Geotechnical Investigation and Pavement Design Report
Horizon Drive and G Road Roundabout
City of Grand Junction, Colorado
RockSol Project No. 599.76
August 31, 2023

Prepared for:

City of Grand Junction
Public Works Department
333 West Avenue, Building D
Grand Junction, Colorado 81501

Attention: Lisa Froshaug, PMP, CFM, Project Engineer

Prepared by:

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ATTACHMENTS

1.0 PROJECT OBJECTIVE AND DESCRIPTION

This report documents the geotechnical engineering investigation and pavement design performed by RockSol Consulting Group, Inc. (RockSol) for the Horizon Drive and G Road Roundabout Project in the City of Grand Junction, Colorado (see Figure 1, *Site Vicinity Map*).

Figure 1 – Project Site Location Map (Google Earth)

This project focuses on the design and construction of a proposed multi-lane roundabout for the City of Grand Junction. A new roundabout is proposed at the 4-way intersection of Horizon Drive and G Road. Improvements also include drainage, curb, gutter, and sidewalk.

The geotechnical investigation was conducted by RockSol for the City of Grand Junction. The scope of work for this geotechnical investigation included:

- Preparing a drilling/sampling program to perform a subsurface investigation and implementing the program to collect soil samples for laboratory testing.
- Performing laboratory tests and analyzing the data.
- Preparing a report that presents subsurface conditions encountered, the results of the laboratory testing, pavement design recommendations, and earthwork/subgrade recommendations.

Surface and groundwater hydrology, hydraulic engineering, and environmental evaluation of site soils and groundwater for possible contaminant characterization were not included in RockSol's geotechnical scope of work.

Unless otherwise specified, all recommendations presented in this report are based on the Colorado Department of Transportation (CDOT) 2022 Standard Specifications for Road and Bridge Construction; the City of Grand Junction Standard Specifications for Road and Bridge Construction; and the City of Grand Junction Transportation Engineering Design Standards.

2.0 PROJECT SITE CONDITIONS

A combination of commercial, residential, and undeveloped land surrounds the project limits (See Figure 1). Currently, Horizon Drive consists of two travel lanes in each direction within the project limits with dedicated left turn lanes in each direction. G Road currently consists of two lanes, one in each direction and a dedicated right and left turn lane as it approaches Horizon Drive from the west. G Road turns into 27 ½ Road to the east of Horizon Drive which consists of one travel lane in each direction with a dedicated right and left turn lane. The existing lanes are approximately 12 feet wide and surfaced with asphalt pavement throughout the project vicinity.

Topography throughout the project limits of consist of nearly flat slopes with mild slopes rising to the southwest along 27 ½ Road.

3.0 GEOLOGICAL CONDITIONS

Based on information presented in the United States Geological Survey (USGS) Geologic Map (See Figure 2, *Site Geology Map*) of the Grand Junction Quadrangle, Mesa County, Colorado, by Roger B. Scott, Paul E. Carrara, William C. Hood, and Kyle E. Murray, dated 2002, the project site is predominantly underlain by alluvium deposited by tributary streams (Holocene and late Pleistocene) (Qa). Alluvium generally consists of silt, sand, and gravel. Alluvium and colluvium (Qac) deposits are mapped near the project site. The colluvium generally consists of sandy silt, silty to clayey sand, and sandy clay. The materials identified by the USGS mapping were consistent with native soils encountered during our geotechnical investigation. Mancos Shale bedrock (Km) is mapped at or near the surface to the west and southeast of the project site, however, no bedrock was encountered during this investigation.

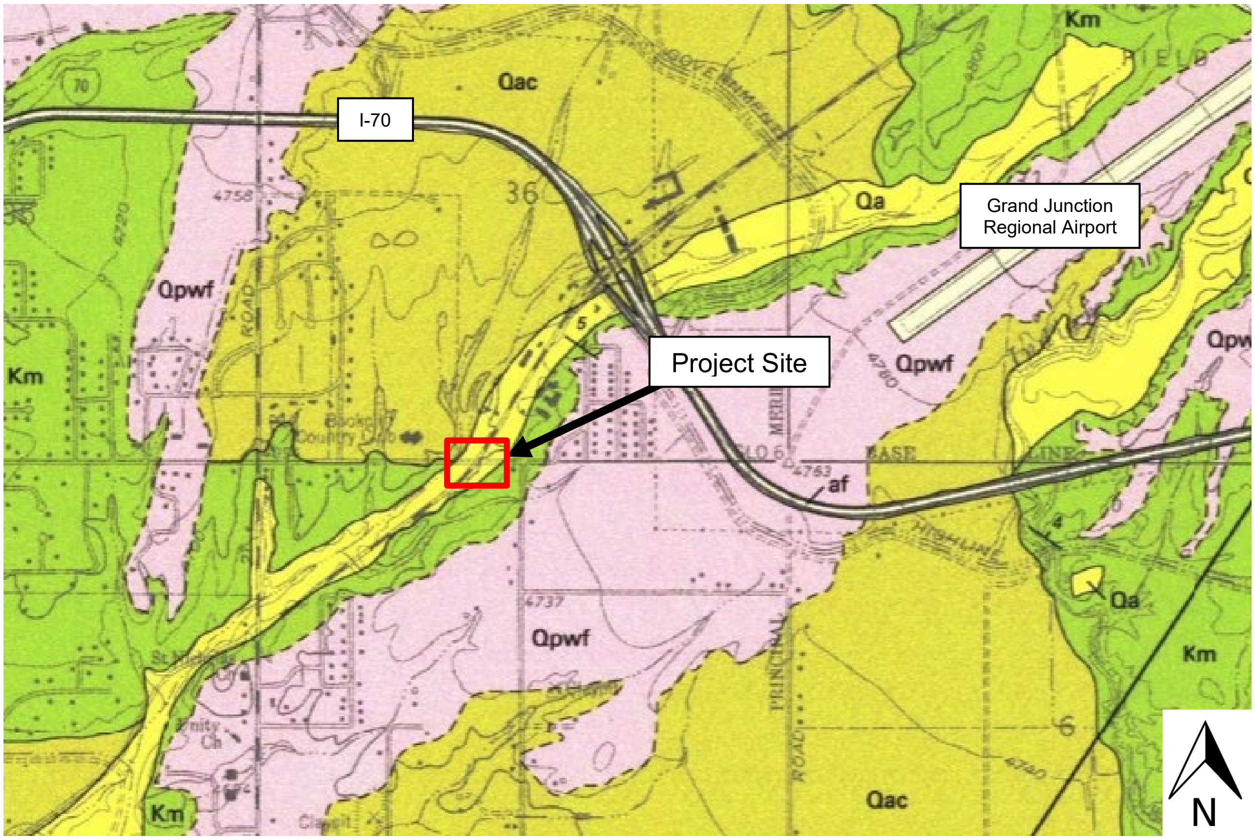


Figure 2 – Site Geology Map (Grand Junction, Mesa County, Colorado 2002)

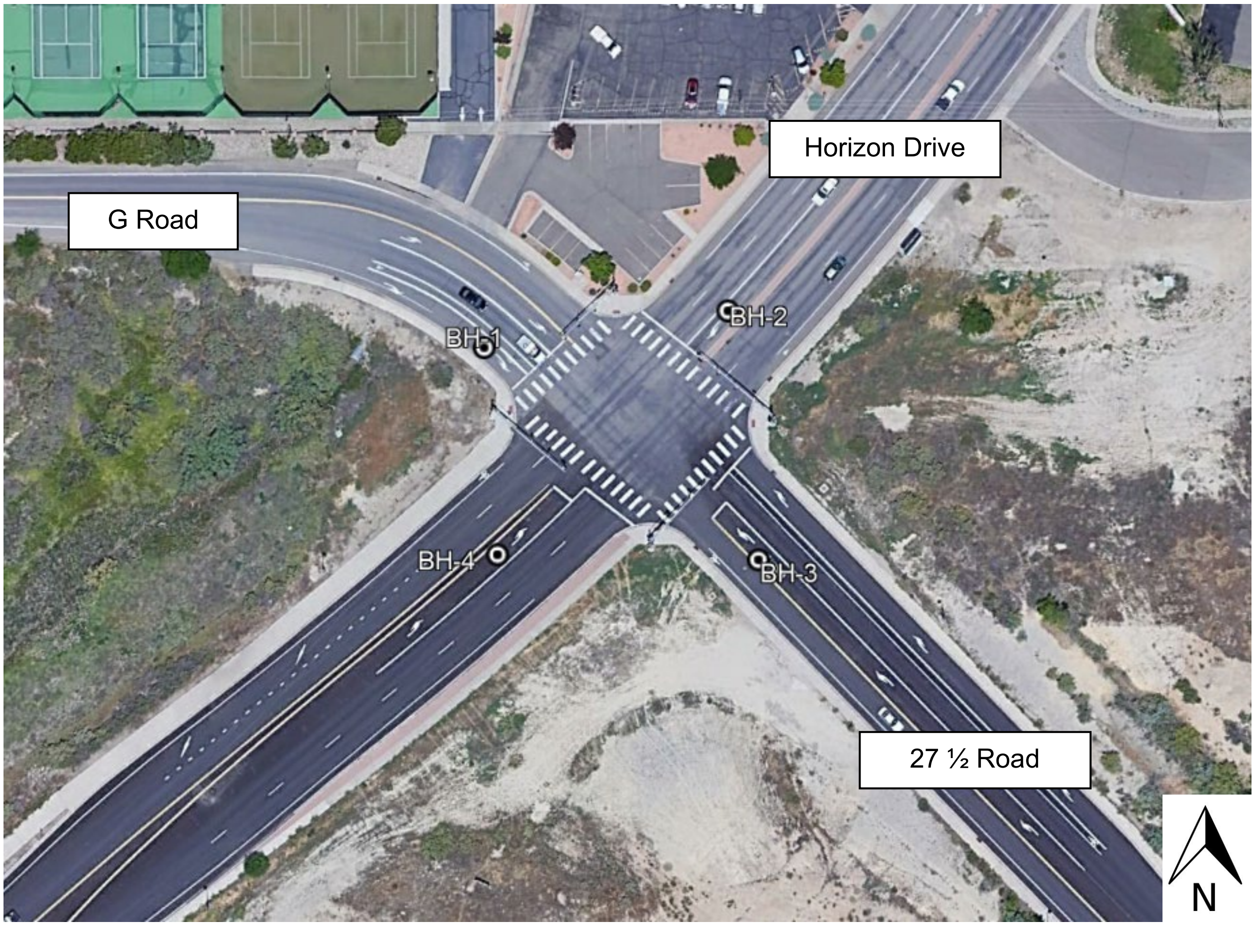
4.0 SUBSURFACE EXPLORATION

For this investigation, RockSol completed a total of 4 boreholes identified as BH-1 through BH-4, shown in Figure 3. All boreholes were drilled for the purpose of soil investigation for pavement design of the proposed roundabout intersection. Boreholes extended to an approximate depth of 10 feet below existing grade.

The locations of the geotechnical investigation boreholes are summarized below in Table 1 and shown in Figure 3 – Borehole Location Plan. Boreholes are shown in relation to 30% design drawings supplied by the City of Grand Junction in Appendix A. The boreholes were drilled on April 11, 2023.

Table 1 – Borehole Location Summary

Borehole ID	Borehole Location
BH-1	Eastbound G Road, Right Turn Lane
BH-2	Southbound Horizon Drive, Left Turn Lane
BH-3	Westbound 27 ½ Road, Left Turn Lane
BH-4	Northbound Horizon Drive, Left Turn Lane



Figrue 3 – Borehole Location Plan (Google Earth)

The boreholes were advanced with a truck mounted Simco 2800 drill rig using 6-inch outside diameter solid stem auger. The boreholes were logged in the field by a representative of RockSol with the depth to groundwater, if encountered, noted at the time of drilling. The boreholes were backfilled at the completion of drilling and groundwater level checks and patched with surface asphalt patch mix when drilled within existing pavement.

Subsurface materials were sampled via bulk samples from auger cuttings. Depths at which the samples were taken are shown on the Borehole Logs (See Appendix B).

5.0 SURFACE AND SUBSURFACE CONDITIONS

The surface and subsurface materials encountered by RockSol at our borehole locations included asphaltic pavement, road subbase (aggregate base course/pit run material), and native soils. Field logging of the soil encountered in the boreholes was per procedures presented in ASTM D-2488. A brief description of the materials encountered is presented below.

5.1 Existing Asphalt Pavement Sections

Asphalt pavement was encountered in all boreholes. The asphalt pavement ranged in thickness from 6 to 7 inches and was underlain by 18 - 30 inches of imported fill gravel base except at BH-3 which was underlain by 18 inches of aggregate base course (ABC). The ABC appeared to be similar to CDOT Class 6 ABC when observed in the field. The fill gravel material generally consisted of 2-4 inches rounded cobbles in a soil matrix. A woven geotextile was encountered between the asphalt and the subbase in Borehole BH-3, shown in Figure 4. A summary of existing pavement section thickness encountered at each borehole location is presented in Table 2. Existing pavement section thicknesses are also shown on the individual borehole logs found in Appendix A.

Table 2 – Existing Pavement Sections

Borehole ID	HMA Pavement Thickness (in)	Base Thickness (in)	Base Material Type
BH-1	7.0	5.0	Fill Gravel
BH-2	6.0	30.0	Fill Gravel
BH-3 (Note 1)	6.0	18.0	ABC
BH-4	6.0	30.0	Fill Gravel

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course
Note 1: Woven geotextile fabric located between HMA and ABC

Figure 4 – Woven Geotextile Encountered below HMA in Borehole BH-3

5.2 Native Subgrade Soils

Native soils were encountered below existing pavement and subbase materials and extended to maximum depths drilled at all borehole locations. Native soils encountered generally consisted of very soft to very stiff, slightly moist to wet, tan-gray to tan-brown, sandy to silty clay. The native soils encountered by RockSol are generally consistent with the alluvium and colluvium materials identified on the USGS Geological Map (See Figure 3*)* found in Section 3.0 of this report.

5.3 Sedimentary Bedrock

Sedimentary Bedrock was not encountered to total depths drilled during drilling operations.

5.4 Groundwater

Groundwater was encountered during drilling/sampling activities at BH-4 at an approximate depth of 4 feet below existing grades at the time of drilling operations. Depth to groundwater where encountered is presented on individual borehole logs in Appendix B. Groundwater encountered at the site may be associated with the alluvium identified in Section 3.0.

Depth to groundwater is subject to change depending on climatic conditions, water flows in nearby drainage channels, local irrigation practices, changes in local topography, and changes in surface storm water management. Long-term monitoring of groundwater elevations is required to establish groundwater fluctuations.

6.0 LABORATORY TESTING

Soil samples retrieved from the borehole locations were examined by the project geotechnical engineer in the RockSol laboratory. Selected samples were tested and classified per the Unified Soil Classification System (USCS). The following laboratory tests were performed in accordance with the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and current local practices:

- Percent Passing No. 200 Sieve (ASTM D-1140)
- Liquid and Plastic Limits (ASTM D-4318)
- Gradation (ASTM D 6913)
- Water-Soluble Sulfates (CDOT CP-L 2103)
- Water-Soluble Chloride Content (CDOT CP-L 2104)
- Standard Test Method for pH of Soils (ASTM D4972-01)
- Soil Resistivity (ASTM G187 - Soil Box)
- Soil Classification (ASTM D-2487 and AASHTO M145)
- Resistance Value (AASHTO T-190)

R-Values (Resistance Values) were tested by CMT Technical Services. All other laboratory tests were performed by RockSol. Laboratory test results are presented in Appendix C and are also summarized on the Borehole Logs presented in Appendix B.

7.0 SUBGRADE CHARACTERIZATION

Laboratory test results were used to characterize the engineering properties of the subsurface material encountered. For soil classification, RockSol conducted sieve analyses and Atterberg Limits tests. Lab testing was also performed on selected samples to determine the water-soluble sulfate content of subsurface materials to assist with cement type recommendations. A summary of physical and chemical test results is included in Appendix C.

7.1 Roadway Subgrade Soil Classification

Subgrade bulk samples of existing roadway grades were obtained at various depths from each pavement borehole location and were tested for AASHTO soil classification. The native subgrade soils tested were classified as A-4 AASHTO soil types. Fill soils and ABC soils tested classified as A-1-b AASHTO soil types. A summary of the roadway subgrade soil classifications is presented in Table 4.

Table 4 – Roadway Subgrade Soil Classifications

Borehole Location	Depth (feet)	AASHTO Classification
BH-1	1 - 10	A-4 (7)
BH-2	0.5 - 5.5	A-4 (1)
BH-2	5.5 - 10	A-4 (2)
BH-3	0.5 - 2	A-1-b (0)
BH-3	2 - 10	A-4 (6)
BH-4	3 - 4	A-4 (0)
BH-4	4 - 10	A-4 (3)

7.2 Water-Soluble Sulfate Content

Cementitious material requirements for concrete in contact with soils or groundwater are based on the percentage of water-soluble sulfate. Mix design requirements for concrete exposed to water-soluble sulfates in soils or water is considered by the Colorado Department of Transportation (CDOT) as shown in Table 5 and in the 2022 CDOT Standard Specifications for Road and Bridge Construction. Water-soluble Sulfate Testing Results are summarized in Table 6.

Table 5 – Requirements to Protect Against Damage to Concrete by Sulfate Attack from External Sources of Sulfate

Water-Soluble Sulfate (SO_4) In dry soil, percent	Sulfate (SO_4) In water, ppm	Cementitious Material Requirements
0.00 to 0.10	0 to 150	Class 0
0.11 to 0.20	151 to 1,500	Class 1
0.21 to 2.0	1,501 to 10,000	Class 2
2.01 or greater	10,001 or greater	Class 3

Table 6 – Water-Soluble Sulfate Testing Summary

Borehole I.D.	Sample Depth (Feet)	Water-Soluble Sulfate (SO_4) In dry soil, percent	Cementitious Material Requirements
BH-1	1 – 10	0.54	Class 2
BH-2	0.5 – 5.5	0.53	Class 2
BH-2	5.5 – 10	1.34	Class 2
BH-3	2 – 10	0.12	Class 1
BH-4	4 – 10	0.60	Class 2

The concentration of water-soluble sulfates measured in soil samples obtained from RockSol's exploratory boreholes ranged from 0.12 percent to 1.34 percent by weight (See Appendices B and C). Based on the results of the water-soluble sulfate testing, Exposure Class 2 may be considered for concrete in contact with subgrade materials at the Horizon Drive and G Road Roundabout. Refer to CDOT's current Specifications in Section 601 for concrete mixtures that satisfy appropriate sulfate exposure Class 2 requirements.

7.3 Corrosion Resistance Level

Water-soluble chloride content, water-soluble sulfate content, pH, and electrical resistivity tests were performed on bulk samples obtained from the boreholes. All corrosion testing was performed in the RockSol laboratory and is summarized in Table 7.

Table 7 – Corrosivity Test Results

Borehole Location	Sample Depth (Feet)	Water-Soluble Chloride (% by weight)	Water-Soluble Sulfate (% by weight)	pH	CR Level
BH-1	1 - 10	0.0162	**0.54**	--	**CR 4**
BH-2	0.5 – 5.5	0.0162	**0.53**	--	**CR 4**
BH-2	5.5 – 10	0.0162	**1.34**	--	**CR 5**
BH-3	2 – 10	0.0444	**0.12**	--	**CR 2**
BH-4	4 – 10	0.0246	**0.60**	7.8	**CR 4**

Comparison of the test results of the sulfate, chloride, and pH testing performed with *Table 1 - Guidelines for Selection of Corrosion Resistance Levels as presented in the CDOT Pipe Materials Selection Guide,* dated April 30, 2015, suggests corrosion resistance levels of CR 2, CR 4, and CR 5 are present within the project limits. Additional testing at specific structure locations may be performed to provide structure specific corrosion resistance recommendations. Of the three variables (water-soluble sulfate, water-soluble chloride, and pH) that are used in determining the CR level, the water-soluble sulfate is the predominant component affecting the CR level selection.

Electrical resistivity testing was performed on a bulk sample from 2 feet to 10 feet in Borehole BH-3 and on a bulk sample from 3 feet to 4 feet in Borehole BH-4 using the soil box method (ASTM G-187) and resulted in resistivities of 370 and 760 ohm-cm, respectively. Based on AASHTO LRFD Bridge Design Specifications, Ninth Edition, Section 10.7.5, resistivity less than 2,000 ohm-cm indicates an aggressive condition. Based on AASHTO criteria, the site soils exhibit an aggressive condition to metals such as steel.

Comparison of the results of the electrical resistivity and pH testing performed with *Table 2 – Minimum Pipe Thickness for Metal Pipes Based on The Resistivity And pH of the Adjacent Soil* as presented in the *CDOT Pipe Materials Selection Guide,* effective April 30, 2015, suggests the minimum required gauge thickness for metal pipe material, if used, for this project is *0.052 inches (18 Gauge) Polymer Coated.* Additional testing at specific structure locations may be performed to provide structure specific recommendations.

7.4 Subgrade Support Test Results (R-Value)

To test the subgrade support characteristics of soils representative of the project site, two R-Value laboratory tests were performed on bulk samples obtained from Borehole BH-1 from a depth of 1 to 10 feet below existing grade and Borehole BH-3 from a depth of 2 to 10 feet below existing grade. R-Value test results of 12 and 14 were obtained from these samples, respectively. The Colorado Department of Transportation (CDOT) Pavement Design Manual equation 4-1 was used to determine the resilient modulus of 6,815 psi and 7,111 psi, respectively.

8.0 PAVEMENT DESIGN RECOMMENDATIONS

Horizon Drive and G Road are classified as minor arterials, and 27 ½ Road is classified as a major collector by the City of Grand Junction. The roadway classifications for this project were found on the website for the City of Grand Junction's Transportation Map as shown in Figure 5.

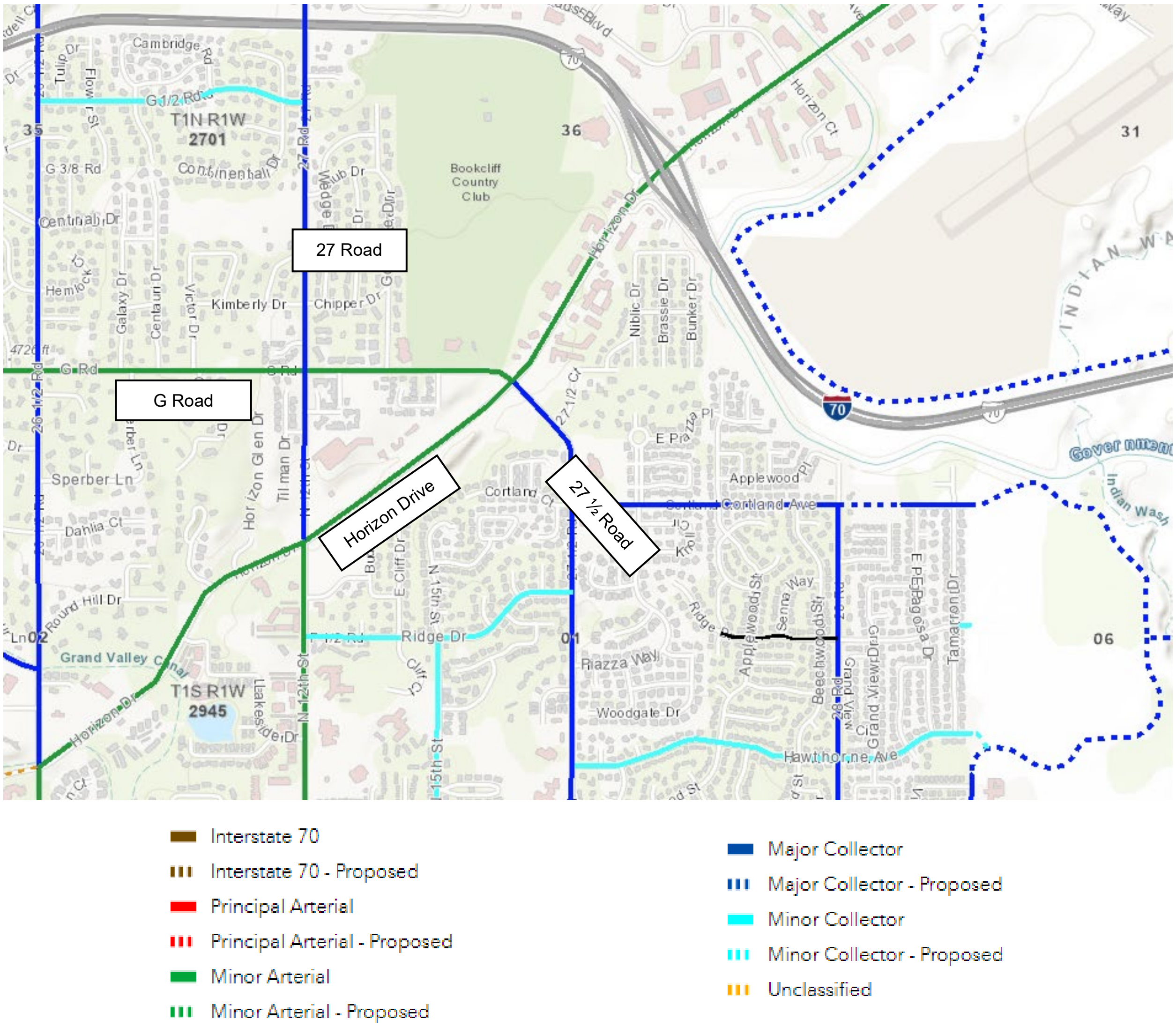


Figure 5 – Roadway Classifications (City of Grand Junction Transportation Map)

A 2-lane roundabout is planned at the intersection of G Road, Horizon Drive, and 27 ½ Road. In this report Hot Mix Asphalt (HMA) pavement is identified as flexible pavement. Portland Cement Concrete (PCC) pavement is identified as rigid pavement.

Pavement thickness evaluation for the development of flexible and rigid pavement design recommendations within the City of Grand Junction right of way were performed in accordance with CDOT's 2021 M-E Pavement Design Manual as modified in 2022 which uses Version 2.3.1 of AASHTO's Pavement Mechanistic-Empirical Design (PMED) software, *Subsection 29.32 – Pavements and Truck Routes* in the City of Grand Junction Municipal Code as passed in Ordinance 5136 on March 15, 2023, and a spreadsheet developed by RockSol to replicate the 1993 AASHTO flexible pavement design as recommended in 29.32.040(a).

8.1 Traffic Loading

Traffic loading was estimated for a 20 and 30-year flexible pavement design life and 30-year rigid pavement design life in accordance with the City of Grand Junction Municipal Code (Subsection 29.32). The average daily traffic (ADT) was taken from current data supplied by the City's

Transportation Engineer and the City of Grand Junction's Transportation Map (Traffic Counts). Based on discussions with the City's Transportation Engineer, it was decided to use the highest traffic count in the pavement designs with a compound growth rate of 2.0 percent.

The ADT from traffic station 1046 for G Road ranged from a low of 4,775 in 2023 to a high of 5,782 in 2007. Using the highest ADT of 5,782 as the 2023 ADT and the compound growth rate of 2 percent, the 2024 ADT used for the pavement design for G Road is 5,898.

The ADT from traffic station 1175 for 27 ½ Road ranged from a low of 10,018 in 2004 to a high of 11,864 in 2018. Using the highest ADT of 11,864 as the 2023 ADT and the compound growth rate of 2 percent, the 2024 ADT used for the pavement design for 27 ½ Road is 12,101.

The ADT from traffic station 1172 for Horizon Drive ranged from a low of 13,319 in 2023 to a high of 23,768 in 2009. Using the highest ADT of 23,768 as the 2023 ADT and the compound growth rate of 2 percent, the 2024 ADT used for the pavement design for Horizon Drive is 24,243.

The Average Annual Daily Truck Traffic (AADTT) has a significant effect on the predicted pavement performance as compared to cars and pick-up trucks. For this project, predominately Class 5 vehicles when using the Federal Highway vehicle type classification system were noted on all roads. Based on discussions with the City's Transportation Engineer, an average of 15.0 percent will be used to determine the AADTT for this project. The compound growth rate of 2 percent was used over a 20-year and 30-year design life to develop the 18,000-pound equivalent single axle loads (ESAL's). The calculated ESAL's was derived from the PMED software. The AADTT used for the pavement designs of roadway segments is shown in Table 8. Based on CDOT's Pavement Design Manual, Cluster 1 truck percentages will be used to model the truck traffic in the PMED software.

Table 8 – Summary of Traffic Loading

Pavement Section Location	2024 ADT	Estimated AADTT	20-Year Flexible Design Life 18k ESALS	30-Year Flexible Design Life 18k ESALS	30-Year Rigid Design Life 18k ESALs
G Road	5,898	890	3,050,000	5,090,000	6,580,000
27 ½ Road	12,101	1,820	6,240,000	10,410,000	13,460,000
Horizon Drive	24,243	3,640	9,350,000	16,620,000	20,190,000
Roundabout (G Rd. + 27 ½ Rd. + Horizon Dr.)	42,242	6,350	16,320,000	27,250,000	35,220,000

8.2 Pavement Subgrade Characterization

Based on R-Value testing, a conservative R-Value of 10 with a corresponding subgrade resilient modulus value of 6,482 psi was used by RockSol as the design R-value for evaluation of new pavement constructed on the existing soils for this project.

To provide an appropriate structural layer for Hot Mix Asphalt (HMA), RockSol recommends 8 inches of a subbase layer of non-stabilized A-1-b CDOT Class 2 Aggregate Base Course (ABC) material be included as part of the pavement design section in addition to 8 inches of CDOT Class 6 ABC directly underlying the pavement. A structural coefficient of 0.12 was used for Class 6 Aggregate Base Course (ABC), 0.11 for Class 2 ABC, and 0.44 for HMA. The Class 2 material must have an R-Value of at least 40 and the Class 6 material must have an R-Value of at least 78 when tested in accordance with AASHTO T 190.

8.3 Pavement Section Recommendations,

Three pavement thickness design procedures were used for the 20 and 30-year design life of new flexible pavement and 30-year design life of new concrete pavement. The first procedure used for flexible and rigid pavement design was performed in accordance with the 2021 Colorado Department of Transportation M-E Pavement Design Manual as modified in 2022 and the PMED software, Version 2.3.1.The second procedure used a spreadsheet developed by RockSol to replicate the 1993 AASHTO flexible pavement design since the AASHTOWare DARWin version 3.1 Pavement Design and Analysis System recommended in subsection 29.32.040 (a) of the City of Grand Junction Transportation Engineering Design Standards is no longer available. The third procedure used the 1998 version of the AASHTO Guide for the Design of Pavement Structures in accordance with subsection 29.32.040 (b) of the City of Grand Junction Transportation Engineering Design Standards. Typical flexible pavement designs for the City of Grand Junction usually include a layer of Class 2 aggregate base course below the Class 6 ABC to help provide a stable platform for the pavement. The concrete pavements typically do not require the Class 2 material, therefore the aggregate base sections presented in this report for concrete pavements are reduced.

8.3.1 Flexible ME-Pavement Design Recommendations

A summary of the PMED minimum pavement section thicknesses for flexible pavement are presented in Table 9 for the 20-year design life and Table 10 for the 30-year design life with the pavement design output sheets included in Appendices D through G.

Table 9 – Flexible Pavement Section Minimum Thickness Recommendations (PMED) (20 Year Design Life)

Pavement Section	Material Type	Thickness (inches)	Appendix
G Road	HMA SX(100) PG 64-22	2.0	D
	HMA S(100) PG 64-22	5.0	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
27 ½ Road	HMA SX(100) PG 64-22	2.0	E
	HMA S(100) PG 64-22	7.0	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
Horizon Drive	HMA SX(100) PG 64-22	2.0	F
	HMA S(100) PG 64-22	7.5	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
Horizon Drive and G Road Roundabout	HMA SX(100) PG 64-22	2.0	G
	HMA S(100) PG 64-22	9.5	
	ABC Class 6	8.0	
	ABC Class 2	8.0	

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

Table 10 – Flexible Pavement Section Minimum Thickness Recommendations (PMED) (30 Year Design Life)

Pavement Section	Material Type	Thickness (inches)	Appendix
G Road	HMA SX(100) PG 64-22	2.0	D
	HMA S(100) PG 64-22	6.0	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
27 ½ Road	HMA SX(100) PG 64-22	2.0	E
	HMA S(100) PG 64-22	8.0	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
Horizon Drive	HMA SX(100) PG 64-22	2.0	F
	HMA S(100) PG 64-22	9.5	
	ABC Class 6	8.0	
	ABC Class 2	8.0	
Horizon Drive and G Road Roundabout	HMA SX(100) PG 64-22	2.0	G
	HMA S(100) PG 64-22	10.5	
	ABC Class 6	8.0	
	ABC Class 2	8.0	

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

8.3.2 Rigid ME-Pavement Design Recommendations

A summary of the PMED minimum pavement section thicknesses for the 30-year design life of rigid pavement are presented in Table 11 and the pavement design output sheets are included in Appendices H through K.

Table 11 – Rigid Pavement Section Minimum Thickness Recommendations (PMED) (30 Year Design Life)

Pavement Section	Material Type	Thickness (inches)	Appendix
G Road	PCC	9.5 or 10.0	H
	ABC Class 6	8.0	
27 ½ Road	PCC	10.0	I
	ABC Class 6	8.0	
Horizon Drive	PCC	10.0	J
	ABC Class 6	8.0	
Horizon Drive and G Road Roundabout	PCC	10.5 or 11.0	K
	ABC Class 6	8.0	

PCC = Portland Cement Concrete; ABC = Aggregate Base Course

8.3.3 AASHTO 1993 Flexible Pavement Design

A summary of the AASHTO 1993 minimum pavement section thicknesses for the 20-year design life of flexible pavement are presented in Table 12 and the 30-year design life of flexible pavement are presented in Table 13. The pavement design output sheets are included in Appendix L.

Table 12 – Flexible Pavement Section Minimum Thickness Recommendations (AASHTO 1993) (20 Year Design Life)

Pavement Section	Material Type	Thickness (inches)
G Road	HMA SX(100) PG 64-22	2.0
	HMA S(100) PG 64-22	3.5
	ABC Class 6	8.0
	ABC Class 2	8.0
27 ½ Road	HMA SX(100) PG 64-22	2.0
	HMA S(100) PG 64-22	4.0
	ABC Class 6	8.0
	ABC Class 2	8.0
Horizon Drive	HMA SX(100) PG 64-22	2.0
	HMA S(100) PG 64-22	5.0
	ABC Class 6	8.0
	ABC Class 2	8.0
Horizon Drive and G Road Roundabout	HMA SX(100) PG 64-22	2.0
	HMA S(100) PG 64-22	5.5
	ABC Class 6	8.0
	ABC Class 2	8.0

Table 13 – Flexible Pavement Section Minimum Thickness Recommendations (AASHTO 1993) (30 Year Design Life)

Pavement Section	Material Type	Thickness (inches)
G Road	SX(100) PG 64-22	2.0
	S(100) PG 64-22	4.0
	ABC Class 6	8.0
	ABC Class 2	8.0
27 ½ Road	SX(100) PG 64-22	2.0
	S(100) PG 64-22	5.0
	ABC Class 6	8.0
	ABC Class 2	8.0
Horizon Drive	SX(100) PG 64-22	2.0
	S(100) PG 64-22	5.5
	ABC Class 6	8.0
	ABC Class 2	8.0
Horizon Drive and G Road Roundabout	SX(100) PG 64-22	2.0
	S(100) PG 64-22	6.5
	ABC Class 6	8.0
	ABC Class 2	8.0

8.3.4 AASHTO 1998 Rigid Pavement Recommendations

A summary of the AASHTO 1998 minimum pavement section thicknesses for the 30-year design life of rigid pavement are presented in Table 14 and the pavement design output sheets are included in Appendix M.

Table 14 – Rigid Pavement Section Minimum Thickness Recommendations (AASHTO 1998) (30 Year Design Life)

Pavement Section	Material Type	Thickness (inches)
G Road	PCC	9.0
	ABC Class 6	8.0
27 ½ Road	PCC	10.0
	ABC Class 6	8.0
Horizon Drive	PCC	10.0
	ABC Class 6	8.0
Horizon Drive and G Road Roundabout	PCC	10.5 or 11.0
	ABC Class 6	8.0

8.4 RockSol Pavement Section Recommendations

After reviewing the various designs, the recommended section by RockSol for the construction of the Horizon Drive and G Road Roundabout is a minimum of 10.5-inches of PCCP with 1.5-inch dowel bars. However, a 11-inch-thick PCCP section may be better suited for construction.

The recommended transverse and longitudinal joint spacing for PCCP should be a maximum of 15 feet. The 8 inches of ABC should consist of material meeting CDOT Class 6 Aggregate Base Course per CDOT 703.03. In order to reduce the constructability issues and to develop a consistent section outside the roundabout, on G Road, 27 ½ Road, and Horizon Drive, RockSol recommends using the 10.0-inch section with 1.25-inch diameter dowel bars with a maximum joint spacing of 15 feet along with the 8 inches of Class 6 ABC. The shoulder should be tied to the curb and gutter or the driving lanes in accordance with CDOT's M-Standards.

If the flexible pavement alternative is selected for some or all of the segments, RockSol recommends the sections shown in Table 9 be used for this project.

Rigid or flexible pavement shall consist of CDOT-approved mix designs.

8.5 Subgrade Preparation (Prior to Pavement Construction)

Prior to construction of new pavements on subgrade soils, the underlying subgrade should be properly prepared by removal of all organic matter (topsoil), debris, loose material, and any deleterious material identified by the Project Engineer followed by scarification, moisture conditioning and re-compaction. The minimum depth of scarification, moisture conditioning and re-compaction in all cases shall be 6 inches. Based on the results of our field and laboratory tests, A-1-b and A-4 soils are anticipated to be encountered at existing pavement subgrade elevations within the project limits.

Materials classified as AASHTO A-1, A-2-4, A-2-5, and A-3 soils shall be compacted at plus or minus 2 percent of Optimum Moisture Content (OMC) and to at least 95 percent of maximum dry density determined in accordance with AASHTO T 180 as modified by CDOT CP 23. All other soil types shall be compacted to 95 percent of the maximum dry density determined in accordance with AASHTO T 99 as modified by CDOT CP 23. Soils with 35 percent fines or less shall be compacted at plus or minus 2 percent of OMC. Soils with greater than 35 percent fines shall be compacted at a moisture content equal to or above OMC to achieve stability of the compacted lift. Stability is defined as the absence of rutting or pumping as observed and documented by the Contractor's Process Control Representative and as approved by the Project Engineer. If the soils cannot be compacted and prove to be unstable at a moisture content equal to or above OMC, then the required moisture content for compaction may be reduced below OMC if approved by the Engineer.

Prior to pavement section construction, subgrade proof rolling with pneumatic tire equipment shall be performed using a minimum axle load of 18 kips per axle after specified subgrade compaction has been obtained. Areas found to be weak and those areas which exhibit soft spots, non-uniform deflection or excessive deflection as determined by the project engineer shall be ripped, scarified, wetted, or dried if necessary, and re-compacted to the requirements for density and moisture. Complete coverage of the proof roller will be required.

Where areas of unstable subgrade soils remain after proof rolling, it is recommended that a maximum of 6 inches of the unstable material be removed and a woven geotextile material such as Mirafi® HP570 or similar product be placed along with 6 inches of a CDOT Class 3 ABC meeting the following requirements:

- Maximum Particle Dimension: 6-inches
- Minus 200 Screen Size: 20% max.
- Liquid Limit (LL): 35 maximum

If the area remains unstable after proof rolling the Class 3 ABC, it is recommended that another layer a woven geotextile material such as Mirafi® HP570 or similar product be placed prior to placing the Class 6 ABC.

9.0 EARTHWORK

To accommodate the new roundabout, new embankment may be required along the roadway alignments. At some locations minor cuts may be required. Materials used to construct embankments, roadway side slopes, structure backfill, and aggregate base course materials should meet the material and moisture density control requirements specified Section 8.5 of this report.

At a minimum, the ground surface underlying all embankment fills should be carefully prepared by removing all organic matter (topsoil), scarification to a minimum depth of 6 inches and recompacting to the requirements for maximum dry density/compaction and moisture content presented in Section 8.5 of this report prior to fill placement.

Where fill material is to be placed on existing slopes steeper than 4 (H):1 (V), benching must be performed to tie the new fill into the existing slope. Benching into the existing slopes shall allow sufficient bench width to accommodate placing and compaction equipment to operate in a horizontal orientation.

Broken concrete, broken asphalt, or other solid materials more than 6 inches in greatest dimension shall not be placed within embankment areas supporting the roadway shoulders and pavement structure. Claystone/shale materials shall not be used for construction of new embankment. Imported fill material used for embankment constructed shall be compatible with designed side slopes. Material excavated from utility trenches may be used for backfilling provided it does not contain unsuitable material. Unsuitable material includes, but is limited to, topsoil, vegetation, brush, sod, trash, and other deleterious substances.

10.0 OTHER DESIGN AND CONSTRUCTION CONSIDERATIONS

Proper construction practices, in accordance with the Colorado Department of Transportation (CDOT) 2022 Standard Specifications for Road and Bridge Construction; the City of Grand

Junction Standard Specifications for Road and Bridge Construction; and the City of Grand Junction Transportation Engineering Design Standards, should be followed during site preparation, earthwork, excavations, roadway and bridge construction, and embankment and retaining wall construction for the suitable long-term performance of the proposed improvements. Excavation support should be provided to maintain onsite safety and the stability of excavations and slopes. Excavations shall be constructed in accordance with local, state, and federal regulations including OSHA guidelines. The contractor must provide a competent person to determine compliance with OSHA excavation requirements. For preliminary planning, existing fill material and native soils may be considered as OSHA Type C soils.

Surface drainage patterns may be altered during construction and local landscape irrigation (if any) must be controlled to prevent excessive moisture infiltration into the subgrade soils during and after construction.

Environmentally contaminated material, if encountered, should be characterized, and removed under the direction of the project environmental consultant. Design and construction plans should be reviewed, and onsite construction should be observed by the professional engineers.

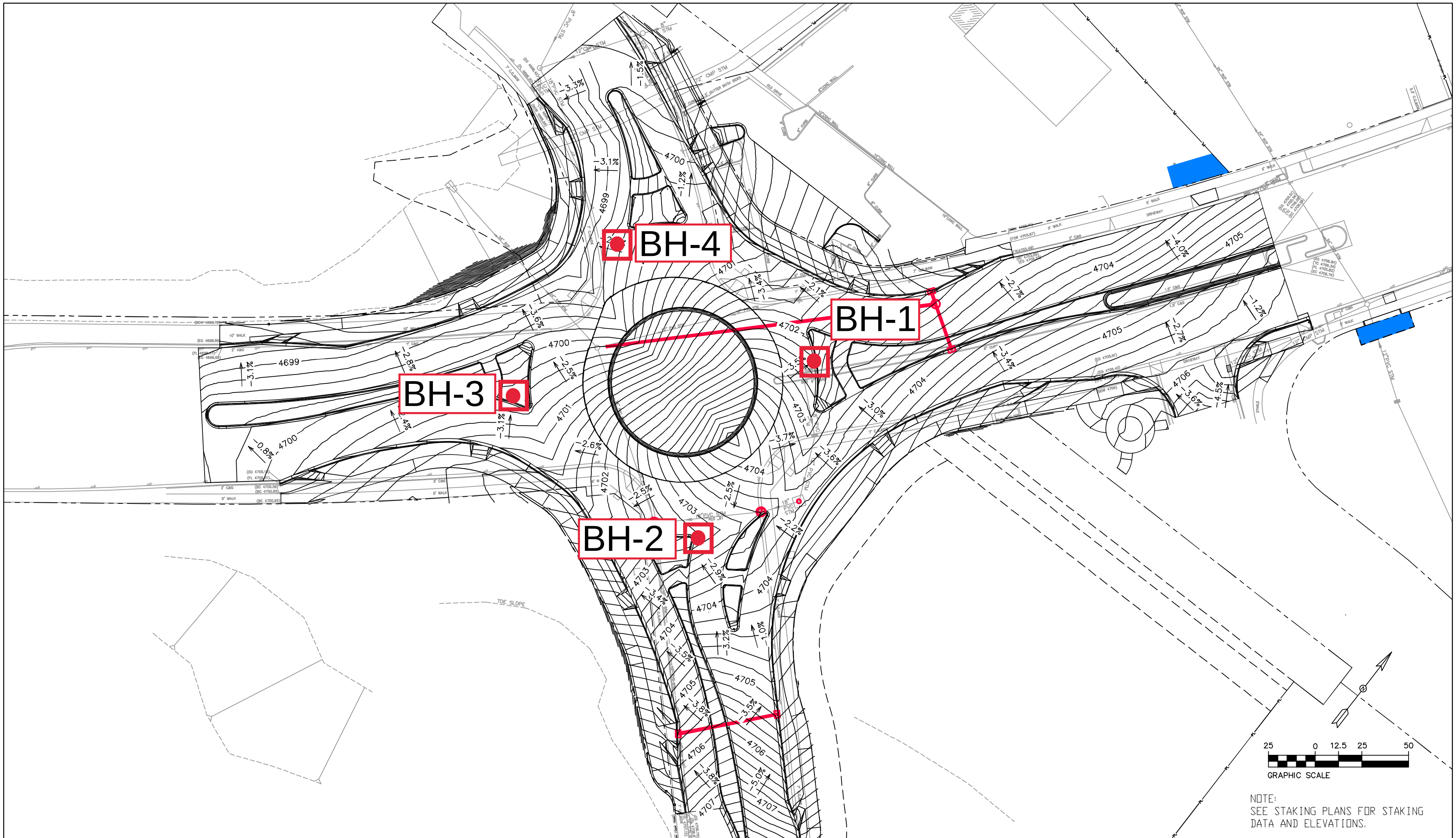
11.0 LIMITATIONS

This geotechnical investigation was conducted in general accordance with the scope of the work. RockSol's geotechnical practices are similar to those used in Colorado with similar soil conditions and based on our understanding of the proposed work. This report has been prepared for use by the City of Grand Junction for the project described in this report. The report is based on our exploratory boreholes and does not consider variations in the subsurface conditions that may exist between boreholes. Additional investigation is required to address such variation. If during construction activities, materials or water conditions appear to be different from those described herein, RockSol should be advised at once so that a re-evaluation of the recommendations presented in this report can be made. RockSol is not responsible for liability associated with interpretation of subsurface data by others.

APPENDIX A

BOREHOLE LOCATION PLANS

Borehole Location Plan



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File Name: TWO TENTH FT CONTOUR MAP.dwg		
Horiz. Scale: AS SHOWN	Vert. Scale: NA	
Unit Information: City of GJ	Unit Leader Initials: LF	
City of Grand Junction Colorado	333 WEST AVE, BLDG C Grand Junction, CO, 81501 Phone: 970-244-1554	

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
606 South 9th Street
Grand Junction, CO, 81501
Phone: 970-683-6351 FAX: 970-683-6369
Region 3 KC

As Constructed
No Revisions:
Revised:
Void:

HORIZON DR AND G RD ROUNDABOUT
TWO TENTH FT CONTOUR
MAP - 1

Designer:	JCS	Structure Numbers	
Detailer:	JCS		
Sht Subset: TWO TENTH FT CONTOUR MAP		Subset Sheets:	X of X

Project No./Code
SHE M555-034
23652
Appendix A

N:\EngProj\F210309 (Horizon Dr and G Rd Roundabout)\60CAD\0DESIGN\TWO TENTH FT CONTOUR MAP.dwg, 3/8/2023 4:54:50 PM

APPENDIX B

LEGEND AND INDIVIDUAL BOREHOLE LOGS

LEGEND

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME Horizon Drive and G Road Roundabout Investigation

PROJECT NUMBER 599.76

PROJECT LOCATION Grand Junction, Colorado

LITHOLOGY

- **Asphalt Pavement**
- **Fill - SAND, clayey to silty**
- **Native - CLAY**
- **Fill - Aggregate Base Course**
- **Native - SAND, silty**
- **Fill - GRAVEL, silty**

SAMPLE TYPE

- Auger Cuttings

Fines Content indicates amount of material, by weight, passing the US No 200 Sieve (%)

GROUND WATER LEVEL AT TIME OF DRILLING

BORING : BH-1

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 4/11/23 **COMPLETED** 4/11/23
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Eastbound G Road, Right Turn Lane
LOGGED BY A. Mannelein **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Center of Lane
WATER DEPTH None Encountered on 4/11/23

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
	0.0		Asphalt pavement, approximately 7 inches thick										
			(Fill) GRAVEL, sandy to slightly silty, approximately 5 inches thick	B BULK									23.8
			(Native) CLAY, with sand and cobbles, moist, tan-brown										
	2.5												
	5.0		**Approximate Bulk Depth 1-10** Liquid Limit= 34 Plastic Limit= 25 Plasticity Index= 9 Fines Content= 78.5 Sulfate= 0.54	B BULK			0.54			34	25	9	78.5
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 4/11/23 **COMPLETED** 4/11/23
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Southbound Horizon Drive, Left Turn Lane
LOGGED BY A. Mannelein **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Center of Lane
WATER DEPTH None Encountered on 4/11/23

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
	0.0		Asphalt pavement, approximately 6 inches thick										
			(Fill) GRAVEL, silty to clayey with sand, slightly moist, gray-brown										
	2.5		**Approximate Bulk Depth 0.5-5.5** Liquid Limit= 25 Plastic Limit= 18 Plasticity Index= 7 Fines Content= 48.8 Sulfate= 0.53	B BULK			0.53			25	18	7	48.8
	5.0												
			(Native) CLAY, sandy to silty, moist, tan-gray										
	7.5		**Approximate Bulk Depth 5.5-10** Liquid Limit= 28 Plastic Limit= 23 Plasticity Index= 5 Fines Content= 67.1 Sulfate= 1.34	B BULK			1.34			28	23	5	67.1
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 4/11/23 **COMPLETED** 4/11/23
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Westbound 27 1/2 Road, Left Turn Lane
LOGGED BY A. Mannelein **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Center of Lane
WATER DEPTH None Encountered on 4/11/23

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
	0.0		Asphalt pavement, approximately 6 inches thick										
			Woven Geotextile Fabric encountered below asphalt pavement Aggregate base course, approximately 18 inches thick	B BULK						NP	NP	NP	16.4
	2.5		(Native) CLAY, with sand, slightly moist, tan-brown **Approximate Bulk Depth 0.5-2** Liquid Limit= NP Plastic Limit= NP Plasticity Index= NP Fines Content= 16.4										
	5.0		**Approximate Bulk Depth 2-10** Liquid Limit= 34 Plastic Limit= 27 Plasticity Index= 7 Fines Content= 83.4 Sulfate= 0.12	B BULK			0.12			34	27	7	83.4
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : BH-4

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 4/11/23 **COMPLETED** 4/11/23
GROUND ELEVATION ____ **STATION NO.** ____
DRILLING CONTRACTOR Colorado Drilling and Sampling
NORTH ____ **EAST** ____
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: Northbound Horizon Drive, Left Turn Lane
LOGGED BY A. Mannelein **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES Center of Lane
▼ **WATER DEPTH** 4.0 ft on 4/11/23

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE	BLOW COUNTS	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
	0.0		Asphalt pavement, approximately 6 inches thick										
			(Fill) GRAVEL, sandy with clay, 2-4 inch cobbles, pit run material	B BULK									3.3
	2.5		**Approximate Bulk Depth 3-4** Liquid Limit= 20 Plastic Limit= 17 Plasticity Index= 3 Fines Content= 47.3										
			(Native) SAND, silty with clay and gravel, brown	B BULK						20	17	3	47.3
		▼	(Native) CLAY, slightly sandy, wet, tan-gray										
	5.0												
	7.5		**Approximate Bulk Depth 4-10** Liquid Limit= 29 Plastic Limit= 24 Plasticity Index= 5 Fines Content= 73.6 Sulfate= 0.60	B BULK			0.60			29	24	5	73.6
	10.0		Bottom of hole at 10.0 feet.										

APPENDIX C

SUMMARY OF LABORATORY TESTS RESULTS

RockSol Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT City of Grand Junction

PROJECT NUMBER 599.76

PROJECT NAME Horizon Drive and G Road Roundabout Investigation

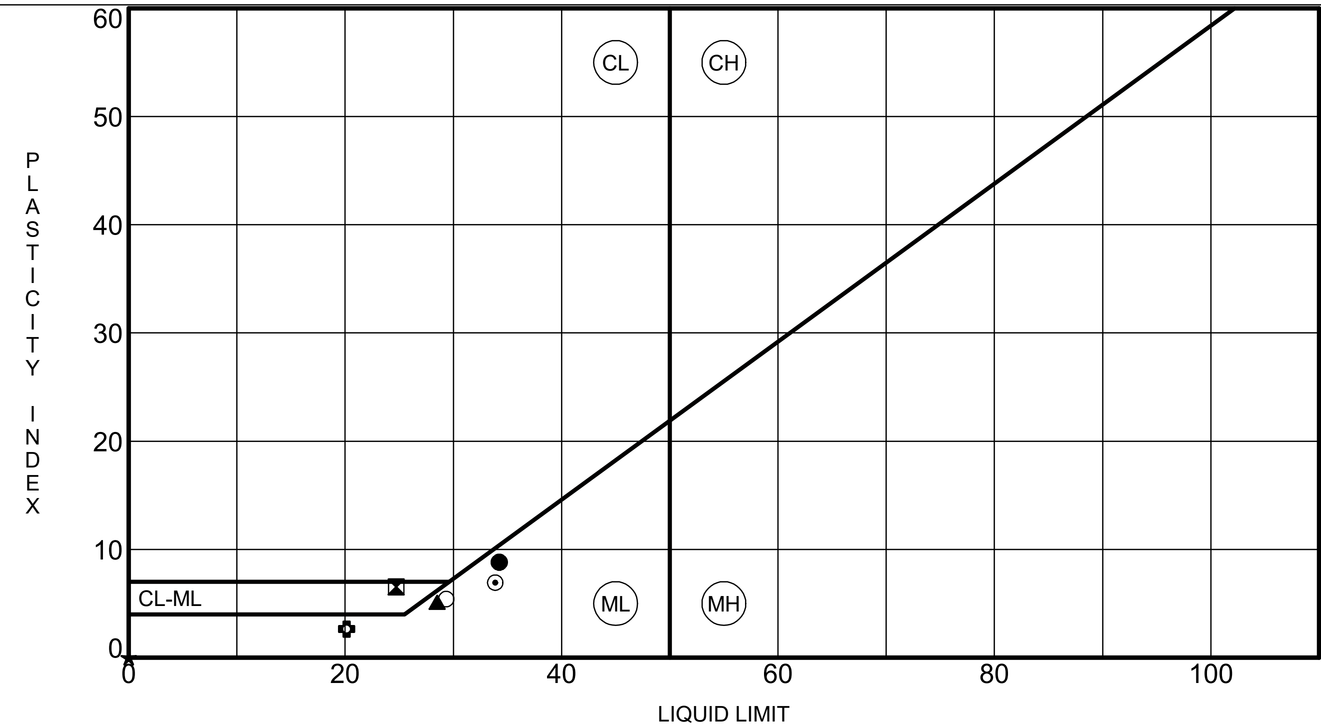
PROJECT LOCATION Grand Junction, Colorado

Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
BH-1	0.58-1					24												
BH-1	1-10	34	25	9		79	ML	A-4 (7)				0.54			0.0162	109.8	16.5	S
BH-2	0.5-5.5	25	18	7		49	GC-GM	A-4 (1)				0.53			0.0162			
BH-2	5.5-10	28	23	5		67	ML	A-4 (2)				1.34			0.0162			
BH-3	0.5-2	NP	NP	NP		16	GM	A-1-b (0)										
BH-3	2-10	34	27	7		83	ML	A-4 (6)				0.12	370 @ 24.5%	8.4	0.0444			
BH-4	0.5-3					3	GW											
BH-4	3-4	20	17	3		47	SM	A-4 (0)					760 @ 22.1%					
BH-4	4-10	29	24	5		74	ML	A-4 (3)				0.60		7.8	0.0246			

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado



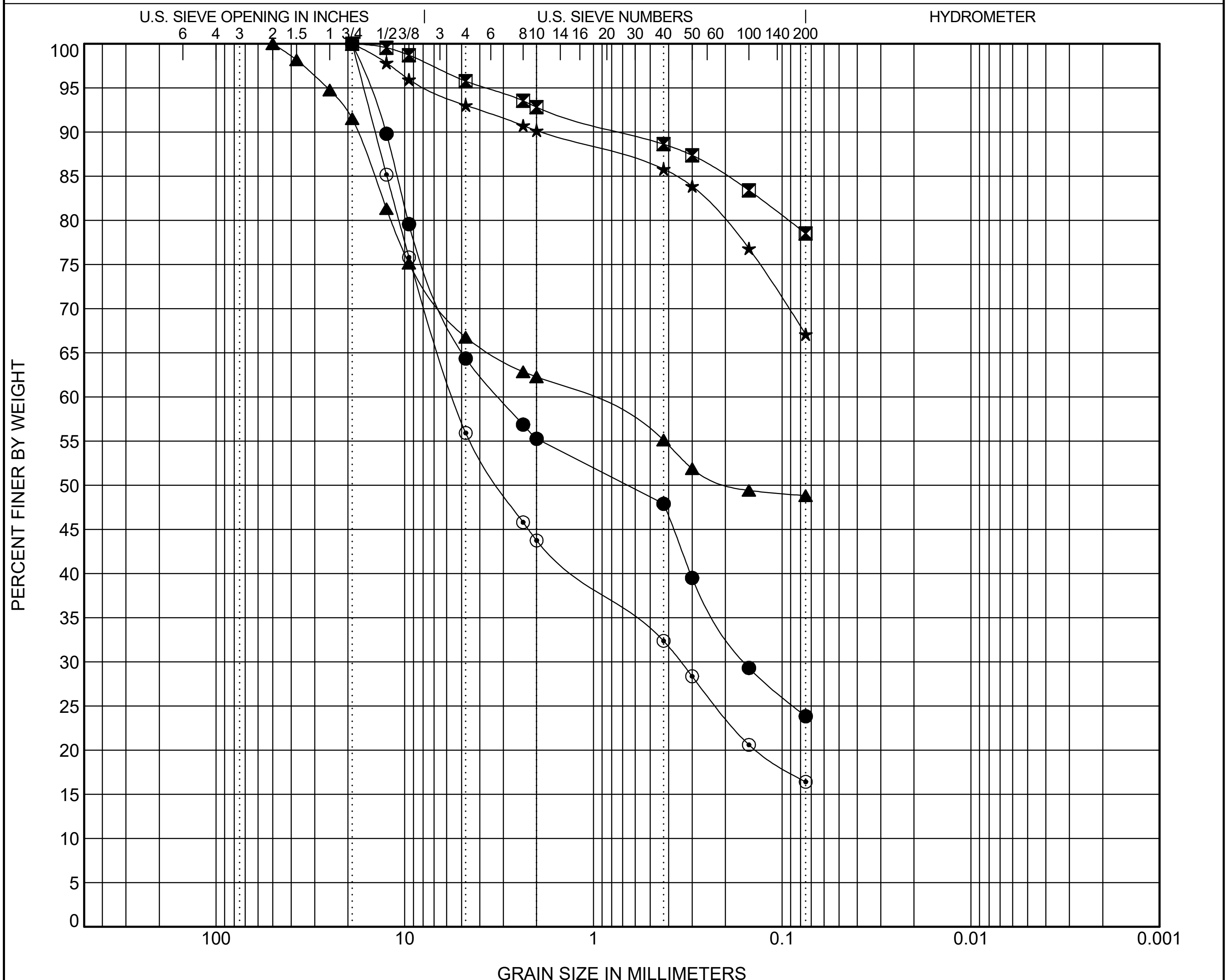
	Specimen Identification		LL	PL	PI	Fines	Classification
●	BH-1	1.0-10.0	34	25	9	78.5	SILT with SAND (ML) (A-4)
⊠	BH-2	0.5-5.5	25	18	7	48.8	SILTY, CLAYEY GRAVEL with SAND (GC-GM) (A-4)
▲	BH-2	5.5-10.0	28	23	5	67.1	SANDY SILT (ML) (A-4)
★	BH-3	0.5-2.0	NP	NP	NP	16.4	SILTY GRAVEL with SAND (GM) (A-1-b)
⊙	BH-3	2.0-10.0	34	27	7	83.4	SILT with SAND (ML) (A-4)
✿	BH-4	3.0-4.0	20	17	3	47.3	SILTY SAND with GRAVEL (SM) (A-4)
○	BH-4	4.0-10.0	29	24	5	73.6	SILT with SAND (ML) (A-4)

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc. RockSol

CLIENT City of Grand Junction **PROJECT NAME** Horizon Drive and G Road Roundabout Investigation

PROJECT NUMBER 599.76 **PROJECT LOCATION** Grand Junction, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	BH-1	0.6-1.0						
⧗	BH-1	1.0-10.0	**SILT with SAND (ML) (A-4)**	**34**	**25**	**9**		
▲	BH-2	0.5-5.5	**SILTY, CLAYEY GRAVEL with SAND (GC-GM) (A-4)**	**25**	**18**	**7**		
★	BH-2	5.5-10.0	**SANDY SILT (ML) (A-4)**	**28**	**23**	**5**		
⊙	BH-3	0.5-2.0	**SILTY GRAVEL with SAND (GM) (A-1-b)**	**NP**	**NP**	**NP**		

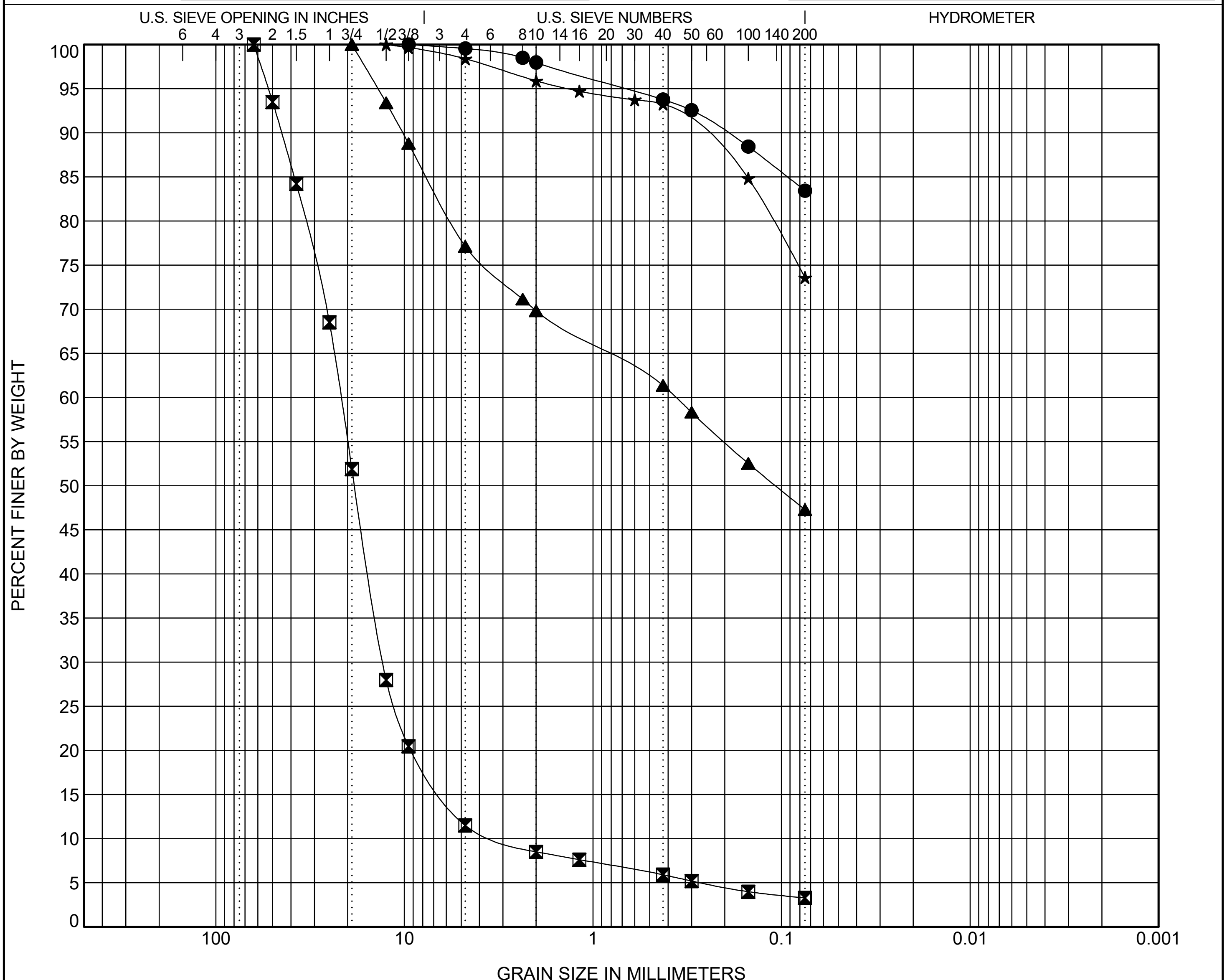
Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**BH-1**	**0.6-1.0**	**19**	**3.163**	**0.157**		**44.7**	**7.4**	**24.1**	**23.8**	
⧗	**BH-1**	**1.0-10.0**	**19**				**7.2**	**4.2**	**10.1**	**78.5**	
▲	**BH-2**	**0.5-5.5**	**50**	**1.224**			**37.7**	**7.2**	**6.3**	**48.8**	
★	**BH-2**	**5.5-10.0**	**19**				**9.8**	**4.4**	**18.7**	**67.1**	
⊙	**BH-3**	**0.5-2.0**	**19**	**5.476**	**0.346**		**56.3**	**11.4**	**16.0**	**16.4**	

GRADATION - STANDARD 599.76_HORIZON DR AND G RD ROUNDABOUT.GPJ ROCKSOL TEMPLATE.GDT 5/10/23

GRAIN SIZE DISTRIBUTION

RockSol

CLIENT City of Grand Junction
PROJECT NAME Horizon Drive and G Road Roundabout Investigation
PROJECT NUMBER 599.76
PROJECT LOCATION Grand Junction, Colorado



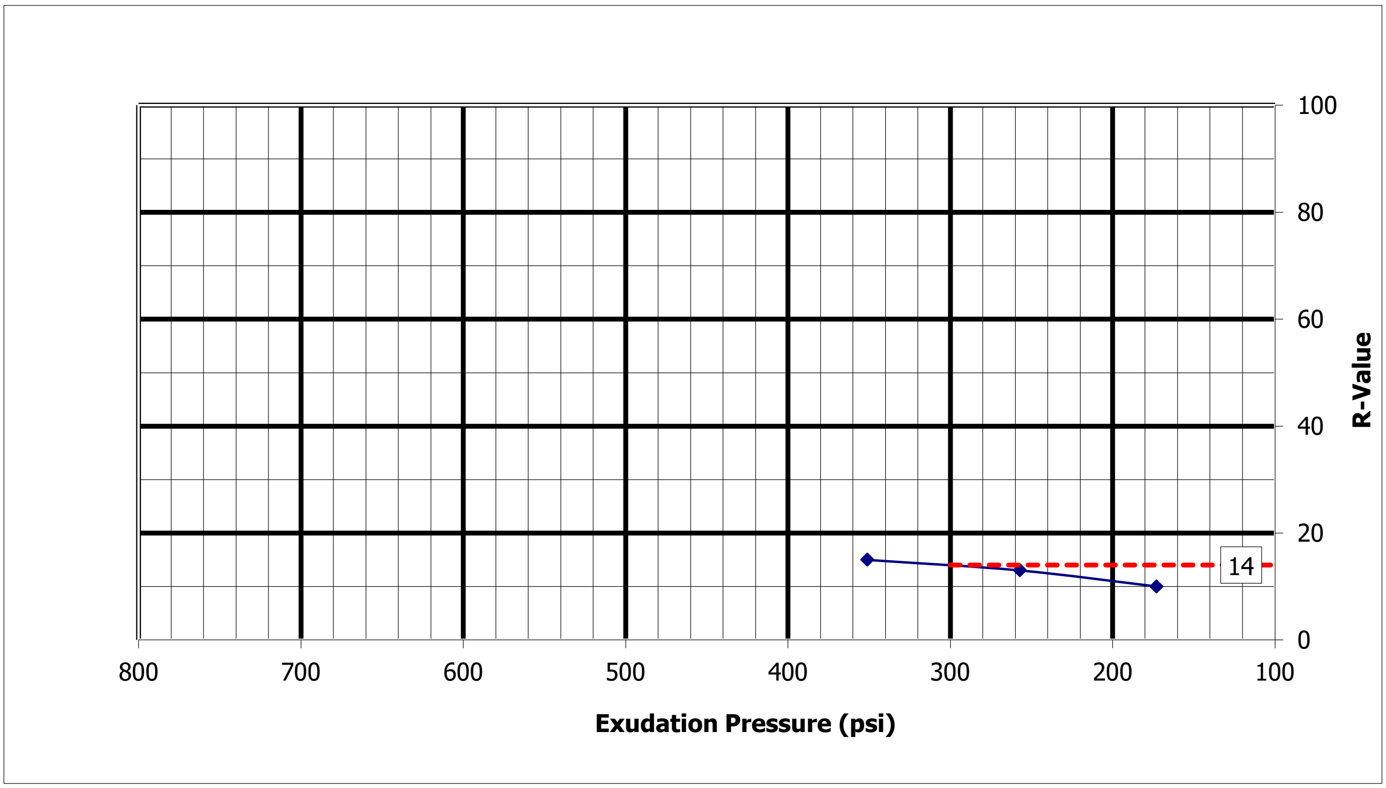
Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● BH-3	2.0-10.0	SILT with SAND (ML) (A-4)	34	27	7		
⧗ BH-4	0.5-3.0	WELL-GRADED GRAVEL (GW)				2.50	7.04
▲ BH-4	3.0-4.0	SILTY SAND with GRAVEL (SM) (A-4)	20	17	3		
★ BH-4	4.0-10.0	SILT with SAND (ML) (A-4)	29	24	5		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
● BH-3	2.0-10.0	9.5				2.0	4.2	10.3	83.4	
⧗ BH-4	0.5-3.0	63	21.726	12.952	3.088	91.5	2.6	2.6	3.3	
▲ BH-4	3.0-4.0	19	0.364			30.2	8.5	14.1	47.3	
★ BH-4	4.0-10.0	12.5				4.1	2.6	19.7	73.6	

GRADATION - STANDARD 599.76_HORIZON DR AND G RD ROUNDABOUT.GPJ ROCKSOL TEMPLATE.GDT 5/10/23

R-VALUE TEST GRAPH (ASTM D2844)

Project Number:	23.022, Rocksol Consulting	Date:	04/19/23
Project Name:	City of GJ Horizon and G (RockSol Project No. 599.76)	Technician:	J. De Los Santos
Lab ID Number:	232294	Reviewer:	G. Hoyos
Sample Location:	BH-3; west bound G Road Lt. Center Turn Lane at 2 to 10 feet (RockSol ID No. GJ 23-56)		
Visual Description:	CLAY, sandy, light brown		



R-Value @ Exudation Pressure 300 psi:	**14**
Specification:	

CDOT Pavement Design Manual, 2011.
Eq. 2.1 & 2.2, page 2-3.

$S_1 = [(R-5)/11.29]+3$ **S_1 = 3.80**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R = 4,060**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

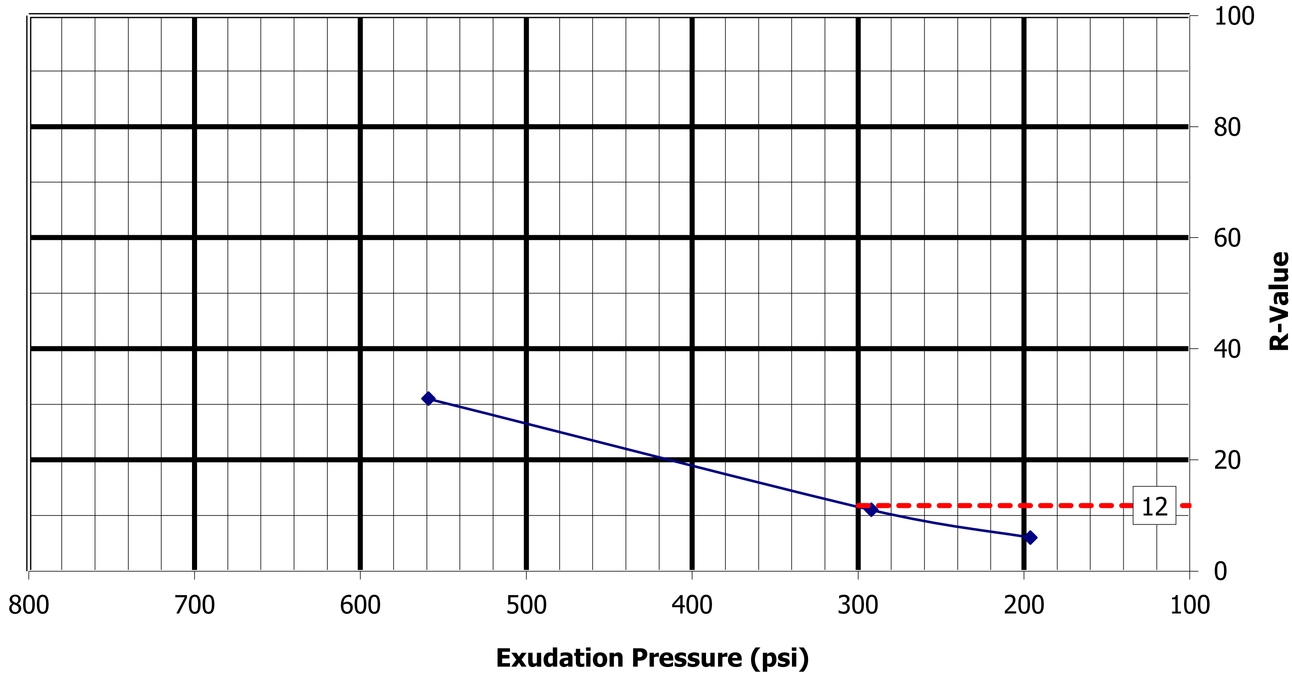
R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	17.1	18.8	21.4
Expansion Pressure, psi:	1.06	0.70	-0.09
Dry Density, pcf:	115.9	112.1	105.1
R-Value:	15	13	10
Exudation Pressure, psi:	351	257	173

Note: The R-Value is measured; the M_R is an approximation from correlation formulas.

R-VALUE TEST GRAPH (ASTM D2844)

Project Number:	23.022, Rocksol Consulting	Date:	04/21/23
Project Name:	City of GJ Horizon and G (RockSol Project No. 599.76)	Technician:	J. Holiman
Lab ID Number:	232295	Reviewer:	G. Hoyos
Sample Location:	BH-1; east bound G Road right turn lane 12 inches to 10 feet (RockSol ID No. GJ 23-54)		
Visual Description:	SAND, clayey, with gravel, light brown		



R-Value @ Exudation Pressure 300 psi:	**12**
Specification:	

CDOT Pavement Design Manual, 2011.
Eq. 2.1 & 2.2, page 2-3.

$S_1 = [(R-5)/11.29]+3$ **S_1 = 3.60**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R = 3,778**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	14.7	17.2	19.3
Expansion Pressure, psi:	4.91	0.76	0.06
Dry Density, pcf:	120.6	114.3	108.6
R-Value:	31	11	6
Exudation Pressure, psi:	559	292	196

Note: The R-Value is measured; the M_R is an approximation from correlation formulas.

APPENDIX D

G ROAD

20 AND 30-YEAR DESIGN LIFE FOR FLEXIBLE PAVEMENT

M-E DESIGN OUTPUT SHEETS

G Road HMA (64-22) Design

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\G Road HMA (64-22) Design.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	5.0
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

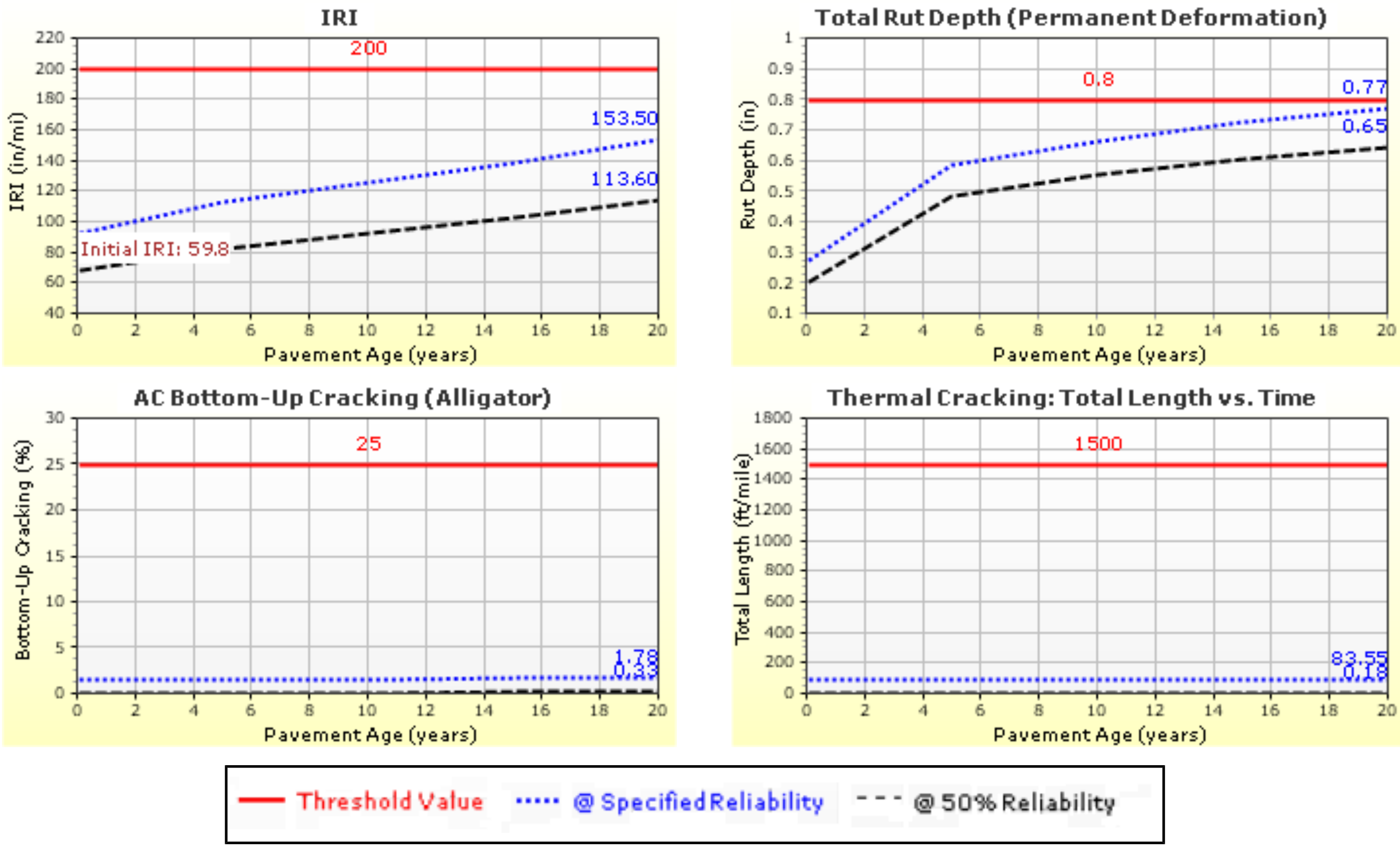
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	890
2034 (10 years)	2,135,670
2044 (20 years)	4,739,040

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	153.45	90.00	99.73	Pass
Permanent deformation - total pavement (in)	0.80	0.77	90.00	93.94	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.78	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.55	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	266.28	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.15	90.00	100.00	Pass

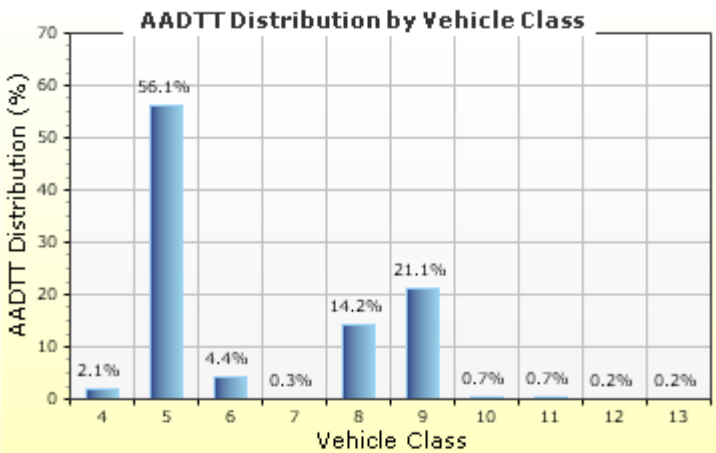
Distress Charts

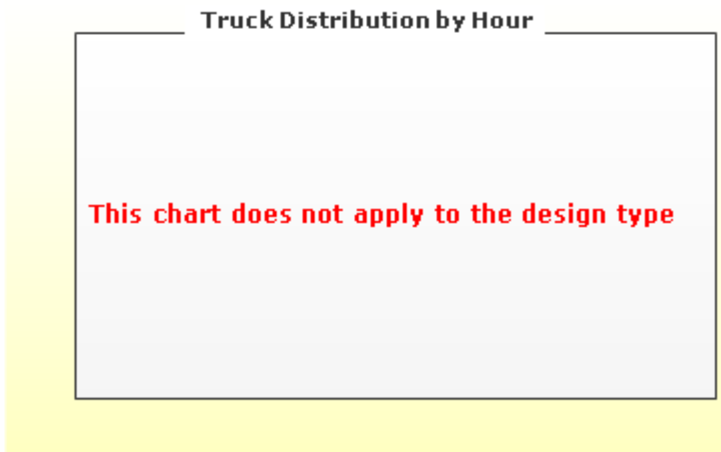


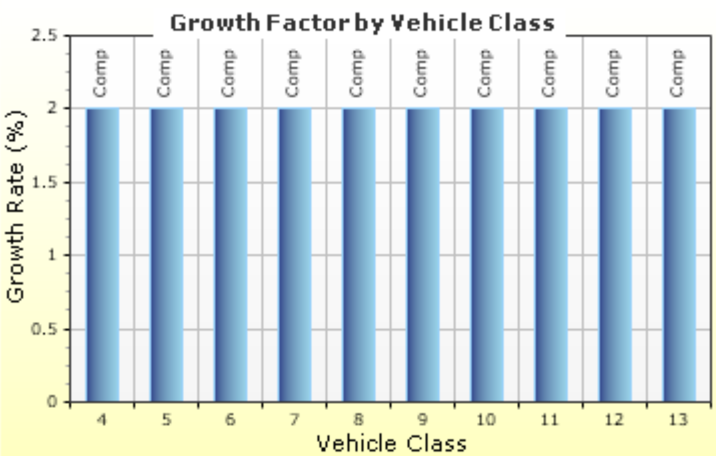
Traffic Inputs

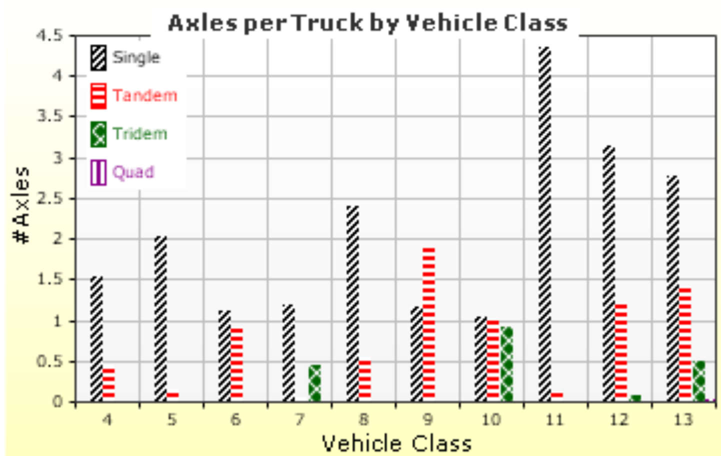
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	890	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

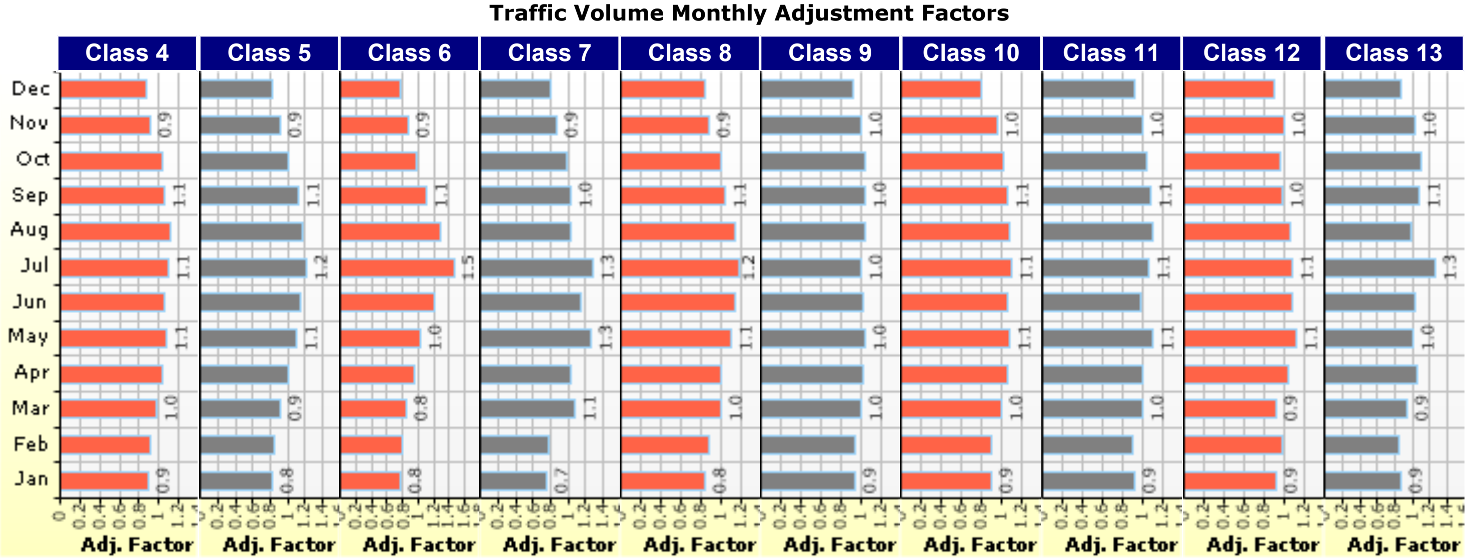








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

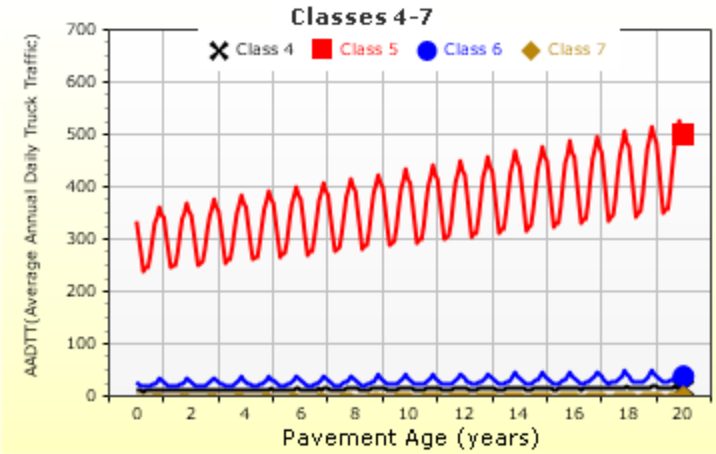
Wheelbase does not apply

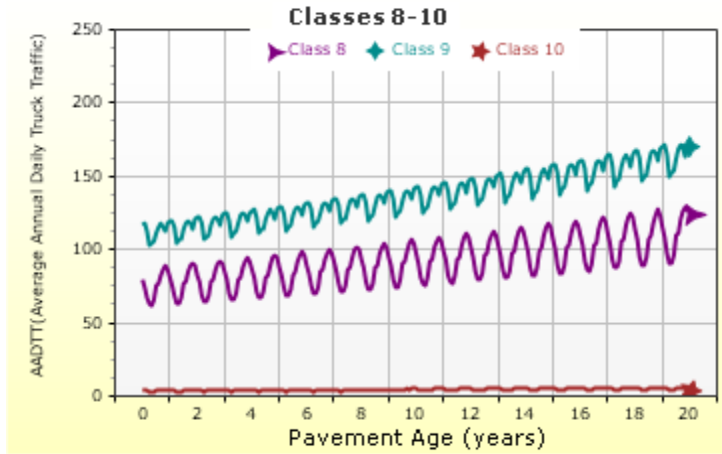
Number of Axles per Truck

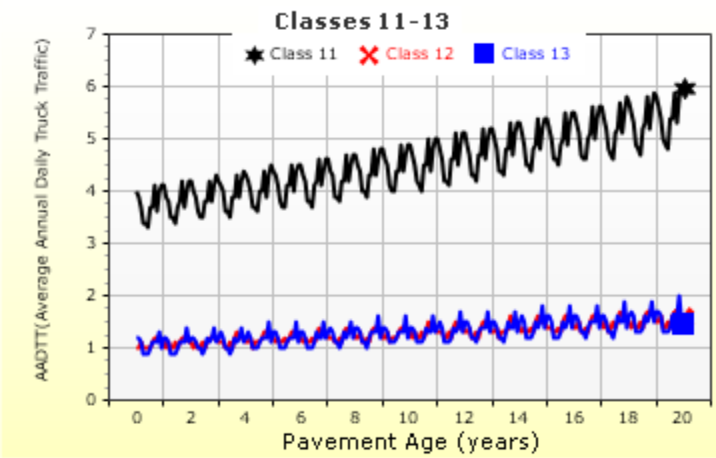
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

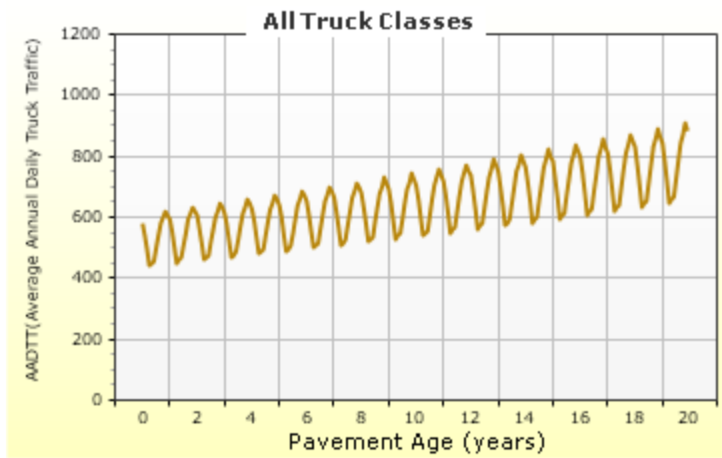
AADTT (Average Annual Daily Truck Traffic) Growth

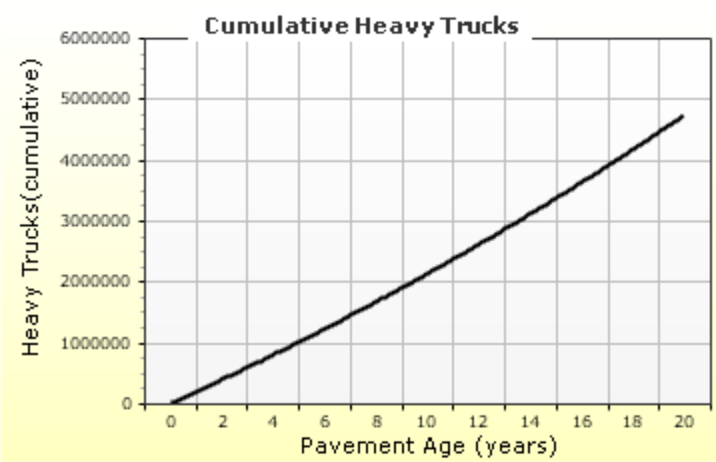
*** Traffic cap is not enforced**







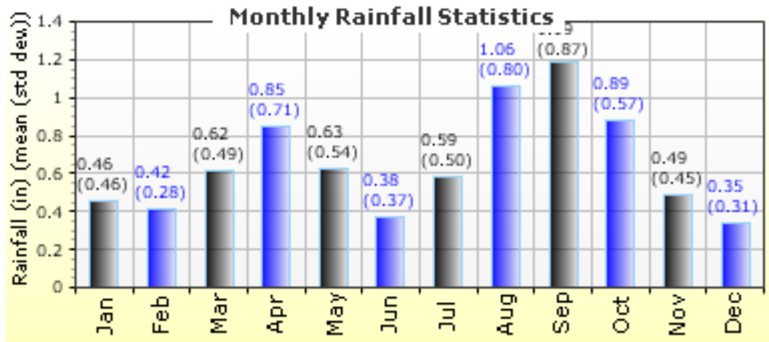




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

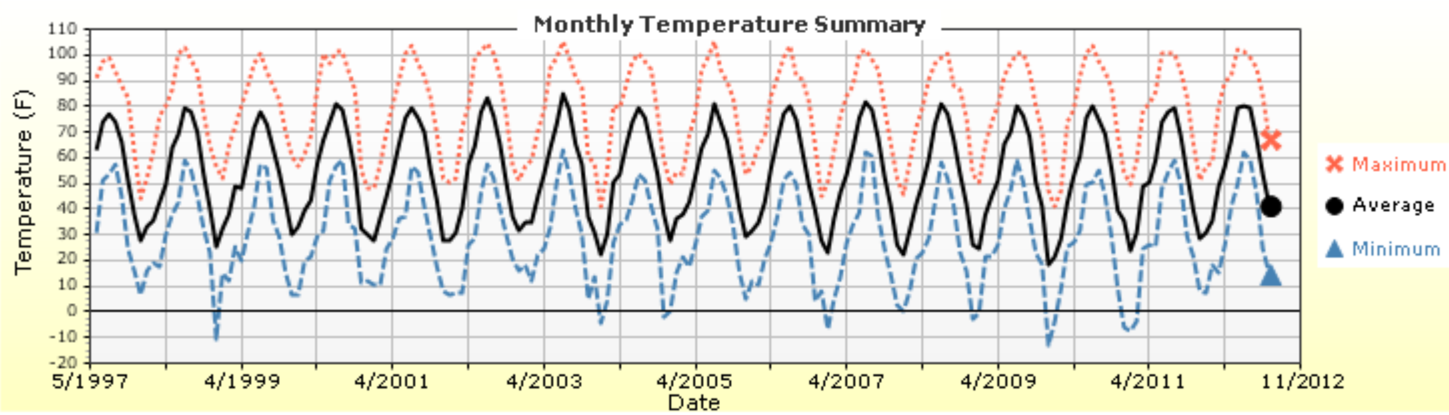


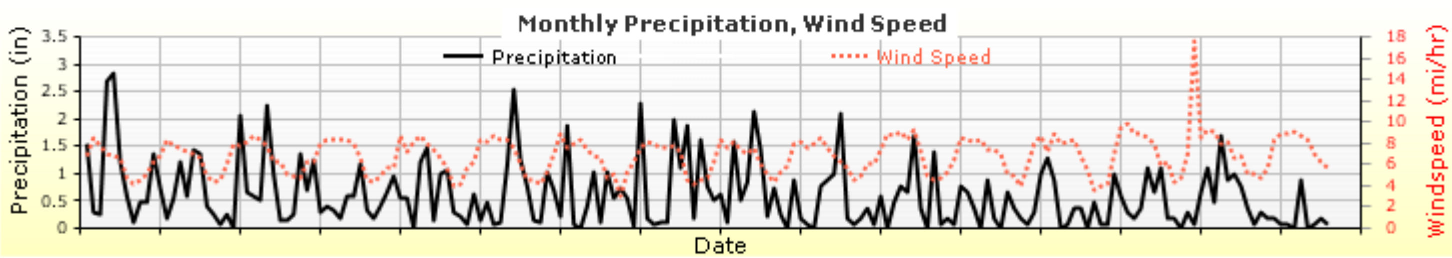
Annual Statistics:

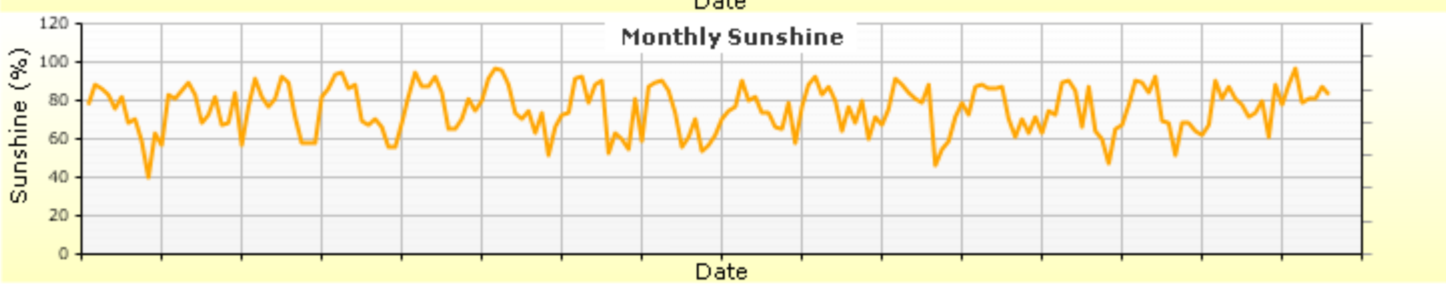
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

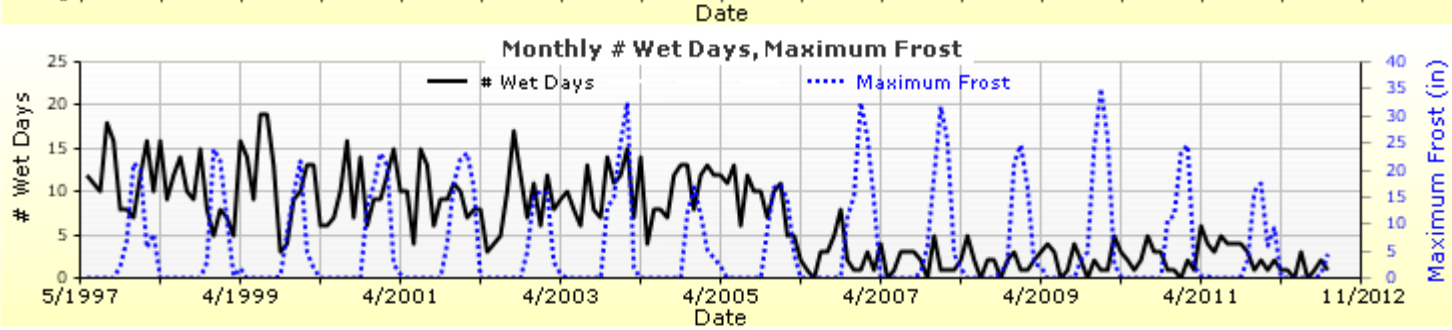
Water table depth (ft) 4.00

Monthly Climate Summary:

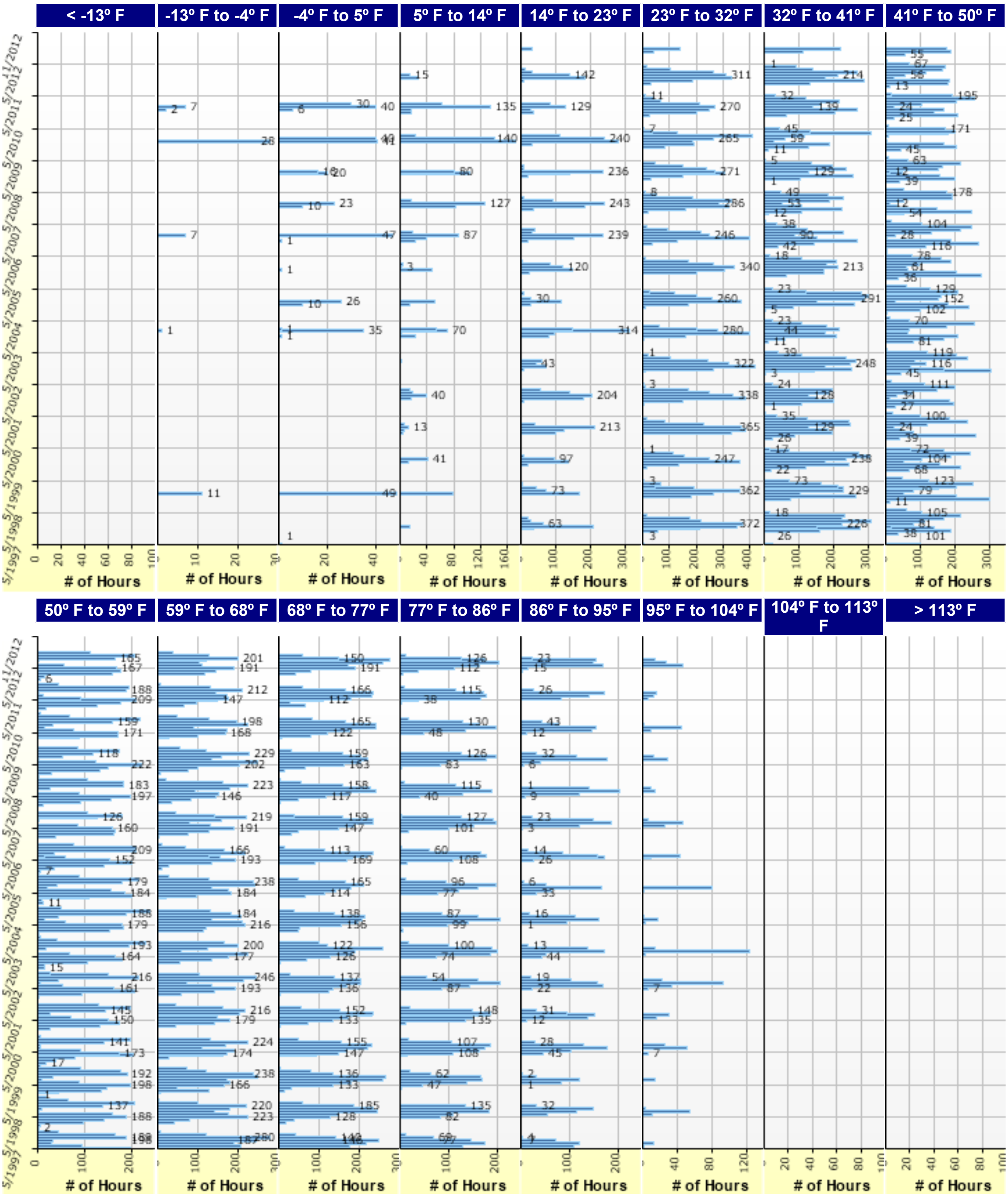








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

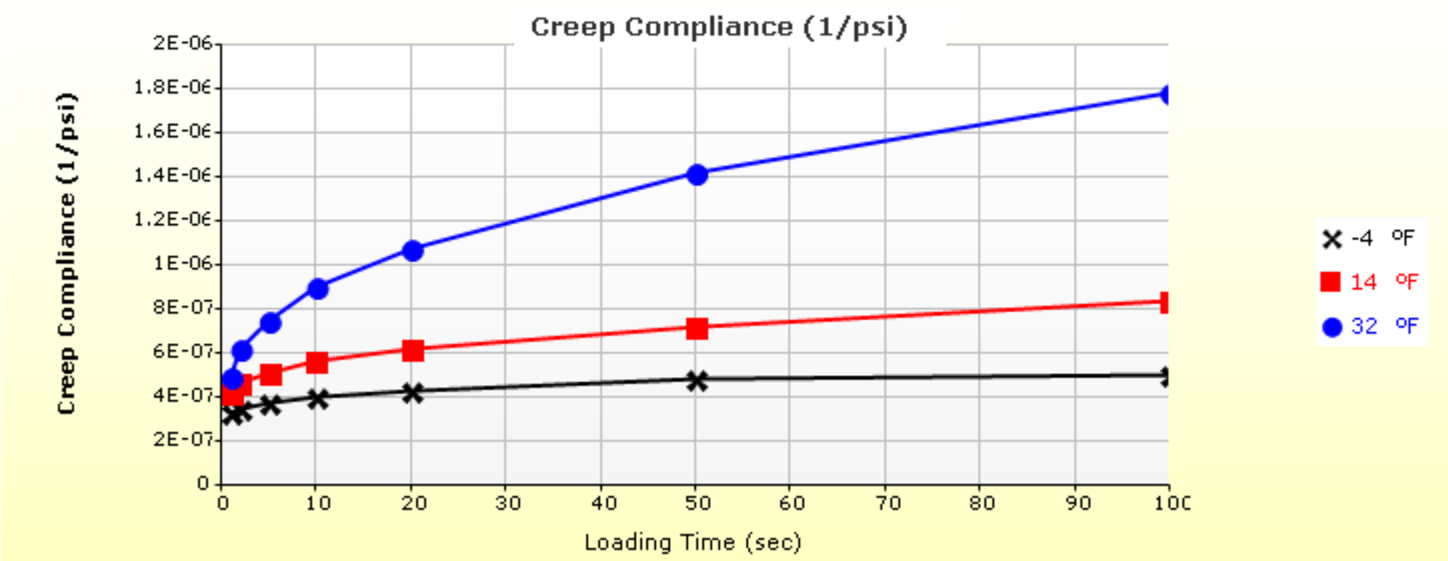
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

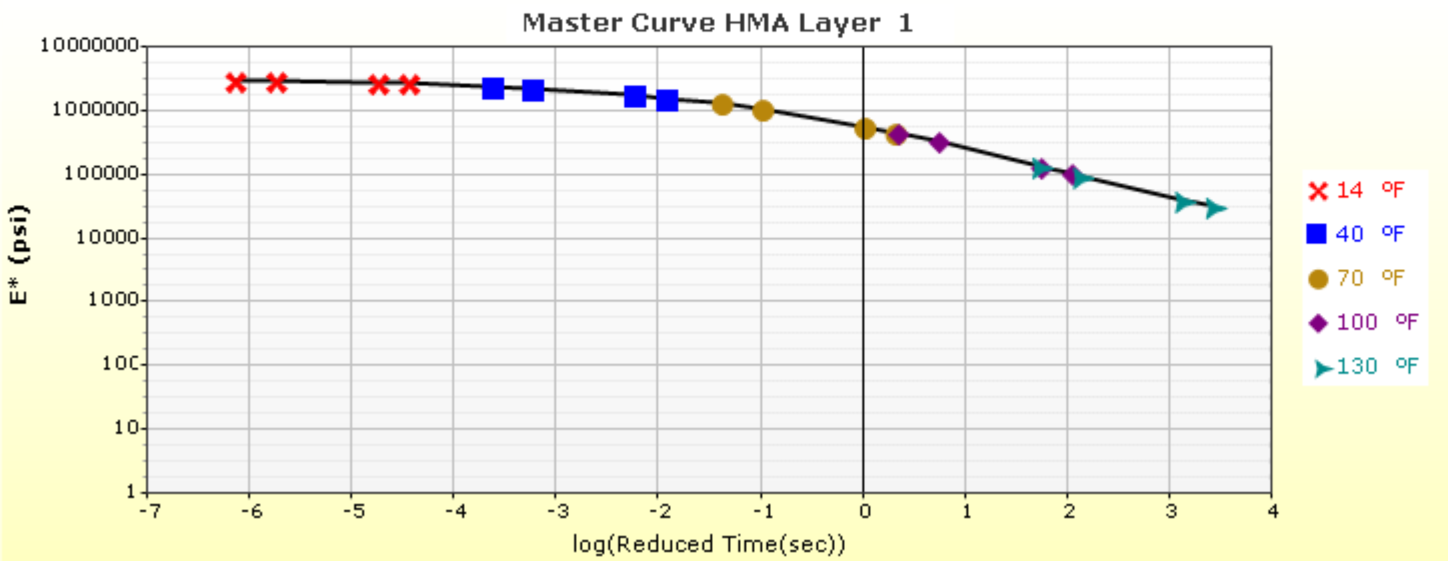
Indirect tensile strength at 14 ºF (psi)	451.00

