Mechanistic–Empirical Pavement Design for Multi-Class Roadways: A Case Study Using AASHTOWare Pavement ME

Submitted to:

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1. Introduction

The choice between flexible (asphalt) and rigid (concrete) pavements plays a vital role in the planning, design, and implementation of highway infrastructure. Flexible pavements are typically composed of multiple asphalt layers that distribute loads gradually and are capable of adjusting to changes in traffic volume and environmental conditions. In contrast, rigid pavements consist of concrete slabs that provide high structural integrity and are especially suited for areas with heavy or repetitive traffic loads, such as freight corridors and industrial zones. Their superior flexural strength allows rigid pavements to resist deformation and cracking more effectively than their flexible counterparts. Figure 1 illustrates the distinct patterns of load distribution between flexible and rigid pavement systems.

In civil engineering practice, the development of reliable and efficient pavement systems requires an in-depth understanding of material properties, load-bearing behavior, and climatic influences. Both flexible and rigid pavements serve important roles depending on site-specific conditions, expected traffic, and long-term maintenance considerations. This report explores the methodologies and principles behind pavement design using the Mechanistic-Empirical Pavement Design Guide (MEPDG), a comprehensive tool that integrates material mechanics with empirical performance data to optimize pavement life and performance.

Moreover, advances in pavement materials, sustainability considerations, and life-cycle cost analysis have further influenced the selection between flexible and rigid designs. The application of MEPDG allows engineers to make informed decisions by simulating long-term behavior under various loading and environmental scenarios, ensuring safe, cost-effective, and durable roadway systems.

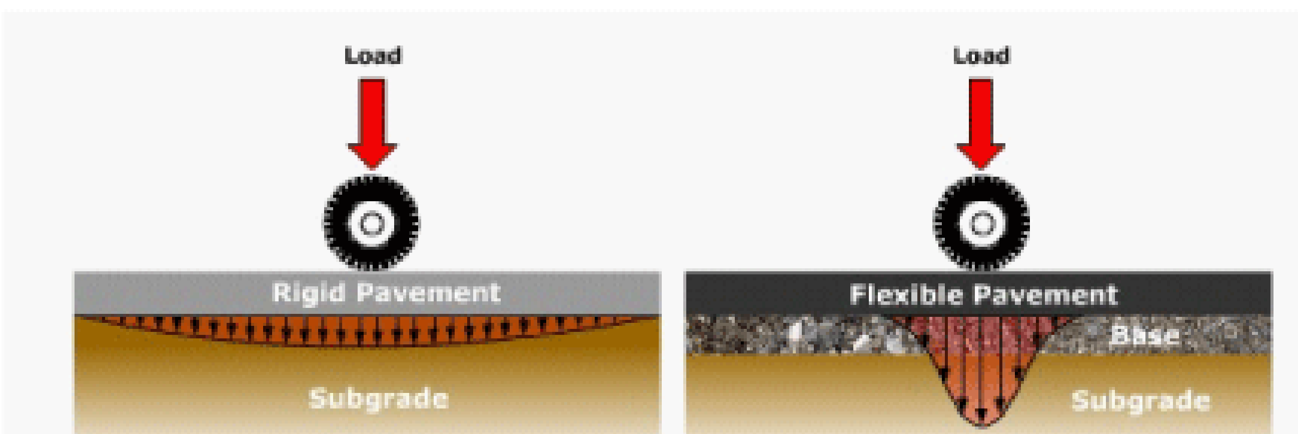


Figure 1. Load distribution between rigid and flexible pavements.

The 1993 AASHTO Guide for the Design of Pavement Structures is one of the most widely utilized frameworks for pavement design across the United States. It was primarily developed based on data collected from the AASHO Road Test conducted in Ottawa, Illinois, during the late 1950s.

Despite its widespread use, the method has significant limitations: it was developed using data from a single environmental condition, low traffic loading, limited materials, and uniform axle loads, making it less adaptable to modern pavement design needs (*1*).

To address these constraints, the transportation community has transitioned toward the Mechanistic-Empirical Pavement Design Guide (MEPDG). This guide combines mechanistic modeling (based on the physics of material behavior) with empirical calibration using long-term performance data. The MEPDG framework allows for a more nuanced evaluation of climate, traffic, subgrade, and material characteristics, offering better performance predictions and durability outcomes (*2*).

Advancements in the MEPDG include probabilistic and reliability-based design approaches, which quantify the likelihood of pavement failure under various uncertainty scenarios. These approaches improve the robustness of design decisions by accounting for variability in inputs such as traffic, moisture, temperature, and construction quality (*3*). Furthermore, the methodology has evolved to support risk-informed pavement management practices, helping agencies to optimize both design and maintenance costs over the pavement lifecycle (*4*).

In practice, the implementation of the MEPDG has required calibration and training efforts across transportation agencies. For example, states such as Maryland have adopted the MEPDG with tailored calibration factors, acknowledging the need for regional adjustment of input models (*5*). Thus, the shift from AASHTO 1993 to MEPDG marks a significant progression in pavement engineering—from simplified empirical estimates to data-driven, performance-based design systems suited to diverse environments and loading conditions.

1. Objectives of the project

The goal of this project is to generate practical and efficient pavement designs for both asphalt and concrete surfaces. This will be achieved through the application of the AASHTOWare Pavement ME Design software.

2. Data collection and research methodology

The development of the Mechanistic-Empirical Pavement Design Guide (MEPDG) was initiated in 1998 by the National Cooperative Highway Research Program. This effort marked a significant step toward advancing pavement design practices through mechanistic-empirical methodologies (TAC, 2011). The Mechanistic-Empirical Pavement Design Guide (MEPDG) approach places greater emphasis on the interaction between geometric design, material characteristics, traffic loading, and environmental factors. As shown in Figure 2, pavement layer thicknesses are determined through an iterative procedure that compares predicted pavement performance against design thresholds for various distress types, continuing the process until all criteria are met at the desired level of reliability.

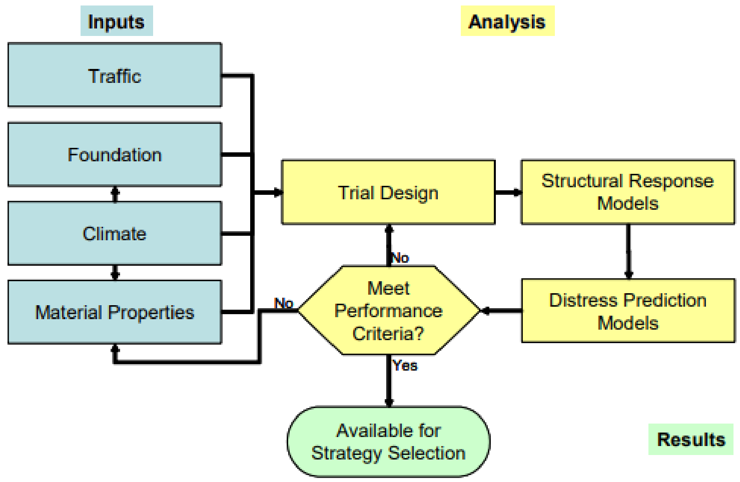


Figure 2. Flow chart for mechanistic-empirical flexible pavement design (4).

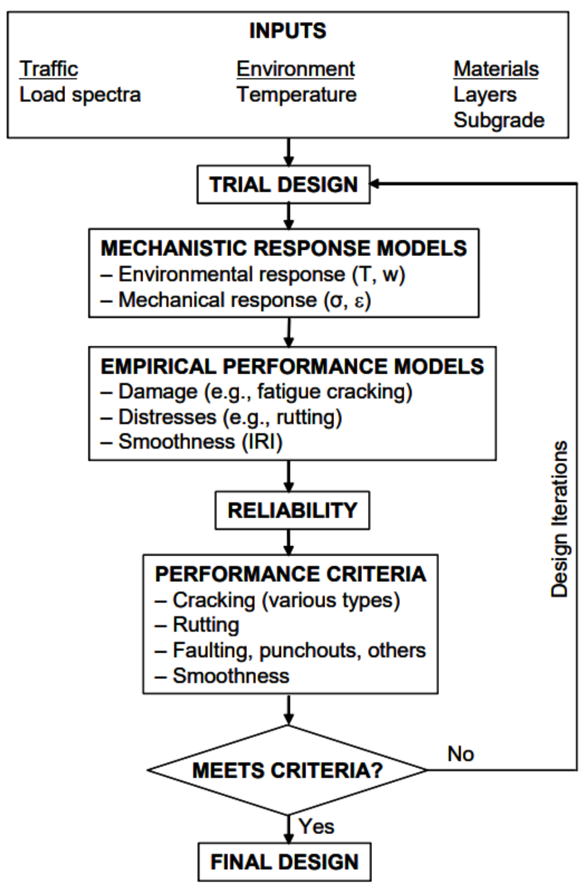


Figure 3. Flow chart for mechanistic-empirical design methodology (4).

As shown in Figure 2, the pavement design process using the MEPDG begins by entering key project information. This includes traffic data like axle load spectrum, environmental conditions such as temperature and moisture (typically based on the closest LTPP climate location), and the material properties of each pavement layer and the subgrade. With these inputs, the engineer creates a trial pavement design, which is then evaluated by the software.

The MEPDG calculates how the pavement will behave under those conditions by estimating stresses, strains, and deflections at specific points within the structure. These responses are then used to predict how the pavement might deteriorate over time—identifying potential issues like fatigue cracking, thermal cracking, rutting, faulting, punchouts, and surface roughness (measured by the International Roughness Index or IRI). The results are checked against design thresholds, using a selected reliability level, which reflects the confidence that the pavement will perform as intended over its expected lifespan (*1*).

If the initial design doesn't meet the performance criteria, adjustments are made, and the process is repeated. This back-and-forth continues until a design is developed that meets all requirements. The step-by-step, data-driven nature of MEPDG helps engineers create pavement designs that are not just structurally sound and long-lasting, but also cost-effective and tailored to local conditions.

To accommodate different project needs and available data, MEPDG uses a hierarchical input system. Level 1 inputs are the most accurate, based on detailed field or lab testing, and are used for high-traffic or high-risk projects. Level 2 inputs are moderately accurate, often based on correlations or limited testing. Level 3 inputs are the least detailed, using default values or local experience, and are generally suited for low-volume roads where early failure poses minimal risk. This flexible approach allows agencies to apply the right level of detail based on the project's importance, resources, and data availability (*4*) (*6*).

3.1 Project location and description

In this project, both flexible (asphalt) and rigid (concrete) pavement designs were developed using the AASHTOWare Pavement ME Design software. The flexible pavement designs were created for Interstate highways, State highways, and local roads within Montgomery, Alabama. For rigid pavements, the design scope was limited to Interstate and State highways. The project location is illustrated in Figure 4 below.

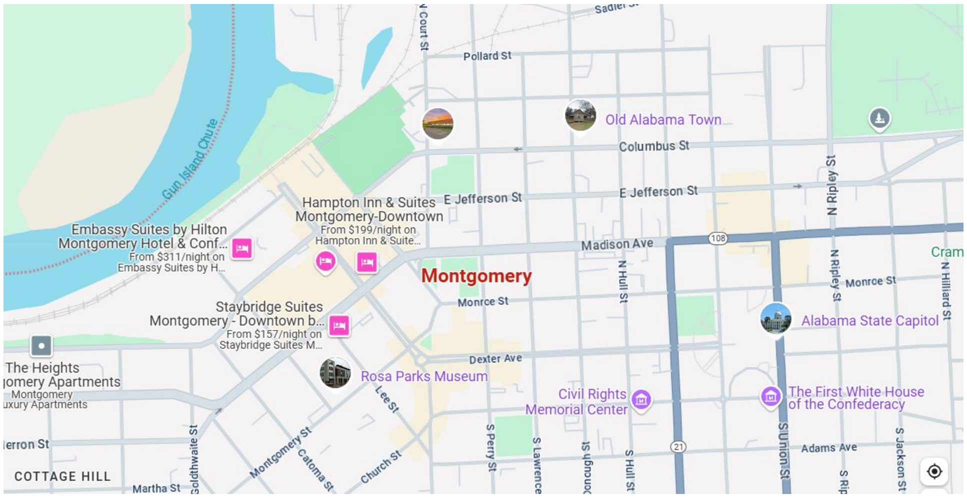


Figure 4. Location of the project site – Montgomery, Alabama.

4. Pavement design inputs

4.1 Traffic input

<u>Interstate:</u> 6000 ADT, 30% Trucks, 4-lane roadway, 75 mph,

<u>State Highway:</u> 1800 ADT, 15% Trucks, 2-lane roadway, 65 mph

<u>Local:</u> 180 ADT, 10% Trucks, 2-lane roadway, 55 mph

- 50% trucks in Design Direction
- 90% trucks in design lane for interstate, 100% in design lane for state and local

* Assume Traffic Capacity, Axle Configuration, Lateral Wander, and Wheelbase default values.

Vehicle Class Distributions:

<u>Interstate:</u> Use Truck Traffic Classification (TTC) Group 3
<u>State Highway:</u> Use TTC Group 5
<u>Local:</u> Use TTC Group 5

*Growth Rate: 2% compound for all vehicle classifications

Monthly Adjustment: Use default Values of 1.0

Axles per truck: Use default Values
Axle Load Distributions: Use default Values

Interstate: Use default values

State Highway: Use default values

Local: Use provided regional values

4.2 Climate input

This project requires that we utilize the weather station close to our project location. The project location is Montgomery, Alabama, hence the weather station located Wetumpka is used for this project. Figure 5 below shows the climate conditions inputs for the project.

Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131

Annual Statistics:

Mean annual air temperature (F):	39.35
Mean annual precipitation (in):	50.32
Freezing index (F - days):	1246.54
Average annual number of freeze/thaw cycles:	130.88
Water table depth (ft)	10.00

Figure 5. Climate conditions inputs for Montgomery, Alabama.

4.3 Proposed structure layer thickness and features

4.3.1 Design life

Design Type:	New Pavement
Pavement Type:	Flexible (Asphalt) or JPCP (Concrete)
Design Life:	Asphalt Pavement – 20 years
	JPCP Pavement – 30 years
Construction Dates:	Base Construction – May 2025
	Pavement Construction – July 2025
	Traffic Opening – August 2025

4.3.2 Performance Criteria

The performance criteria used in the design of both asphalt and rigid pavements are summarized in Tables 1 and 2.

Table 1. Asphalt Pavement Performance Criteria for Design.

Asphalt Pavement							
Functional Classification	**Alligator Cracking**	**Total Rutting**	**Transverse Cracking**	**Longitudinal Cracking**	**Terminal IRI**	**Initial IRI**	**AC Rutting**
	(% Lane)	**(in.)**	**(ft./mile)**	**(% Lane)**	**(in./mile)**	**(in./mile)**	**(in.)**
Interstate	10	0.4	500	20	160	50	0.25
State Highway	20	0.5	700	25	200	50	0.25
Local	30	1	1500	35	300	50	0.35

Table 2. Rigid Pavement Performance Criteria for design.

JPCP Pavement				
Functional Classification	**Slabs Cracked**	**Mean Transverse Joint Faulting**	**Terminal IRI**	**Initial IRI**
	(%)	**(in.)**	**(in./mile)**	**(in./mile)**
Interstate	10	0.15	160	65
State Highway	25	0.2	210	65

4.3.3 Reliability

The table below outlines the reliability levels assigned to each road functional classification

Table 3. Reliability Criteria for both Asphalt and Rigid Pavements.

Functional Classification	**Reliability Level**	
	Asphalt	**JPCP**
Interstate	95	95
State Highway	90	90
Local	75	--

4.4 Pavement material input

Asphalt

Thickness: User determined

Unit Weight: 140 pcf
Effective Binder Content: 10.2%
Air Voids: 7%
Poisson Ratio: 0.35
Asphalt Binder: Superpave Grade
*Leave all other inputs as default

Concrete

Thickness: User determined

Unit Weight: 150 pcf

Poisson's Ratio: 0.2
15 ft. joint spacing
Dowel Spacing: 12 inches Dowel Diameter:
PCC Thickness < or = 10 in., use 1.25 in. dowel
PCC Thickness > 10 in., use 1.5 in. Dowel
*Leave all other inputs as default

Base Material (Non-stabilized base):

Thickness: User Determined
Crushed Gravel (A-1-a)
Resilient Modulus: 30,000 psi
Poisson's Ratio: 0.35
k0: 0.5, Layer is compacted
*Leave all other inputs as default

Subgrade Material:

Thickness: User Determined

A-3
Resilient Modulus: 16,500 psi
Poisson's Ratio: 0.40
k0: 0.50
*Leave all other inputs as default

Calibration Coefficients

Use global calibration coefficients.

5. Analysis method

For this project in Montgomery, Alabama, the asphalt binder grade PG 64-22 was selected to match local climate and performance requirements. This grade was determined based on guidelines and recommendations from the Alabama Department of Transportation (ALDOT).

Table 4 presents the recommended minimum thicknesses for asphalt concrete and base layers, as specified by the AASHTO 1993 design guide.

Table 4. Minimum asphalt and base thicknesses recommended from AASHTO.

Traffic, ESAL	Asphalt Concrete	Aggregate Base
< 50,000	1.0 (or surface treatment)	4.0
50,000 – 150,000	2.0	4.0
150,001 – 500,000	2.5	4.0
500,001 – 2,000,000	3.0	6.0
2,000,001 – 7,000,000	3.5	6.0
> 7,000,000	4.0	6.0

Interstate

AADT = 6000, 30% Trucks, 4-Lane Roadway, and 75 mph speed.

TTC group = 3

AADTT = 6000 * 0.3

AADTT = 1800 vpd.

The AADTT considering trucks in design direction and the trucks in design lane

AADTT = 1800 ×0.5 × 0.9

AADTT = 810 vpd

Table 5. Total Truck Traffic estimation for the Interstate Highway.

AADTT (vpd)	**810**									
Class	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
% TTC 3	0.9	11.6	3.6	0.2	6.7	62.0	4.8	2.6	1.4	6.2
AADTT	7.3	94.0	29.2	1.6	54.3	502.2	38.9	21.1	11.3	50.2
Truck Traffic/year	295,650									
ESAL for 20 years (Asphalt pavement)	7,183,517 (Geometric formula)					7,188,440 (From AASHTOWare)				
ESAL for 30 years (Rigid pavement)	11,993,953 (Geometric formula)					12,002,200 (From AASHTOWare)				

Since the ESAL value for our project exceeds 7 million, the AASHTO design guide recommends a minimum asphalt layer thickness of 4 inches and a base layer thickness of 6 inches.

State Highway

AADT = 1800, 15% Trucks, 2-Lane Roadway, and 65 mph speed.

TTC group = 5

AADTT = 1800 × 0.15

AADTT = 270 vpd.

The AADTT considering trucks in design direction and the trucks in design lane

AADTT = 270 × 0.5 × 1.0

AADTT = 135 vpd

Table 6. Total Truck Traffic estimation for State Highway.

AADTT (vpd)	**135**									
Class	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
% TTC 5	0.9	14.2	3.5	0.6	6.9	54.0	5.0	2.7	1.2	11.0
Truck Traffic/year	49275									
ESAL for 20 years (Asphalt pavement)	1,197,253 (Geometric formula)						1,198,070 (From AASHTOWare)			
ESAL for 30 years (Rigid pavement)	1,998,992 (Geometric formula)						2,000,360 (From AASHTOWare)			

For an ESAL range between 500,001 and 2 million, the AASHTO design guide recommends a minimum asphalt layer thickness of 3 inches and a base layer thickness of 6 inches.

Local Road

Flexible Pavement only

AADT = 180, 10% Trucks, 2-Lane Roadway, and 55 mph speed.

TTC group = 5%.

AADTT = 180 * 0.10

AADTT = 18 vpd.

The AADTT considering trucks in design direction and the trucks in design lane

AADTT = 18 × 0.5 × 1.0

AADTT = 9 vpd

Table 7. Total Truck Traffic estimation for Local Highway.

AADTT (vpd)	9									
Class	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
% TTC 5	0.9	14.2	3.5	0.6	6.9	54.0	5.0	2.7	1.2	11.0
AADTT	0.1	1.3	0.3	0.1	0.6	4.9	0.5	0.2	0.1	1.0
Truck Traffic/year	3,285									
ESAL for 20 years (Asphalt pavement)	79,817 (Geometric formula)						79,870 (From AASHTOWare)			

For an ESAL range of 50,000 to 150,000, the AASHTO guide recommends a minimum of 2 inches for the asphalt layer and 4 inches for the base layer.

6. Results and discussions

6.1 Flexible pavements

6.1.1 Interstate highway

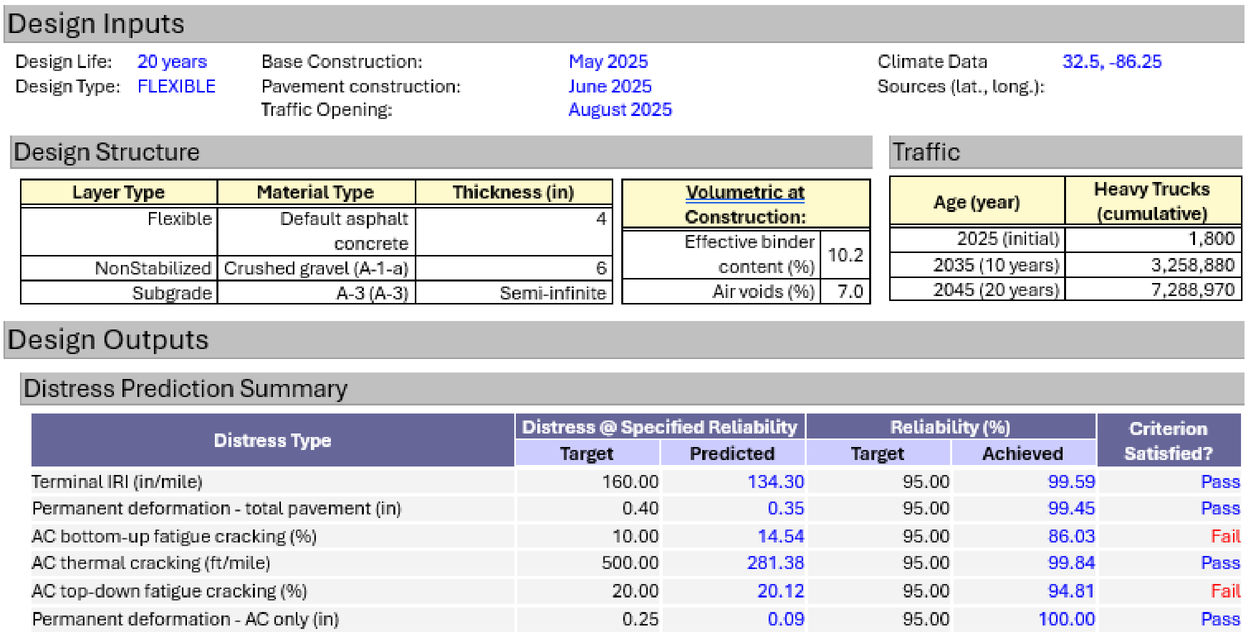
A detailed evaluation involving five design trials was conducted to determine the most cost-effective pavement section with an optimal thickness for the interstate freeway. The analysis was guided by performance criteria essential for ensuring reliable freeway performance. Based on ESAL loading specific to interstate highways, the minimum required thicknesses were set at 4 inches for the asphalt layer and 6 inches for the crushed gravel base. A summary of the results from these design trials is presented in the table below.

Table 8. Design trials for interstate asphalt pavement.

Trial	Asphalt Thickness (Inches)	Crushed Gravel Thickness (Inches)	PG Grade	Result	Remarks
1	5	6	PG 58-10	Fail	AC thermal cracking (ft/mile)
2	4	6	PG 58-16	Fail	AC thermal cracking (ft/mile), AC bottom-up fatigue cracking (%), AC top-down fatigue cracking (%)
3	4	6	PG 58-22	Fail	AC bottom-up fatigue cracking (%)
4	4	6	PG 64-22	Fail	AC bottom-up fatigue cracking (%), AC top-down fatigue cracking (%)
5	**5**	**7**	**PG 64-22**	**Pass**	

In the first trial, an asphalt concrete (AC) thickness of 5 inches and a 6-inch crushed gravel base were tested using PG 58-10 binder. However, the pavement failed primarily due to thermal cracking, indicating that the selected binder grade lacked adequate thermal resistance. In response, the second trial reduced the asphalt thickness to 4 inches while keeping the same base and used PG 58-16. This trial also failed, showing multiple forms of cracking, including thermal, bottom-up, and top-down fatigue cracking.

For the third trial, the asphalt thickness remained at 4 inches, but the binder grade was upgraded to PG 58-22. Despite this change, the design still failed, this time due to bottom-up fatigue cracking. In the fourth trial, the binder was further improved to PG 64-22, yet the design again failed due to both bottom-up and top-down fatigue cracking. These results confirmed that the asphalt thickness of 4 inches was insufficient for interstate-level loading, even with a higher-performance binder.



Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE
Base Construction: May 2025
Pavement construction: June 2025
Traffic Opening: August 2025
Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	4
NonStabilized	Crushed gravel (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2035 (10 years)	3,258,880
2045 (20 years)	7,288,970

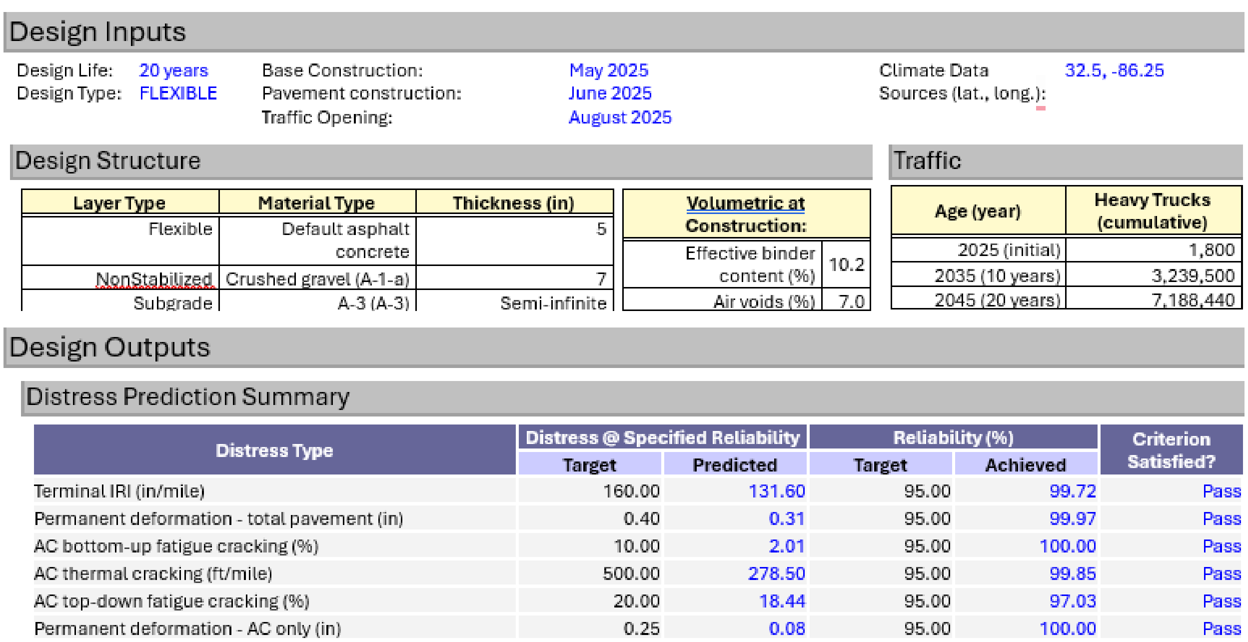
Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	134.30	95.00	99.59	Pass
Permanent deformation - total pavement (in)	0.40	0.35	95.00	99.45	Pass
AC bottom-up fatigue cracking (%)	10.00	14.54	95.00	86.03	Fail
AC thermal cracking (ft/mile)	500.00	281.38	95.00	99.84	Pass
AC top-down fatigue cracking (%)	20.00	20.12	95.00	94.81	Fail
Permanent deformation - AC only (in)	0.25	0.09	95.00	100.00	Pass

Figure 6. Performance outputs from trial 4 – Interstate Highway asphalt pavement.

The fifth trial increased the asphalt thickness to 5 inches and the base thickness to 7 inches while maintaining PG 64-22. This configuration successfully met all performance criteria, passing the MEPDG evaluation. Based on this outcome, the combination of a 5-inch asphalt layer, 7-inch base layer, and PG 64-22 binder was identified as the most cost-effective and reliable solution for the interstate pavement section. The final design outputs are summarized in the figure below.



Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE
Base Construction: May 2025
Pavement construction: June 2025
Traffic Opening: August 2025
Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	5
NonStabilized	Crushed gravel (A-1-a)	7
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2035 (10 years)	3,239,500
2045 (20 years)	7,188,440

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	131.60	95.00	99.72	Pass
Permanent deformation - total pavement (in)	0.40	0.31	95.00	99.97	Pass
AC bottom-up fatigue cracking (%)	10.00	2.01	95.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	278.50	95.00	99.85	Pass
AC top-down fatigue cracking (%)	20.00	18.44	95.00	97.03	Pass
Permanent deformation - AC only (in)	0.25	0.08	95.00	100.00	Pass

Figure 7. Interstate Highway asphalt pavement final design output.

6.1.2 State highway

As per ESAL-based design guidelines, flexible pavements on state highways should have a minimum of 3 inches of asphalt concrete (AC) and a 6-inch crushed gravel base to ensure adequate structural support. These values are intended to provide sufficient structural capacity under expected traffic conditions. To identify a suitable design, four pavement trials were conducted using various binder grades and asphalt thicknesses.

The first trial used a 3-inch AC layer with a PG 58-16 binder, which failed due to thermal cracking. The second trial increased the AC thickness to 4 inches with PG 58-10, but thermal cracking persisted. In the third trial, the binder was switched back to PG 58-16 while keeping the 4-inch thickness, yet the design still failed from the same distress.

In the final trial, the AC thickness was returned to 3 inches, and the binder was changed to PG 52-22, which performs better in colder conditions. This trial met all performance requirements, indicating that the improved binder grade was the key factor in resolving thermal cracking issues.

Based on the trial results, the most efficient and reliable design for state highway pavement consists of 3 inches of asphalt concrete, 6 inches of crushed gravel, and a PG 52-22 binder. This combination meets performance standards while minimizing material use and cost.

Table 9. Design trials for state asphalt pavement.

Trial	Asphalt Thickness (Inches)	Crushed Gravel Thickness (Inches)	PG Grade	Result	Remarks
1	3	6	PG 58-16	Fail	AC thermal cracking (ft/mile)
2	4	6	PG 58-10	Fail	AC thermal cracking (ft/mile)
3	4	6	PG 58-16	Fail	AC thermal cracking (ft/mile)
4	**3**	**6**	**PG 52-22**	**Pass**	

Design Inputs

Design Life:	20 years	Base Construction:	May 2025	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	FLEXIBLE	Pavement construction:	June 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	4
NonStabilized	Crushed gravel (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2035 (10 years)	545,647
2045 (20 years)	1,227,800

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	130.70	90.00	99.99	Pass
Permanent deformation - total pavement (in)	0.50	0.27	90.00	100.00	Pass
AC bottom-up fatigue cracking (%)	20.00	1.46	90.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	1571.24	90.00	26.18	Fail
AC top-down fatigue cracking (%)	25.00	12.21	90.00	99.98	Pass
Permanent deformation - AC only (in)	0.25	0.06	90.00	100.00	Pass

Figure 8. Performance outputs from trial 3 – State Highway asphalt pavement.

The final design outputs are summarized in the figure below.

Design Inputs

Design Life:	20 years	Base Construction:	May 2025	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	FLEXIBLE	Pavement construction:	June 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	3
NonStabilized	Crushed gravel (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2035 (10 years)	539,917
2045 (20 years)	1,198,070

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	121.40	90.00	100.00	Pass
Permanent deformation - total pavement (in)	0.50	0.33	90.00	100.00	Pass
AC bottom-up fatigue cracking (%)	20.00	1.47	90.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	228.28	90.00	100.00	Pass
AC top-down fatigue cracking (%)	25.00	7.86	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.08	90.00	100.00	Pass

Figure 9. State Highway asphalt pavement final design outputs.

6.1.3 Local roads

We conducted four design trials to identify the most efficient and cost-effective pavement section for local roads. The first trial used a 1-inch asphalt concrete layer with a 6-inch crushed gravel base and PG 52-16 binder. This configuration failed due to thermal cracking, indicating that both the binder grade and AC thickness were insufficient for local road conditions.

For the second trial, the AC thickness increased to 2 inches while maintaining the 6-inch base and switching to PG 52-10. However, the pavement still failed due to thermal cracking. In the third trial, the base thickness was reduced to 4 inches while keeping the AC at 2 inches, but thermal cracking remained a concern with the same PG 52-10 grade.

The fourth and final trial retained the 2-inch asphalt and 4-inch base but used a binder with improved low-temperature performance (PG 52-22). This trial successfully passed all performance requirements, indicating that PG 52-22 was better suited to withstand thermal distress in local road environments.

Based on the results, the most practical and reliable pavement design for local roads consists of 2 inches of asphalt concrete and 4 inches of crushed gravel base using PG 52-22 binder. This combination balances performance with material efficiency and satisfies both structural and environmental demands.

Table 10. Design trials for local asphalt pavement.

Trial	Asphalt Thickness (Inches)	Crushed Gravel Thickness (Inches)	PG Grade	Result	Remarks
1	1	6	PG 52-16	Fail	AC thermal cracking (ft/mile)
2	2	6	PG 52-10	Fail	AC thermal cracking (ft/mile)
3	2	4	PG 52-10	Fail	AC thermal cracking (ft/mile)
4	**2**	**4**	**PG 52-22**	**Pass**	

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	2
NonStabilized	Crushed gravel (A-1-a)	4
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	18
2035 (10 years)	36,376
2045 (20 years)	81,853

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	300.00	120.40	75.00	100.00	Pass
Permanent deformation - total pavement (in)	1.00	0.22	75.00	100.00	Pass
AC bottom-up fatigue cracking (%)	30.00	0.76	75.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	2447.72	75.00	26.79	Fail
AC top-down fatigue cracking (%)	35.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.35	0.03	75.00	100.00	Pass

Figure 10. Performance outputs from trial 3 – Local Highway asphalt pavement.

The final design outputs are summarized in the figure below.

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base Construction: May 2025
Pavement construction: June 2025
Traffic Opening: August 2025

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	2
NonStabilized	Crushed gravel (A-1-a)	4
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	18
2035 (10 years)	36,376
2045 (20 years)	81,853

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	300.00	102.30	75.00	100.00	Pass
Permanent deformation - total pavement (in)	1.00	0.22	75.00	100.00	Pass
AC bottom-up fatigue cracking (%)	30.00	0.76	75.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	147.63	75.00	100.00	Pass
AC top-down fatigue cracking (%)	35.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.35	0.04	75.00	100.00	Pass

Figure 11. Local Highway asphalt pavement final design outputs.

6.2 Rigid pavements

6.2.1 Interstate highway

For the design of the rigid interstate pavement, a two-layer system was considered, consisting of a jointed plain concrete slab over a compacted crushed gravel base placed on the natural subgrade. A total of five design trials were performed, beginning with a concrete thickness of 7 inches and a base thickness of 6 inches, following AASHTO design practices. This initial configuration failed due to excessive transverse cracking in the concrete slab.

In the following trials, the concrete thickness was gradually increased in 0.5-inch increments while keeping the base thickness constant at 6 inches. Trials with concrete slab thicknesses of 7.5, 8, and 8.5 inches all failed due to continued transverse cracking in the JPCP layer, indicating that these thicknesses were still inadequate to withstand the traffic and environmental stresses of interstate highway conditions.

Each trial result showed a reduction in cracking severity as thickness increased, suggesting improved load distribution and stress reduction. However, none of these intermediate configurations met the design criteria for long-term performance and durability under high-volume interstate traffic loading.

The final trial, which used a concrete thickness of 9 inches and maintained a 6-inch crushed gravel base, successfully met all performance criteria, including limits on transverse cracking. Therefore, this configuration was selected as the most suitable and structurally reliable design for the rigid pavement section of the interstate highway.

Table 11. Design trials for rigid interstate highway.

Trial	Concrete Thickness (Inches)	Crush Gravel Base Course (Inches)	Result	Remarks
1	7	6	Fail	JPCP transverse cracking (%)
2	7.5	6	Fail	JPCP transverse cracking (%)
3	8	6	Fail	JPCP transverse cracking (%)
4	8.5	6	Fail	JPCP transverse cracking (%)
5	**9**	**6**	**Pass**	

Design Inputs

Design Life:	30 years	Existing Construction:	-	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	JPCP	Pavement construction:	July 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	8.5
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2040 (15 years)	5,116,300
2055 (30 years)	12,002,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	90.48	95.00	100.00	Pass
Mean joint faulting (in)	0.15	0.07	95.00	100.00	Pass
JPCP transverse cracking (% slabs)	10.00	18.45	95.00	72.01	Fail

Figure 12. Performance outputs from trial 4 – Interstate Rigid Pavement.

The final design outputs are summarized in the figure below.

Design Inputs

Design Life:	30 years	Existing Construction:	-	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	JPCP	Pavement construction:	July 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	9
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2040 (15 years)	5,116,300
2055 (30 years)	12,002,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	88.83	95.00	100.00	Pass
Mean joint faulting (in)	0.15	0.07	95.00	100.00	Pass
JPCP transverse cracking (% slabs)	10.00	9.07	95.00	96.70	Pass

Figure 13. Final design outputs for Interstate Highway rigid pavement.

6.2.2 State highway

For the rigid pavement design of a state highway, a layered structure consisting of a jointed plain concrete slab over a 6-inch crushed gravel base course was used. Four design trials were conducted to determine the minimum slab thickness required to meet performance standards, particularly focusing on limiting transverse cracking in the concrete layer.

In the first three trials, concrete thicknesses of 6.0, 6.5, and 7.0 inches were evaluated, all paired with a constant 6-inch base. Each of these trials failed due to excessive transverse cracking in the JPCP layer, indicating that the slab was not thick enough to resist cracking under anticipated traffic and environmental loads.

The final trial increased the concrete slab thickness to 7.5 inches, while keeping the base layer unchanged. This configuration successfully met all performance requirements and showed acceptable levels of transverse cracking. As a result, the trial with 7.5 inches of concrete and 6 inches of crushed gravel base was identified as the most reliable and cost-effective design for rigid pavements on state highways.

Table 12. Design trials for a rigid pavement-state highway.

Trial	Concrete Thickness (Inches)	Crush Gravel Base Course (Inches)	Result	Remarks
1	6	6	Fail	JPCP transverse cracking (%)
2	6.5	6	Fail	JPCP transverse cracking (%)
3	7	6	Fail	JPCP transverse cracking (%)
4	**7.5**	**6**	**Pass**	

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing Construction: -
Pavement construction: July 2025
Traffic Opening: August 2025

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	7
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2040 (15 years)	852,717
2055 (30 years)	2,000,360

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	210.00	84.82	90.00	100.00	Pass
Mean joint faulting (in)	0.20	0.02	90.00	100.00	Pass
JPCP transverse cracking (% slabs)	25.00	27.10	90.00	86.11	Fail

Figure 14. Performance outputs from trial 3 – State Highway Rigid Pavement.

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing Construction: -
Pavement construction: July 2025
Traffic Opening: August 2025

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	7.5
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2040 (15 years)	852,717
2055 (30 years)	2,000,360

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	210.00	78.93	90.00	100.00	Pass
Mean joint faulting (in)	0.20	0.02	90.00	100.00	Pass
JPCP transverse cracking (% slabs)	25.00	11.33	90.00	99.96	Pass

Figure 15. Final design outputs for State Highway Rigid Pavement.

7. Conclusions

This study used MEPDG design trials to evaluate suitable pavement structures for different roadway types under realistic loading and environmental conditions. For interstate flexible pavements, the optimal design was achieved with 5 inches of asphalt concrete over 7 inches of crushed gravel, using a PG 64-22 binder, which met all required performance standards. On the rigid side, interstate highways required a 9-inch concrete slab over a 6-inch base course to effectively resist transverse cracking and ensure long-term durability.

State highways required slightly different design solutions. For flexible pavements, a combination of a 3-inch asphalt layer, 6-inch crushed gravel base, and PG 52-22 binder performed best. Previous trials using PG 58-10 and PG 58-16 showed thermal cracking, confirming that selecting an appropriate binder is just as important as determining thickness. For rigid pavements on state highways, a 7.5-inch concrete layer with a 6-inch base was sufficient to pass design criteria and mitigate cracking issues.

For local roadways, where traffic loads are relatively low, a simpler yet effective pavement structure was recommended. A 2-inch asphalt layer over a 4-inch granular base, paired with a PG 52-22 binder, performed well and passed all evaluation metrics. Earlier designs using PG 52-10 and PG 52-16 failed due to thermal cracking, reinforcing the need to choose binder grades carefully even for low-volume roads.

Overall, the design recommendations reflect the need to balance pavement thickness, material properties, and binder performance based on road function and traffic volume. These findings support practical, cost-effective decision-making in pavement design that can improve roadway longevity, reduce maintenance needs, and adapt to both climatic and loading conditions.

Key insights from the design trials:

- Reliability levels significantly influence the required pavement thickness.
- Thicker layers with lower-grade binders can often be more economical than thinner layers with high-grade binders, depending on environmental factors.
- Minimum temperature in binder selection plays a larger role in pavement performance than maximum temperature, especially for preventing thermal cracking.

8. References

1. Boone, J. N. Comparison of Ontario Pavement Designs Using the AASHTO 1993 Empirical Method and the Mechanistic-Empirical Pavement Design Guide Method.
2. Li, Q., D. X. Xiao, K. C. P. Wang, K. D. Hall, and Y. Qiu. Mechanistic-Empirical Pavement Design Guide (MEPDG): A Bird's-Eye View. *Journal of Modern Transportation*, Vol. 19, No. 2, 2011, pp. 114–133. https://doi.org/10.1007/BF03325749.
3. Luo, Z., F. Xiao, and R. Sharma. Efficient Reliability-Based Approach Asphalt Pavement Design. *Construction and Building Materials*, Vol. 64, 2014, pp. 157–165. https://doi.org/10.1016/j.conbuildmat.2014.04.071.
4. Schwartz, C.W. (2007). Implementation of the NCHRP 1-37A Design Guide Final Report.Pdf
5. Pavement Design, Construction, and Management A Digital Handbook (2015).Pdf
6. AASHTO Guide for Design-Build Procurement 2008.

9. APPENDIX

9.1 Interstate highway final design outputs-asphalt pavement

Madhav Joshi and Kamal Gautam Interstate-Asphalt

Tenant: Kamal Gautam   Workspace: System Workspace

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base Construction: May 2025
Pavement construction: June 2025
Traffic Opening: August 2025

Climate Data Sources (lat., long.): 32.5, -86.25

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	5
NonStabilized	Crushed gravel (A-1-a)	7
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

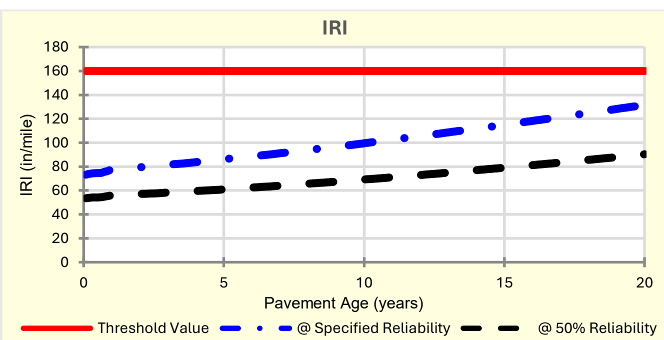
Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2035 (10 years)	3,239,500
2045 (20 years)	7,188,440

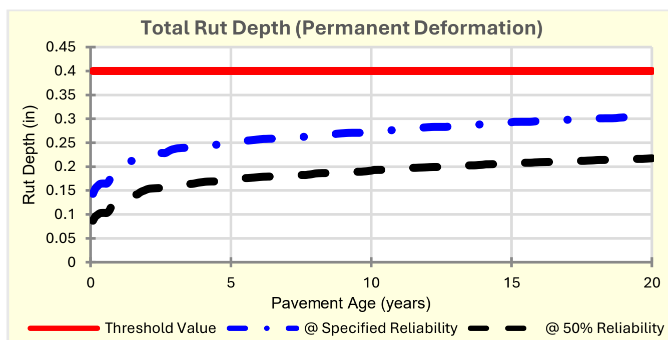
Design Outputs

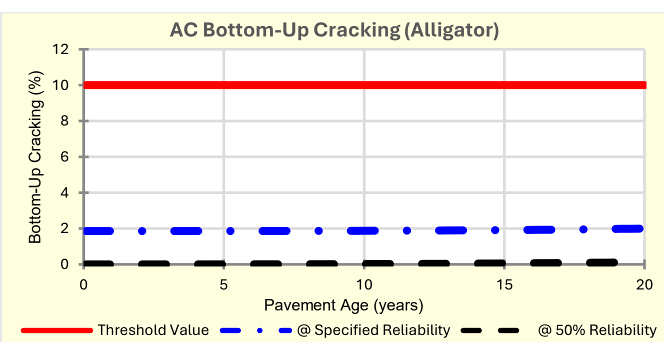
Distress Prediction Summary

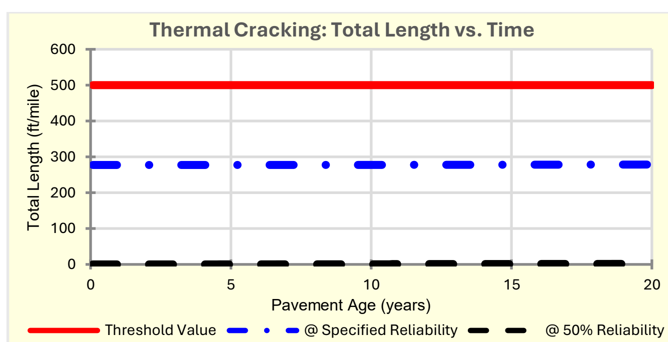
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	131.60	95.00	99.72	Pass
Permanent deformation - total pavement (in)	0.40	0.31	95.00	99.97	Pass
AC bottom-up fatigue cracking (%)	10.00	2.01	95.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	278.50	95.00	99.85	Pass
AC top-down fatigue cracking (%)	20.00	18.44	95.00	97.03	Pass
Permanent deformation - AC only (in)	0.25	0.08	95.00	100.00	Pass

Distress Charts





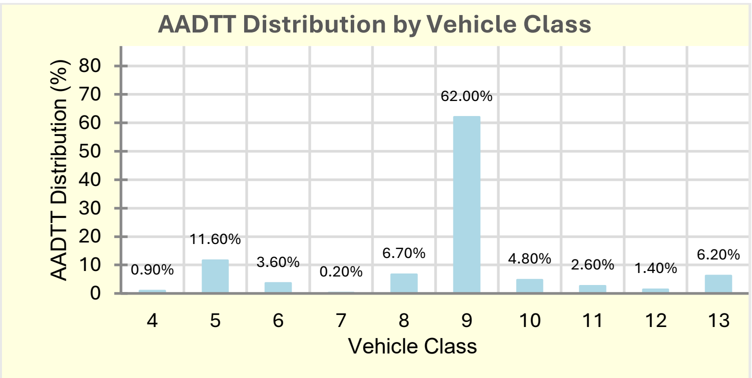




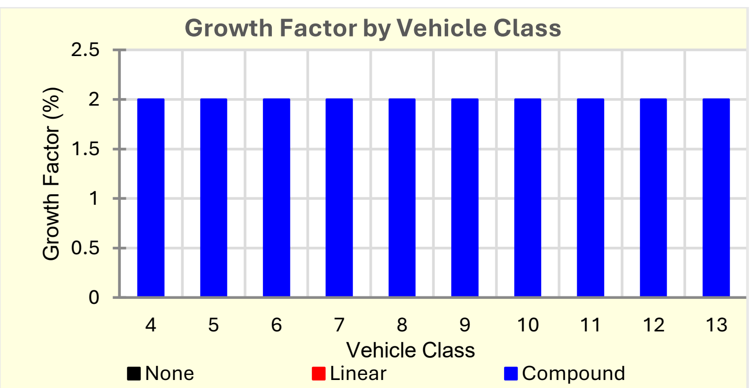
Traffic Inputs

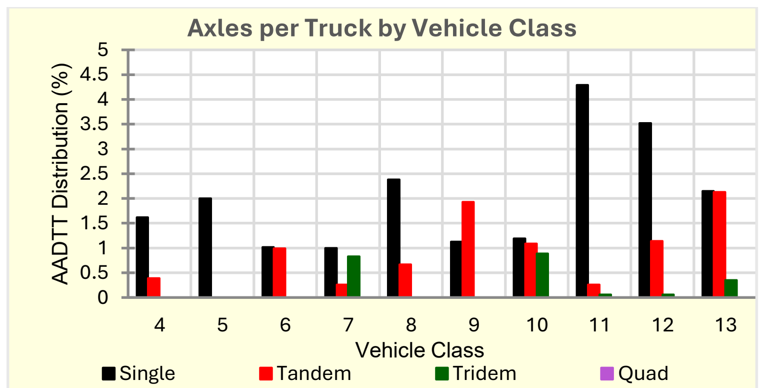
Graphical Representation of Traffic Inputs

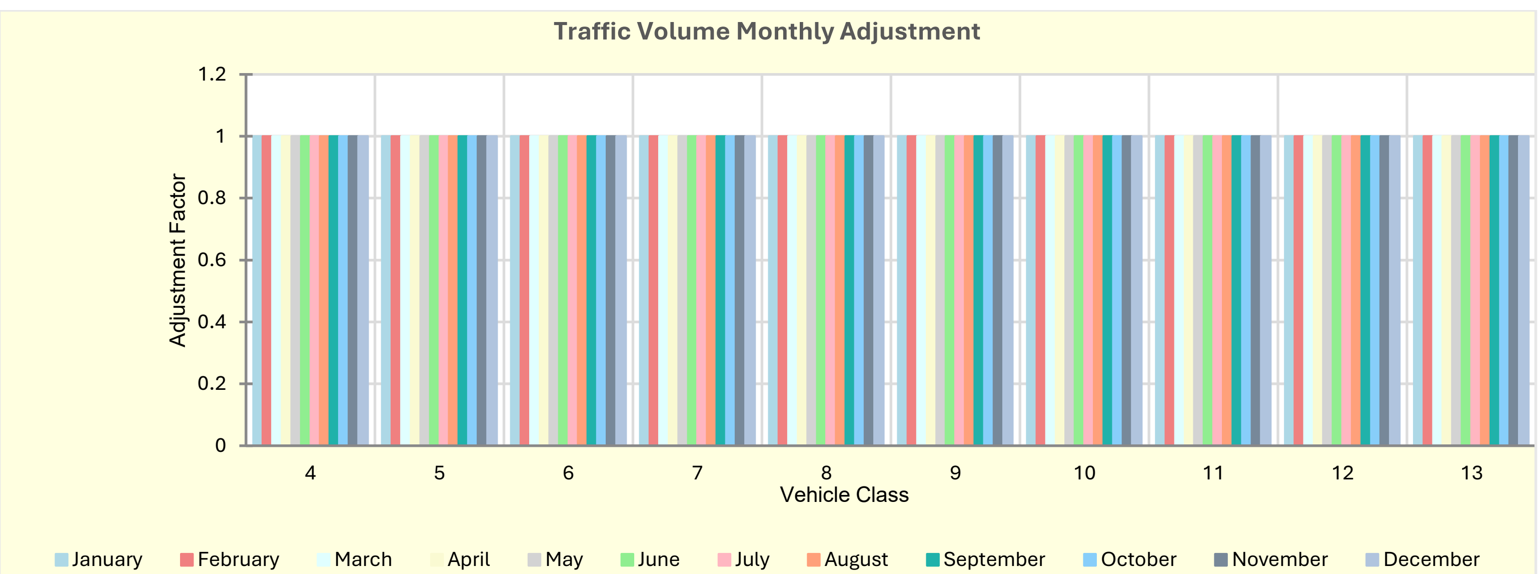
Initial two-way AADTT	1800
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	90
Operation speed (mph)	75
Axle Distribution	NCHRP 1-37A



Truck Distribution by Hour does not apply to the design type.







Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors (Level 3: Default MAF)

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.9%	2%	Compound
Class 5	11.6%	2%	Compound
Class 6	3.6%	2%	Compound
Class 7	0.2%	2%	Compound
Class 8	6.7%	2%	Compound
Class 9	62.0%	2%	Compound
Class 10	4.8%	2%	Compound
Class 11	2.6%	2%	Compound
Class 12	1.4%	2%	Compound
Class 13	6.2%	2%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

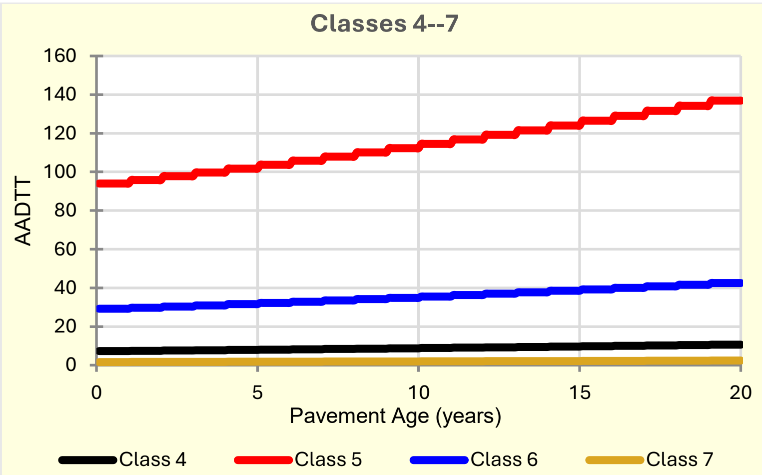
Wheelbase does not apply

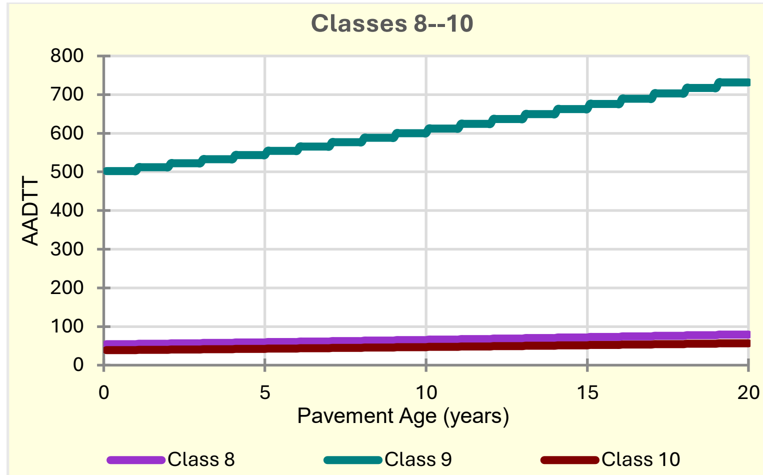
Number of Axles per Truck

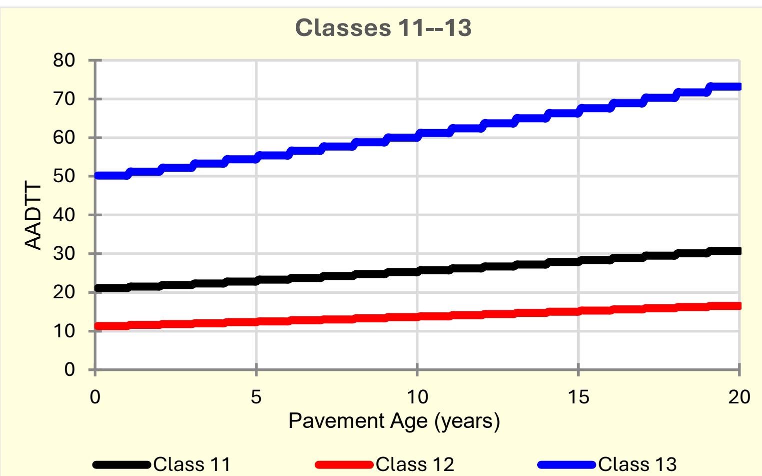
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

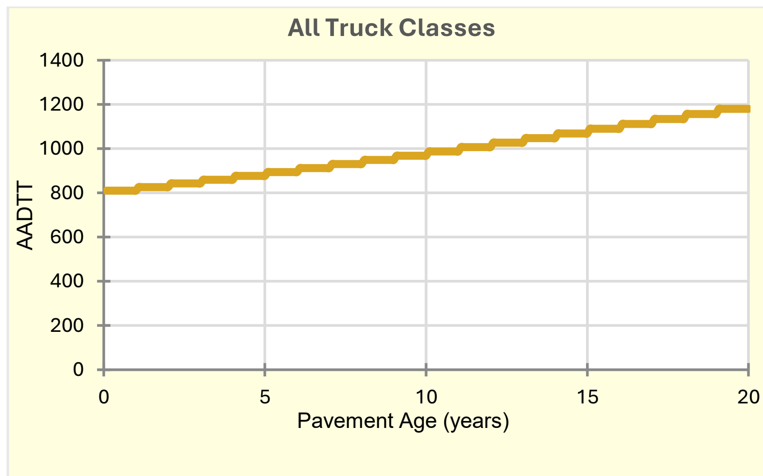
AADTT (Average Annual Daily Truck Traffic) Growth

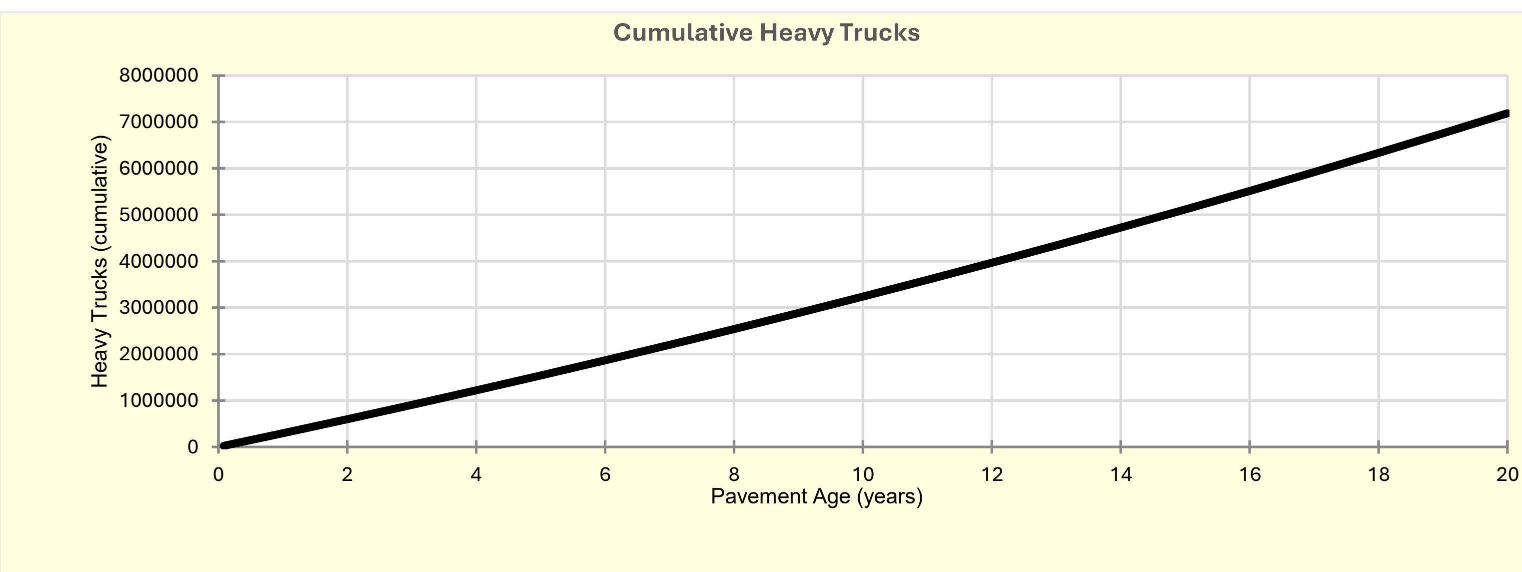
* Traffic cap is not enforced

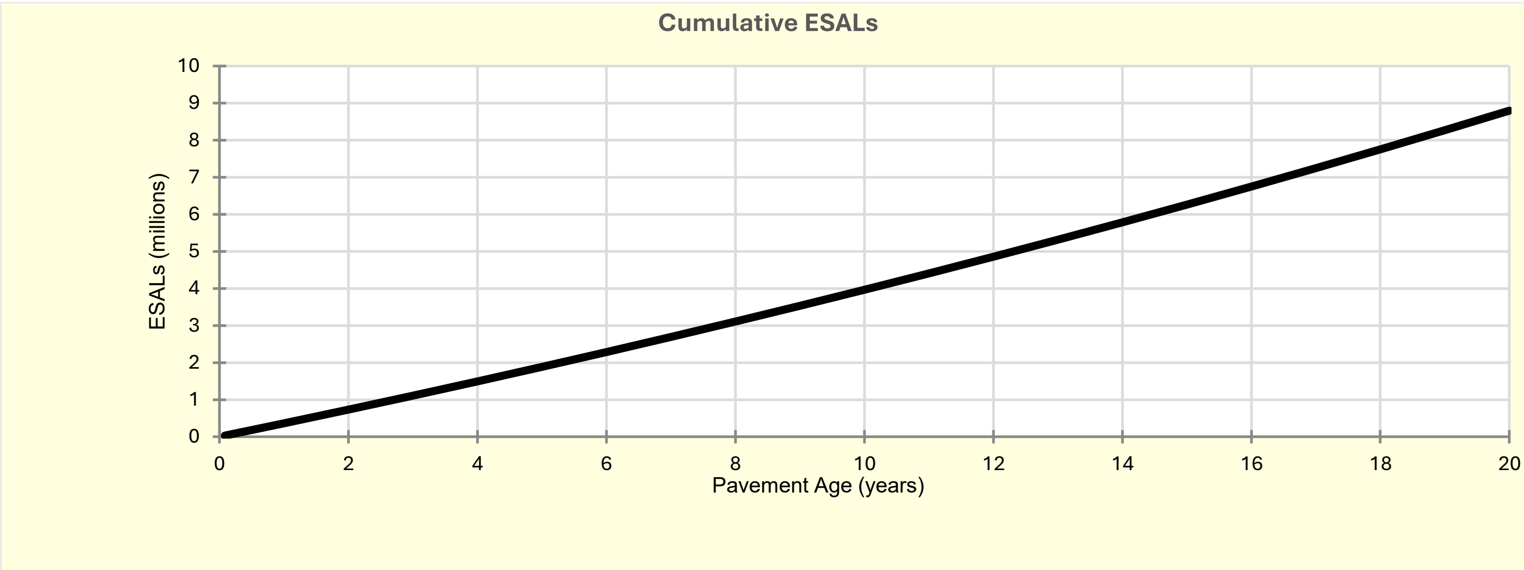











Cumulative ESALs
ESALs (millions)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)

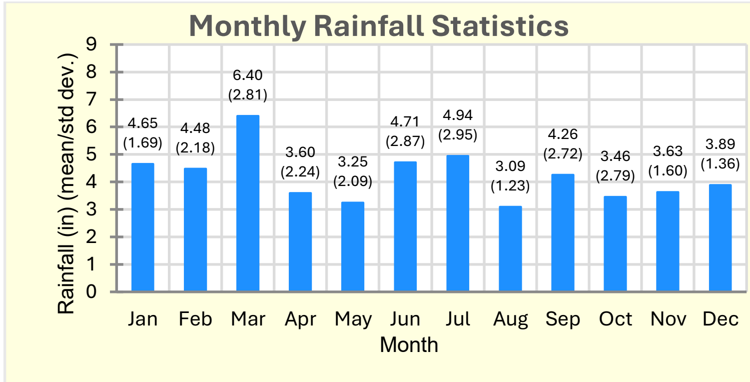
Climate Inputs

Climate Data Sources:

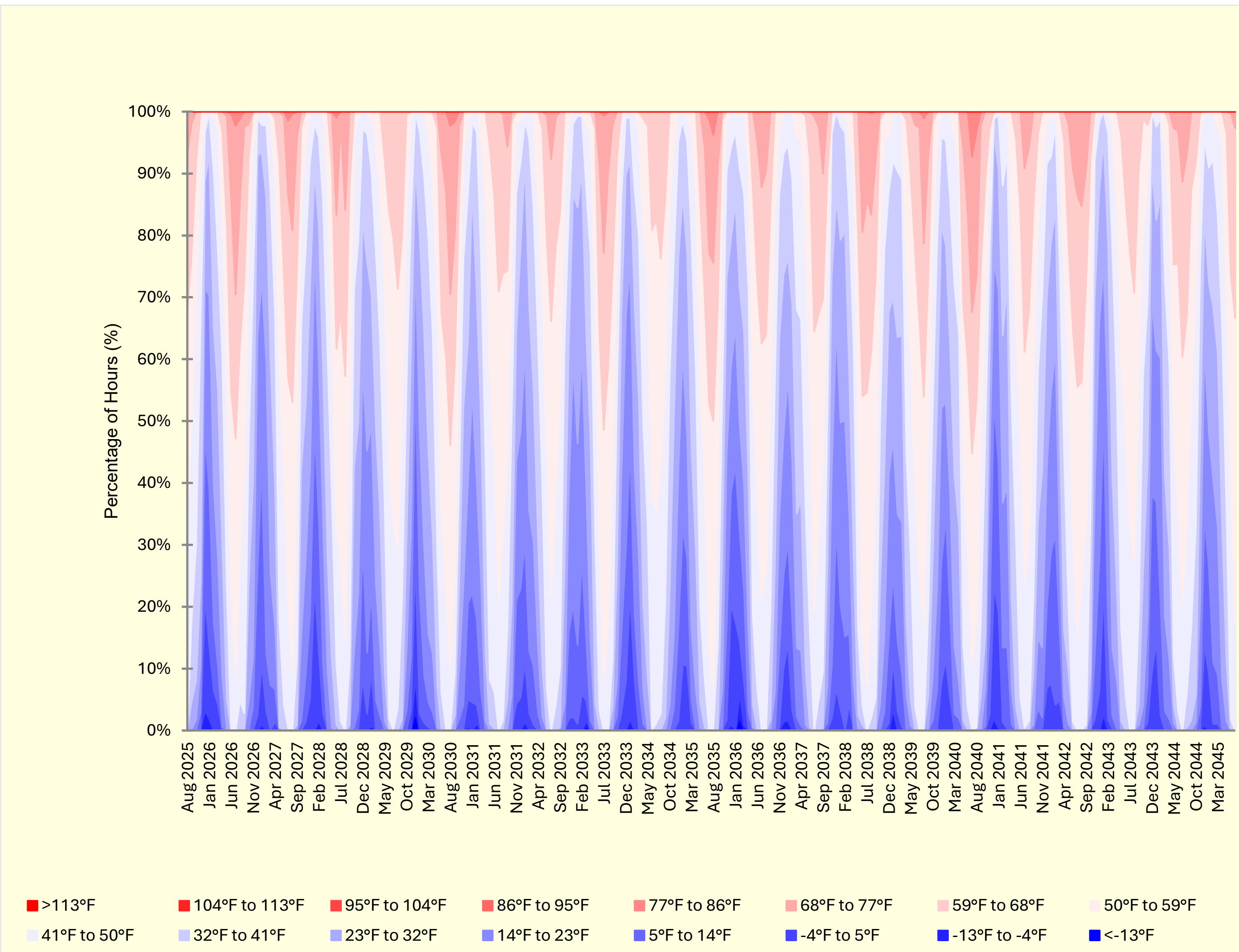
Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131

Annual Statistics:

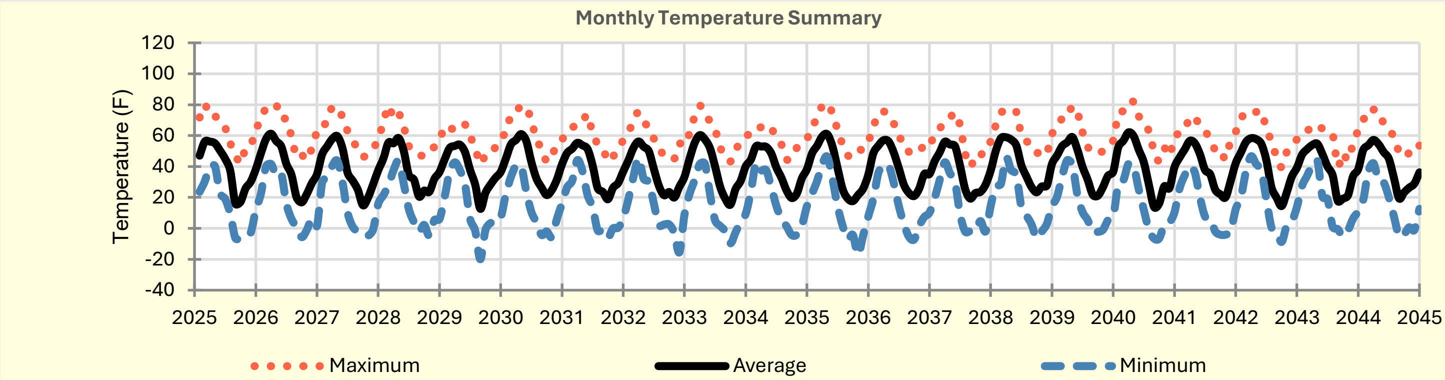
Mean annual air temperature (F):	39.35
Mean annual precipitation (in):	50.32
Freezing index (F - days):	1246.54
Average annual number of freeze/thaw cycles:	130.88
Water table depth (ft)	10.00

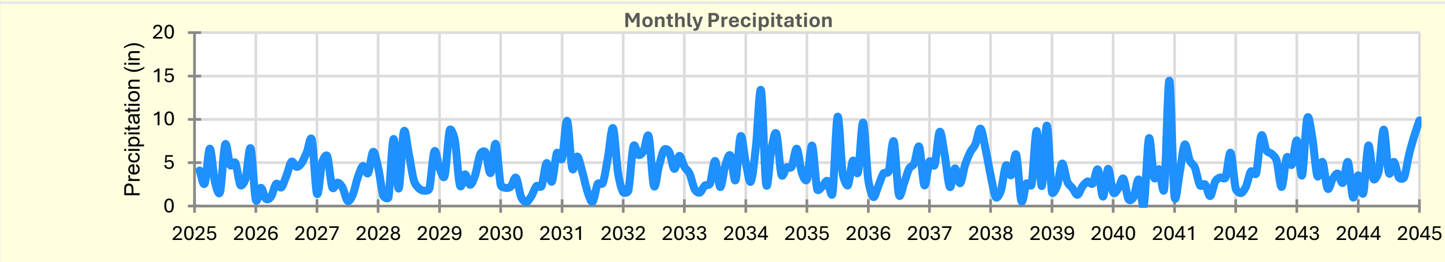


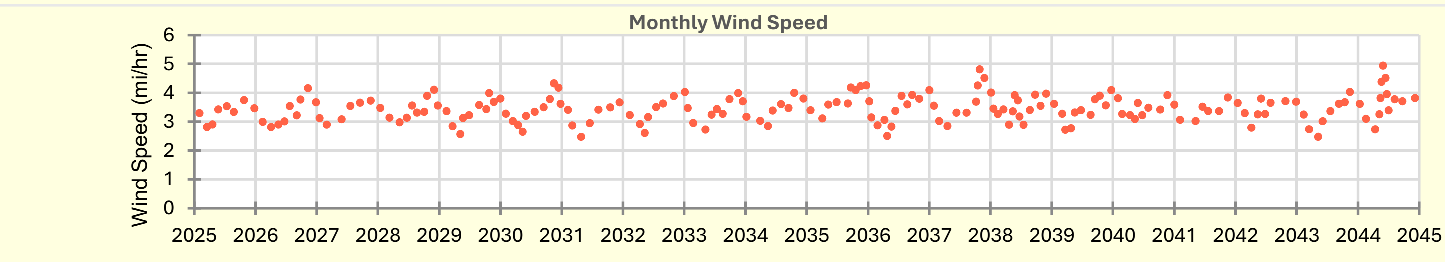
Hourly Air Temperature Distribution by Month:

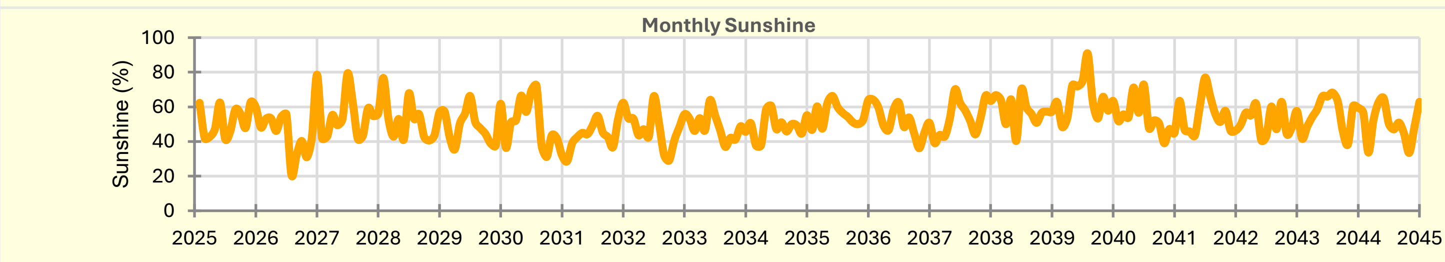


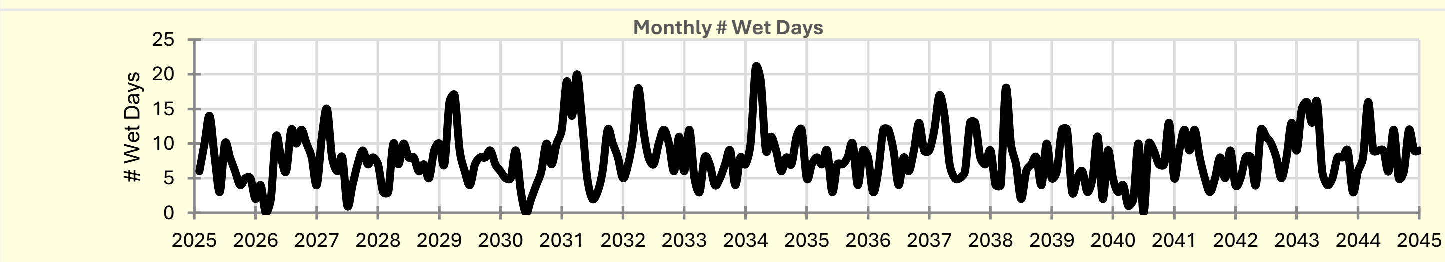
Monthly Climate Summary:

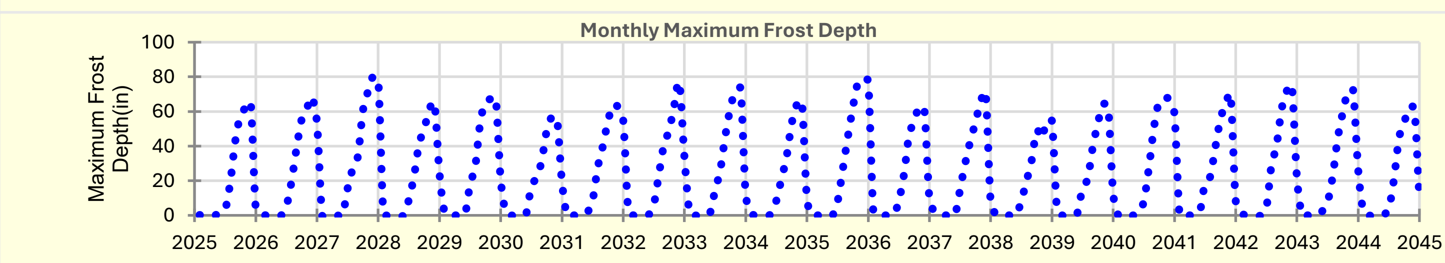












Design Properties

HMA Design Properties

Multilayer Rutting Model	False
NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Using Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

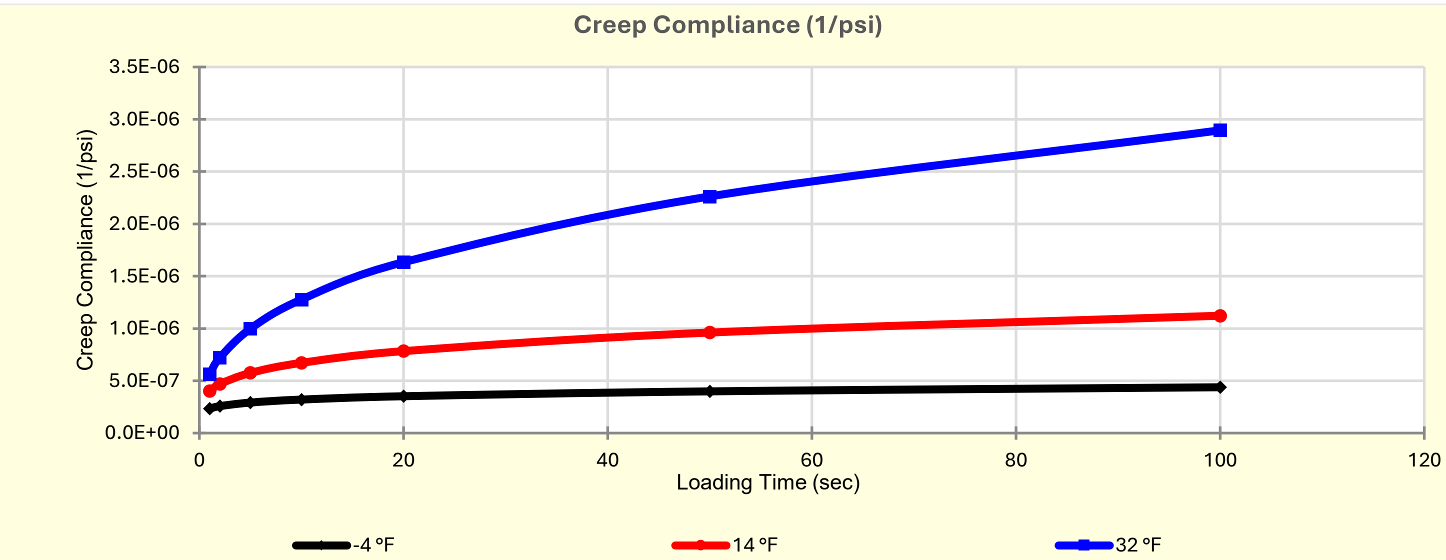
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed gravel (A-1-a)	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-3 (A-3)	Subgrade (5)	-

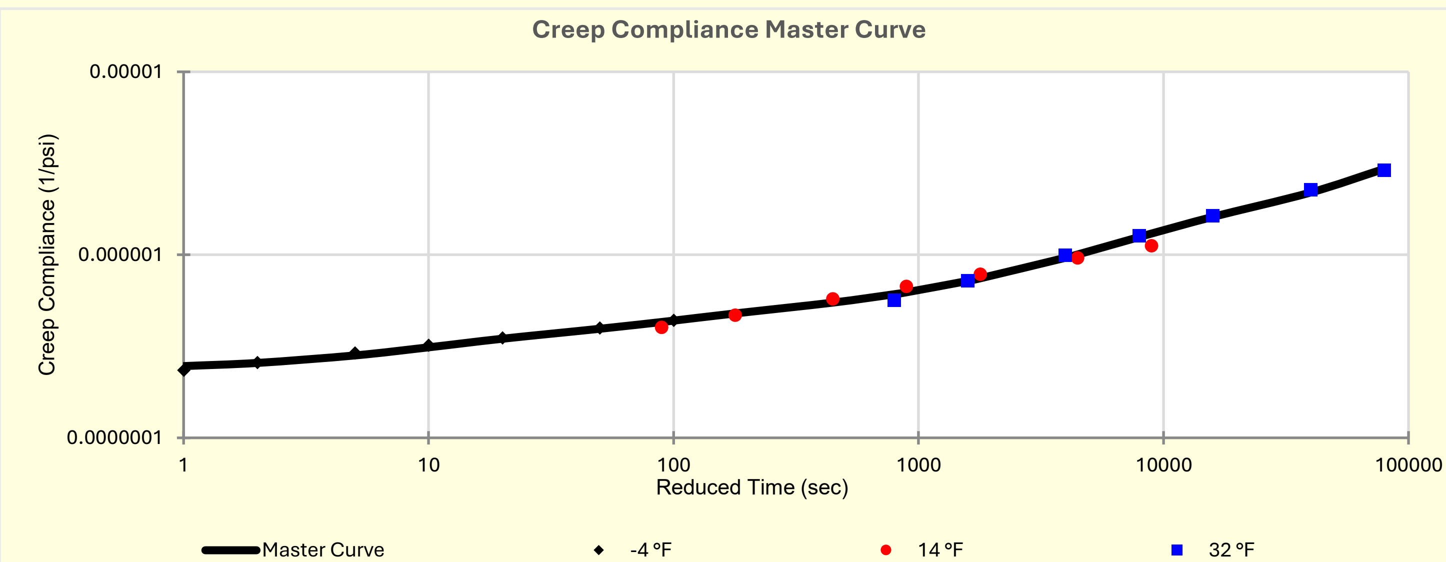
Thermal Cracking

Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/°F)	-
Aggregate coefficient of thermal contraction (in/in/°F)	5E-06
Voids in Mineral Aggregate (%)	17.2

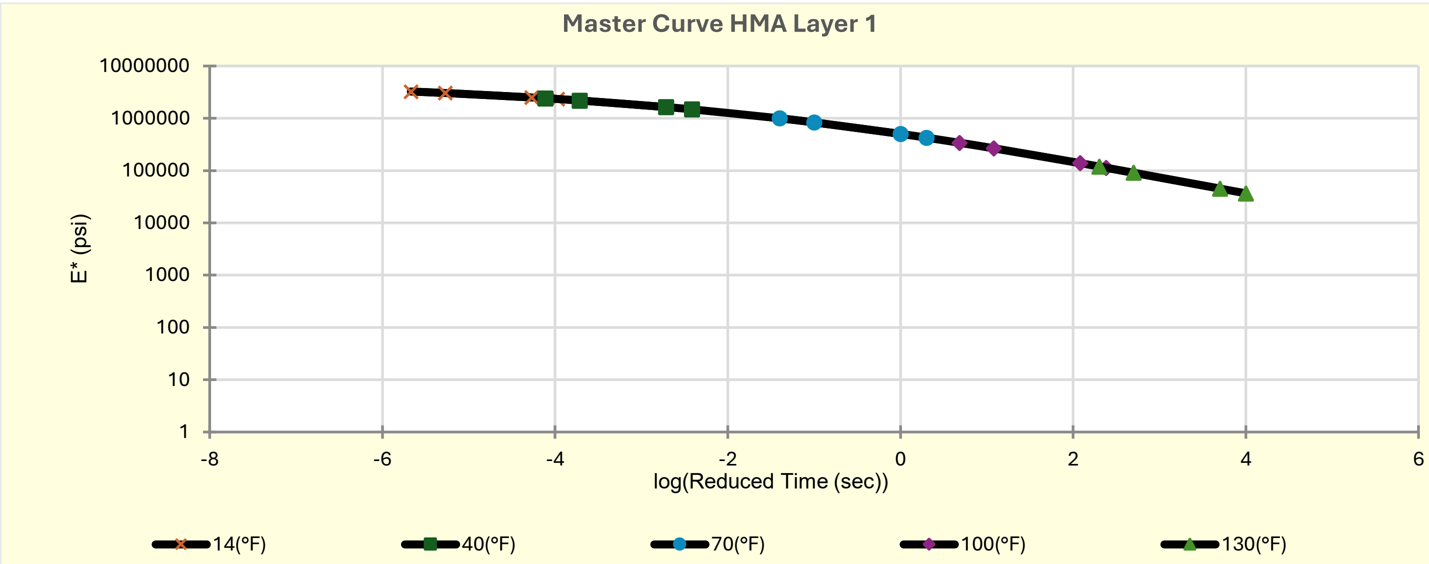
Indirect Tensile Strength (Input Level: 3)	
Test Temperature (°F)	Indirect Tensile Strength (psi)
14	434.76016859352126

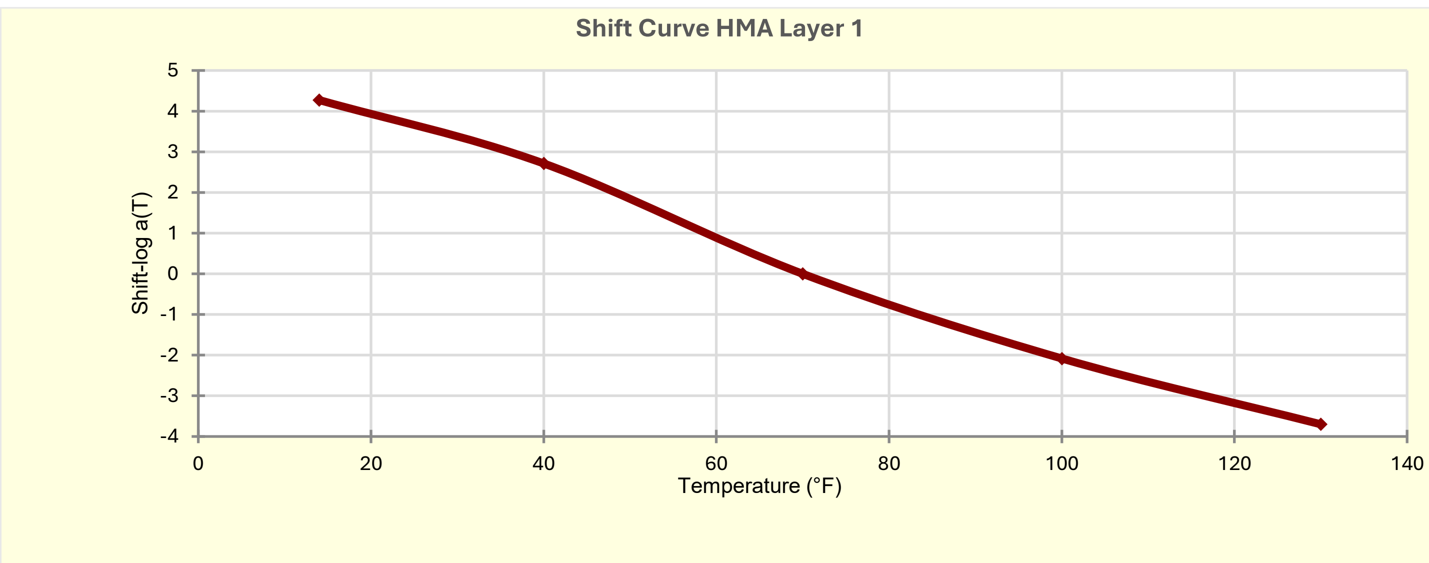
Creep Compliance (1/psi) (Input Level: 3)			
Loading time (sec)	-4 °F	14 °F	32 °F
1	2.34E-07	4.01E-07	5.63E-07
2	2.57E-07	4.69E-07	7.21E-07
5	2.91E-07	5.75E-07	9.98E-07
10	3.20E-07	6.71E-07	1.28E-06
20	3.52E-07	7.83E-07	1.63E-06
50	3.99E-07	9.61E-07	2.26E-06
100	4.38E-07	1.12E-06	2.89E-06

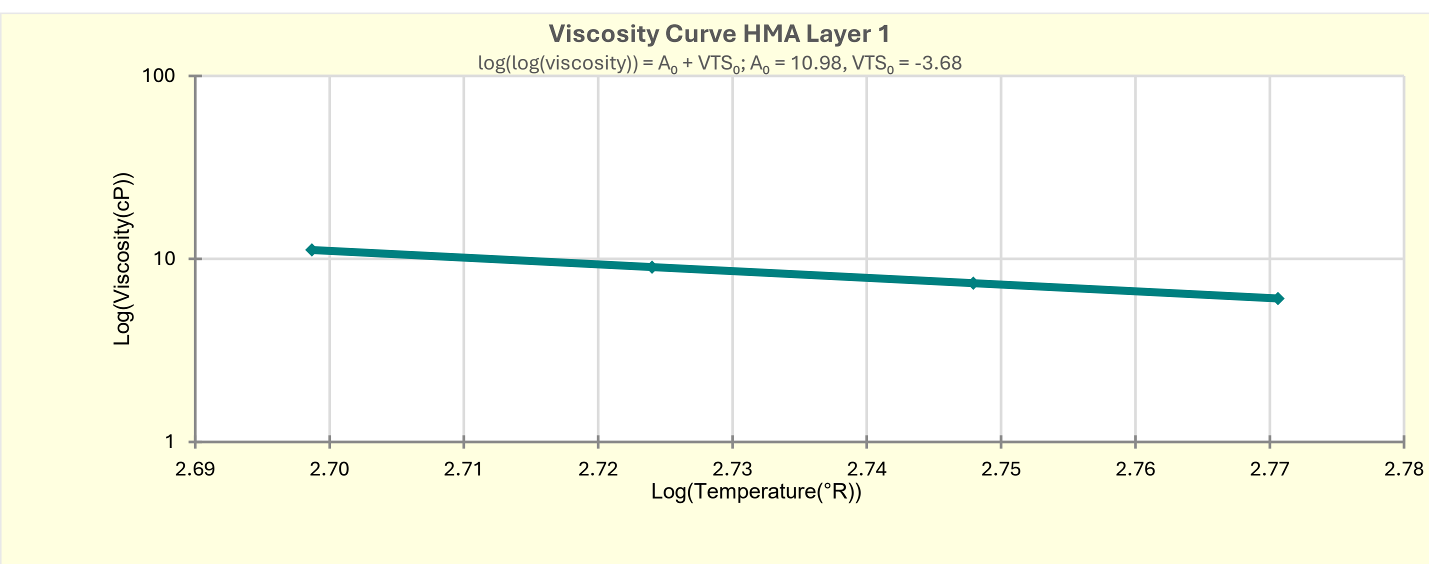




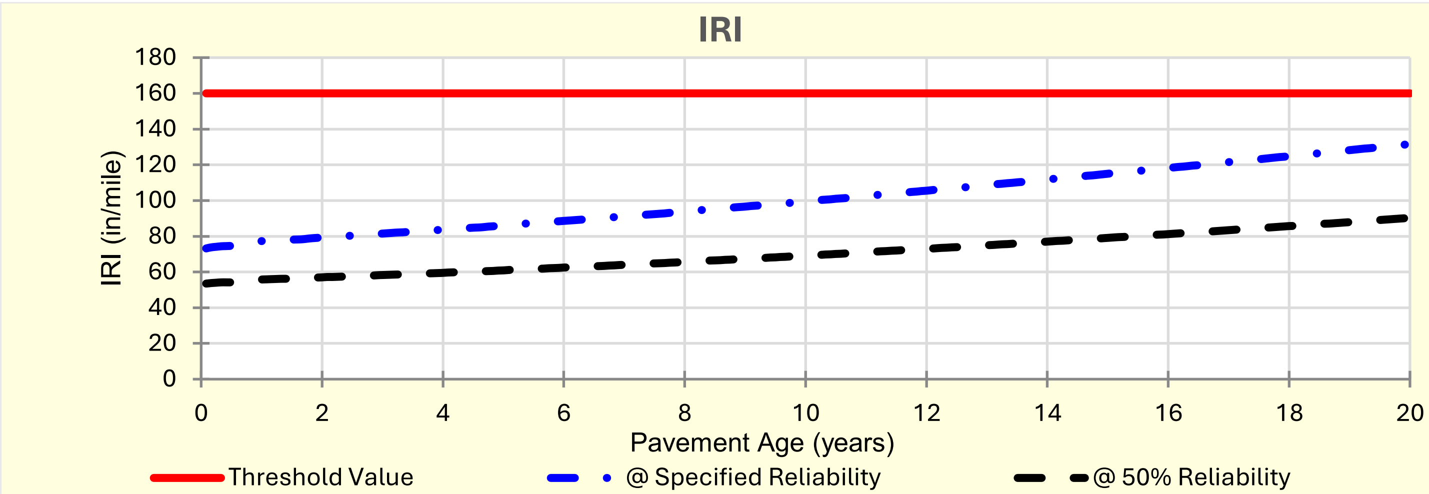
HMA Layer 1 (Proposed Overlay): Layer 1 Flexible : Default asphalt concrete

