content and dry density need to be entered in the PMED software when the in place resilient modulus values are used.

GDOT generally does not use the Dynamic Cone Penetrometer (DCP) for pavement evaluations and in estimating the resilient modulus of the unbound materials and soils. However, the DCP (ASTM D6951/D6951M-18) was used in the field investigation of all non-LTPP roadway segments included in the local calibration process. Equation 6 was used to calculate the resilient modulus from the penetration rate measured with a standard 17.6-lb (8-kg) DCP and may be applied to fine- and coarse-grained soils, granular construction materials, and weak stabilized or modified materials. It is suggested that the DCP be considered for future use for rehabilitation design for the unbound pavement layers and subgrade, especially when FWD deflection basin data are unavailable.

$$M_R = 17.6\left(\frac{292}{(DPI)^{1.12}}\right)^{0.64}(C_{DCP}) \tag{6}$$

Where:

M_R = Resilient modulus of unbound material, MP_a.

DPI = Penetration rate or index, mm/blow.

C_{DCP} = Adjustment factor for converting the elastic modulus to a laboratory resilient modulus value.

The resilient modulus values can be estimated from the DCP tests using equation 6, but those values need to be adjusted to laboratory conditions. Table 8.21 provides the adjustment factors recommended for use in estimating resilient modulus from the DCP penetration rate. (It should be noted and understood that the PMED does not adjust the resilient modulus values calculated from the DCP and the values in Table 8.21 have not been field verified for GDOT).

Table 8.21—Resilient Modulus Values Derived for Subgrade Soil from DCP Tests for Use in Georgia

Material/Soil Class		Condition	Adjustment Factor, C_{DCP}
Fine-Grained; Low Plasticity Soil	Clay-Silt	Above Optimum Water Content	1.90
	Soil-Sand Mix	At or Below Optimum Water Content	1.05
	Soil-Aggregate Mix with Large Aggregate	At or Below Optimum Water Content	0.60
Coarse-Grained Material	Soil-Aggregate Mix	At or Below Optimum Water Content	0.60
	Crushed Aggregate	At or Below Optimum Water Content	1.04

The resilient modulus of aggregate or granular base/subbase is dependent on the resilient modulus of the supporting layers. As a rule of thumb, the resilient modulus entered into PMED for a granular base layer should be less than three times the resilient modulus of the supporting layer to avoid decompaction of that layer. This layer modulus ratio is dependent on the type of base and thickness of the base layer.

Table 8.22—Summary of the Adjustment Factors Recommended for Use in Georgia to Convert Backcalculated Layer Modulus Values to Laboratory Equivalent Modulus Values

Layer & Material Type	**Layer Description**	**Adjustment Factor, (M_R/E)**	
		FHWA Pamphlet	**Georgia Sites**
Aggregate Base Layers	Granular base under a Portland Cement Concrete (PCC) surface	1.32	---
	Granular base under a CAM layer, semi-rigid pavement	---	0.75
	Granular base above a stabilized material (a Sandwich Section)	1.43	---
	Granular base under an HMA surface or base	0.62	0.60
Subgrade Soil/Foundation	Soil under a CAM layer, no granular base	---	1.00
	Soil under a semi-rigid pavement with a granular base/subbase	---	0.50
	Soil Under a Stabilized Subgrade	0.75	---
	Soil under a full-depth HMA pavement	0.52	---
	Soil under flexible pavement with a granular base/subbase	0.35	0.50
Cement Aggregate Base Layer	Cement stabilized or treated aggregate layers	---	1.50
HMA Mixtures	HMA surface and base layers, 41 °F	1.00	0.9
	HMA surface and base layers, 77 °F	0.36	0.6
	HMA surface and base layers, 104 °F	0.25	0.5

Finally, the optimum water content is generally provided for the different unbound materials and soils encountered along a project and may also be used as a means to estimate resilient modulus. Figure 8.4 can be used to adjust the resilient modulus of the unbound aggregate base layer to ensure that it is in agreement with the above rule of thumb. Note that as the base comprises a single layer, only a single adjustment based on base layer thickness and subgrade resilient modulus is required.

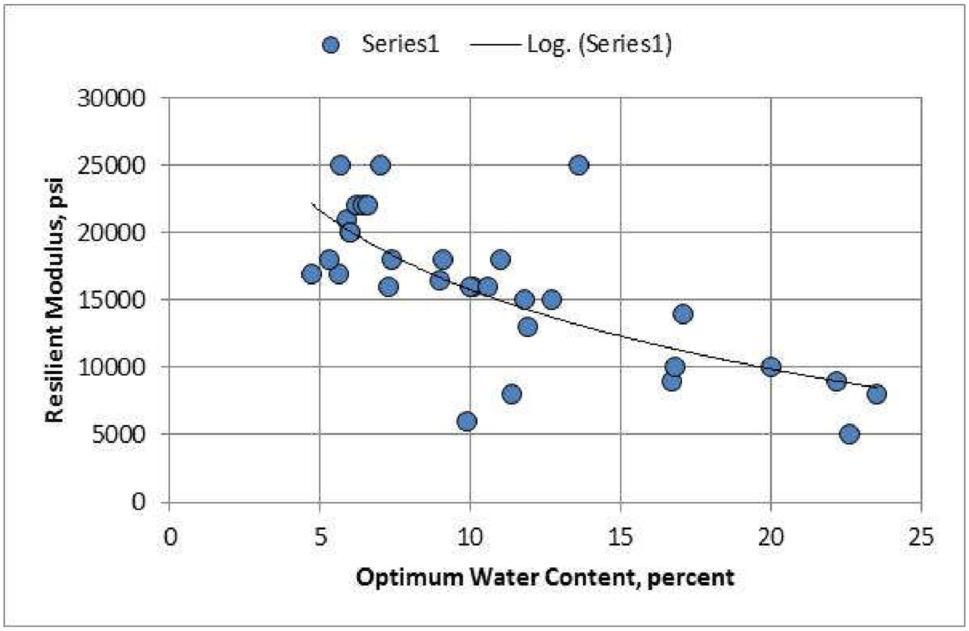


Figure 8.4—Estimating the Resilient Modulus from the Optimum Water Content

8.6.3 Poisson's Ratio

Poisson's ratio is another input parameter needed for the unbound materials and soils. Table 8.23 lists the values that were used during the regional calibration refinement effort and are recommended for use in future design runs.

Table 8.23—Poisson's Ratio Suggested for Use for Unbound Layers

GDOT Soil Class	Description	Poisson's Ratio
IA1 to IA2	Medium to well-graded sand or clayey sand	0.40
IA3	Fine-grained, silty, or clayey sand	0.40
IIB4	High plasticity fine-grained soils (clays and silts).	0.45
IIB2 to IIB3	Low plasticity fine-grained soils (clays and silts).	0.40
IIB1 or Better	Non-plastic or low plasticity fine-grained soil or coarse-grained soil with more than 35 percent fines or material passing the #200 sieve.	0.35
IIIC1	High plasticity and expansive clay soils.	0.45
I or Base	Soil-Aggregate base materials which are predominately coarse-grained.	0.35
GAB	Crushed gravel or crushed stone base materials used as a base or subbase layer.	0.30

8.6.4 Hydraulic Properties

The other input parameters for the unbound layers are more difficult to measure and were not readily available for use in the regional calibration refinement effort. For these inputs, the default values recommended for use in the MOP Second Edition were used to predict the distresses. Therefore, the MOP default values are also recommended for use in Georgia for the following properties.

1. Soil saturated hydraulic conductivity.
2. Soil-water characteristic curves.

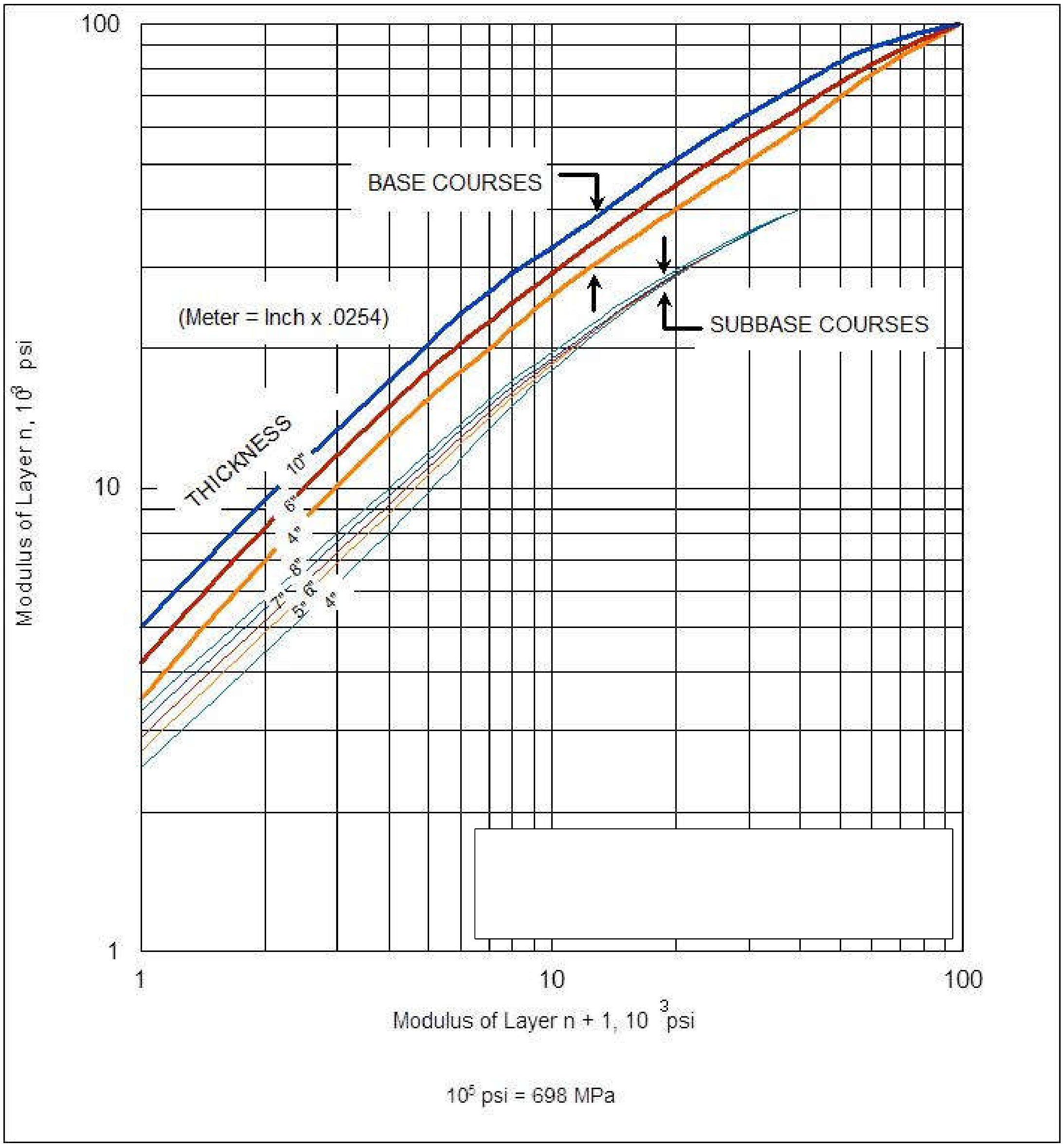
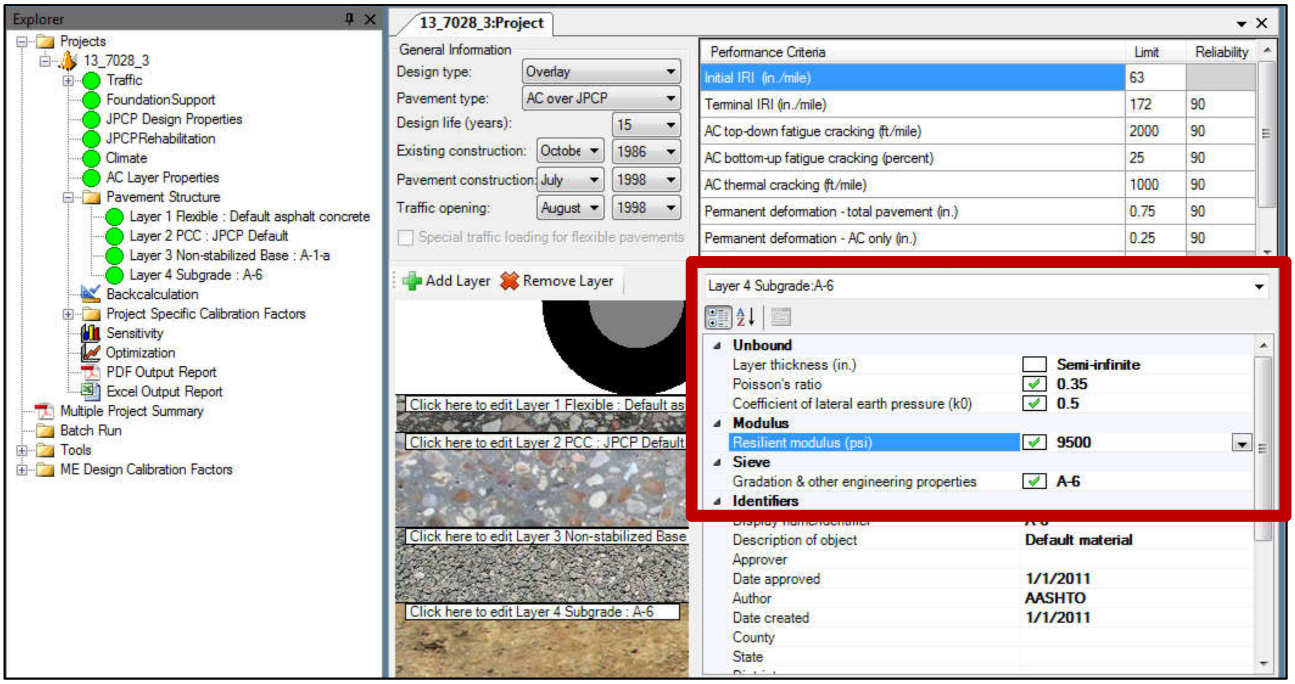


Figure 8.5—Limiting Layer Modulus Criterion of Unbound Aggregate Base Layers

8.6.5 Screen Shots for the Unbound Base and Subgrade Layer Properties

The following are screen shot examples that show the unbound base and subgrade layer property inputs, as discussed within this section of Chapter 8. The material and layer properties are the same between the aggregate base and subgrade or embankment layers. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the Unbound Layers



