City of Grand Junction
2022 Transportation Corridor Improvements
Subsurface Investigation, Geotechnical Report and Pavement Design
Professional Geotechnical Services On-Call RFP-4739-20-DH
Contract Renewal Option #4887-22-DH

Prepared for:
City of Grand Junction, Engineering Manager
333 West Avenue, Bldg C Grand Junction, CO, 81501

Attention: Mr. Ken Haley, PE Project Manager

February 28, 2023
Updated November 1, 2024

RockSol Project No. 599.70

RockSol Consulting Group, Inc.

566 West Crete Circle #2
Grand Junction, Colorado 81505
303-962-9300

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1.0 INTRODUCTION

This report documents the geotechnical engineering investigation performed by RockSol Consulting Group, Inc. (RockSol) for the City of Grand Junction (City) 2022 Transportation Corridor Improvements Project. Proposed improvements include roadway widening, drainage improvements, intersection improvements, and pedestrian improvements along B ½ Road, D ½ Road, F ½ Road, and 26 ½ Road. The project also includes extending a three-sided culvert at Grand Valley Canal and 26 ½ Road.

Roadway improvement segments include:

- 0.85 miles of B ½ Road between 29 Road extending just east of 29 ¾ Road
- 0.83 miles of D ½ Road between D ½ Court extending East to 30 Road
- 0.82 miles of F ½ Road between 30 Road extending East to Lewis Gulch
- 0.72 miles of 26 ½ Road between Horizon Drive and G Road

The distances listed for the improvement segments are approximate. See Appendix A for the improvement segment locations.

26½ Road has two lanes in each travel direction for 300 feet in the southern portion of the project area, and all other roadways have one lane in each travel direction in their respective project areas. Each roadway segment consists of flexible pavement. Significant changes in the road surface profiles are not anticipated due to intersecting roadways and residential access driveways.

Pavement design will be provided for hot mix asphalt (flexible pavement), RockSol understands that concrete pavement (rigid pavement) is not being considered for the corridor improvements by the City. Pavement sections will include options for full reconstruction and for rehabilitation of existing pavement with a widened addition (saddlebag) design alternative.

Pavement Design recommendations for Pavement design will be completed in accordance with the City of Grand Junction Transportation Engineering Design Standards (TEDS) Section 29.32.040, AASHTO Guide for Design of Pavement Structures (latest edition), and the Pavement Mechanistic-Empirical Pavement Design (PMED) as outlined in CDOT's 2021 Pavement Design Manual.

The scope of work for this geotechnical investigation included:

- Structural capacity evaluation of the existing pavement based on the thickness and condition of the existing pavement for each project roadway.
- Preparing a drilling/sampling program to perform a subsurface investigation and implementing the program to collect soil samples for laboratory testing.
- Performing laboratory tests on recovered soil samples and analyzing the data.
- Preparing a report that presents the field and laboratory data obtained, geological setting and conditions, and geotechnical design parameters for roadway pavement rehabilitation and new pavement recommendations for 20-years of life.
- Geotechnical recommendations for the three-sided culvert extension

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. A groundwater study/evaluation was not included in this geotechnical investigation scope of work.

2.0 ROAD MAINTENANCE AND TYPICAL REHABILITATION TECHNIQUES

In the interest of energy conservation, the environment, and reduction of greenhouse gases, an emphasis is placed on building and constructing roadways to minimize the quantity of materials needed, utilize recycled materials, use local materials, reduce water use, and minimize energy consumption while keeping the construction and maintenance cost-efficient and cost-effective. The use of Reclaimed Asphalt Pavement (RAP) in hot mix asphalt (HMA), base stabilization and subgrade treatment using the Full Depth Reclamation (FDR) process, and the rehabilitation/maintenance of existing roadways using Cold In-place Recycling (CIR) method, are some of the recycling technologies being practiced in the state of Colorado. It should be noted that the use of recycled materials is made on a case-by-case basis based on thorough evaluation of material properties, past performance of the recycled material, benefit/cost analysis, and engineering judgment.

Recycling and reusing these materials will save energy, conserve natural resources, and reduce greenhouse gas emissions (carbon footprint). The use of RAP in HMA is an efficient use of this material as it is possible with conventional HMA production and placement equipment, provides a reduction in virgin asphalt binder and aggregate demand, and thus conserves natural resources. RAP is also used as recycled aggregate base and helps reduce the pavement structural section due to its increased strength in comparison to conventional aggregate base. FDR and CIR utilize 100% of the existing recycled pavement, may reduce required new HMA thickness, and offer some of the most significant cost and environmental savings over conventional methods.

The following are general descriptions of typical maintenance or rehabilitation techniques for use on City of Grand Junction roads for informational purposes. Performance life will vary based on existing pavement conditions.

2.1 Crack Seal

Crack sealing is a routine technique used to temporarily treat roadways cracks. It is also a necessary step prior to more advanced rehabilitation techniques. Crack sealing prevents moisture from infiltrating the pavement crack and causing more extensive problems such as potholes and road subgrade failure. Typically, crack sealing is performed when the width of the crack is less than 0.75 inches.

2.2 Crack Filling

Crack filling is the placement of asphalt emulsion mixed with sand into non-working cracks to reduce water infiltration and to reinforce the adjacent pavement it only fills the void and reduces intrusion of water and debris into the crack and does not move with the pavement as it expands and contracts. It is a much more permanent and durable solution used to fix cracks that are much deeper and wider than 0.75 inches.

2.3 Chip Seal

A chip seal is a maintenance technique that extends the life of a typical road pavement surface for approximately 5 years. Prior to chip sealing a road segment, the required crack sealing and subgrade restoration and patching should be completed. The road segment is then swept prior to the application of an asphalt-based emulsion. Crushed aggregate (chip) is then applied and rolled into the emulsion. A fog sealant is then sprayed uniformly over the top of the chips. Excess chips are swept away prior to the final step of road striping.

2.4 Slurry Seal

Slurry seal is a maintenance technique for road experiencing less traffic volume and lower speeds (such as a rural subdivision road) that extends the life of road surfaces for approximately 5 years. It is a mixture of asphalt emulsion and finer-grained aggregate. Prior to slurry sealing a road segment, the required crack sealing and subgrade restoration and patching should be completed. Slurry seal is then applied by a truck with a squeegee or spray applicator.

2.5 Cape Seal

A cape seal consists of a bottom course of chip seal covered with a wearing course of slurry seal. Both pavement surface treatments are non-structural preventive maintenance applications that are classified as pavement preservation techniques. Such techniques can extend pavement life and improve safety. In a cape seal application, covering a single layer of chip seal with slurry seal prevents the aggregate from the chip seal application from being dislodged and can be especially effective for roads that are plowed in winter and those with curb and gutter. Cape seals can extend pavement performance by approximately 8 years.

2.6 Asphalt Rejuvenator

Asphalt Rejuvenator is the application of petroleum-based products (e.g., AsPenTM, Anova) to penetrate the pavement surface and replace the binders that have been lost over time due to oxidation, weathering, etc. It is an ideal treatment for weathered pavements. Crack sealant is applied to pavement cracks prior to the asphalt rejuvenator application. Asphalt rejuvenators can extend pavement performance by approximately 3 years.

2.7 Mill and Overlay

Milling is the process of removing and recycling the top layer (typically 2 inches) of asphalt. Overlay is the application of a new layer of asphalt pavement over existing or milled asphalt pavement. This process is typically used when curb and gutter currently exists, when the vertical profile cannot be raised, and when the existing asphalt pavement has enough depth. A road in very poor condition can be rehabilitated with milling and overlay. Milling and overlay can extend pavement performance by approximately 10 to 20 years.

2.8 Thin Overlay

When the existing asphalt pavement has enough depth and a road is in good condition, a 1-inch overlay can be applied as a rehabilitation technique to correct surface irregularities and minor distresses. A thin overlay can extend pavement performance for up to 10 years.

2.9 Conventional Overlay

When the existing asphalt does not have enough depth to be milled or is severely distressed causing a structural deficiency that adversely affects the load carrying capability of the pavement structure, the pavement should have an overlay. Conditions which reduce the load carrying capacity include inadequate thickness, cracking, rutting, and disintegration. Following crack sealing, a conventional 2-inch overlay usually can extend pavement performance by at least 10 to 20 years.

2.10 Cold-In-Place Recycling (CIR)

Pavement is removed by cold planing to a depth of 3 to 4 inches leaving sufficient amount of existing pavement to support the equipment during the construction process. The material is crushed, sized, and mixed with an asphalt emulsion and other additives. Then the material is placed and compacted. Within two to five days of placing the CIR material, a layer of hot mix asphalt is laid down. Typically, a 3-piece “train” is used consisting of a cold planning machine, a screening/crushing/mixing unit, and conventional laydown and rolling equipment. Single-unit recycling equipment is also becoming available. This “train” occupies only one lane, thus maximizing traffic flow. Typically, 1.5 to 4 inches of asphalt is placed as the wearing surface. CIR and overlay can extend pavement performance by 20 years.

2.11 Full-Depth Reclamation (FDR)

The full depth reclamation process is when asphalt layers of the existing pavement and a portion of the underlying materials are pulverized in-place four to ten inches deep to produce a stabilized material. The stabilized material is mixed with water, cement, or an asphalt emulsion, then shaped and compacted in preparation for a new wearing surface such as hot mix asphalt. The wearing surface is typically placed within one to three days of completing the FDR material. The FDR methodology is ideal for straightaway roadways such as arterials and collector roads with no curb and gutter, but CDOT has used it on mountainous switchbacks in locations like Hoosier Pass. Typically, 2 to 4 inches of asphalt is placed as the wearing surface. FDR and overlay can provide pavement performance by at least 20 years, depending on traffic loading.

2.12 Full Reconstruction

Transitioning a gravel, chip sealed or asphalt-paved surface with a very low condition index may be a good candidate for full reconstruction. Full reconstruction of an arterial road typically includes 4 inches of subbase soil, a minimum of 4 inches of aggregate base course material, and a minimum of 4 inches of HMA. In addition to road improvements, drainage improvements are also ideally incorporated in full reconstruction projects. Full-depth reconstruction can extend pavement performance by at least 20 years.

3.0 SUBSURFACE EXPLORATION

For this investigation, RockSol drilled and sampled a total of 40 boreholes. The locations of the geotechnical investigation of boreholes are shown in the following subsections of this report and in Appendix A. The boreholes were completed on January 3 and January 9, 2023.

The borehole locations were identified in the field prior to drilling by RockSol personnel using a Global Positioning System (GPS) device. A truck mounted Simco 2800 drill rig was used for drilling and sampling. Borehole B-3 was advanced to an approximate depth of 25 feet below existing grade using 6-inch hollow stem augers for the proposed three-sided culvert widening at Grand Valley Canal and 26 ½ Road. All other boreholes were advanced to depths ranging from approximately 5 feet to 15 feet using 4-inch and 6-inch outside diameter solid stem augers for pavement design and utility improvement/excavation purposes.

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. Each borehole was backfilled at the completion of drilling and groundwater level checks and patched with an asphalt cold-patch mix.

Subsurface materials were obtained by collecting bulk material brought to the surface from the drill auger and collecting discrete samples using modified California barrel and standard split spoon samplers. 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 are used with the modified California barrel sampler to retain samples for density, swell, and unconfined compressive strength testing. Sample retaining liners are not used with the standard split spoon sampler.

Standard Penetration Tests (SPT) and Penetration Tests (PT) were performed at selected intervals using an automatic hammer lift system. The standard split spoon sampling method is the SPT described by ASTM Method D-1586. PT were performed using the modified California barrel sampler. A standard hammer weighing 140 pounds falling 30 inches per ASTM D3550 was used for both the SPT and PT. 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. 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. 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 in Appendix B. Subsurface materials were identified in the field by a representative of RockSol using visual-manual methods as described in ASTM D 2488.

4.0 LABORATORY TESTING

Field logs and soil samples retrieved from the borehole locations were reviewed under the supervision of the project geotechnical engineer. Based on that review, laboratory tests were assigned on selected samples to characterize the appropriate engineering properties of the subsurface material encountered.

Selected samples were tested and classified per the American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS). The following laboratory tests were performed in accordance with the American Society for Testing and Materials (ASTM), 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 (HACH Method 8113)
- 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)
- Moisture/Density Relationship (Proctor) (AASHTO T99 Method A)
- Resistance Value (R-Value, AASHTO T190)

R-Values (Resistance Values) and were submitted to Cesare, Inc. for testing. All other laboratory tests were performed by RockSol. Laboratory test results are presented in Appendix C and are also summarized on the Borehole Logs presented in Appendix B.

5.0 SUBGRADE CHARACTERIZATION

Subgrade bulk samples were obtained at various depths from each borehole location and were tested for soil classification as well as selected Modified California and split-spoon samples. For soil classification, RockSol conducted sieve analyses and Atterberg Limits tests. Lab testing was also performed on selected samples to determine pH and water-soluble sulfate and chloride contents of subsurface materials to assist with cement type and corrosion resistance recommendations.

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-1-b, A-2-4, A-4, A-6, and A-7-6 soil types (See Appendix C).

Based on subgrade soil classifications obtained, special mitigation methods for expansive soil are not deemed necessary for new pavement construction.

RockSol assigned four R-Values to determine subgrade support characteristics. R-value test results were 10 (26 ½ Road), 11 (B ½ Road), 14 (D ½ Road), and 21 (F ½ Road). The R-value test graphs are included in Appendix C. 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 each subject roadway, based on our analyses of the field and laboratory test results.

Two moisture/density relationship (standard proctor) tests were performed to assist in earthwork operations for utility improvements. The results of the two proctor tests are presented in Appendix C.

Subsurface soil conditions and characterization results are described in the following report sections for each subject roadway.

5.1 Sulfate Resistance

Cementitious material requirements for concrete in contact with site soils or groundwater are based on the percentage of water-soluble sulfates in either soil or groundwater that will be in contact with concrete constructed for this project. Mix design requirements for concrete exposed to water soluble sulfates in soils or water are shown in Table 1, and in the Standard Specifications for Road and Bridge Construction, dated 2022 (from CDOT Table 601-2).

Table 1 – 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

The concentration of water-soluble sulfates (percent by weight) measured in soil samples obtained in the upper 5 to 10 feet from RockSol's exploratory boreholes ranged from the following with the associated CDOT Severity of Sulfate Exposure Class:

- B ½ Road – 1.06 percent and 1.50 percent – **Class 2**
- D ½ Road – 1.42 percent and 2.01 percent – **Class 3**
- F ½ Road – 0.13 percent – **Class 1**
- 26 ½ Road – 0.03 percent to 1.95 percent (average of 1.01 percent) – **Class 2**

Refer to CDOT's current *Standard Specifications for Road and Bridge Construction Section 601* for concrete mixtures that satisfy appropriate sulfate exposure *Class* requirements.

6.0 B ½ ROAD

B ½ Road is a minor arterial generally consisting of flat roadway grades. The project alignment is approximately 0.85 miles along B ½ Road between 29 Road and just east of 29 ¾ Road (approximately 800 feet west of 30 Road). The existing roadway generally ranges in width from 24 feet to 28 feet, with paved and non-paved shoulders. Residential structures and agricultural fields are located throughout the project alignment, along with a golf course on the south side, just east of Merles Way.

6.1 Geological Conditions

Based on information presented in the United States Geological Survey (USGS) Geologic Map of the Grand Junction Quadrangle, Mesa County, Colorado (Map MF-2363), dated 2002 (See Figure 1), Terrace alluvium 30 of the Colorado River is mapped at or near the surface for the entirety of the project roadway alignment. Mancos Shale (Km) bedrock is mapped at or near the surface, approximately 2,000 feet north of the project adjacent to the Colorado River.

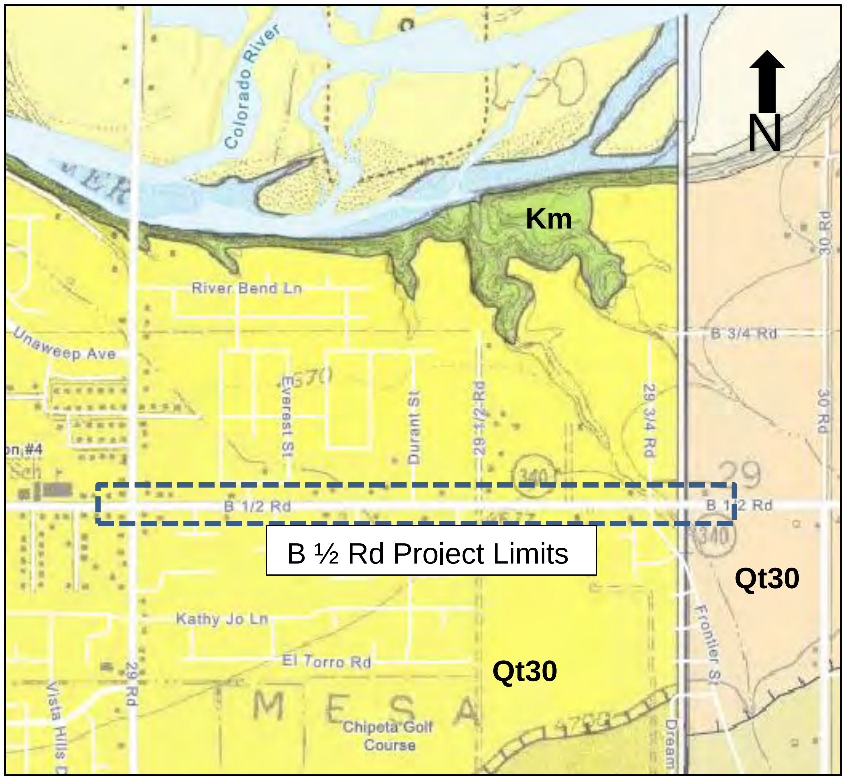


Figure 1. B ½ Road Geologic Map

6.2 Surface Condition and Subsurface Investigation

The surface and subsurface materials encountered by RockSol at our borehole locations included asphalt pavement, aggregate base course fill material, and native soils. The information for each roadway segment is found in the Borehole Logs in Appendix B and as follows.

6.2.1 Existing Asphalt Pavement Sections

Ten boreholes were taken in B ½ Road as shown in Figure 2. The locations are identified as B-51 through B-60. Full-depth asphalt pavement thickness for B ½ Road has an average of about 6.5 inches and ranges in thickness from 4.5 inches to 11.5 inches. Aggregate base course (ABC) was noted below the asphalt and ranged in thickness from approximately 3 to 10 inches (average thickness of 5.5 inches).

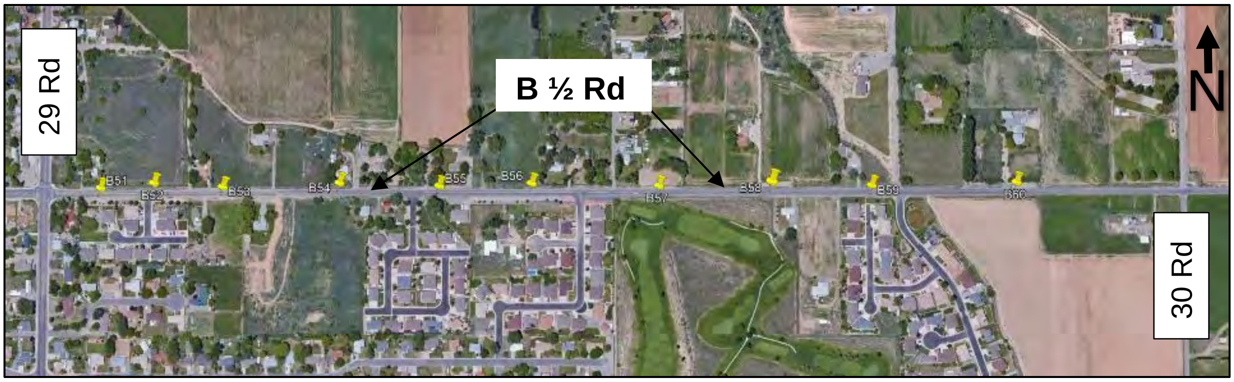


Figure 2. Borehole locations on B ½ Road

A limited pavement distress survey consisting of identifying the existing type and severity of distresses along the surface of B ½ Road following SHRP2 Solutions severity level and rating criteria (See Appendix D). A summary of the pavement distresses and photographs are included in Appendix D. In general, the pavement distresses noted along B ½ Road include the following:

- Approximately 25 percent low severity fatigue cracking in the right wheel path (both directions of travel).
- Low to moderate severity longitudinal cracking occurs frequently in the westbound lane and occasionally in the eastbound lane.
- Low severity and infrequent transverse cracking.
- Low to moderate severity and frequent patch deterioration.
- Low severity and occasional rutting (< 0.25-inches in depth).
- A chipseal surfacing was noted along B ½ Road from Merles Way to the eastern project limit. The chipseal appeared to have flushing/bleeding of tack/emulsion.

Figure 3. Typical longitudinal and transverse cracking along B ½ Road with fatigue cracking in wheel path and minor patch deterioration along the perimeter.

6.2.2 Fill Material
Aggregate base course (ABC) fill material was noted below the existing asphalt pavement at each borehole location. The ABC generally consisted of well-graded sand with silt and gravel and silty sand with gravel (AASHTO classifications A-1-a and A-1-b).

6.2.3 Native Subgrade Soils
Native soils generally consist of lean clay with sand, sandy lean clay, clayey sand, clayey gravel with sand, and silty sand with gravel with general AASHTO classifications of A-2-4, A-2-6, A-4, A-6, and A-7-6. One R-value sample was obtained at Borehole B-52 from a depth of 10 inches to 5 feet below the surface. The resultant R-Value was 11; however, RockSol used an R-Value of 10 for pavement design purposes. An R-Value 10 correlates to a resilient modulus of 6,482 psi, when using CDOT equation 4-1 as stated in the 2021 CDOT M-E Pavement Design Manual.

6.2.4 Bedrock
Based on the field exploration performed for this study, bedrock was not encountered to the maximum depths explored, approximately 5 feet to 15 feet below existing grades.

6.2.5 Groundwater
Groundwater was noted at an approximate depth of 10 feet below existing grade at borehole location B-58 during drilling/sampling operations. Groundwater was not noted in Boreholes B-51 through B-57, B-59, and B-60 during drilling operations.

7.0 D ½ ROAD

D ½ Road is a minor arterial generally consisting of flat roadway grades. The project alignment is approximately 0.83 miles of D ½ Road between D ½ Court extending east to 30 Road. The existing roadway generally has a width of 24 feet, with non-paved shoulders. At the eastern and western ends of the project alignment, D ½ Road widens to include turn lanes (western limit) or a center median (eastern limit) with paved shoulders. Residential structures and agricultural fields are located throughout the project alignment, along with a public park on the west side.

7.1 Geological Conditions

Based on information presented in the United States Geological Survey (USGS) Geologic Map of the Grand Junction Quadrangle, Mesa County, Colorado (Map MF-2363), dated 2002 (See Figure 4), alluvium and colluvium (Qac) deposits are mapped at or near the surface for the entirety of the project roadway alignment. Mancos Shale (Km) bedrock is mapped at or near the surface, approximately 6,000 feet south of the project, adjacent to the Colorado River.

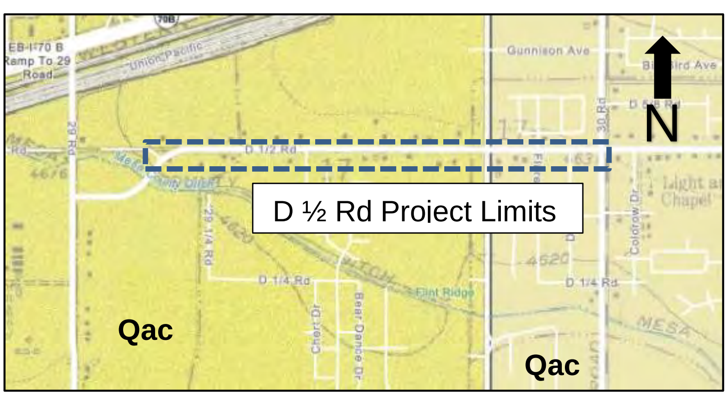


Figure 4. D ½ Road Geologic Map

7.2 Surface Condition and Subsurface Investigation

The surface and subsurface materials encountered by RockSol at our borehole locations included asphalt pavement, aggregate base course fill material, and native soils. The information for each roadway segment is found in the Borehole Logs in Appendix B and as follows.

7.2.1 Existing Asphalt Pavement Sections

Ten boreholes were taken in D ½ Road as shown in Figure 5. The locations are identified as B-41 through B-50. Full-depth asphalt pavement thickness for D ½ Road has an average of approximately 8.5 inches and ranged in thickness from 6.5 inches to 11.0 inches. Aggregate base course (ABC) was noted below the asphalt and ranged in thickness from approximately 6 to 10 inches (average thickness of approximately 6.0 inches). ABC was not noted in Borehole B-48 below the asphalt pavement section.

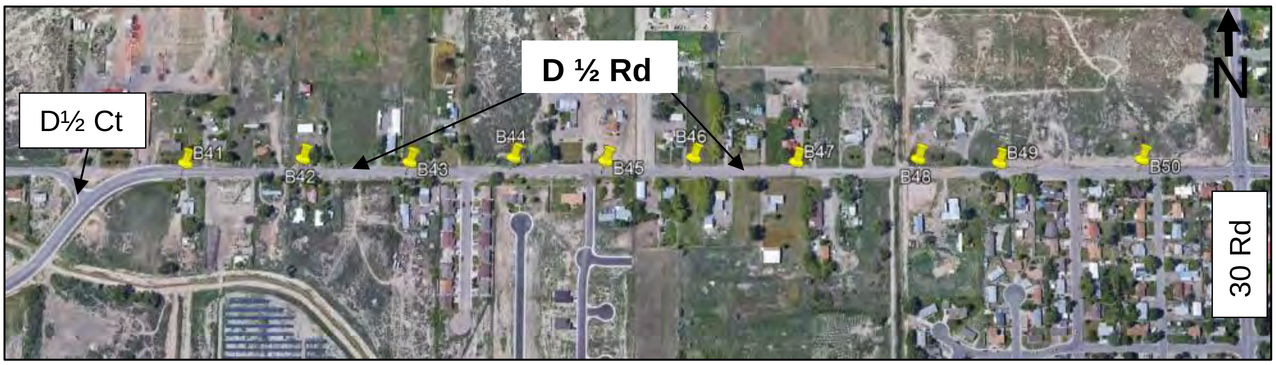


Figure 5. Borehole locations on D ½ Road

A limited pavement distress survey was performed along the surface of D ½ Road. The survey consisted of identifying the existing type and severity of distresses, following SHRP2 Solutions severity level and rating criteria (See Appendix D). A summary of the pavement distresses and photographs are included in Appendix D. Minimal distress was noted along D ½ Road. Low severity and infrequent transverse cracking (see Figure 6) was noted; however, the pavement appears to be in good condition.

Figure 6. Typical infrequent and low severity transverse cracking along D ½ Road.

7.2.2 Fill Material

Aggregate base course (ABC) fill material was noted below the existing asphalt pavement at all but one borehole location (B-48). The ABC generally consisted of well-graded sand with clay and gravel and silty sand with gravel (general AASHTO classifications of A-1-a, A-1-b, and A-2-6).

7.2.3 Native Subgrade Soils

Native soils generally consist of lean clay with sand, sandy lean clay, silt, and sandy gravel and cobbles with AASHTO classifications of A-4 and A-6 soils, based on the samples tested. One R-value sample was obtained at Borehole B-49 from a depth of 18 inches to 5 feet below the surface. The resultant R-Value was 14; however, RockSol used an R-Value of 10 for pavement design purposes. An R-Value 10 correlates to a resilient modulus of 6,482 psi, when using CDOT equation 4-1 as stated in the 2021 CDOT M-E Pavement Design Manual.

7.2.4 Bedrock

Based on the field exploration performed for this study, bedrock was not encountered to the maximum depths explored, approximately 5 feet to 15 feet below existing grades.

7.2.5 Groundwater

Groundwater was noted at an approximate depth of 6 feet below existing grade at borehole locations B-43 and B-44 and at 8 feet below existing grade at borehole location B-48 during drilling/sampling operations. Groundwater was not noted in Boreholes B-41, B-42, B-45 through B-47, B-49, and B-50 during drilling operations.

8.0 F ½ ROAD

F ½ Road is a major collector generally consisting of flat roadway grades. The project alignment is approximately 0.82 miles along F ½ Road between 30 Road extending East to Lewis Gulch (just west of Alleghany Drive). The existing roadway generally has a width of 24 feet and widens to 48 feet, just east of 30 Road, with paved and non-paved shoulders. Residential structures and agricultural fields are located throughout the project alignment. Thunder Mountain Elementary School is on the south side of F ½ Road, just west of Lewis Gulch. The eastern roadway alignment has concrete curb and gutter and sidewalks, adjacent to the elementary school.

8.1 Geological Conditions

Based on information presented in the United States Geological Survey (USGS) Geologic Map of the Clifton quadrangle, Mesa County, Colorado Miscellaneous Field Studies Map MF-2359, dated 2001 (See Figure 7), alluvium and colluvium (Qac) deposits (predominantly alluvium, sheetwash, and debris flow deposits) consisting of sandy silt and clayey silt with pebble to boulder size sandstone and shale bedrock fragments. Mancos Shale (Km) bedrock is mapped at or near the surface, approximately 2,500 feet north of the project.

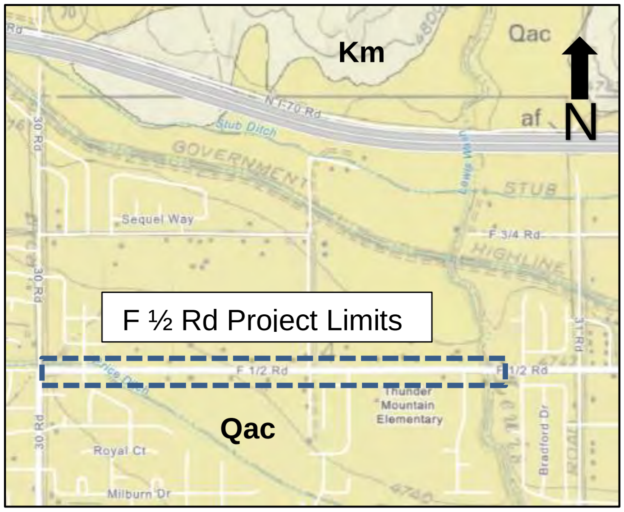


Figure 7. F ½ Road Geologic Map

8.2 Surface Condition and Subsurface Investigation

The surface and subsurface materials encountered by RockSol at our borehole locations included asphalt pavement, aggregate base course, fill material, and native soils. The information for each roadway segment is found in the Borehole Logs in Appendix B and as follows.

8.2.1 Existing Asphalt Pavement Sections

Ten boreholes were taken in F ½ Road as shown in Figure 8. The locations are identified as B-21 through B-30. Full-depth asphalt pavement thickness for F ½ Road has an average of about 6.0 inches and ranges in thickness from 4.5 inches to 9.0 inches. Aggregate base course (ABC) was noted below the asphalt at all but one location (Borehole B-25) and ranged in thickness from approximately 3 to 8 inches (average thickness of approximately 6 inches).

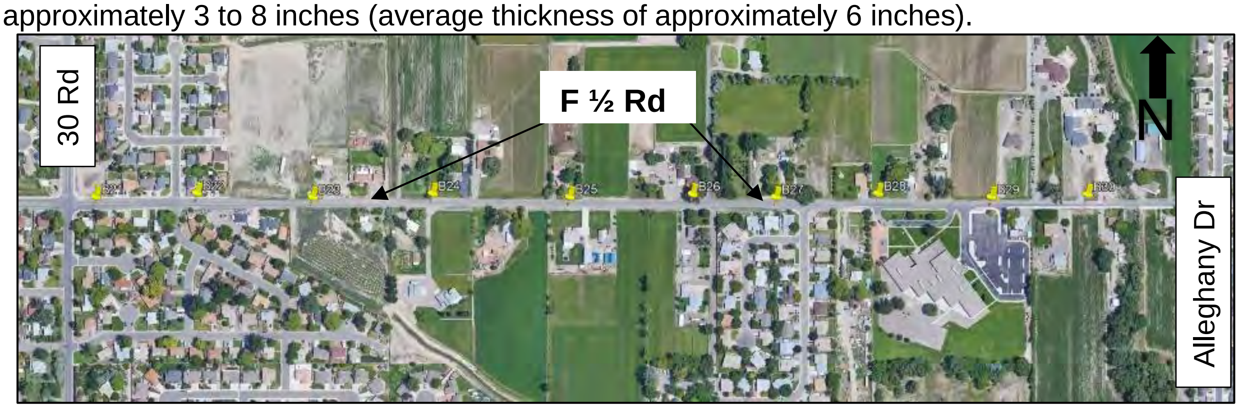


Figure 8. Borehole locations on F ½ Road

A limited pavement distress survey consisting of identifying the existing type and severity of distresses along the surface of F ½ Road following SHRP2 Solutions severity level and rating criteria (See Appendix D). A summary of the pavement distresses and photographs are included in Appendix D. An open irrigation/drainage ditch runs parallel to westbound F ½ Road for most of the project alignment. The westbound lane does appear to have more distress in the right wheel path with a defined longitudinal crack approximately 5 feet in from edge of pavement. Water flow from the adjacent irrigation ditch may increase the moisture content of subgrade soils beneath F ½ Road. In general, the pavement distresses noted along F ½ Road include the following:

- Approximately 25 percent low to moderate severity fatigue cracking (occasionally in the eastbound direction and more frequent in the westbound direction).
- Occasional moderate to high severity block cracking.
- Moderate to high severity longitudinal and transverse (20-foot intervals) cracking occurring frequently in both directions.
- Low severity and infrequent patch deterioration (minimal locations).
- Low severity and infrequent rutting (< 0.25-inches in depth on average)
- Low severity potholes (few locations).

Figure 9. High severity fatigue cracking in wheel path

8.2.2 Fill Material

Aggregate base course (ABC) fill material was noted below the existing asphalt pavement at each borehole location. The ABC generally consisted of well-graded sand with silt and gravel and silty sand with gravel (AASHTO classifications A-1-a and A-1-b).

8.2.3 Native Subgrade Soils

Native soils generally consist of lean clay with sand, sandy lean clay, sandy silty clay, silty clay with sand, silty clayey sand with gravel, sandy silty clay with gravel, silty sand with gravel, silty gravel with sand, and sandy cobbles with general AASHTO classifications of A-1-a, A-2-4, A-4, and A-6. One R-value sample was obtained at Borehole B-23 from a depth of 2.5 feet to 3.5 feet below the surface. The resultant R-Value was 21; however, based on the subsurface conditions encountered during drilling and the classification test results, RockSol used an R-Value of 10 for pavement design purposes. An R-Value 10 correlates to a resilient modulus of 6,482 psi, when using CDOT equation 4-1 as stated in the 2021 CDOT M-E Pavement Design Manual.

8.2.4 Bedrock

Based on the field exploration performed for this study, bedrock was not encountered to the maximum depths explored, approximately 5 feet to 15 feet below existing grades along F ½ Road.

8.2.5 Groundwater

Groundwater was noted at an approximate depth of 13 feet below existing grade at borehole location B-25 during drilling/sampling operations. Groundwater was not noted in Boreholes B-21 through B-24 and B-26 through B-30 during drilling operations; however, very moist subgrade soil conditions were noted in the boreholes, typically 3 to 4 feet below existing grades. An open irrigation/drainage ditch runs parallel to westbound F ½ Road for most of the project alignment. Water flow from the adjacent irrigation ditch may cause an increase in moisture content of subgrade soils beneath F ½ Road.

9.0 26 ½ ROAD

26 ½ Road is a major arterial generally consisting of flat roadway grades. The project alignment is approximately 0.72 miles along 26 ½ Road between Horizon Drive and G Road. The existing roadway generally has a width of 35 feet with paved shoulders and widens to 70 feet (two lanes in each direction) at the southern limit near Horizon Drive, with paved shoulders, concrete curb, gutter, and sidewalk. Residential structures are located throughout the project alignment. 26 ½ Road crosses over two canal/ditch systems at the southern portion of the roadway alignment.

9.1 Geological Conditions

Based on information presented in the United States Geological Survey (USGS) Geologic map of the Grand Junction quadrangle, Mesa County, Colorado, Miscellaneous Field Studies Map MF-2363, dated 2002 (See Figure 10), alluvium deposits (Qa) from tributary streams, alluvium and colluvium (Qac) deposits (predominantly alluvium, sheetwash, and debris flow deposits) are mapped at or near the surface in the southern portion of the 26 ½ Road alignment. The alluvium and colluvium deposits generally consist of sandy silt and clayey silt with pebble to boulder size sandstone and shale bedrock fragments and cobbly pebble gravel, in a coarse to medium coarse sand matrix. Mancos Shale (Km) bedrock is mapped at or near the surface in the central and northern portions of the roadway alignment. Mancos Shale bedrock was encountered in three of our boreholes (B-3, B-5, and B-8) at depths varying between 5 feet and 13 feet below existing grades during drilling operations.

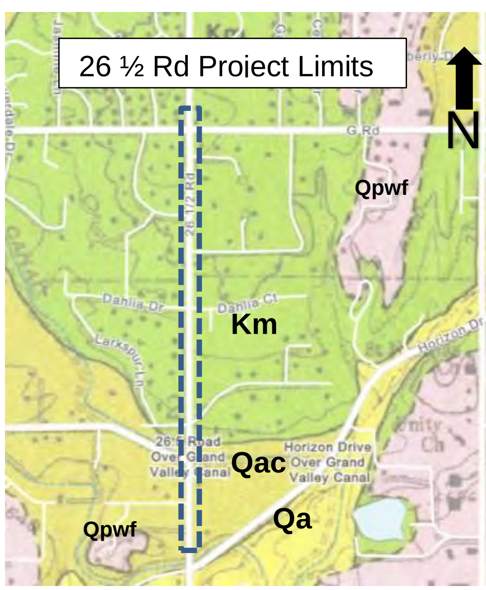


Figure 10. 26½ Road Geologic Map

9.2 Surface Condition and Subsurface Investigation

The surface and subsurface materials encountered by RockSol at our borehole locations included asphalt pavement, aggregate base course, fill material, native soils, and shale bedrock. The information for each roadway segment is found in the Borehole Logs in Appendix B and as follows.

9.2.1 Existing Asphalt Pavement Sections

Ten boreholes were taken in 26 ½ Road as shown in Figure 11. The locations are identified as B-1 through B-10. Asphalt pavement thickness for 26 ½ Road has an average of about 7.0 inches and ranges in thickness from 3 inches to 10.0 inches. Aggregate base course (ABC) was noted below the asphalt at all but one location (Borehole B-3) and ranged in thickness from approximately 1.5 to 12 inches (average thickness of approximately 5 inches).

Figure 11. Borehole locations on 26 ½ Road

A limited pavement distress survey consisting of identifying the existing type and severity of distresses along the surface of 26 ½ Road following SHRP2 Solutions severity level and rating criteria (See Appendix D). Pavement appears to possibly have some minor widened shoulders (less than 2 feet) in the past. Chipseal surfacing was noted over the entire project roadway alignment, hiding the widened shoulder joint. A summary of the pavement distresses and photographs are included in Appendix D. In general, the pavement distresses (See Figure 12) noted along 26 ½ Road include the following:

- Approximately 40 percent moderate (frequent) to high (occasional) severity fatigue cracking in both lanes in the right wheel path, for the entire roadway alignment.
- Moderate (frequent) to high (occasional) severity block cracking.
- Minimal locations with depressions.
- Moderate severity longitudinal cracking occurs occasionally in both directions.
- High severity transverse cracking occurs frequently across both lanes.
- Low severity and infrequent patch deterioration (minimal locations).
- A minimal amount of polished aggregate along an old chipseal surface.
- Moderate severity and frequent rutting (0.25 to 0.75-inches in depth on average).

Figure 12. Typical pavement distress along 26 ½ Rd

9.2.2 Fill Material

Aggregate base course (ABC) fill material was noted below the existing asphalt pavement at all but one (B-3) borehole location. The ABC generally consisted of well-graded sand with silt and gravel and silty sand with gravel (typical AASHTO classifications of A-1-a and A-1-b). Gravelly sand and sandy cobble fill material were noted in the upper 2 to 3 feet at most borehole locations underlying the aggregate base course.

9.2.3 Native Subgrade Soils

Native soils generally consist of lean clay with sand, sandy lean clay, lean clay, silty clay with sand, silty sand, clayey sand with gravel, gravelly lean clay, and silty gravel with sand, with general AASHTO classifications of A-1-a, A-1-b, A-2-4, A-4, A-6, and A-7-6. One R-value sample was obtained at Borehole B-6 from a depth of 30 inches to 5 feet below the surface. The resultant R-Value was 10. An R-Value 10 correlates to a resilient modulus of 6,482 psi, when using CDOT equation 4-1 as stated in the 2021 CDOT M-E Pavement Design Manual.

9.2.4 Bedrock

Based on the field exploration performed for this study, bedrock was encountered at three borehole locations (B-3, B-5, and B-8) at depths ranging from 5 feet to 13 feet below existing grades. Bedrock was not noted to the maximum depths explored, approximately 5 feet to 15 feet below existing grades at the other borehole locations along 26 ½ Road.

9.2.5 Groundwater

Groundwater was not noted in the boreholes during drilling operations. The canals were not flowing water at the time of our drilling operations. Groundwater may be encountered adjacent to the canal crossings when the canals are in use/transmitting water.

10.0 PAVEMENT DESIGN RECOMMENDATIONS

26 ½ Road and F ½ Road are classified as minor arterials and B ½ Road and F ½ Road are classified as major collectors by the City of Grand Junction. The roadway classifications for this project were found on the website for the City of Grand Junction's Transportation Map.

Pavement designs for all four roadways include options for full reconstruction and widened sections/saddlebag (new HMA) and for rehabilitating existing pavement (mill and fill/overlay and Cold-In-Place Recycling options) alternatives. In this report Hot Mix Asphalt (HMA) pavement is identified as flexible pavement. Segments evaluated in this report that are in a poor condition may require a substantial level of rehabilitation such as full depth patching, cold-in-place recycling, or deep milling prior to placement of an asphalt-paved surface, depending on traffic level and existing structural condition.

Pavement thickness evaluation for the development of flexible pavement design recommendations within the City of Grand Junction right of way were performed in accordance with CDOT's 2021 Mechanistic-Empirical Pavement Design Manual which uses Version 2.3.1 of AASHTO's Pavement Mechanistic-Empirical Design (PMED) software, *Subsection 29.32 – Pavements and Truck Routes* (April 21, 2004) in the City of Grand Junction Municipal Code, and 1993 *AASHTO Guide for the Design of Pavements* and the *Guideline for the Design and Use of Asphalt Pavements for Colorado Roadways* (January, 2006), published by the Colorado Asphalt Pavement Association.

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.

10.1 Traffic Loading

Traffic loading was estimated for a 20-year flexible pavement design life in accordance with CDOT. The Average Daily Traffic (ADT) for each roadway were obtained from the traffic counts found on the website for the City of Grand Junction's Transportation Map and summarized in Table 2.

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, Class 5 vehicles, when using the Federal Highway vehicle type classification system, were used for the roadway segments. Based on the ADT for each roadway, 10.0 percent trucks were estimated to determine AADTT for this project. The AADTT used for the pavement designs of roadway segments is shown in Table 2.

A compound growth rate of 2.2 percent over a 20-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 2.

Table 2 – Summary of Traffic Loading

Pavement Section	ADT (2024)	AADTT (2024)	20-Year Design Life 18k ESALS
26 ½ Road	6,500	650	2,020,000
B ½ Road	6,950	695	2,160,000
D ½ Road	6,550	655	2,030,000
F ½ Road	2,200	220	680,000

10.2 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-1-b, A-2-4, A-2-6, A-4, A-6, and A-7-6 soil types.

RockSol assigned four R-Values to determine subgrade support characteristics. R-value test results were 10 (26 ½ Road), 11 (B ½ Road), 14 (D ½ Road), and 21 (F ½ Road). The R-value test graphs are included in Appendix C. 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 each subject roadway, based on our analyses of the field and laboratory test results.

To provide an appropriate structural layer for new HMA (full reconstruction or widened/saddlebag) pavement, RockSol recommends 12 inches of a subbase layer of non-stabilized *Pit Run* (CDOT Class 3) material be included as part of the pavement design section in addition to 4 inches of Aggregate Base Course (ABC) directly underlying the pavement for each roadway segment.

The Class 3 *Pit Run* 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.

10.3 Pavement Section Recommendations,

Pavement designs for all four roadways include options for full reconstruction and widened sections/saddlebag (new HMA) and for rehabilitating existing pavement (mill and fill/overlay and Cold-In-Place Recycling options) alternatives. If pavement rehabilitation is selected with new widened/saddlebag pavement, the thickness of the top lift of the widened section should match the thickness of the top lift of the overlay/rehabilitated section. Two pavement thickness design procedures were utilized for the 20-year design life of new and overlay HMA pavement.

- 2021 Colorado Department of Transportation M-E Pavement Design Manual along with the 2022 addendum and the PMED software, Version 2.3.1.
- Spreadsheet developed by RockSol to replicate the 1993 AASHTO flexible pavement design since 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.

10.3.1 Flexible ME-Pavement Design (New Reconstruction Pavement and Widening)

A summary of the PMED recommended pavement section thicknesses for new reconstructed and widened/saddlebag flexible pavement are presented in Table 3 and the pavement design output sheets are included in Appendix E.

Table 3 – New Flexible Pavement Section Thickness Recommendations (PMED) (20 Year Design Life)

Pavement Section	Material Type	Thickness (inches)	Appendix
26 ½ Rd, B ½ Rd, D ½ Rd	SX(75) PG 64-28	2.0	E
	SX(75) PG 64-22	4.0	
	ABC Class 6	4.0	
	ABC Class 3 Pit Run	12.0	
F ½ Rd	SX(75) PG 64-28	2.0	
	SX(75) PG 64-22	3.0	
	ABC Class 6	4.0	
	ABC Class 3 Pit Run	12.0	

HMA = Hot Mix Asphalt; ABC = Aggregate Base Course

10.3.2 AASHTO 1993 Flexible Pavement Design (New Reconstruction Pavement and Widening)

A summary of the AASHTO 1993 Pavement Design recommended pavement section thicknesses for new reconstructed and widened/saddlebag flexible pavement are presented in Table 4 and the pavement design output sheets are included in Appendix F.

Table 4 – Flexible Pavement Section Thickness Recommendations (AASHTO 1993) (20 Year Design Life)

Pavement Section	Material Type	Thickness (inches)	Appendix
26 ½ Road, B ½ Road, and D ½ Road	SX(75) PG 64-28	2.5	F
	SX(75) PG 64-22	3.0	
	ABC Class 6	4.0	
	ABC Class 3 Pit Run	12.0	
F ½ Road	SX(75) PG 64-28	2.0	
	SX(75) PG 64-22	2.0	
	ABC Class 6	4.0	
	ABC Class 3 Pit Run	12.0	

An average structural coefficient of 0.10 was used for Class 6 Aggregate Base Course (ABC) and for Class 3 ABC. A structural coefficient of 0.44 was used for HMA.

RockSol recommends the pavement thicknesses shown in Table 3 be used since the PMED software accounts for site specific variables that AASHTO 1993 does not. HMA pavement shall consist of CDOT-approved mix designs. The bottom layers of the new HMA should consist of SX(75) PG 64-22. To resist rutting and thermal cracking damage, the top 2 to 2½ inches of new HMA should consist of SX(75) PG 64-28 material. ABC should consist of material meeting CDOT Class 6 Aggregate Base Course (R-Value 78) and pit run should consist of material meeting CDOT Class 3 Aggregate Base Course (R-Value 40) per CDOT 703.03.

10.3.3 Pavement Rehabilitation Design (Mill and Overlay and CIR and Overlay)

Roadways evaluated in this report that are in a poor condition may require a substantial level of rehabilitation such as full-depth reconstruction, cold-in-place recycling (CIR), or deep milling prior to placement of an asphalt-paved surface depending on traffic level and existing structural condition.

For each of the four project roadways, areas with localized moderate to severe fatigue cracking should be removed to the full depth of the existing pavement and replaced with HMA patch. Longitudinal and transverse cracks should be filled or sealed without over-band for the entire roadway alignments. It is estimated that longitudinal and transverse cracks would likely reflect upward to the surface within 8 to 10 years, but crack sealing beginning at about 8 years followed every 3-5 years as a type of preventive maintenance will ensure the overall good structural condition of the four project roadways over many years.

The PMED and AASHTO 1993 mill and overlay output sheets are included in Appendices G and H and are summarized in Table 5.

Table 5 – Mill and Overlay Pavement Section Recommendations (20 Year Design Life)

Roadway	Milling (inches)	HMA Thickness using AASHTO 1993 (inches)	HMA Thickness using PMED (inches)
26 ½ Rd	2.0	5.5 SX (75) PG 64-28	3.0 SX (75) PG 64-28
B ½ Rd	2.0	5.5 SX (75) PG 64-28	3.5 SX (75) PG 64-28
D ½ Rd	2.0	4.0 SX (75) PG 64-28	2.5 SX (75) PG 64-28
F ½ Rd	2.0	4.0 SX (75) PG 64-28	2.5 SX (75) PG 64-28

NOTE: A 6-foot-wide milling machine should be used to taper the depth of milling to match the existing concrete gutters, where present, along the roadway segments.

SX(75) PG 64-22 may be considered for the bottom layers of the recommended overlay HMA thicknesses, provided the top 2 to 2½ inches of new HMA lift consists of SX(75) PG 64-28. If pavement rehabilitation is selected with new widened/saddlebag pavement, the thickness of the top lift of the widened section should match the thickness of the top lift of the overlay/rehabilitated section.

The AASHTO 1993 component analysis procedure to determine the required structural number is reduced by the existing structural number of the HMA to determine the structural number for the overlay. In order to determine the existing structural coefficients of the pavement and aggregate base course, RockSol used *CDOT Figure 5.3 Structural Layer Coefficients of Existing Pavement (Form #903 3/04)* shown in Appendices H and J. The existing structural coefficients for the existing pavement varied from 0.23 to 0.27 for the four project roadways. The structural coefficient used for the existing aggregate base course is 0.10, for all four roadways.

In areas with localized moderate to severe fatigue cracking, where full depth/patching pavement is required, cold-in-place recycling (CIR) may be considered as a design alternative. CIR can minimize the quantity of materials needed by utilizing recycled materials. PMED and AASHTO 1993 cold-in-place recycling (CIP) output sheets are included in Appendices I and J and are summarized in Table 6.

Table 6 – CIR and Overlay Pavement Section Alternative (20 Year Design Life)

Roadway	CIR (inches)	HMA Thickness using AASHTO 1993 (inches)	HMA Thickness using PMED (inches)
26 ½ Rd	4.0	2.5 SX (100) PG 64-28	2.0 SX (100) PG 64-28
B ½ Rd	4.0	3.0 SX (100) PG 64-28	2.5 SX (100) PG 64-28
D ½ Rd	4.0	1.0 SX (100) PG 64-28	2.0 SX (100) PG 64-28
F ½ Rd	4.0	1.5 SX (100) PG 64-28	2.0 SX (100) PG 64-28

10.4 Subgrade Preparation (Prior to Pavement Construction)

Prior to construction of new pavements on base materials, the underlying base 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 recompaction. The minimum depth of scarification, moisture conditioning and re-compaction in all cases shall be 6 inches. Cobbles greater than 6 inches in diameter, if encountered, should be removed from the scarification zone.

Prior to pavement section construction, base 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.

All pavement base preparation, including final proof-rolling, pavement materials, and pavement construction shall conform to the latest edition of the Colorado Department of Transportation (CDOT) Standard Specifications for Road and Bridge Construction. At a minimum, roadway base moisture conditioning and compaction should meet the compaction specifications outlined in Table 7.

Table 7 – Roadway Base Compaction Specifications

AASHTO Classification	Minimum Relative Compaction (Percentage of MDD), %	Moisture Content (Deviation from OMC)
A-1, A-2-4, A-2-5, A-3	95% of AASHTO T99	-3 to +3
A-2-6, A-2-7	95% of AASHTO T99	-2 to +2
A-4, A-5, A-6 and A-7	95% of AASHTO T99	-2 to +2

MDD = Maximum Dry Density; OMC = Optimum Moisture Content

Based on the results of our field and laboratory tests, A-1-a, A-1-b, A-2-4, A-2-6, A-4, A-6, and A-7-6 soils are anticipated to be encountered at existing pavement subgrade elevations within the project limits. 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 max.

11.0 THREE-SIDED CULVERT EXTENSION DISCUSSION

As part of this project, the existing single-cell three-sided structure that carries Grand Valley Canal water under 26 ½ Road will be extended to the east to accommodate the roadway widening. Borehole B-3 was advanced at the approximate location of the proposed culvert extension at Grand Valley Canal and 26 ½ Road. The culvert extension will require removal of accumulated soil and vegetation and control of the water flow in the canal during construction. The walls on the east side are relatively short in length and appear to be constructed as typical wingwalls. The extension could be accomplished by adding pre-cast sections or cast-in-place structure elements. RockSol understands that cast-in-place construction is anticipated by the City. Shale bedrock was encountered at an approximate depth of 5 feet below existing grade in Borehole B-3. The depth of the existing canal bottom is approximately 8 feet below existing grade. The existing three-sided structure is founded on driven piles into shale bedrock.

Figure 13. Existing Culvert

11.1 Driven Pile Foundation System

The sedimentary shale bedrock encountered in Borehole B-3 is considered suitable bearing material for supporting the proposed three-sided culvert extension structure.

The proposed structure may be supported on driven steel H-piles (Grade 50 steel). RockSol recommends the piles be driven to practical refusal in the bedrock.

Based on the subsurface conditions encountered in Borehole B-3, practical refusal is estimated to occur within 10 feet of penetration into bedrock.

For the LRFD method, a nominal (ultimate) geotechnical capacity (combined skin and end bearing) of 28 kips per square inch multiplied by the steel cross section area (expressed in square inches) of the pile, can be used. A resistance factor of 0.65 is recommended for LRFD strength limit state design for axial compression if beginning of restrike (BOR) measurements are used with PDA monitoring. If end of drive (EOD) measurements are used with PDA monitoring, a resistance factor of 0.60 is recommended.

Additional design and construction considerations for driven piles are presented below.

(a) Steel piling, pile driving equipment, and installation of the driven steel H-piles should follow the guidelines specified in "CDOT SSRBC, Section 502, 2023" in its entirety.

(b) Lateral load parameters presented in Table 8 may be used for lateral load analysis. Battered piles may be used to resist the lateral loads. The battered piles inclination should be within one (1) horizontal to four (4) vertical.

(c) RockSol anticipates that 10 feet of pile penetration into bedrock will be required to meet refusal criteria. The actual length of the piles should be determined during installation.

(d) Center to center pile spacing should not be less than 30 inches or 2.5 pile diameters. For evaluation of horizontal pile foundation movement, the effects of group interaction shall be evaluated in accordance with AASHTO LRFD Bridge Design Specifications, Section 10.7.2.4.

(e) Based on the conditions encountered in our boreholes, if significant penetration (greater than 10 feet) into bedrock is necessary for lateral resistance requirements, pre-drilling will be required within the bedrock. Pile tips should be protected against damage using driving shoes during penetration into the sedimentary bedrock.

(f) Potential damage to adjacent structures during pile installation due to noise and vibrations should be evaluated.

Recommended lateral resistance parameters for driven piles constructed are presented in Table 8. The parameters listed are for use with LPILE® or equivalent software.

Table 8 - Driven Pile Lateral Resistance Parameters

Borehole Material	L-Pile Soil Type	Undrained Shear Strength (psf)	Angle of Internal Friction (degrees)	Subgrade Reaction Coefficient (pci)	Strain Factor ε_{50} (%)	Unit Weight (pcf)
Shale Bedrock	Stiff clay w/o free water (#3)	8,000	0	2,000	0.004	125 (Total)

11.2 Vertical Earth Loads and Lateral Earth Pressures

Lateral earth pressures will also be influenced by the width of the backfill zone adjacent to the culvert extension walls. For narrow backfill zones, lateral earth pressures will be influenced by the existing, in-place soils. For relatively wide backfill zones, lateral earth pressures will be influenced by the backfill soils. RockSol recommends the use of CDOT Class 1 Structure backfill material or Class 2 Structure backfill for backfill of the culvert structure extension. Class 2 Structure backfill shall be composed of suitable materials developed on the project (Refer to current CDOT Standards and Specifications Section 703.08).

Vertical Earth Load Parameters

In addition to traffic loads, vertical earth loads will be applied from soil and pavement placed above the structure extension. Where fill material is to be placed, RockSol recommends placement of CDOT Structure Backfill (Class 1 or Class 2) material adjacent to and immediately above the culvert structure. If less than one foot of soil cover is placed, the culvert top slab must be designed for application of full live load per AASHTO. Above the Structure Backfill (Class 1 or Class 2) material, roadway embankment material may be placed. For design, an unfactored earth load of 130 pounds per cubic foot (pcf) is recommended as a minimum value for CDOT Structure Backfill (Class 1 or Class 2) and embankment soil. Pavement material will impose a greater unit weight than soil and pavement will be constructed over most of the proposed culvert structure.

Lateral Earth Pressure Parameters

Lateral earth pressures will occur from soils adjacent to the sides of the culvert extension. To assist with design, lateral earth pressure parameters are presented in Table 9 for the existing soils and CDOT Class 1 Structure backfill material. Based on the subsurface conditions encountered in Borehole B-3, approximately 3 feet of silty to gravelly sand fill material overlying 2 feet of native sandy clay soil is anticipated to be predominately encountered above the shale bedrock, encountered at an approximate depth of 5 feet below the existing grade. The sandy clay soil is not recommended for use as structural backfill.

Table 9 – Lateral Earth Pressure Parameters

Soil Type	Total Unit Weight (γ) pcf	Effective Friction Angle, φ′ (degrees)	Cohesion (psf)	Lateral Earth Pressure Coefficients (Notes 1 and 2)		
				Active (k_a)	At-Rest (k_o)	Passive (k_p) (Note 3)
CDOT Class 1 Structure Backfill (CDOT Section 703.08)	130	34	0	0.28	0.44	3.54
(Fill) SAND, silty to gravelly (CDOT Class 2)	130	32	0	0.31	0.47	3.25

Note 1: Based on Rankine Theory of earth pressure.
Note 2: For horizontal backslope and foreslope.
Note 3: Full value, no reduction applied.

11.3 Structure Backfill Recommendations

The minimum compaction recommended by RockSol for this project are summarized in Tables 10 and 11 and are based on requirements outlined in CDOT Standard Specifications for Road and Bridge Construction (SSRBC), 2019, and Section 103.14 of City of Grand Junction's Standard Specifications for Construction of Underground Utilities.

Table 10 – CDOT Compaction Specifications

Type of Material	Relative Compaction Percent of Maximum	Moisture Content Deviation from Optimum
Clay Soils A-4, A-5, A-6, and A-7	95% Min. AASHTO T-99 (Standard Proctor Method)	0% to +2% (>35% fines) -2% to +2% (≤35% fines) **Note 1**
Sands, Gravels and Silts A-1, A-2, and A-3	95% Min. AASHTO T-180 (Modified Proctor Method)	-2% to +2% As needed for compaction

Note 1: 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 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.

Table 11 – City of Grand Junction Compaction Specifications

Type of Material	Relative Compaction Percent of Maximum	Moisture Content Deviation from Optimum
All Backfill Material	95% Min. AASHTO T-99 (Standard Proctor Method)	-2% to +2%
All Backfill Material	90% Min. AASHTO T-180 (Modified Proctor Method)	-2% to +2%

A representative of the geotechnical engineer or the City should observe and test fill placement operations.

11.4 Seismic Design Parameters

Based on the Standard Penetration Resistance encountered for the onsite subsurface conditions, it is our opinion that the three-sided culvert extension meets criteria for Seismic Site Class C. Shear wave velocity testing was not performed by RockSol. 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 proposed waterline alignment. The seismic acceleration coefficients obtained (data based on 0.05-degree grid spacing) are presented in Table 12.

Table 12 – Seismic Acceleration Coefficients (IBC 2018)

Approximate Location (Latitude°/Longitude°)	Peak Ground Acceleration (PGA)	Spectral Acceleration Coefficient - S_s (Period 0.2 sec)	Spectral Acceleration Coefficient - S_1 (Period 1.0 sec)
26 ½ Rd & Grand Valley Canal (39.098/ -108.561)	0.132	0.24	0.066

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 13.

Table 13 – Seismic Site Factor Values

Approximate Location (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)
26 ½ Rd & Grand Valley Canal (39.098/ -108.561)	1.268	1.3	1.5

Table 14 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 12 and 13, shown above. The seismic performance zone was determined *IBC-2018* Tables 1613.2.5(1) and (2). Seismic Design output sheets are summarized in Appendix K.

Table 14 – Seismic Performance Zone

Approximate Location (Latitude°/Longitude°)	Acceleration Coefficient at 1.0 seconds (S_{D1})	Acceleration Coefficient at 0.2 seconds (S_{DS})	Seismic Design Category [(1)]
26 ½ Rd & Grand Valley Canal (39.098/ -108.561)	0.066	0.208	B

12.0 OTHER DESIGN AND CONSTRUCTION CONSIDERATIONS

Proper construction practices and adherence to project plans and specifications should be followed during site preparation, earthwork, excavations, and construction of utilities, pavements, and structures 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 surface drainage must be controlled to prevent water ponding and excessive moisture infiltration into the subgrade soils during and after construction.

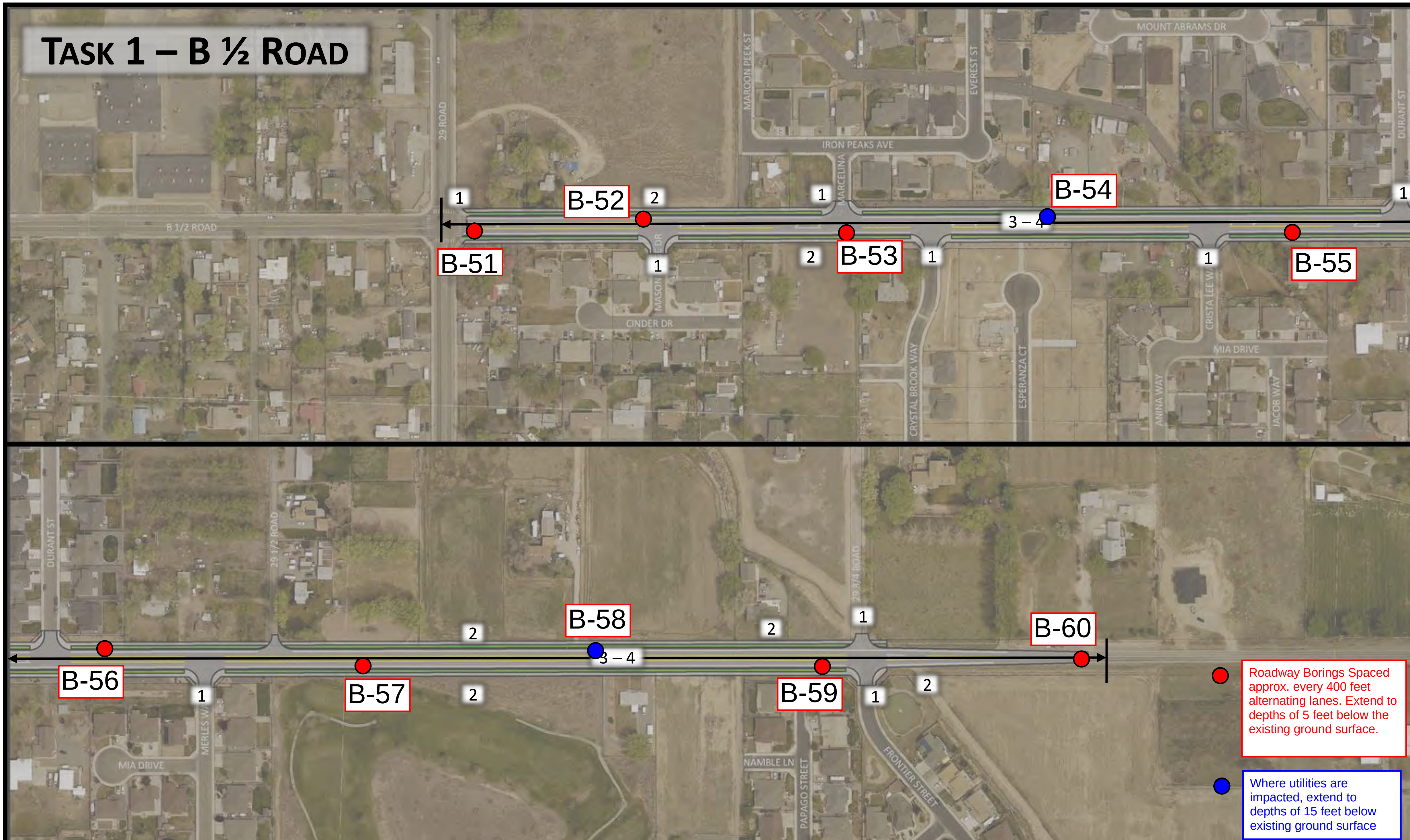
The actual subsurface conditions between boring locations may vary from the information obtained at specific boring locations and described in this report. Design and construction plans should be reviewed, and onsite construction should be observed by professional engineers.

13.0 LIMITATIONS

This geotechnical investigation was conducted in general accordance with the scope of the work. The geotechnical practices are similar to that used in Colorado with similar soil conditions and our understanding of the proposed work. This report has been prepared by RockSol for City of Grand Junction exclusively for the project roadway segments 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 as soon as possible so that a re-evaluation of the recommendations presented in this report can be made. RockSol is not responsible for liability associated with interpretation of subsurface data by others.

APPENDIX A

SITE LOCATION MAPS
(PREPARED BY CITY OF GRAND JUNCTION)

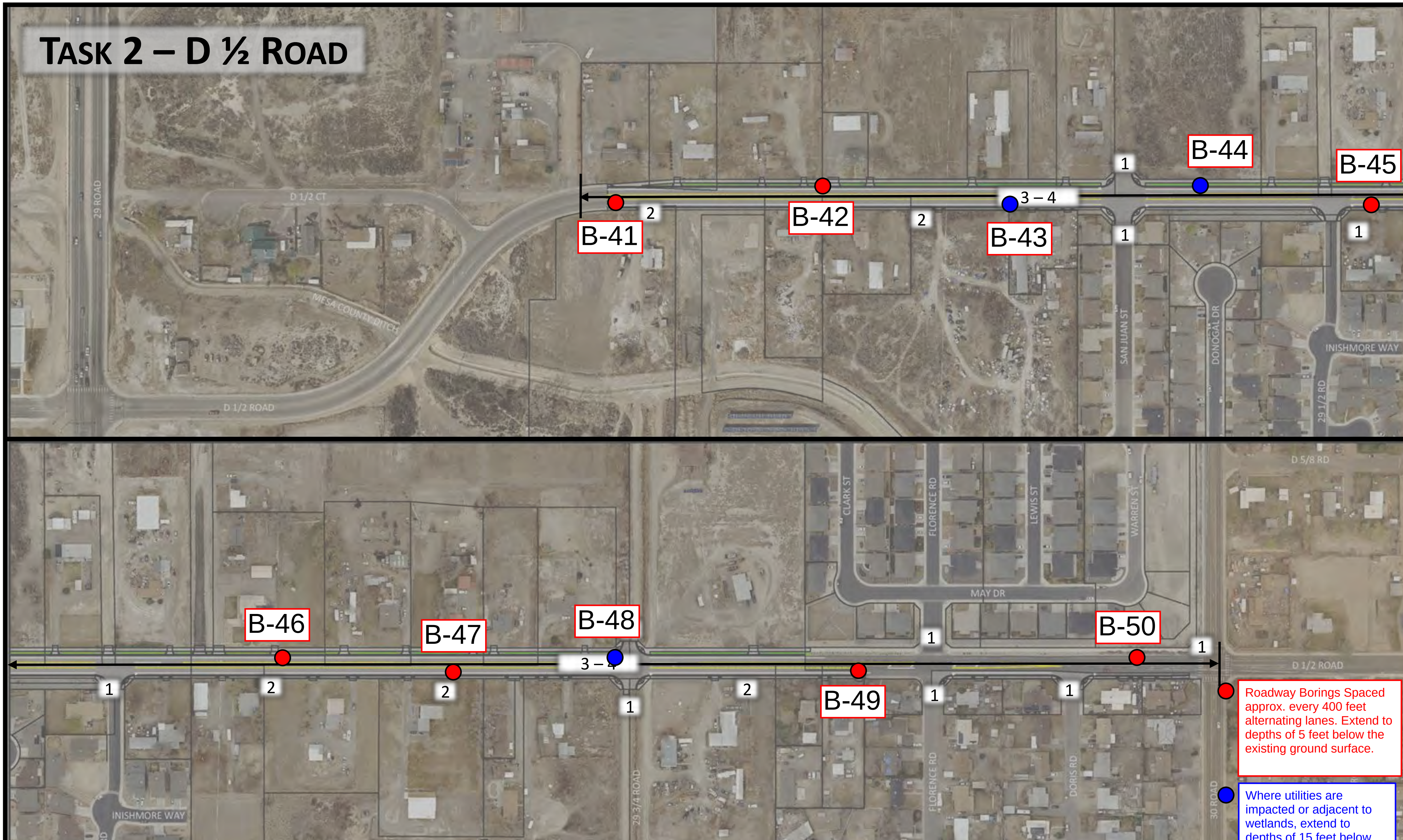


Borehole locations shown are as identified by the City. Some borehole locations were moved due to utility conflicts.

DESCRIPTION	DATE					SCALE				
REVISION		DRAWN BY	JCS	DATE	2022		City of Grand Junction COLORADO	PUBLIC WORKS ENGINEERING DIVISION PROJECT NO.F210313	B 1/2 ROAD PRELIMINARY DESIGN April 19, 2022	1
REVISION		DESIGNED BY	JCS	DATE	2022					
REVISION		CHECKED BY	KH	DATE	2022					
REVISION		APPROVED BY		DATE						

1	Correct/Improve ADA/Pedestrian Access
2	Impacts to Irrigation/Drainage Patterns
3	Impacts to Utilities
4	Right of Way Impacts (Varies Significantly)

Task 2 – D ½ Road



Borehole locations shown are as identified by the City. Some borehole locations were moved due to utility conflicts.

DESCRIPTION	DATE			
REVISION		DRAWN BY JCS	DATE 2022	SCALE
REVISION		DESIGNED BY JCS	DATE 2022	
REVISION		CHECKED BY KH	DATE 2022	
REVISION		APPROVED BY	DATE	

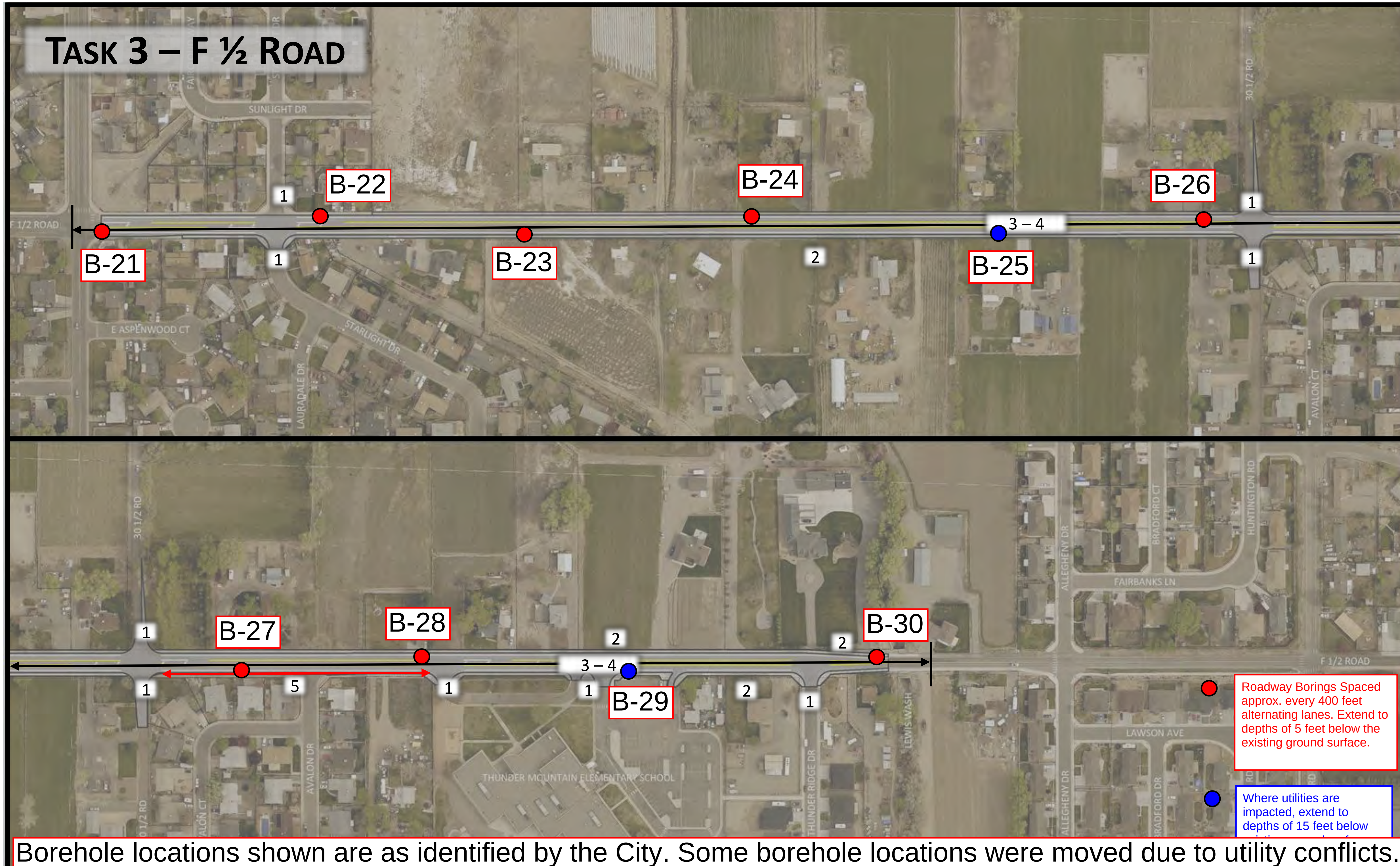
CITY OF Grand Junction COLORADO

PUBLIC WORKS ENGINEERING DIVISION
PROJECT NO. F210305

D 1/2 ROAD PRELIMINARY DESIGN
April 19, 2022

1

1	Correct/Improve ADA/Pedestrian Access	3	Impacts to Utilities
2	Impacts to Irrigation/Drainage Patterns	4	Right of Way Impacts (Varies Significantly)



DESCRIPTION	DATE		
REVISION		DRAWN BY JCS	DATE 2022
REVISION		DESIGNED BY JCS	DATE 2022
REVISION		CHECKED BY KH	DATE 2022
REVISION		APPROVED BY	DATE

SCALE

CITY OF Grand Junction COLORADO

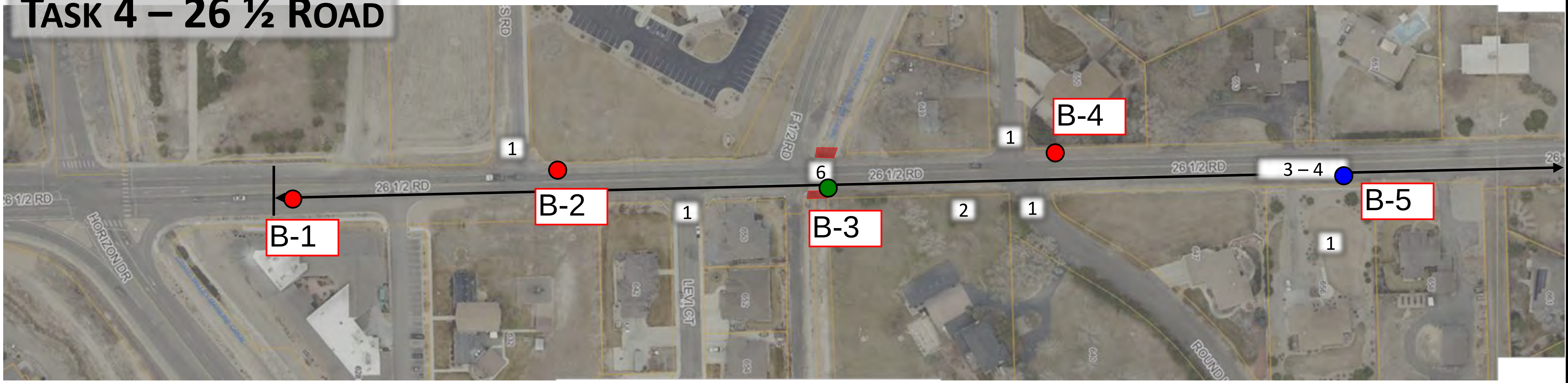
PUBLIC WORKS ENGINEERING DIVISION
PROJECT NO. F210307

F 1/2 ROAD PRELIMINARY DESIGN
April 19, 2022

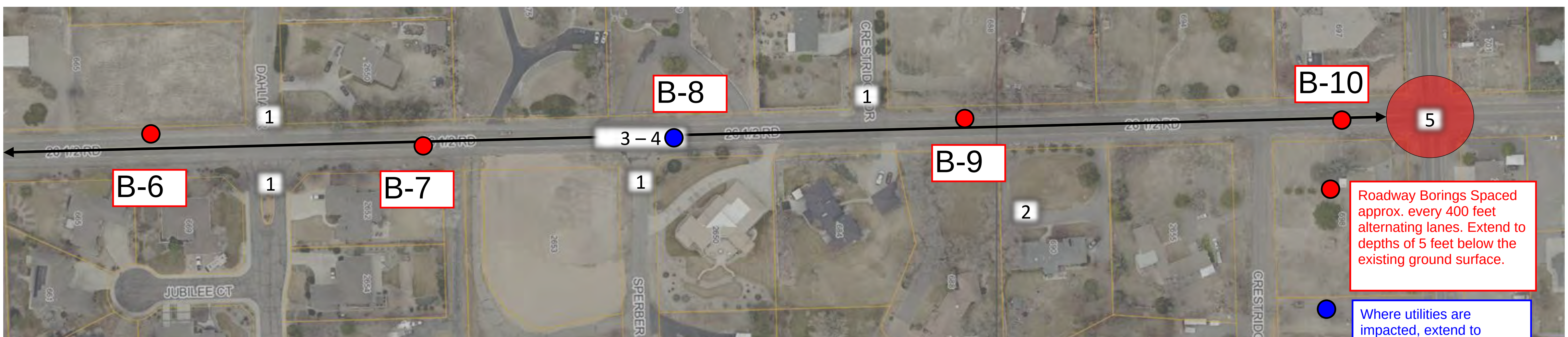
1

1	Correct/Improve ADA/Pedestrian Access	3	Impacts to Utilities	5	Replace Existing 4-foot Sidewalk
2	Impacts to Irrigation/Drainage Patterns	4	Right of Way Impacts (Varies Significantly)		

TASK 4 – 26 ½ ROAD



Borehole locations shown are as identified by the City. Some borehole locations were moved due to utility conflicts.



Roadway Borings Spaced approx. every 400 feet alternating lanes. Extend to depths of 5 feet below the existing ground surface.

Where utilities are impacted, extend to depths of 15 feet below existing ground surface

For Box Culvert Widening, Extend to a depth of 25 feet below existing ground surface.

1	Correct/Improve ADA/Pedestrian Access	3	Impacts to Utilities	5	Roundabout Project (by Others)
2	Impacts to Drainage Patterns	4	Right of Way Impacts (~60-foot Existing)	6	Widen Existing Box Culvert

APPENDIX B

LEGEND AND INDIVIDUAL BOREHOLE LOGS

RockSol Consulting Group, Inc.

LEGEND

CLIENT City of Grand Junction

PROJECT NUMBER 599.70

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT LOCATION Grand Junction, Colorado

LITHOLOGY

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

SAMPLE TYPE

- BULK SAMPLE (Auger Cuttings)
- GRAB SAMPLE FROM 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

CLIENT City of Grand Junction

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/9/23 **COMPLETED** 1/9/23

EXISTING ELEVATION ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL

NORTH **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"

BORING LOCATION: `60' N of 26.5 & Horizon Dr, SB left turn lane

LOGGED BY A. Kachin **HAMMER TYPE** Automatic

GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23

NOTES ~3' from center line

2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 10 inches thick										
	1		Aggregate base course, approximately 5 inches thick	B BULK									11.1
	2		(Fill) SAND, clayey with gravel, brown	B BULK						26	15	11	36.1
	3–5		(Native) CLAY, sandy	B BULK						33	16	17	66.2
			Bottom of hole at 5.0 feet.										

BORING : B-2

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~90' N of 26.5 & Northacres Rd, SB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
			Aggregate base course, dark brown, approximately 4 inches thick	B BULK									
	1		(Native) CLAY, sandy with gravel in parts, trace shale, slightly moist, light brown										
	3			B BULK						42	23	19	71.8
	5		Bottom of hole at 5.0 feet.										

BORING : B-3

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Hollow Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: S side of box culvert at 26.5 & F 1/2 Rd
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~20' E of pavement edge
2ND DEPTH --- on **3RD DEPTH** --- on

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		(Fill) SAND, silty with gravel, brown to dark brown	B BULK						NP	NP	NP	24.5
			(Native) CLAY, sandy, weathered SHALE in parts, moist, brown to gray	B BULK						34	16	18	60.8
	5		(Bedrock) SHALE, very stiff to very hard, slightly moist to moist, dark gray	MC	19/12			107.4	19.2				
				MC	29/12		0.03	119.4	13.8				
	10			MC	56/12	3.6		119.6	14.1				
	15			MC	62/12	7.6		120.2	14.6				
	20												
	25		Bottom of hole at 25.0 feet.										

RockSol Consulting Group, Inc.

CLIENT	City of Grand Junction	**PROJECT NAME**	Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER	599.70	**PROJECT LOCATION**	Grand Junction, Colorado

DATE STARTED 1/9/23 **COMPLETED** 1/9/23

EXISTING ELEVATION ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL

NORTH **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"

BORING LOCATION: ~40' N of 26.5 & Hollyhock Lane, SB paved shoulder

LOGGED BY A. Kachin **HAMMER TYPE** Automatic

GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23

NOTES ~4' from pavement edge

2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 2.5 inches thick										
			Aggregate base course, dark brown, approximately 1.5 inches thick										
			Asphalt pavement, approximately 2 inches thick										
	1		(Fill) GRAVEL, sandy	B BULK						NP	NP	NP	19.2
	2		(Native) SAND, silty, fine-grained, light brown to tan										
	3–4			B BULK						NP	NP	NP	47.4
	5		Bottom of hole at 5.0 feet.										

BORING : B-5

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~460' N of 26.5 & Hollyhock Lane, NB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~4' from center
2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 7.5 inches thick										
			Aggregae base course, brown, approximately 6 inches thick	B BULK									7.7
			(Fill) GRAVEL, sandy	B BULK						NP	NP	NP	15.2
	2.5		(Native) SAND, fine-grained, clayey, slightly moist										
	5.0			B BULK						NP	NP	NP	26.8
	7.5												
	10.0		(Native) CLAY, sandy, moist	GB					14.1				
				B BULK			0.74			44	25	19	89.9
	12.5		(Bedrock) CLAYSTONE/SHALE, weathered, slightly moist										
				B BULK						38	21	17	90.3
	15.0		Bottom of hole at 15.0 feet.										

BORING : B-6

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~90' S of 26.5 & Dahlia Dr, SB paved shoulder
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~2' from pavement edge
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 3 inches thick										
			Aggregate base course, approximately 2 inches thick	B BULK									
			(Fill) COBBLES, sandy, slightly moist, dark brown										
	1			B BULK									12.8
	2												
			(Native) silty GRAVEL with sand, moist, brown										
	3												
	4			B BULK						NP	NP	NP	15.0
	5		Bottom of hole at 5.0 feet.	GB					18.2				

BORING : B-7

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~240' N of 26.5 & Dahlia Dr, NB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 8.5 inches thick										
	1		Aggregate base course, approximately 4 inches thick	B BULK									
	2		(Fill) COBBLES and GRAVEL, sandy, dark brown	B BULK									17.7
	3–5		(Native) CLAY, sandy, light brown	B BULK						33	21	12	69.7
			Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-8

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~40' N of 26.5 & Sperber Lane, NB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement approximately 8 inches thick										
			Aggregate base course, approximately 4 inches thick	BULK									
			(Fill) COBBLES, gravelly	BULK									16.5
	2.5		(Native) CLAY, sandy, light brown	BULK			1.95			25	14	11	85.1
	5.0												
			(Bedrock) SHALE, weathered from 6-7 feet, stiff to hard, dark gray										
	7.5			BULK			1.32			34	18	16	84.0
	10.0			SS	15/20/24								83.8
			Bottom of hole at 10.5 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~180' N of 26.5 & Crestridge Dr, SB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 8 inches thick										
	1		Aggregate base course, silty SAND with gravel, approximately 12 inches thick	B BULK						NP	NP	NP	20.4
	2–5		(Native) CLAY, sandy, SHALE in parts, slightly moist, brown to light brown	B BULK						28	16	12	64.9
			Bottom of hole at 5.0 feet.										

BORING : B-10

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~150' S of 26.5 & G Rd, NB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
			Aggregate base course, approximately 4 inches thick										
	1		(Fill) COBBLES, sandy	B BULK									15.3
	2		(Native) CLAY, silty with sand, brown to light brown to tan	B BULK						28	22	6	74.2
	3												
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-21

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~80' E of F 1/2 & 30 Rd, WB paved shoulder
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~8' from pavement edge
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 5 inches thick										
			Aggregate base course, dark brown, approximately 7 inches thick	B BULK									26.3
	1		(Native) CLAY, sandy, moist, brown to light brown										
	2												
	3			B BULK						27	16	11	78.0
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-22

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~80' E of F 1/2 & Starlight Dr, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~4' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 8 inches thick										
			Aggregate base course, slightly moist, brown, approximately 3 inches thick	B BULK									
	1		(Fill) COBBLES, sandy, brown, loose										
	2			B BULK									12.4
	3		(Native) GRAVEL, silty with sand, very moist, brown to gray										
	4			B BULK						NP	NP	NP	14.3
	5		Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-23

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/9/23 **COMPLETED** 1/9/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 6.0"
BORING LOCATION: ~550' E of F 1/2 & Starlight Dr, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/9/23
NOTES ~8' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 9 inches thick										
	1		Aggregate base course, moist, dark brown, approximately 6 inches thick	B BULK									
	2		(Fill) COBBLES, sandy, moist, brown	B BULK									9.4
	3		(Native) sandy silty CLAY with gravel, moist, dark brown	B BULK						24	17	7	54.2
	4		(Native) silty CLAY with sand, wet, brown to gray	B BULK						25	19	6	75.2
	5		Bottom of hole at 5.0 feet.	GB					22.2				

BORING : B-24

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: Driveway of 3027 F 1/2 Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~4' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 5 inches thick										
			Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
	1		(Native) CLAY, sandy to slightly sandy, moist to very moist, brown										
	3			B BULK						27	16	11	63.5
	5		Bottom of hole at 5.0 feet.										

