SUBMITTED TO:
Felsburg Holt & Ullevig
6400 S Fiddlers Green Circle,
Suite 1500
Greenwood Village, CO
80111

BY:
Shannon & Wilson, Inc.
1321 Bannock Street, Ste 200
Denver, CO 80204

(303) 825-3800
www.shannonwilson.com

PAVEMENT DESIGN REPORT

US 6 West Edwards Improvement Design

EAGLE COUNTY, CO

March 2022

Shannon & Wilson No: 101726-200

SHANNON & WILSON

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Submitted To: Felsburg Holt & Ullevig
6400 S Fiddlers Green Circle, Suite 1500
Greenwood Village, CO 80111
Attn: Ms. Michelle Stevens

Subject: PAVEMENT DESIGN REPORT, US 6 WEST EDWARDS IMPROVEMENT DESIGN, EAGLE COUNTY, CO

Shannon & Wilson prepared this report as a consultant to Felsburg Holt & Ullevig. This report presents our data review, reconnaissance, geotechnical considerations, and pavement design for the project.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON

COLORADO LICENSED
AARON L. LEOPOLD
54314
PROFESSIONAL ENGINEER

3/17/2022

Aaron L. Leopold, PE
Senior Geotechnical Engineer

Gregory R. Fischer, PhD, PE
President

ALL:GRF:DAA/

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1 INTRODUCTION

This report presents the results of our subsurface exploration program and geotechnical engineering recommendations for the US 6 West Edwards Improvement Design project (the Project) located in Edwards, Colorado (refer to Figure 1). The report summarizes our subsurface explorations and laboratory testing, discusses regional geology and potential geological hazards within the project area, and provides pavement design recommendations for construction. Our services were conducted in general accordance with our proposal to Felsburg Holt & Ullevig (FHU), dated July 30, 2019, our budget amendment, dated September 27, 2021, and our budget amendment 2, dated January 18, 2022. Under this agreement we:

- Performed a subsurface investigation, including observing and logging five borings, obtaining permits, completing utility locates, and coordinating traffic control;
- Completed geotechnical laboratory tests on retrieved soil samples;
- Evaluated geologic hazards;
- Evaluated site conditions with respect to proposed construction;
- Provided recommendations for pavement design aspects of the project; and
- Prepared this pavement design report.

The scope of our services did not include any environmental assessment or evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below the site; or construction issues (e.g., disposal or restoration) related to these considerations. If a service is not specifically indicated in this report, do not assume it was performed.

This report was prepared for the exclusive use of FHU, other members of the team, Eagle County, and the Colorado Department of Transportation (CDOT). We understand this report will be used for the design of the proposed interchange improvements. This report should not be used for other purposes without Shannon & Wilson's review. The opinions and recommendations provided in this report should not be made available for use by others or for purposes other than those described herein.

2 SITE AND PROJECT DESCRIPTION

We understand that the updated limits of the Project along US 6 extend approximately 200 feet east and west of the Hillcrest Drive intersection (refer to Figure 2). The proposed Project will replace the current three-way, stop-sign controlled intersection at Hillcrest Drive with a single lane roundabout. Included in the work is removal of the existing intersection, possible road realignments, utility relocations, and earthwork. The alignment of US 6 is parallel to the Eagle River, located approximately 60 feet south at its closest proximity.

We also understand that with reduced project traffic speed, the project team was able to reduce the extent and ultimately cost of the proposed project. The updated alignment removed a previously designed retaining wall and keeps the highway within two feet of existing grade.

3 FIELD EXPLORATIONS AND LABORATORY TESTING

Shannon & Wilson conducted a subsurface exploration program on July 1, 2020 to explore conditions beneath the existing US 6 road. Our subsurface exploration program consisted of drilling and sampling five borings, designated SW-01 through SW-05. Refer to Figure 2 for locations of our subsurface explorations. Borings SW-01 and SW-05 were drilled adjacent to the existing pavement and borings SW-02 through SW-04 were drilled through the existing pavement. Appendix A presents a discussion of the drilling, sampling, and testing procedures used in completing the borings. Appendix A also presents the individual exploration logs and an explanation of the symbols and terminology used.

Geotechnical laboratory tests were performed on selected samples retrieved from the borings to determine index and engineering properties of the materials encountered in the proposed work areas. Laboratory testing included natural water content, grain size distribution, liquid and plastic Atterberg limits determinations, percent fines, and R-value. The laboratory test results are presented in Appendix B along with a brief discussion of the laboratory testing procedures and results. The natural water contents, Atterberg limits, and percent fines are also indicated on the individual boring logs in Appendix A.

4 REGIONAL GEOLOGY AND SUBSURFACE CONDITIONS

We based our understanding of the geology and subsurface conditions at the Project site on our review of regional geologic maps and information presented in geotechnical reports published by others near the project. In general, the subsurface materials consisted of fill, native soil, and bedrock of the Eagle Valley Formation and Eagle Valley Evaporite (see Figure 3). Specifically, geologic mapping by Lidke (2008) indicates that surficial soils along the alignment predominantly consist of Holocene to middle Pleistocene-age undifferentiated alluvium and colluvium. The material is described as interfingered stream channel, flood-plain, fan, sheetwash, and colluvial deposits.

4.1 Asphalt

Borings SW-02 through SW-04 were all drilled in US 6 and encountered 7.5 to 9 inches of asphalt. Base course was not encountered beneath the asphalt in any of the borings.

4.2 Overburden

Overburden was encountered in all of the borings and consisted of fill and alluvium. Fill was encountered in all of the borings drilled along US 6, at the surface or directly beneath the asphalt. The fill extended to depths of 4 to 7 feet or to the termination of the boring. The fill generally consisted of medium dense to dense, silty to clayey sand and gravel.

Undivided alluvium and colluvium was encountered in borings SW-01, SW-03, SW-04, and SW-05 beneath the fill and extended to the bottom of each boring. The undivided alluvium and colluvium consisted of loose to dense, silty to clayey sand with varying amounts of gravel; medium stiff, sandy lean clay; overlying very dense gravel with varying amounts of silt and sand in the borings that extended below a depth of 7 feet.

4.3 Bedrock

The Project is situated on the eastern edge of the Eagle Basin within the central portion of the Rocky Mountains. The project area is mapped as being underlain by the Eagle Valley Formation and the Eagle Valley Evaporite, both Pennsylvanian in age. The Eagle Valley Formation is noted by gray and reddish-gray siltstone, shale, sandstone, carbonate rocks, and local lenses of gypsum. The Eagle Valley Evaporite contains gypsum, anhydrite, and interbedded siltstone and minor amounts of dolomite (Tweto and others, 1978). We did not encounter bedrock during our explorations.

4.4 Groundwater

Groundwater was not encountered in any of the borings during drilling. Due to the proximity of the Project site to the Eagle River, groundwater levels can be anticipated to correspond closely to the level of water in the river. Fluctuations in the river and groundwater levels due seasonal variation, flooding, and precipitation are likely.

5 GEOLOGIC HAZARDS AND DESIGN CONSIDERATIONS

Based on our study of available geologic information, our reconnaissance and our knowledge of the geology of the area, there are geologic hazards along the Project alignment. The hazards that may impact roadway improvements are described below.

5.1 Swelling Soil and Bedrock

Many of the soil/rock formations in Colorado are susceptible to volume change by swelling/shrinking. This geologic phenomenon has the potential to cause substantial damage to lightly loaded structures (such as pavements) when exposed to water. Subsurface conditions encountered in the existing explorations generally consisted of granular soils, which are not swell-susceptible. One thin layer of fine-grained material was encountered near the ground surface, but in our opinion, there is likely a low swell potential along the Project alignment.

5.2 Evaporite Dissolution and Subsidence

Large areas of Colorado are underlain by Mesozoic and/or Paleozoic evaporate deposits (White, 2012). As stated by White (2012), the evaporite bedrock, which contains evaporative minerals, can dissolve in the presence of fresh water. The dissolution of such rocks can alter the ground and surface water flows, and create subsurface voids such as caverns, open fissures, and solution pipes. Subsidence of the ground surface and sinkhole openings are a geologic hazard. Based on White (2012), the Project site is within the Eagle Collapse Center and is in the center of an evaporate bedrock zone. Additionally, subsidence maps (White, 2012) indicate there are multiple sinkholes within the Project extents.

Based on our review of the available data and the reported presence of nearby sinkholes, there is potential for evaporite-related subsidence at the Project site. However, identifying subsurface voids before they develop into sinkhole features is challenging. Subsurface explorations (borings) can be utilized, but borings only sample a relatively small cross-sectional area at discrete points, and it is possible for conditions to vary between borings. Geophysical methods can be implemented to characterize conditions on a laterally continuous basis, but in our experience, interpreting the results of geophysical surveys is often challenging and highly subjective.

To the extent that voids are identified, mitigation to reduce the likelihood of sinkholes developing could consist of filling the voids with grout. However, in our experience detailed mapping and mitigation of sinkholes is often not cost effective for roadway improvement projects such as this, when the costs of the investigation and mitigation are considered relative to the project costs and consequences of potential roadway settlement. As such, more cost-effective mitigation is likely to consist of maintaining positive surface drainage.

5.3 Collapse-Prone Soils

The occurrence of collapsible soils (soils that rapidly settle upon the introduction of water) in semi-arid regions of Western Colorado is well documented (White and Greenman, 2008). White and Greenman (2008) indicated that surficial colluvial deposits and debris flow sediments are prone to collapse. Because of rapid deposition (usually during storm events) and subsequent drying, these soils commonly exhibit loose, open structures with low moisture contents. These soils may also be derived from evaporite bedrock with a high gypsum content that can dissolve on wetting and contribute to collapse.

Mapping by White and Greenman (2008) indicates several case histories of collapsing soils in the vicinity of the Project site. Additionally, geologic mapping (Lidke, 1998) indicates the presence of undivided alluvium and colluvium along the alignment. This material is described as being evaporite-rich and susceptible to collapse and piping-related (internal erosion) subsidence. As such, there is potential for collapse-related settlement to affect the Project.

5.4 Corrosive Soil

The soil encountered at the project site can be corrosive to substructure elements. To assist in estimating the corrosion potential at the site, a sample was tested for pH, resistivity, water soluble sulfates, and chlorides. The results are presented in Exhibit 5-1 and in Table B-1 in Appendix B.

Exhibit 5-1: Corrosion Testing Results

Boring	Sample	Material	pH	Resistivity (ohm-cm)	Water-Soluble Sulfates (%)	Chlorides (%)
SW-05	S-1	Fill	9.7	5,900	0.38	<0.01

NOTES:
Water-soluble sulfate and chloride values are shown as percent weight in dry soil.
ohm-cm = ohm-centimeter

The resistivity measured in the sample was 5,900 ohm-centimeters. Based on correlations developed by Roberge (2012), this value suggests moderately corrosive subsurface conditions for metal in contact with subsurface materials across the site.

The concentration of water-soluble sulfates measured in the sample was 0.38% by weight. Criteria in the CDOT Standard Specifications (CDOT, 2021b) indicate the above sulfate contents require Class 2 cementitious materials. CDOT Standard Specifications also specify Class S2 sulfate resistance for all concrete structures to protect against potential sulfate attack. Based on the corrosion test results and the above specifications, we recommend Class S2 sulfate resistance for proposed concrete structures.

6 PAVEMENT DESIGN

In general, the performance of a pavement system depends on the pavement material and thicknesses, traffic loads and repetitions, subgrade strength, design life, and subgrade drainage characteristics.

Pavement design for proposed improvements to US 6, roundabout, and portions of Hillcrest Drive are based on the procedures outlined in the 2020 Colorado Department of Transportation (CDOT) M-E Pavement Design Manual (PDM) (2020) and the CDOT M-E Pavement Design Manual 2021 Addendum (2021a) using Version 2.3.1 of the AASHTOWare Pavement M-E Design (Pavement M-E) software (AASHTO, 2013). Based on information provided in the CDOT Online Transportation Information System (OTIS) database (2020), we understand US 6 and roundabout pavements are to be designed to a 'major collector' level performance criteria identified in Tables 2.4 through 2.6 of the PDM. For Hillcrest Drive, the same performance criteria was used for design as US 6. (Note the design criteria in CDOT Tables 2.4 through 2.6 does not vary between major collectors and local roads.) Further, based on the relatively urban nature of the site, a reliability index of 90% was selected for design.

Based on discussions with FHU, we understand that the proposed roundabout will be paved with Portland cement concrete (PCC) along with the adjacent portion of US 6. Tie-in segments of US 6 will consist of full reconstruction with hot mix asphalt (HMA) and a functional 2-inch mill and overlay.

6.1 Traffic Loading

To perform a mechanistic-empirical (M-E) pavement design, detailed traffic loading information is required for the analysis. Specifically, a design average annual daily truck traffic (AADTT) and a distribution of truck vehicle type is required.

For our analysis, we reviewed the available information provided in OTIS (CDOT, 2020) as well as the Project traffic study prepared by FHU (2019) assessing traffic patterns for the proposed roundabout configuration. The information available in the OTIS database consists of a 2018 traffic study, which indicates a constant AADTT value of 390 trucks per day in the project limits. In general, the 2018 traffic study projects a higher truck traffic volume along US 6 than indicated in the FHU study, but the FHU traffic study does provide a traffic distribution breakdown of vehicles accessing the roundabout. Exhibit 6-3 summarizes the design traffic loading and various analysis distribution factor used in our pavement analysis. We used the OTIS traffic loading assessing the east- and west-legs of the roundabout with the traffic projections from FHU for Hillcrest Drive (roundabout north-leg) and the likely distribution of traffic loading accessing the roundabout.

Exhibit 6-3: Pavement Analysis Design Traffic Loading

Roadway	2022 AADTT[1] (truck per day)	Growth[2] Rate (%)	Directional Distribution Factor (%)	Number of Lanes in Design Direction	Lane Distribution Factor (%)	Traffic Speed (mph)
US 6	432	2.6	60	1	100	15
Roundabout	305	2.6	100	1	100	13
Hillcrest Drive	78	2.0	60	1	100	15

NOTE:

1 A paving date of 2022 is anticipated.

2 Annually compounded.

AADTT = Average Annual Daily Truck Traffic; mph = Miles Per Hour;

The 2018 OTIS traffic study also indicates the distribution of single-unit (vehicle classes 4 through 7) and combination trucks (vehicle classes 8 through 13) is approximately 69% and 31%, respectively. A more detailed breakdown of truck distributions is not available from the OTIS database, but CDOT does provide guidance regarding the distribution truck vehicle types. Based on guidance in Table 3.6 of the PDM, we selected 'Cluster 1' which distributes approximately 62.9% and 37.1% of the AADTT to single-unit and combination-unit trucks, respectively.

6.2 Pavement Subgrade Conditions

The subgrade strength for the Project was evaluated by using a Hveem stabilometer (R-value) test result and our experience. A bulk silty sand sample (AASHTO soil classification A-1-b) tested from boring SW-03 resulted in an R-value of 77. However, other portions of the subgrade consisted of silty, clayey sand (AASHTO soil classifications A-2-4 and A-4), clayey sand (AASHTO A-2-6 soil) and lean clay (AASHTO A-6 soil).

Because of the potential for variable subgrade materials and based on discussions with CDOT, the subgrade was designed for an A-6 soil with an R-value of 5 and an R-value of 30 for the A-2-6 soils. Areas with A-1-b, A-4 and A-2-4 are anticipated to have a greater R-value than the design R-values of 5 and 30.

Only one boring through the US 6 pavement encountered the lean clay stratum at a depth of 4 feet, and sand with varying clay content were observed directly below the existing pavement. For the proposed rehabilitation analysis (mill and overlay), we analyzed a 12-inch-thick layer of clayey sand (AASHTO A-2-6 soil) overlying lean clay (AASHTO A-6 soil). For all new pavements, a design subgrade consisting of lean clay was assumed. Lastly, for new flexible pavement, CDOT indicated that new flexible pavements should consist of a minimum of 8 inches of CDOT Class 1 aggregate base course (ABC) with an additional 6 inches of CDOT Class 6 ABC.

The design subgrade strength was determined from a correlation from R-value to resilient modulus developed by CDOT and provided in the PDM. This resulted in a design resilient modulus of 5,350 and 8,770 pounds per square inch for the R-value of 5 subgrade and R-value of 30soil used in our analyses.

6.3 Groundwater and Drainage

Based on conditions encountered in the subsurface explorations, we anticipate that groundwater will be located more than 10 feet below the proposed road grade. We understand the design team will utilize inlets and storm drains to manage project surface water. The design team also discussed using a detention pond to collect surface water. We did not perform any geotechnical borings for potential ponds. As discussed in Section 5.3, there are potential collapsible soils within the project vicinity. Utilizing inlets and controlling surface water to promote positive drainage is the preferred alternative to reduce the risk of introducing new moisture and inducing the collapse of soils.

6.4 Pavement Rehabilitation

We understand the existing HMA pavements at tie-in points will receive a 2-inch mill and functional overlay. Borings SW-02 through SW-04 indicate the existing HMA thickness is 9-, 8-, and 7-1/2-inches thick, respectively, paved on native subgrade. (No ABC material was observed below the HMA.) For our analysis, we assumed the same subgrade conditions as described in Section 6.2, with approximately 5-1/2 inches of the existing HMA in place (after the milling). Shannon & Wilson was not scoped to obtain pavement cores or perform a pavement assessment of the existing pavement. Therefore, we made the following assumptions for our analysis:

- A level 3 analysis of for the existing pavement which is in good overall condition with existing HMA and subgrade ruts up to ½-inch;

- The existing pavement was designed for a 20-year period with AC 20 binder; and
- A 10-year analysis period for the functional overlay.

Our analysis indicates the proposed 2-inch mill and overlay meets CDOT's performance criteria for pavement rehabilitation. Refer to Appendix C for our overlay analysis. For Hillcrest Drive, we understand the existing pavements at the roundabout will be fully reconstructed and tie-in at the existing overpass of the Eagle River.

6.5 Recommended Pavement Section

The recommended pavement sections are summarized below. Each proposed section exceeds performance criteria provided in Tables 2.4 and 2.5 of the PDM for minor arterials. We understand a minimum thickness of 8 inches of PCC was requested by CDOT. Refer to Appendix C for our Pavement M-E analysis runs for each of the below sections as well a complete list of our design assumptions.

Exhibit 6-4: Recommended Pavement Sections

	PAVEMENT SECTIONS	
Roadway	HMA Alternative	PCC Alternative[1]
US 6	6-1/2 in. HMA 6 in. Class 6 ABC 8 in. Class 1 ABC	8 in. PCC 6 in. Class 6 ABC
Roundabout	-	8 in. PCC 6 in. Class 6 ABC
Hillcrest Drive	5 in. HMA 6 in. Class 6 ABC	-

NOTE:

1 PCC paving alternative assumes: (a) transverse joints with a 15 feet maximum length, (b) 1-1/4-inch-diameter dowels at transverse joints, and (c) PCC pavement tied to PCC shoulders or PCC curb and gutter.

ABC = Aggregate Base Course; Alt. = Alternative; HMA = Hot Mix Asphalt; in. = inches; PCC = Portland Cement Concrete

7 CONSTRUCTION CONSIDERATIONS RECOMMENDATIONS

The applicability of the design recommendations provided in this report is contingent on good construction practice. Poor construction techniques may alter conditions from those on which our recommendations are based, therefore resulting pavement distress. The following sections present additional construction and material considerations for this project.

7.1 Site Preparation

We recommend that brush and other vegetation be cleared, and roots and stumps be removed from all areas to be graded. Any existing surficial topsoil and any soil containing organics should be stripped and removed. The depth of this removal is anticipated to be less than 6 inches. Topsoil and organic-rich soils are not considered suitable for reuse as fill and should be removed from the site.

Care should be taken to avoid disturbing subgrade soils and supporting soils that will remain in place, as they can rut and pump under repeated construction traffic. The final subgrade surface should be sloped to promote positive drainage.

7.2 Excavation

We anticipate that excavation for the proposed construction will occur in surficial soil. In general, we anticipate that it will be feasible to excavate the overburden material at the site using conventional excavating equipment, such as a hydraulic excavator.

7.3 Pavement Subgrade Preparation

The exposed surface should be cleared and stripped in accordance with the CDOT Standard Specifications (CDOT, 2021b). After the subgrade is cut to grade, the exposed subgrade should be scarified to a depth of 8 inches, moisture-conditioned, compacted to a dense and unyielding condition (as indicated in Section 7.4), and then proof-rolled.

Proof rolls should be completed in accordance with Section 203.08 of the CDOT Standard Specifications (CDOT, 2021b). Any areas that are delineated to be soft, loose, or yielding during proof-rolling should be removed and replaced with AASHTO A-1 or A-2-4 soils. We recommend a maximum over-excavation depth of 2 feet. If soft or yielding soils are encountered after over-excavating 2 feet, a geogrid (Tensar biaxial BX1200, Tensar triaxial TX5, or equivalent) should be installed at the base of the over-excavation before backfilling.

7.4 Fill Materials, Placement, and Compaction

Fill material should be placed in horizontal lifts and be compacted to a dense and unyielding condition. Subgrade preparation, moisture treatment, and compaction should be conducted in accordance with Section 203.07 of the CDOT Standard Specifications for Road and Bridge Construction (CDOT, 2021b).

7.5 Paving Materials

7.5.1 Hot Mix Asphalt (HMA)

The HMA mix design should be in accordance with CDOT and Superpave standards and be in accordance with CDOT Section 401 from the most recent CDOT Standard Specification (2021b). Based on the binder selection procedure provided in the 2021 PDM is based on the anticipated pavement temperatures, traffic patterns, and local availability. The CDOT specifies the use of software developed by the FHWA Long Term Pavement Performance (LTPP) Bind (2020) to determine appropriate binder for each improvement segment. Appendix C provides the output from the LTPP Bind software which indicates that a performance grade (PG) 58-34 binder is appropriate for all HMA paving lifts of the Project. Based on discussions with CDOT, a PG 58-28 binder can be used for lower lifts.

Based on discussions with CDOT, and due to local availability, we recommend using a Grade SX mix for all HMA lifts. For the Grade SX mix, CDOT recommends that lift thickness range between 1-1/2 and 3 inches. Based on the anticipated traffic loading and the elevation of the site, we recommend a Superpave design gyratory number (N) of 75 be used for mix design of the pavement. In addition, a tack coat should be placed between subsequent lifts if the underlying lift is left uncovered for greater than 24 hours.

7.5.2 Portland Cement Concrete (PCC)

We recommend using CDOT Concrete Class P from the most recent CDOT Standard Specification (2021b).

7.5.3 Aggregate Base Course (ABC)

We recommend using CDOT Class 1 and Class 6 ABC from the most recent CDOT Standard Specification (2021b). The CDOT Class 1 material should have a minimum R-value of 70 and the CDOT Class 6 material should have a minimum R-value of 78. ABC material should be placed in maximum 6-inch-thick lifts and compacted to a dense and unyielding condition and to at least 95% of the maximum dry density (AASHTO T180).

8 LIMITATIONS

This report was prepared for the exclusive use of FHU, their subconsultants, and CDOT for use in design of the US 6 West Edwards Improvement Design project. Our evaluations, analyses, conclusions, and recommendations are based on the limitations of our approved scope, schedule and budget described in the agreement for professional services dated July 30, 2019. This report should be made available to prospective contractors and/or the

Contractor for information on factual data only, and not as a warranty of subsurface conditions. This report should not be used without our approval if any of the following occurs:

- Conditions change due to natural forces or human activity under, at, or adjacent to the site.
- Assumptions stated in this report have changed.
- Project details change or new information becomes available such that our analyses, conclusions, and recommendations may be affected.
- If the site ownership or land use has changed.
- More than 5 years has passed since the date of this report.
- Unanticipated soil conditions are commonly encountered and cannot be fully determined by a limited boring and testing program. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

Within the limitations of scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical and geological principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied.

Shannon & Wilson has prepared the attached document, "Important Information about Your Geotechnical Report," to assist you and others in understanding the use and limitations of our reports.

9 REFERENCES

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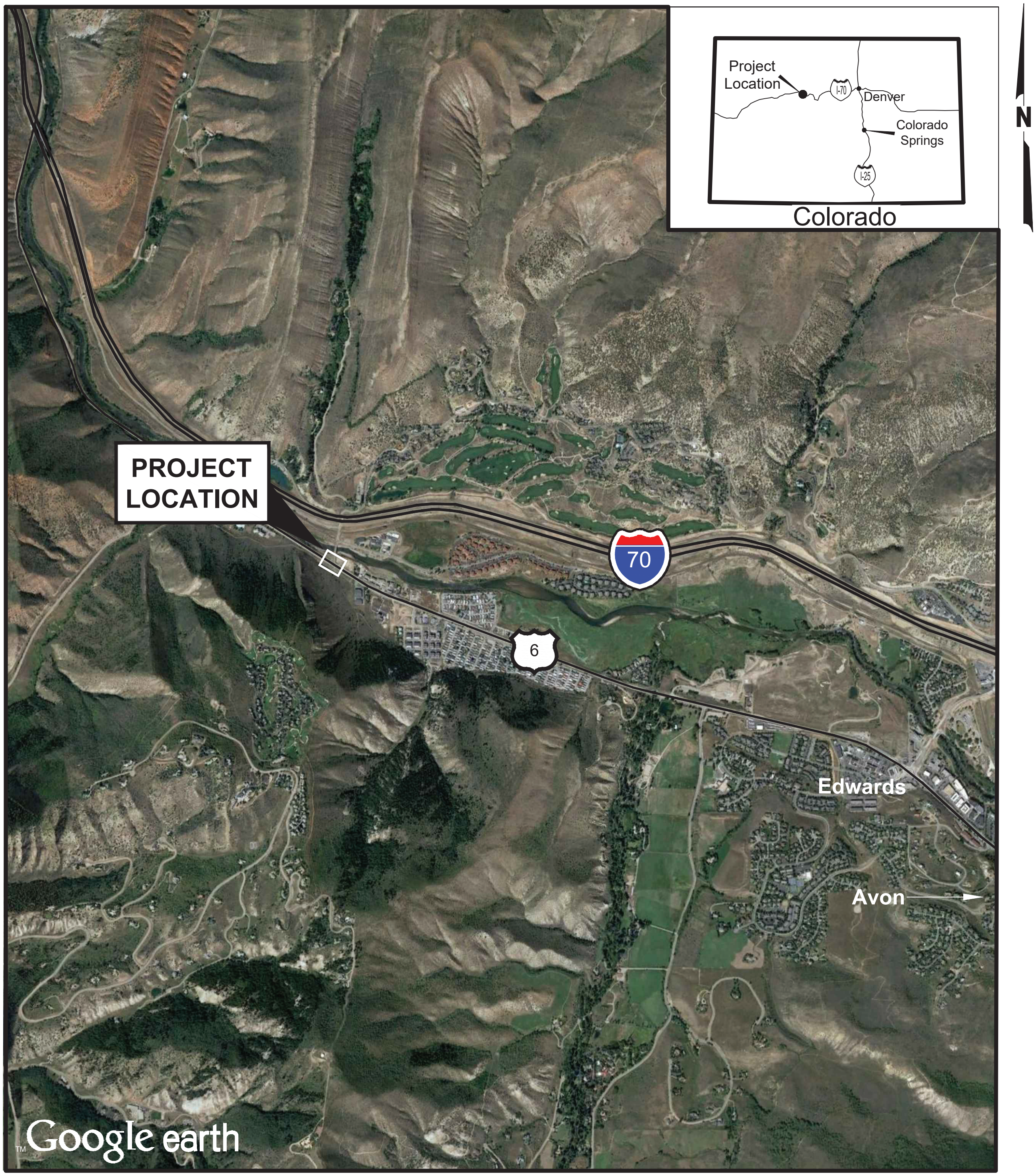


0 1/2 1

Approximate Scale in Miles

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

US 6 West Edwards Improvement Design
Eagle County, Colorado

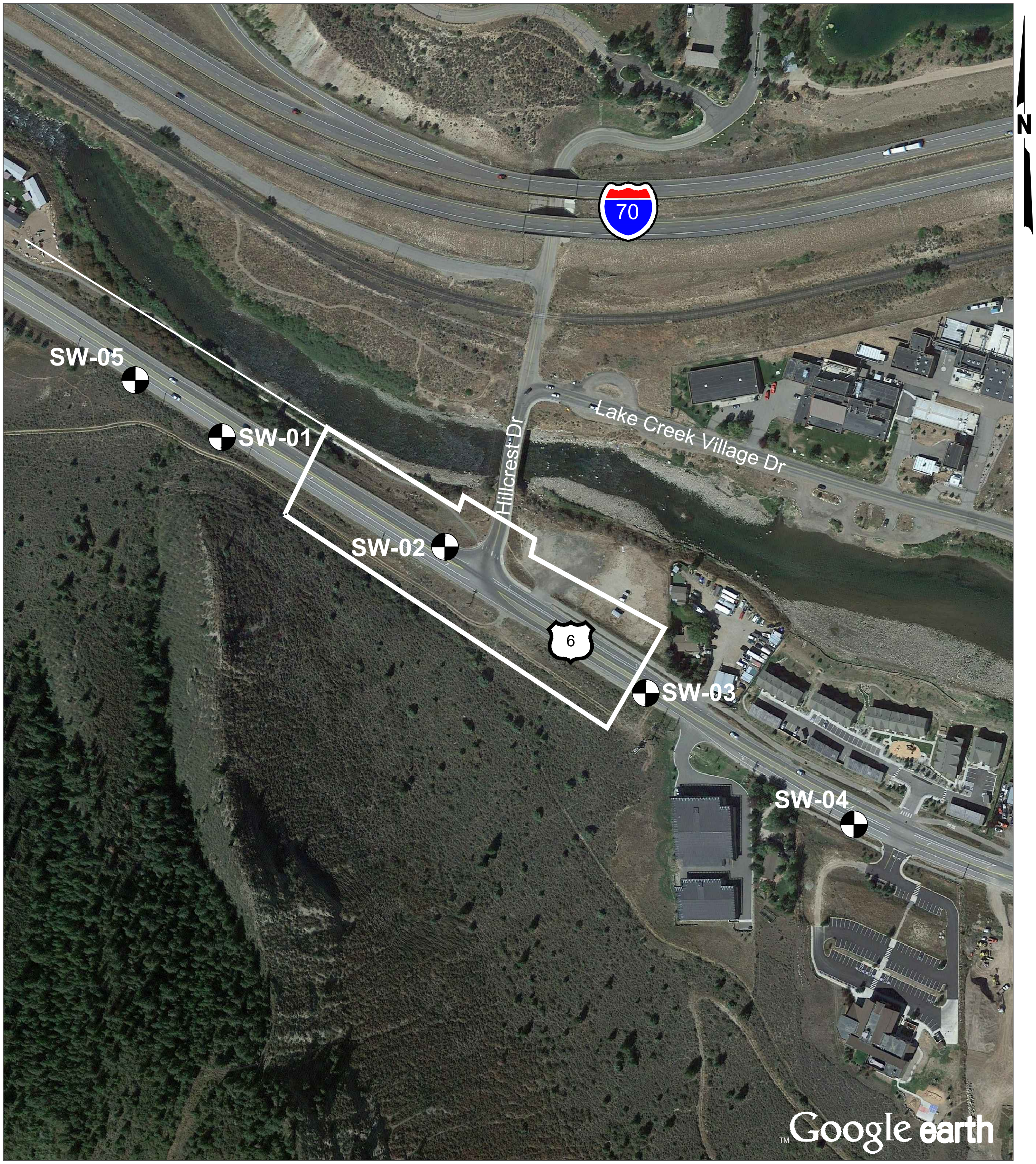
VICINITY MAP

March 2022 101726-200

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

Filename: I:\EF\DEN\101000s\101726 US 6 West Edwards\200 FinalDesign\Drafting\101726-200_Fig1.dwg Date: 08-19-2020 Login: BWV



LEGEND

SW-01 Boring Designation and Approximate Location

Approximate Updated Project Limits

0 300 600

Scale in Feet

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced with permission granted by Google Earth™ Mapping Service.

US 6 West Edwards Improvement Design
Eagle County, Colorado

SITE AND EXPLORATION PLAN

March 2022 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 2

Filename: I:\EF\DEN\101000s\101726 US 6 West Edwan\200 FinalDesign\Drafting\101726-200_Fig 2.dwg Date: 12-06-2021 Login: ALL

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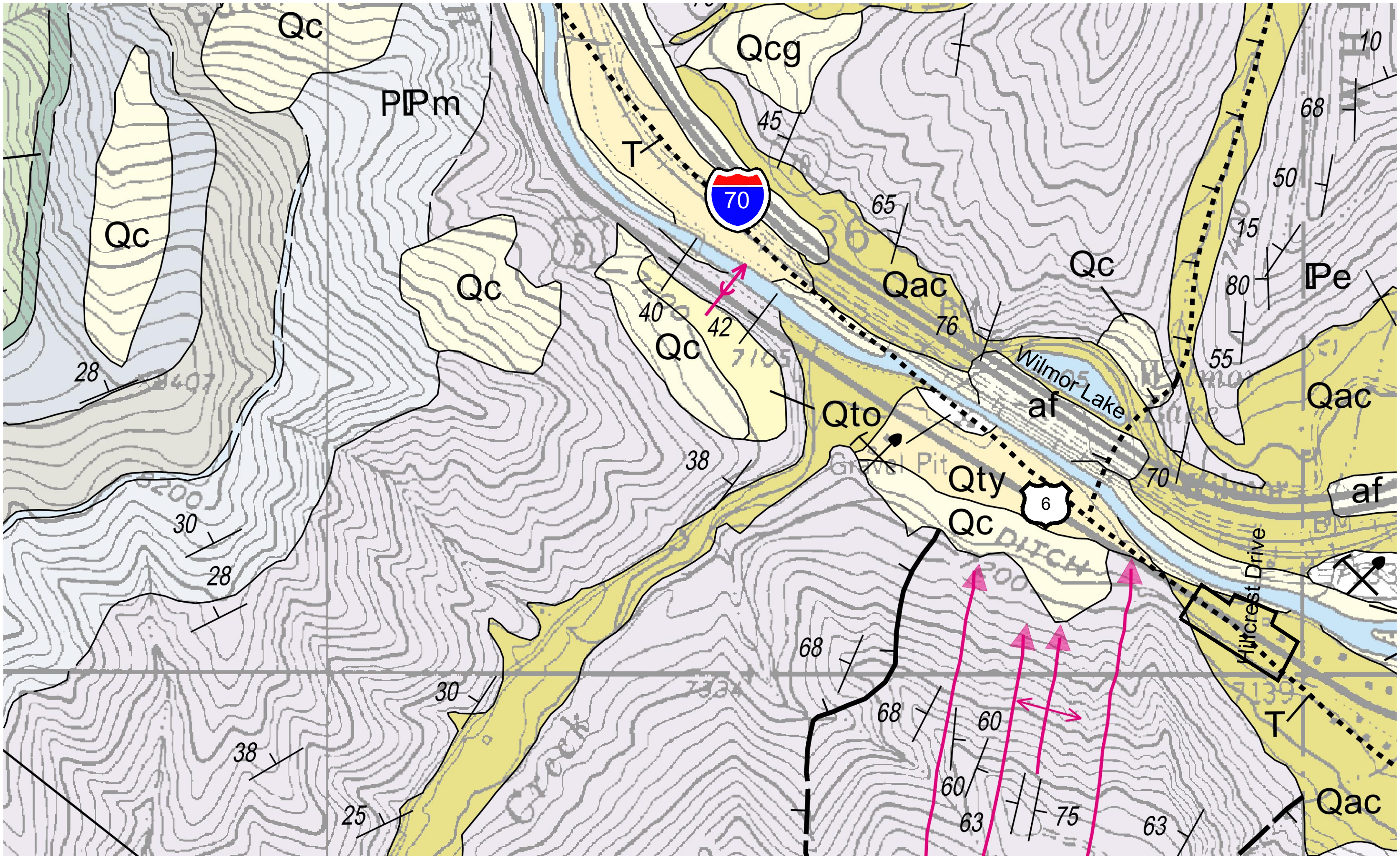

Approximate Scale in Feet: 0, 1,000, 2,000

— Approximate Updated Project Limits

Generated from Lidke, 2008.

RELEVANT GEOLOGIC UNITS AND FEATURES

af - Artificial Fill
Pe - Eagle Valley Formation
Qac - Undivided Alluvium and Colluvium
Qc - Colluvium Undifferentiated
Qto - Older Terrace Alluvium of Eagle River
Qty - Younger Terrace Alluvium of Eagle River
T - Inferred Fault

US 6 West Edwards Improvement Design
Eagle County, Colorado

GEOLOGIC MAP

March 2022 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 3

Appendix A

Subsurface Explorations

APPENDIX A: SUBSURFACE EXPLORATIONS

CONTENTS

Figures

APPENDIX A: SUBSURFACE EXPLORATIONS

A.1 INTRODUCTION

Shannon & Wilson's field exploration program was conducted on July 1, 2020, and consisted of drilling five borings designated SW-01 through SW-05 at the locations shown on Figure 2. The methods used to conduct the field exploration program are described below.

A.2 EXPLORATIONS

The borings were coordinated (including subcontractor coordination, utility locates, and traffic control) and observed by a representative from Shannon & Wilson. The boring logs are presented in Figures A-2 to A-6. The exploration logs represent our interpretation of the contents of the field log and select results of laboratory testing. The borings were drilled by Vine Laboratories, Inc. of Commerce City, Colorado (under subcontract to Shannon & Wilson) using a CME 55 truck mounted drill rig. The borings were advanced to depths of approximately 5.5 to 14.5 feet using 4-inch-outside-diameter (O.D.) solid-stem auger. Upon completion of drilling, borings were backfilled with flowfill mixed on site and borings SW-02 through SW-04 were patched with asphalt.

A.2.1 Soil Classification System

During drilling, our representative collected samples and prepared field logs of the explorations. Soil classification for this project was based on ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), and ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Soils were also classified using the AASHTO Soil Classification System based on AASHTO Standard M 145. The Unified Soil Classification System is summarized in Figure A-1.

A.2.2 Standard Penetration Test (SPT)

Disturbed samples were obtained in the borings in general accordance with the Standard Penetration Test (SPT) (ASTM Designation: D1586). The SPT consists of driving a 2-inch-outside-diameter (O.D.), 1.375-inch I.D. split-spoon sampler 18 inches. An automatic, free-falling 140-pound hammer was used to advance the split spoon sampler. The energy transfer ratio for the hammer on the CME 55 truck mounted rig was 83%, dated July 15, 2019, provided by Vine Laboratories. During sampling, the Shannon & Wilson field representative recorded the number of blows for each 6-inch increment of penetration and summed the blow counts for the last two 6-inch increments. This sum is recorded as the penetration resistance number, or N-value. If high penetration resistance prevented driving the total length of the sampler, the Shannon & Wilson field representative recorded the partial penetration depth and blow count. The N-values provide a means for evaluating the relative density or compactness of cohesionless (granular) soils and consistency or stiffness of cohesive (fine-grained) soils (see Figure A-1). The raw N-values are shown on the individual boring logs. Representative portions of the split-spoon sample obtained in conjunction with the SPT were placed in a screw-top plastic jar and transported to our laboratory.

A.2.3 Modified California (MC) Test and Sampling

Samples were also obtained using a Modified California (MC) barrel sampler. The MC test procedure is similar to the SPT, except the sample barrel is larger (2½-inch O.D.) and lined with 2-inch-diameter brass tubing. The MC sampler is only driven 12 inches. During sampling, the Shannon & Wilson field representative recorded the number of blows for each 6-inch increment of penetration. As a result of the larger diameter, the MC sampler yields slightly higher raw blow count numbers when compared to SPT N-values for similar soils. Because the difference in blow counts does not significantly impact our evaluation, we used the field MC blow counts over the 12-inch increment to define the relative density and consistency/stiffness of the subsurface materials following SPT terminology. Representative samples were sealed in the brass liner tubes with plastic caps and transported to our laboratory for further testing.

A.2.4 Bulk Sampling

Approximately 20 to 30 pounds of cuttings from each location were placed in a plastic bag and transported to our laboratory for further evaluation and testing. The bulk samples are composite samples sometimes spanning over several soil layers. The UCSC classification of the composite bulk samples has not been incorporated into the boring logs for this reason.

Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

S&W INORGANIC SOIL CONSTITUENT DEFINITIONS

CONSTITUENT[2]	FINE-GRAINED SOILS (50% or more fines)[1]	COARSE-GRAINED SOILS (less than 50% fines)[1]
Major	***Silt, Lean Clay, Elastic Silt,*** or ***Fat Clay***[3]	***Sand*** or ***Gravel***[4]
Modifying (Secondary) Precedes major constituent	30% or more coarse-grained: ***Sandy*** or ***Gravelly***[4]	More than 12% fine-grained: ***Silty*** or ***Clayey***[3]
Minor Follows major constituent	15% to 30% coarse-grained: ***with Sand*** or ***with Gravel***[4]	5% to 12% fine-grained: ***with Silt*** or ***with Clay***[3]
	30% or more total coarse-grained *and* lesser coarse-grained constituent is 15% or more: ***with Sand*** or ***with Gravel***[5]	15% or more of a second coarse-grained constituent: ***with Sand*** or ***with Gravel***[5]

[1]All percentages are by weight of total specimen passing a 3-inch sieve.
[2]The order of terms is: *Modifying Major with Minor*.
[3]Determined based on behavior.
[4]Determined based on which constituent comprises a larger percentage.
[5]Whichever is the lesser constituent.

MOISTURE CONTENT TERMS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

STANDARD PENETRATION TEST (SPT) SPECIFICATIONS

Hammer:	140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/4 rope turns, > 100 rpm NOTE: If automatic hammers are used, blow counts shown on boring logs should be adjusted to account for efficiency of hammer.
Sampler:	10 to 30 inches long Shoe I.D. = 1.375 inches Barrel I.D. = 1.5 inches Barrel O.D. = 2 inches
N-Value:	Sum blow counts for second and third 6-inch increments. Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches.

NOTE: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.

PARTICLE SIZE DEFINITIONS

DESCRIPTION	SIEVE NUMBER AND/OR APPROXIMATE SIZE
FINES	< #200 (0.075 mm = 0.003 in.)
SAND	
Fine	#200 to #40 (0.075 to 0.4 mm; 0.003 to 0.02 in.)
Medium	#40 to #10 (0.4 to 2 mm; 0.02 to 0.08 in.)
Coarse	#10 to #4 (2 to 4.75 mm; 0.08 to 0.187 in.)
GRAVEL	
Fine	#4 to 3/4 in. (4.75 to 19 mm; 0.187 to 0.75 in.)
Coarse	3/4 to 3 in. (19 to 76 mm)
COBBLES	3 to 12 in. (76 to 305 mm)
BOULDERS	> 12 in. (305 mm)

RELATIVE DENSITY / CONSISTENCY

COHESIONLESS SOILS		COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
< 4	Very loose	< 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
> 50	Very dense	15 - 30	Very stiff
		> 30	Hard

WELL AND BACKFILL SYMBOLS

Bentonite Cement Grout	Surface Cement Seal
Bentonite Grout	Asphalt or Cap
Bentonite Chips	Slough
Silica Sand	Inclinometer or Non-perforated Casing
Perforated or Screened Casing	Vibrating Wire Piezometer

PERCENTAGES TERMS [1, 2]

Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

[1]Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.

[2]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

US 6 West Edwards Improvement Design
Eagle County, Colorado

SOIL CLASSIFICATION AND LOG KEY

March 2022 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 3

2013 BORING CLASS1 US6 101726.GPJ SWNEW.GDT 8/19/20

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(Modified From USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL		TYPICAL IDENTIFICATIONS
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Gravel *(less than 5% fines)*	GW		Well-Graded Gravel; Well-Graded Gravel with Sand
			GP		Poorly Graded Gravel; Poorly Graded Gravel with Sand
		Silty or Clayey Gravel *(more than 12% fines)*	GM		Silty Gravel; Silty Gravel with Sand
			GC		Clayey Gravel; Clayey Gravel with Sand
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Sand *(less than 5% fines)*	SW		Well-Graded Sand; Well-Graded Sand with Gravel
			SP		Poorly Graded Sand; Poorly Graded Sand with Gravel
		Silty or Clayey Sand *(more than 12% fines)*	SM		Silty Sand; Silty Sand with Gravel
			SC		Clayey Sand; Clayey Sand with Gravel
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML		Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt
			CL		Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay
		Organic	OL		Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH		Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt
			CH		Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay
		Organic	OH		Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT		Peat or other highly organic soils (see ASTM D4427)

NOTE: No. 4 size = 4.75 mm = 0.187 in.; No. 200 size = 0.075 mm = 0.003 in.

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, Sand with Silt)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart. Graphics shown on the logs for these soil types are a combination of the two graphic symbols (e.g., SP and SM).

2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand)* indicate that the soil properties are close to the defining boundary between two groups.

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SOIL CLASSIFICATION AND LOG KEY

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SHANNON & WILSON, INC.
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FIG. A-1
Sheet 2 of 3

GRADATION TERMS

Poorly Graded	Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2487, if tested.
Well-Graded	Full range and even distribution of grain sizes present. Meets criteria in ASTM D2487, if tested.