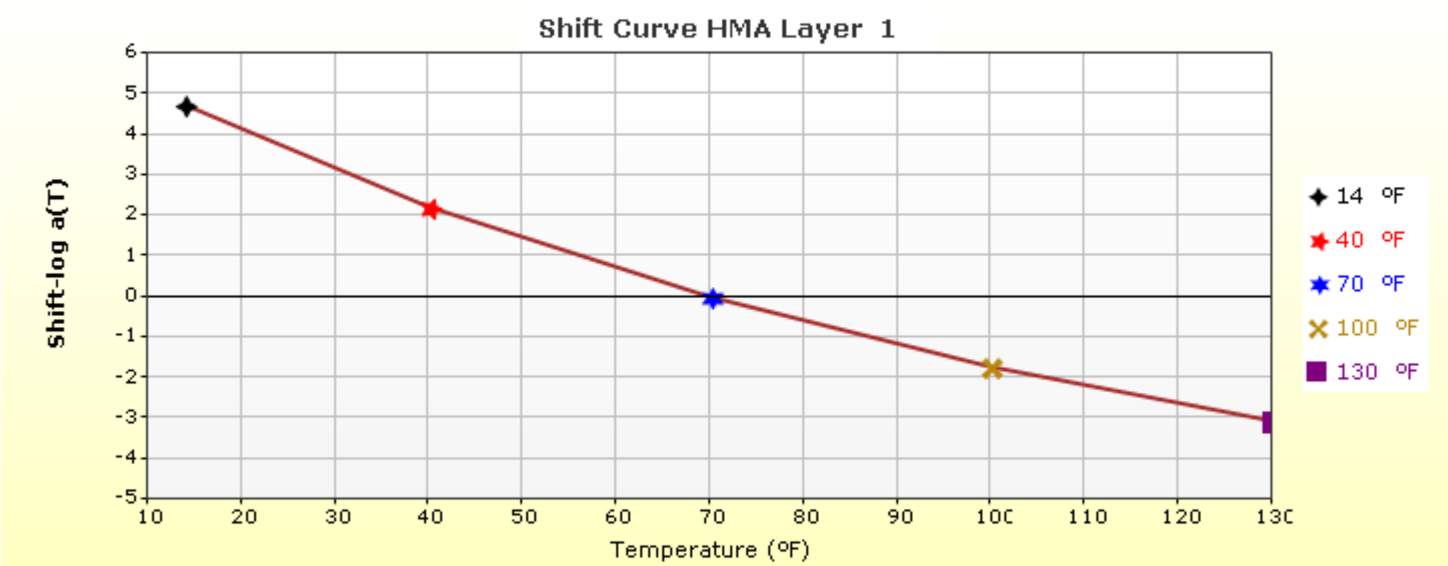
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

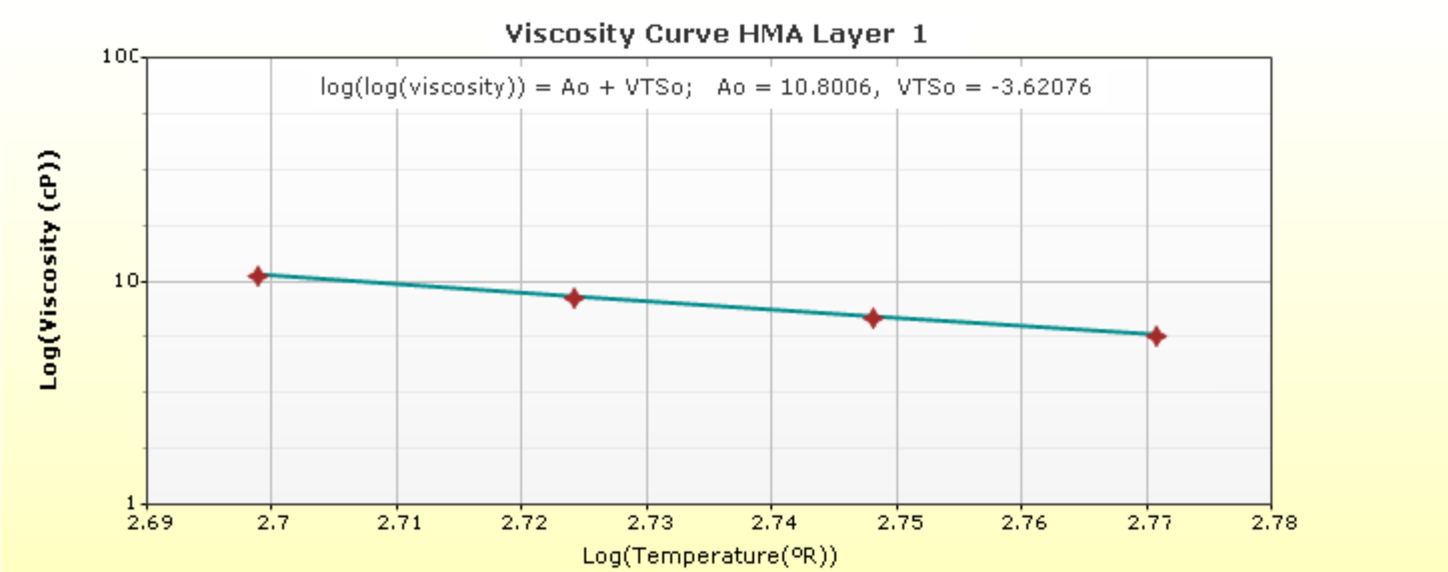
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



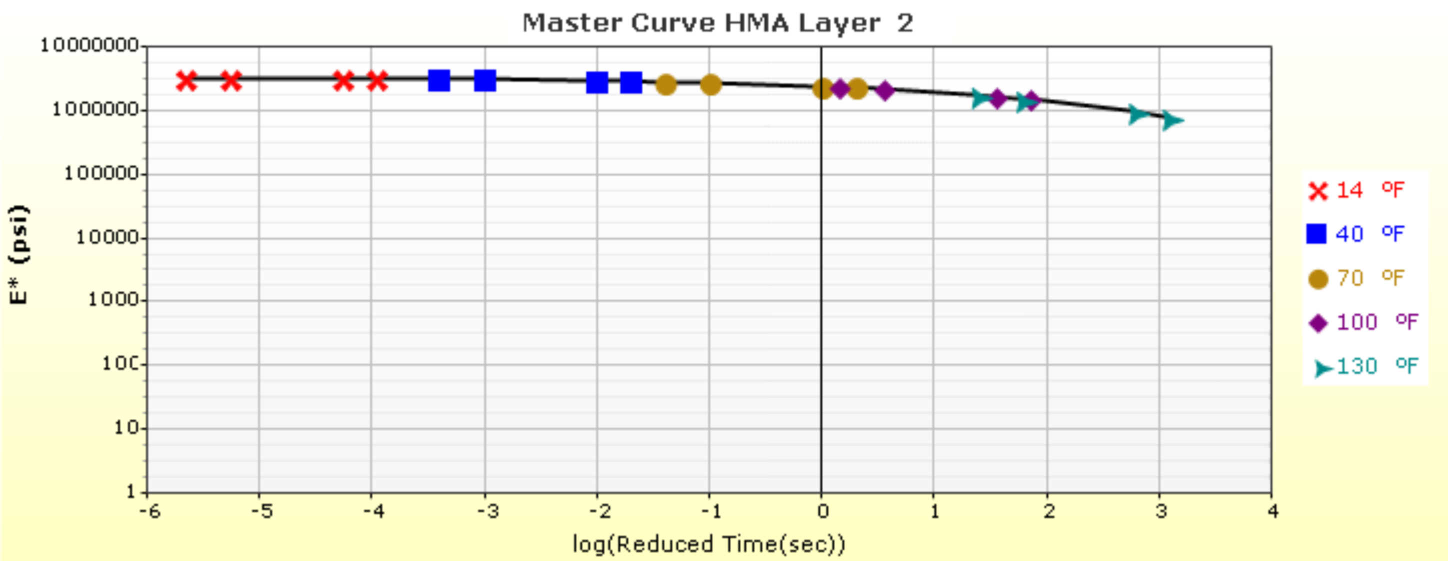
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

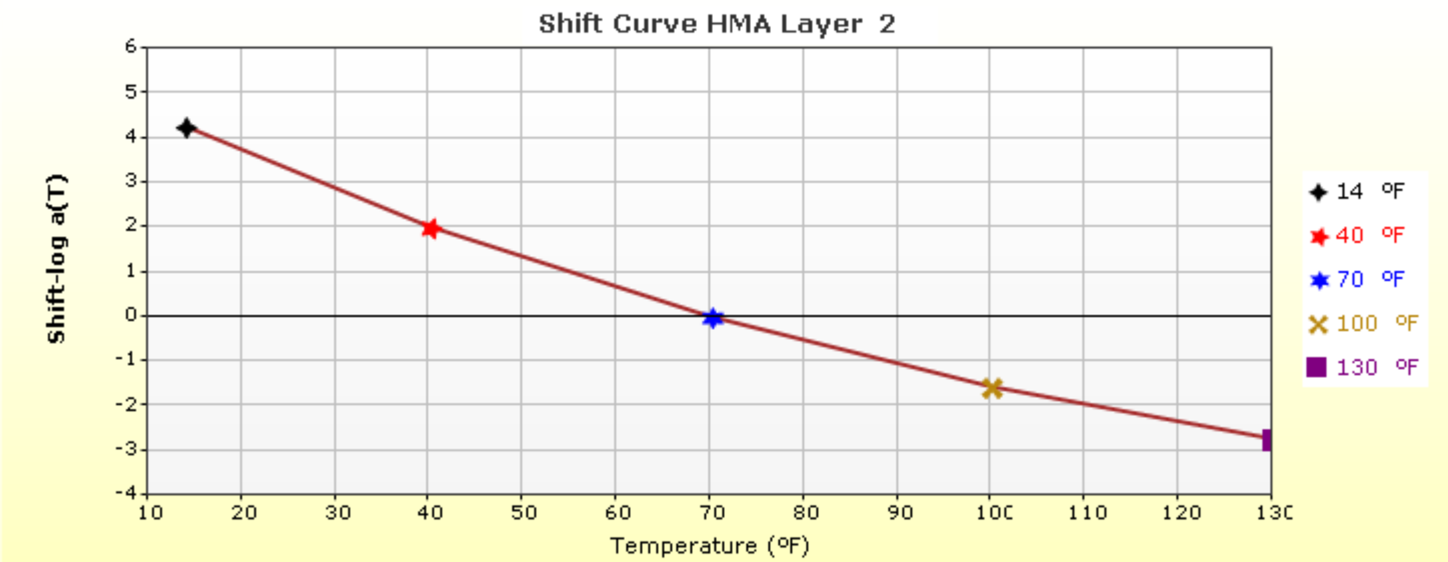


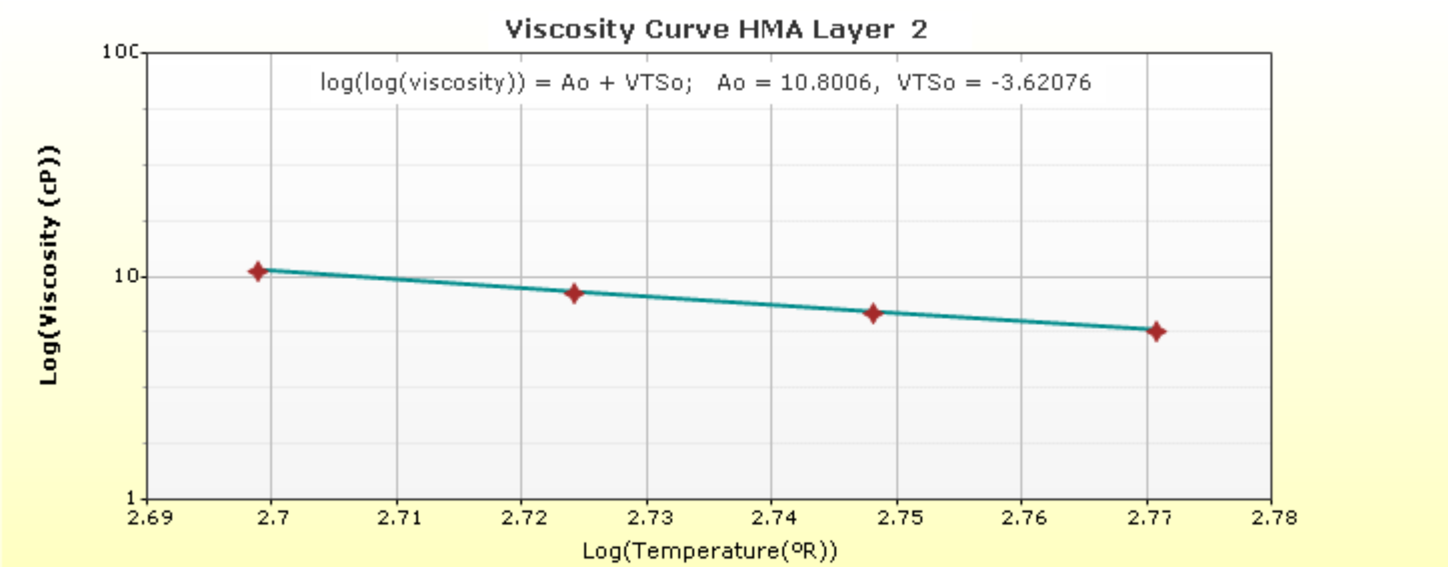




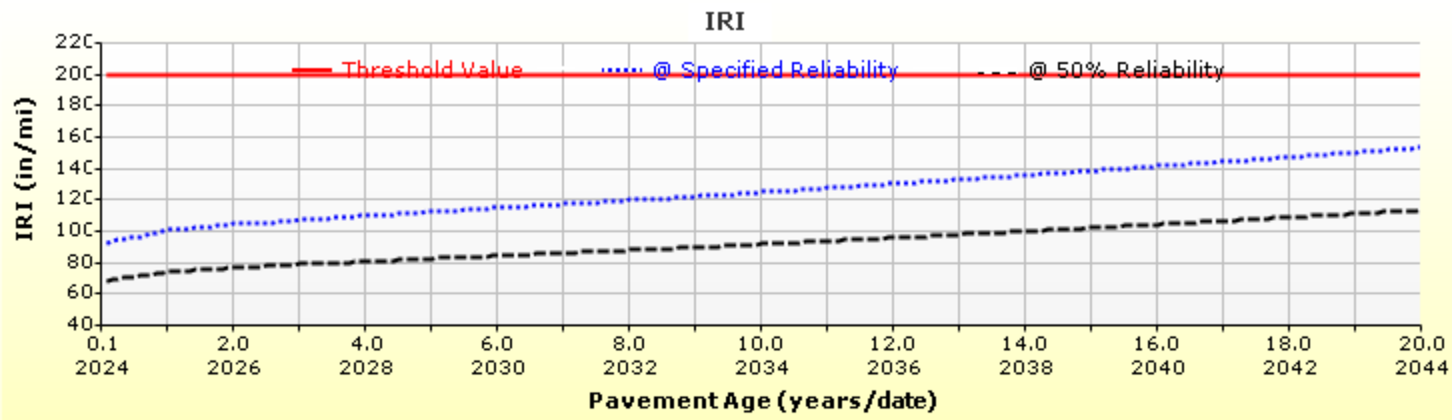
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

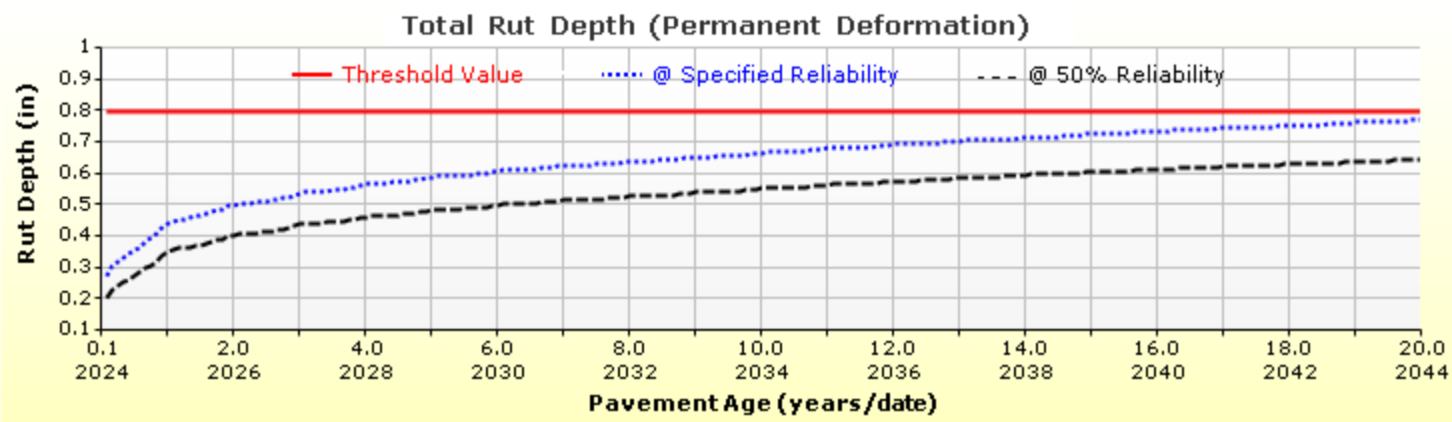


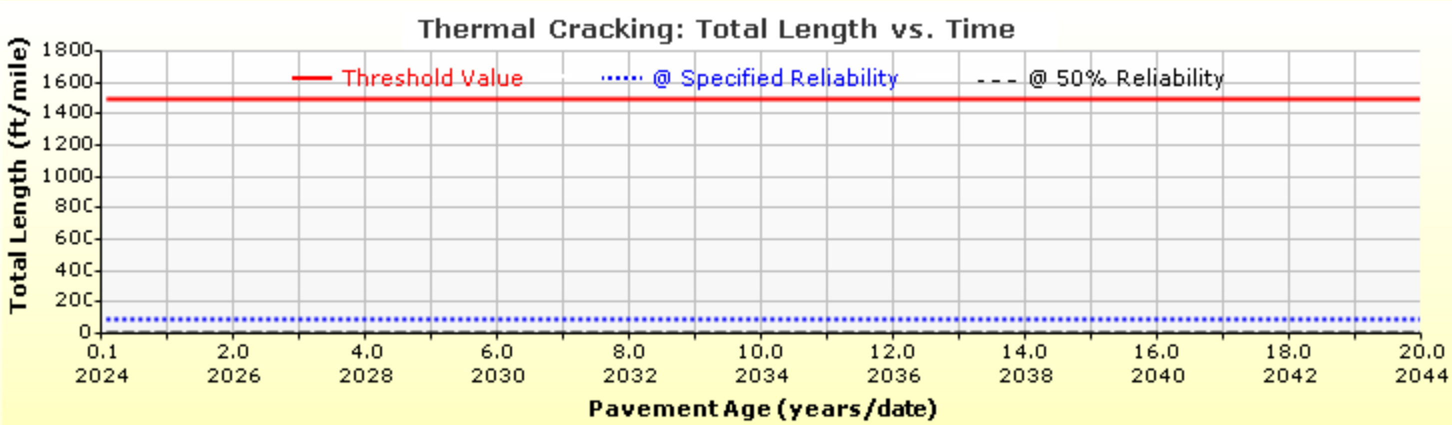


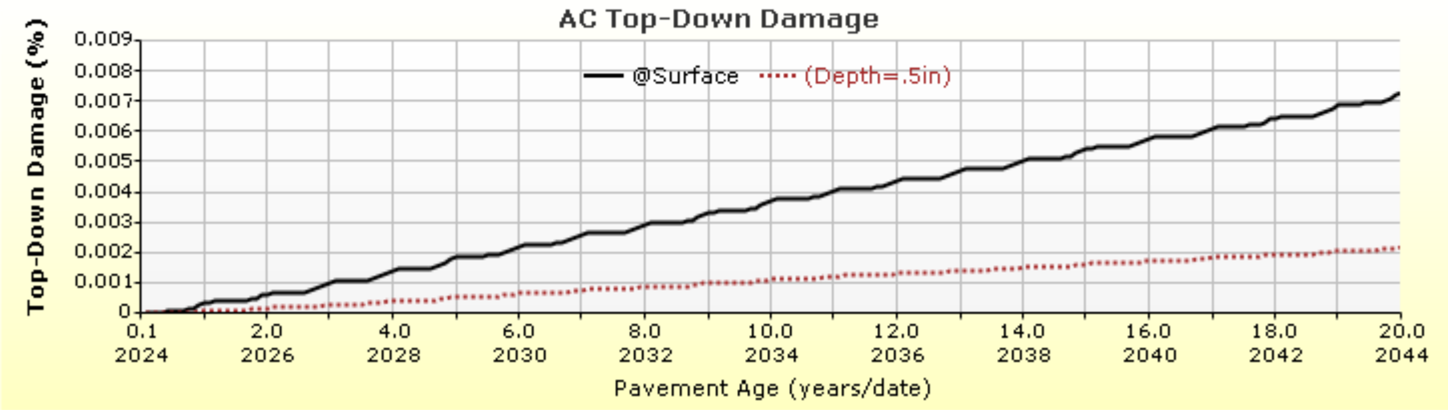


Analysis Output Charts

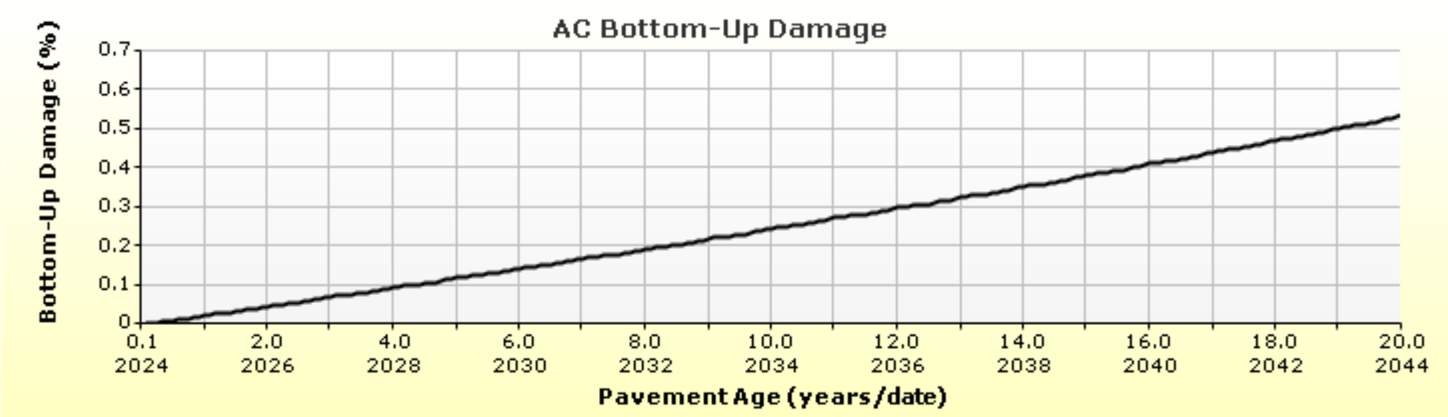




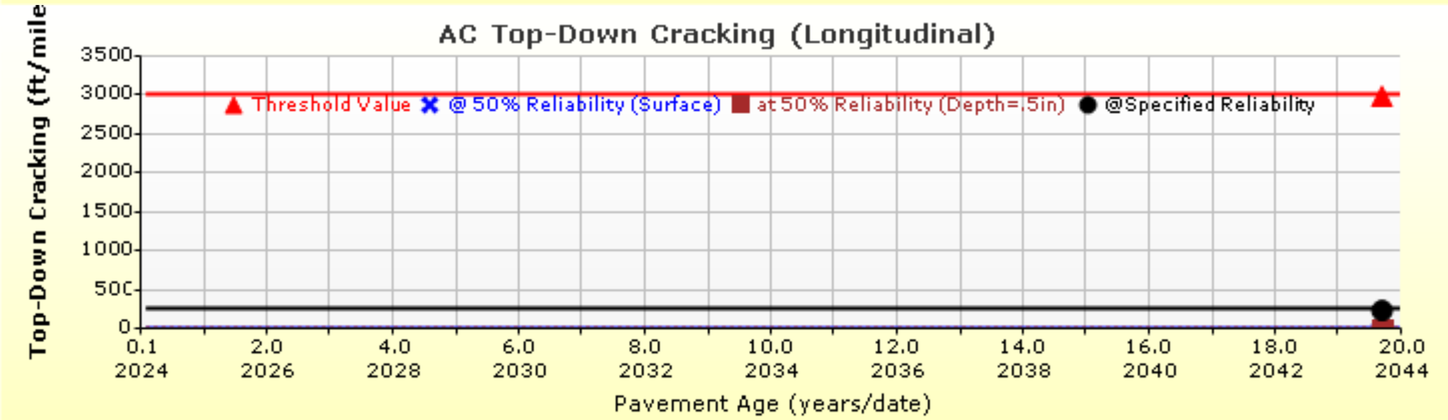




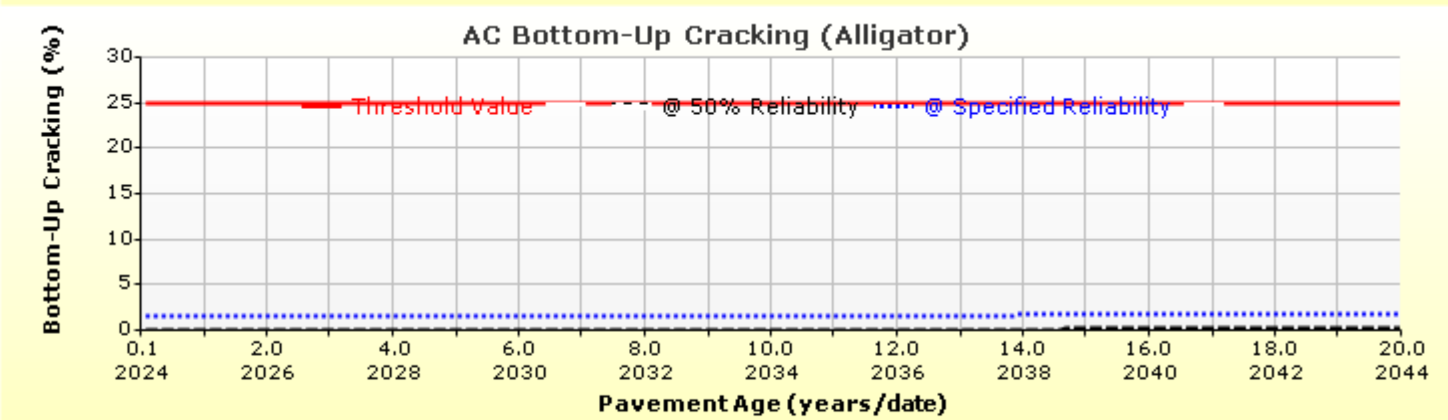
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



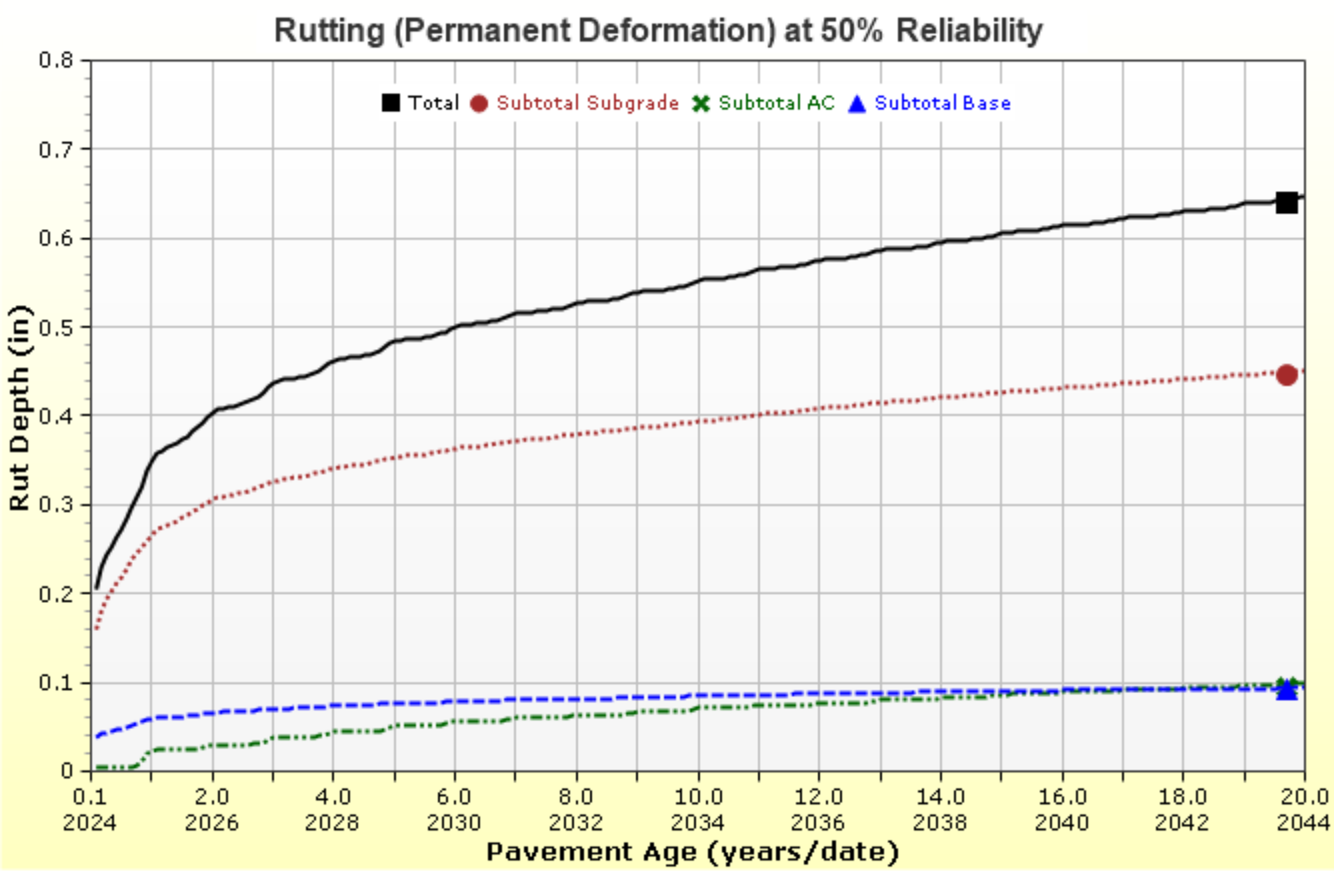
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



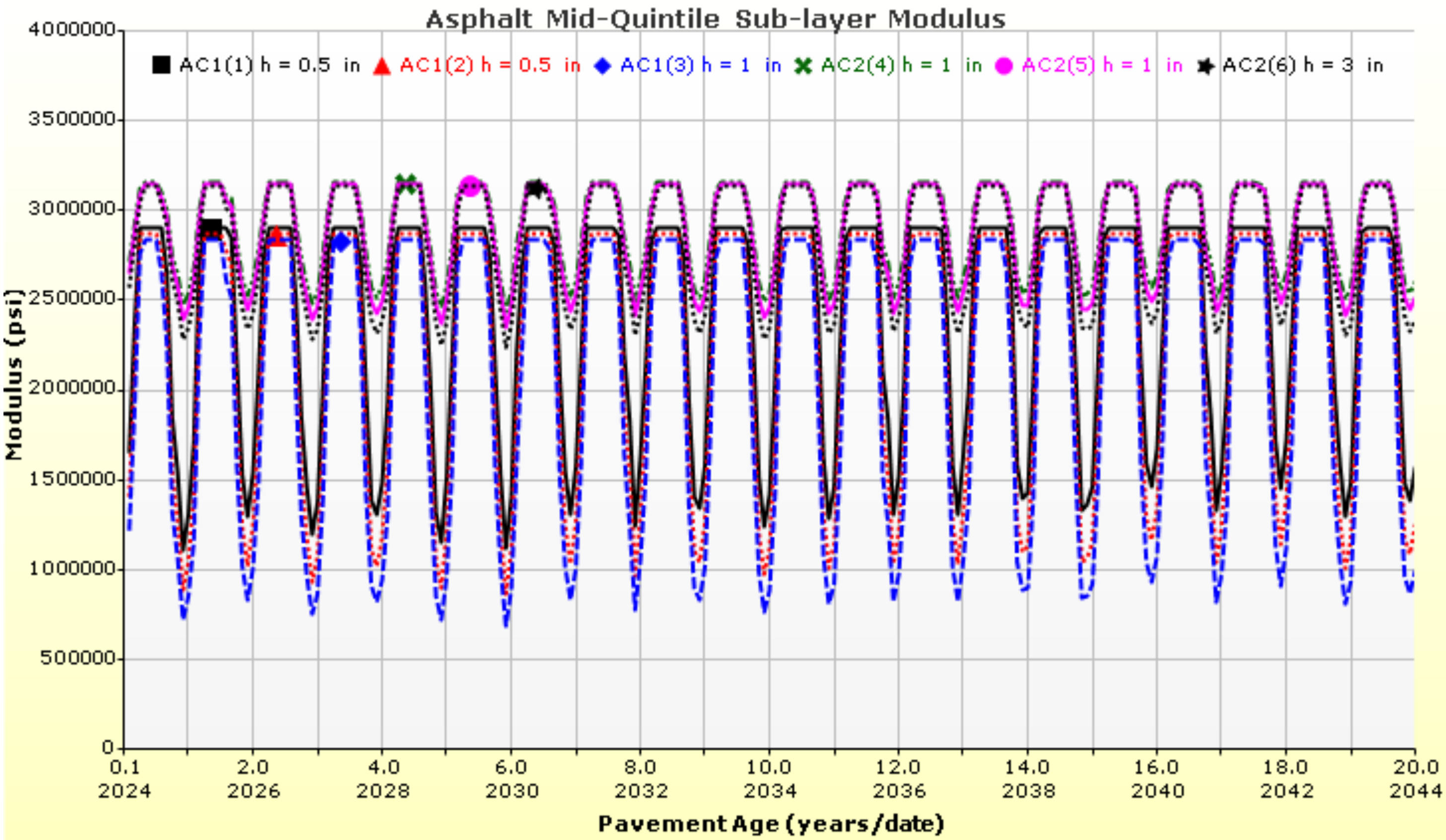
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)



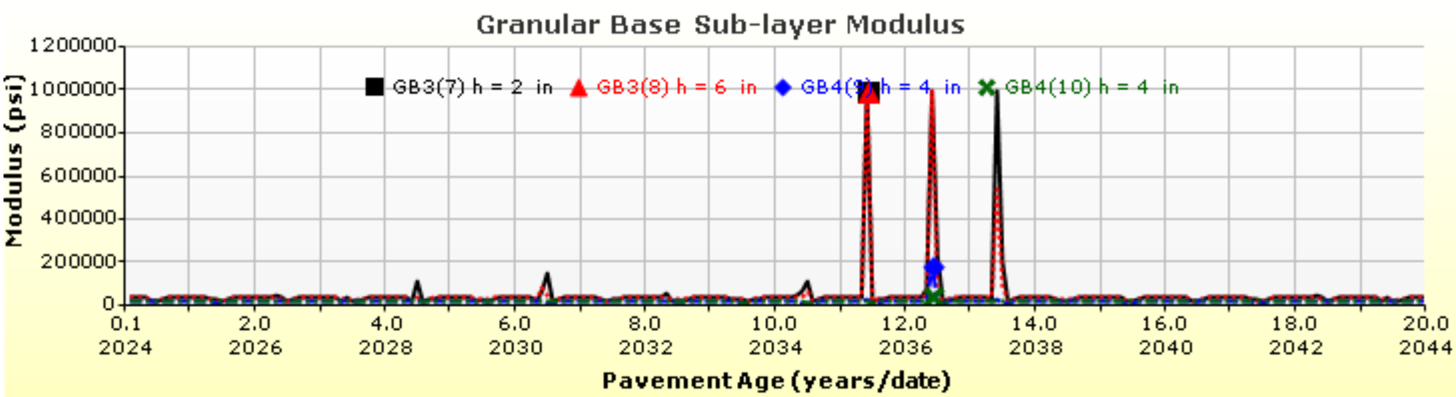
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



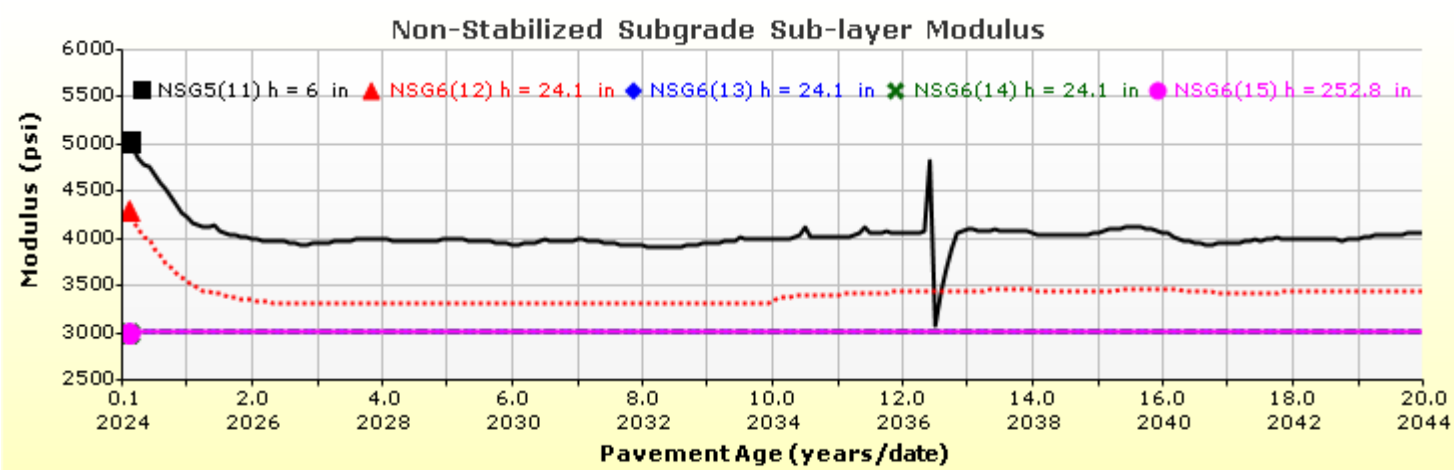
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 3 in
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 6 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 6 in
NSG6(12) h = 24.1 in
NSG6(13) h = 24.1 in
NSG6(14) h = 24.1 in
NSG6(15) h = 252.8 in
Modulus (psi)
6000
5500
5000
4500
4000
3500
3000
2500
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 1
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$
$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$
$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at( )
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1+e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

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	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	6.0
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

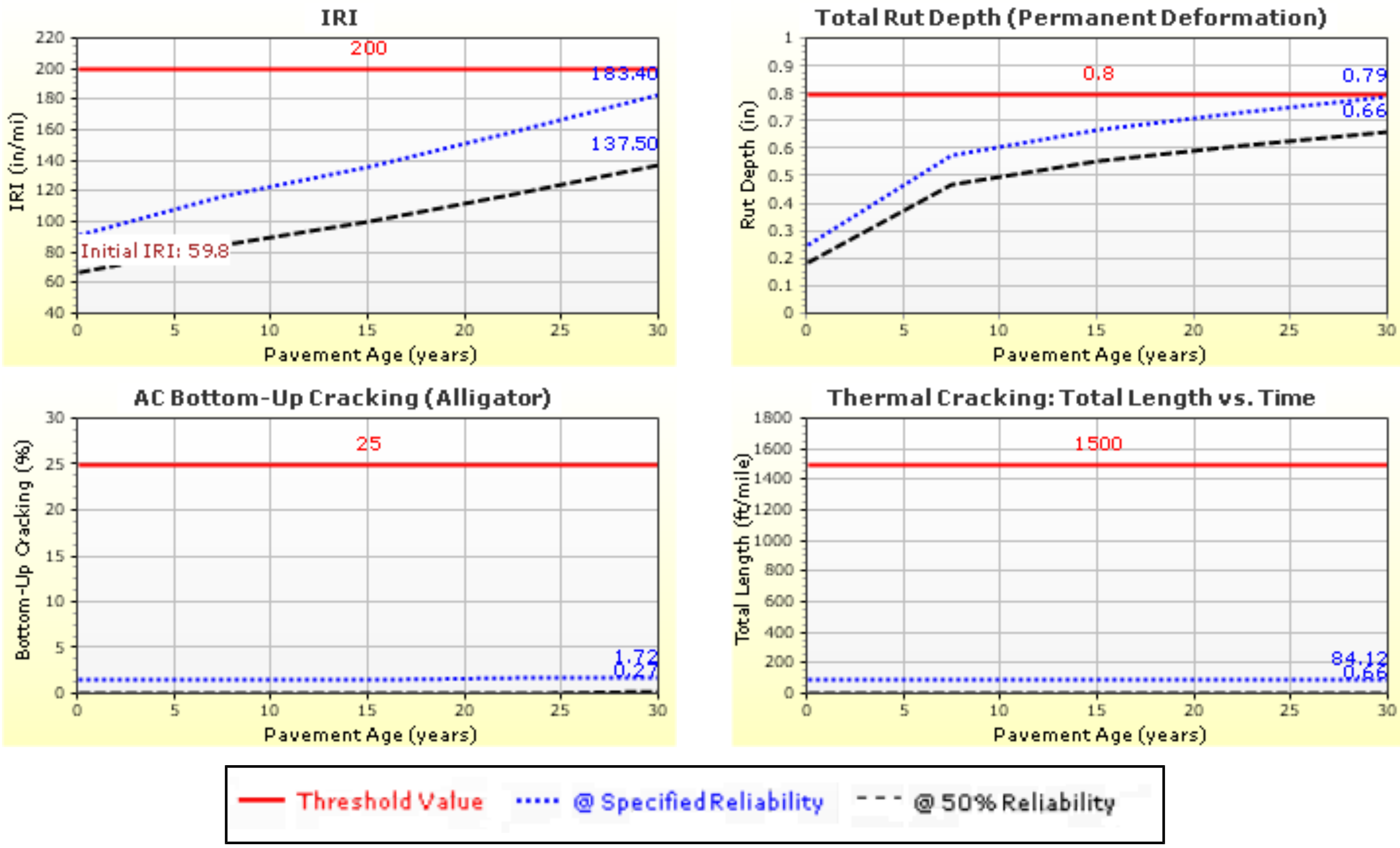
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	890
2039 (15 years)	3,372,970
2054 (30 years)	7,912,540

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	183.40	90.00	95.95	Pass
Permanent deformation - total pavement (in)	0.80	0.79	90.00	91.78	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.72	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	84.12	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	259.35	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.19	90.00	100.00	Pass

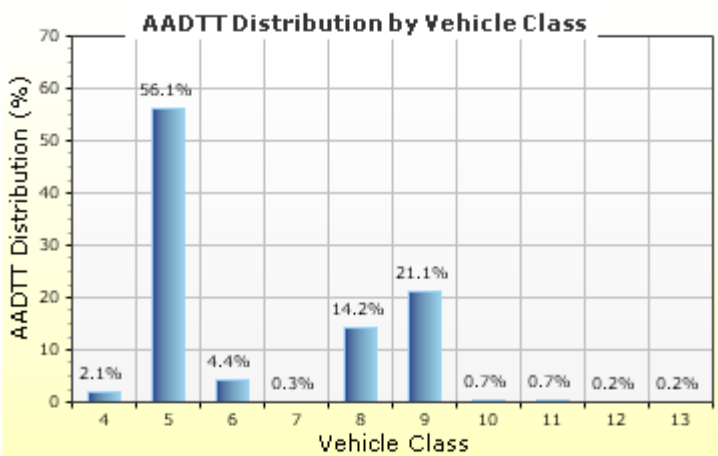
Distress Charts

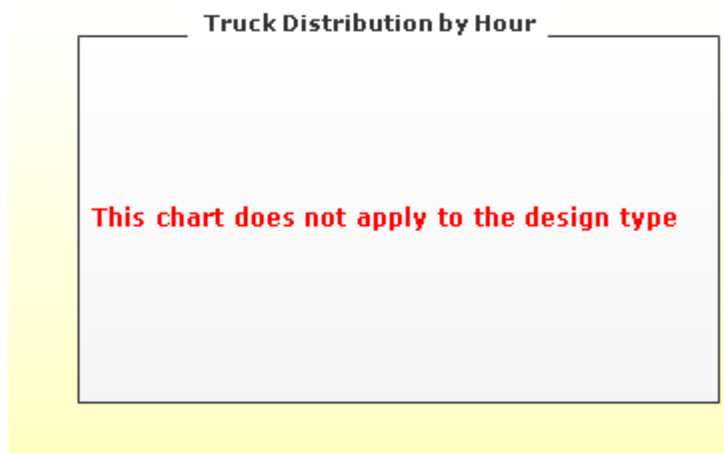


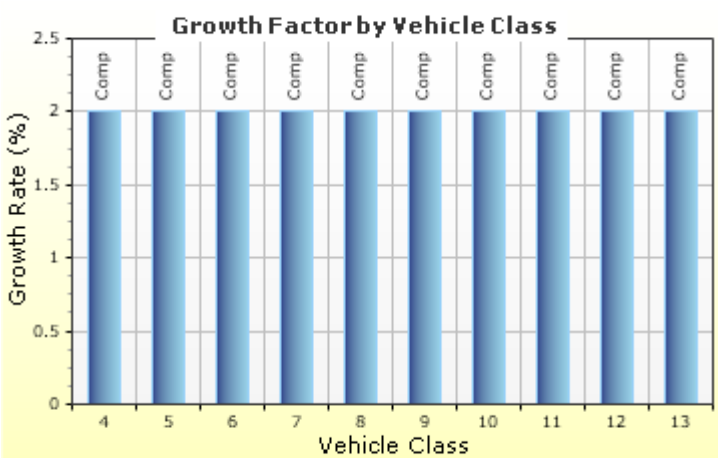
Traffic Inputs

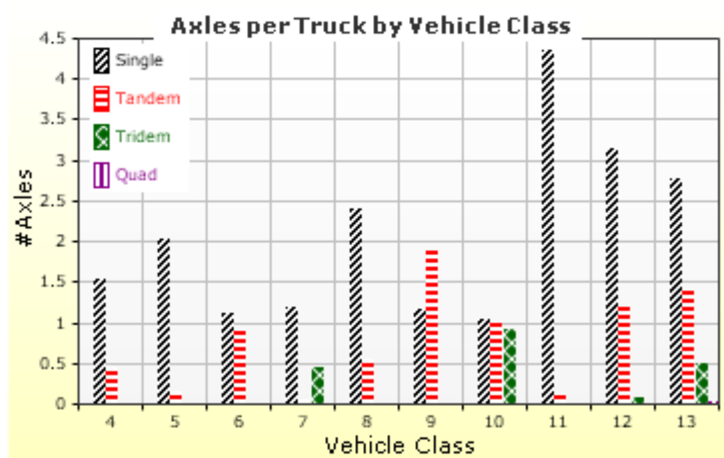
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	890	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

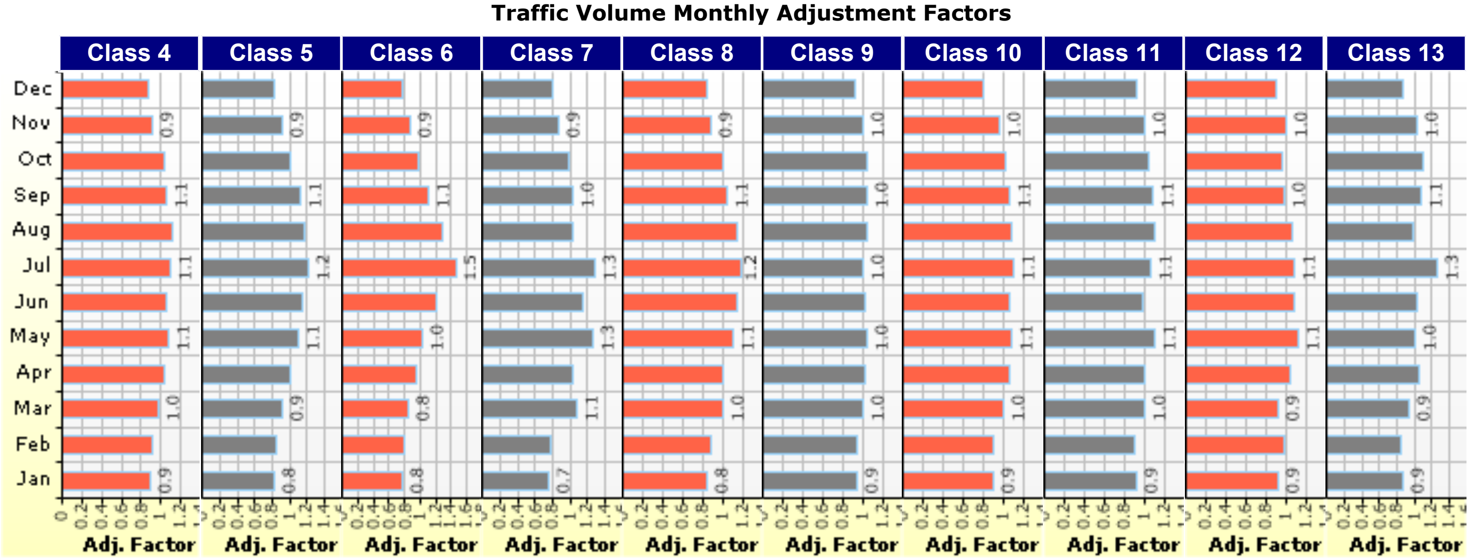








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

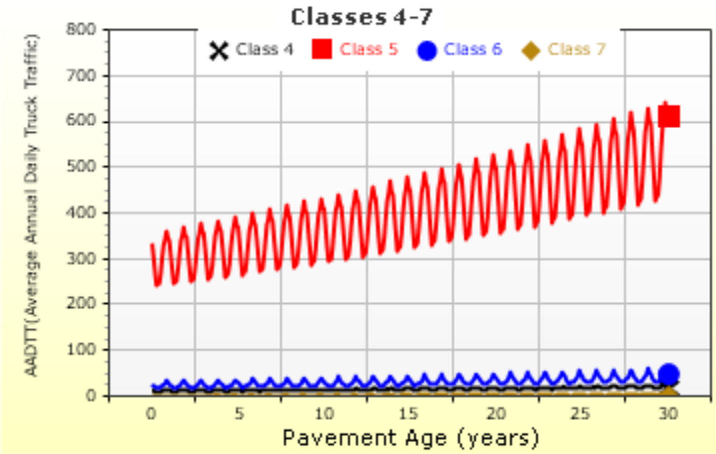
Wheelbase does not apply

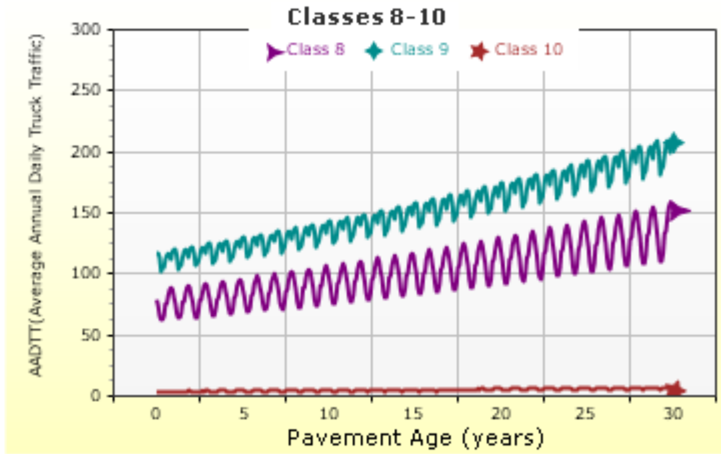
Number of Axles per Truck

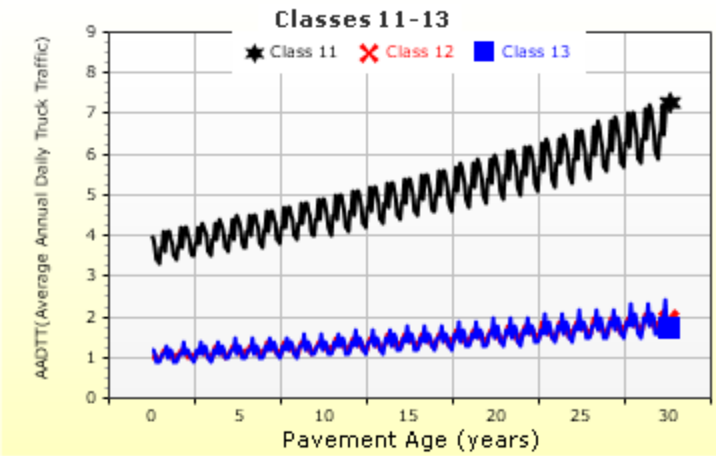
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

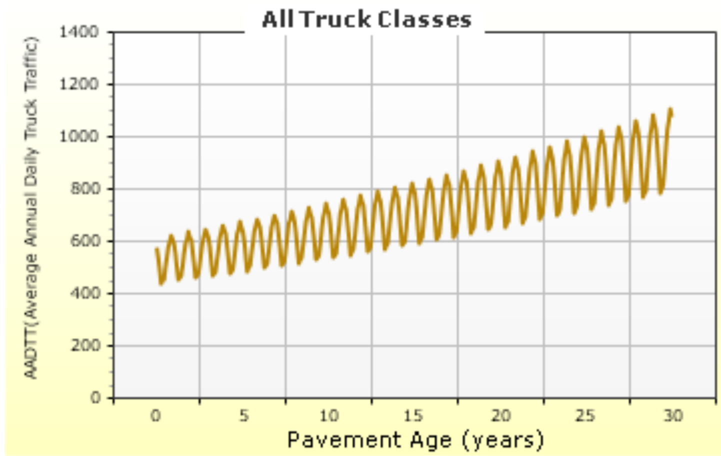
AADTT (Average Annual Daily Truck Traffic) Growth

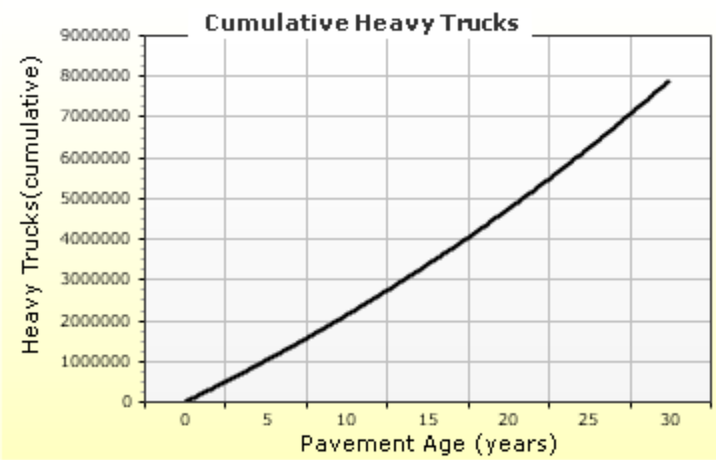
*** Traffic cap is not enforced**







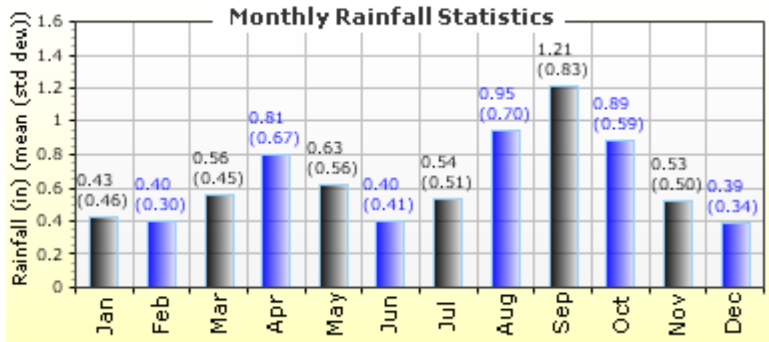




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

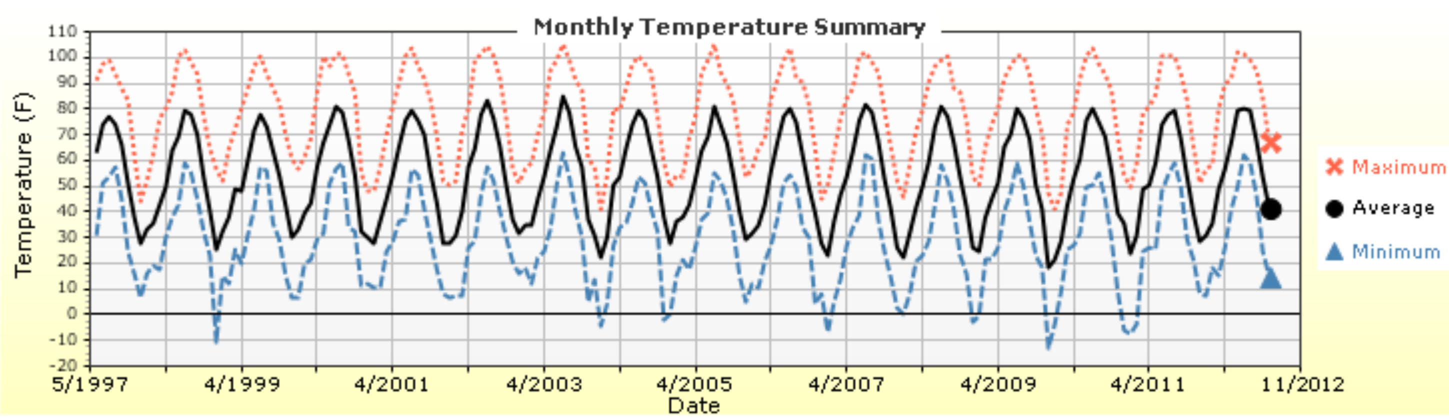


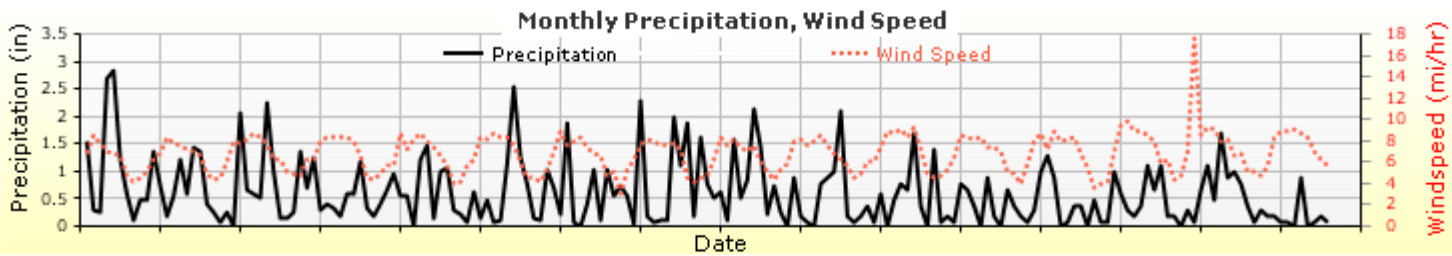
Annual Statistics:

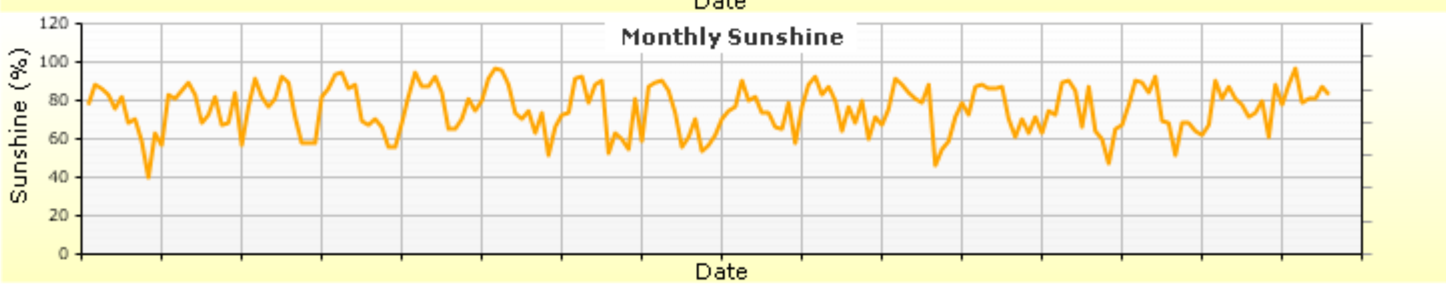
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

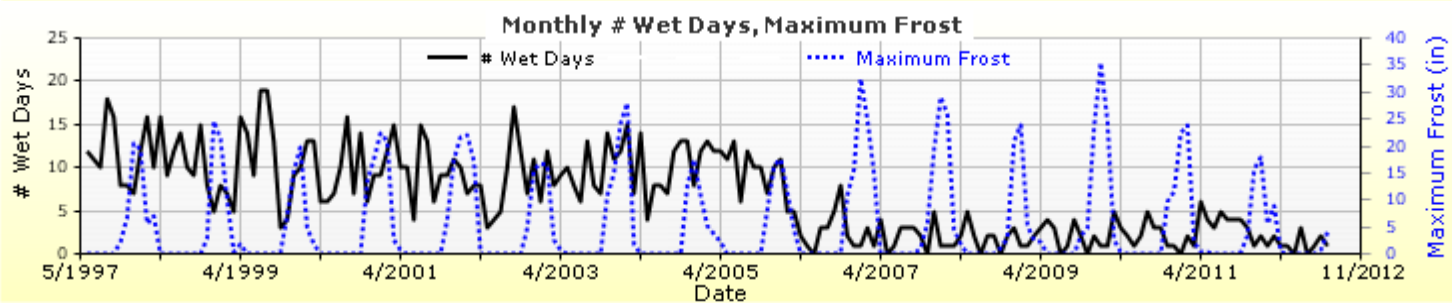
Water table depth (ft) 4.00

Monthly Climate Summary:

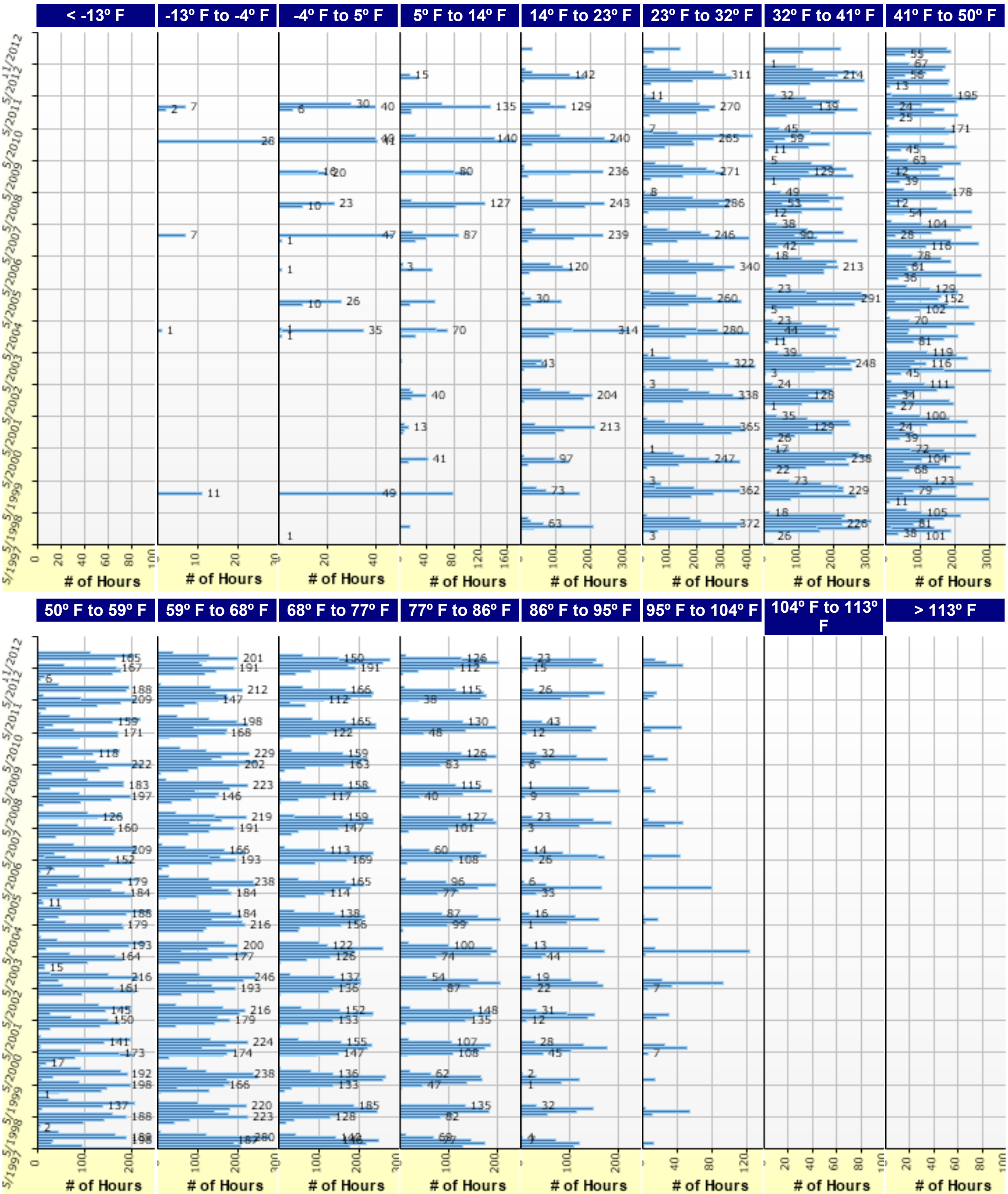








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

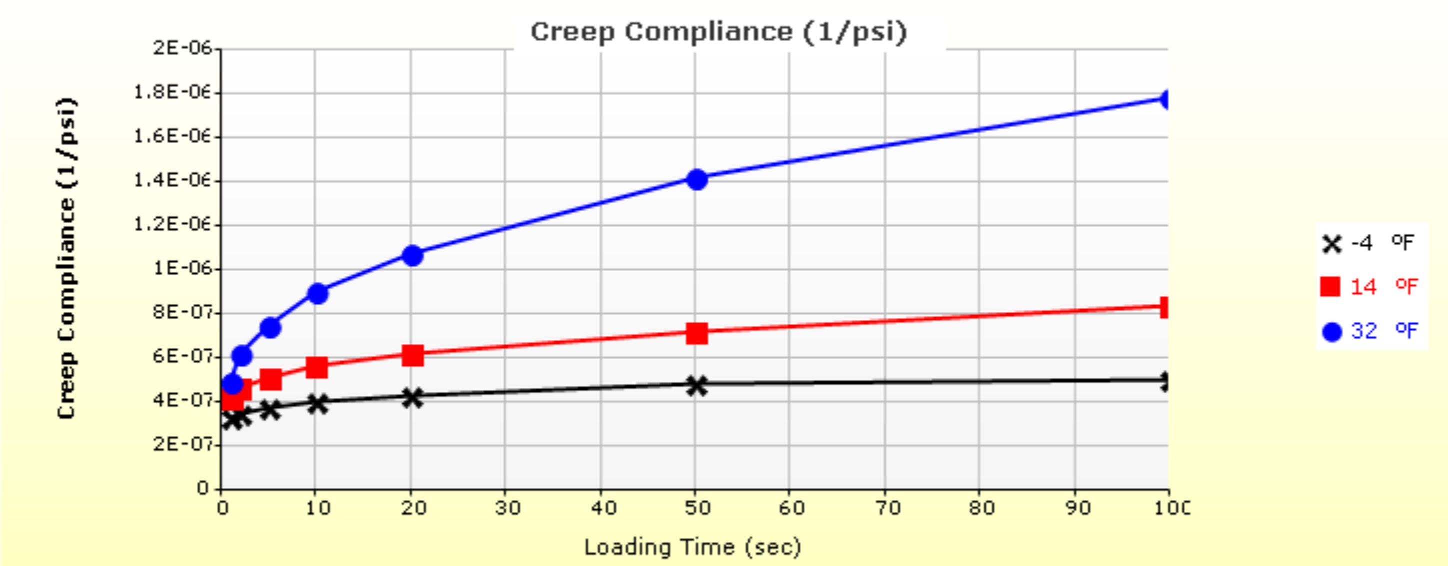
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

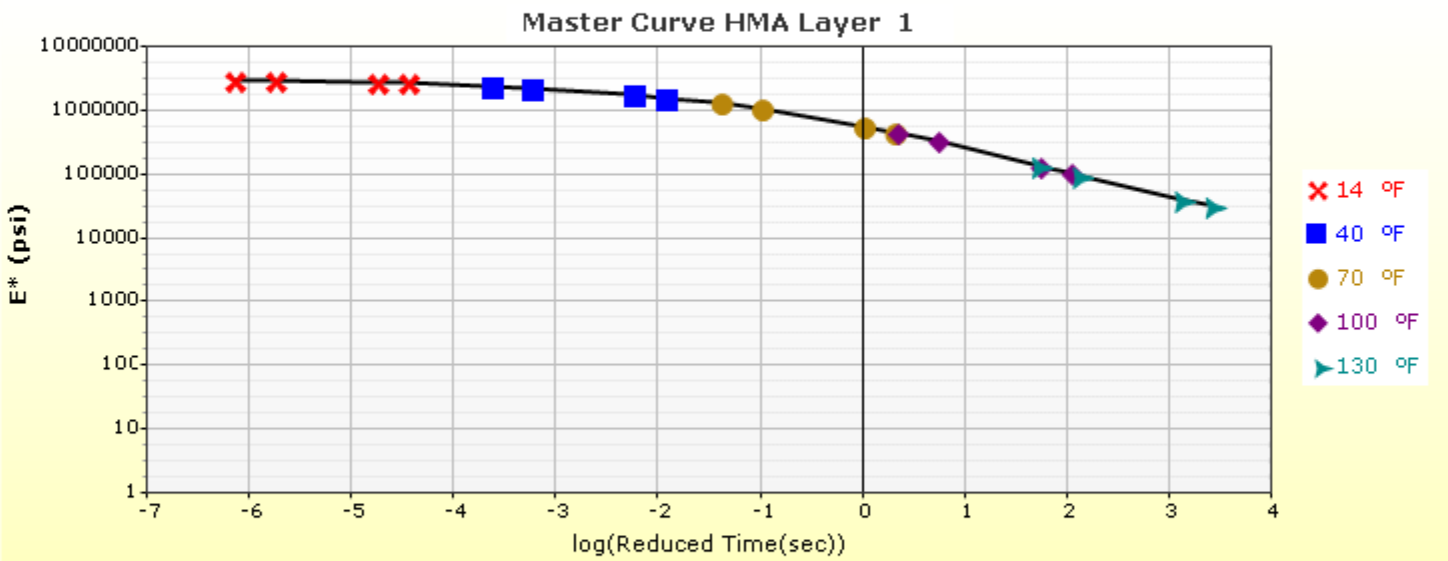
Indirect tensile strength at 14 ºF (psi)	451.00

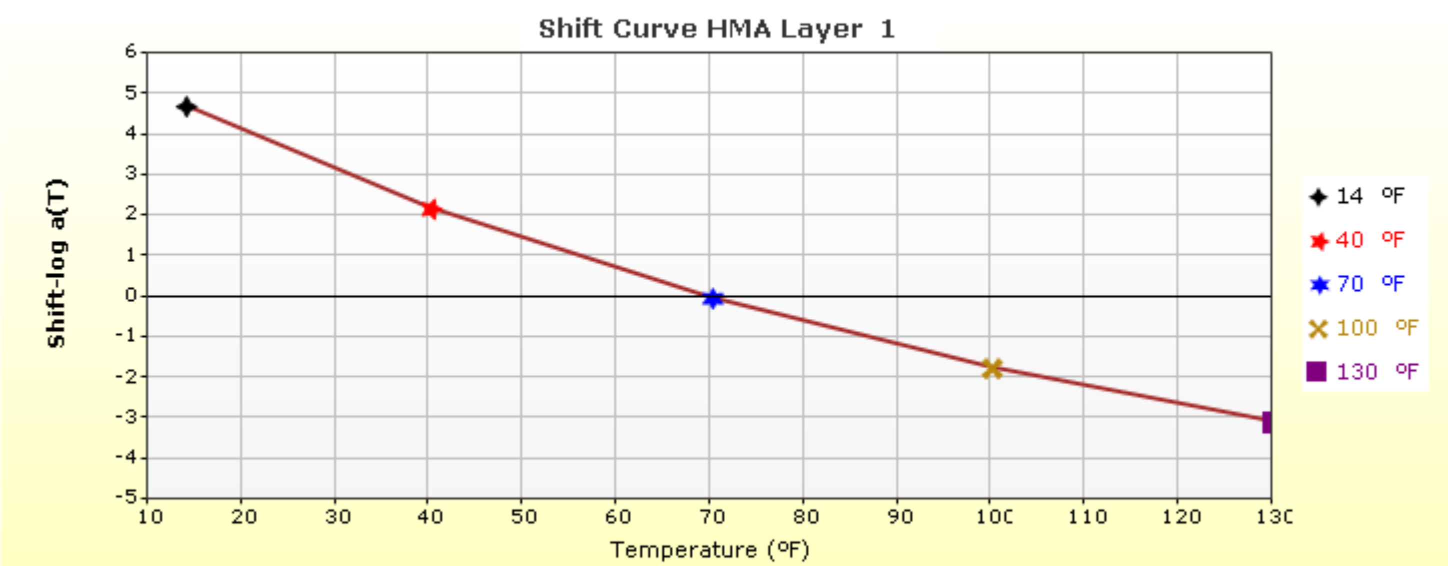
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

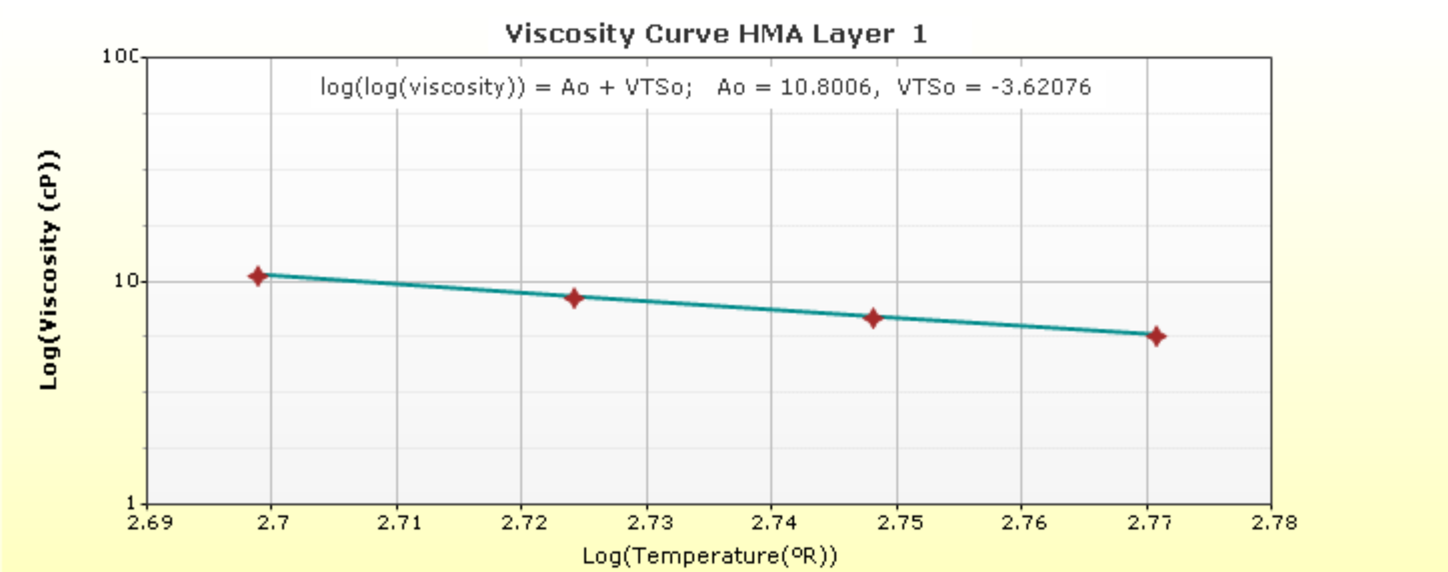
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



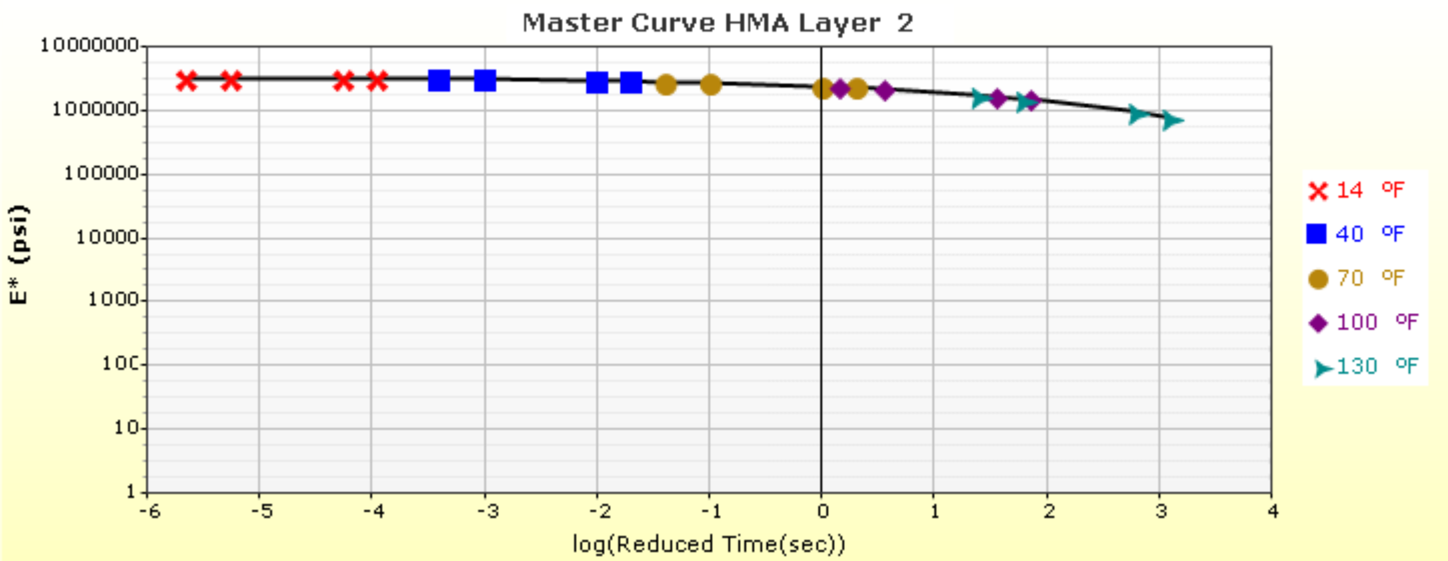
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

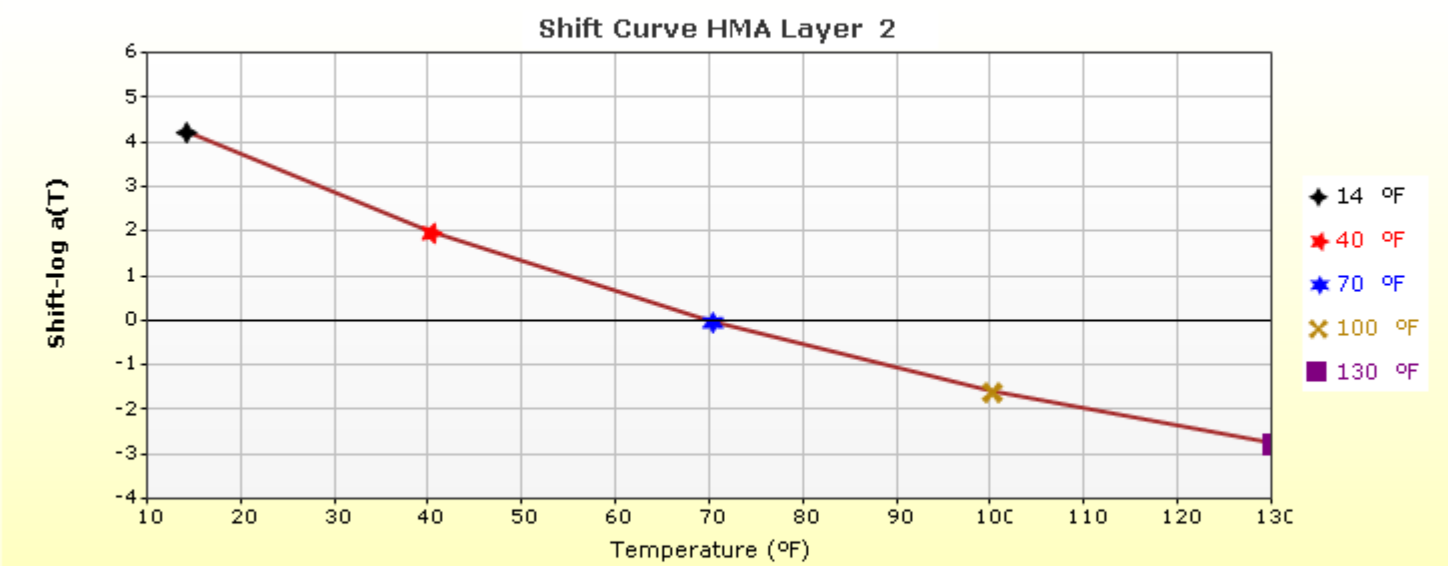


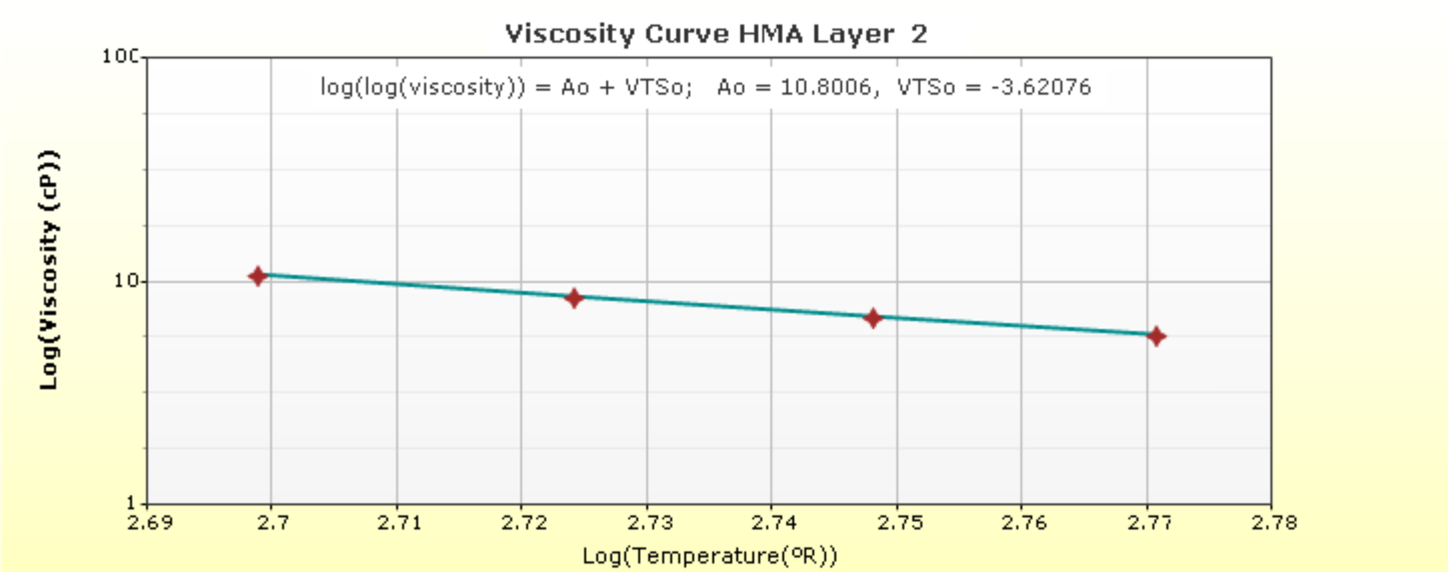




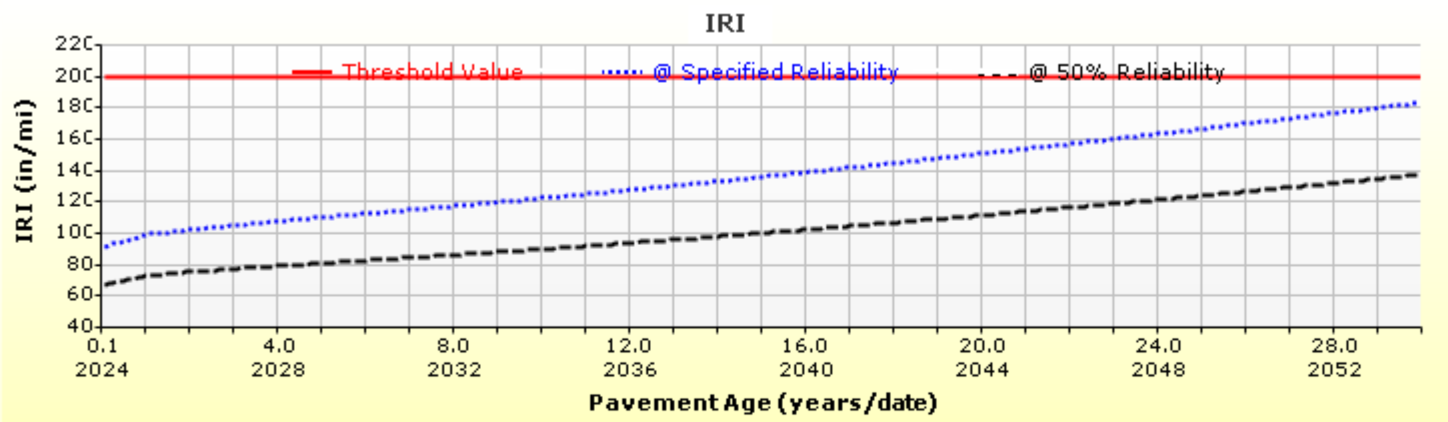
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

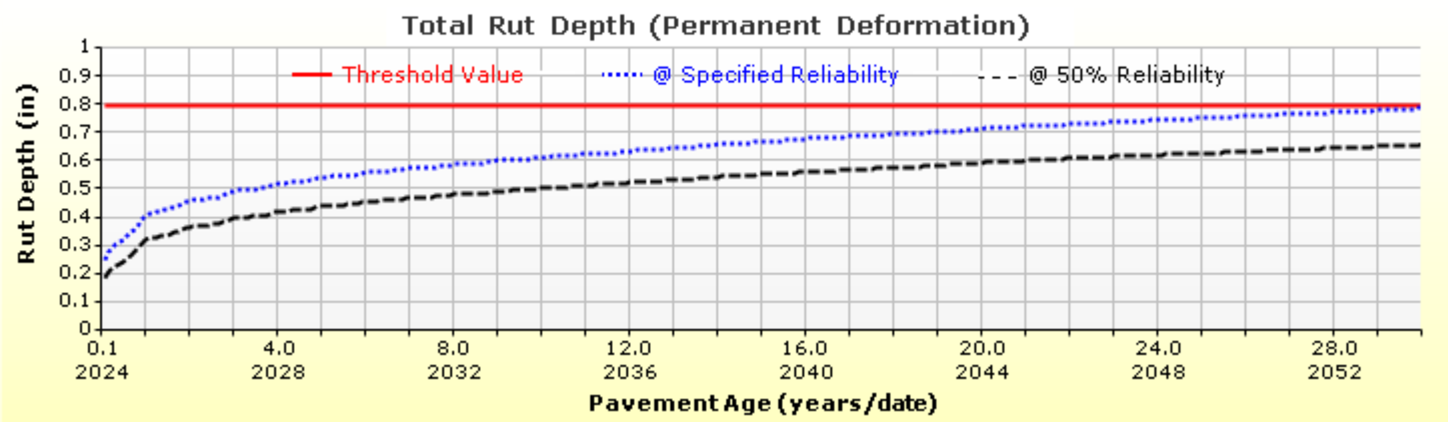


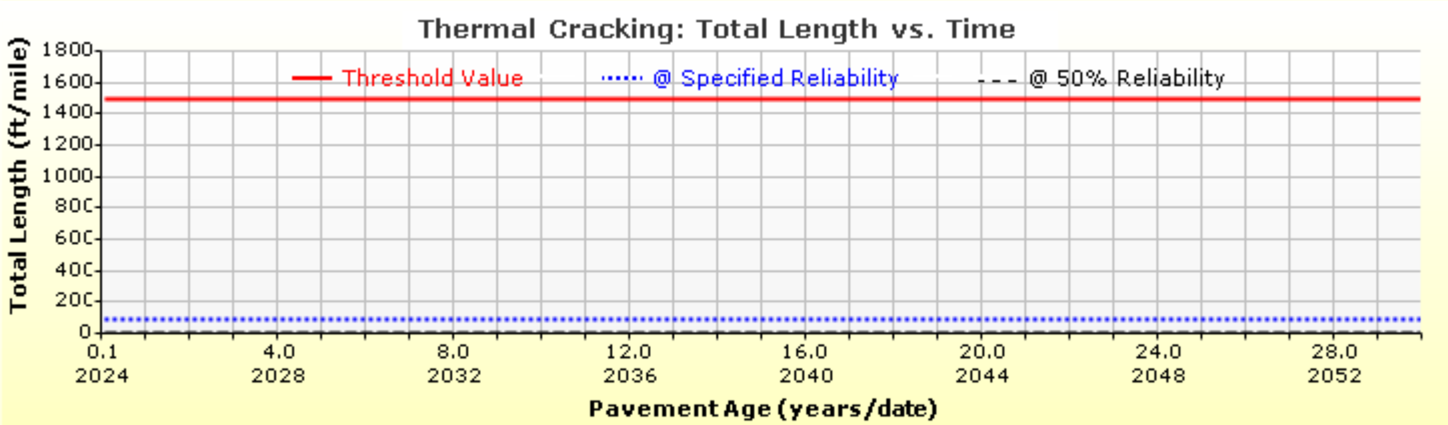


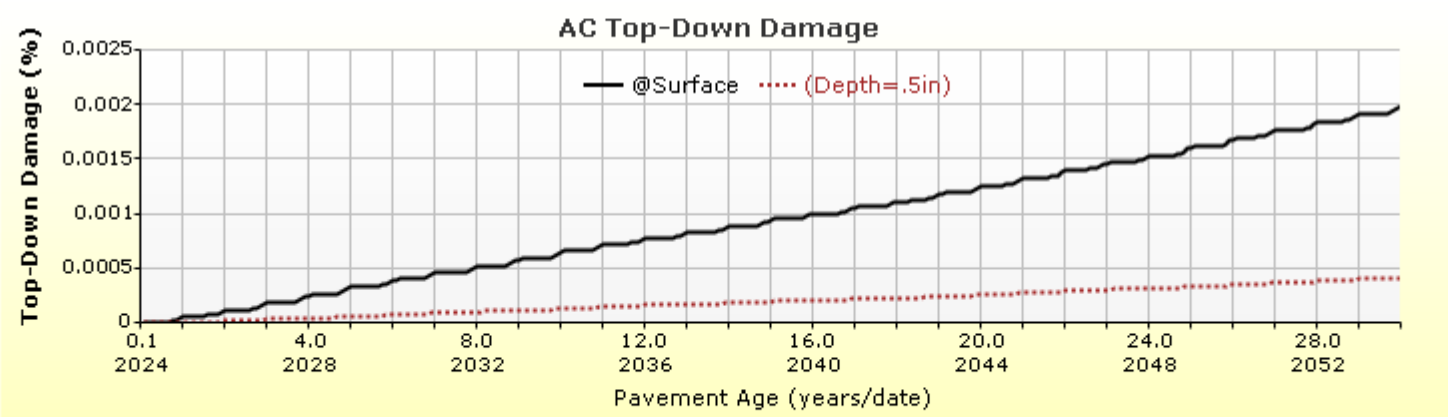


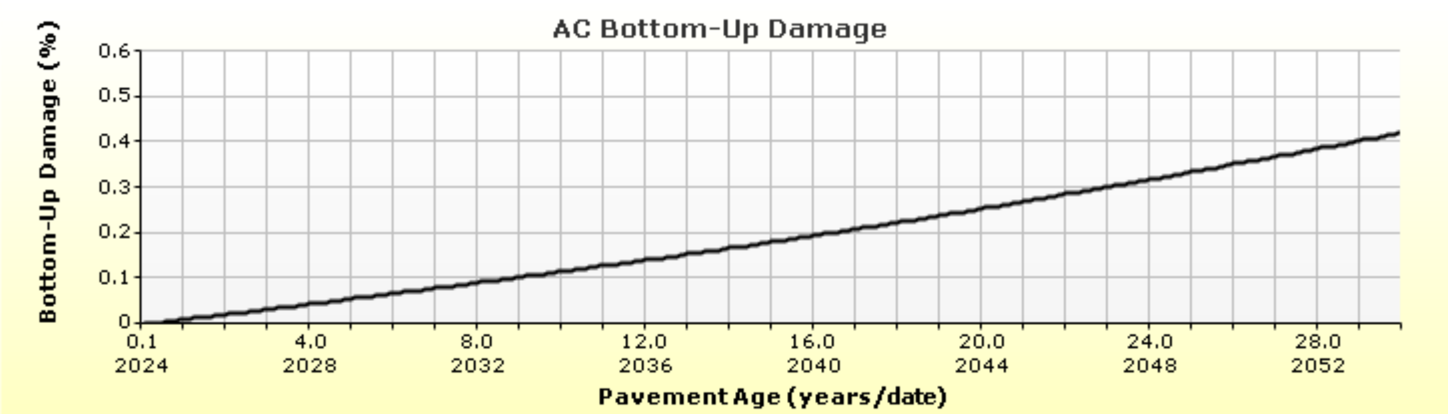
Analysis Output Charts

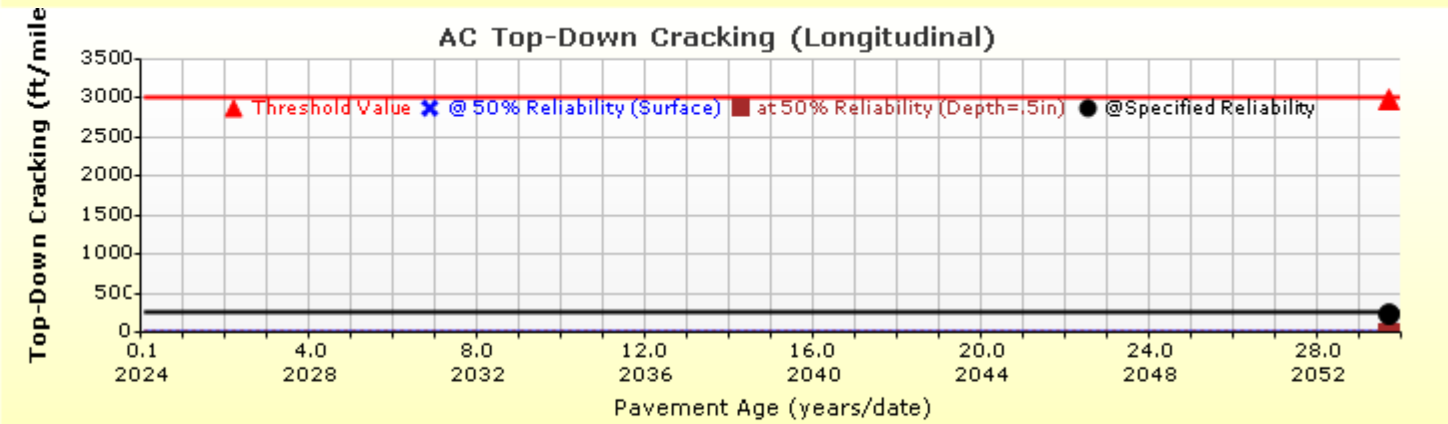


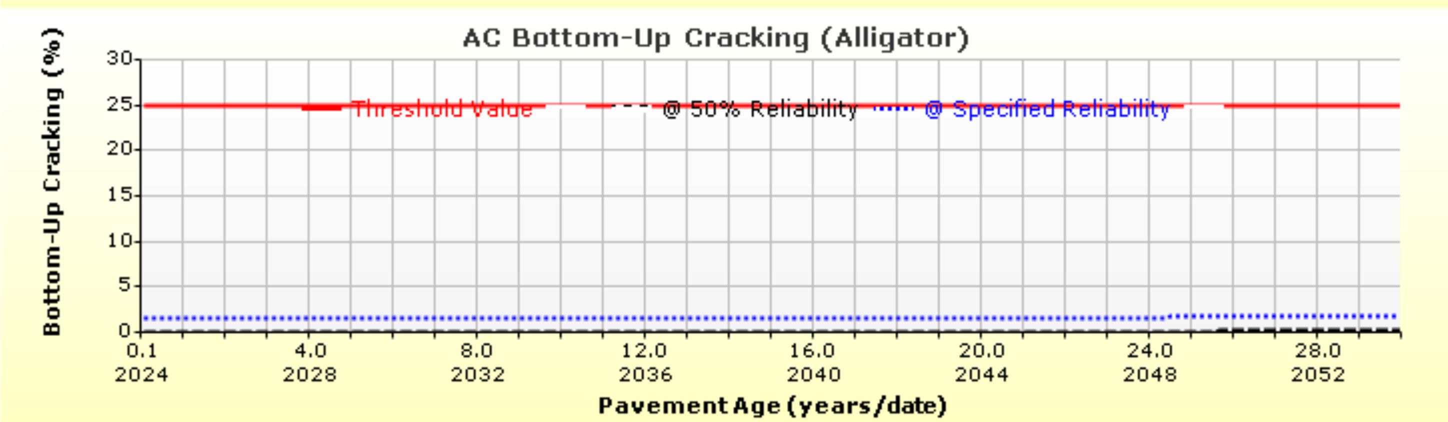


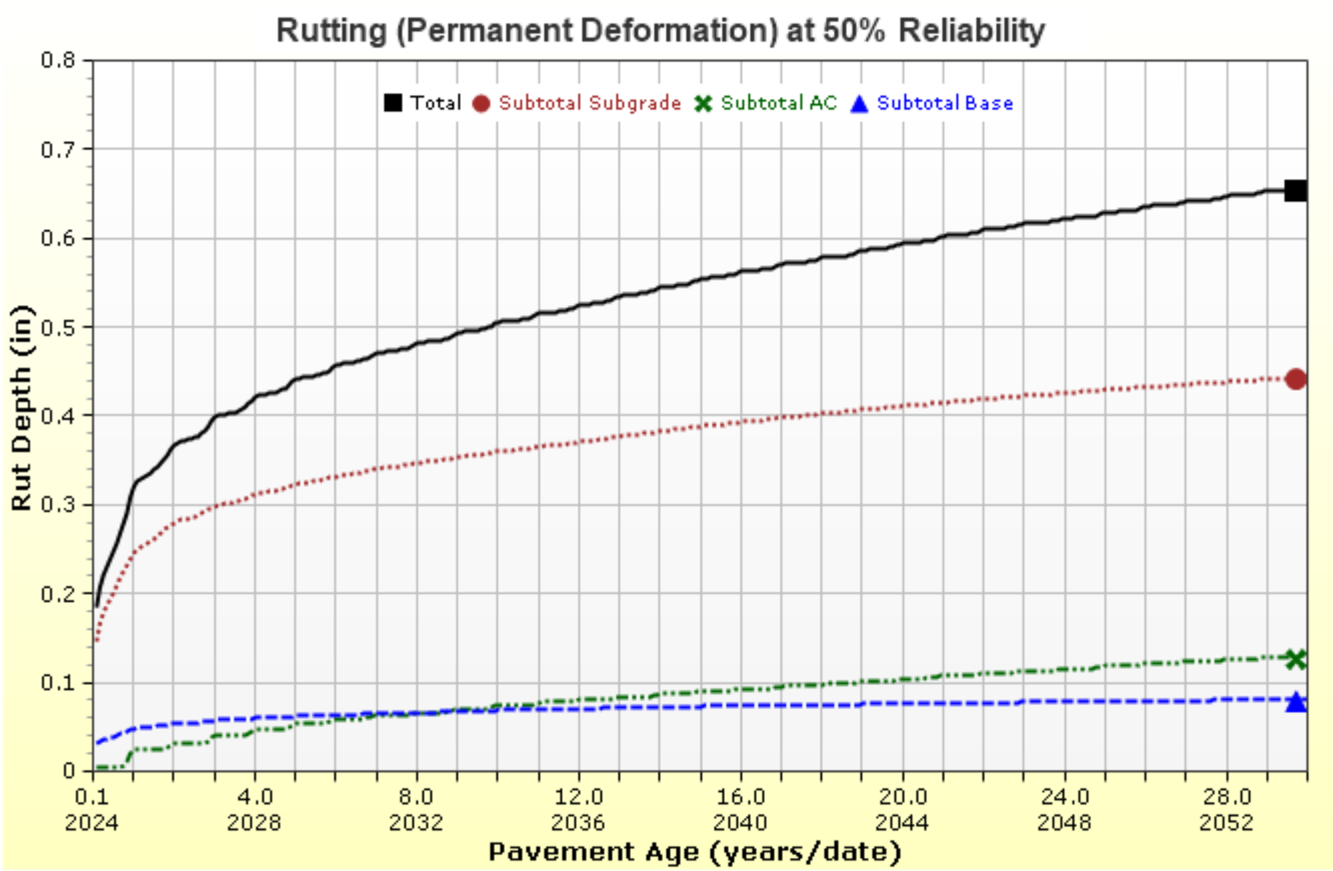


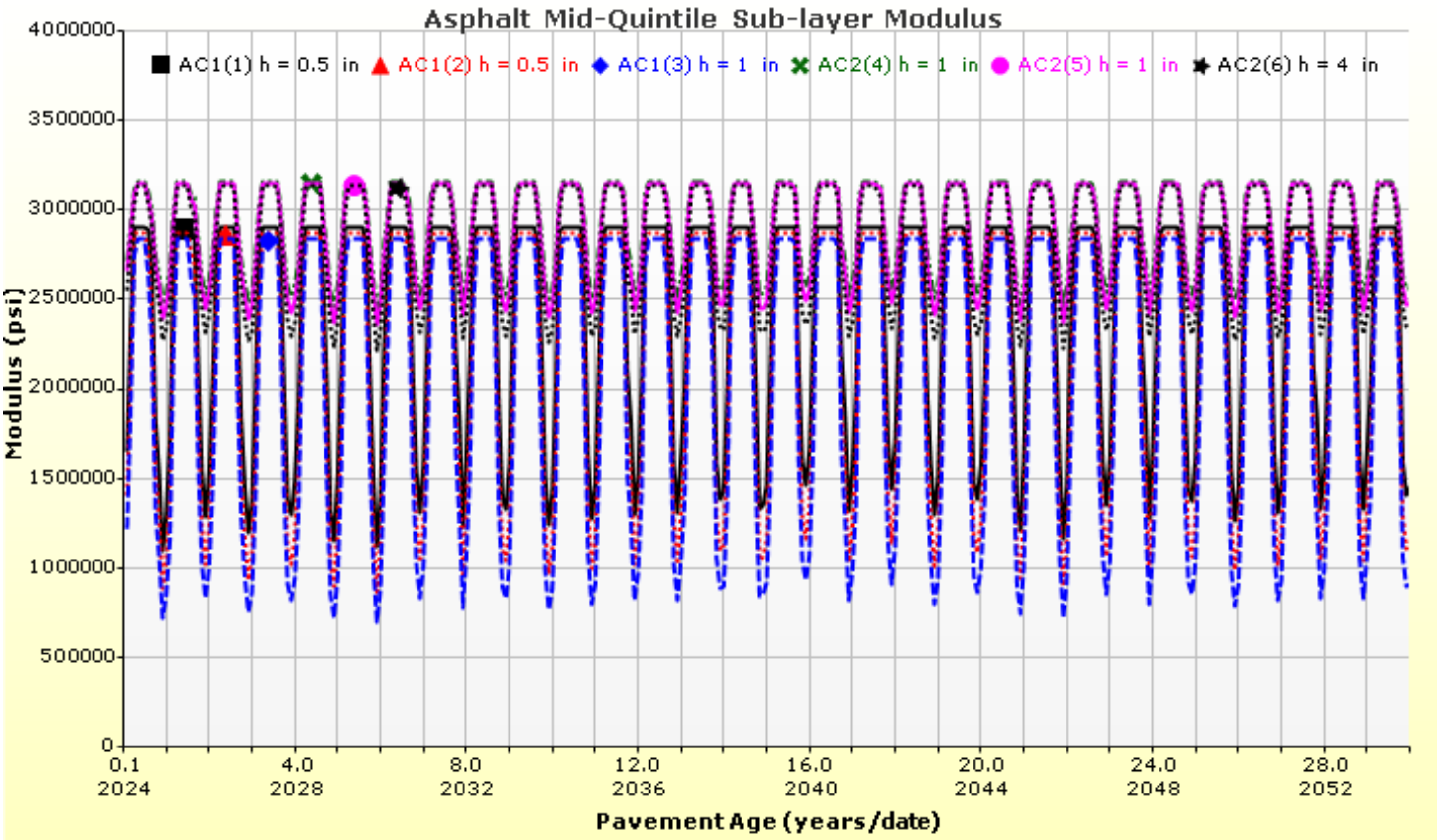

AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.0025
0.002
0.0015
0.001
0.0005
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

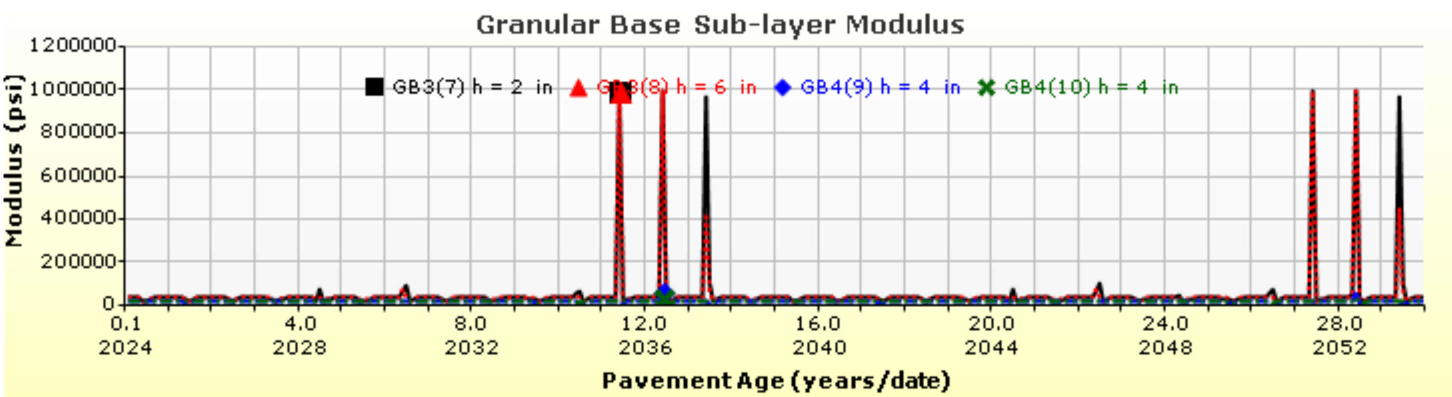

AC Bottom-Up Damage
Bottom-Up Damage (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