Explorer

- Projects
  - 13_7028_3
    - Traffic
    - FoundationSupport
    - JPCP Design Properties
    - JPCPRehabilitation
    - Climate
    - AC Layer Properties
    - Pavement Structure
      - Layer 1 Flexible : Default asphalt concrete
      - Layer 2 PCC : JPCP Default
      - Layer 3 Non-stabilized Base : A-1-a
      - Layer 4 Subgrade : A-6
    - Backcalculation
    - Project Specific Calibration Factors
    - Sensitivity
    - Optimization
    - PDF Output Report
    - Excel Output Report
- Multiple Project Summary
- Batch Run
- Tools
- ME Design Calibration Factors

13_7028_3:Project

General Information

Design type: Overlay

Pavement type: AC over JPCP

Design life (years): 15

Existing construction: Octobe 1986

Pavement construction: July 1998

Traffic opening: August 1998

☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	90
AC top-down fatigue cracking (ft/mile)	2000	90
AC bottom-up fatigue cracking (percent)	25	90
AC thermal cracking (ft/mile)	1000	90
Permanent deformation - total pavement (in.)	0.75	90
Permanent deformation - AC only (in.)	0.25	90

Layer 4 Subgrade:A-6

Unbound

Layer thickness (in.)	☐	**Semi-infinite**
Poisson's ratio	☑	**0.35**
Coefficient of lateral earth pressure (k0)	☑	**0.5**

Modulus

Resilient modulus (psi)	☑	**9500**

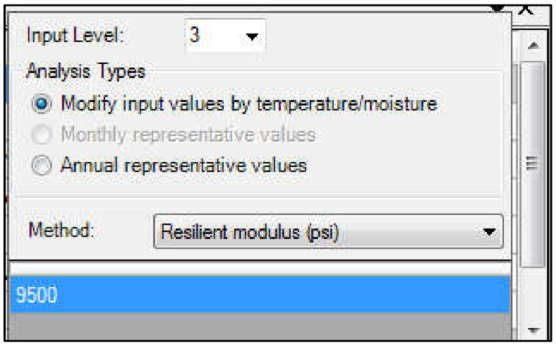
Sieve

Gradation & other engineering properties	☑	**A-6**

Identifiers

Description of object	**Default material**
Approver	
Date approved	**1/1/2011**
Author	**AASHTO**
Date created	**1/1/2011**
County	
State	

Resilient Modulus Drop Down Arrow



Input Level: 3

Analysis Types

● Modify input values by temperature/moisture

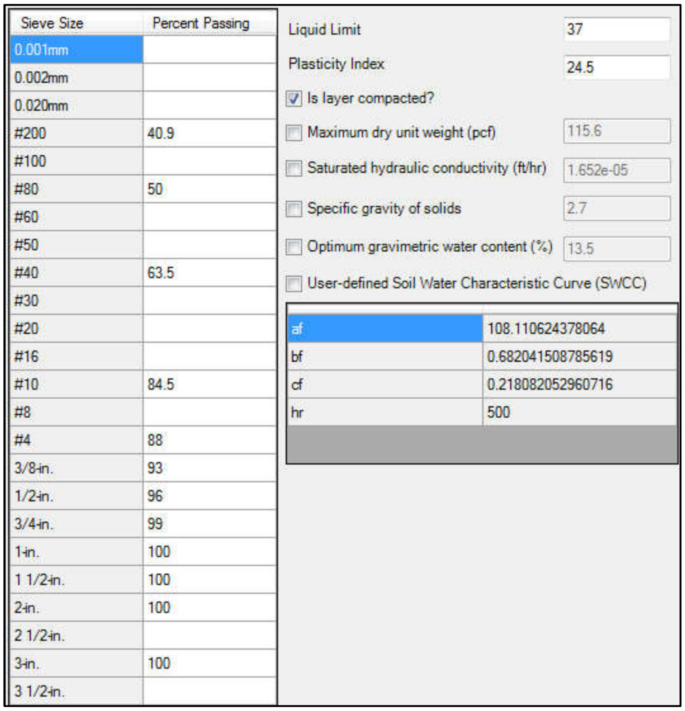
○ Monthly representative values

○ Annual representative values

Method: Resilient modulus (psi)

9500

Sieve; Gradation & Other Engineering Properties Drop Down Arrow



Sieve Size	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	40.9
#100	
#80	50
#60	
#50	
#40	63.5
#30	
#20	
#16	
#10	84.5
#8	
#4	88
3/8-in.	93
1/2-in.	96
3/4-in.	99
1-in.	100
1 1/2-in.	100
2-in.	100
2 1/2-in.	
3-in.	100
3 1/2-in.	

Liquid Limit: 37

Plasticity Index: 24.5

☑ Is layer compacted?

☐ Maximum dry unit weight (pcf): 115.6

☐ Saturated hydraulic conductivity (ft/hr): 1.652e-05

☐ Specific gravity of solids: 2.7

☐ Optimum gravimetric water content (%): 13.5

☐ User-defined Soil Water Characteristic Curve (SWCC)

af	108.110624378064
bf	0.682041508785619
cf	0.218082052960716
hr	500

8.7 CEMENT AGGREGATE BASE MIXTURES

The compressive strength (modulus of rupture), elastic modulus, and density are required inputs in the PMED software for any cementitious or pozzolonic stabilized material. The agency specific calibration factors are determined based on the quality of the CAM material. The LTPP database for test sections with cementitious layers did not contain material properties for these test sections. Table 8.24 provides the layer properties for interim use until the distress prediction models have been calibrated with more test sections. The minimum elastic modulus for all CAM layers is 100,000 psi. The other layer and material properties inputs for the cement aggregate base mixtures are the same as for the stabilized subgrade layers under Section 8.8.

Table 8.24—28-Day Strength and Elastic Moduli Suggested for Use for Cement Aggregate Base Layers

Description of CAM Layer	28-Day Compressive Strength, psi	28-Day Elastic Modulus, psi	Density, pcf
High Strength CTB (intact cores recovered with cement content greater than 6 percent)	1,500	2,100,000	150
Moderate Strength CTB (intact cores recovered with cement contents greater than 4 percent but less than 6 percent)	600	1,350,000	150
Low Strength CTB (intact cores cannot be recovered with cement content generally less than 4 percent)	Semi-Rigid Pavement Simulation not applicable; assume conventional flexible pavement with high stiffness GAB layer.		

8.8 STABILIZED SUBGRADE FOR STRUCTURAL LAYERS

The compressive strength (modulus of rupture), elastic modulus, and density are required inputs to the PMED software for any cementitious or pozzolonic stabilized material. The agency specific calibration factors are determined based on the quality of the CAM material. The LTPP database for test sections with cementitious layers did not contain material properties for these test sections. Table 8.25 provides the layer properties for interim use until the distress prediction models have been calibrated with more test sections. The minimum elastic modulus for all CAM layers is 100,000 psi. The other layer and material properties inputs for the cement aggregate base mixtures are the same as for the stabilized subgrade layers under Section 8.8.

Table 8.25—Resilient Modulus and Poisson's Ratio Values Suggested for Use for Stabilized Subgrade Layers

Type of Stabilized Subgrade	Recommended Representative Annual Resilient Modulus, psi	Recommended Poisson's Ratio
Soil Cement and Cement Stabilized Soils	100,000	0.2
Lime-Fly Ash Stabilized Soils	50,000	0.30
Lime Stabilized Soils	3 times the resilient modulus of the soil at optimum water content and maximum dry unit weight.	0.35

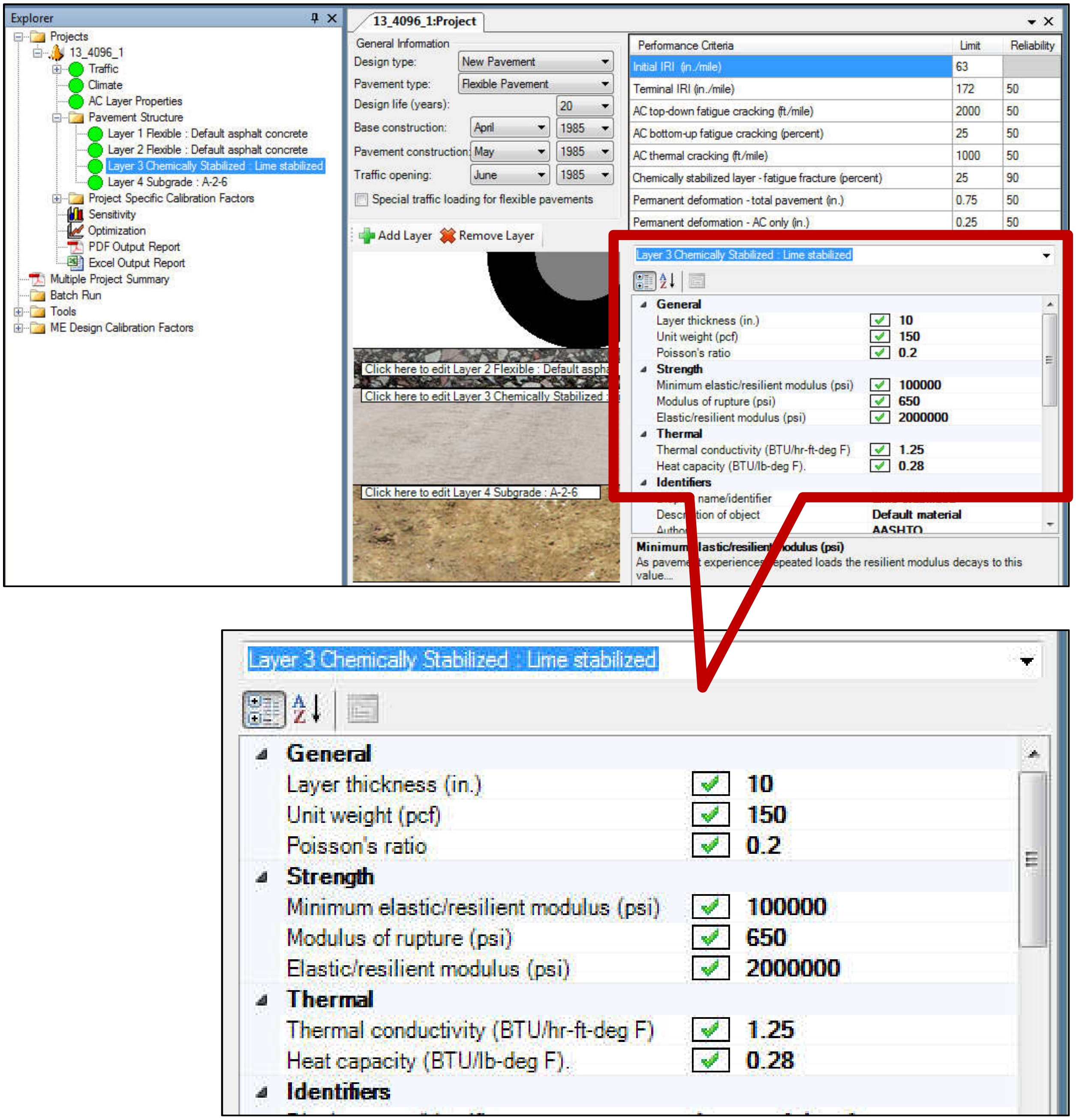
For a full-depth flexible pavement when the HMA mixture is placed directly over the stabilized subgrade soil, this is considered a semi-rigid pavement. As noted in previous chapters, semi-rigid pavements were not calibrated during the original global calibration studies, as well as for

GDOT local calibration study. Example screen shots showing the stabilized layer material property inputs are included at the end of this section below.

8.8.1 Screen Shots for the Stabilized Base/Subgrade Layer Properties

The following are screen shot examples that show the stabilized base or subgrade layer property inputs, as discussed within this section of Chapter 8. The material and layer properties are the same between the cement stabilized base layers and the cement or lime stabilized subgrade soil. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for the Stabilized Base/Subgrade Layers



General Information
Design type: New Pavement
Pavement type: Flexible Pavement
Design life (years): 20
Base construction: April 1985
Pavement construction: May 1985
Traffic opening: June 1985
☐ Special traffic loading for flexible pavements

Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Chemically stabilized layer - fatigue fracture (percent)	25	90
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50

Layer 3 Chemically Stabilized : Lime stabilized

General		
Layer thickness (in.)	☑	10
Unit weight (pcf)	☑	150
Poisson's ratio	☑	0.2
Strength		
Minimum elastic/resilient modulus (psi)	☑	100000
Modulus of rupture (psi)	☑	650
Elastic/resilient modulus (psi)	☑	2000000
Thermal		
Thermal conductivity (BTU/hr-ft-deg F)	☑	1.25
Heat capacity (BTU/lb-deg F).	☑	0.28
Identifiers		
name/identifier		
Desc tion of object		Default material
Autho		AASHTO

Minimum lastic/resilient odulus (psi)
As paveme t experiences epeated loads the resilient modulus decays to this value...

8.9 BEDROCK

Table 8.26 provides guidance on determining the inputs for a bedrock layer when it exists within the project limits. For locations where the depth to bedrock exceeds 100 inches or has more than 100 inches of soil above it, assume the subgrade is infinite and do not enter the bedrock layer. An example screen shot showing the bedrock material property inputs are included at the end of this section below.

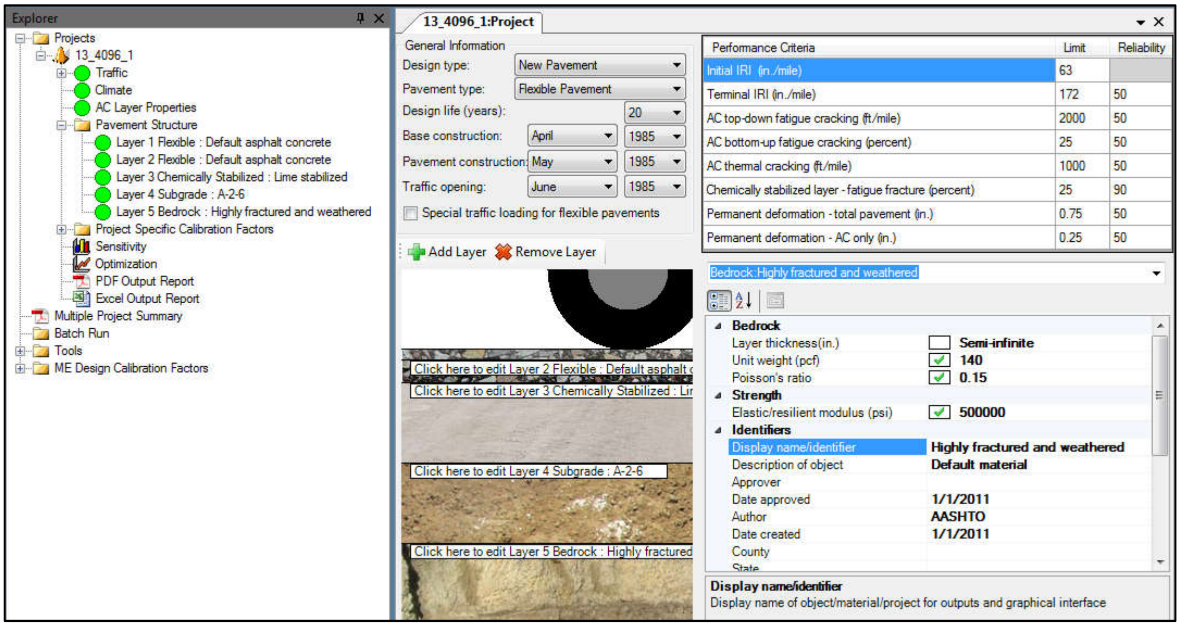
Table 8.26—Layer Properties for Bedrock

Bedrock Parameters		Recommended Input Value
Depth to Bedrock		Estimate based on the soil borings or topography.
Elastic Modulus	Severely Weathered Bedrock	50,000 psi
	Highly Fractured Bedrock	500,0000 psi
	Massive and Continuous Bedrock	1,000,000 psi
Poisson's Ratio	Severely Weathered Bedrock	0.30
	Highly Fractured Bedrock	0.20
	Massive and Continuous Bedrock	0.15
Unit Weight		140 pcf

8.9.1 Screen Shots for the Bedrock Properties

The following are screen shot examples that show the bedrock layer property inputs, as discussed within this section of Chapter 8. The drop-down arrows are used to access or select specific information and other input values for the project.