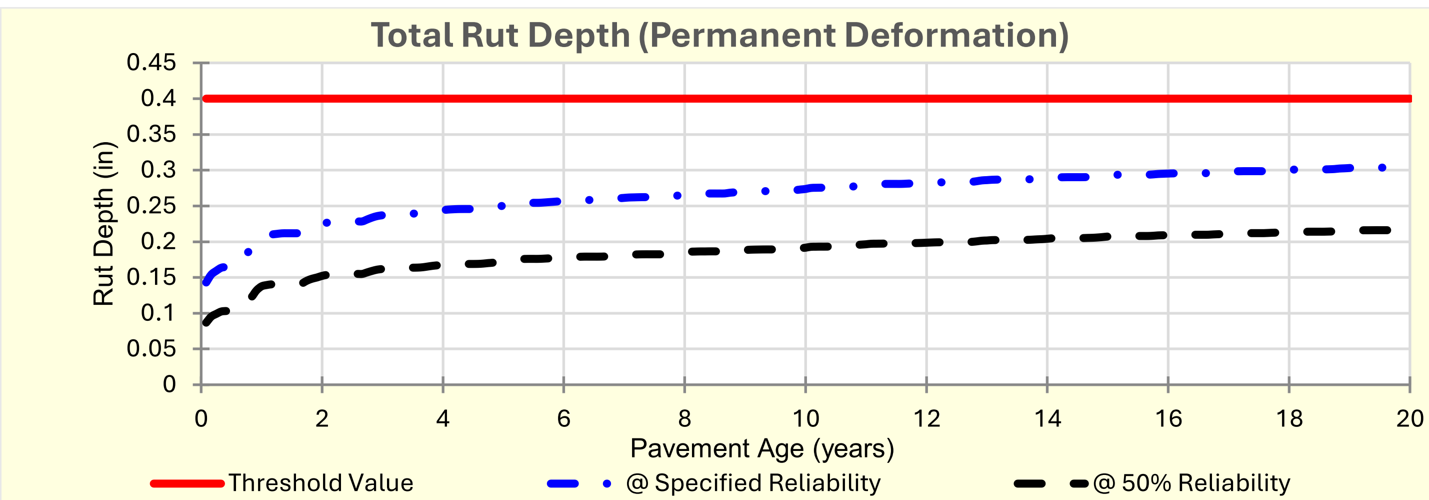


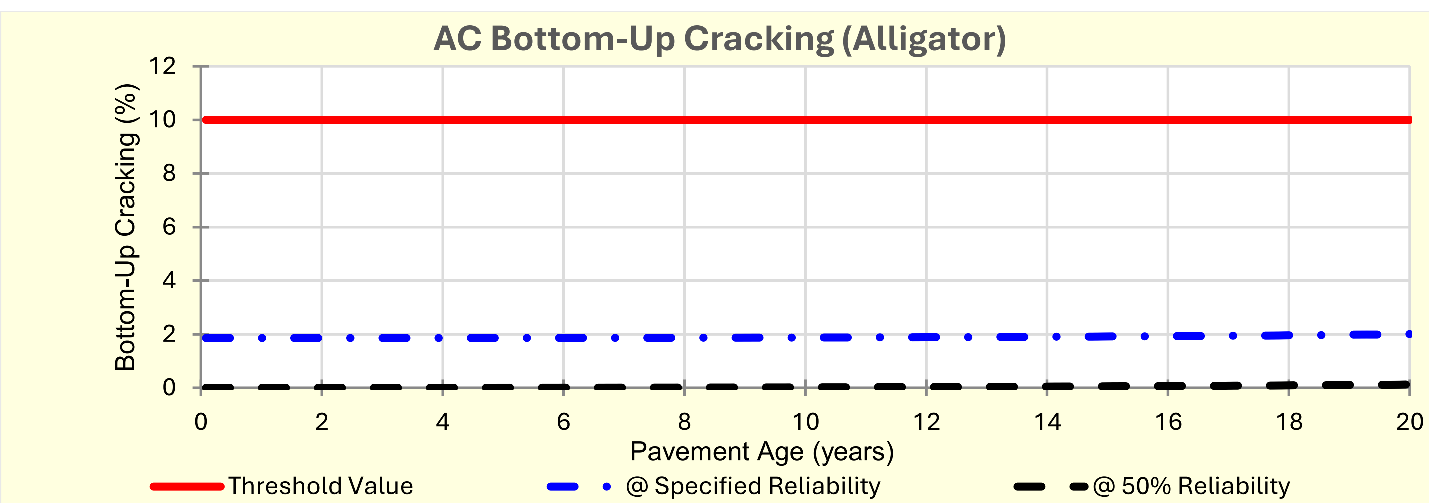


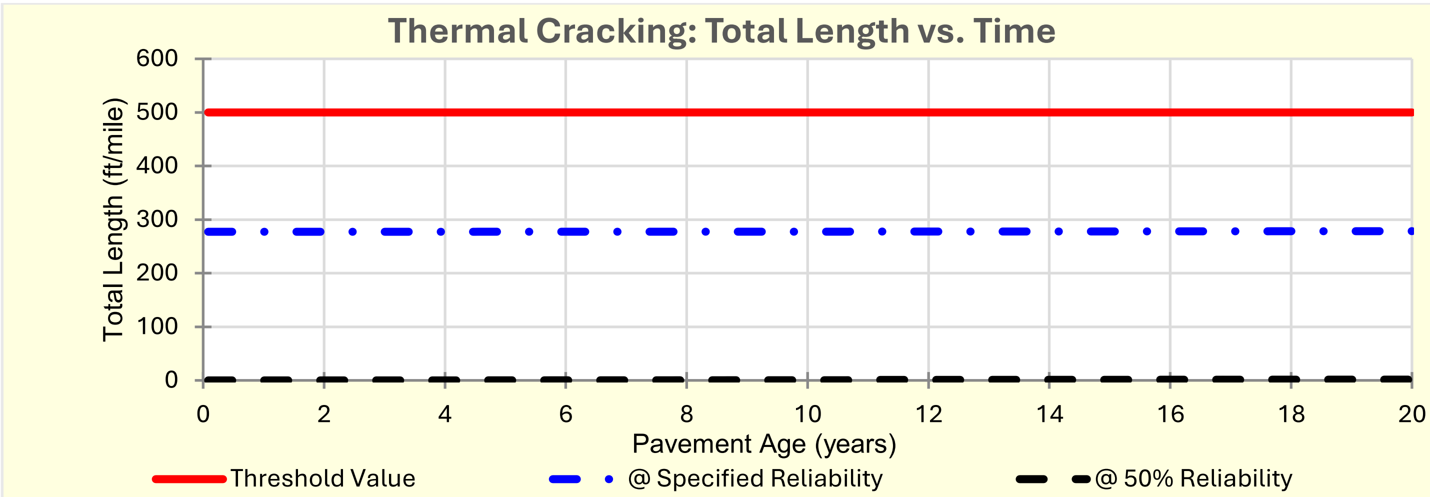


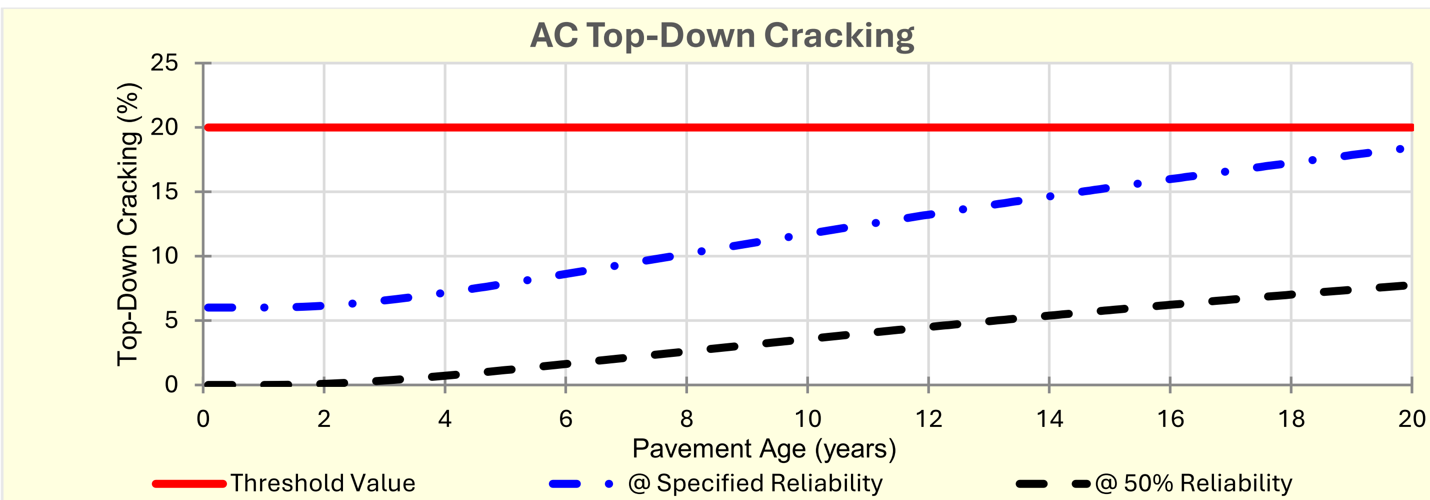
Analysis Output Charts

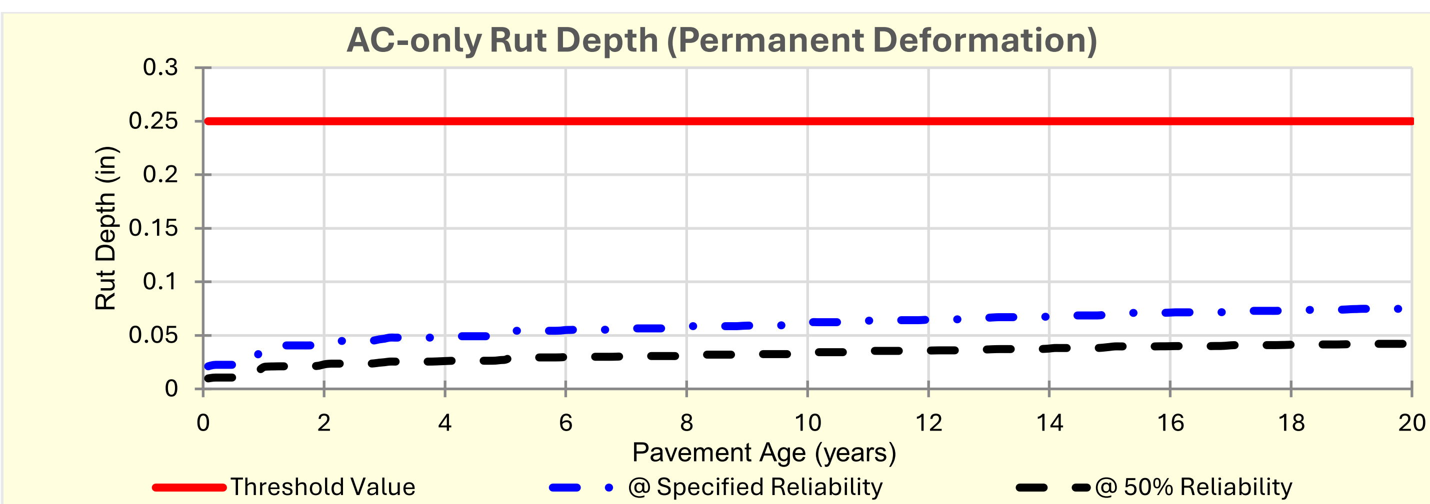


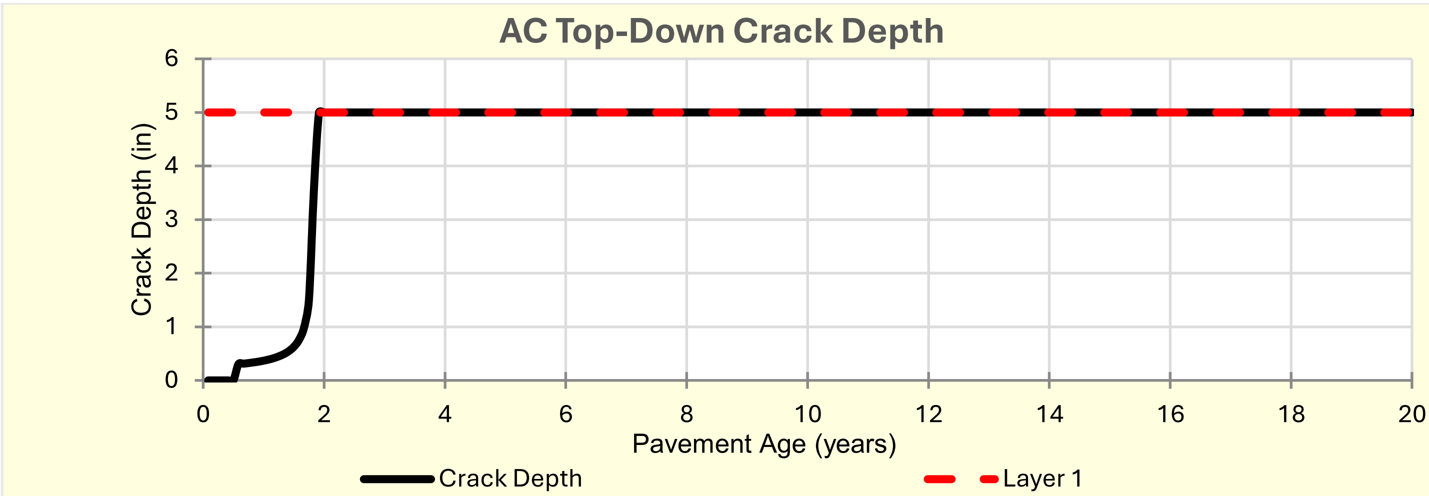


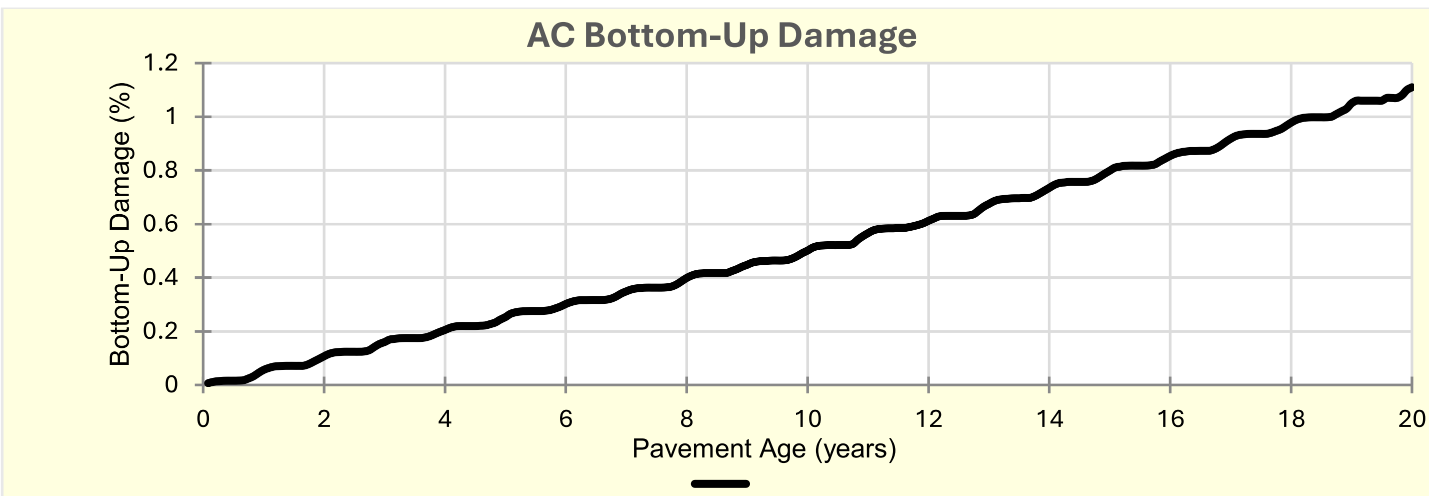


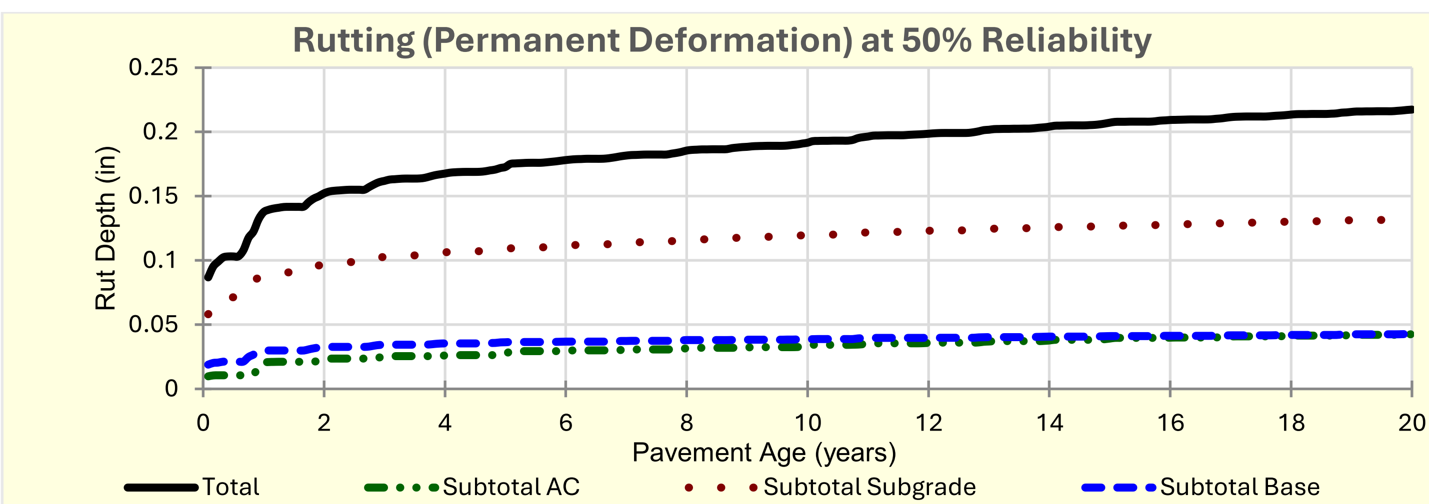

Thermal Cracking: Total Length vs. Time
Total Length (ft/mile)
600
500
400
300
200
100
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

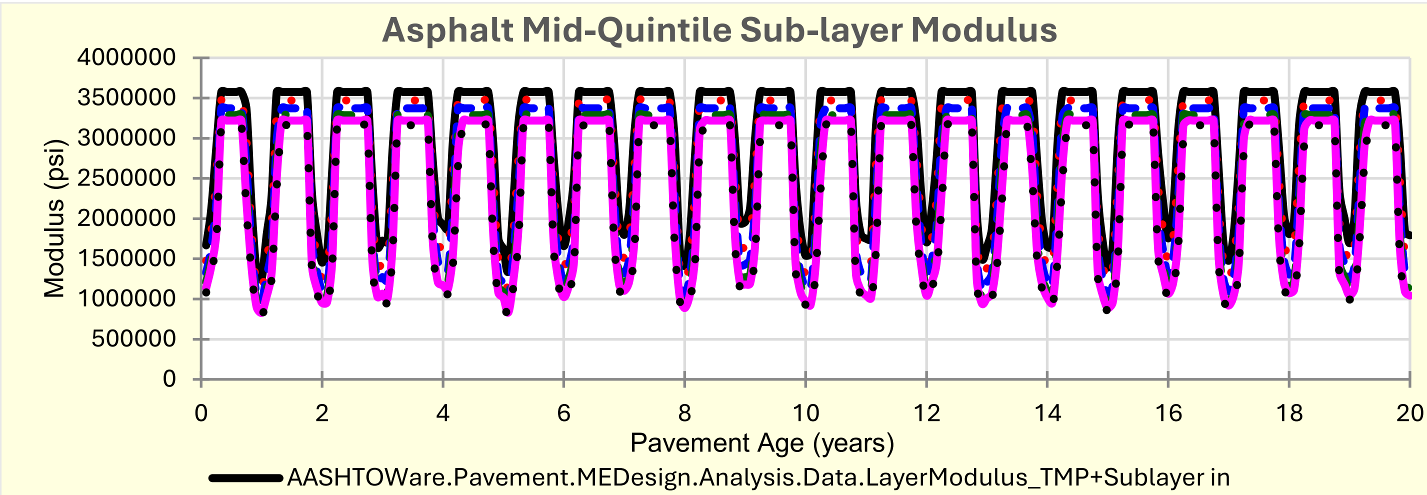

AC Top-Down Cracking
Top-Down Cracking (%)
25
20
15
10
5
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

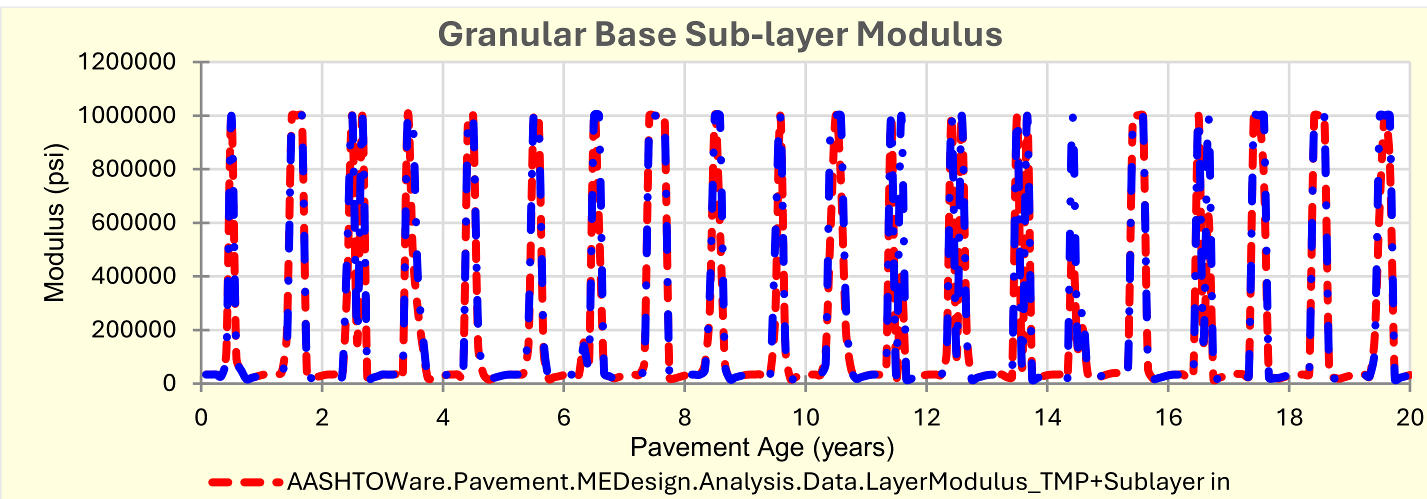

AC-only Rut Depth (Permanent Deformation)
Rut Depth (in)
0.3
0.25
0.2
0.15
0.1
0.05
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

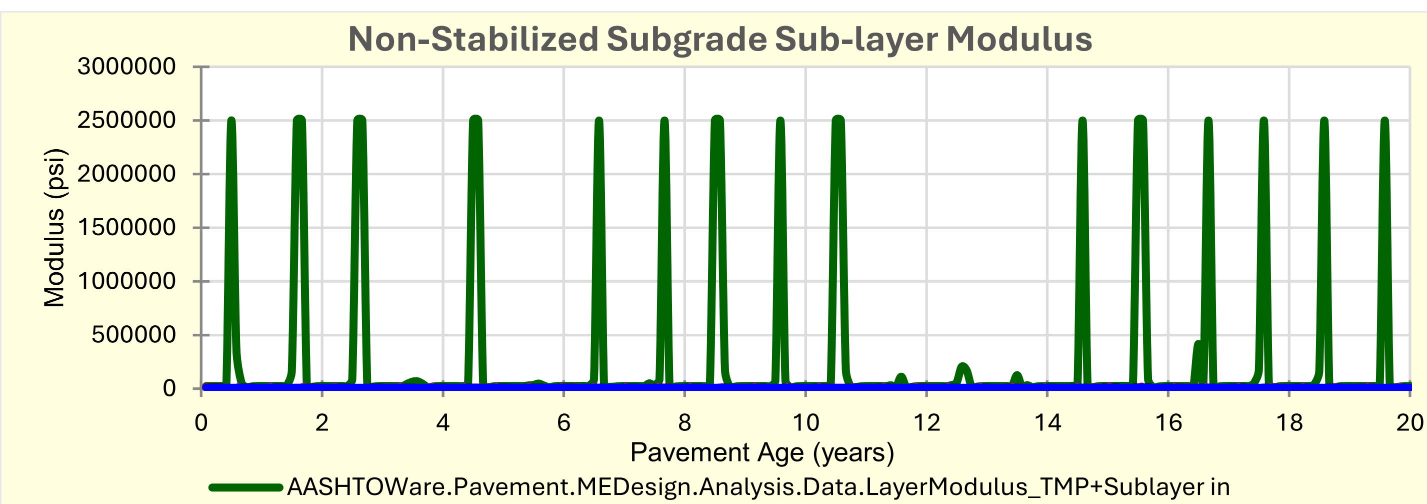

AC Top-Down Crack Depth
Crack Depth (in)
Pavement Age (years)
Crack Depth
Layer 1


AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years)


Rutting (Permanent Deformation) at 50% Reliability
Rut Depth (in)
Pavement Age (years)
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base


Asphalt Mid-Quintile Sub-layer Modulus
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Granular Base Sub-layer Modulus
1200000
1000000
800000
600000
400000
200000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Non-Stabilized Subgrade Sub-layer Modulus
3000000
2500000
2000000
1500000
1000000
500000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in

Layer Information

Layer 1 Flexible (Proposed Overlay) : Default asphalt concrete

Asphalt		
Thickness (in)		5.0
Unit Weight (pcf)		140.0
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

Parameter	Percent Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference Temperature (°F)	70
Effective binder content (%)	10.2
Air void (%)	7
Thermal conductivity (BTU/hr-ft-°F)	0.67
Heat Capacity (BTU/lb-°F)	0.23
Percent Content by Weight (%)	4.5
Aggregate Parameter	0.402
Dynamic Modulus E* Fitting Method	1-37A

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/30/2010 5:00:00 AM
Approver	
Date approved	10/30/2010 5:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized base : Crushed gravel (A-1-a)

Unbound	
Layer thickness (in)	7
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	30000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	Crushed gravel (A-1-a)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.1
Saturated hydraulic conductivity (ft/hr)	False	0.05328
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.255496829960335
bf	1.2911570438718638
cf	0.8263617065521088
hr	117.4

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8 in	57.2
1/2 in	63.1
3/4 in	72.7
1 in	78.8
1 1/2 in	85.8
2 in	91.6
2 1/2 in	
3 in	
3 1/2 in	97.6

Layer 3 Subgrade : A-3 (A-3)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	16500.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	A-3 (A-3)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	True	120.0
Saturated hydraulic conductivity (ft/hr)	False	0.00365
Specific gravity of solids	False	2.7
Water Content (%)	False	8.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.849631876739616
bf	2.857643419754946
cf	0.9167554911487317
hr	100

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	5.2
#100	
#80	33
#60	
#50	
#40	76.8
#30	
#20	
#16	
#10	93.4
#8	
#4	95.3
3/8 in	96.6
1/2 in	97.1
3/4 in	98
1 in	98.6
1 1/2 in	99.2
2 in	99.7
2 1/2 in	
3 in	
3 1/2 in	99.9

Calibration Coefficients

AC Cracking

AC Top Down Cracking

$$L(t) = L_{Max} e^{-\left(\frac{C_1 \rho}{t - C_3 t_o}\right)^{C_2 \beta}}$$

$$t_0(\text{Days}) = \frac{k_{L1}}{1 + e^{(k_{L2} \times 100 \times a_0 / 2A_0) + (k_{L3} \times HT) + (k_{L4} \times LT) + (k_{L5} \times \log_{10} AADTT)}}$$

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' \log_{10}(D*100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 2.5219	c2: 0.8069	c3: 1			c1: 1.31	c2: (0.867 + 0.2583 * hac) * 1 + 0	c3: 6000
kL1: 64271618	kL2: 0.2855	kL3: 0.011	kL4: 0.01488	kL5: 3.266			

Top Down Cracking Standard Deviation	Bottom Up Cracking Standard Deviation
0.3657 * TOP + 3.6563	1.13 + 13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 3.75
k2: 2.87
k3: 1.46
Bf1: (5.014 * Pow(hac,-3.416)) * 1 + 0
Bf2: 1.38
Bf3: 0.88

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)

ε_r = resilient strain(in/in)

T = layer temperature(°F)

N = number of load repetitions

AC Rutting Standard Deviation	0.24 * Pow(RUT,0.8026) + 0.001	
AC Layer 1	K1: -2.45 K2: 3.01 K3: 0.22	Br1: 0.4 Br2: 0.52 Br3: 1.36

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4 * log_{10}(Damage)}}$$

C1: 0	C2: 75	C3: 2	C4: 2

CSM Cracking Standard Deviation

CTB*1

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1}\left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

k1: 0.972	k2: 0.0825	Bc1: 1	Bc2: 1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

Thermal Fracture

$$C_f = \beta_{t1} N\left[\frac{1}{\sigma_d} log\left(\frac{C}{h_{AC}}\right)\right]$$

$$\Delta C = A(\Delta K)^n$$

$$A = k_t \beta_t 10^{[4.389 - 2.52 \log(E_{HMA} \sigma_m n)]}$$

Cf = Observed amount of thermal cracking, ft. / 500ft.
β_{t1} = Regression coefficient determined through global calibration (400)
N[z] = Standard normal distribution evaluated at [z]
σ_d = Standard deviation of the logarithm of crack depth in the pavement (0.769), in.
C = Crack depth, in.
h_{AC} = Thickness of asphalt layer, in.
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = Asphalt mixture stiffness, MPa
σ_m = Undamaged mixture tensile strength, MPa
k_t = Regression coefficient determined through field calibration
β_t = Calibration parameter

Level 1 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 2 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 3 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	

Unbound Layer Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

δ_a = permanent deformation for the layer
N = number of repetitions
ε_v = average vertical strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Base Rutting		Subgrade Rutting	
k1: 0.965	Bs1: 1	k1: 0.635	Bs1: 1
Standard Deviation: 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation: 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

9.2 State highway final design outputs-asphalt pavement

Madhav Joshi and Kamal Gautam State-Asphalt

Tenant: Kamal Gautam Workspace: System Workspace

Design Inputs

Design Life:	20 years	Base Construction:	May 2025	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	FLEXIBLE	Pavement construction:	June 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	3
NonStabilized	Crushed gravel (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

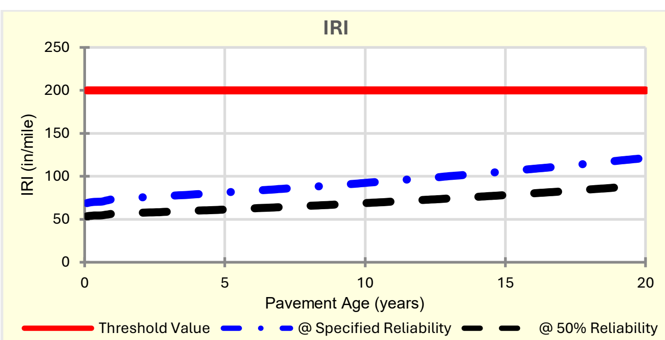
Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2035 (10 years)	539,917
2045 (20 years)	1,198,070

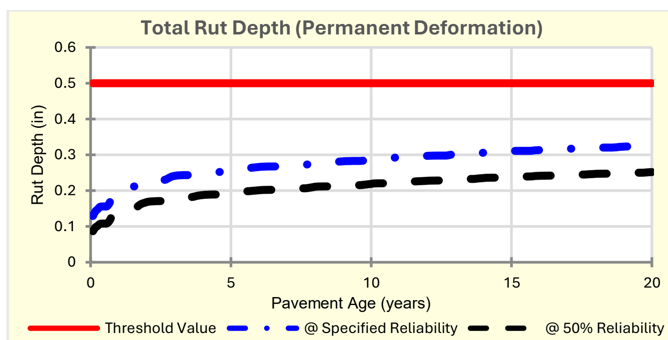
Design Outputs

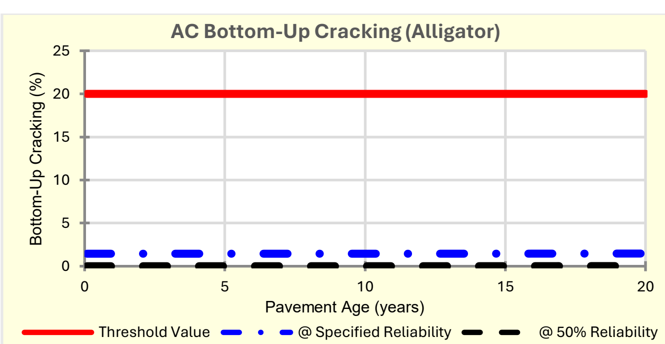
Distress Prediction Summary

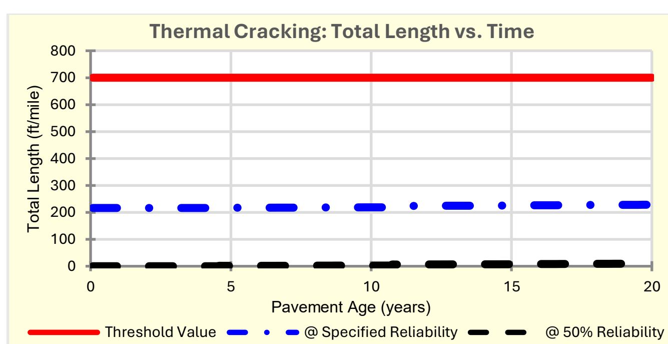
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	121.40	90.00	100.00	Pass
Permanent deformation - total pavement (in)	0.50	0.33	90.00	100.00	Pass
AC bottom-up fatigue cracking (%)	20.00	1.47	90.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	228.28	90.00	100.00	Pass
AC top-down fatigue cracking (%)	25.00	7.86	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.25	0.08	90.00	100.00	Pass

Distress Charts





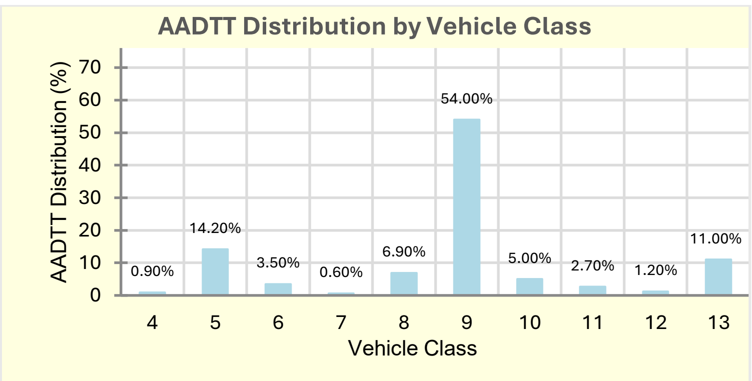




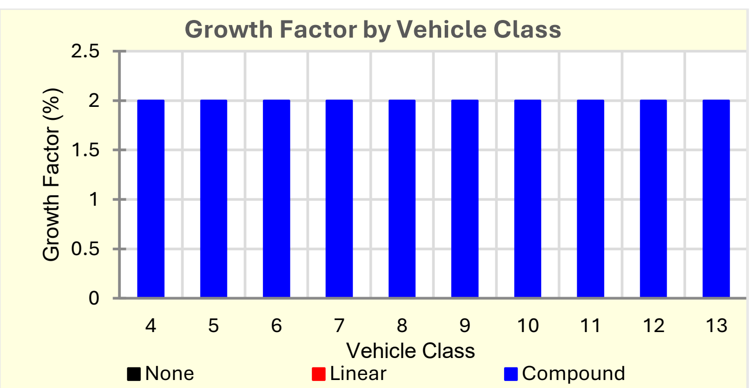
Traffic Inputs

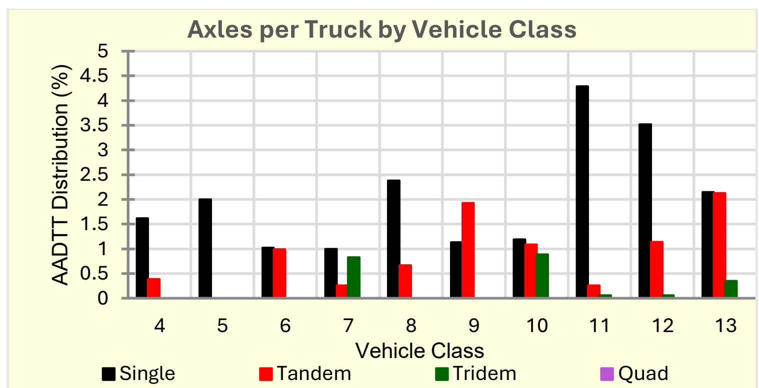
Graphical Representation of Traffic Inputs

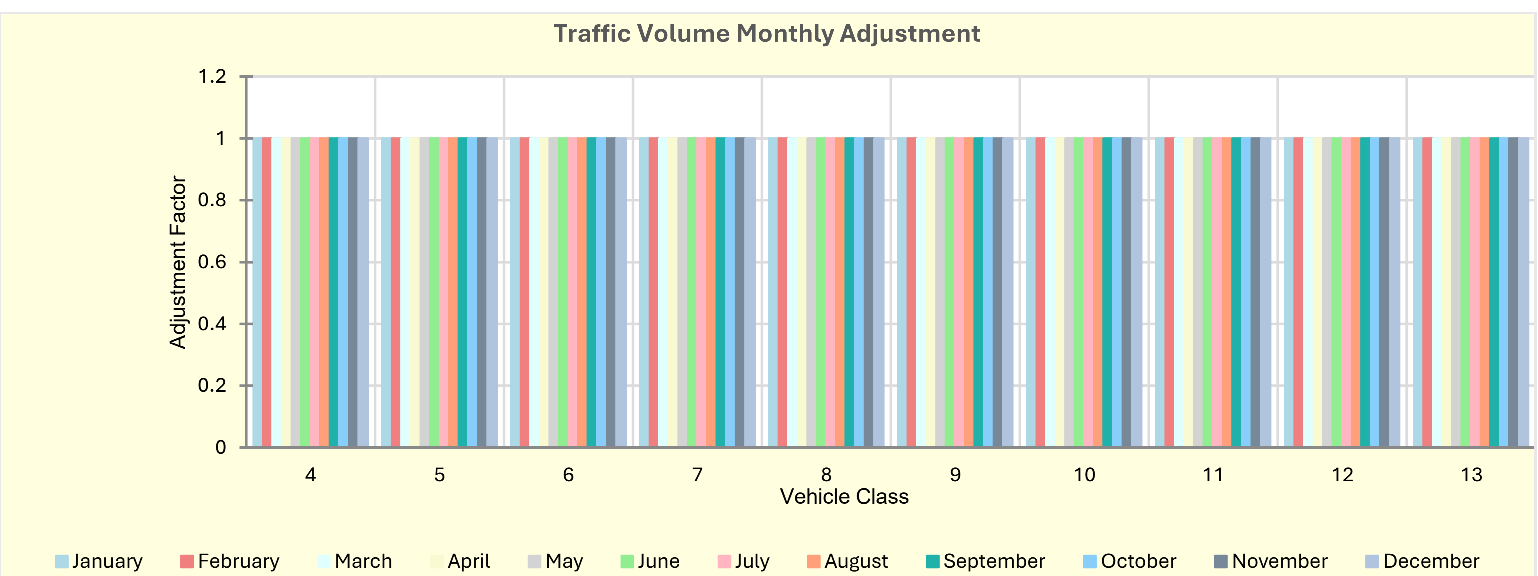
Initial two-way AADTT	270
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	100
Operation speed (mph)	65
Axle Distribution	NCHRP 1-37A



Truck Distribution by Hour does not apply to the design type.







Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors (Level 3: Default MAF)

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.9%	2%	Compound
Class 5	14.2%	2%	Compound
Class 6	3.5%	2%	Compound
Class 7	0.6%	2%	Compound
Class 8	6.9%	2%	Compound
Class 9	54.0%	2%	Compound
Class 10	5.0%	2%	Compound
Class 11	2.7%	2%	Compound
Class 12	1.2%	2%	Compound
Class 13	11.0%	2%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

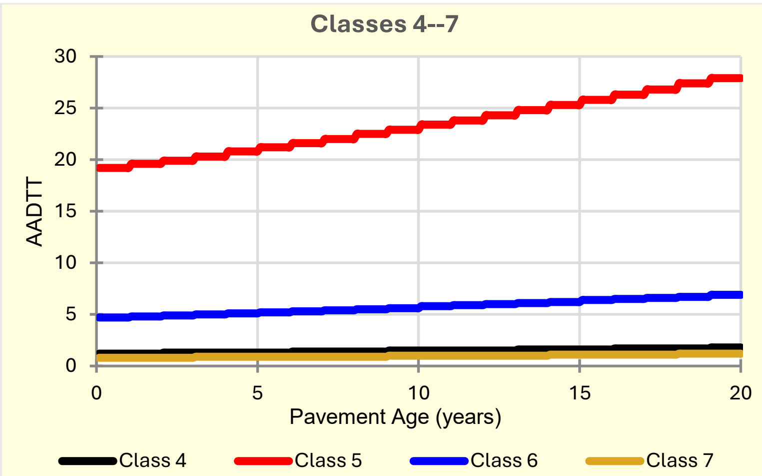
Wheelbase does not apply

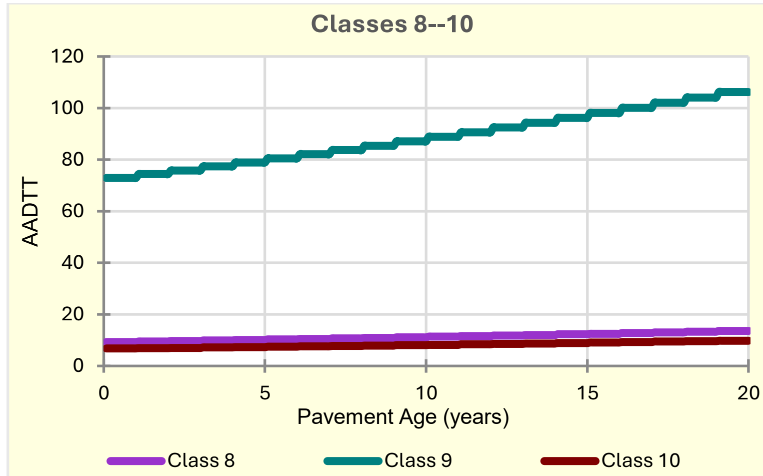
Number of Axles per Truck

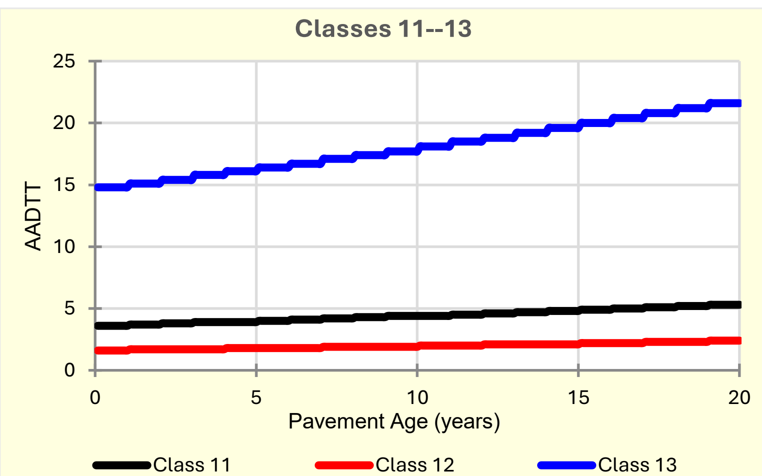
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

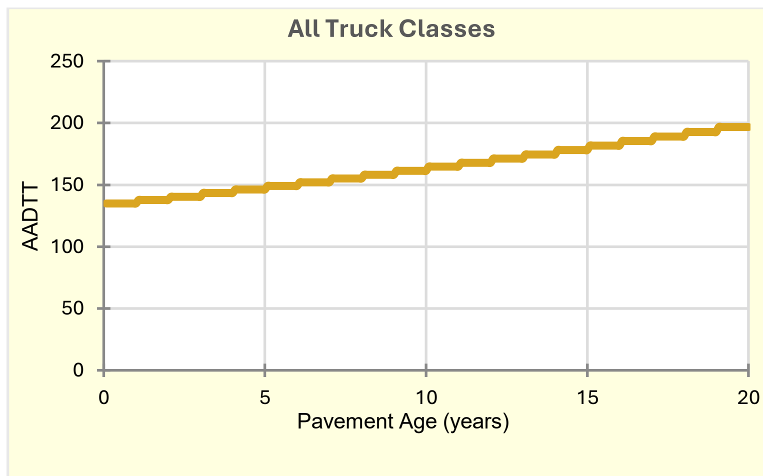
AADTT (Average Annual Daily Truck Traffic) Growth

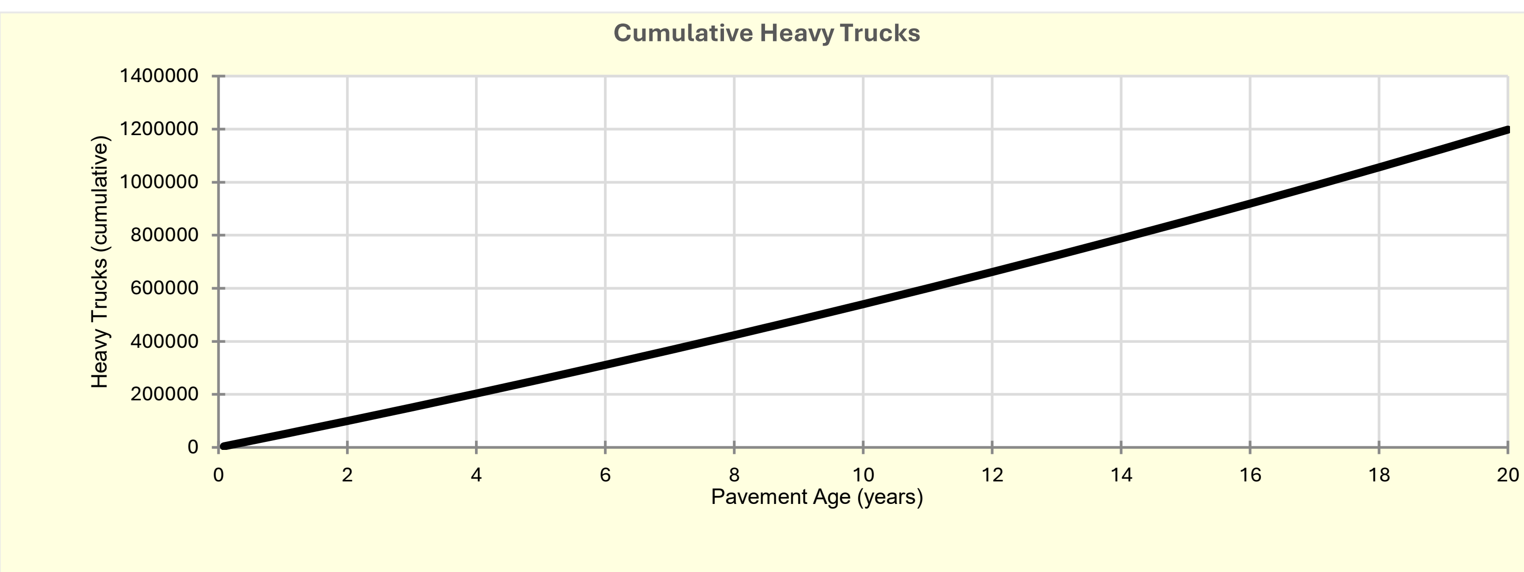
* Traffic cap is not enforced

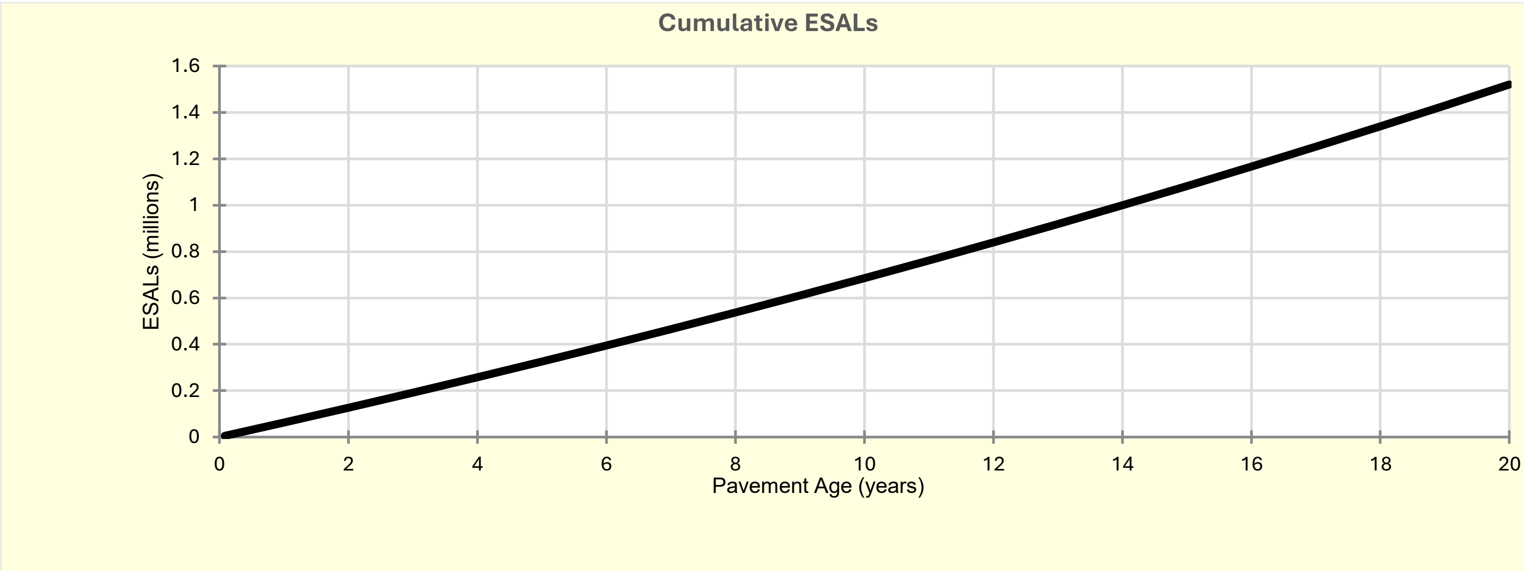








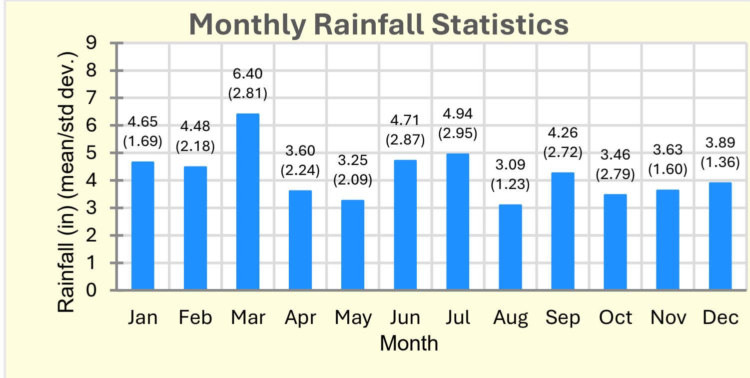



Cumulative ESALs
ESALs (millions)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)

Climate Inputs

Climate Data Sources:

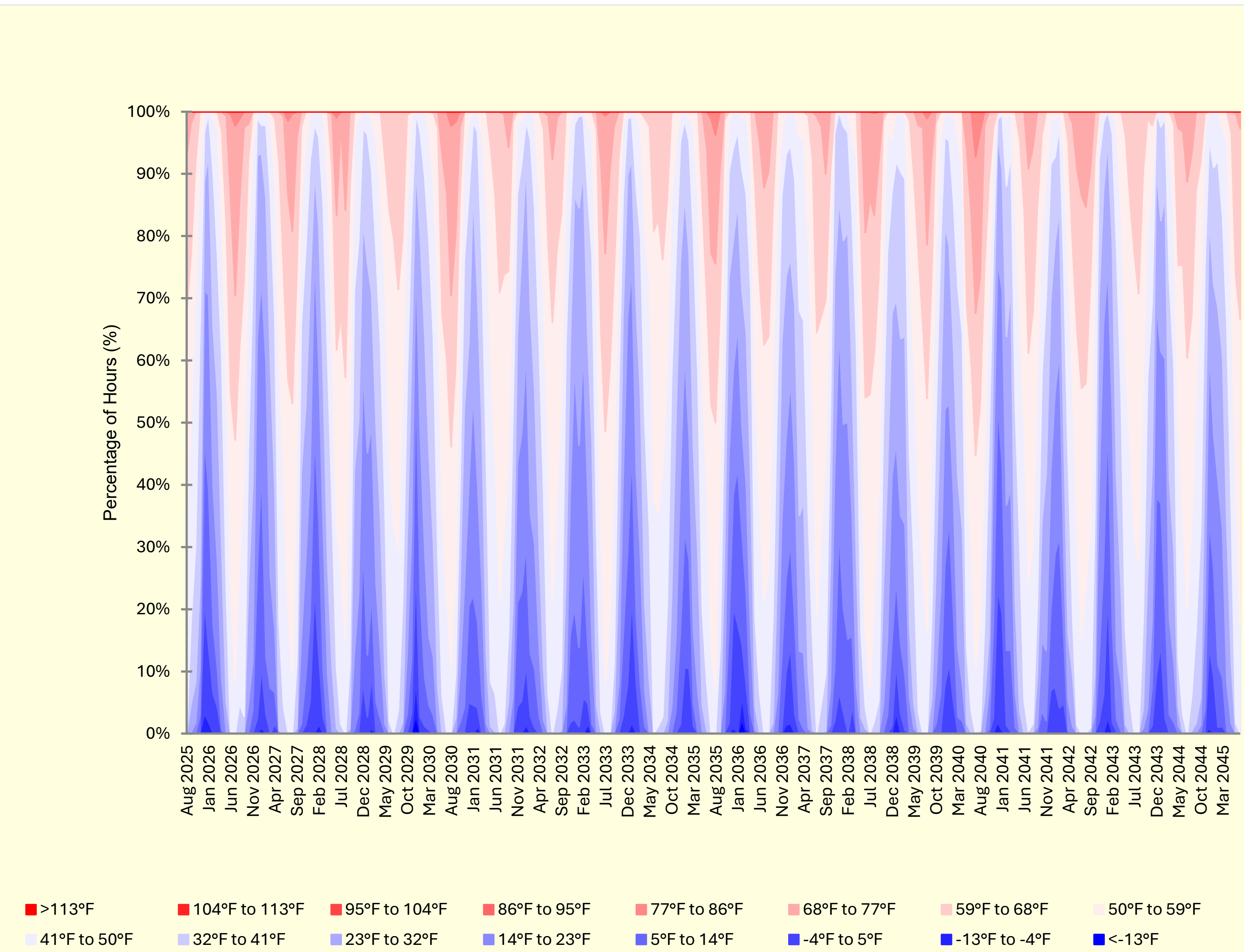
Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131



