Geotechnical Investigation Report
F 1/2 Road Parkway and 24 1/2 Road Widening
City of Grand Junction, Colorado
RockSol Project No. 599.37
August 2, 2023

Prepared for:

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

Attention: Brendan Hines, P.E., Project Engineer

Prepared by:

RockSol Consulting Group, Inc.
566 W Crete Circle, Unit 2
Grand Junction, Colorado 81505
(970) 822-4350

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1.0 PROJECT OBJECTIVE AND DESCRIPTION

This report documents the geotechnical engineering investigation performed by RockSol Consulting Group, Inc. (RockSol) for the F 1/2 Road Parkway and 24 1/2 Road Widening Project in the City of Grand Junction, Colorado (see Image 1, *Site Vicinity Map*).

Image 1 – Site Vicinity Map (Google Earth)

This project focuses on the design and construction of two sites for the City of Grand Junction. Site 1 includes new construction for F ½ Road Parkway connecting 24 Road and 25 Road, as well as major improvements of existing adjacent roads/driveways, a new roundabout at the 24 ½ Intersection, and a new realignment of the F ½ Road and 25 Road intersection. F ½ Road Parkway and 25 Road will be 4-lane roads with turn lanes and a center median.

In addition to the new parkway, major improvements will be made to 25 Road beginning at the intersection with F Road/Patterson Road, up to the intersection with Blichmann Avenue. North of Blichmann Avenue, 25 Road will be accessed by a new intersection off the diagonal portion of the parkway adjacent to the Heritage Heights development. In addition to the parkway and 25 Road work, improvements will be made to 25 Road north of F ½ Road, as well as to F ½ Road east of 25 Road.

Improvements are planned for F ¼ Road, Zenith Lane, and Flat Top Lane, which will continue east and connect with 25 Road. Lastly, the western leg of Foresight Circle will be modified at the connection to 25 Road.

Included in the new parkway construction will be an extension of the existing box culvert to the north that carries Leach Creek water under F ½ Road to accommodate the Parkway Widening.

Site 2 consists of widening and reconstruction of 24 ½ Road, from F 3/8 Road north to Jack Creek Road (Canyon View Park), approximately 1.5 miles. Construction will include minor widening of the existing two lanes to incorporate a center turn lane, shoulder widening, and sidewalks to accommodate pedestrian and bike traffic. This construction will be completed in a separate project, but the City of Grand Junction would like to complete the Geotechnical Work at the same time as F ½ Parkway.

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 the field and laboratory data obtained, geological setting and conditions, geotechnical design parameters for the proposed structures, project site improvements, and roadway pavement thickness 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) 2021 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 farm, commercial, residential, and undeveloped land immediately surrounds the project limits. The Colorado River is located approximately 0.5 miles southwest of the project site.

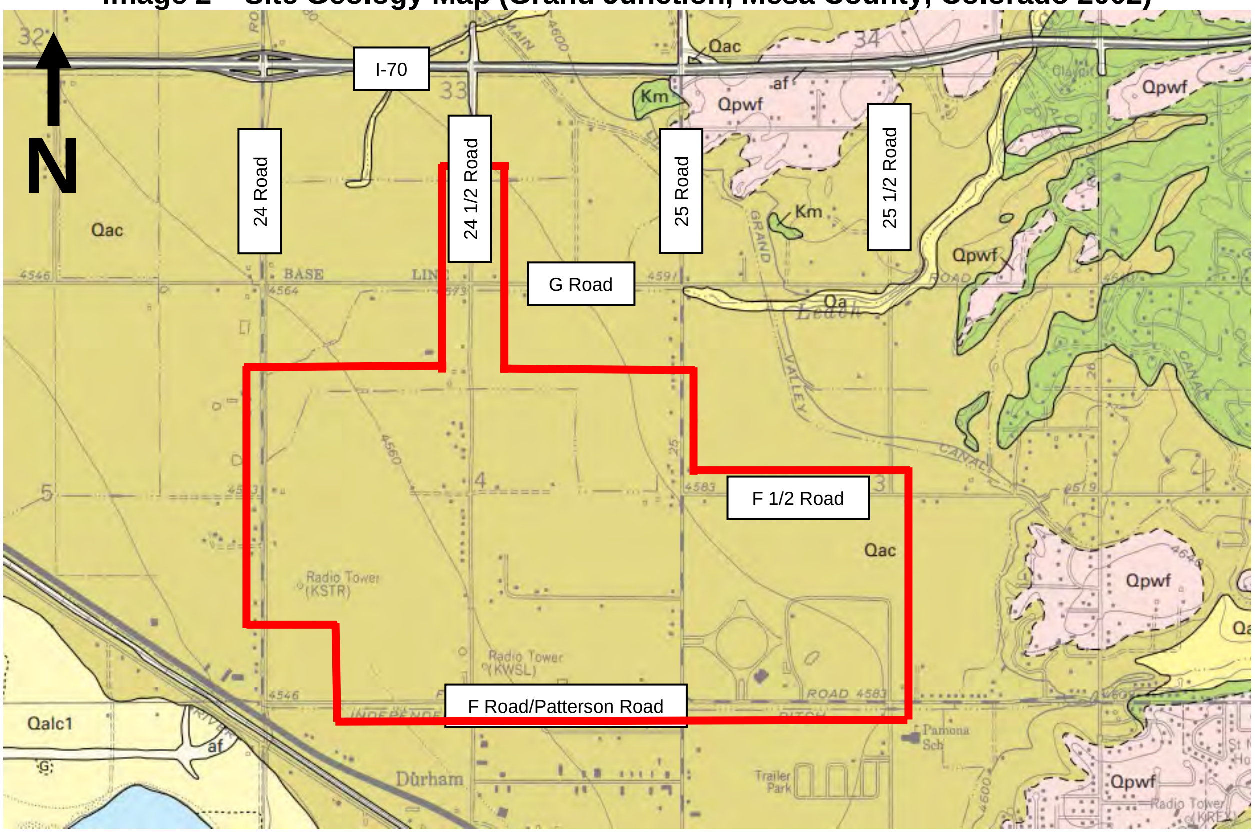
Currently, 24 ½ Road consists of one travel lane in each direction within Site 2 project limits. 25 Road currently consists of two lanes, one in each direction and a center turn lane within the project vicinity. F ½ Road consists of one travel lane in each direction with a center turn lane. The existing lanes are approximately 12 feet wide and surfaced with asphalt pavement throughout the project vicinity.

Topography throughout the project limits consist of nearly flat slopes in all directions. Within the project vicinity, Main Line Grand Valley Canal crosses 25 ½ Road between G road and F ½ Road, and North Leach Creek runs along the south side of G Road and then along the east side of 24 Road.

3.0 GEOLOGICAL CONDITIONS

Based on information presented in the United States Geological Survey (USGS) Geologic Map (See Image 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, alluvium and colluvium, undivided, (Holocene and late Pleistocene) (Qac) is mapped at the project site, as well as at the immediate surrounding areas. Alluvium generally consists of silt, sand and gravel and 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 in two locations northeast of the project site. This correlates with the Claystone/shale bedrock identified at the bottom of Boreholes LC-2 and LC-3.

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



4.0 SUBSURFACE EXPLORATION

For this investigation, RockSol completed a total of 25 boreholes identified as B-1 through B-6, F-1 through F-16, and LC-1 through LC-3. (See Figures 1 through 5).

Boreholes F-1 through F-16 were drilled for the purpose of improvements, modifications, and new alignments within Site 1, including the design of the new F ½ Road connecting 24 Road and 25 Road. Boreholes B-1 through B-6 were drilled along 24 ½ Road for the purpose of rehabilitation and road widening within Site 2 (See Figures 1 through 4). Boreholes LC-1 through LC-3 were drilled at the intersection of 24 Road and F ½ Road (See Figure 1). To assist with development of pavement thickness and structure foundation recommendations, “B” and “F” boreholes extended to approximate depths of 5 feet to 10 feet and “LC” boreholes extended to approximate depths of 20 feet to 40 feet for characterization of subsurface conditions, including depths to bedrock and groundwater.

The locations of the geotechnical investigation boreholes are summarized below in Table 1. The boreholes were drilled between October 4, 2021, and October 20, 2021.

Table 1 – Borehole and Pavement Core Location Summary

Borehole ID	Borehole Location
B-1	24 ½ Road, at Tennis Court, southbound lane
B-2	24 ½ Road, just west of 6 Road, southbound lane
B-3	24 ½ Road, just south of roundabout, northbound lane
B-4	675 24 ½ Road, southbound shoulder
B-5	24 ½ Road, just north of Ajay Avenue, northbound lane
B-6	24 ½ Road at F 3/8 Road intersection, northbound lane
F-1	New F ½ Rd, ~240 feet east of existing F ½ Road and Market Street
F-2	Field along new proposed F ½ Road
F-3	Field near 24 ½ Road and new F ½ Road
F-4	Northeast side of 24 ½ Road and F ½ Road
F-5	24 ½ Road, ~135 feet north of F 3/8 Road
F-6	Southeast side of 24 ½ Road and F ½ Road
F-7	24 ¾ Road and west side of new F ½ Road
F-8	New F ½ Road alignment, vacant land
F-9	East end of proposed F ½ Road, west of 25 Road
F-10	653 25 Road (private property)
F-11	25 Road, front 645 25 Road, northbound lane
F-12	Corner of F 1/2 Road and 25 Road, ~18 feet off 25 Road
F-13	F ¼ Road, westbound lane
F-14	25 Road, ~320 feet south of F ¼ Road
F-15	Foresight Circle, ~250 feet east of 25 Road, eastbound lane
F-16	Field north of 6.5 Climb Gym (new road alignment)
LC-1	Northeast corner of 24 Road and F ½ Road (wingwall)
LC-2	Northeast corner of F ½ Road and 24 Road intersection
LC-3	Southeast corner of F ½ Road and 24 Road intersection

Boreholes were advanced with a truck mounted Simco 2800 drill rig using 4.25-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 and resistance of the soil to penetration of the sampler was performed using modified California barrel and standard split spoon samplers. Penetration Tests were performed using an automatic lift system and a hammer weighing 140 pounds falling 30 inches. The modified California barrel sampler has an outside diameter of approximately 2.5 inches and an inside diameter of 2 inches. The standard split spoon sampler used had an outside diameter of 2 inches and an inside diameter of 1⅜-inches. Brass tube liners were used with the modified California barrel sampler. Brass tube liners are not used with the standard split spoon sampler.

The standard split spoon sampling method is the Standard Penetration Test (SPT) described by ASTM Method D-1586.

The modified California Barrel sampling method is similar to the SPT test with the difference being the sampler dimensions and the number of 6-inch intervals driven with the hammer per ASTM D-3550. It is RockSol's experience that blow counts obtained with the modified California sampler tend to be slightly greater than a standard split spoon sampler.

The boreholes were logged in general accordance with ASTM D-2488. Penetration resistance values (blow counts) were recorded for each sampling event. Blow counts, when properly evaluated, indicate the relative density or consistency of the soils. Depths at which the samples were taken, the type of sampler used, and the blow counts that were obtained are shown on the Borehole Logs (See Appendix A).

5.0 SURFACE AND SUBSURFACE CONDITIONS

The surface and subsurface materials encountered by RockSol at our borehole locations included asphaltic pavement, road base (aggregate base course/pit run material), topsoil, fill material, native soils, and sedimentary bedrock. A brief description of the materials encountered is presented below.

5.1 Existing Asphalt Pavement Sections

Asphalt pavement was encountered in Boreholes B-1, B-3, B-5, B-6, F-5, F-11, and F-13 through F-15. Asphalt pavement ranged in thickness from 2 to 7 inches and was underlain by 4 to 12 inches of aggregate base course (ABC). 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)	ABC Thickness (in)
B-1	6.0	11.0
B-3	5.0	12.0
B-5	7.0	11.0
B-6	5.0	11.0
F-5	6.0	6.0
F-11	6.0	6.0
F-13	2.0	10.0
F-14	6.0	4.0
F-15	3.0	9.0

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

5.2 Fill Material

Fill material was encountered in Boreholes B-6, F-5, F-11, F-14, and F-15 and extended to depths ranging from 2 feet to 4 feet below existing grades. Fill material generally consisted of a rocky and gravelly sand mixture and is locally described as pit-run material.

5.3 Native Subgrade Soils

Native soils were encountered at the ground surface of Boreholes B-2, B-4, F-1 through F-4, F-6 through F-10, F-12, F-16, and LC-1 through LC-3, and below existing pavement and fill materials at all other borehole locations. Native soils extended to maximum depths drilled at the borehole locations, except for Borehole LC-3. Native soils encountered generally consisted of very soft to very stiff, moist to wet, brown, sandy to silty clay to clay with sand or gravel. At Borehole LC-2, a medium stiff to very hard, brown to gray, very moist, sand with silt and gravel was encountered below the sandy clay layer, and at Borehole LC-3, a native sandy gravel was located at the ground surface. The native soils encountered by RockSol are generally consistent with the alluvium and colluvium materials identified on the USGS Geological Map (See Image 2) found in Section 3.0 of this report.

5.4 Sedimentary Bedrock

Claystone/shale bedrock was encountered in Boreholes LC-2 and LC-3 at depths of approximately 37 feet and 40 feet, respectively, below existing grades. Claystone/Shale was identified in the field as slightly moist, gray, and medium stiff to very hard, and is consistent with the Mancos Shale Formation mapped near the project site on the USGS Geological Map (Image 2). Bedrock was not encountered to the depth drilled at any other borehole locations for this project.

5.5 Groundwater

Groundwater was encountered during drilling/sampling activities at borehole locations B-2 and LC-1 through LC-3 at approximate depths ranging from 7 feet to 10 feet below existing grades at the time of drilling operations. Additionally, piezometers were installed in Boreholes LC-2 and LC-3 for continued groundwater monitoring. Depth to groundwater where encountered is recorded in Table 3, *Approximate Depths to Groundwater* and presented on individual borehole logs in Appendix A. Depth to sedimentary bedrock, if encountered is included in Table 3.

Table 3 – Approximate Depths to Groundwater

Borehole I.D.	Depth to Bedrock (feet)	Depth to Groundwater at time of drilling, (feet)	Depth to Groundwater 11/1/2021, (feet)	Depth to Groundwater 11/30/2021, (feet)	Depth to Groundwater 12/30/2021, (feet)
B-2	-	7.0	-	-	-
LC-1	-	7.0	-	-	-
LC-2	37.0	7.0	5.1	4.8	7.0
LC-3	40.0	10.0	10.3	10.6	10.0

Depth to groundwater is subject to change depending on climatic conditions, water flows in North Leach Creek and Main Line Grand Valley Canal, 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:

- Natural Moisture Content (ASTM D-2216)
- Percent Passing No. 200 Sieve (ASTM D-1140)
- Liquid and Plastic Limits (ASTM D-4318)
- Dry Density (ASTM D-2937)
- 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)
- Swell Test (Denver Swell Test, modified from ASTM D-4546)
- Resistance Value (AASHTO T-190)

R-Values (Resistance Values) were tested by Cesare, Inc. and water-soluble chlorides were tested by Colorado Analytical Laboratories. All other laboratory tests were performed by RockSol. Laboratory test results are presented in Appendix B and are also summarized on the Borehole Logs presented in Appendix A.

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. Swell tests were used to determine the swell or consolidation characteristics of the subsurface materials. 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 B.

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 subgrade soils tested generally varied between A-4 and A-6 AASHTO soil types. A summary of the roadway subgrade soil classifications is presented in Table 4 and summarized by group index in Table 5.

Table 4 – Roadway Subgrade Soil Classifications

Borehole Location	Depth (feet)	AASHTO Classification
B-1	2-10	A-6 (9)
B-2	0-7	A-6 (7)
B-3	2-9	A-6 (8)
B-5	3-10	A-6 (16)
B-6	4-10	A-4 (0)
F-1	0-5	A-6 (17)
F-2	0-6	A-6 (17)
F-3	0-4	A-6 (13)
F-4	0-5	A-6 (10)
F-5	2-10	A-6 (8)
F-6	0-7	A-6 (10)
F-7	0-5	A-6 (8)
F-8	0-5	A-4 (3)
F-9	0-3	A-6 (13)
F-10	0-5	A-4 (7)
F-16	0-10	A-6 (8)
LC-1	0-5	A-6 (7)
LC-2	0-5	A-4 (4)
LC-3	2-4	A-6 (7)

Table 5 – Soil Classifications by Group Index Range

AASHTO Soil Type	Group Index Range	Number of Tests
A-4	0 – 7	4
A-6	7 – 10	10
A-6	11 – 17	6

7.2 Swell/Consolidation Potential of Subgrade Soils

Based on swell test results and plasticity index (PI) testing, the subgrade soils encountered within the upper 3 to 10 feet of the pavement surface exhibit low consolidation potential and no swell potential (-1.7 percent consolidation to 0.0 percent swell under 500 pounds per square foot (psf) surcharge pressure).

Based on the swell test results and subgrade soil classifications obtained, special mitigation methods for expansive soil are not deemed necessary for new pavement construction or for the proposed improvements planned for this project.

However, based on consolidation and penetration data obtained from the boreholes drilled, special mitigation is recommended for design and construction of shallow foundation systems being considered (See Section 9) due to settlement potential and constructability. Mitigation may consist of over excavation and replacement with coarse, granular material with geosynthetic fabrics and geogrids to help stabilize shallow foundation soils.

7.3 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 6 and in the CDOT Standard Specifications for Road and Bridge Construction, dated 2022. Water-soluble Sulfate Testing Results are summarized in Table 7.

Table 6: Concrete Sulfate Exposure Class

Water-Soluble Sulfate (SO_4) in Dry Soil, (%)	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	1,500 to 10,000	Class 2
2.01 or greater	10,001 or greater	Class 3

Table 7 – Water-Soluble Sulfate Testing Summary

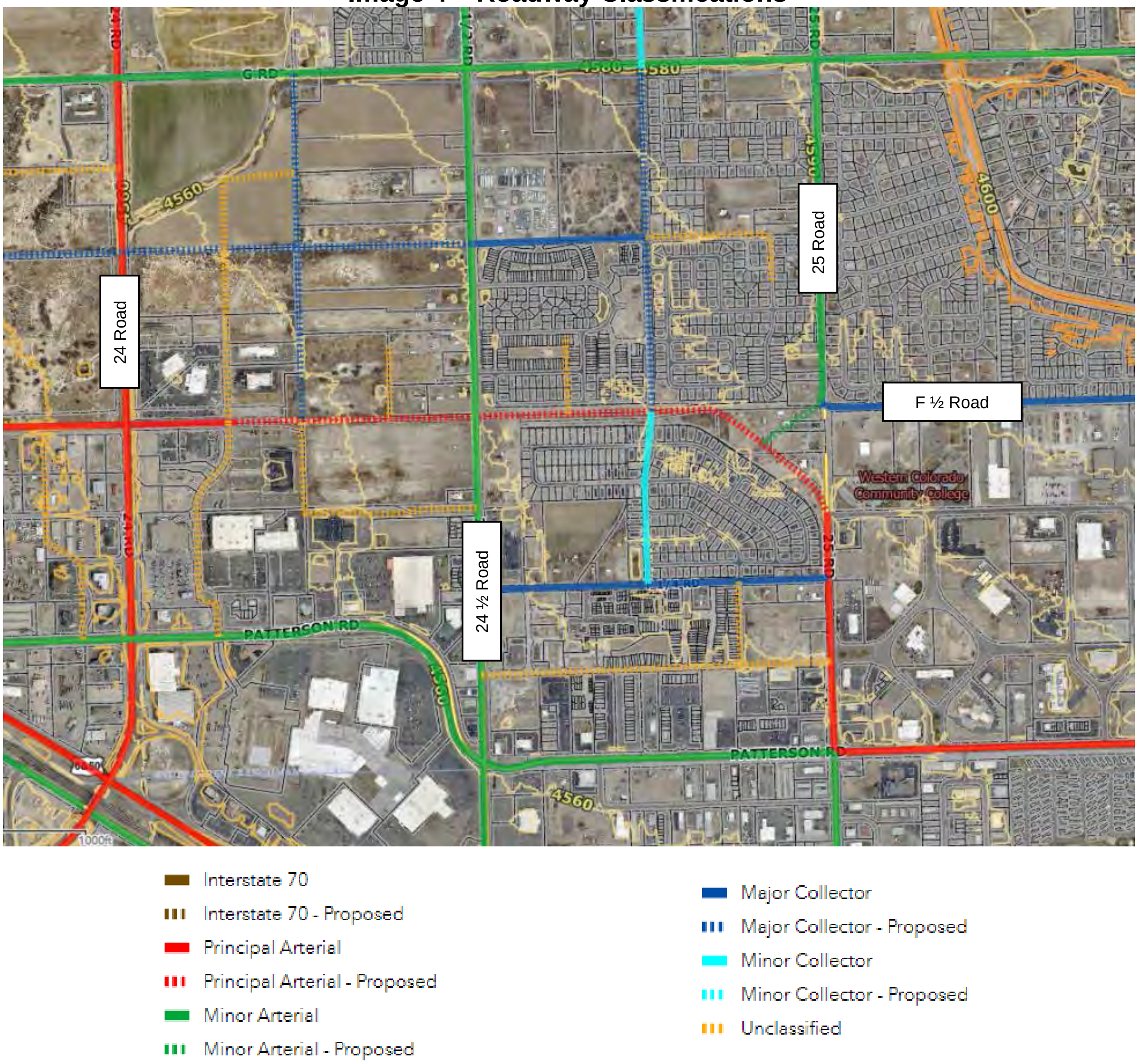
Borehole I.D.	Sample Depth (Feet)	Water-Soluble Sulfate (SO_4) in dry soil, percent	Cementitious Material Requirements
F-1	0-5	0.38	Class 2
F-4	0-5	0.16	Class 1
F-5	2-10	0.26	Class 2
F-8	0-5	0.28	Class 2
F-10	0-5	1.04	Class 2
F-16	0-10	0.14	Class 1
LC-1	0-5	0.51	Class 2
LC-2	20	0.47	Class 2
LC-3	20	0.19	Class 1
LC-3	30	0.15	Class 1

The concentration of water-soluble sulfates measured in soil samples obtained from RockSol's exploratory boreholes ranged from 0.14 percent to 1.04 percent by weight. Based on the results of the water-soluble sulfate testing, **Class 2** cementitious material mix design requirements for concrete exposed to water soluble sulfates in soils is recommended. Refer to CDOT's current *Standard Specifications for Road and Bridge Construction Section 601* for concrete mixtures that satisfy appropriate sulfate exposure *Class* requirements.

8.0 PAVEMENT DESIGN RECOMMENDATIONS

24 Road and F ½ Road are classified as principal arterials, 24 ½ Road and F Road/Patterson Road are classified as minor arterials. All other roadways applicable to Sites 1 and 2 are classified as minor collector or unclassified roadways by the City of Grand Junction. The roadway classification for this project were found on the website for the City of Grand Junction's Transportation Map as shown in Image 4.

Image 4 – Roadway Classifications



New pavement is planned for the New F ½ Road connecting 24 Road and 25 Road, as well as the reconstruction of 24 ½ Road from F 3/8 Road to Jack Creek, and a new F ½ Road and 24 ½ Road roundabout. New pavement is also planned for 25 Road and the new 25 Road and F ½ Road intersection, as well as for the reconstruction of Foresight Circle and F ¼ 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).

The correlation of subgrade soil R-Value to Resilient Modulus for this report was performed using equation 4-1 from CDOT's 2021 Mechanistic-Empirical Pavement Design Manual.

8.1 Traffic Loading

Traffic loading was estimated for a 30-year flexible pavement design life and 30-year rigid pavement design life in accordance with the City of Grand Junction Municipal Code (Subsection 29.32.030). RockSol included the estimated traffic loading for a 20-year flexible pavement design life since it is recommended in CDOT's Pavement Design Manual for reconstruction using flexible pavement. The current average daily traffic (ADT) for 24 ½ Road was supplied to RockSol by the Transportation Engineer from the City of Grand Junction. The ADT for 24 Road and 25 Road were obtained from the traffic counts found on the website for the City of Grand Junction's Transportation Map. The ADT for F ½ Road was estimated to be 16,000 by the City of Grand Junction. Since this project will close the gap between 24 and 25 Roads, it was estimated by the Transportation Engineer for the City of Grand Junction that 24 ½ Road, Foresight Circle and F ¼ Roads, as well as the 24 ½ Road and F ½ Road roundabout within this area will have an increase of approximately 10 percent above the current ADT. 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 24 ½ Road. Based on the ADT from 24 ½ Road, an average of 12.9 percent trucks will be used for this project. The AADTT used for the pavement designs of roadway segments is shown in Table 9. A compound growth rate of 2.2 percent over a 20-year and 30-year design life was used to develop the 18,000-pound equivalent single axle loads (ESAL's) from the PMED calculated value. Based on CDOT's Pavement Design Manual, Cluster 1 truck percentages will be used to model the truck traffic in the PMED software. Traffic data and projections are summarized in Table 9.

Table 9 – Summary of Traffic Loading

Pavement Section	Estimated Truck Traffic	20-Year Flexible Design Life 18k ESALS	30-Year Flexible Design Life 18k ESALS	30-Year Rigid Design Life 18k ESALs
F ½ Road (Site 1)	2,100	5,510,000	9,300,000	12,020,000
24 ½ Road (Site 2)	1,078	3,770,000	6,360,000	8,230,000
24 ½ Road & F ½ Road Roundabout (Site 1)	3,178	8,330,000	14,070,000	18,190,000
25 Road (Site 1)	850	2,970,000	5,020,000	6,490,000
25 Road & F ½ Road Intersection (Site 1)	2,950	7,730,000	13,060,000	16,890,000
Foresight Circle & F ¼ Road (Site 1)	231	810,000	1,360,000	1,760,000

8.2 Pavement Subgrade Characterization

Subgrade bulk samples within the upper 5 to 10 feet of existing roadway grades were obtained at each borehole location and were tested for AASHTO soil classification. The subgrade soils tested were AASHTO classified as A-1-a, A-4, and A-6 soil types (See Sections 5.2 and 5.3).

Based on R-Value testing, a conservative R-Value of 5 with a corresponding subgrade resilient modulus value of 5,356 psi was used by RockSol as the design R-value for evaluation of new pavement constructed on the existing soils at 24 ½ Road, F ½ Road, 24 ½ Road, and F ½ Road roundabout, F ¼ Road, and Foresight Circle.

An 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 at 25 Road, and the F ½ Road and 25 Road intersection.

To provide an appropriate structural layer for Hot Mix Asphalt (HMA), RockSol recommends 12 inches of a subbase layer of non-stabilized A-1-b Pit Run (Class 3) material be included as part of the pavement design section in addition to 8 inches of Aggregate Base Course (ABC) directly underlying the pavement. A structural coefficient of 0.12 was used for Class 6 Aggregate Base Course (ABC), 0.11 for Class 3 ABC, and 0.44 for HMA. The Class 3 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 developed for new flexible and rigid 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 for rigid pavement in accordance with subsection 29.32.040 (b) of the City of Grand Junction Transportation Engineering Design Standards. The thicknesses of ABC Class 3 and Class 6 were taken from the typical sections supplied to RockSol by the City of Grand Junction. Class 2 ABC may be used in lieu of Class 3 ABC.

8.3.1 Flexible ME-Pavement Design Recommendations

A summary of the PMED recommended pavement section thicknesses for the 20 and 30-year design life of flexible pavement Site 1 and Site 2 are presented in Table 10 and the pavement design output sheets are included in Appendices C through H.

Table 10 – PMED Flexible Pavement Section Thickness Recommendations

Pavement Section	Material Type	20-year Pavement Design Thickness (inches)	30-year Pavement Design Thickness (inches)	Appendix
F ½ Road (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	C
	HMA SX(100) PG 64-22	5.5	6.5	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	14.0	14.0	
24 ½ Road (Site 2)	HMA SX(100) PG 64-28	2.0	2.0	D
	HMA SX(100) PG 64-22	5.0	6.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	10.0	10.0	
24 ½ Road & F ½ Road Roundabout (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	E
	HMA SX(100) PG 64-22	8.0	9.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	16.0	16.0	
25 Road (Site 1)	SX(100) PG 64-28	2.0	2.0	F
	SX(100) PG 64-22	5.0	6.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	10.0	10.0	
25 Road & F ½ Road Intersection (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	G
	HMA SX(100) PG 64-22	7.0	9.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	12.0	12.0	
Foresight Circle and F ¼ Road (Site 1)	HMA SX(75) PG 64-28	2.0	2.0	H
	HMA SX(75) PG 64-22	4.0	5.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	12.0	12.0	

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

8.3.2 Rigid ME-Pavement Design Recommendations

A summary of the PMED recommended pavement section thicknesses for the 30-year design life of rigid pavement Site 1 and Site 2 are presented in Table 11 and the pavement design output sheets are included in Appendices C1 through H1.

Table 11 – PMED Rigid Pavement Section Thickness Recommendations

Pavement Section	Material Type	Thickness (inches)	Appendix
F ½ Road (Site 1)	PCC	9.0	C1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
24 ½ Road (Site 2)	PCC	9.0	D1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
24 ½ Road & F ½ Road Roundabout (Site 1)	PCC	9.0	E1
	ABC Class 6	8.0	
	ABC Class 2 or 3	16.0	
25 Road (Site 1)	PCC	9.0	F1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
25 Road & F ½ Road Intersection (Site 1)	PCC	9.0	G1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
Foresight Circle and F ¼ Road (Site 1)	PCC	8.0	H1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	

PCC = Portland Cement Concrete; ABC = Aggregate Base Course

8.3.3 AASHTO 1993 Flexible Pavement Design

A summary of the AASHTO 1993 Pavement Design recommended pavement section thicknesses for the 20 and 30-year design life of flexible pavement Site 1 and Site 2 are presented in Table 12 and the pavement design output sheets are included in Appendices I through N.

Table 12 – AASHTO 1993 Flexible Pavement Section Thickness Recommendations

Pavement Section	Material Type	20-year Pavement Design Thickness (inches)	30-year Pavement Design Thickness (inches)	Appendix
F ½ Road (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	I
	HMA SX(100) PG 64-22	3.0	4.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	14.0	14.0	
24 ½ Road (Site 2)	HMA SX(100) PG 64-28	2.0	2.0	J
	HMA SX(100) PG 64-22	3.5	4.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	10.0	10.0	
24 ½ Road & F ½ Road Roundabout (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	K
	HMA SX(100) PG 64-22	3.0	5.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	16.0	16.0	
25 Road (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	L
	HMA SX(100) PG 64-22	2.5	3.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	10.0	10.0	
25 Road & F ½ Road Intersection (Site 1)	HMA SX(100) PG 64-28	2.0	2.0	M
	HMA SX(100) PG 64-22	3.5	4.0	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	12.0	12.0	
Foresight Circle and F ¼ Road (Site 1)	HMA SX(75) PG 64-28	2.0	2.0	N
	HMA SX(75) PG 64-22	1.0	1.5	
	ABC Class 6	8.0	8.0	
	ABC Class 2 or 3	12.0	12.0	

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

8.3.4 AASHTO 1998 Rigid Pavement Design

A summary of the AASHTO 1998 Pavement Design recommended pavement section thicknesses for the 30-year design life of rigid pavement Site 1 and Site 2 are presented in Table 13 and the pavement design output sheets are included in Appendices I1 through N1.

Table 13 – AASHTO 1998 Rigid Pavement Section Thickness Recommendations

Pavement Section	Material Type	Thickness (inches)	Appendix
F ½ Road (Site 1)	PCC	9.5	I1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
24 ½ Road (Site 2)	PCC	8.5	J1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
24 ½ Road & F ½ Road Roundabout (Site 1)	PCC	10.0	K1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
25 Road (Site 1)	PCC	8.5	L1
	ABC Class 6	8.0	
	ABC Class 2 or 3	10.0	
25 Road & F ½ Road Intersection (Site 1)	PCC	10.0	M1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	
Foresight Circle and F ¼ Road (Site 1)	PCC	7.0 (Note 1)	N1
	ABC Class 6	8.0	
	ABC Class 2 or 3	12.0	

Note 1: Minimum recommended thickness by AASHTO and CDOT is 7.0 inches for rigid pavement design.

RockSol recommends the pavement thicknesses shown in Table 10 for the 20-year design life or Table 11 be used since the PMED software accounts for site specific variables that AASHTO 1993 and 1998 do not. The 20-year design life is recommended since the top layer of most HMA pavements will require rehabilitation within 20 years after construction that should remove the top-down fatigue cracking along with other surface defects and there is no significant difference between the 20 and 30-year design lives for the predicted rutting and bottom-up fatigue cracking. HMA or Rigid pavement shall consist of CDOT-approved mix designs. The bottom layers of HMA should consist of Grading S or SX(100) PG 64-22 for all roads except Foresight Circle and F ¼ Road. Grading SX(75) PG 64-22 is recommended on Foresight Circle and F ¼ Road since the 20-year design traffic is less than 3,000,000 18k ESAL's. To resist rutting and thermal cracking damage, the top two inches of HMA should consist of Grading SX(100) PG 64-28 material. Grading SX(75) PG 64-28 is recommended for the top two inches of Foresight Circle and F ¼ Road. Grading SX(75) may be feasible and the top layer for all roads but will decrease the resistance to rutting. ABC should consist of material meeting CDOT Class 6 Aggregate Base Course and pit run should consist of material meeting CDOT Class 2 or 3 Aggregate Base Course per CDOT 703.03.

8.4 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-a, A-4, and A-6 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.

Where areas of unstable, wet subgrade soils are encountered, overexcavation and replacement with Class 3 Aggregate Base Course meeting the following requirements:

- Maximum Particle Dimension: 8-inches
- Percent passing No. 4 sieve: 20% min.
- Minus 200 Screen Size: 20% max.
- Plasticity Index (PI): 7 maximum

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.

9.0 CONCRETE BOX CULVERT EXTENSION DISCUSSION

As part of this project, the existing three-cell concrete box culvert (CBC) structure that carries Leach Creek water under F ½ Road will be extended to the North to accommodate the parkway widening (See Image 3). RockSol anticipates the CBC extensions will be performed in a phased approach. RockSol understands the extensions will be with precast CBC components.

Image 3 – North Side of F ½ Road CBC (Looking Southeast)

The CBC extensions will require removal of accumulated soil and vegetation and control of the water flow in Leach Creek during construction. Currently, block retaining walls are in place on the north side of the CBC structure, as well as on the south side. The walls on the west side of Leach Creek are roughly parallel with 24 Road for significant distances while the walls on the east side are relatively short in length and constructed as typical wingwalls. The wall blocks appear to be consistent with the "Redi-Rock" type of blocks. Design information and as-built plans of the retaining walls were not available from the City, so the wall backfill type and bottom of wall elevations are not confirmed. Several construction-phase images of the wall construction appear to show some type of granular material was placed behind the retaining wall on the south side of F ½ Road. A plan sheet identified as a "Record Drawing" showing an end view of the existing CBC structure and a typical detail of a RediRock Wall are shown in Appendix O.

The short, existing block retaining wall on the northeast side of the CBC structure will need to be reconstructed as part of the CBC extension. The existing block retaining wall on the northwest side of the CBC will require consideration as to whether it is left in place or modified to allow the CBC extension. An image of the west wall on the north side of the CBC is shown in Image 4.

Image 4 – North Side of F ½ Road CBC (Looking southwest)

Whether the west side retaining wall can be left in place or will require removal will depend on how the CBC will be extended. If a portion of the existing retaining wall is to be removed, RockSol anticipates temporary shoring will be required.

RockSol anticipates soft, yielding subgrade conditions will be encountered within the Leach Creek channel that will require stabilization to allow placement of the CBC extensions and wingwalls. The amount, or degree, of stabilization will depend on whether heavy equipment will need to access the bottom of the Leach Creek channel during construction or if all heavy equipment can stay out of the channel and work from the sides. It will be important that the stabilization of the CBC subgrade soils does not adversely impact, or otherwise destabilize, the existing retaining wall. Modifications to the existing retaining walls will also require continuation of the proper "behind the wall" drainage systems.

At a minimum, RockSol recommends the following subgrade stabilization and subgrade improvements for proper support of the CBC extensions. RockSol recommends ground improvement consisting of overexcavation of subgrade soils to a minimum depth of 5 feet below the bottom of the CBC bottom slab and replacement with at least 2-feet of a Class 3 Aggregate Base Course to provide a stable working platform. Over the Class 3 material, a minimum of 3 feet of crushed aggregate material meeting CDOT No. 57 Concrete Aggregate which is fully wrapped every 12-inches with a CDOT approved Class 1 stabilization/separator geotextile. The crushed aggregate and geotextile shall extend horizontally beyond the limits of the CBC a minimum of 1 foot in each direction (north/south and east/west). Placement of the aggregate material should be in horizonal lifts with a maximum lift thickness of 6 inches. Compaction of each lift with vibratory methods using lightweight equipment is recommended.

RockSol evaluated three scenarios to illustrate the issues associated with subgrade stabilization for the CBC extension in front of the existing west side retaining wall and removal of a portion of the existing wall to allow CBC extension. Each scenario was modeled with RocScience Slide program. The scenarios are identified as Case 1, Case 2, and Case 3. A summary output of each model is included in Appendix P of this report.

Case 1 was our model which simulates the existing condition of the channel and existing wall. Our model is not intended to be a precise representation of the existing conditions but a reasonable approximation. We created this model to be the basis of Cases 2 and 3. The Factor of Safety (FOS) of Case 1 was 1.48 which indicates a satisfactory FOS. The observed conditions at the existing wall would indicate satisfactory wall performance, suggesting our model is appropriate.

Case 2 was prepared to model a scenario where the existing retaining wall is left in place and a limited subexcavation is performed adjacent to the wall to remove unstable channel soils prior to replacement with suitable materials and construction of the CBC extension. For our model we assumed the subexcavation extended 3.5 feet below the bottom of the blocks placed for the wall. We also assumed the water in the channel was controlled and kept at the bottom of the excavation. In this model a FOS of 0.961 was obtained indicating movement of the wall is likely unless the bottom of the wall is stabilized with some form of temporary, or permanent, shoring. Another consideration if the existing retaining wall is left in place is the compatibility of the edge of the CBC extension with the outside edge of the wall blocks.

Case 3 was prepared to model a scenario where a portion of the existing retaining wall is removed to allow extension of the CBC structure. Our model assumed a cut slope that extended to the same subexcavation elevation noted in Case 2. The cut slope extended to the back of the existing curb and gutter of 24 Road and did not remove any of the existing roadway structure. The cut slope obtained was approximately 1H:1.25V. With traffic loading considered in the roadway the resulting FOS was 0.996, indicating slope movement is likely without temporary, or permanent, shoring or flattening the cut slope. To flatten the cut slope a portion of the existing roadway of 24 Road would need to be removed and a temporary traffic detour condition created.

10.0 EARTHWORK

New Embankment

To accommodate the new F ½ Road and widening of 24 Road, 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 8.4 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 8.4 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 construction 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.

11.0 SEISMICITY DISCUSSION

11.1 General

The City of Grand Junction uses the 2018 International Building Code (IBC-2018) for development of seismic design parameters. The IBC-2018 references the American Society of Civil Engineers 7-16 (ASCE 7-16) seismic design code. Based on the subsurface conditions encountered, it is our opinion that the subject site meets criteria for Seismic Site Class D. Shear wave velocity testing was not performed by RockSol. Seismic design parameters for Seismic Site Class D are discussed below.

For final design, RockSol recommends performing shear wave velocity testing or performing penetration tests to a depth of 100 feet if determination of Seismic Site Class C conditions is necessary, otherwise Seismic Site Class D may be used for final design. Seismic design parameters for Seismic Site Class D are discussed below.

11.2 Seismic Design Parameters

Seismic design parameters were obtained from the United States Geological Survey (USGS) Earthquake Design Maps using the 2018 International Building Code specifications which reference ASCE 7-16. Values were obtained using the USGS site: https://seismicmaps.org . Since the proposed grandstands are structures, whose primary occupancy is public assembly with an occupant load greater than 300, the grandstands qualify as risk category III per Table 1604.5 of the *IBC-2018*. Interpolated values for Peak Ground Acceleration Coefficient (PGA), Spectral Acceleration Coefficient at Period 0.2 sec (S_s), and Spectral Acceleration Coefficient at Period 1.0 sec (S_1) were obtained using the latitude and longitude for the site. The seismic acceleration coefficients obtained (data based on 0.05-degree grid spacing) are presented in Table 14.

Table 14 – Seismic Acceleration Coefficients

F 1/2 Road and 24 Road (Latitude°/Longitude°)	Peak Ground Acceleration (PGA)	Spectral Acceleration Coefficient - S_s (Period 0.2 sec)	Spectral Acceleration Coefficient - S_1 (Period 1.0 sec)
(39° 05’ 56.69”/ -108° 36’ 29.08”)	0.13	0.236	0.065

The acceleration coefficients are then used to obtain Site Factors F_a, and F_v based on the defined Site Class as shown in Tables 1613.2.3(1) and 1613.2.3(2) of the *IBC-2018*. A summary of the Site Factor values obtained are shown in Table 15.

Table 15 – Seismic Site Factor Values

F 1/2 Road and 24 Road (Latitude°/Longitude°)	F_{pga} (at zero-period on acceleration spectrum)	F_a (for short period range of acceleration spectrum)	F_v (for long period range of acceleration spectrum)
(39° 05' 56.69"/ -108° 36' 29.08")	1.54	1.6	2.4

Table 16 summarizes the Seismic Zone determination and horizontal response spectral Acceleration Coefficients (S_{D1}) and (S_{DS}) obtained for the proposed structures. Seismic Performance Zone determination is based on the value of the horizontal response spectral Acceleration Coefficient at 1.0 Seconds, S_{D1}, as determined by *Eq. 16-39* of the IBC-2018 and the horizontal response spectral Acceleration Coefficient at 0.2 Seconds, S_{DS}, as determined by *Eq. 16-38.* Values for S_1 and F_v are presented in Tables 14 and 15, shown above. The seismic performance zone was determined *IBC-2018* Tables 1613.2.5(1) and (2).

Table 16 – Seismic Performance Zone

F 1/2 Road and 24 Road (Latitude°/Longitude°)	Acceleration Coefficient (S_{D1})	Acceleration Coefficient, S_{DS}	Seismic Design Category
(39° 05' 56.69"/ -108° 36' 29.08")	0.105	0.252	B

Note: Seismic Design Category B (For Risk Category II) is assigned when $0.167g \le S_{DS} < 0.33g$

12.0 OTHER DESIGN AND CONSTRUCTION CONSIDERATIONS

Proper construction practices, in accordance with the Colorado Department of Transportation (CDOT) 2021 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.

13.0 LIMITATIONS

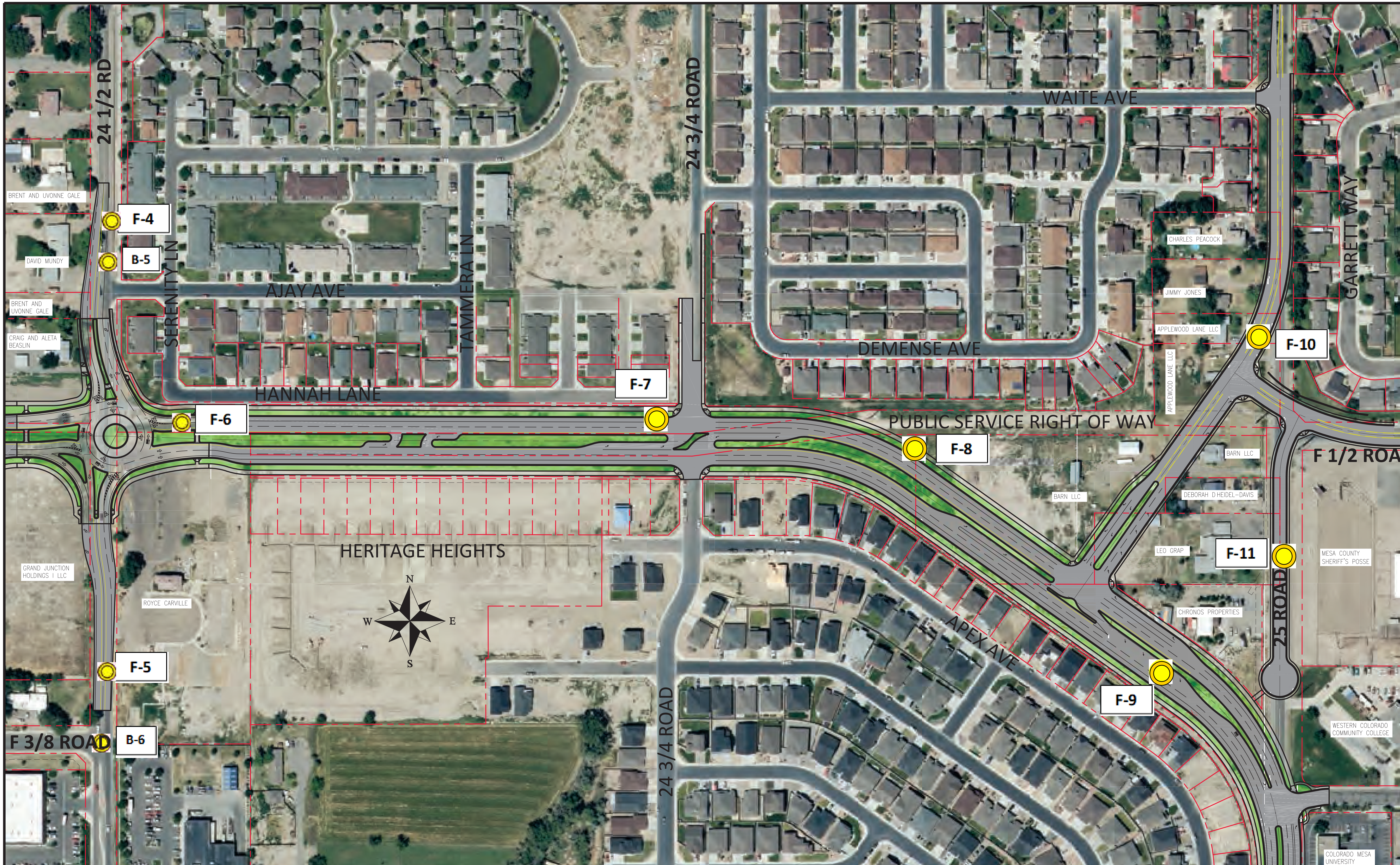
This geotechnical investigation was conducted in general accordance with the scope of work. RockSol's geotechnical practices are similar to those used in Colorado with similar soil conditions and based on our understanding of the proposed work. This report has been prepared for use by the City of Grand 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.

DESCRIPTION	DATE			
REVISION △		DRAWN BY JCS	DATE 2019	SCALES: 0 50 100 200
REVISION △		DESIGNED BY JCS	DATE 2019	
REVISION △		CHECKED BY TCP	DATE 2019	
REVISION △		APPROVED BY TCP	DATE 2019	

CITY OF Grand Junction COLORADO

PUBLIC WORKS ENGINEERING DIVISION

Figure 1: F.5 Road Parkway Conceptual Layout
24 Road to 24.5 Road



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DRAWN BY	JCS	DATE	2019
DESIGNED BY	JCS	DATE	2019
CHECKED BY	TCP	DATE	2019
APPROVED BY	TCP	DATE	2019

SCALES: 0 50 100 200

CITY OF Grand Junction COLORADO

PUBLIC WORKS ENGINEERING DIVISION

Figure 2: F.5 Road Parkway Conceptual Layout 24.5 Road to 25 Road

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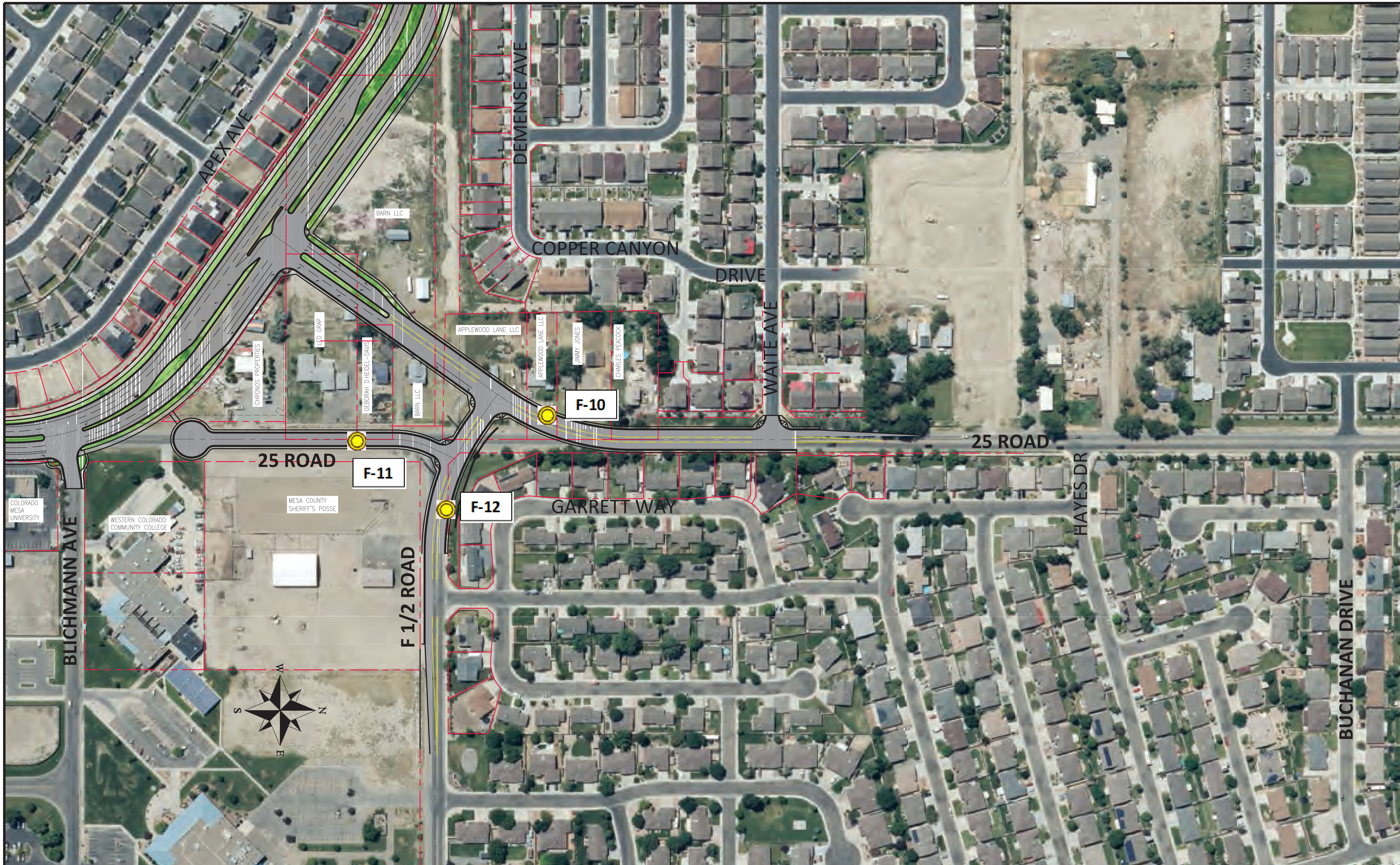
DRAWN BY JCS DATE 2019
DESIGNED BY JCS DATE 2019
CHECKED BY TCP DATE 2019
APPROVED BY TCP DATE 2019

SCALES: 0 50 100 200

CITY OF Grand Junction COLORADO

PUBLIC WORKS ENGINEERING DIVISION

Figure 3: F.5 Road Parkway Conceptual Layout
25 Road from F.5 Road to F Road/Patterson Road



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DESIGNED BY	JCS	DATE	2019
CHECKED BY	TCP	DATE	2019
APPROVED BY	TCP	DATE	2019

SCALES:

0 50 100 200

CITY OF Grand Junction COLORADO

PUBLIC WORKS
ENGINEERING DIVISION

Figure 4: F.5 Road Parkway Conceptual Layout
25 Road from Buchanan Drive to F.5 Road

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REVISION △	–

DRAWN BY	JCS	DATE	2019
DESIGNED BY	JCS	DATE	2019
CHECKED BY	TCP	DATE	2019
APPROVED BY	TCP	DATE	2019

SCALES: 0 50 100 200

CITY OF Grand Junction COLORADO

PUBLIC WORKS ENGINEERING DIVISION

Figure 5: F.5 Road Parkway Conceptual Layout 24.5 Road from Brookwillow Loop to Tennis Courts

APPENDIX A

LEGEND AND INDIVIDUAL BOREHOLE LOGS

RockSol
Consulting Group, Inc.

LEGEND

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado

LITHOLOGY

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

SAMPLE TYPE

B Bulk Sample (Auger Cuttings)

MODIFIED CALIFORNIA SAMPLER
2.5" O.D. AND 2" I.D.
WITH BRASS LINERS INCLUDED

SPLIT SPOON SAMPLER
2" O.D. AND 1 3/8" I.D.
NO LINERS

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

15/12 Indicates 15 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 12 inches.

50/11 Indicates 50 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 11 inches.

5,5,5 Indicates 5 blows, 5 blows, 5 blows of a 140 pound hammer falling 30 inches was required to drive the sampler 18 inches.

GROUND WATER LEVEL AT TIME OF DRILLING
GROUND WATER LEVEL AT 2ND MEASUREMENT
GROUND WATER LEVEL AT 3RD MEASUREMENT

BORING : B-1

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24.5 Rd., SB lane, at Tennis Court
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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										
			Aggregate Base Course, approximately 11 inches thick	B BULK									
			(Native) CLAY, with sand, moist to very moist, brown, medium stiff										
	2.5												
				MC	6/12			103.7	18.9				
	5.0		**Approximate Bulk Depth 2-10** Liquid Limit= 27 Plastic Limit= 13 Plasticity Index= 14 Fines Content= 83.3	B BULK						27	13	14	83.3
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-2

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24.5 Rd. SB Shoulder, just west of 6 Rd.
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH 7.0 ft on 10/20/21

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		(Native) CLAY, sandy, very moist, brown, very stiff										
	2.5												
			Approximate Bulk Depth 0-7 Liquid Limit= 28 Plastic Limit= 13 Plasticity Index= 15 Fines Content= 68.9	B BULK						28	13	15	68.9
	5.0												
			Bottom of hole at 7.0 feet.										

BORING : B-3

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR McCracken Drilling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24.5 Rd. NB lane, just south of roundabout
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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 5 inches thick										
			Aggregate Base Course, approximately 12 inches thick	B BULK									
			(Native) CLAY, sandy, very moist, brown, medium stiff										
	2.5												
				MC	5/12			105.8	19.6				
	5.0		**Approximate Bulk Depth 2-9** Liquid Limit= 28 Plastic Limit= 12 Plasticity Index= 16 Fines Content= 66.6	B BULK						28	12	16	66.6
	7.5												
			Bottom of hole at 9.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 675 24.5 Rd., SB shoulder
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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		(Native) CLAY, silty, very wet, brown, very stiff										
	2.5		Large rock @ 2'-3'										
	5.0												
	7.5			B BULK									
	10.0												
			Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24.5 Rd., NB lane, just north of Ajay Ave
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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										
			Aggregate Base Course, approximatley 11 inches thick										
			(Native) CLAY, very moist, brown, soft										
	2.5												
	5.0			MC	3/12			98.3	24.9				
			Approximate Bulk Depth 3-10 Liquid Limit= 33 Plastic Limit= 14 Plasticity Index= 19 Fines Content= 88.6	B BULK						33	14	19	88.6
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : B-6

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24.5 Rd. NB lane, @ F 3/8 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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 5 inches thick										
			Aggregate Base Course										
			(Fill) SAND, gravelly										
	2.5												
			(Native) CLAY, silty, with sand, very moist, brown, very stiff										
	5.0												
			Approximate Bulk Depth 4-10 Liquid Limit= 19 Plastic Limit= 15 Plasticity Index= 4 Fines Content= 73.1	B BULK						19	15	4	73.1
	7.5												
	10.0												
			Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-1

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/4/21 **COMPLETED** 10/4/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION:
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/4/21

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		(Native) CLAY, moist to very moist, brown, soft										
	2.5		**Approximate Bulk Depth 0-5** Liquid Limit= 38 Plastic Limit= 19 Plasticity Index= 19 Fines Content= 88.8 Sulfate= 0.38	B BULK			0.38			38	19	19	88.8
				MC	3/12	0.0		97.9	19.5				
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-2

PAGE 1 OF 1

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/5/21 **COMPLETED** 10/5/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Field along new proposed F.5 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, moist, brown, stiff										
	2.5												
			Approximate Bulk Depth 0-6 Liquid Limit= 37 Plastic Limit= 19 Plasticity Index= 18 Fines Content= 92.3	BULK						37	19	18	92.3
				MC	9/12			105.9	16.9				
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-3

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/5/21 **COMPLETED** 10/5/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Field near 24.5 Rd and new F.5 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, moist, brown, soft										
			Approximate Bulk Depth 0-4 Liquid Limit= 33 Plastic Limit= 18 Plasticity Index= 15 Fines Content= 92.2	B BULK						33	18	15	92.2
	2.5												
				MC	3/12			103.3	13.1				
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-4

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/5/21 **COMPLETED** 10/5/21

GROUND ELEVATION **STATION NO.**

DRILLING CONTRACTOR Colorado Drilling and Sampling

LATITUDE 39.1 **LONGITUDE** 108.6

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: NE side of 24.5 Rd. and F.5 Rd

LOGGED BY D. Compton **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

NOTES

WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, with sand, moist, brown, soft										
	2.5		**Approximate Bulk Depth 0-5** Liquid Limit= 37 Plastic Limit= 21 Plasticity Index= 16 Fines Content= 72.2 Sulfate= 0.16	B BULK			0.16			37	21	16	72.2
	5.0												
			(Native) CLAY, silty, very moist, brown, soft										
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-5

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION:
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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										
			Aggregate Base Course, approximately 6 inches thick										
			(Fill) SAND, gravelly										
	2.5		(Native) CLAY, with sand, very moist, brown, very stiff										
	5.0		**Approximate Bulk Depth 2-10** Liquid Limit= 27 Plastic Limit= 14 Plasticity Index= 13 Fines Content= 81.3 Sulfate= 0.26	B BULK			0.26			27	14	13	81.3
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-6

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/5/21 **COMPLETED** 10/5/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: SE side of 24.5 Rd and F.5 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, with gravel, moist to very moist, brown, stiff										
	2.5			MC	11/12			103.0	21.1				
			Approximate Bulk Depth 0-7 Liquid Limit= 32 Plastic Limit= 18 Plasticity Index= 14 Fines Content= 79.9	B BULK						32	18	14	79.9
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-7

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/5/21 **COMPLETED** 10/5/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 24 3/4 RD and new F.5 Rd (west side)
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, with sand, slightly moist, brown, very stiff										
	2.5		**Approximate Bulk Depth 0-5** Liquid Limit= 30 Plastic Limit= 18 Plasticity Index= 12 Fines Content= 79.6	B BULK						30	18	12	79.6
				MC	22/12			109.5	4.8				73.7
			(Native) CLAY, silt, moist, brown, stiff										
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-8

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/5/21 **COMPLETED** 10/5/21

GROUND ELEVATION **STATION NO.**

DRILLING CONTRACTOR Colorado Drilling and Sampling

LATITUDE 39.1 **LONGITUDE** 108.6

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: New F.5 alignment, Vacant land

LOGGED BY D. Compton **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

NOTES

WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, silty with sand, slightly moist to moist, brown, medium stiff										
	2.5		**Approximate Bulk Depth 0-5** Liquid Limit= 26 Plastic Limit= 19 Plasticity Index= 7 Fines Content= 75.4 Sulfate= 0.28	B BULK			0.28			26	19	7	75.4
	5.0			MC	6/12			107.2	9.2				62.4
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-9

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/5/21 **COMPLETED** 10/5/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: East end new proposed F.5, west of 25 Rd.
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/5/21

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		(Native) CLAY, moist, brown, soft **Approximate Bulk Depth 0-3** Liquid Limit= 33 Plastic Limit= 18 Plasticity Index= 15 Fines Content= 89.5	B BULK						33	18	15	89.5
	2.5												
	5.0												
			(Native) CLAY, silty, very moist, brown, soft										
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-10

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Private property, 653 25 Rd. (new road)
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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		(Native) CLAY, with sand, moist, brown, medium stiff **Approximate Bulk Depth 0-5** Liquid Limit= 30 Plastic Limit= 20 Plasticity Index= 10 Fines Content= 79.1 Sulfate= 1.04	BULK			1.04			30	20	10	79.1
	2			MC	5/12			101.4	18.3				76.5
	5		Bottom of hole at 5.0 feet.										

BORING : F-11

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: 25 Rd. NB lane, Front 645 25 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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										
			Aggregate Base Course, approximately 6 inches thick										
			(Fill) SAND, gravelly										
	2.5												
			(Native) CLAY, silty, very moist, brown, stiff										
	5.0												
				B BULK									
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-12

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Corner of F.5 and 25 Rd, ~18' off 25 Rd
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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		(Native) CLAY, sandy, very moist, brown, very soft										
	2.5												
	5.0			B BULK									
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-13

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: F 1/4 Rd. WB lane
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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 2 inches thick										
			Aggregate Base Course, approximately 10 inches thick										
			(Native) CLAY, silty, very moist, brown, very stiff										
	2.5			B BULK									
	5.0												
	7.5												
	10.0												
			Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-14

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION:
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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										
			Aggregate Base Course, approximately 4 inches thick										
			(Fill) CLAY, silty, slightly moist to moist, brown, hard	MC	24/12			114.2	10.8				
			(Fill) SAND, gavelly										
	2.5												
			(Native) CLAY, silty, very moist, brown, stiff	B BULK									
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

RockSol Consulting Group, Inc.

BORING : F-15

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/20/21 **COMPLETED** 10/20/21

GROUND ELEVATION **STATION NO.**

DRILLING CONTRACTOR Colorado Drilling and Sampling

LATITUDE 39.1 **LONGITUDE** 108.6

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: Foresight Circle, EB, ~250' E of 25 Rd

LOGGED BY D. Compton **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

NOTES

WATER DEPTH None Encountered on 10/20/21

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 3 inches thick										
			Aggregate Base Course, approximately 9 inches thick										
			(Fill) SAND, gravelly										
			(Native) CLAY, silty, very moist, brown, stiff	B BULK									
	2.5												
	5.0												
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : F-16

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 10/20/21 **COMPLETED** 10/20/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: Field N of 6.5 Climb Gym - new road
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS:
NOTES
WATER DEPTH None Encountered on 10/20/21

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		(Native) CLAY, with sand, slightly moist, brown, stiff										
	2.5			MC	14/12			95.8	7.1				96.5
	5.0		**Approximate Bulk Depth 0-10** Liquid Limit= 28 Plastic Limit= 16 Plasticity Index= 12 Fines Content= 84.7 Sulfate= 0.14	B BULK			0.14			28	16	12	84.7
	7.5												
	10.0		Bottom of hole at 10.0 feet.										

BORING : LC-1

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/4/21 **COMPLETED** 10/4/21

GROUND ELEVATION **STATION NO.**

DRILLING CONTRACTOR Colorado Drilling and Sampling

LATITUDE 39.1 **LONGITUDE** 108.6

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"

BORING LOCATION: NE corner of 24 Rd and F.5 Rd - wingwall

LOGGED BY D. Compton **HAMMER TYPE** Automatic

GROUND WATER LEVELS:

NOTES

▼ **WATER DEPTH** 7.0 ft on 10/4/21

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		(Native) CLAY, with sand, moist to wet, brown, soft										
			Approximate Bulk Depth 0-5 Liquid Limit= 27 Plastic Limit= 15 Plasticity Index= 12 Fines Content= 76.6 Sulfate= 0.51	B BULK			0.51			27	15	12	76.6
	5												
	7.0 ▼												
	10												
				SS	1/2/2				28.5				84.1
	15												
	20												
				SS	1/2/2				29.5				49.5
			Bottom of hole at 21.5 feet.										

BORING : LC-2

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/4/21 **COMPLETED** 10/4/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: NE Corner of F.5 Rd and 24 Rd underpass
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** 7.0 ft on 10/4/21
NOTES
2ND DEPTH 5.1 ft on 11/1/21 **3RD DEPTH** 4.8 ft on 11/30/21

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	FINES CONTENT (%)
	0		(Native) CLAY, sandy, moist to wet, soft **Approximate Bulk Depth 0-5** Liquid Limit= 25 Plastic Limit= 15 Plasticity Index= 10 Fines Content= 68.2	BULK						25	15	10	68.2
	5												
	10			MC		-0.2		87.9	25.0				55.1
	15												
	20			SS	1/1/2		0.47		29.0				58.4
	25		(Native) SAND, with silt and gravel, slightly moist, brown to gray, medium stiff to very hard										
	30			SS	81/12				6.4	NP	NP	NP	7.7
	35												
			(Bedrock) Shale, very moist to slightly moist, gray, medium stiff to very hard										
	40			SS	50/3				15.1				42.1
			Bottom of hole at 40.3 feet.										

BORING : LC-3

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 10/4/21 **COMPLETED** 10/4/21
GROUND ELEVATION **STATION NO.**
DRILLING CONTRACTOR Colorado Drilling and Sampling
LATITUDE 39.1 **LONGITUDE** 108.6
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.25"
BORING LOCATION: SE corner of F.5 Rd and 24 Rd underpass
LOGGED BY D. Compton **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** 10.0 ft on 10/4/21
NOTES
2ND DEPTH 10.3 ft on 11/1/21 **3RD DEPTH** 10.6 ft on 11/30/21

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	SWELL POTENTIAL (%)	SULFATE (%)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
	0		(Native) GRAVEL, sandy, moist, brown, stiff	BULK									58.1
			(Native) CLAY, with sand, very moist to wet, brown, soft **Approximate Bulk Depth 0-2** Fines Content= 58.1 **Approximate Bulk Depth 2-4** Liquid Limit= 28 Plastic Limit= 15 Plasticity Index= 13 Fines Content= 74.9	BULK						28	15	13	74.9
	5			MC	4/12	-1.7		102.2	19.6				
	10			SS	1/1/1				26.6	29	16	13	94.4
	15												
	20			SS	1/1/1		0.19		34.4				83.7
	25		(Native) CLAY, with sand, slightly moist to moist, brown, hard										
	30			SS	71/10		0.15		6.2				
	35												
	40		(Bedrock) SHALE, slightly moist, gray, very hard	SS	50/1				14.8				53.2
			Bottom of hole at 40.1 feet.										

APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

RockSol Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT City of Grand Junction

PROJECT NUMBER 599.37

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

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
B-1	2-10	27	13	14		83	CL	A-6 (9)										
B-1	3								18.9	103.7								
B-2	0-7	28	13	15		69	CL	A-6 (7)										
B-3	2-9	28	12	16		67	CL	A-6 (8)										
B-3	4								19.6	105.8								
B-5	5								24.9	98.3								
B-6	4-10	19	15	4		73	CL-ML	A-4 (0)										
F-1	0-5	38	19	19		89	CL	A-6 (17)				0.38	420 @ 28.2%	8.0	0.0787			
F-1	3				0.0				19.5	97.9								
F-2	0-6	37	19	18		92	CL	A-6 (17)										
F-2	3								16.9	105.9								
F-3	0-4	33	18	15		92	CL	A-6 (13)										
F-3	4								13.1	103.3								
F-4	0-5	37	21	16		72	CL	A-6 (10)				0.16	580 @ 26.4%	8.0	0.0332			
F-5	2-10	27	14	13		81	CL	A-6 (8)				0.26	690 @ 19.0%	8.2	0.0159			
F-6	0-7	32	18	14		80	CL	A-6 (10)										
F-6	2								21.1	103.0								
F-7	0-5	30	18	12		80	CL	A-6 (8)										
F-7	3					74			4.8	109.5								
F-8	0-5	26	19	7		75	CL-ML	A-4 (3)				0.28	970 @ 19.8%	7.9	0.0157			
F-8	5					62			9.2	107.2								
F-9	0-3	33	18	15		90	CL	A-6 (13)										
F-10	0-5	30	20	10		79	CL	A-4 (7)				1.04	320 @ 25.3%	8.0	0.1012			
F-10	2					76			18.3	101.4								
F-14	1								10.8	114.2								
F-16	0-10	28	16	12		85	CL	A-6 (8)				0.14	670 @ 25.2%	8.1	0.0054			
F-16	2					97			7.1	95.8								
LC-1	0-5	27	15	12		77	CL	A-6 (7)				0.51	530 @ 19.6%	8.1	0.0334			
LC-1	12					84			28.5									
LC-1	20					50			29.5									

RockSol Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT City of Grand Junction

PROJECT NUMBER 599.37

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT LOCATION Grand Junction, Colorado

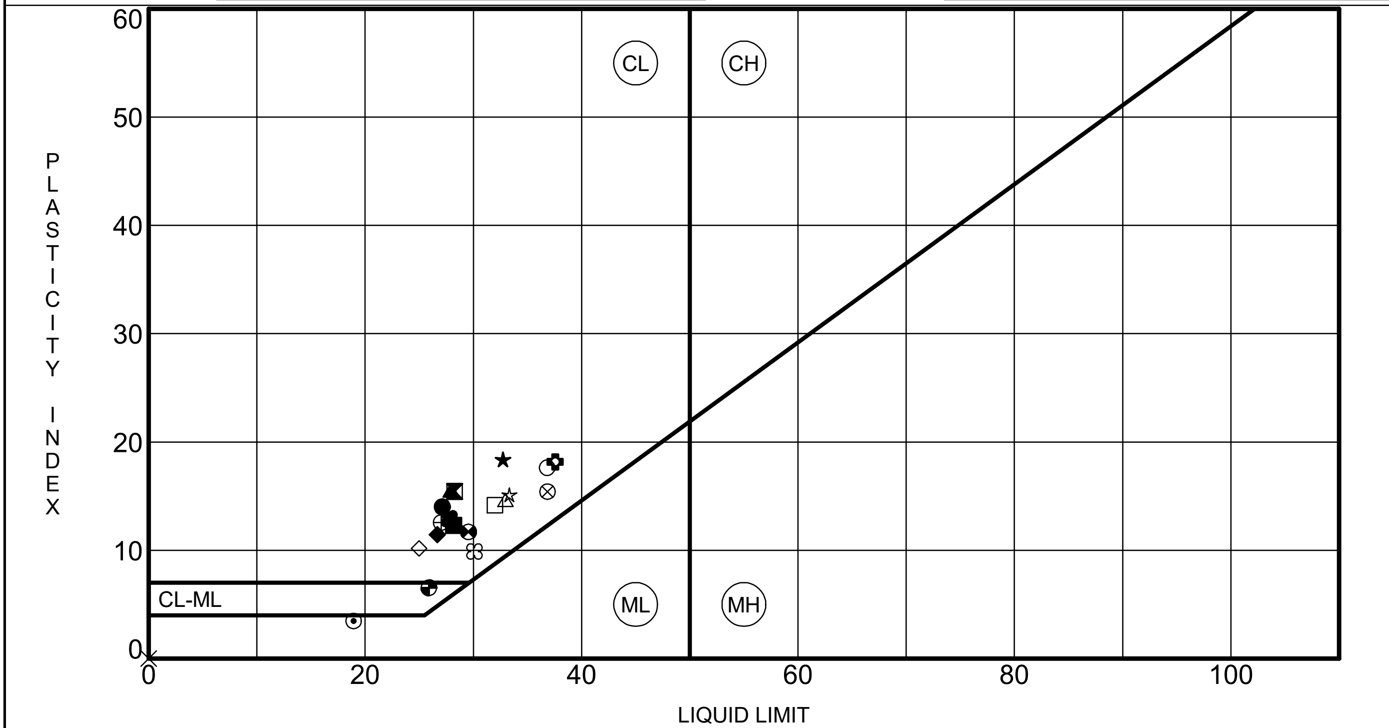
Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
LC-2	0-5	25	15	10		68	CL	A-4 (4)										
LC-2	10				-0.2	55			25.0	87.9								
LC-2	20					58			29.0			0.47						
LC-2	30	NP	NP	NP		8	SP-SM	A-1-a (0)	6.4									
LC-2	40					42			15.1									
LC-3	0-2					58												
LC-3	2-4	28	15	13		75	CL	A-6 (7)										
LC-3	5				-1.7				19.6	102.2								
LC-3	10	29	16	13		94	CL	A-6 (11)	26.6									
LC-3	20					84			34.4			0.19		8.1				
LC-3	30								6.2			0.15						
LC-3	40					53			14.8									

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification		LL	PL	PI	Fines	Classification
B-1	2.0-10.0	27	13	14	83.3	LEAN CLAY with SAND (CL) (A-6)
B-2	0.0-7.0	28	13	15	68.9	SANDY LEAN CLAY (CL) (A-6)
B-3	2.0-9.0	28	12	16	66.6	SANDY LEAN CLAY (CL) (A-6)
B-5	3.0-10.0	33	14	19	88.6	LEAN CLAY (CL) (A-6)
B-6	4.0-10.0	19	15	4	73.1	SILTY CLAY with SAND (CL-ML) (A-4)
F-1	0.0-5.0	38	19	19	88.8	LEAN CLAY (CL) (A-6)
F-2	0.0-6.0	37	19	18	92.3	LEAN CLAY (CL) (A-6)
F-3	0.0-4.0	33	18	15	92.2	LEAN CLAY (CL) (A-6)
F-4	0.0-5.0	37	21	16	72.2	LEAN CLAY with SAND (CL) (A-6)
F-5	2.0-10.0	27	14	13	81.3	LEAN CLAY with SAND (CL) (A-6)
F-6	0.0-7.0	32	18	14	79.9	LEAN CLAY with GRAVEL (CL) (A-6)
F-7	0.0-5.0	30	18	12	79.6	LEAN CLAY with SAND (CL) (A-6)
F-8	0.0-5.0	26	19	7	75.4	SILTY CLAY with SAND (CL-ML) (A-4)
F-9	0.0-3.0	33	18	15	89.5	LEAN CLAY (CL) (A-6)
F-10	0.0-5.0	30	20	10	79.1	LEAN CLAY with SAND (CL) (A-4)
F-16	0.0-10.0	28	16	12	84.7	LEAN CLAY with SAND (CL) (A-6)
LC-1	0.0-5.0	27	15	12	76.6	LEAN CLAY with SAND (CL) (A-6)
LC-2	0.0-5.0	25	15	10	68.2	SANDY LEAN CLAY (CL) (A-4)
LC-2	30.0	NP	NP	NP	7.7	POORLY GRADED SAND with SILT and GRAVEL (SP-SM) (A-1-a)
LC-3	2.0-4.0	28	15	13	74.9	LEAN CLAY with SAND (CL) (A-6)

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

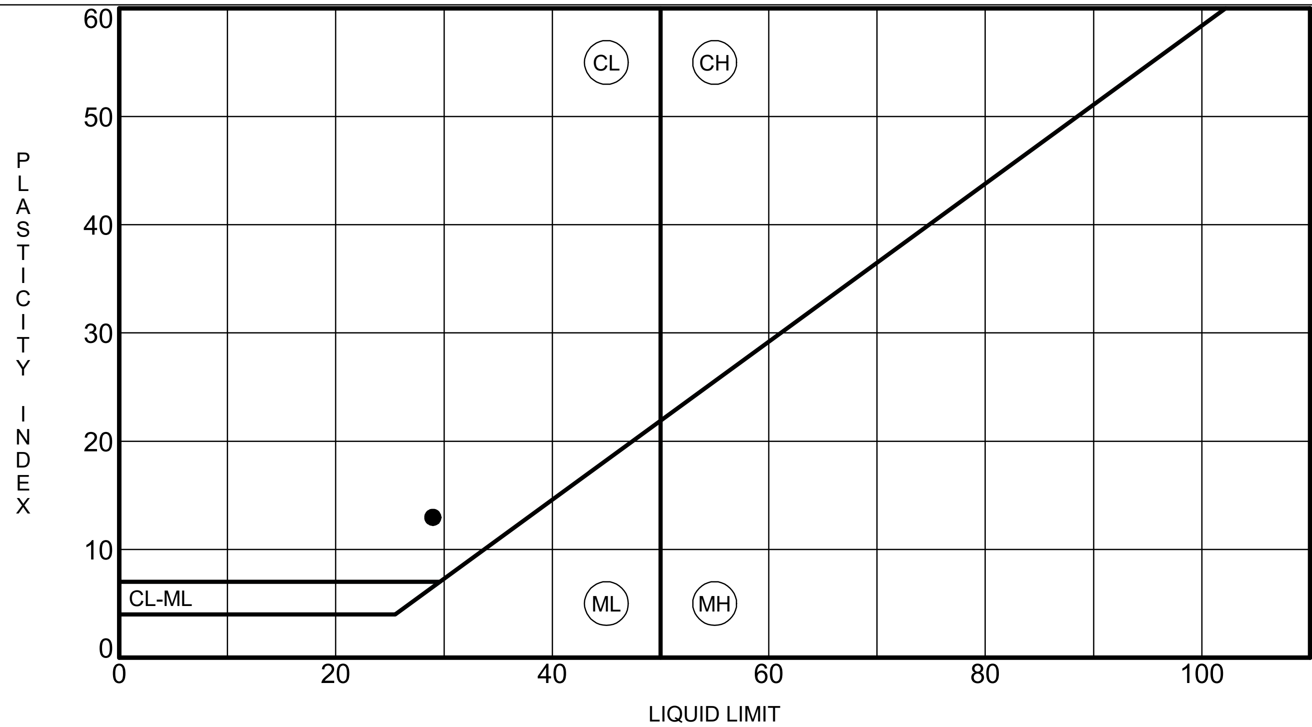
RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**LC-3**	**10.0**	**29**	**16**	**13**	**94.4**	**LEAN CLAY (CL) (A-6)**

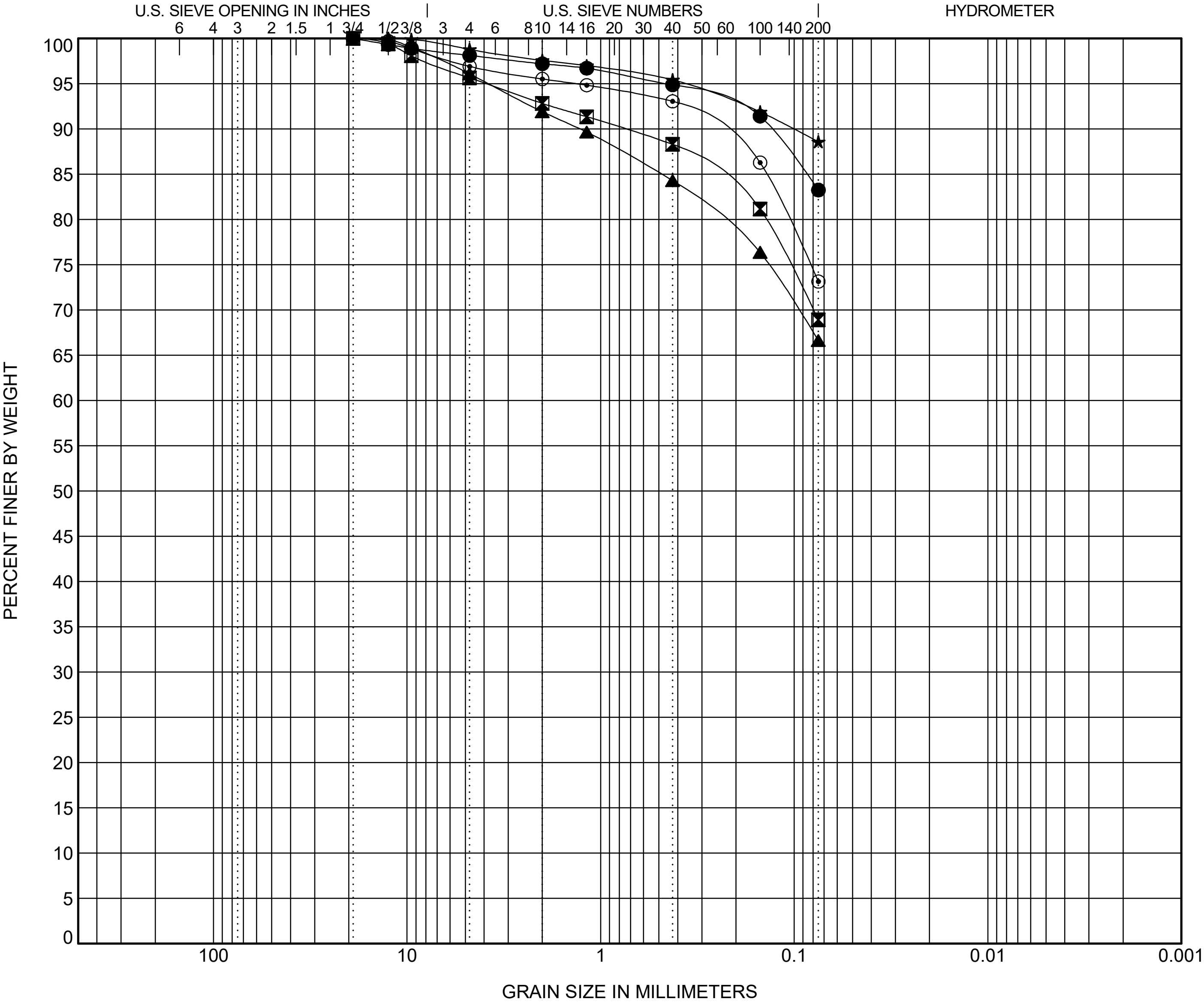
ATTERBERG LIMITS - STANDARD 599.37_CITY OF GJ PARKWAY PROJECT.GPJ ROCKSOL TEMPLATE.GDT 12/9/21

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● B-1	2.0-10.0	**LEAN CLAY with SAND (CL) (A-6)**	27	13	14		
⧗ B-2	0.0-7.0	**SANDY LEAN CLAY (CL) (A-6)**	28	13	15		
▲ B-3	2.0-9.0	**SANDY LEAN CLAY (CL) (A-6)**	28	12	16		
★ B-5	3.0-10.0	**LEAN CLAY (CL) (A-6)**	33	14	19		
⊙ B-6	4.0-10.0	**SILTY CLAY with SAND (CL-ML) (A-4)**	19	15	4		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
● B-1	2.0-10.0	19				2.8	2.3	11.6	83.3	
⧗ B-2	0.0-7.0	19				7.2	4.5	19.4	68.9	
▲ B-3	2.0-9.0	12.5				8.1	7.6	17.7	66.6	
★ B-5	3.0-10.0	12.5				2.4	2.2	6.8	88.6	
⊙ B-6	4.0-10.0	19				4.5	2.5	19.9	73.1	

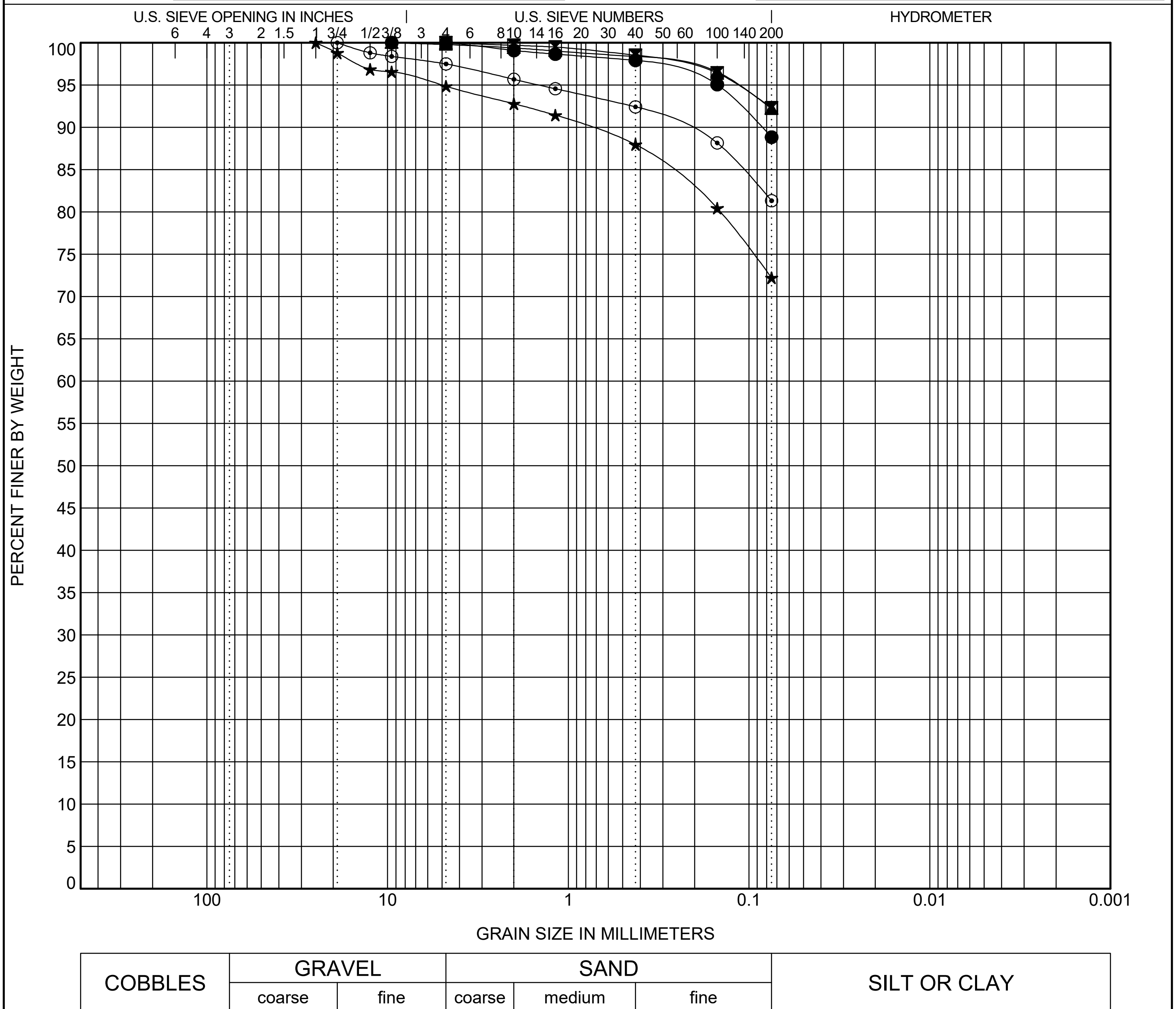
GRADATION - STANDARD 599.37_CITY OF GJ PARKWAY PROJECT.GPJ ROCKSOL TEMPLATE.GDT 12/9/21

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	**F-1**	**0.0-5.0**	**LEAN CLAY (CL) (A-6)**	**38**	**19**	**19**		
⌧	**F-2**	**0.0-6.0**	**LEAN CLAY (CL) (A-6)**	**37**	**19**	**18**		
▲	**F-3**	**0.0-4.0**	**LEAN CLAY (CL) (A-6)**	**33**	**18**	**15**		
★	**F-4**	**0.0-5.0**	**LEAN CLAY with SAND (CL) (A-6)**	**37**	**21**	**16**		
⊙	**F-5**	**2.0-10.0**	**LEAN CLAY with SAND (CL) (A-6)**	**27**	**14**	**13**		

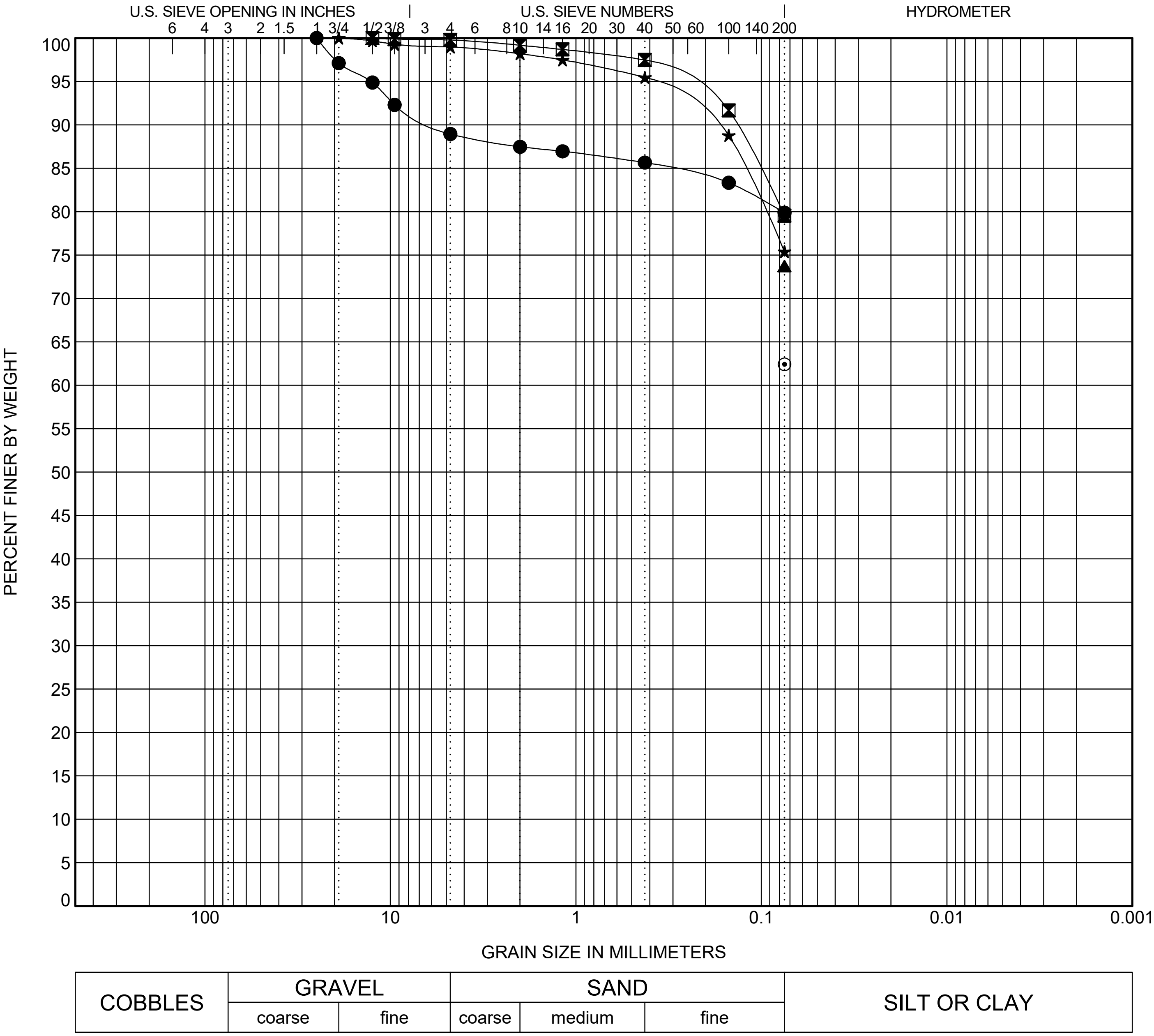
Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**F-1**	**0.0-5.0**	**9.5**				**0.9**	**1.2**	**9.1**	**88.8**	
⌧	**F-2**	**0.0-6.0**	**4.75**				**0.3**	**1.2**	**6.2**	**92.3**	
▲	**F-3**	**0.0-4.0**	**9.5**				**0.6**	**1.0**	**6.2**	**92.2**	
★	**F-4**	**0.0-5.0**	**25**				**7.2**	**4.8**	**15.7**	**72.2**	
⊙	**F-5**	**2.0-10.0**	**19**				**4.3**	**3.2**	**11.1**	**81.3**	

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**F-6**	**0.0-7.0**	**LEAN CLAY with GRAVEL (CL) (A-6)**	**32**	**18**	**14**		
⧗	**F-7**	**0.0-5.0**	**LEAN CLAY with SAND (CL) (A-6)**	**30**	**18**	**12**		
▲	**F-7**	**3.0**	**LEAN CLAY with SAND (CL) (A-6)**					
★	**F-8**	**0.0-5.0**	**SILTY CLAY with SAND (CL-ML) (A-4)**	**26**	**19**	**7**		
⊙	**F-8**	**5.0**	**SILTY CLAY with SAND (CL-ML) (A-4)**					

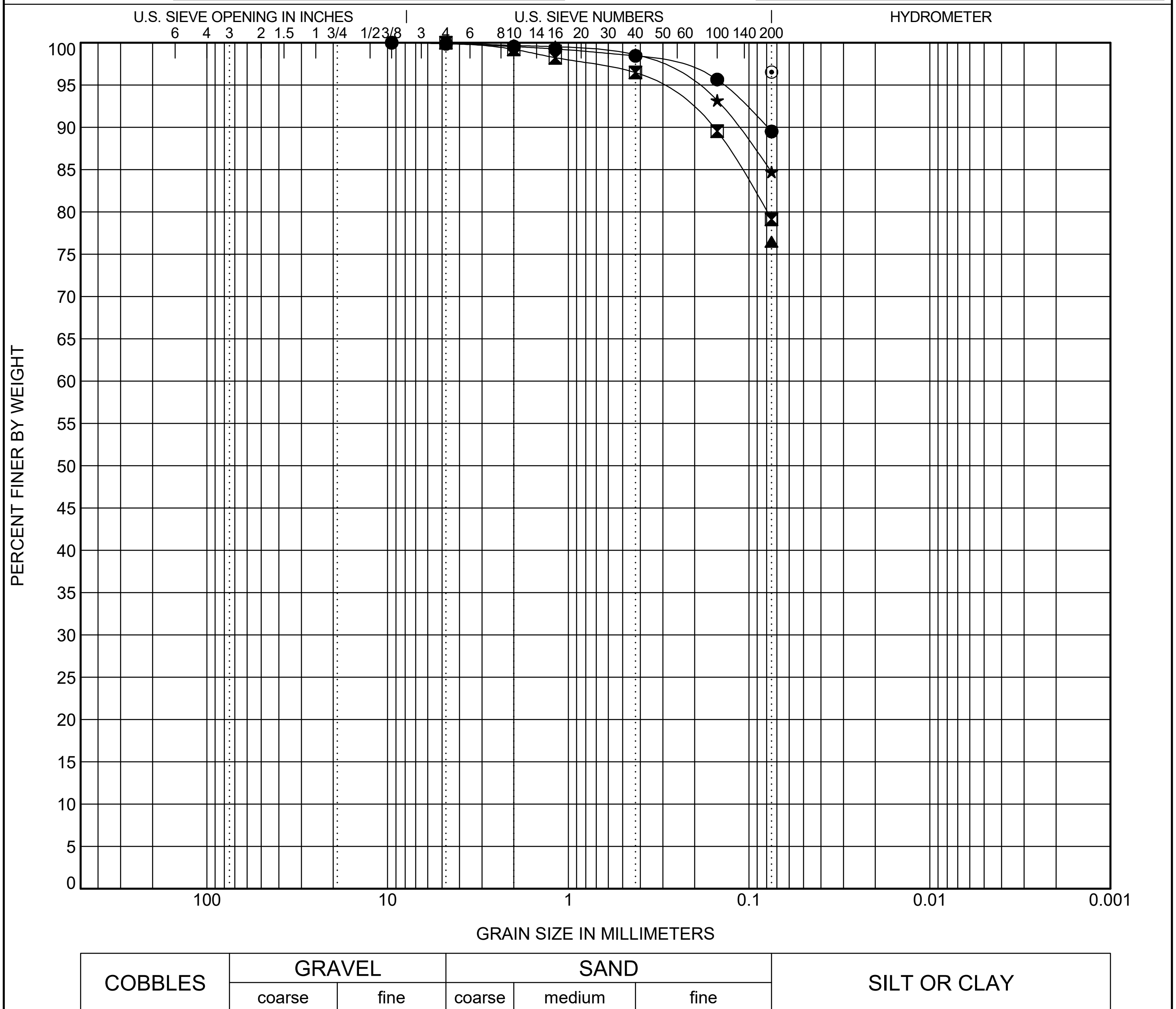
	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**F-6**	**0.0-7.0**	**25**				**12.5**	**1.8**	**5.8**	**79.9**	
⧗	**F-7**	**0.0-5.0**	**12.5**				**0.8**	**1.7**	**17.9**	**79.6**	
▲	**F-7**	**3.0**	**0.075**							**73.7**	
★	**F-8**	**0.0-5.0**	**19**				**1.8**	**2.7**	**20.1**	**75.4**	
⊙	**F-8**	**5.0**	**0.075**							**62.4**	

GRAIN SIZE DISTRIBUTION

RocksSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**F-9**	**0.0-3.0**	**LEAN CLAY (CL) (A-6)**	**33**	**18**	**15**		
⊠	**F-10**	**0.0-5.0**	**LEAN CLAY with SAND (CL) (A-4)**	**30**	**20**	**10**		
▲	**F-10**	**2.0**	**LEAN CLAY with SAND (CL) (A-4)**					
★	**F-16**	**0.0-10.0**	**LEAN CLAY with SAND (CL) (A-6)**	**28**	**16**	**12**		
⊙	**F-16**	**2.0**	**LEAN CLAY with SAND (CL) (A-6)**					

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**F-9**	**0.0-3.0**	**9.5**				**0.5**	**1.1**	**8.9**	**89.5**	
⊠	**F-10**	**0.0-5.0**	**4.75**				**0.8**	**2.7**	**17.4**	**79.1**	
▲	**F-10**	**2.0**	**0.075**							**76.5**	
★	**F-16**	**0.0-10.0**	**4.75**				**0.3**	**1.1**	**13.9**	**84.7**	
⊙	**F-16**	**2.0**	**0.075**							**96.5**	

RockSol Consulting Group, Inc.

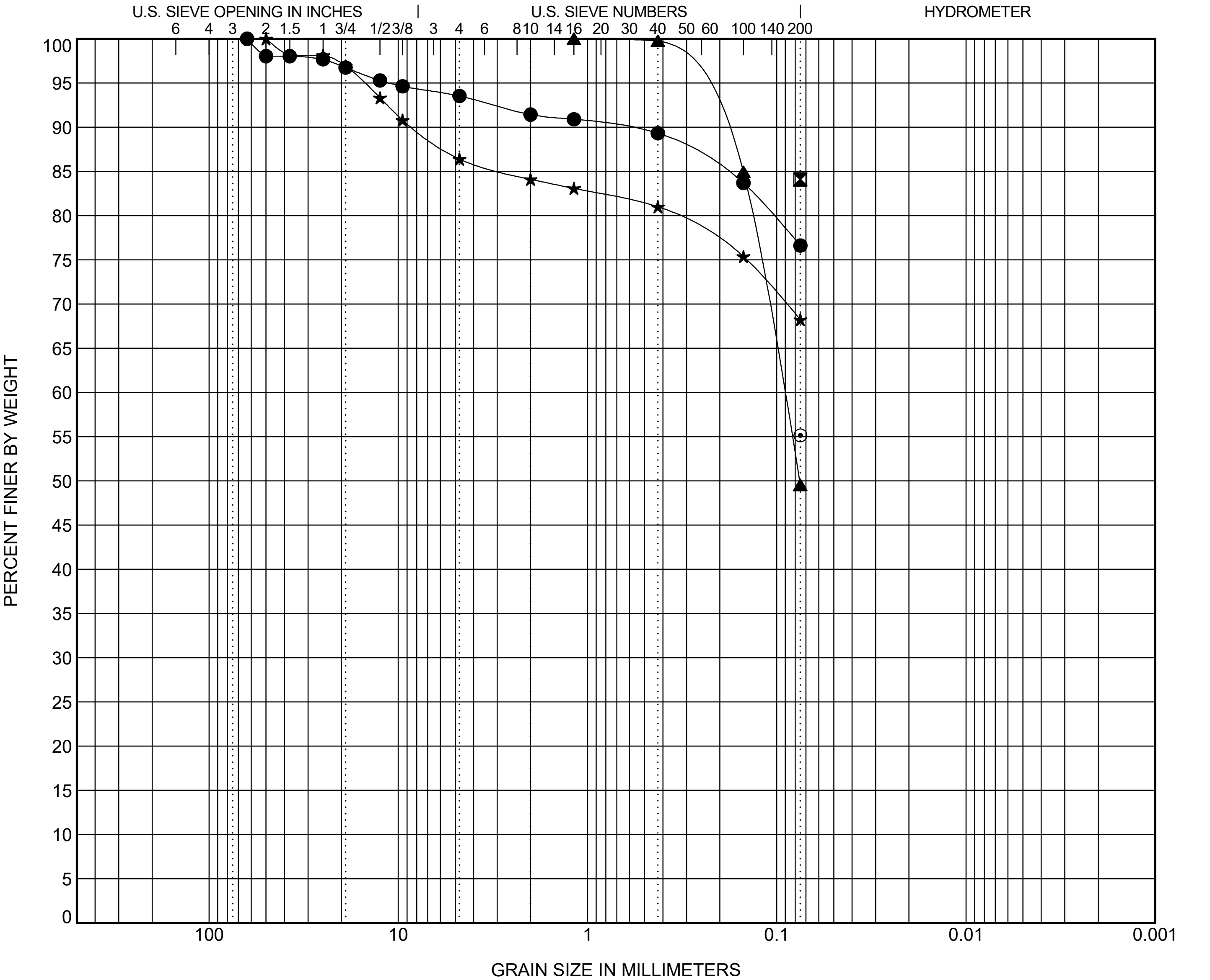
GRAIN SIZE DISTRIBUTION

CLIENT City of Grand Junction

PROJECT NAME F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37

PROJECT LOCATION Grand Junction, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**LC-1**	**0.0-5.0**	**LEAN CLAY with SAND (CL) (A-6)**	**27**	**15**	**12**		
⊠	**LC-1**	**12.0**	**LEAN CLAY with SAND (CL) (A-6)**					
▲	**LC-1**	**20.0**	**LEAN CLAY with SAND (CL) (A-6)**					
★	**LC-2**	**0.0-5.0**	**SANDY LEAN CLAY (CL) (A-4)**	**25**	**15**	**10**		
⊙	**LC-2**	**10.0**	**SANDY LEAN CLAY (CL) (A-4)**					

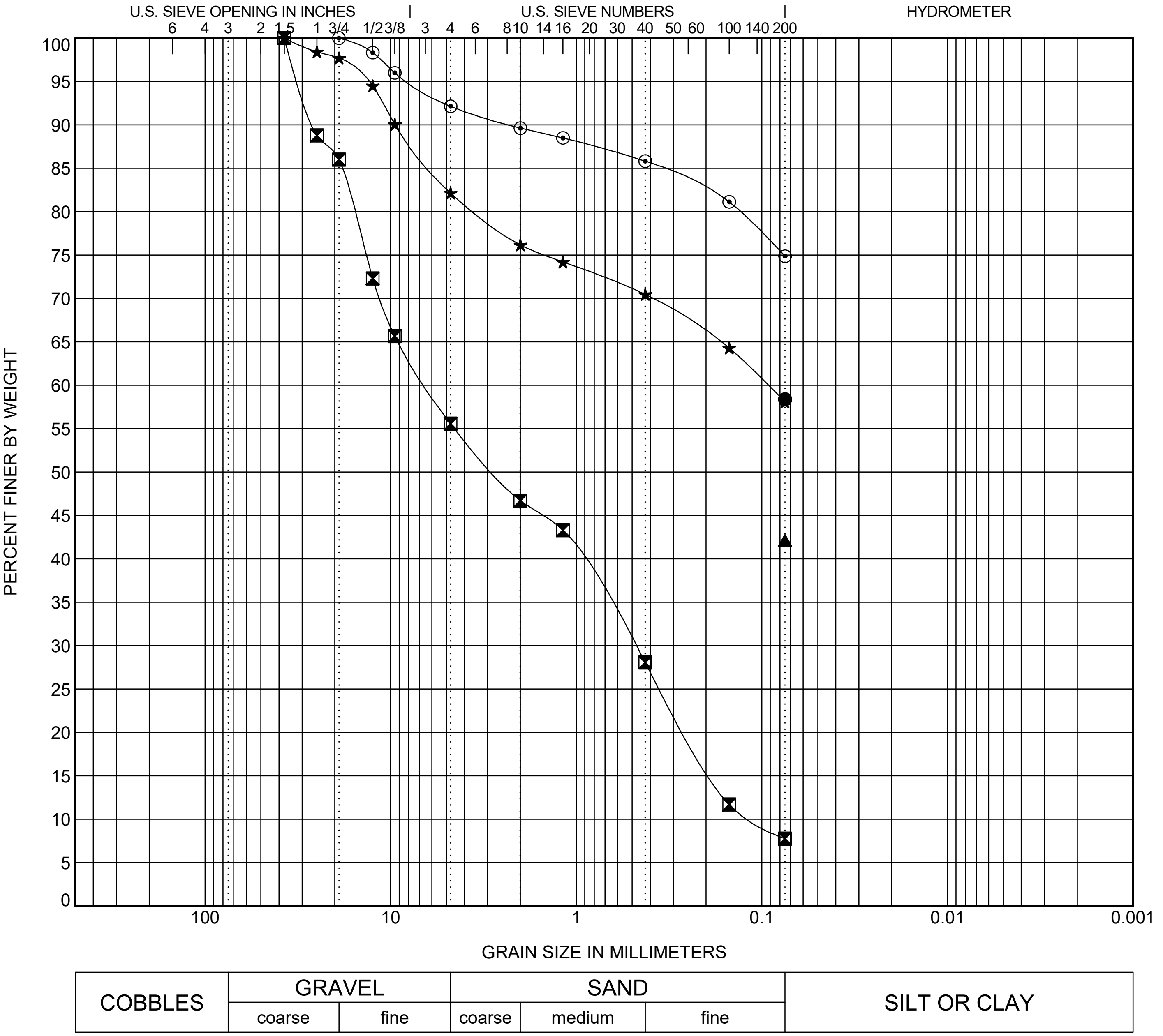
	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**LC-1**	**0.0-5.0**	**63**				**8.6**	**2.1**	**12.7**	**76.6**	
⊠	**LC-1**	**12.0**	**0.075**							**84.1**	
▲	**LC-1**	**20.0**	**1.18**	**0.092**			**0.0**	**0.2**	**50.2**	**49.5**	
★	**LC-2**	**0.0-5.0**	**50**				**15.9**	**3.1**	**12.8**	**68.2**	
⊙	**LC-2**	**10.0**	**0.075**							**55.1**	

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	LC-2	20.0	SANDY LEAN CLAY (CL) (A-4)					
⊠	LC-2	30.0	POORLY GRADED SAND with SILT and GRAVEL (SP-SM) (A-1-a)	NP	NP	NP	0.33	57.77
▲	LC-2	40.0	POORLY GRADED SAND with SILT and GRAVEL					
★	LC-3	0.0-2.0	SANDY GRAVEL					
⊙	LC-3	2.0-4.0	LEAN CLAY with SAND (CL) (A-6)	28	15	13		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	LC-2	20.0	0.075							58.4	
⊠	LC-2	30.0	37.5	6.442	0.484	0.112	53.3	18.7	20.3	7.7	
▲	LC-2	40.0	0.075							42.1	
★	LC-3	0.0-2.0	37.5	0.093			23.8	5.7	12.4	58.1	
⊙	LC-3	2.0-4.0	19				10.4	3.8	10.9	74.9	

GRAIN SIZE DISTRIBUTION

RockSol Consulting Group, Inc.