Overall Screen Shot for Bedrock



General Information

Design type: New Pavement

Pavement type: Flexible Pavement

Design life (years): 20

Base construction: April 1985

Pavement construction: May 1985

Traffic opening: June 1985

☐ Special traffic loading for flexible pavements

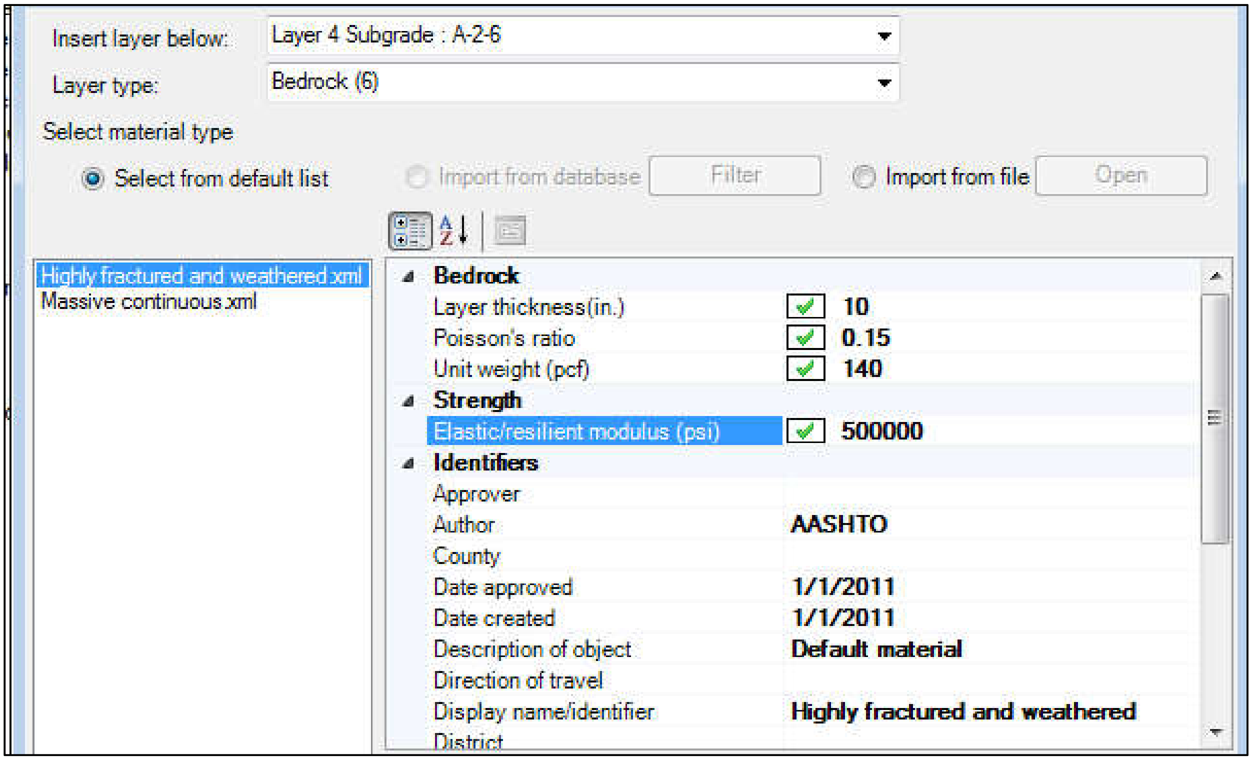
Performance Criteria	Limit	Reliability
Initial IRI (in./mile)	63	
Terminal IRI (in./mile)	172	50
AC top-down fatigue cracking (ft/mile)	2000	50
AC bottom-up fatigue cracking (percent)	25	50
AC thermal cracking (ft/mile)	1000	50
Chemically stabilized layer - fatigue fracture (percent)	25	90
Permanent deformation - total pavement (in.)	0.75	50
Permanent deformation - AC only (in.)	0.25	50

Bedrock:Highly fractured and weathered

Bedrock		
Layer thickness(in.)	☐	**Semi-infinite**
Unit weight (pcf)	☑	**140**
Poisson's ratio	☑	**0.15**
Strength		
Elastic/resilient modulus (psi)	☑	**500000**
Identifiers		
Display name/identifier		**Highly fractured and weathered**
Description of object		**Default material**
Approver		
Date approved		**1/1/2011**
Author		**AASHTO**
Date created		**1/1/2011**
County		
State		

Display name/identifier
Display name of object/material/project for outputs and graphical interface

Bedrock Layer Properties



Insert layer below: Layer 4 Subgrade : A-2-6

Layer type: Bedrock (6)

Select material type

● Select from default list ○ Import from database Filter ○ Import from file Open

Highly fractured and weathered.xml
Massive continuous.xml

Bedrock		
Layer thickness(in.)	☑	**10**
Poisson's ratio	☑	**0.15**
Unit weight (pcf)	☑	**140**
Strength		
Elastic/resilient modulus (psi)	☑	**500000**
Identifiers		
Approver		
Author		**AASHTO**
County		
Date approved		**1/1/2011**
Date created		**1/1/2011**
Description of object		**Default material**
Direction of travel		
Display name/identifier		**Highly fractured and weathered**
District		

CHAPTER 9—GEORGIA CALIBRATION FACTORS

Through the calibration efforts of RP 11-17 both LTPP and non-LTPP test sections were used to estimate the precision and bias of the transfer functions in the MOP for predicting the performance indicators (distress and roughness) of GDOT’s pavements in PMED. The resulting distress prediction models, or transfer functions, can be used to optimize new pavement and rehabilitation design strategies, and used in forecasting of maintenance, repair, rehabilitation, and reconstruction costs.

A summary of the input parameters and associated design level used to determine the calibration factors for v.2.3 of PMED is found in Table 9.1. Further details on the input library utilized for GDOT’s local calibration are documented in the Task 2 interim report provided from RP 11-17 and are defined in the MOP.

Table 9.1— Input Levels used in Calibration of PMED Transfer Functions

Input Group		Performance Indicator	Calibration Input Level		
			1	2	3
Truck Traffic		Axle Load Distributions (single, tandem, tridem)	X		
		Truck Volume Distribution	X		
		Lane and Directional Truck Distributions	X		
		Tire Pressure			X
		Axle Configuration, Tire Spacing			X
		Truck Wander			X
Climate		Temperature, Wind Speed, Cloud Cover, Precipitation, Relative Humidity	X		
Material Properties	Unbound Layers and Subgrade	Resilient Modulus- All Unbound Layers	X	X	
		Classification and Volumetric Properties	X		
		Moisture-Density Relationships	X		
		Soil-Water Characteristic Relationships			X
		Saturated Hydraulic Conductivity			X
	HMA	HMA Dynamic Modulus			X
		HMA Creep Compliance and Indirect Tensile Strength		X	X
		Volumetric Properties	X	X	
		HMA Coefficient of Thermal Expansion			X

	PCC	PCC Elastic Modulus	X	X	
		PCC Flexural Strength	X	X	
		PCC Indirect Tensile Strength (CRCP Only)		X	
		PCC Coefficient of Thermal Expansion	X		
All Materials		Unit Weight	X	X	
		Poisson's Ratio			X
		Other Thermal Properties; conductivity, heat capacity, surface absorptivity			X
Existing Pavement		Condition of Existing Layers	X	X	

9.1 BASELINE FILES FOR THE CALIBRATION FACTORS

Some of the GDOT calibration factors for both flexible and rigid (JPCP) pavements are different than the global calibration factors. As such, 14 baseline files were created that include the GDOT calibration factors, so the designer does not have to manually enter these values for every design problem. The files listed in Table 9.2 contain the recommended calibration factors up to v.2.3 of PMED and the MOP Second Edition only. The most recent Edition of the MOP and subsequent software updates may contain different coefficients and require recalibration.

The designer will need to open the appropriate PMED file listed above. These files are located along with the other available files from the GDOT materials library. Once the file is opened in the software, use the “Save As” function to rename the file under the appropriate convention. Once saved, make the appropriate revisions or changes to the baseline file using project specific features and layer properties.

Table 9.2— GDOT Baseline Files

Pavement Type	Baseline File Name	Applicable Design Strategy
New Pavement	GA_Generic_NewFlexible_Neat Mixes	Conventional, deep-strength or full-depth design strategy. The baseline file was setup as a conventional and deep-strength pavement without subgrade stabilization. If a full-depth pavement is considered, the granular aggregate base layer would need to be removed or deleted; and if a stabilized subgrade is needed, that layer would need to be added. The calibration factors for all transfer functions for these design strategies are the same. This baseline file is also applicable to the fractured PCC slab with an HMA/AC overlay strategy
	GA_Generic_NewFlexible_PMA Mixes	
	GA_Generic_SemiRigid	Semi-rigid pavement design
	GA_Generic_Inverted Pavement	Inverted pavement design
	New_JPCP	JPCP design strategy; the new (2014) global calibration factors were validated
	New_CRCP	CRCP design strategy; the global calibration factors were not changed because of insufficient sections and data
Rehabilitation/ Overlay	GA_Generic_AC Overlay_Flexible_Neat Mixes	HMA/AC overlay design strategy
	GA_Generic_AC Overlay_Flexible_PMA Mixes	
	GA_Generic_AC Over SemiRigid	
	JPCP_over_AC	JPCP design strategy
	CRCP_over_AC	CRCP design strategy
	Unbonded_JPCP_over_JPCP	Unbonded JPCP overlay strategy
	Unbonded_CRCP_over_JPCP	Unbonded CRCP overlay strategy
	JPCP_Restore	Diamond grinding, slab replacement, and retrofit dowels (if needed) strategy.

9.2 TRANSFER FUNCTION CALIBRATION COEFFICIENTS

The remainder of this chapter simply lists the GDOT calibration factors for each transfer function for both flexible and rigid pavements. Tables 9.3 to 9.6 list the appropriate flexible pavement calibration factors from the GDOT local calibration study, which are included in the above baseline files in the GDOT material library, and Tables 9.7 and 9.8 list the appropriate rigid pavement (JPCP) calibration factors. The values highlighted in these tables represent the GDOT calibration factors as determined through RP 11-17 that differ from the global calibration factors for Version 2.3 of the PMED software.

The calibration coefficients for the IRI regression equation for both the flexible and rigid pavements are not included within this chapter because the local calibration factors are the same as for the global calibration factors – they remained unchanged. In addition, the calibration coefficients for the reflection cracking regression equation for HMA/AC overlay of flexible and rigid pavements are the same as for the global calibration factors.

Along with the Third Edition MOP that was published in 2020, PMED Version 2.6 released in July 2020 will contain an updated top down cracking model and transfer function. New validation and potentially additional data will be necessary in order to implement or use the top down cracking as a design criterion in future software iterations.

Example screen shots showing the calibration factor inputs are included at the end of this section.

Table 9.3— HMA/AC Rutting: GDOT Calibration Factors

Transfer Function Coefficient	**Global Value**	**GDOT Value**	
		Neat Mixtures	**PMA Mixtures**
K1	-3.35412	-2.45	-2.55
K2	1.5606	1.5606	1.5606
K3	0.4791	0.30	0.30

Global Standard Deviation Equation:

$$\sigma_{RutDepth,HMA} = 0.24 * Pow(Rut, 0.8026) + 0.001$$

GDOT Standard Deviation Equation:

$$\sigma^{Georgia}_{RutDepth,HMA} = 0.20 * Pow(Rut, 0.550) + 0.001$$

Table 9.4— Unbound Layer Rutting: GDOT Calibration Factors

Transfer Function Coefficient	Global Value	GDOT Value
Coarse-Grained, Bs1	1.0	0.50
Fine-Grained, Bs1	1.0	0.30

NOTE: The standard deviation equation for the unbound layer rutting was not changed from the local calibration process.

Table 9.5— HMA/AC Bottom-Up Fatigue Cracking: GDOT Calibration Factors

Transfer Function Coefficient	Global Value	GDOT Value (Typical HMA Mixtures)
K1	0.007566	0.00151
K2	3.9492	3.9492
K3	1.281	1.281
C1	1.0	2.2
C2	1.0	2.2
C3	6,000	6,000

Global Standard Deviation Equation:

$$\sigma_{Bottom-Up} = 1.13 + \frac{13}{1 + e^{7.57 - 15.5 Log(DI + 0.0001)}}$$

GDOT Standard Deviation Equation:

$$\sigma_{Bottom-Up}^{Georgia} = 1.0 + \frac{10}{1 + e^{7.5 - 6.5 Log(DI + 0.0001)}}$$

Table 9.6—HMA/AC Thermal Transverse Cracking: GDOT Calibration Factors

Transfer Function Coefficient	Global Value	GDOT Value (Typical HMA Mixtures)
Bt1	1.5	35
Bt3	1.5	35

NOTE: The standard deviation equation was not revised from the local calibration process. However, 50 percent reliability is recommended for use in design so the standard deviation equation will have no impact (see Table 4.7 in Section 4 of this Guide).