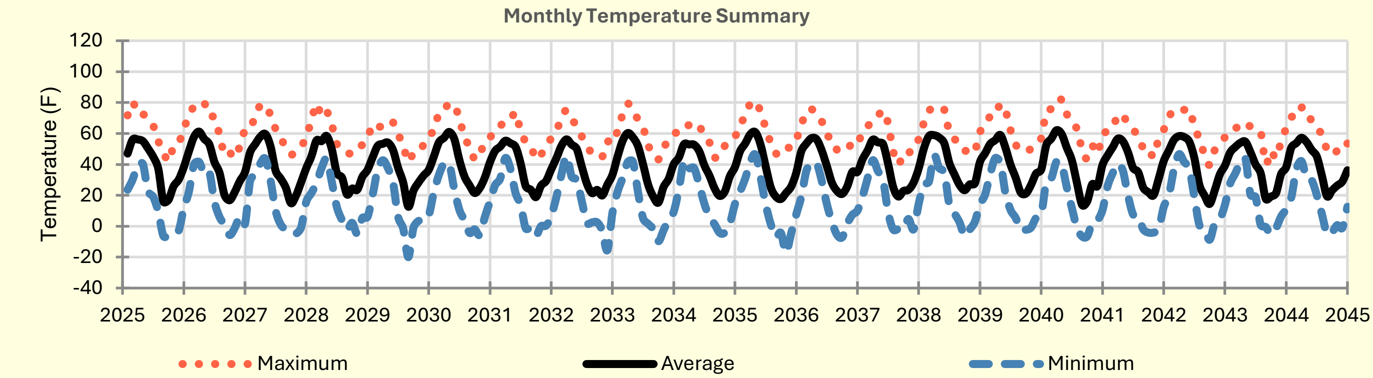
Annual Statistics:

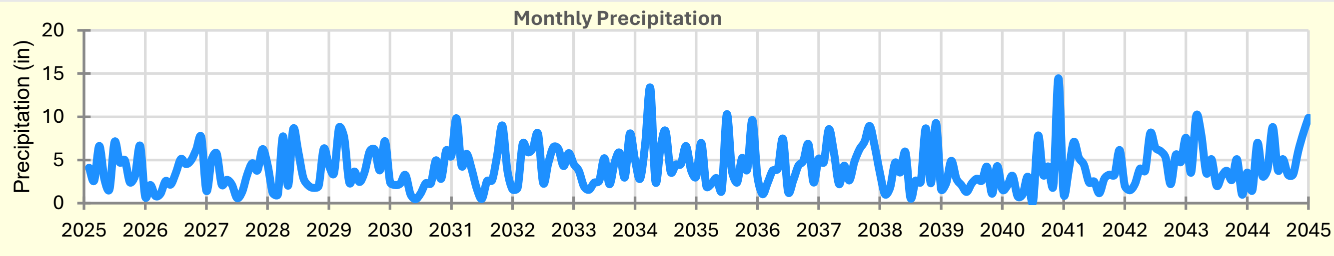
Mean annual air temperature (F):	39.35
Mean annual precipitation (in):	50.32
Freezing index (F - days):	1246.54
Average annual number of freeze/thaw cycles:	130.88
Water table depth (ft)	10.00

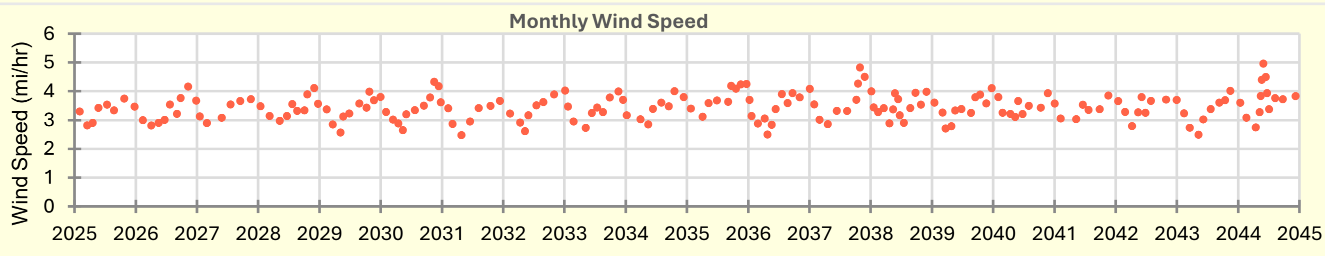
Hourly Air Temperature Distribution by Month:

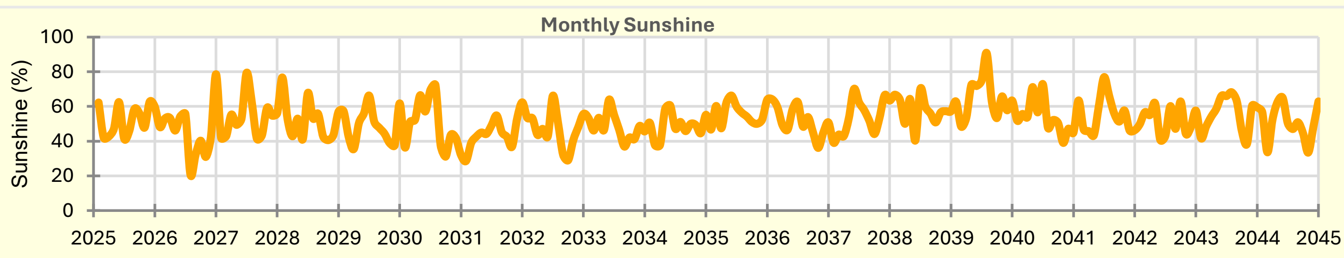


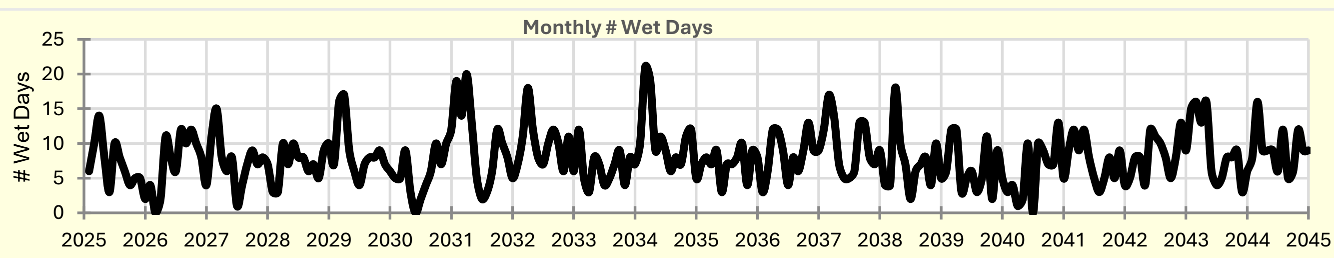
Monthly Climate Summary:

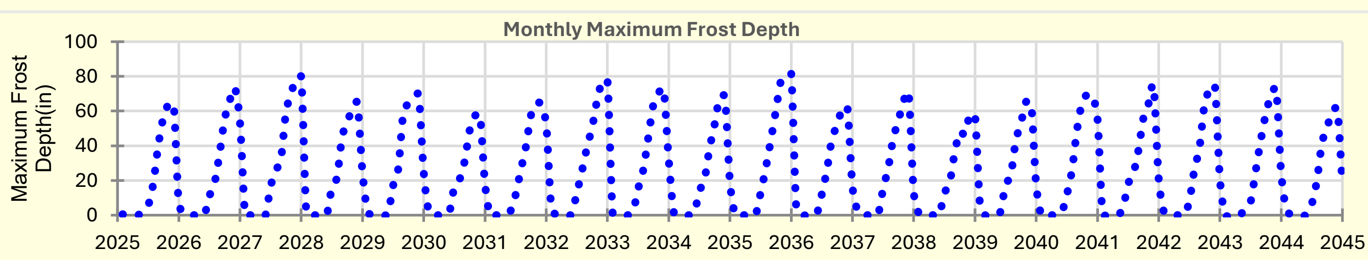












Design Properties

HMA Design Properties

Multilayer Rutting Model	False
NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Using Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

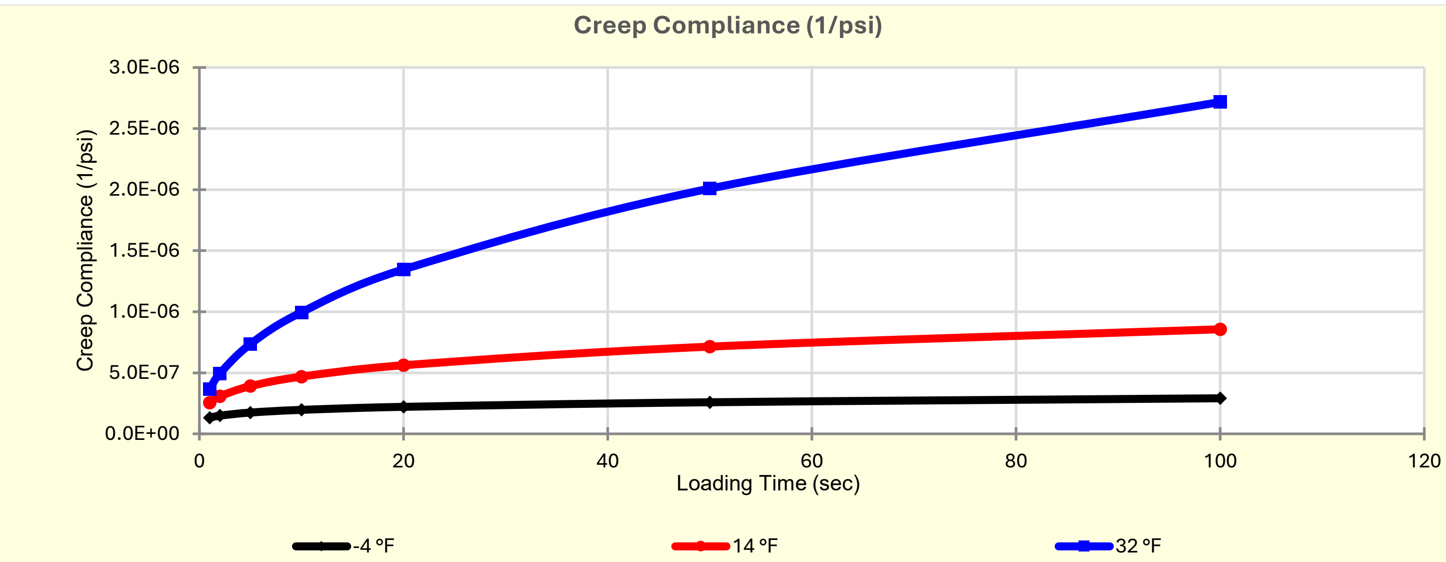
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed gravel (A-1-a)	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-3 (A-3)	Subgrade (5)	-

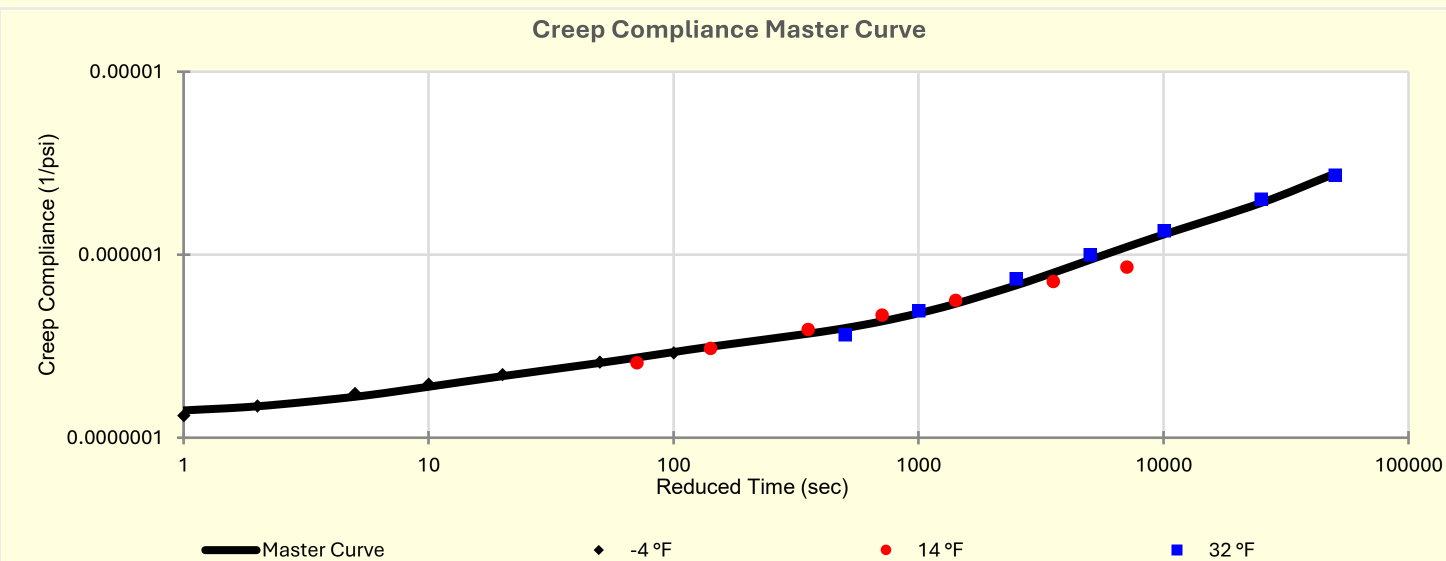
Thermal Cracking

Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/°F)	-
Aggregate coefficient of thermal contraction (in/in/°F)	5E-06
Voids in Mineral Aggregate (%)	17.2

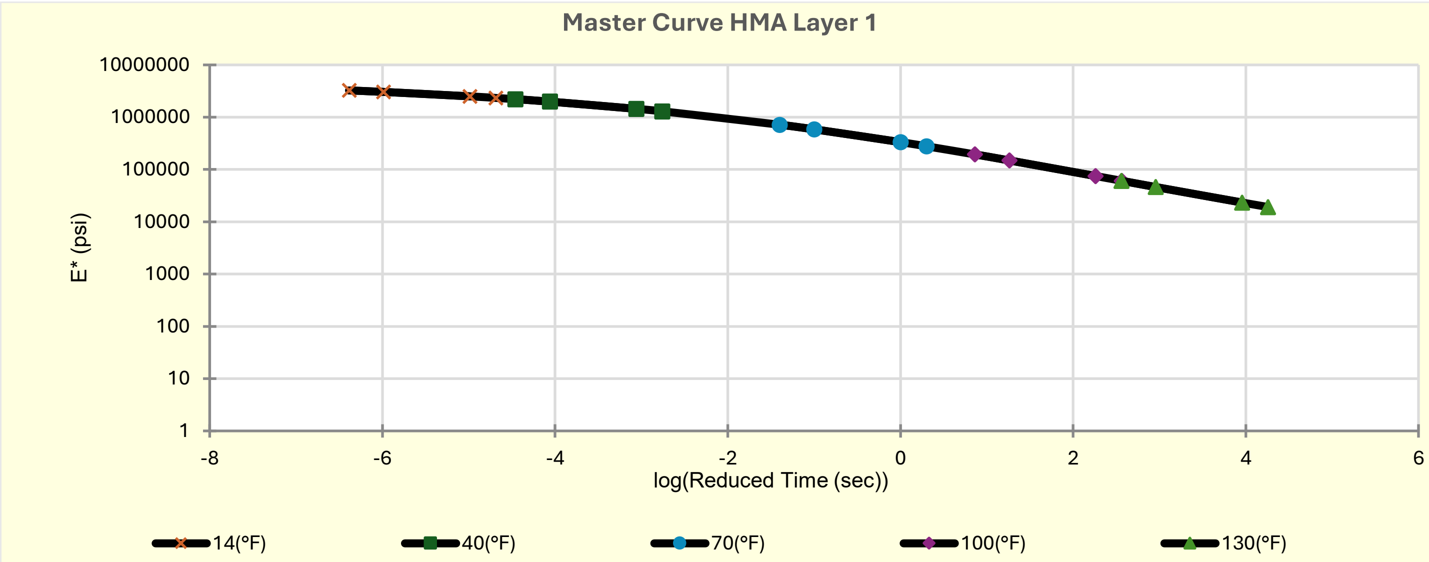
Indirect Tensile Strength (Input Level: 3)	
Test Temperature (°F)	Indirect Tensile Strength (psi)
14	403.08172152700604

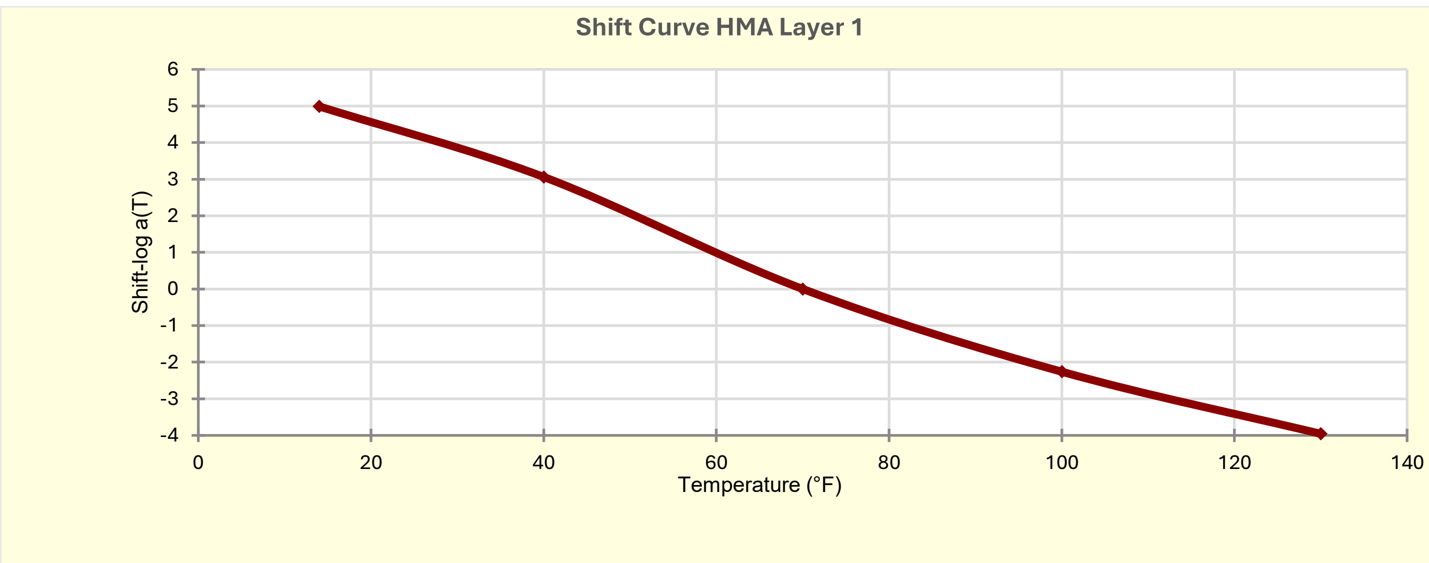
Creep Compliance (1/psi) (Input Level: 3)			
Loading time (sec)	-4 °F	14 °F	32 °F
1	1.32E-07	2.56E-07	3.65E-07
2	1.49E-07	3.07E-07	4.93E-07
5	1.74E-07	3.91E-07	7.36E-07
10	1.96E-07	4.68E-07	9.95E-07
20	2.21E-07	5.62E-07	1.35E-06
50	2.59E-07	7.14E-07	2.01E-06
100	2.91E-07	8.56E-07	2.72E-06

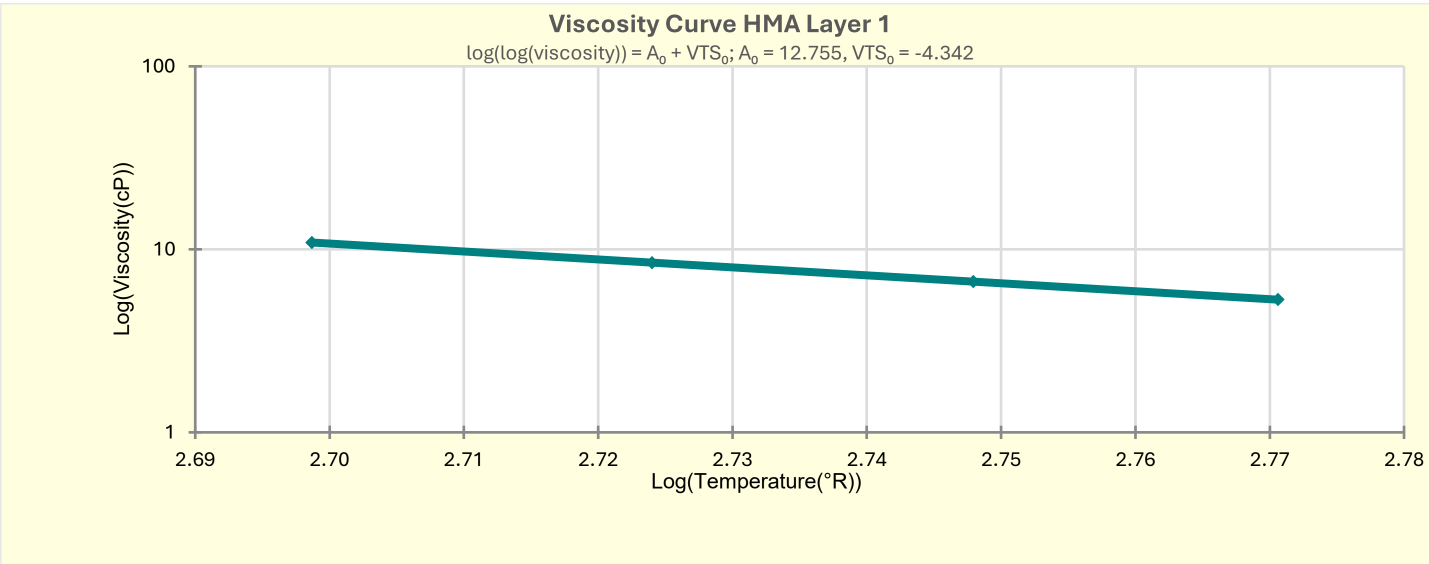




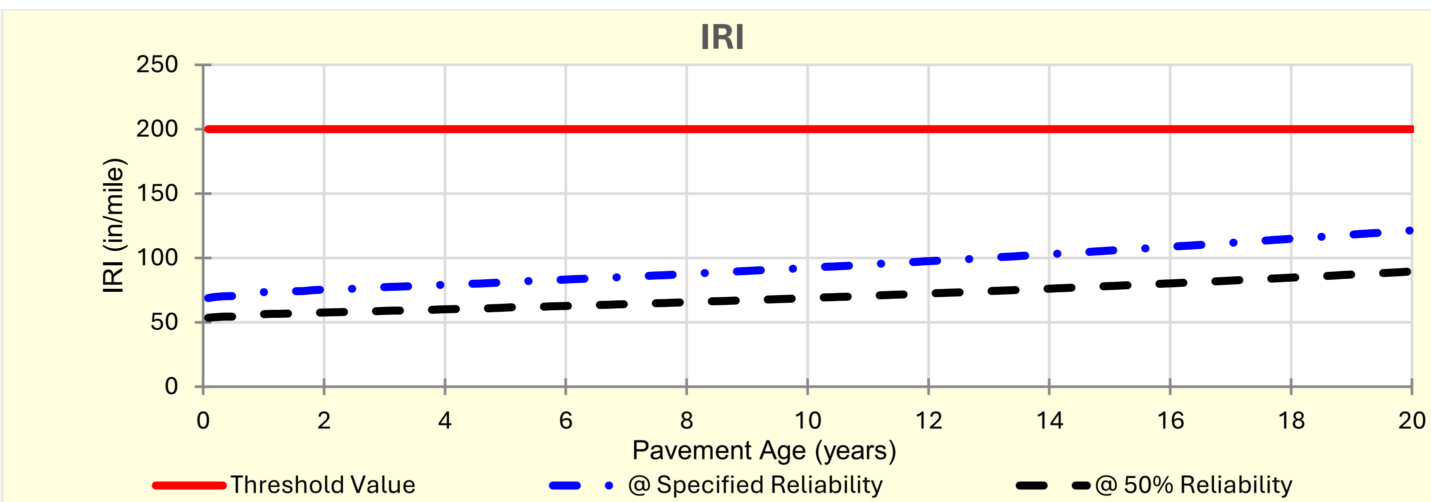
HMA Layer 1 (Proposed Overlay): Layer 1 Flexible : Default asphalt concrete

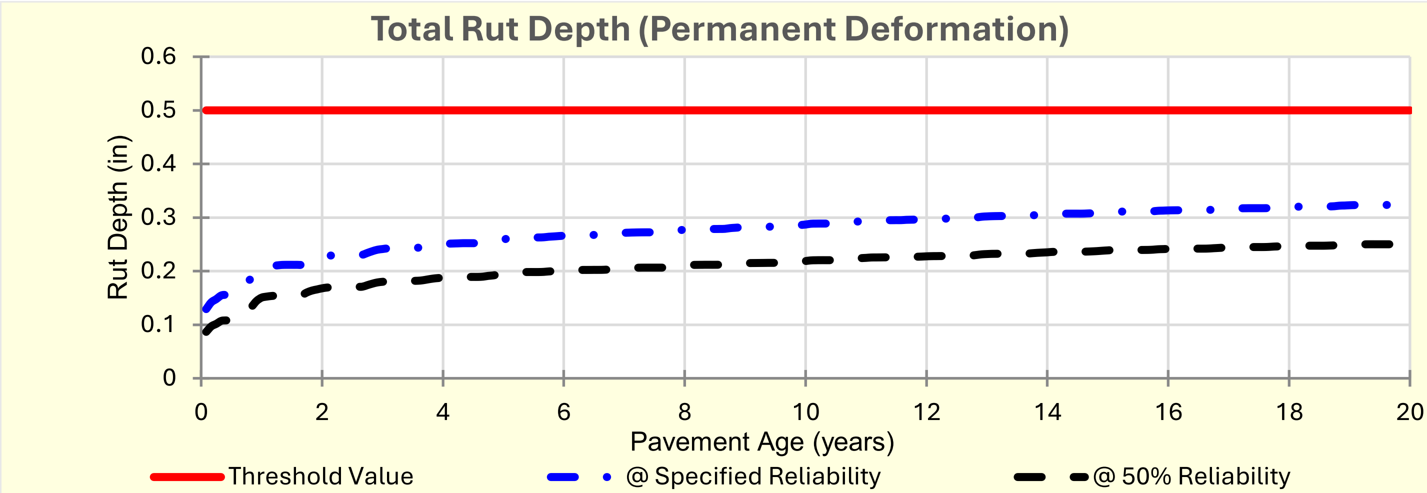


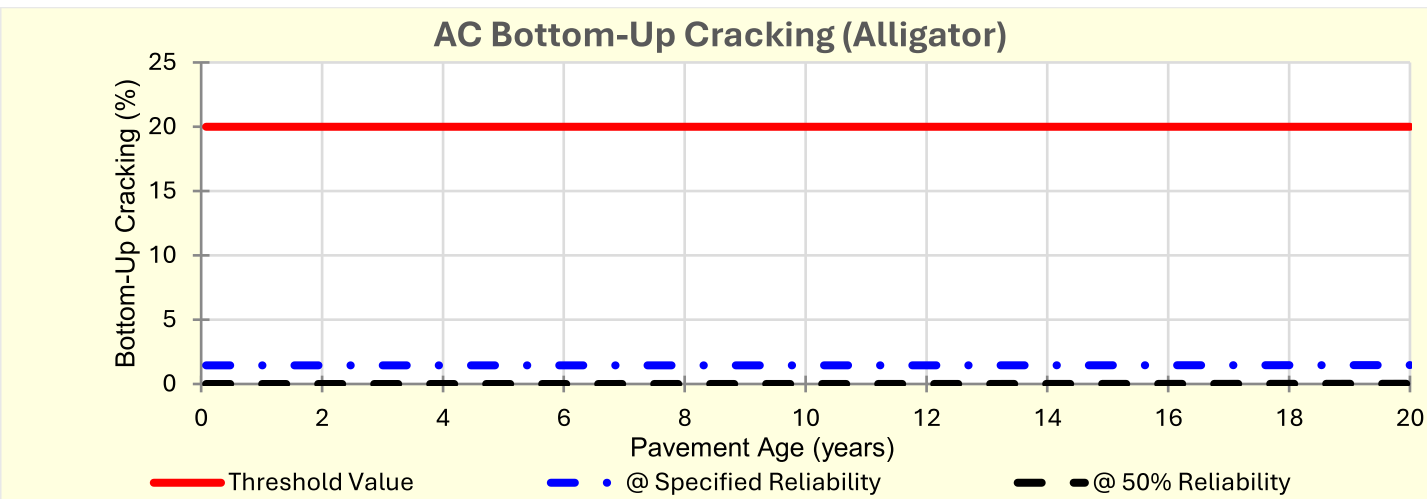


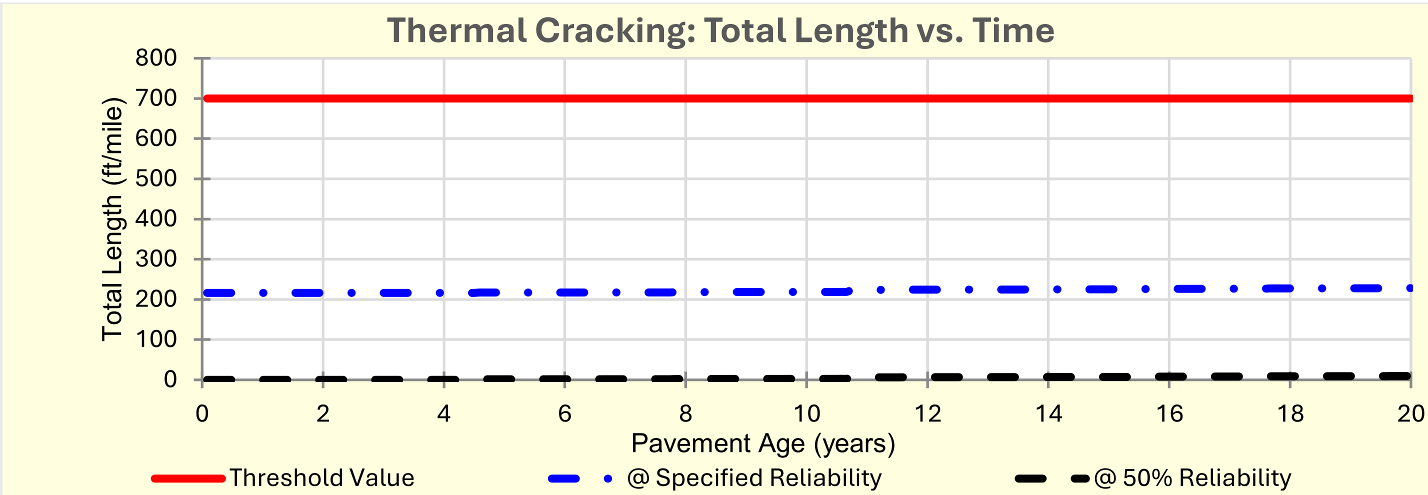


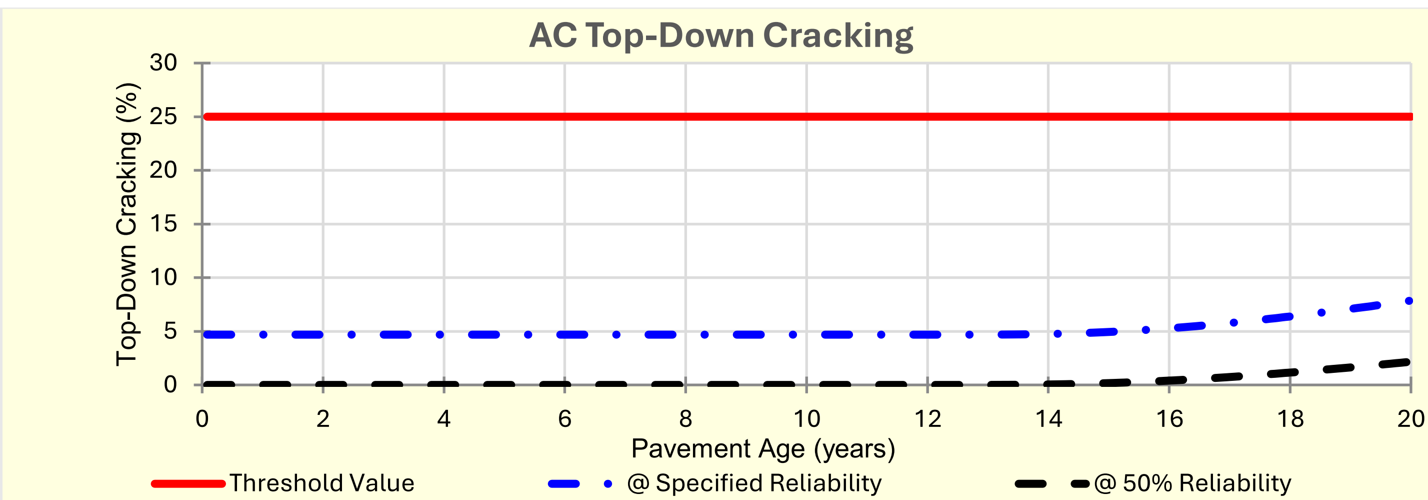
Analysis Output Charts

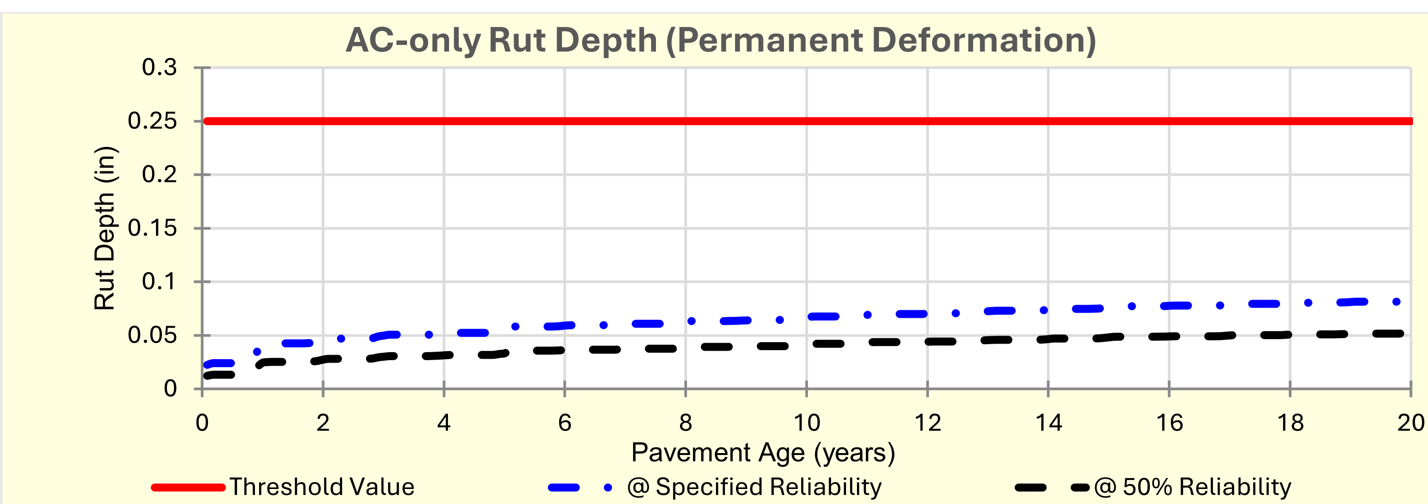


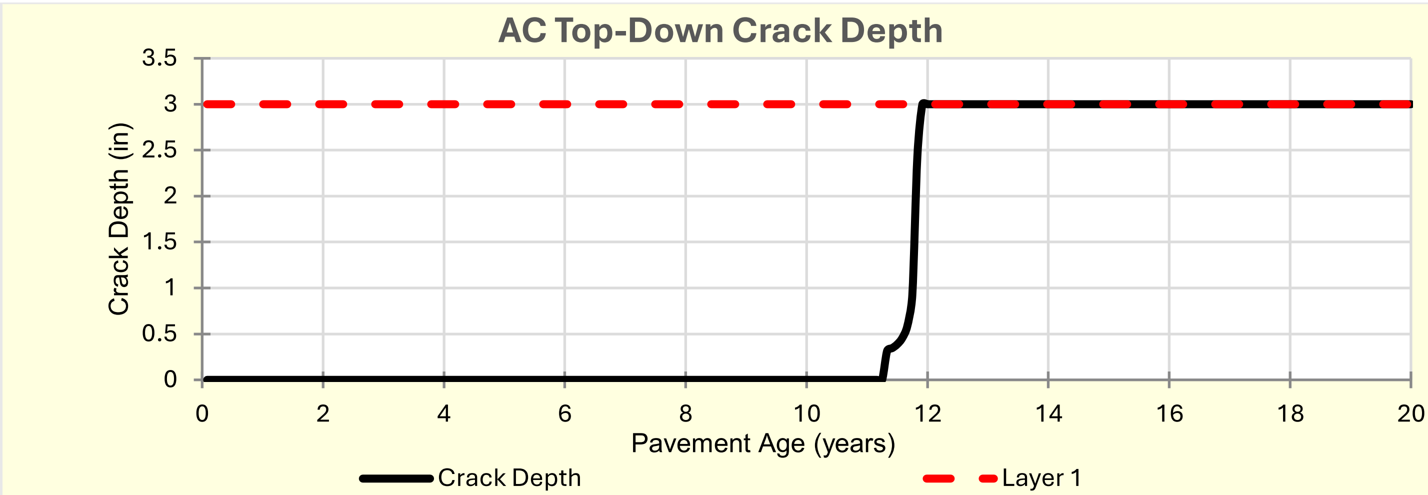

Total Rut Depth (Permanent Deformation)
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

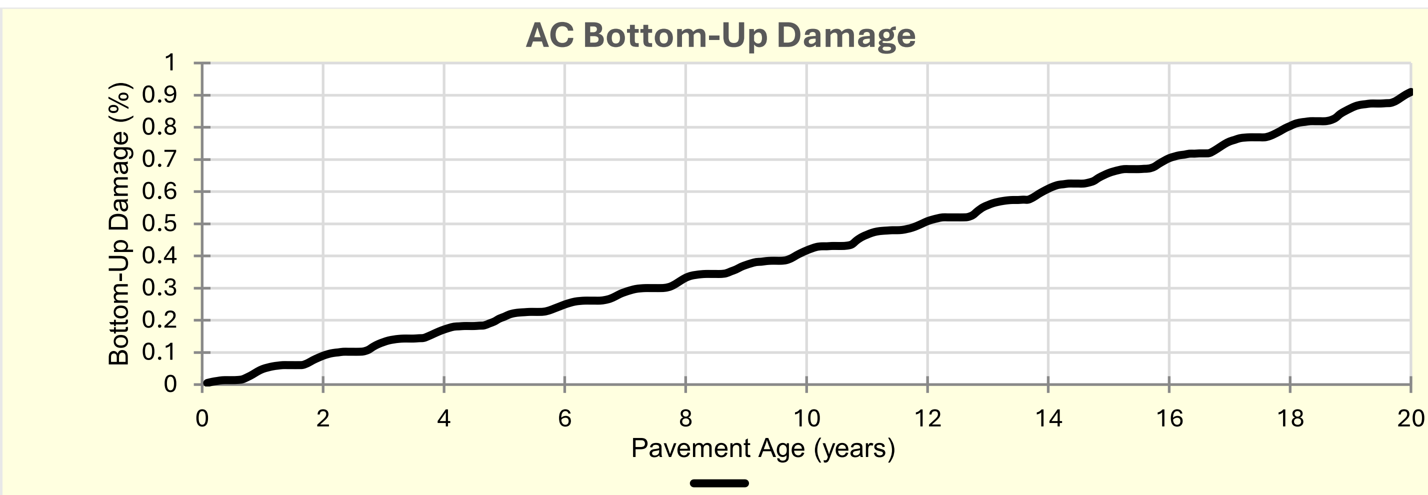

Thermal Cracking: Total Length vs. Time
Total Length (ft/mile)
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability


AC Top-Down Cracking
Top-Down Cracking (%)
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

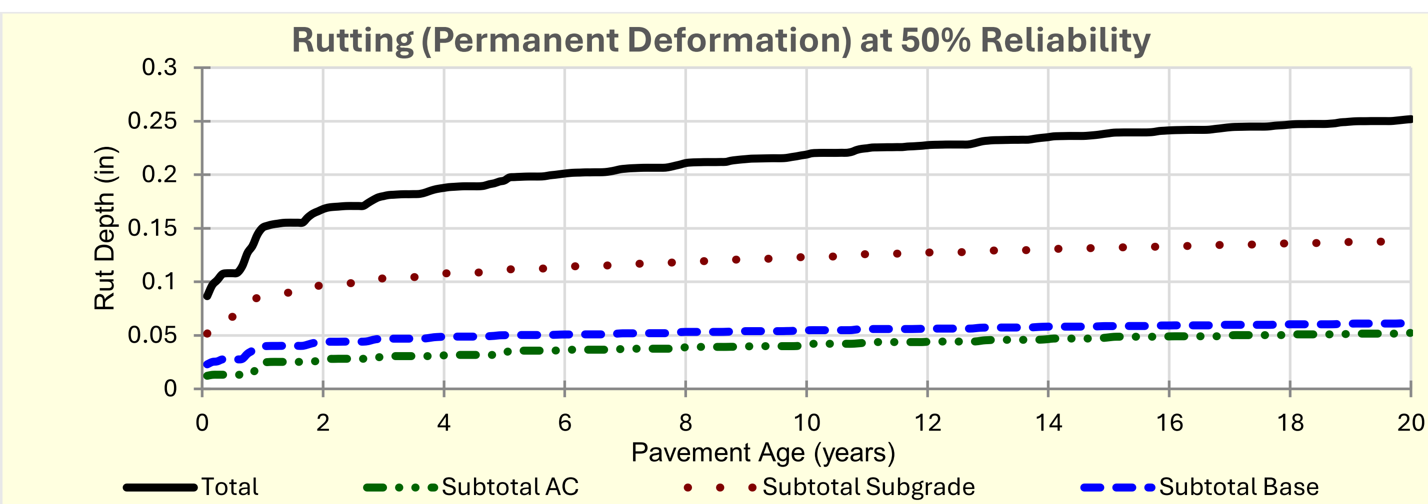

AC-only Rut Depth (Permanent Deformation)
Rut Depth (in)
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability



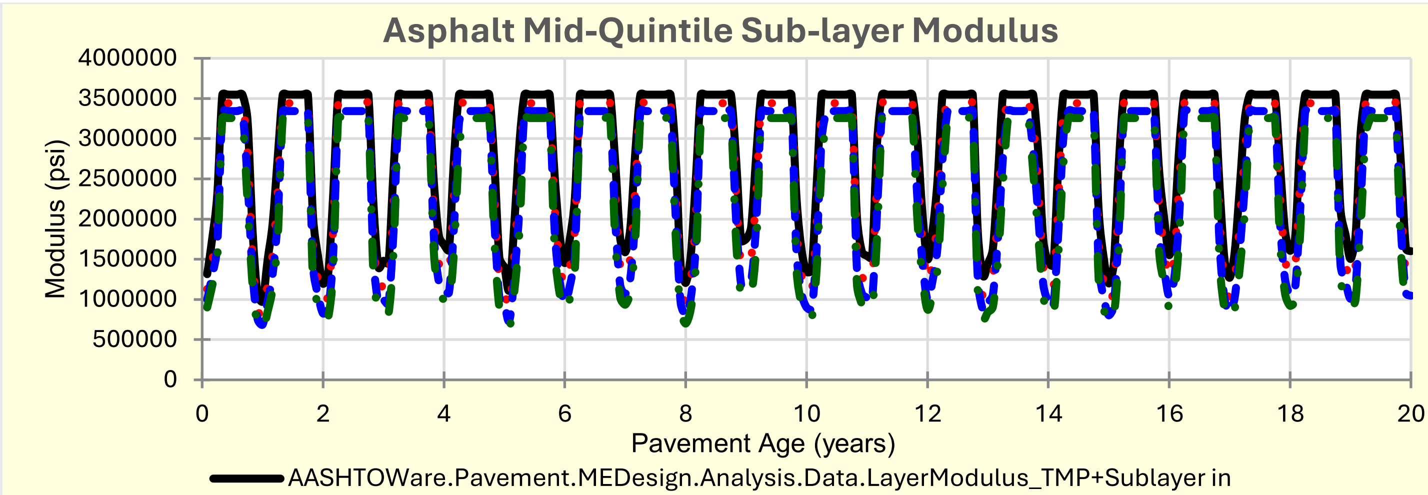
AC Top-Down Crack Depth
Crack Depth (in)
3.5
3
2.5
2
1.5
1
0.5
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
Crack Depth
Layer 1

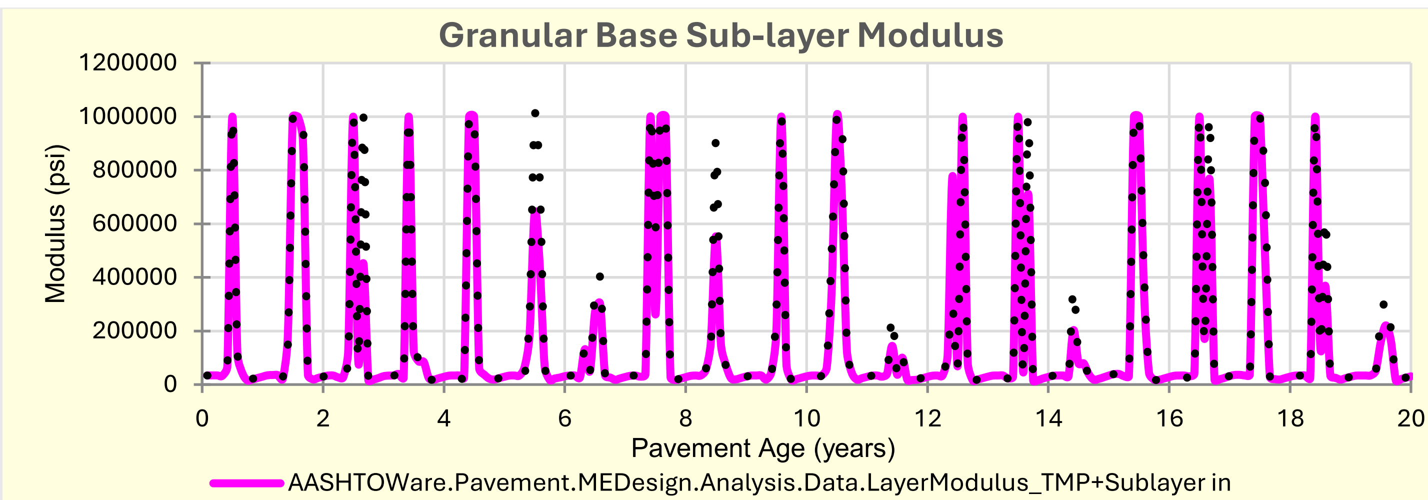


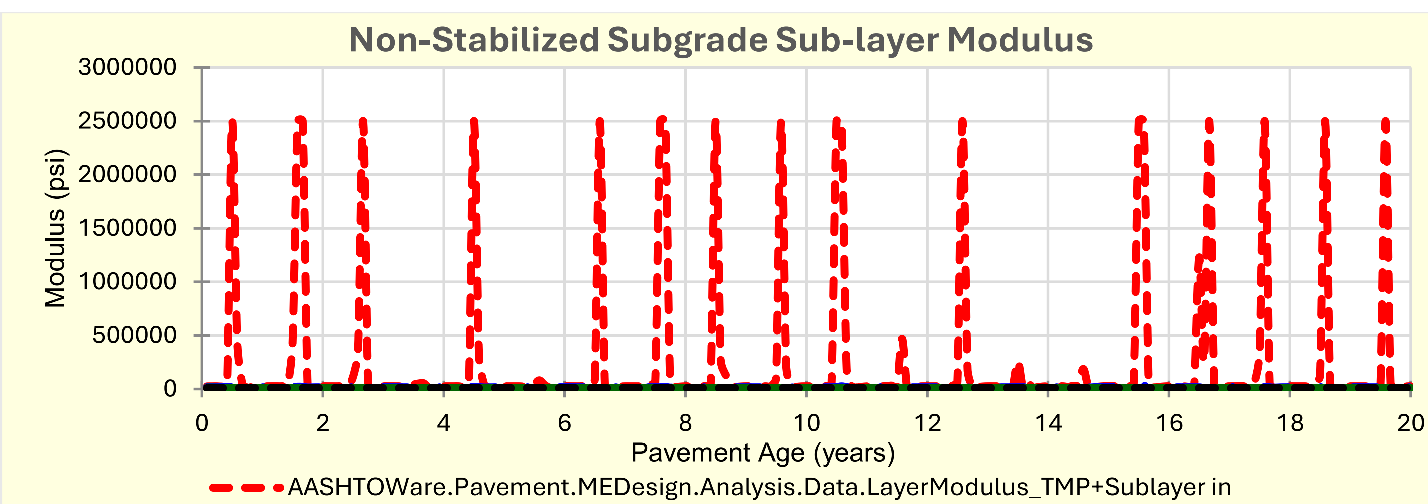
AC Bottom-Up Damage
Bottom-Up Damage (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)



Rutting (Permanent Deformation) at 50% Reliability
Rut Depth (in)
0.3
0.25
0.2
0.15
0.1
0.05
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base


Asphalt Mid-Quintile Sub-layer Modulus
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Granular Base Sub-layer Modulus
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Non-Stabilized Subgrade Sub-layer Modulus
Modulus (psi)
3000000
2500000
2000000
1500000
1000000
500000
0
0 2 4 6 8 10 12 14 16 18 20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in

Layer Information

Layer 1 Flexible (Proposed Overlay) : Default asphalt concrete

Asphalt		
Thickness (in)		3.0
Unit Weight (pcf)		140.0
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

Parameter	Percent Value
Grade	Superpave Performance Grade
Binder Type	52-22
A	12.755
VTS	-4.342