CEMENTATION TERMS[1]

Weak	Crumbles or breaks with handling or slight finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

PLASTICITY[2]

DESCRIPTION	VISUAL-MANUAL CRITERIA	APPROX. PLASITICTY INDEX RANGE
Nonplastic	A 1/8-in. thread cannot be rolled at any water content.	< 4
Low	A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.	4 to 10
Medium	A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit.	10 to 20
High	It take considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit.	> 20

ADDITIONAL TERMS

Mottled	Irregular patches of different colors.
Bioturbated	Soil disturbance or mixing by plants or animals.
Diamict	Nonsorted sediment; sand and gravel in silt and/or clay matrix.
Cuttings	Material brought to surface by drilling.
Slough	Material that caved from sides of borehole.
Sheared	Disturbed texture, mix of strengths.

PARTICLE ANGULARITY AND SHAPE TERMS[1]

Angular	Sharp edges and unpolished planar surfaces.
Subangular	Similar to angular, but with rounded edges.
Subrounded	Nearly planar sides with well-rounded edges.
Rounded	Smoothly curved sides with no edges.
Flat	Width/thickness ratio > 3.
Elongated	Length/width ratio > 3.

[1]Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.
[2]Adapted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

ACRONYMS AND ABBREVIATIONS

ATD	At Time of Drilling
Diam.	Diameter
Elev.	Elevation
ft.	Feet
FeO	Iron Oxide
gal.	Gallons
Horiz.	Horizontal
HSA	Hollow Stem Auger
I.D.	Inside Diameter
in.	Inches
lbs.	Pounds
MgO	Magnesium Oxide
mm	Millimeter
MnO	Manganese Oxide
NA	Not Applicable or Not Available
NP	Nonplastic
O.D.	Outside Diameter
OW	Observation Well
pcf	Pounds per Cubic Foot
PID	Photo-Ionization Detector
PMT	Pressuremeter Test
ppm	Parts per Million
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
rpm	Rotations per Minute
SPT	Standard Penetration Test
USCS	Unified Soil Classification System
q_u	Unconfined Compressive Strength
VWP	Vibrating Wire Piezometer
Vert.	Vertical
WOH	Weight of Hammer
WOR	Weight of Rods
Wt.	Weight

STRUCTURE TERMS[1]

Interbedded	Alternating layers of varying material or color with layers at least 1/4-inch thick; singular: bed.
Laminated	Alternating layers of varying material or color with layers less than 1/4-inch thick; singular: lamination.
Fissured	Breaks along definite planes or fractures with little resistance.
Slickensided	Fracture planes appear polished or glossy; sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps that resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

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Eagle County, Colorado

SOIL CLASSIFICATION AND LOG KEY

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SHANNON & WILSON, INC.
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FIG. A-1
Sheet 3 of 3

Total Depth:	14.5 ft.	Latitude:	~ 39.65467°	Drilling Method:	Solid-Stem Auger	Hole Diam.:	4 in.
Top Elevation:	~	Longitude:	~ -106.63098°	Drilling Company:	Vine Laboratories	Rod Type.:	AWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 55 Truck	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

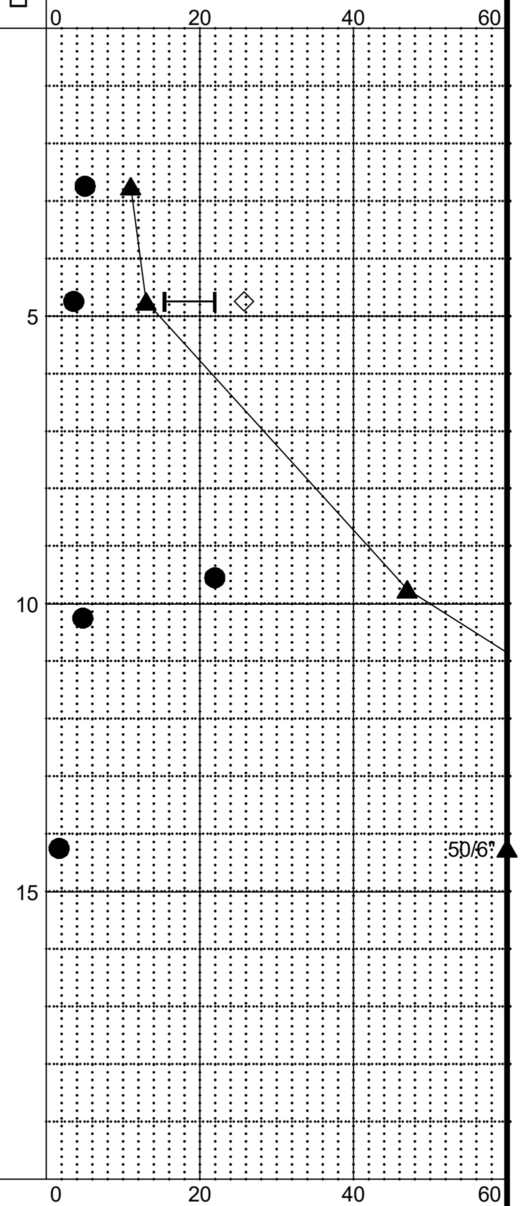
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples	Ground Water
Medium dense, red-brown, *Silty, Clayey Gravel with Sand (GC-GM);* moist. Fill A-2-4		S-1, S-2	Groundwater not encountered in boring
Dense, red, *Clayey Sand (SC);* moist. Undivided Alluvium and Colluvium	7.5	S-3	
Very dense, red-brown, *Poorly Graded Gravel with Silt and Sand (GP-GM);* moist. Undivided Alluvium and Colluvium	10.1	S-4	
BOTTOM OF BORING COMPLETED ON 07/01/2020	14.5		

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered

Standard Penetration Test

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit —●— Liquid Limit

Natural Water Content

NOTES

1. Refer to Figure A-1 for explanation of symbols, codes, abbreviations and definitions.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. USCS designation is based on visual-manual classification and selected lab testing.

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LOG OF BORING SW-01

March 2022 101726-200

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FIG. A-2

MASTER LOG E POCKETPEN LAT&LONG US6 101726.GPJ 8/31/20

QCL 3

Total Depth:	*5.5 ft.*	Latitude:	*~ 39.65406°*	Drilling Method:	*Solid-Stem Auger*	Hole Diam.:	*4 in.*
Top Elevation:	~	Longitude:	*~ -106.62937°*	Drilling Company:	*Vine Laboratories*	Rod Type.:	*AWJ*
Vert. Datum:		Station:	~	Drill Rig Equipment:	*CME 55 Truck*	Hammer Type:	*Automatic*
Horiz. Datum:		Offset:	~	Other Comments:			

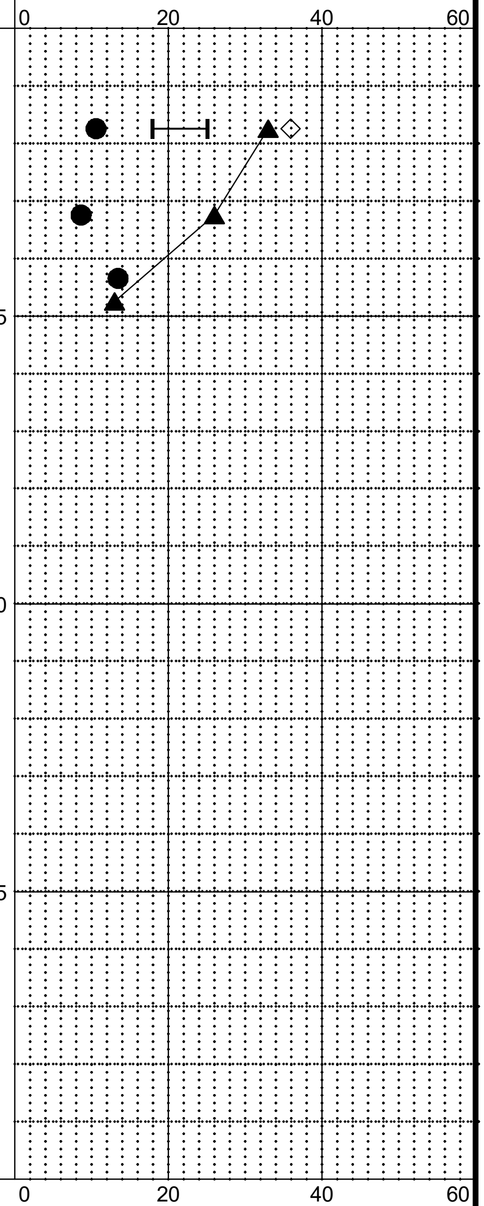
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples	Ground Water
9 inches of Asphalt.	0.8		Groundwater not encountered in boring
Medium dense to dense, red-brown to dark red-brown, *Silty, Clayey Sand with Gravel (SC-SM);* moist. Fill A-4 - Few asphalt fragments below 4.5 feet.	5.5	S-1 S-2 S-3	
BOTTOM OF BORING COMPLETED ON 07/01/2020			

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: *140 lbs / 30 inches*



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
Standard Penetration Test
Modified California Sampler

NOTES

1. Refer to Figure A-1 for explanation of symbols, codes, abbreviations and definitions.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. USCS designation is based on visual-manual classification and selected lab testing.

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LOG OF BORING SW-02

March 2022 | 101726-200

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FIG. A-3

MASTER_LOG_E_POCKETPEN_LAT&LONG_US6_101726.GPJ 8/31/20

QCL 3

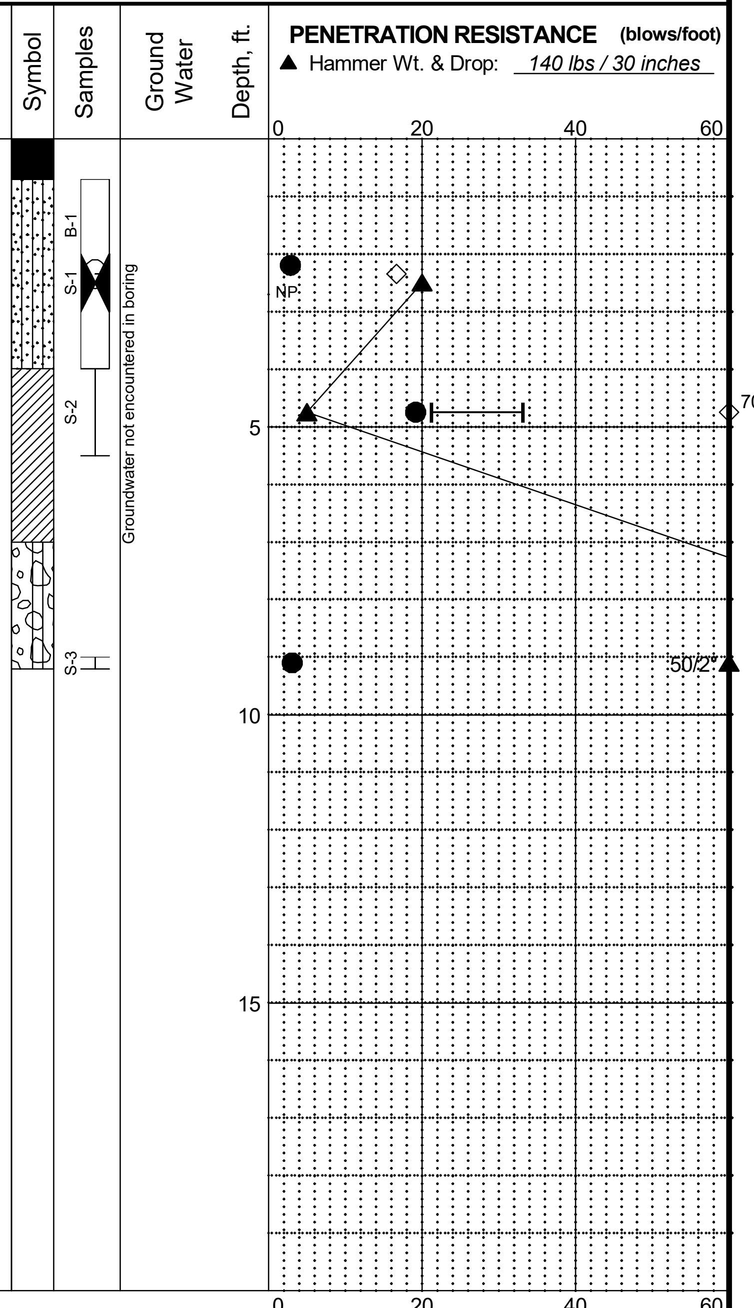
Total Depth:	*9.2 ft.*	Latitude:	*~ 39.65322°*	Drilling Method:	*Solid-Stem Auger*	Hole Diam.:	*4 in.*
Top Elevation:	*~*	Longitude:	*~ -106.62793°*	Drilling Company:	*Vine Laboratories*	Rod Type.:	*AWJ*
Vert. Datum:		Station:	*~*	Drill Rig Equipment:	*CME 55 Truck*	Hammer Type:	*Automatic*
Horiz. Datum:		Offset:	*~*	Other Comments:	*Auger refusal at 3 feet. Offset boring 3 feet to south.*		

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.
8 inches of Asphalt.	0.7
Medium dense, red-brown, *Silty Sand with Gravel (SM);* moist. Fill A-1-b	4.0
Medium stiff, red-brown, *Sandy Lean Clay (CL);* moist; few gravel. Undivided Alluvium and Colluvium A-6	7.0
Very dense, red-brown, *Poorly Graded Gravel with Silt and Sand (GP-GM);* moist. Undivided Alluvium and Colluvium	9.2

BOTTOM OF BORING
COMPLETED ON 07/01/2020



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- G Grab Sample
- Modified California Sampler
- Standard Penetration Test

NOTES

1. Refer to Figure A-1 for explanation of symbols, codes, abbreviations and definitions.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. USCS designation is based on visual-manual classification and selected lab testing.

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Eagle County, Colorado

LOG OF BORING SW-03

March 2022 101726-200

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FIG. A-4

MASTER_LOG_E_POCKETPEN_LAT&LONG_US6_101726.GPJ 8/31/20

QCL 3

Total Depth:	5.5 ft.	Latitude:	~ 39.65251°	Drilling Method:	Solid-Stem Auger	Hole Diam.:	4 in.
Top Elevation:	~	Longitude:	~ -106.62641°	Drilling Company:	Vine Laboratories	Rod Type.:	AWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 55 Truck	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

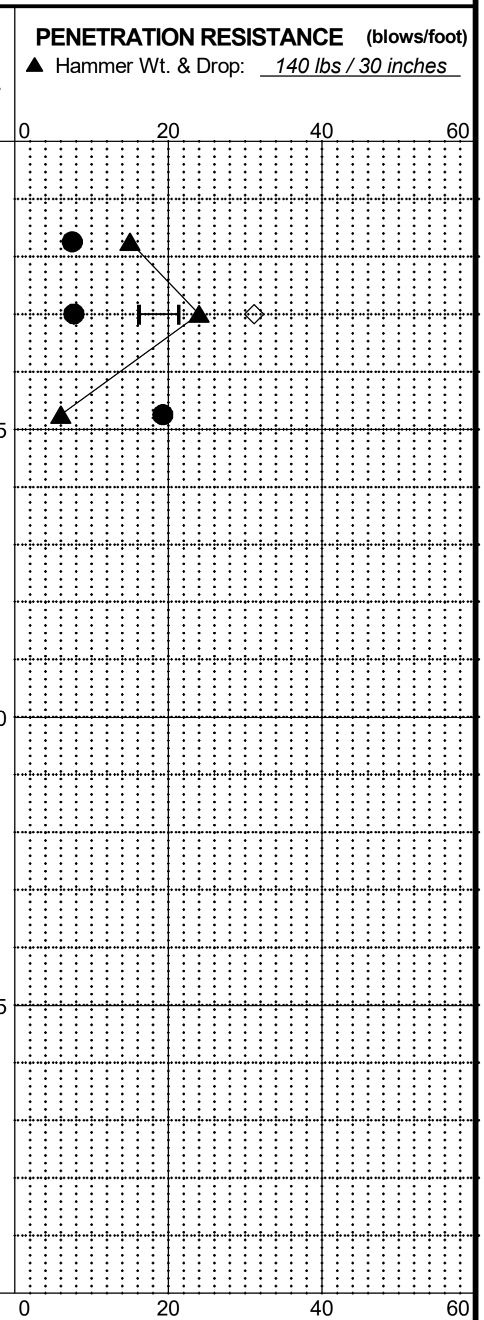
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
7.5 inches of Asphalt.	0.6	
Medium dense, dark red-brown, *Silty, Clayey Sand with Gravel (SC-SM);* moist. Fill A-2-4	4.0	S-1, S-2
Loose, dark red-brown, *Clayey Sand (SC);* moist. Undivided Alluvium and Colluvium	5.5	S-3

BOTTOM OF BORING
COMPLETED ON 07/01/2020

Groundwater not encountered in boring



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
Standard Penetration Test
Modified California Sampler

NOTES

1. Refer to Figure A-1 for explanation of symbols, codes, abbreviations and definitions.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. USCS designation is based on visual-manual classification and selected lab testing.

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Eagle County, Colorado

LOG OF BORING SW-04

March 2022 101726-200

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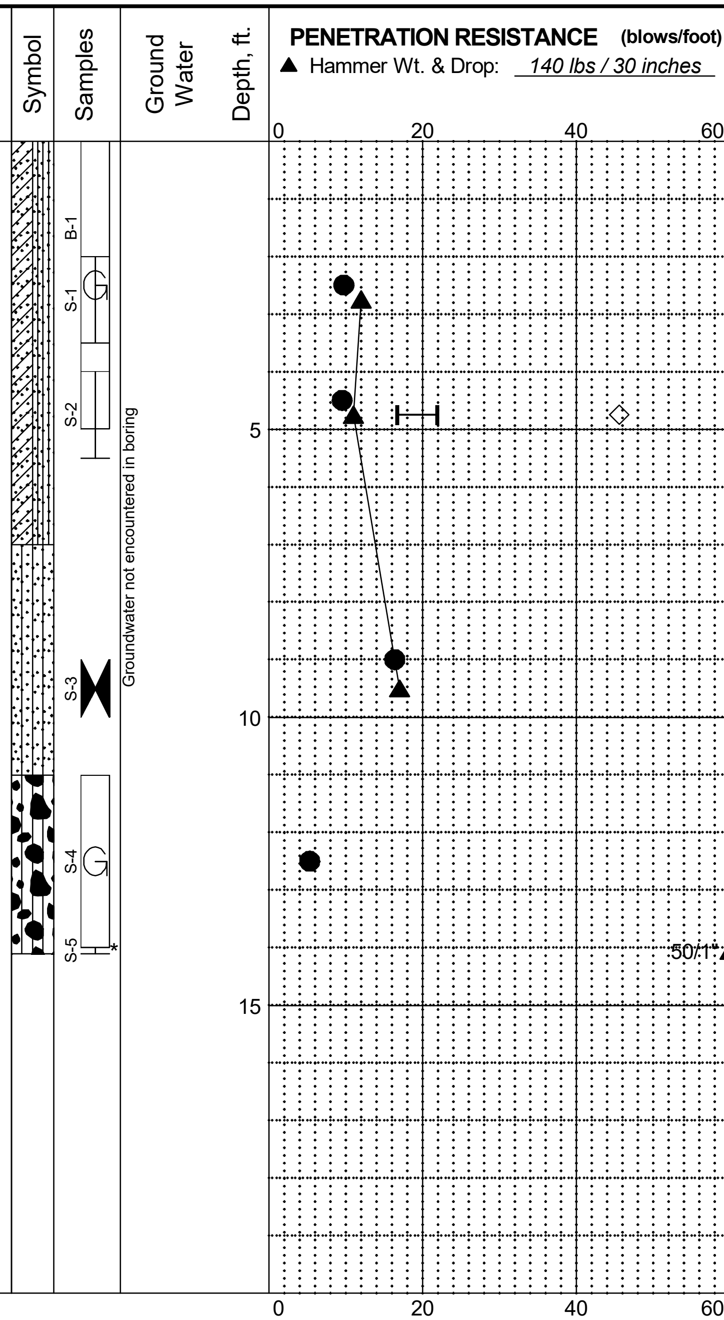
FIG. A-5

Total Depth:	14.1 ft.	Latitude:	~ 39.65499°	Drilling Method:	Solid-Stem Auger	Hole Diam.:	4 in.
Top Elevation:	~	Longitude:	~ -106.63161°	Drilling Company:	Vine Laboratories	Rod Type.:	AWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:	CME 55 Truck	Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.
Medium dense, red-brown *Silty, Clayey Sand with Gravel (SC-SM);* moist. Fill A-4	
Medium dense, red-brown, *Silty Sand (SM);* moist. Undivided Alluvium and Colluvium	7.0
Very dense, red-brown, *Silty Gravel with Sand (GM);* moist. Undivided Alluvium and Colluvium	11.0
BOTTOM OF BORING COMPLETED ON 07/01/2020	14.1



LEGEND

* Sample Not Recovered

Grab Sample

Standard Penetration Test

Modified California Sampler

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit

Natural Water Content

NOTES

1. Refer to Figure A-1 for explanation of symbols, codes, abbreviations and definitions.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. USCS designation is based on visual-manual classification and selected lab testing.

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LOG OF BORING SW-05

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FIG. A-6

APPENDIX B: LABORATORY TEST RESULTS

Appendix B

Laboratory Test Results

CONTENTS

Tables

Figures

APPENDIX B: LABORATORY TEST RESULTS

B.1 INTRODUCTION

Laboratory tests were completed on soil samples retrieved from the borings in general accordance with American Association of State Highway Transportation Officials (AASHTO) and Colorado Department of Transportation (CDOT) methods. The laboratory testing program was performed to classify the materials into similar geologic groups and provide data that can be used for design of the project. The geotechnical laboratory testing was performed at our in-house laboratory in Denver, Colorado and at Vine Laboratories in Commerce City, Colorado, and included index tests and geotechnical engineering property tests. A summary of the laboratory test results is presented in Table B-1. The following sections describe the laboratory testing procedures.

B.2 GEOTECHNICAL TESTS

B.2.1 Water Content

Water content was determined for selected samples in general accordance with AASHTO T265, Laboratory Determination of Moisture Content in Soils. To perform this test, a sample was weighed before and after oven-drying, and the water content was calculated. Water content determinations are shown graphically on the boring logs and are also summarized in Table B-1. A water content test was taken on each sample.

B.2.2 Grain Size Analysis

The grain size distribution of selected samples was determined in general accordance with AASHTO T88, Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis. Results of these analyses are presented as grain size distribution curves by boring number series on Figure B-1 and summarized in Table B-1.

Selected samples were tested for the percentage of material passing the No. 200 sieve in general accordance with AASHTO T11, Standard Method of Test for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing. The percent fines (silt- and clay-sized particles passing the No. 200 sieve) are shown graphically on the boring logs in Appendix A and are also summarized in Table B-1.

B.2.3 Atterberg Limits

Soil plasticity was determined by performing Atterberg limits tests on selected fine-grained samples. The tests were completed in general accordance with AASHTO T89, Standard Test

Method for Determining the Liquid Limit of Soils and AASHTO T90, Standard Test Method for Determining the Plastic Limit and Plasticity Index of Soils. The Atterberg limits include liquid limit (LL), plastic limit (PL), and plasticity index (PI equals LL minus PL) and are generally used to assist in classification of soils, to indicate soil consistency (when compared to natural water content), and to provide correlation to soil properties. The results of the Atterberg limits tests are plotted on a plasticity chart on Figure B-2, shown graphically on the boring logs in Appendix A, and summarized in Table B-1.

B.2.4 R-Value

One Hveem Staboilometer (R-value) test was completed by Vine Laboratories, Inc., of Commerce City, Colorado on a bulk subgrade sample. The test was completed in general accordance with ASTM D2844, Standard Method of Test for Resistance R-value and Expansion Pressure of Compacted Soils. The R-value test result is summarized in Table B-1 and presented on Figure B-3.

Table B-1 - Summary of Laboratory Test Results

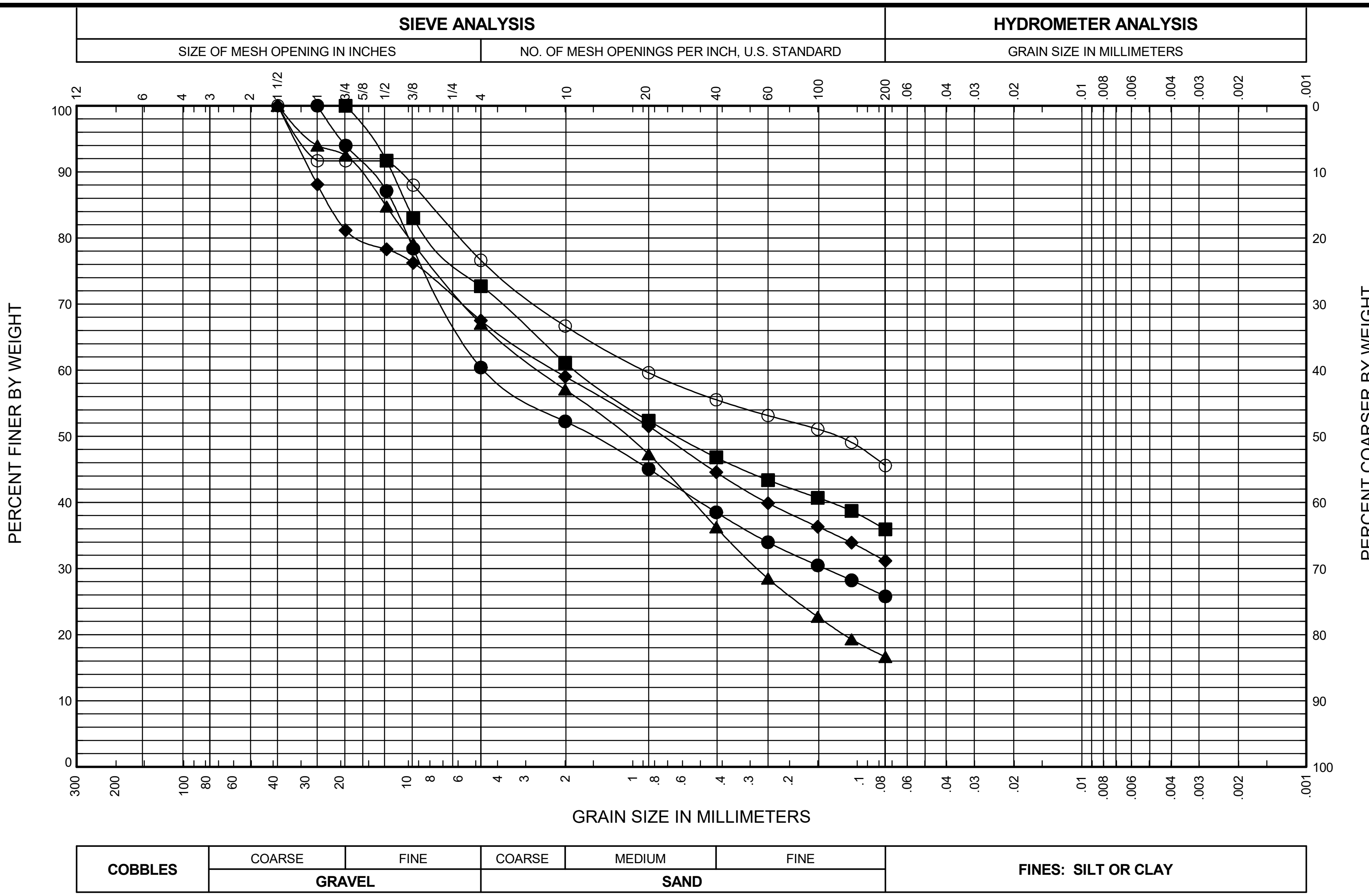
SAMPLE DATA						Natural Moisture Content	GRAIN-SIZE ANALYSES[2]			ATTERBERG LIMITS[3]			CORROSIVITY				
Boring	Sample	Depth (feet) Top	Depth (feet) Bottom	USCS Symbol[1]	AASHTO Designation	Natural Moisture Content (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	pH	Resistivity (ohm-cm)	Sulfates (%)	Chlorides (%)	R- Value
SW-01	S-1	2	3.5			5.0											
	S-2	4	5.5	GC-GM	A-2-4	3.6	40	34	26	22	15	7					
	S-3A	9	10.1			22.0											
	S-3B	10.1	10.4			4.8											
	S-4	14	14.5			1.7											
SW-02	S-1	1	2.5	SC-SM	A-4	10.6	27	37	36	25	18	7					
	S-2	2.5	4			8.6											
	S-3	4	5.5			13.5											
SW-03	B-1	0.7	4	SM	A-1-b	2.8	33	50	17	NV	NP	NP					77
	S-2	4	5.5	CL	A-6	19.2			70	33	21	12					
	S-3	9	9.2			3.1											
SW-04	S-1	1	2.5			7.5											
	S-2	2.5	3.5	SC-SM	A-2-4	7.7	33	36	31	21	16	5					
	S-3	4	5.5			19.3											
SW-05	S-1	2	3.5			9.7							9.7	5,900	0.38	<0.01	
	S-2	4	5.5	SC-SM	A-4	9.5	23	31	46	22	17	5					
	S-3	9	10			16.4											
	S-4	11	14			5.3											

NOTES:

1 Refer to Appendix A, Figure A-1 for definitions.

2 Gravel defined as particles larger than the No. 4 sieve size, Sand as particles between the No. 4 and No. 200 sieve sizes, and Fines as particles passing the No. 200 siev

3 NP = Non Plastic; NV = No Value



SAMPLE ID	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● SW-01, S-2	4.0	GC-GM	Silty, Clayey Gravel with Sand	25.8	3.6	22	15	7
■ SW-02, S-1	1.0	SC-SM	Silty, Clayey Sand with Gravel	35.9	10.6	25	18	7
▲ SW-03, B-1	0.7	SM	Silty Sand with Gravel	16.6	2.8	NV	NP	NP
◆ SW-04, S-2	2.5	SC-SM	Silty, Clayey Sand with Gravel	31.1	7.7	21	16	5
○ SW-05, S-2	4.0	SC-SM	Silty, Clayey Sand with Gravel	45.6	9.5	22	17	5

US 6 West Edwards Improvement Design
Eagle County, Colorado

GRAIN SIZE DISTRIBUTION

March 2022

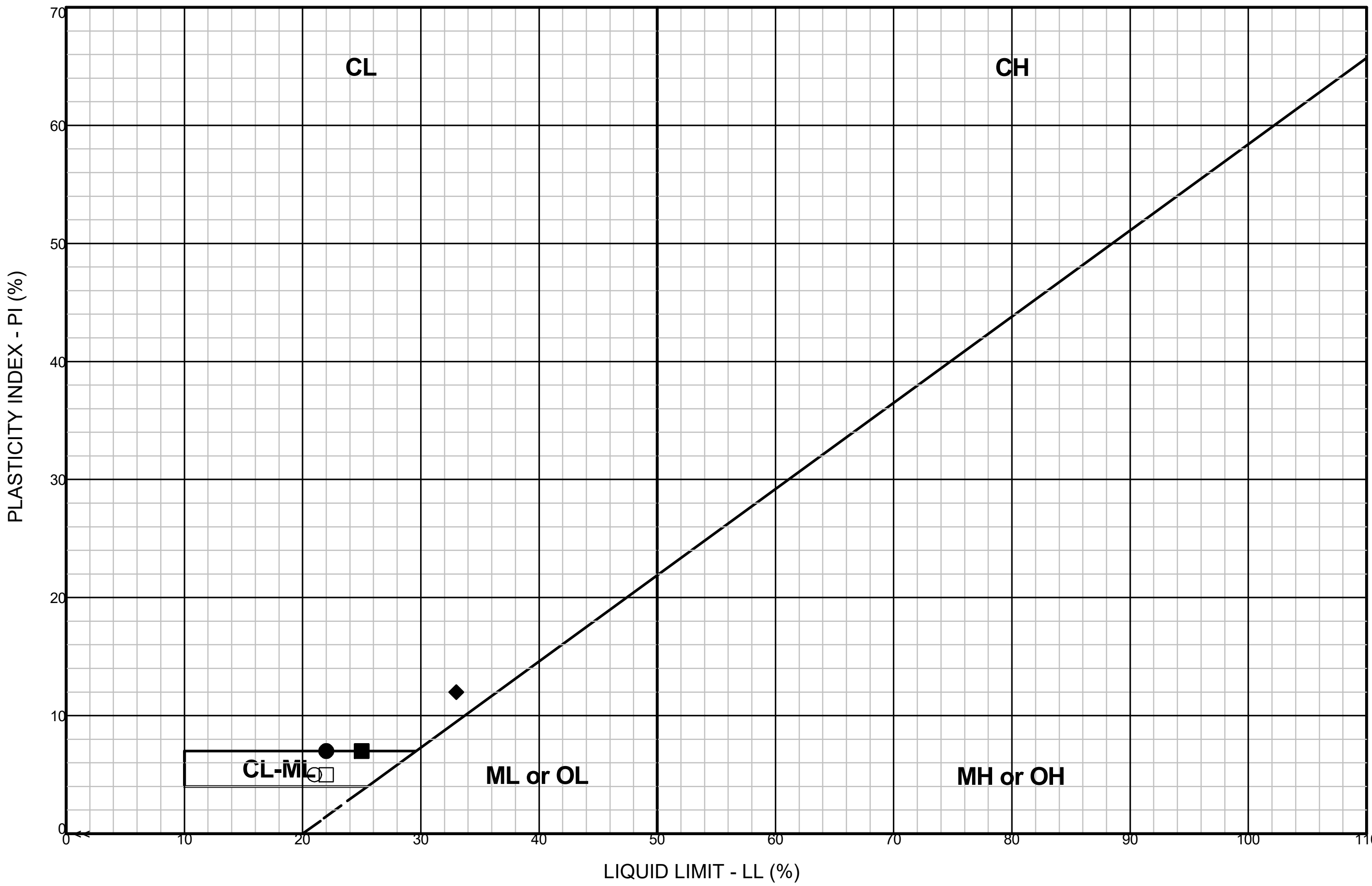
101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-1

Felsburg Holt & Ullevig

FIG. B-1



LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

SAMPLE ID	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
● SW-01, S-2	4.0	GC-GM	Silty, Clayey Gravel with Sand	22	15	7	3.6	25.8
■ SW-02, S-1	1.0	SC-SM	Silty, Clayey Sand with Gravel	25	18	7	10.6	35.9
SW-03, B-1	0.7	SM	Silty Sand with Gravel	NV	NP	NP	2.8	16.6
◆ SW-03, S-2	4.0	CL	Sandy Lean Clay	33	21	12	19.2	70.0
○ SW-04, S-2	2.5	SC-SM	Silty, Clayey Sand with Gravel	21	16	5	7.7	31.1
□ SW-05, S-2	4.0	SC-SM	Silty, Clayey Sand with Gravel	22	17	5	9.5	45.6

US 6 West Edwards Improvement Design
Eagle County, Colorado

PLASTICITY CHART

March 2022

101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

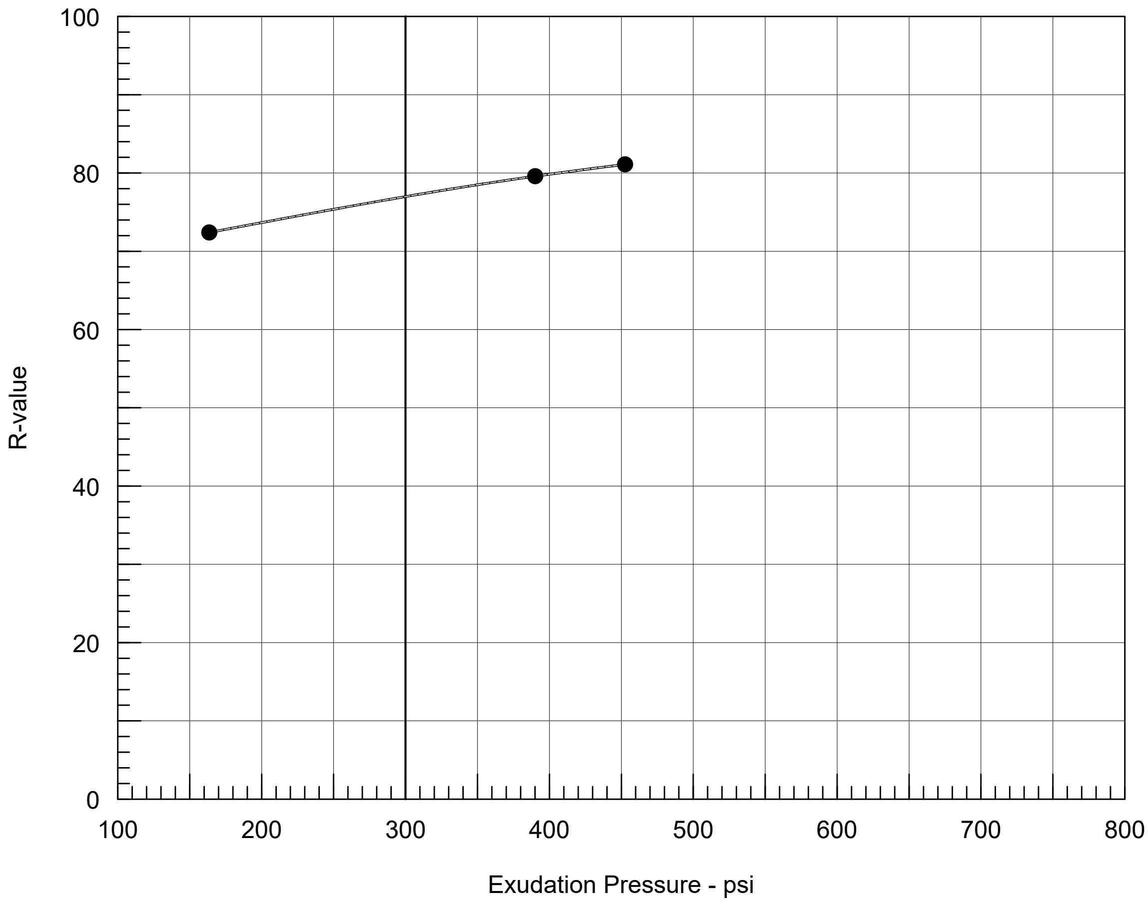
FIG. B-2

Felsburg Holt & Ullevig

ATT MAIN US6 101726.GPJ 8/20/20

FIG. B-2

R-VALUE TEST REPORT



Resistance R-Value and Expansion Pressure - AASHTO T 190

No.	Compact. Pressure psi	Density pcf	Moist. %	Expansion Pressure psi	Horizontal Press. psi @ 160 psi	Sample Height in.	Exud. Pressure psi	R Value	R Value Corr.
1	350	136.2	6.3	0.00	15	2.49	453	81.1	81.1
2	350	135.3	8.0	0.00	26	2.62	164	70.0	72.4
3	350	137.1	6.6	0.00	18	2.59	390	78.3	79.6

Test Results	Material Description
R-value at 300 psi exudation pressure = 77.0	SW-03 / B-1 0.7-4'

Project No.: 101726-200

Project: US-6

Location: SW-03 / B-1 0.7-4'

Sample Number: S2018

Date: 7/21/2020

Tested by: Juan Romero

Checked by: Clay Hollowell

Remarks:

R-VALUE TEST REPORT

Vine Laboratories

FIG. B-3

APPENDIX C: PAVEMENT M-E OUTPUT FILES

Appendix C

Pavement M-E Output Files

Pavement M-E Output Files

Analyses 01 - US 6, 6.5 inches HMA over 6 inches Class 6 ABC over 8 inches Class 1 ABC, 20 Year Analysis

Analyses 02 - US 6, 2 inch Mill & 2 inch Overlay, 10 Year Analysis

Analyses 03 - US 6, 8 inches PCC over 6 inches ABC, 30 Year Analysis

Analyses 04 - US 6 Roundabout, 8 inches PCC over 6 inches ABC, 30 Year Analysis

Analyses 05 - Hillcrest Drive, 5 inches HMA over 6 inches ABC, 20 Year Analysis

01_US6_6.5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\01_US6_6.5inHMA_6inABC_20yr.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: August, 2022
Pavement construction: August, 2022
Traffic opening: August, 2022

Climate Data Sources (Lat/Lon): 39.643, -106.918

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R5 Level 1 SX(75) PG 58-34	2.0
Flexible	R3 Level 1 SX(75) PG 58-28 United	4.5
NonStabilized	A-1-a	6.0
Subgrade	A-1-a	8.0
Subgrade	A-6	8.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	14.4
Air voids (%)	5.2

Traffic

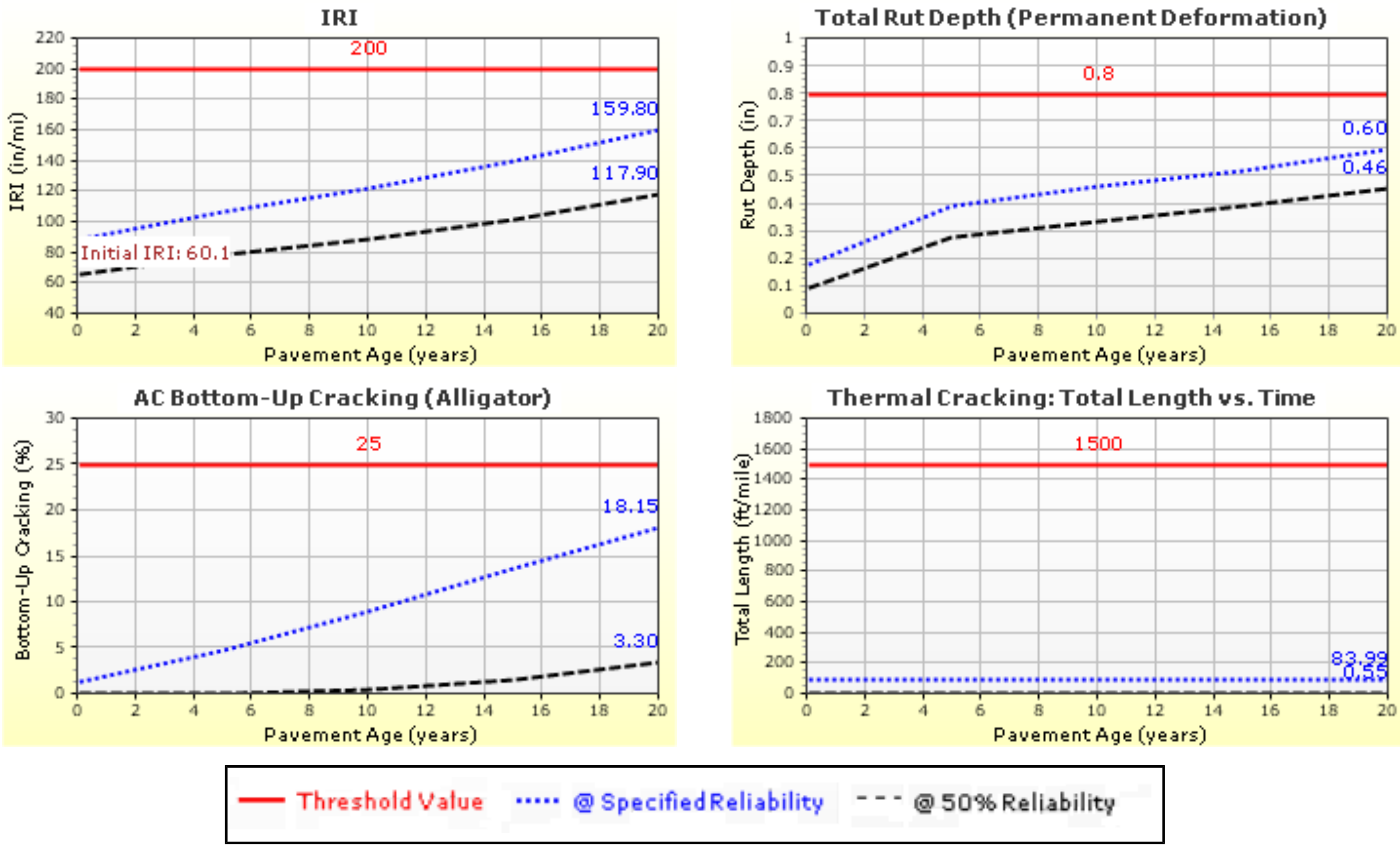
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2032 (10 years)	1,065,540
2042 (20 years)	2,442,880

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	159.81	90.00	99.39	Pass
Permanent deformation - total pavement (in)	0.80	0.60	90.00	99.92	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	18.15	90.00	96.95	Pass
AC thermal cracking (ft/mile)	1500.00	83.99	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	323.65	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.41	90.00	99.98	Pass