Table 9.7—JPCP Mid-Slab Cracking: GDOT Calibration Factors (Use for all JPCP Applications: Overlays and Restoration)

Transfer Function Coefficient	Global Value	GDOT Value
C1	2.0	2.0
C2	1.22	1.22
C4	0.52	0.52
C5	-2.17	-2.17
Standard Deviation	3.5522 * Pow(CRACK,0.3415) + 0.75	3.5522*Pow(CRACK,0.3415)+0.75

Table 9.8—JPCP Faulting: GDOT Calibration Factors (Use for all JPCP Applications: Overlays and Restoration)

Transfer Function Coefficient	Global Value	GDOT Value
C1	0.595	0.595
C2	1.636	1.636
C3	0.00217	0.00217
C4	0.00444	0.00444
C5	250	250
C6	0.47	0.47
C7	7.3	7.3
C8	400	400
Standard Deviation	0.07162*Pow(FAULT,0.368)+0.00806	0.07162*Pow(FAULT,0.368)+ 0.00806

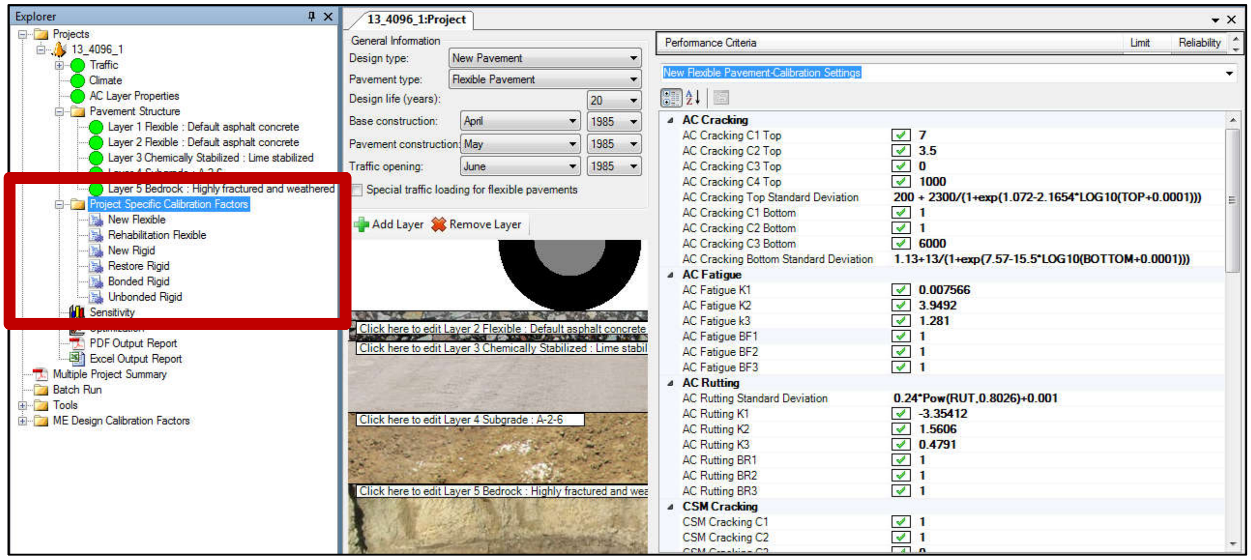
Table 9.9—CRCP Punchout: GDOT Calibration Factors (All CRCP Applications)

Transfer Function Coefficient	Global Value	GDOT Value
C1	2	2
C2	1.22	1.22
C3	107.73	107.73
C4	2.475	2.475
C5	-0.785	-0.785
Standard Deviation	2.208*Pow(PO,0.5316)	2.208*Pow(PO,0.5316)

9.3 SCREEN SHOTS FOR THE CALIBRATION COEFFICIENTS

The following are screen shot examples that show the calibration coefficient inputs, as presented within this section of Chapter 9. The purpose of the screenshots are to show the general location of the items and the details within the screenshot should not be used directly. It should be noted that the actual values for the calibration factors in the screenshots are not always equal to the values that should be used.

Overall Screen Shot for Calibration Coefficients – Flexible Pavements



General Information

Design type: New Pavement

Pavement type: Flexible Pavement

Design life (years): 20

Base construction: April 1985

Pavement construction: May 1985

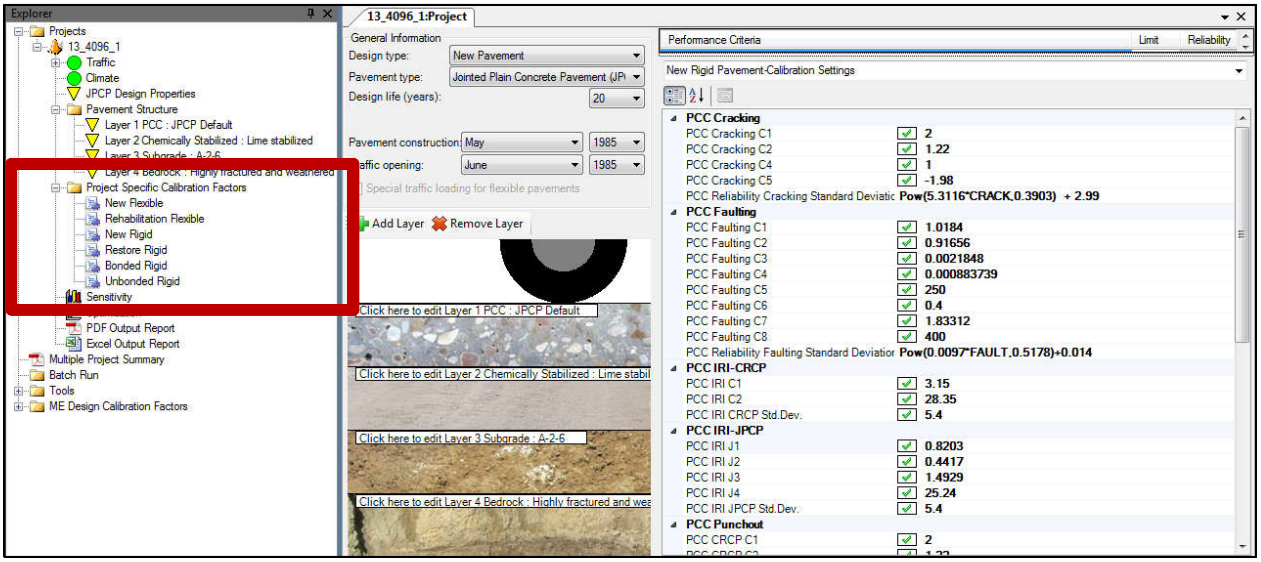
Traffic opening: June 1985

☐ Special traffic loading for flexible pavements

New Flexible Pavement-Calibration Settings

AC Cracking	
AC Cracking C1 Top	☑ 7
AC Cracking C2 Top	☑ 3.5
AC Cracking C3 Top	☑ 0
AC Cracking C4 Top	☑ 1000
AC Cracking Top Standard Deviation	200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))
AC Cracking C1 Bottom	☑ 1
AC Cracking C2 Bottom	☑ 1
AC Cracking C3 Bottom	☑ 6000
AC Cracking Bottom Standard Deviation	1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))
AC Fatigue	
AC Fatigue K1	☑ 0.007566
AC Fatigue K2	☑ 3.9492
AC Fatigue k3	☑ 1.281
AC Fatigue BF1	☑ 1
AC Fatigue BF2	☑ 1
AC Fatigue BF3	☑ 1
AC Rutting	
AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001
AC Rutting K1	☑ -3.35412
AC Rutting K2	☑ 1.5606
AC Rutting K3	☑ 0.4791
AC Rutting BR1	☑ 1
AC Rutting BR2	☑ 1
AC Rutting BR3	☑ 1
CSM Cracking	
CSM Cracking C1	☑ 1
CSM Cracking C2	☑ 1

Overall Screen Shot for Calibration Coefficients – Rigid Pavements



General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete Pavement (JPI

Design life (years): 20

Pavement construction: May 1985

affic opening: June 1985

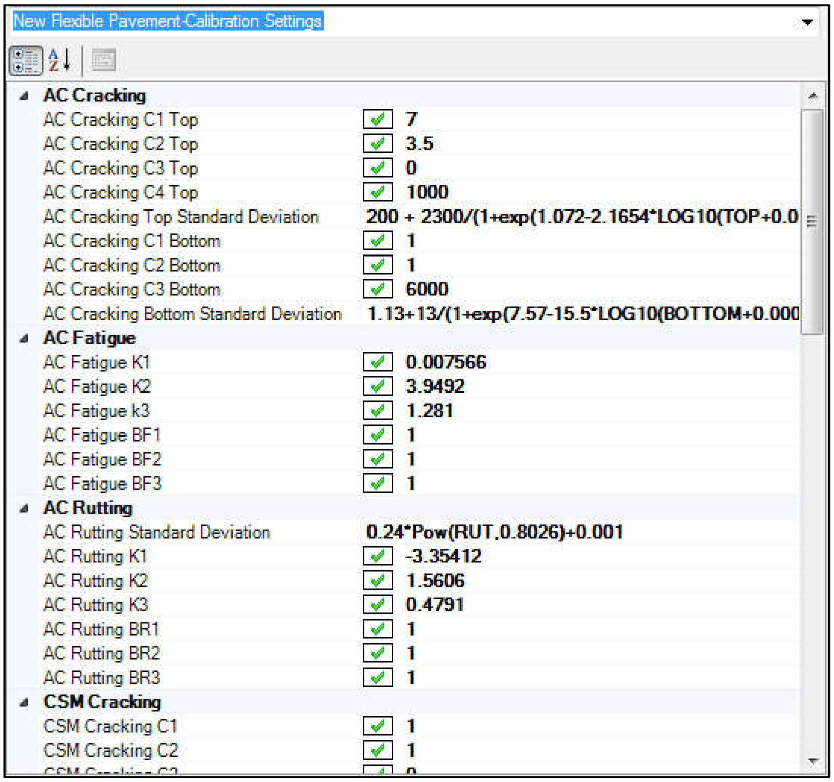
Special traffic loading for flexible pavements

New Rigid Pavement-Calibration Settings

PCC Cracking	
PCC Cracking C1	☑ 2
PCC Cracking C2	☑ 1.22
PCC Cracking C4	☑ 1
PCC Cracking C5	☑ -1.98
PCC Reliability Cracking Standard Deviatic	Pow(5.3116*CRACK,0.3903) + 2.99
PCC Faulting	
PCC Faulting C1	☑ 1.0184
PCC Faulting C2	☑ 0.91656
PCC Faulting C3	☑ 0.0021848
PCC Faulting C4	☑ 0.000883739
PCC Faulting C5	☑ 250
PCC Faulting C6	☑ 0.4
PCC Faulting C7	☑ 1.83312
PCC Faulting C8	☑ 400
PCC Reliability Faulting Standard Deviatior	Pow(0.0097*FAULT,0.5178)+0.014
PCC IRI-CRCP	
PCC IRI C1	☑ 3.15
PCC IRI C2	☑ 28.35
PCC IRI CRCP Std.Dev.	☑ 5.4
PCC IRI-JPCP	
PCC IRI J1	☑ 0.8203
PCC IRI J2	☑ 0.4417
PCC IRI J3	☑ 1.4929
PCC IRI J4	☑ 25.24
PCC IRI JPCP Std.Dev.	☑ 5.4
PCC Punchout	
PCC CRCP C1	☑ 2

NOTE: The PCC cracking C4 and C5 values are different from the GDOT values.

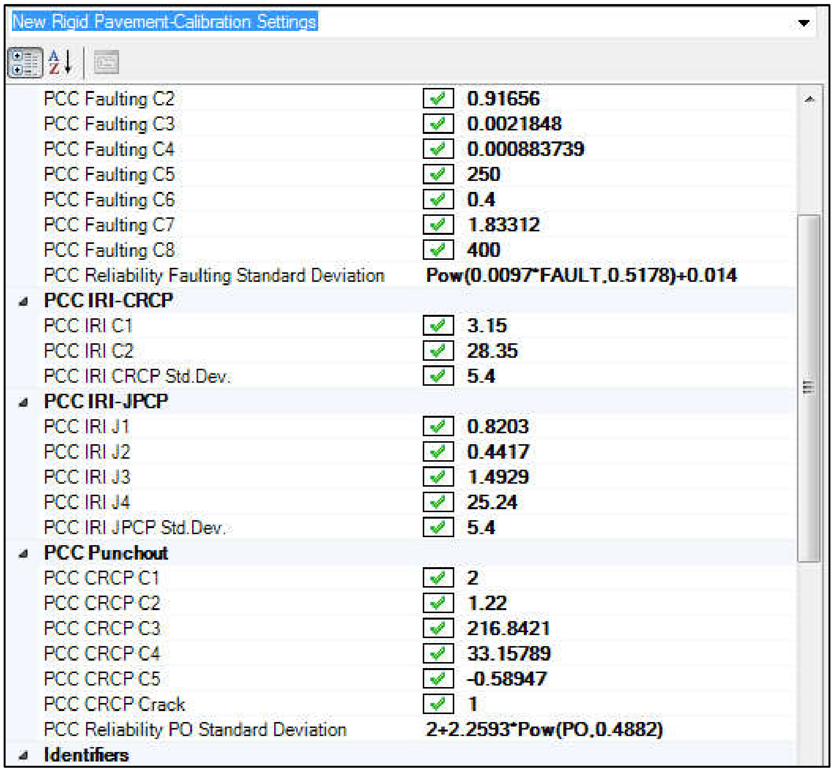
Flexible Pavement Calibration Coefficients



New Flexible Pavement-Calibration Settings

AC Cracking		
AC Cracking C1 Top	☑	7
AC Cracking C2 Top	☑	3.5
AC Cracking C3 Top	☑	0
AC Cracking C4 Top	☑	1000
AC Cracking Top Standard Deviation		200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0
AC Cracking C1 Bottom	☑	1
AC Cracking C2 Bottom	☑	1
AC Cracking C3 Bottom	☑	6000
AC Cracking Bottom Standard Deviation		1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.000
AC Fatigue		
AC Fatigue K1	☑	0.007566
AC Fatigue K2	☑	3.9492
AC Fatigue k3	☑	1.281
AC Fatigue BF1	☑	1
AC Fatigue BF2	☑	1
AC Fatigue BF3	☑	1
AC Rutting		
AC Rutting Standard Deviation		0.24*Pow(RUT,0.8026)+0.001
AC Rutting K1	☑	-3.35412
AC Rutting K2	☑	1.5606
AC Rutting K3	☑	0.4791
AC Rutting BR1	☑	1
AC Rutting BR2	☑	1
AC Rutting BR3	☑	1
CSM Cracking		
CSM Cracking C1	☑	1
CSM Cracking C2	☑	1

Rigid Pavement Calibration Coefficients



New Rigid Pavement-Calibration Settings

PCC Faulting C2	☑	0.91656
PCC Faulting C3	☑	0.0021848
PCC Faulting C4	☑	0.000883739
PCC Faulting C5	☑	250
PCC Faulting C6	☑	0.4
PCC Faulting C7	☑	1.83312
PCC Faulting C8	☑	400
PCC Reliability Faulting Standard Deviation		Pow(0.0097*FAULT,0.5178)+0.014
PCC IRI-CRCP		
PCC IRI C1	☑	3.15
PCC IRI C2	☑	28.35
PCC IRI CRCP Std.Dev.	☑	5.4
PCC IRI-JPCP		
PCC IRI J1	☑	0.8203
PCC IRI J2	☑	0.4417
PCC IRI J3	☑	1.4929
PCC IRI J4	☑	25.24
PCC IRI JPCP Std.Dev.	☑	5.4
PCC Punchout		
PCC CRCP C1	☑	2
PCC CRCP C2	☑	1.22
PCC CRCP C3	☑	216.8421
PCC CRCP C4	☑	33.15789
PCC CRCP C5	☑	-0.58947
PCC CRCP Crack	☑	1
PCC Reliability PO Standard Deviation		2+2.2593*Pow(PO,0.4882)
Identifiers		

CHAPTER 10—CONCLUSIONS AND IMPLEMENTATION PLAN

The foundation for implementation of the MEPDG and associated software for GDOT pavement design practices is well established as evident by the contents of this document. However, the transition to these practices still requires the completion of on-going and future research efforts regarding the PMED software and its inputs. This chapter serves to identify the remaining needs and tasks necessary for implementation and continual use of PMED and all future iterations of the software. Additional information on this topic may be found in the official GDOT Implementation Plan (Von Quintus et al., 2016).