General Info

Name	Value
Reference Temperature (°F)	70
Effective binder content (%)	10.2
Air void (%)	7
Thermal conductivity (BTU/hr-ft-°F)	0.67
Heat Capacity (BTU/lb-°F)	0.23
Percent Content by Weight (%)	4.5
Aggregate Parameter	0.402
Dynamic Modulus E* Fitting Method	1-37A

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/30/2010 5:00:00 AM
Approver	
Date approved	10/30/2010 5:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized base : Crushed gravel (A-1-a)

Unbound	
Layer thickness (in)	6
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	30000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	Crushed gravel (A-1-a)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.1
Saturated hydraulic conductivity (ft/hr)	False	0.05328
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2554968299603350
bf	1.2911570438718638
cf	0.8263617065521088
hr	117.4

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8 in	57.2
1/2 in	63.1
3/4 in	72.7
1 in	78.8
1 1/2 in	85.8
2 in	91.6
2 1/2 in	
3 in	
3 1/2 in	97.6

Layer 3 Subgrade : A-3 (A-3)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	16500.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	A-3 (A-3)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	True	120.0
Saturated hydraulic conductivity (ft/hr)	False	0.00365
Specific gravity of solids	False	2.7
Water Content (%)	False	8.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.849631876739616
bf	2.857643419754946
cf	0.9167554911487317
hr	100

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	5.2
#100	
#80	33
#60	
#50	
#40	76.8
#30	
#20	
#16	
#10	93.4
#8	
#4	95.3
3/8 in	96.6
1/2 in	97.1
3/4 in	98
1 in	98.6
1 1/2 in	99.2
2 in	99.7
2 1/2 in	
3 in	
3 1/2 in	99.9

Calibration Coefficients

AC Cracking

AC Top Down Cracking					AC Bottom Up Cracking		
$$L(t) = L_{Max} e^{-\left(\frac{C_1 \rho}{t - C_3 t_o}\right)^{C_2 \beta}}$$ $$t_0(\text{Days}) = \frac{k_{L1}}{1 + e^{(k_{L2} \times 100 \times a_0/2A_0) + (k_{L3} \times HT) + (k_{L4} \times LT) + (k_{L5} \times \log_{10} AADTT)}}$$					$$FC = \left(\frac{6000}{1 + e^{\left(C_1 * C_1' + C_2 * C_2' \log_{10}(D*100)\right)}}\right) * \left(\frac{1}{60}\right)$$ $$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$ $$C_1' = -2 * C_2'$$		
c1: 2.5219	c2: 0.8069	c3: 1			c1: 1.31	c2: 2.1585	c3: 6000
kL1: 64271618	kL2: 0.2855	kL3: 0.011	kL4: 0.01488	kL5: 3.266			
Top Down Cracking Standard Deviation					**Bottom Up Cracking Standard Deviation**		
0.3657 * TOP + 3.6563					1.13 + 13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))		

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$ $$C = 10^M$$ $$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$	k1: 3.75
	k2: 2.87
	k3: 1.46
	Bf1: 0.02054
	Bf2: 1.38
	Bf3: 0.88

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$$\varepsilon_p = plastic\ strain(in/in)$$

$$\varepsilon_r = resilient\ strain(in/in)$$

$$T = layer\ temperature(^\circ F)$$

$$N = number\ of\ load\ repetitions$$

AC Rutting Standard Deviation	0.24 * Pow(RUT,0.8026) + 0.001	
AC Layer 1	K1: -2.45 K2: 3.01 K3: 0.22	Br1: 0.4 Br2: 0.52 Br3: 1.36

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4 * log_{10}(Damage)}}$$

C1: 0	C2: 75	C3: 2	C4: 2

CSM Cracking Standard Deviation

CTB*1

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1}\left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

k1: 0.972	k2: 0.0825	Bc1: 1	Bc2: 1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

Thermal Fracture

$$C_f = \beta_{t1} N\left[\frac{1}{\sigma_d} log\left(\frac{C}{h_{AC}}\right)\right]$$

$$\Delta C = A(\Delta K)^n$$

$$A = k_t \beta_t 10^{[4.389 - 2.52 \log(E_{HMA} \sigma_m n)]}$$

Cf = Observed amount of thermal cracking, ft. / 500ft.
β_{t1} = Regression coefficient determined through global calibration (400)
N[z] = Standard normal distribution evaluated at [z]
σ_d = Standard deviation of the logarithm of crack depth in the pavement (0.769), in.
C = Crack depth, in.
h_{AC} = Thickness of asphalt layer, in.
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = Asphalt mixture stiffness, MPa
σ_m = Undamaged mixture tensile strength, MPa
k_t = Regression coefficient determined through field calibration
β_t = Calibration parameter

Level 1 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 2 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 3 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	

Unbound Layer Rutting			
$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left\| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right\|$$		$\delta_a = permanent\ deformation\ for\ the\ layer$ $N = number\ of\ repetitions$ $\varepsilon_v = average\ vertical\ strain(in/in)$ $\varepsilon_0, \beta, \rho = material\ properties$ $\varepsilon_r = resilient\ strain(in/in)$	
Base Rutting		**Subgrade Rutting**	
k1: 0.965	Bs1: 1	k1: 0.635	Bs1: 1
Standard Deviation: 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation: 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

9.3 Local highway design outputs-asphalt pavement

AASHTOWare™ PAVEMENT ME DESIGN

Madhav Joshi and Kamal Gautam Local-Asphalt

Tenant: Kamal Gautam   Workspace: System Workspace

Design Inputs

Design Life:	20 years	Base Construction:	May 2025	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	FLEXIBLE	Pavement construction:	June 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	2
NonStabilized	Crushed gravel (A-1-a)	4
Subgrade	A-3 (A-3)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.2
Air voids (%)	7.0

Traffic

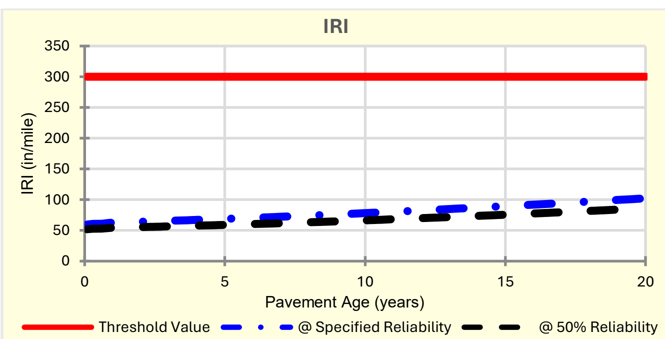
Age (year)	Heavy Trucks (cumulative)
2025 (initial)	18
2035 (10 years)	35,994
2045 (20 years)	79,872

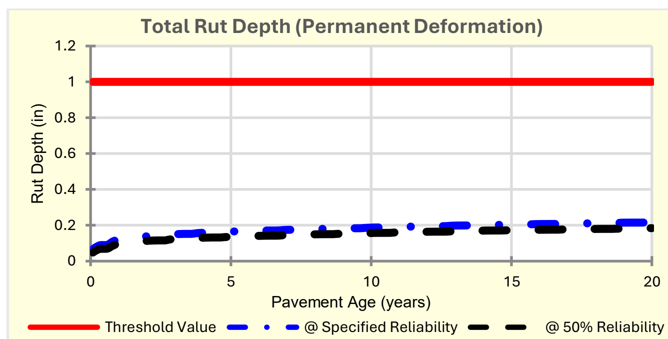
Design Outputs

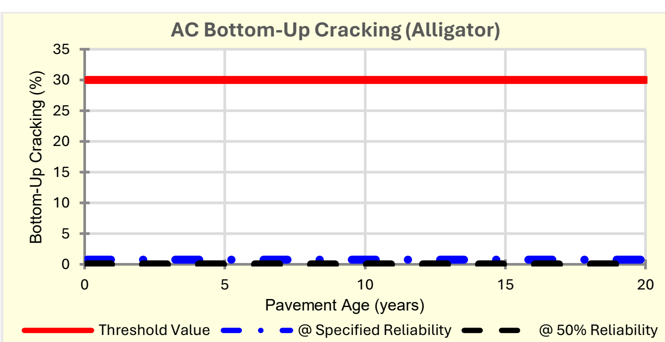
Distress Prediction Summary

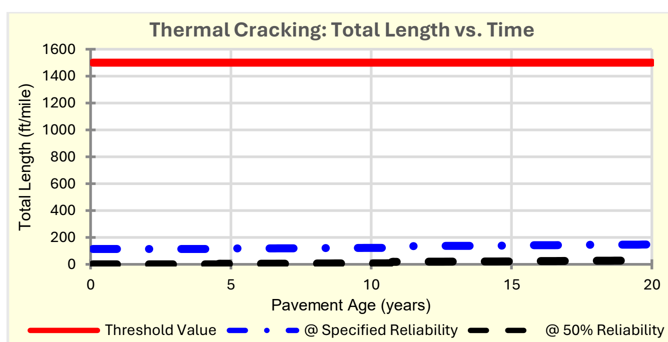
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	300.00	102.20	75.00	100.00	Pass
Permanent deformation - total pavement (in)	1.00	0.22	75.00	100.00	Pass
AC bottom-up fatigue cracking (%)	30.00	0.76	75.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	147.63	75.00	100.00	Pass
AC top-down fatigue cracking (%)	35.00	2.47	75.00	100.00	Pass
Permanent deformation - AC only (in)	0.35	0.04	75.00	100.00	Pass

Distress Charts





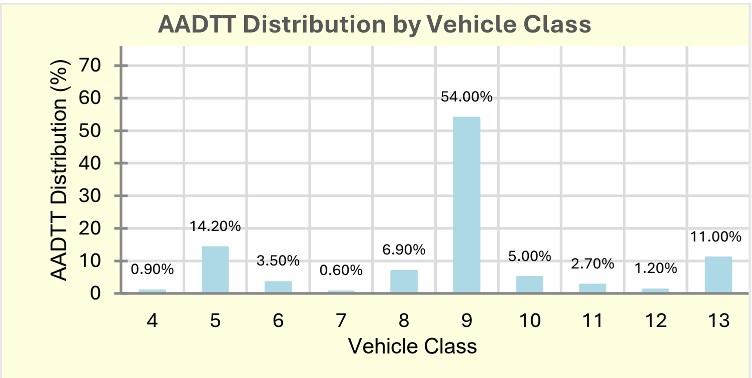




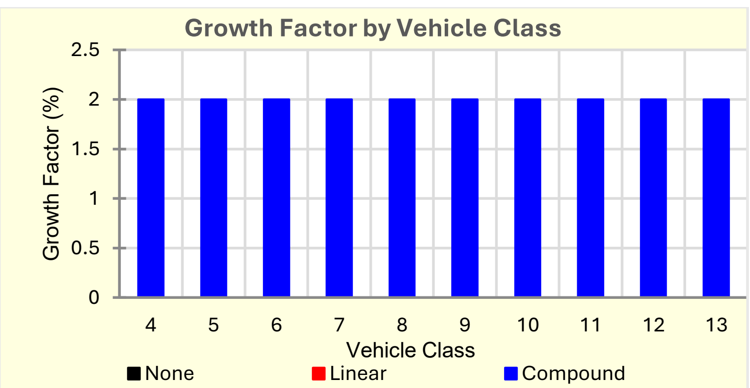
Traffic Inputs

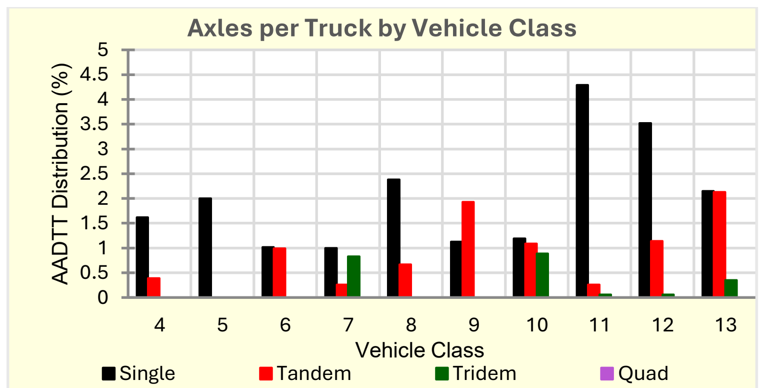
Graphical Representation of Traffic Inputs

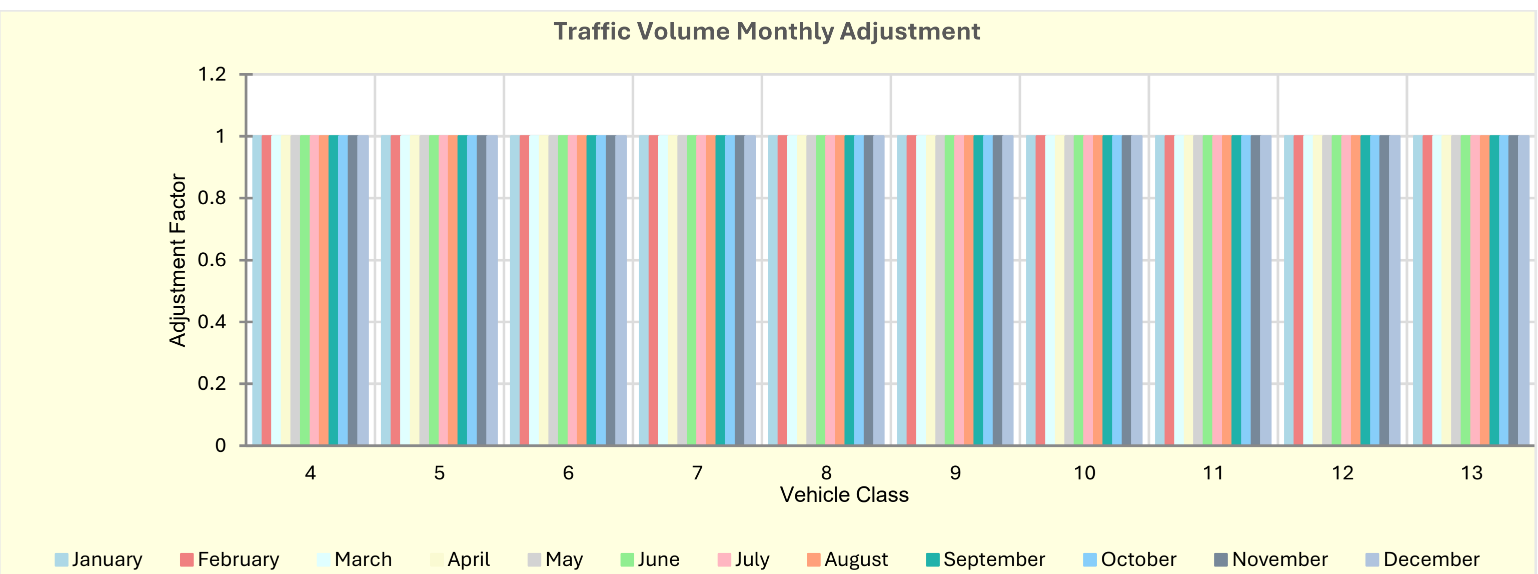
Initial two-way AADTT	18
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	100
Operation speed (mph)	55
Axle Distribution	NCHRP 1-37A



Truck Distribution by Hour does not apply to the design type.







Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors (Level 3: Default MAF)

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.9%	2%	Compound
Class 5	14.2%	2%	Compound
Class 6	3.5%	2%	Compound
Class 7	0.6%	2%	Compound
Class 8	6.9%	2%	Compound
Class 9	54.0%	2%	Compound
Class 10	5.0%	2%	Compound
Class 11	2.7%	2%	Compound
Class 12	1.2%	2%	Compound
Class 13	11.0%	2%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

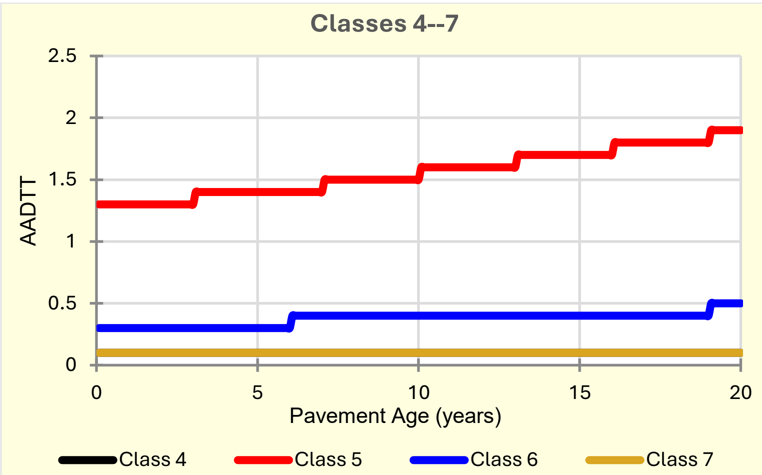
Wheelbase does not apply

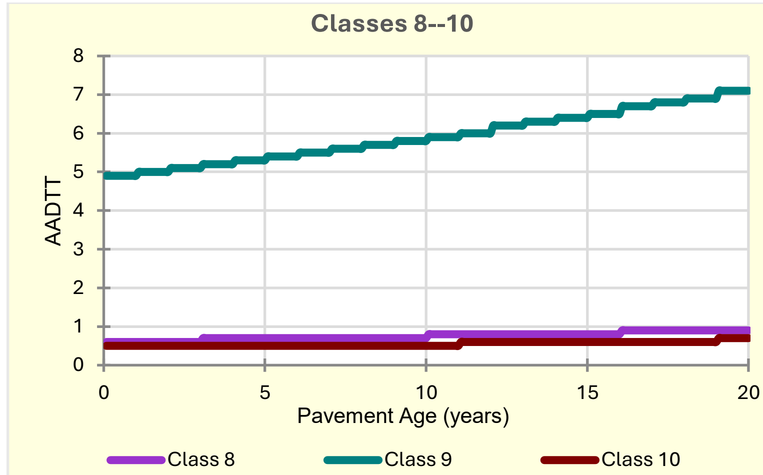
Number of Axles per Truck

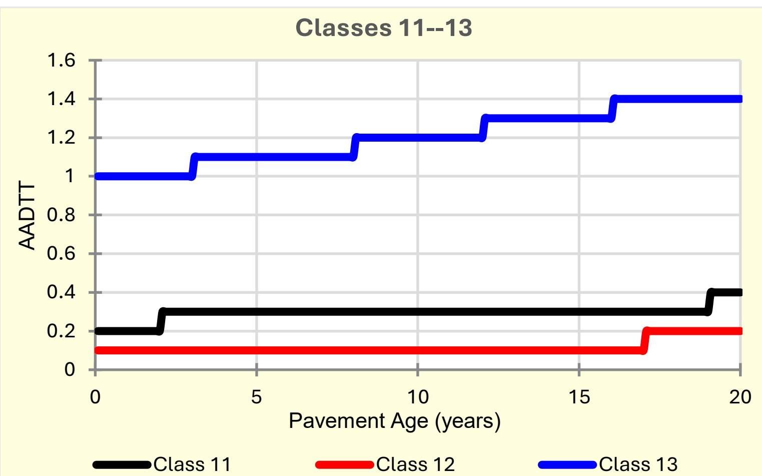
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

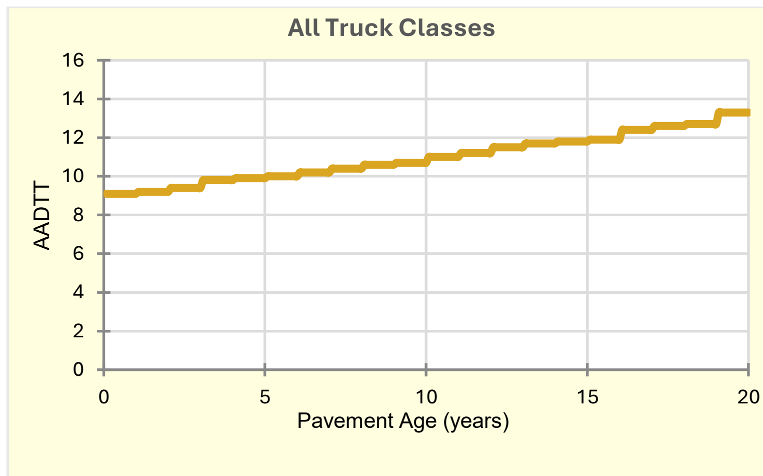
AADTT (Average Annual Daily Truck Traffic) Growth

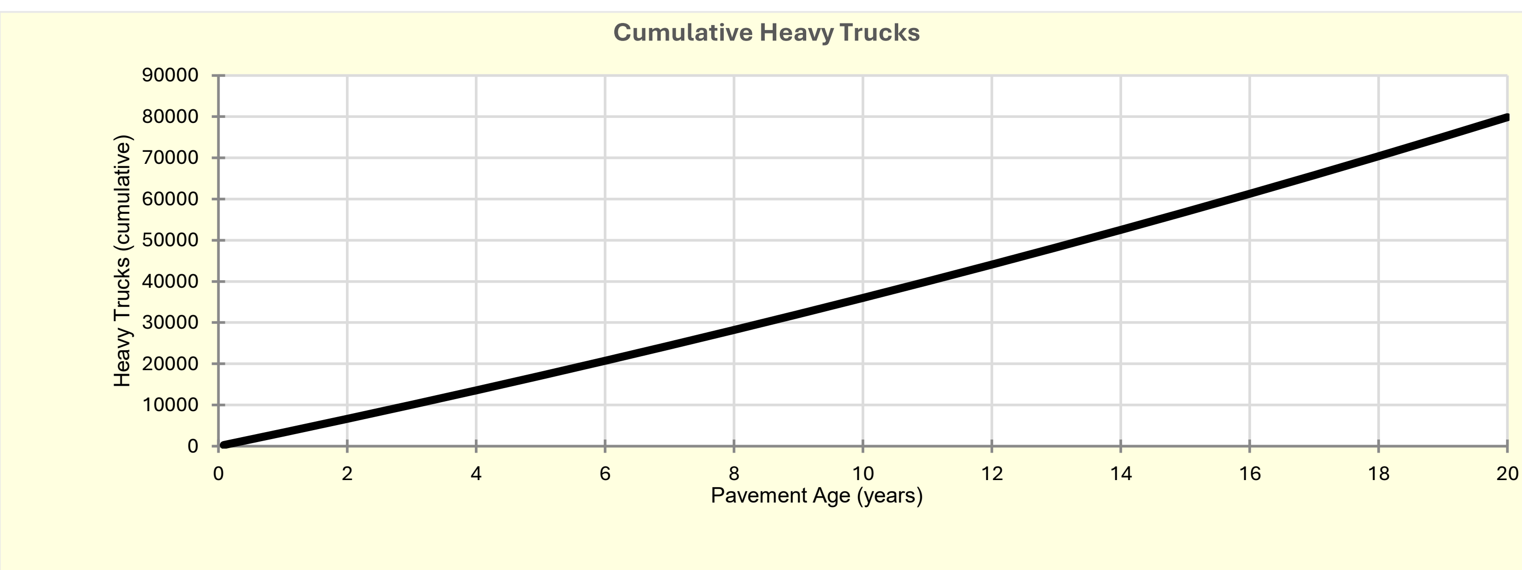
* Traffic cap is not enforced

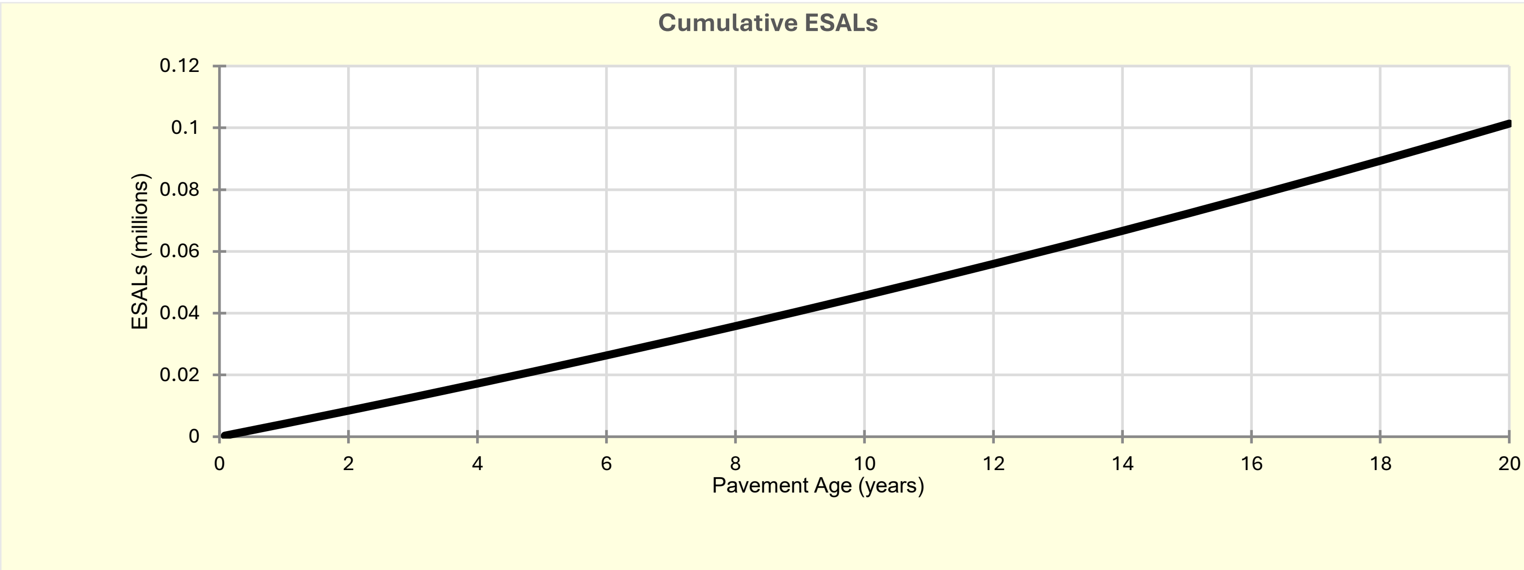








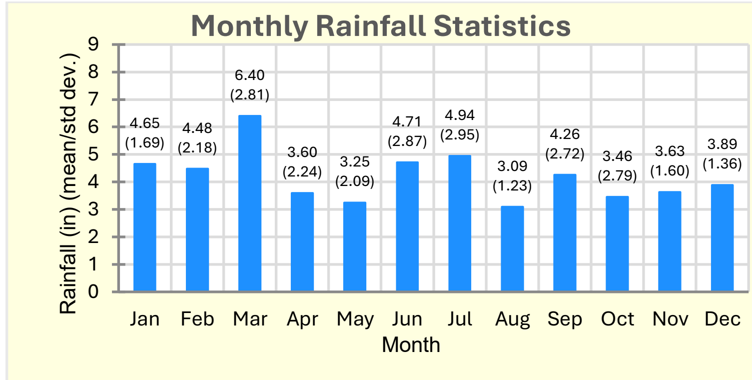



Cumulative ESALs
ESALs (millions)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)

Climate Inputs

Climate Data Sources:

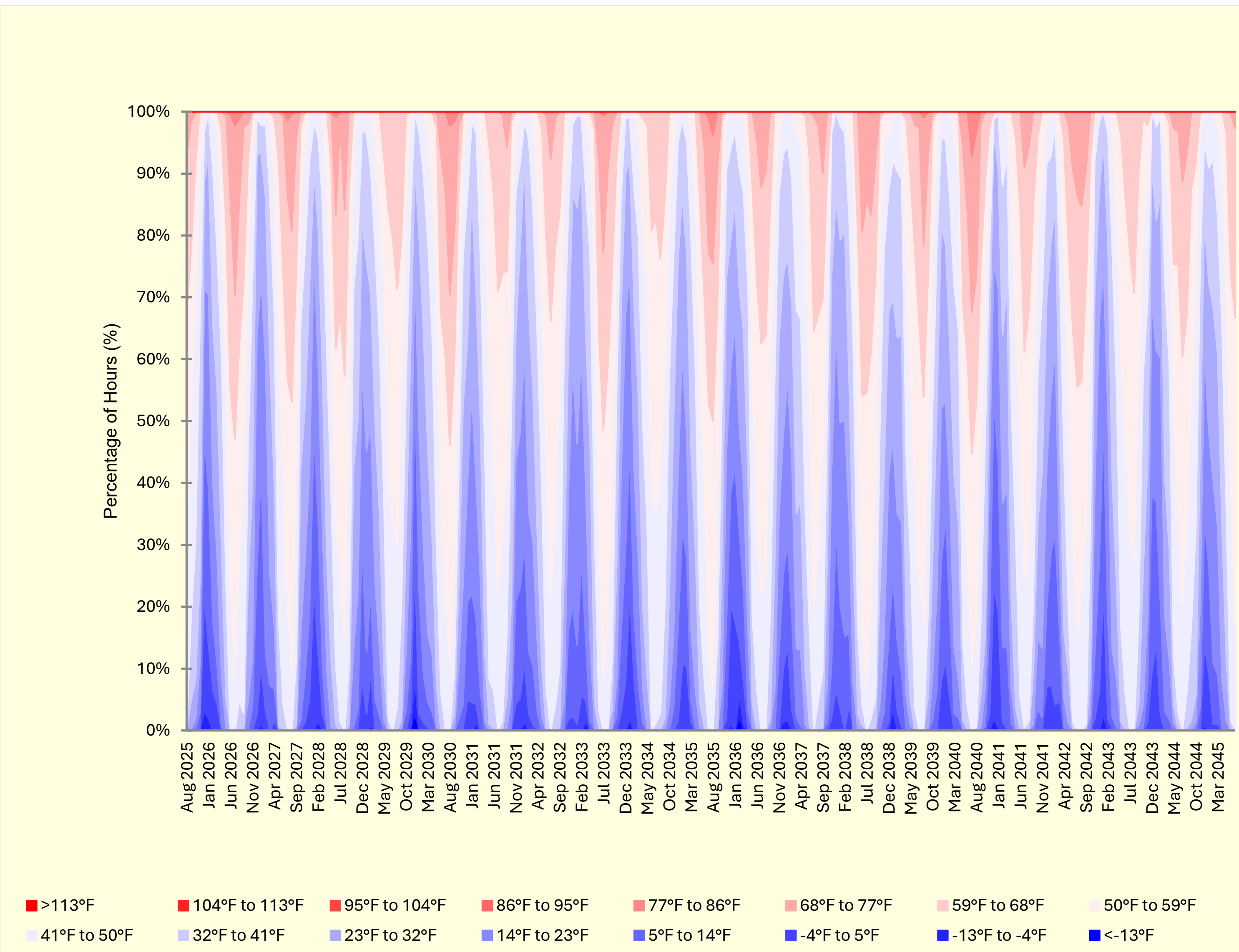
Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131



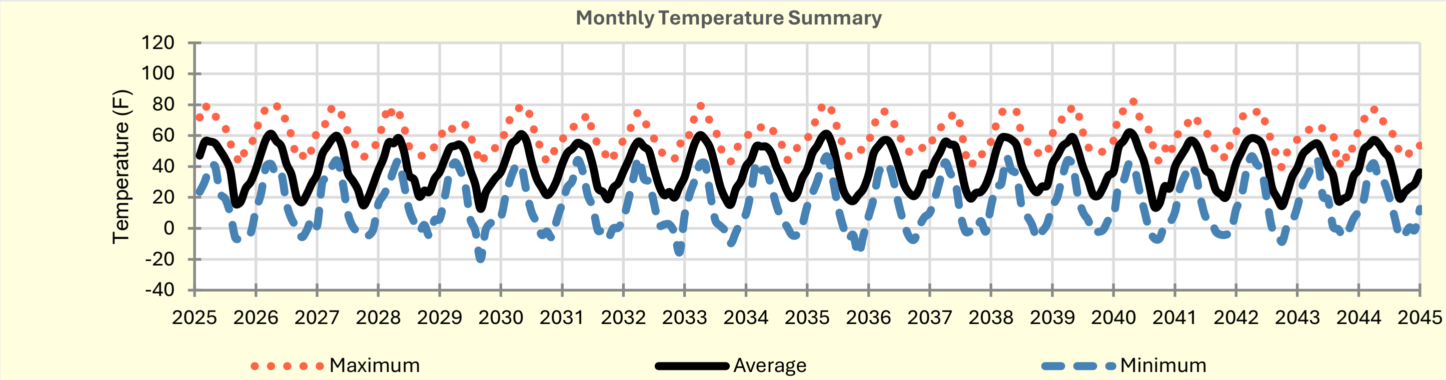
Annual Statistics:

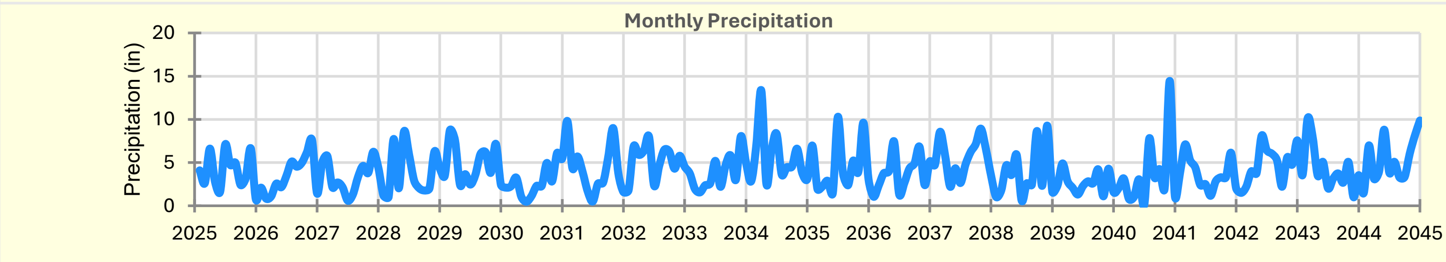
Mean annual air temperature (F):	39.35
Mean annual precipitation (in):	50.32
Freezing index (F - days):	1246.54
Average annual number of freeze/thaw cycles:	130.88
Water table depth (ft)	10.00

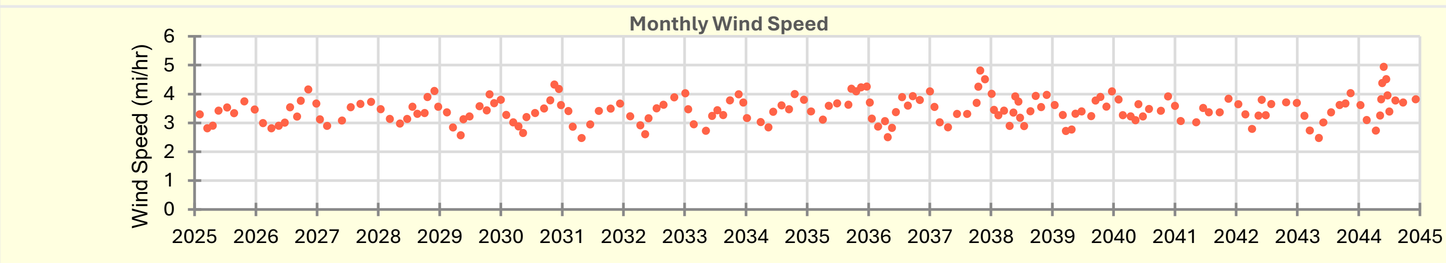
Hourly Air Temperature Distribution by Month:

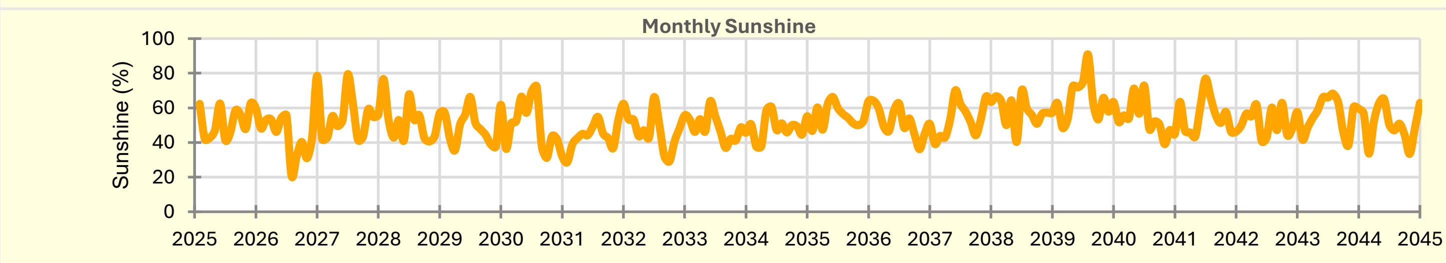


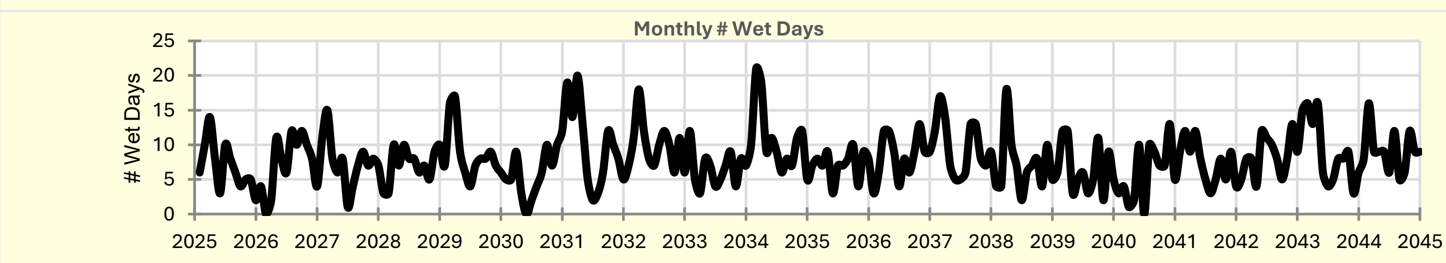
Monthly Climate Summary:

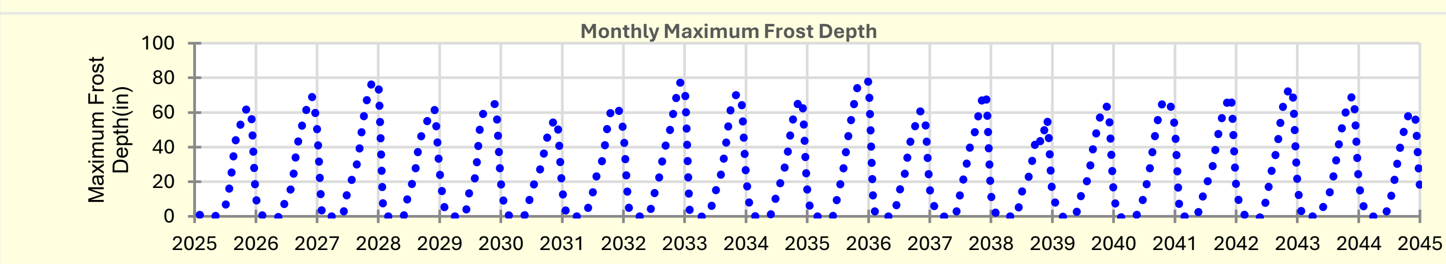












Design Properties

HMA Design Properties

Multilayer Rutting Model	False
NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Using Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

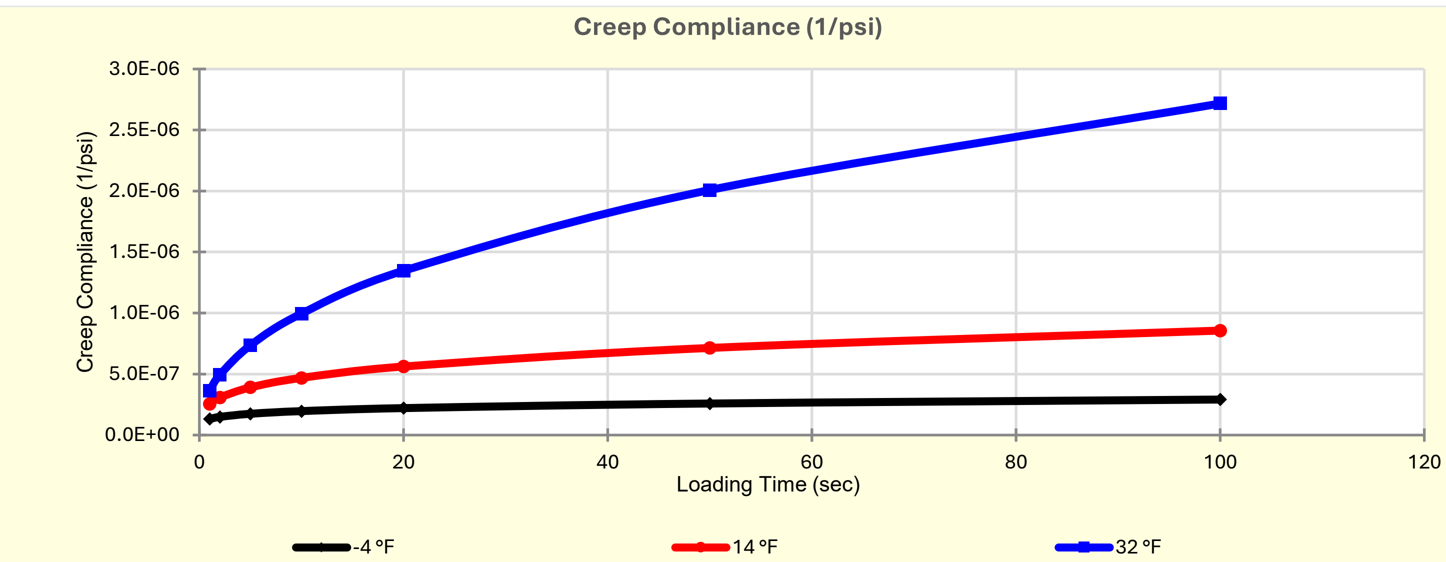
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed gravel (A-1-a)	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-3 (A-3)	Subgrade (5)	-

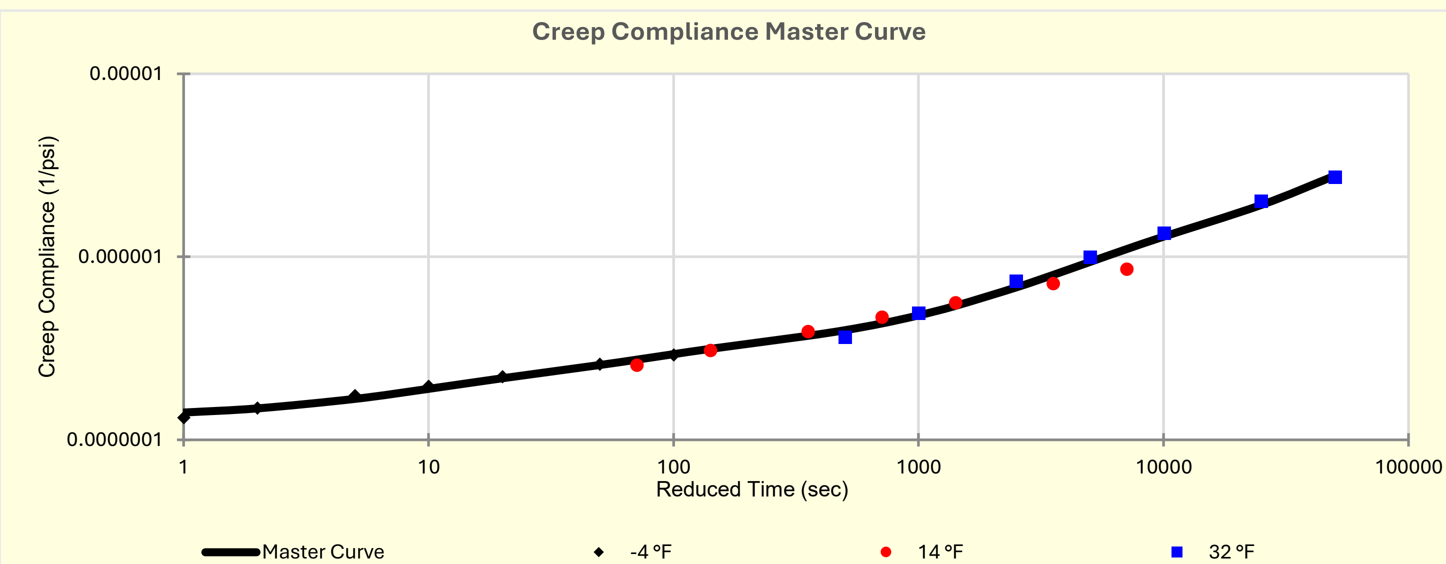
Thermal Cracking

Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/°F)	-
Aggregate coefficient of thermal contraction (in/in/°F)	5E-06
Voids in Mineral Aggregate (%)	17.2

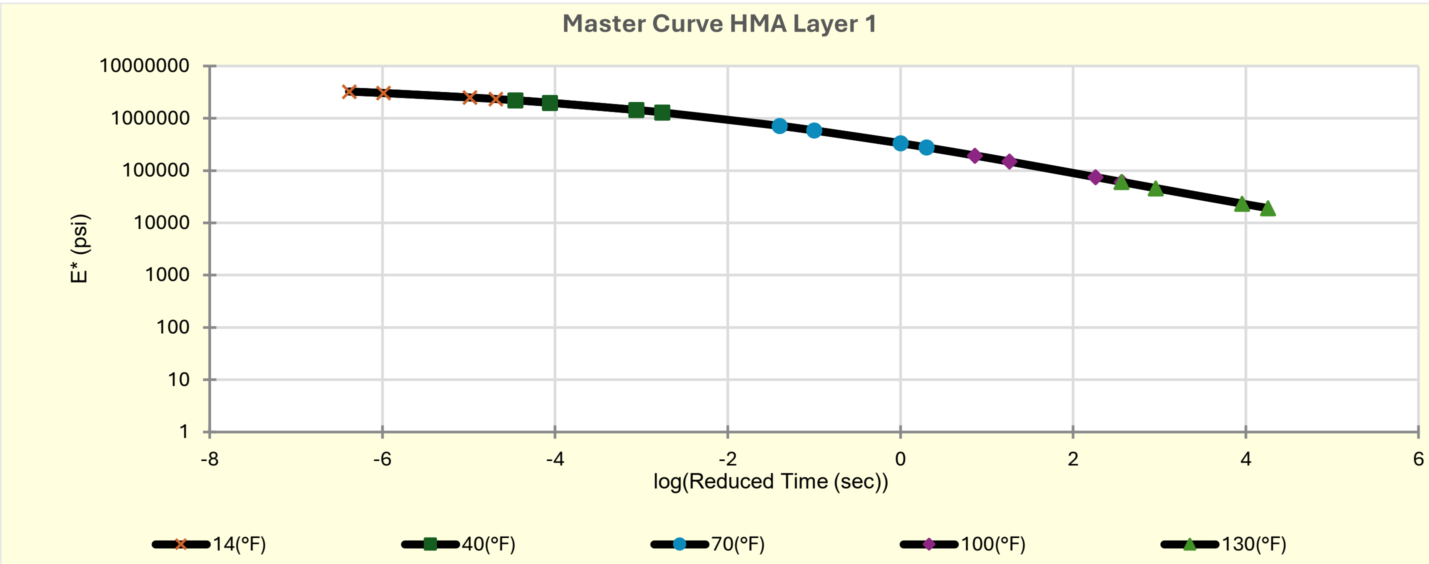
Indirect Tensile Strength (Input Level: 3)	
Test Temperature (°F)	**Indirect Tensile Strength (psi)**
14	403.08172152700604

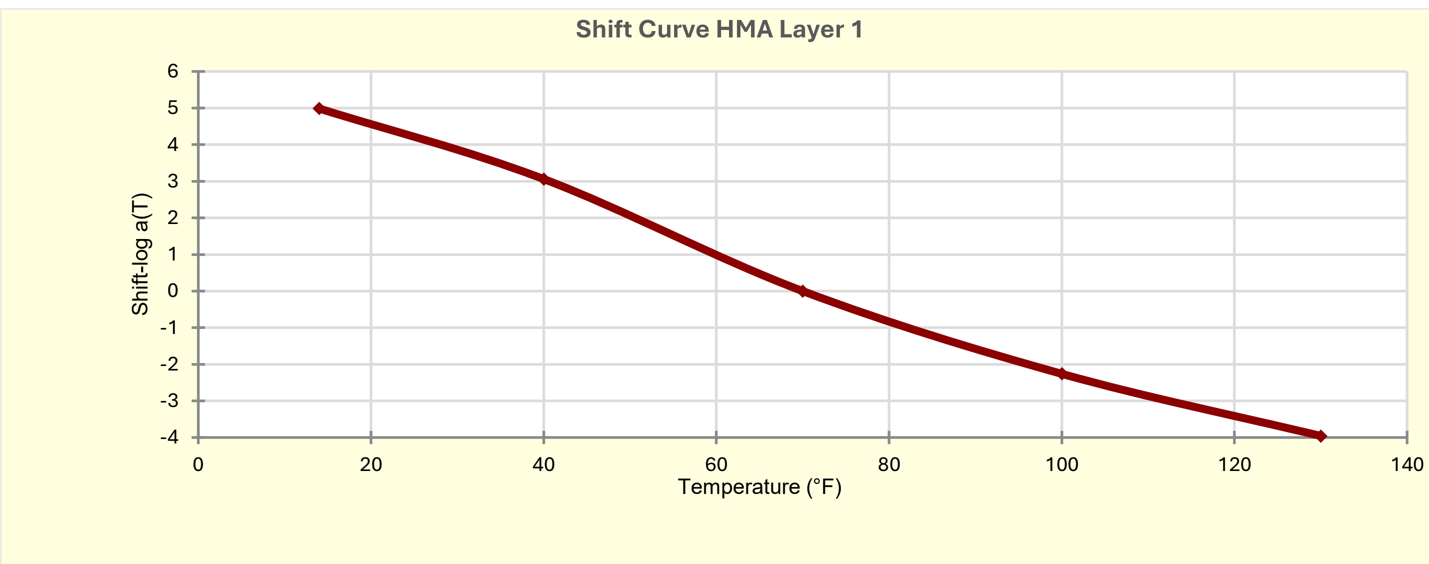
Creep Compliance (1/psi) (Input Level: 3)			
Loading time (sec)	**-4 °F**	**14 °F**	**32 °F**
1	1.32E-07	2.56E-07	3.65E-07
2	1.49E-07	3.07E-07	4.93E-07
5	1.74E-07	3.91E-07	7.36E-07
10	1.96E-07	4.68E-07	9.95E-07
20	2.21E-07	5.62E-07	1.35E-06
50	2.59E-07	7.14E-07	2.01E-06
100	2.91E-07	8.56E-07	2.72E-06