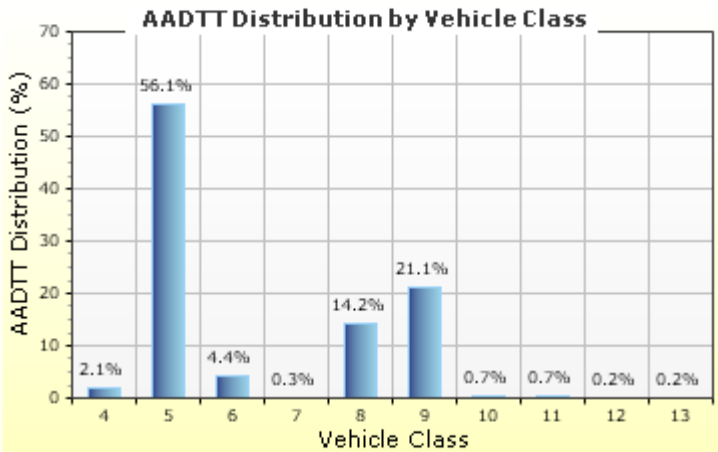
Distress Charts

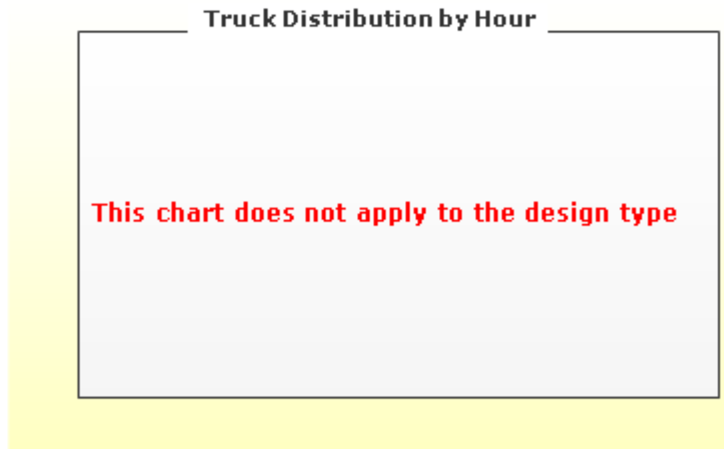


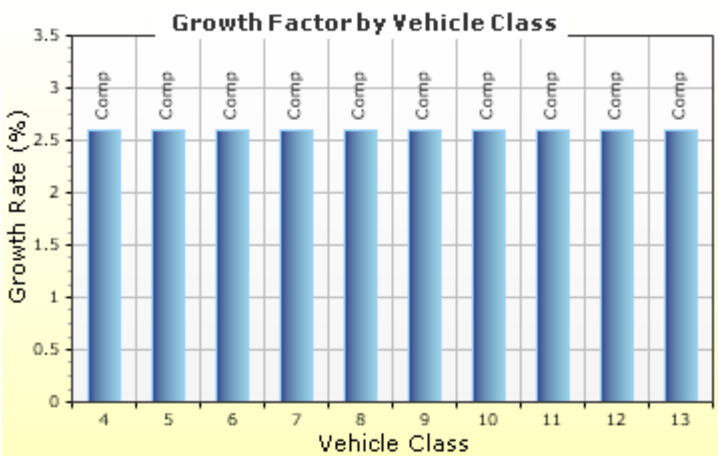
Traffic Inputs

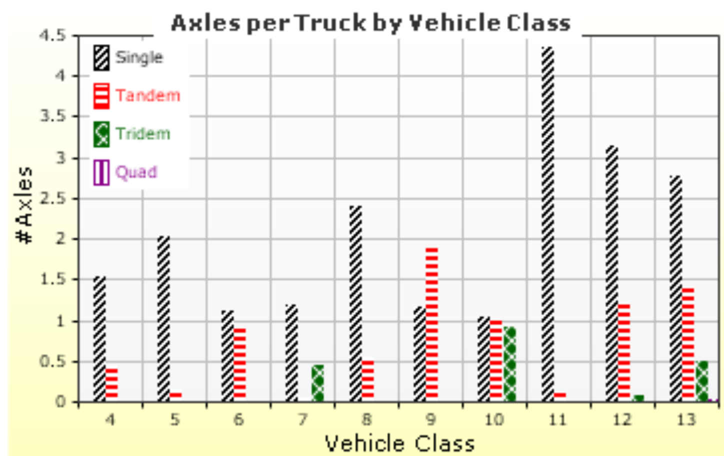
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	432	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)	15.0

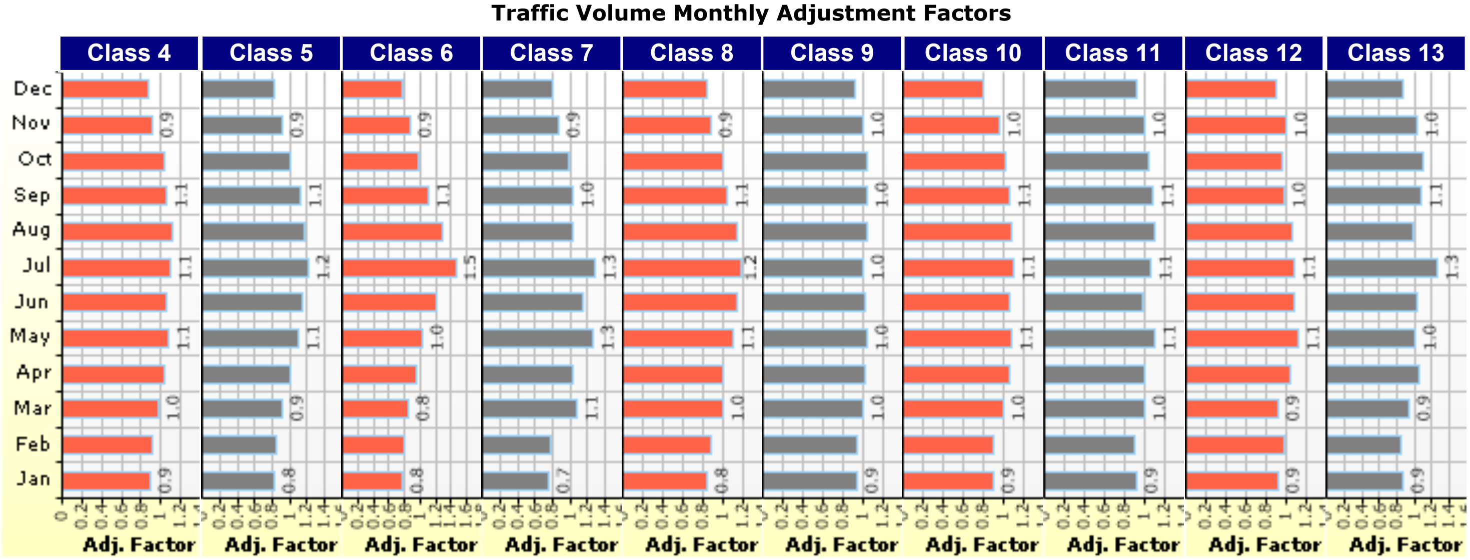








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.6%	Compound
Class 5	56.1%	2.6%	Compound
Class 6	4.4%	2.6%	Compound
Class 7	0.3%	2.6%	Compound
Class 8	14.2%	2.6%	Compound
Class 9	21.1%	2.6%	Compound
Class 10	0.7%	2.6%	Compound
Class 11	0.7%	2.6%	Compound
Class 12	0.2%	2.6%	Compound
Class 13	0.2%	2.6%	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

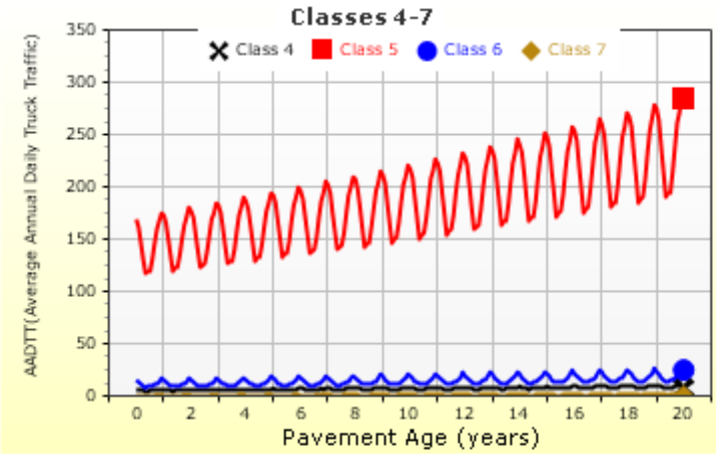
Wheelbase does not apply

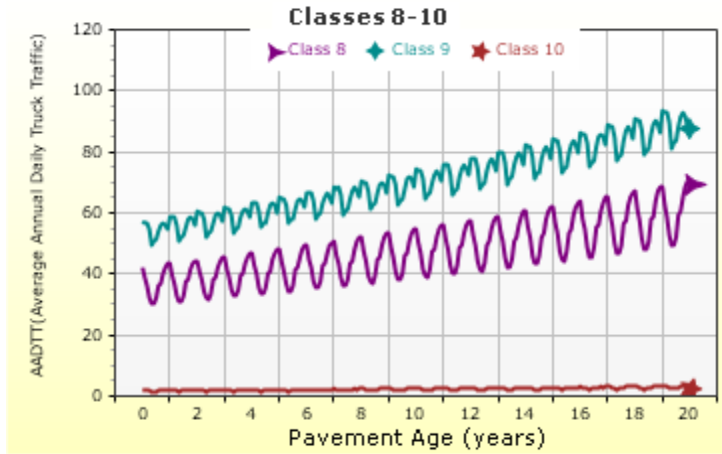
Number of Axles per Truck

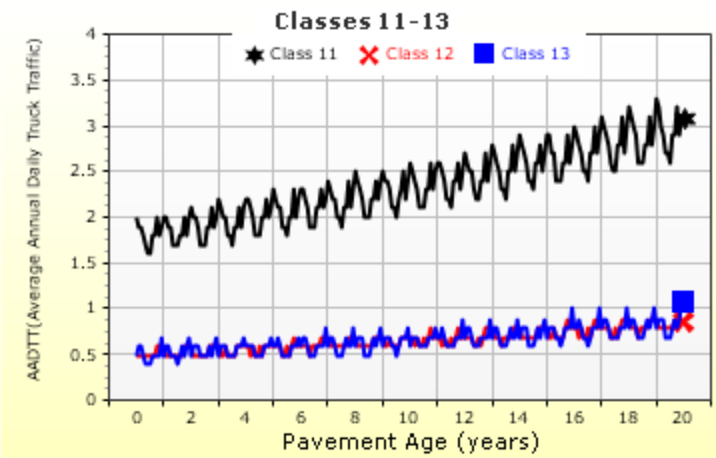
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

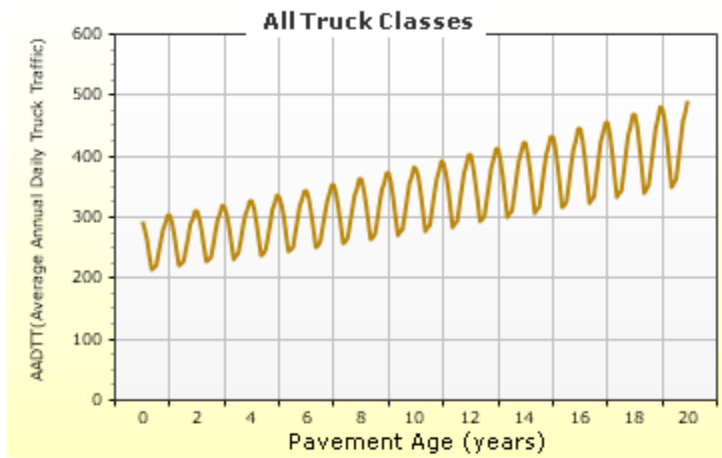
AADTT (Average Annual Daily Truck Traffic) Growth

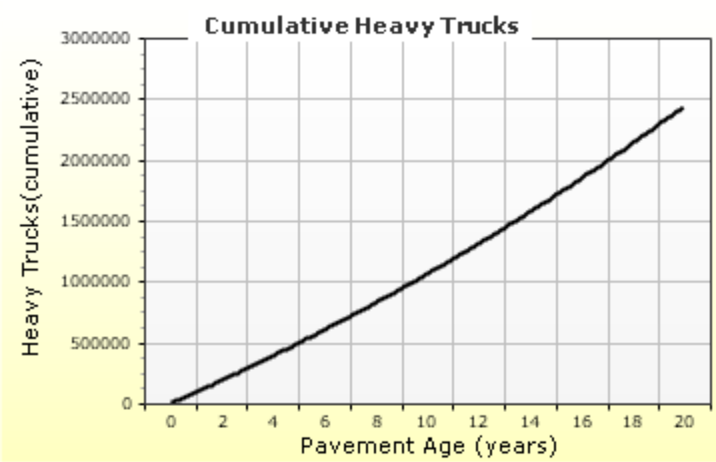
*** Traffic cap is not enforced**







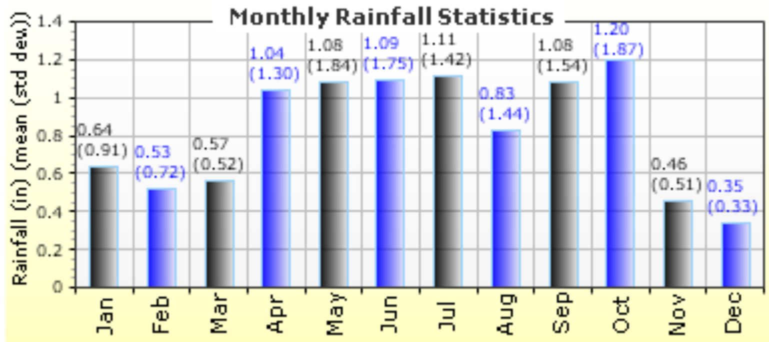




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
EAGLE CO, CO	39.64300 -106.91800 6535

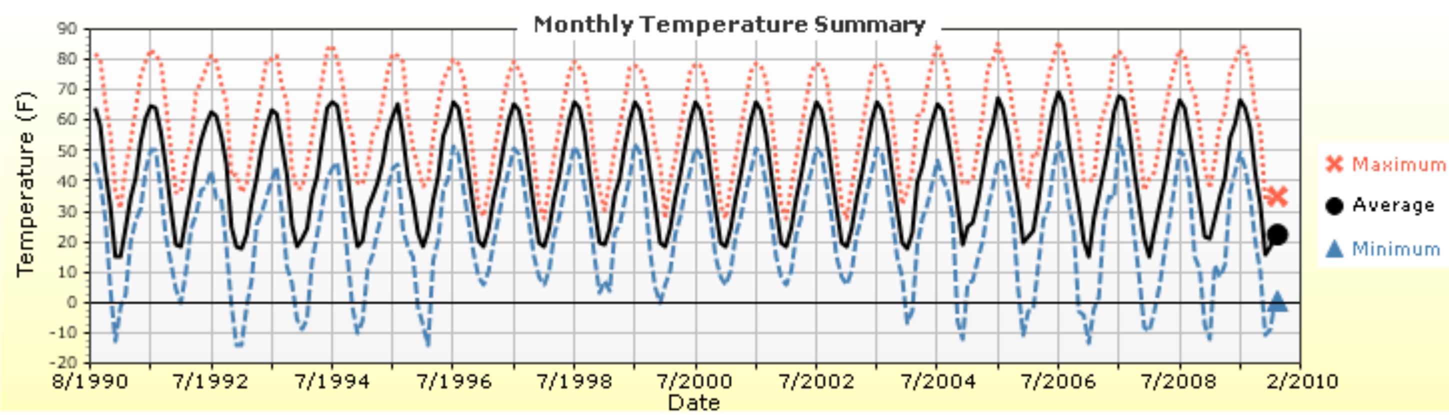


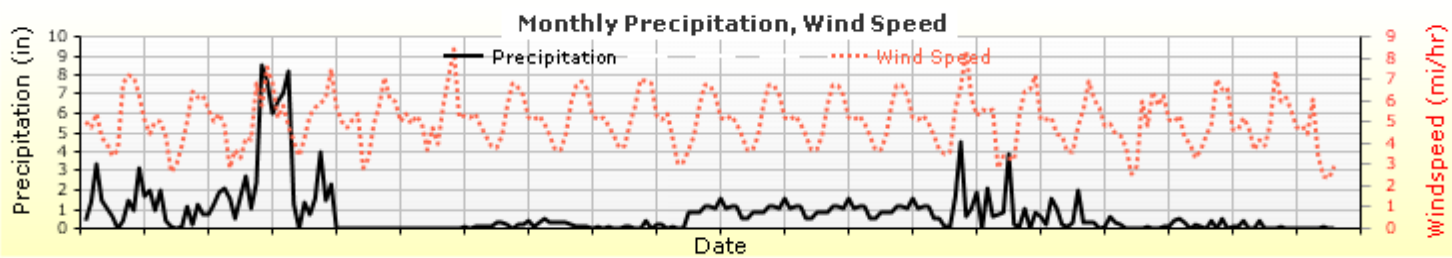
Annual Statistics:

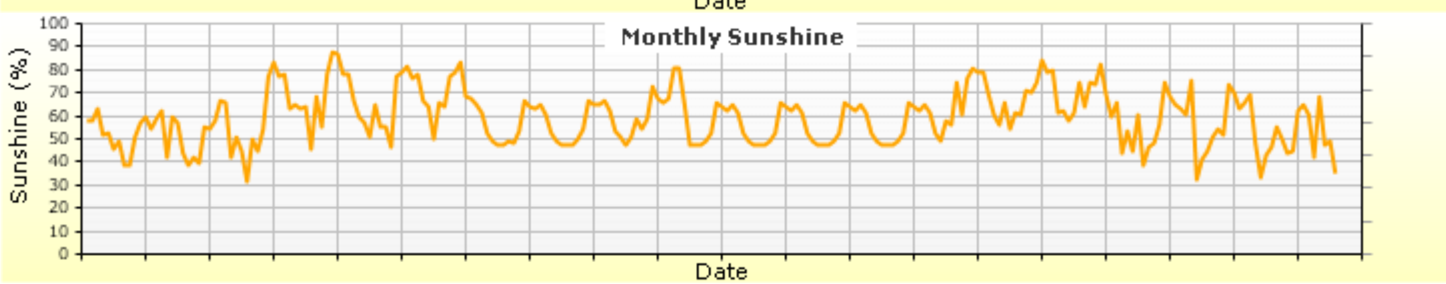
Mean annual air temperature (ºF)	42.99
Mean annual precipitation (in)	9.96
Freezing index (ºF - days)	1046.13
Average annual number of freeze/thaw cycles:	95.09

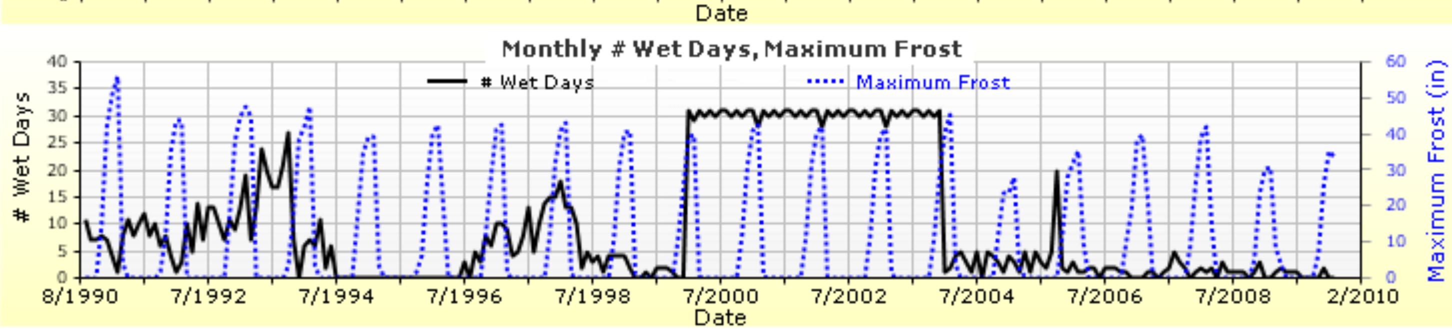
Water table depth (ft) 10.00

Monthly Climate Summary:









01_US6_6.5inHMA_6inABC_20yr

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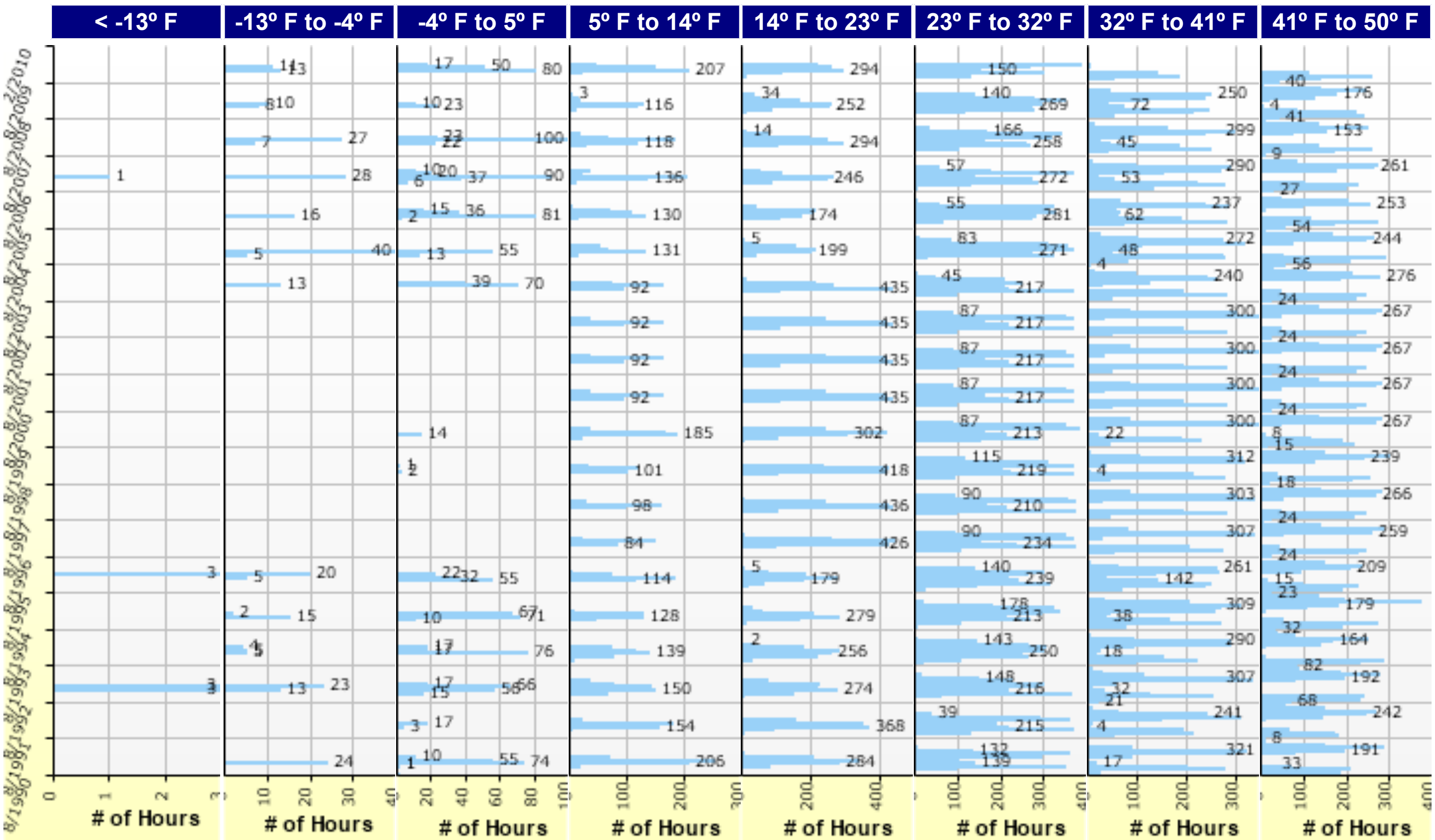
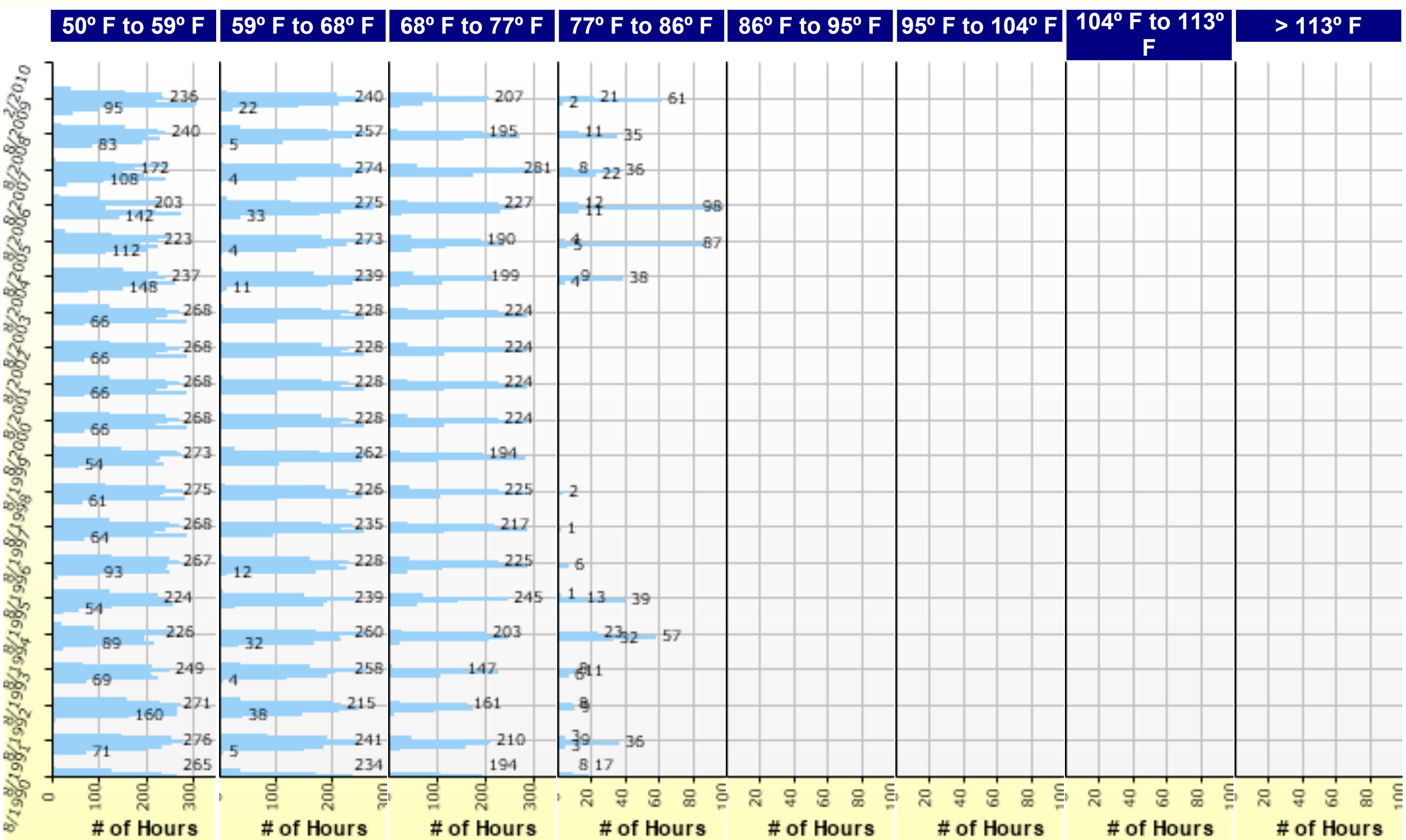
Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
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

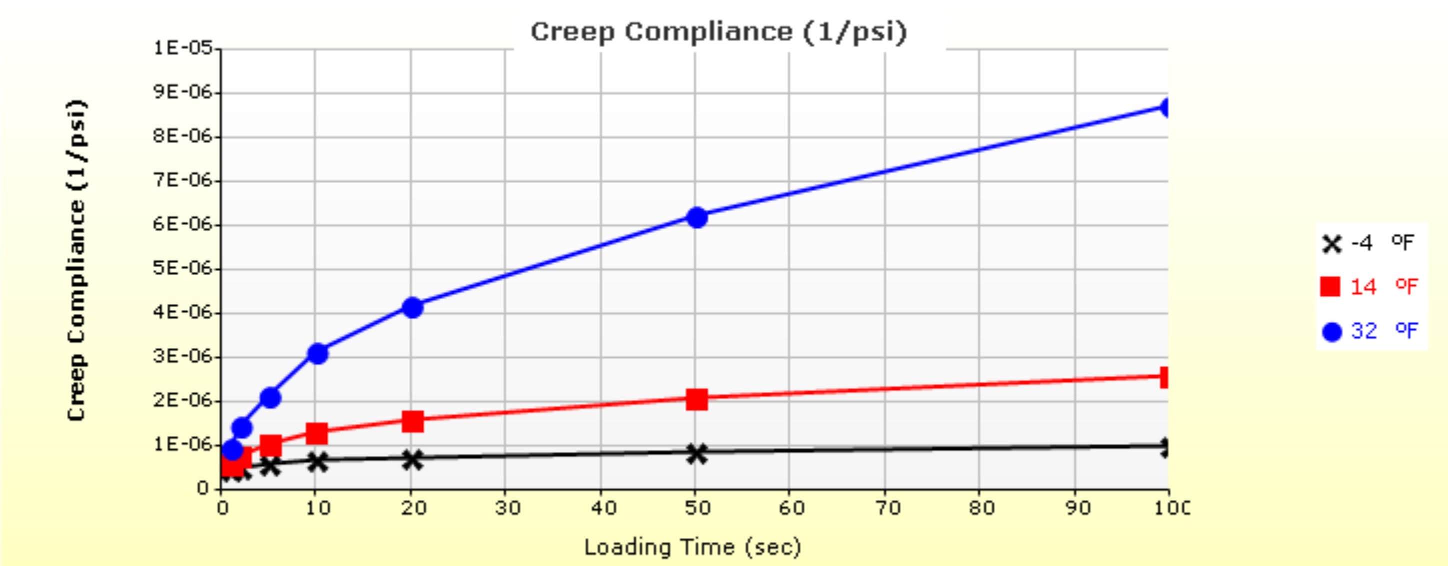
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Flexible : R3 Level 1 SX (75) PG 58-28 United	Flexible (1)	1.00
Layer 3 Non-stabilized Base : A-1-a	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	1.00
Layer 5 Subgrade : A-6	Subgrade (5)	1.00
Layer 6 Subgrade : A-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

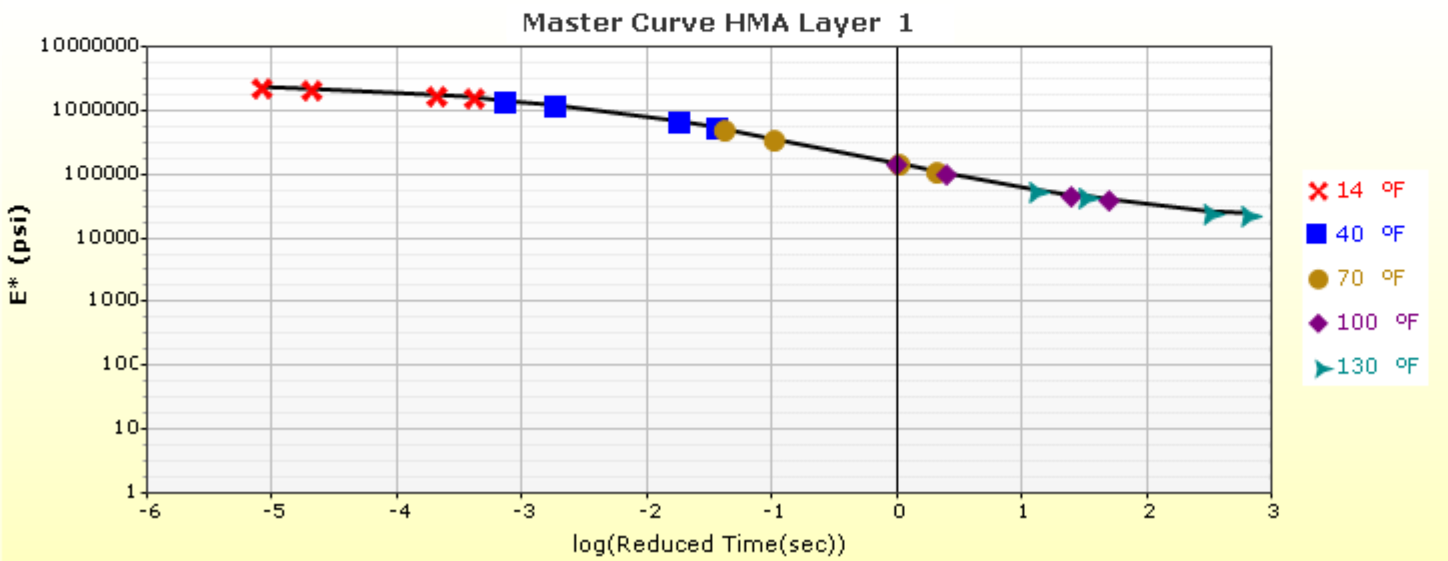
Indirect tensile strength at 14 ºF (psi)	446.00

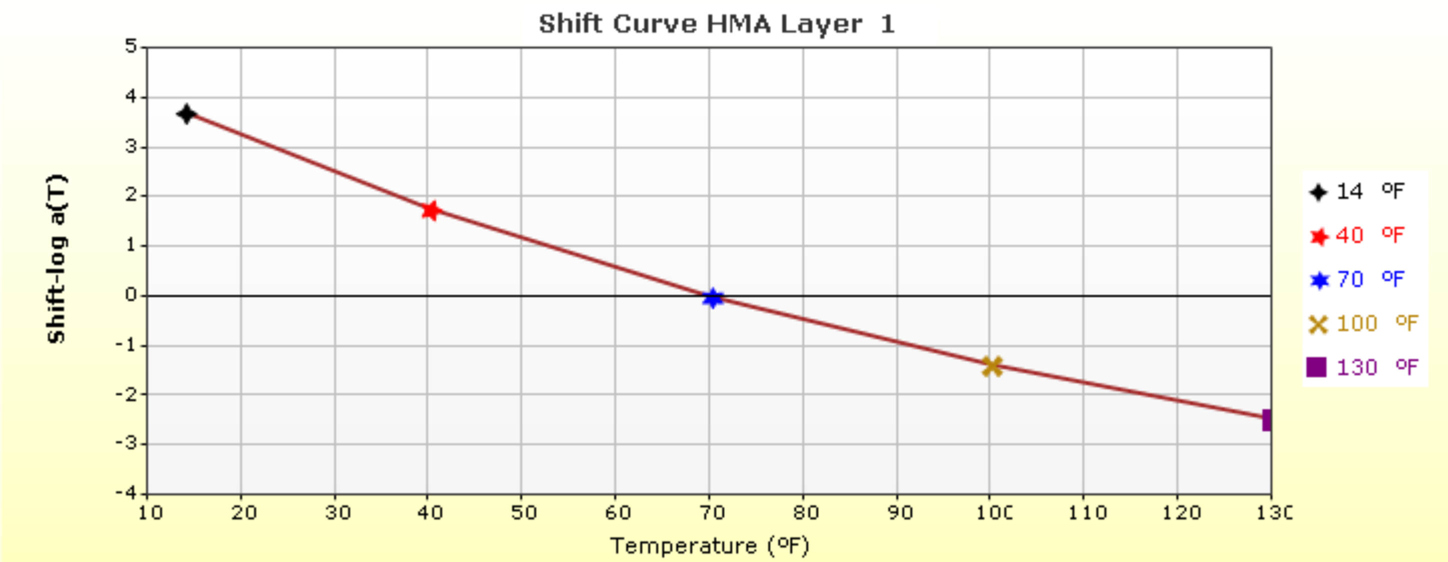
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

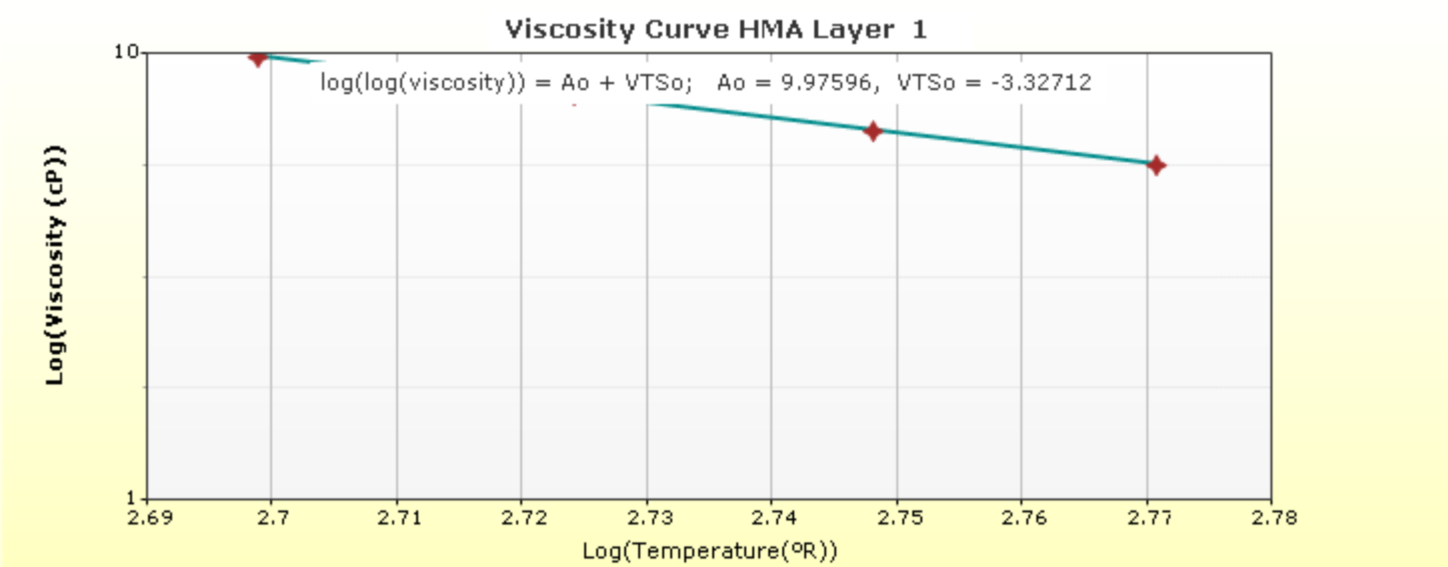
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



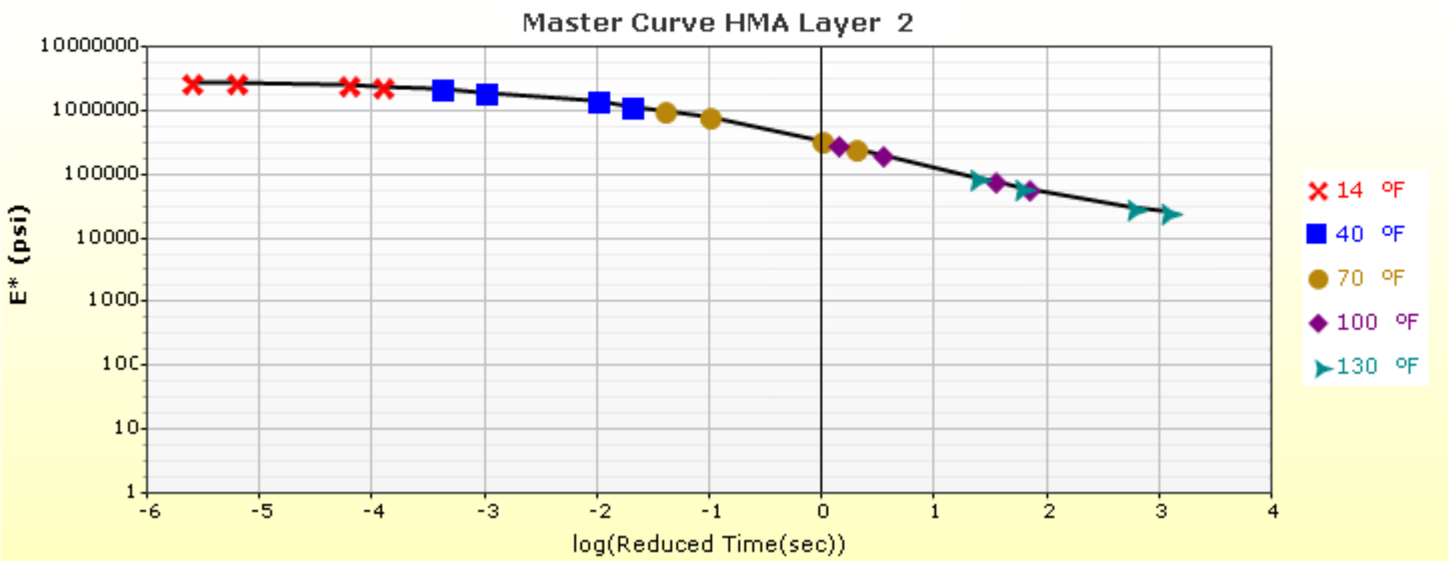
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

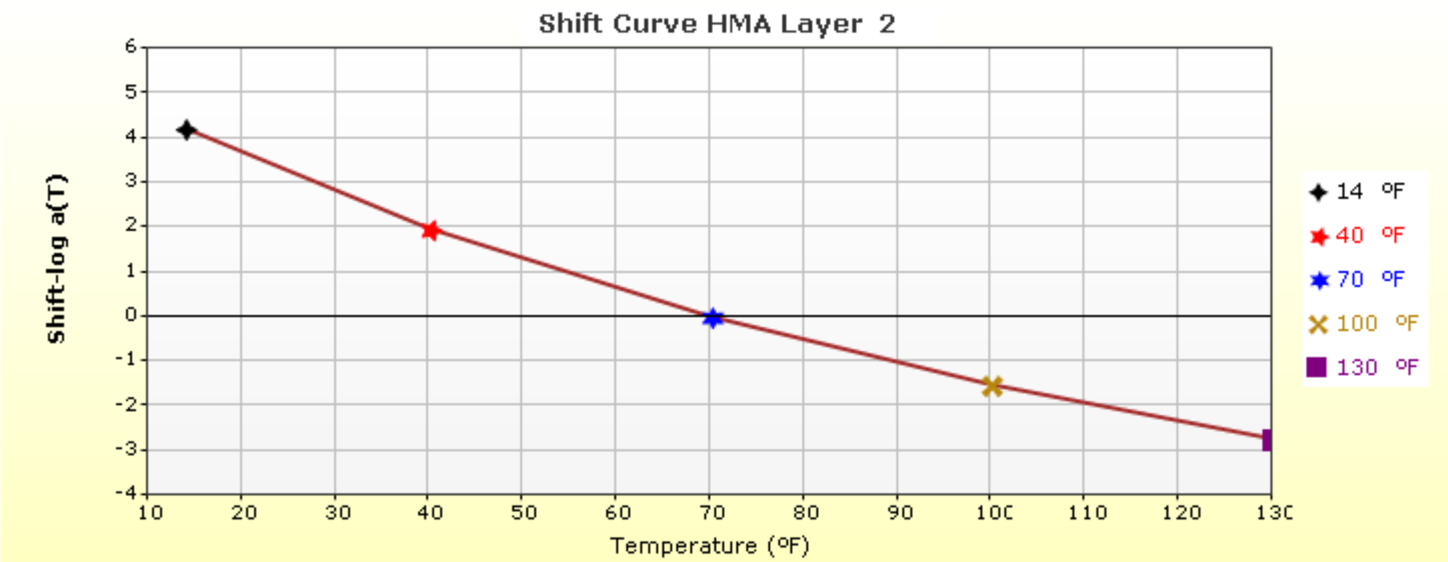


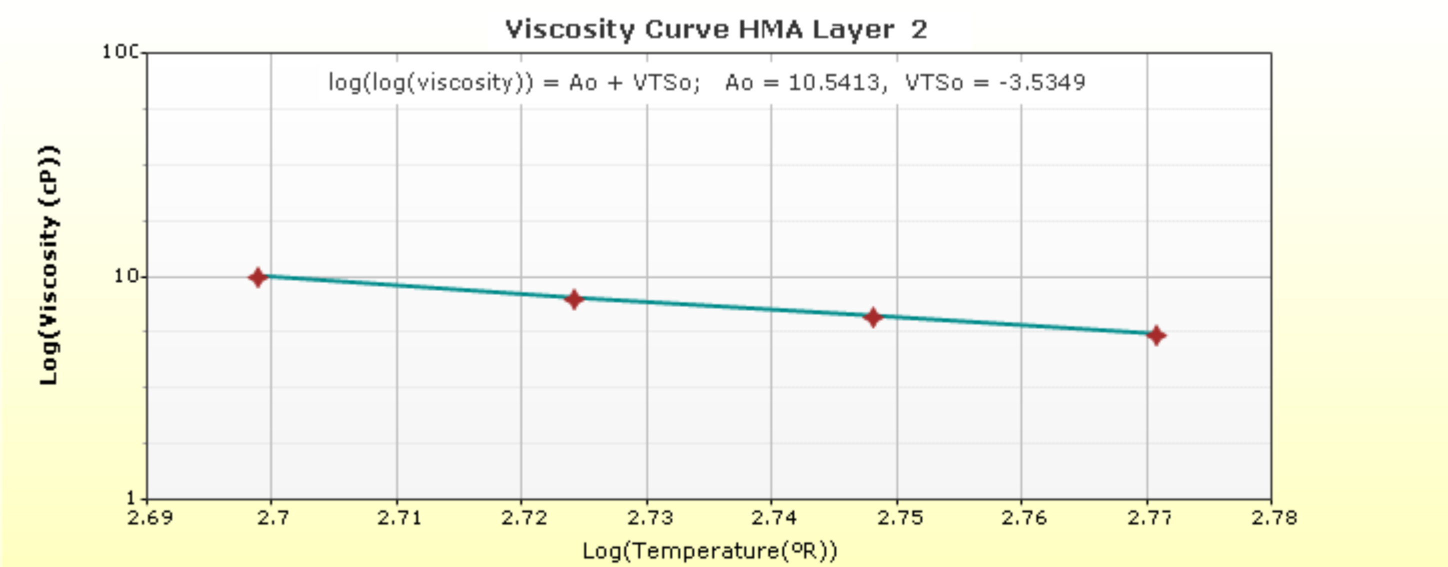




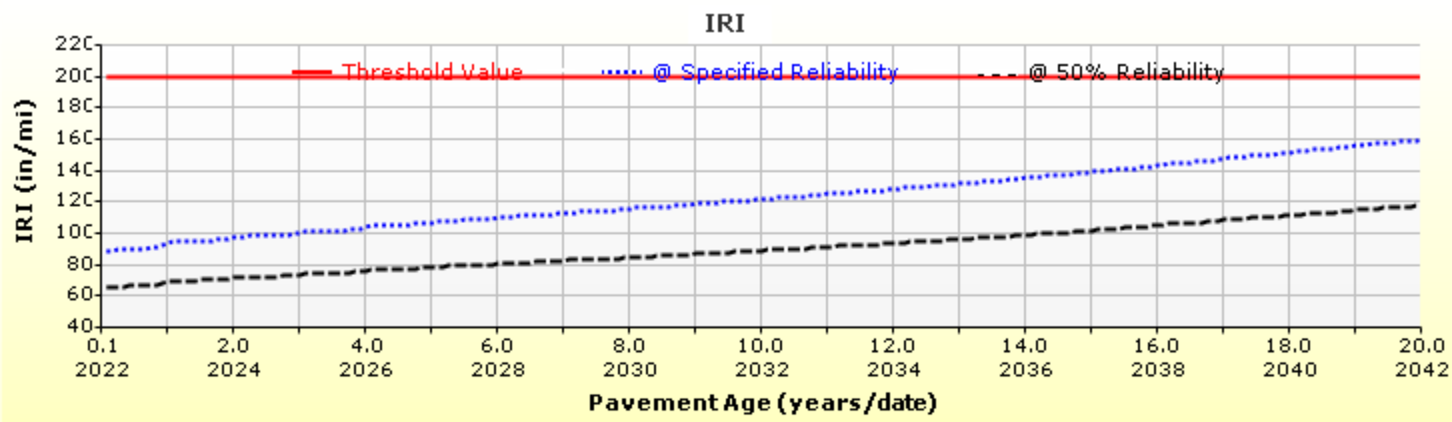
HMA Layer 2: Layer 2 Flexible : R3 Level 1 SX(75) PG 58-28 United