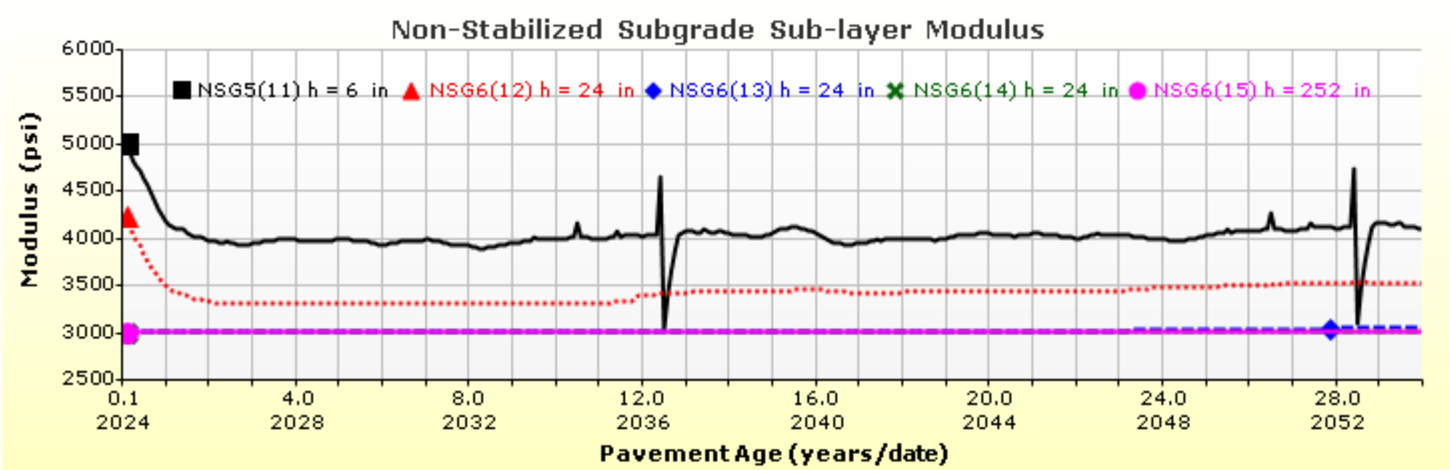

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2024
4.0
2028
8.0
2032
12.0
2036
16.0
2040
20.0
2044
24.0
2048
28.0
2052
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 6 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 6 in
NSG6(12) h = 24 in
NSG6(13) h = 24 in
NSG6(14) h = 24 in
NSG6(15) h = 252 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	6.0	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

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:

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

$\varepsilon_p = plastic\ strain(in/in)$
$\varepsilon_r = resilient\ strain(in/in)$
$T = layer\ temperature(°F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24 * Pow(RUT,0.8026) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_r = resilient strain(in/in)	
Granular		**Fine**	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking						
AC Top Down Cracking				**AC Bottom Up Cracking**		
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$				$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D*100))}}\right) * \left(\frac{1}{60}\right)$ $C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C_1' = -2 * C_2'$		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 1	c2: 1	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1.13 + 13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))		

CSM Cracking			
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$			
C1: 0	C2: 75	C3: 5	C4: 3
CSM Standard Deviation			
CTB*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

APPENDIX E

27 ½ ROAD

20 AND 30-YEAR DESIGN LIFE FOR FLEXIBLE PAVEMENT

M-E DESIGN OUTPUT SHEETS

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	7.0
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

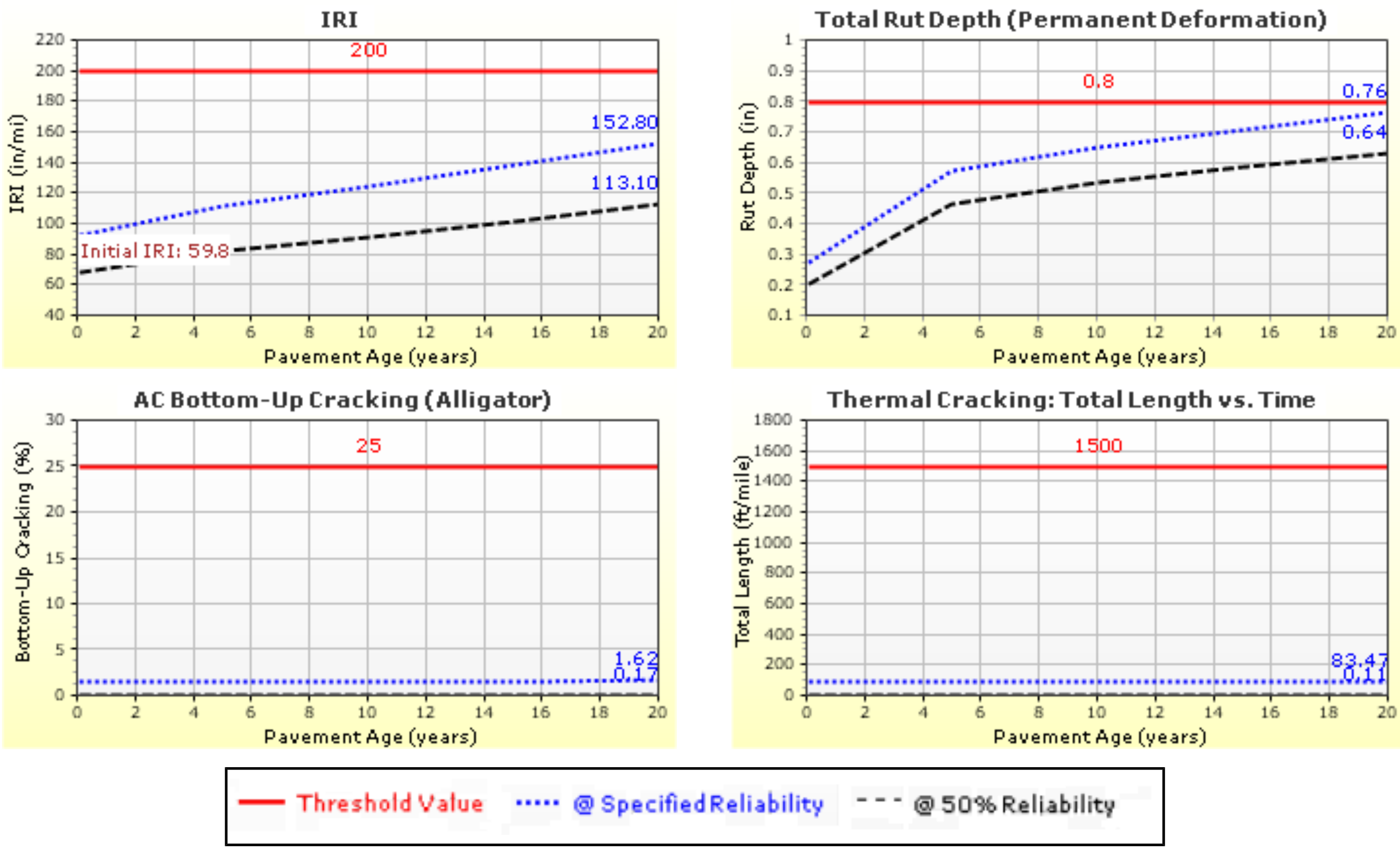
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	1,820
2034 (10 years)	4,367,330
2044 (20 years)	9,691,080

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	152.75	90.00	99.75	Pass
Permanent deformation - total pavement (in)	0.80	0.76	90.00	94.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.62	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.47	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	257.09	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.22	90.00	100.00	Pass

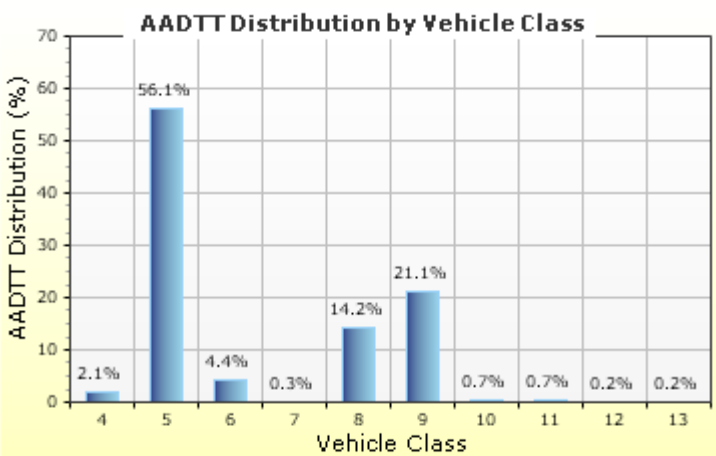
Distress Charts

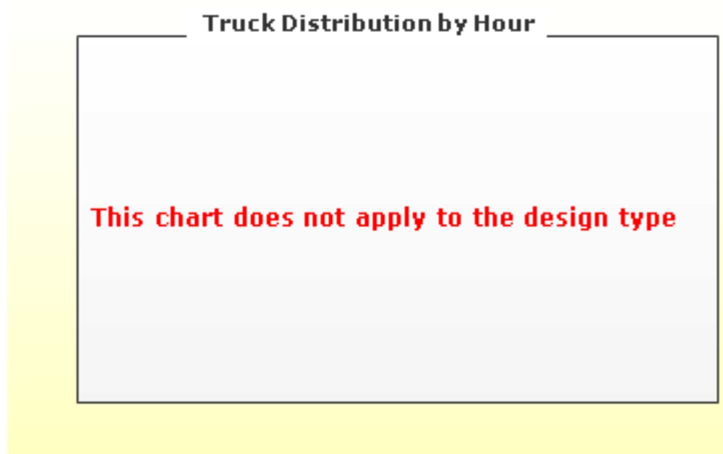


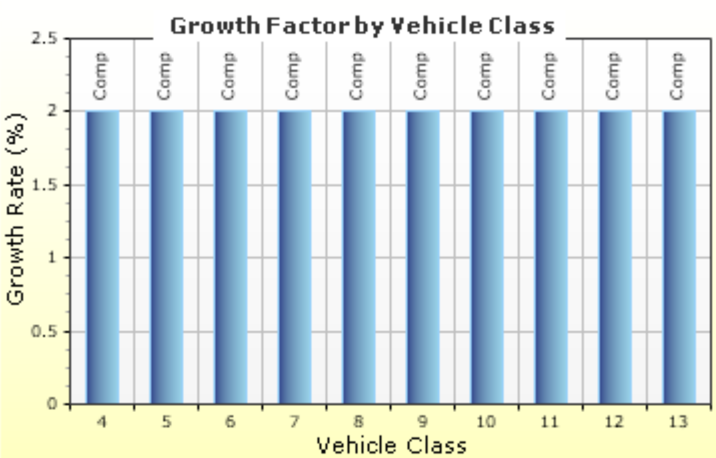
Traffic Inputs

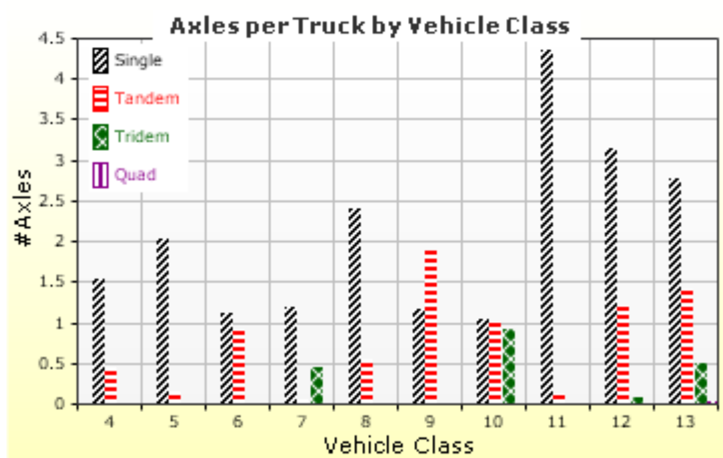
Graphical Representation of Traffic Inputs

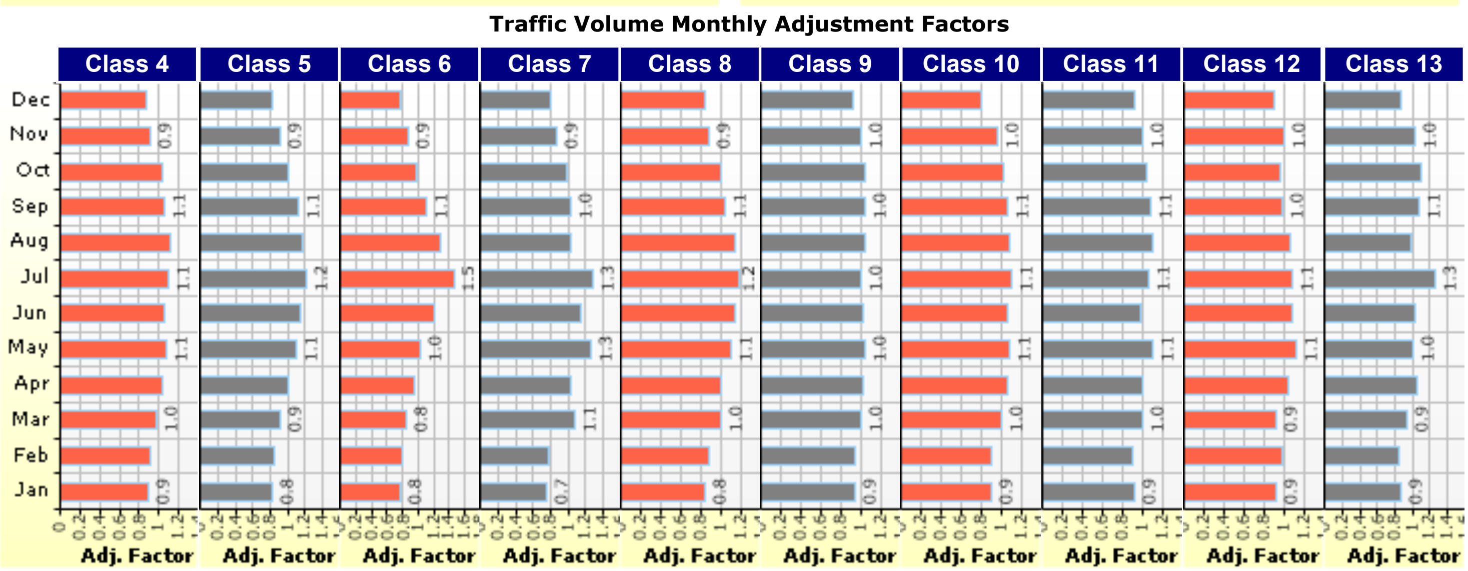
Initial two-way AADTT:	1,820	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0











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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

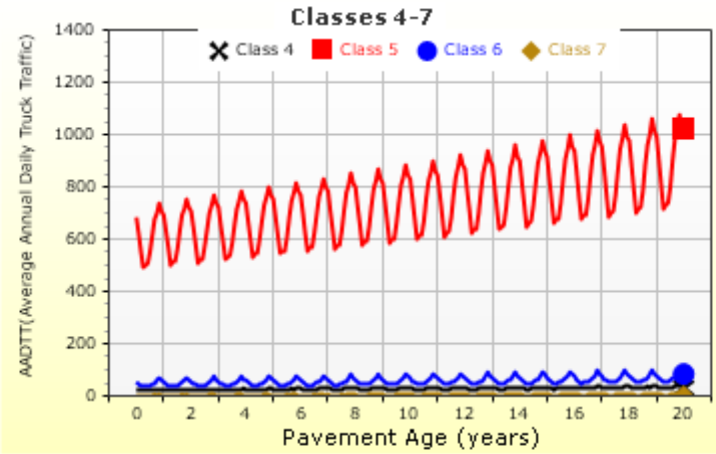
Wheelbase does not apply

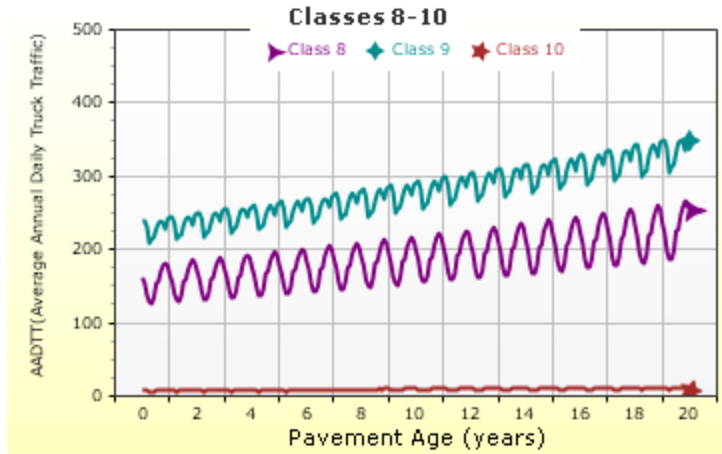
Number of Axles per Truck

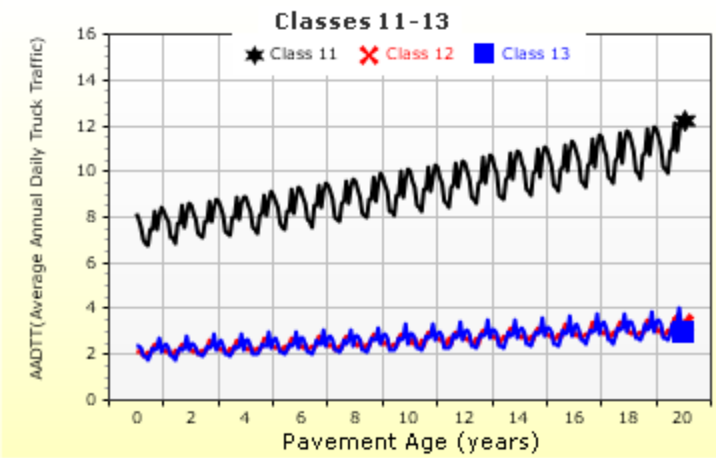
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

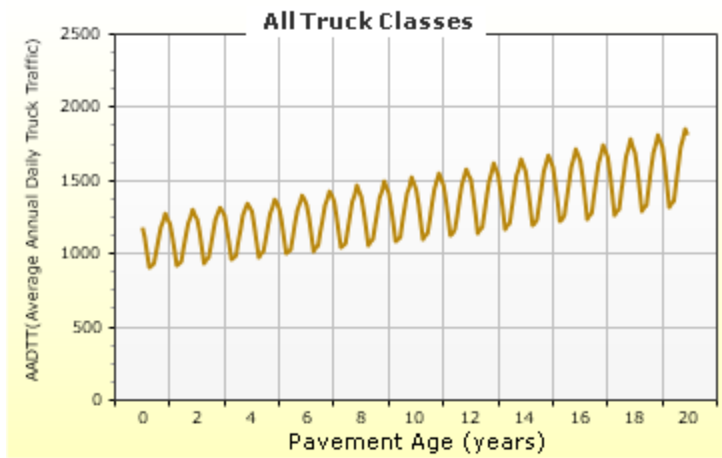
AADTT (Average Annual Daily Truck Traffic) Growth

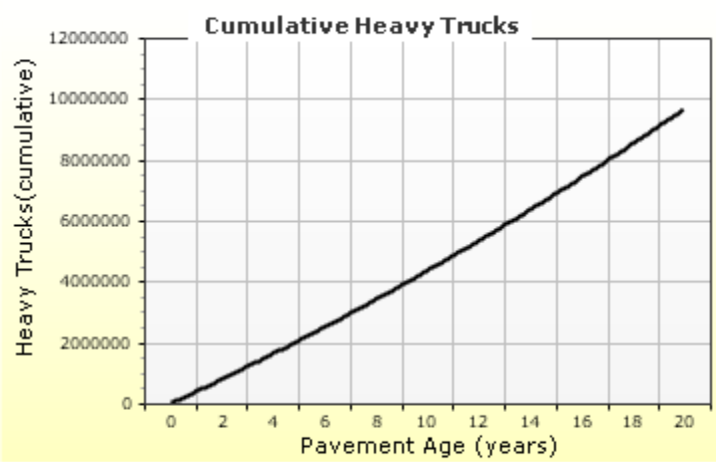
*** Traffic cap is not enforced**







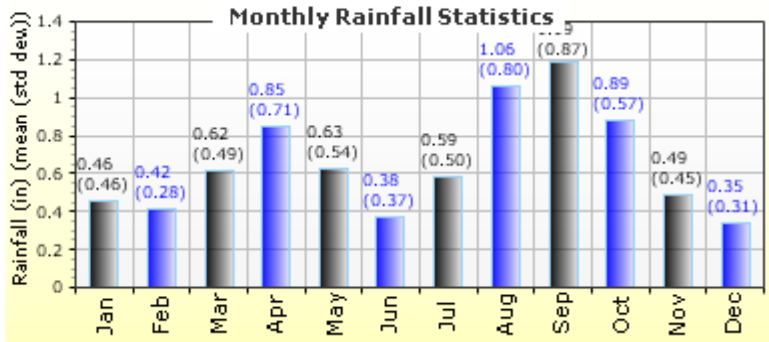




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

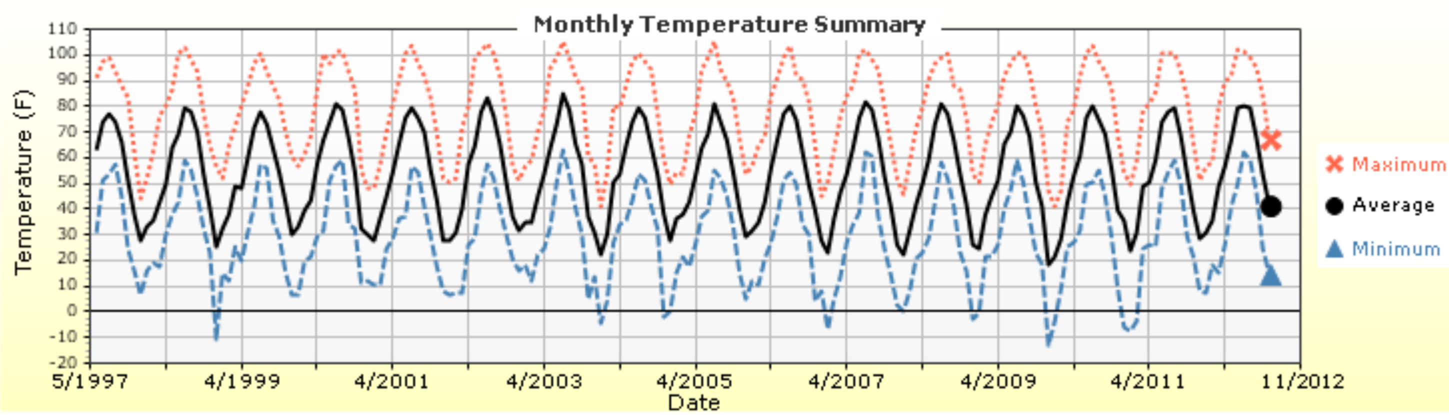


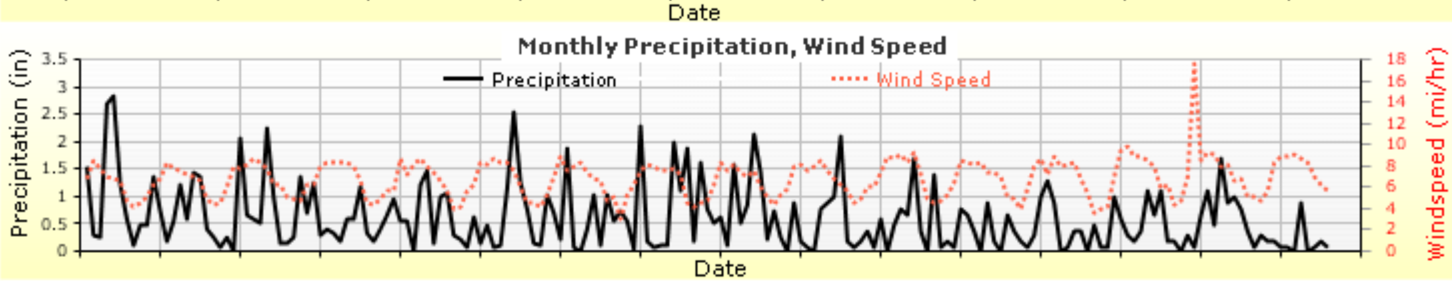
Annual Statistics:

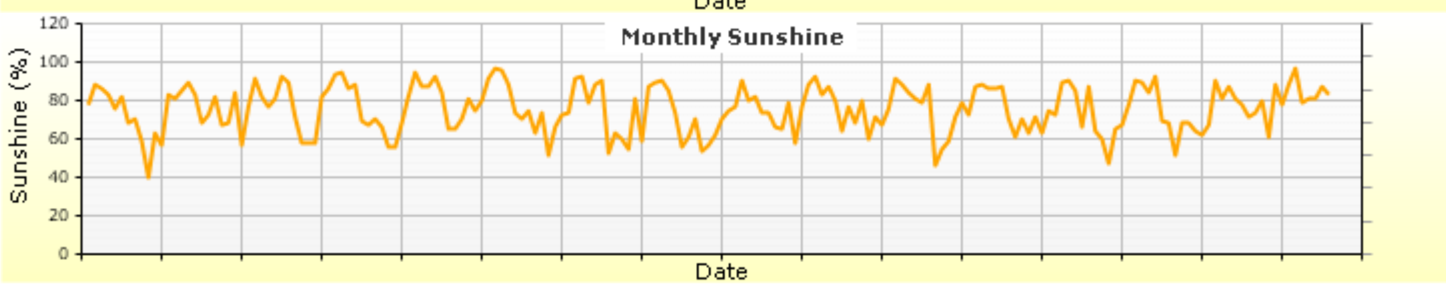
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

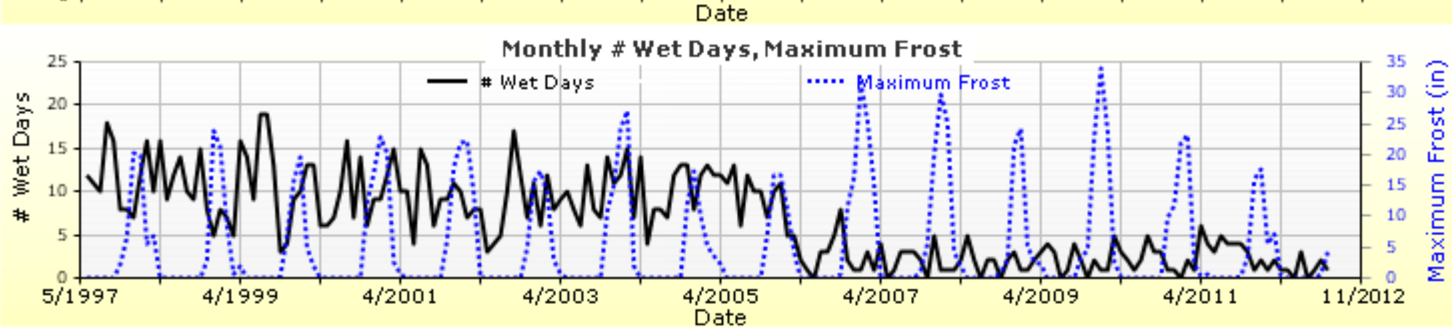
Water table depth (ft) 4.00

Monthly Climate Summary:

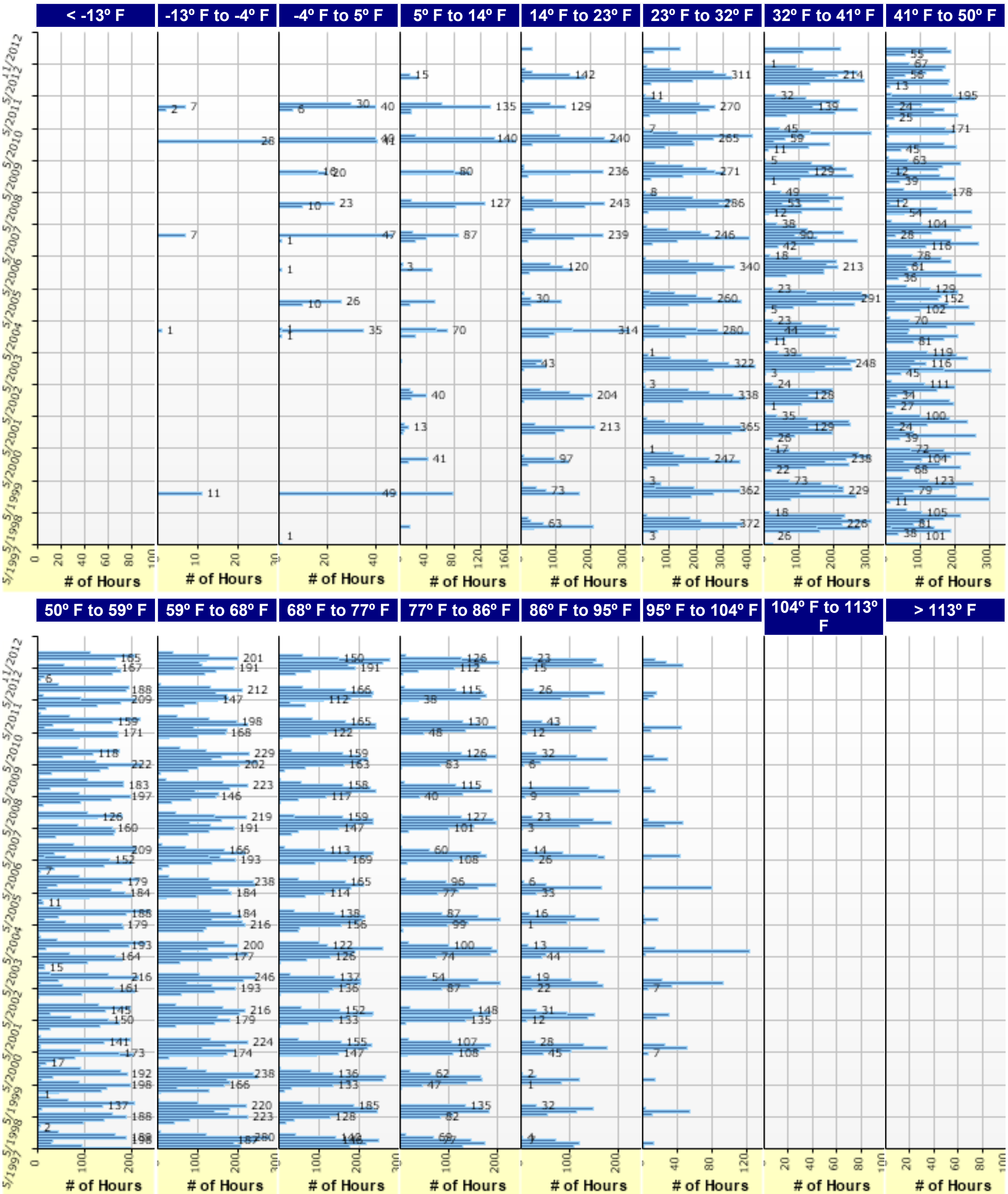








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

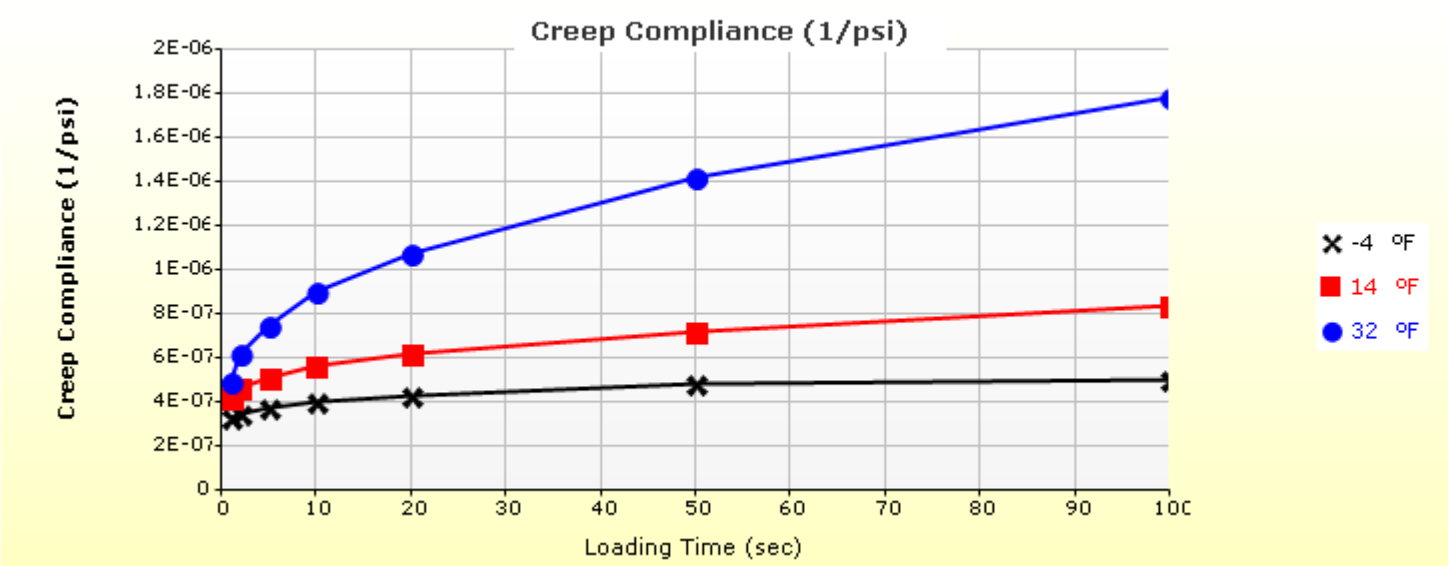
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

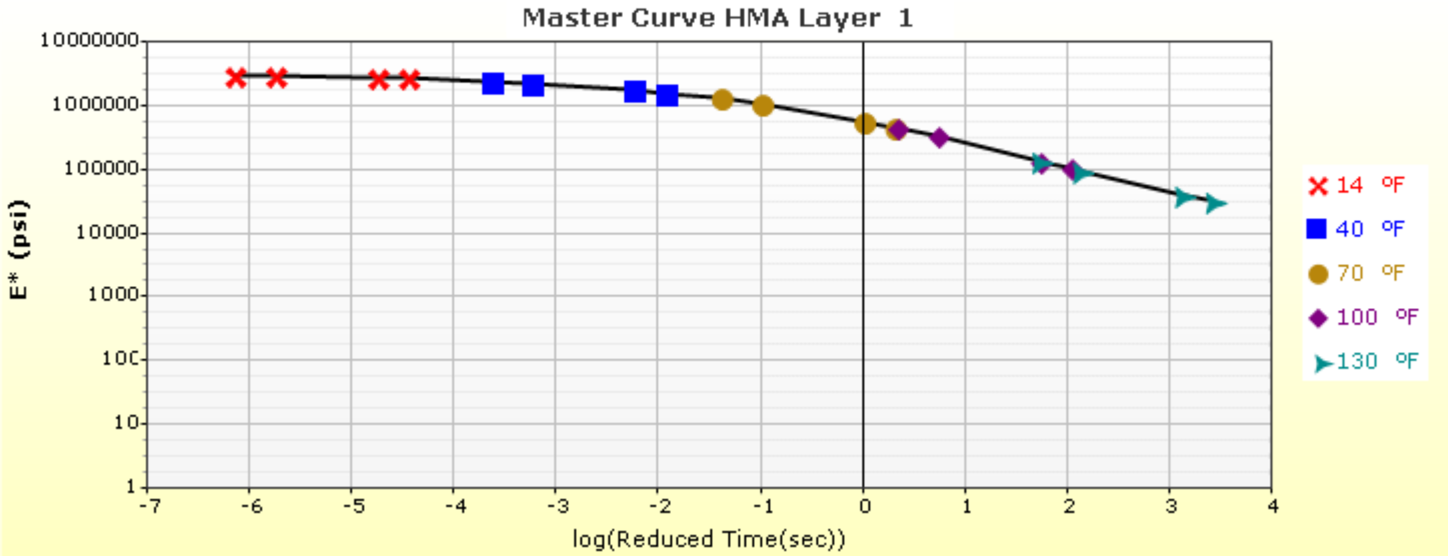
Thermal Cracking (Input Level: 1)

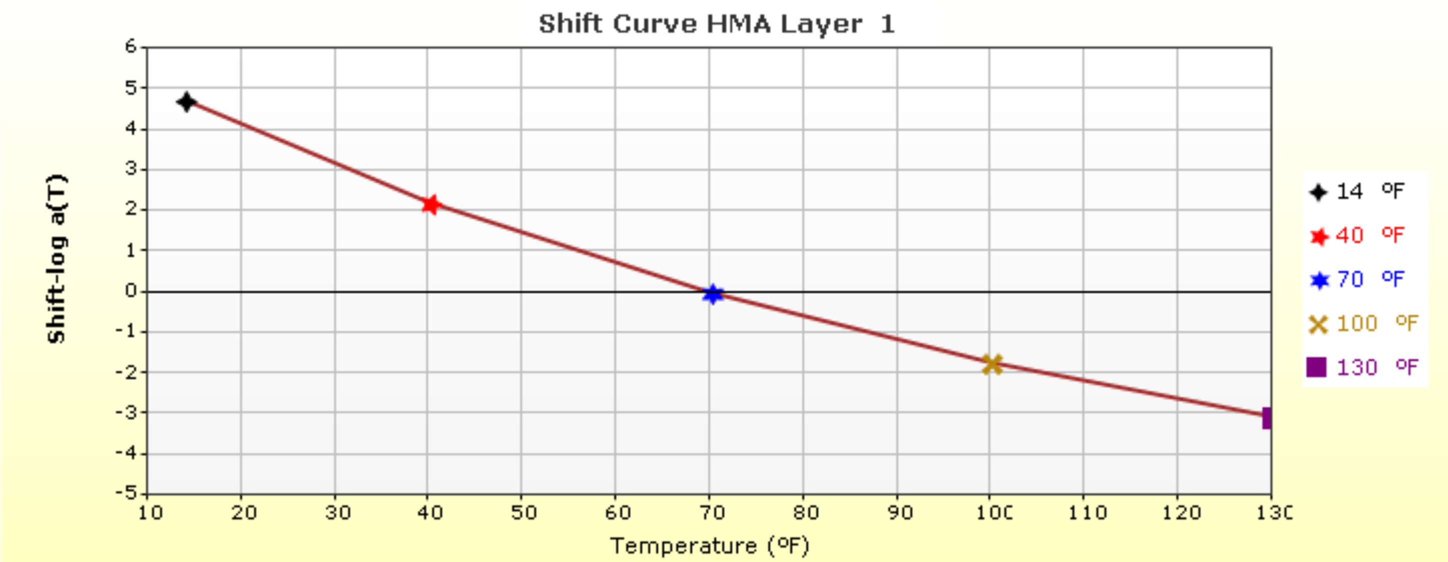
Indirect tensile strength at 14 ºF (psi)	451.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

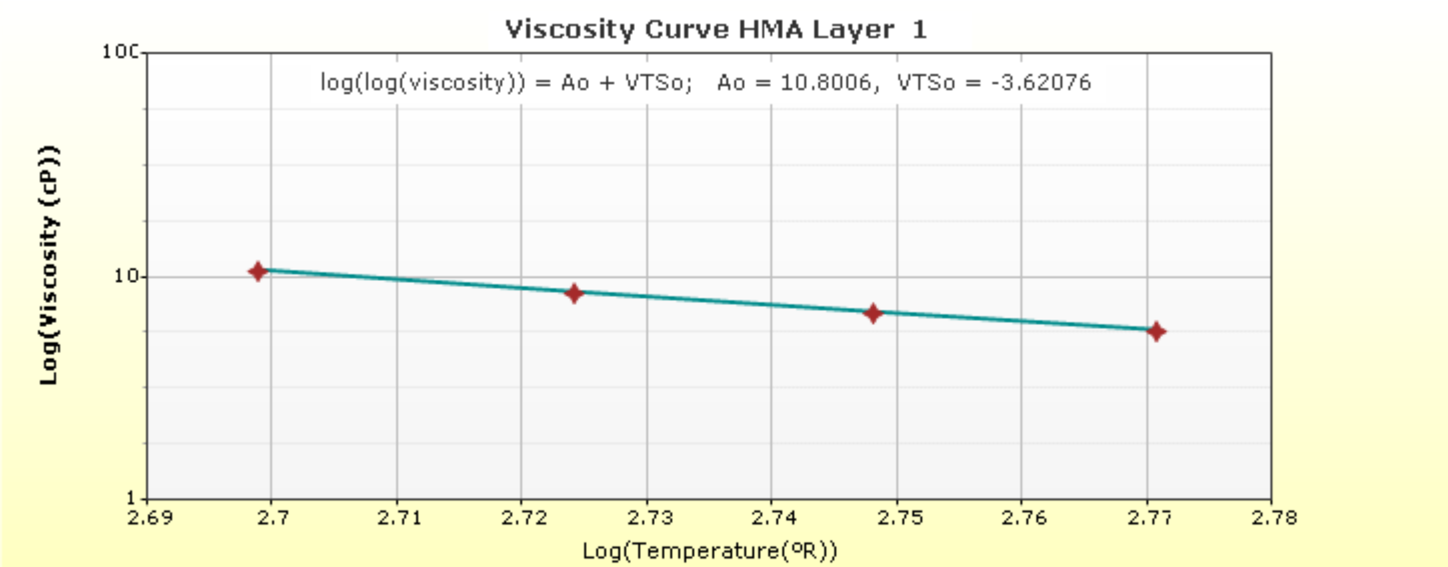
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



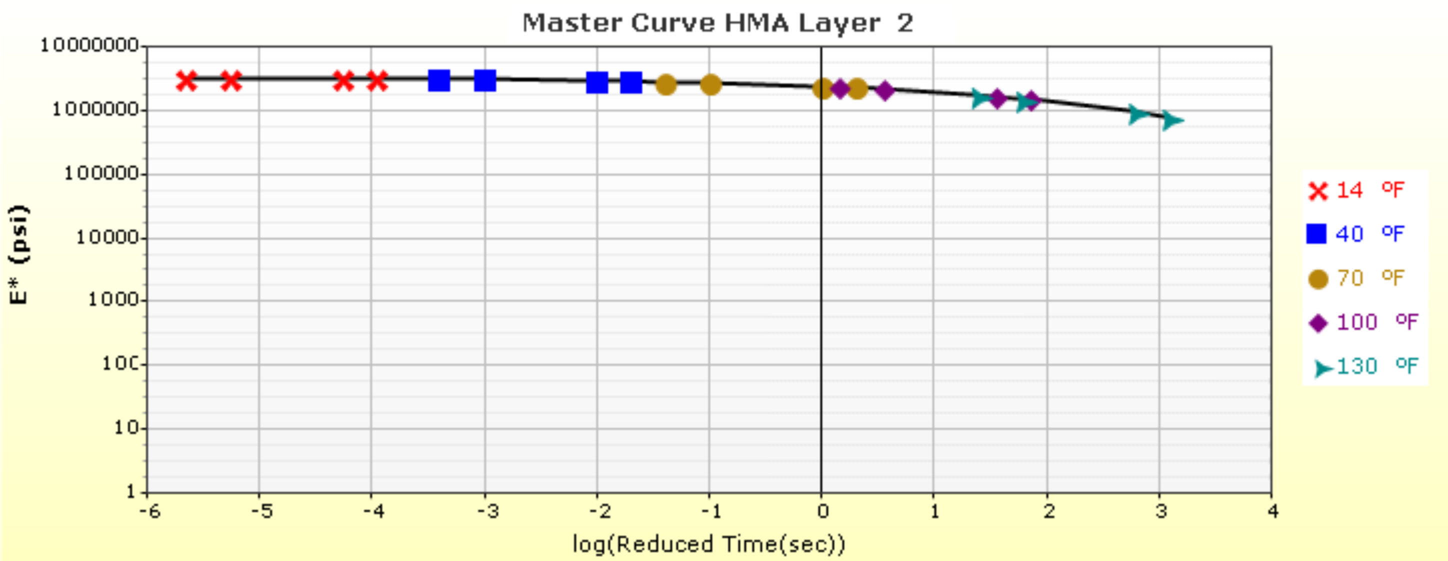
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

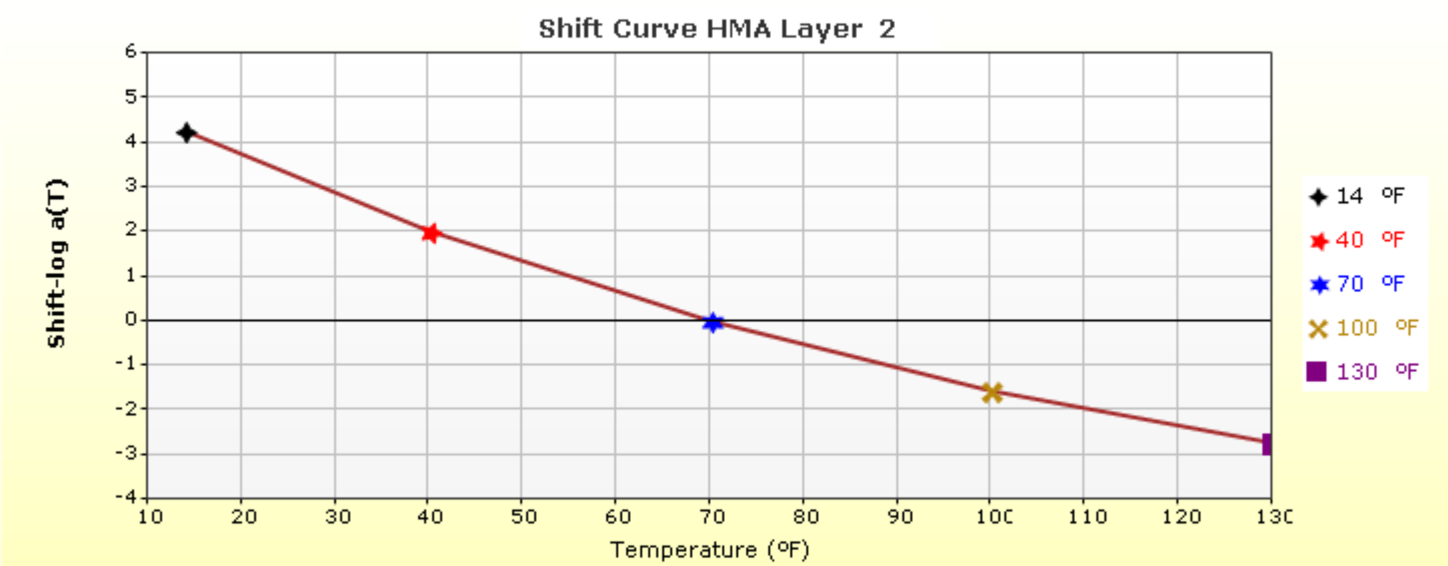


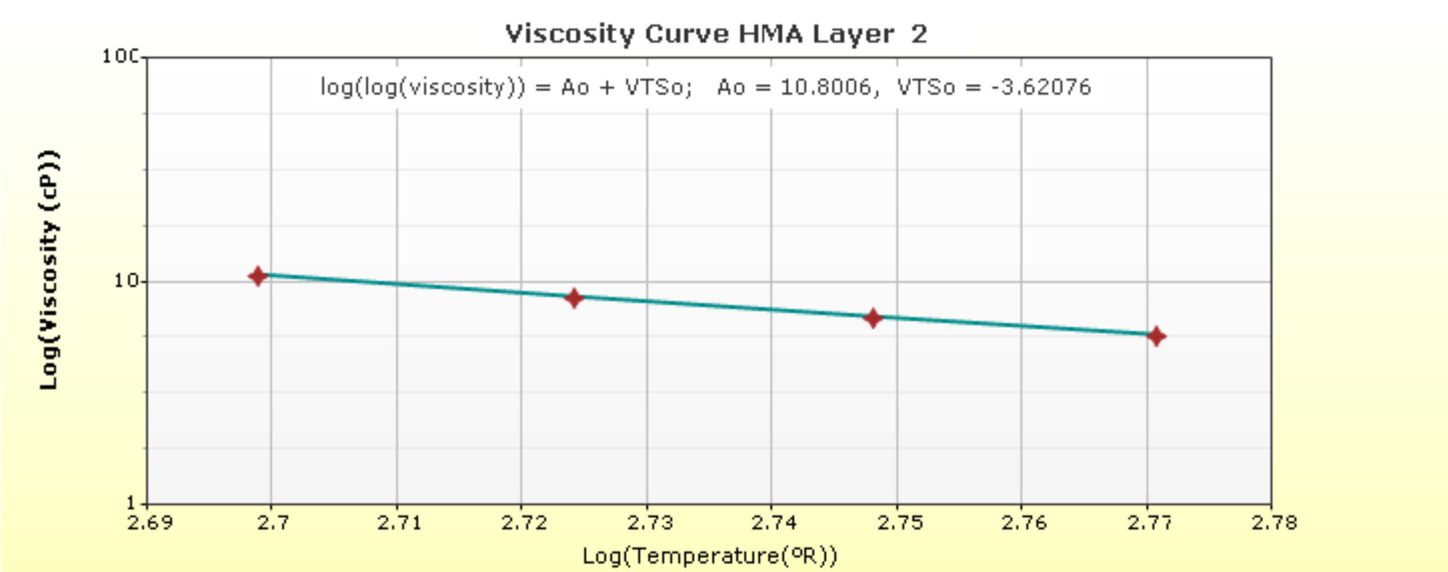




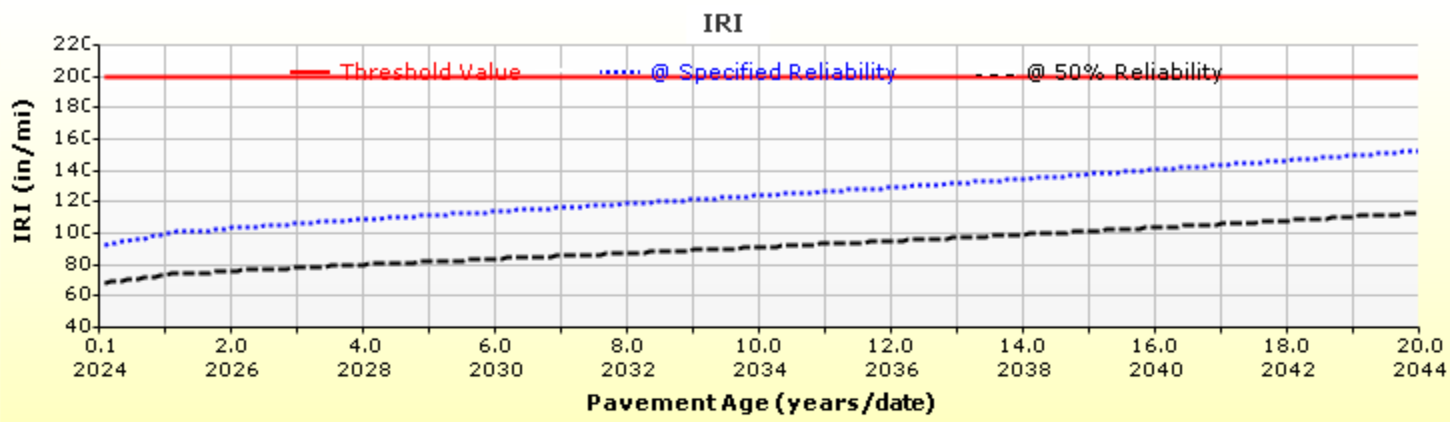
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

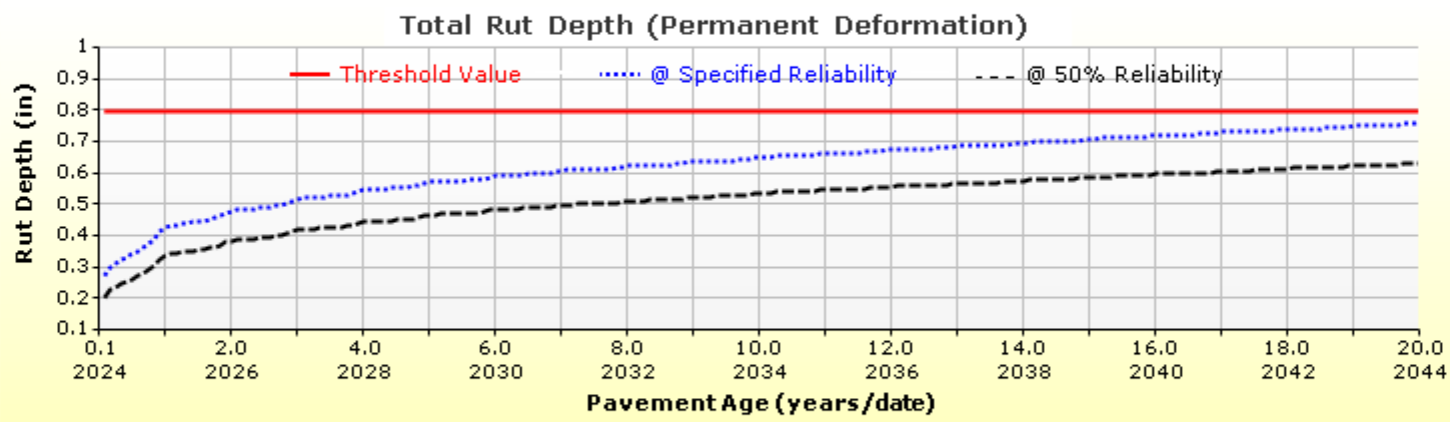


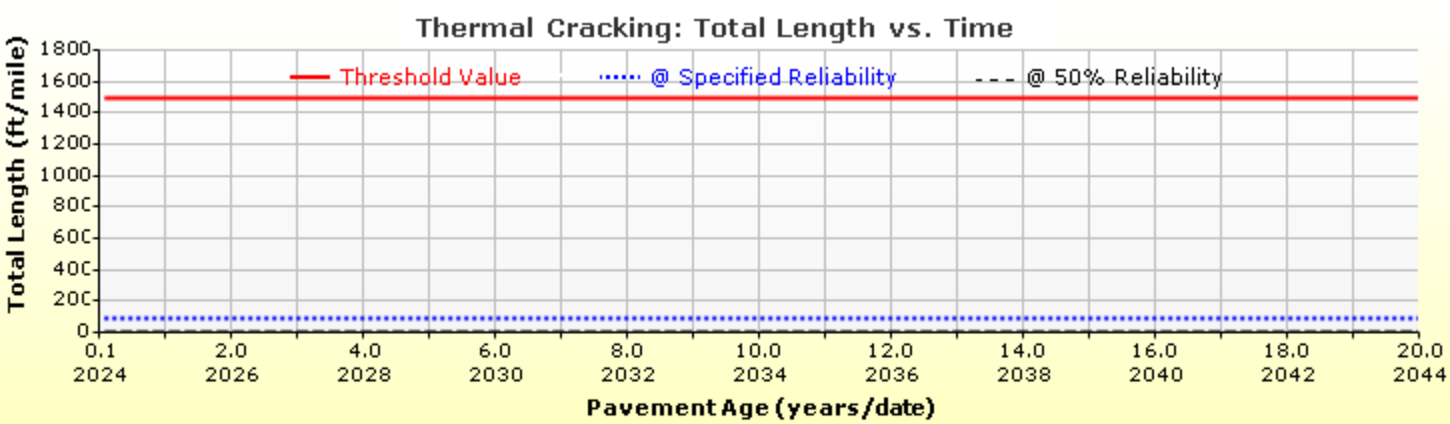


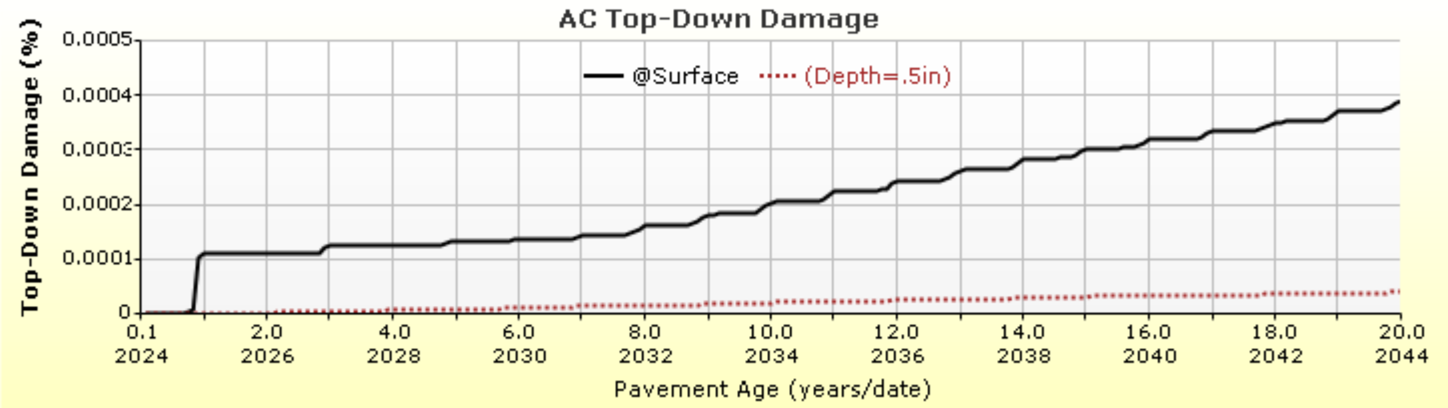


Analysis Output Charts

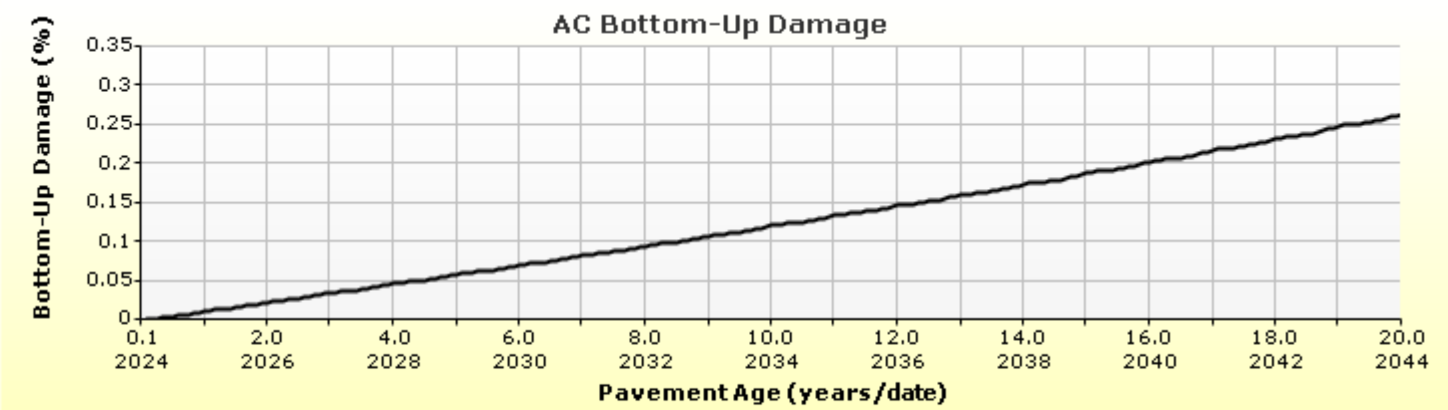




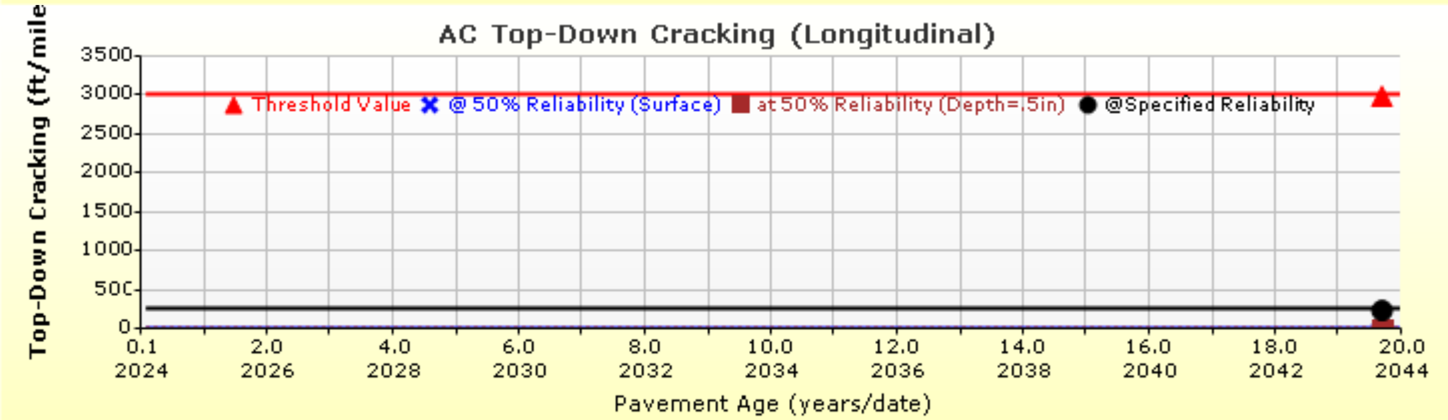




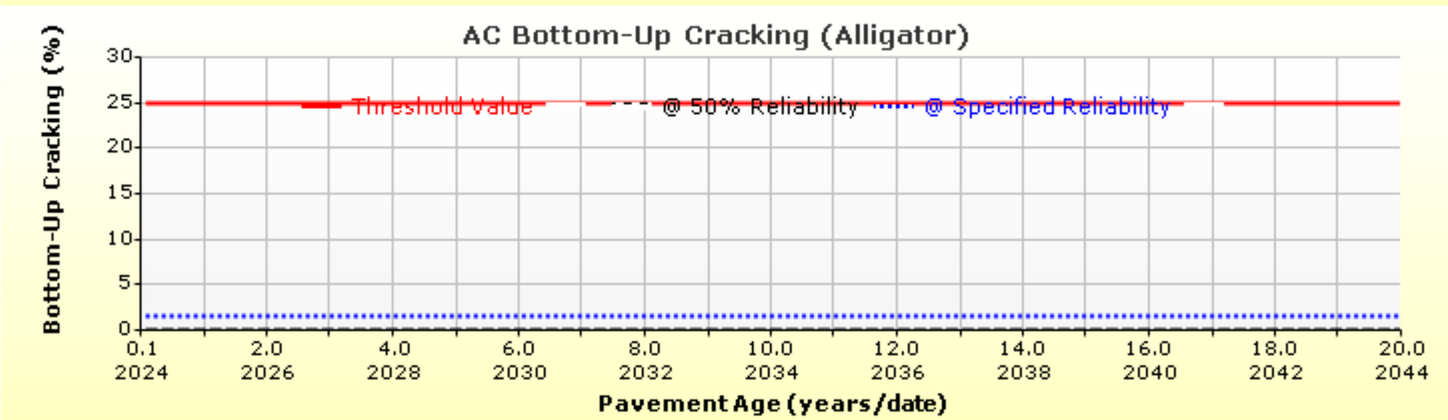
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



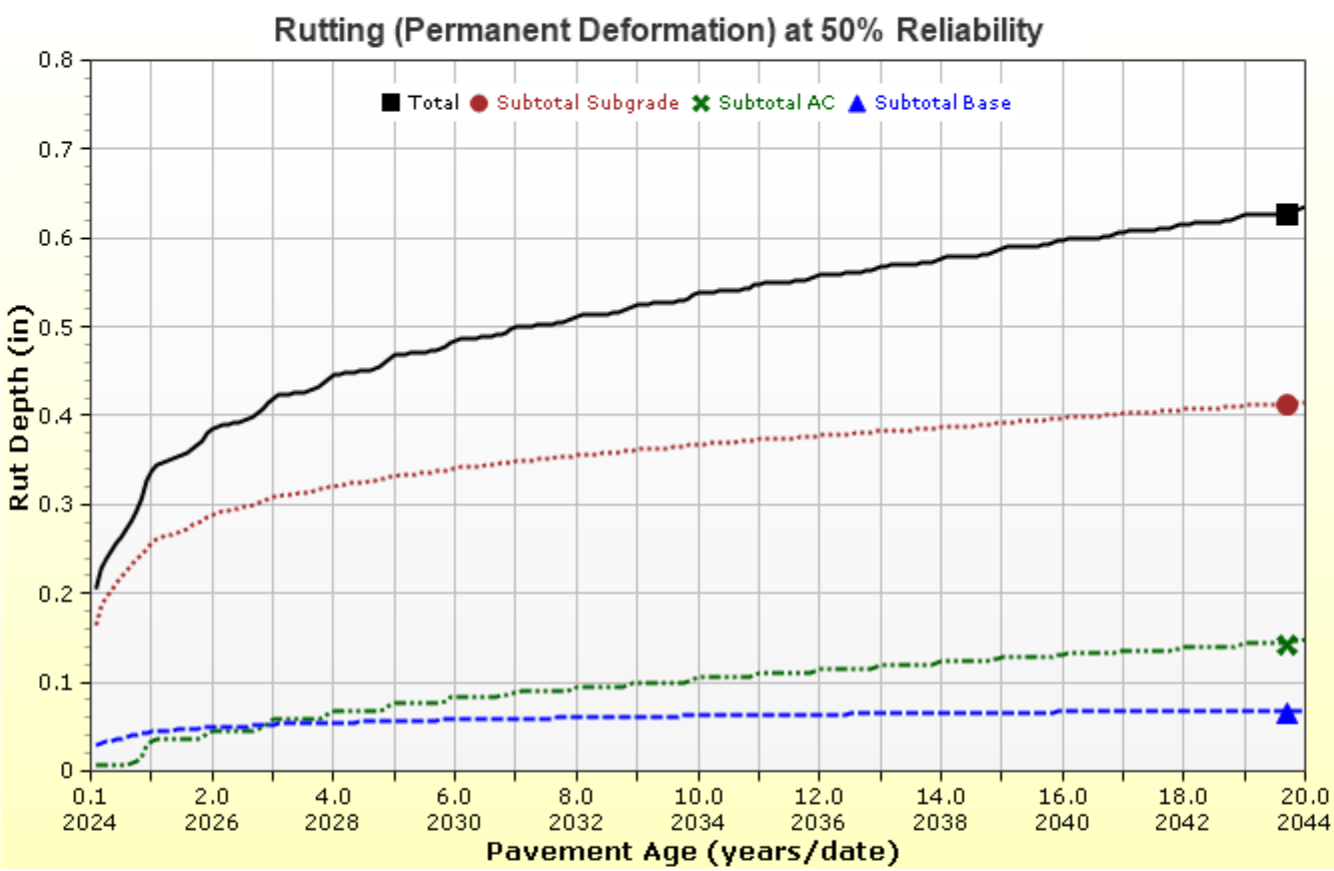
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

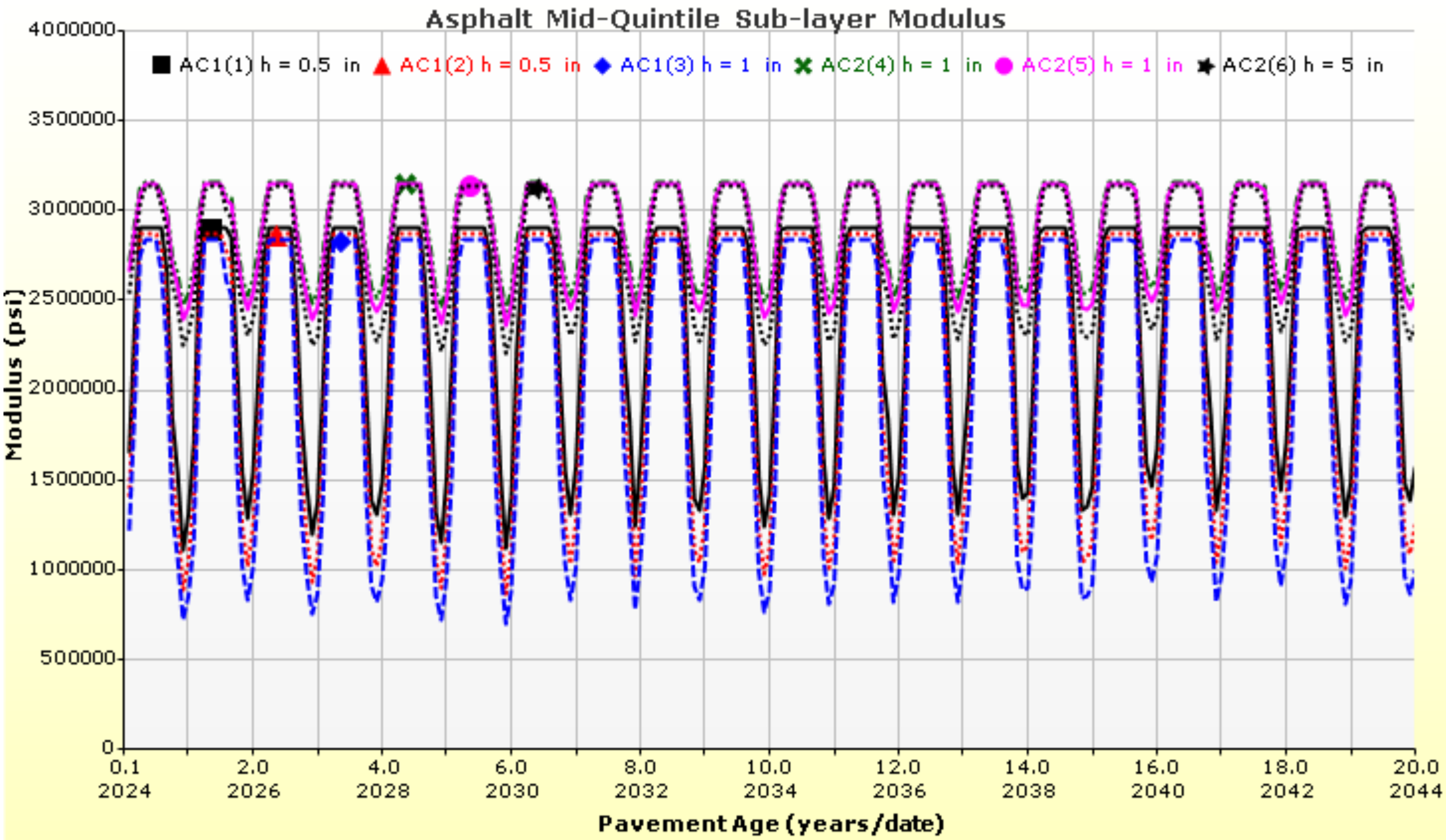


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

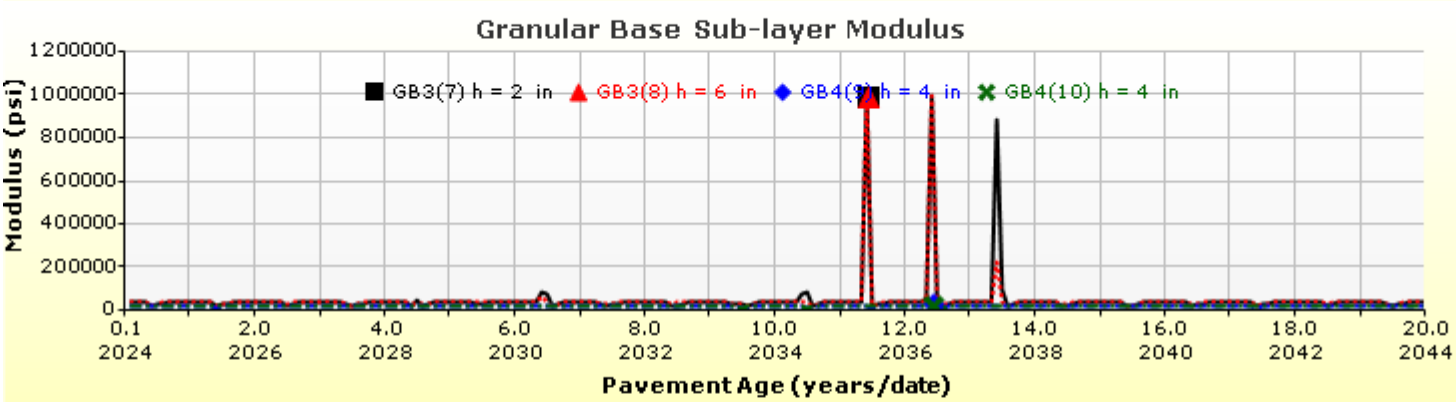


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

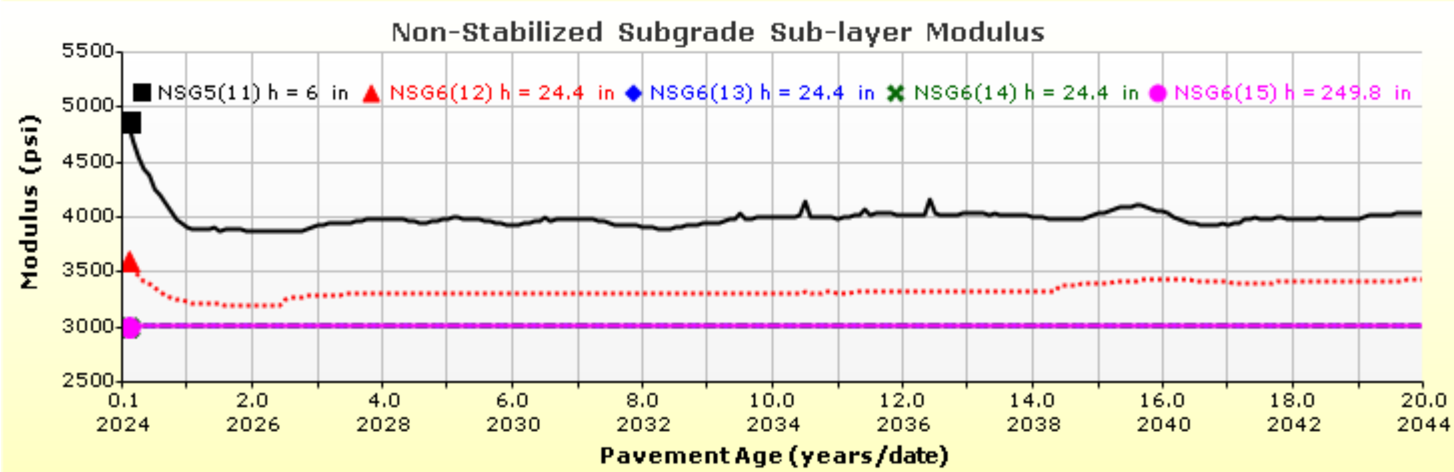

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 5 in
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 6 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 6 in
NSG6(12) h = 24.4 in
NSG6(13) h = 24.4 in
NSG6(14) h = 24.4 in
NSG6(15) h = 249.8 in
Modulus (psi)
5500
5000
4500
4000
3500
3000
2500
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	7.0	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

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:

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

$\varepsilon_p = plastic\ strain(in/in)$
$\varepsilon_r = resilient\ strain(in/in)$
$T = layer\ temperature(°F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24 * Pow(RUT,0.8026) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at( )
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

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	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	8.0
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

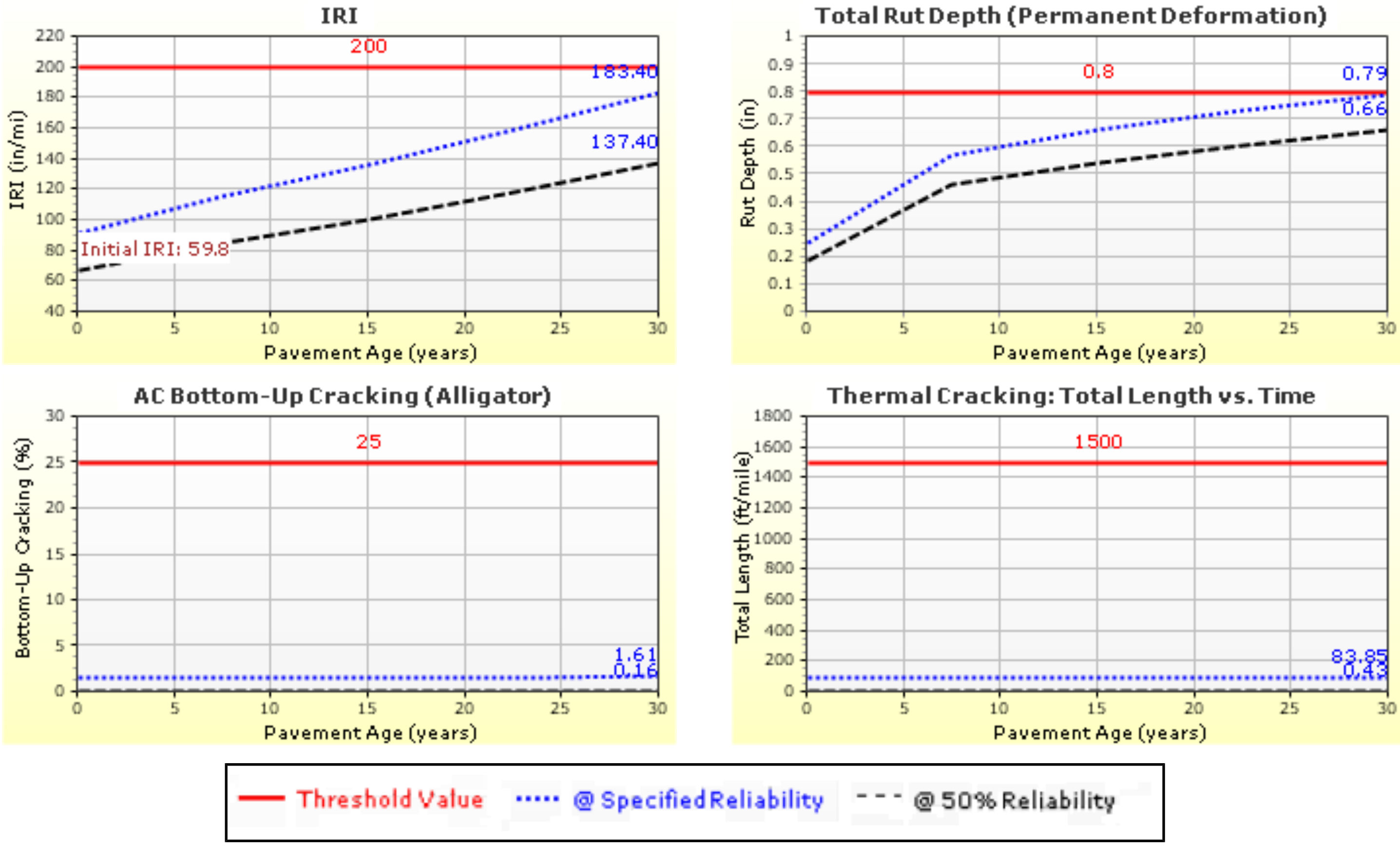
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	1,820
2039 (15 years)	6,897,530
2054 (30 years)	16,180,700

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	183.37	90.00	95.96	Pass
Permanent deformation - total pavement (in)	0.80	0.79	90.00	90.91	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.61	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.85	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	259.00	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.26	90.00	100.00	Pass

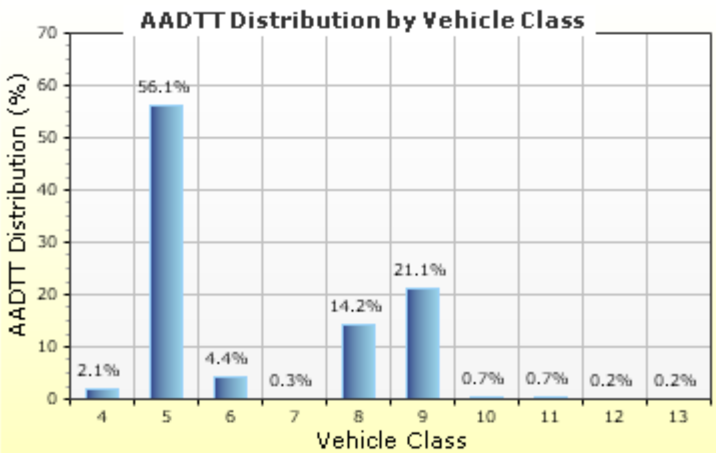
Distress Charts

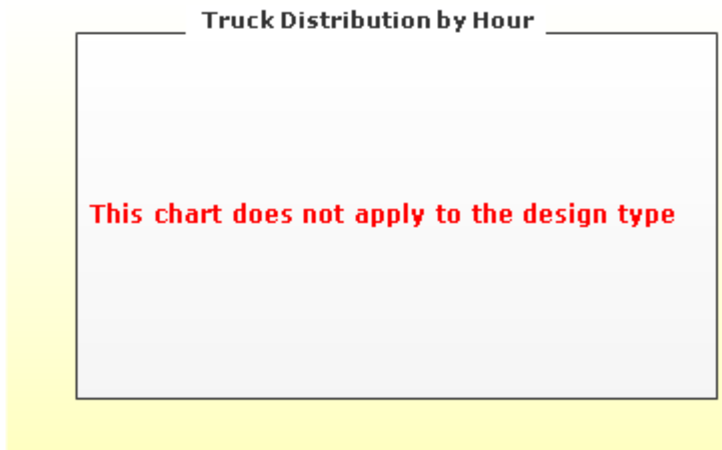


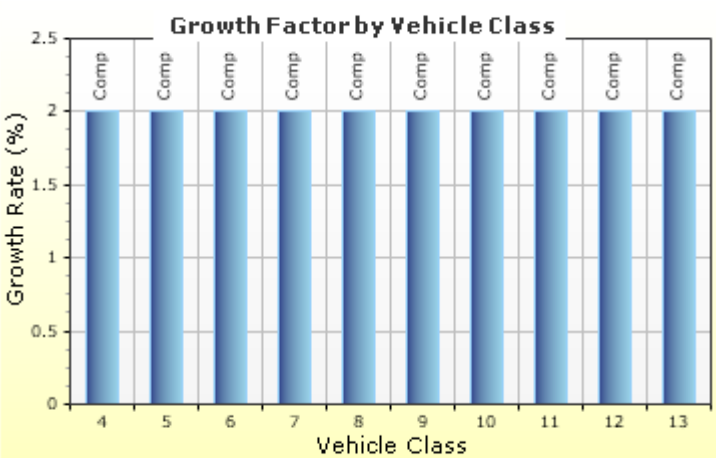
Traffic Inputs

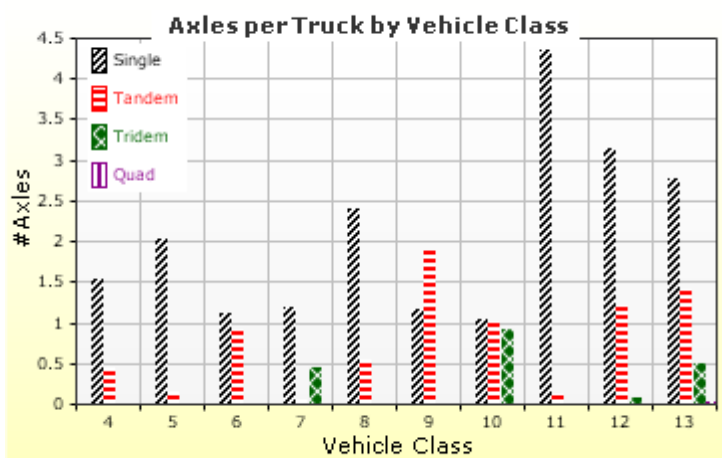
Graphical Representation of Traffic Inputs

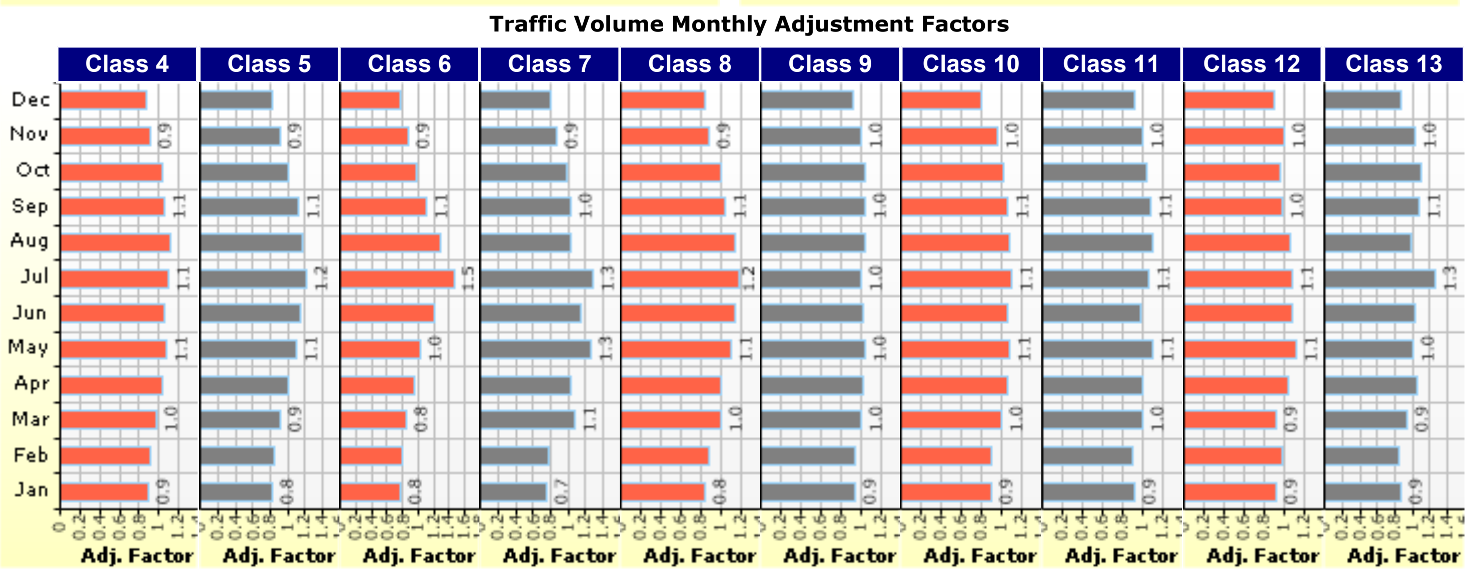
Initial two-way AADTT:	1,820	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0











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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

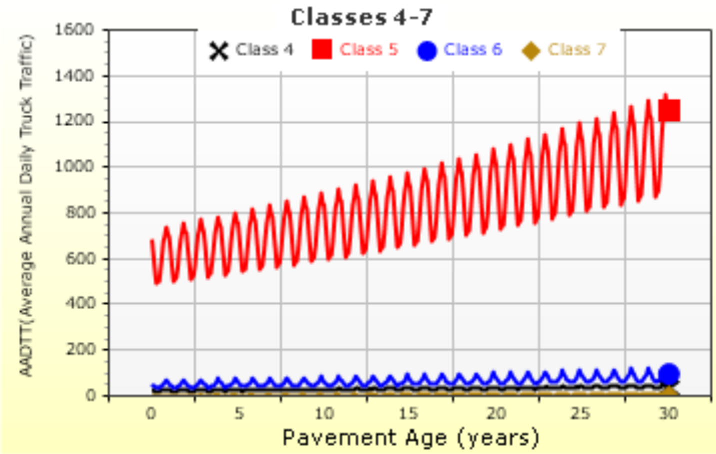
Wheelbase does not apply

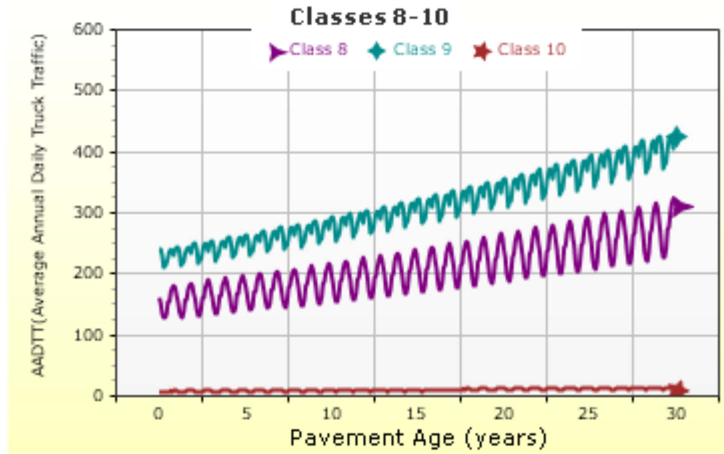
Number of Axles per Truck

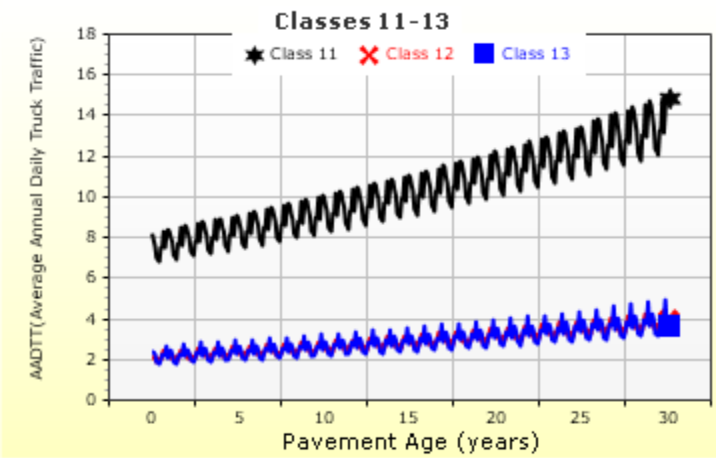
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

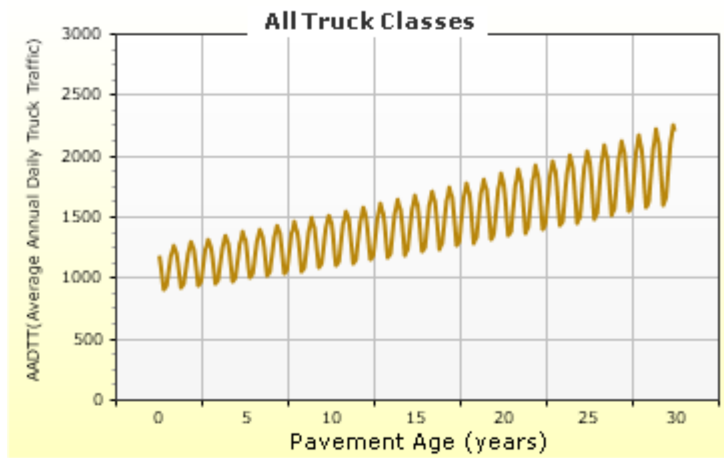
AADTT (Average Annual Daily Truck Traffic) Growth

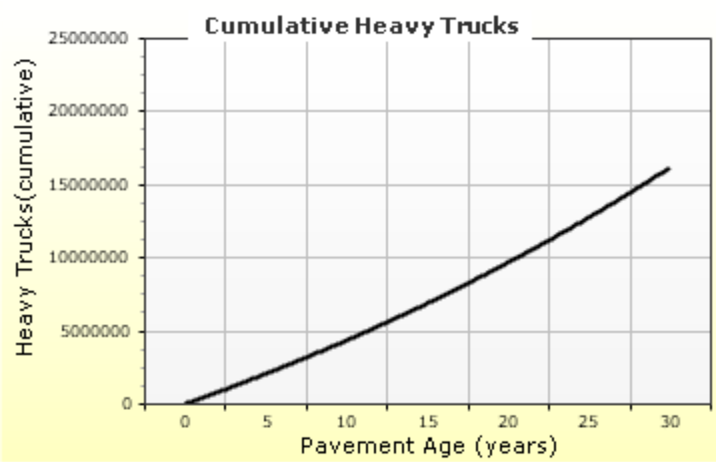
*** Traffic cap is not enforced**











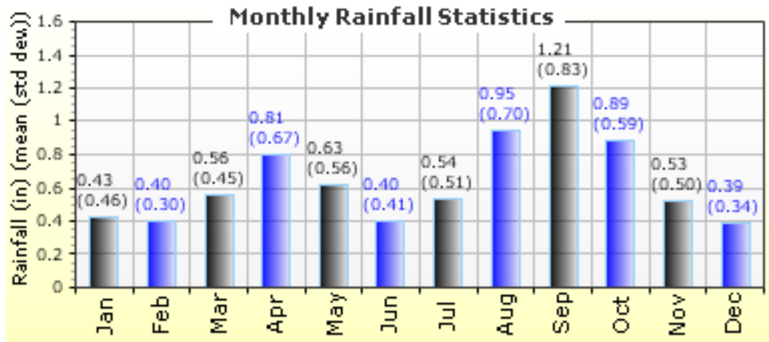
27.5 Road HMA (64-22) 30-year Design

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\27.5 Road HMA (64-22) 30-year Design.dgpx

Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

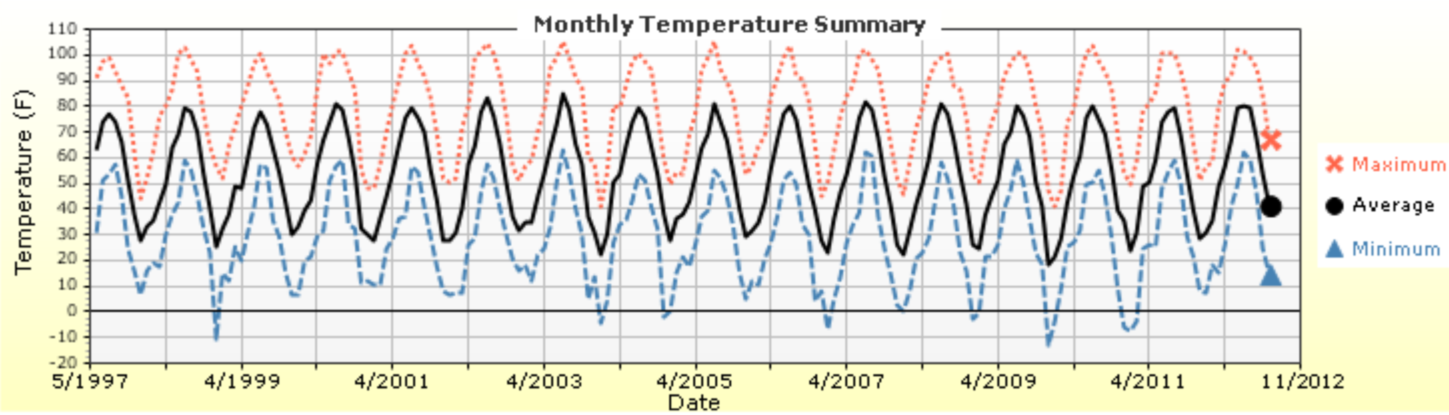


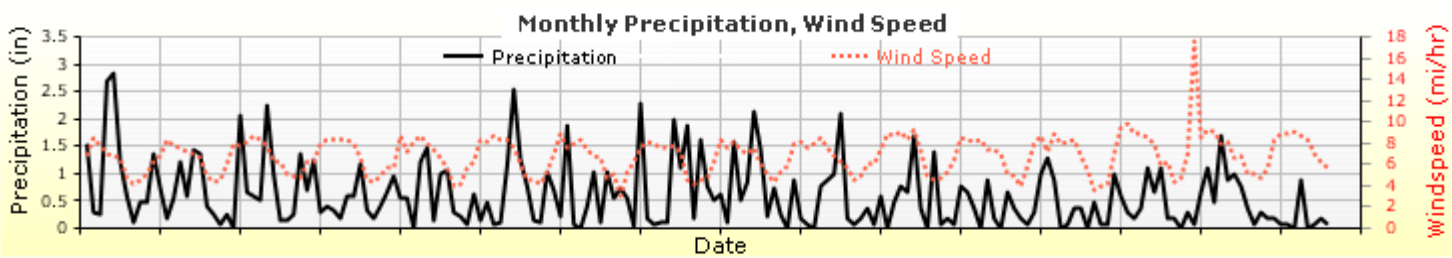
Annual Statistics:

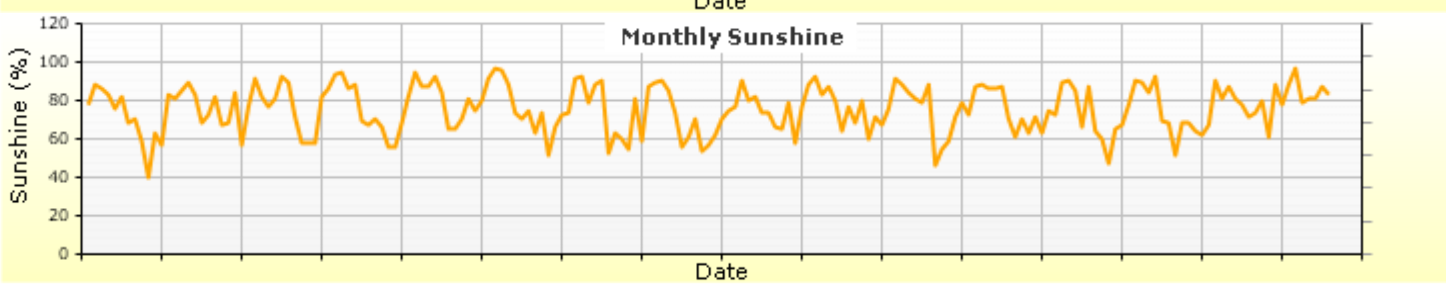
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

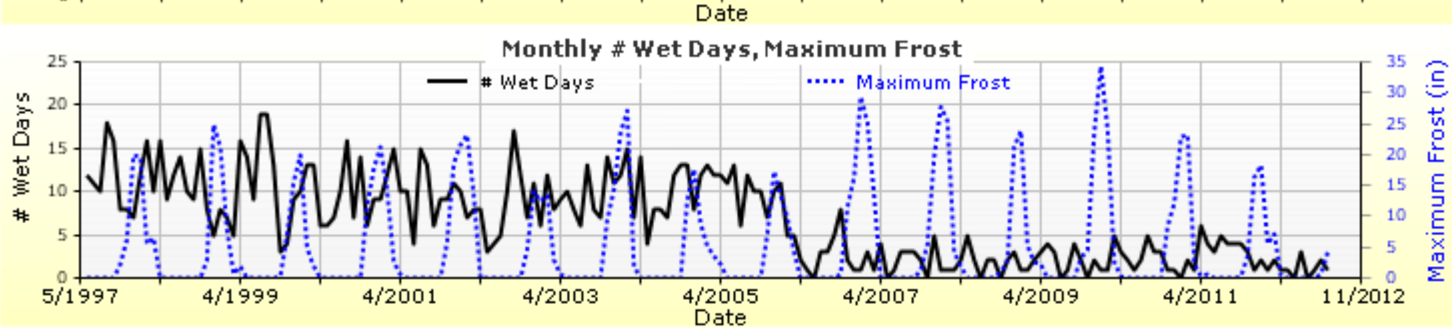
Water table depth (ft)	4.00

Monthly Climate Summary:

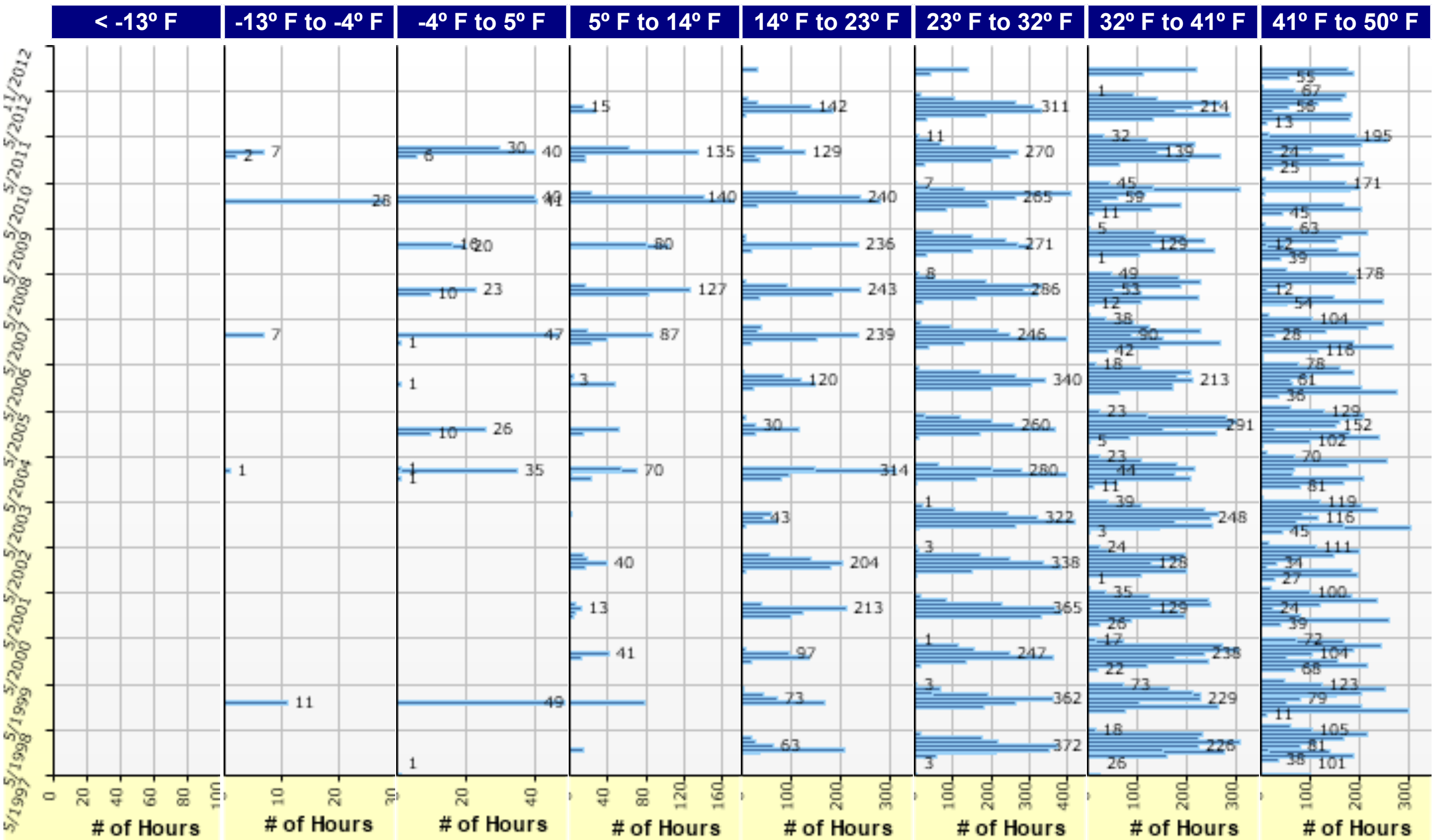


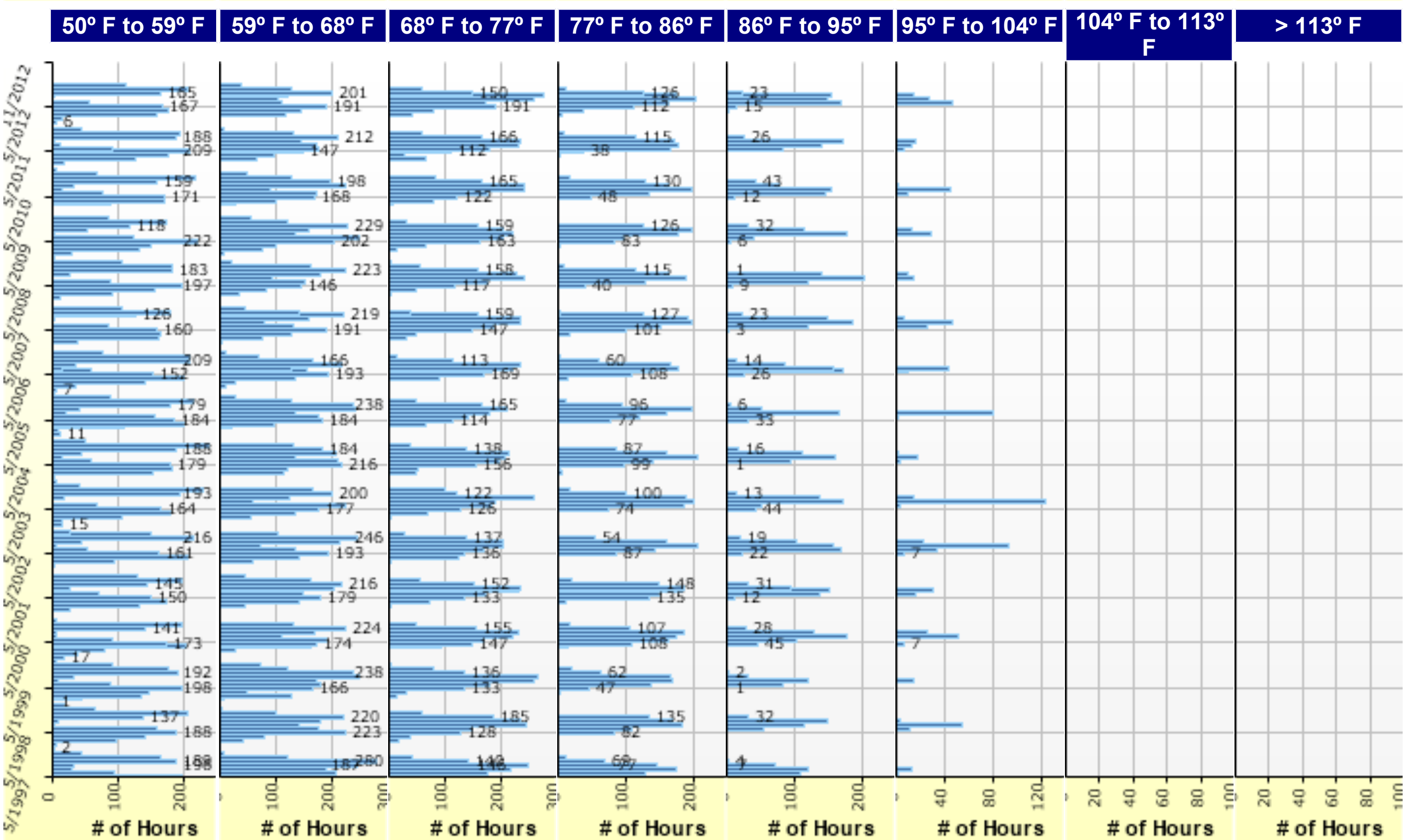






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

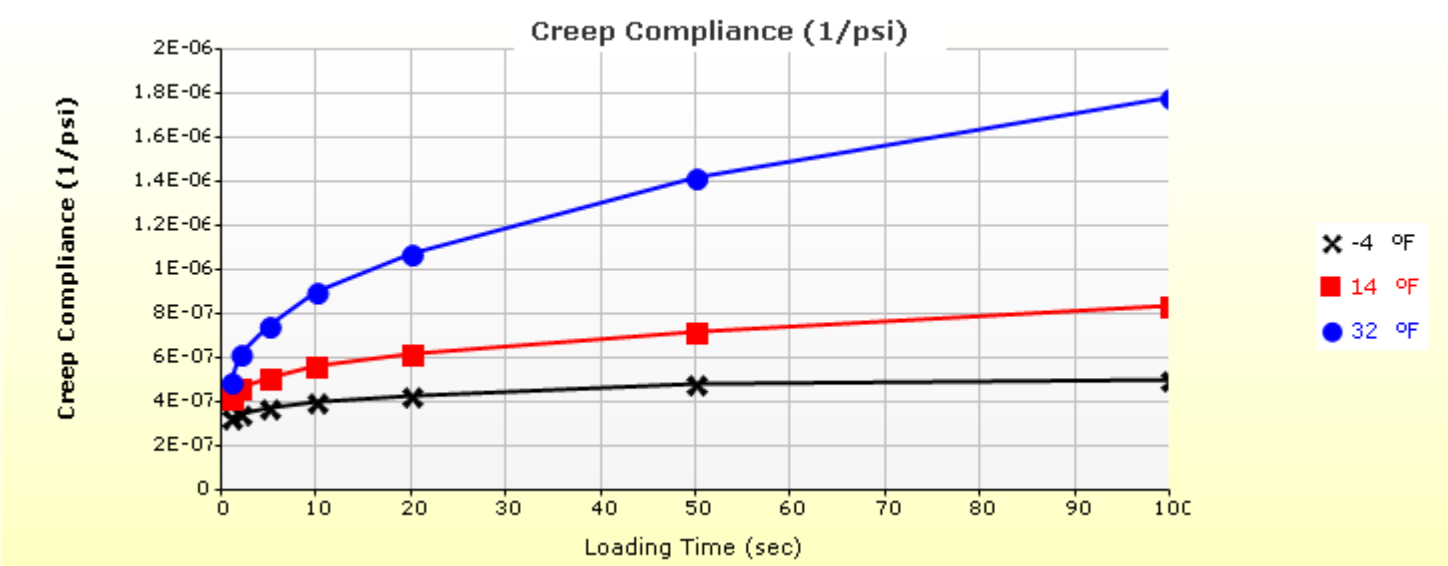
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