10.1 IMPLEMENTATION ACTIVITIES

GDOT has been preparing for the implementation of the MEPDG methodology for several years through its sponsorship of MEPDG-related activities. The following list highlights the major activities that may be considered implemented or recognized by the most recent calibration efforts and included in current PMED practices.

1. GDOT Project 10-09: GDOT Load Spectra Program. February 2011 – February 2013 (Selezneva et al., 2014)

2. Report GDOT-TO-01-Task 1, Literature Search and Synthesis – Verification and Local Calibration/Validation of the MEPDG Performance Models for use in Georgia, July 2013 (Von Quintus et al., 2013a)

3. Report GDOT-TO-01 Task 2, Validation of the MEPDG Transfer Functions using the LTPP Test Sections in Georgia, July 2013 (Von Quintus et al., 2013b)

4. GDOT Project 10-10: Georgia Concrete Pavement Performance and Longevity. May 2010 – February 2012 (Tsai et al, 2014)
5. GDOT Project 10-04: Determination of Coefficient of Thermal Expansion for Portland Cement Concrete for MEPDG Implementation, October 2012 (Kim, 2012)
6. GDOT Project 05-19: Improving GDOT's Highway Pavement Preservation (Tsai et al., 2009)
7. GDOT Research Project 12-07: Measurements of Dynamic Modulus and Resilient Modulus of Roadway Test Sites, December 2013 (Kim, 2013)
8. Report GDOT-TO-02-Task 3, Calibration of the MEPDG Transfer Functions in Georgia, July 2014 (Von Quintus et al., 2014)
9. Report FHWA/GA-DOT-RD-014-1117: Georgia DOT Pavement ME Design User Input Guide, November 2014; and Georgia DOT Pavement ME Design Software Manual, 2015 (Von Quintus et al., 2015)

Since the adoption of these efforts toward implementing the MEPDG methodology and development of the GDOT input libraries, more activities have been conducted that have not yet been integrated into the most recent calibration and PMED practices. These include both completed and ongoing GDOT research projects as well as other reports and activities. Three notable highlights from these efforts include (1) improvement of predicted pavement performance using MERRA climate data, (2) expansion of the existing HMA materials library, and (3) establishment of an extensive concrete material properties library.

1. GDOT Research Project 16-10: Improvement of Climate Data for use in MEPDG Calibration and other Pavement Analysis (Durham et al., 2019)

2. GDOT Research Project 16-19: Effects of Asphalt Mixture Characteristics on Dynamic Modulus and Fatigue Performance (Kim et al, 2019)
3. GDOT Research Project 18-03: Development of Concrete Material Property Database for Pavement ME Input. October 2018 – Ongoing.
4. GDOT Research Project 18-04: Development of Equivalent Single Axle Load (ESAL) Factor for Georgia Pavement Design. October 2018 – Ongoing.
5. GDOT Research Project 19-16: Improvement of Climate Data for use in MEPDG Calibration and other Pavement Analysis- Phase II. August 2019 – Ongoing.
6. Continued performance monitoring and use in future updates to the local calibration coefficients of the transfer function.
7. Improved design manuals, workshop, and training materials on using the PMED software.

The completion of these activities has provided GDOT with valuable information and data necessary for conducting concurrent pavement designs using PMED. Before these designs may be considered as a GDOT approved design strategy, further actions must be taken to verify and validate their effect on the PMED performance predictions.

10.2 REMAINING IMPLEMENTATION ITEMS

While the existing resources have provided GDOT with the necessary tools to perform preliminary designs, several actions must be taken to ensure the continual operation of the PMED software. The following sections discuss the most pertinent actions required to reach full implementation.

10.2.1 Truck Traffic Input Library

Expansion of the WIM database and continual developments under RP 18-04 will result in increased truck weight data for improving on the truck traffic default values. As a result, the traffic input libraries will need to be expanded and updated to include of the new WIM data.

The analysis of the added WIM data should be used to determine if the existing traffic inputs need to be revised and/or expanded to cover the range of GDOT roadway classifications. It is strongly recommended that the WIM data be used to confirm whether the default input values (especially the normalized axle load spectra or distribution) need to be revised or additional default values be added to the truck traffic library.

10.2.2 Climate Data

Updates to the PMED climate input process in v.2.5 of the software have not been evaluated for their effect on pavement performance using the GDOT calibration sections because the NARR and MERRA-2 hourly climate data were not available at the time the calibration was performed. Further, the improved MERRA data outlined in RP 16-10 as well as the custom climate files developed as part of the new climate study will have both direct and indirect effect on pavement design inputs. Upon completion of RP 16-19, the new climate data inputs should be verified and validated to see if the data show significant changes in the software analysis. Due to the impact of climate on the pavement performance models, it is likely that a recalibration of the transfer function coefficients will be necessary.

10.2.3. Materials/Layer Input Library

1. AC/HMA materials:

The further expansion of the GDOT HMA library under RP 16-19 has provided the dynamic modulus, dynamic shear modulus, and phase angle inputs for several standardized HMA mixtures. Presently, the transfer function coefficients for rutting and fatigue cracking represent general conditions that are not specific to these measured mixture characteristics. A reevaluation of these distress models is required before considering the additional inputs in current designs.

Recent changes have been made to the indirect tensile and creep compliance inputs for HMA materials in PMED v.2.5 and the current edition of the MOP. These properties were not available for the latest calibration of GDOT transfer functions and remain undocumented in the GDOT materials library. Therefore, material testing is still required to determine laboratory derived fatigue cracking coefficients from flexural bending beam fatigue tests or the indirect tensile strength test. The flexural bending beam fatigue test should be performed in accordance with AASHTO T 321, and the indirect tensile test in accordance with ASTM D6931. The laboratory derived fatigue cracking coefficients must be used to determine the field-derived, mixture specific fracture coefficients that impact flexible pavement performance models in PMED.

2. PCC materials

No testing data was available in the GDOT material library for local calibration of the PCC materials with the exception of the coefficient of thermal expansion (CTE). As a result, level 2 and 3 inputs were relied upon for all current rigid pavement transfer functions. Ongoing research efforts have provided extensive laboratory measurements on several standardize concrete mixtures to be added to this library. New measurements include fresh mixture, volume characteristic, thermal, and strength properties. Upon the completion of this library, the new material properties will need to be verified, validated, and included in the latest recalibration before implemented in the PMED input process.

3. Unbound/Base materials:

   Resilient modulus testing of both unbound granular aggregate base (GAB) materials and subgrade soils is already included in the GDOT material library. Although the resilient modulus testing of GAB materials is fairly complete, the resilient modulus of subgrade soils should be expanded to include all major soil types or classes throughout the state. Additionally, extensive laboratory testing on cement stabilized base materials is still omitted from the input library.

10.2.4. Recalibration and Verification

Global calibration of the PMED transfer functions was completed under NCHRP Projects 1-37A and 1-40, and as a part of the annual software updates in 2018, primarily using data extracted from the Long Term Pavement Performance (LTPP) database over a wide range of pavement sections from across the United States, including some in Canada. Under RP 11-17, the transfer functions were initially verified and calibrated using performance data from Georgia LTPP and non-LTPP roadway segments with current design and materials and construction standards, as part of the early MEPDG implementation process in Georgia.

However, the verification-calibration effort is not a one-time activity and should be conducted periodically to verify if the accuracy and bias of existing transfer functions with consideration to new materials, techniques, and design strategies have changed. Additionally, future versions of the software will continue to introduce new or improved prediction models that must be validated. For example, a new top-down cracking transfer function is expected to release in v.2.6 of PMED.

This distress model will require validation and potentially new data before being considered as a design criterion. As a result of these changes and recent additions to the GDOT input library, recalibration is required to establish more accurate relationships between the computed structural responses, accumulated damage, and observed pavement distresses.

In October 2019, the web-based Calibration Assistance Tool (CAT, v1.0) was made available to help agencies conduct comparisons between versions and perform local calibrations of the PMED performance models. The tool was developed in accordance with the 11-step procedure given in the AASHTO Local Calibration Guide and is a full-factor web application, consisting of a calibration database with a subset of LTPP sections used in the global calibration and user-defined test sections. While more convenient than previous calibration methods, this tool requires significant user engagement and engineering decisions. In order to utilize the CAT for current and future iterations of the PMED design practices, GDOT must continue monitoring existing test sections and establish additional sections with newer mixtures, design strategies, and materials. These activities will provide long term performance data and ensure the transfer functions are producing reliable results.

10.3 CONCLUSIONS

The contents of this report provide GDOT with the means to develop pavement designs and evaluate certain performance criteria in accordance with the MEPDG MOP Second and Third Editions. Recent additions to the PMED input library also included in this report are available, but not yet used to calibrate the performance prediction models, and can be used in current and future software versions. In order to ensure the long-term success of implementing the MEPDG, the remaining services outlined in this chapter will greatly help current and future pavement design engineers:

1. Select the most appropriate design strategies for specific conditions,
2. Easily identify the most representative materials, traffic, and climate data that are specific to Georgia conditions,
3. Streamline the design process to focus on making engineering decisions instead of manually entering input data, and
4. Use designs and models that are calibrated to Georgia specific field conditions

These services must be procured through either outsourced contracts or Research Needs Statements (RNS). Once completed, GDOT can fully endorse and complete the transition from the existing pavement design methodologies to the ME-based approach.

CHAPTER 11—INPUT WORKSHEET

This chapter of the Input User Guide provides a series of worksheets or checklists for the designer to use, at least in the beginning, for setting up a design problem and selecting the inputs. One worksheet is provided for flexible pavements and one for rigid pavements. Each worksheet includes the recommended default values for those input parameters that should remain unchanged, and references the sections and/or appropriate tables in this User Input Guide.

Multiple example problems are included in a separate document, defined as Volume 2, to the Input User Guide. All appropriate worksheets have been completed for each example design problem and are included in Volume 2.

CHECK LIST OF INPUTS FOR NEW AND REHABILITATED FLEXIBLE PAVEMENT DESIGNS

Input Parameter		GDOT Input Value	Comment
General Information	Design Type	New Pavement or Overlay	Section 3.1.1
	Pavement Type	Flexible Pavement or AC over AC	
	Design Life, years	(20)*	Section 3.3
	Base/Subgrade Construction Date		Section 3.4; Table 3.2
	Pavement Construction Date		
	Traffic Opening Date		
Performance Criteria	Initial IRI, in./mi.		Section 4.1, Table 4.1
	Terminal IRI, in./mi.		Section 4.2.1, Table 4.6
	Top Down Fatigue Cracking, ft./mi.	(5,000)**	Not considered in design.
	Bottom-Up Fatigue Cracking, %		Section 4.2, Tables 4.2 and 4.5
	Thermal (Transverse) Cracking, ft./mi.		
	Permanent Deformation (Rut Depth)- Total Pavement, inches		
	Permanent Deformation (Rut Depth)- AC Only, inches		
	AC Total Cracking (Overlays), %		Section 4.2, Table 4.5
	Reliability Level, percent		Section 4.3, Table 4.7
Traffic, Site Features	Two-Way Average Annual Daily Truck Traffic		Section 5.1
	Number of Lanes in Design Direction		
	Percent Trucks in Design Direction (DDF)	(50)*	
	Percent of Trucks in Design Lane (LDF)		Section 5.1; Table 5.1
	Operational Speed		Section 5.1
	Traffic Capacity Cap	(Not Enforced)*	Section 5.2
General Traffic, Axle Configuration	Avg. Axle Width	(8.5)*	Section 5.3; use global default values
	Dual Tire Spacing	(12)*	
	Tire Pressure	(120)*	
	Tandem Axle Spacing	(51.6)*	
	Tridem Axle Spacing	(49.2)*	
	Quad Axle Spacing	(49.2)*	

** - Default values should be used.*

*** - Excessively high value used so that top-down cracking does not control design when the optimization tool is being used.*

Traffic; Lateral Wander	Mean Wheel Location		(18)*	Section 5.4; not used for flexible design.
	Traffic Wander, Standard Deviation		(10)*	Section 5.4; use global default values
	Design Lane Width		(12)**	Section 5.4; not used for flexible design.
Traffic, Wheelbase	Average Axle Spacing (short/medium/long)		12/15/18*	Section 5.5; not used for flexible design,
	Percent trucks within each axle spacing (short/medium/long)		17/22/61*	
Traffic; Volume	Normalized Vehicle Class Distribution (TTC Group)			Section 5.6, Table 5.2
	Growth Rate & Function			Section 5.6
	Monthly Adjustment Factors		(GDOT Defaults)*	Section 5.7: Tables 5.3 or 5.4
	Number of Axles per Truck Type		(GDOT Defaults)*	Section 5.9, Table 5.6
	Hourly Distribution Factors		(Defaults)	Section 5.8; not used.
Traffic; Axle Loads	Single Axles			Section 5.10; Table 5.7
	Tandem Axles			
	Tridem Axles			
	Quad Axles			
Climate	Location:	Longitude		Section 6.1
		Latitude		
		Elevation, ft.		
	Depth to Water Table, ft.			Section 6.2; Table 6.1
	Climate Station			Section 6.3, 6.5 Table 6.2-6.3
AC (HMA) Layer Properties: New and Existing Layers	Multi Layer Rutting Parameters		False	Section 7.1.1; not used
	Shortwave Absorptivity		(0.85)*	Section 7.1.2; use global default value
	Endurance Limit Applied		False	Section 7.1.3; not used
	Layer Interface (Interface Friction)		(1)*	Section 7.1.4; use global default value for all layers
	Rehabilitation (Condition of existing flexible pavement)	Milled Thickness		Section 7.1.6
		Fatigue Cracking; input level 2		Section 7.1.5, Figure 7.1
		Pavement Rating; input level 3		Section 7.1.5, Table 7.2
		Rut Depth in existing layers; input levels 1 & 2		Section 7.1.5, use global default values; Table 7.1
		Total Rut Depth, input level 3		Section 7.1.5, use global default values
Bedrock	Elastic Modulus, psi			Section 8.9, Table 8.26,
	Poisson's Ratio			
	Unit Weight, pcf		(140)*	Section 8.9, Table 8.26; used only when subgrade thickness is less than 100 inches.