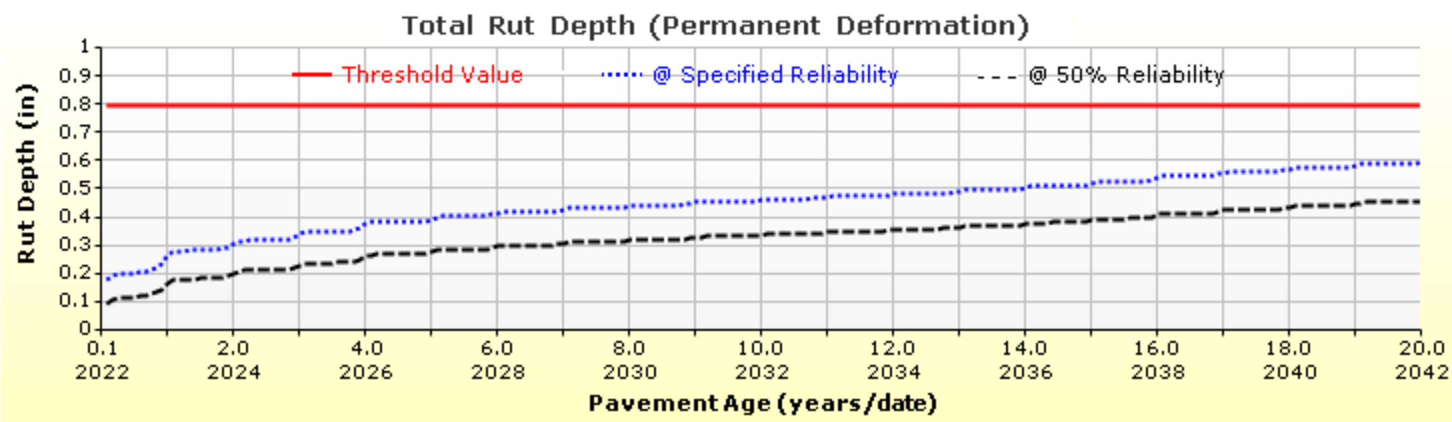


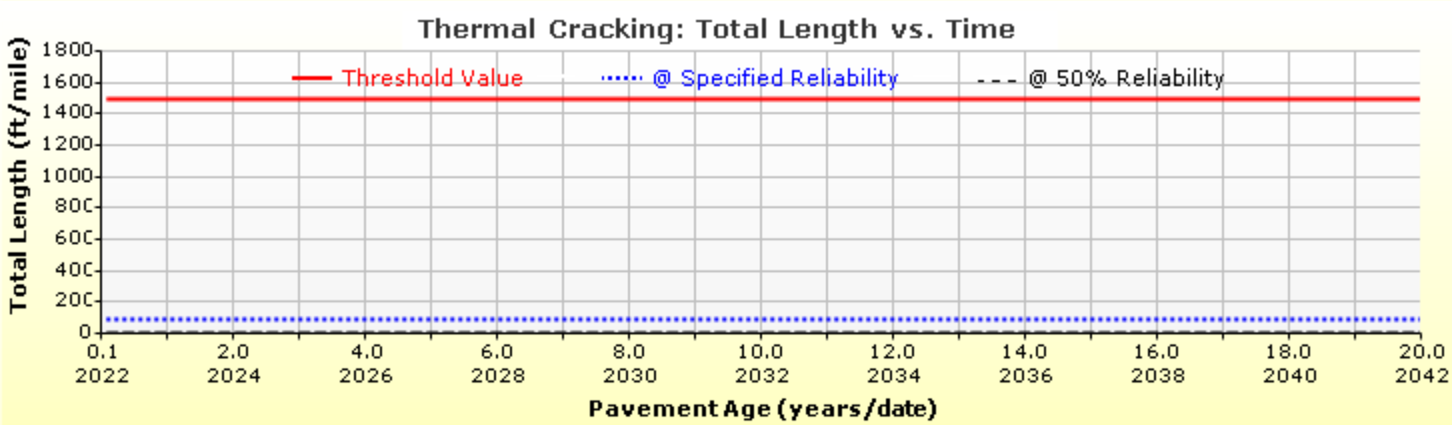


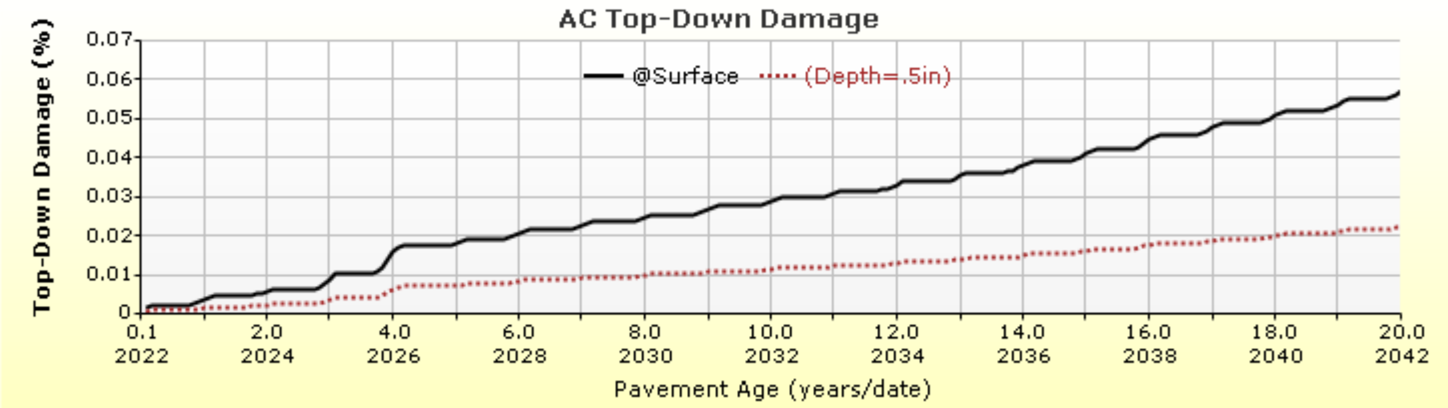


Analysis Output Charts

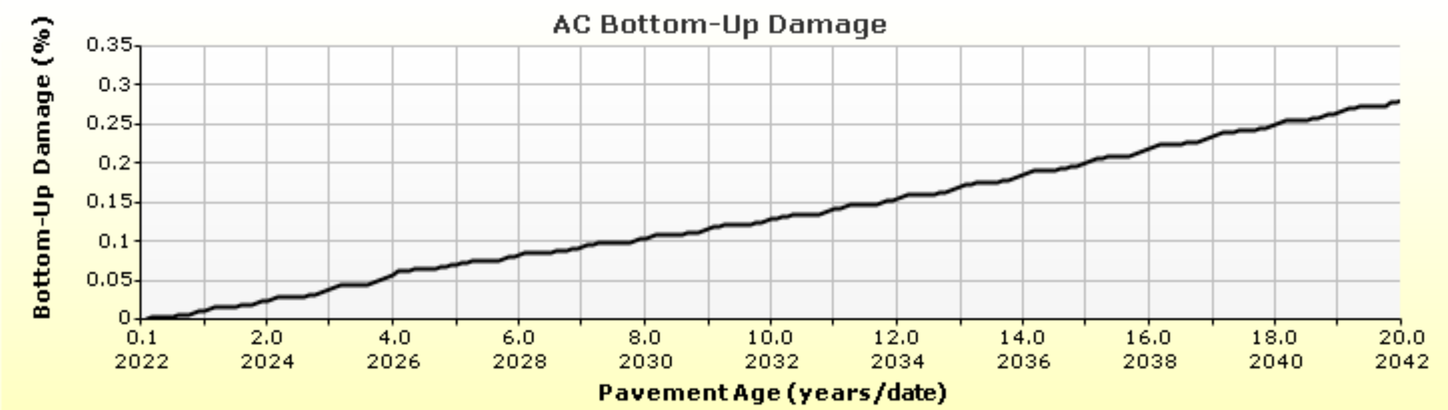




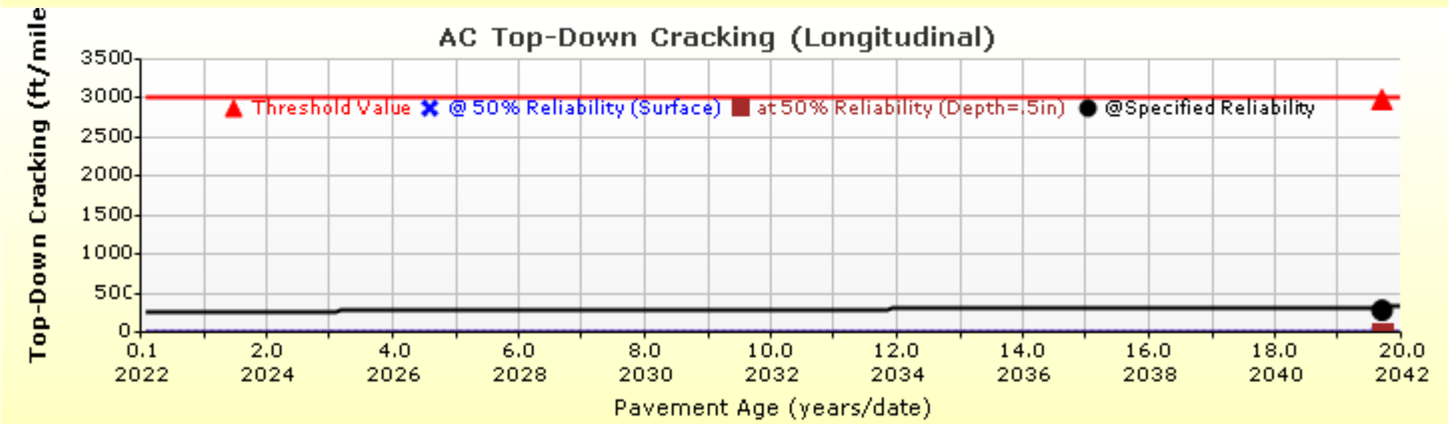




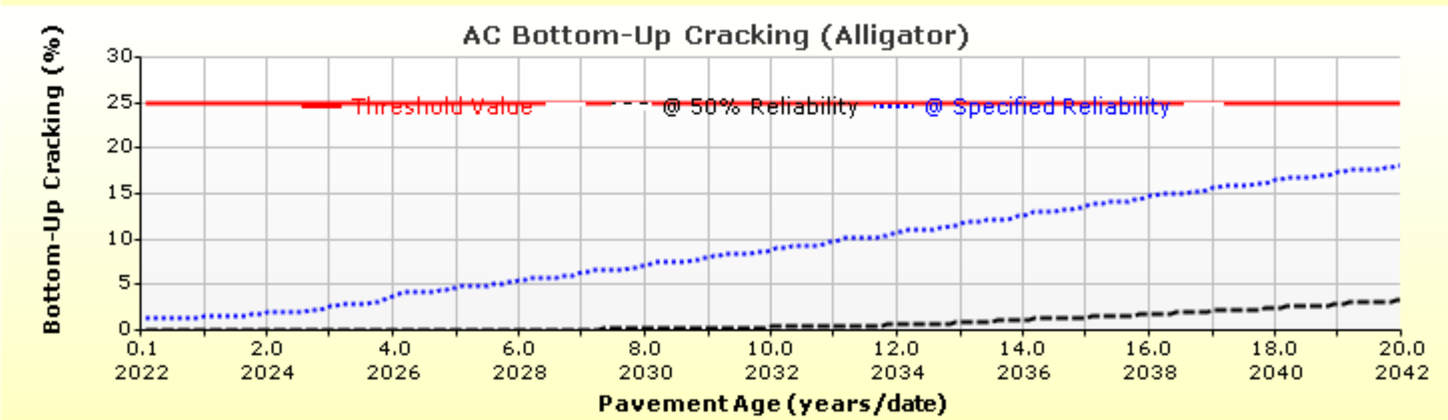
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



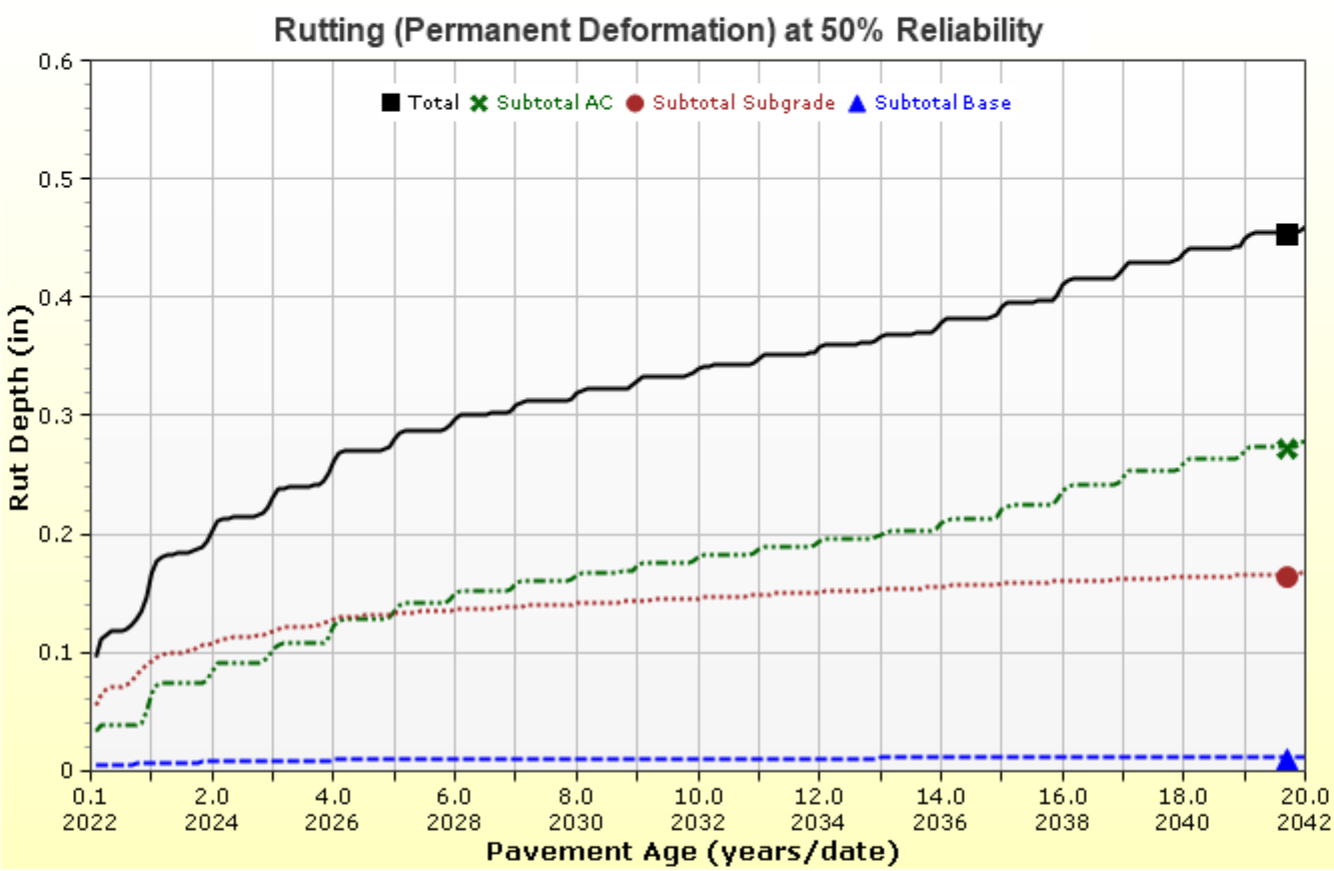
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



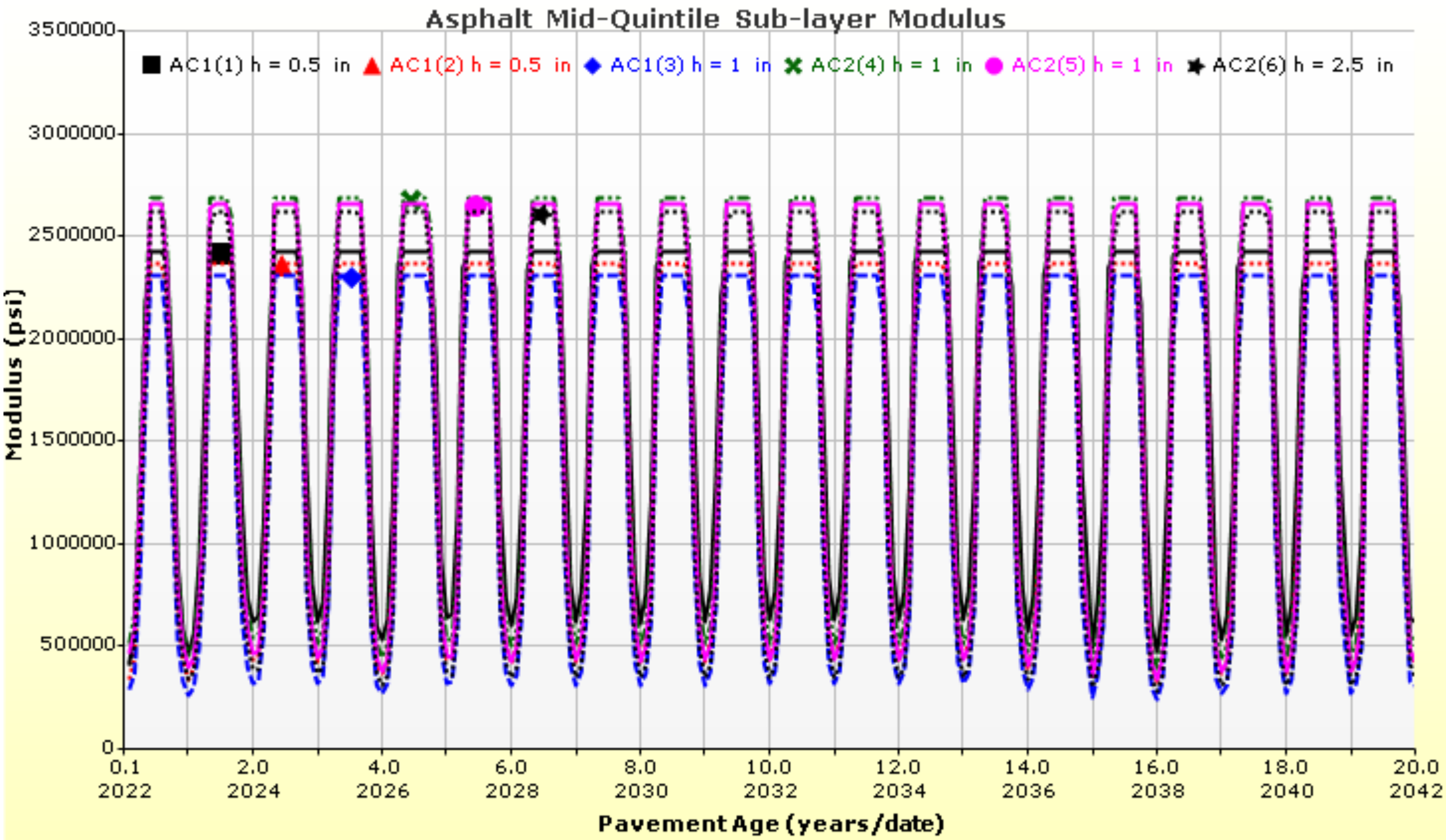
AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042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



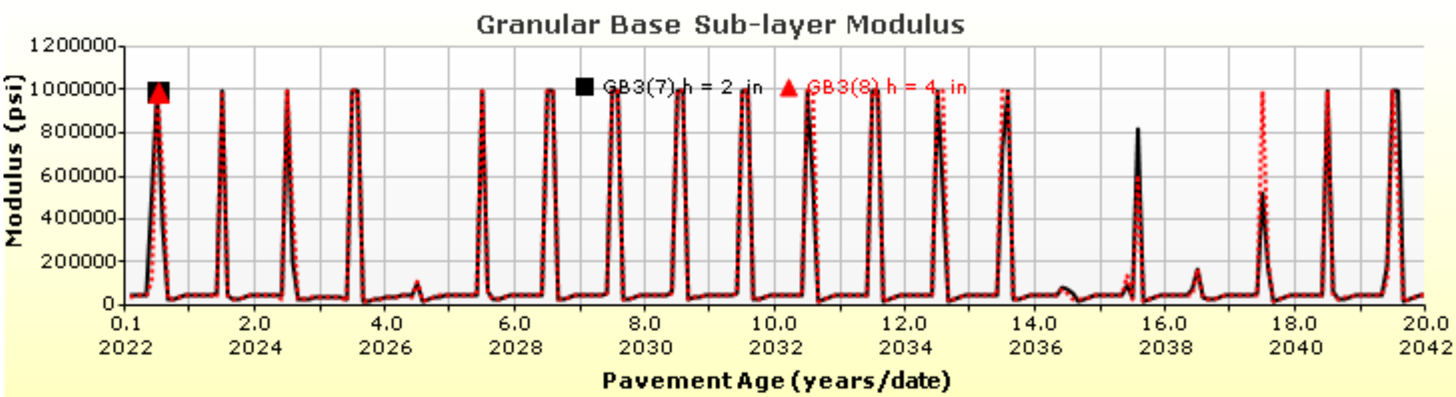
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



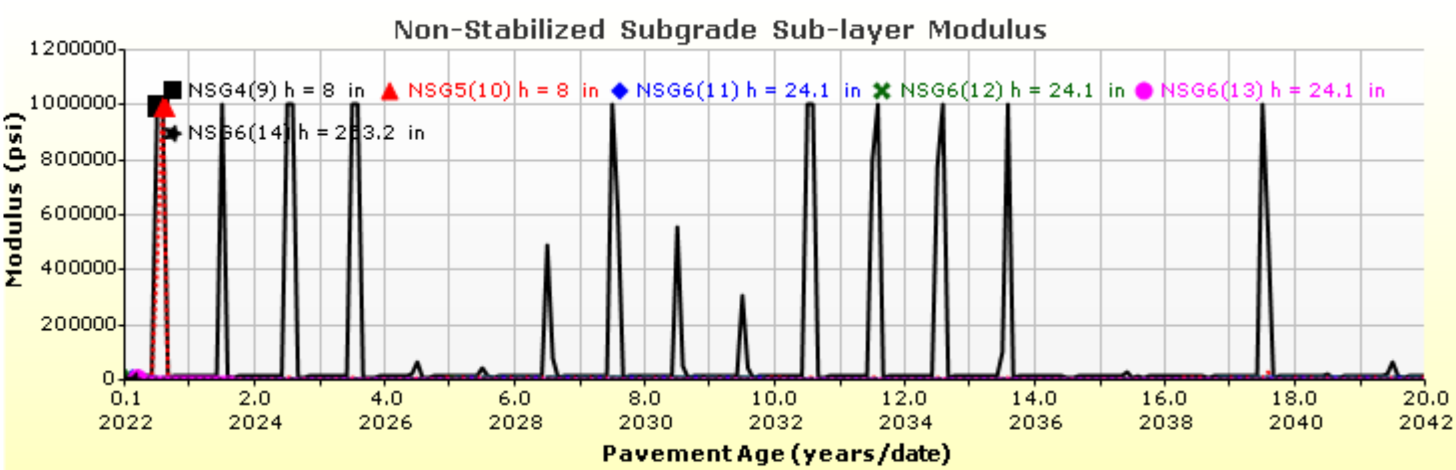
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
2.0
2024
4.0
2026
6.0
2028
8.0
2030
10.0
2032
12.0
2034
14.0
2036
16.0
2038
18.0
2040
20.0
2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 2.5 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 = 8 in
NSG5(10) h = 8 in
NSG6(11) h = 24.1 in
NSG6(12) h = 24.1 in
NSG6(13) h = 24.1 in
NSG6(14) h = 253.2 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

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	1291280	1808320	2249869	2393659
40	424726	794978	1289510	1499050
70	98659	198153	405545	529690
100	37405	59422	109288	143776
130	23504	29885	43077	51915

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
136.4	3093	80
147.2	1519	82
158	784	84

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	14.4
Air voids (%)	5.2
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R5 Level 1 SX(75) PG 58-34
Description of object	Mix ID # FS1958
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 : R3 Level 1 SX(75) PG 58-28 United

Asphalt		
Thickness (in)	4.5	
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	2067099	2488999	2785899	2873299
40	930800	1472800	2008399	2196999
70	207600	439600	838700	1039200
100	52500	101200	215300	291900
130	24100	35400	60900	78900

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
136.4	2227.6	80
147.2	1068.2	82
158	540.1	84

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.5
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(75) PG 58-28
Description of object	Mix ID # FS1918
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : A-1-a

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)
30000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
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 4 Subgrade : A-1-a

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
11000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
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)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5350.0

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

Layer 6 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)
5350.0

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

Identifiers

Field	Value
Display name/identifier	A-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566	k2: 3.9492
k3: 1.281	Bf1: 130.3674
Bf2: 1	Bf3: 1.217799

AC Rutting (using Multilayer Calibration)

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)

ε_r = resilient strain(in/in)

T = layer temperature(°F)

N = number of load repetitions

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

Thermal Fracture

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

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

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

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

k = refression coefficient determined through field calibration

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

σ = standard deviation of the log of the depth of cracks in the pavments

C = crack depth(in)

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

ΔC = Change in the crack depth due to a cooling cycle

ΔK = Change in the stress intensity factor due to a cooling cycle

A, n = Fracture parameters for the asphalt mixture

E = mixture stiffness

σ_M = Undamaged mixture tensile strength

β_t = Calibration parameter

Level 1 K: 6.3	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

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

N_f = number of repetitions to fatigue cracking

σ_s = Tensile stress(psi)

M_r = modulus of rupture(psi)

k1: 1	k2: 1	Bc1: 1	Bc2:1

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: 1	C2: 1	C3: 0	C4: 1000

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

02_US6_2in_Mill_2inOL-10yrDL

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\02_US6_2in_Mill_2inOL-10yrDL.dgpx

Design Inputs

Design Life: 10 years
Design Type: ACC_ACC

Existing construction: August, 2002
Pavement construction: August, 2022
Traffic opening: August, 2022

Climate Data Sources (Lat/Lon): 39.643, -106.918

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	R5 Level 1 SX(75) PG 58-34	2.0
Flexible (existing)	AC-20 Level 3	5.5
Subgrade	A-2-6	12.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	14.4
Air voids (%)	5.2

Traffic

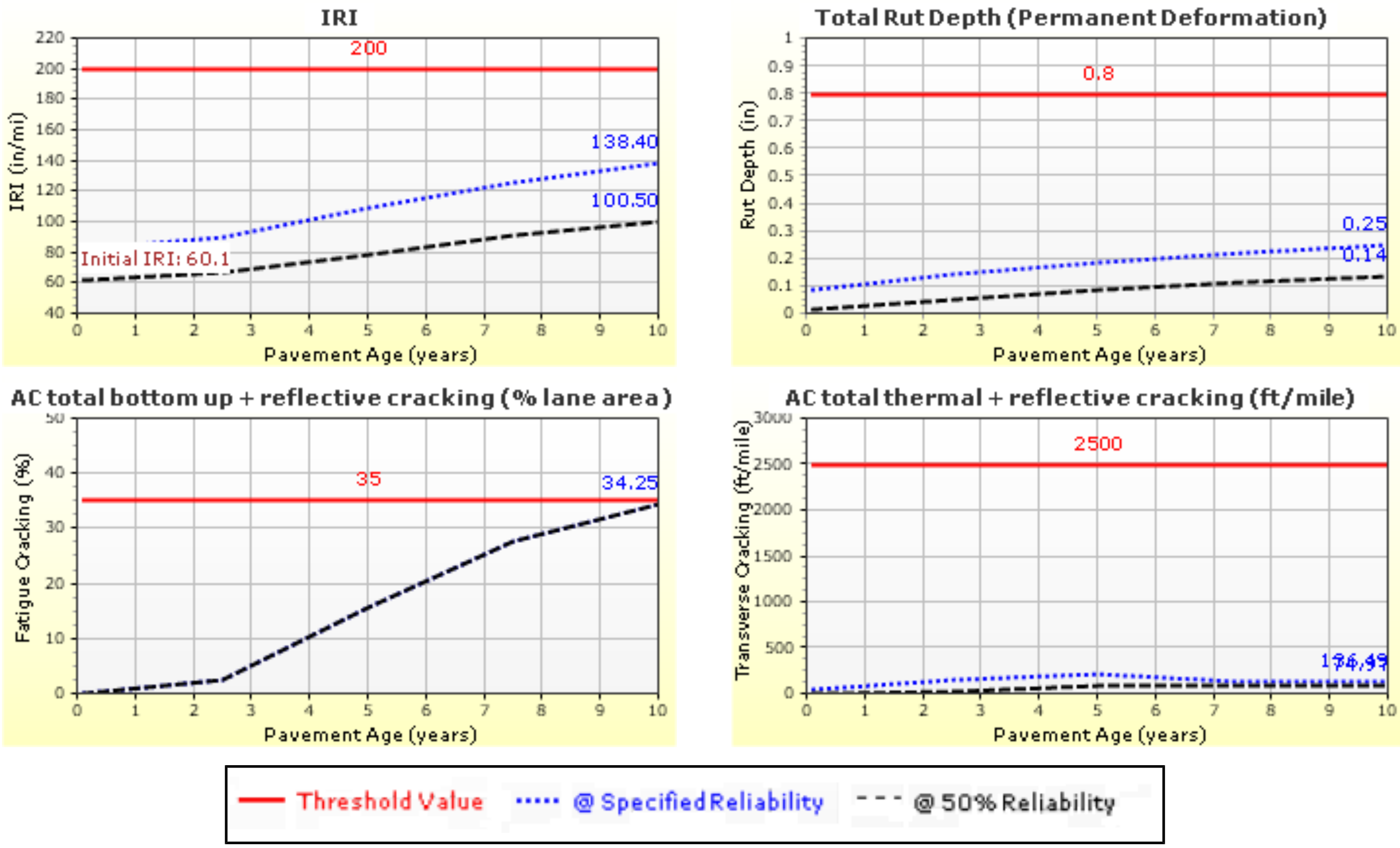
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2027 (5 years)	498,627
2032 (10 years)	1,065,540

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	138.45	90.00	99.96	Pass
Permanent deformation - total pavement (in)	0.80	0.25	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	34.25	50.00	52.20	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	136.49	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.25	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	0.01	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	578.84	90.00	100.00	Pass

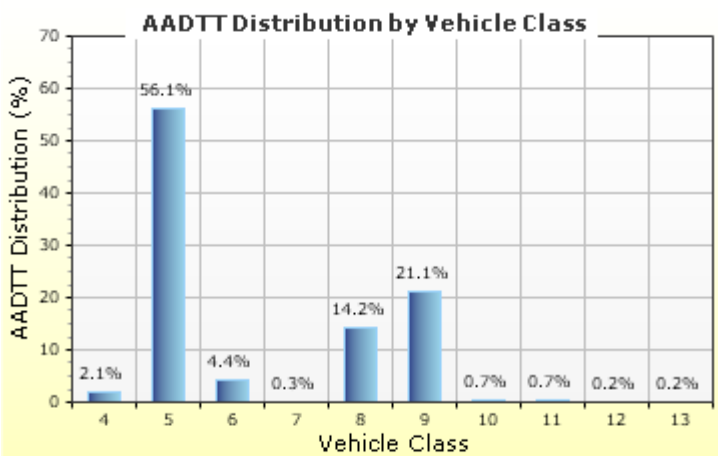
Distress Charts

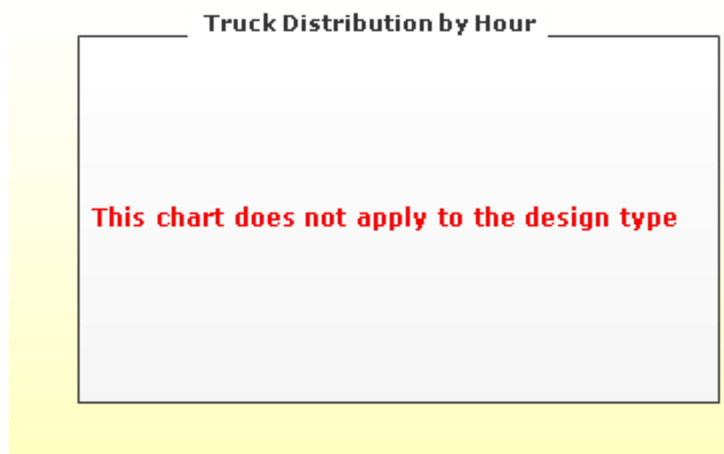


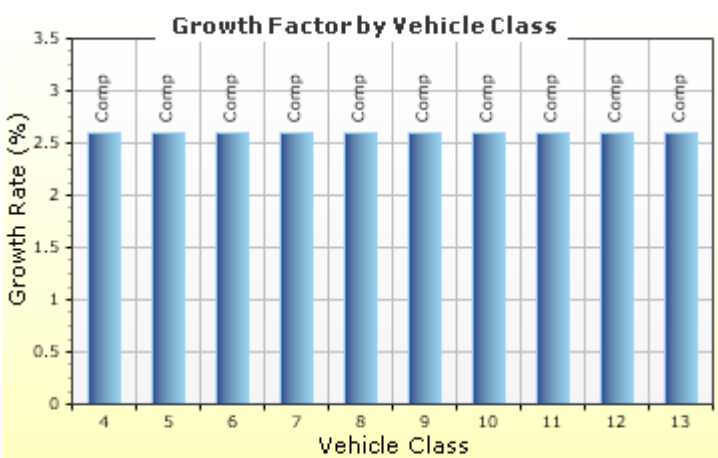
Traffic Inputs

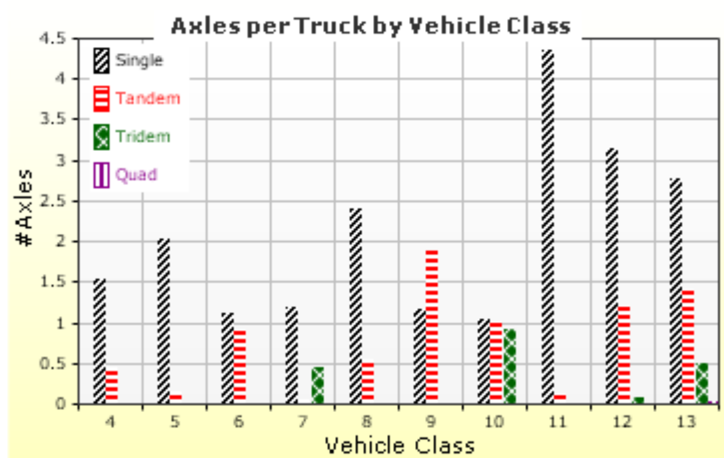
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	432	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)	15.0

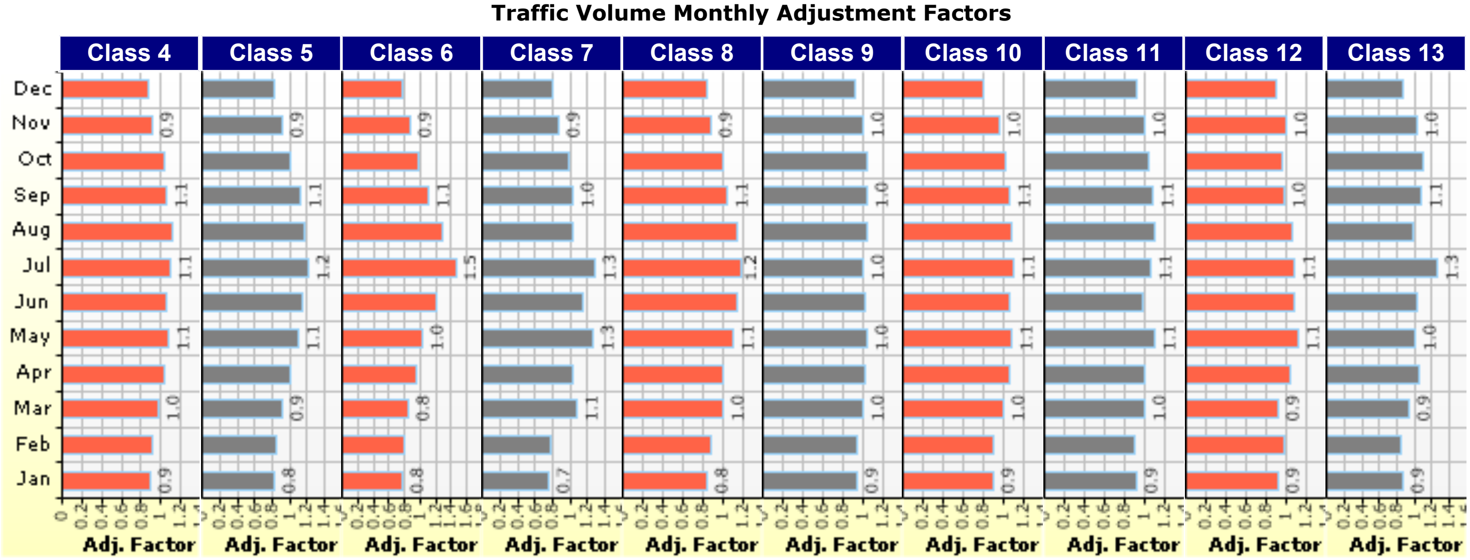








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.6%	Compound
Class 5	56.1%	2.6%	Compound
Class 6	4.4%	2.6%	Compound
Class 7	0.3%	2.6%	Compound
Class 8	14.2%	2.6%	Compound
Class 9	21.1%	2.6%	Compound
Class 10	0.7%	2.6%	Compound
Class 11	0.7%	2.6%	Compound
Class 12	0.2%	2.6%	Compound
Class 13	0.2%	2.6%	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

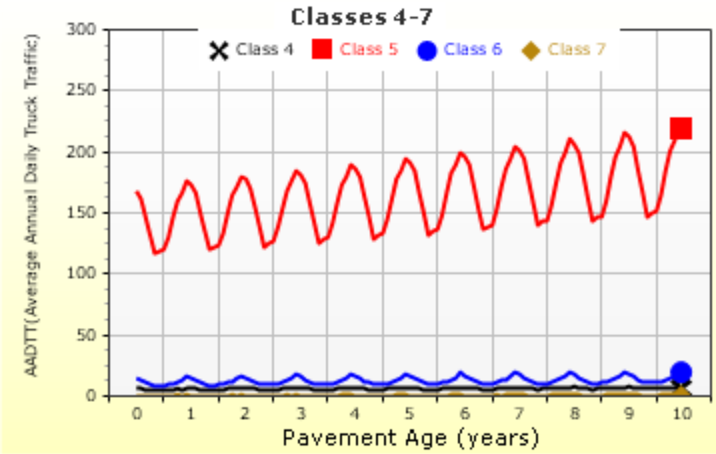
Wheelbase does not apply

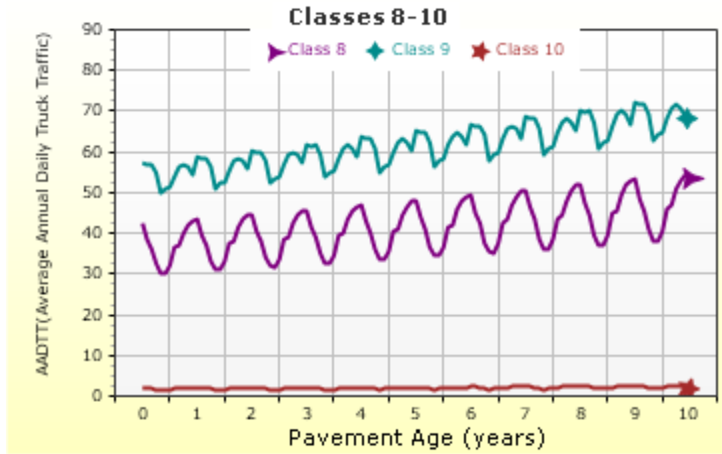
Number of Axles per Truck

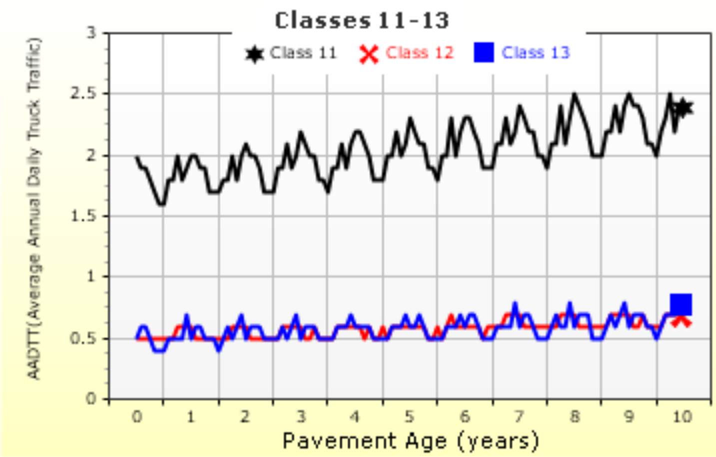
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

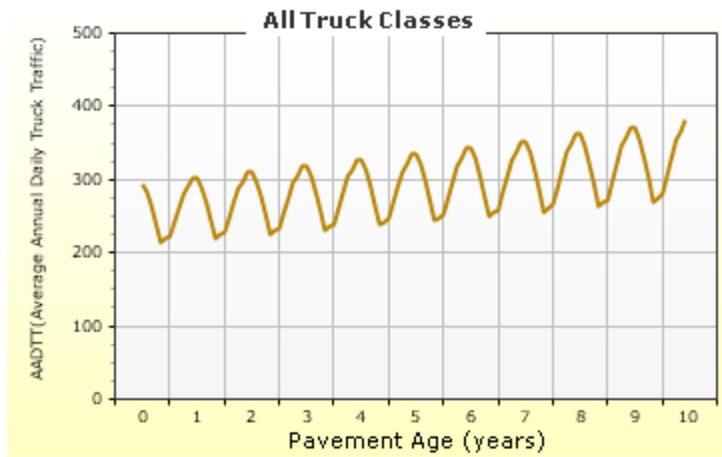
AADTT (Average Annual Daily Truck Traffic) Growth