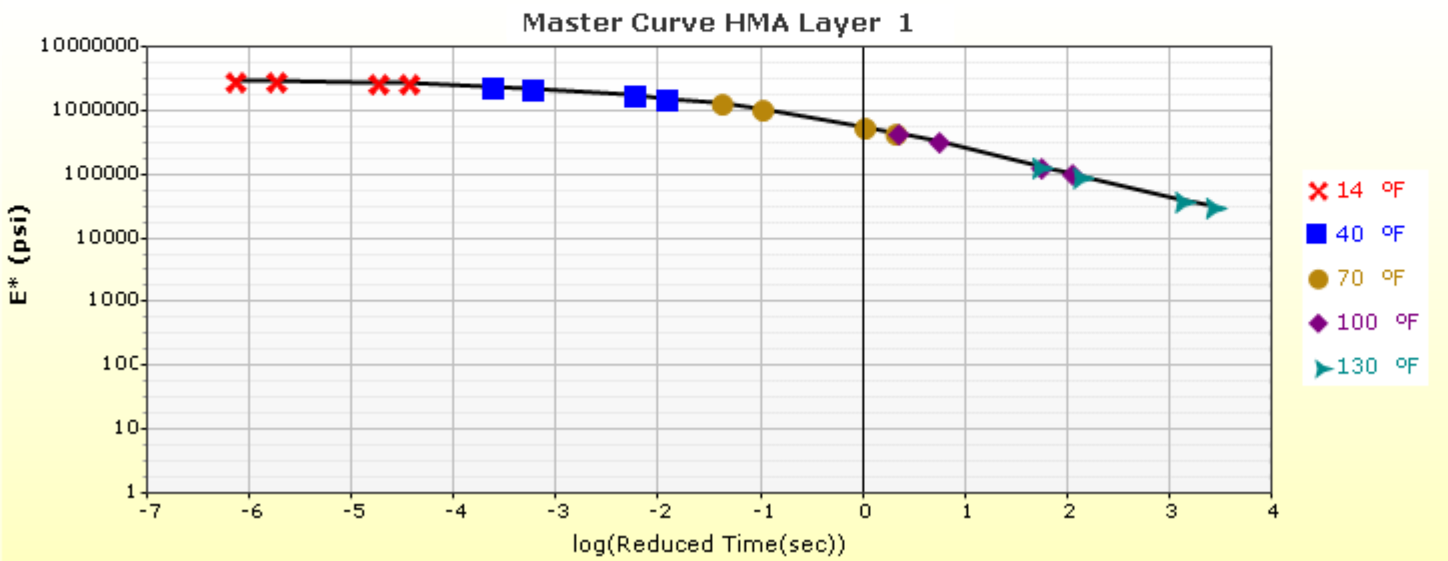
Thermal Cracking (Input Level: 1)

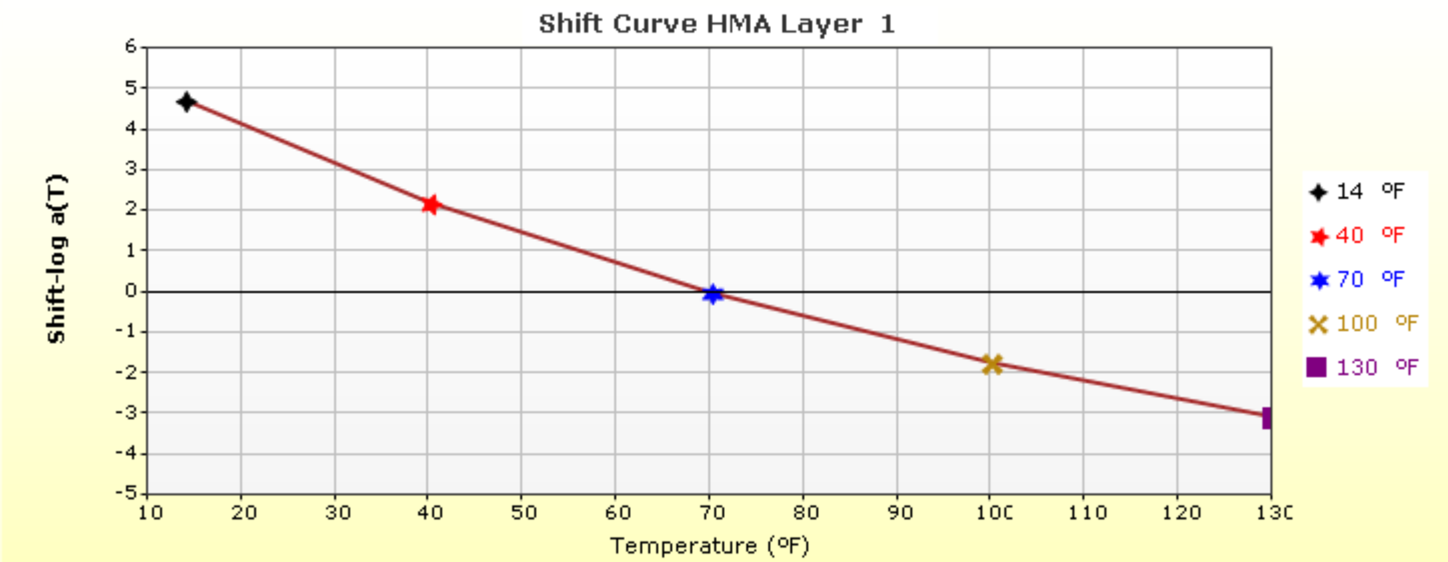
Indirect tensile strength at 14 ºF (psi)	451.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

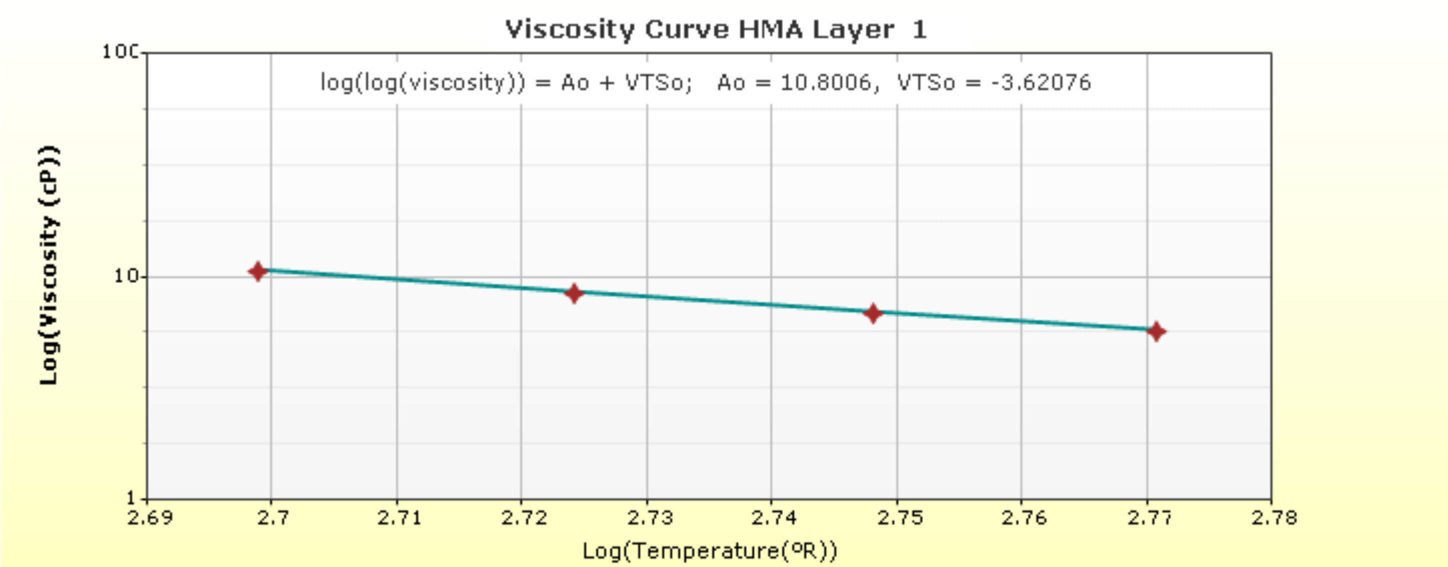
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



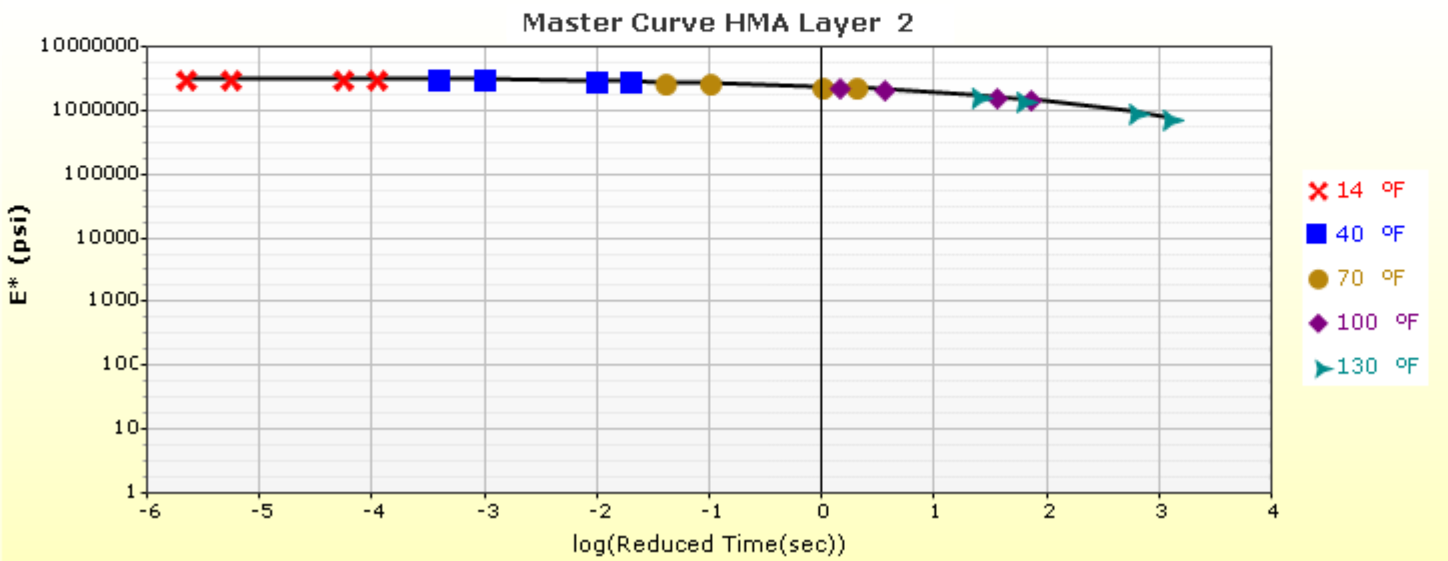
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

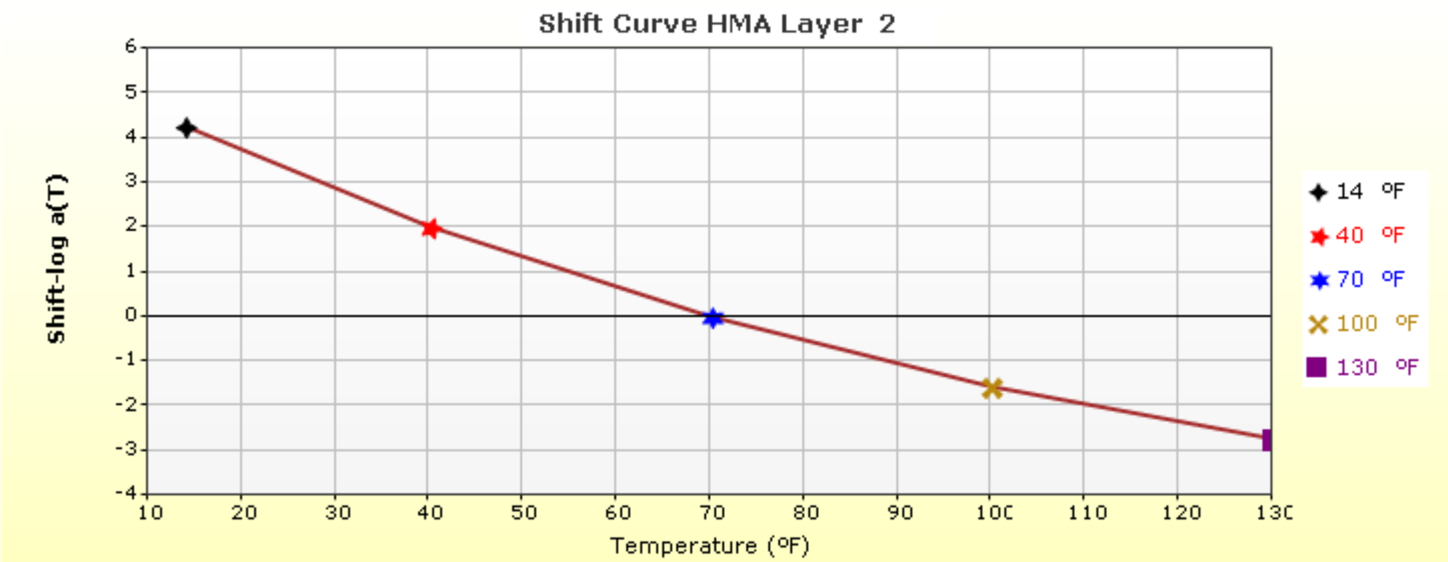


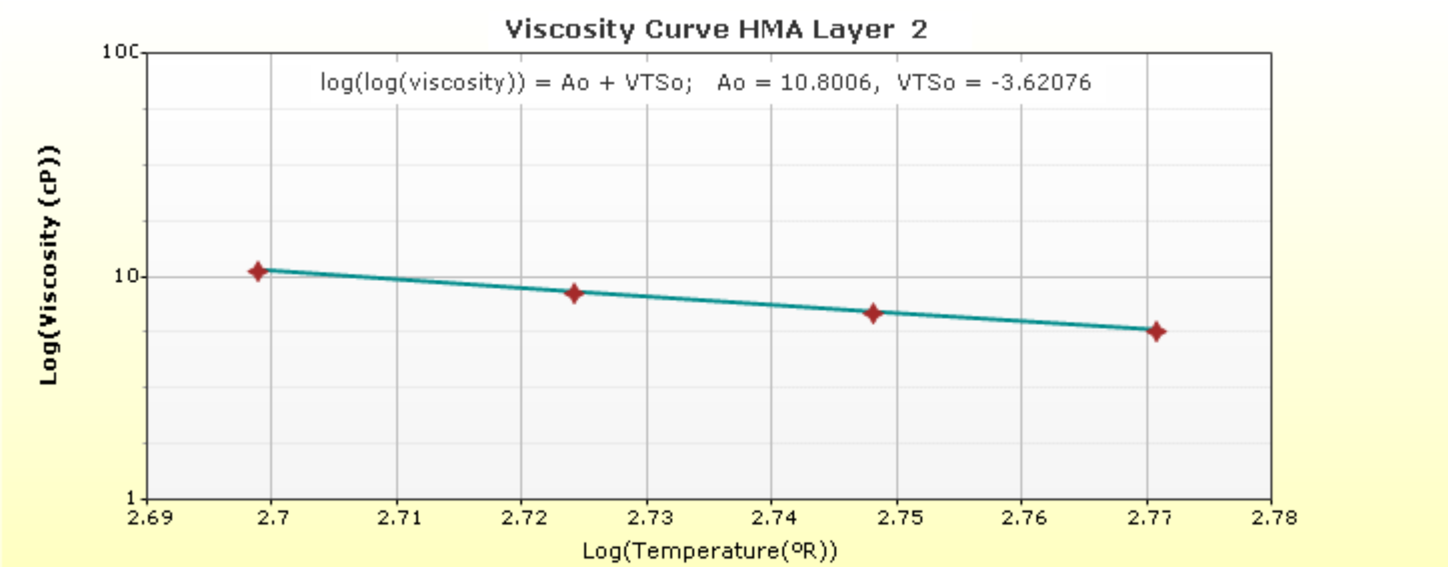




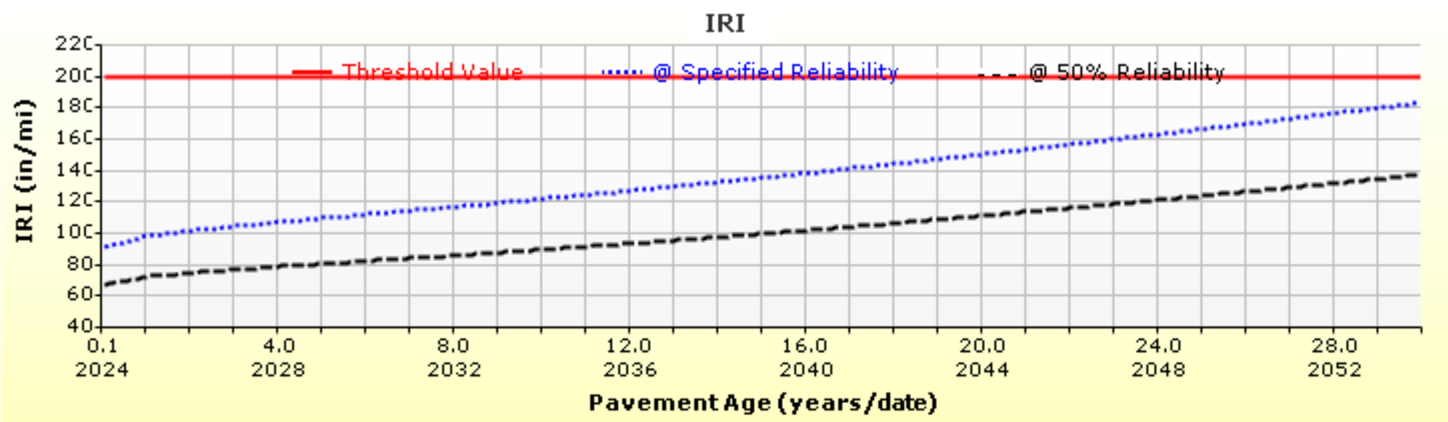
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

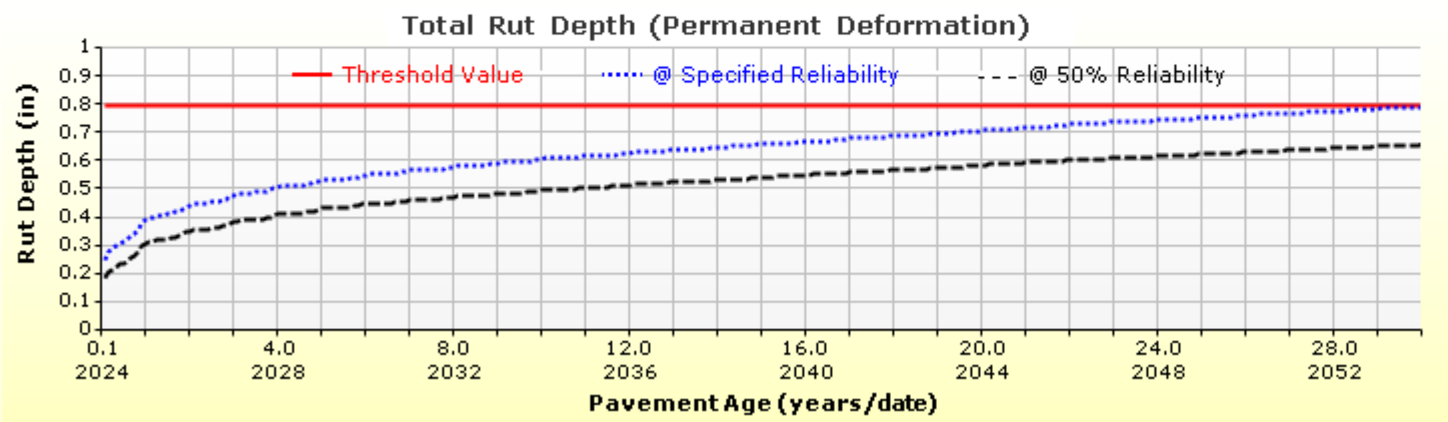


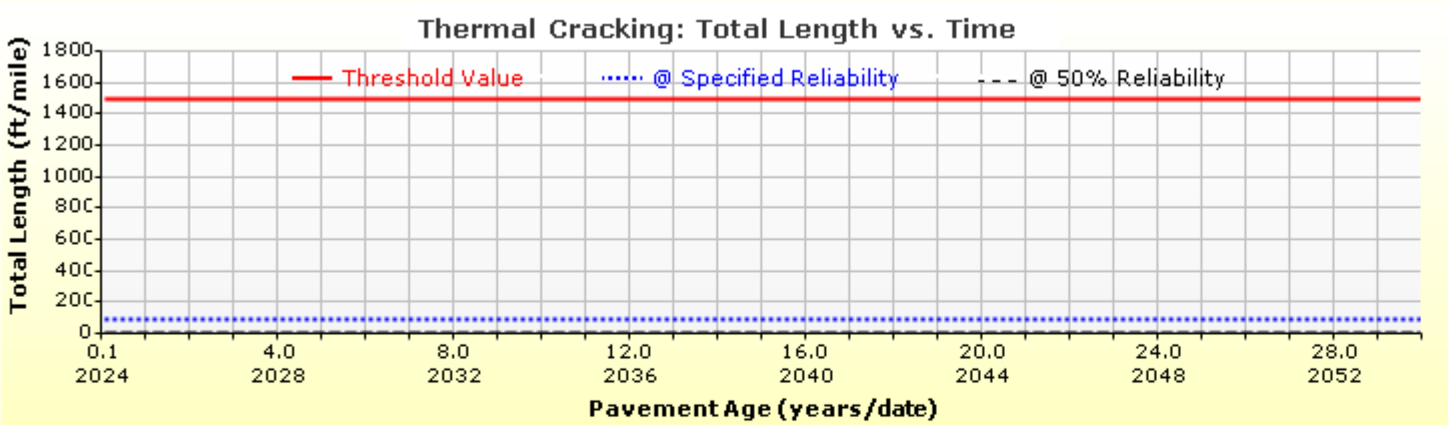


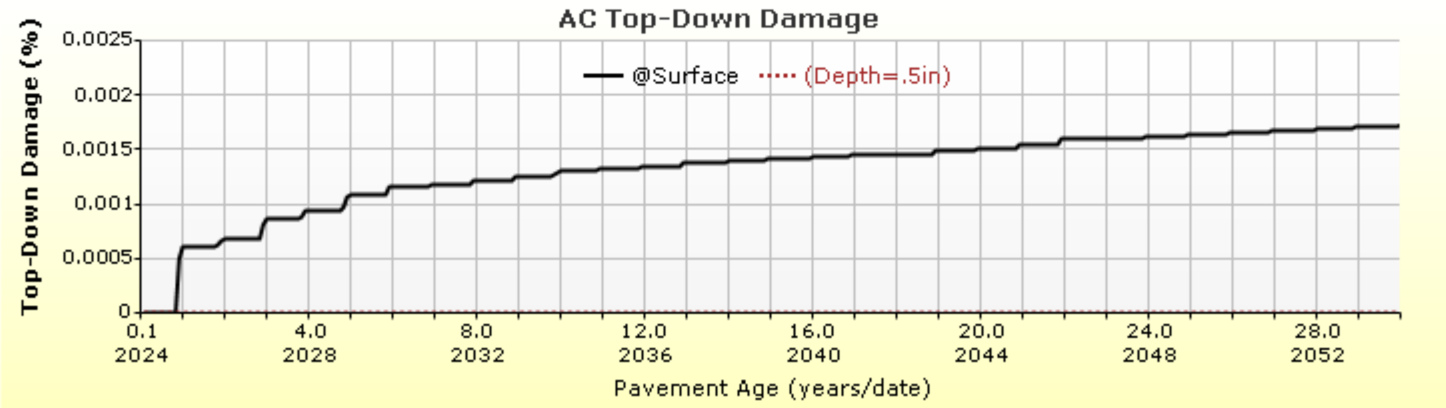


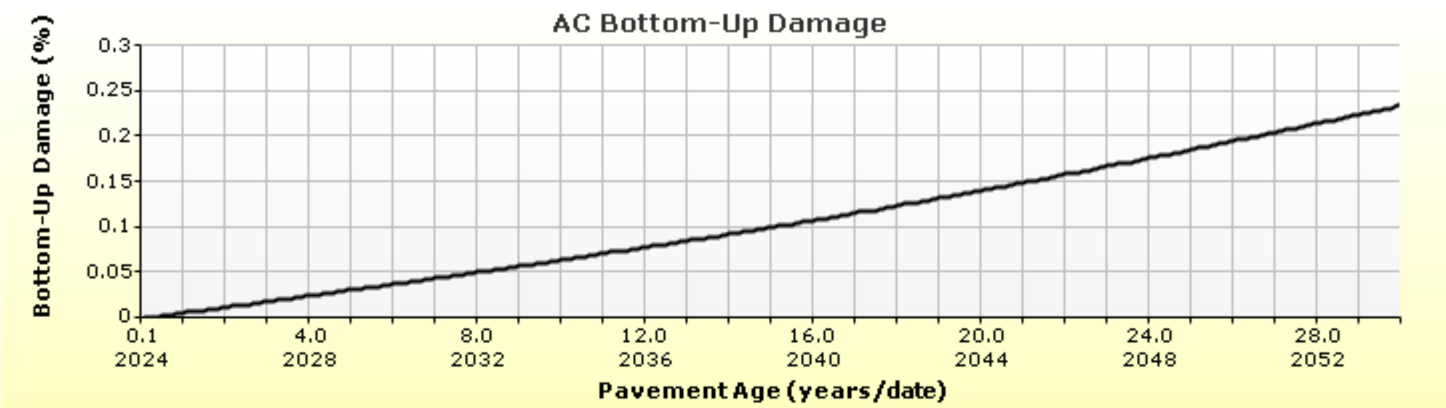
Analysis Output Charts

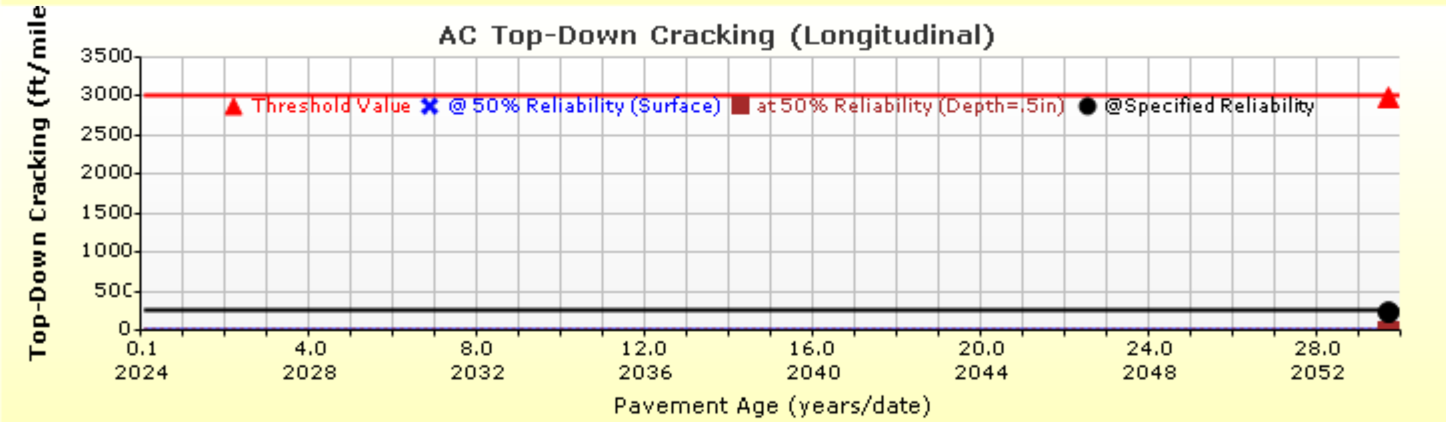


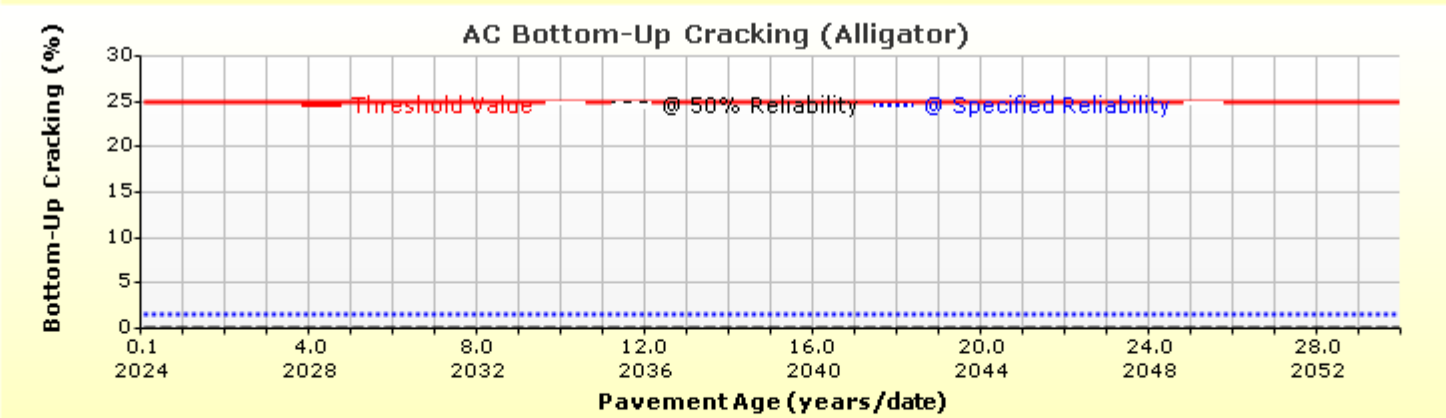


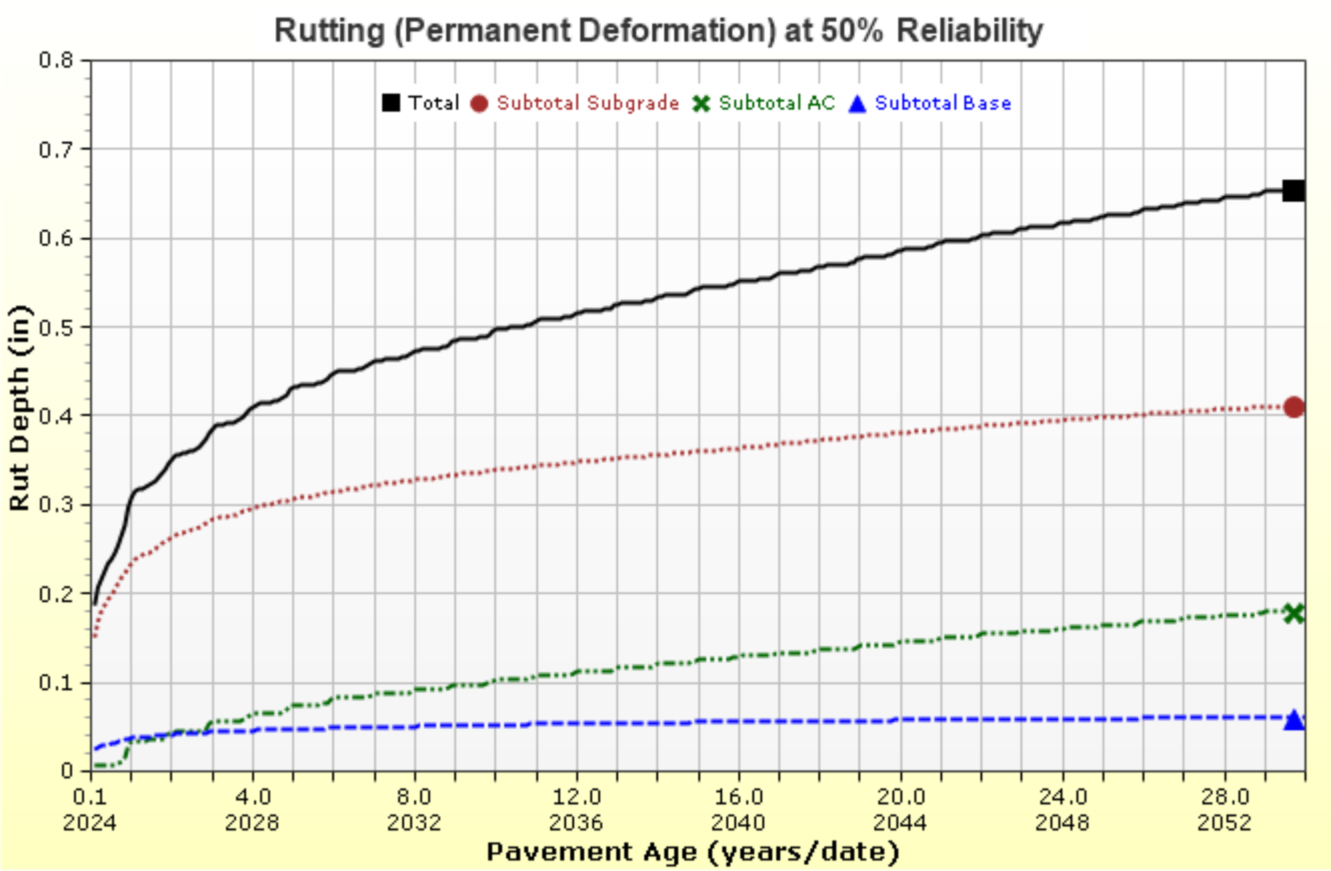


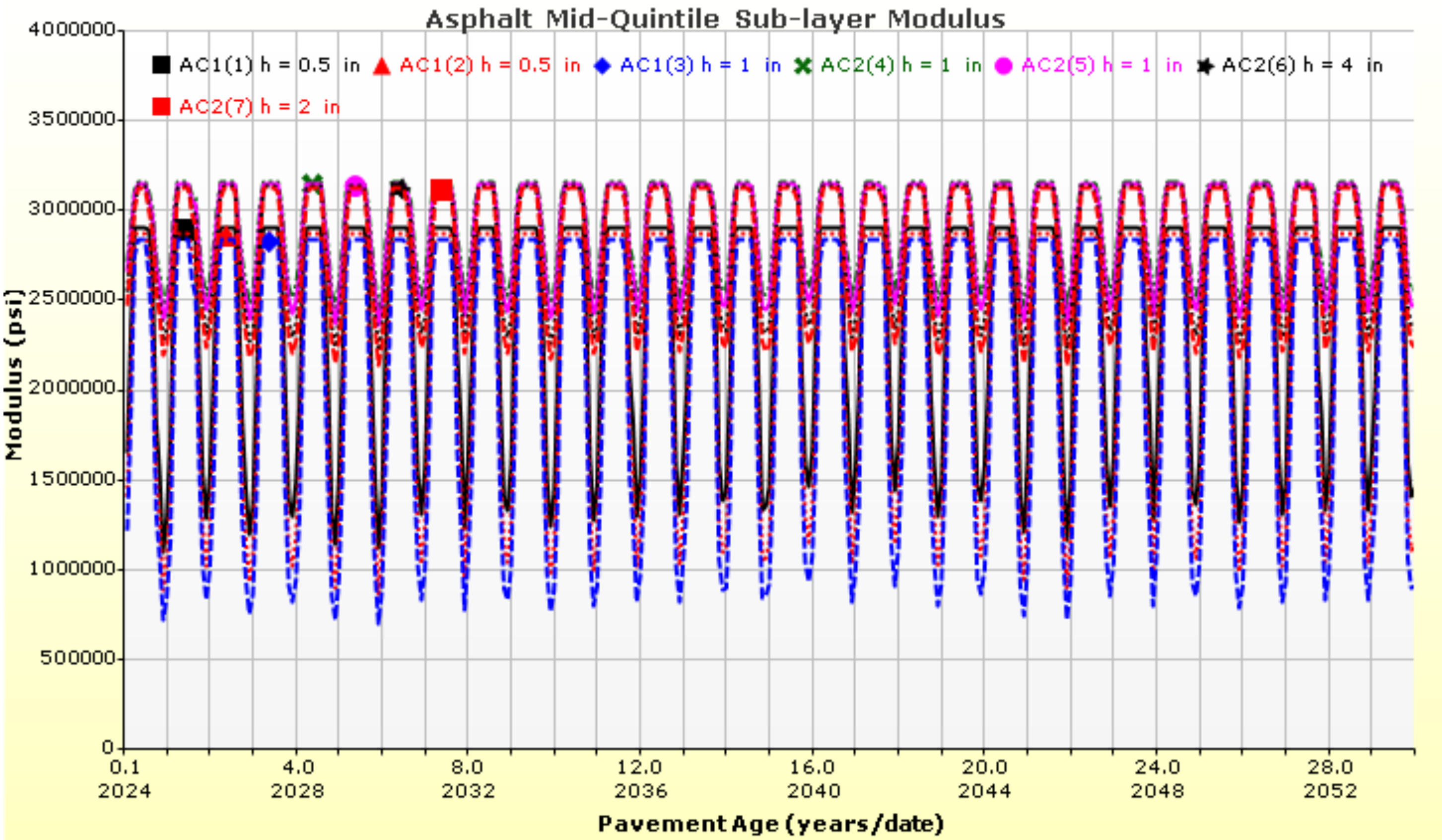

AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.0025
0.002
0.0015
0.001
0.0005
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

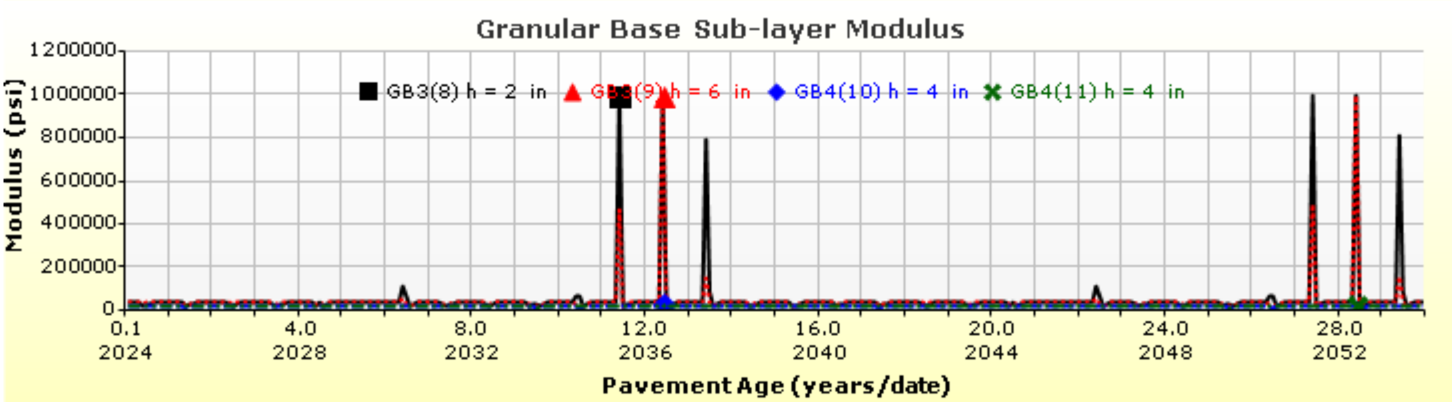

AC Bottom-Up Damage
Bottom-Up Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

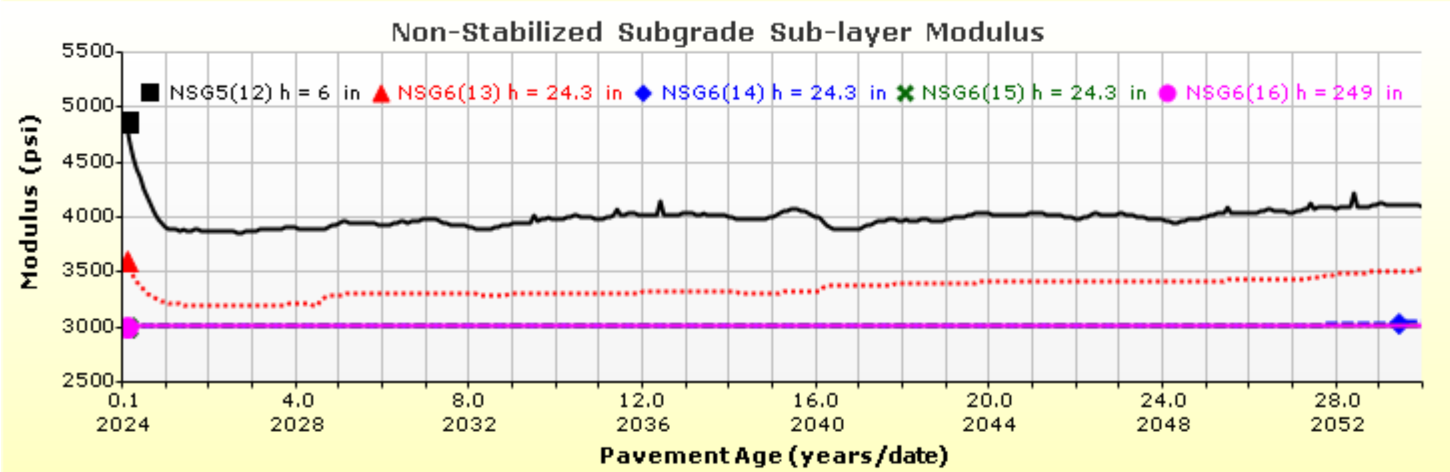

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2024
4.0
2028
8.0
2032
12.0
2036
16.0
2040
20.0
2044
24.0
2048
28.0
2052
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 2 in
Modulus (psi)
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 6 in
GB4(10) h = 4 in
GB4(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 6 in
NSG6(13) h = 24.3 in
NSG6(14) h = 24.3 in
NSG6(15) h = 24.3 in
NSG6(16) h = 249 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	8.0	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.007566	k2: 3.9492
k3: 1.281	Bf1: 1
Bf2: 1	Bf3: 1

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at( )
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

AC Bottom Up Cracking

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 1	c2: 1	c3: 6000

AC Cracking Top Standard Deviation	AC Cracking Bottom Standard Deviation
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))	1.13 + 13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

APPENDIX F

HORIZON DRIVE

20 AND 30-YEAR DESIGN LIFE FOR FLEXIBLE PAVEMENT

M-E DESIGN OUTPUT SHEETS

Horizon Drive HMA (64-22) Design

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\Horizon Drive HMA (64-22) Design.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	7.5
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

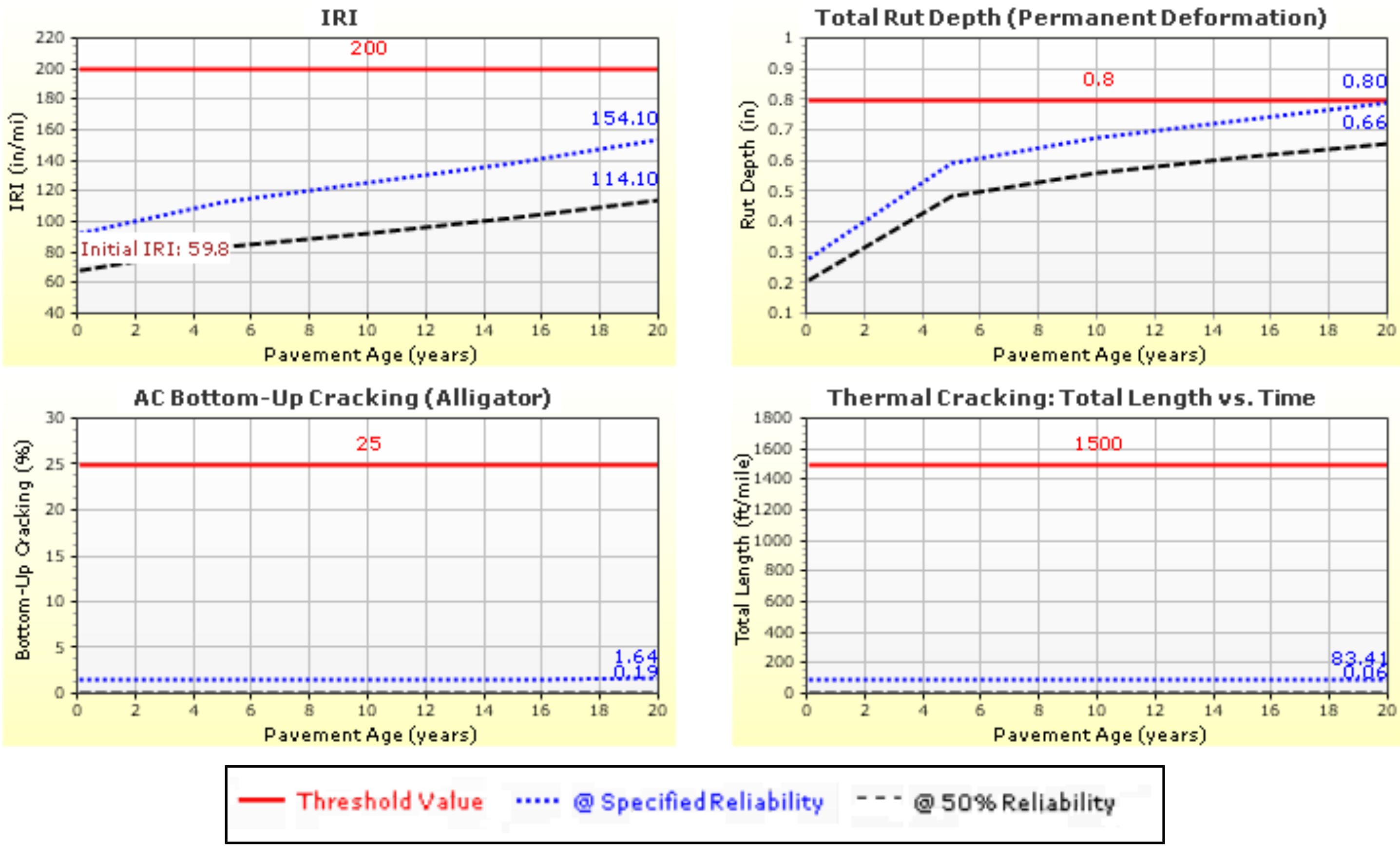
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	3,640
2034 (10 years)	6,550,990
2044 (20 years)	14,536,600

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	154.08	90.00	99.71	Pass
Permanent deformation - total pavement (in)	0.80	0.79	90.00	90.88	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.64	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.41	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	257.45	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.25	90.00	100.00	Pass

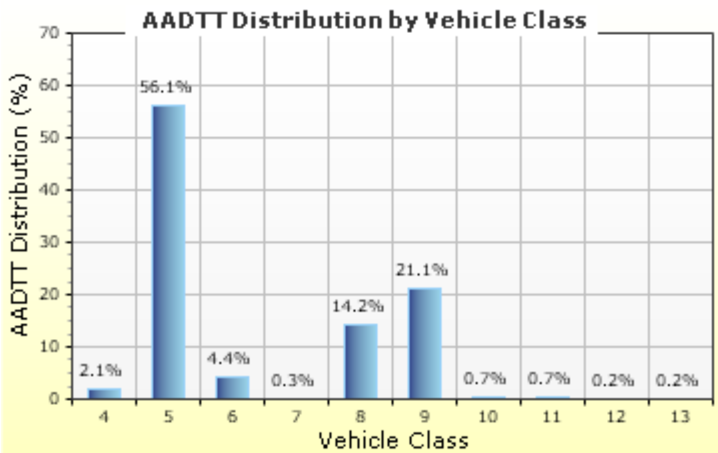
Distress Charts

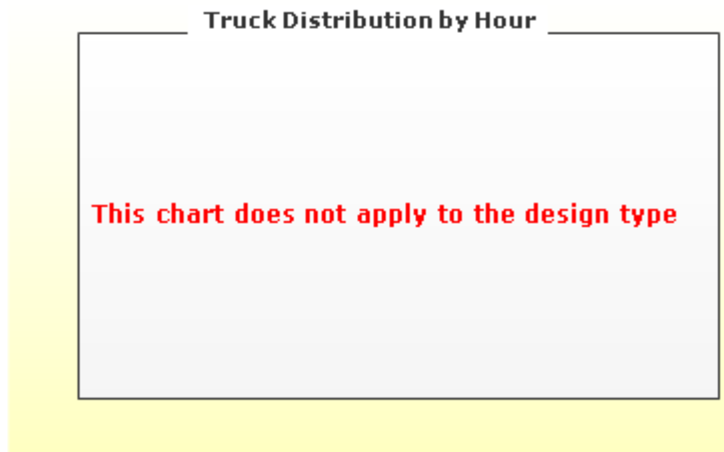


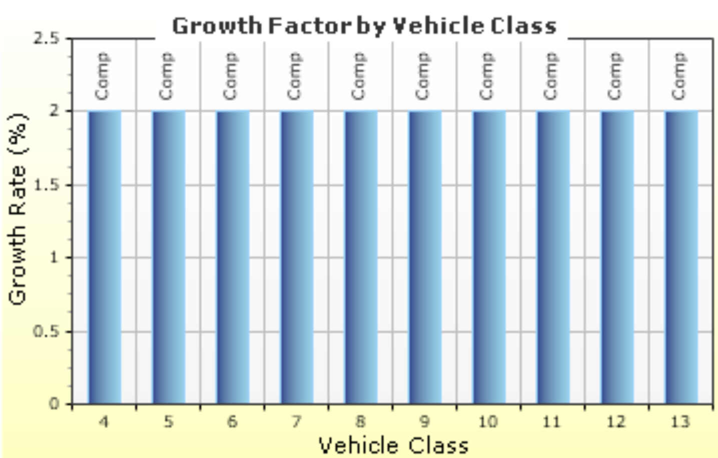
Traffic Inputs

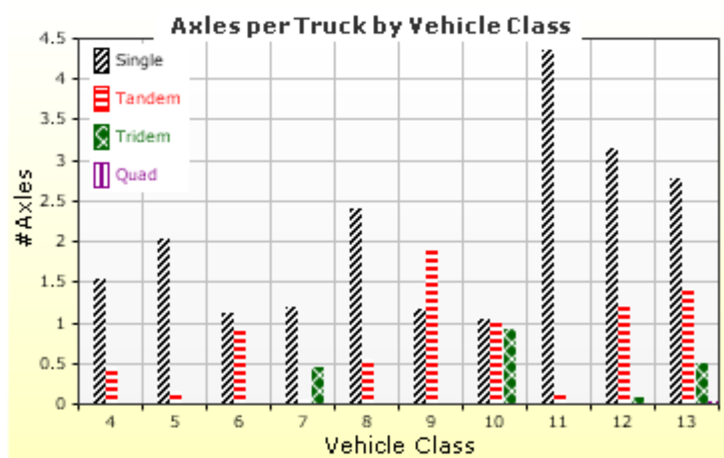
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,640	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

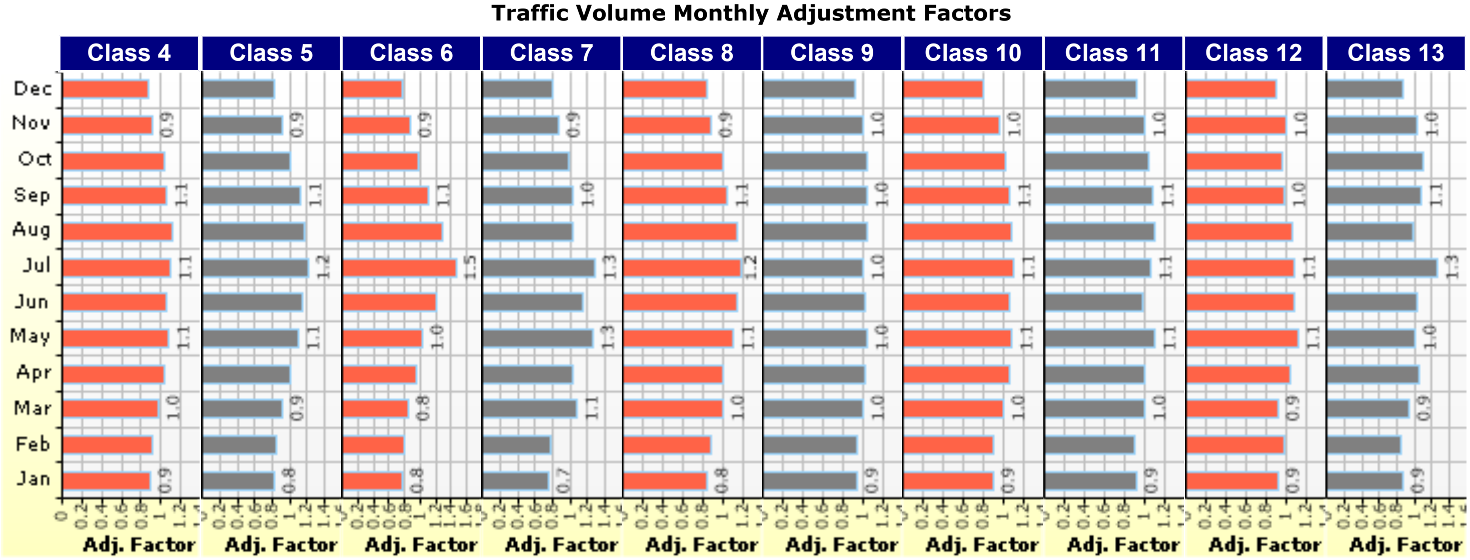








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

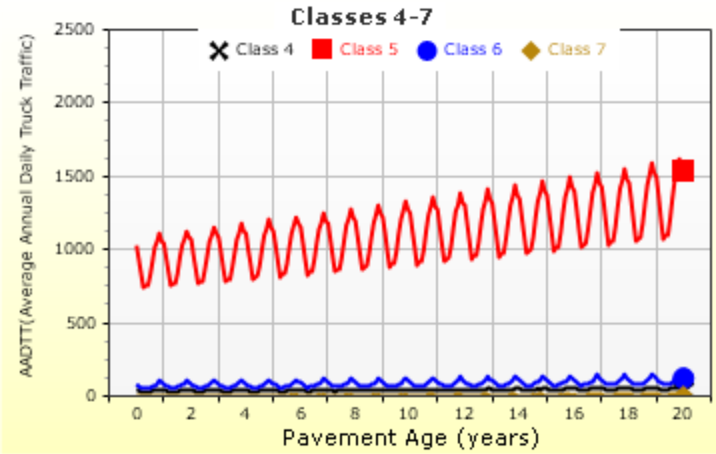
Wheelbase does not apply

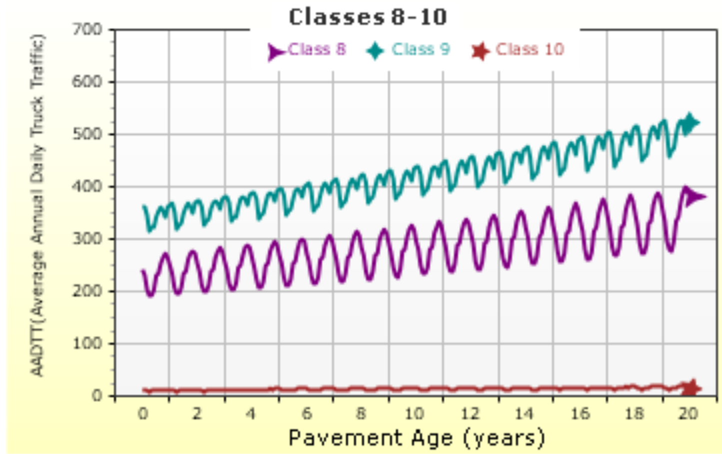
Number of Axles per Truck

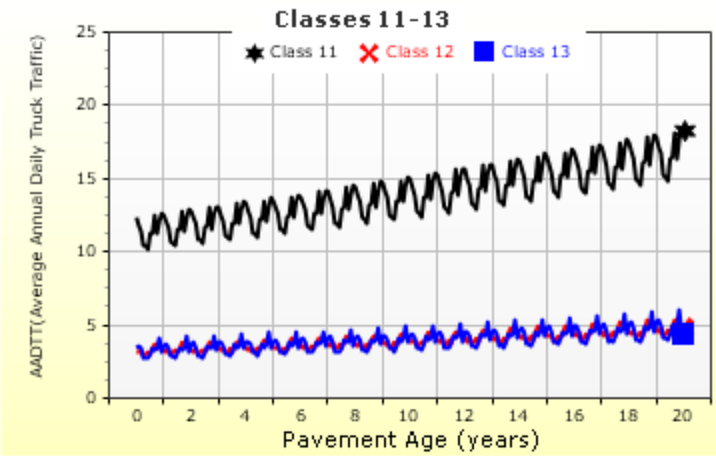
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

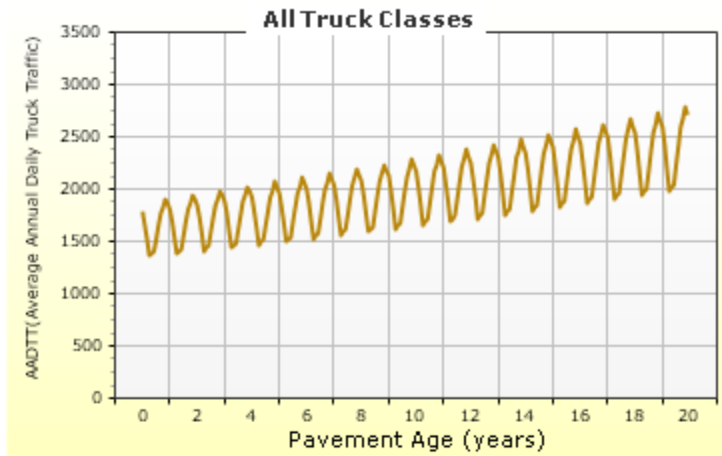
AADTT (Average Annual Daily Truck Traffic) Growth

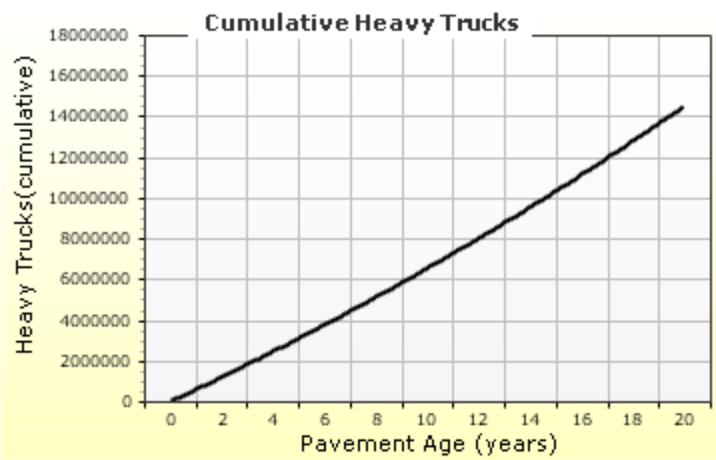
*** Traffic cap is not enforced**







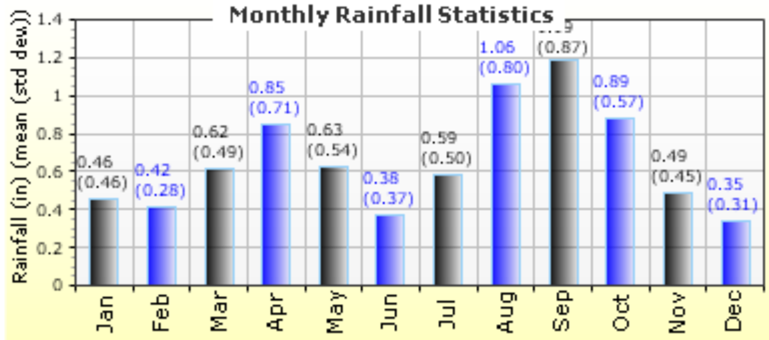




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

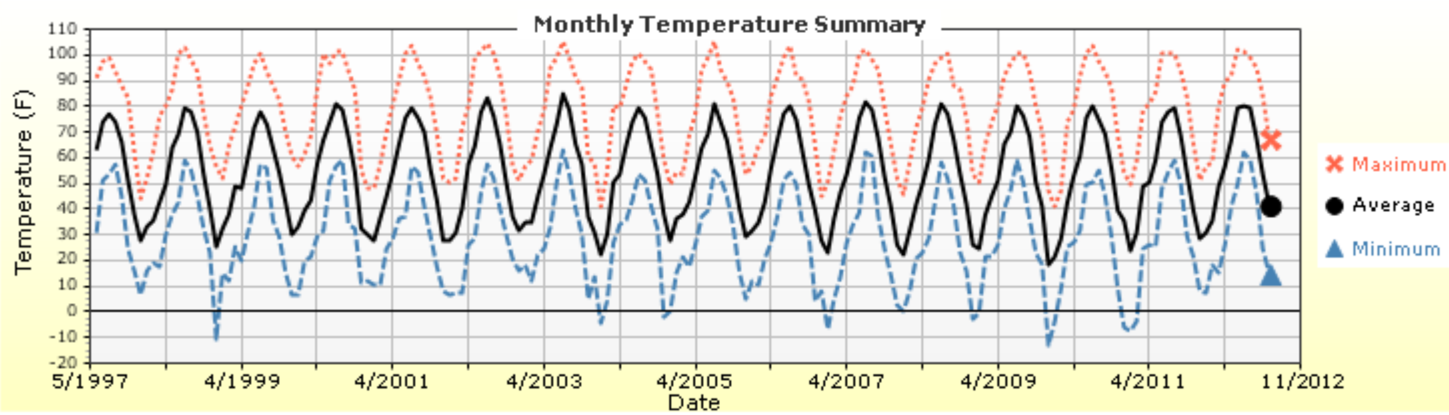


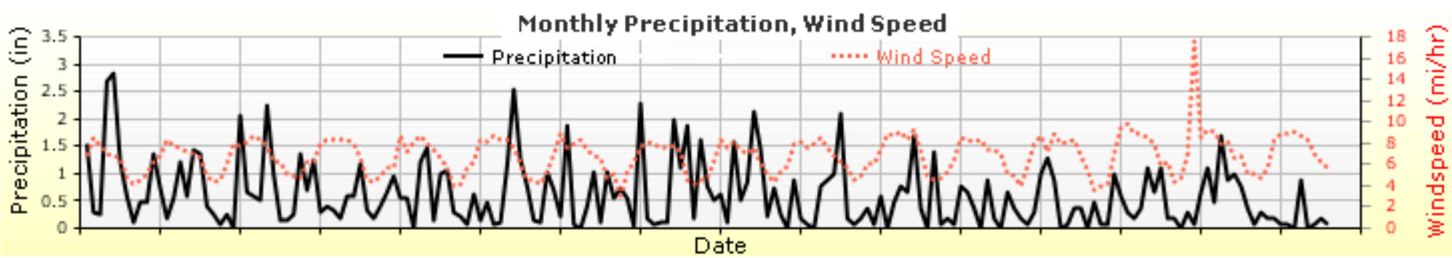
Annual Statistics:

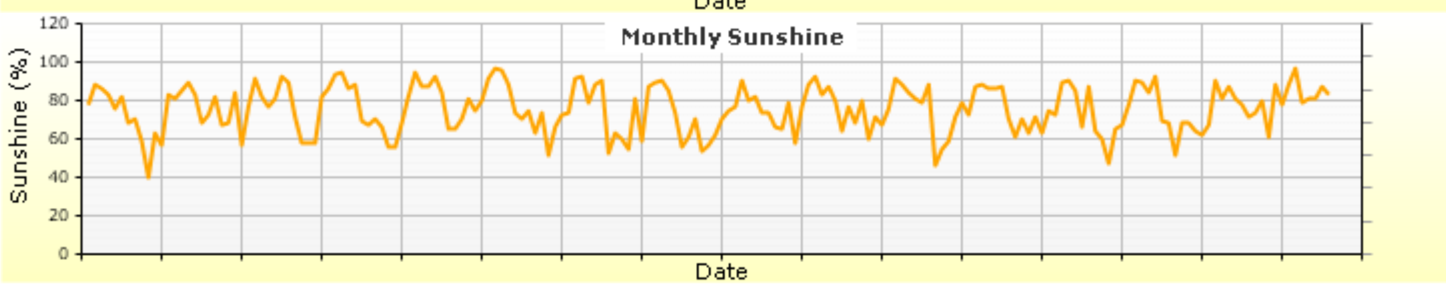
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

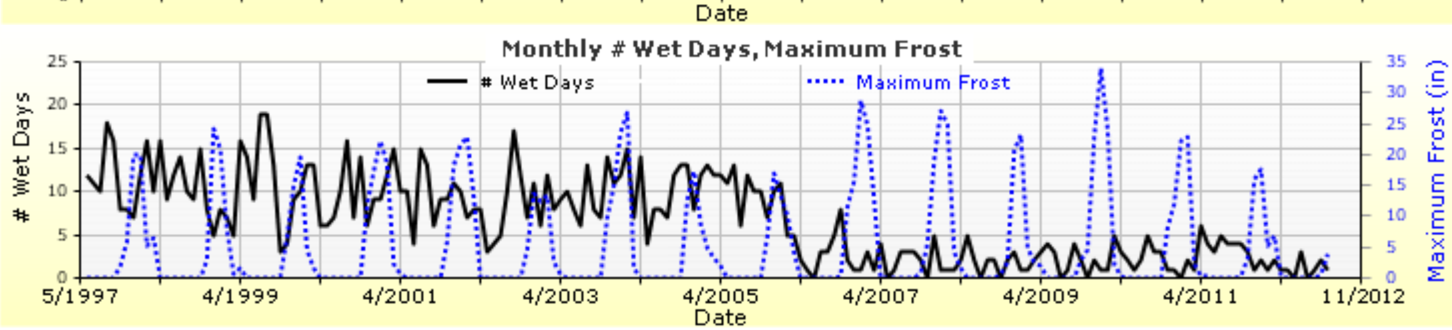
Water table depth (ft) 4.00

Monthly Climate Summary:

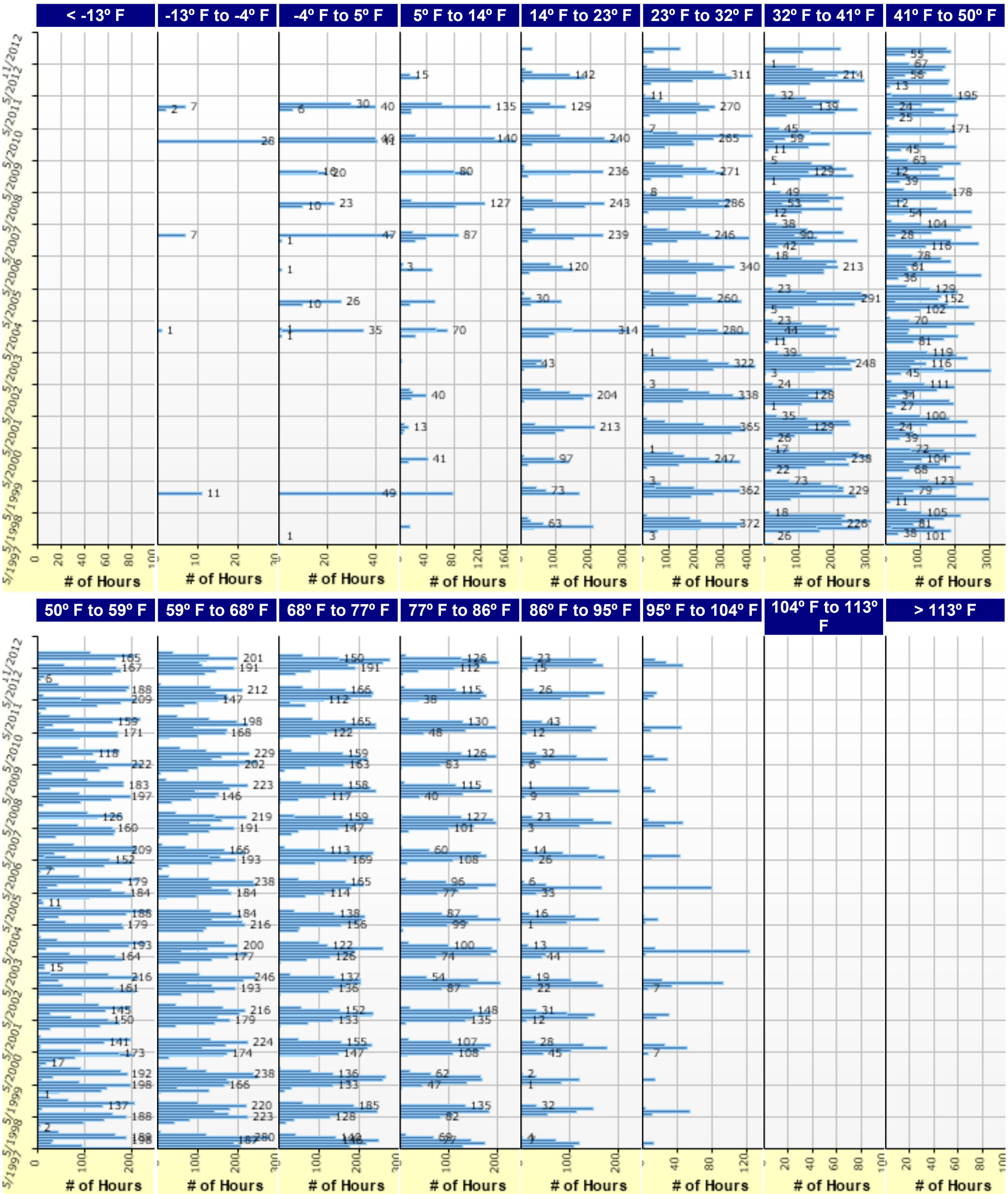








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

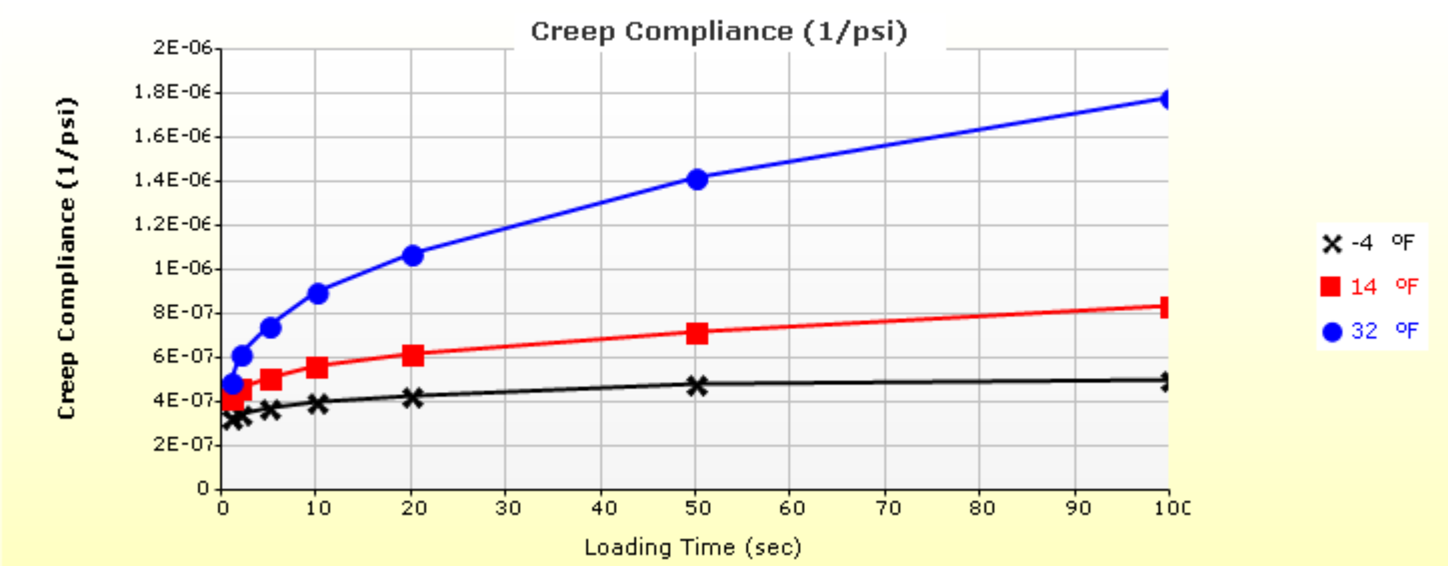
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

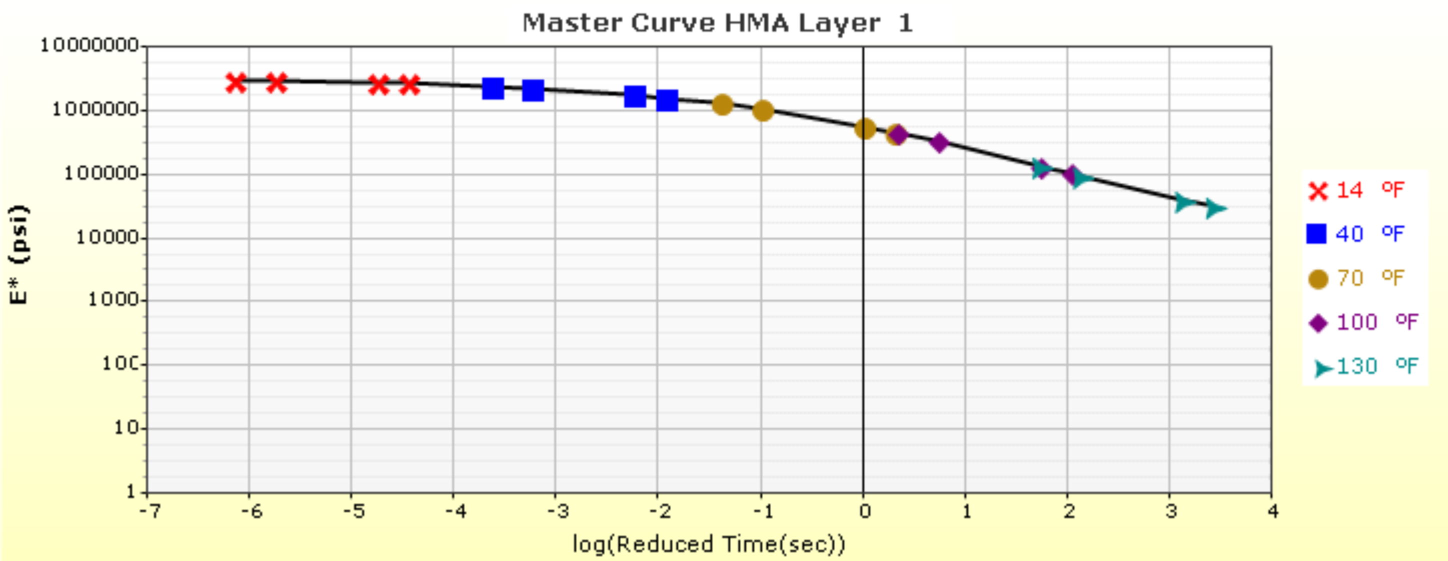
Indirect tensile strength at 14 ºF (psi)	451.00

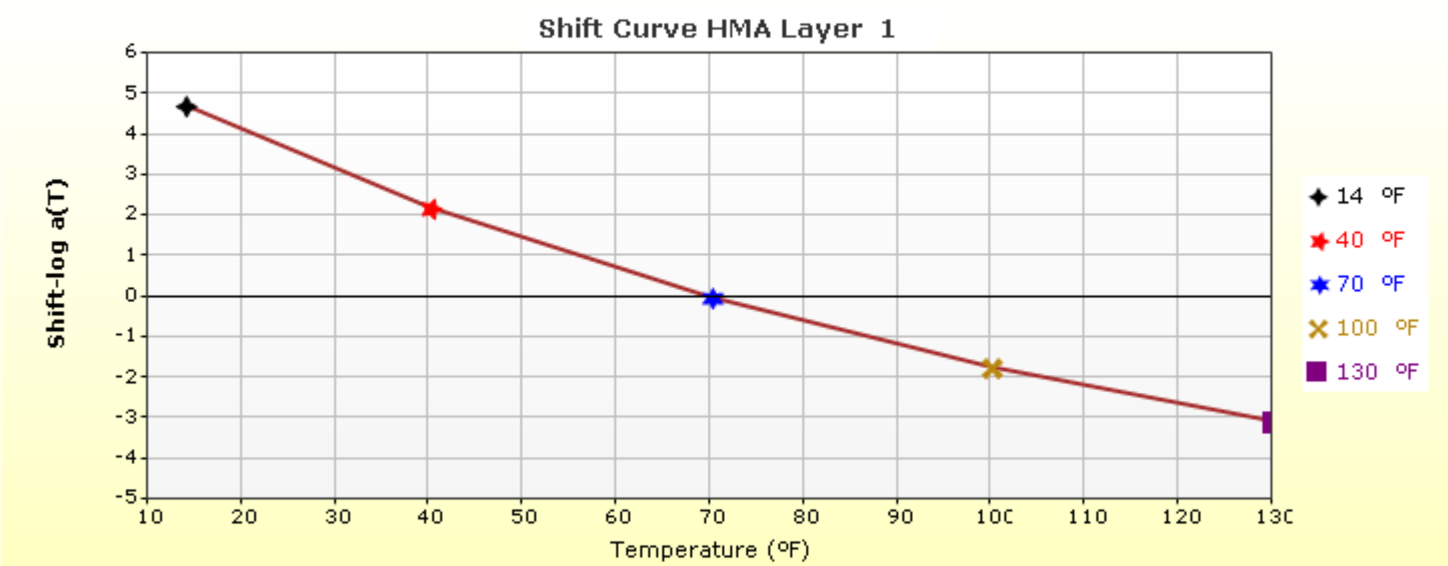
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

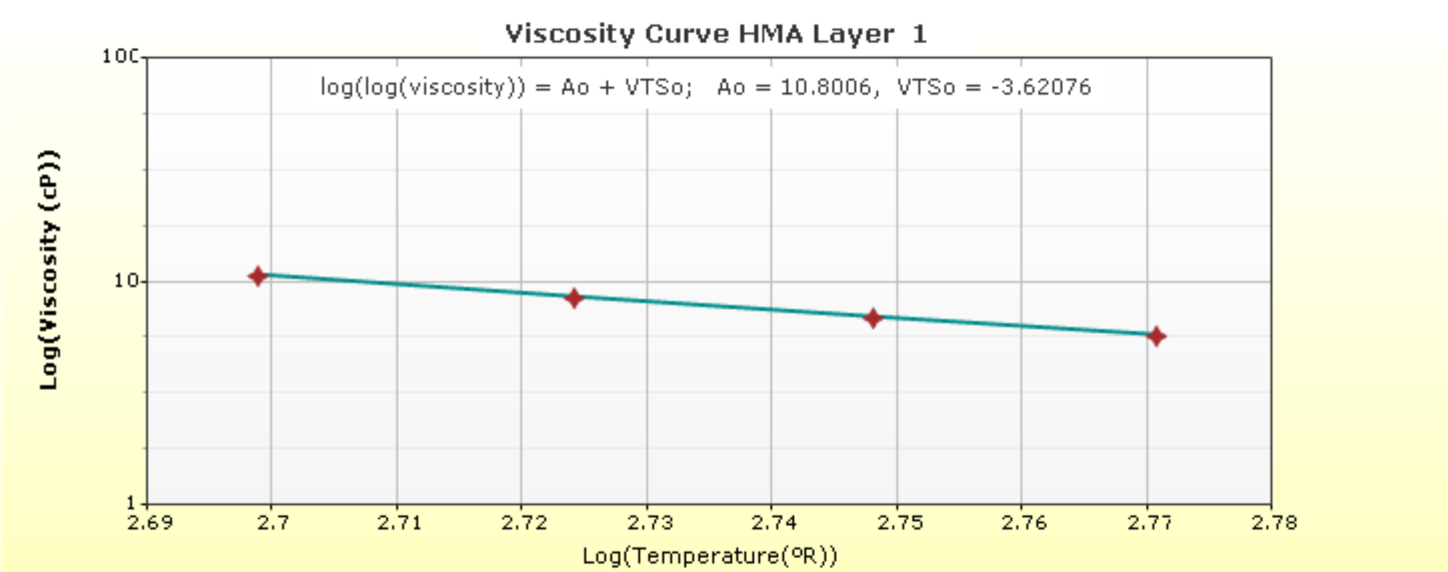
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



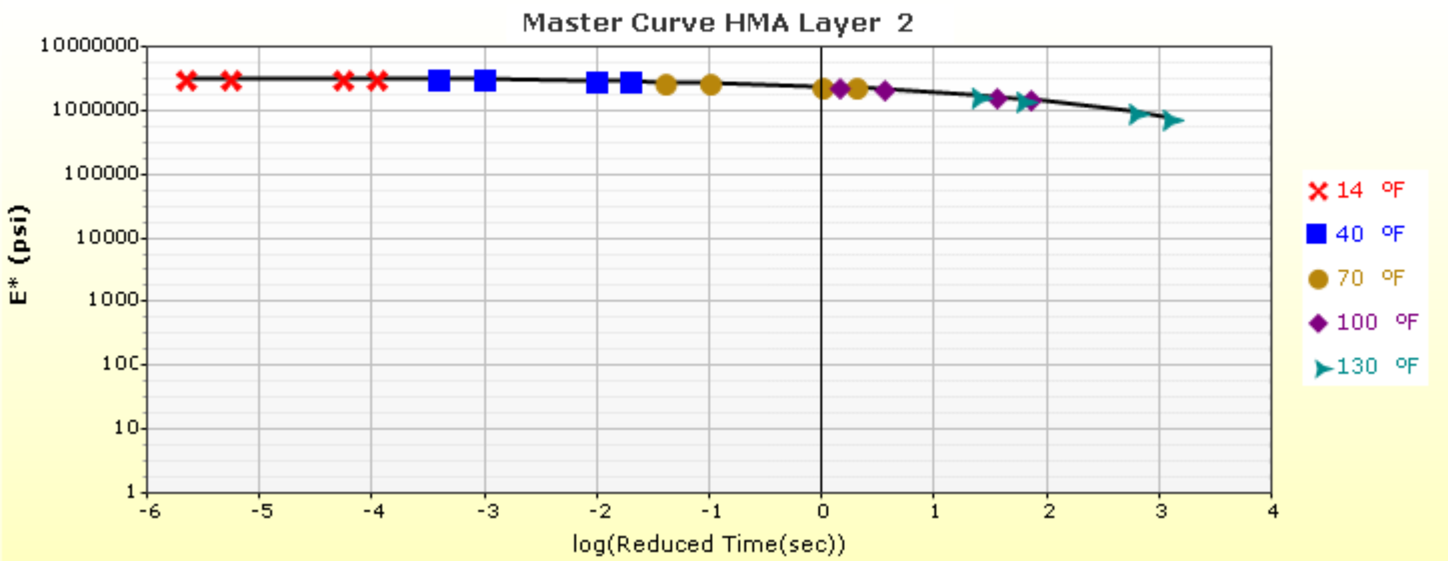
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

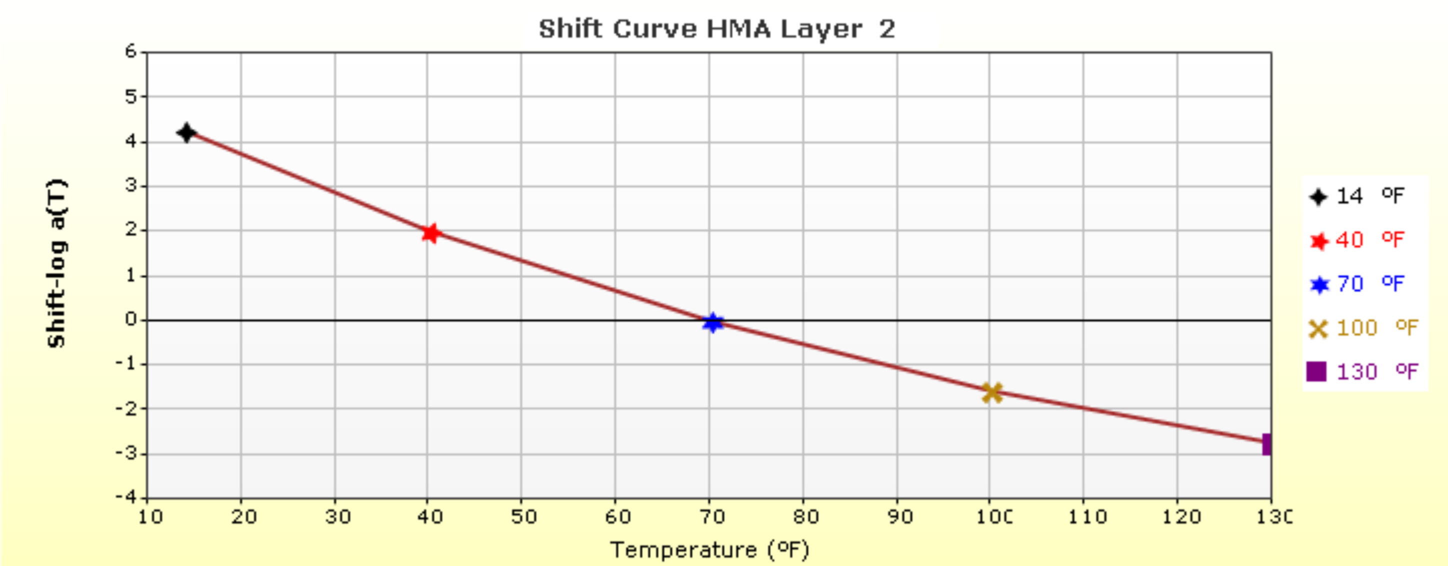


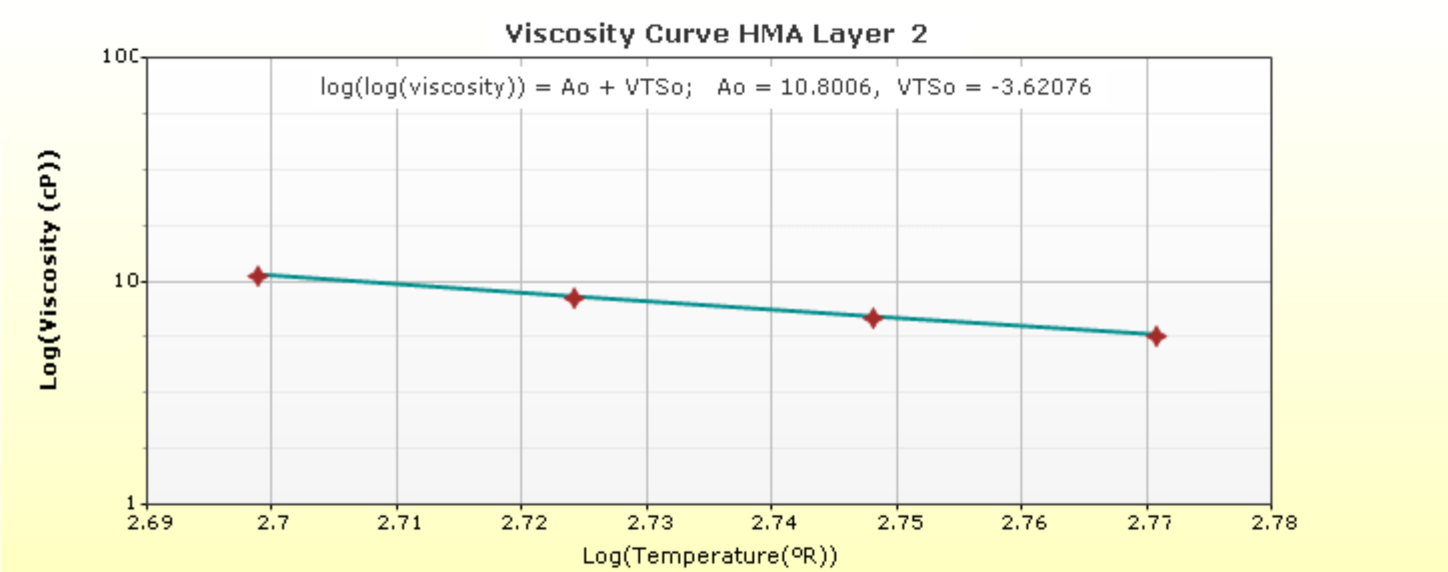




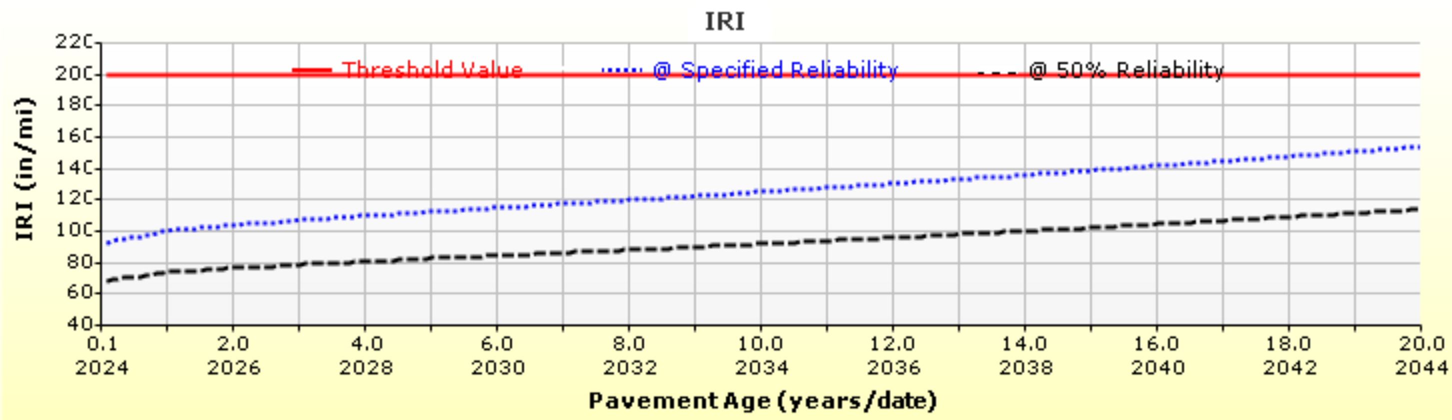
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

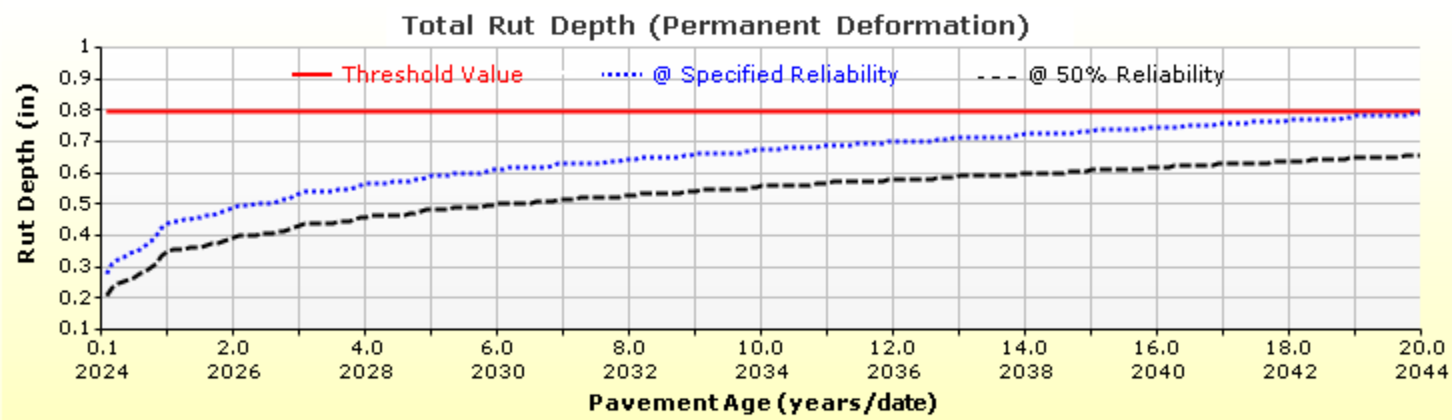


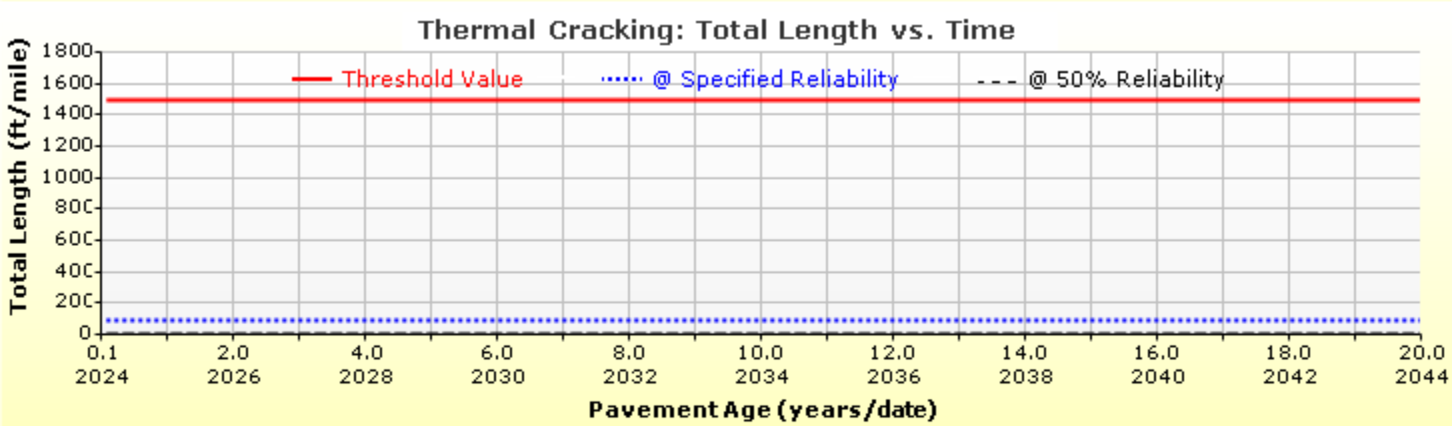


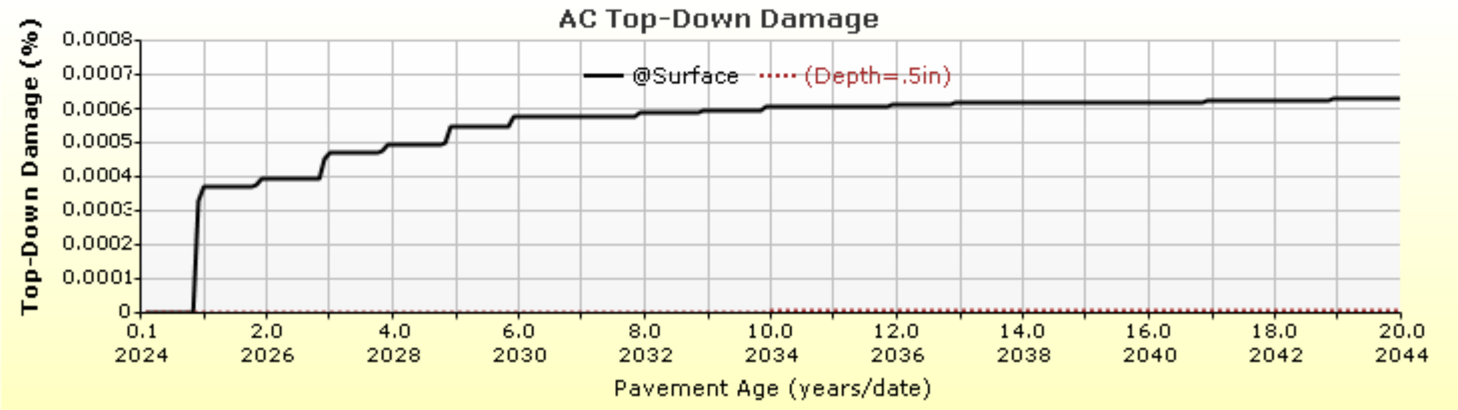


Analysis Output Charts

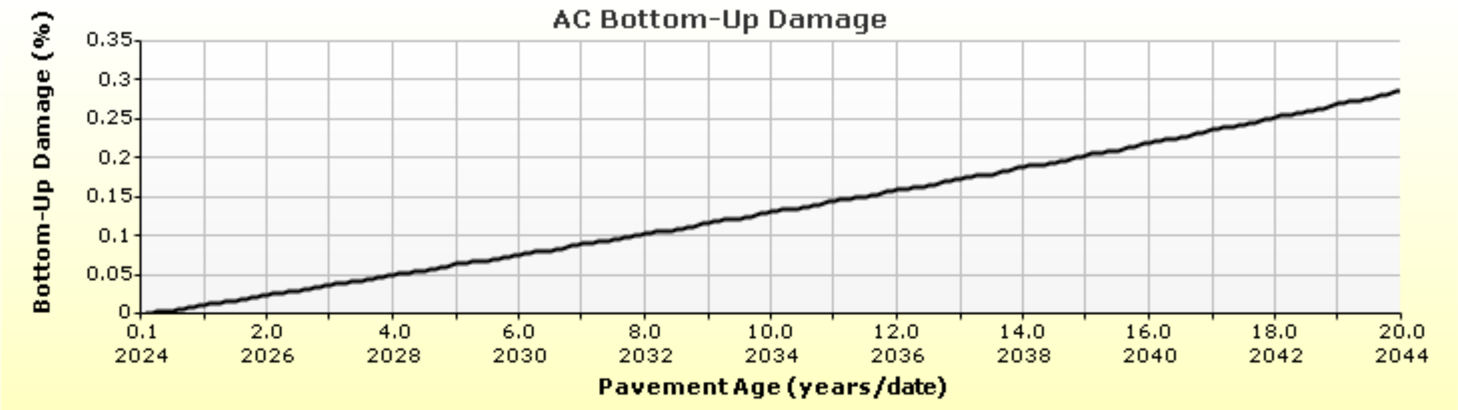




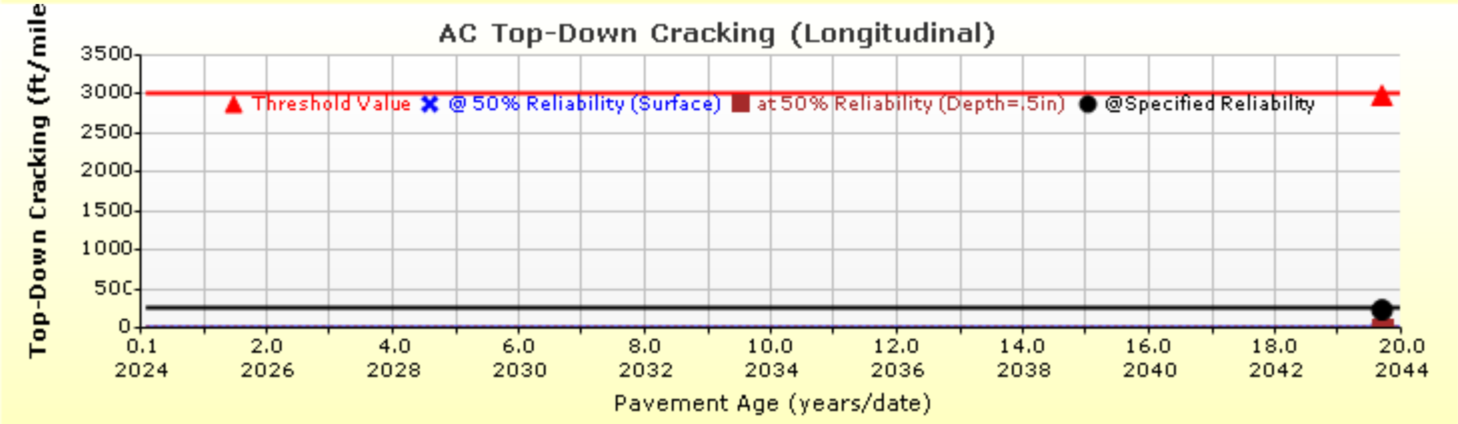




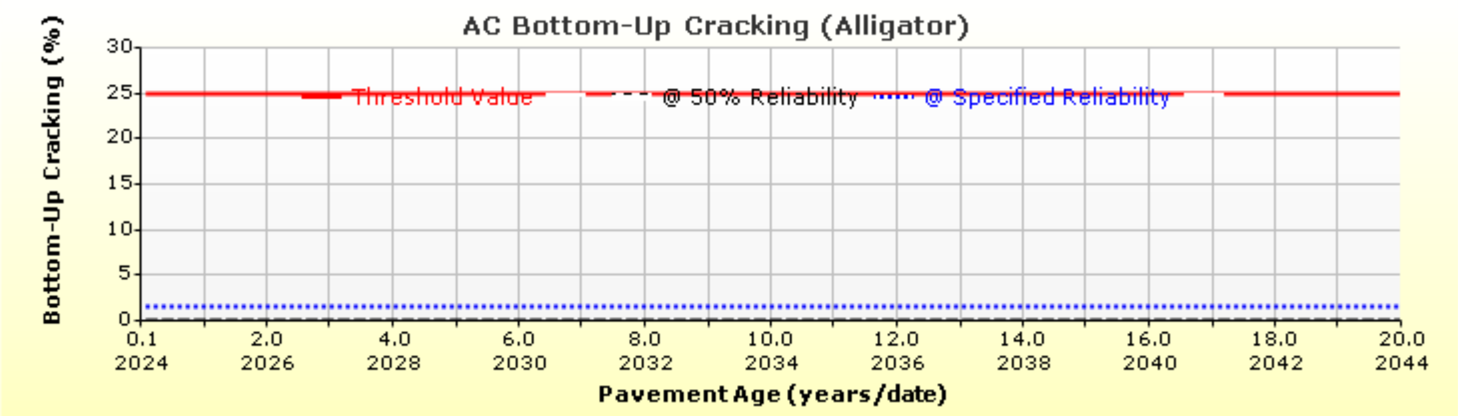
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



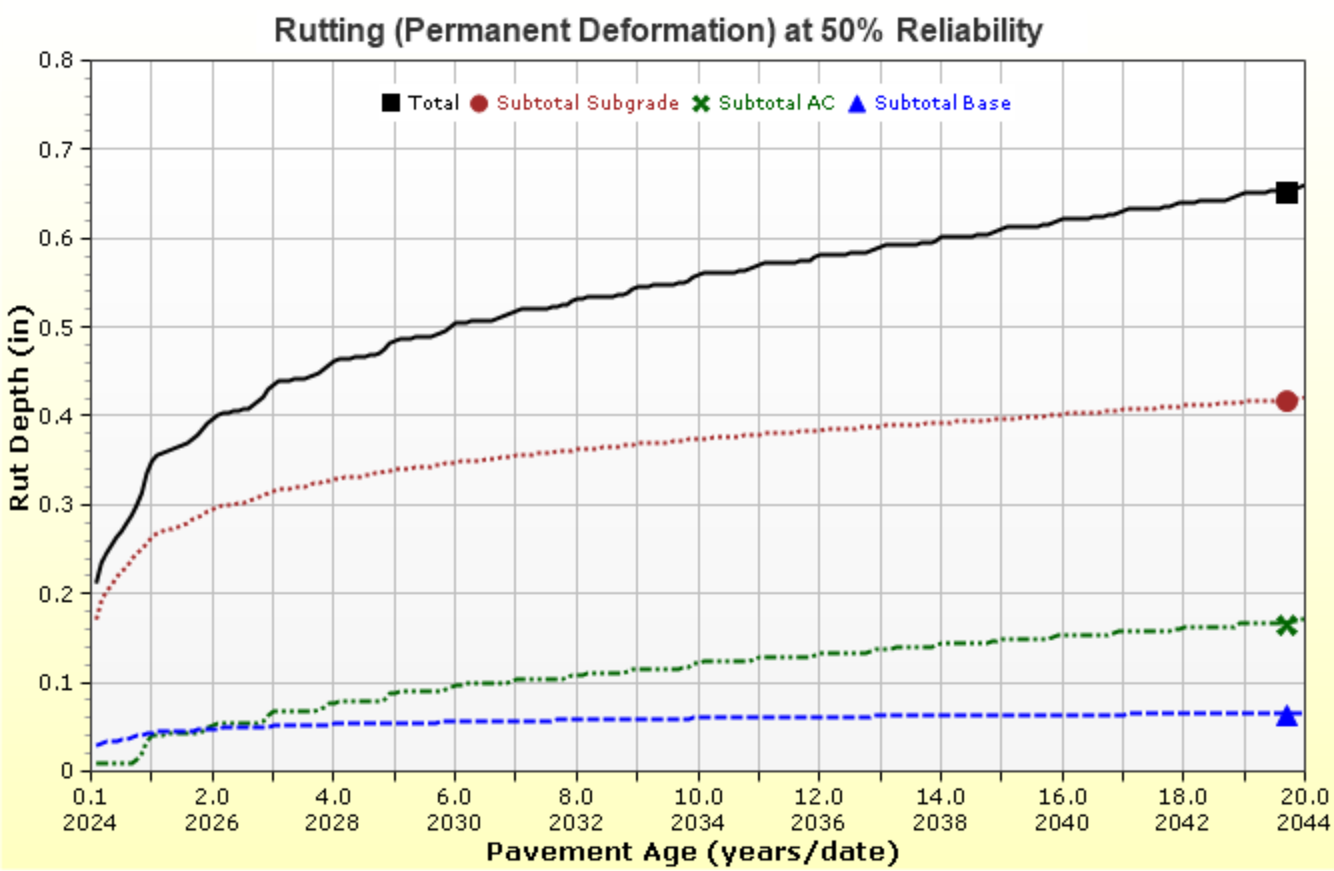
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