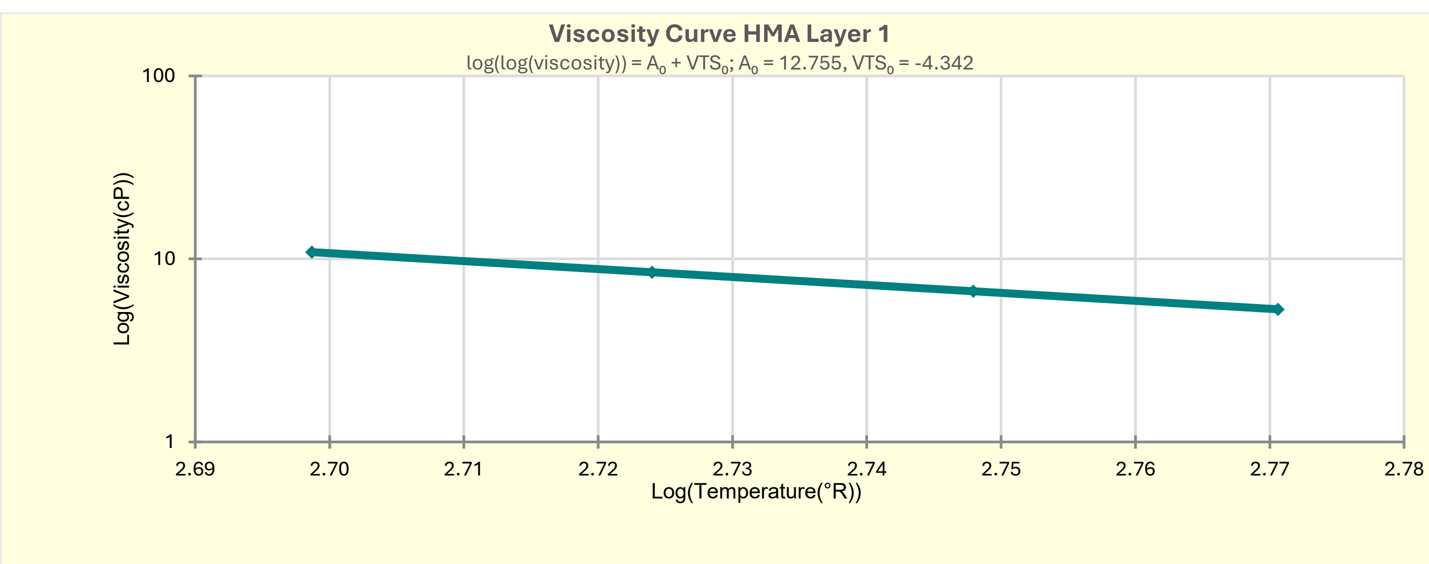




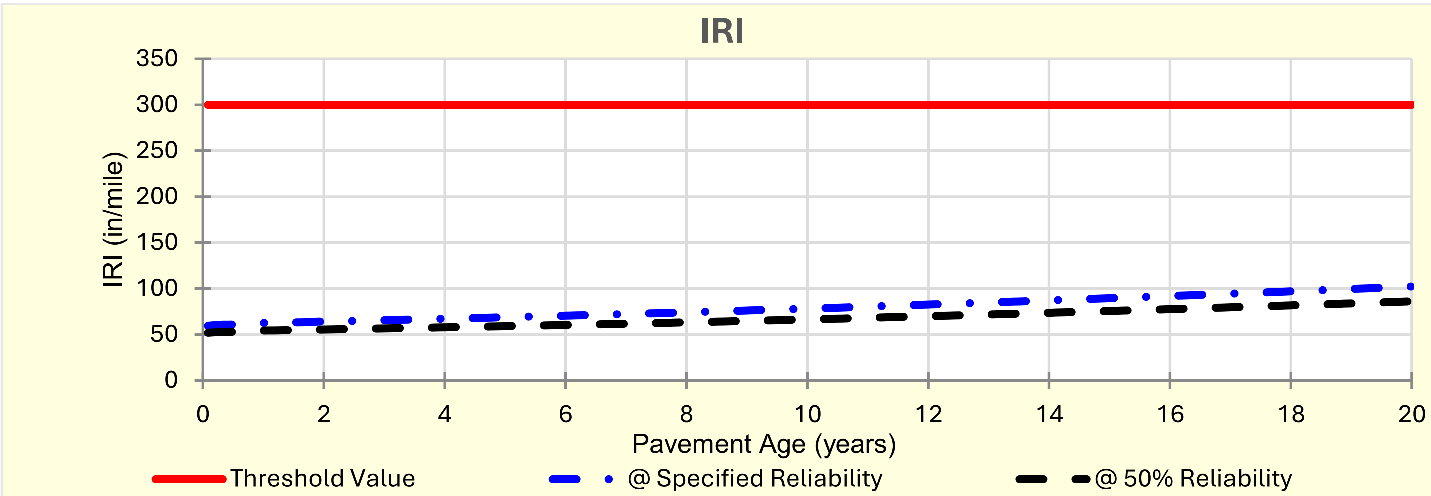
HMA Layer 1 (Proposed Overlay): Layer 1 Flexible : Default asphalt concrete

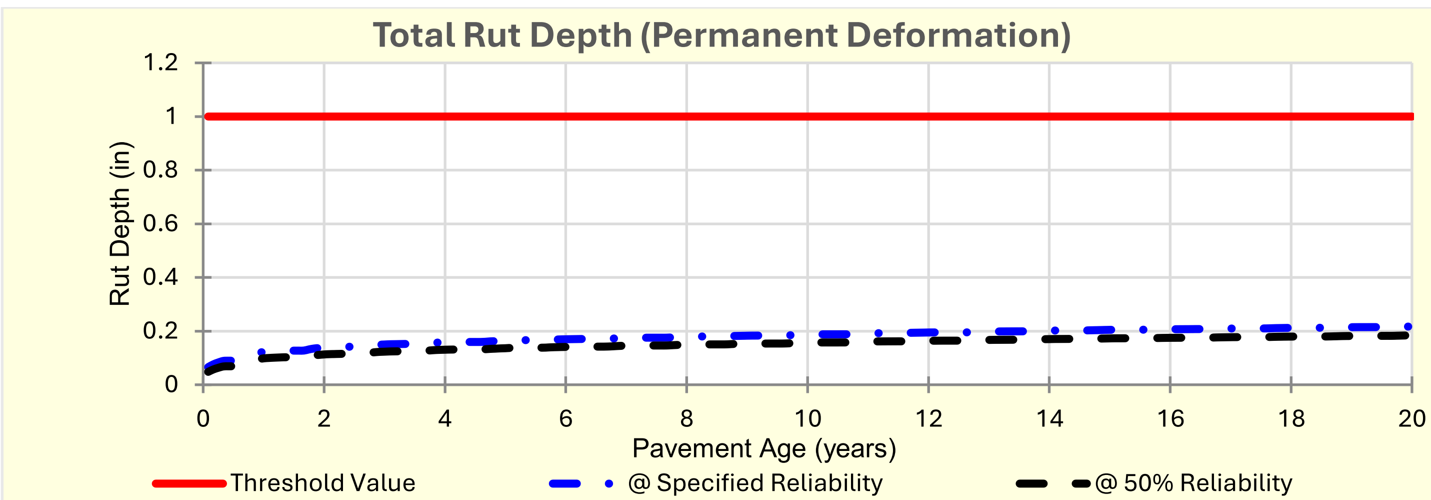


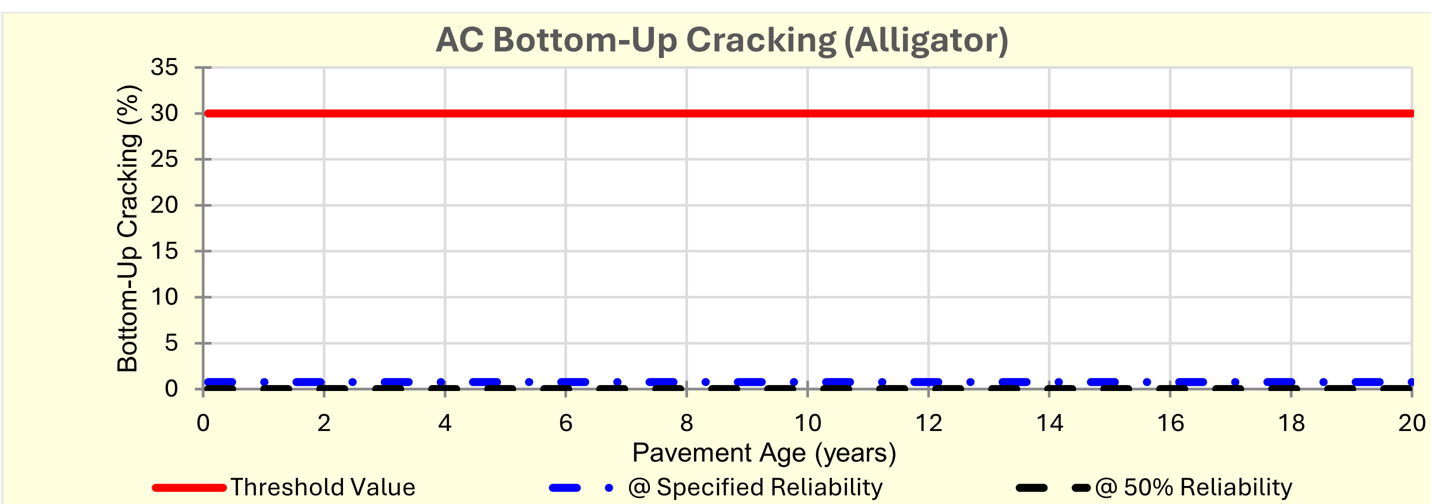


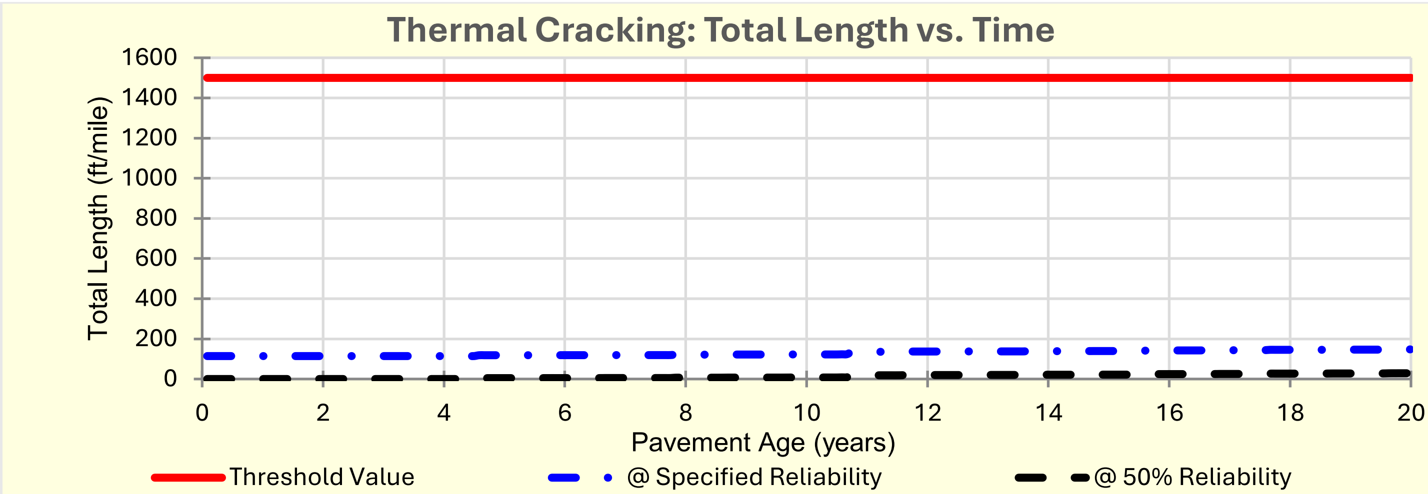


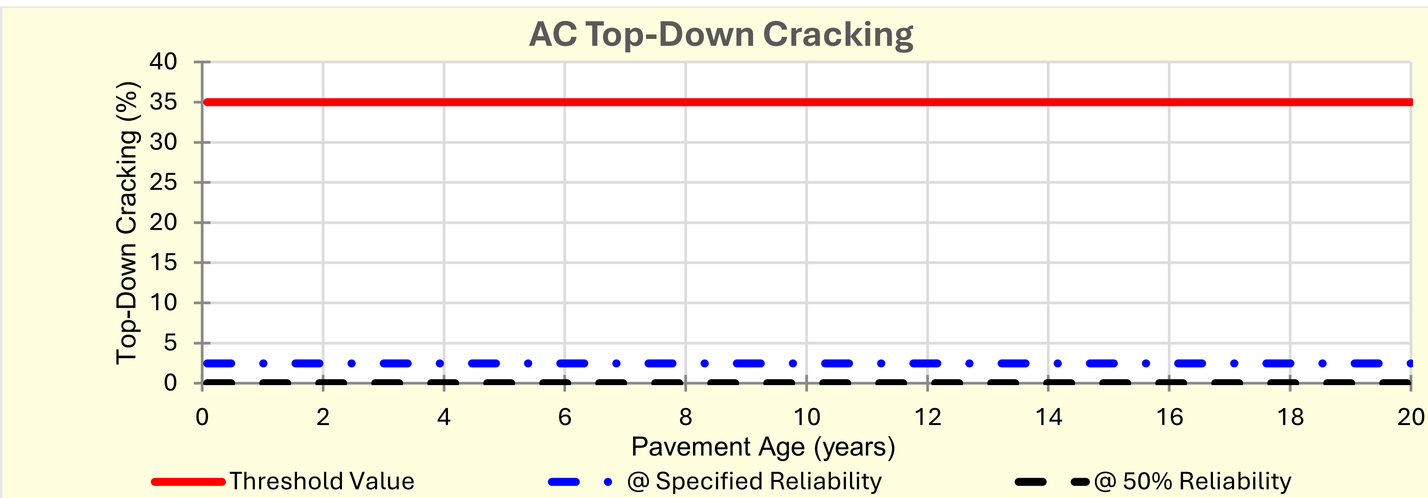
Analysis Output Charts

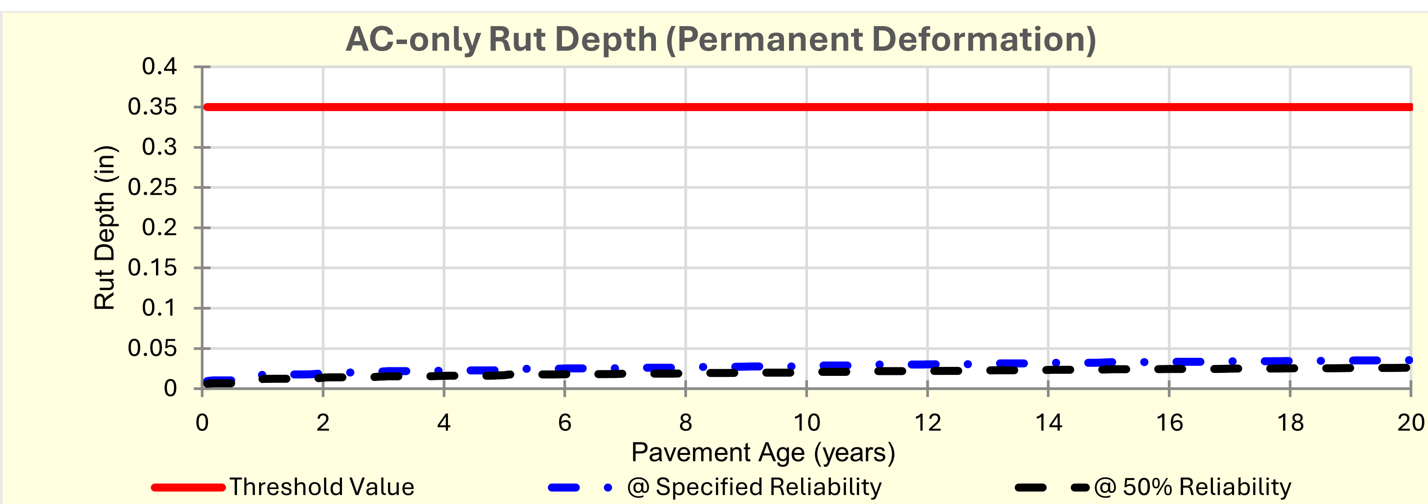


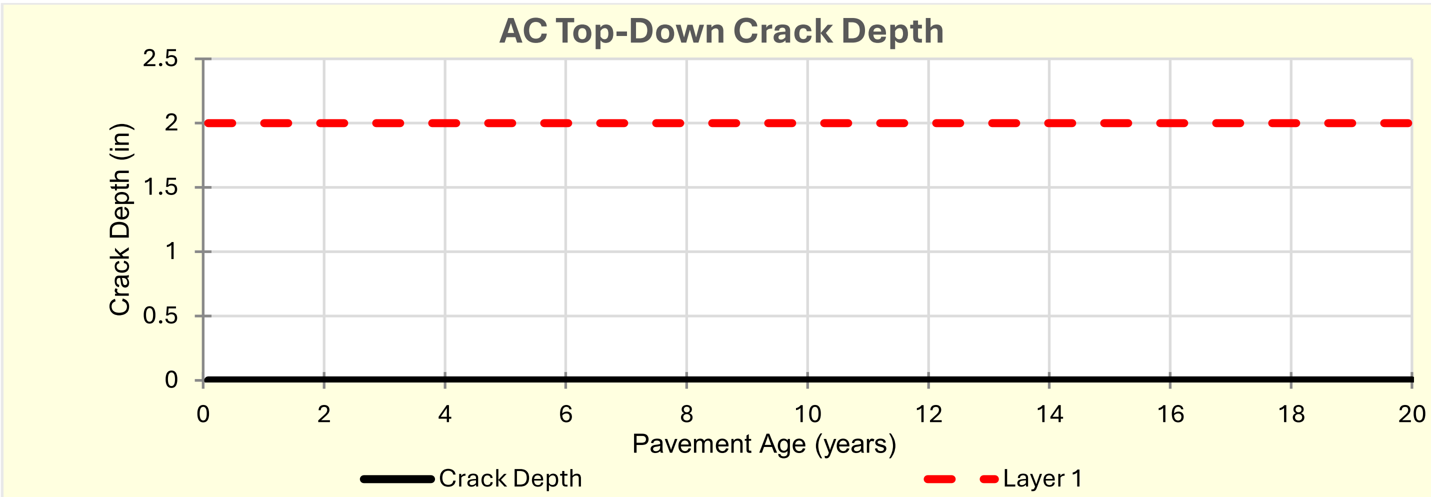


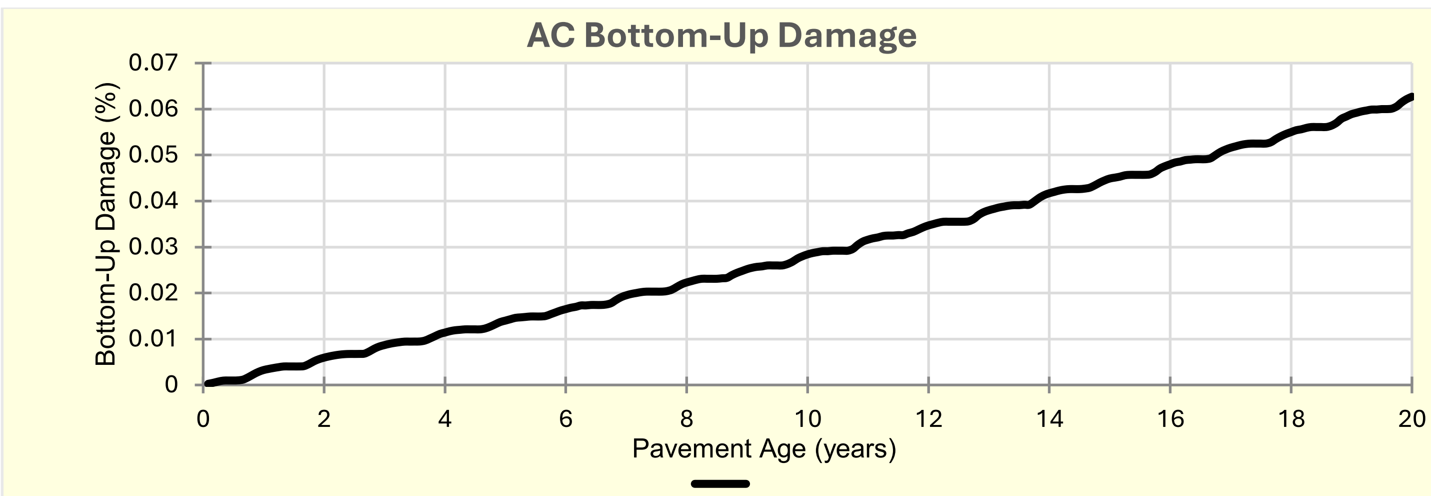


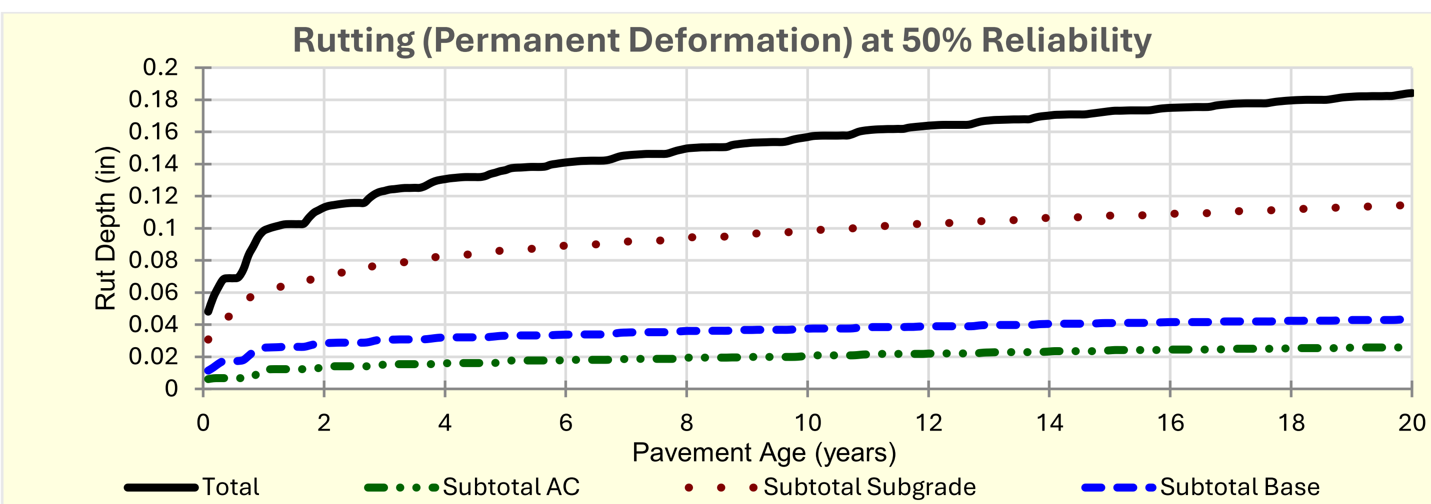

Thermal Cracking: Total Length vs. Time
Total Length (ft/mile)
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

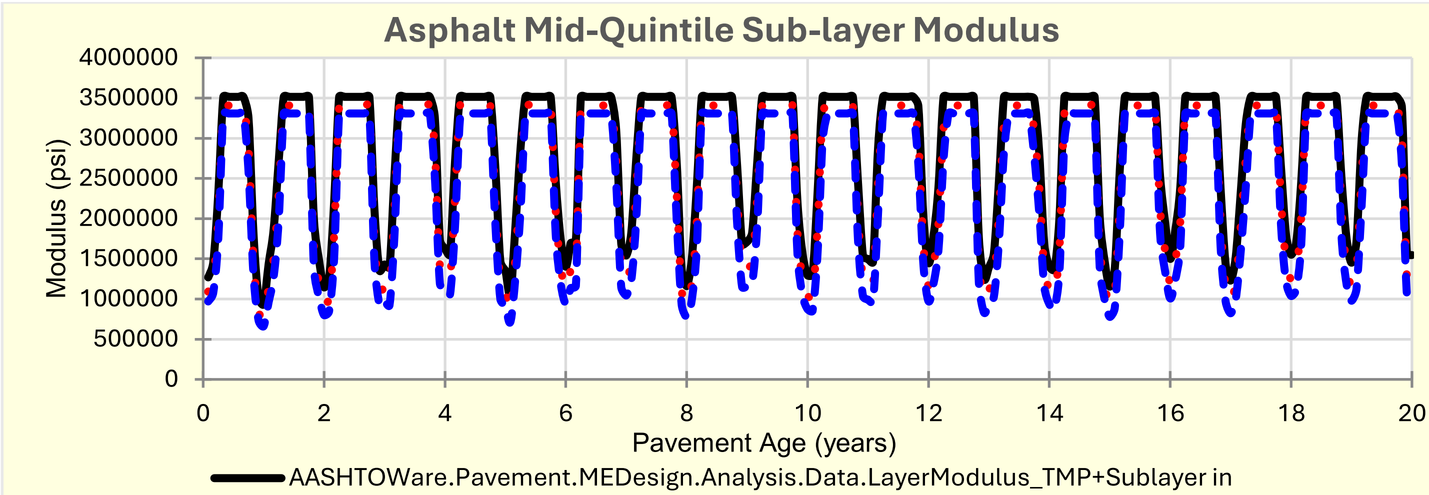

AC Top-Down Cracking
Top-Down Cracking (%)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

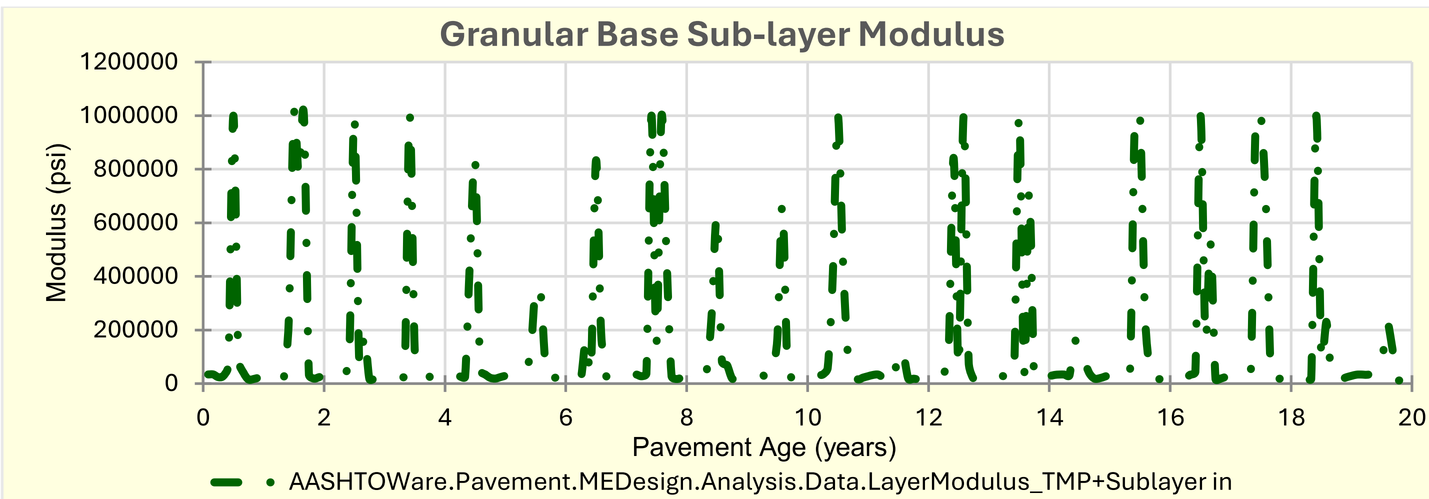

AC-only Rut Depth (Permanent Deformation)
Rut Depth (in)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Threshold Value
@ Specified Reliability
@ 50% Reliability

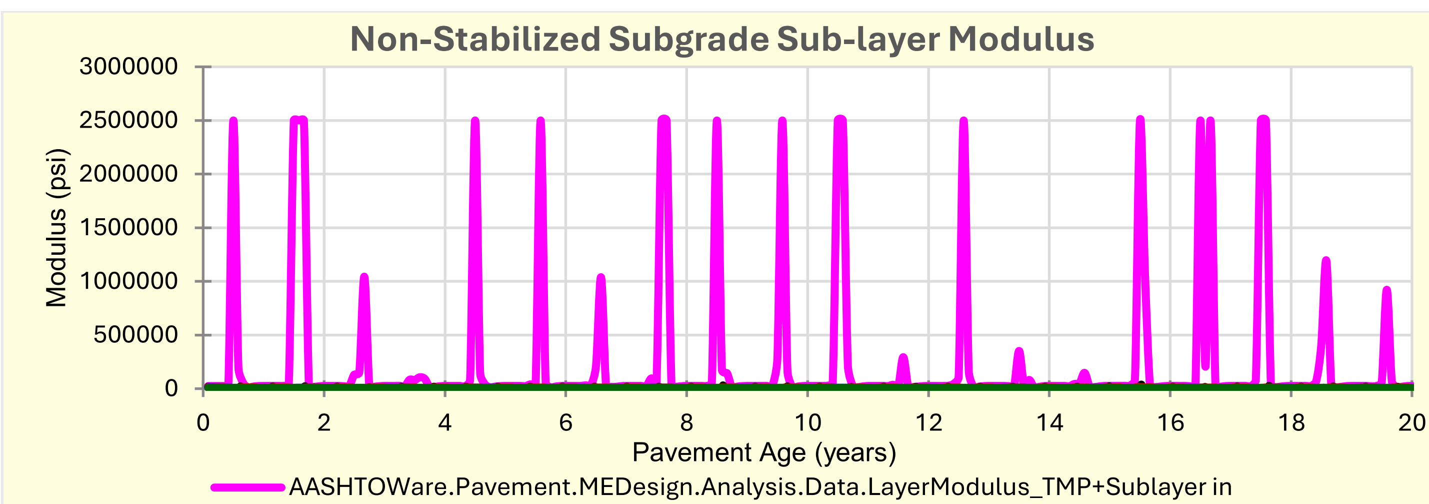

AC Top-Down Crack Depth
Crack Depth (in)
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Crack Depth
Layer 1


AC Bottom-Up Damage
Bottom-Up Damage (%)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)


Rutting (Permanent Deformation) at 50% Reliability
Rut Depth (in)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base


Asphalt Mid-Quintile Sub-layer Modulus
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Granular Base Sub-layer Modulus
1200000
1000000
800000
600000
400000
200000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in


Non-Stabilized Subgrade Sub-layer Modulus
3000000
2500000
2000000
1500000
1000000
500000
0
Modulus (psi)
0
2
4
6
8
10
12
14
16
18
20
Pavement Age (years)
AASHTOWare.Pavement.MEDesign.Analysis.Data.LayerModulus_TMP+Sublayer in

Layer Information

Layer 1 Flexible (Proposed Overlay) : Default asphalt concrete

Asphalt		
Thickness (in)		2.0
Unit Weight (pcf)		140.0
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

Parameter	Percent Value
Grade	Superpave Performance Grade
Binder Type	52-22
A	12.755
VTS	-4.342

General Info

Name	Value
Reference Temperature (°F)	70
Effective binder content (%)	10.2
Air void (%)	7
Thermal conductivity (BTU/hr-ft-°F)	0.67
Heat Capacity (BTU/lb-°F)	0.23
Percent Content by Weight (%)	4.5
Aggregate Parameter	0.402
Dynamic Modulus E* Fitting Method	1-37A

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/30/2010 5:00:00 AM
Approver	
Date approved	10/30/2010 5:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized base : Crushed gravel (A-1-a)

Unbound	
Layer thickness (in)	4
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	30000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	Crushed gravel (A-1-a)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.1
Saturated hydraulic conductivity (ft/hr)	False	0.05328
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.255496829960335
bf	1.2911570438718638
cf	0.8263617065521088
hr	117.4

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8 in	57.2
1/2 in	63.1
3/4 in	72.7
1 in	78.8
1 1/2 in	85.8
2 in	91.6
2 1/2 in	
3 in	
3 1/2 in	97.6

Layer 3 Subgrade : A-3 (A-3)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	16500.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	A-3 (A-3)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	True	120.0
Saturated hydraulic conductivity (ft/hr)	False	0.00365
Specific gravity of solids	False	2.7
Water Content (%)	False	8.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.849631876739616
bf	2.857643419754946
cf	0.9167554911487317
hr	100

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	5.2
#100	
#80	33
#60	
#50	
#40	76.8
#30	
#20	
#16	
#10	93.4
#8	
#4	95.3
3/8 in	96.6
1/2 in	97.1
3/4 in	98
1 in	98.6
1 1/2 in	99.2
2 in	99.7
2 1/2 in	
3 in	
3 1/2 in	99.9

Calibration Coefficients

AC Cracking

AC Top Down Cracking

$$L(t) = L_{Max} e^{-\left(\frac{C_1 \rho}{t - C_3 t_o}\right)^{C_2 \beta}}$$

$$t_0(\text{Days}) = \frac{k_{L1}}{1 + e^{(k_{L2} \times 100 \times a_0/2A_0) + (k_{L3} \times HT) + (k_{L4} \times LT) + (k_{L5} \times \log_{10} AADTT)}}$$

c1: 2.5219	c2: 0.8069	c3: 1		
kL1: 64271618	kL2: 0.2855	kL3: 0.011	kL4: 0.01488	kL5: 3.266

Top Down Cracking Standard Deviation

0.3657 * TOP + 3.6563

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' \log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1.31	c2: 2.1585	c3: 6000

Bottom Up Cracking Standard Deviation

1.13 + 13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 3.75
k2: 2.87
k3: 1.46
Bf1: 0.02054
Bf2: 1.38
Bf3: 0.88

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$$

$$C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$$

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)

ε_r = resilient strain(in/in)

T = layer temperature(°F)

N = number of load repetitions

AC Rutting Standard Deviation		0.24 * Pow(RUT,0.8026) + 0.001
AC Layer 1	K1: -2.45 K2: 3.01 K3: 0.22	Br1: 0.4 Br2: 0.52 Br3: 1.36

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4 * \log_{10}(Damage)}}$$

C1: 0	C2: 75	C3: 2	C4: 2

CSM Cracking Standard Deviation

CTB*1

CSM Fatigue			
k1: 0.972	k2: 0.0825	Bc1: 1	Bc2: 1

$$N_f = 10^{\left(\frac{k_1 \beta_{c1}\left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

N_f = number of repetitions to fatigue cracking
σ_s = Tensile stress(psi)
M_r = modulus of rupture(psi)

IRI Flexible Pavements			
C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

Thermal Fracture

$$C_f = \beta_{t1} N \left[\frac{1}{\sigma_d} log\left(\frac{C}{h_{AC}}\right)\right]$$

$$\Delta C = A(\Delta K)^n$$

$$A = k_t \beta_t 10^{[4.389 - 2.52\log(E_{HMA}\sigma_m n)]}$$

Cf = Observed amount of thermal cracking, ft. / 500ft.
β_{t1} = Regression coefficient determined through global calibration (400)
N[z] = Standard normal distribution evaluated at [z]
σ_d = Standard deviation of the logarithm of crack depth in the pavement (0.769), in.
C = Crack depth, in.
h_{AC} = Thickness of asphalt layer, in.
ΔC = Change in the crack depth due to a cooling cycle
ΔK = Change in the stress intensity factor due to a cooling cycle
A, n = Fracture parameters for the asphalt mixture
E = Asphalt mixture stiffness, MPa
σ_m = Undamaged mixture tensile strength, MPa
k_t = Regression coefficient determined through field calibration
β_t = Calibration parameter

Level 1 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 2 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	
Level 3 K: ((3 * Pow(10,-7)) * Pow(MAAT,4.0319)) * 1 + 0	

Unbound Layer Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right)\left|e^{-\left(\frac{\rho}{N}\right)^{\beta}}\right|$$

δ_a = permanent deformation for the layer
N = number of repetitions
ε_v = average vertical strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Base Rutting		Subgrade Rutting	
k1: 0.965	Bs1: 1	k1: 0.635	Bs1: 1
Standard Deviation: 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation: 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

9.4 Interstate highway final design outputs-JPCP

Madhav Joshi and Kamal Gautam Interstate-JPCP

Tenant: Kamal Gautam   Workspace: System Workspace

Design Inputs

Design Life:	30 years	Existing Construction:	-	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	JPCP	Pavement construction:	July 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	9
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

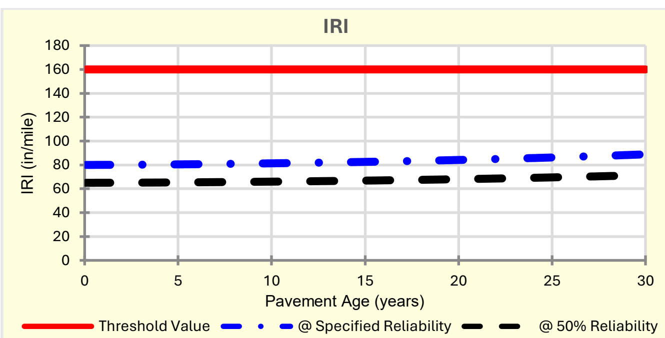
Age (year)	Heavy Trucks (cumulative)
2025 (initial)	1,800
2040 (15 years)	5,116,300
2055 (30 years)	12,002,200

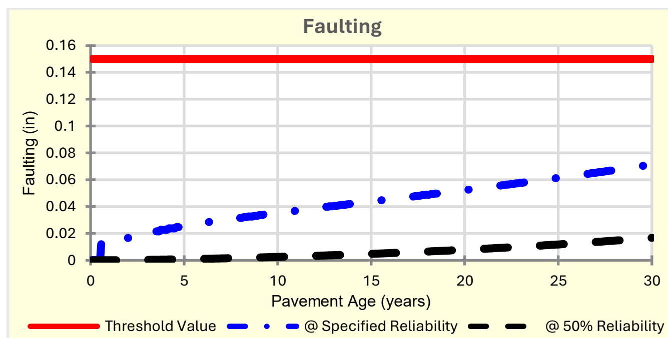
Design Outputs

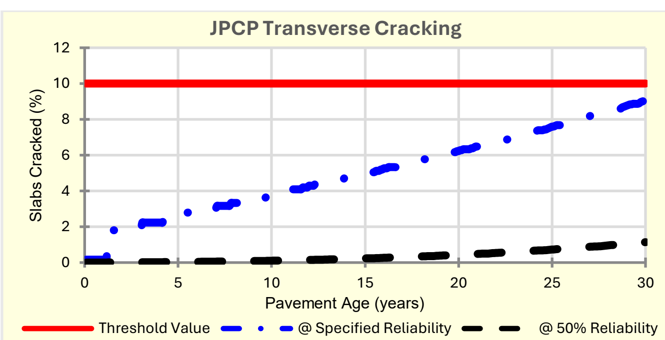
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	160.00	88.83	95.00	100.00	Pass
Mean joint faulting (in)	0.15	0.07	95.00	100.00	Pass
JPCP transverse cracking (% slabs)	10.00	9.07	95.00	96.70	Pass

Distress Charts



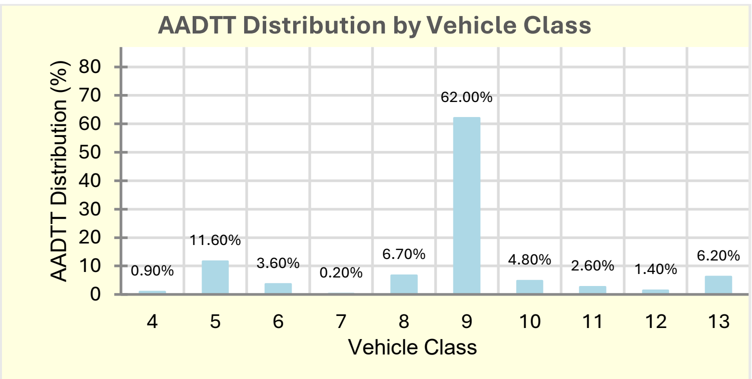


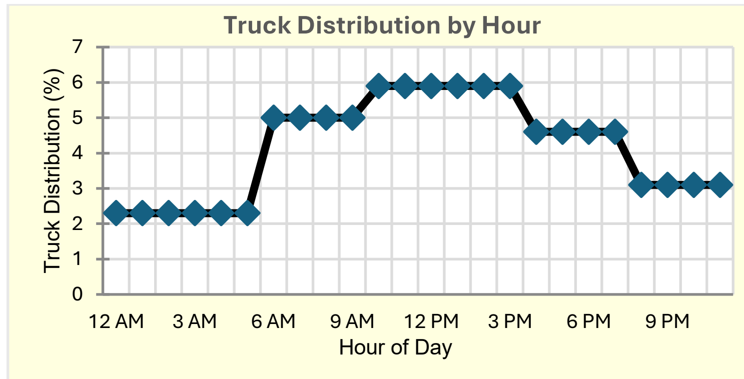


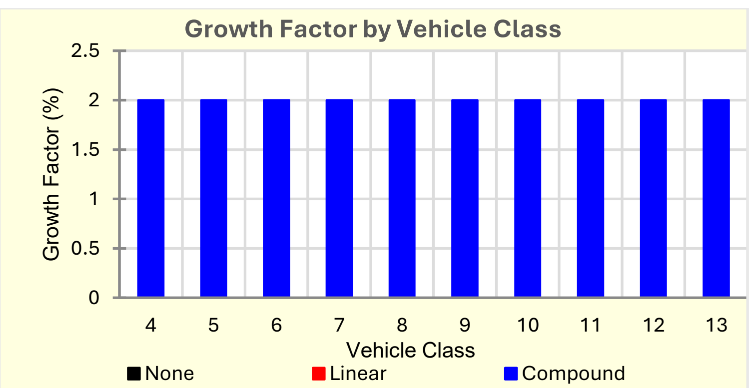
Traffic Inputs

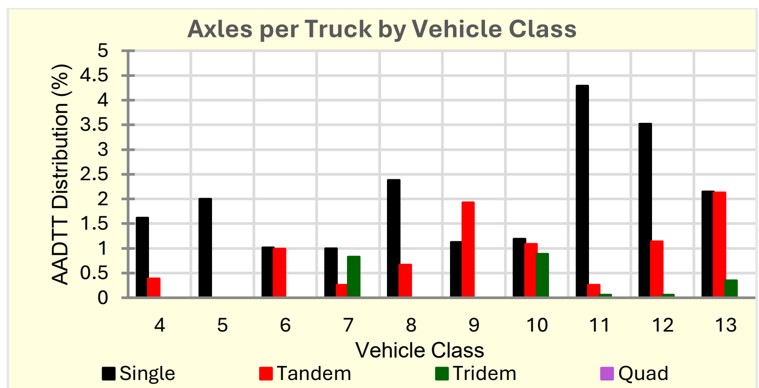
Graphical Representation of Traffic Inputs

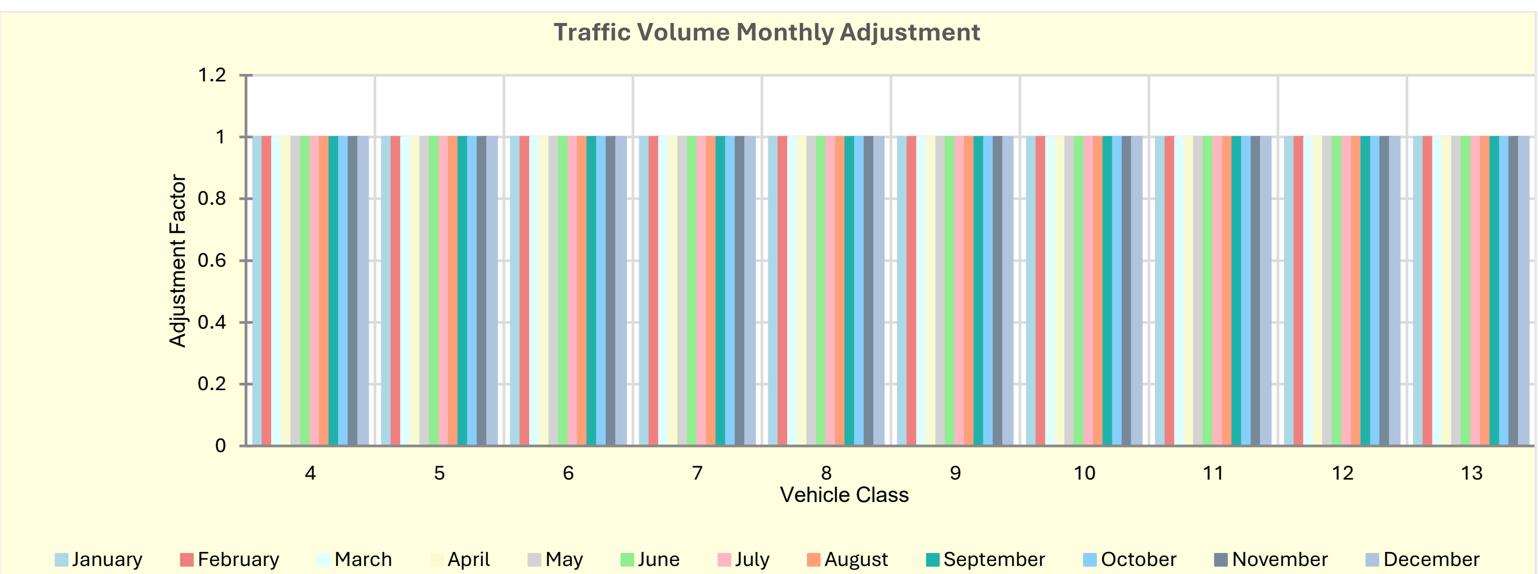
Initial two-way AADTT	1800
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	90
Operation speed (mph)	75
Axle Distribution	NCHRP 1-37A











Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors (Level 3: Default MAF)

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.9%	2%	Compound
Class 5	11.6%	2%	Compound
Class 6	3.6%	2%	Compound
Class 7	0.2%	2%	Compound
Class 8	6.7%	2%	Compound
Class 9	62.0%	2%	Compound
Class 10	4.8%	2%	Compound
Class 11	2.6%	2%	Compound
Class 12	1.4%	2%	Compound
Class 13	6.2%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	2.3%	12 PM	5.9%
1 AM	2.3%	1 PM	5.9%
2 AM	2.3%	2 PM	5.9%
3 AM	2.3%	3 PM	5.9%
4 AM	2.3%	4 PM	4.6%
5 AM	2.3%	5 PM	4.6%
6 AM	5%	6 PM	4.6%
7 AM	5%	7 PM	4.6%
8 AM	5%	8 PM	3.1%
9 AM	5%	9 PM	3.1%
10 AM	5.9%	10 PM	3.1%
11 AM	5.9%	11 PM	3.1%
		Total	100.0%

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

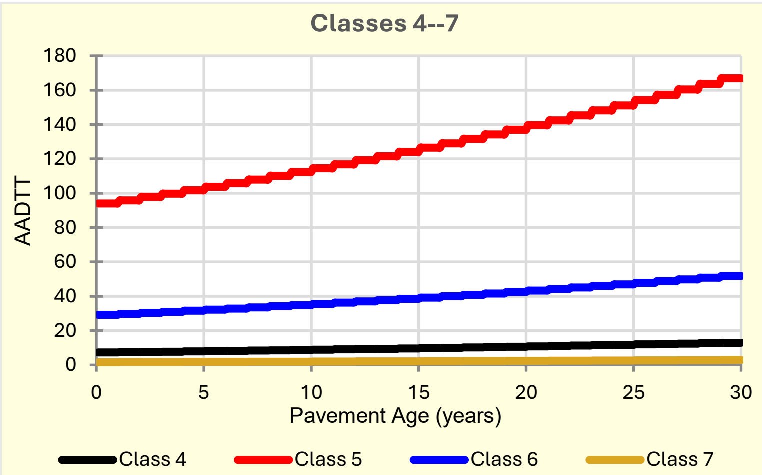
Wheelbase			
Value Type	Axle Type		
	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