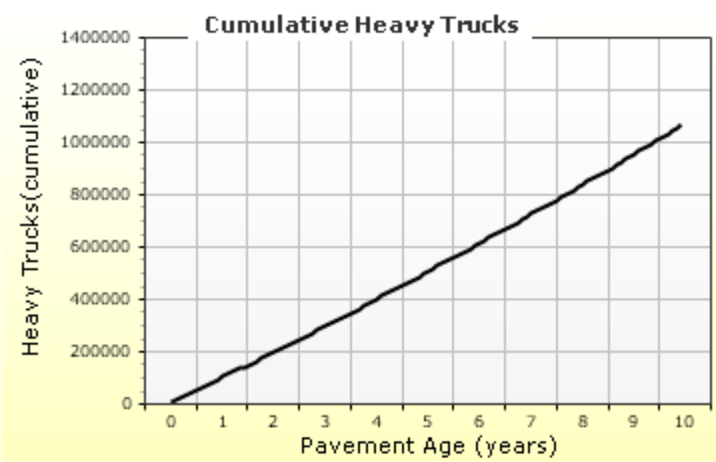
*** Traffic cap is not enforced**











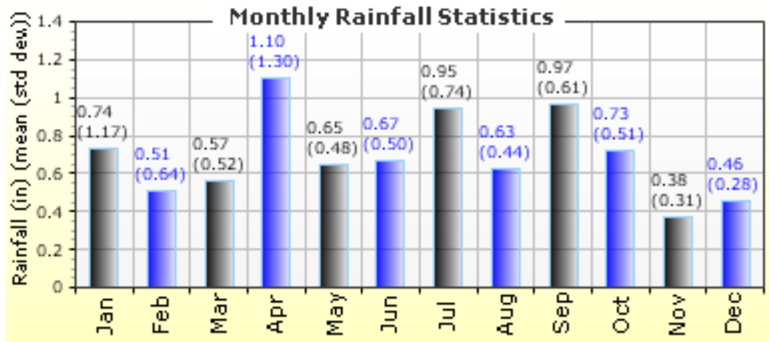
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
EAGLE CO, CO	39.64300 -106.91800 6535

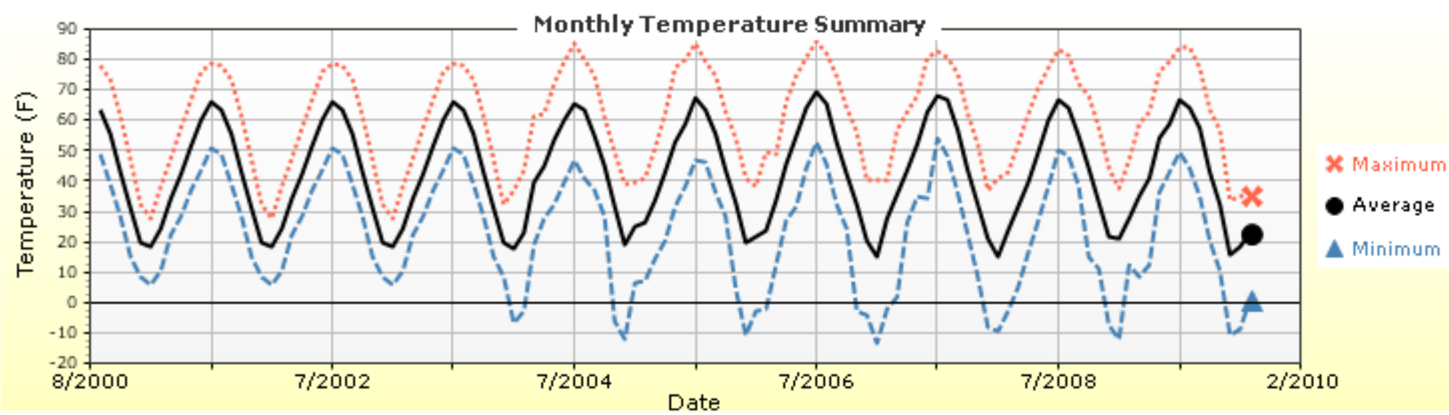
Annual Statistics:

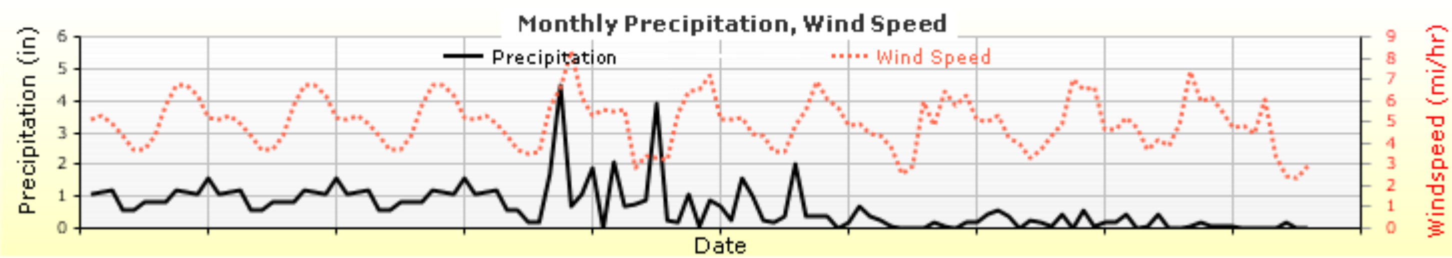
Mean annual air temperature (ºF)	43.36
Mean annual precipitation (in)	8.35
Freezing index (ºF - days)	1027.21
Average annual number of freeze/thaw cycles:	90.65

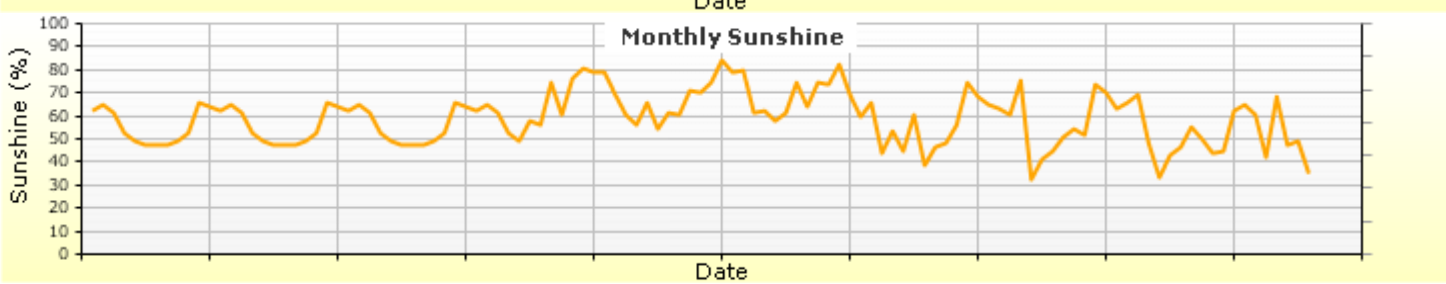


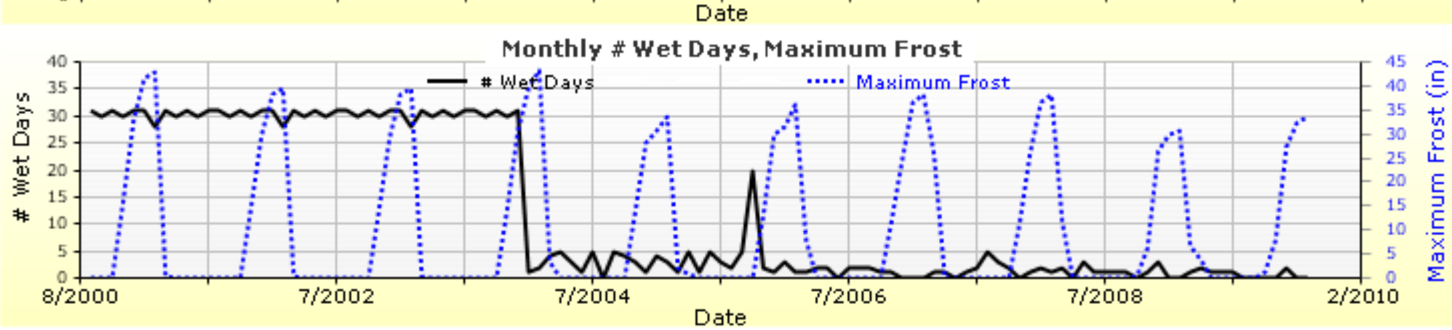
Water table depth (ft)	10.00

Monthly Climate Summary:

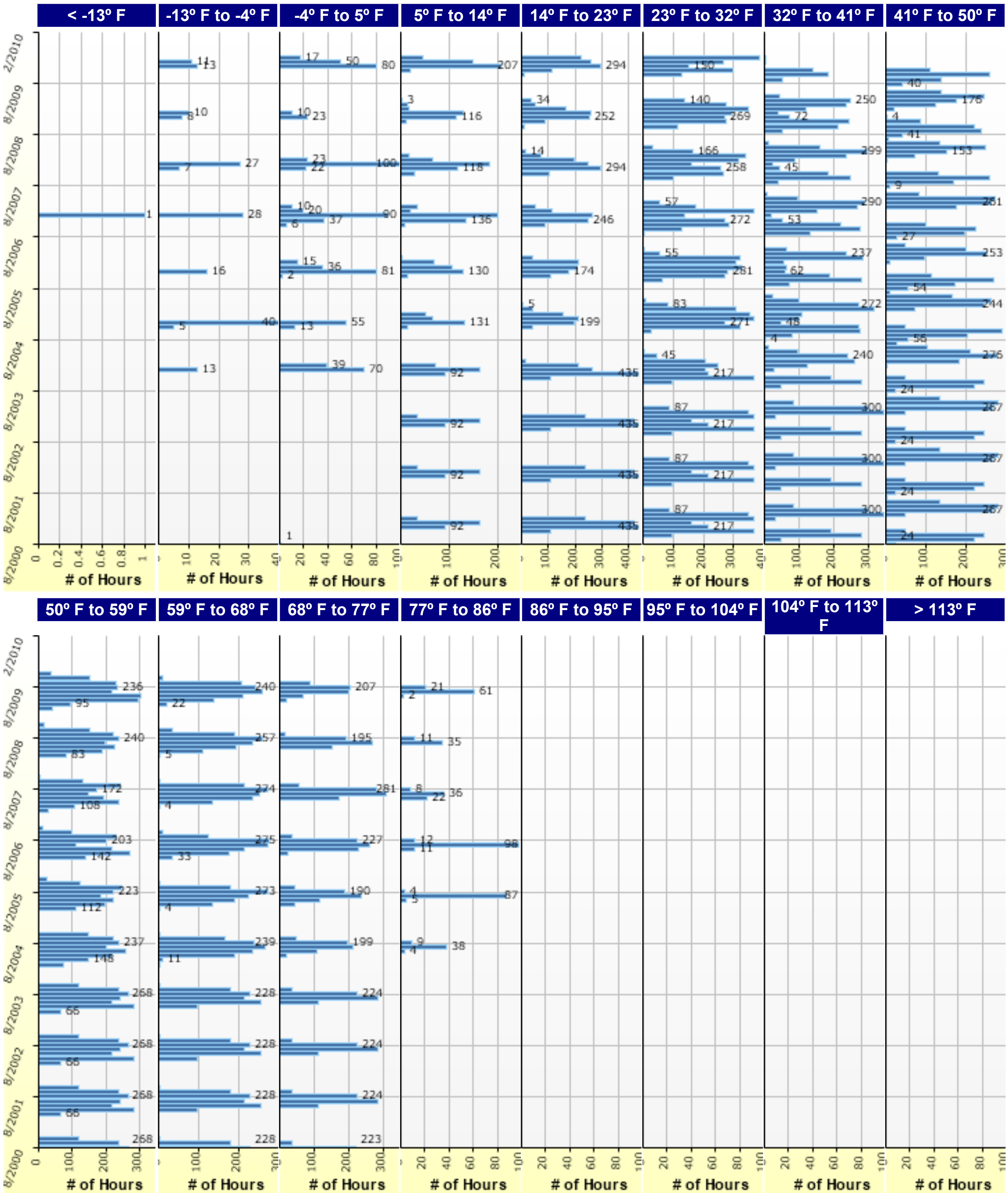








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
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 : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Flexible : AC-20 Level 3 (existing)	Flexible (1)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 4 Subgrade : A-6	Subgrade (5)	-

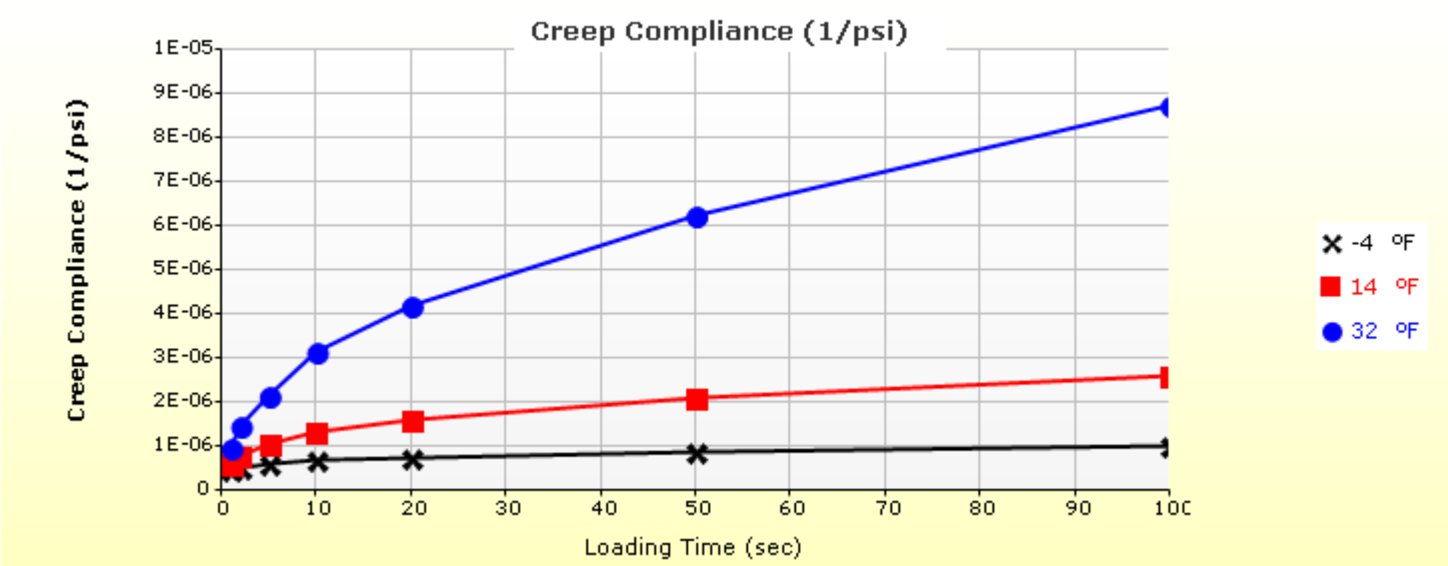
HMA Rehabilitation (Input Level: 3)

Milled thickness (in)	2.00
Structural rating	Good
Environmental rating	Good
Total rut depth (in)	0.25

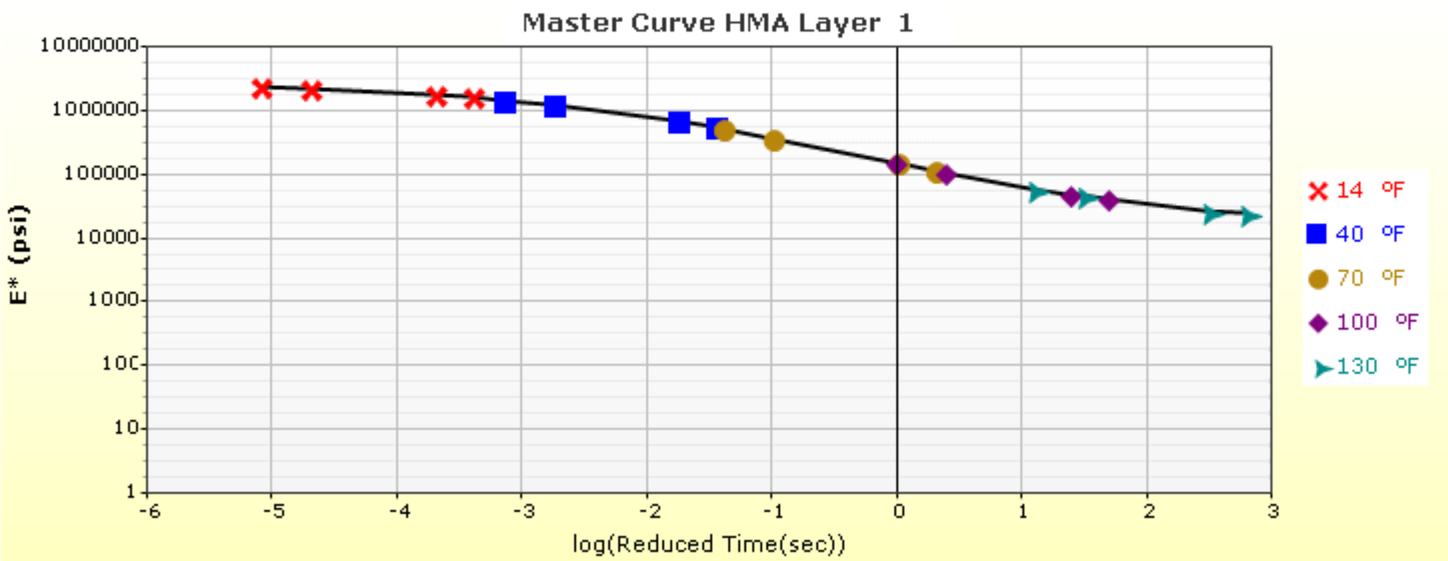
Thermal Cracking (Input Level: 1)

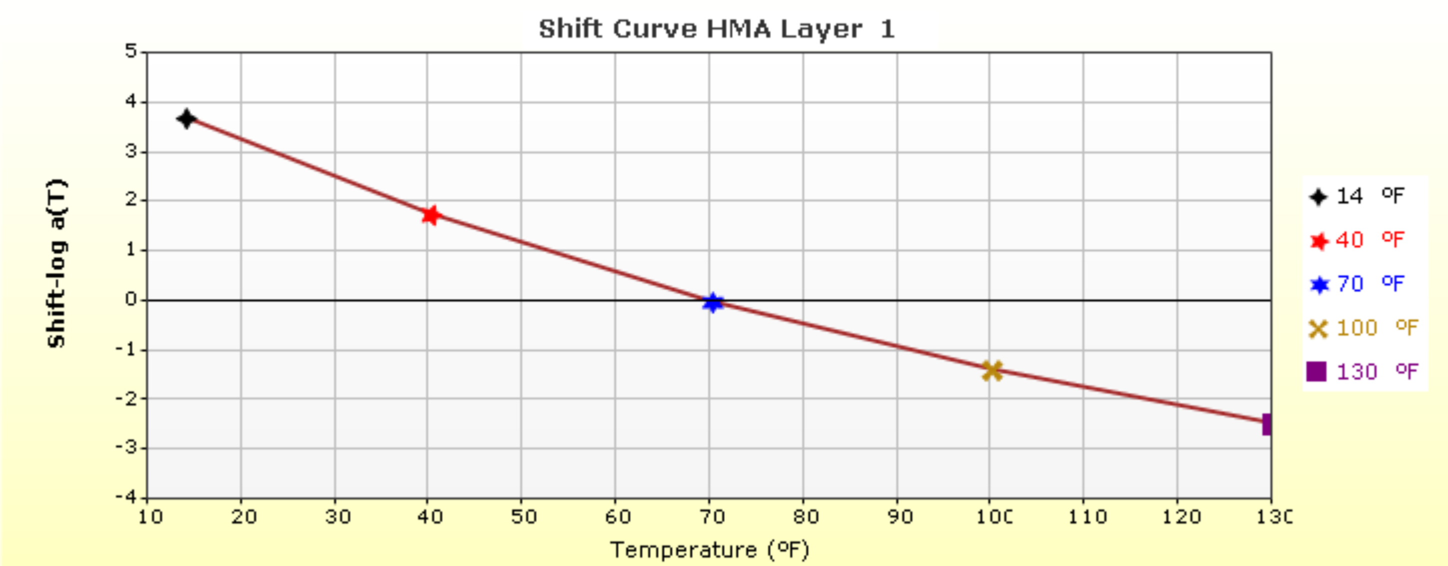
Indirect tensile strength at 14 ºF (psi)	446.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

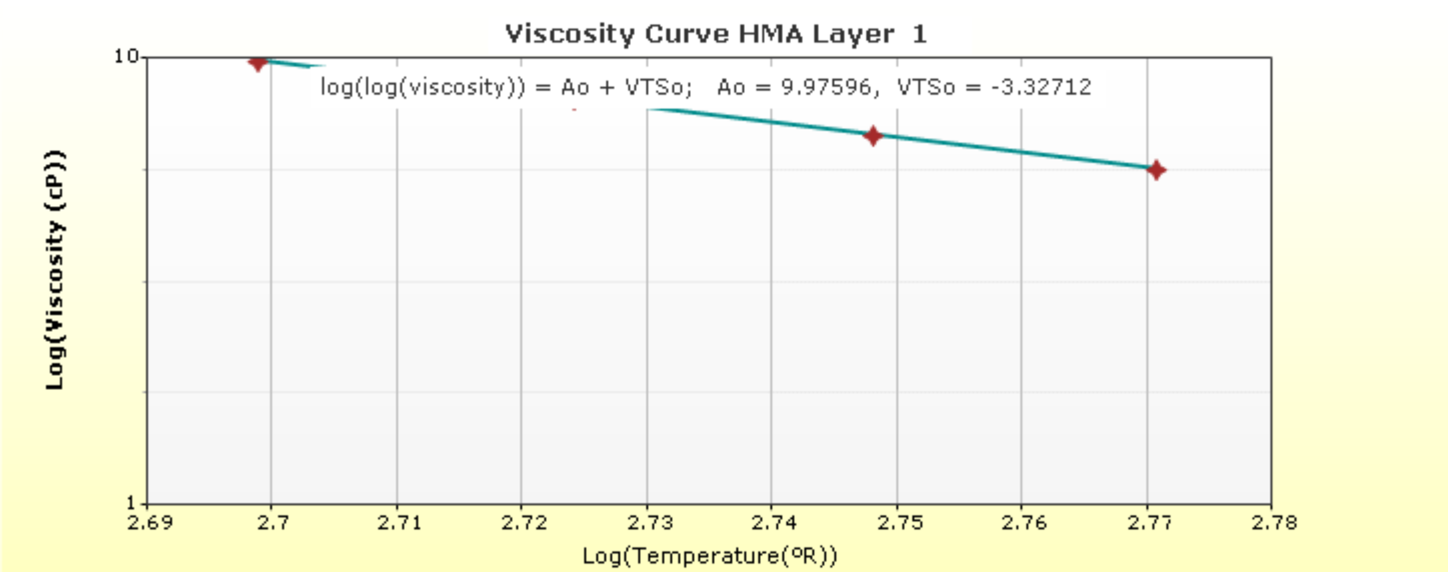
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



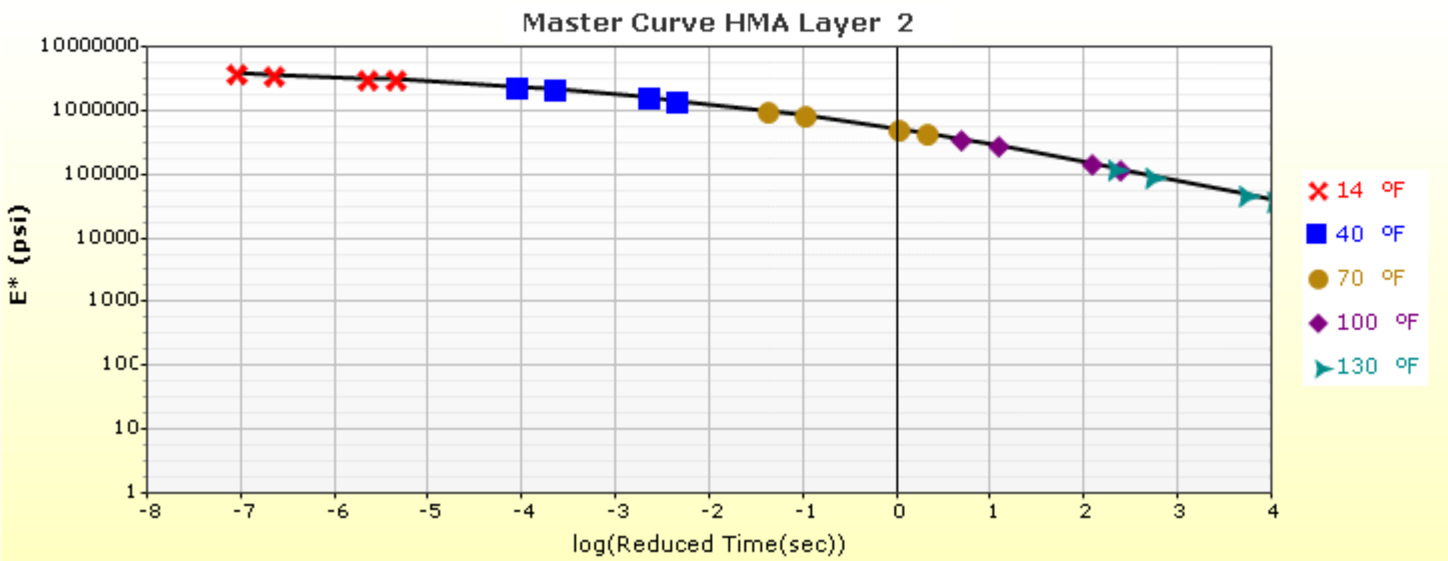
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

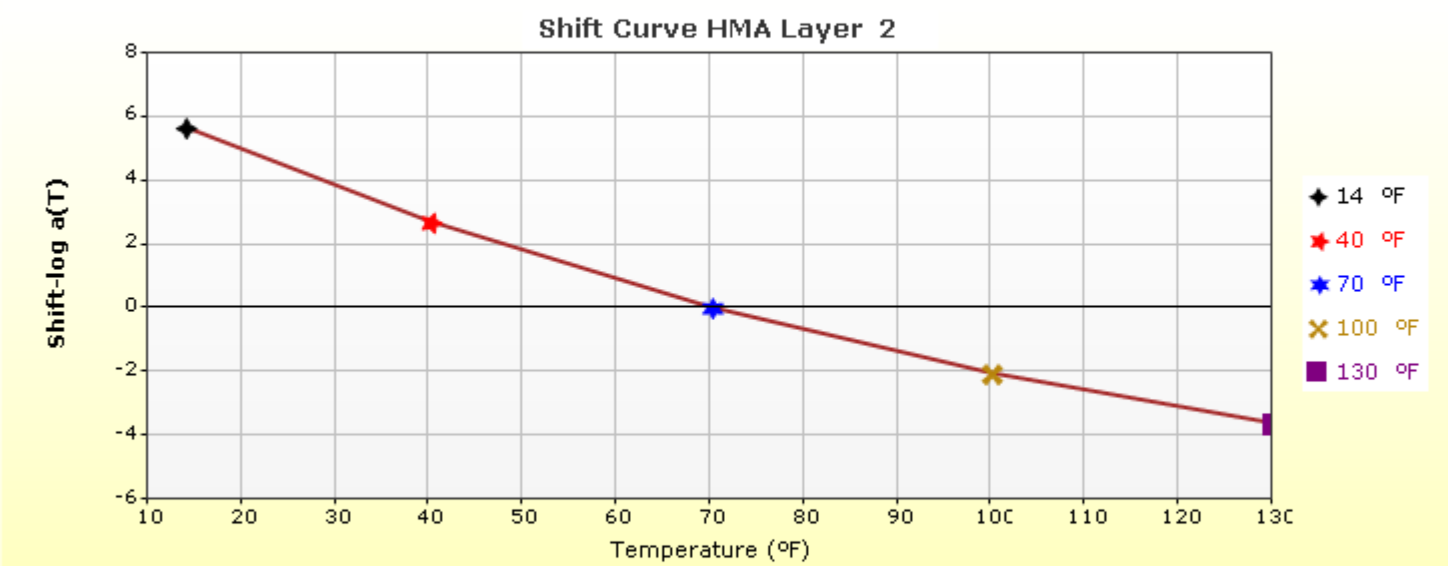


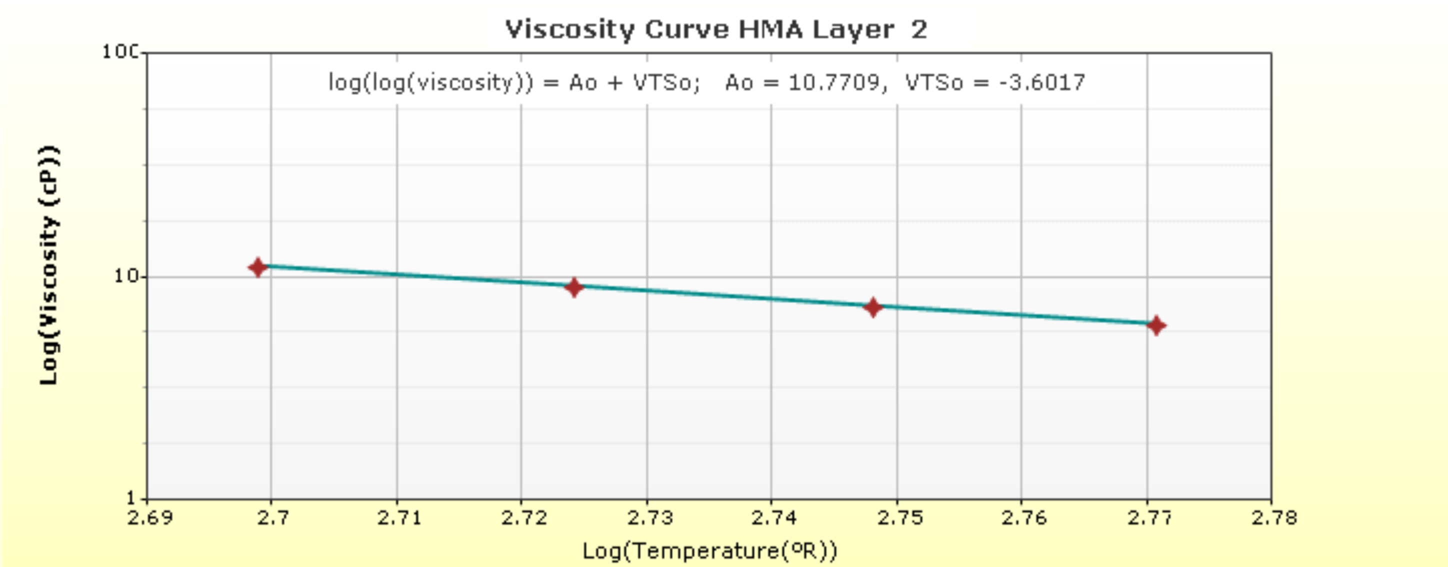




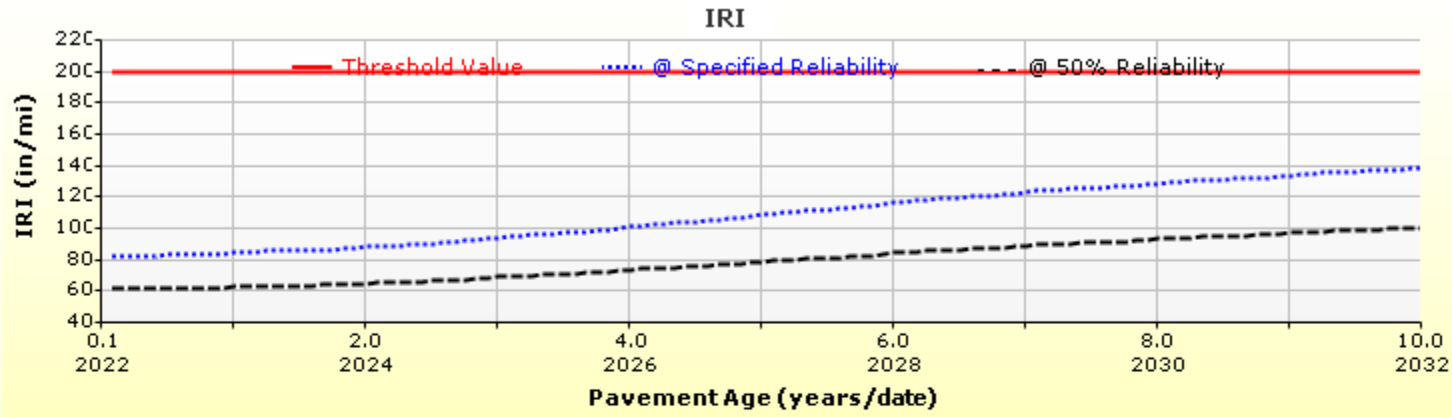
HMA Layer 2: Layer 2 Flexible : AC-20 Level 3(existing)

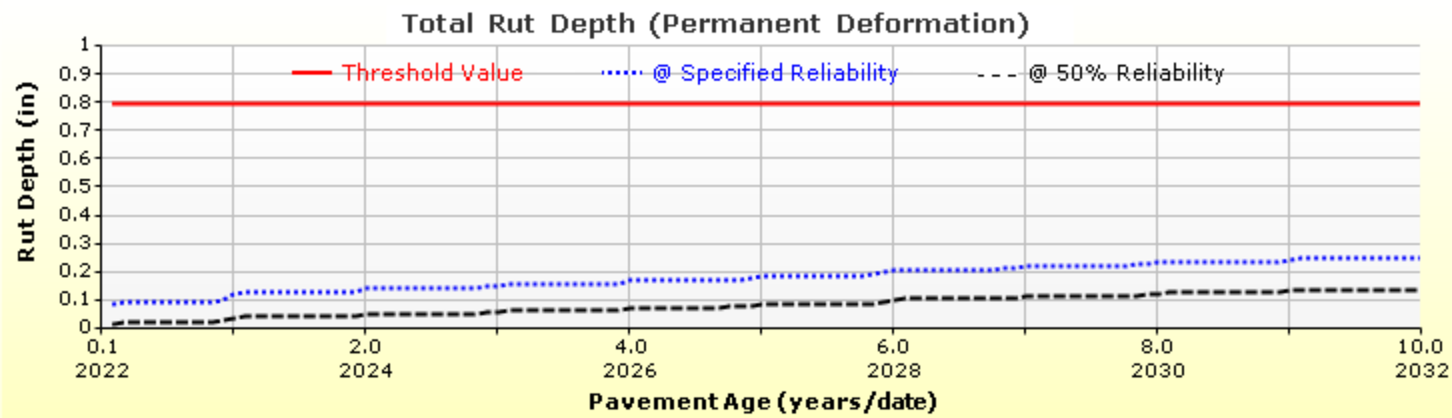


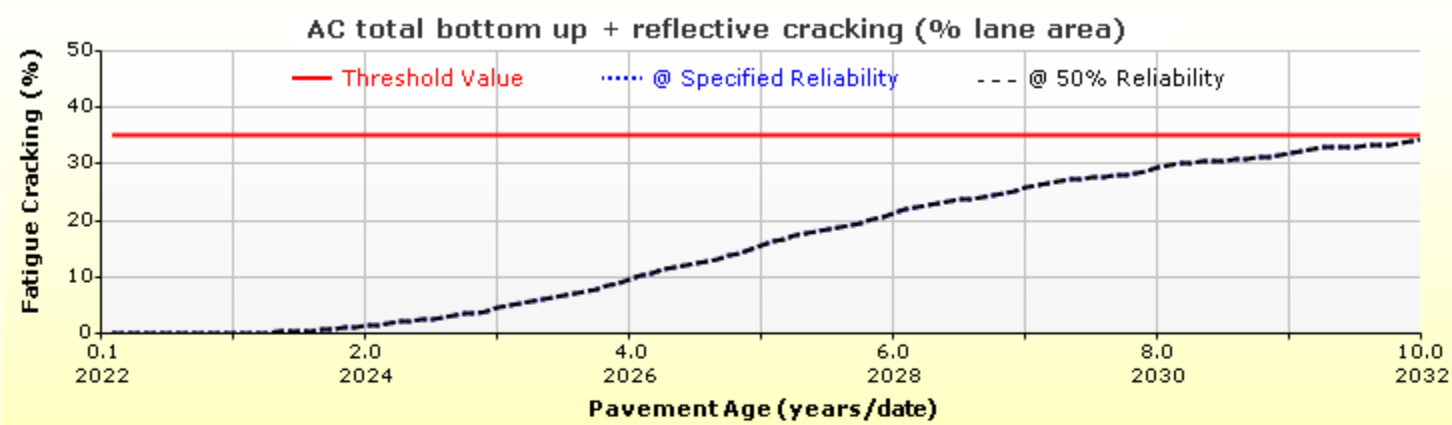


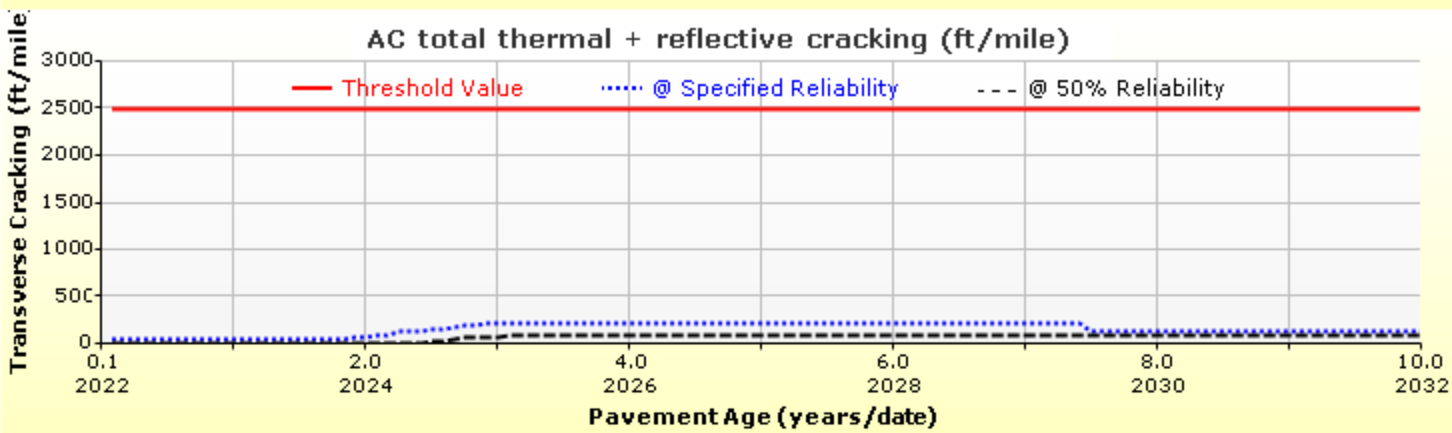


Analysis Output Charts



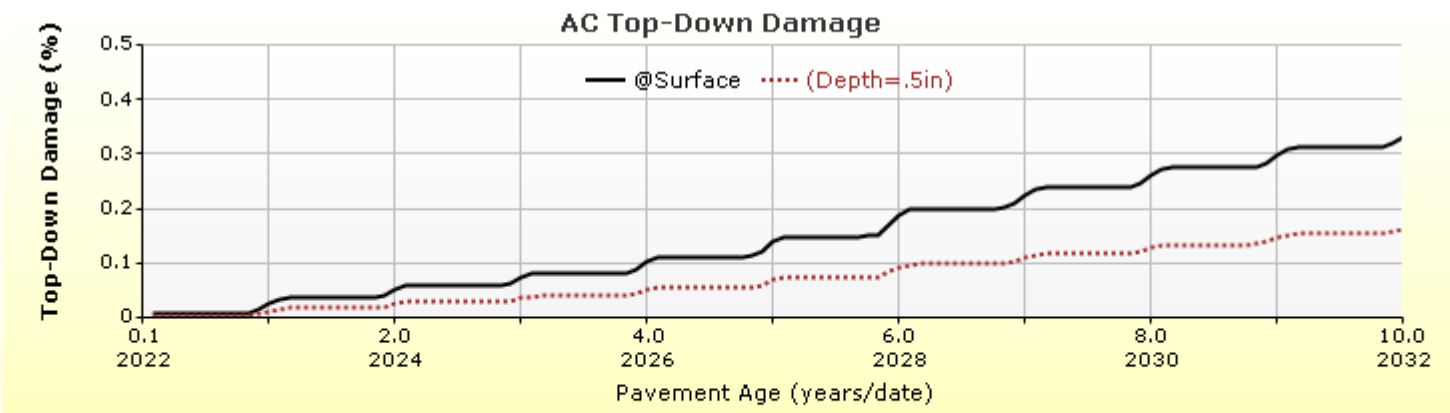


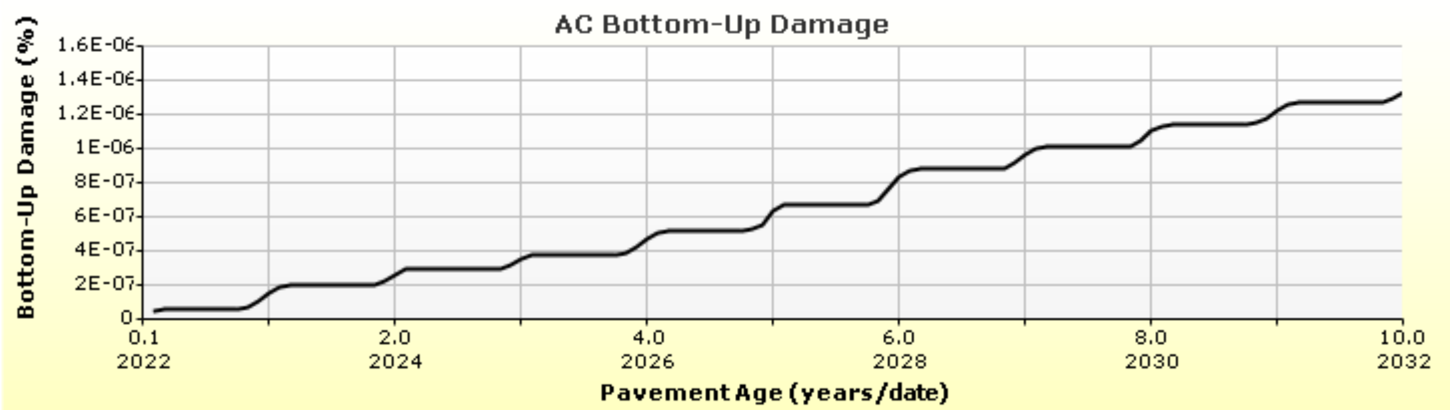


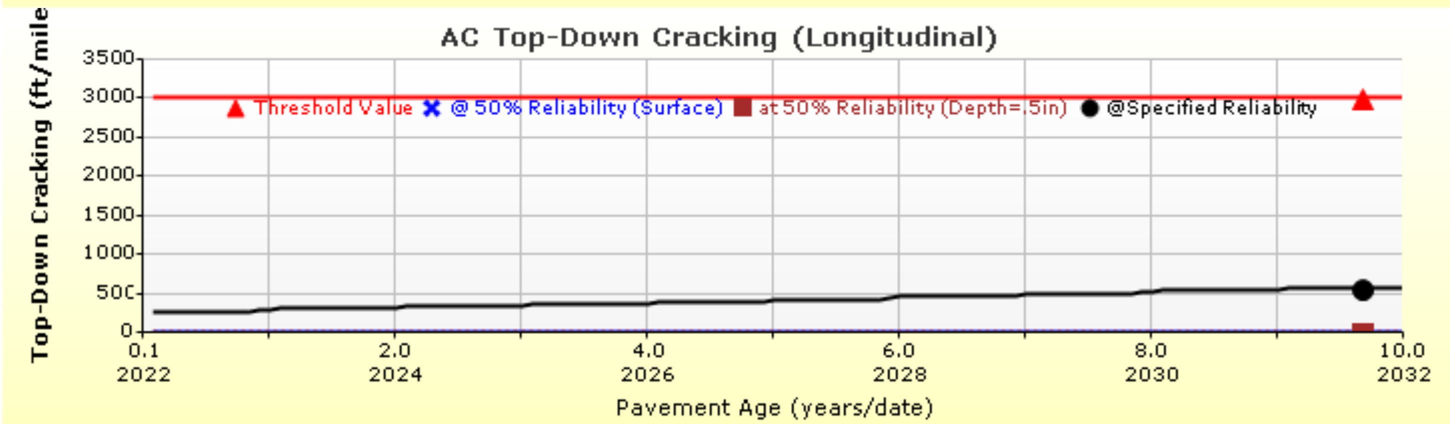


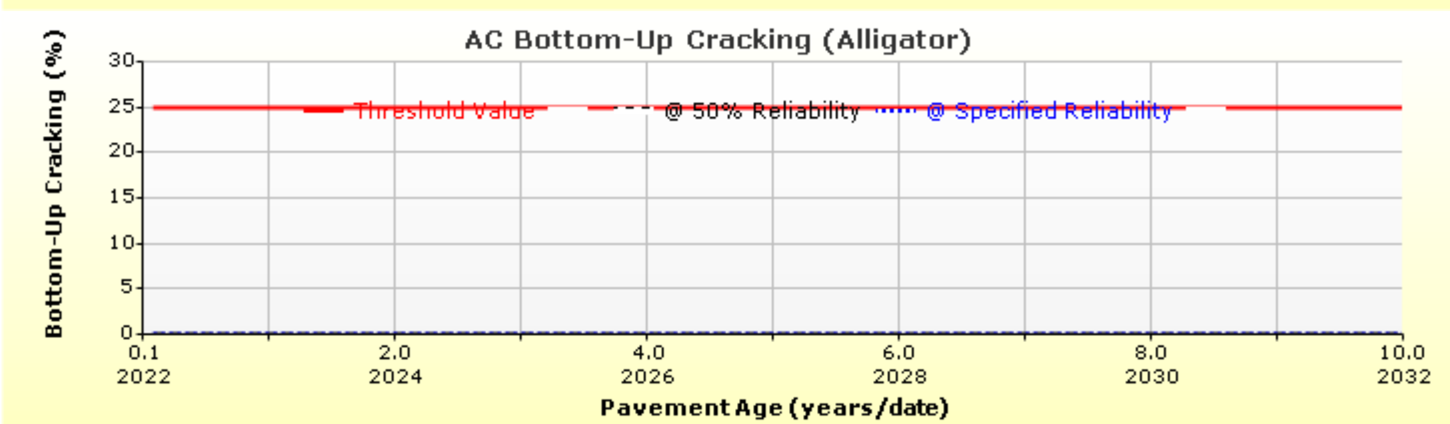
02_US6_2in_Mill_2inOL-10yrDL

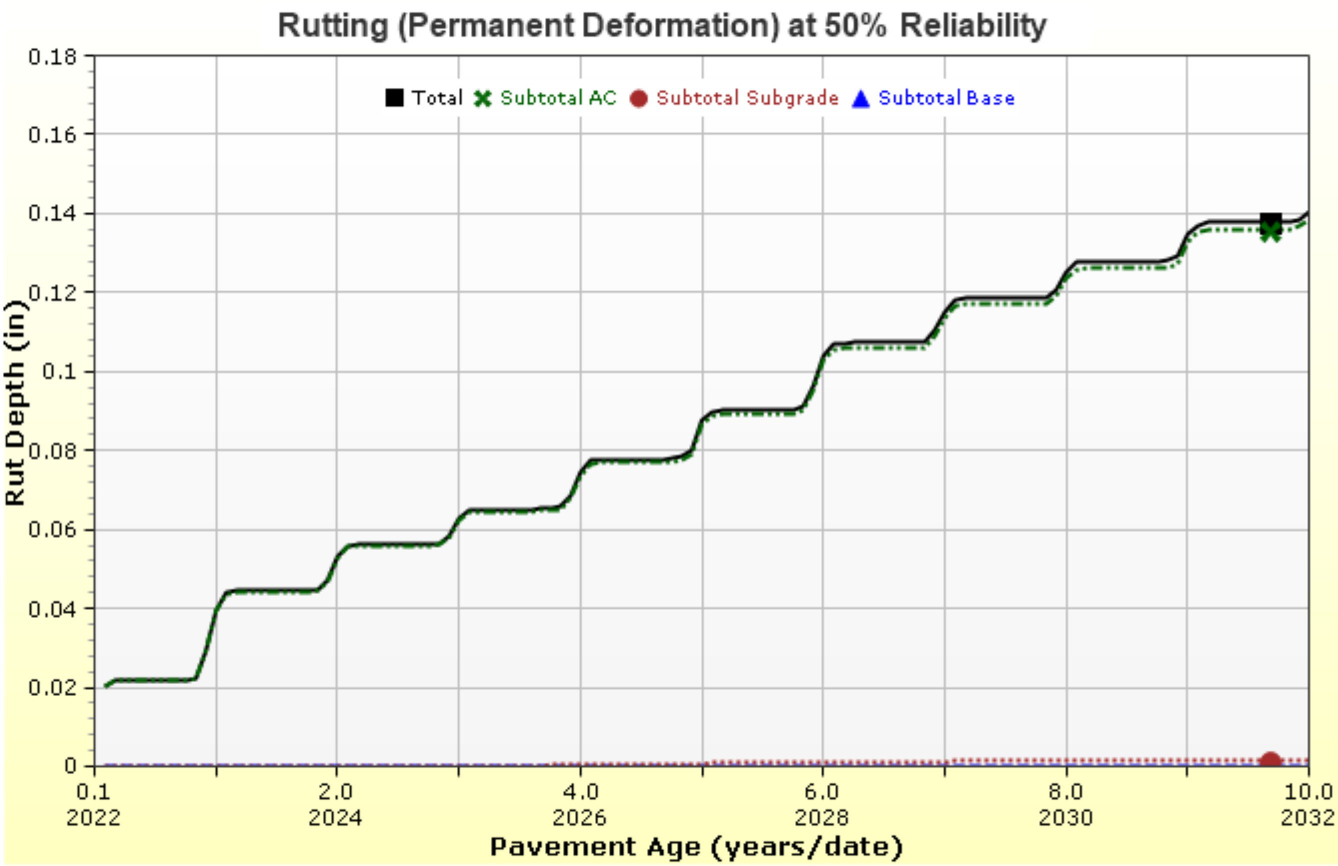
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\02_US6_2in_Mill_2inOL-10yrDL.dgpx