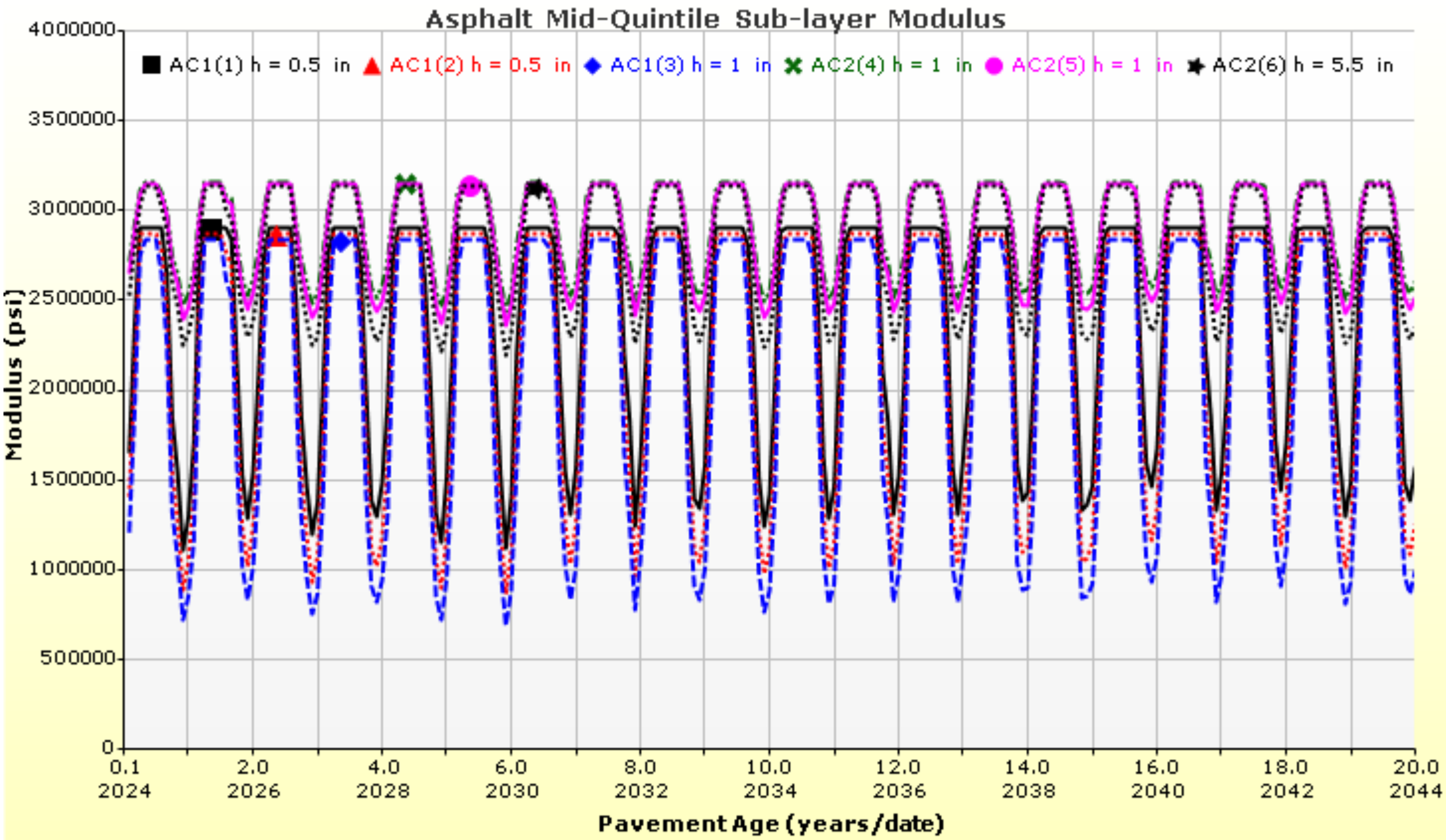


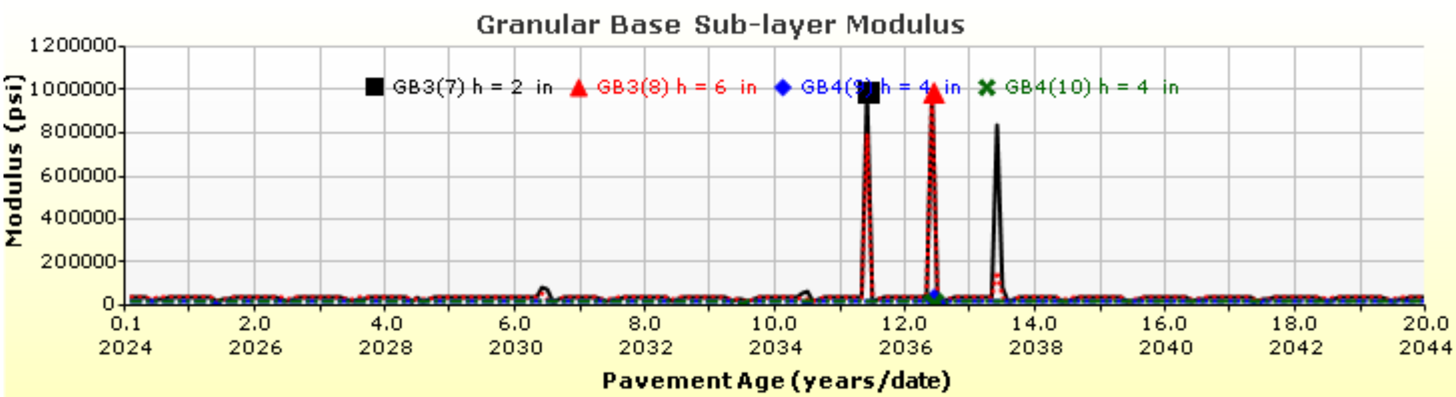
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)

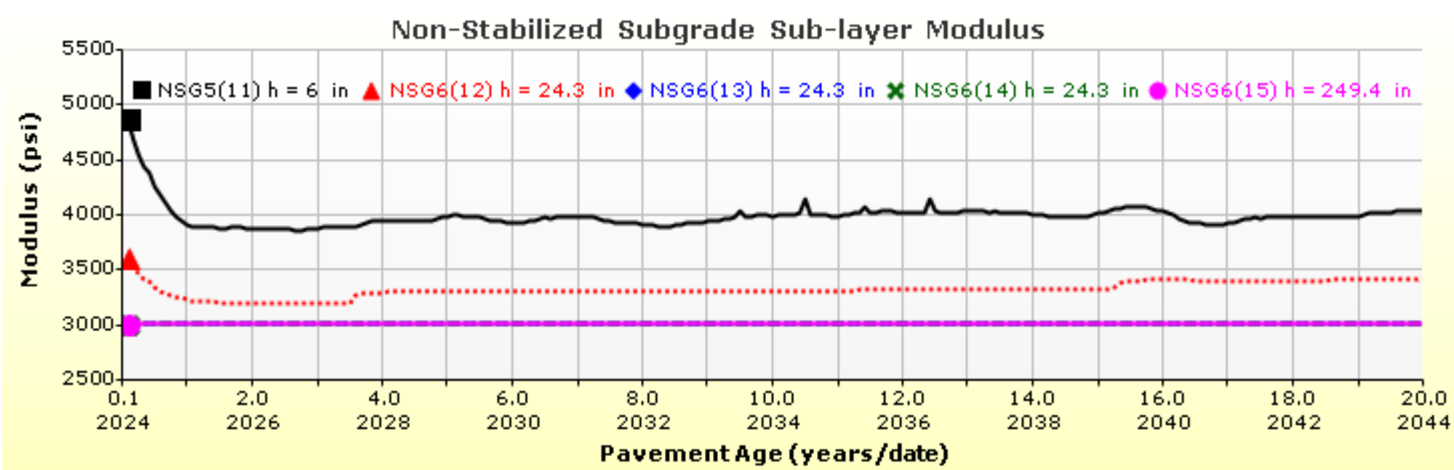


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 5.5 in
Modulus (psi)
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 6 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 6 in
NSG6(12) h = 24.3 in
NSG6(13) h = 24.3 in
NSG6(14) h = 24.3 in
NSG6(15) h = 249.4 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	7.5	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

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	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	9.5
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

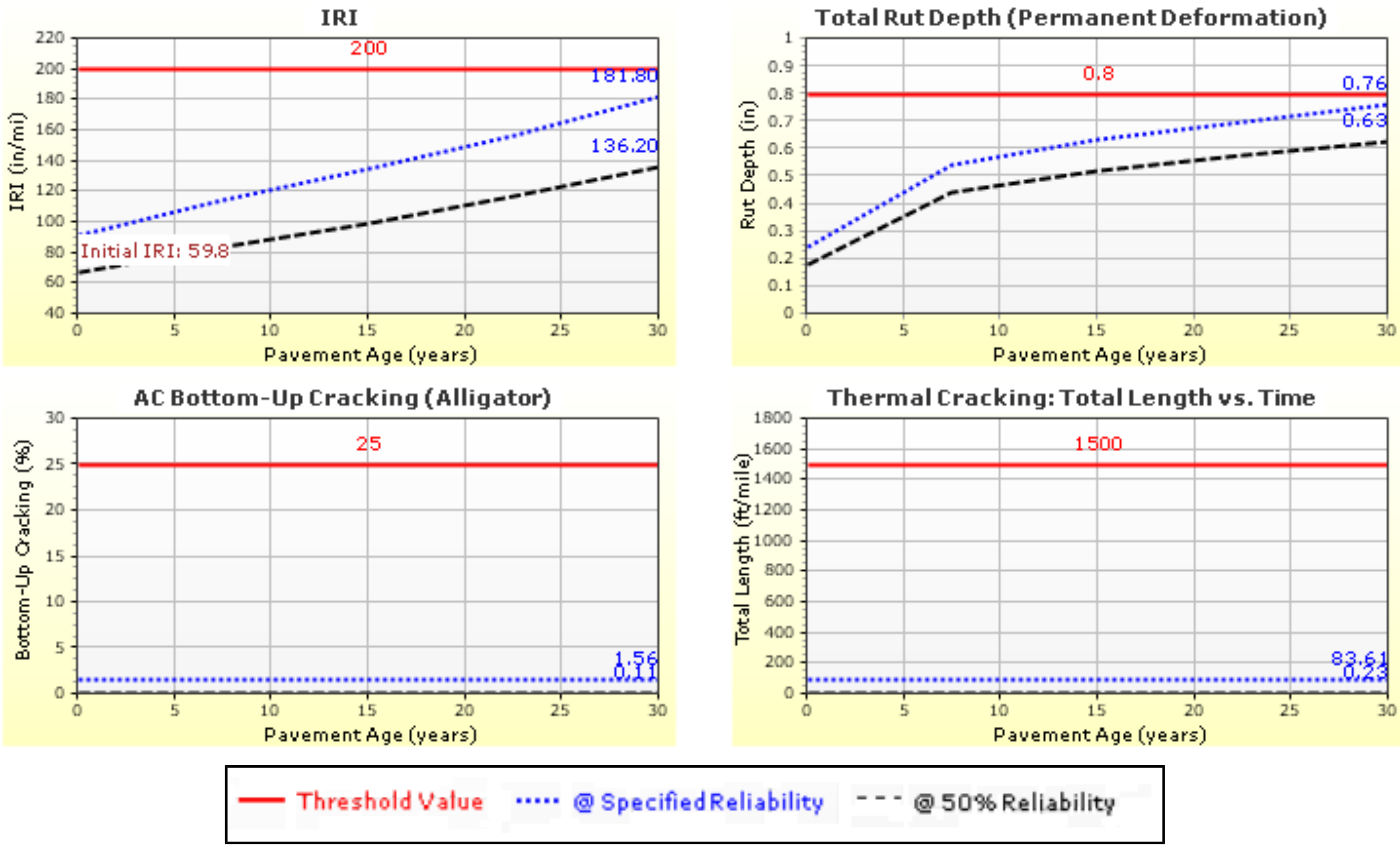
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	3,640
2039 (15 years)	10,346,300
2054 (30 years)	24,271,100

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	181.82	90.00	96.34	Pass
Permanent deformation - total pavement (in)	0.80	0.76	90.00	95.11	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.56	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.61	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	282.77	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.28	90.00	100.00	Pass

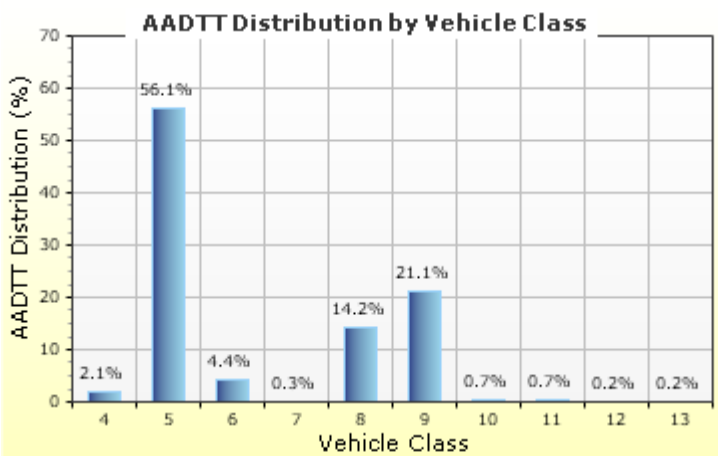
Distress Charts

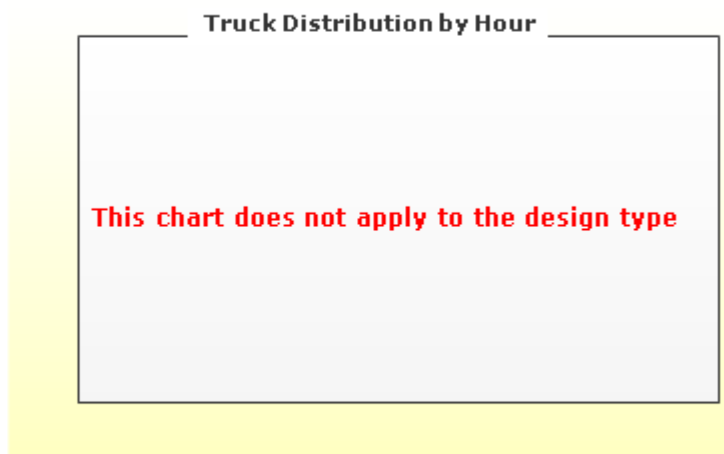


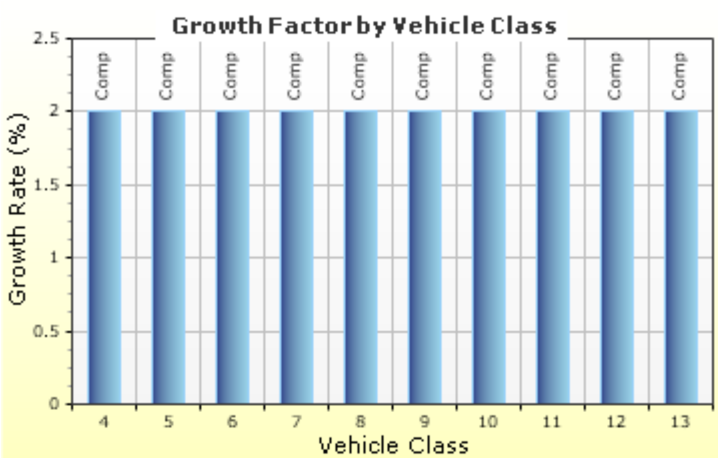
Traffic Inputs

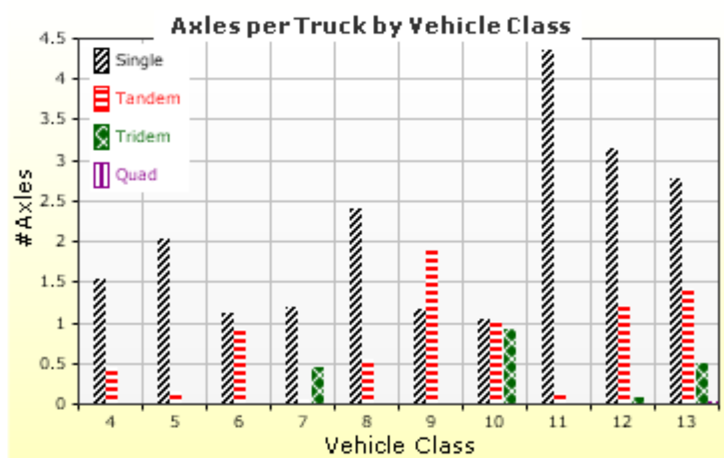
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,640	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

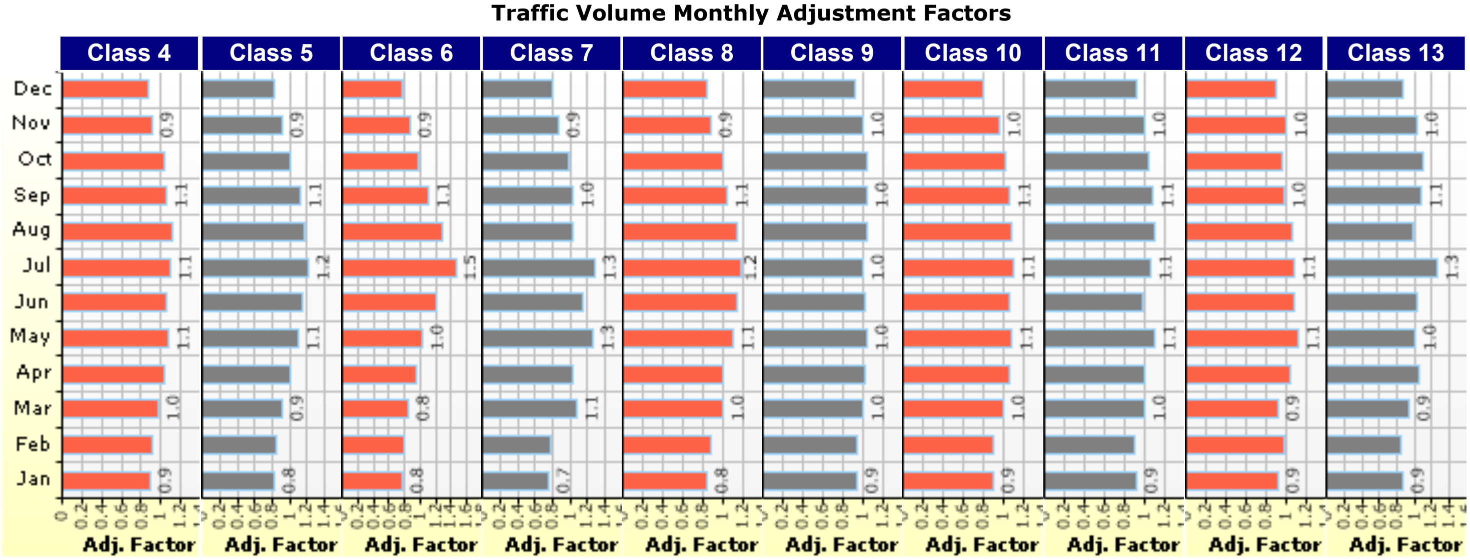








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

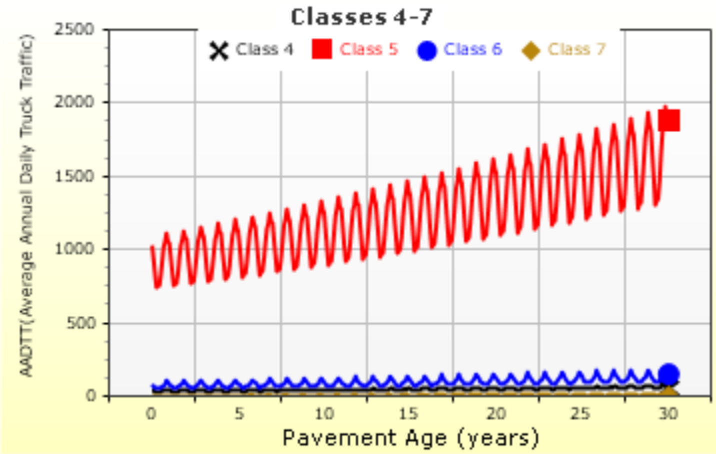
Wheelbase does not apply

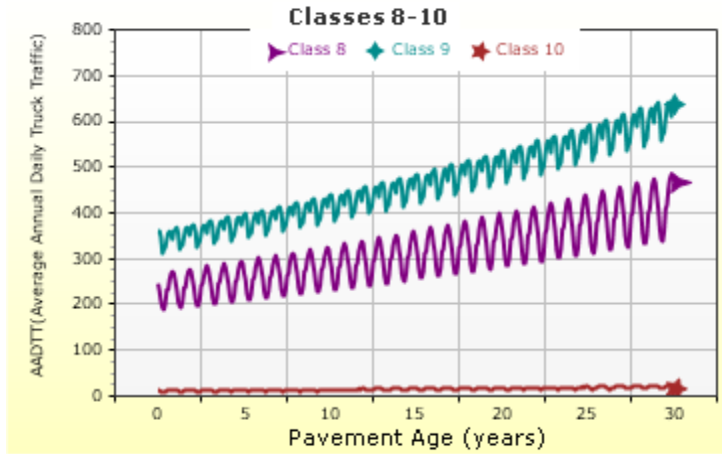
Number of Axles per Truck

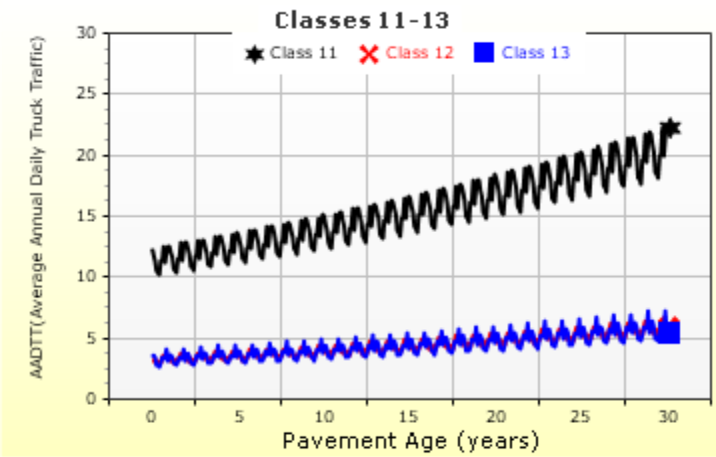
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

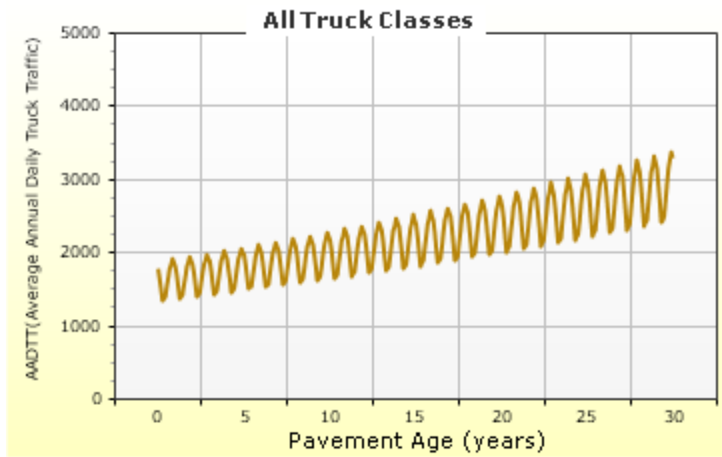
AADTT (Average Annual Daily Truck Traffic) Growth

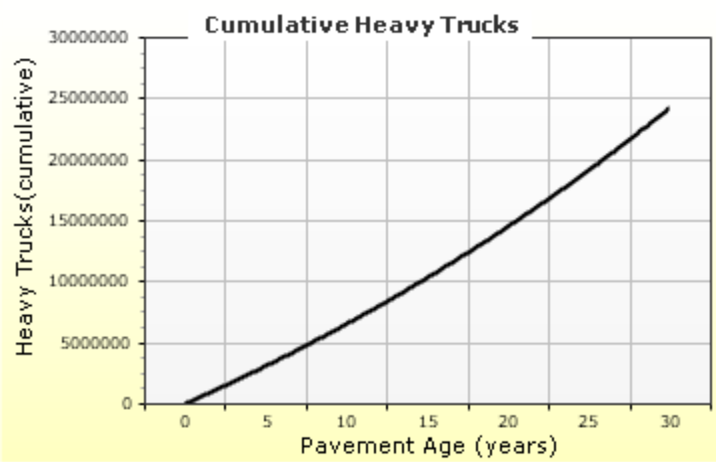
*** Traffic cap is not enforced**







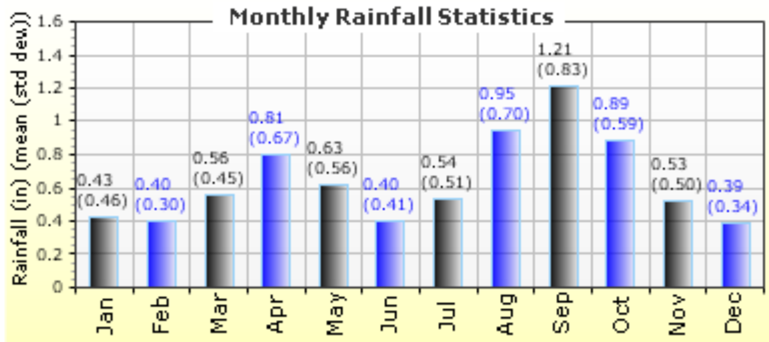




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

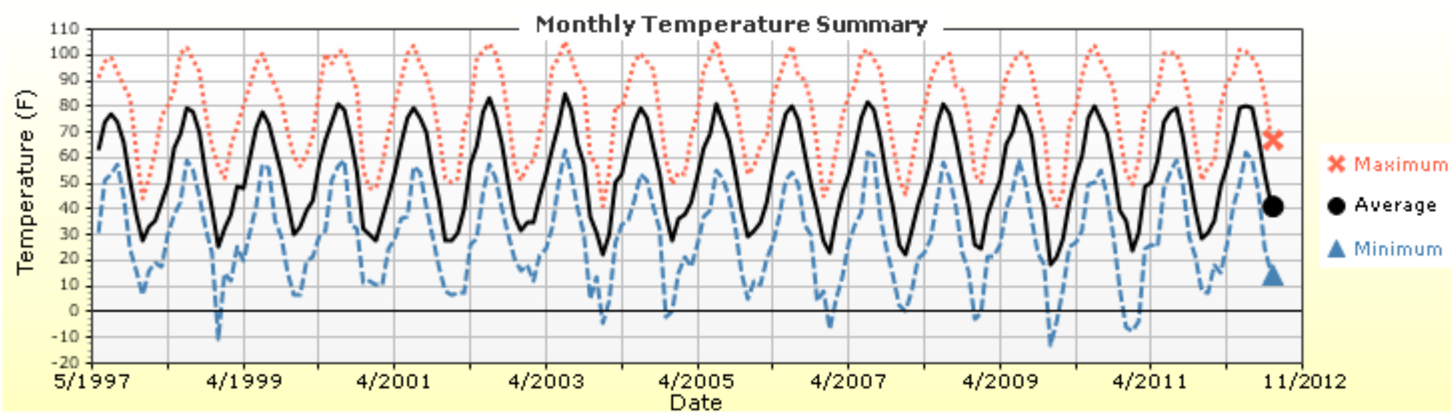


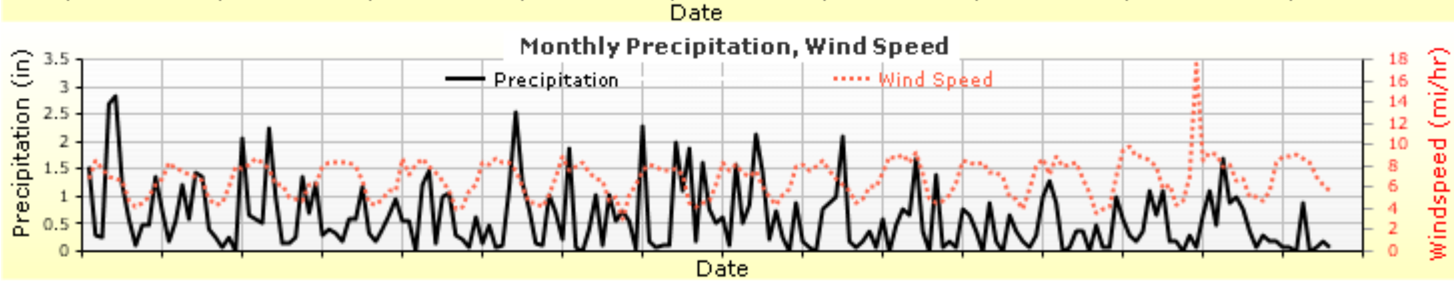
Annual Statistics:

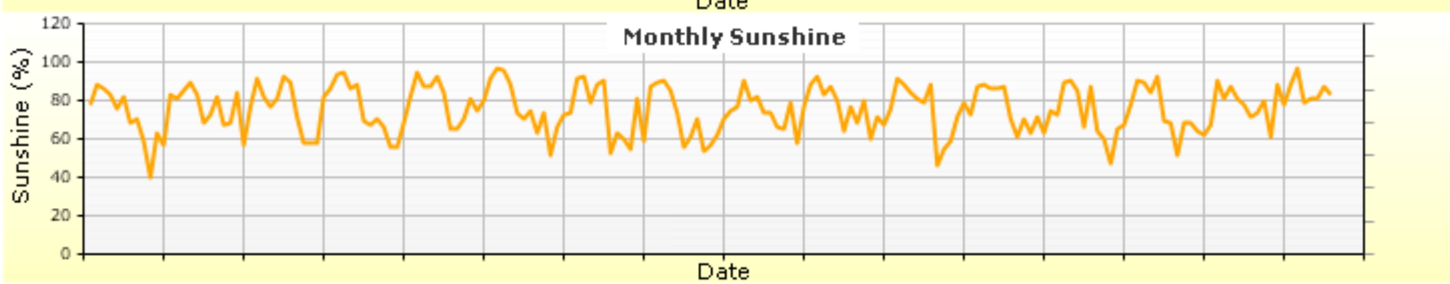
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

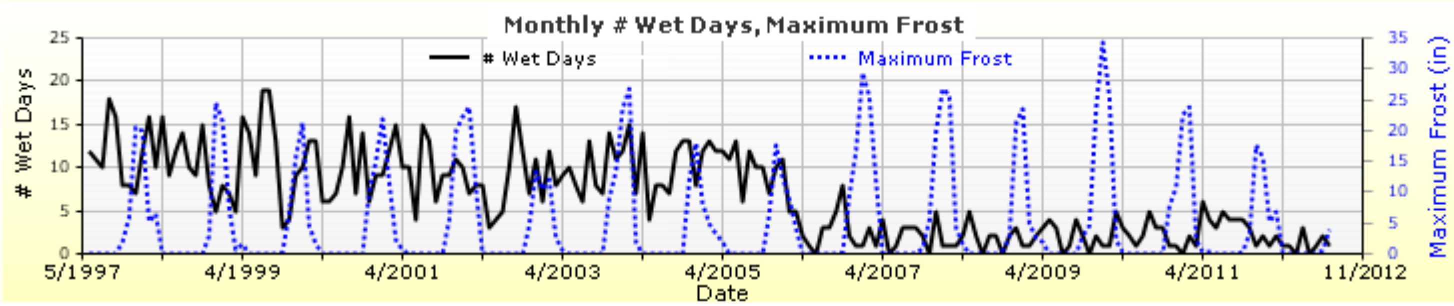
Water table depth (ft)	4.00

Monthly Climate Summary:

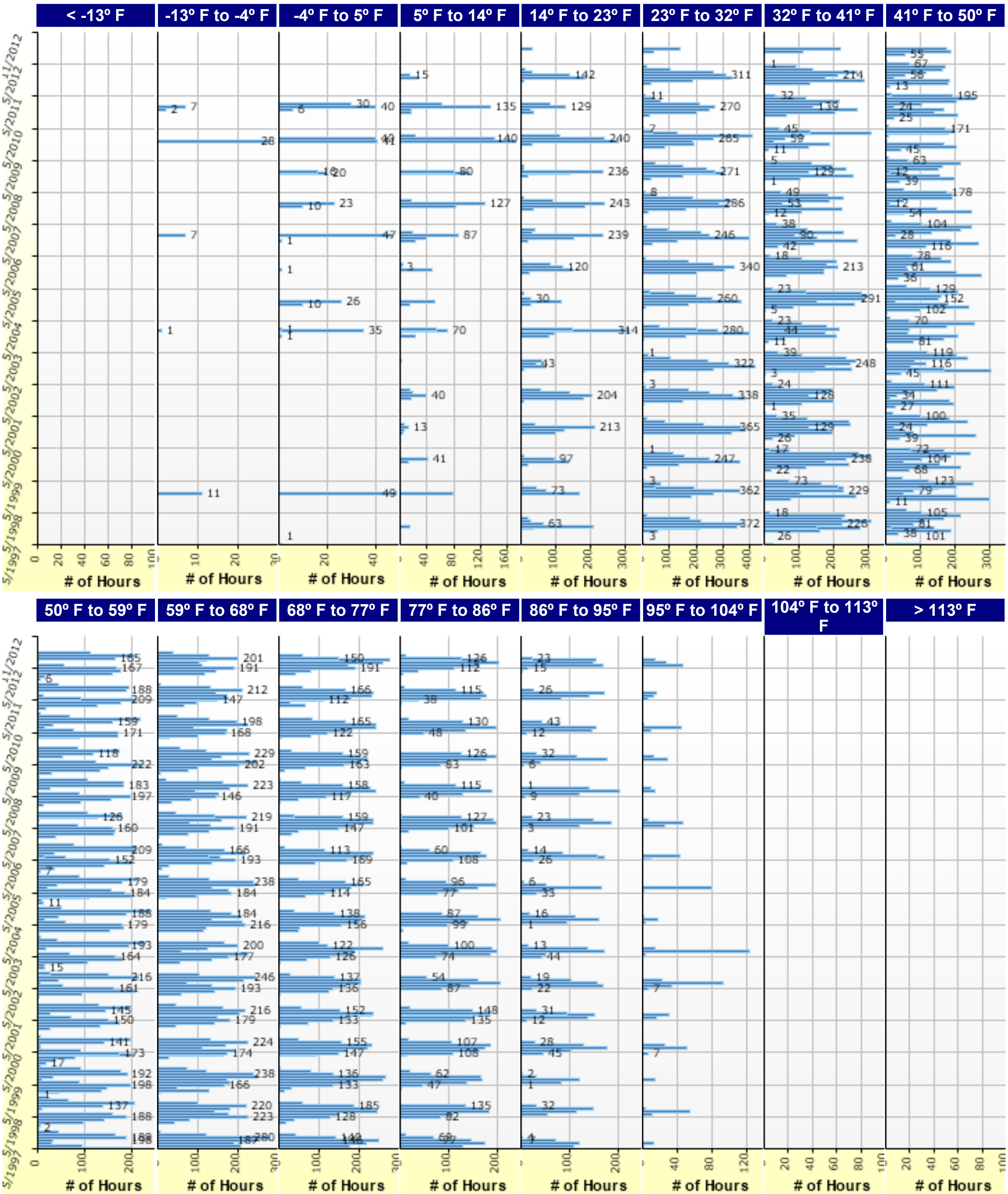








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

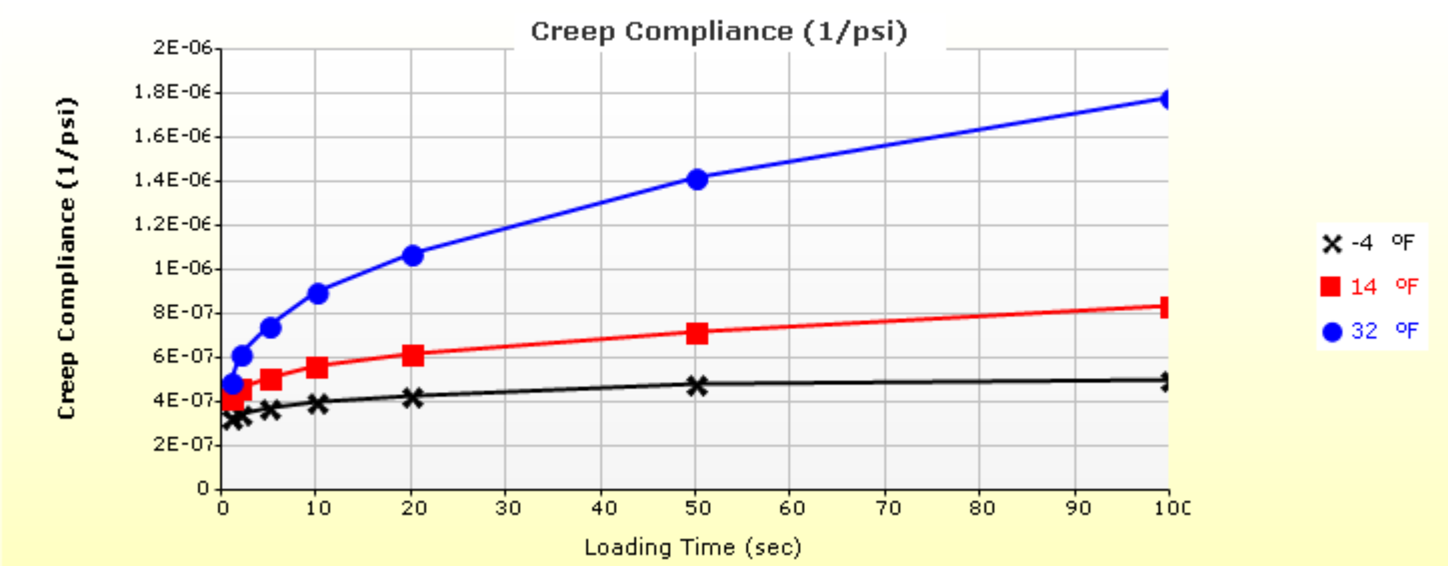
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

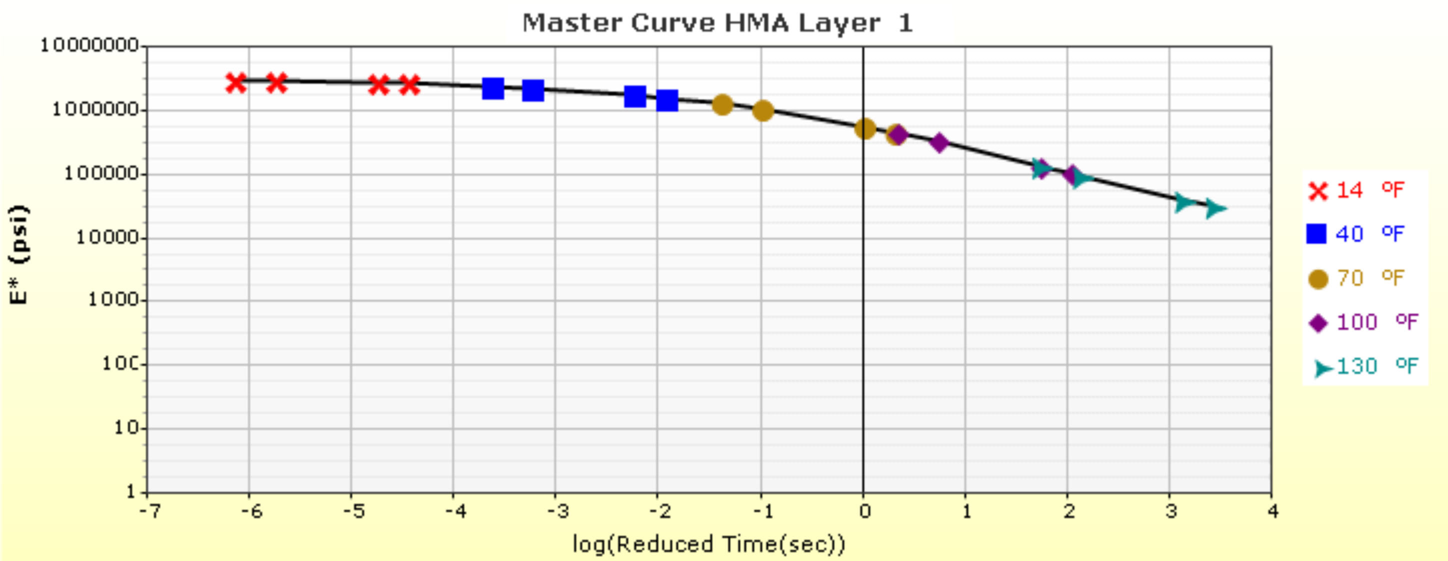
Indirect tensile strength at 14 ºF (psi)	451.00

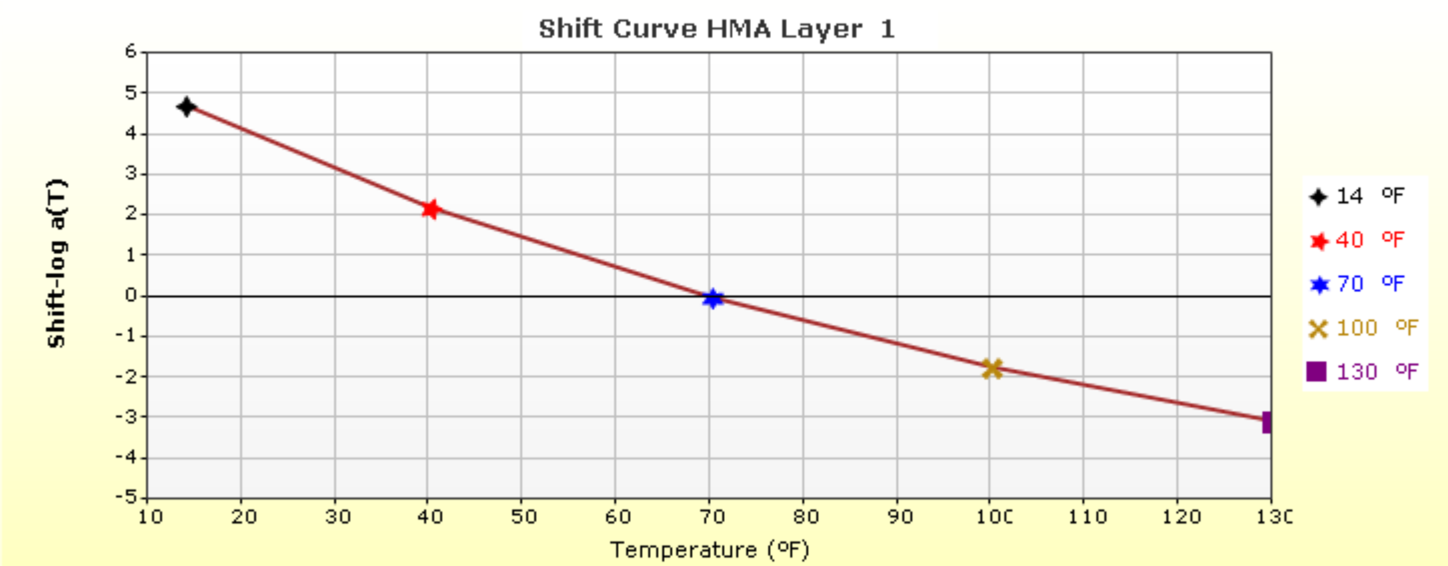
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

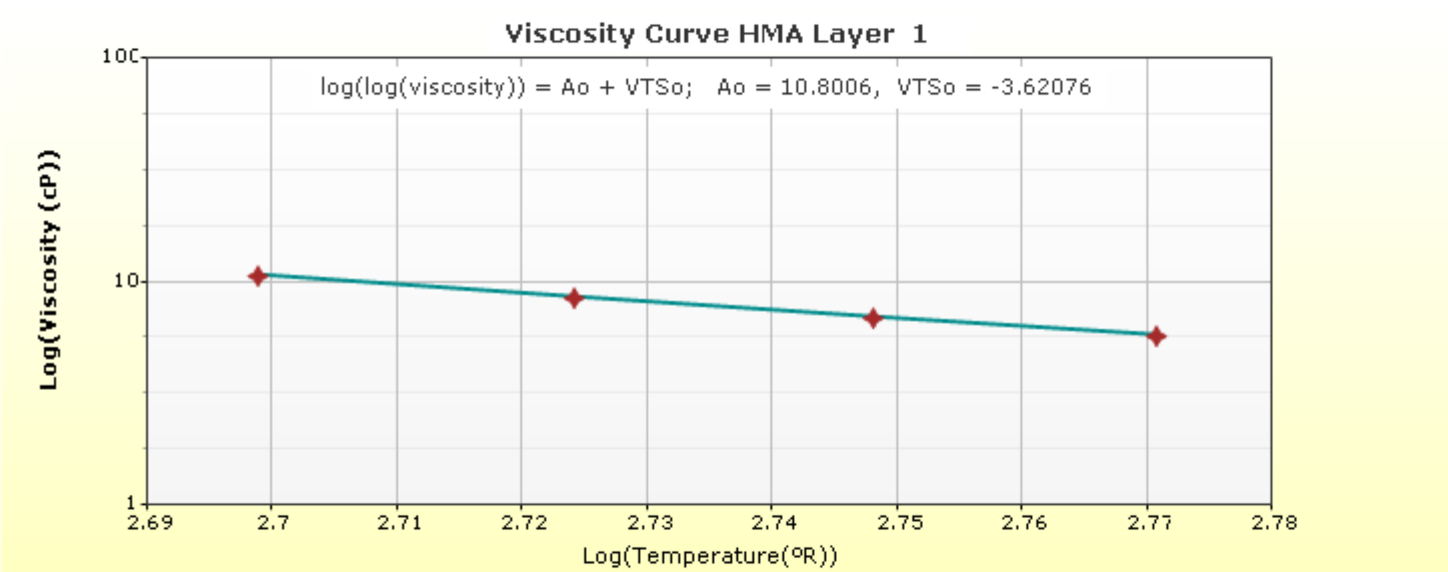
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



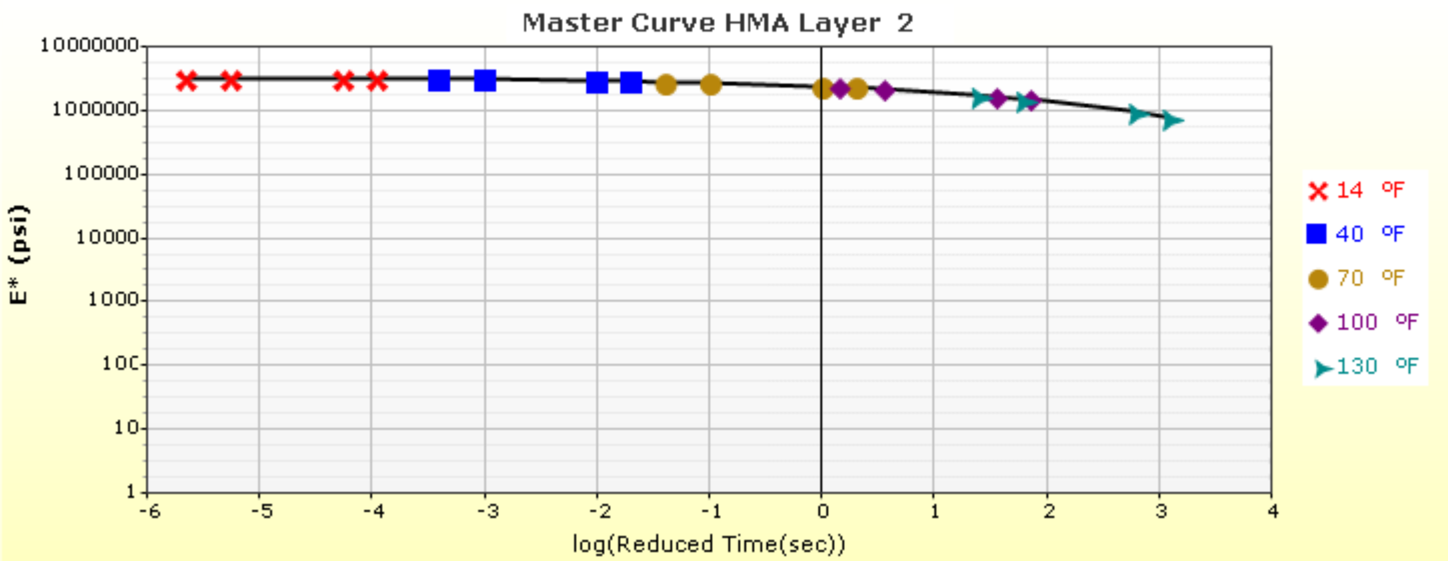
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

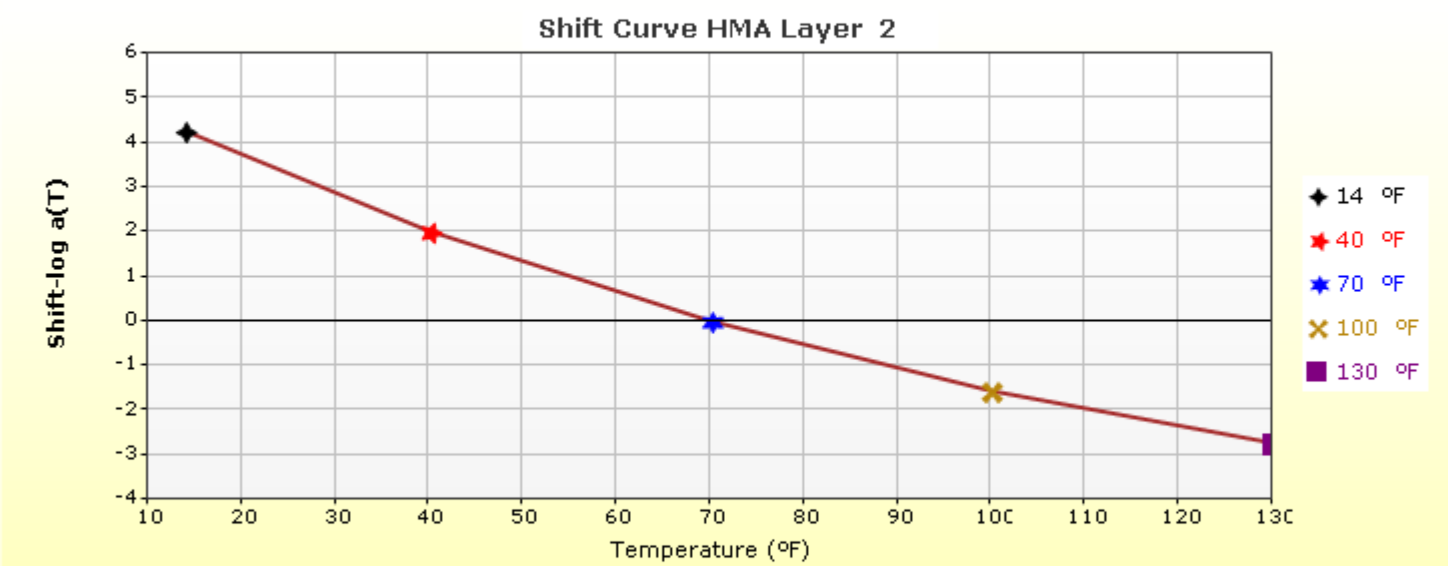


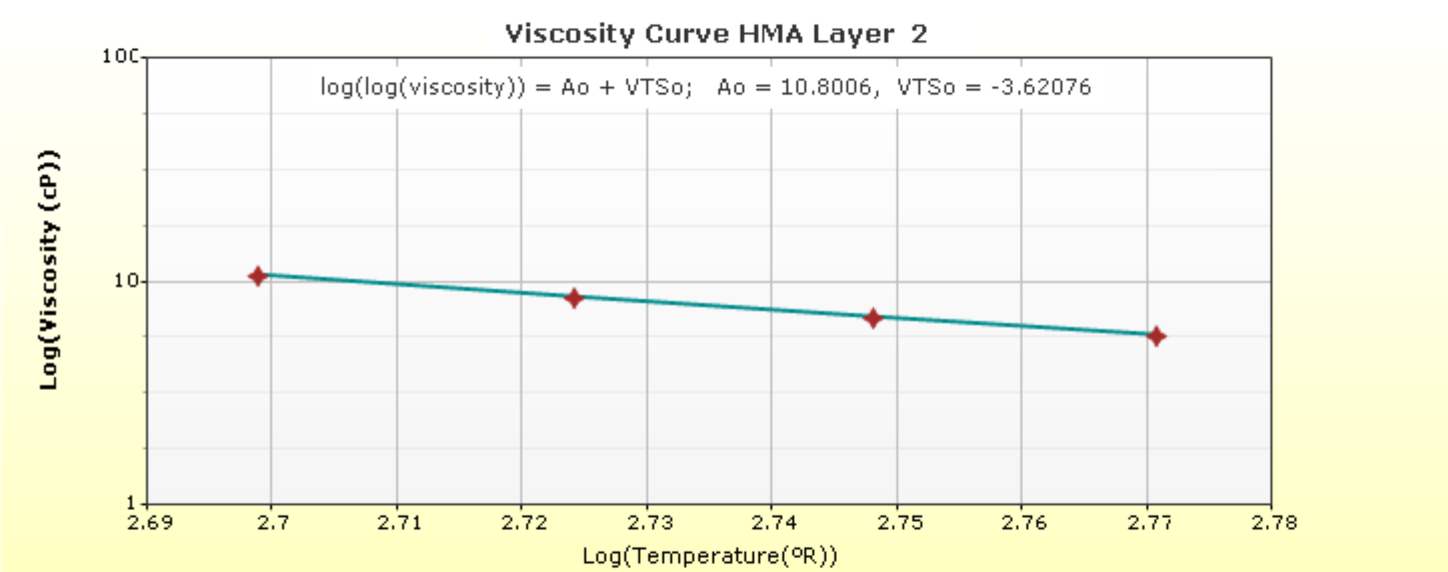




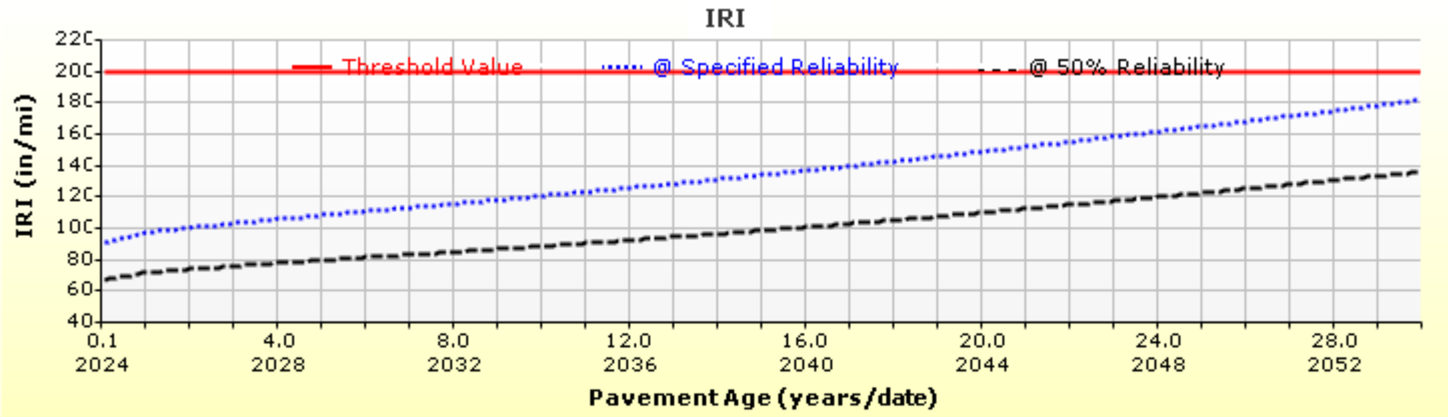
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

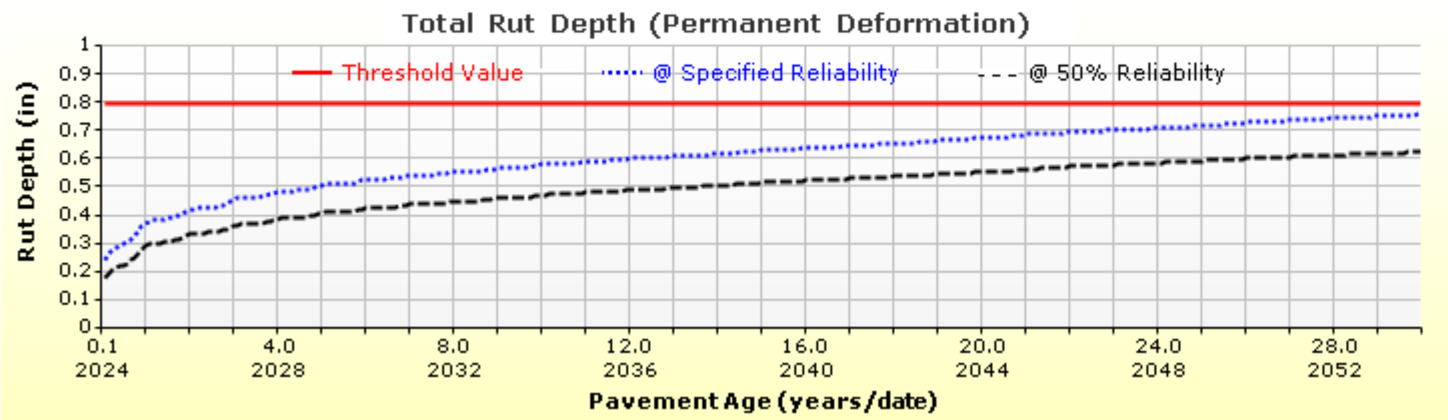


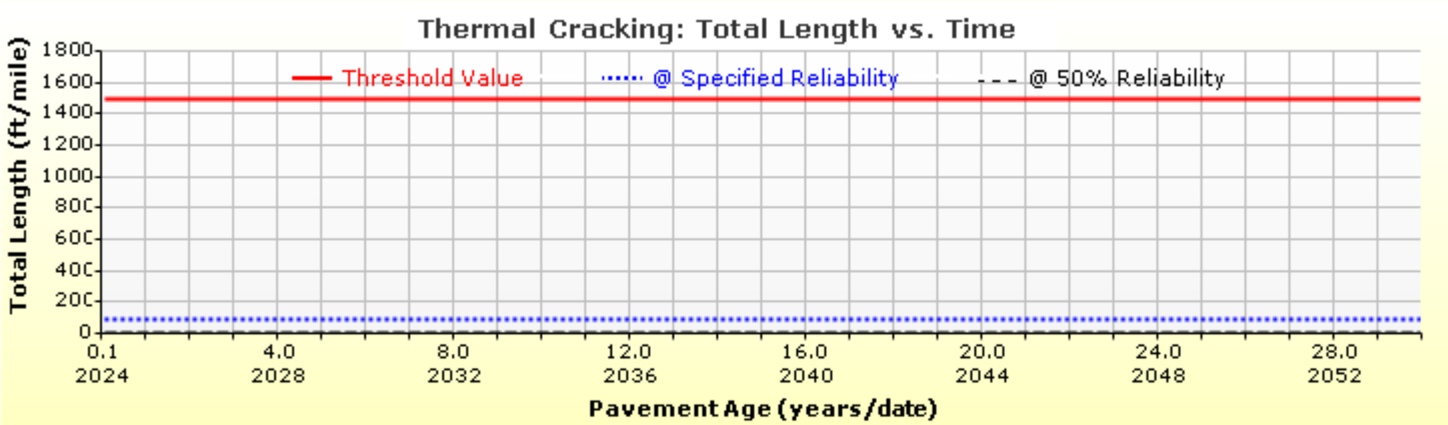


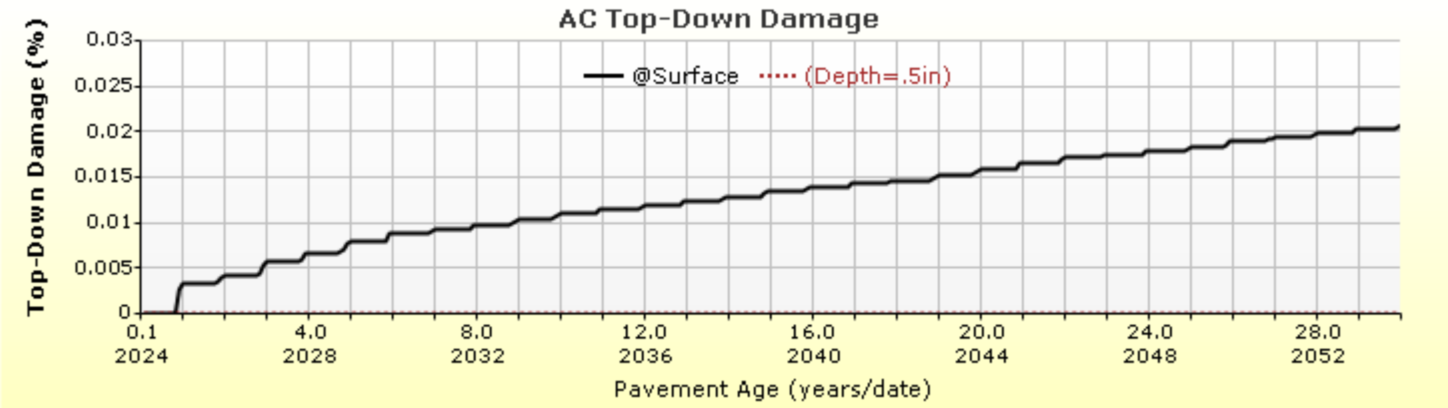


Analysis Output Charts

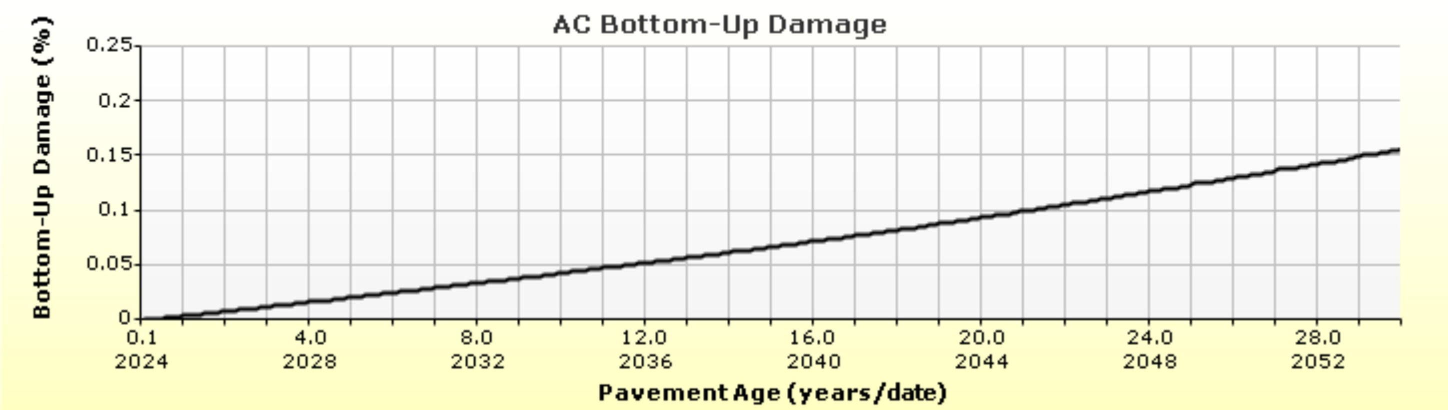




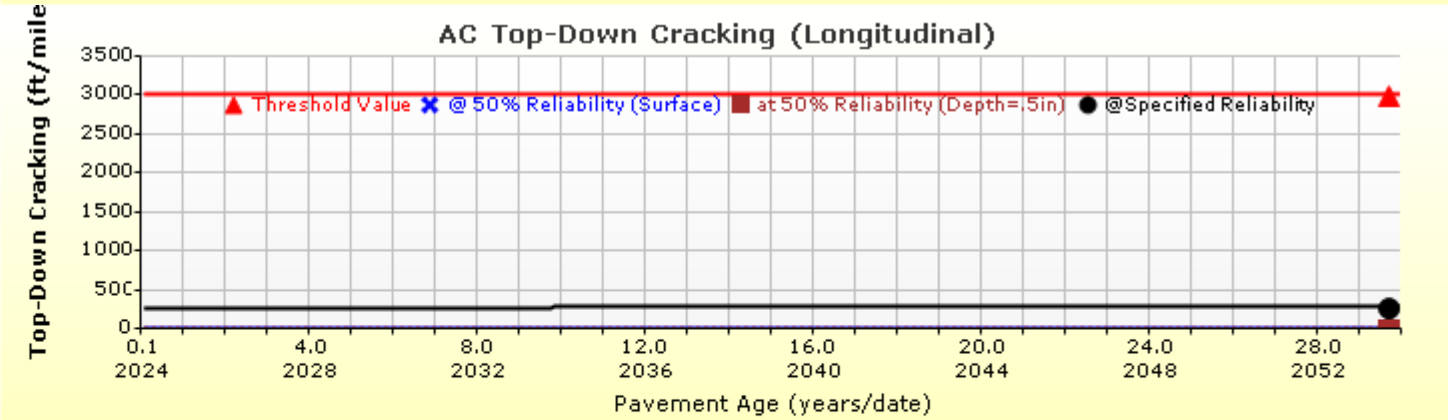




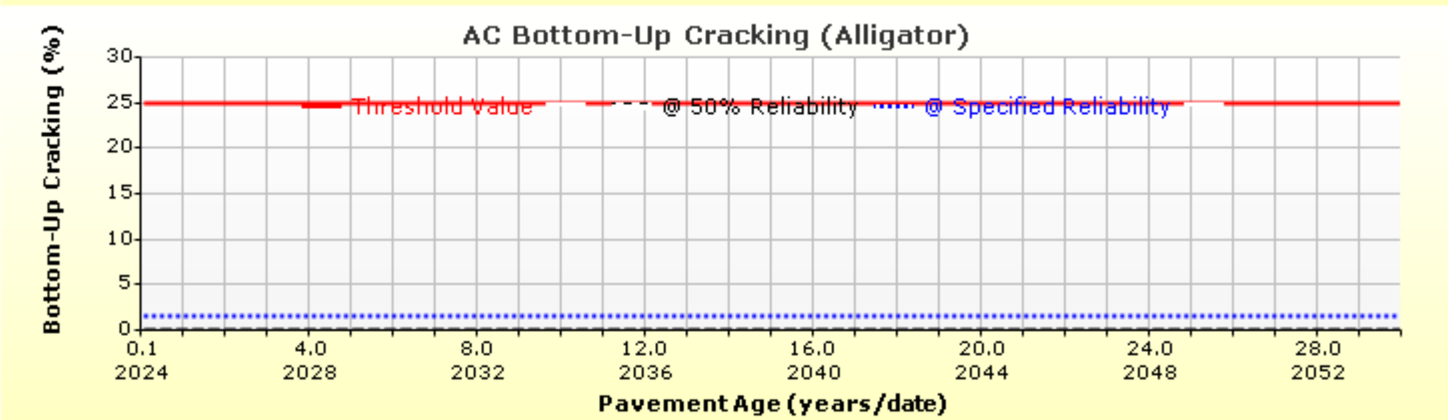
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.03
0.025
0.02
0.015
0.01
0.005
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



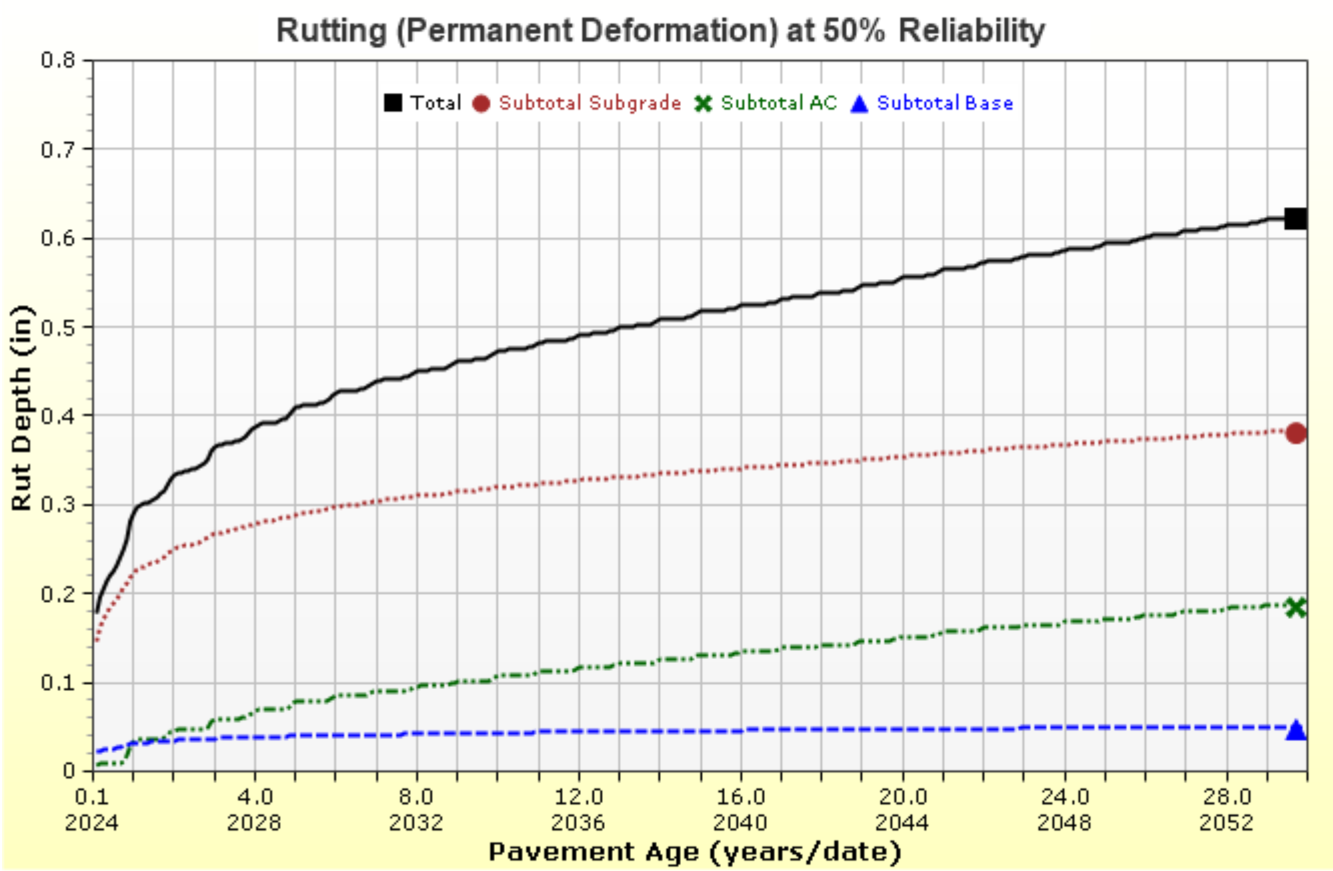
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.25
0.2
0.15
0.1
0.05
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



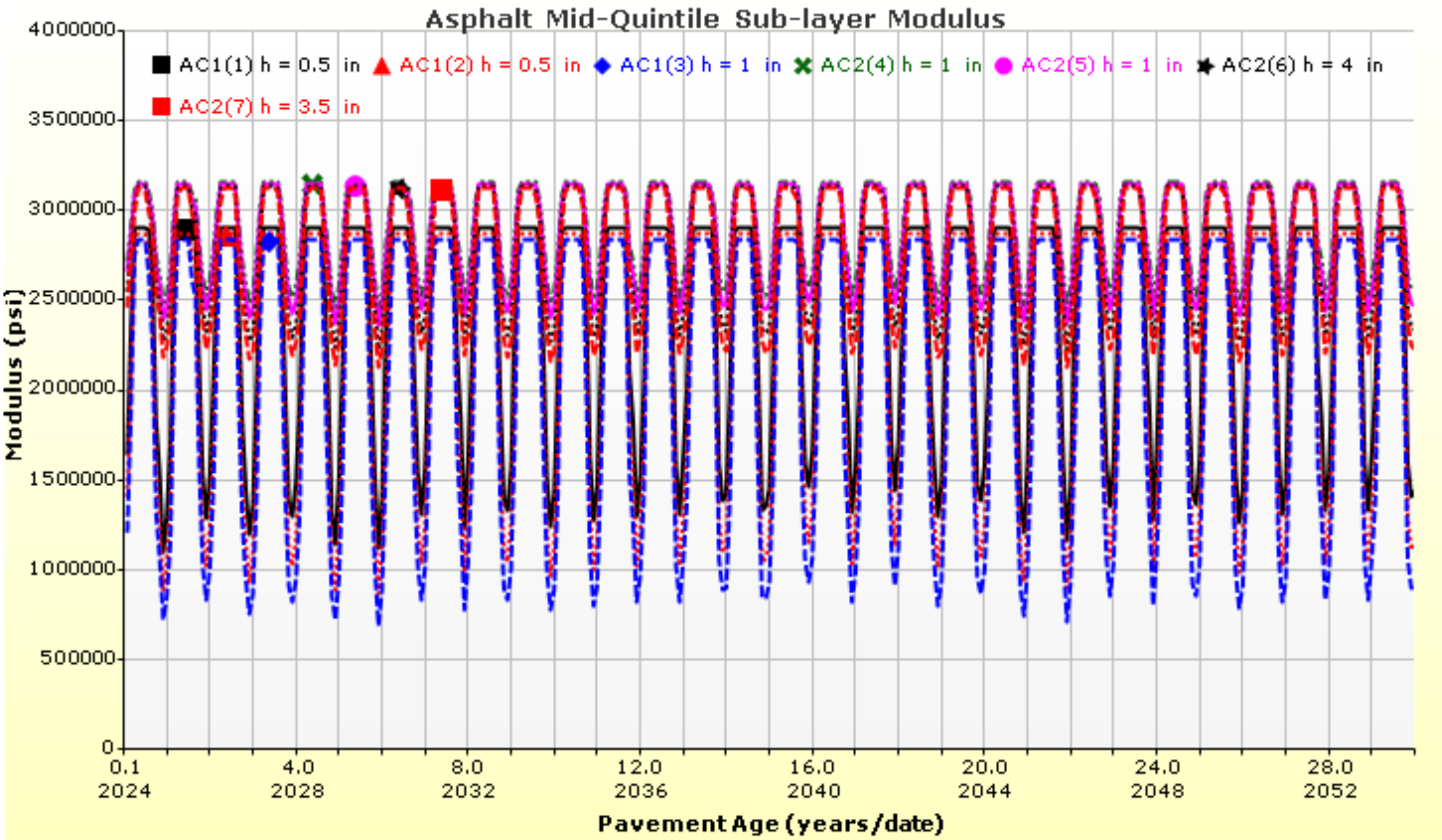
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

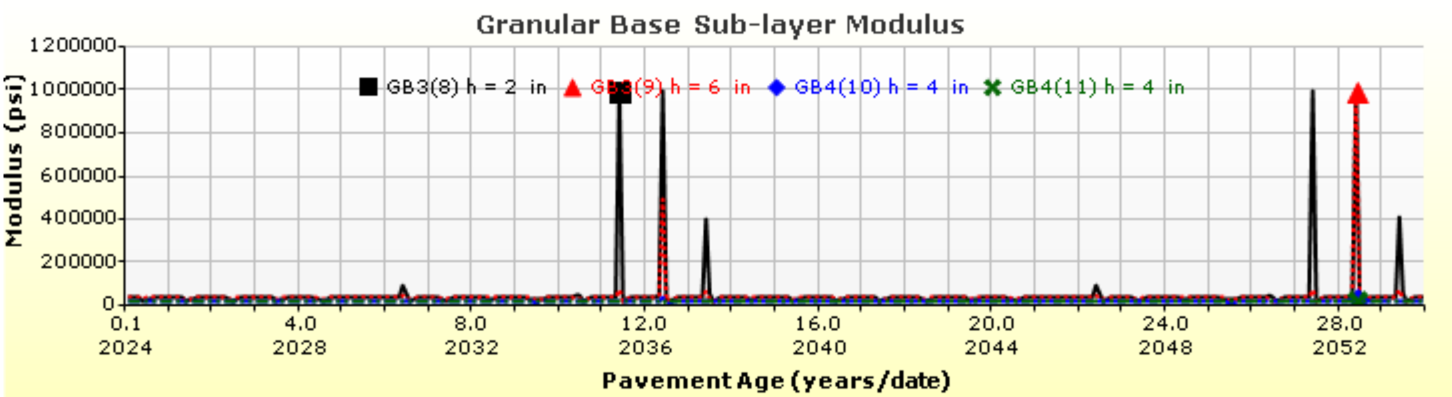


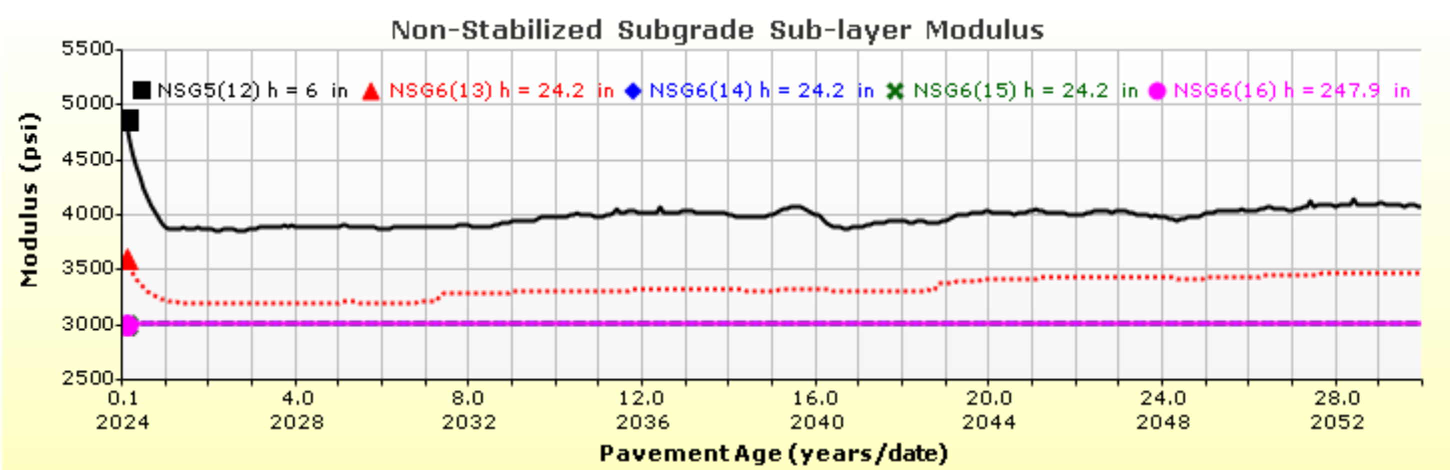
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 3.5 in
Modulus (psi)
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 6 in
GB4(10) h = 4 in
GB4(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 6 in
NSG6(13) h = 24.2 in
NSG6(14) h = 24.2 in
NSG6(15) h = 24.2 in
NSG6(16) h = 247.9 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	9.5	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at( )
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

AC Bottom Up Cracking

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 1	c2: 1	c3: 6000

AC Cracking Top Standard Deviation	AC Cracking Bottom Standard Deviation
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))	1.13 + 13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

APPENDIX G

HORIZON DRIVE AND G ROAD ROUNDABOUT

20 AND 30-YEAR DESIGN LIFE FOR FLEXIBLE

PAVEMENT M-E DESIGN PAVEMENT OUTPUT SHEETS

Horizon Drive and G Road Roundabout HMA Design

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\Horizon Drive and G Road Roundabout HMA Design.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	9.5
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

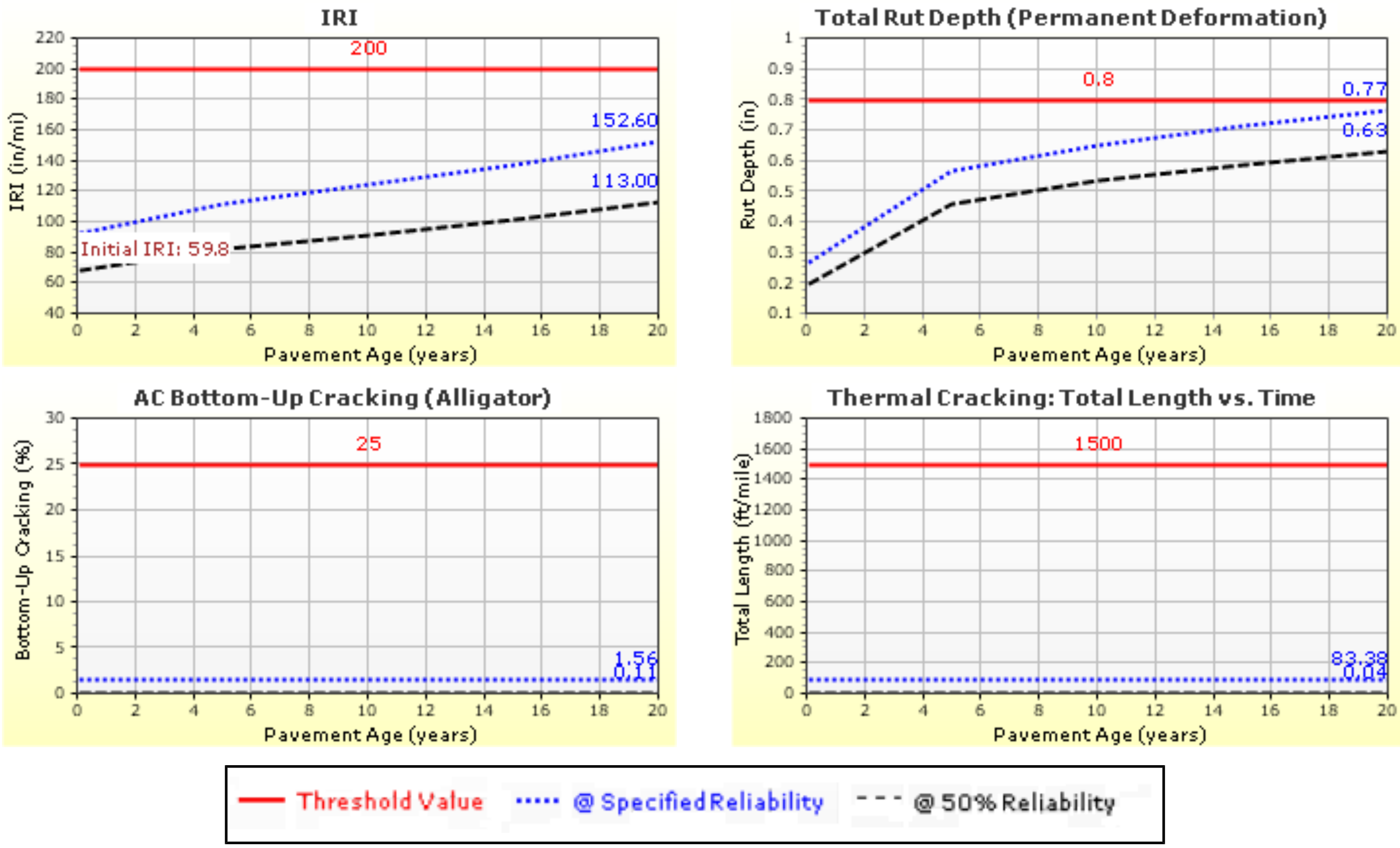
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	6,350
2034 (10 years)	11,428,200
2044 (20 years)	25,359,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	152.63	90.00	99.75	Pass
Permanent deformation - total pavement (in)	0.80	0.77	90.00	94.50	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.56	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.38	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	289.98	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.28	90.00	100.00	Pass

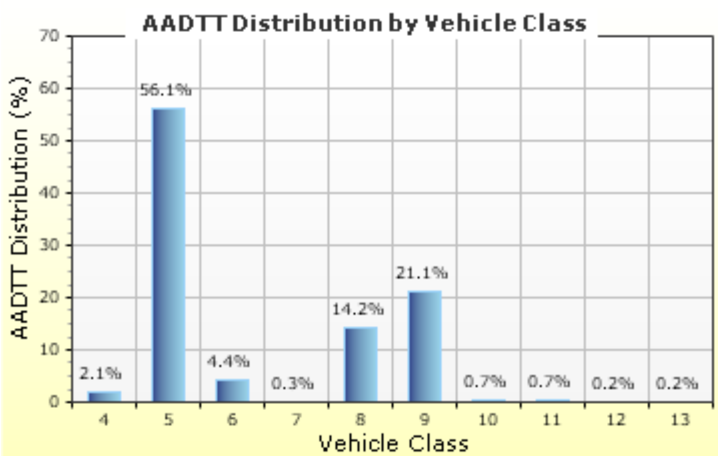
Distress Charts

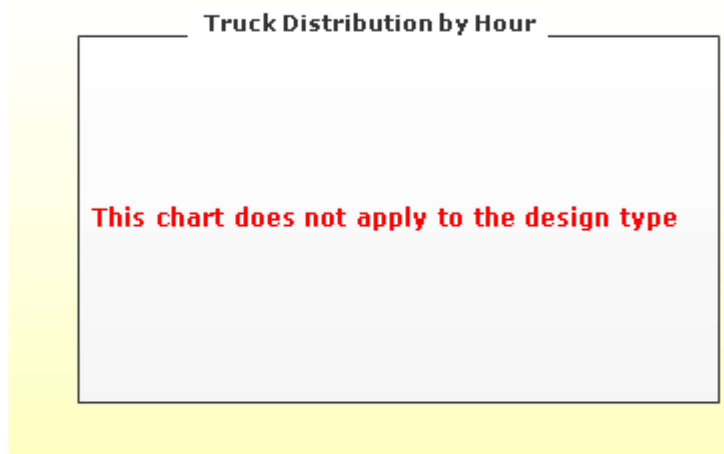


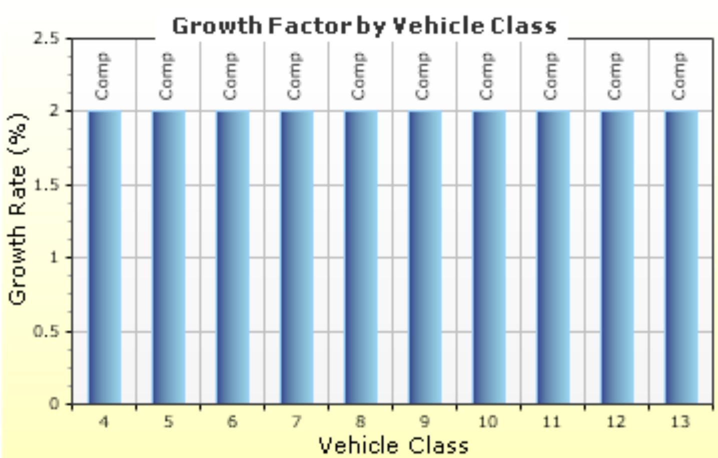
Traffic Inputs

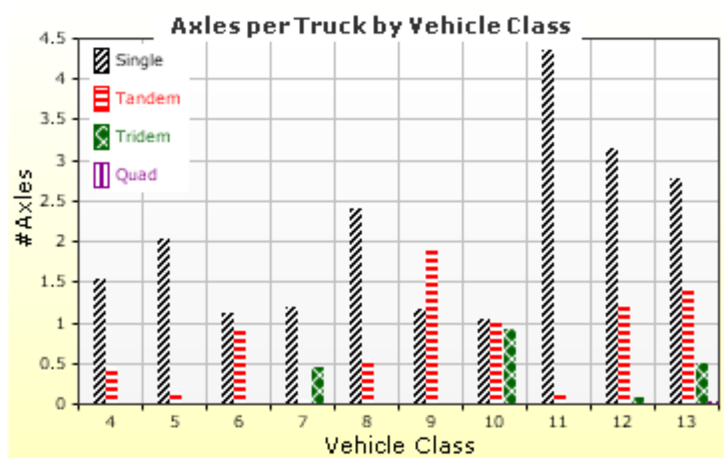
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	6,350	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

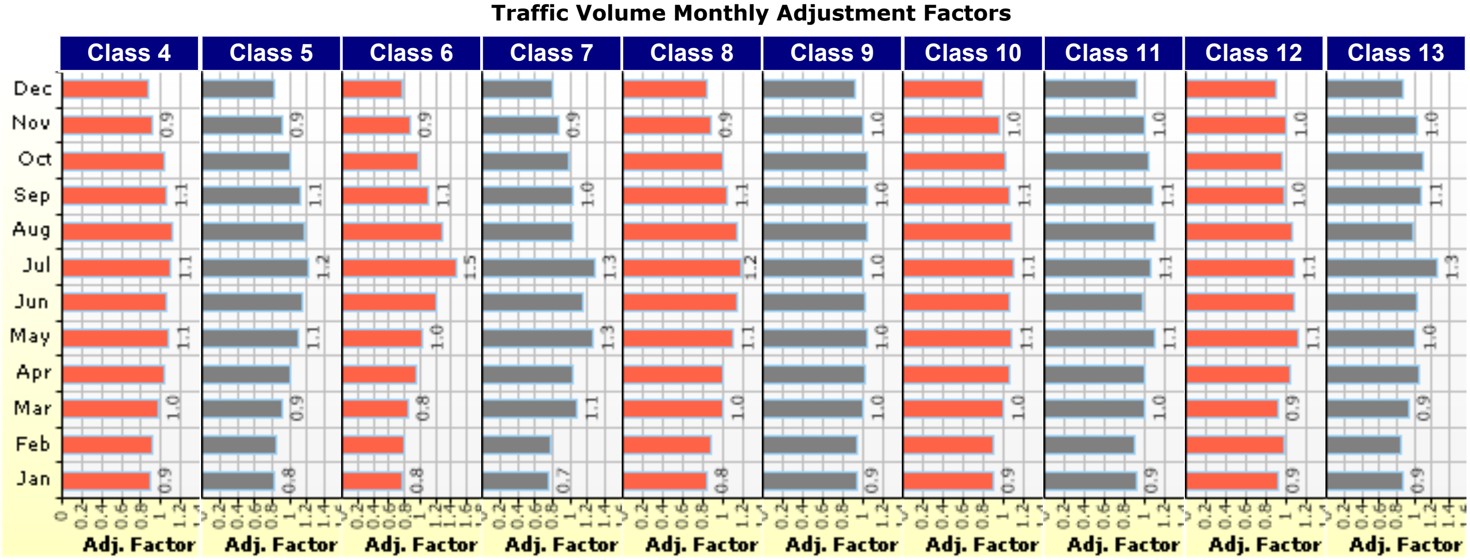








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

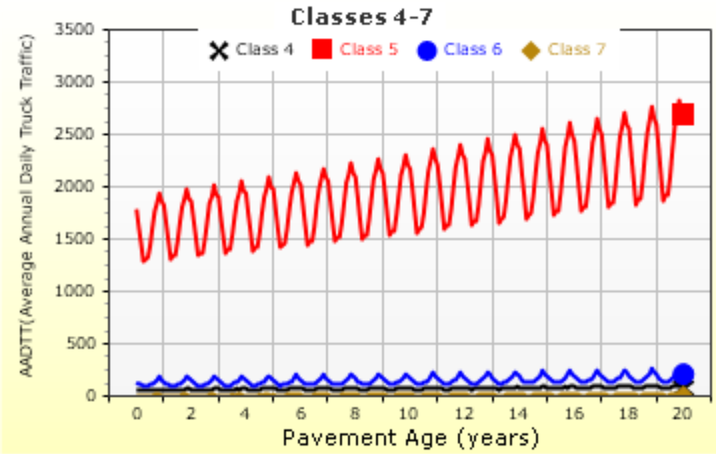
Wheelbase does not apply

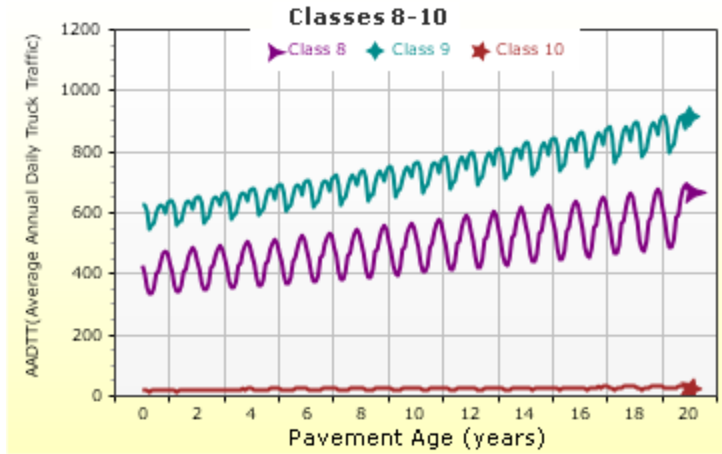
Number of Axles per Truck

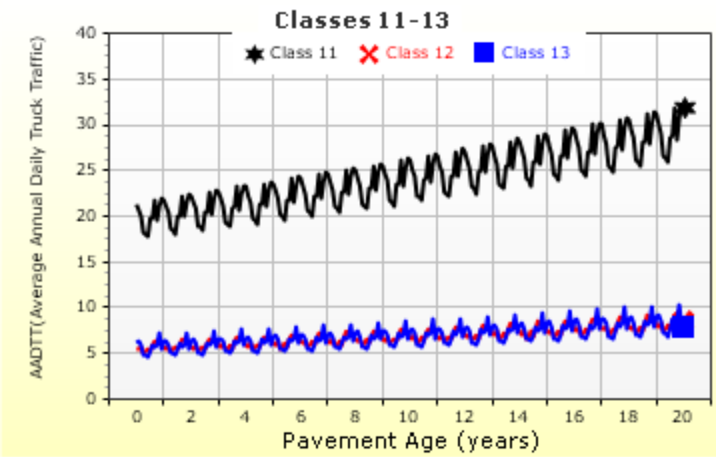
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

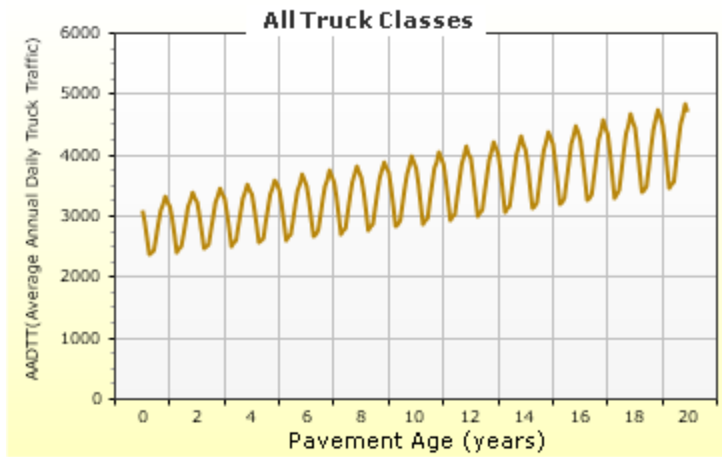
AADTT (Average Annual Daily Truck Traffic) Growth

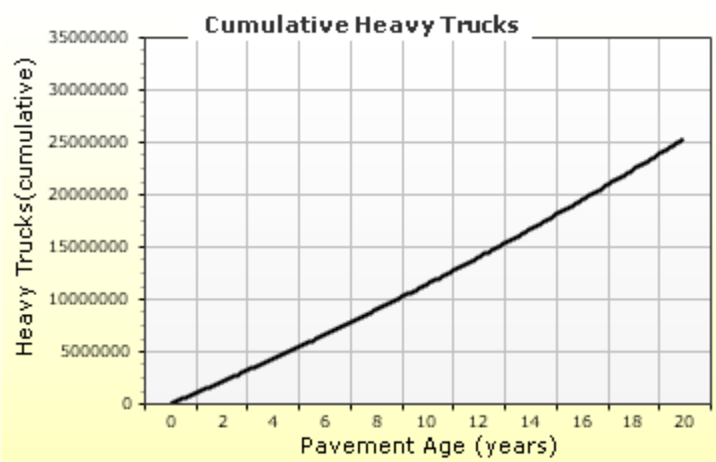
*** Traffic cap is not enforced**







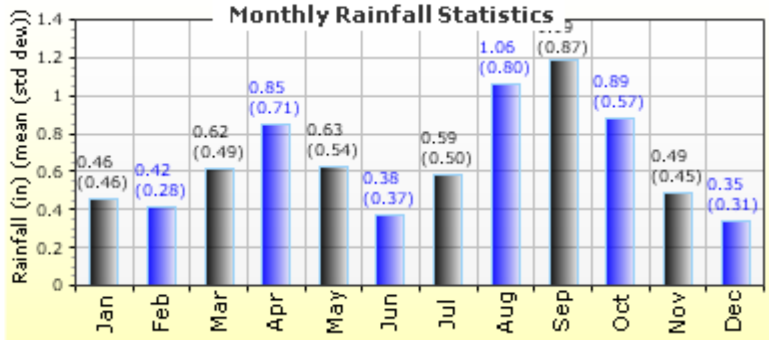




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

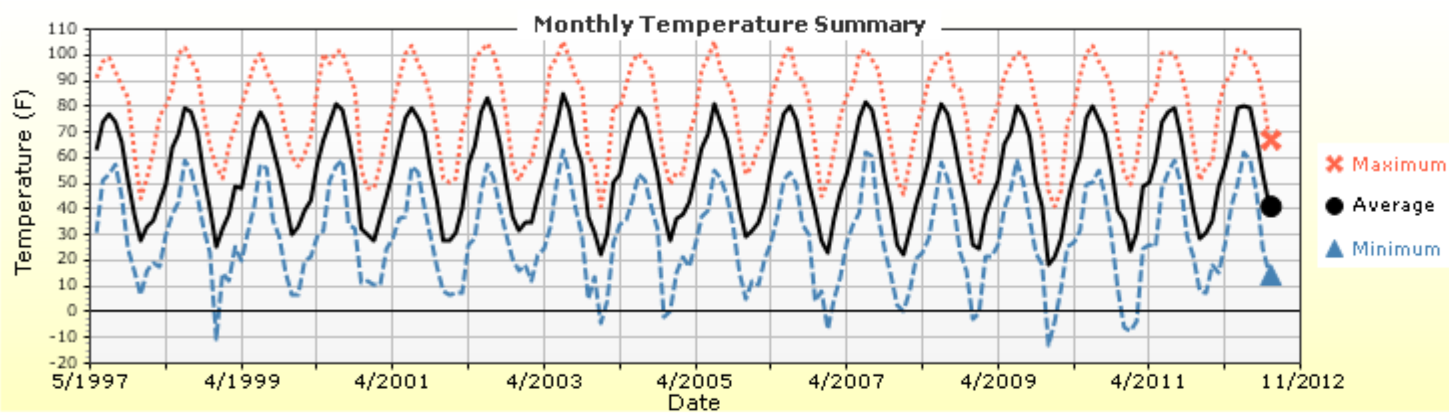


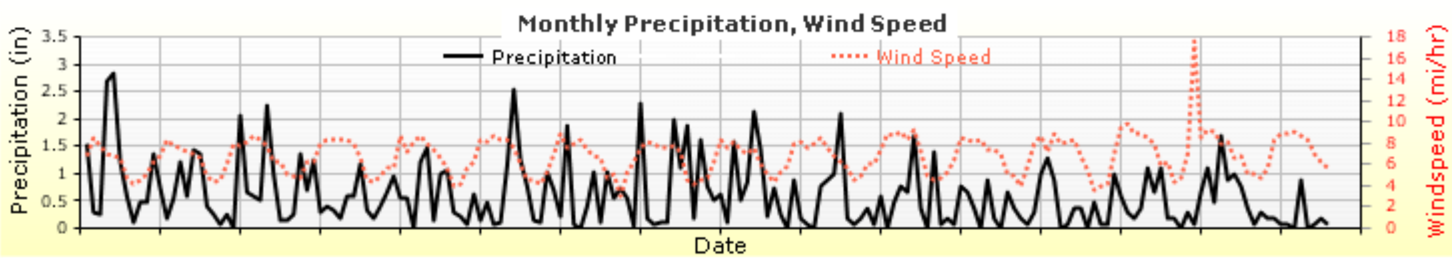
Annual Statistics:

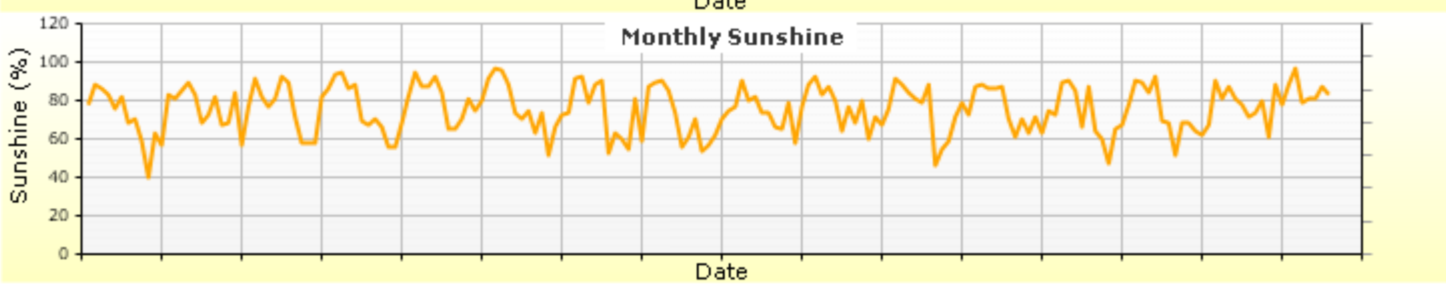
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

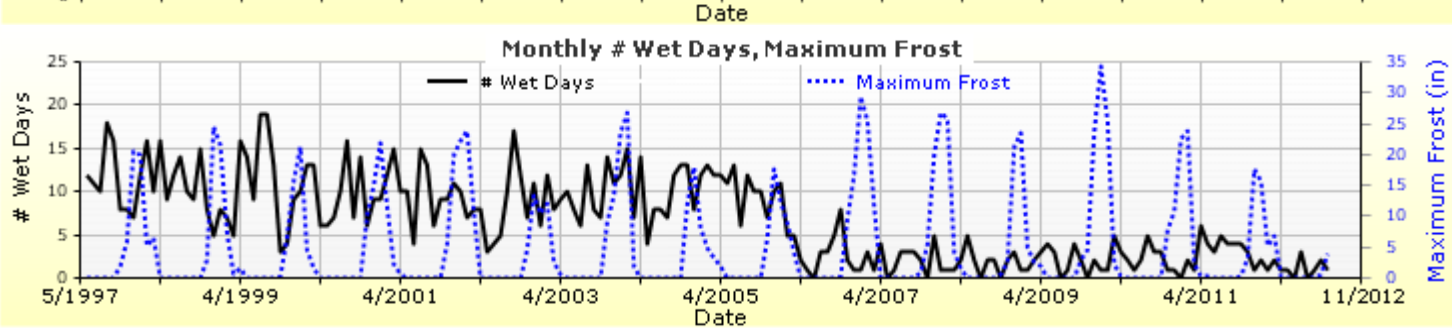
Water table depth (ft)	4.00

Monthly Climate Summary:

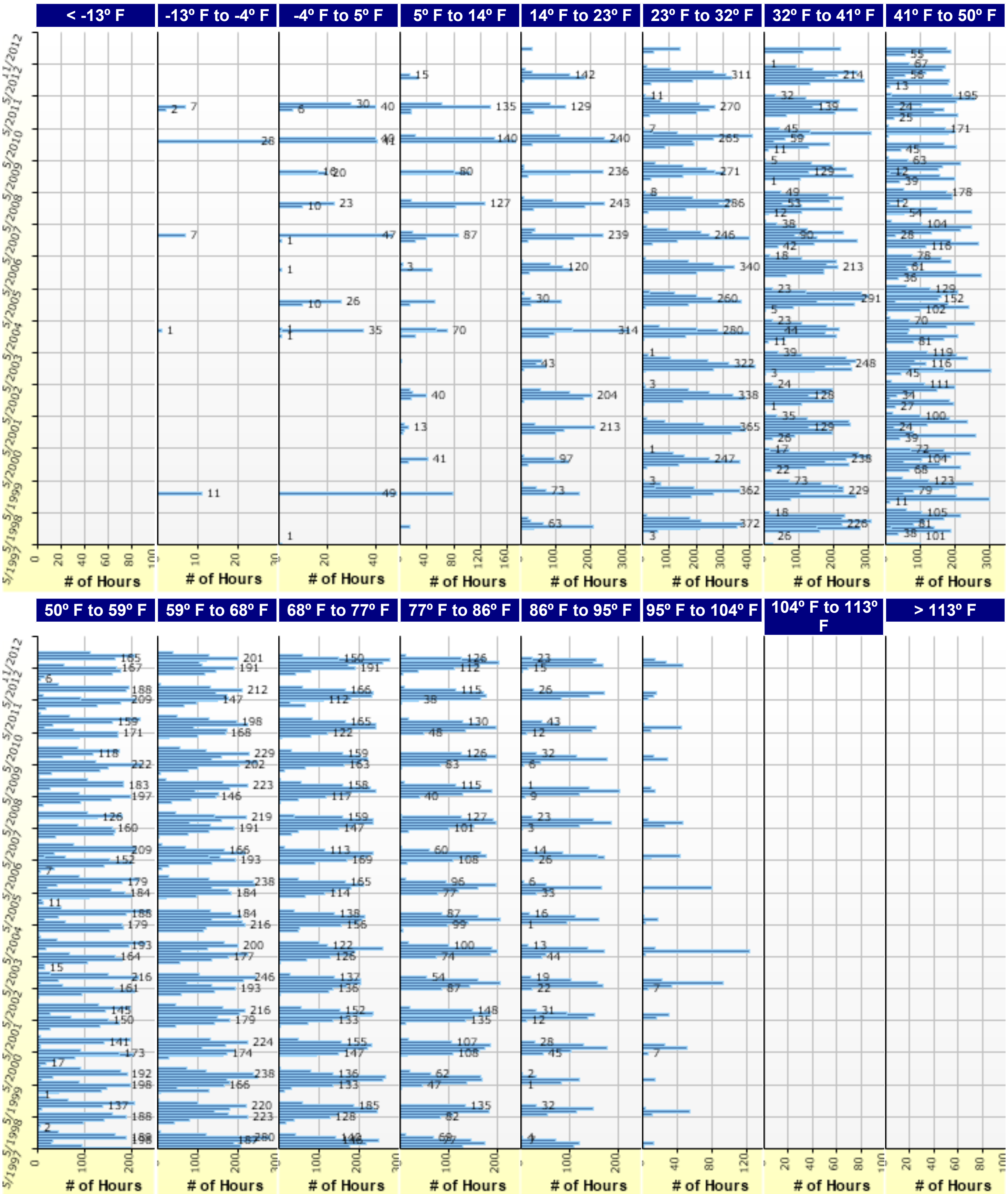








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

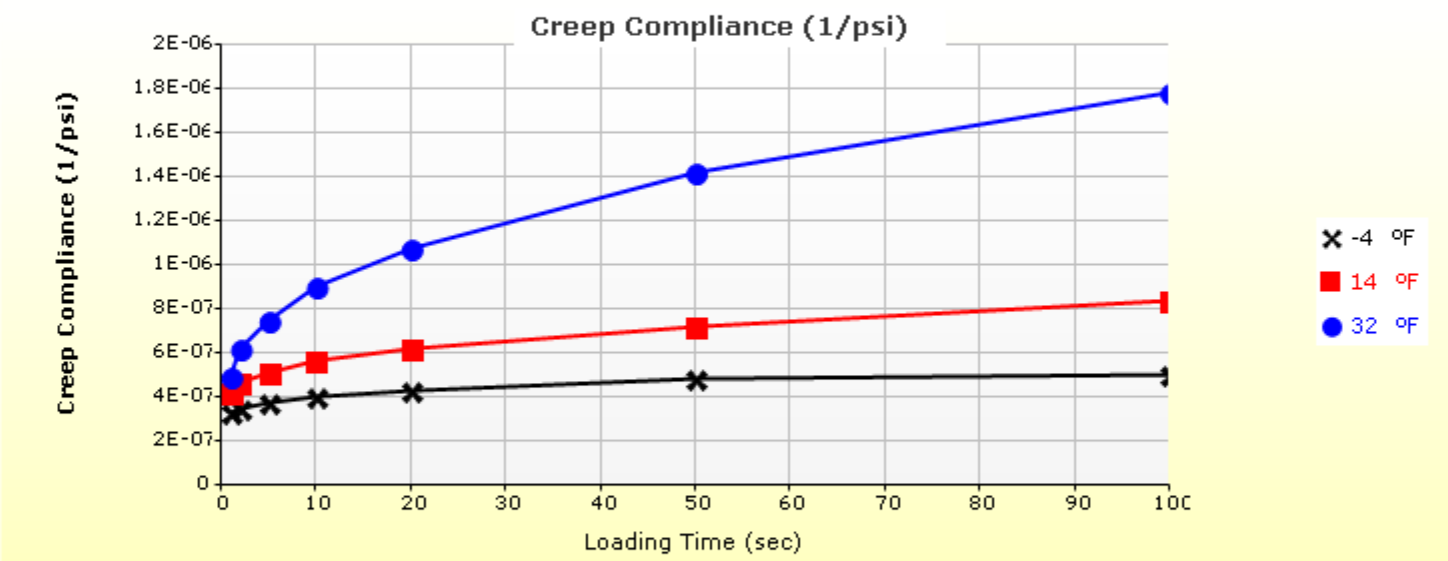
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