BORING : B-25

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH
EAST
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~10' E of 3040 F 1/2 Rd driveway, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** 13.0 ft on 1/3/23
NOTES ~8' from center line
2ND DEPTH --- on
3RD DEPTH --- on

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 (%)
	0.0		Asphalt pavement, approximately 6.5 inches thick										
			(Native) SAND, silty, dark brown	B BULK						23	19	4	43.6
	2.5		(Native) CLAY, minor sand in parts, slightly moist to wet, brown, soft	B BULK						26	17	9	73.0
	5.0												
	7.5												
	10.0												
	12.5	▼											
	15.0		Bottom of hole at 15.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-26

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~90' W of F 1/2 & 30 1/2 Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~4' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 4.5 inches thick										
			Aggregate base course, approximately 6 inches thick	B BULK									
	1		(Native) COBBLES, sandy, loose										
	2												
	3			B BULK						19	16	3	29.0
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-27

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~120' W of F 1/2 & Avalon Dr, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
	1		Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
	2		(Native) silty SAND with gravel, loose							NP	NP	NP	36.9
	3			B BULK									
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-28

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~10' W of Thunder Mtn Elementary W drop-off lane entrance, El
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~8' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 4.5 inches thick										
			Aggregate base course, dark brown, approximately 8 inches thick	B BULK									22.5
	1		(Native) sandy silty CLAY, light brown, soft										
	2												
	3			B BULK					11.4	22	17	5	58.1
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-29

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~40' W of Thunder Mtn Elementary E parking lot exit, EB paved s
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~2' from pavement edge
2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 4.5 inches thick										
			Aggregate base course, approximately 4 inches thick	B BULK									
			(Native) sandy silty CLAY, moist, brown to dark brown										
	2.5												
				B BULK			0.13			23	17	6	64.4
	5.0												
	7.5												
			(Native) lean CLAY with sand, very wet, brown to dark brown										
	10.0												
				B BULK					16.8	26	16	10	77.1
	12.5												
	15.0												
			Bottom of hole at 15.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~30' E of F 1/2 & Thunder Ridge Dr, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 4.5 inches thick										
			Aggregate base course, approximately 6 inches thick	B BULK									
	1		(Native) sandy silty CLAY, moist to very moist, soft										
	2												
	3			B BULK						21	16	5	66.6
	4												
	5												
			Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-41

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~350' E of D 1/2 Rd & D 1/2 Ct, EB paved shoulder
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~3' from pavement edge
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
			Aggregate base course, approximately 6 inches thick	B BULK									16.4
	1		(Native) CLAY, moist, light brown to dark brown										
	2												
	3			B BULK						35	22	13	74.4
	4												
	5		Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: Driveway of 2932 D 1/2 Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 11 inches thick										
	1		Aggregate base course, approximately 6 inches thick	B BULK						35	22	13	9.5
			(Native) lean CLAY, moist, brown										
	2												
	3			B BULK						27	17	10	86.6
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-43

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~230' W of D 1/2 & San Juan St, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: 1ST DEPTH 6.0 ft on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on 3RD DEPTH --- on

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 (%)
	0.0		Asphalt pavement, approximately 6.5 inches thick										
			Aggregate base course, sandy, brown, approximately 6 inches thick	B BULK									
			(Fill) COBBLES and GRAVEL, sandy										
	2.5												
			(Native) lean CLAY with sand, moist, dark brown, soft	B BULK					18.8	27	16	11	80.6
	5.0												
		▼	(Native) CLAY, wet, light brown to gray, soft										
	7.5												
	10.0			B BULK					26.6	29	18	11	94.2
	12.5												
	15.0		Bottom of hole at 15.0 feet.										

BORING : B-44

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23

EXISTING ELEVATION ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL

NORTH **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"

BORING LOCATION: ~170' E of D 1/2 & San Juan St, WB lane

LOGGED BY A. Kachin **HAMMER TYPE** Automatic

GROUND WATER LEVELS: ▼ **1ST DEPTH** 6.0 ft on 1/3/23

NOTES ~8' from center line

2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 10 inches thick										
			Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
			(Native) CLAY, slightly moist, brown to brownish gray, soft										
	2.5												
				B BULK						27	17	10	86.2
	5.0												
		▼	(Native) CLAY, wet, light brown to gray										
	7.5												
	10.0												
				B BULK						32	17	15	93.5
	12.5												
	15.0		Bottom of hole at 15.0 feet.										

BORING : B-45

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~520' E of D 1/2 & San Juan St, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~11' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7.5 inches thick										
			Aggregate base course, approximately 6 inches thick	B BULK									18.3
	1		(Native) CLAY, slightly moist, dark brown to brown, soft										
	2												
	3			B BULK			1.42			29	16	13	86.5
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-46

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23

EXISTING ELEVATION ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL

NORTH **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"

BORING LOCATION: ~900' E of D 1/2 & San Juan St, WB lane

LOGGED BY A. Kachin **HAMMER TYPE** Automatic

GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23

NOTES Center of lane

2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 11 inches thick										
	1		Aggregate base course, approximately 10 inches thick	B BULK									21.2
	2		(Native) SILT, moist to vrey moist, dark brown										
	3			B BULK						23	20	3	91.0
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-47

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~10' W of driveway at 2968 D 1/2 Rd, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES At white edge line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 9 inches thick										
	1		Aggregate base course, approximately 6 inches thick	B BULK									18.1
			(Native) COBBLES										
	2		(Native) CLAY, sandy, moist to very moist, soft										
	3			B BULK						32	19	13	86.4
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-48

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~610' W of D 1/2 & Florence Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** 8.0 ft on 1/3/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 11 inches thick										
			(Native) CLAY, sandy, slightly moist, light brown	BULK						29	13	16	72.3
			(Native) lean CLAY, moist, brown to dark brown to gray, soft										
	2.5												
	5.0			BULK			2.01		20.7	33	19	14	89.5
	7.5												
			(Native) lean CLAY, wet, brown to dark brown to gray, soft										
	10.0												
				BULK					24.0	34	17	17	95.2
	12.5												
	15.0		Bottom of hole at 15.0 feet.										

BORING : B-49

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~300' W of D 1/2 & Florence Rd, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES At white edge line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 9.5 inches thick										
	1		Aggregate base course, slightly moist, brown, approximately 8 inches thick	B BULK									
	2		(Native) CLAY, moist to very moist, brown to dark brown, soft										
	3			B BULK						29	19	10	91.1
	4												
	5		Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-50

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~75' W of D 1/2 & Doris Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 6.5 inches thick										
			Aggregate base course, sandy, dark brown, approximately 6 inches thick	B BULK									12.4
	1		(Native) CLAY, very moist to wet, brown to dark brown, soft										
	2												
	3			B BULK						31	21	10	86.9
	4												
	5		Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~230' E of B 1/2 & 29 Rd, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 11.5 inches thick										
	1		Aggregate base course, approximately 10 inches thick	B BULK									17.5
	2		(Native) clayey SAND with 3-5" cobbles in parts, dark brown to red, loose										
	3			B BULK						30	18	12	49.4
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-52

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~20' E of B 1/2 & Mason Ridge Dr, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES Center of lane
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 6.5 inches thick										
			Aggregate base course, approximately 4 inches thick	B BULK						NP	NP	NP	9.7
	1		(Native) CLAY, moist to very moist, dark brown to light tan, soft										
	2												
	3			B BULK			1.06			37	19	18	64.0
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-53

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~20' W of B 1/2 & Marcellina Dr, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
	1		Aggregate base course, dark brown, approximately 6 inches thick	B BULK									18.5
	2		(Native) CLAY, cobbles in parts, sandy, moist, light brown, soft										
	3			B BULK						44	16	28	63.2
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-54

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~350' W of B 1/2 & Christa Lee Way, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~2' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 6.5 inches thick										
			Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
			(Native) CLAY, sandy, with gravel and cobbles in parts, moist										
	2.5			B BULK						32	16	16	57.8
			(Native) clayey GRAVEL with SAND, brown to gray										
	5.0			B BULK						28	17	11	32.1
	7.5		(Native) clayey GRAVEL with SAND, brown to gray										
				B BULK						28	18	10	27.7
	10.0		(Native) sandy COBBLES with gravel										
	12.5												
	15.0		Bottom of hole at 15.0 feet.										

BORING : B-55

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70

PROJECT LOCATION Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23

EXISTING ELEVATION ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL

NORTH **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"

BORING LOCATION: ~100' E of B 1/2 & Christa Lee Way, EB lane

LOGGED BY A. Kachin **HAMMER TYPE** Automatic

GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23

NOTES ~10' from center line

2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7 inches thick										
	1		Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
	2–5		(Native) CLAY, moist, light brown	B BULK			1.50			35	17	18	72.0
	5		Bottom of hole at 5.0 feet.										

BORING : B-56

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~100' E of B 1/2 & Durant St, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~2' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 6 inches thick										
			Aggregate base course, approximately 4 inches thick	B BULK									22.0
	1		(Native) CLAY, light brown, soft										
	2												
	3			B BULK						39	17	22	74.3
	4												
	5		Bottom of hole at 5.0 feet.										

BORING : B-57

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~200' E of B 1/2 & 29 1/2 Rd, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~10' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 4 inches thick										
			Aggregate base course, dark brown, approximately 4 inches thick	B BULK									
			(Native) CLAY, light brown										
	1												
	2												
	3			B BULK						36	18	18	71.1
	4												
	5		Bottom of hole at 5.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-58

CLIENT City of Grand Junction | **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 | **PROJECT LOCATION** Grand Junction, Colorado

DATE STARTED 1/3/23 **COMPLETED** 1/3/23 | **EXISTING ELEVATION** ft **PROPOSED ELEVATION** ft

DRILLING CONTRACTOR HRL | **NORTH** **EAST**

DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0" | **BORING LOCATION:** ~40' E of driveway at 2960 B 1/2 Rd, WB lane

LOGGED BY A. Kachin **HAMMER TYPE** Automatic | **GROUND WATER LEVELS:** ▼ **1ST DEPTH** 10.0 ft on 1/3/23

NOTES ~4' from center line | **2ND DEPTH** --- on **3RD DEPTH** --- on

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 (%)
	0.0		Asphalt pavement, approximately 7.5 inches										
			Aggregate base course, dark brown, approximately 6 inches thick	B BULK						NP	NP	NP	18.0
			(Native) CLAY, sandy, light brown, soft										
	2.5			B BULK						32	16	16	66.9
	5.0		(Native) CLAY, cobbles in parts, very moist										
	7.5												
	10.0	▼	(Native) CLAY, cobbles in parts, wet										
	12.5												
	15.0		Bottom of hole at 15.0 feet.										

RockSol Consulting Group, Inc.

BORING : B-59

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~130' W of B 1/2 & 29 3/4 Rd, EB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~8' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 4.5 inches thick										
			Aggregate base course, approximately 3 inches thick										
			(Native) SAND, with gravel and cobbles										
	2			B BULK						24	21	3	36.3
	3		(Native) CLAY, sandy										
	4			B BULK						27	17	10	63.6
	5		Bottom of hole at 5.0 feet.										

BORING : B-60

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado
DATE STARTED 1/3/23 **COMPLETED** 1/3/23
EXISTING ELEVATION ft **PROPOSED ELEVATION** ft
DRILLING CONTRACTOR HRL
NORTH **EAST**
DRILLING METHOD Solid Stem Auger **HOLE SIZE** 4.0"
BORING LOCATION: ~550' E of B 1/2 & 29 1/2 Rd, WB lane
LOGGED BY A. Kachin **HAMMER TYPE** Automatic
GROUND WATER LEVELS: **1ST DEPTH** None Encountered on 1/3/23
NOTES ~3' from center line
2ND DEPTH --- on **3RD DEPTH** --- on

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		Asphalt pavement, approximately 7.5 inches thick										
	1		Aggregate base course, dark brown, approximately 6 inches thick	B BULK									
	2–5		(Native) CLAY, moist, light brown	B BULK						38	23	15	60.4
	5		Bottom of hole at 5.0 feet.										

APPENDIX C

SUMMARY OF PHYSICAL AND CHEMICAL TEST RESULTS

RockSol
Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT City of Grand Junction

PROJECT NUMBER 599.70

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

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	0.83-1.25					11												
B-1	1.25-3	26	15	11		36	SC	A-6 (0)										
B-1	3-5	33	16	17		66	CL	A-6 (9)										
B-2	0.92-5	42	23	19		72	CL	A-7-6 (13)										
B-3	0-3	NP	NP	NP		24	GM	A-1-b (0)										
B-3	3-5	34	16	18		61	CL	A-6 (8)										
B-3	5								19.2	107.4								
B-3	7								13.8	119.4		0.03						
B-3	10				3.6				14.1	119.6								
B-3	15				7.6				14.6	120.2								
B-4	0.5-2	NP	NP	NP		19	GM	A-1-b (0)										
B-4	2-5	NP	NP	NP		47	SM	A-4 (0)										
B-5	0.62-1.12					8												
B-5	1.12-2	NP	NP	NP		15	GM	A-1-a (0)										
B-5	2-10	NP	NP	NP		27	SM	A-2-4 (0)										
B-5	10-13	44	25	19		90	CL	A-7-6 (19)				0.74						
B-5	10.1								14.1									
B-5	13-15	38	21	17		90	CL	A-6 (16)										
B-6	0.42-2.5					13												
B-6	2.5-5	NP	NP	NP		15	GM	A-1-a (0)										
B-6	5								18.2									
B-7	1-3					18												
B-7	3-5	33	21	12		70	CL	A-6 (7)										
B-8	1-2.5					16												
B-8	2.5-6	25	14	11		85	CL	A-6 (7)				1.95	300 @ 18.9%	7.3	0.0249			
B-8	6-10	34	18	16		84	CL	A-6 (12)				1.32		8.0				
B-8	9					84												
B-9	0.67-1.67	NP	NP	NP		20	SM	A-1-b (0)										
B-9	1.67-5	28	16	12		65	CL	A-6 (5)										
B-10	0.92-2					15												

RockSol Consulting Group, Inc.

SUMMARY OF PHYSICAL & CHEMICAL TEST RESULTS

CLIENT City of Grand Junction

PROJECT NUMBER 599.70

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

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-10	2-5	28	22	6		74	CL-ML	A-4 (3)										
B-21	0.42-1					26												
B-21	1-5	27	16	11		78	CL	A-6 (6)										
B-22	0.92-3					12												
B-22	3-5	NP	NP	NP		14	GM	A-1-a (0)										
B-23	1.25-2.5					9												
B-23	2.5-3.5	24	17	7		54	CL-ML	A-4 (1)										
B-23	3.5-5	25	19	6		75	CL-ML	A-4 (3)										
B-23	5								22.2									
B-24	0.92-5	27	16	11		64	CL	A-6 (4)										
B-25	0.54-3	23	19	4		44	SC-SM	A-4 (0)										
B-25	3-5	26	17	9		73	CL	A-4 (4)										
B-26	0.87-5	19	16	3		29	SM	A-2-4 (0)										
B-27	2-5	NP	NP	NP		37	SM	A-4 (0)										
B-28	0.37-1.04					23												
B-28	1.04-5	22	17	5		58	CL-ML	A-4 (0)	11.4									
B-29	0.71-8	23	17	6		64	CL-ML	A-4 (1)				0.13	3200 @ 10.9%	7.7	0.0219			
B-29	8-15	26	16	10		77	CL	A-4 (5)	16.8									
B-30	0.87-5	21	16	5		67	CL-ML	A-4 (1)										
B-41	0.58-1.08					16												
B-41	1.08-5	35	22	13		74	CL	A-6 (9)										
B-42	0.92-1.42	35	22	13		10	SW-SC	A-2-6 (0)										
B-42	1.42-5	27	17	10		87	CL	A-4 (7)										
B-43	1.08-6	27	16	11		81	CL	A-6 (7)	18.8									
B-43	6-15	29	18	11		94	CL	A-6 (9)	26.6									
B-44	1.33-6	27	17	10		86	CL	A-4 (7)								115.3	13.1	S
B-44	6-15	32	17	15		93	CL	A-6 (13)										
B-45	0.625-1.125					18												
B-45	1.125-5	29	16	13		87	CL	A-6 (10)				1.42						
B-46	0.92-1.75					21												

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction
PROJECT NUMBER 599.70
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT LOCATION Grand Junction, Colorado

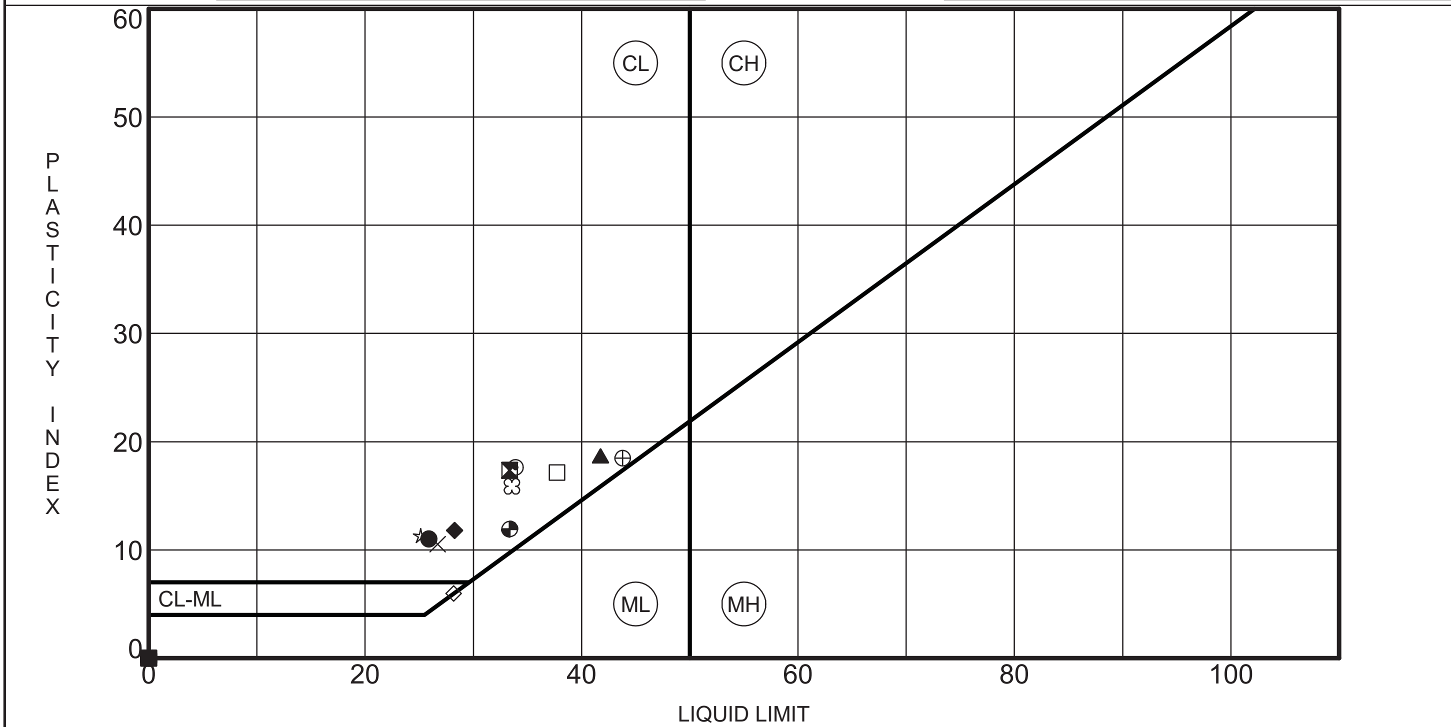
Borehole	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	Swell Potential (%)	%<#200 Sieve	Classification		Water Content (%)	Dry Density (pcf)	Unconfined Compressive Strength (psi)	Sulfate (%)	Resistivity (ohm-cm)	pH	Chlorides (%)	Proctor S=Standard M=Modified		
							USCS	AASHTO								MDD	OMC	S/M
B-46	1.75-5	23	20	3		91	ML	A-4 (1)										
B-47	0.75-1.25					18												
B-47	2-5	32	19	13		86	CL	A-6 (10)										
B-48	0.92-1.25	29	13	16		72	CL	A-6 (9)										
B-48	1.25-8	33	19	14		90	CL	A-6 (12)	20.7			2.01	1000 @ 17.3%	7.9	0.0387			
B-48	8-15	34	17	17		95	CL	A-6 (16)	24.0									
B-49	1.5-5	29	19	10		91	CL	A-4 (8)										
B-50	0.54-1.04					12												
B-50	1.04-5	31	21	10		87	CL	A-4 (8)										
B-51	0.96-1.79					17												
B-51	1.79-5	30	18	12		49	SC	A-6 (3)										
B-52	0.54-0.87	NP	NP	NP		10	SW-SM	A-1-a (0)										
B-52	0.87-5	37	19	18		64	CL	A-6 (9)				1.06						
B-53	0.58-1.08					18												
B-53	1.08-5	44	16	28		63	CL	A-7-6 (15)										
B-54	1.04-4	32	16	16		58	CL	A-6 (6)										
B-54	4-7	28	17	11		32	GC	A-2-6 (0)										
B-54	7-10	28	18	10		28	GC	A-2-4 (0)										
B-55	1.08-5	35	17	18		72	CL	A-6 (11)				1.50						
B-56	0.5-0.83					22												
B-56	0.83-5	39	17	22		74	CL	A-6 (15)										
B-57	0.67-5	36	18	18		71	CL	A-6 (11)										
B-58	0.62	NP	NP	NP		18	SM	A-1-b (0)										
B-58	1.12-5	32	16	16		67	CL	A-6 (8)								114.0	14.8	S
B-59	0.62-3	24	21	3		36	SM	A-4 (0)										
B-59	3-5	27	17	10		64	CL	A-4 (4)										
B-60	1.12-5	38	23	15		60	CL	A-6 (7)										

RockSol Consulting Group, Inc.

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



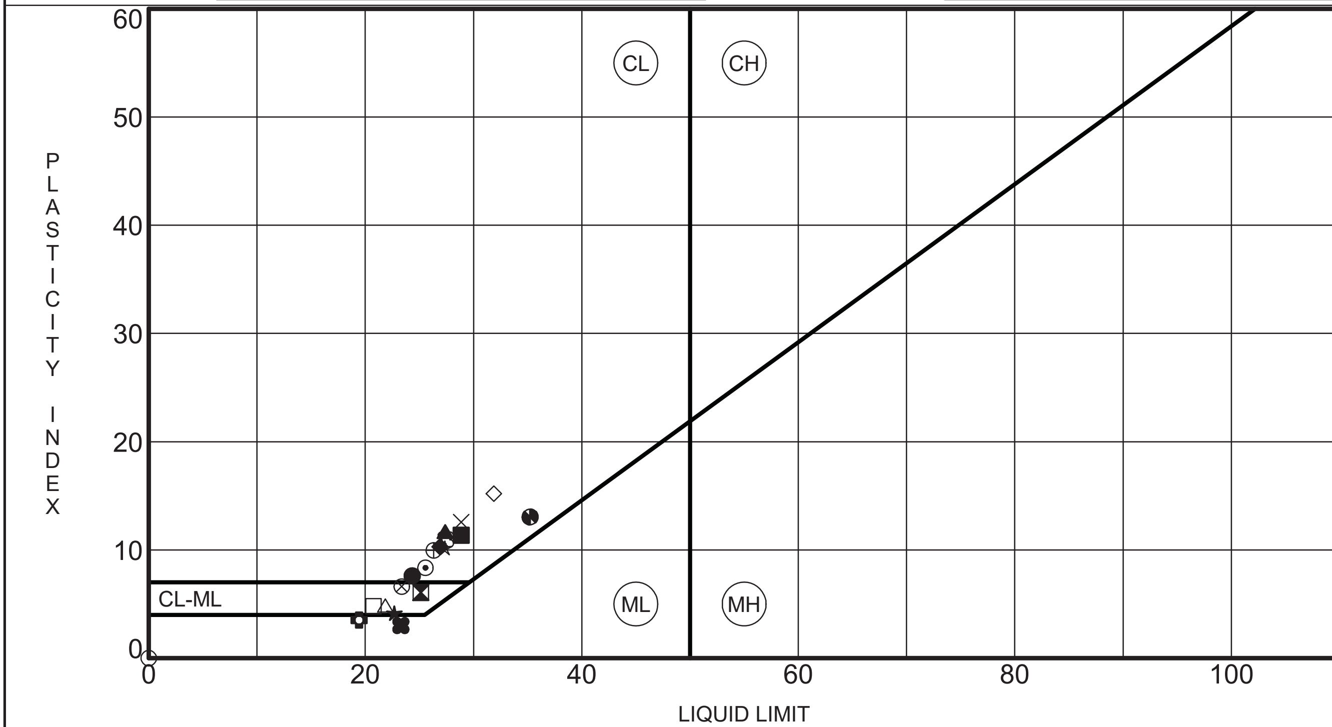
	Specimen Identification		LL	PL	PI	Fines	Classification
●	B-1	1.3-3.0	26	15	11	36.1	CLAYEY SAND with GRAVEL (SC) (A-6)
⊠	B-1	3.0-5.0	33	16	17	66.2	GRAVELLY LEAN CLAY (CL) (A-6)
▲	B-2	0.9-5.0	42	23	19	71.8	LEAN CLAY with SAND (CL) (A-7-6)
★	B-3	0.0-3.0	NP	NP	NP	24.5	SILTY GRAVEL with SAND (GM) (A-1-b)
⊙	B-3	3.0-5.0	34	16	18	60.8	SANDY LEAN CLAY (CL) (A-6)
✿	B-4	0.5-2.0	NP	NP	NP	19.2	SILTY GRAVEL with SAND (GM) (A-1-b)
○	B-4	2.0-5.0	NP	NP	NP	47.4	SILTY SAND (SM) (A-4)
△	B-5	1.1-2.0	NP	NP	NP	15.2	SILTY GRAVEL with SAND (GM) (A-1-a)
⊗	B-5	2.0-10.0	NP	NP	NP	26.8	SILTY SAND (SM) (A-2-4)
⊕	B-5	10.0-13.0	44	25	19	89.9	LEAN CLAY (CL) (A-7-6)
□	B-5	13.0-15.0	38	21	17	90.3	LEAN CLAY (CL) (A-6)
◉	B-6	2.5-5.0	NP	NP	NP	15.0	SILTY GRAVEL with SAND (GM) (A-1-a)
◕	B-7	3.0-5.0	33	21	12	69.7	SANDY LEAN CLAY (CL) (A-6)
☆	B-8	2.5-6.0	25	14	11	85.1	LEAN CLAY (CL) (A-6)
✤	B-8	6.0-10.0	34	18	16	84.0	LEAN CLAY with SAND (CL) (A-6)
■	B-9	0.7-1.7	NP	NP	NP	20.4	SILTY SAND with GRAVEL (SM) (A-1-b)
◆	B-9	1.7-5.0	28	16	12	64.9	SANDY LEAN CLAY (CL) (A-6)
◇	B-10	2.0-5.0	28	22	6	74.2	SILTY CLAY with SAND (CL-ML) (A-4)
×	B-21	1.0-5.0	27	16	11	78.0	LEAN CLAY with SAND (CL) (A-6)
✖	B-22	3.0-5.0	NP	NP	NP	14.3	SILTY GRAVEL with SAND (GM) (A-1-a)

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



	Specimen Identification		LL	PL	PI	Fines	Classification
●	B-23	2.5-3.5	24	17	7	54.2	SANDY SILTY CLAY with GRAVEL (CL-ML) (A-4)
⧗	B-23	3.5-5.0	25	19	6	75.2	SILTY CLAY with SAND (CL-ML) (A-4)
▲	B-24	0.9-5.0	27	16	11	63.5	SANDY LEAN CLAY (CL) (A-6)
★	B-25	0.5-3.0	23	19	4	43.6	SILTY, CLAYEY SAND with GRAVEL (SC-SM) (A-4)
⊙	B-25	3.0-5.0	26	17	9	73.0	LEAN CLAY with SAND (CL) (A-4)
✿	B-26	0.9-5.0	19	16	3	29.0	SILTY SAND with GRAVEL (SM) (A-2-4)
○	B-27	2.0-5.0	NP	NP	NP	36.9	SILTY SAND with GRAVEL (SM) (A-4)
△	B-28	1.0-5.0	22	17	5	58.1	SANDY SILTY CLAY (CL-ML) (A-4)
⊗	B-29	0.7-8.0	23	17	6	64.4	SANDY SILTY CLAY (CL-ML) (A-4)
⊕	B-29	8.0-15.0	26	16	10	77.1	LEAN CLAY with SAND (CL) (A-4)
□	B-30	0.9-5.0	21	16	5	66.6	SANDY SILTY CLAY (CL-ML) (A-4)
◉	B-41	1.1-5.0	35	22	13	74.4	LEAN CLAY with SAND (CL) (A-6)
◕	B-42	0.9-1.4	35	22	13	9.5	WELL-GRADED SAND with CLAY and GRAVEL (SW-SC) (A-2-6)
☆	B-42	1.4-5.0	27	17	10	86.6	LEAN CLAY (CL) (A-4)
✧	B-43	1.1-6.0	27	16	11	80.6	LEAN CLAY with SAND (CL) (A-6)
■	B-43	6.0-15.0	29	18	11	94.2	LEAN CLAY (CL) (A-6)
◆	B-44	1.3-6.0	27	17	10	86.2	LEAN CLAY (CL) (A-4)
◇	B-44	6.0-15.0	32	17	15	93.5	LEAN CLAY (CL) (A-6)
×	B-45	1.1-5.0	29	16	13	86.5	LEAN CLAY (CL) (A-6)
✖	B-46	1.8-5.0	23	20	3	91.0	SILT (ML) (A-4)

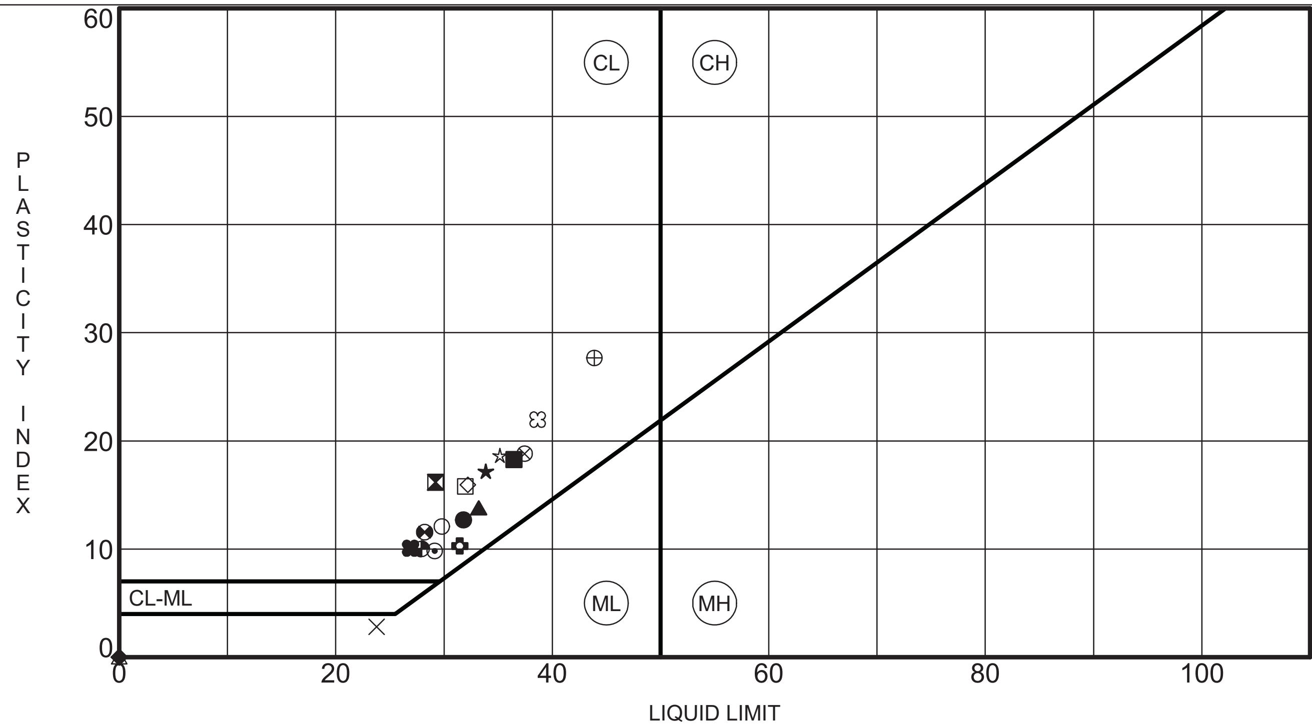
ATTERBERG LIMITS - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



	Specimen Identification		LL	PL	PI	Fines	Classification
●	B-47	2.0-5.0	32	19	13	86.4	LEAN CLAY (CL) (A-6)
⊠	B-48	0.9-1.3	29	13	16	72.3	LEAN CLAY with SAND (CL) (A-6)
▲	B-48	1.3-8.0	33	19	14	89.5	LEAN CLAY (CL) (A-6)
★	B-48	8.0-15.0	34	17	17	95.2	LEAN CLAY (CL) (A-6)
⊙	B-49	1.5-5.0	29	19	10	91.1	LEAN CLAY (CL) (A-4)
✿	B-50	1.0-5.0	31	21	10	86.9	LEAN CLAY (CL) (A-4)
○	B-51	1.8-5.0	30	18	12	49.4	CLAYEY SAND (SC) (A-6)
△	B-52	0.5-0.9	NP	NP	NP	9.7	WELL-GRADED SAND with SILT and GRAVEL (SW-SM) (A-1-a)
⊗	B-52	0.9-5.0	37	19	18	64.0	SANDY LEAN CLAY (CL) (A-6)
⊕	B-53	1.1-5.0	44	16	28	63.2	SANDY LEAN CLAY (CL) (A-7-6)
□	B-54	1.0-4.0	32	16	16	57.8	SANDY LEAN CLAY (CL) (A-6)
⊗	B-54	4.0-7.0	28	17	11	32.1	CLAYEY GRAVEL with SAND (GC) (A-2-6)
◕	B-54	7.0-10.0	28	18	10	27.7	CLAYEY GRAVEL with SAND (GC) (A-2-4)
☆	B-55	1.1-5.0	35	17	18	72.0	LEAN CLAY with SAND (CL) (A-6)
✿	B-56	0.8-5.0	39	17	22	74.3	LEAN CLAY with SAND (CL) (A-6)
■	B-57	0.7-5.0	36	18	18	71.1	LEAN CLAY with SAND (CL) (A-6)
◆	B-58	0.61.1	NP	NP	NP	18.0	SILTY SAND with GRAVEL (SM) (A-1-b)
◇	B-58	1.1-5.0	32	16	16	66.9	SANDY LEAN CLAY (CL) (A-6)
×	B-59	0.6-3.0	24	21	3	36.3	SILTY SAND with GRAVEL (SM) (A-4)
✖	B-59	3.0-5.0	27	17	10	63.6	SANDY LEAN CLAY (CL) (A-4)

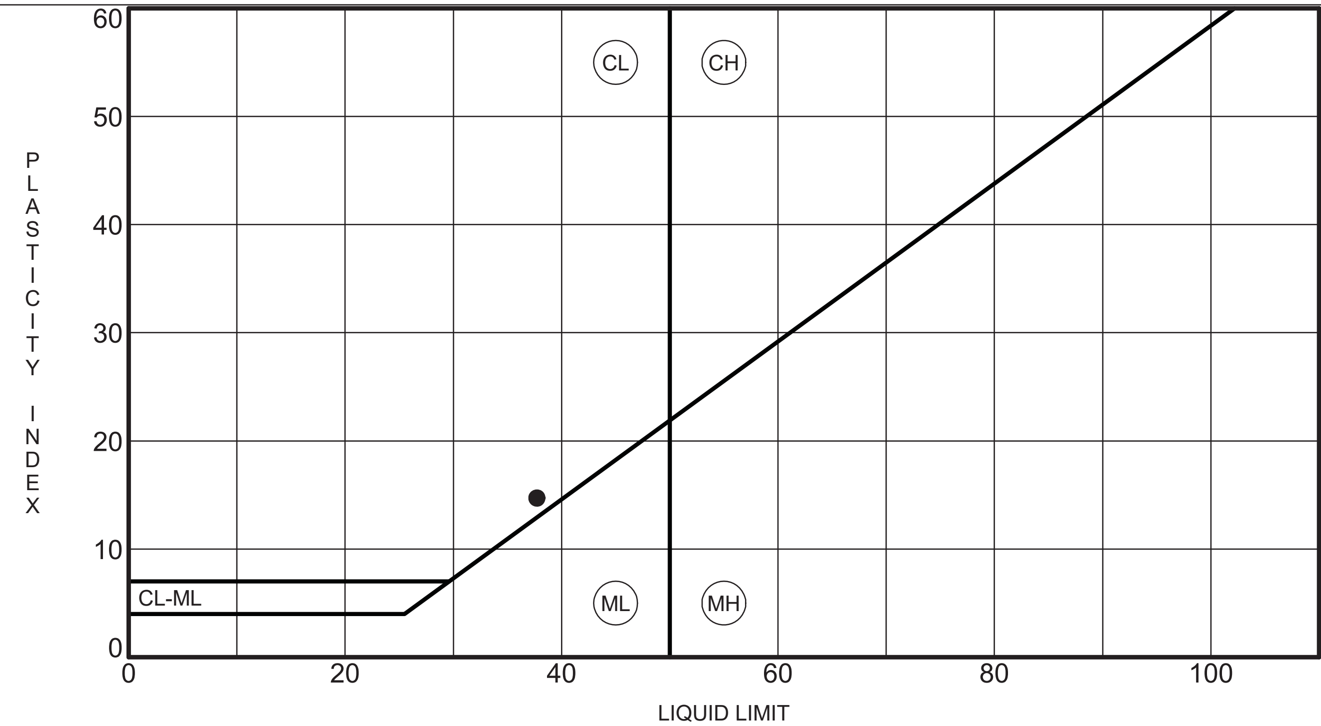
ATTERBERG LIMITS - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

ATTERBERG LIMITS RESULTS
AASHTO T89 Method A/T90

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



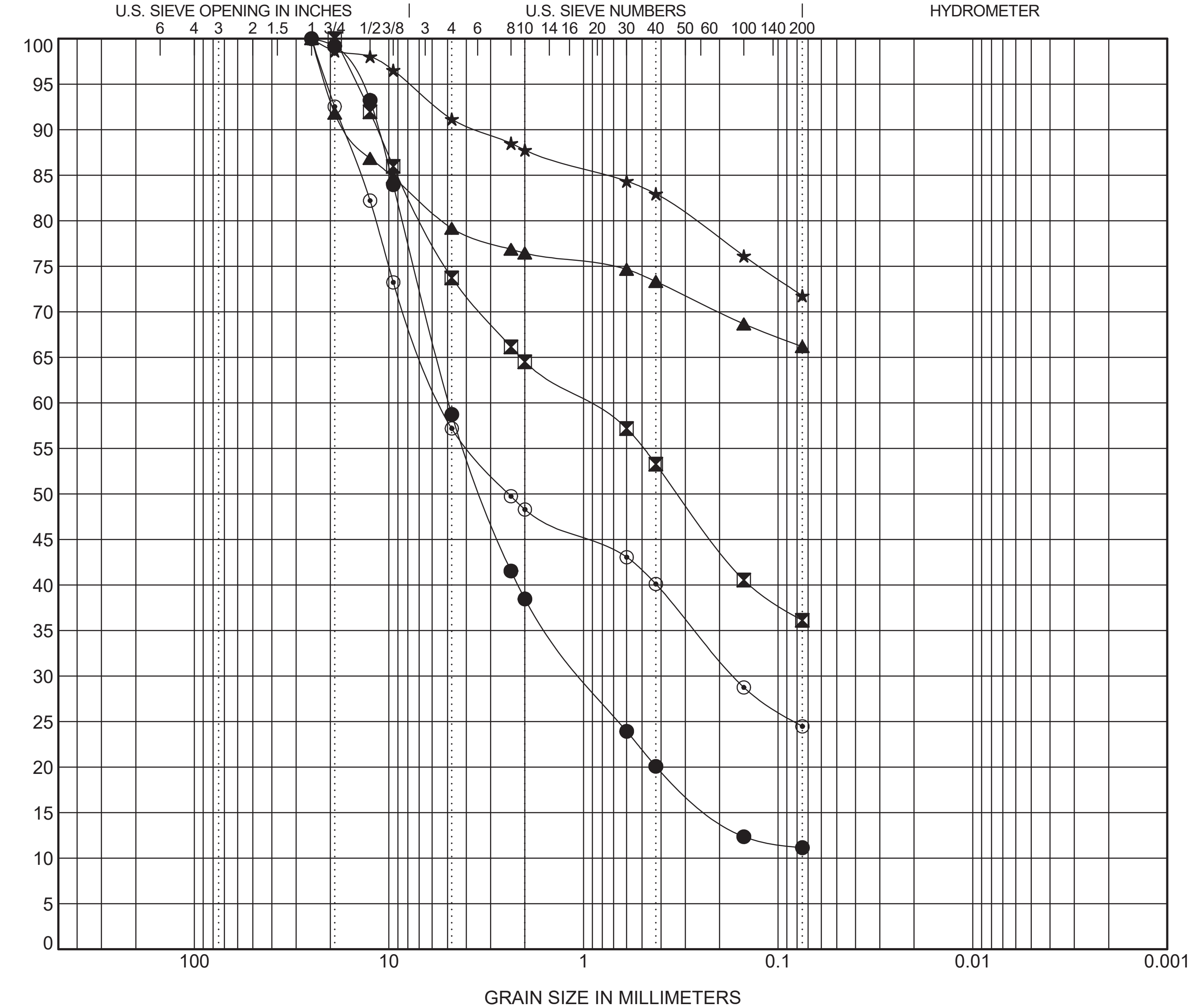
	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-60**	**1.1-5.0**	**38**	**23**	**15**	**60.4**	**SANDY LEAN CLAY (CL) (A-6)**

GRAIN SIZE DISTRIBUTION

RockSol

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **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	0.8-1.3	**Aggregate base course**				5.17	127.04
⊠	B-1	1.3-3.0	**CLAYEY SAND with GRAVEL (SC) (A-6)**	26	15	11		
▲	B-1	3.0-5.0	**GRAVELLY LEAN CLAY (CL) (A-6)**	33	16	17		
★	B-2	0.9-5.0	**LEAN CLAY with SAND (CL) (A-7-6)**	42	23	19		
⊙	B-3	0.0-3.0	**SILTY GRAVEL with SAND (GM) (A-1-b)**	NP	NP	NP		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-1	0.8-1.3	25	4.919	0.992		61.5	18.4	8.9	11.1	
⊠	B-1	1.3-3.0	19	0.952			35.5	11.2	17.2	36.1	
▲	B-1	3.0-5.0	25				23.6	3.1	7.2	66.2	
★	B-2	0.9-5.0	25				12.2	4.8	11.2	71.8	
⊙	B-3	0.0-3.0	25	5.364	0.168		51.7	8.2	15.6	24.5	

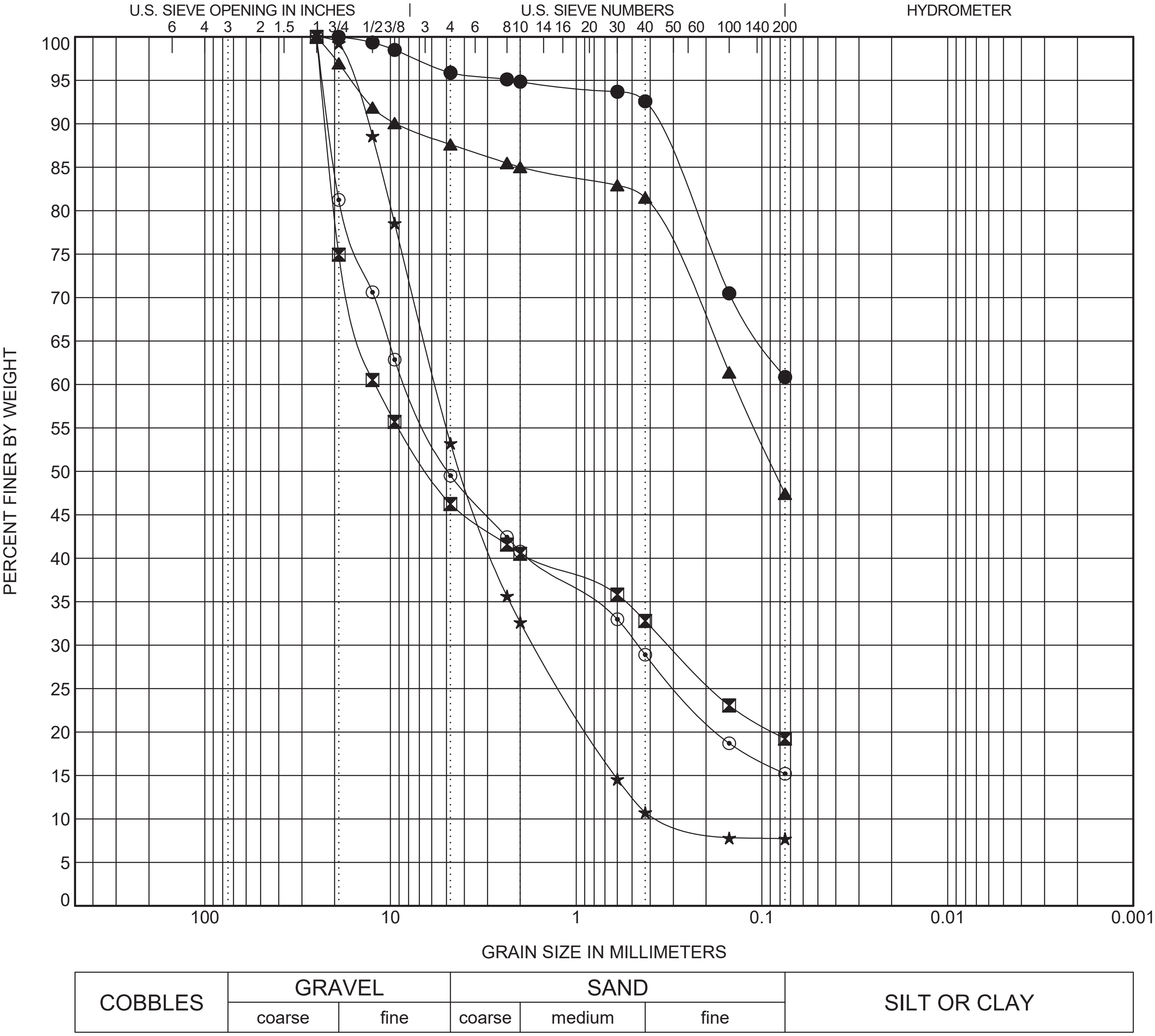
GRADATION - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

GRAIN SIZE DISTRIBUTION

RockSol

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	B-3	3.0-5.0	SANDY LEAN CLAY (CL) (A-6)	34	16	18		
⊠	B-4	0.5-2.0	SILTY GRAVEL with SAND (GM) (A-1-b)	NP	NP	NP		
▲	B-4	2.0-5.0	SILTY SAND (SM) (A-4)	NP	NP	NP		
★	B-5	0.6-1.1	Aggregate base course				1.51	17.54
⊙	B-5	1.1-2.0	SILTY GRAVEL with SAND (GM) (A-1-a)	NP	NP	NP		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-3	3.0-5.0	19				5.2	2.3	31.7	60.8	
⊠	B-4	0.5-2.0	25	12.131	0.315		59.5	7.7	13.6	19.2	
▲	B-4	2.0-5.0	25	0.14			15.0	3.5	34.1	47.4	
★	B-5	0.6-1.1	25	5.716	1.678	0.326	67.4	21.9	3.0	7.7	
⊙	B-5	1.1-2.0	25	8.191	0.467		59.2	11.9	13.7	15.2	

GRAIN SIZE DISTRIBUTION

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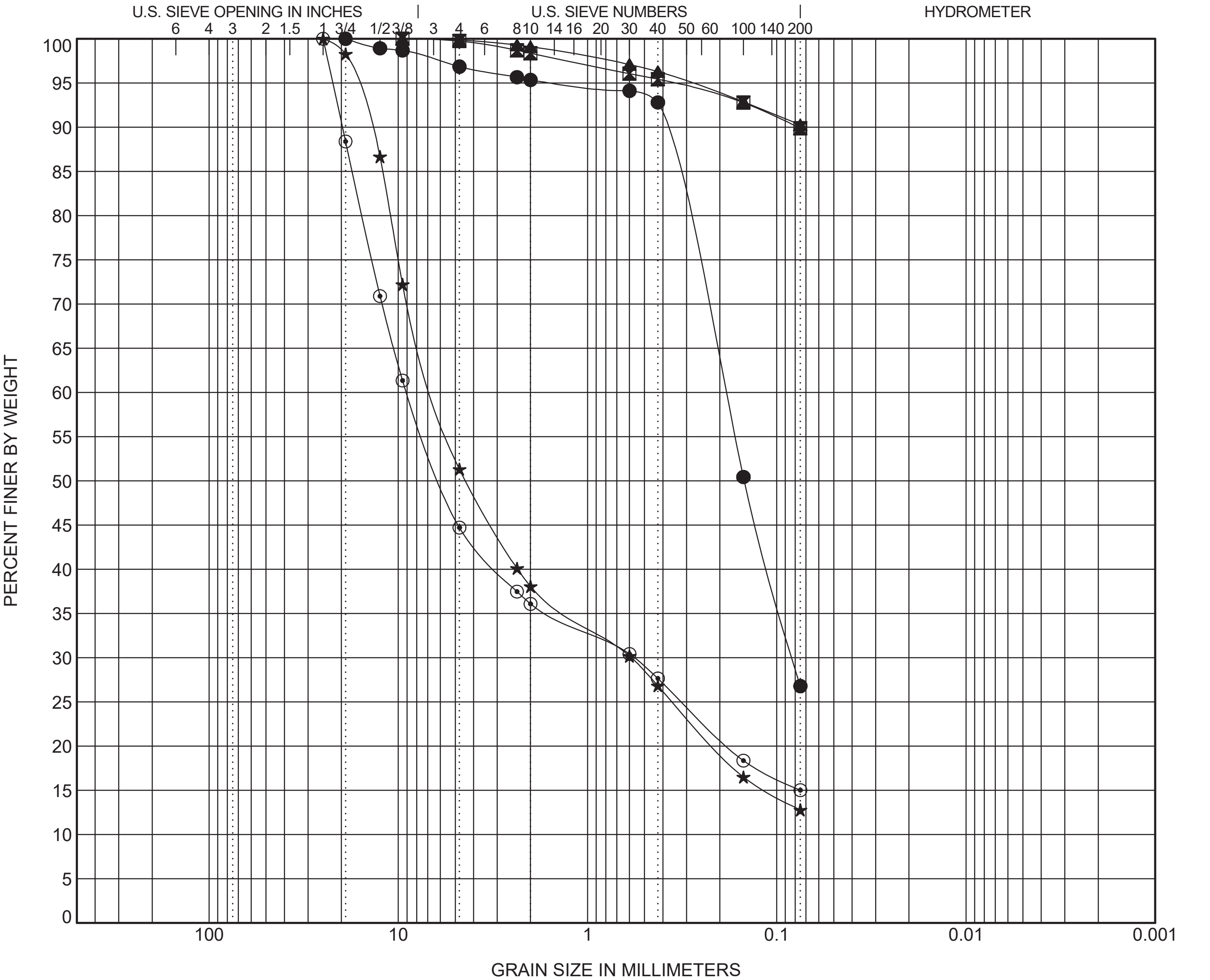

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-5	2.0-10.0	**SILTY SAND (SM) (A-2-4)**	NP	NP	NP		
⊠	B-5	10.0-13.0	**LEAN CLAY (CL) (A-7-6)**	44	25	19		
▲	B-5	13.0-15.0	**LEAN CLAY (CL) (A-6)**	38	21	17		
★	B-6	0.4-2.5	**(Fill) COBBLES, sandy**					
⊙	B-6	2.5-5.0	**SILTY GRAVEL with SAND (GM) (A-1-a)**	NP	NP	NP		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt / %Clay
●	B-5	2.0-10.0	19	0.19	0.082		4.7	2.5	66.0	26.8
⊠	B-5	10.0-13.0	9.5				1.6	2.9	5.5	89.9
▲	B-5	13.0-15.0	9.5				0.9	2.8	6.0	90.3
★	B-6	0.4-2.5	25	6.336	0.589		61.9	11.2	14.0	12.8
⊙	B-6	2.5-5.0	25	8.982	0.57		63.9	8.4	12.6	15.0

GRAIN SIZE DISTRIBUTION

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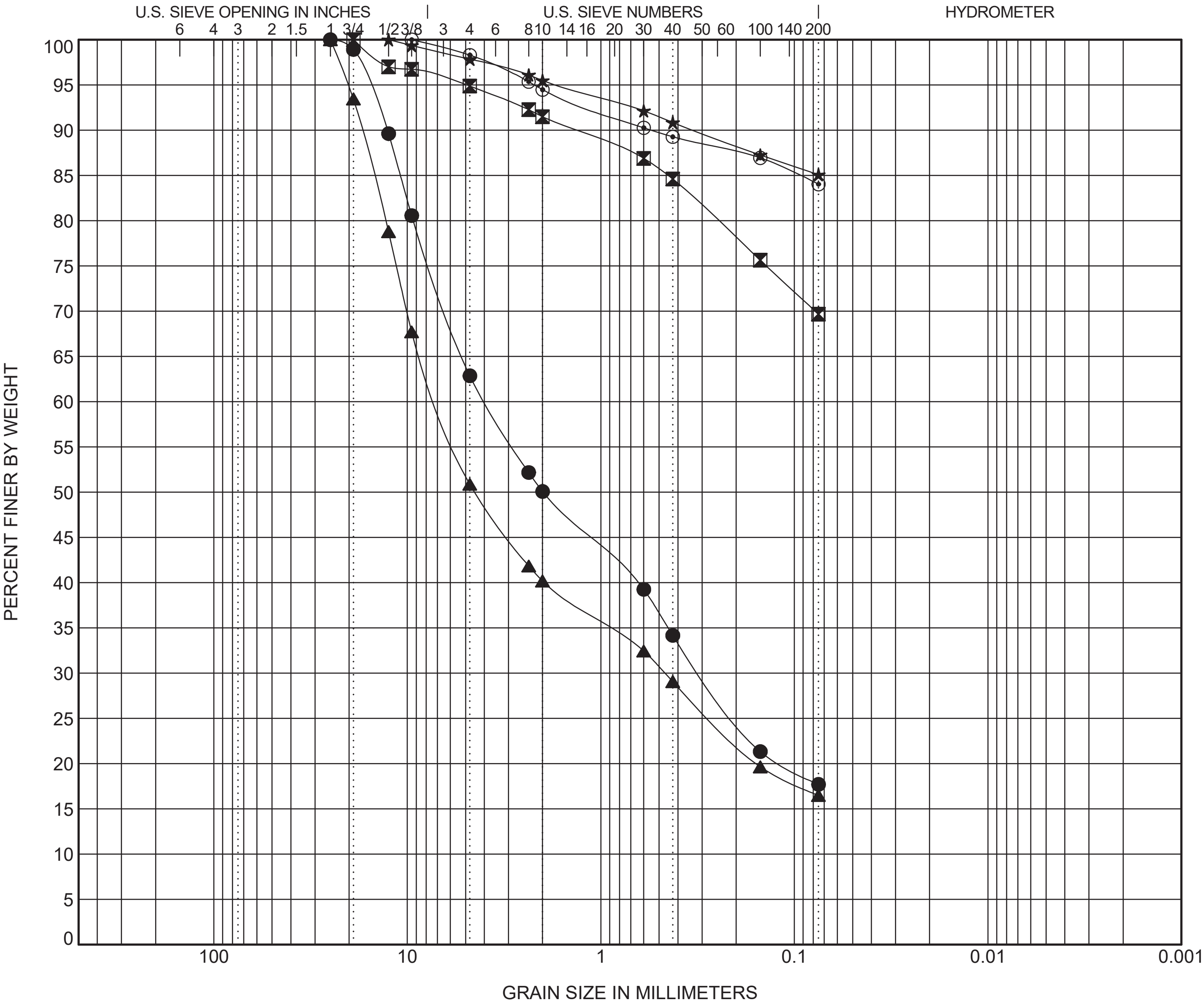

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	B-7	1.0-3.0	(Fill) COBBLES and GRAVEL, sandy					
⊠	B-7	3.0-5.0	SANDY LEAN CLAY (CL) (A-6)	33	21	12		
▲	B-8	1.0-2.5	CLAY, sandy					
★	B-8	2.5-6.0	LEAN CLAY (CL) (A-6)	25	14	11		
⊙	B-8	6.0-10.0	LEAN CLAY with SAND (CL) (A-6)	34	18	16		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-7	1.0-3.0	25	3.941	0.303		49.9	15.9	16.5	17.7	
⊠	B-7	3.0-5.0	19				8.5	6.9	14.9	69.7	
▲	B-8	1.0-2.5	25	6.916	0.468		59.8	11.1	12.6	16.5	
★	B-8	2.5-6.0	12.5				4.5	4.6	5.8	85.1	
⊙	B-8	6.0-10.0	9.5				5.5	5.2	5.2	84.0	

GRAIN SIZE DISTRIBUTION

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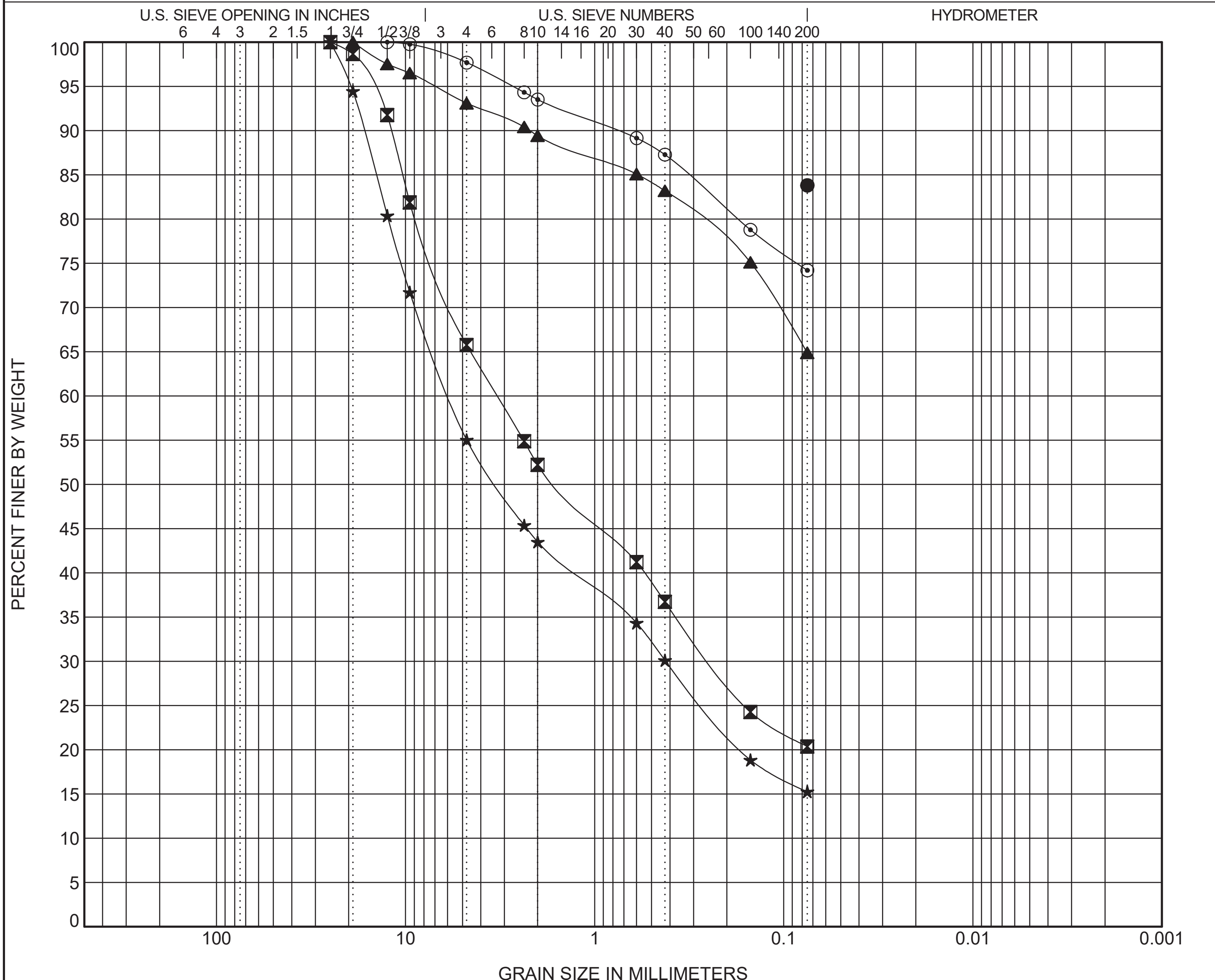

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-8	9.0	(Bedrock) SHALE					
⧗	B-9	0.7-1.7	SILTY SAND with GRAVEL (SM) (A-1-b)	NP	NP	NP		
▲	B-9	1.7-5.0	SANDY LEAN CLAY (CL) (A-6)	28	16	12		
★	B-10	0.9-2.0	(Fill) COBBLES					
⊙	B-10	2.0-5.0	SILTY CLAY with SAND (CL-ML) (A-4)	28	22	6		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-8	9.0	0.075							83.8	
⧗	B-9	0.7-1.7	25	3.281	0.242		47.8	15.5	16.3	20.4	
▲	B-9	1.7-5.0	19				10.6	6.2	18.3	64.9	
★	B-10	0.9-2.0	25	5.838	0.42		56.5	13.4	14.9	15.3	
⊙	B-10	2.0-5.0	12.5				6.5	6.2	13.1	74.2	

GRADATION - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

GRAIN SIZE DISTRIBUTION

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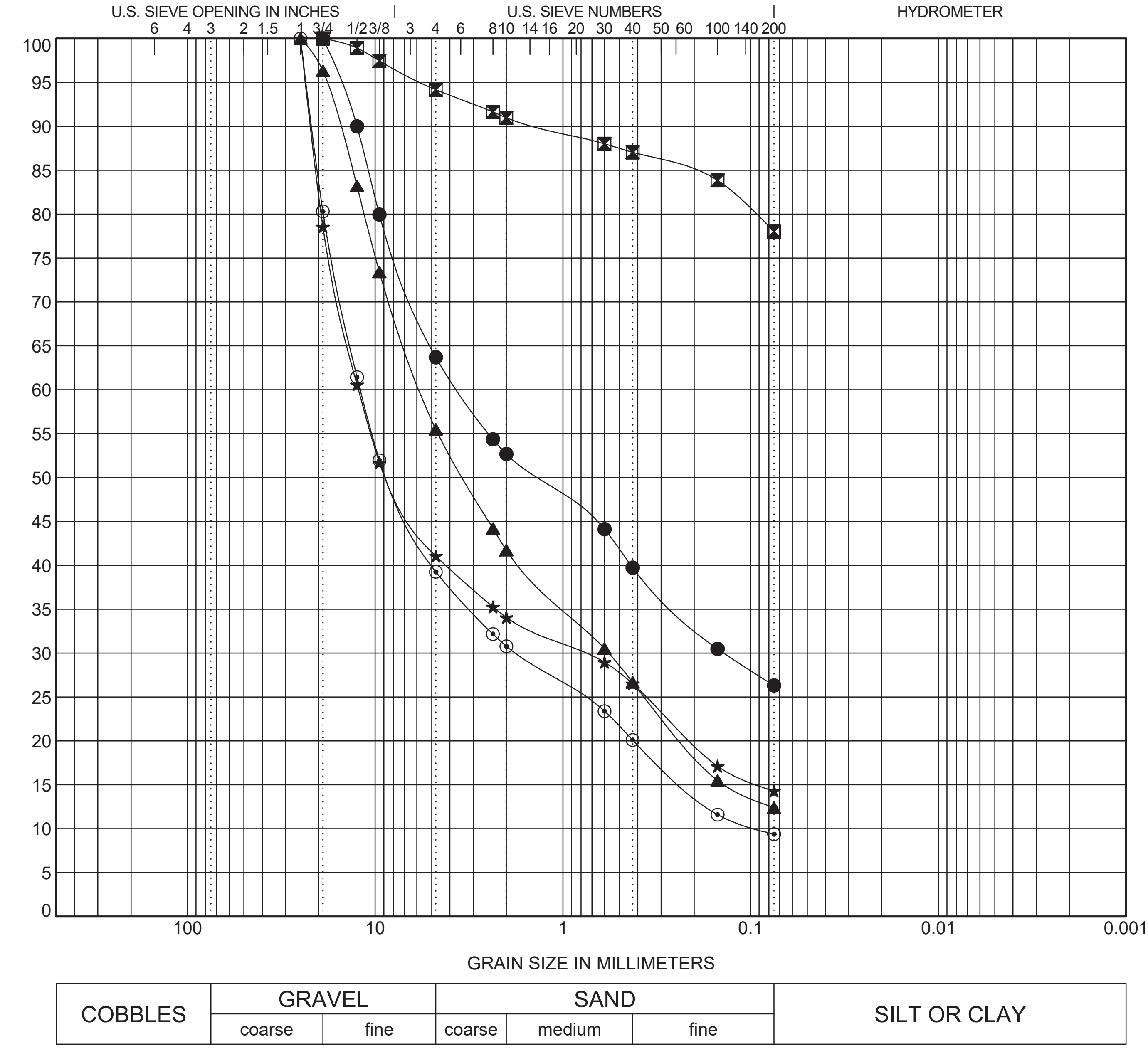


	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**B-21**	**0.4-1.0**	**Aggregate base course**					
⊠	**B-21**	**1.0-5.0**	**LEAN CLAY with SAND (CL) (A-6)**	**27**	**16**	**11**		
▲	**B-22**	**0.9-3.0**	**(Fill) COBBLES, sandy**				**1.32**	**129.15**
★	**B-22**	**3.0-5.0**	**SILTY GRAVEL with SAND (GM) (A-1-a)**	**NP**	**NP**	**NP**		
⊙	**B-23**	**1.3-2.5**	**(Fill) COBBLES, sandy**				**2.84**	**131.55**

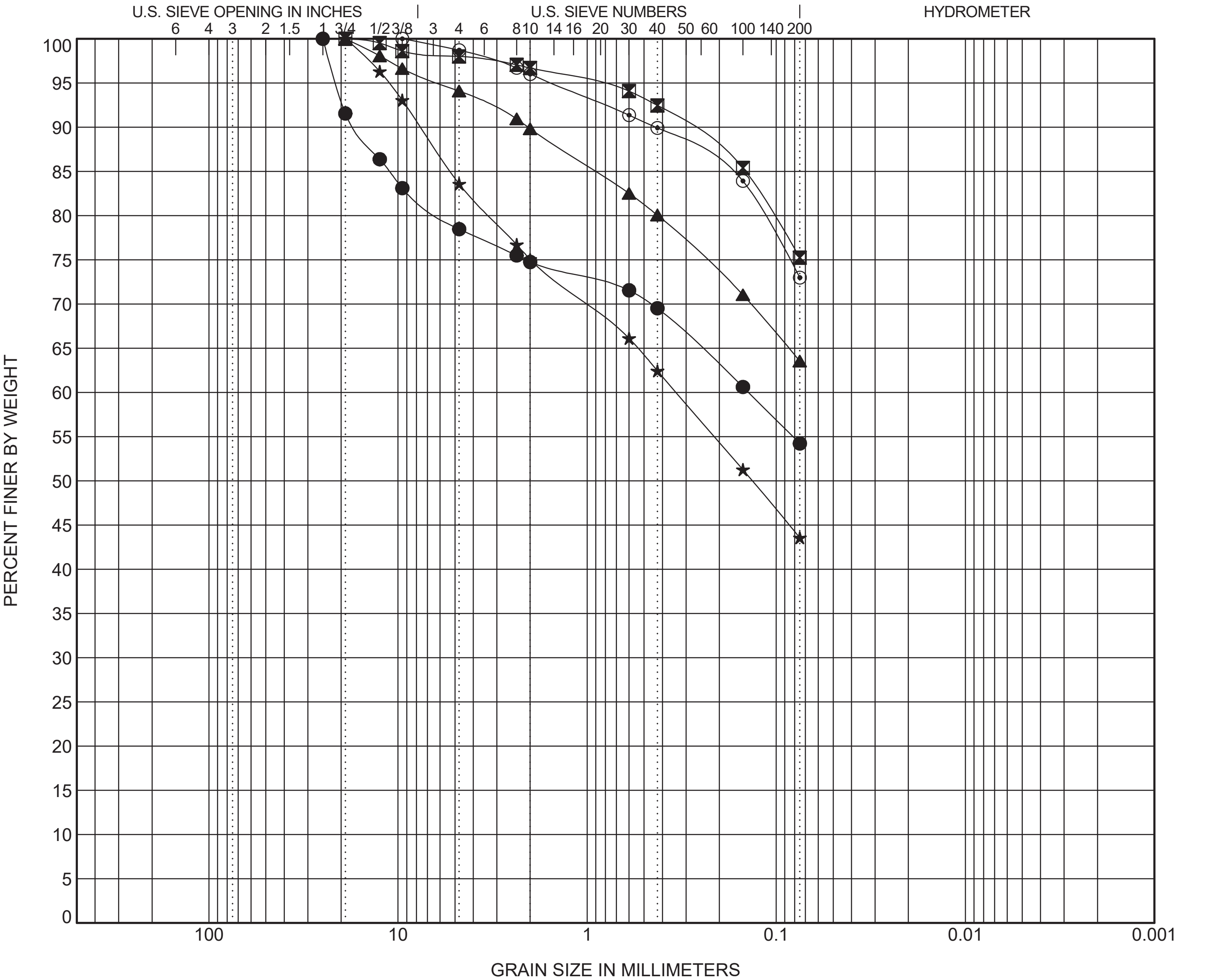
	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**B-21**	**0.4-1.0**	**19**	**3.602**	**0.138**		**47.3**	**12.9**	**13.4**	**26.3**	
⊠	**B-21**	**1.0-5.0**	**19**				**9.0**	**3.9**	**9.0**	**78.0**	
▲	**B-22**	**0.9-3.0**	**25**	**5.656**	**0.573**		**58.3**	**15.0**	**14.3**	**12.4**	
★	**B-22**	**3.0-5.0**	**25**	**12.283**	**0.768**		**65.9**	**7.5**	**12.2**	**14.3**	
⊙	**B-23**	**1.3-2.5**	**25**	**11.992**	**1.762**	**0.091**	**69.2**	**10.7**	**10.7**	**9.4**	

GRAIN SIZE DISTRIBUTION

RockSol

CLIENT City of Grand Junction | **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 | **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-23	2.5-3.5	**SANDY SILTY CLAY with GRAVEL (CL-ML) (A-4)**	24	17	7		
⧗	B-23	3.5-5.0	**SILTY CLAY with SAND (CL-ML) (A-4)**	25	19	6		
▲	B-24	0.9-5.0	**SANDY LEAN CLAY (CL) (A-6)**	27	16	11		
★	B-25	0.5-3.0	**SILTY, CLAYEY SAND with GRAVEL (SC-SM) (A-4)**	23	19	4		
⊙	B-25	3.0-5.0	**LEAN CLAY with SAND (CL) (A-4)**	26	17	9		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-23	2.5-3.5	25	0.14			25.2	5.2	15.3	54.2	
⧗	B-23	3.5-5.0	19				3.3	4.2	17.2	75.2	
▲	B-24	0.9-5.0	19				10.2	9.8	16.5	63.5	
★	B-25	0.5-3.0	19	0.339			25.0	12.6	18.9	43.6	
⊙	B-25	3.0-5.0	9.5				4.0	6.1	16.9	73.0	

GRAIN SIZE DISTRIBUTION

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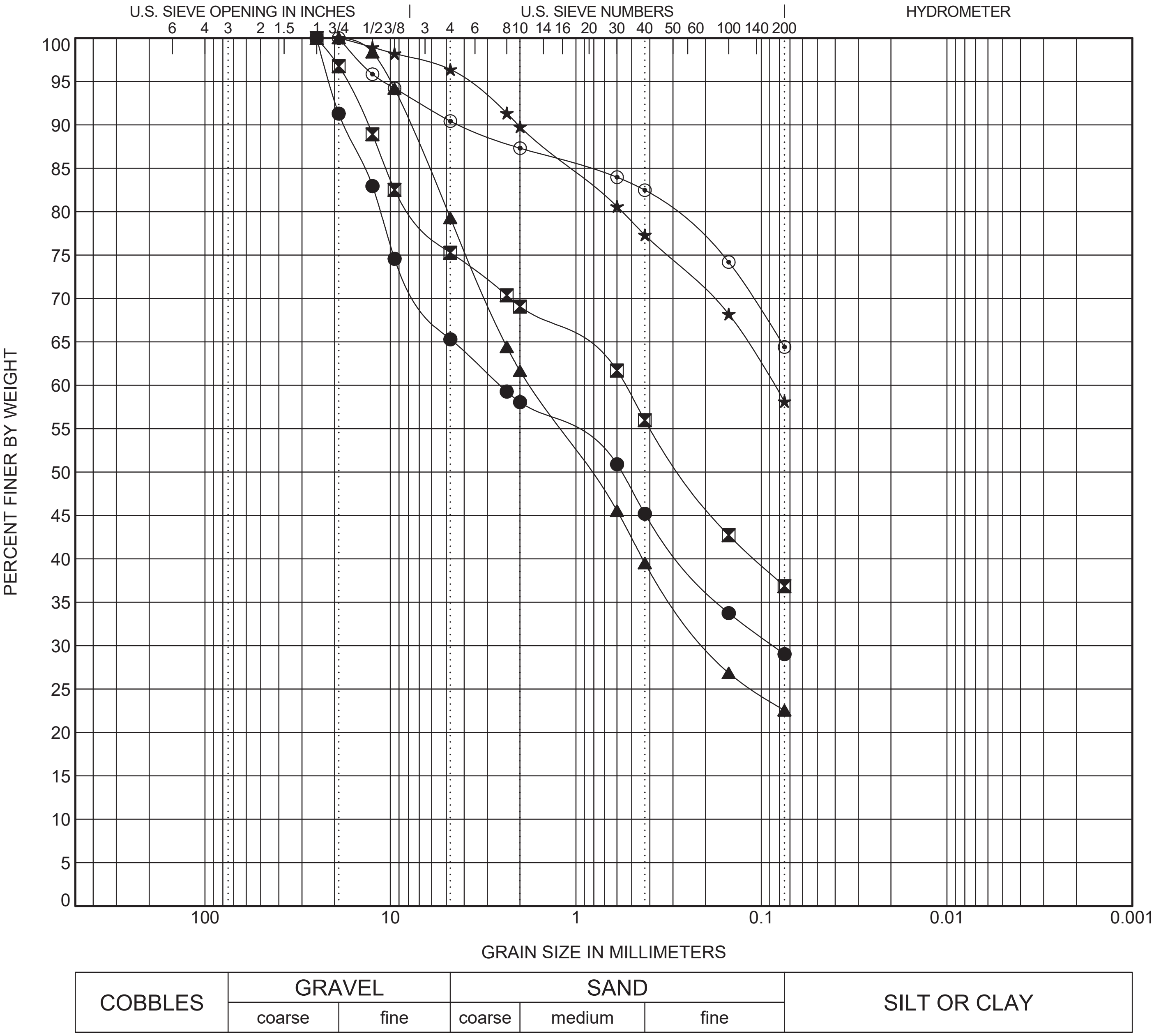

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● B-26	0.9-5.0	**SILTY SAND with GRAVEL (SM) (A-2-4)**	19	16	3		
⊠ B-27	2.0-5.0	**SILTY SAND with GRAVEL (SM) (A-4)**	NP	NP	NP		
▲ B-28	0.4-1.0	**Aggregate base course**					
★ B-28	1.0-5.0	**SANDY SILTY CLAY (CL-ML) (A-4)**	22	17	5		
⊙ B-29	0.7-8.0	**SANDY SILTY CLAY (CL-ML) (A-4)**	23	17	6		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
● B-26	0.9-5.0	25	2.568	0.087		41.9	12.9	16.2	29.0	
⊠ B-27	2.0-5.0	25	0.542			30.9	13.1	19.1	36.9	
▲ B-28	0.4-1.0	19	1.768	0.194		38.3	22.1	17.0	22.5	
★ B-28	1.0-5.0	19	0.085			10.2	12.5	19.2	58.1	
⊙ B-29	0.7-8.0	19				12.7	4.8	18.1	64.4	

GRAIN SIZE DISTRIBUTION

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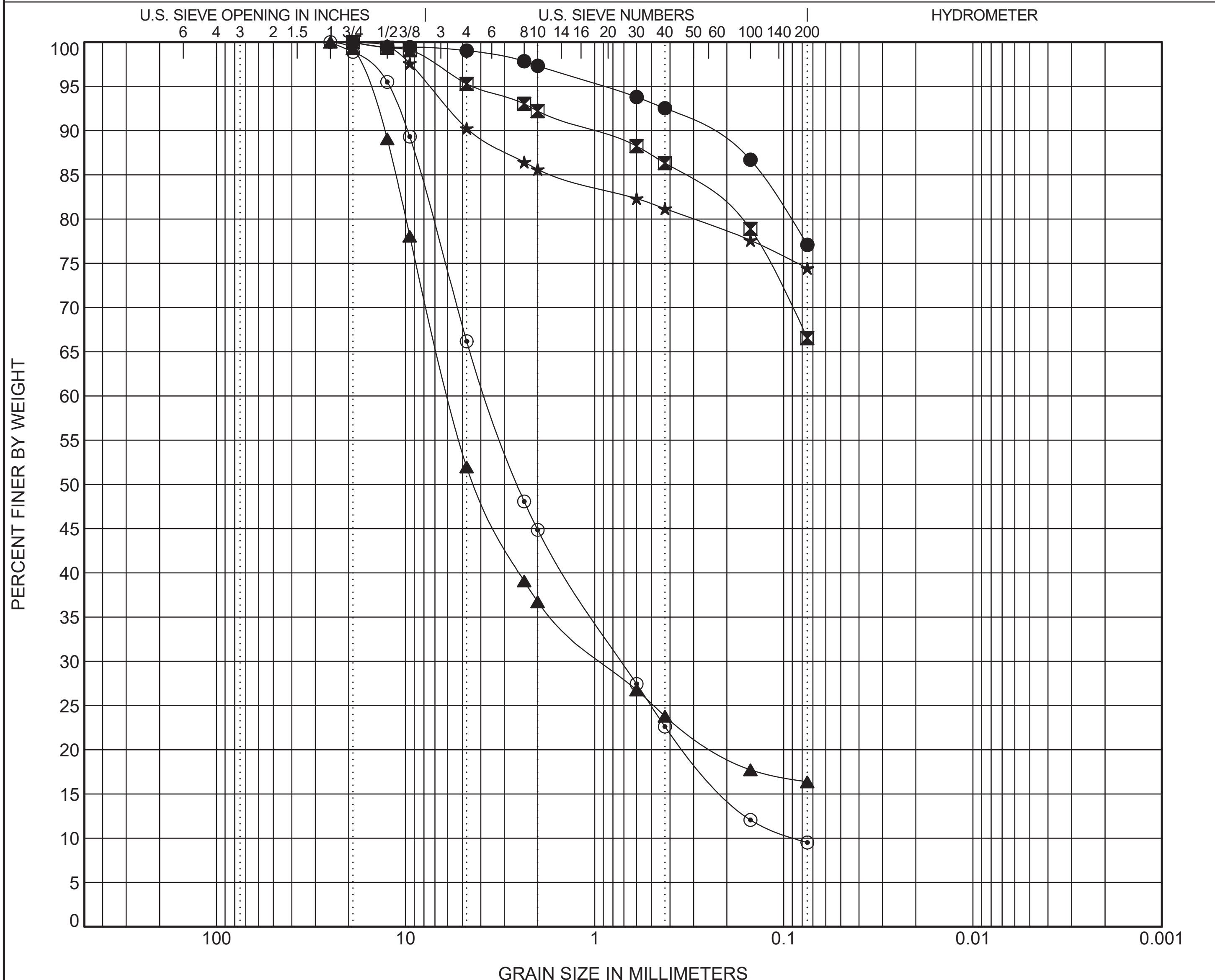

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● B-29	8.0-15.0	LEAN CLAY with SAND (CL) (A-4)	26	16	10		
⧗ B-30	0.9-5.0	SANDY SILTY CLAY (CL-ML) (A-4)	21	16	5		
▲ B-41	0.6-1.1	Aggregate base course					
★ B-41	1.1-5.0	LEAN CLAY with SAND (CL) (A-6)	35	22	13		
⊙ B-42	0.9-1.4	WELL-GRADED SAND w CLAY & GRAVEL (SW-SC)(A-2-6)	35	22	13	1.60	43.74

Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
● B-29	8.0-15.0	19				2.7	4.8	15.5	77.1	
⧗ B-30	0.9-5.0	19				7.8	5.9	19.8	66.6	
▲ B-41	0.6-1.1	25	5.881	0.887		63.3	12.9	7.4	16.4	
★ B-41	1.1-5.0	19				14.4	4.4	6.7	74.4	
⊙ B-42	0.9-1.4	25	3.741	0.716	0.086	55.1	22.2	13.1	9.5	

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GRAIN SIZE DISTRIBUTION

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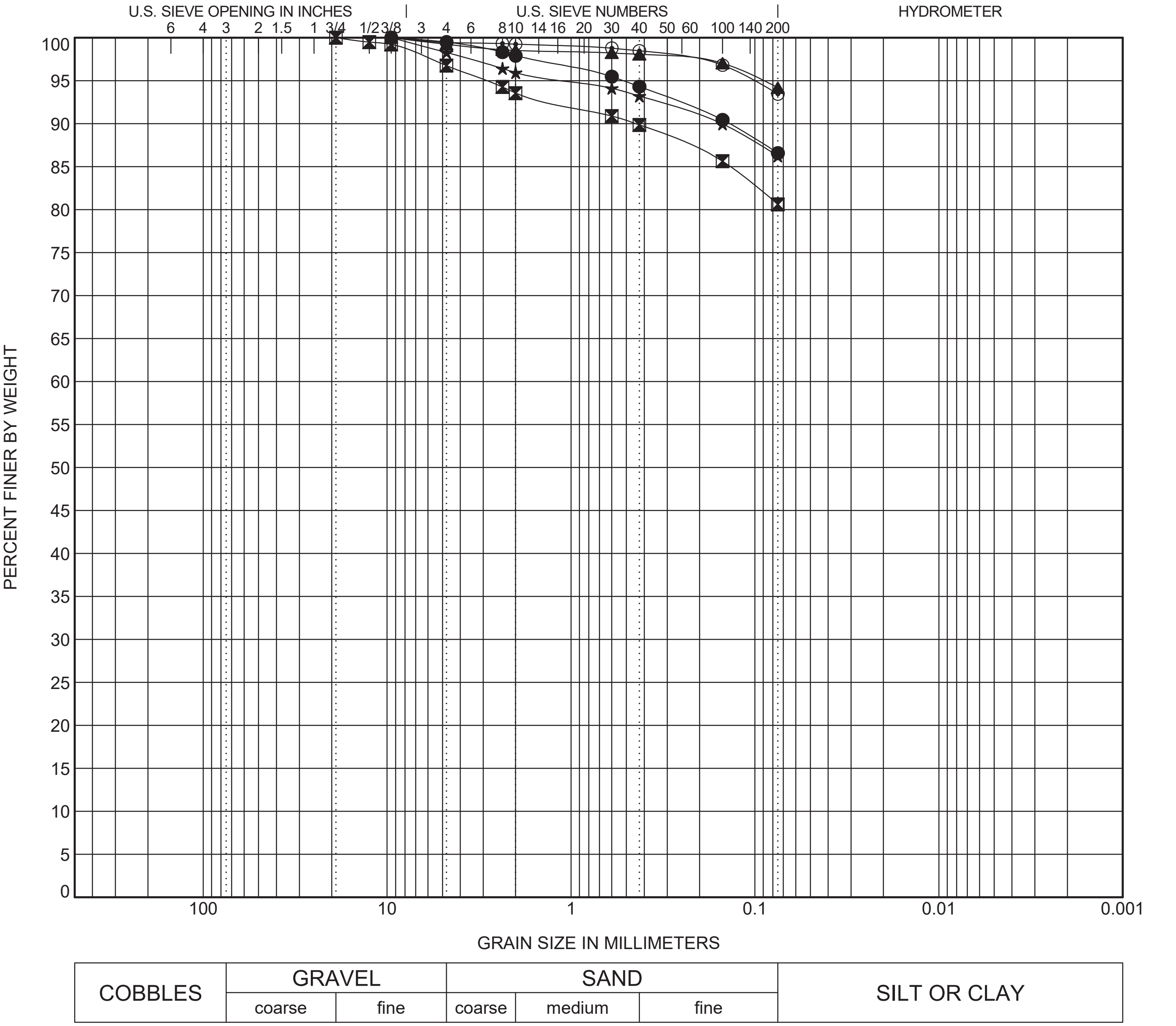
PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-42	1.4-5.0	LEAN CLAY (CL) (A-4)	27	17	10		
⧗	B-43	1.1-6.0	LEAN CLAY with SAND (CL) (A-6)	27	16	11		
▲	B-43	6.0-15.0	LEAN CLAY (CL) (A-6)	29	18	11		
★	B-44	1.3-6.0	LEAN CLAY (CL) (A-4)	27	17	10		
⊙	B-44	6.0-15.0	LEAN CLAY (CL) (A-6)	32	17	15		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-42	1.4-5.0	9.5				2.1	3.6	7.7	86.6	
⧗	B-43	1.1-6.0	19				6.4	3.7	9.2	80.6	
▲	B-43	6.0-15.0	9.5				1.5	0.5	3.9	94.2	
★	B-44	1.3-6.0	9.5				4.1	2.7	7.0	86.2	
⊙	B-44	6.0-15.0	9.5				0.7	0.8	5.0	93.5	

GRAIN SIZE DISTRIBUTION

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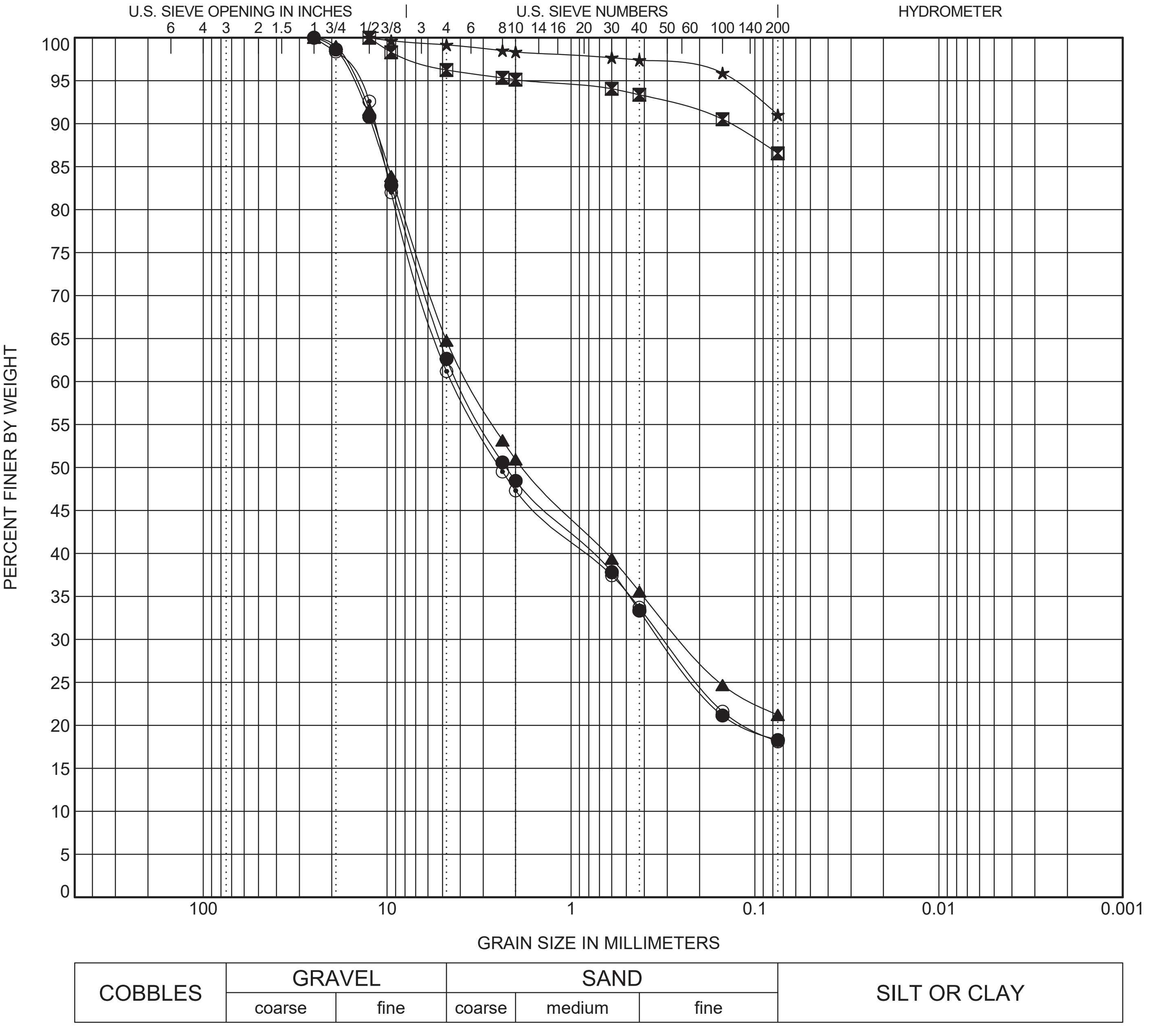
PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements
PROJECT NUMBER 599.70
PROJECT LOCATION Grand Junction, Colorado



Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	**B-45**	**0.6-1.1**	**Aggregate base course**					
⧗	**B-45**	**1.1-5.0**	**LEAN CLAY (CL) (A-6)**	**29**	**16**	**13**		
▲	**B-46**	**0.9-1.8**	**Aggregate base course**					
★	**B-46**	**1.8-5.0**	**SILT (ML) (A-4)**	**23**	**20**	**3**		
⊙	**B-47**	**0.8-1.3**	**Aggregate base course**					

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	**B-45**	**0.6-1.1**	**25**	**4.076**	**0.32**		**51.6**	**15.1**	**15.1**	**18.3**	
⧗	**B-45**	**1.1-5.0**	**12.5**				**4.9**	**1.7**	**6.8**	**86.5**	
▲	**B-46**	**0.9-1.8**	**25**	**3.567**	**0.25**		**49.1**	**15.4**	**14.4**	**21.2**	
★	**B-46**	**1.8-5.0**	**12.5**				**1.6**	**1.0**	**6.4**	**91.0**	
⊙	**B-47**	**0.8-1.3**	**25**	**4.424**	**0.309**		**52.7**	**13.6**	**15.6**	**18.1**	

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GRAIN SIZE DISTRIBUTION

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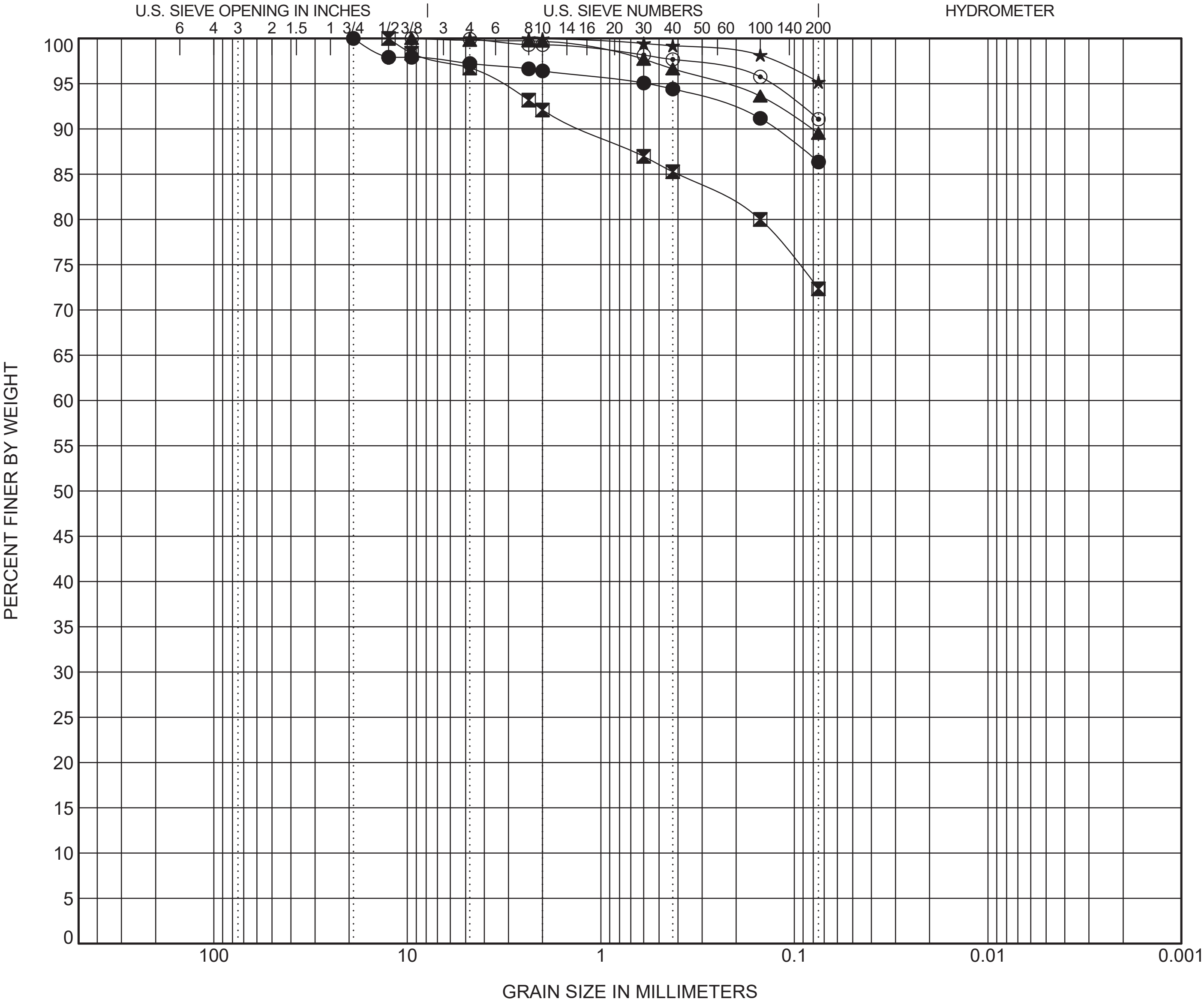
PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-47	2.0-5.0	LEAN CLAY (CL) (A-6)	32	19	13		
⊠	B-48	0.9-1.3	LEAN CLAY with SAND (CL) (A-6)	29	13	16		
▲	B-48	1.3-8.0	LEAN CLAY (CL) (A-6)	33	19	14		
★	B-48	8.0-15.0	LEAN CLAY (CL) (A-6)	34	17	17		
⊙	B-49	1.5-5.0	LEAN CLAY (CL) (A-4)	29	19	10		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-47	2.0-5.0	19				3.6	2.0	8.1	86.4	
⊠	B-48	0.9-1.3	12.5				7.9	6.8	12.9	72.3	
▲	B-48	1.3-8.0	9.5				0.3	3.0	7.1	89.5	
★	B-48	8.0-15.0	4.75				0.0	0.8	4.0	95.2	
⊙	B-49	1.5-5.0	9.5				0.7	1.6	6.6	91.1	

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GRAIN SIZE DISTRIBUTION

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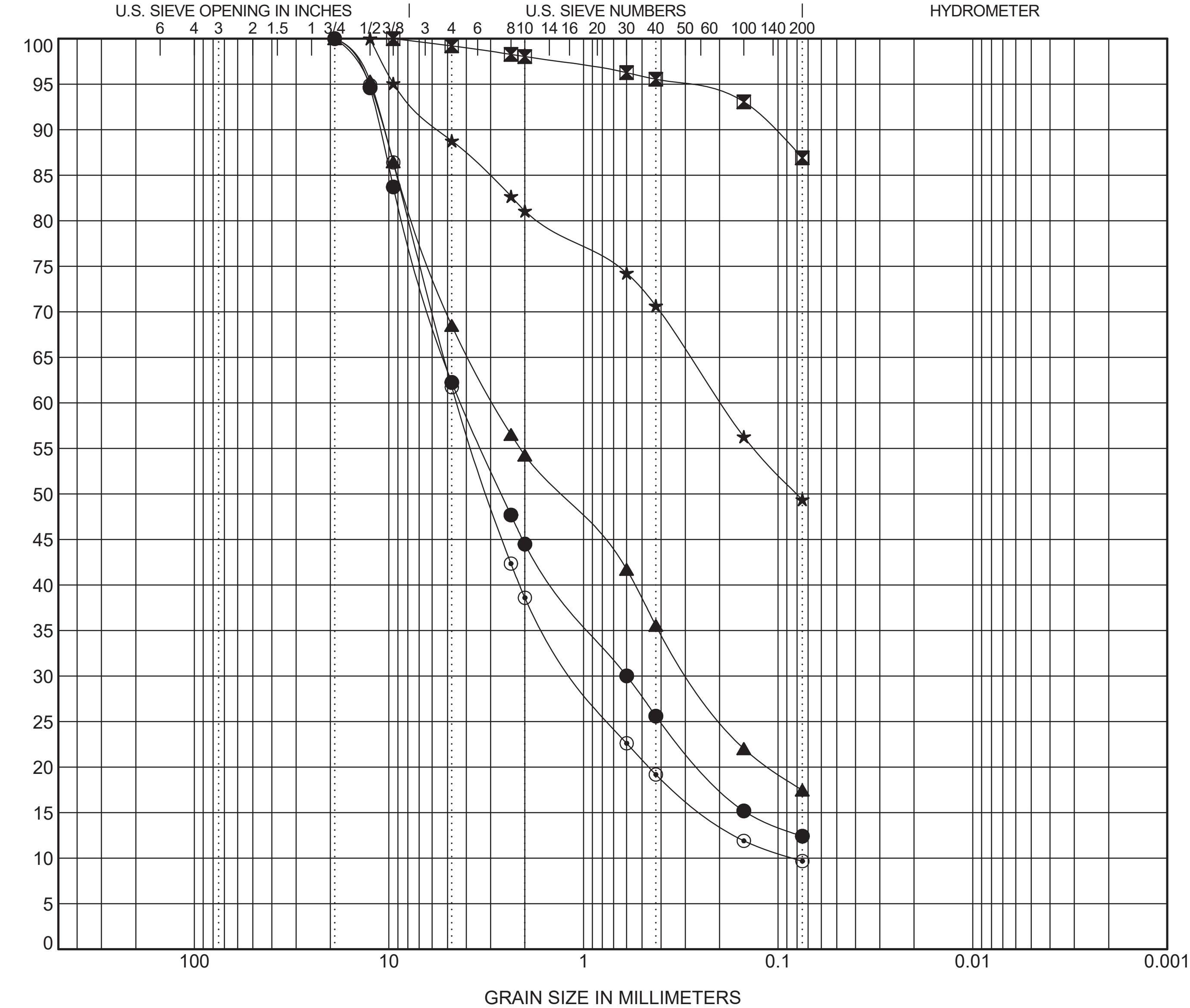

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-50	0.5-1.0	Aggregate base course				2.06	104.18
☒	B-50	1.0-5.0	LEAN CLAY (CL) (A-4)	31	21	10		
▲	B-51	1.0-1.8	Aggregate base course					
★	B-51	1.8-5.0	CLAYEY SAND (SC) (A-6)	30	18	12		
⊙	B-52	0.5-0.9	WELL-GRADED SAND w SILT & GRAVEL (SW-SM) (A-1-a)	NP	NP	NP	2.95	53.73

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-50	0.5-1.0	19	4.265	0.599		55.5	18.9	13.2	12.4	
☒	B-50	1.0-5.0	9.5				2.0	2.5	8.6	86.9	
▲	B-51	1.0-1.8	19	2.891	0.277		45.7	18.7	18.1	17.5	
★	B-51	1.8-5.0	12.5	0.196			18.9	10.4	21.3	49.4	
⊙	B-52	0.5-0.9	19	4.463	1.047	0.083	61.4	19.4	9.5	9.7	

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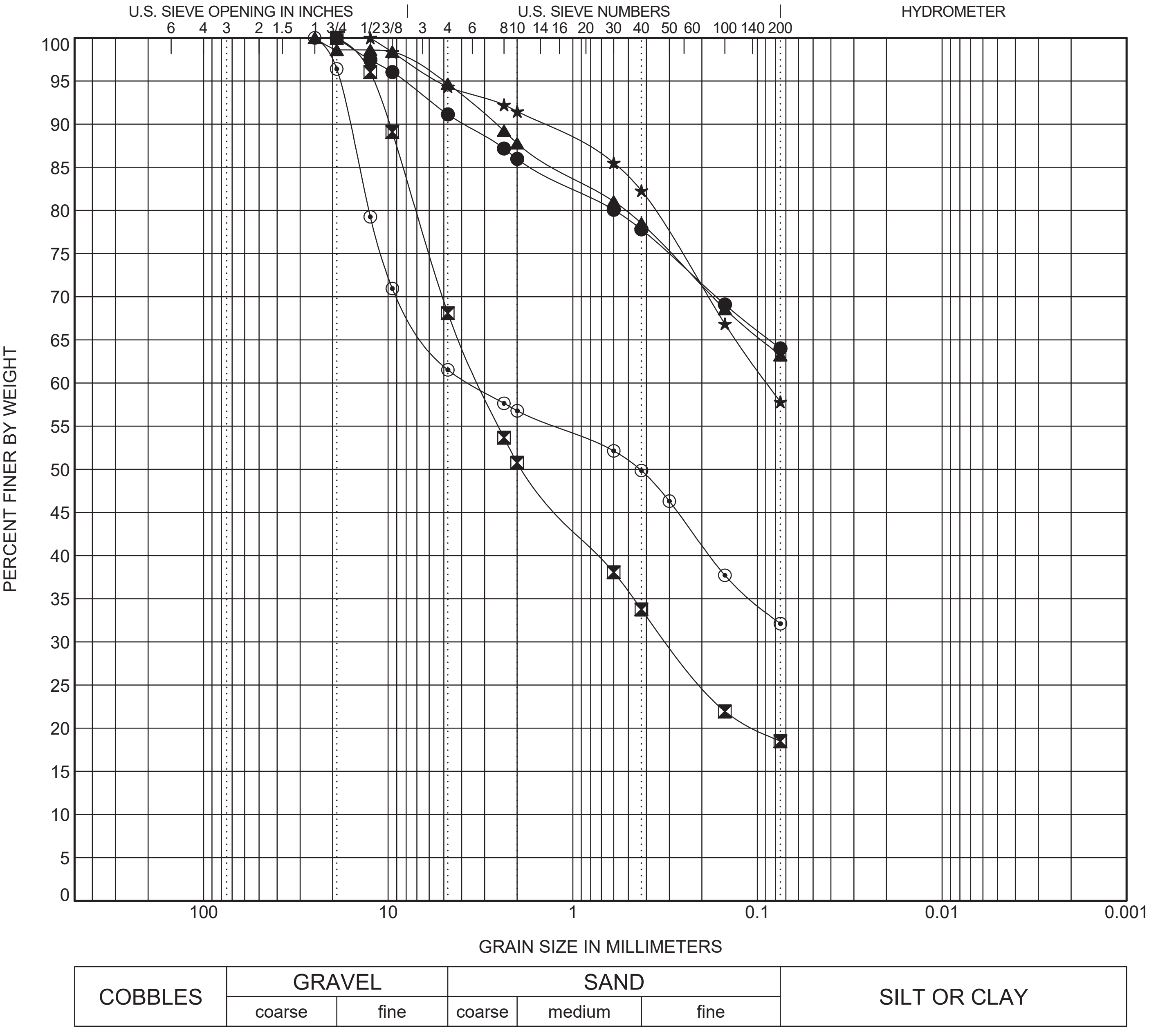

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● B-52	0.9-5.0	**SANDY LEAN CLAY (CL) (A-6)**	37	19	18		
⊠ B-53	0.6-1.1	**Aggregate base course**					
▲ B-53	1.1-5.0	**SANDY LEAN CLAY (CL) (A-7-6)**	44	16	28		
★ B-54	1.0-4.0	**SANDY LEAN CLAY (CL) (A-6)**	32	16	16		
⊙ B-54	4.0-7.0	**CLAYEY GRAVEL with SAND (GC) (A-2-6)**	28	17	11		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
● B-52	0.9-5.0	19				14.0	8.2	13.8	64.0	
⊠ B-53	0.6-1.1	19	3.207	0.305		49.2	17.0	15.3	18.5	
▲ B-53	1.1-5.0	25				12.2	9.3	15.3	63.2	
★ B-54	1.0-4.0	12.5	0.089			8.5	9.2	24.5	57.8	
⊙ B-54	4.0-7.0	25	3.611			43.2	6.9	17.7	32.1	

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GRAIN SIZE DISTRIBUTION

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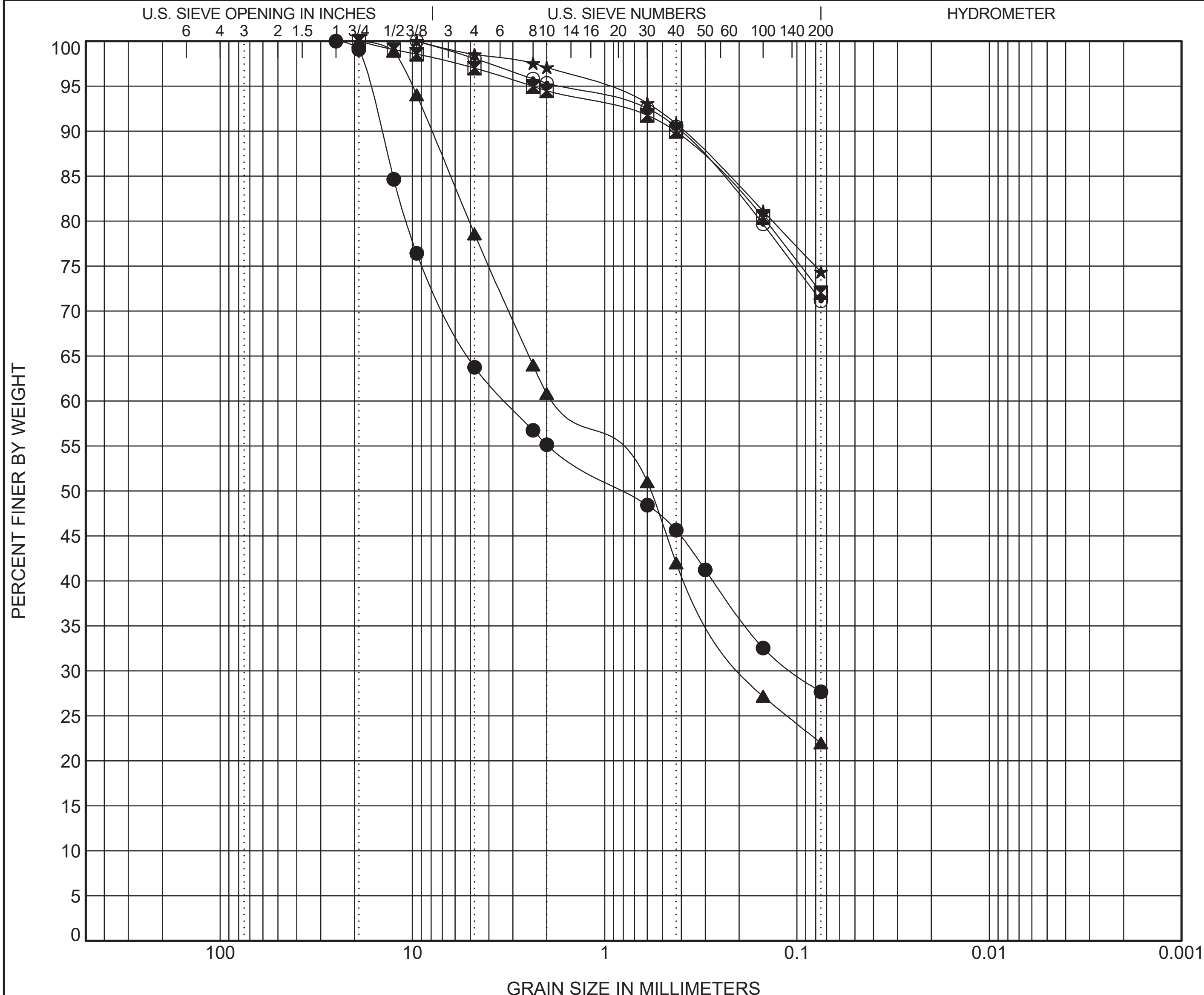

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	B-54	7.0-10.0	CLAYEY GRAVEL with SAND (GC) (A-2-4)	28	18	10		
⧗	B-55	1.1-5.0	LEAN CLAY with SAND (CL) (A-6)	35	17	18		
▲	B-56	0.5-0.8	Aggregate base course					
★	B-56	0.8-5.0	LEAN CLAY with SAND (CL) (A-6)	39	17	22		
⊙	B-57	0.7-5.0	LEAN CLAY with SAND (CL) (A-6)	36	18	18		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-54	7.0-10.0	25	3.269	0.104		44.9	9.5	18.0	27.7	
⧗	B-55	1.1-5.0	19				5.5	4.5	17.9	72.0	
▲	B-56	0.5-0.8	19	1.806	0.183		39.2	18.8	20.0	22.0	
★	B-56	0.8-5.0	9.5				2.9	6.3	16.5	74.3	
⊙	B-57	0.7-5.0	9.5				4.7	4.8	19.4	71.1	

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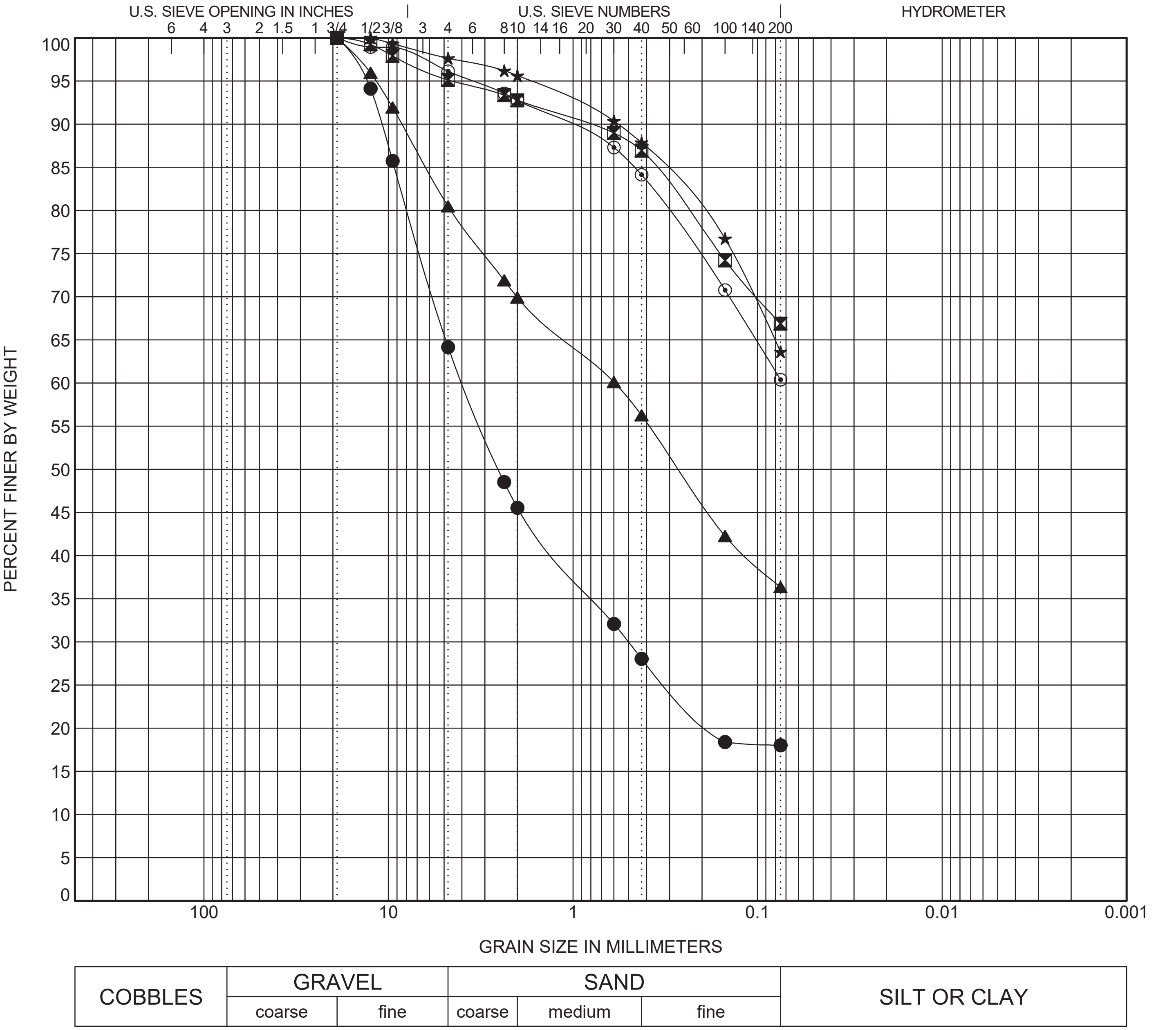


Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	B-58	0.61.1	SILTY SAND with GRAVEL (SM) (A-1-b)	NP	NP	NP		
⧗	B-58	1.1-5.0	SANDY LEAN CLAY (CL) (A-6)	32	16	16		
▲	B-59	0.6-3.0	SILTY SAND with GRAVEL (SM) (A-4)	24	21	3		
★	B-59	3.0-5.0	SANDY LEAN CLAY (CL) (A-4)	27	17	10		
⊙	B-60	1.1-5.0	SANDY LEAN CLAY (CL) (A-6)	38	23	15		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Coarse Sand	%Fine Sand	%Silt	%Clay
●	B-58	0.61.1	19	3.944	0.503		54.5	17.5	10.0	18.0	
⧗	B-58	1.1-5.0	19				7.2	5.8	20.1	66.9	
▲	B-59	0.6-3.0	19	0.594			30.1	13.6	19.9	36.3	
★	B-59	3.0-5.0	12.5				4.4	7.8	24.2	63.6	
⊙	B-60	1.1-5.0	19				7.3	8.6	23.8	60.4	

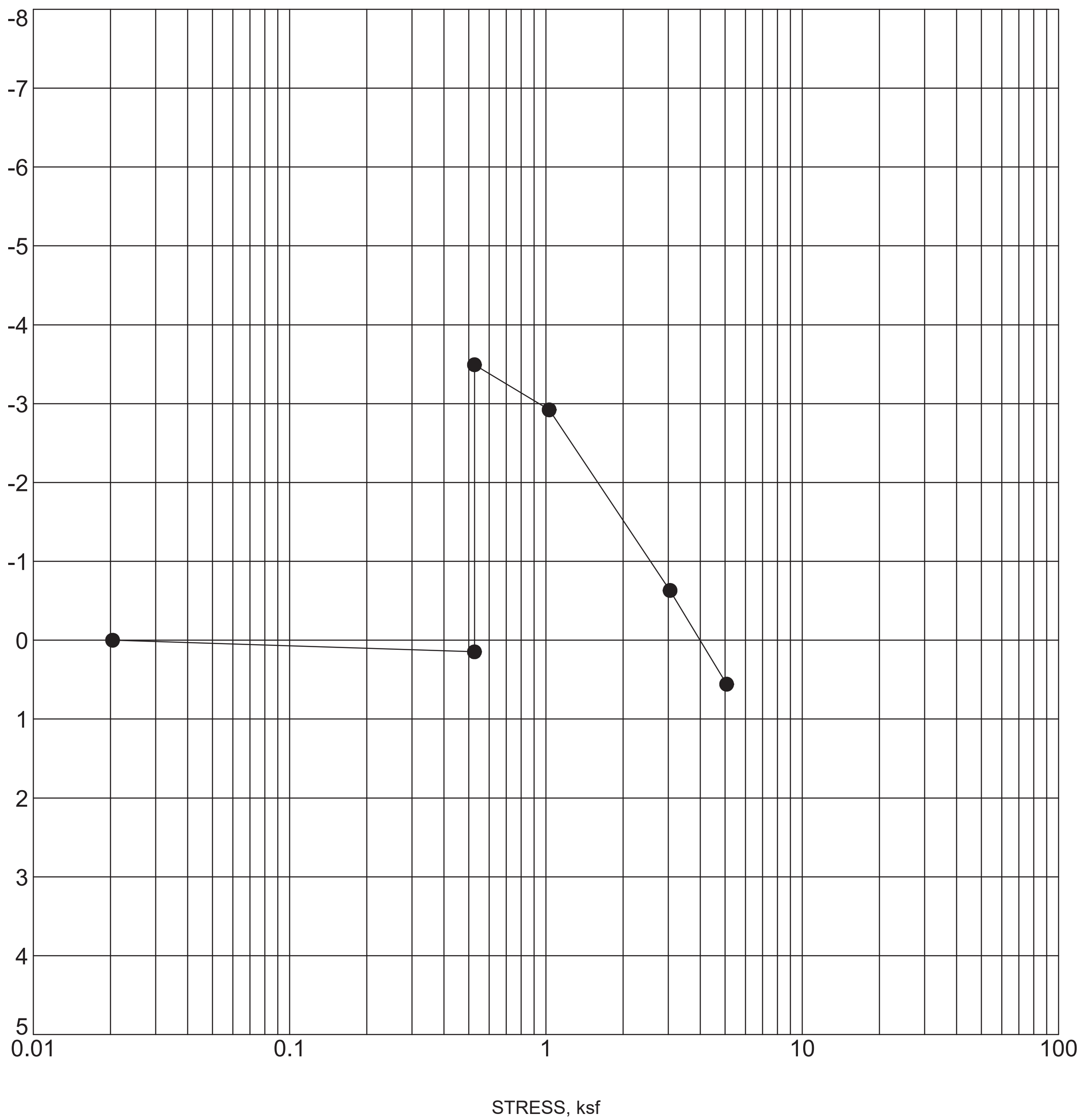
GRADATION - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado



Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● **B-3**	**10**	**(Bedrock) SHALE**	**3.6**	**119.6**	**14.1**

SWELL - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

SWELL - CONSOLIDATION TEST

RockSol Consulting Group, Inc.

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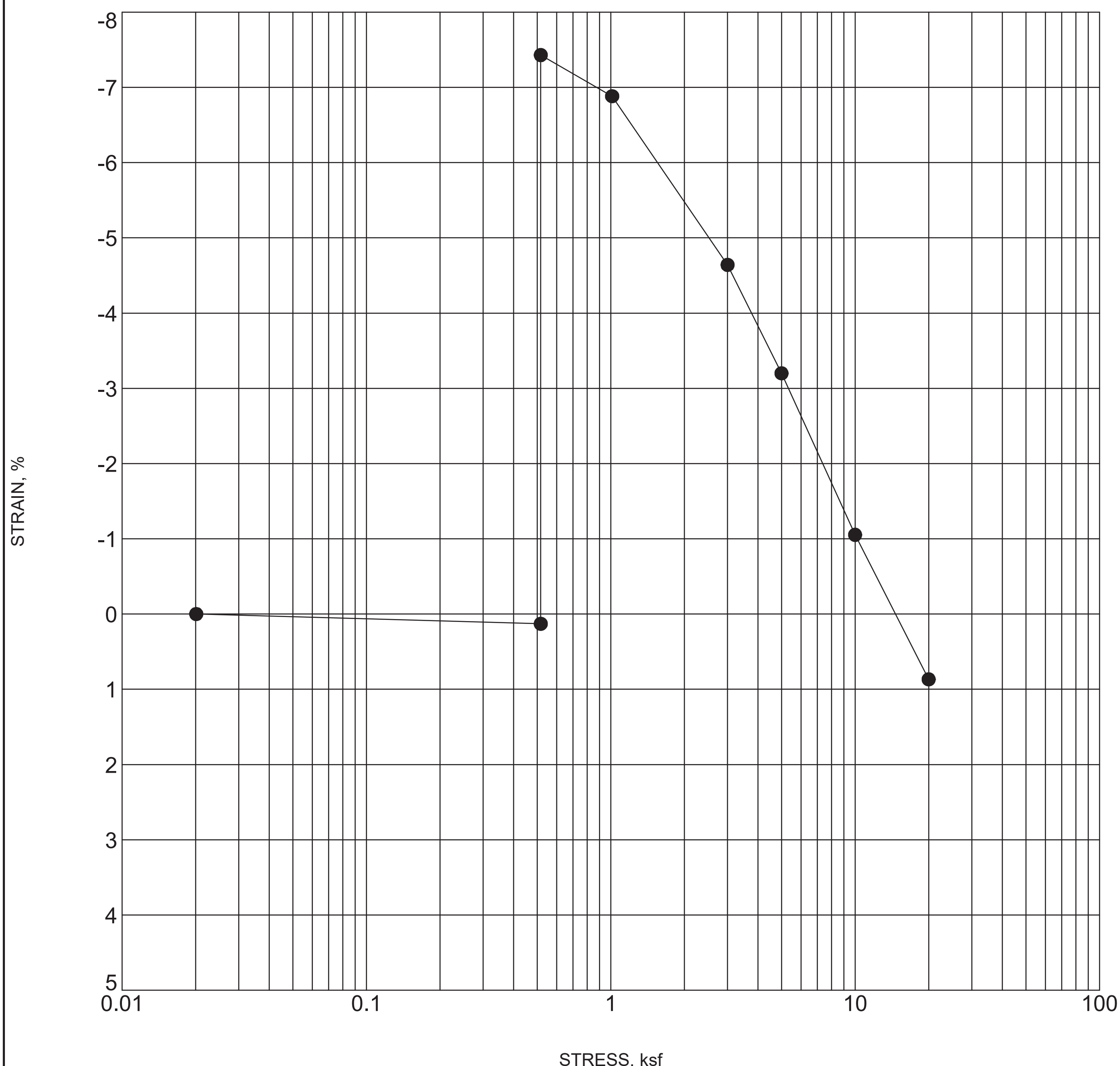


Specimen Identification		Classification	Swell/Consol. (%)	γ_d (pcf)	MC%
● B-3	15	(Bedrock) SHALE	7.6	120.2	14.6

SWELL - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

RockSol

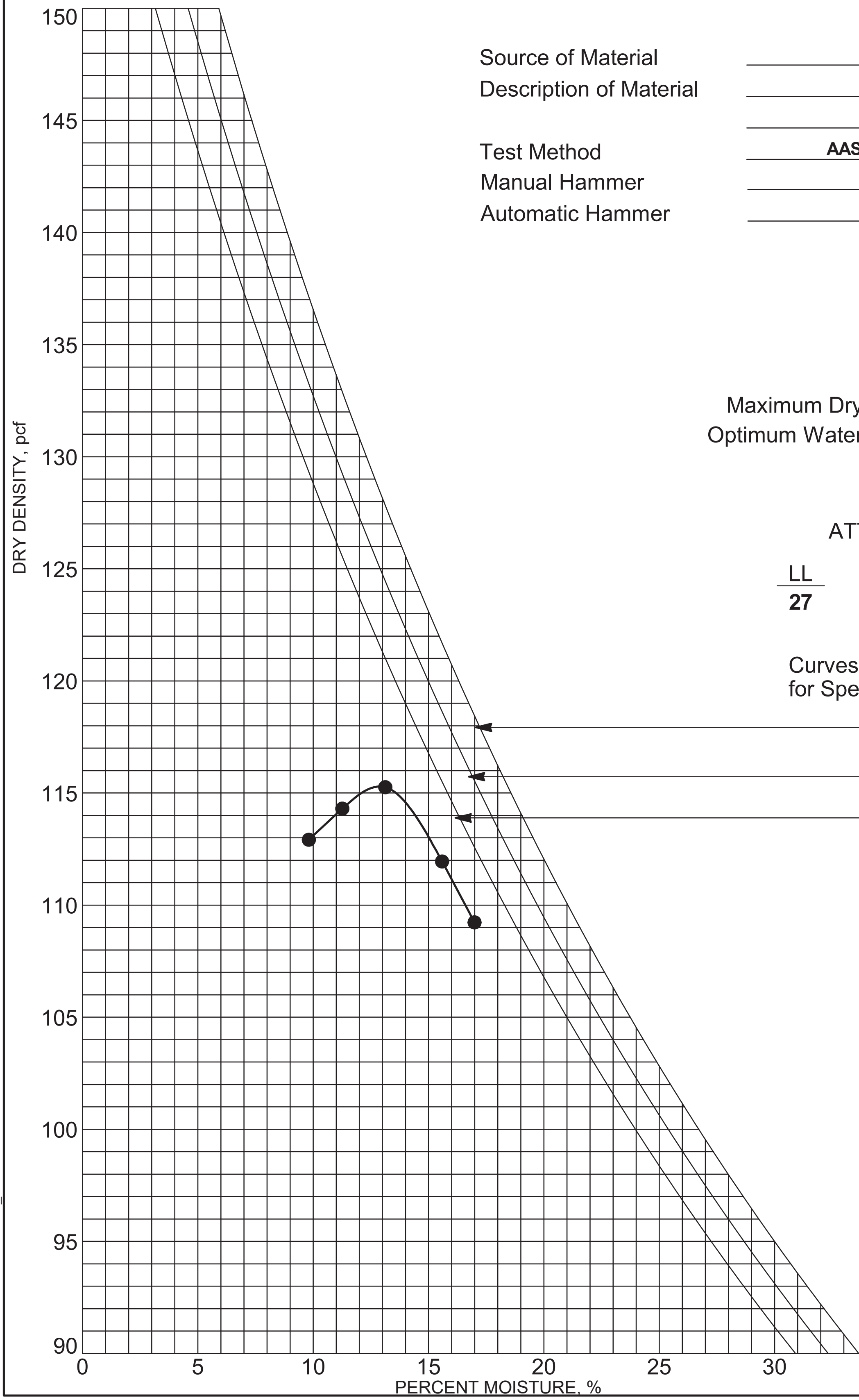
CLIENT City of Grand Junction

PROJECT NAME Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70

PROJECT LOCATION Grand Junction, Colorado

Source of Material	**B-44 1-6 ft**
Description of Material	**LEAN CLAY(CL)**
	A-4 (7)
Test Method	**AASHTO T99 Method A**
Manual Hammer	X
Automatic Hammer	



TEST RESULTS

Maximum Dry Density **115.3 PCF**

Optimum Water Content **13.1 %**

ATTERBERG LIMITS

LL	PL	PI
27	**17**	**10**

Curves of 100% Saturation
for Specific Gravity Equal to:

2.80

2.70

2.60

RockSol

CLIENT City of Grand Junction **PROJECT NAME** Grand Junction 2022 Transportation Corridor Improvements

PROJECT NUMBER 599.70 **PROJECT LOCATION** Grand Junction, Colorado

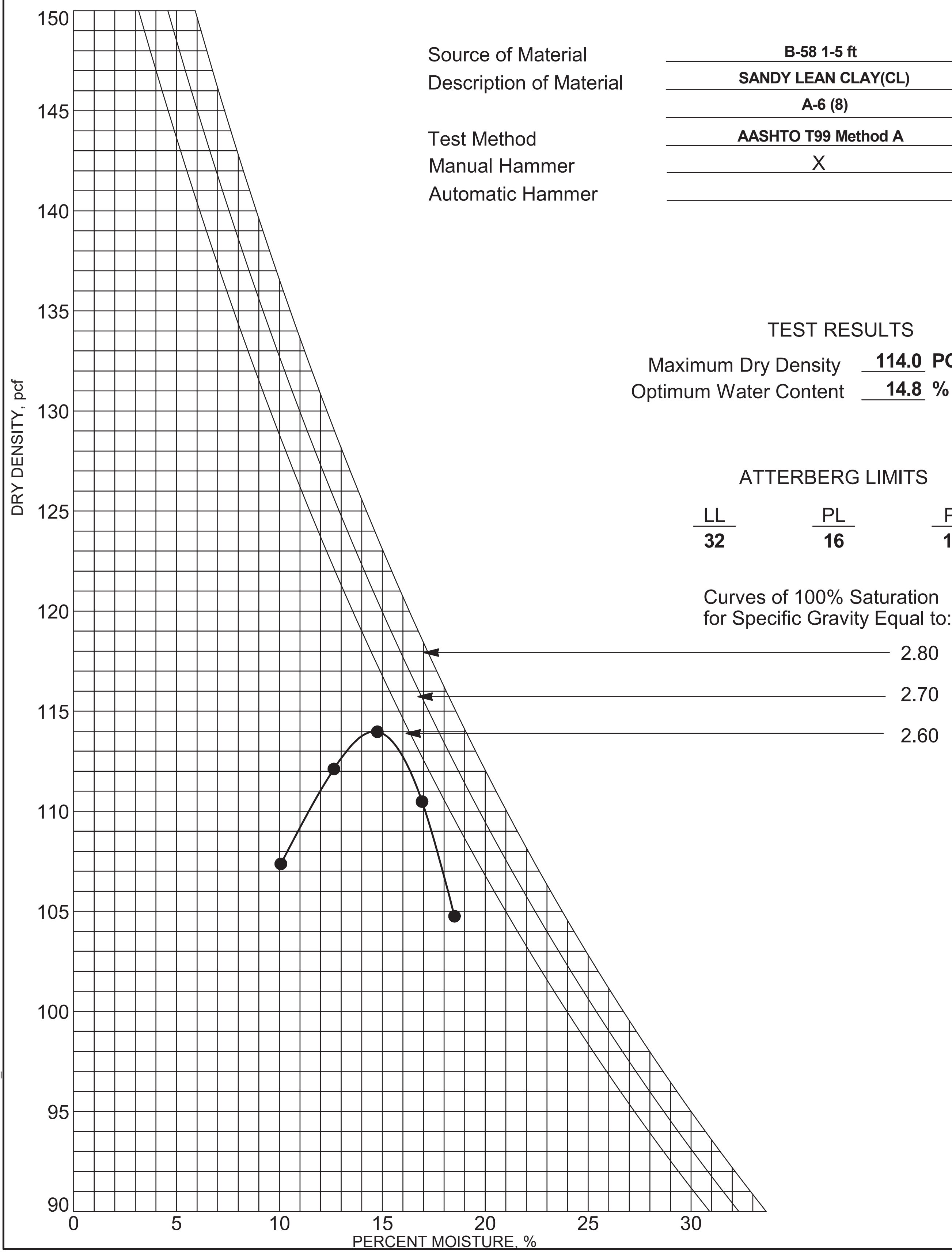
Source of Material	**B-58 1-5 ft**
Description of Material	**SANDY LEAN CLAY(CL)**
	A-6 (8)
Test Method	**AASHTO T99 Method A**
Manual Hammer	X
Automatic Hammer	

TEST RESULTS

Maximum Dry Density	**114.0**	**PCF**
Optimum Water Content	**14.8**	**%**

ATTERBERG LIMITS

LL	PL	PI
32	**16**	**16**



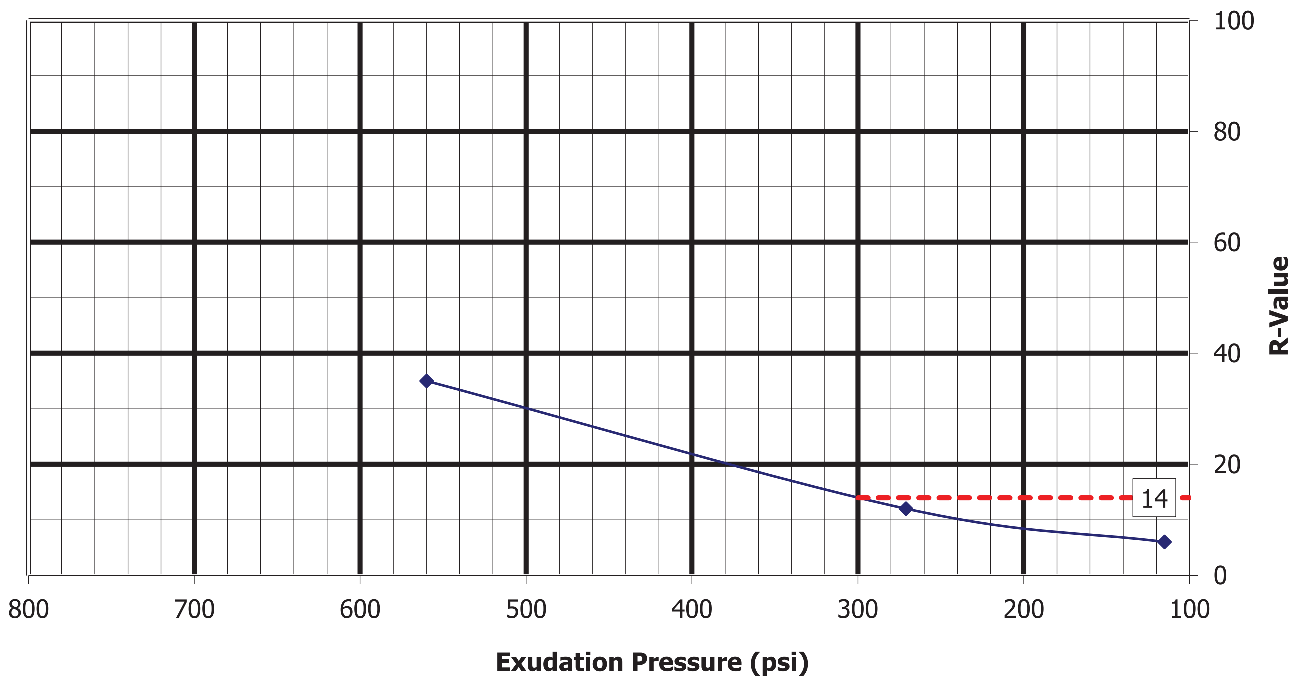
PROCTOR - STANDARD 599.70_CITY OF GJ 2022 TRANSPORTATION CORRIDOR IMPROVEMENTS PROJECT.GPJ ROCKSOL TEMPLATE.GDT 2/9/23

CMT TECHNICAL SERVICES

AASHTO ACCREDITED

R-VALUE TEST GRAPH (AASHTO T190)

Project Number:	23.022, RockSol Consulting	Date:	01/12/23
Project Name:	GJ 2022 Transportation Improvement Corridors (RockSol Project No. 599.70)	Technician:	J. De Los Santos
Lab ID Number:	232027	Reviewer:	G. Hoyos
Sample Location:	B-49 (B) at 18 inches to 5 feet; D 1/2 Road east bound paved shoulder		
Visual Description:	SAND, clayey, brown		



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

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

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

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

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

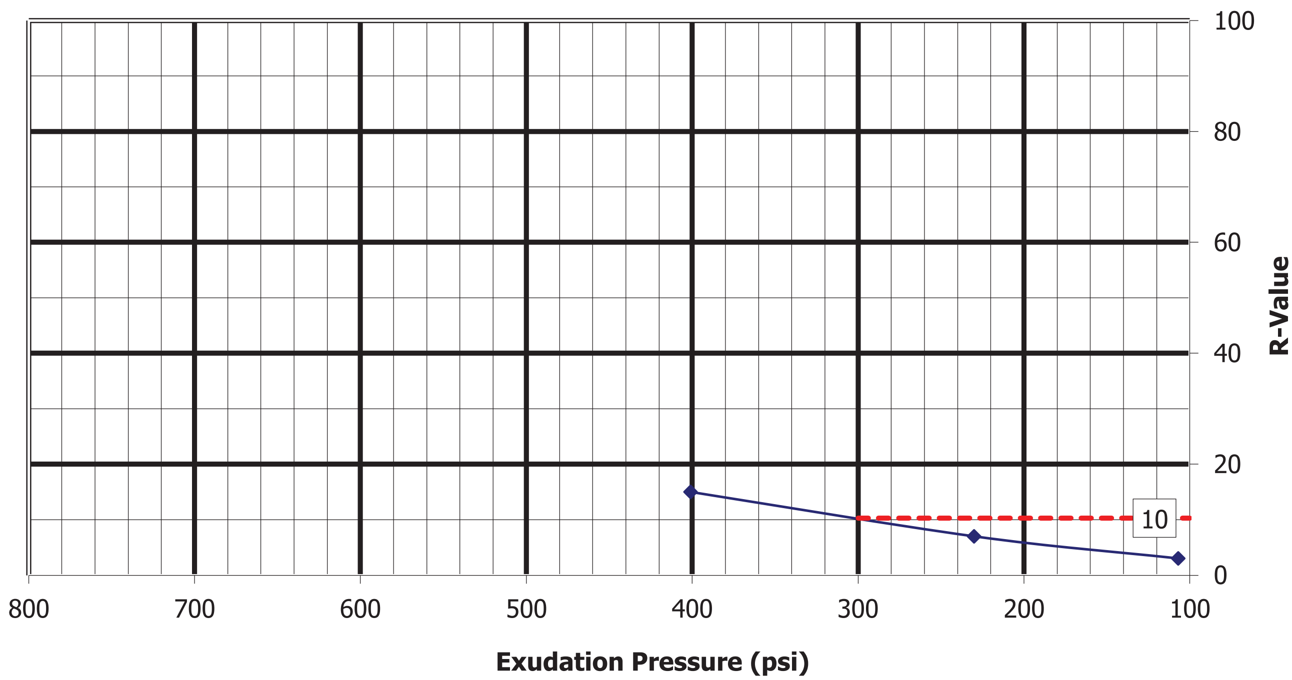
R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	12.5	14.4	19.0
Expansion Pressure, psi:	0.45	0.12	-0.21
Dry Density, pcf:	124.5	119.9	110.3
R-Value:	35	12	6
Exudation Pressure, psi:	560	271	115

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

R-VALUE TEST GRAPH (AASHTO T190)

Project Number:	23.022, RockSol Consulting	Date:	01/12/23
Project Name:	GJ 2022 Transportation Improvement Corridors (RockSol Project No. 599.70)	Technician:	J. De Los Santos
Lab ID Number:	232028	Reviewer:	G. Hoyos
Sample Location:	B-6 (C) at 30 inches to 5 feet; 26-1/2 road south bound lane		
Visual Description:	SAND, clayey, with gravel, brown		



R-Value @ Exudation Pressure 300 psi:	10
Specification:	

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

$S_1 = [(R-5)/11.29]+3$ **S_1 = 3.47**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R = 3,597**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

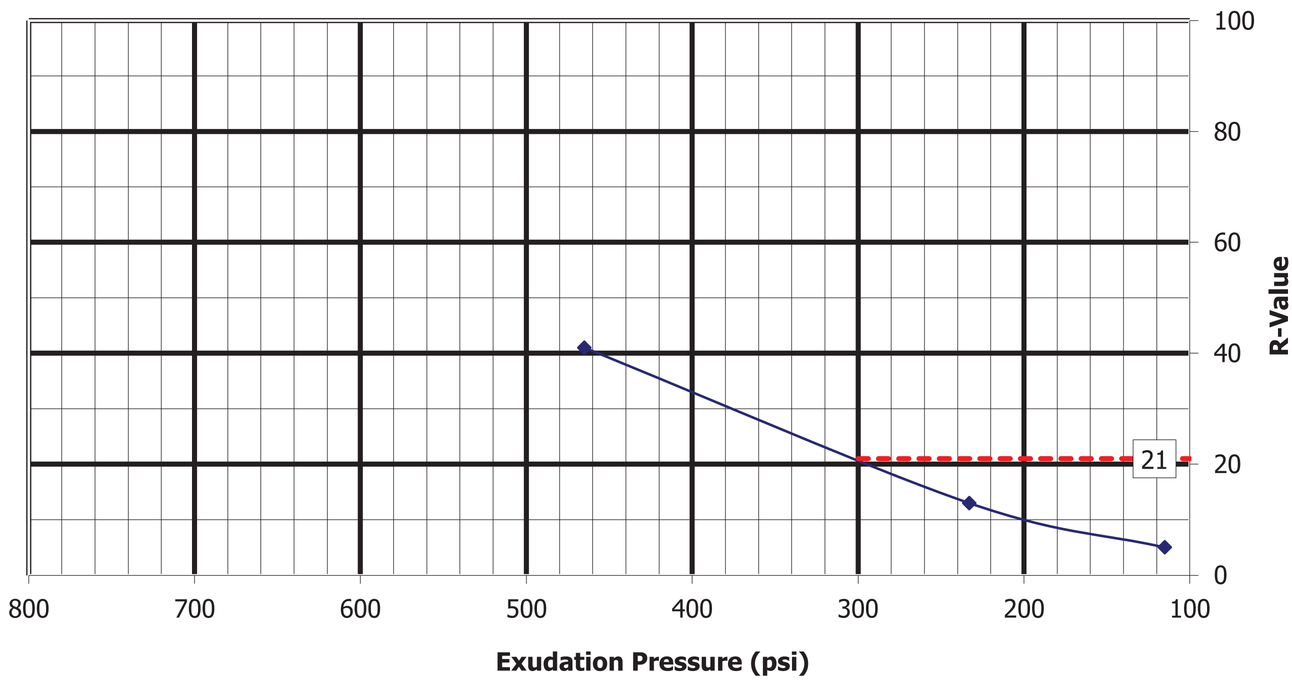
R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	13.3	15.1	20.2
Expansion Pressure, psi:	0.41	-0.12	-0.21
Dry Density, pcf:	124.3	118.7	107.5
R-Value:	15	7	3
Exudation Pressure, psi:	401	230	107

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

R-VALUE TEST GRAPH (AASHTO T190)

Project Number:	23.022, RockSol Consulting	Date:	01/12/23
Project Name:	GJ 2022 Transportation Improvement Corridors (RockSol Projcect No. 599.70)	Technician:	J. De Los Santos
Lab ID Number:	232029	Reviewer:	G. Hoyos
Sample Location:	B-23 (C) at 2.5 to 3.5 feet; F 1/2 Road east bound lane		
Visual Description:	SAND, clayey, with gravel, brown		



R-Value @ Exudation Pressure 300 psi:	21
Specification:	

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

$S_1 = [(R-5)/11.29]+3$ **S_1 = 4.42**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R = 5,104**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

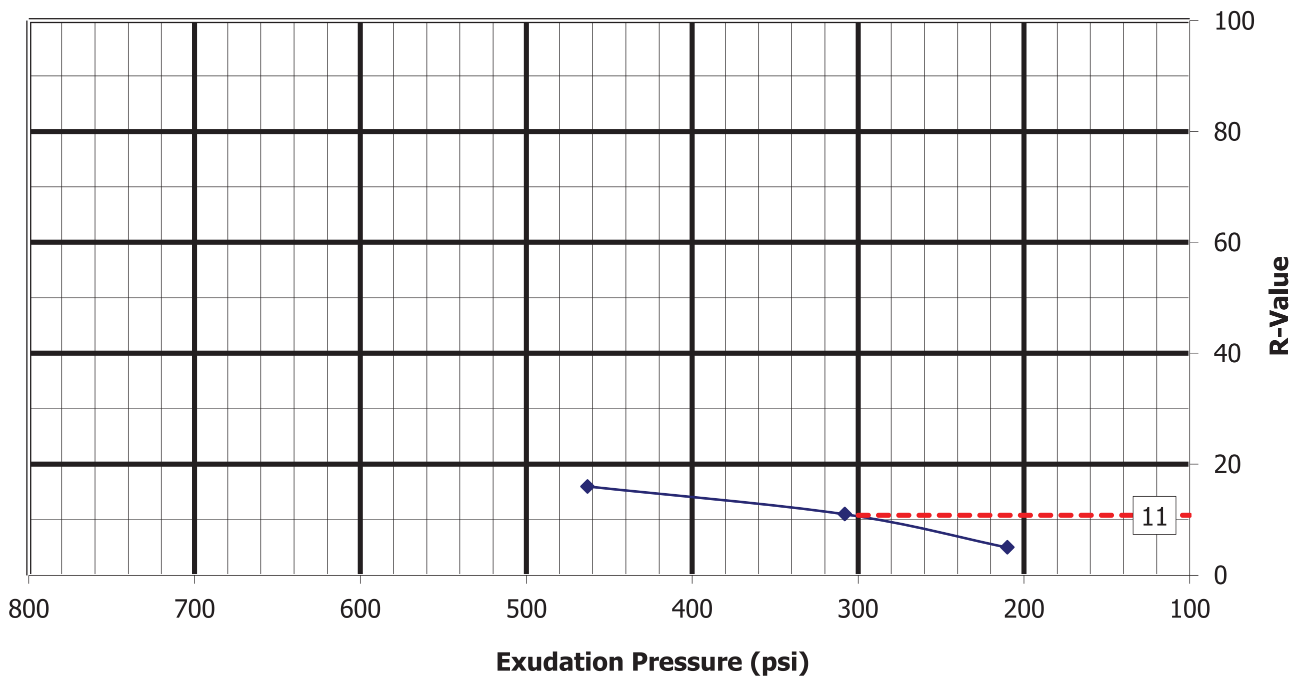
R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	11.2	13.7	15.3
Expansion Pressure, psi:	0.11	-0.06	-0.18
Dry Density, pcf:	125.5	121.9	117.6
R-Value:	41	13	5
Exudation Pressure, psi:	465	233	115

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

R-VALUE TEST GRAPH (AASHTO T190)

Project Number:	23.022, RockSol Consulting	Date:	01/16/23
Project Name:	GJ 2022 Transportation Improvement Corridors (RockSol Projcect No. 599.70)	Technician:	J. De Los Santos
Lab ID Number:	232030	Reviewer:	G. Hoyos
Sample Location:	B-52 (B) at 10 inches to 5 feet; B 1/2 Road west bound lane		
Visual Description:	CLAY, sandy, with gravel, brown		



R-Value @ Exudation Pressure 300 psi:	**11**
Specification:	

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

$S_1 = [(R-5)/11.29]+3$ **S_1= 3.51**

$M_R = 10^{[(S_1+18.72)/6.24]}$ **M_R= 3,657**

M_R = Resilient Modulus, psi

S_1 = the Soil Support Value

R = the R-Value obtained

Test Specimen:	1	2	3
Moisture Content, %:	13.7	16.1	18.8
Expansion Pressure, psi:	-0.24	-0.33	-0.42
Dry Density, pcf:	123.5	117.6	111.9
R-Value:	16	11	5
Exudation Pressure, psi:	463	308	210

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

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APPENDIX D

SUMMARY OF PAVEMENT DISTRESSES AND PHOTOGRAPHS AND SHRP2 SEVERITY CRITERIA

PAVEMENT EVALUATION CHECKLIST (FLEXIBLE)

PROJECT NO.: 599.70
PROJECT CODE (SA #):
DATE: 2/1/2023

LOCATION: 26 1/2 Road
DIRECTION: MP Horizon Dr to MP G Rd
BY: A. Kachin & Dave Eller
TITLE: Materials Technician

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Alligator (Fatigue) Cracking	med/high	frequent med/occasional high
Bleeding	none	
Block Cracking	med/high	frequent med/occasional high
Corrugation	none	
Depression	minimal spot locations	
Joint Reflection Cracking (from PCC Slab)	NA	
Lane/Shoulder Joint Separation	none	
Longitudinal Cracking	med	occasional
Transverse Cracking	high	frequent
Patch Deterioration	low	infrequent patches
Polished Aggregate	minimal - old chipseal on top	
Potholes	none	
Raveling/Weathering	none	
Rutting	med	frequent
Slippage Cracking	none	
OTHER		

Main pavement distress is Alligator cracking in the wheel path.
Rutting on average .25-.75 in depth.
Pavement appears to possibly have some minor widened shoulders (less than 2ft) in the past - chipseal over entire section now hides joint.

PAVEMENT EVALUATION CHECKLIST (FLEXIBLE)

PROJECT NO.: 599.70
PROJECT CODE (SA #):
DATE: 2/2/2023

LOCATION: B 1/2 Road
DIRECTION: MP 29 Rd to MP 29 3/4 Rd
BY: A. Kachin & Dave Eller
TITLE: Materials Technician

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Alligator (Fatigue) Cracking	low	very minimal
Bleeding	med	East End wheel paths/chipseal
Block Cracking	low	occasional
Corrugation	None	
Depression	None	
Joint Reflection Cracking (from PCC Slab)	N/A	
Lane/Shoulder Joint Separation	none	
Longitudinal Cracking	low/med	frequent/occasional
Transverse Cracking	low	infrequent
Patch Deterioration	low/med	frequent
Polished Aggregate	None	
Potholes	none	
Raveling/Weathering	none	
Rutting	low	occasional
Slippage Cracking	none	
OTHER		

Longitudinal cracking worse in WB lane
Very frequent patching in EB lane
Chipseal from Merles Way to East end of project appears to have flushing/bleeding of tack/emulsion for the chipseal
Rutting < .25 in depth


10
9
8
7
6
5
25FT
4
3
2

PAVEMENT EVALUATION CHECKLIST (FLEXIBLE)

PROJECT NO.: 599.70
PROJECT CODE (SA #):
DATE: 2/2/2023

LOCATION: D 1/2 Road
DIRECTION: MP D.5 Court to MP 30Rd
BY: A. Kachin & Dave Eller
TITLE: Materials Technician

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Alligator (Fatigue) Cracking	none	
Bleeding	none	
Block Cracking	none	
Corrugation	none	
Depression	none	
Joint Reflection Cracking (from PCC Slab)	N/A	
Lane/Shoulder Joint Separation	none	
Longitudinal Cracking	none	
Transverse Cracking	low	infrequent
Patch Deterioration	none	
Polished Aggregate	none	
Potholes	none	
Raveling/Weathering	none	
Rutting	none	
Slippage Cracking	none	
OTHER		

None to very low distress

PAVEMENT EVALUATION CHECKLIST (FLEXIBLE)

PROJECT NO.: 599.70
PROJECT CODE (SA #):
DATE: 2/2/2023

LOCATION: F 1/2 Road
DIRECTION: MP 30 Rd to MP Lewis Gulch
BY: A. Kachin & Dave Eller
TITLE: MAterials Technician

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Alligator (Fatigue) Cracking	low/med	occasional EB/more WB
Bleeding	none	
Block Cracking	med/high	occasional
Corrugation	none	
Depression	none	
Joint Reflection Cracking (from PCC Slab)	N/A	
Lane/Shoulder Joint Separation	none	
Longitudinal Cracking	med/high	frequent
Transverse Cracking	med/high	frequent
Patch Deterioration	low	minimal locations
Polished Aggregate	none	
Potholes	low	few
Raveling/Weathering	low	
Rutting	low	infrequent
Slippage Cracking	none	
OTHER		

Block cracking is most frequent by F 1/2 and 30 Rd intersection
Thermal transverse cracking frequent about 20' apart
Rutting on average < .25 in depth
WB lane 5' from edge of pavement has a consistent longitudinal crack with some alligator cracking in wheel path on the majority of the east end of project
Note - there is open drainage ditch for irrigation that runs parallel to the WB lane for most of this section. The WB lane does appear to have more distress in the right wheel path with a defined longitudinal crack approx. 5 ft in from edge of oil. This "possibly" could be related to moisture in the ground from this irrigation ditch. Our pavement report might note this irrigation can have impact on roadway subgrade

APPENDIX E

PMED 20-YEAR DESIGN LIFE OUTPUT – NEW PAVEMENT

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

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

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	4.0
NonStabilized	Crushed stone	4.0
NonStabilized	River-run gravel	12.0
Subgrade	A-4	38.0
Bedrock	Highly fractured and weathered	Semi-infinite

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

Traffic

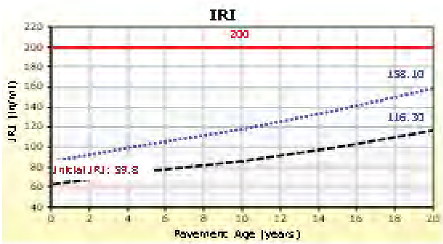
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	650
2034 (10 years)	1,490,320
2044 (20 years)	3,136,550

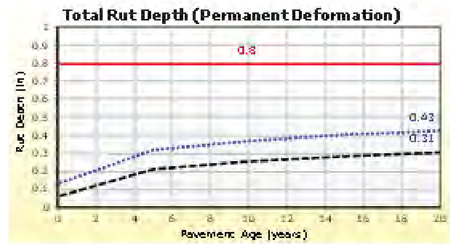
Design Outputs

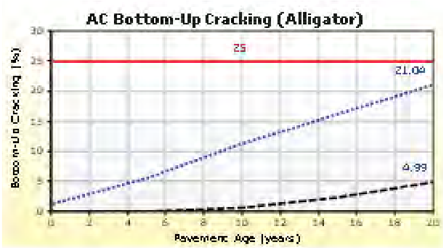
Distress Prediction Summary

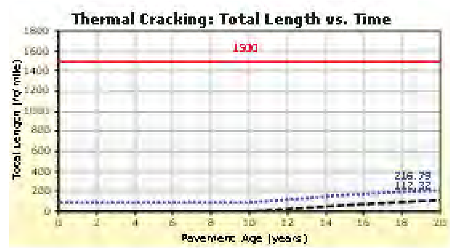
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	158.12	90.00	99.48	Pass
Permanent deformation - total pavement (in)	0.80	0.43	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	21.04	90.00	94.49	Pass
AC thermal cracking (ft/mile)	1500.00	216.79	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1367.81	90.00	99.77	Pass
Permanent deformation - AC only (in)	0.65	0.30	90.00	100.00	Pass

Distress Charts





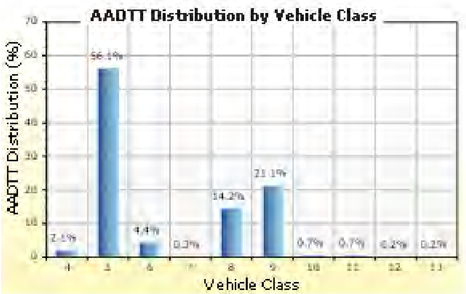


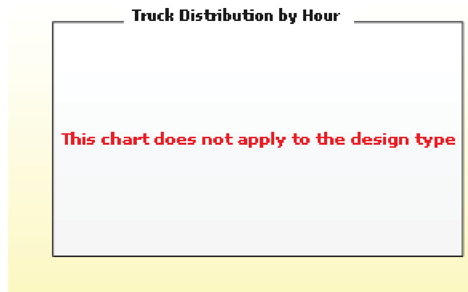


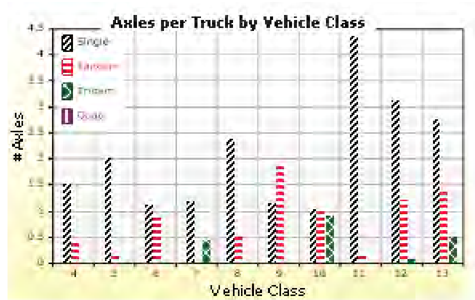
Traffic Inputs

Graphical Representation of Traffic Inputs

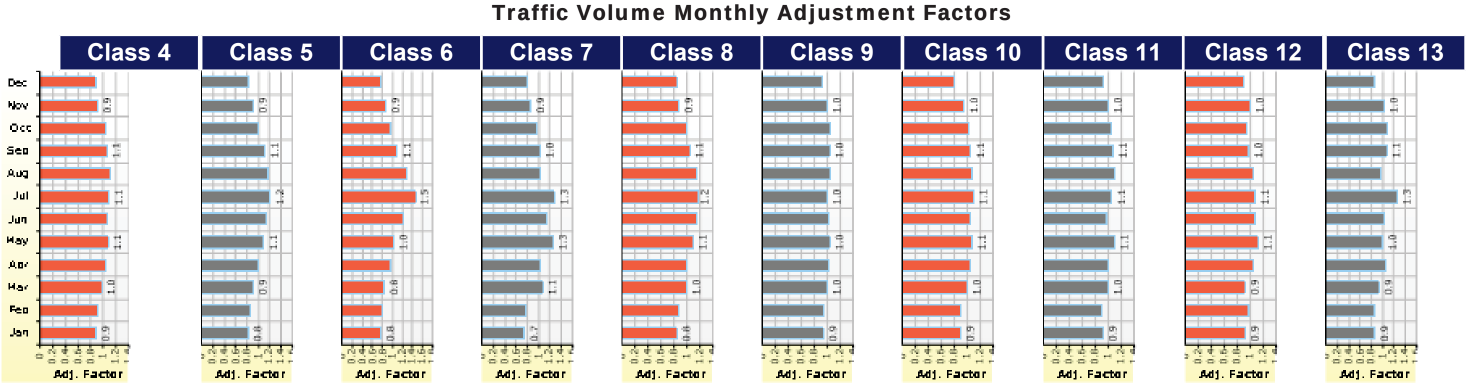
Initial two-way AADTT:	650	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

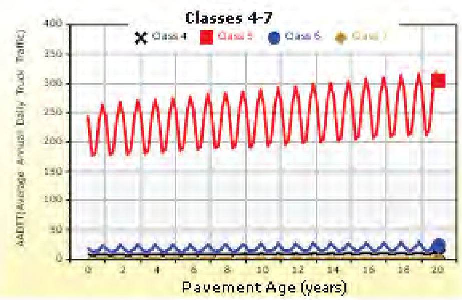
Wheelbase does not apply

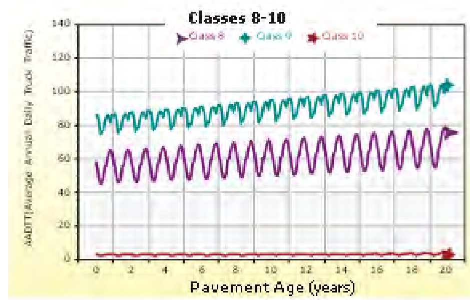
Number of Axles per Truck

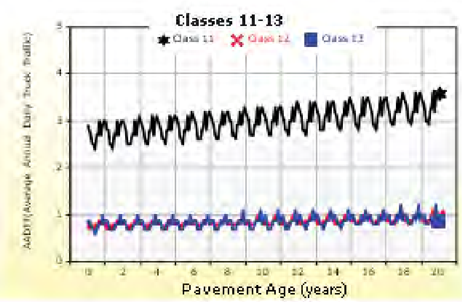
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

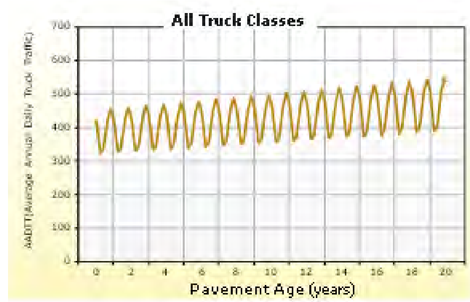
AADTT (Average Annual Daily Truck Traffic) Growth

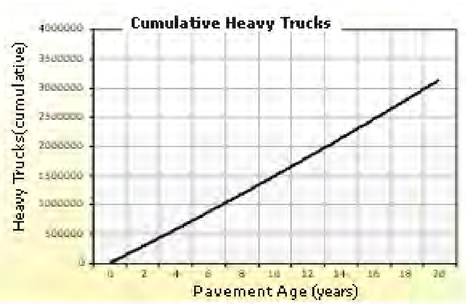
*** Traffic cap is not enforced**







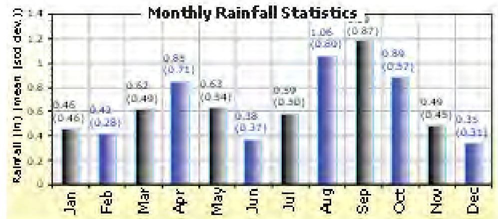




Climate Inputs

Climate Data Sources:

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

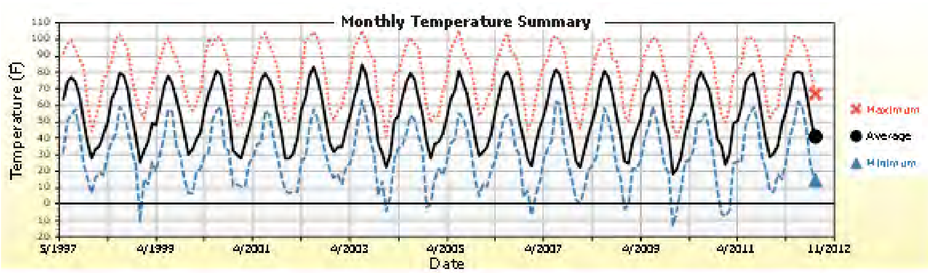


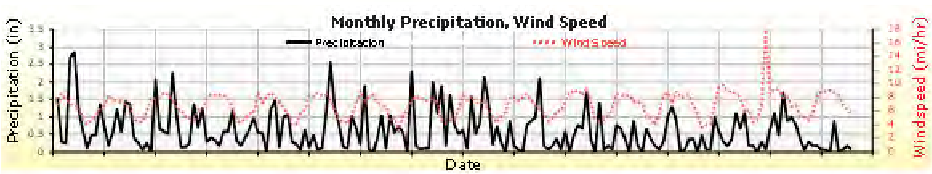
Annual Statistics:

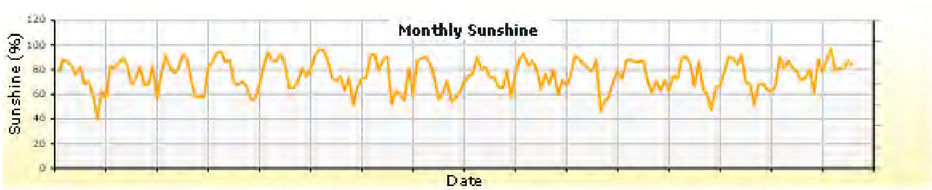
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

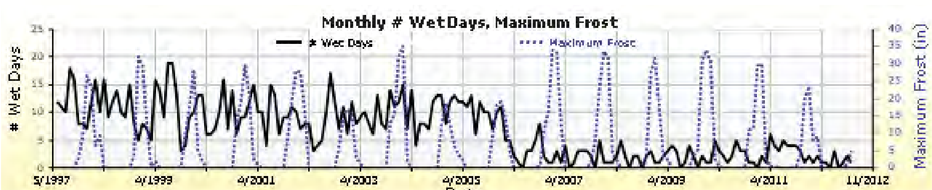
Water table depth (ft) 10.00

Monthly Climate Summary:

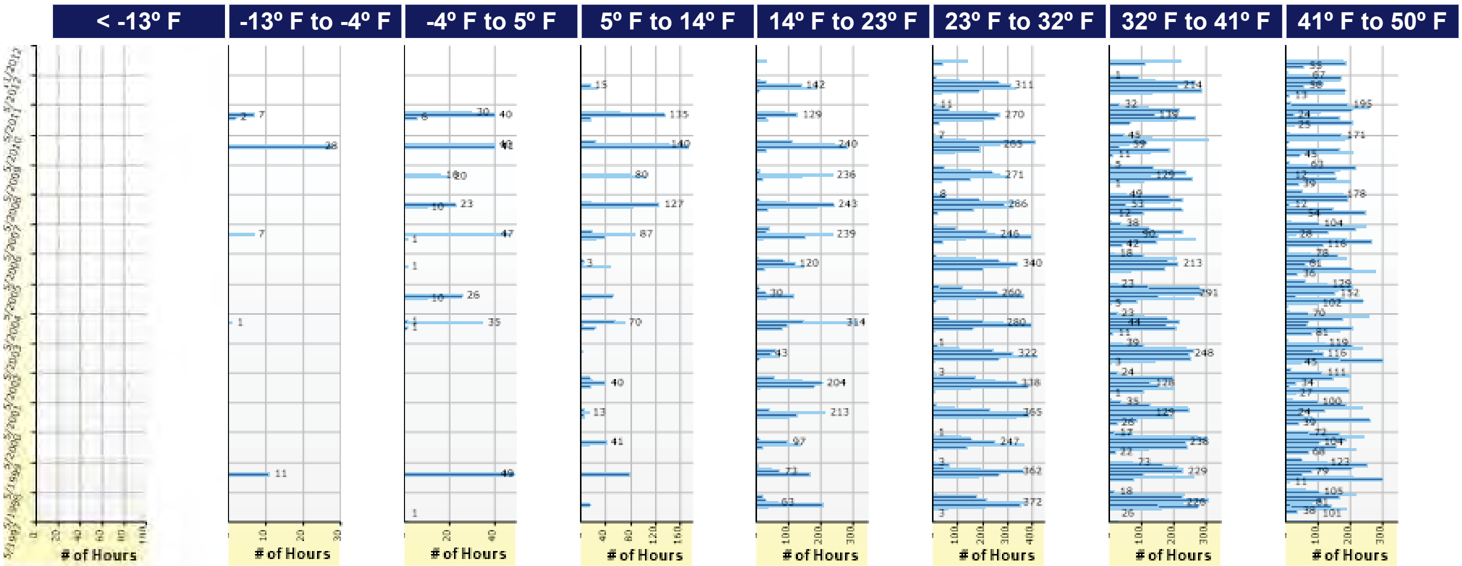


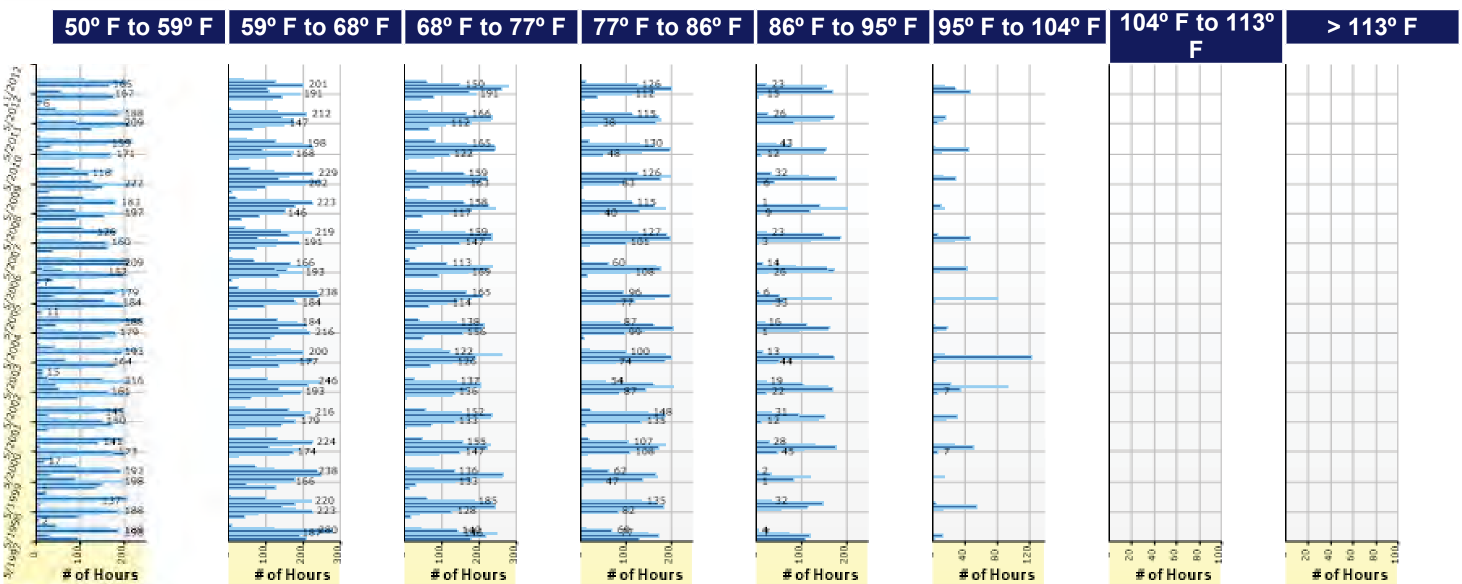






Hourly Air Temperature Distribution by Month:





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

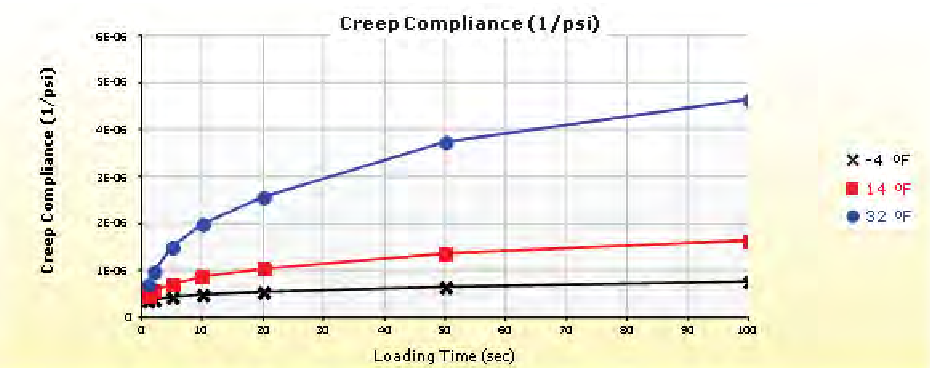
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : River-run gravel	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Bedrock : Highly fractured and weathered	Bedrock (6)	-

Thermal Cracking (Input Level: 1)

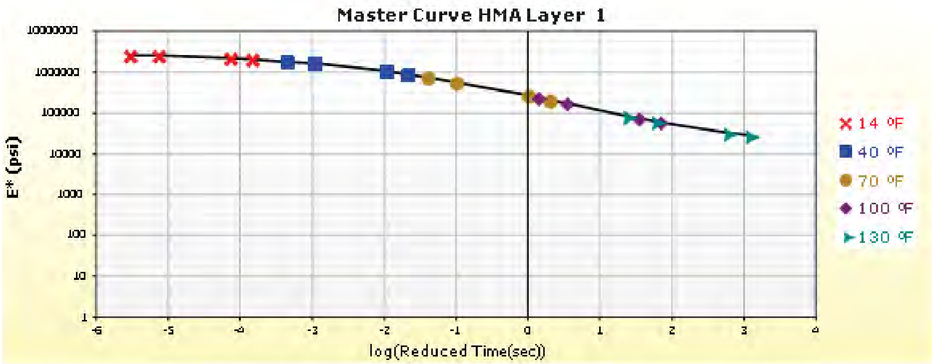
Indirect tensile strength at 14 ºF (psi)	519.00

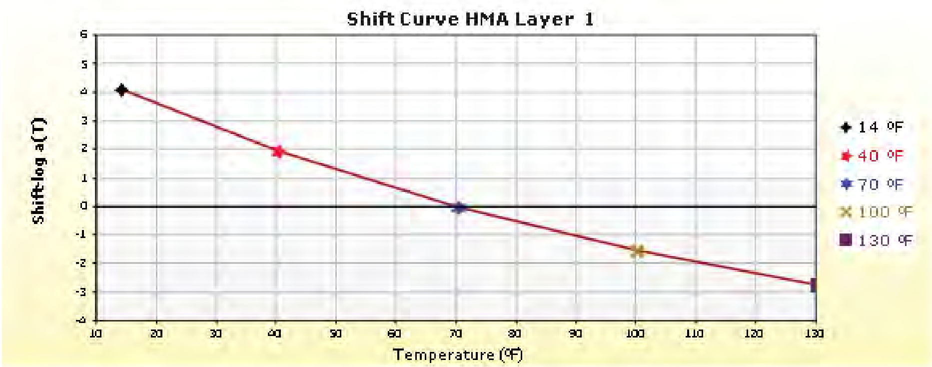
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

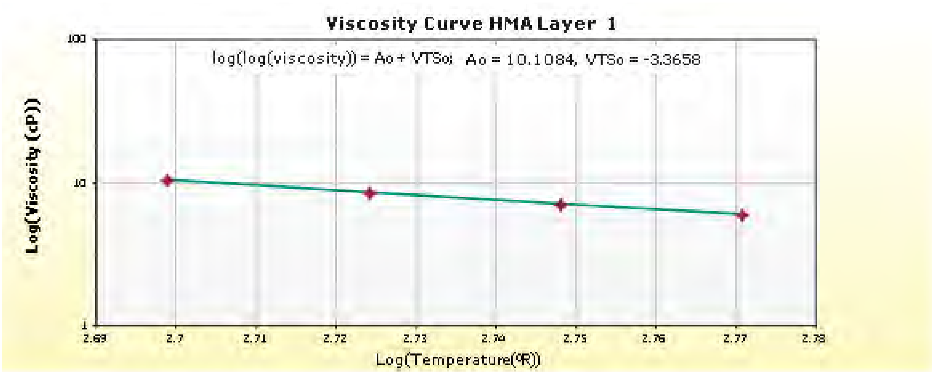
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



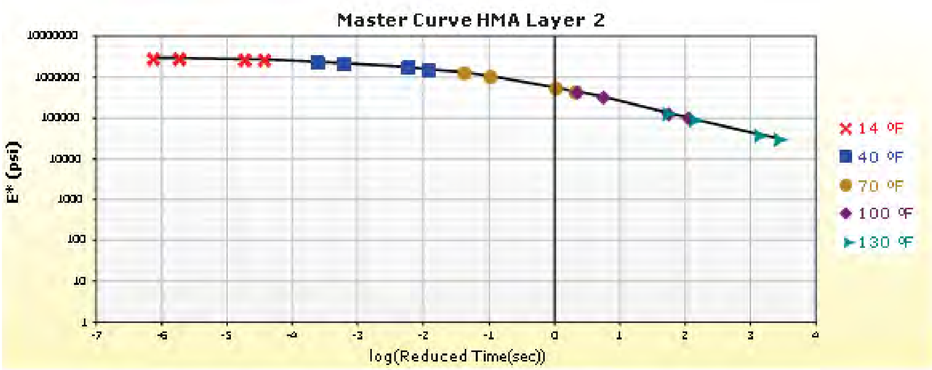
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

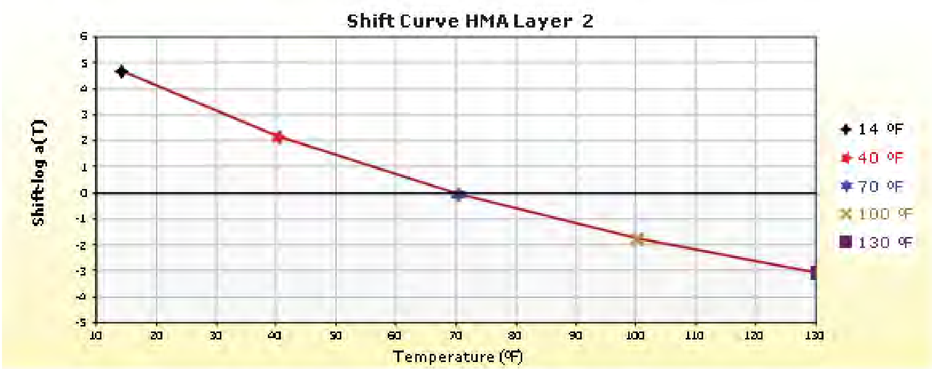


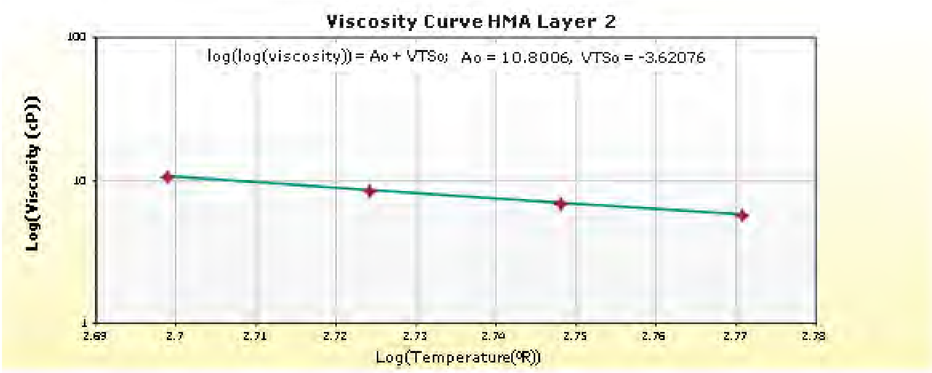




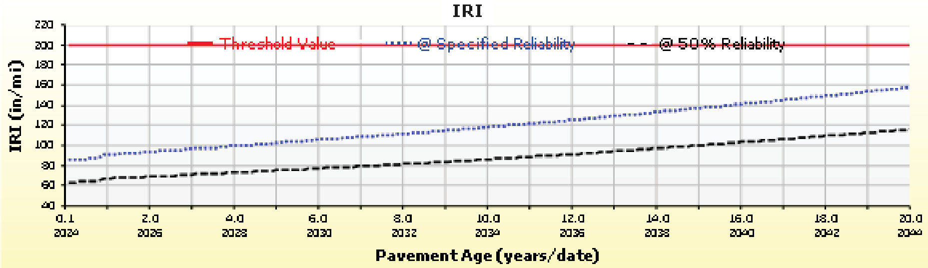
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