Subgrade (embankment and natural soil layers)	Thickness, inches (if applicable)		Section 8.6
	Poisson's Ratio		Section 8.6.3, Table 8.23
	Resilient Modulus		Section 8.6.2, Table 8.20
	Coefficient of Lateral Pressure	(0.50)*	Not used.
	Is Layer Compacted?		Always check this box for the upper subgrade layer, if used.
	Specific Gravity	(2.7)*	Section 8.6.1
	Saturated Hydraulic Conductivity	(5.051e-02)	Section 8.6.4
	Soil-Water Characteristic Curve	Calculated	
	Water Content		Section 8.6.1, Table 8.18, and Figure 8.3
	Dry Unit Weight		
	Gradation		
	Plasticity Index		
	Liquid Limit		
Stabilized Subgrade Layer; Soil Cement and Lime Stabilized Soil (Assumed to be a coarse-grained soil; A-1-b)	Thickness, inches		Section 8.8
	Poisson's Ratio		Section 8.8, Table 8.25
	Coefficient of Lateral Earth Pressure	(0.50)*	Not used.
	Resilient Modulus		Section 8.8, Use annual representative modulus value; Table 8.25
	AASHTO Soil Classification	(A-1-b)*	Section 8.8
	Specific Gravity	(2.7)*	Section 8.8, use default values for an A-1-b soil
	Saturated Hydraulic Conductivity	(1.803e-03)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum	(9.3)*	
	Dry Unit Weight; Modified Proctor	(124.0)*	
	Gradation		
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	
Unbound Granular Aggregate Base (GAB) Layer	Thickness, inches		Section 8.6
	Poisson's Ratio		Section 8.6.3, Table 8.23
	Coefficient of Lateral Earth Pressure	(0.50)*	Not used.
	Classification	(Crushed Stone)*	Section 8.6.2, Table 8.19; software calculates monthly resilient modulus
	Resilient Modulus		
	Is Layer Compacted?	Yes	Always check this box when the layer is compacted.
	Specific Gravity	(2.7)*	Section 8.6.1; Use global default values for a Crushed Stone
	Saturated Hydraulic Conductivity	(5.054e-02)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum		Section 8.6.1, Table 8.19
	Dry Unit Weight; Modified Proctor		
	Gradation		Section 8.6.1
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	

Asphalt Stabilized or Treated Base	The inputs for an asphalt stabilized or treated base layer are the same as for an AC/HMA layer		See AC/HMA layer inputs.
Cement Stabilized or Treated Base Layer	Thickness, inches		Section 8.1 & 8.7
	Unit Weight, pcf	(150)*	Section 8.7
	Poisson’s Ratio	(0.20)*	
	Minimum Elastic Modulus, psi	(100,000)*	
	28-day Compressive Strength, psi		Section 8.7, Table 8.24
	28-day Elastic/Resilient Modulus, psi		
	Thermal Conductivity	(1.25)*	Section 8.1 & 8.7
	Heat Capacity	(0.28)*	
AC/HMA (Existing) Layer(s)	Same inputs as for new AC/HMA layers, except for modulus or condition of existing layer.		Section 8.1 and 8.3
	Number of existing HMA/AC layers		No more than 2 layers.
	Thickness after milling		Section 7.1.6 and 8.1
	Existing HMA – Backcalculated Modulus		Section 8.3 (input level 1)
New AC/HMA Layers – Base Layer; if present	Thickness, inches		Section 8.1, Table 8.1
	Unit Weight, pcf		Section 8.3.1, Table 8.3
	Effective Asphalt Content by Volume, %		Section 8.3.1, Table 8.3
	Air Voids, %		Section 8.3.1, Table 8.3
	Poisson’s Ratio	True (Calculated)*	Section 8.3.1, use global default values
	Dynamic Modulus		Section 8.3.3.
	Gradation		Section 8.3.2, Table 8.6
	Estar Predictive Model; G*-based model	False (Calculated)*	Section 8.3.2, use global default equation
	Reference Temp., °F	(70)*	Section 8.3.2, use global default value
	Asphalt Binder Grade		Section 8.3.2, Table 8.5
	Tensile Strength, psi	(Calculated)*	Section 8.3.3, use global default value
	Creep Compliance	(Calculated)*	Section 8.3.2, use global default value
	Thermal Conductivity	(0.67)*	Section 8.3.4, use global default value
	Heat Capacity	(0.23)*	
	Thermal Contraction	(Calculated)*	

New AC/HMA Layers – Binder Layer; if present	Thickness, inches		Section 8.1, Table 8.1
	Unit Weight, pcf		Section 8.3.1, Table 8.3
	Effective Asphalt Content by Volume, %		Section 8.3.1, Table 8.3
	Air Voids, %		Section 8.3.1, Table 8.3
	Poisson's Ratio	True (Calculated)*	Section 8.3.1, use global default values
	Dynamic Modulus		Section 8.3.3.
	Gradation		Section 8.3.2, Table 8.6
	Estar Predictive Model; G*-based model	False (Calculated)*	Section 8.3.2, use global default equation
	Reference Temp., °F	(70)*	Section 8.3.2, use global default value
	Asphalt Binder Grade		Section 8.3.2, Table 8.5
	Tensile Strength, psi	(Calculated)*	Section 8.3.3, use global default value
	Creep Compliance	(Calculated)*	Section 8.3.2, use global default value
	Thermal Conductivity	(0.67)*	Section 8.3.4, use global default value
	Heat Capacity	(0.23)*	
	Thermal Contraction	(Calculated)*	
New AC/HMA Layers – Wearing Surface or Surface Layer	Thickness, inches		Section 8.1, Table 8.1
	Unit Weight, pcf		Section 8.3.1, Table 8.3
	Effective Asphalt Content by Volume, %		Section 8.3.1, Table 8.3
	Air Voids, %		Section 8.3.1, Table 8.3
	Poisson's Ratio	True (Calculated)*	Section 8.3.1, use global default values
	Dynamic Modulus		Section 8.3.3.
	Gradation		Section 8.3.2, Table 8.6
	Estar Predictive Model; G*-based model	False (Calculated)*	Section 8.3.2, use global default equation
	Reference Temp., °F	(70)*	Section 8.3.2, use global default value
	Asphalt Binder Grade		Section 8.3.2, Table 8.5
	Tensile Strength, psi	(Calculated)*	Section 8.3.3, use global default value
	Creep Compliance	(Calculated)*	Section 8.3.2, use global default value
	Thermal Conductivity	(0.67)*	Section 8.3.4, use global default value
	Heat Capacity	(0.23)*	
	Thermal Contraction	(Calculated)*	
Georgia Calibration Factors	Bottom-Up Fatigue Cracking		Section 9; Table 9.5
	Permanent Deformation (AC Rut Depth)		Section 9; Table 9.3
	Permanent Deformation (Rut Depth); Coarse-Grained Soil		Section 9; Table 9.4
	Permanent Deformation (Rut Depth); Fine-Grained Soil		
	HMA IRI Regression Equation		Section 9, use global calibration factors.
	Reflection Cracking		Section 9, use global calibration factors.

CHECK LIST OF INPUTS FOR NEW AND REHABILITATED RIGID PAVEMENT DESIGNS: JPCP

Input Parameter		GDOT Input Value	Comment
General Information	Design Type	New Pavement, Overlay, or Restoration	Section 3.1.2
	Pavement Type	AC over JPCP; JPCP over JPCP or CRCP (bonded & unbonded)	
	Design Life, years	(20)*	Section 3.3
	Base/Subgrade Construction Date		Section 3.4; Table 3.2
	Pavement Construction Date		
	Traffic Opening Date		
Performance Criteria	Initial IRI, in./mi.		Section 4.1, Table 4.1
	Terminal IRI, in./mi.		Section 4.2, Table 4.6
	JPCP Transverse (Mid-Slab) Cracking, %		Section 4.2, Table 4.3
	JPCP Joint Faulting, inches		
	Reliability Level, percent		Section 4.3, Table 4.7
Traffic, Site Features	Two-Way Average Annual Daily Truck Traffic		Section 5.1
	Number of Lanes in Design Direction		
	Percent Trucks in Design Direction (DDF)	(50)*	
	Percent of Trucks in Design Lane (LDF)		Section 5.1, Table 5.1
	Operational Speed		Section 5.1
	Traffic Capacity Cap	(Not Enforced)*	Section 5.2; not used
General Traffic, Axle Configuration			Section 5.3; use global default values.
	Dual Tire Spacing	(12)*	
	Dual Tire Pressure	(120)*	
	Tandem Axle Spacing	(51.6)*	
	Tridem Axle Spacing	(49.2)*	
	Quad Axle Spacing	(49.2)*	
Traffic; Lateral Wander	Mean Wheel Location	(18)*	Section 5.4; use global default values.
	Wander, Standard Deviation	(10)*	
	Design Lane Width	(12)*	
Traffic, Wheelbase	Average Axle Spacing (short/medium/long)	(12/15/18)*	Section 5.5; use global default values.
	Percent Trucks within each axle spacing (short/medium/long)	(17/22/61)*	

** - Default values should be used.*

Traffic; Volume	Normalized Vehicle Class Distribution (TTC Group)			Section 5.6, Table 5.2
	Growth Rate & Function			Section 5.6
	Monthly Adjustment Factors		(Use GDOT Defaults)*	Section 5.7; Tables 5.3 or 5.4
	Hourly Distribution Factors		(Use GDOT Defaults)*	Section 5.8, Table 5.5
	Number of Axles per Truck Type		(Use GDOT Defaults)*	Section 5.9, Table 5.6
Traffic; Axle Loads	Single Axles			Section 5.10; Table 5.7
	Tandem Axles			
	Tridem Axles			
	Quad Axles			
Climate	Location:	Longitude		Section 6.1
		Latitude		
		Elevation, ft.		
	Depth to Water Table, ft.			Section 6.2; Table 6.1
	Climate Station			Section 6.3, 6.5 Table 6.2-6.3
JPCP Design Properties	Shortwave Absorptivity		(0.85)*	Section 7.2.1; use global default value
	PCC Joint Spacing, ft.			Section 7.2.2
	Sealant Type			Section 7.2.3
	Dowelled Joints			Section 7.2.4
	Widened Slabs			Section 7.2.5
	Tied Shoulders			Section 7.2.6
	Erodibility Index			Section 7.2.7, Table 7.4
	PCC Base Contact Friction			Section 7.2.8
	Permanent Curl/Warp Effective Temperature Difference		(-10F)*	Section 7.2.9
Foundation Support	Modulus of Subgrade Reaction or Resilient Modulus		(Calculated)*	Section 7.2.10
JPCP (Existing) Rehabilitation	Same inputs as for new JPCP except for modulus or condition of existing layer.			See PCC Layer
	Slabs cracked or replaced before restoration			Section 7.2.11
	Slabs repaired or replaced after restoration			Section 7.2.11
Bedrock	Resilient Modulus, psi			Section 8.9, Table 8.26, default values are bedrock condition dependent; used only when subgrade thickness is less than 100 inches.
	Poisson’s Ratio			
	Unit Weight, pcf		(140)*	Section 8.9, Table 8.26; used only when subgrade thickness is less than 100 inches.

Subgrade (embankment and natural soil layers)	Thickness, inches (if applicable)		Section 8.6
	Poisson’s Ratio		Section 8.6.3, Table 8.23
	Resilient Modulus		Section 8.6.2, Table 8.20
	Coefficient of Lateral Pressure	(0.50)*	Not used.
	Is Layer Compacted?		Always check this box for the upper subgrade layer, if used.
	Specific Gravity	(2.7)*	Section 8.6.1
	Saturated Hydraulic Conductivity	(5.051e-02)	Section 8.6.4
	Soil-Water Characteristic Curve	Calculated	
	Water Content		Section 8.6.1, Table 8.18, and Figure 8.3
	Dry Unit Weight		
	Gradation		Section 8.6.1
	Plasticity Index		
	Liquid Limit		
Stabilized Subgrade Layer; Soil Cement and Lime Stabilized Soil (Assumed to be a coarse-grained soil; A-1-b)	Thickness, inches		Section 8.8
	Poisson’s Ratio		Section 8.8, Table 8.25
	Coefficient of Lateral Earth Pressure	(0.50)*	Not used.
	Resilient Modulus		Section 8.8, Use annual representative modulus value; Table 8.25
	AASHTO Soil Classification	(A-1-b)*	Section 8.8
	Specific Gravity	(2.7)*	Section 8.8, use default values for an A-1-b soil
	Saturated Hydraulic Conductivity	(1.803e-03)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum	(9.3)*	
	Dry Unit Weight; Modified Proctor	(124.0)*	
	Gradation		
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	
Unbound Granular Aggregate Base (GAB) Layer	Thickness, inches		Section 8.6
	Poisson’s Ratio		Section 8.6.3, Table 8.23
	Coefficient of Lateral Earth Pressure	(0.50)**	Not used.
	Classification	(Crushed Stone)*	Section 8.6.2, Table 8.19; software calculates monthly resilient modulus
	Resilient Modulus		
	Is Layer Compacted?	(Yes)*	Always check this box when the layer is compacted.
	Specific Gravity	(2.7)*	Section 8.6.1; Use global default values for a Crushed Stone
	Saturated Hydraulic Conductivity	(5.054e-02)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum		Section 8.6.1, Table 8.19
	Dry Unit Weight; Modified Proctor		
	Gradation		Section 8.6.1
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	

Cement Stabilized or Treated Base Layer	Thickness, inches		Section 8.1 & 8.7
	Unit Weight, pcf	(150)*	Section 8.7
	Poisson’s Ratio	(0.20)*	
	Minimum Elastic Modulus, psi	(100,000)	
	28-Day Compressive Strength, psi		Section 8.7, Table 8.24
	28-Day Elastic/Resilient Modulus, psi		
	Thermal Conductivity	(1.25)*	Section 8.1 & 8.7
	Heat Capacity	(0.28)*	
AC/HMA Layer or Interlayer	Thickness, inches		Section 8.1, Table 8.1
	Unit Weight, pcf		Section 8.3.1, Table 8.3
	Effective Asphalt Content by Volume, %		Section 8.3.1, Table 8.3
	Air Voids, %		Section 8.3.1, Table 8.3
	Poisson’s Ratio	True (Calculated)*	Section 8.3.1, use global default values
	Dynamic Modulus		Section 8.3.3.
	Gradation		Section 8.3.2, Table 8.6
	Estar Predictive Model; G*-based model	False (Calculated)*	Section 8.3.2, use global default equation
	Reference Temp., °F	(70)*	Section 8.3.2, use global default value
	Asphalt Binder Grade		Section 8.3.2, Table 8.5
	Tensile Strength, psi	(Calculated)*	Section 8.3.3, use global default value
	Creep Compliance	(Calculated)*	Section 8.3.2, use global default value
	Thermal Conductivity	(0.67)*	Section 8.3.4, use global default value
	Heat Capacity	(0.23)*	
	Thermal Contraction	(Calculated)*	

PCC Layer	Thickness, inches			Section 8.2, Table 8.1
	Unit Weight, pcf		(150)*	Section 8.4.1, Table 8.8
	Poisson's Ratio		(0.2)*	Section 8.4.1, Table 8.9
	Coefficient of Thermal Expansion			Section 8.4.2, Tables 8.10 - 8.11
	Thermal Conductivity		(0.67)*	Section 8.4.2
	Heat Capacity		(0.23)*	
	Cement Type		(Type I)*	Section 8.4.3, Table 8.7
	Cementitious Material Content		(660)*	
	Water to cement ratio		(0.45)*	
	Aggregate Type			Section 8.4.3, Tables 8.11 - 8.12
	PCC Zero-stress temperature		(Calculated)*	Section 8.4.3, Use global default value
	Ultimate shrinkage		(Calculated)*	
	Reversible shrinkage		(50)*	
	Time to develop 50% ultimate shrinkage, days		(35)*	
	Curing Method			Section 8.4.3
	PCC Strength, psi	Flexural	(705)*	Section 8.4.4, Tables 8.13 – 8.15
		Compressive	(6097)*	
	Elastic Modulus, ksi		(4,500)*	
Georgia Calibration Factors	Mid-Slab Cracking, %			Section 9; Table 9.7
	Joint Faulting, inches			Section 9; Table 9.8
	IRI, in./mi.			Section 9; use global calibration factors.