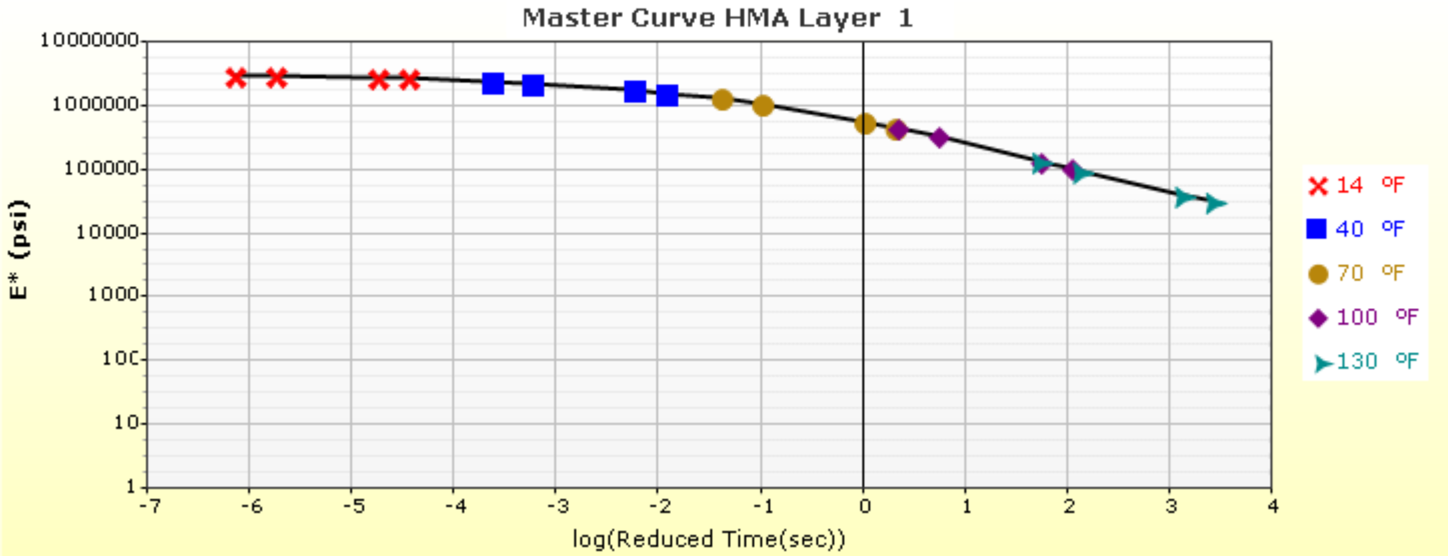
Thermal Cracking (Input Level: 1)

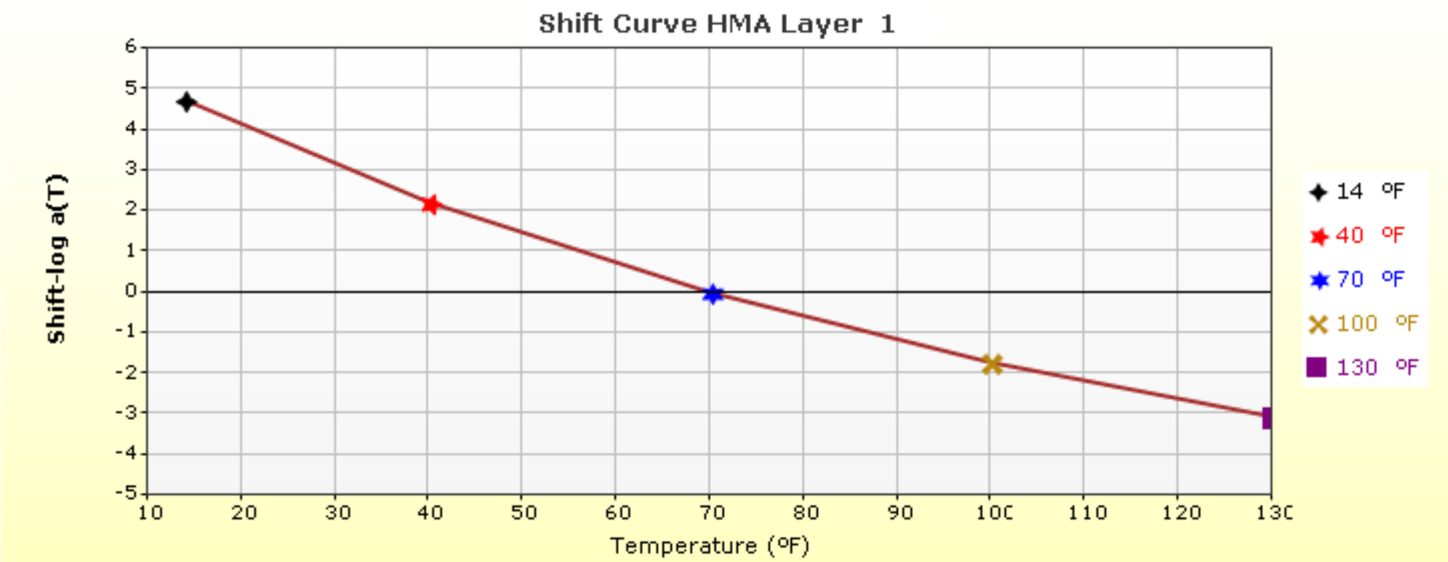
Indirect tensile strength at 14 ºF (psi)	451.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

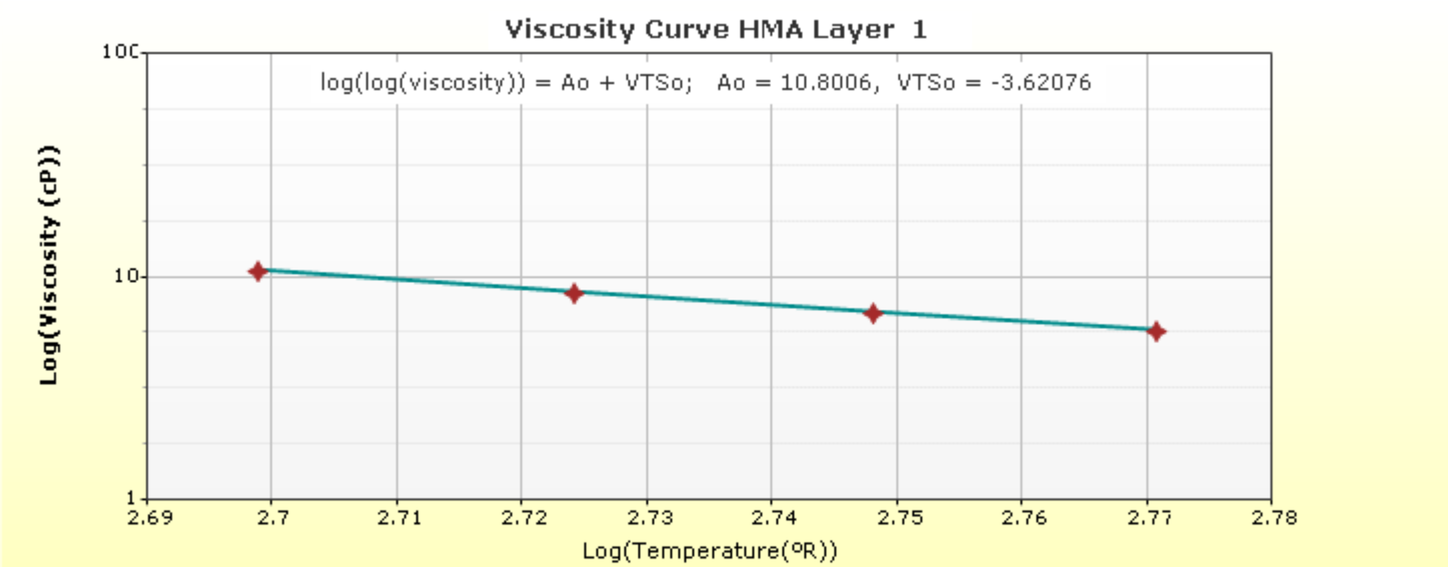
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



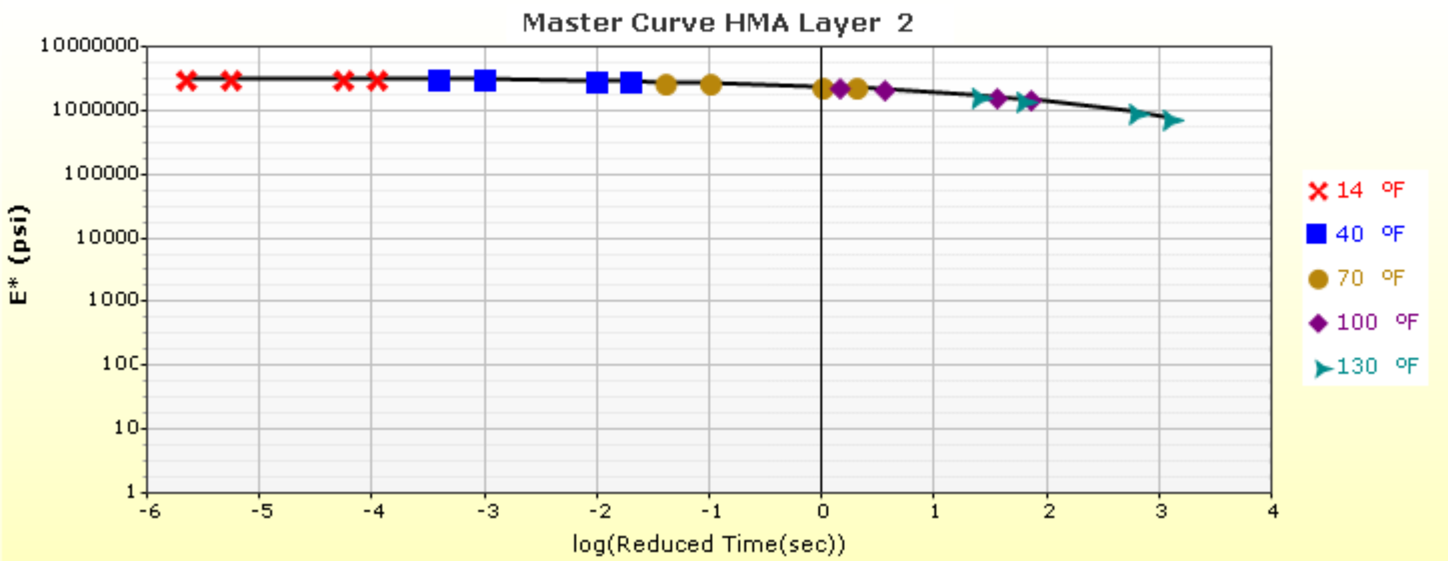
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

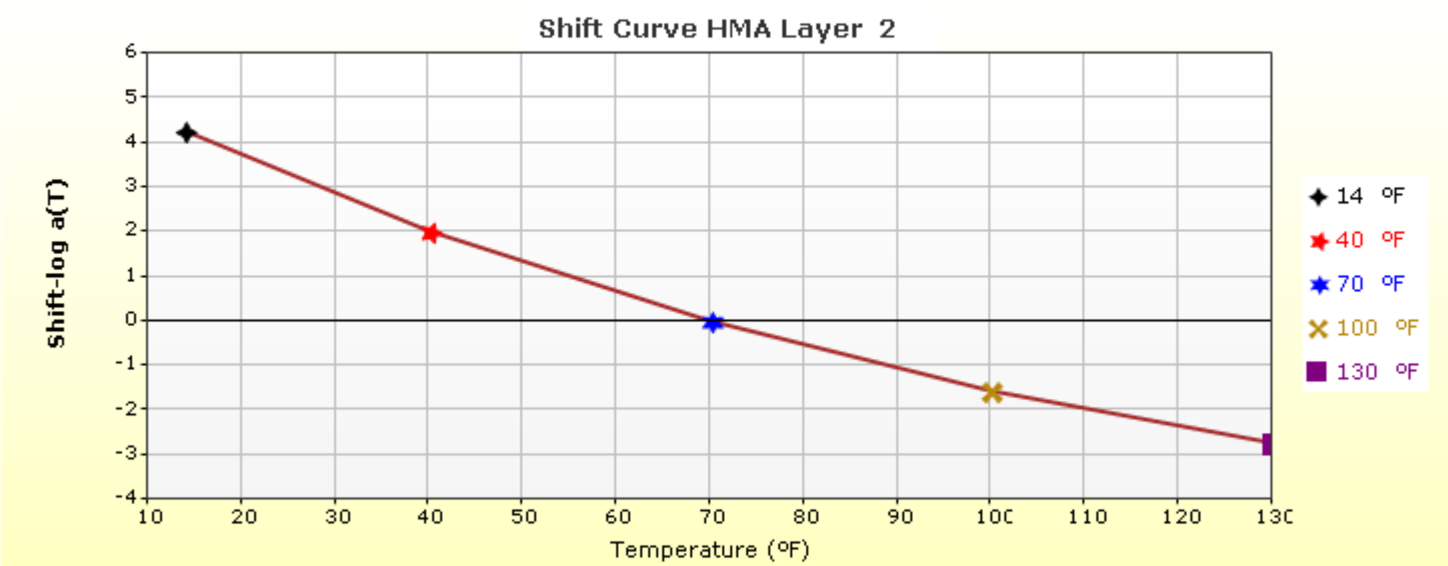


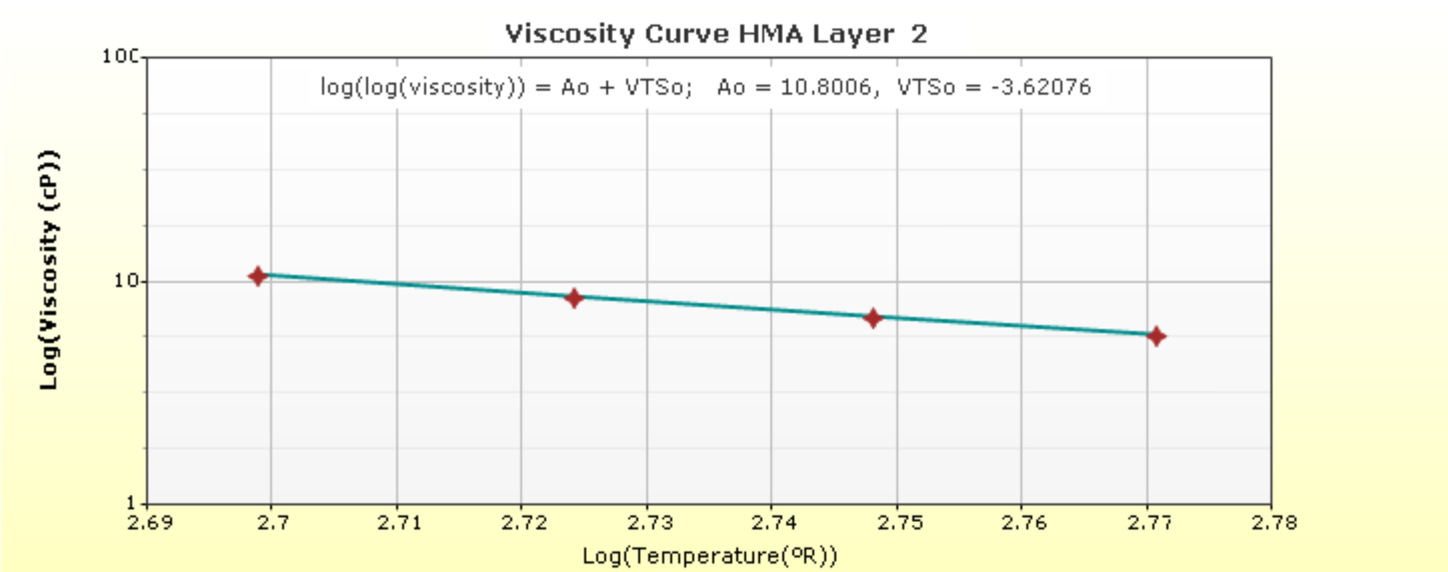




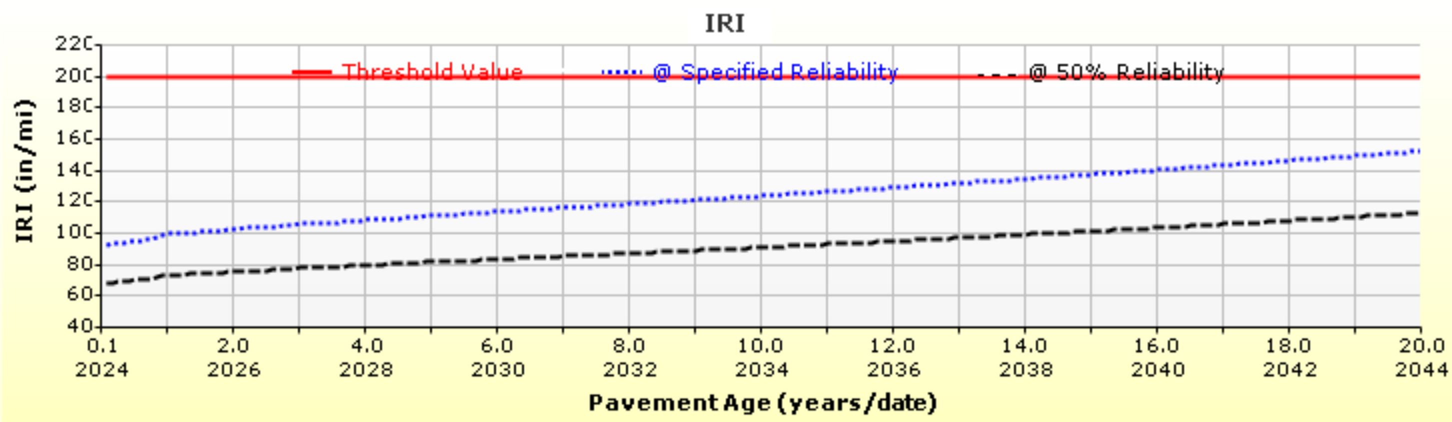
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

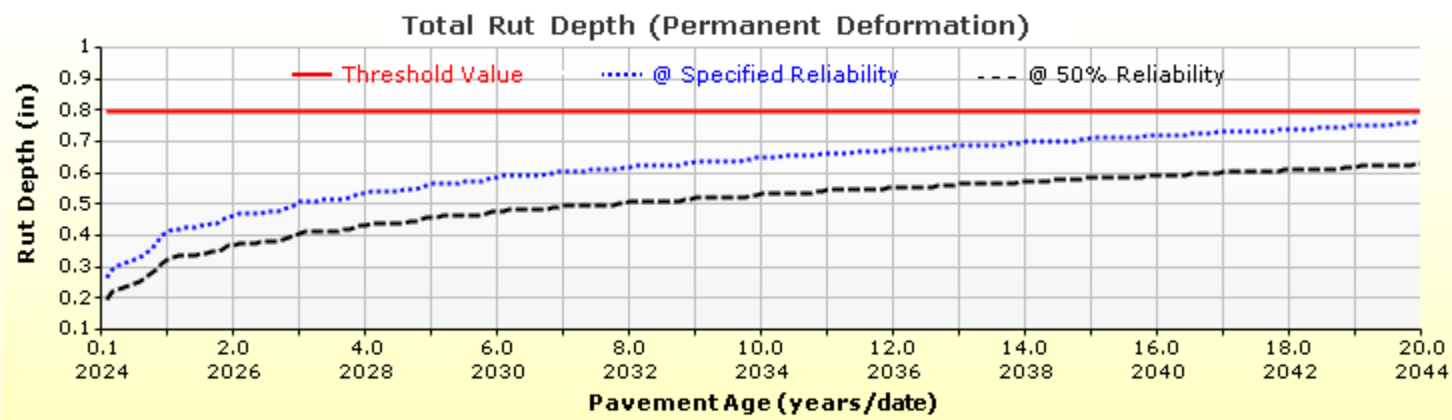


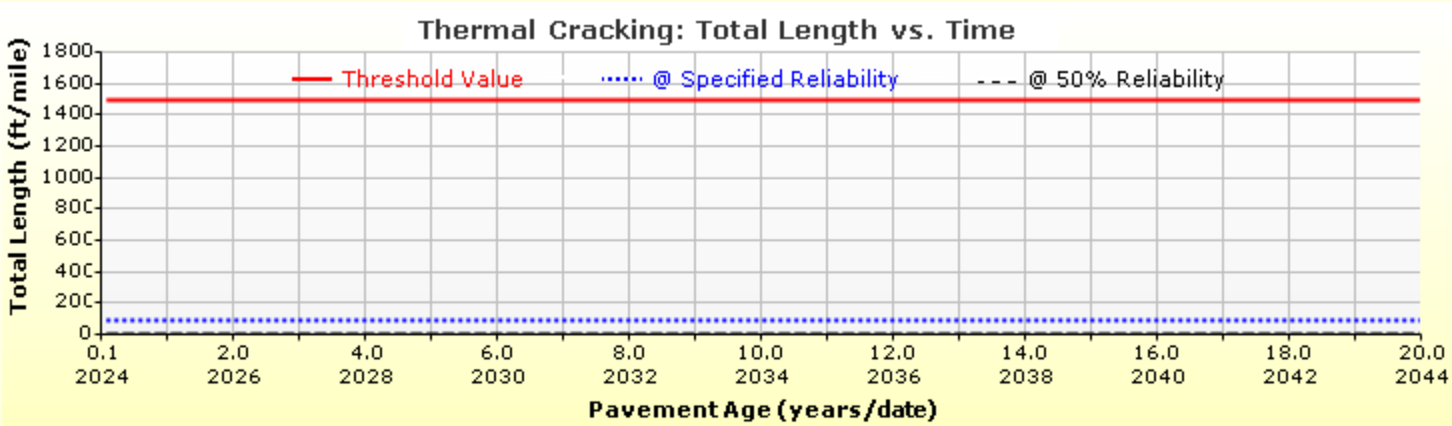


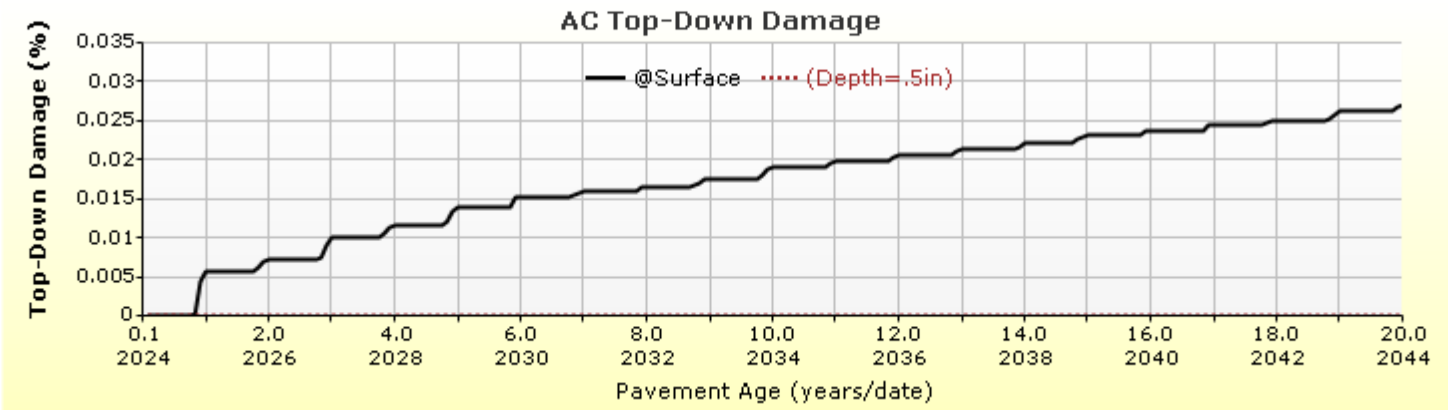


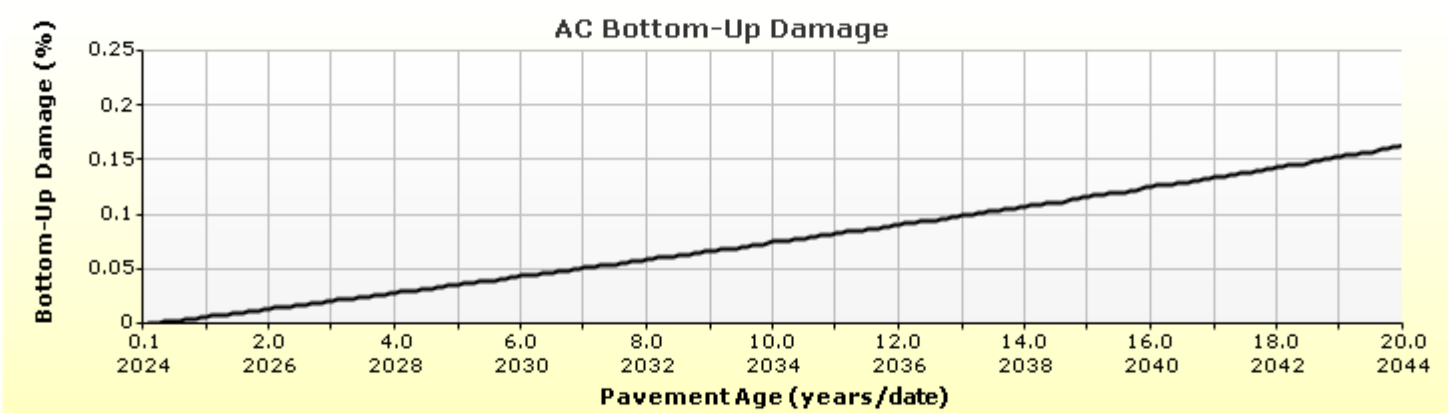
Analysis Output Charts

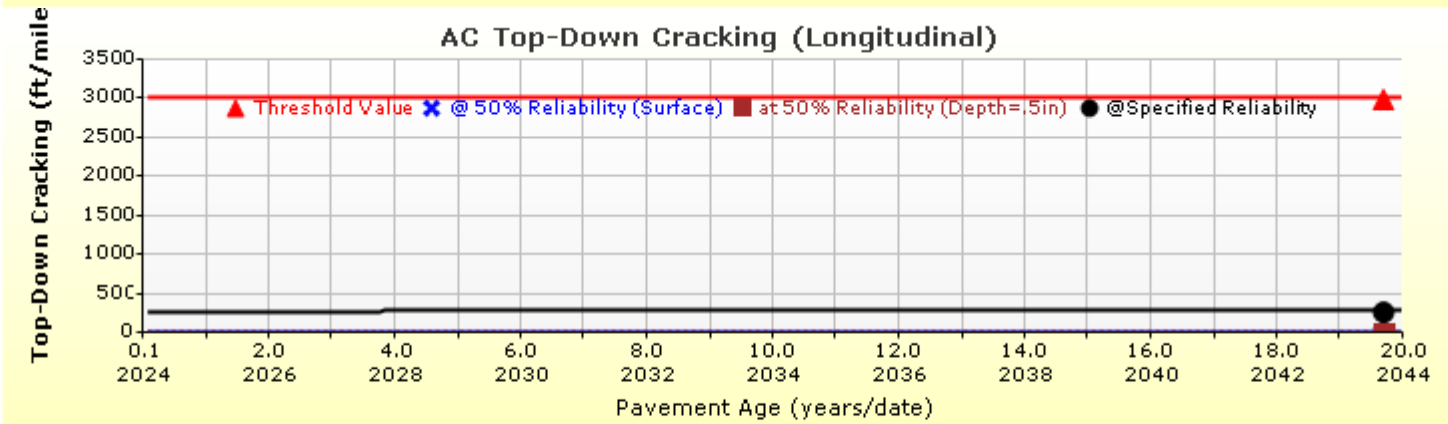


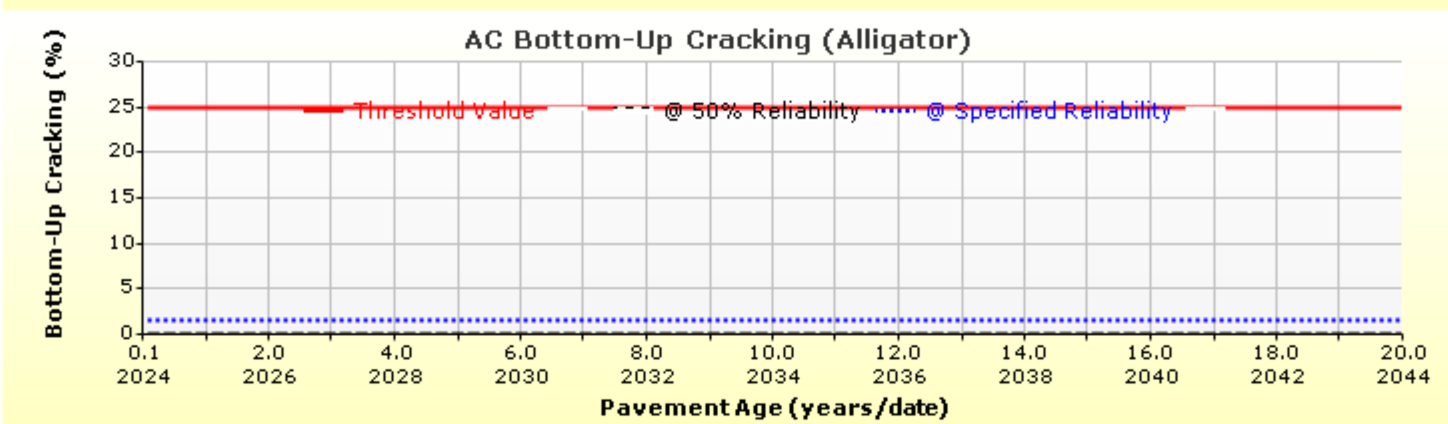


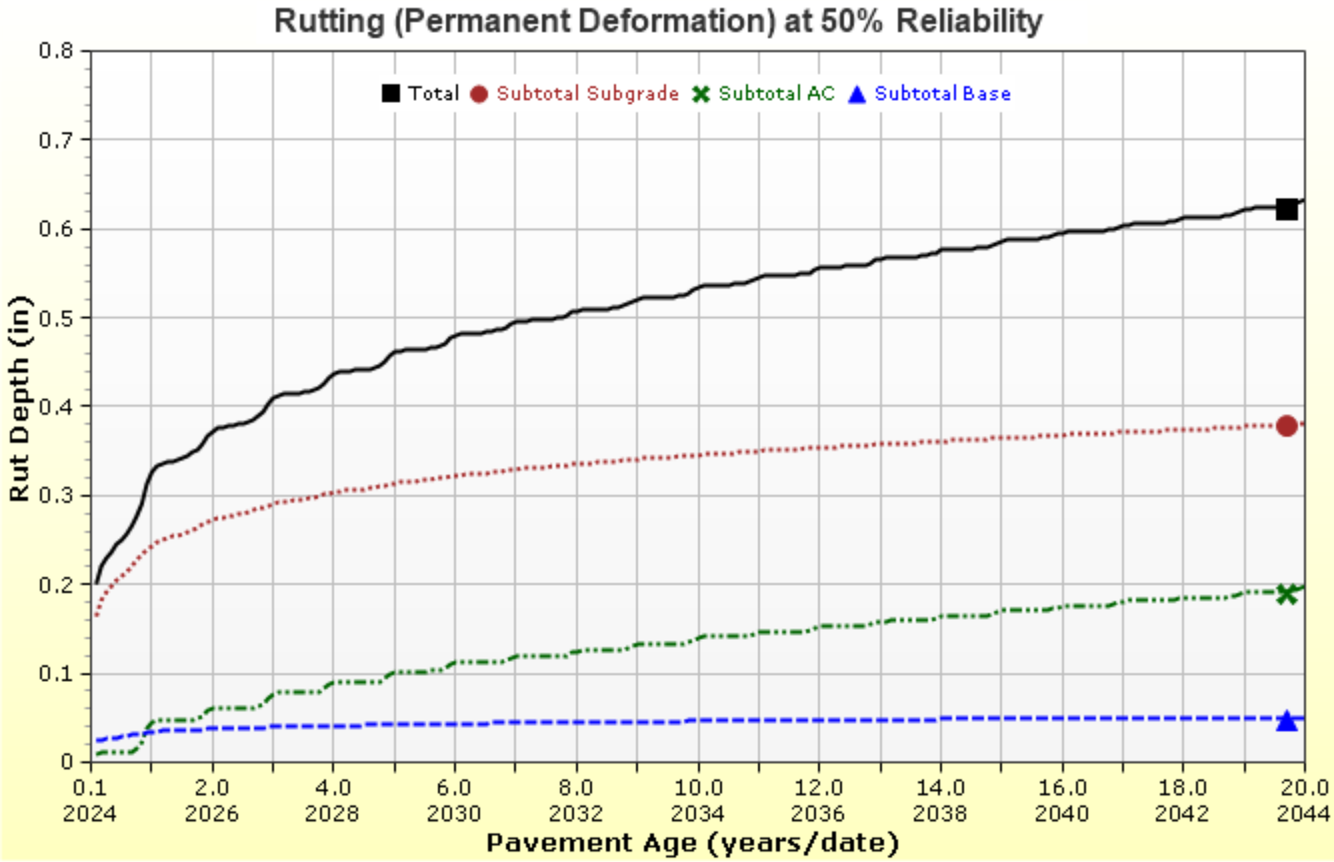


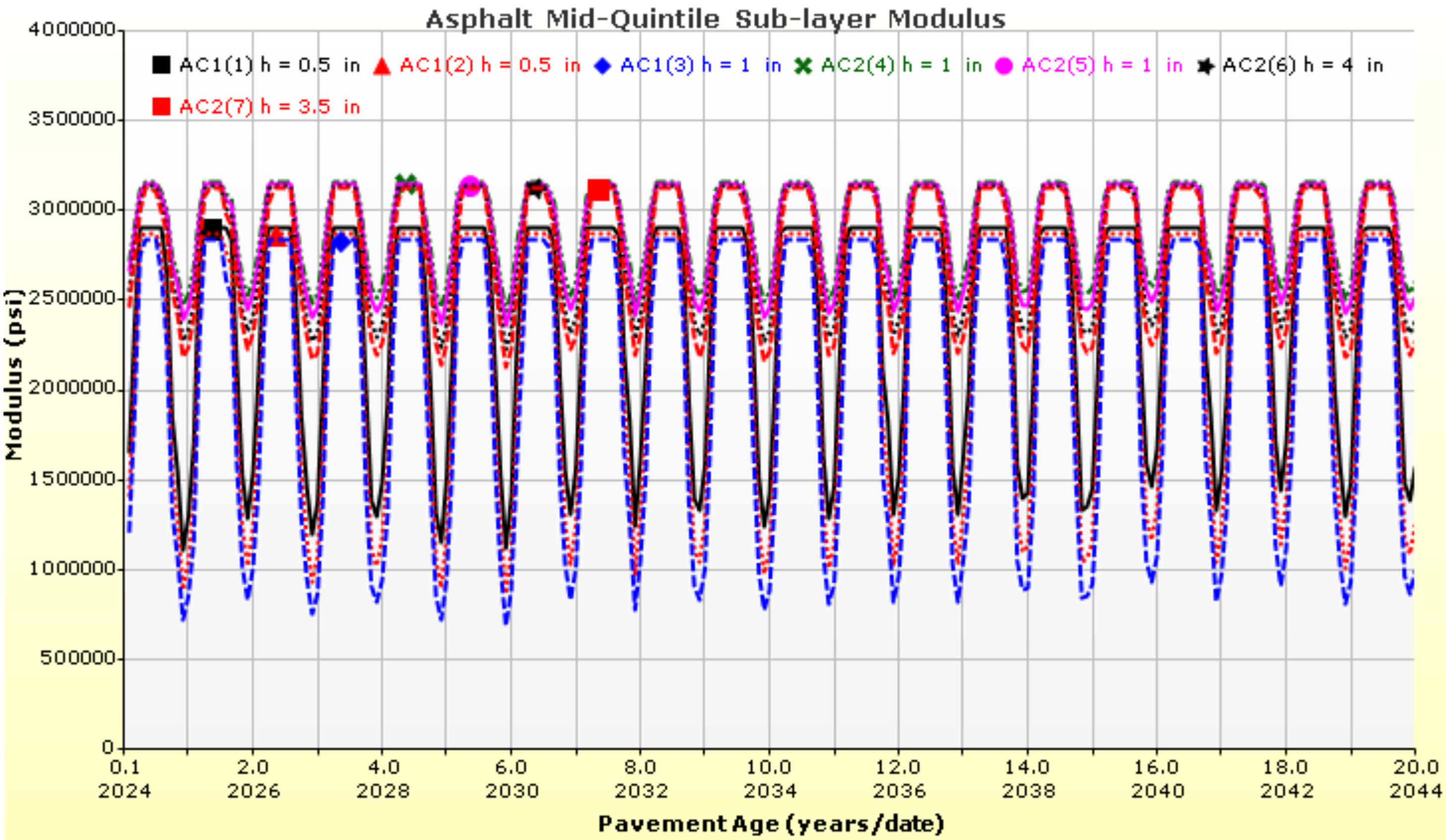

AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)


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

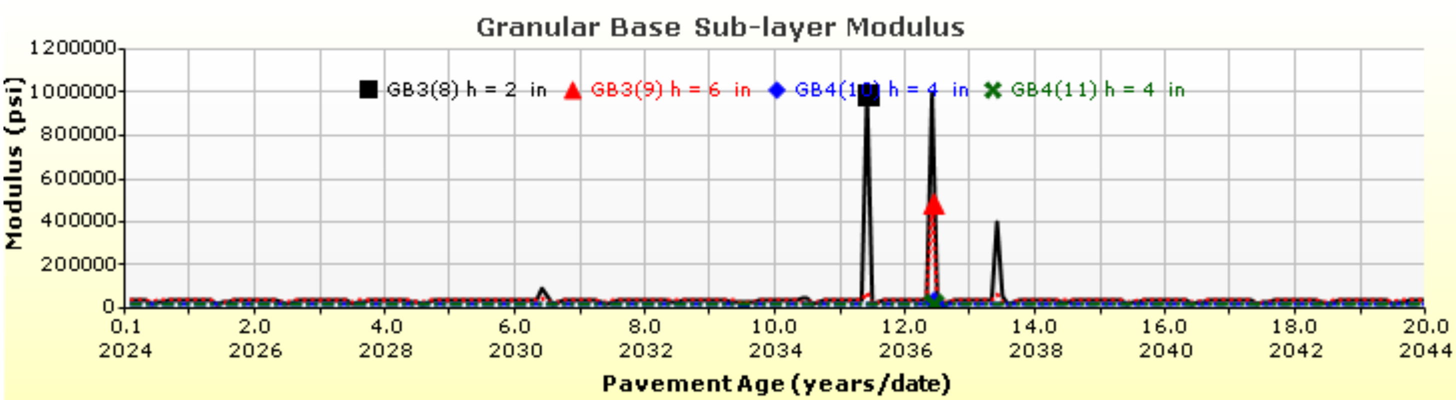

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

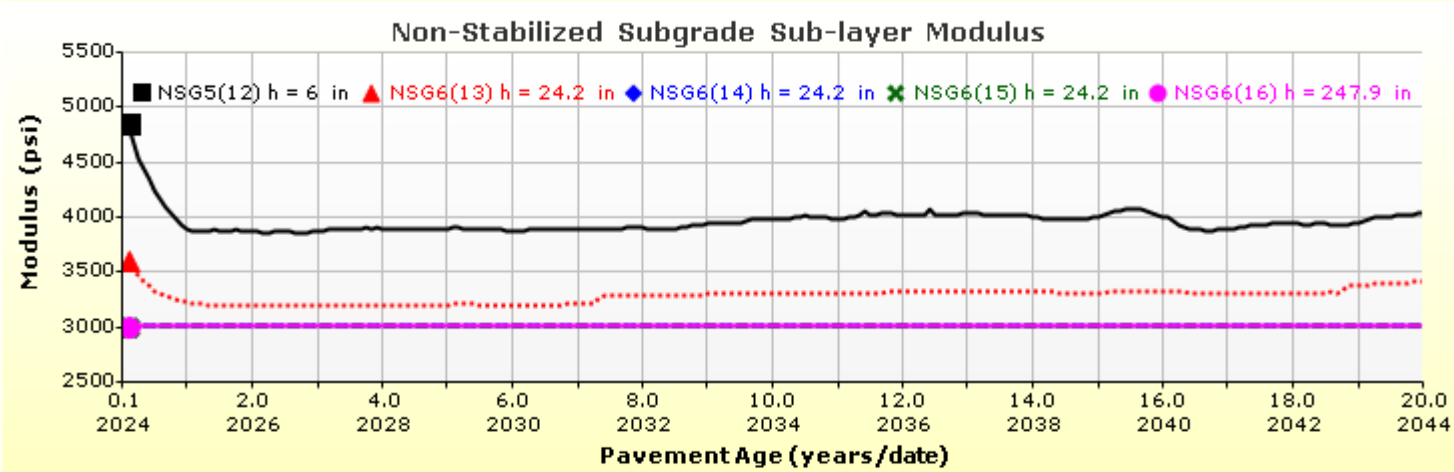

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 3.5 in
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 6 in
GB4(10) h = 4 in
GB4(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 6 in
NSG6(13) h = 24.2 in
NSG6(14) h = 24.2 in
NSG6(15) h = 24.2 in
NSG6(16) h = 247.9 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	9.5	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

AC Fatigue

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

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	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2024
Pavement construction: July, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R2 Level 1 SX(100) PG 64-22	2.0
Flexible	R4 Level 1 S(100) PG 64-22	10.5
NonStabilized	Crushed gravel	8.0
NonStabilized	CDOT Class 2 ABC	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.2
Air voids (%)	5.1

Traffic

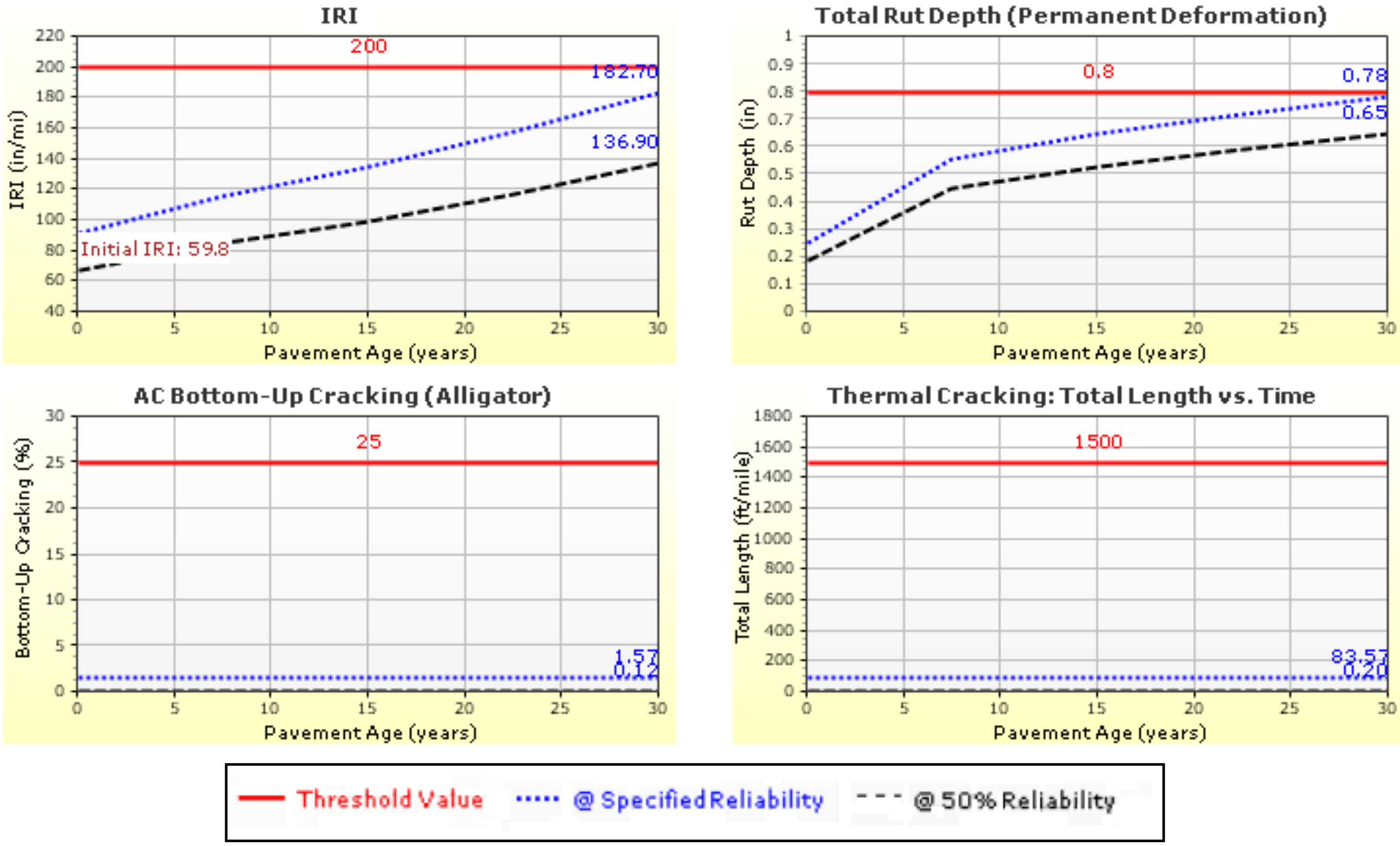
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	6,350
2039 (15 years)	18,049,200
2054 (30 years)	42,341,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	182.72	90.00	96.12	Pass
Permanent deformation - total pavement (in)	0.80	0.78	90.00	92.35	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	1.57	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	83.57	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	342.86	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.31	90.00	100.00	Pass

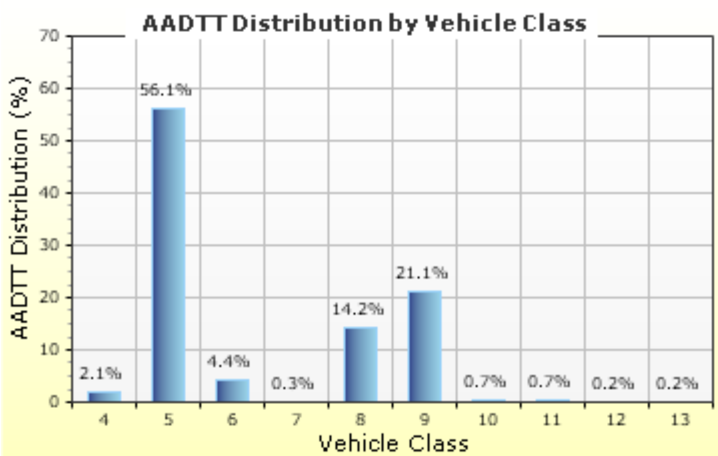
Distress Charts

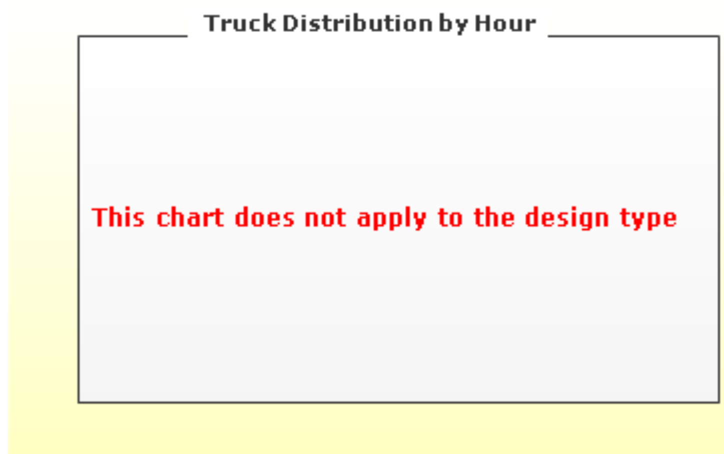


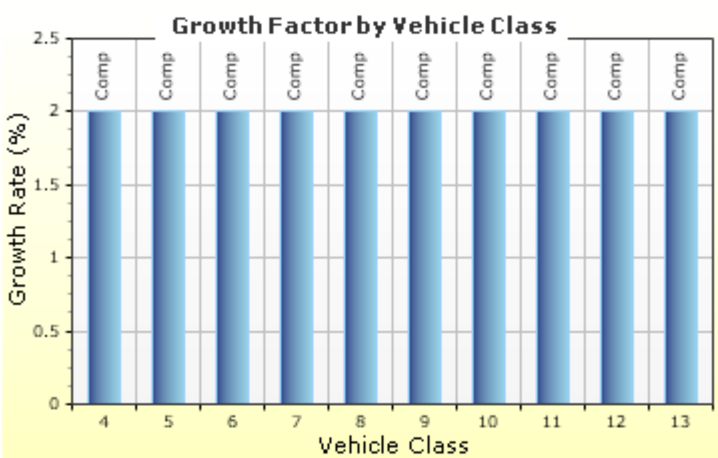
Traffic Inputs

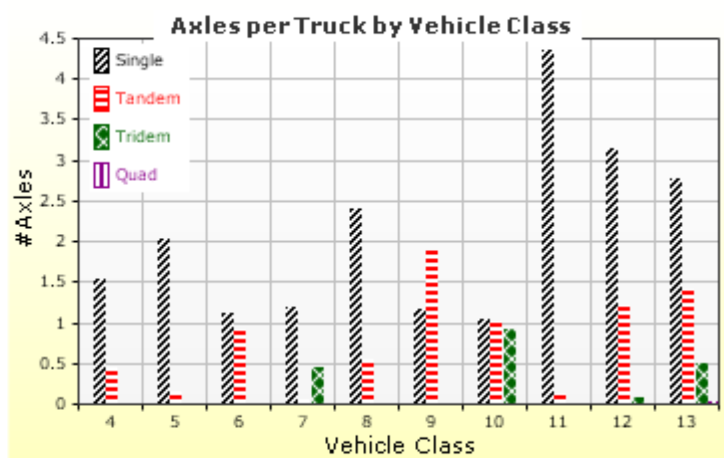
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	6,350	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

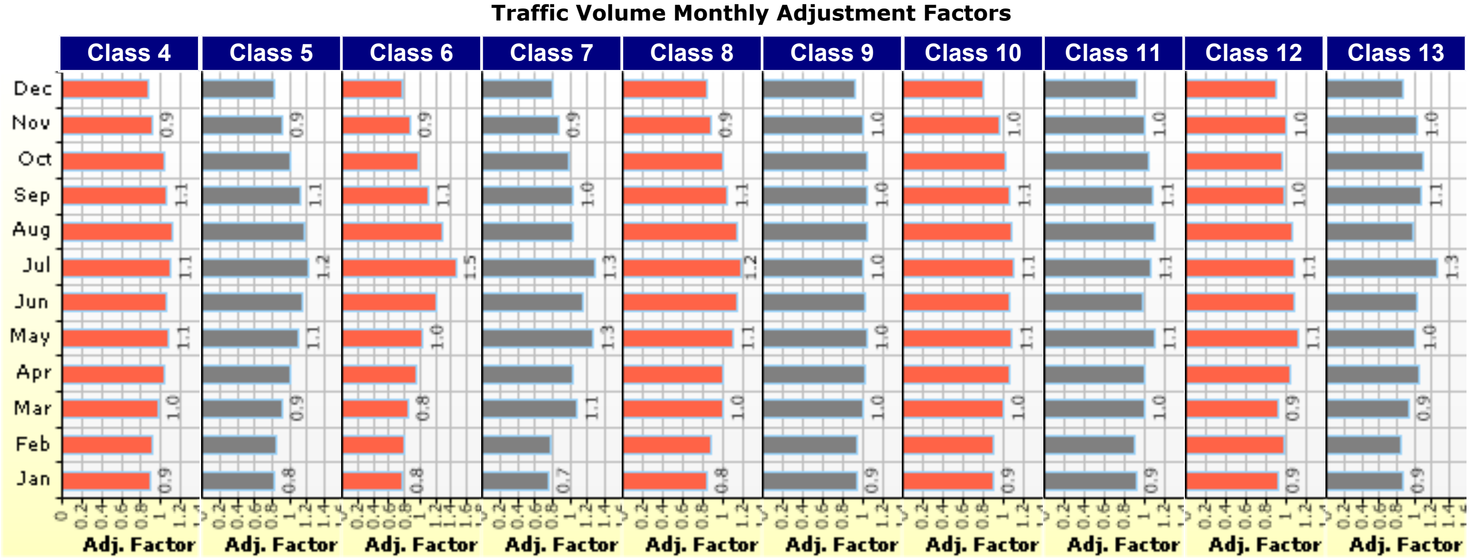








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	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

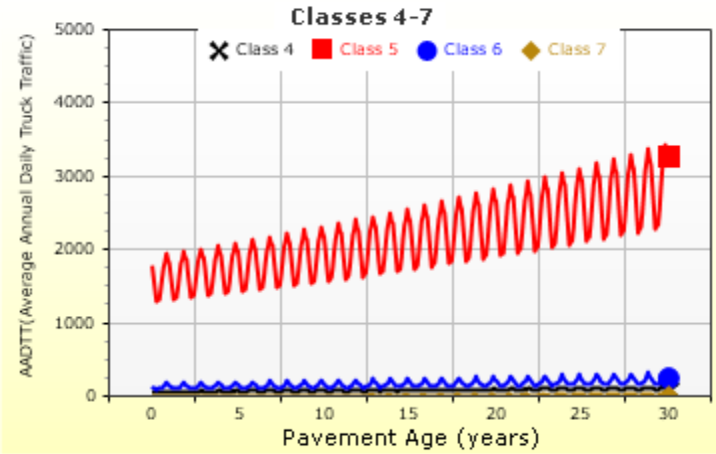
Wheelbase does not apply

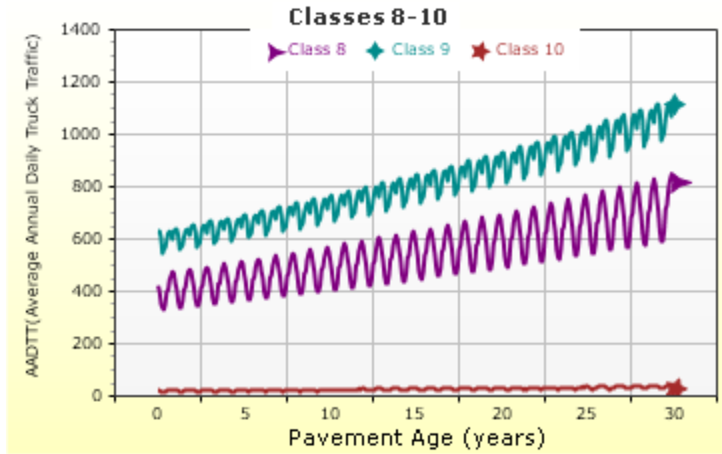
Number of Axles per Truck

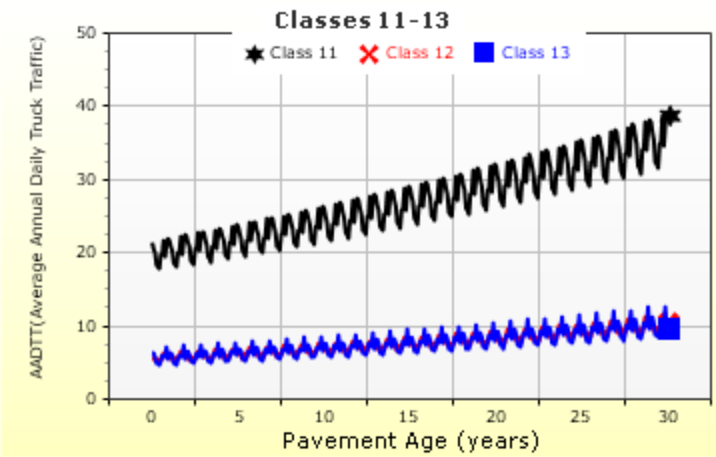
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

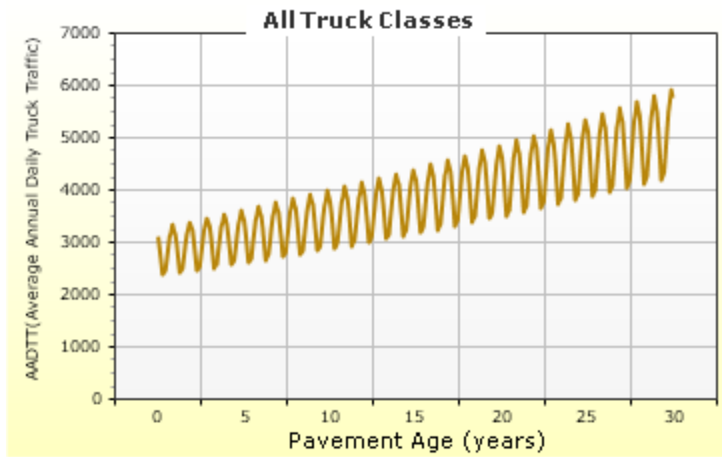
AADTT (Average Annual Daily Truck Traffic) Growth

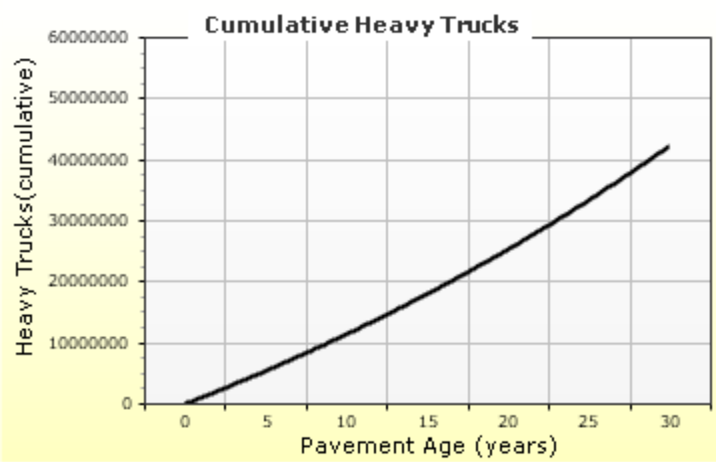
*** Traffic cap is not enforced**







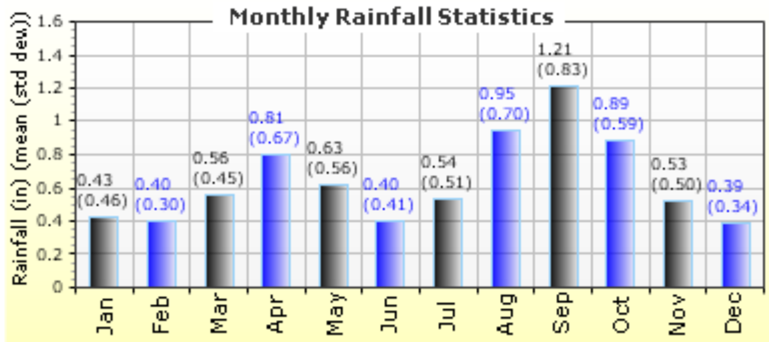




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

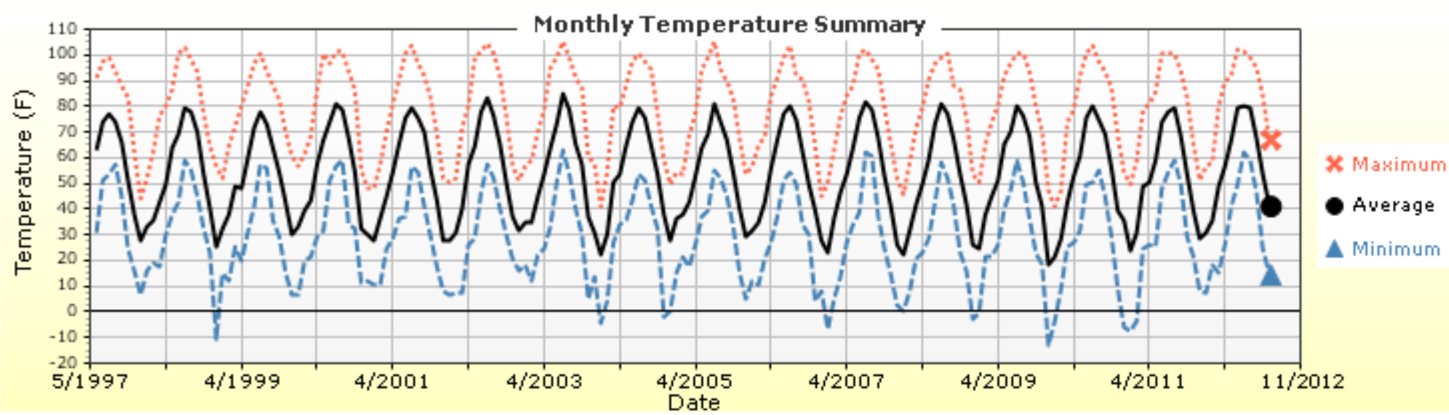


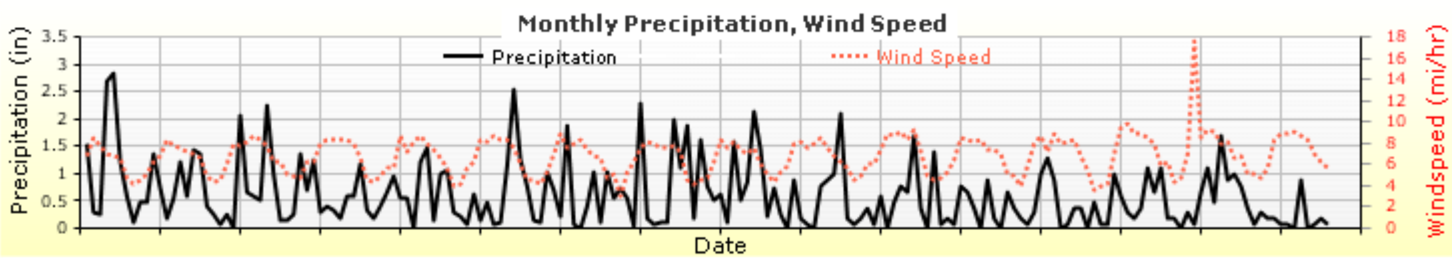
Annual Statistics:

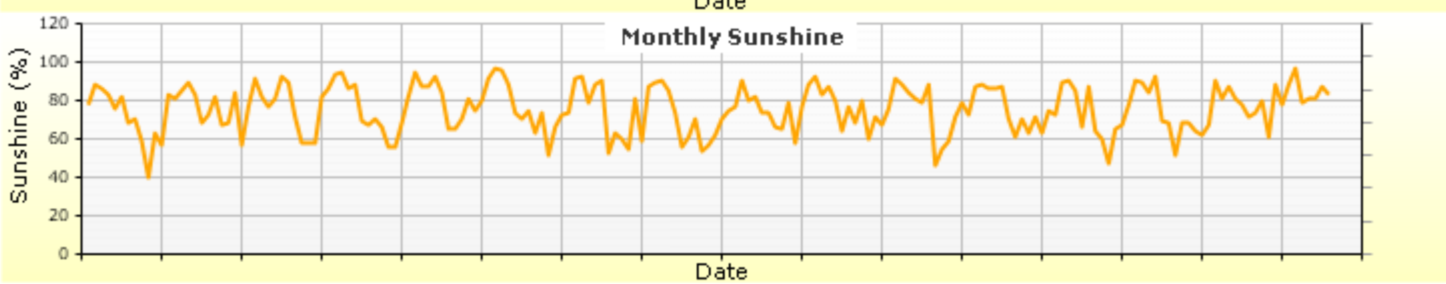
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

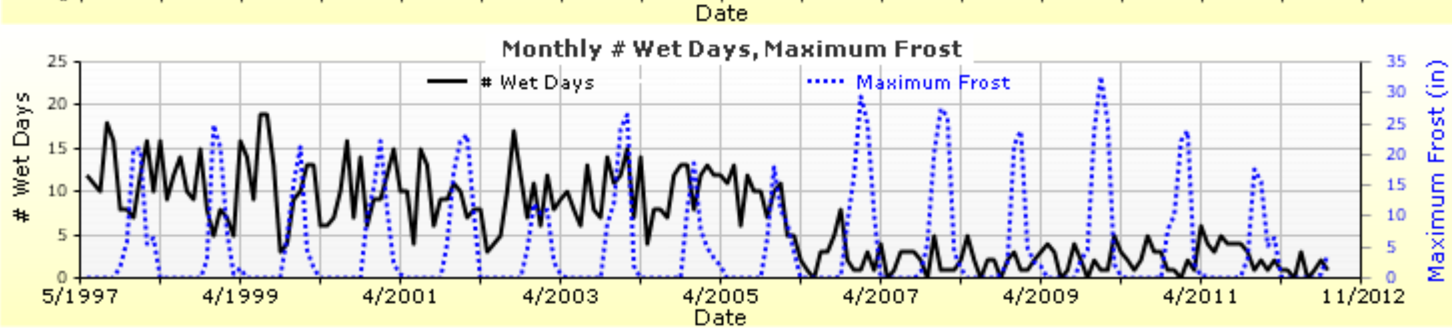
Water table depth (ft) 4.00

Monthly Climate Summary:

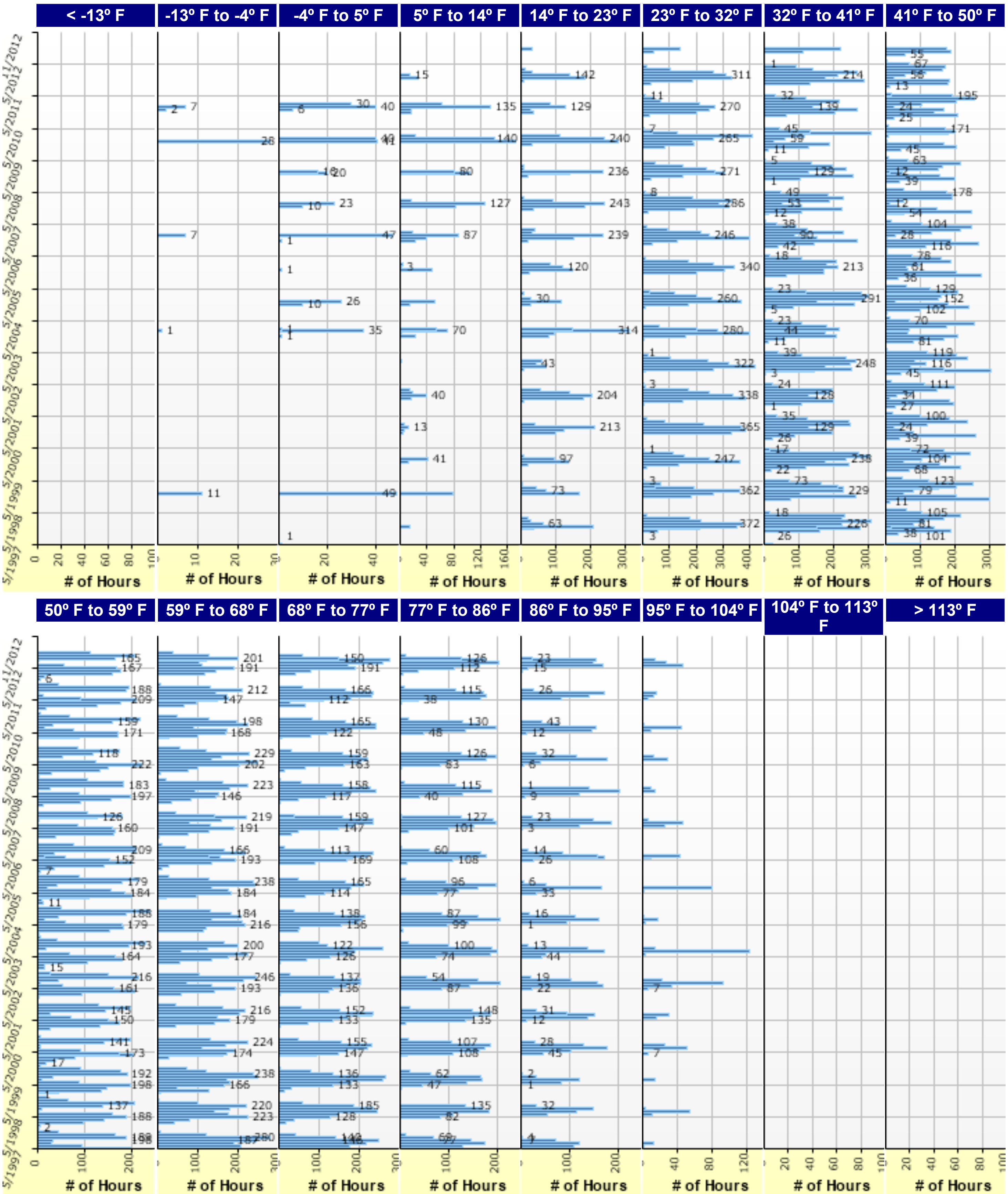








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

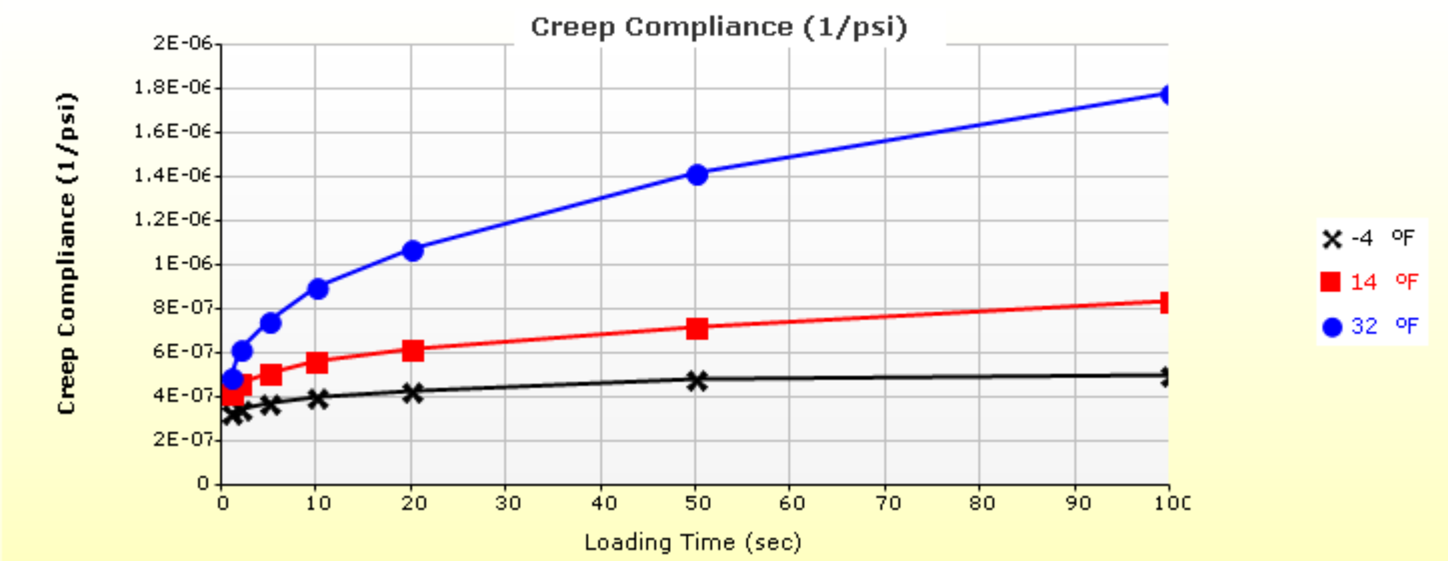
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 2 Flexible : R4 Level 1 S (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : CDOT Class 2 ABC	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Subgrade : A-4	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

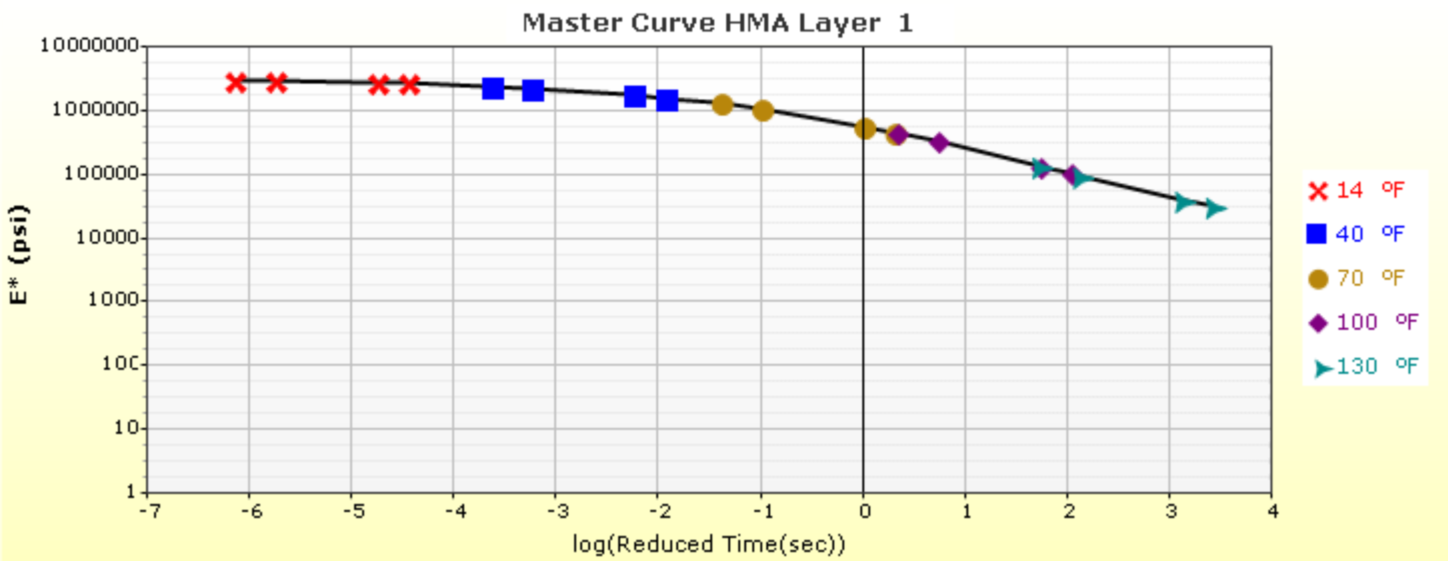
Indirect tensile strength at 14 ºF (psi)	451.00

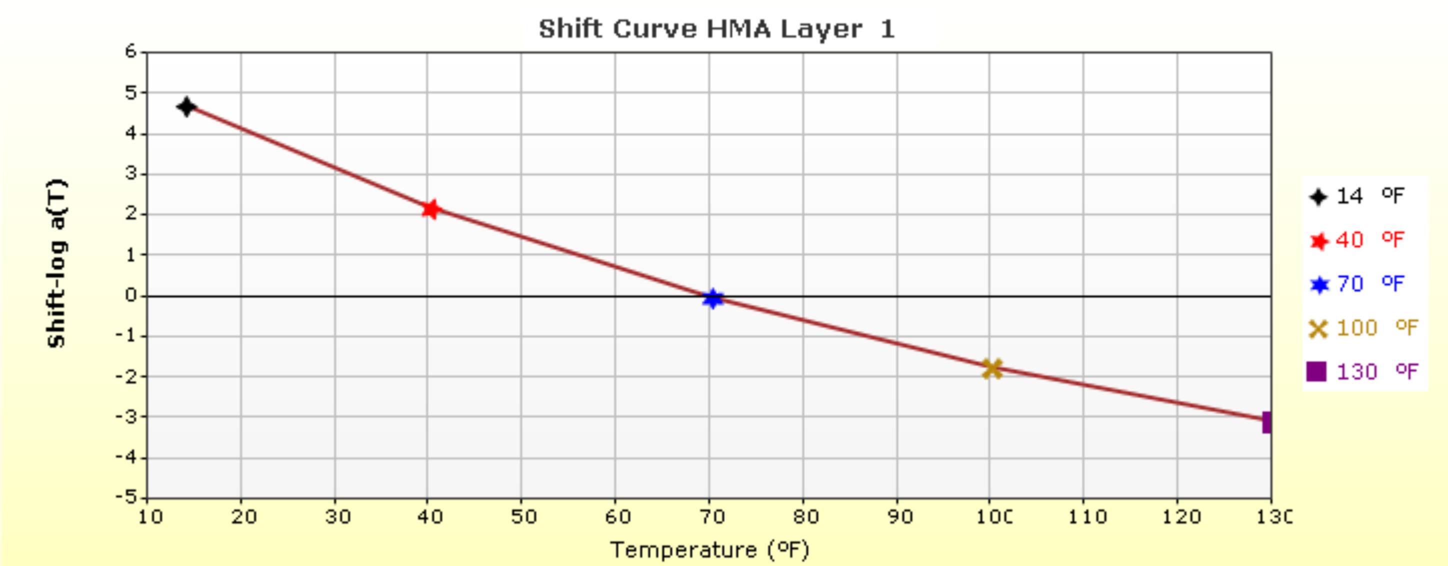
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.3

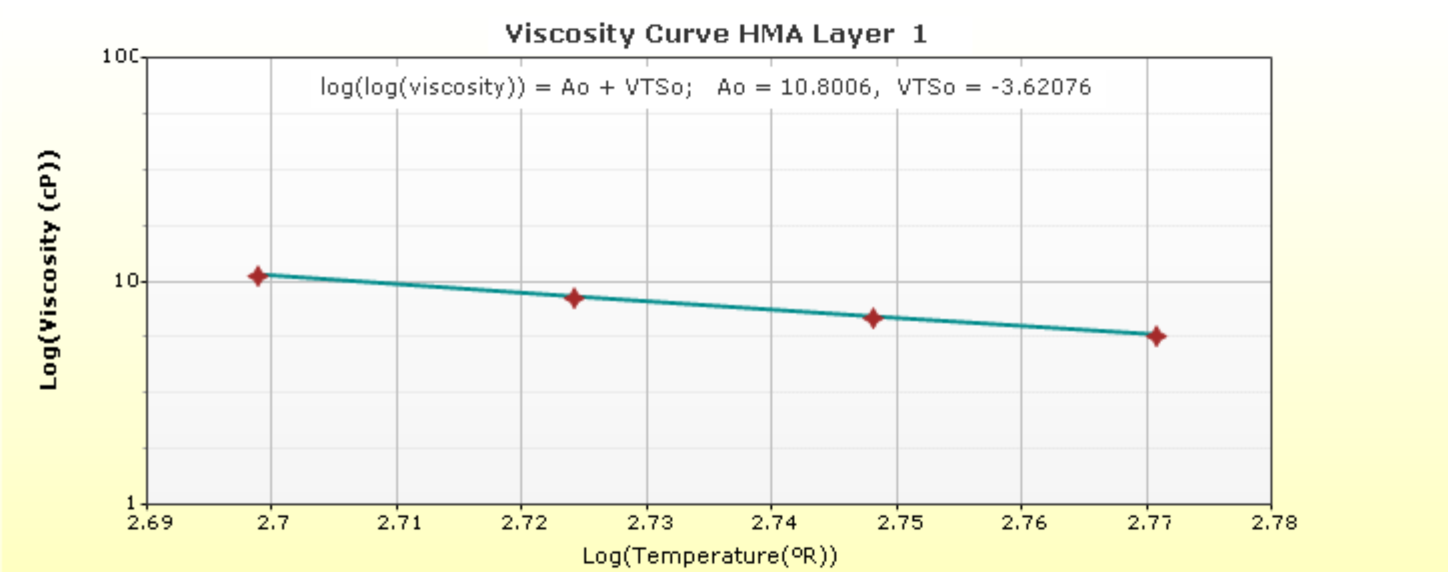
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.34e-007	4.19e-007	4.99e-007
2	3.53e-007	4.64e-007	6.19e-007
5	3.79e-007	5.15e-007	7.49e-007
10	4.05e-007	5.70e-007	9.08e-007
20	4.31e-007	6.26e-007	1.08e-006
50	4.87e-007	7.27e-007	1.43e-006
100	5.05e-007	8.41e-007	1.79e-006



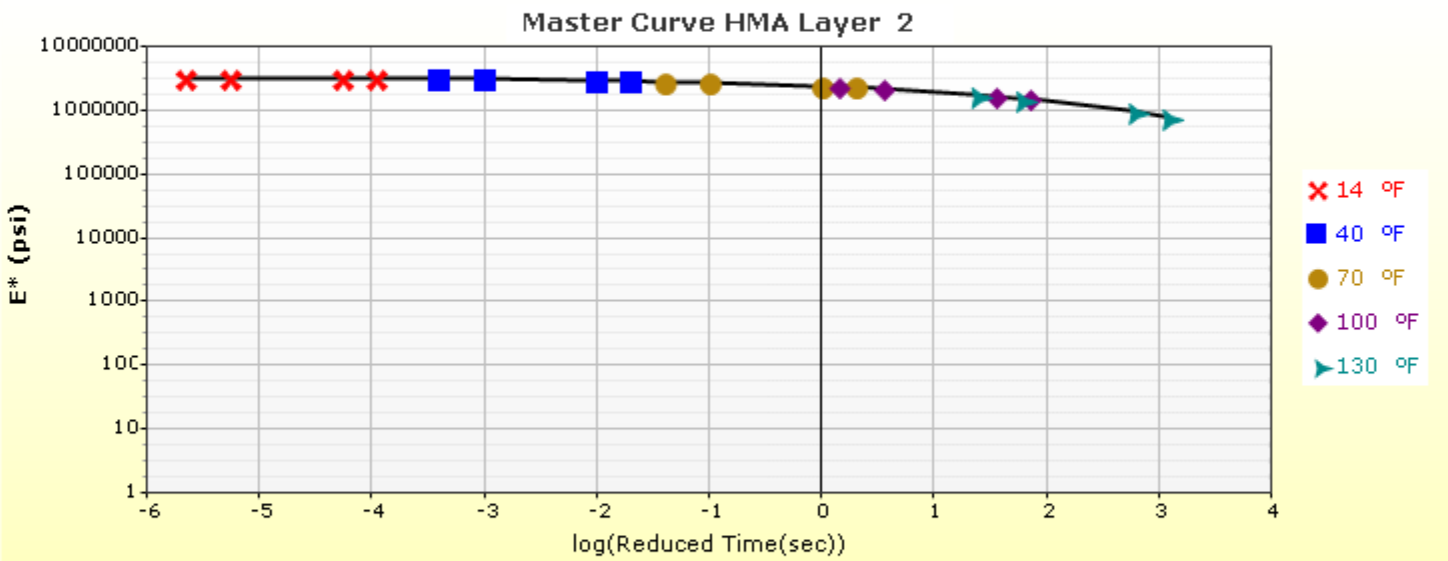
HMA Layer 1: Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

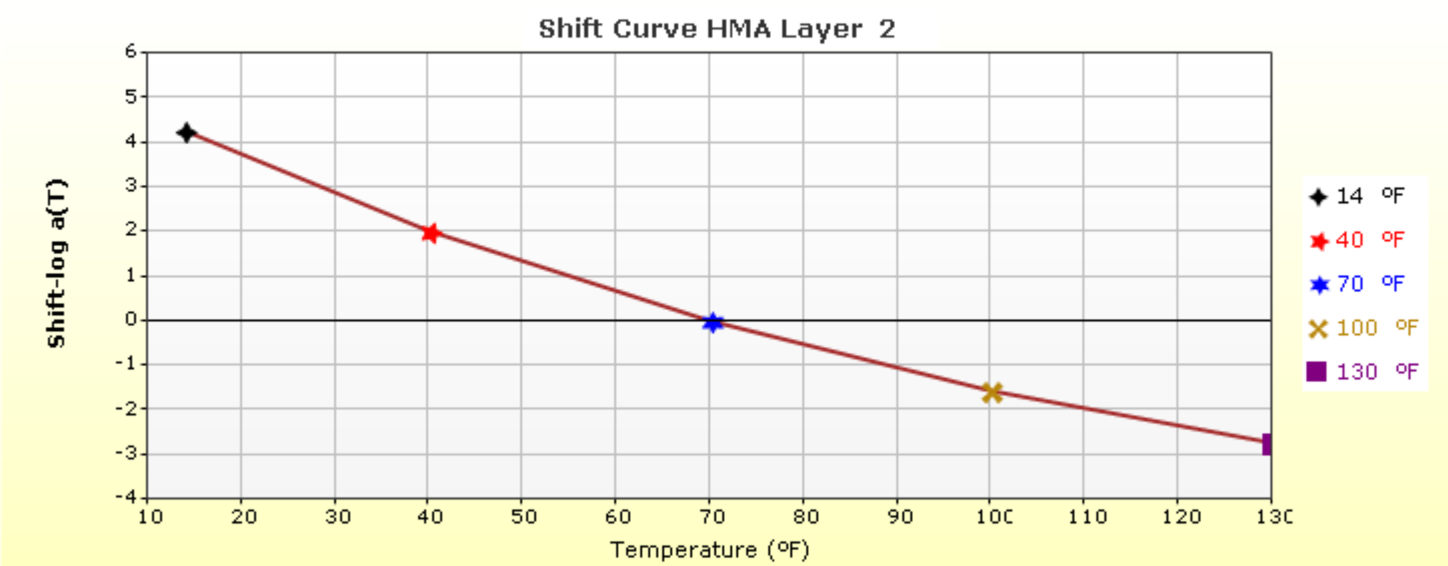


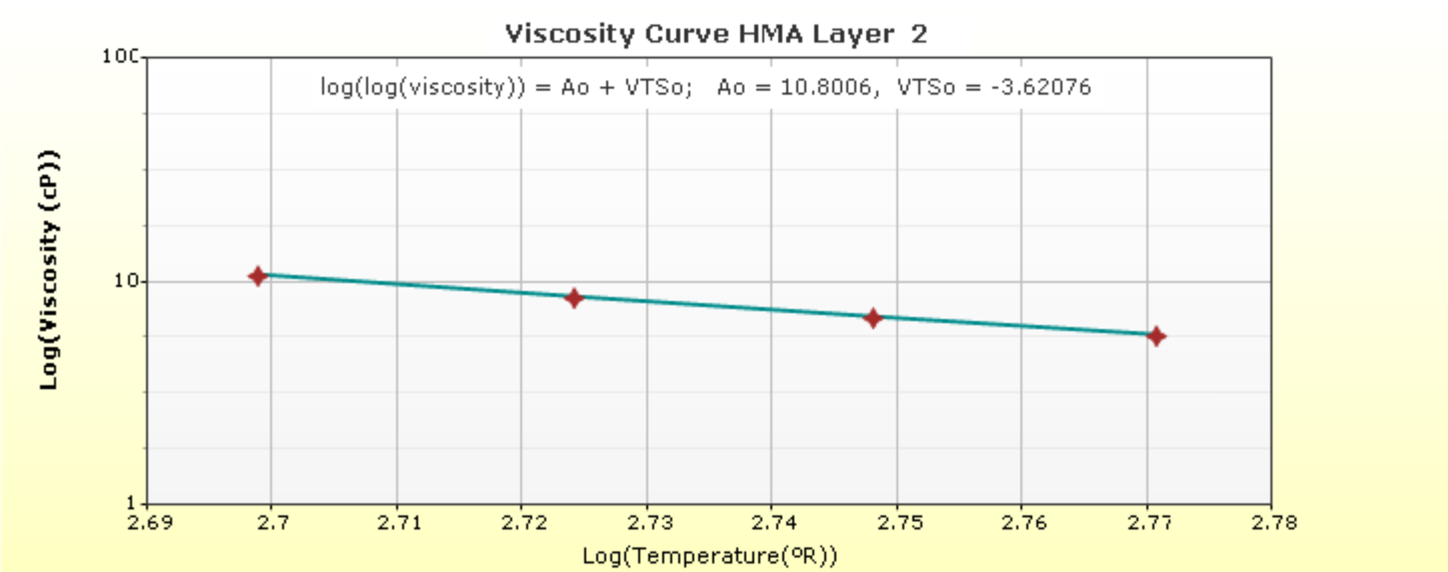




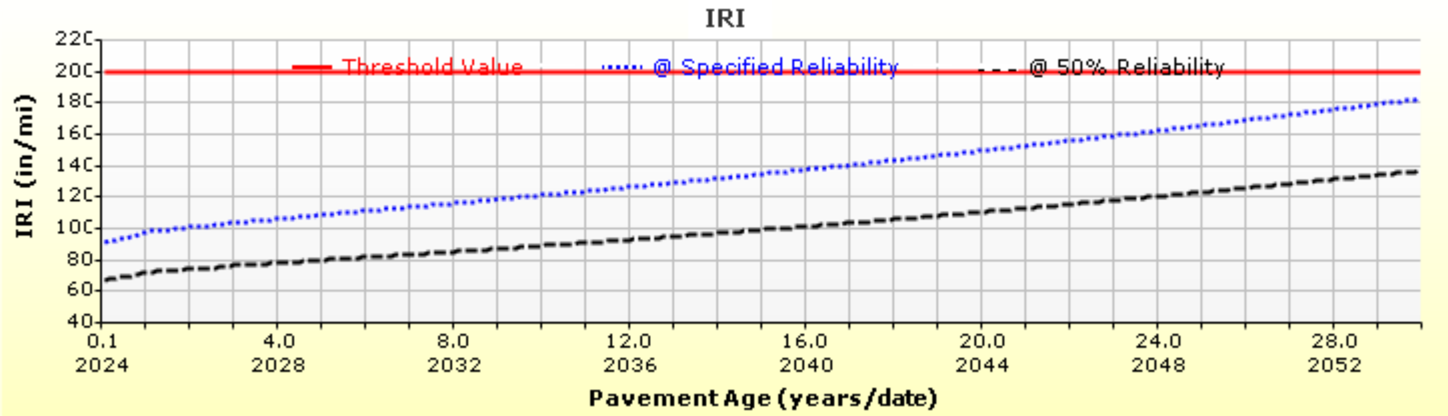
HMA Layer 2: Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

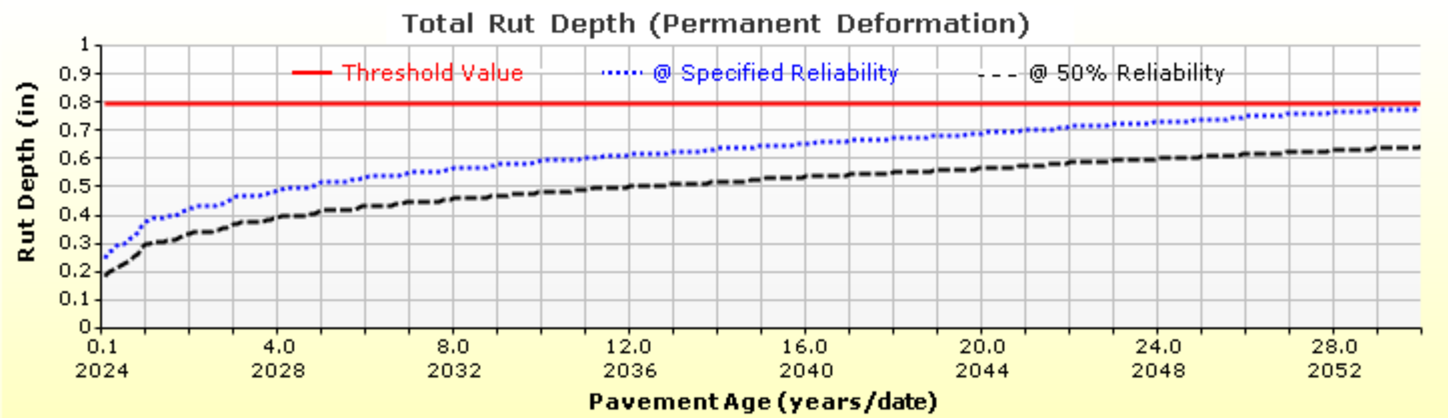


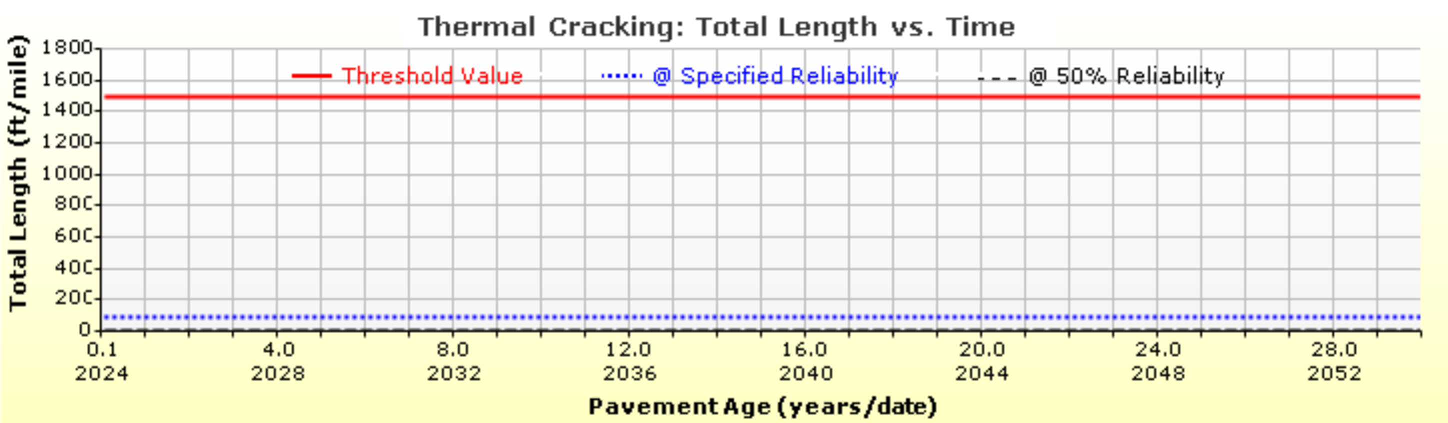


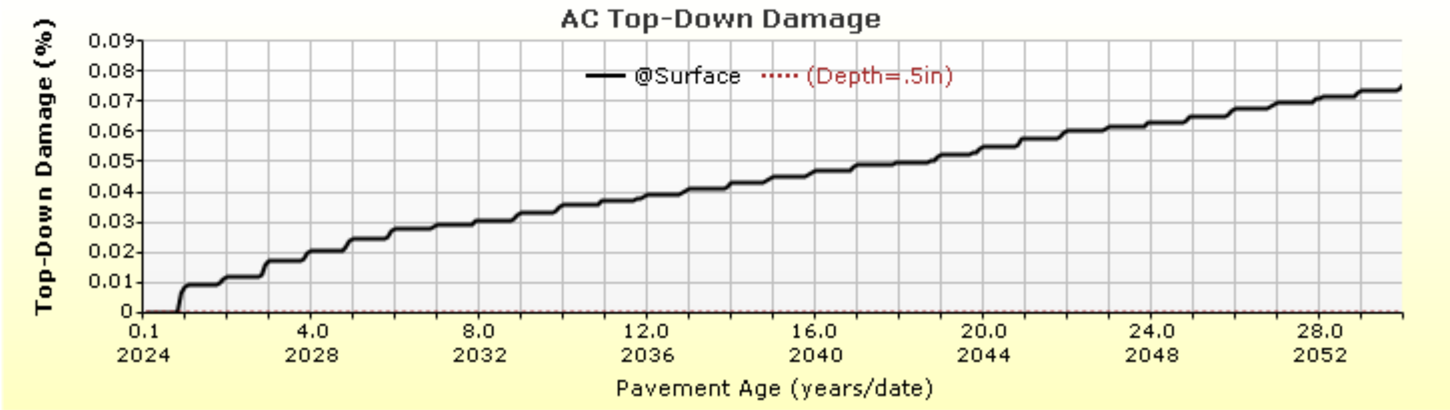


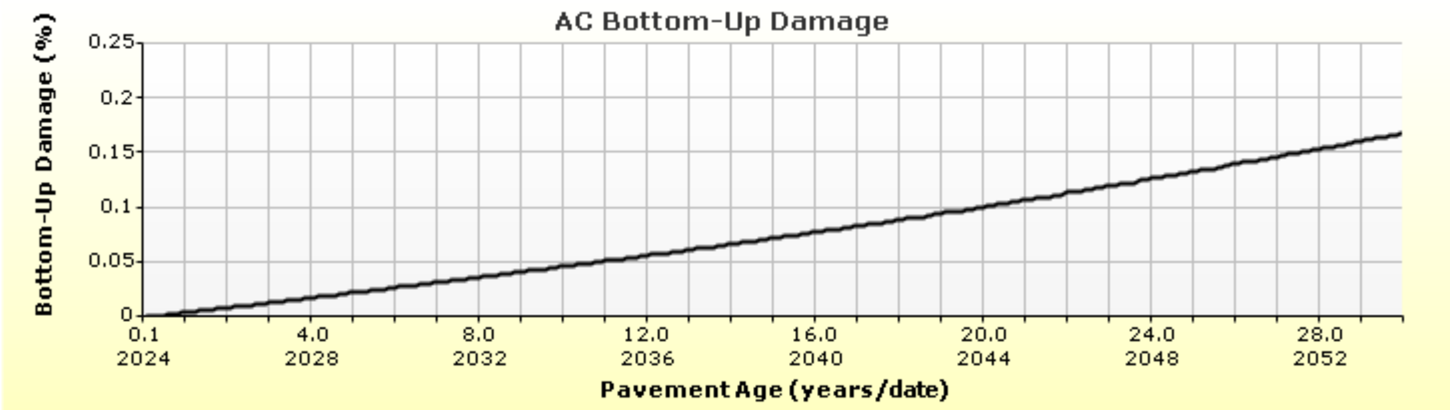
Analysis Output Charts

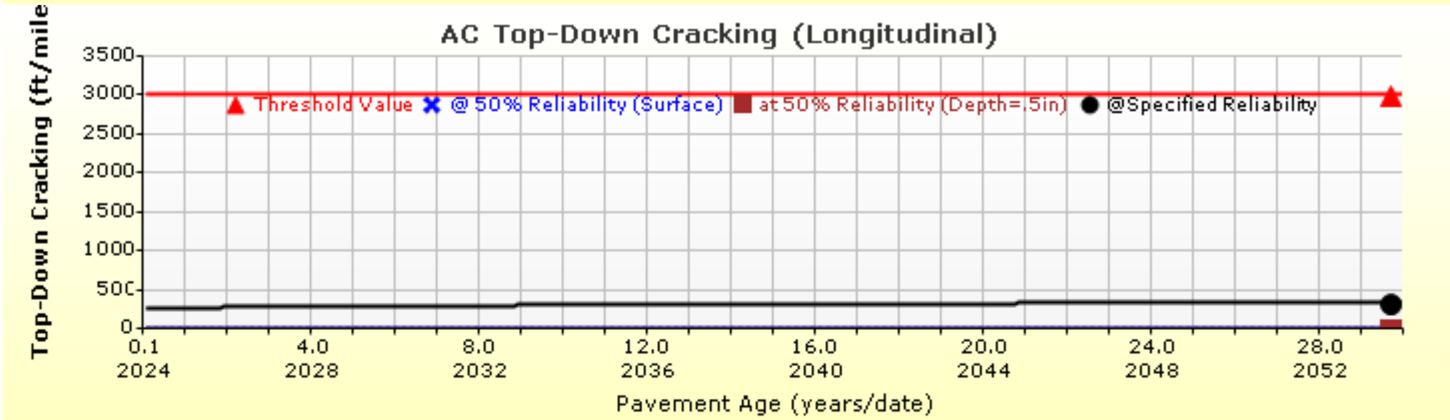


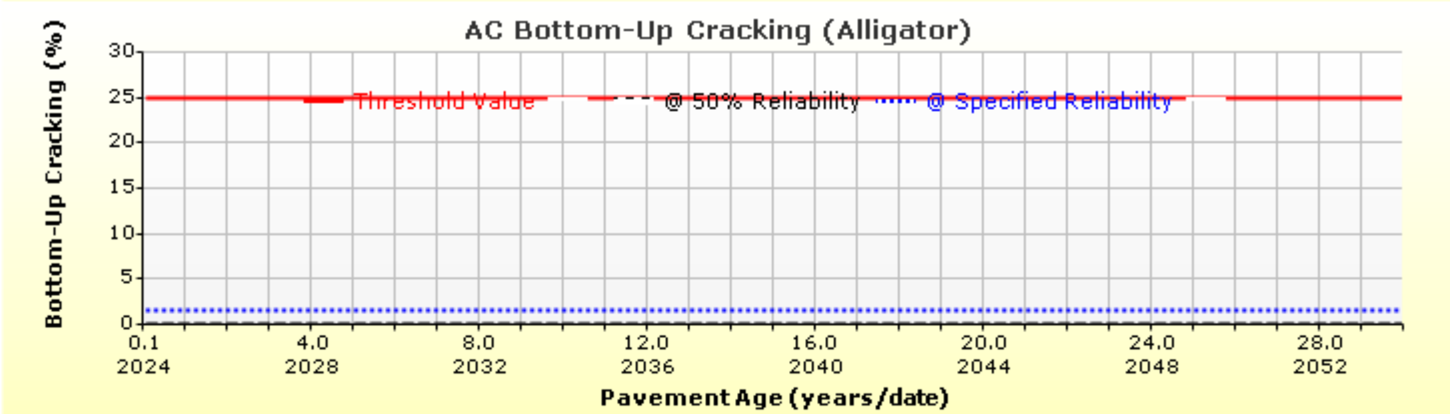


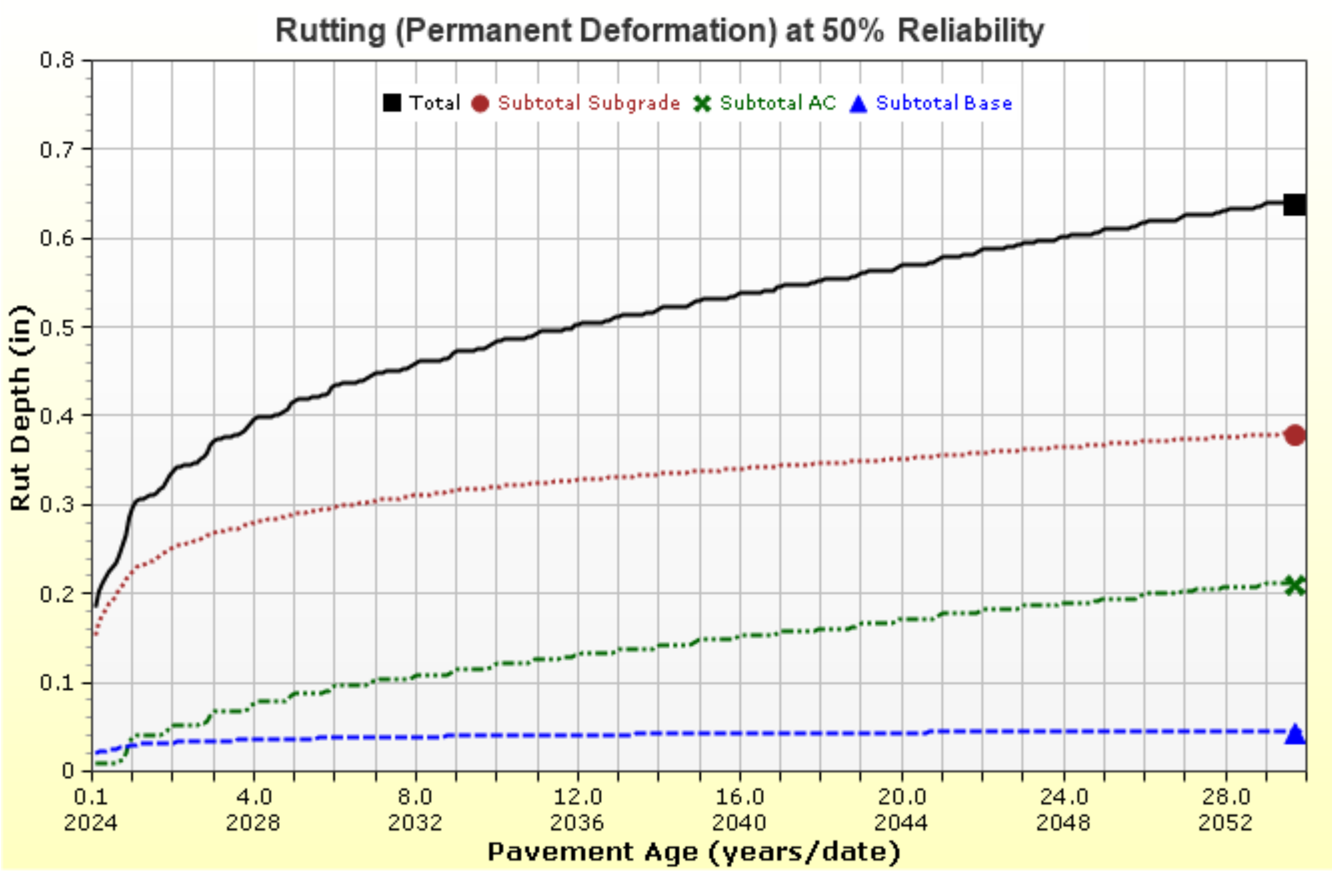


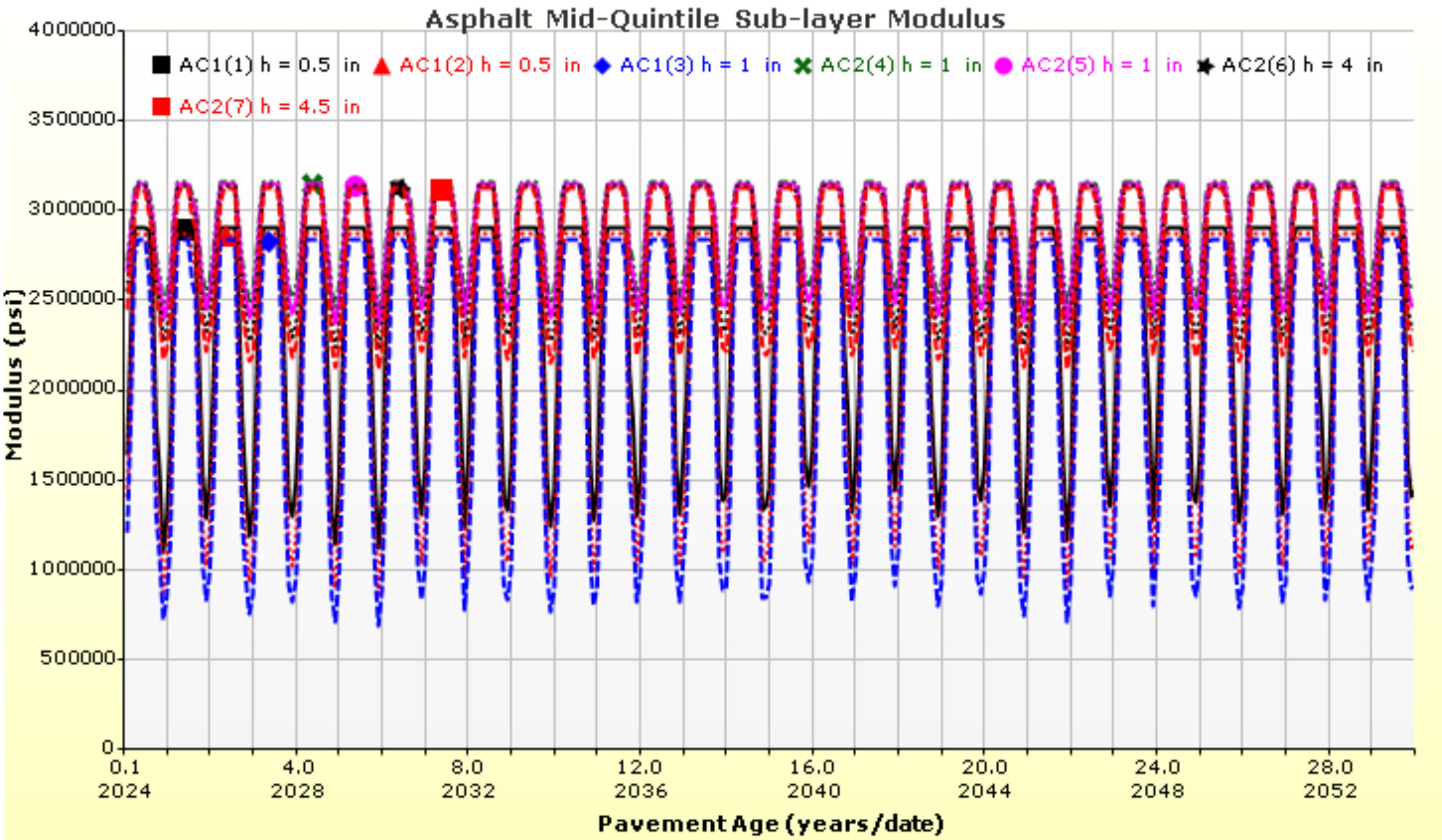

AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)