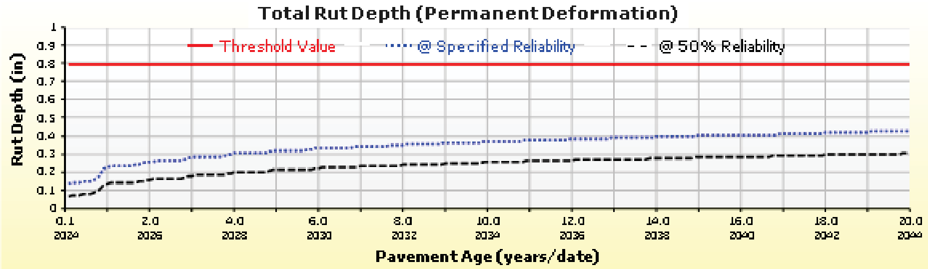


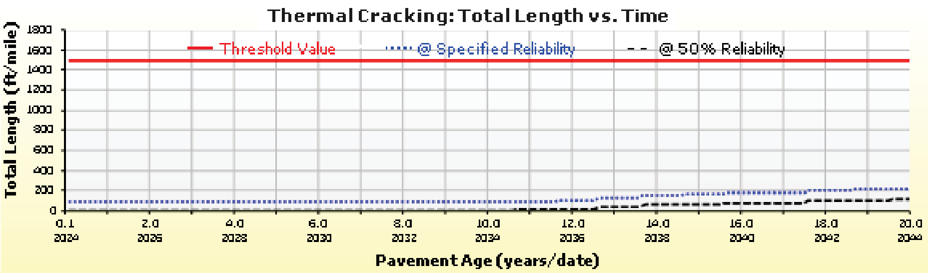


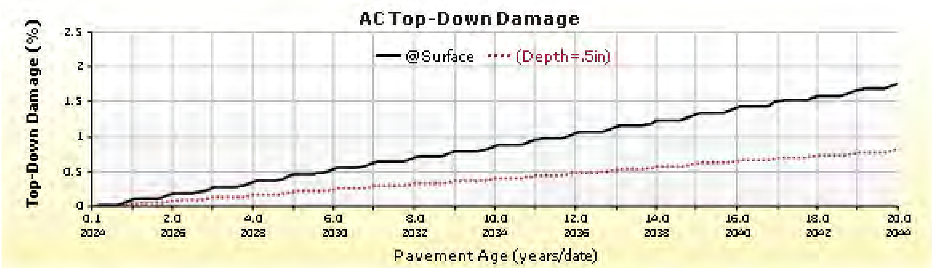


Analysis Output Charts

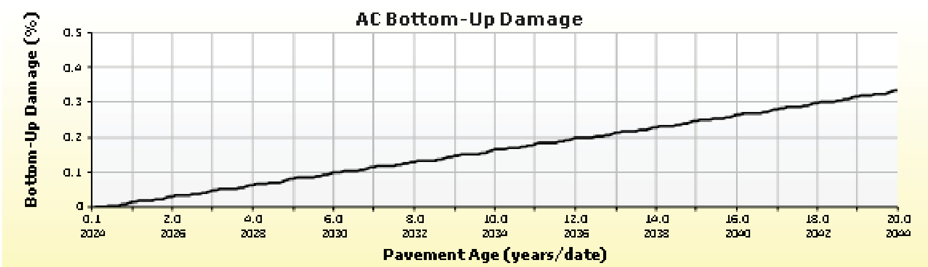




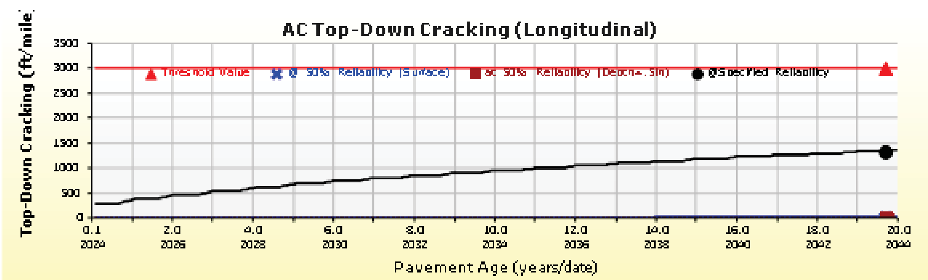




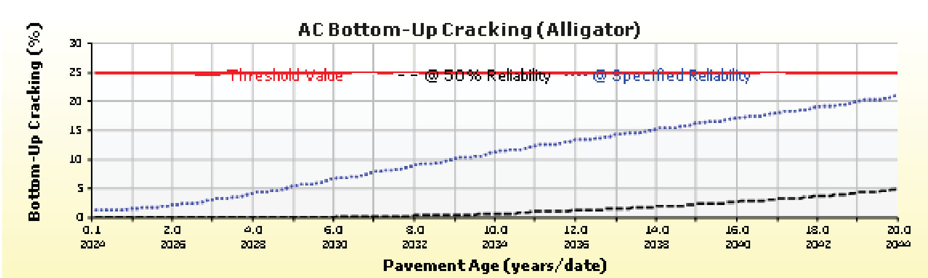
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



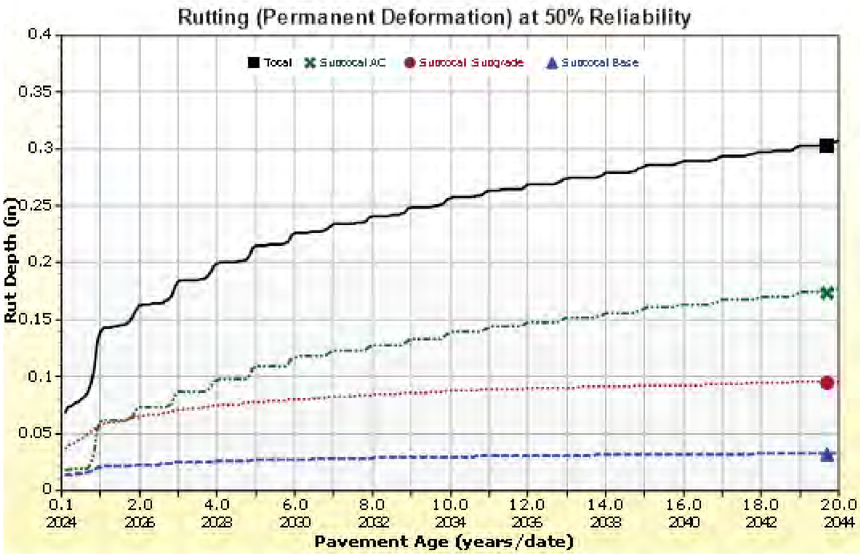
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



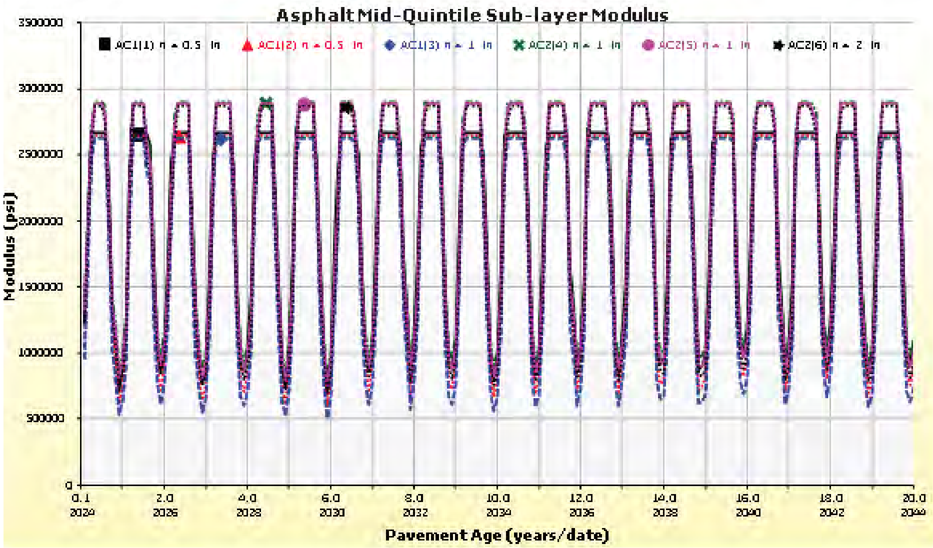
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
@ 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
Pavement Age (years/date)



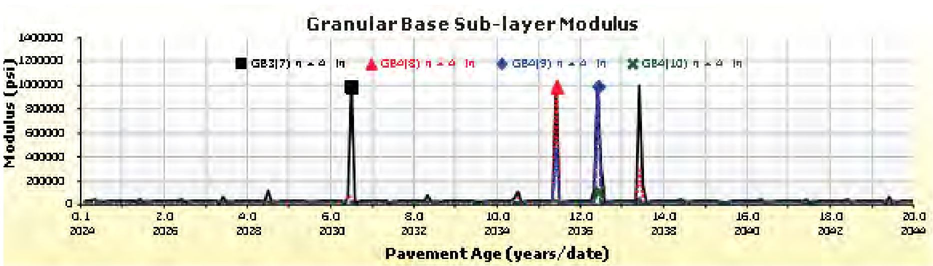
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



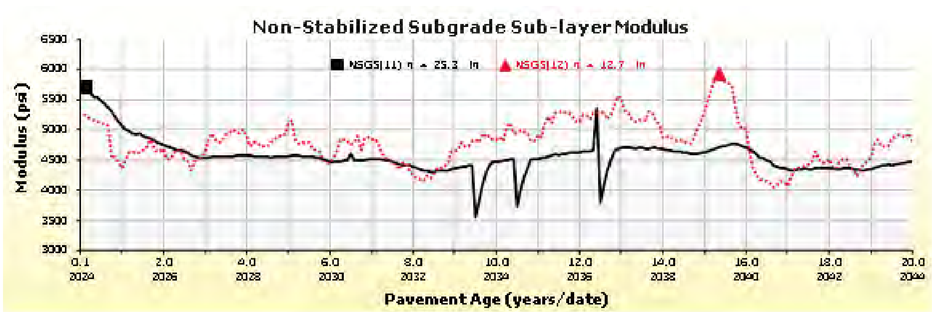
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
Pavement Age (years/date)



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)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 4 in
GB4(8) h = 4 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
1400000
1200000
1000000
800000
600000
400000
200000
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSGS(11) h = 25.3 in
NSGS(12) h = 12.7 in
Modulus (psi)
6500
6000
5500
5000
4500
4000
3500
3000
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : 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

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

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

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

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(100) PG 64-22

Asphalt		
Thickness (in)	4.0	
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	15

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	4.0
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)
21000.0

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 : River-run gravel

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	River-run 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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

Unbound	
Layer thickness (in)	38.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 6 Bedrock : Highly fractured and weathered

Bedrock	
Layer thickness(in)	Semi-infinite
Poisson's ratio	0.15
Unit weight (pcf)	140

Strength	
Elastic/resilient modulus (psi)	500000

Identifiers

Field	Value
Display name/identifier	Highly fractured and weathered
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

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 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

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

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

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	4.0
NonStabilized	Crushed stone	4.0
NonStabilized	River-run gravel	12.0
Subgrade	A-6	Semi-infinite

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

Traffic

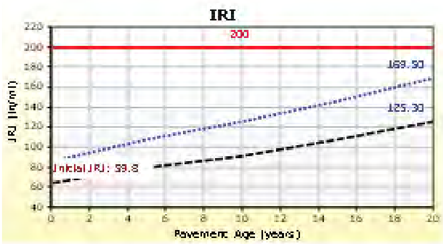
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	695
2034 (10 years)	1,593,490
2044 (20 years)	3,353,700

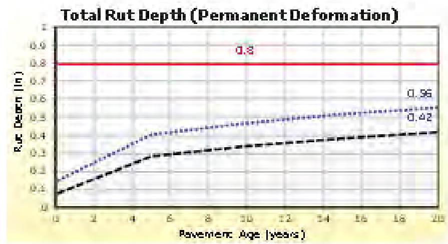
Design Outputs

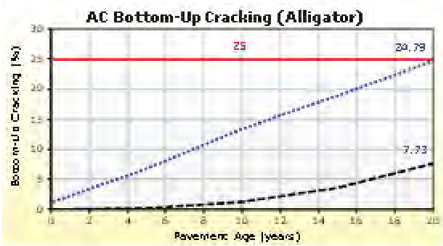
Distress Prediction Summary

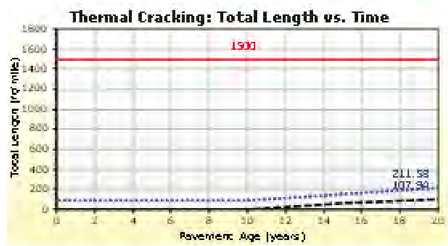
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	169.46	90.00	98.49	Pass
Permanent deformation - total pavement (in)	0.80	0.56	90.00	99.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	24.79	90.00	90.28	Pass
AC thermal cracking (ft/mile)	1500.00	211.58	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	835.83	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.39	90.00	99.99	Pass

Distress Charts







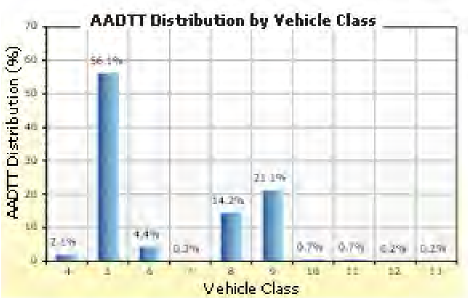


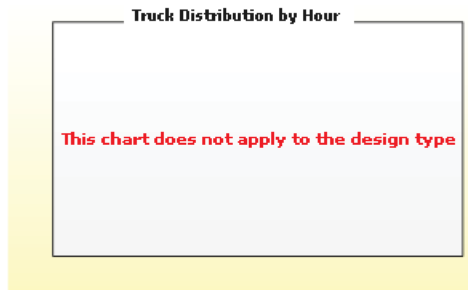
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

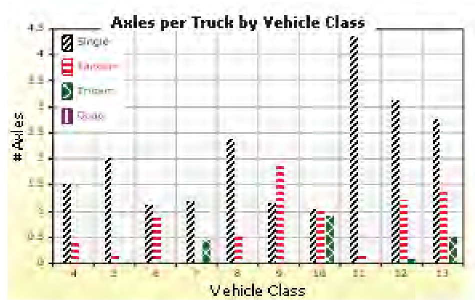
Traffic Inputs

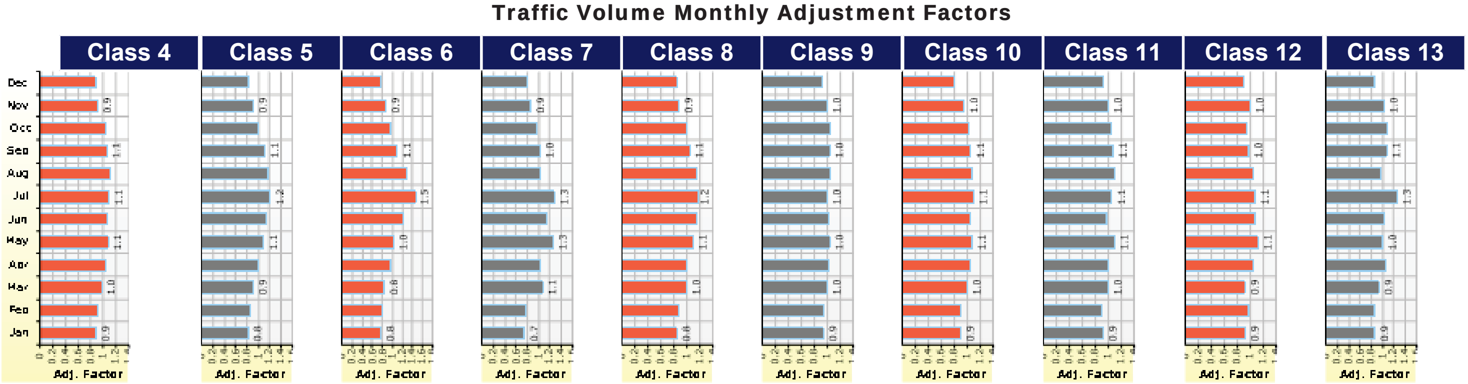
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	695	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0









Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

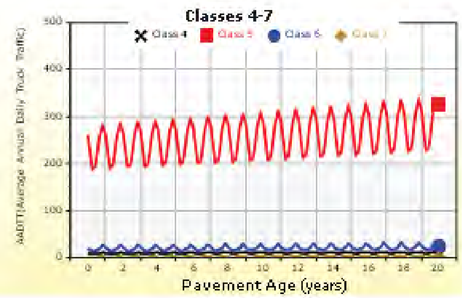
Wheelbase does not apply

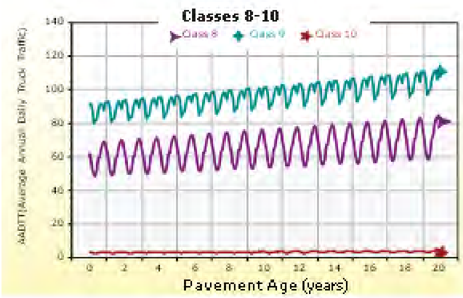
Number of Axles per Truck

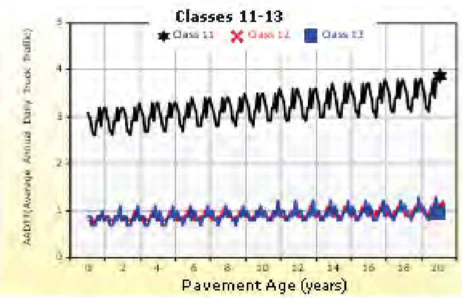
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

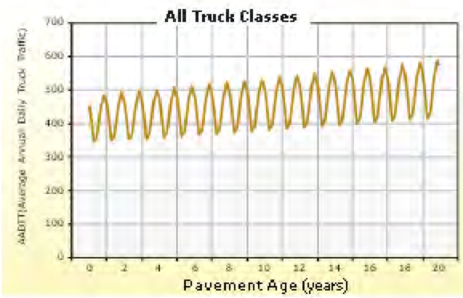
AADTT (Average Annual Daily Truck Traffic) Growth

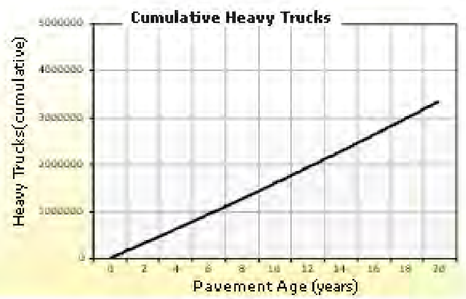
*** Traffic cap is not enforced**







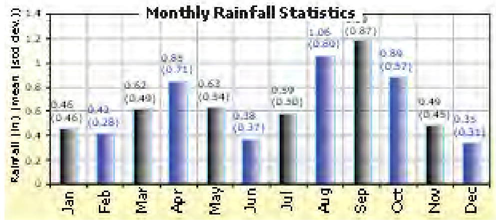




Climate Inputs

Climate Data Sources:

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

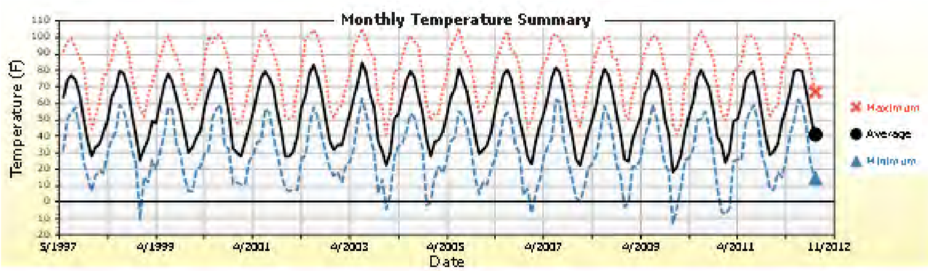


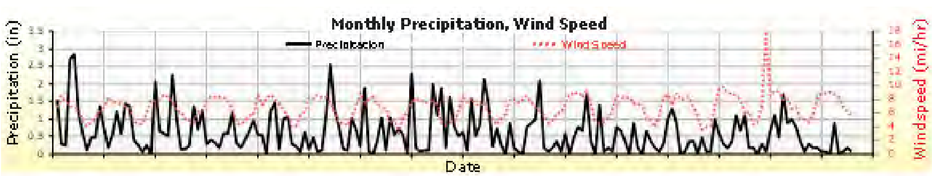
Annual Statistics:

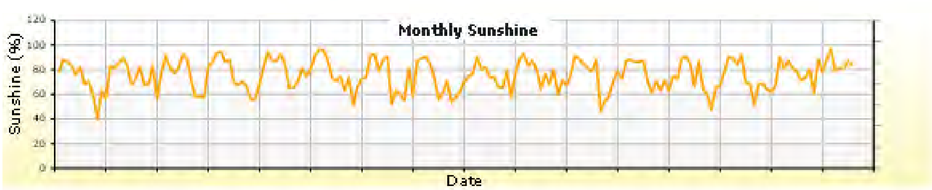
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

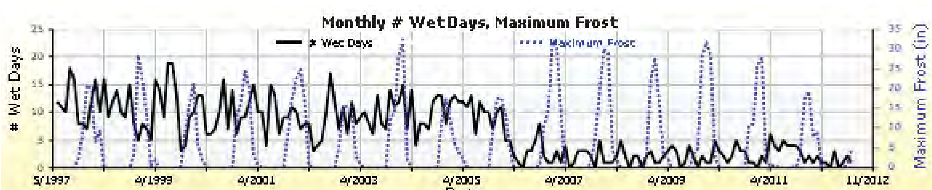
Water table depth (ft) 10.00

Monthly Climate Summary:

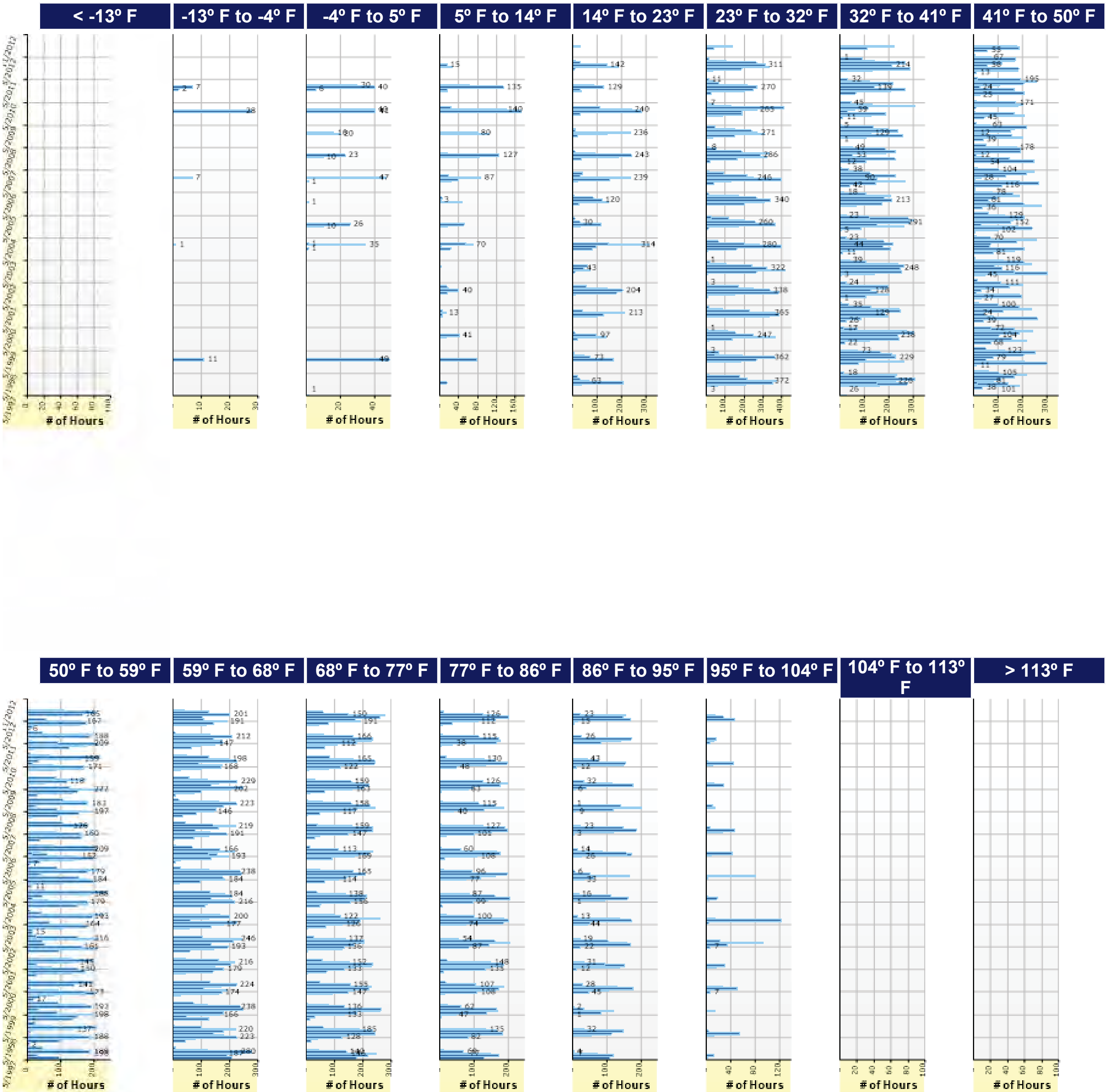








Hourly Air Temperature Distribution by Month:



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

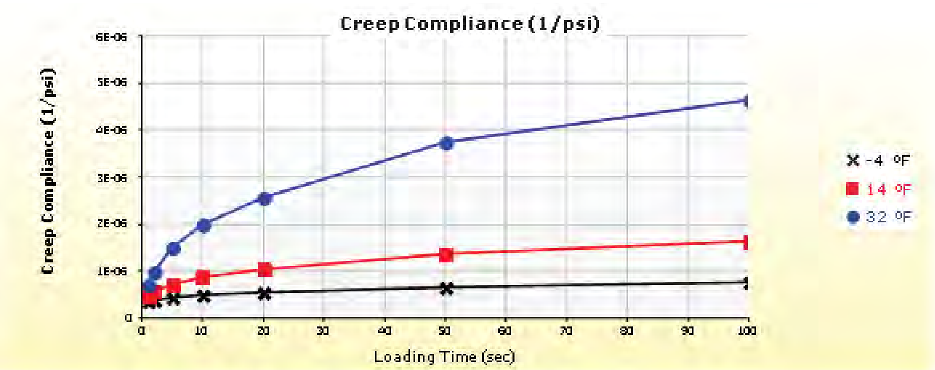
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	1.00
Layer 2 Flexible : R2 Level 1 SX (100) PG 64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : River-run gravel	Non-stabilized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

Thermal Cracking (Input Level: 1)

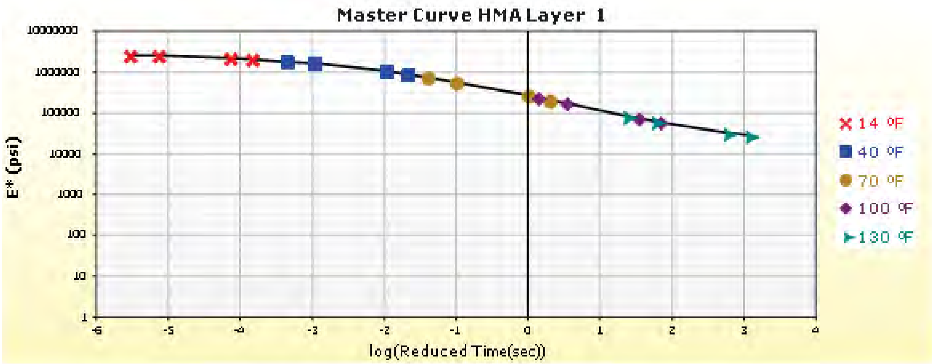
Indirect tensile strength at 14 ºF (psi)	519.00

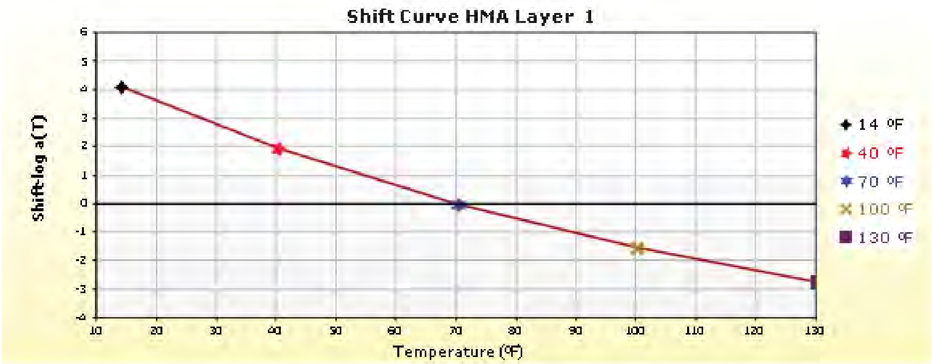
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

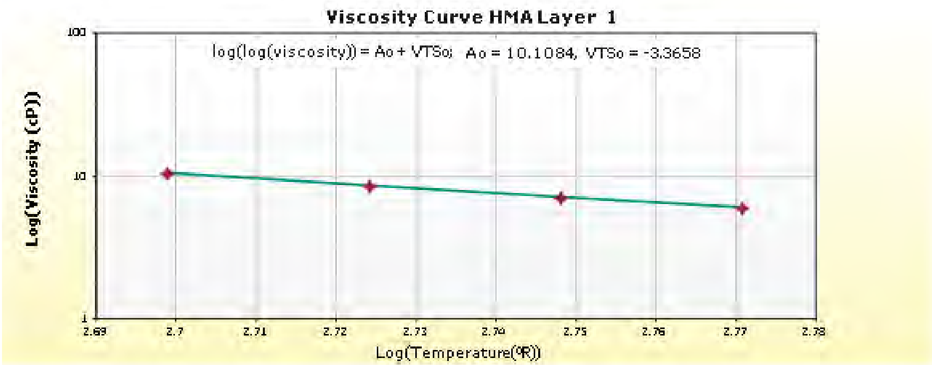
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



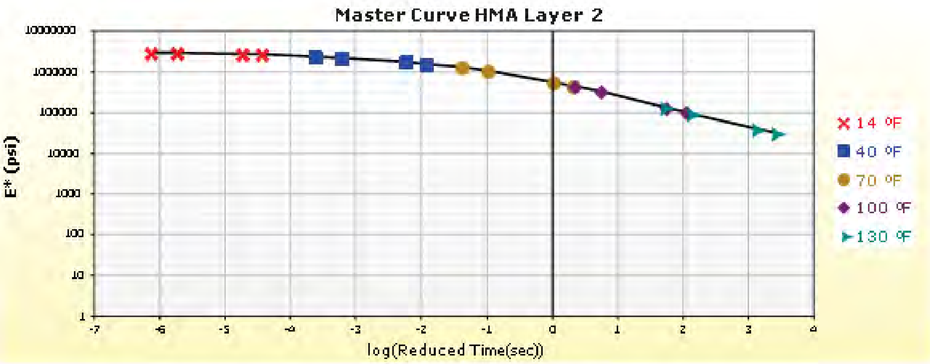
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

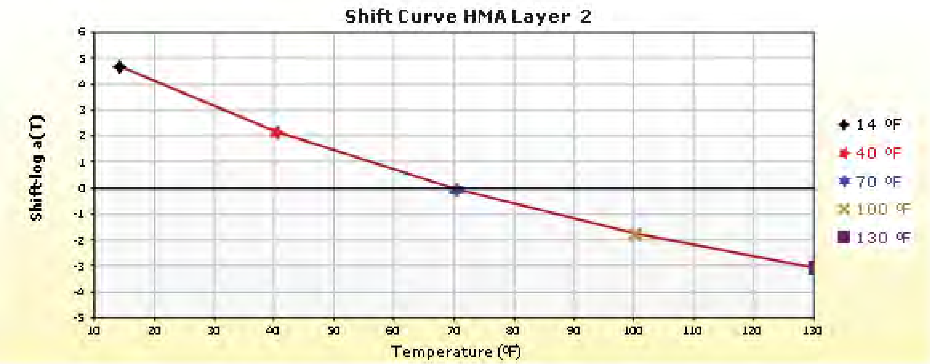


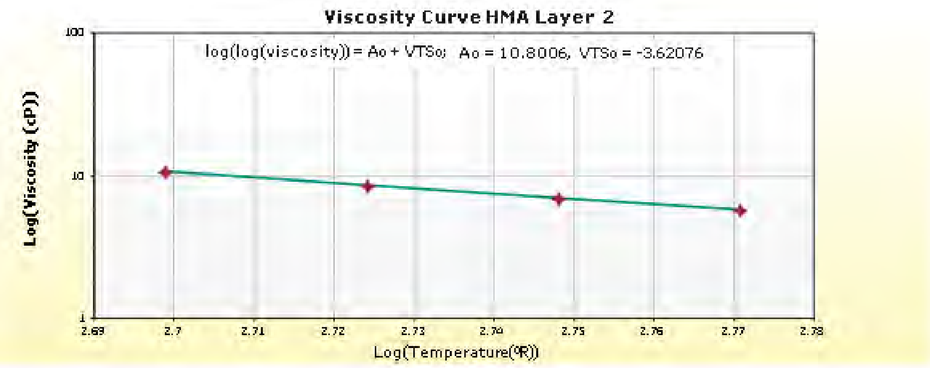




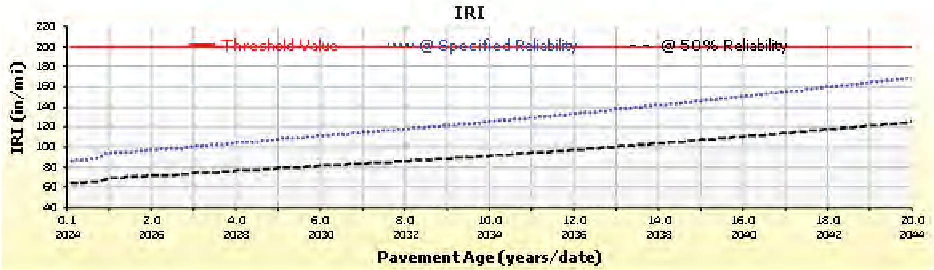
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

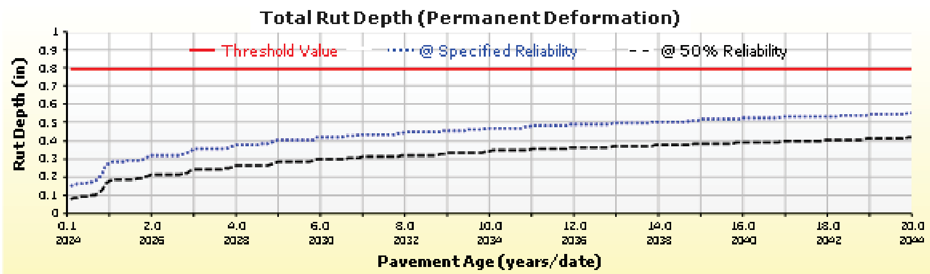


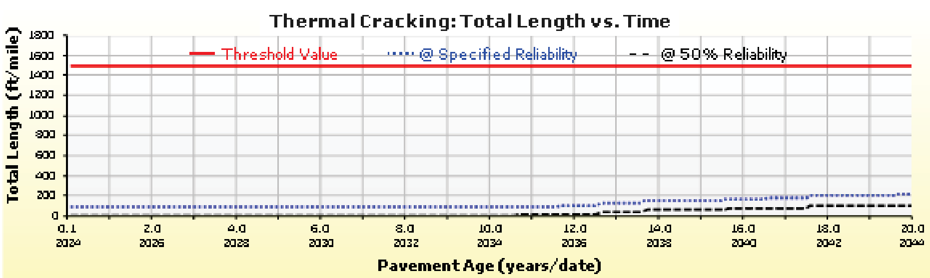


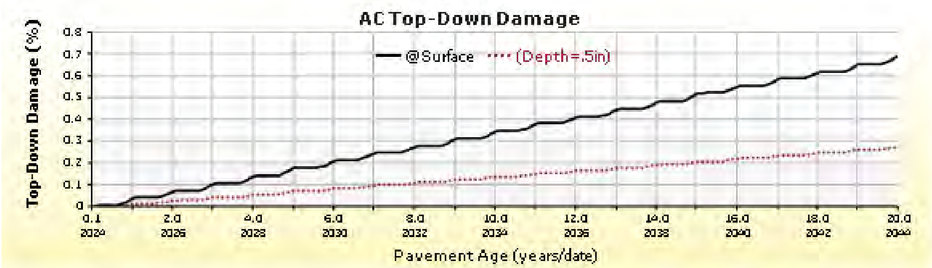


Analysis Output Charts

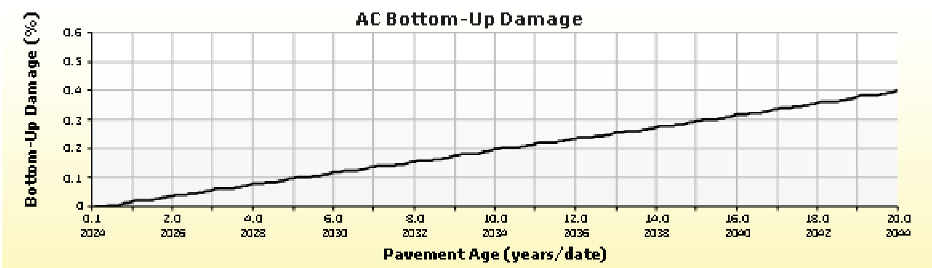




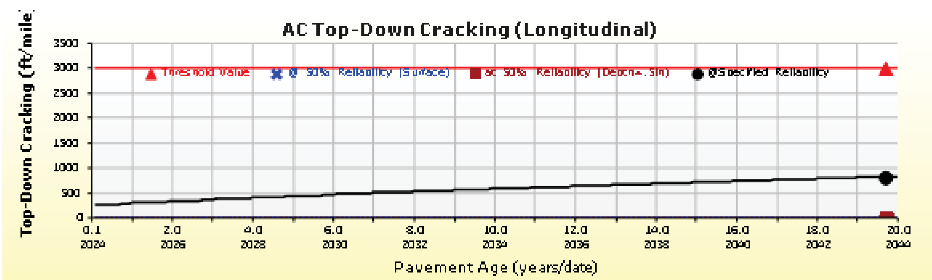




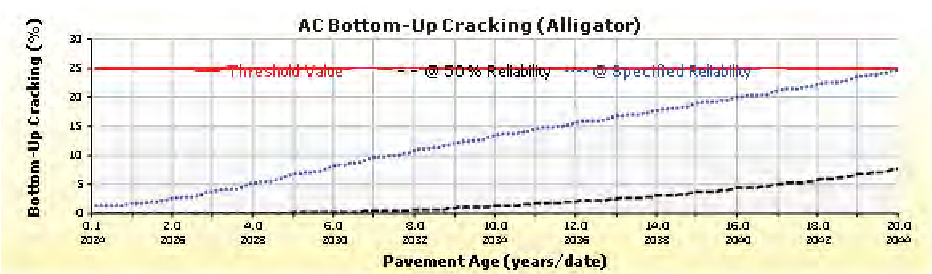
AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
Pavement Age (years/date)



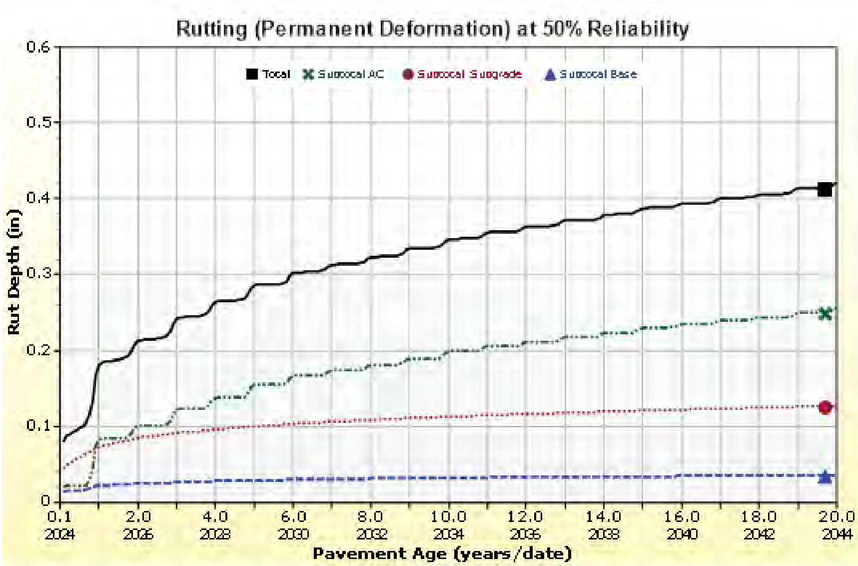
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



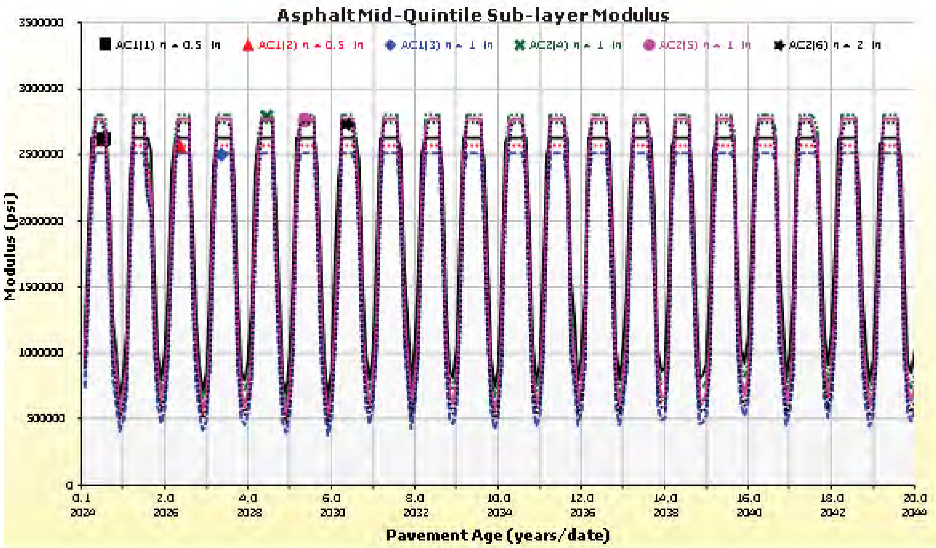
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)



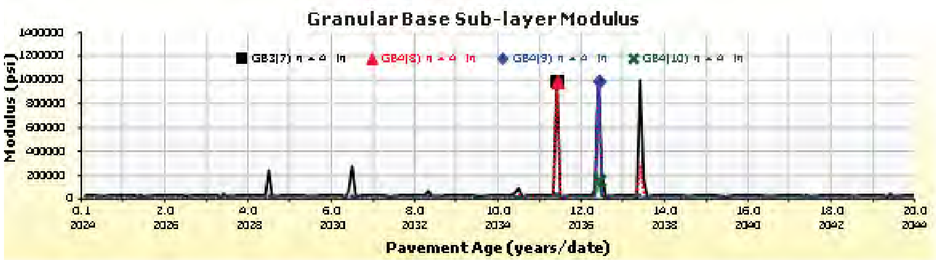
AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Pavement Age (years/date)



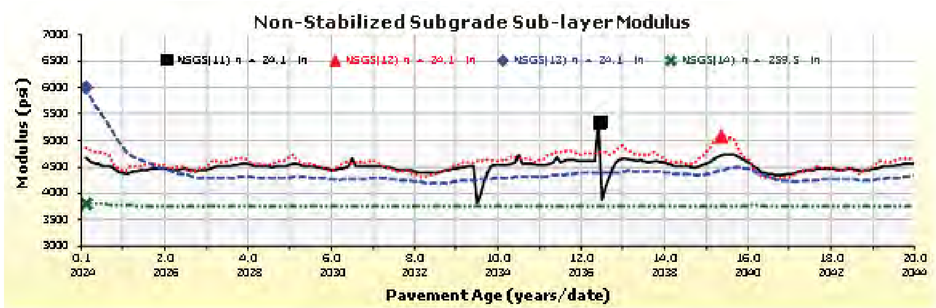
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
Pavement Age (years/date)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2024
2.0
2026
4.0
2028
6.0
2030
8.0
2032
10.0
2034
12.0
2036
14.0
2038
16.0
2040
18.0
2042
20.0
2044



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 = 4 in
GB4(8) h = 4 in
GB4(9) h = 4 in
GB4(10) h = 4 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSGS(11) h = 24.1 in
NSGS(12) h = 24.1 in
NSGS(13) h = 24.1 in
NSGS(14) h = 239.5 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)	4.0	
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	15

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	4.0
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)
21000.0

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 : River-run gravel

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	River-run 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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-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)
6482.0

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

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:

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

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

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

$T = layer\ temperature(°F)$

$N = number\ of\ load\ repetitions$

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

D.5_New_AC

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\D.5_New_AC.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

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

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	4.0
NonStabilized	Crushed stone	4.0
NonStabilized	River-run gravel	12.0
Subgrade	A-4	Semi-infinite

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

Traffic

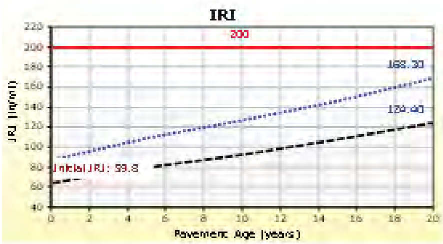
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	655
2034 (10 years)	1,501,780
2044 (20 years)	3,160,680

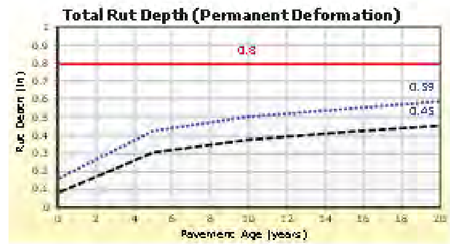
Design Outputs

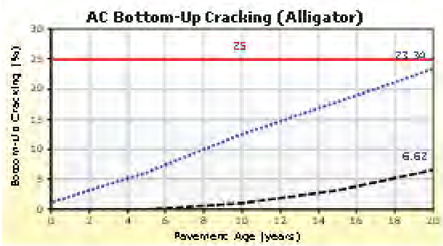
Distress Prediction Summary

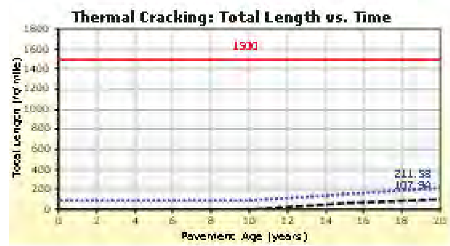
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	168.27	90.00	98.64	Pass
Permanent deformation - total pavement (in)	0.80	0.59	90.00	99.95	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	23.34	90.00	92.06	Pass
AC thermal cracking (ft/mile)	1500.00	211.58	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	775.87	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.39	90.00	99.99	Pass

Distress Charts







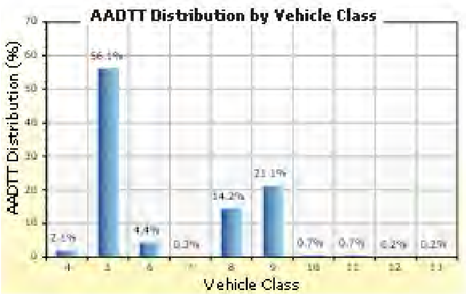


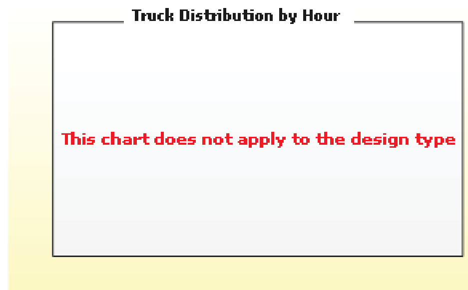
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

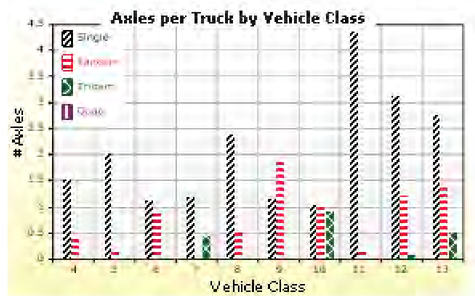
Traffic Inputs

Graphical Representation of Traffic Inputs

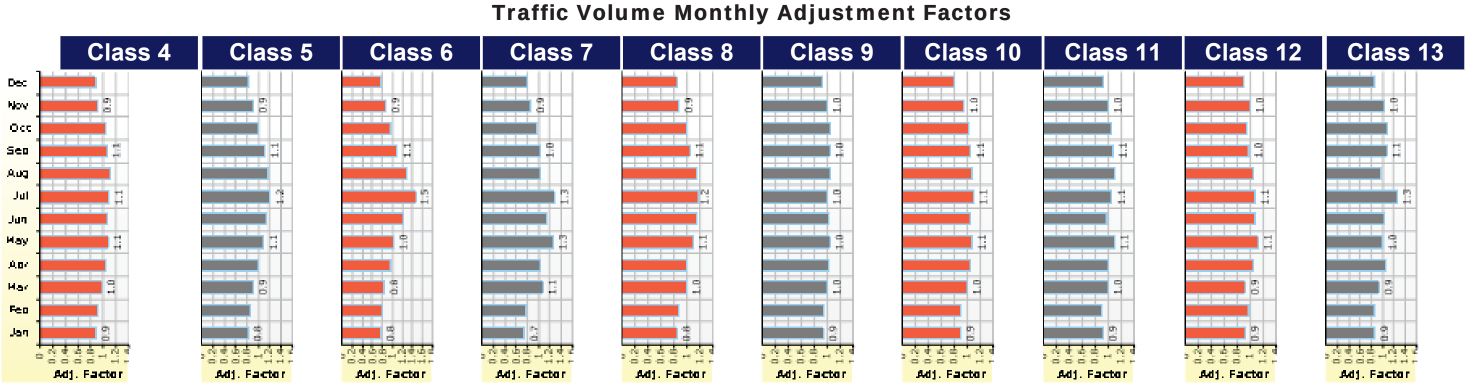
Initial two-way AADTT:	655	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

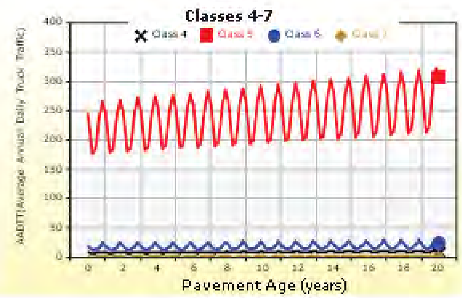
Wheelbase does not apply

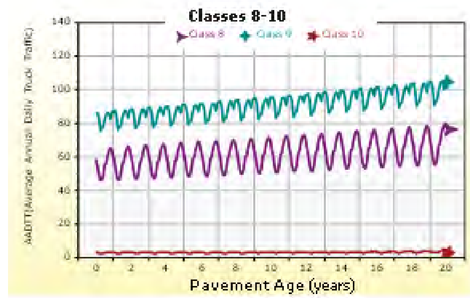
Number of Axles per Truck

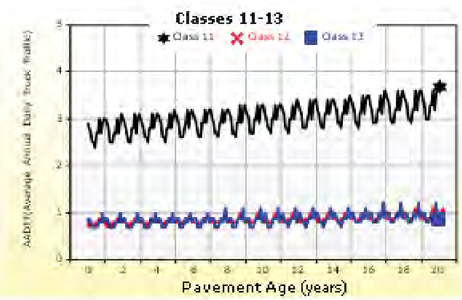
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

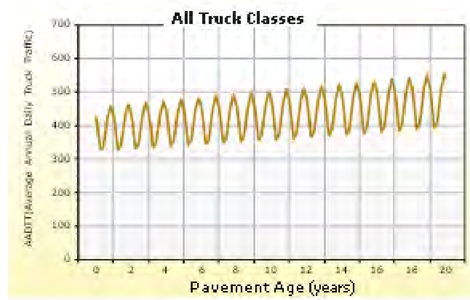
AADTT (Average Annual Daily Truck Traffic) Growth

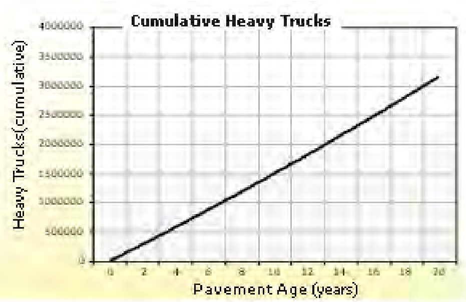
*** Traffic cap is not enforced**







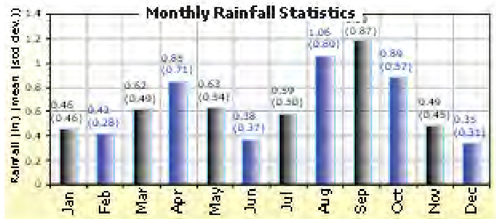




Climate Inputs

Climate Data Sources:

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

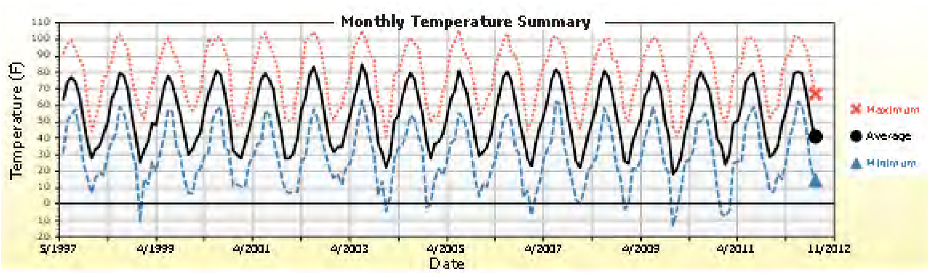


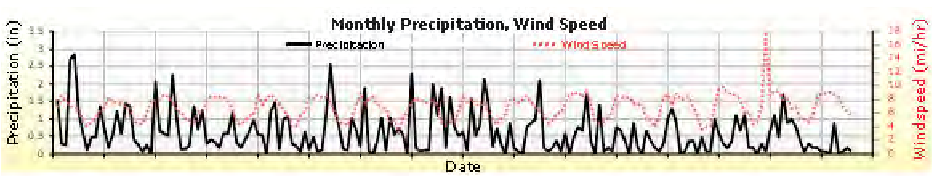
Annual Statistics:

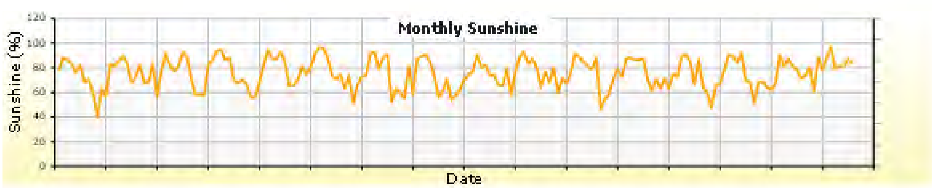
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

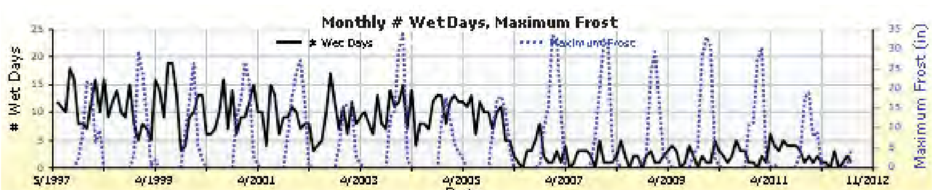
Water table depth (ft) 10.00

Monthly Climate Summary:

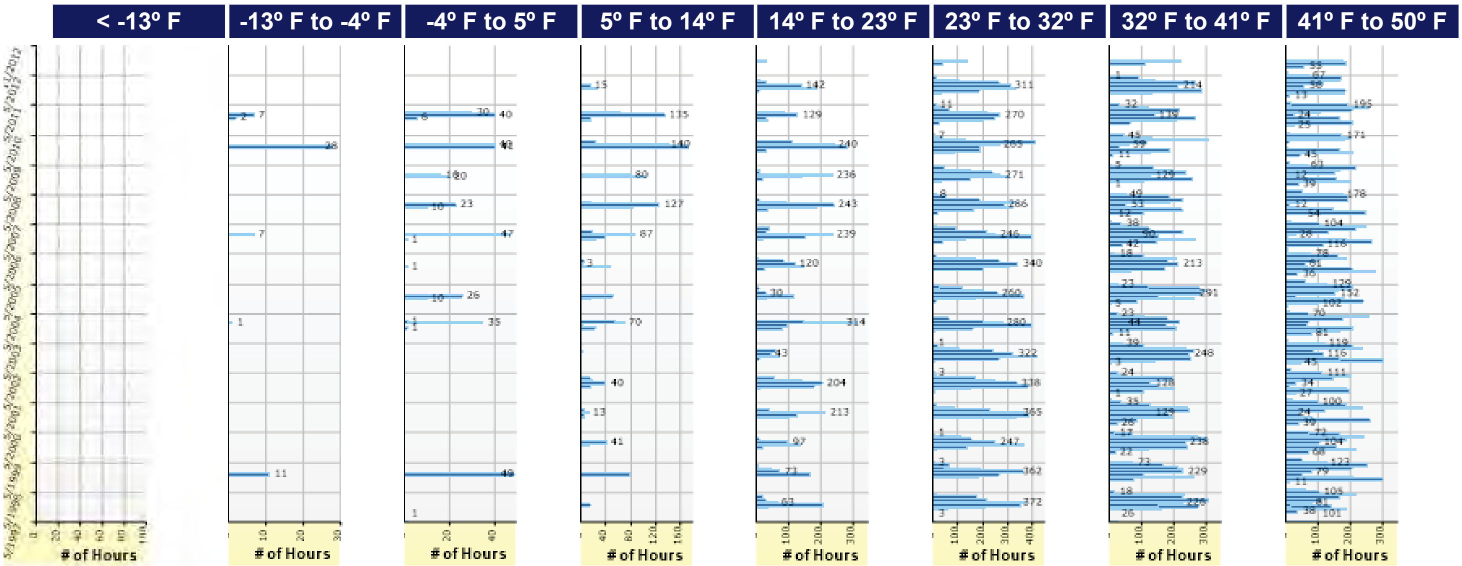


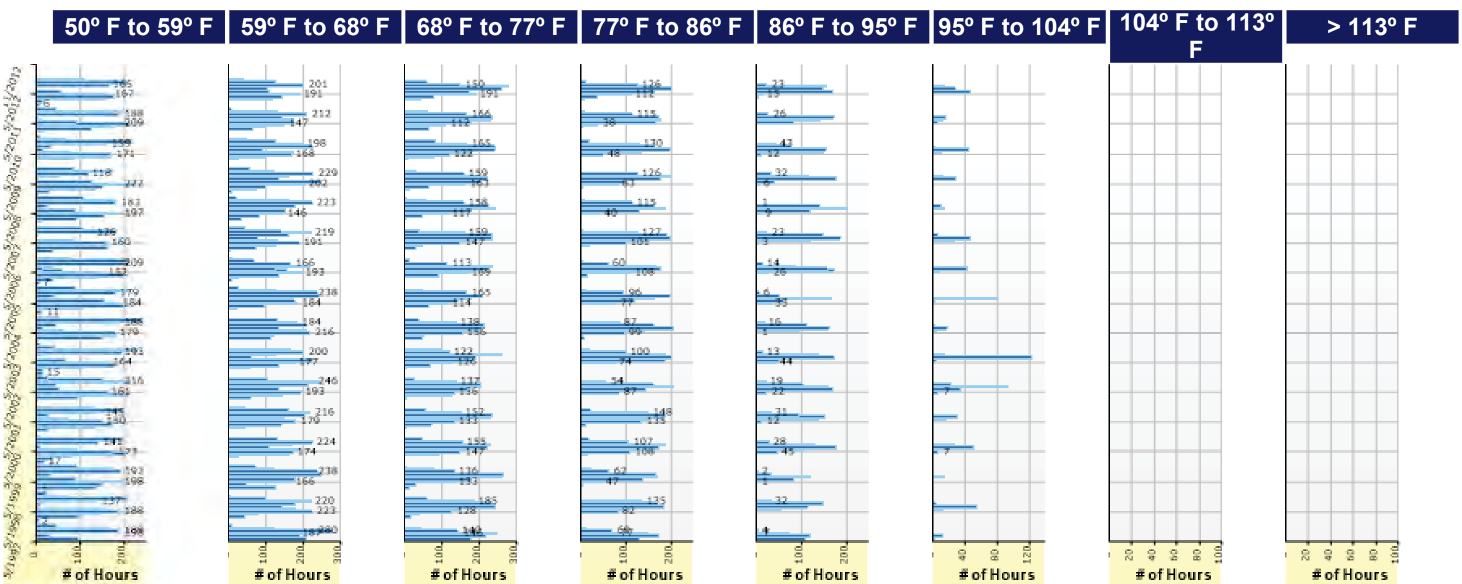






Hourly Air Temperature Distribution by Month:





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

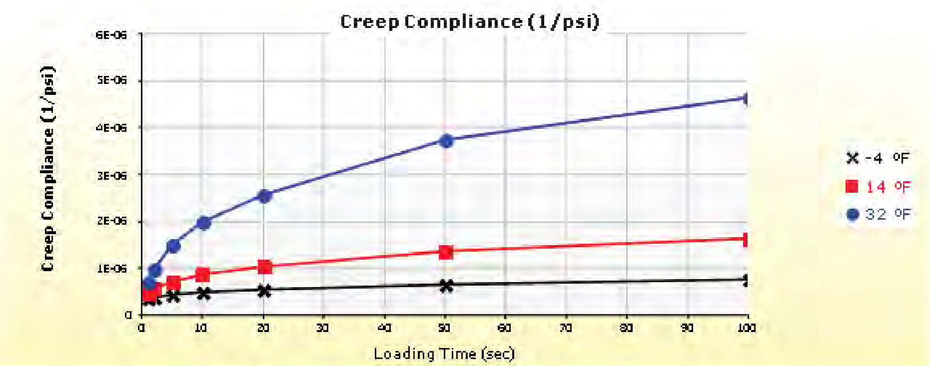
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

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 : River-run gravel	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

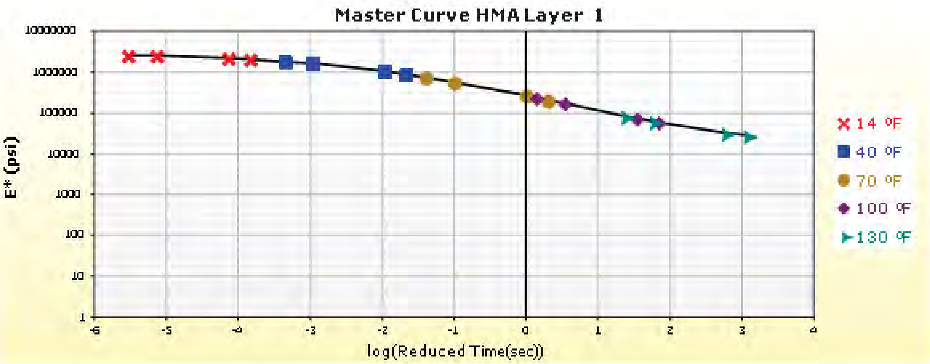
Thermal Cracking (Input Level: 1)

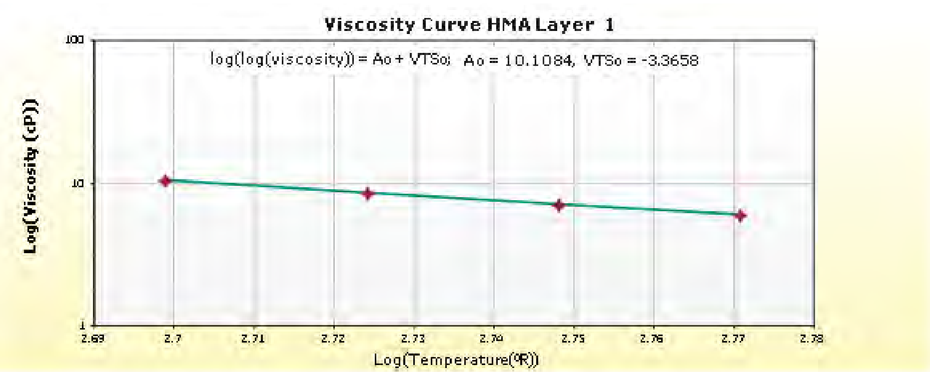
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

	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

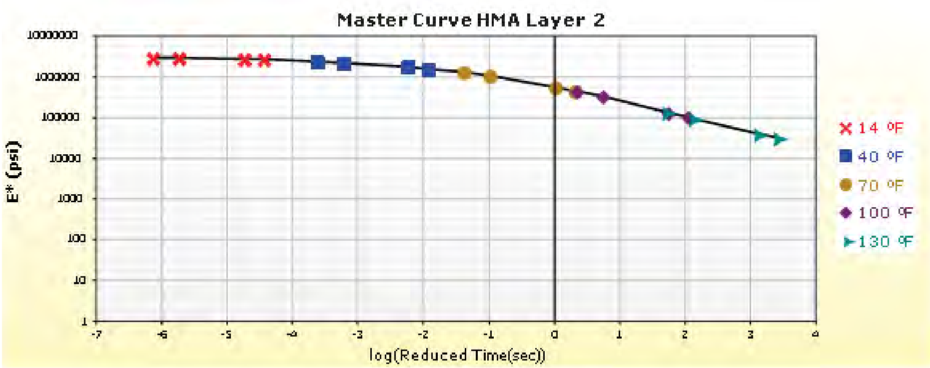


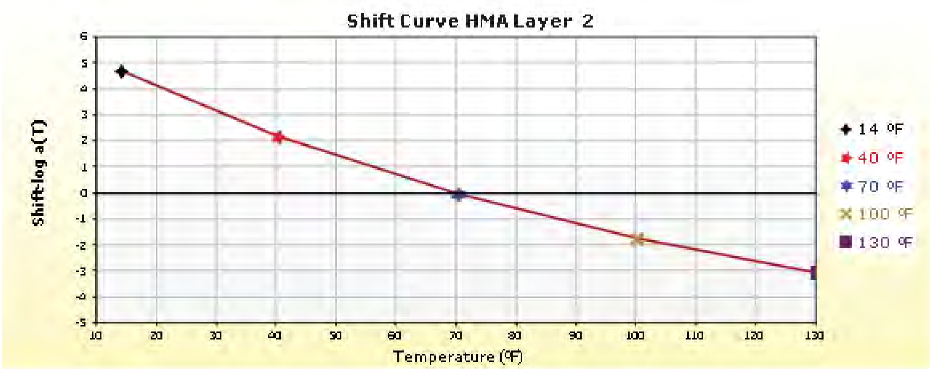
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

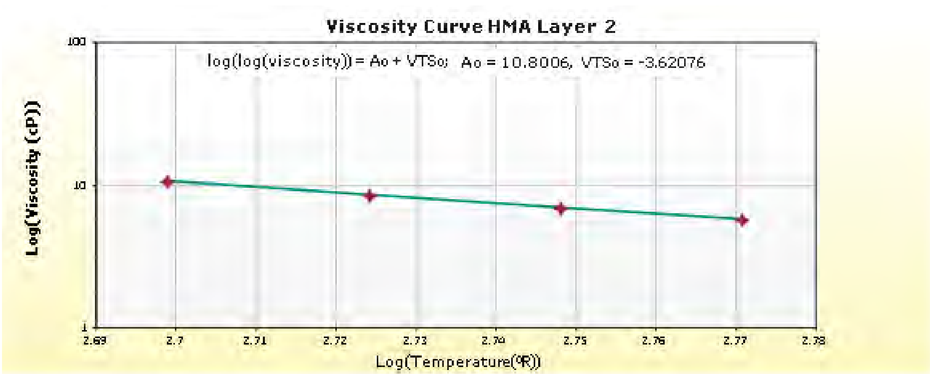




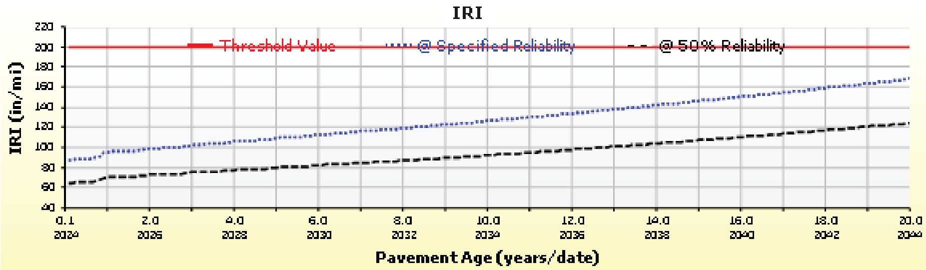
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

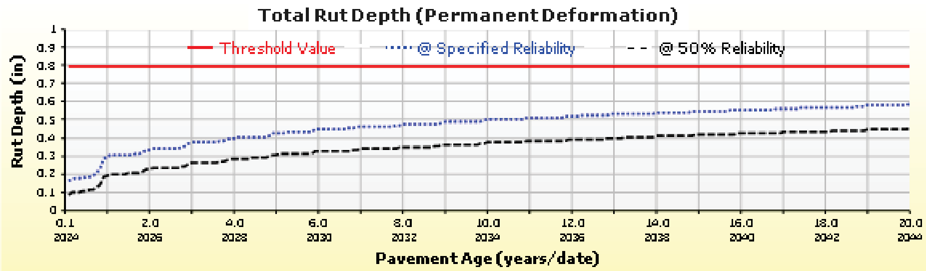


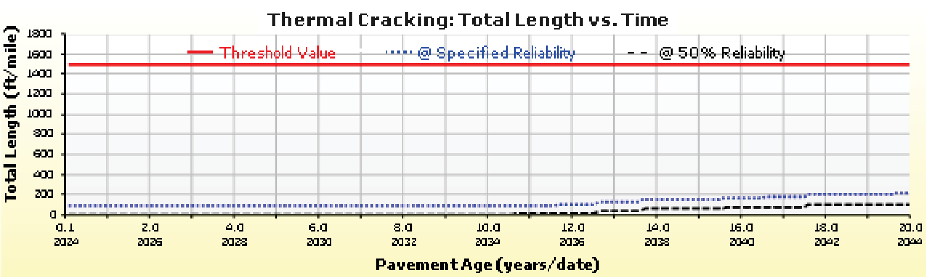


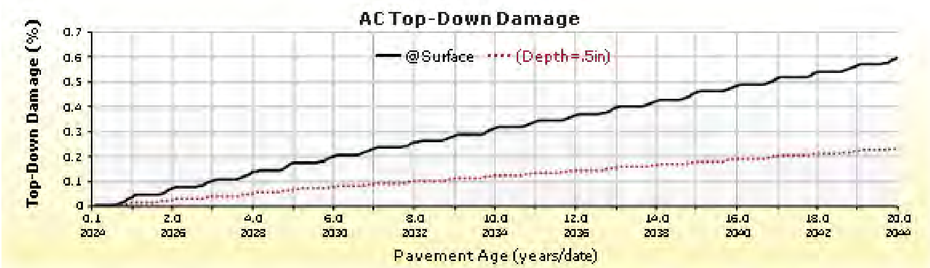


Analysis Output Charts

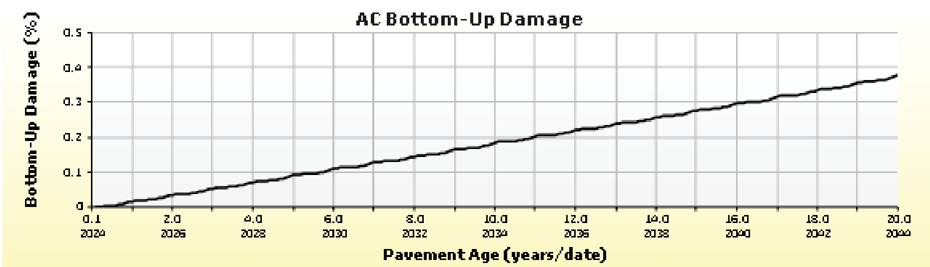




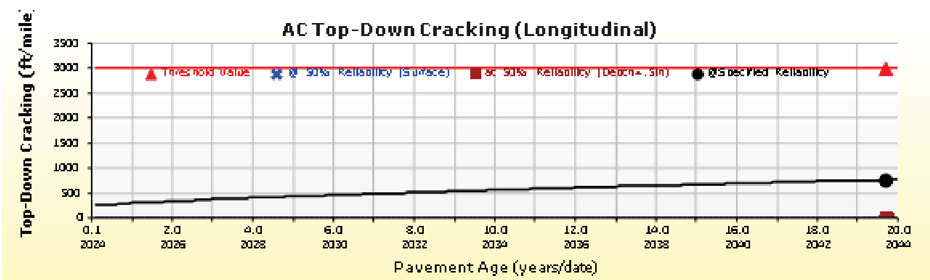




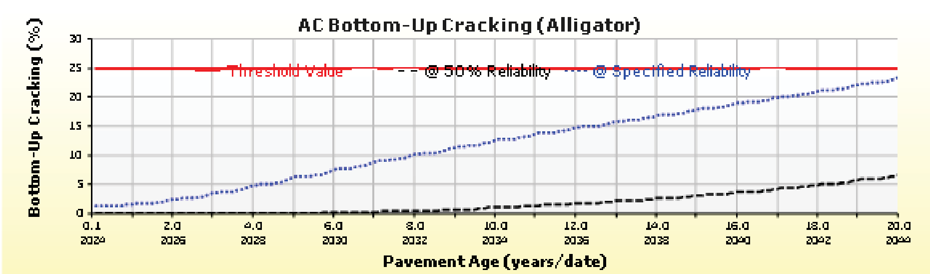
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



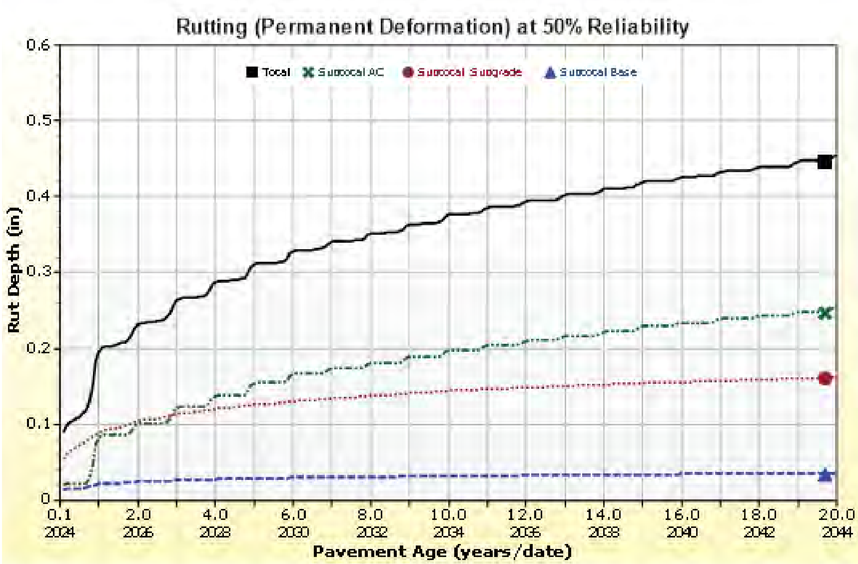
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

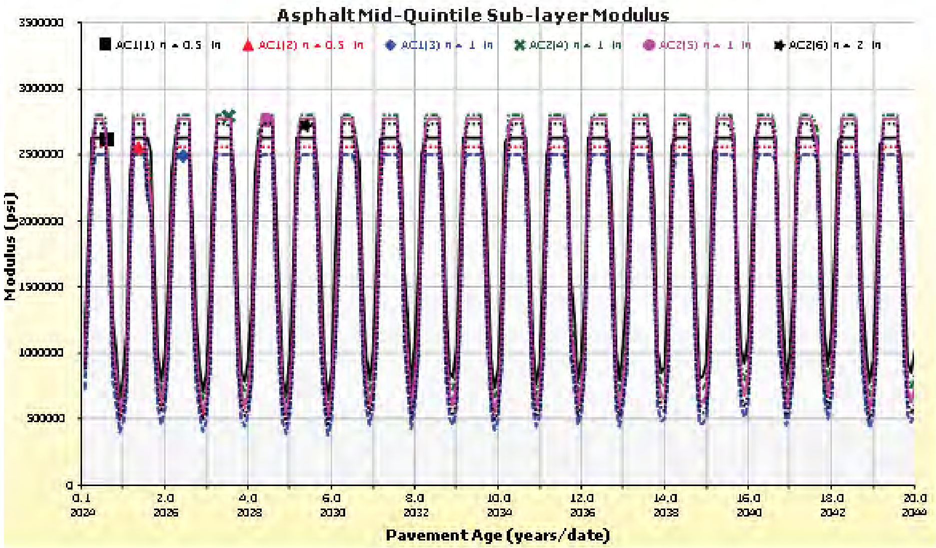


AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)

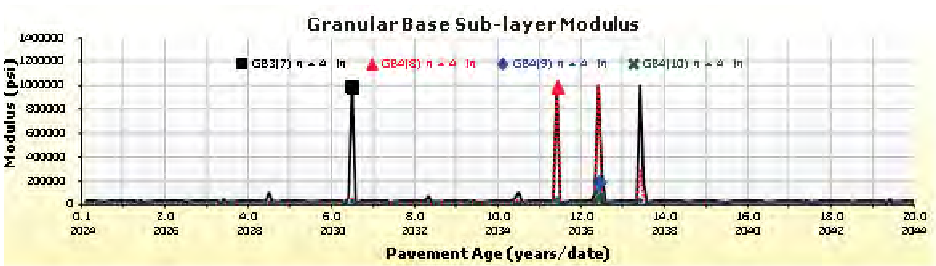


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

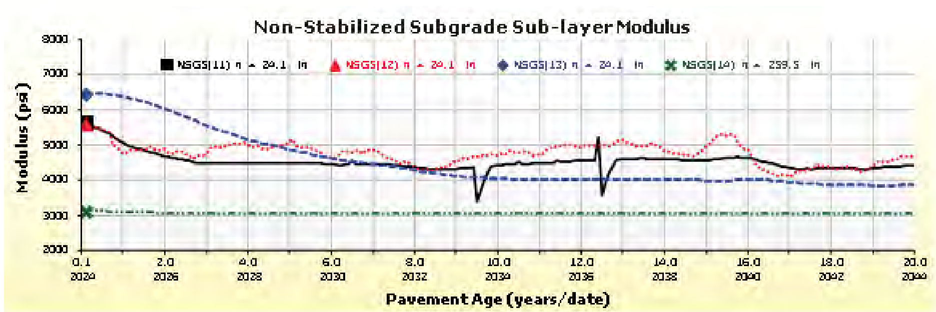

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
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?	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)	4.0	
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	15

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	4.0
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)
21000.0

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 : River-run gravel

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	River-run 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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

AC Fatigue

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

F.5_New_AC

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\F.5_New_AC.dgpx

Design Inputs

Design Life:	20 years	Base construction:	May, 2024	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	FLEXIBLE	Pavement construction:	June, 2024		
		Traffic opening:	September, 2024		

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	3.0
NonStabilized	Crushed stone	4.0
NonStabilized	River-run gravel	12.0
Subgrade	A-4	Semi-infinite

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

Traffic

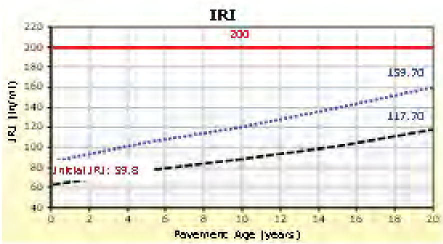
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	220
2034 (10 years)	504,415
2044 (20 years)	1,061,600

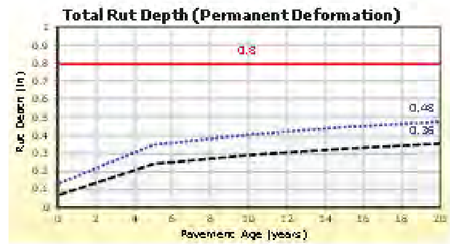
Design Outputs

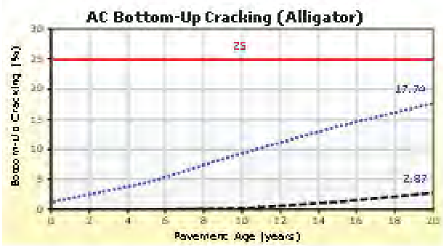
Distress Prediction Summary

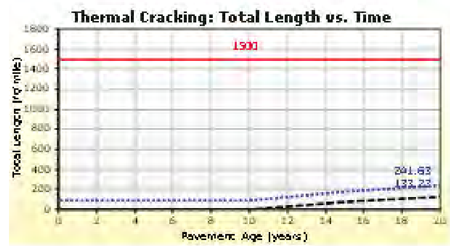
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	159.65	90.00	99.40	Pass
Permanent deformation - total pavement (in)	0.80	0.48	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	17.74	90.00	97.17	Pass
AC thermal cracking (ft/mile)	1500.00	241.63	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	692.12	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.29	90.00	100.00	Pass

Distress Charts





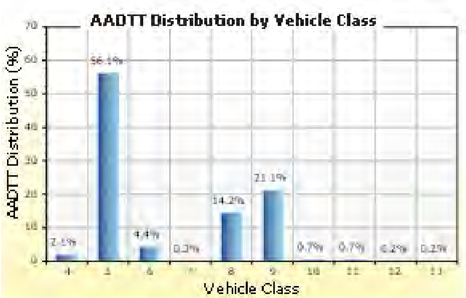


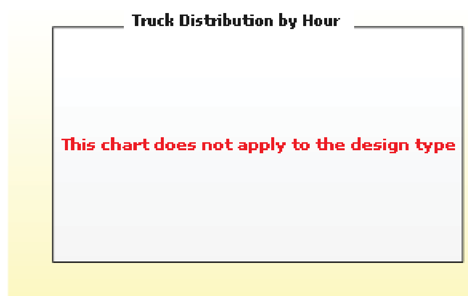


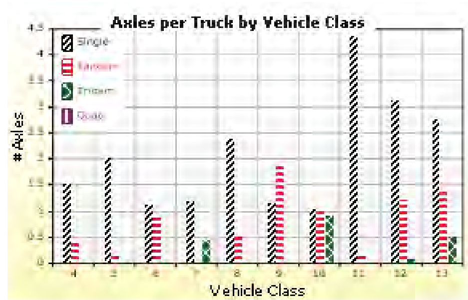
Traffic Inputs

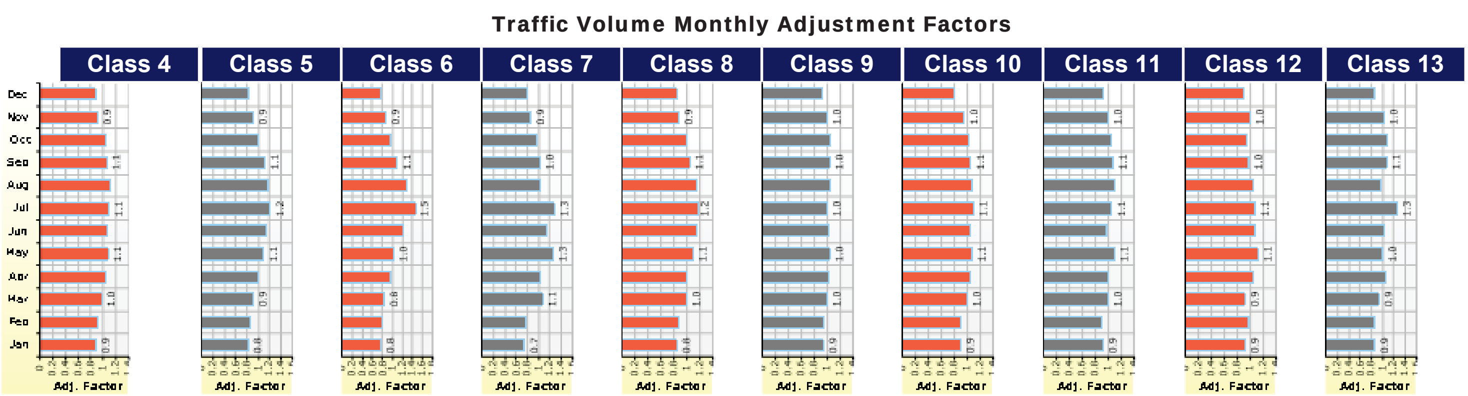
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	220	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0









Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

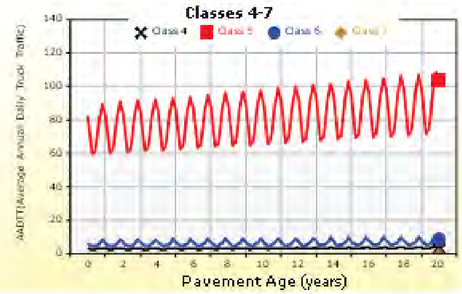
Wheelbase does not apply

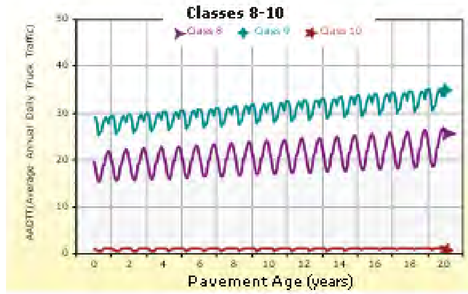
Number of Axles per Truck

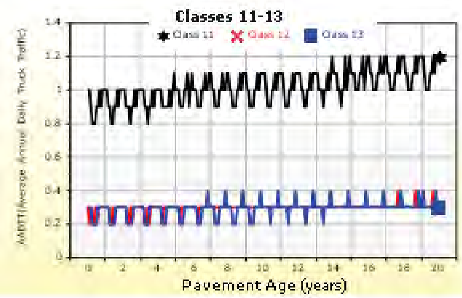
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

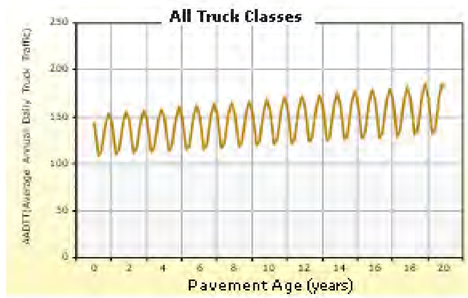
AADTT (Average Annual Daily Truck Traffic) Growth

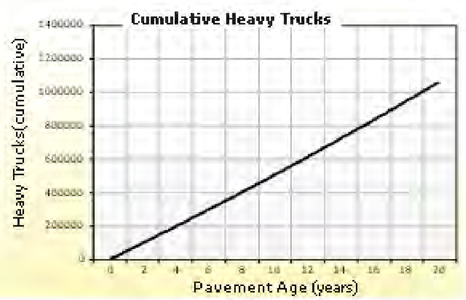
*** Traffic cap is not enforced**







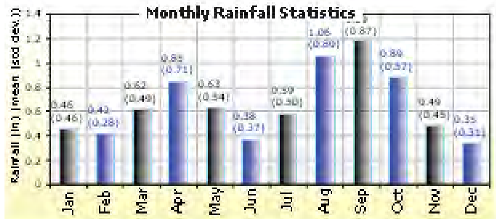




Climate Inputs

Climate Data Sources:

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

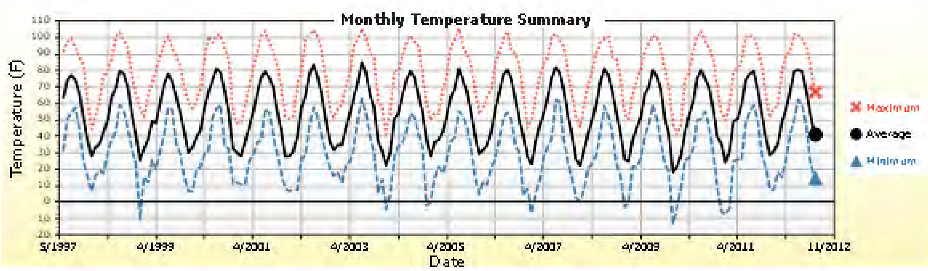


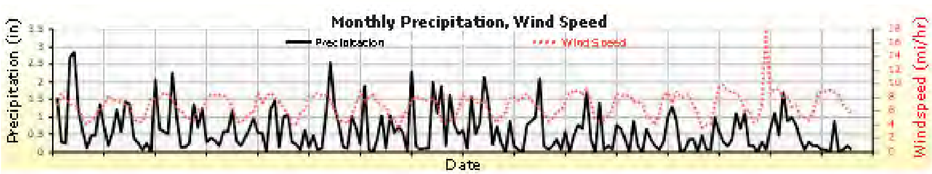
Annual Statistics:

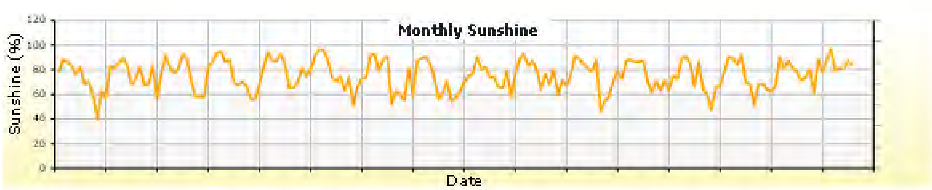
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in)	7.96
Freezing index (ºF - days)	360.58
Average annual number of freeze/thaw cycles:	111.77

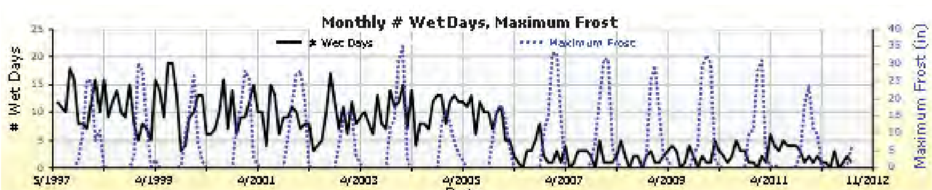
Water table depth (ft) 10.00

Monthly Climate Summary:

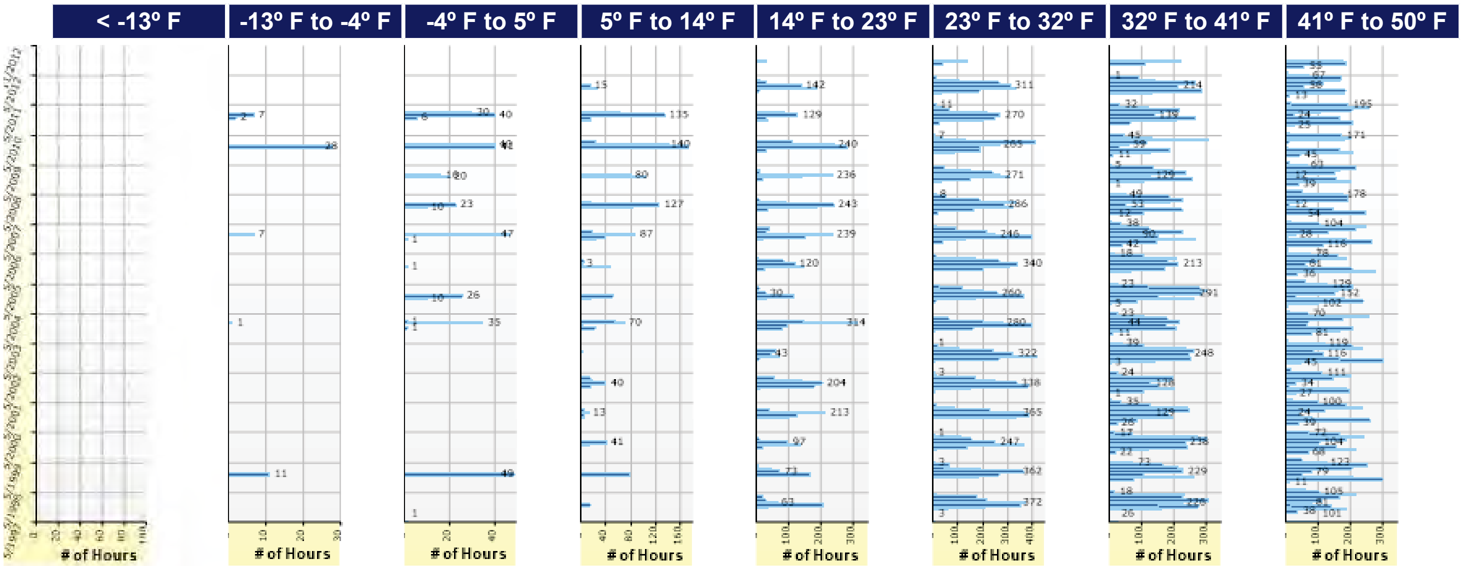


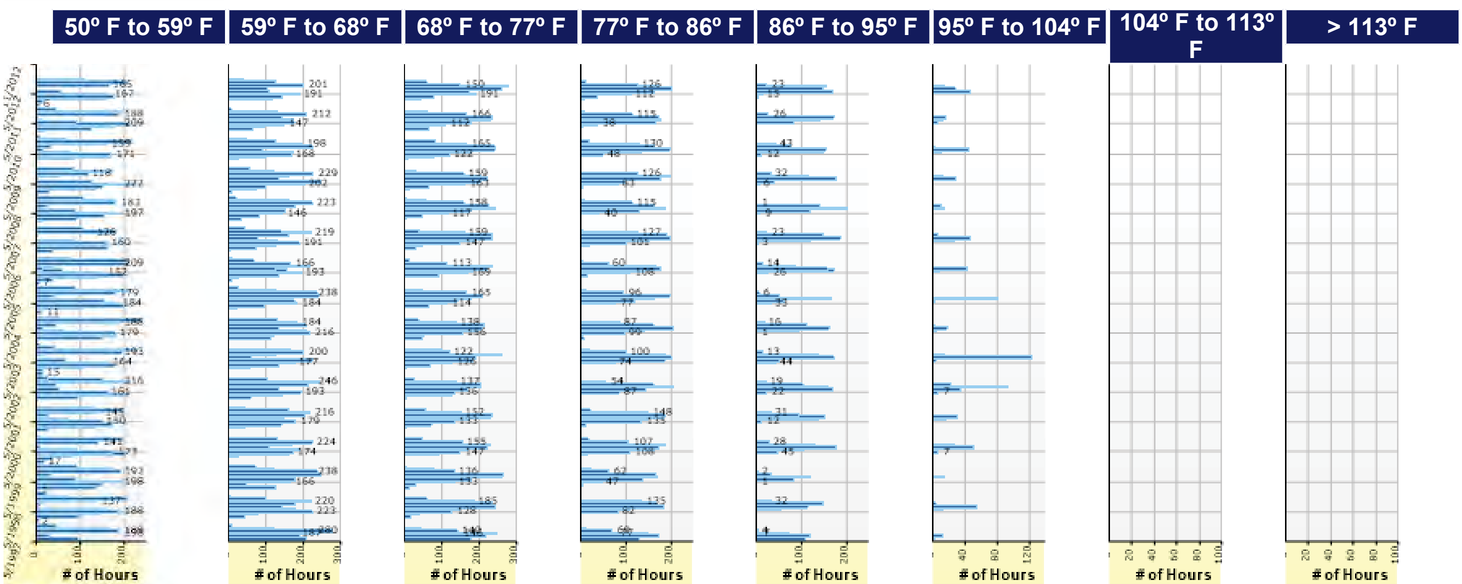






Hourly Air Temperature Distribution by Month:





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

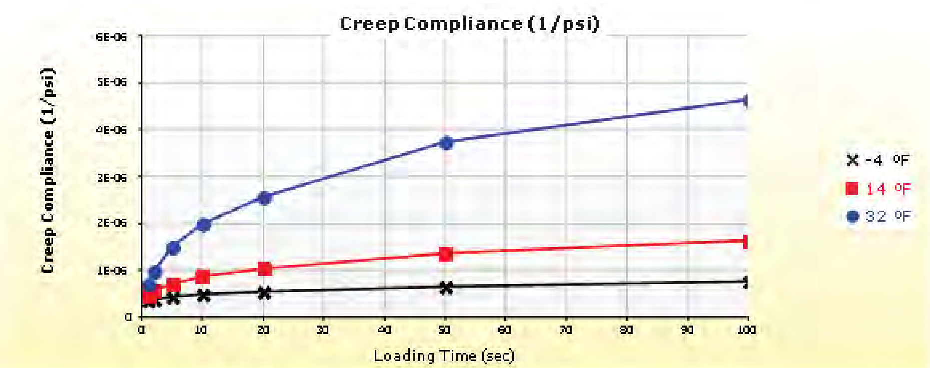
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

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 : River-run gravel	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

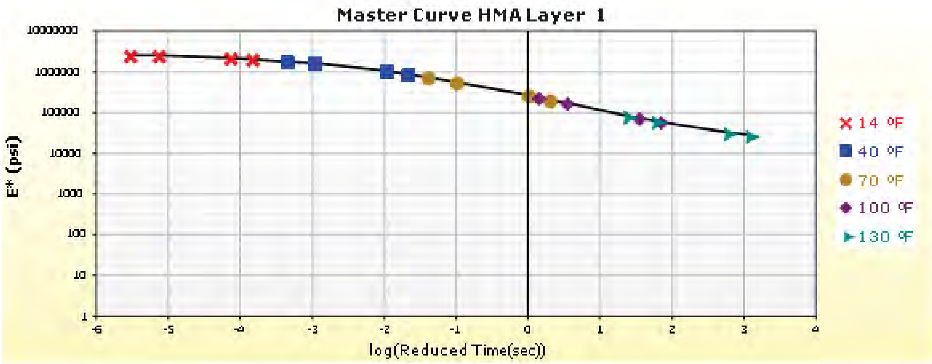
Thermal Cracking (Input Level: 1)

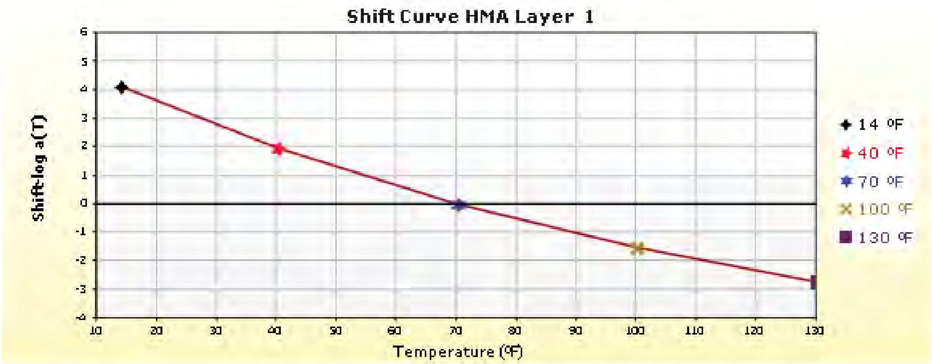
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

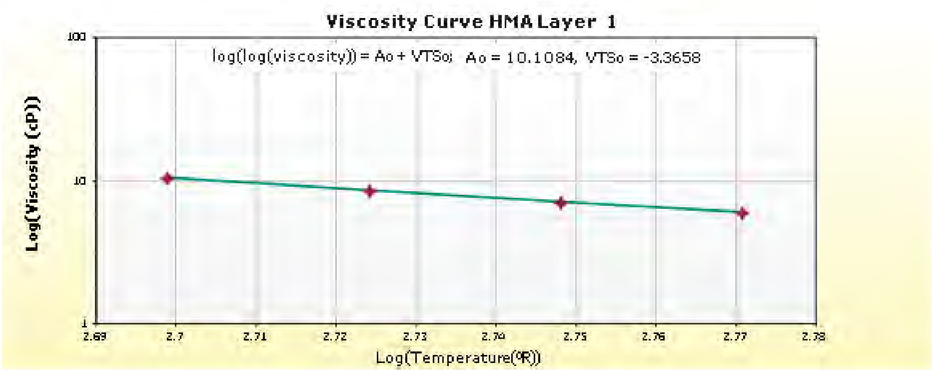
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



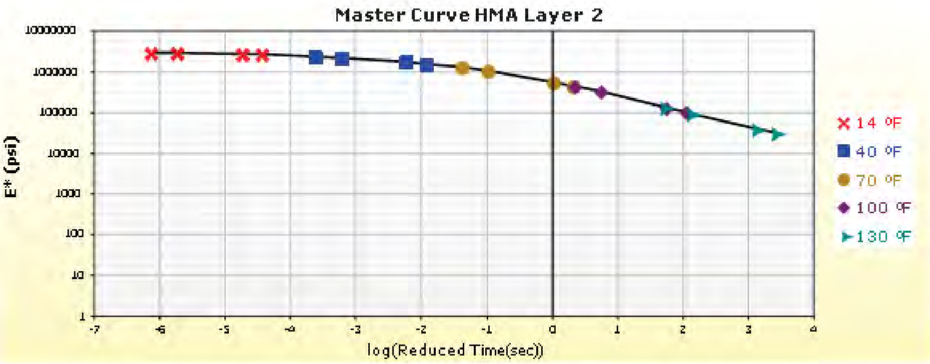
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

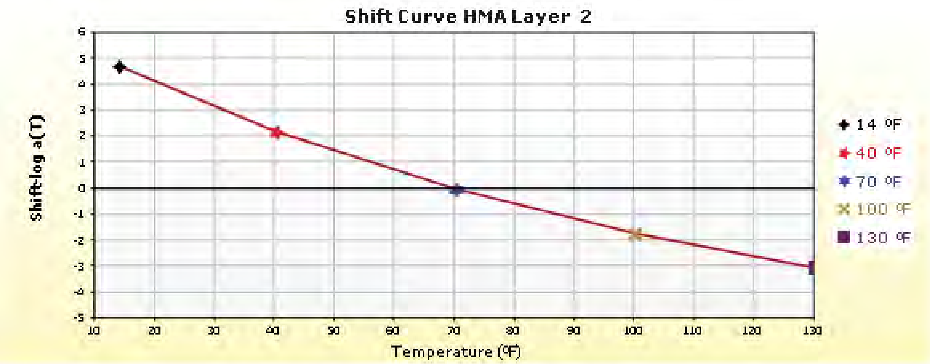


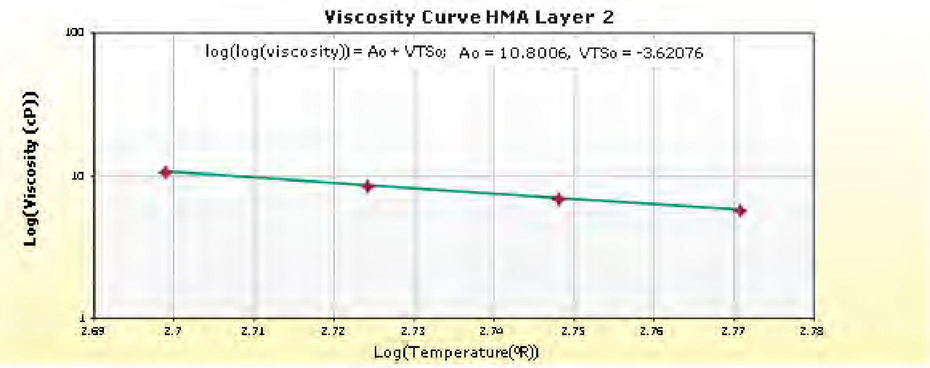




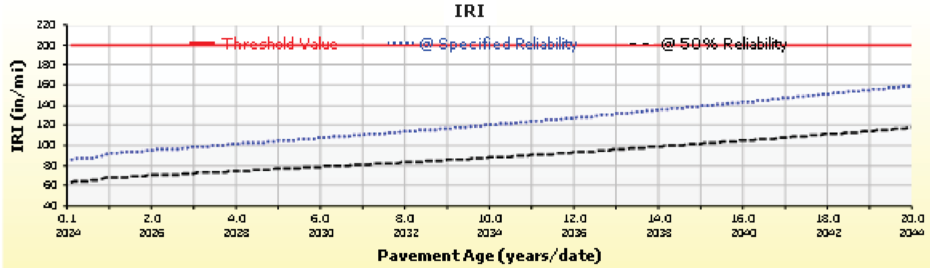
HMA Layer 2: Layer 2 Flexible : R2 Level 1 SX(100) PG 64-22

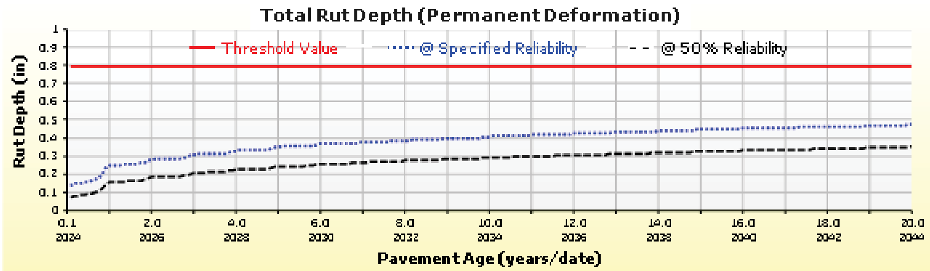


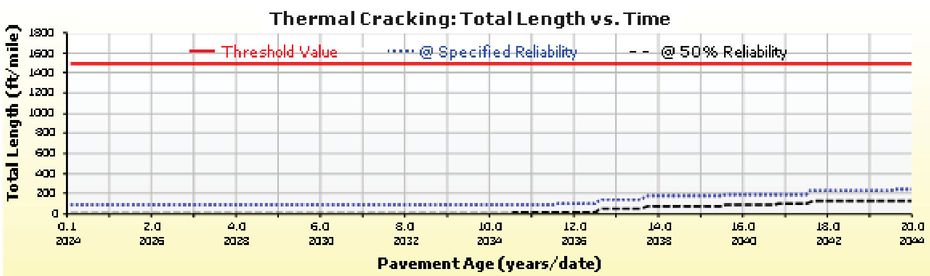


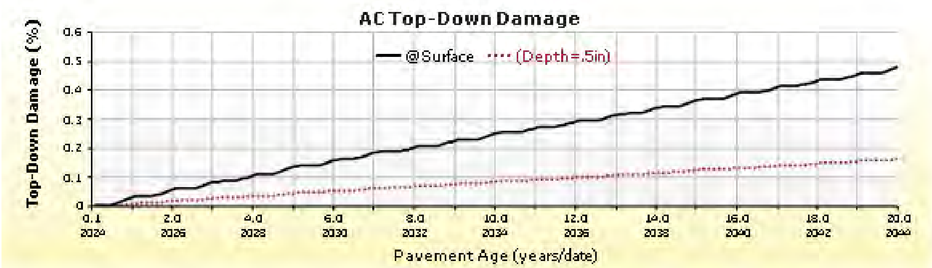


Analysis Output Charts

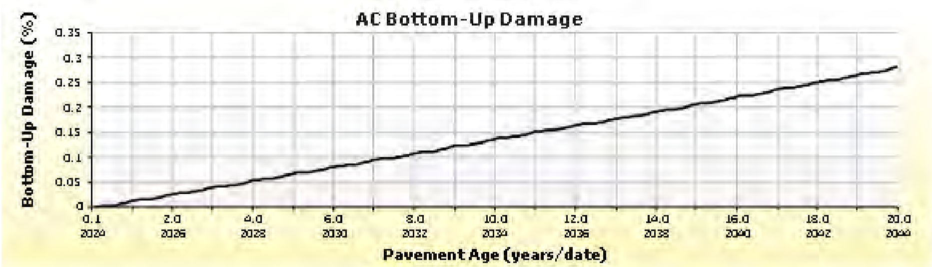




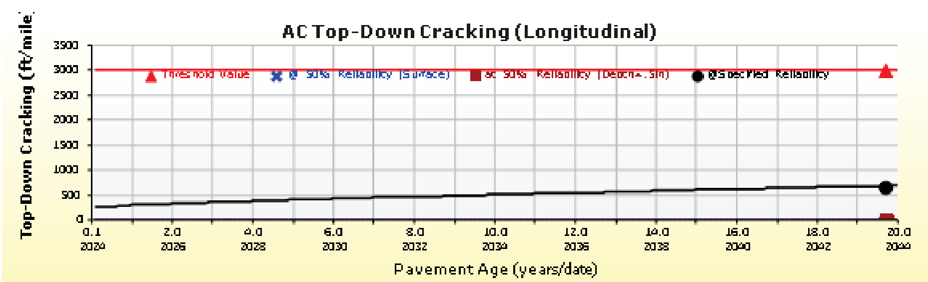




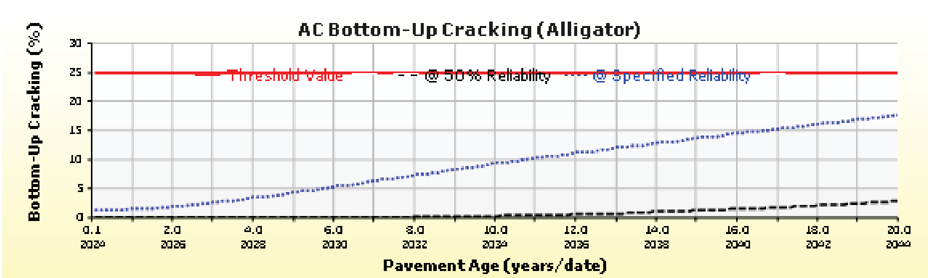
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



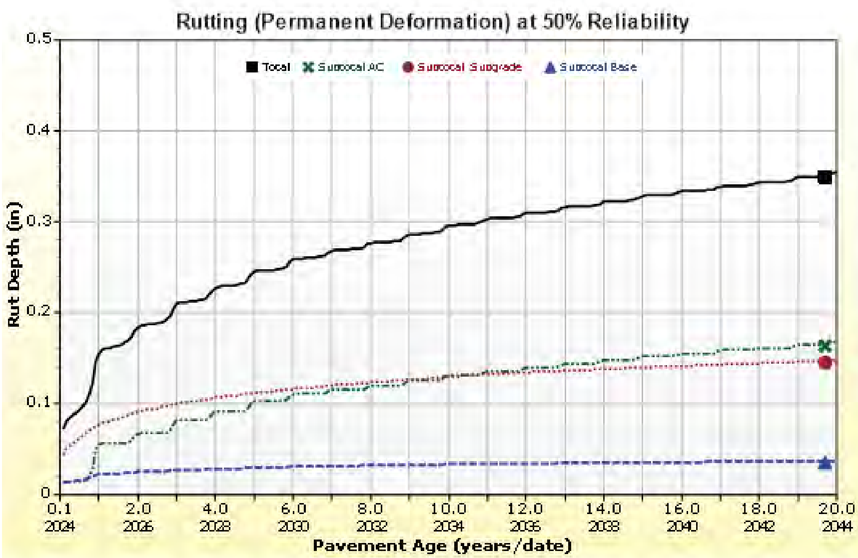
AC Bottom-Up Damage
Bottom-Up Damage (%)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



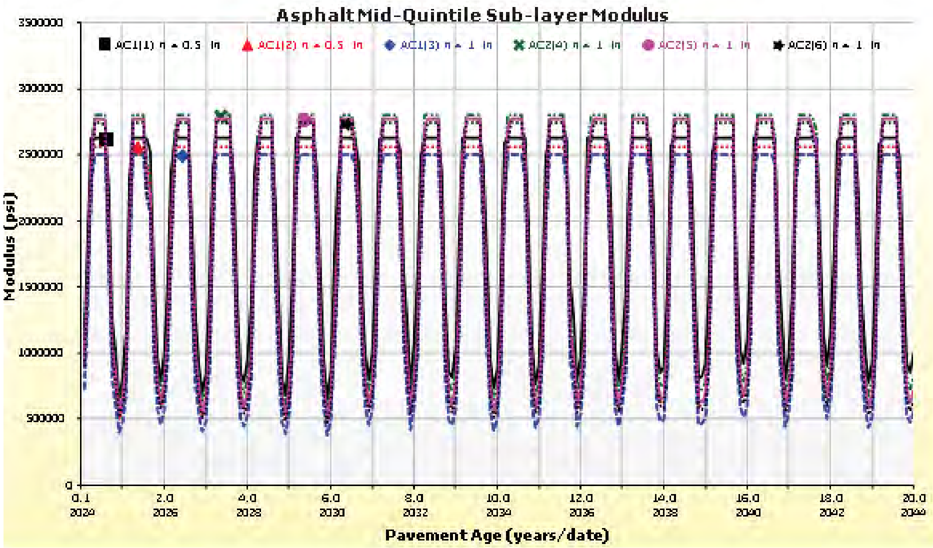
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
0
500
1000
1500
2000
2500
3000
3500
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



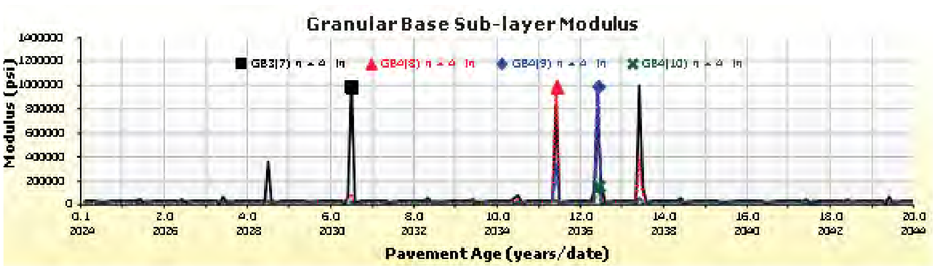
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
0
5
10
15
20
25
30
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



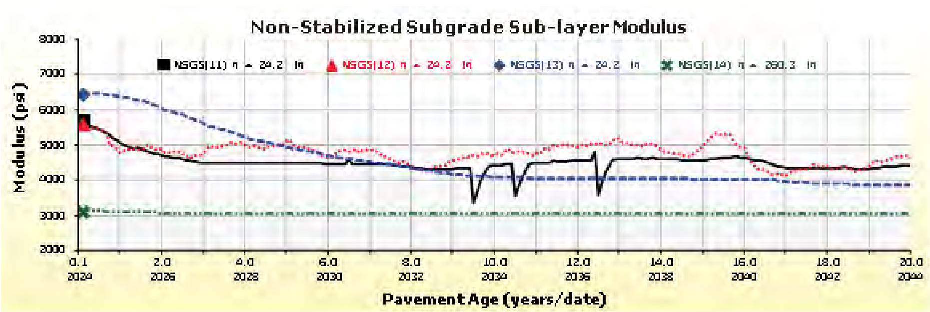
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
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?	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)	3.0	
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	15

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	4.0
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)
21000.0

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 : River-run gravel

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	River-run 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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

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

AASHTO 1993 20-YEAR DESIGN LIFE OUTPUT – NEW PAVEMENT

26.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Projec

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi) = 6,482

2,020,000 = Design Life ESALs

SN = 3.935 = Required SN when B equals (or slightly exceeds) A

$\text{Log}_{10}\text{ESAL}$ = A = 6.30535

=

Thickness Equation= B = 6.30538 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.94
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Composite HMA over ABC
(using specified layer of ABC)
Inches of ABC = 16.0
Calculated Inches of HMA = 5.31 Use 5.5 inches

Table 1.4 Reliability and Standard Normal Deviate

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

B.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

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) for Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,160,000 = Design Life ESALs

SN = 3.975 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.33445

=

Thickness Equation= B = 6.33491 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44

Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 9.03
FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

(Use Table 1.4 from CDOT Pavement Design Manual)

Composite HMA over ABC
(using specified layer of ABC)

Inches of ABC = 16.0

Calculated Inches of HMA = 5.40 Use 5.5 inches

Table 1.4 Reliability and Standard Normal Deviate

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

RockSol Consulting Group, Inc.

D.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi) = 6,482

2,030,000 = Design Life ESALs

SN = 3.938 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.30750

=

Thickness Equation= B = 6.30760 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44

Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.95
FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

(Use Table 1.4 from CDOT Pavement Design Manual)

Composite HMA over ABC
(using specified layer of ABC)

Inches of ABC = 16.0

Calculated Inches of HMA = 5.31 Use 5.5 inches

Table 1.4 Reliability and Standard Normal Deviate

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

F.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

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) for Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi) = 6,482

680,000 = Design Life ESALs

SN = 3.335 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 5.83251

=

Thickness Equation= B = 5.83271 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44

Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 7.58

FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

(Use Table 1.4 from CDOT Pavement Design Manual)

Composite HMA over ABC
(using specified layer of ABC)

Inches of ABC = 16.0

Calculated Inches of HMA = 3.94 Use 4 inches

Table 1.4 Reliability and Standard Normal Deviate

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

RockSol Consulting Group, Inc.

RockSol Project No. 599.70

APPENDIX G

PMED 20-YEAR DESIGN LIFE OUTPUT – MILL AND OVERLAY REHABILITATION

26.5 Road 2 inch mill and 3 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\26.5 Road 2 inch mill and 3 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	3.0
Flexible (existing)	Default asphalt concrete	5.0
NonStabilized	Crushed stone	5.0
Subgrade	A-4	48.0
Bedrock	Highly fractured and weathered	Semi-infinite

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

Traffic

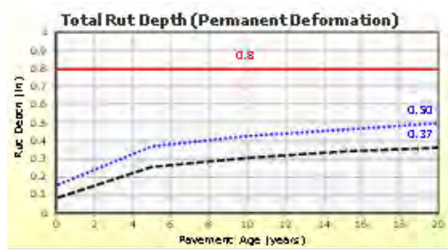
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	650
2034 (10 years)	1,490,320
2044 (20 years)	3,136,550

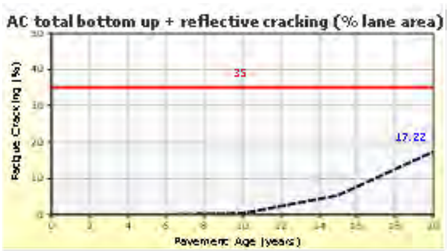
Design Outputs

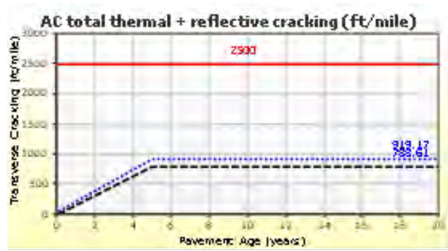
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	179.83	90.00	96.71	Pass
Permanent deformation - total pavement (in)	0.80	0.50	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	17.22	50.00	97.68	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	919.17	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.35	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1530.31	90.00	99.44	Pass

Distress Charts



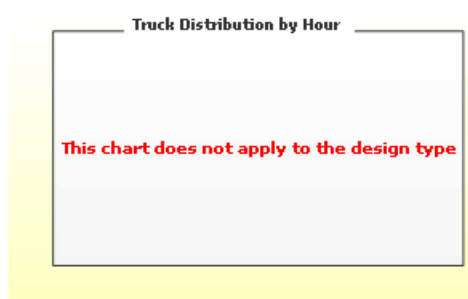


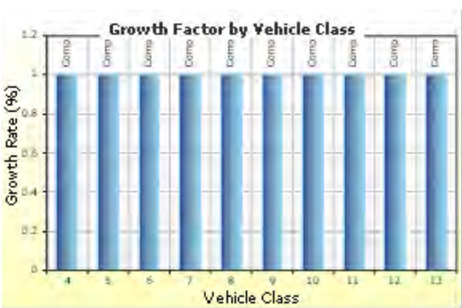


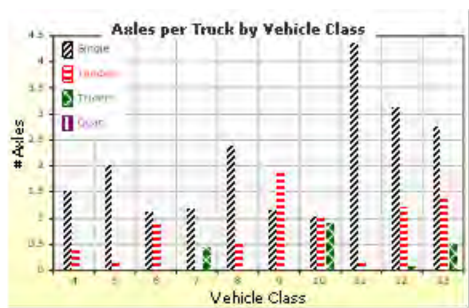
Traffic Inputs

Graphical Representation of Traffic Inputs

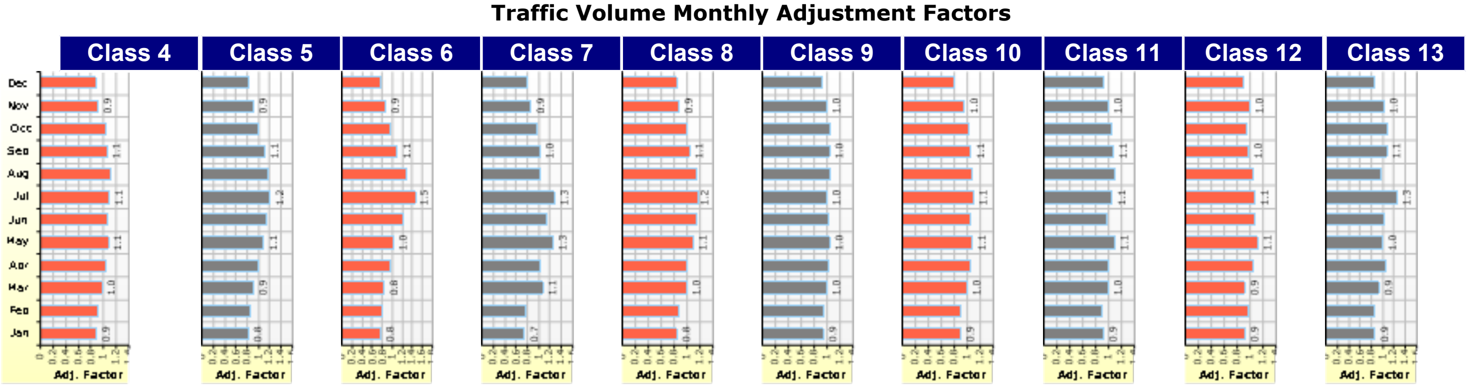
Initial two-way AADTT:	650	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

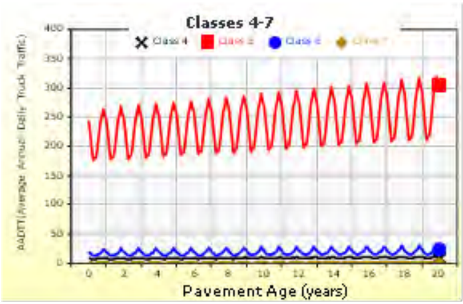
Wheelbase does not apply

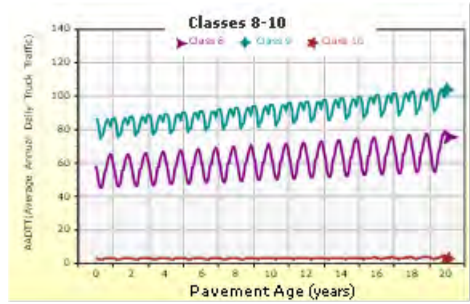
Number of Axles per Truck

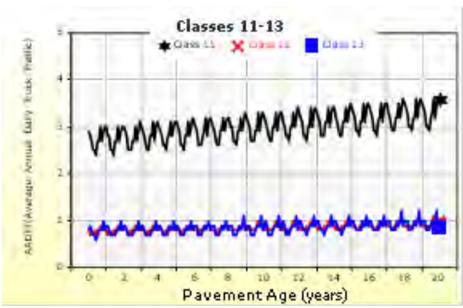
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

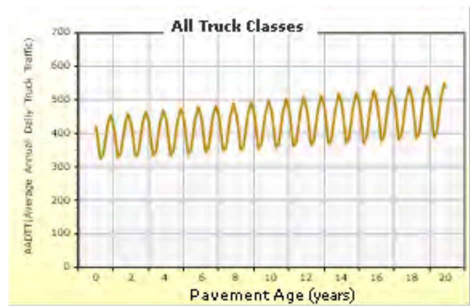
AADTT (Average Annual Daily Truck Traffic) Growth

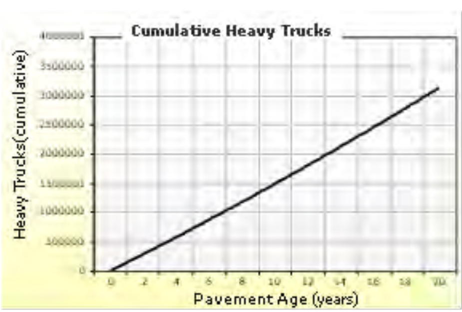
*** Traffic cap is not enforced**







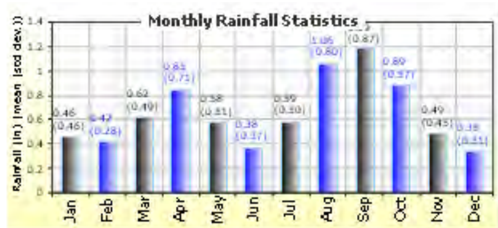




Climate Inputs

Climate Data Sources:

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

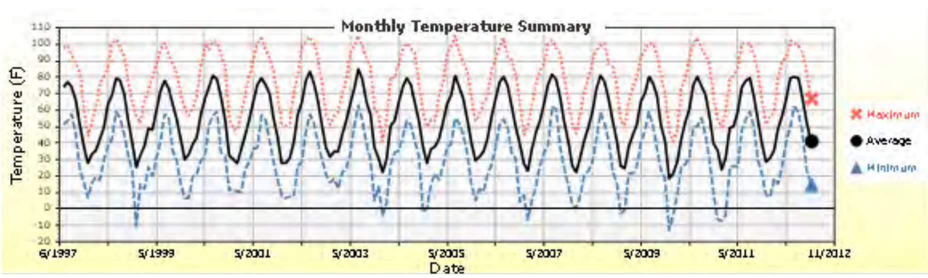


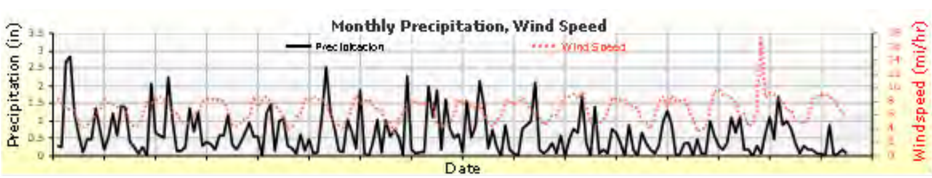
Annual Statistics:

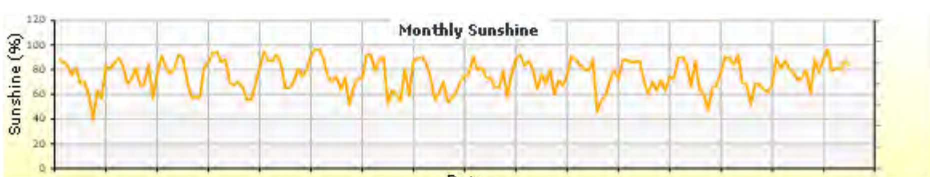
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

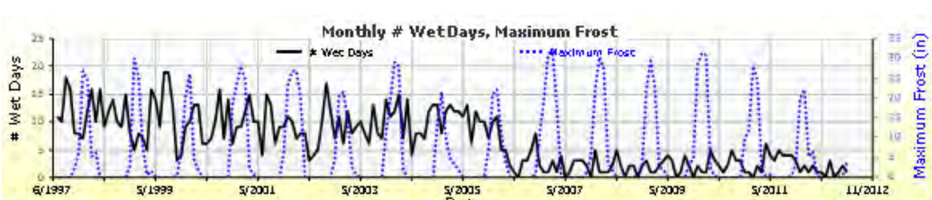
Water table depth (ft) 10.00

Monthly Climate Summary:

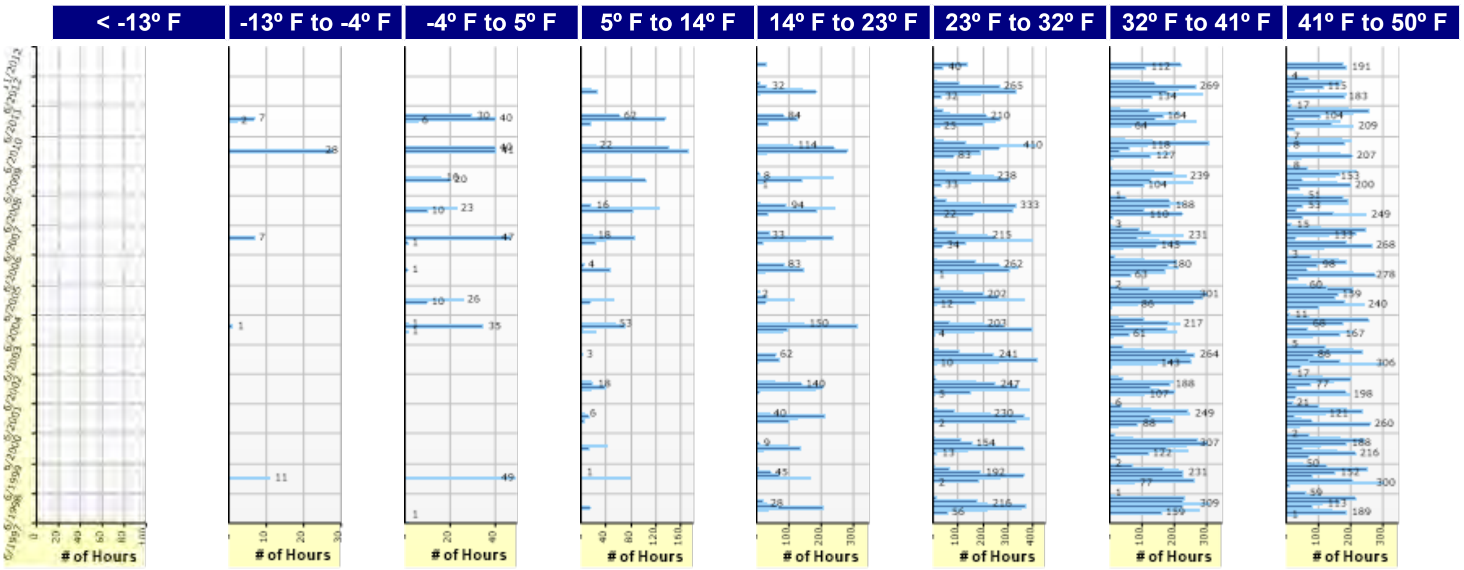


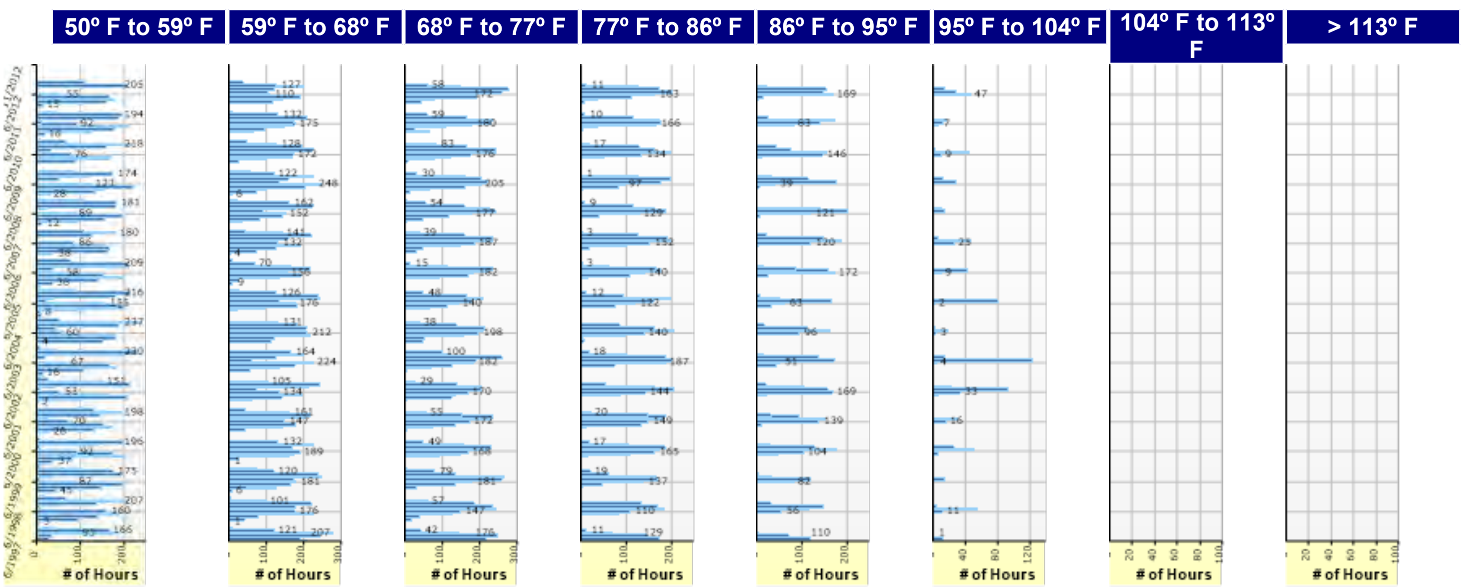






Hourly Air Temperature Distribution by Month:





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 : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	1.00
Layer 5 Bedrock : Highly fractured and weathered	Bedrock (6)	-

HMA Rehabilitation (Input Level: 2)

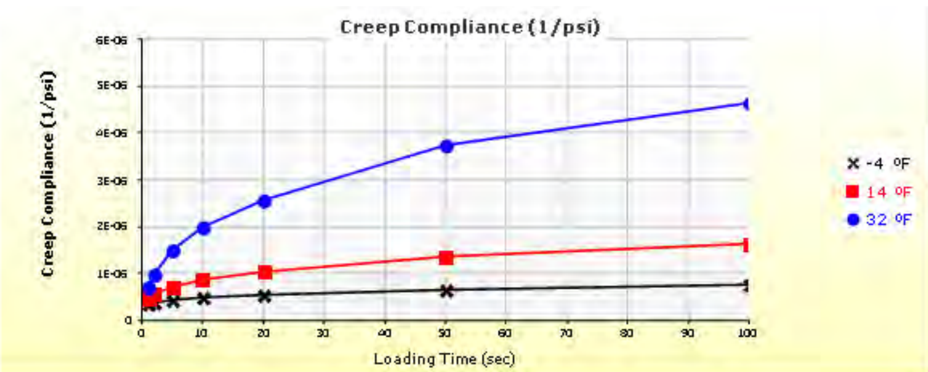
Milled thickness (in)	2.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	1052.00 (Medium)
Total rut depth (in)	-

Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 4 Subgrade : A-4	Subgrade (5)	0.00
Layer 5 Bedrock : Highly fractured and weathered	Bedrock (6)	0.00

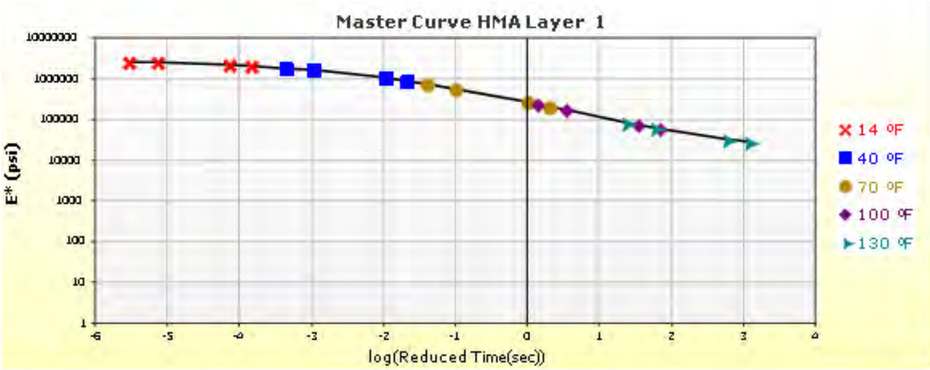
Thermal Cracking (Input Level: 1)

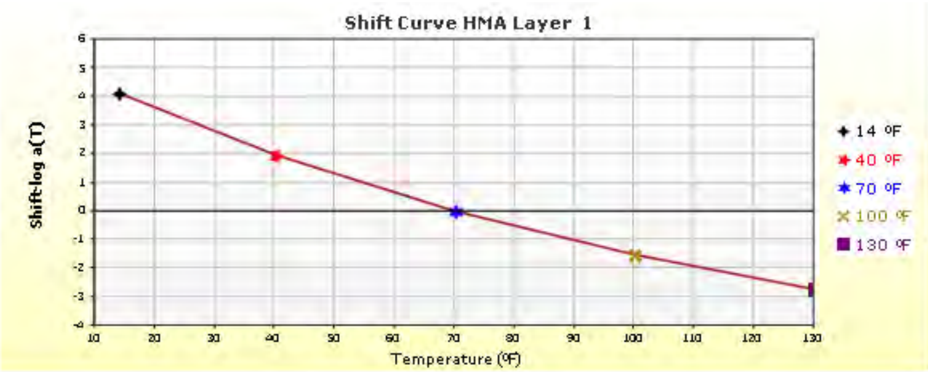
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

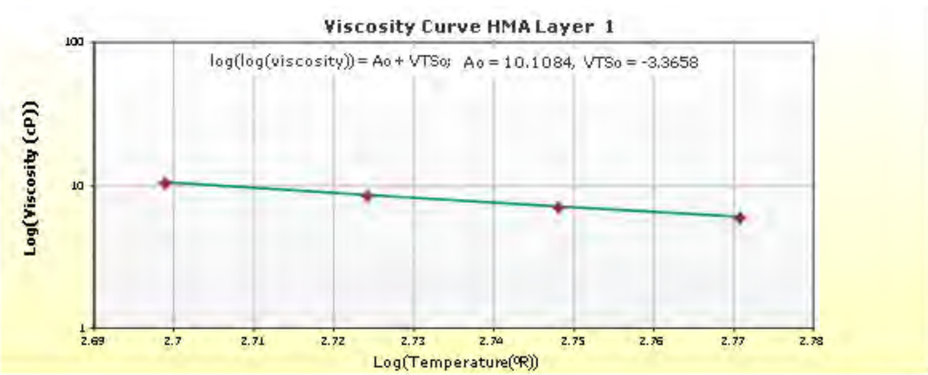
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



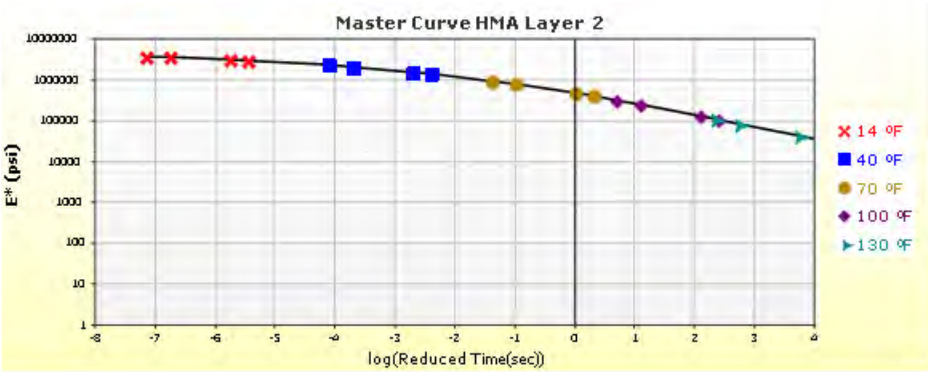
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

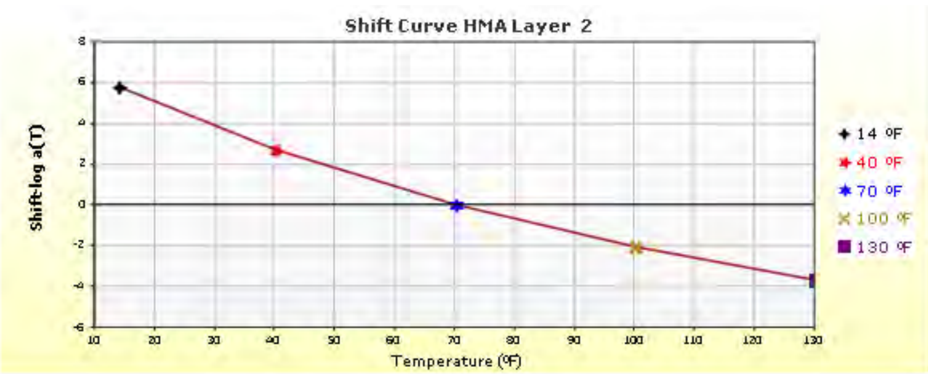


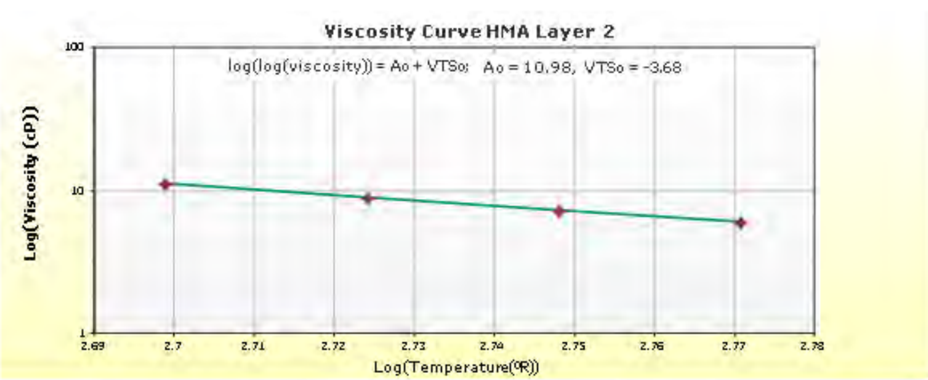




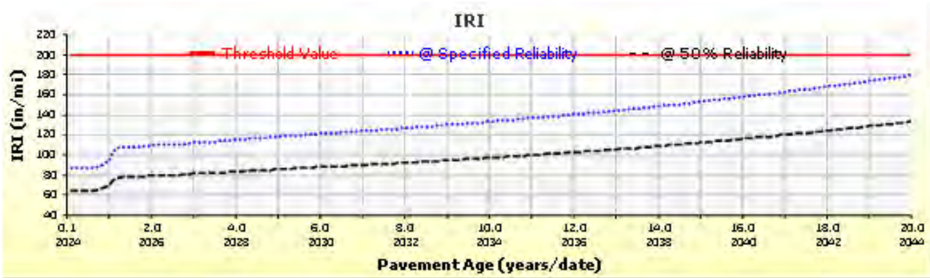
HMA Layer 2: Layer 2 Flexible : Default asphalt concrete(existing)

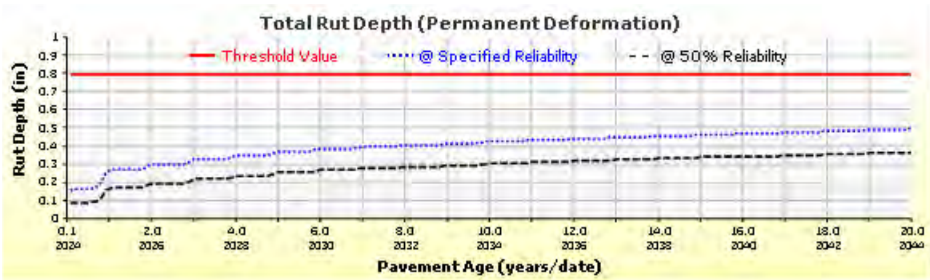


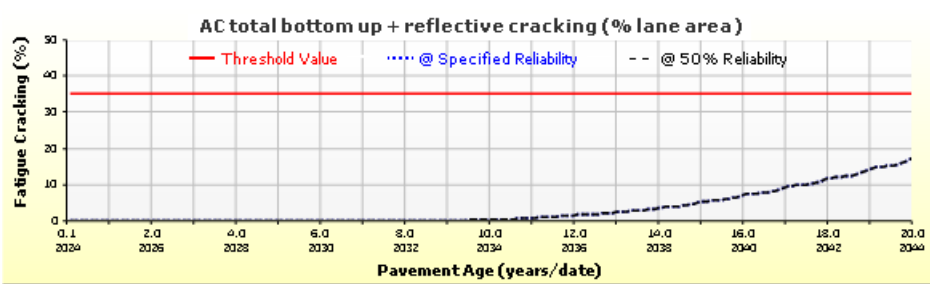


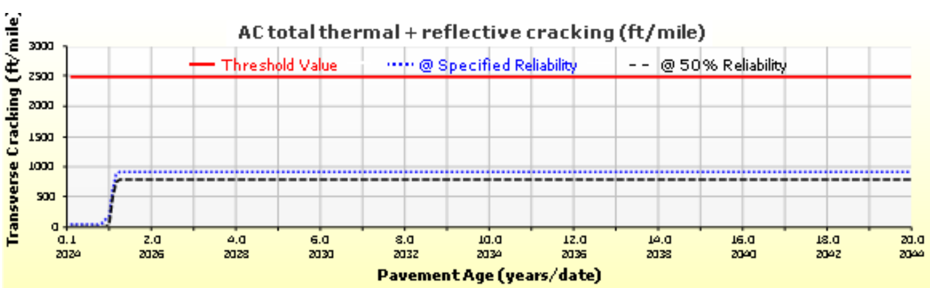


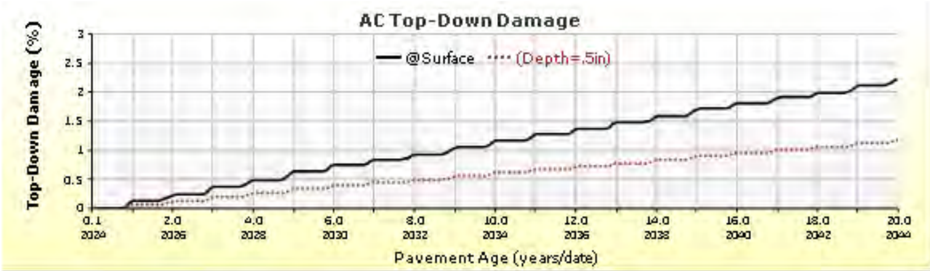
Analysis Output Charts

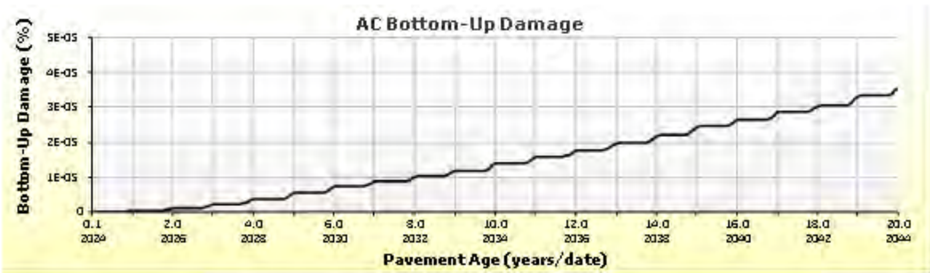


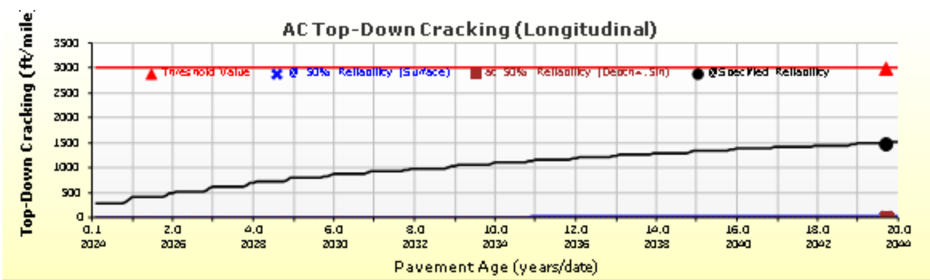


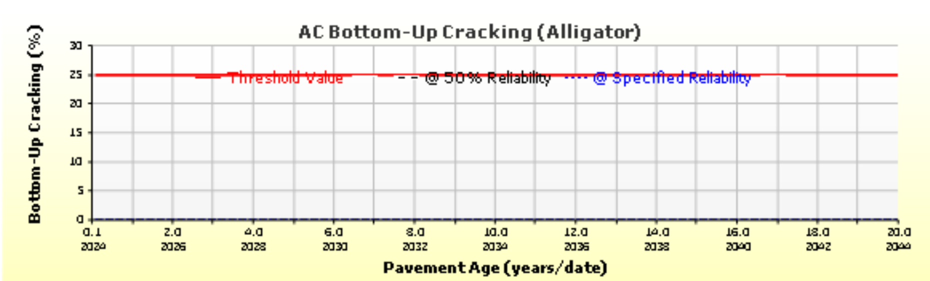


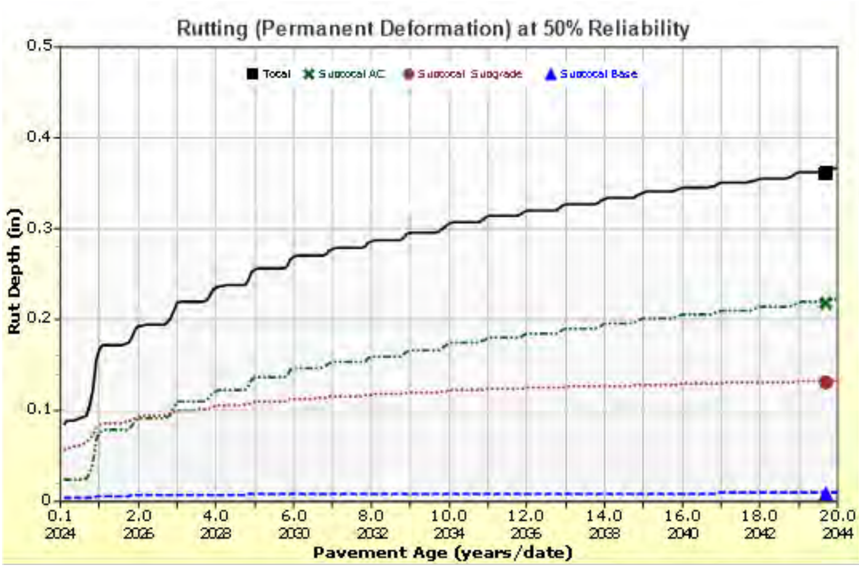



AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)

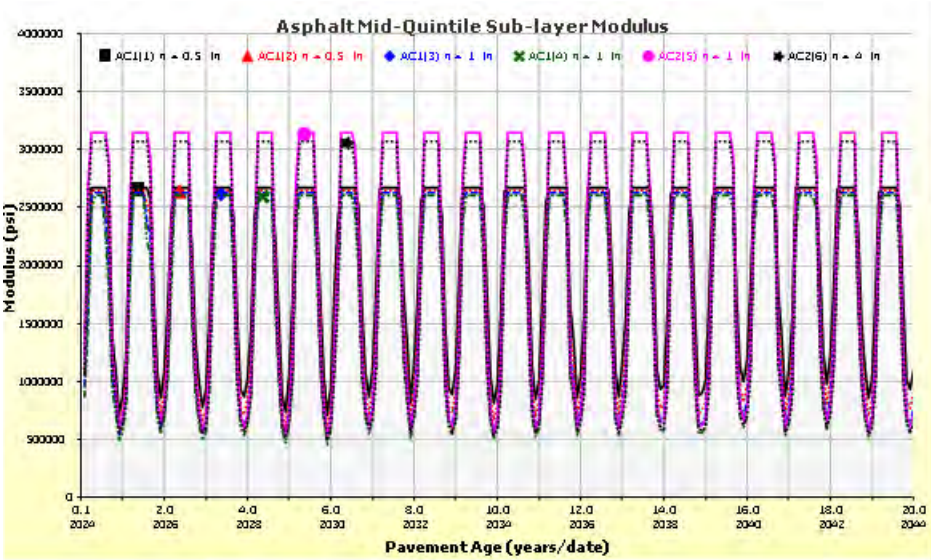

AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

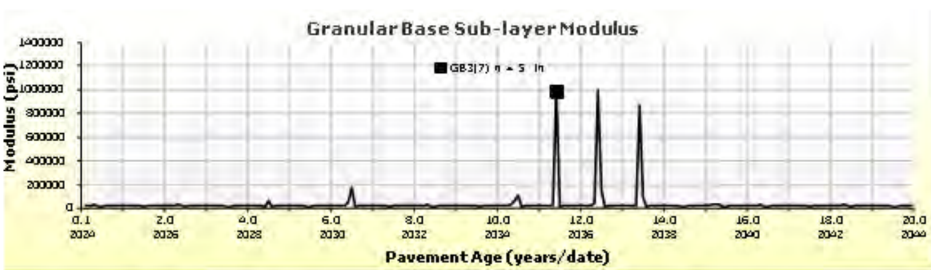

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)

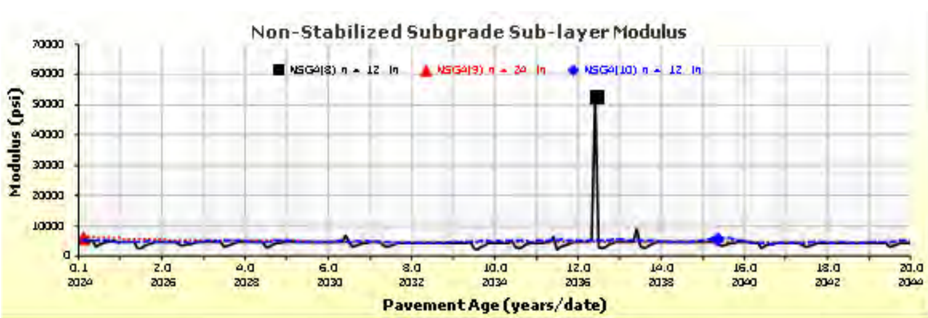

AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
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
AC1(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 = 5 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 12 in
NSG4(9) h = 24 in
NSG4(10) h = 12 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	3.0	
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 : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	5.0
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)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
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 Subgrade : A-4

Unbound	
Layer thickness (in)	48.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 5 Bedrock : Highly fractured and weathered

Bedrock	
Layer thickness(in)	Semi-infinite
Poisson's ratio	0.15
Unit weight (pcf)	140

Strength	
Elastic/resilient modulus (psi)	500000

Identifiers

Field	Value
Display name/identifier	Highly fractured and weathered
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

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

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

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

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

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

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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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				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			
$FC_{ctb} = C_1 + \frac{C_2}{1+e^{C_3 - C_4(Damage)}}$			
C1: 0	C2: 75	C3: 5	C4: 3
CSM Standard Deviation			
CTB*11			

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

B.5 Road 2 inch mill and 3.5 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\B.5 Road 2 inch mill and 3.5 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	3.5
Flexible (existing)	Default asphalt concrete	4.5
NonStabilized	Crushed stone	5.5
Subgrade	A-6	Semi-infinite

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

Traffic

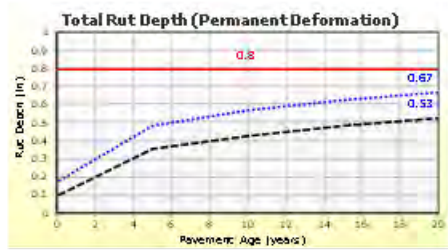
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	695
2034 (10 years)	1,593,490
2044 (20 years)	3,353,700

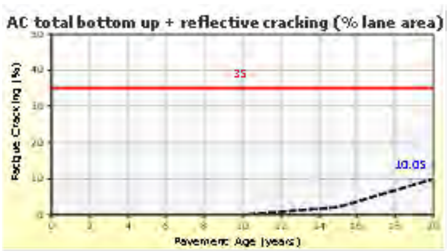
Design Outputs

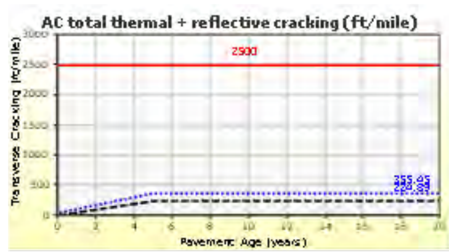
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	178.71	90.00	97.00	Pass
Permanent deformation - total pavement (in)	0.80	0.67	90.00	99.23	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	10.05	50.00	99.99	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	355.45	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.48	90.00	99.80	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1033.83	90.00	99.99	Pass

Distress Charts





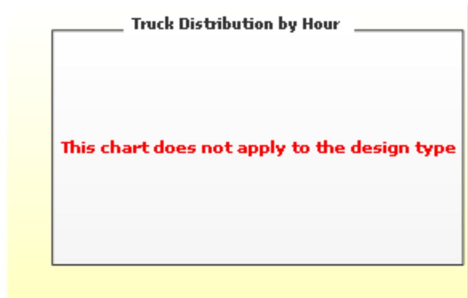


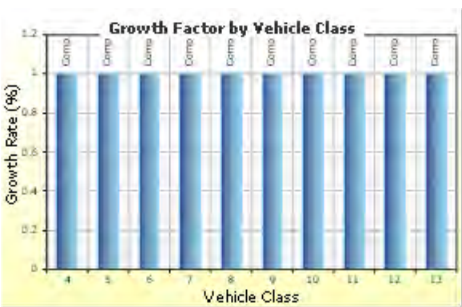
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

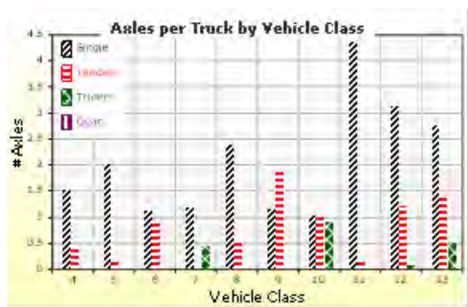
Traffic Inputs

Graphical Representation of Traffic Inputs

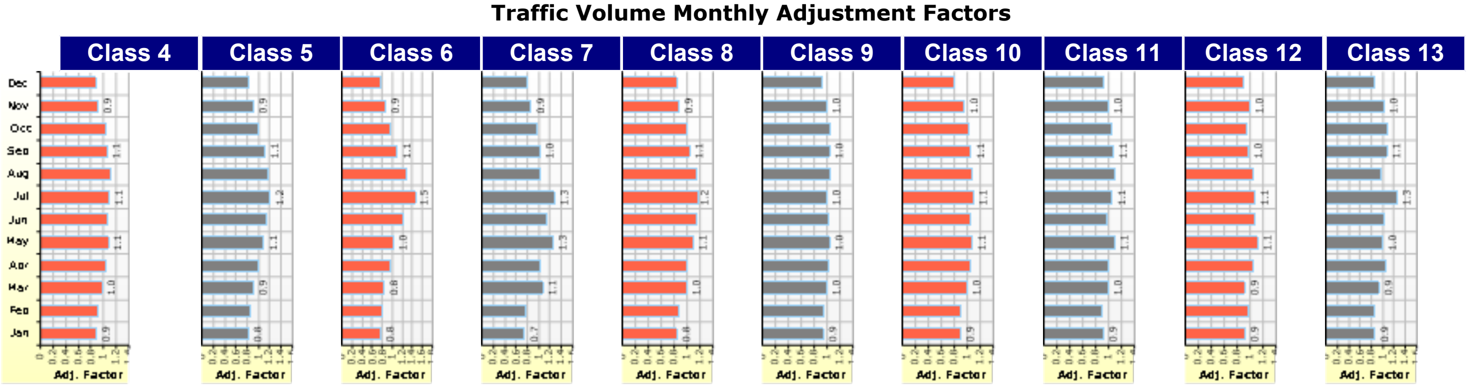
Initial two-way AADTT:	695	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

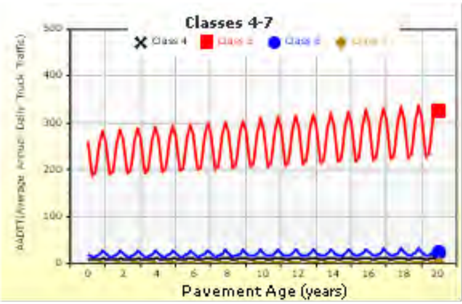
Wheelbase does not apply

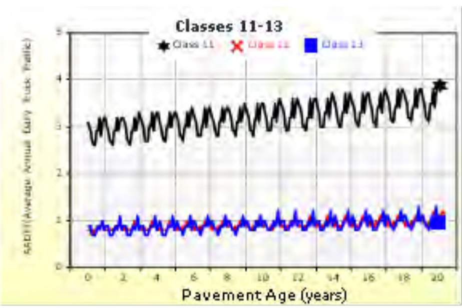
Number of Axles per Truck

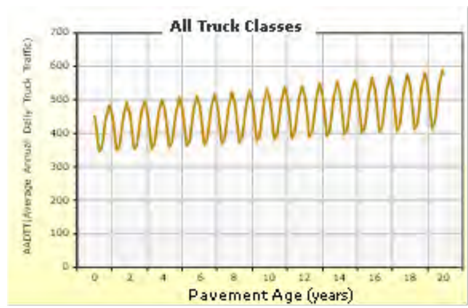
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

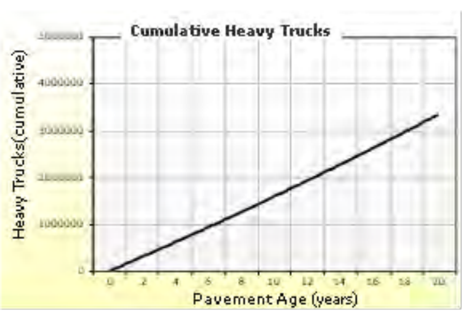
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





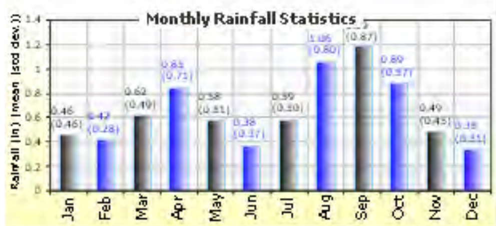




Climate Inputs

Climate Data Sources:

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

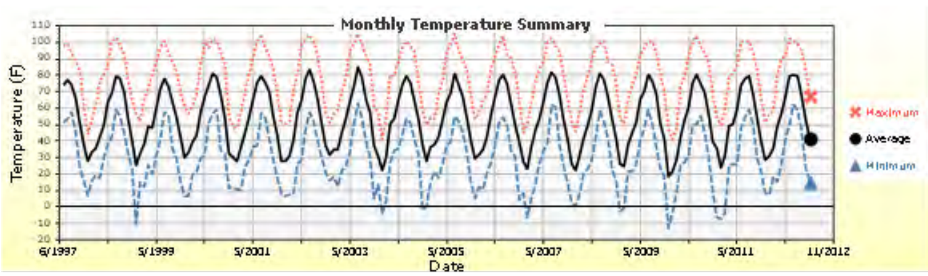


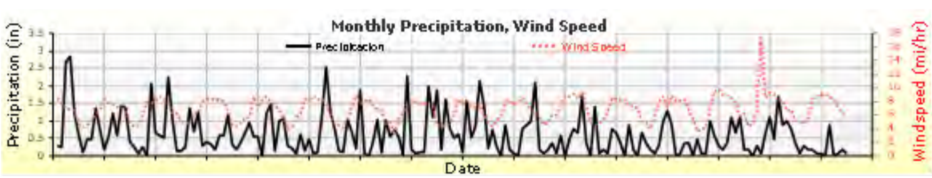
Annual Statistics:

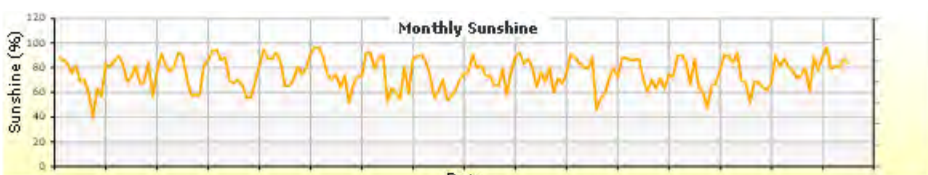
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

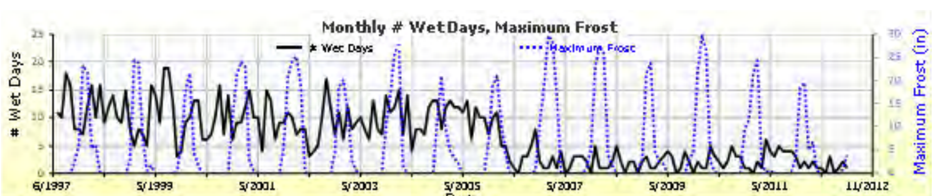
Water table depth (ft) 10.00

Monthly Climate Summary:

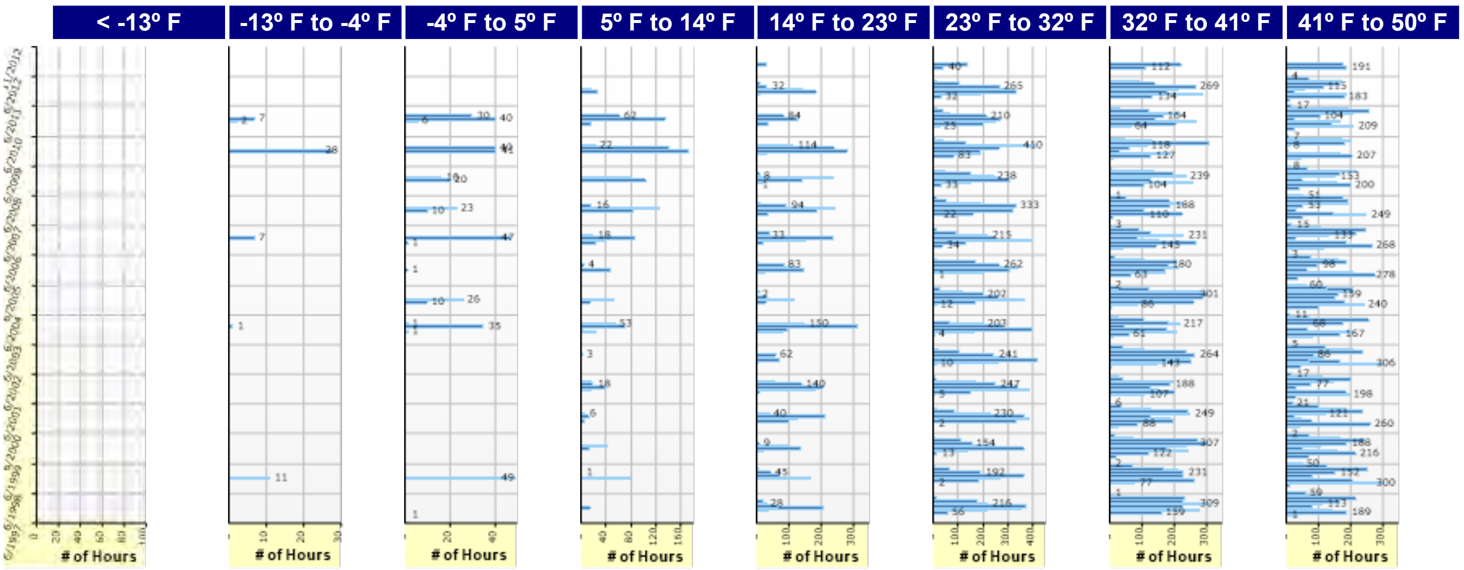


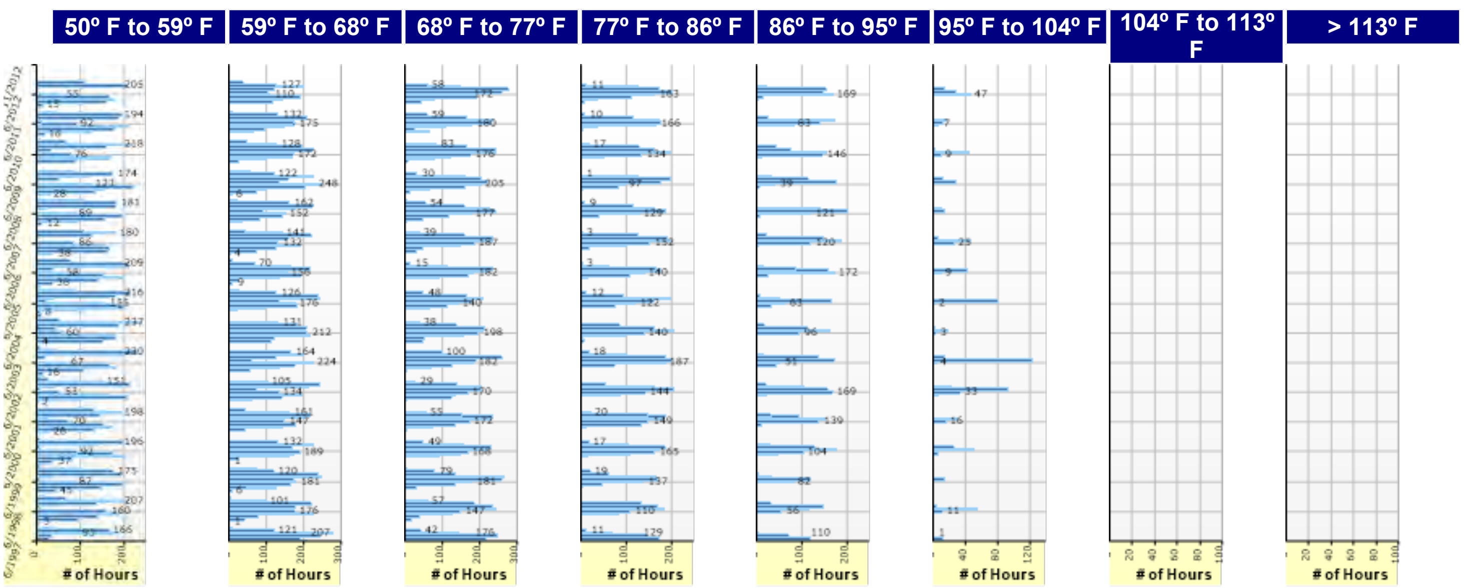






Hourly Air Temperature Distribution by Month:





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 : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-6	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

Milled thickness (in)	2.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	300.00 (Medium)
Total rut depth (in)	-

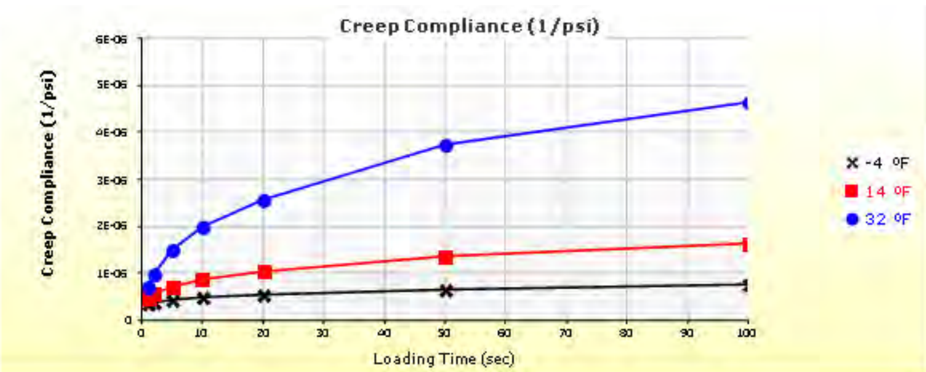
Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 4 Subgrade : A-6	Subgrade (5)	0.00

Thermal Cracking (Input Level: 1)

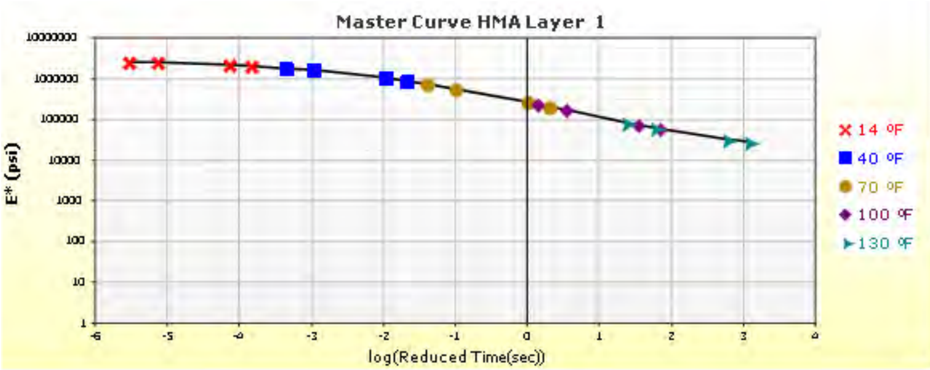
Indirect tensile strength at 14 ºF (psi)	519.00

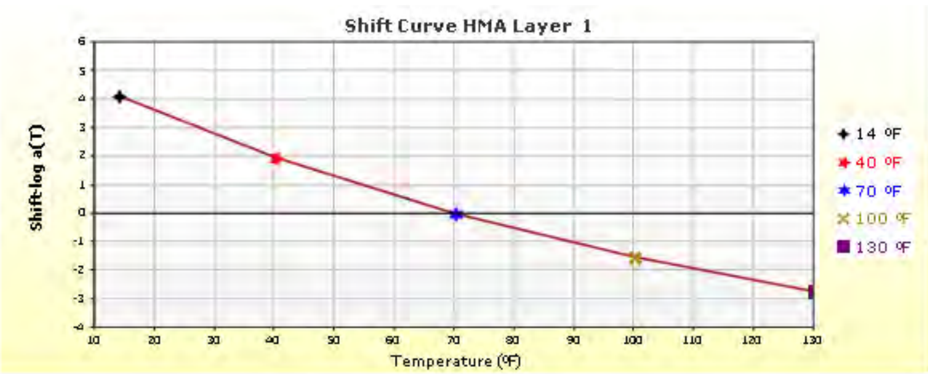
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

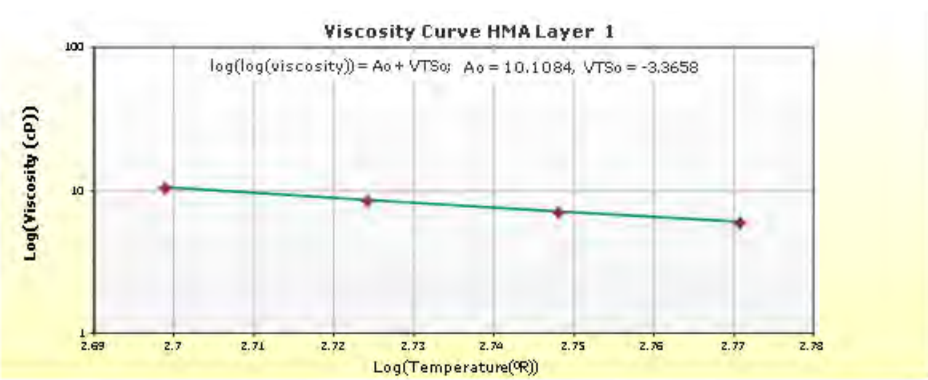
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



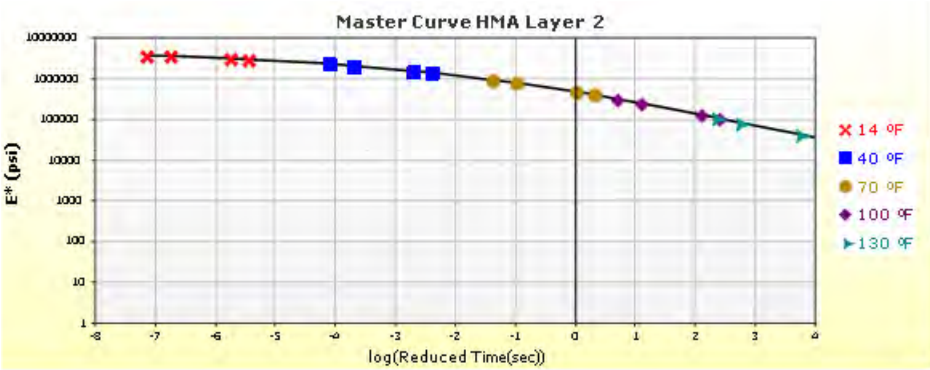
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

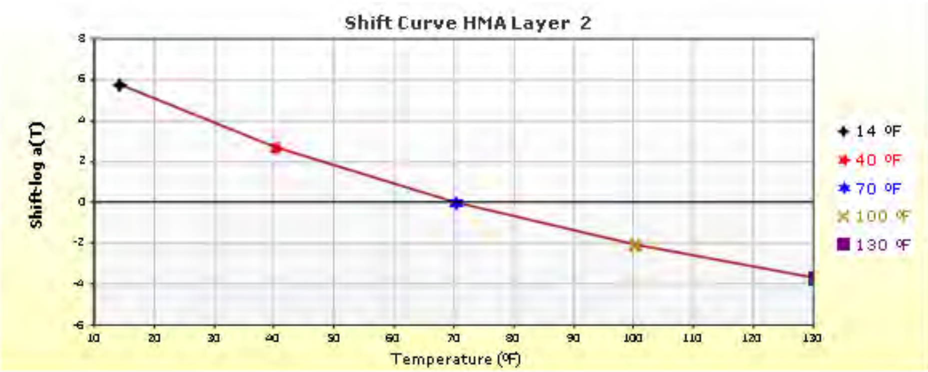


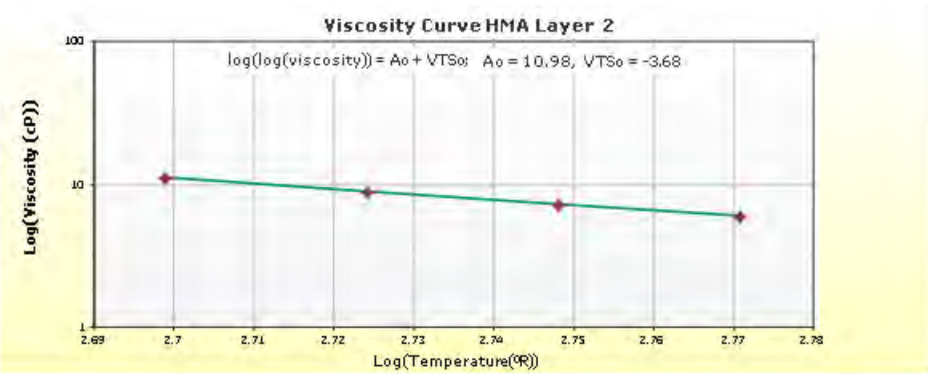




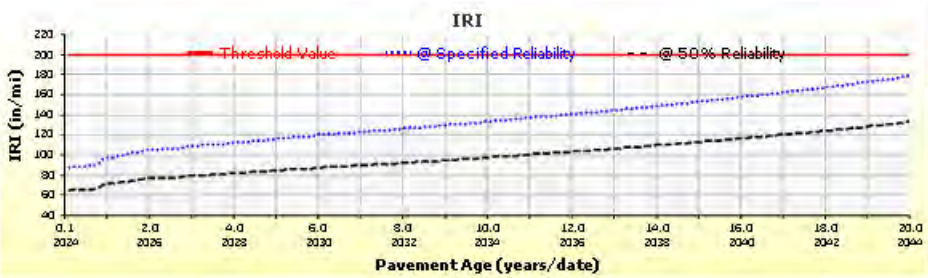
HMA Layer 2: Layer 2 Flexible : Default asphalt concrete(existing)