CHECK LIST OF INPUTS FOR NEW AND REHABILITATED RIGID PAVEMENT DESIGNS: CRCP

Input Parameter		GDOT Input Value	Comment
General Information	Design Type	New Pavement, Overlay, or Restoration	Section 3.1.2
	Pavement Type	AC over CRCP; CRCP over JPCP or CRCP (bonded & unbonded)	
	Design Life, years	(20)*	Section 3.3
	Base/Subgrade Construction Date		Section 3.4; Table 3.2
	Pavement Construction Date		
	Traffic Opening Date		
Performance Criteria	Initial IRI, in./mi.		Section 4.1, Table 4.1
	Terminal IRI, in./mi.		Section 4.2, Table 4.6
	CRCP Punchouts per mile		Section 4.2, Table 4.4
	Reliability Level, percent		Section 4.3, Table 4.7
Traffic, Site Features	Two-Way Average Annual Daily Truck Traffic		Section 5.1
	Number of Lanes in Design Direction		
	Percent Trucks in Design Direction (DDF)	(50)*	
	Percent of Trucks in Design Lane (LDF)		Section 5.1, Table 5.1
	Operational Speed		Section 5.1
	Traffic Capacity Cap	(Not Enforced)*	Section 5.2; not used
General Traffic, Axle Configuration	Avg. Axle Width	(8.5)*	Section 5.3; use global default values
	Dual Tire Spacing	(12)*	
	Dual Tire Pressure	(120)*	
	Tandem Axle Spacing	(51.6)*	
	Tridem Axle Spacing	(49.2)*	
	Quad Axle Spacing	(49.2)*	
Traffic; Lateral Wander	Mean Wheel Location	(18)*	Section 5.4
	Wander, Standard Deviation	(10)*	Section 5.4; use global default values
	Design Lane Width	(12)*	Section 5.4
Traffic, Wheelbase	Average Axle Spacing (short/medium/long)	(12/15/18)*	Section 5.5
	Percent Trucks within each axle spacing (short/medium/long)	(17/22/61)*	

** - Default values should be used.*

Traffic; Volume	Normalized Vehicle Class Distribution (TTC Group)			Section 5.6, Table 5.2
	Growth Rate & Function			Section 5.6
	Monthly Adjustment Factors		(Use GDOT Defaults)*	Section 5.7; Tables 5.3 or 5.4
	Hourly Distribution Factors		(Use GDOT Defaults)*	Section 5.8, Table 5.6
	Number of Axles per Truck Type		(Use GDOT Defaults)*	Section 5.9, Table 5.5
Traffic; Axle Loads	Single Axles			Section 5.10; Table 5.7
	Tandem Axles			
	Tridem Axles			
	Quad Axles			
Climate	Location:	Longitude		Section 6.1
		Latitude		
		Elevation, ft.		
	Depth to Water Table, ft.			Section 6.2; Table 6.1
	Climate Station			Section 6.3, 6.5 Table 6.2-6.3
Foundation Support	Modulus of Subgrade Reaction or Resilient Modulus		(Calculated)*	Section 7.2.10
CRCP Design Properties	Shortwave Absorptivity		(0.85)*	Section 7.2.1; use global default value
	Shoulder Type			Section 7.3
	Permanent Curl/Warp Effective Temperature Difference		(-10F)*	Section 7.2.9
	Steel, percent reinforcement			Section 7.3
	Bar Diameter, in.			
	Steel Depth, in.			
	Base/Slab Friction Coefficient			Section 7.3, Table 7.5
	Generate Crack Spacing		(True)*	Software calculates crack spacing.
CPCP (Existing) Rehabilitation	Same inputs as for new CRCP except for modulus or condition of existing layer.			See PCC Layer for CRCP
	Number of Punchouts per mile			Section 7.3
Bedrock	Resilient Modulus, psi			Section 8.9, Table 8.26, default values are bedrock condition dependent; used only when subgrade thickness is less than 100 inches.
	Poisson's Ratio			
	Unit Weight, pcf		(140)*	Section 8.9, Table 8.26; used only when subgrade thickness is less than 100 inches.

Subgrade (embankment and natural soil layers)	Thickness, inches (if applicable)		Section 8.6
	Poisson’s Ratio		Section 8.6.3, Table 8.23
	Resilient Modulus		Section 8.6.2, Table 8.20
	Coefficient of Lateral Pressure	(0.50)*	Not used.
	Is Layer Compacted?		Always check this box for the upper subgrade layer, if used.
	Specific Gravity	(2.7)*	Section 8.6.1
	Saturated Hydraulic Conductivity	(5.051e-02)	Section 8.6.4
	Soil-Water Characteristic Curve	Calculated	
	Water Content		Section 8.6.1, Table 8.18, and Figure 8.3
	Dry Unit Weight		
	Gradation		Section 8.6.1
	Plasticity Index		
	Liquid Limit		
Stabilized Subgrade Layer; Soil Cement and Lime Stabilized Soil	Thickness, inches		Section 8.8
	Poisson’s Ratio		Section 8.8, Table 8.25
	Coefficient of Lateral Earth Pressure	(0.50)*	Not used.
	Resilient Modulus		Section 8.8, Use annual representative modulus value; Table 8.25
	AASHTO Soil Classification	(A-1-b)*	Section 8.8
	Specific Gravity	(2.7)*	Section 8.8, use default values for an A-1-b soil
	Saturated Hydraulic Conductivity	(1.803e-03)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum	(9.3)*	
	Dry Unit Weight; Modified Proctor	(124.0)*	
	Gradation		
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	
Unbound Granular Aggregate Base (GAB) Layer	Thickness, inches		Section 8.6
	Poisson’s Ratio		Section 8.6.3, Table 8.23
	Coefficient of Lateral Earth Pressure	(0.50)**	Not used.
	Classification	(Crushed Stone)*	Section 8.6.2, Table 8.19; software calculates monthly resilient modulus
	Resilient Modulus		
	Is Layer Compacted?	(Yes)*	Always check this box when the layer is compacted.
	Specific Gravity	(2.7)*	Section 8.6.1; Use global default values for a Crushed Stone
	Saturated Hydraulic Conductivity	(5.054e-02)*	
	Soil-Water Characteristic Curve	Calculated	
	Water Content; Optimum	(7.4)*	Section 8.6.1, Table 8.19
	Dry Unit Weight; Modified Proctor	(127.2)*	
	Gradation		Section 8.6.1
	Plasticity Index	(1)*	
	Liquid Limit	(6)*	

Cement Stabilized or Treated Base Layer	Thickness, inches		Section 8.1 & 8.7
	Unit Weight, pcf	(150)*	Section 8.7
	Poisson's Ratio	(0.20)*	
	Minimum Elastic Modulus, psi	(100,000)	
	28-Day Compressive Strength, psi		Section 8.7, Table 8.24
	28-Day Elastic/Resilient Modulus, psi		
	Thermal Conductivity	(1.25)*	Section 8.1 & 8.7
	Heat Capacity	(0.28)*	
AC/HMA Layer or Interlayer	Thickness, inches		Section 8.1, Table 8.1
	Unit Weight, pcf		Section 8.3.1, Table 8.3
	Effective Asphalt Content by Volume, %		Section 8.3.1, Table 8.3
	Air Voids, %		Section 8.3.1, Table 8.3
	Poisson's Ratio	True (Calculated)*	Section 8.3.1, use global default values
	Dynamic Modulus		Section 8.3.3.
	Gradation		Section 8.3.2, Table 8.6
	Estar Predictive Model; G*-based model	False (Calculated)*	Section 8.3.2, use global default equation
	Reference Temp., °F	(70)*	Section 8.3.2, use global default value
	Asphalt Binder Grade		Section 8.3.2, Table 8.5
	Tensile Strength, psi	(Calculated)*	Section 8.3.3, use global default value
	Creep Compliance	(Calculated)*	Section 8.3.2, use global default value
	Thermal Conductivity	(0.67)*	Section 8.3.4, use global default value
	Heat Capacity	(0.23)*	
	Thermal Contraction	(Calculated)*	

PCC Layer	Thickness, inches			Section 8.2, Table 8.1
	Unit Weight, pcf		(150)*	Section 8.4.1, Table 8.8
	Poisson’s Ratio		(0.2)*	Section 8.4.1, Table 8.9
	Coefficient of Thermal Expansion			Section 8.4.2, Tables 8.10 - 8.11
	Thermal Conductivity		(0.67)*	Section 8.4.2
	Heat Capacity		(0.23)*	
	Cement Type		(Type I)*	Section 8.4.3, Table 8.7
	Cementitious Material Content		(660)*	
	Water to cement ratio		(0.45)*	
	Aggregate Type			Section 8.4.3, Tables 8.11 - 8.12
	PCC Zero-stress temperature		(Calculated)*	Section 8.4.3, Use global default value
	Ultimate shrinkage		(Calculated)*	
	Reversible shrinkage		(50)*	
	Time to develop 50% ultimate shrinkage, days		(35)*	
	Curing Method			Section 8.4.3
	PCC Strength, psi	Flexural	(705)*	Section 8.4.4, Tables 8.13 – 8.15
		Compressive	(6097)*	
	Elastic Modulus, ksi		(4,500)*	
Georgia CRCP Calibration Factors	Number of Punchouts per mile			Section 9; Table 9.9
	IRI, in./mi.			Section 9; Use global calibration factors.

APPENDIX A—HMA DATABASE (KIM ET AL., 2019)

Table A.1

Mixture Type:	A 12.5_64_M1	XML File:	L*_PG64_12.5_A_R3-LG

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	740,802	1,082,794	1,202,705	1,586,888	1,706,096	1,924,615
68	150,334	278,518	336,268	564,559	658,669	818,440
104	24,296	46,335	58,625	113,719	142,644	198,566
130	11,119	19,491	24,290	46,322	58,611	83,996

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	8850	79.1
158	4220	82
168.8	2070	84.1

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	14	86
#4 Sieve	26	74
#200 Sieve	94.2	5.8

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	8850	79.1
158	4220	82
168.8	2070	84.1

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	14	86
#4 Sieve	26	74
#200 Sieve	94.2	5.8

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Note: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.2

Mixture Type:	A.12.5_64_M2	XML File:	L*_PG64_12.5_A_R3-FP

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	913,266	1,203,332	1,342,315	1,646,168	1,775,603	1,961,809
68	196,746	348,622	411,796	649,274	741,030	894,448
104	33,991	70,120	89,932	173,205	212,727	301,364
130	19,970	39,240	55,296	102,271	139,928	188,459

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	27500	73.7
158	10800	76.8
168.8	6600	79.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	73
#200 Sieve	94.1	5.9

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	27500	73.7
158	10800	76.8
168.8	6600	79.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	61
#200 Sieve	5.9	55.1

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Note: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.3

Mixture Type:	A 12.5_67_N	XML File:	L*_PG67_12.5_A_R2

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	787,225	1,089,505	1,207,067	1,545,325	1,661,798	1,870,709
68	192,088	325,597	382,568	599,750	686,073	833,912
104	38,301	66,256	82,046	142,791	175,827	228,559
130	18,543	29,902	37,036	63,196	79,242	104,091

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	147.2	26600
158	158	12400
168.8	168.8	5780

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.8
Air Voids (%)	6.3
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	13	87
#4 Sieve	25	75
#200 Sieve	93.7	6.3

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147	26600	72.1
158	12400	75.3
169	5780	78.5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.8
Air Voids (%)	6.3
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	13	87
#4 Sieve	25	62
#200 Sieve	6.3	55.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.8
Air Voids (%)	6.3
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 67-22

Note: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.4

Mixture Type:	A 12.5_76_N	XML File:	L*_PG76_12.5_A_R2

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	829,119	1,118,111	1,264,046	1,585,167	1,726,851	1,930,605
68	177,587	304,657	359,764	573,195	658,991	807,522
104	35,227	59,261	73,824	127,260	158,583	205,713
130	18,567	29,167	35,573	60,107	74,603	98,547

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
158	14100	65.8
168.8	6770	67.2
179.6	8140	67.8

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	5.7
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	10	90
#4 Sieve	27	73
#200 Sieve	93.7	6.3

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
158	14100	65.8
168.8	6770	67.2
179.6	8140	67.8

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	5.7
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	10	90
#4 Sieve	27	63
#200 Sieve	6.3	56.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	5.7
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 76-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.5

Mixture Type:	A 19_64_N	XML File:	L*_PG64_19_A_R2

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,080,201	1,378,093	1,534,188	1,835,810	1,977,396	2,154,776
68	259,963	430,811	501,396	759,378	859,191	1,021,609
104	49,660	86,728	108,870	187,266	232,492	296,430
130	24,494	41,822	51,610	91,408	113,125	150,931