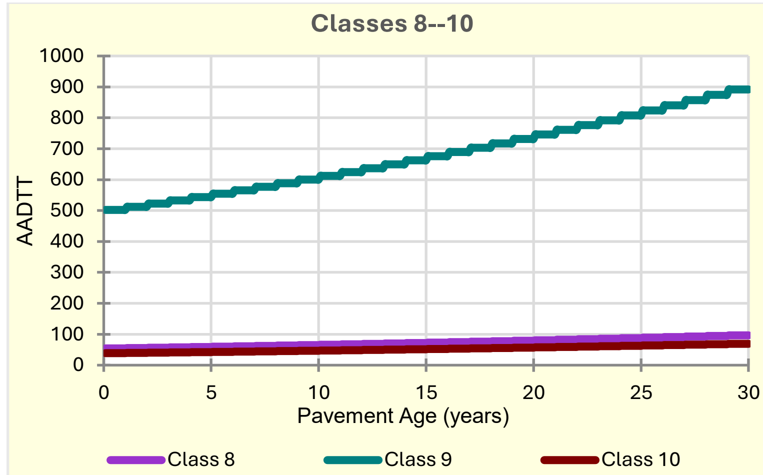
Number of Axles per Truck

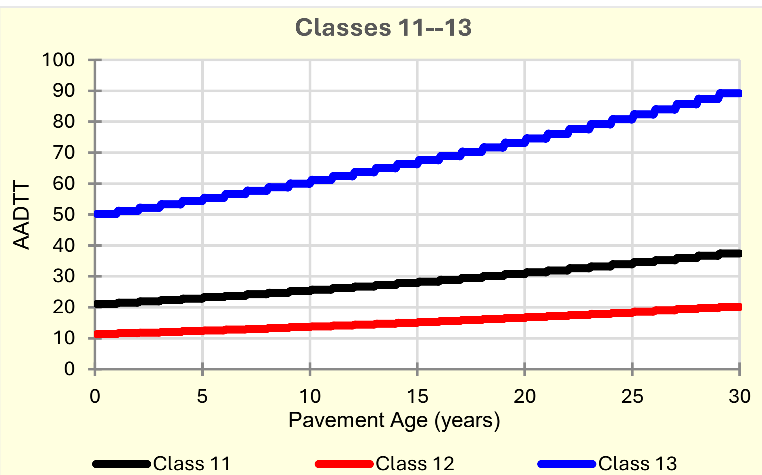
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

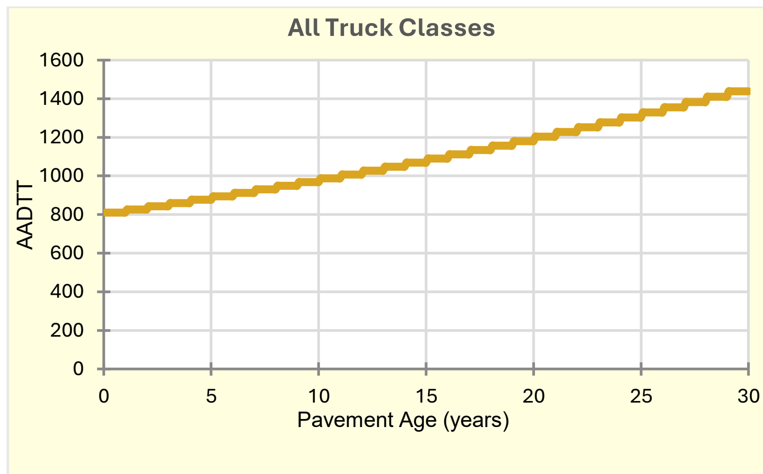
AADTT (Average Annual Daily Truck Traffic) Growth

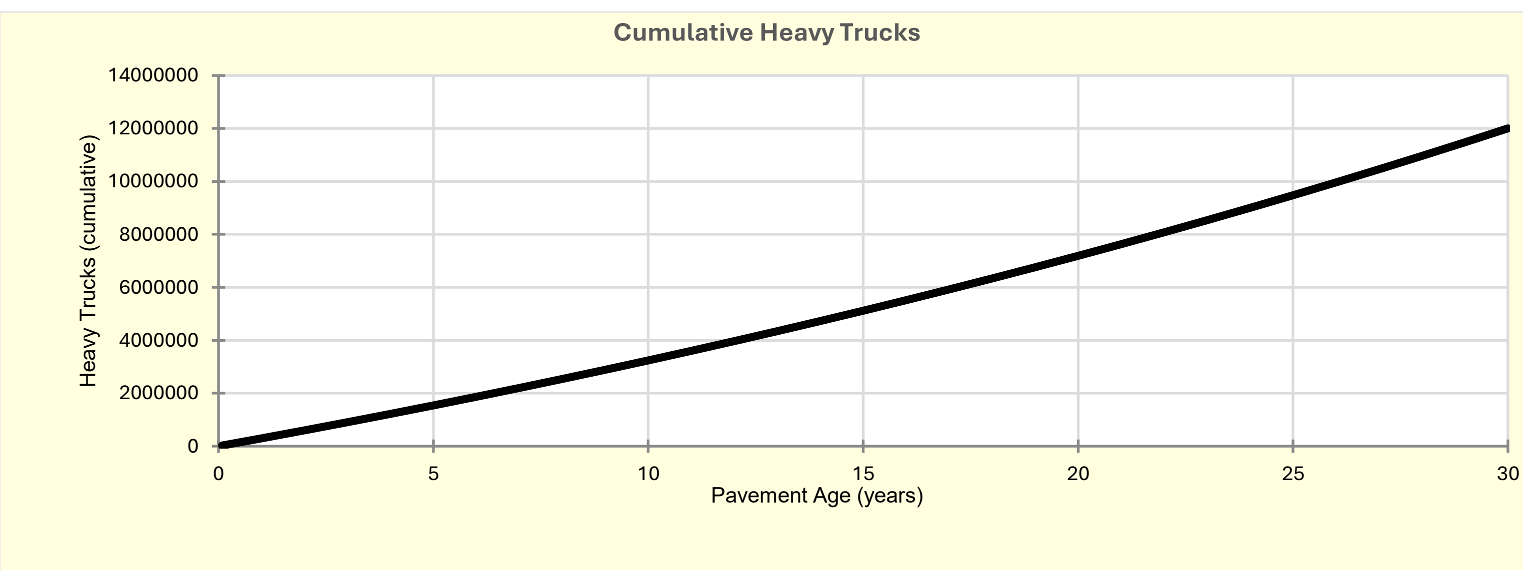
* Traffic cap is not enforced

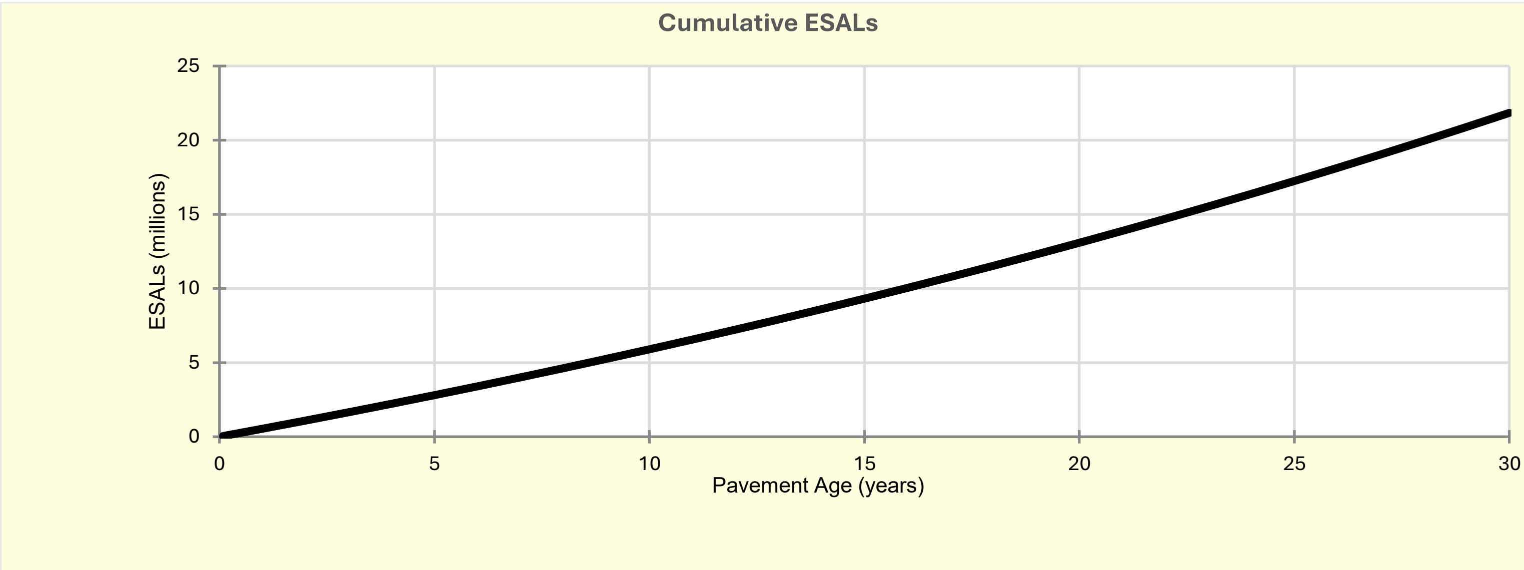








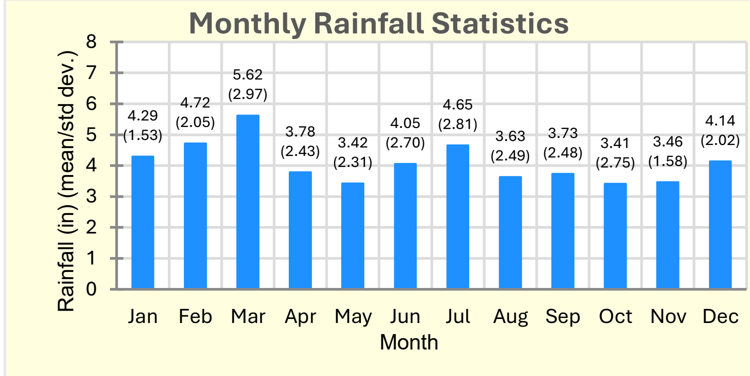



Cumulative ESALs
ESALs (millions)
0
5
10
15
20
25
0
5
10
15
20
25
30
Pavement Age (years)

Climate Inputs

Climate Data Sources:

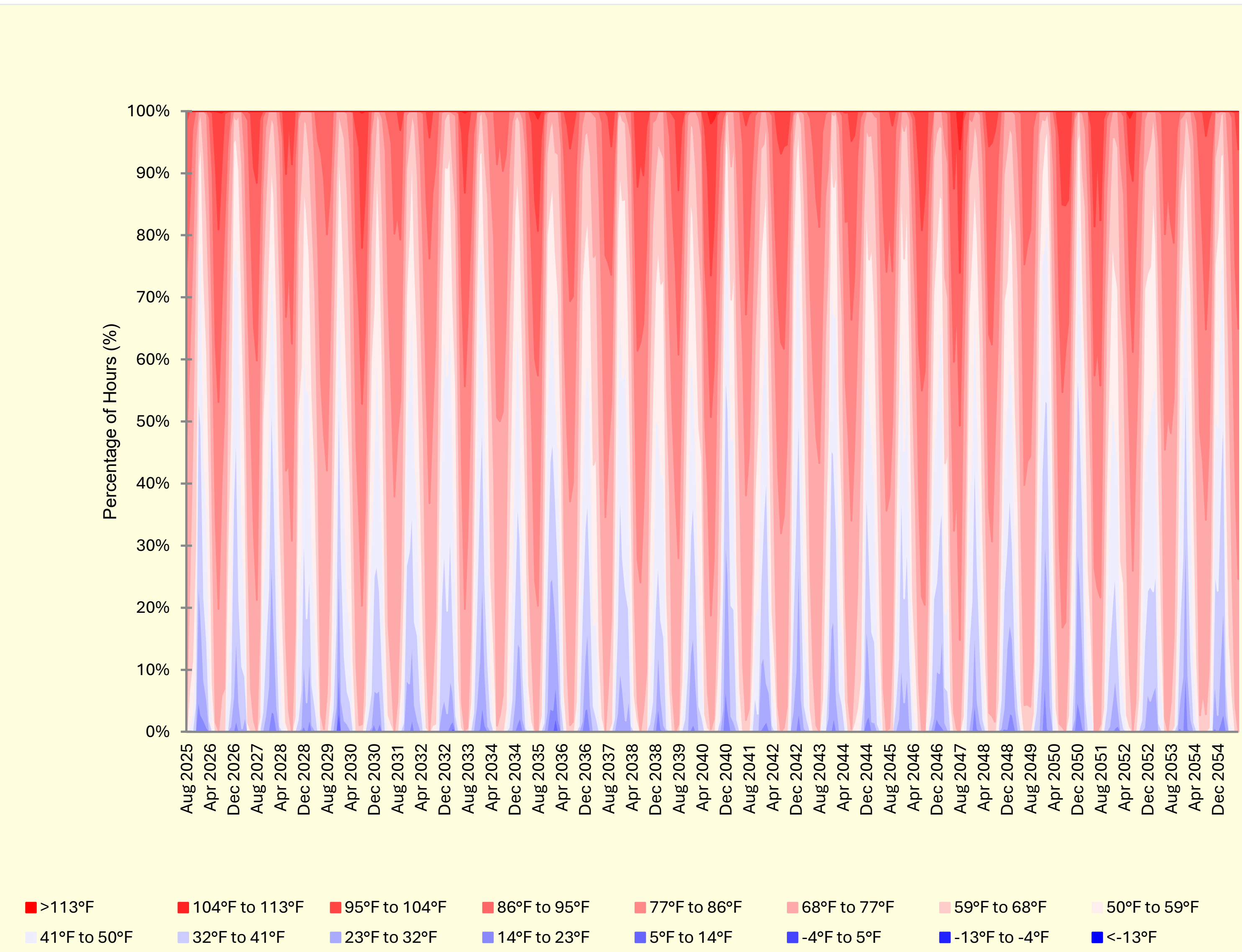
Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131



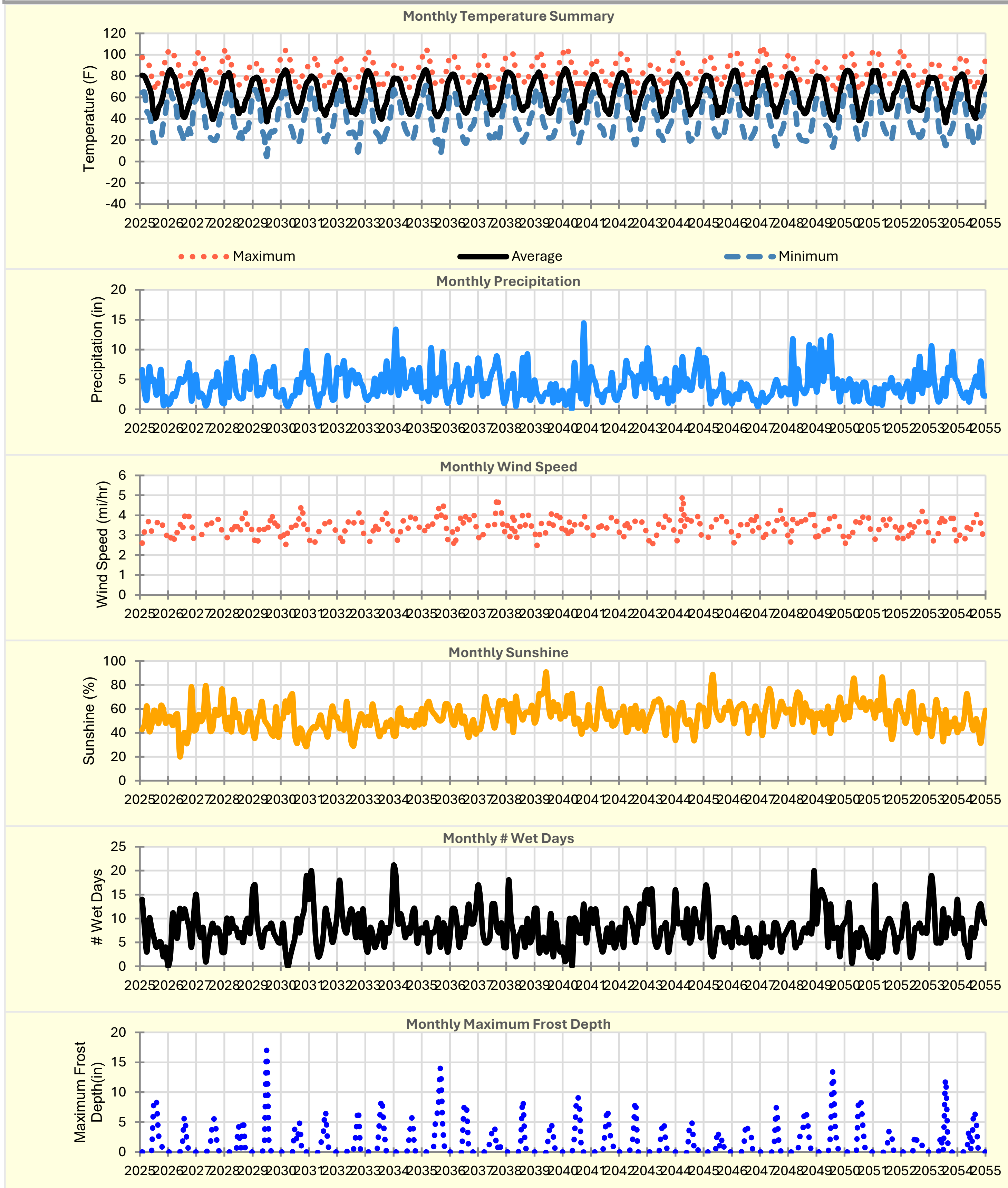
Annual Statistics:

Mean annual air temperature (F):	63.95
Mean annual precipitation (in):	48.90
Freezing index (F - days):	16.24
Average annual number of freeze/thaw cycles:	33.78
Water table depth (ft)	10.00

Hourly Air Temperature Distribution by Month:



Monthly Climate Summary:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC Surface shortwave absorptivity	0.85

PCC joint spacing (ft)	
Is joint spacing random?	False
Joint spacing (ft)	15.00

Doweled Joints	
Is joint doweled?	True
Dowel diameter (in)	1.25
Dowel spacing (in)	12.00

Widened Slab	
Is slab widened?	False
Slab width (ft)	12.00

Sealant type	Preformed

PCC-Base Interface Friction	
Nondimensional Friction Factor	0.1
Friction Degradation Factor	300
Characteristic Length (in)	2.5

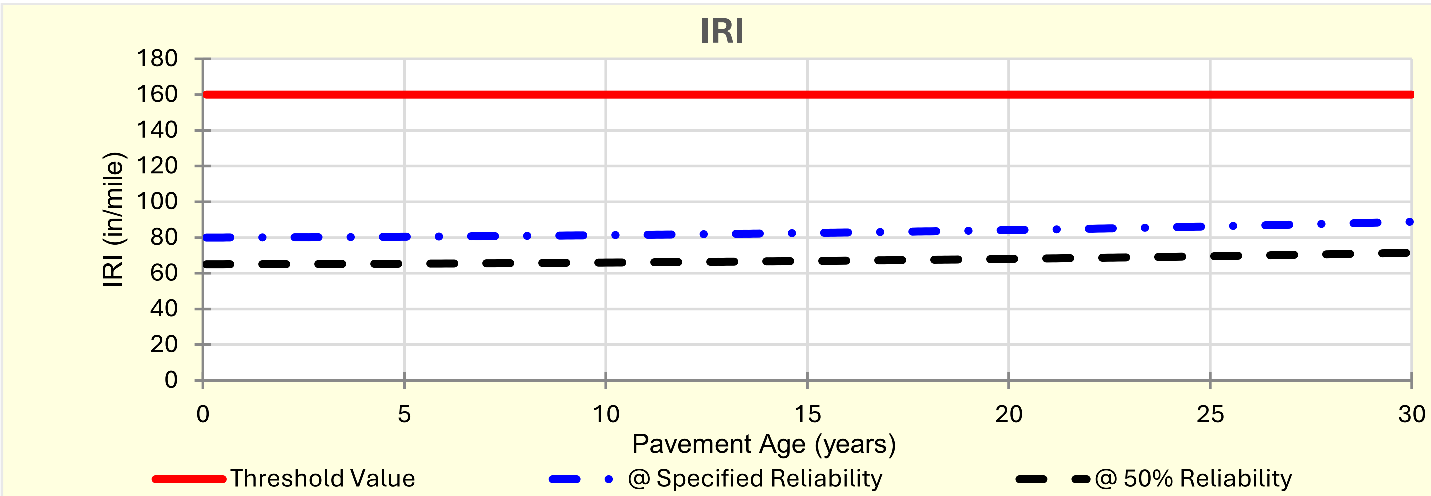
Tied Shoulders	
Tied shoulders	False
Load transfer efficiency (%)	-

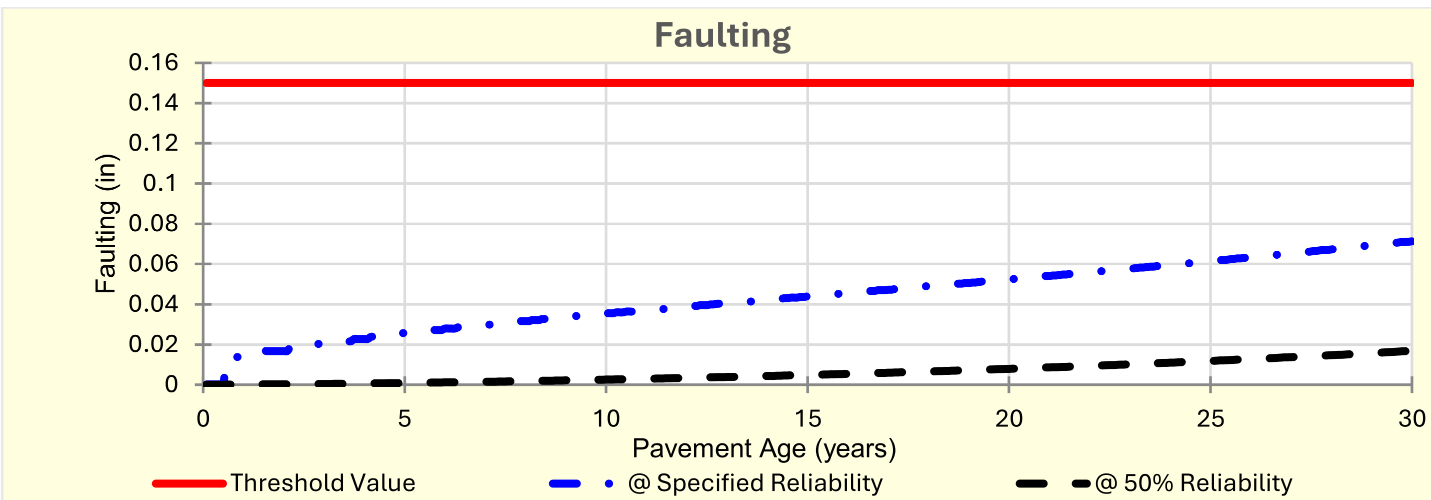
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	240.00

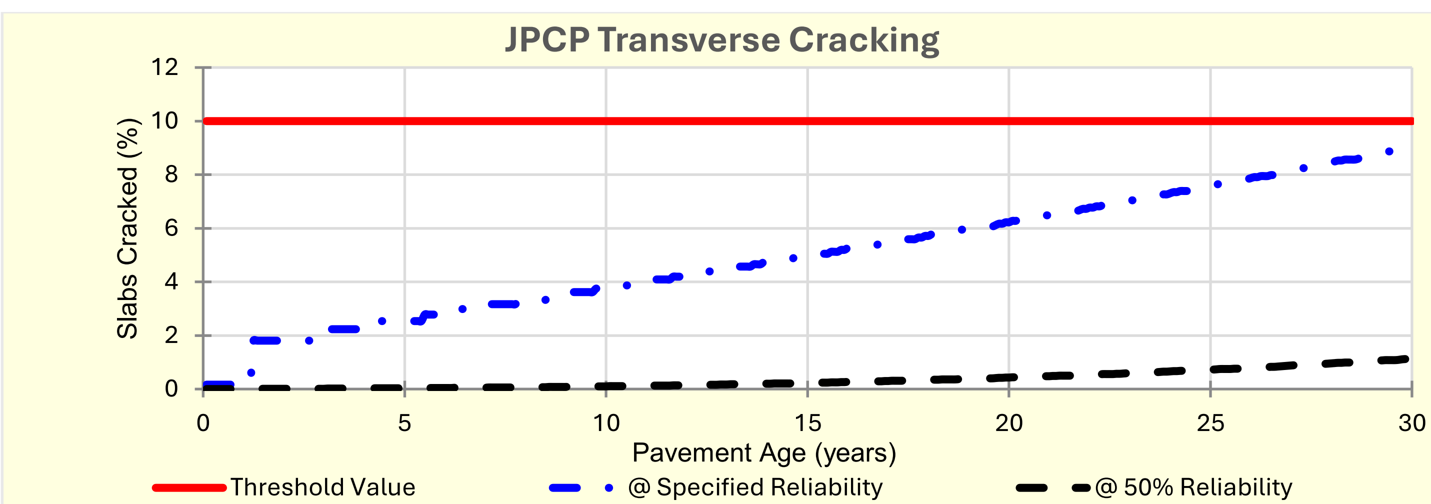
Erodibility index	5

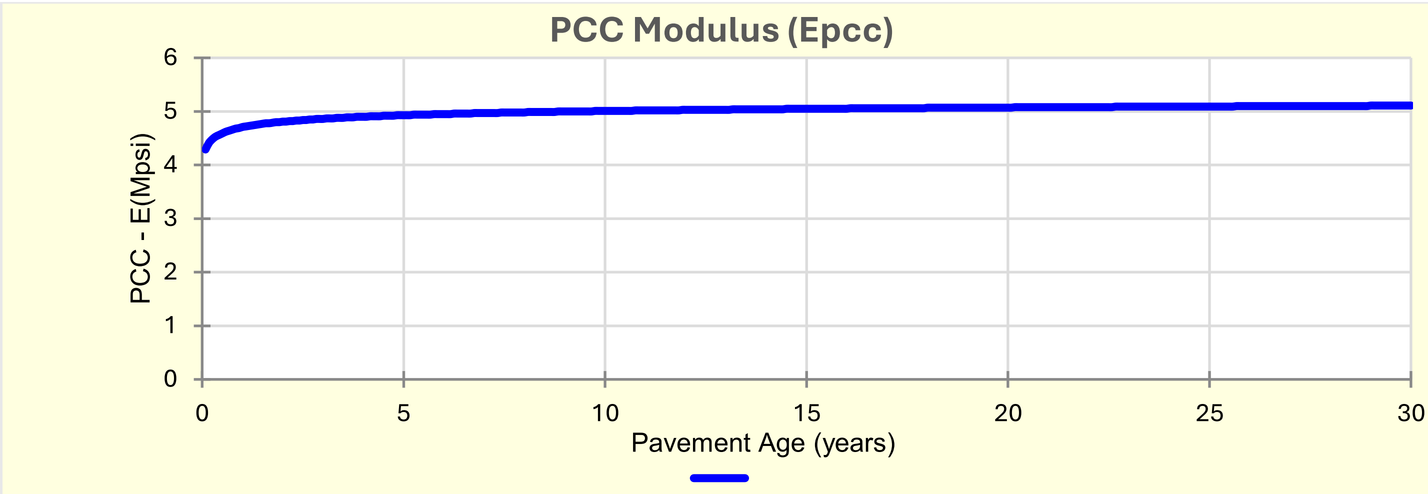
Permanent curl/warp effective temperature difference (°F)	- 10.00

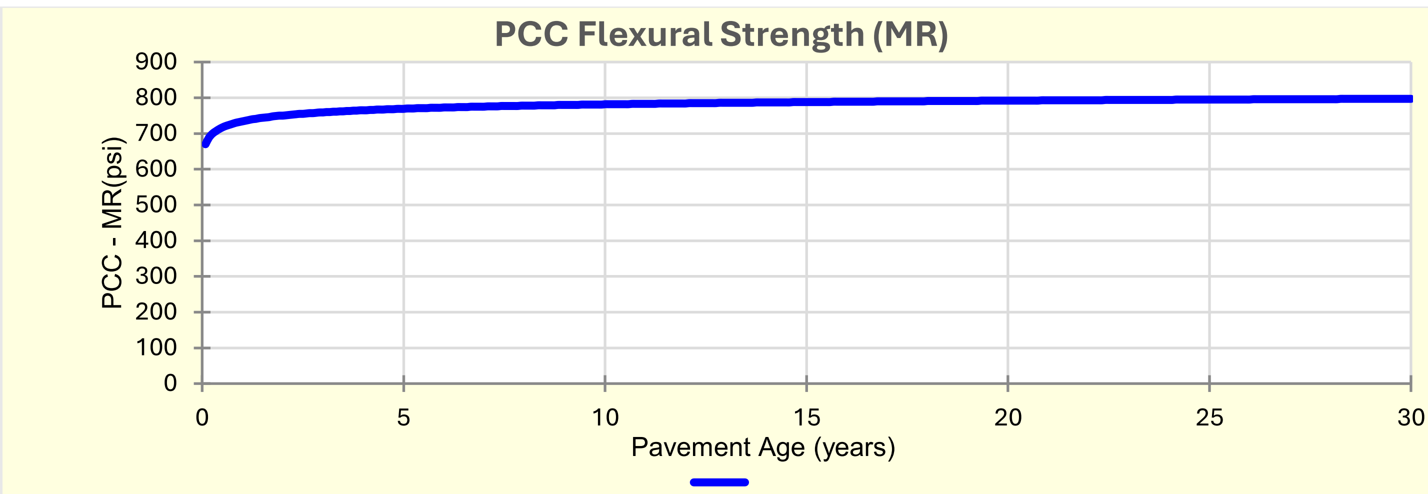
Analysis Output Charts

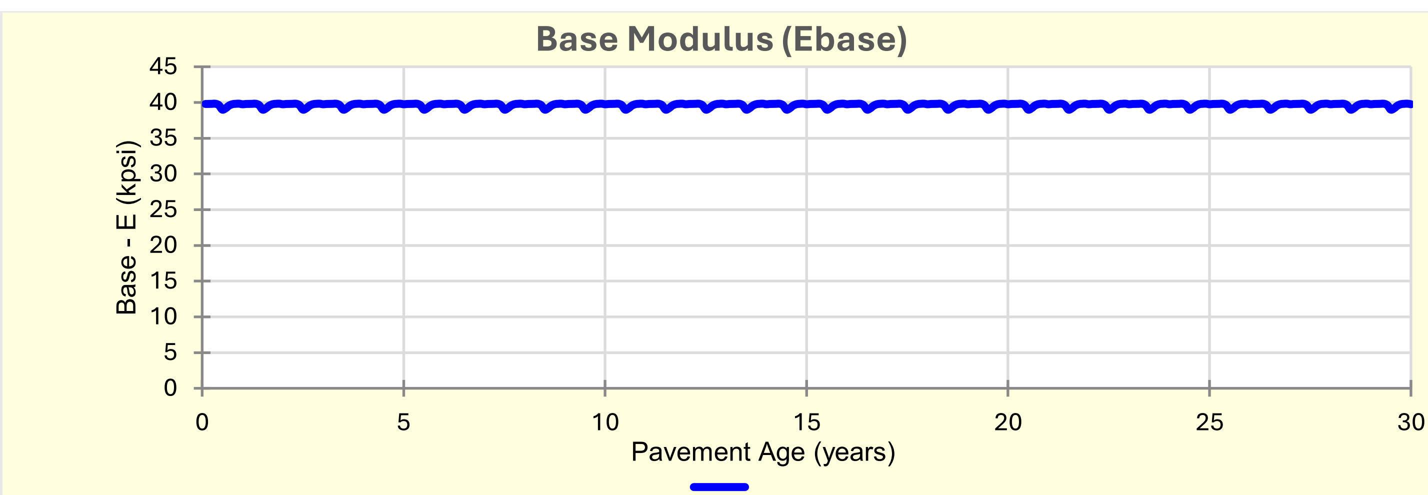


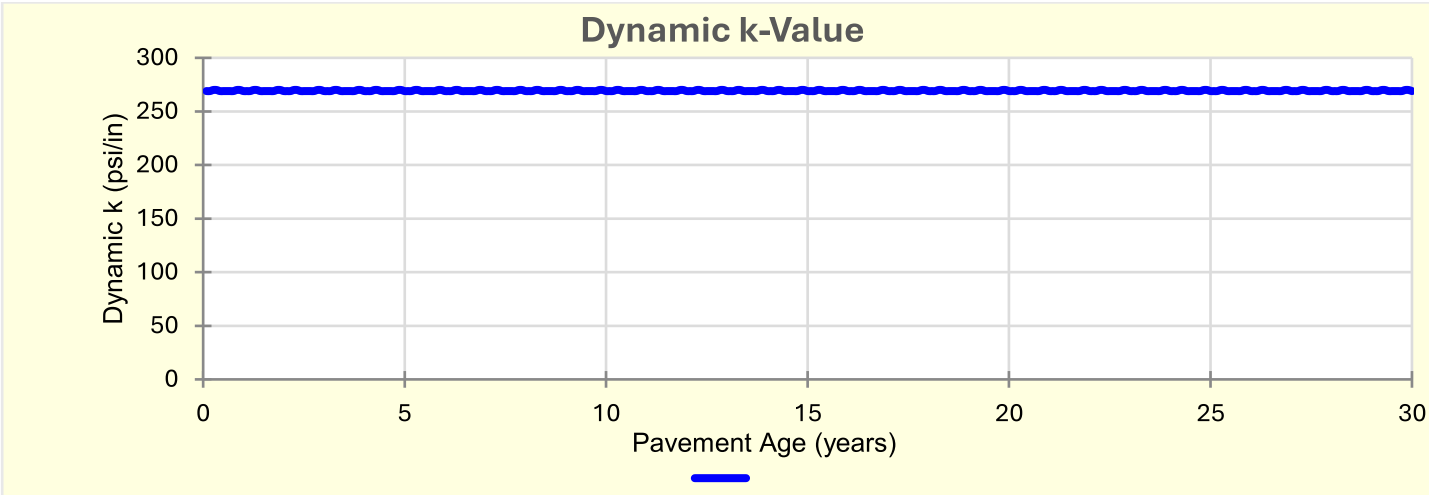


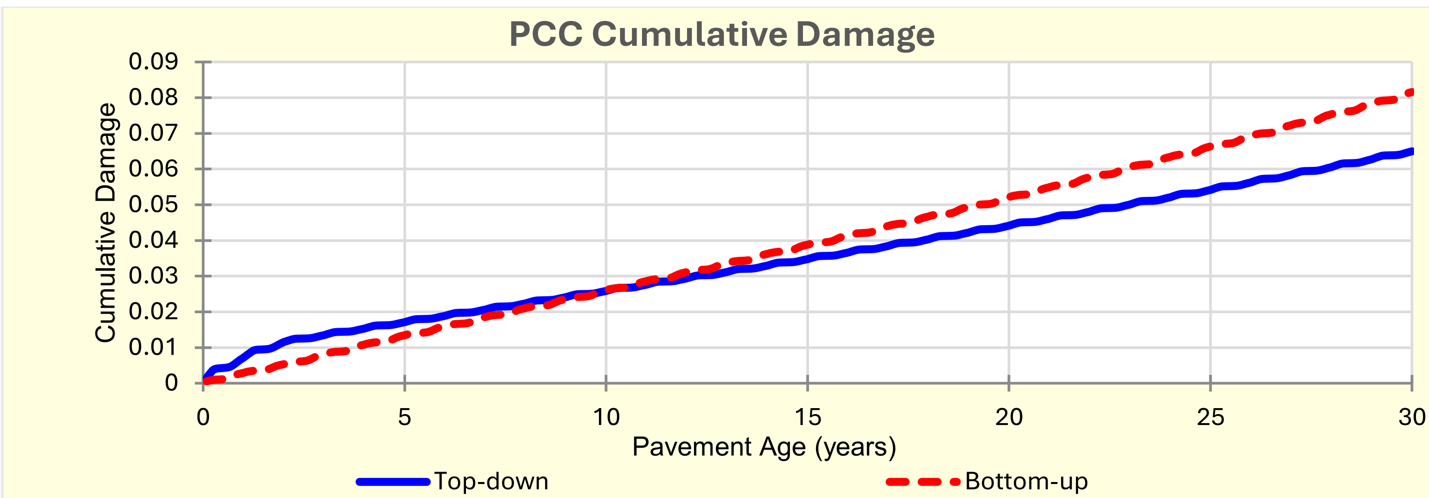


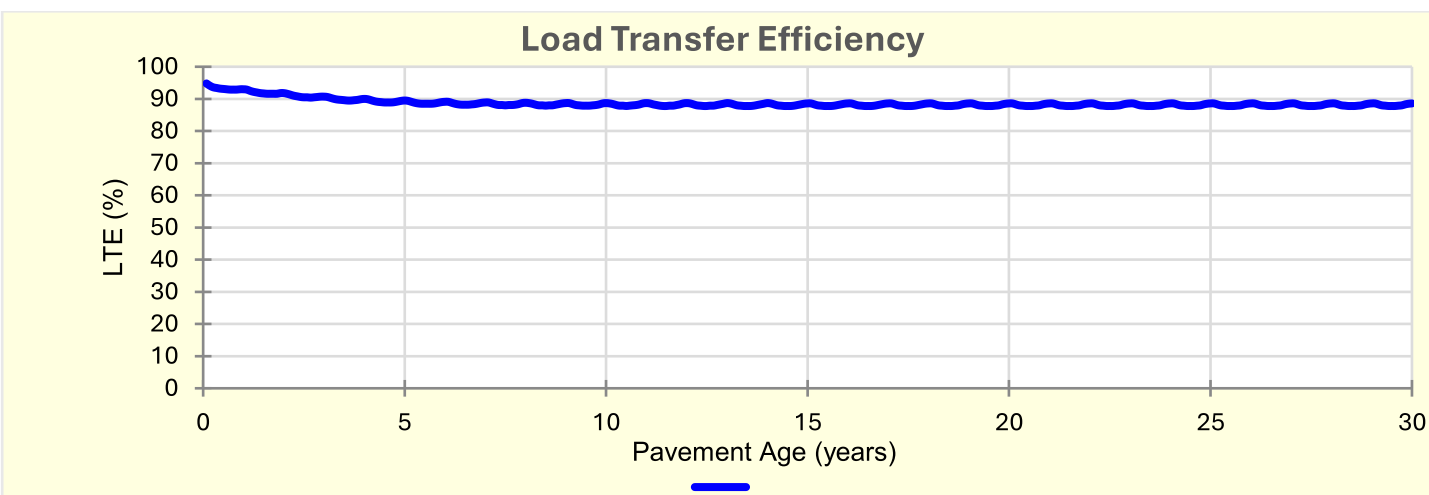

PCC Modulus (Epcc)
PCC - E(Mpsi)
Pavement Age (years)
0
1
2
3
4
5
6
0
5
10
15
20
25
30


PCC Flexural Strength (MR)
PCC - MR(psi)
Pavement Age (years)
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30


Base Modulus (Ebase)
Base - E (kpsi)
Pavement Age (years)
0
5
10
15
20
25
30
35
40
45
0
5
10
15
20
25
30


Dynamic k-Value
Dynamic k (psi/in)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
Pavement Age (years)


PCC Cumulative Damage
Cumulative Damage
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
Pavement Age (years)
Top-down
Bottom-up


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
Pavement Age (years)

Layer Information

Layer 1 PCC (Proposed Overlay) : Default JPCP 1

PCC	
Thickness (in)	9
Unit weight (pcf)	150
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/deg F X 10^-6)	4.9
PCC thermal conductivity (BTU/hr-ft-°F)	1.25
PCC heat capacity (BTU/lb-°F)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		600
Water to cement ratio		0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (°F)	Calculated Internally?	True
	User Value	-
	Calculated Value	117.415
Ultimate Shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	632.3
Reversible Shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing Compound		

Identifiers

Field	Value
Display name/identifier	Default JPCP 1
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

PCC strength and modulus (Input Level: 3)

28-Day PCC modulus of rupture (psi)	690
28-Day PCC elastic modulus (psi)	4200000

Layer 2 Non-stabilized base : Crushed stone (A-1-a)

Unbound	
Layer thickness (in)	6
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	30000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	Crushed stone (A-1-a)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.1
Saturated hydraulic conductivity (ft/hr)	False	0.05328
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.255496829960335
bf	1.2911570438718638
cf	0.8263617065521088
hr	117.4

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8 in	57.2
1/2 in	63.1
3/4 in	72.7
1 in	78.8
1 1/2 in	85.8
2 in	91.6
2 1/2 in	
3 in	
3 1/2 in	97.6

Layer 3 Subgrade : A-3 (A-3)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	16500.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	A-3 (A-3)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	True	120.0
Saturated hydraulic conductivity (ft/hr)	False	0.00365
Specific gravity of solids	False	2.7
Water Content (%)	False	8.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.849631876739616
bf	2.857643419754946
cf	0.9167554911487317
hr	100

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	5.2
#100	
#80	33
#60	
#50	
#40	76.8
#30	
#20	
#16	
#10	93.4
#8	
#4	95.3
3/8 in	96.6
1/2 in	97.1
3/4 in	98
1 in	98.6
1 1/2 in	99.2
2 in	99.7
2 1/2 in	
3 in	
3 1/2 in	99.9

Calibration Coefficients

IRI-jpcp		
C1 - Cracking C2 - Spalling C3 - Faulting C4 - Site Factor	C1: 0.446	C2: 0.373
	C3: 0.993	C4: 46.422
	Reliability Standard Deviation	
	15.345 * Ln(IRI) - 54.951	
	Initial IRI Standard Deviation	
	5.4	

JPCP Transverse Cracking

$$\text{Crk}_{Bottom-up/Top-down} = \frac{100}{1 + C_4 \left(FD_{bottom-up/top-down}\right)^{C_5}}$$

$$\text{Crk}_{Total} = Crk_{Bottom-up} + Crk_{Top-down} - \left(Crk_{Bottom-up} \times Crk_{Top-down}\right)$$

$$FD_{bottom-up/top-down} = \sum \frac{n_{i,j,k,l,m,n,o}}{N_{i,j,k,l,m,n,o}}$$

$$\log\left(N_{i,j,k,l,m,n}\right) = C_1 \left(\frac{MR_i}{\sigma_{i,j,k,l,m,n}}\right)^{C_2} + 0.431 - \log\left(1 - C_c \frac{\sigma^0_{i,j,m} + \sigma_{NL}}{\sigma_{Total}}\right)$$

Fatigue Coefficients		**Cracking Coefficients**	
C1: 2	C2: 1.22	C4: 0.431	C5: -2.303
PCC Reliability Crack Standard Deviation			
4.5194 * Pow(CRACK,0.3293) + 0.1			
Friction Damage Degradation			1
Curling and Other Stresses (CC Factor)			1
Built-in Curling A			6
Built-in Curling B			20

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$

$$C_{34} = C_3 + (C_4 * FR^{0.25})$$

$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_S}\right)\right]^{C_6}$$

$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$

$$C_8 = DowelDeterioration$$

C1: 0.2	C2: 1.636	C3: 0.005	C4: 0.00444
C5: 250	C6: 0.2	C7: 20	C8: 400

PCC Reliability Fault Standard Deviation

0.1 * Pow(FAULT,0.2711) + 0.0001

9.5 State highway final design outputs-JPCP

Madhav Joshi and Kamal Gautam State-JPCP

Tenant: Kamal Gautam | Workspace: System Workspace

Design Inputs

Design Life:	30 years	Existing Construction:	-	Climate Data Sources (lat., long.):	32.5, -86.25
Design Type:	JPCP	Pavement construction:	July 2025		
		Traffic Opening:	August 2025		

Design Structure

Layer Type	Material Type	Thickness (in)
PCC	Default JPCP 1	7.5
NonStabilized	Crushed stone (A-1-a)	6
Subgrade	A-3 (A-3)	Semi-infinite

Joint Design	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

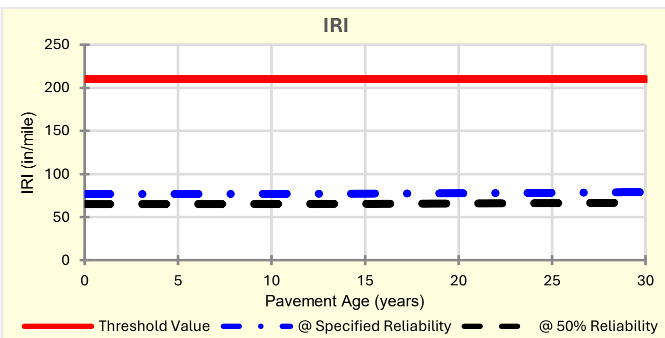
Age (year)	Heavy Trucks (cumulative)
2025 (initial)	270
2040 (15 years)	852,717
2055 (30 years)	2,000,360

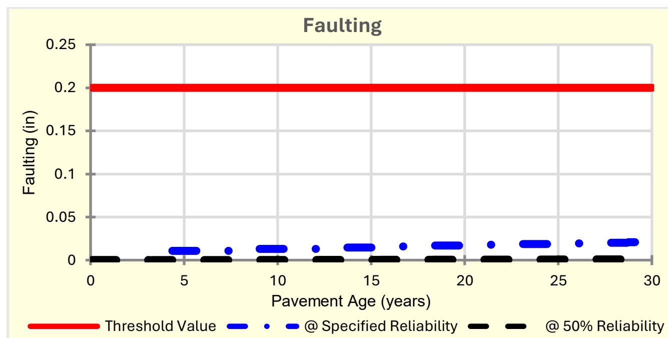
Design Outputs

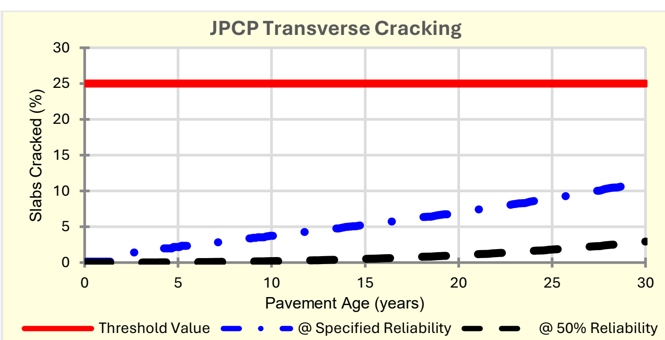
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	210.00	78.93	90.00	100.00	Pass
Mean joint faulting (in)	0.20	0.02	90.00	100.00	Pass
JPCP transverse cracking (% slabs)	25.00	11.33	90.00	99.96	Pass

Distress Charts



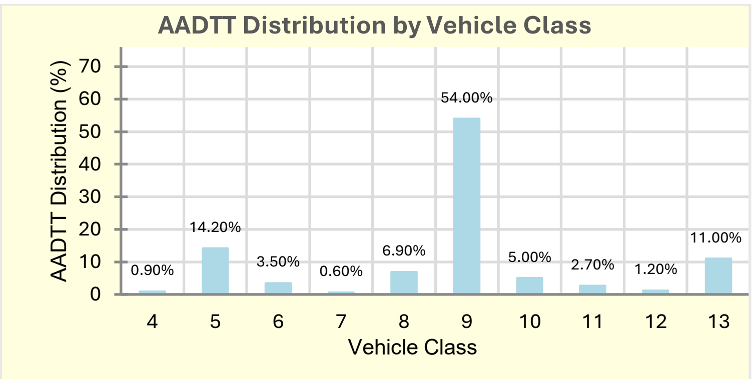


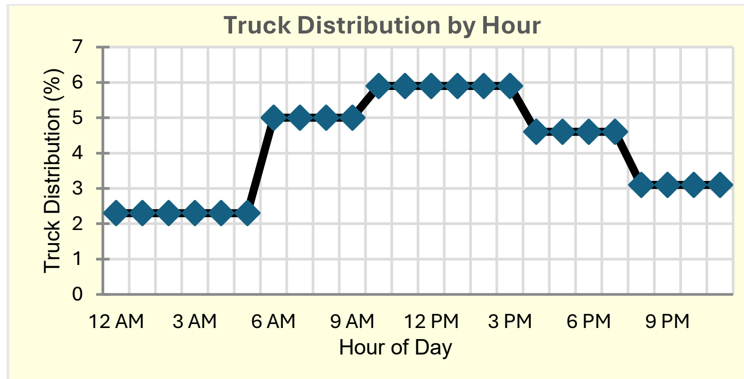


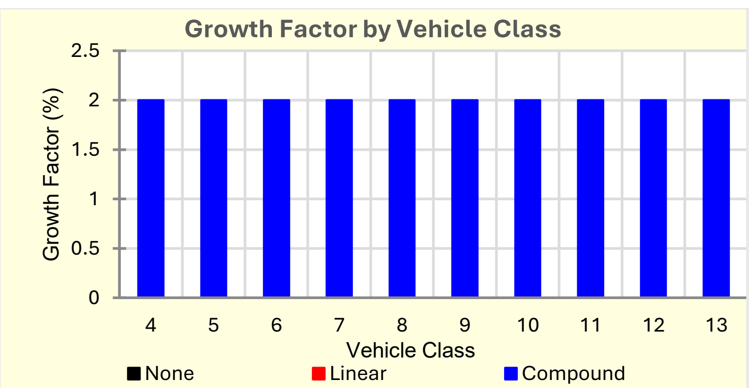
Traffic Inputs

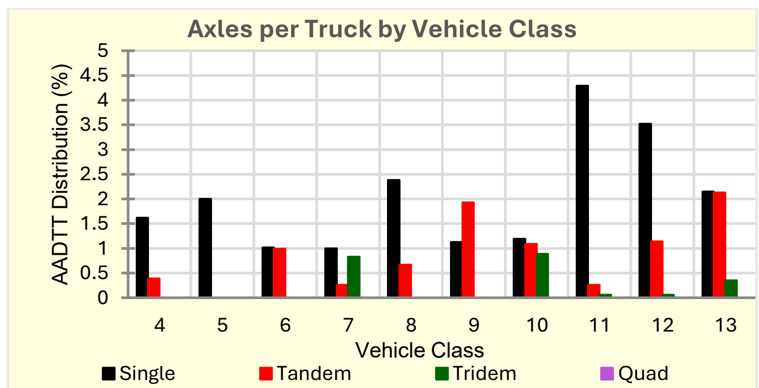
Graphical Representation of Traffic Inputs