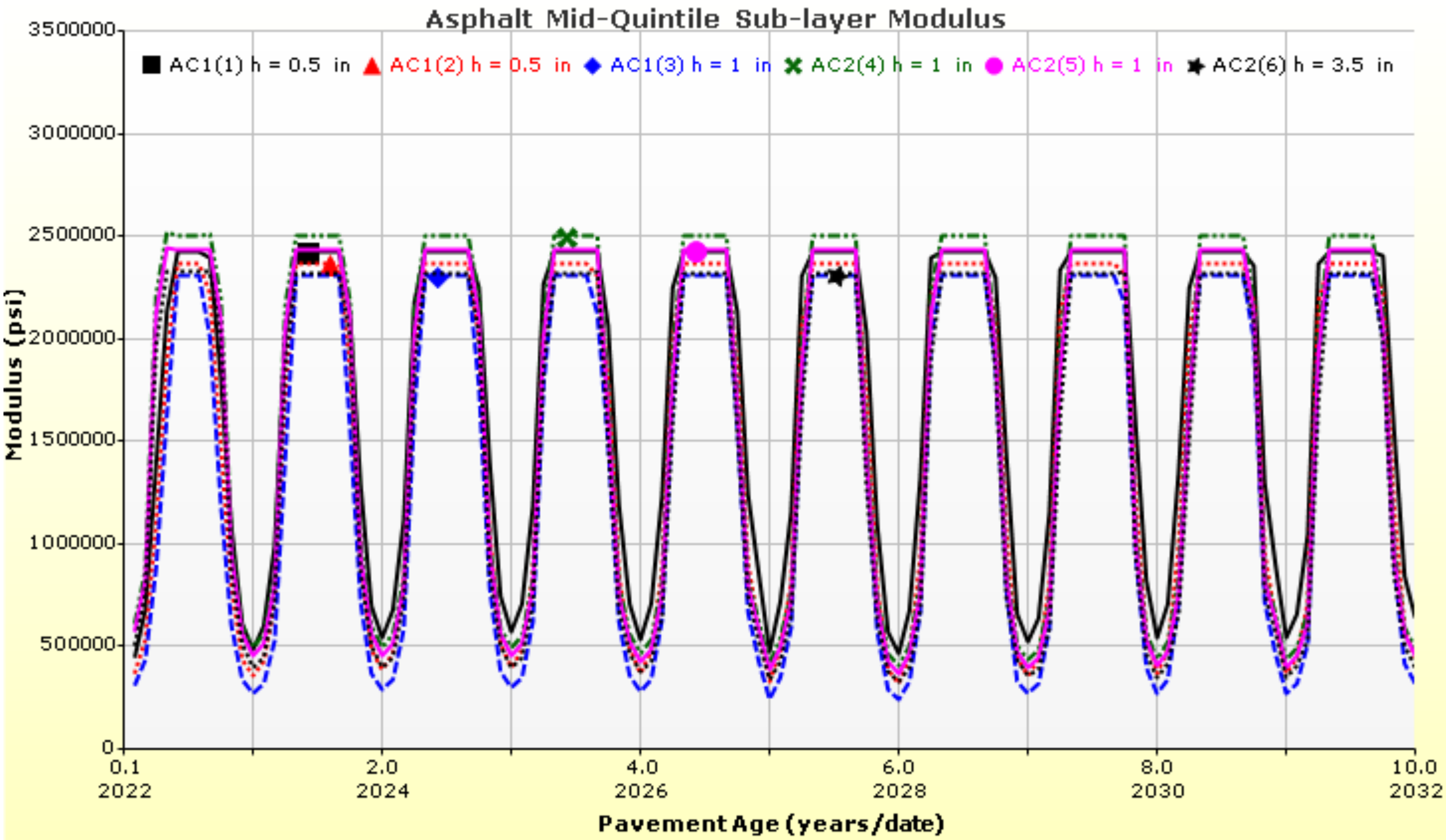




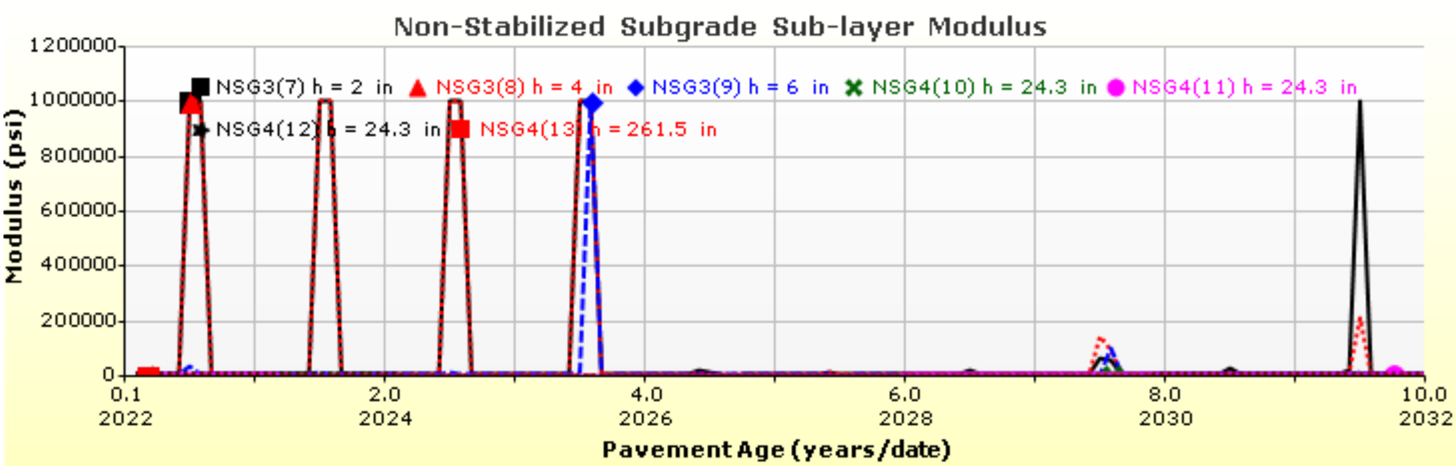




Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1
2022
2.0
2024
4.0
2026
6.0
2028
8.0
2030
10.0
2032
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 3.5 in
Modulus (psi)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG3(7) h = 2 in
NSG3(8) h = 4 in
NSG3(9) h = 6 in
NSG4(10) h = 24.3 in
NSG4(11) h = 24.3 in
NSG4(12) h = 24.3 in
NSG4(13) h = 261.5 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

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	1291280	1808320	2249869	2393659
40	424726	794978	1289510	1499050
70	98659	198153	405545	529690
100	37405	59422	109288	143776
130	23504	29885	43077	51915

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
136.4	3093	80
147.2	1519	82
158	784	84

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	14.4
Air voids (%)	5.2
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	R5 Level 1 SX(75) PG 58-34
Description of object	Mix ID # FS1958
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 : AC-20 Level 3(existing)

Asphalt		
Thickness (in)	5.5	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
3/4-inch sieve	100
3/8-inch sieve	83
No.4 sieve	53
No.200 sieve	6.5

Asphalt Binder

Parameter	Value
Grade	Viscosity Grade
Binder Type	AC 20
A	10.7709
VTS	-3.6017

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.5
Thermal conductivity (BTU/hr-ft-ºF)	0.67
Heat capacity (BTU/lb-ºF)	0.23

Identifiers

Field	Value
Display name/identifier	AC-20 Level 3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 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

Layer 3 Subgrade : A-2-6

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)
8770.0

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

Identifiers

Field	Value
Display name/identifier	A-2-6
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	32.0
Plasticity Index	15.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	122.5
Saturated hydraulic conductivity (ft/hr)	False	7.363e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	10

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	75.5741
bf	0.9351
cf	0.4315
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	24.8
#100	
#80	32.4
#60	
#50	
#40	43.5
#30	
#20	
#16	
#10	59.4
#8	
#4	67.2
3/8-in.	78.8
1/2-in.	83.3
3/4-in.	90.4
1-in.	94.5
1 1/2-in.	97.7
2-in.	99.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

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)
5350.0

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

Identifiers

Field	Value
Display name/identifier	A-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 130.3674	
Bf2: 1	
Bf3: 1.21779	

AC Rutting (using Multilayer Calibration)

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

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

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

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

Where:

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

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

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

$T = layer\ temperature(°F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.1414 * 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 2 K: 0.5	
Level 3 K: 6.3	

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

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Top Standard Deviation	AC Cracking Bottom Standard Deviation
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))	1.15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))

CSM Cracking

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

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

CSM Standard Deviation

CTB*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

03_US6_8inPCC_6inABC_30yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\03_US6_8inPCC_6inABC_30yr.dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

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

Climate Data Sources (Lat/Lon): 39.643, -106.918

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R3 Level 1 Grand Jct Ready Mix	7.8
NonStabilized	A-1-a	6.0
Subgrade	A-6	8.0
Subgrade	A-6	Semi-infinite

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

Traffic

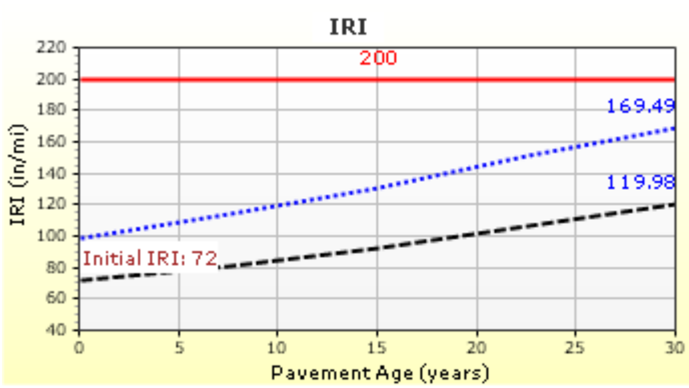
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2037 (15 years)	1,710,080
2052 (30 years)	4,223,270

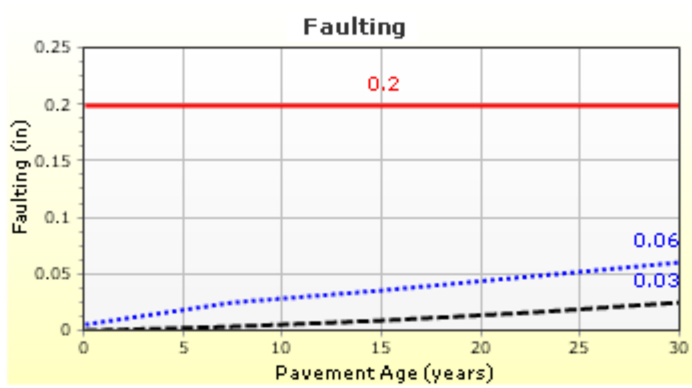
Design Outputs

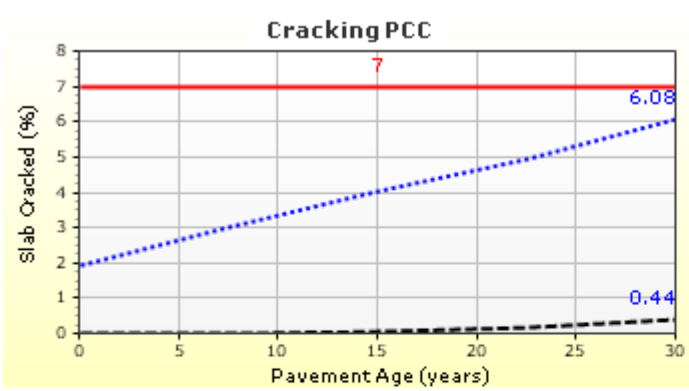
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	169.49	90.00	98.08	Pass
Mean joint faulting (in)	0.20	0.06	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	6.08	90.00	93.21	Pass

Distress Charts



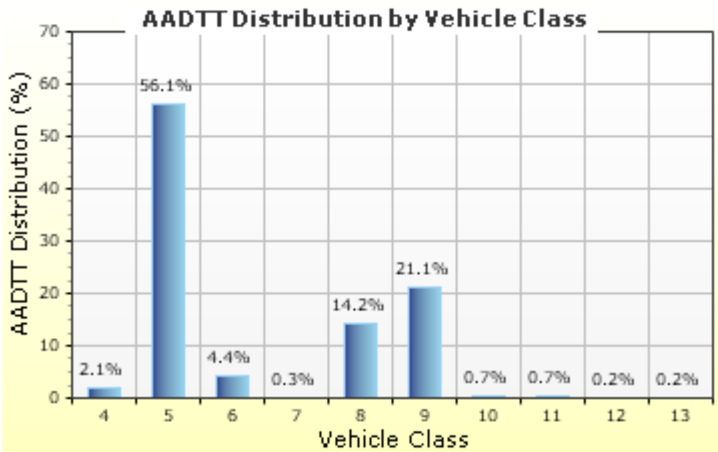


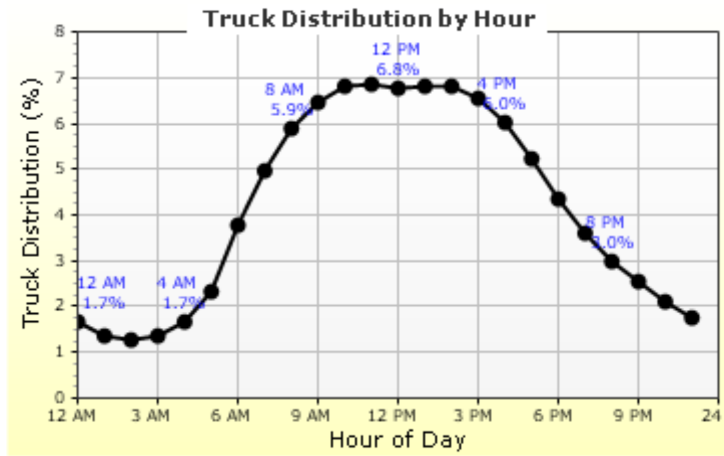


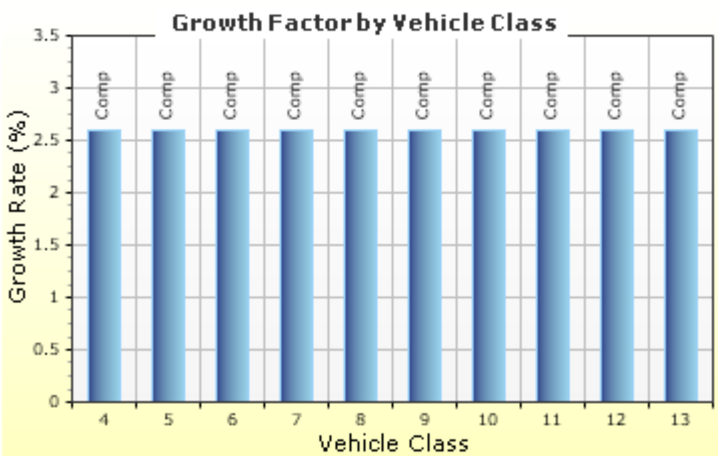
Traffic Inputs

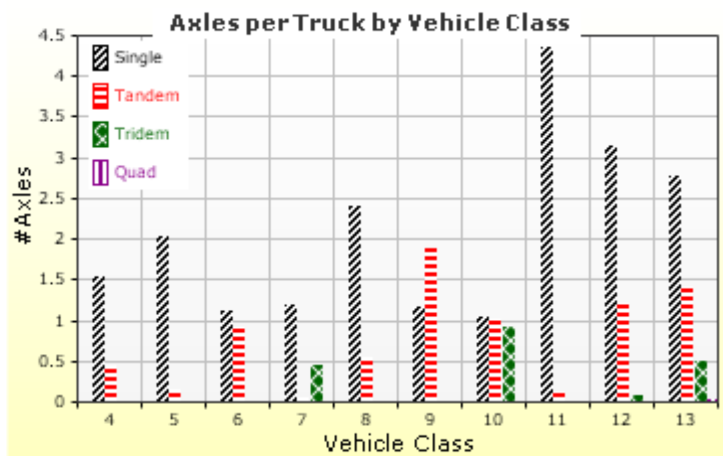
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	432	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)	15.0

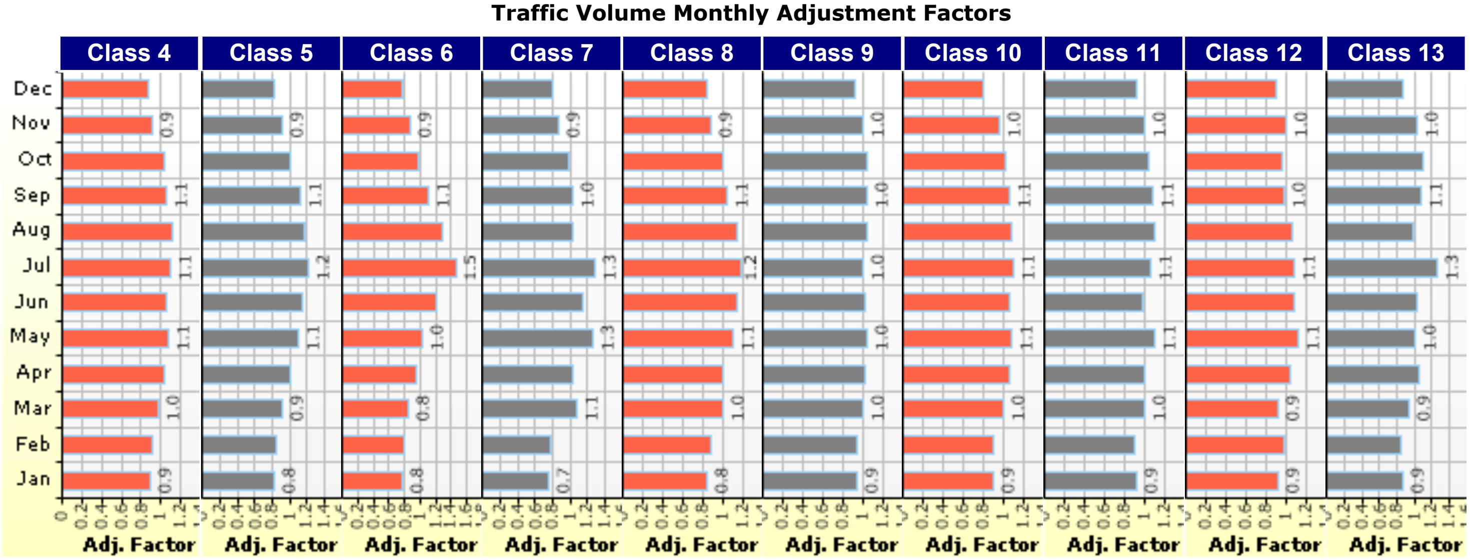








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.6%	Compound
Class 5	56.1%	2.6%	Compound
Class 6	4.4%	2.6%	Compound
Class 7	0.3%	2.6%	Compound
Class 8	14.2%	2.6%	Compound
Class 9	21.1%	2.6%	Compound
Class 10	0.7%	2.6%	Compound
Class 11	0.7%	2.6%	Compound
Class 12	0.2%	2.6%	Compound
Class 13	0.2%	2.6%	Compound

Truck Distribution by Hour

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

Axle Configuration

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

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

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

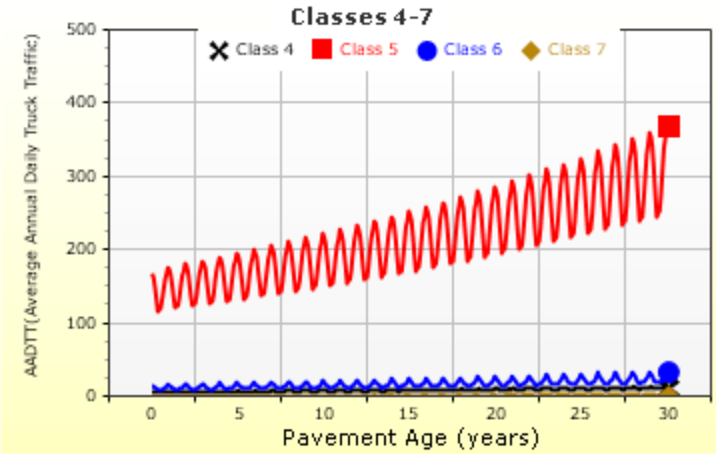
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

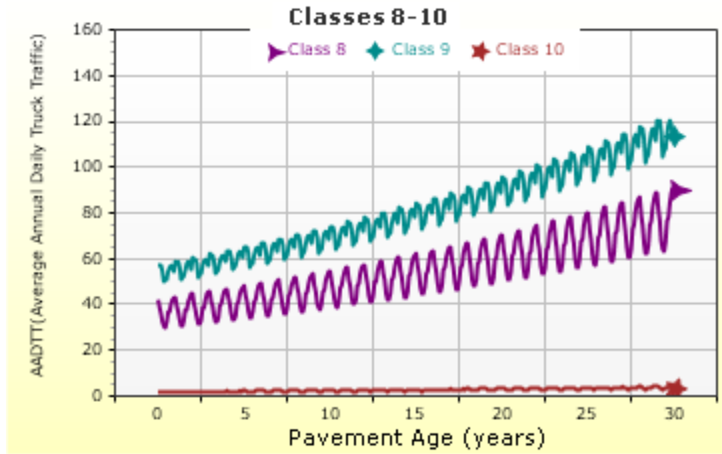
Number of Axles per Truck

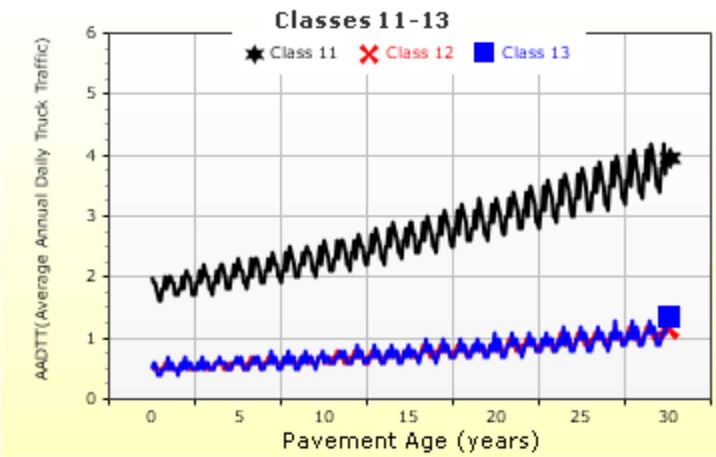
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

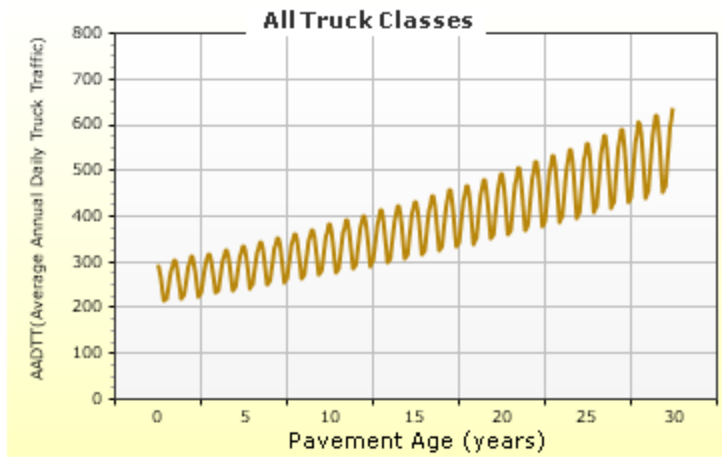
AADTT (Average Annual Daily Truck Traffic) Growth

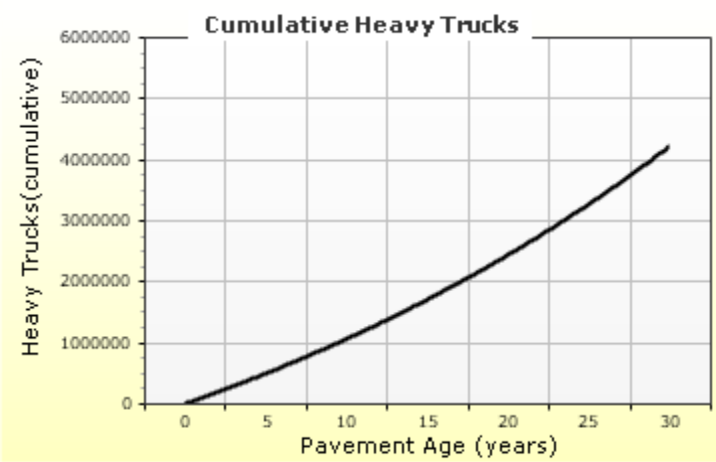
*** Traffic cap is not enforced**







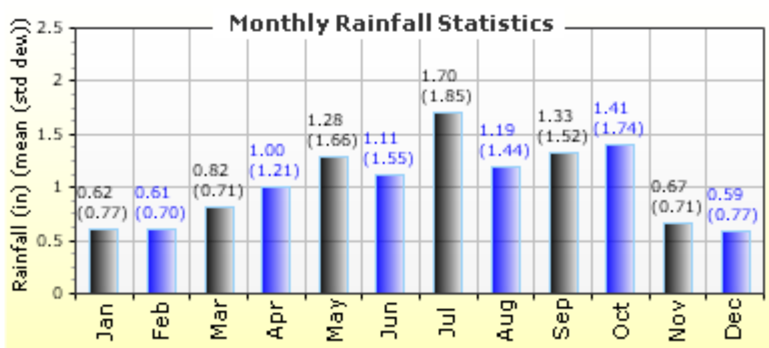




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
EAGLE CO, CO	39.64300 -106.91800 6535

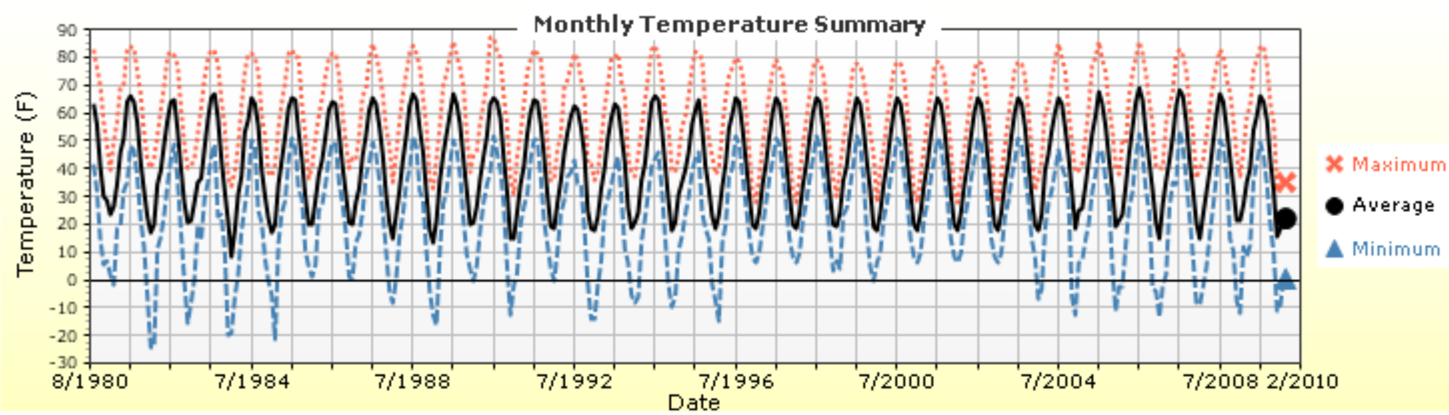


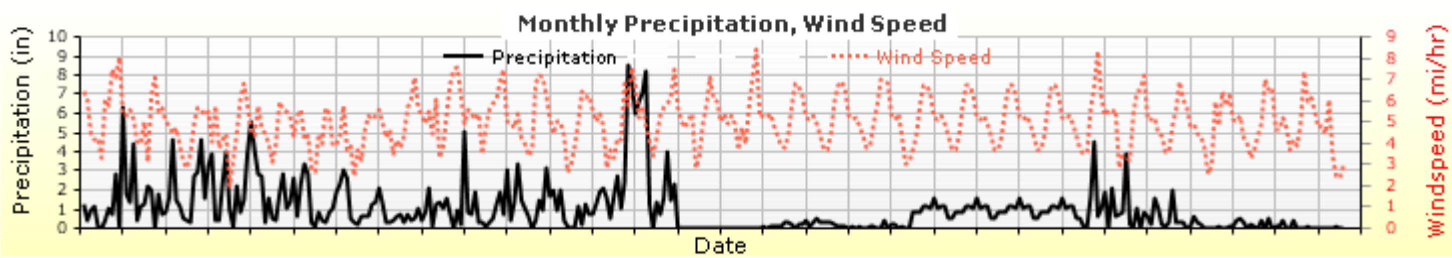
Annual Statistics:

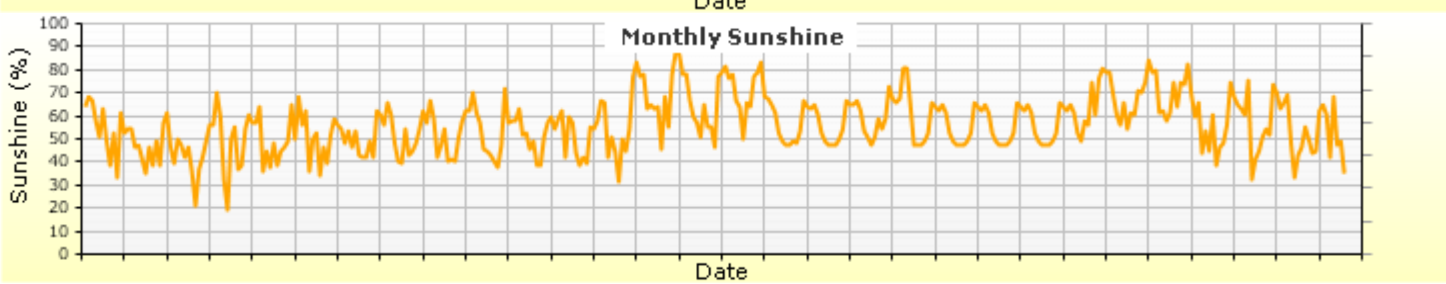
Mean annual air temperature (ºF)	42.94
Mean annual precipitation (in)	12.34
Freezing index (ºF - days)	1043.59
Average annual number of freeze/thaw cycles:	100.58

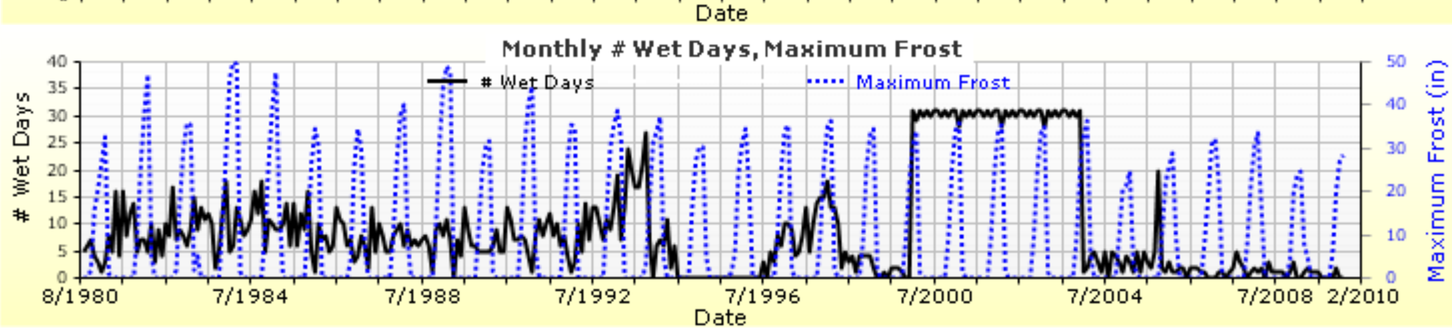
Water table depth (ft) 10.00

Monthly Climate Summary:

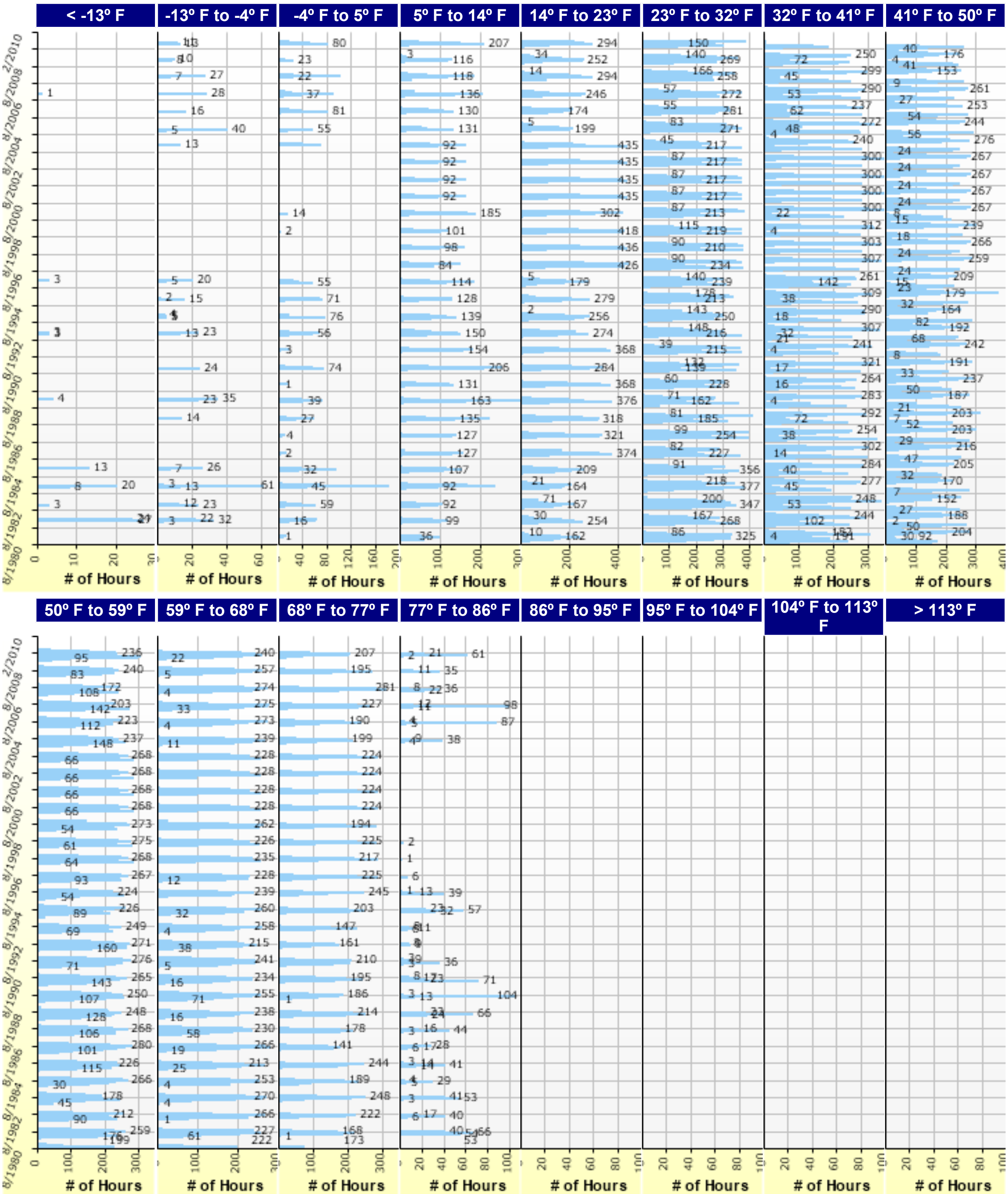








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

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

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

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

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

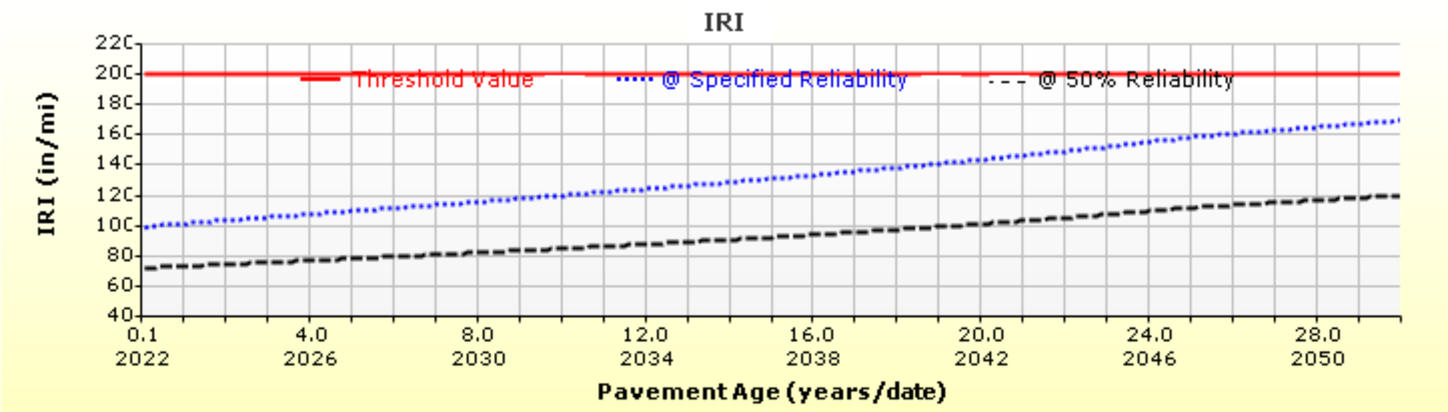
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

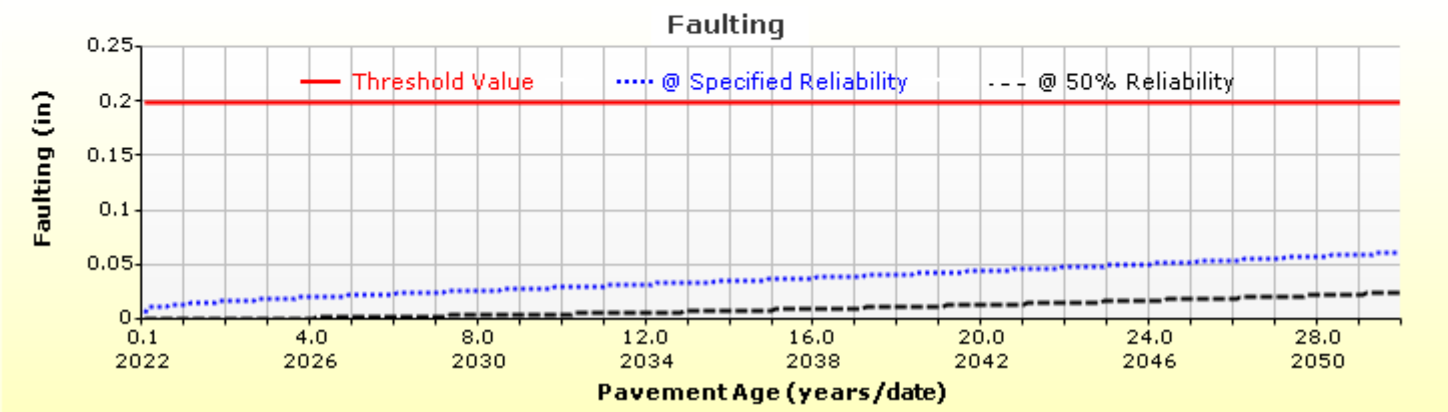
Sealant type	Other(Including No Sealant... Liquid... Silicone)