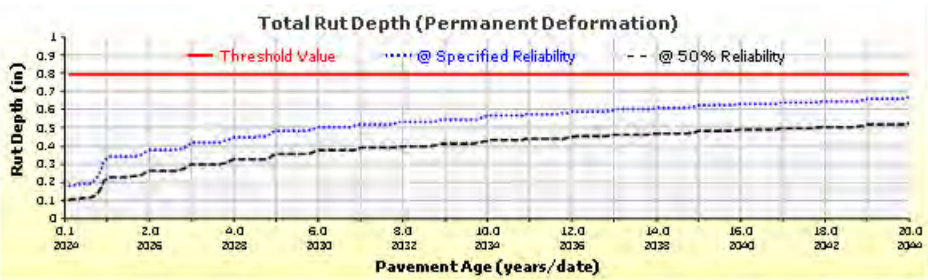


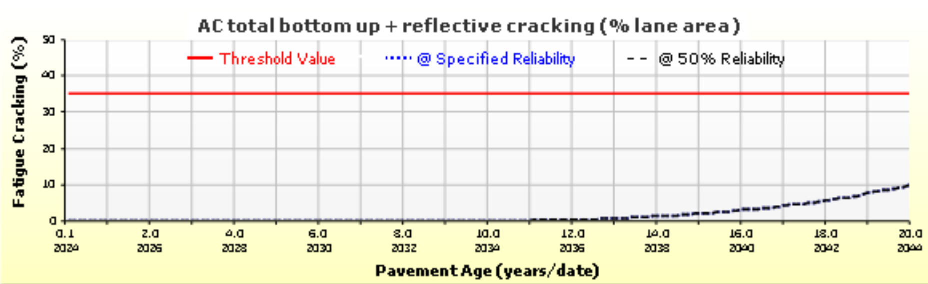


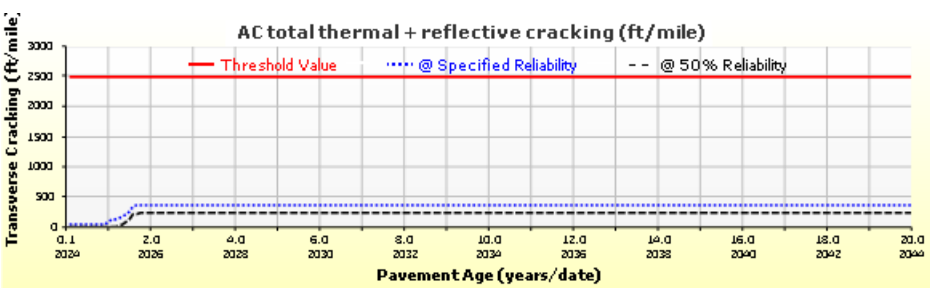


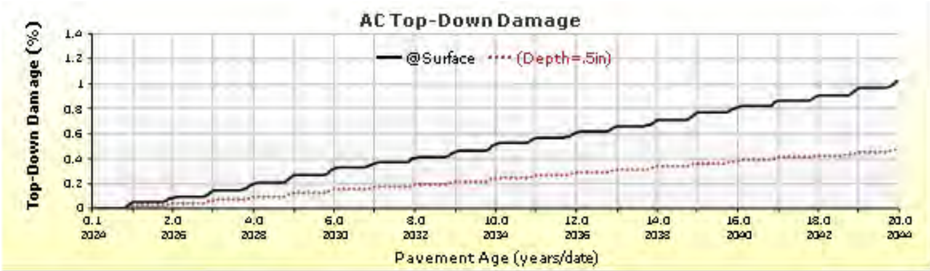
Analysis Output Charts



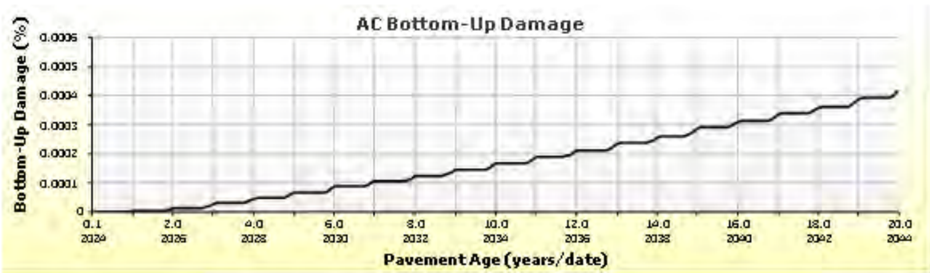




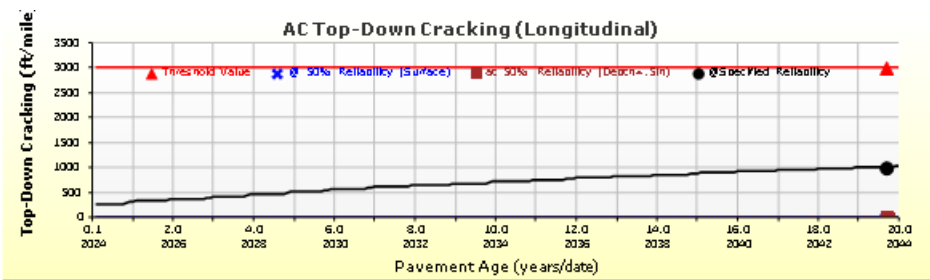




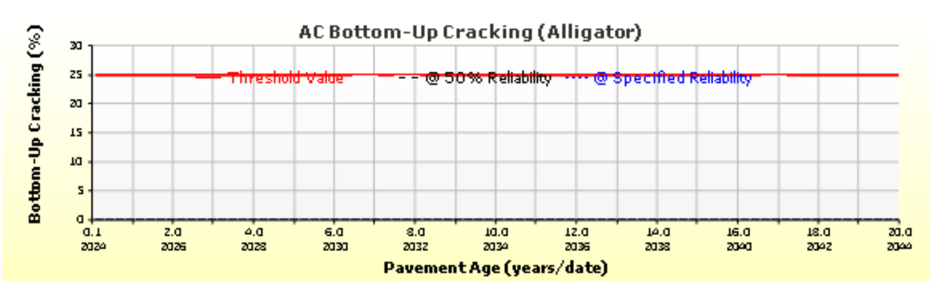
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



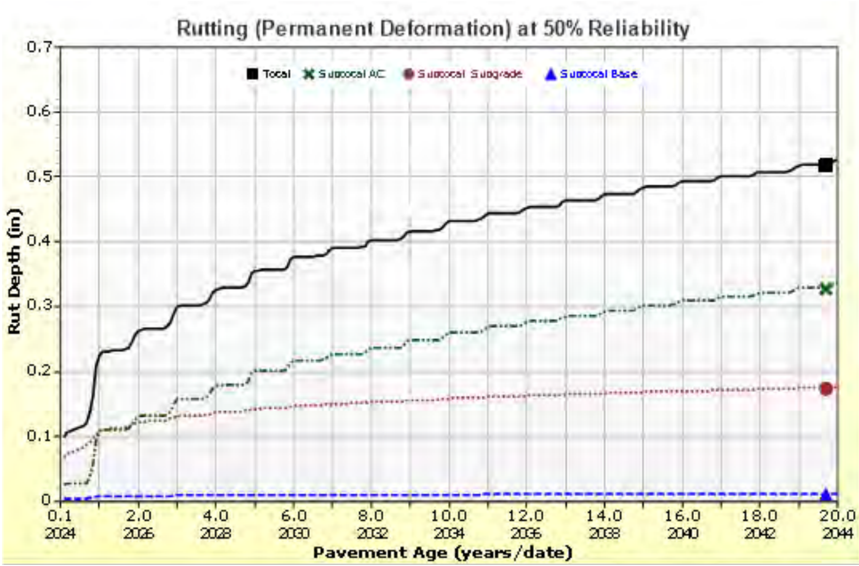
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



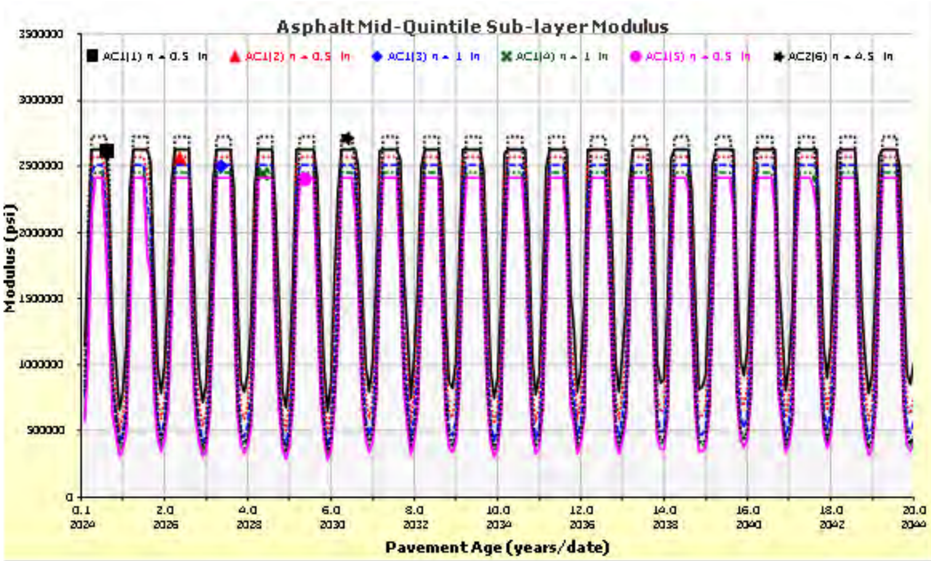
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)



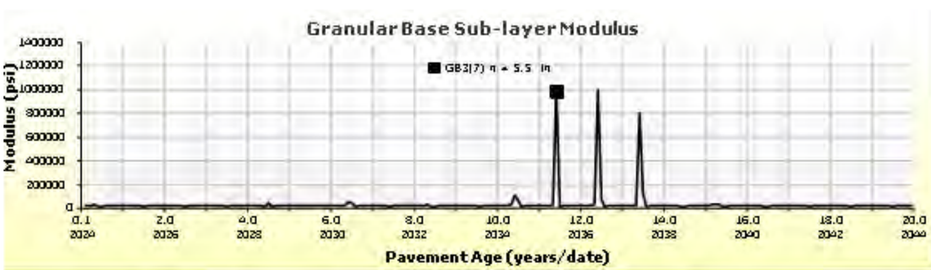
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



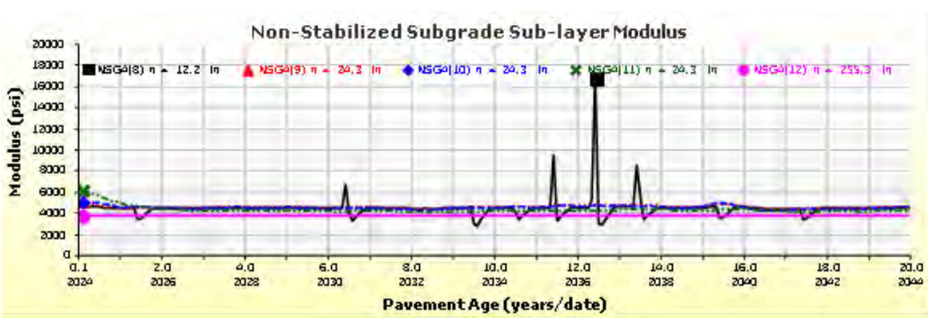
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



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



Granular Base Sub-layer Modulus
GB3(7) h = 5.5 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 12.2 in
NSG4(9) h = 24.3 in
NSG4(10) h = 24.3 in
NSG4(11) h = 24.3 in
NSG4(12) h = 255.3 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	3.5	
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	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 : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	4.5	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	5.5
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)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
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 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)
6482.0

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

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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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

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

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: 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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

D.5 Road 2 inch mill and 2.5 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\D.5 Road 2 inch mill and 2.5 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.5
Flexible (existing)	Default asphalt concrete	6.5
NonStabilized	Crushed stone	5.0
Subgrade	A-4	Semi-infinite

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

Traffic

Age (year)	Heavy Trucks (cumulative)
2024 (initial)	655
2034 (10 years)	1,501,780
2044 (20 years)	3,160,680

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	176.62	90.00	97.41	Pass
Permanent deformation - total pavement (in)	0.80	0.67	90.00	99.37	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	9.28	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	430.41	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.44	90.00	99.94	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	433.30	90.00	100.00	Pass

D.5 Road 2 inch mill and 2.5 inch Overlay

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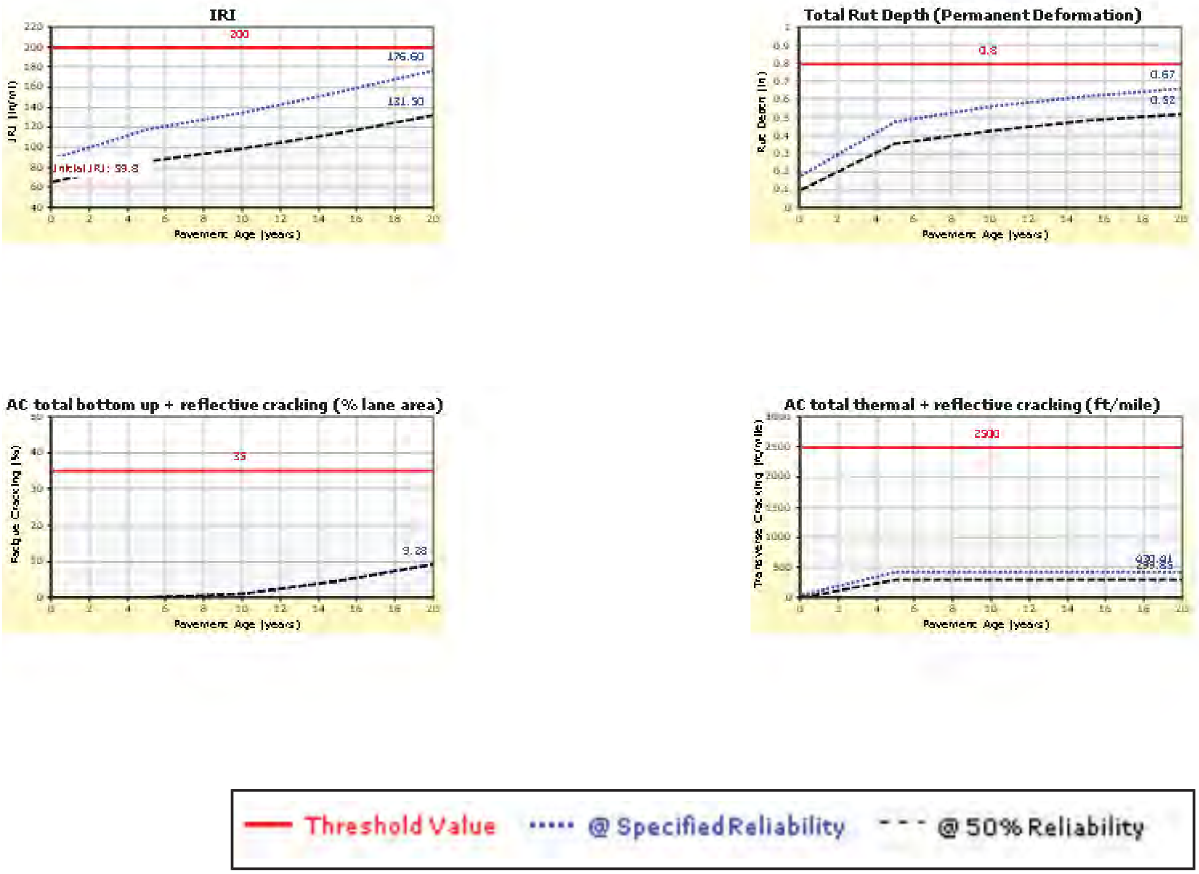
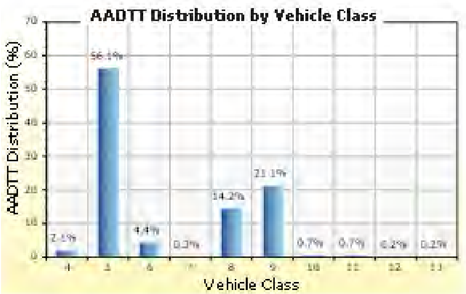
Distress Charts

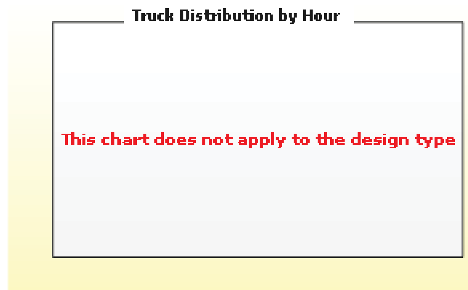


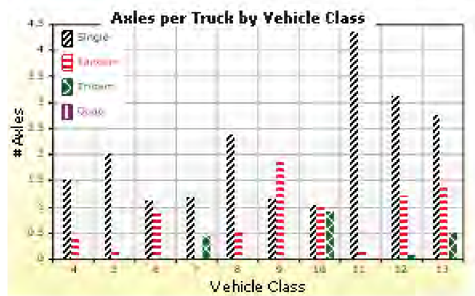
Traffic Inputs

Graphical Representation of Traffic Inputs

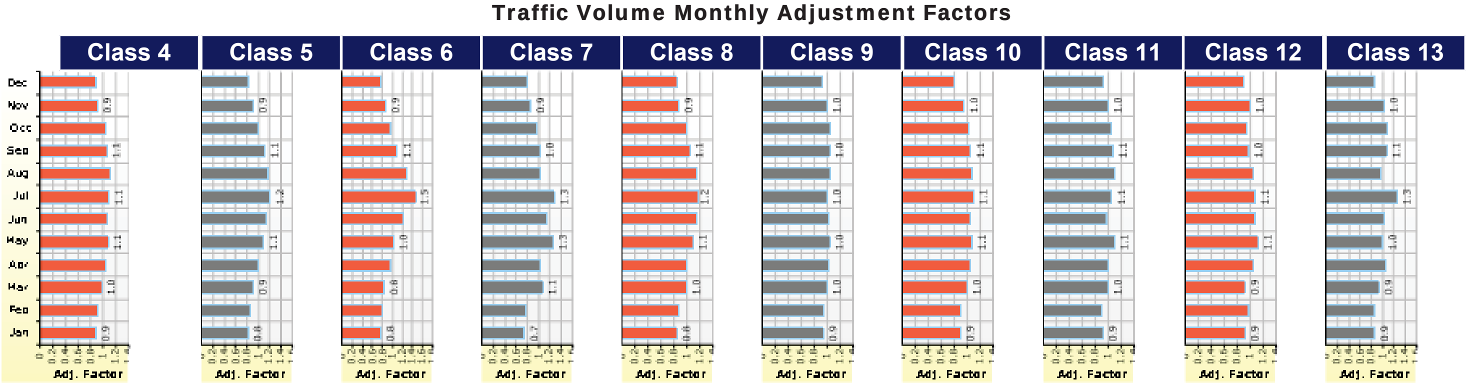
Initial two-way AADTT:	655	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

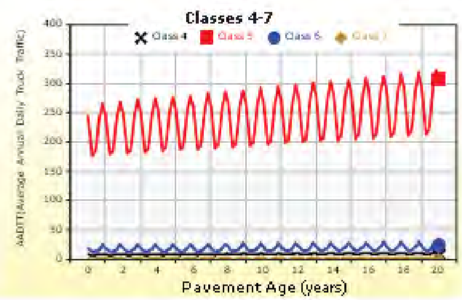
Wheelbase does not apply

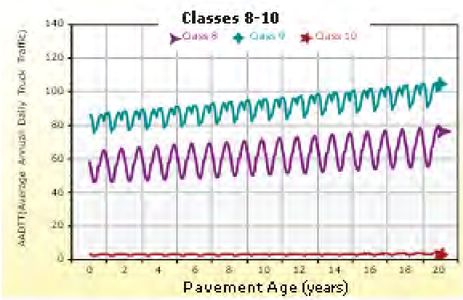
Number of Axles per Truck

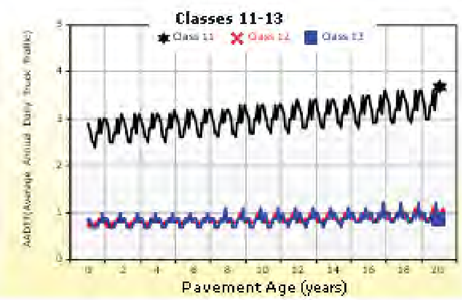
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

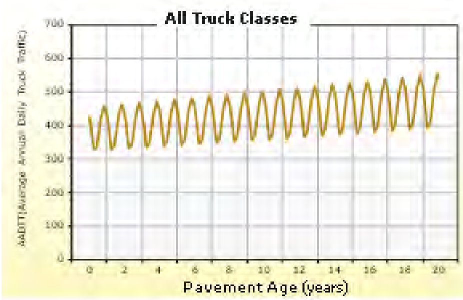
AADTT (Average Annual Daily Truck Traffic) Growth

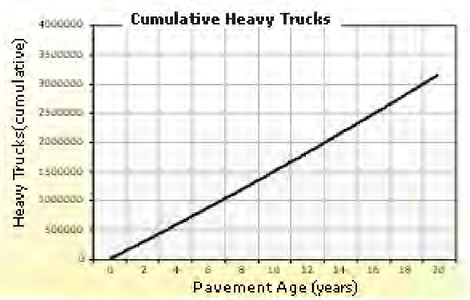
*** Traffic cap is not enforced**







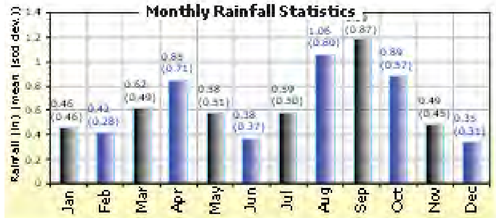




Climate Inputs

Climate Data Sources:

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

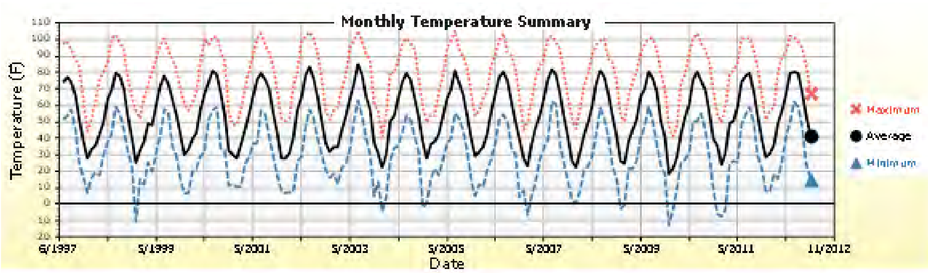


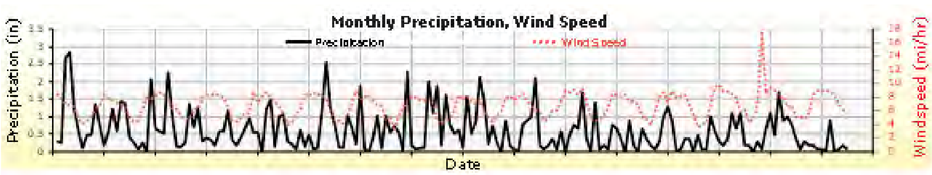
Annual Statistics:

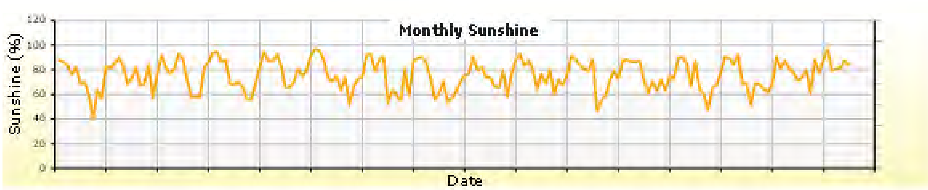
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

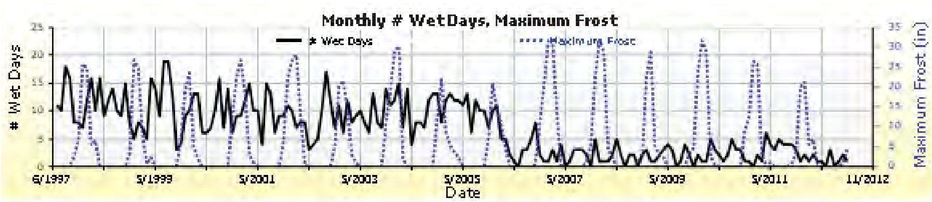
Water table depth (ft) 10.00

Monthly Climate Summary:

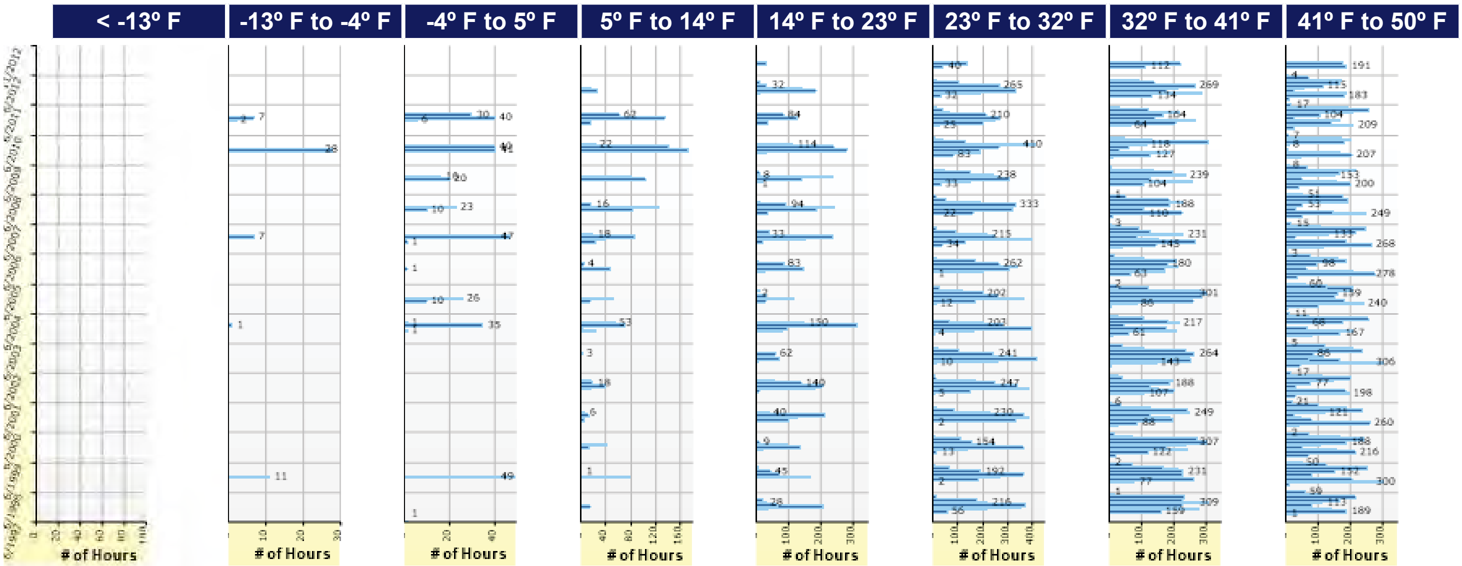


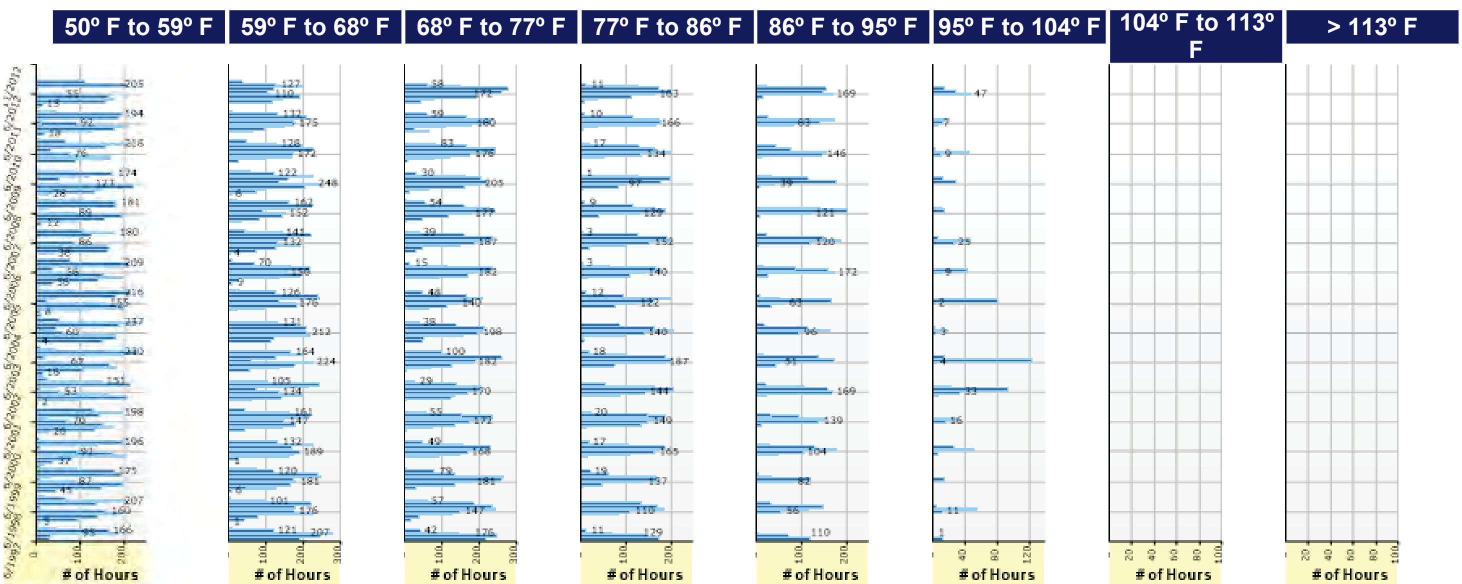






Hourly Air Temperature Distribution by Month:





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 : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

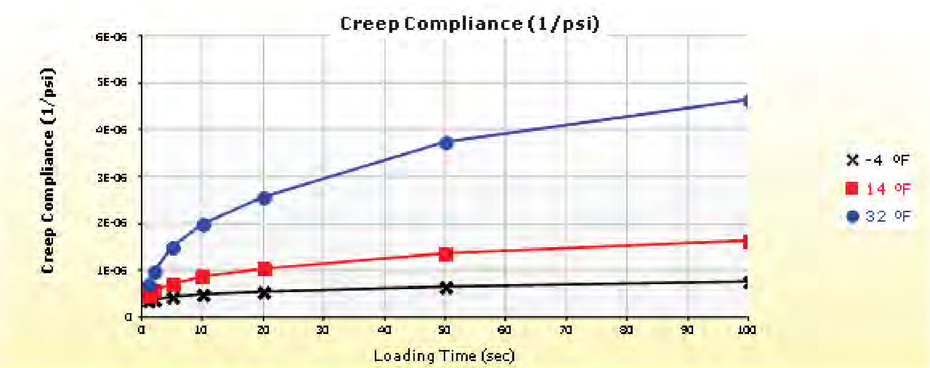
Milled thickness (in)	2.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	400.00 (Medium)
Total rut depth (in)	-

Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 4 Subgrade : A-4	Subgrade (5)	0.00

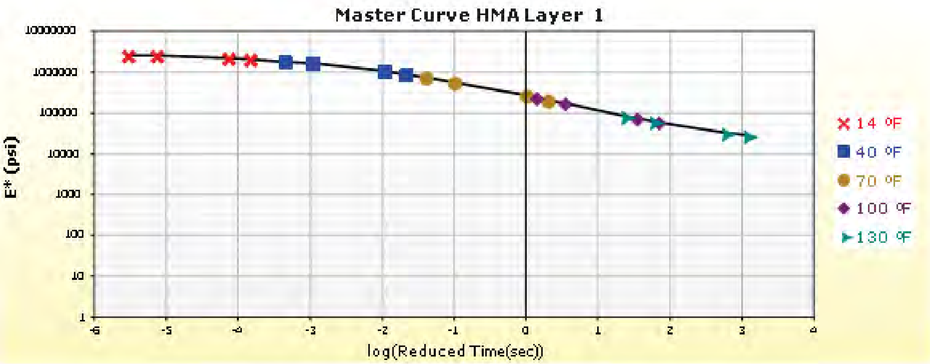
Thermal Cracking (Input Level: 1)

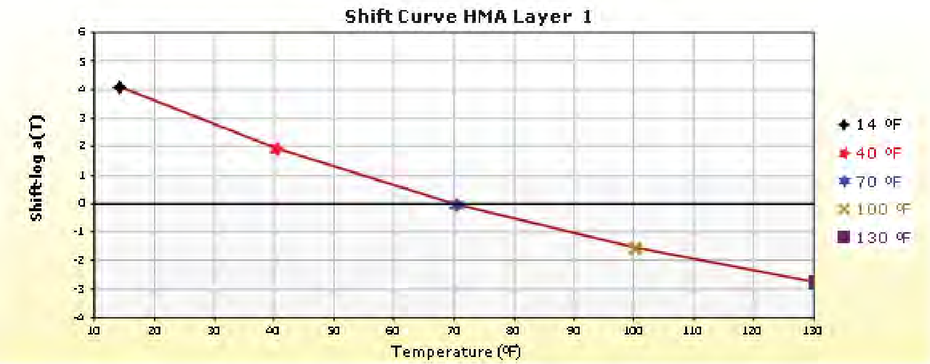
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

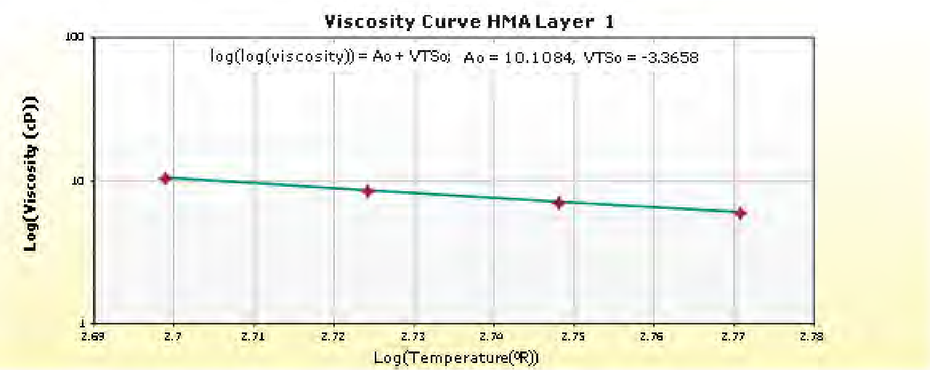
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



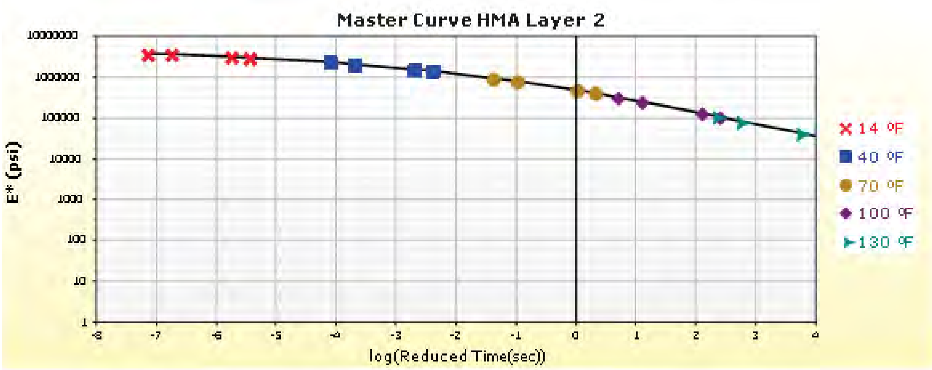
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

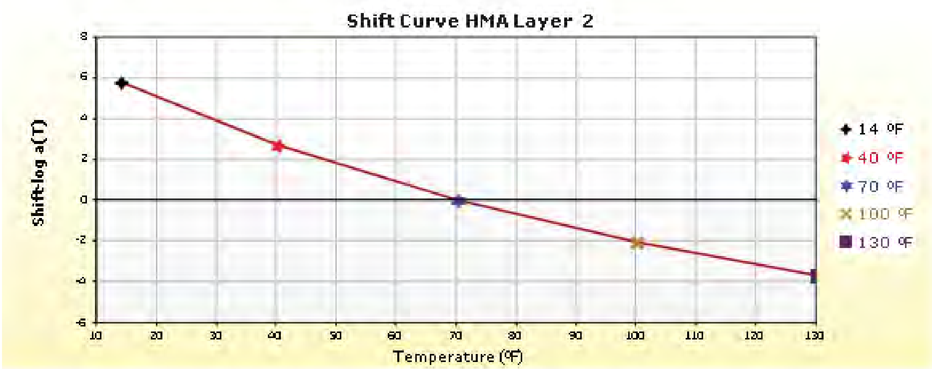


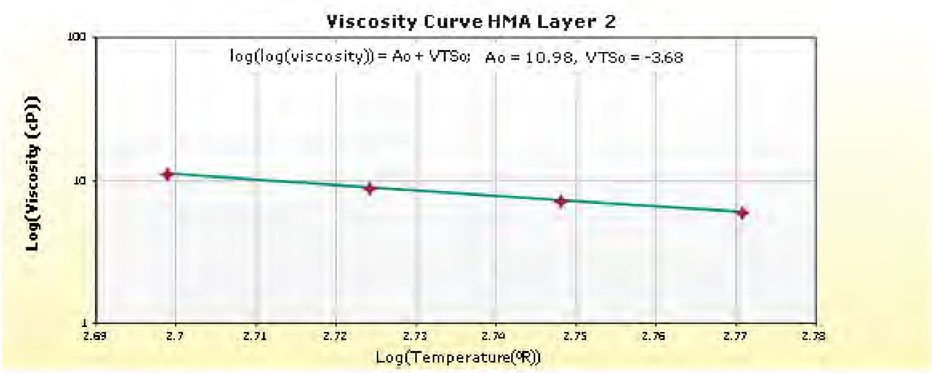




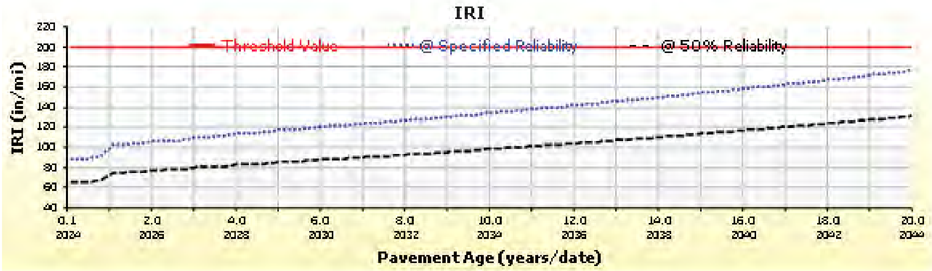
HMA Layer 2: Layer 2 Flexible : Default asphalt concrete(existing)

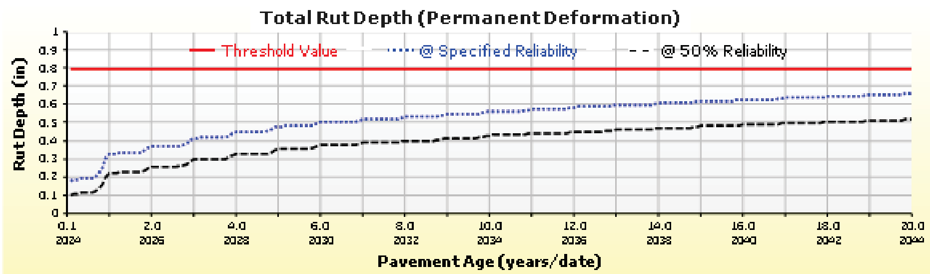


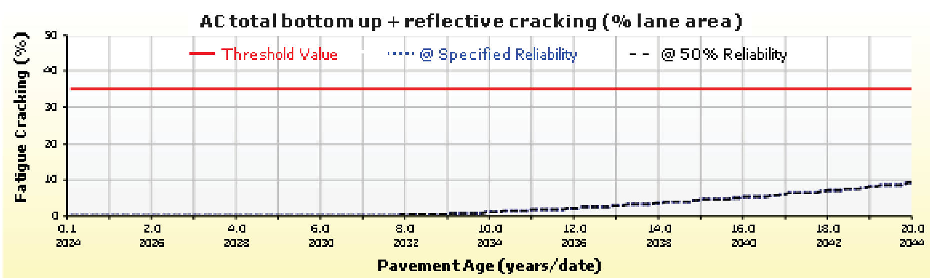


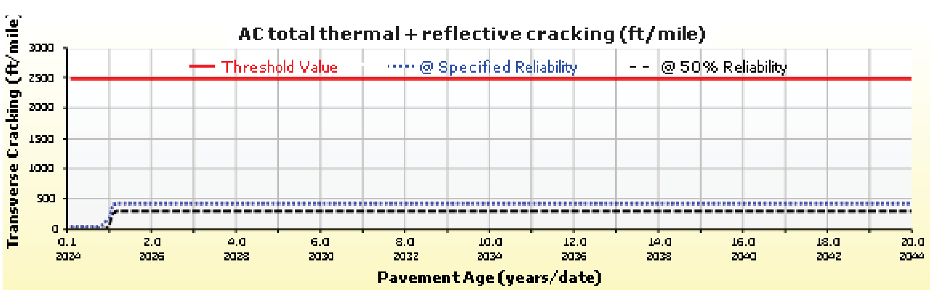


Analysis Output Charts









D.5 Road 2 inch mill and 2.5 inch Overlay

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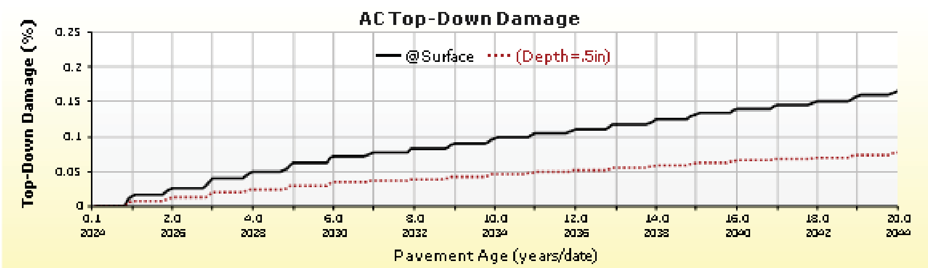
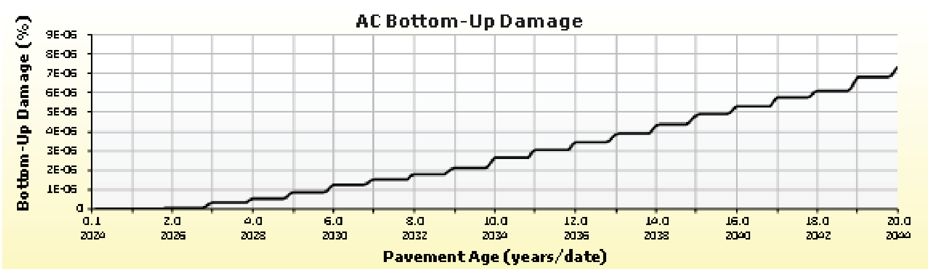
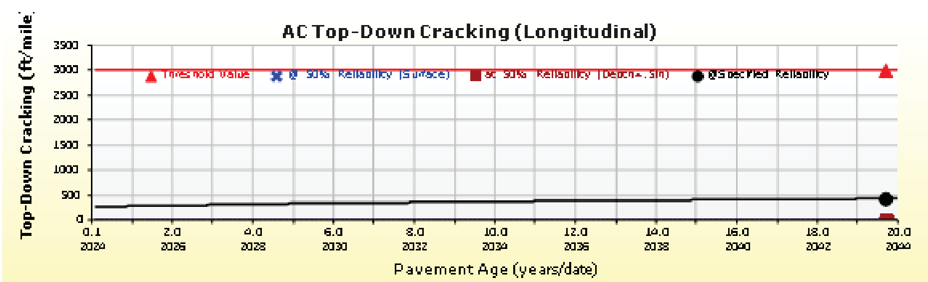
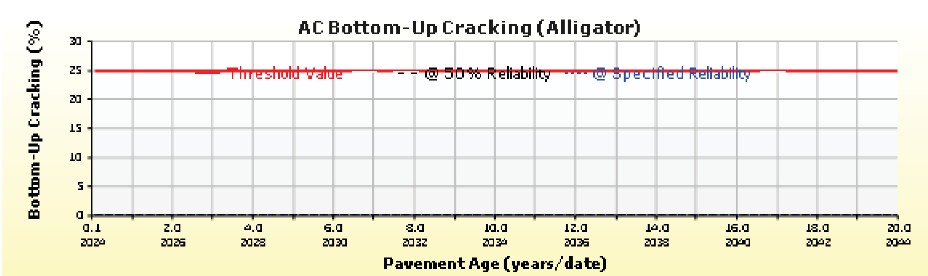
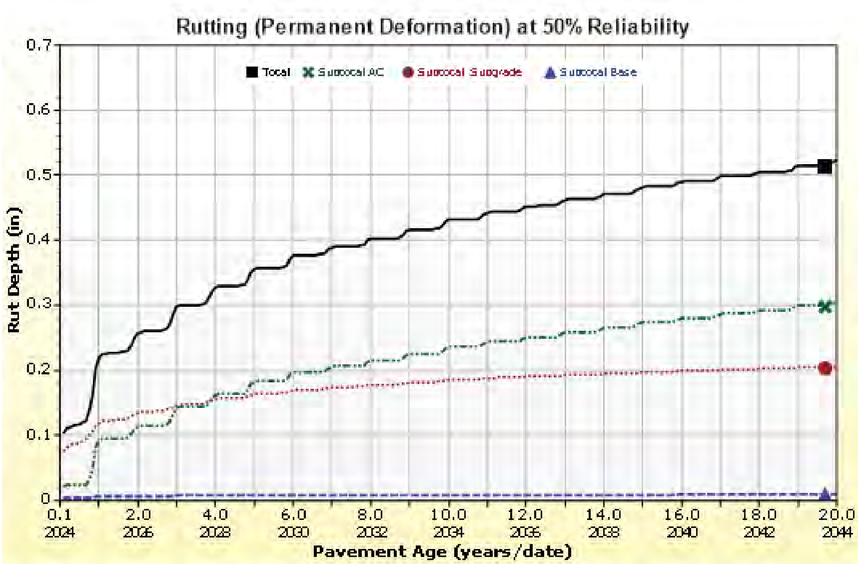


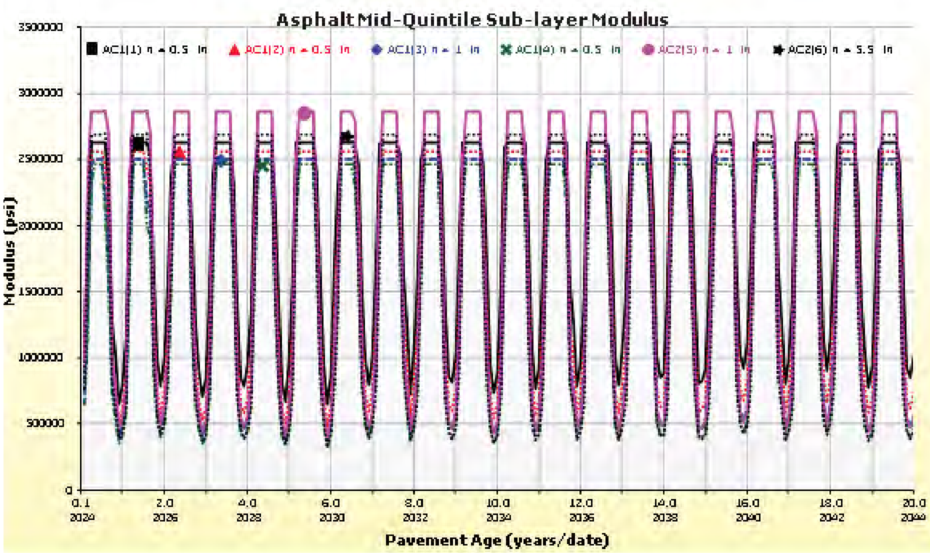




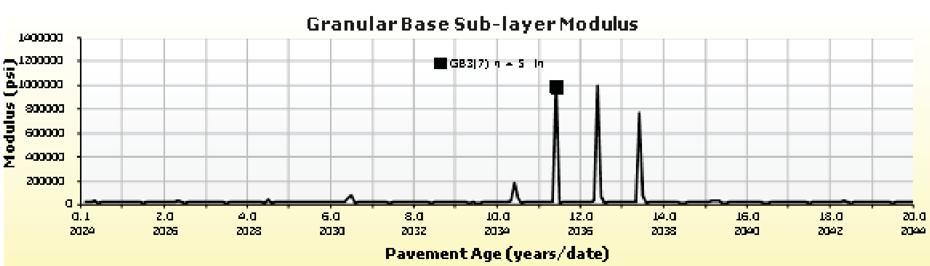




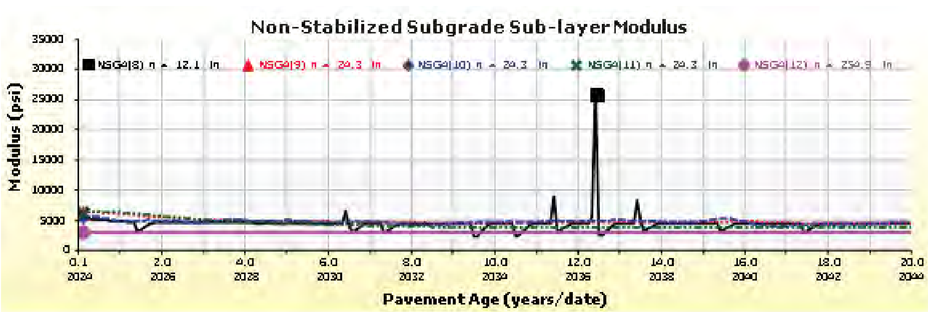
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



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



Granular Base Sub-layer Modulus
GB3(7) h = 5 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 12.1 in
NSG4(9) h = 24.3 in
NSG4(10) h = 24.3 in
NSG4(11) h = 24.3 in
NSG4(12) h = 254.9 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	2.5	
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	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 : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	6.5	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	5.0
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)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
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 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC = Crack length increment, in

ΔD = Incremental damage ratio

$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$ = Calibration factors (local and global)

$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$ = Crack length increments caused by bending, shearing, and thermal loading

A, n = HMA material fracture properties

N = Total number of days

$(SIF)_B, (SIF)_S, (SIF)_T$ = Stress intensity factors caused by bending, shearing, and thermal loading

D = Damage ratio

h_{OL} = Overlay thickness, in

RCR = Cracks in the underlying layers reflected, %

EX_CRK = Transverse cracking in underlying pavement layers, ft/mile (transverse cracking)
Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

F.5 Road 2 inch mill and 2.5 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\F.5 Road 2 inch mill and 2.5 inch Overlay.dgpx

Design Inputs

Design Life:	20 years	Existing construction:	May, 1995	Climate Data Sources (Lat/Lon)	39.134, -108.538
Design Type:	ACC_ACC	Pavement construction:	June, 2024		
		Traffic opening:	September, 2024		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.5
Flexible (existing)	Default asphalt concrete	4.0
NonStabilized	Crushed stone	6.0
Subgrade	A-4	Semi-infinite

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

Traffic

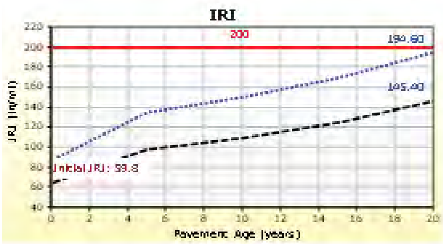
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	220
2034 (10 years)	504,415
2044 (20 years)	1,061,600

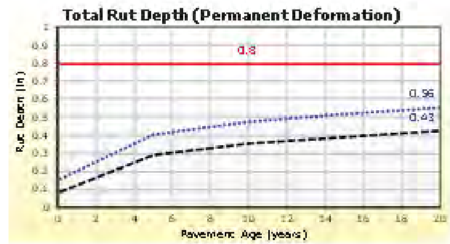
Design Outputs

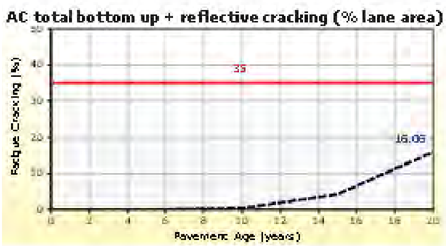
Distress Prediction Summary

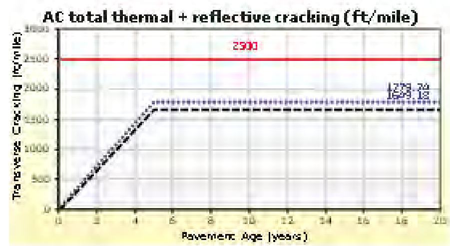
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	194.62	90.00	92.24	Pass
Permanent deformation - total pavement (in)	0.80	0.56	90.00	99.99	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	16.06	50.00	98.65	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	1779.74	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.32	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1677.64	90.00	98.98	Pass

Distress Charts





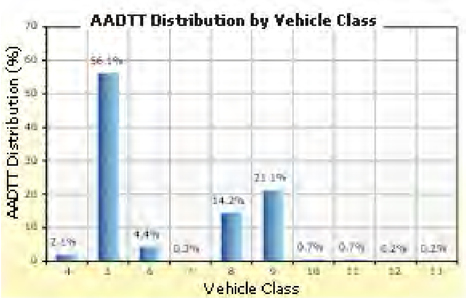


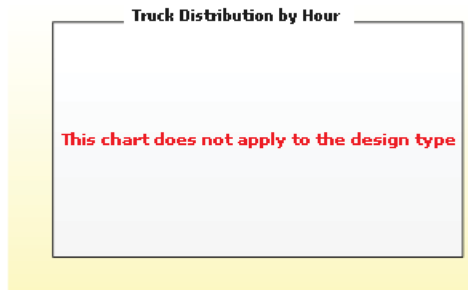


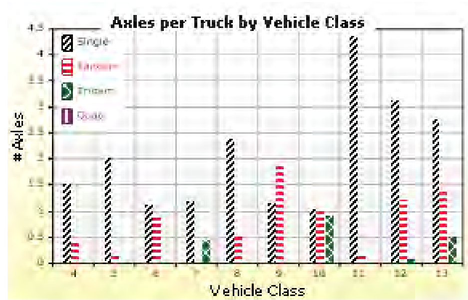
Traffic Inputs

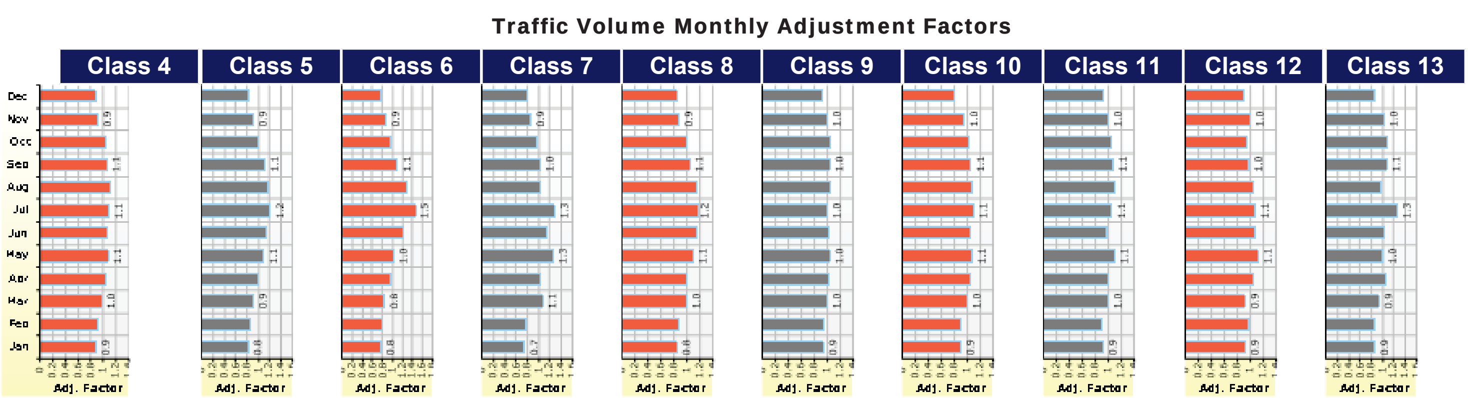
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	220	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0









Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

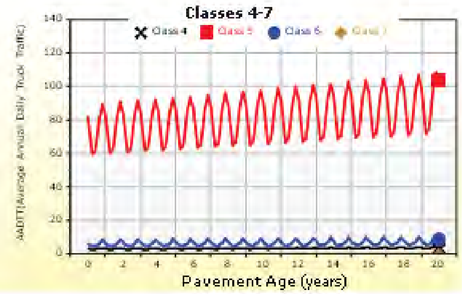
Wheelbase does not apply

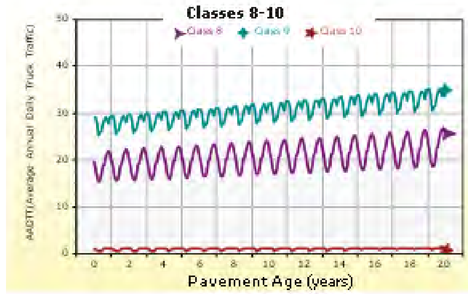
Number of Axles per Truck

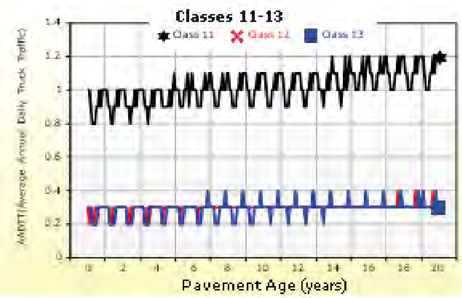
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

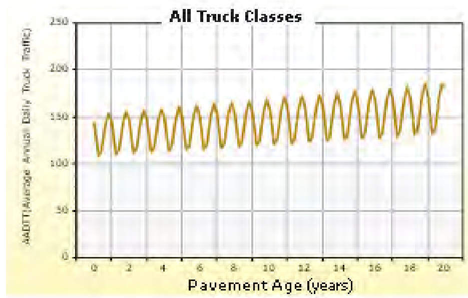
AADTT (Average Annual Daily Truck Traffic) Growth

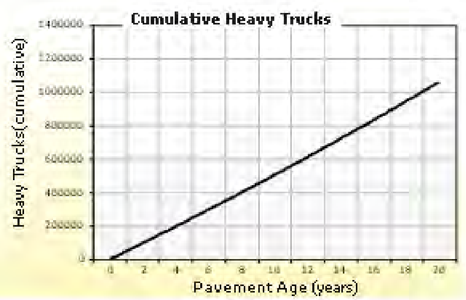
*** Traffic cap is not enforced**







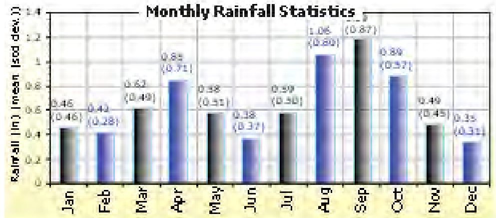




Climate Inputs

Climate Data Sources:

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

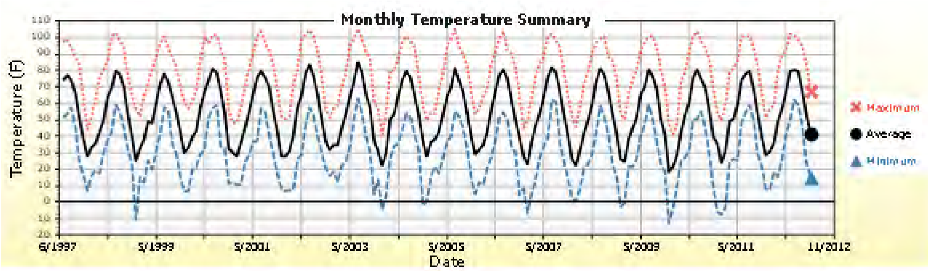


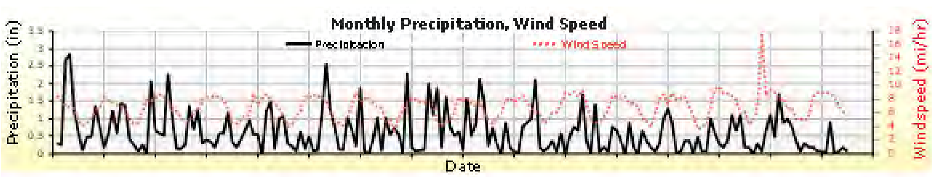
Annual Statistics:

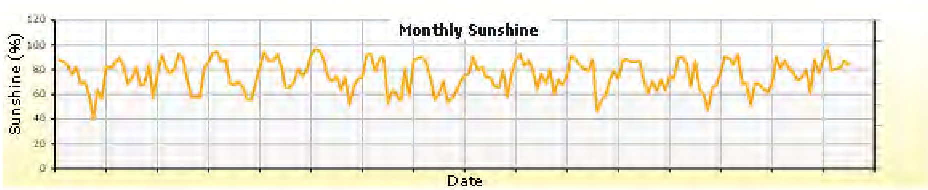
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

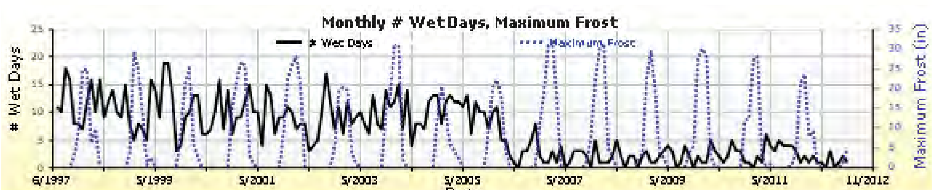
Water table depth (ft) 10.00

Monthly Climate Summary:

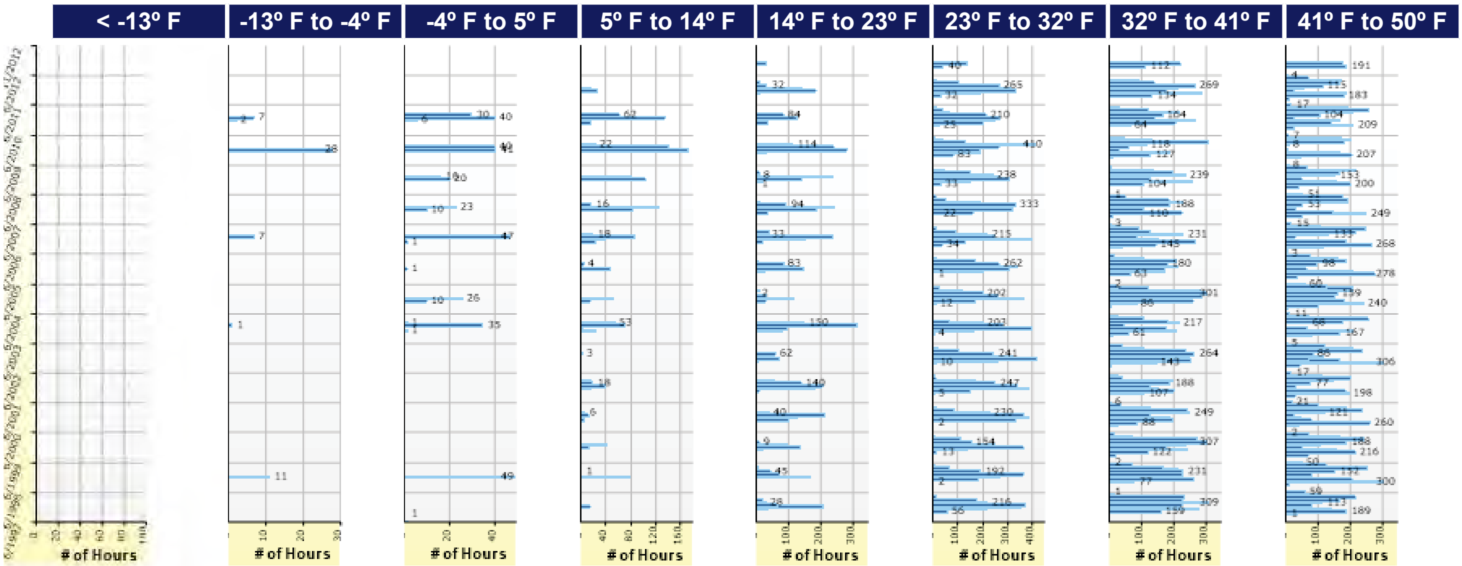


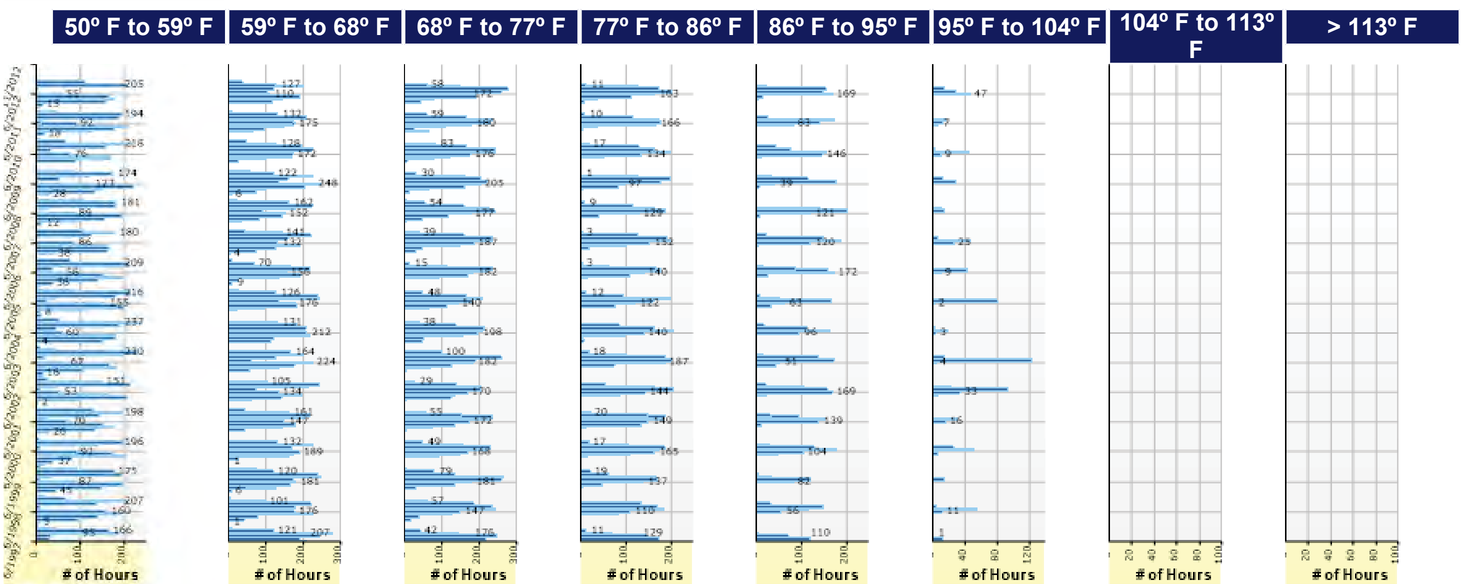






Hourly Air Temperature Distribution by Month:





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 : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

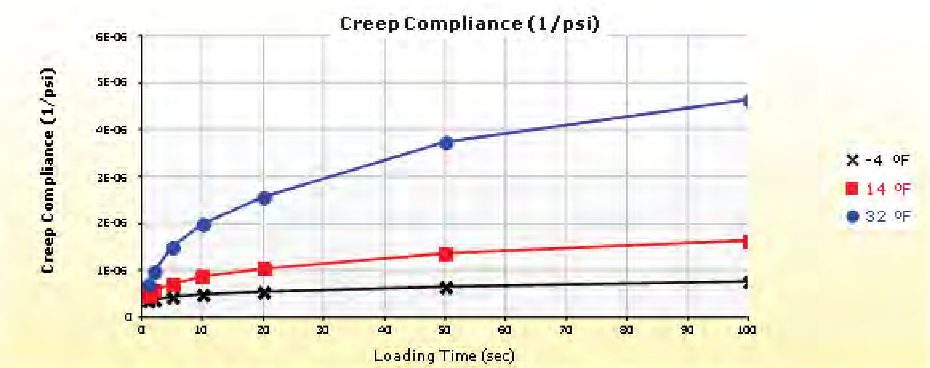
Milled thickness (in)	2.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	2200.00 (Medium)
Total rut depth (in)	-

Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 4 Subgrade : A-4	Subgrade (5)	0.00

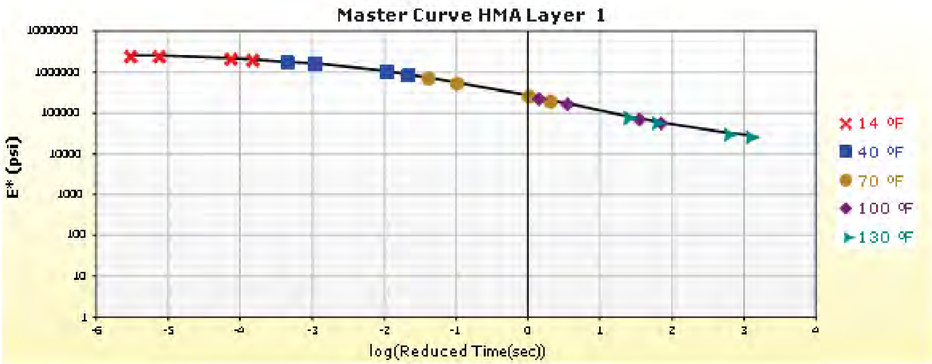
Thermal Cracking (Input Level: 1)

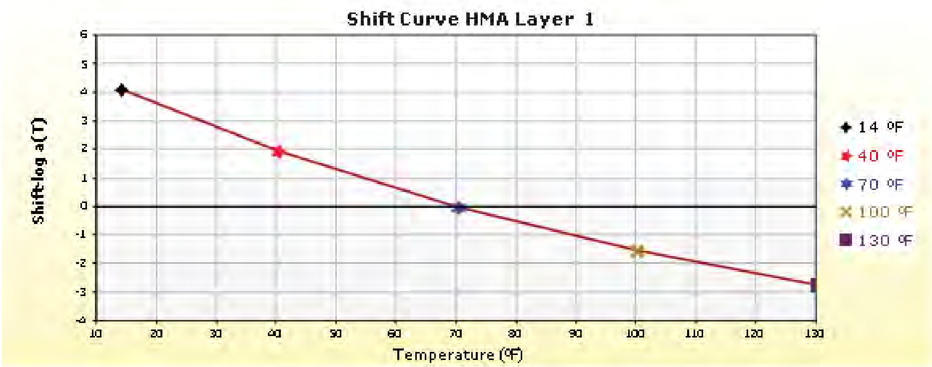
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

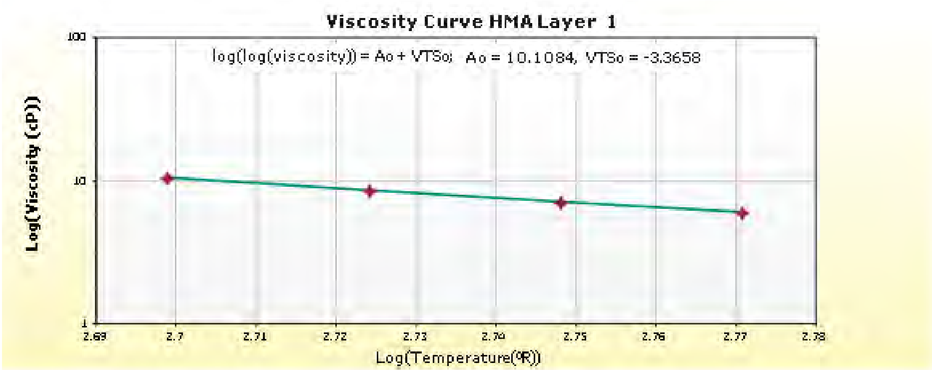
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



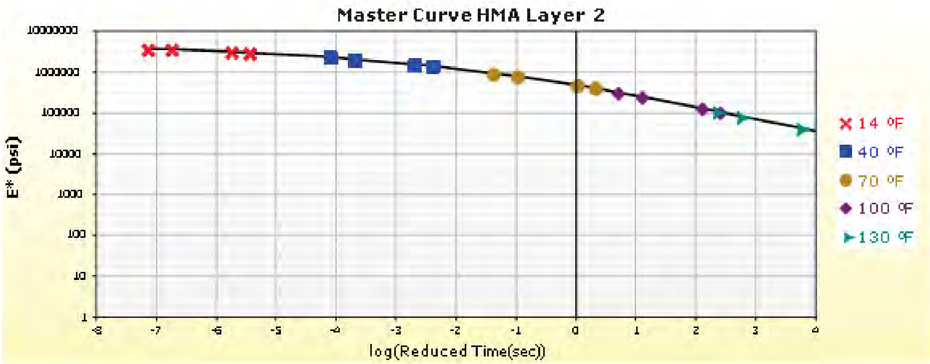
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

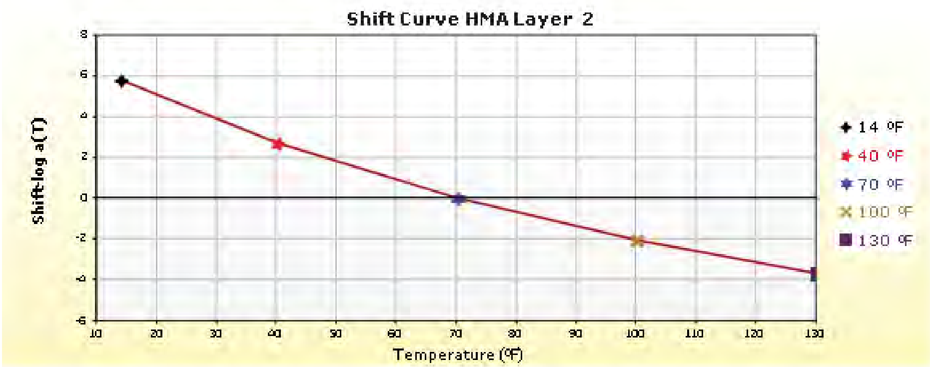


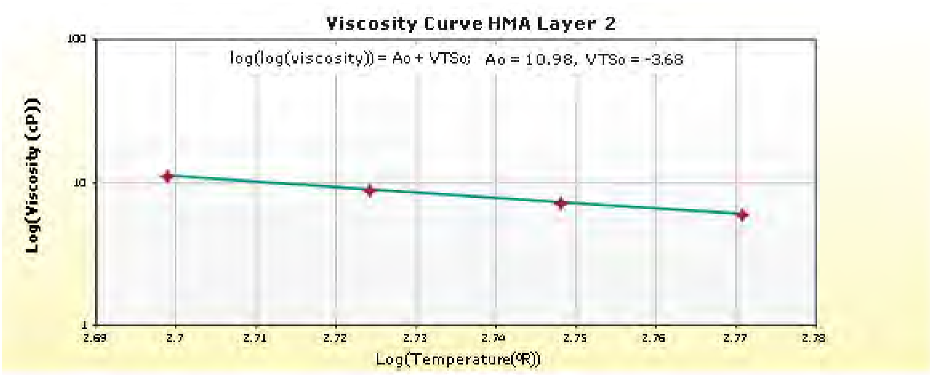




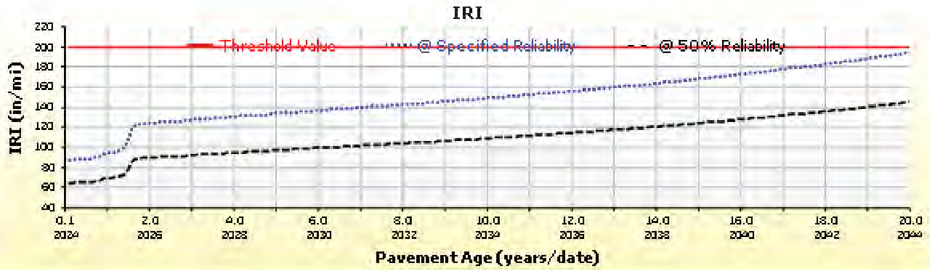
HMA Layer 2: Layer 2 Flexible : Default asphalt concrete(existing)

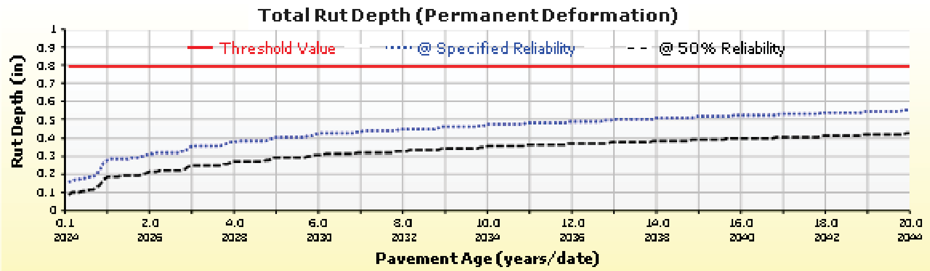


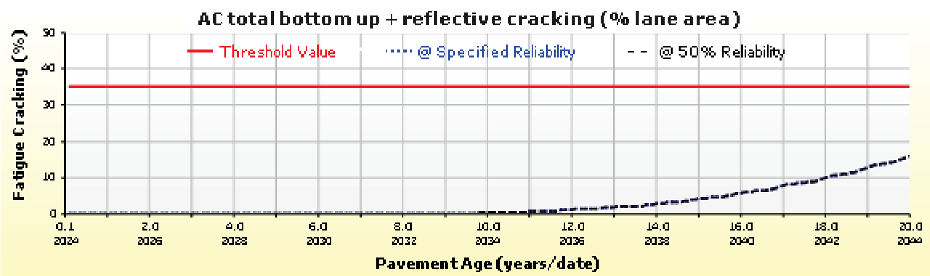


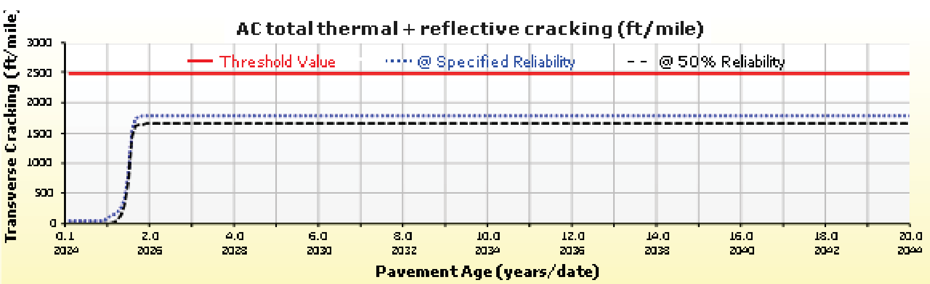


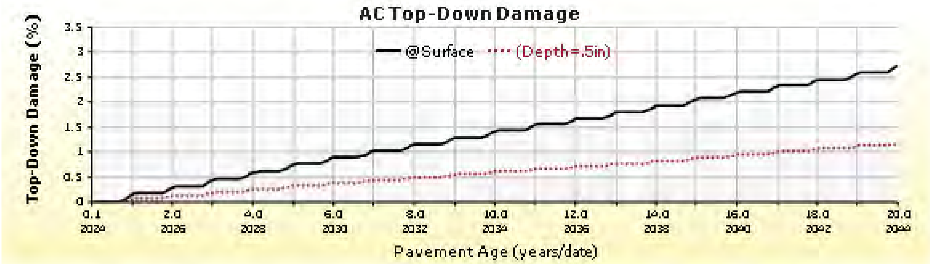
Analysis Output Charts



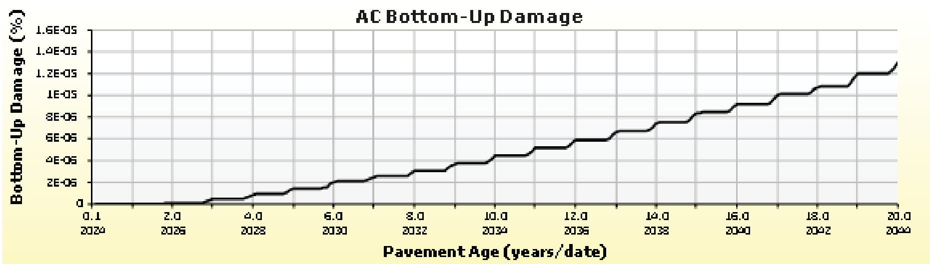




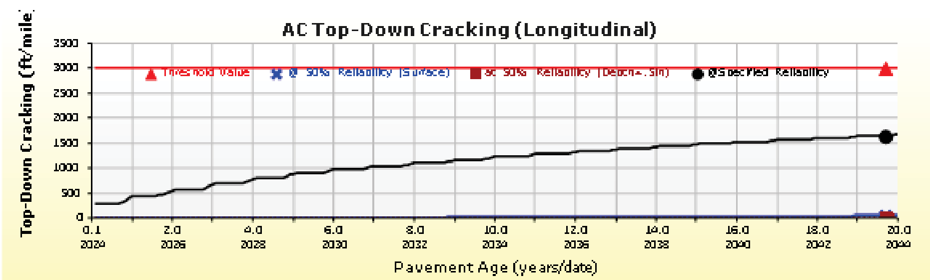




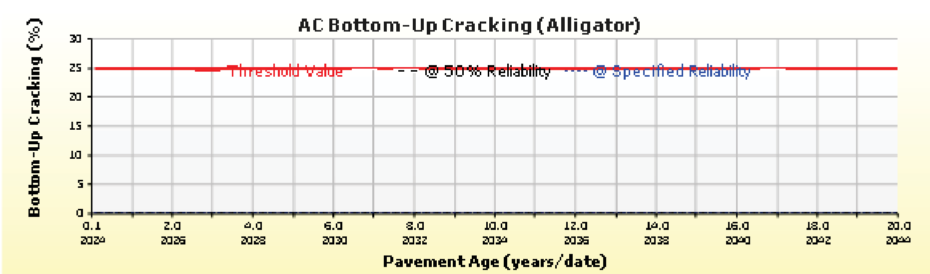
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



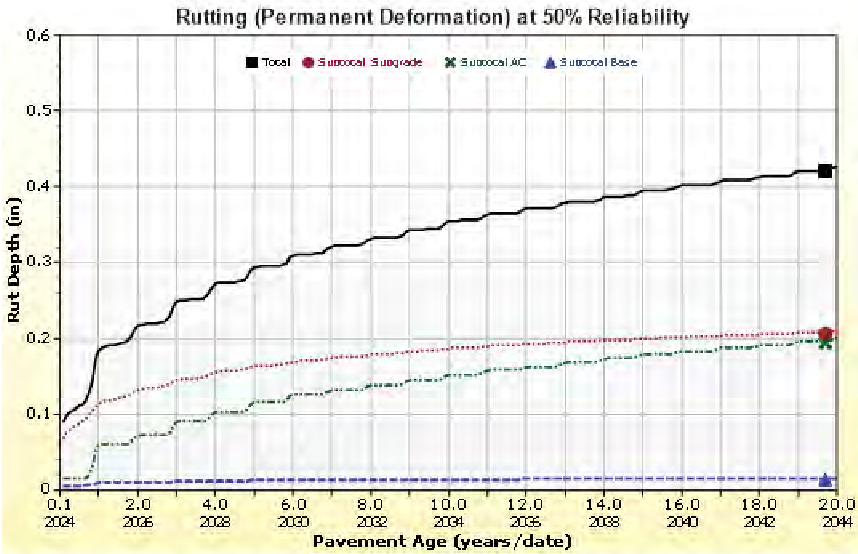
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



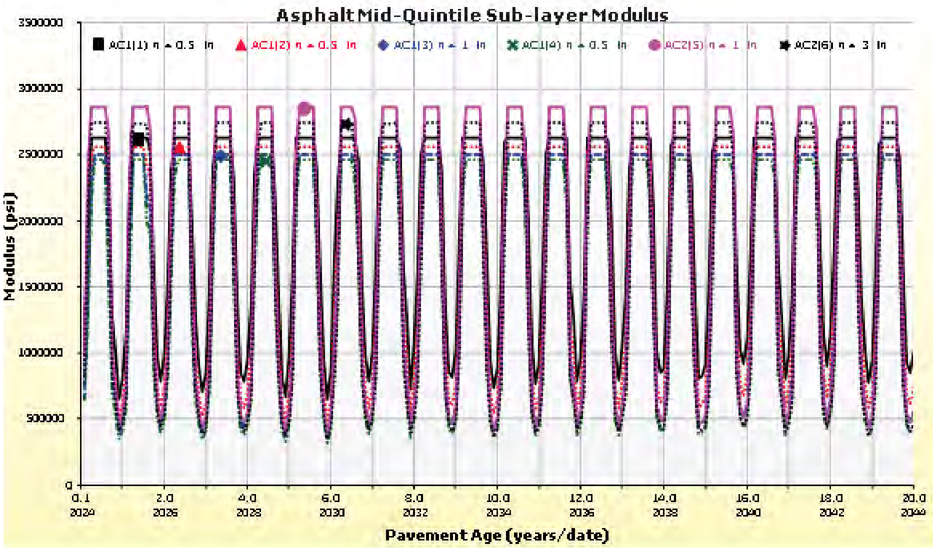
AC Top-Down Cracking (Longitudinal)
Threshold Value
@Specified Reliability
Top-Down Cracking (ft/mile)
Pavement Age (years/date)



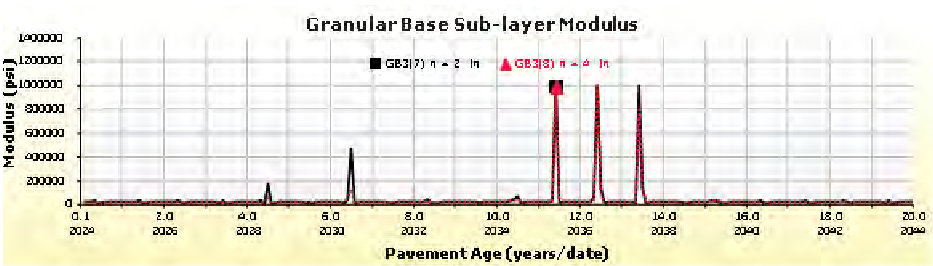
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



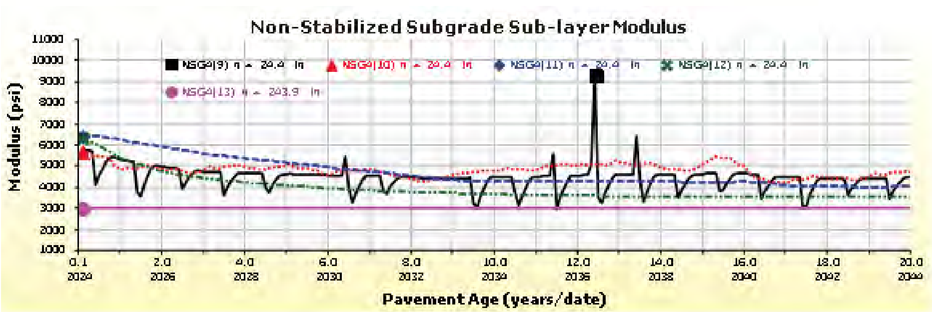
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
Pavement Age (years/date)



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



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(9) h = 24.4 in
NSG4(10) h = 24.4 in
NSG4(11) h = 24.4 in
NSG4(12) h = 24.4 in
NSG4(13) h = 243.9 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	2.5	
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	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 : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 3 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
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 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

AC Fatigue

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1\Delta_{bending} + k_2\Delta_{shaering} + k_3\Delta_{thermal}$$

$$\Delta D = \frac{C_1k_1\Delta_{bending} + C_2k_2\Delta_{shearing} + C_3k_3\Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC = Crack length increment, in
ΔD = Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$ = Calibration factors (local and global)
$\Delta_{bending}$, $\Delta_{shearing}$, $\Delta_{thermal}$ = Crack length increments caused by bending, shearing, and thermal loading
A, n = HMA material fracture properties
N = Total number of days
$(SIF)_B$, $(SIF)_S$, $(SIF)_T$ = Stress intensity factors caused by bending, shearing, and thermal loading
D = Damage ratio
h_{OL} = Overlay thickness, in
RCR = Cracks in the underlying layers reflected, %
EX_CRK = Transverse cracking in underlying pavement layers, ft/mile (transverse cracking)
Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

APPENDIX H

AASHTO 1993 20-YEAR DESIGN LIFE OUTPUT
MILL AND OVERLAY REHABILITATION

26.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

RockSol Consulting Group, Inc.