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

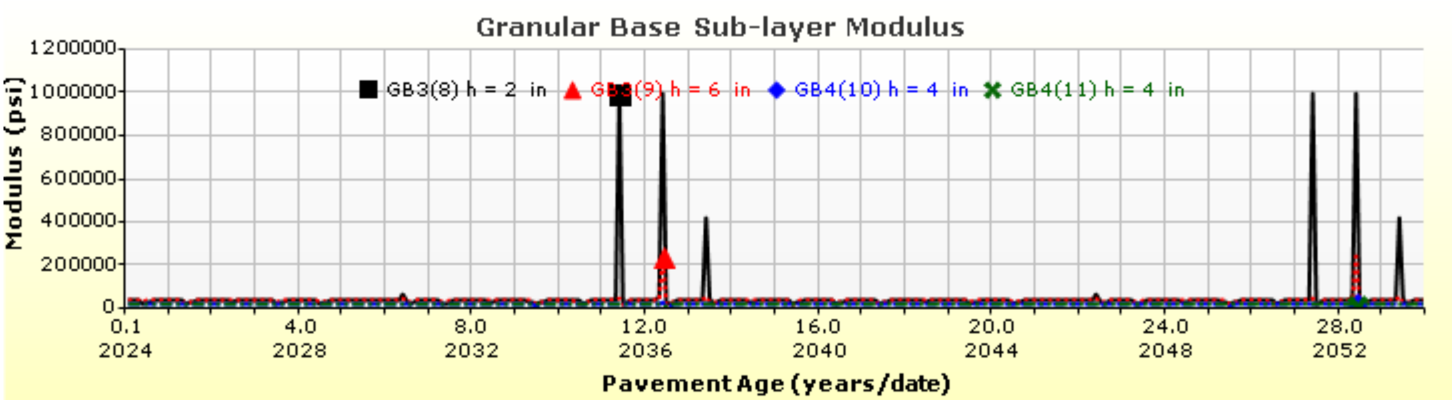

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

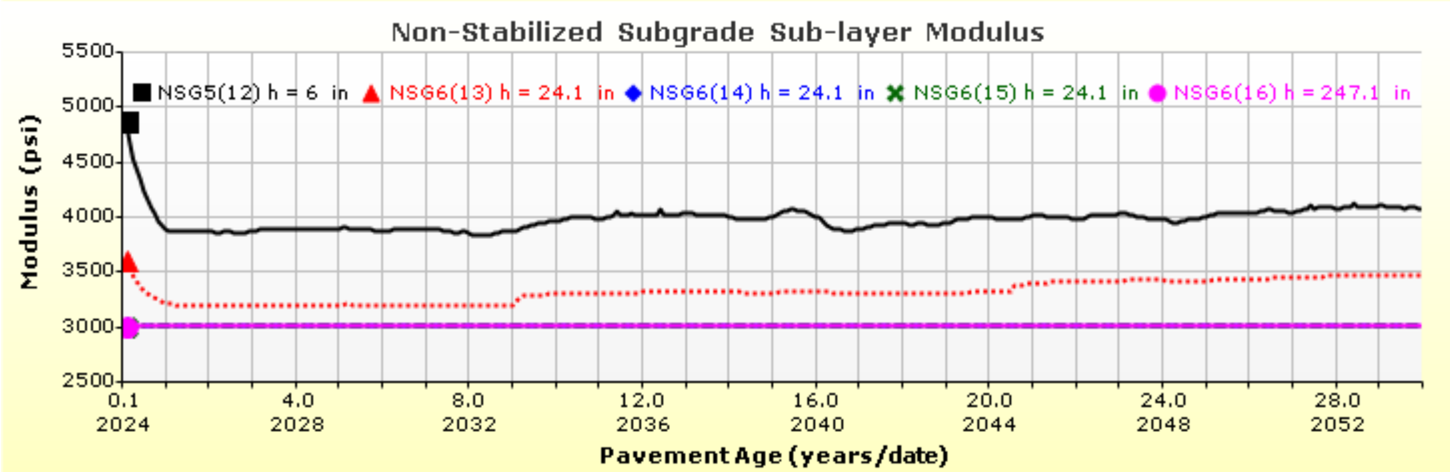

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2024
4.0
2028
8.0
2032
12.0
2036
16.0
2040
20.0
2044
24.0
2048
28.0
2052
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 4.5 in
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 6 in
GB4(10) h = 4 in
GB4(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 6 in
NSG6(13) h = 24.1 in
NSG6(14) h = 24.1 in
NSG6(15) h = 24.1 in
NSG6(16) h = 247.1 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2333549	2642179	2861449	2927779
40	1309490	1791270	2219829	2365949
70	379514	695090	1127310	1318450
100	87238	174824	349546	452545
130	29326	49265	92795	122034

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	1857	81.6
158	889	83.1
168.8	451	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.2
Air voids (%)	5.1
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R2 Level 1 SX(100) PG 64-22
Description of object	Mix ID # FS1938
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	2

Layer 2 Flexible : R4 Level 1 S(100) PG 64-22

Asphalt		
Thickness (in)	10.5	
Unit weight (pcf)	150.7	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	3066800	3098200	3172300	3192100
40	2806000	2874100	3039900	3085600
70	2266800	2396000	2735700	2835600
100	1522600	1696200	2219300	2393200
130	820200	975200	1545400	1773100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
168.8	451	85
147.2	1857	81.6
158	889	83.1

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.59
Air voids (%)	6.34
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R4 Level 1 S(100) PG 64-22
Description of object	Mix ID # FSA 0931-031
Author	CDOT
Date Created	5/3/2016 12:00:00 AM
Approver	CDOT - MP
Date approved	5/3/2016 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	S
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 4 Non-stabilized Base : CDOT Class 2 ABC

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	CDOT Class 2 ABC
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
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?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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 5 Subgrade : A-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 6 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

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	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
σ = standard deviation of the log of the depth of cracks in the pavments
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 = mixture stiffness
σ_M = Undamaged mixture tensile strength
β_t = Calibration parameter

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

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: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade 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 veritcal strain(in/in)
$\varepsilon_0, \beta, \rho$ = material properties
ε_r = resilient strain(in/in)

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477 * Pow(BASERUT,0.6711) + 0.001		Standard Deviation (BASERUT) 0.1235 * Pow(SUBRUT,0.5012) + 0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

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	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 0	C2: 75	C3: 5	C4: 3

CSM Standard Deviation

CTB*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

APPENDIX H

G ROAD

RIGID PAVEMENT M-E DESIGN OUTPUT SHEETS

G Road PCCP Design (No Class 2)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\G Road PCCP Design (No Class 2).dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.5
NonStabilized	Crushed gravel	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

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

Traffic

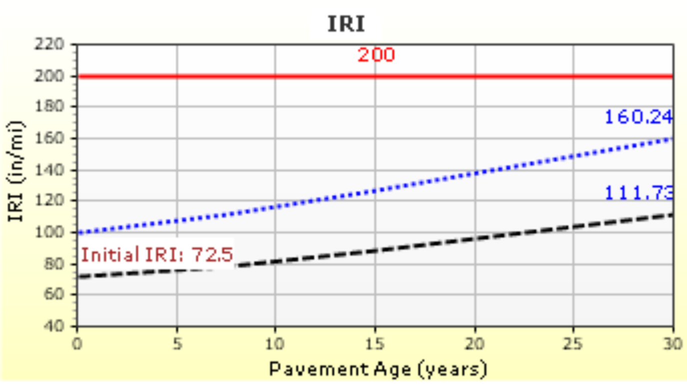
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	890
2039 (15 years)	3,372,970
2054 (30 years)	7,912,540

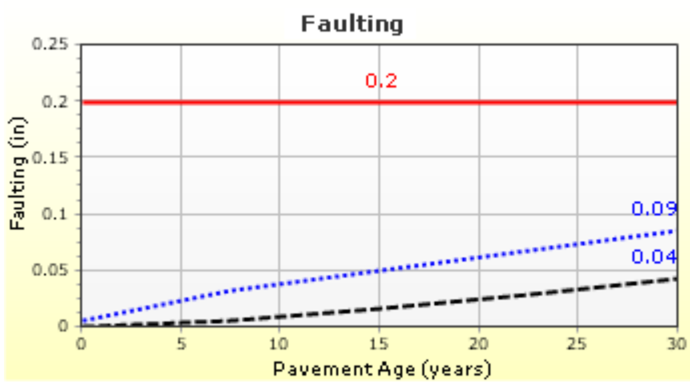
Design Outputs

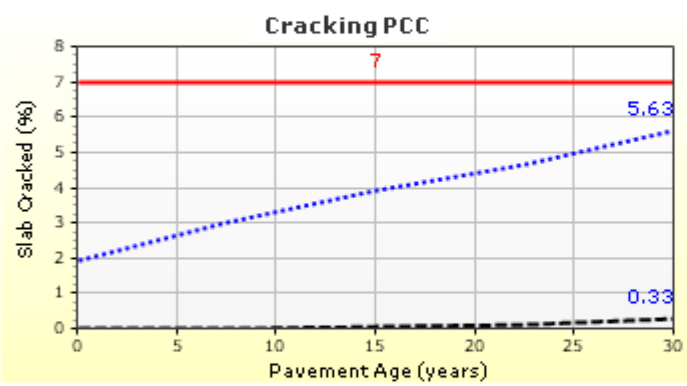
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	160.24	90.00	99.01	Pass
Mean joint faulting (in)	0.20	0.09	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	5.63	90.00	94.66	Pass

Distress Charts



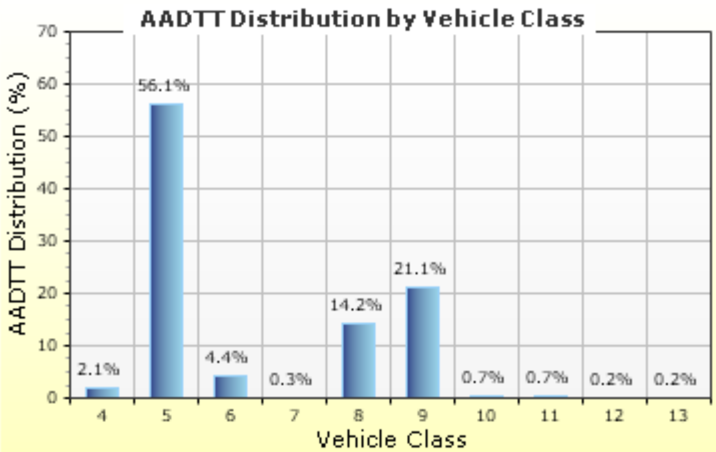


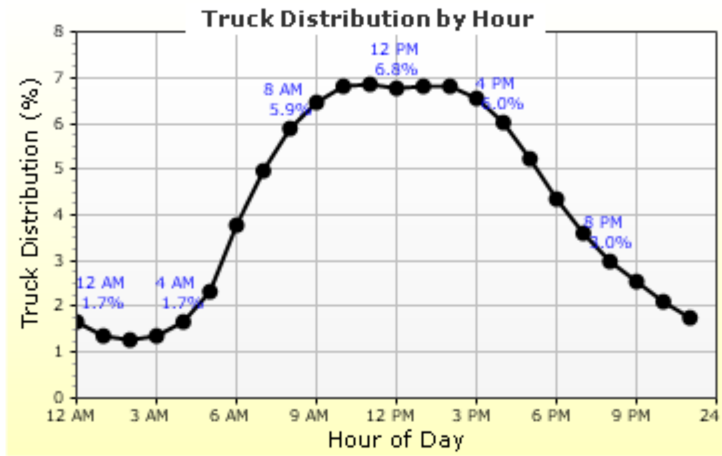


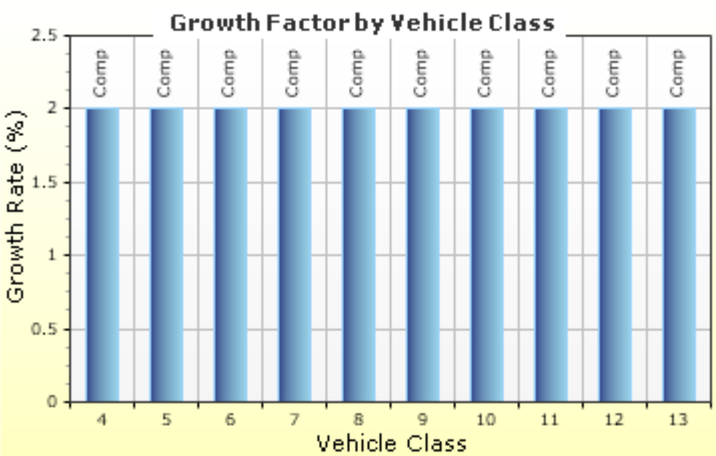
Traffic Inputs

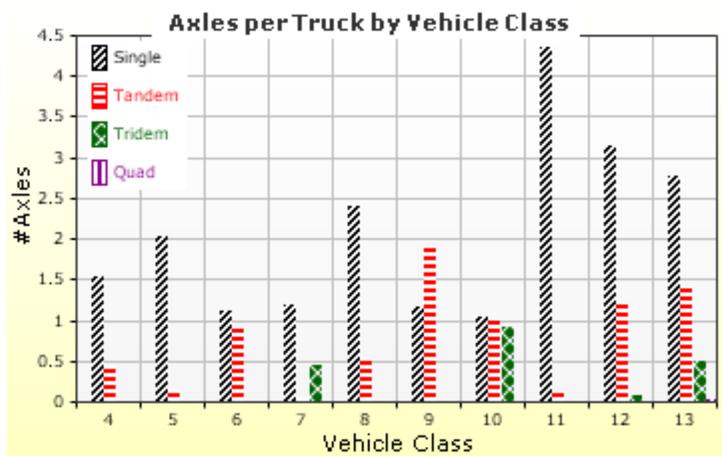
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	890	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

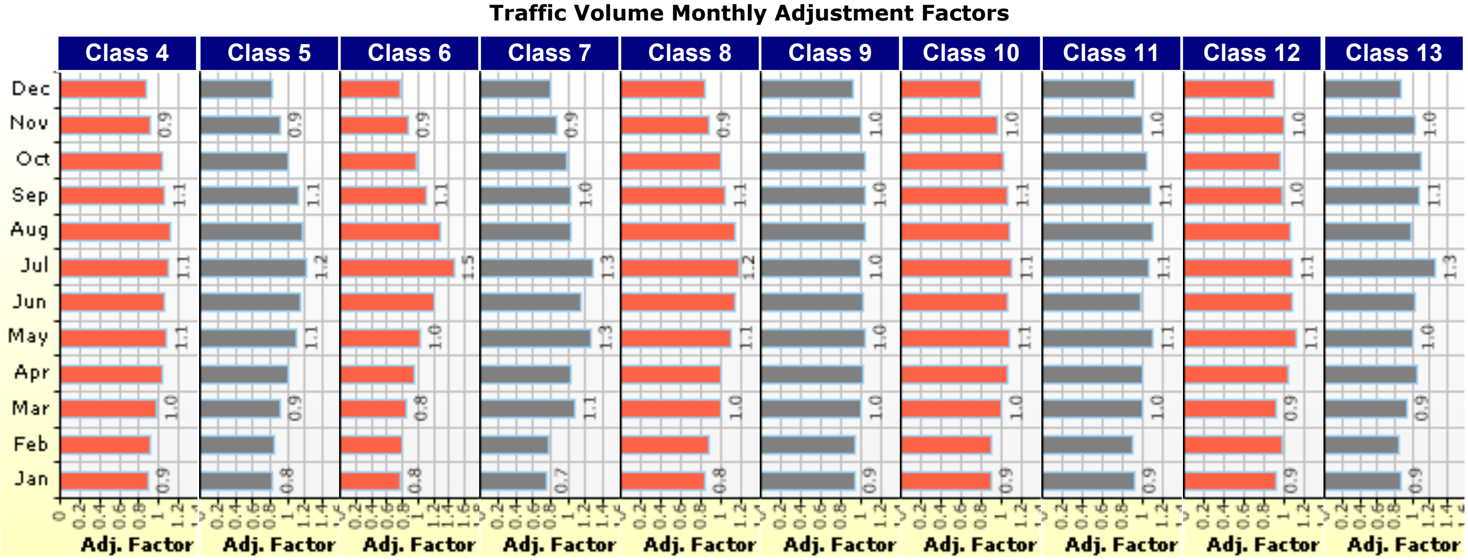








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	1.65%	12 PM	6.75%
1 AM	1.37%	1 PM	6.81%
2 AM	1.28%	2 PM	6.83%
3 AM	1.36%	3 PM	6.56%
4 AM	1.66%	4 PM	6.02%
5 AM	2.32%	5 PM	5.23%
6 AM	3.8%	6 PM	4.35%
7 AM	4.95%	7 PM	3.59%
8 AM	5.9%	8 PM	2.98%
9 AM	6.48%	9 PM	2.56%
10 AM	6.83%	10 PM	2.12%
11 AM	6.85%	11 PM	1.75%
		Total	100%

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

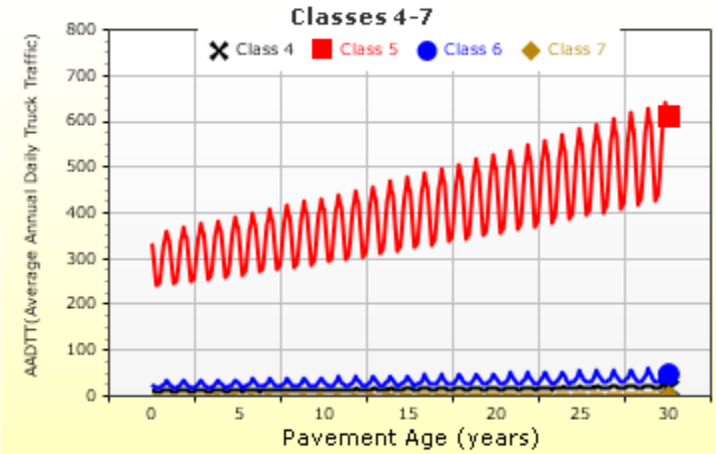
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

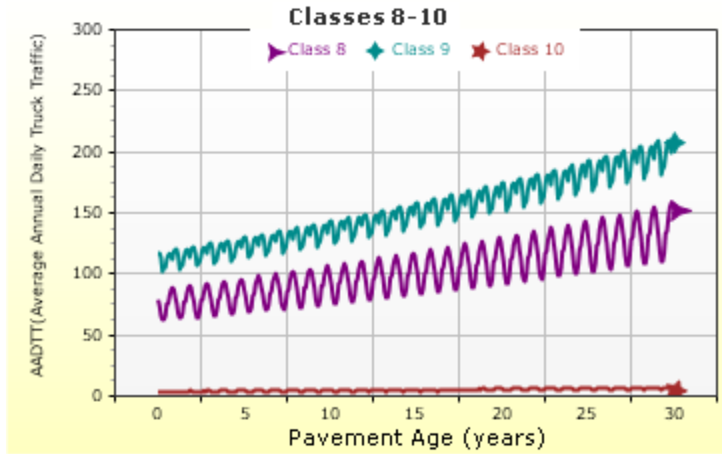
Number of Axles per Truck

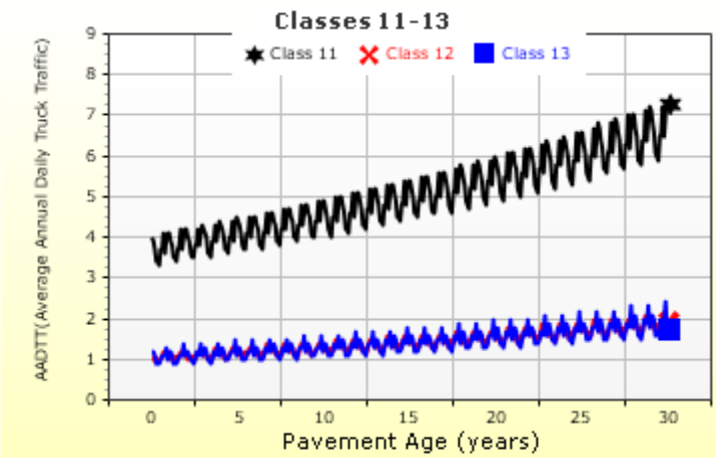
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

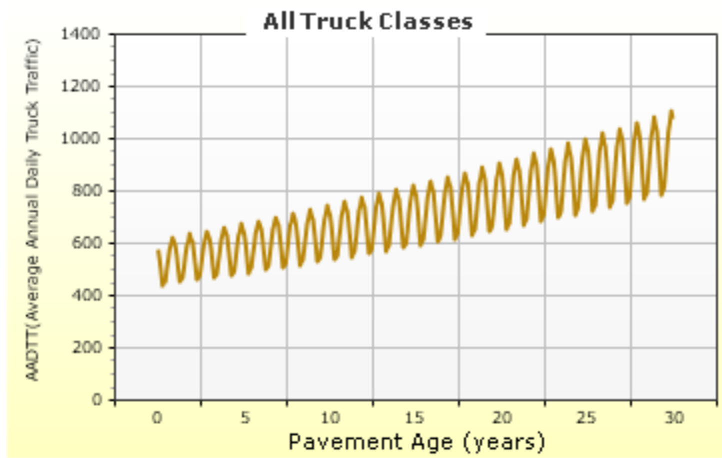
AADTT (Average Annual Daily Truck Traffic) Growth

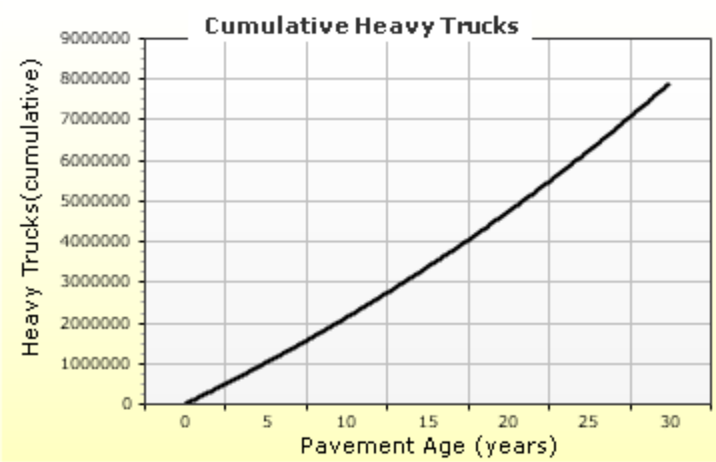
*** Traffic cap is not enforced**







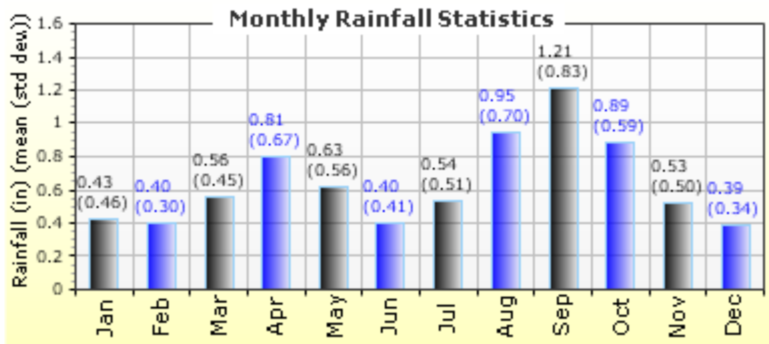




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

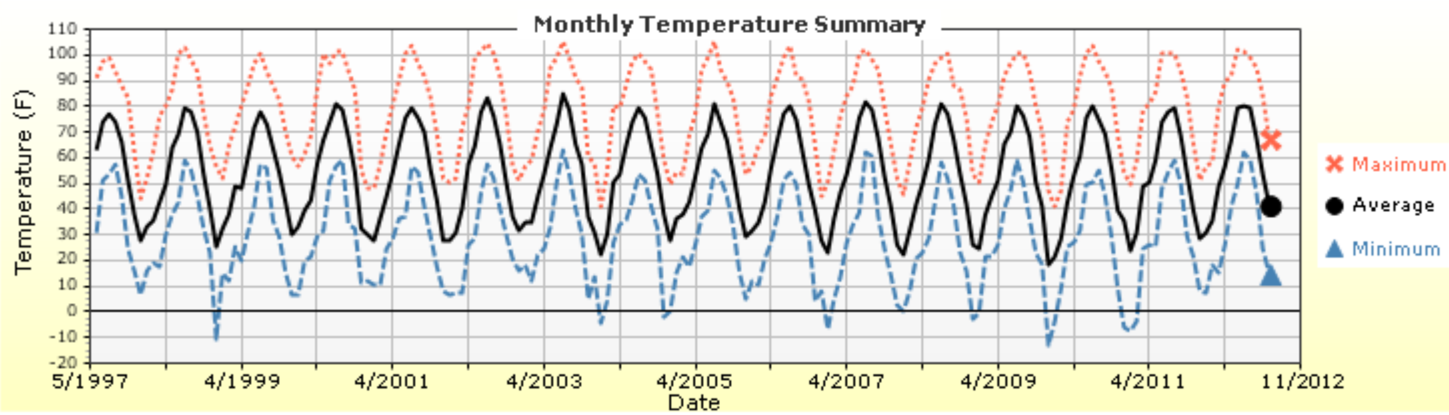


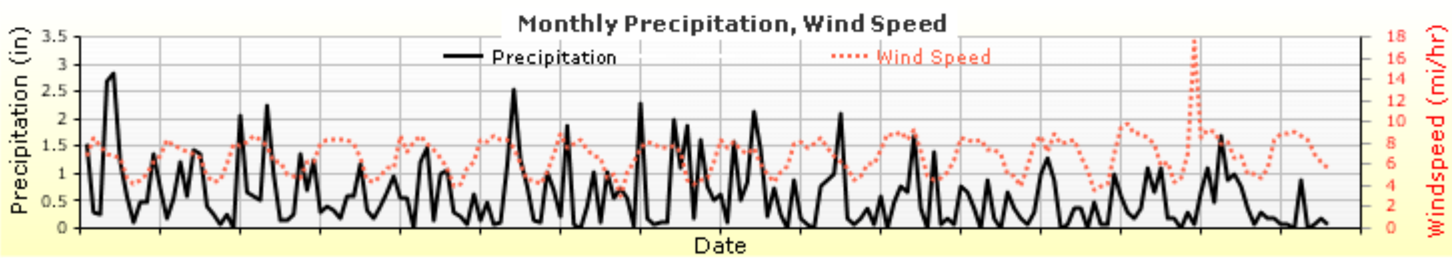
Annual Statistics:

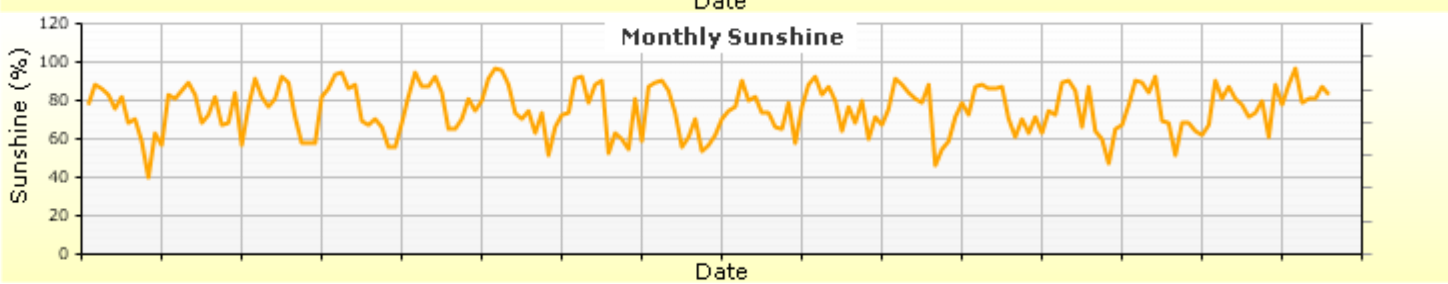
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

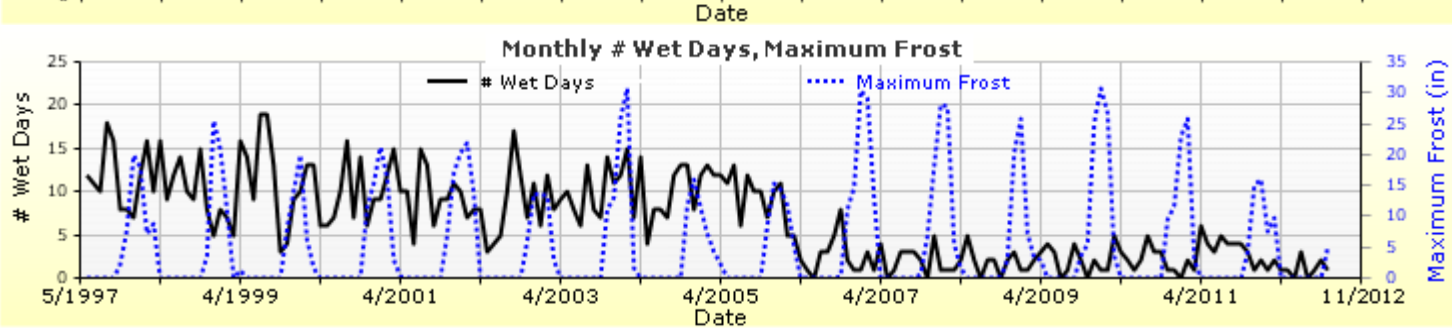
Water table depth (ft) 4.00

Monthly Climate Summary:

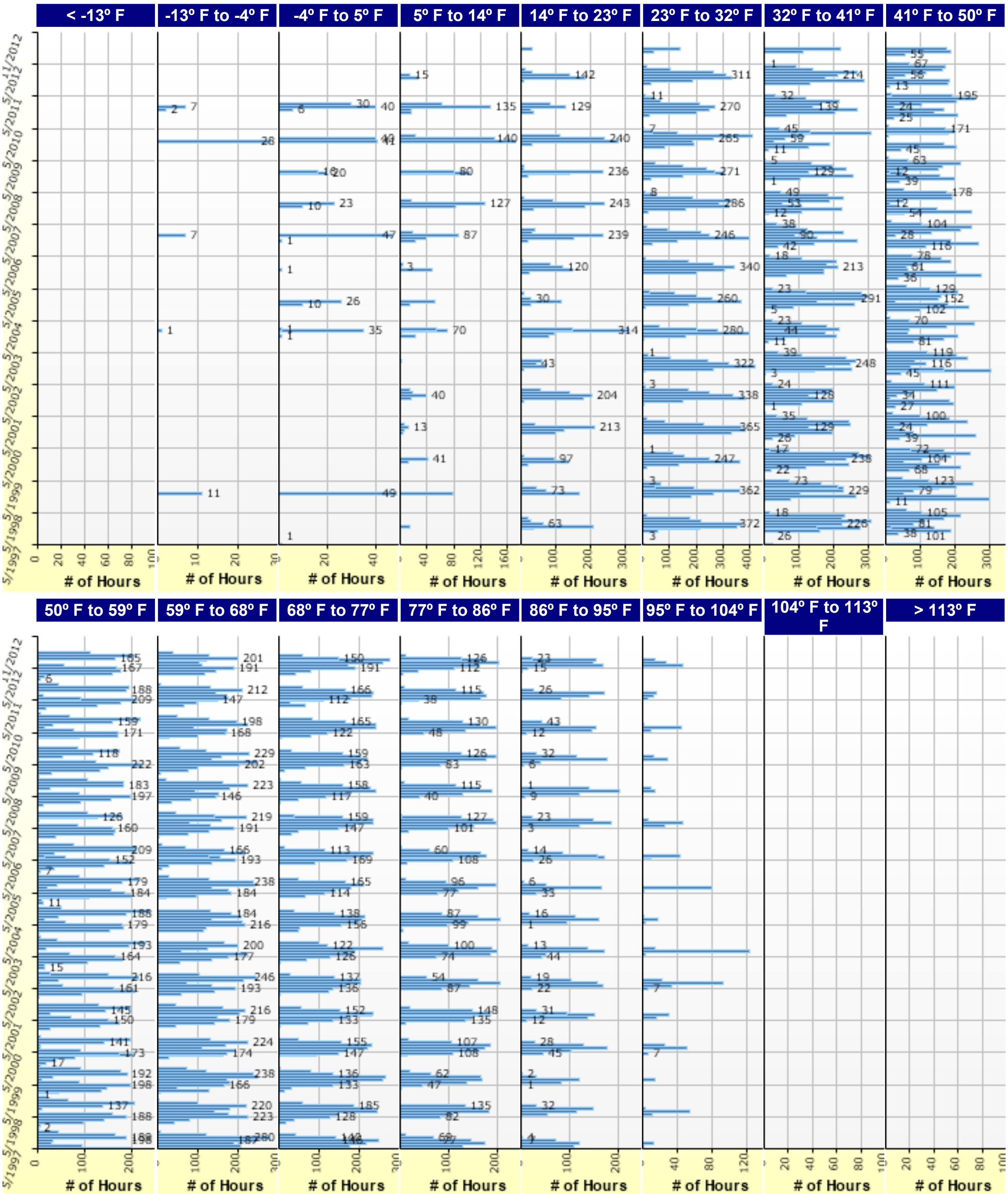








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

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

Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

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

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

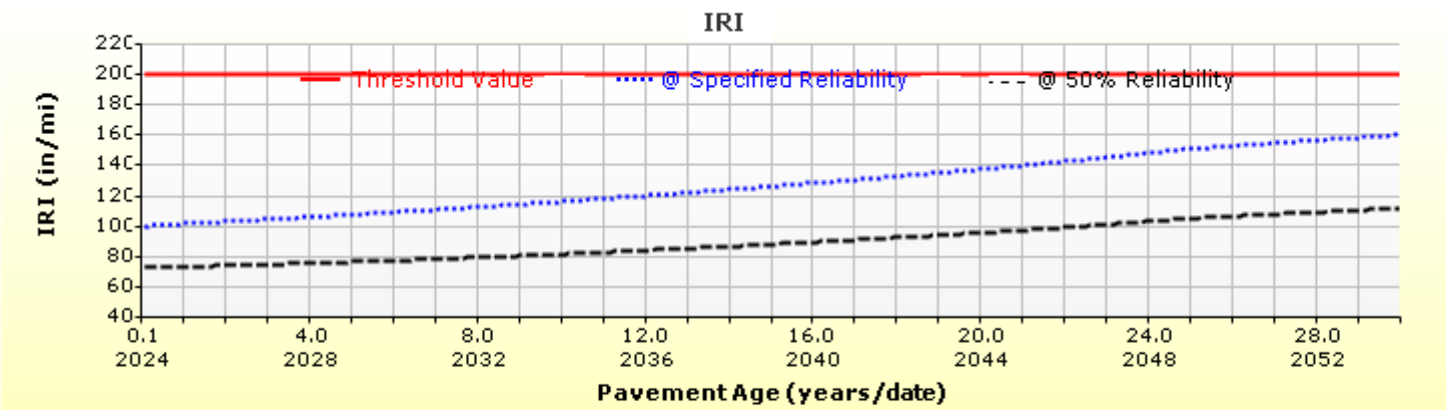
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

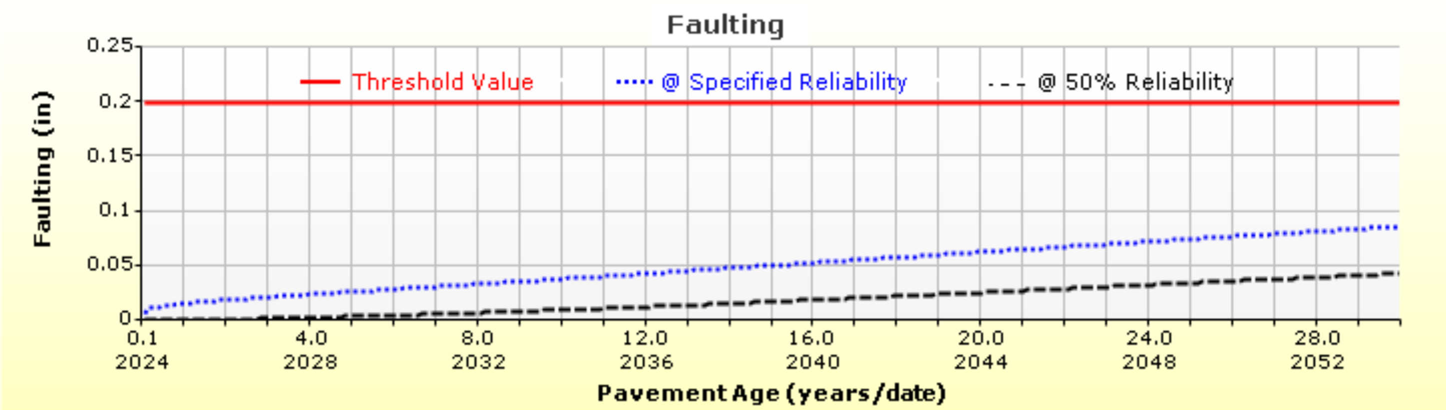
Sealant type	Other(Including No Sealant... Liquid... Silicone)

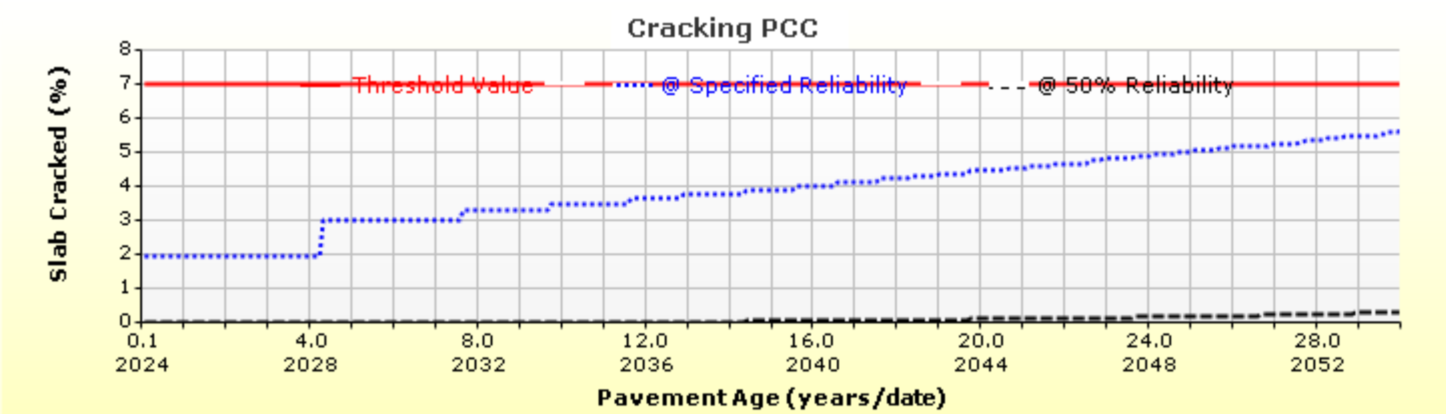
Erodibility index	3

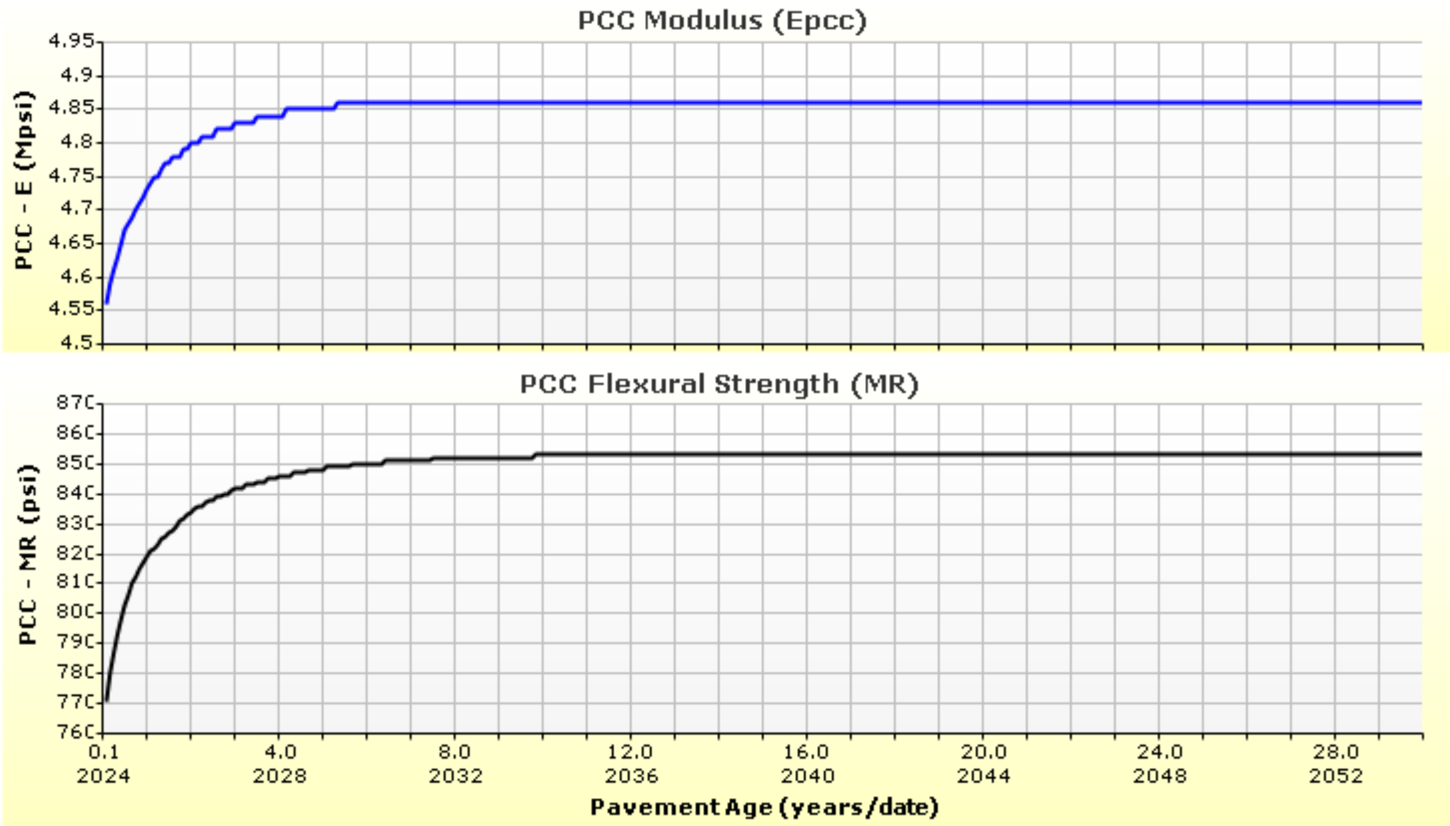
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

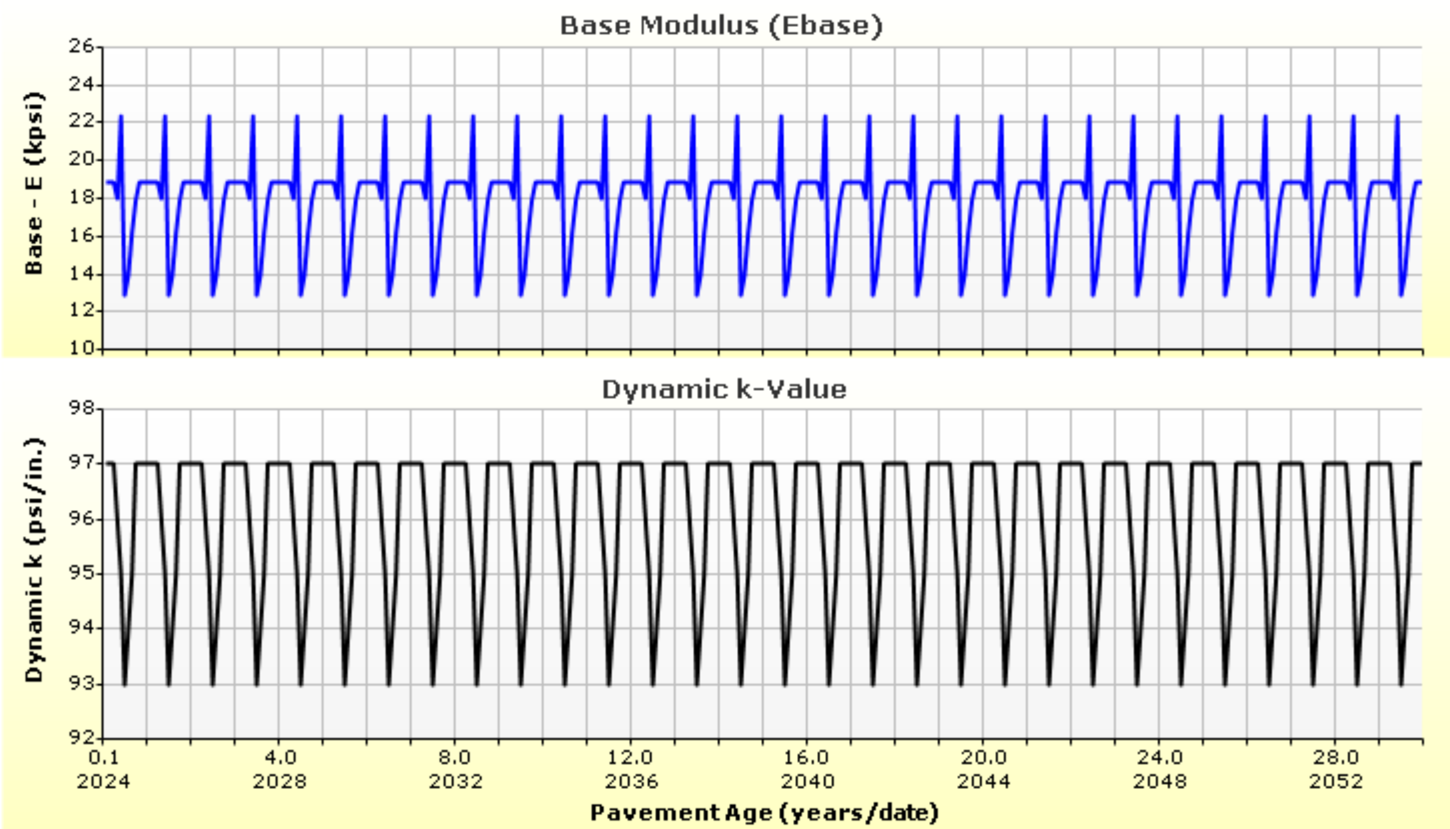




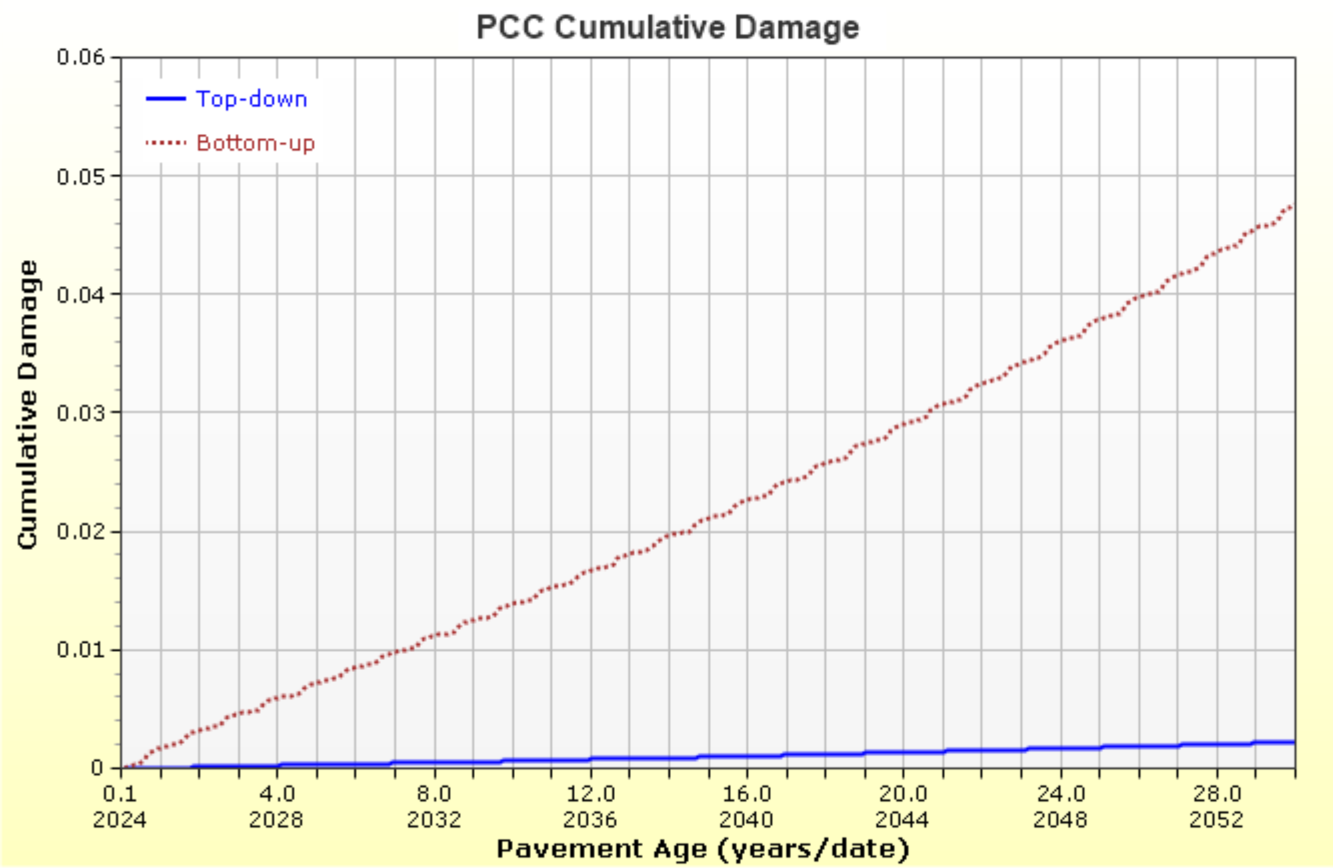


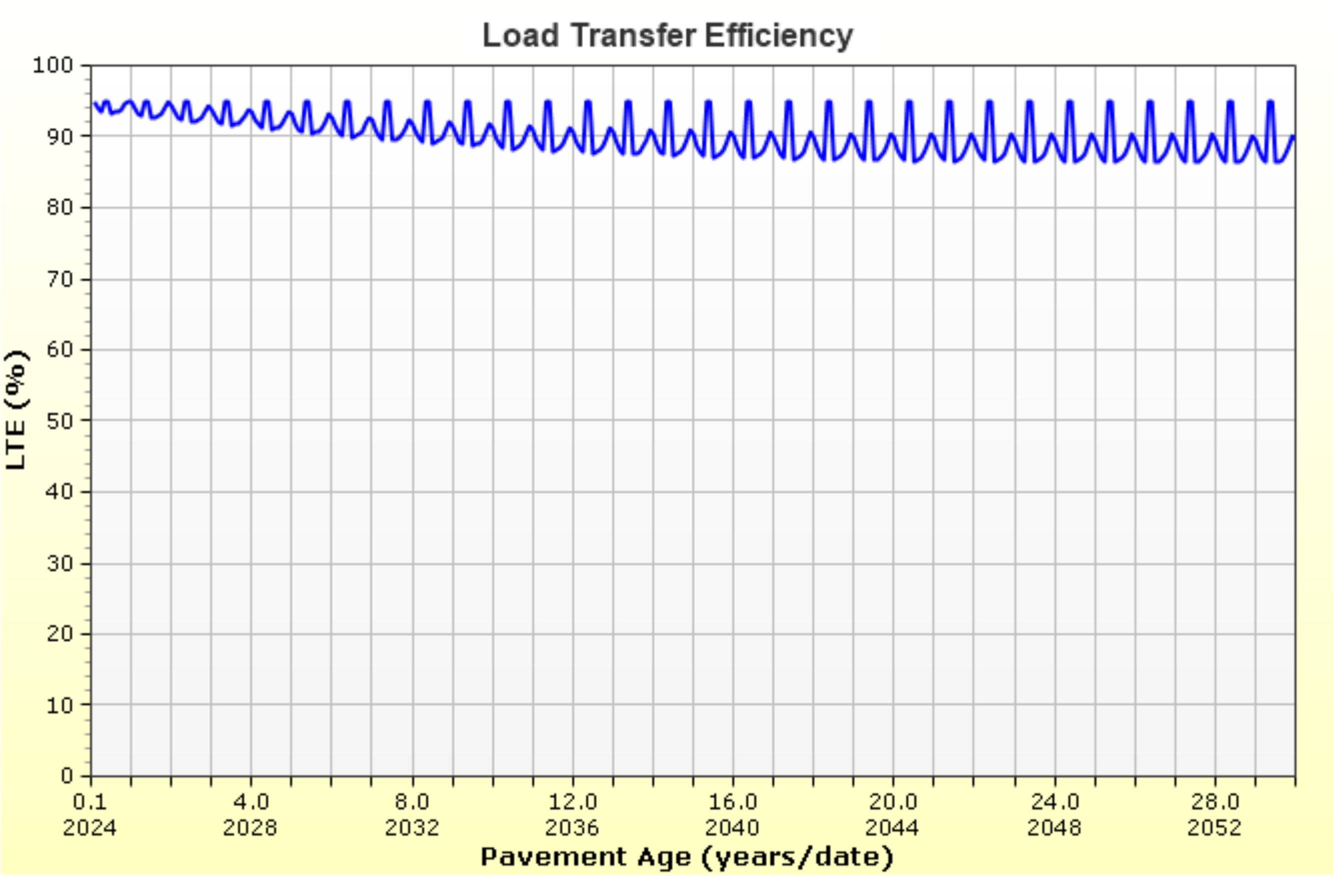


PCC Modulus (Epcc)
PCC - E (Mpsi)
4.95
4.9
4.85
4.8
4.75
4.7
4.65
4.6
4.55
4.5
PCC Flexural Strength (MR)
PCC - MR (psi)
870
860
850
840
830
820
810
800
790
780
770
760
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



Base Modulus (Ebase)
Base - E (kpsi)
26
24
22
20
18
16
14
12
10
Dynamic k-Value
Dynamic k (psi/in.)
98
97
96
95
94
93
92
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.5
Unit weight (pcf)	140.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.86
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		563
Water to cement ratio		0.36
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	90.7
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	516.0
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	560	3230000
14-day	620	3500000
28-day	710	4030000
90-day	730	4240000
20-year/28-day	1.2	1.2

Identifiers

Field	Value
Display name/identifier	R4 Level 1 Lawson
Description of object	Mix ID # 2009105
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 4/1/6
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400
PCC Reliability Faulting Standard Deviation			
0.0831*Pow(FAULT,0.3426) + 0.00521			

IRI-jpcp

C1 - Cracking	C1: 0.8203	C2: 0.4417
C2 - Spalling	C3: 1.4929	C4: 25.24
C3 - Faulting	**Reliability Standard Deviation**	
C4 - Site Factor	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$
$$CRK = \frac{100}{1 + C4\ FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05
PCC Reliability Cracking Standard Deviation			
Pow(57.08*CRACK,0.33) + 1.5			

APPENDIX I

27 ½ ROAD

RIGID PAVEMENT M-E DESIGN OUTPUT SHEETS

27.5 Road PCCP Design (No Class 2)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\27.5 Road PCCP Design (No Class 2).dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	10.0
NonStabilized	Crushed gravel	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	12.0

Traffic

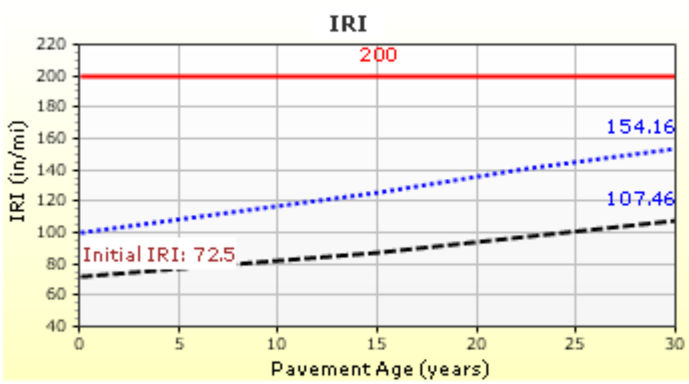
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	1,820
2039 (15 years)	6,897,530
2054 (30 years)	16,180,700

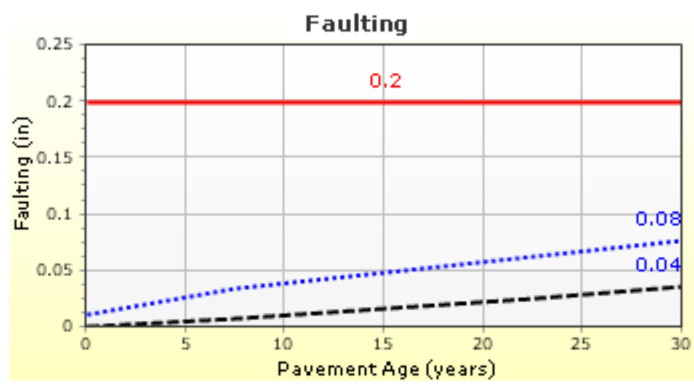
Design Outputs

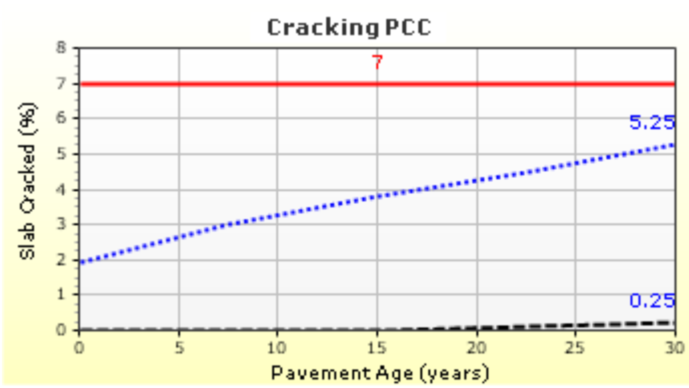
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	154.16	90.00	99.44	Pass
Mean joint faulting (in)	0.20	0.08	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	5.25	90.00	95.81	Pass

Distress Charts



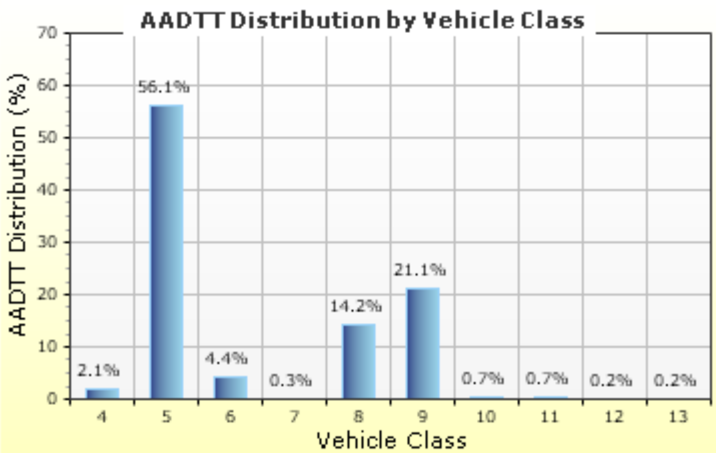


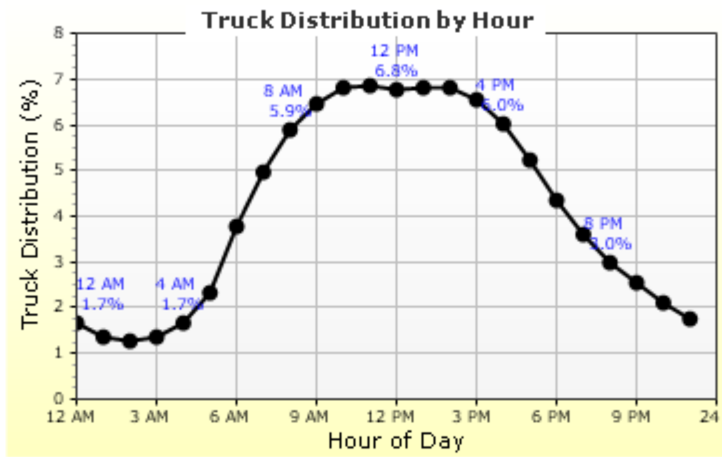


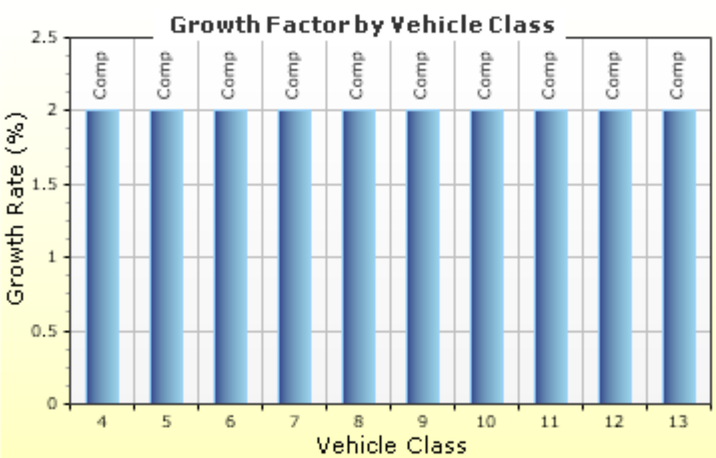
Traffic Inputs

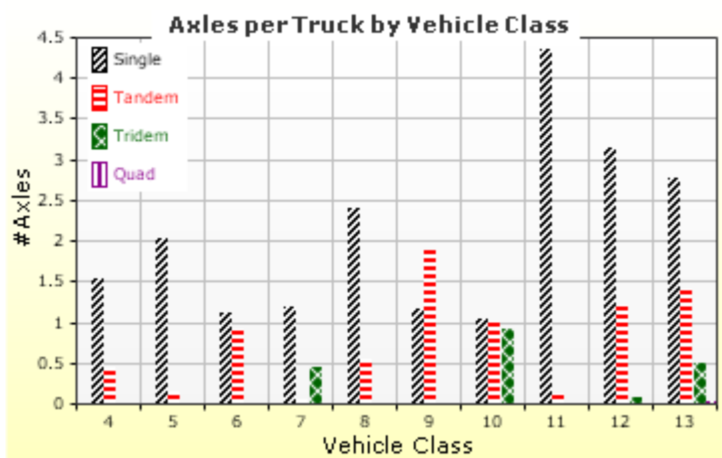
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	1,820	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

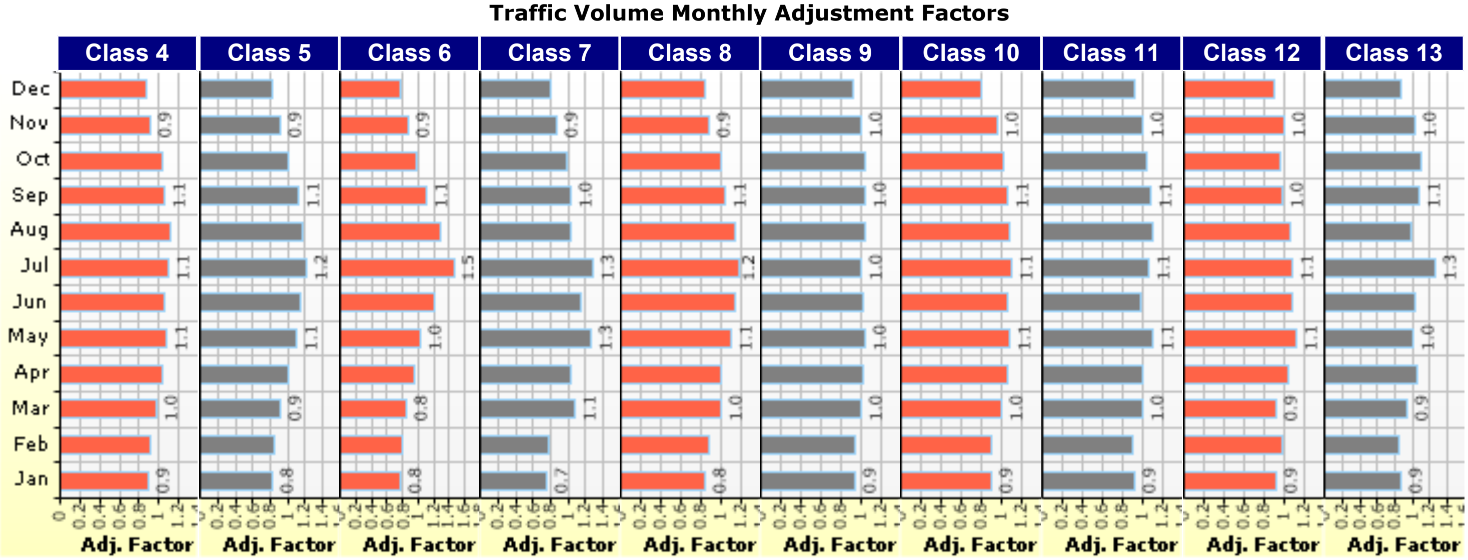








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	1.65%	12 PM	6.75%
1 AM	1.37%	1 PM	6.81%
2 AM	1.28%	2 PM	6.83%
3 AM	1.36%	3 PM	6.56%
4 AM	1.66%	4 PM	6.02%
5 AM	2.32%	5 PM	5.23%
6 AM	3.8%	6 PM	4.35%
7 AM	4.95%	7 PM	3.59%
8 AM	5.9%	8 PM	2.98%
9 AM	6.48%	9 PM	2.56%
10 AM	6.83%	10 PM	2.12%
11 AM	6.85%	11 PM	1.75%
		Total	100%

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

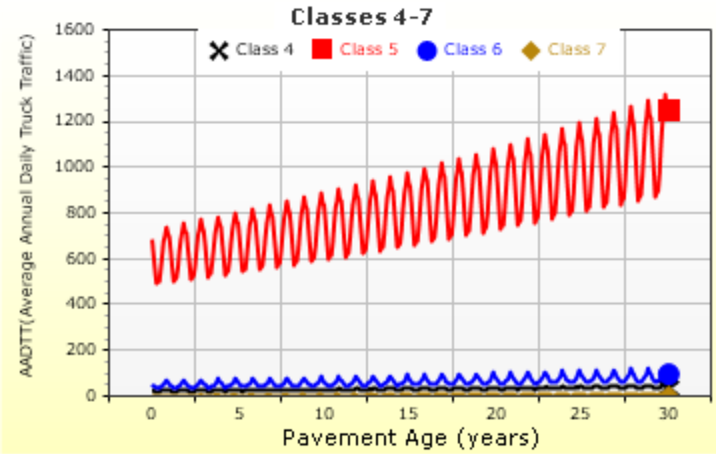
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

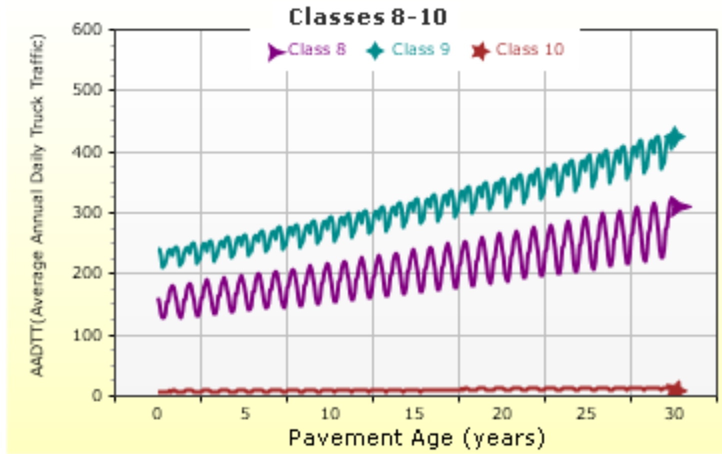
Number of Axles per Truck

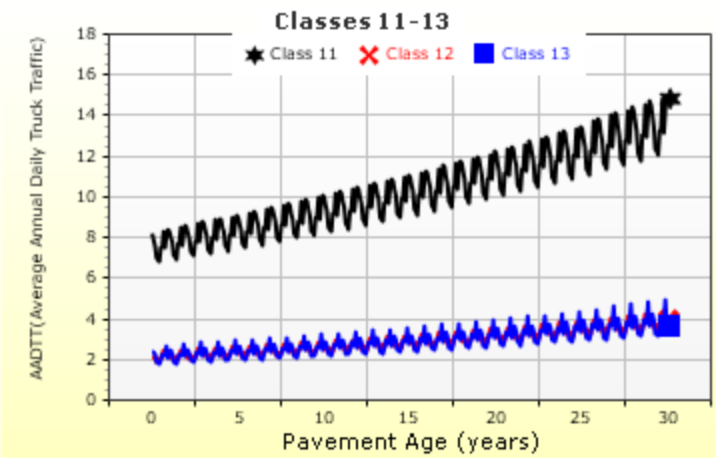
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

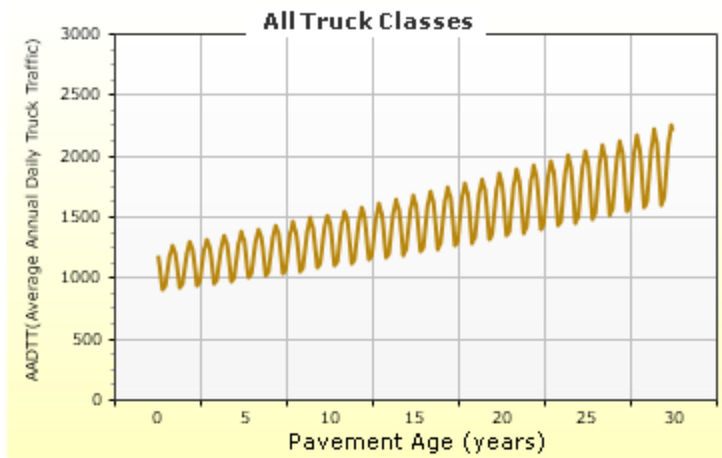
AADTT (Average Annual Daily Truck Traffic) Growth

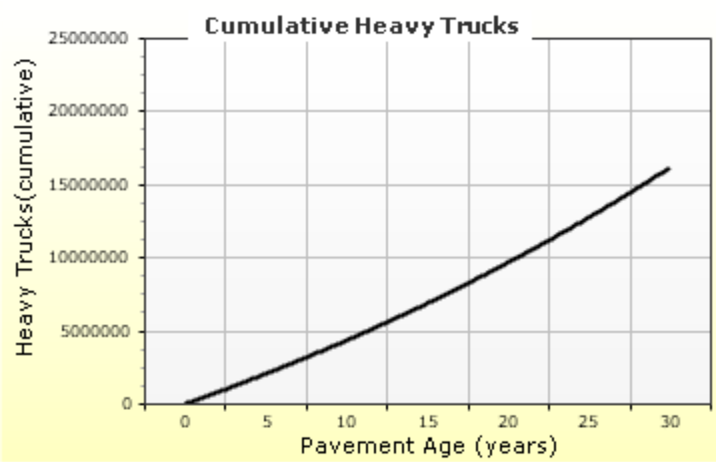
*** Traffic cap is not enforced**







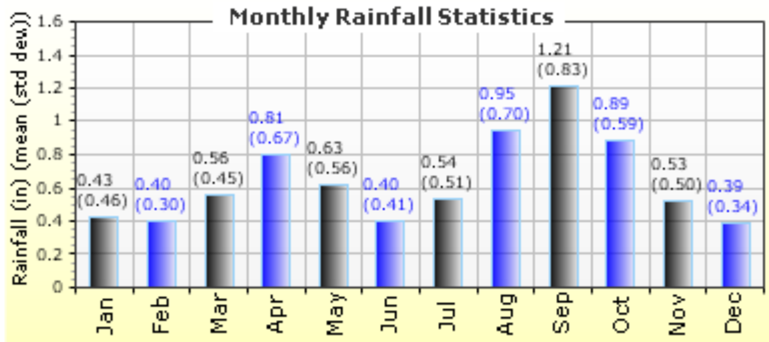




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

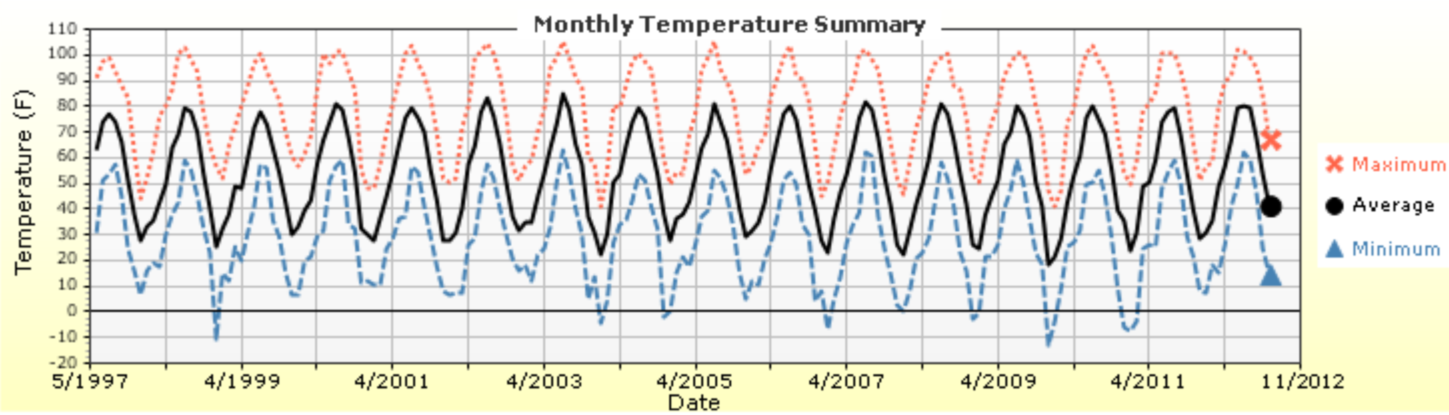


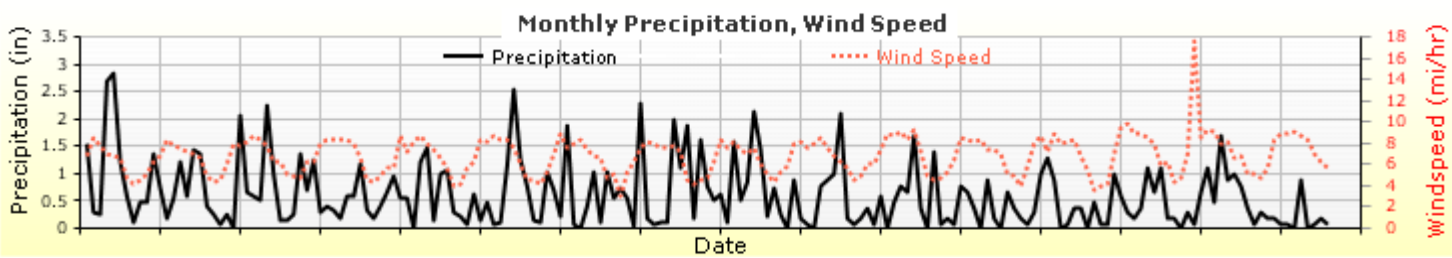
Annual Statistics:

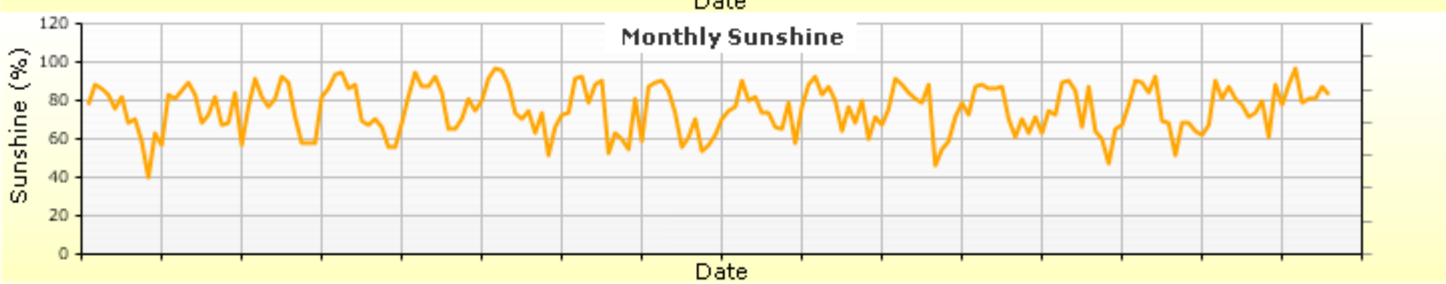
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

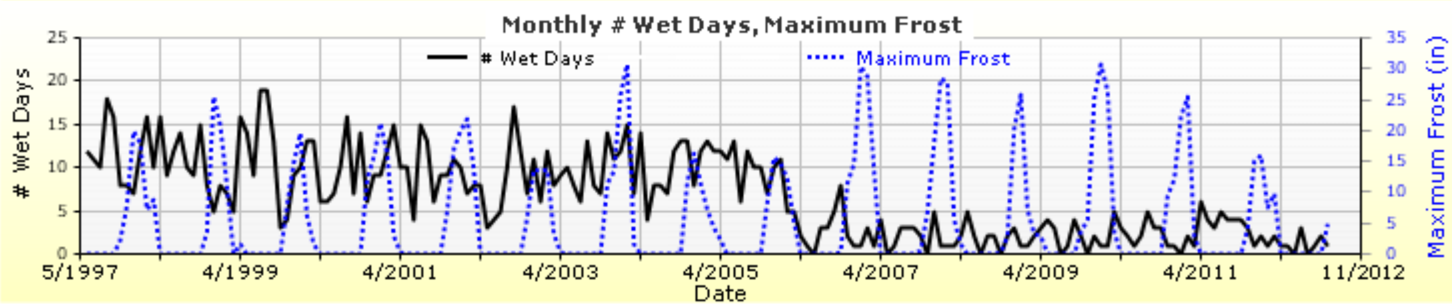
Water table depth (ft)	4.00

Monthly Climate Summary:

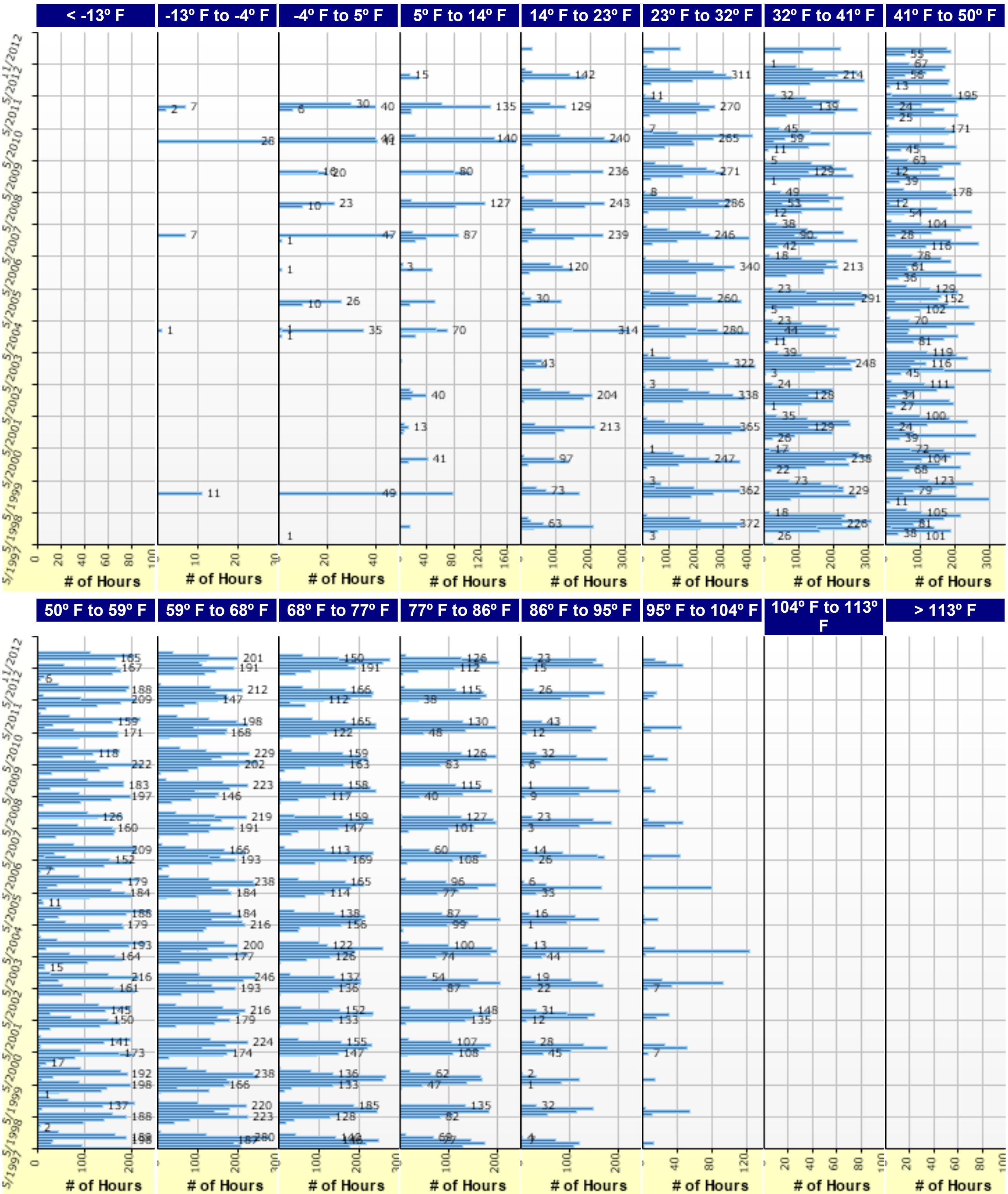








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in)	1.50
Dowel spacing (in)	12.00

Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

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

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

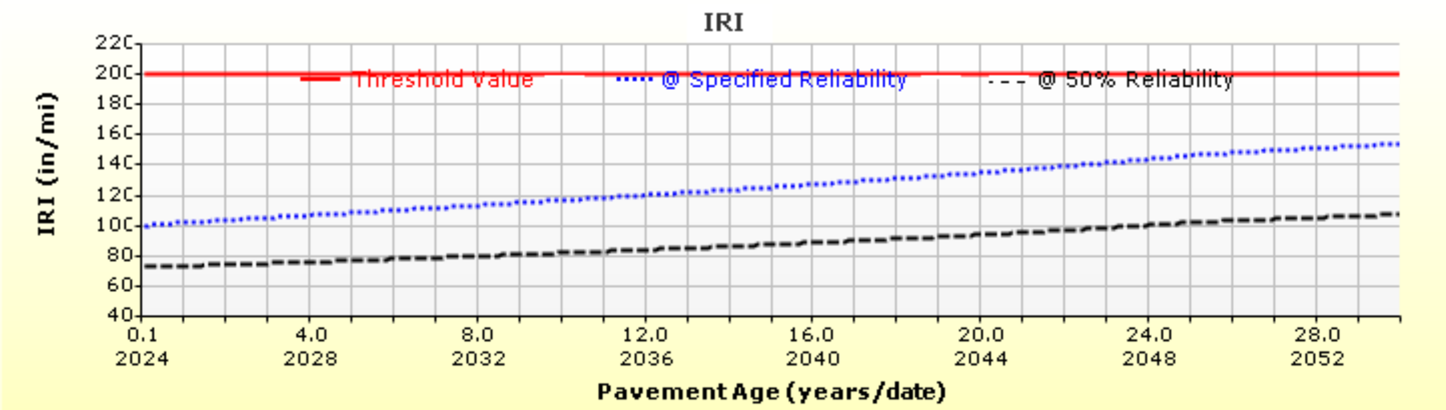
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

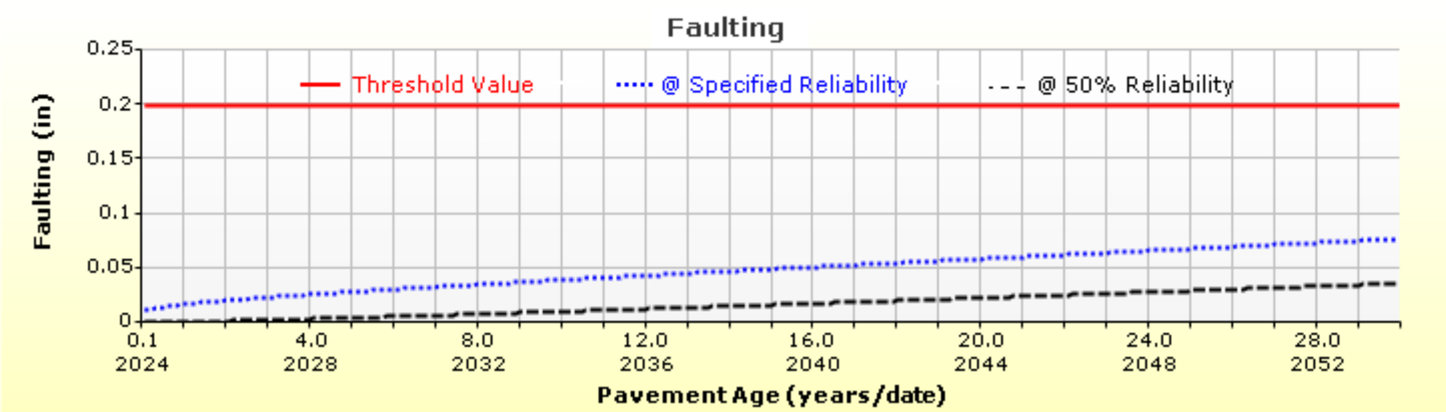
Sealant type	Other(Including No Sealant... Liquid... Silicone)

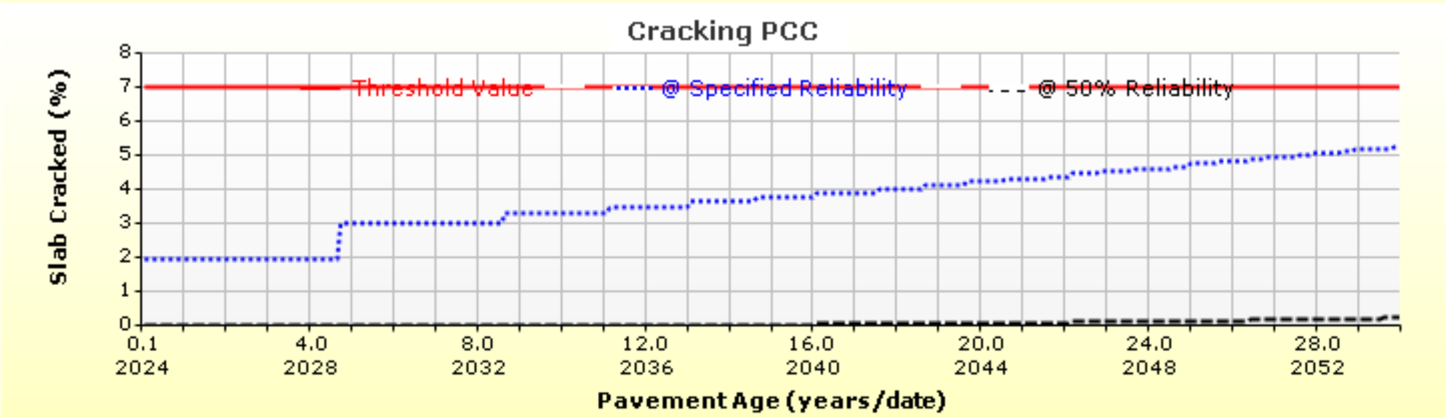
Erodibility index	3

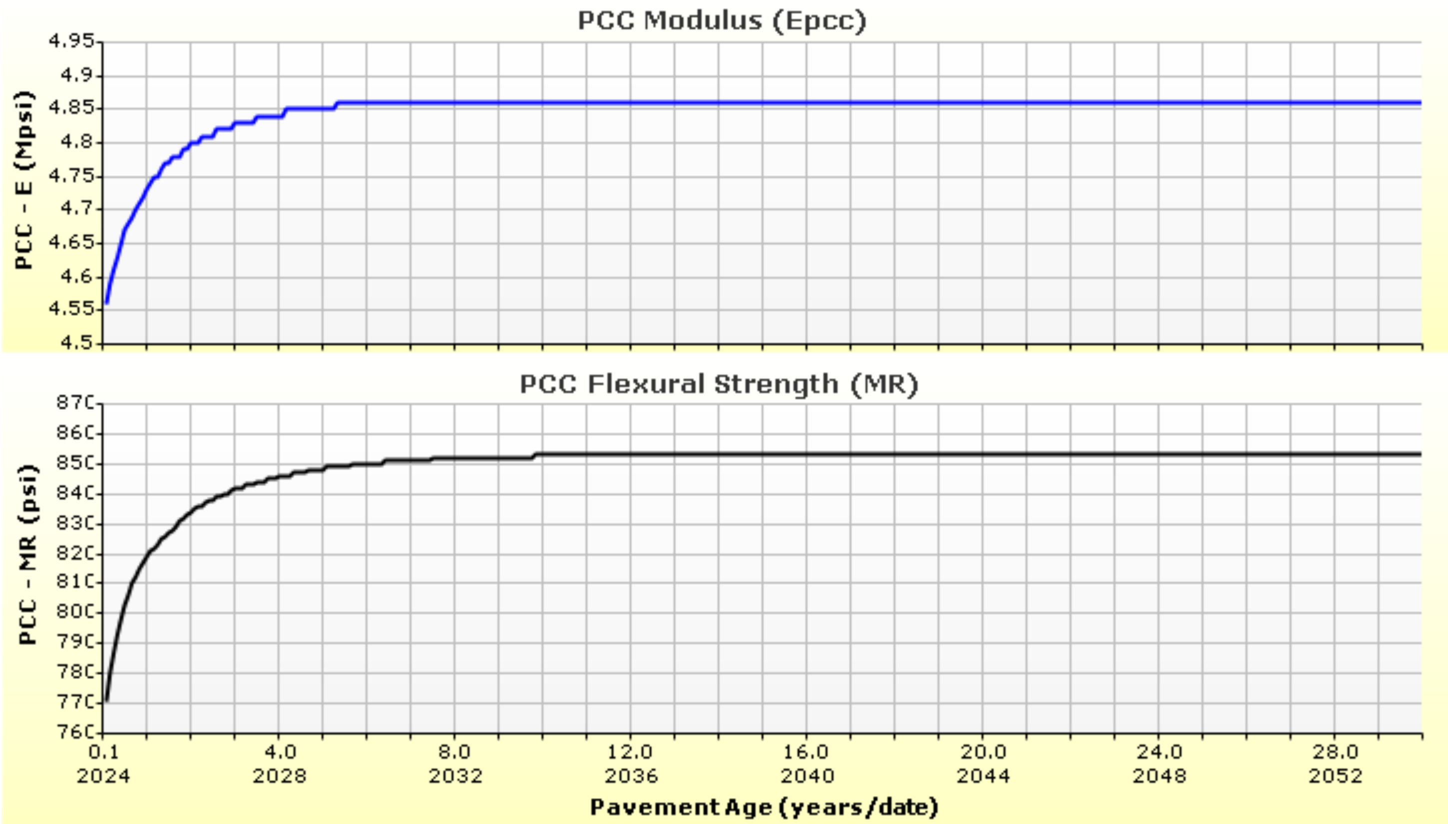
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

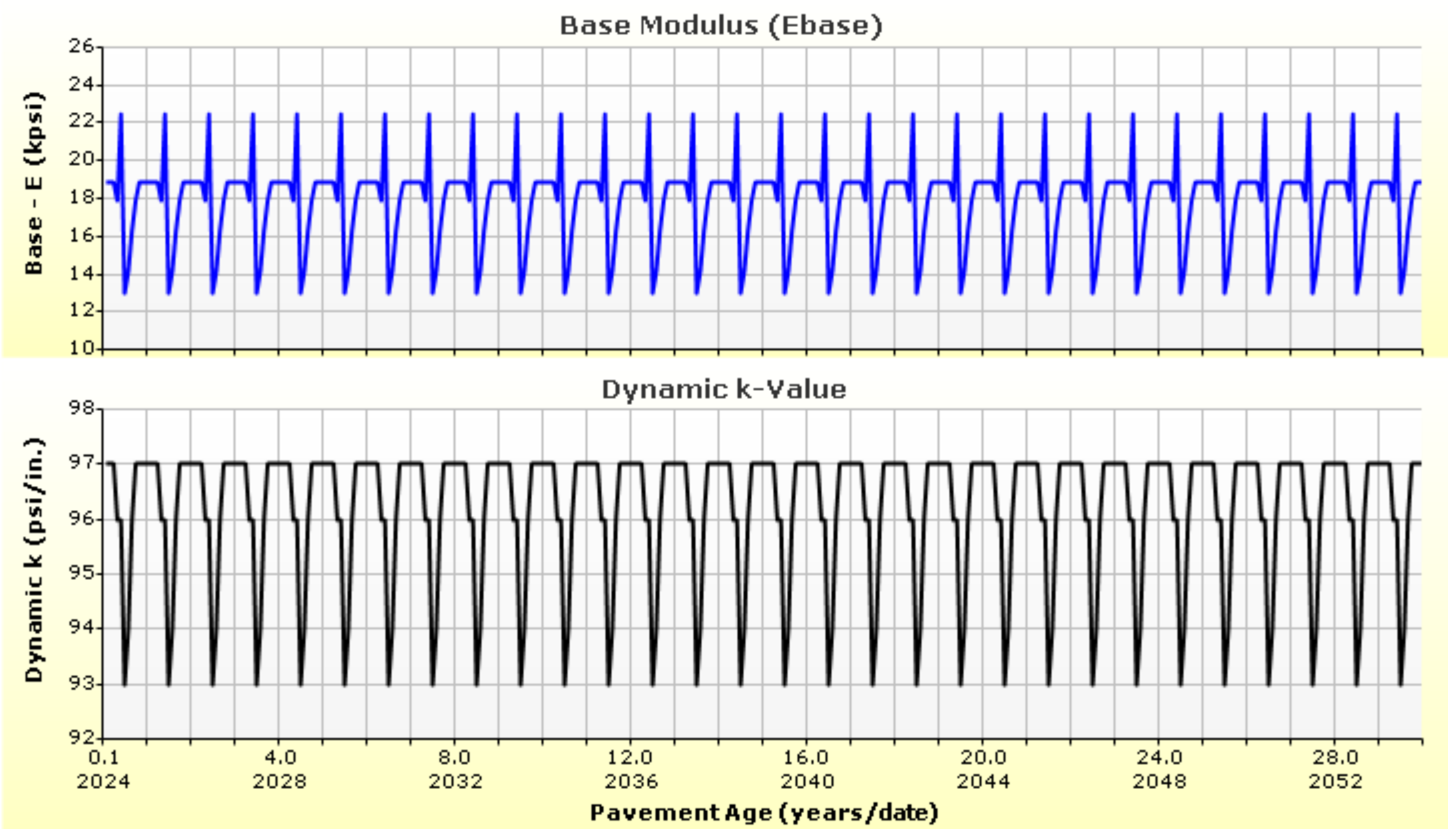




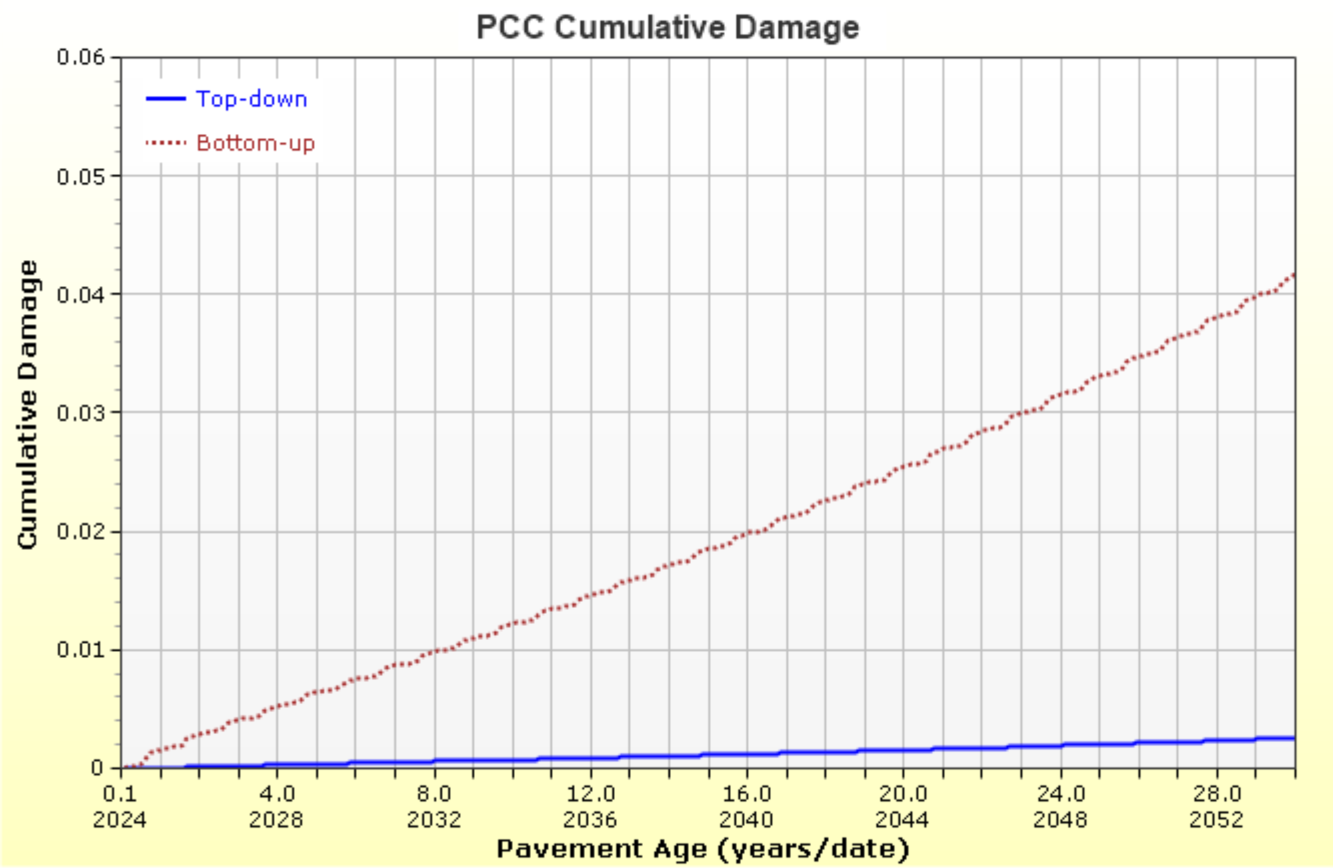




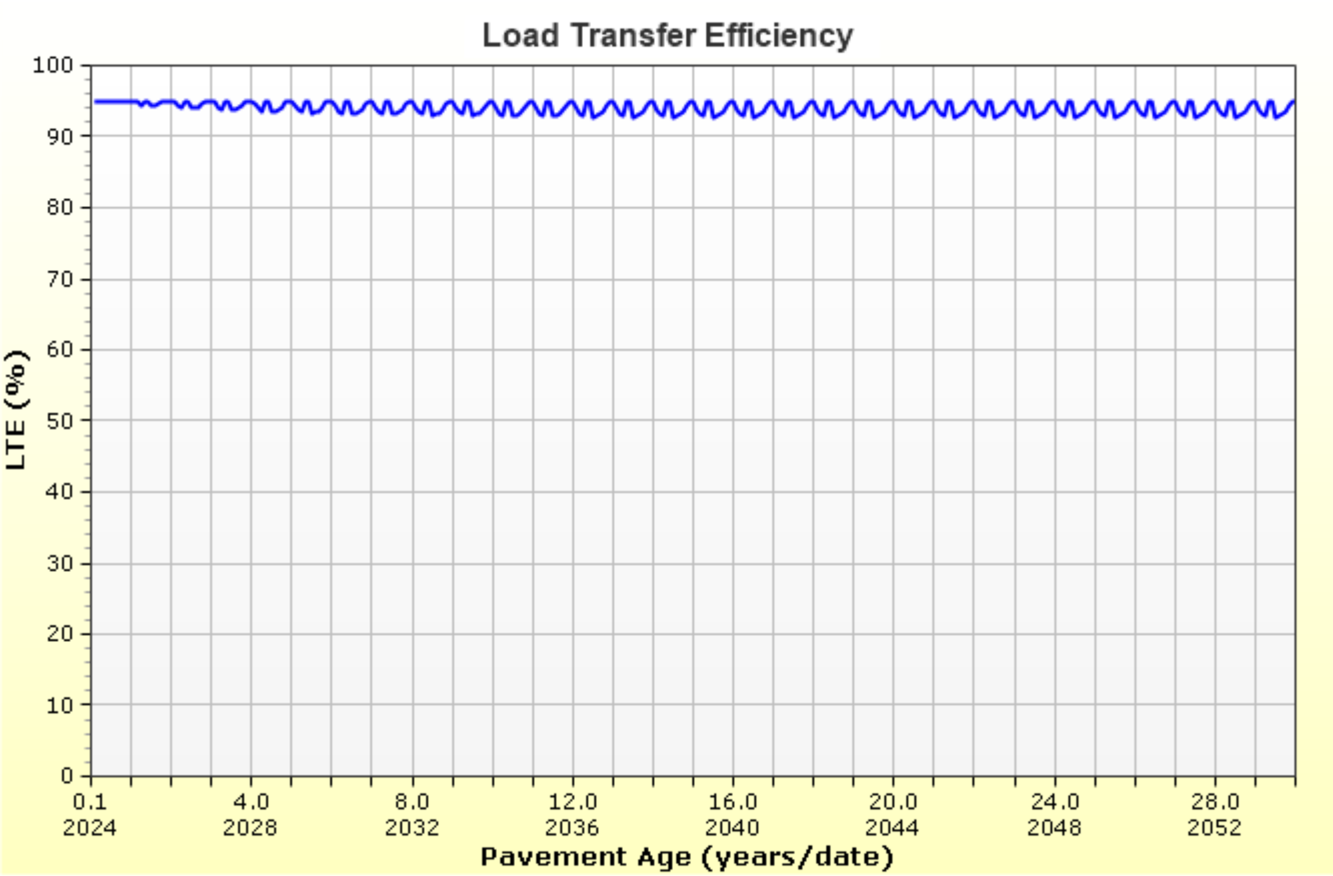
PCC Modulus (Epcc)
PCC - E (Mpsi)
4.95
4.9
4.85
4.8
4.75
4.7
4.65
4.6
4.55
4.5
PCC Flexural Strength (MR)
PCC - MR (psi)
870
860
850
840
830
820
810
800
790
780
770
760
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



Base Modulus (Ebase)
Base - E (kpsi)
26
24
22
20
18
16
14
12
10
Dynamic k-Value
Dynamic k (psi/in.)
98
97
96
95
94
93
92
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	10.0
Unit weight (pcf)	140.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.86
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		563
Water to cement ratio		0.36
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	90.7
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	516.0
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

Identifiers

Field	Value
Display name/identifier	R4 Level 1 Lawson
Description of object	Mix ID # 2009105
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 4/1/6
User defined field 2	
User defined field 3	
Revision Number	0

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	560	3230000
14-day	620	3500000
28-day	710	4030000
90-day	730	4240000
20-year/28-day	1.2	1.2

Layer 2 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400
PCC Reliability Faulting Standard Deviation			
0.0831*Pow(FAULT,0.3426) + 0.00521			

IRI-jpcp

C1 - Cracking C2 - Spalling C3 - Faulting C4 - Site Factor	C1: 0.8203	C2: 0.4417
	C3: 1.4929	C4: 25.24
	Reliability Standard Deviation	
	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$
$$CRK = \frac{100}{1 + C4\, FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05
PCC Reliability Cracking Standard Deviation			
Pow(57.08*CRACK,0.33) + 1.5			

APPENDIX J

HORIZON DRIVE

RIGID PAVEMENT M-E DESIGN OUTPUT SHEETS

Horizon Drive PCCP Design (No Class 2)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\Horizion and G Road Roundabout\Horizon Drive PCCP Design (No Class 2).dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	10.0
NonStabilized	Crushed gravel	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

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

Traffic

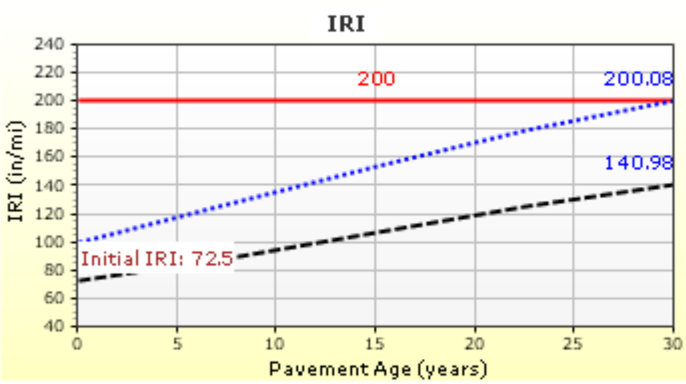
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	3,640
2039 (15 years)	10,346,300
2054 (30 years)	24,271,100

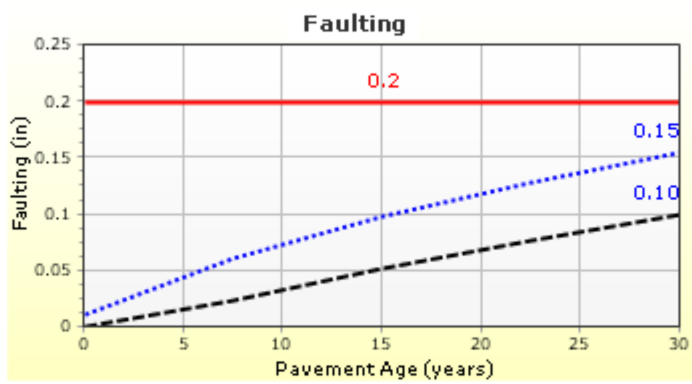
Design Outputs

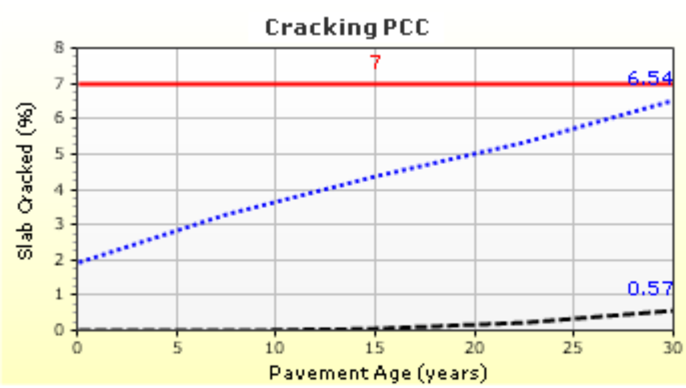
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	200.08	90.00	89.97	Fail
Mean joint faulting (in)	0.20	0.15	90.00	99.03	Pass
JPCP transverse cracking (percent slabs)	7.00	6.54	90.00	91.64	Pass