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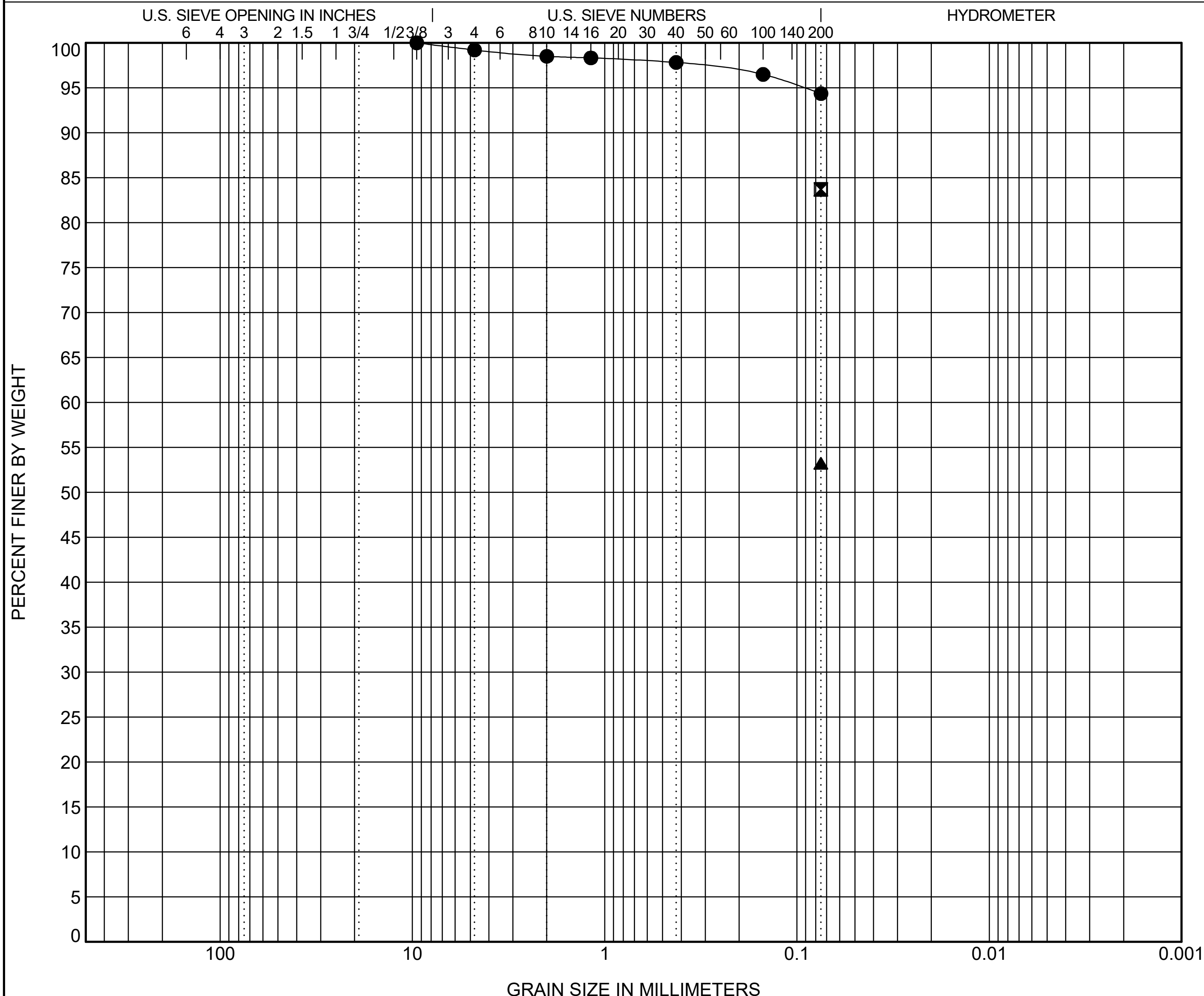
PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

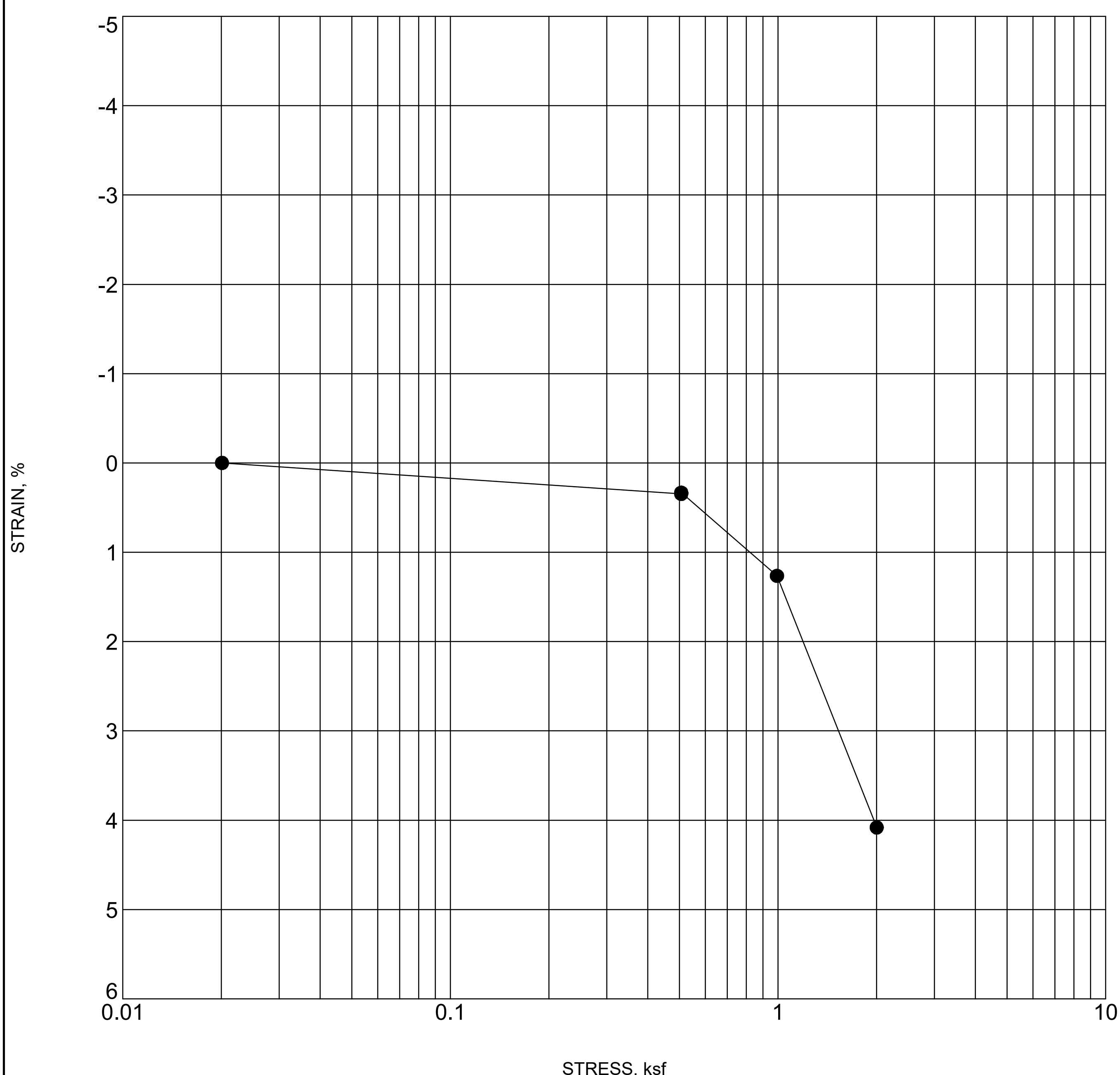
	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**LC-3**	**10.0**	**LEAN CLAY (CL) (A-6)**	**29**	**16**	**13**		
⧗	**LC-3**	**20.0**	**LEAN CLAY**					
▲	**LC-3**	**40.0**	**LEAN CLAY**					

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**LC-3**	**10.0**	**9.5**				**1.5**	**0.7**	**3.5**	**94.4**	
⧗	**LC-3**	**20.0**	**0.075**							**83.7**	
▲	**LC-3**	**40.0**	**0.075**							**53.2**	

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
PROJECT NUMBER 599.37
PROJECT LOCATION Grand Junction, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● F-1	3	CLAY	0.0	97.9	19.5

SWELL - STANDARD 599.37_CITY OF GJ PARKWAY PROJECT.GPJ ROCKSOL TEMPLATE.GDT 12/9/21

SWELL - CONSOLIDATION TEST

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PROJECT NAME F.5 Road Parkway and 24.5 Road Widening
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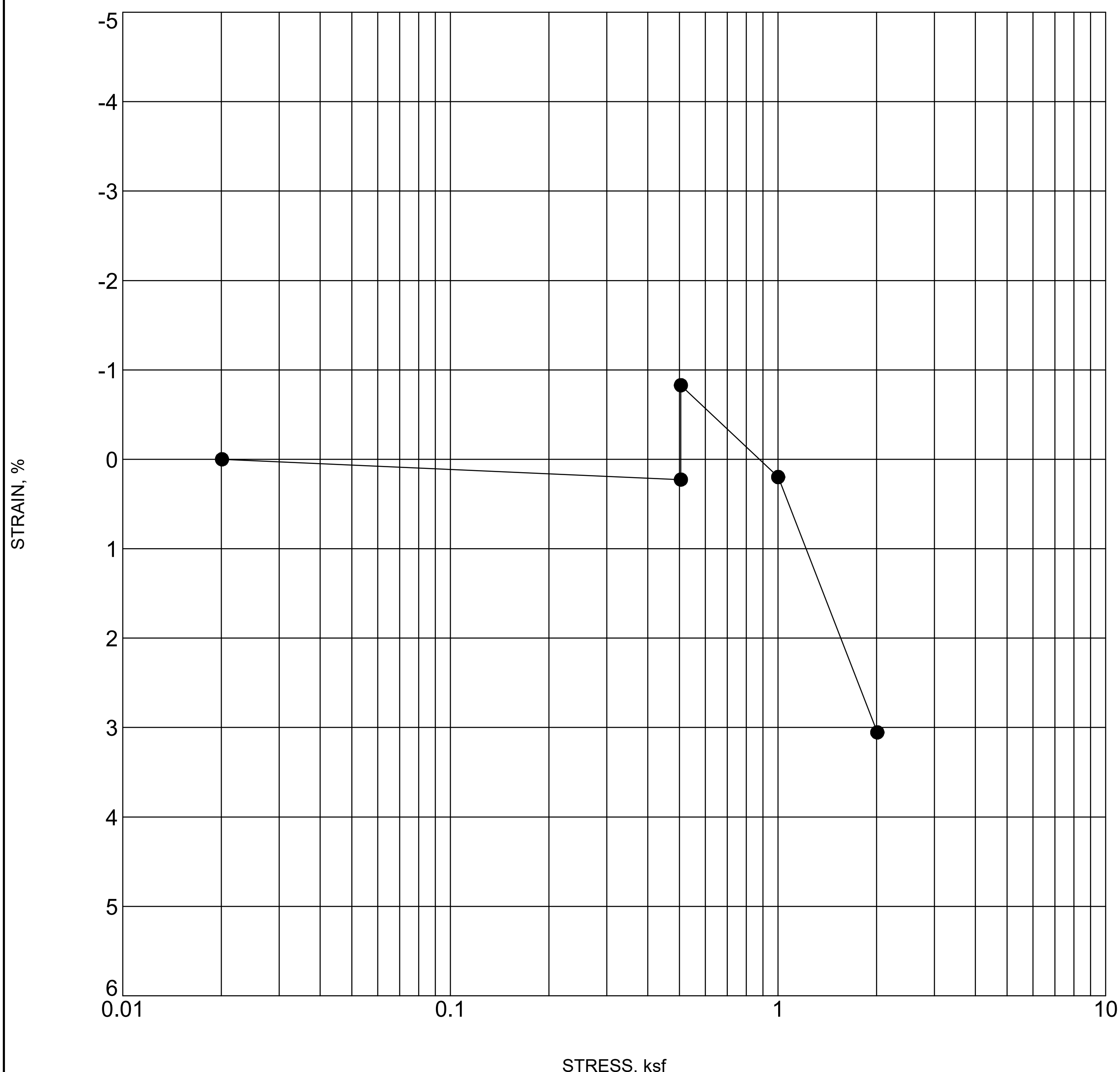


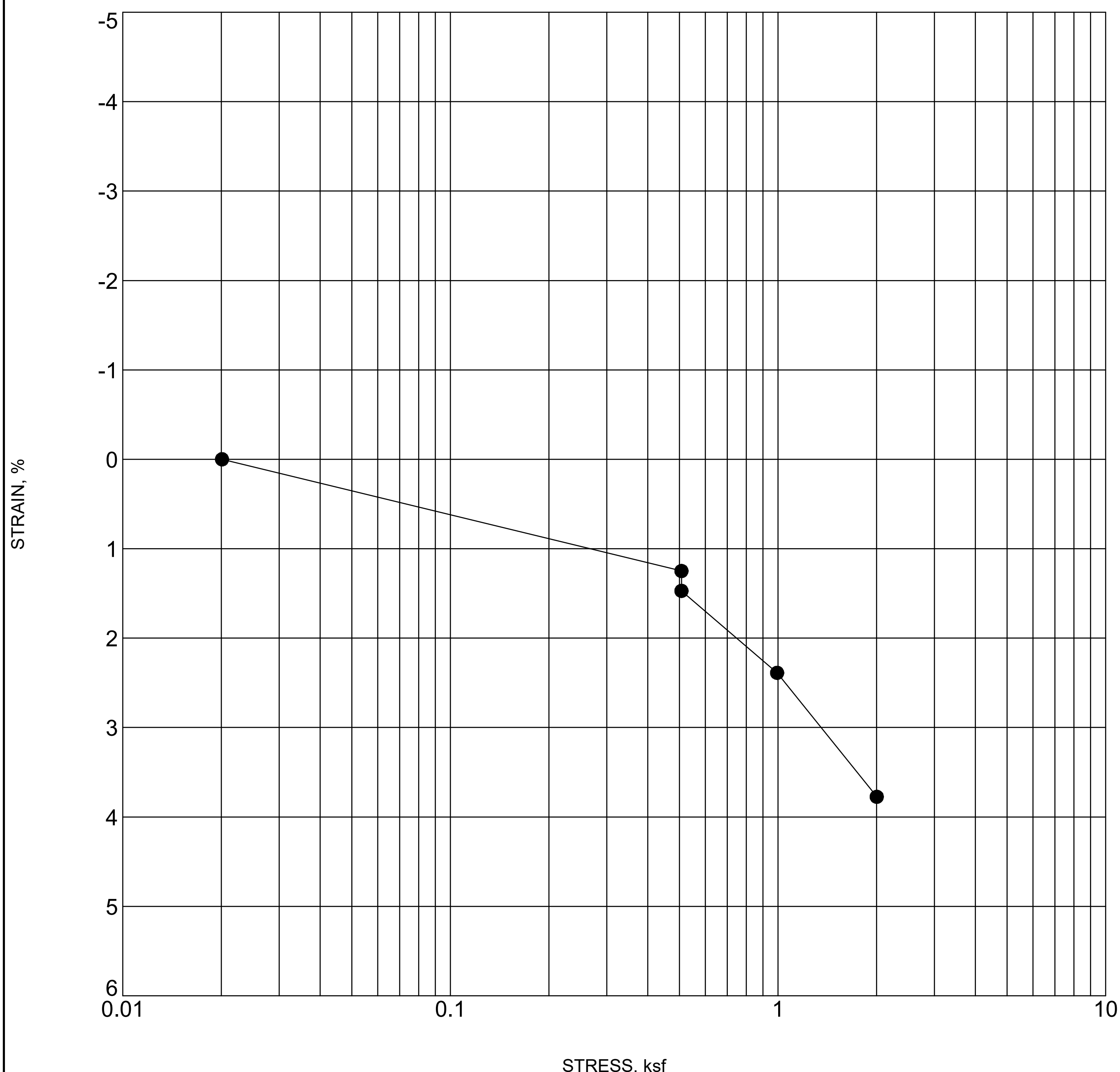
Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● F-3	4	**CLAY**		**103.3**	**13.1**

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● LC-2	10	SANDY LEAN CLAY (CL) (A-4)	-0.2	87.9	25.0

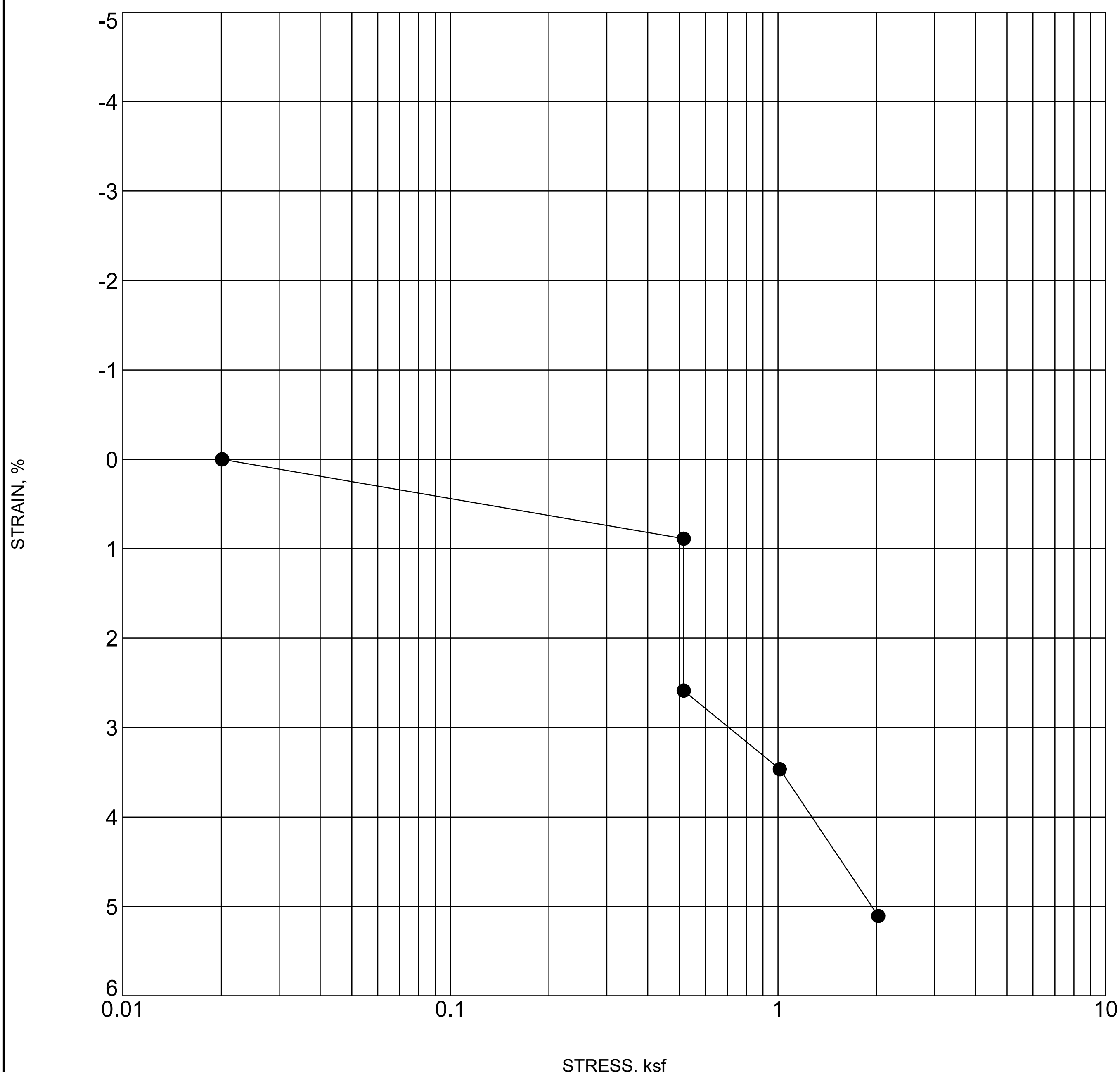
SWELL - STANDARD 599.37_CITY OF GJ PARKWAY PROJECT.GPJ ROCKSOL TEMPLATE.GDT 12/9/21

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction | **PROJECT NAME** F.5 Road Parkway and 24.5 Road Widening

PROJECT NUMBER 599.37 | **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● LC-3	5	CLAY, with SAND	-1.7	102.2	19.6

APPENDIX C

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT
SHEETS F ½ ROAD

Design Inputs

Design Life:	20 years	Base construction:	May, 2022	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	FLEXIBLE	Pavement construction:	June, 2022		
		Traffic opening:	September, 2022		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	5.5
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	14.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

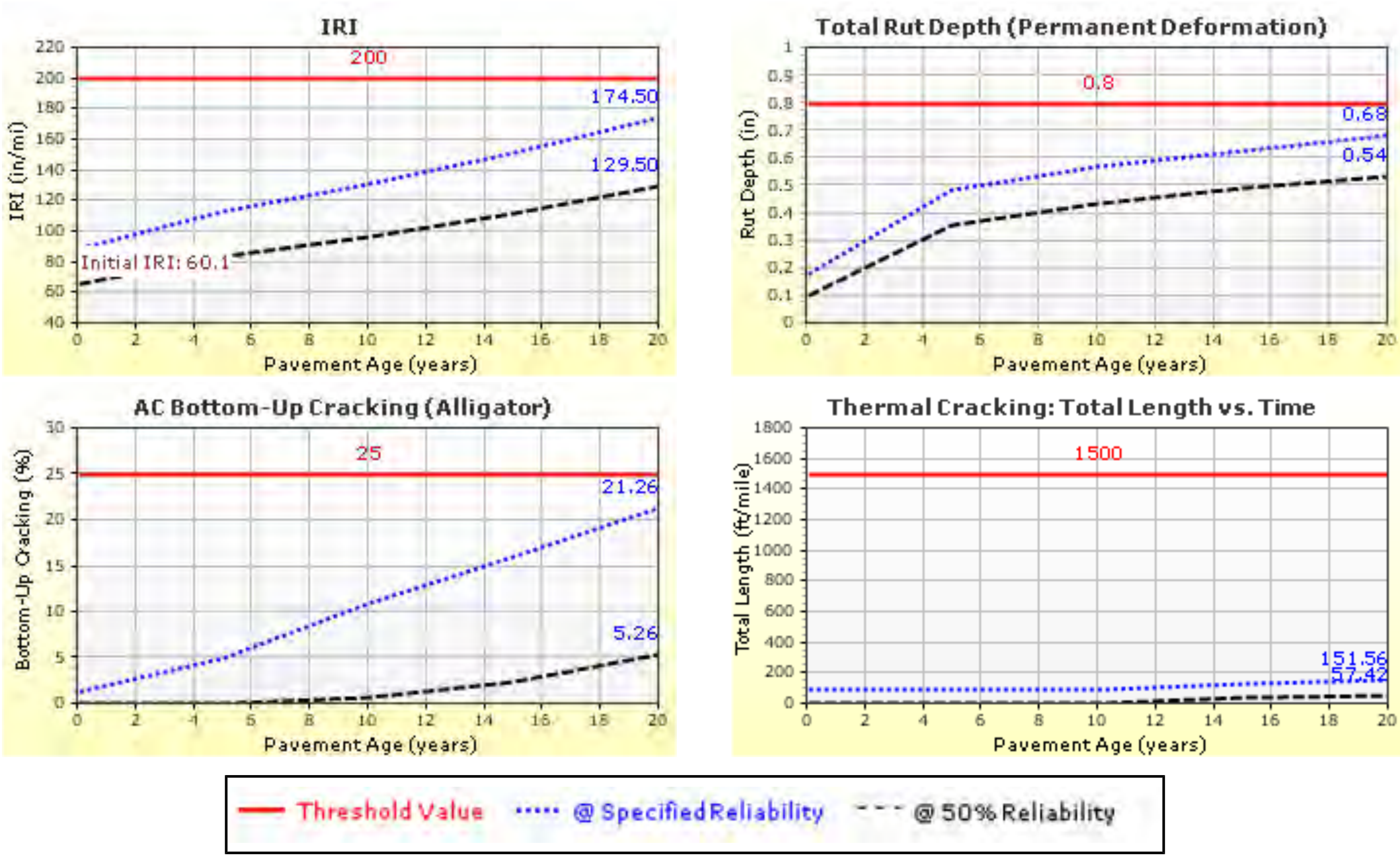
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,100
2032 (10 years)	3,814,160
2042 (20 years)	8,555,580

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	174.46	90.00	97.78	Pass
Permanent deformation - total pavement (in)	0.80	0.68	90.00	98.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	21.26	90.00	94.31	Pass
AC thermal cracking (ft/mile)	1500.00	151.56	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	382.11	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.49	90.00	99.70	Pass

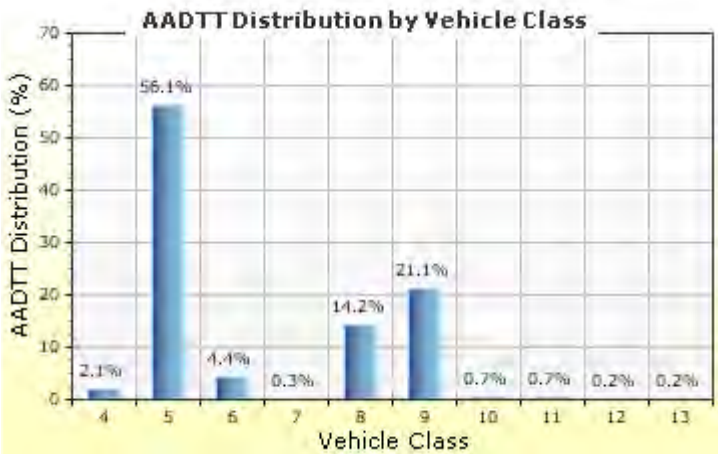
Distress Charts

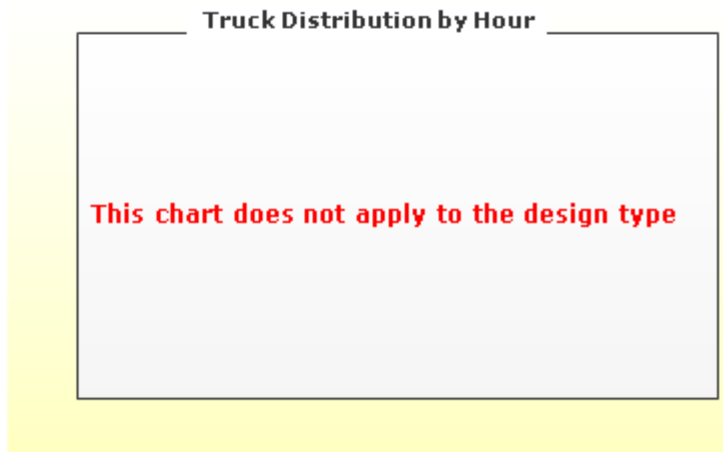


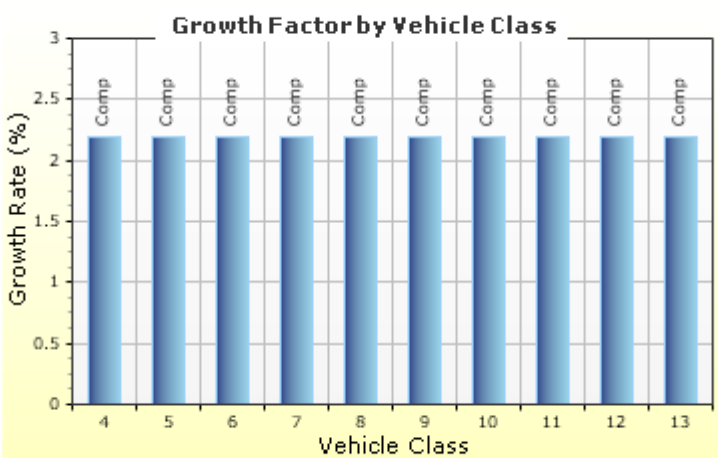
Traffic Inputs

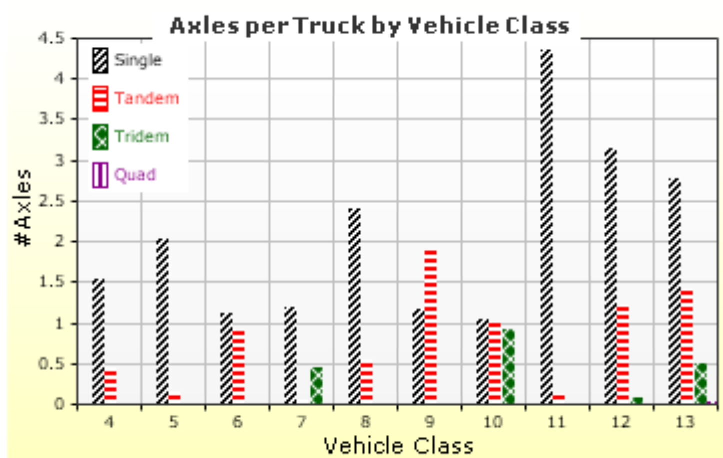
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,100	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

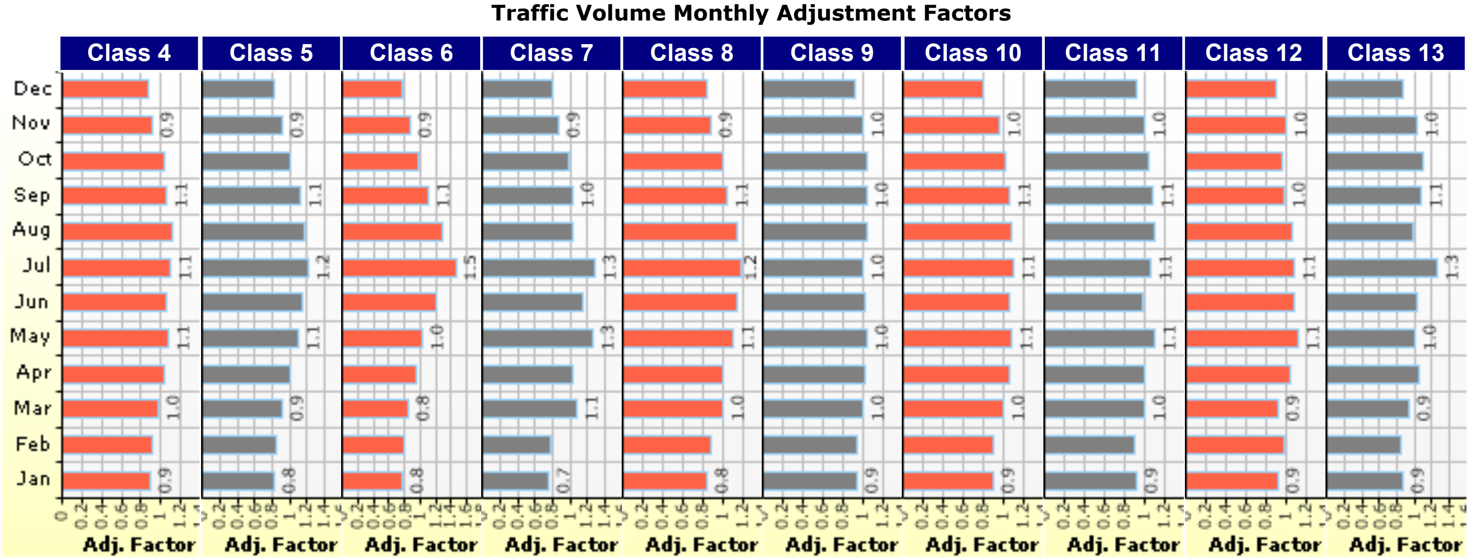








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

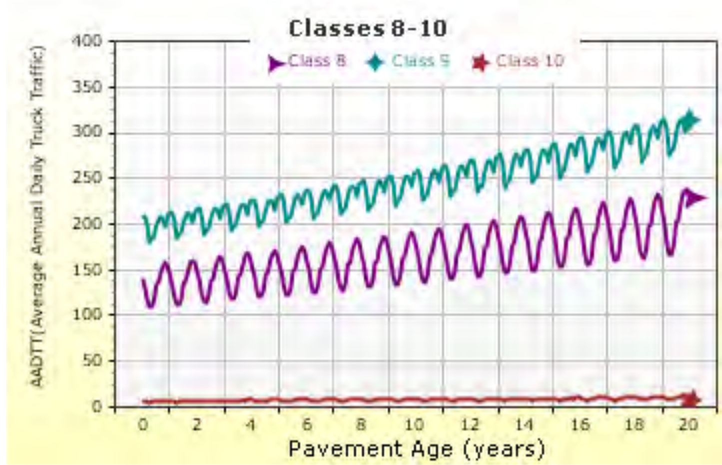
Wheelbase does not apply

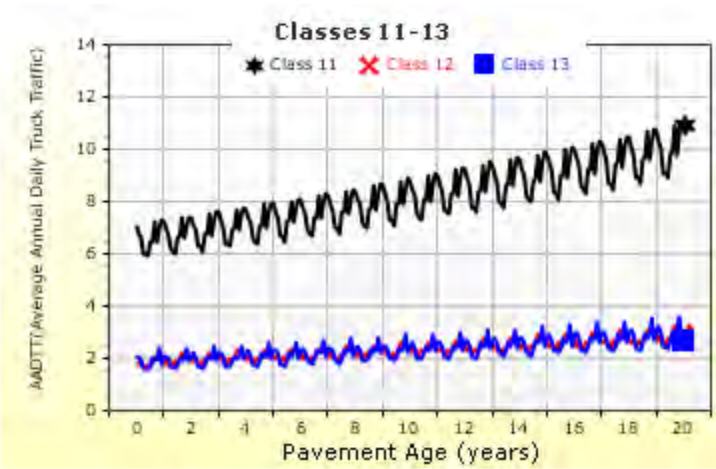
Number of Axles per Truck

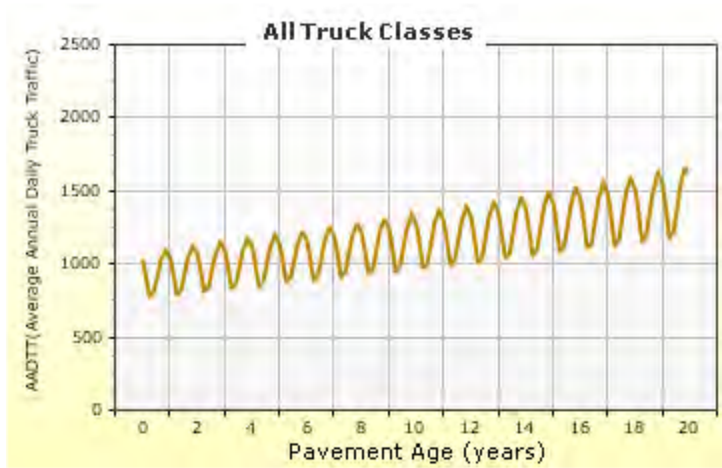
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

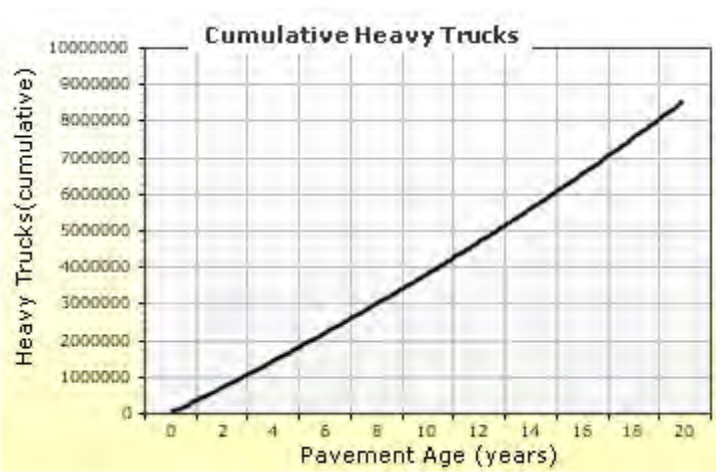
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





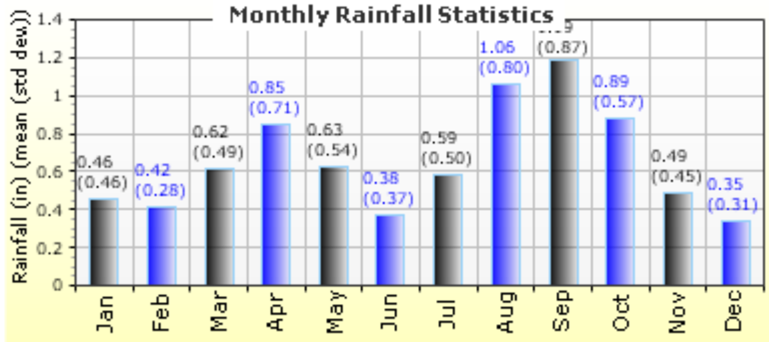




Climate Inputs

Climate Data Sources:

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

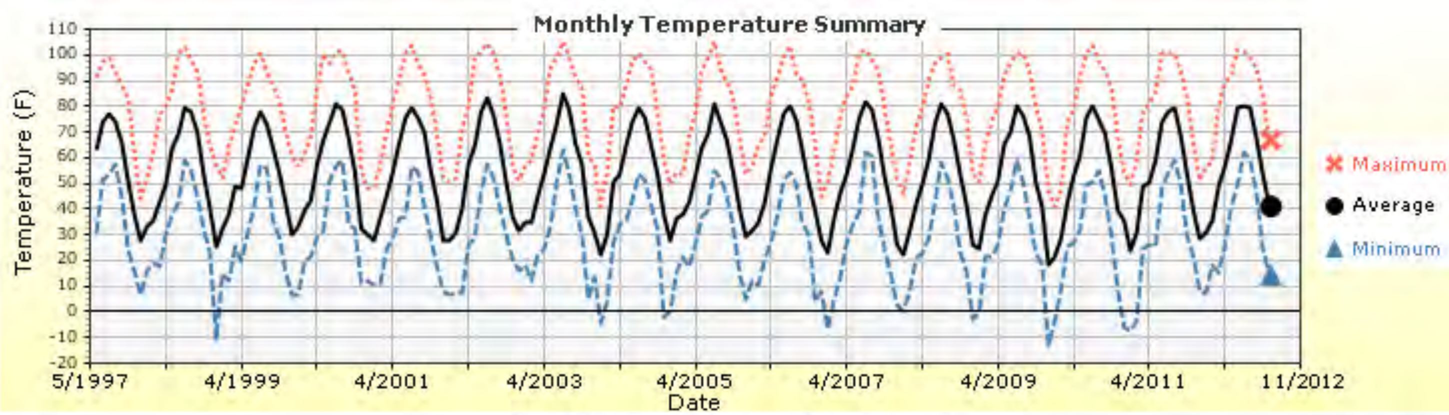


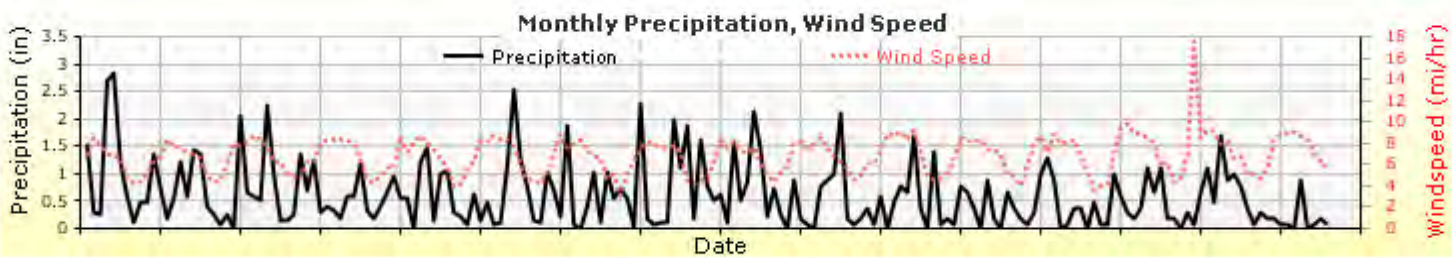
Annual Statistics:

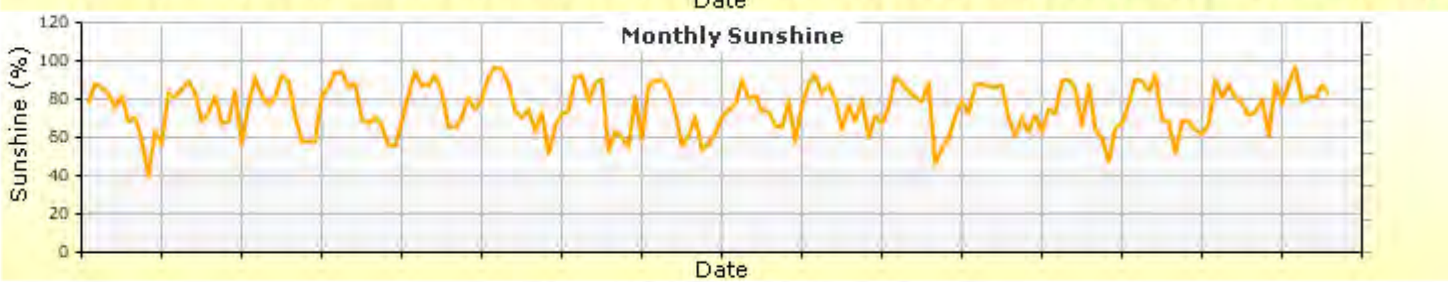
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

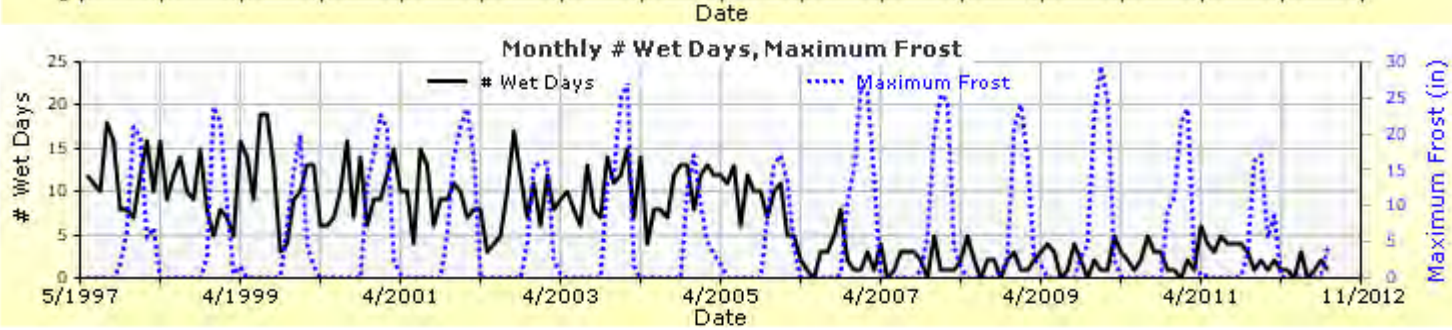
Water table depth (ft)	10.00

Monthly Climate Summary:

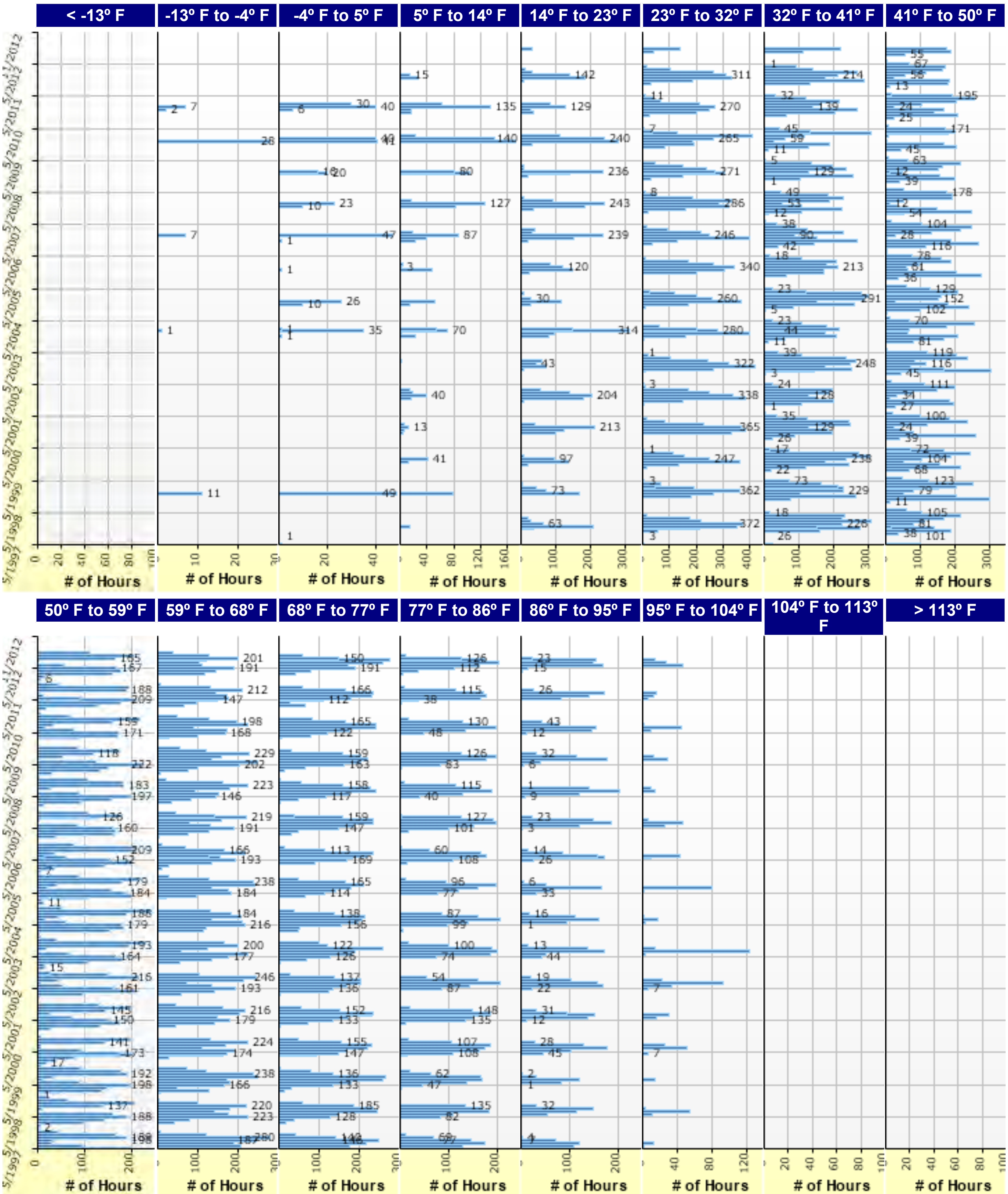








Hourly Air Temperature Distribution by Month:



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

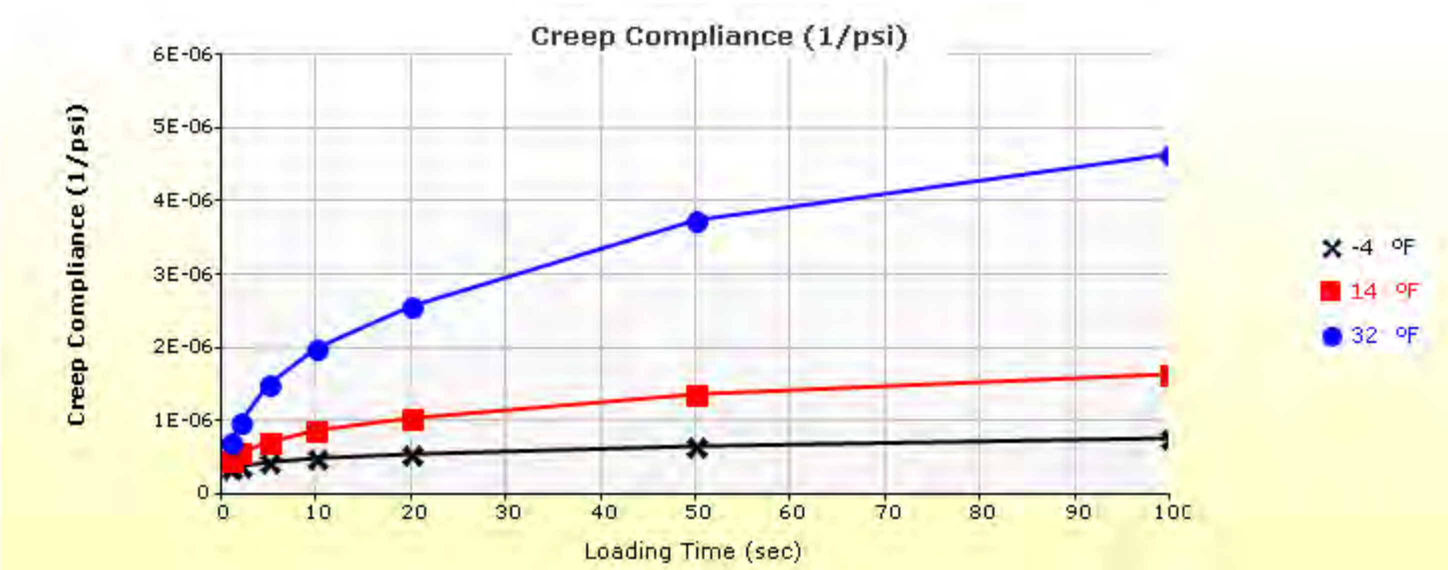
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

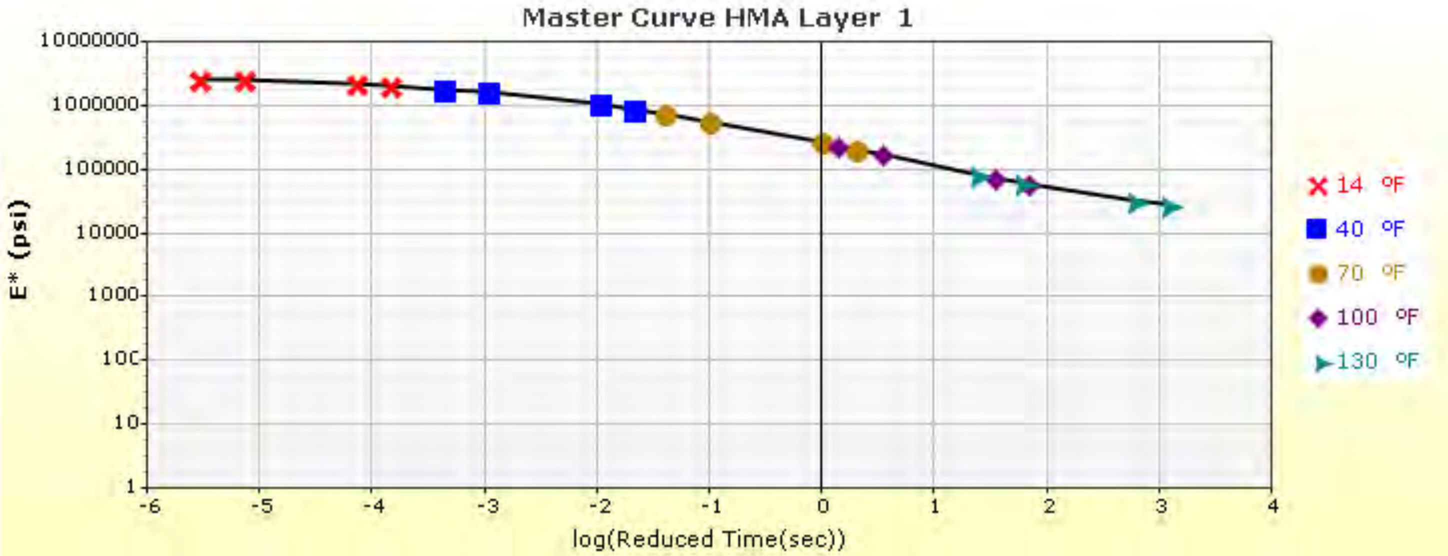
Indirect tensile strength at 14 ºF (psi)	519.00

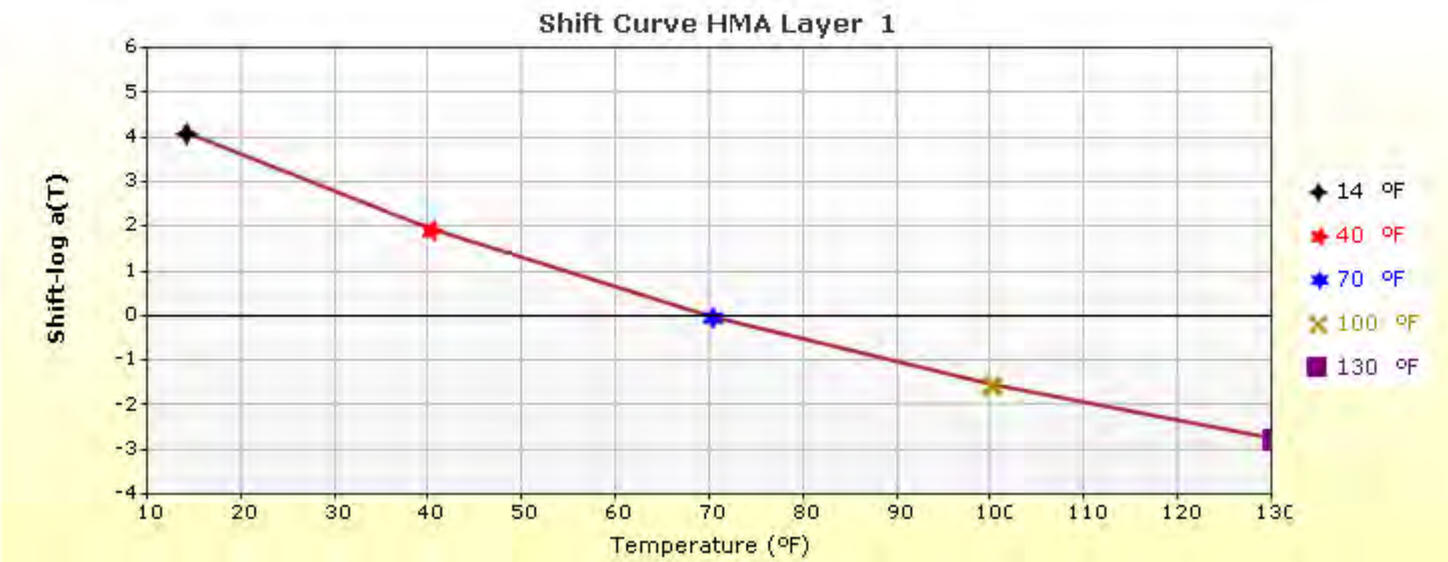
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

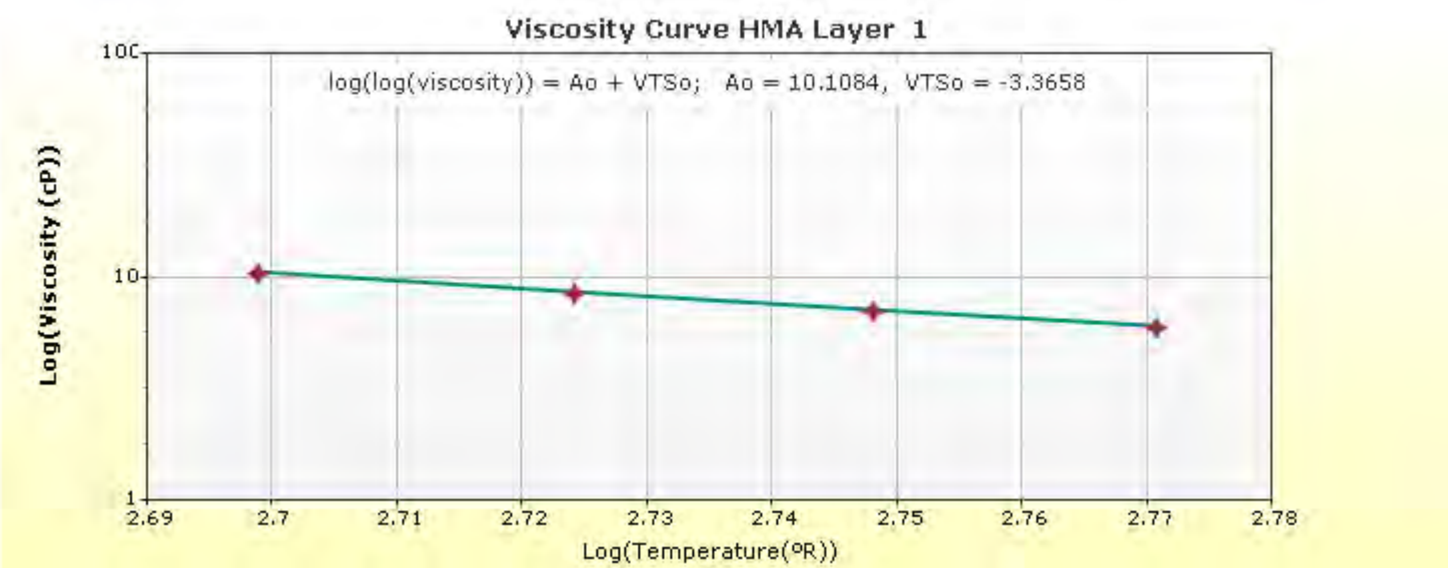
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



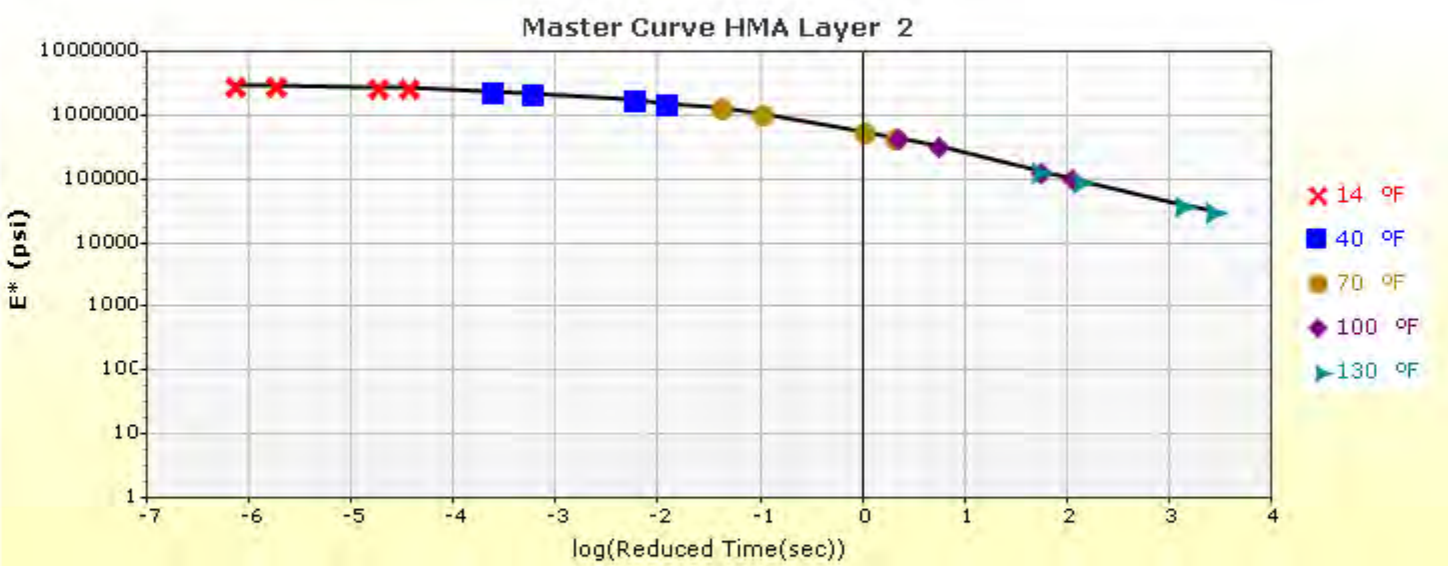
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

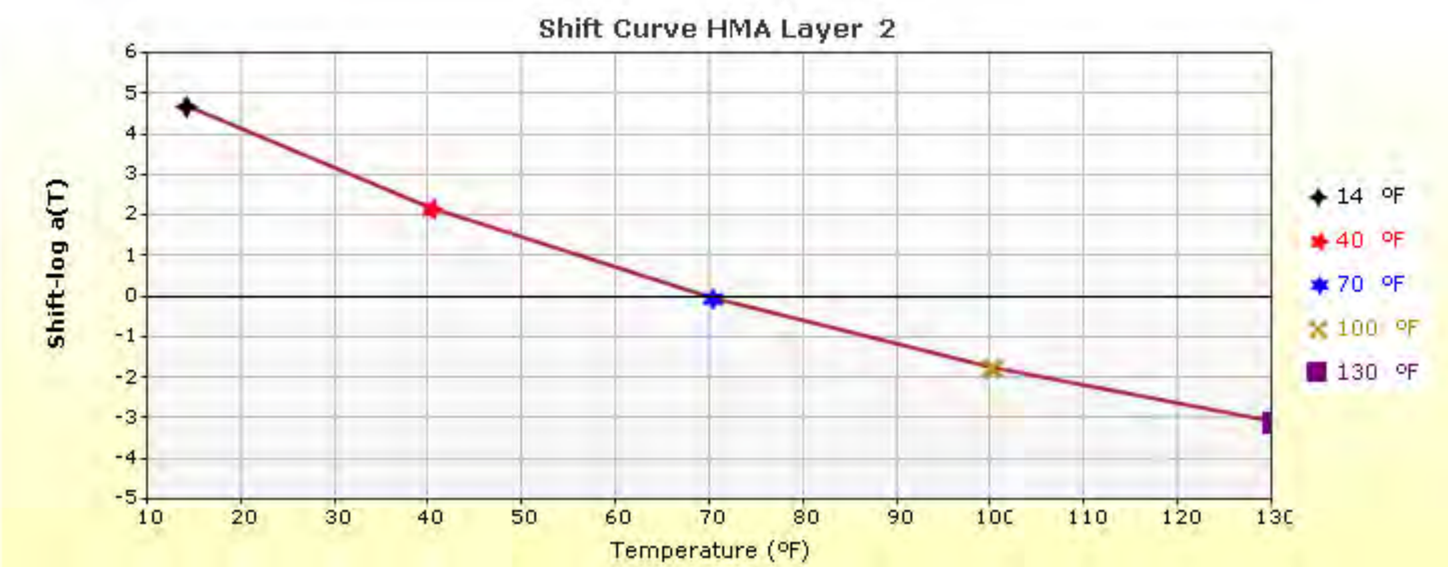


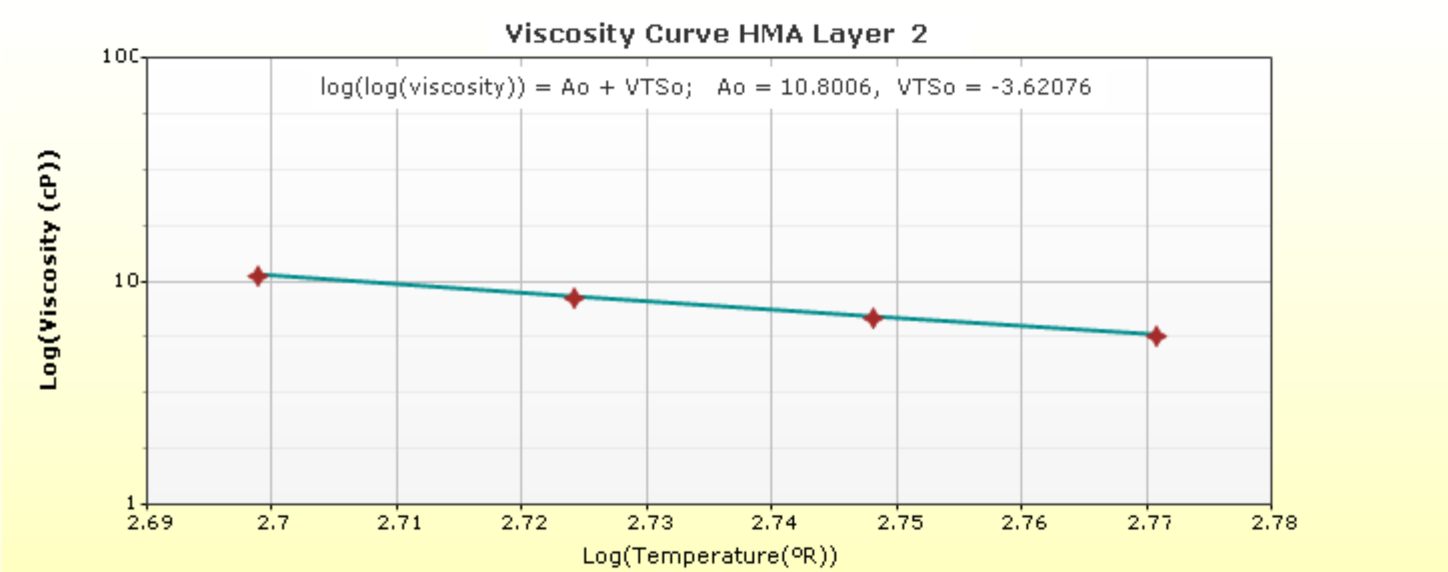




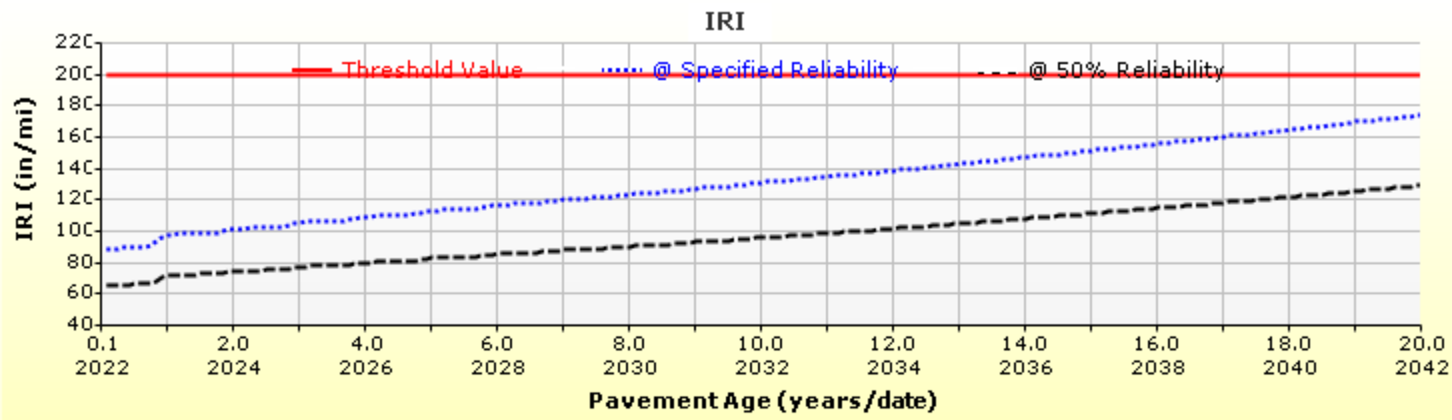
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

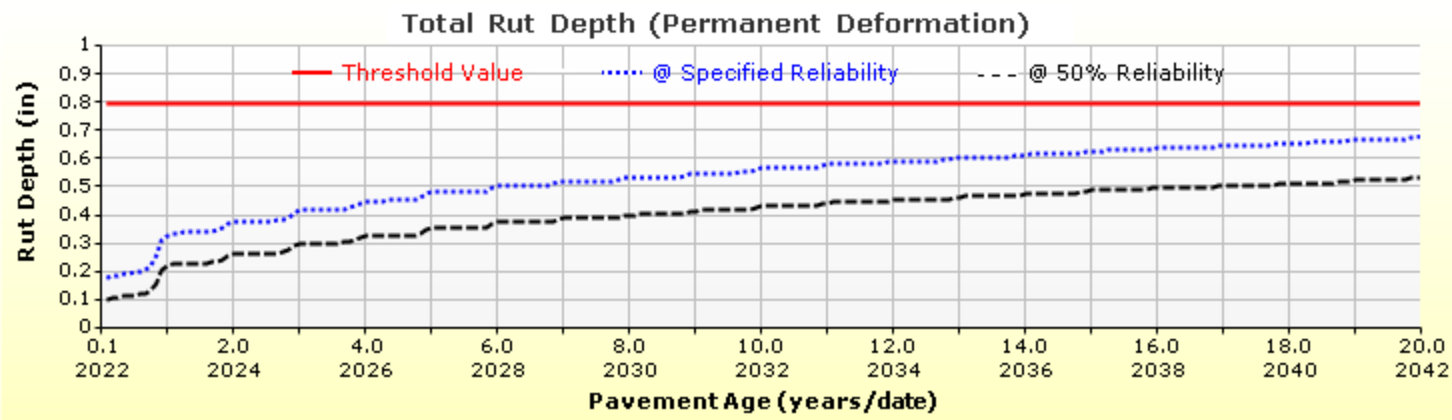


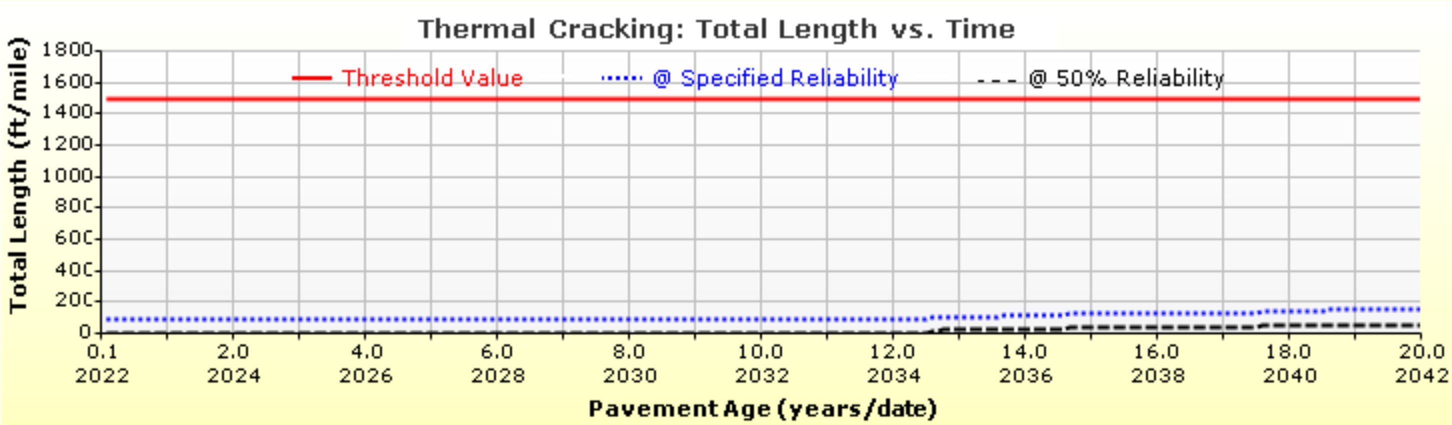


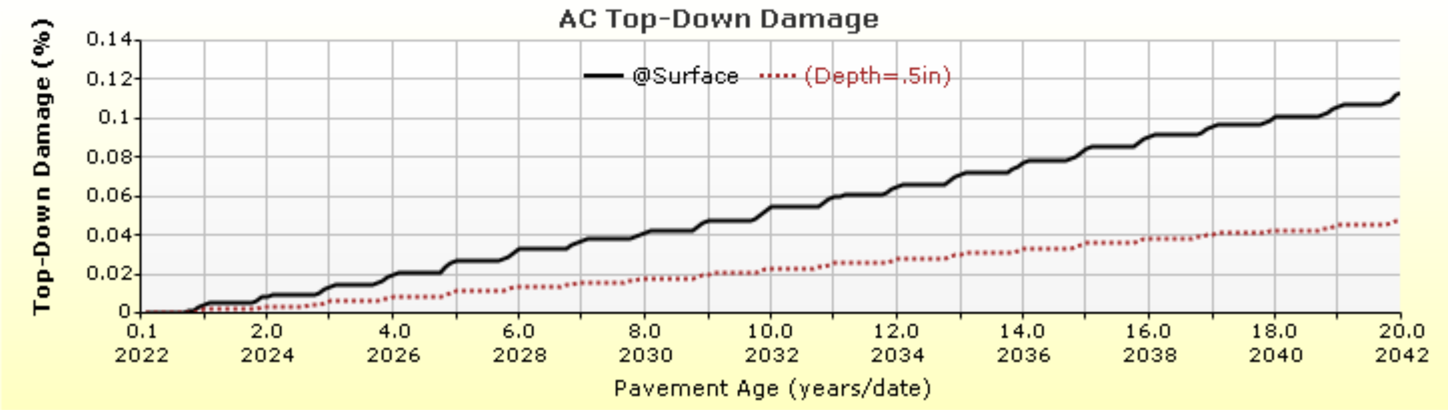


Analysis Output Charts

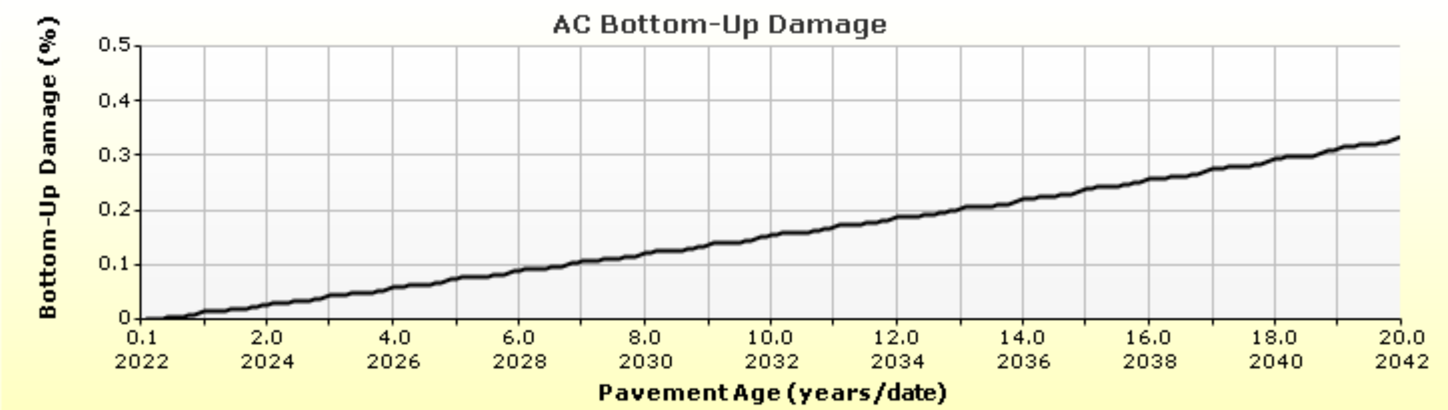




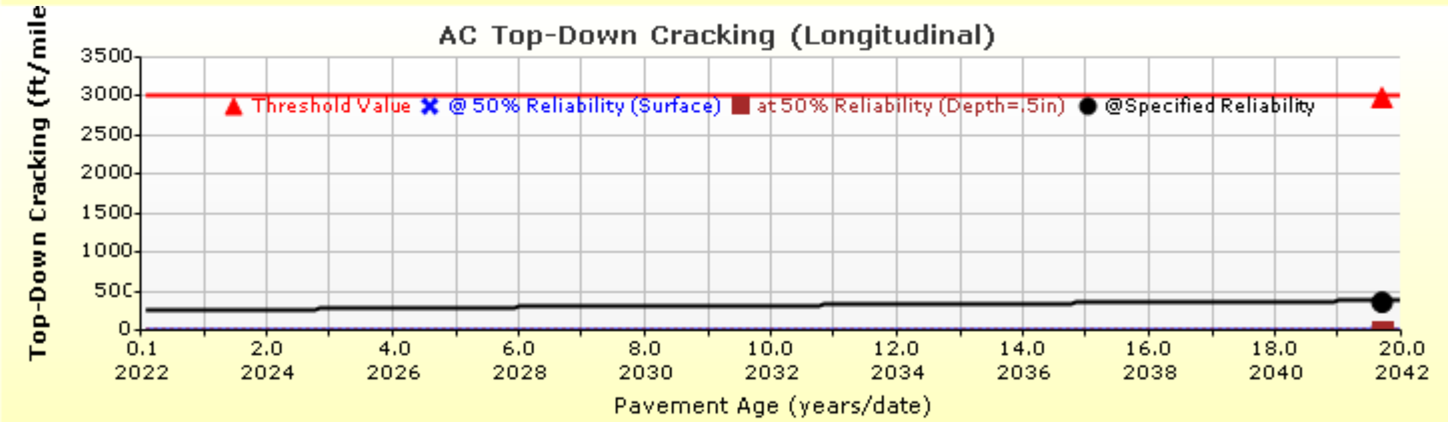




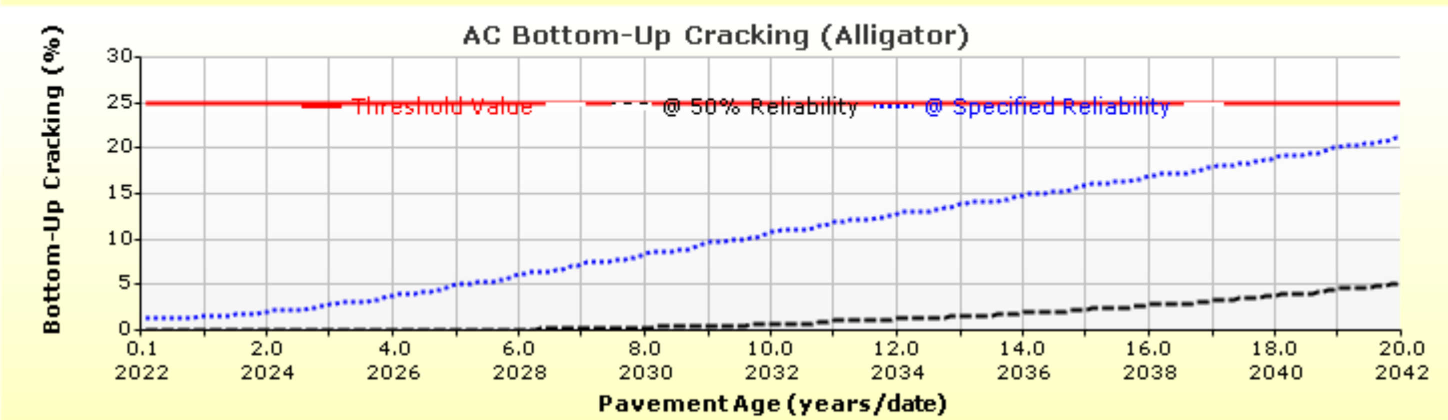
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



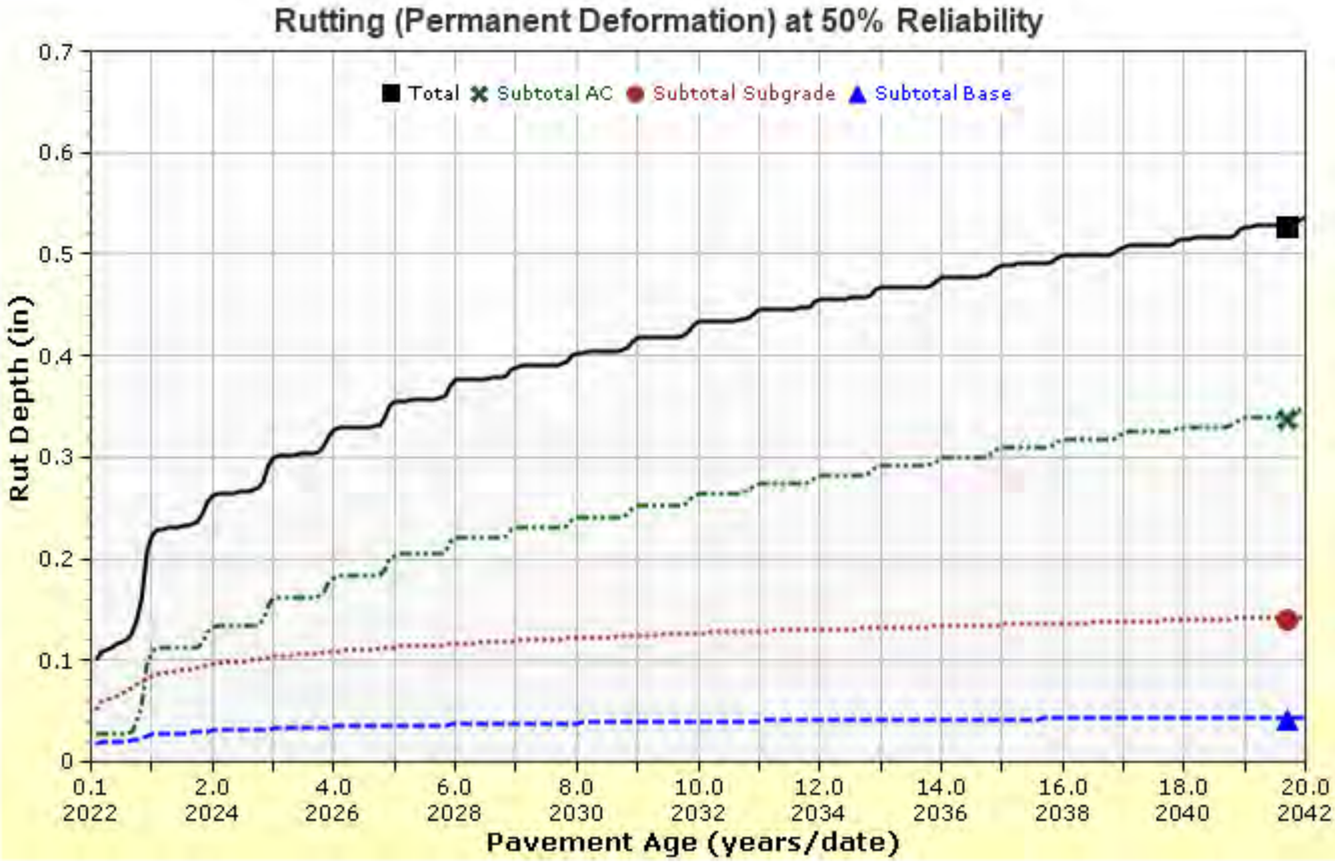
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.5
0.4
0.3
0.2
0.1
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

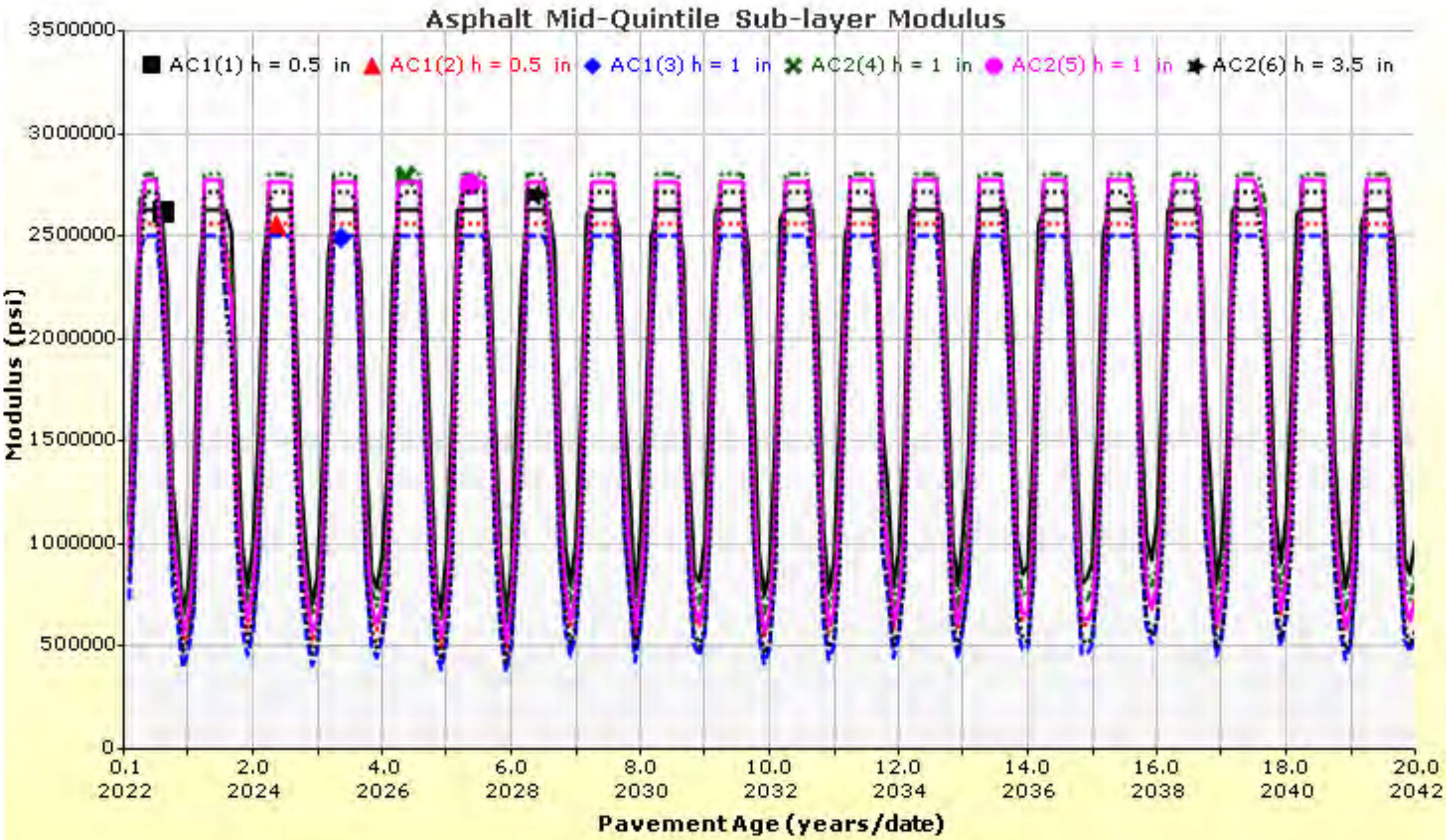


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

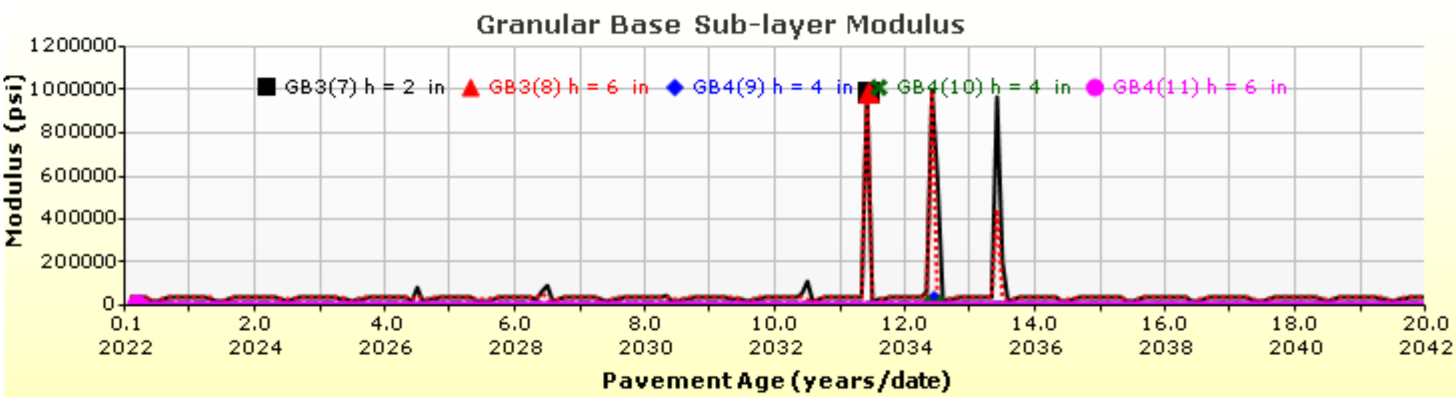


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

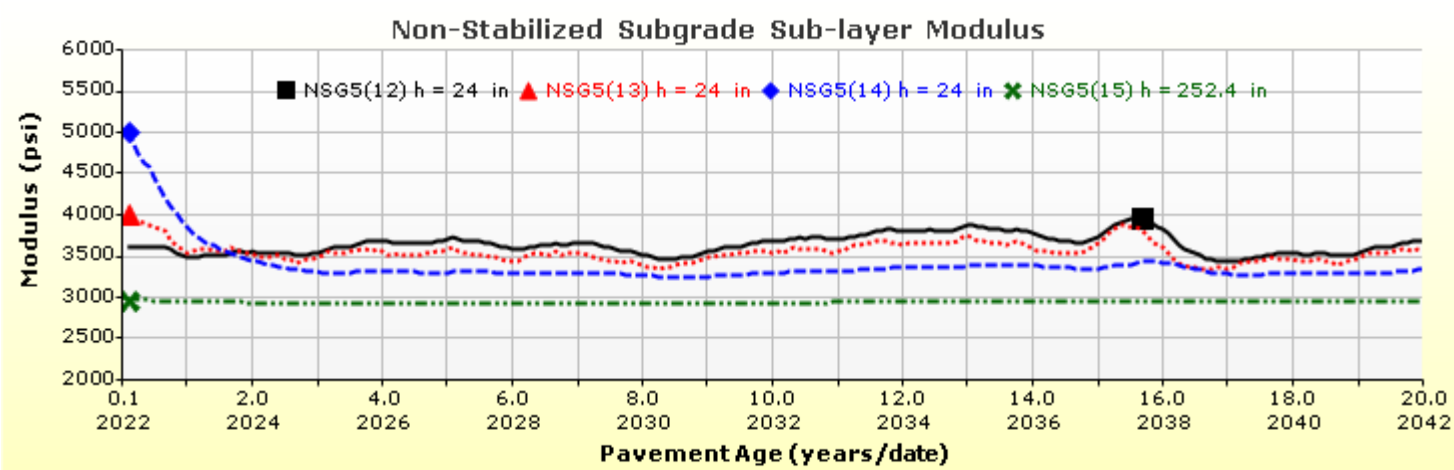

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



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 = 3.5 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
GB4(11) h = 6 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 24 in
NSG5(13) h = 24 in
NSG5(14) h = 24 in
NSG5(15) h = 252.4 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	5.5	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	14.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674	
Bf2: 1	
Bf3: 1.217799	

AC Rutting

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

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

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

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

Where:

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

$\varepsilon_p = plastic\ strain(^{in}/_{in})$
$\varepsilon_r = resilient\ strain(^{in}/_{in})$
$T = layer\ temperature(^\circ F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

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

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

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

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 6.3	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: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 0.75	Bc2:1.1

Subgrade Rutting

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

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

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

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

F.5 Road (Updated)(30-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\F.5 Road (Updated)(30-year).dgpx

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	6.5
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	14.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

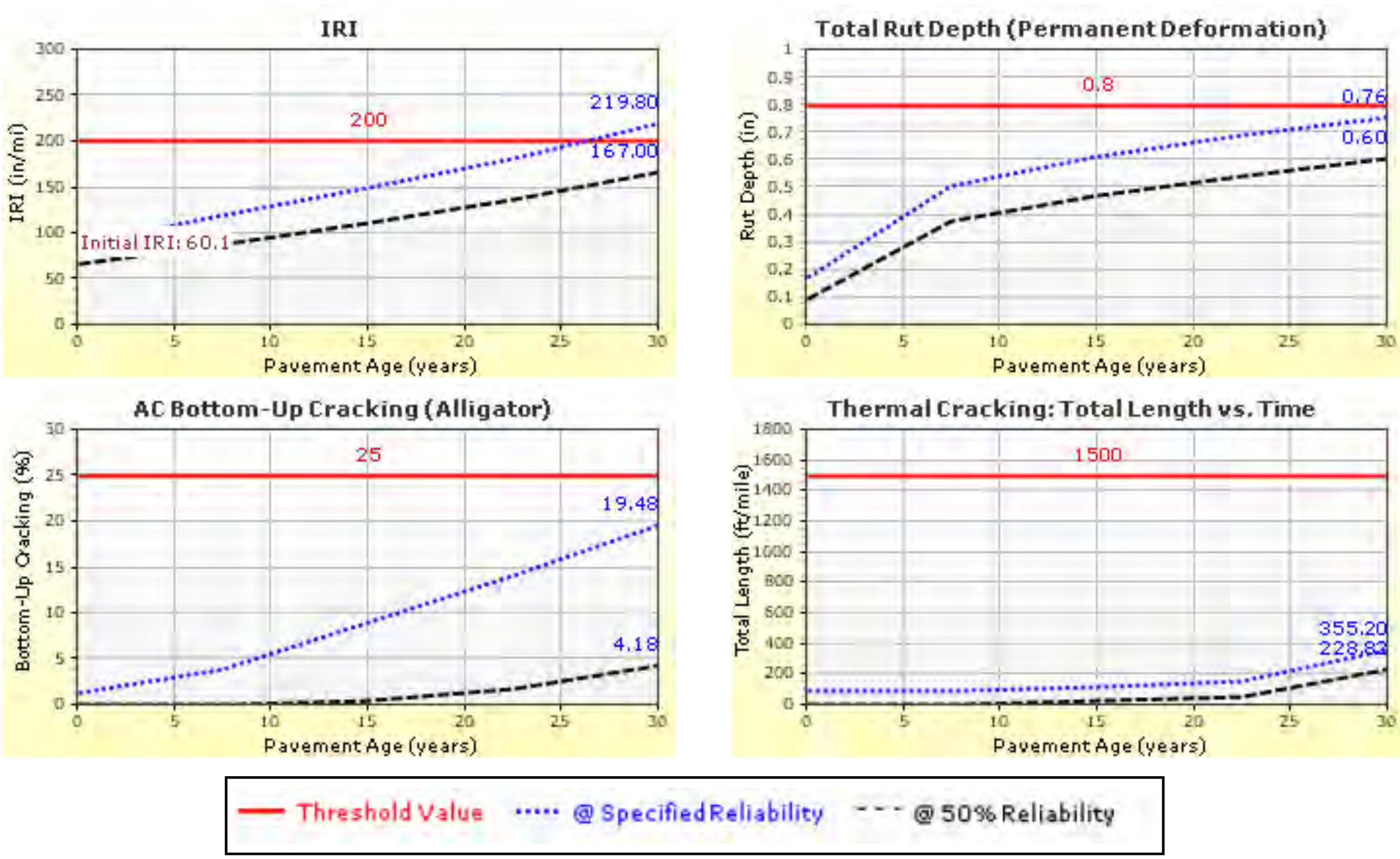
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,100
2037 (15 years)	6,056,020
2052 (30 years)	14,449,700

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	219.79	90.00	78.86	Fail
Permanent deformation - total pavement (in)	0.80	0.76	90.00	95.19	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	19.48	90.00	95.94	Pass
AC thermal cracking (ft/mile)	1500.00	355.20	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	315.18	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.56	90.00	97.94	Pass

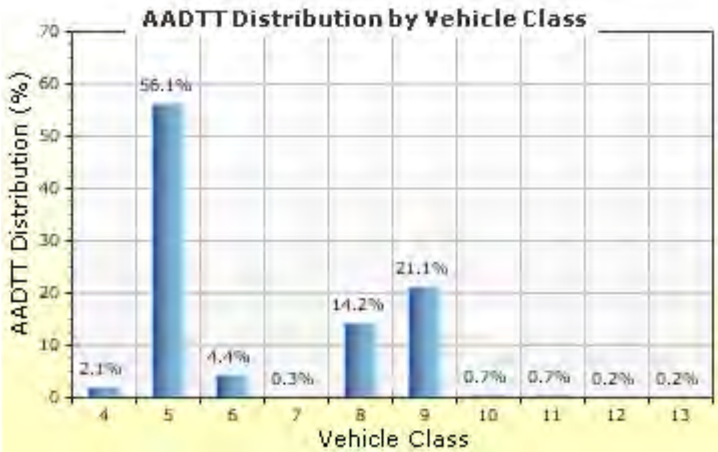
Distress Charts

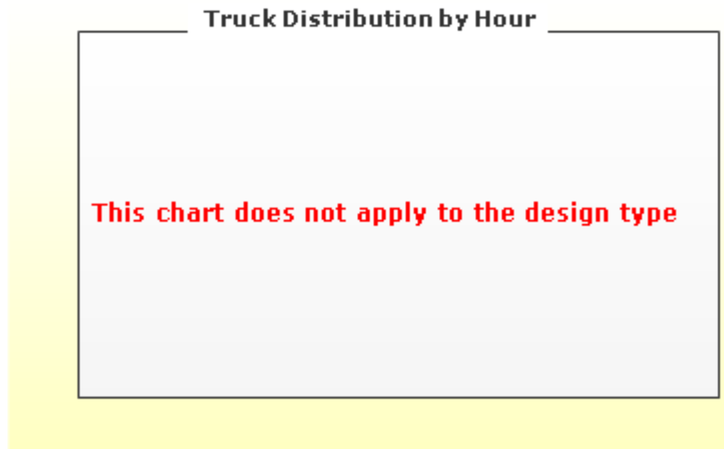


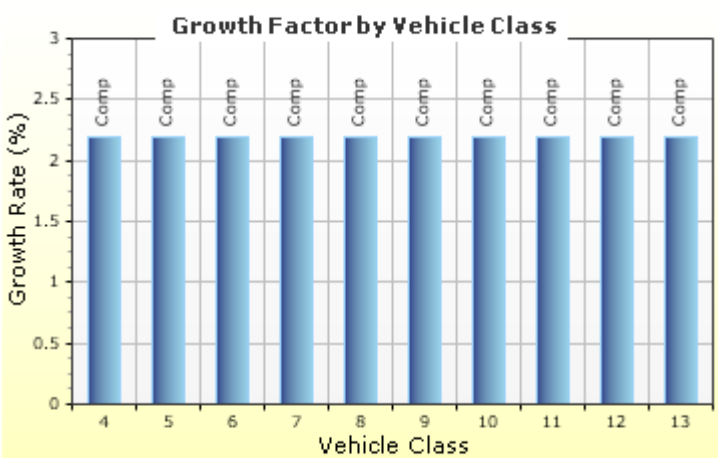
Traffic Inputs

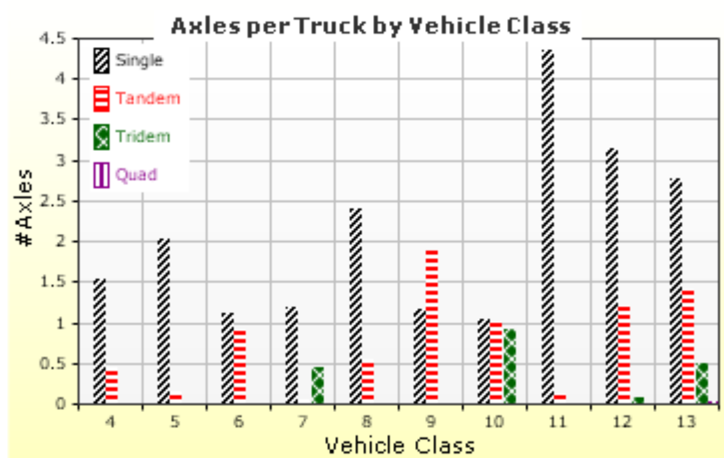
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,100	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

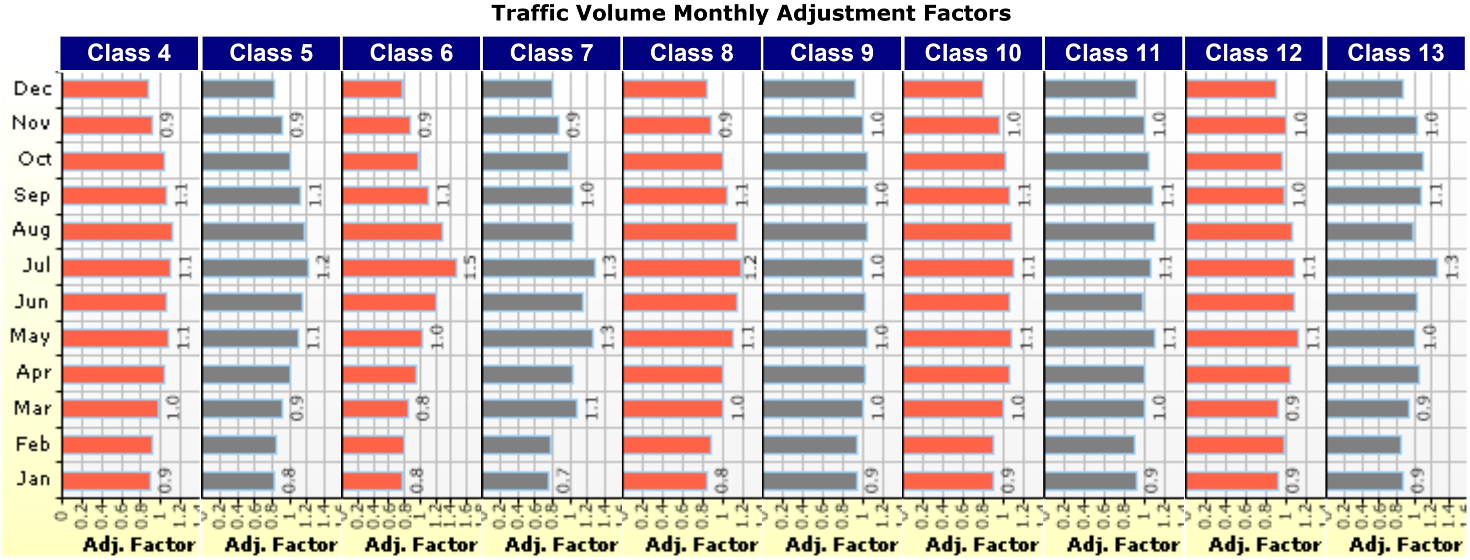








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

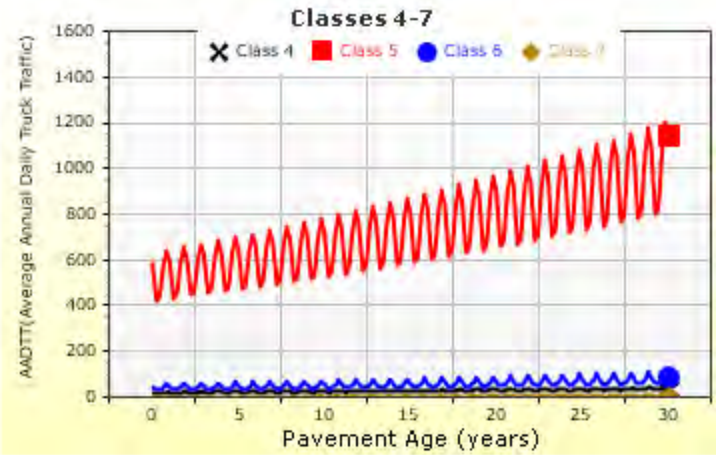
Wheelbase does not apply

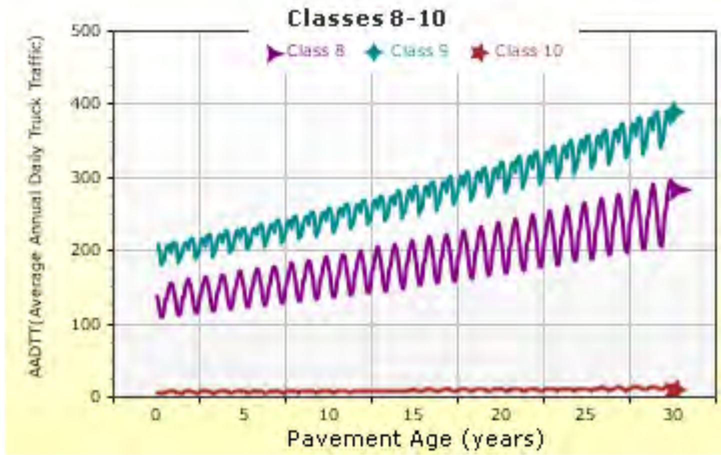
Number of Axles per Truck

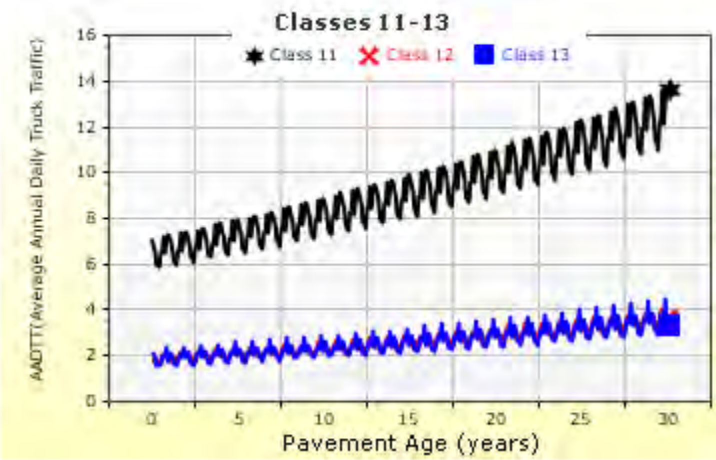
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

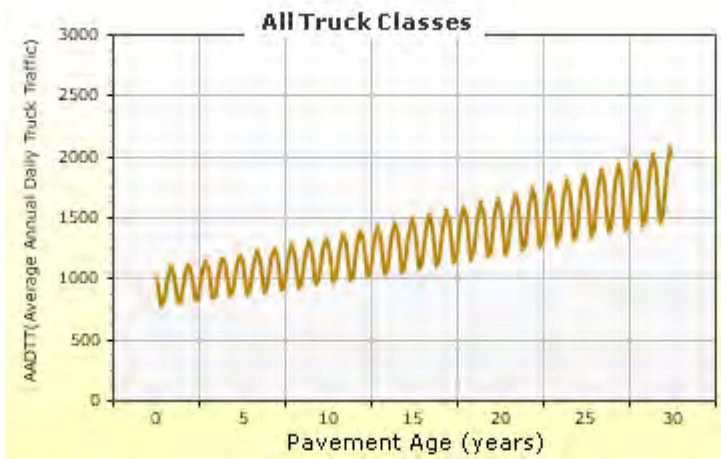
AADTT (Average Annual Daily Truck Traffic) Growth

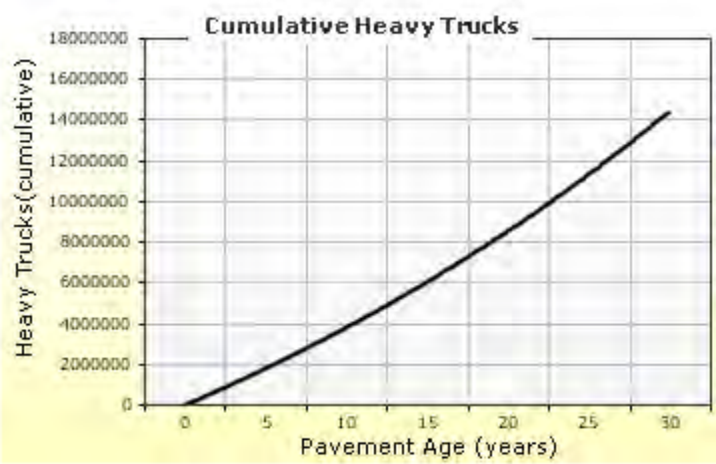
*** Traffic cap is not enforced**







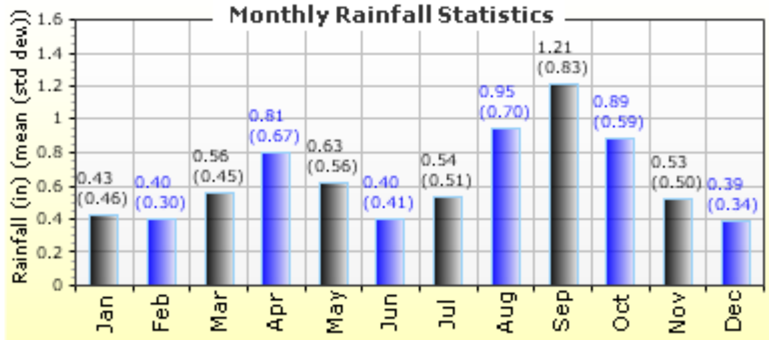




Climate Inputs

Climate Data Sources:

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

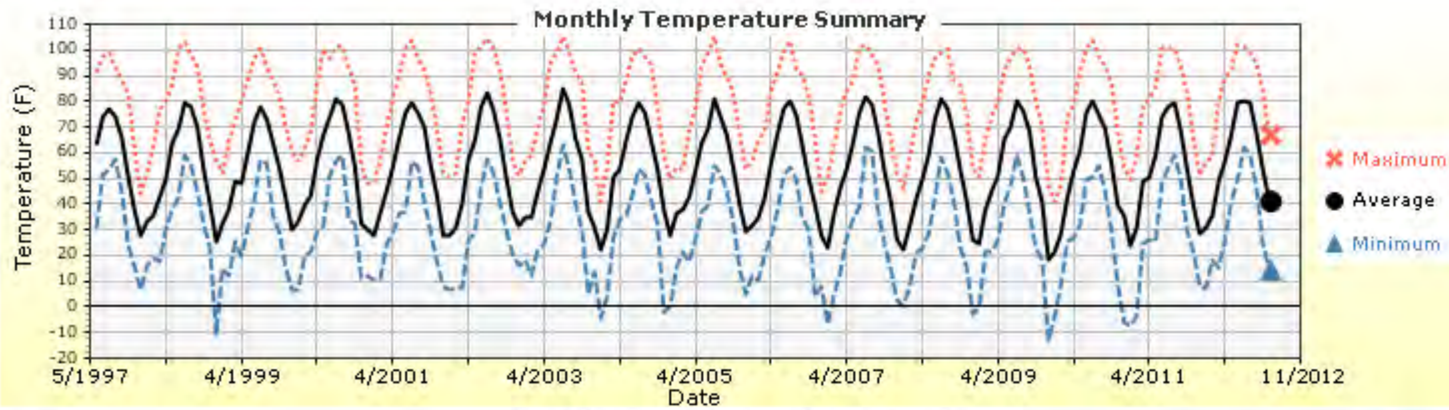


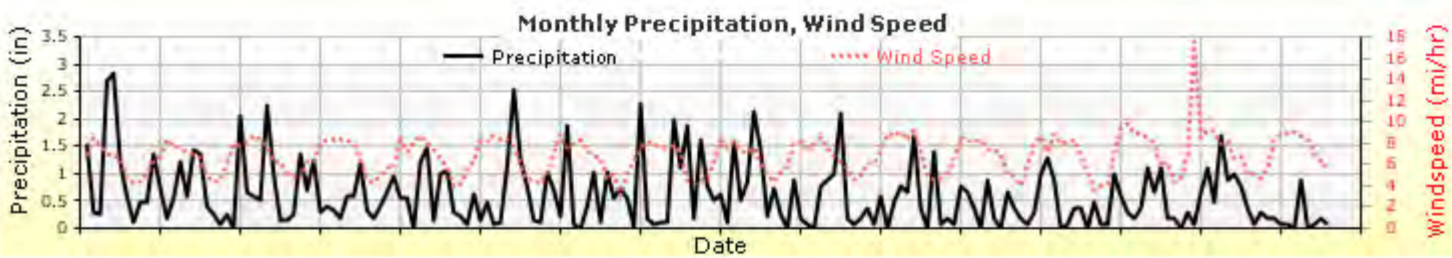
Annual Statistics:

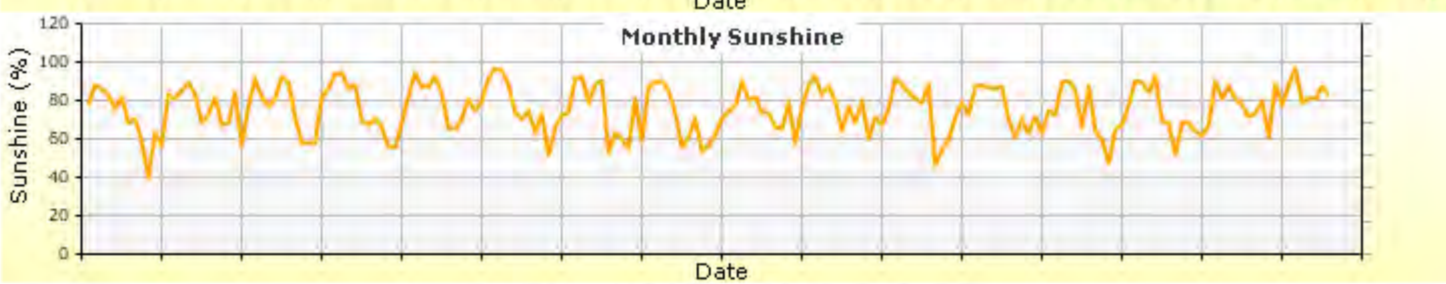
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

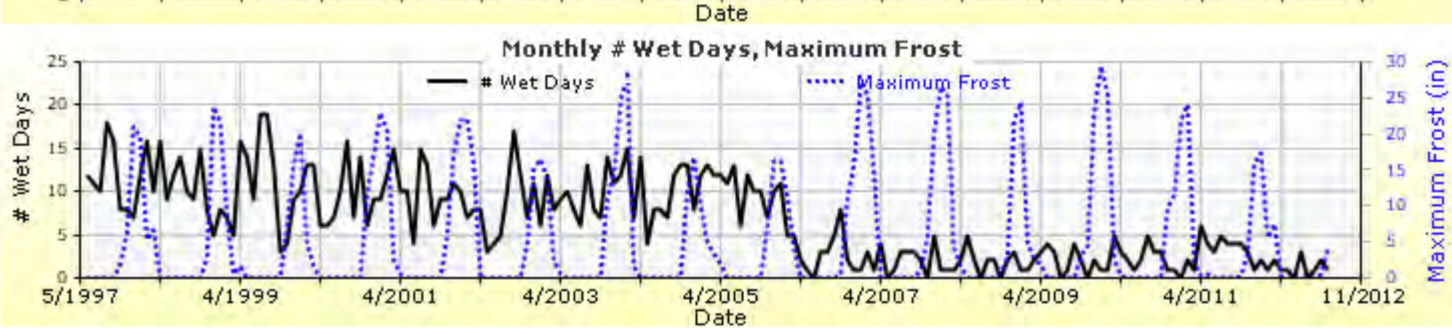
Water table depth (ft)	10.00

Monthly Climate Summary:

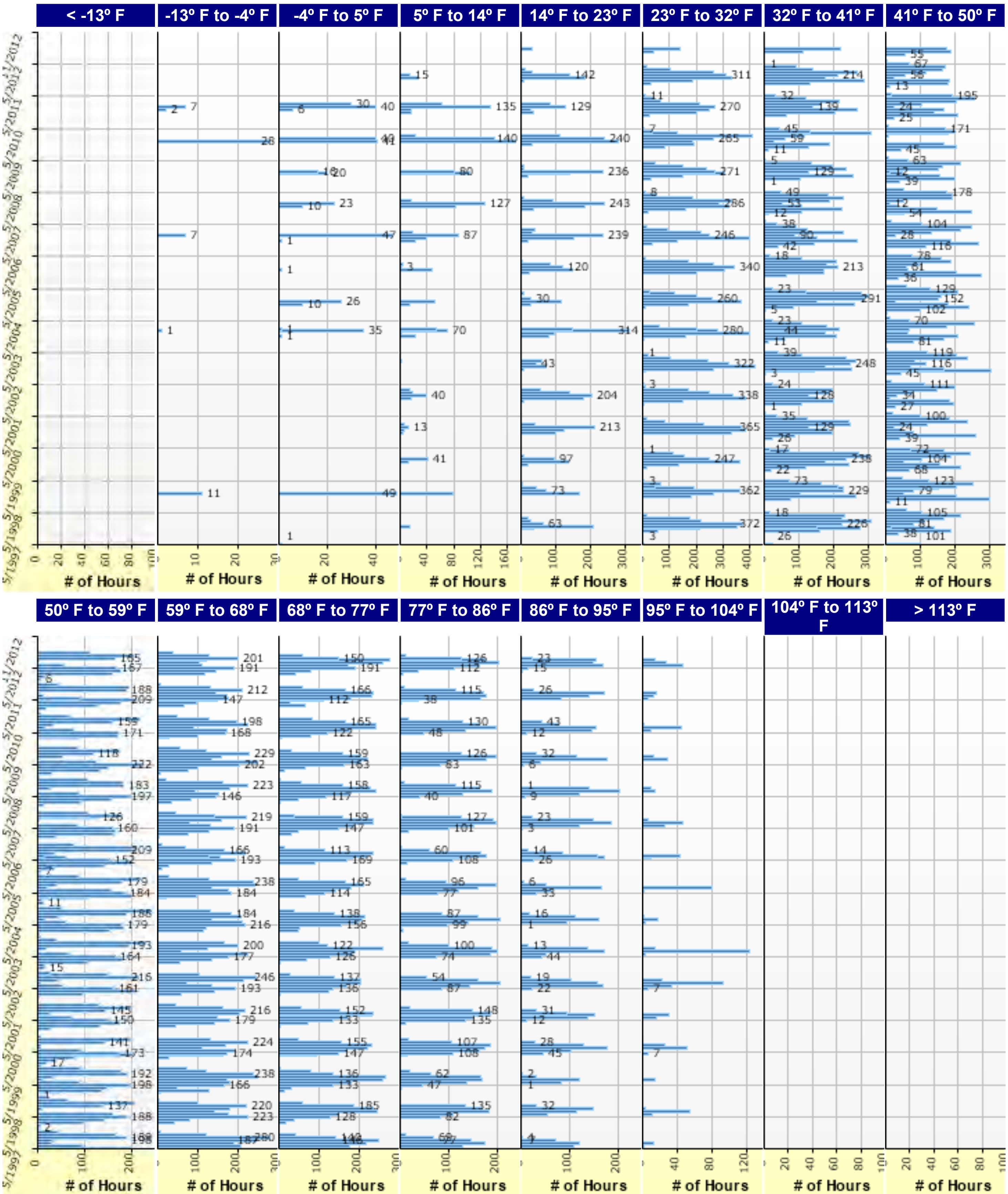








Hourly Air Temperature Distribution by Month:



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 : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (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 : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

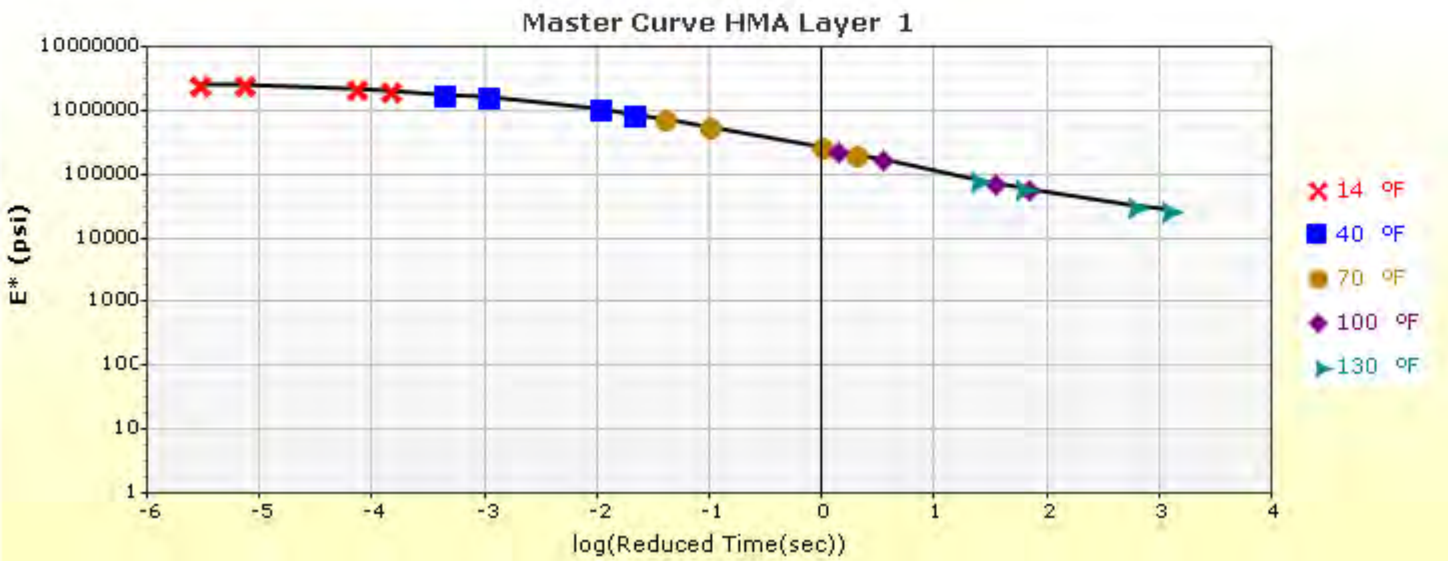
Thermal Cracking (Input Level: 1)

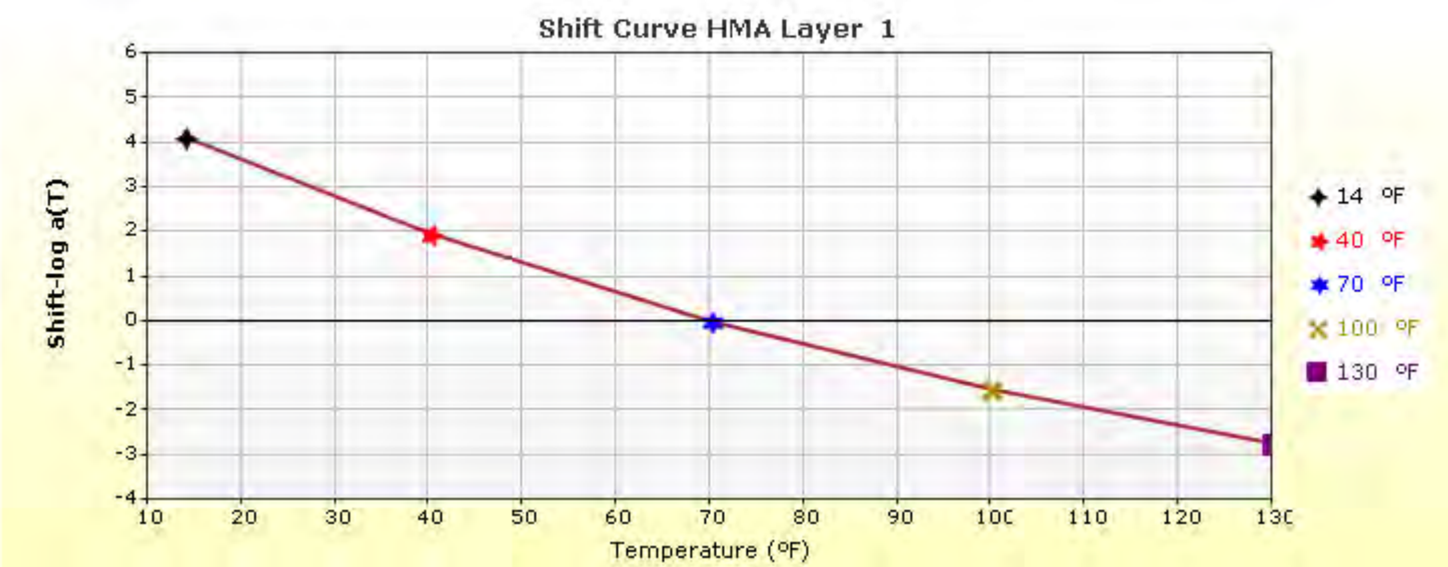
Indirect tensile strength at 14 ºF (psi)	519.00

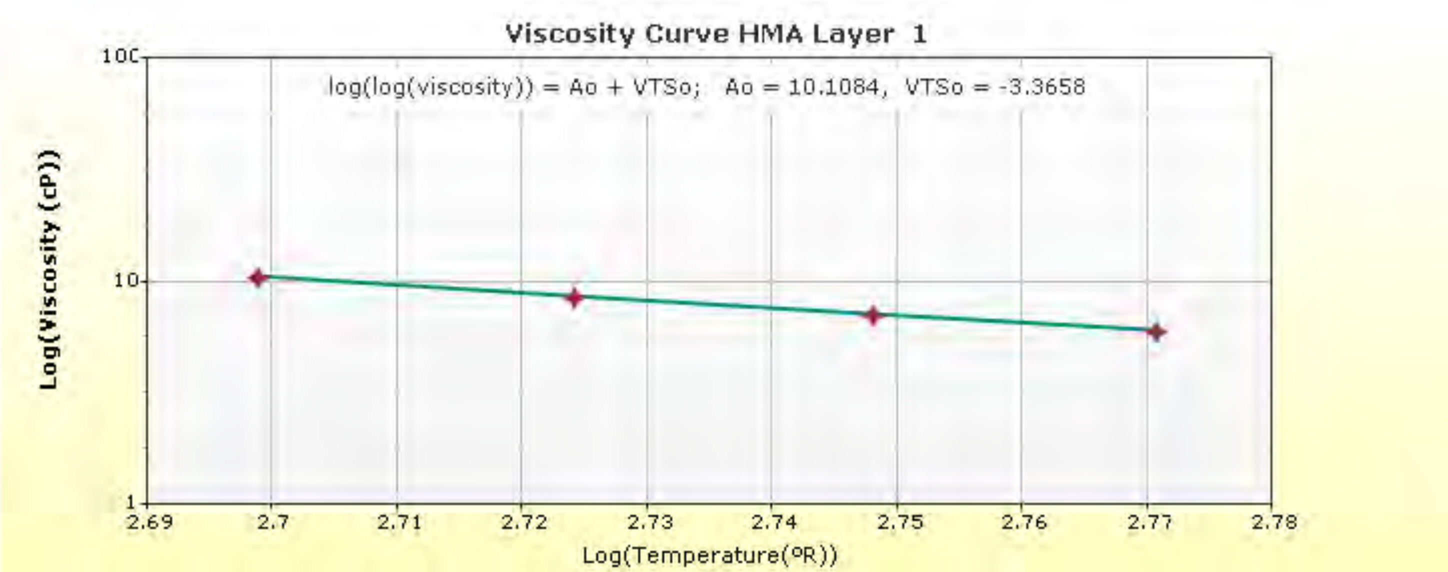
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006

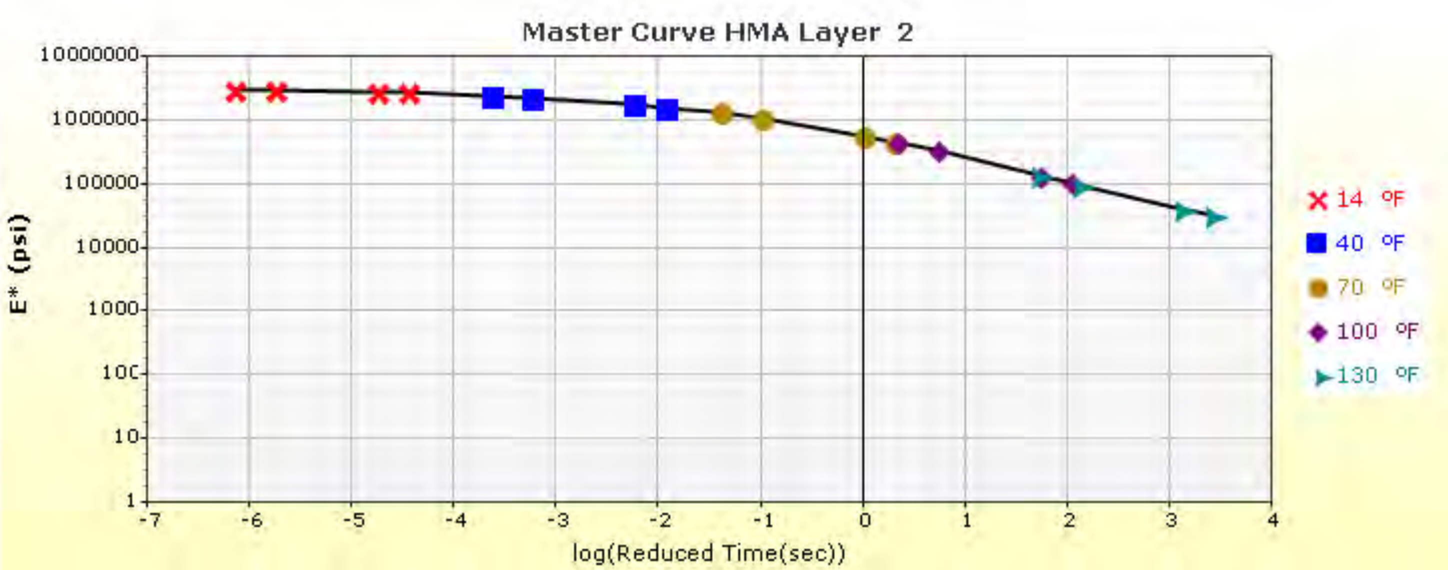
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

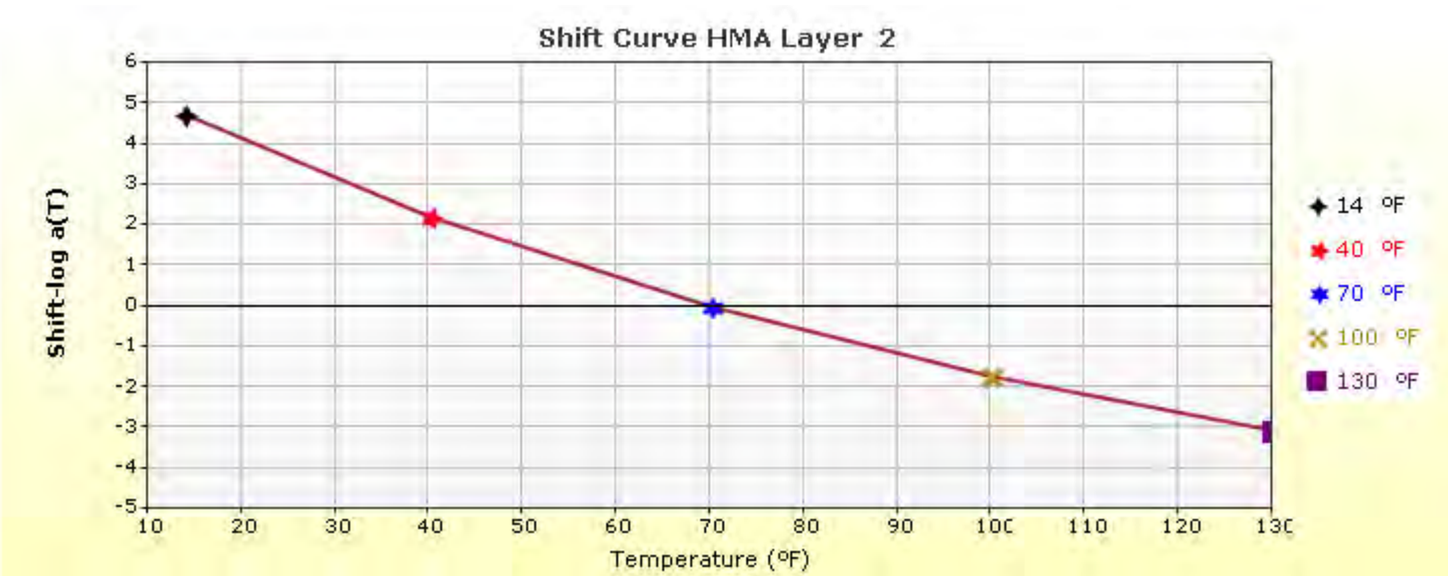


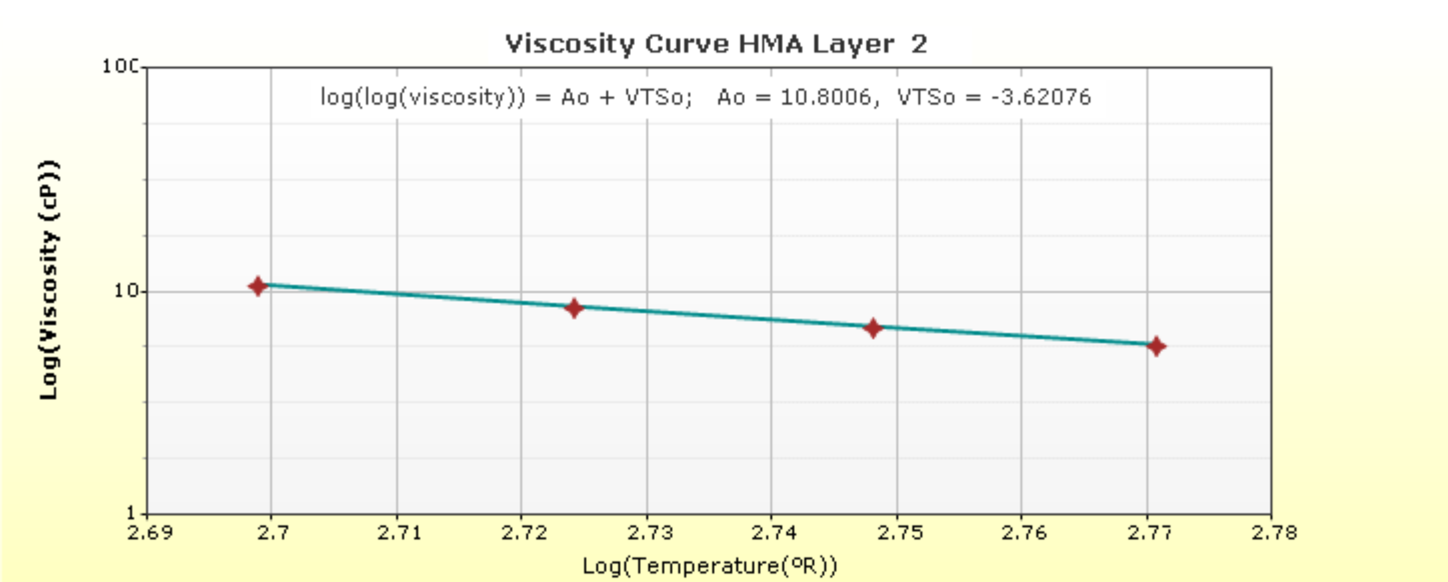




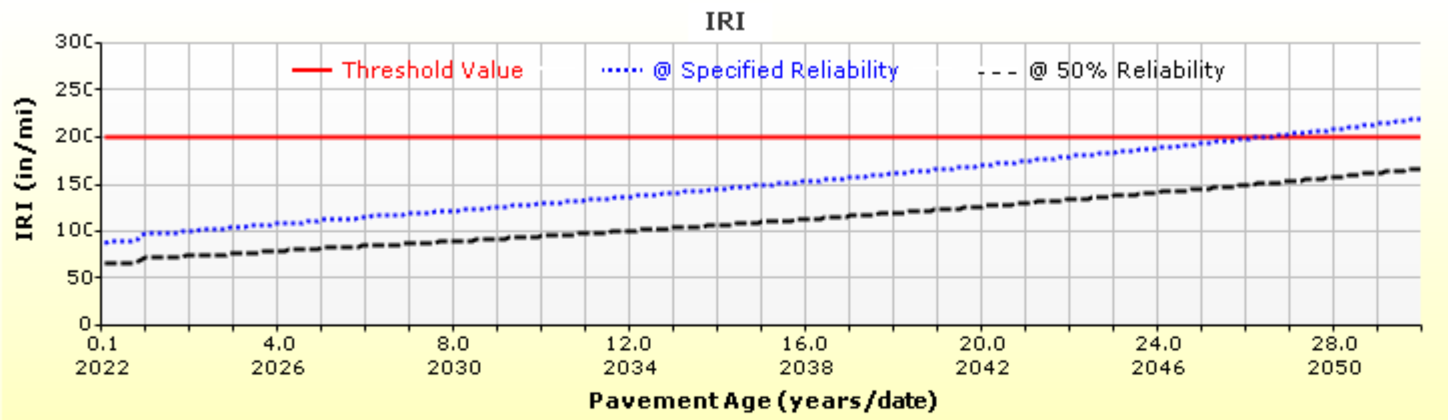
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

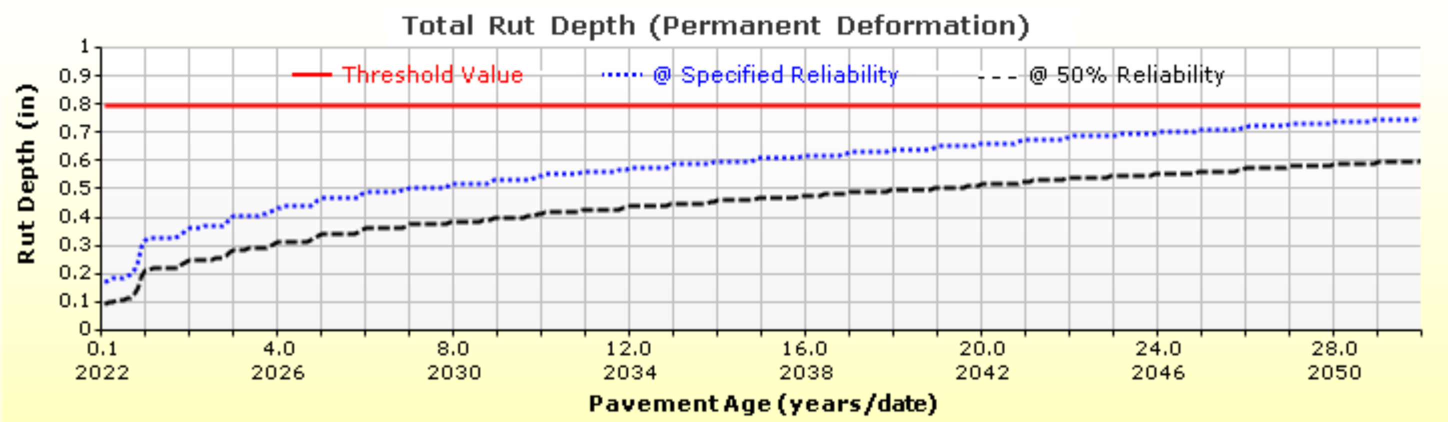


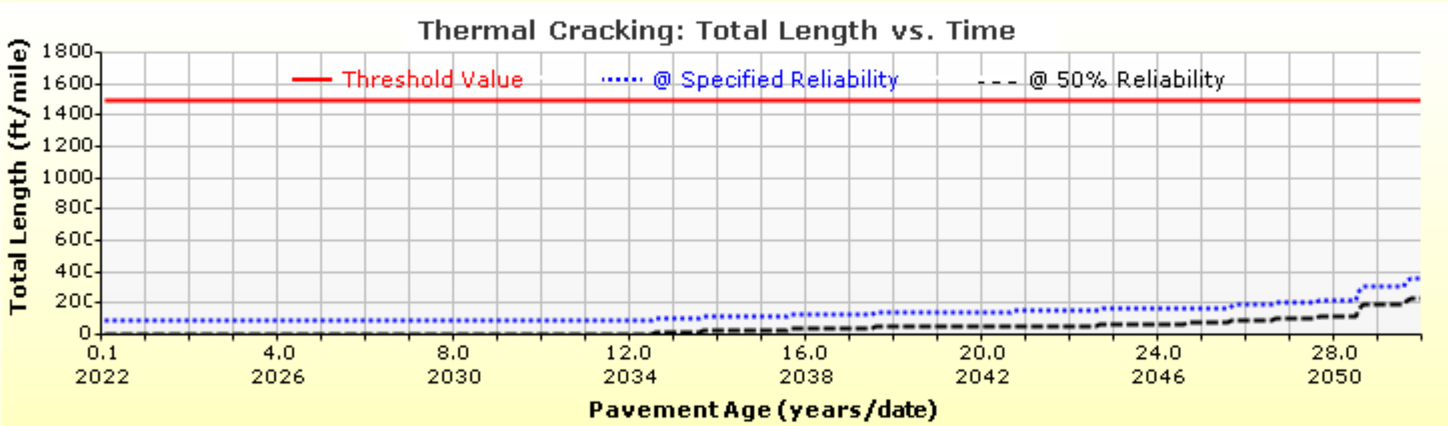


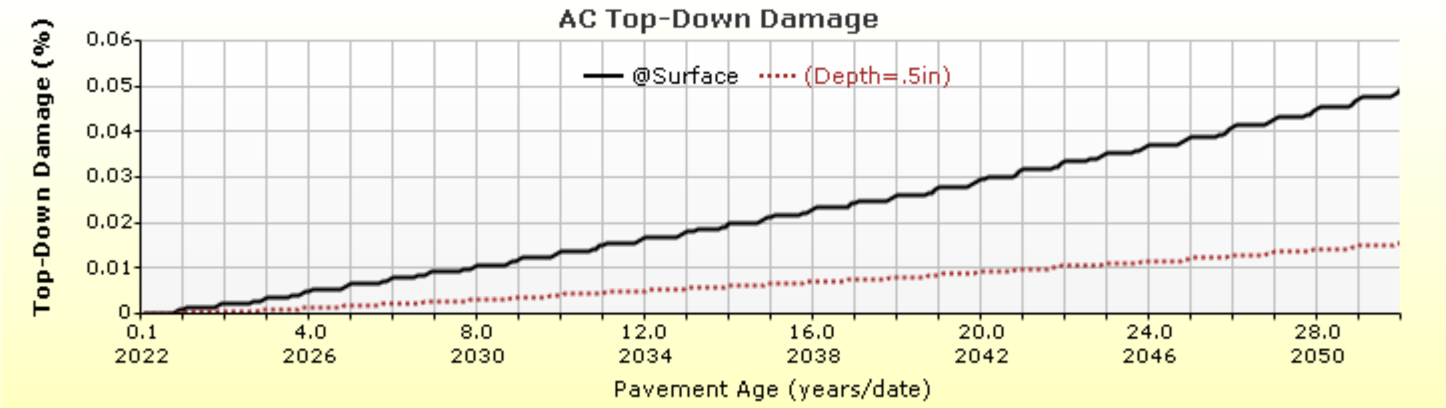


Analysis Output Charts

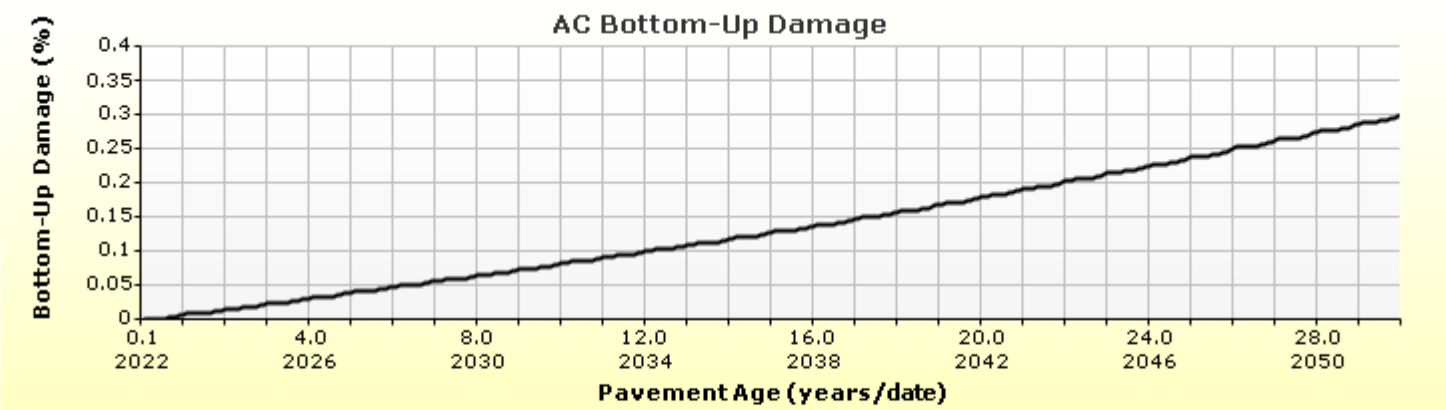




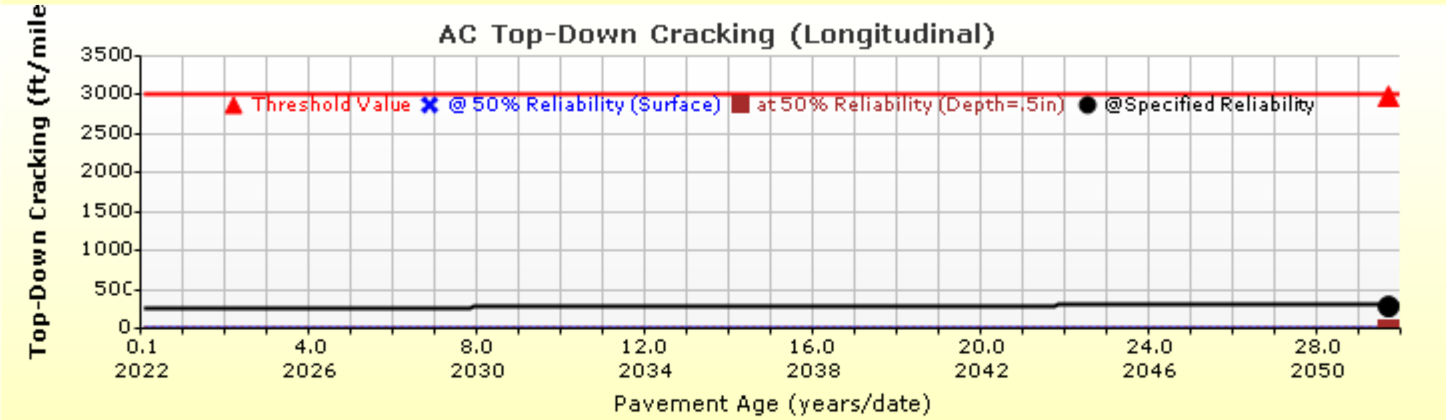




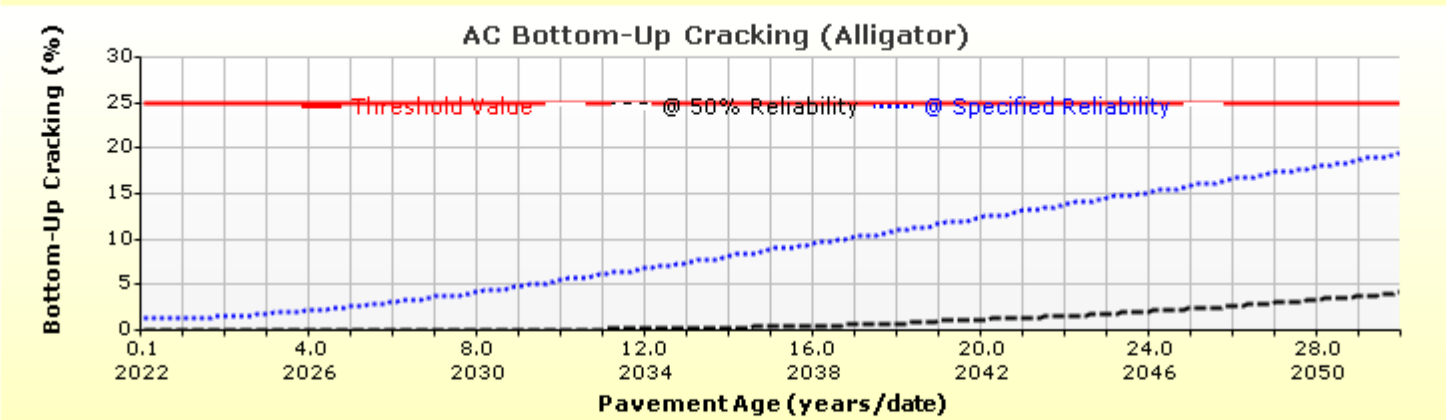
AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
Pavement Age (years/date)