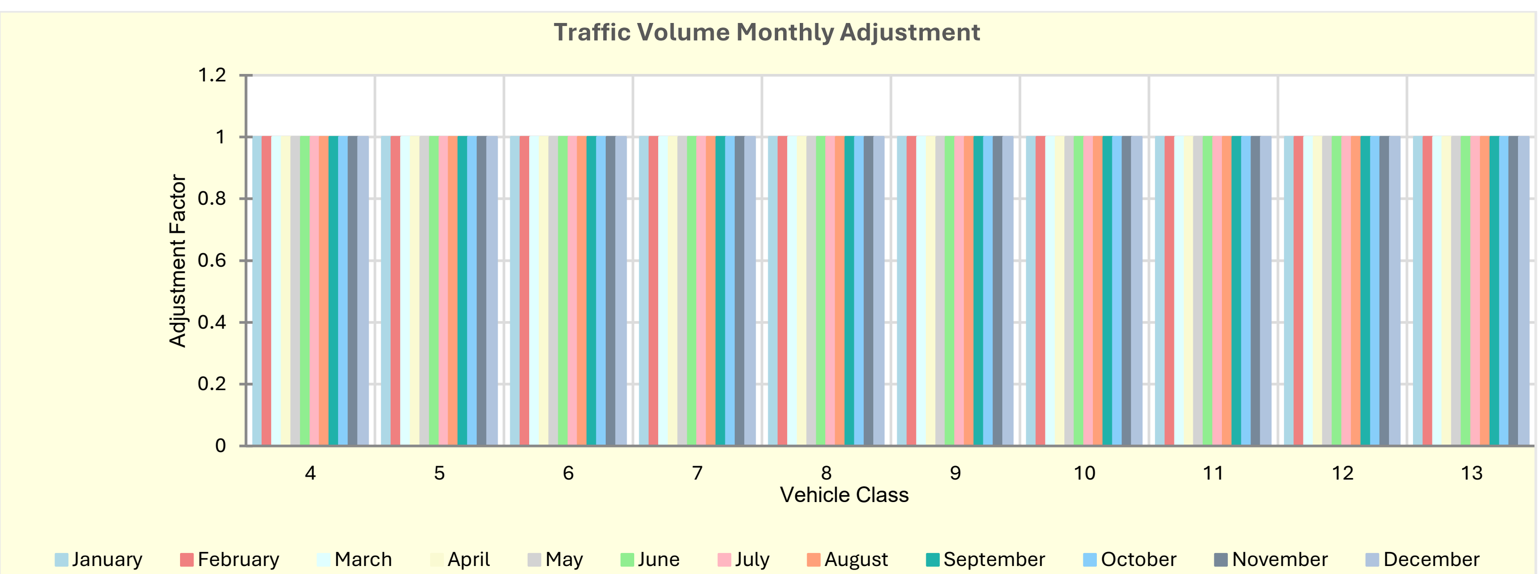
Initial two-way AADTT	270
Number of lanes in design direction	1
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	100
Operation speed (mph)	65
Axle Distribution	NCHRP 1-37A











Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors (Level 3: Default MAF)

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.9%	2%	Compound
Class 5	14.2%	2%	Compound
Class 6	3.5%	2%	Compound
Class 7	0.6%	2%	Compound
Class 8	6.9%	2%	Compound
Class 9	54.0%	2%	Compound
Class 10	5.0%	2%	Compound
Class 11	2.7%	2%	Compound
Class 12	1.2%	2%	Compound
Class 13	11.0%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	2.3%	12 PM	5.9%
1 AM	2.3%	1 PM	5.9%
2 AM	2.3%	2 PM	5.9%
3 AM	2.3%	3 PM	5.9%
4 AM	2.3%	4 PM	4.6%
5 AM	2.3%	5 PM	4.6%
6 AM	5%	6 PM	4.6%
7 AM	5%	7 PM	4.6%
8 AM	5%	8 PM	3.1%
9 AM	5%	9 PM	3.1%
10 AM	5.9%	10 PM	3.1%
11 AM	5.9%	11 PM	3.1%
		Total	100.0%

Axle Configuration

Traffic Wander	
Mean wheel location (in)	18.0
Traffic wander standard deviation (in)	10.0
Design lane width (ft)	12.0

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12.0
Tire pressure (psi)	120.0

Average Axle Spacing	
Tandem axle spacing (in)	51.6
Tridem axle spacing (in)	49.2
Quad axle spacing (in)	49.2

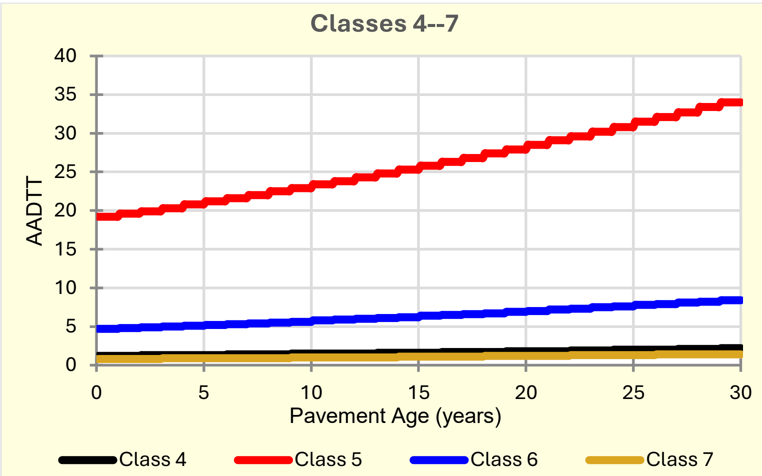
Wheelbase			
Value Type	Axle Type		
	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

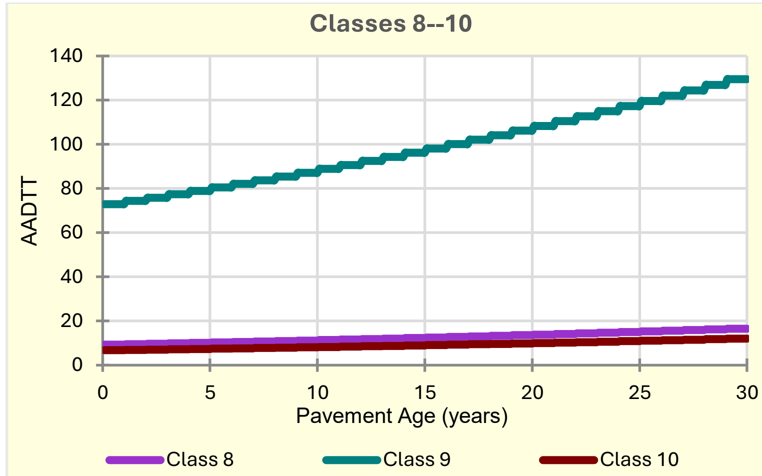
Number of Axles per Truck

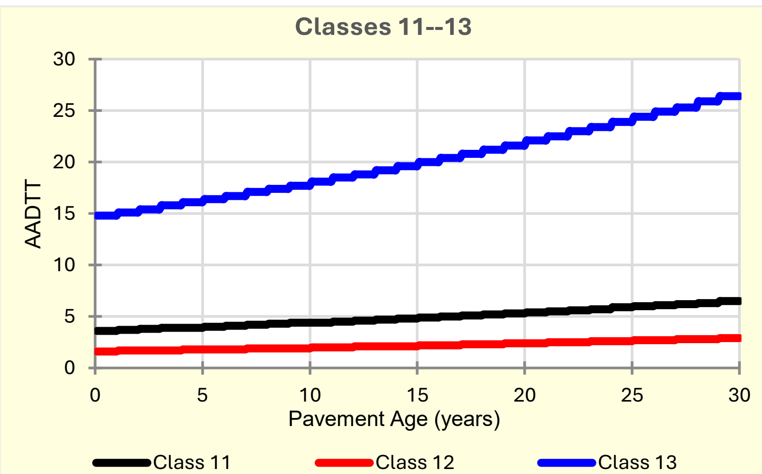
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

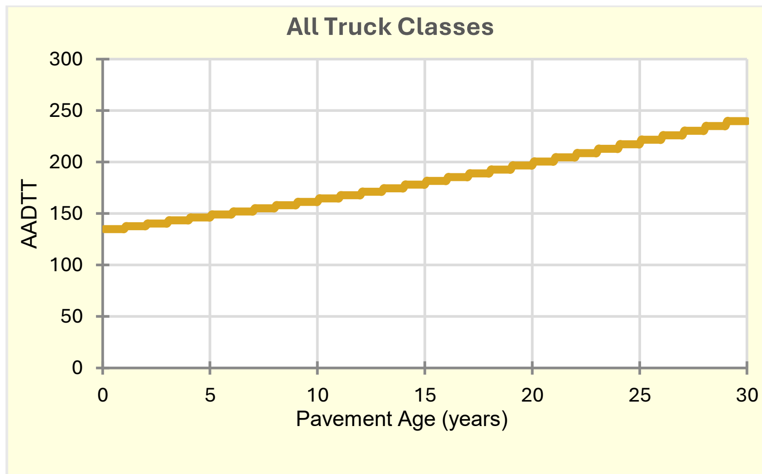
AADTT (Average Annual Daily Truck Traffic) Growth

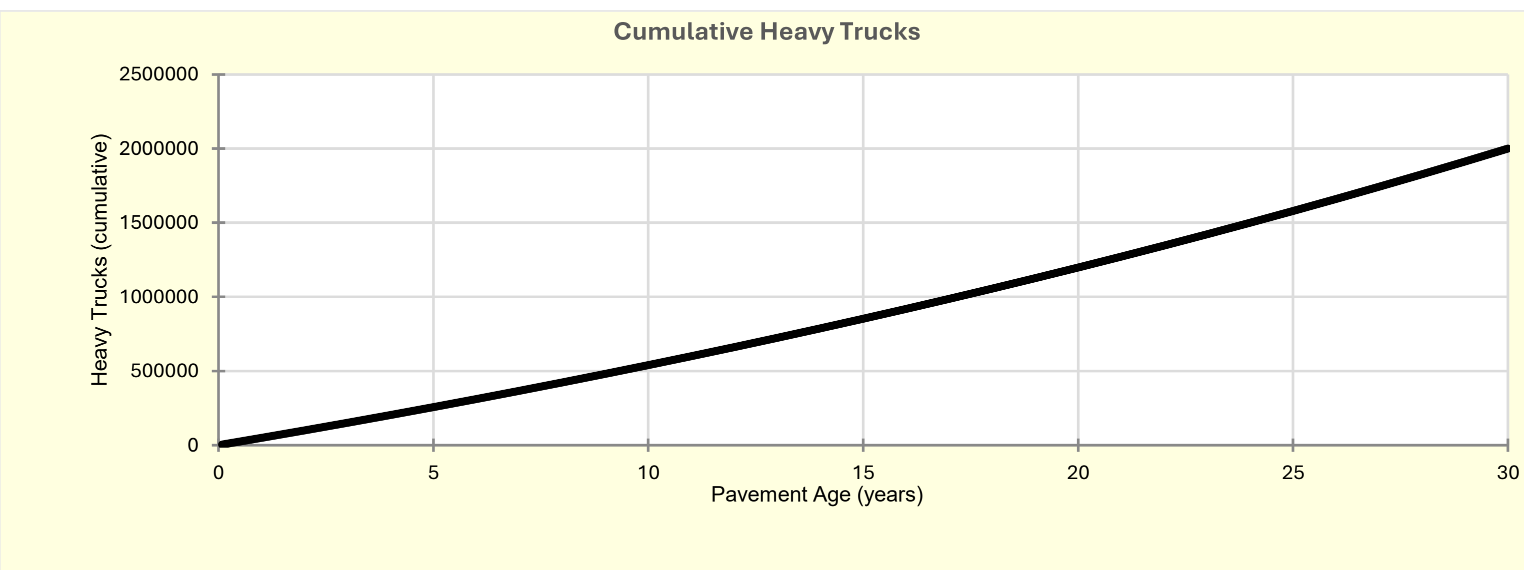
* Traffic cap is not enforced

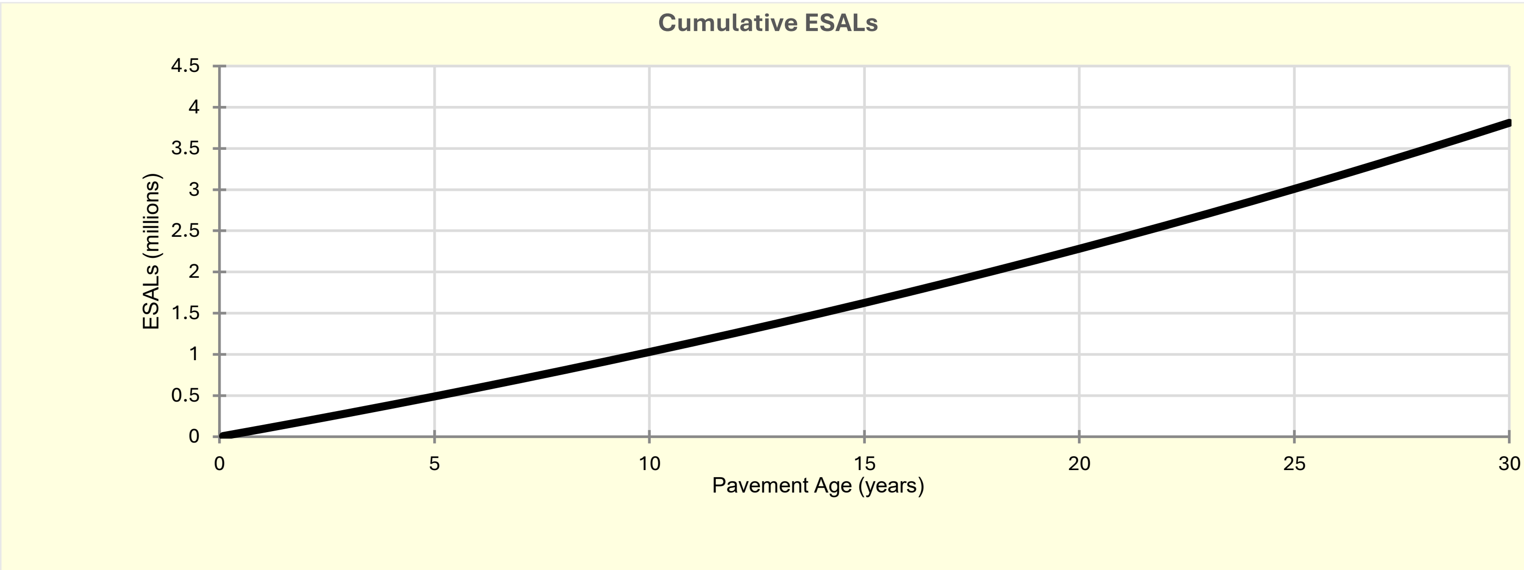








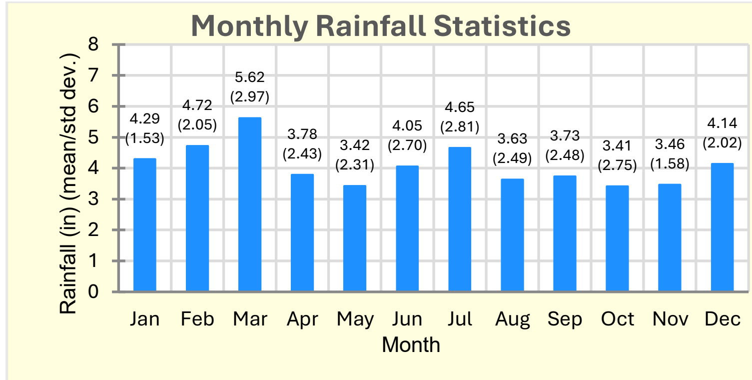



Cumulative ESALs
ESALs (millions)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
Pavement Age (years)

Climate Inputs

Climate Data Sources:

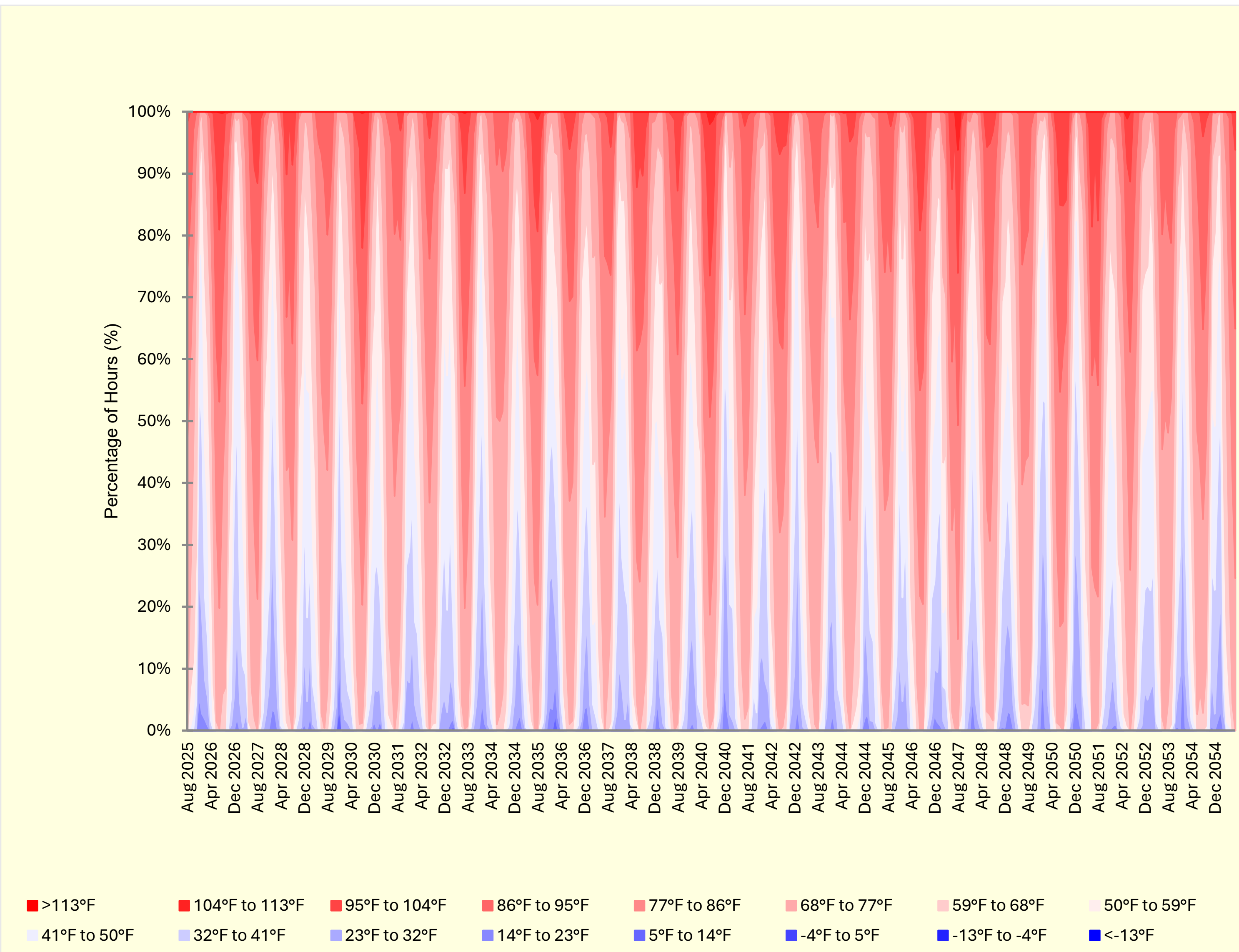
Climate Station Cities:	Location (lat, long, elevation(ft))
Wetumpka, AL	32.50000, -86.25000, 131



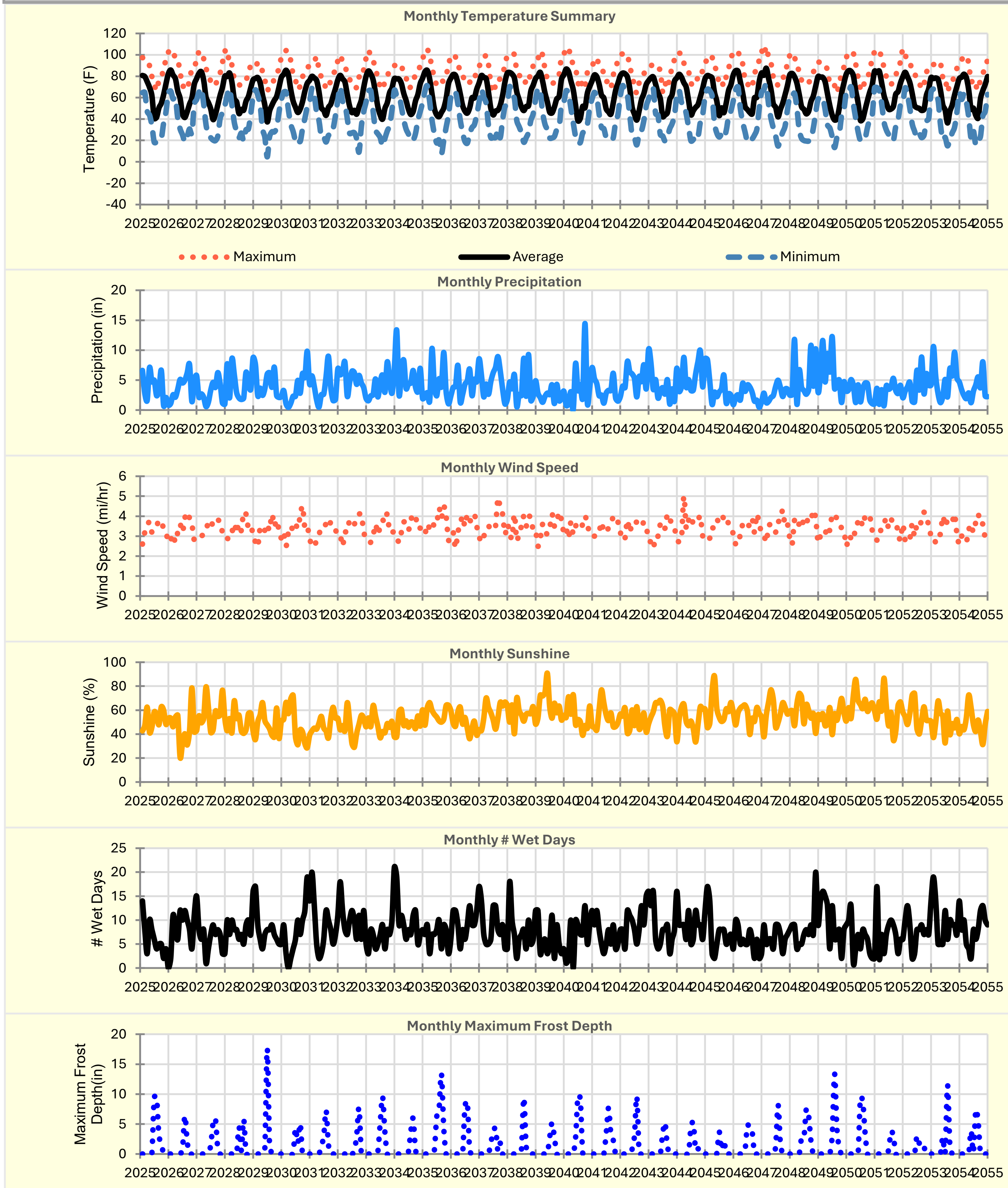
Annual Statistics:

Mean annual air temperature (F):	63.95
Mean annual precipitation (in):	48.90
Freezing index (F - days):	16.24
Average annual number of freeze/thaw cycles:	33.78
Water table depth (ft)	10.00

Hourly Air Temperature Distribution by Month:



Monthly Climate Summary:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC Surface shortwave absorptivity	0.85

PCC joint spacing (ft)	
Is joint spacing random?	False
Joint spacing (ft)	15.00

Doweled Joints	
Is joint doweled?	True
Dowel diameter (in)	1.25
Dowel spacing (in)	12.00

Widened Slab	
Is slab widened?	False
Slab width (ft)	12.00

Sealant type	Preformed

PCC-Base Interface Friction	
Nondimensional Friction Factor	0.1
Friction Degradation Factor	300
Characteristic Length (in)	2.5

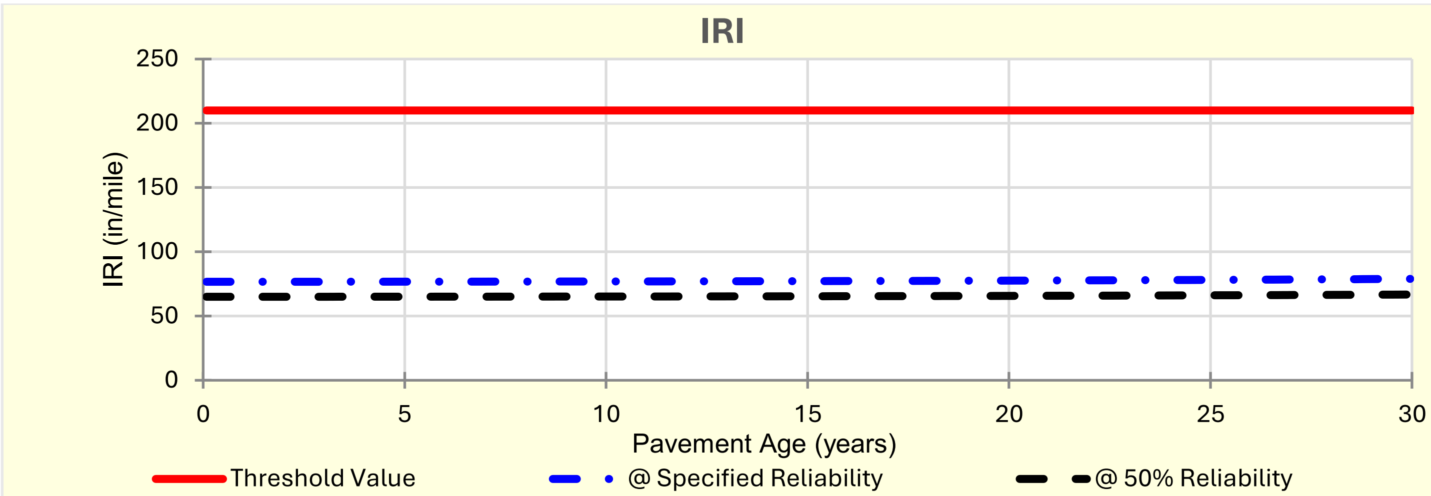
Tied Shoulders	
Tied shoulders	False
Load transfer efficiency (%)	-

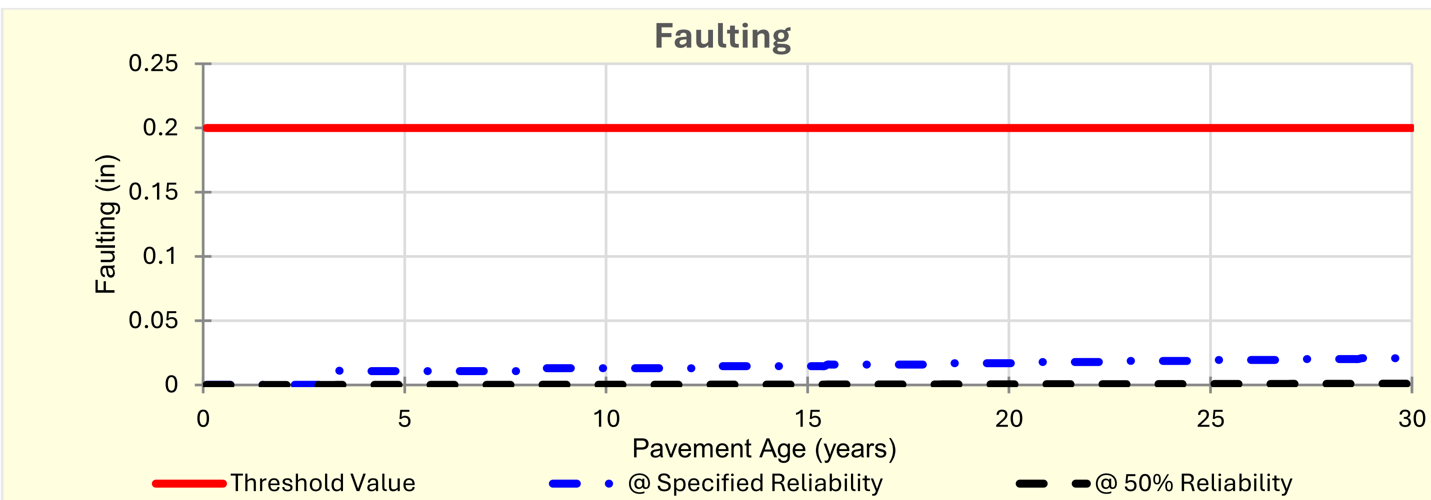
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	240.00

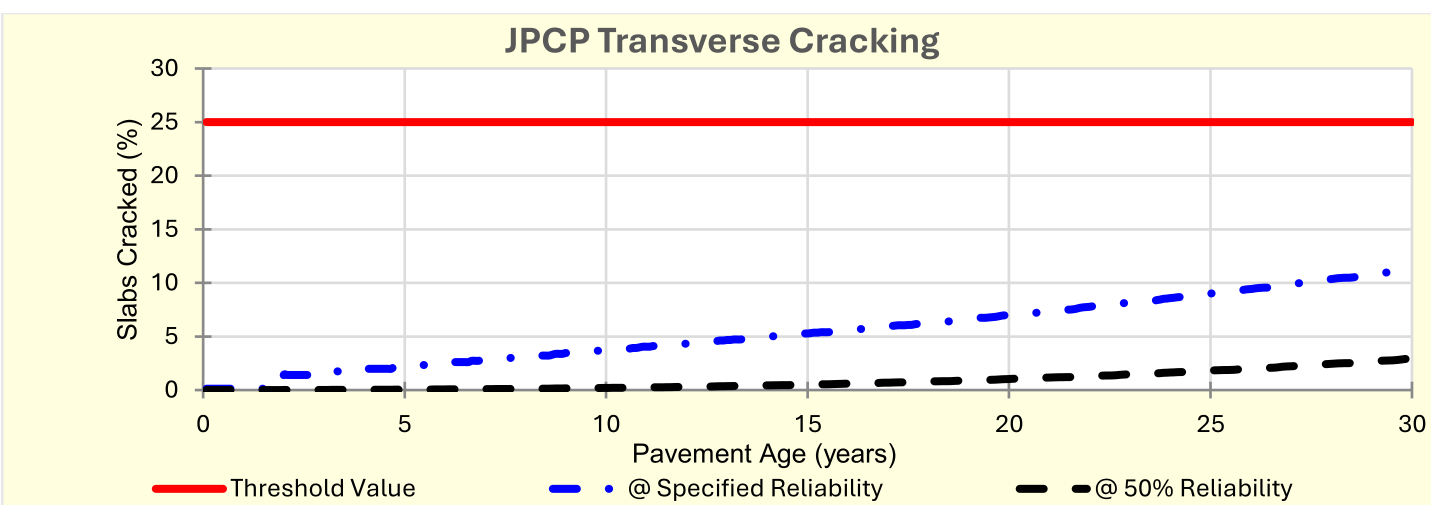
Erodibility index	5

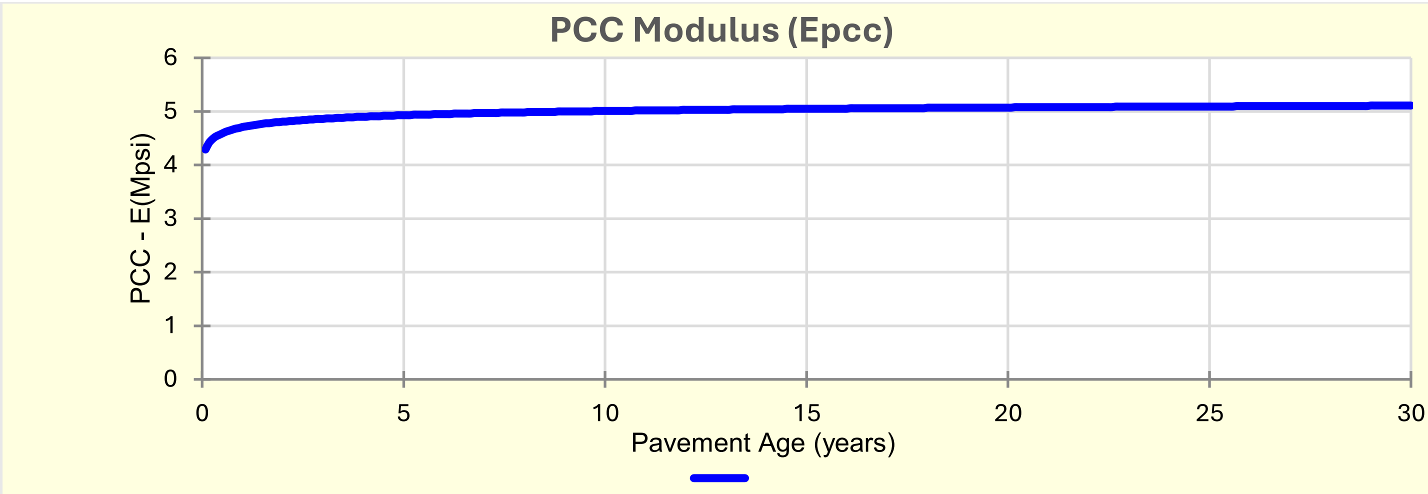
Permanent curl/warp effective	-
temperature difference (°F)	10.00

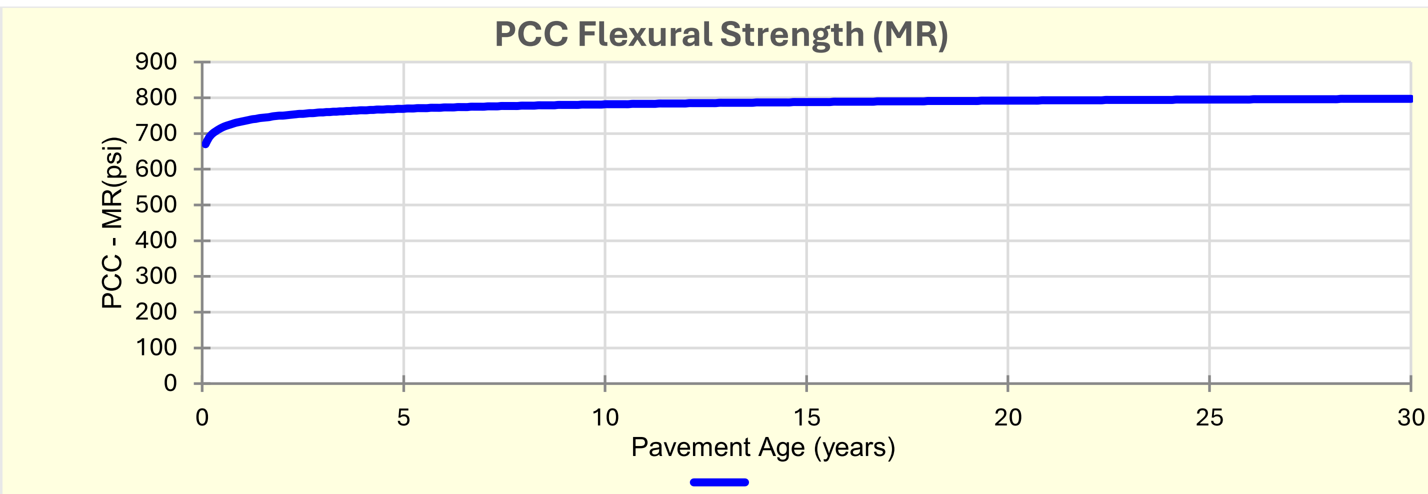
Analysis Output Charts

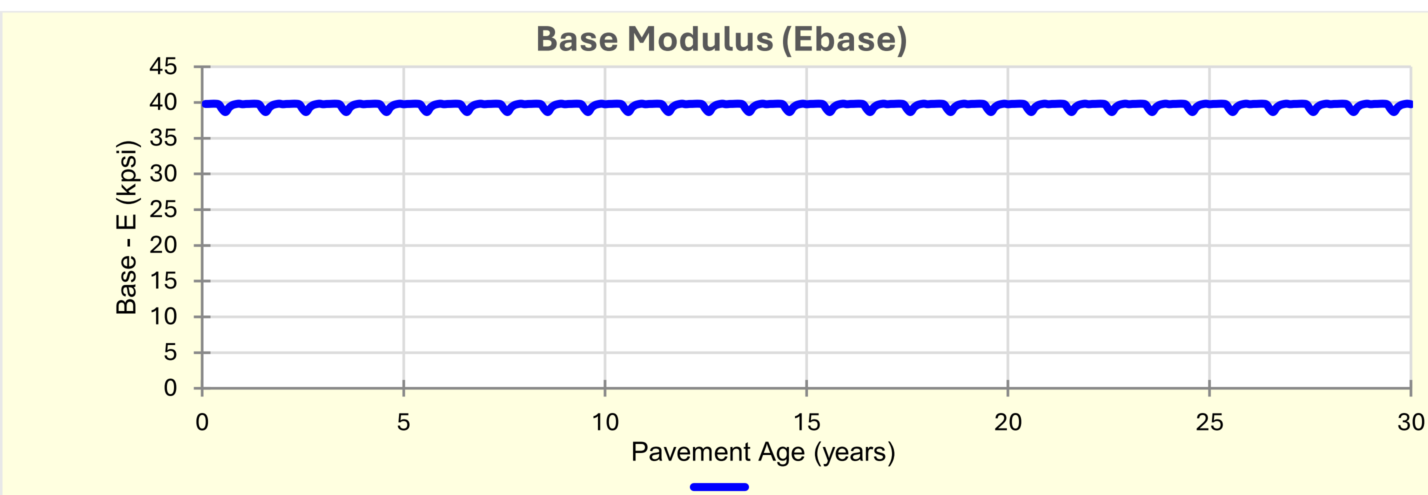


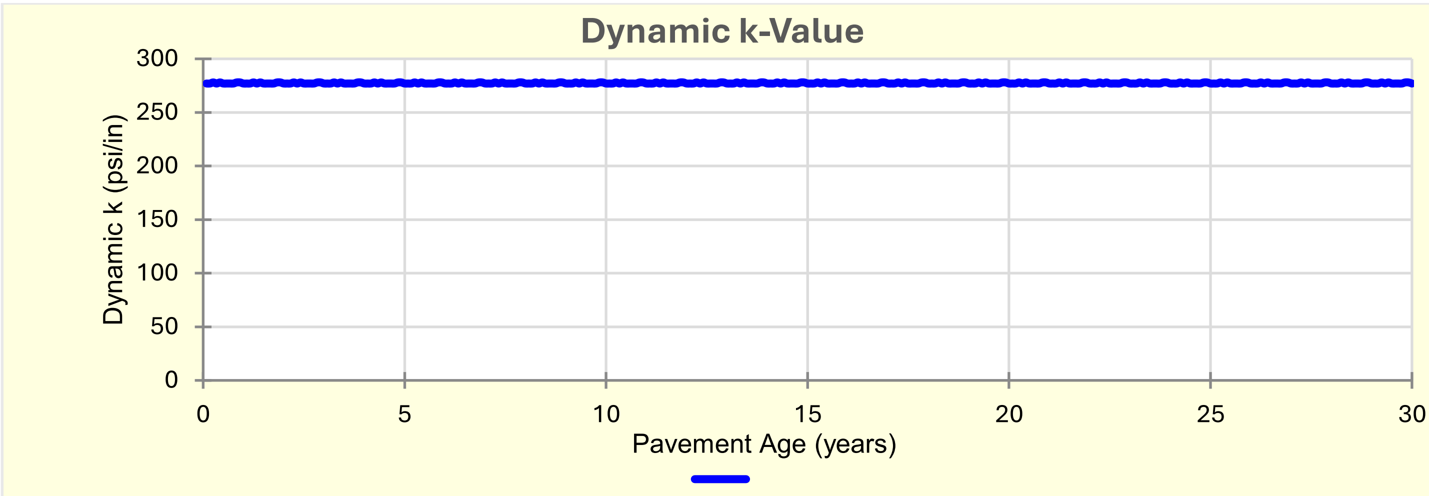


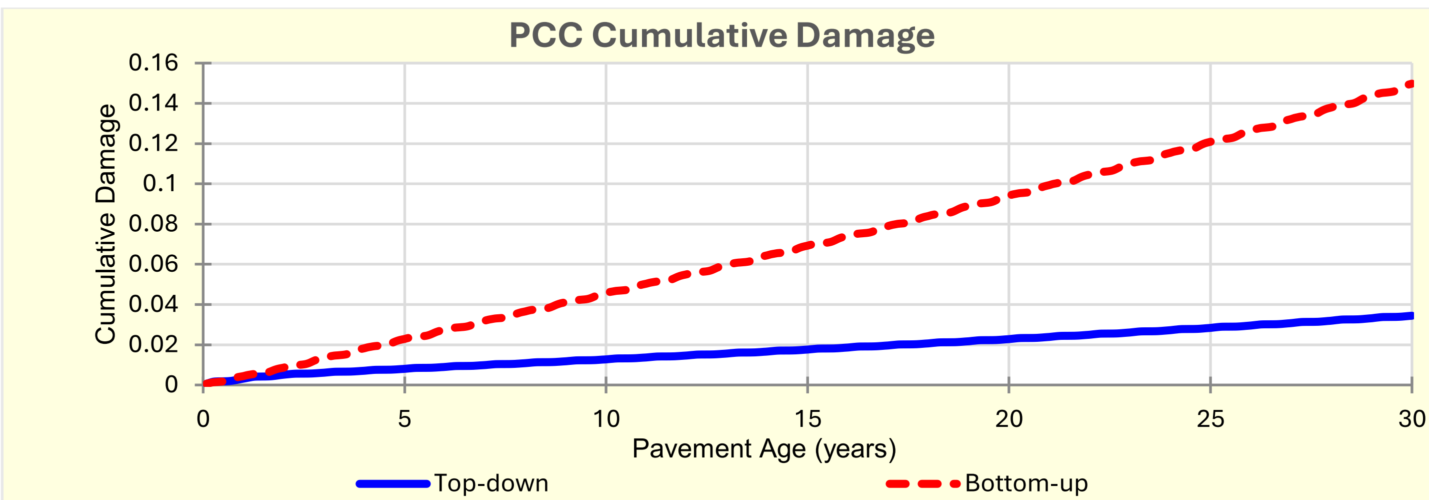


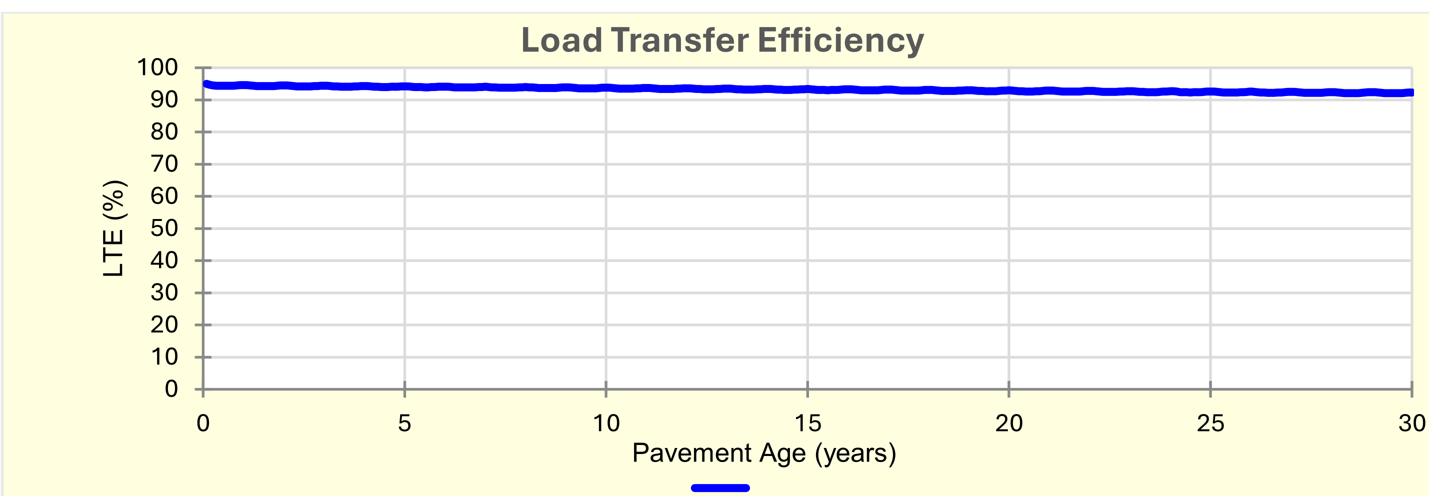

PCC Modulus (Epcc)
PCC - E(Mpsi)
0
1
2
3
4
5
6
0
5
10
15
20
25
30
Pavement Age (years)


PCC Flexural Strength (MR)
PCC - MR(psi)
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25
30
Pavement Age (years)


Base Modulus (Ebase)
Base - E (kpsi)
0
5
10
15
20
25
30
35
40
45
0
5
10
15
20
25
30
Pavement Age (years)


Dynamic k-Value
Dynamic k (psi/in)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
Pavement Age (years)


PCC Cumulative Damage
Cumulative Damage
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
Pavement Age (years)
Top-down
Bottom-up


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
Pavement Age (years)

Layer Information

Layer 1 PCC (Proposed Overlay) : Default JPCP 1

PCC	
Thickness (in)	7.5
Unit weight (pcf)	150
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/deg F X 10^-6)	4.9
PCC thermal conductivity (BTU/hr-ft-°F)	1.25
PCC heat capacity (BTU/lb-°F)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		600
Water to cement ratio		0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (°F)	Calculated Internally?	True
	User Value	-
	Calculated Value	117.415
Ultimate Shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	632.3
Reversible Shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing Compound		

Identifiers

Field	Value
Display name/identifier	Default JPCP 1
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

PCC strength and modulus (Input Level: 3)

28-Day PCC modulus of rupture (psi)	690
28-Day PCC elastic modulus (psi)	4200000

Layer 2 Non-stabilized base : Crushed stone (A-1-a)

Unbound	
Layer thickness (in)	6
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	30000.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	Crushed stone (A-1-a)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.1
Saturated hydraulic conductivity (ft/hr)	False	0.05328
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.255496829960335
bf	1.2911570438718638
cf	0.8263617065521088
hr	117.4

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8 in	57.2
1/2 in	63.1
3/4 in	72.7
1 in	78.8
1 1/2 in	85.8
2 in	91.6
2 1/2 in	
3 in	
3 1/2 in	97.6

Layer 3 Subgrade : A-3 (A-3)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
MR Method:	Resilient Modulus (psi)
Resilient Modulus (psi)	16500.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor	-

Identifiers

Field	Value
Display name/identifier	A-3 (A-3)
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State/Province	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	True	120.0
Saturated hydraulic conductivity (ft/hr)	False	0.00365
Specific gravity of solids	False	2.7
Water Content (%)	False	8.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.849631876739616
bf	2.857643419754946
cf	0.9167554911487317
hr	100

Sieve Size	% Passing
0.001 mm	
0.002 mm	
0.02 mm	
#200	5.2
#100	
#80	33
#60	
#50	
#40	76.8
#30	
#20	
#16	
#10	93.4
#8	
#4	95.3
3/8 in	96.6
1/2 in	97.1
3/4 in	98
1 in	98.6
1 1/2 in	99.2
2 in	99.7
2 1/2 in	
3 in	
3 1/2 in	99.9

Calibration Coefficients

IRI-jpcp		
C1 - Cracking C2 - Spalling C3 - Faulting C4 - Site Factor	C1: 0.446	C2: 0.373
	C3: 0.993	C4: 46.422
	Reliability Standard Deviation	
	15.345 * Ln(IRI) - 54.951	
	Initial IRI Standard Deviation	
	5.4	

JPCP Transverse Cracking

$$\text{Crk}_{Bottom-up/Top-down} = \frac{100}{1 + C_4 \left(FD_{bottom-up/top-down} \right)^{C_5}}$$

$$\text{Crk}_{Total} = Crk_{Bottom-up} + Crk_{Top-down} - \left(Crk_{Bottom-up} \times Crk_{Top-down} \right)$$

$$FD_{bottom-up/top-down} = \sum \frac{n_{i,j,k,l,m,n,o}}{N_{i,j,k,l,m,n,o}}$$

$$\log\left(N_{i,j,k,l,m,n}\right) = C_1 \left(\frac{MR_i}{\sigma_{i,j,k,l,m,n}} \right)^{C_2} + 0.431 - \log\left(1 - C_c \frac{\sigma^0_{i,j,m} + \sigma_{NL}}{\sigma_{Total}} \right)$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.431	C5: -2.303
PCC Reliability Crack Standard Deviation			
			4.5194 * Pow(CRACK,0.3293) + 0.1
Friction Damage Degradation			1
Curling and Other Stresses (CC Factor)			1
Built-in Curling A			6
Built-in Curling B			20

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$

$$C_{34} = C_3 + (C_4 * FR^{0.25})$$

$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s} \right) \right]^{C_6}$$

$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$

$$C_8 = DowelDeterioration$$

C1: 0.2	C2: 1.636	C3: 0.005	C4: 0.00444
C5: 250	C6: 0.2	C7: 20	C8: 400
PCC Reliability Fault Standard Deviation			
			0.1 * Pow(FAULT,0.2711) + 0.0001