Mill and Overlay Option

RockSol Project No. 599.70

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,020,000 = Design Life ESALs

SN = 3.935 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.30535

=

Thickness Equation= B = 6.30538 with no drainage reduction

Design Mr = 6,482 psi

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

0.77310145	A
4.94	B
3964.2437	C
0.67596689	D
-0.19281088	E
0.200000	F
4.94	G
6.48916779	H
-0.56408	I

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.94
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 1.65

Calculated Inches of New HMA = 5.19

Existing HMA Thickness = 5
Existing HMA Structual Layer Coefficient = 0.23
Existing ABC Thickness = 5
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years	0.12
9 to 15 years	0.09
more than 16 years	0.05
Estimated air voids[1]	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,&6	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

B.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

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) for Post-2015 CDOT Correlation

RockSol Consulting Group, Inc.

Mill and Overlay Option

RockSol Project No. 599.70

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,160,000 = Design Life ESALs

SN = 3.975 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.33445

=

Thickness Equation= B = 6.33491 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Design Mr = 6,482 psi

0.77310145	A
4.98	B
4133.8633	C
0.66464349	D
-0.19609576	E
0.200000	F
4.98	G
6.52198328	H
-0.56408	I

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 9.03
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 1.675

Calculated Inches of New HMA = 5.23

Existing HMA Thickness = 4.5
Existing HMA Structual Layer Coefficient = 0.25
Existing ABC Thickness = 5.5
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
3 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination	
less than 8 years:	0.12
8 to 15 years:	0.09
more than 15 years:	0.08
Estimated air voids[1]:	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.08
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,4.5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

D.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

RockSol Consulting Group, Inc.

Mill and Overlay Option

RockSol Project No. 599.70

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,030,000 = Design Life ESALs

SN = 3.938 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.30750

=

Thickness Equation= B = 6.30760 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Design Mr = 6,482 psi

0.77310145	A
4.94	B
3976.76689	C
0.67509784	D
-0.19305908	E
0.200000	F
4.94	G
6.49163816	H
-0.56408	I

Structural Coefficient of HMA = 0.44

Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.95
FULL DEPTH HMA

Initial Serviceability Index= 4.5

Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44

Reliability, R (percent) = 90

Standard Normal Deviate (ZR) = -1.282

(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 2.355

Calculated Inches of New HMA = 3.60

Existing HMA Thickness = 6.5

Existing HMA Structual Layer Coefficient = 0.27

Existing ABC Thickness = 6

ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years:	0.12
9 to 15 years:	0.09
more than 16 years:	0.05
Estimated air voids[1]:	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,&5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

F.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

RockSol Consulting Group, Inc.

Mill and Overlay Option

RockSol Project No. 599.70

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) for Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi) = 6,482

680,000 = Design Life ESALs

SN = 3.335 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 5.83251

=

Thickness Equation= B = 5.83271 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
4.34	B
2022.89545	C
0.94080897	D
-0.13853372	E
0.200000	F
4.34	G
5.96221799	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 7.58
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 1.6

Calculated Inches of New HMA = 3.94

Existing HMA Thickness = 4
Existing HMA Structual Layer Coefficient = 0.25
Existing ABC Thickness = 6
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years	0.12
9 to 15 years	0.09
more than 16 years	0.06
Estimated air voids¹	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted²)	
Classes 1,2,3,4,&5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

APPENDIX I

PMED 20-YEAR DESIGN LIFE OUTPUT – CIR AND OVERLAY REHABILITATION

26.5 Road 4 inch CIR and 2 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\26.5 Road 4 inch CIR and 2 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.0
Flexible (OL)	CIR Layer	4.0
Flexible (existing)	Default asphalt concrete	3.0
NonStabilized	Crushed stone	5.0
Subgrade	A-4	46.0
Bedrock	Highly fractured and weathered	Semi-infinite

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

Traffic

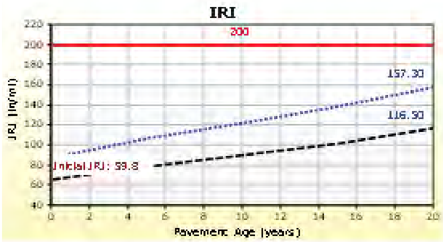
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	650
2034 (10 years)	1,490,320
2044 (20 years)	3,136,550

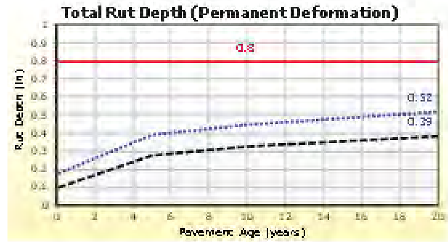
Design Outputs

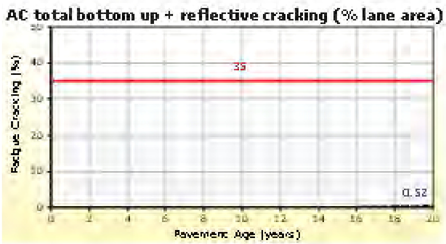
Distress Prediction Summary

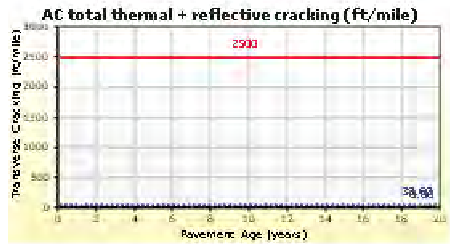
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	157.34	90.00	99.56	Pass
Permanent deformation - total pavement (in)	0.80	0.52	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	0.52	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.36	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.51	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	654.91	90.00	100.00	Pass

Distress Charts







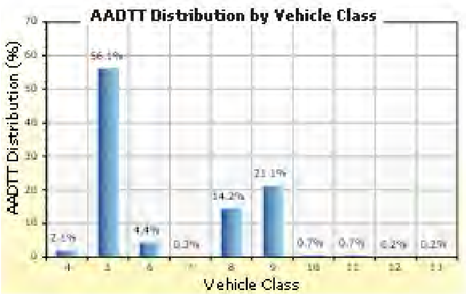


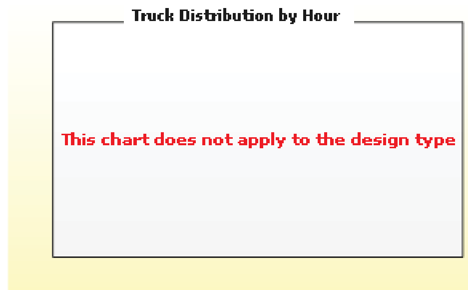
Threshold Value ••••• @ Specified Reliability - - - @ 50% Reliability

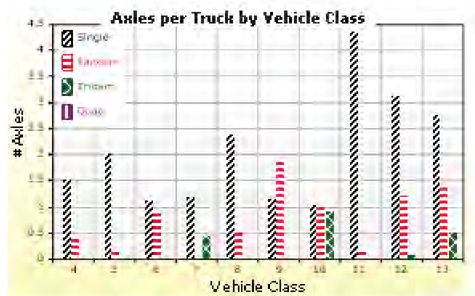
Traffic Inputs

Graphical Representation of Traffic Inputs

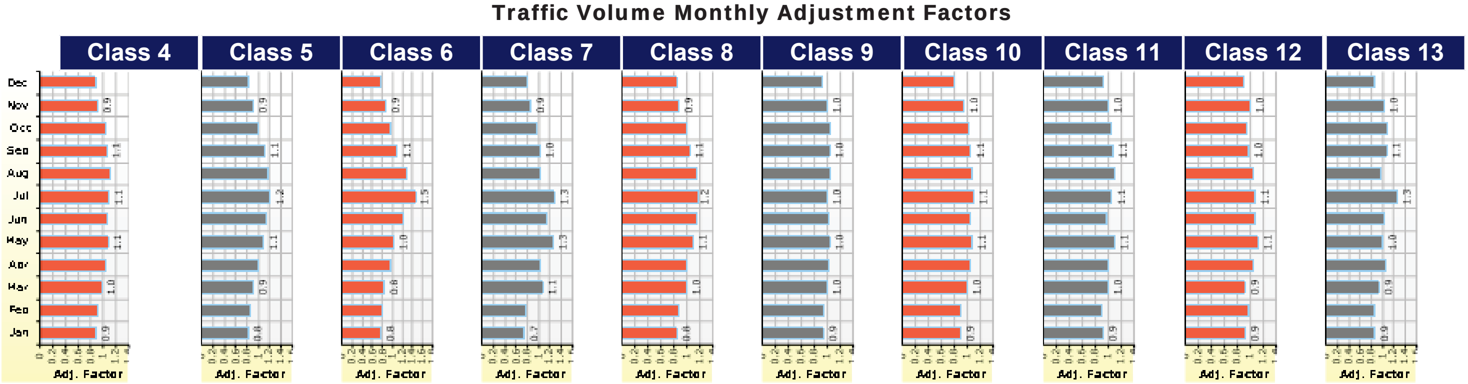
Initial two-way AADTT:	650	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

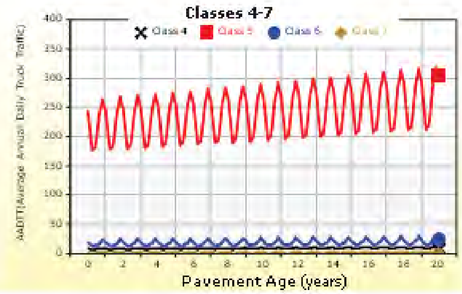
Wheelbase does not apply

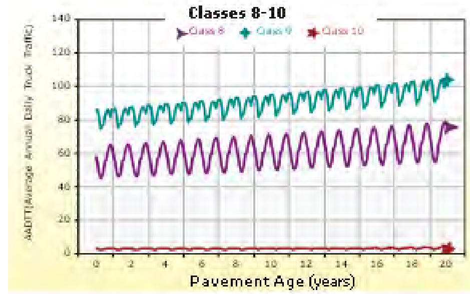
Number of Axles per Truck

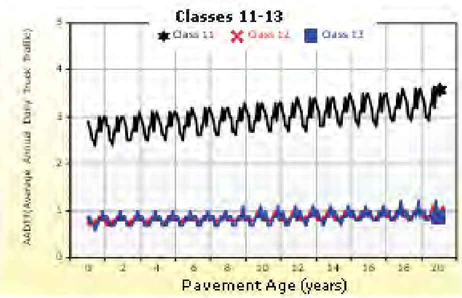
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

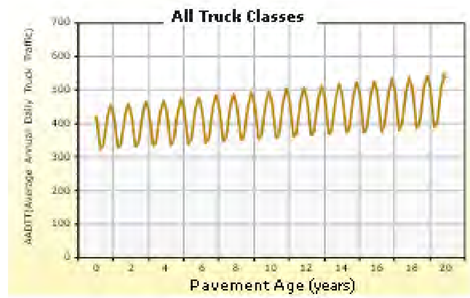
AADTT (Average Annual Daily Truck Traffic) Growth

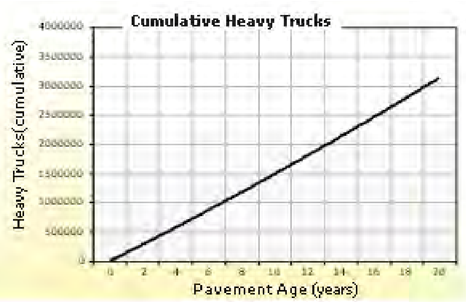
*** Traffic cap is not enforced**







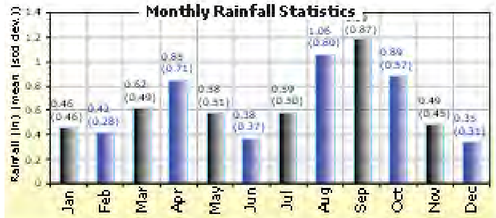




Climate Inputs

Climate Data Sources:

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

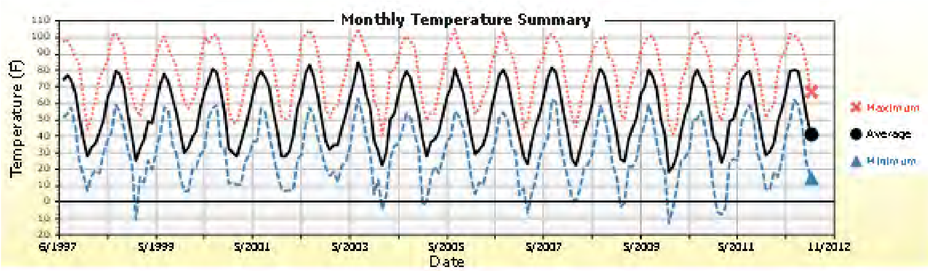


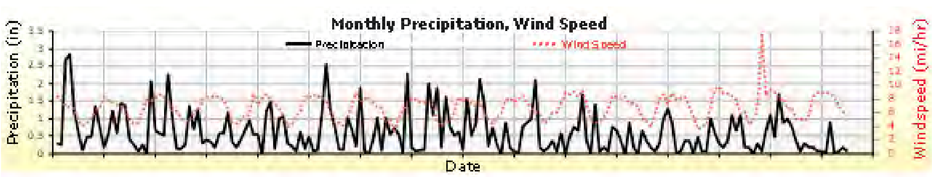
Annual Statistics:

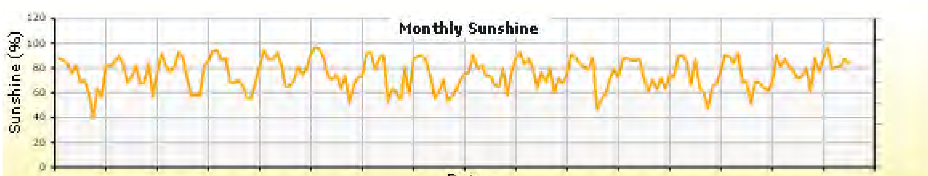
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

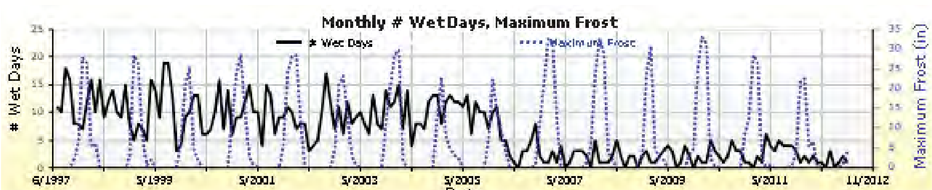
Water table depth (ft) 10.00

Monthly Climate Summary:

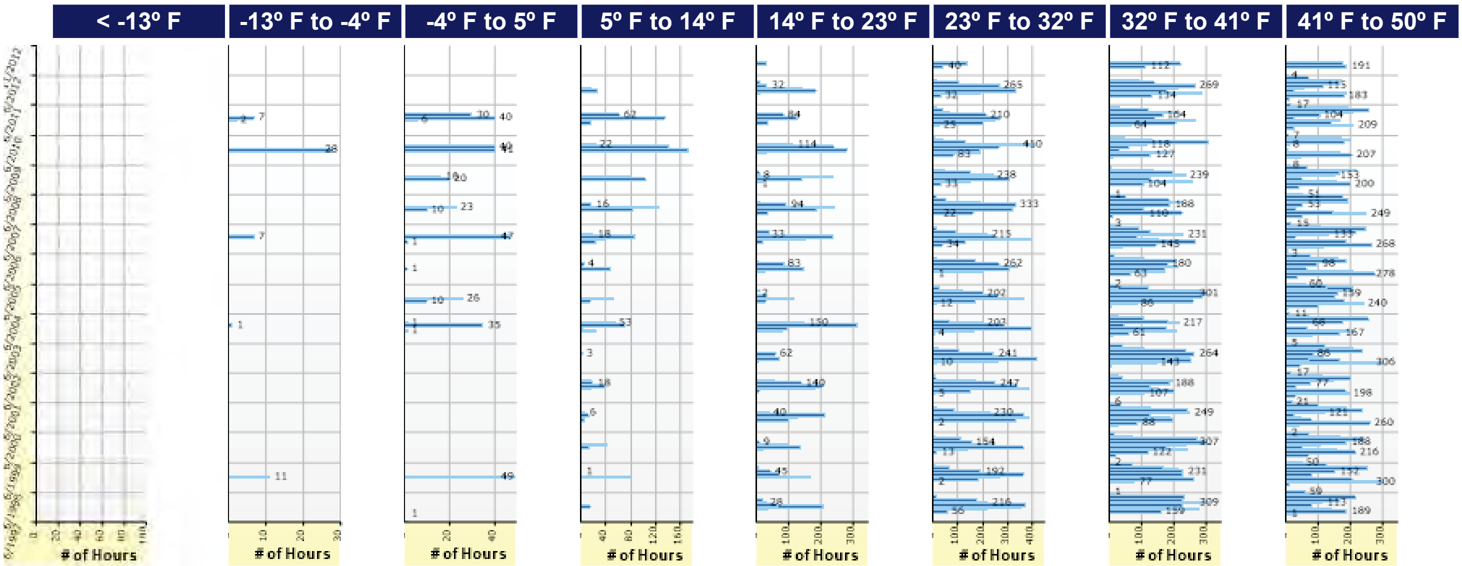


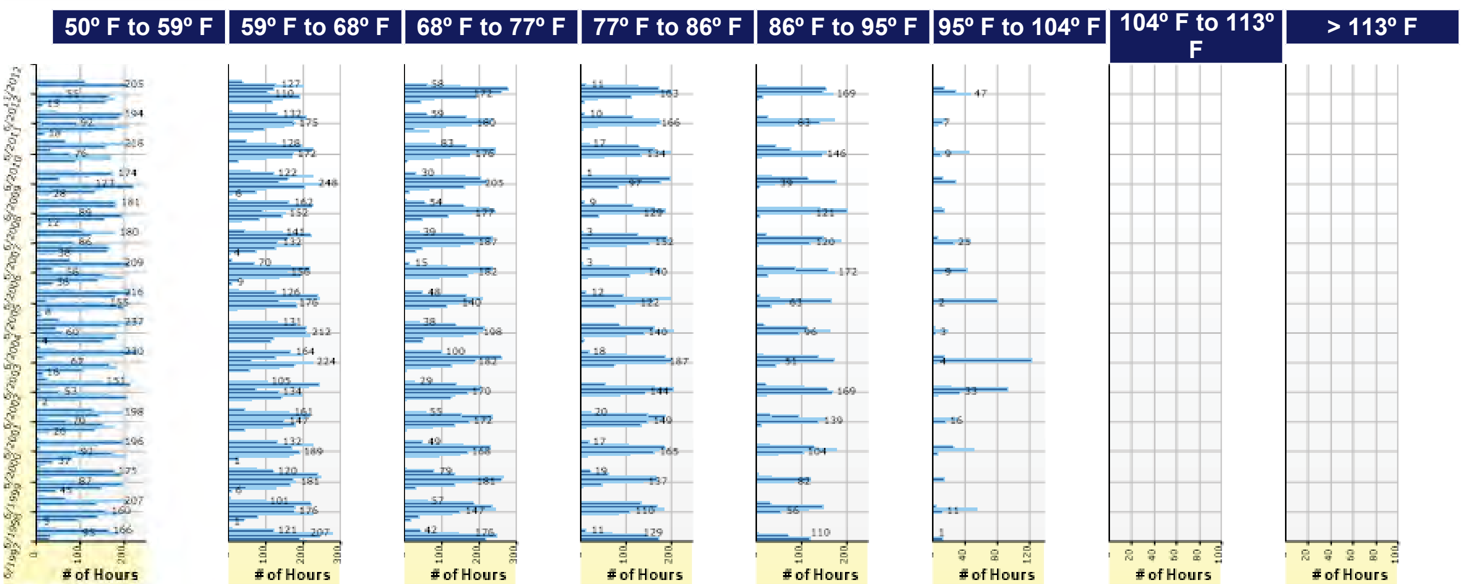






Hourly Air Temperature Distribution by Month:





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 : CIR Layer	Flexible (1)	1.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	1.00
Layer 6 Bedrock : Highly fractured and weathered	Bedrock (6)	-

HMA Rehabilitation (Input Level: 2)

Milled thickness (in)	4.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	0.00 (Low)
Total rut depth (in)	-

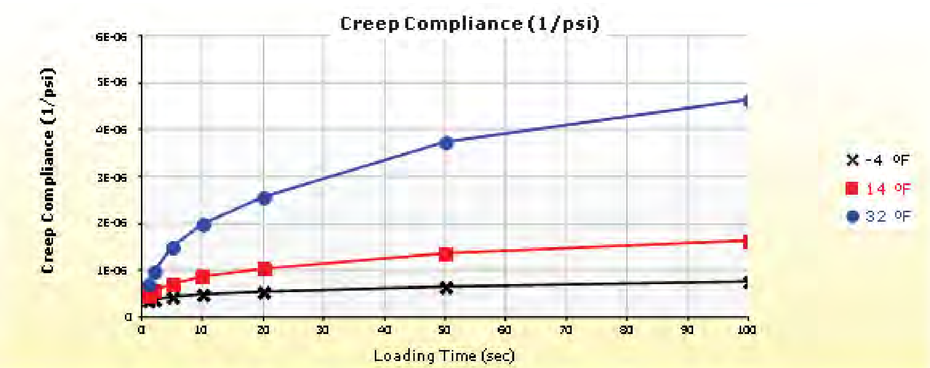
Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : CIR Layer	Flexible (1)	0.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 5 Subgrade : A-4	Subgrade (5)	0.00
Layer 6 Bedrock : Highly fractured and weathered	Bedrock (6)	0.00

Thermal Cracking (Input Level: 1)

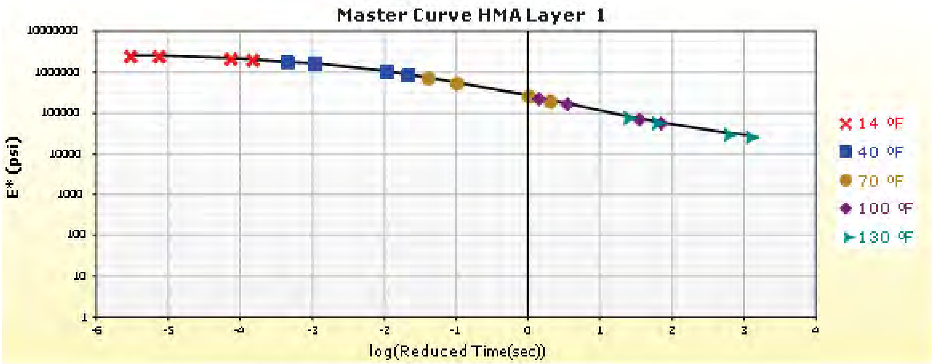
Indirect tensile strength at 14 ºF (psi)	519.00

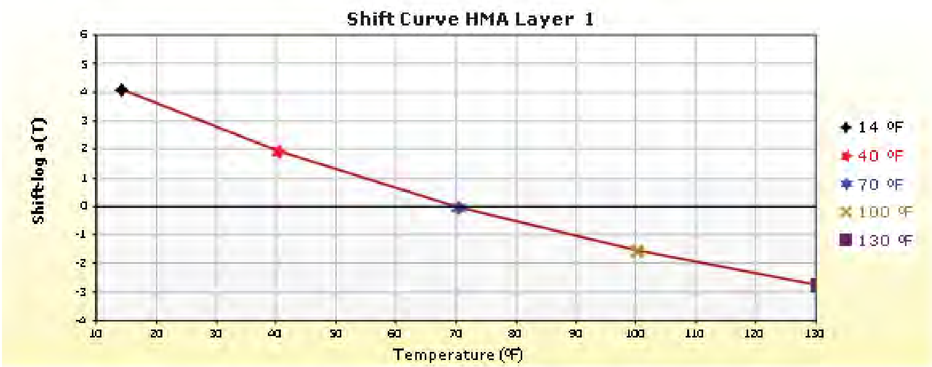
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

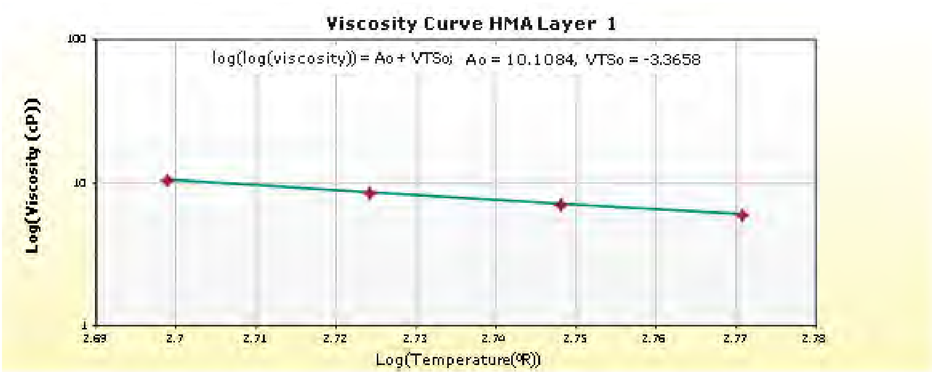
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



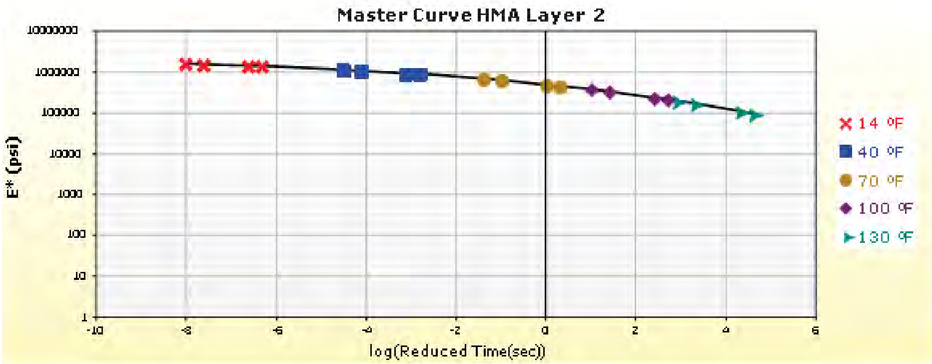
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

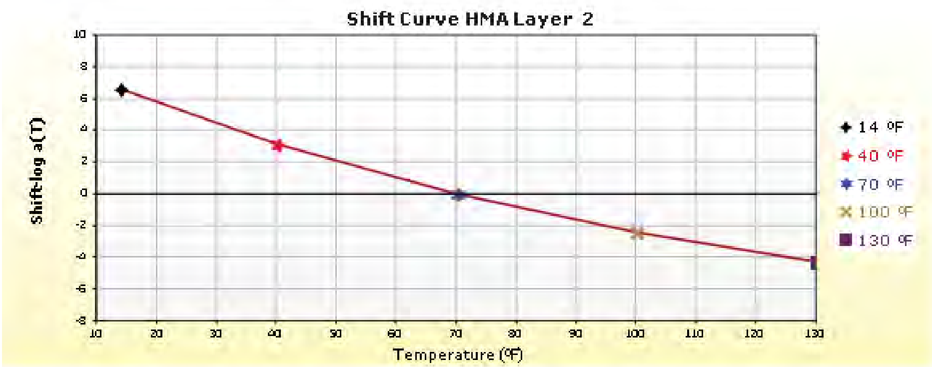


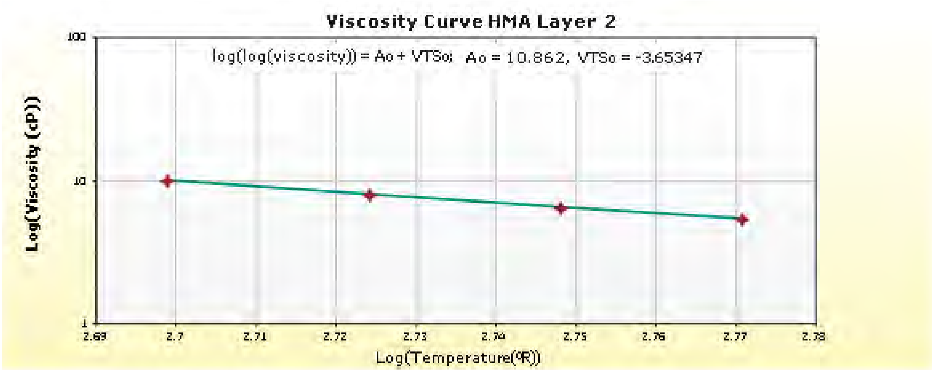




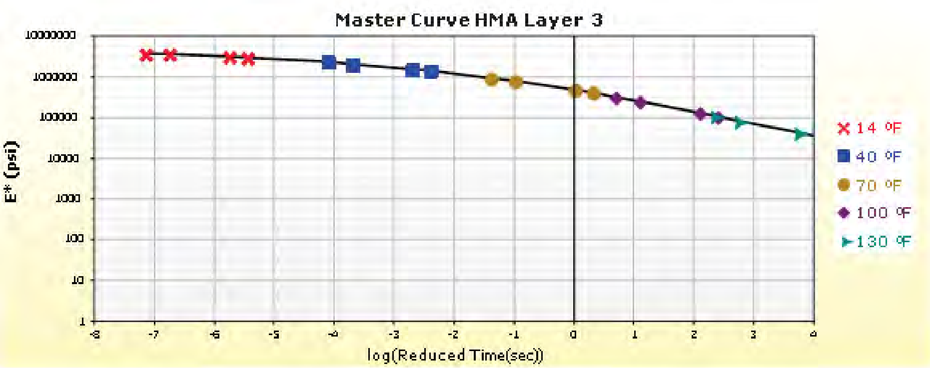
HMA Layer 2: Layer 2 Flexible : CIR Layer

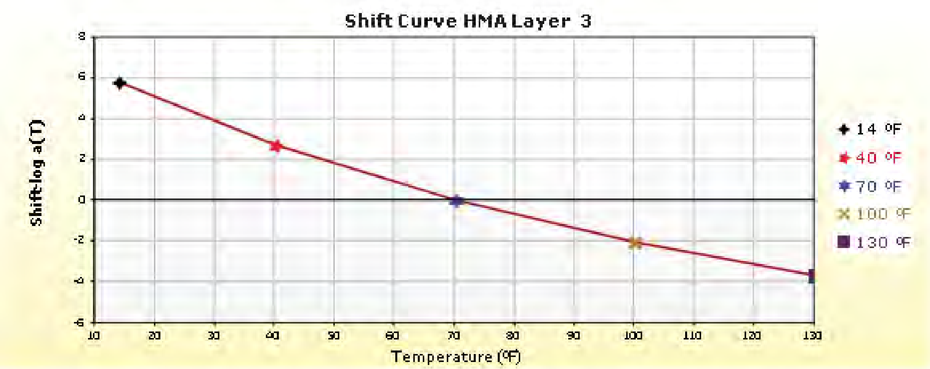


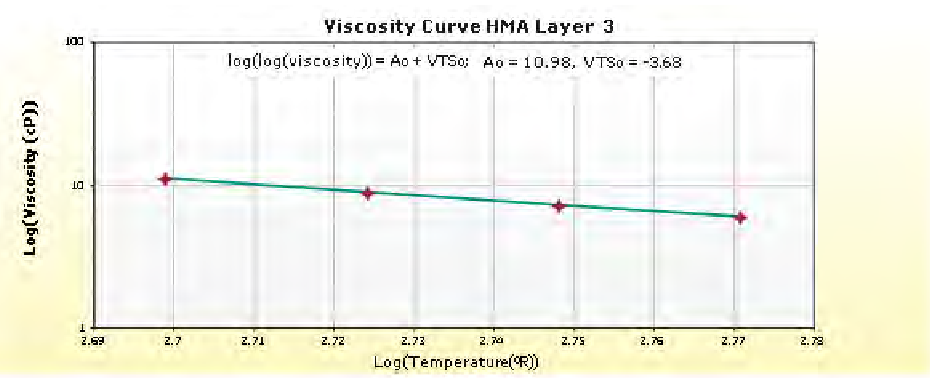




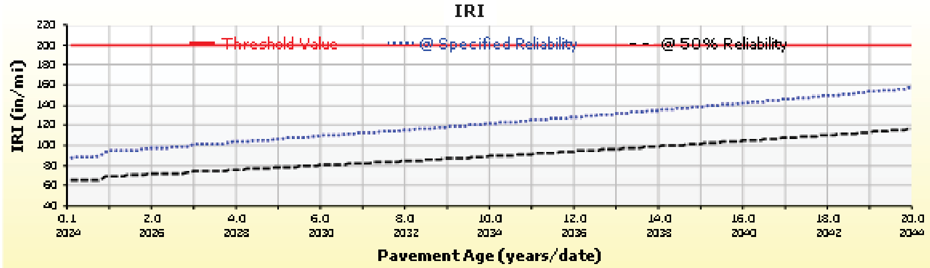
HMA Layer 3: Layer 3 Flexible : Default asphalt concrete(existing)

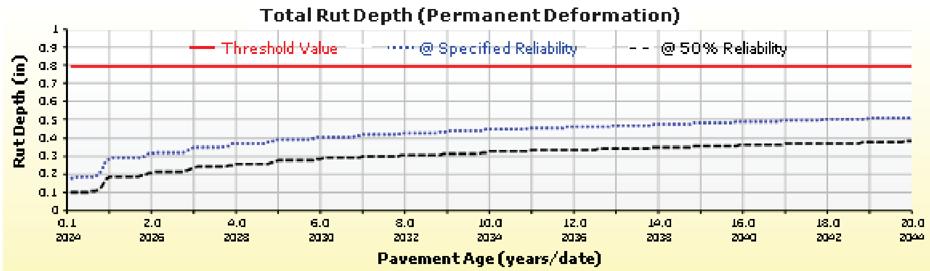


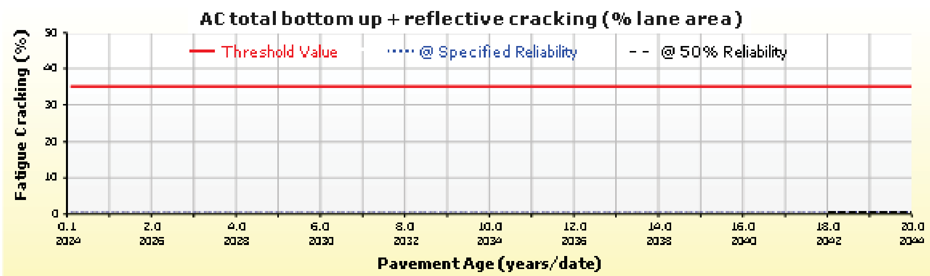


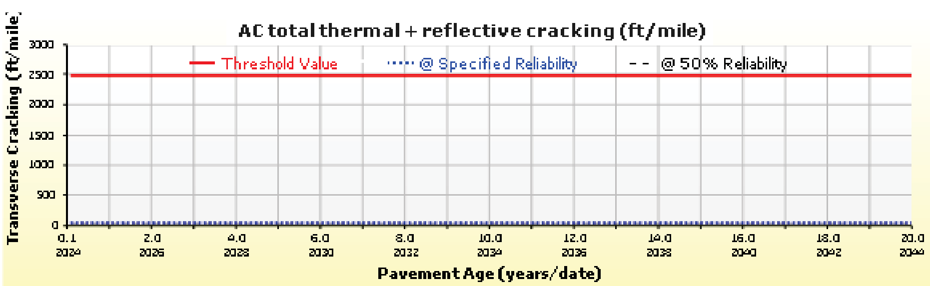


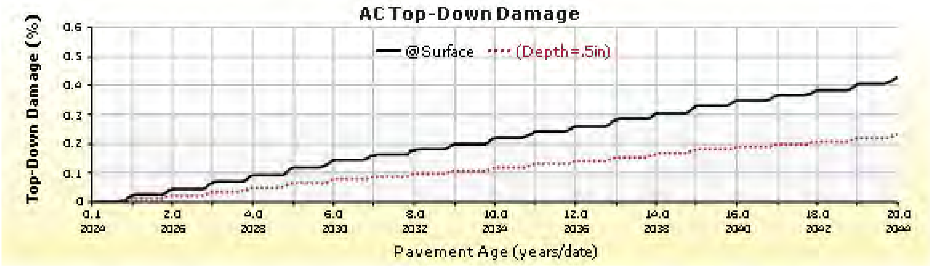
Analysis Output Charts



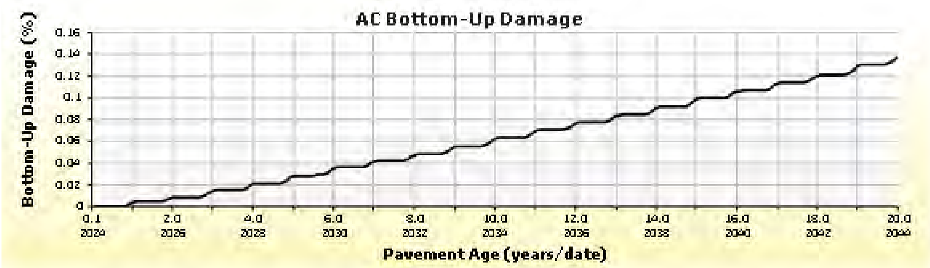




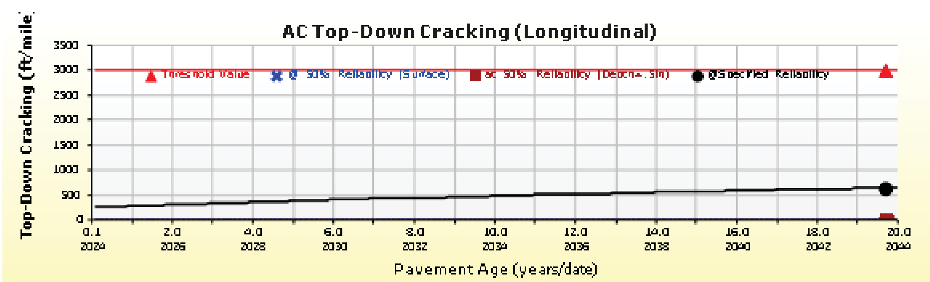




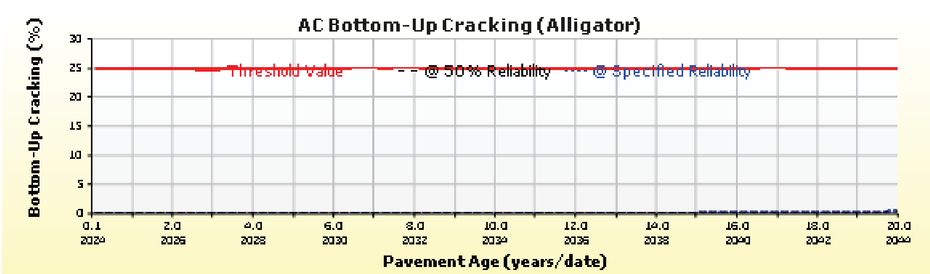
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



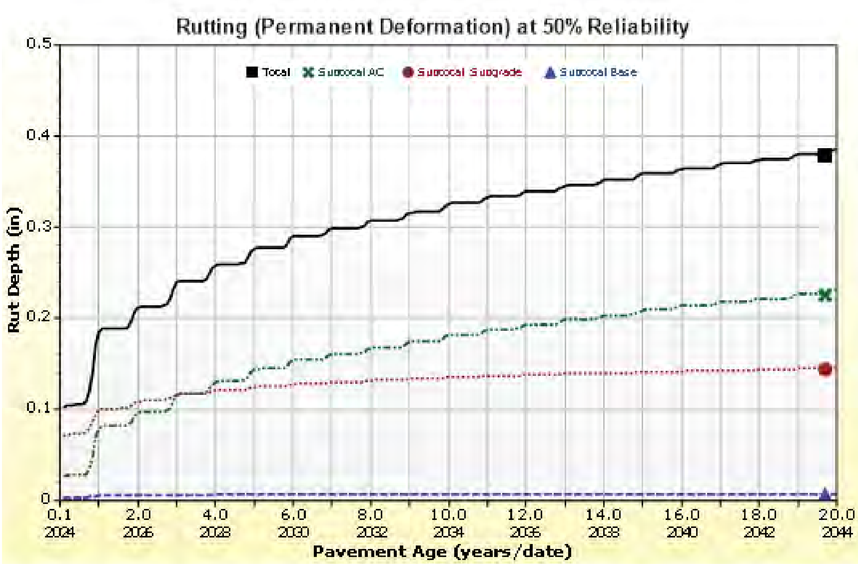
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

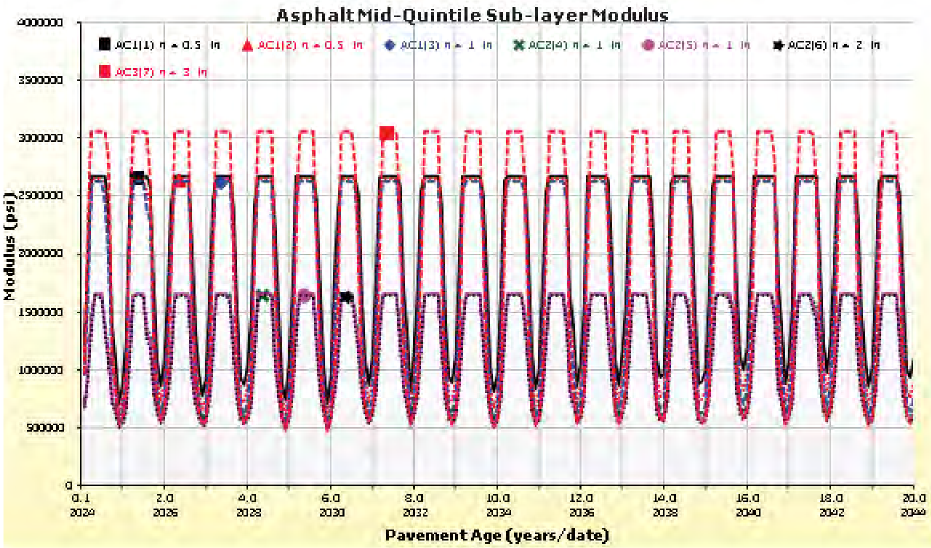


AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Pavement Age (years/date)

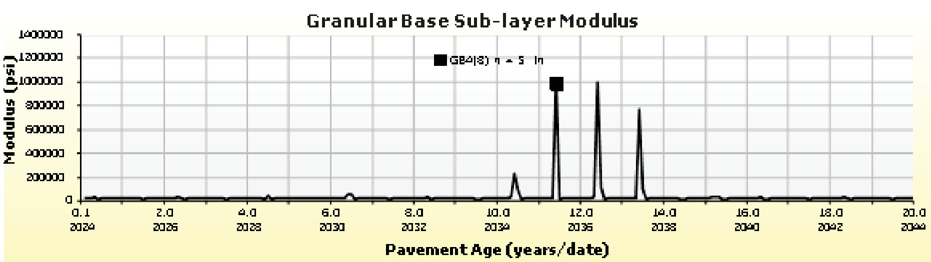


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

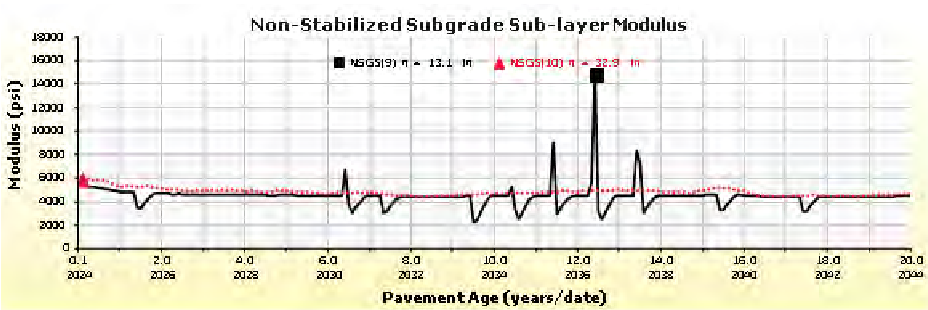

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
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?	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 : CIR Layer

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	146.5	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1203200	1339800	1398500	1533300	1590400	1664700
40	739800	862600	917600	1049200	1107000	1184300
70	370200	455800	496300	598000	645100	710100
100	169100	217900	242100	306100	337200	381700
130	75400	99900	112500	147400	165100	191100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	835	82
158	419	84
136.4	1758	80

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	6.5
Air voids (%)	12.8
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	CIR Layer
Description of object	
Author	CDOT
Date Created	5/9/2018 12:00:00 AM
Approver	CDOT
Date approved	5/9/2018 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 Flexible : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	3.0	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 4 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	5.0
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)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Water Content (%)	False	7.4

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

Unbound	
Layer thickness (in)	46.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 6 Bedrock : Highly fractured and weathered

Bedrock	
Layer thickness(in)	Semi-infinite
Poisson's ratio	0.15
Unit weight (pcf)	140

Strength	
Elastic/resilient modulus (psi)	500000

Identifiers

Field	Value
Display name/identifier	Highly fractured and weathered
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

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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

B.5 Road 4 inch CIR and 2.5 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\B.5 Road 4 inch CIR and 2.5 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.5
Flexible (OL)	CIR Layer	4.0
Flexible (existing)	Default asphalt concrete	2.5
NonStabilized	Crushed stone	5.5
Subgrade	A-6	Semi-infinite

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

Traffic

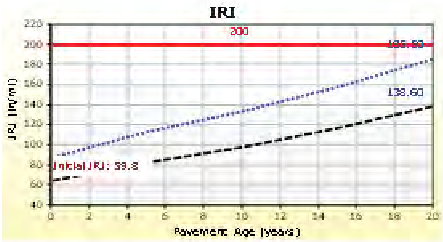
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	695
2034 (10 years)	1,593,490
2044 (20 years)	3,353,700

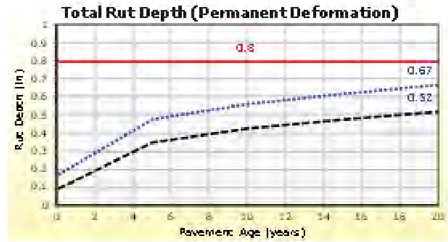
Design Outputs

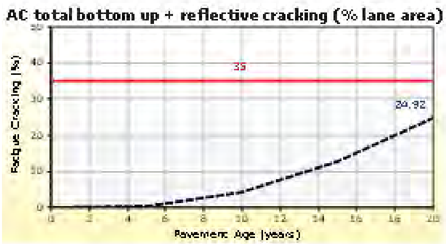
Distress Prediction Summary

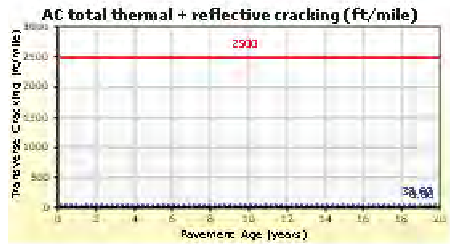
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	185.51	90.00	95.33	Pass
Permanent deformation - total pavement (in)	0.80	0.67	90.00	99.30	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	24.92	50.00	81.75	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.49	90.00	99.72	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	24.90	50.00	53.98	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	420.06	90.00	100.00	Pass

Distress Charts





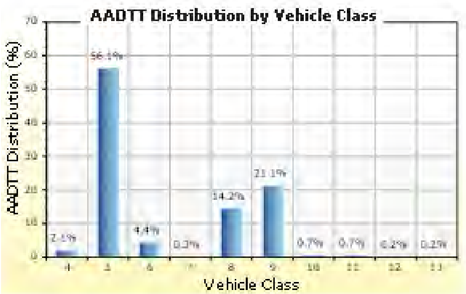


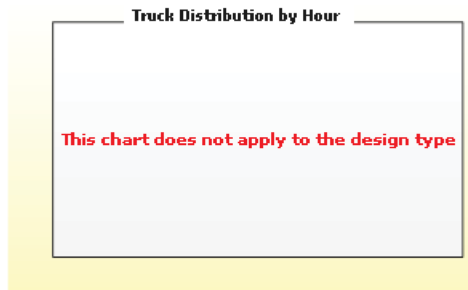


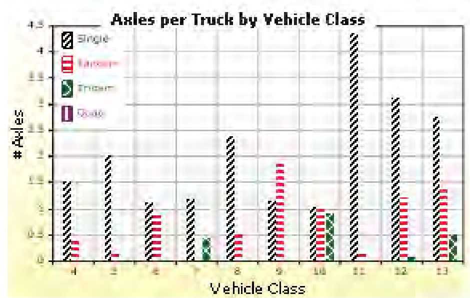
Traffic Inputs

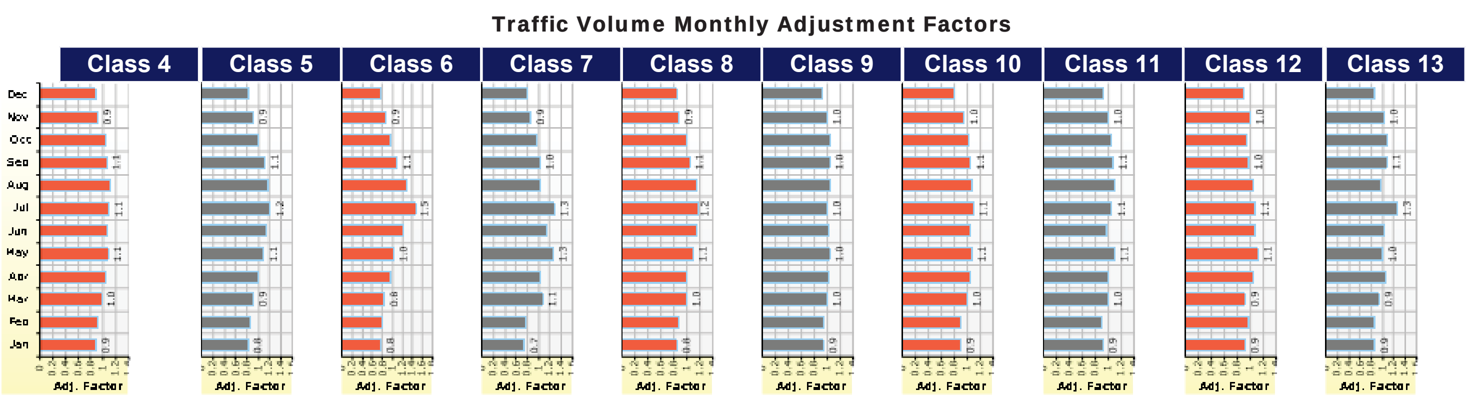
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	695	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0









Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.9	0.8	0.8	0.7	0.8	0.9	0.9	0.9	0.9	0.9
February	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.8
March	1.0	0.9	0.8	1.1	1.0	1.0	1.0	1.0	0.9	0.9
April	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.1
May	1.1	1.1	1.0	1.3	1.1	1.0	1.1	1.1	1.1	1.0
June	1.1	1.1	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0
July	1.1	1.2	1.5	1.3	1.2	1.0	1.1	1.1	1.1	1.3
August	1.1	1.2	1.3	1.0	1.1	1.0	1.1	1.1	1.1	1.0
September	1.1	1.1	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.1
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.1
November	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0
December	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	0.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

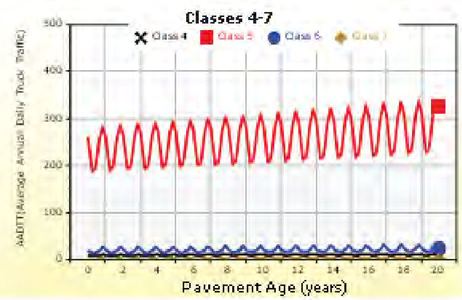
Wheelbase does not apply

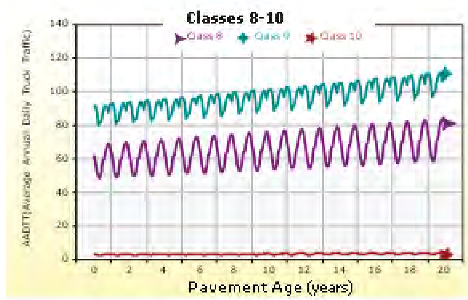
Number of Axles per Truck

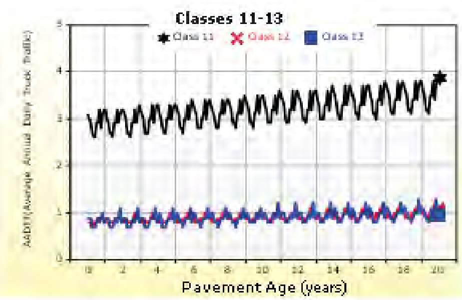
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

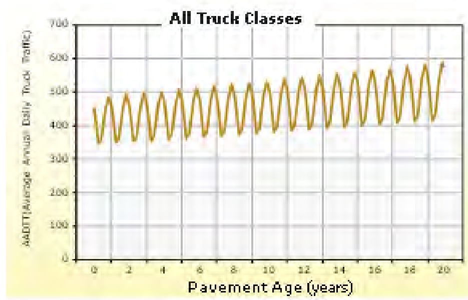
AADTT (Average Annual Daily Truck Traffic) Growth

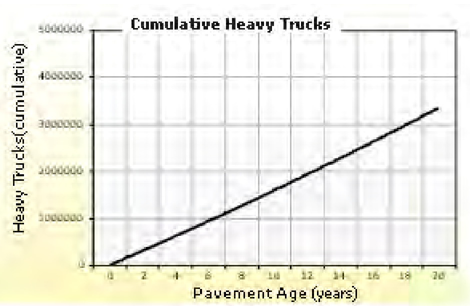
*** Traffic cap is not enforced**







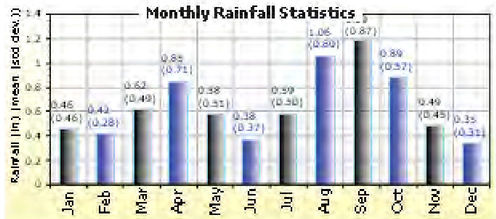




Climate Inputs

Climate Data Sources:

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

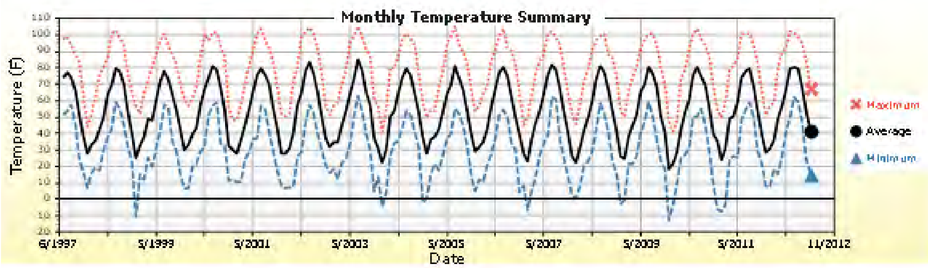


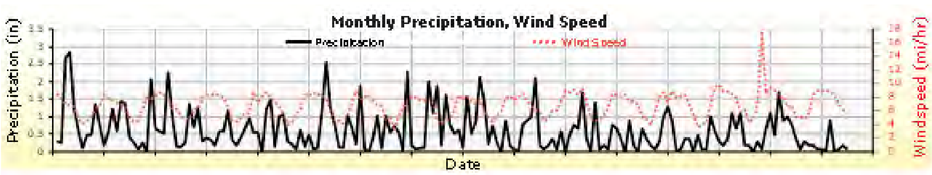
Annual Statistics:

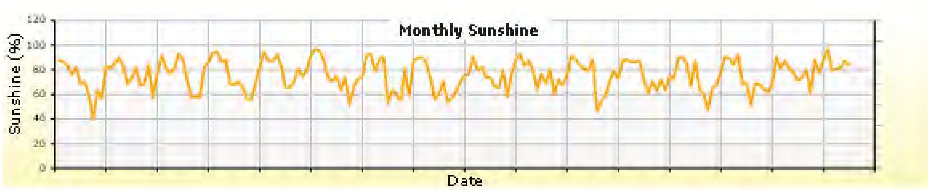
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

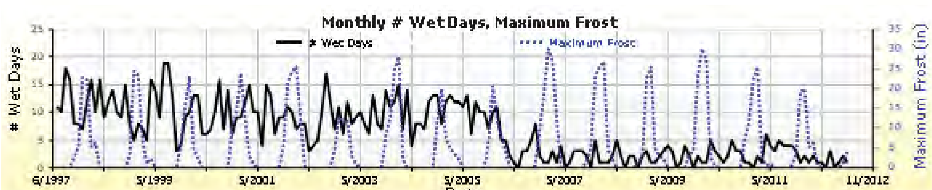
Water table depth (ft) 10.00

Monthly Climate Summary:

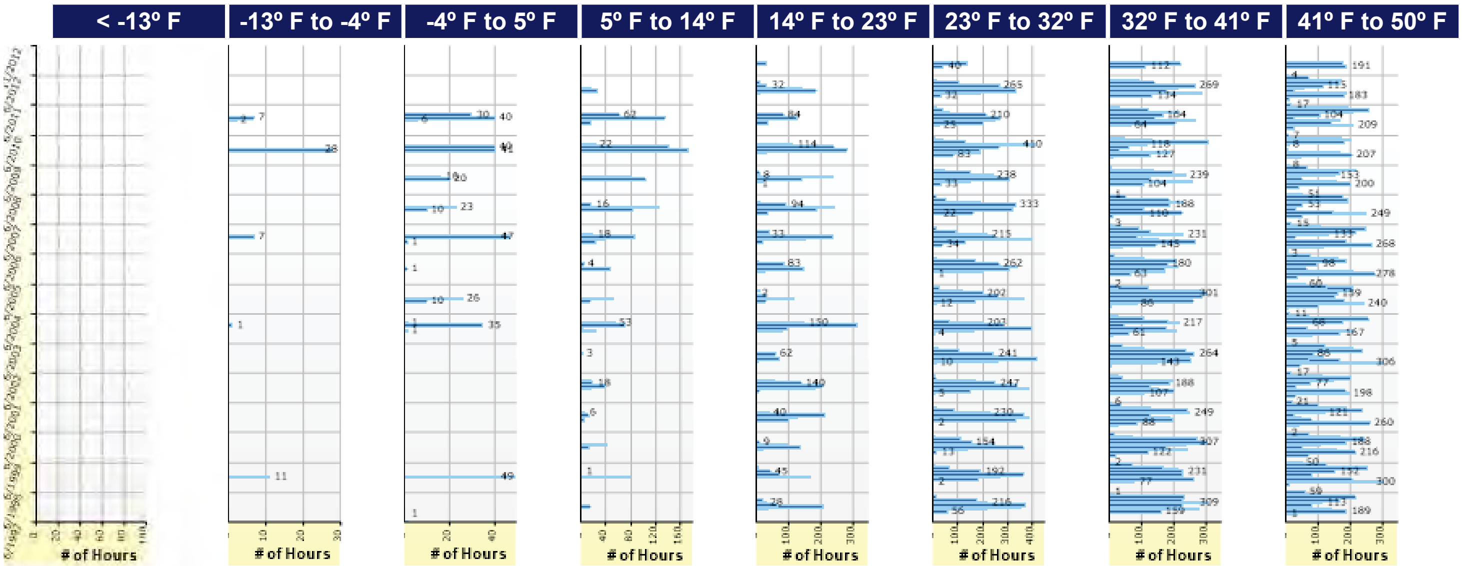


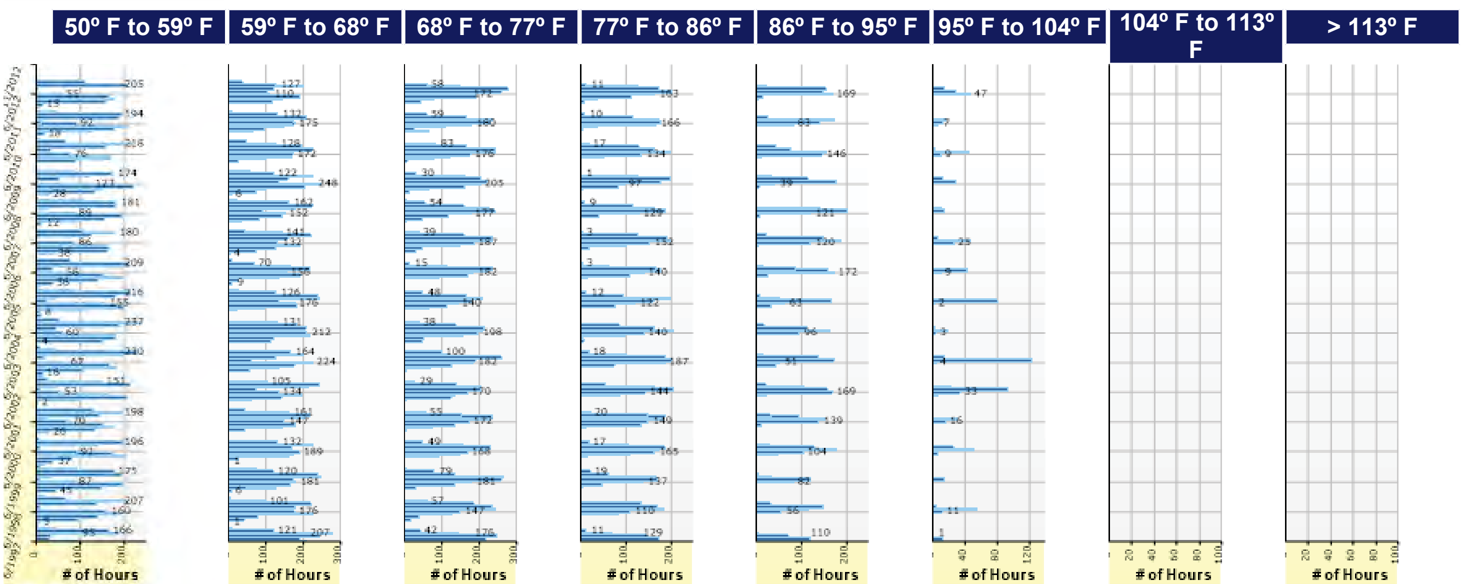






Hourly Air Temperature Distribution by Month:





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 : CIR Layer	Flexible (1)	1.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

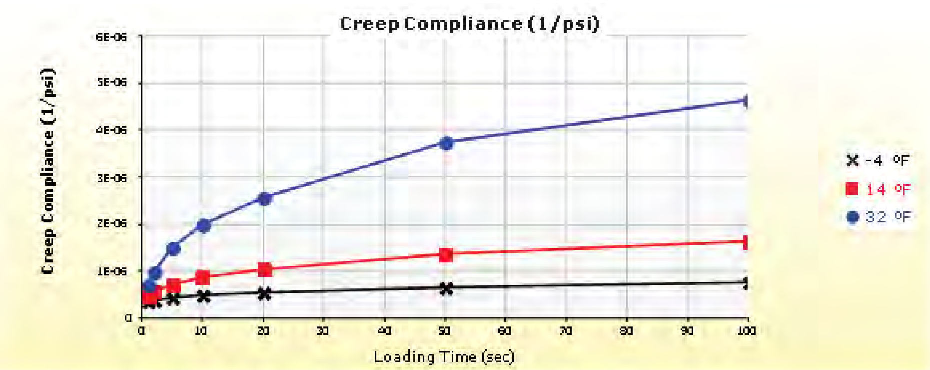
Milled thickness (in)	4.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	0.00 (Low)
Total rut depth (in)	-

Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : CIR Layer	Flexible (1)	0.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 5 Subgrade : A-6	Subgrade (5)	0.00

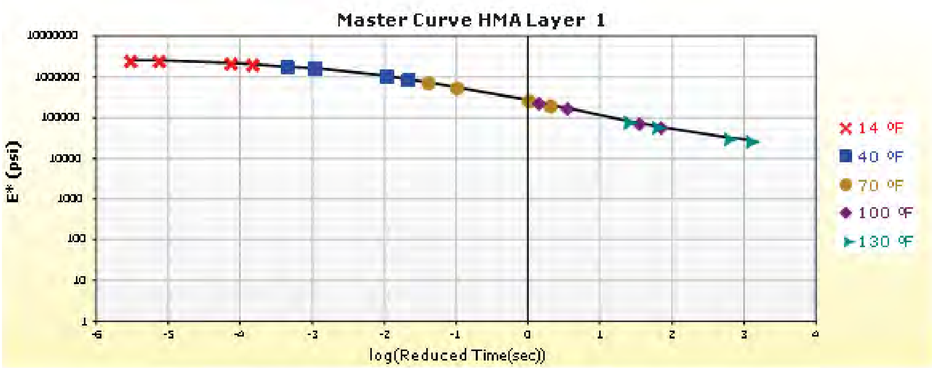
Thermal Cracking (Input Level: 1)

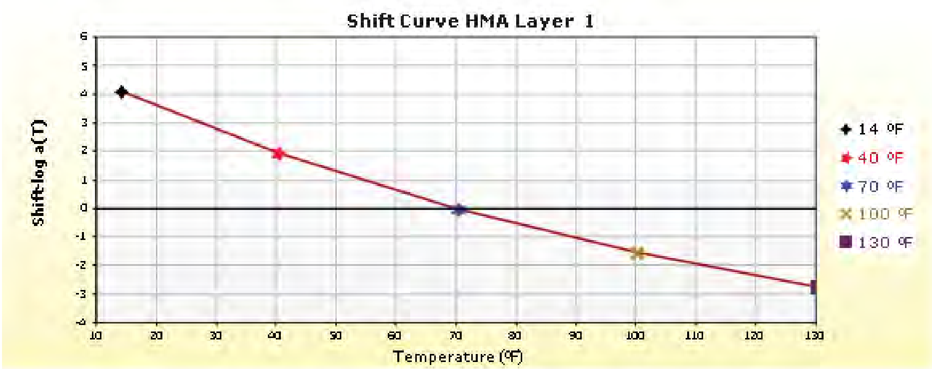
Indirect tensile strength at 14 ºF (psi)	519.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

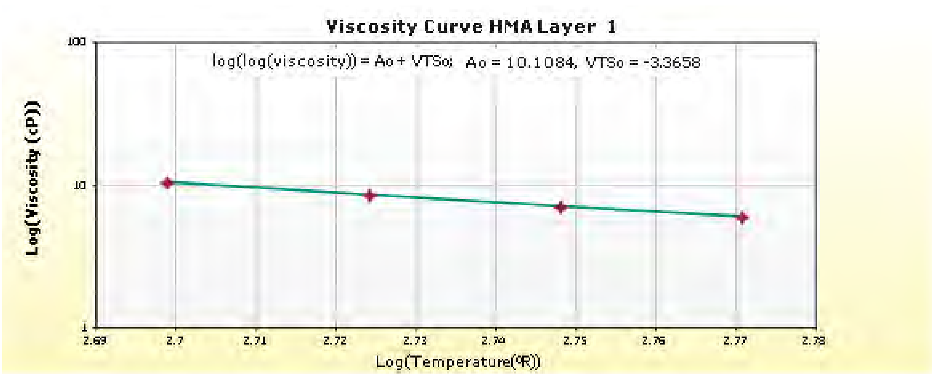
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



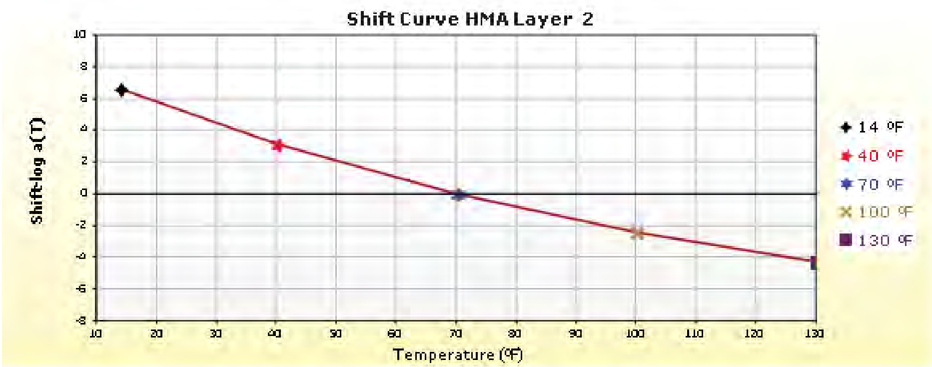
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

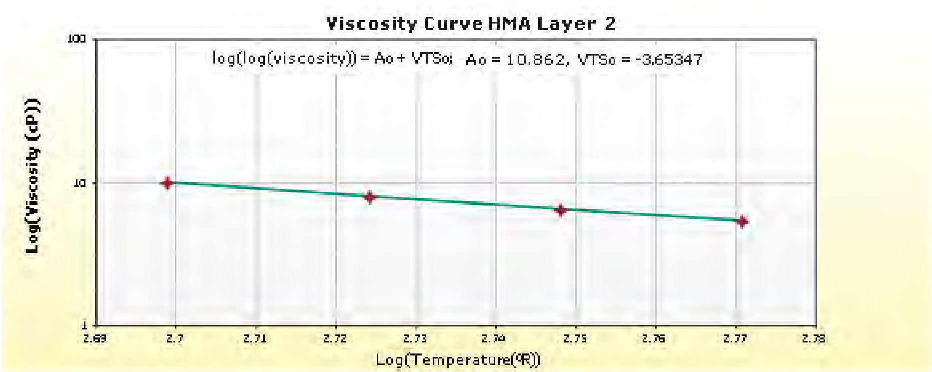




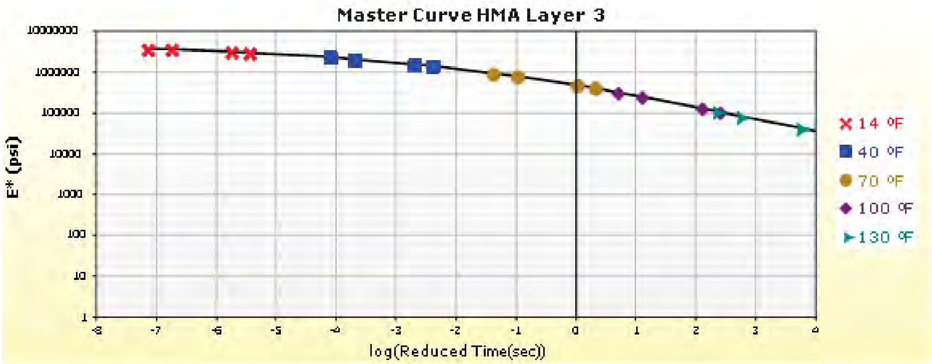


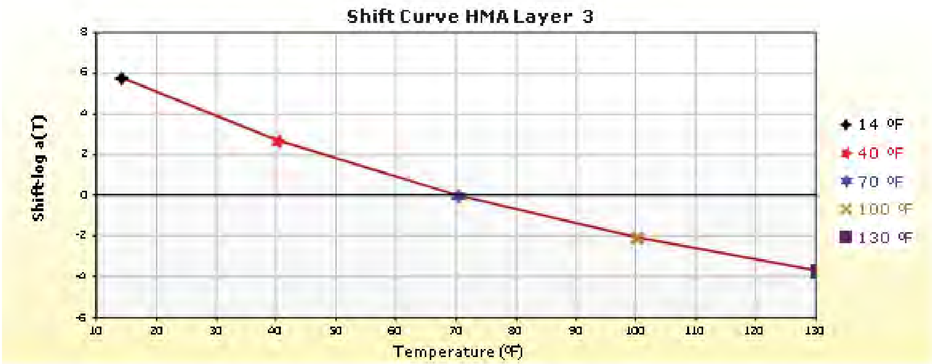
HMA Layer 2: Layer 2 Flexible : CIR Layer

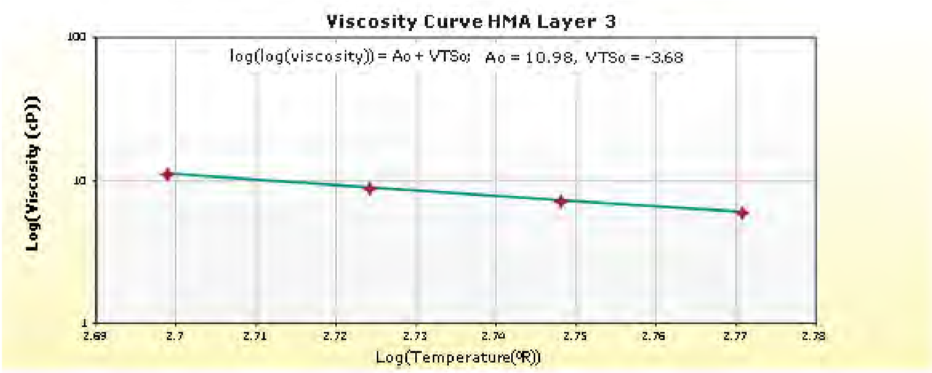




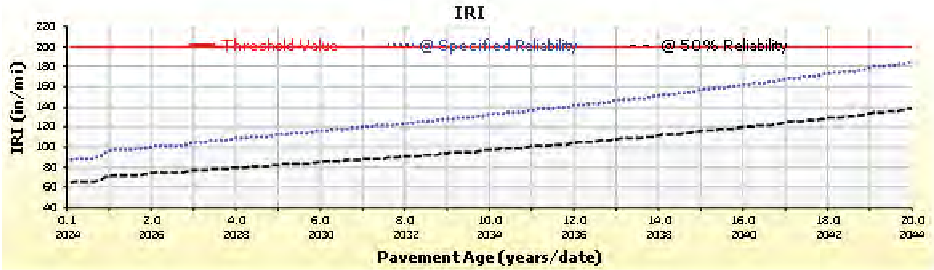
HMA Layer 3: Layer 3 Flexible : Default asphalt concrete(existing)

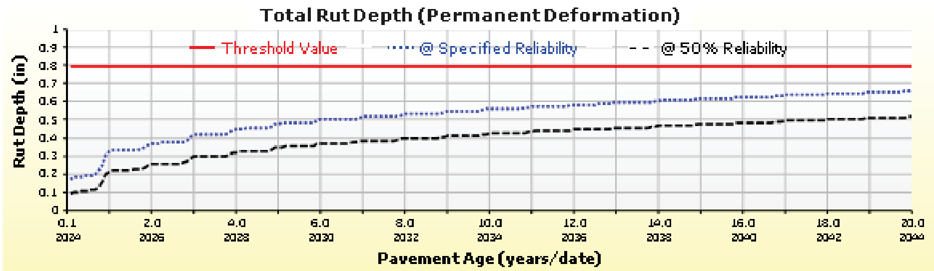


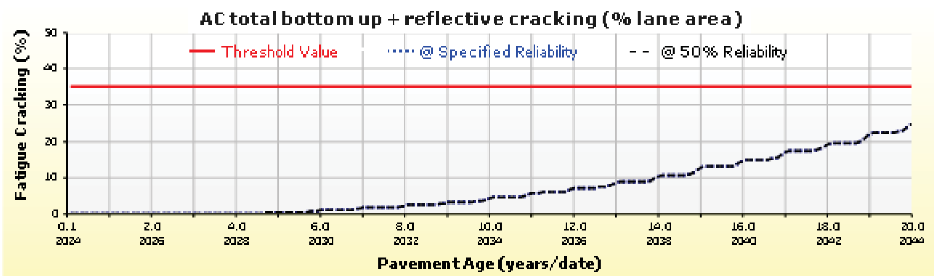


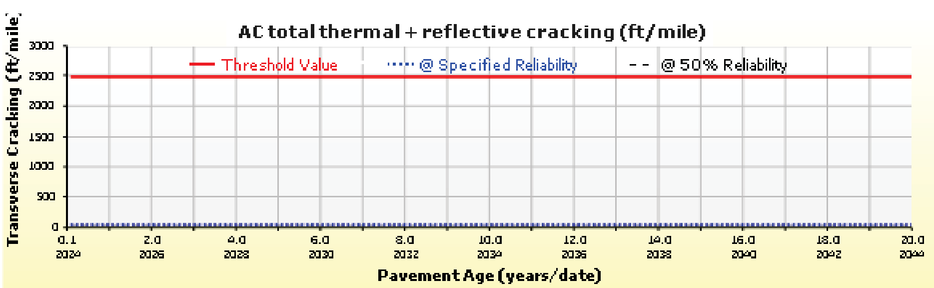


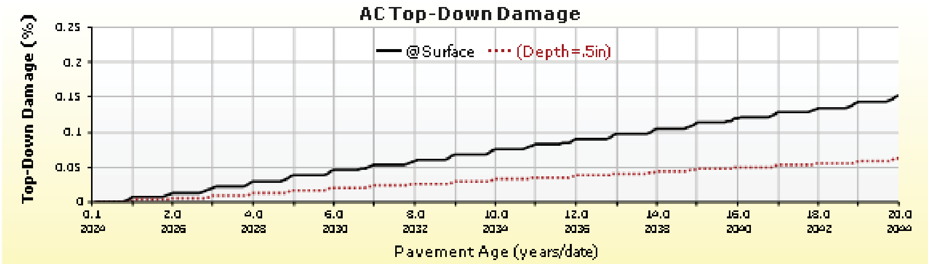
Analysis Output Charts



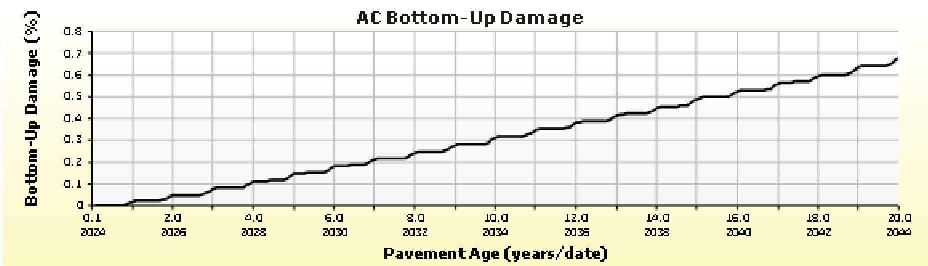




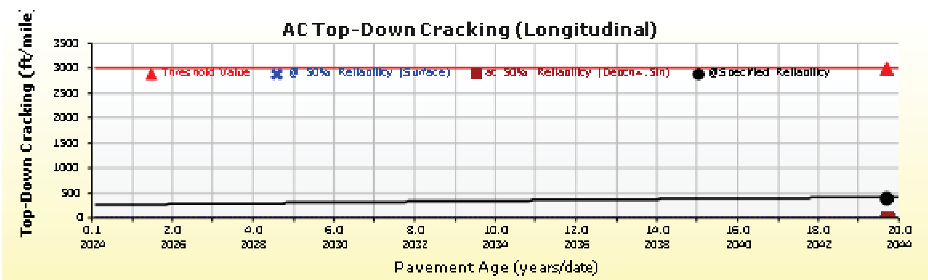




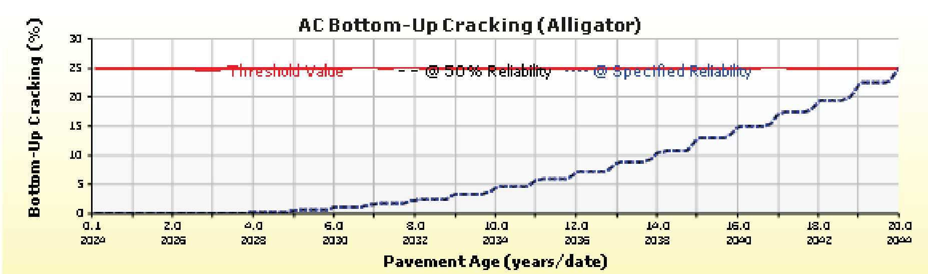
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



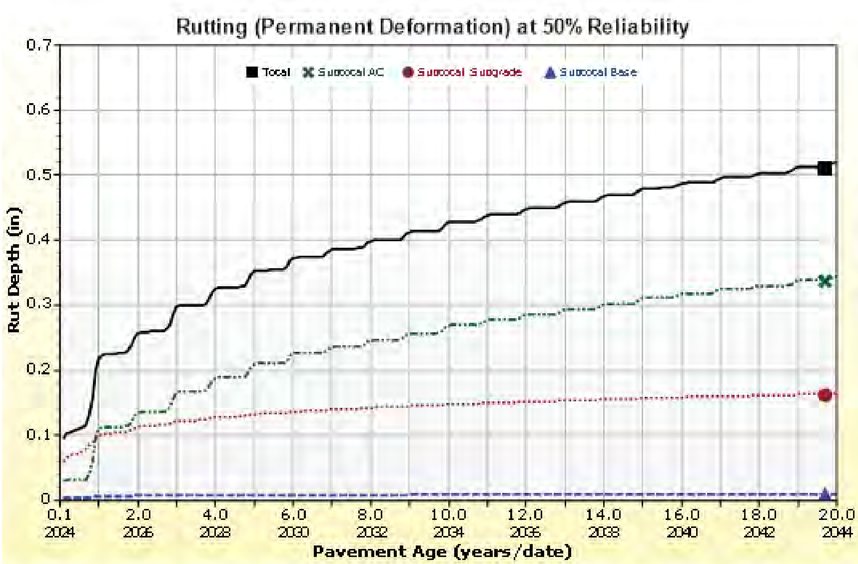
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

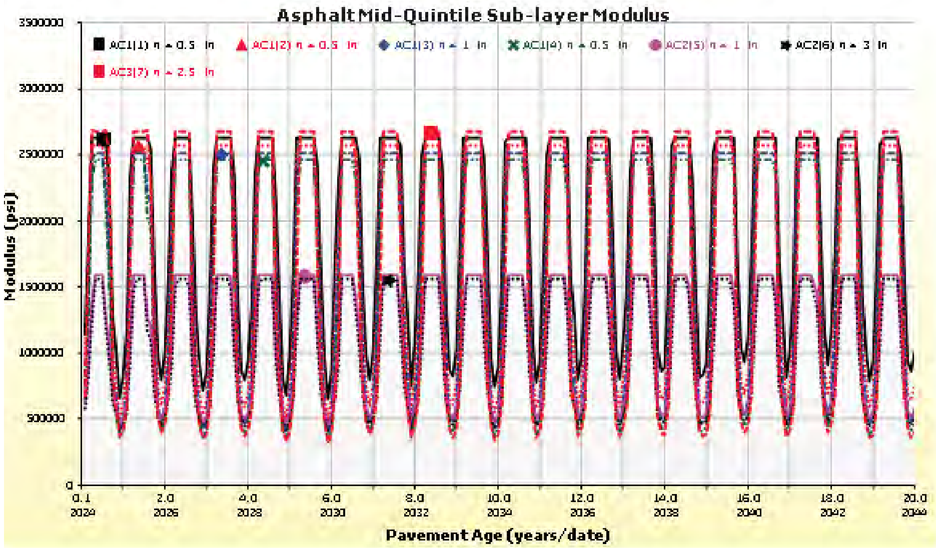


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
@ 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
Pavement Age (years/date)

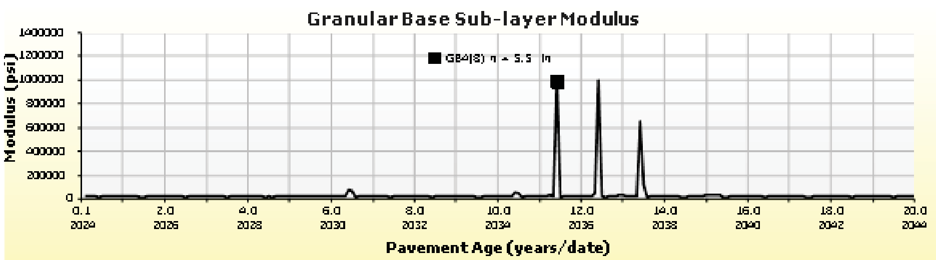


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

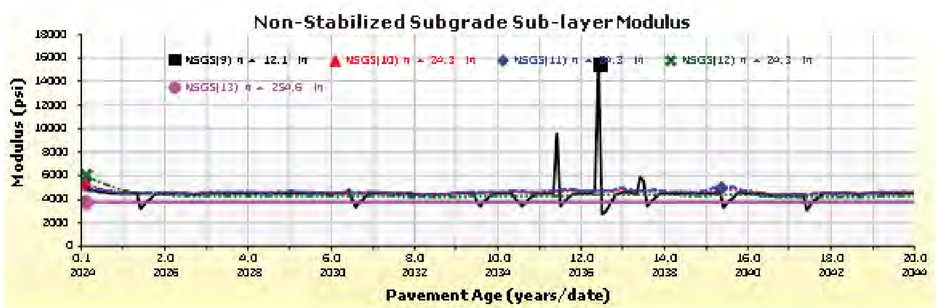

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
Pavement Age (years/date)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2024
2.0
2026
4.0
2028
6.0
2030
8.0
2032
10.0
2034
12.0
2036
14.0
2038
16.0
2040
18.0
2042
20.0
2044



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC1(4) h = 0.5 in
AC2(5) h = 1 in
AC2(6) h = 3 in
AC3(7) h = 2.5 in
Modulus (psi)
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB4(8) h = 5.5 in
Modulus (psi)
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSGS(9) h = 12.1 in
NSGS(10) h = 24.3 in
NSGS(11)
NSGS(12) h = 24.3 in
NSGS(13) h = 254.6 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	2.5	
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	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 : CIR Layer

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	146.5	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1203200	1339800	1398500	1533300	1590400	1664700
40	739800	862600	917600	1049200	1107000	1184300
70	370200	455800	496300	598000	645100	710100
100	169100	217900	242100	306100	337200	381700
130	75400	99900	112500	147400	165100	191100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	835	82
158	419	84
136.4	1758	80

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	6.5
Air voids (%)	12.8
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	CIR Layer
Description of object	
Author	CDOT
Date Created	5/9/2018 12:00:00 AM
Approver	CDOT
Date approved	5/9/2018 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 Flexible : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	2.5	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 4 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	5.5
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)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-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)
6482.0

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

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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC = Crack length increment, in

ΔD = Incremental damage ratio

$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$ = Calibration factors (local and global)

$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$ = Crack length increments caused by bending, shearing, and thermal loading

A, n = HMA material fracture properties

N = Total number of days

$(SIF)_B, (SIF)_S, (SIF)_T$ = Stress intensity factors caused by bending, shearing, and thermal loading

D = Damage ratio

h_{OL} = Overlay thickness, in

RCR = Cracks in the underlying layers reflected, %

EX_CRK = Transverse cracking in underlying pavement layers, ft/mile (transverse cracking)
Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

D.5 Road 4 inch CIR and 2 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\D.5 Road 4 inch CIR and 2 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.0
Flexible (OL)	CIR Layer	4.0
Flexible (existing)	Default asphalt concrete	4.5
NonStabilized	Crushed stone	6.0
Subgrade	A-4	Semi-infinite

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

Traffic

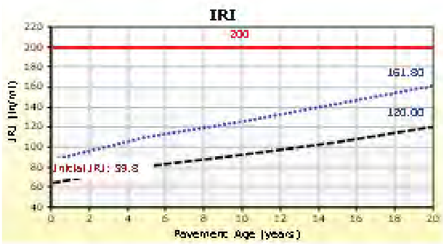
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	655
2034 (10 years)	1,501,780
2044 (20 years)	3,160,680

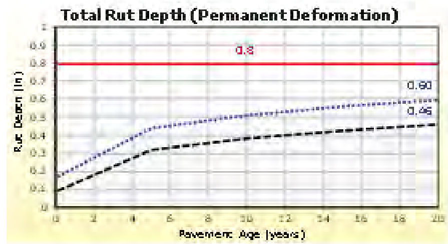
Design Outputs

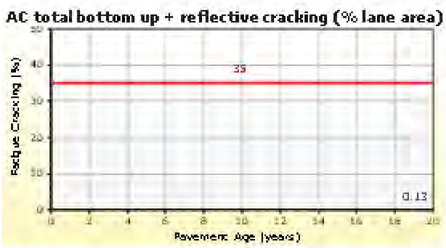
Distress Prediction Summary

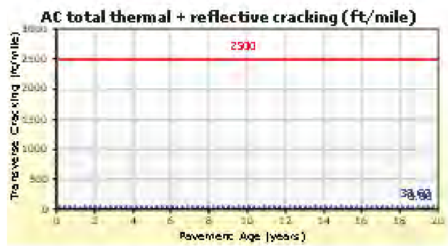
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	161.78	90.00	99.30	Pass
Permanent deformation - total pavement (in)	0.80	0.60	90.00	99.92	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	0.13	50.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.40	90.00	99.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.13	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	282.77	90.00	100.00	Pass