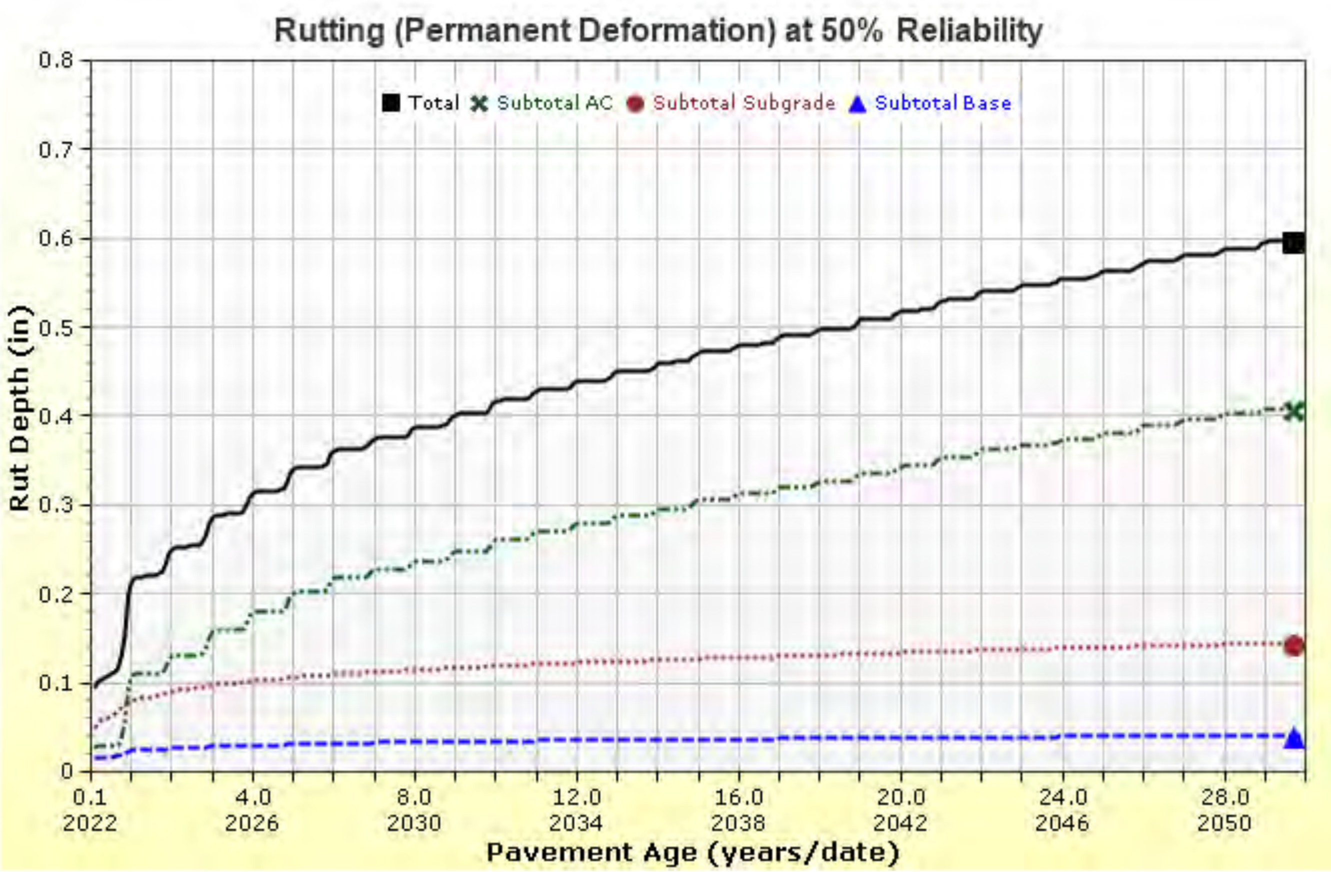
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

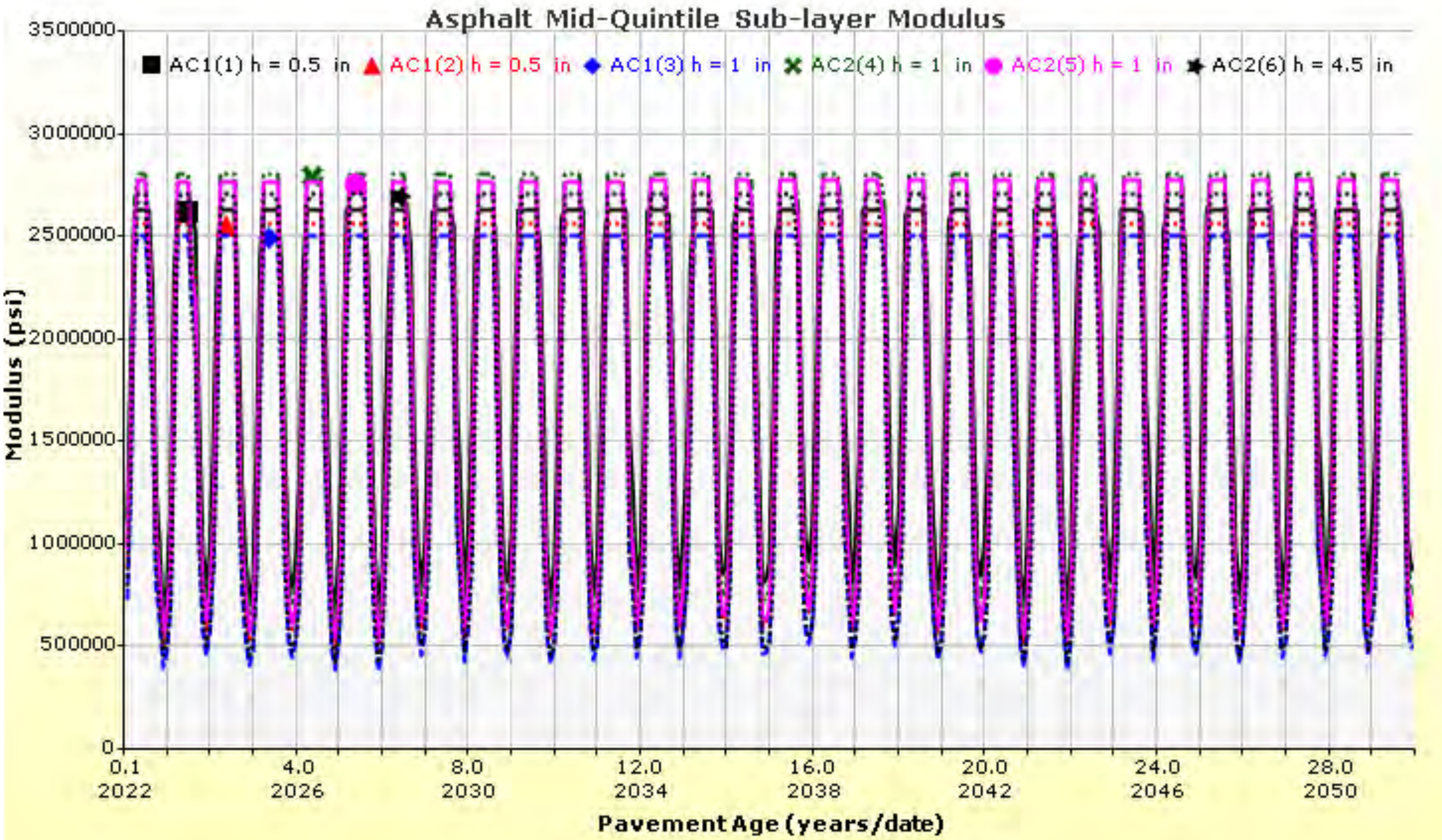


AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Pavement Age (years/date)

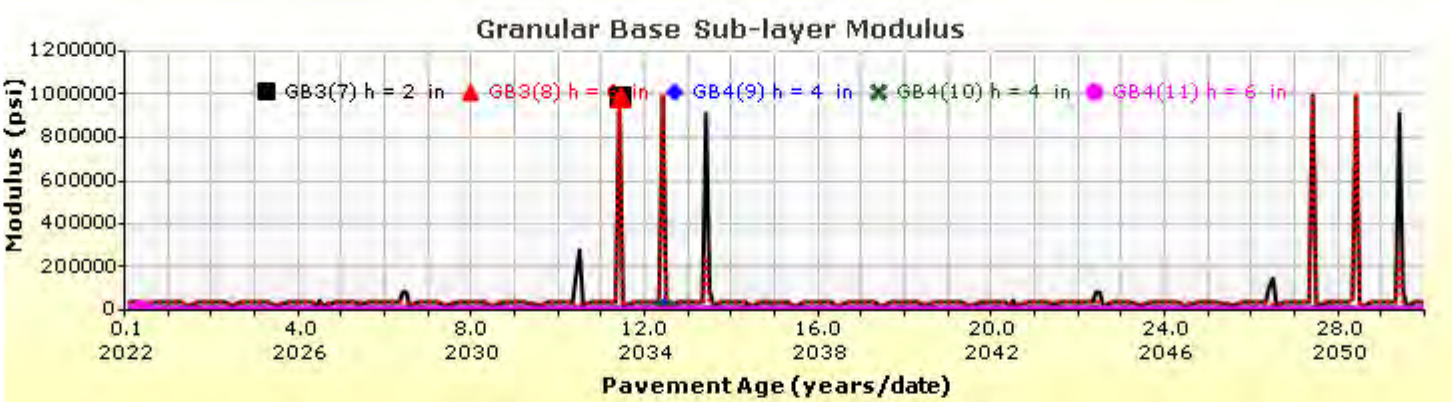


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Pavement Age (years/date)

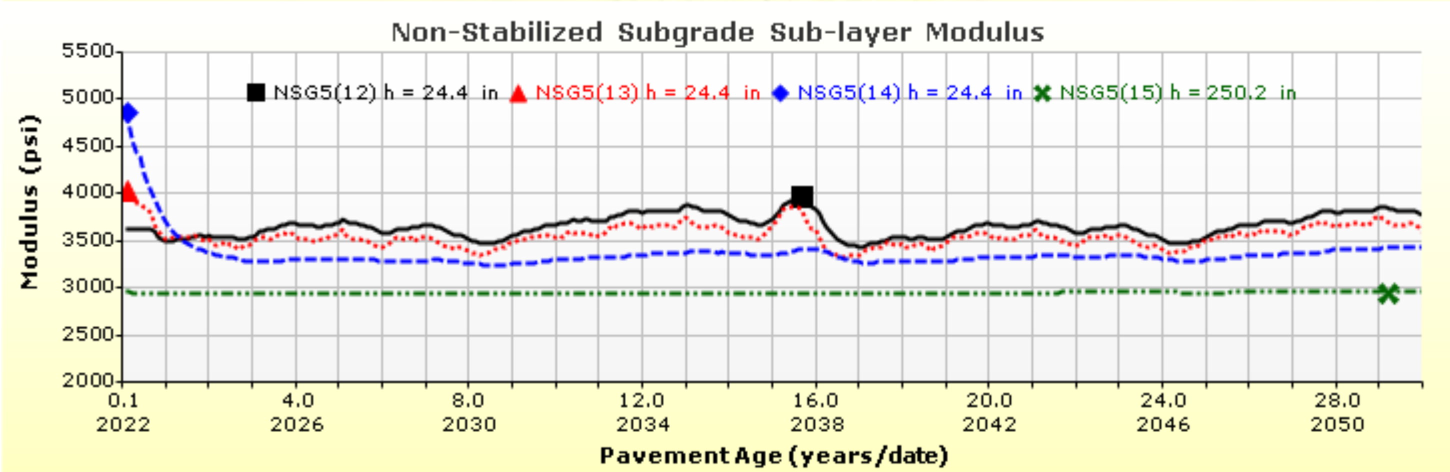

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
Pavement Age (years/date)



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 = 4.5 in
Modulus (psi)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
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
GB4(11) h = 6 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 24.4 in
NSG5(13) h = 24.4 in
NSG5(14) h = 24.4 in
NSG5(15) h = 250.2 in
Modulus (psi)
5500
5000
4500
4000
3500
3000
2500
2000
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	6.5	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	14.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

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

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

APPENDIX C1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
F ½ ROAD

PCCP F.5 Road

File Name: C:\Users\RSPavement\Documents\PMED Designs\My ME Design\Projects\F.5 Road\PCCP F.5 Road.dgpx

Design Inputs

Design Life:	30 years	Existing construction:	-	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	JPCP	Pavement construction:	May, 2022		
		Traffic opening:	August, 2022		

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	12.0
Subgrade	A-6	Semi-infinite

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

Traffic

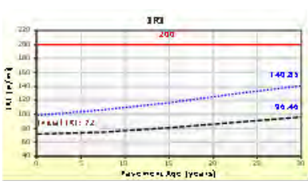
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,100
2037 (15 years)	6,056,020
2052 (30 years)	14,449,700

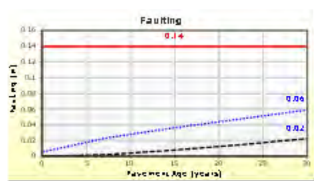
Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	140.85	90.00	99.86	Pass
Mean joint faulting (in)	0.14	0.06	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	6.04	90.00	93.34	Pass

Distress Charts

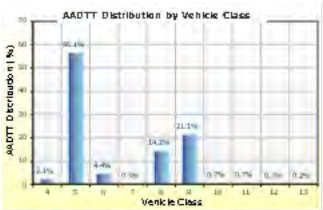


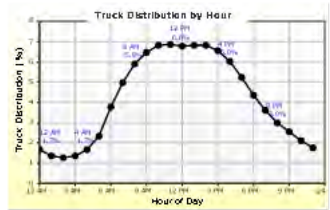


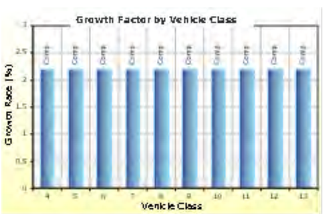
Traffic Inputs

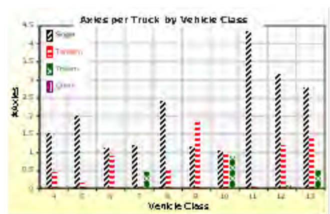
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,100	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

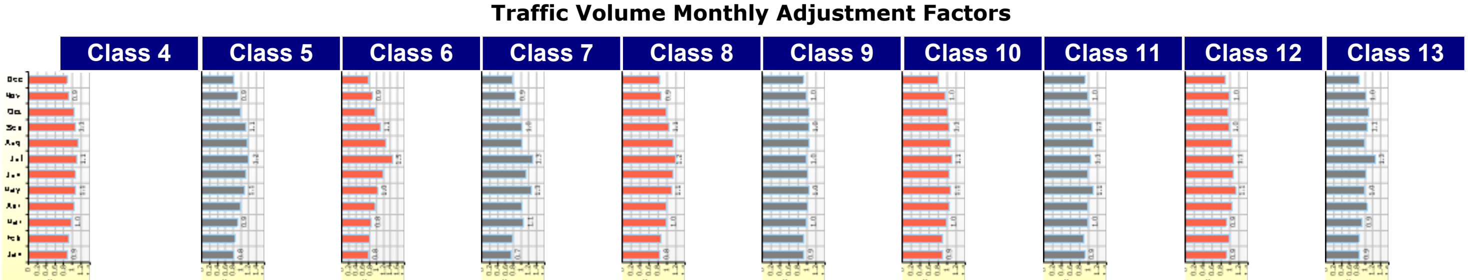








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

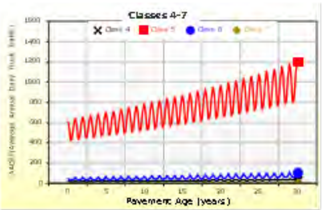
Wheelbase			
Axle Type / Value Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

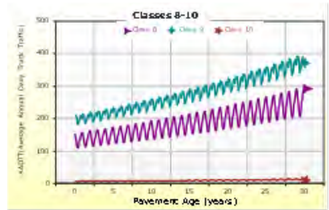
Number of Axles per Truck

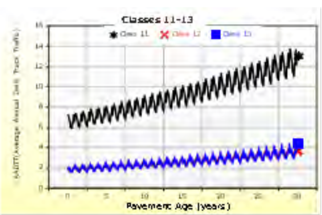
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

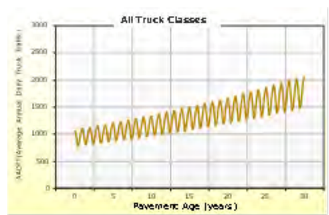
AADTT (Average Annual Daily Truck Traffic) Growth

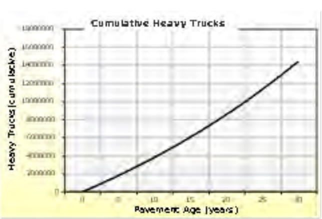
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

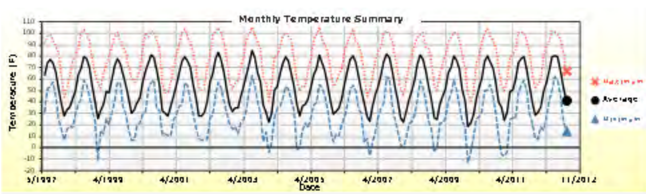
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

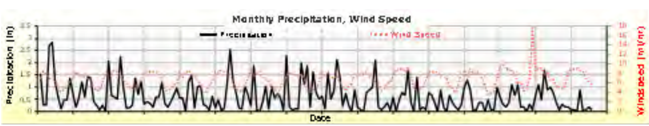
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

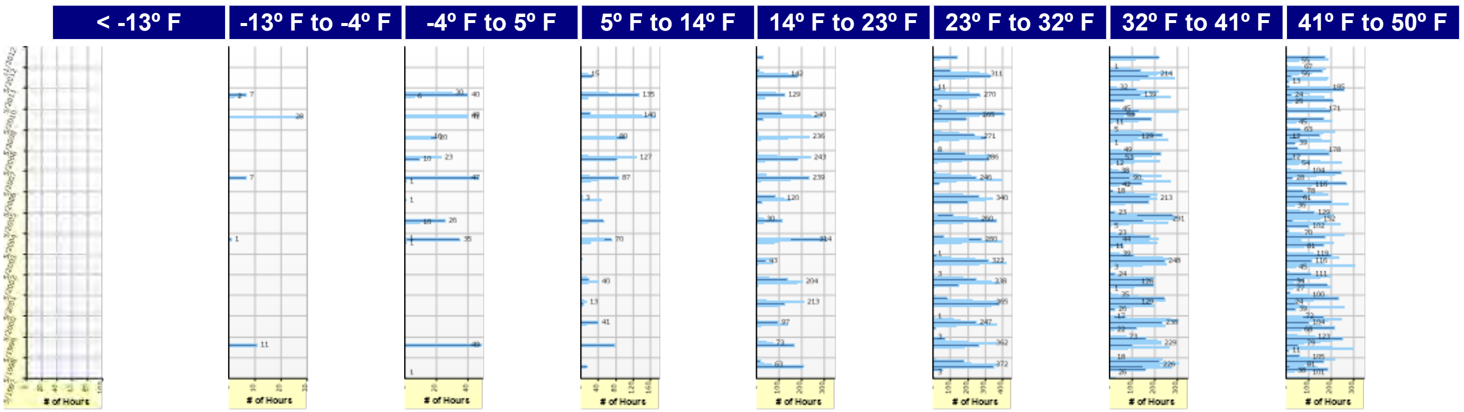
Water table depth (ft)	10.00

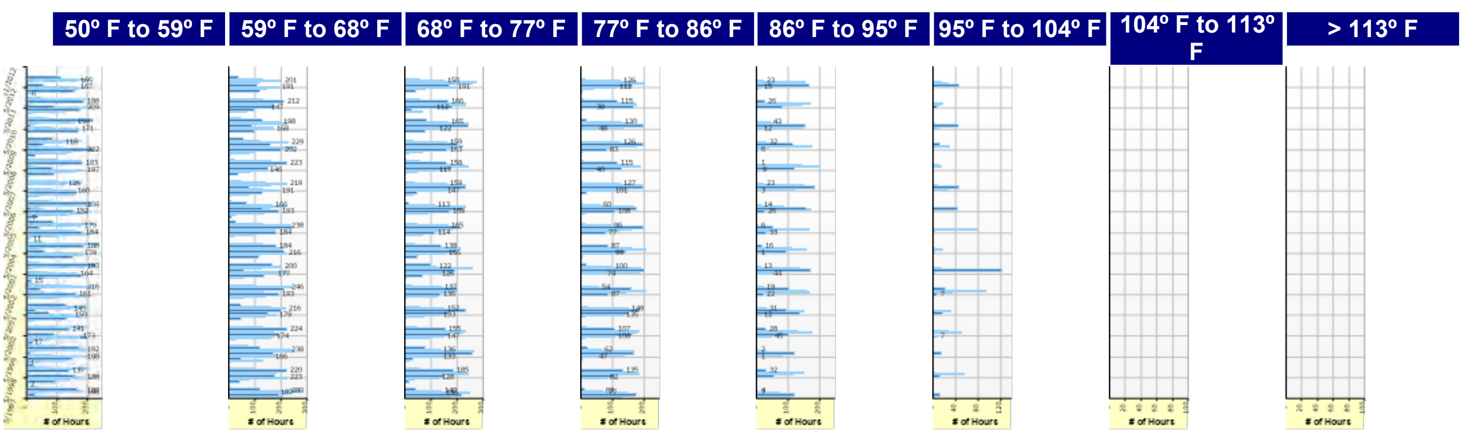
Monthly Climate Summary:





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)	12.00

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

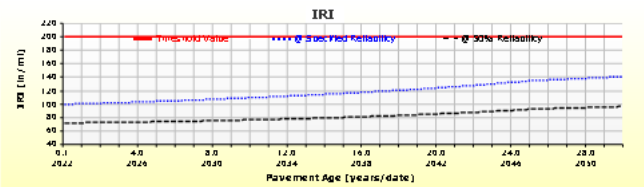
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

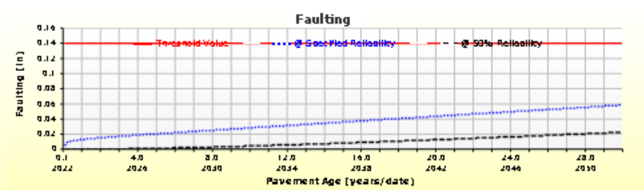
Sealant type	Other(Including No Sealant... Liquid... Silicone)

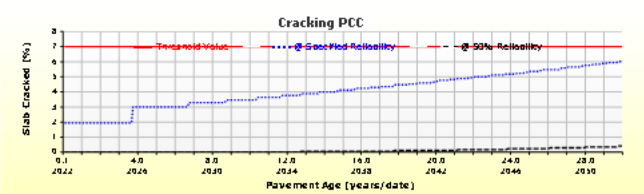
Erodibility index	4

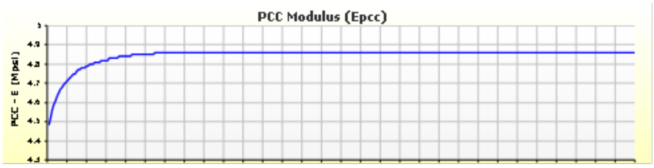
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

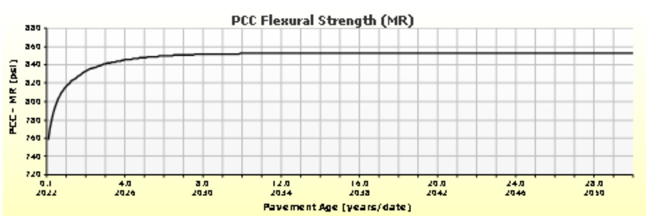




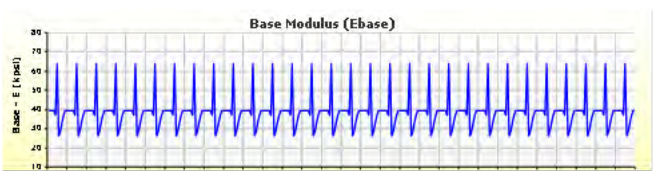




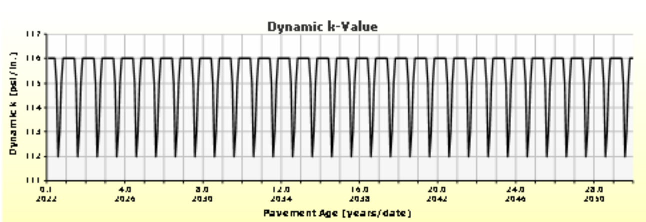
PCC Modulus (Epcc)
PCC - E (Mpsi)



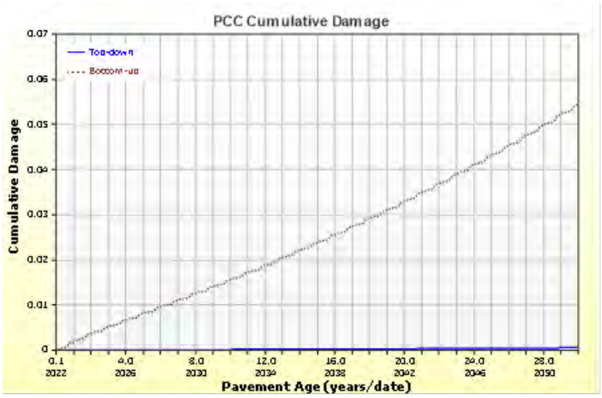
PCC Flexural Strength (MR)
PCC - MR (psi)
Pavement Age (years/date)

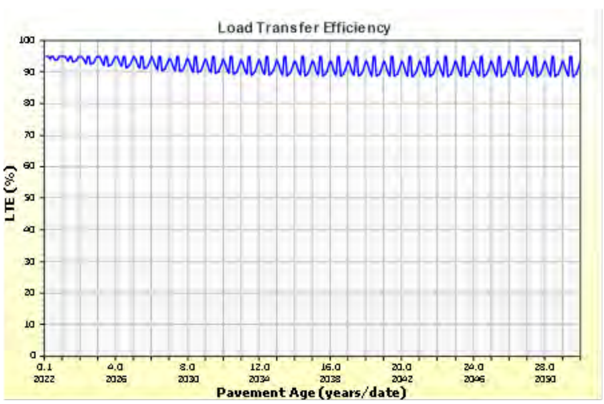


Base Modulus (Ebase)
Base - E (kpsi)



Dynamic k-Value
Dynamic k (psi/in.)
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.0
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

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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-6

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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 D

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT
SHEETS 24 ½ ROAD

24.5 Road (Updated)(20-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\24.5 Road (Updated)(20-year).dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	5.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	10.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

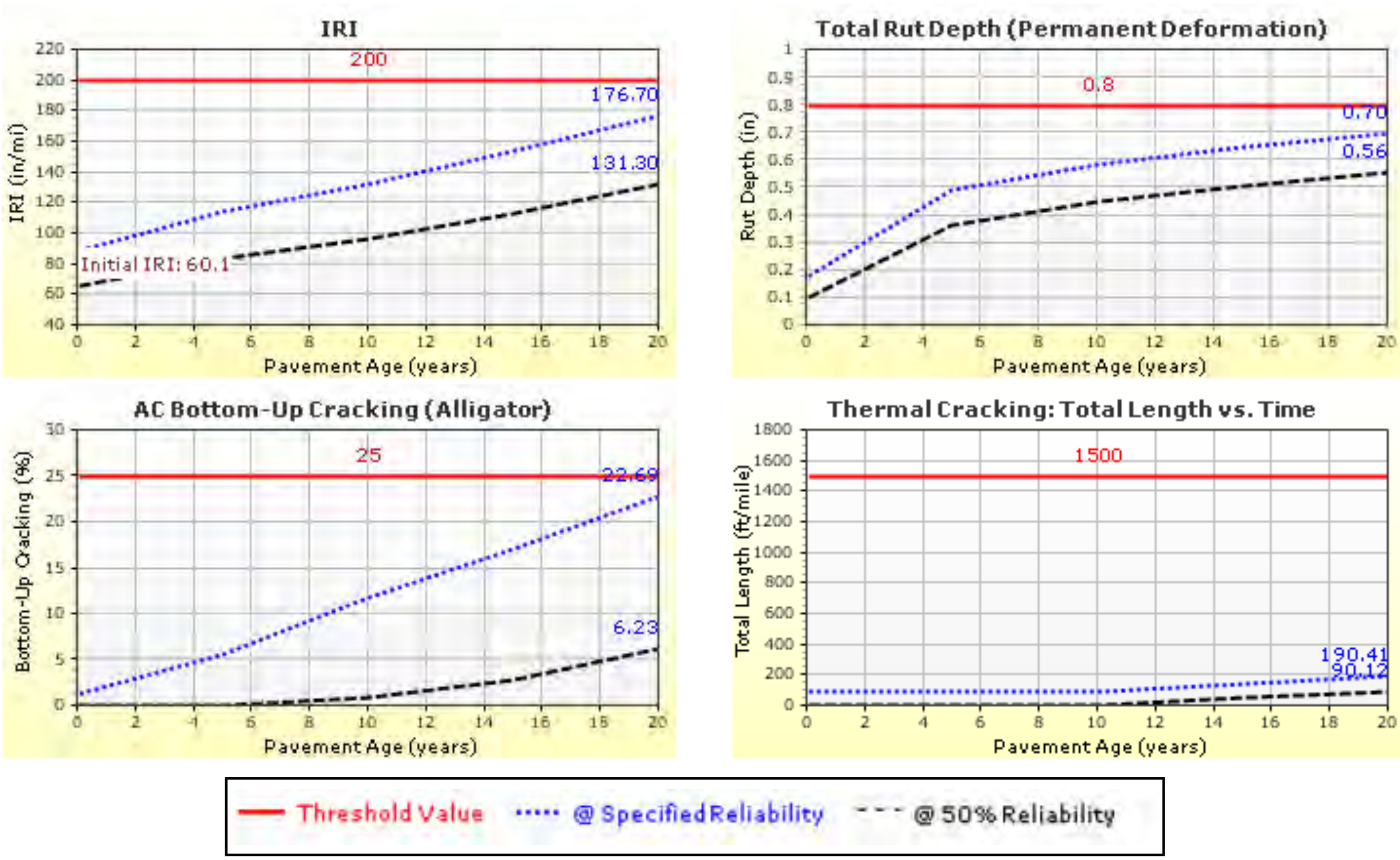
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	1,078
2032 (10 years)	2,610,580
2042 (20 years)	5,855,820

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	176.69	90.00	97.38	Pass
Permanent deformation - total pavement (in)	0.80	0.70	90.00	98.40	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	22.69	90.00	92.80	Pass
AC thermal cracking (ft/mile)	1500.00	190.41	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	445.43	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.51	90.00	99.52	Pass

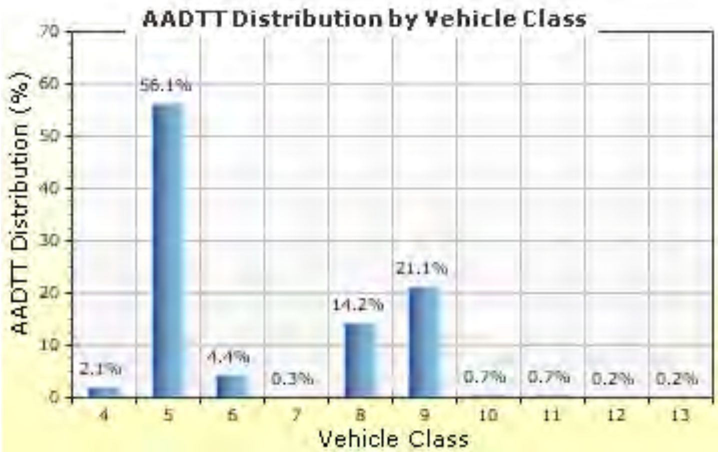
Distress Charts

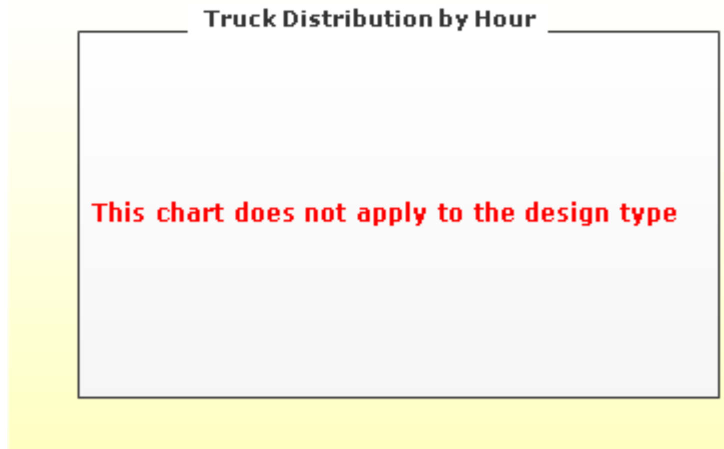


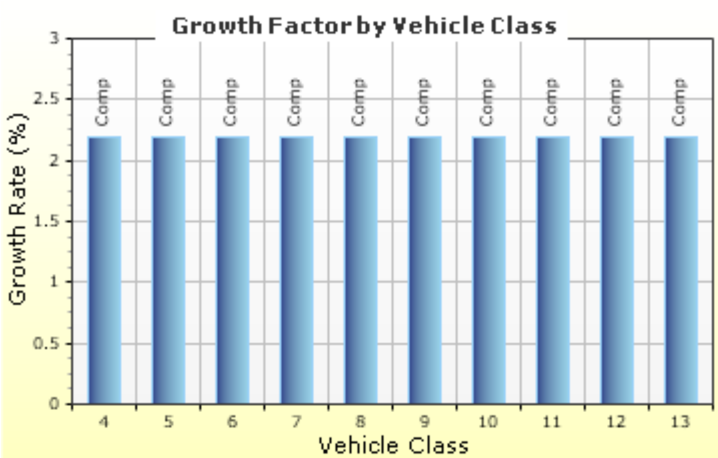
Traffic Inputs

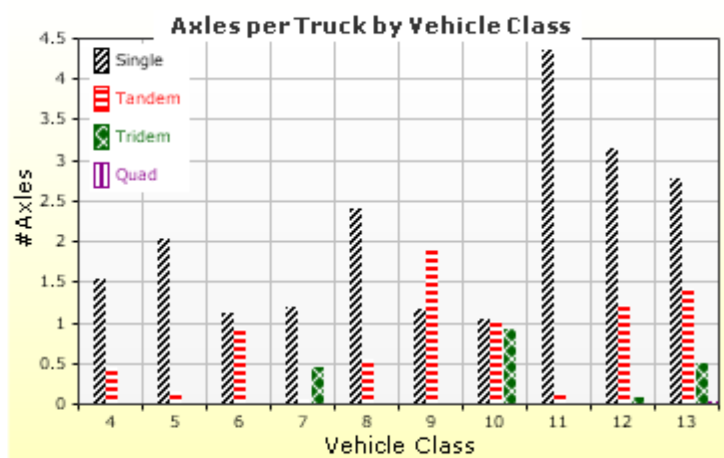
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	1,078	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)	25.0

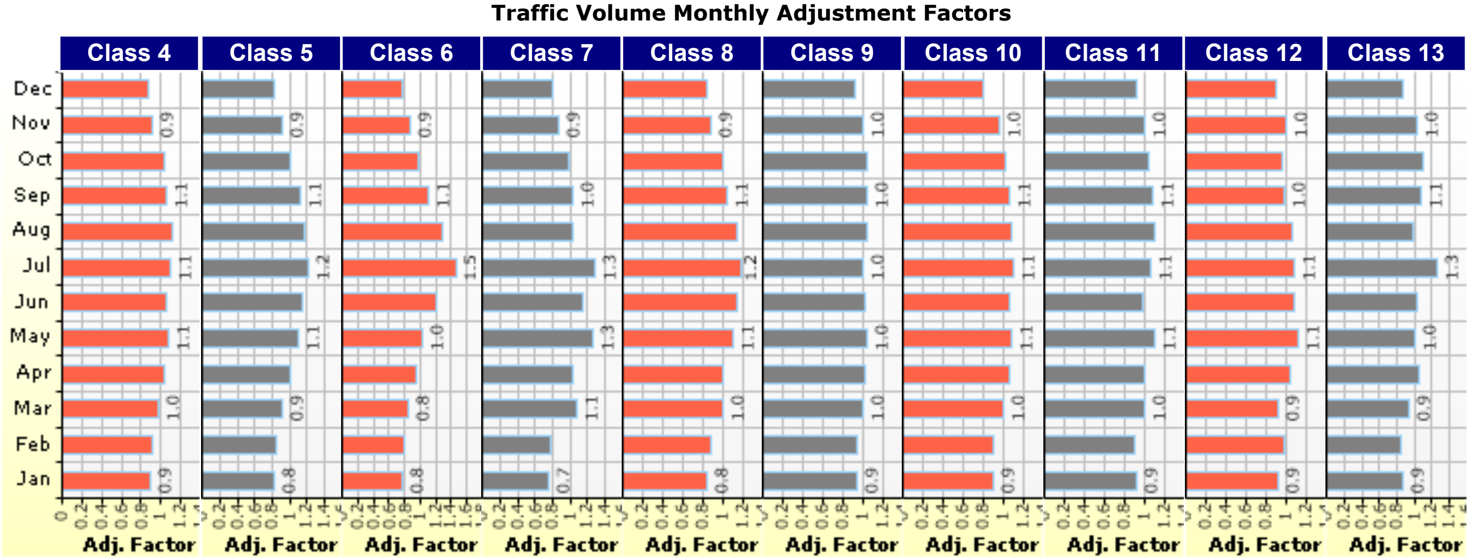








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

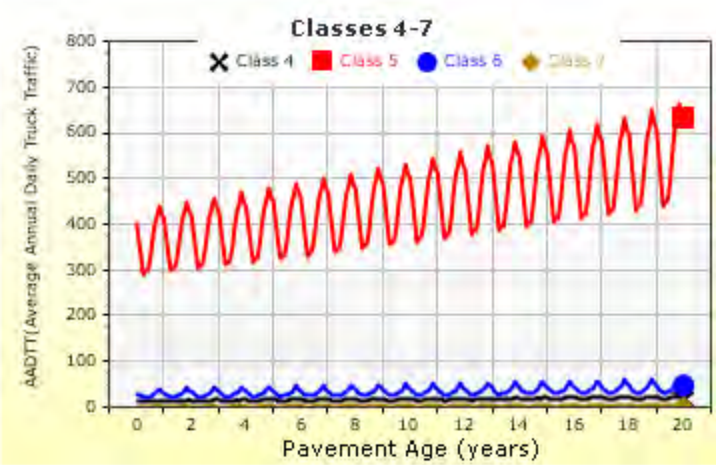
Wheelbase does not apply

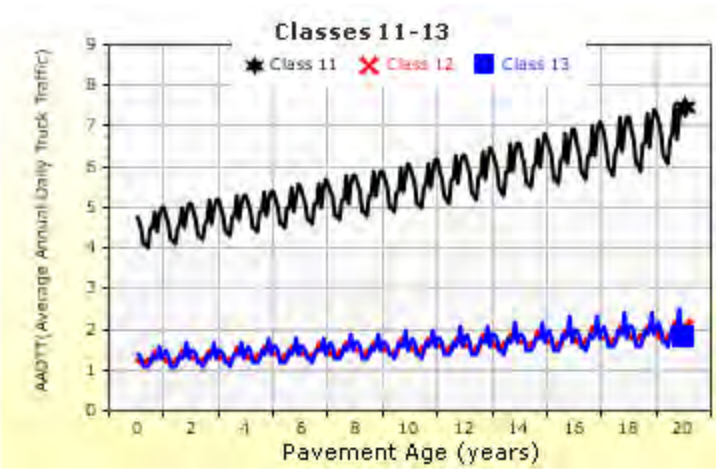
Number of Axles per Truck

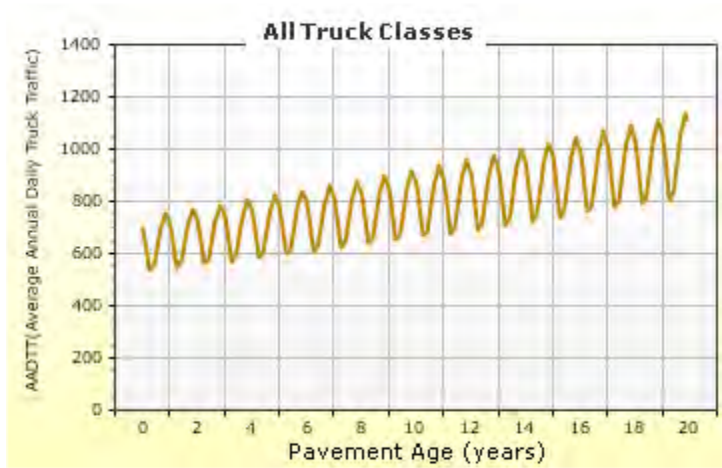
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

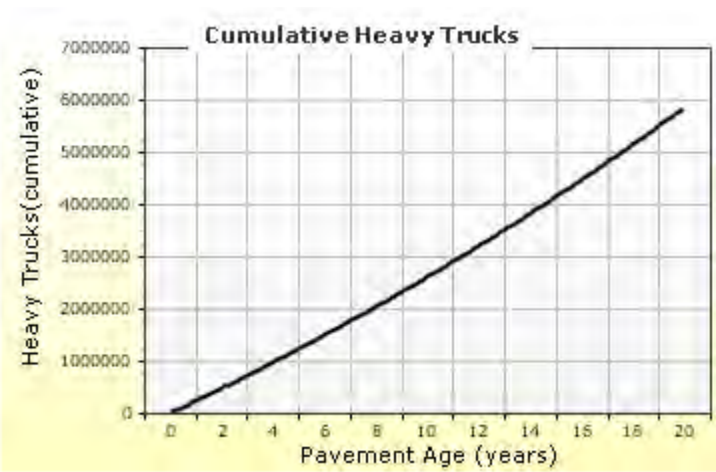
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





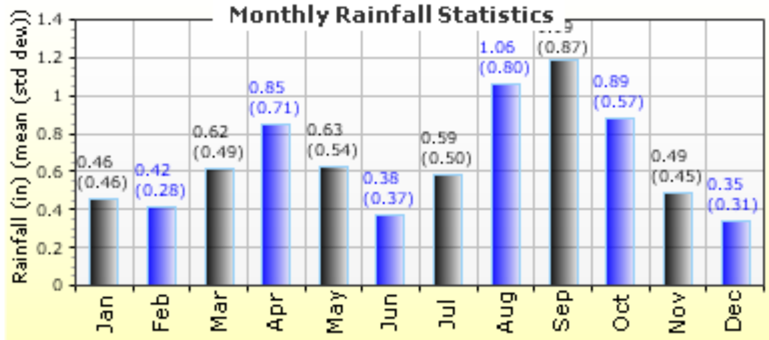




Climate Inputs

Climate Data Sources:

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

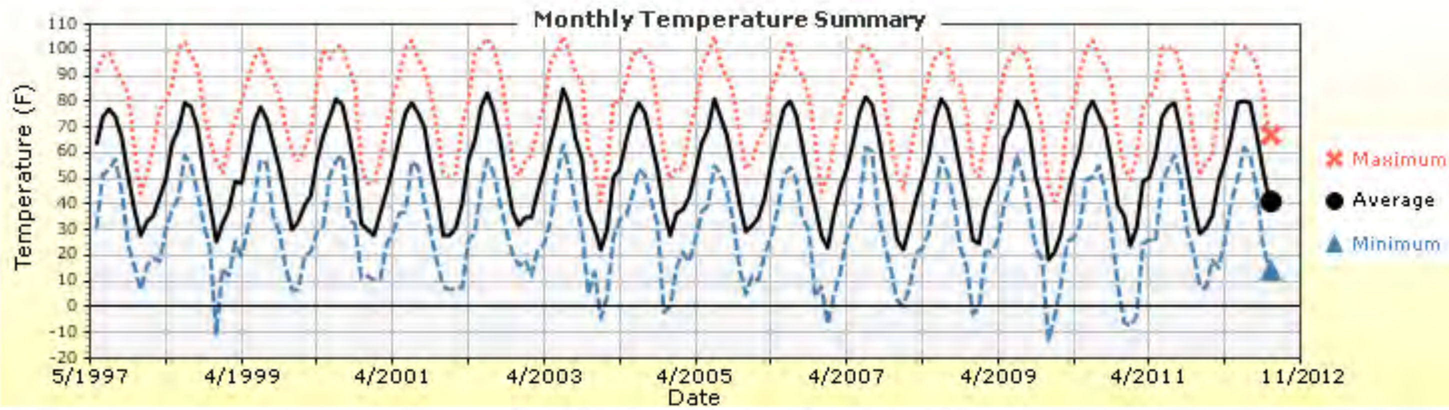


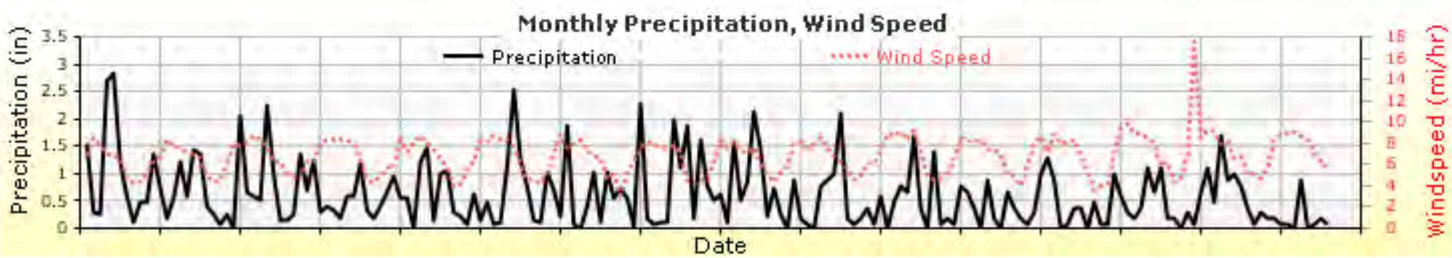
Annual Statistics:

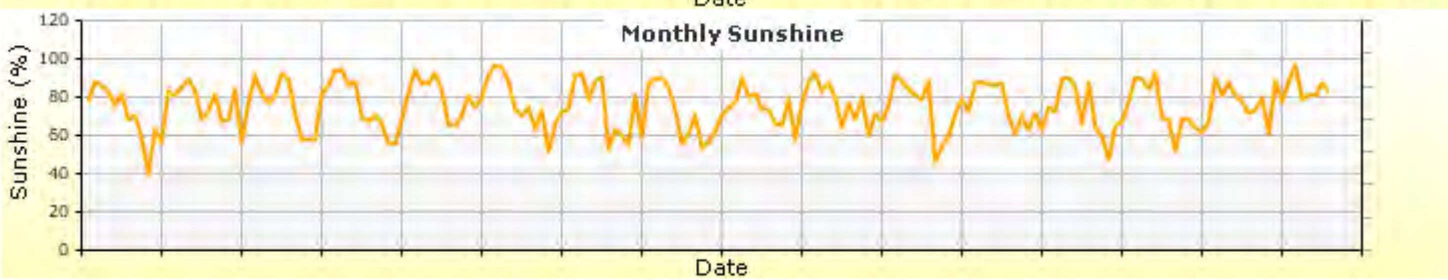
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

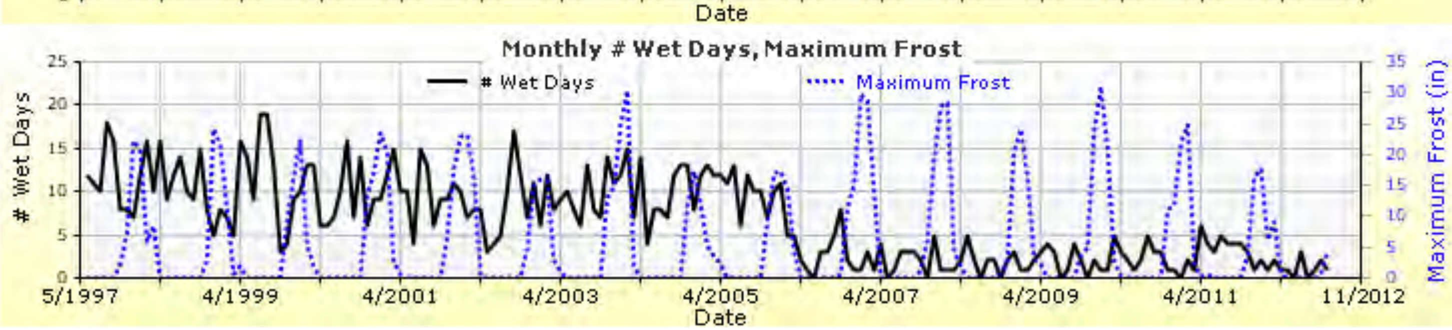
Water table depth (ft)	10.00

Monthly Climate Summary:

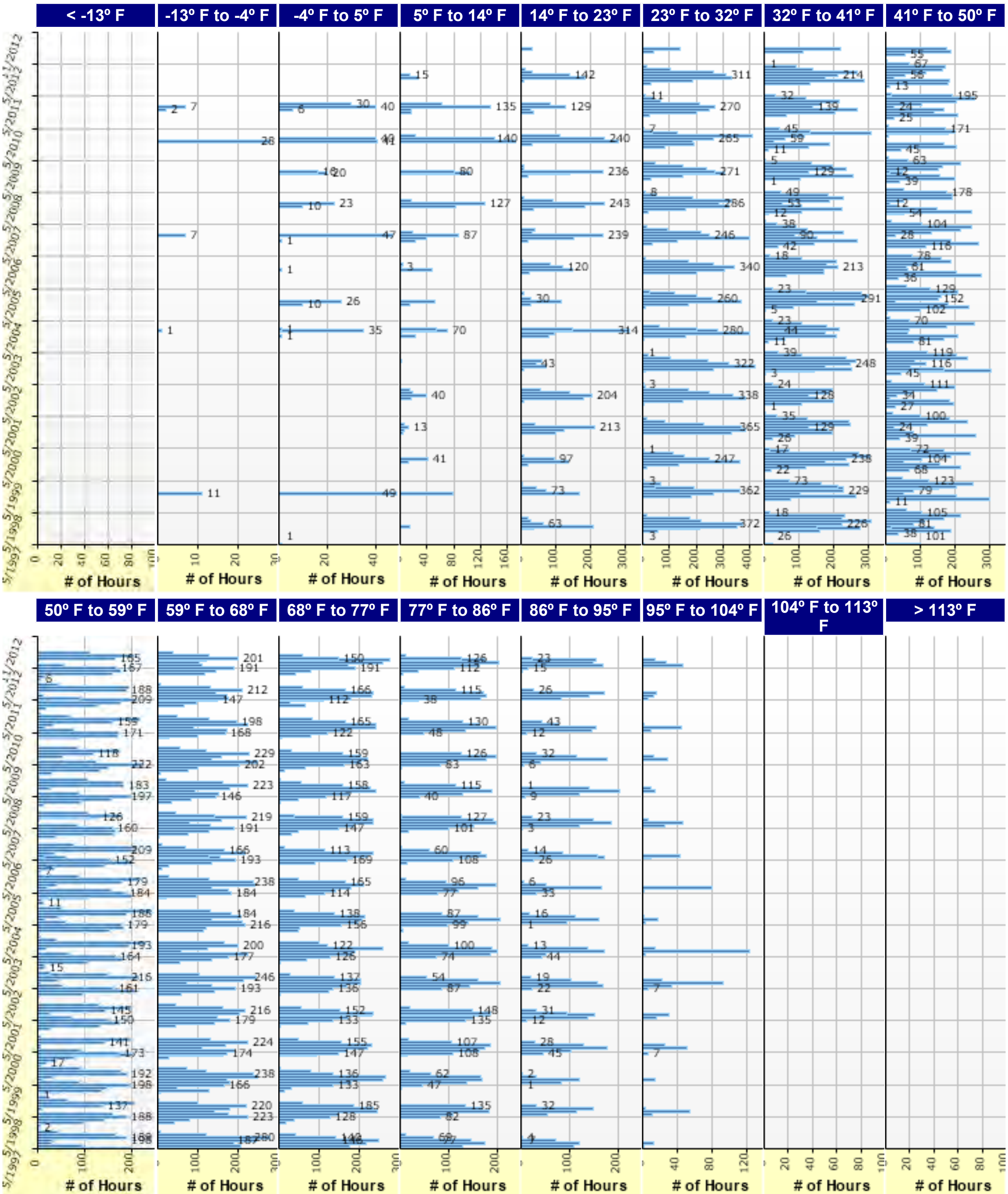








Hourly Air Temperature Distribution by Month:



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

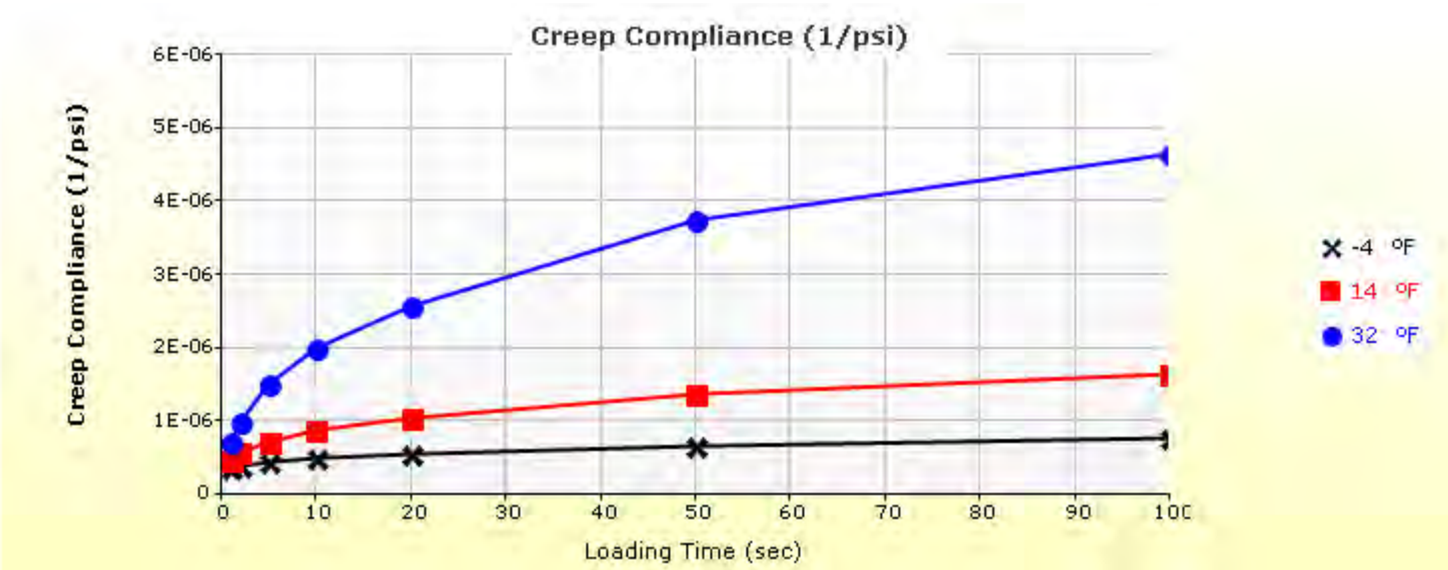
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

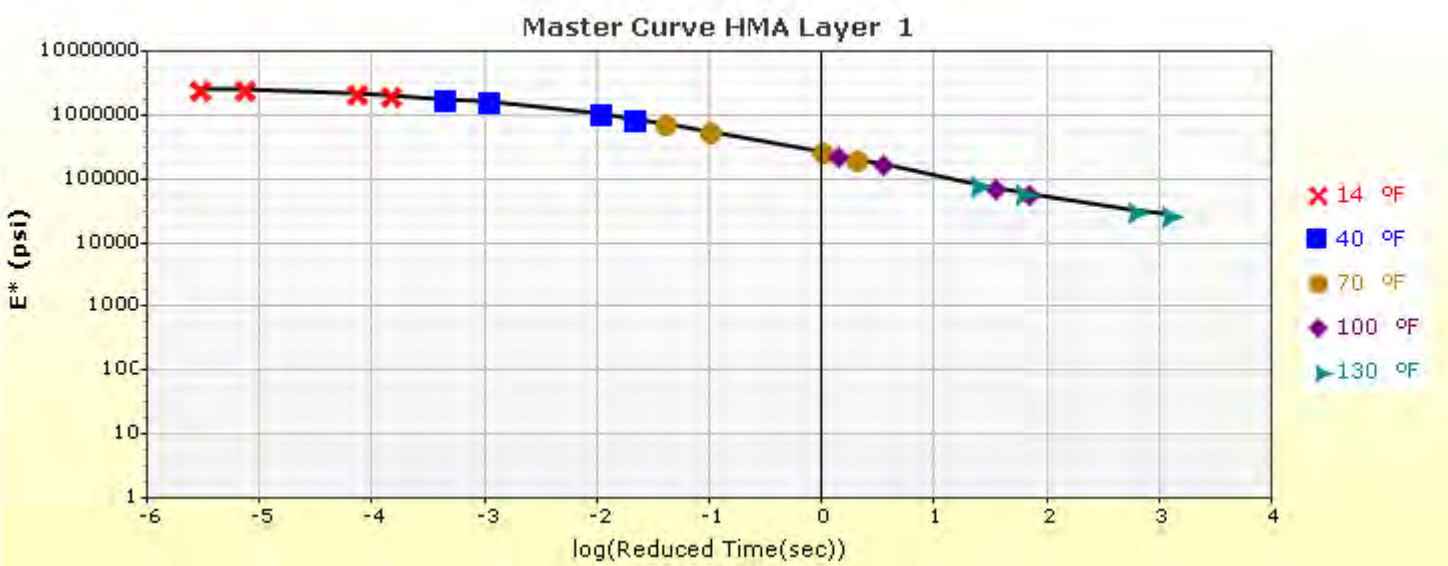
Indirect tensile strength at 14 ºF (psi)	519.00

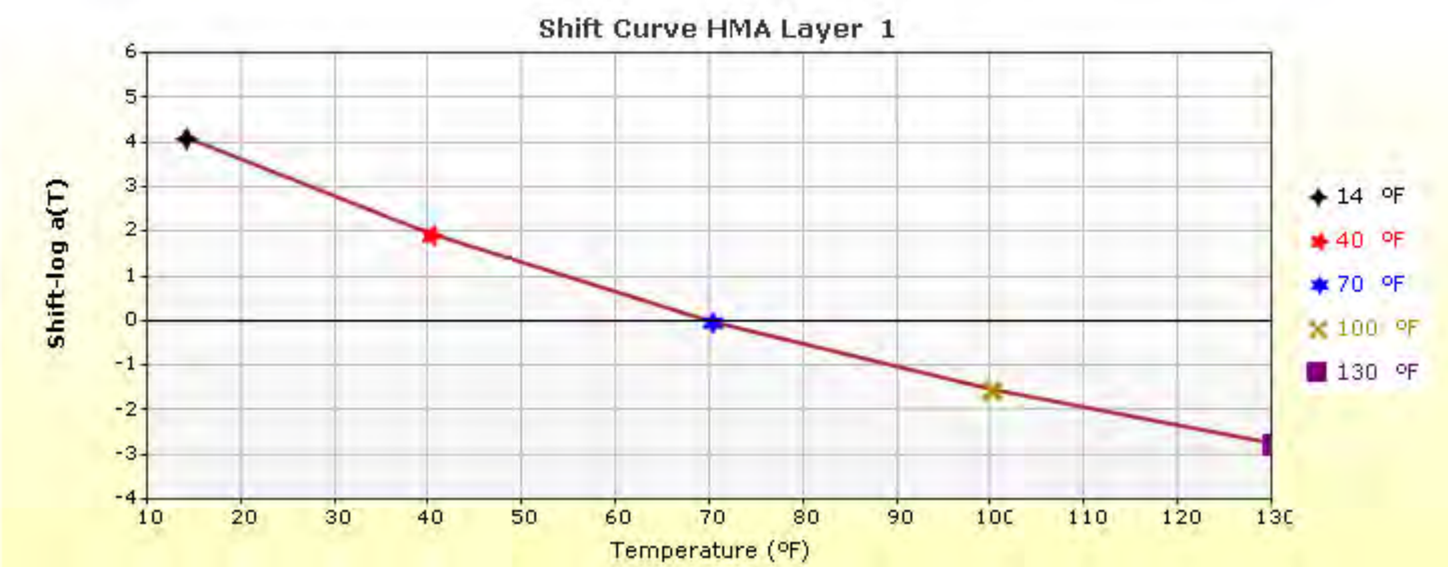
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

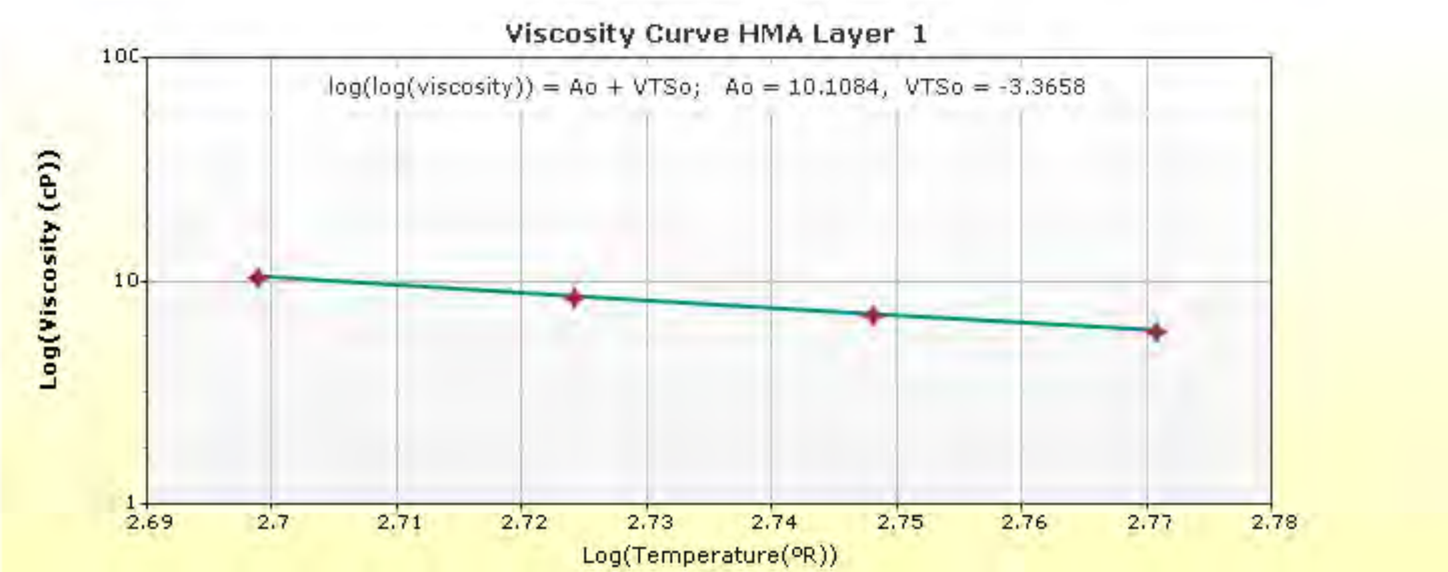
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



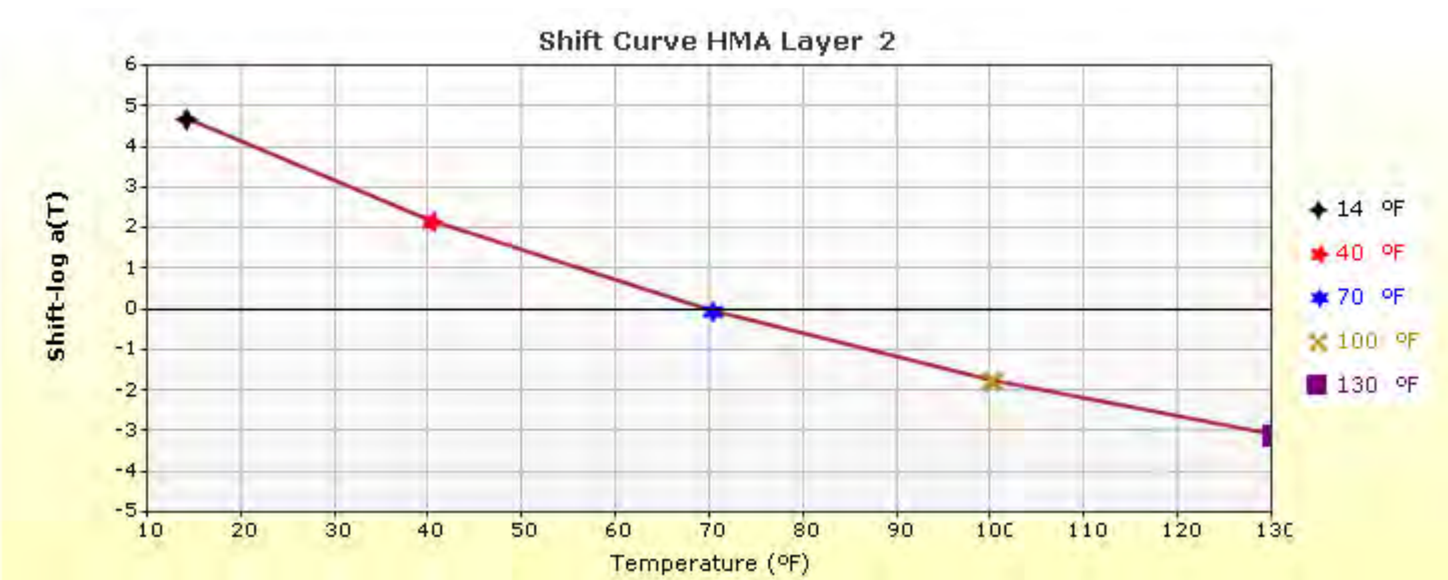
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

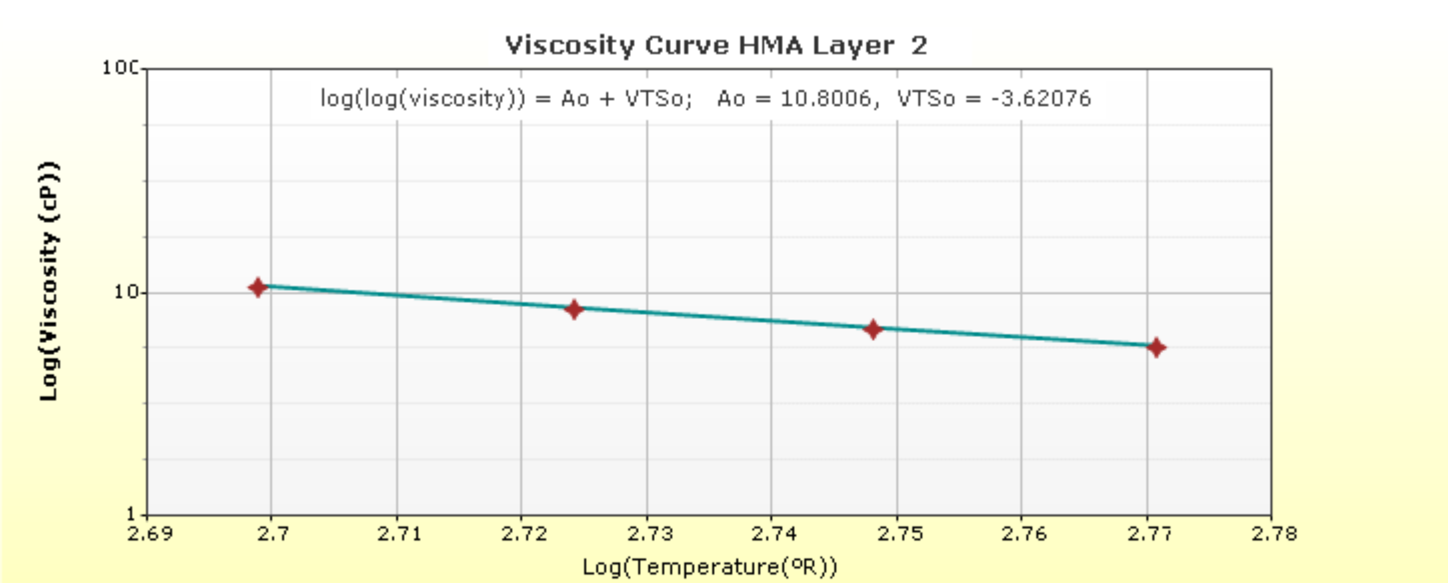




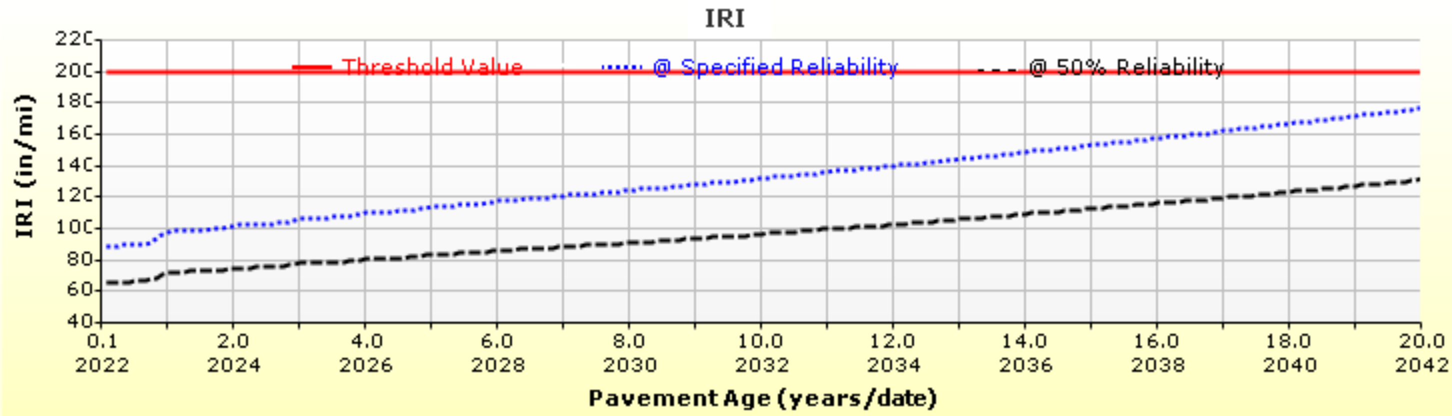


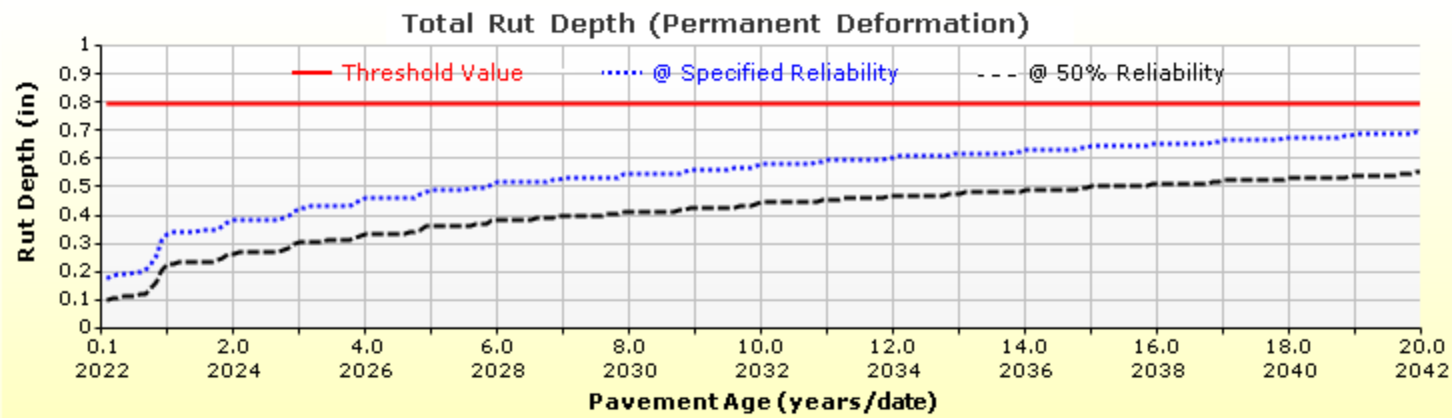
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

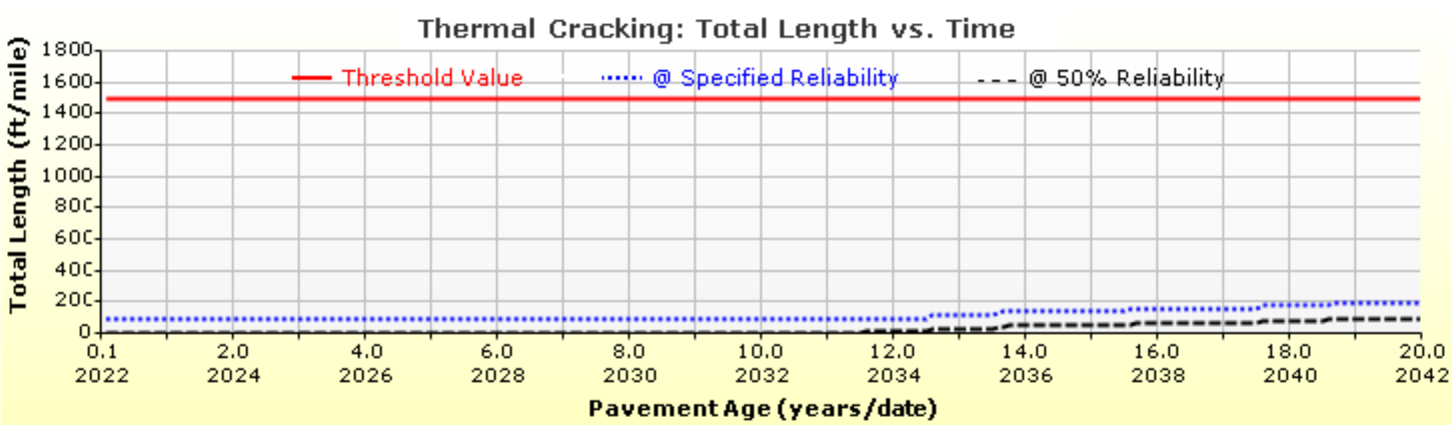


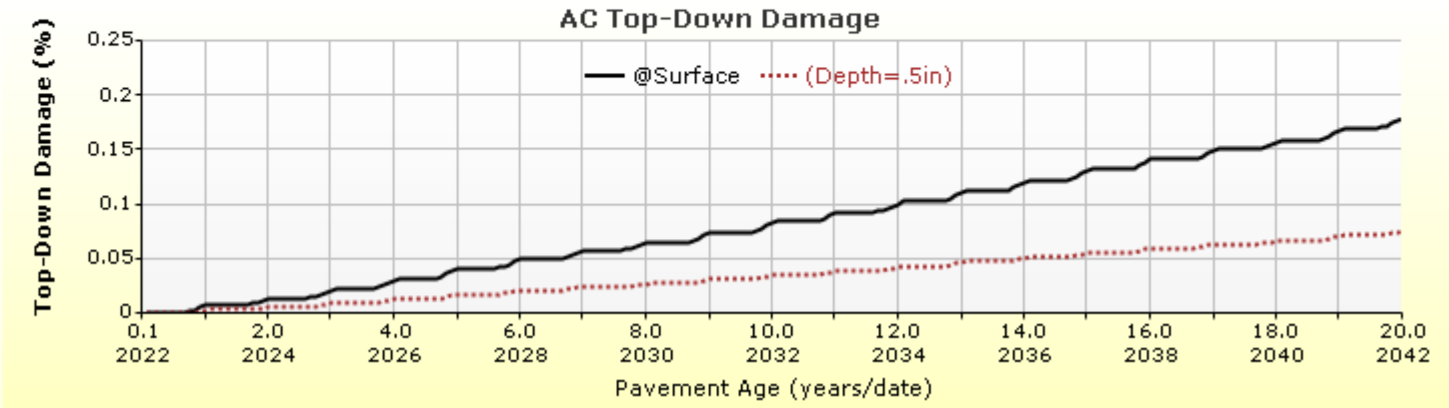


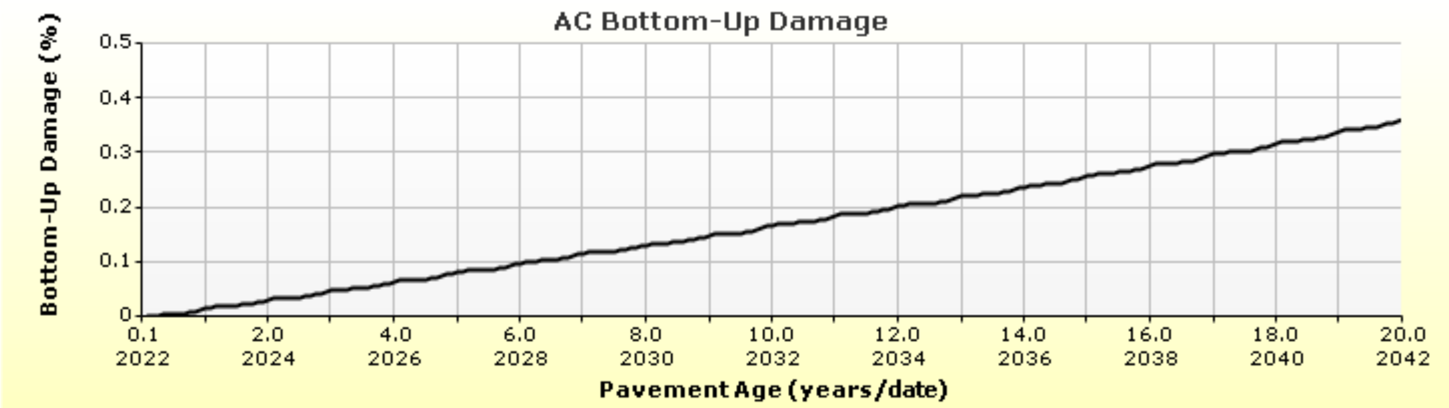
Analysis Output Charts

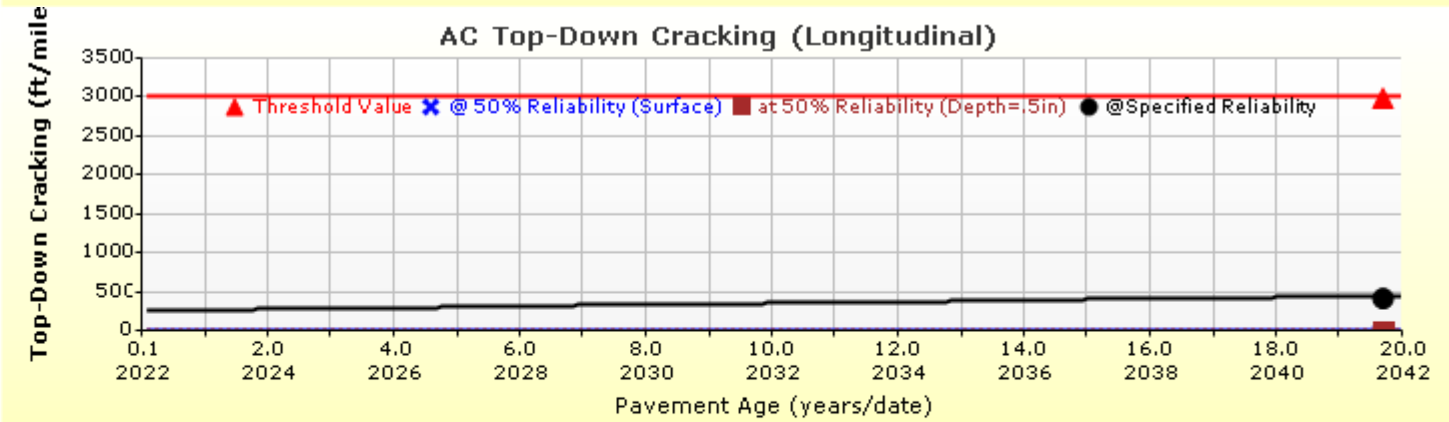


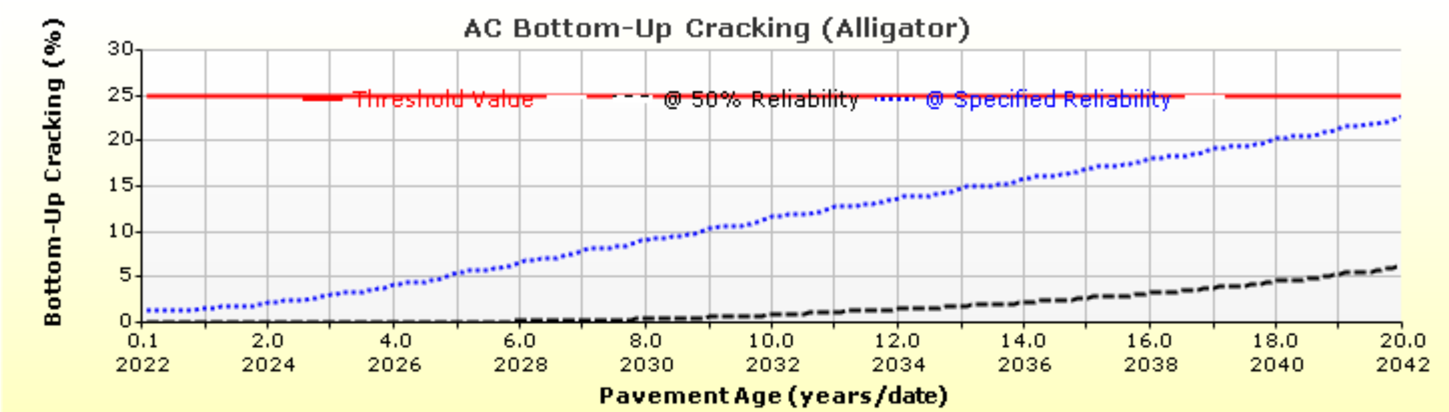


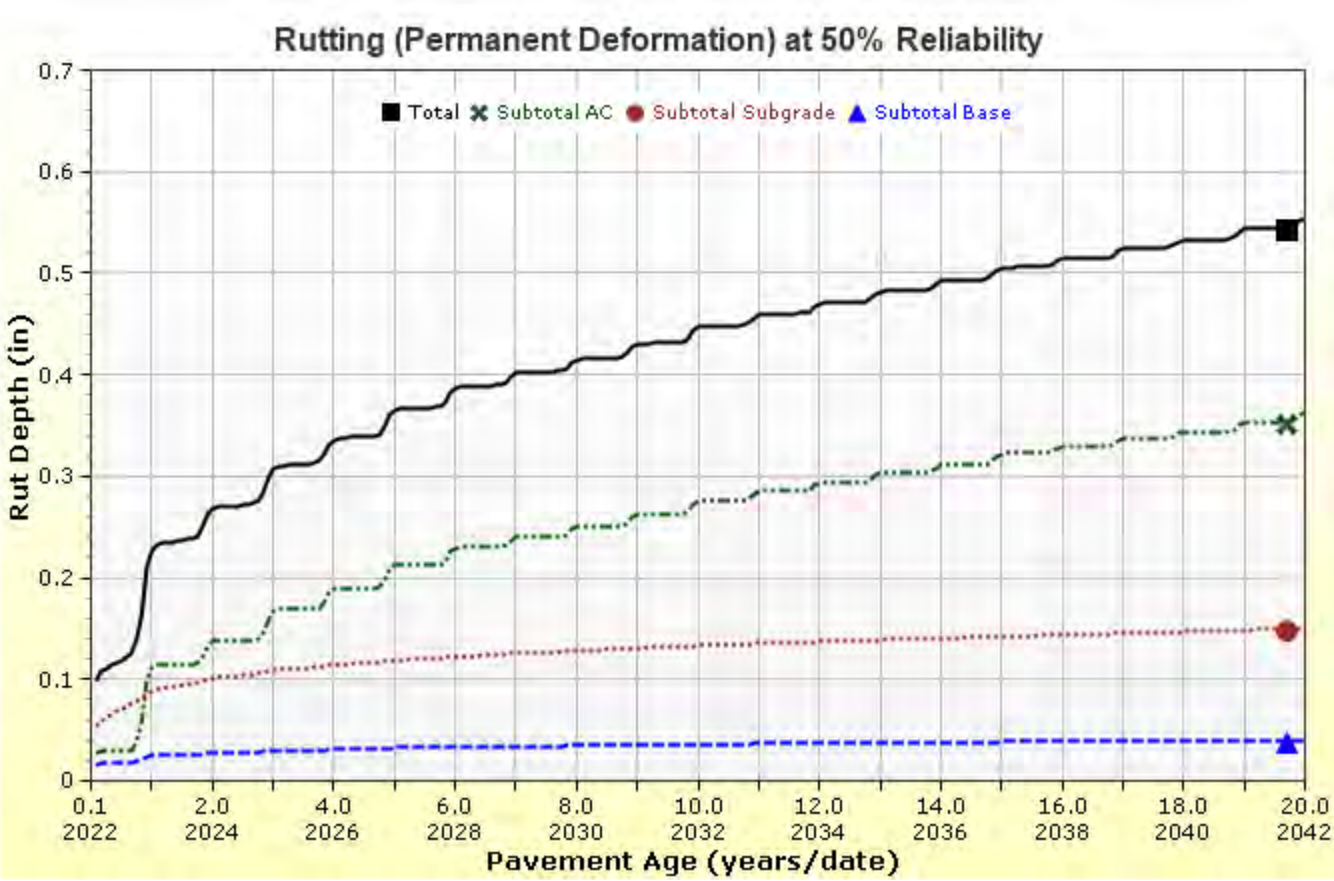



AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)

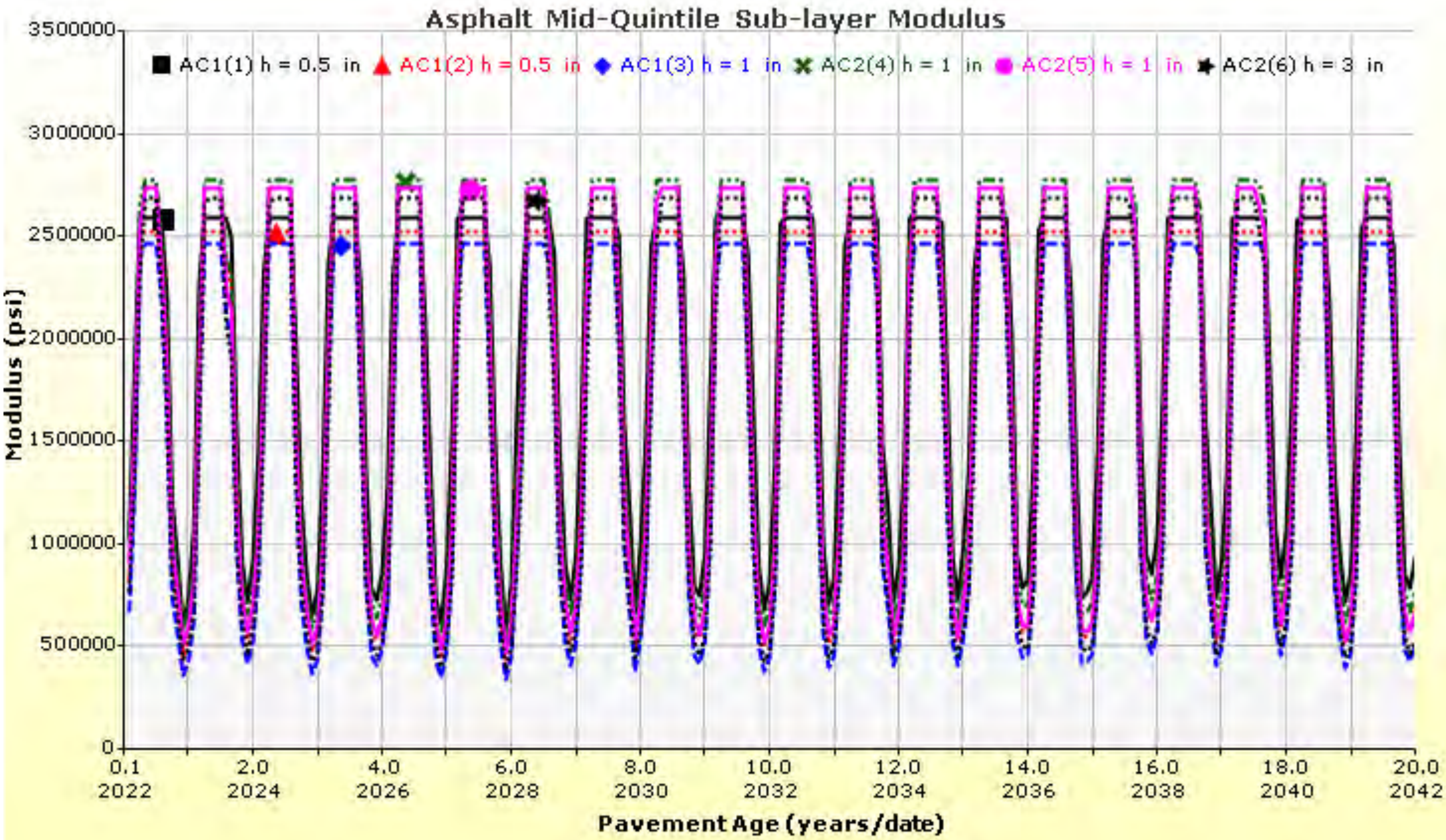

AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

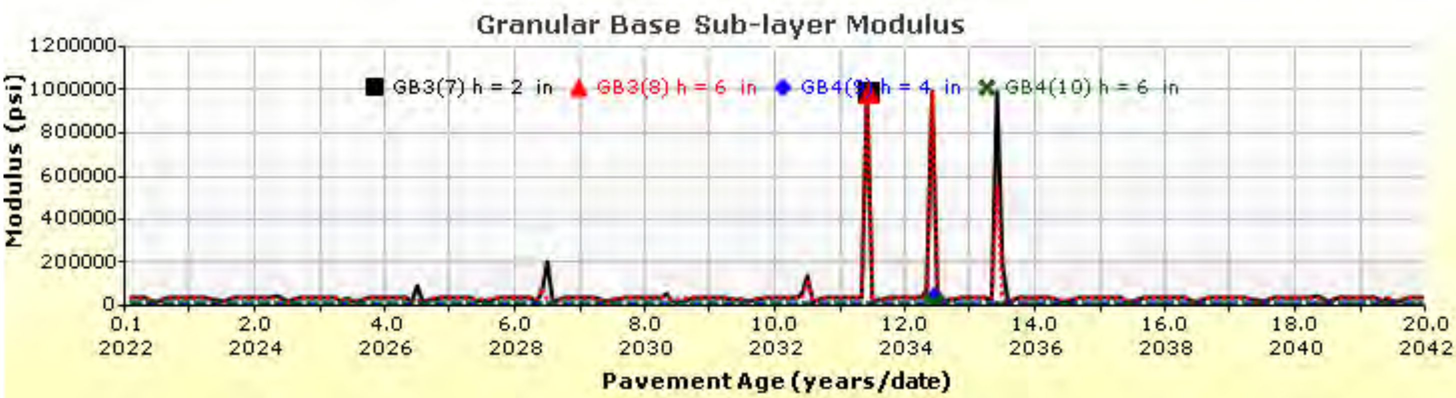

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)

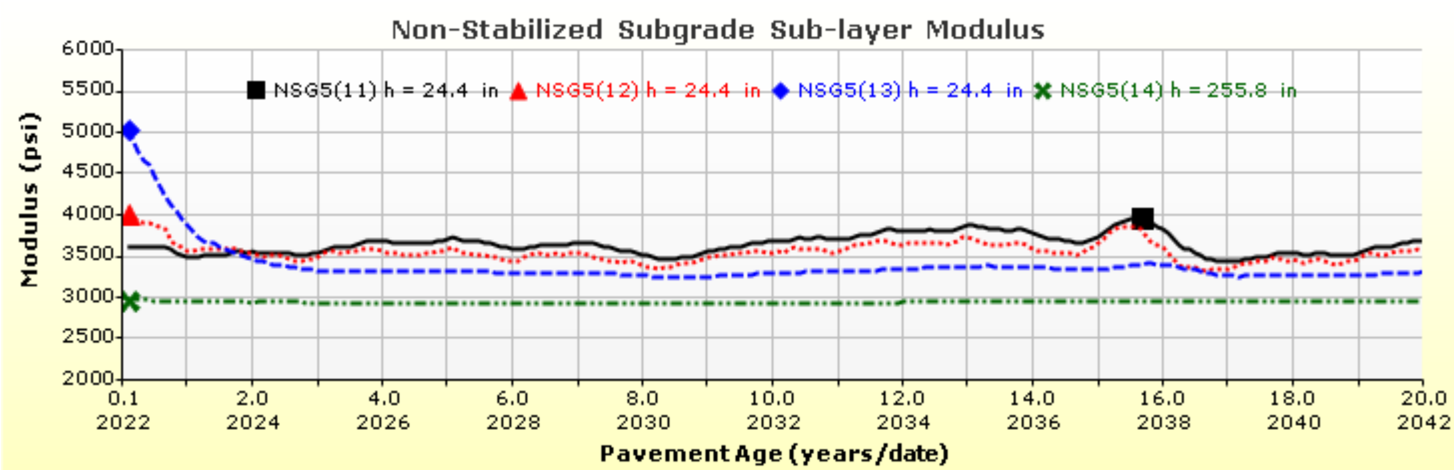

AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
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)
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 = 6 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 24.4 in
NSG5(12) h = 24.4 in
NSG5(13) h = 24.4 in
NSG5(14) h = 255.8 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	5.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	10.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
Bf2: 1
Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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 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: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	6.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	10.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

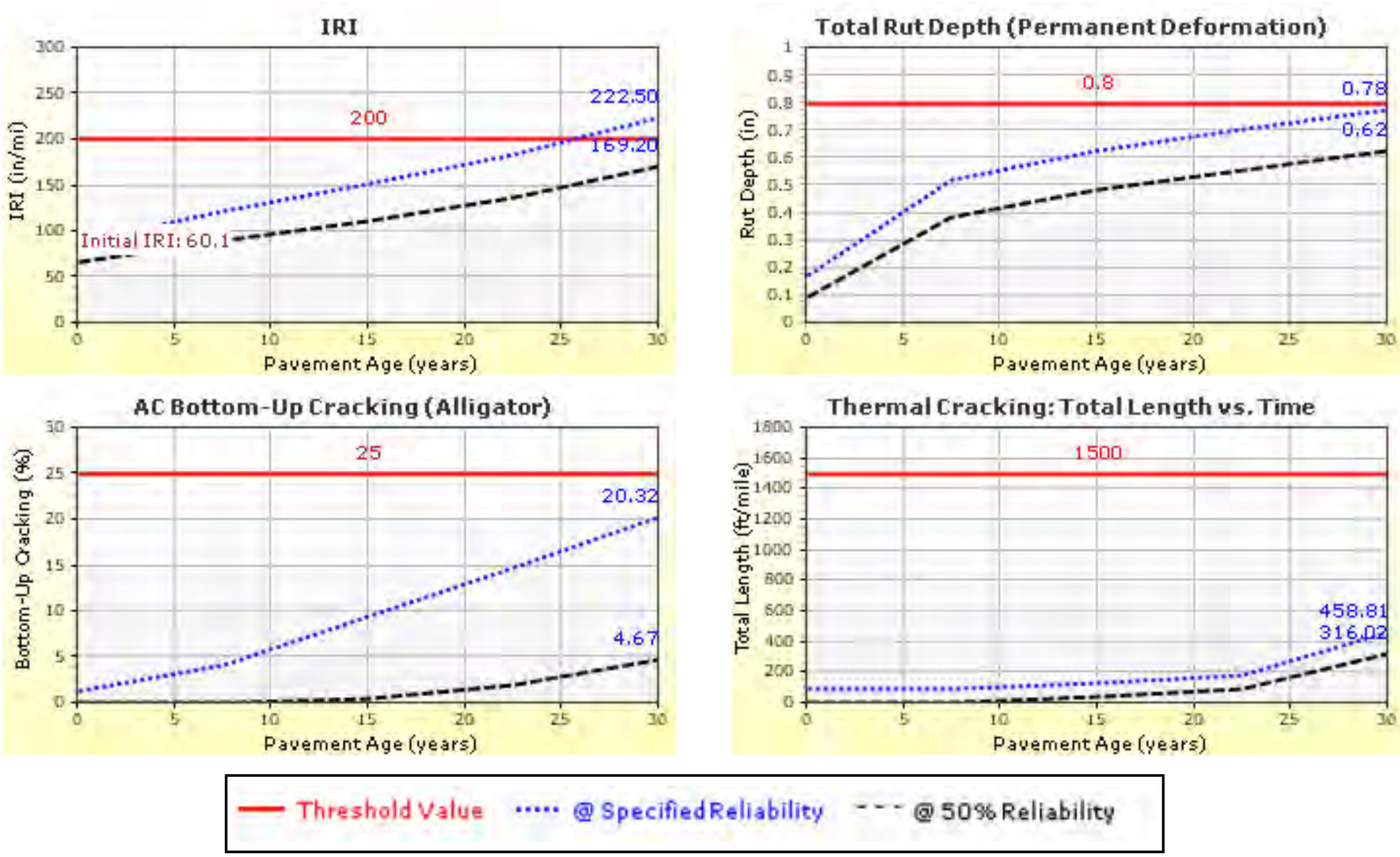
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	1,078
2037 (15 years)	4,145,010
2052 (30 years)	9,890,000

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	222.48	90.00	77.05	Fail
Permanent deformation - total pavement (in)	0.80	0.78	90.00	92.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	20.32	90.00	95.20	Pass
AC thermal cracking (ft/mile)	1500.00	458.81	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	331.04	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.58	90.00	96.98	Pass

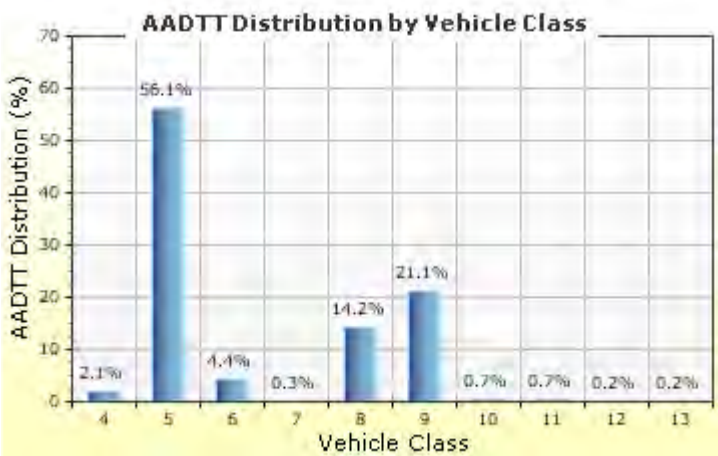
Distress Charts

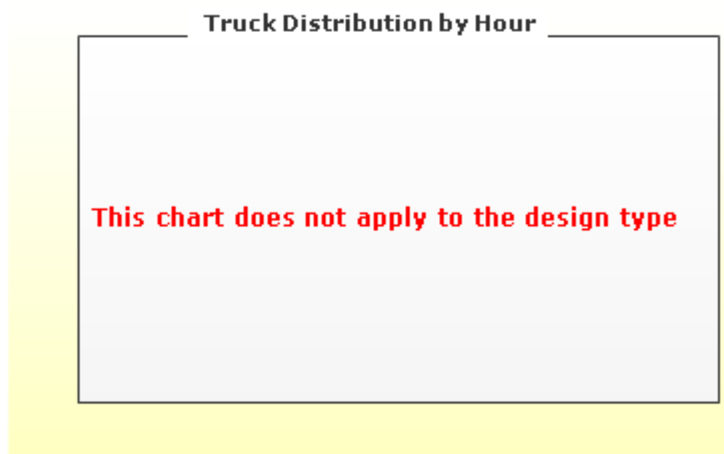


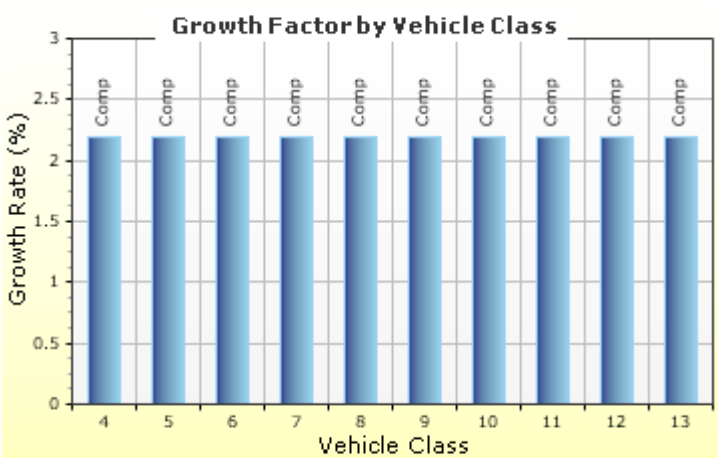
Traffic Inputs

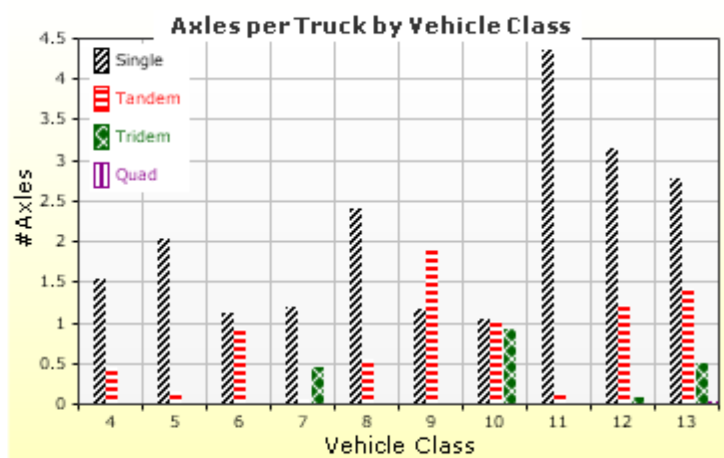
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	1,078	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)	25.0

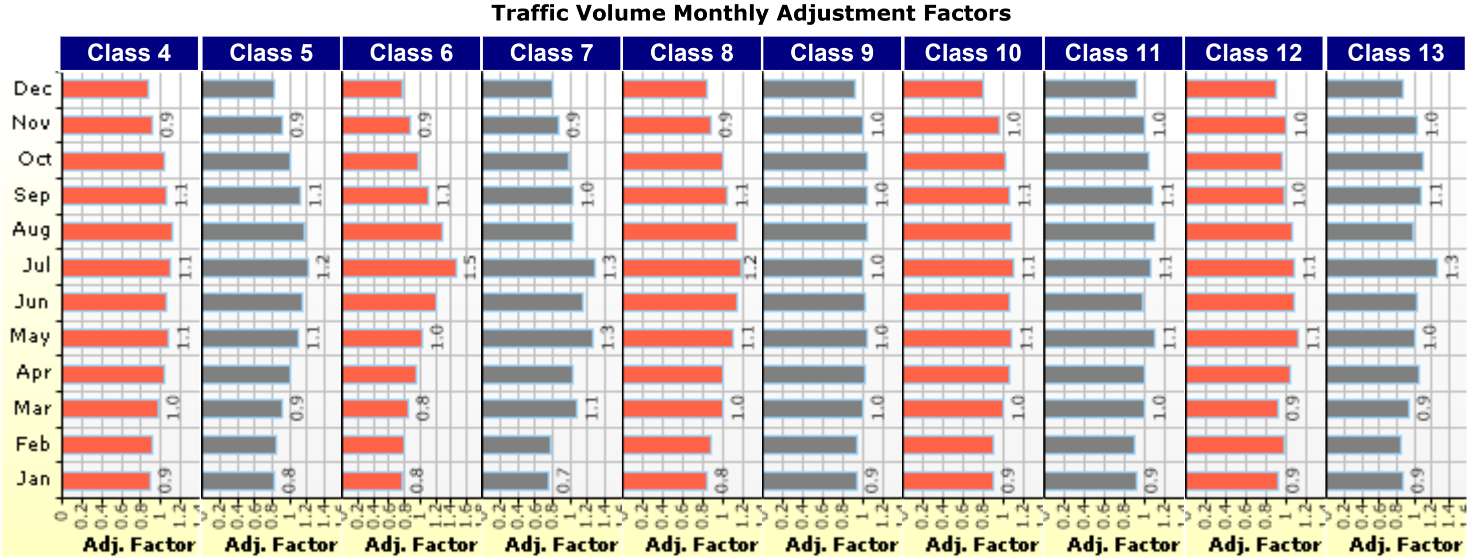








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

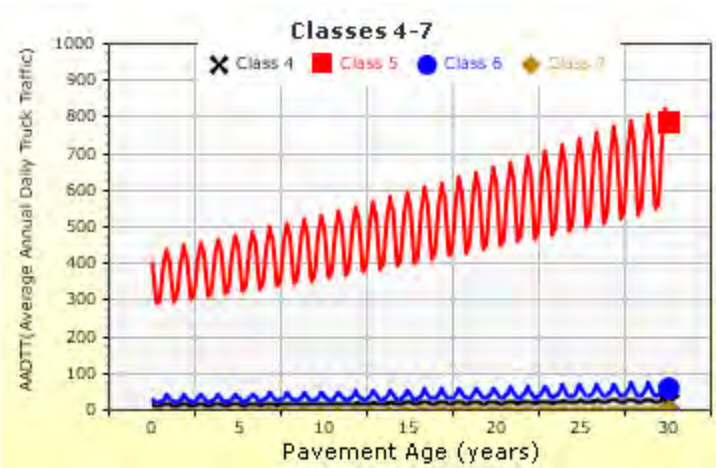
Wheelbase does not apply

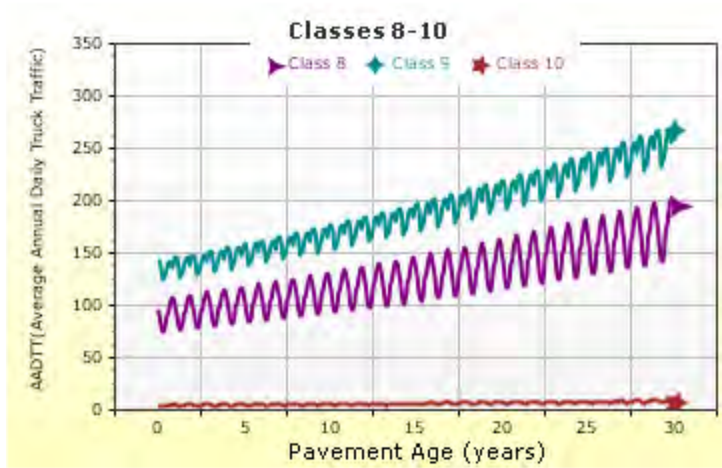
Number of Axles per Truck

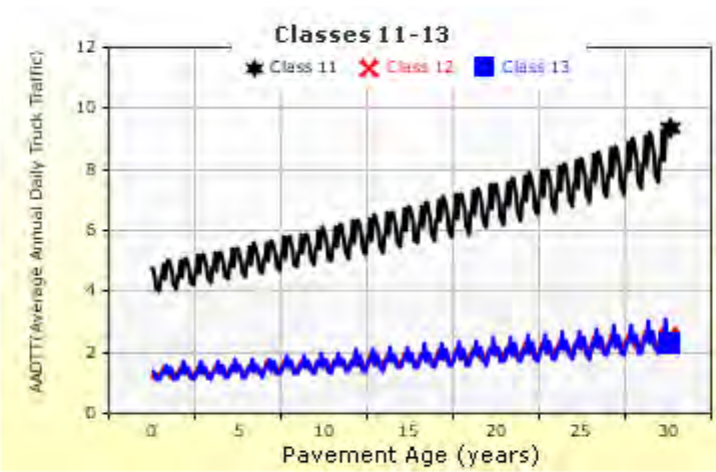
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

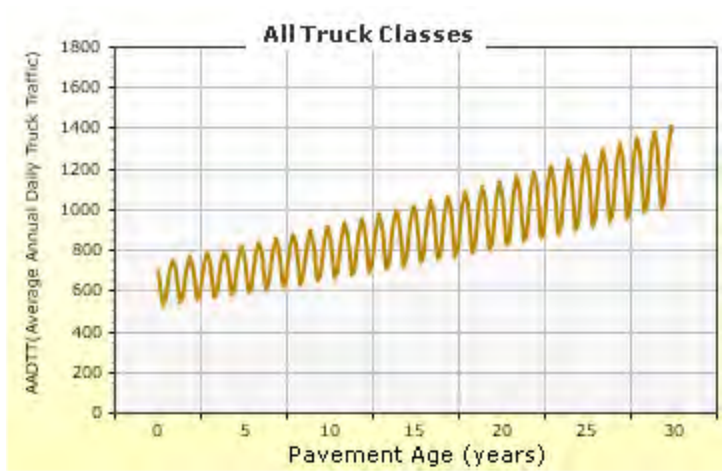
AADTT (Average Annual Daily Truck Traffic) Growth

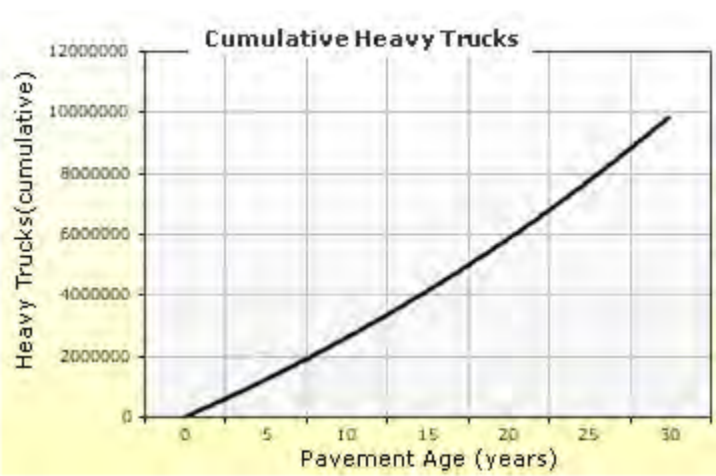
*** Traffic cap is not enforced**











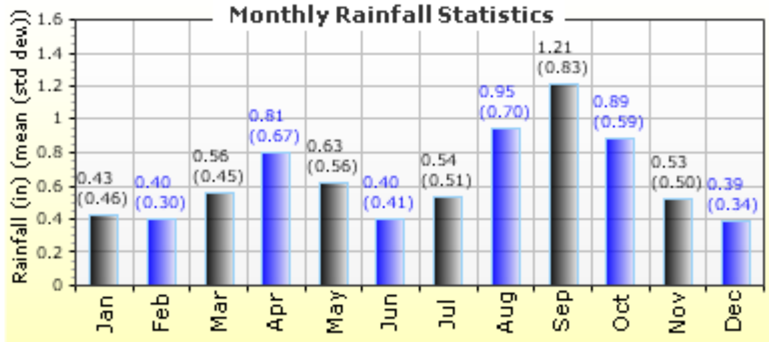
Climate Inputs

Climate Data Sources:

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

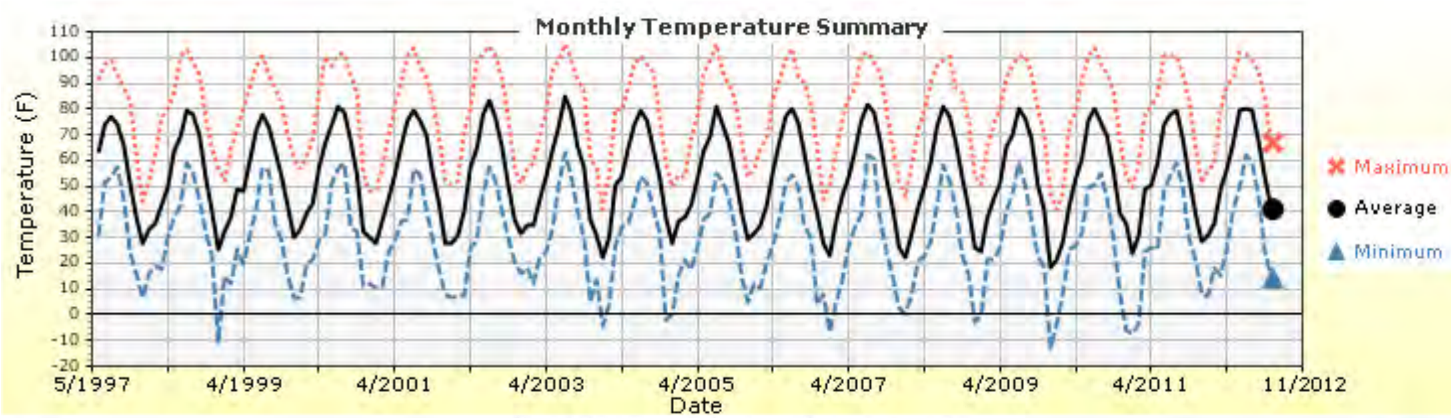
Annual Statistics:

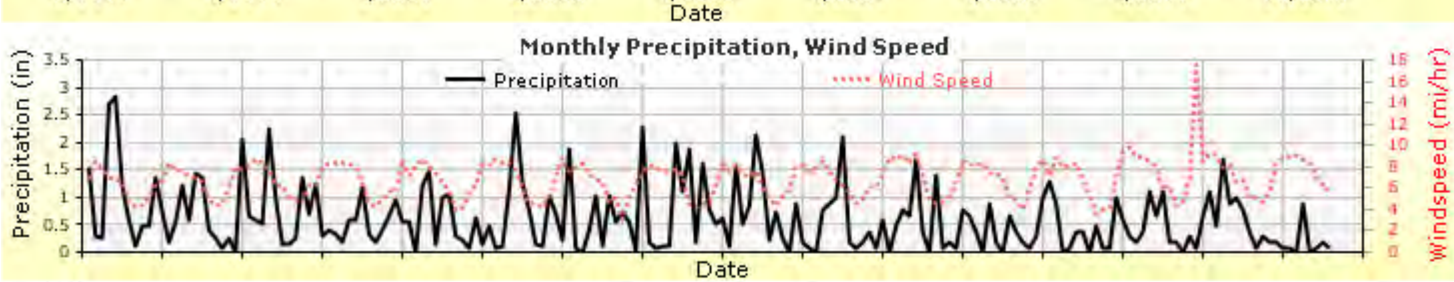
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

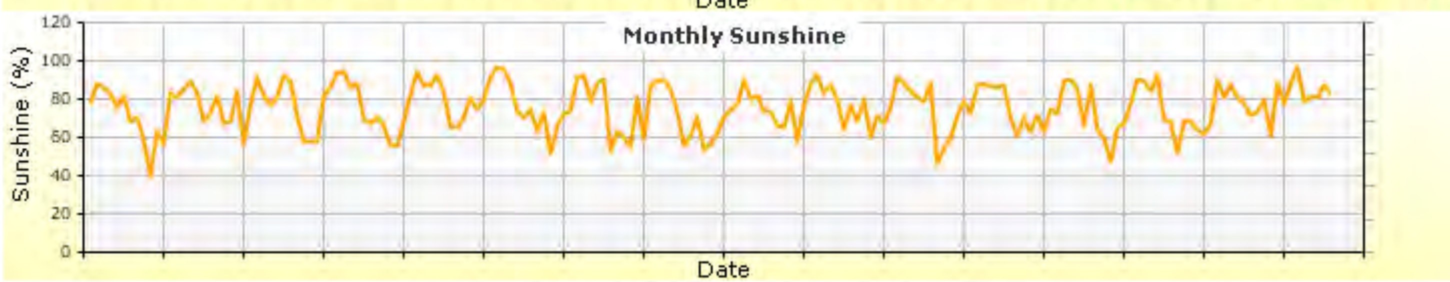


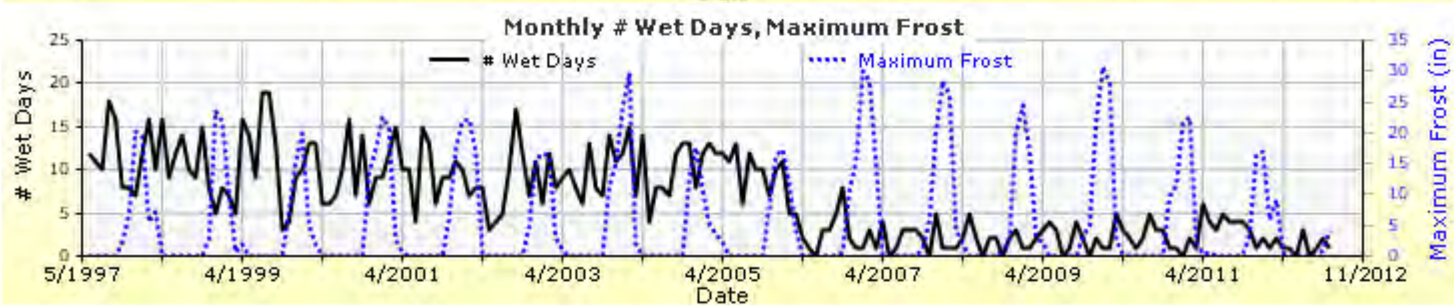
Water table depth (ft) 10.00

Monthly Climate Summary:

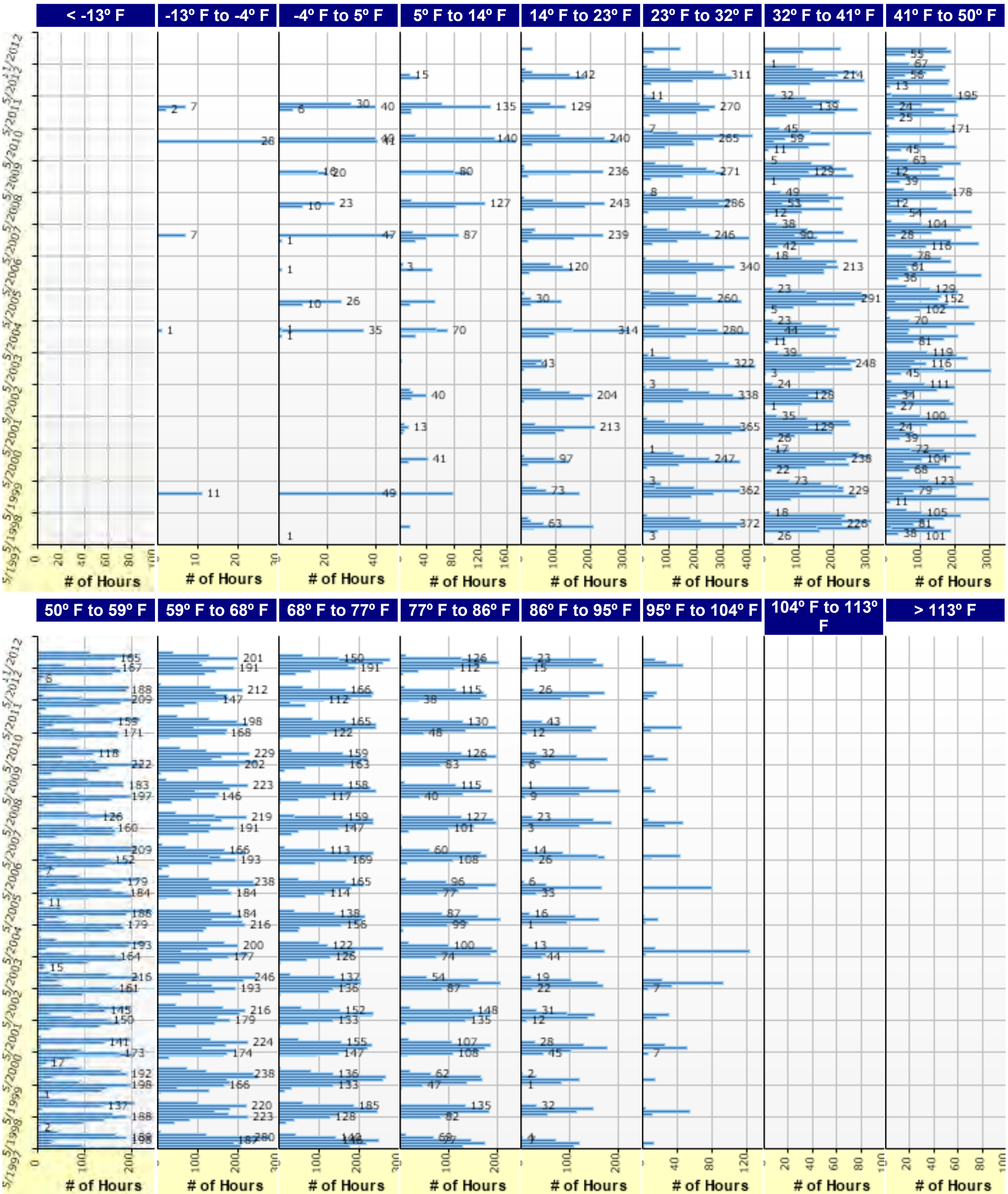








Hourly Air Temperature Distribution by Month:



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

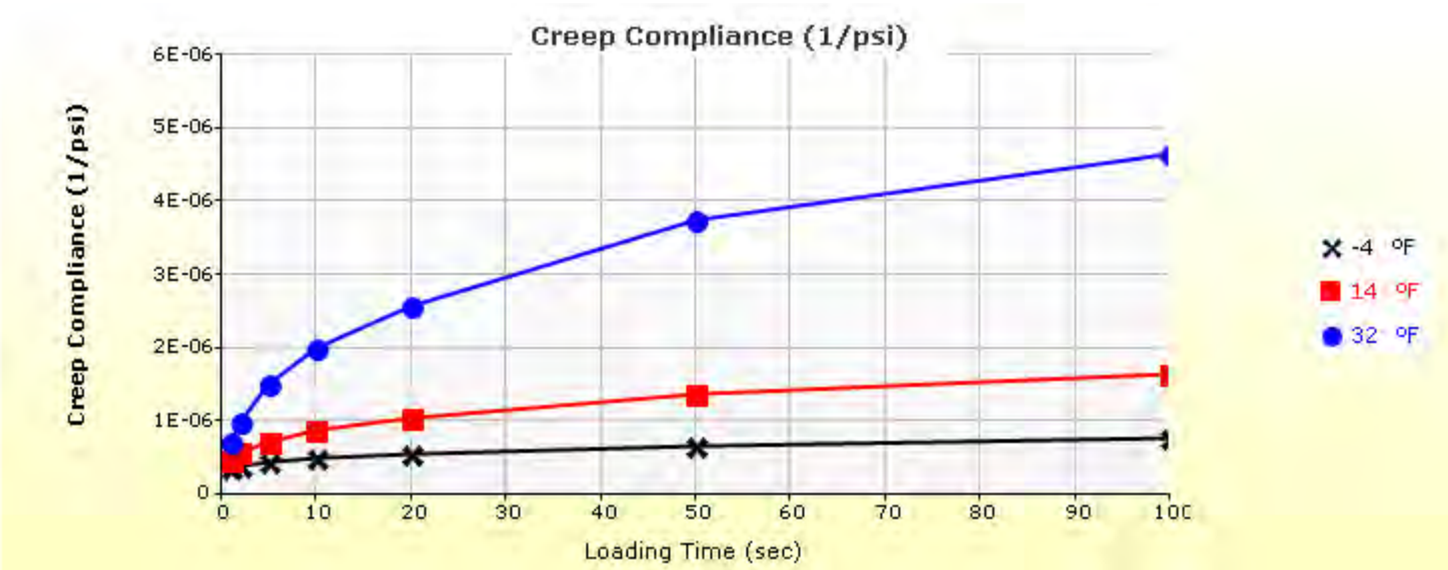
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

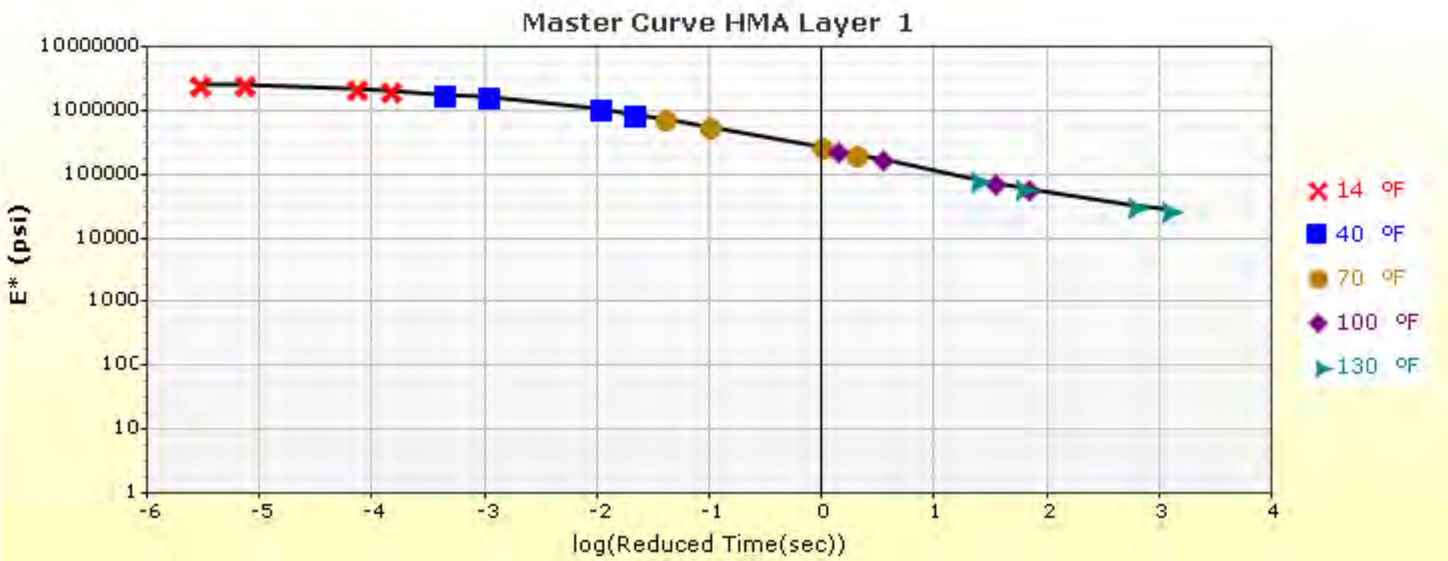
Indirect tensile strength at 14 ºF (psi)	519.00

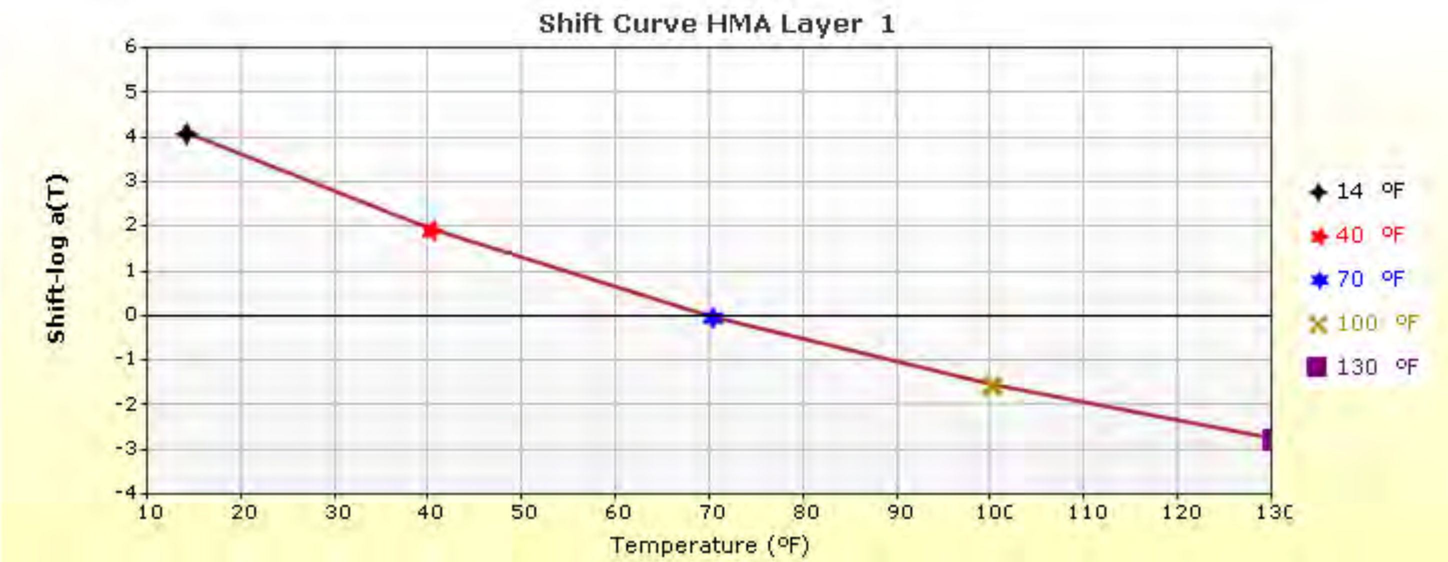
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

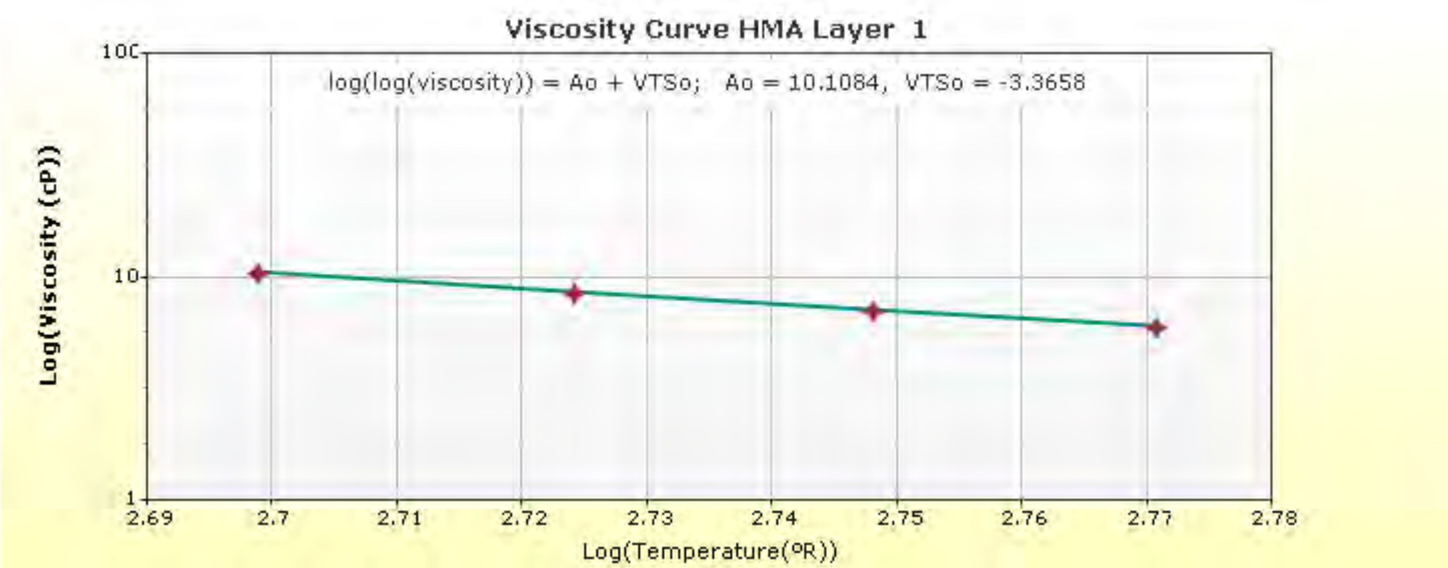
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



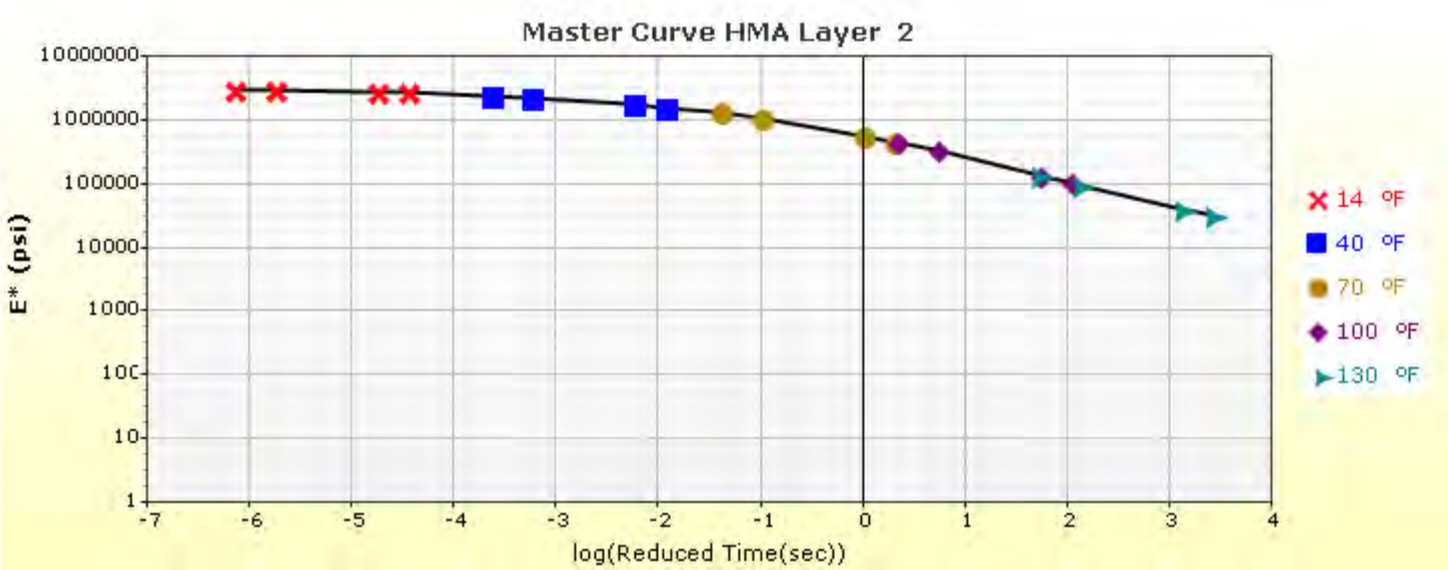
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

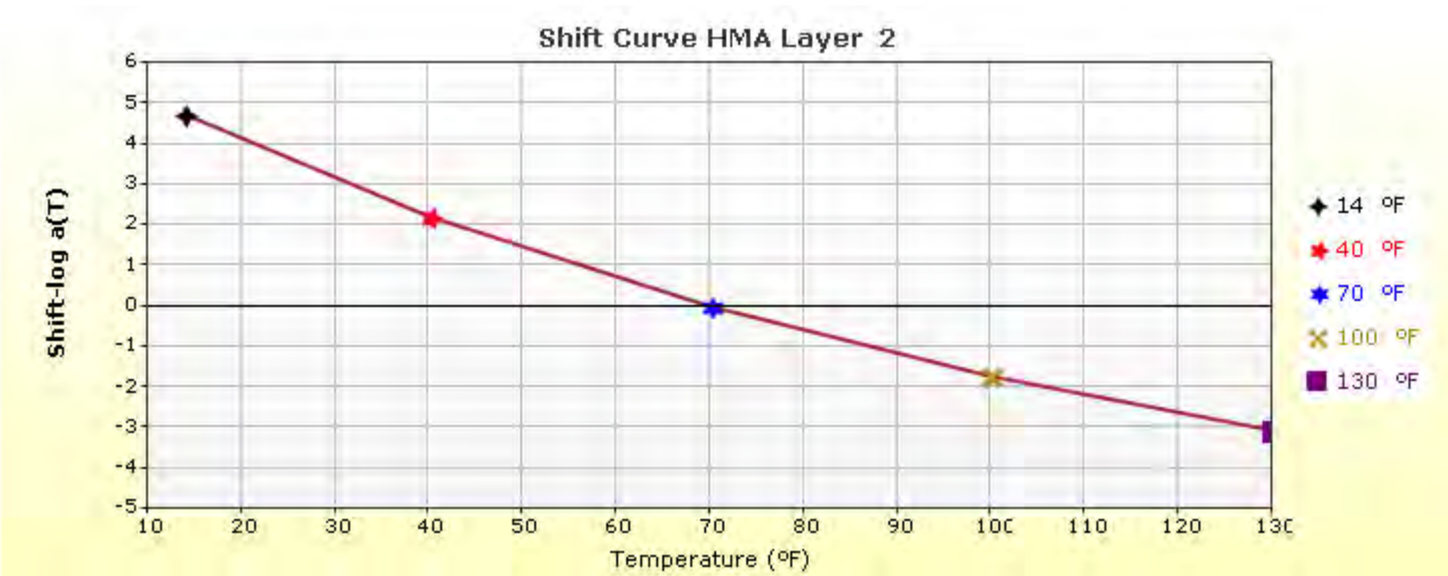


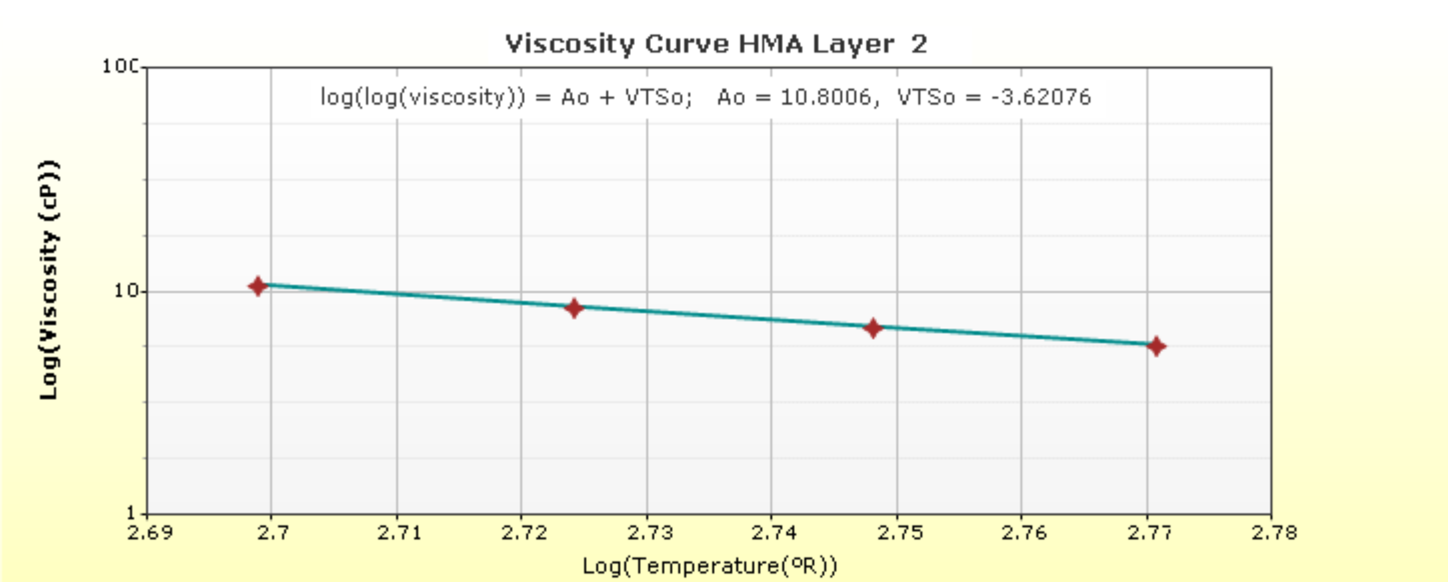




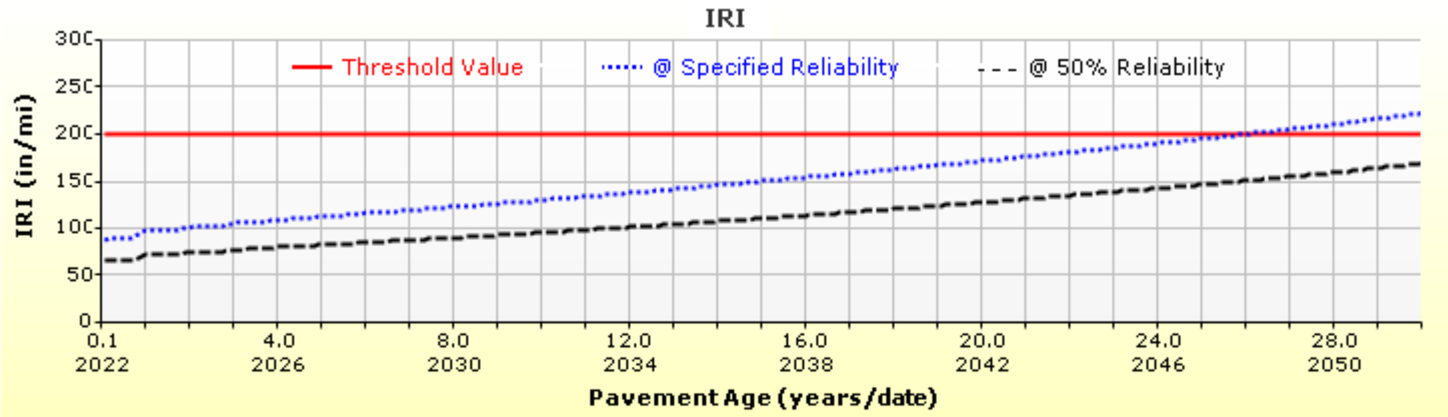
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

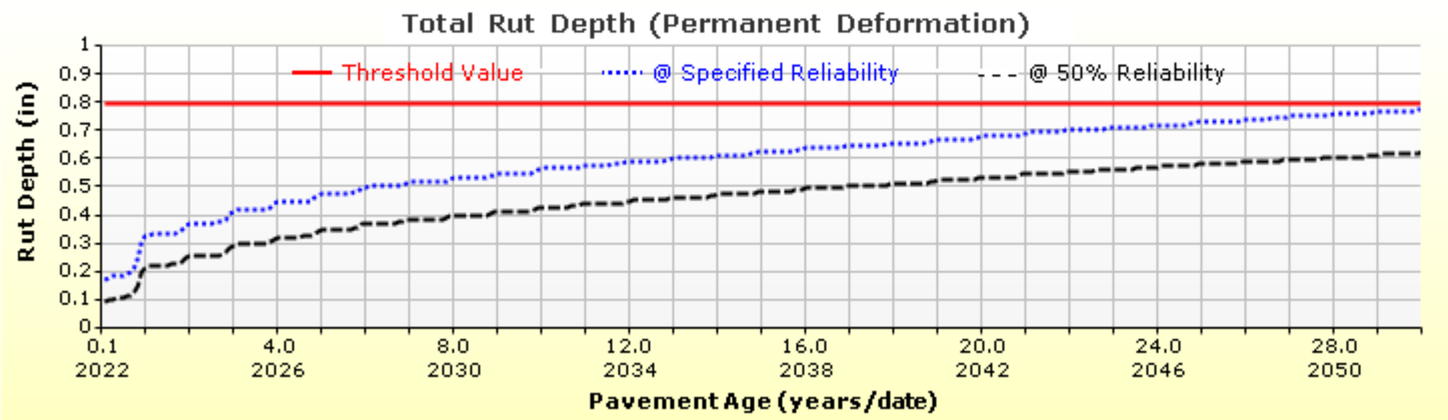


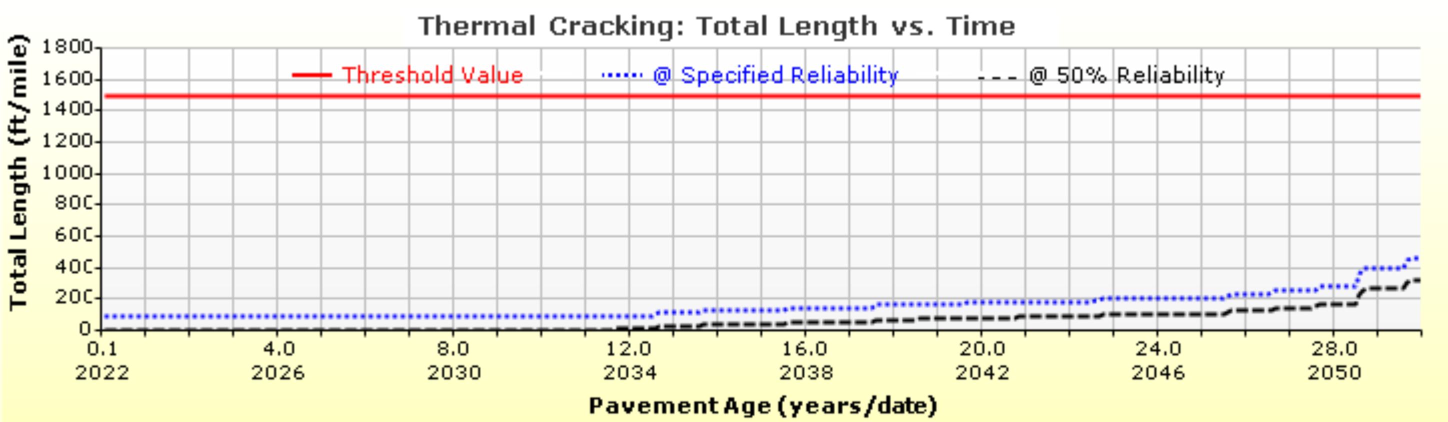


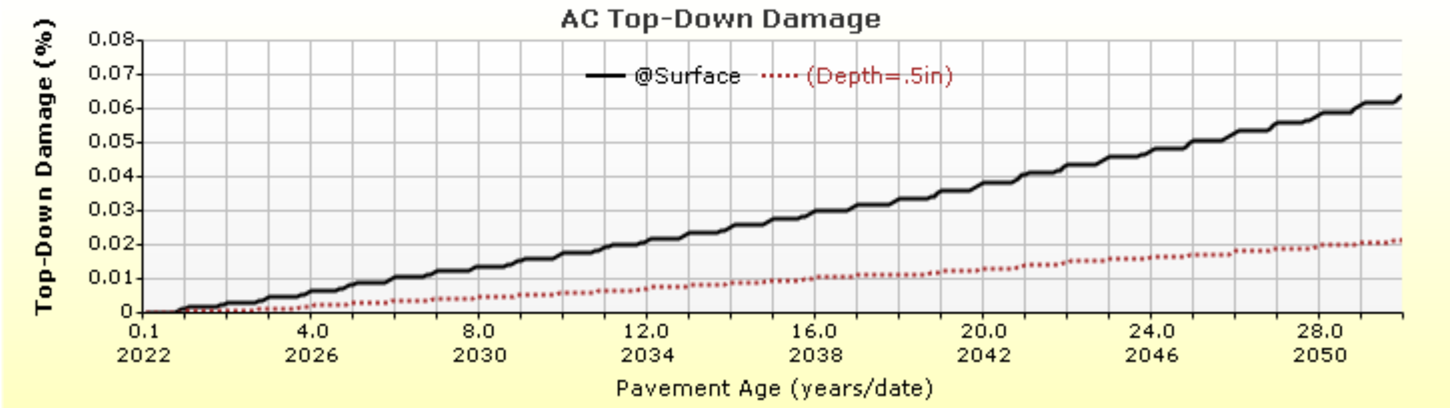


Analysis Output Charts

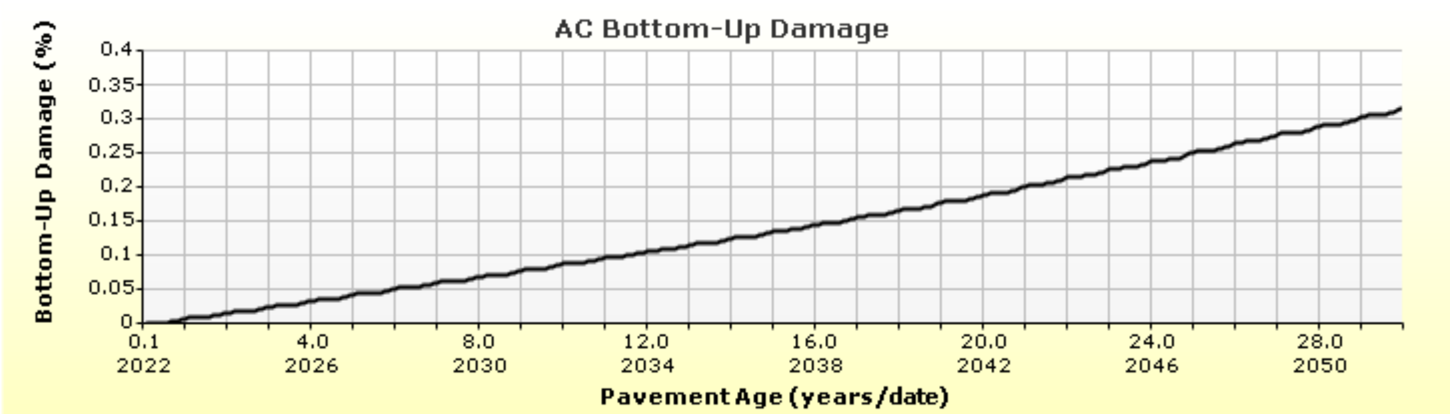




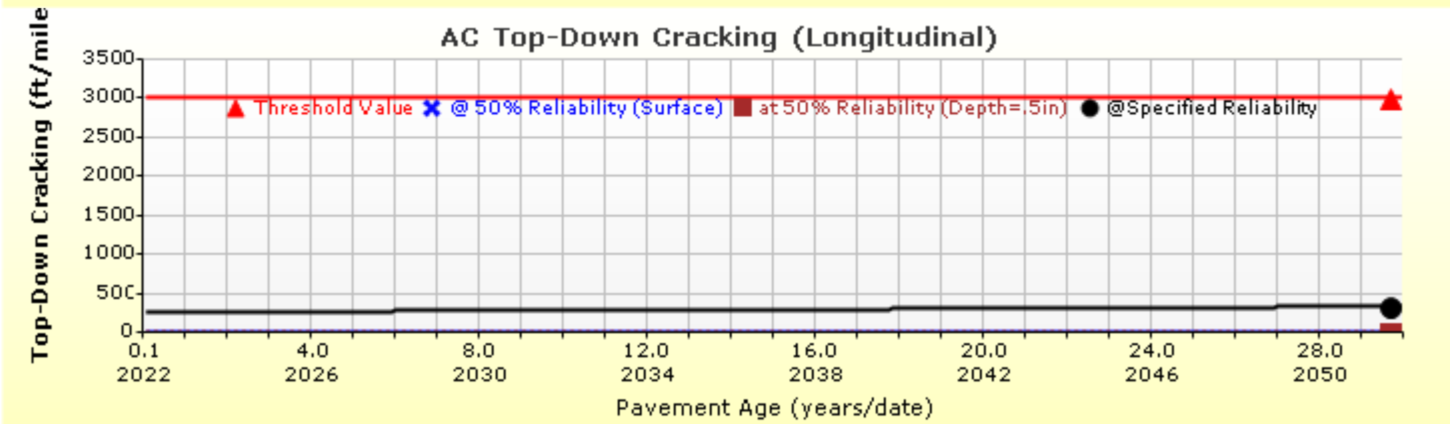




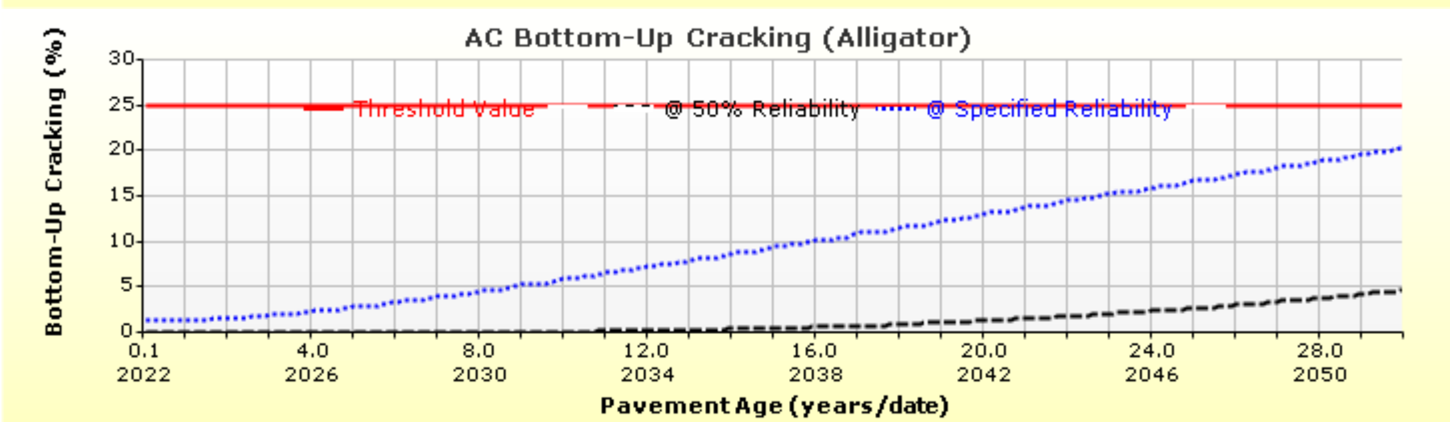
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2022 2026 2030 2034 2038 2042 2046 2050
Pavement Age (years/date)



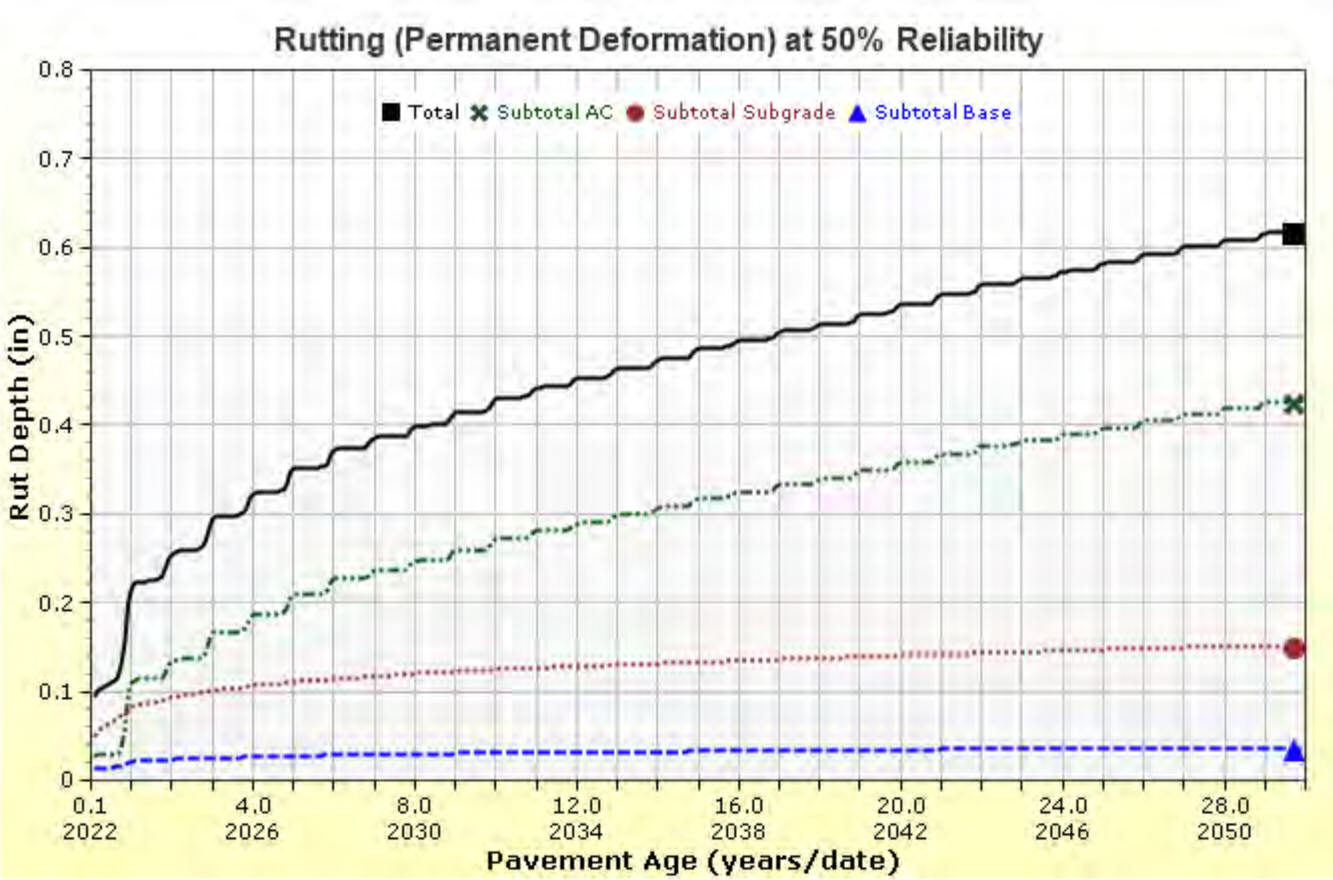
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2022 2026 2030 2034 2038 2042 2046 2050
Pavement Age (years/date)



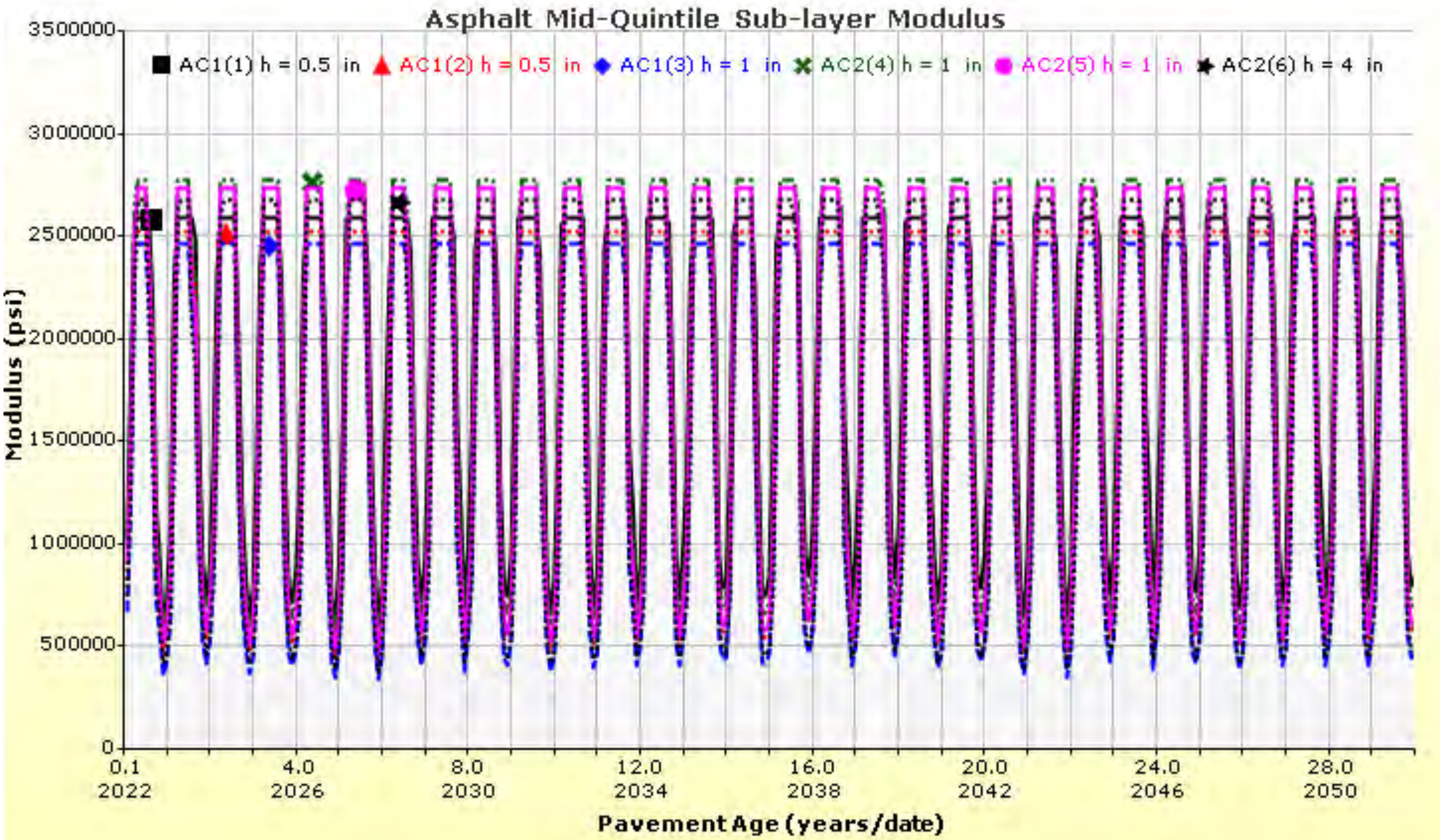
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2022 2026 2030 2034 2038 2042 2046 2050
Pavement Age (years/date)



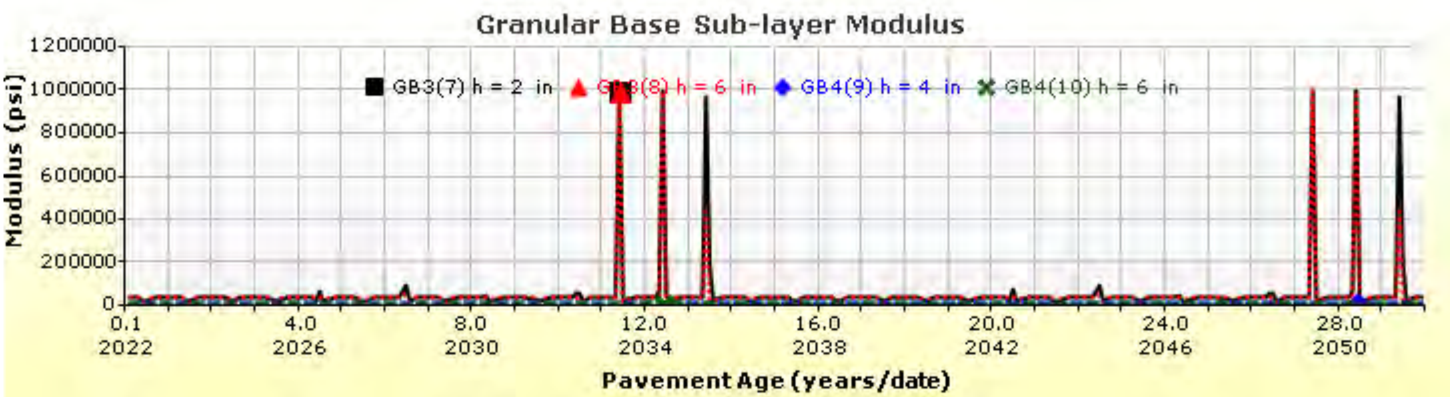
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 4.0 8.0 12.0 16.0 20.0 24.0 28.0
2022 2026 2030 2034 2038 2042 2046 2050
Pavement Age (years/date)



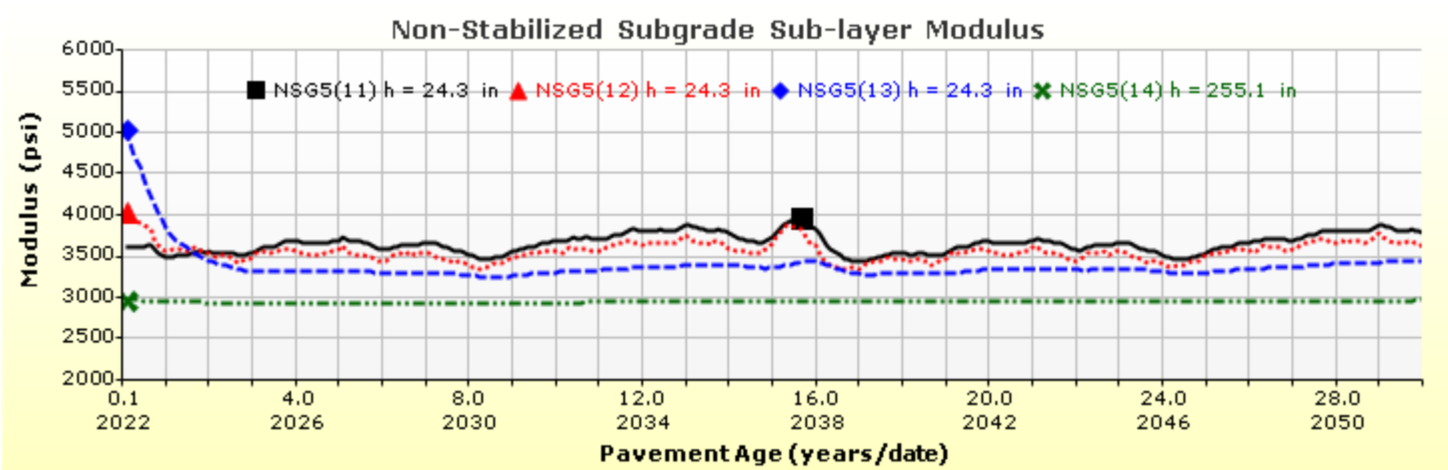
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



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 = 6 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 24.3 in
NSG5(12) h = 24.3 in
NSG5(13) h = 24.3 in
NSG5(14) h = 255.1 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	6.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	10.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting

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

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

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

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

Where:

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

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

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

$T = layer\ temperature(°F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

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

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

APPENDIX D1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD

PCCP 24.5 Road

File Name: C:\Users\RSPavement\Documents\PMED Designs\My ME Design\Projects\F.5 Road\PCCP 24.5 Road.dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2022
Traffic opening: August, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	12.0
Subgrade	A-6	Semi-infinite

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

Traffic

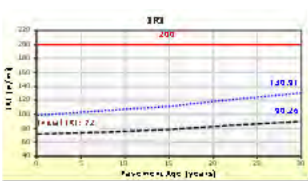
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	980
2037 (15 years)	3,768,190
2052 (30 years)	8,990,910

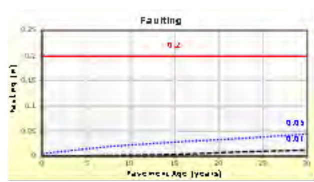
Design Outputs

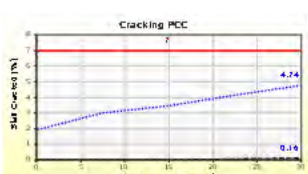
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	130.91	90.00	99.97	Pass
Mean joint faulting (in)	0.20	0.05	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	4.74	90.00	97.21	Pass

Distress Charts



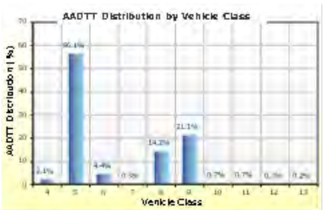


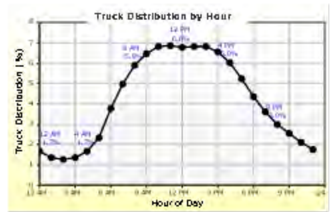


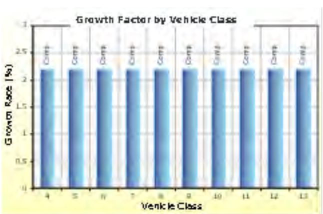
Traffic Inputs

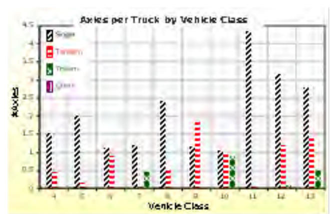
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	980	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)	25.0

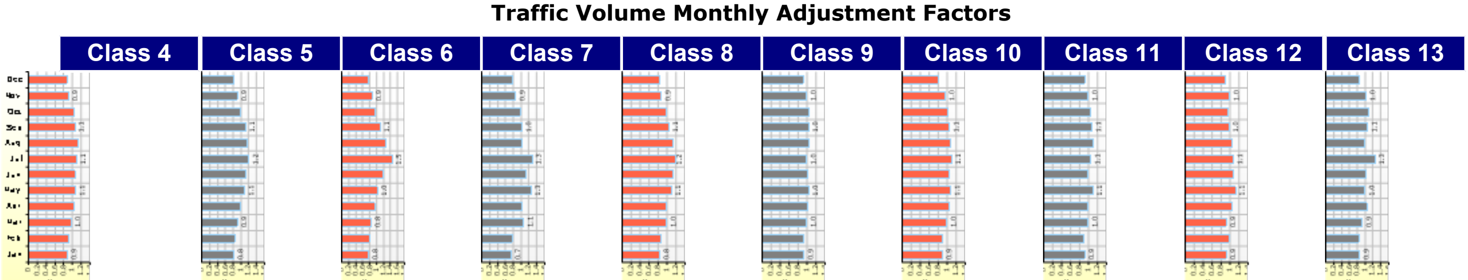








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

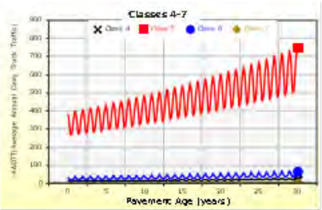
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

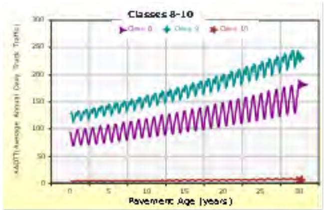
Number of Axles per Truck

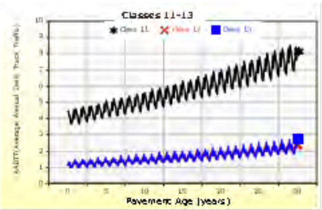
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

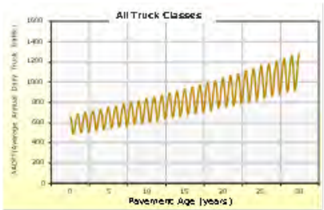
AADTT (Average Annual Daily Truck Traffic) Growth

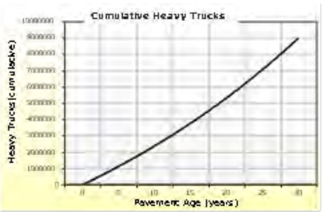
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

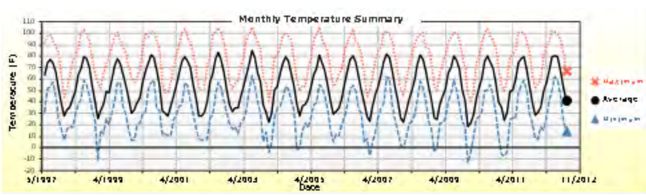
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

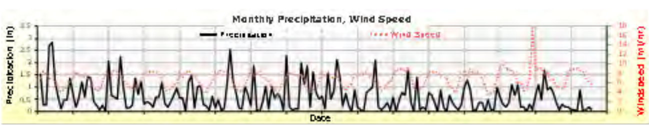
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

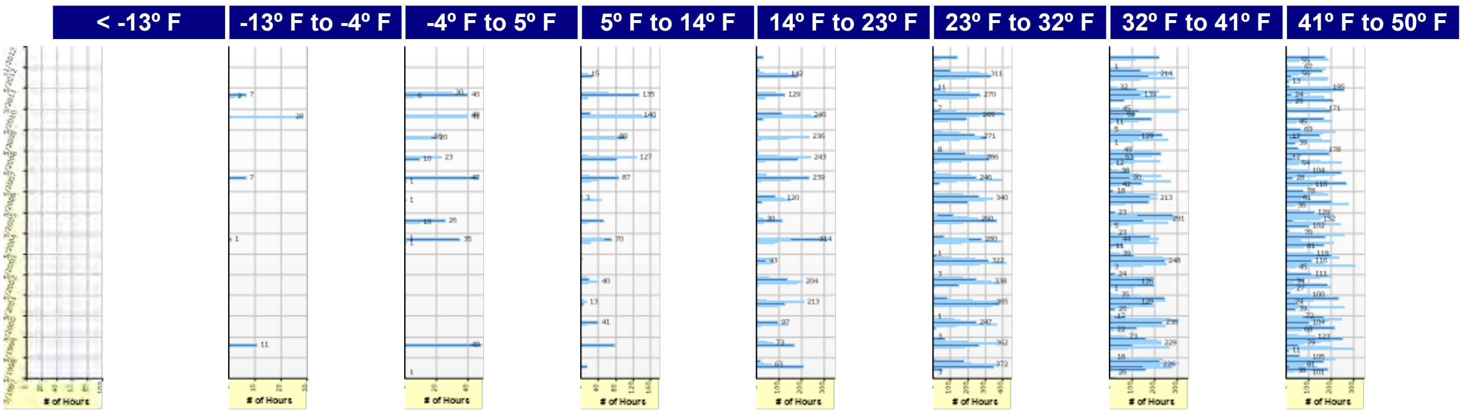
Water table depth (ft) 10.00

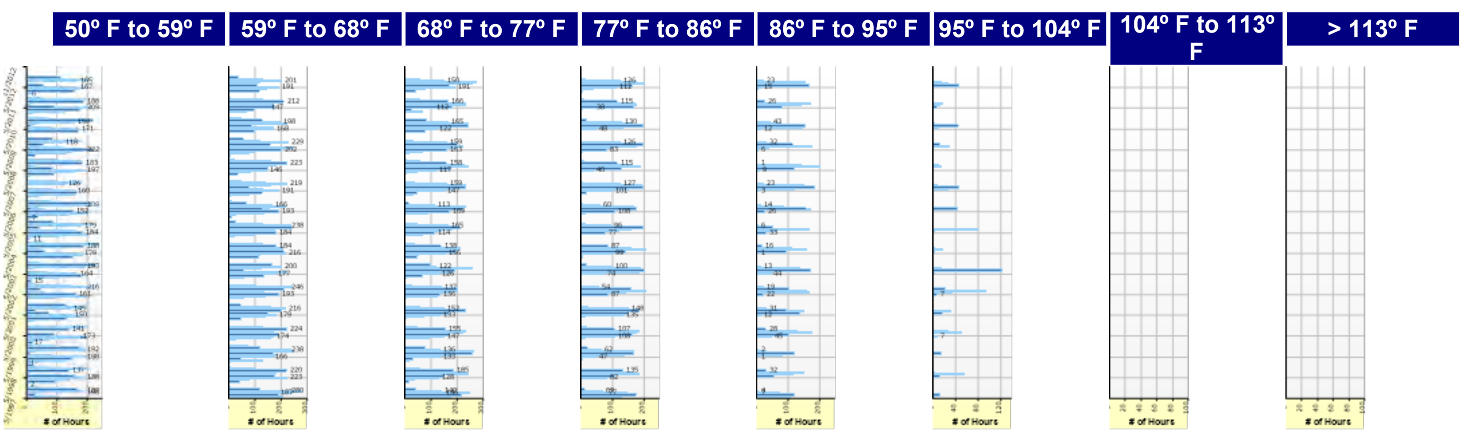
Monthly Climate Summary:





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)	12.00

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

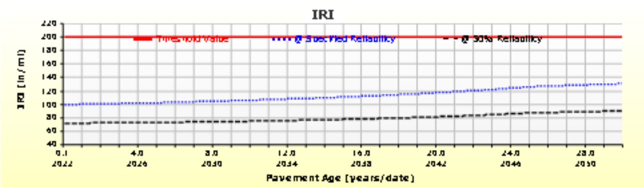
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

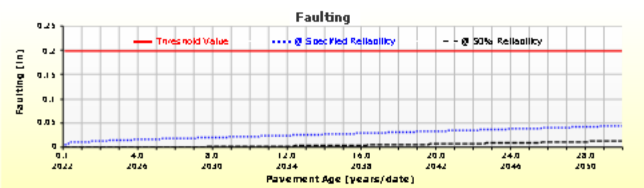
Sealant type	Other(Including No Sealant... Liquid... Silicone)

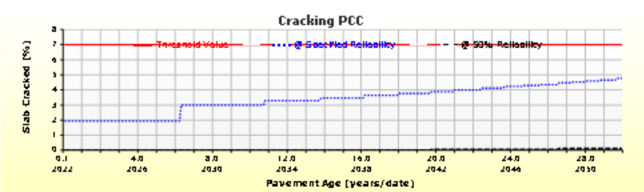
Erodibility index	4

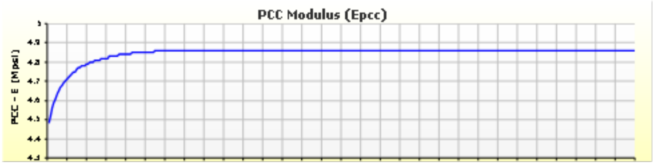
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

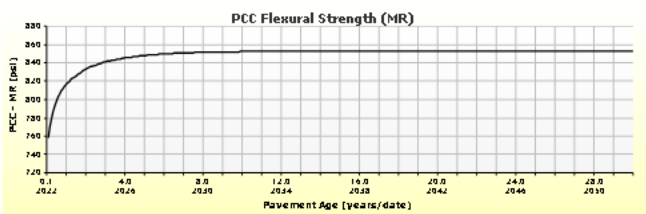




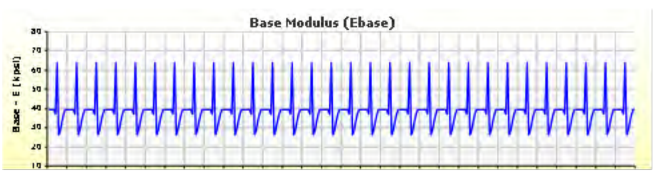




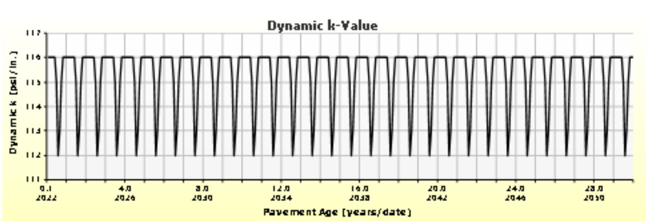
PCC Modulus (Epcc)
PCC - E (Mpsi)



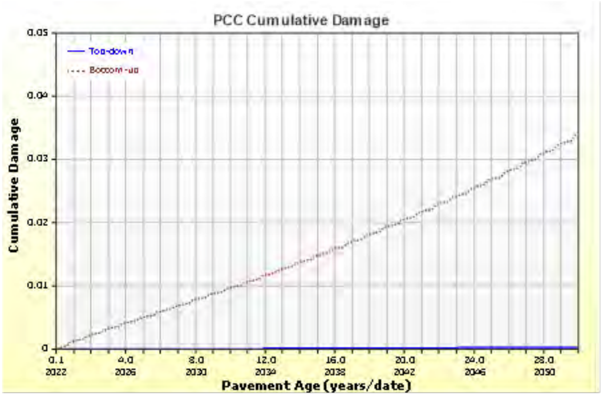
PCC Flexural Strength (MR)
PCC - MR (psi)
Pavement Age (years/date)



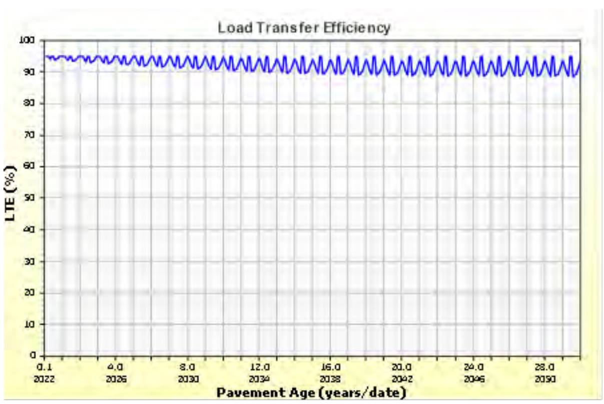
Base Modulus (Ebase)
Base - E (kpsi)



Dynamic k-Value
Dynamic k (psi/in.)
Pavement Age (years/date)



PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.0
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

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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-6

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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 E

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT
SHEETS 24 ½ ROAD & F ½ ROAD ROUNDABOUT

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	8.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	16.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

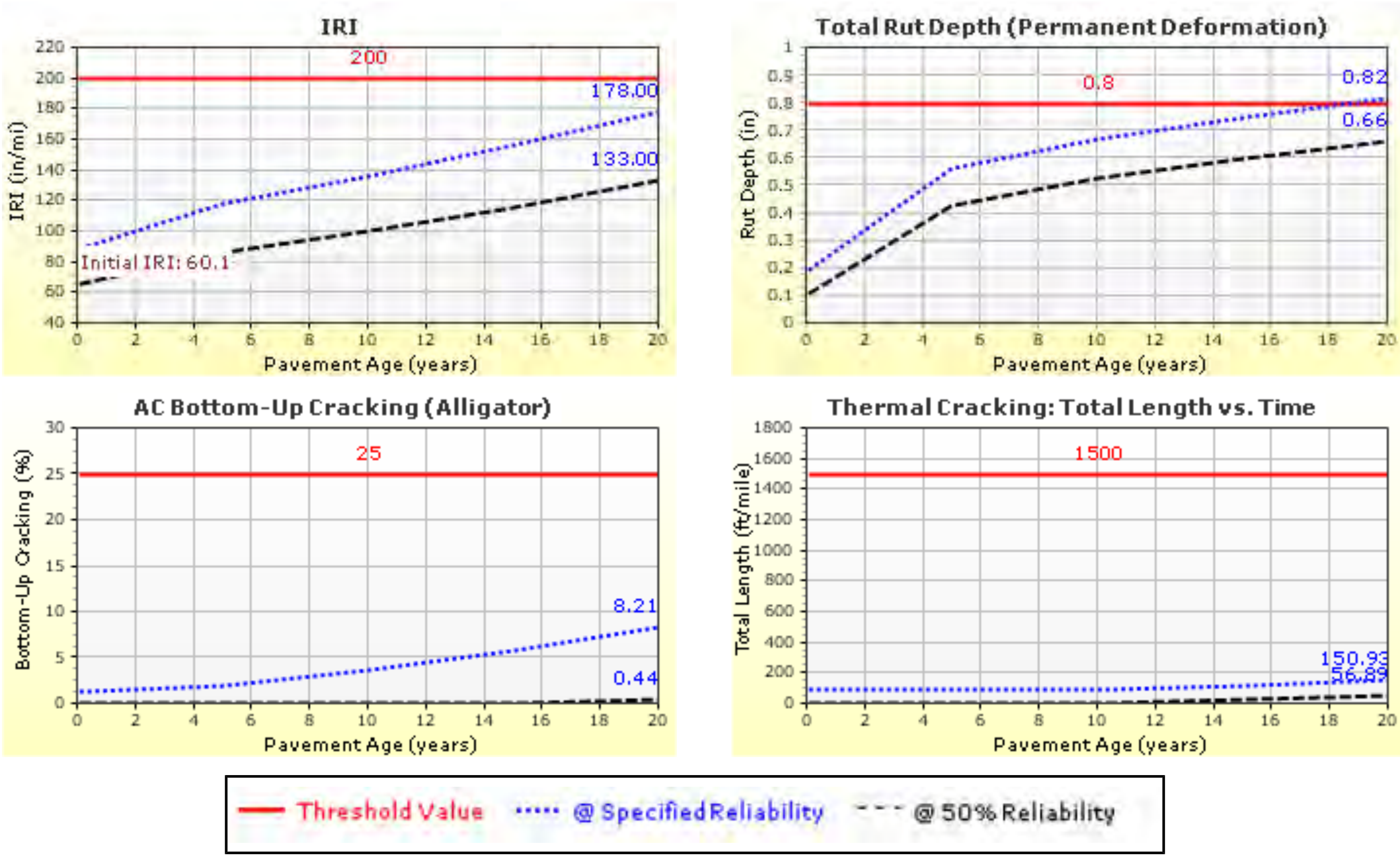
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	3,178
2032 (10 years)	5,772,100
2042 (20 years)	12,947,400

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	178.01	90.00	97.18	Pass
Permanent deformation - total pavement (in)	0.80	0.82	90.00	87.29	Fail
AC bottom-up fatigue cracking (% lane area)	25.00	8.21	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	150.93	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	280.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.65	90.00	90.68	Pass

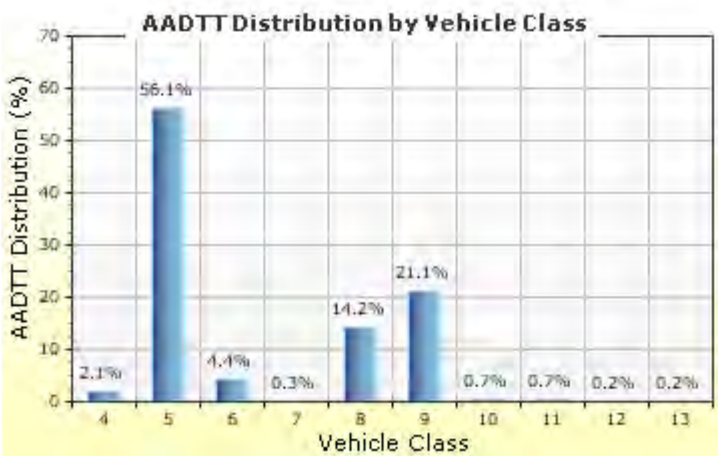
Distress Charts

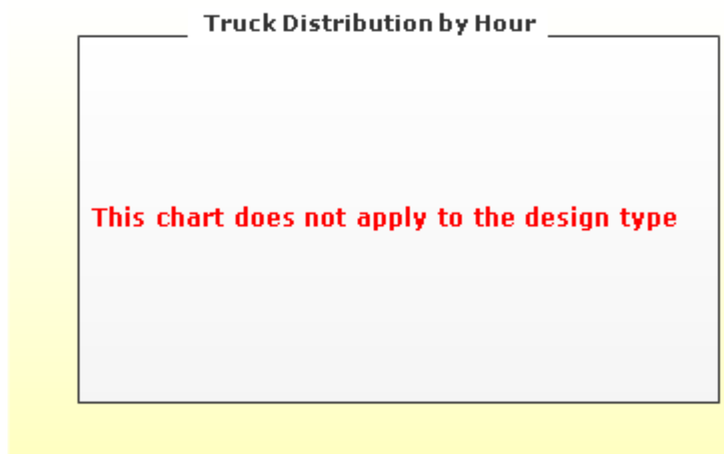


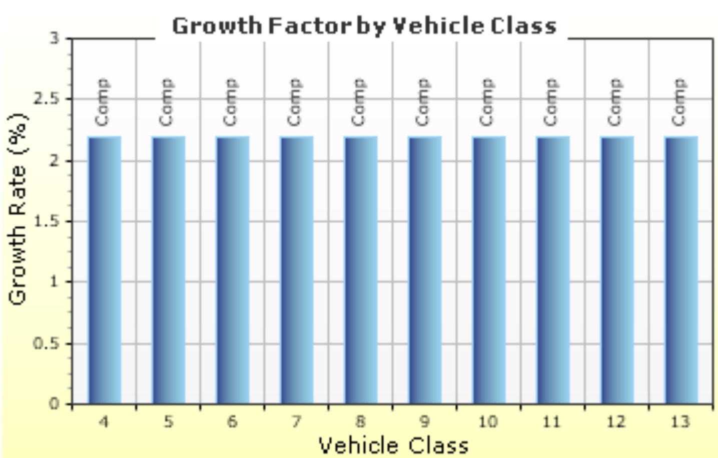
Traffic Inputs

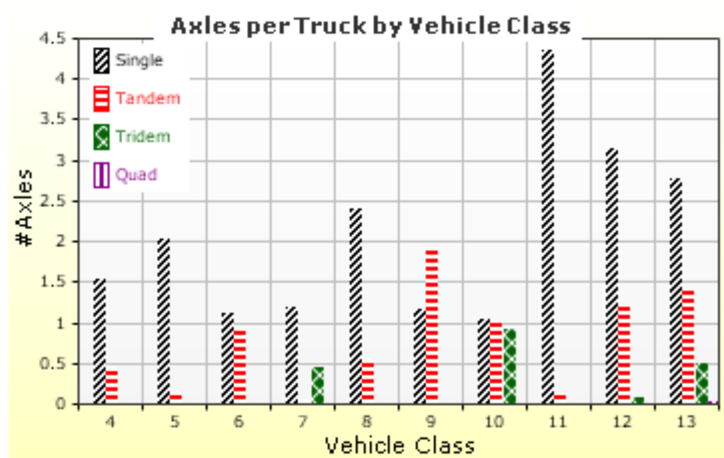
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,178	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)	20.0

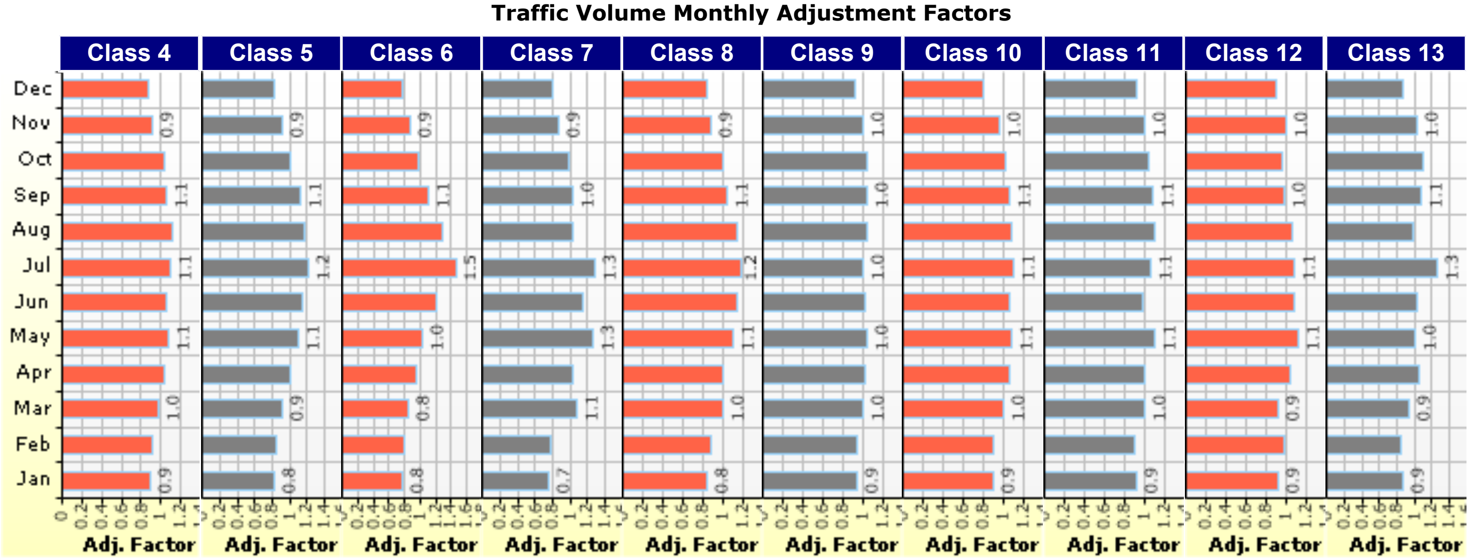








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

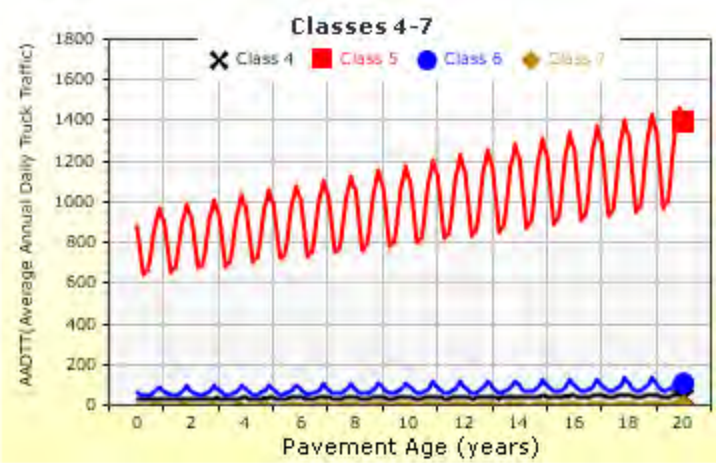
Wheelbase does not apply

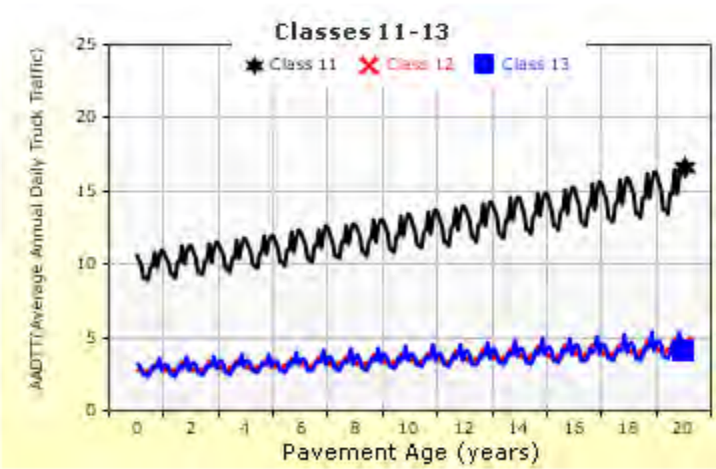
Number of Axles per Truck

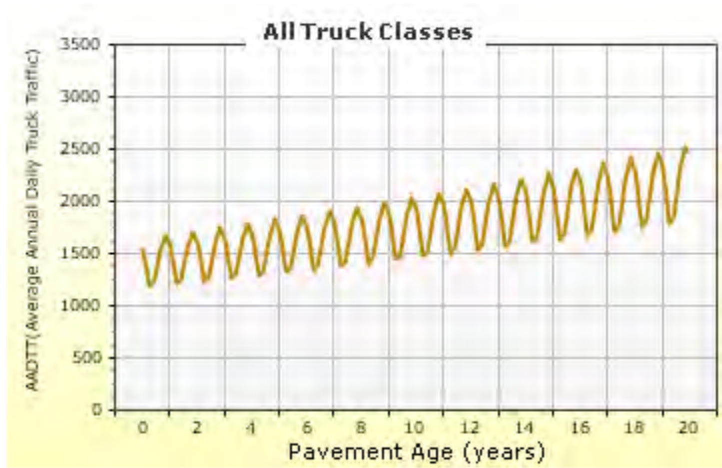
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

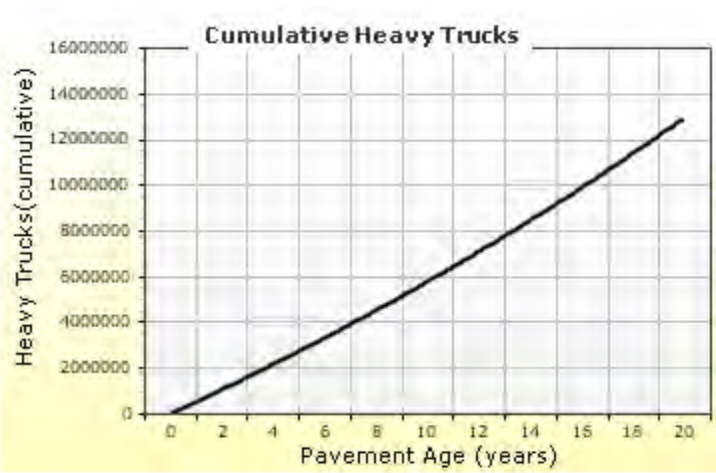
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





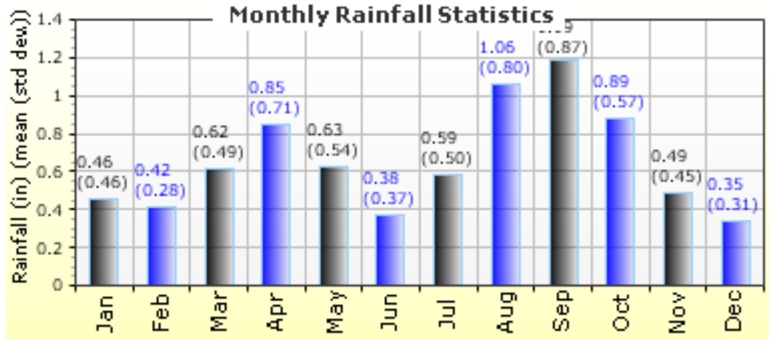




Climate Inputs

Climate Data Sources:

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

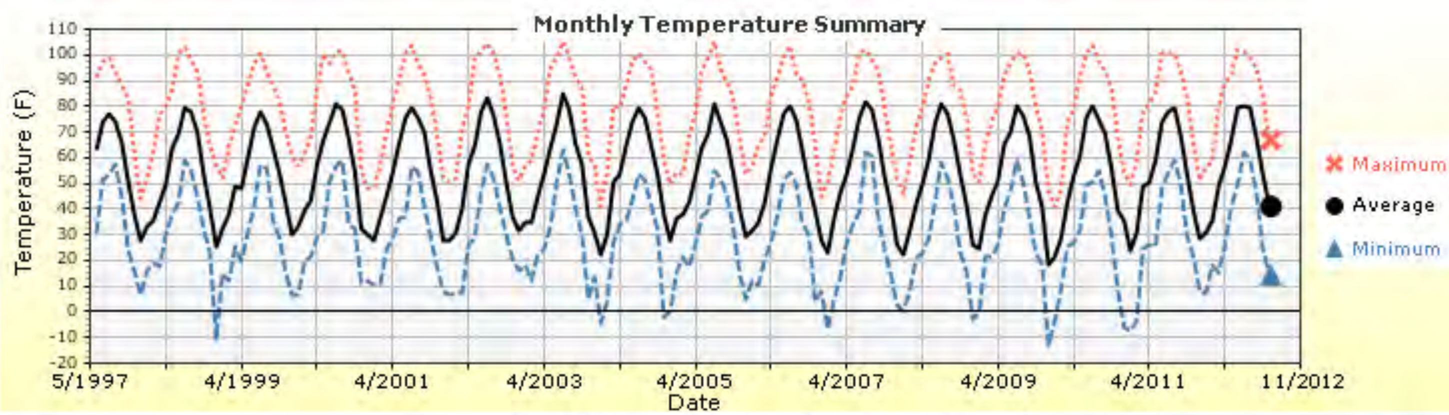


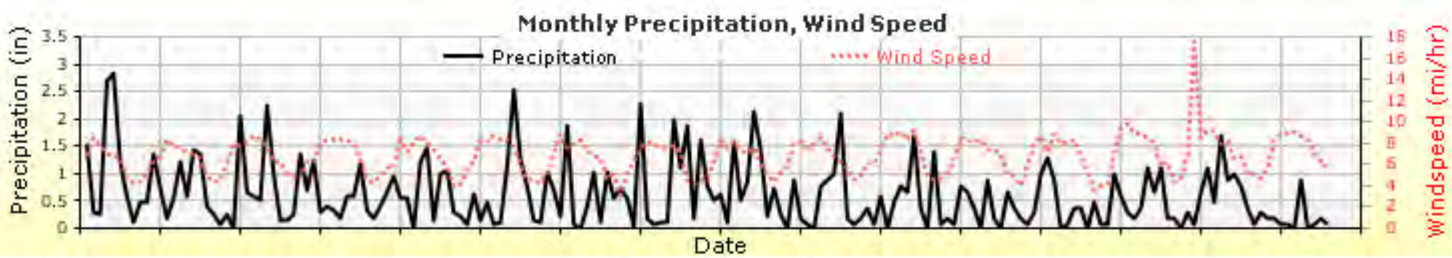
Annual Statistics:

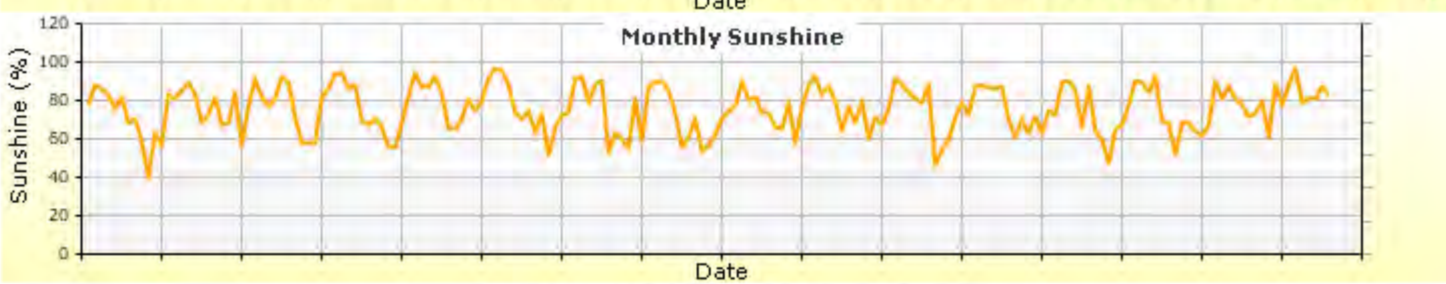
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

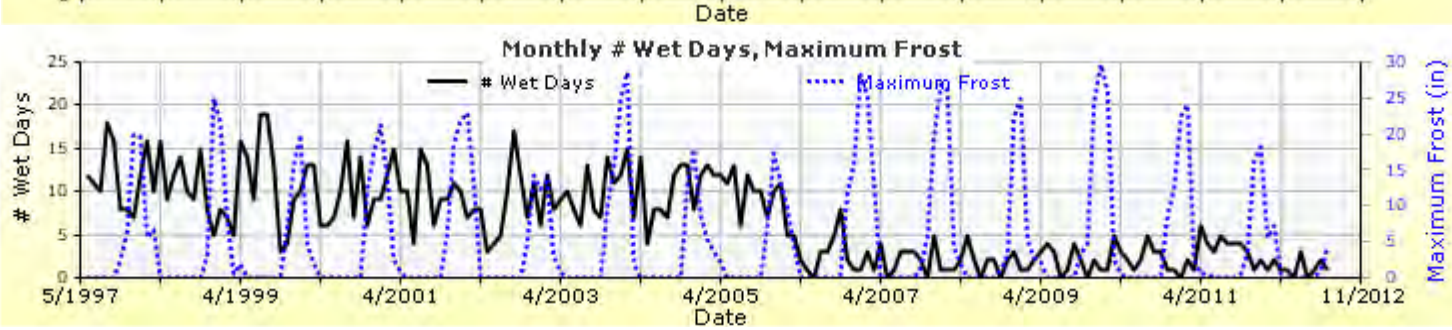
Water table depth (ft) 10.00

Monthly Climate Summary:

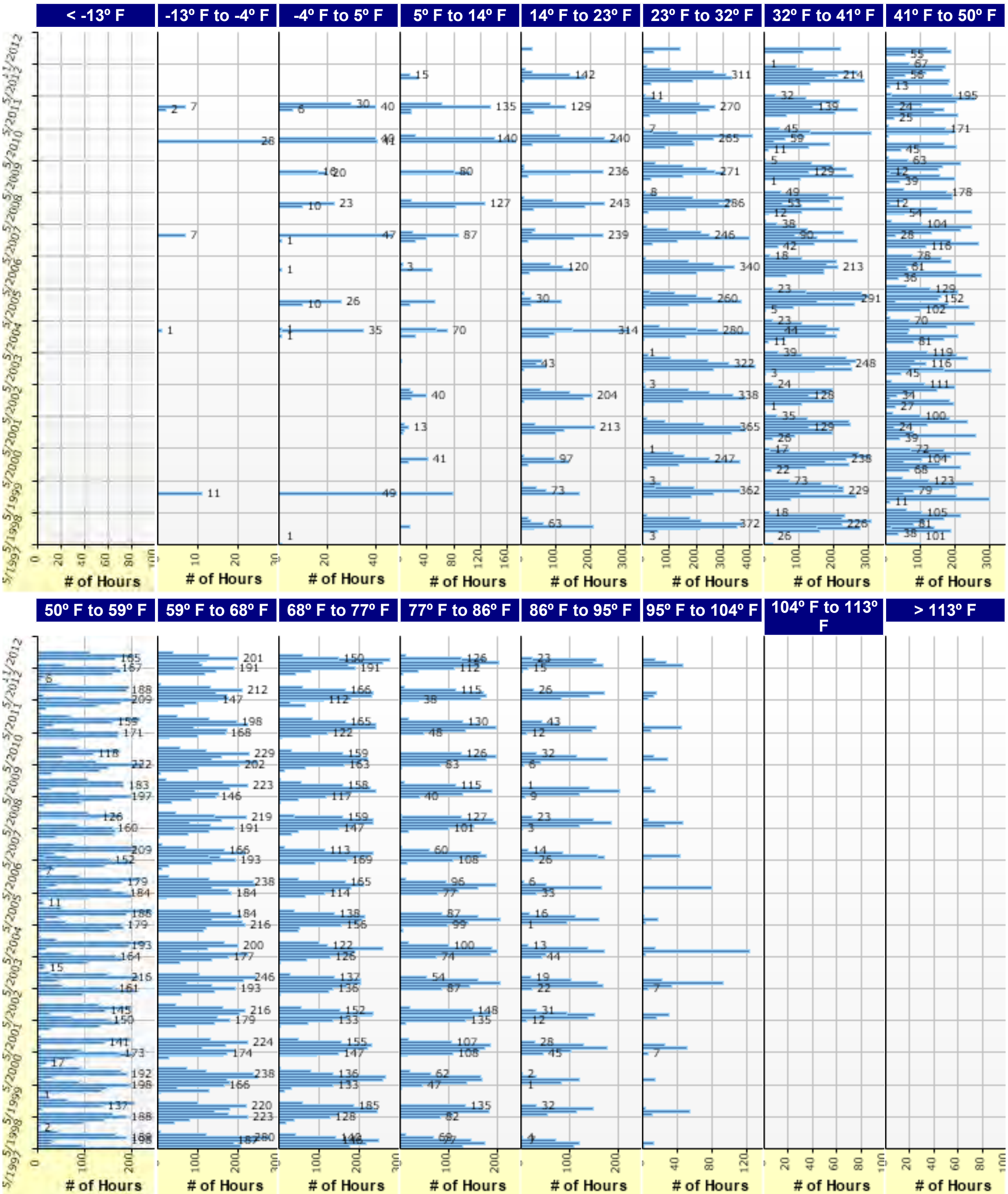








Hourly Air Temperature Distribution by Month:



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 : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (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 : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

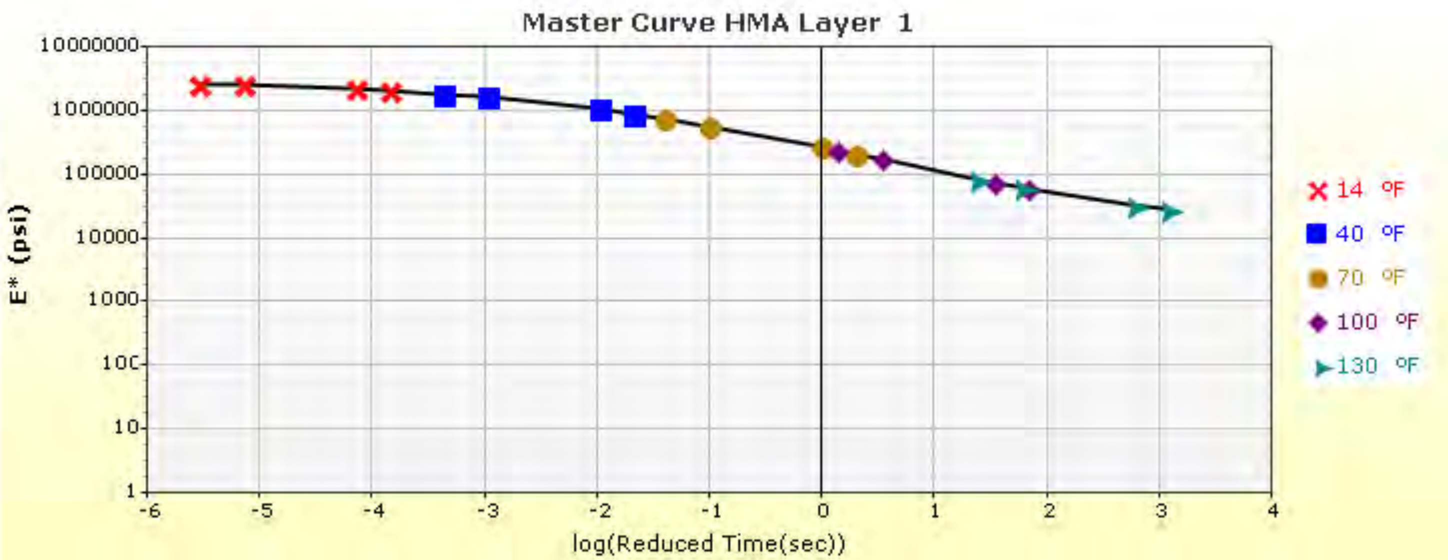
Thermal Cracking (Input Level: 1)

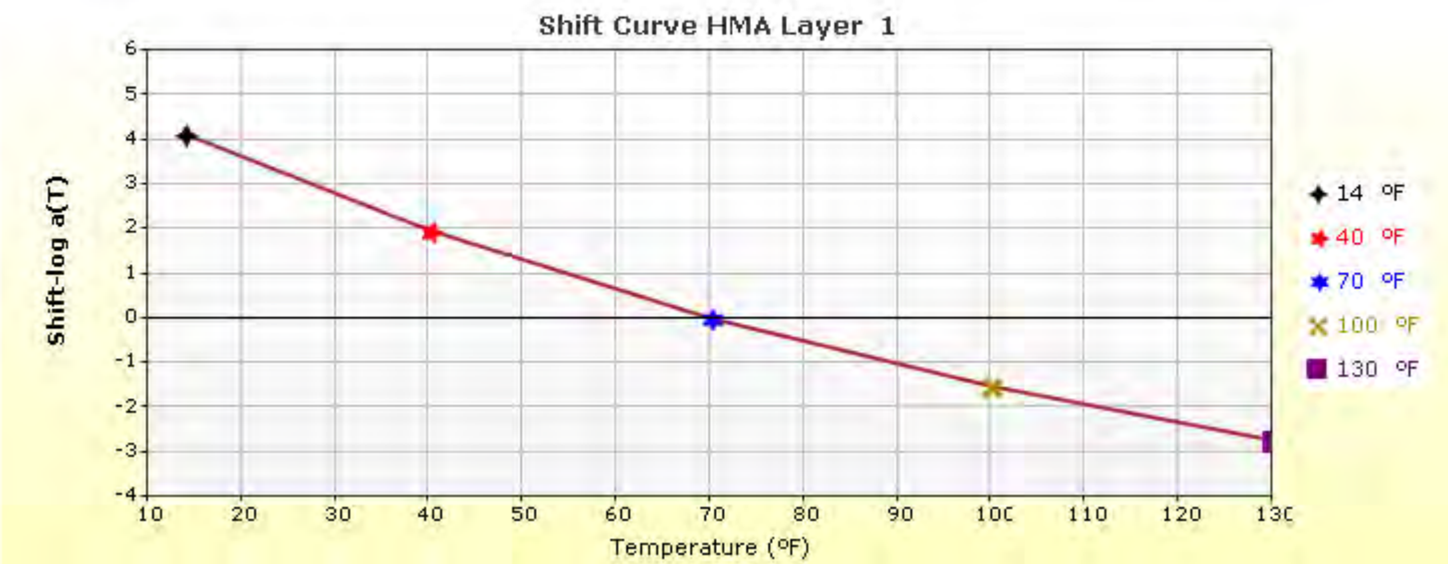
Indirect tensile strength at 14 ºF (psi)	519.00

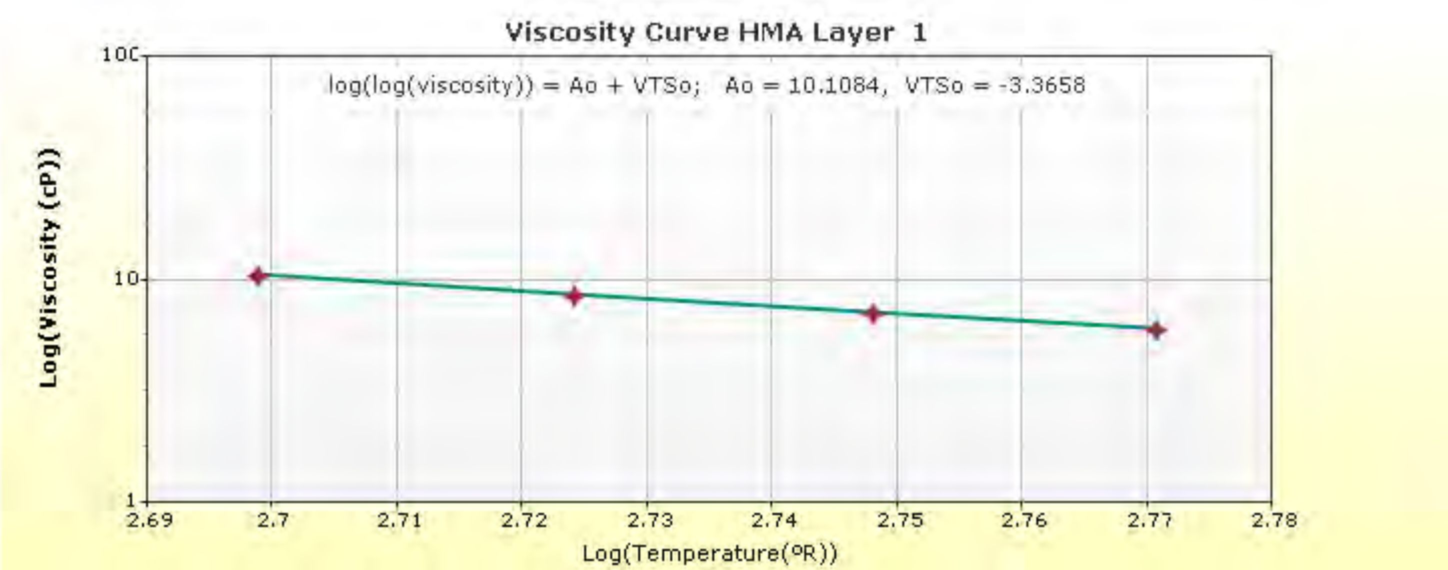
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006

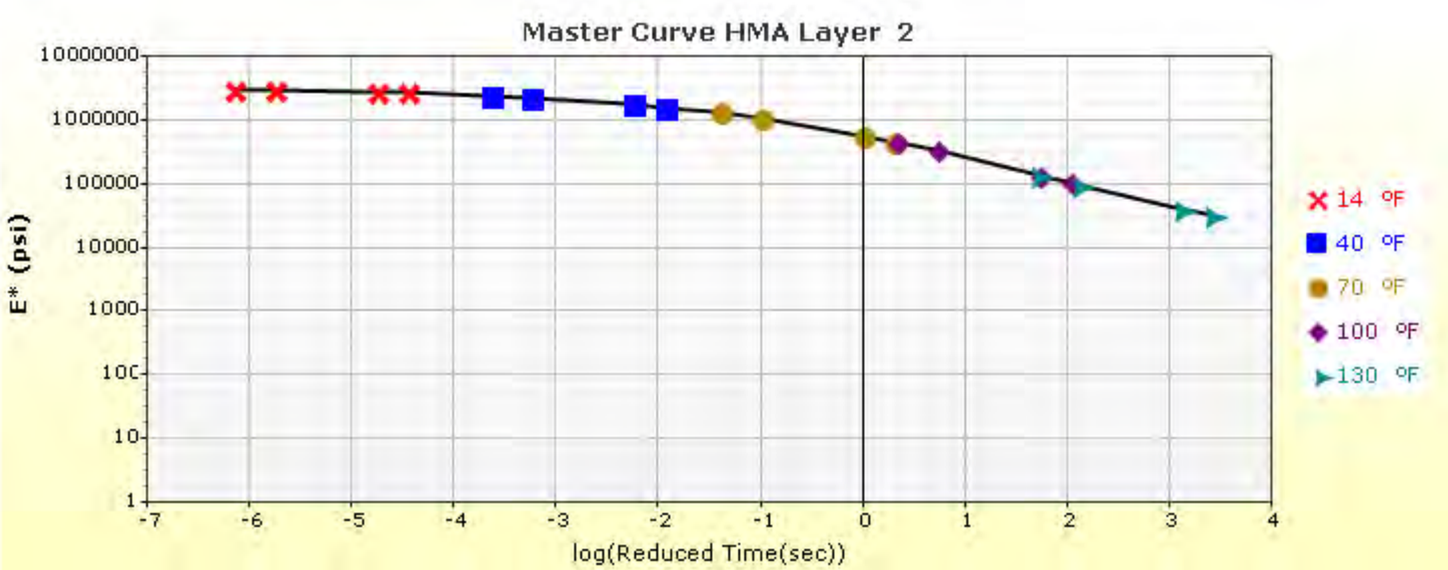
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

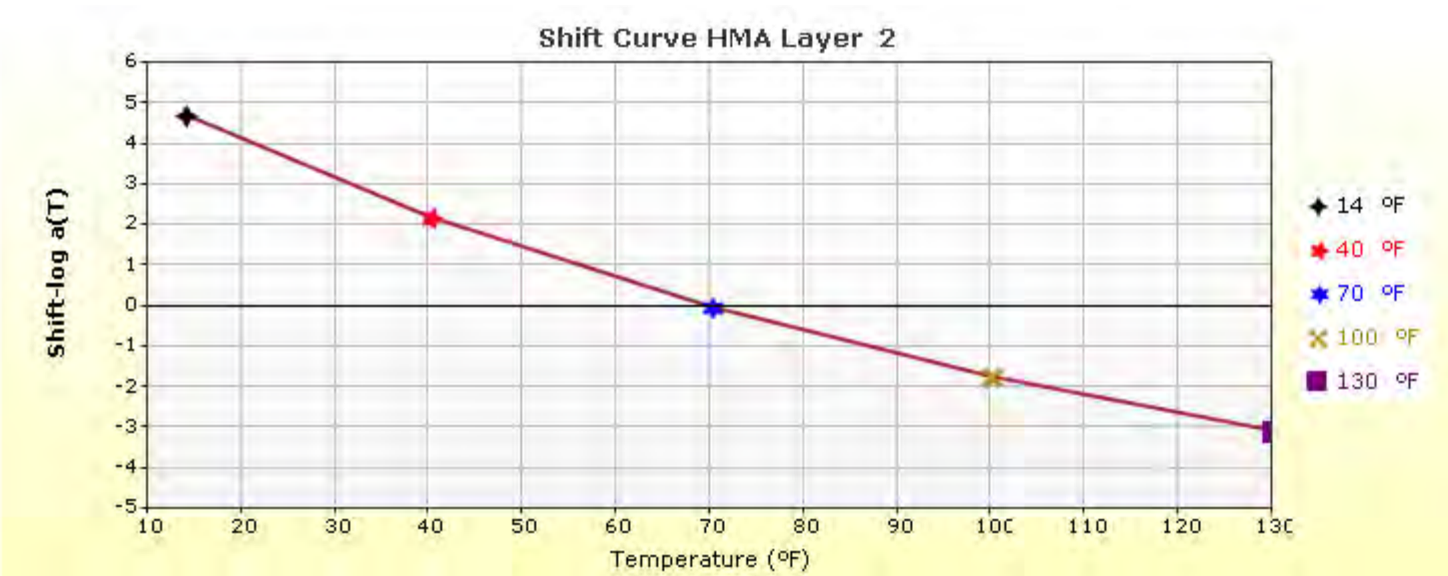


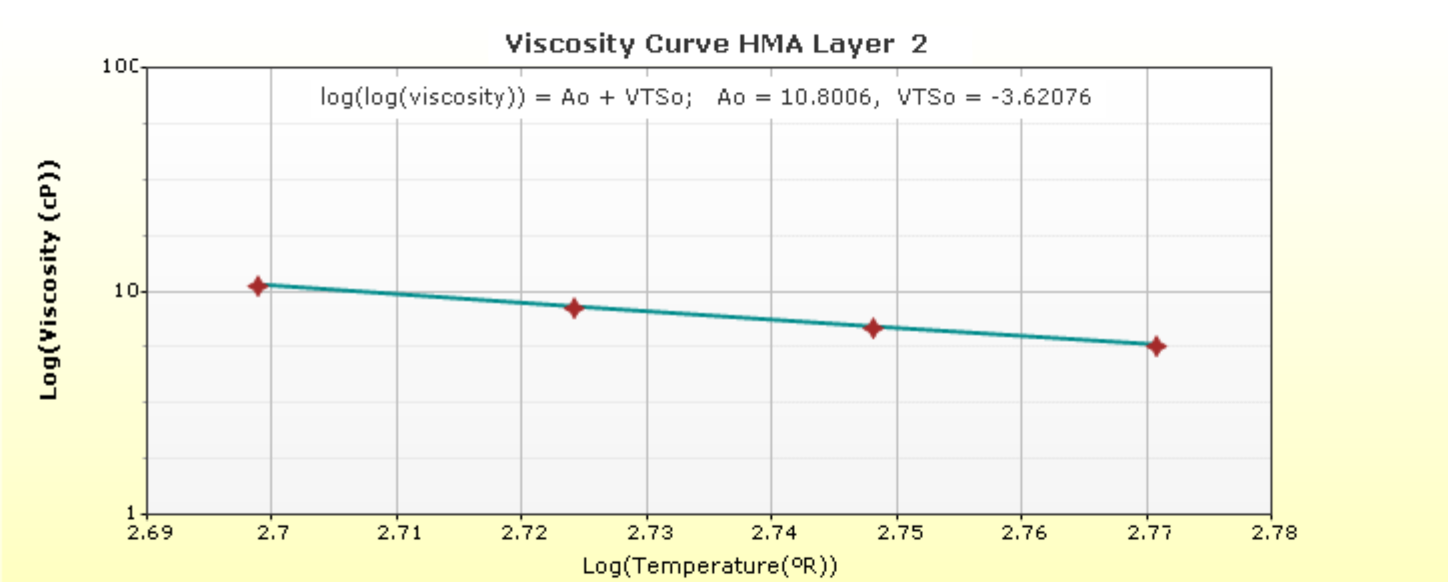




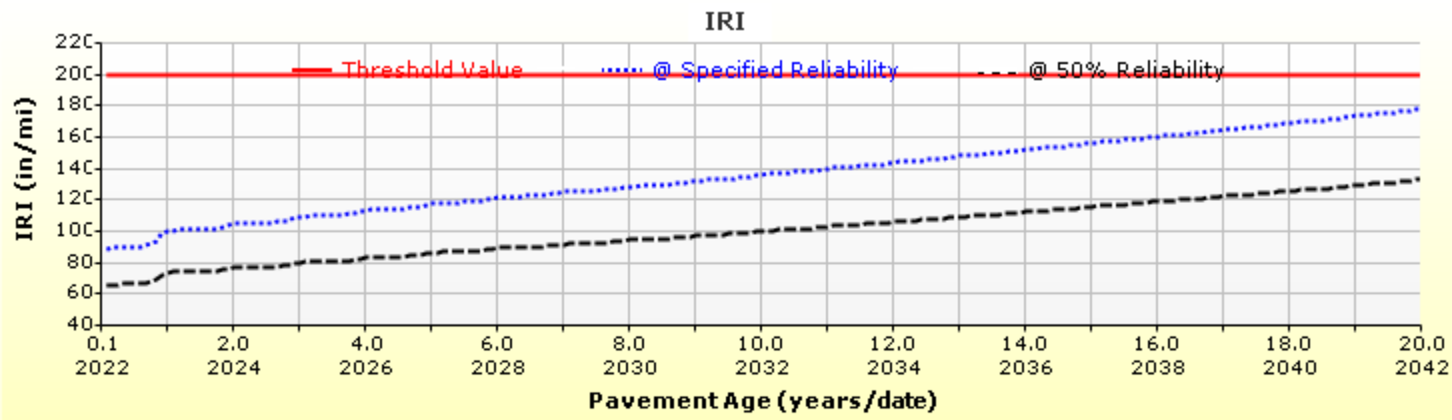
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

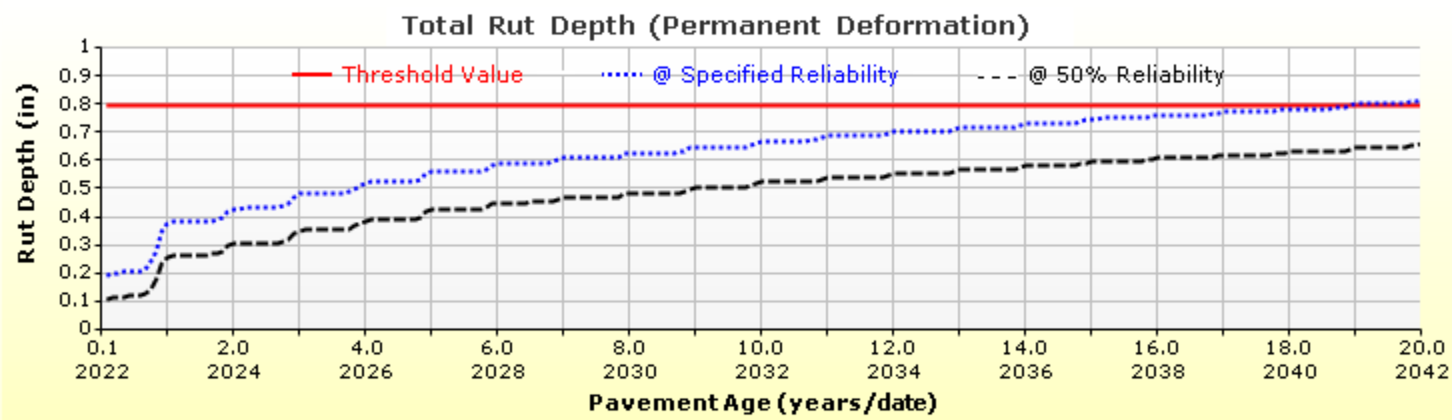


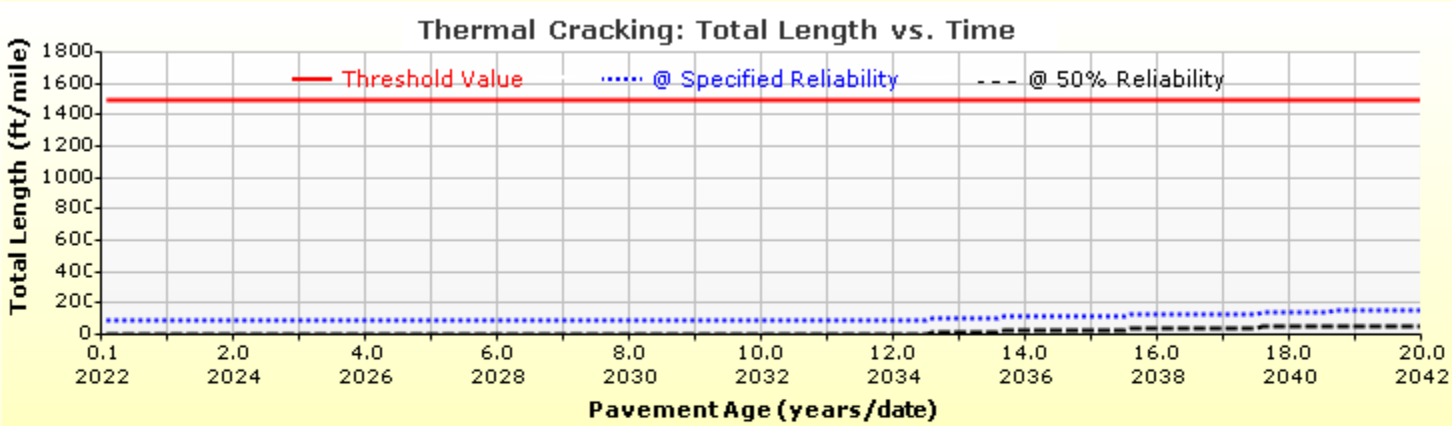


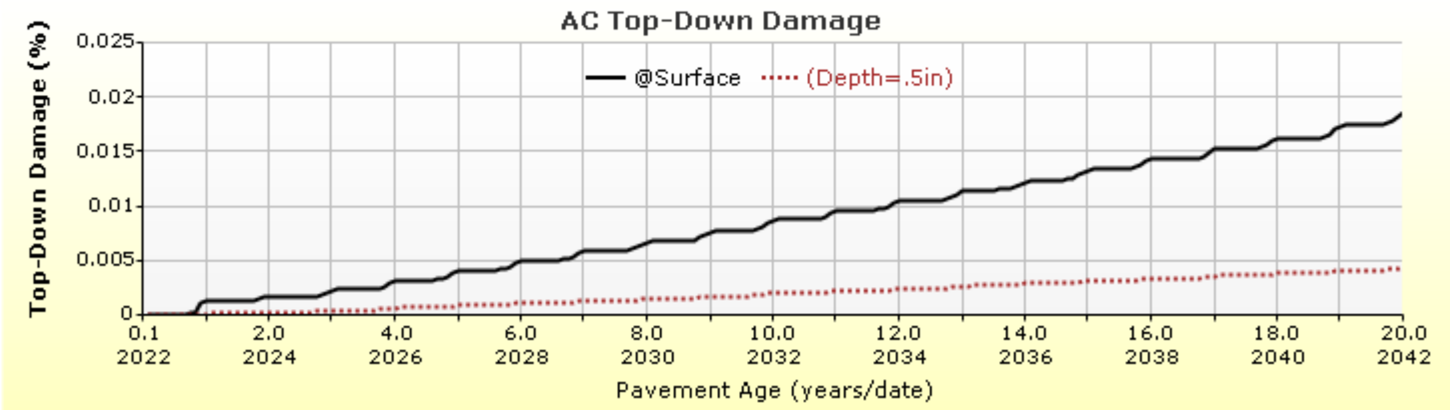


Analysis Output Charts

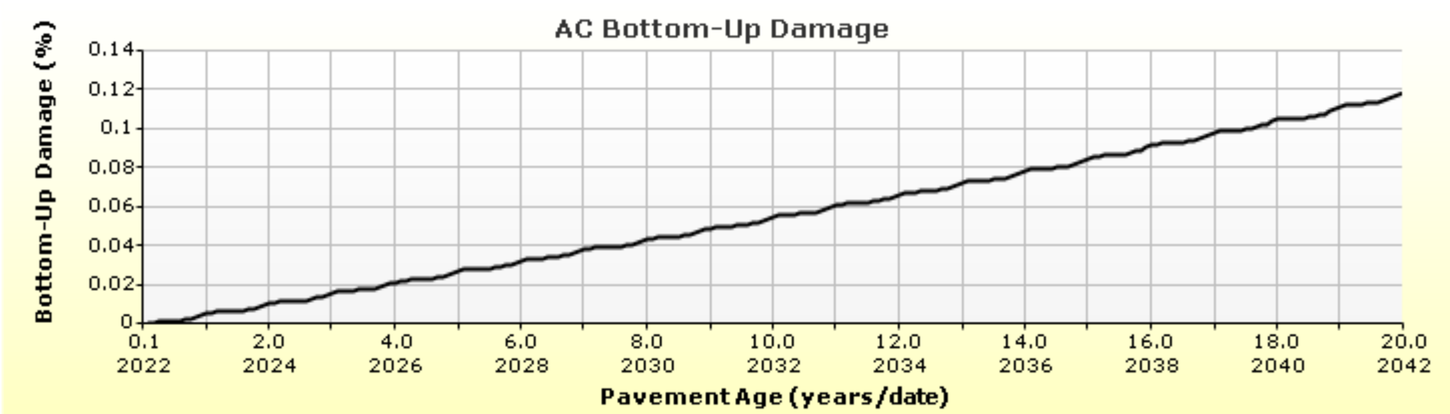




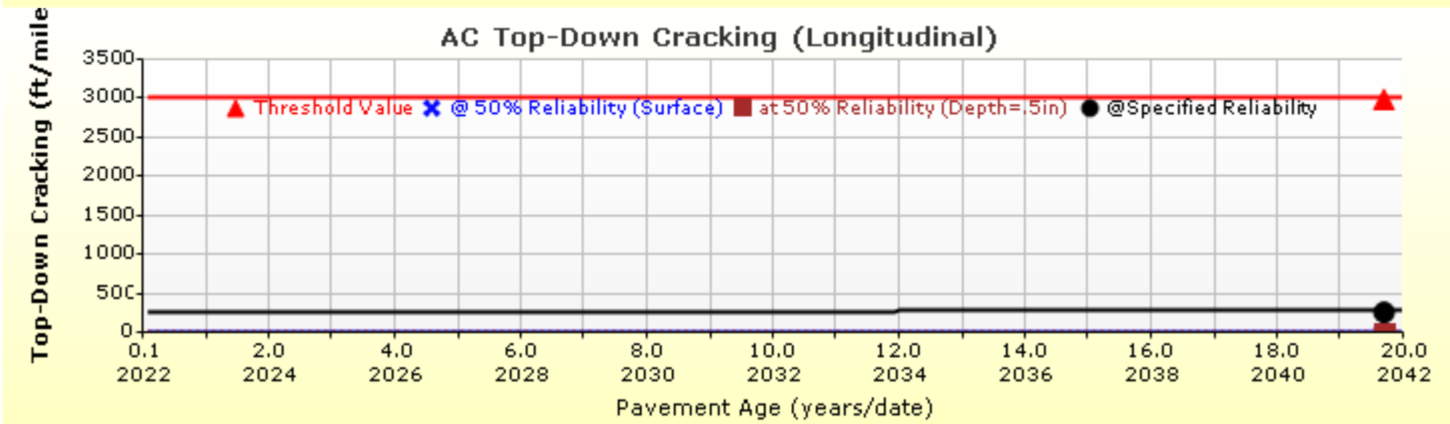




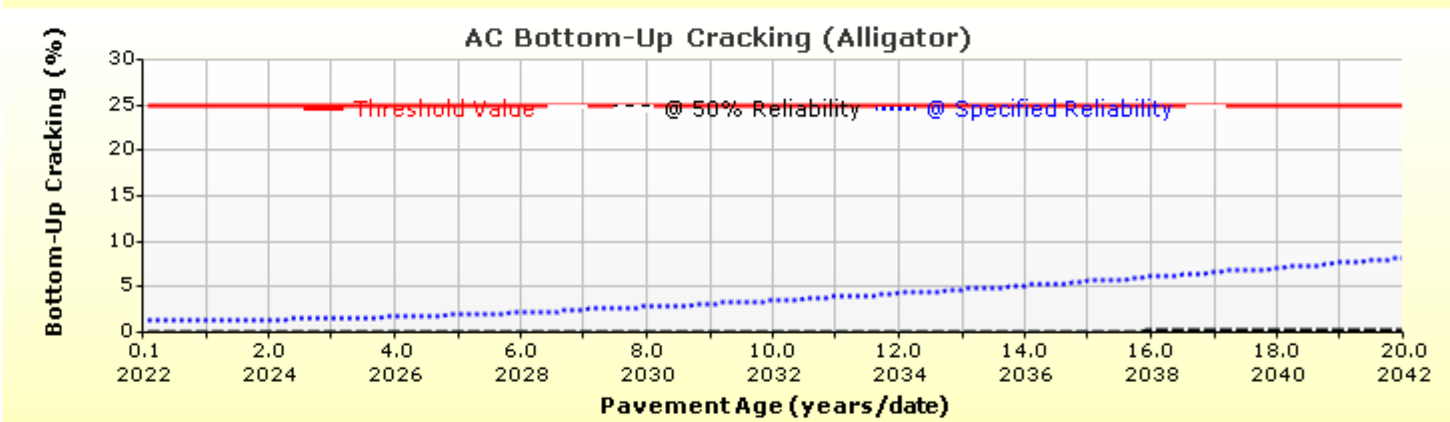
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.025
0.02
0.015
0.01
0.005
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



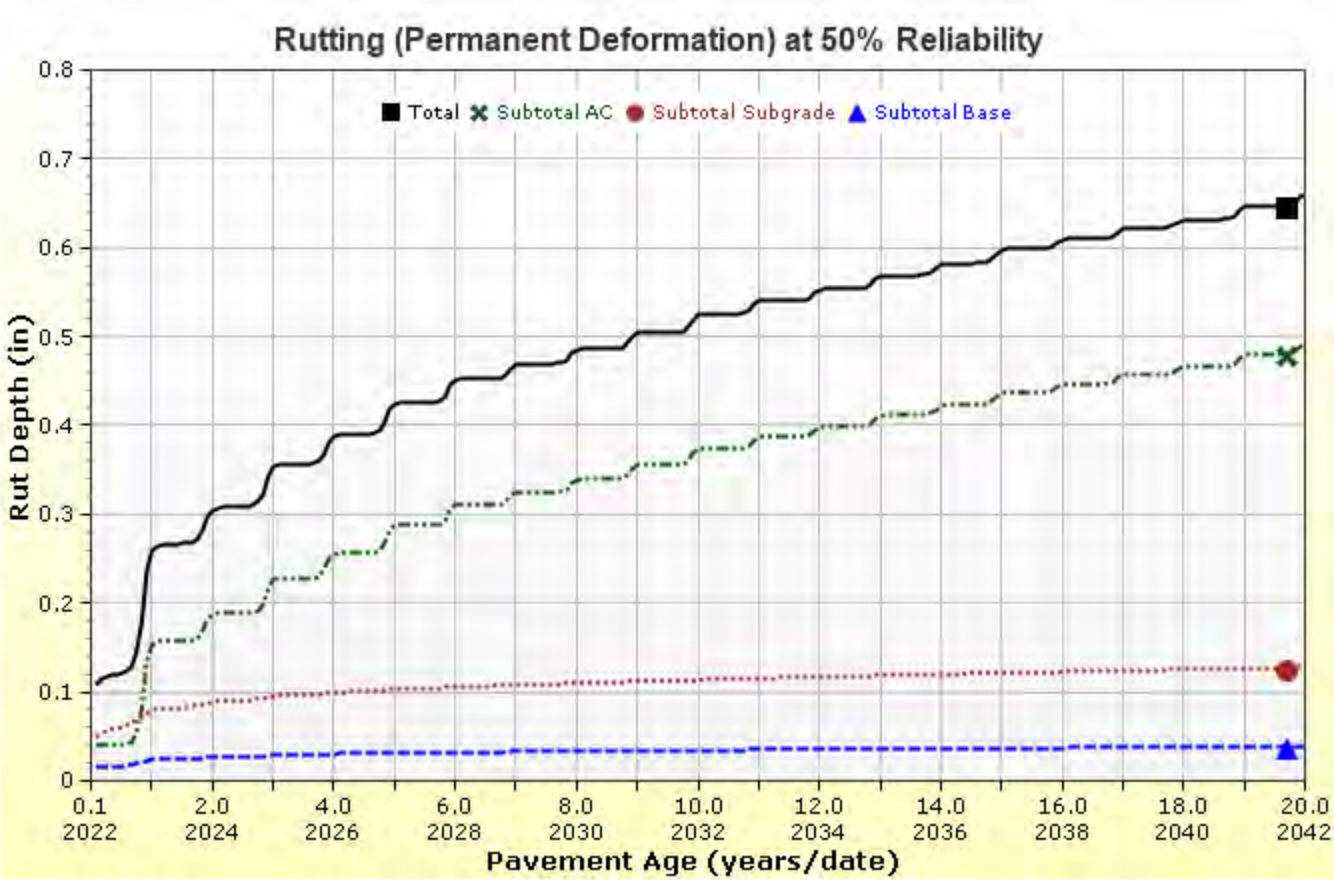
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

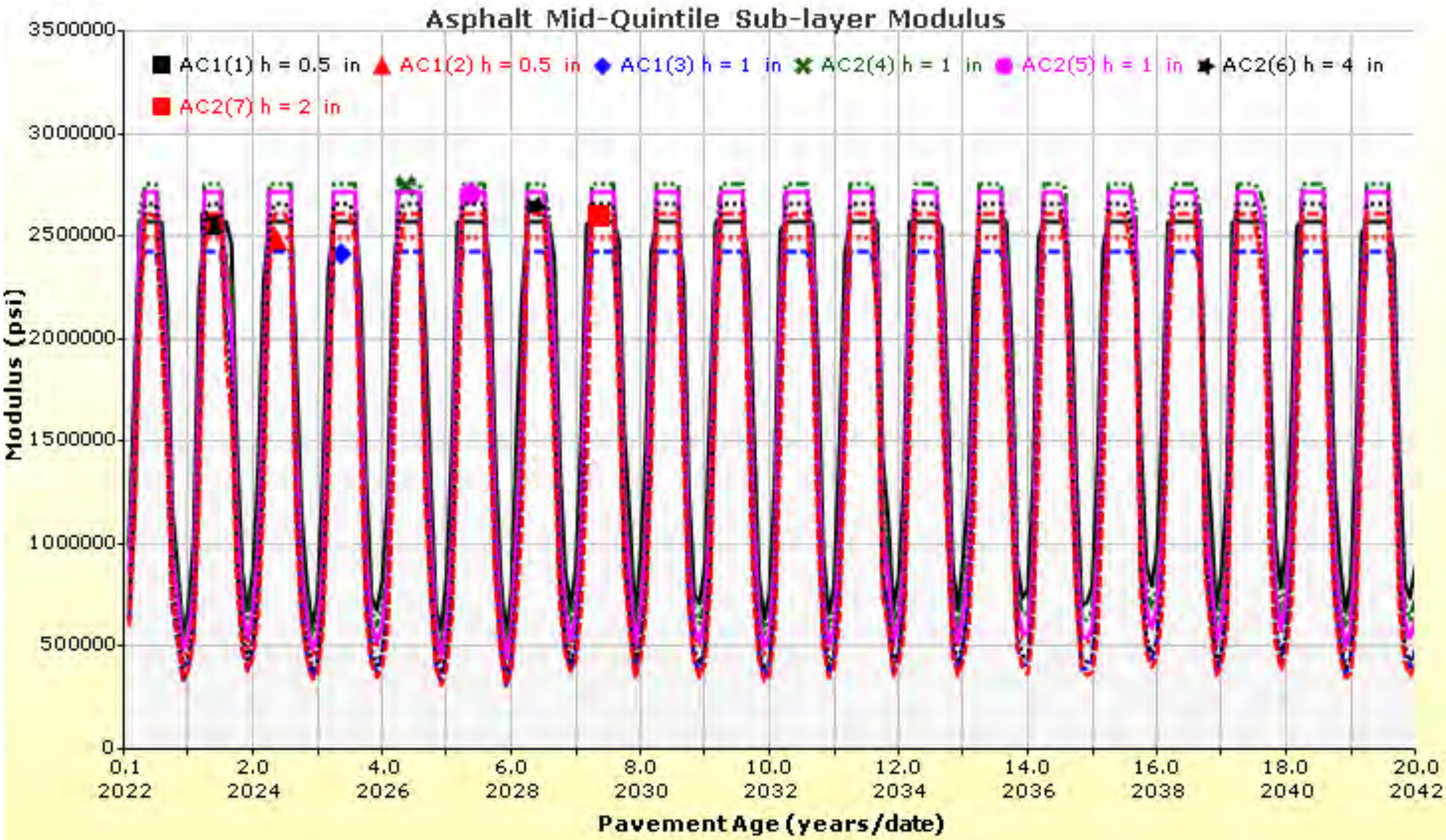


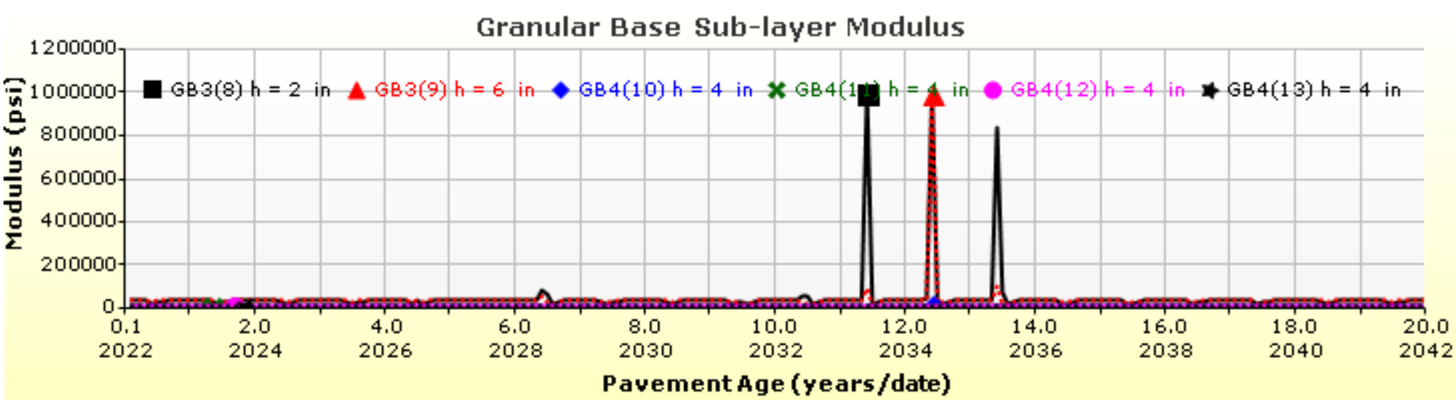
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