Distress Charts



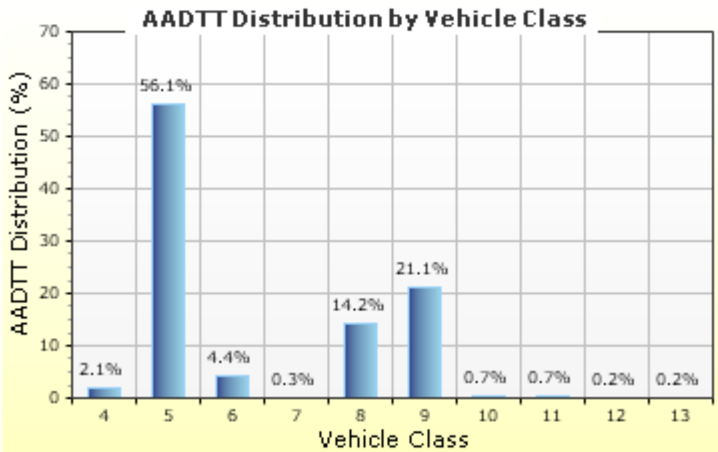


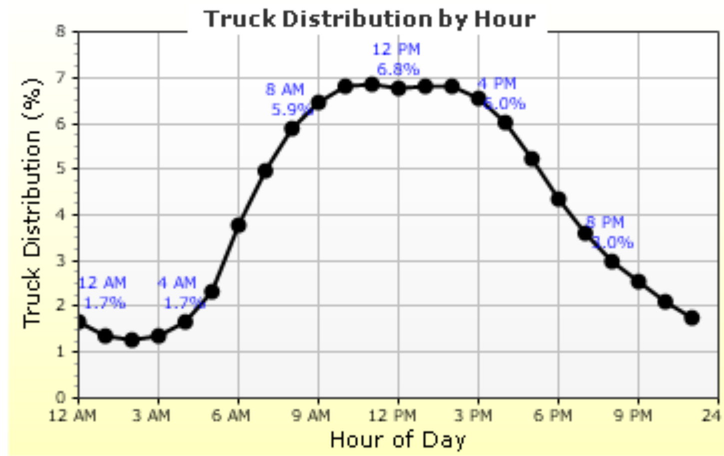


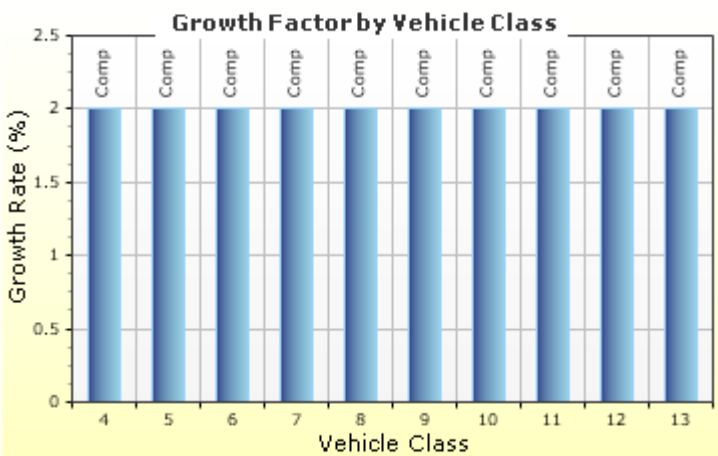
Traffic Inputs

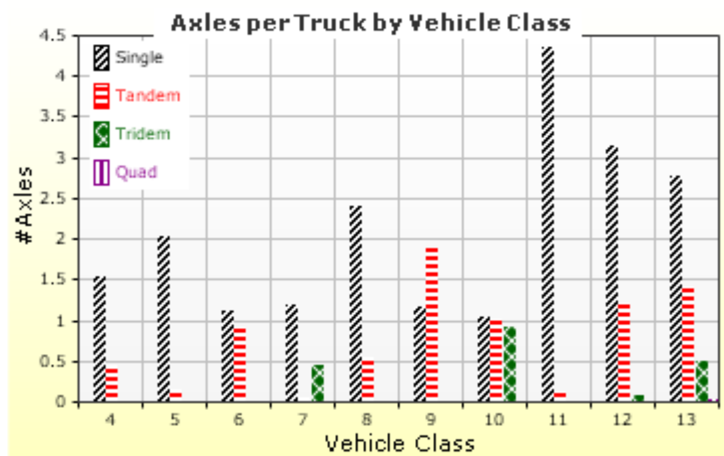
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,640	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

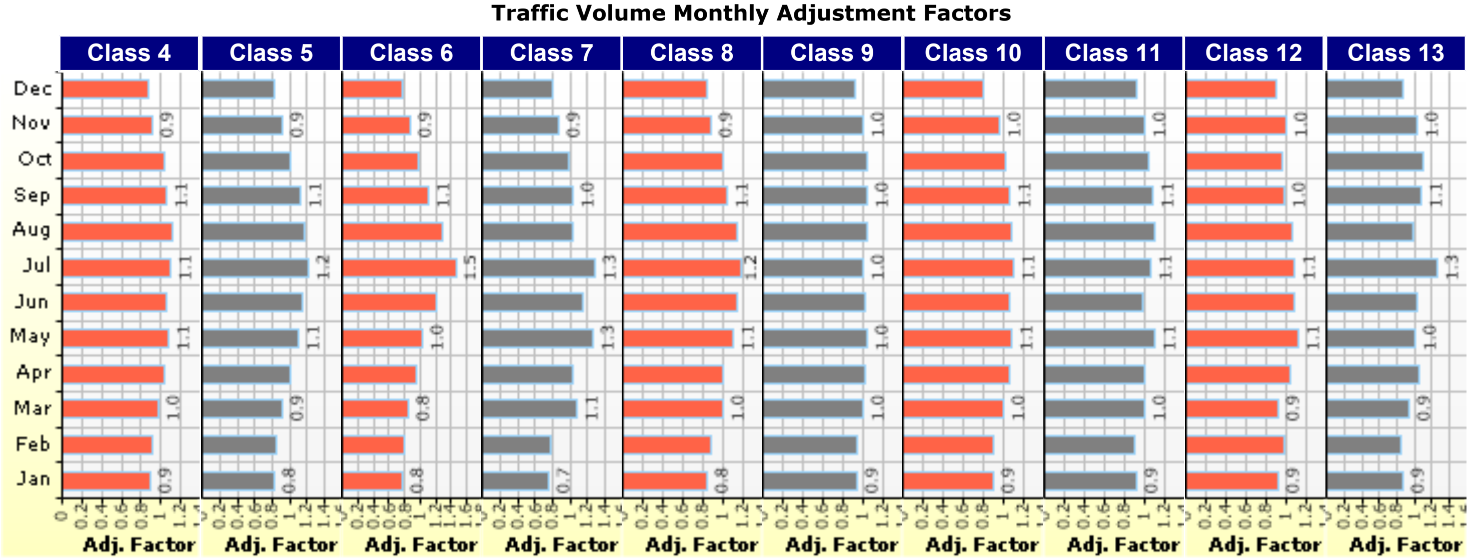








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	1.65%	12 PM	6.75%
1 AM	1.37%	1 PM	6.81%
2 AM	1.28%	2 PM	6.83%
3 AM	1.36%	3 PM	6.56%
4 AM	1.66%	4 PM	6.02%
5 AM	2.32%	5 PM	5.23%
6 AM	3.8%	6 PM	4.35%
7 AM	4.95%	7 PM	3.59%
8 AM	5.9%	8 PM	2.98%
9 AM	6.48%	9 PM	2.56%
10 AM	6.83%	10 PM	2.12%
11 AM	6.85%	11 PM	1.75%
		Total	100%

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

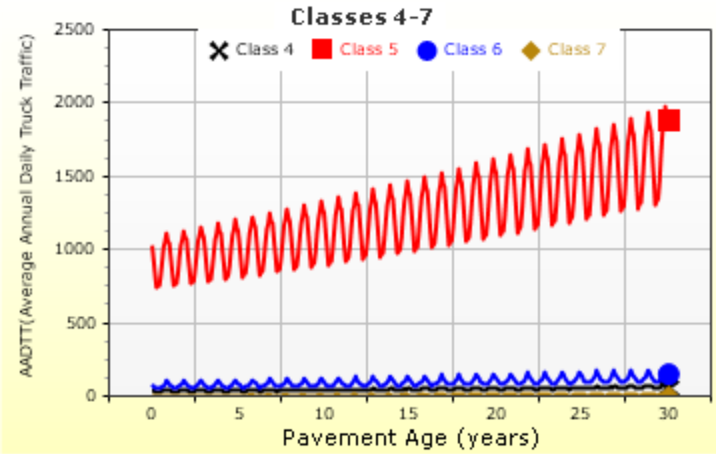
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

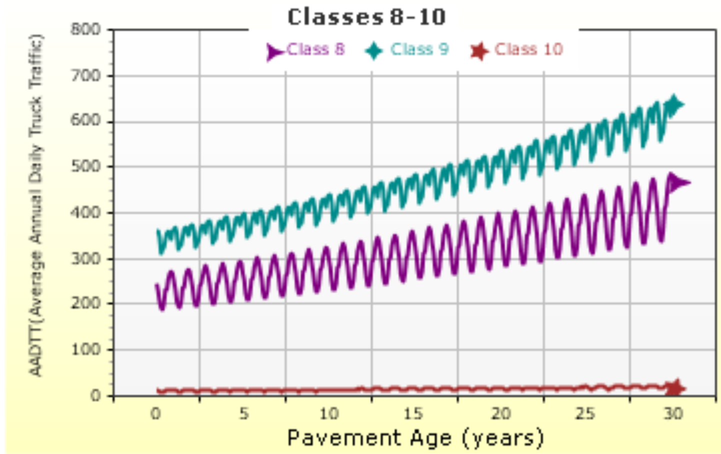
Number of Axles per Truck

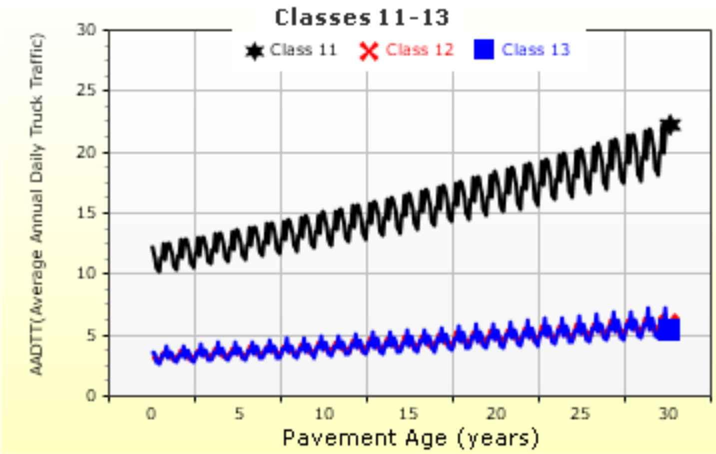
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

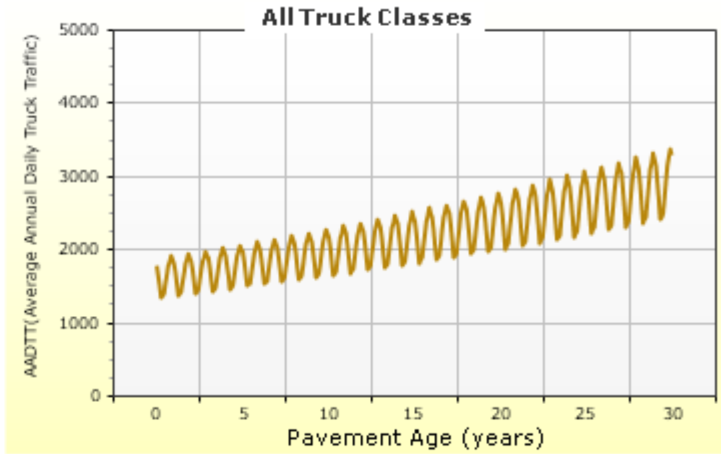
AADTT (Average Annual Daily Truck Traffic) Growth

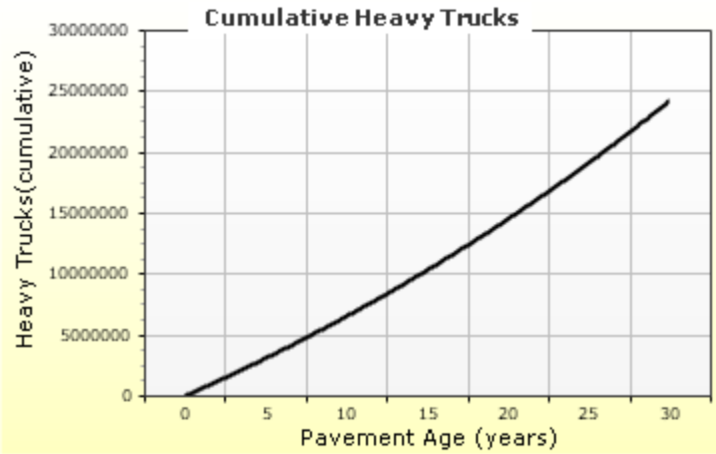
*** Traffic cap is not enforced**







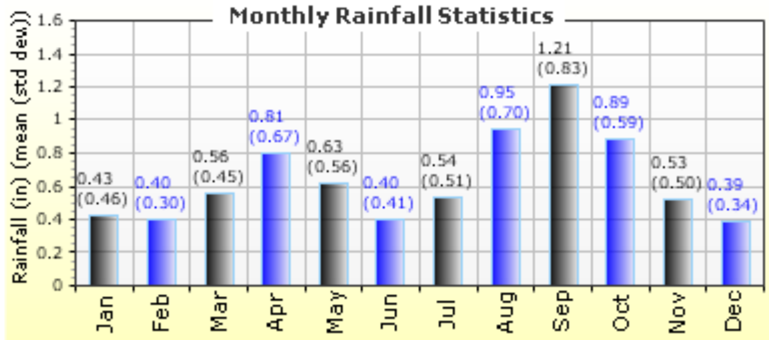




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

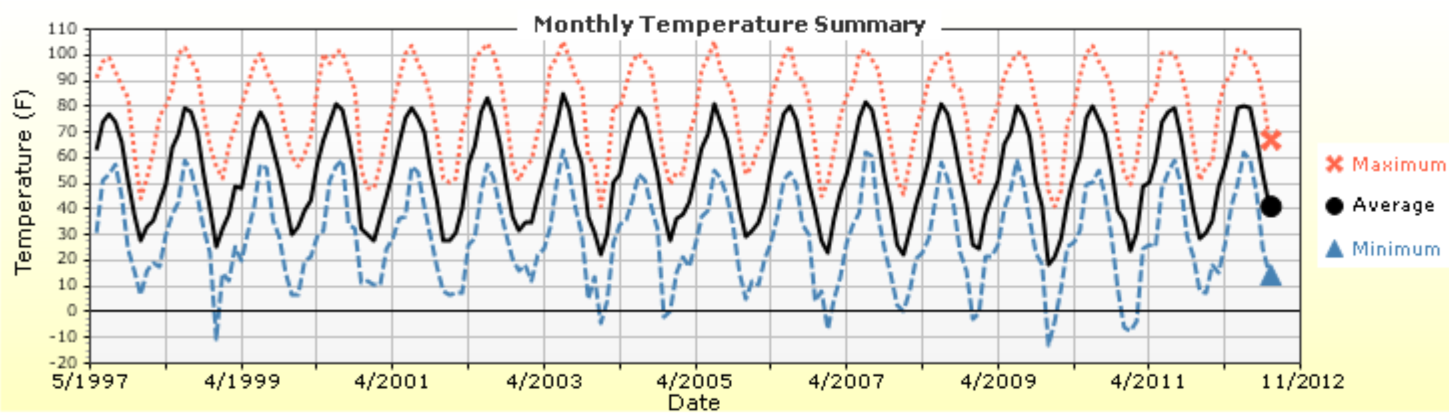


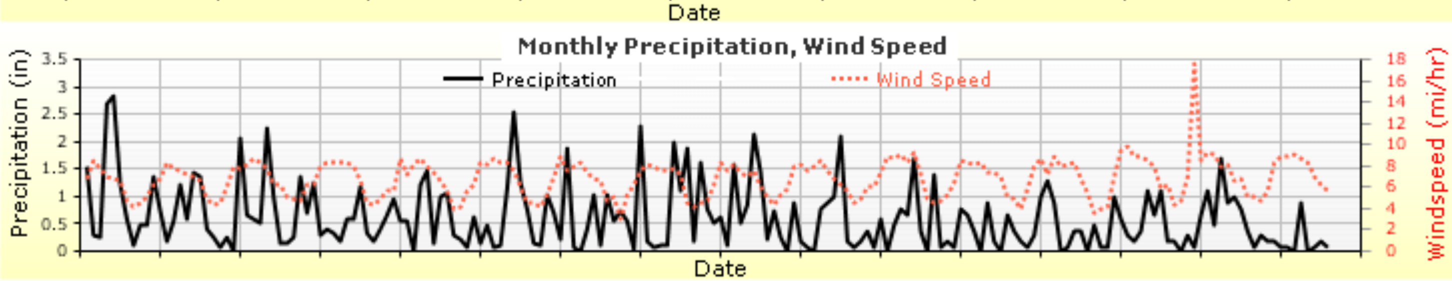
Annual Statistics:

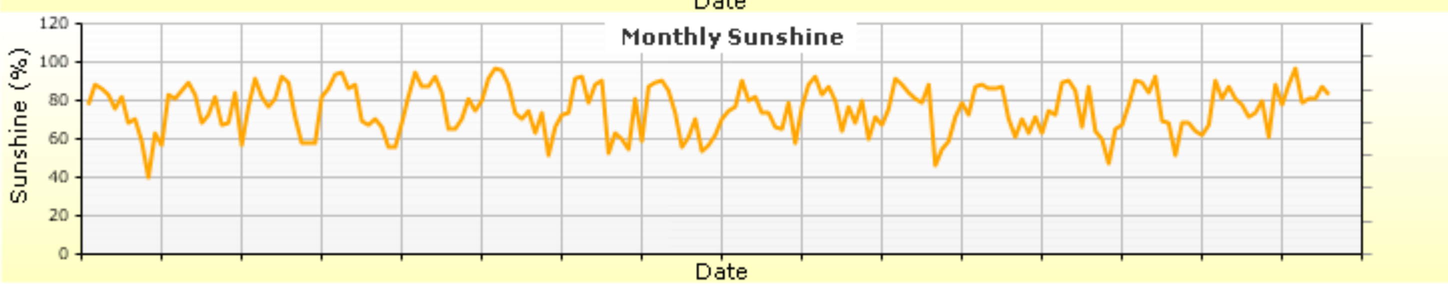
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

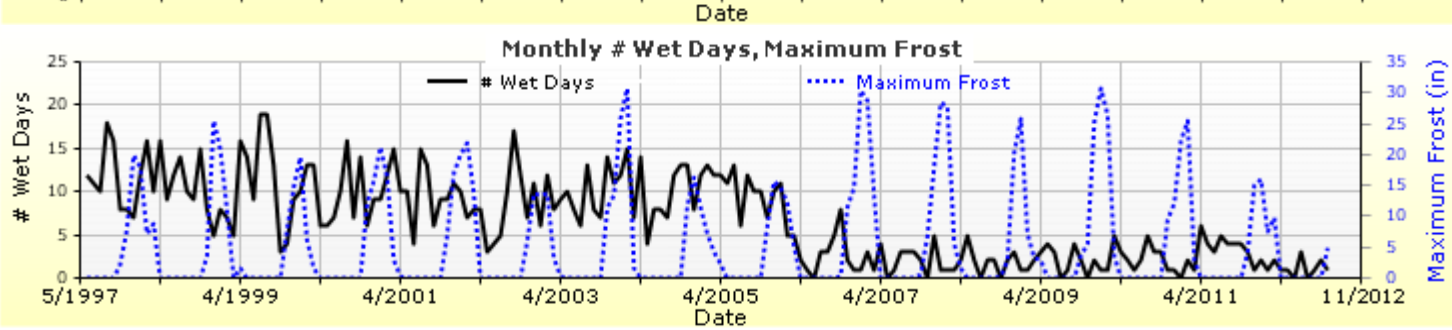
Water table depth (ft)	4.00

Monthly Climate Summary:

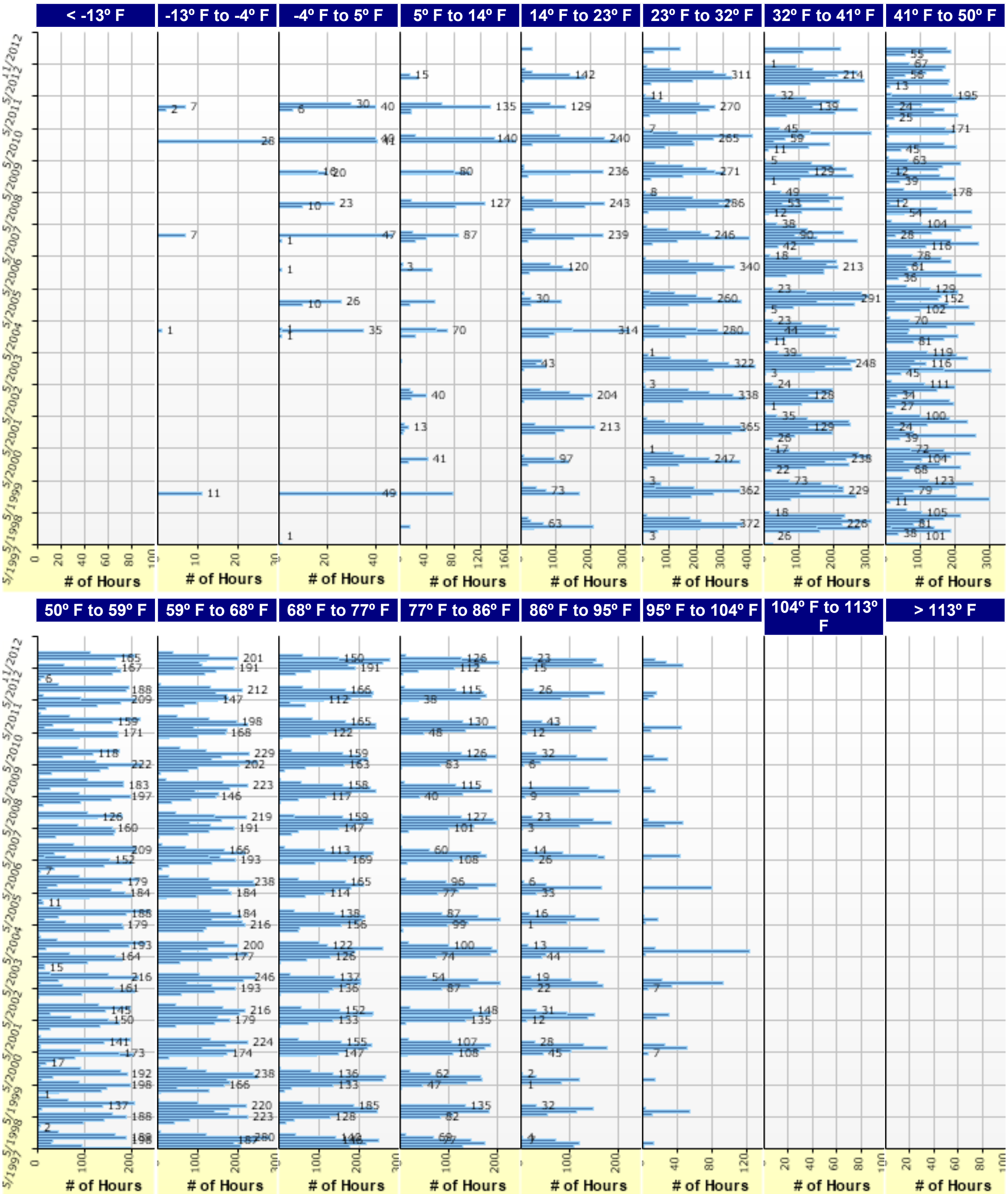








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

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

Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

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

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

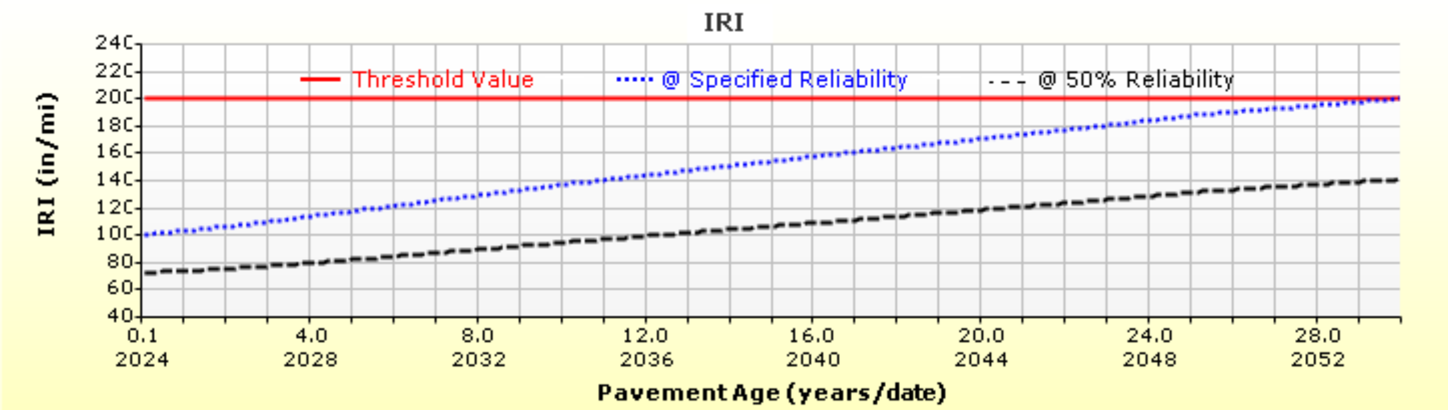
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

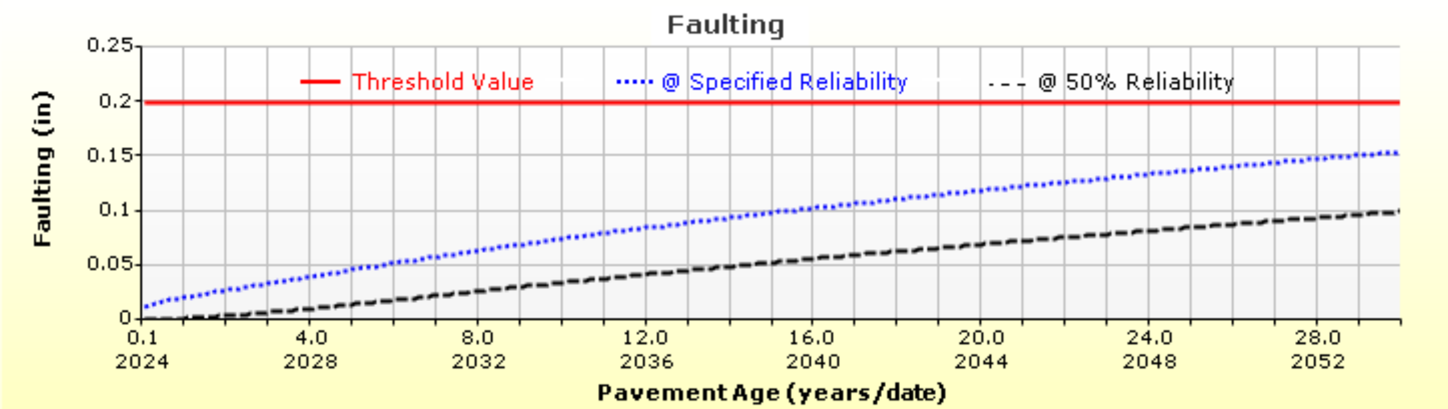
Sealant type	Other(Including No Sealant... Liquid... Silicone)

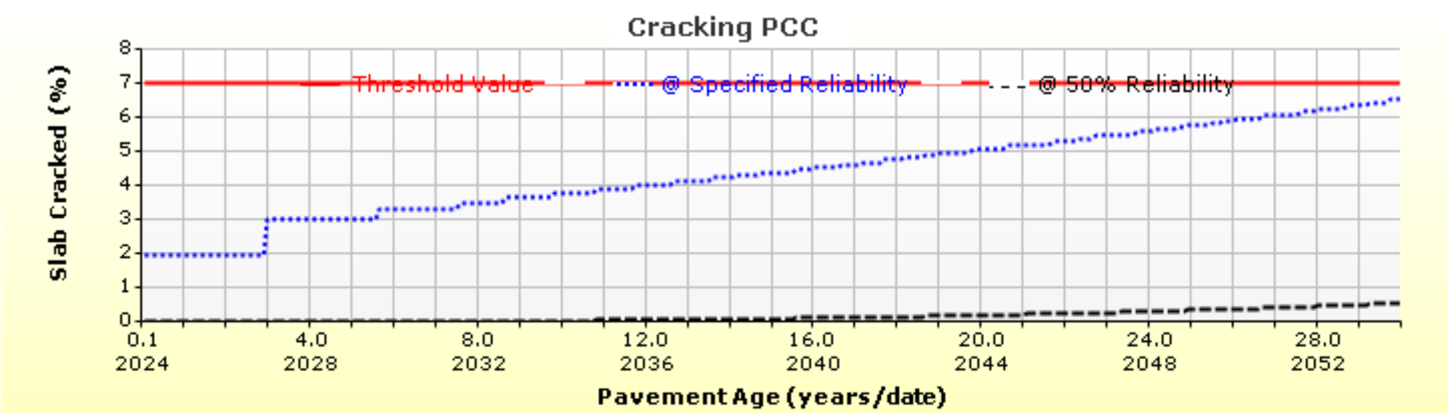
Erodibility index	3

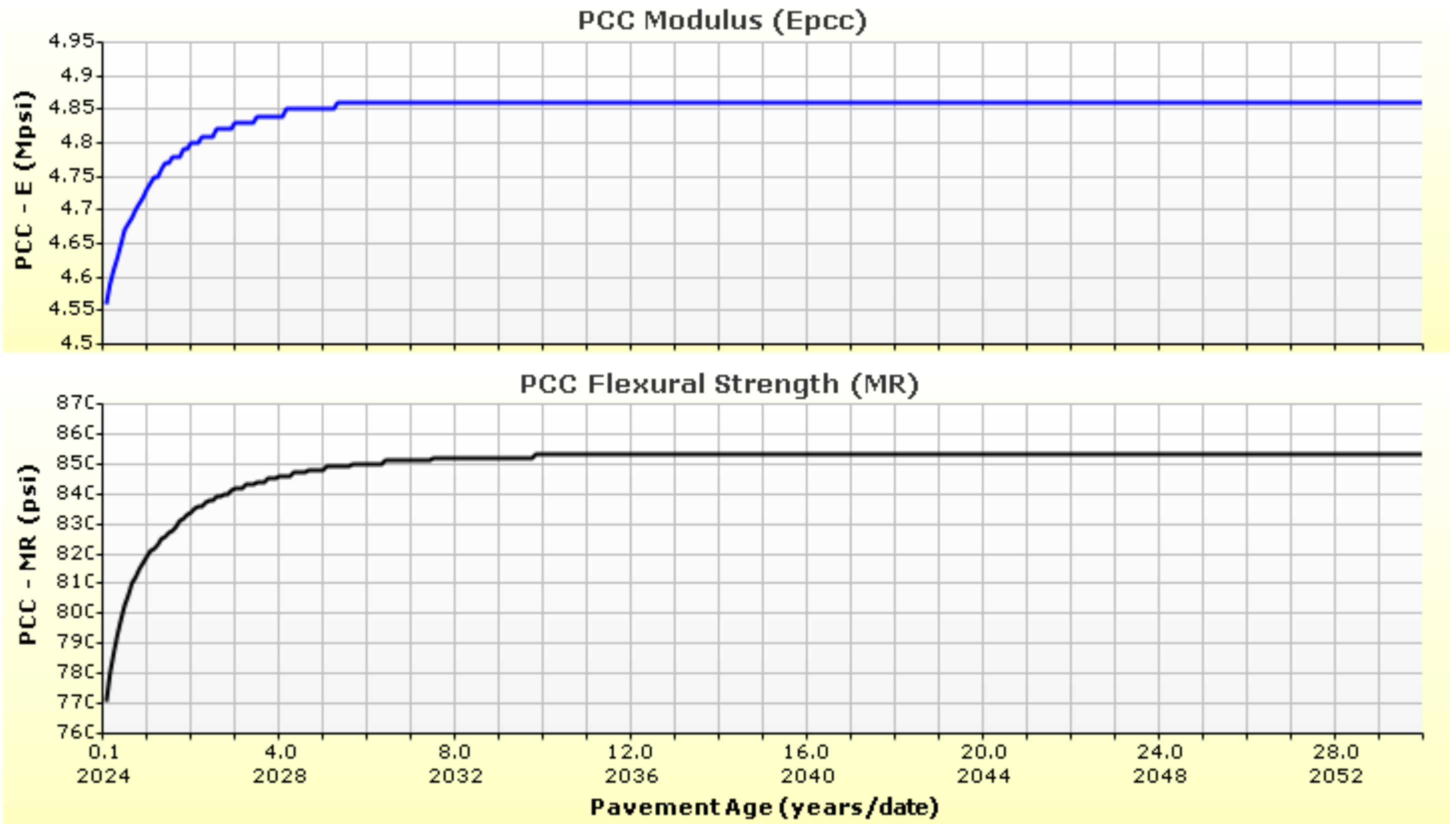
Permanent curl/warp effective temperature difference (ºF)	-10.00

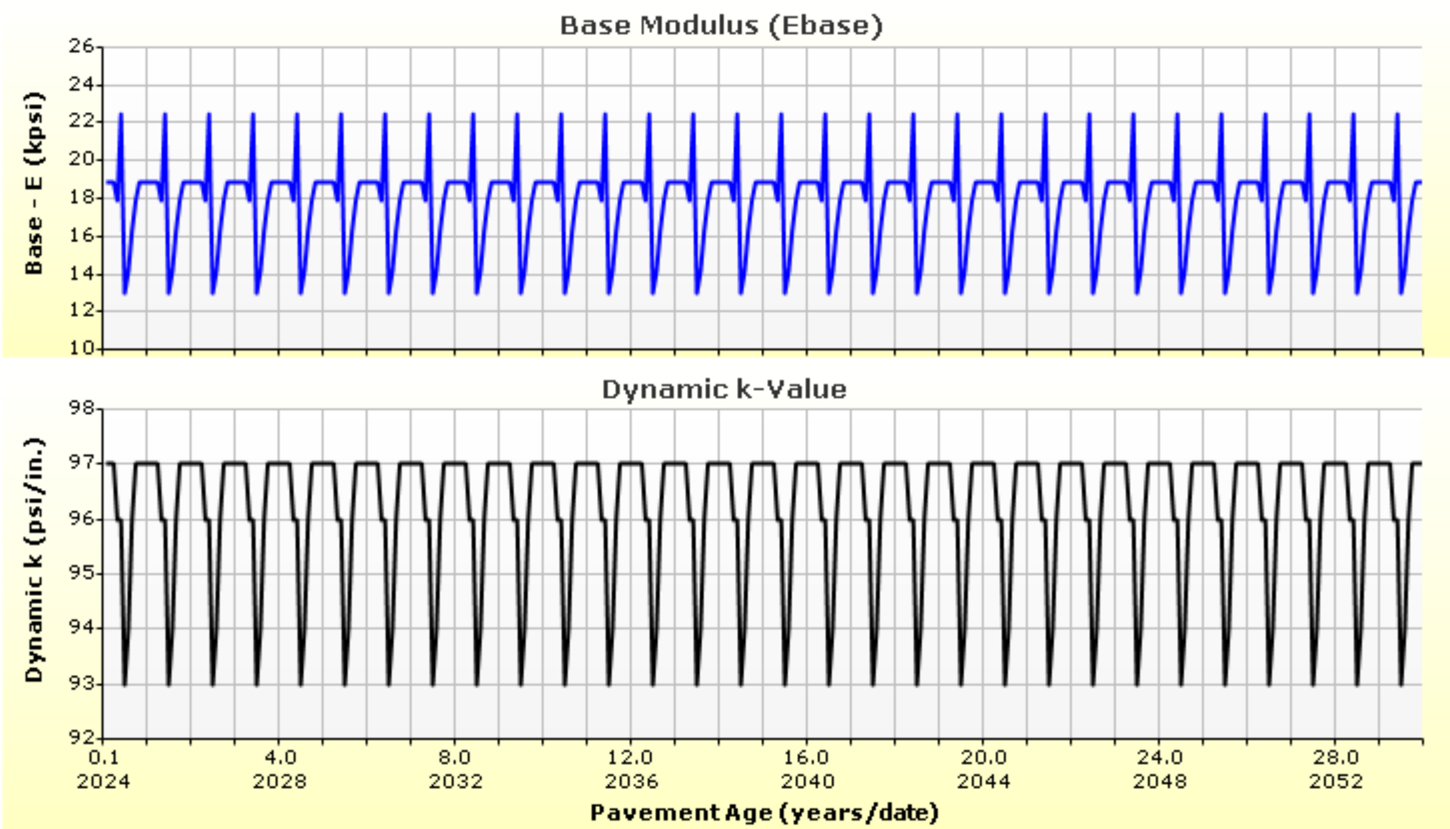
Analysis Output Charts

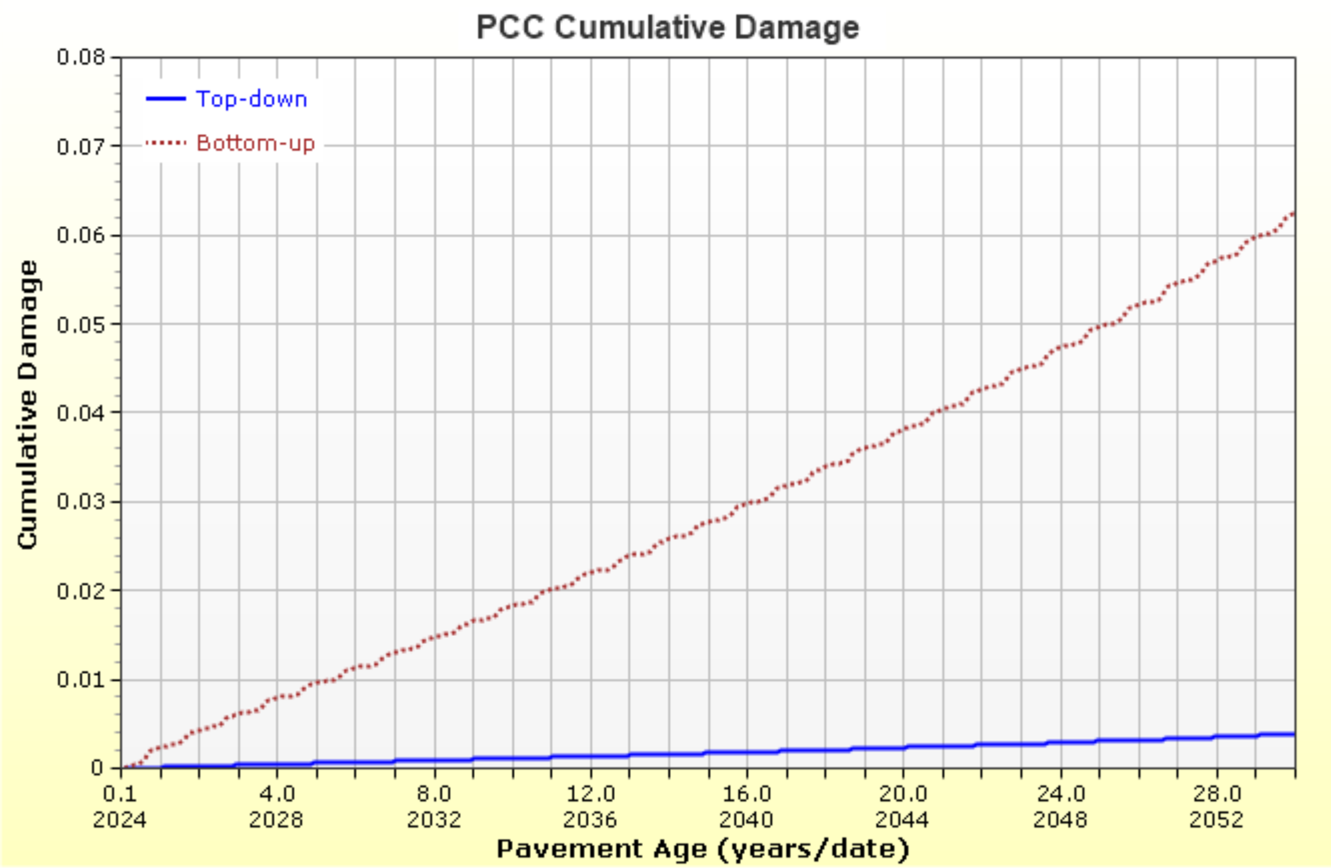


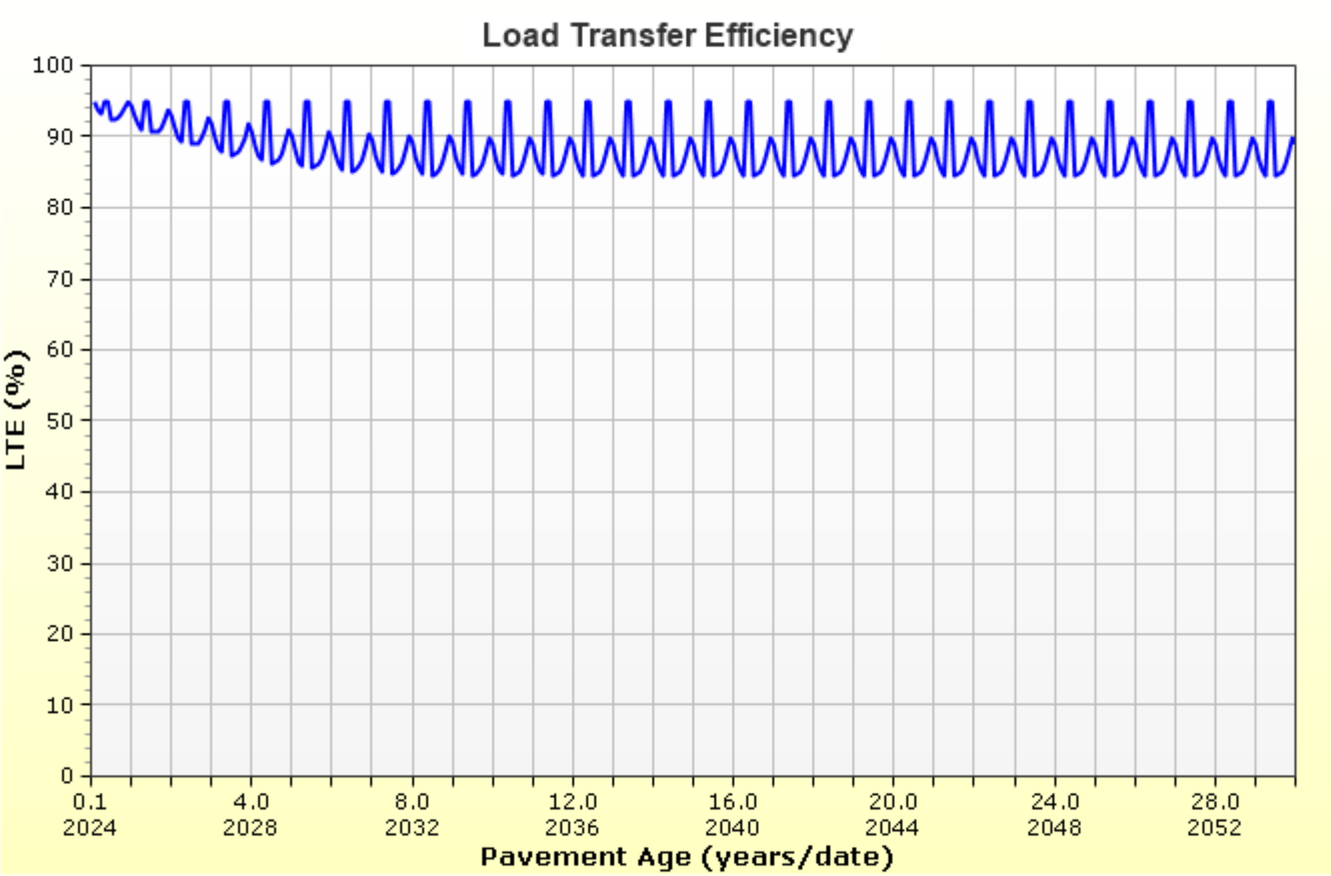





PCC Modulus (Epcc)
PCC - E (Mpsi)
4.95
4.9
4.85
4.8
4.75
4.7
4.65
4.6
4.55
4.5
PCC Flexural Strength (MR)
PCC - MR (psi)
870
860
850
840
830
820
810
800
790
780
770
760
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2024 2028 2032 2036 2040 2044 2048 2052
Pavement Age (years/date)


Base Modulus (Ebase)
Base - E (kpsi)
26
24
22
20
18
16
14
12
10
Dynamic k-Value
Dynamic k (psi/in.)
98
97
96
95
94
93
92
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2024 2028 2032 2036 2040 2044 2048 2052
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	10.0
Unit weight (pcf)	140.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.86
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		563
Water to cement ratio		0.36
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	90.7
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	516.0
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

Identifiers

Field	Value
Display name/identifier	R4 Level 1 Lawson
Description of object	Mix ID # 2009105
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 4/1/6
User defined field 2	
User defined field 3	
Revision Number	0

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	560	3230000
14-day	620	3500000
28-day	710	4030000
90-day	730	4240000
20-year/28-day	1.2	1.2

Layer 2 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400

PCC Reliability Faulting Standard Deviation

0.0831*Pow(FAULT,0.3426) + 0.00521

IRI-jpcp

C1 - Cracking	C1: 0.8203	C2: 0.4417
C2 - Spalling	C3: 1.4929	C4: 25.24
C3 - Faulting	**Reliability Standard Deviation**	
C4 - Site Factor	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

$$CRK = \frac{100}{1 + C4\, FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05

PCC Reliability Cracking Standard Deviation

Pow(57.08*CRACK,0.33) + 1.5

APPENDIX K

HORIZON DRIVE AND G ROAD ROUNDABOUT

RIGID PAVEMENT M-E DESIGN PAVEMENT OUTPUT SHEETS

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2024
Traffic opening: September, 2024

Climate Data Sources (Lat/Lon): 39.134, -108.538

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	10.5
NonStabilized	Crushed gravel	8.0
Subgrade	A-4	6.0
Subgrade	A-4	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.50
Slab width (ft)	12.0

Traffic

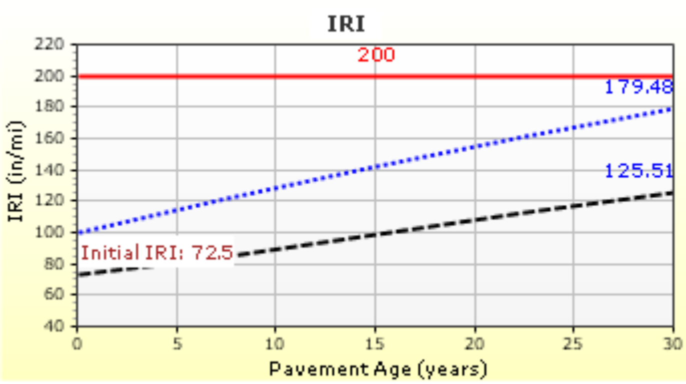
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	6,350
2039 (15 years)	18,049,200
2054 (30 years)	42,341,000

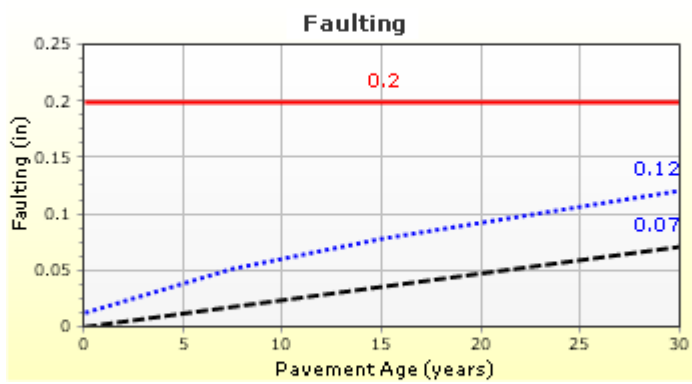
Design Outputs

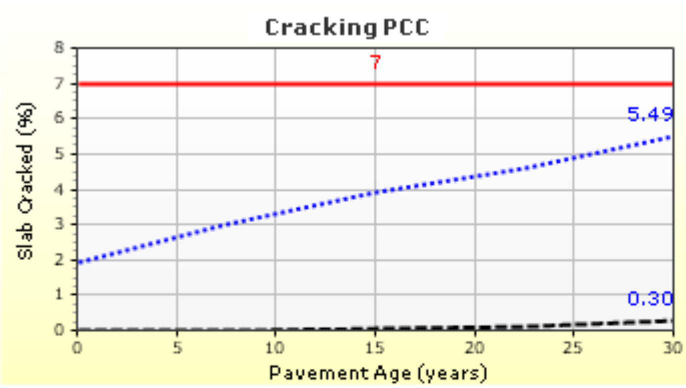
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	179.48	90.00	96.15	Pass
Mean joint faulting (in)	0.20	0.12	90.00	99.95	Pass
JPCP transverse cracking (percent slabs)	7.00	5.49	90.00	95.08	Pass

Distress Charts





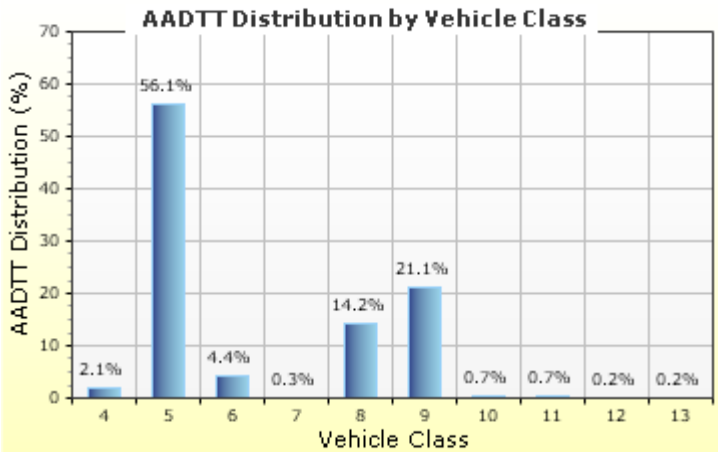


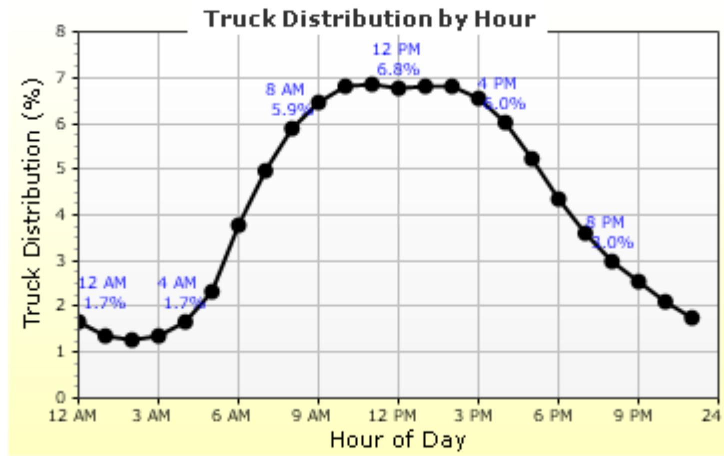
Threshold Value | @ Specified Reliability | @ 50% Reliability

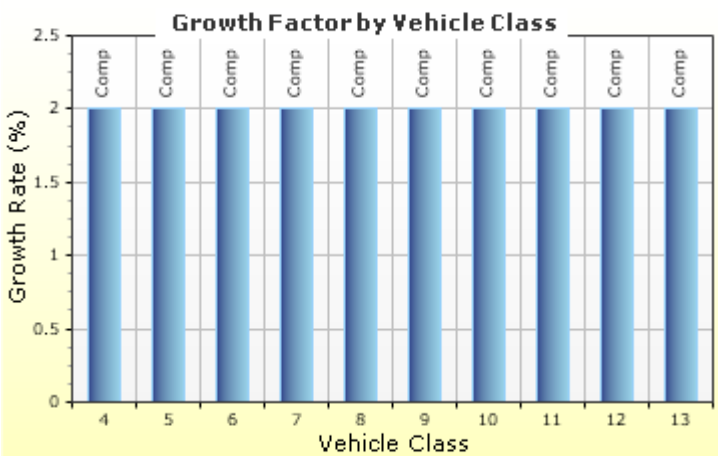
Traffic Inputs

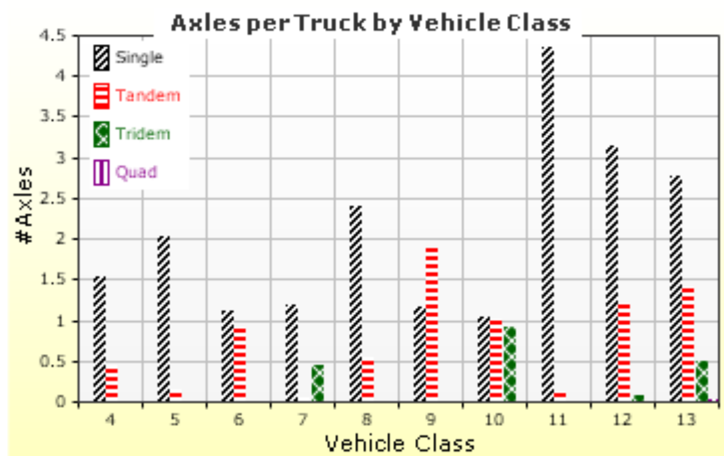
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	6,350	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	35.0

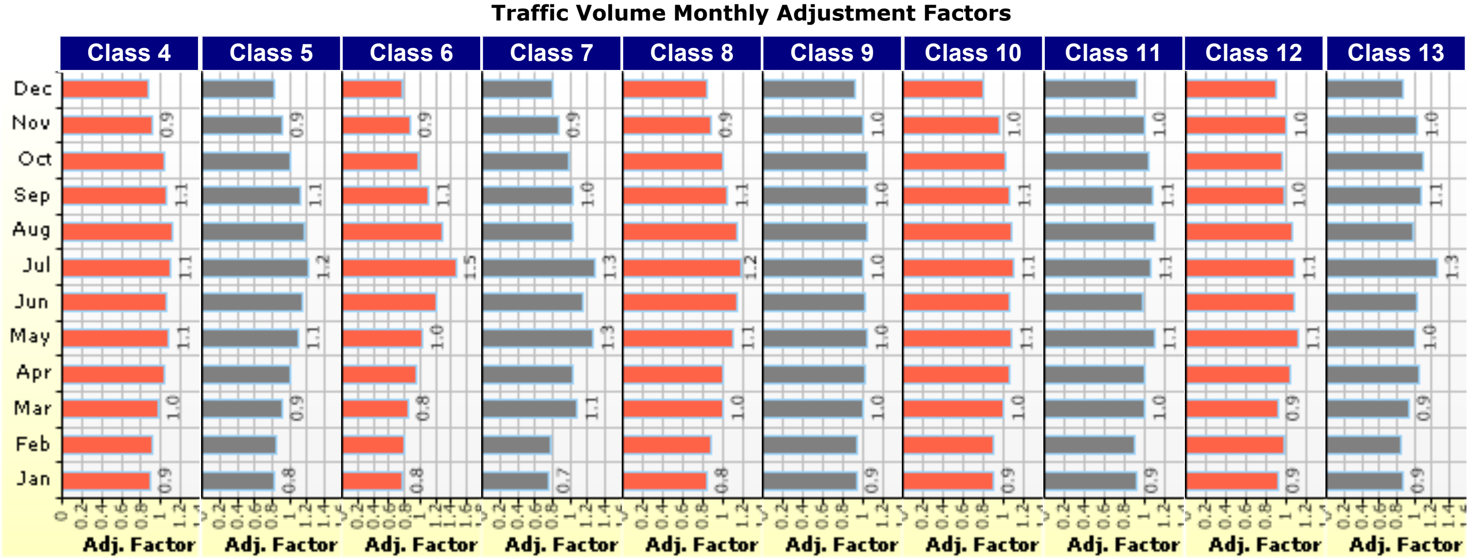








Traffic Volume Monthly Adjustment Factors



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	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2%	Compound
Class 5	56.1%	2%	Compound
Class 6	4.4%	2%	Compound
Class 7	0.3%	2%	Compound
Class 8	14.2%	2%	Compound
Class 9	21.1%	2%	Compound
Class 10	0.7%	2%	Compound
Class 11	0.7%	2%	Compound
Class 12	0.2%	2%	Compound
Class 13	0.2%	2%	Compound

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	1.65%	12 PM	6.75%
1 AM	1.37%	1 PM	6.81%
2 AM	1.28%	2 PM	6.83%
3 AM	1.36%	3 PM	6.56%
4 AM	1.66%	4 PM	6.02%
5 AM	2.32%	5 PM	5.23%
6 AM	3.8%	6 PM	4.35%
7 AM	4.95%	7 PM	3.59%
8 AM	5.9%	8 PM	2.98%
9 AM	6.48%	9 PM	2.56%
10 AM	6.83%	10 PM	2.12%
11 AM	6.85%	11 PM	1.75%
		Total	100%

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

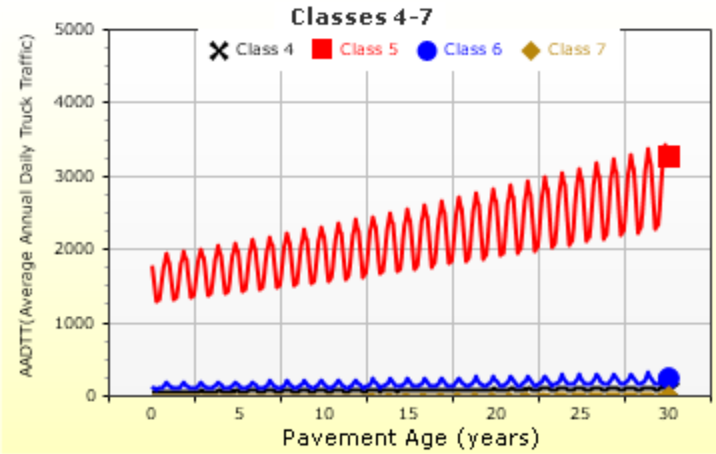
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

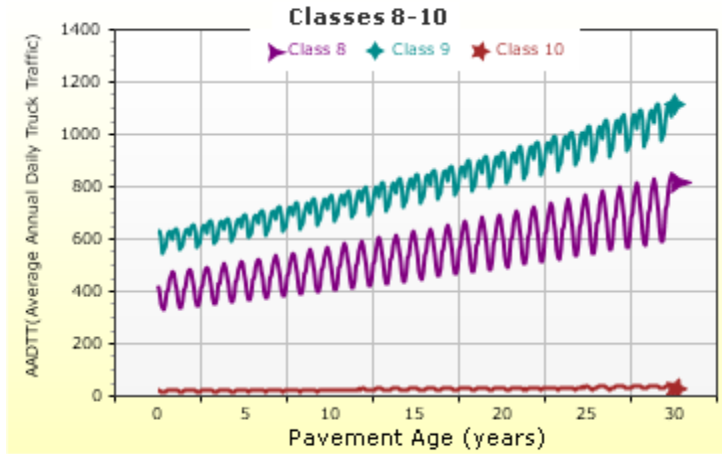
Number of Axles per Truck

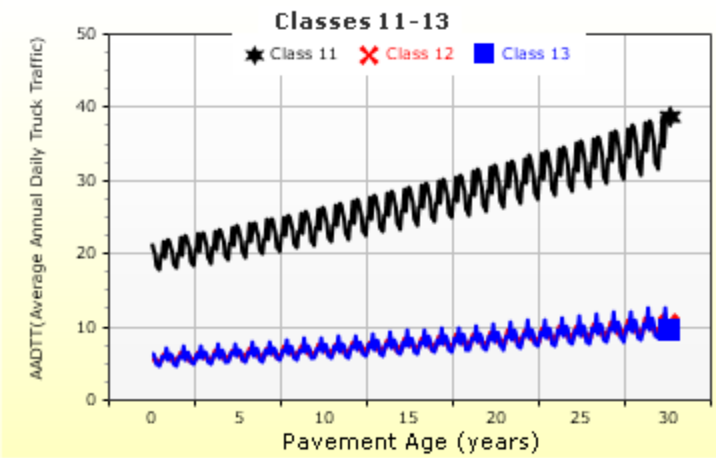
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4	0.51	0.04

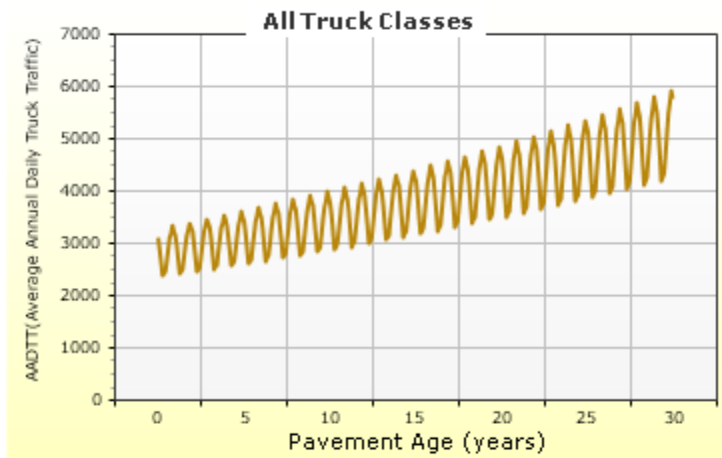
AADTT (Average Annual Daily Truck Traffic) Growth

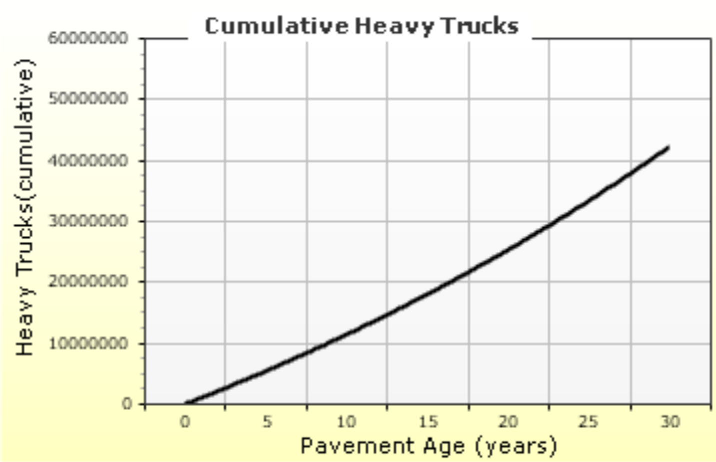
*** Traffic cap is not enforced**







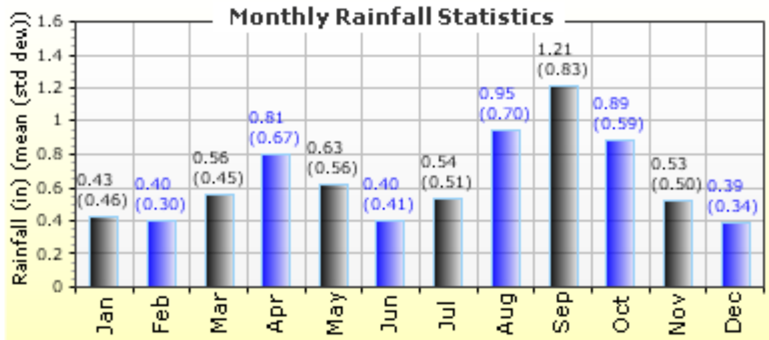




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

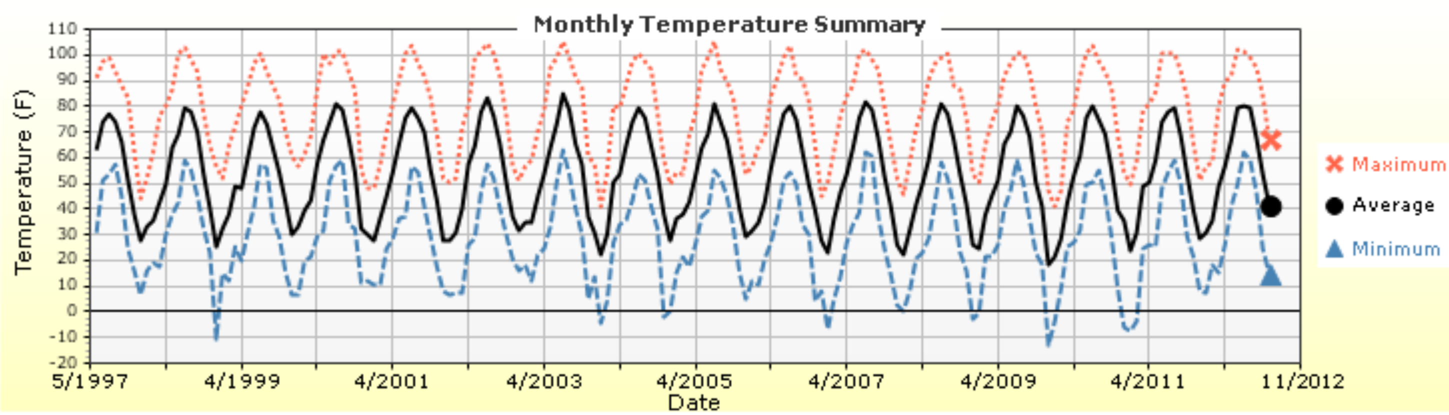


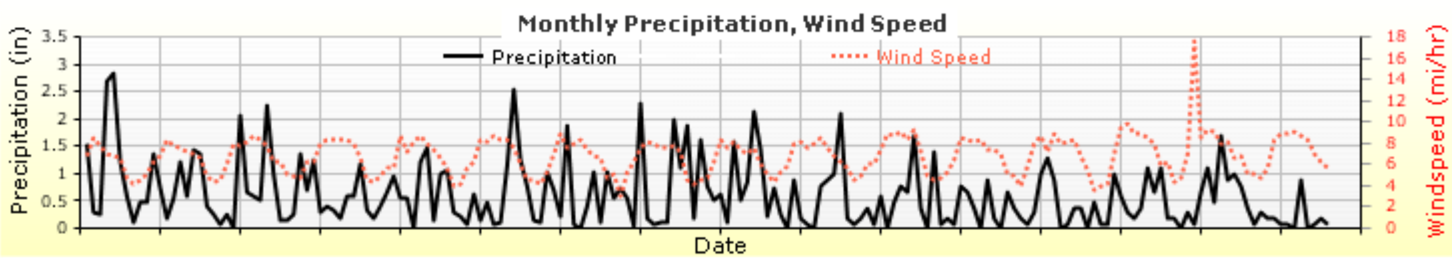
Annual Statistics:

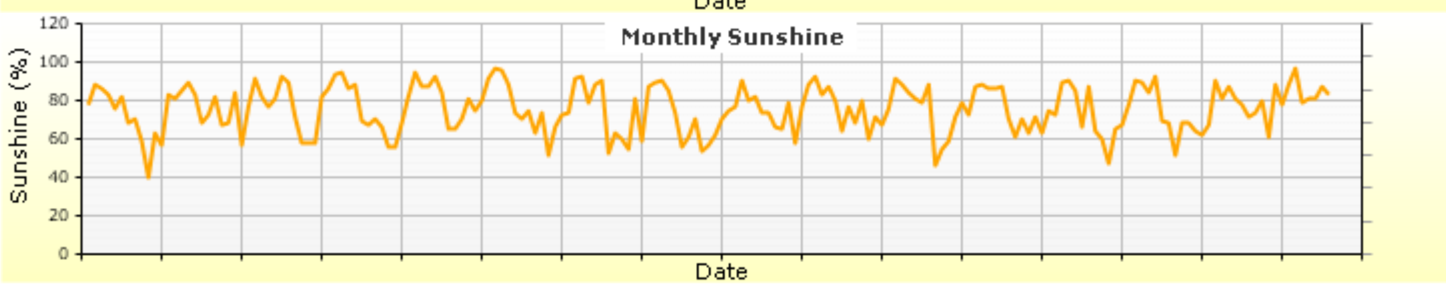
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

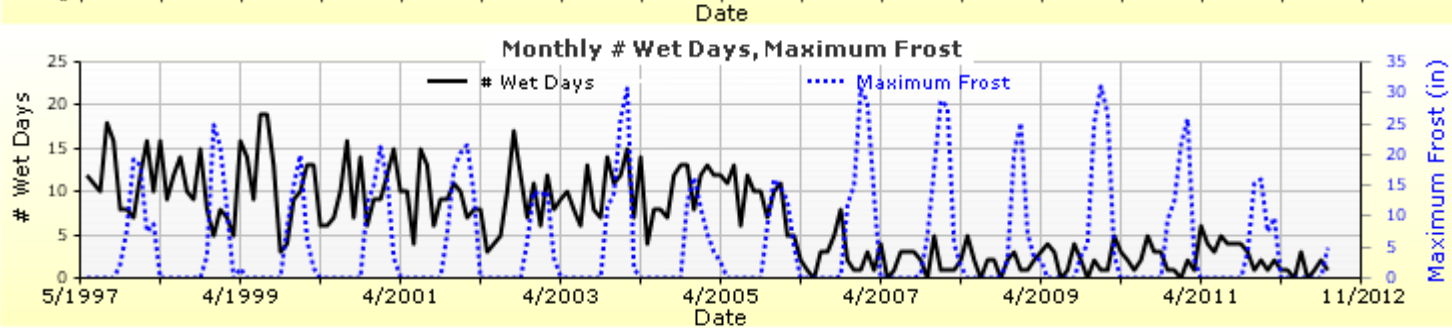
Water table depth (ft)	4.00

Monthly Climate Summary:

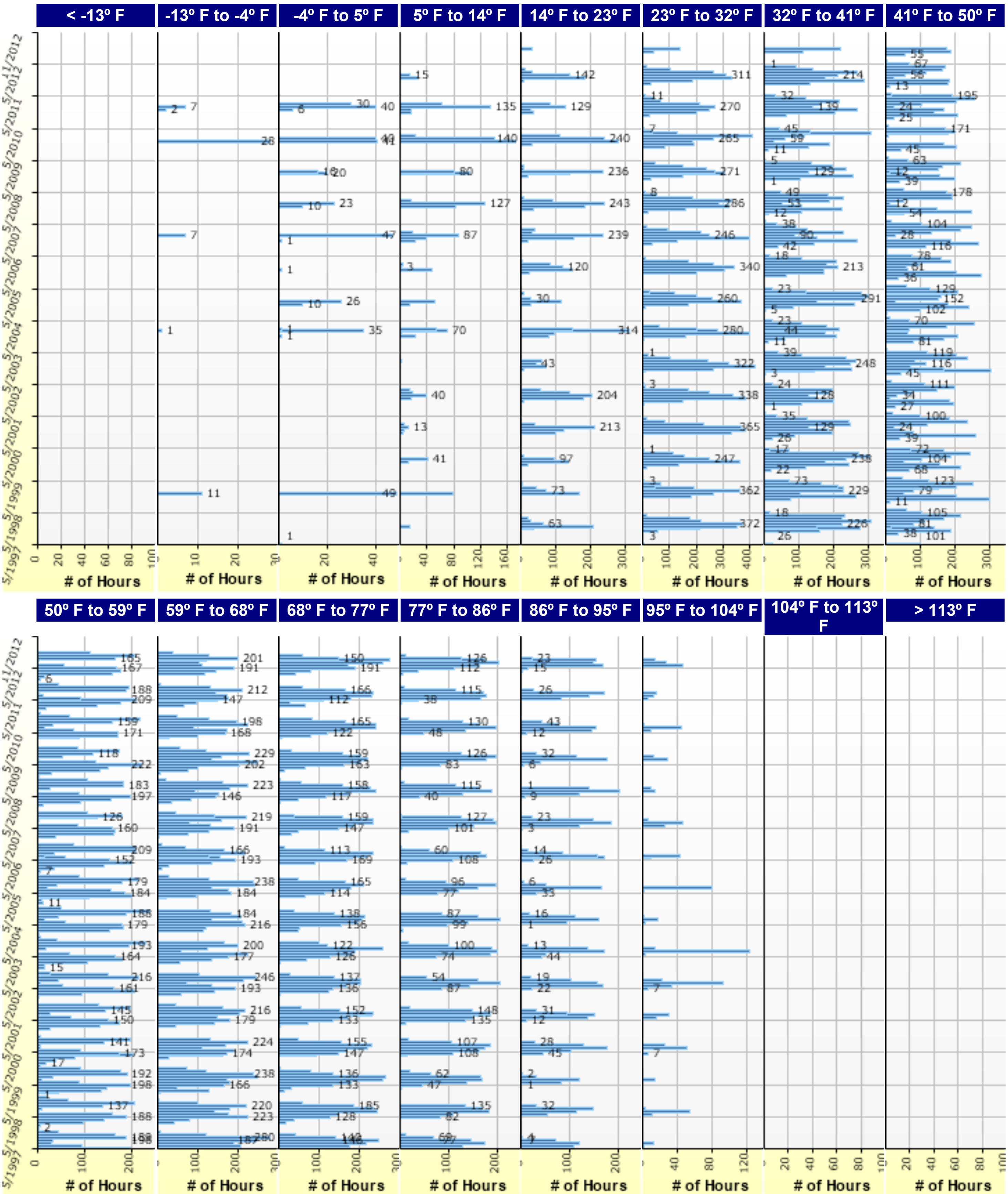








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in)	1.50
Dowel spacing (in)	12.00

Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

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

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

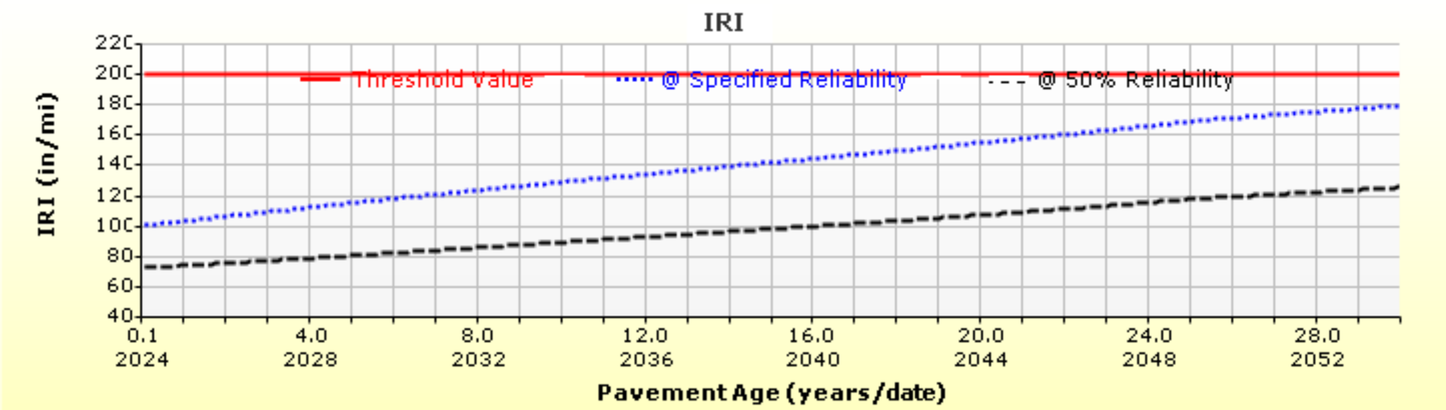
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

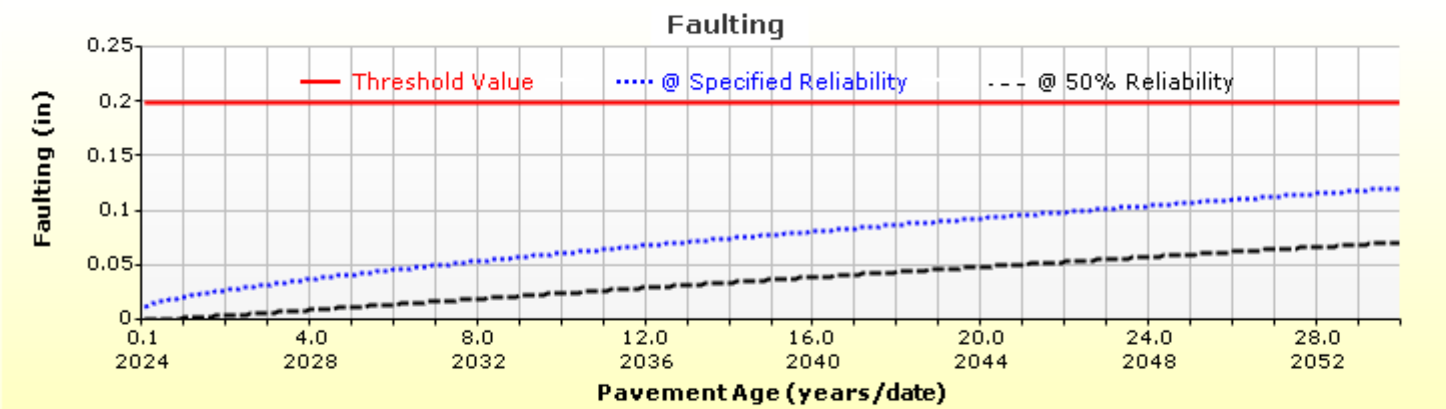
Sealant type	Other(Including No Sealant... Liquid... Silicone)

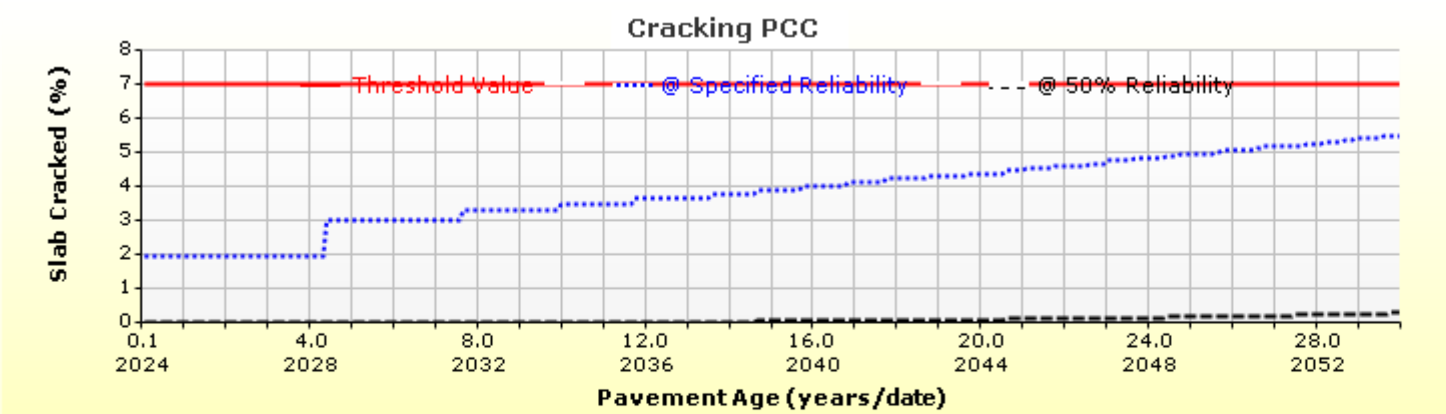
Erodibility index	3

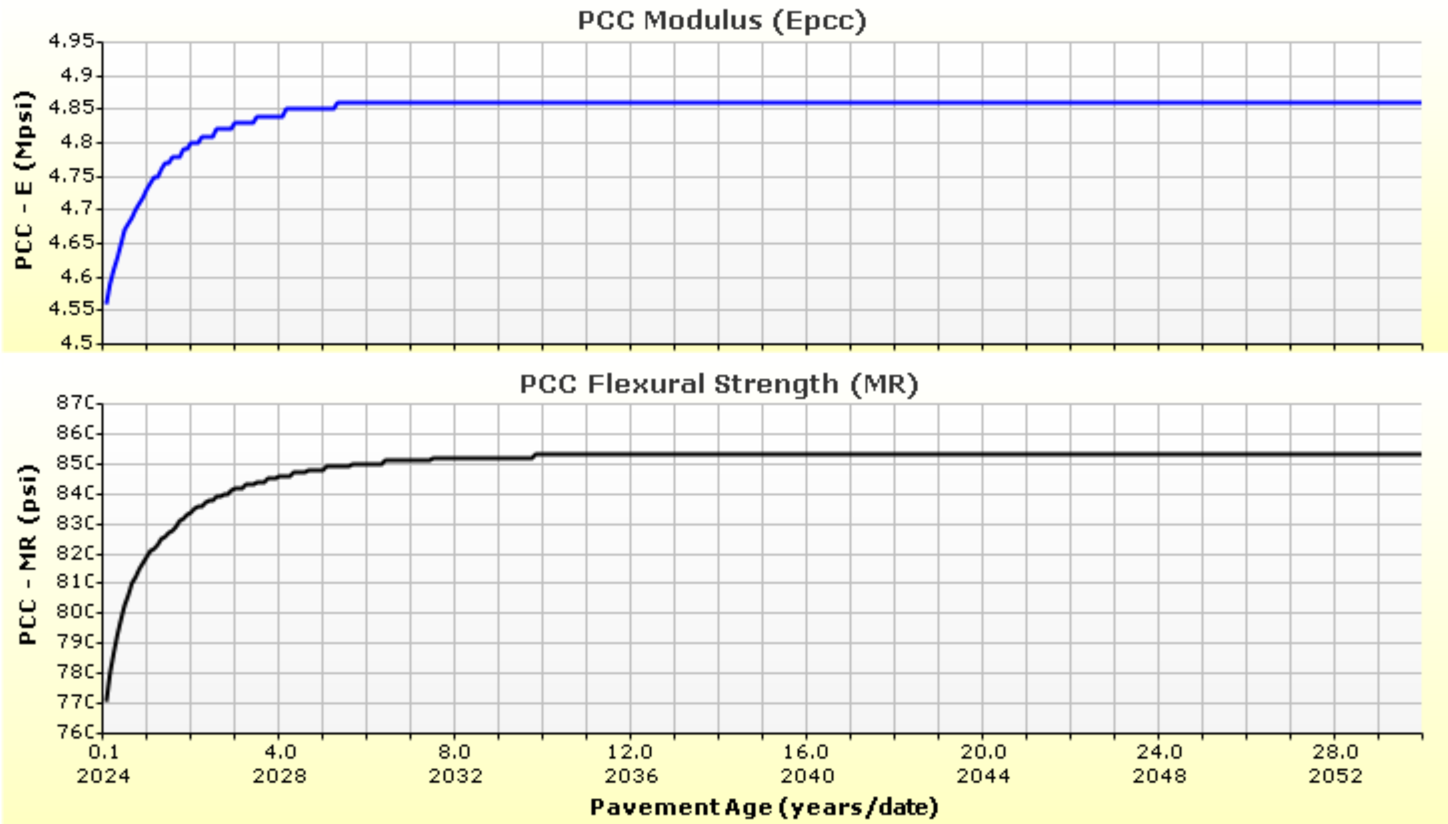
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

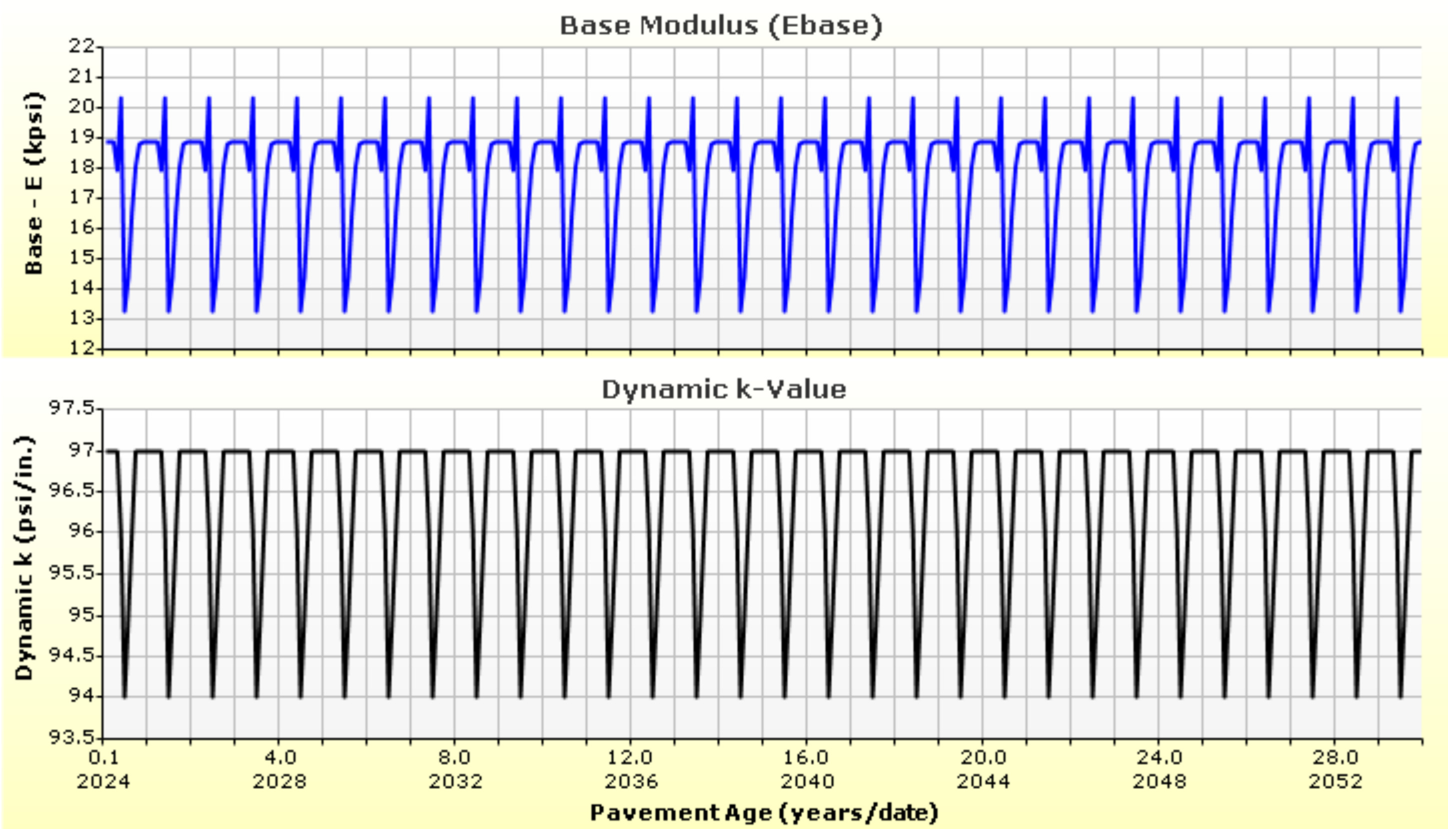




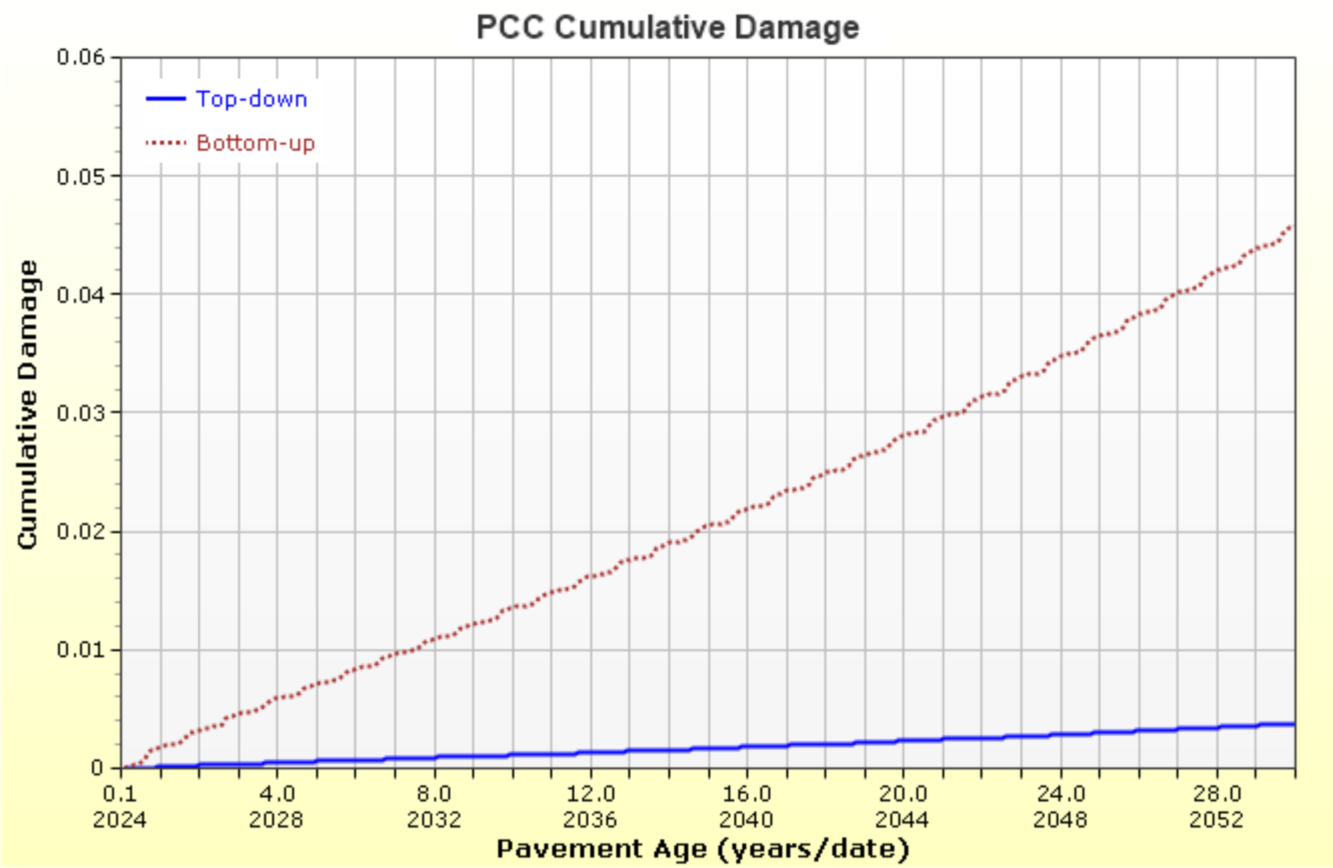


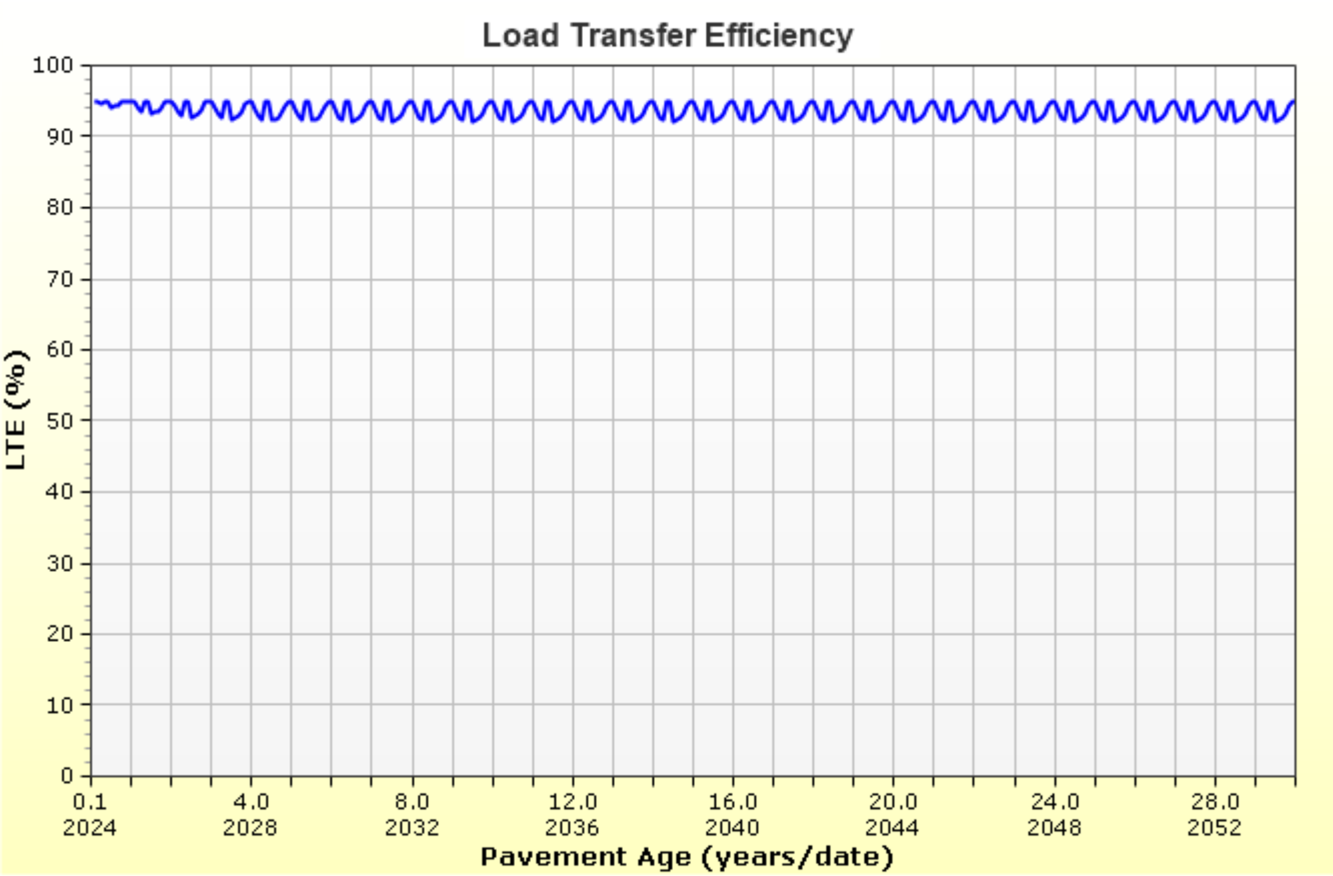


PCC Modulus (Epcc)
PCC - E (Mpsi)
4.95
4.9
4.85
4.8
4.75
4.7
4.65
4.6
4.55
4.5
PCC Flexural Strength (MR)
PCC - MR (psi)
870
860
850
840
830
820
810
800
790
780
770
760
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)



Base Modulus (Ebase)
Base - E (kpsi)
22
21
20
19
18
17
16
15
14
13
12
Dynamic k-Value
Dynamic k (psi/in.)
97.5
97
96.5
96
95.5
95
94.5
94
93.5
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2024
4.0 2028
8.0 2032
12.0 2036
16.0 2040
20.0 2044
24.0 2048
28.0 2052
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	10.5
Unit weight (pcf)	140.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.86
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		563
Water to cement ratio		0.36
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	90.7
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	516.0
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	560	3230000
14-day	620	3500000
28-day	710	4030000
90-day	730	4240000
20-year/28-day	1.2	1.2

Identifiers

Field	Value
Display name/identifier	R4 Level 1 Lawson
Description of object	Mix ID # 2009105
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 4/1/6
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Crushed gravel

Unbound	
Layer thickness (in)	8.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

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

Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	42

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#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-4

Unbound	
Layer thickness (in)	6.0
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in)	Semi-infinite
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
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
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	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	119
Saturated hydraulic conductivity (ft/hr)	False	7.589e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	68.8377
bf	0.9983
cf	0.4757
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

Calibration Coefficients

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: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400

PCC Reliability Faulting Standard Deviation

0.0831*Pow(FAULT,0.3426) + 0.00521

IRI-jpcp

C1 - Cracking
C2 - Spalling
C3 - Faulting
C4 - Site Factor

C1: 0.8203	C2: 0.4417
C3: 1.4929	C4: 25.24

Reliability Standard Deviation

5.4

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$
$$CRK = \frac{100}{1 + C4\ FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05

PCC Reliability Cracking Standard Deviation

Pow(57.08*CRACK,0.33) + 1.5

APPENDIX L

AASHTO 1993 20 AND 30-YEAR DESIGN LIFE OF FLEXIBLE PAVEMENT

OUTPUT SHEETS

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	3,050,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **3.9795**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
6.4843	≤	6.4843

Full HMA:

Depth=	**9.04**	in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**5.04**	in	Use 5.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10
If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

3,050,000 = Design Life ESALs

SN = 3.979 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.48430

=

Thickness Equation= B = 6.48429 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
4.98	B
4153.25499	C
0.66340786	D
-0.05038191	E
0.200000	F
4.98	G
6.5256488	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.04
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 5.04 Use 5.5 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	5,090,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.2673**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
6.7067	≤	6.7071

Full HMA:

Depth=	**9.70**	in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**5.70**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10
If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

5,090,000 = Design Life ESALs

SN = 4.267 = Required SN when B equals (or slightly exceeds) A

Log_{10}ESAL = A = 6.70672
=
Thickness Equation= B = 6.70709 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.27	B
5559.65179	C
0.59677491	D
-0.05600731	E
0.200000	F
5.27	G
6.75407427	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.70
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 5.70 Use 6.0 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	6,240,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.3860**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
6.7952	≤	6.7956

Full HMA:

Depth=	**9.97**	in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**5.97**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10
If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

6,240,000 = Design Life ESALs

SN = 4.386 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.79518

=

Thickness Equation= B = 6.79558 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.39	B
6241.2611	C
0.57528509	D
-0.05809946	E
0.200000	F
5.39	G
6.84465303	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.97
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 5.97 Use 6.0 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

27 1/2 Road
(30-year Design Life)

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	10,410,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.6950**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
7.0175	≤	7.0175

Full HMA:

Depth=	**10.67**	in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**6.67**	in	Use 7.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10
If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

10,410,000 = Design Life ESALs

SN = 4.695 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.01745
=
Thickness Equation= B = 7.01754 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.70	B
8337.18177	C
0.5312194	D
-0.06291893	E
0.200000	F
5.70	G
7.0714336	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.67
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 6.67 Use 7.0 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	9,350,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.6290**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
6.9708	≤	6.9711

Full HMA:

Depth= **10.52** in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**6.52**	in	Use 7.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10
If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

9,350,000 = Design Life ESALs

SN = 4.629 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.97081
=
Thickness Equation= B = 6.97109 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.63	B
7847.62389	C
0.53940525	D
-0.06196409	E
0.200000	F
5.63	G
7.02403649	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.52
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 6.52 Use 7.0 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	16,620,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.9926**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
7.2206	≤	7.2207

Full HMA:

Depth= **11.35** in

HMA over ABC:

Depth ABC= **16** in

Depth HMA= **7.35** in — Use 7.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

If Mr is based on R-Value ===> R-Value = 10
Mr = 6,482 psi For Post-2015 CDOT Correlation

16,620,000 = Design Life ESALs

SN = 4.993 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.22063
=
Thickness Equation= B = 7.22073 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.99	B
10859.5785	C
0.50074056	D
-0.06674865	E
0.200000	F
5.99	G
7.27846038	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 11.35
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 7.35 Use 7.5 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	16,320,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **4.9810**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
7.2127	≤	7.2130

Full HMA:

Depth= **11.32** in

HMA over ABC:

Depth ABC= **16** in
Depth HMA= **7.32** in Use 7.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

If Mr is based on R-Value ===> R-Value = 10
Mr = 6,482 psi For Post-2015 CDOT Correlation

16,320,000 = Design Life ESALs

SN = 4.981 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.21272
=
Thickness Equation= B = 7.21301 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.98	B
10751.1776	C
0.5017563	D
-0.06661352	E
0.200000	F
5.98	G
7.27060279	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 11.32
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 7.32 Use 7.5 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

INITIAL VALUES

Initial Serviceability Index=	2.5
Final Serviceability Index=	2
Overall Standard Deviation, So=	0.44
Reliability, R (percent)=	90
Standard Normal Deviate (ZR)=	-1.282
Structural Coefficient of HMA=	0.44
Structural Coefficient of ABC=	0.11
Design Life ESALs=	27,250,000
R-Value=	**10**

INTERMEDIATE CALCULATIONS

Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5

FINAL CALCULATIONS

SN= **5.3230**

Such That:

Log_{10}ESAL	≤	**Thickness Equation**
7.4354	≤	7.4355

Full HMA:

Depth=	**12.10**	in

HMA over ABC:

Depth ABC=	**16**	in	
Depth HMA=	**8.10**	in	Use 8.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

ESAL's = the number of Equivalent 18-kip axle loads for the appropriate design period
Mr = subgrade Resilient Modulus in pounds per square inch (psi)

R-Value = 10

If Mr is based on R-Value ===> Mr = 6,482 psi For Post-2015 CDOT Correlation

27,250,000 = Design Life ESALs

SN = 5.323 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.43537

=

Thickness Equation= B = 7.43548 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
6.32	B
14347.9982	C
0.47624757	D
-0.07018147	E
0.200000	F
6.32	G
7.49664098	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.11

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 12.10
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.0

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 8.10 Use 8.5 inches

Reliability, R (percent)	Standard Normal Deviate(Z_R)
50	0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
98	-2.054

APPENDIX M

AASHTO 1998 RIGID PAVEMENT DESIGN OUTPUT SHEETS

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

Results

Project # 599.76
Description: G Road Segment

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	6.58	million
Initial Serviceability	4.5	
Terminal Serviceability	2	
28-day Mean PCC Modulus of Rupture	650	psi
Elastic Modulus of Slab	3,400,000	psi
Elastic Modulus of Base	12,000	psi
Base Thickness	8.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**8.76**	in

Temperature Differential

Mean Annual Wind Speed	8.8	mph
Mean Annual Air Temperature	50.3	^{o}F
Mean Annual Precipitation	15.3	in
Maximum Positive Temperature Differential	**7.13**	^{o}F

Modulus of Subgrade Reaction

Period	Description	Subgrade k-Value, psi

Seasonally Adjusted Modulus of Subgrade Reaction		psi/in
Modulus of Subgrade Reaction Adjusted for Rigid Layer and Fill Section		psi/in

Traffic

Performance Period		years
Two-Way ADT		
Number of Lanes in Design Direction		
Percent of All Trucks in Design Lane		
Percent Trucks in Design Direction		

Vehicle Class	Percent of ADT	Annual Growth	Initial Truck Factor	Annual Growth in Truck Factor	Accumulated 18-kip ESALs (millions)

Total Calculated Cumulative ESALs		million

Faulting

Doweled

Dowel Diameter	1.25	in
Drainage Coefficient	1.00	
Average Fault for Design Years with Design Inputs	**0.04**	in
Criteria Check **PASS**		

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.08**	in
Criteria Check **FAIL**		

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

Results

Project # 599.76
Description: 27 1/2 Road Segment

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	13.46	million
Initial Serviceability	4.5	
Terminal Serviceability	2	
28-day Mean PCC Modulus of Rupture	650	psi
Elastic Modulus of Slab	3,400,000	psi
Elastic Modulus of Base	12,000	psi
Base Thickness	8.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**9.82**	in

Temperature Differential

Mean Annual Wind Speed	8.8	mph
Mean Annual Air Temperature	50.3	^{o}F
Mean Annual Precipitation	15.3	in
Maximum Positive Temperature Differential	**7.78**	^{o}F

Modulus of Subgrade Reaction

Period	Description	Subgrade k-Value, psi

Seasonally Adjusted Modulus of Subgrade Reaction psi/in

Modulus of Subgrade Reaction Adjusted for Rigid Layer
and Fill Section psi/in

Traffic

Performance Period years
Two-Way ADT
Number of Lanes in Design Direction
Percent of All Trucks in Design Lane
Percent Trucks in Design Direction

Vehicle Class	Percent of ADT	Annual Growth	Initial Truck Factor	Annual Growth in Truck Factor	Accumulated 18-kip ESALs (millions)

Total Calculated Cumulative ESALs million

Faulting

Doweled

Dowel Diameter	1.25	in
Drainage Coefficient	1.00	

Average Fault for Design Years with Design Inputs	**0.05**	in
Criteria Check **PASS**		

Nondoweled

Drainage Coefficient 1

Average Fault for Design Years with Design Inputs	**0.09**	in
Criteria Check **FAIL**		

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

Results

Project # 599.76
Description: Horizon Drive Segment

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	20.19	million
Initial Serviceability	4.5	
Terminal Serviceability	2	
28-day Mean PCC Modulus of Rupture	650	psi
Elastic Modulus of Slab	3,400,000	psi
Elastic Modulus of Base	12,000	psi
Base Thickness	8.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**10.47**	in

Temperature Differential

Mean Annual Wind Speed	8.8	mph
Mean Annual Air Temperature	50.3	^{o}F
Mean Annual Precipitation	15.3	in
Maximum Positive Temperature Differential	**8.11**	^{o}F

Modulus of Subgrade Reaction

Period	Description	Subgrade k-Value, psi

Seasonally Adjusted Modulus of Subgrade Reaction		psi/in
Modulus of Subgrade Reaction Adjusted for Rigid Layer and Fill Section		psi/in

Traffic

Performance Period		years
Two-Way ADT		
Number of Lanes in Design Direction		
Percent of All Trucks in Design Lane		
Percent Trucks in Design Direction		

Vehicle Class	Percent of ADT	Annual Growth	Initial Truck Factor	Annual Growth in Truck Factor	Accumulated 18-kip ESALs (millions)

Total Calculated Cumulative ESALs		million

Faulting

Doweled

Dowel Diameter	1.25	in
Drainage Coefficient	1.00	
Average Fault for Design Years with Design Inputs	**0.05**	in
Criteria Check **PASS**		

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.09**	in
Criteria Check **FAIL**		

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

Results

Project # 599.76
Description: Horizon Drive and G Road Roundabout

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	35.22	million
Initial Serviceability	4.5	
Terminal Serviceability	2	
28-day Mean PCC Modulus of Rupture	650	psi
Elastic Modulus of Slab	3,400,000	psi
Elastic Modulus of Base	12,000	psi
Base Thickness	8.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**11.43**	in

Temperature Differential

Mean Annual Wind Speed	8.8	mph
Mean Annual Air Temperature	50.3	^{o}F
Mean Annual Precipitation	15.3	in
Maximum Positive Temperature Differential	**8.52**	^{o}F

Modulus of Subgrade Reaction

Period	Description	Subgrade k-Value, psi

Seasonally Adjusted Modulus of Subgrade Reaction		psi/in
Modulus of Subgrade Reaction Adjusted for Rigid Layer and Fill Section		psi/in

Traffic

Performance Period		years
Two-Way ADT		
Number of Lanes in Design Direction		
Percent of All Trucks in Design Lane		
Percent Trucks in Design Direction		

Vehicle Class	Percent of ADT	Annual Growth	Initial Truck Factor	Annual Growth in Truck Factor	Accumulated 18-kip ESALs (millions)

Total Calculated Cumulative ESALs		million

Faulting

Doweled

Dowel Diameter	1.25	in
Drainage Coefficient	1.00	
Average Fault for Design Years with Design Inputs	**0.06**	in

Criteria Check **PASS**

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.10**	in

Criteria Check **FAIL**