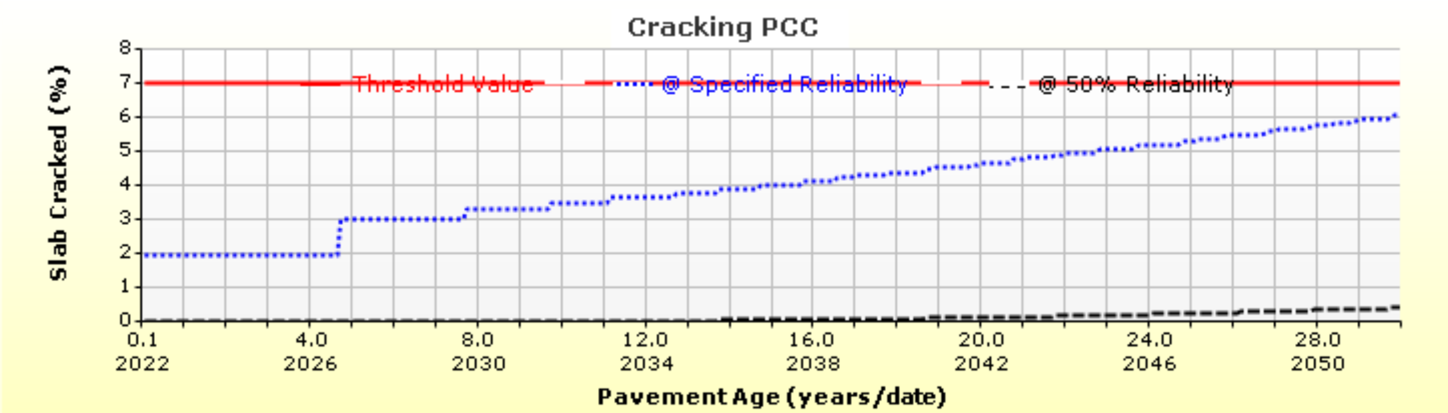
Erodibility index	4

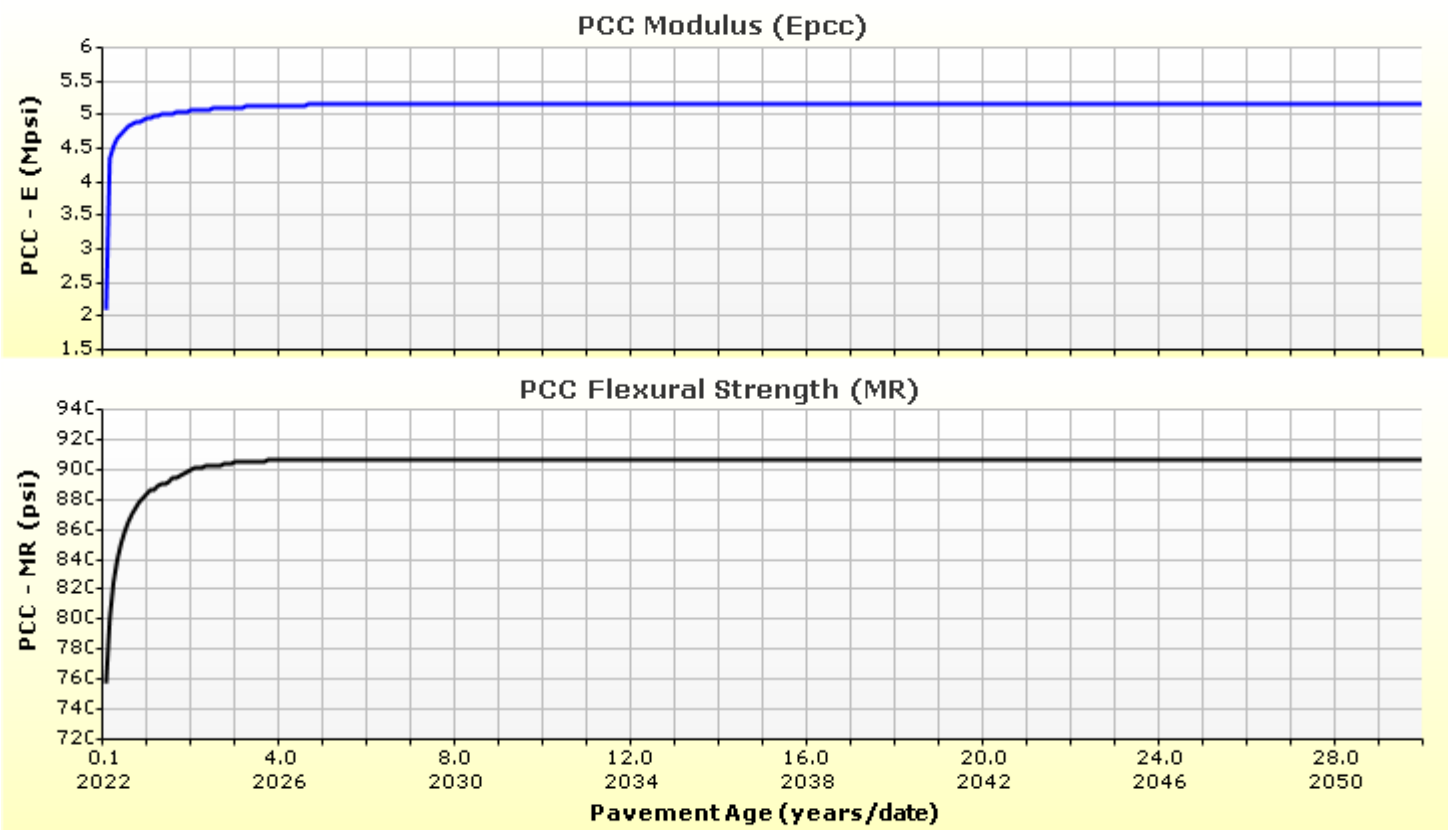
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

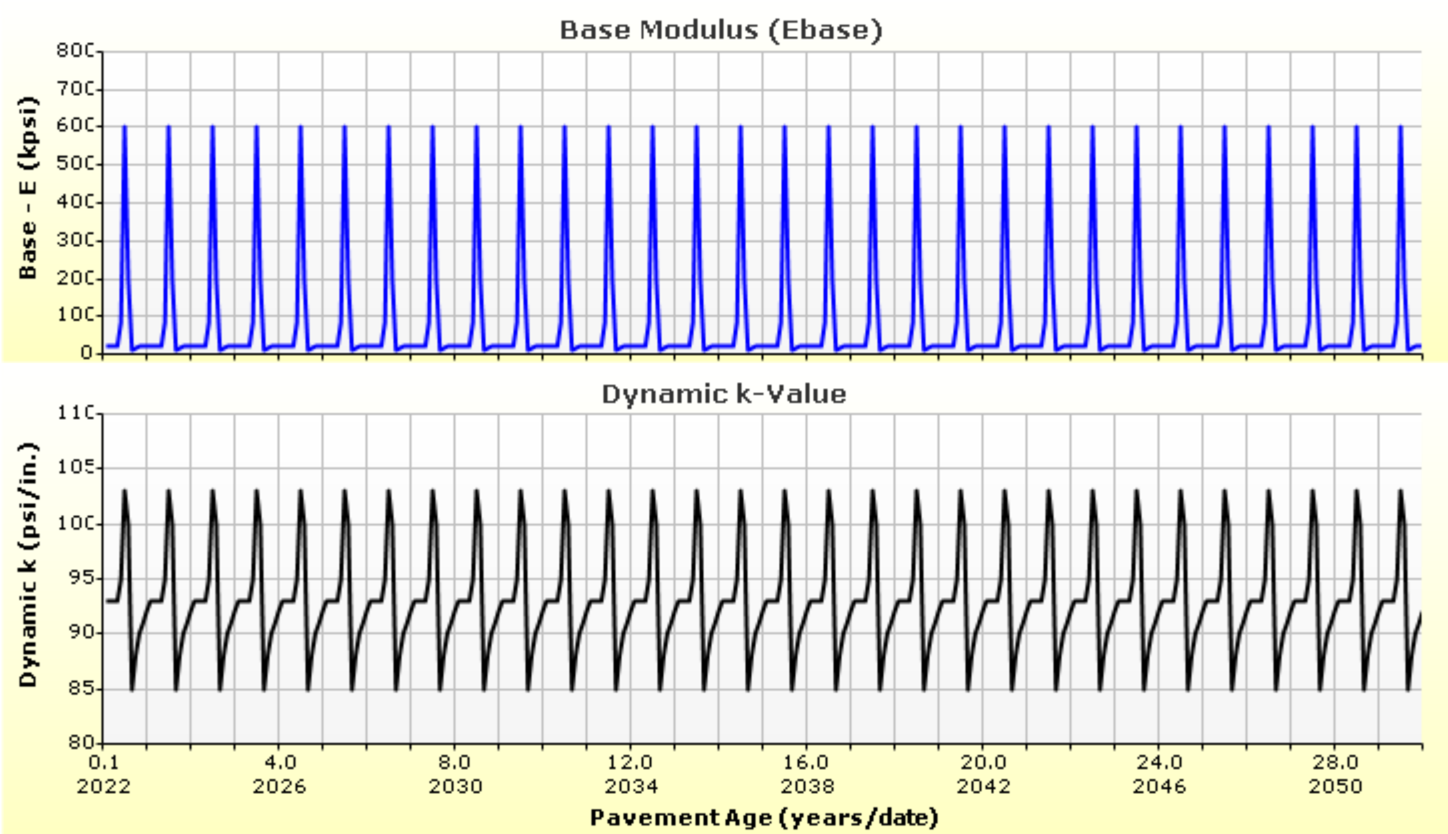




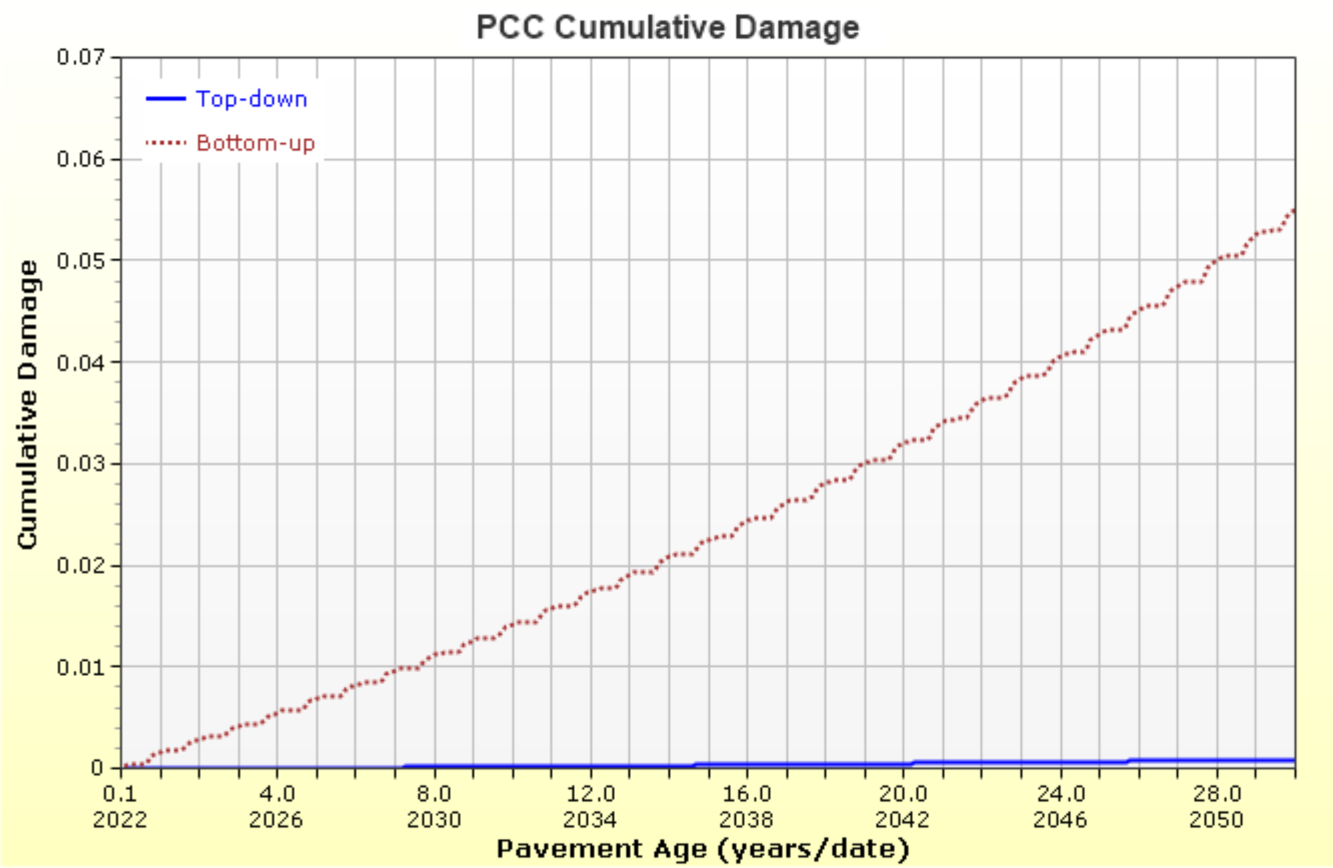


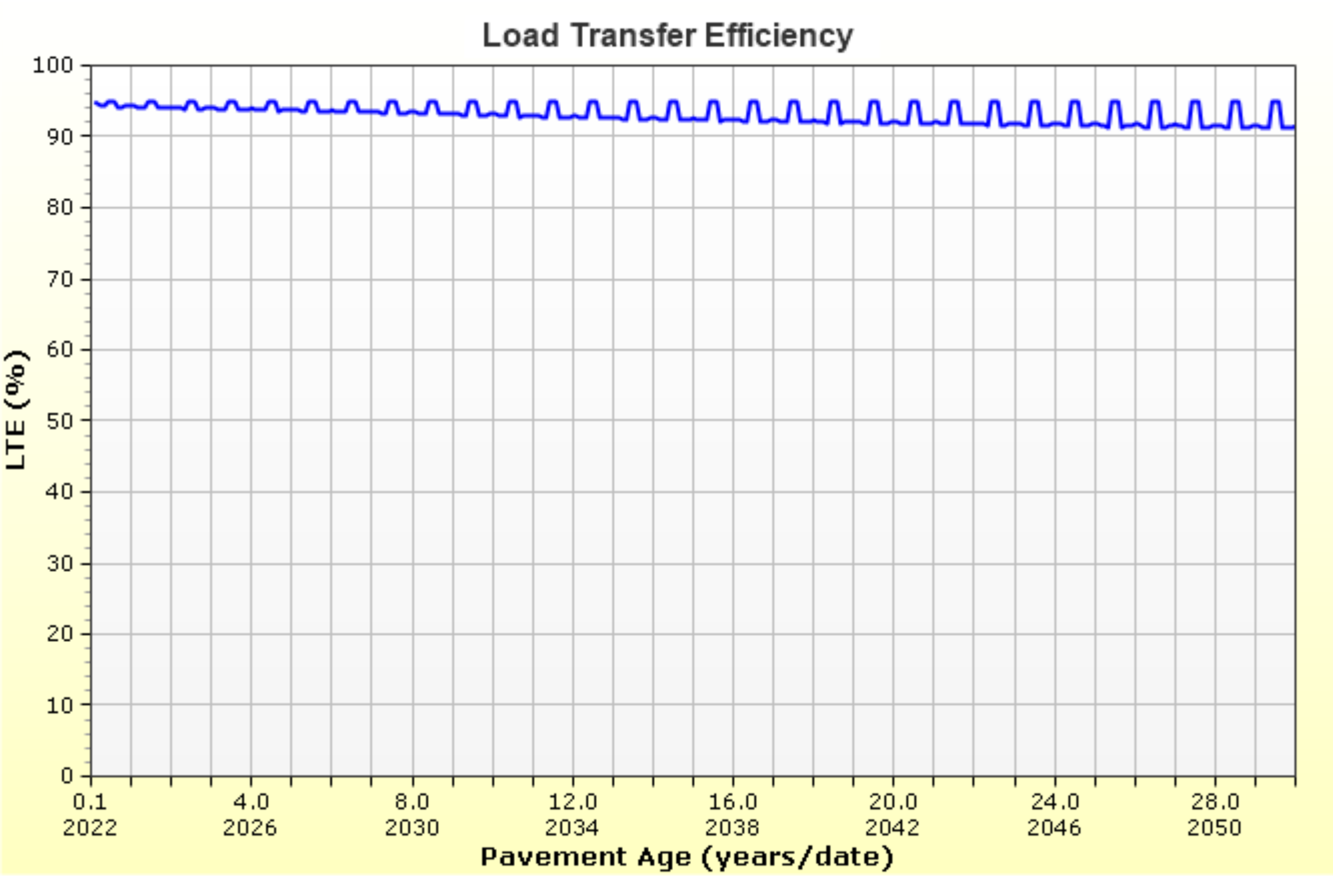


PCC Modulus (Epcc)
PCC - E (Mpsi)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
PCC Flexural Strength (MR)
PCC - MR (psi)
940
920
900
880
860
840
820
800
780
760
740
720
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



Base Modulus (Ebase)
Base - E (kpsi)
800
700
600
500
400
300
200
100
0
Dynamic k-Value
Dynamic k (psi/in.)
110
105
100
95
90
85
80
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)


PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)


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

Layer Information

Layer 1 PCC : R3 Level 1 Grand Jct Ready Mix

PCC	
Thickness (in)	7.8
Unit weight (pcf)	138.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.84
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		660
Water to cement ratio		0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	97.1
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	688.9
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	570	3560000
14-day	645	3860000
28-day	730	4300000
90-day	810	4550000
20-year/28-day	1.2	1.2

Identifiers

Field	Value
Display name/identifier	R3 Level 1 Grand Jct Ready Mix
Description of object	Mix ID # 2009092
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 3
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : A-1-a

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
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 3 Subgrade : A-6

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5350.0

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

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)
5350.0

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

Identifiers

Field	Value
Display name/identifier	A-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$
$$C_{34} = C_3 + (C_4 * FR^{0.25})$$
$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s}\right)\right]^{C_6}$$
$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$
$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$
$$C_8 = DowelDeterioration$$

C1: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400

PCC Reliability Faulting Standard Deviation

0.0831 * Pow(FAULT,0.3426) + 0.00521

IRI-jpcp

C1 - Cracking C2 - Spalling C3 - Faulting C4 - Site Factor	C1: 0.8203	C2: 0.4417
	C3: 1.4929	C4: 25.24
	Reliability Standard Deviation	
	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

$$CRK = \frac{100}{1 + C4\ FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05

PCC Reliability Cracking Standard Deviation

Pow(57.08*CRACK,0.33) + 1.5

04_US6_Roundabout-8inPCC_6inABC_8inSB_30yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\04_US6_Roundabout-8inPCC_6inABC_8inSB_30yr.dgpx

Design Inputs

Design Life: 30 years
Design Type: JPCP

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

Climate Data Sources (Lat/Lon): 39.643, -106.918

Design Structure

Layer type	Material Type	Thickness (in)
PCC	R3 Level 1 Grand Jct Ready Mix	7.8
NonStabilized	A-1-a	6.0
Subgrade	A-6	8.0
Subgrade	A-6	Semi-infinite

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

Traffic

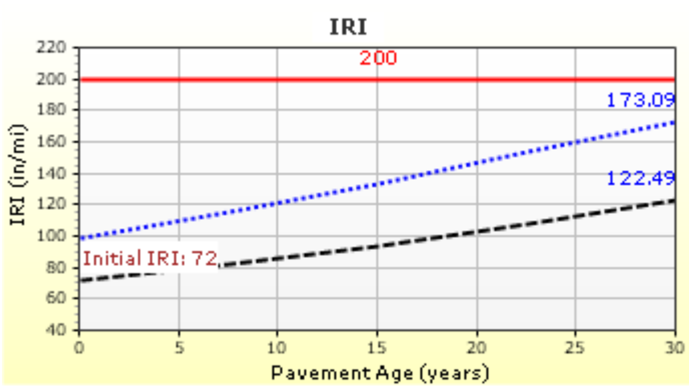
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	305
2037 (15 years)	2,012,240
2052 (30 years)	4,969,510

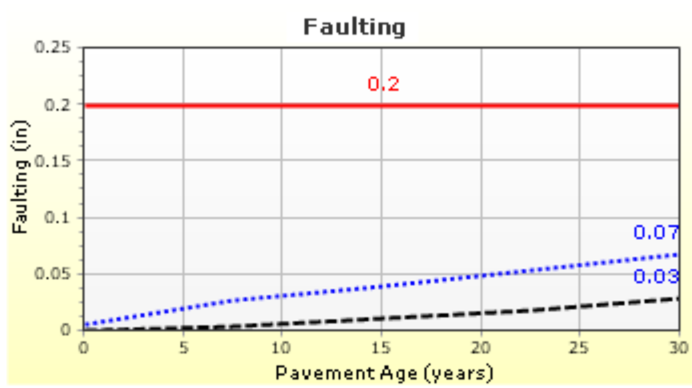
Design Outputs

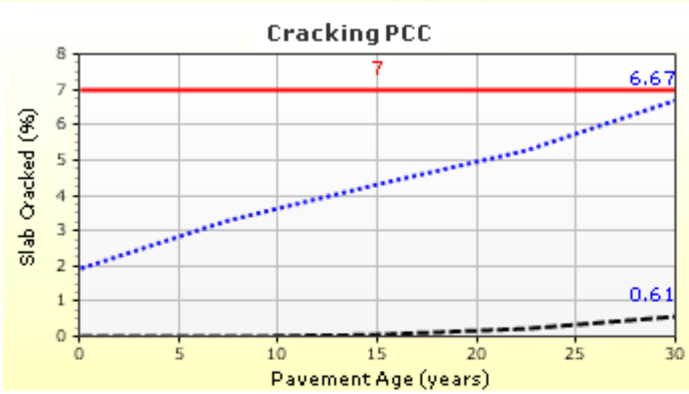
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	173.09	90.00	97.52	Pass
Mean joint faulting (in)	0.20	0.07	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	6.67	90.00	91.18	Pass

Distress Charts



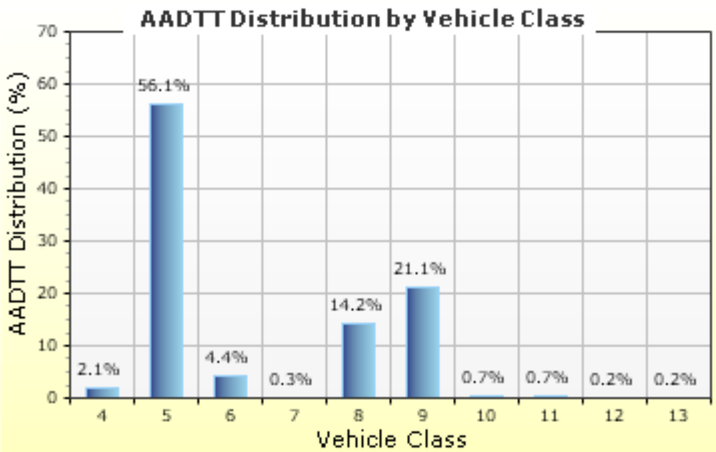


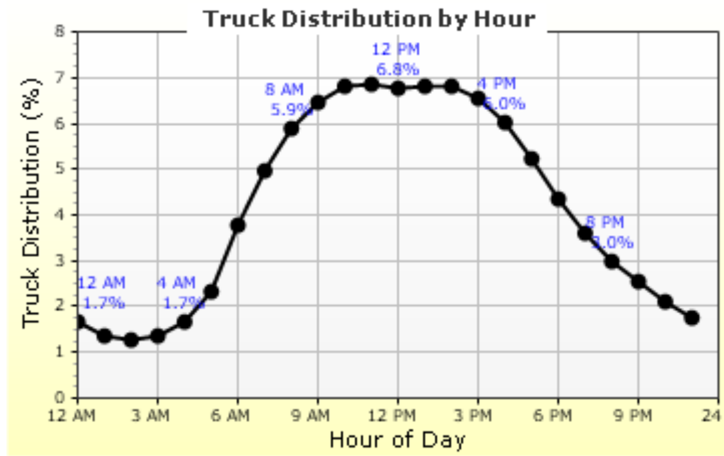


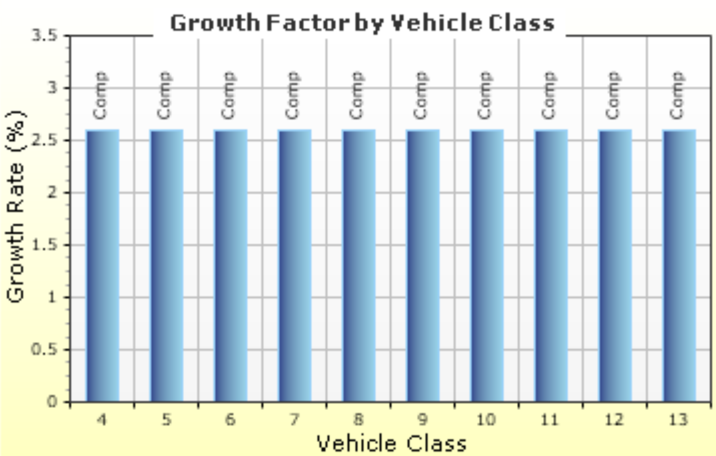
Traffic Inputs

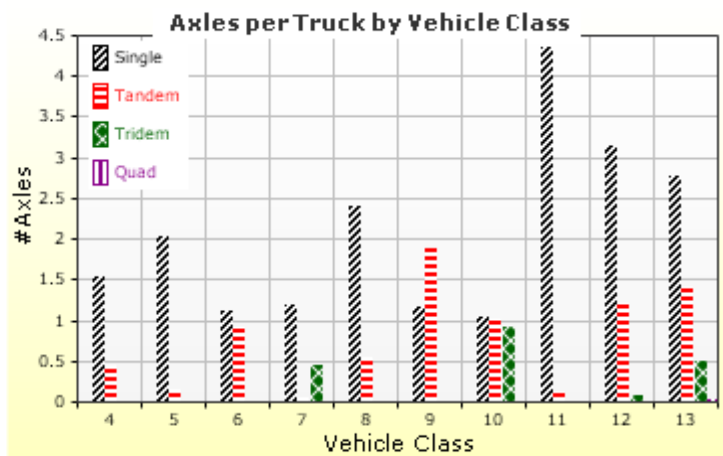
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	305	Percent of trucks in design direction (%):	100.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	13.0

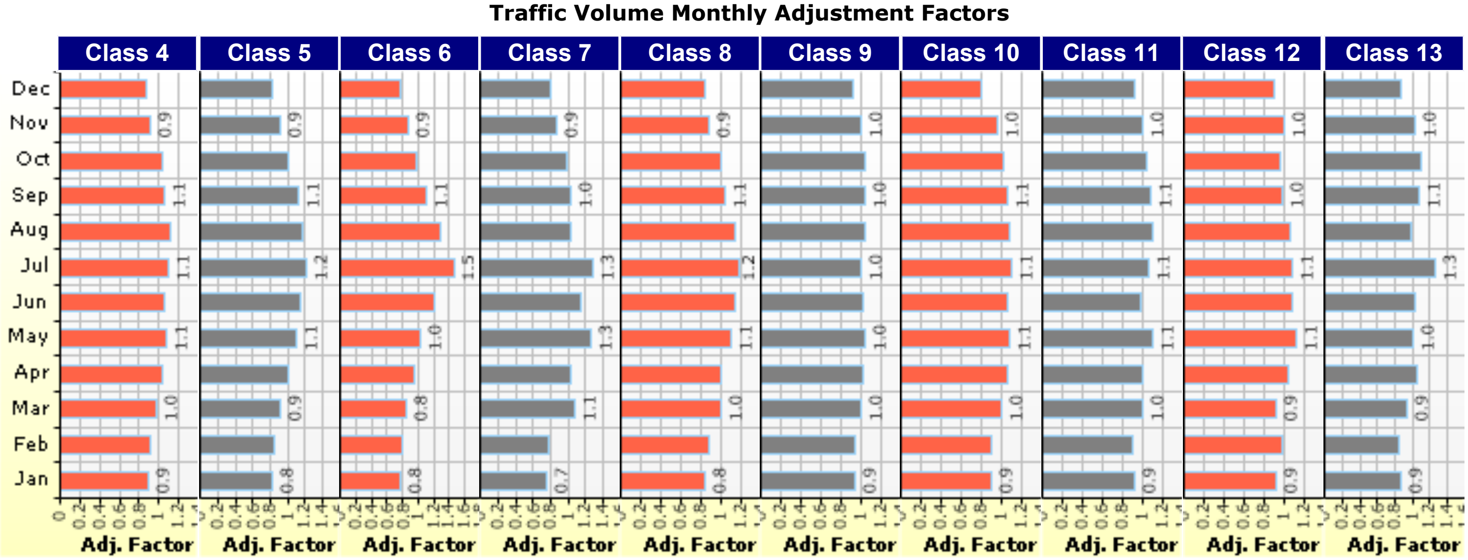








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.6%	Compound
Class 5	56.1%	2.6%	Compound
Class 6	4.4%	2.6%	Compound
Class 7	0.3%	2.6%	Compound
Class 8	14.2%	2.6%	Compound
Class 9	21.1%	2.6%	Compound
Class 10	0.7%	2.6%	Compound
Class 11	0.7%	2.6%	Compound
Class 12	0.2%	2.6%	Compound
Class 13	0.2%	2.6%	Compound

Truck Distribution by Hour

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

Axle Configuration

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

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

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

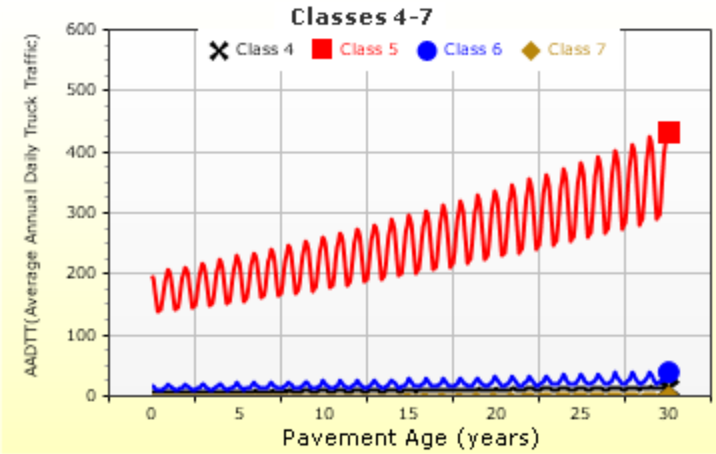
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

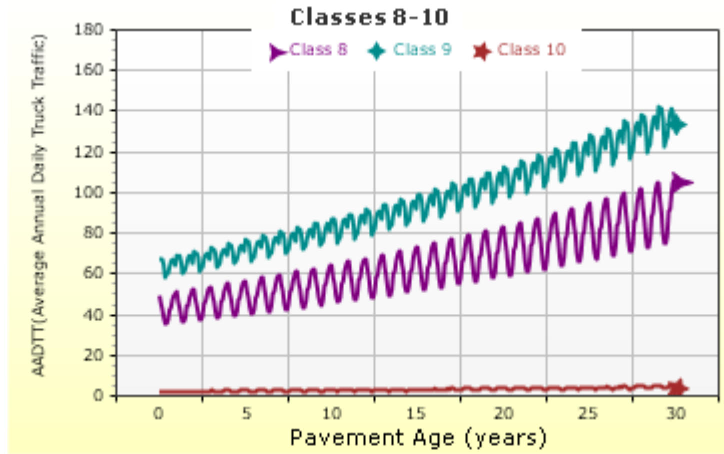
Number of Axles per Truck

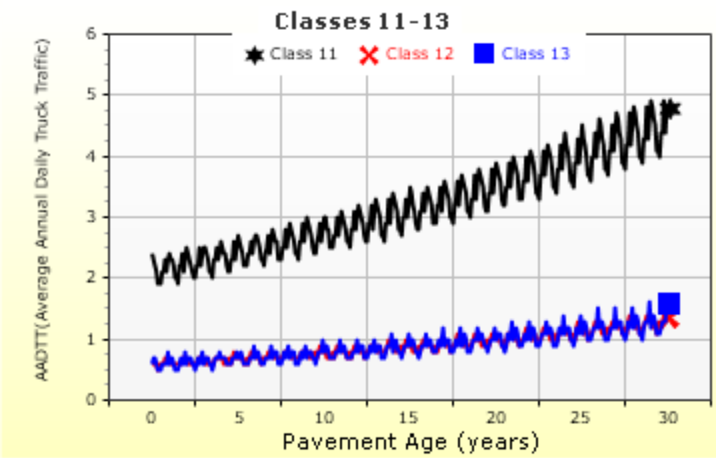
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

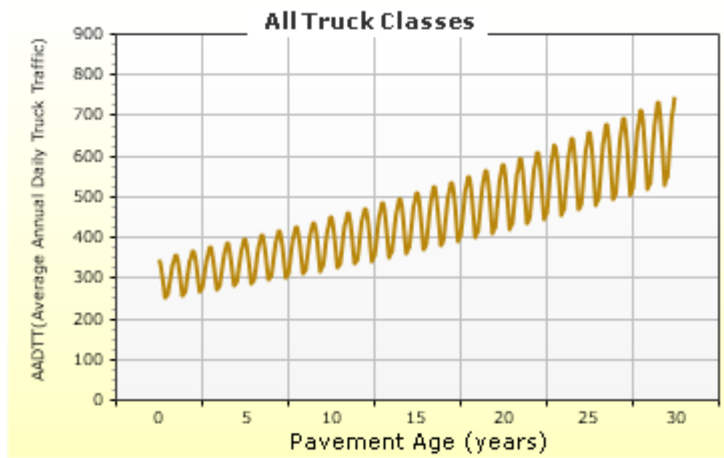
AADTT (Average Annual Daily Truck Traffic) Growth

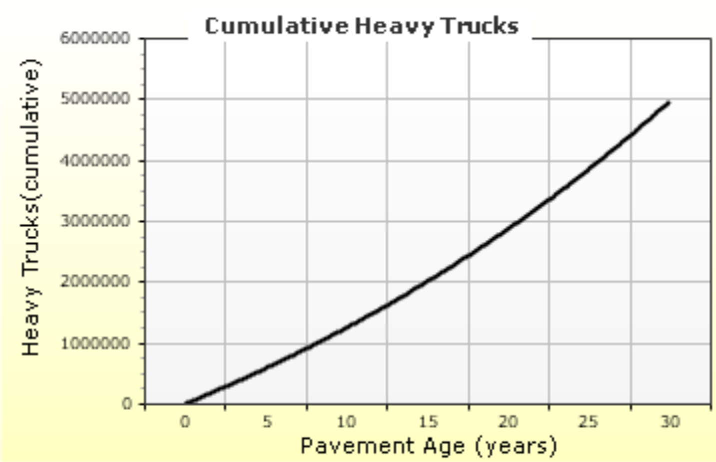
*** Traffic cap is not enforced**







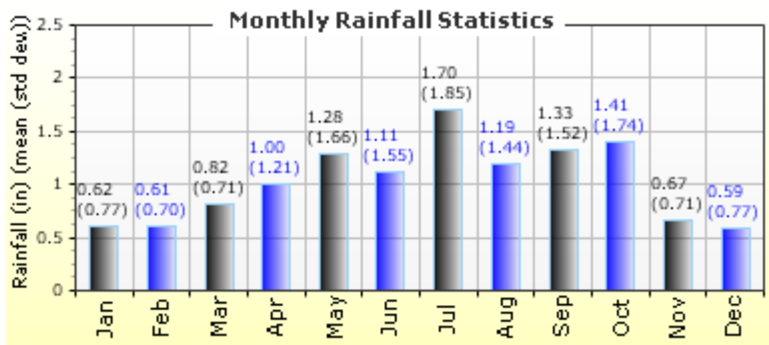




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
EAGLE CO, CO	39.64300 -106.91800 6535

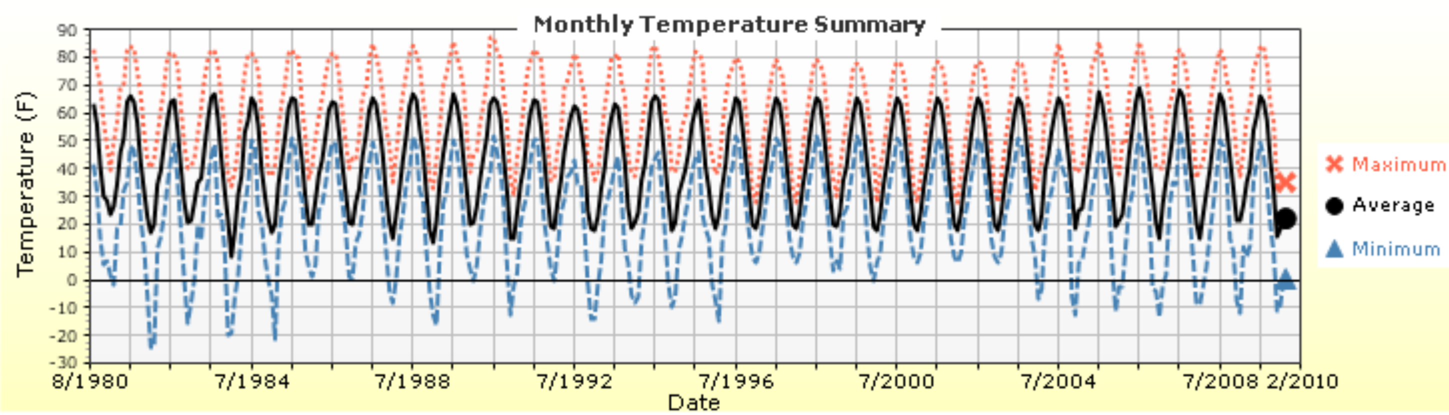


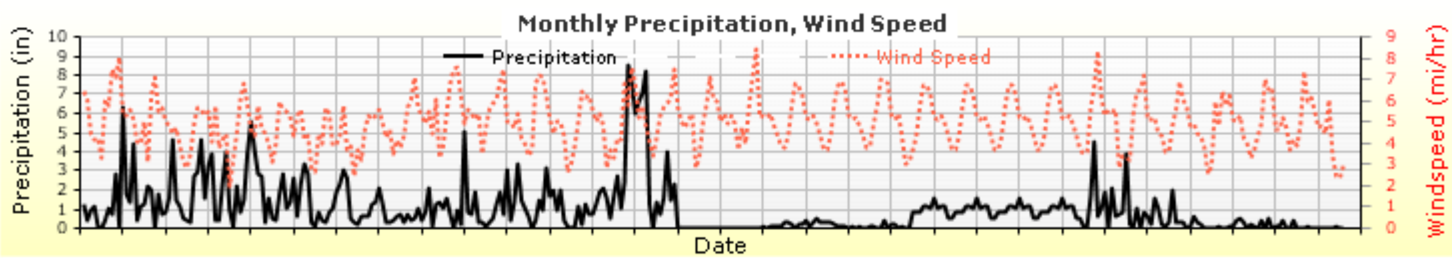
Annual Statistics:

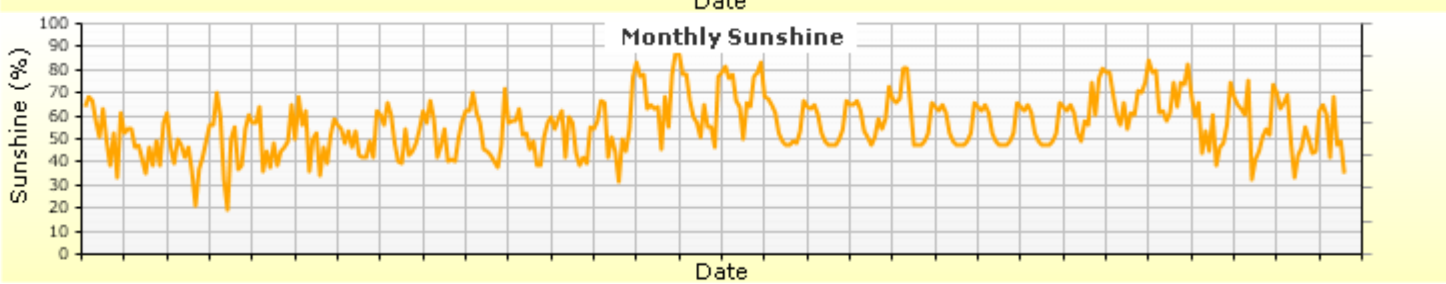
Mean annual air temperature (ºF)	42.94
Mean annual precipitation (in)	12.34
Freezing index (ºF - days)	1043.59
Average annual number of freeze/thaw cycles:	100.58

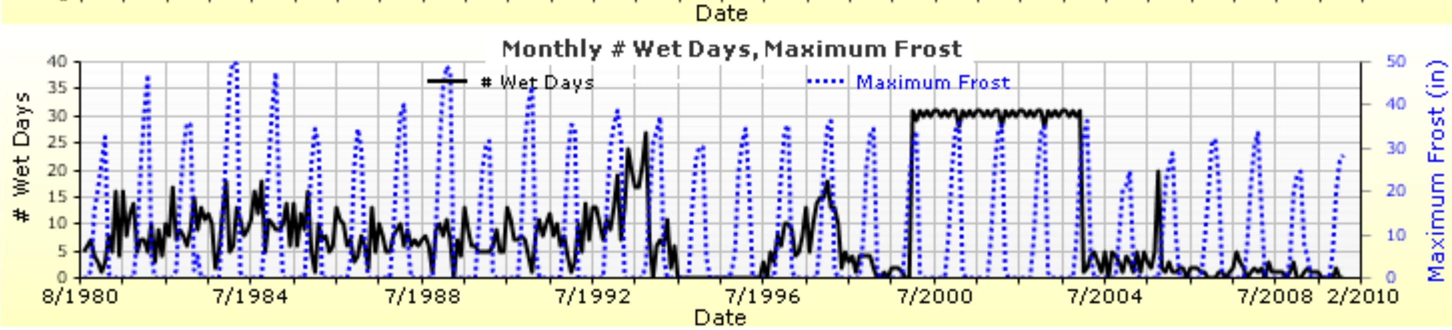
Water table depth (ft)	10.00

Monthly Climate Summary:

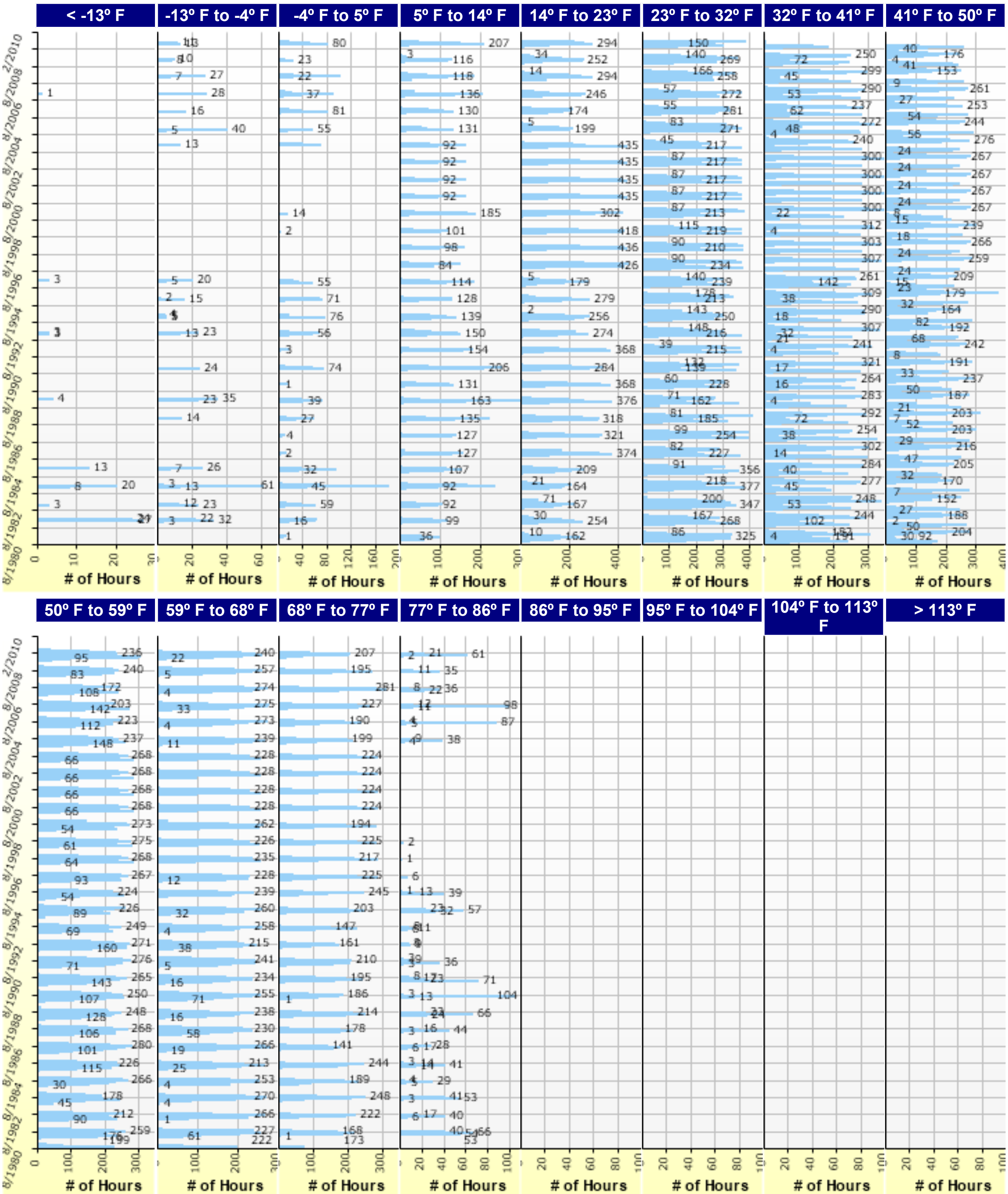








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

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

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

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

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

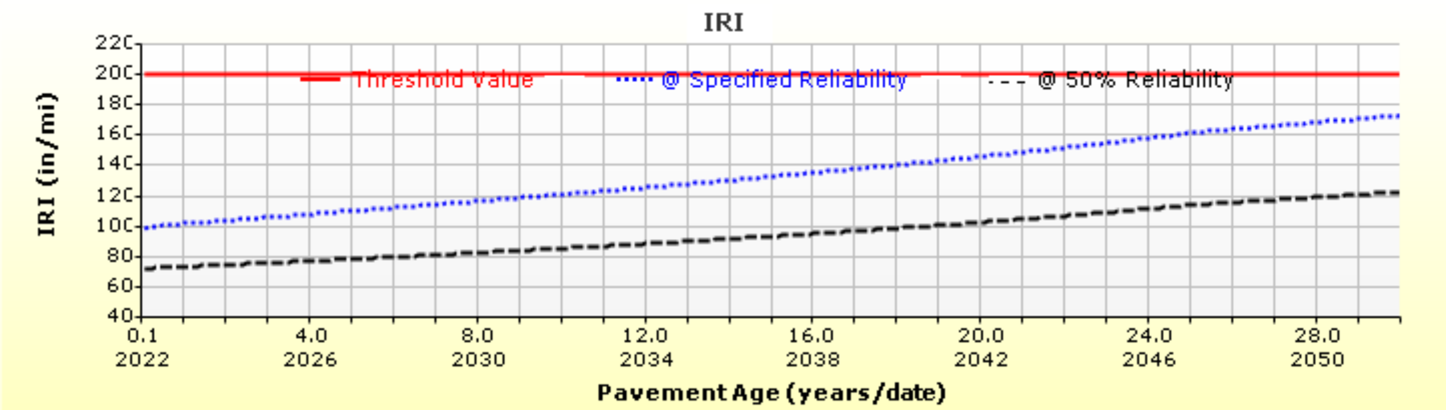
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