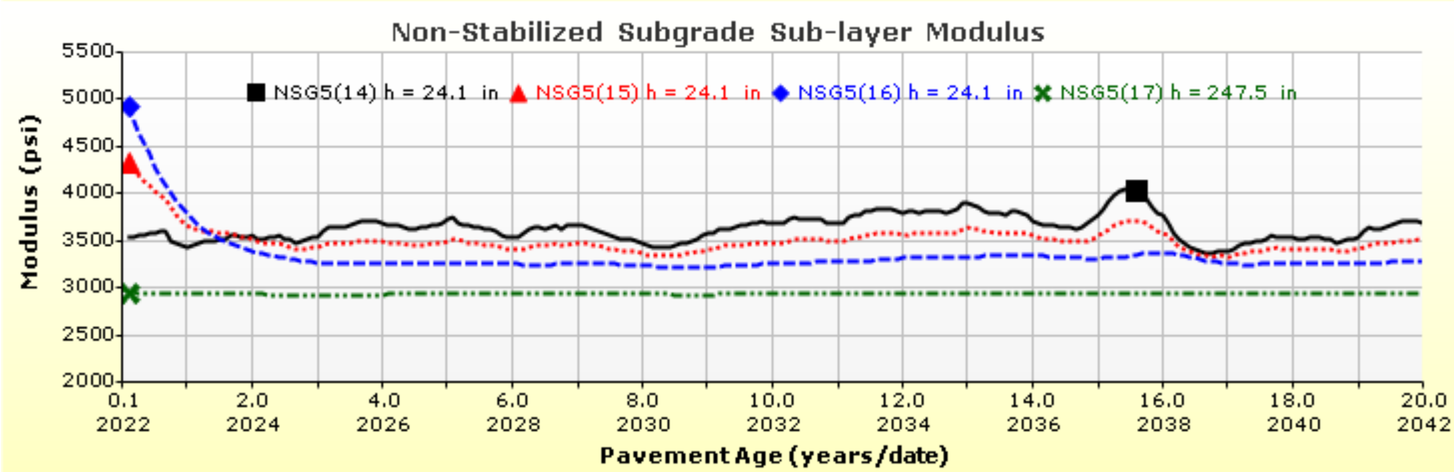


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
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)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
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
GB4(12) h = 4 in
GB4(13) h = 4 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(14) h = 24.1 in
NSG5(15) h = 24.1 in
NSG5(16) h = 24.1 in
NSG5(17) h = 247.5 in
Modulus (psi)
5500
5000
4500
4000
3500
3000
2500
2000
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	8.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	16.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
	Bf2: 1
	Bf3: 1.217799

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:

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

$\varepsilon_p = plastic\ strain({}^{in}/_{in})$

$\varepsilon_r = resilient\ strain({}^{in}/_{in})$

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

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

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

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

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N(\,) = standard\ normal\ distribution\ evaluated\ at(\,)$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 6.3	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: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

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

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$

$\sigma_s = Tensile\ stress(psi)$

$M_r = modulus\ of\ rupture(psi)$

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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking				**IRI Flexible Pavements**			
$FC_{ctb} = C_1 + \frac{C_2}{1+e^{C_3 - C_4(Damage)}}$				C1 - Rutting C2 - Fatigue Crack		C3 - Transverse Crack C4 - Site Factors	
C1: 0	C2: 75	C3: 5	C4: 3	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*1							

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	9.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	16.0
Subgrade	A-6 (R-Value = 5)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

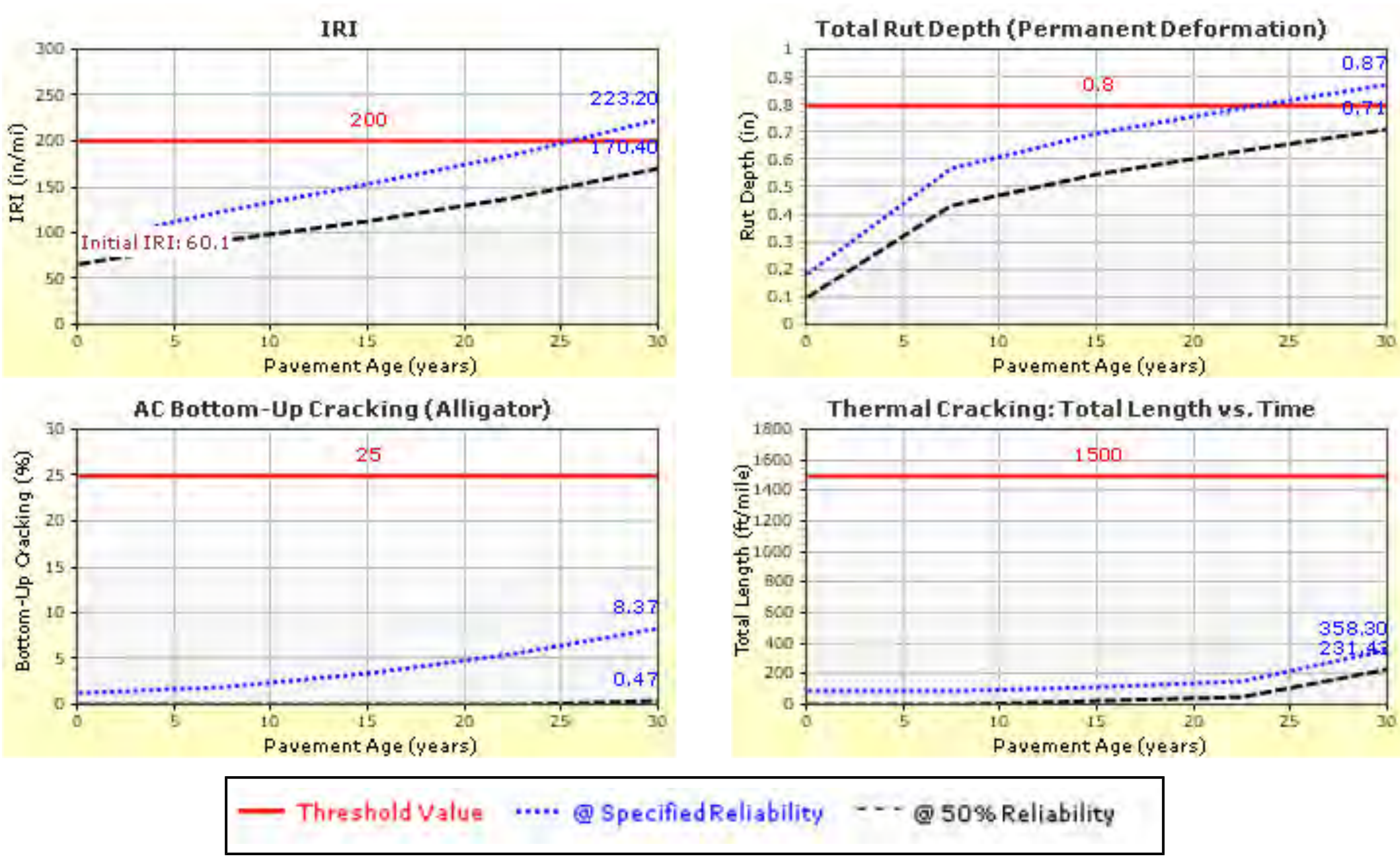
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	3,178
2037 (15 years)	9,164,780
2052 (30 years)	21,867,200

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	223.24	90.00	76.37	Fail
Permanent deformation - total pavement (in)	0.80	0.87	90.00	75.79	Fail
AC bottom-up fatigue cracking (% lane area)	25.00	8.37	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	358.30	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	279.94	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.70	90.00	81.02	Fail

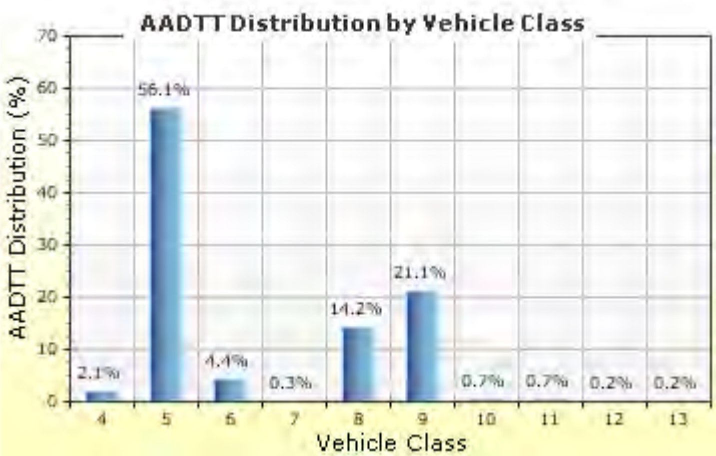
Distress Charts

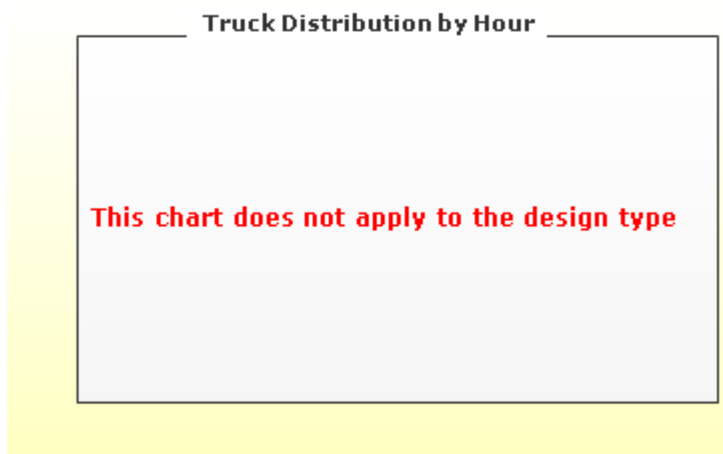


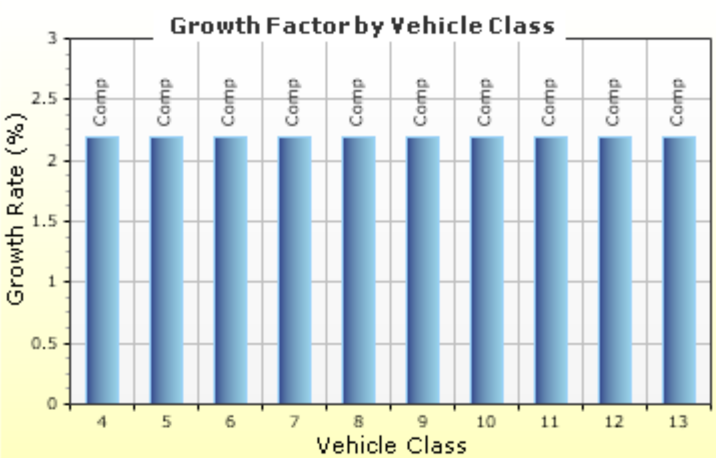
Traffic Inputs

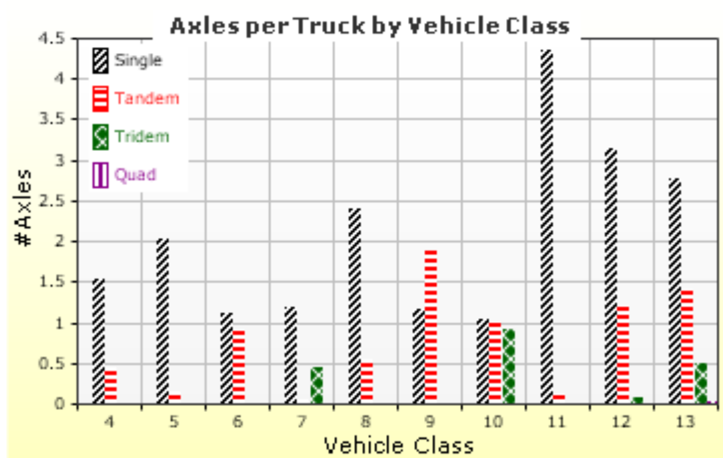
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,178	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)	20.0

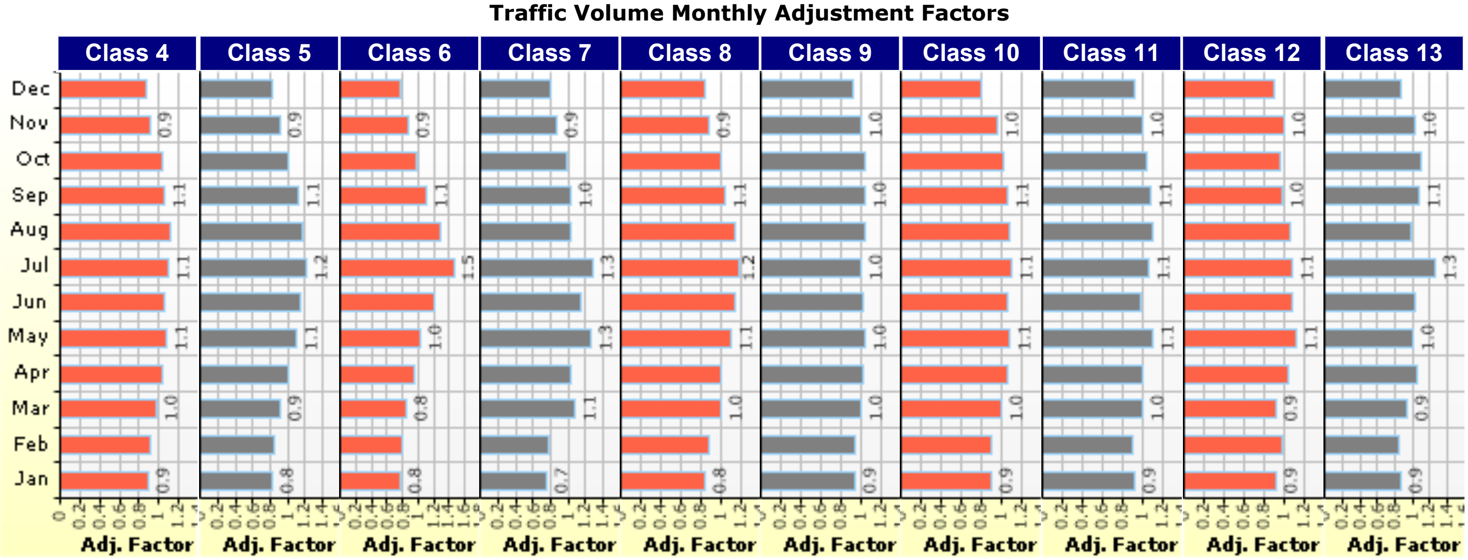








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

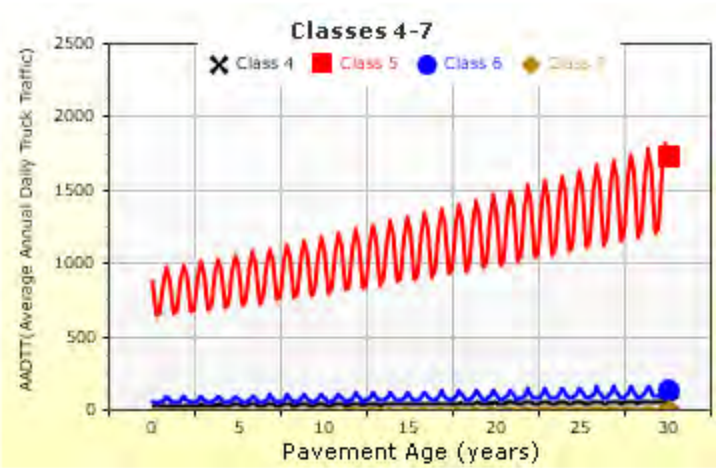
Wheelbase does not apply

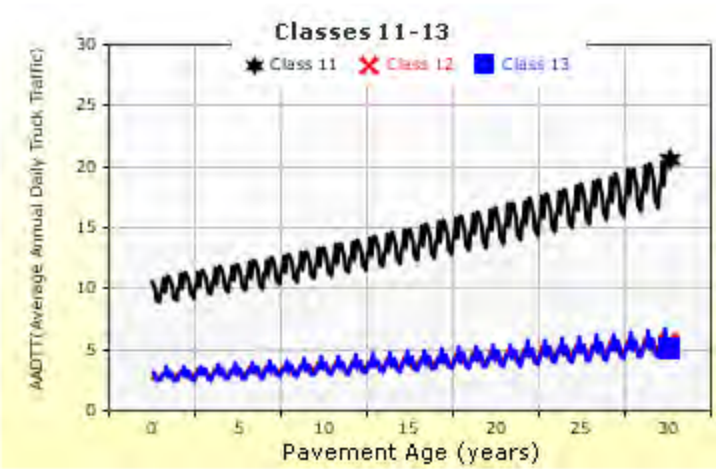
Number of Axles per Truck

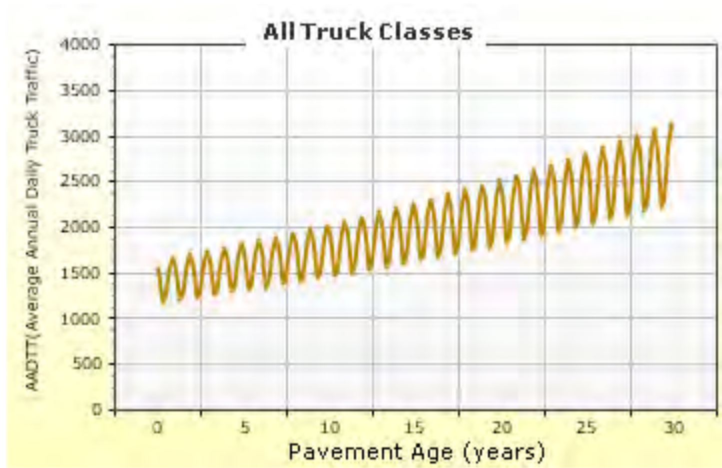
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

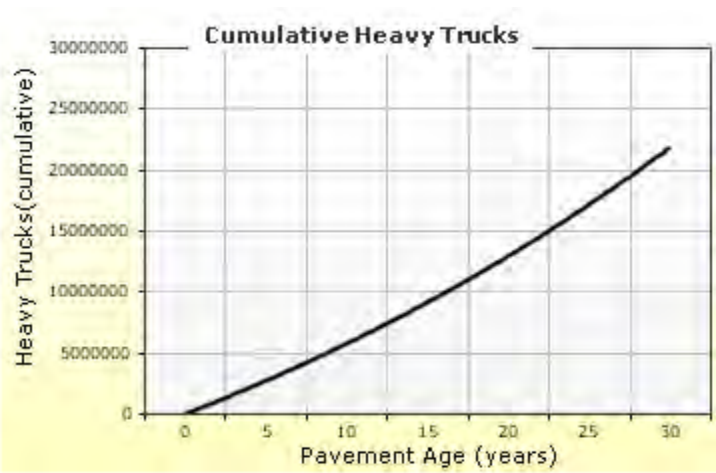
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





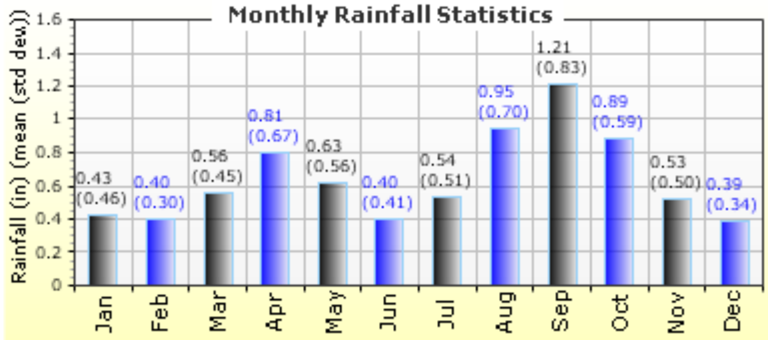




Climate Inputs

Climate Data Sources:

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

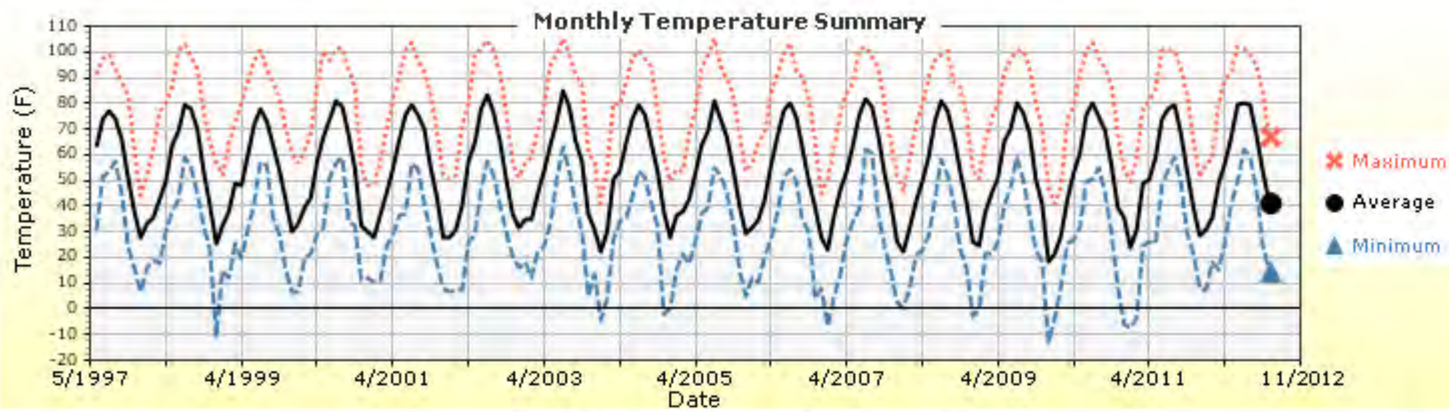


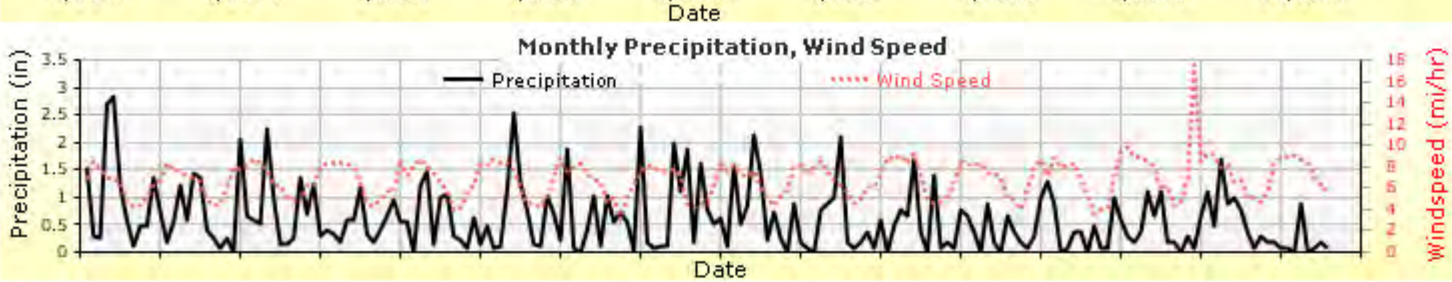
Annual Statistics:

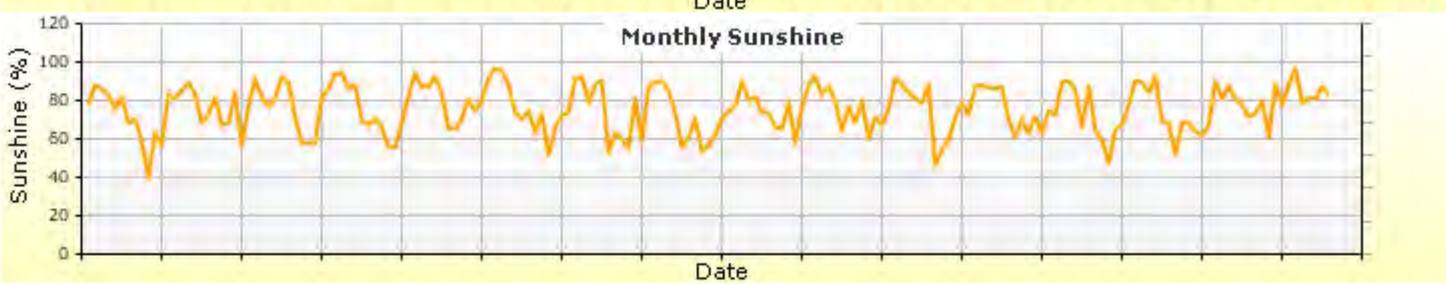
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

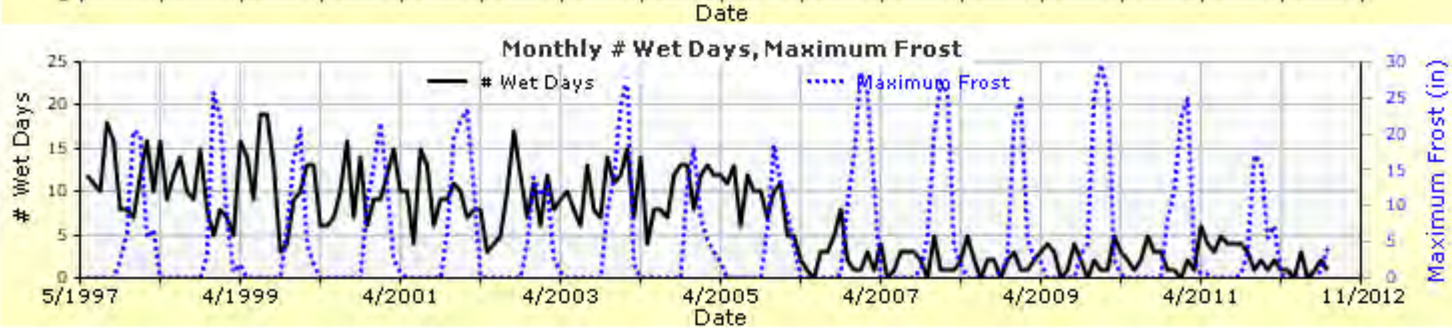
Water table depth (ft)	10.00

Monthly Climate Summary:

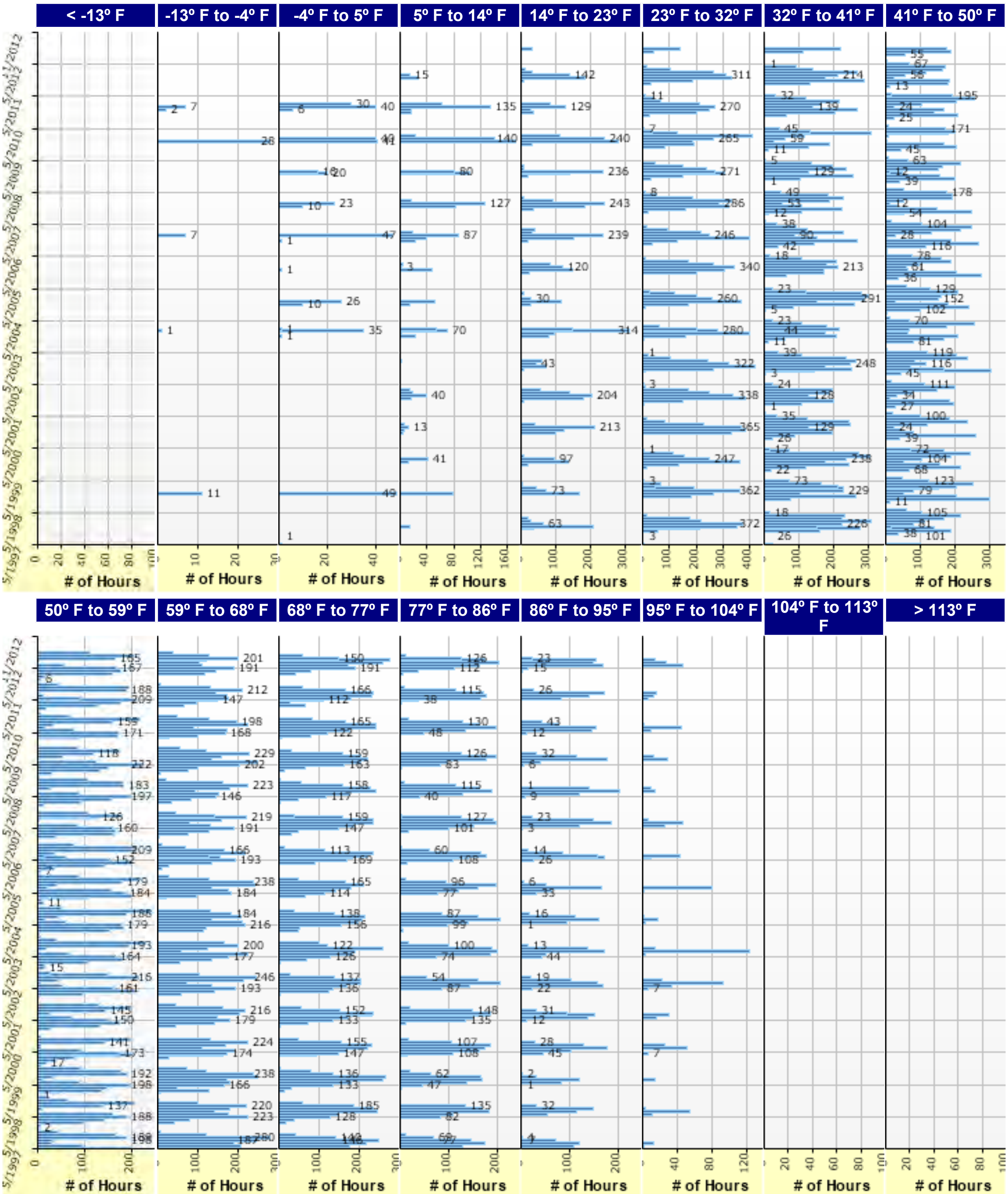








Hourly Air Temperature Distribution by Month:



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 : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (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 : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6 (R-Value = 5)	Subgrade (5)	-

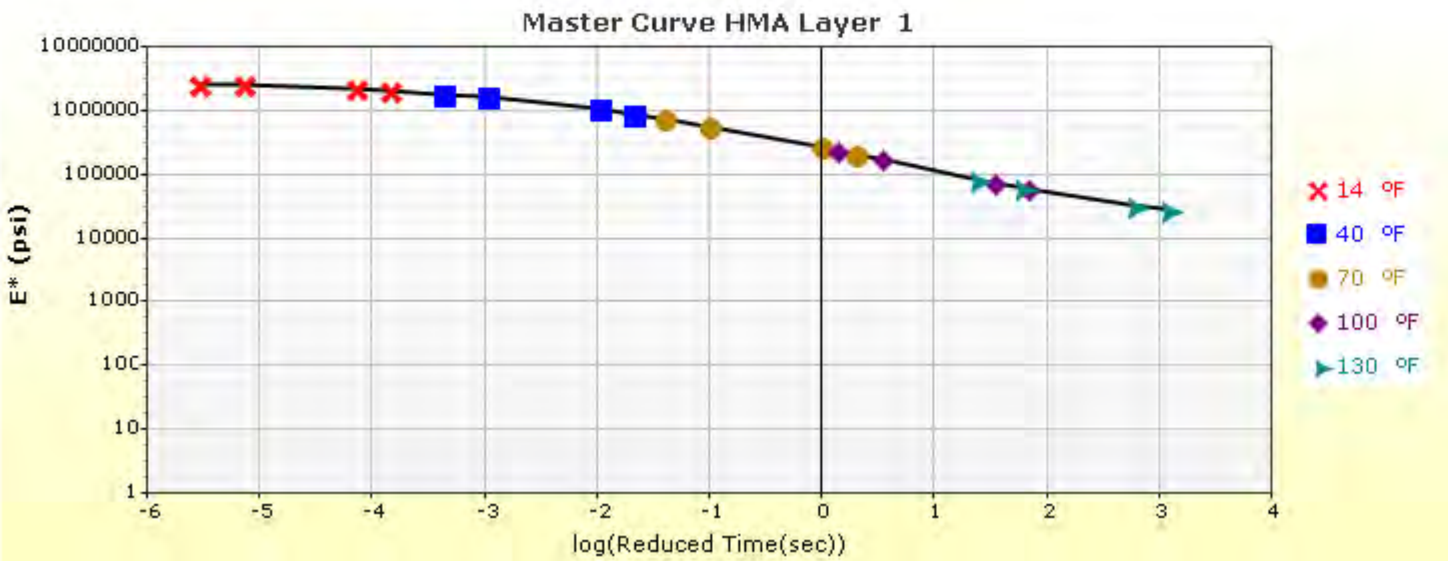
Thermal Cracking (Input Level: 1)

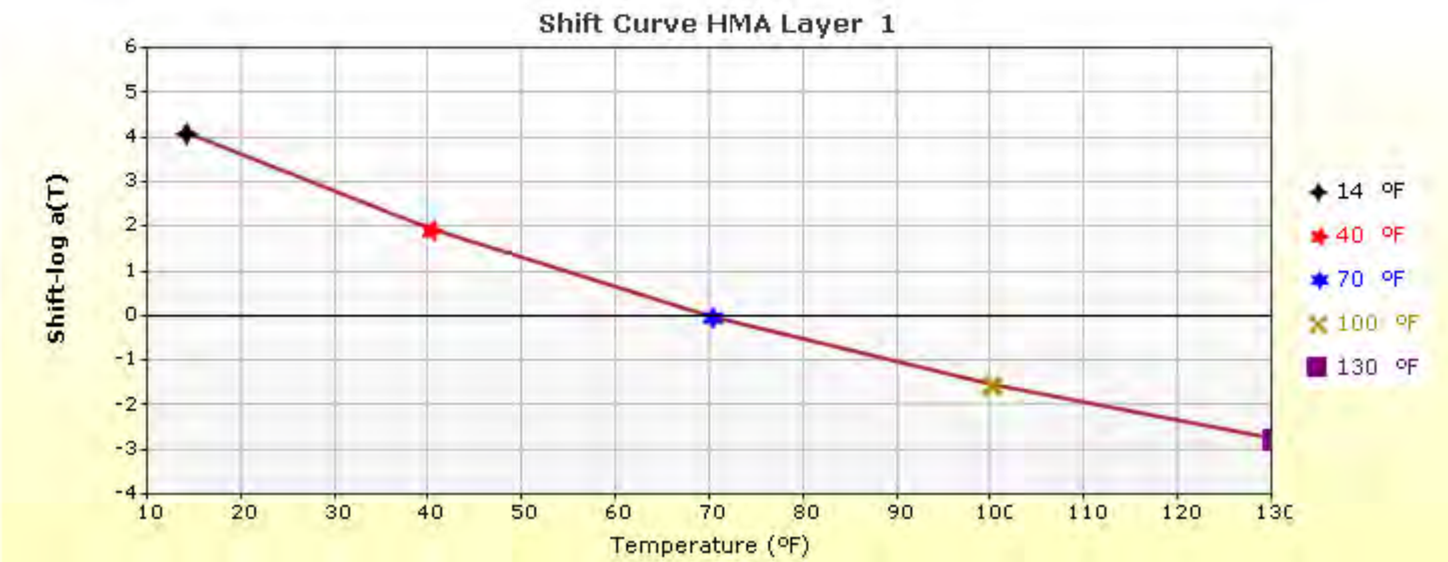
Indirect tensile strength at 14 ºF (psi)	519.00

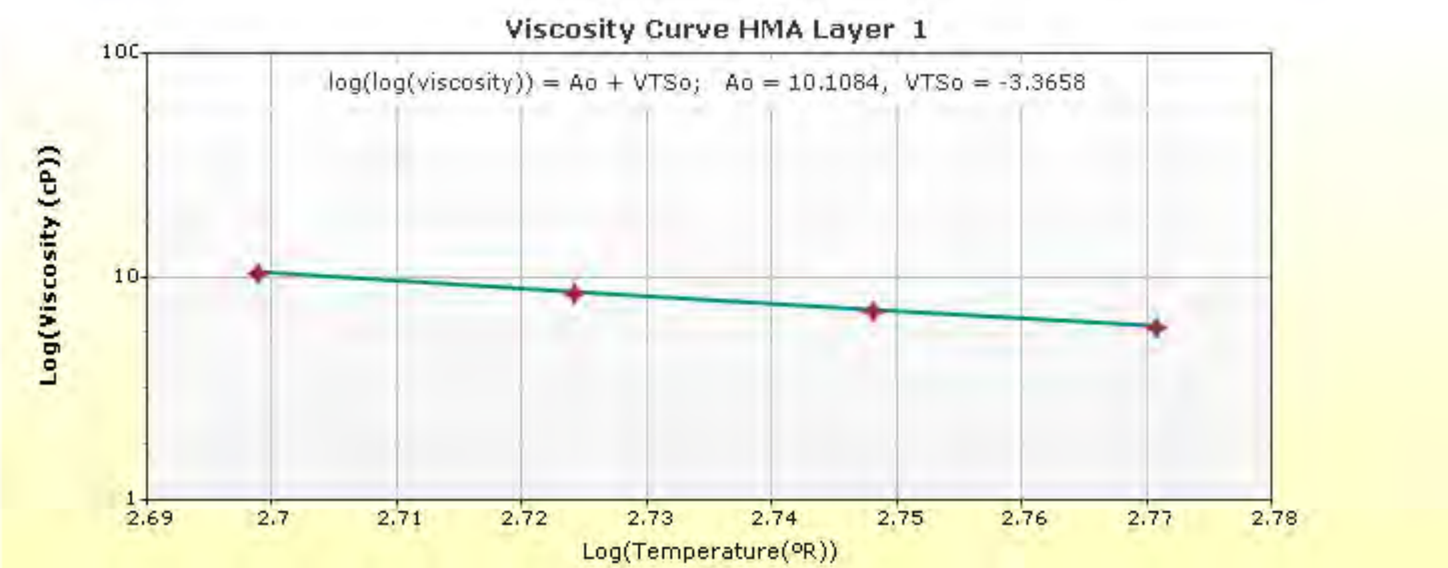
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006

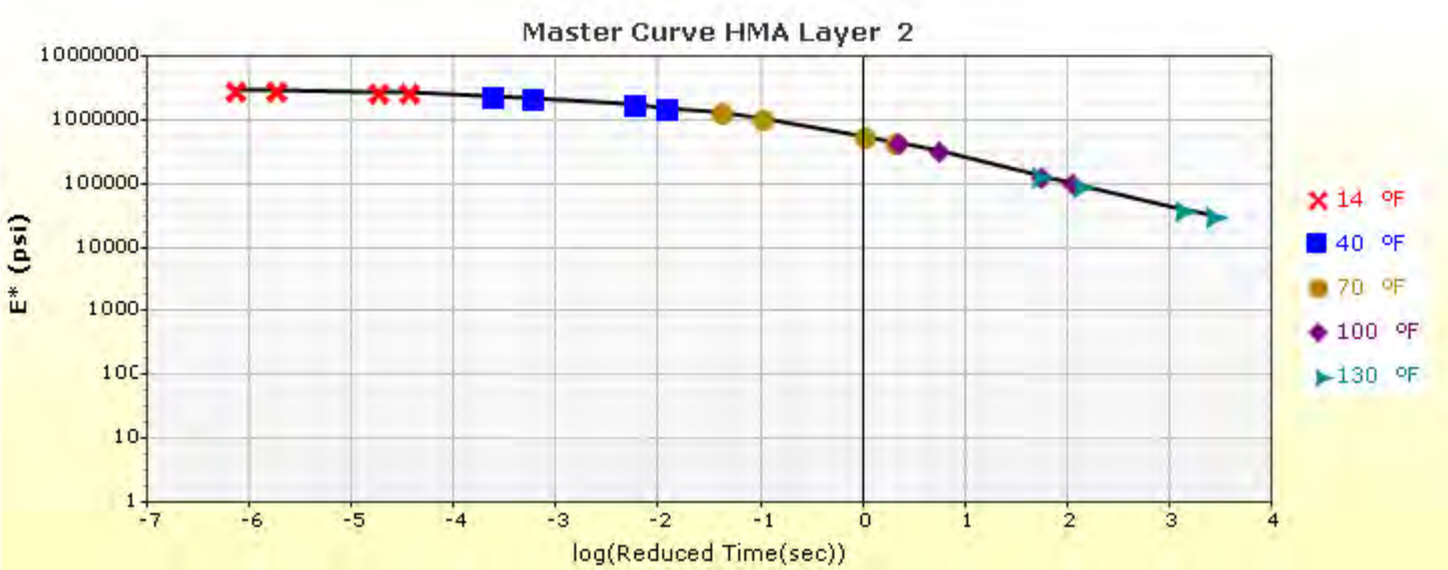
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

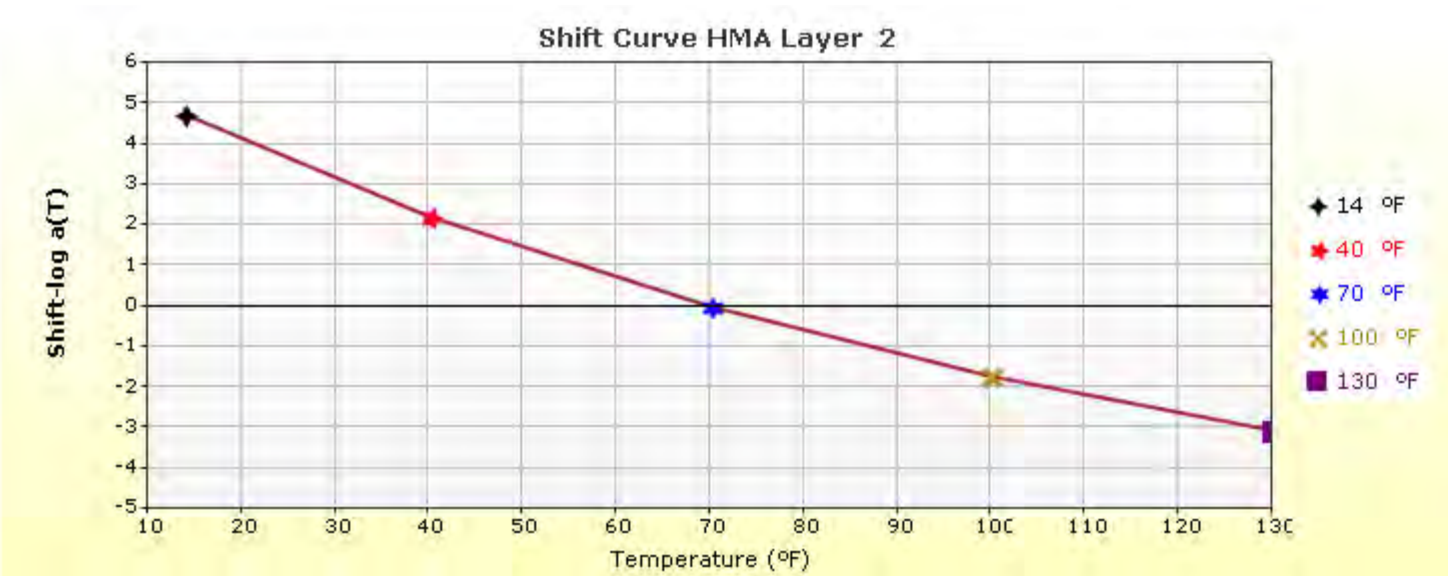


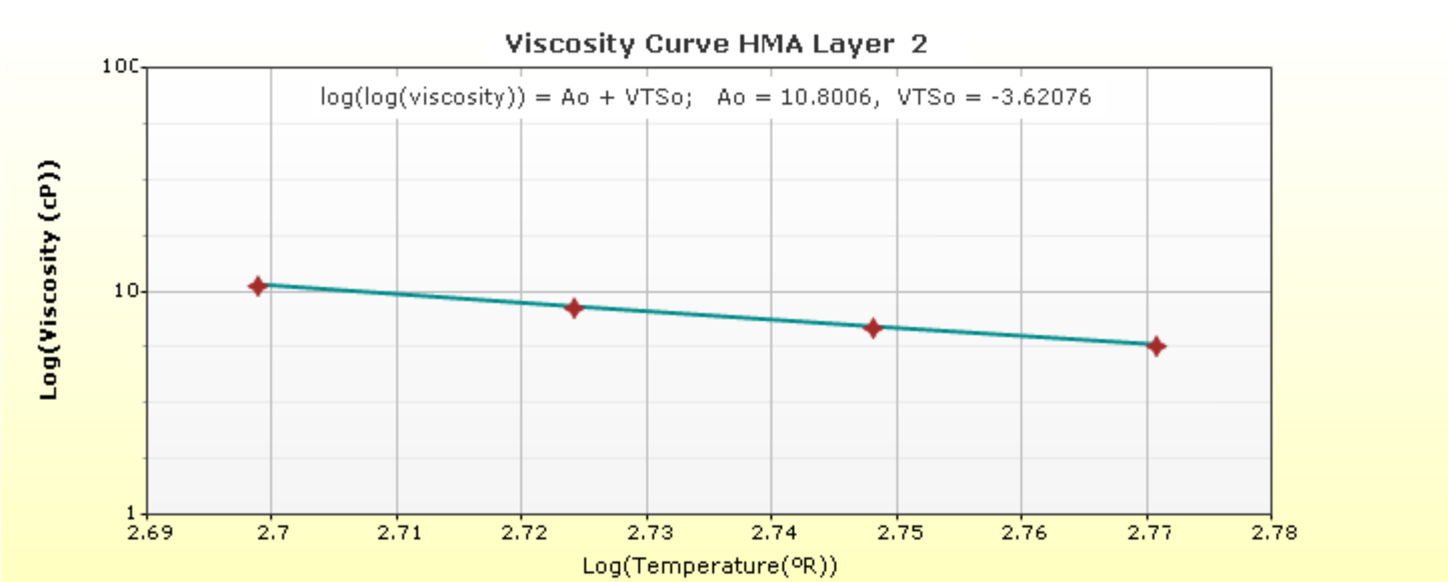




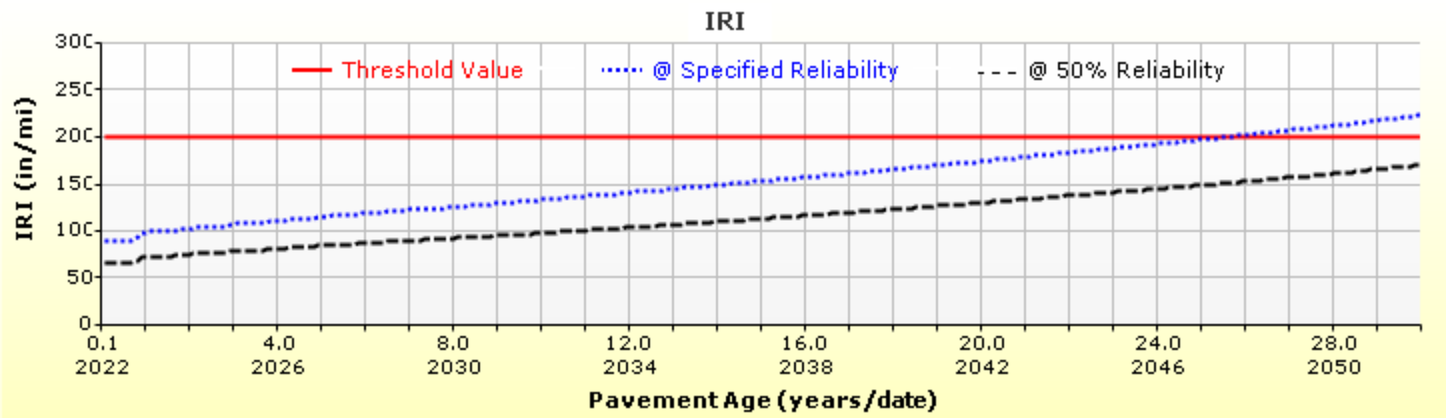
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

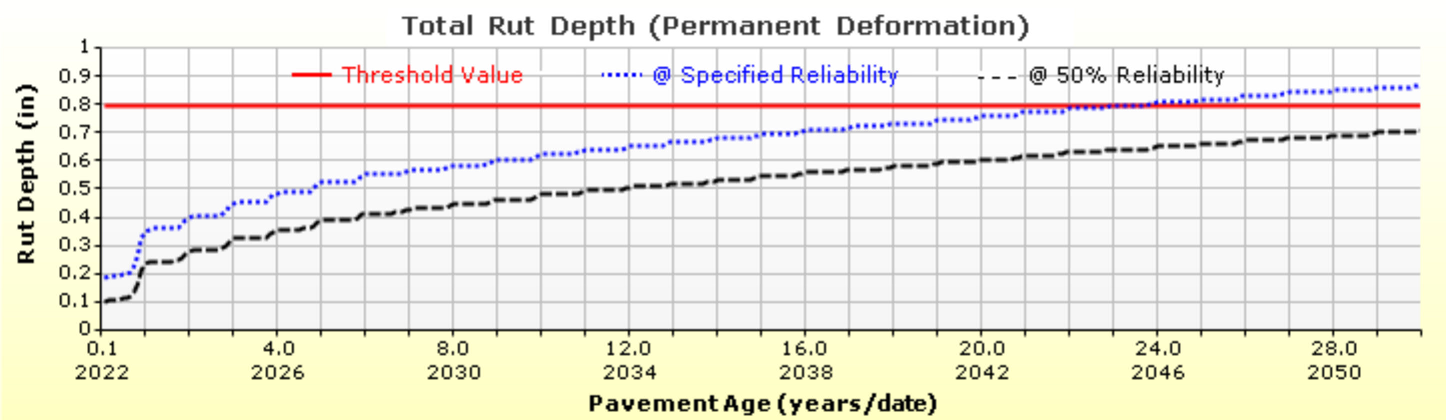


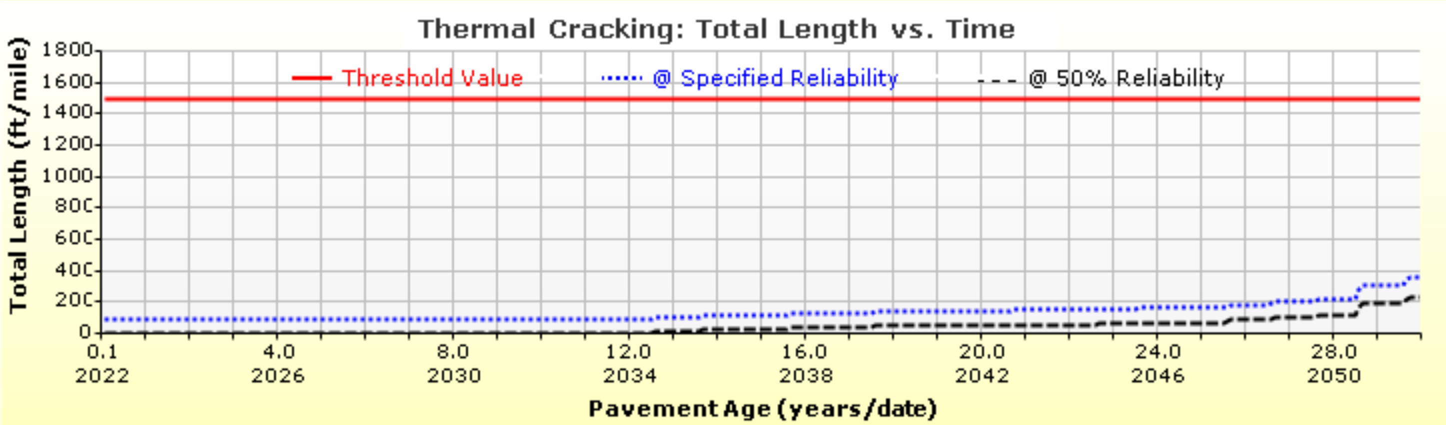


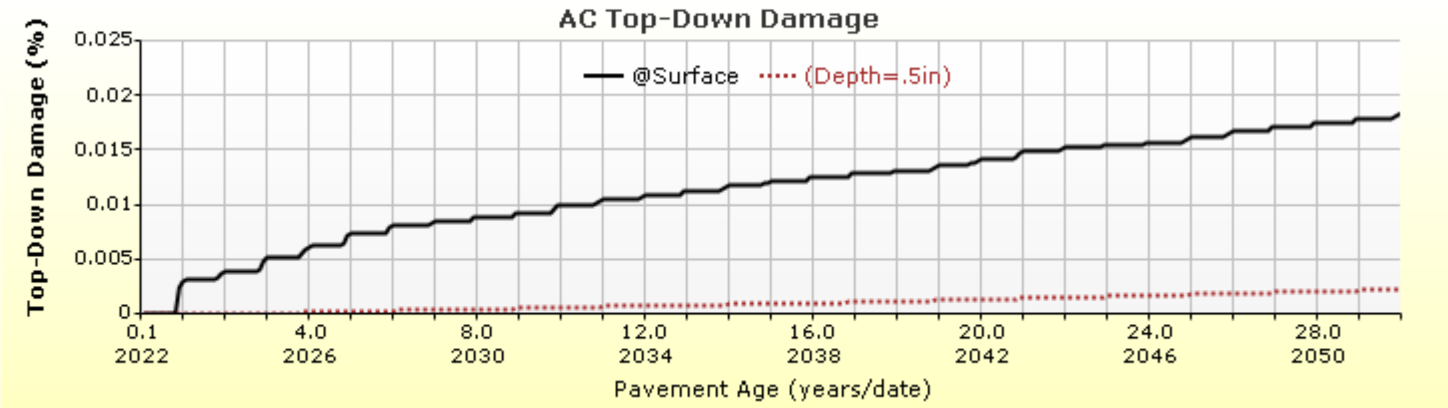


Analysis Output Charts

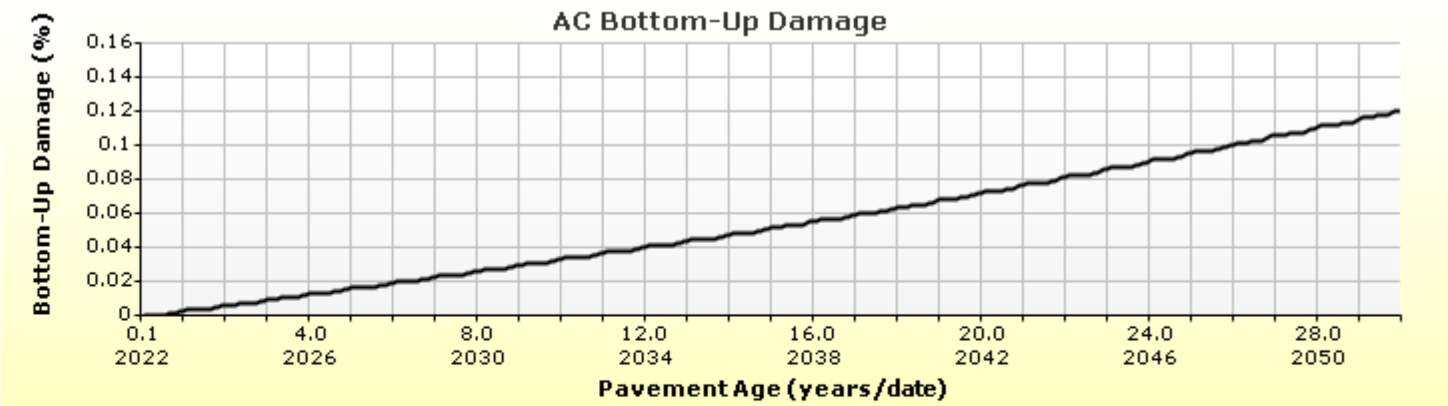




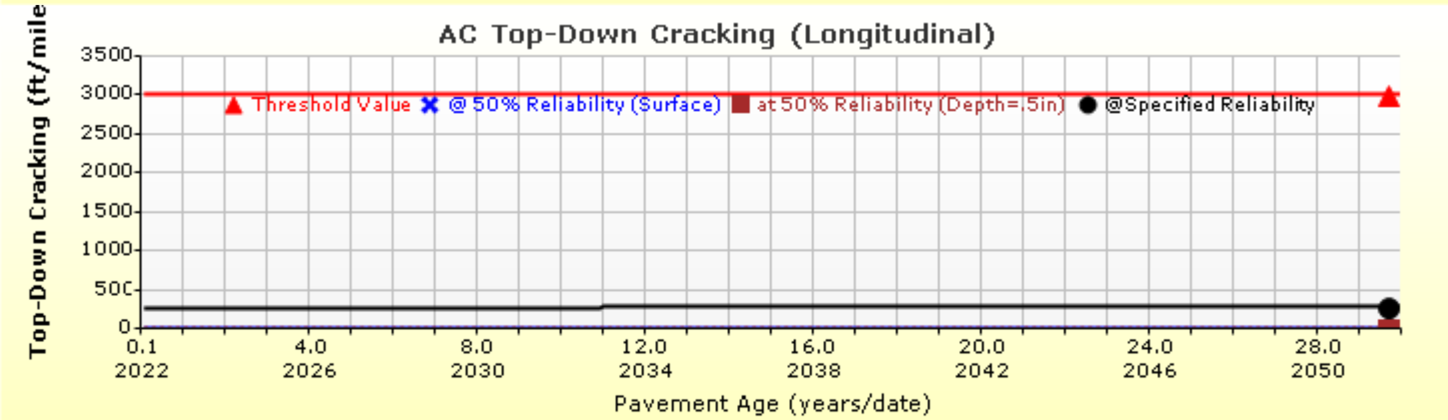




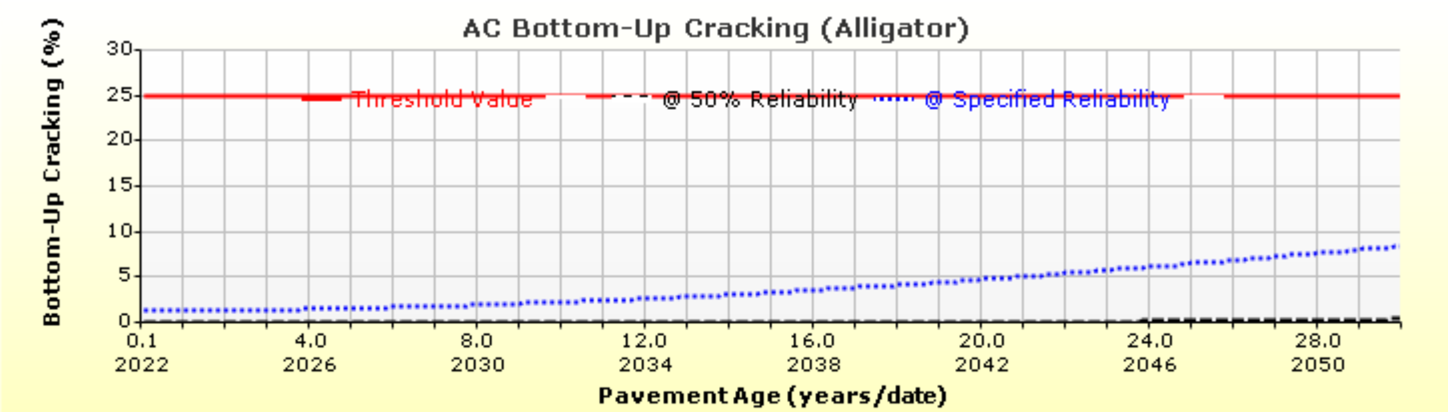
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.025
0.02
0.015
0.01
0.005
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



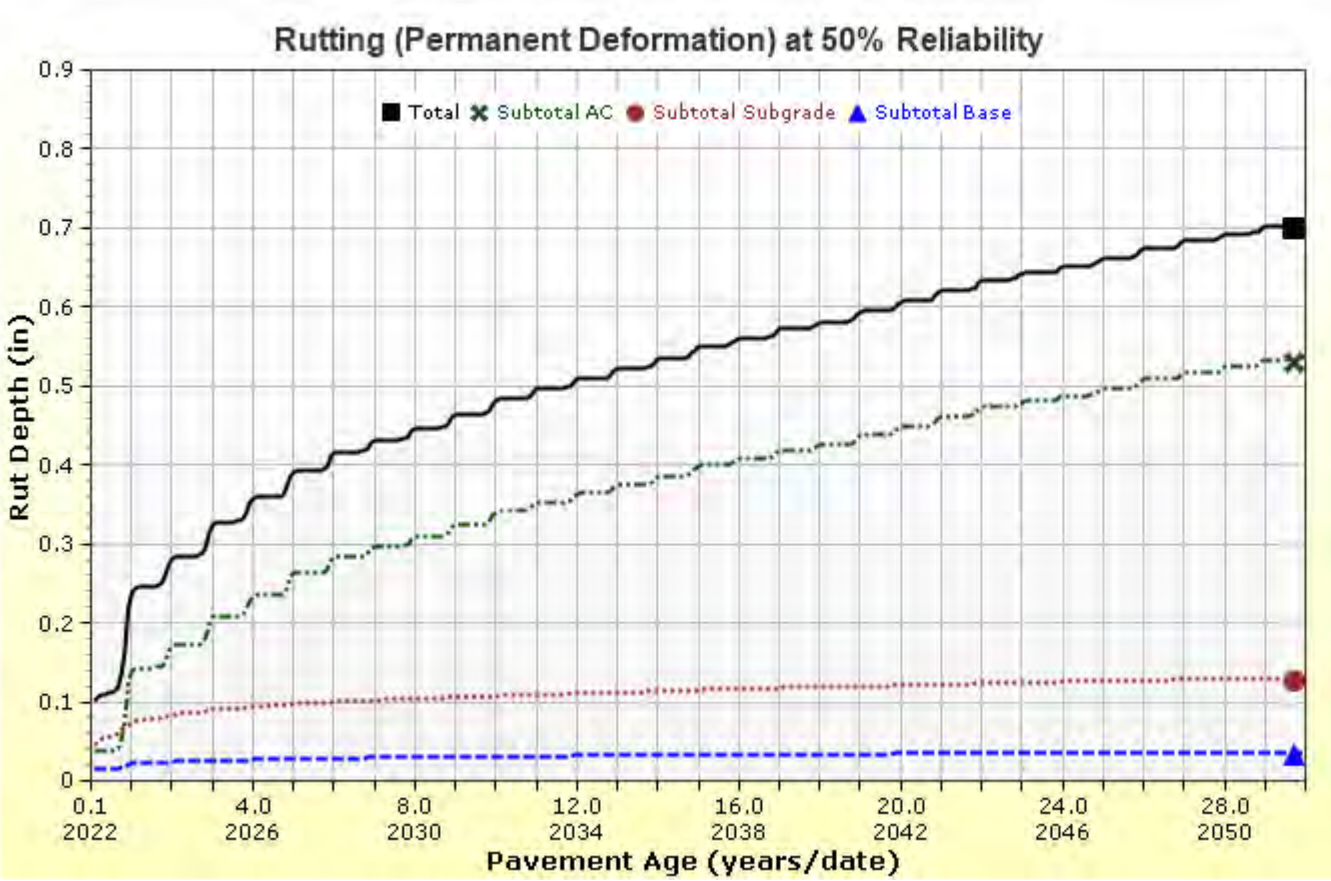
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

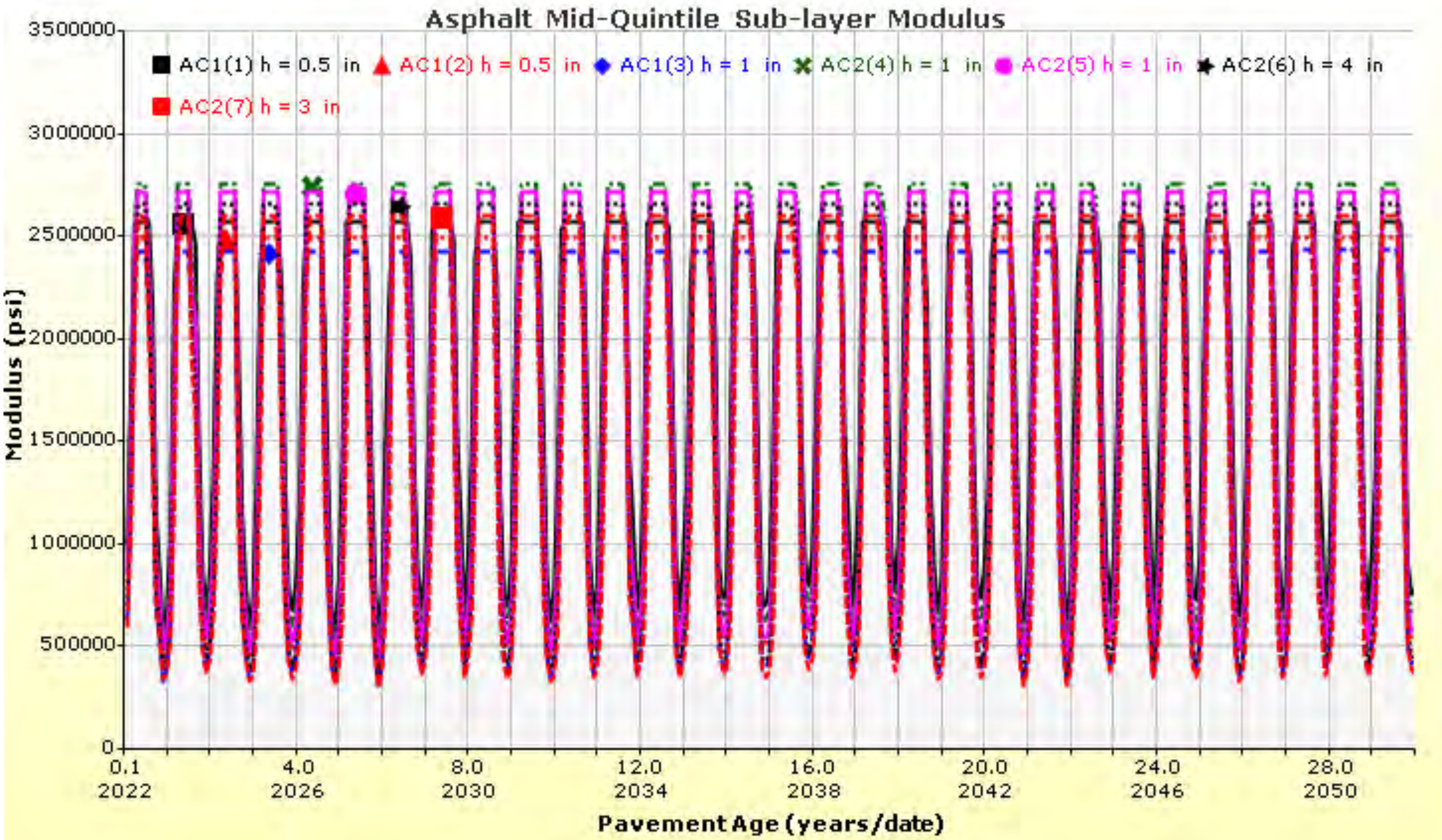


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

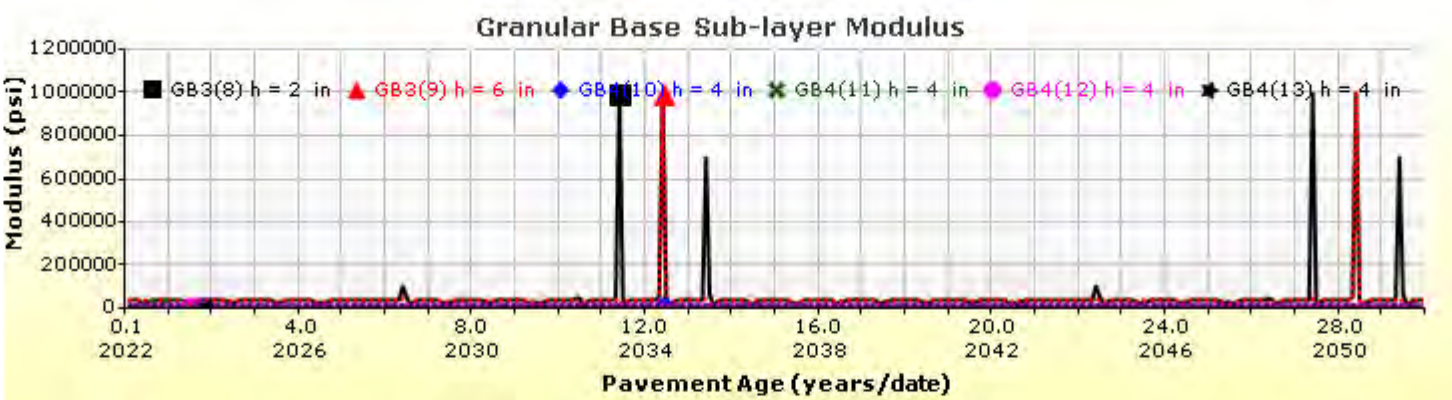


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

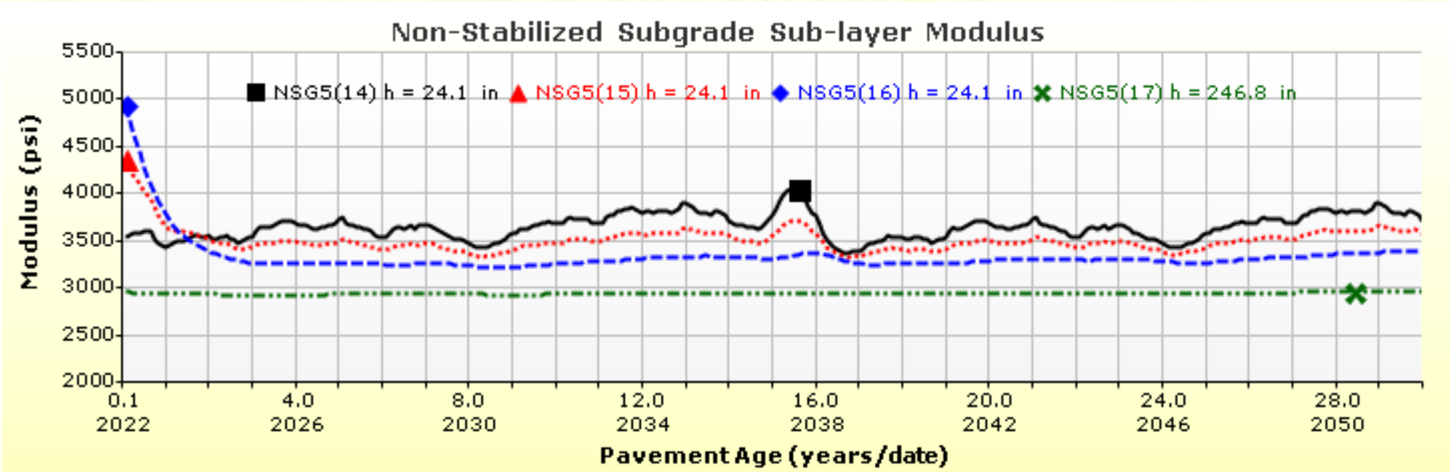

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
Pavement Age (years/date)



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 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
GB4(12) h = 4 in
GB4(13) h = 4 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(14) h = 24.1 in
NSG5(15) h = 24.1 in
NSG5(16) h = 24.1 in
NSG5(17) h = 246.8 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	9.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	16.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6 (R-Value = 5)

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6 (R-Value = 5)
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
Bf2: 1
Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

AC Bottom Up Cracking

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

APPENDIX E1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD & F ½ ROAD ROUNDABOUT

PCCP 24.5 & F.5 roundabout

File Name: C:\Users\RSPavement\Documents\PMED Designs\My ME Design\Projects\F.5 Road\PCCP 24.5 & F.5 roundabout.dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2022
Traffic opening: August, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	16.0
Subgrade	A-6	Semi-infinite

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

Traffic

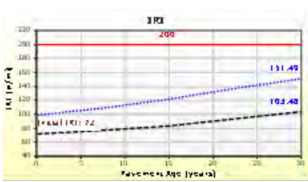
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	3,080
2037 (15 years)	8,882,160
2052 (30 years)	21,192,900

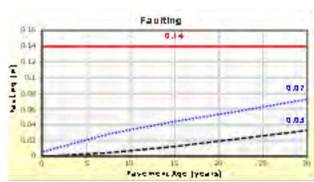
Design Outputs

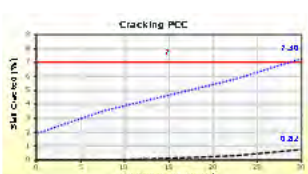
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	151.49	90.00	99.50	Pass
Mean joint faulting (in)	0.14	0.07	90.00	99.97	Pass
JPCP transverse cracking (percent slabs)	7.00	7.30	90.00	88.91	Fail

Distress Charts



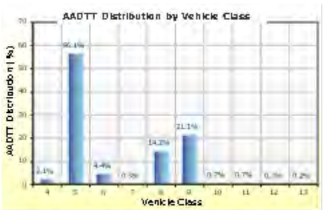


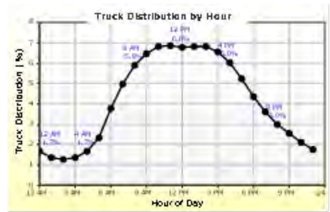


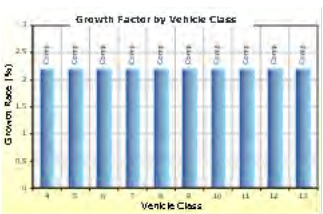
Traffic Inputs

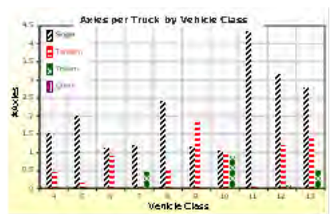
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,080	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)	20.0

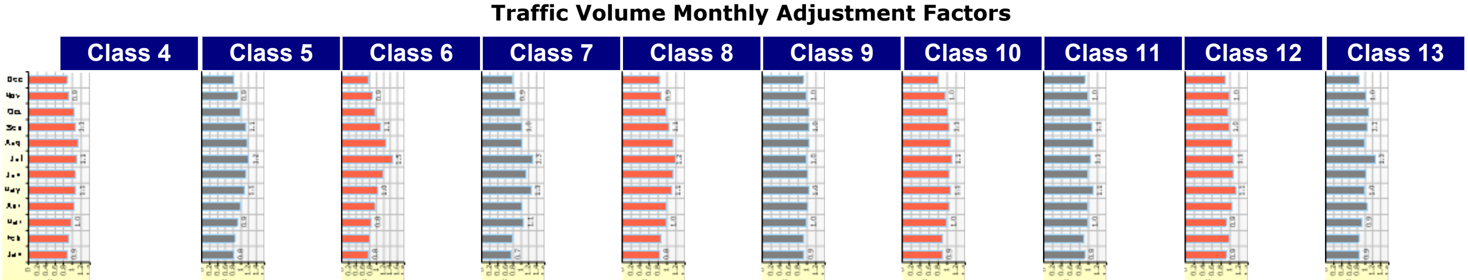








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

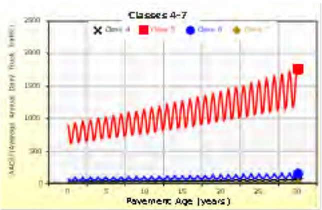
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

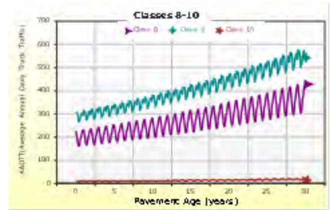
Number of Axles per Truck

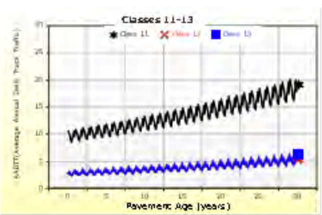
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

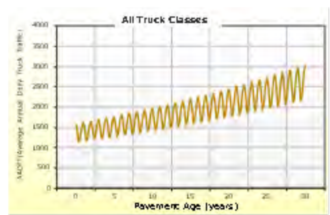
AADTT (Average Annual Daily Truck Traffic) Growth

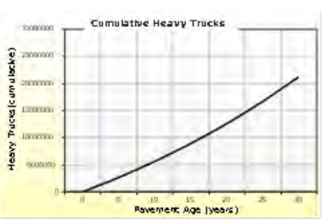
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

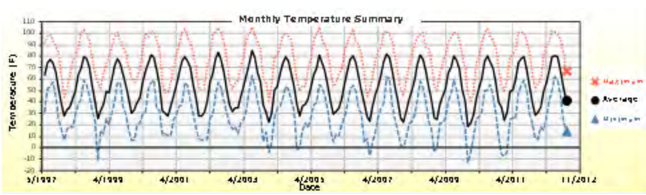
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

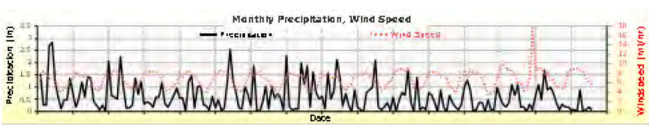
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

Water table depth (ft) 10.00

Monthly Climate Summary:



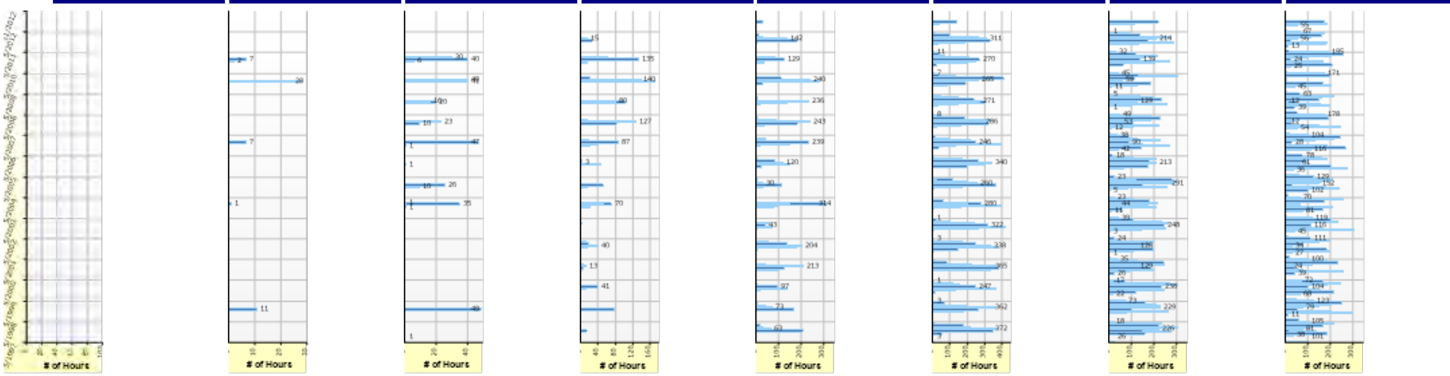


PCCP 24.5 & F.5 roundabout

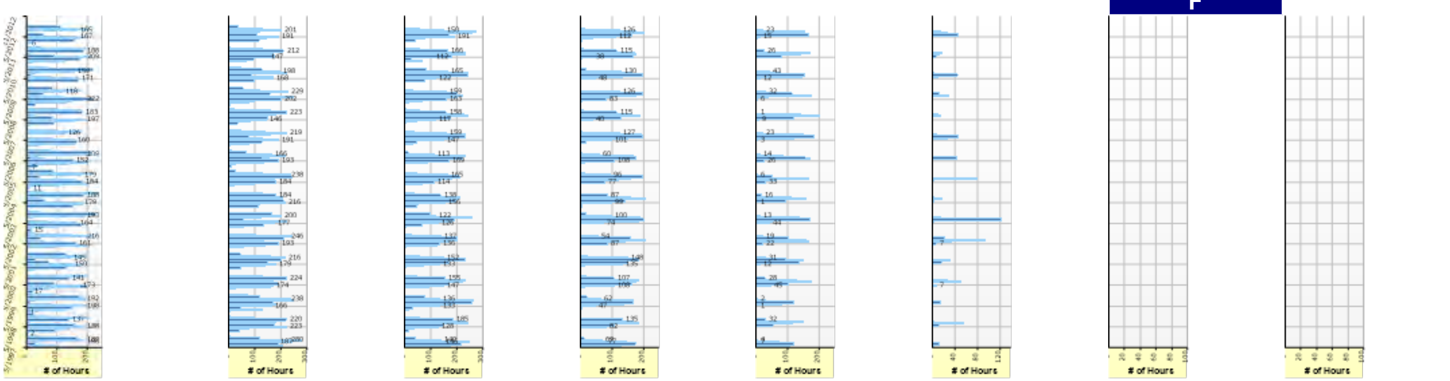
File Name: C:\Users\RSPavement\Documents\PMED Designs\My ME Design\Projects\F.5 Road\PCCP 24.5 & F.5 roundabout.dgpx

Hourly Air Temperature Distribution by Month:

< -13º F	-13º F to -4º F	-4º F to 5º F	5º F to 14º F	14º F to 23º F	23º F to 32º F	32º F to 41º F	41º F to 50º F



50º F to 59º F	59º F to 68º F	68º F to 77º F	77º F to 86º F	86º F to 95º F	95º F to 104º F	104º F to 113º F	> 113º F



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

PCC joint spacing (ft)	
Is joint spacing random ?	False
Joint spacing (ft)	12.00

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

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

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

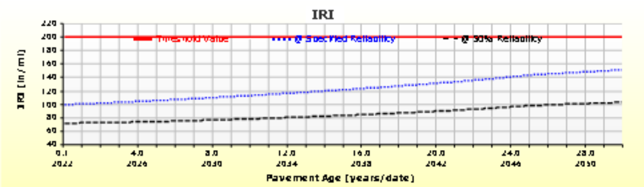
Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

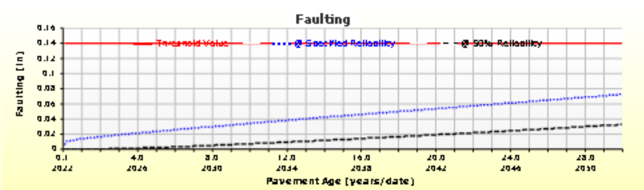
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

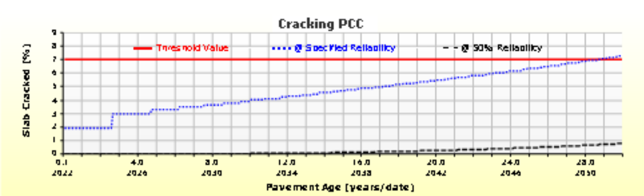
Erodibility index	4

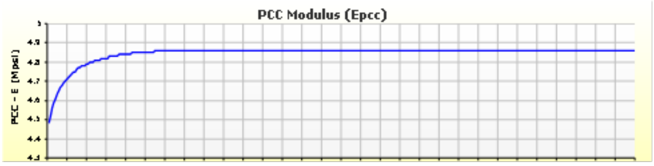
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

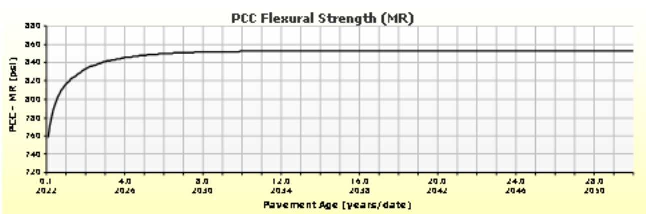




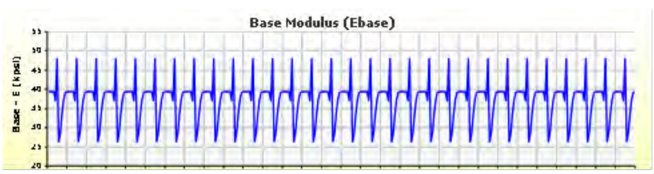




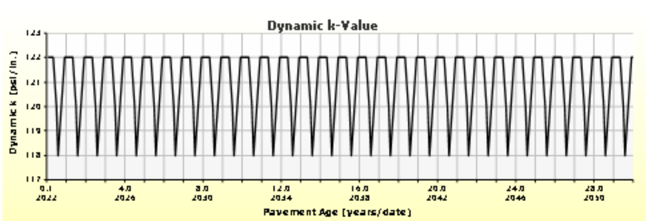
PCC Modulus (Epcc)
PCC - E (Mpsi)



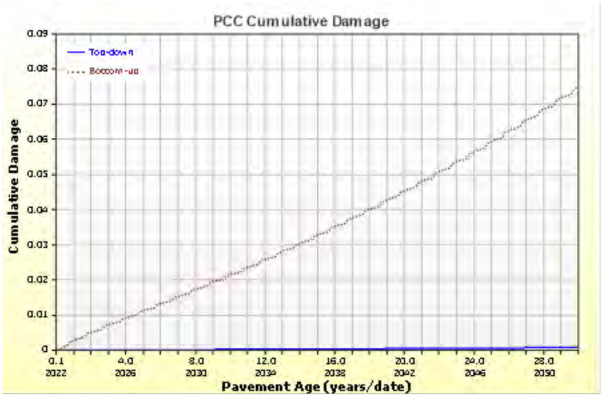
PCC Flexural Strength (MR)
PCC - MR (psi)
Pavement Age (years/date)

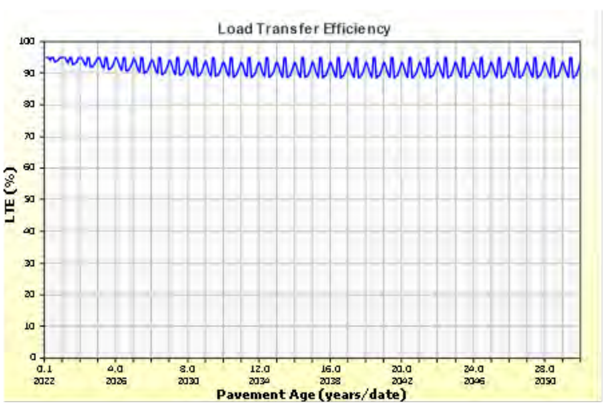


Base Modulus (Ebase)
Base - E (kpsi)



Dynamic k-Value
Dynamic k (psi/in.)
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.0
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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	16.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-6

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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 F

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD

Design Inputs

Design Life:	20 years	Base construction:	May, 2022	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	FLEXIBLE	Pavement construction:	June, 2022		
		Traffic opening:	September, 2022		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	5.0
NonStabilized	Crushed stone	8.0
NonStabilized	A-1-b (Pit run) R value 40	10.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

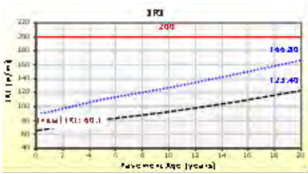
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	850
2032 (10 years)	2,058,440
2042 (20 years)	4,617,300

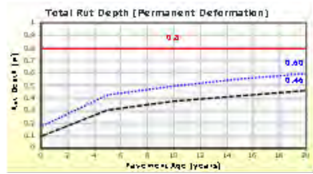
Design Outputs

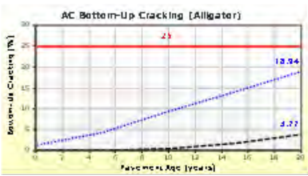
Distress Prediction Summary

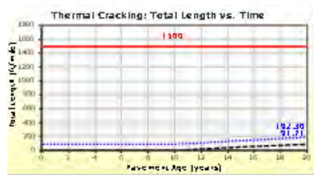
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	166.80	90.00	98.81	Pass
Permanent deformation - total pavement (in)	0.80	0.60	90.00	99.93	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	18.94	90.00	96.36	Pass
AC thermal cracking (ft/mile)	1500.00	192.30	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	522.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.40	90.00	99.99	Pass

Distress Charts







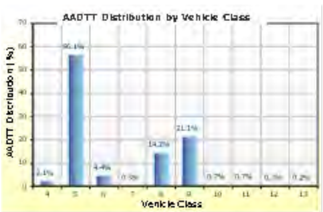


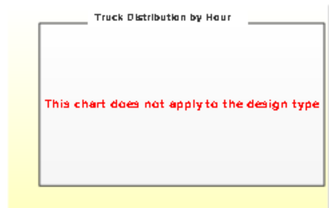
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

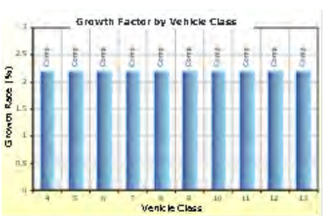
Traffic Inputs

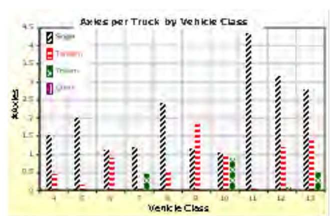
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	850	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

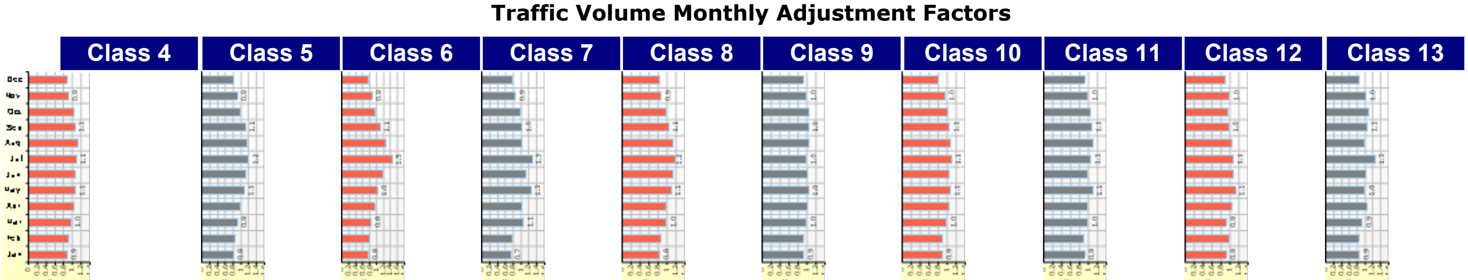








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

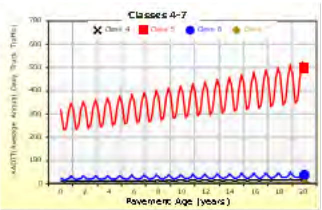
Wheelbase does not apply

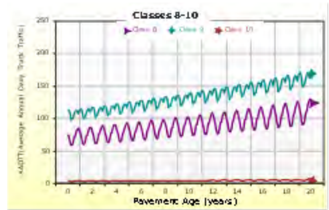
Number of Axles per Truck

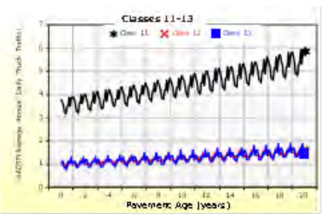
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

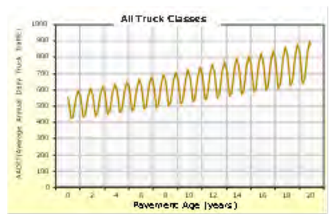
AADTT (Average Annual Daily Truck Traffic) Growth

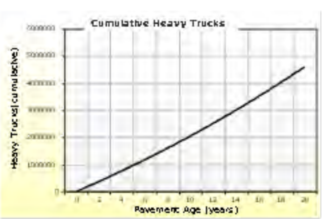
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

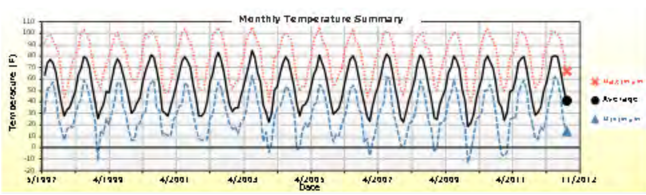
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

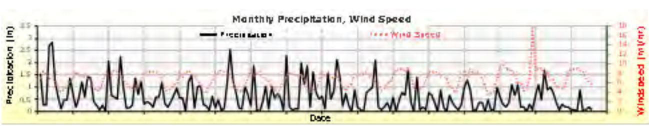
Annual Statistics:

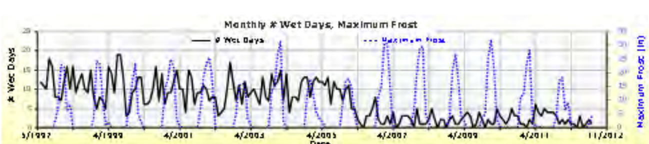
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

Water table depth (ft) 10.00

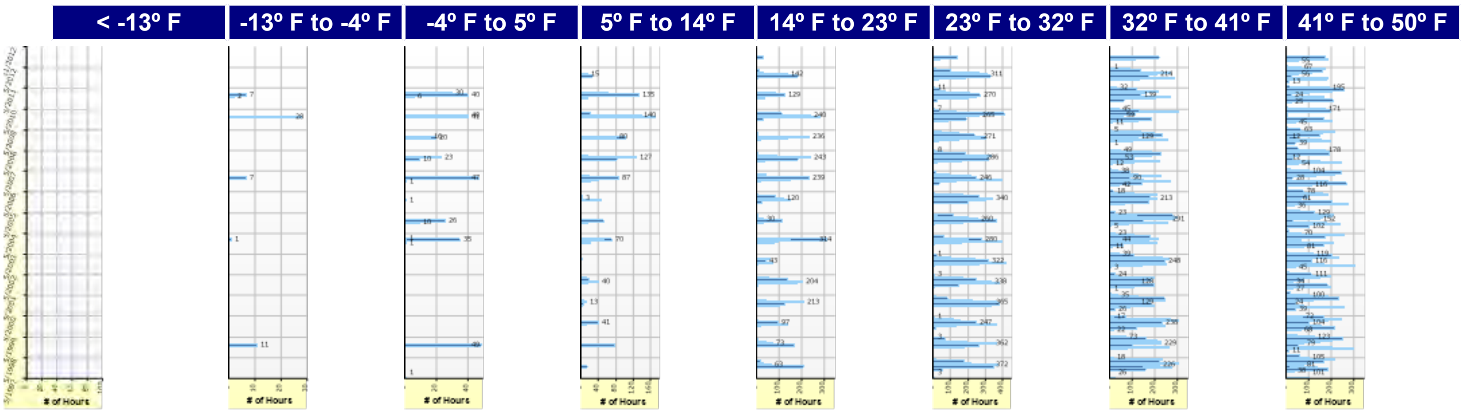
Monthly Climate Summary:

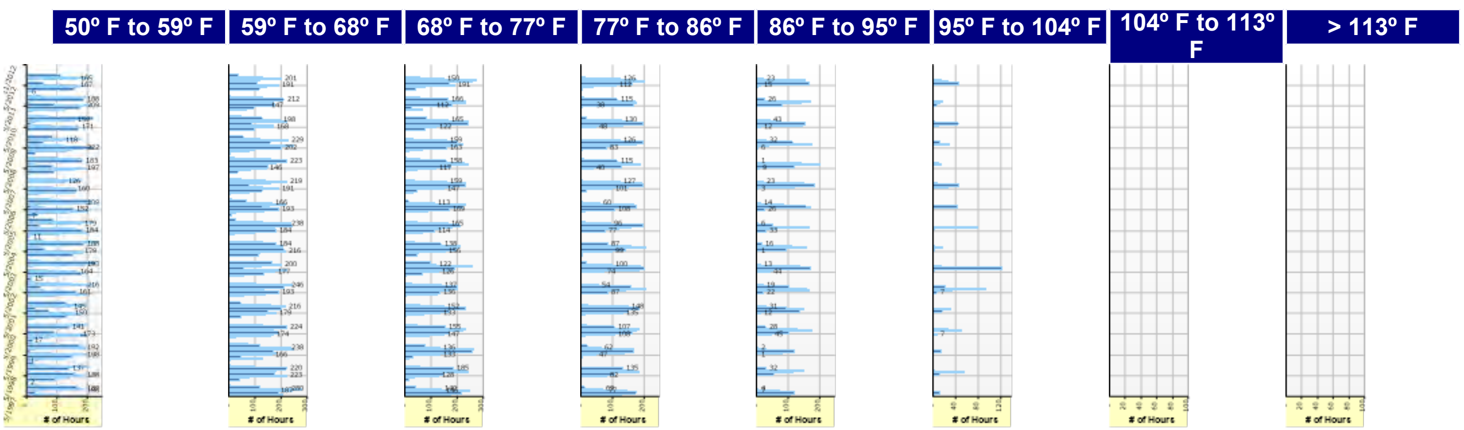






Hourly Air Temperature Distribution by Month:





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

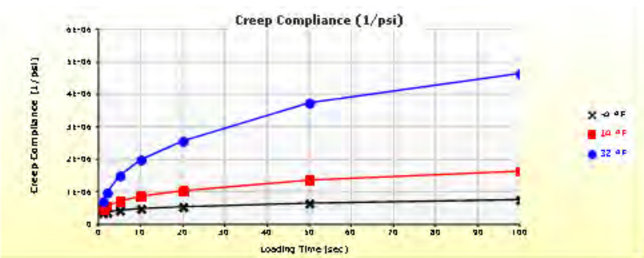
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b (Pit run) R value 40	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4 (R-Value 10)	Subgrade (5)	-

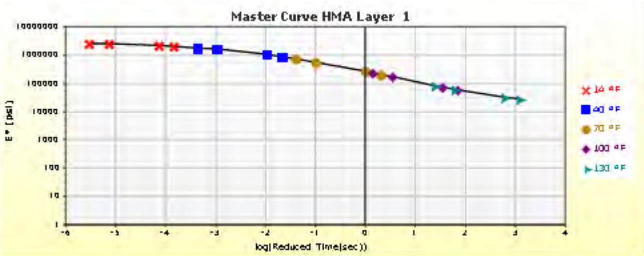
Thermal Cracking (Input Level: 1)

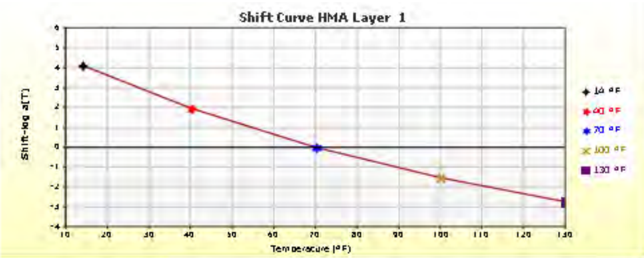
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

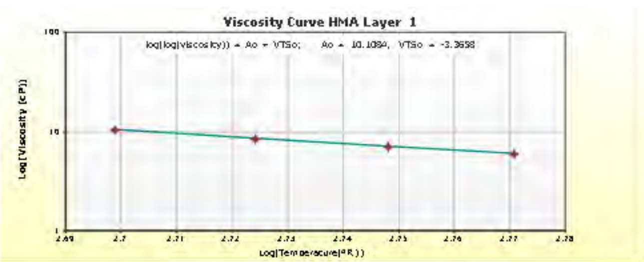
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



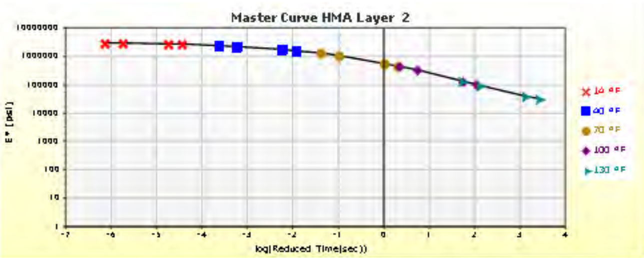
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

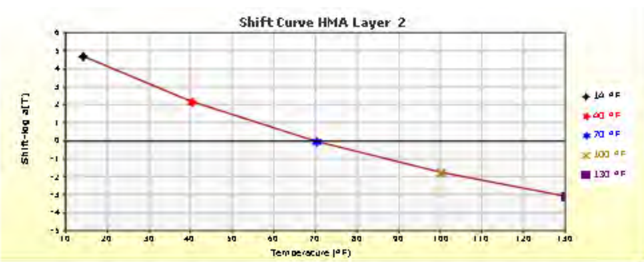


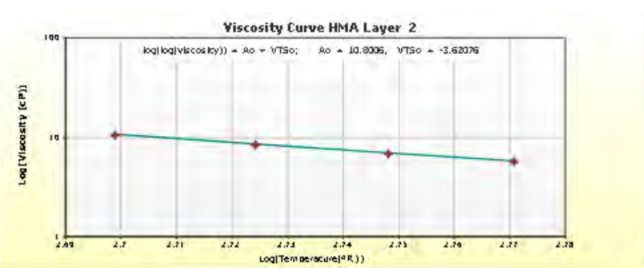




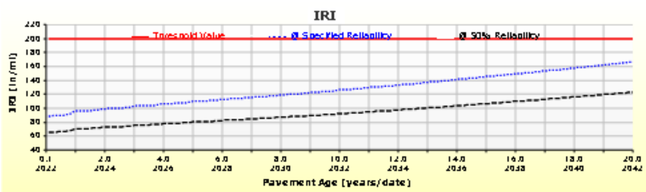
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

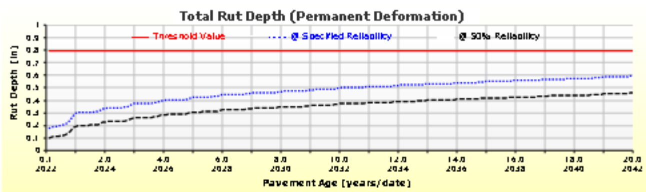


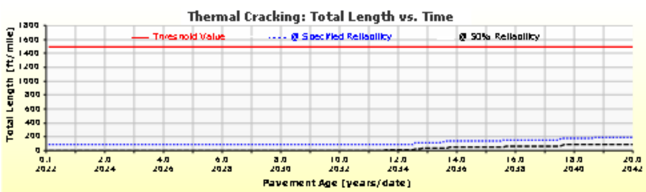


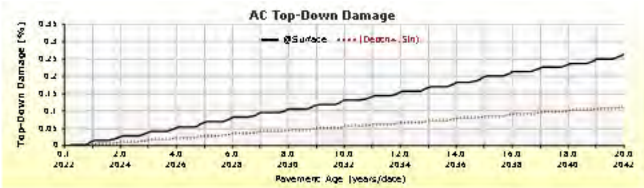


Analysis Output Charts

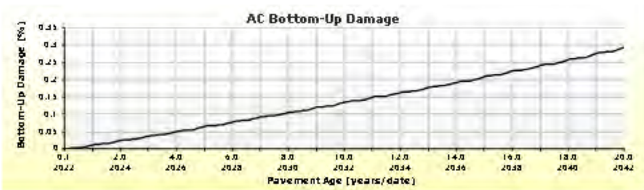




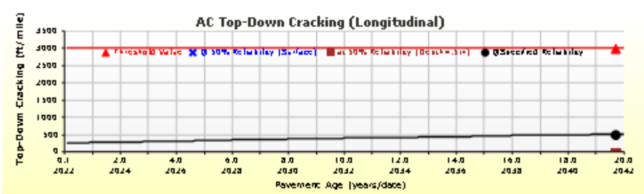




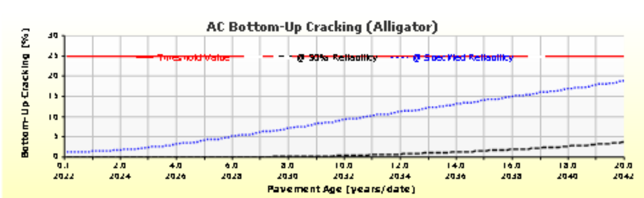
AC Top-Down Damage
Top-Down Damage (%)
Pavement Age (years/date)



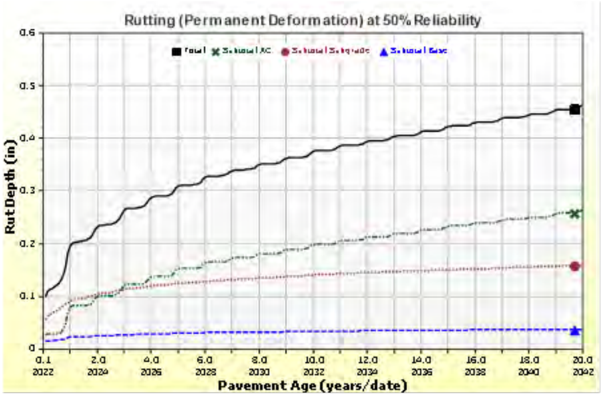
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



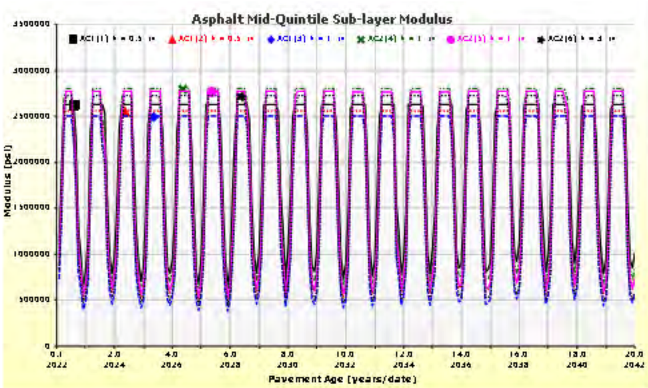
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)



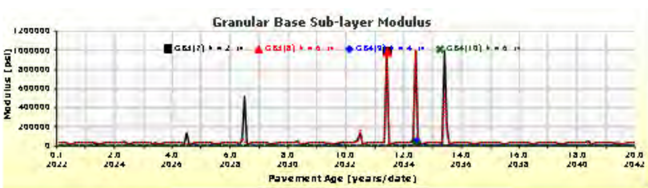
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)

Non-Stabilized Subgrade Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

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 3 Non-stabilized Base : Crushed stone

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 stone
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	20

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 : A-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	10.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$
$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$
$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$
$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

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

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

AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

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

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N(\,) = standard\ normal\ distribution\ evaluated\ at(\,)$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 6.3	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: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

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

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

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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking				IRI Flexible Pavements			
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$				C1 - Rutting C2 - Fatigue Crack		C3 - Transverse Crack C4 - Site Factors	
C1: 0	C2: 75	C3: 5	C4: 3	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*1							

25 Road HMA (30-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\25 Road HMA (30-year).dgpx

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	6.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	10.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

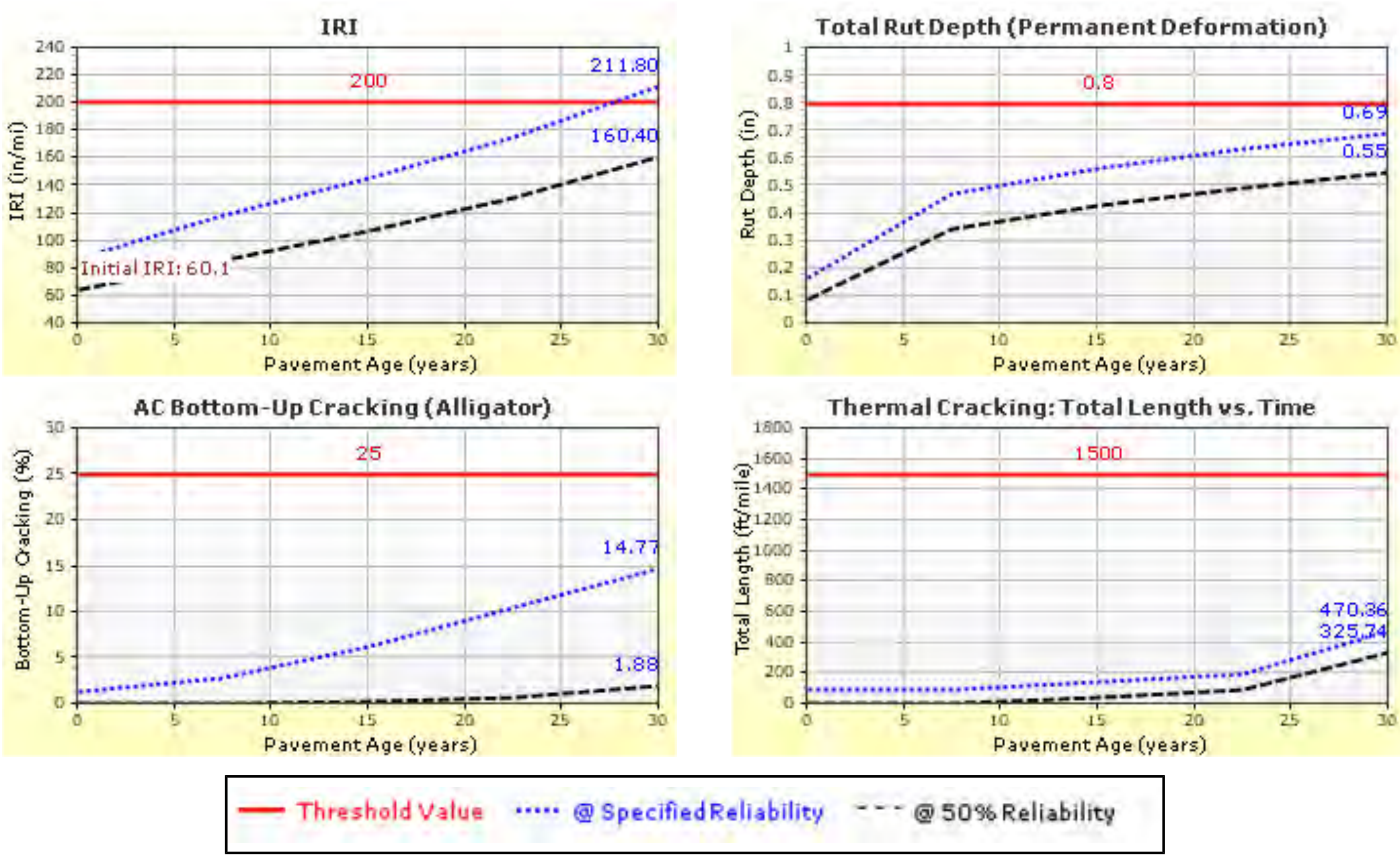
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	850
2037 (15 years)	3,268,330
2052 (30 years)	7,798,240

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	211.76	90.00	83.85	Fail
Permanent deformation - total pavement (in)	0.80	0.69	90.00	98.71	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	14.77	90.00	98.93	Pass
AC thermal cracking (ft/mile)	1500.00	470.36	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	332.63	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.49	90.00	99.67	Pass

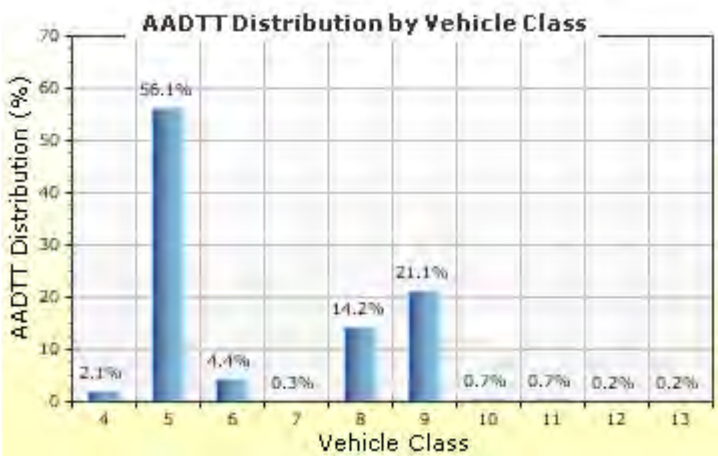
Distress Charts

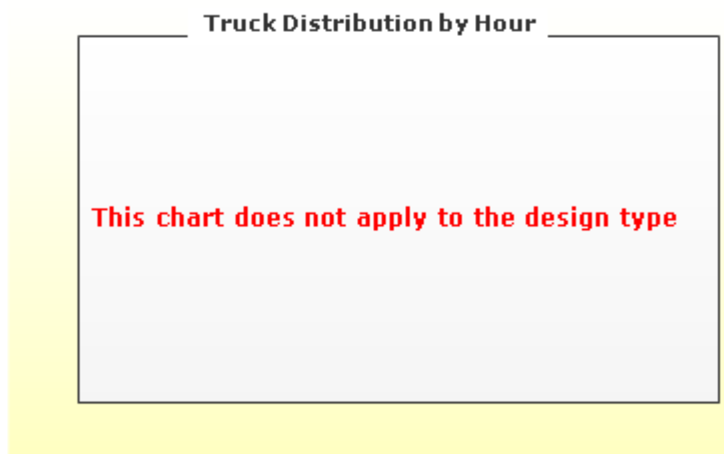


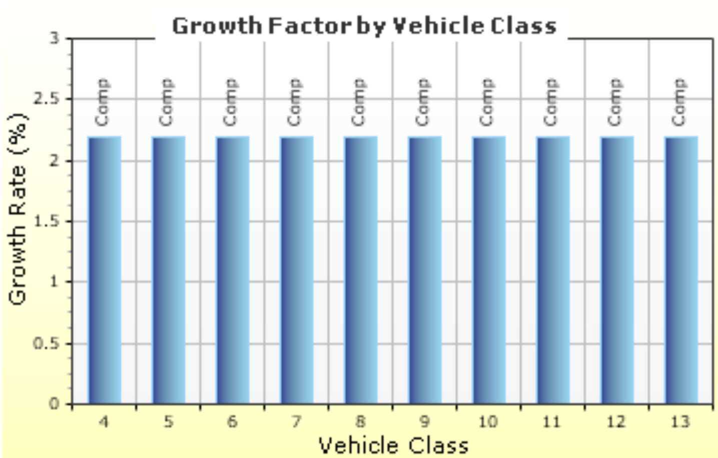
Traffic Inputs

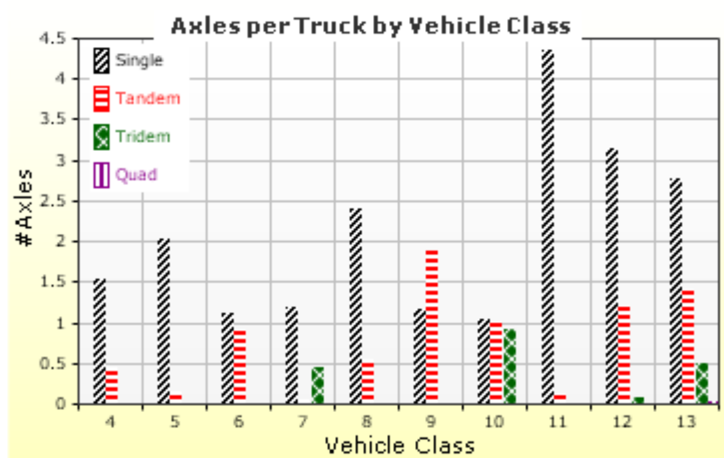
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	850	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

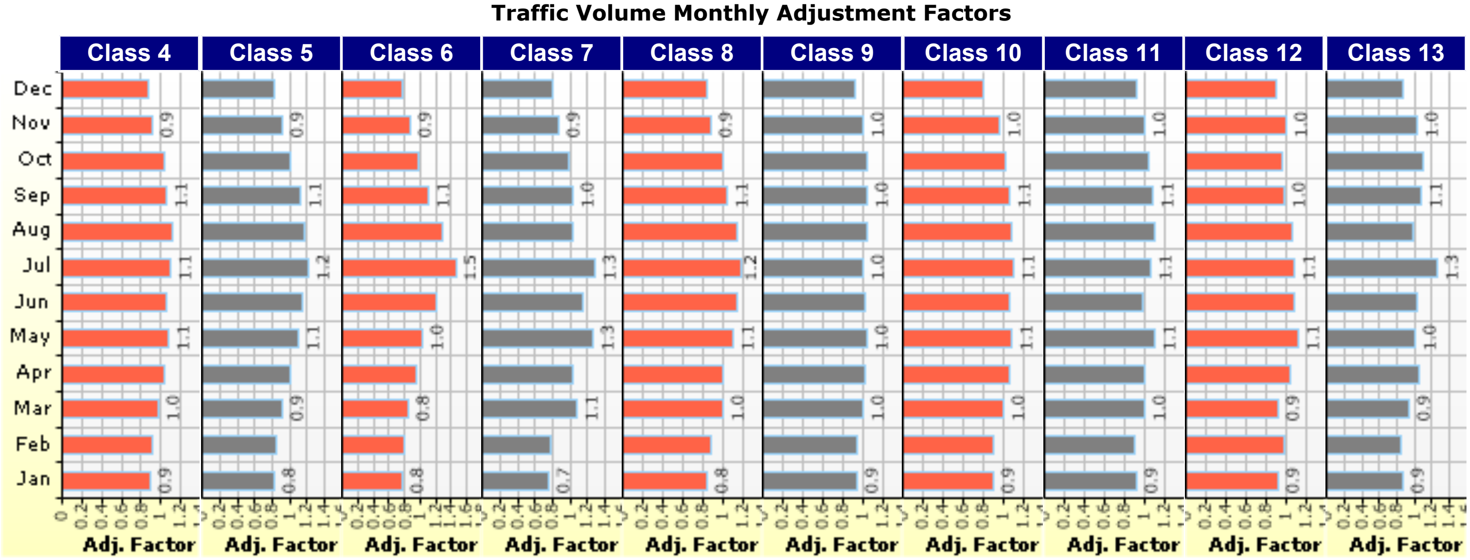








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

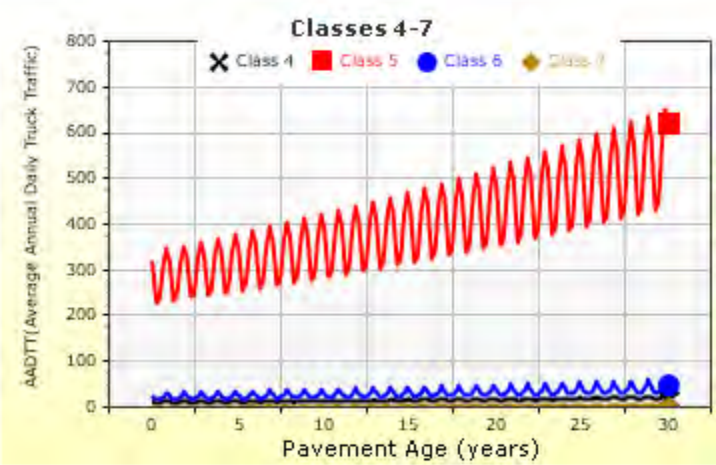
Wheelbase does not apply

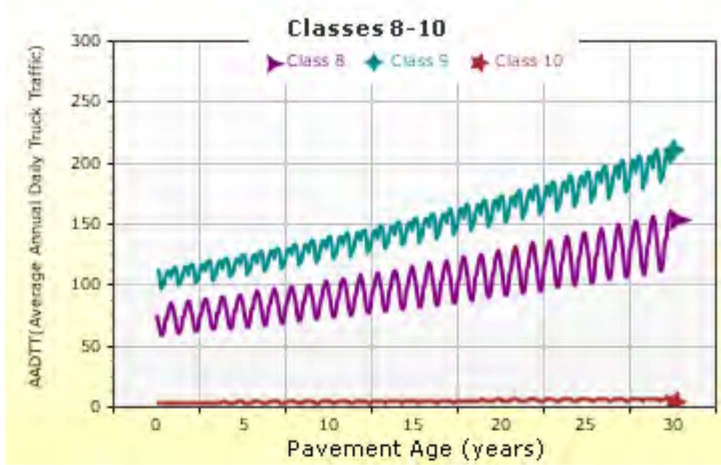
Number of Axles per Truck

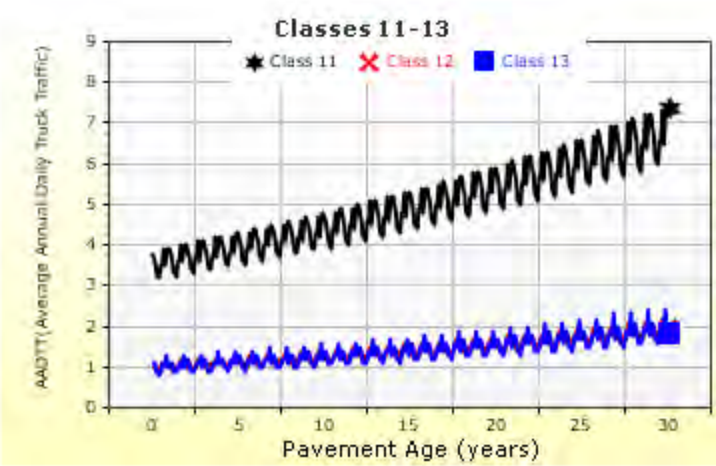
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

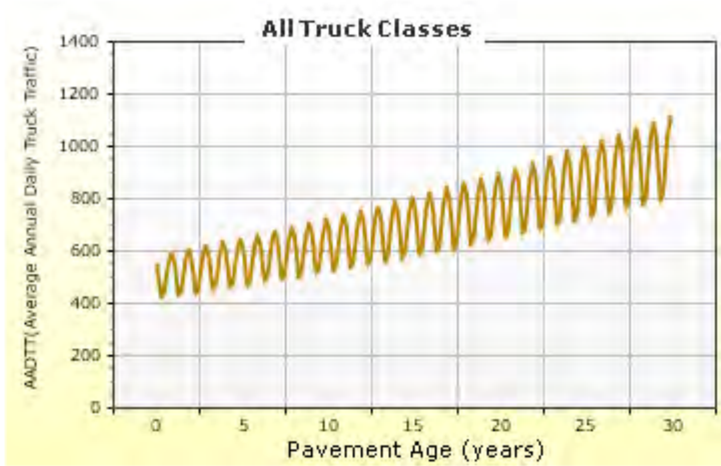
AADTT (Average Annual Daily Truck Traffic) Growth

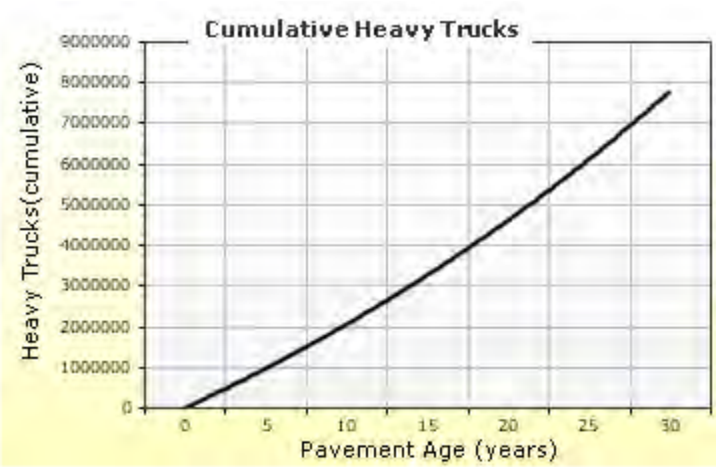
*** Traffic cap is not enforced**







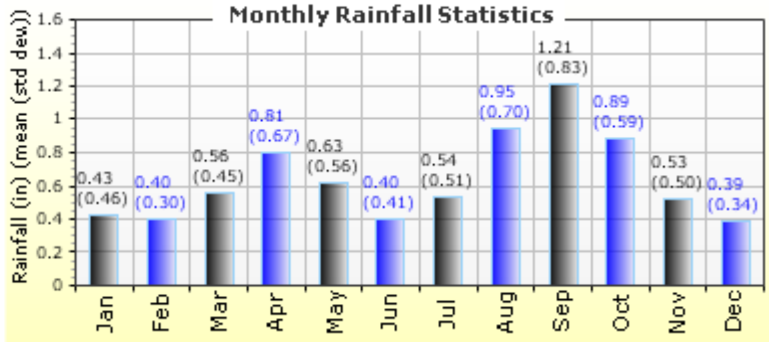




Climate Inputs

Climate Data Sources:

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

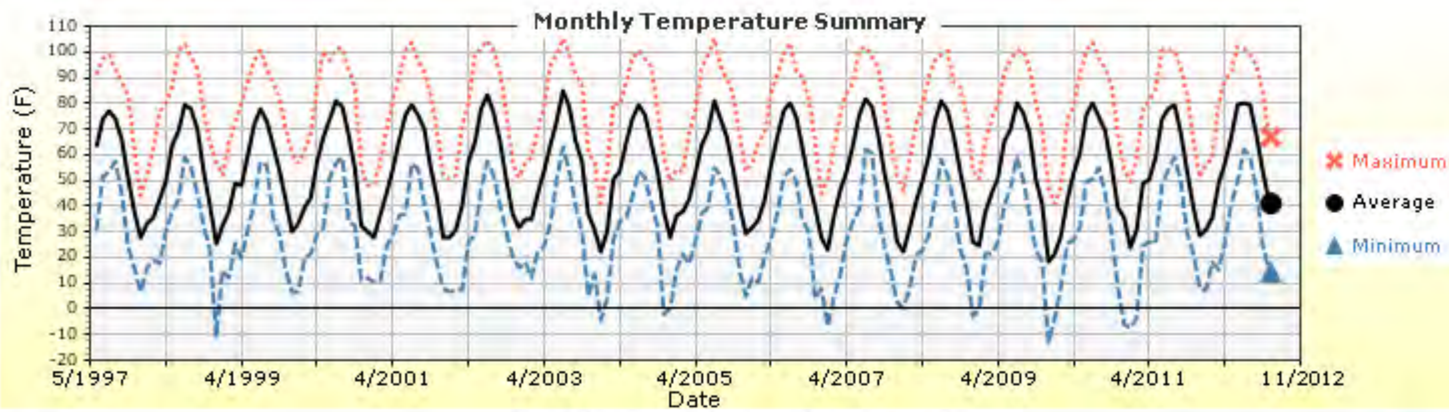


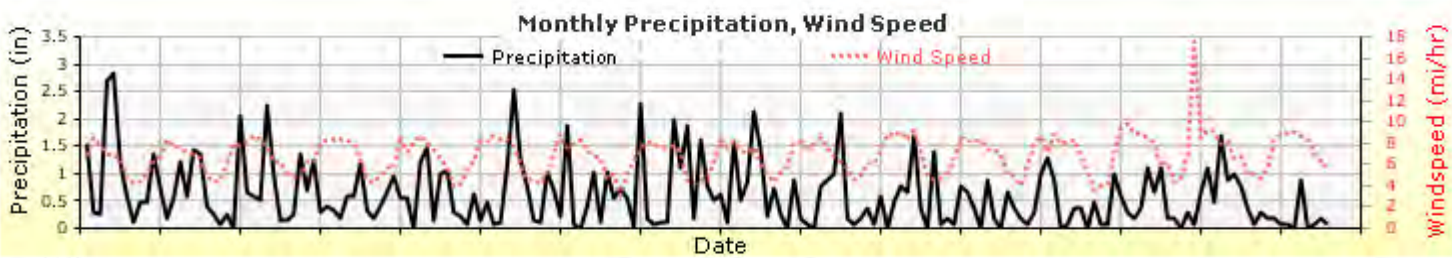
Annual Statistics:

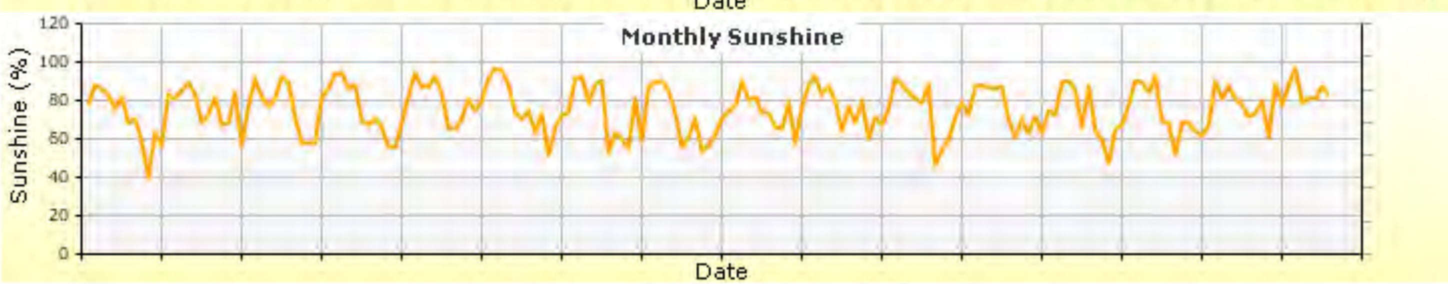
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

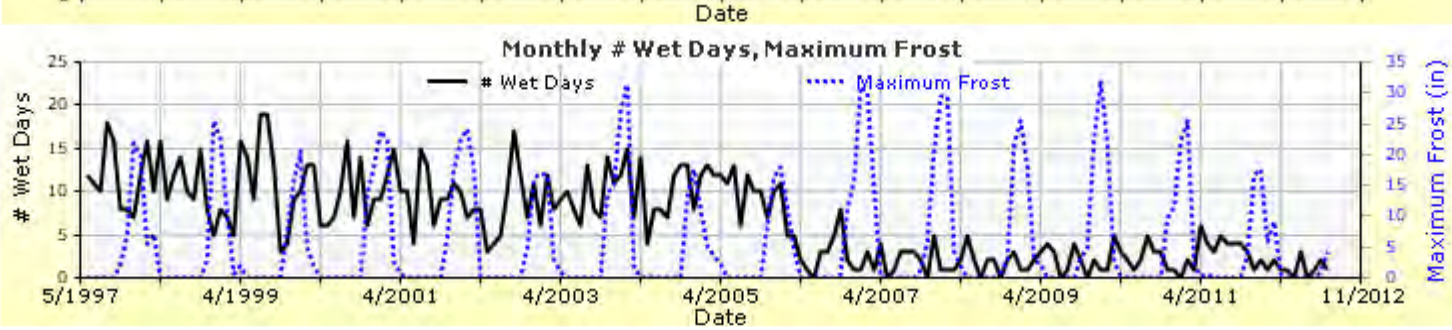
Water table depth (ft)	10.00

Monthly Climate Summary:

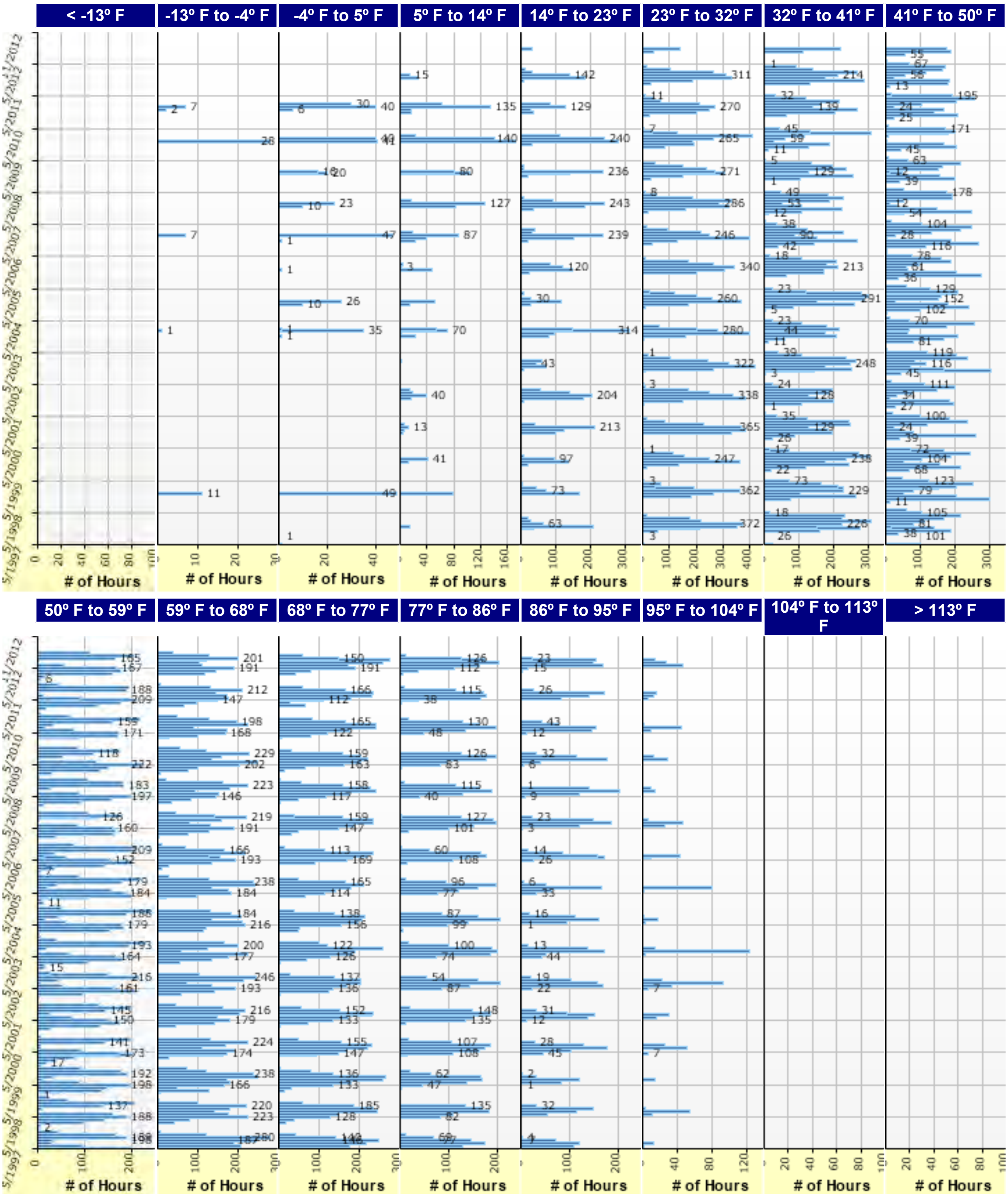








Hourly Air Temperature Distribution by Month:



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

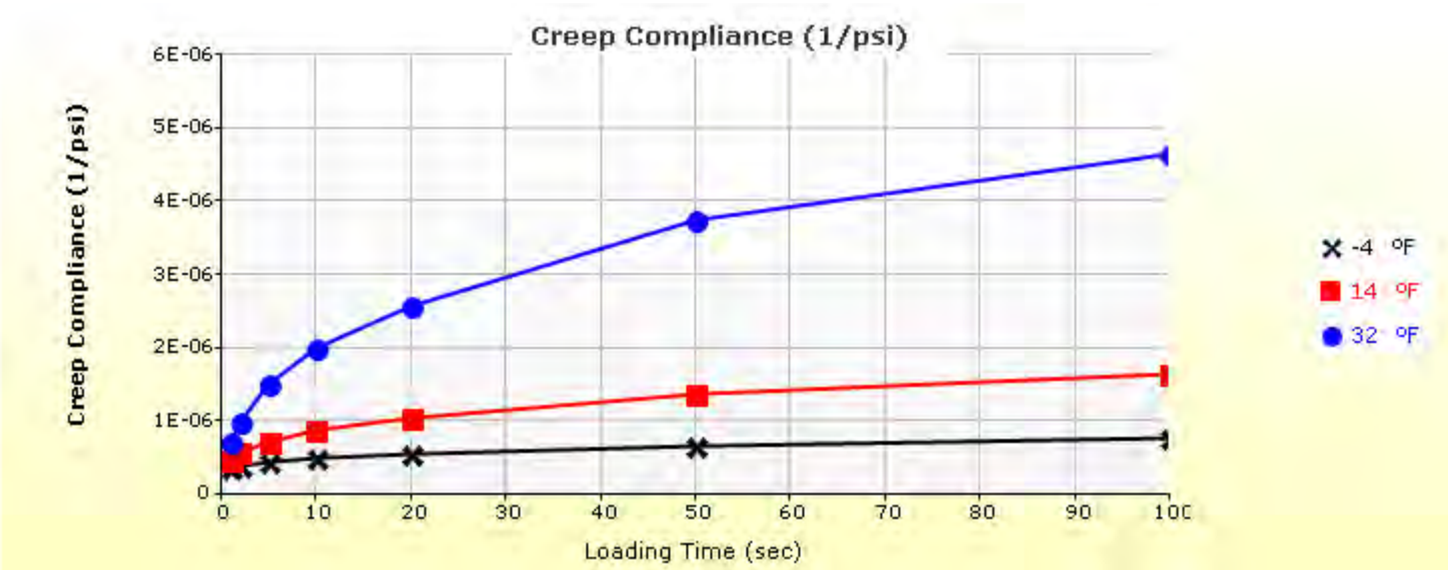
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (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 : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4 (R-Value 10)	Subgrade (5)	-

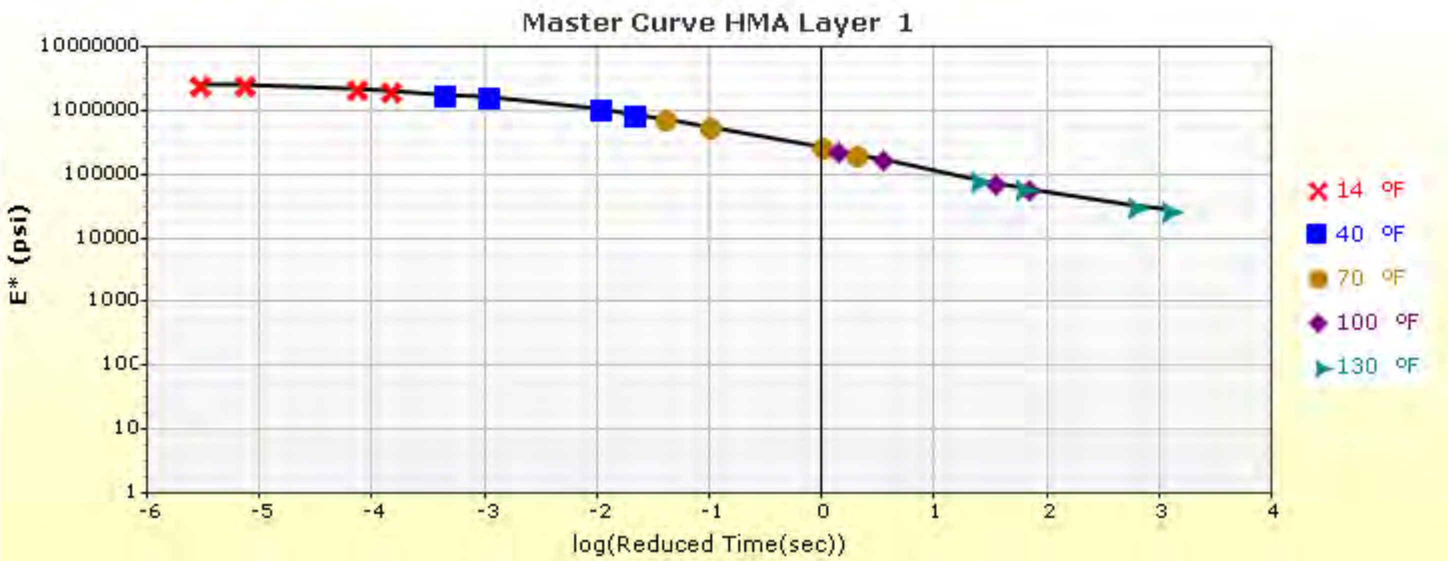
Thermal Cracking (Input Level: 1)

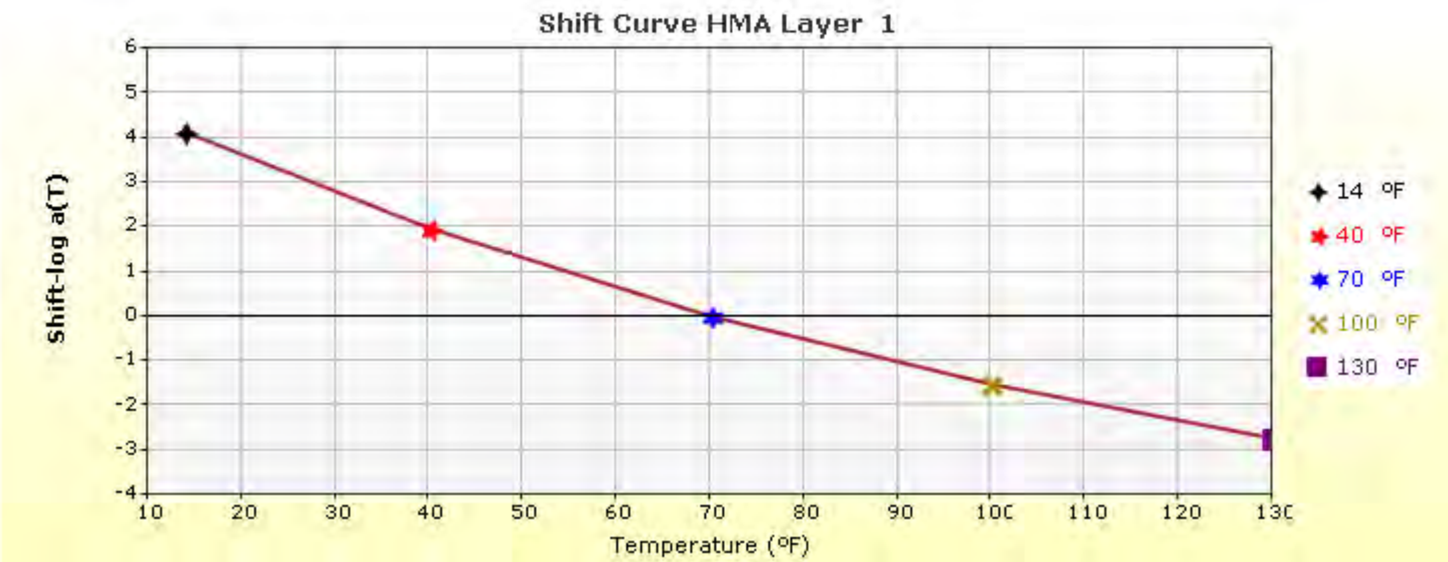
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

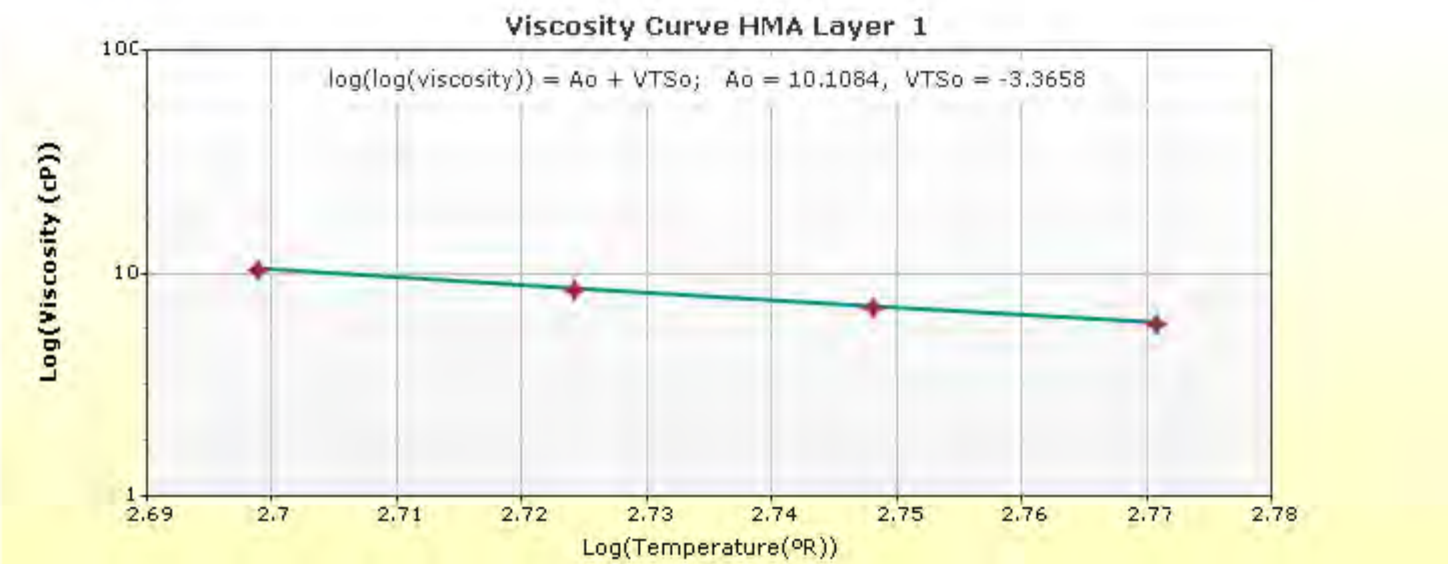
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



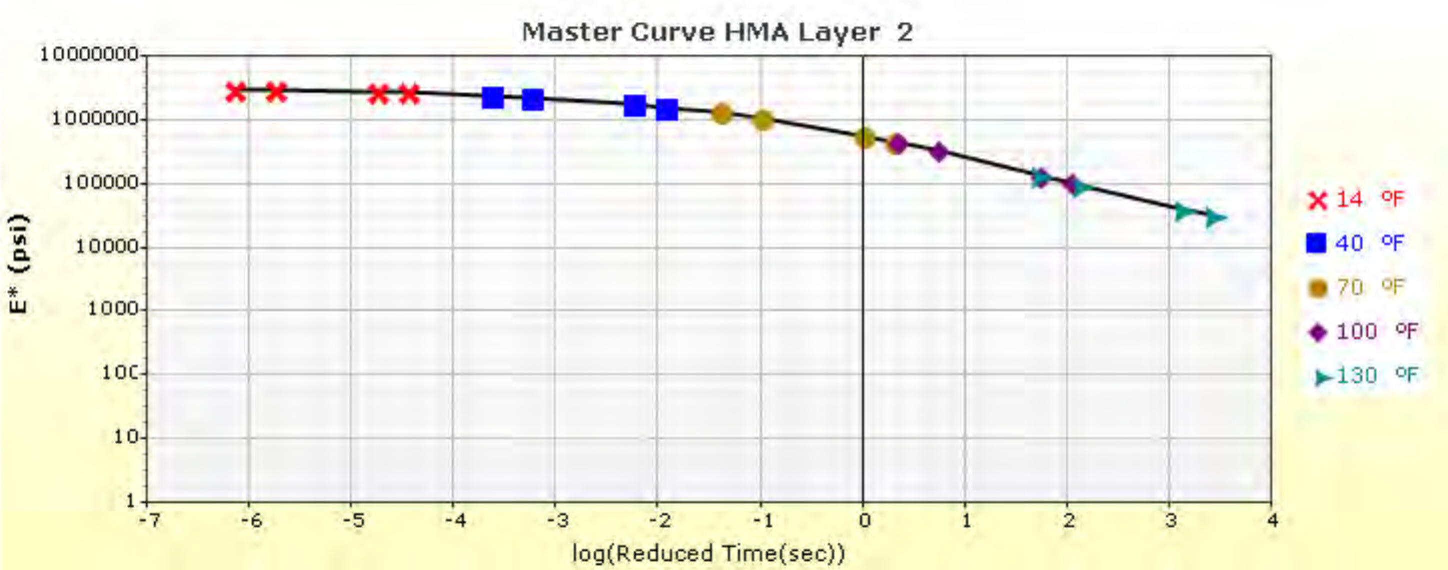
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

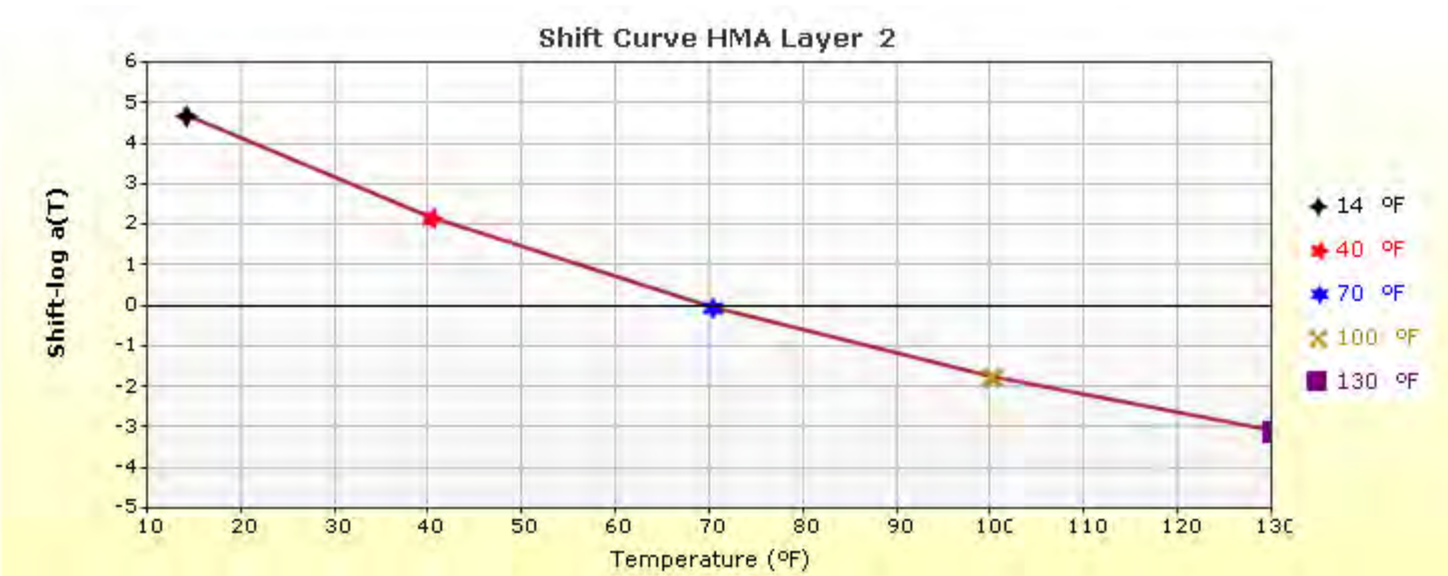


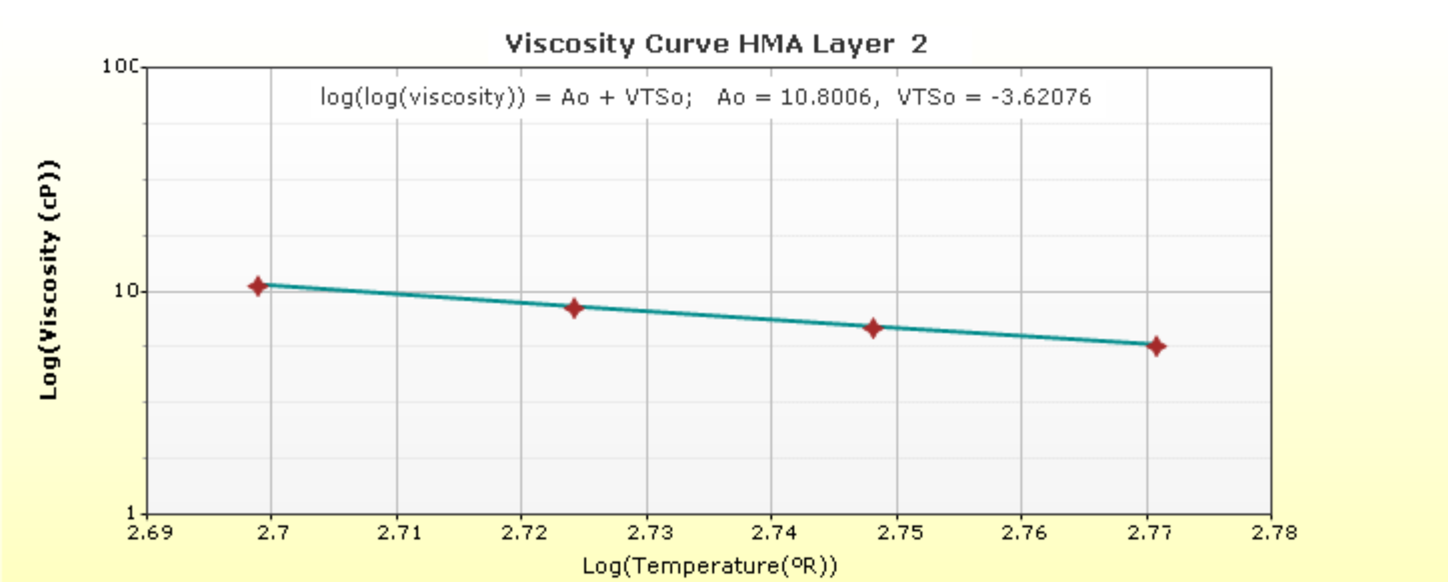




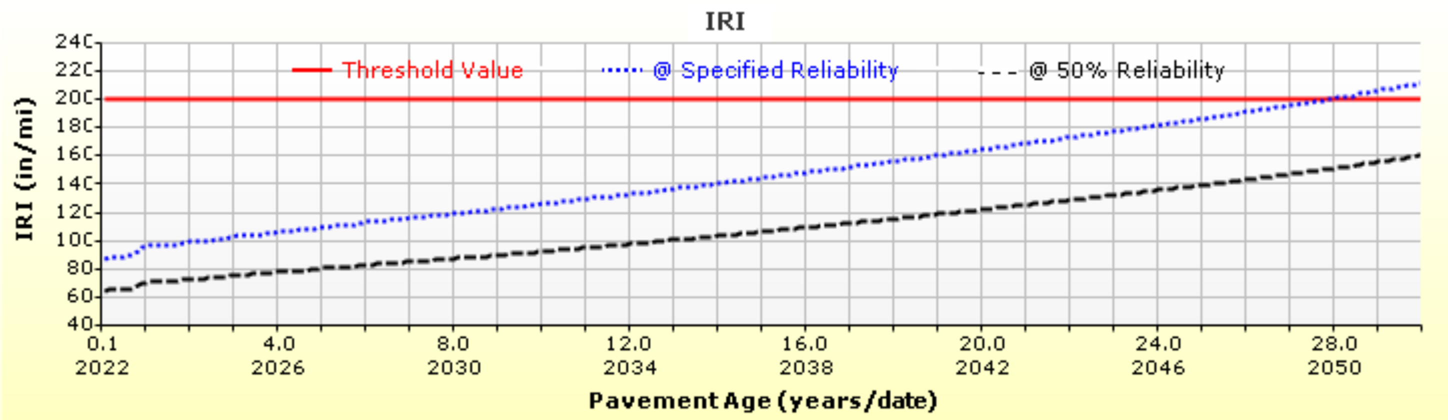
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

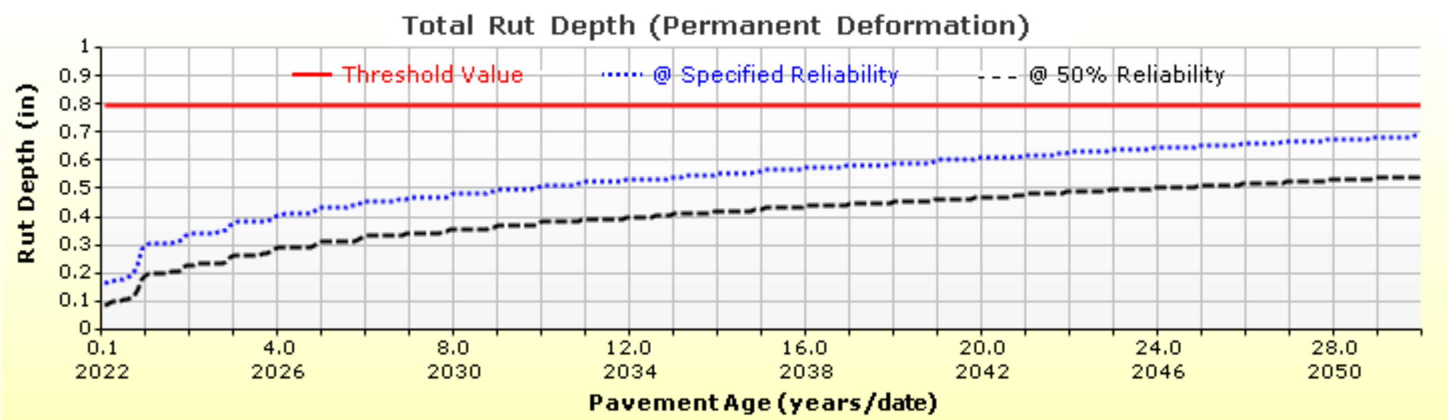


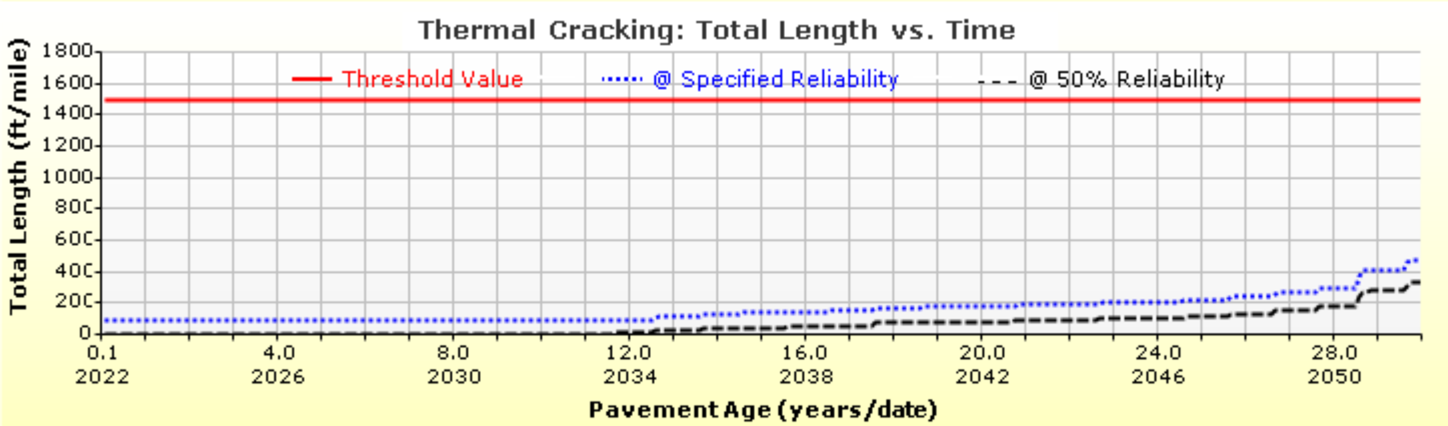


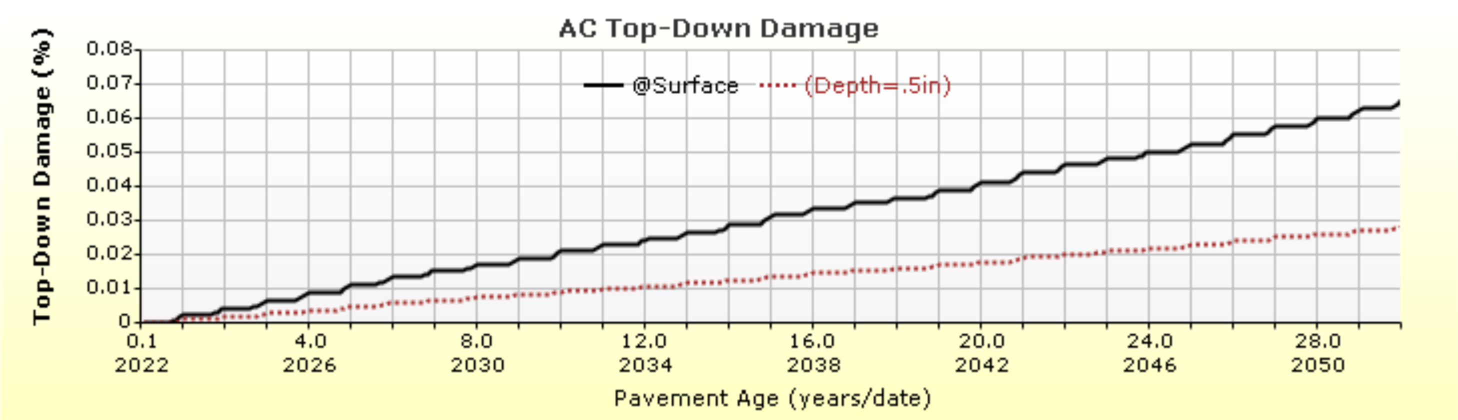


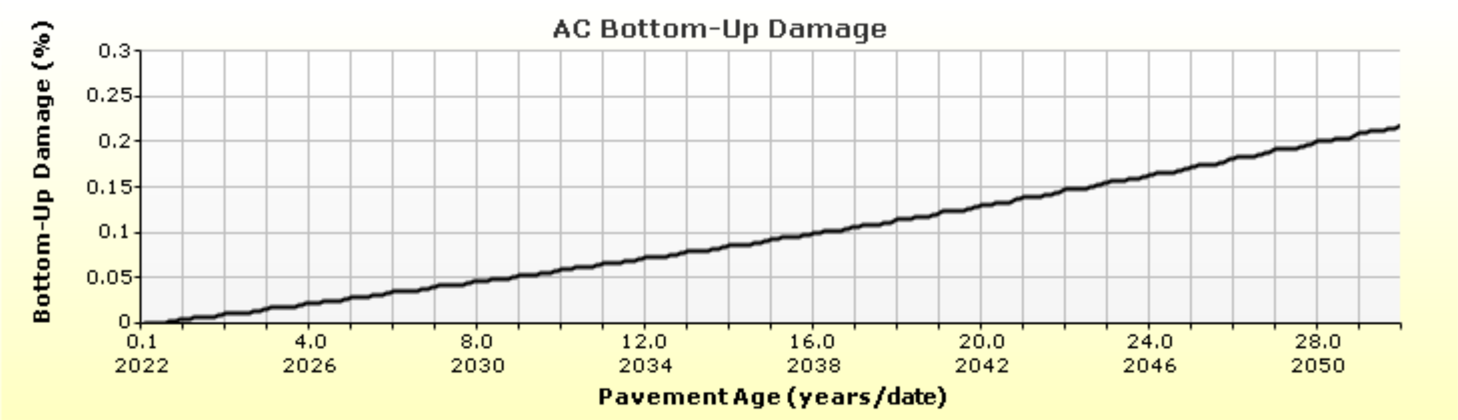
Analysis Output Charts

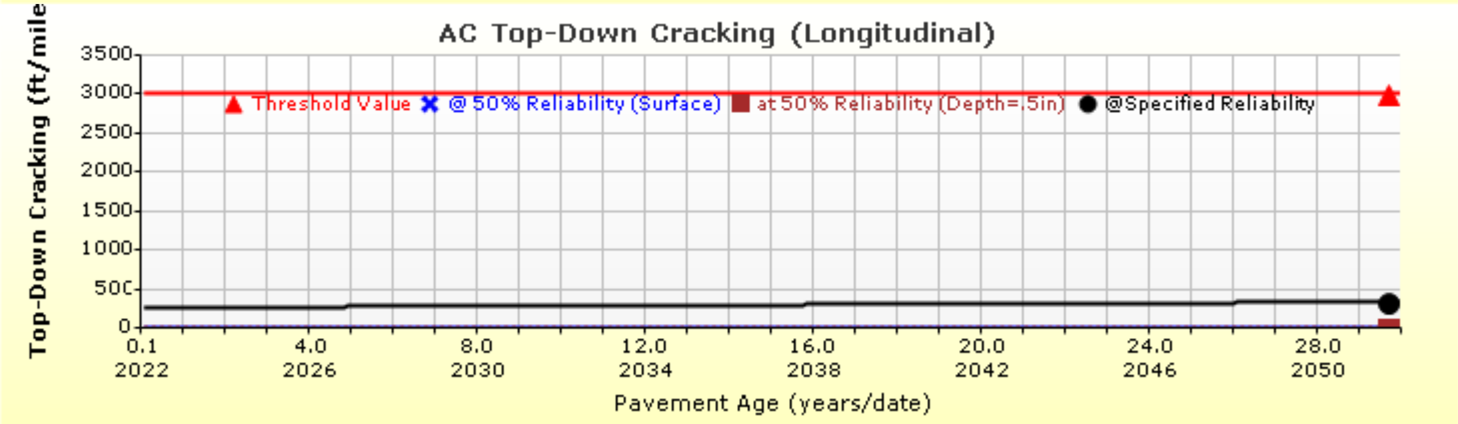


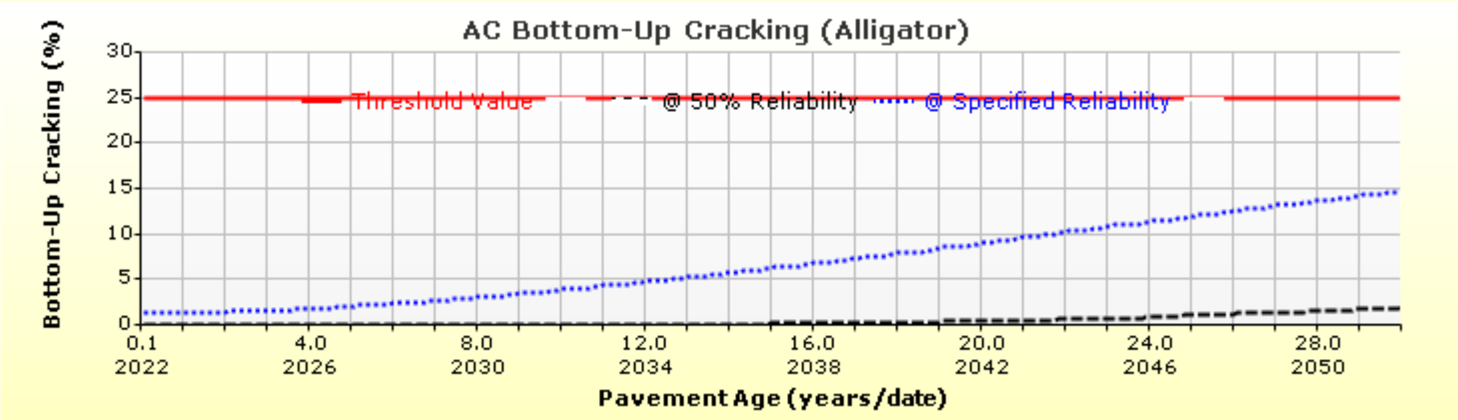


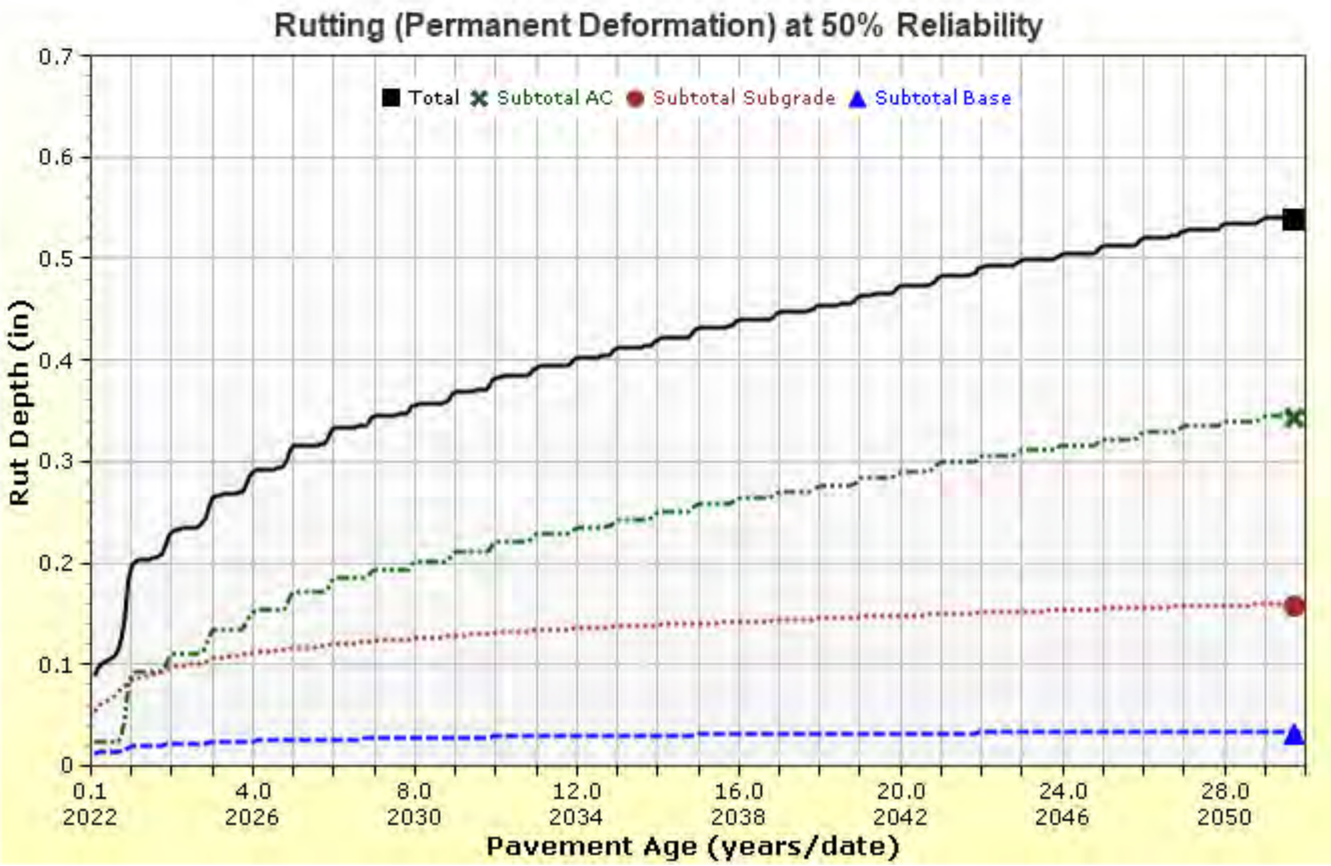



AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

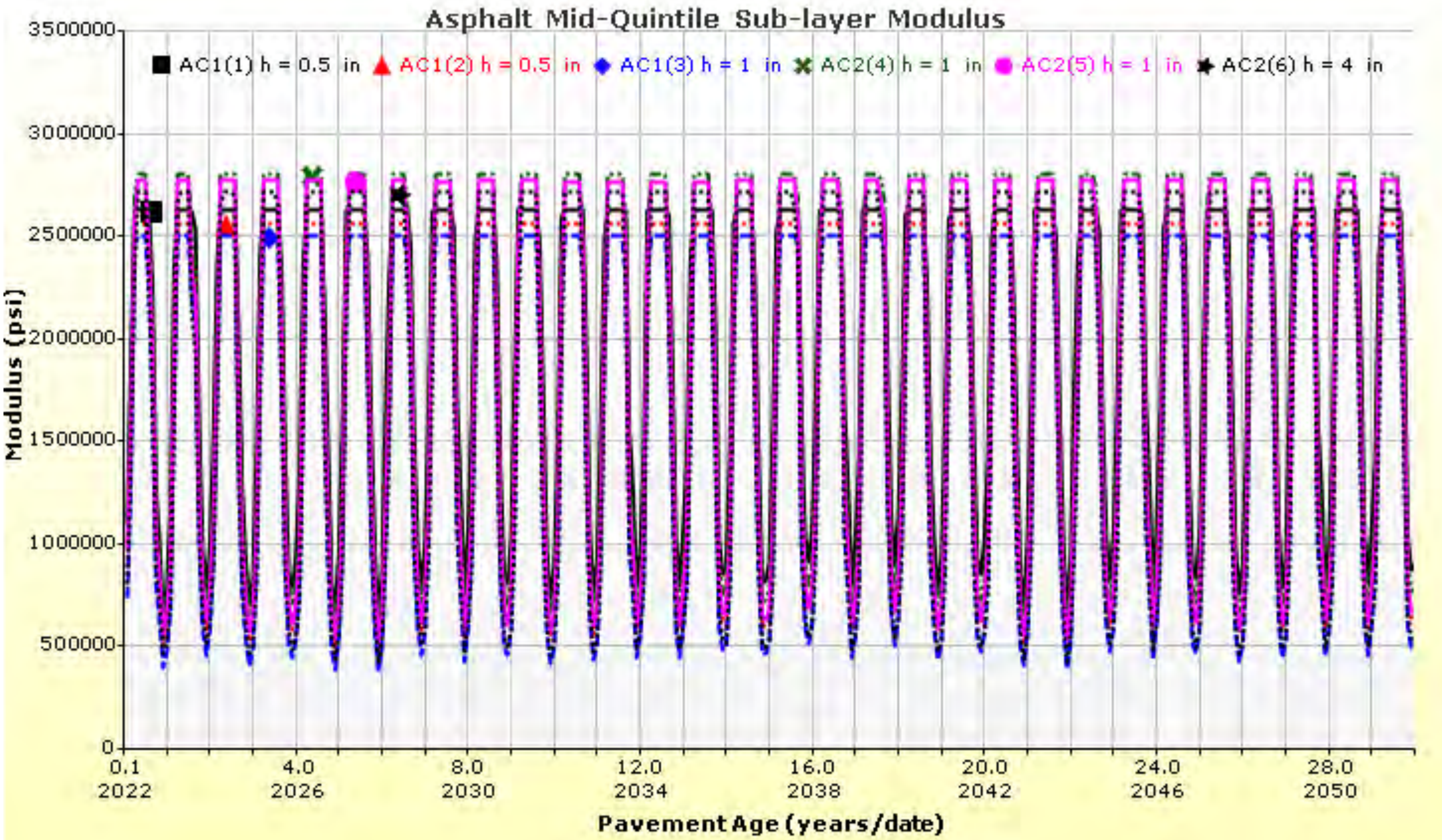

AC Bottom-Up Damage
Bottom-Up Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)


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 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

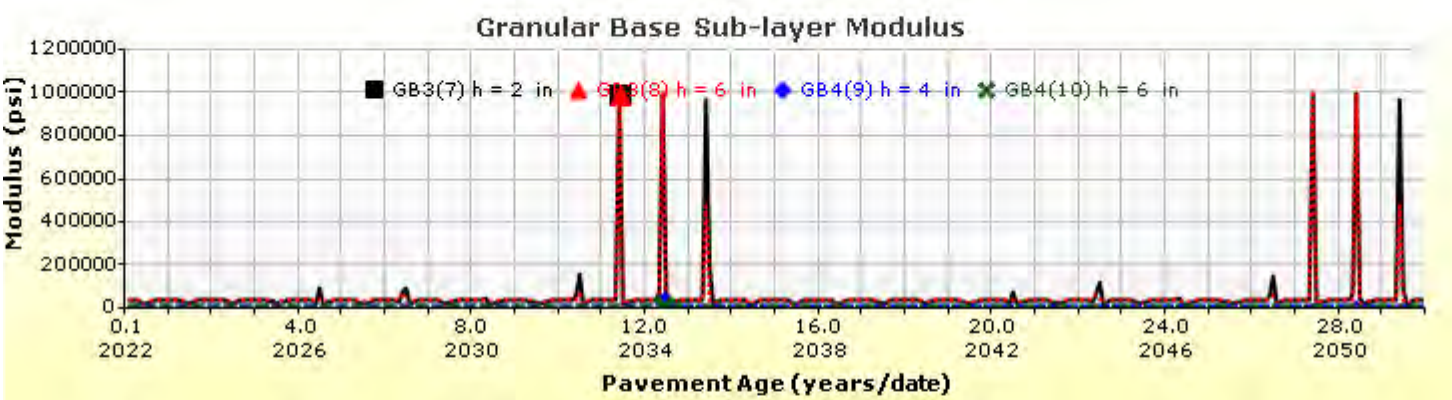

AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



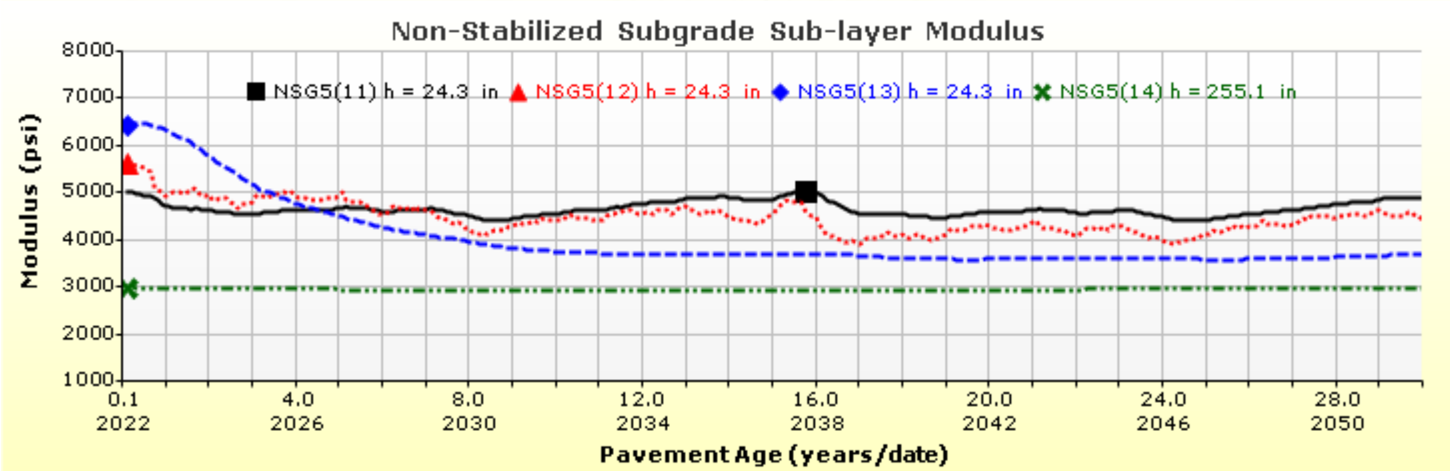
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
Pavement Age (years/date)



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 = 6 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 24.3 in
NSG5(12) h = 24.3 in
NSG5(13) h = 24.3 in
NSG5(14) h = 255.1 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	6.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	10.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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: 130.3674
	Bf2: 1
	Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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			
$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$		$\delta_a = permanent\ deformation\ for\ the\ layer$ $N = number\ of\ repetitions$ $\varepsilon_v = average\ veritcal\ strain(in/in)$ $\varepsilon_0, \beta, \rho = material\ properties$ $\varepsilon_r = resilient\ strain(in/in)$	
Granular		**Fine**	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking				**IRI Flexible Pavements**			
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$				C1 - Rutting C2 - Fatigue Crack		C3 - Transverse Crack C4 - Site Factors	
C1: 0	C2: 75	C3: 5	C4: 3	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*1							

APPENDIX F1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2022
Traffic opening: August, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	12.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

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

Traffic

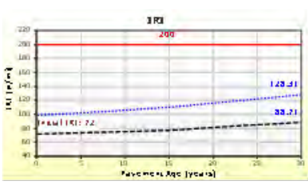
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	850
2037 (15 years)	3,268,330
2052 (30 years)	7,798,240

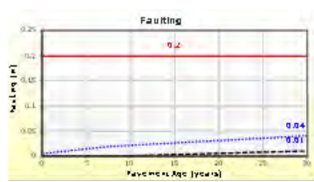
Design Outputs

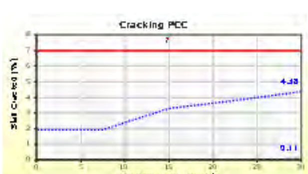
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	128.31	90.00	99.98	Pass
Mean joint faulting (in)	0.20	0.04	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	4.38	90.00	98.06	Pass

Distress Charts



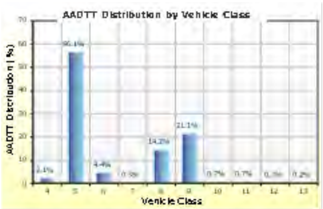


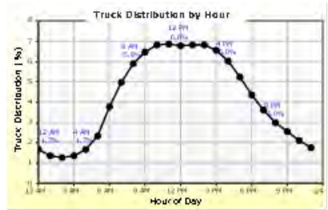


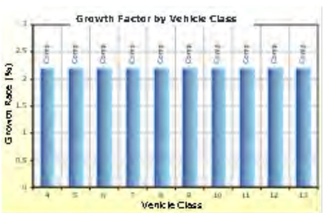
Traffic Inputs

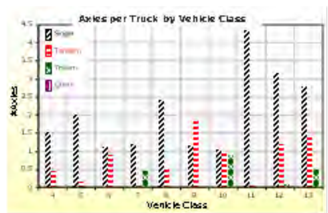
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	850	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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

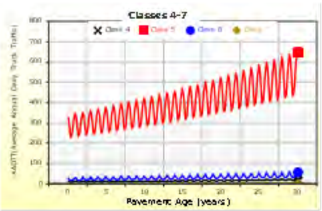
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

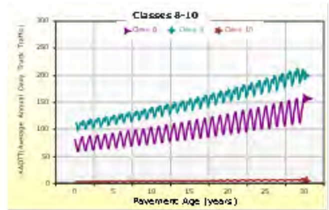
Number of Axles per Truck

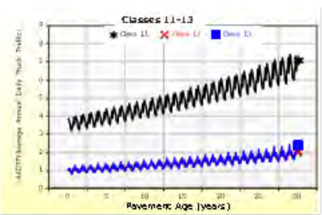
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

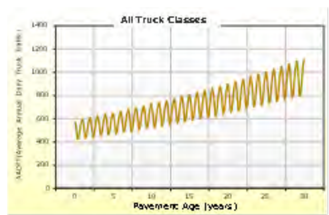
AADTT (Average Annual Daily Truck Traffic) Growth

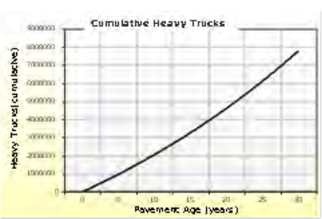
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

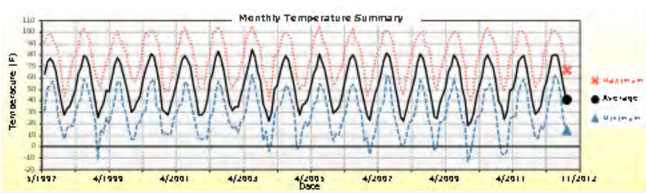
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

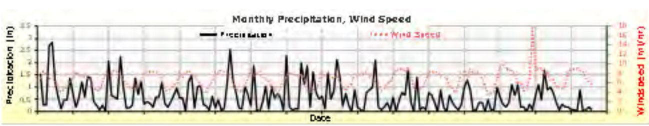
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

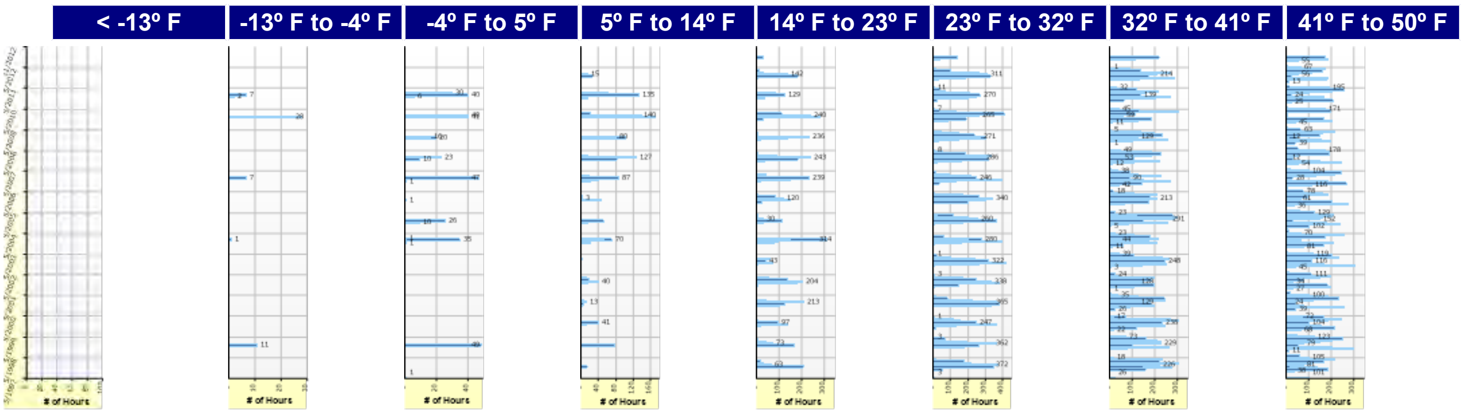
Water table depth (ft) 10.00

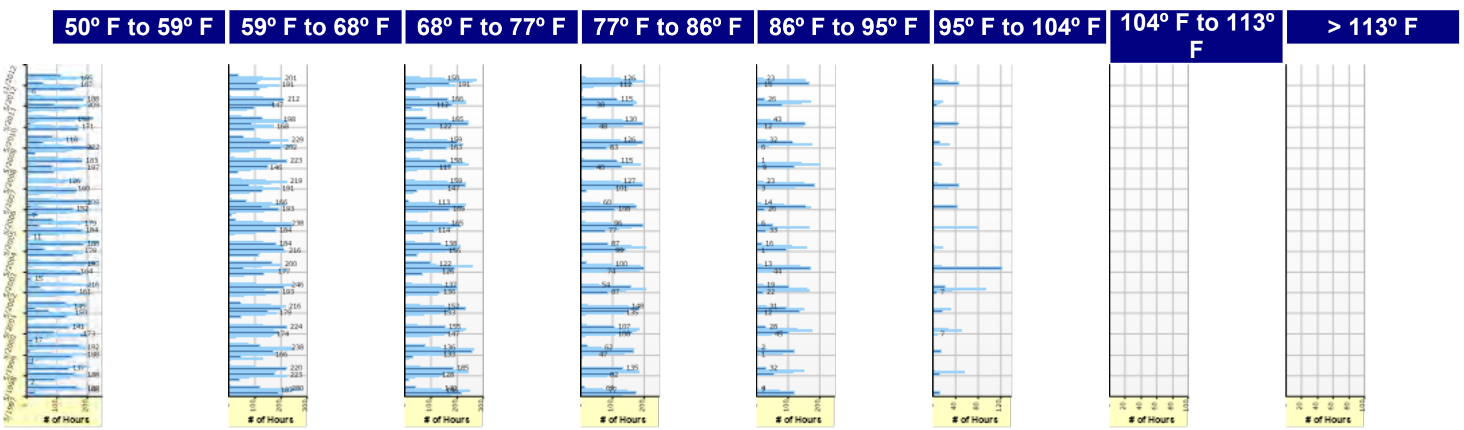
Monthly Climate Summary:





Hourly Air Temperature Distribution by Month:





Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

PCC joint spacing (ft)	
Is joint spacing random ?	False
Joint spacing (ft)	12.00

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

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

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

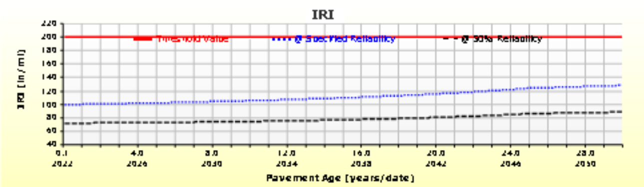
Tied Shoulders	
Tied shoulders	True
Load transfer efficiency (%)	50.00

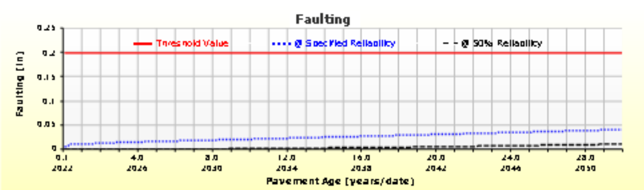
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

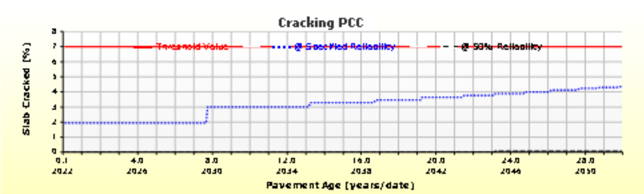
Erodibility index	4

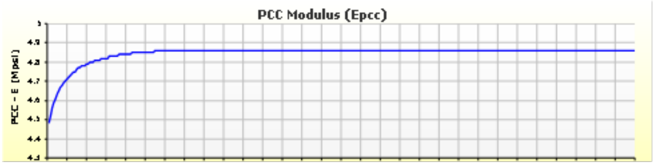
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

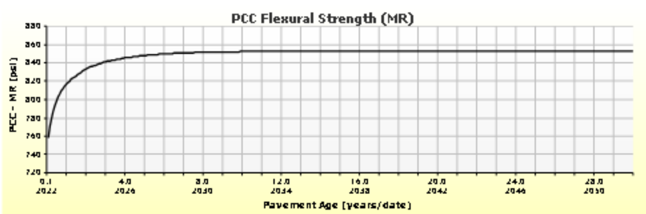




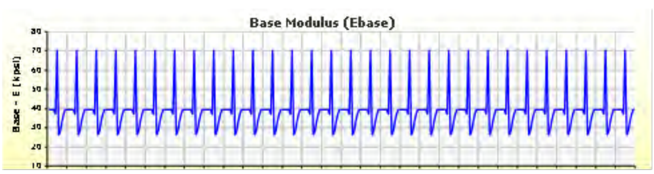




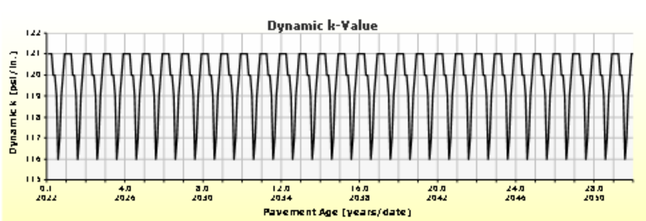
PCC Modulus (Epcc)
PCC - E [Mpsi]
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3



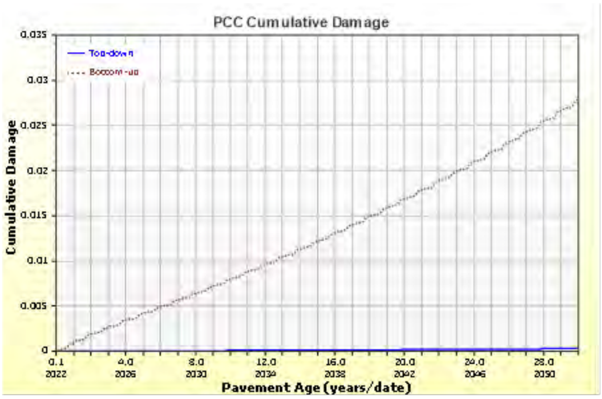
PCC Flexural Strength (MR)
PCC - MR [psi]
880
860
840
820
800
780
760
740
720
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age [years/date]

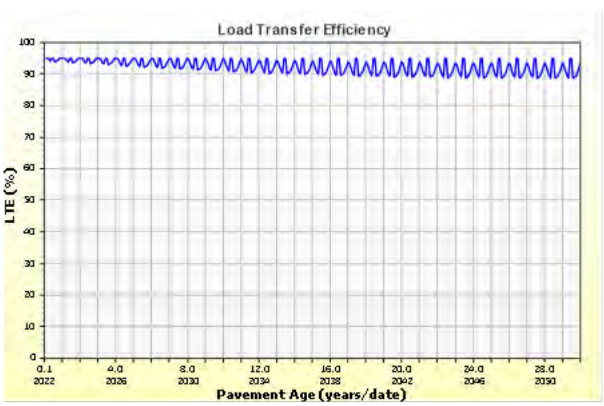


Base Modulus (Ebase)
Base - E [kpsi]
80
70
60
50
40
30
20
10



Dynamic k-Value
Dynamic k [psi/in.]
122
121
120
119
118
117
116
115
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age [years/date]


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
Pavement Age (years/date)


Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.0
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

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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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 G

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD & F ½ ROAD INTERSECTION

Design Inputs

Design Life:	20 years	Base construction:	May, 2022	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	FLEXIBLE	Pavement construction:	June, 2022		
		Traffic opening:	September, 2022		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	7.0
NonStabilized	Crushed stone	8.0
NonStabilized	A-1-b (Pit run) R value 40	12.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

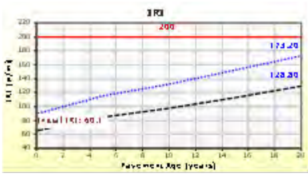
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,950
2032 (10 years)	5,357,990
2042 (20 years)	12,018,500

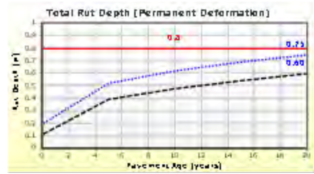
Design Outputs

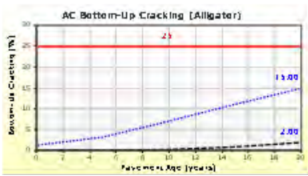
Distress Prediction Summary

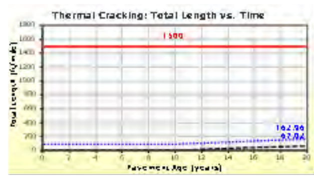
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	173.25	90.00	98.00	Pass
Permanent deformation - total pavement (in)	0.80	0.75	90.00	95.90	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	15.00	90.00	98.83	Pass
AC thermal cracking (ft/mile)	1500.00	162.96	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	316.06	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.55	90.00	98.61	Pass

Distress Charts





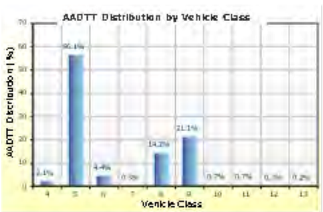


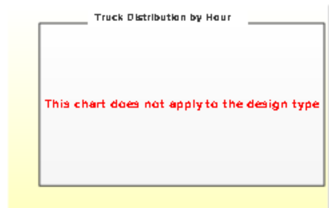


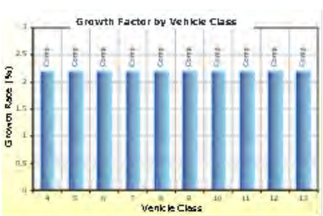
Traffic Inputs

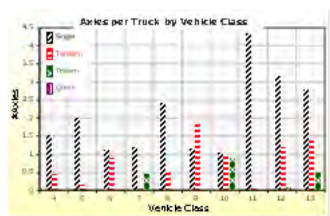
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,950	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)	25.0

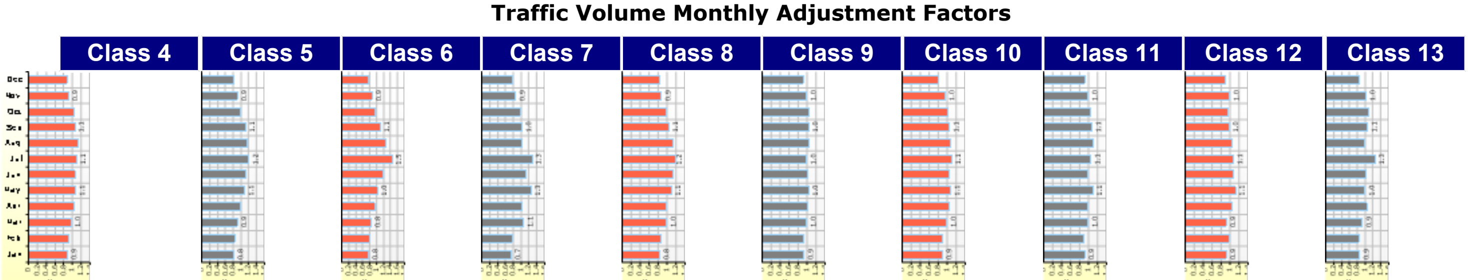








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

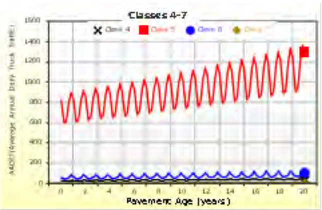
Wheelbase does not apply

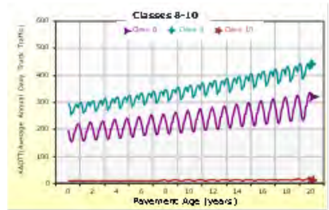
Number of Axles per Truck

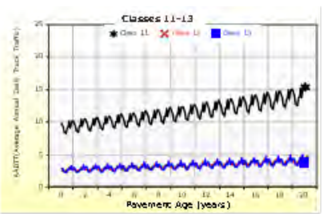
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

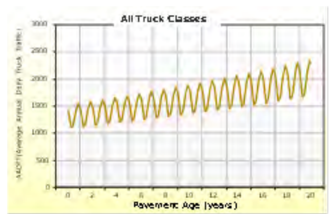
AADTT (Average Annual Daily Truck Traffic) Growth

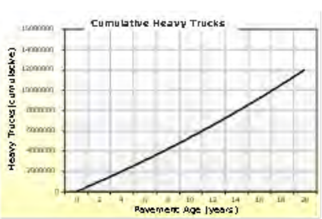
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

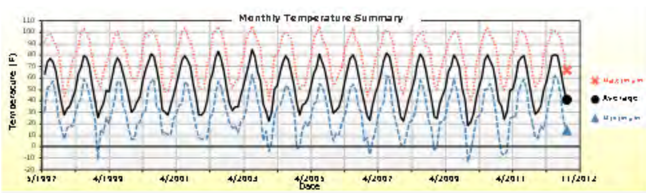
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

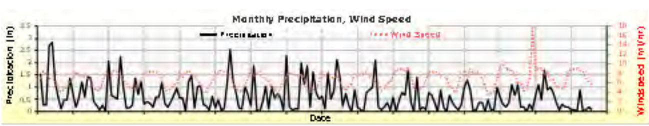
Annual Statistics:

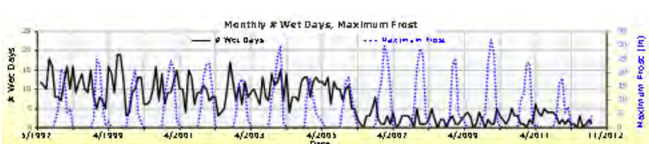
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

Water table depth (ft) 10.00

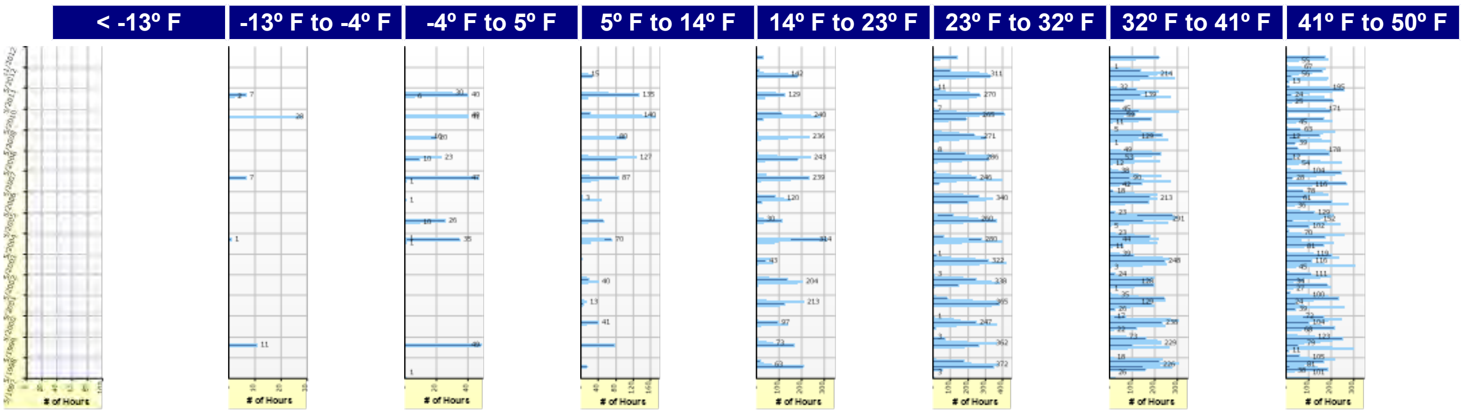
Monthly Climate Summary:

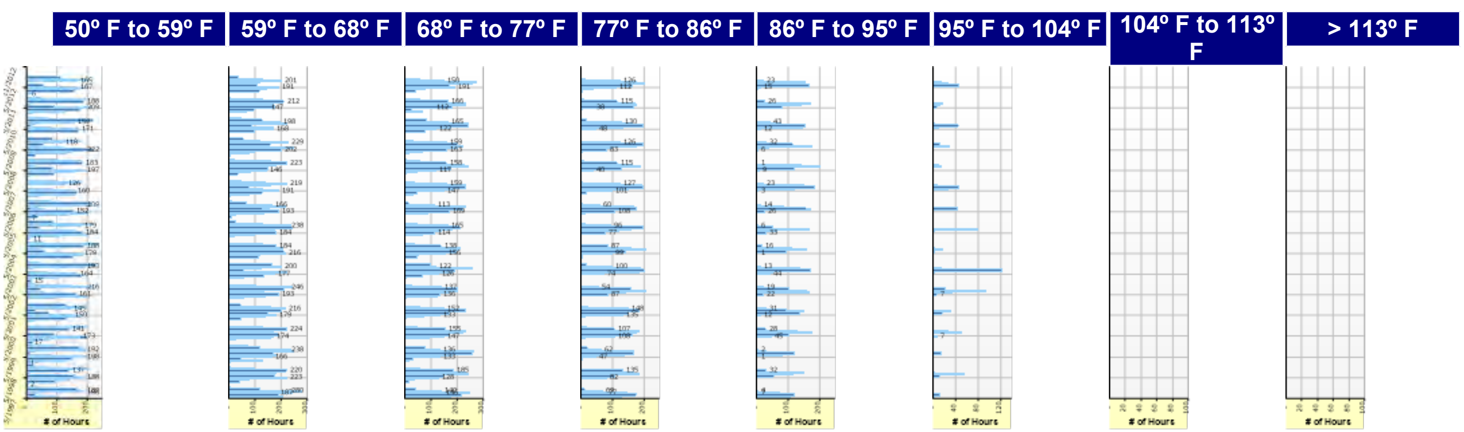






Hourly Air Temperature Distribution by Month:





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

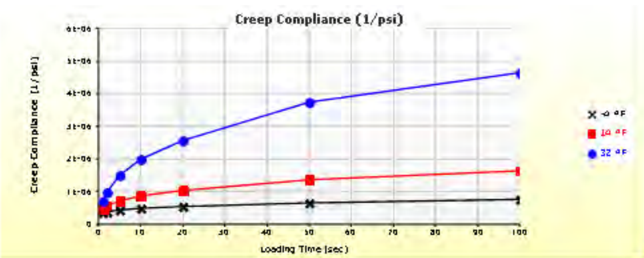
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b (Pit run) R value 40	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4 (R-Value 10)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

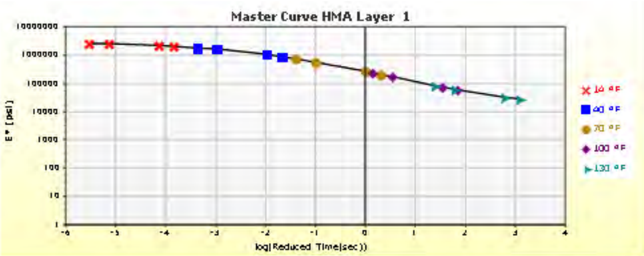
Indirect tensile strength at 14 ºF (psi)	519.00

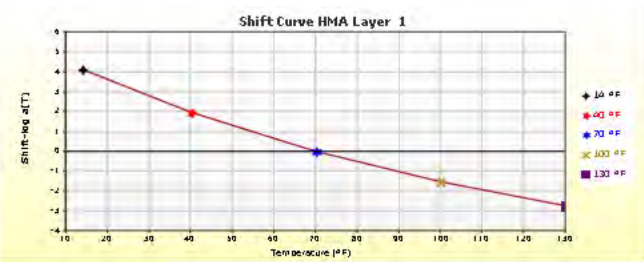
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

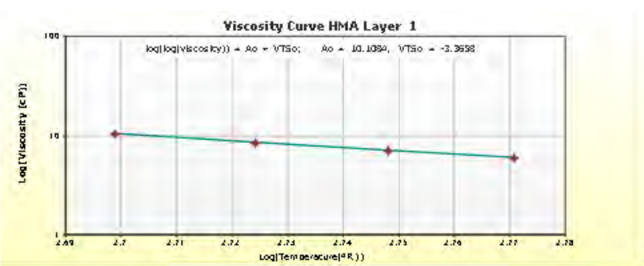
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



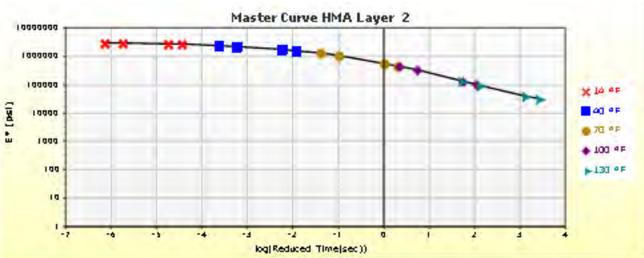
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

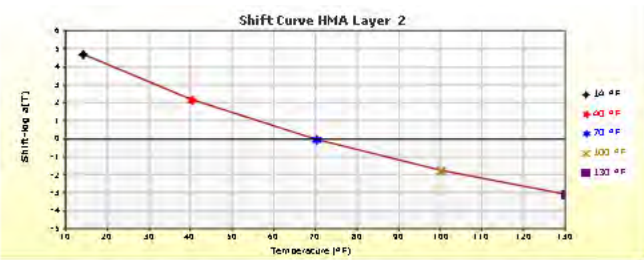


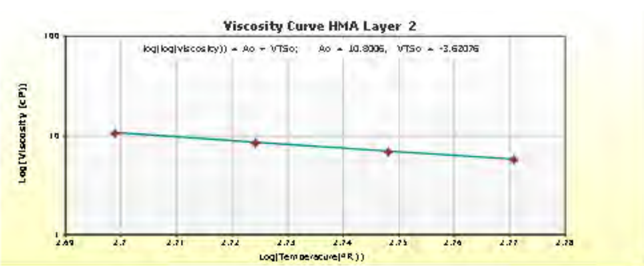




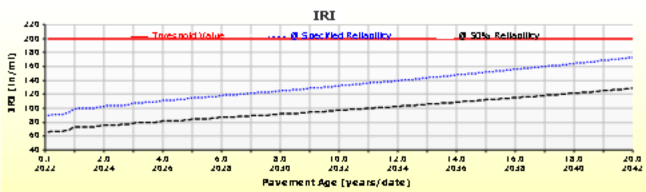
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

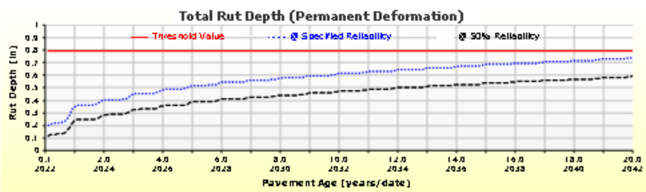


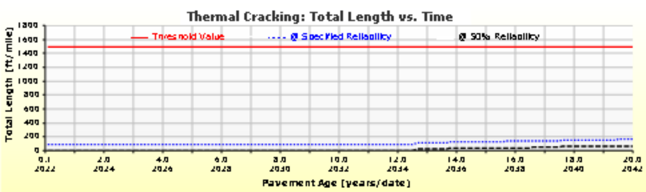




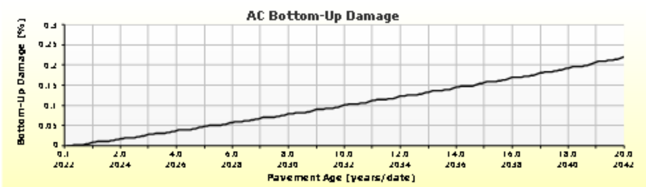
Analysis Output Charts



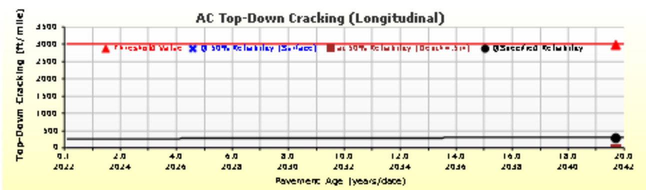




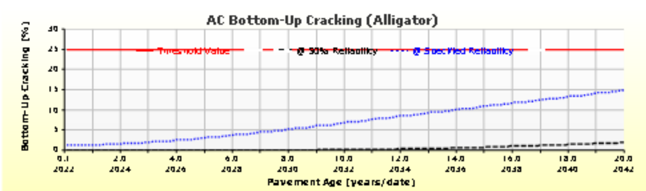
AC Top-Down Damage
@Surface
Top-Down Damage (%)
Pavement Age (years/date)



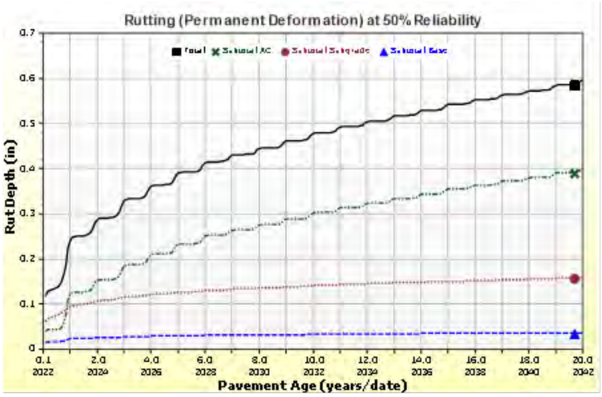
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

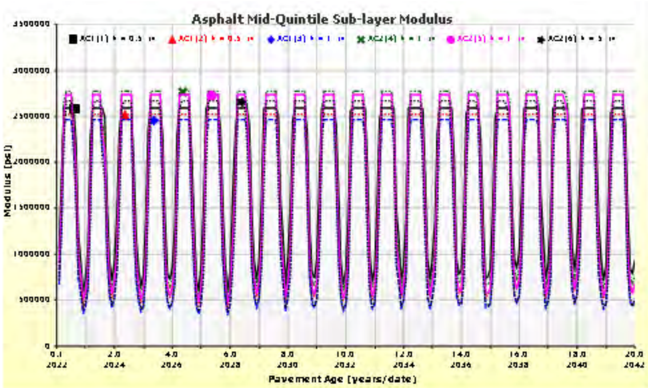


AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)

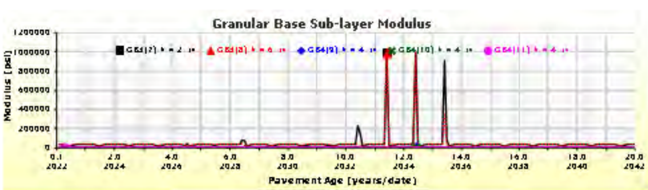


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Rut Depth (in)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)

Non-Stabilized Subgrade Sub-layer Modulus
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	7.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

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 3 Non-stabilized Base : Crushed stone

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 stone
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	20

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 : A-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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: 130.3674	
Bf2: 1	
Bf3: 1.217799	

AC Rutting

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

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

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

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

Where:

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

$\varepsilon_p = plastic\ strain({}^{in}/_{in})$

$\varepsilon_r = resilient\ strain({}^{in}/_{in})$

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 Br2:1 Br3:1

Thermal Fracture

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

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

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

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$

$k = refression\ coefficient\ determined\ through\ field\ calibration$

$N(\ ) = standard\ normal\ distribution\ evaluated\ at(\ )$

$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$

$C = crack\ depth(in)$

$h_{ac} = thickness\ of\ asphalt\ layer(in)$

$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$

$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$

$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$

$E = mixture\ stiffness$

$\sigma_M = Undamaged\ mixture\ tensile\ strength$

$\beta_t = Calibration\ parameter$

Level 1 K: 6.3	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: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

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

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$

$\sigma_s = Tensile\ stress(psi)$

$M_r = modulus\ of\ rupture(psi)$

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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

AC Bottom Up Cracking

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

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

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

c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

25 and F.5 Road Intersection HMA (30-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\25 and F.5 Road Intersection HMA (30-year).dgpx

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(100) PG 64-28	2.0
Flexible	R2 Level 1 SX(100) PG 64-22	9.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	12.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.7

Traffic

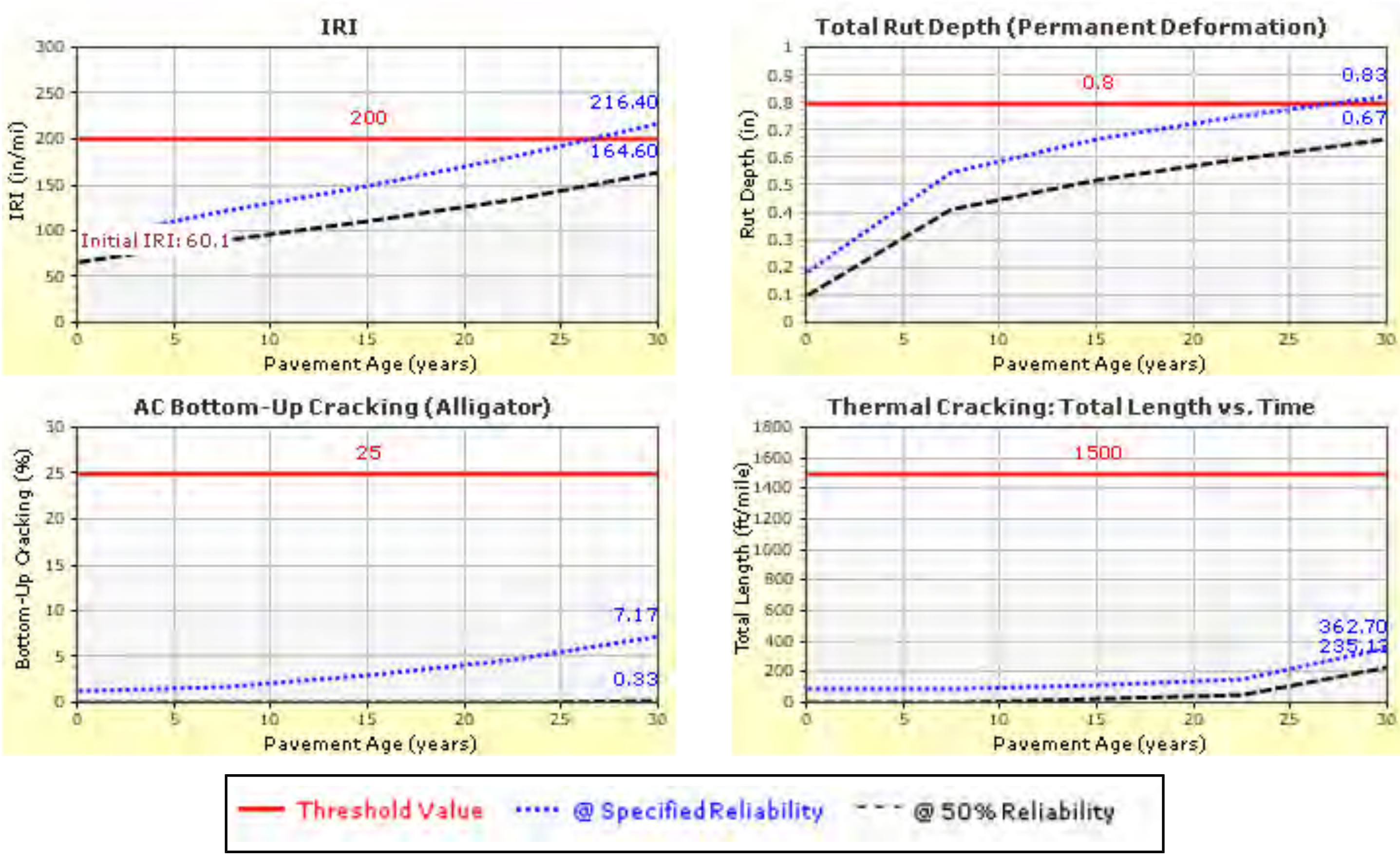
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,950
2037 (15 years)	8,507,270
2052 (30 years)	20,298,300

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	216.39	90.00	80.94	Fail
Permanent deformation - total pavement (in)	0.80	0.83	90.00	85.65	Fail
AC bottom-up fatigue cracking (% lane area)	25.00	7.17	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	362.70	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	271.63	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.64	90.00	91.57	Pass

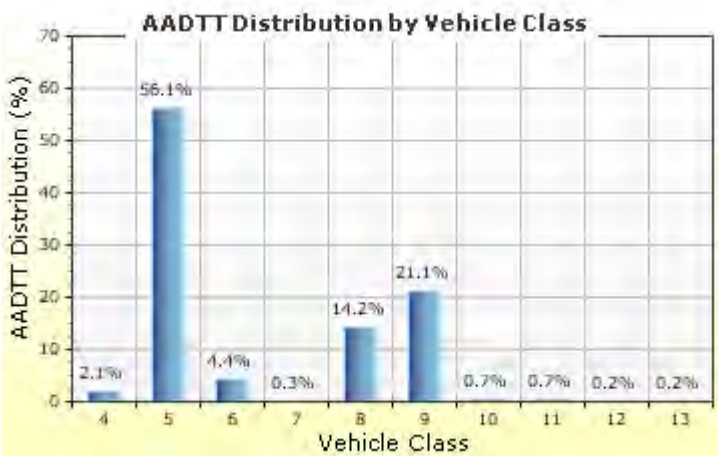
Distress Charts

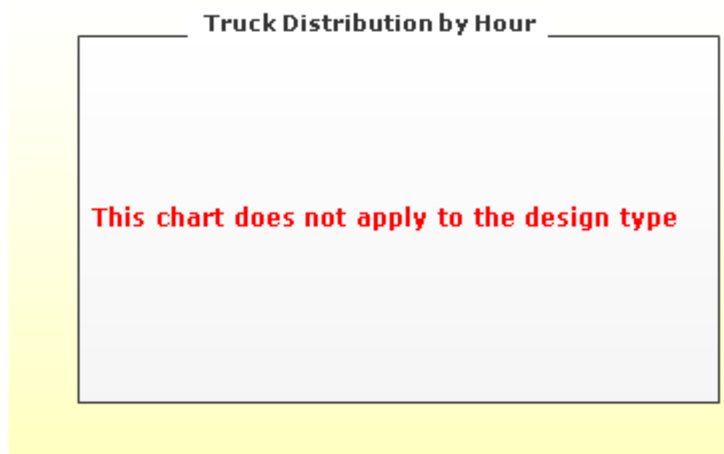


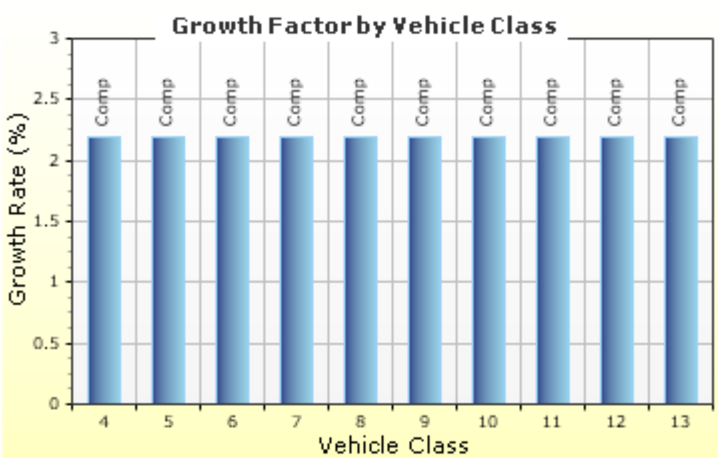
Traffic Inputs

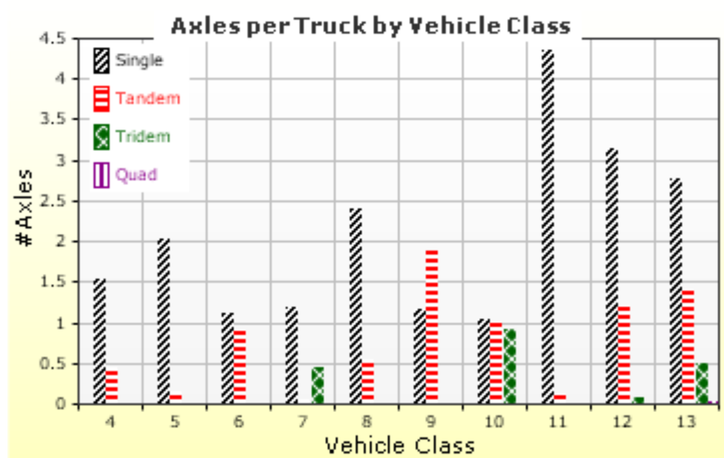
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,950	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)	25.0

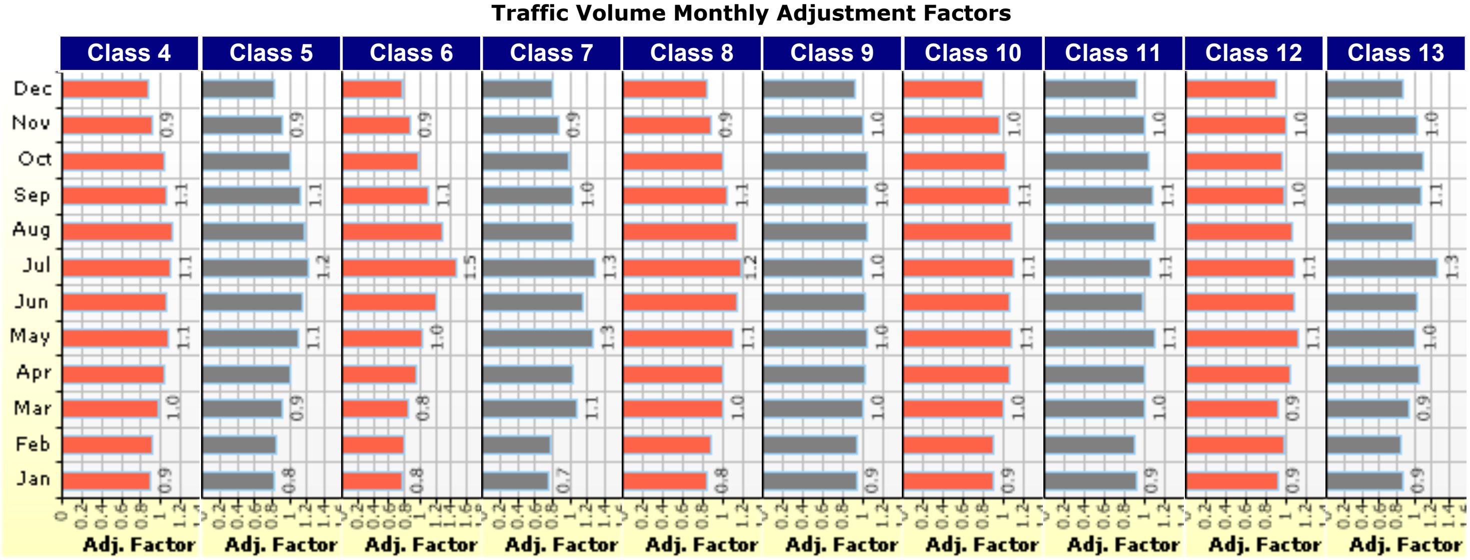








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

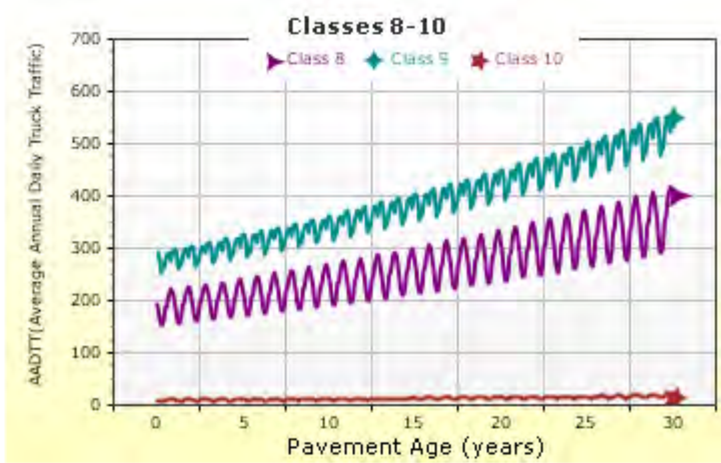
Wheelbase does not apply

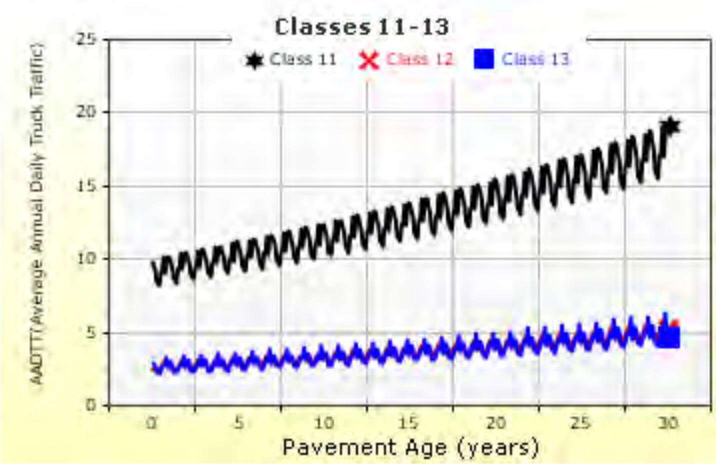
Number of Axles per Truck

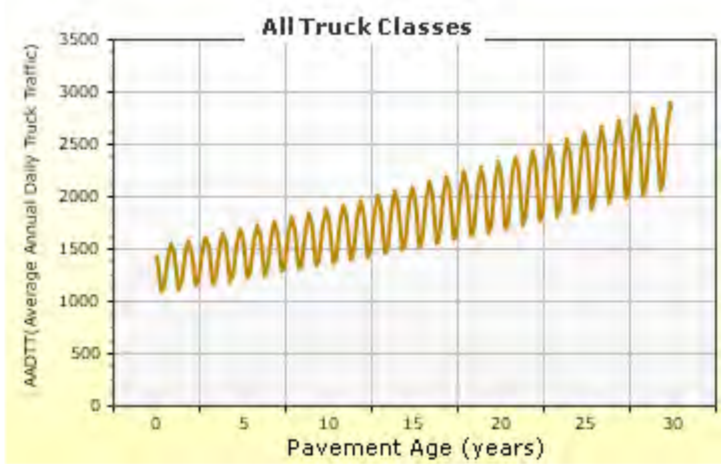
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

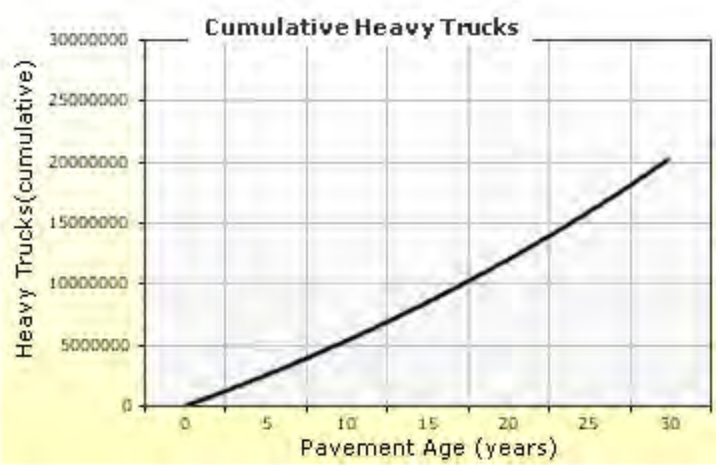
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





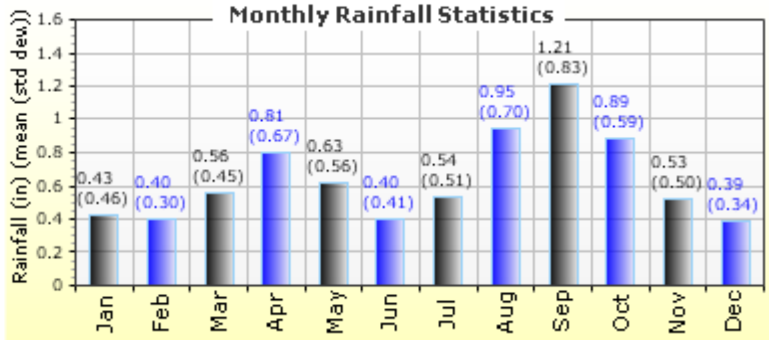




Climate Inputs

Climate Data Sources:

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

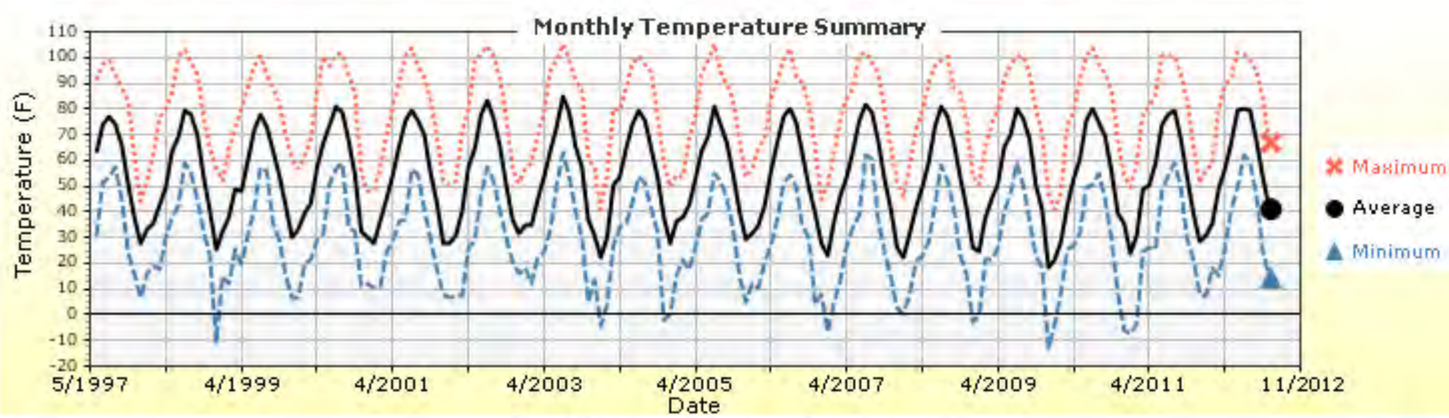


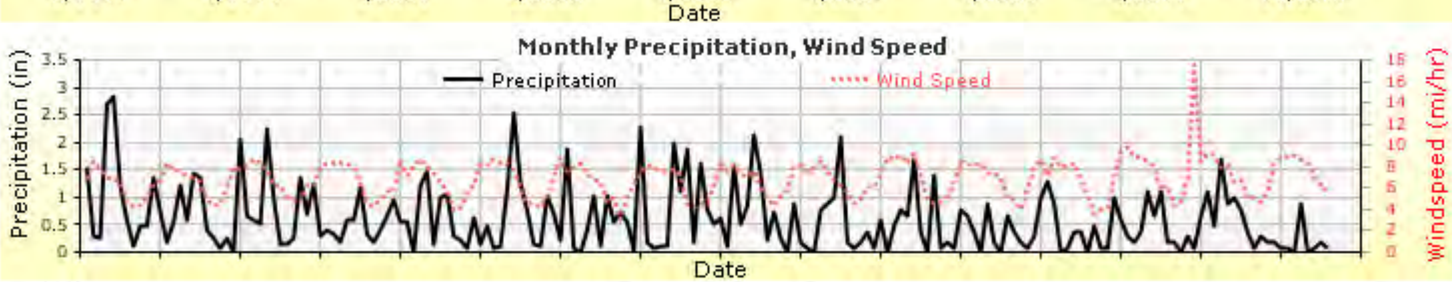
Annual Statistics:

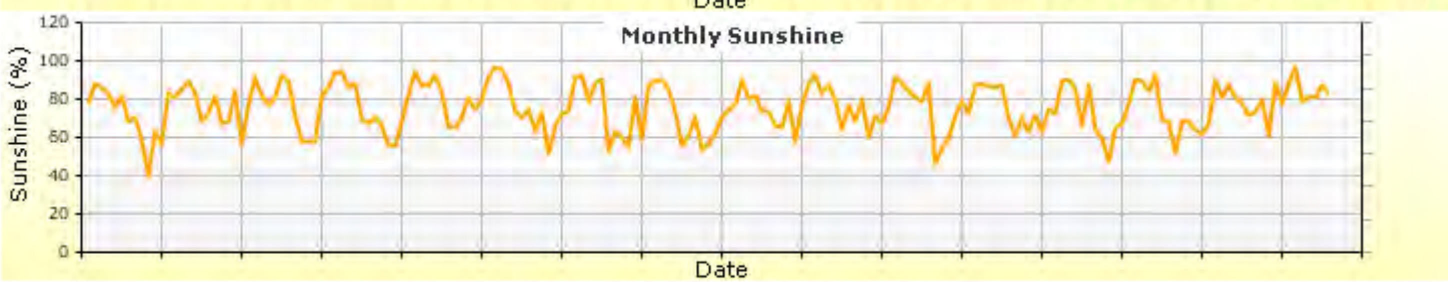
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

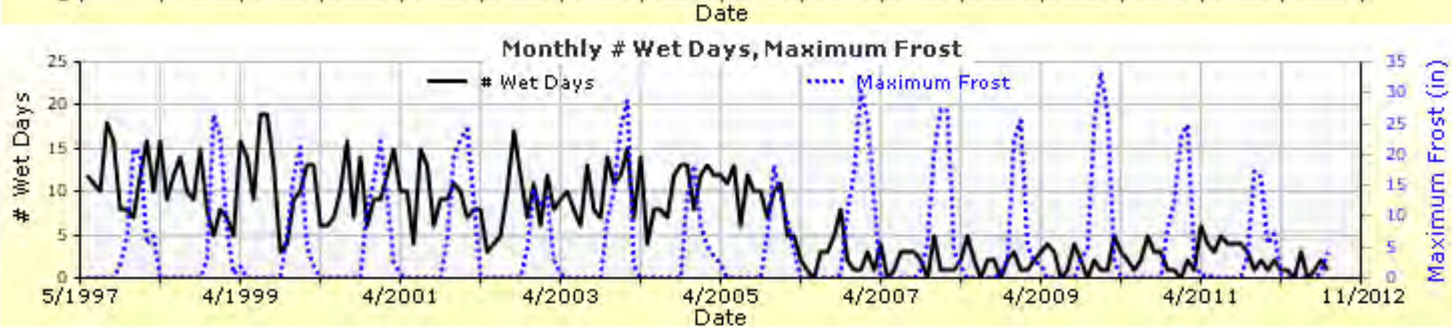
Water table depth (ft)	10.00

Monthly Climate Summary:

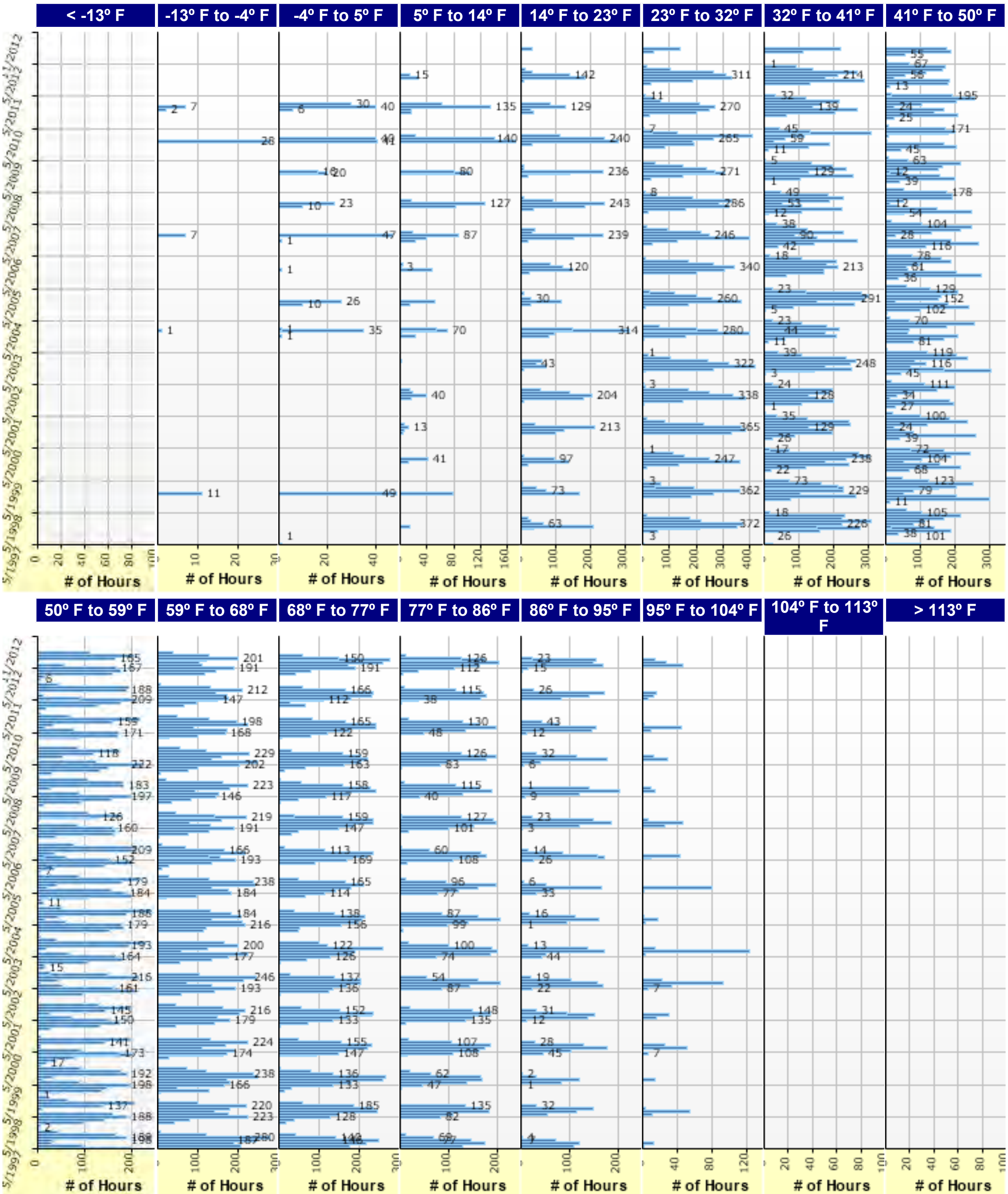








Hourly Air Temperature Distribution by Month:



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

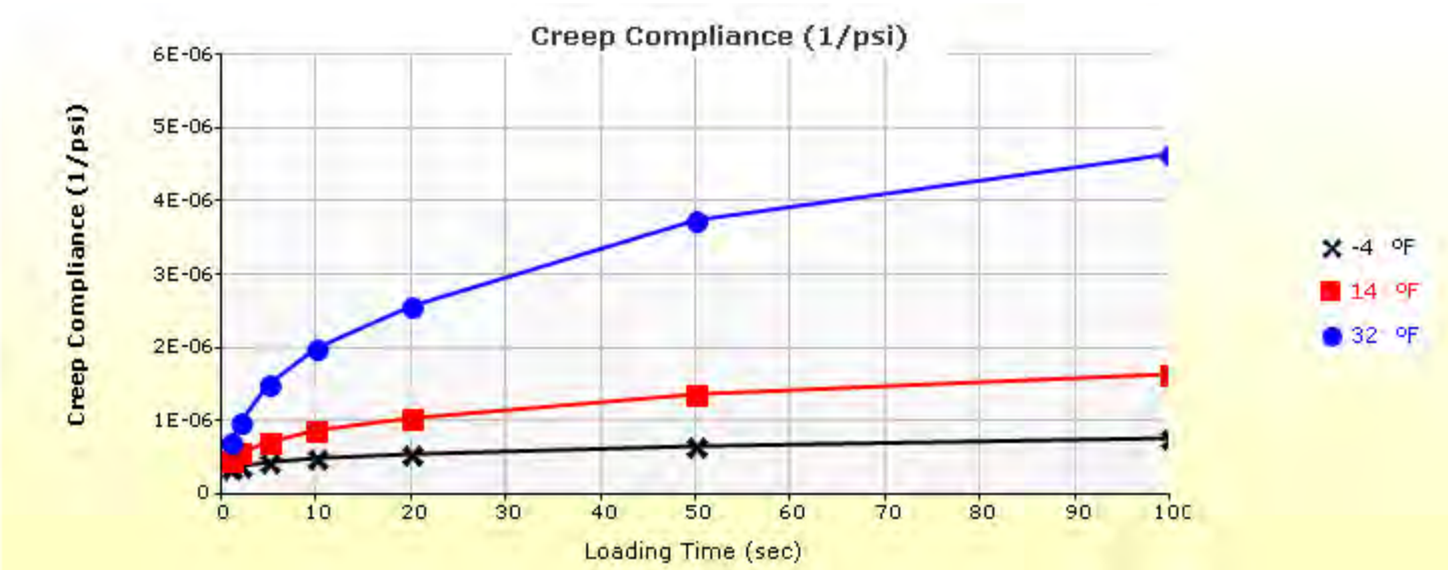
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4 (R-Value 10)	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

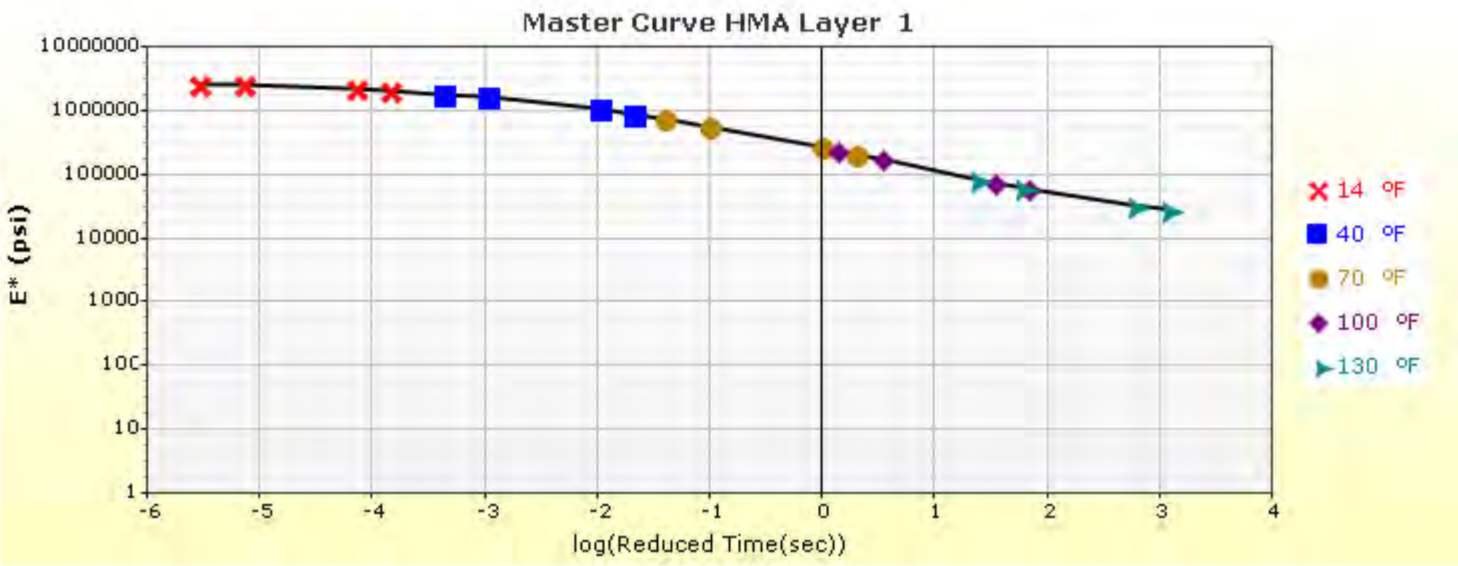
Indirect tensile strength at 14 ºF (psi)	519.00

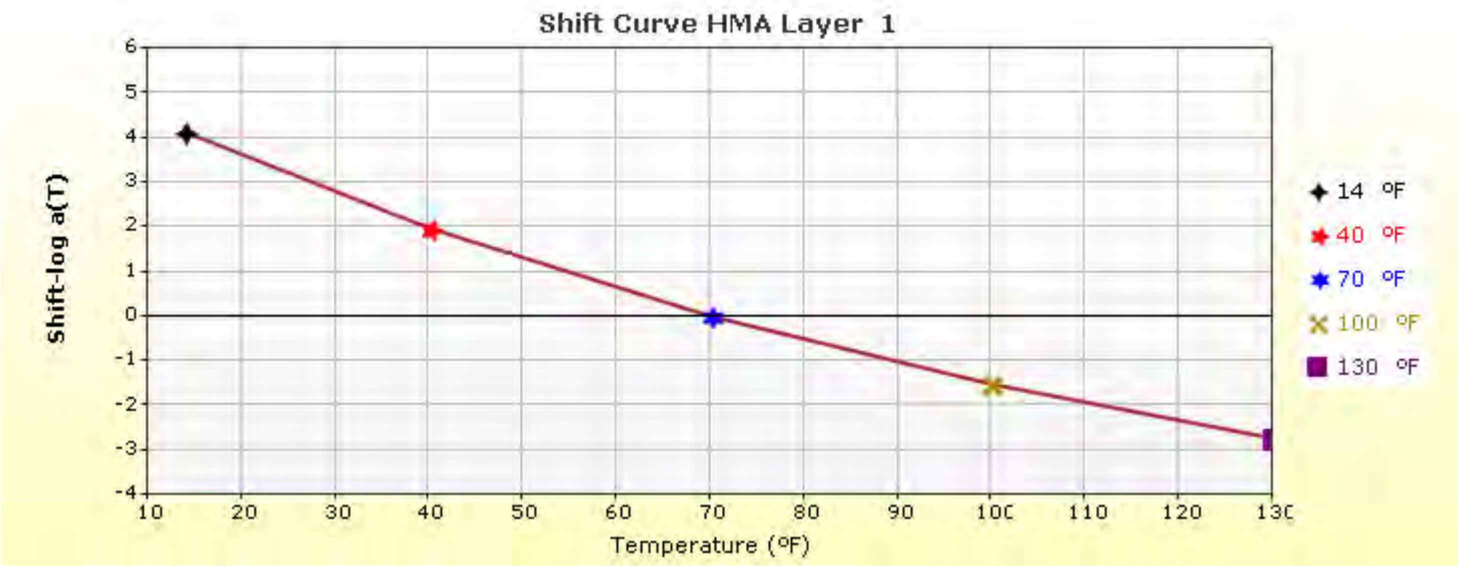
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

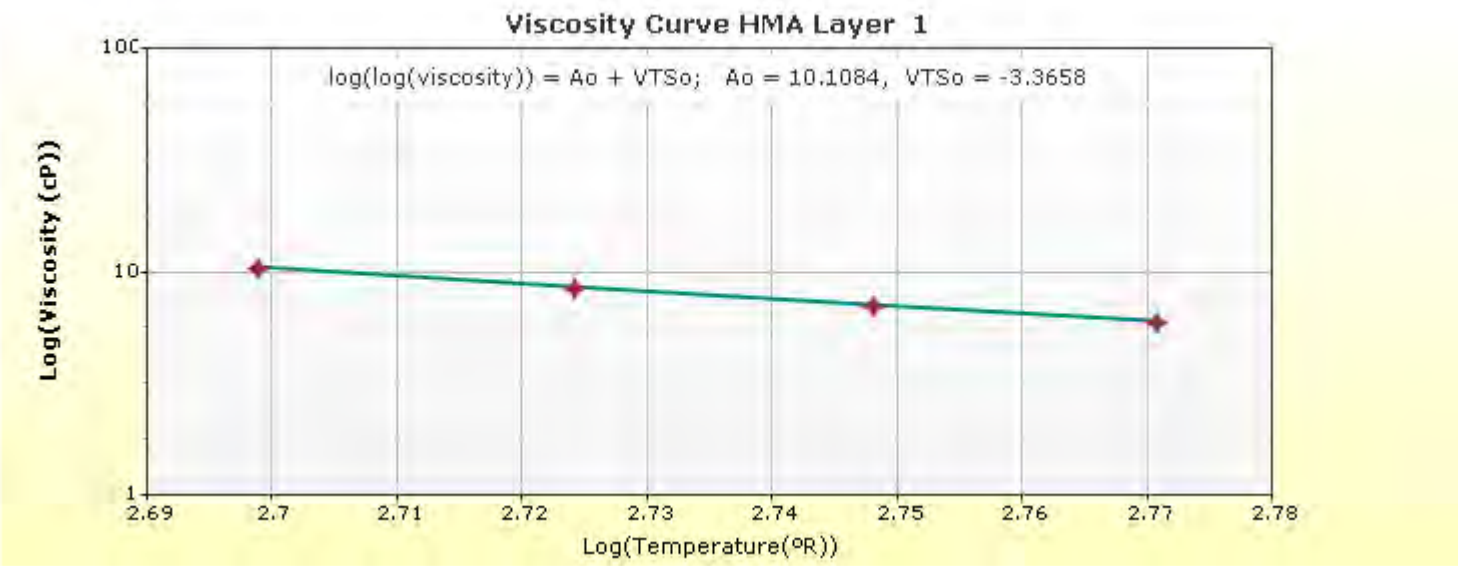
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