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	49700	60.4
158	31300	62.2
168.8	16500	63.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	5	95
3/8 Inch Sieve	11	89
#4 Sieve	27	73
#200 Sieve	94.2	5.8

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	49700	60.4
158	31300	62.2
168.8	16500	63.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	5	95
3/8 Inch Sieve	11	84
#4 Sieve	27	57
#200 Sieve	5.8	51.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.6

Mixture Type:	A 19_64_N2	XML File:	L*_PG64_19_A_R1

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,604,374	1,905,957	2,067,163	2,321,134	2,449,785	2,560,126
68	419,108	668,293	765,958	1,100,487	1,223,621	1,409,156
104	88,175	155,884	191,065	327,445	394,311	500,186
130	54,060	91,967	115,782	198,940	247,199	343,452

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	10.1
Air Voids (%)	5.0
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	1	99
3/8 Inch Sieve	9	91
#4 Sieve	19	81
#200 Sieve	94.7	5.3

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	49700	60.4
158	31300	62.2
168.8	16500	63.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	10.1
Air Voids (%)	5.0
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	1	95
3/8 Inch Sieve	9	84
#4 Sieve	19	57
#200 Sieve	5.3	51.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.7

Mixture Type:	A 25_64_N	XML File:

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,491,958	1,756,555	1,875,438	2,161,550	2,283,430	2,438,814
68	518,414	718,035	814,243	1,085,754	1,212,228	1,390,576
104	112,825	181,733	218,814	359,743	438,885	573,577
130	112,825	181,733	218,814	359,743	438,885	573,577

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	37100	72.6
158	17500	75.6
168.8	7890	78.4

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	12	88
3/8 Inch Sieve	9	91
#4 Sieve	20	80
#200 Sieve	94.3	5.7

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	37100	72.6
158	17500	75.6
168.8	7890	78.4

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	12	88
3/8 Inch Sieve	9	79
#4 Sieve	20	59
#200 Sieve	5.7	53.3

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.2
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.8

Mixture Type:	A 25_64_N2	XML File:	L*_PG64_25_A_R1

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,556,596	1,890,369	2,066,300	2,351,759	2,486,870	2,625,608
68	381,566	628,307	729,361	1,081,872	1,216,166	1,414,382
104	68,568	108,719	140,700	229,344	297,634	381,114
130	34,913	50,039	62,015	97,443	125,624	167,944

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.8
Air Voids (%)	5.2
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	7	93
3/8 Inch Sieve	9	91
#4 Sieve	15	85
#200 Sieve	94.5	5.5

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	37100	72.6
158	17500	75.6
168.8	7890	78.4

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.8
Air Voids (%)	5.2
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	9	91
3/8 Inch Sieve	7	84
#4 Sieve	15	69
#200 Sieve	5.5	63.5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.8
Air Voids (%)	5.2
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.9

Mixture Type:	B 9.5_64_M1	XML File:	L*_PG64_9.5_B_R3-A

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	707,903	1,004,842	1,143,469	1,491,896	1,631,093	1,857,805
68	135,249	244,567	293,579	492,606	573,874	723,054
104	26,470	47,501	58,462	108,497	133,205	186,318
130	14,879	24,650	30,313	54,053	67,772	98,849

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	24300	73.6
158	1170	76.6
168.8	6800	79.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	1	99
#4 Sieve	28	72
#200 Sieve	94	6

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	24300	73.6
158	1170	76.6
168.8	6800	79.2

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	1	99
#4 Sieve	28	71
#200 Sieve	6	65

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.10

Mixture Type:	B 9.5_64_M2	XML File:	L*_PG64_9.5_B_R3-V

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	726,463	1,059,151	1,180,868	1,560,876	1,682,118	1,905,371
68	151,093	273,425	328,405	548,293	638,450	796,580
104	29,619	52,882	65,149	121,003	148,834	207,462
130	15,871	26,004	31,375	56,328	69,451	100,315

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	5780	80.8
158	11500	78.4
168.8	19600	75.4

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	6	94
#4 Sieve	27	73
#200 Sieve	93.5	6.5

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	5780	80.8
158	11500	78.4
168.8	19600	75.4

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	6	94
#4 Sieve	27	67
#200 Sieve	6.5	60.5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.6
Air Voids (%)	6.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.11

Mixture Type:	B 9.5_67_S	XML File:	L*_PG67_9.5_B_R4

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	778,386	1,050,892	1,189,409	1,493,084	1,629,393	1,824,386
68	154,455	275,617	328,315	530,523	612,484	750,601
104	24,939	49,370	62,359	119,532	148,018	202,299
130	11,980	23,189	29,765	58,146	73,784	109,831

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	23600	72.2
158	10600	75.6
168.8	4910	78.6

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.8
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	3	97
#4 Sieve	28	72
#200 Sieve	94.7	5.3

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	23600	72.2
158	10600	75.6
168.8	4910	78.6

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.8
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	3	97
#4 Sieve	28	69
#200 Sieve	5.3	63.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.8
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 67-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.12

Mixture Type:	B 12.5_64_M	XML File:	L*_PG64_12.5_B_R3

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	713,383	1,077,654	1,200,054	1,606,245	1,729,371	1,937,672
68	139,056	263,348	321,364	555,823	654,698	822,028
104	24,366	43,769	54,864	105,353	132,701	187,020
130	12,516	19,494	23,735	42,183	53,201	74,579

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	14300	76.7
158	9440	79.6
168.8	5170	81.9

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.6
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	13	87
#4 Sieve	25	75
#200 Sieve	94	6

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	14300	76.7
158	9440	79.6
168.8	5170	81.9

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.6
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	13	97
#4 Sieve	25	69
#200 Sieve	6	63.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.5
Air Voids (%)	5.6
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.13

Mixture Type:	B 12.5_67_S	XML File:	L*_PG67_12.5_B_R4

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	799,436	1,098,798	1,226,957	1,560,258	1,685,026	1,894,083
68	178,701	307,743	364,226	578,586	666,209	811,324
104	40,797	72,786	89,099	159,438	192,590	267,258
130	26,760	43,528	57,073	95,217	125,372	167,782

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	26800	73.8
158	10800	77.3
168.8	5270	80.3

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.1
Air Voids (%)	6.0
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	14	86
#4 Sieve	25	75
#200 Sieve	95	5

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	26800	73.8
158	10800	77.3
168.8	5270	80.3

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.1
Air Voids (%)	6.0
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	0
3/8 Inch Sieve	14	14
#4 Sieve	25	25
#200 Sieve	5	5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.1
Air Voids (%)	6.0
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 67-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.14

Mixture Type:	B 19_64_M	XML File:	L*_PG64_19_B_R3

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,328,492	1,666,382	1,844,406	2,154,559	2,300,147	2,463,630
68	280,235	496,408	584,651	912,001	1,034,218	1,232,022
104	21,279	41,131	54,178	106,296	137,938	206,862
130	5,605	8,689	11,188	19,543	26,533	38,301

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	10.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	1	99
3/8 Inch Sieve	14	86
#4 Sieve	25	75
#200 Sieve	94	6

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	10.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	1	0
3/8 Inch Sieve	14	14
#4 Sieve	25	25
#200 Sieve	6	5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	10.5
Air Voids (%)	5.5
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Table A.15

Mixture Type:	B 25_64_M	XML File:	L*_PG64_25_B_R3

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,155,865	1,551,697	1,677,457	2,059,318	2,169,615	2,361,791
68	312,972	521,710	611,119	924,418	1,050,408	1,234,732
104	65,957	113,107	139,266	241,927	295,964	383,009
130	33,987	53,689	65,279	111,491	137,751	182,596

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	33500	72.6
158	17200	75.4
168.8	17700	76.1

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.4
Air Voids (%)	5.9
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	8	92
3/8 Inch Sieve	10	90
#4 Sieve	17	83
#200 Sieve	95	5

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	33500	72.6
158	17200	75.4
168.8	17700	76.1

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.4
Air Voids (%)	5.9
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	10	90
3/8 Inch Sieve	8	82
#4 Sieve	17	65
#200 Sieve	5	60

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	9.4
Air Voids (%)	5.9
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 64-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.16

Mixture Type:	C 9.5_67_M	XML File:	L*_PG67_9.5_C_R3

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (^{o}F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	1,042,729	1,338,882	1,493,116	1,797,075	1,938,251	2,119,050
68	252,870	416,779	484,584	735,545	832,459	993,556
104	47,958	78,495	100,325	164,872	209,851	264,927
130	22,643	34,356	43,766	70,134	91,120	118,701

Asphalt Binder: Superpave Binder Test Data

Temperature (^{o}F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	15900	77.7
158	7850	80.2
168.8	3240	82.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.9
Air Voids (%)	5.0
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	5	95
#4 Sieve	32	68
#200 Sieve	94.5	5.5

Asphalt Binder: Superpave Binder Test Data

Temperature (^{o}F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2	15900	77.7
158	7850	80.2
168.8	3240	82.7

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.9
Air Voids (%)	5.0
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	5	95
#4 Sieve	32	63
#200 Sieve	5.5	57.5

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	12.9
Air Voids (%)	5.0
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 67-22

Notes: The table summarizes the test data using extracted asphalt binder from asphalt plant mix.

Table A.17

Mixture Type:	C 12.5_67_M	XML File:

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	869,851	1,189,925	1,322,964	1,667,244	1,791,974	2,000,302
68	192,115	337,801	400,017	639,995	734,224	895,946
104	34,875	64,822	80,557	149,572	183,594	249,302
130	17,203	30,483	37,530	70,132	86,785	125,192

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	73
#200 Sieve	93.9	6.1

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	61
#200 Sieve	6.1	54.9

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 67-22

Table A.18

Mixture Type:	C 12.5_76_M	XML File:	L*_PG76_12.5_C_R3

Level 1

Asphalt Mix: Dynamic Modulus Table

Temperature (°F)	Mixture |E*|, psi					
	0.1 Hz	**0.5 Hz**	**1 Hz**	**5 Hz**	**10 Hz**	**25 Hz**
39.2	565,772	851,214	953,092	1,301,342	1,417,104	1,608,734
68	133,118	233,060	278,933	459,431	536,563	668,467
104	27,968	46,100	56,895	98,431	122,377	161,150
130	14,093	20,212	24,970	39,117	50,048	64,680

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Level 2

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	73
#200 Sieve	93.9	6.1

Asphalt Binder: Superpave Binder Test Data

Temperature (°F)	Angular Freq. = 10 rad/sec	
	G* (Pa)	Delta (degree)
147.2		
158		
168.8		

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Level 3

Asphalt Mix: Aggregate Gradation

	Cumulative % Retained	Percent Passing
3/4 Inch Sieve	0	100
3/8 Inch Sieve	12	88
#4 Sieve	27	61
#200 Sieve	6.1	54.9

Asphalt General: Volumetric Properties as Built

Effective Binder Content (%)	11.5
Air Voids (%)	5.8
Total Unit Weight (pcf)	145

Asphalt Binder: Superpave Binder Grading:	PG 76-22

APPENDIX B—UNBOUND LAYER MATERIAL PROPERTIES (KIM ET AL., 2013)

Table C.1- Subgrade Soil Properties

Source	Percent Passing (%)				% Clay	% Volume Change	% Swell	% Shrink	Max. Dry Density (pcf)	Opt. Moisture Content (%)	LL (%)	PI (%)	Eros Index
	#10	#40	#60	#200									
Lincoln	99.3	96.8	93.8	48.9	40.7	24.5	20.5	4.0	93.4	23.5	39.9	8.6	4.23
Washington	99.8	84.6	56.1	23.8	20.6	4.7	4.5	0.2	117.8	11.0	23.0	6.6	7.30
Coweta	89.5	64.6	48.9	28.3	24.0	12.2	11.2	1.0	105.3	16.7	42.5	11.0	6.69
Walton	89.4	61.5	50.5	36.3	28.3	4.0	1.0	3.0	104.8	16.8	40.5	12.7	5.71
Chatham	99.9	97.4	93.5	3.6	1.8	0.0	3.6	0.0	97.4	12.7	0.0	0.0	9.76
Lowndes	99.0	74.9	52.9	12.2	4.5	0.0	0.0	0.0	113.1	4.7	0.0	0.0	8.65
Franklin	97.3	89.4	70.9	31.1	19.6	5.2	3.0	2.2	105.1	22.6	39.3	9.8	6.32
Cook	79.9	66.4	46.6	25.0	18.4	0.6	0.6	0.0	113.1	9.9	0.0	0.0	7.06
Toombs	84.2	37.8	17.6	6.2	4.6	1.1	0.1	1.0	119.3	11.9	0.0	0.0	9.39

Table C.2- GAB Material Characteristics

QPL ID	Aggregate Group	Source Location	GAB Character	W_{opt} (%)	Max. γ_d (pcf)	W_{actual} (%)	Actual γ_d (pcf)	Percent Compaction	LA Abrasion (%)	Bulk Specify Gravity
011C	II	Lithonia	Granite Gneiss	5.7	133.9	4.3	133	99	50	2.614
013C	I	Dalton	Limestone	6.6	142.5	4.7	139	98	25	2.702
024C	II	Gainsville	Mylonitic Gneiss	6	136.6	6.7	134	98	39	2.605
028C	II	Hitchcock	Mylonitic Gneiss	6.2	141.2	5.6	138	98	18	2.697
050C	II	Stockbridge	Granite Gneiss	5.9	134.2	5.9	134	100	42	2.611
101C	II	Demorest	Meta-sandstone	5.3	137.4	5	137	100	32	2.642
108T	I	Mayo Mine	Limerock	13.6	112.6	11.5	110	98	N/A	N/A
118C	II	Columbus	Granite Gneiss	6	137.2	6.5	135	98	33	2.677
141C	II	Dahlonega	Granite Gneiss	5.6	135.2	4	132	98	34	2.646
158C	II	Walton County	Biotite Gneiss	6.4	135	4.5	132	98	41	2.64
165T	II	I-75 Unadilla	Recycled Concrete	7	134	8.5	131	98	N/A	N/A

Table C.3- GAB Aggregate Gradations

	Sieve	2"	1 1/2"	3/4 in	No. 10	No. 60	No. 200
	mm	**50**	**37.5**	**19**	**2**	**0.25**	**0.075**
% Passing	**MIN**	100	97	60	25	5	4
	MAX	100	100	90	45	30	11
	011C	100	100	70	33	16	5
	013C	100	100	90	38	10	7
	024C	100	100	74	26	10	4
	028C	100	100	71	30	14	6
	050C	100	100	85	43	20	6
	101C	100	100	87	26	14	7
	118C	100	100	71	31	14	6
	141C	100	100	82	36	18	6
	158C	100	100	77	29	13	5
	165T	100	100	72	29	7	4

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