Distress Charts







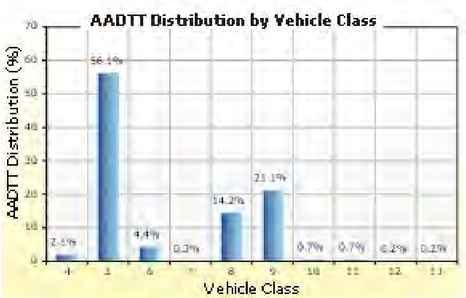


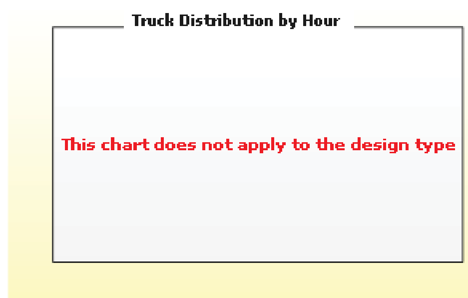
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

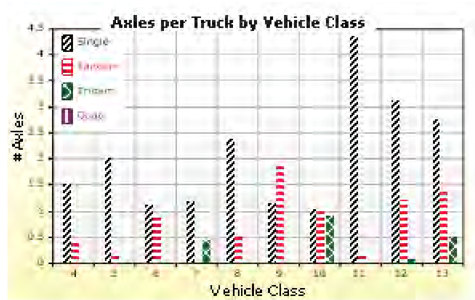
Traffic Inputs

Graphical Representation of Traffic Inputs

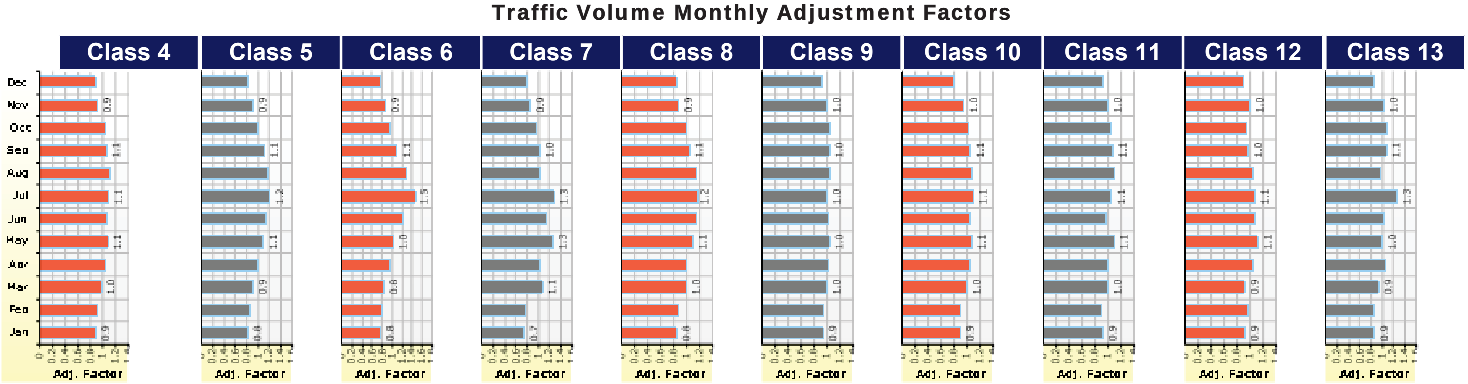
Initial two-way AADTT:	655	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

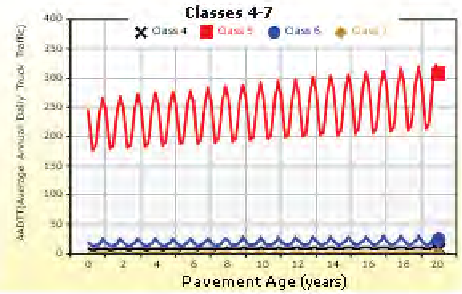
Wheelbase does not apply

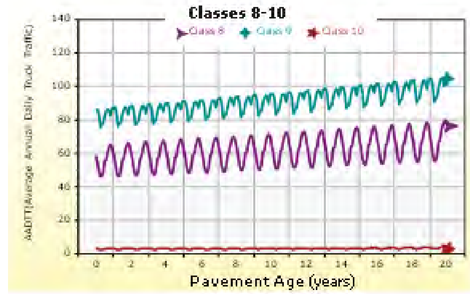
Number of Axles per Truck

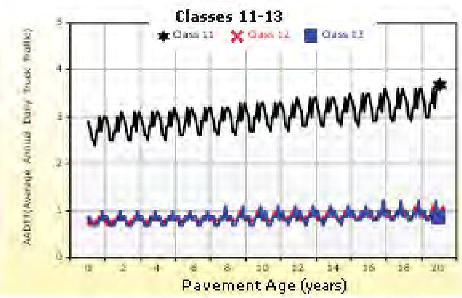
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

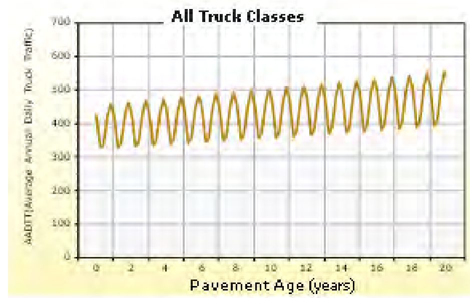
AADTT (Average Annual Daily Truck Traffic) Growth

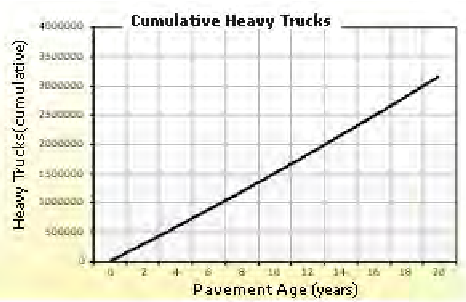
*** Traffic cap is not enforced**







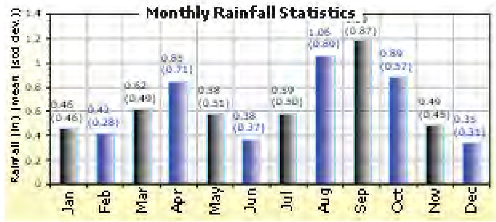




Climate Inputs

Climate Data Sources:

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

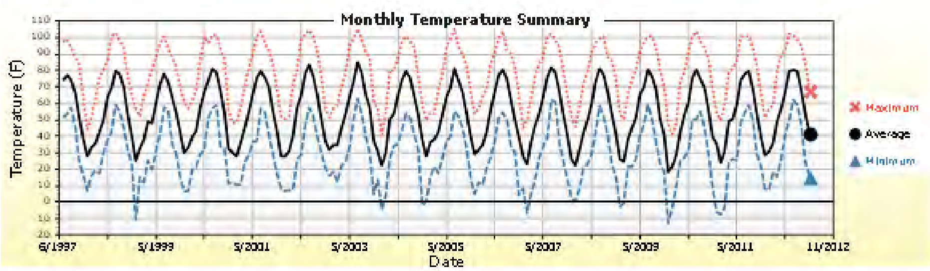


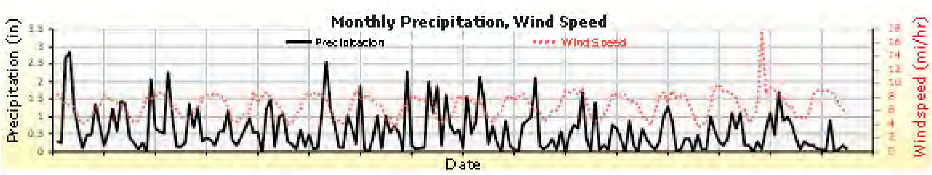
Annual Statistics:

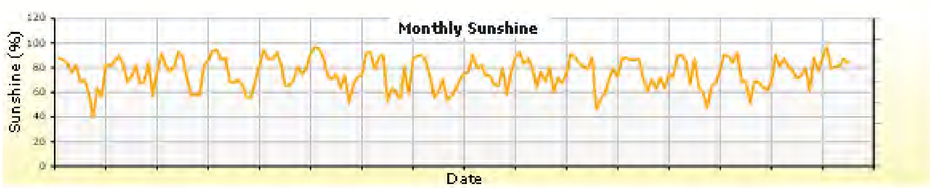
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

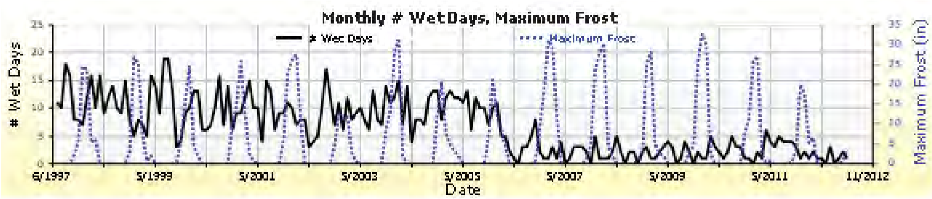
Water table depth (ft) 10.00

Monthly Climate Summary:

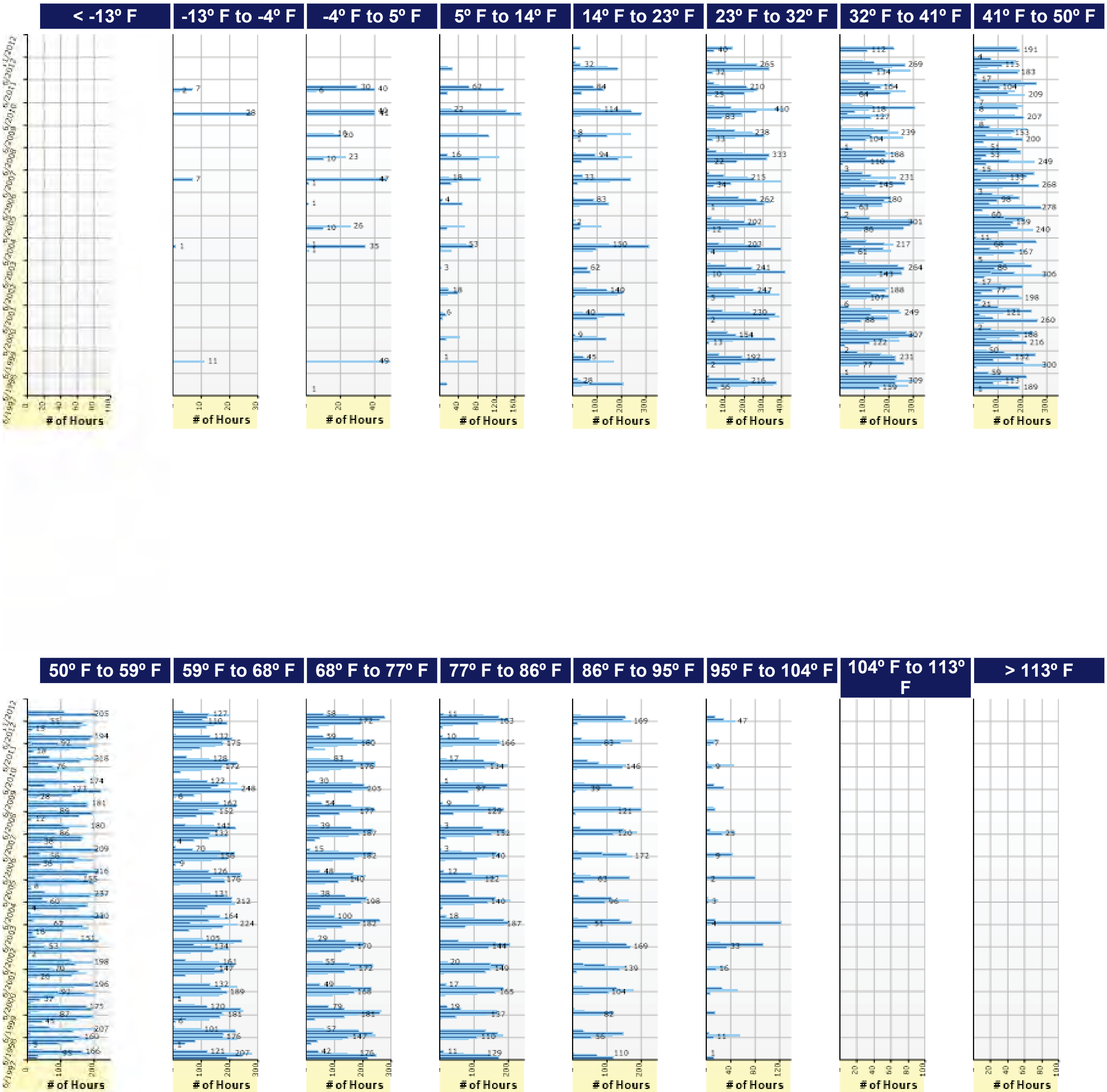








Hourly Air Temperature Distribution by Month:



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 : CIR Layer	Flexible (1)	1.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

Milled thickness (in)	4.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	0.00 (Low)
Total rut depth (in)	-

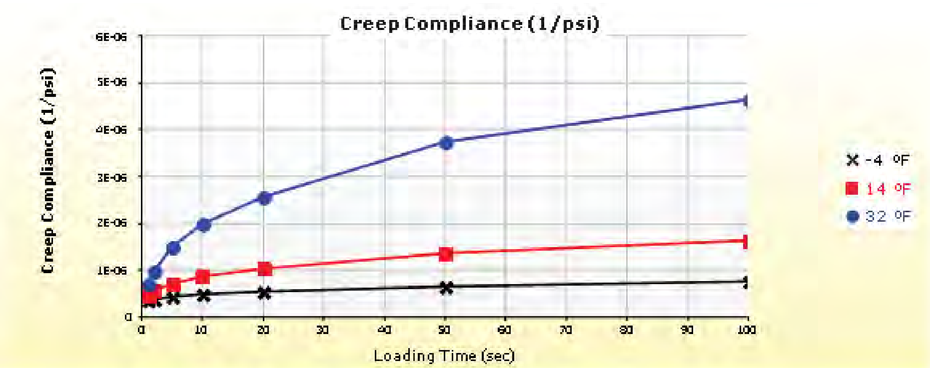
Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : CIR Layer	Flexible (1)	0.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 5 Subgrade : A-4	Subgrade (5)	0.00

Thermal Cracking (Input Level: 1)

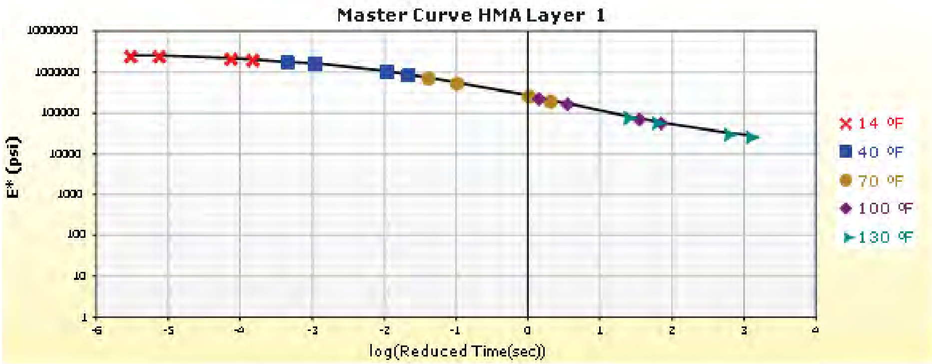
Indirect tensile strength at 14 ºF (psi)	519.00

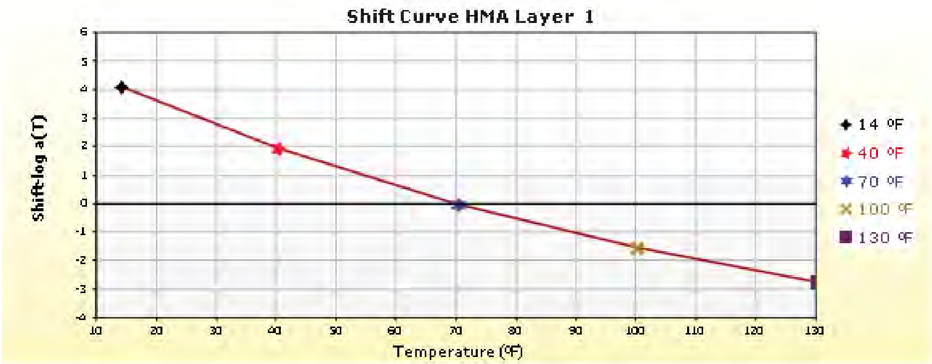
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

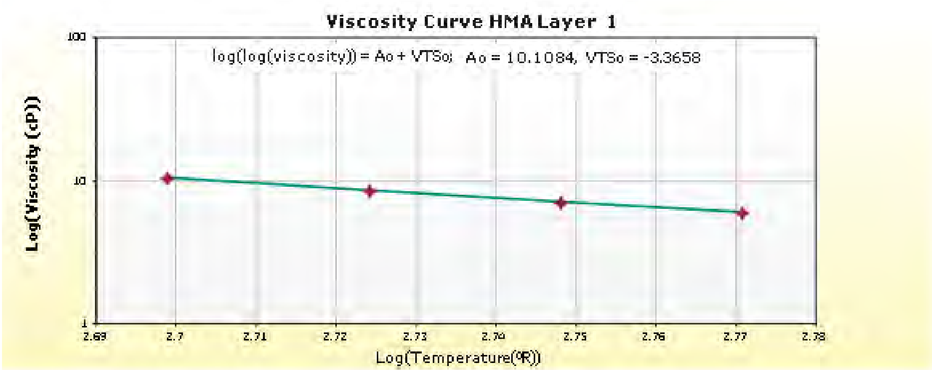
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



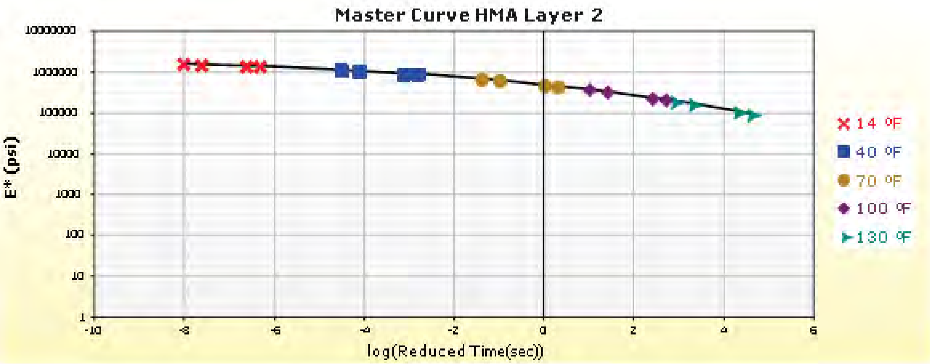
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

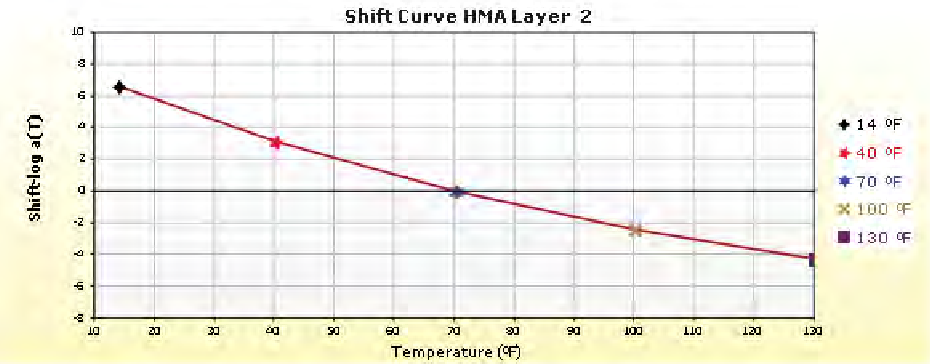


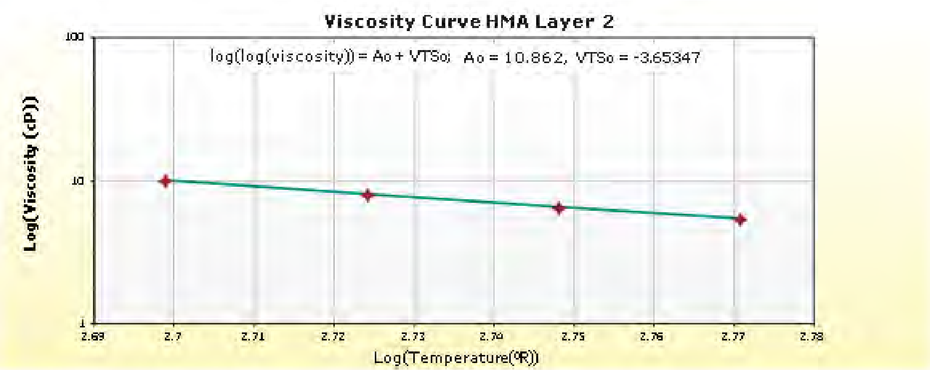




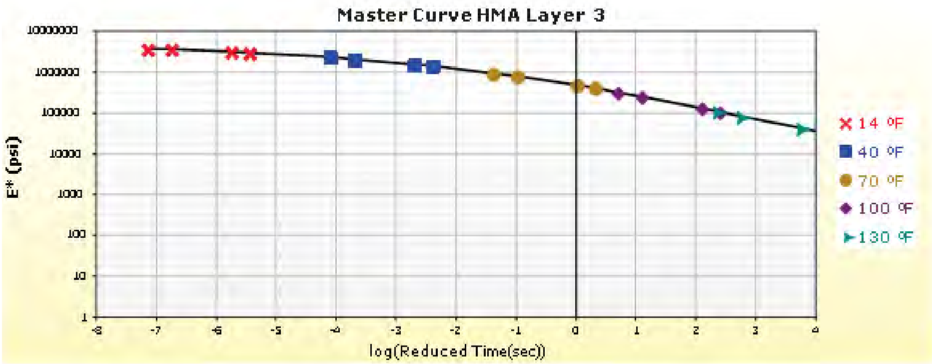
HMA Layer 2: Layer 2 Flexible : CIR Layer

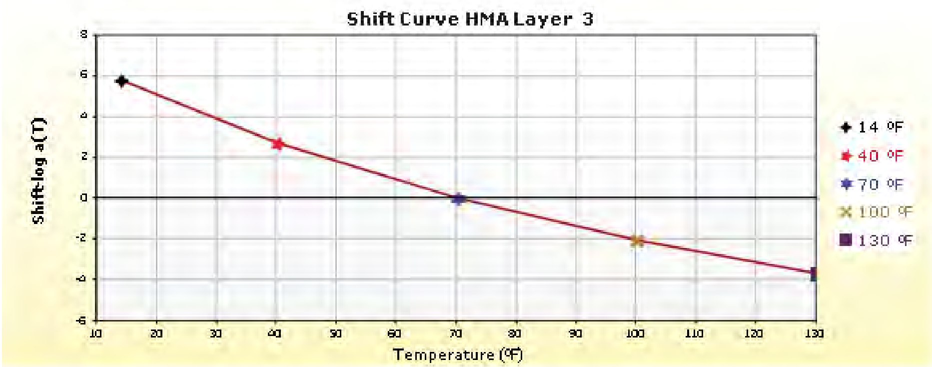


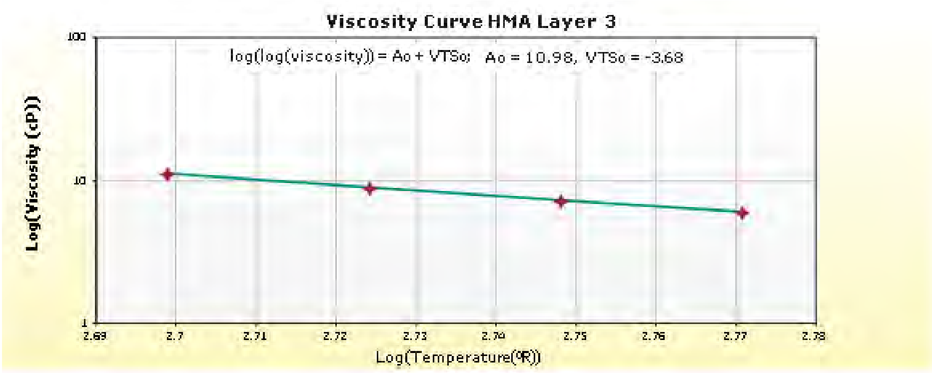




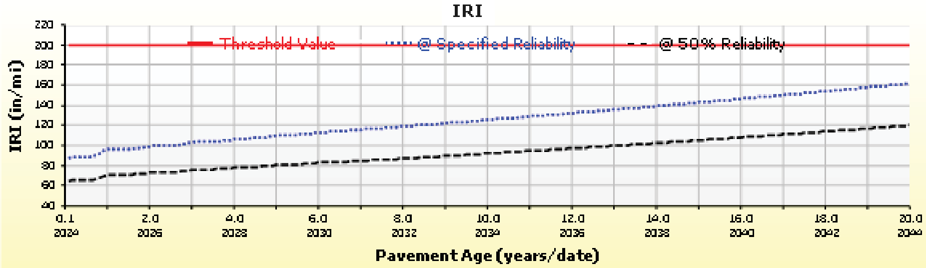
HMA Layer 3: Layer 3 Flexible : Default asphalt concrete(existing)

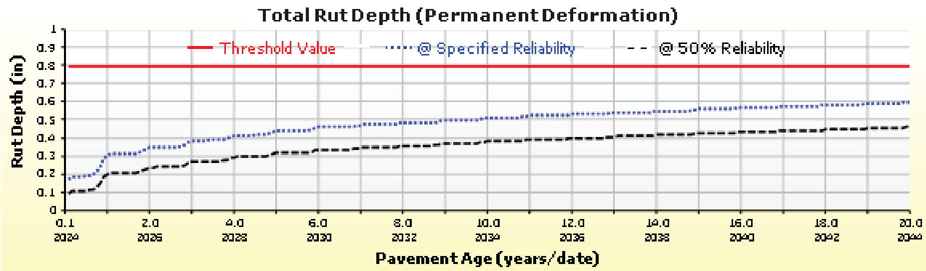


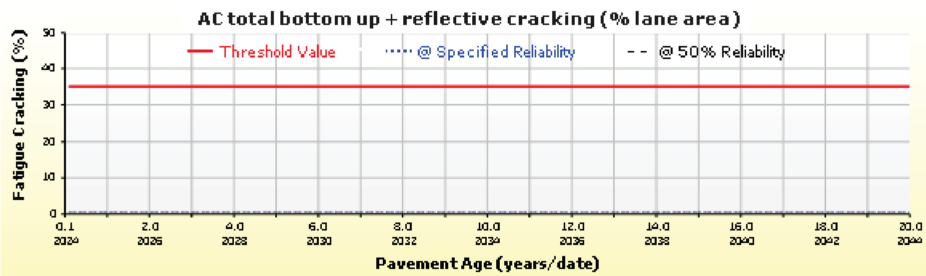


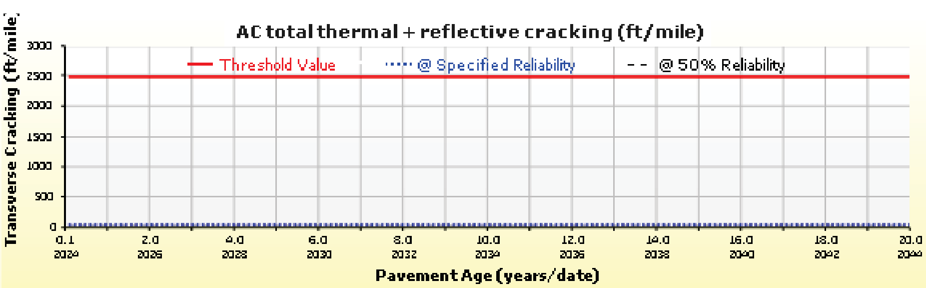


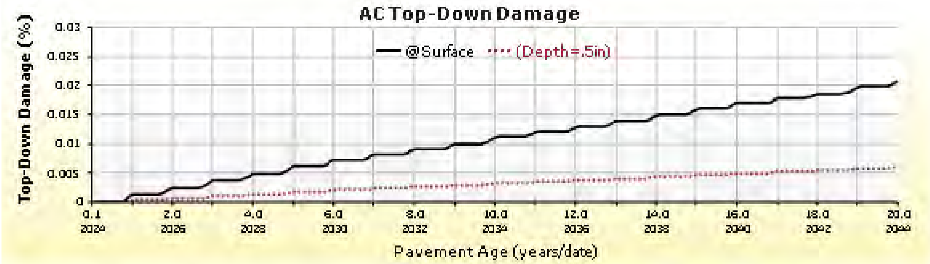
Analysis Output Charts

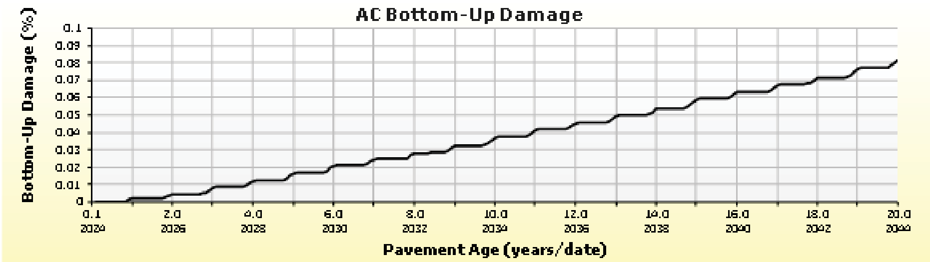


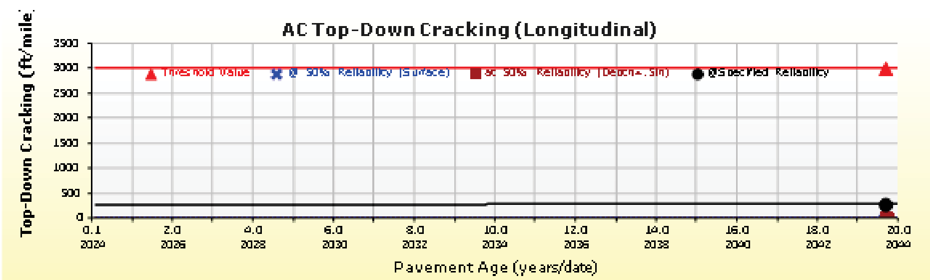


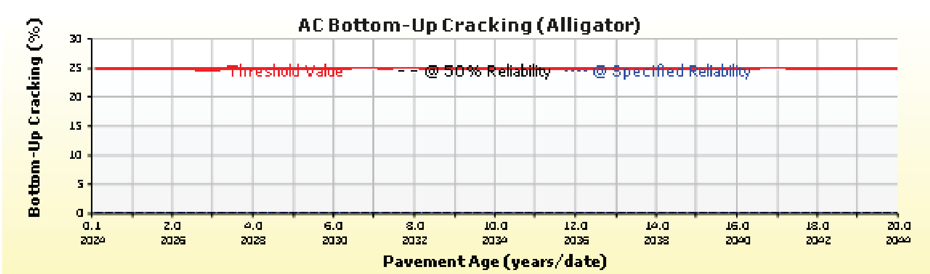


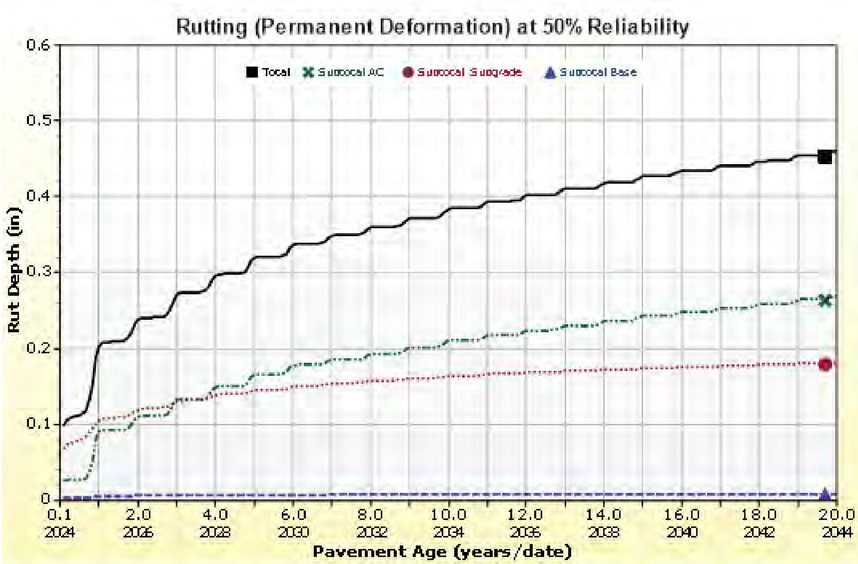



AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)

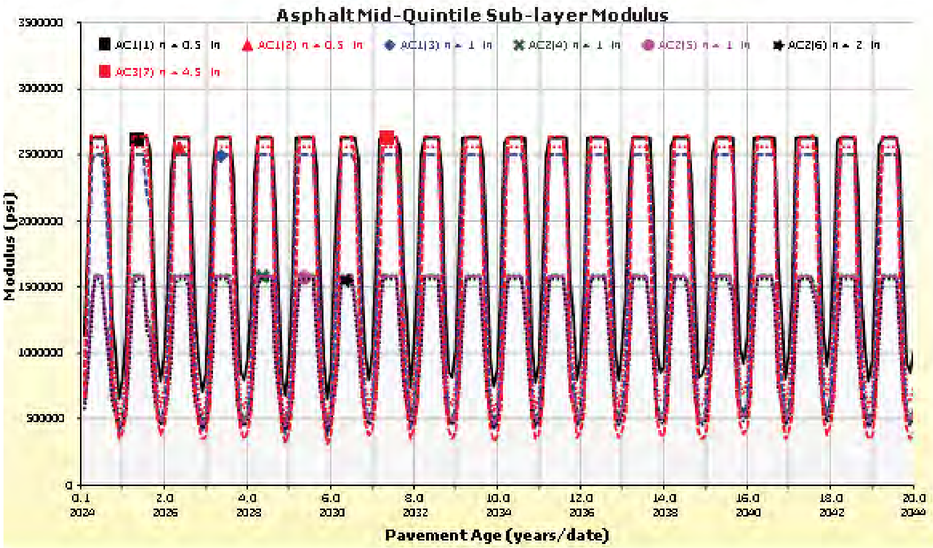

AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)


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

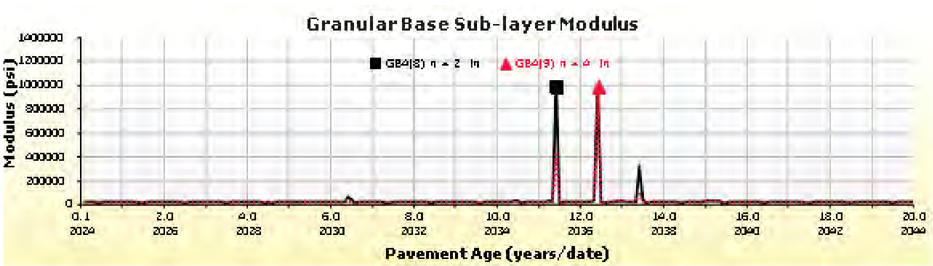

AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)



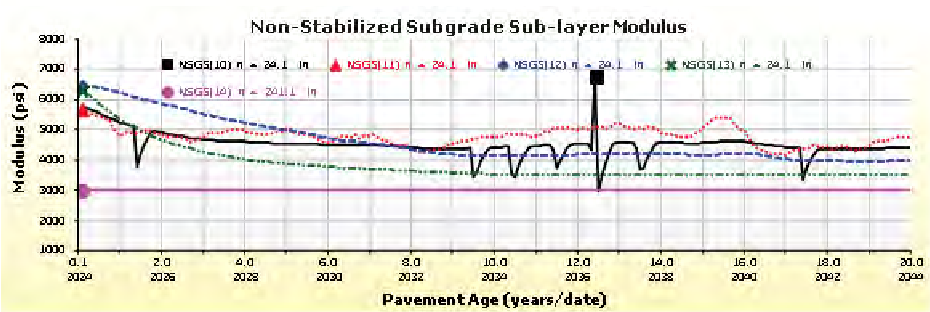
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
Pavement Age (years/date)



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
AC3(7) h = 4.5 in
Modulus (psi)
Pavement Age (years/date)



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



Non-Stabilized Subgrade Sub-layer Modulus
NSGS(10) h = 24.1 in
NSGS(11) h = 24.1 in
NSGS(12) h = 24.1 in
NSGS(13) h = 24.1 in
NSGS(14) h = 241.1 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 : CIR Layer

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	146.5	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1203200	1339800	1398500	1533300	1590400	1664700
40	739800	862600	917600	1049200	1107000	1184300
70	370200	455800	496300	598000	645100	710100
100	169100	217900	242100	306100	337200	381700
130	75400	99900	112500	147400	165100	191100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	835	82
158	419	84
136.4	1758	80

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	6.5
Air voids (%)	12.8
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	CIR Layer
Description of object	
Author	CDOT
Date Created	5/9/2018 12:00:00 AM
Approver	CDOT
Date approved	5/9/2018 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 Flexible : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	4.5	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 4 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

F.5 Road 4 inch CIR and 2 inch Overlay

File Name: C:\Users\Rlepro\Documents\ME Pavement\My ME Design\Projects\F.5 Road 4 inch CIR and 2 inch Overlay.dgpx

Design Inputs

Design Life: 20 years
Design Type: ACC_ACC

Existing construction: May, 1995
Pavement construction: June, 2024
Traffic opening: September, 2024

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

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R3 Level 1 SX(100) PG 64-28	2.0
Flexible (OL)	CIR Layer	4.0
Flexible (existing)	Default asphalt concrete	2.0
NonStabilized	Crushed stone	6.0
Subgrade	A-4	Semi-infinite

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

Traffic

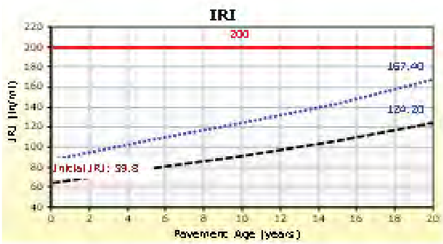
Age (year)	Heavy Trucks (cumulative)
2024 (initial)	220
2034 (10 years)	504,415
2044 (20 years)	1,061,600

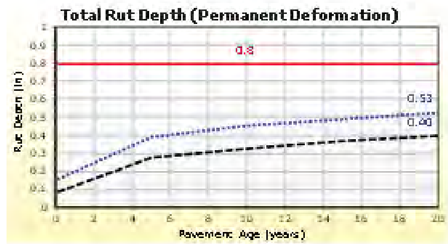
Design Outputs

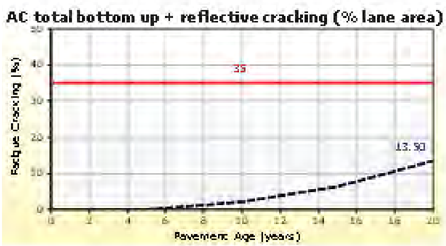
Distress Prediction Summary

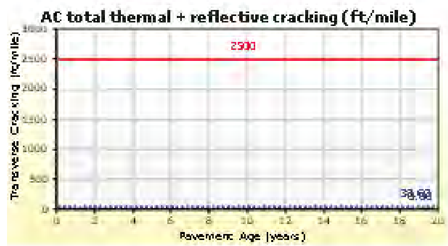
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	167.36	90.00	98.78	Pass
Permanent deformation - total pavement (in)	0.80	0.53	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	13.50	50.00	99.72	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	38.60	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.32	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	13.50	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	501.26	90.00	100.00	Pass

Distress Charts





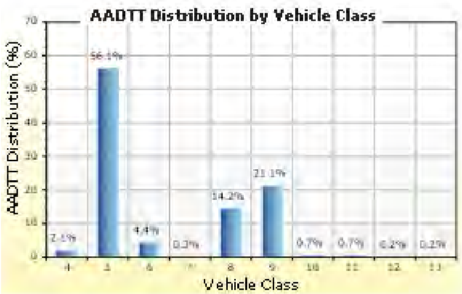


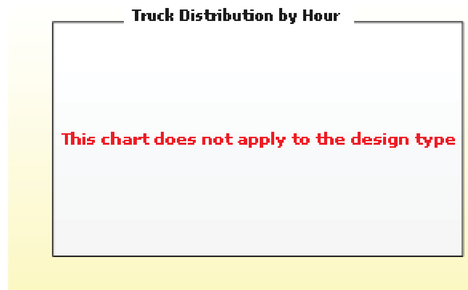


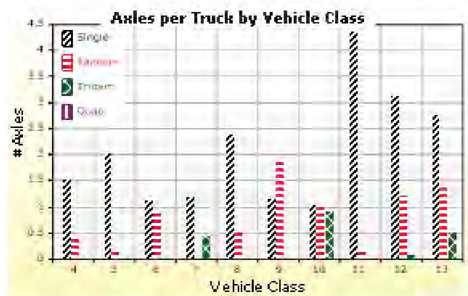
Traffic Inputs

Graphical Representation of Traffic Inputs

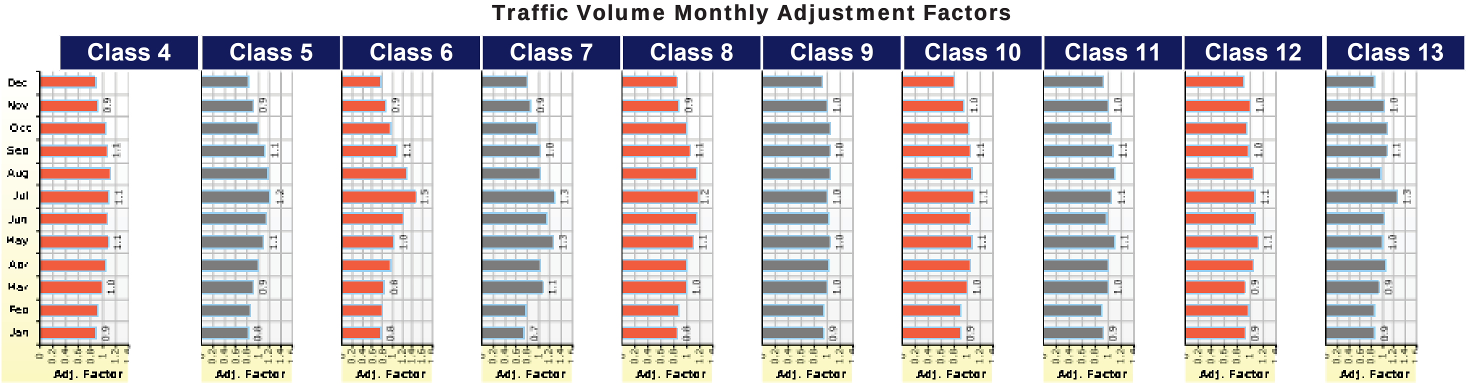
Initial two-way AADTT:	220	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0







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%	1%	Compound
Class 5	56.1%	1%	Compound
Class 6	4.4%	1%	Compound
Class 7	0.3%	1%	Compound
Class 8	14.2%	1%	Compound
Class 9	21.1%	1%	Compound
Class 10	0.7%	1%	Compound
Class 11	0.7%	1%	Compound
Class 12	0.2%	1%	Compound
Class 13	0.2%	1%	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

F.5 Road 4 inch CIR and 2 inch Overlay

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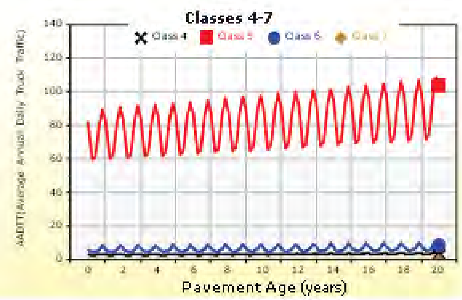
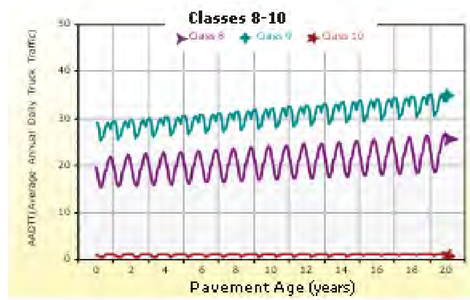
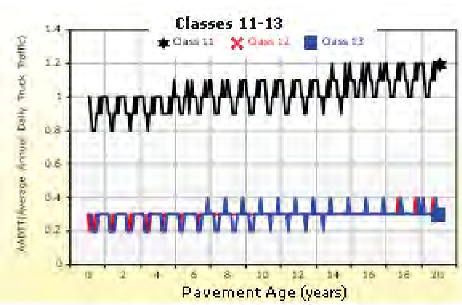
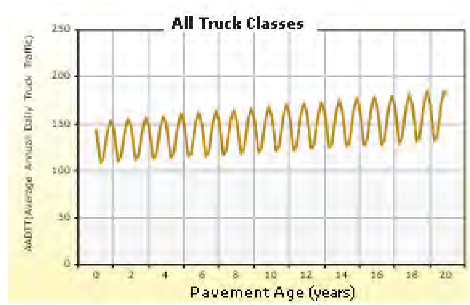
AADTT (Average Annual Daily Truck Traffic) Growth

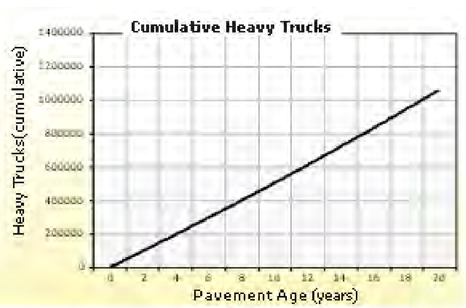
*** Traffic cap is not enforced**







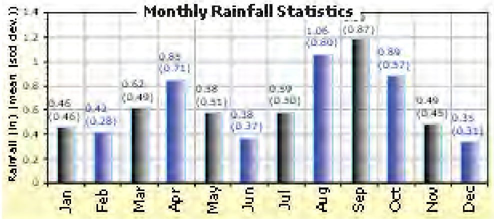




Climate Inputs

Climate Data Sources:

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

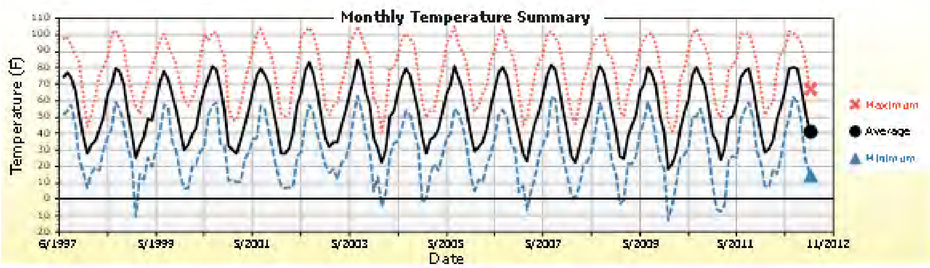


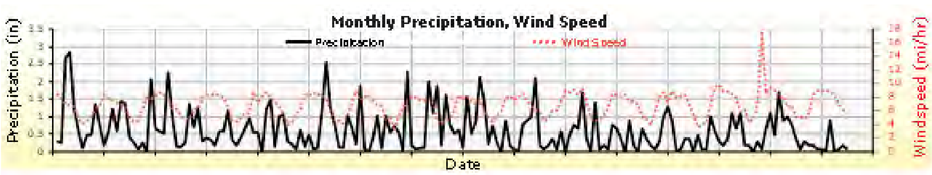
Annual Statistics:

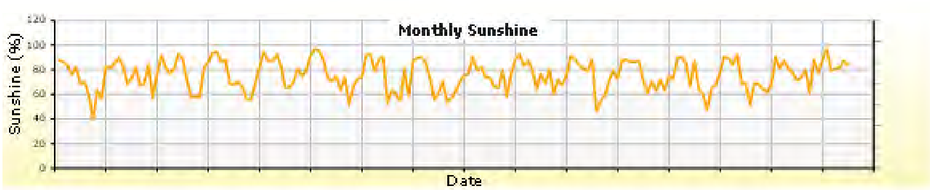
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in)	7.92
Freezing index (ºF - days)	362.08
Average annual number of freeze/thaw cycles:	111.71

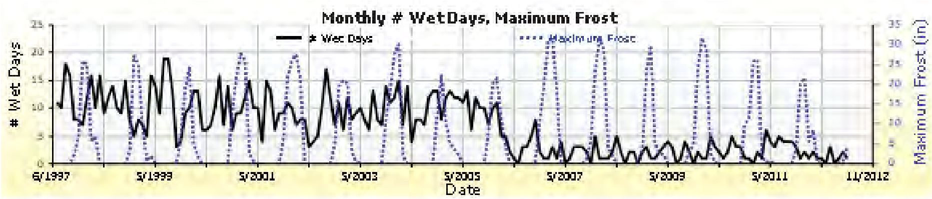
Water table depth (ft)	10.00

Monthly Climate Summary:









F.5 Road 4 inch CIR and 2 inch Overlay

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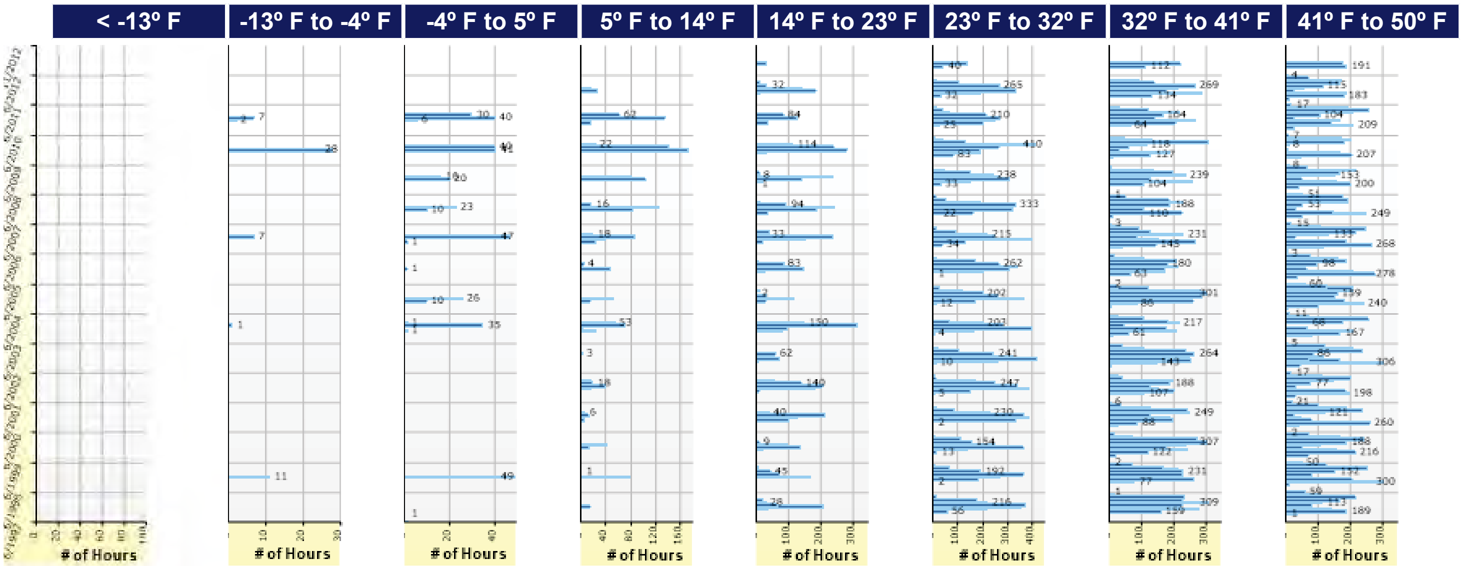
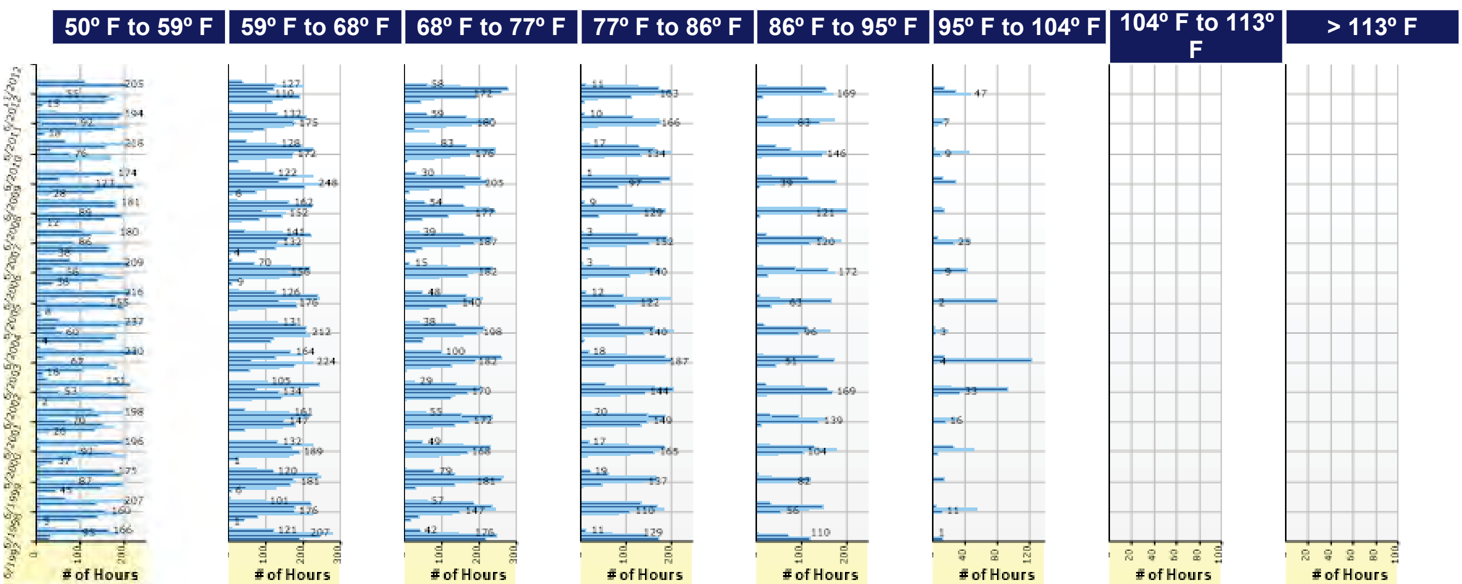
Hourly Air Temperature Distribution by Month:





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 : CIR Layer	Flexible (1)	1.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

HMA Rehabilitation (Input Level: 2)

Milled thickness (in)	4.00
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	0.00 (Low)
Total rut depth (in)	-

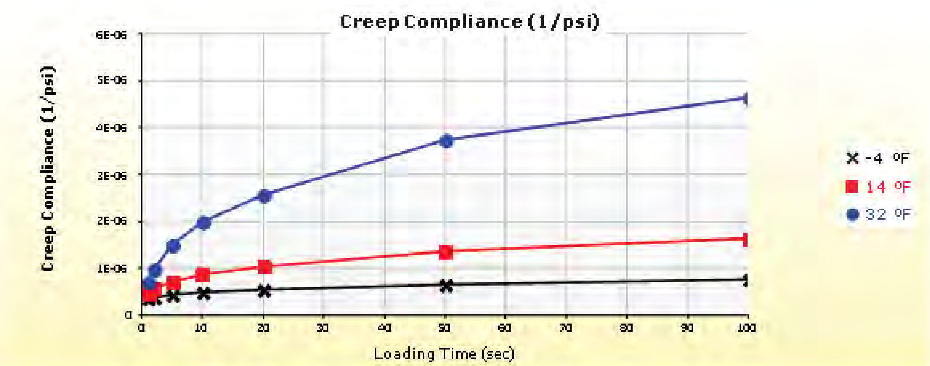
Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : R3 Level 1 SX (100) PG 64-28	Flexible (1)	-
Layer 2 Flexible : CIR Layer	Flexible (1)	0.00
Layer 3 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	0.00
Layer 5 Subgrade : A-4	Subgrade (5)	0.00

Thermal Cracking (Input Level: 1)

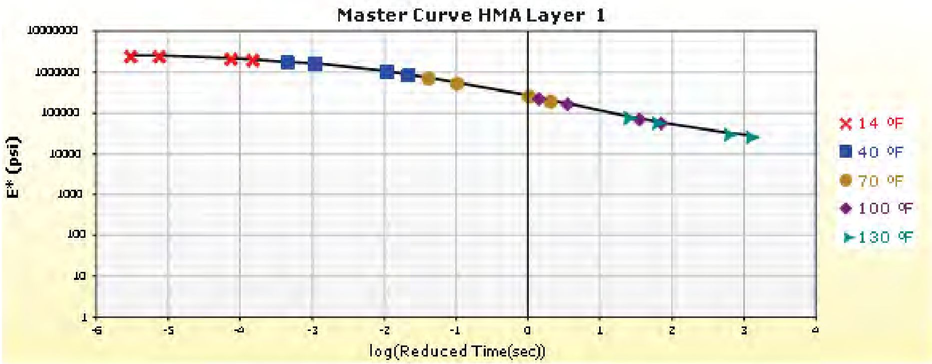
Indirect tensile strength at 14 ºF (psi)	519.00

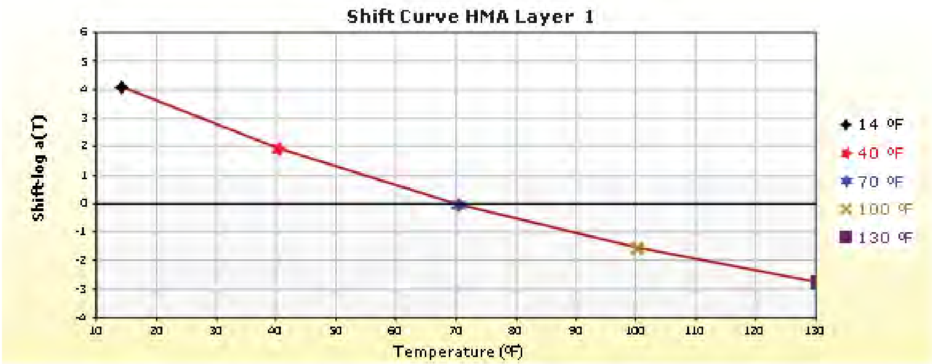
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	16.4

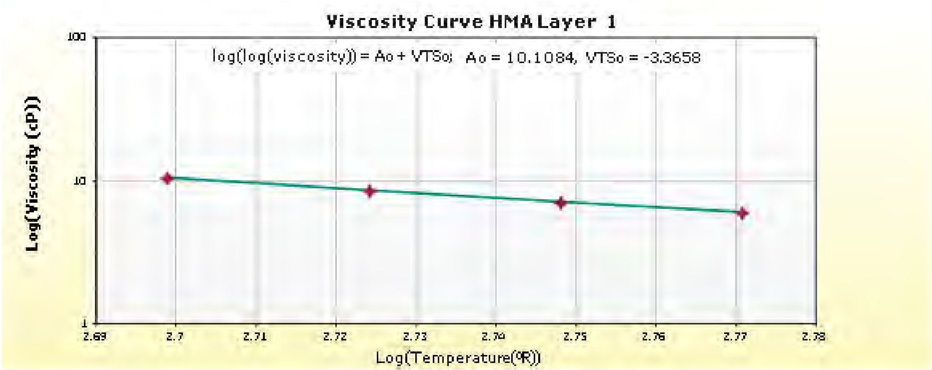
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	3.61e-007	4.73e-007	7.12e-007
2	4.04e-007	5.74e-007	9.97e-007
5	4.51e-007	7.35e-007	1.52e-006
10	5.11e-007	8.78e-007	1.99e-006
20	5.67e-007	1.04e-006	2.59e-006
50	6.57e-007	1.37e-006	3.75e-006
100	7.68e-007	1.66e-006	4.66e-006



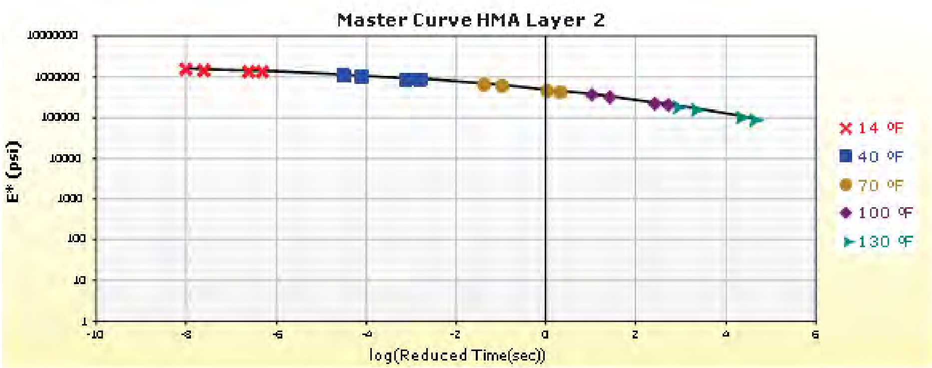
HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(100) PG 64-28

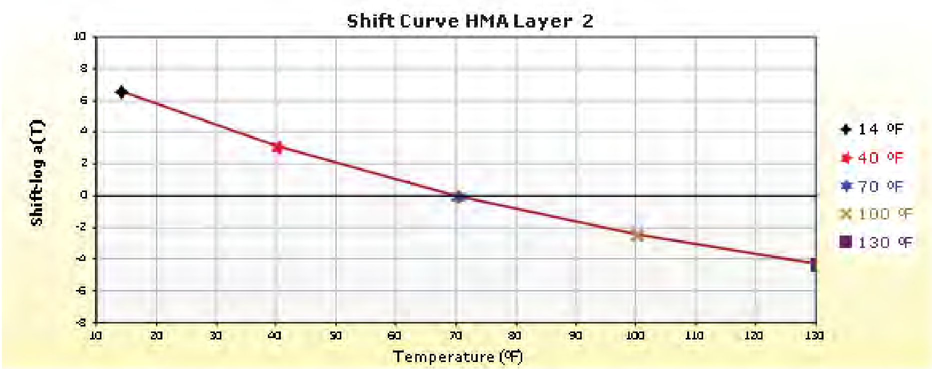


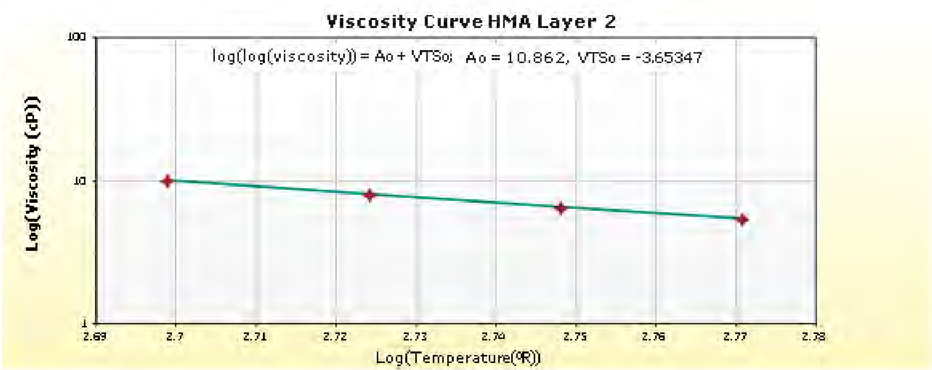




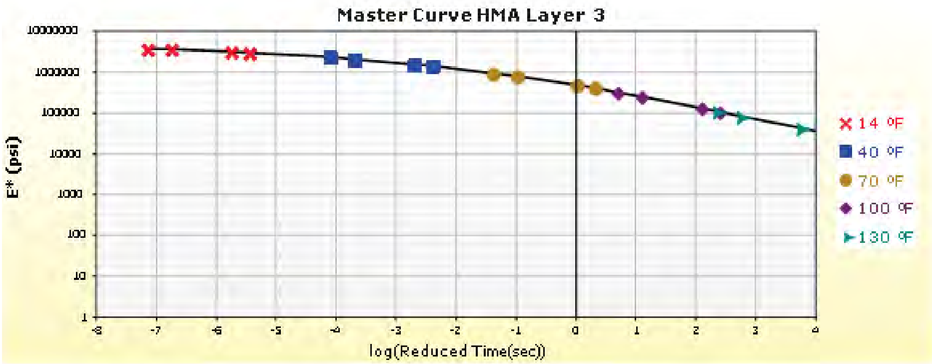
HMA Layer 2: Layer 2 Flexible : CIR Layer

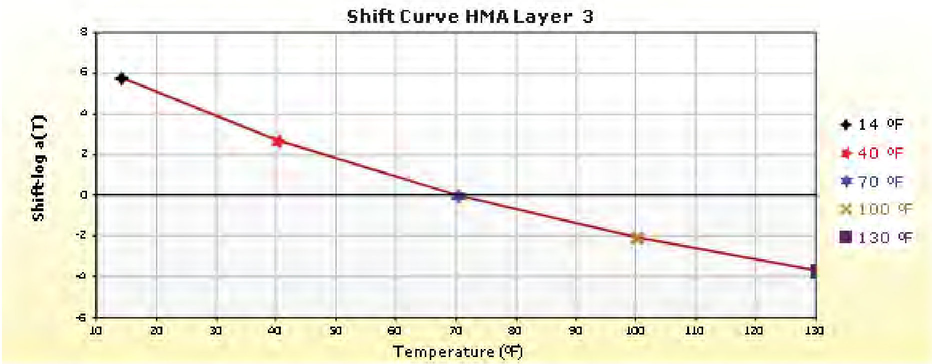


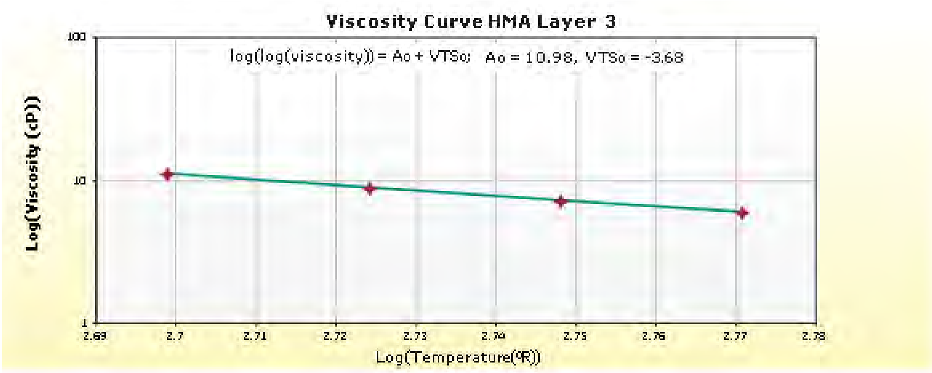




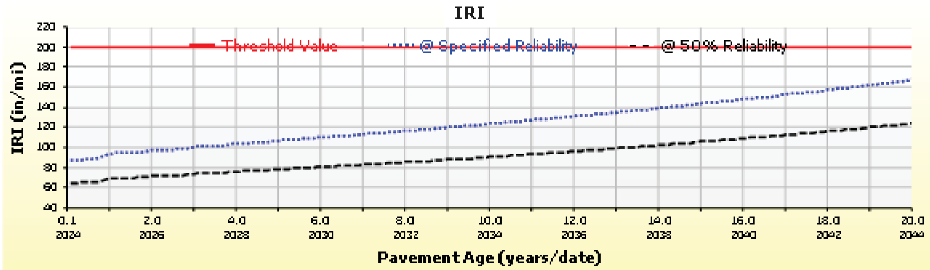
HMA Layer 3: Layer 3 Flexible : Default asphalt concrete(existing)

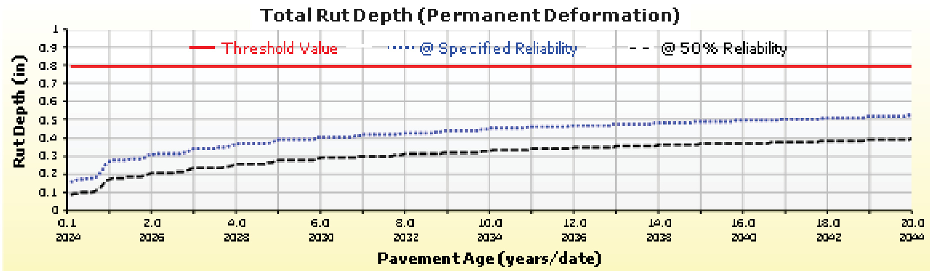


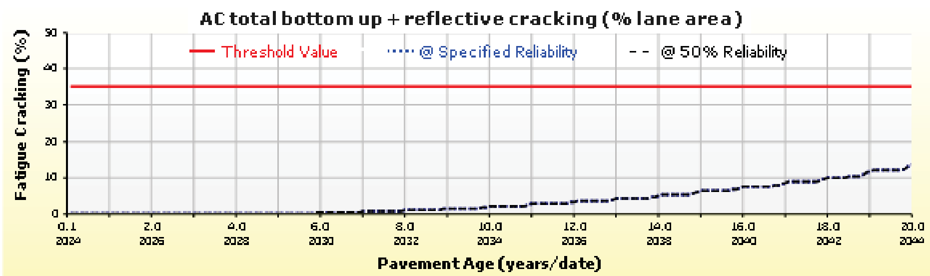


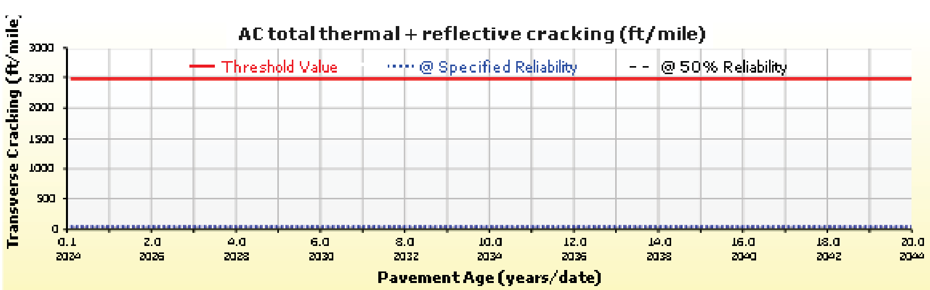


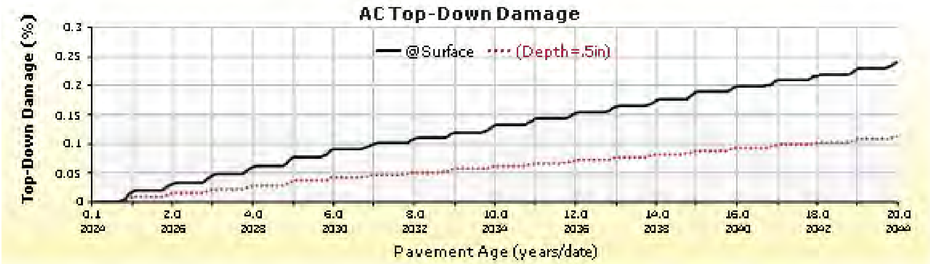
Analysis Output Charts



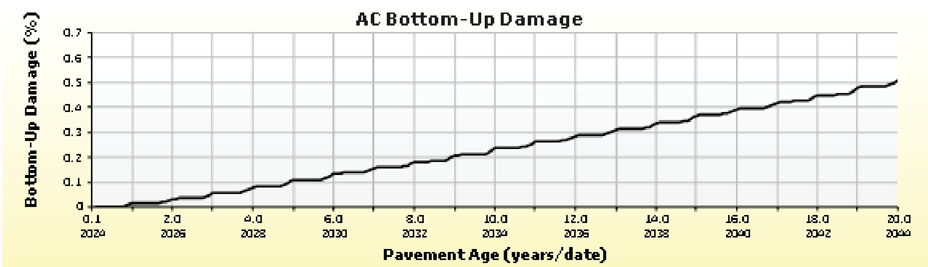




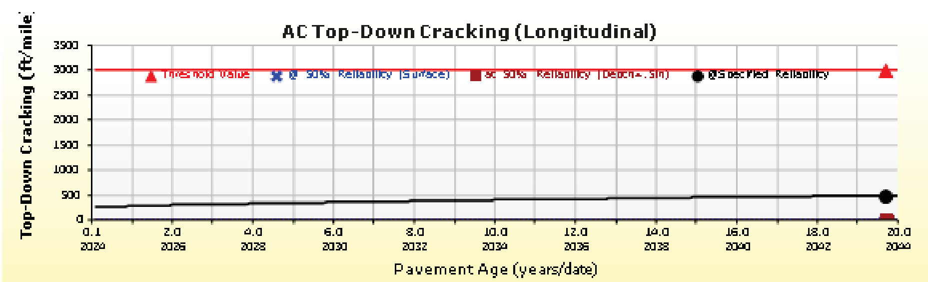




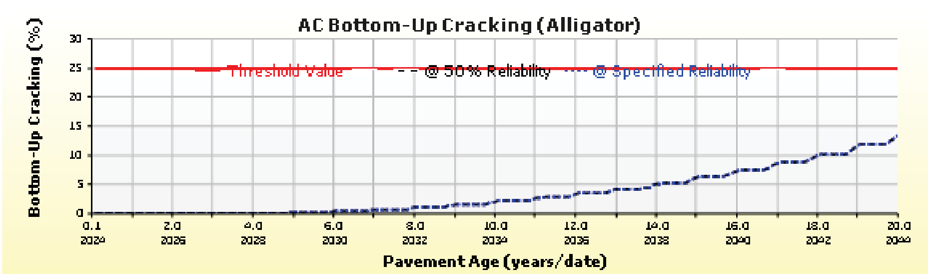
AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
Pavement Age (years/date)



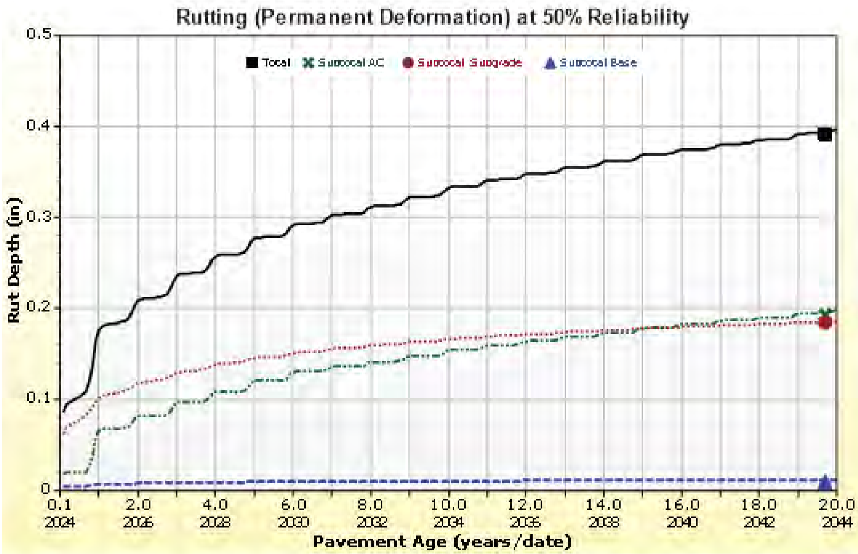
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)



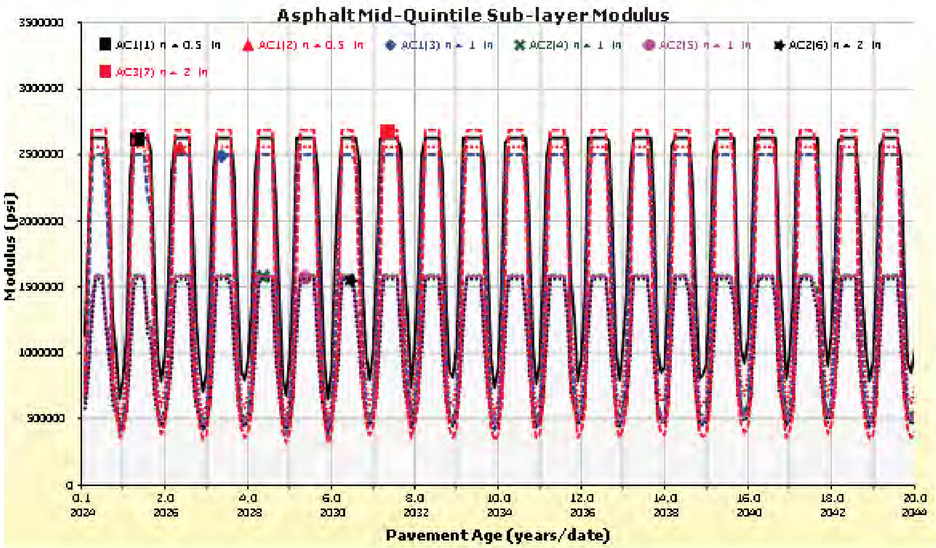
AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Threshold Value
@Specified Reliability
Pavement Age (years/date)



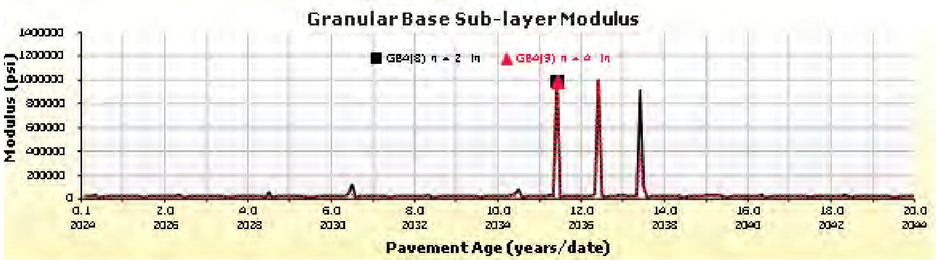
AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Pavement Age (years/date)



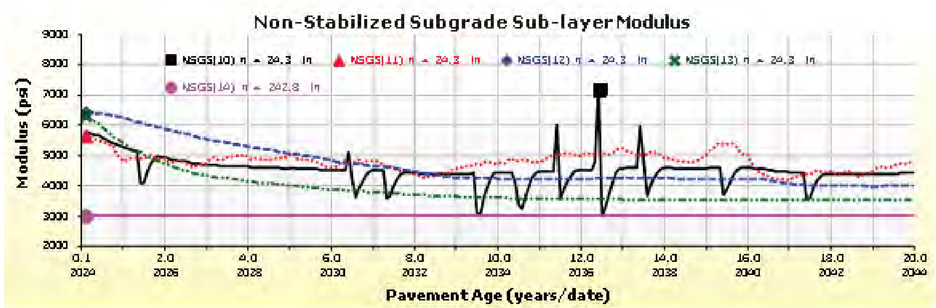
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1 2024
2.0 2026
4.0 2028
6.0 2030
8.0 2032
10.0 2034
12.0 2036
14.0 2038
16.0 2040
18.0 2042
20.0 2044
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 2 in
AC3(7) h = 2 in
Modulus (psi)
Pavement Age (years/date)



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



Non-Stabilized Subgrade Sub-layer Modulus
NSGS(10) h = 24.3 in
NSGS(11) h = 24.3 in
NSGS(12) h = 24.3 in
NSGS(13) h = 24.3 in
NSGS(14) h = 242.8 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 : CIR Layer

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	146.5	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
14	1203200	1339800	1398500	1533300	1590400	1664700
40	739800	862600	917600	1049200	1107000	1184300
70	370200	455800	496300	598000	645100	710100
100	169100	217900	242100	306100	337200	381700
130	75400	99900	112500	147400	165100	191100

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
147.2	835	82
158	419	84
136.4	1758	80

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	6.5
Air voids (%)	12.8
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	CIR Layer
Description of object	
Author	CDOT
Date Created	5/9/2018 12:00:00 AM
Approver	CDOT
Date approved	5/9/2018 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 Flexible : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	2.0	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	23

Layer 4 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in)	6.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
17000.0

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	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

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

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

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	8.7
#100	
#80	12.9
#60	
#50	
#40	20.0
#30	
#20	
#16	
#10	33.8
#8	
#4	44.7
3/8-in.	57.2
1/2-in.	63.1
3/4-in.	72.7
1-in.	78.8
1 1/2-in.	85.8
2-in.	91.6
2 1/2-in.	
3-in.	
3 1/2-in.	97.6

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
6482.0

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

Identifiers

Field	Value
Display name/identifier	A-4
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Calibration Coefficients

AC Fatigue

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	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: 1.5	
Level 2 K: 0.5	
Level 3 K: 1.5	

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*11

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

Reflective Cracking

$$\Delta C = k_1 \Delta_{bending} + k_2 \Delta_{shaering} + k_3 \Delta_{thermal}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{bending} + C_2 k_2 \Delta_{shearing} + C_3 k_3 \Delta_{thermal}}{h_{OL}}$$

$$\Delta_{Bending} = A(SIF)_B^n$$

$$\Delta_{Shearing} = A(SIF)_S^n$$

$$\Delta_{Thermal} = A(SIF)_T^n$$

$$D = \sum_{i=1}^{N} \Delta D$$

$$RCR = \left(\frac{100}{C4 + e^{C5 \log D}}\right) * EX\_CRK$$

Where

ΔC	=	Crack length increment, in
ΔD	=	Incremental damage ratio
$k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$	=	Calibration factors (local and global)
$\Delta_{bending}, \Delta_{shearing}, \Delta_{thermal}$	=	Crack length increments caused by bending, shearing, and thermal loading
A, n	=	HMA material fracture properties
N	=	Total number of days
$(SIF)_B, (SIF)_S, (SIF)_T$	=	Stress intensity factors caused by bending, shearing, and thermal loading
D	=	Damage ratio
h_{OL}	=	Overlay thickness, in
RCR	=	Cracks in the underlying layers reflected, %
EX_CRK	=	Transverse cracking in underlying pavement layers, ft/mile (transverse cracking) Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

APPENDIX J

AASHTO 1993 20-YEAR DESIGN LIFE OUTPUT
CIR AND OVERLAY REHABILITATION

26.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

CIR and Overlay Option

RockSol Project No. 599.70

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,020,000 = Design Life ESALs

SN = 3.935 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.30535

=

Thickness Equation= B = 6.30538 with no drainage reduction

Design Mr = 6,482 psi

0.77310145	A
4.94	B
3964.2437	C
0.67596689	D
-0.19281088	E
0.200000	F
4.94	G
6.48916779	H
-0.56408	I

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.94
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 2.95

Calculated Inches of New HMA = 2.24

Existing HMA Thickness = 7
Existing HMA Structual Layer Coefficient = 0.35 Weighted average (4*0.44 +3*0.23)/7 = 0.35
Existing ABC Thickness = 5
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years:	0.12
9 to 15 years:	0.09
more than 16 years:	0.06
Estimated air voids:	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[3])	
Classes 1,2,3,4,&6	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

B.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

CIR and Overlay Option

RockSol Consulting Group, Inc.

RockSol Project No. 599.70

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) for Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,160,000 = Design Life ESALs

SN = 3.975 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.33445

=

Thickness Equation= B = 6.33491 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Design Mr = 6,482 psi

0.77310145	A
4.98	B
4133.8633	C
0.66464349	D
-0.19609576	E
0.200000	F
4.98	G
6.52198328	H
-0.56408	I

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 9.03
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 2.84

Calculated Inches of New HMA = 2.58

Existing HMA Thickness = 6.5
Existing HMA Structual Layer Coefficient = 0.36 Weighted average (4*0.44 +2.5*0.23)/6.5
Existing ABC Thickness = 5
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years:	0.12
9 to 15 years:	0.09
more than 16 years:	0.06
Estimated air voids:	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,&5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

D.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

RockSol Consulting Group, Inc.

CIR and Overlay Option

RockSol Project No. 599.70

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) - Post-2015 CDOT Correlation

R-Value = 10

If Mr is based on R-Value ===> Mr (psi)= 6,482

2,030,000 = Design Life ESALs

SN = 3.938 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 6.30750

=

Thickness Equation= B = 6.30760 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Design Mr = 6,482 psi

0.77310145	A
4.94	B
3976.76689	C
0.67509784	D
-0.19305908	E
0.200000	F
4.94	G
6.49163816	H
-0.56408	I

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 8.95
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 3.575

Calculated Inches of New HMA = 0.83

Existing HMA Thickness = 8.5
Existing HMA Structual Layer Coefficient = 0.35 Weighted average (4*0.44 +4.5*0.27)/8.5
Existing ABC Thickness = 6
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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

Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

Factor Description	Factor
Load associated cracking:	
Virtually none:	0.12
More than 6ft. blocks:	0.10
2 ft. to 5 ft. blocks:	0.08
less than 2 ft blocks:	0.06
Average age of layer combination:	
less than 8 years:	0.12
9 to 15 years:	0.09
more than 16 years:	0.05
Estimated air voids[1]	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,&5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

F.5 Road - City of Grand Junction (City) 2022 Transportation Corridor Improvements Project

RockSol Consulting Group, Inc.

CIR and Overlay Option

RockSol Project No. 599.70

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) for Post-2015 CDOT Correlation

If Mr is based on R-Value ===> R-Value = 10; Mr (psi) = 6,482

680,000 = Design Life ESALs

SN = 3.335 = Required SN when B equals (or slightly exceeds) A

$Log_{10}ESAL$ = A = 5.83251

=

Thickness Equation= B = 5.83271 with no drainage reduction

When A = B, ESAL's and SN agree, then calculate thickness
Take Calculated Thickness and round appropriately for design thickness

Design Mr = 6,482 psi

0.77310145	A
4.34	B
2022.89545	C
0.94080897	D
-0.13853372	E
0.200000	F
4.34	G
5.96221799	H
-0.56408	I

Structural Coefficient of HMA = 0.44
Structural Coefficient of ABC = 0.1

Design Serviceability Loss (ΔPSI)= 2.0

Calculated thickness, inches = 7.58
FULL DEPTH HMA

Initial Serviceability Index= 4.5
Final Serviceability Index = 2.5

Overall Standard Deviation, So = 0.44
Reliability, R (percent) = 90
Standard Normal Deviate (ZR) = -1.282
(Use Table 1.4 from CDOT Pavement Design Manual)

Existing Structual Number = 2.88

Calculated Inches of New HMA = 1.03

Existing HMA Thickness = 6
Existing HMA Structual Layer Coefficient = 0.38 Weighted average (4*0.44 +2*0.25)/6
Existing ABC Thickness = 6
ABC Structual Layer Coefficient = 0.1

Table 1.4 Reliability and Standard Normal Deviate

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
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Figure 5.3 Structural Layer Coefficients of Existing Pavements (CDOT Form #903 3/04)

Asphalt Surface Course

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9 to 15 years:	0.09
more than 16 years:	0.06
Estimated air voids[1]	
0 - 2%	0.09
3 - 6%	0.12
7 - 10%	0.09
more than 10%	0.06

Base layers

Factor Description	Factor
Untreated aggregate base (except as noted[2])	
Classes 1,2,3,4,&5	0.11
Classes 3 & 7	0.10
Class 6	0.06
Emulsion asphalt treated base	0.16

APPENDIX K

SEISMIC DESIGN OUTPUT SHEETS

26.5 & Grand Valley Canal

Latitude, Longitude: 39.098, -108.561

Date	2/28/2023, 2:31:21 PM
Design Code Reference Document	ASCE7-16
Risk Category	II
Site Class	C - Very Dense Soil and Soft Rock

Type	Value	Description
S_S	0.24	MCE_R ground motion. (for 0.2 second period)
S_1	0.066	MCE_R ground motion. (for 1.0s period)
S_{MS}	0.312	Site-modified spectral acceleration value
S_{M1}	0.099	Site-modified spectral acceleration value
S_{DS}	0.208	Numeric seismic design value at 0.2 second SA
S_{D1}	0.066	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	B	Seismic design category

Type	Value	Description
F_a	1.3	Site amplification factor at 0.2 second
F_v	1.5	Site amplification factor at 1.0 second
PGA	0.132	MCE_G peak ground acceleration
F_{PGA}	1.268	Site amplification factor at PGA
PGA_M	0.168	Site modified peak ground acceleration
T_L	4	Long-period transition period in seconds
SsRT	0.24	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.253	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.066	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.07	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)
PGAd	0.5	Factored deterministic acceleration value. (Peak Ground Acceleration)
PGA_{UH}	0.132	Uniform-hazard (2% probability of exceedance in 50 years) Peak Ground Acceleration
C_{RS}	0.946	Mapped value of the risk coefficient at short periods
C_{R1}	0.932	Mapped value of the risk coefficient at a period of 1 s
C_V	0.74	Vertical coefficient

DISCLAIMER