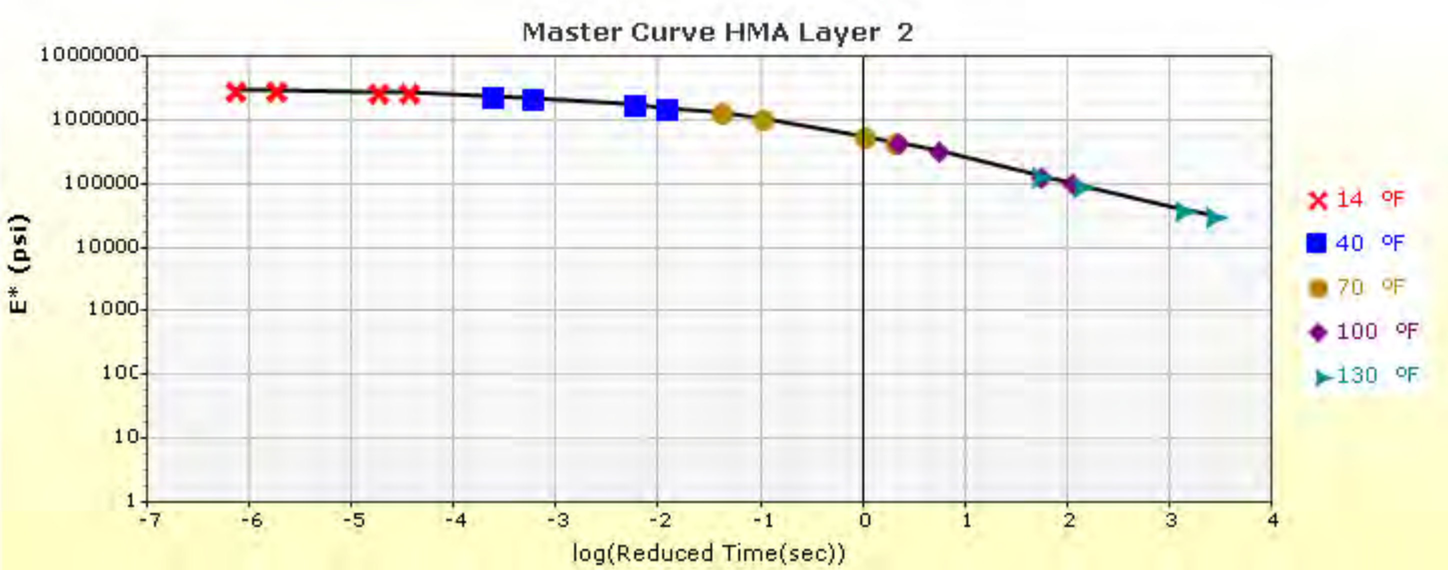
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

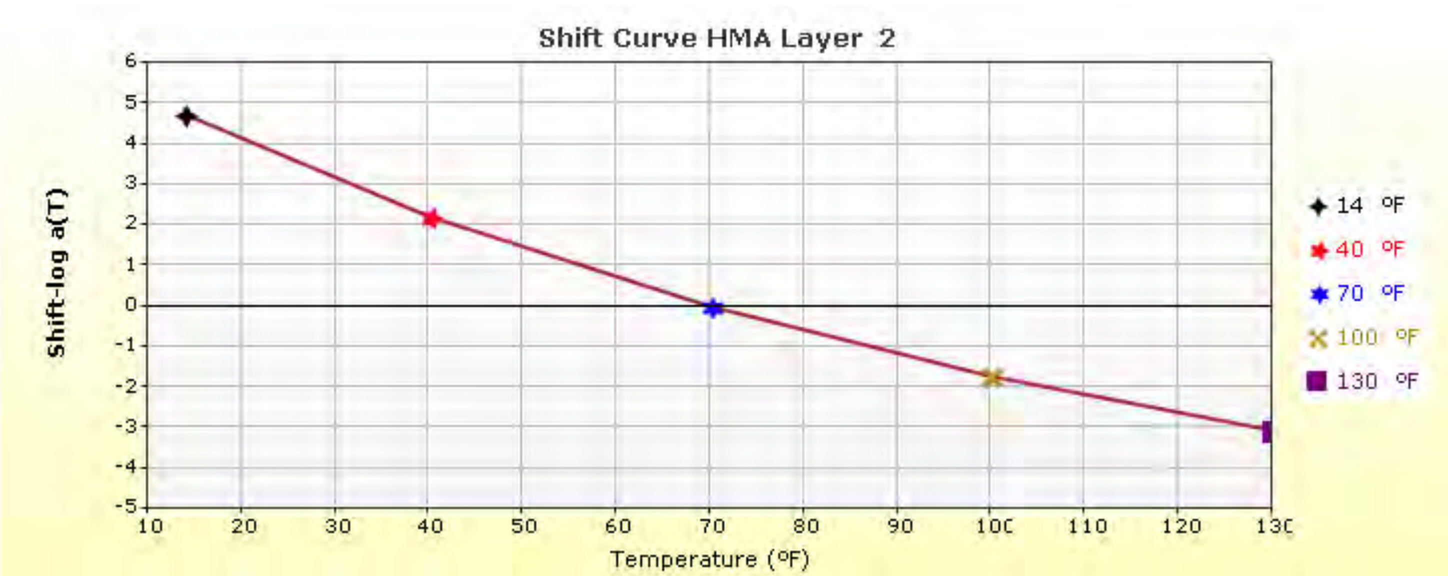


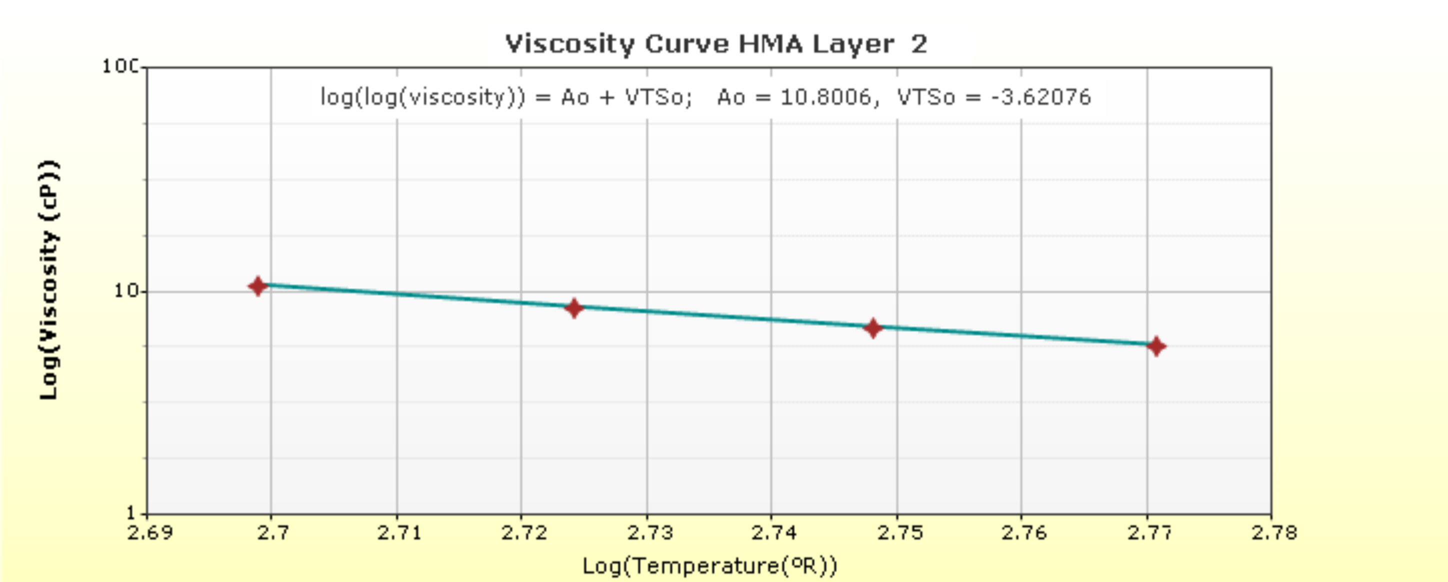




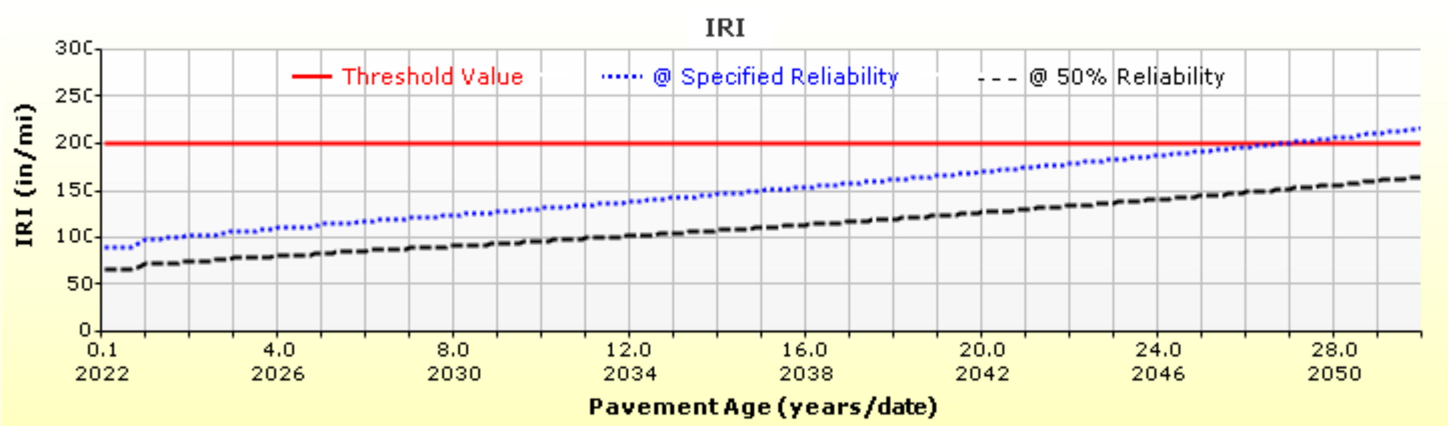
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

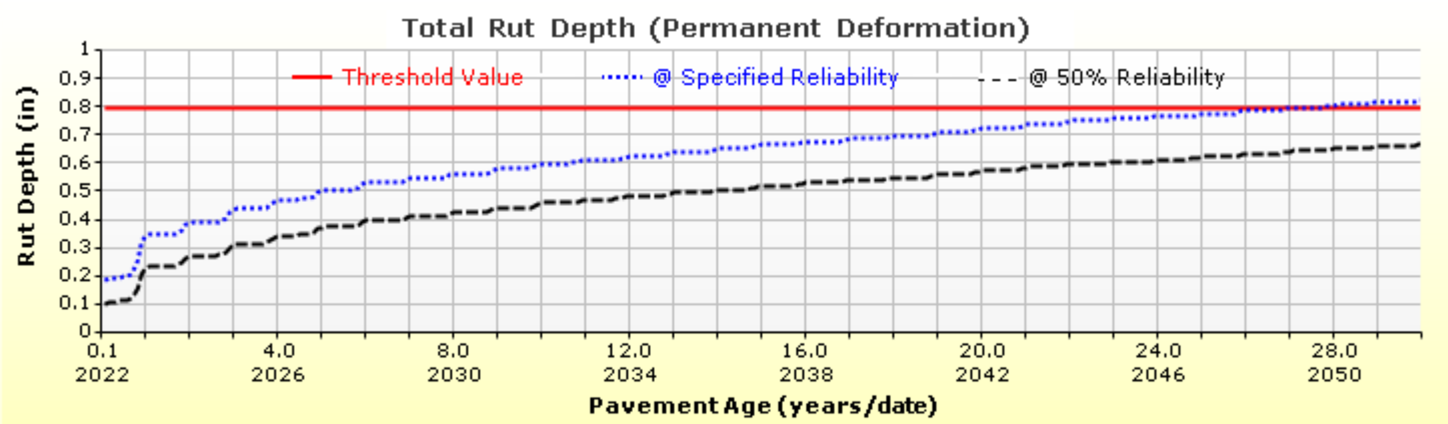


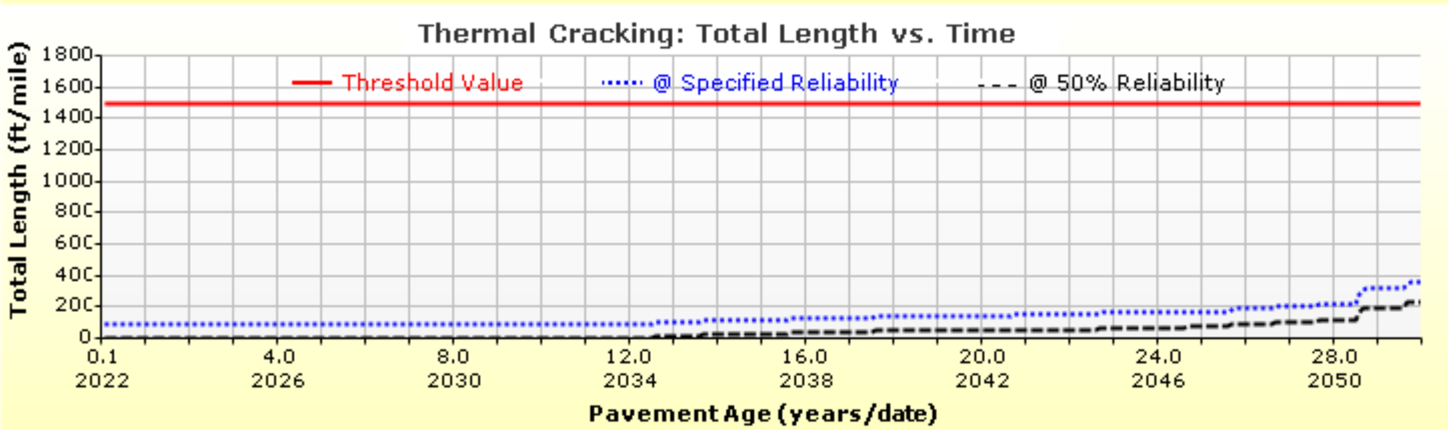


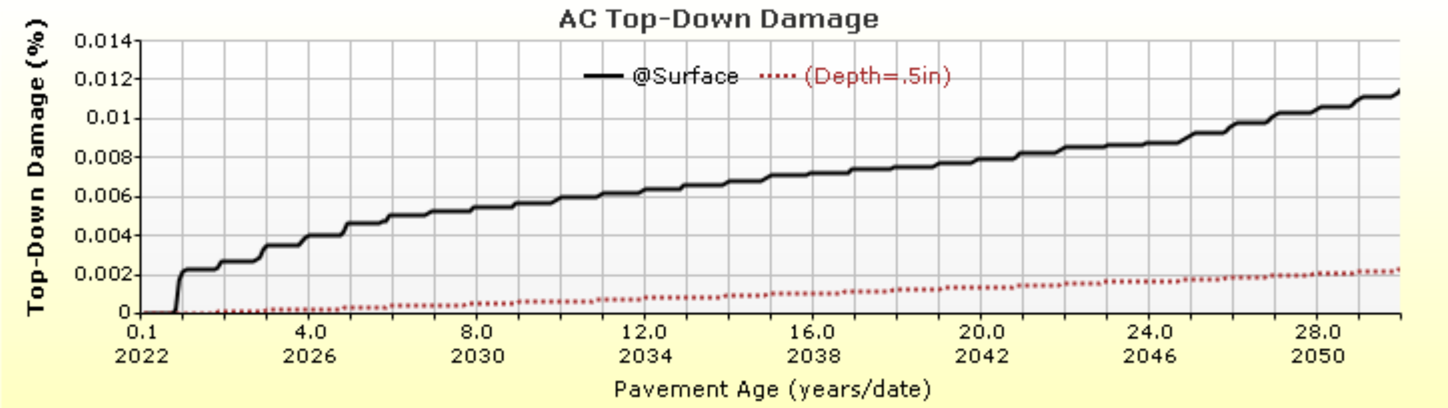


Analysis Output Charts

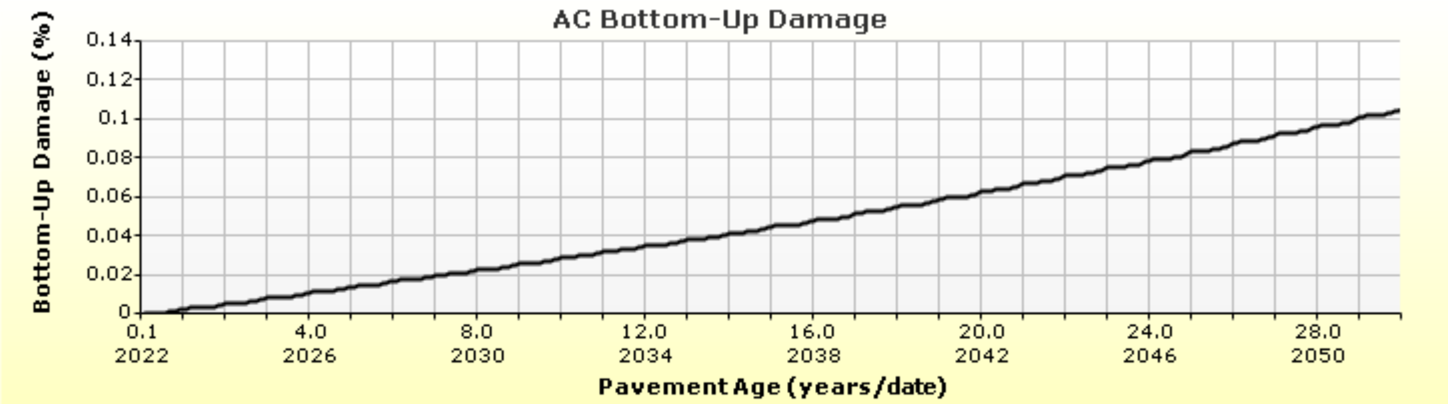




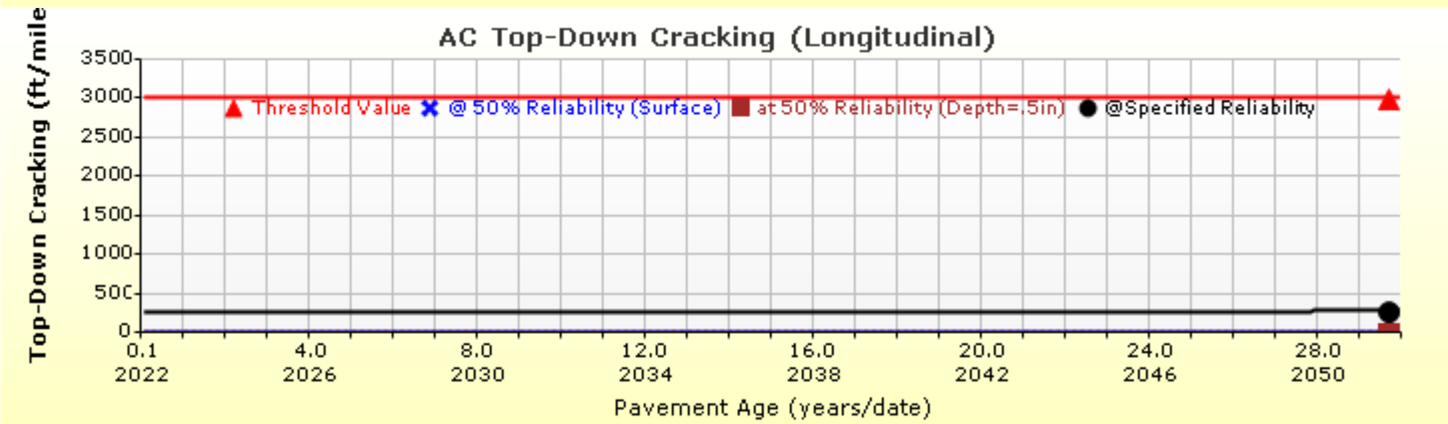




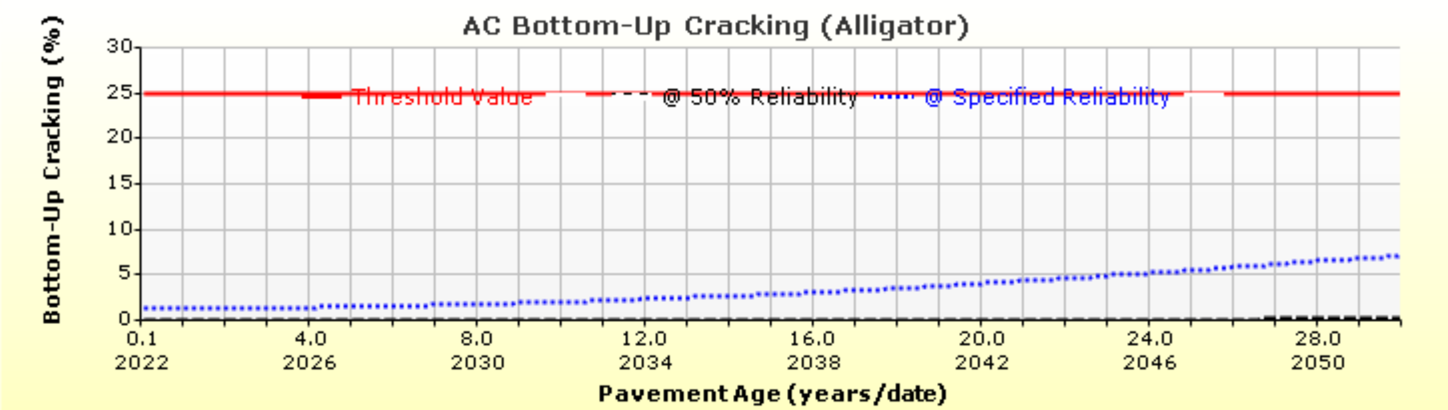
AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
Pavement Age (years/date)



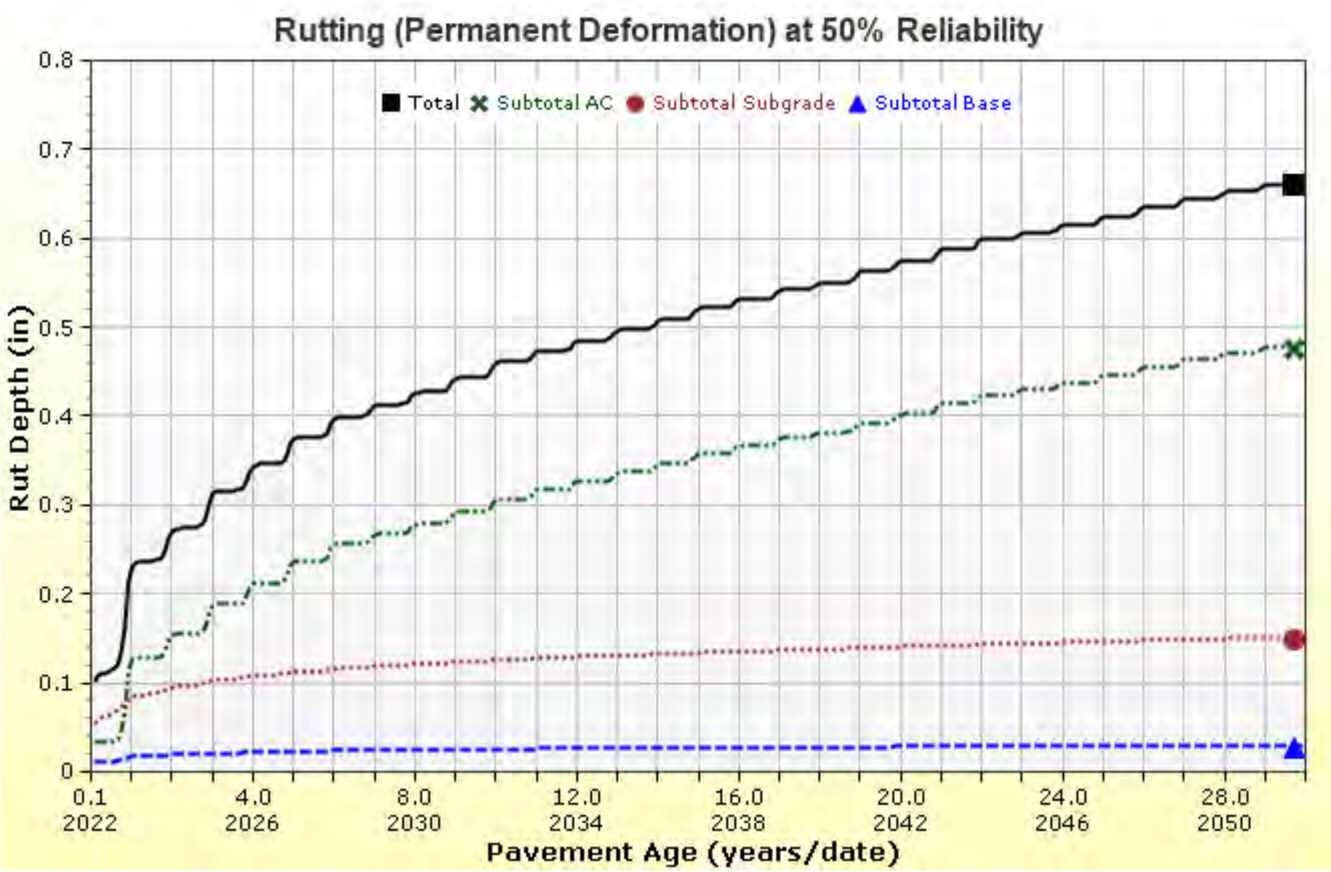
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



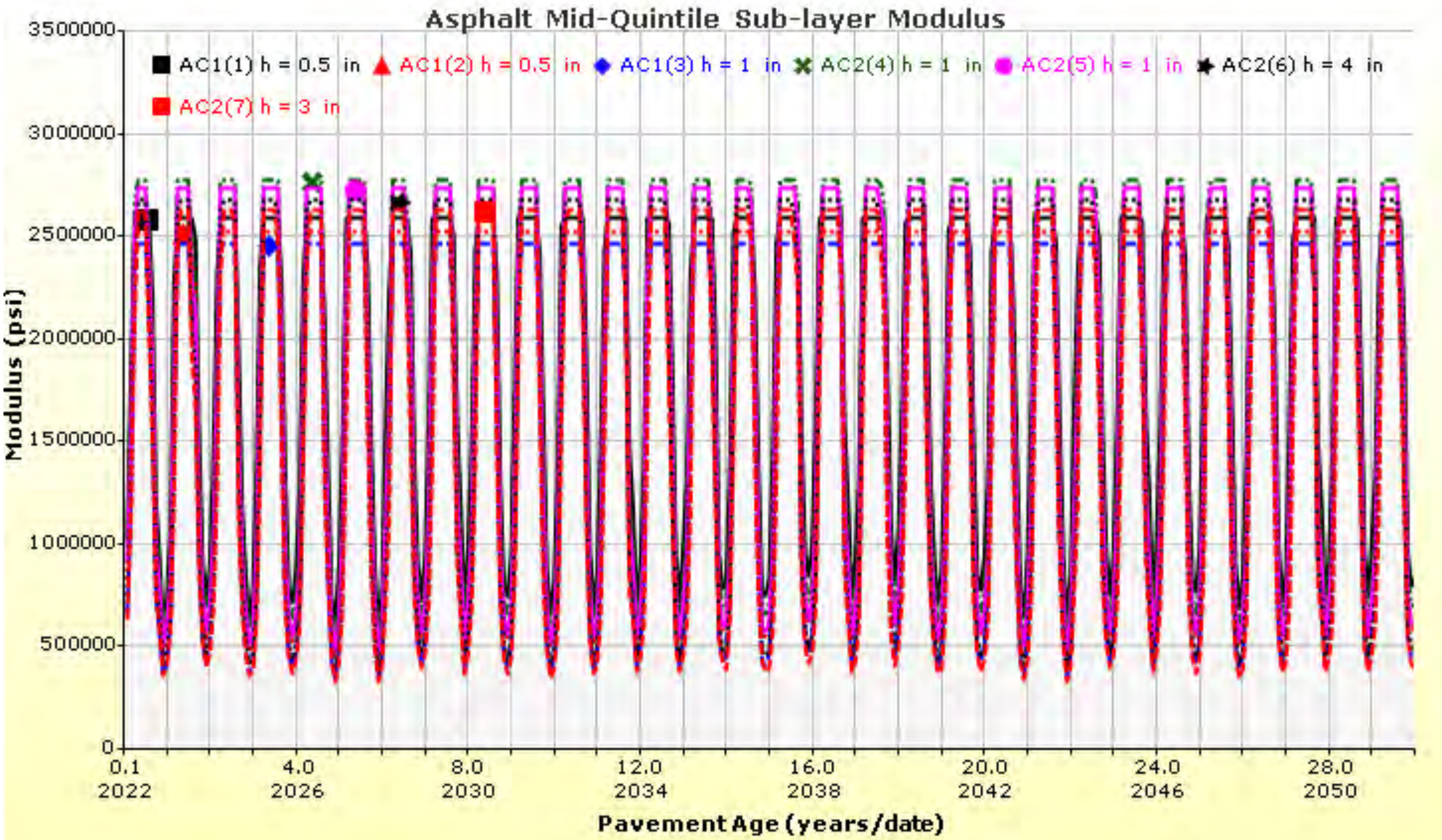
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Pavement Age (years/date)



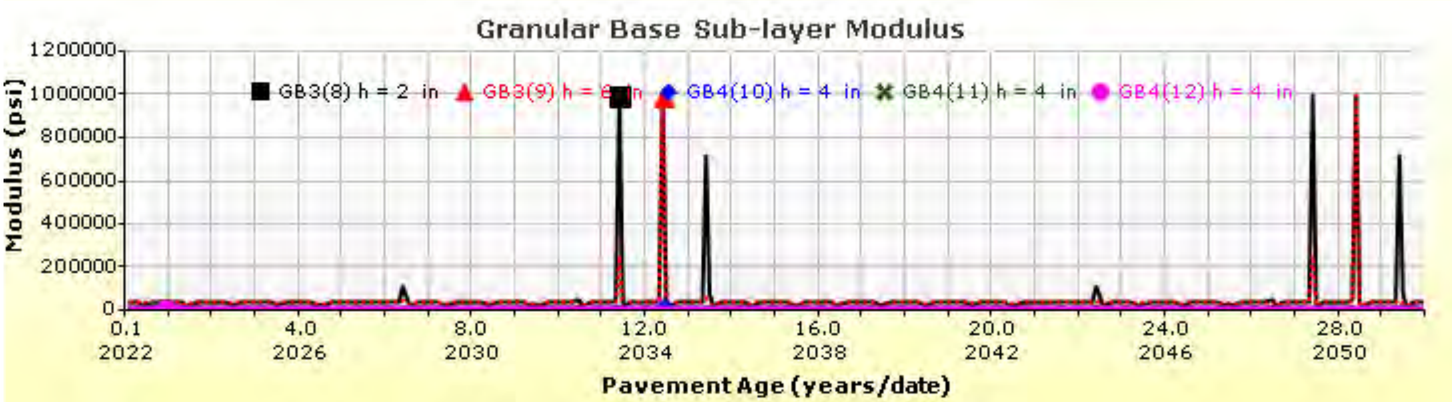
AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Pavement Age (years/date)



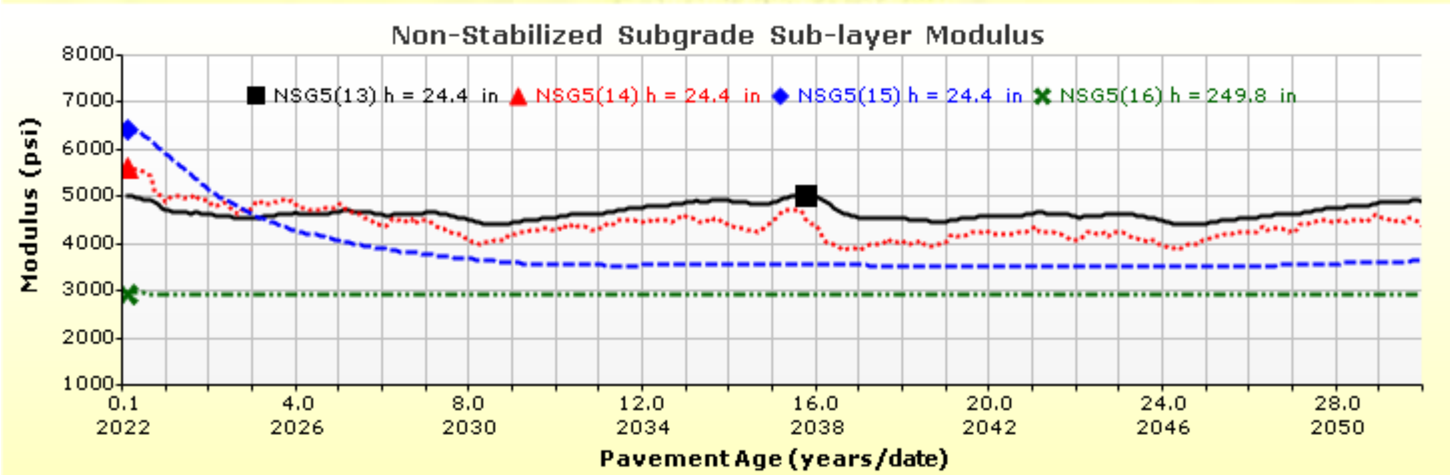
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



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 in
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 8 in
GB4(10) h = 4 in
GB4(11) h = 4 in
GB4(12) h = 4 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 24.4 in
NSG5(14) h = 24.4 in
NSG5(15) h = 24.4 in
NSG5(16) h = 249.8 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

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	1687360	2134249	2493389	2608869
40	697463	1127680	1612900	1802220
70	173403	334774	616373	765125
100	54259	93163	175106	227742
130	27890	38645	60413	74657

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(100) PG 64-28
Description of object	Mix ID # FS1959
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	0

Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

Asphalt		
Thickness (in)	9.0	
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 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	41

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 : A-1-b

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

APPENDIX G1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD & F ½ ROAD INTERSECTION

PCCP F.5 & 25 Road intersection

File Name: C:\Users\RSPavement\Documents\PMED Designs\My ME Design\Projects\F.5 Road\PCCP F.5 & 25 Road intersection.dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2022
Traffic opening: August, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	9.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	12.0
Subgrade	A-4 (R-Value 10)	Semi-infinite

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

Traffic

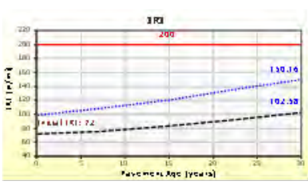
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	2,950
2037 (15 years)	8,507,270
2052 (30 years)	20,298,300

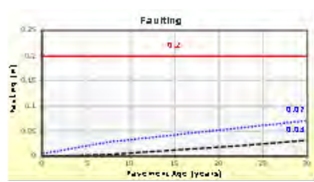
Design Outputs

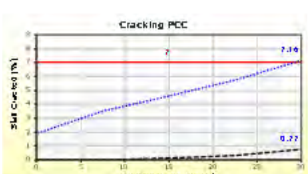
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	150.16	90.00	99.57	Pass
Mean joint faulting (in)	0.20	0.07	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	7.16	90.00	89.43	Fail

Distress Charts





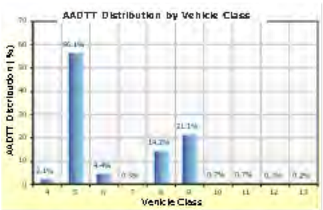


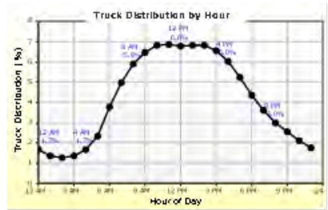
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

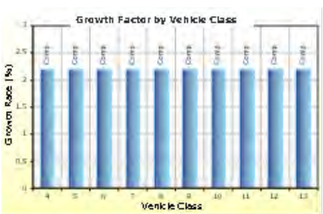
Traffic Inputs

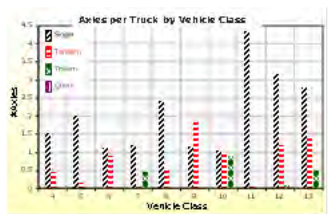
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	2,950	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)	25.0

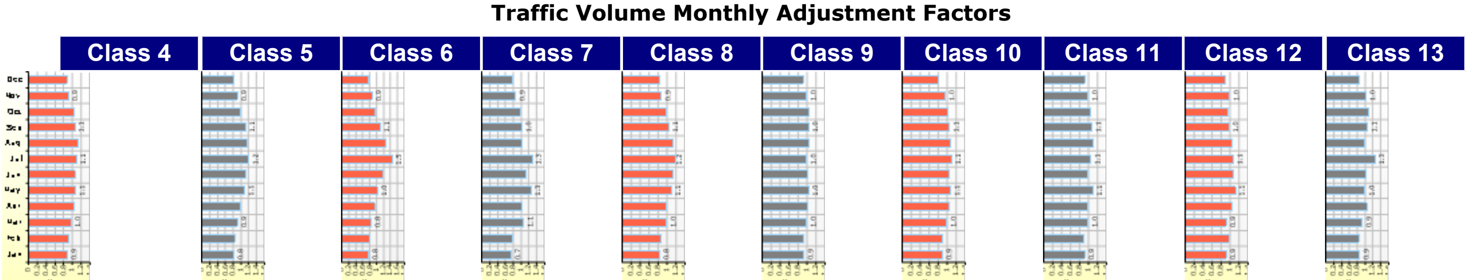








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

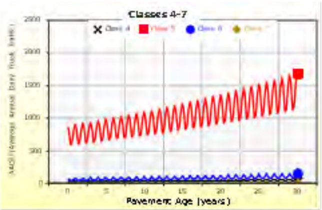
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

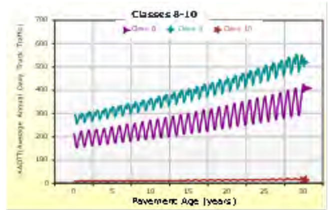
Number of Axles per Truck

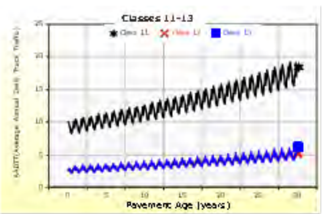
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

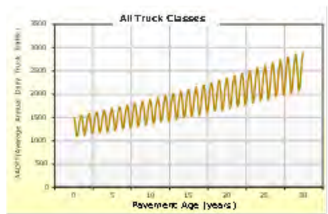
AADTT (Average Annual Daily Truck Traffic) Growth

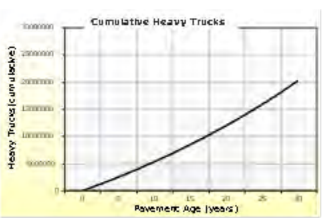
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

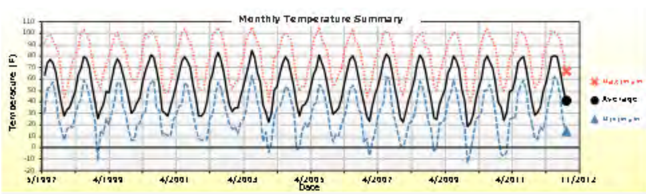
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

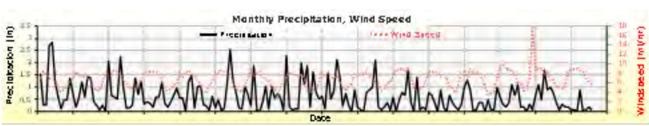
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

Water table depth (ft) 10.00

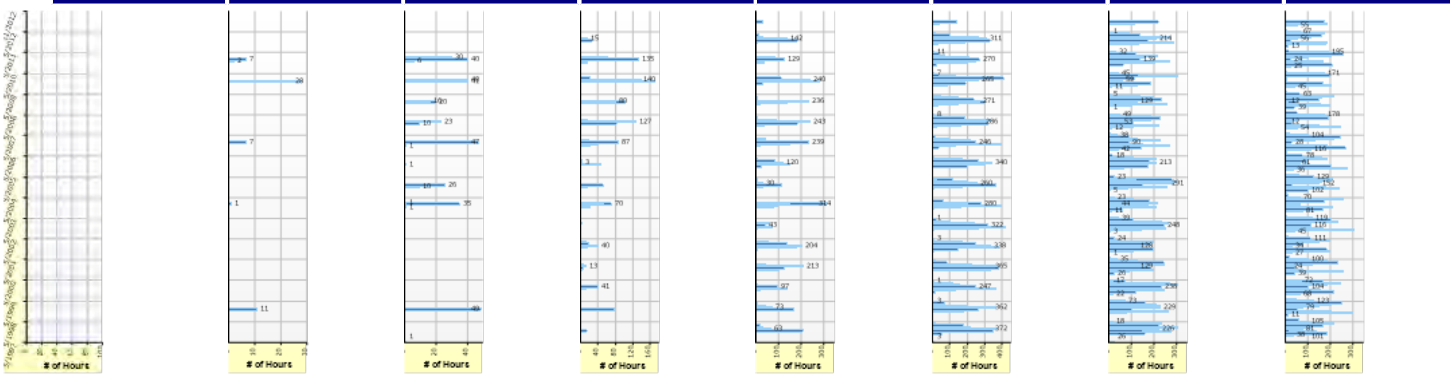
Monthly Climate Summary:



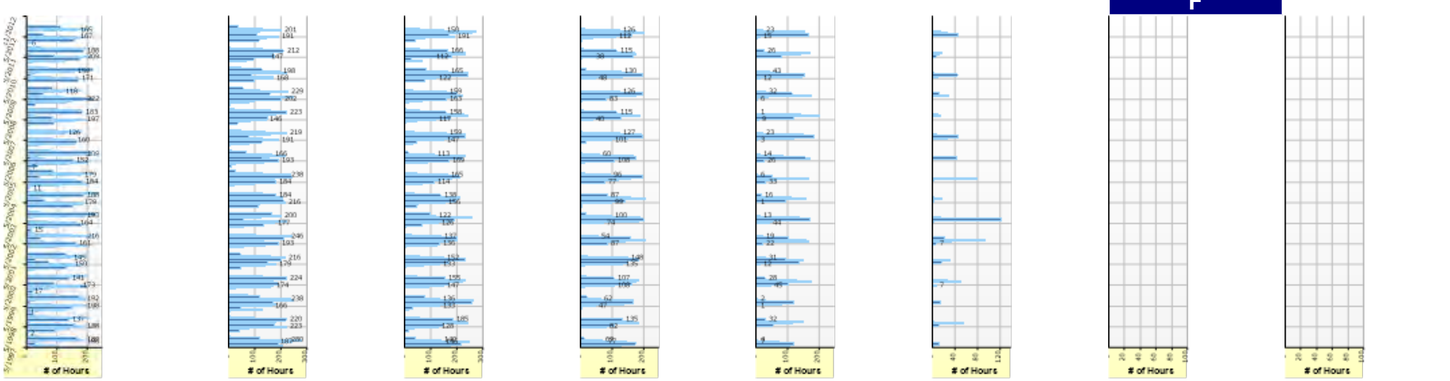


Hourly Air Temperature Distribution by Month:

< -13º F	-13º F to -4º F	-4º F to 5º F	5º F to 14º F	14º F to 23º F	23º F to 32º F	32º F to 41º F	41º F to 50º F



50º F to 59º F	59º F to 68º F	68º F to 77º F	77º F to 86º F	86º F to 95º F	95º F to 104º F	104º F to 113º F	> 113º F



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)	12.00

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

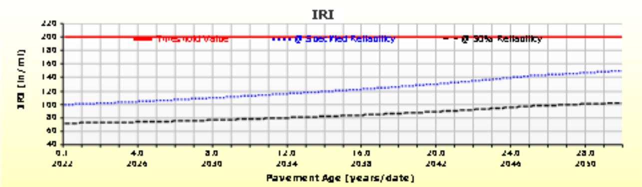
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

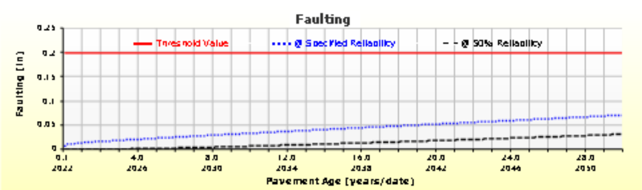
Sealant type	Other(Including No Sealant... Liquid... Silicone)

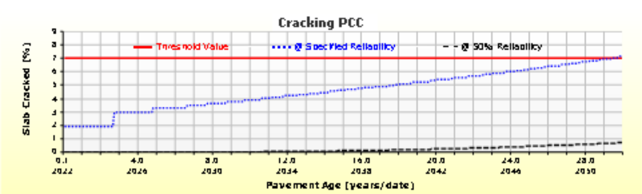
Erodibility index	4

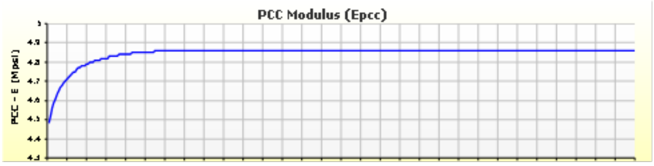
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

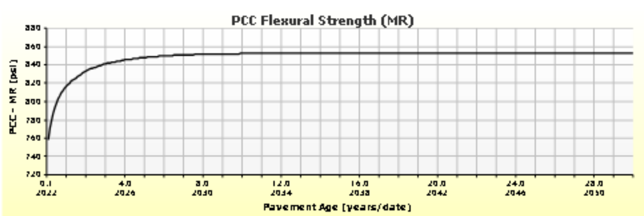




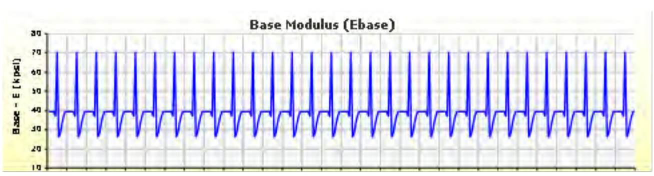




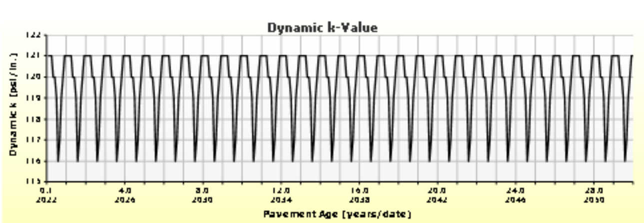
PCC Modulus (Epcc)
PCC - E (Mpsi)



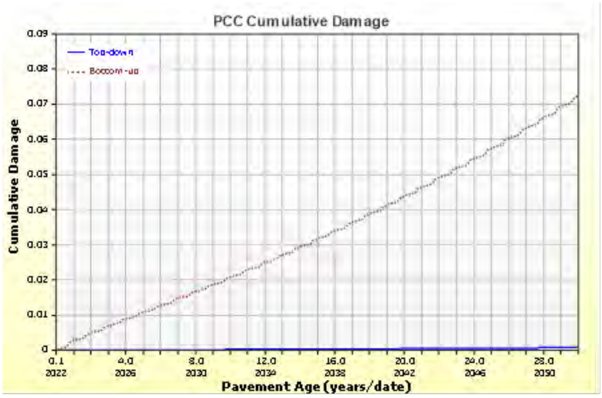
PCC Flexural Strength (MR)
PCC - MR (psi)
Pavement Age (years/date)



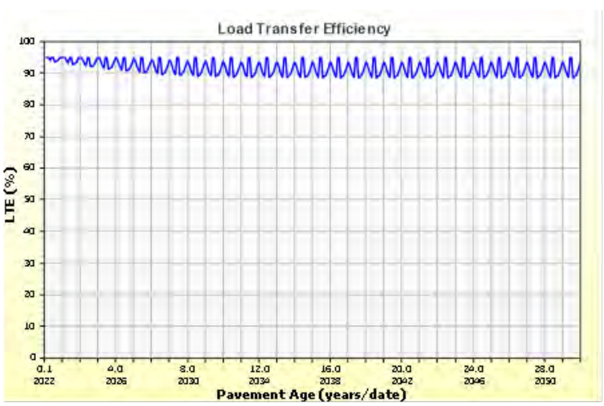
Base Modulus (Ebase)
Base - E (kpsi)



Dynamic k-Value
Dynamic k (psi/in.)
Pavement Age (years/date)



PCC Cumulative Damage
Cumulative Damage
Pavement Age (years/date)



Load Transfer Efficiency
LTE (%)
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	9.0
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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-4 (R-Value 10)

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 (R-Value 10)
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?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-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 H

20 and 30-YEAR
FLEXIBLE ME-PAVEMENT DESIGN OUTPUT SHEETS
FORESIGHT CIRCLE AND F ¼ ROADS

Forsight Circle and F.25 Road HMA (20-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\Forsight Circle and F.25 Road HMA (20-year).dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Level 1 SX(75) PG 64-28	2.0
Flexible	R2 Level 1 SX(75) PG 64-22	4.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	12.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.8
Air voids (%)	5.7

Traffic

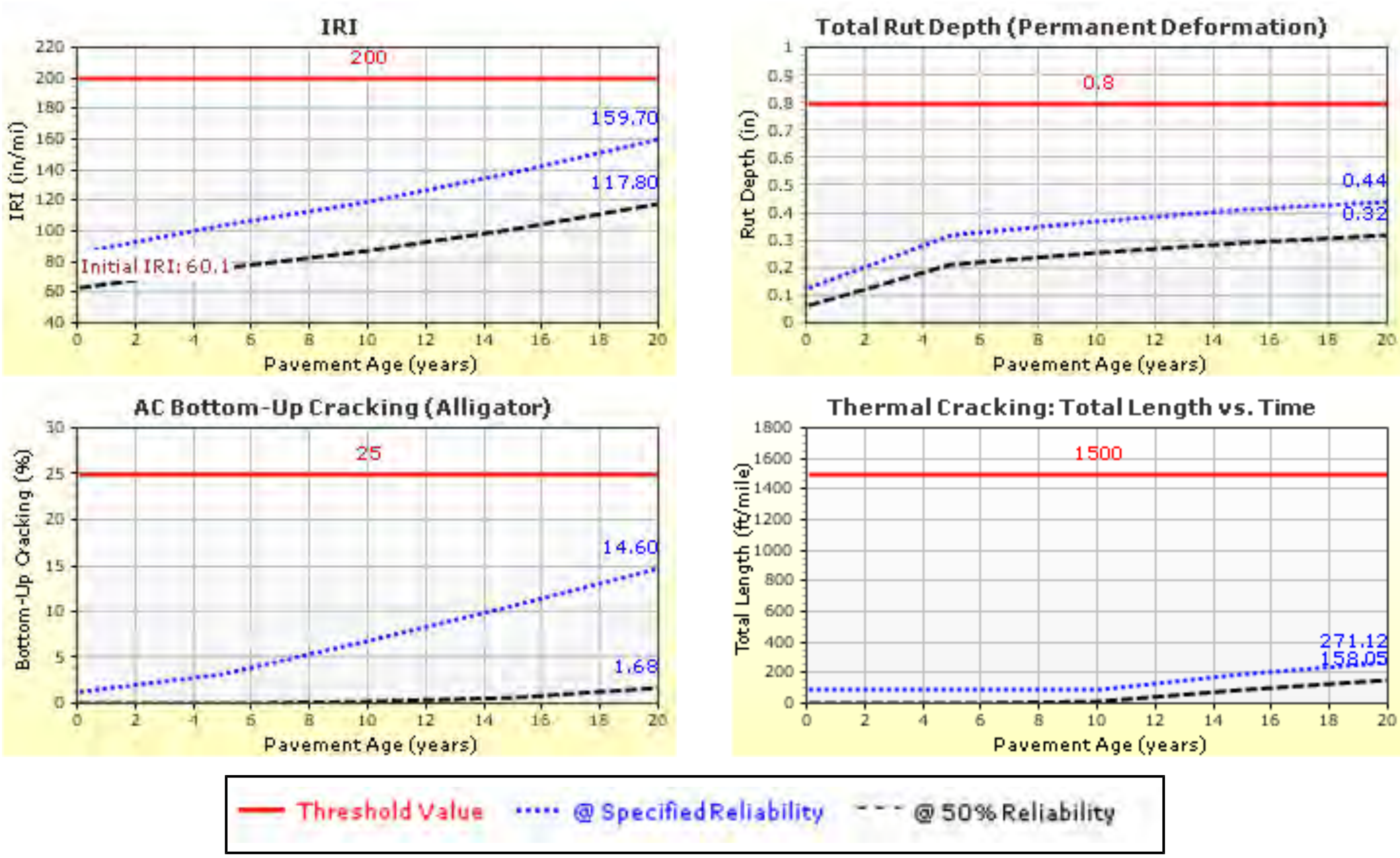
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	231
2032 (10 years)	559,410
2042 (20 years)	1,254,820

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	159.74	90.00	99.40	Pass
Permanent deformation - total pavement (in)	0.80	0.44	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	14.60	90.00	98.96	Pass
AC thermal cracking (ft/mile)	1500.00	271.12	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	282.89	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.29	90.00	100.00	Pass

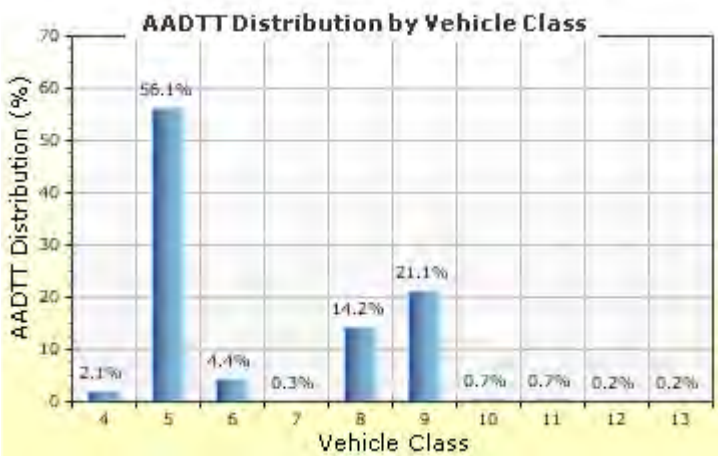
Distress Charts

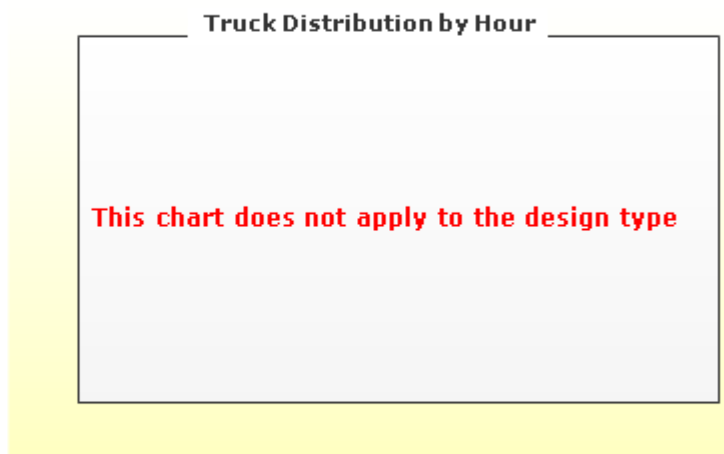


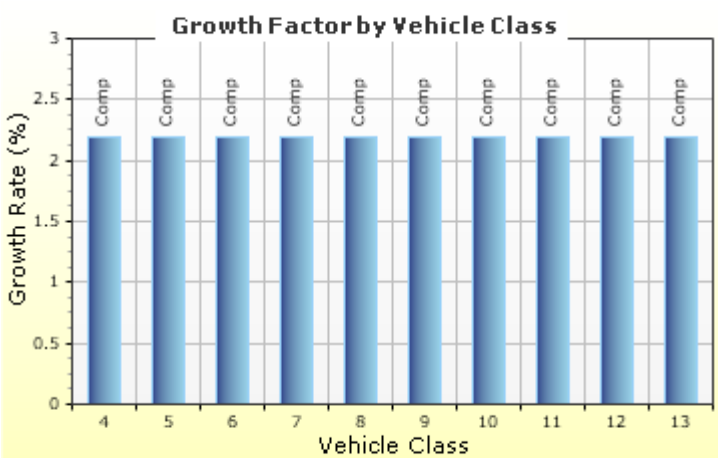
Traffic Inputs

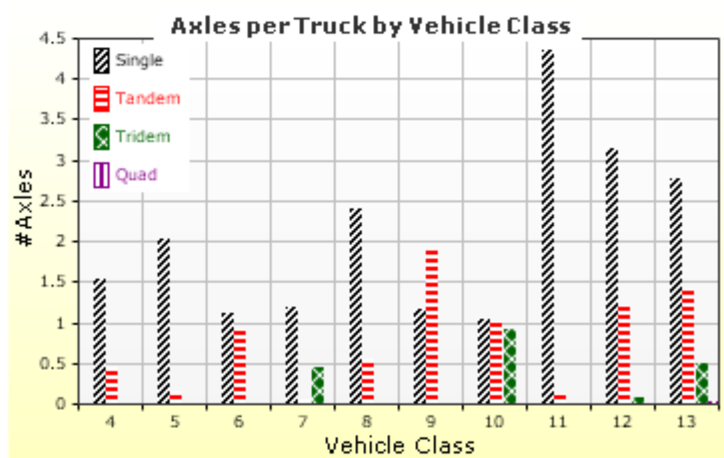
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	231	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)	25.0

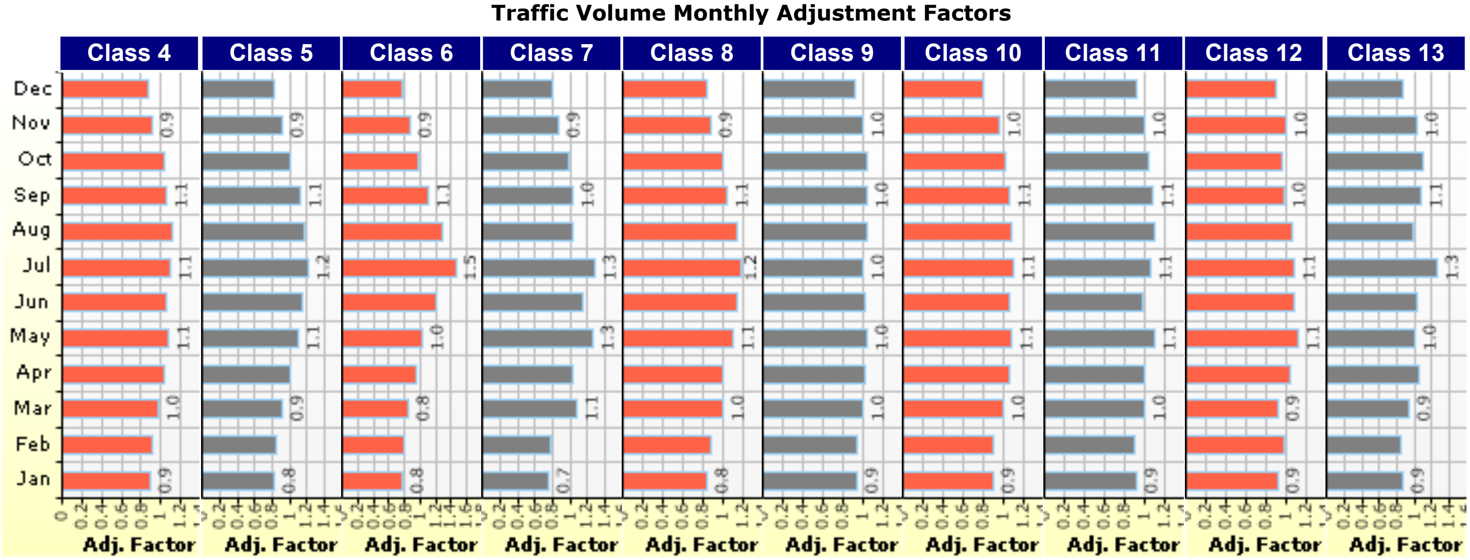








Traffic Volume Monthly Adjustment Factors



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

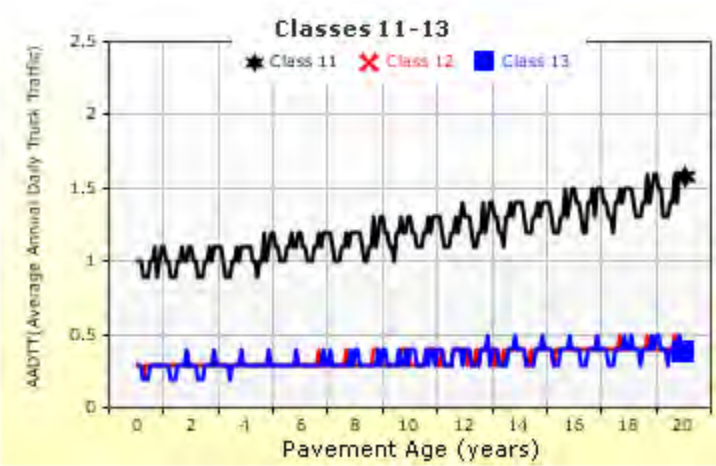
Wheelbase does not apply

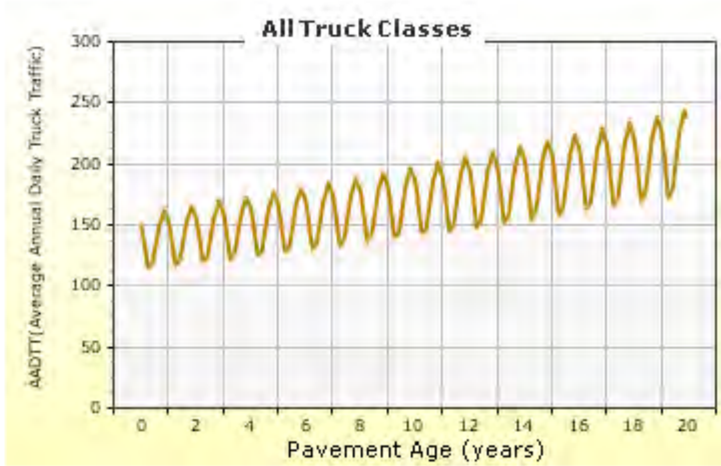
Number of Axles per Truck

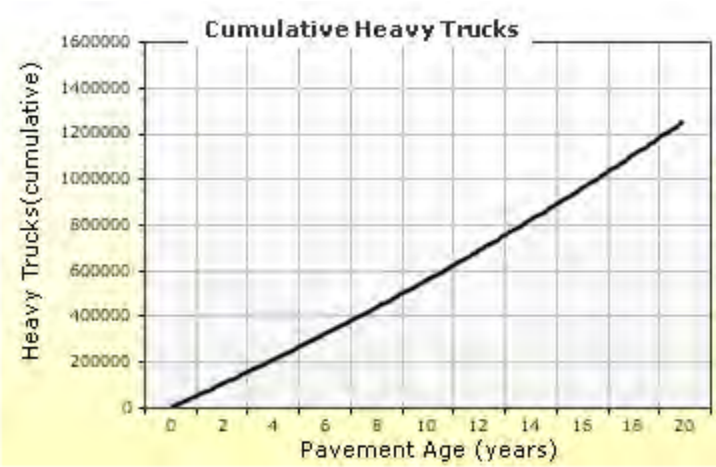
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**



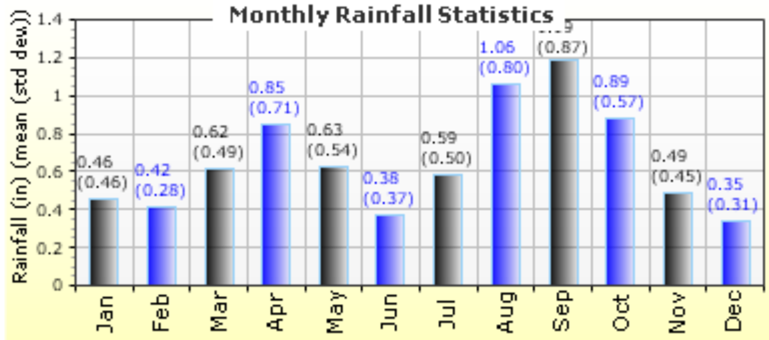




Climate Inputs

Climate Data Sources:

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

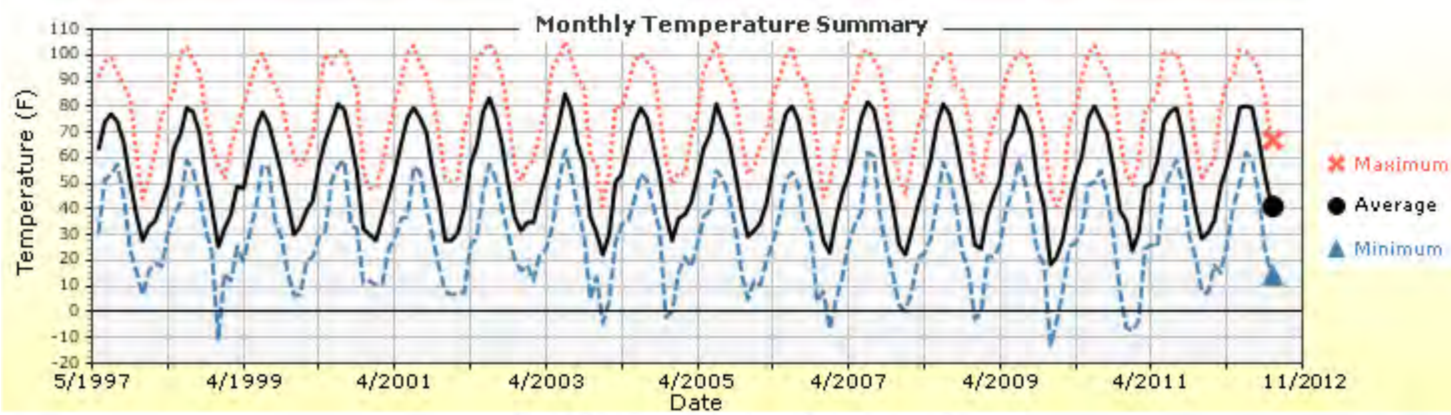


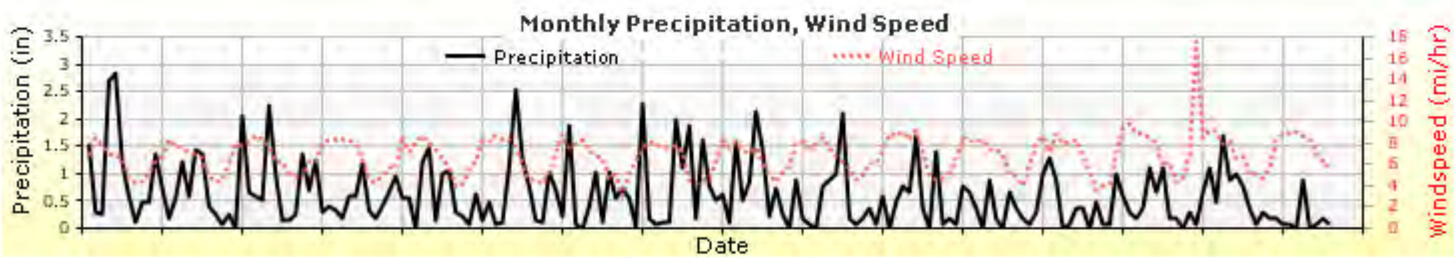
Annual Statistics:

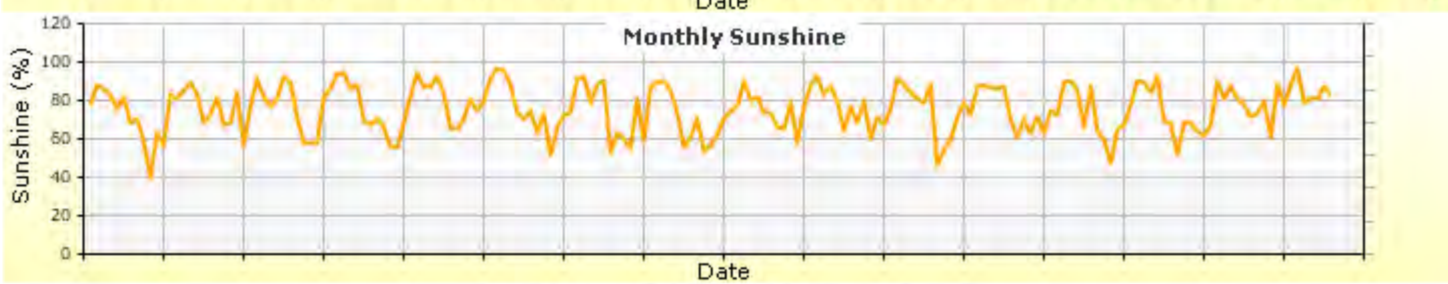
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

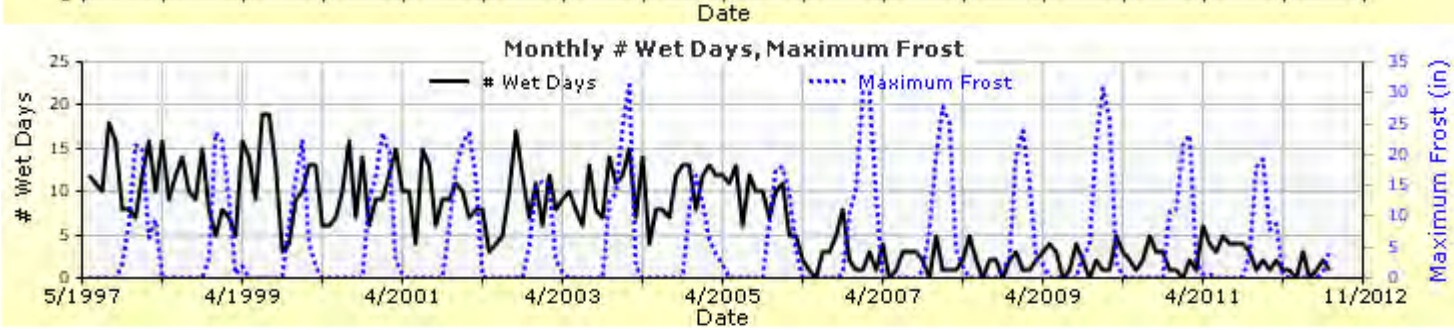
Water table depth (ft)	10.00

Monthly Climate Summary:





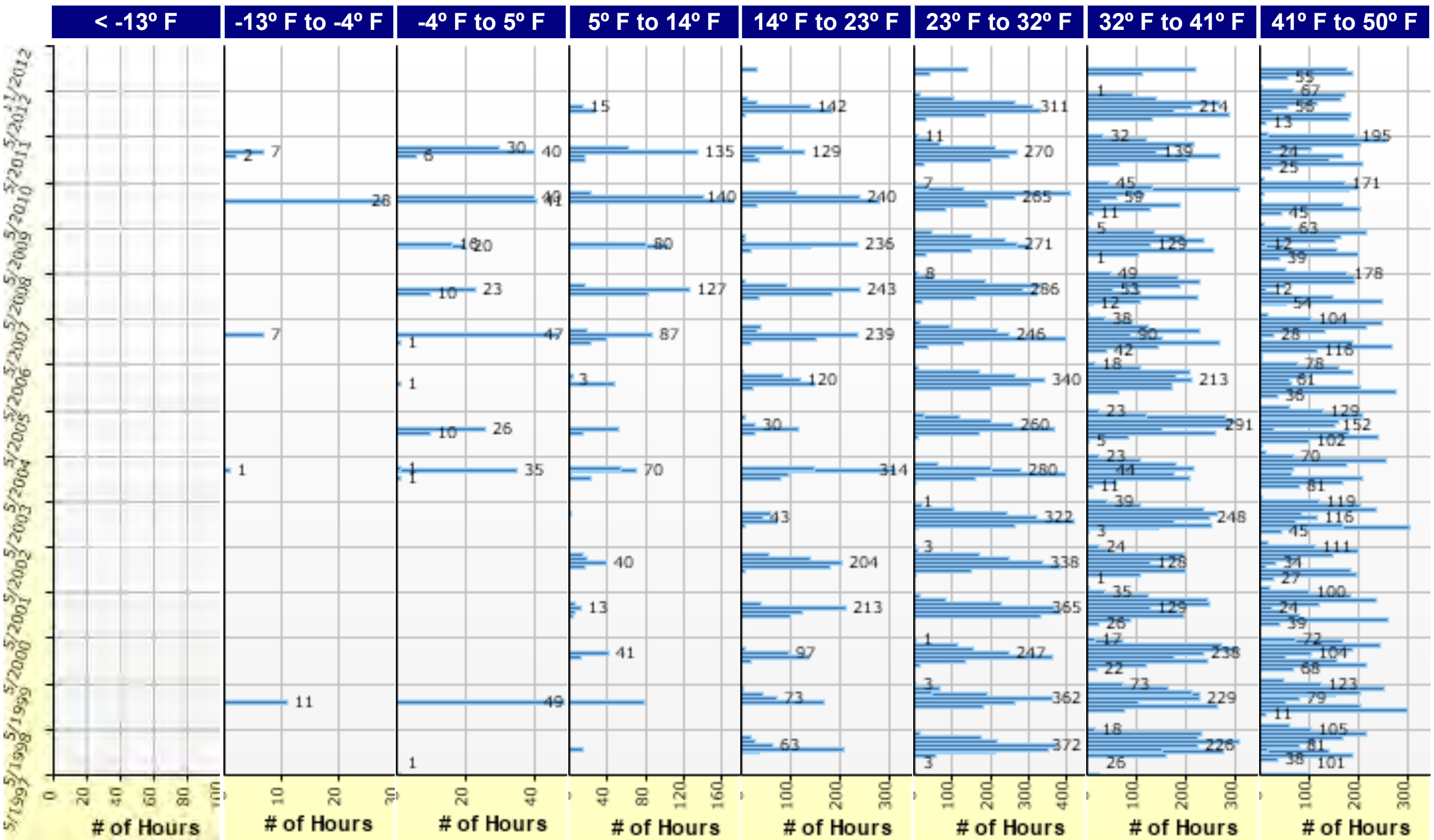


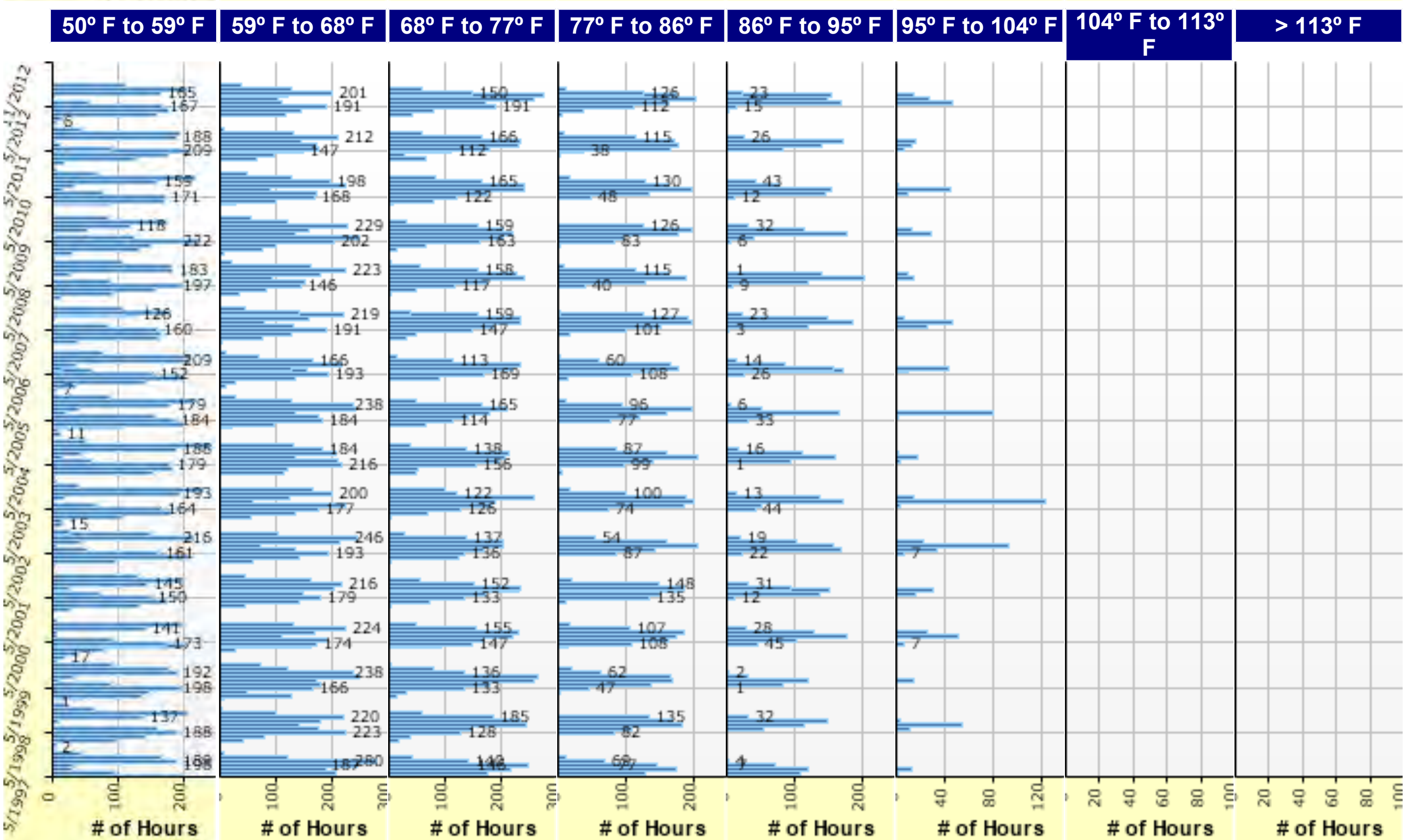


Forsight Circle and F.25 Road HMA (20-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\Forsight Circle and F.25 Road HMA (20-year).dgpx

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

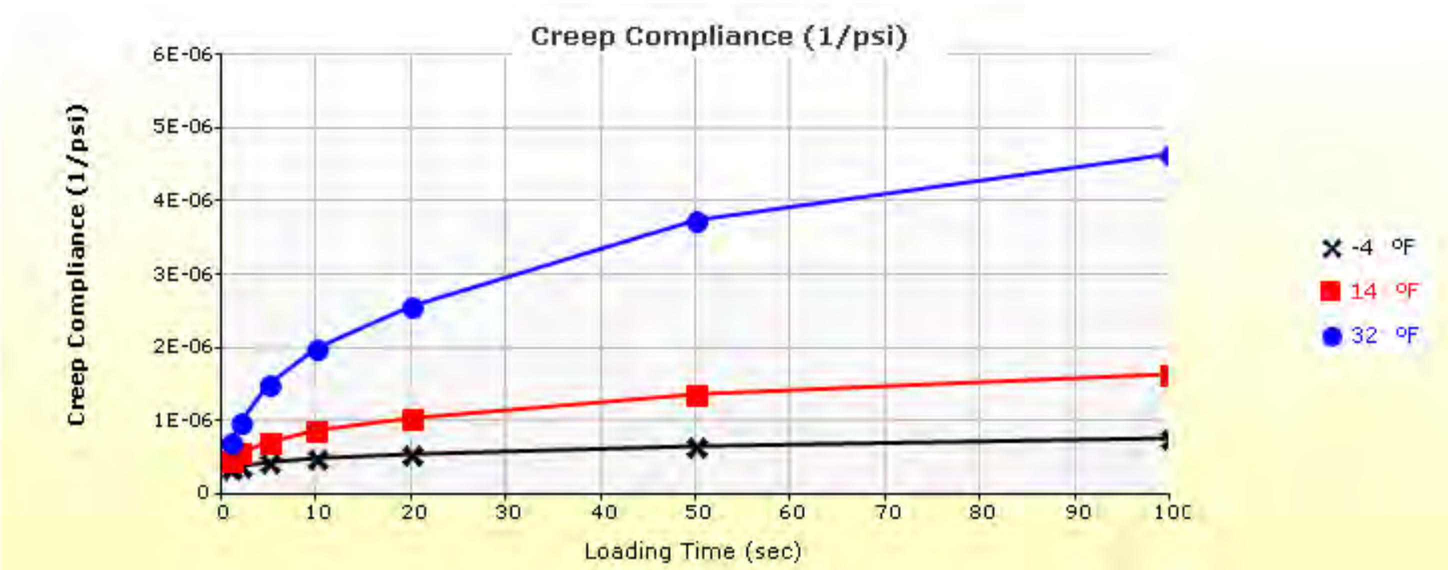
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Level 1 SX(75) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (75) 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 : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6	Subgrade (5)	-

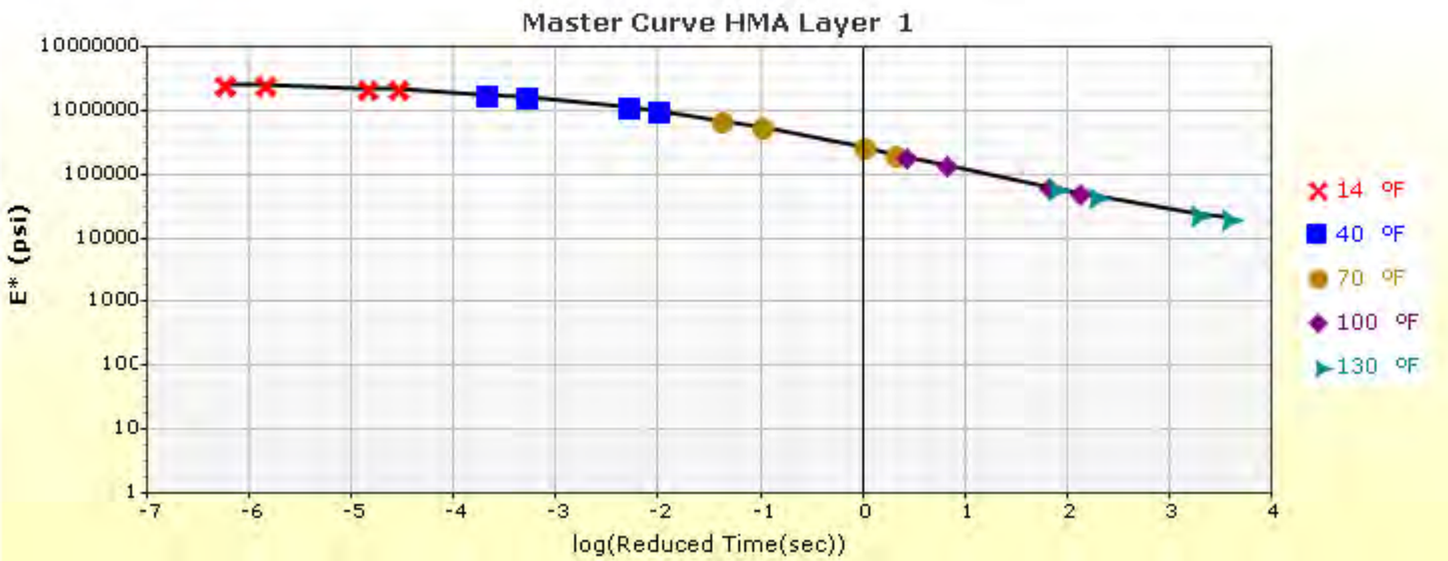
Thermal Cracking (Input Level: 1)

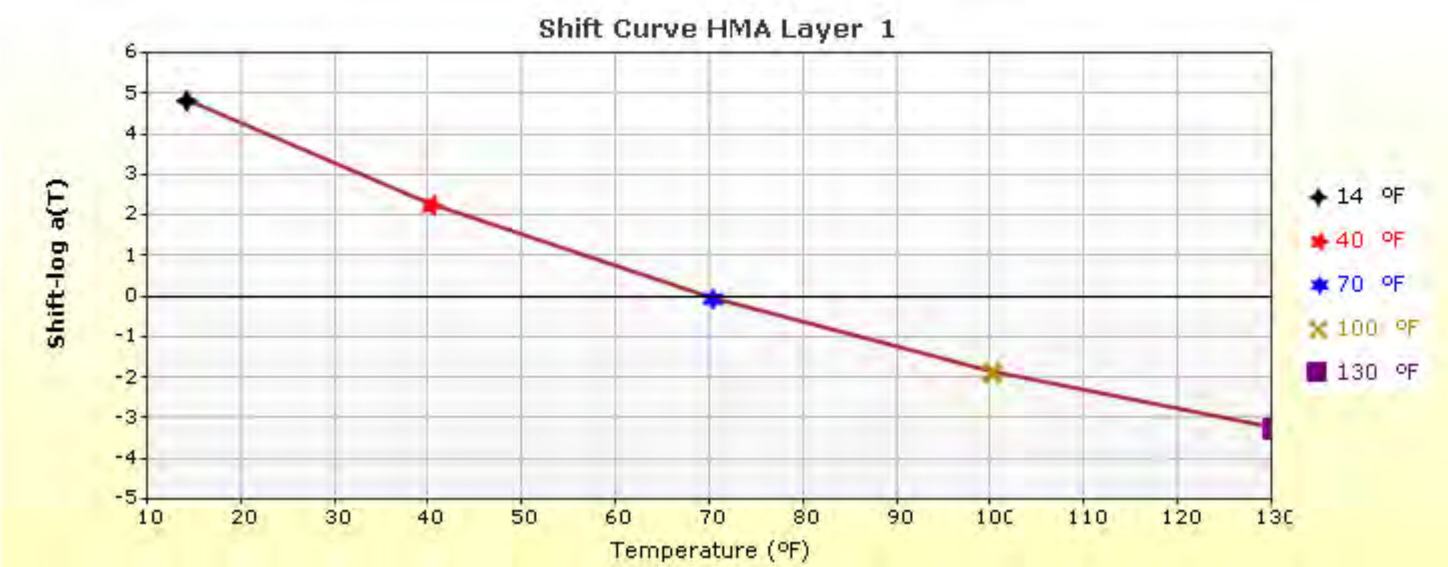
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	17.5

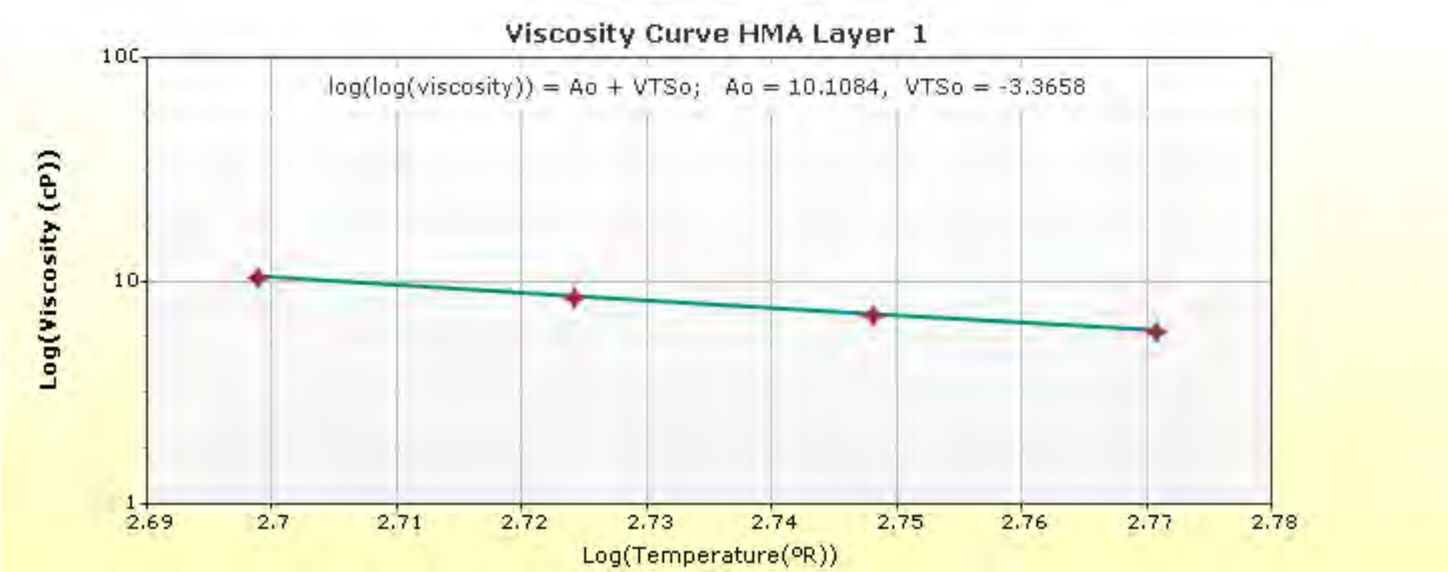
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



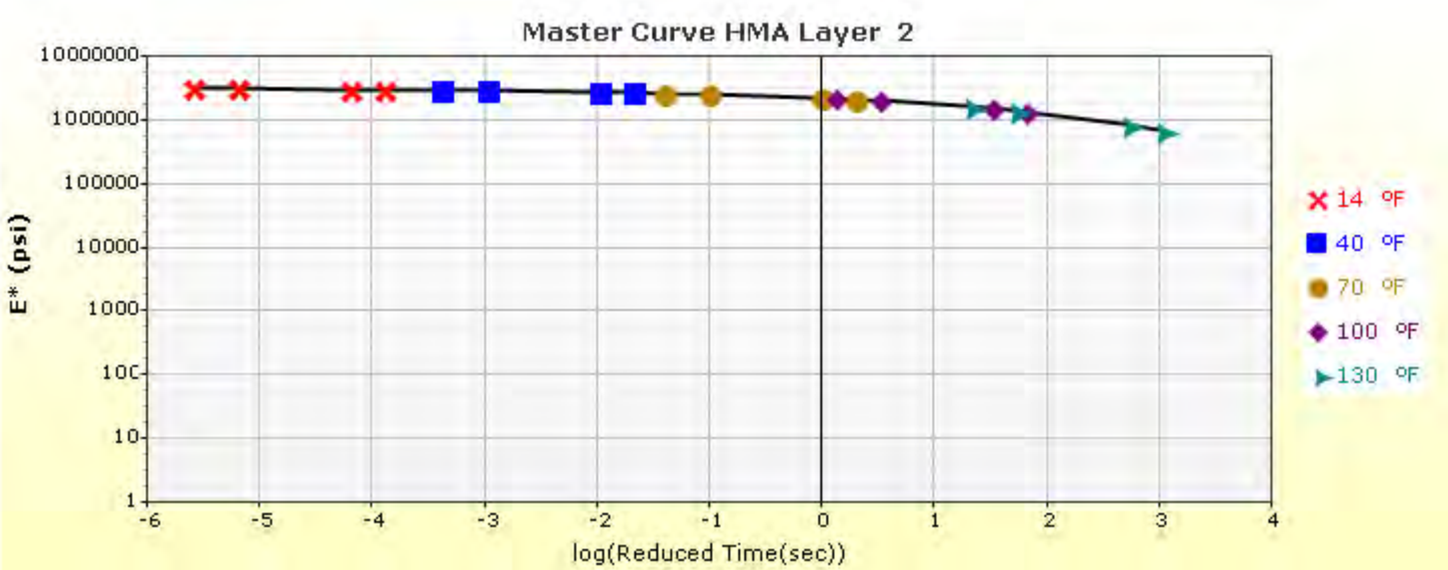
HMA Layer 1: Layer 1 Flexible : Level 1 SX(75) PG 64-28

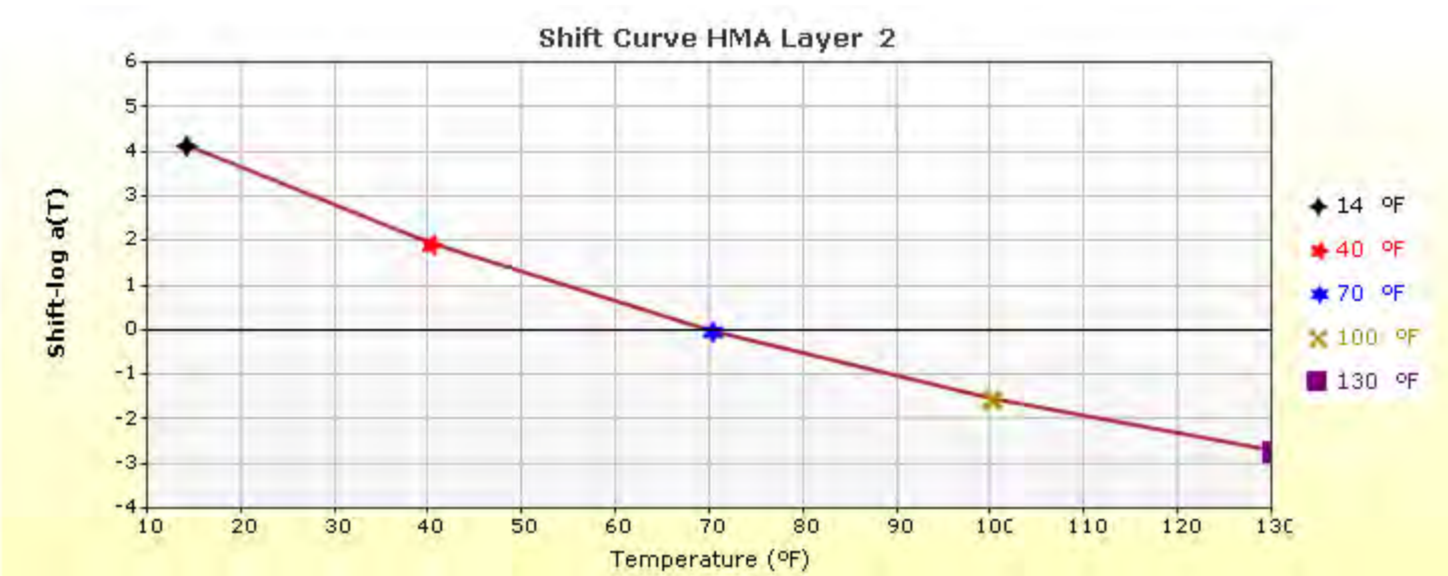


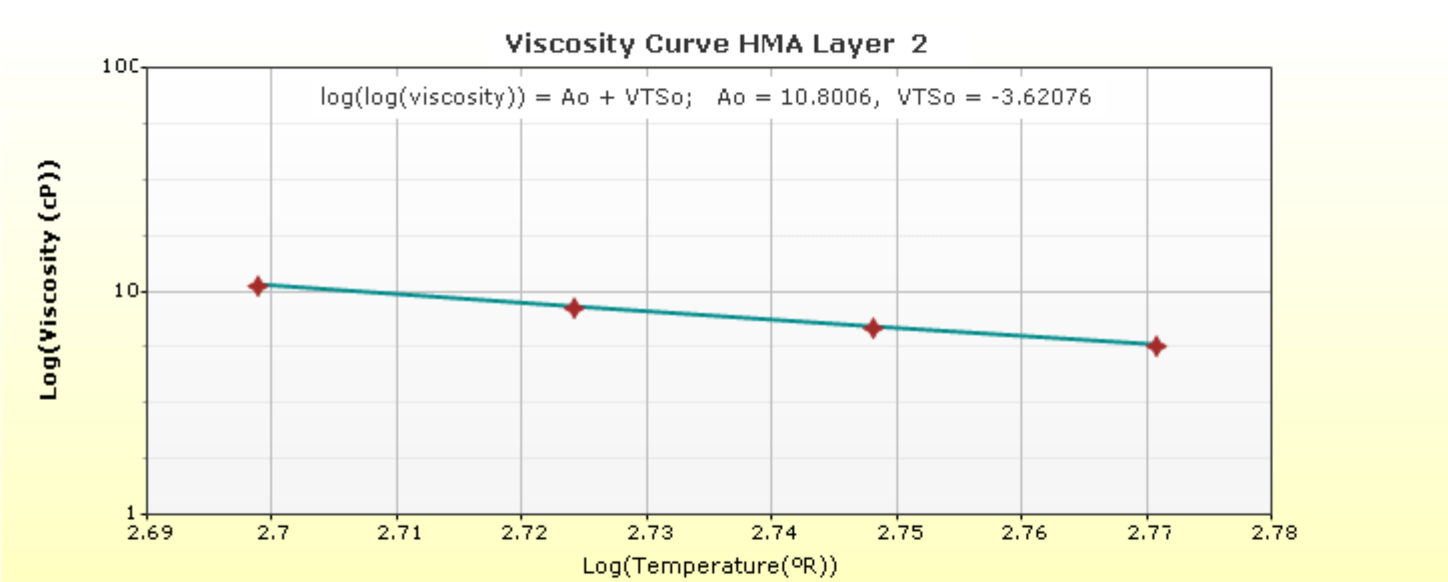




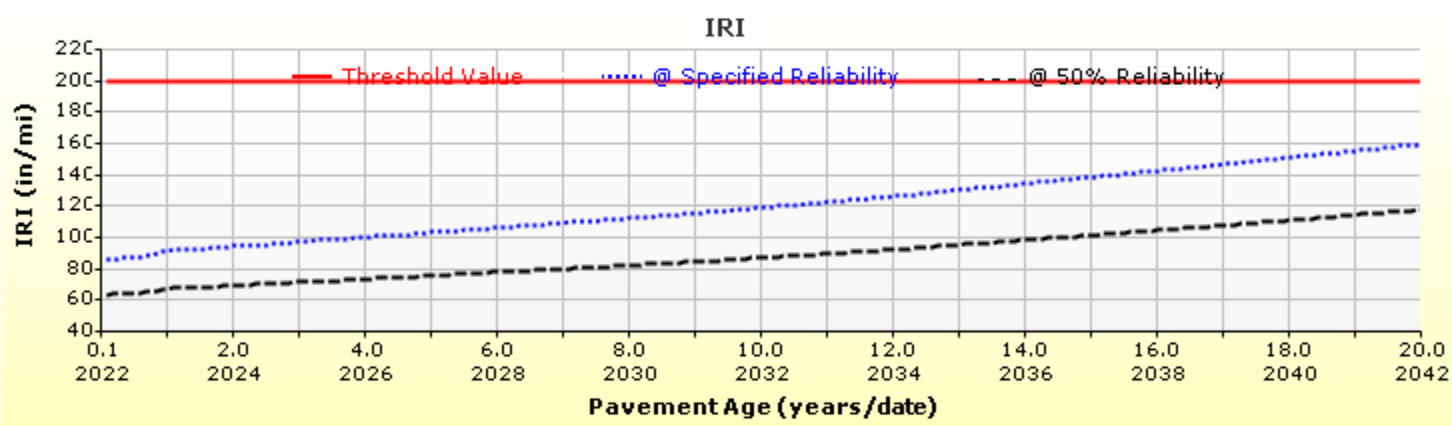
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(75) PG 64-22

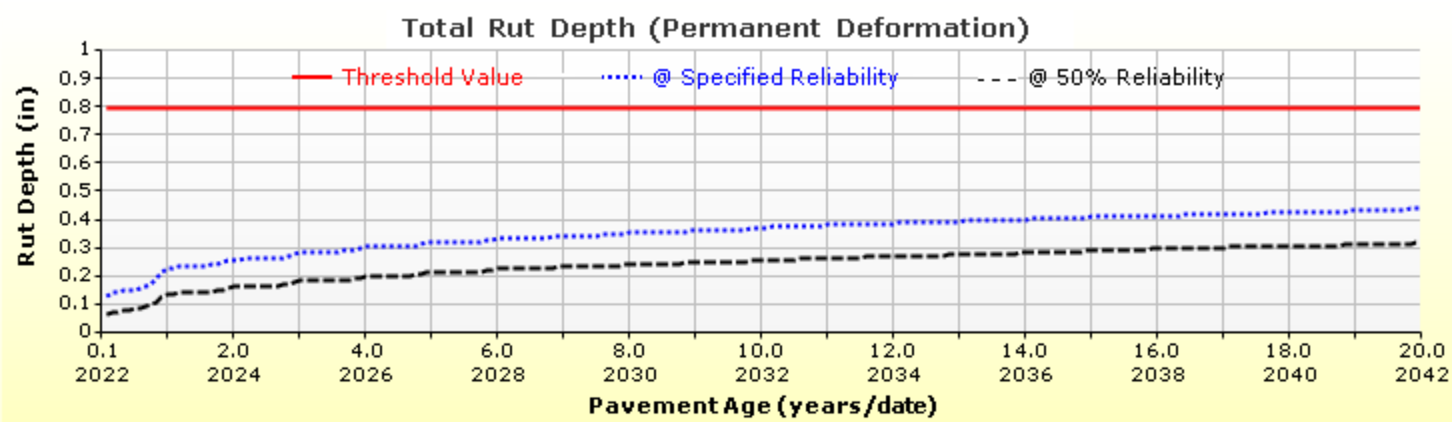


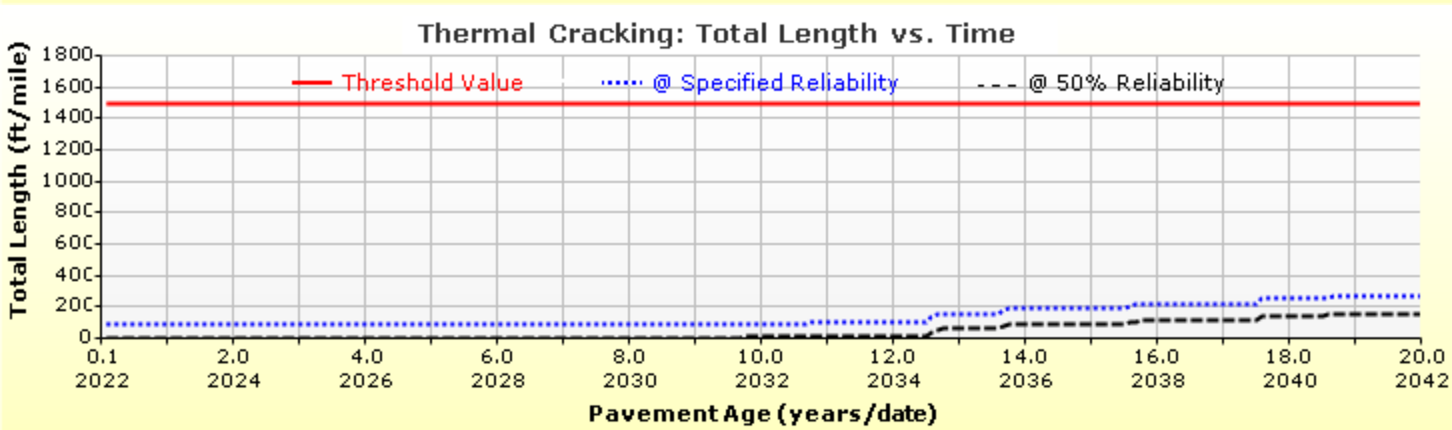


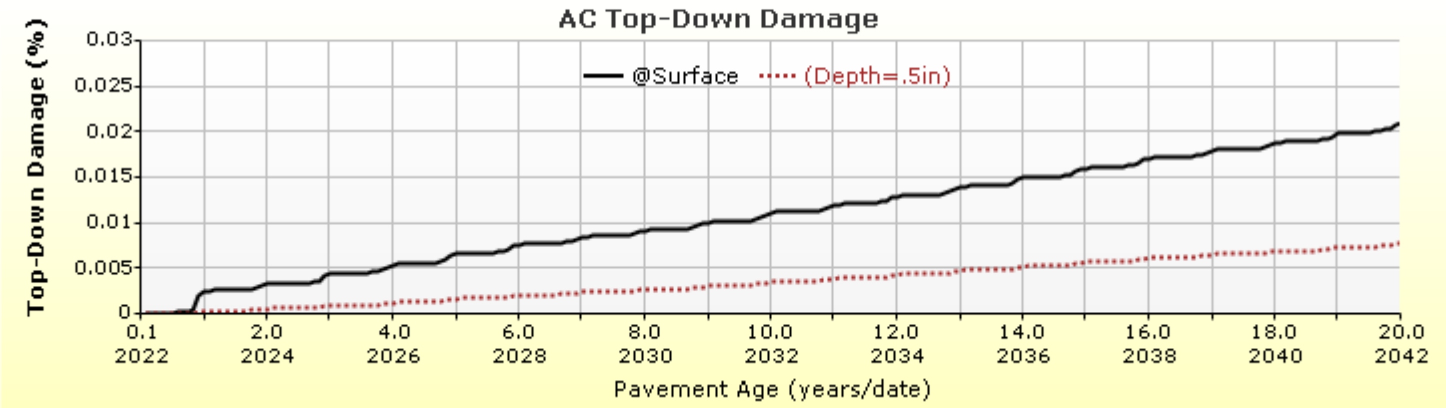


Analysis Output Charts

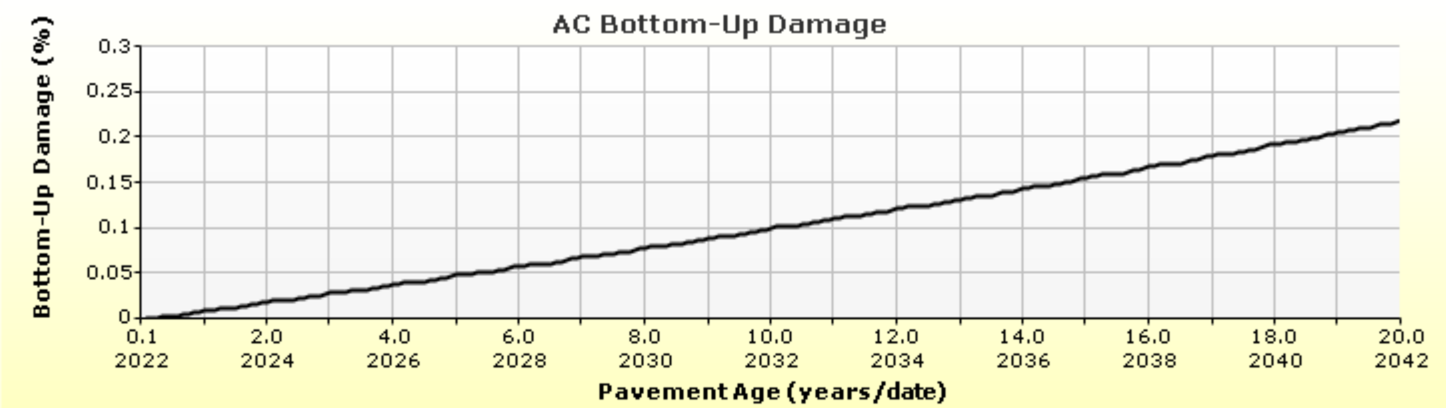




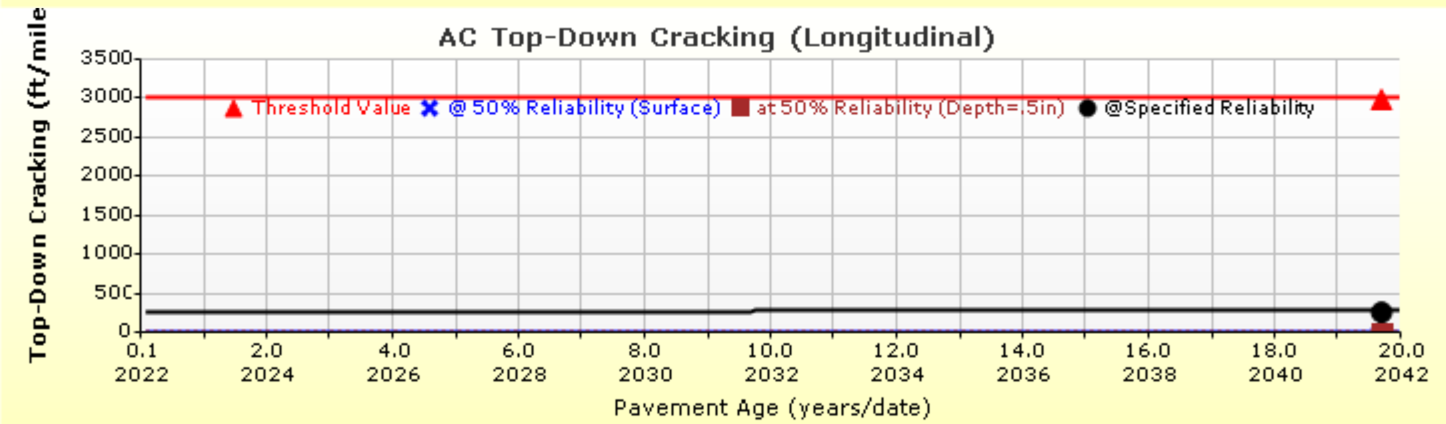




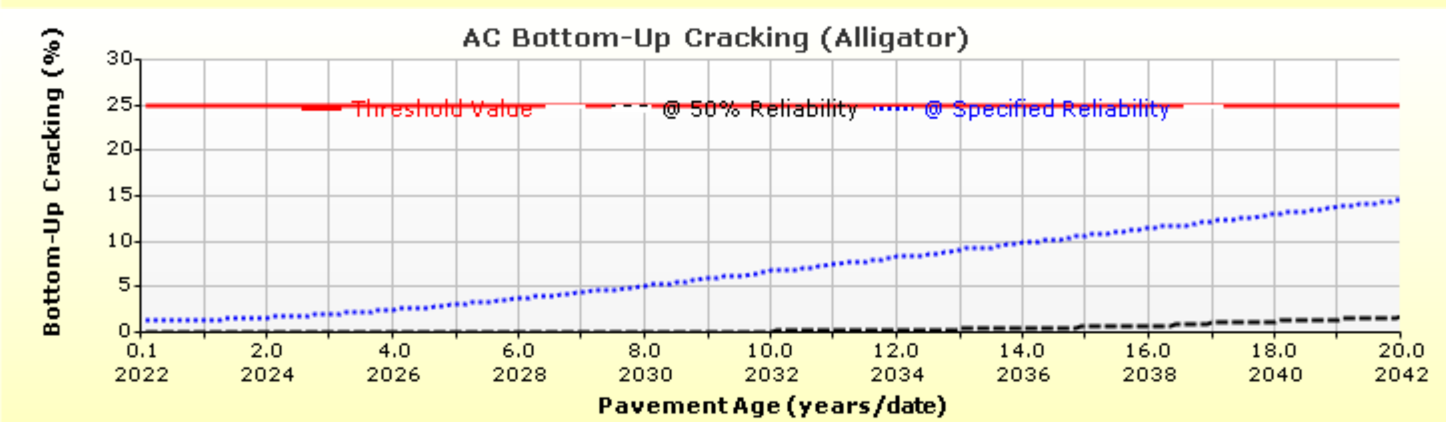
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.03
0.025
0.02
0.015
0.01
0.005
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



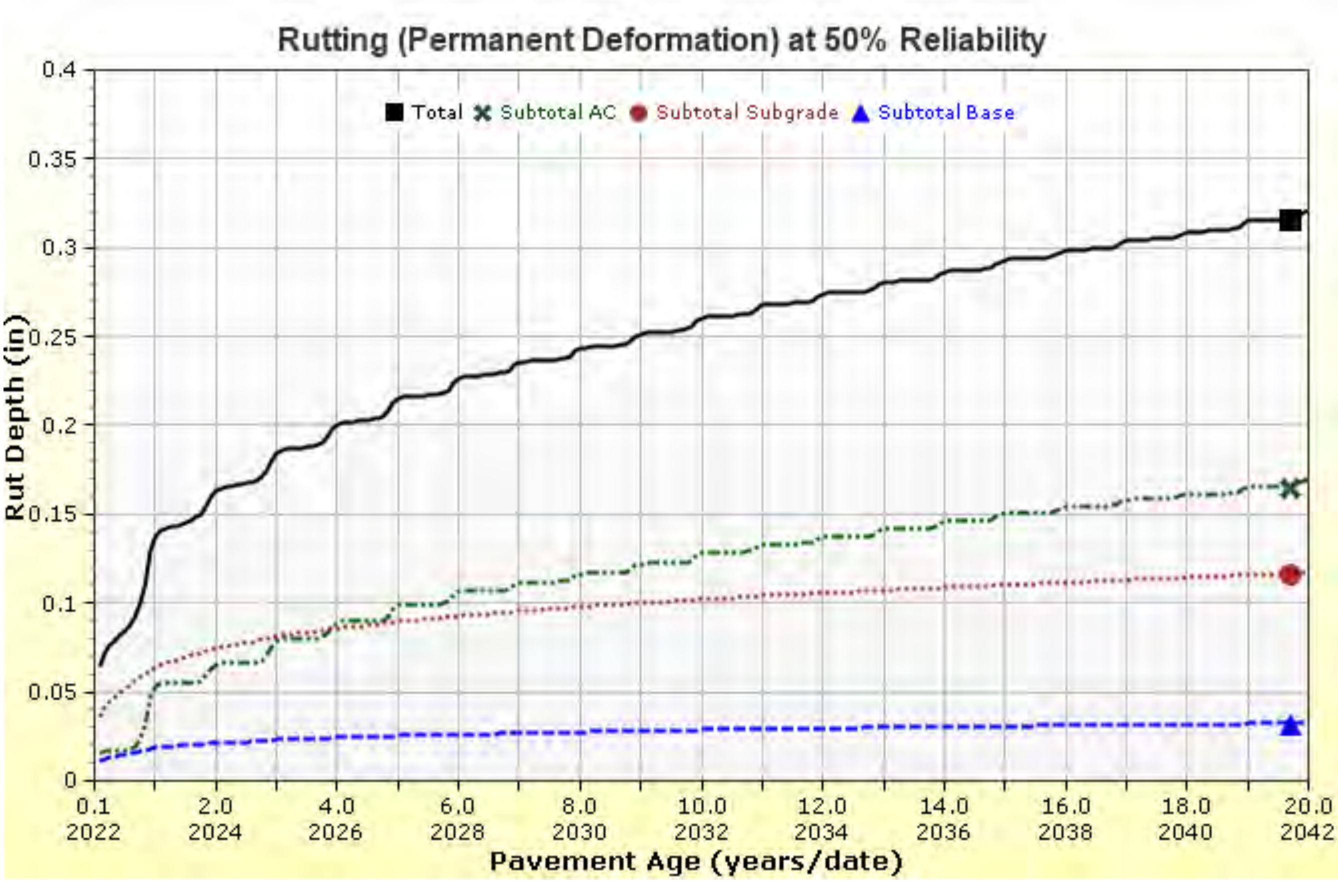
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



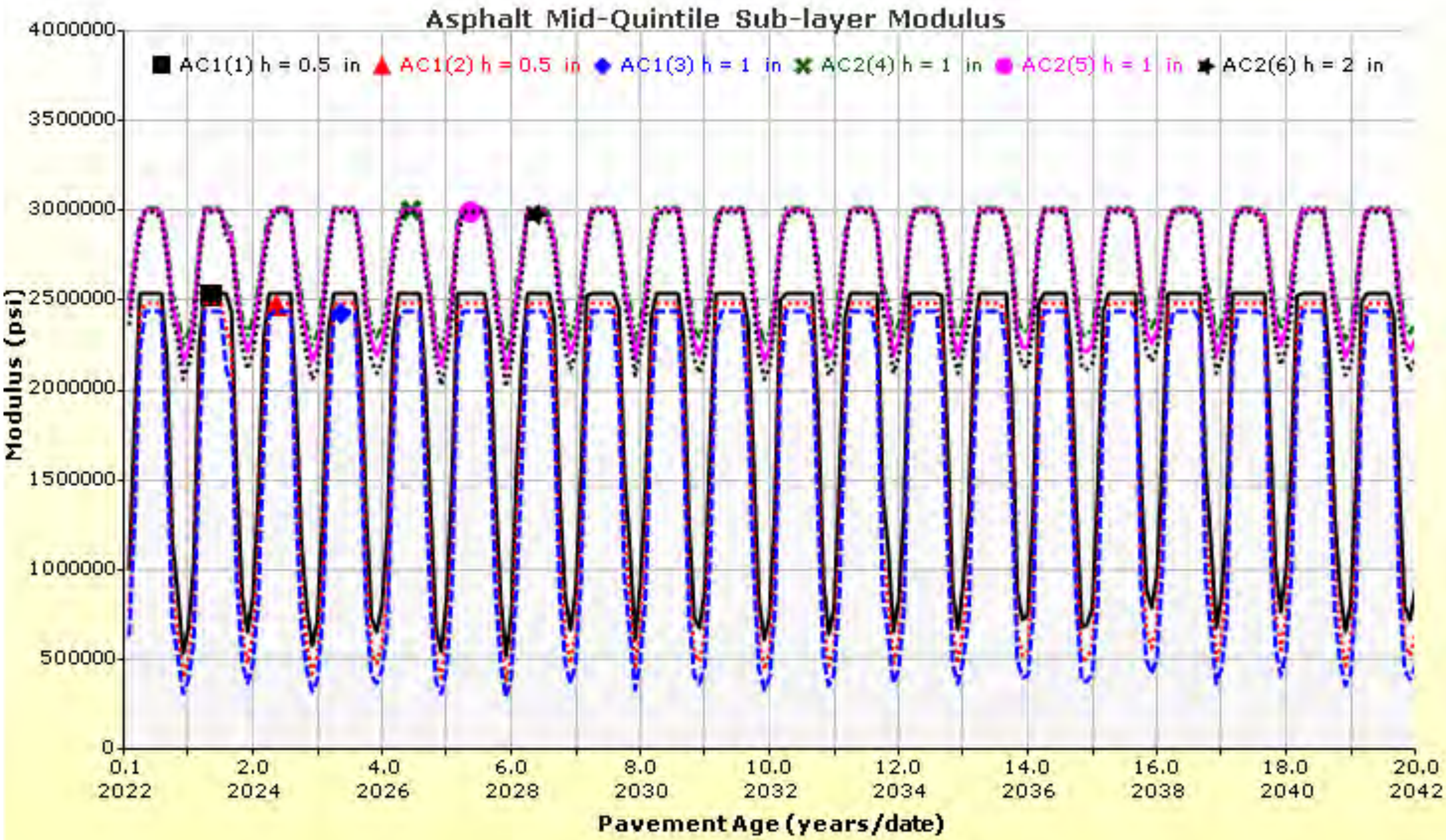
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

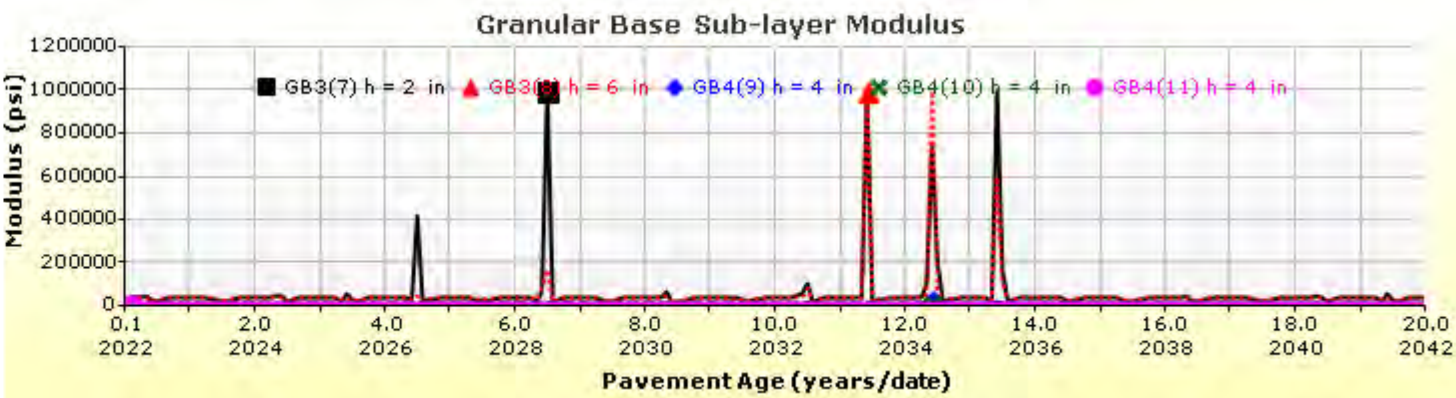


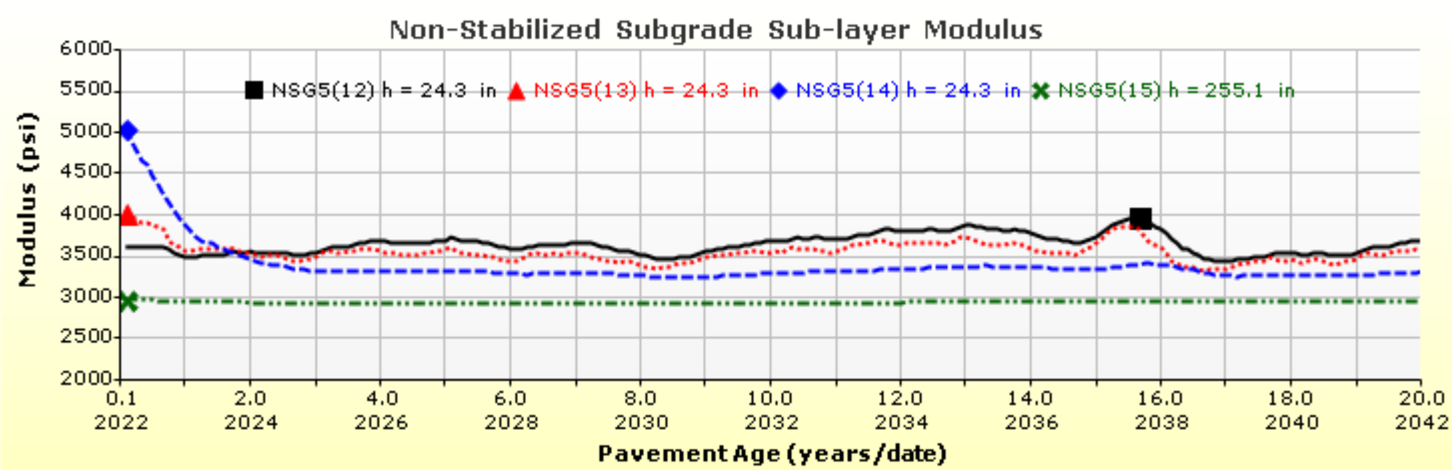
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
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 = 2 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
GB4(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(12) h = 24.3 in
NSG5(13) h = 24.3 in
NSG5(14) h = 24.3 in
NSG5(15) h = 255.1 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Level 1 SX(75) PG 64-28

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.788
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1936600	2082200	2480800	2602400
40	885500	1043400	1602700	1818200
70	208200	266500	571200	743100
100	52200	64400	140400	195000
130	22500	25400	43100	55900

Identifiers

Field	Value
Display name/identifier	Level 1 SX(75) PG 64-28
Description of object	Mix ID # FS27378
Author	Jay Goldbaum
Date Created	11/11/2020 12:00:00 AM
Approver	CDOT
Date approved	1/1/0001 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	0

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

Layer 2 Flexible : R2 Level 1 SX(75) PG 64-22

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	140.5	
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	2910500	2947100	3034800	3058600
40	2620500	2695700	2882400	2934800
70	2057300	2190500	2549800	2658300
100	1334300	1500400	2017600	2195500
130	697600	836500	1365200	1584000

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 (%)	11.8
Air voids (%)	6.9
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(75) PG 64-22
Description of object	Mix ID # 19127A
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	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	41

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 : A-1-b

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 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 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: 0.021	c2: 2.35	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 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

Forsight Circle and F.25 Road HMA (30-year)

File Name: C:\Users\goldbaum\Documents\My PMED Designs\My ME Design\Projects\F.5 Road\Forsight Circle and F.25 Road HMA (30-year).dgpx

Design Inputs

Design Life: 30 years
Design Type: FLEXIBLE

Base construction: May, 2022
Pavement construction: June, 2022
Traffic opening: September, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Level 1 SX(75) PG 64-28	2.0
Flexible	R2 Level 1 SX(75) PG 64-22	5.0
NonStabilized	Crushed gravel	8.0
NonStabilized	A-1-b	12.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.8
Air voids (%)	5.7

Traffic

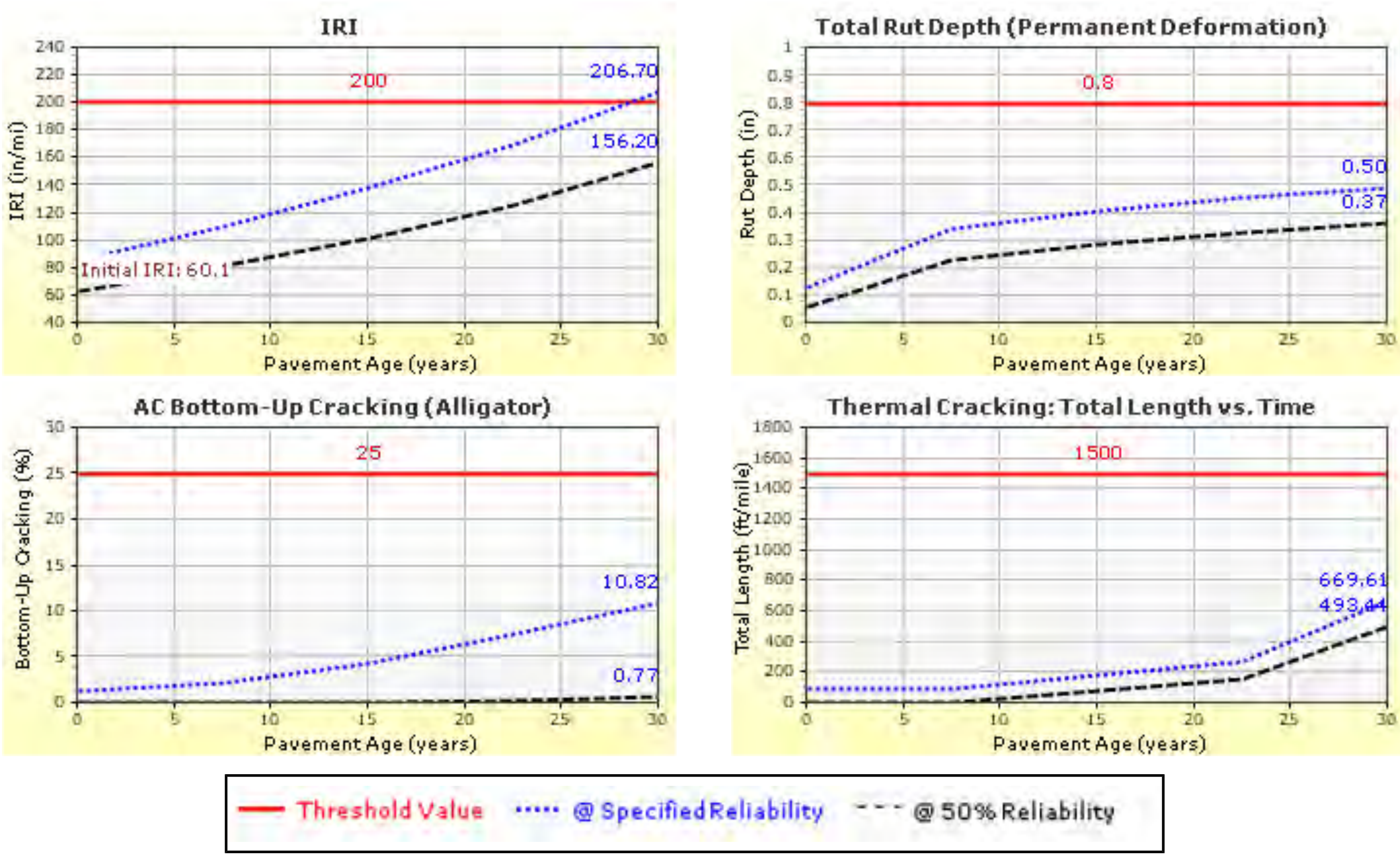
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	231
2037 (15 years)	888,216
2052 (30 years)	2,119,290

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	206.73	90.00	86.67	Fail
Permanent deformation - total pavement (in)	0.80	0.50	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	10.82	90.00	99.90	Pass
AC thermal cracking (ft/mile)	1500.00	669.61	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	305.59	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.35	90.00	100.00	Pass

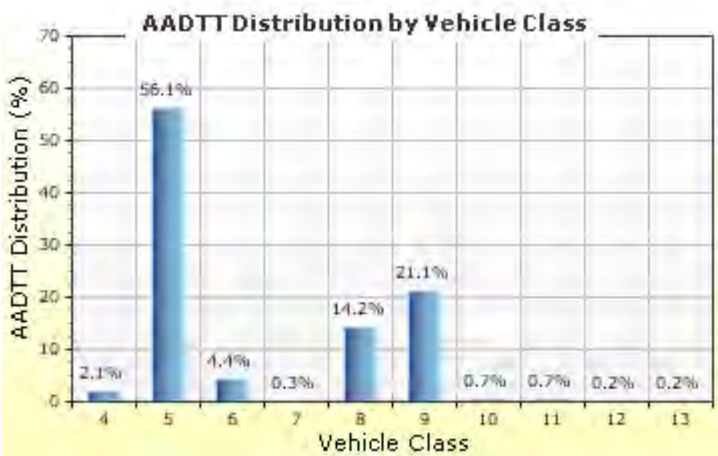
Distress Charts

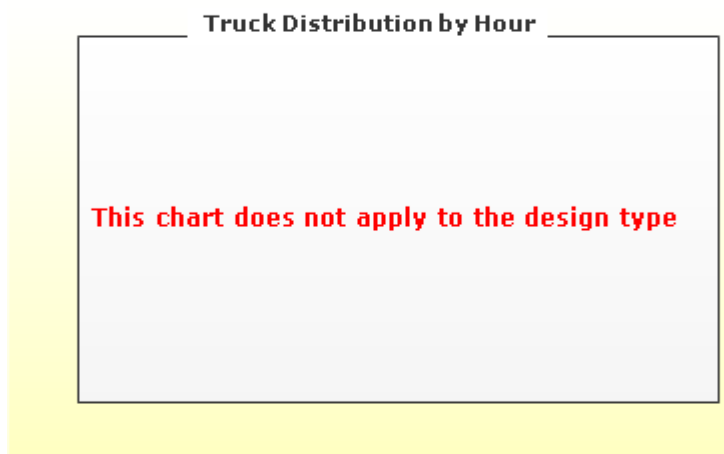


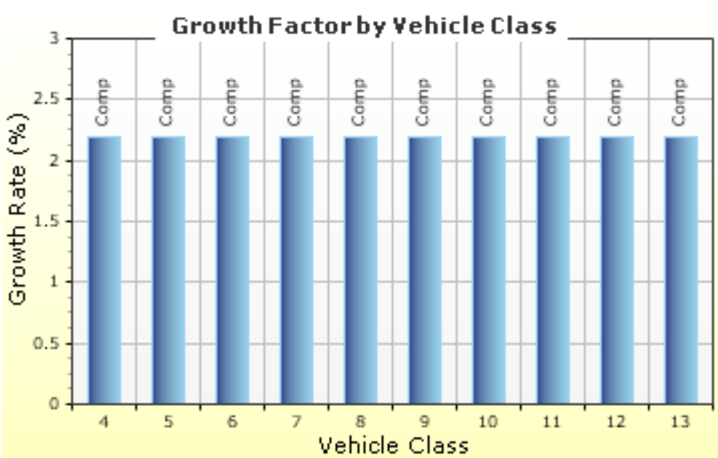
Traffic Inputs

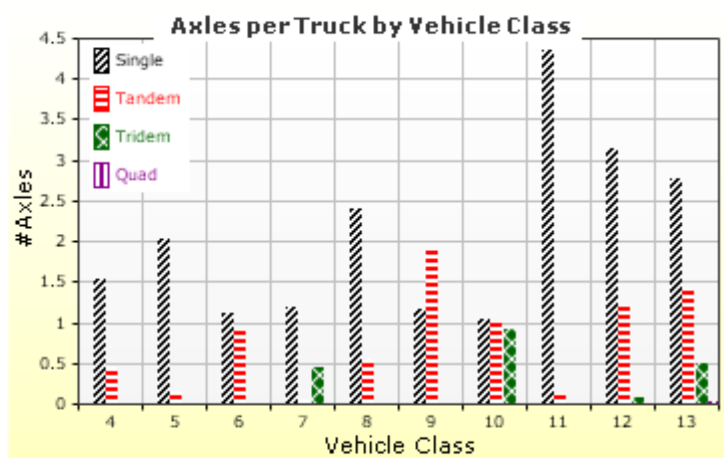
Graphical Representation of Traffic Inputs

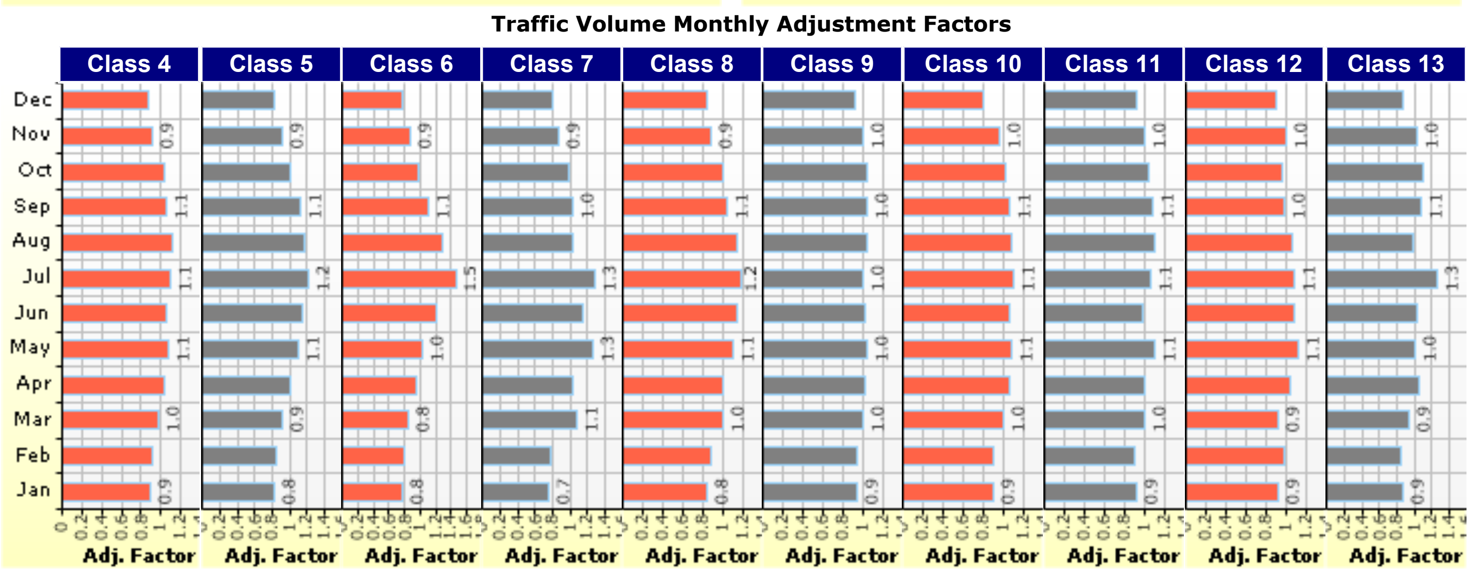
Initial two-way AADTT:	231	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	25.0











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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

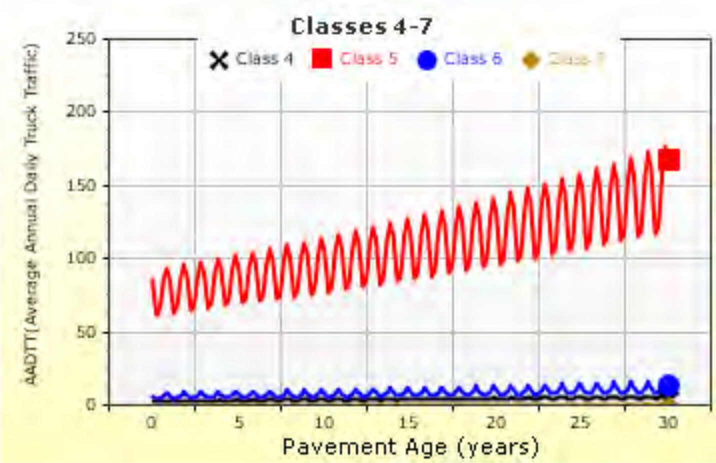
Wheelbase does not apply

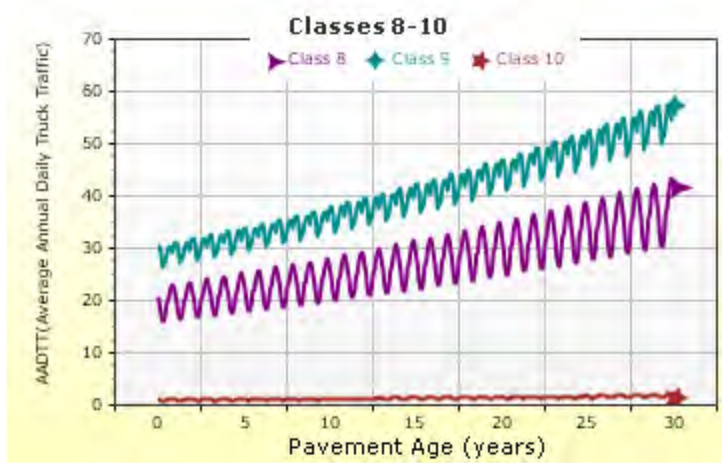
Number of Axles per Truck

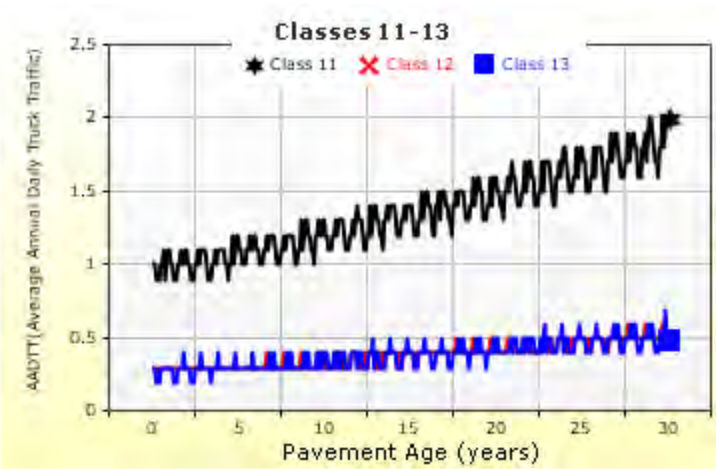
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

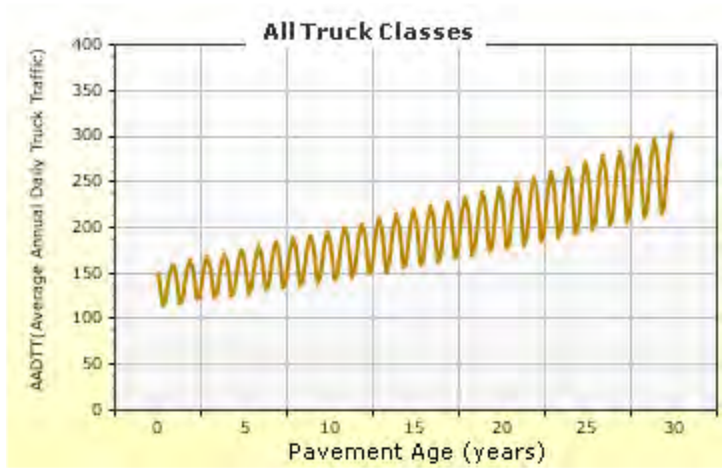
AADTT (Average Annual Daily Truck Traffic) Growth

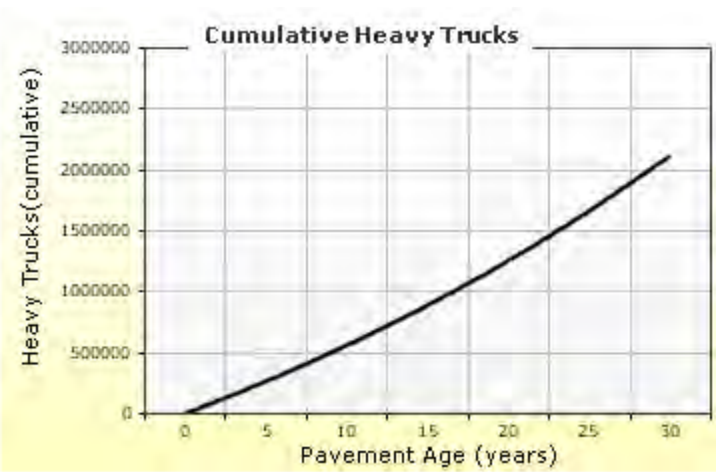
*** Traffic cap is not enforced**







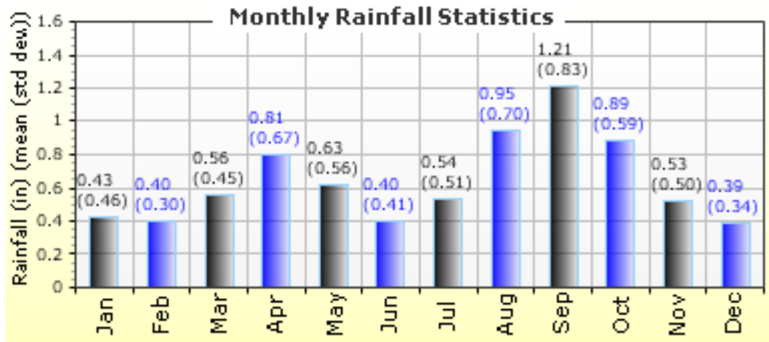




Climate Inputs

Climate Data Sources:

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

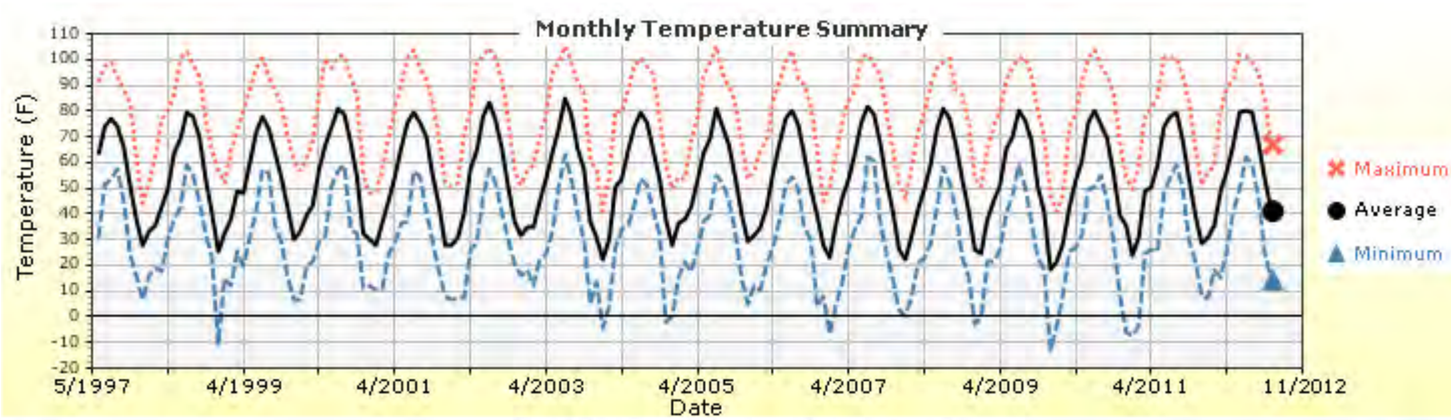


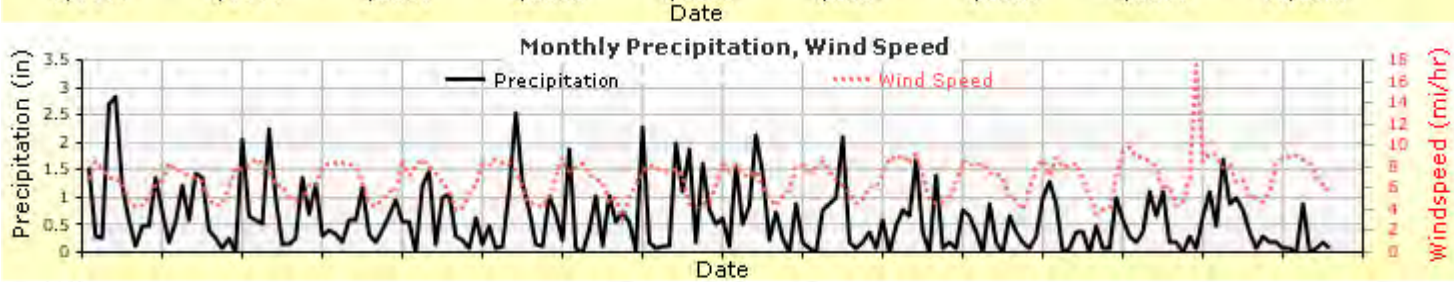
Annual Statistics:

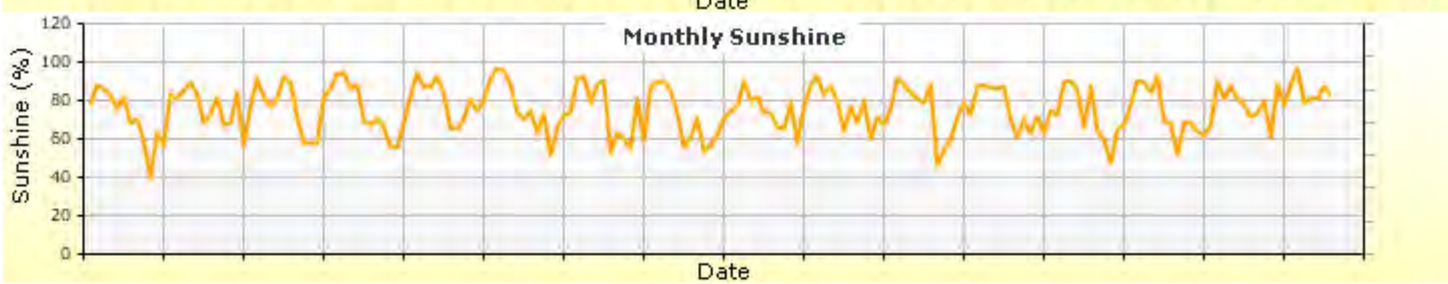
Mean annual air temperature (ºF)	53.55
Mean annual precipitation (in)	7.76
Freezing index (ºF - days)	398.73
Average annual number of freeze/thaw cycles:	111.77

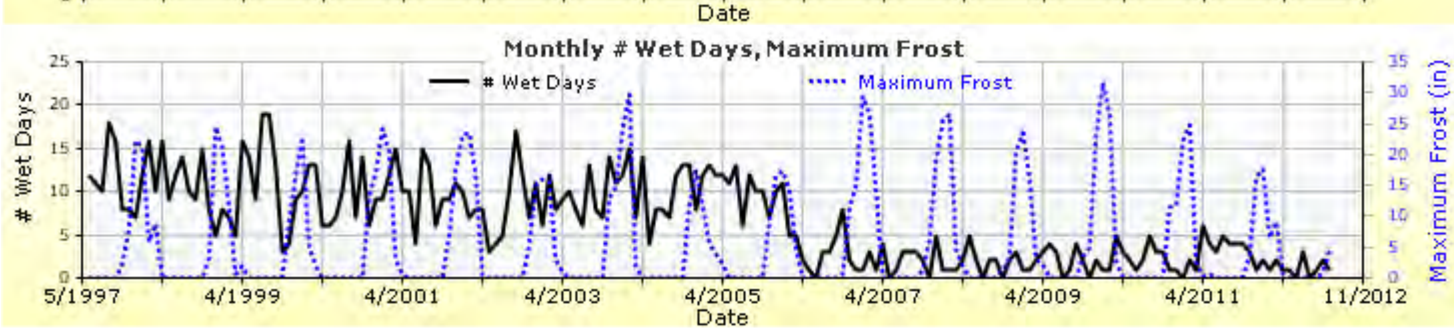
Water table depth (ft)	10.00

Monthly Climate Summary:

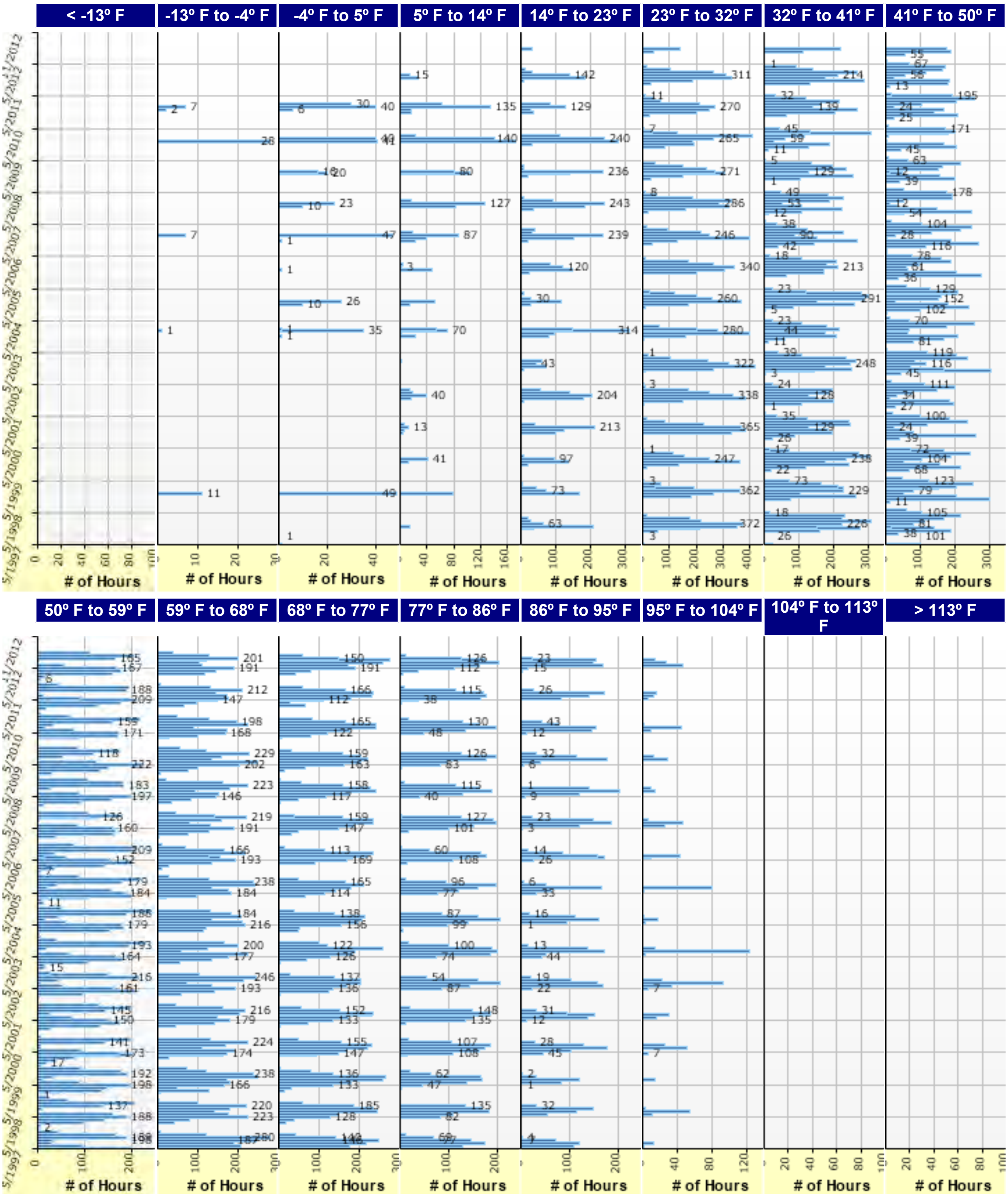








Hourly Air Temperature Distribution by Month:



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

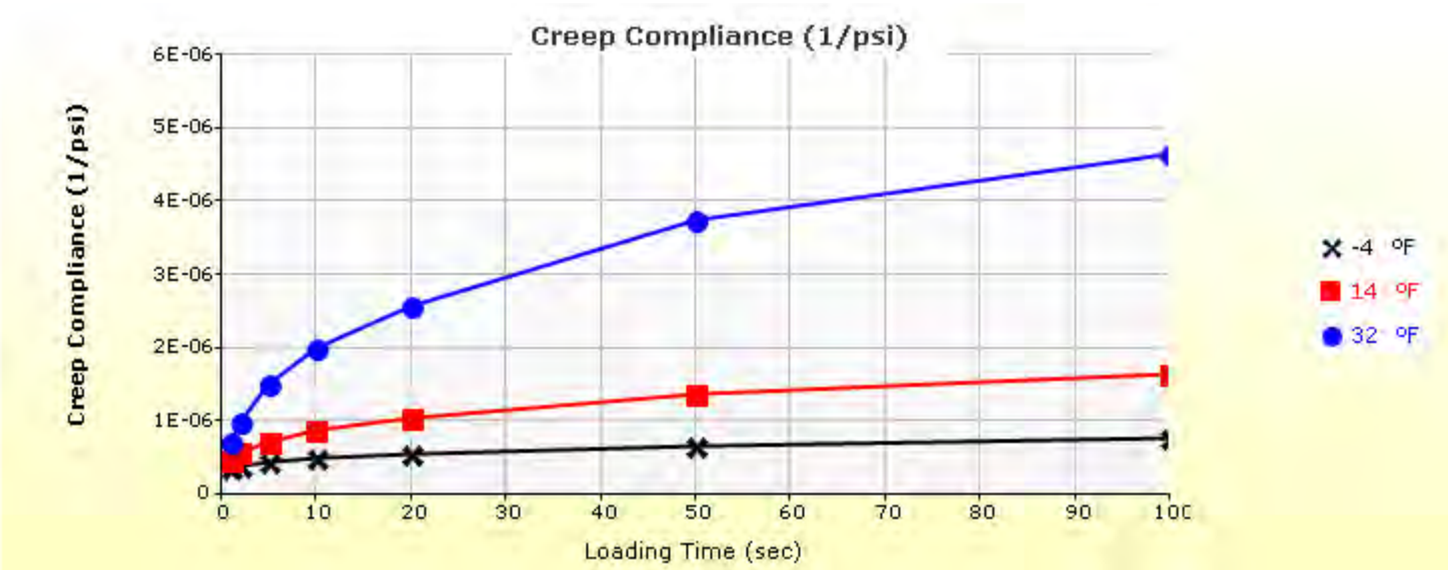
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Level 1 SX(75) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (75) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : A-1-b	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

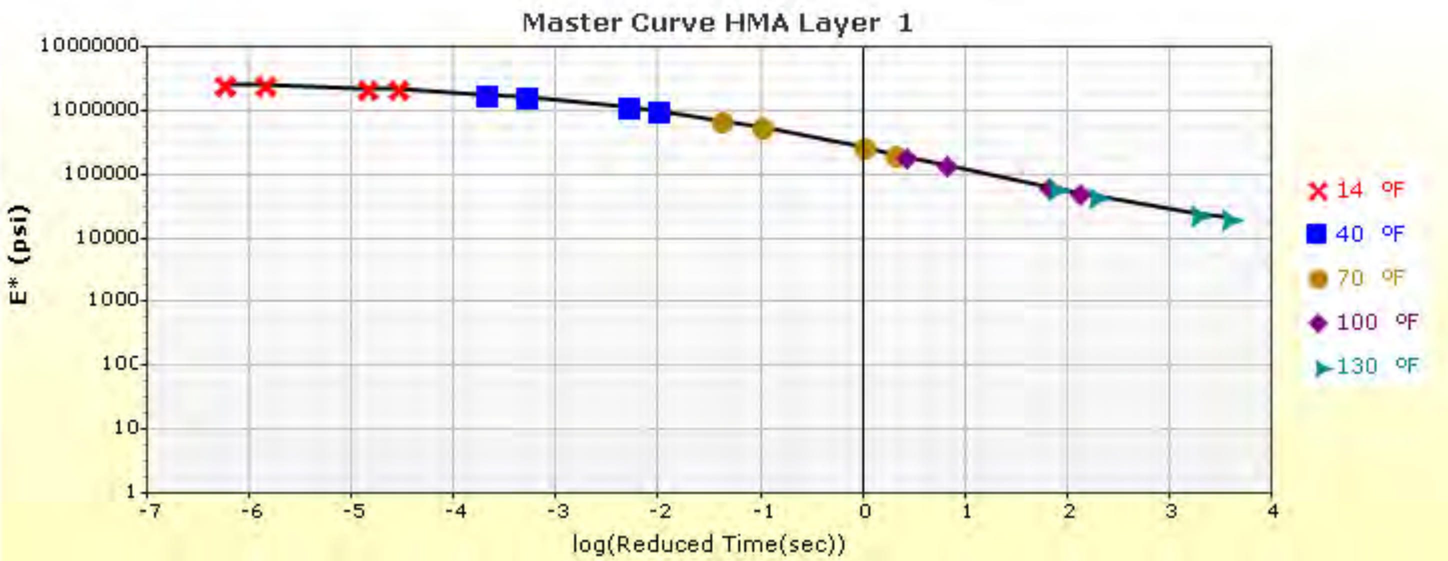
Indirect tensile strength at 14 ºF (psi)	519.00

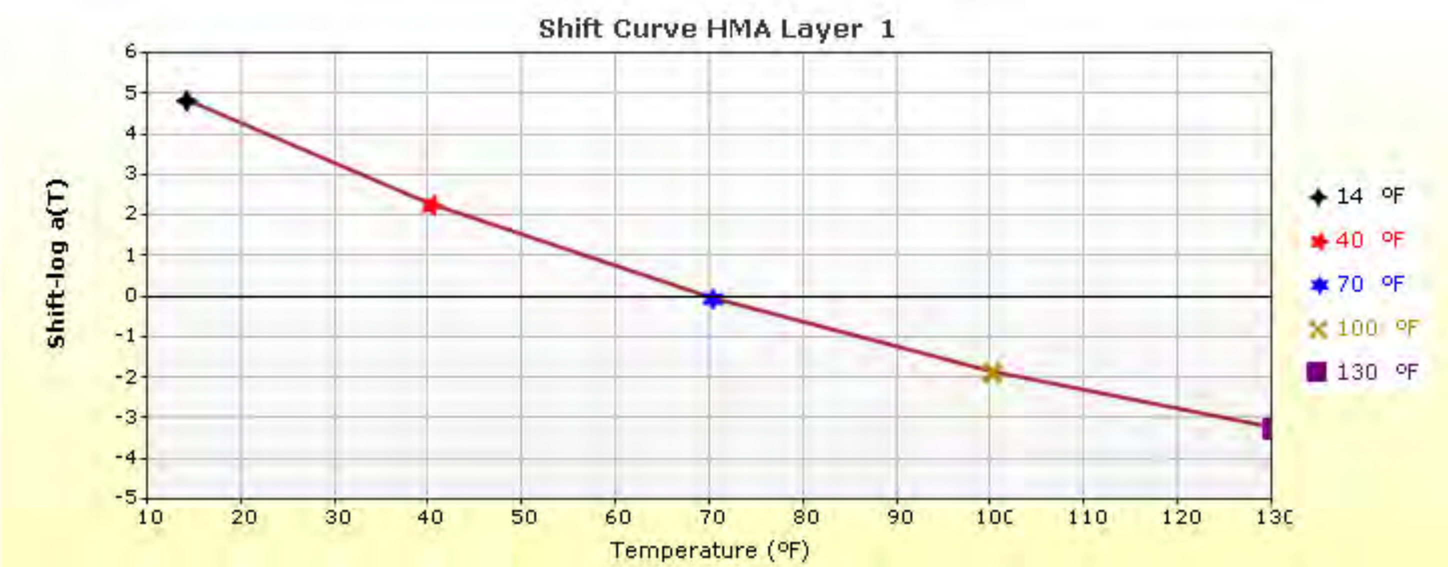
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	17.5

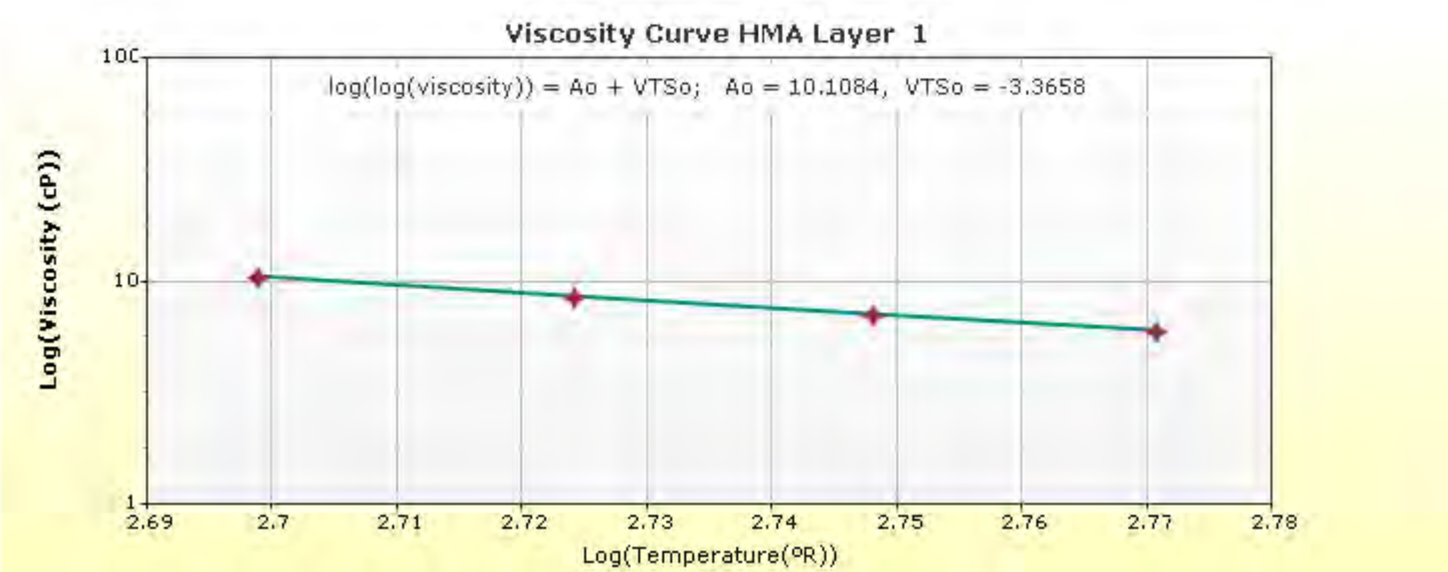
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



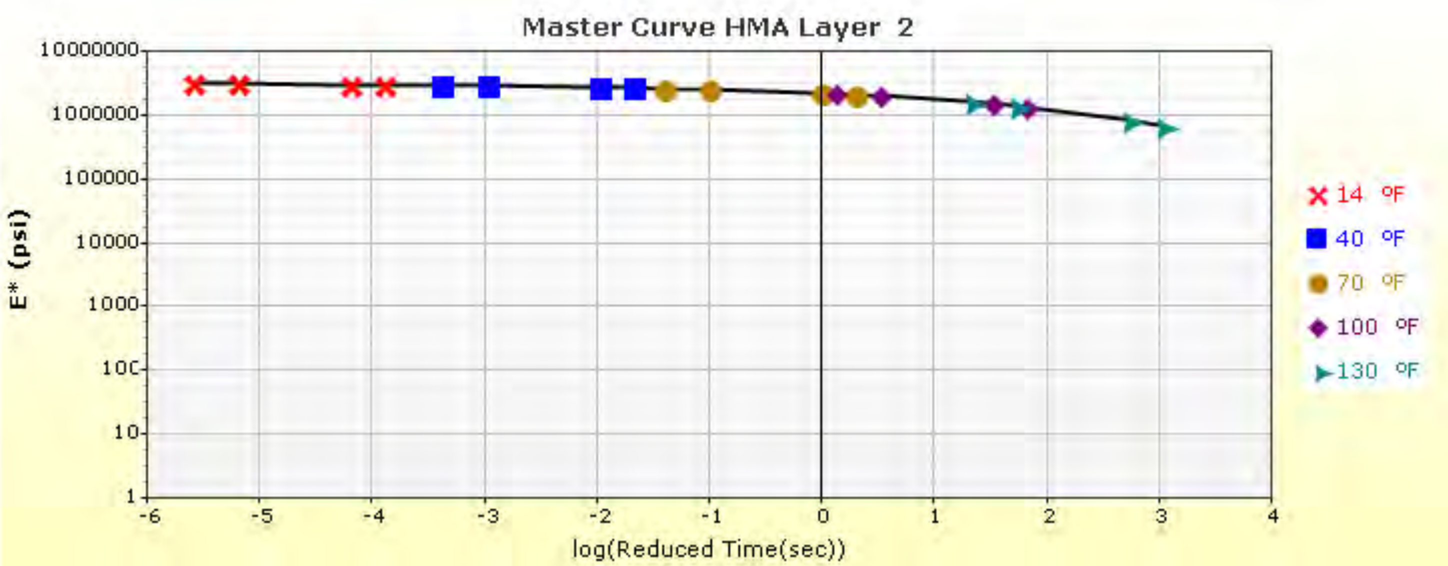
HMA Layer 1: Layer 1 Flexible : Level 1 SX(75) PG 64-28

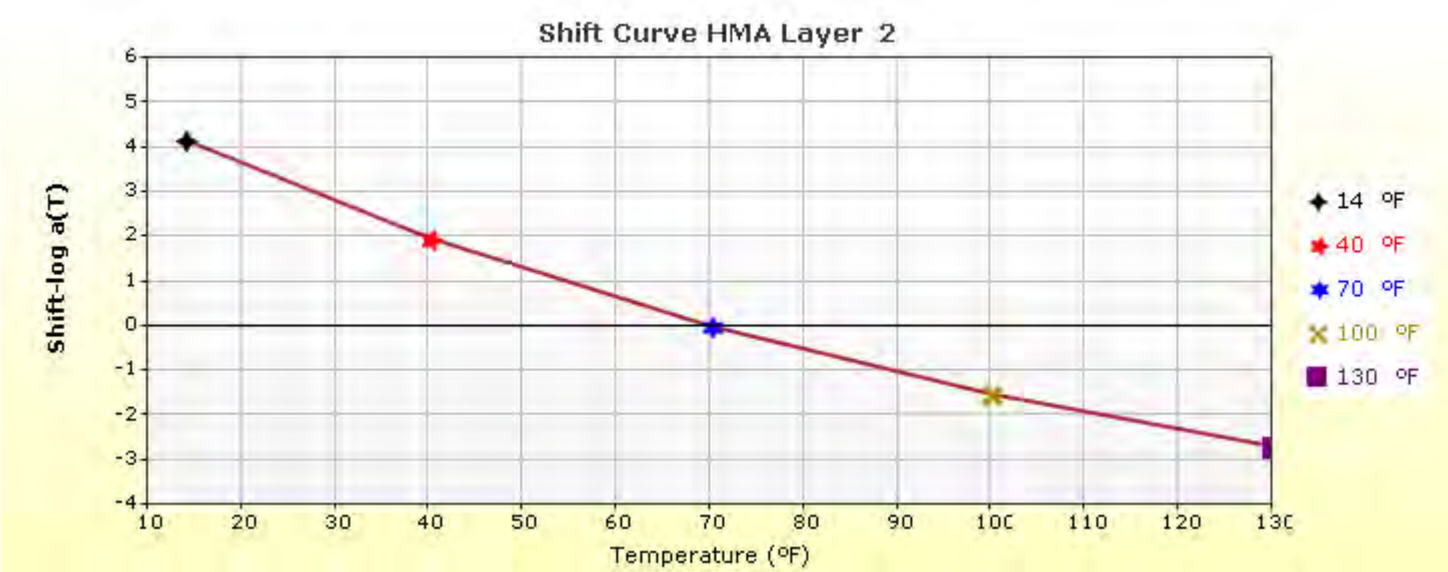


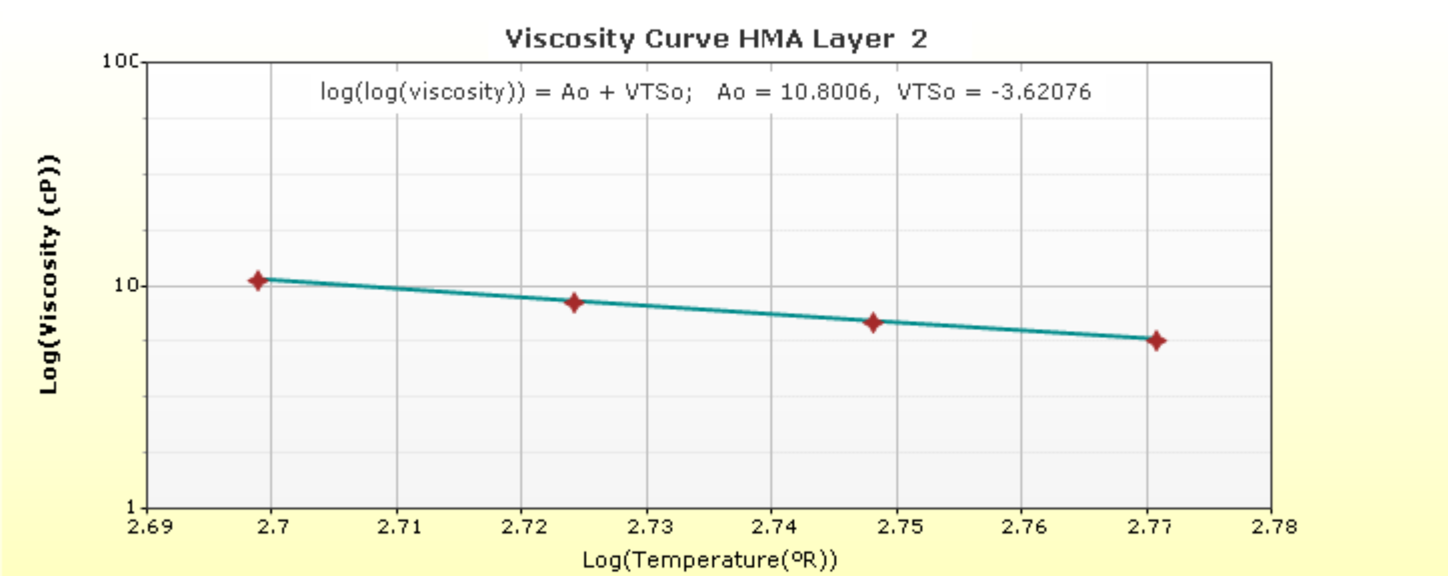




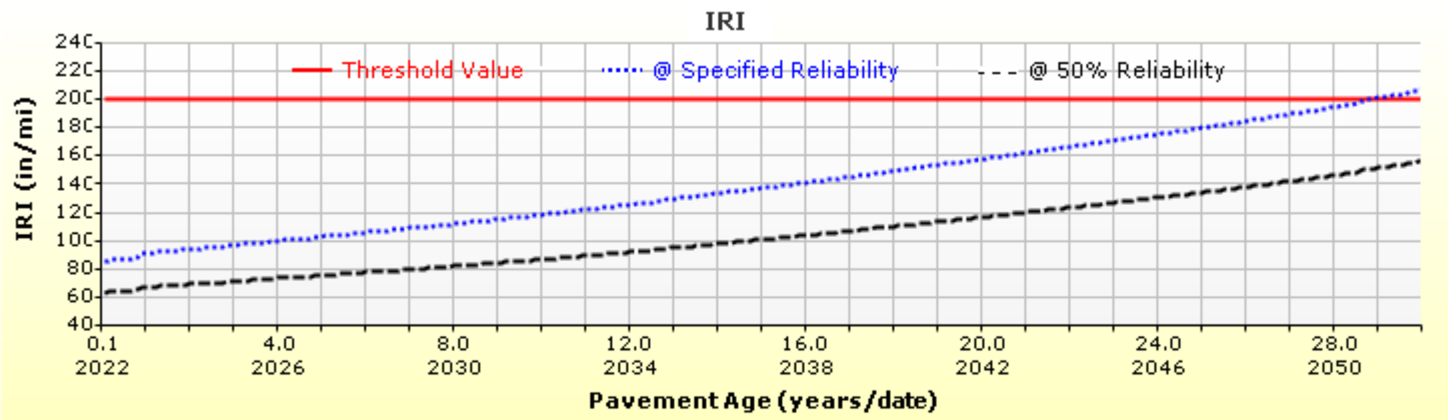
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(75) PG 64-22

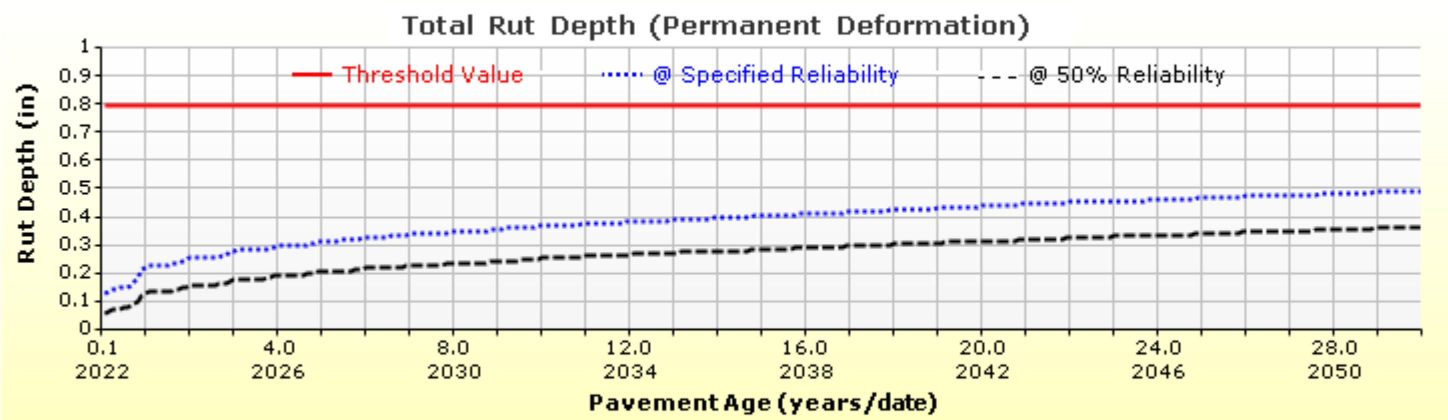


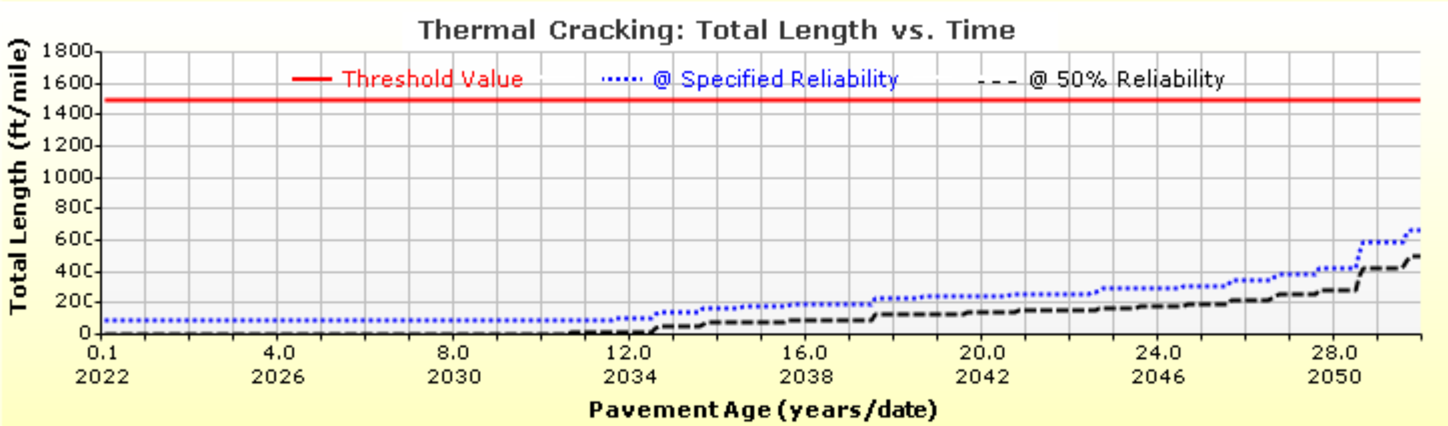


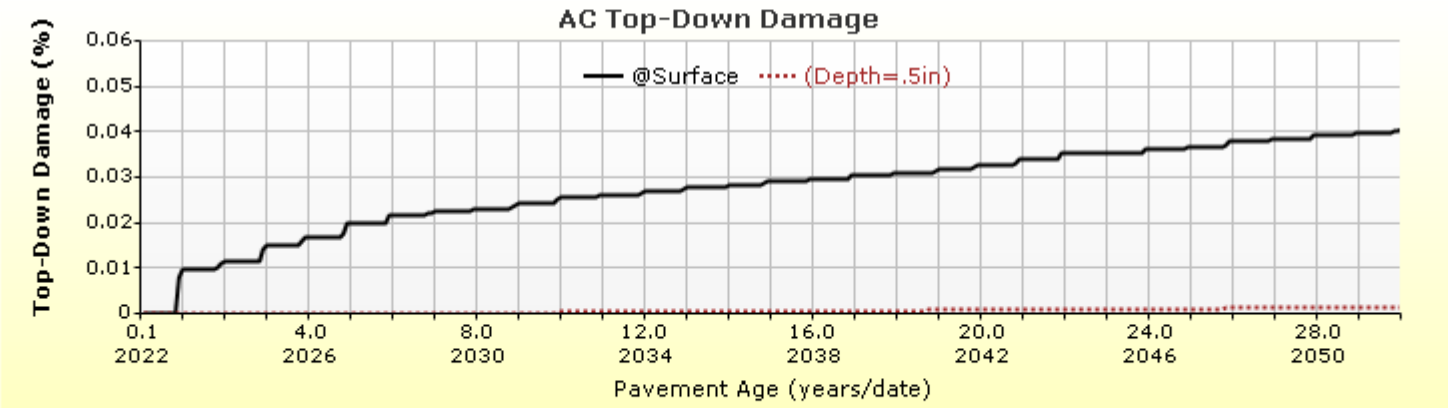


Analysis Output Charts

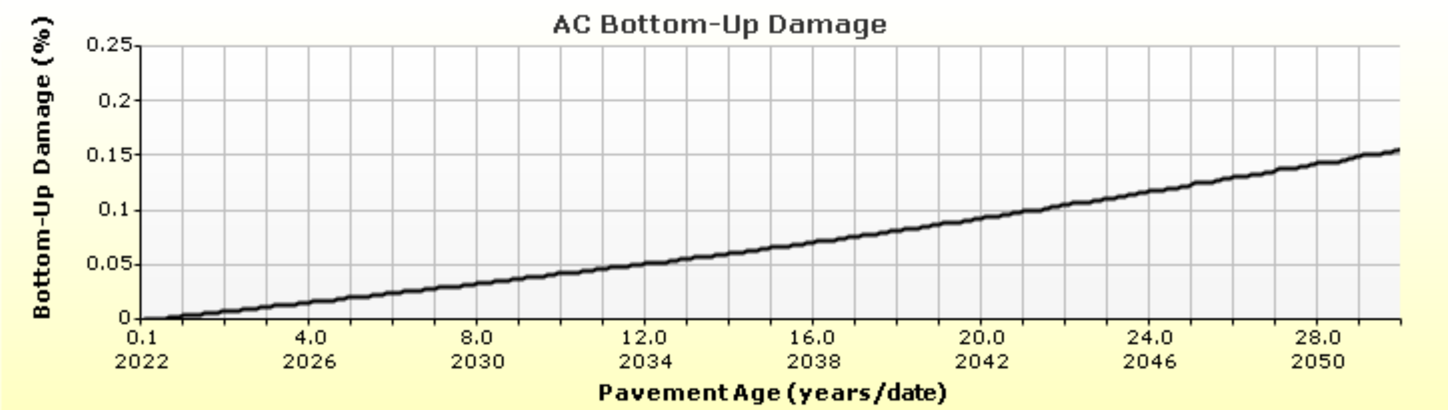




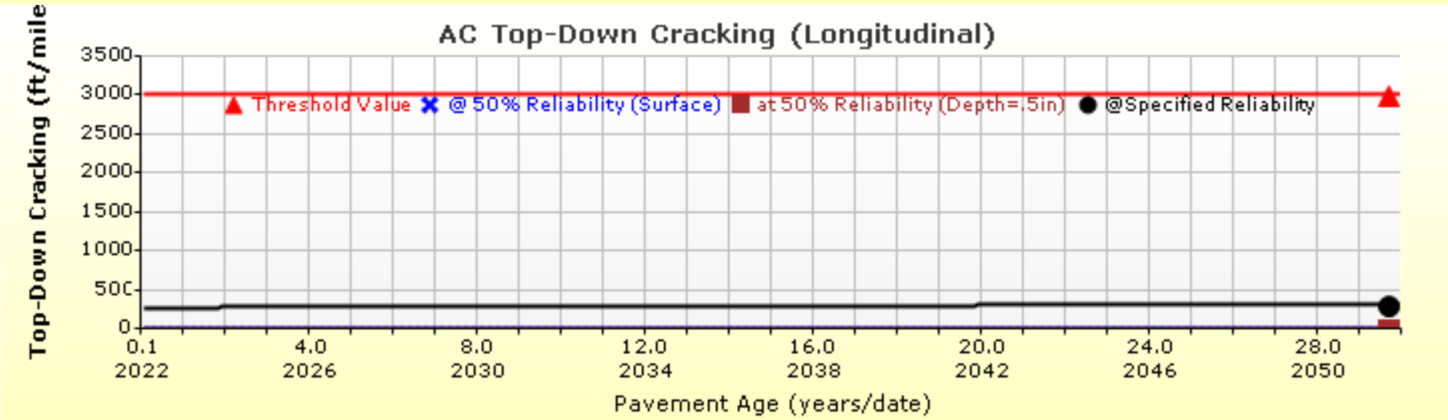




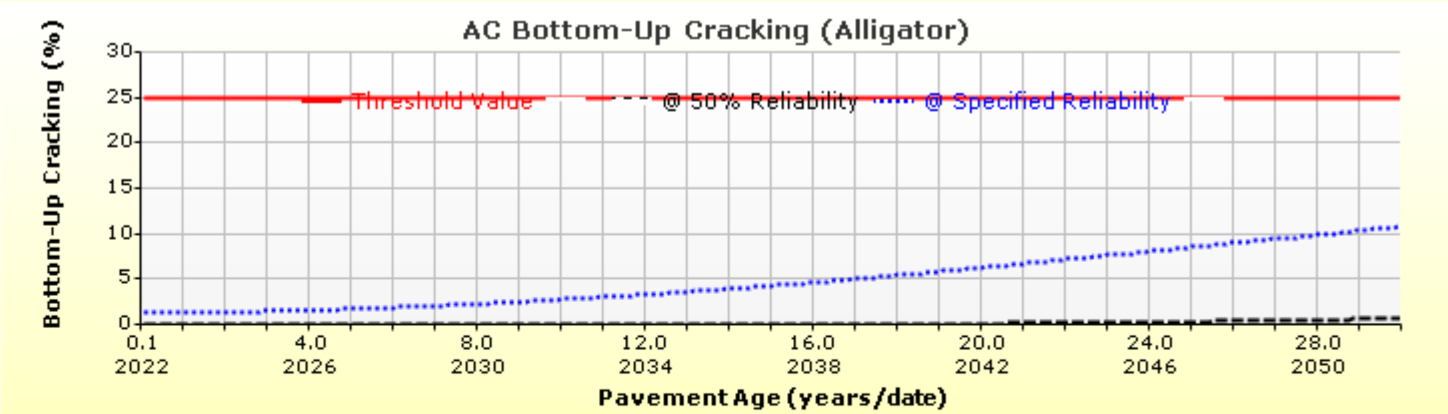
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



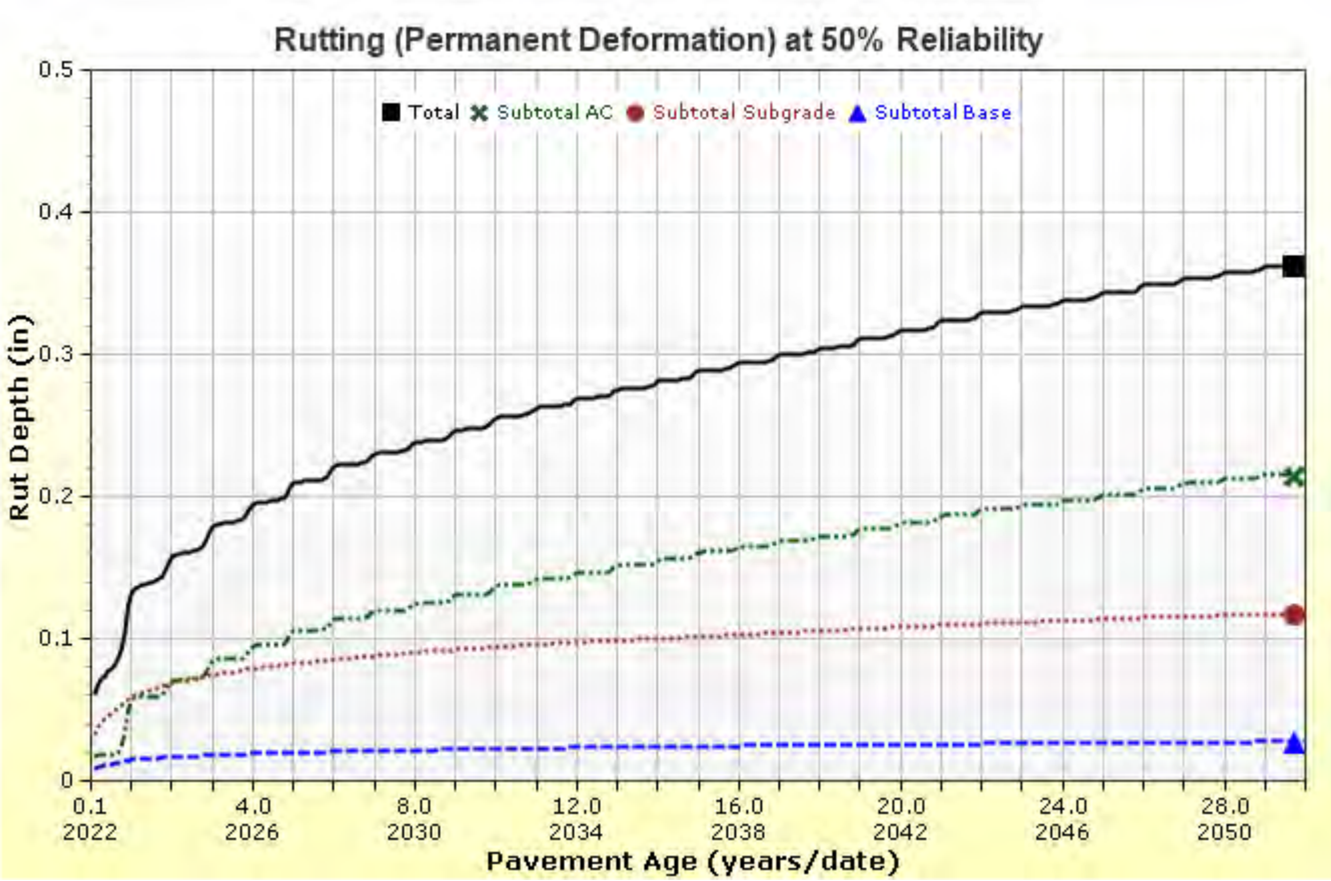
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

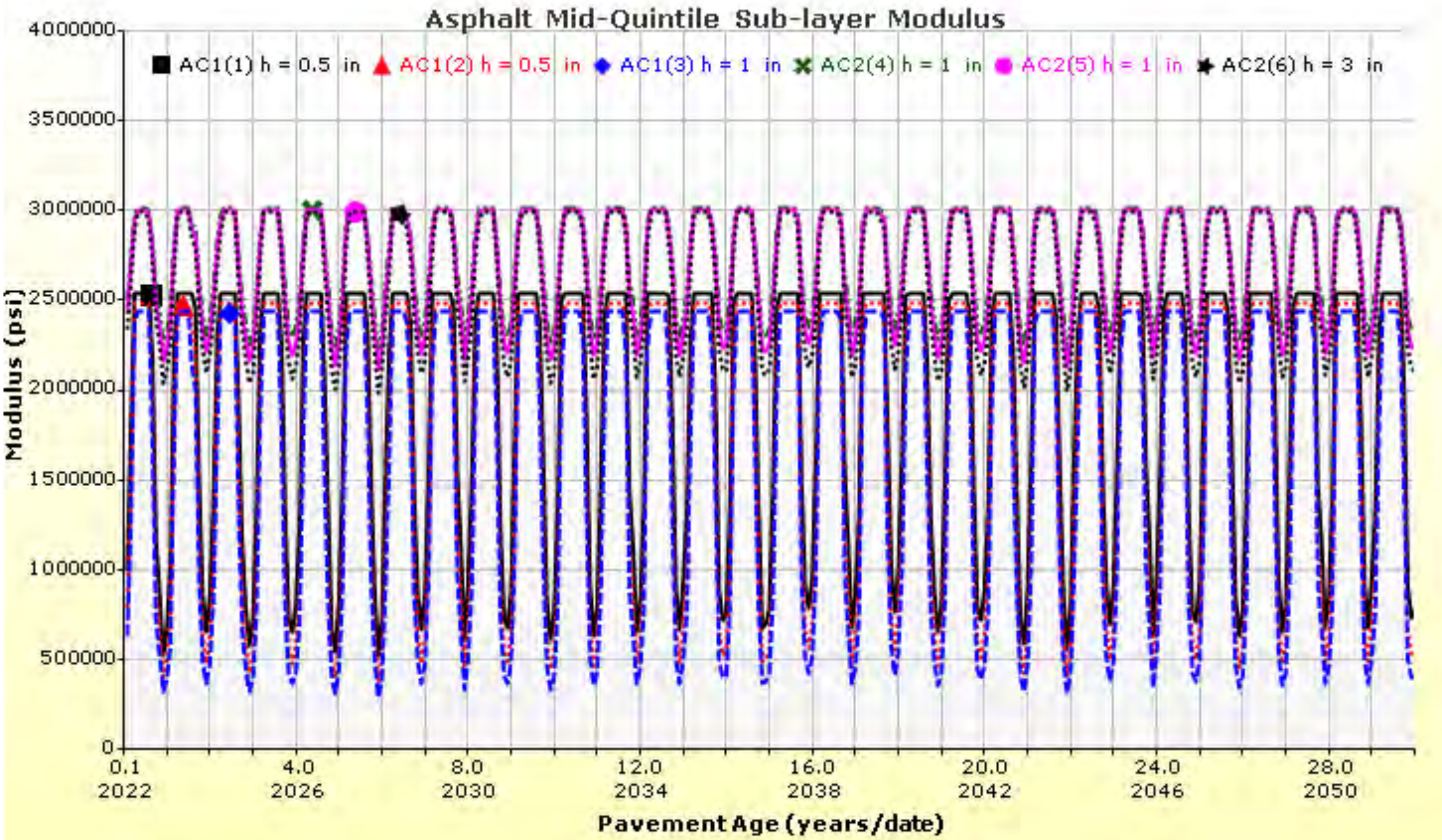


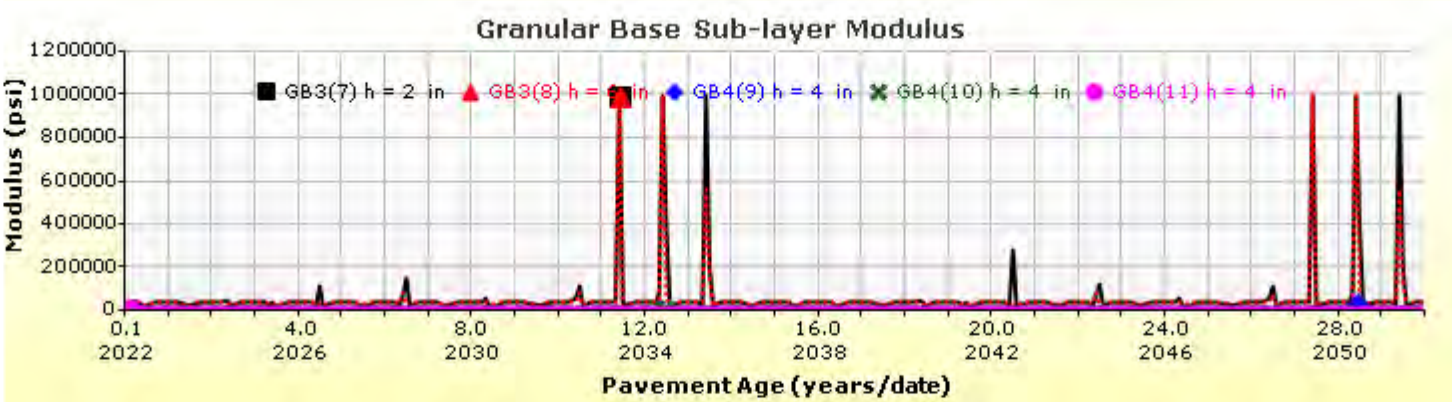
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

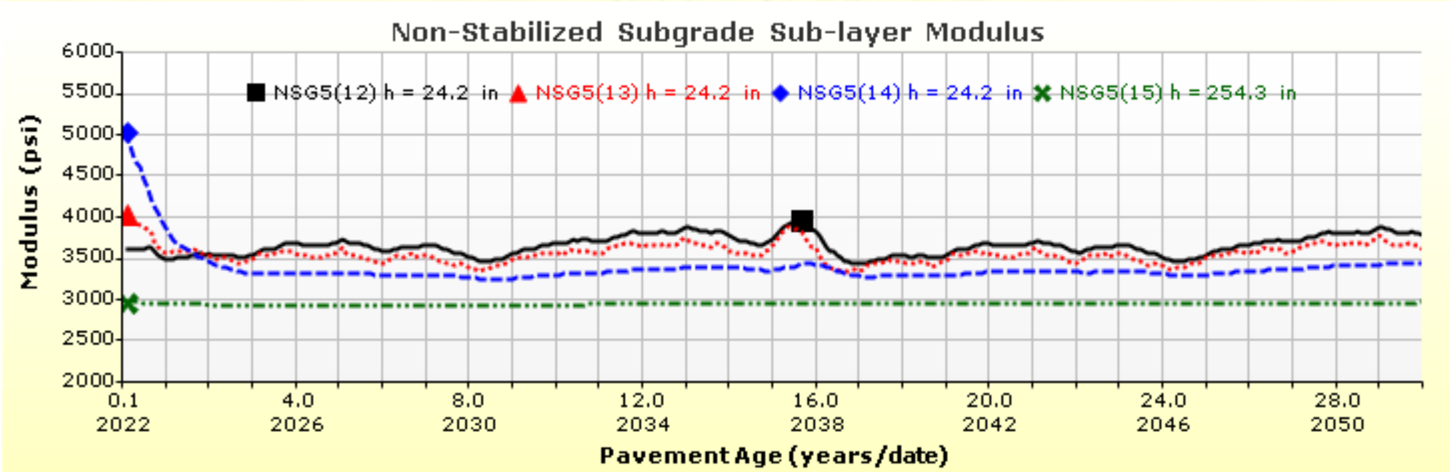


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
4.0
2026
8.0
2030
12.0
2034
16.0
2038
20.0
2042
24.0
2046
28.0
2050
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)
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 2 in
GB4(9) h = 4 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 = 24.2 in
NSG5(13) h = 24.2 in
NSG5(14) h = 24.2 in
NSG5(15) h = 254.3 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Level 1 SX(75) PG 64-28

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	1936600	2082200	2480800	2602400
40	885500	1043400	1602700	1818200
70	208200	266500	571200	743100
100	52200	64400	140400	195000
130	22500	25400	43100	55900

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	3051	81.6
158	1495	83.1
168.8	772	85

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.788
Air voids (%)	5.7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Level 1 SX(75) PG 64-28
Description of object	Mix ID # FS27378
Author	Jay Goldbaum
Date Created	11/11/2020 12:00:00 AM
Approver	CDOT
Date approved	1/1/0001 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	0

Layer 2 Flexible : R2 Level 1 SX(75) PG 64-22

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	140.5	
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	2910500	2947100	3034800	3058600
40	2620500	2695700	2882400	2934800
70	2057300	2190500	2549800	2658300
100	1334300	1500400	2017600	2195500
130	697600	836500	1365200	1584000

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 (%)	11.8
Air voids (%)	6.9
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(75) PG 64-22
Description of object	Mix ID # 19127A
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	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	41

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 : A-1-b

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 5 Subgrade : A-6

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)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

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	0.1414 * Pow(RUT,0.25) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791	Br1:4.3 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: 6.3	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: 6.3	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: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking

AC Top Down Cracking

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

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

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1 + 15/(1+exp(-3.1472-4.1349*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: 50	C2: 0.55	C3: 0.0111	C4: 0.02

APPENDIX H1

RIGID ME-PAVEMENT DESIGN OUTPUT SHEETS
FORESIGHT CIRCLE AND F ¼ ROADS

Design Inputs

Design Life: 30 years
Design Type: JPCP

Existing construction: -
Pavement construction: May, 2022
Traffic opening: August, 2022

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

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R4 Level 1 Lawson	8.0
NonStabilized	Crushed stone	8.0
Subgrade	A-1-b (Pit run) R value 40	12.0
Subgrade	A-6	Semi-infinite

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

Traffic

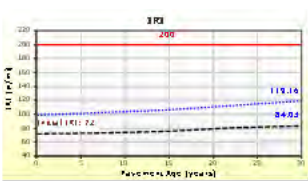
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	210
2037 (15 years)	807,470
2052 (30 years)	1,926,620

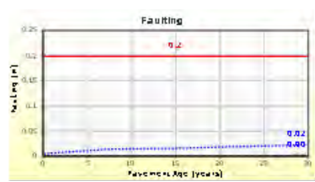
Design Outputs

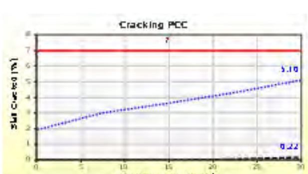
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	119.16	90.00	100.00	Pass
Mean joint faulting (in)	0.20	0.02	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	5.10	90.00	96.26	Pass

Distress Charts





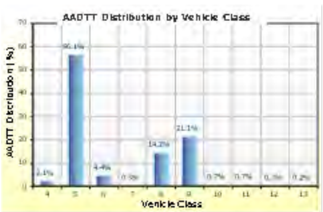


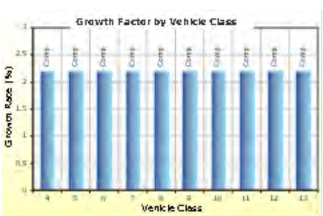
Threshold Value · @ Specified Reliability · @ 50% Reliability

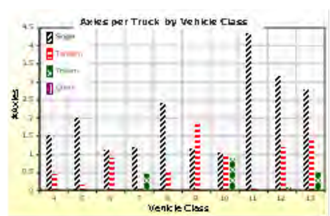
Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT:	210	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)	25.0

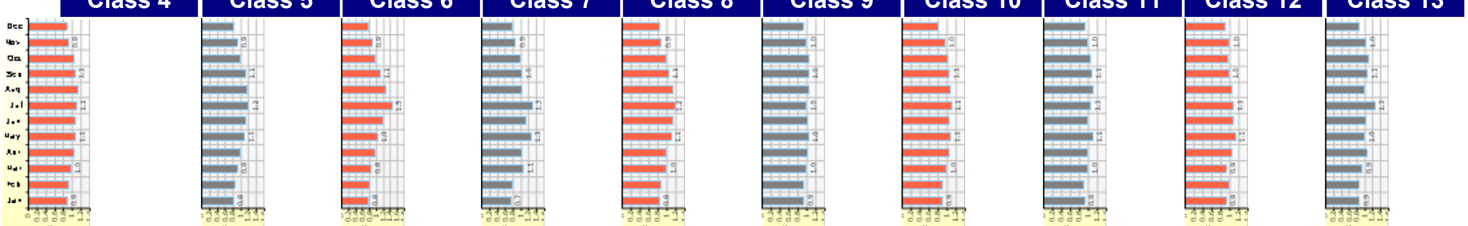






Traffic Volume Monthly Adjustment Factors

Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13



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%	2.2%	Compound
Class 5	56.1%	2.2%	Compound
Class 6	4.4%	2.2%	Compound
Class 7	0.3%	2.2%	Compound
Class 8	14.2%	2.2%	Compound
Class 9	21.1%	2.2%	Compound
Class 10	0.7%	2.2%	Compound
Class 11	0.7%	2.2%	Compound
Class 12	0.2%	2.2%	Compound
Class 13	0.2%	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

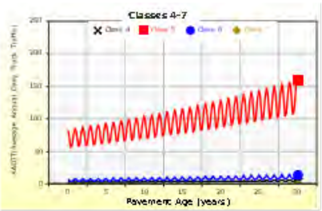
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

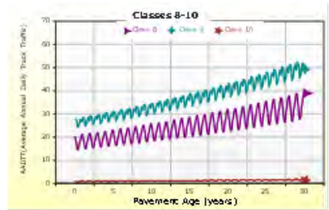
Number of Axles per Truck

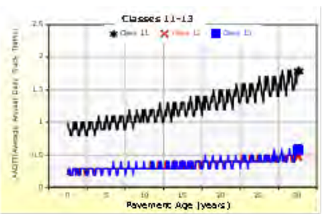
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

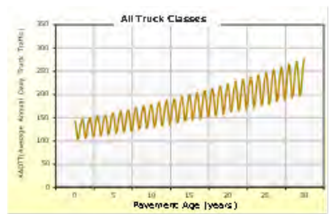
AADTT (Average Annual Daily Truck Traffic) Growth

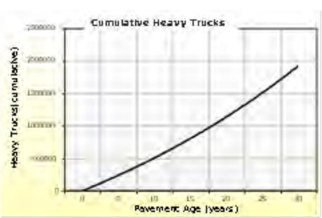
*** Traffic cap is not enforced**











Climate Inputs

Climate Data Sources:

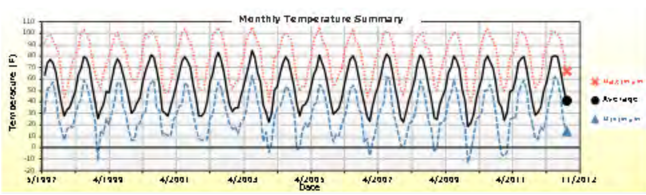
Climate Station Cities:	Location (lat lon elevation(ft))
GRAND JUNCTION, CO	39.13400 -108.53800 4839

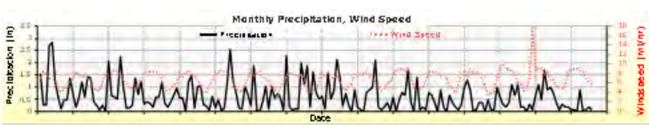
Annual Statistics:

Mean annual air temperature (ºF)	53.51
Mean annual precipitation (in)	7.75
Freezing index (ºF - days)	399.81
Average annual number of freeze/thaw cycles:	111.77

Water table depth (ft) 10.00

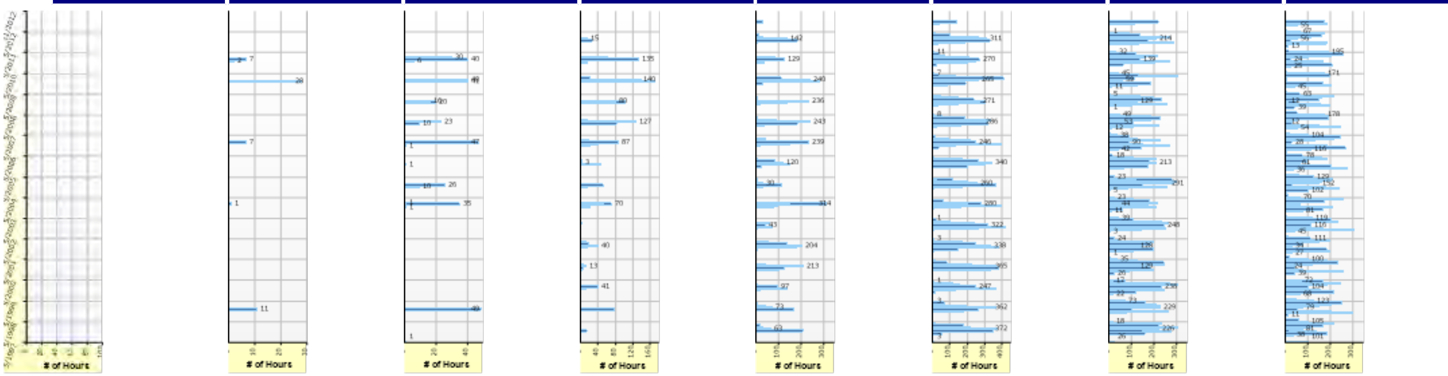
Monthly Climate Summary:



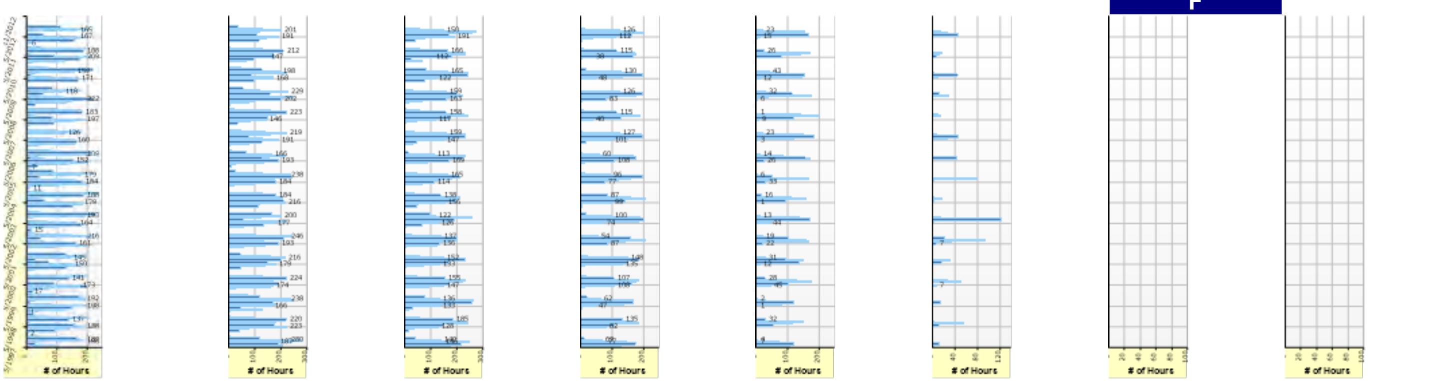


Hourly Air Temperature Distribution by Month:

< -13º F	-13º F to -4º F	-4º F to 5º F	5º F to 14º F	14º F to 23º F	23º F to 32º F	32º F to 41º F	41º F to 50º F



50º F to 59º F	59º F to 68º F	68º F to 77º F	77º F to 86º F	86º F to 95º F	95º F to 104º F	104º F to 113º F	> 113º F



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)	12.00

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

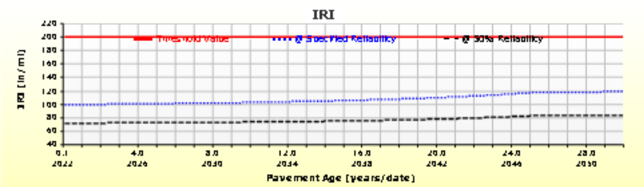
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

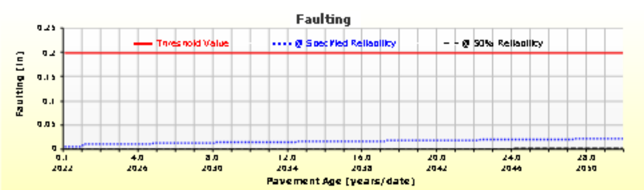
Sealant type	Other(Including No Sealant... Liquid... Silicone)

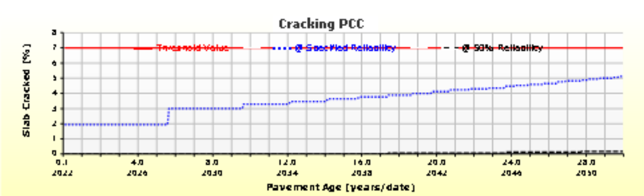
Erodibility index	4

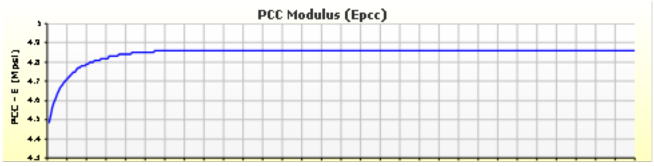
Permanent curl/warp effective temperature difference (ºF)	-10.00

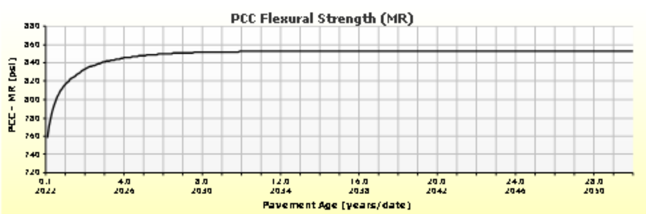
Analysis Output Charts

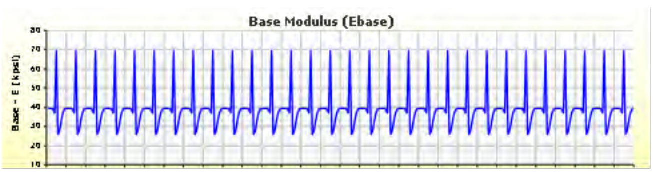


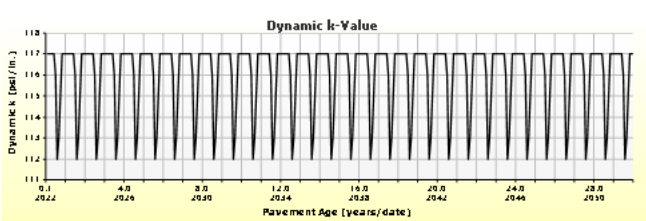


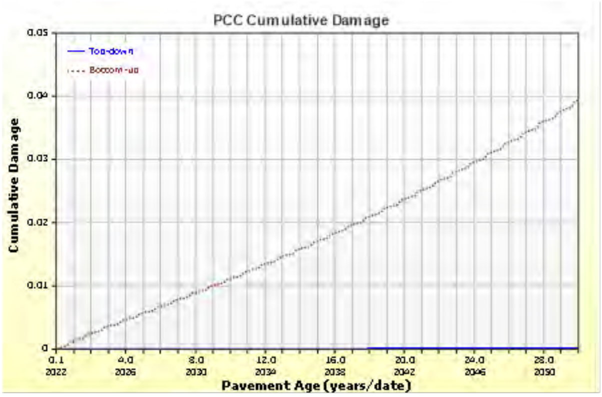



PCC Modulus (Epcc)
PCC - E (Mpsi)

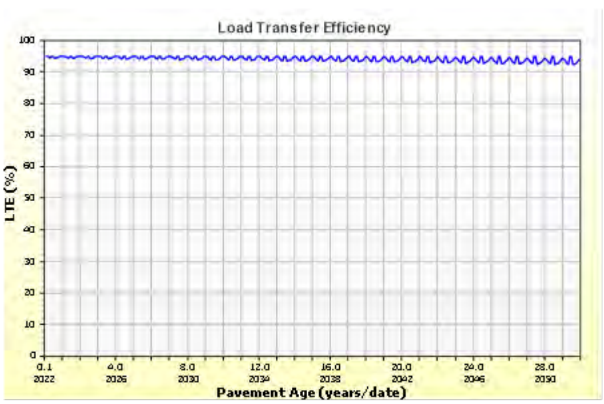

PCC Flexural Strength (MR)
PCC - MR (psi)
Pavement Age (years/date)


Base Modulus (Ebase)
Base - E (kpsi)


Dynamic k-Value
Dynamic k (psi/in.)
Pavement Age (years/date)



PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)

Layer Information

Layer 1 PCC : R4 Level 1 Lawson

PCC	
Thickness (in)	8.0
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

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 stone

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 stone
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	20

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-1-b (Pit run) R value 40

Unbound	
Layer thickness (in)	12.0
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)
9494.0

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

Identifiers

Field	Value
Display name/identifier	A-1-b (Pit run) R value 40
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	11.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	124.2
Saturated hydraulic conductivity (ft/hr)	False	2.303e-03
Specific gravity of solids	False	2.7
Water Content (%)	False	9.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	5.8206
bf	0.4621
cf	3.8497
hr	126.8000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	13.4
#100	
#80	20.8
#60	
#50	
#40	37.6
#30	
#20	
#16	
#10	64.0
#8	
#4	74.2
3/8-in.	82.3
1/2-in.	85.8
3/4-in.	90.8
1-in.	93.6
1 1/2-in.	96.7
2-in.	98.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.4

Layer 4 Subgrade : A-6

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5355.0

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

Identifiers

Field	Value
Display name/identifier	A-6
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	33.0
Plasticity Index	16.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	108.6
Saturated hydraulic conductivity (ft/hr)	False	1.856e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	108.4091
bf	0.6801
cf	0.2161
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	63.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

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 I

20 and 30-YEAR
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
F ½ ROAD

ROADWAY	**F 1/2 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	5,510,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.5762**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.7412	≤	6.7413	
Full HMA:			
Depth=	**10.40**	in	Use 10.5 inches
HMA over ABC:			
Depth Class 3 ABC=	**14**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**4.72**	in	Use 5.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

F.5 Road Improvements

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 = 5
If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

5,510,000 = Design Life ESALs

SN = 4.576 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.74115 Design Mr = 5,356 psi
=
Thickness Equation= B = 6.74128 with no drainage reduction

0.58083479	A
5.58	B
7472.70323	C
0.5463995	D
-0.06117091	E
0.200000	F
5.58	G
6.98569395	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.40
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 Class 3 ABC = 14.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 4.72 Use 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

ROADWAY	**F 1/2 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	9,300,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.9040**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.9685	≤	6.9690	
Full HMA:			
Depth=	**11.15**	in	Use 11.5 inches
HMA over ABC:			
Depth Class 3 ABC=	**14**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.46**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

F.5 Road Improvements

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 = 5

If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

9,300,000 = Design Life ESALs

SN = 4.904 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.96848

=

Thickness Equation= B = 6.96900 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
5.90	B
10051.9322	C
0.5088348	D
-0.06568685	E
0.200000	F
5.90	G
7.21792982	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 11.15
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 Class 3 ABC = 14.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 5.46 Use 6 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 I1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
F ½ ROAD

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 # 599.37
Description: F.5 Road

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	12.02	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	15,696	psi
Base Thickness	20.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**8.88**	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	**7.21**	^{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	**0.07**	in
Criteria Check **PASS**		

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.09**	in
Criteria Check **PASS**		

APPENDIX J

20 and 30-Year
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD

ROADWAY	**24 1/2 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	3,770,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.3497**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.5763	≤	6.5765	
Full HMA:			
Depth=	**9.89**	in	Use 10.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**10**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.20**	in	Use 5.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

24.5 Road Improvements

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 = 5
If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

3,770,000 = Design Life ESALs

SN = 4.350 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.57634
=
Thickness Equation= B = 6.57647 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
5.35	B
6026.19975	C
0.58154061	D
-0.0574745	E
0.200000	F
5.35	G
6.81718832	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.89
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 Class 3 ABC = 10.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 5.20 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

ROADWAY	**24 1/2 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	6,360,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.6640**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.8035	≤	6.8035	
Full HMA:			
Depth=	**10.60**	in	Use 11.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**10**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.92**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

24.5 Road Improvements

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 = 5

If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

6,360,000 = Design Life ESALs

SN = 4.664 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.80346

=

Thickness Equation= B = 6.80350 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
5.66	B
8104.07523	C
0.53499381	D
-0.06247503	E
0.200000	F
5.66	G
7.04922243	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.60

FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.0

Composite HMA over ABC

(using specified layer of ABC)

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

Inches of Class 3 ABC = 10.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 5.92 Use 6 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 J1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD

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 # 599.37
Description: 24.5 Road

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	8.23	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	15,696	psi
Base Thickness	20.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**8.33**	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	**6.83**	^{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	**0.08**	in

Criteria Check **PASS**

APPENDIX K

20 and 30-Year
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD AND F ½ ROAD ROUNDABOUT

ROADWAY	**: 1/2 and 24 1/2**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	8,330,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.8331**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.9206	≤	6.9208	
Full HMA:			
Depth=	**10.98**	in	Use 11.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**16**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**4.80**	in	Use 5.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

F.5 Road and 24.5 Road Roundabout

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 = 5

If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

8,330,000 = Design Life ESALs

SN = 4.833 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.92065

=

Thickness Equation= B = 6.92078 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
5.83	B
9440.91361	C
0.51587862	D
-0.06478996	E
0.200000	F
5.83	G
7.16881142	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.98

FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.0

Composite HMA over ABC

(using specified layer of ABC)

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

Inches of Class 3 ABC = 16.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 4.80 Use 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

ROADWAY	**: 1/2 and 24 1/2**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	14,070,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**5.1750**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
7.1483	≤	7.1484	
Full HMA:			
Depth=	**11.76**	in	Use 12.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**16**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.58**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

F.5 Road and 24.5 Road Roundabout

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 = 5
If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

14,070,000 = Design Life ESALs

SN = 5.175 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.14829
=
Thickness Equation= B = 7.14837 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
6.18	B
12688.3699	C
0.48622069	D
-0.06874194	E
0.200000	F
6.18	G
7.40036196	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 11.76
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 Class 3 ABC = 16.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 5.58 Use 6 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 K1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
24 ½ ROAD AND F ½ ROAD ROUNDABOUT

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 # 599.37
Description: F.5 Road and 24.5 Road Roundabout

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	18.19	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	14,663	psi
Base Thickness	24.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**9.48**	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	**7.59**	^{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	**0.07**	in

Criteria Check **PASS**

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.10**	in

Criteria Check **PASS**

APPENDIX L

20 and 30-YEAR
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD

ROADWAY	**25 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	2,970,000		
R-Value=	**10**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	6482		
Design Mr=	6482		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**3.9652**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.4728	≤	6.4729	
Full HMA:			
Depth=	**9.01**	in	Use 9.5 inches
HMA over ABC:			
Depth Class 3 ABC=	**10**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**4.33**	in	Use 4.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

25 Road Improvements

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

2,970,000 = Design Life ESALs

SN = 3.965 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.47276
=
Thickness Equation= B = 6.47290 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
4.97	B
4091.72391	C
0.66736897	D
-0.05008287	E
0.200000	F
4.97	G
6.51395822	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.01
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 Class 3 ABC = 10.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 4.33 Use 4.5 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

ROADWAY	**25 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	5,020,000		
R-Value=	**10**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	6482		
Design Mr=	6482		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.2593**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.7007	≤	6.7010	
Full HMA:			
Depth=	**9.68**	in	Use 10.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**10**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.00**	in	Use 5.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

25 Road Improvements

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

5,020,000 = Design Life ESALs

SN = 4.259 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.70070

=

Thickness Equation= B = 6.70101 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.26	B
5515.6412	C
0.59834503	D
-0.05586034	E
0.200000	F
5.26	G
6.74784945	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 9.68

FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.0

Composite HMA over ABC

(using specified layer of ABC)

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

Inches of Class 3 ABC = 10.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 5.00 Use 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 L1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD

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 # 599.37
Description: 25 Road

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	6.49	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	15,696	psi
Base Thickness	20.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**7.99**	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	**6.56**	^{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	**0.08**	in

Criteria Check **PASS**

APPENDIX M

20 and 30-YEAR
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD & F ½ ROAD INTERSECTION

ROADWAY	25 and F.5 Road
INITIAL VALUES	
Initial Serviceability Index=	4.5
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=	7,730,000
R-Value=	**10**
INTERMEDIATE CALCULATIONS	
Calculated Mr=	6482
Design Mr=	6482
Design Serviceability Loss (ΔPSI)=	2.5
FINAL CALCULATIONS	
SN=	**4.5131**

	Such That:	
Log_{10}ESAL	≤	**Thickness Equation**
6.8882	≤	6.8883

Full HMA:

Depth=	**10.26**	in	Use 10.5 inches

HMA over ABC:

Depth Class 3 ABC=	**12**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.08**	in	Use 5.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

25 and F.5 Road Intersection

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

7,730,000 = Design Life ESALs

SN = 4.513 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.88818

=

Thickness Equation= B = 6.88831 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.51	B
7044.52518	C
0.5552979	D
-0.06019067	E
0.200000	F
5.51	G
6.93947826	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 10.26
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 Class 3 ABC = 12.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 5.08 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

ROADWAY	**25 and F.5 Road**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	13,060,000		
R-Value=	**10**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	6482		
Design Mr=	6482		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**4.8380**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
7.1159	≤	7.1164	
Full HMA:			
Depth=	**11.00**	in	Use 10.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**12**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**5.81**	in	Use 6.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

25 and F.5 Road Intersection

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

13,060,000 = Design Life ESALs

SN = 4.838 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 7.11594
=
Thickness Equation= B = 7.11640 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
5.84	B
9482.23317	C
0.51537367	D
-0.06485344	E
0.200000	F
5.84	G
7.17223189	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 11.00
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 Class 3 ABC = 12.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 5.81 Use 6 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 M1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
25 ROAD & F ½ ROAD INTERSECTION

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 # 599.37
Description: 25 and F.5 Road Intersection

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	16.89	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	15,696	psi
Base Thickness	20.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness	**9.40**	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	**7.54**	^{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	**0.07**	in

Criteria Check **PASS**

Nondoweled

Drainage Coefficient	1	
Average Fault for Design Years with Design Inputs	**0.09**	in

Criteria Check **PASS**

APPENDIX N

20 and 30-YEAR
FLEXIBLE 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
FORESIGHT CIRCLE AND F ¼ ROADS

ROADWAY	**Foresight Circle**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	810,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**3.5198**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
5.9085	≤	5.9086	
Full HMA:			
Depth=	**8.00**	in	Use 8.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**12**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**2.82**	in	Use 3.0 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

Foresight Circle and F 1/4 Road Improvements

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 = 5
If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

810,000 = Design Life ESALs

SN = 3.520 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 5.90849
=
Thickness Equation= B = 5.90863 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
4.52	B
2512.1743	C
0.83547934	D
-0.04000548	E
0.200000	F
4.52	G
6.13188166	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 Class 3 ABC = 0.11
Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 8.00
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 Class 3 ABC = 12.0
Inches of Class 6 ABC = 8.0
Calculated Inches of HMA = 2.82 Use 3.0 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

ROADWAY	**Foresight Circle**		
INITIAL VALUES			
Initial Serviceability Index=	4.5		
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=	1,360,000		
R-Value=	**5**		
INTERMEDIATE CALCULATIONS			
Calculated Mr=	5356		
Design Mr=	5356		
Design Serviceability Loss (ΔPSI)=	2.5		
FINAL CALCULATIONS			
SN=	**3.7841**		
	Such That:		
Log_{10}ESAL	≤	**Thickness Equation**	
6.1335	≤	6.1336	
Full HMA:			
Depth=	**8.60**	in	Use 9.0 inches
HMA over ABC:			
Depth Class 3 ABC=	**12**	in	
Depth Class 6 ABC=	**8**	in	
Depth HMA=	**3.42**	in	Use 3.5 inches

THIS SHEET USES THE "NEW" CDOT R-VALUE TO RESILIENT MODULUS EQUATION

Foresight Circle and F 1/4 Road Improvements

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 = 5

If Mr is based on R-Value ===> Mr = 5,356 psi For Post-2015 CDOT Correlation

1,360,000 = Design Life ESALs

SN = 3.784 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.13354

=

Thickness Equation= B = 6.13356 with no drainage reduction

Design Mr = 5,356 psi

0.58083479	A
4.78	B
3374.24206	C
0.72422096	D
-0.04615132	E
0.200000	F
4.78	G
6.36295367	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 Class 3 ABC = 0.11

Structural Coefficient of Class 6 ABC = 0.12

Design Serviceability Loss (ΔPSI)= 2.5

Calculated thickness, inches = 8.60

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 Class 3 ABC = 12.0

Inches of Class 6 ABC = 8.0

Calculated Inches of HMA = 3.42 Use 3.5 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 N1

RIGID 1993 AASHTO PAVEMENT DESIGN OUTPUT SHEETS
FORESIGHT CIRCLE AND F ¼ ROADS

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 # 599.37
Description: Foresight Circle and F.25 Road

Location: Grand Junction, CO

Slab Thickness Design

Pavement Type	JPCP	
18-kip ESALs Over Initial Performance Period (million)	1.76	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	15,696	psi
Base Thickness	20.0	in.
Mean Effective k-Value	125	psi/in
Reliability Level	90	%
Overall Standard Deviation	0.34	
Calculated Design Thickness		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		^{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 in
Criteria Check

Nondoweled

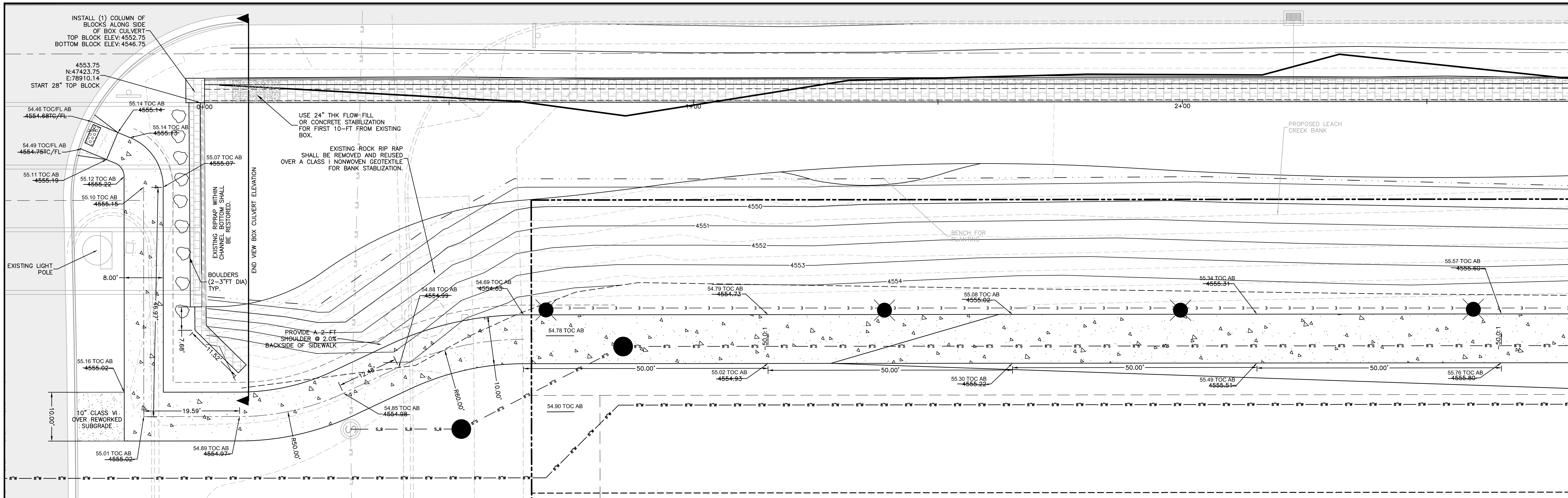
Drainage Coefficient 1

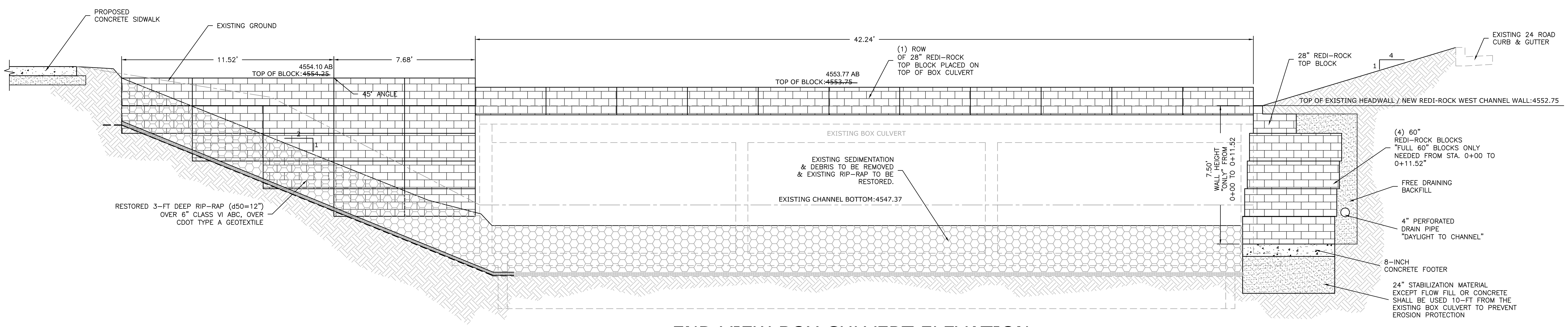
Average Fault for Design Years with Design Inputs in
Criteria Check

APPENDIX O

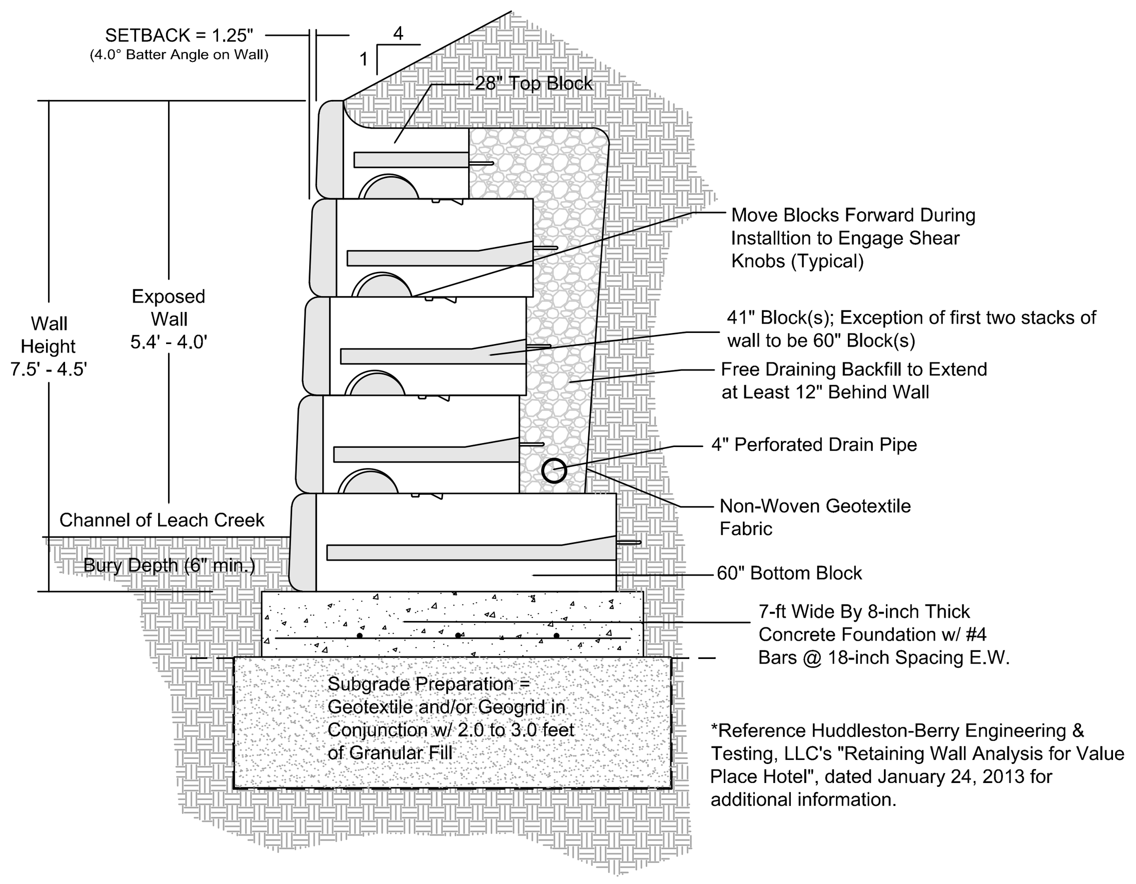
RECORD DRAWING CBC STRUCTURE

(FROM VALUE PLACE HOTEL PLAN SET)





END VIEW BOX CULVERT ELEVATION



"Reference Huddleston-Berry Engineering & Testing, LLC's "Retaining Wall Analysis for Value Place Hotel", dated January 24, 2013 for additional information.

Typical Redi-Rock Retaining Wall

Not to Scale

RECORD DRAWING

RECORD DRAWINGS WERE PREPARED BASED OFF OF SURVEY DATA PROVIDED BY POLARIS SURVEYING.

CITY OF GRAND JUNCTION ENGINEERING
APPROVED FOR CONSTRUCTION FOR ONE YEAR FROM THIS DATE.
BY:______________ DATE:__________
ACCEPTED AS CONSTRUCTED
BY:______________ DATE:__________

"All details, construction, inspections, and testing shall conform to the City of Grand Junction Standard Contract Documents for Capital Improvements Construction. Contractor shall have a copy of the accepted plans and current City of Grand Junction Standard Documents for Capital Improvements Construction on site and available at all times."

0' 10' 20' 30'

schwerdt design group
architecture | interiors | planning
2231 sw wanamaker rd suite 303
topeka, kansas 66614-4275
phone: 785.273.7540
fax: 785.273.7579
5929 north may avenue suite 411
oklahoma city, ok 73112-3961
phone: 405.842.1190
fax: 405.842.1244

COLORADO REGISTERED PROFESSIONAL ENGINEER 29778 9/22/14

A · C · G
AUSTIN CIVIL GROUP, INC.
Land Planning • Civil Engineering • Development Services
336 Main Street, Suite 203 Grand Junction, Colorado 81501
(970) 242-7540

NEW BUILDING FOR:
VALUE PLACE HOTEL
651 MARKET STREET, GRAND JUNCTION, CO 81505

SUBMISSION DATES
9-9-13
RECORD DRAWING

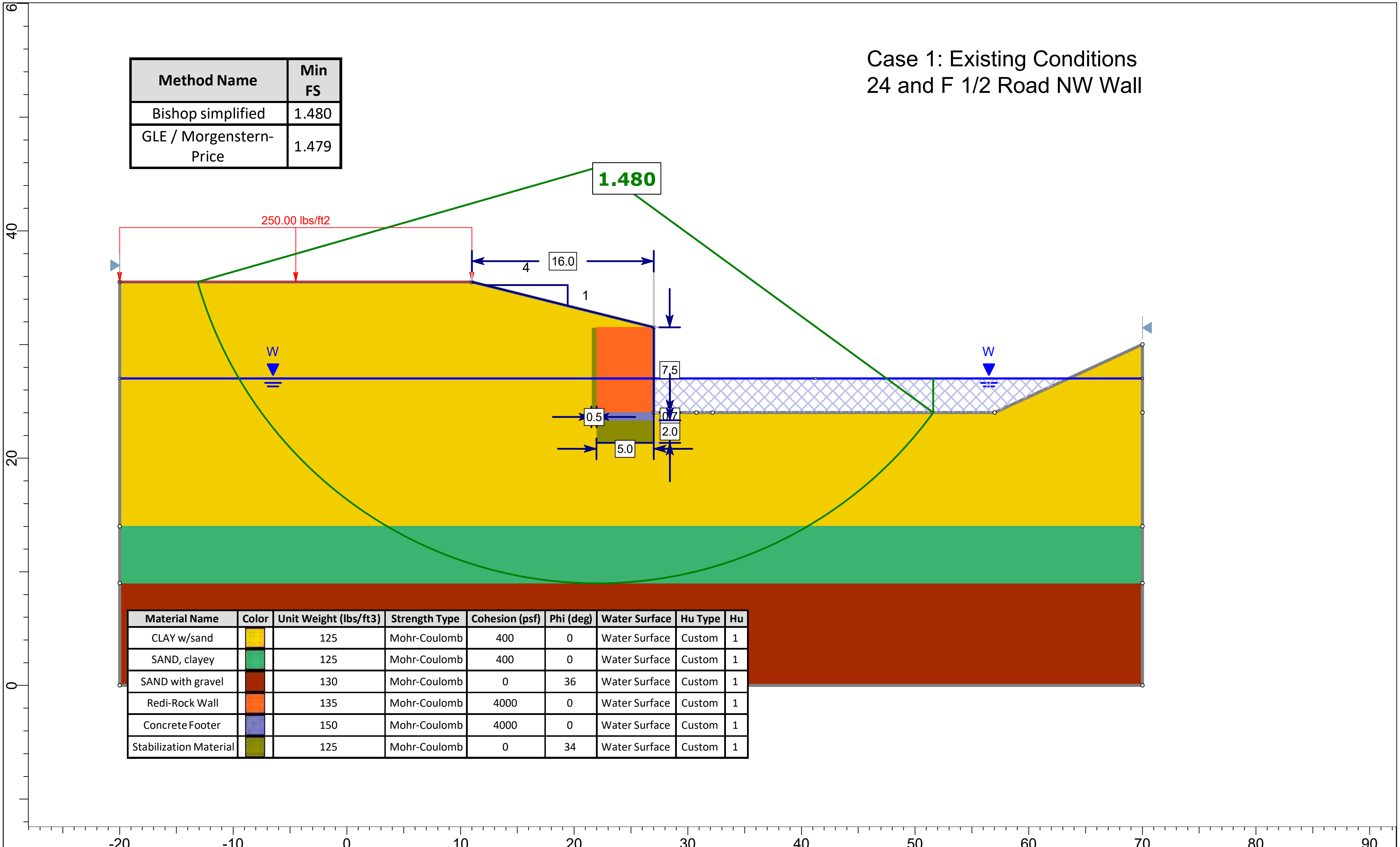
SHEET TITLE
LEACH CREEK DETAILS

PROJECT NUMBER
111095

SHEET NUMBER
C015

APPENDIX P

SLOPE STABILITY MODELS AT NW WALL



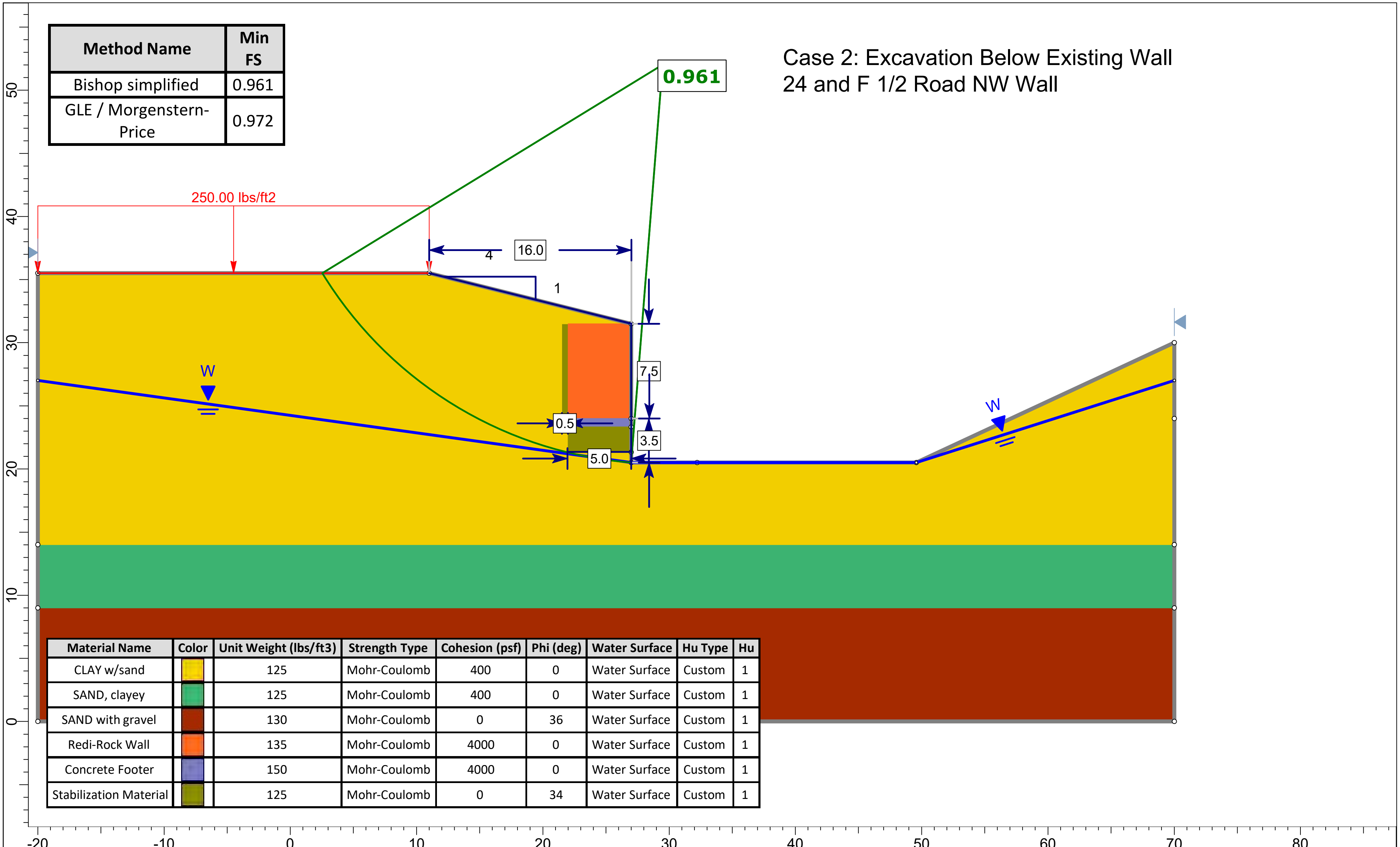
Method Name	Min FS
Bishop simplified	1.480
GLE / Morgenstern-Price	1.479

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
CLAY w/sand		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND, clayey		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND with gravel		130	Mohr-Coulomb	0	36	Water Surface	Custom	1
Redi-Rock Wall		135	Mohr-Coulomb	4000	0	Water Surface	Custom	1
Concrete Footer		150	Mohr-Coulomb	4000	0	Water Surface	Custom	1
Stabilization Material		125	Mohr-Coulomb	0	34	Water Surface	Custom	1

rocscience

SLIDEINTERPRET 9.019

Project	SLIDE - An Interactive Slope Stability Program		
Group	Group 1	*Scenario*	Master Scenario
Drawn By		*Company*	
Date	1/27/2022, 10:52:54 AM	*File Name*	Retaining Wall Area.slmd



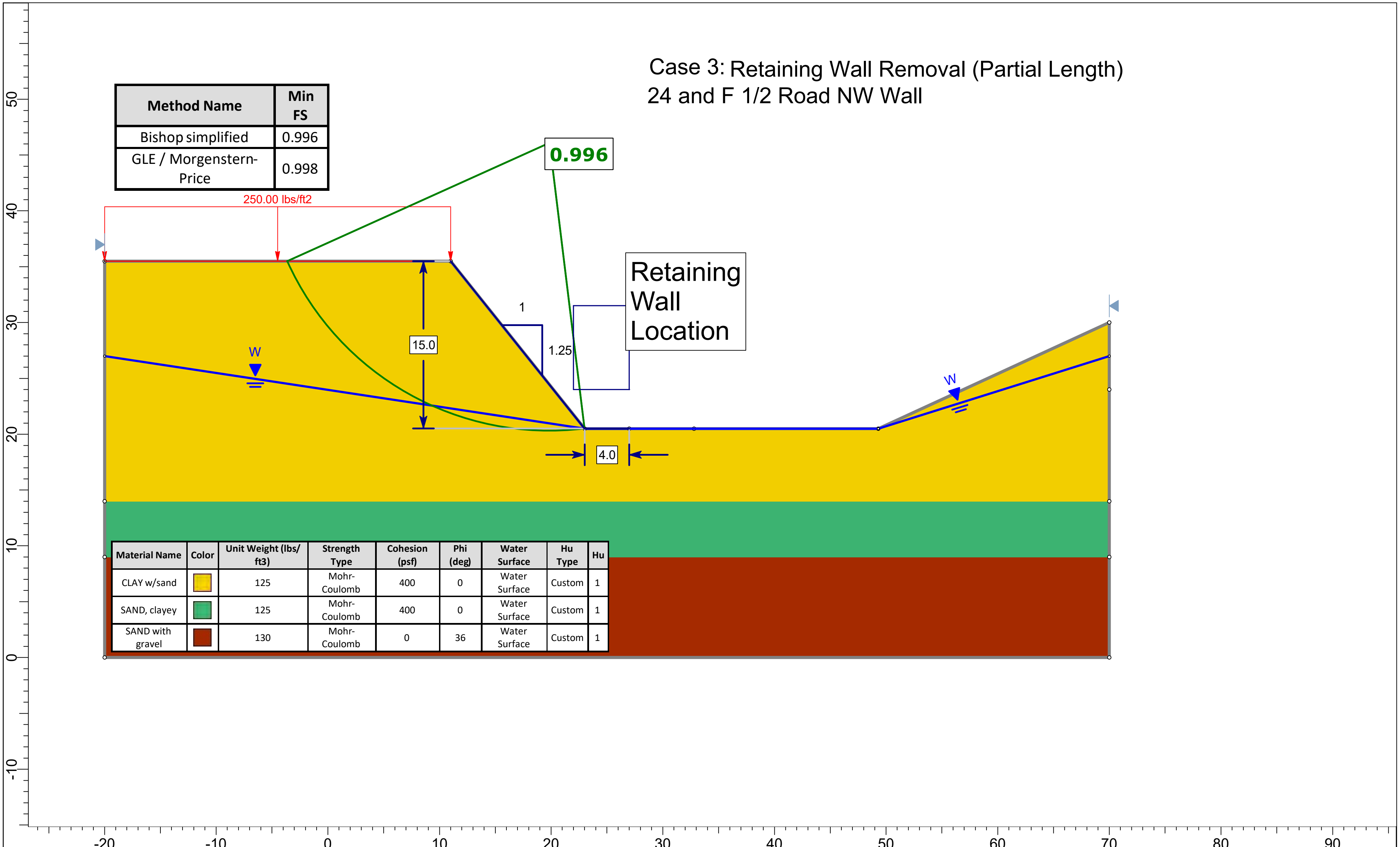
Method Name	Min FS
Bishop simplified	0.961
GLE / Morgenstern-Price	0.972

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
CLAY w/sand		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND, clayey		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND with gravel		130	Mohr-Coulomb	0	36	Water Surface	Custom	1
Redi-Rock Wall		135	Mohr-Coulomb	4000	0	Water Surface	Custom	1
Concrete Footer		150	Mohr-Coulomb	4000	0	Water Surface	Custom	1
Stabilization Material		125	Mohr-Coulomb	0	34	Water Surface	Custom	1

rocscience	*Project* SLIDE - An Interactive Slope Stability Program		
	Group Group 1	*Scenario* Master Scenario	
	Drawn By	*Company*	
SLIDEINTERPRET 9.019	*Date* 1/27/2022, 10:52:54 AM	*File Name* Retaining Wall Area.slmd	

Case 3: Retaining Wall Removal (Partial Length)
24 and F 1/2 Road NW Wall

Method Name	Min FS
Bishop simplified	0.996
GLE / Morgenstern-Price	0.998



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
CLAY w/sand		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND, clayey		125	Mohr-Coulomb	400	0	Water Surface	Custom	1
SAND with gravel		130	Mohr-Coulomb	0	36	Water Surface	Custom	1

rocscience	*Project* SLIDE - An Interactive Slope Stability Program		
	Group Group 1	*Scenario* Master Scenario	
	Drawn By	*Company*	
SLIDEINTERPRET 9.019	*Date* 1/27/2022, 10:52:54 AM	*File Name* Retaining Wall Area_Cut Slope.slmd	