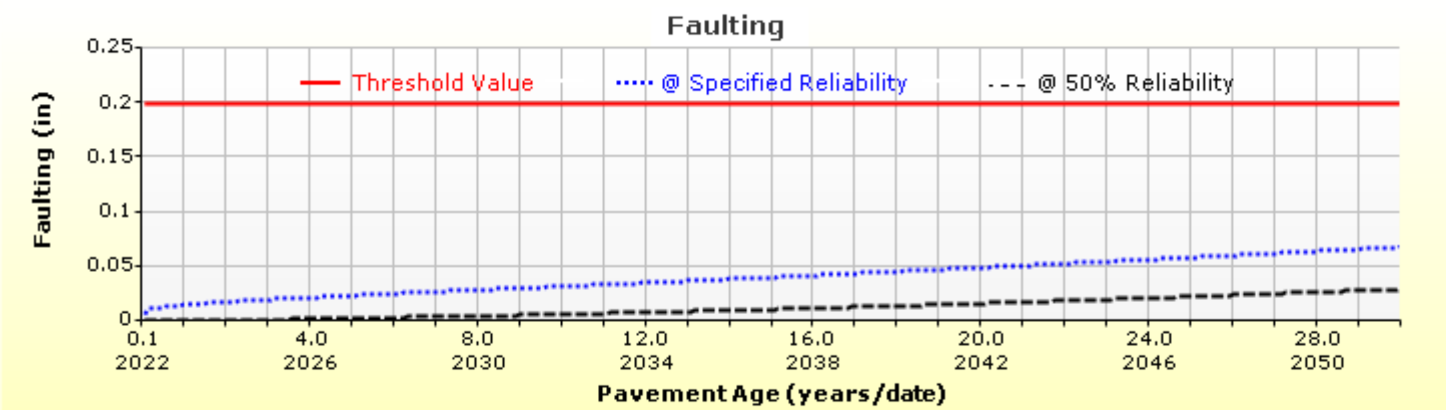
Sealant type	Other(Including No Sealant... Liquid... Silicone)

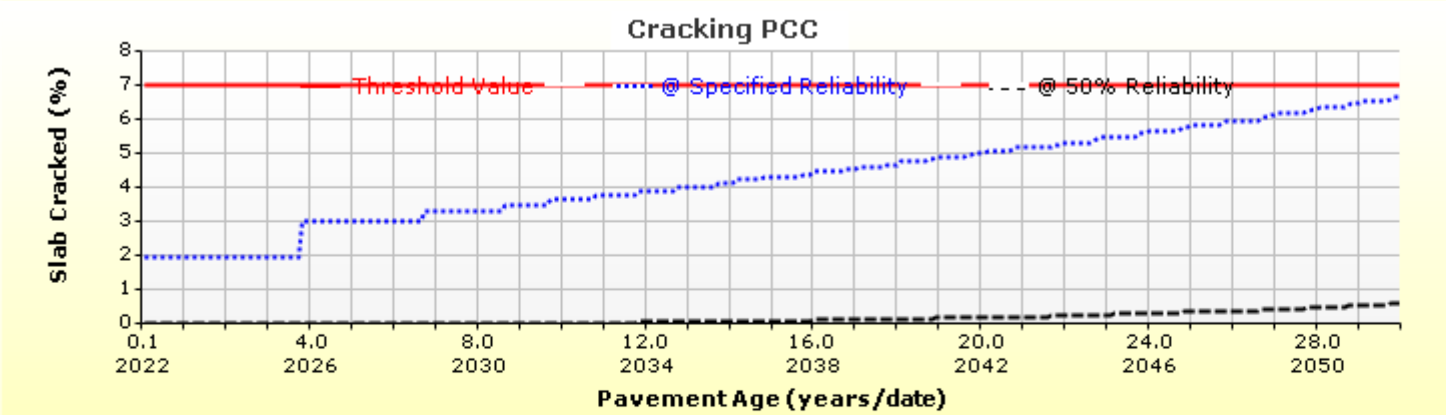
Erodibility index	4

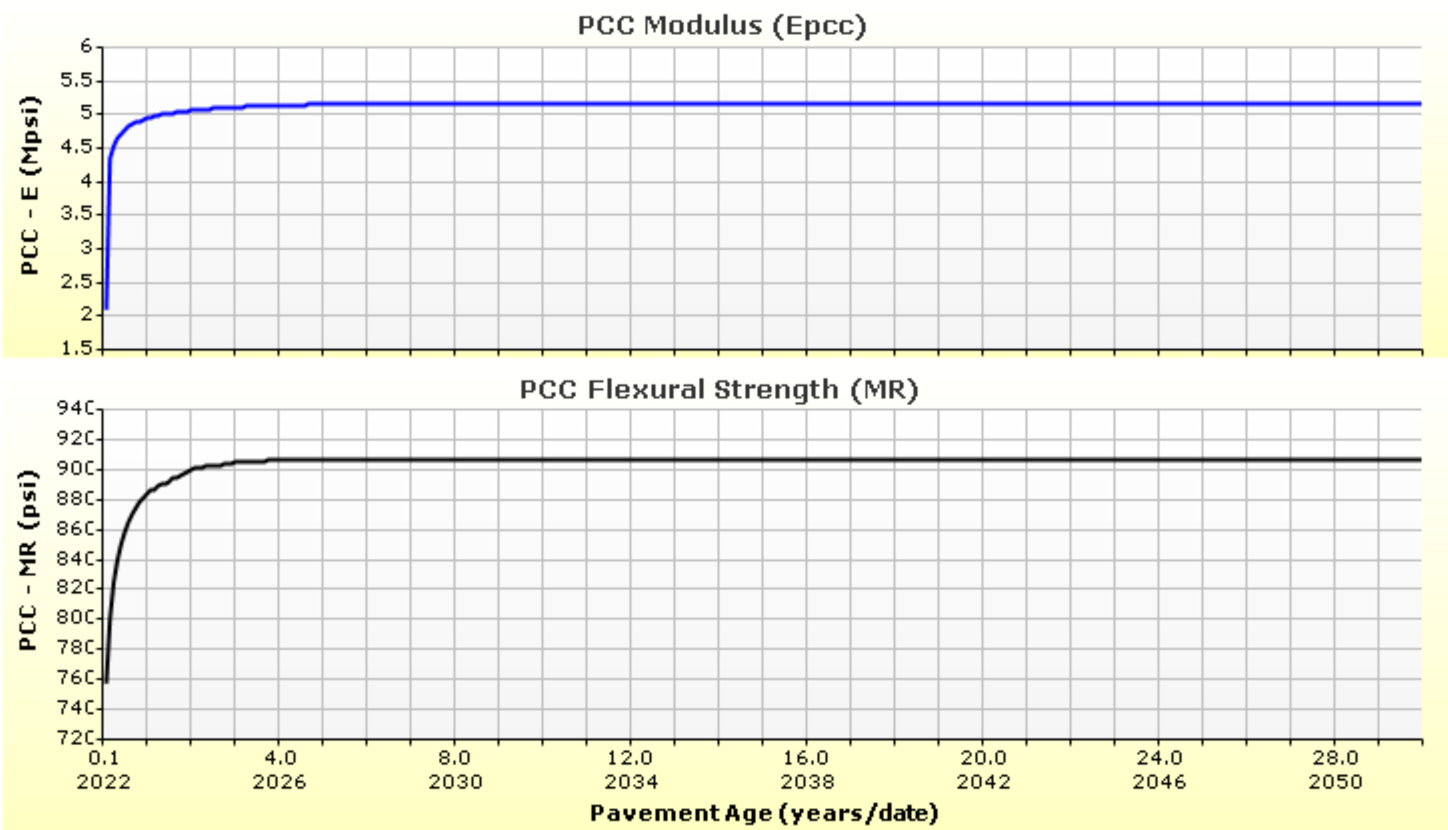
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

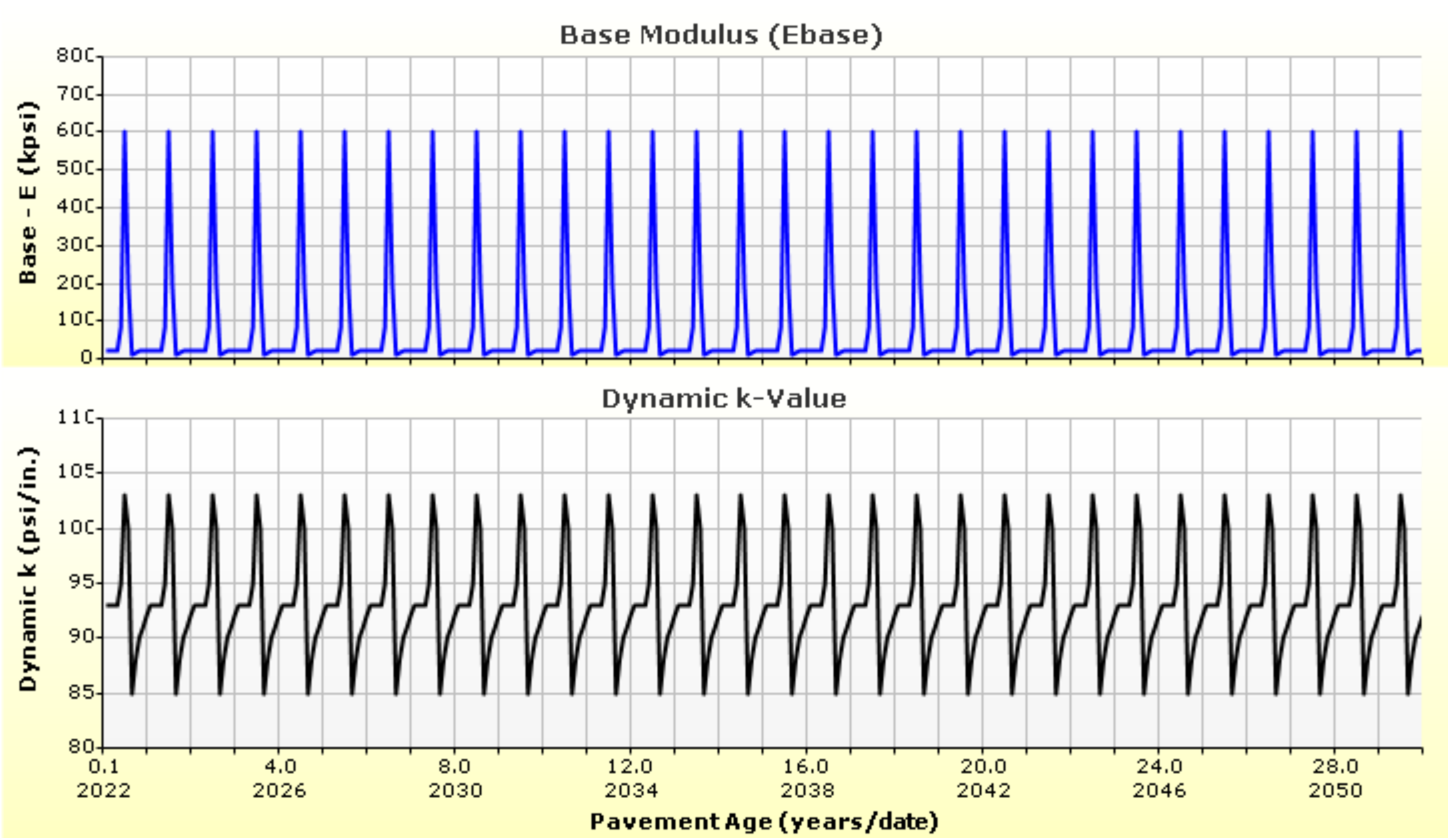




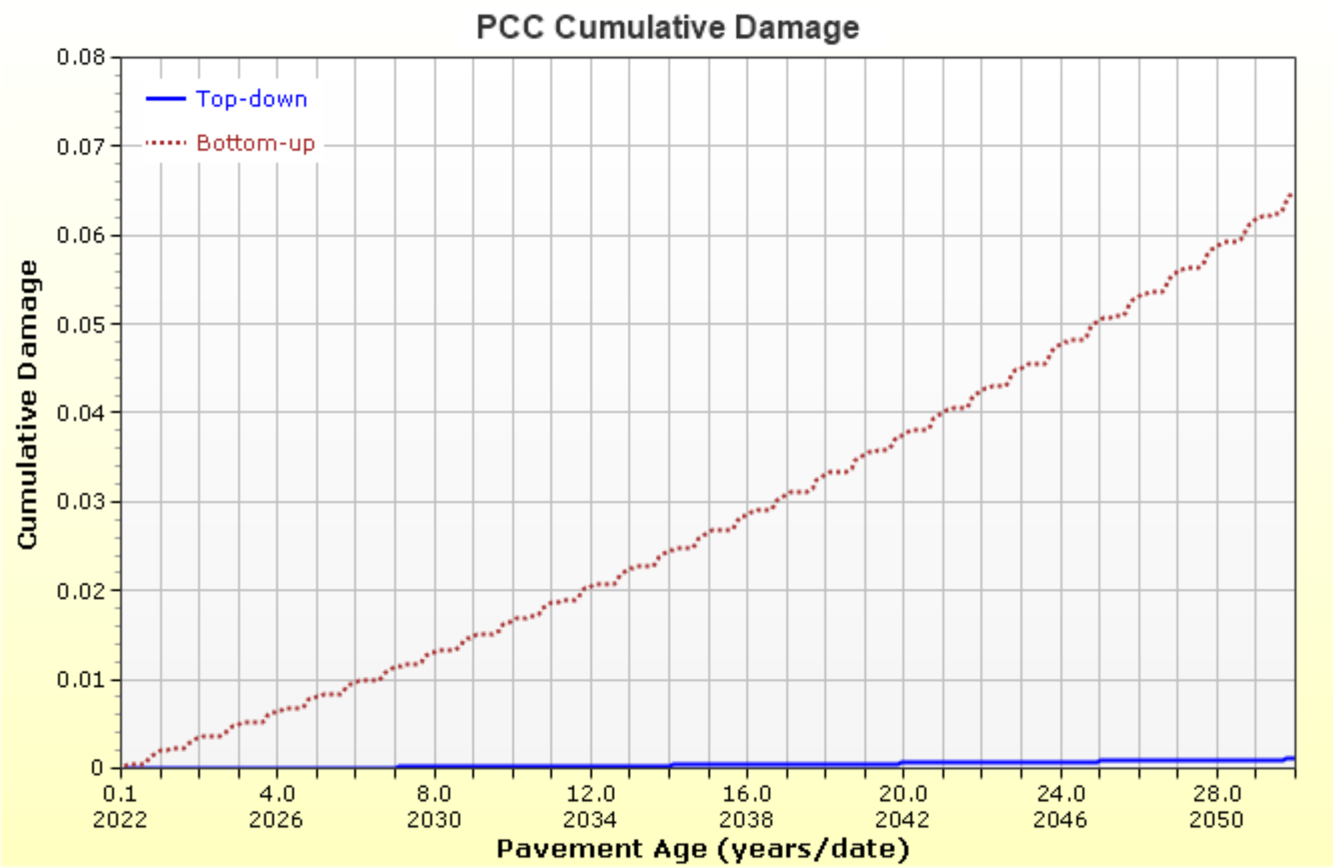




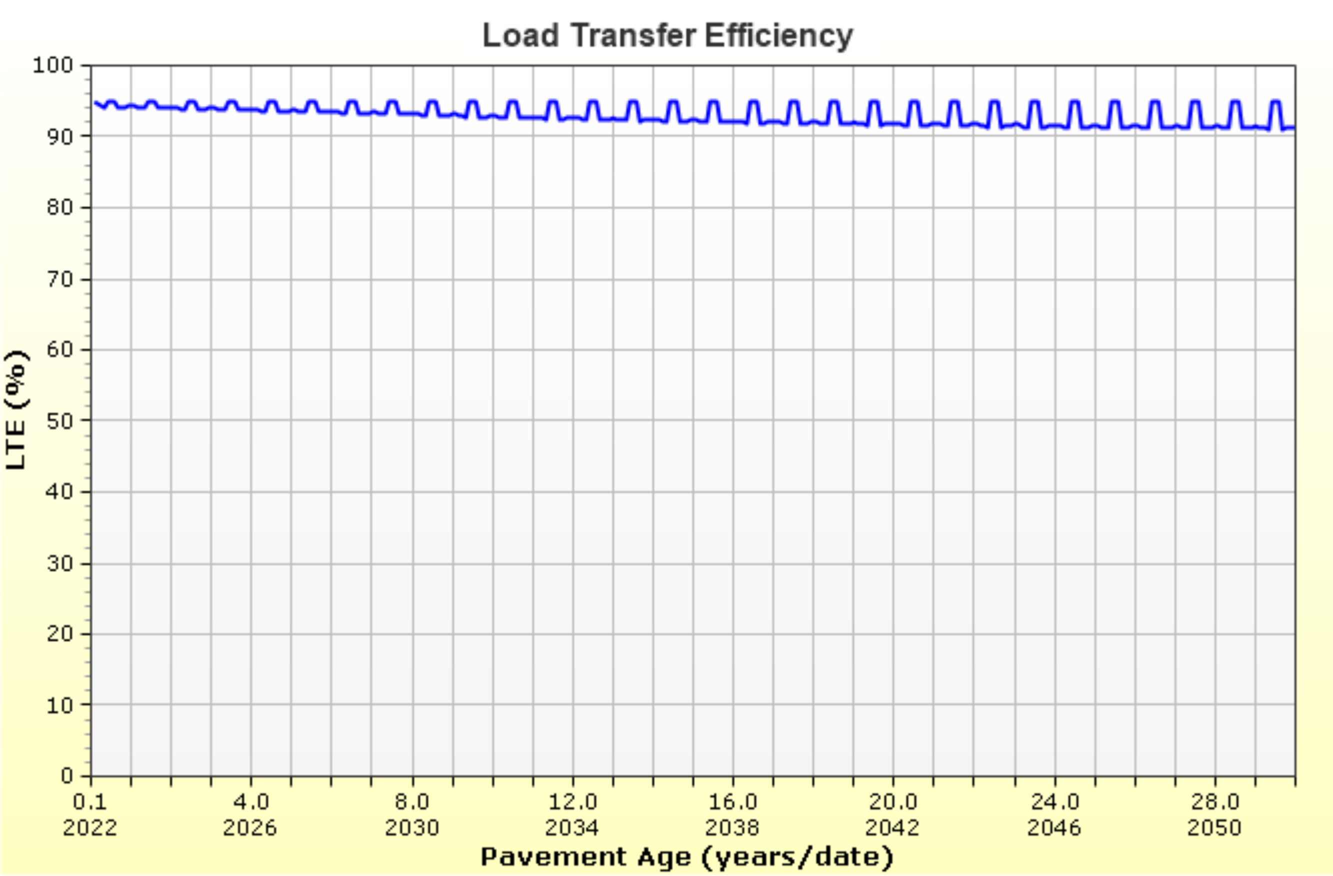
PCC Modulus (Epcc)
PCC - E (Mpsi)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
PCC Flexural Strength (MR)
PCC - MR (psi)
940
920
900
880
860
840
820
800
780
760
740
720
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



Base Modulus (Ebase)
Base - E (kpsi)
800
700
600
500
400
300
200
100
0
Dynamic k-Value
Dynamic k (psi/in.)
110
105
100
95
90
85
80
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)



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

Layer Information

Layer 1 PCC : R3 Level 1 Grand Jct Ready Mix

PCC	
Thickness (in)	7.8
Unit weight (pcf)	138.6
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in/in/ºF x 10^-6)	4.84
PCC thermal conductivity (BTU/hr-ft-ºF)	1.25
PCC heat capacity (BTU/lb-ºF)	0.28

Mix		
Cement type		Type I (1)
Cementitious material content (lb/yd^3)		660
Water to cement ratio		0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	97.1
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	688.9
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 1)

Time	Modulus of rupture (psi)	Elastic modulus (psi)
7-day	570	3560000
14-day	645	3860000
28-day	730	4300000
90-day	810	4550000
20-year/28-day	1.2	1.2

Identifiers

Field	Value
Display name/identifier	R3 Level 1 Grand Jct Ready Mix
Description of object	Mix ID # 2009092
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	Region 3
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : A-1-a

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)
15000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
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 3 Subgrade : A-6

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
5350.0

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

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)
5350.0

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

Identifiers

Field	Value
Display name/identifier	A-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$
$$C_{34} = C_3 + (C_4 * FR^{0.25})$$
$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s}\right)\right]^{C_6}$$
$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$
$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$
$$C_8 = DowelDeterioration$$

C1: 0.5104	C2: 0.00838	C3: 0.00147	C4: 0.008345
C5: 5999	C6: 0.8404	C7: 5.9293	C8: 400
PCC Reliability Faulting Standard Deviation			
0.0831 * Pow(FAULT,0.3426) + 0.00521			

IRI-jpcp

C1 - Cracking	C1: 0.8203	C2: 0.4417
C2 - Spalling	C3: 1.4929	C4: 25.24
C3 - Faulting	**Reliability Standard Deviation**	
C4 - Site Factor	5.4	

PCC Cracking

$$\log(N) = C1 \cdot \left(\frac{MR}{\sigma}\right)^{C2}$$

$$CRK = \frac{100}{1 + C4\, FD^{C5}}$$

Fatigue Coefficients		Cracking Coefficients	
C1: 2	C2: 1.22	C4: 0.6	C5: -2.05
PCC Reliability Cracking Standard Deviation			
Pow(57.08*CRACK,0.33) + 1.5			

05_HillcrestDr_5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Rev3\05_HillcrestDr_5inHMA_6inABC_20yr.dgpx

Design Inputs

Design Life: 20 years
Design Type: FLEXIBLE

Base construction: August, 2022
Pavement construction: August, 2022
Traffic opening: August, 2022

Climate Data Sources (Lat/Lon): 39.643, -106.918

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R5 Level 1 SX(75) PG 58-34	2.0
Flexible	R3 Level 1 SX(75) PG 58-28 United	3.0
NonStabilized	A-1-a	6.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	4.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	14.4
Air voids (%)	5.2

Traffic

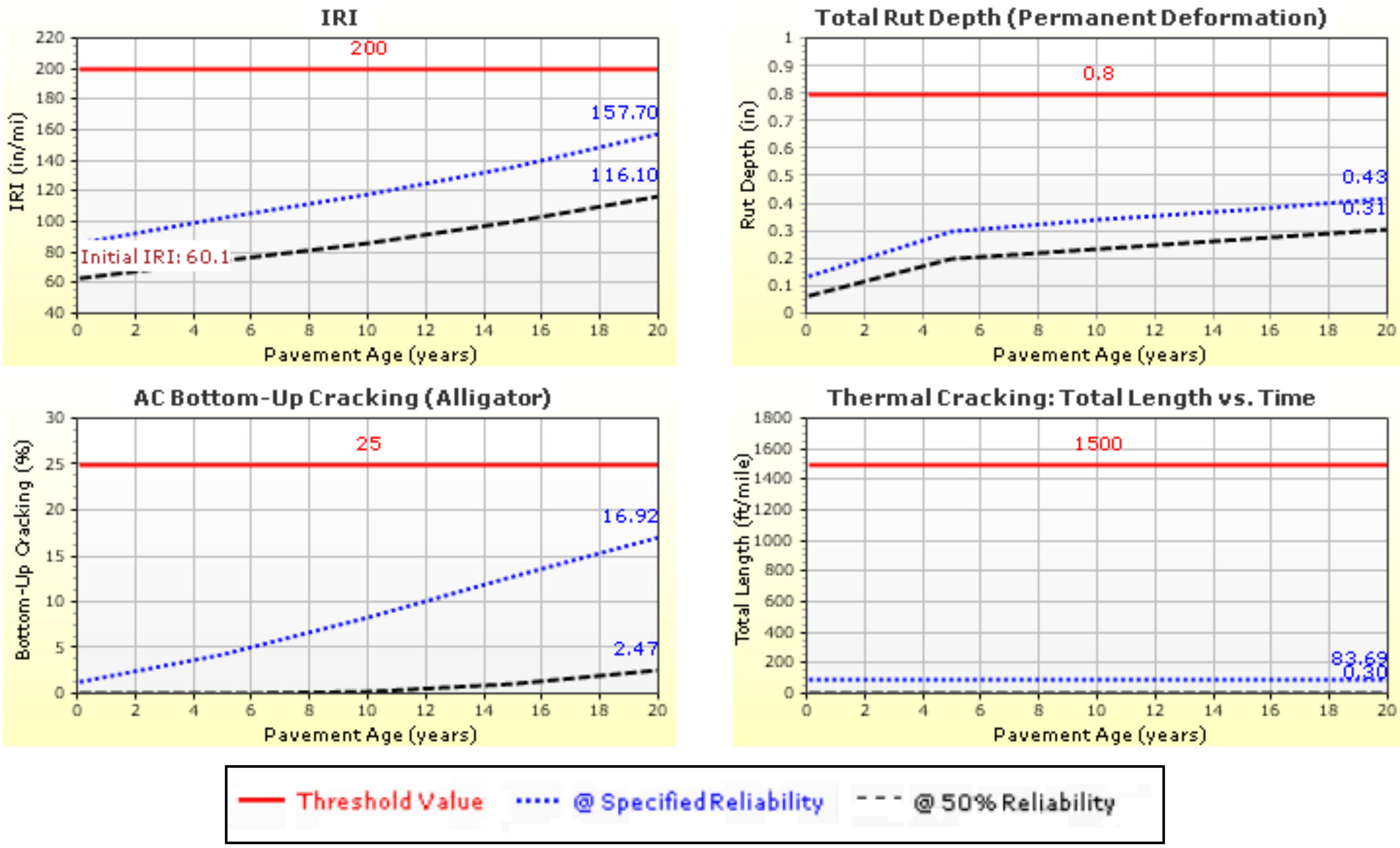
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	78
2032 (10 years)	187,171
2042 (20 years)	415,332

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	157.71	90.00	99.51	Pass
Permanent deformation - total pavement (in)	0.80	0.42	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	16.92	90.00	97.72	Pass
AC thermal cracking (ft/mile)	1500.00	83.69	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	571.50	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.24	90.00	100.00	Pass

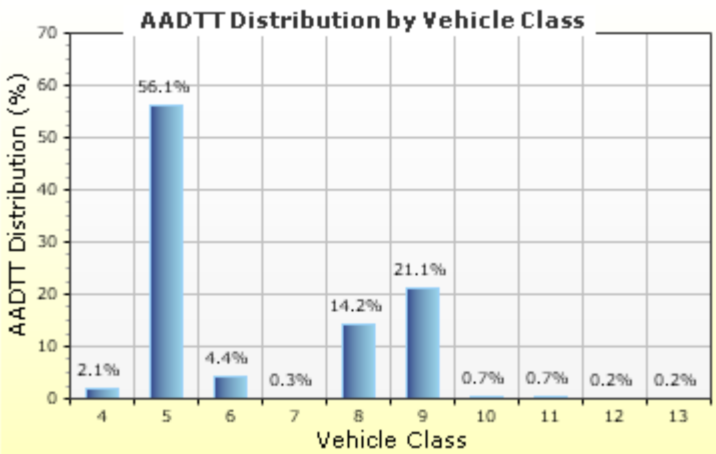
Distress Charts

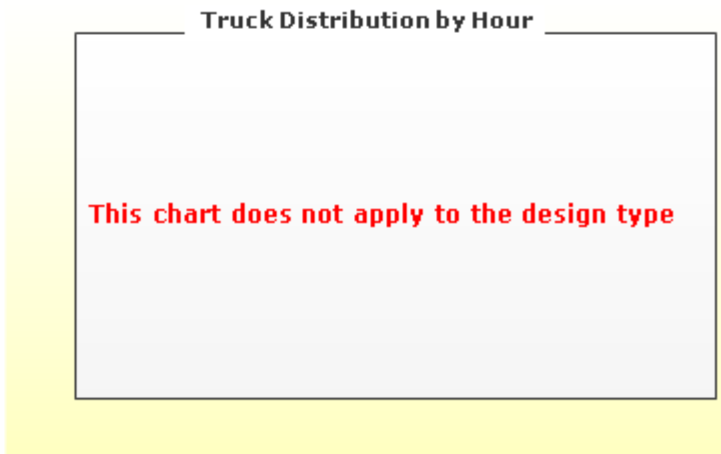


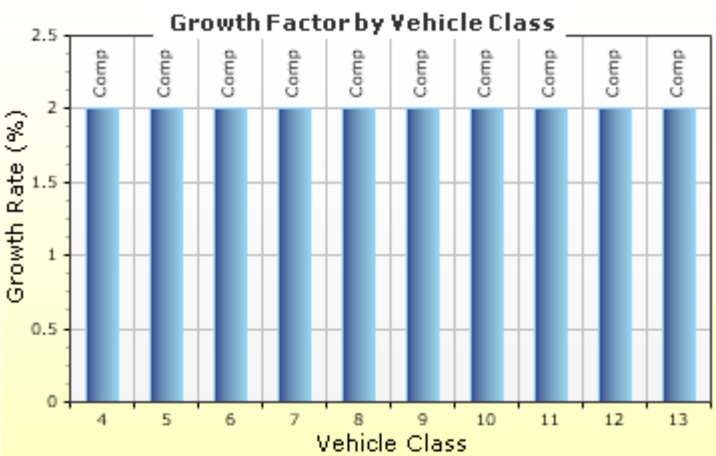
Traffic Inputs

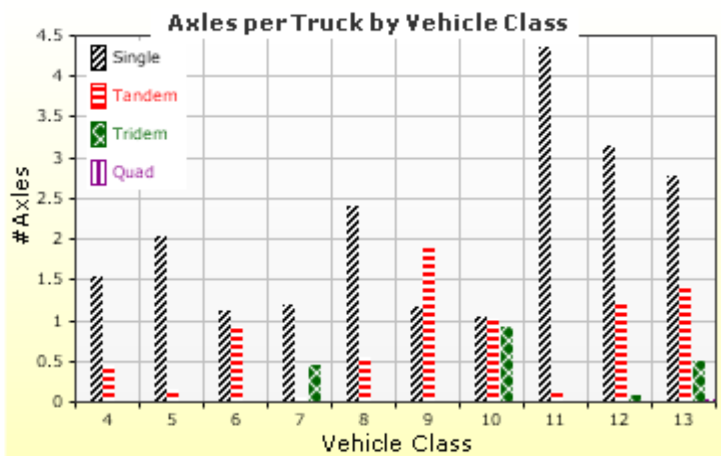
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	78	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)	15.0

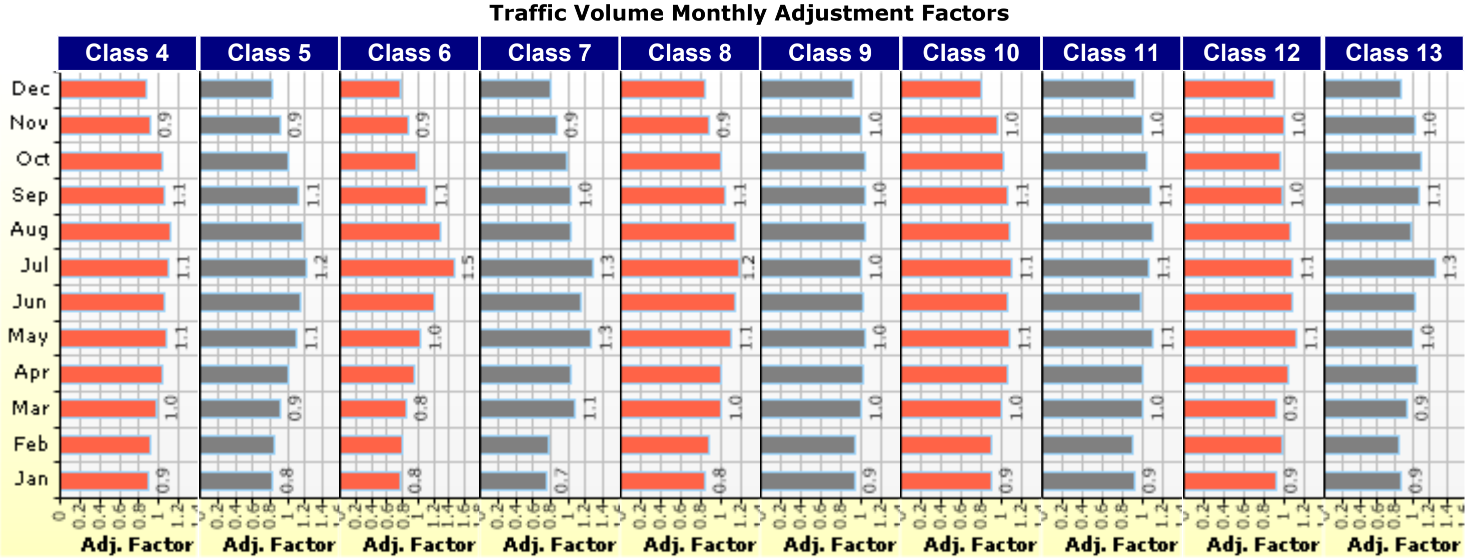








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

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

Truck Distribution by Hour does not apply

Axle Configuration

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

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

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

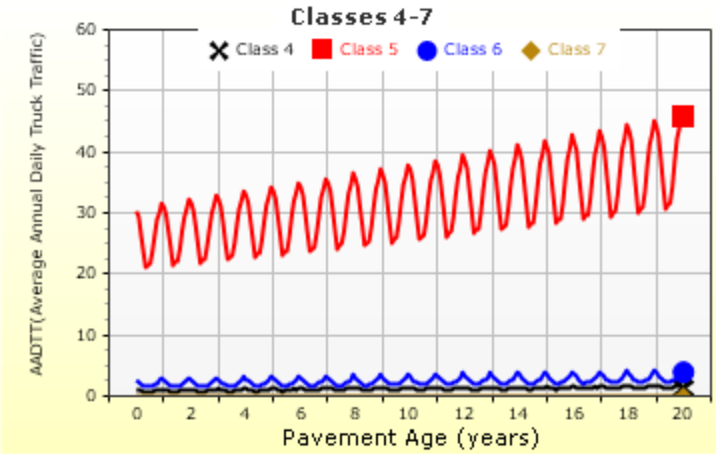
Wheelbase does not apply

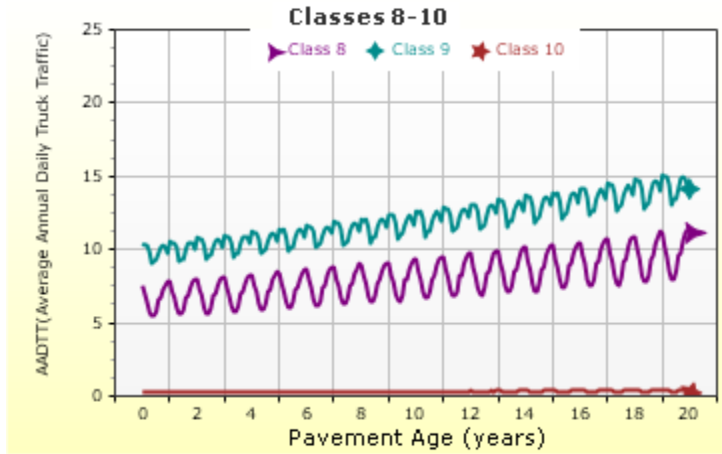
Number of Axles per Truck

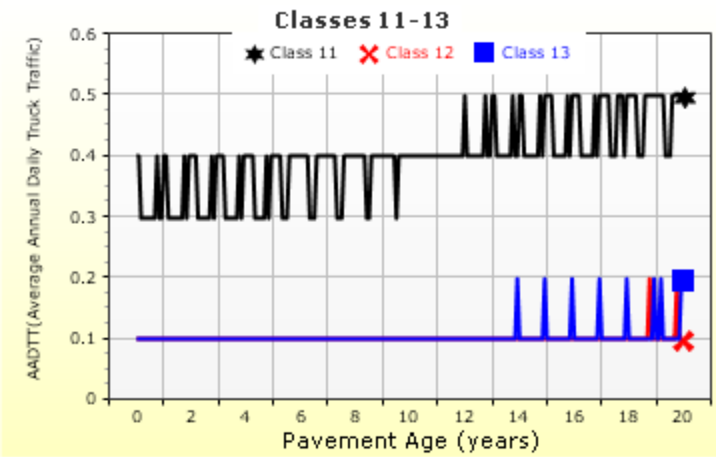
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

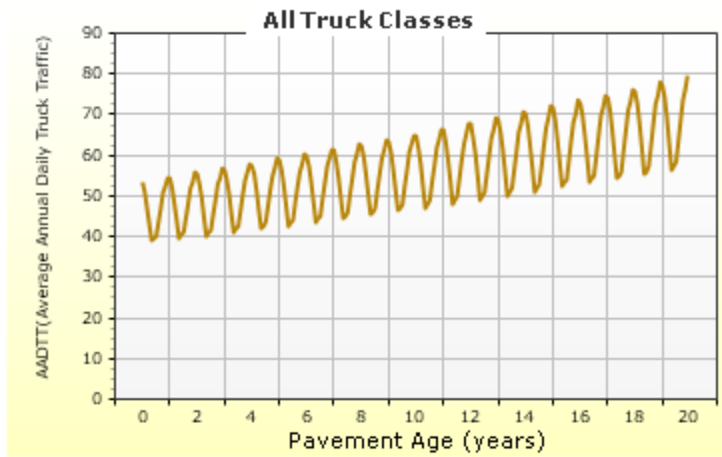
AADTT (Average Annual Daily Truck Traffic) Growth

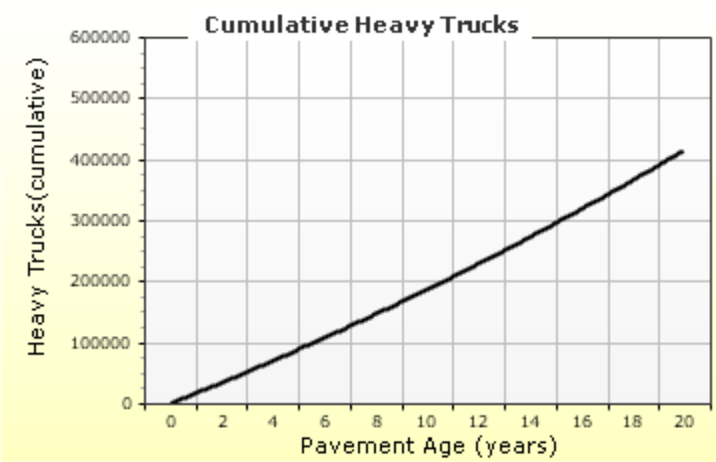
*** Traffic cap is not enforced**







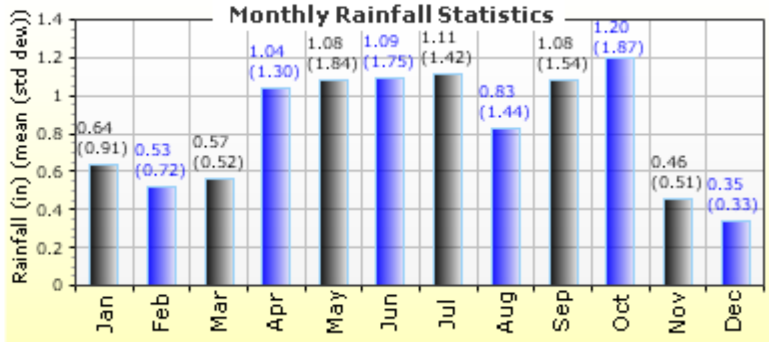




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
EAGLE CO, CO	39.64300 -106.91800 6535

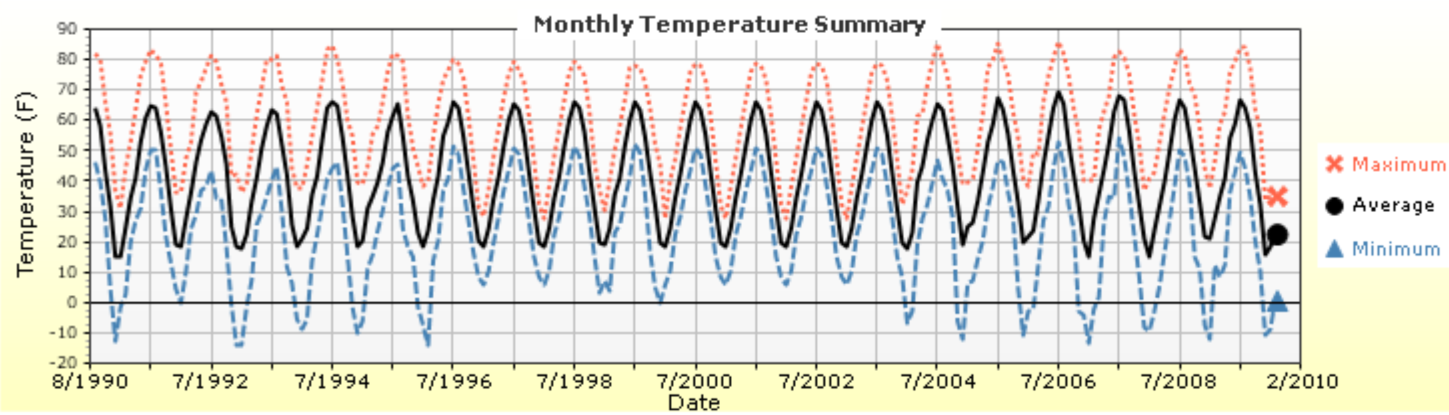


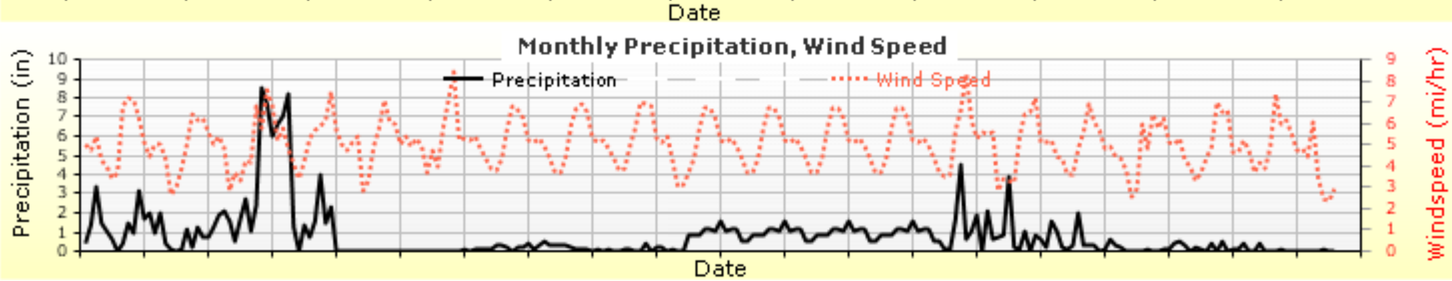
Annual Statistics:

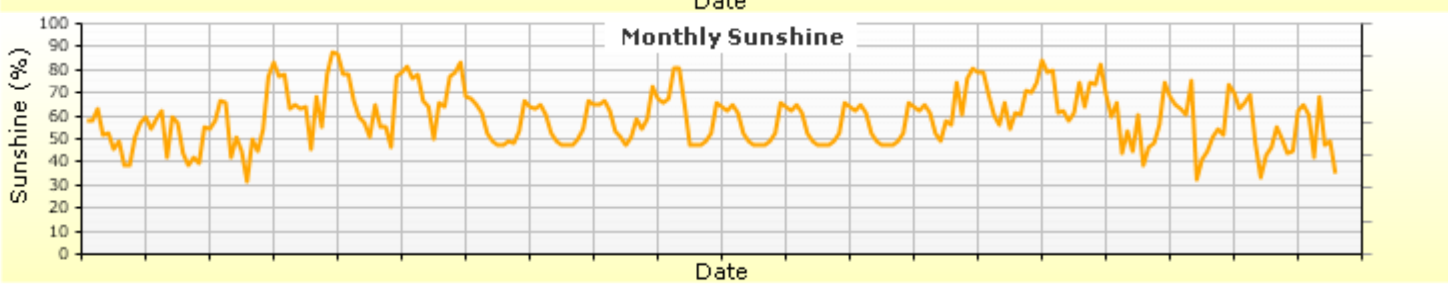
Mean annual air temperature (ºF)	42.99
Mean annual precipitation (in)	9.96
Freezing index (ºF - days)	1046.13
Average annual number of freeze/thaw cycles:	95.09

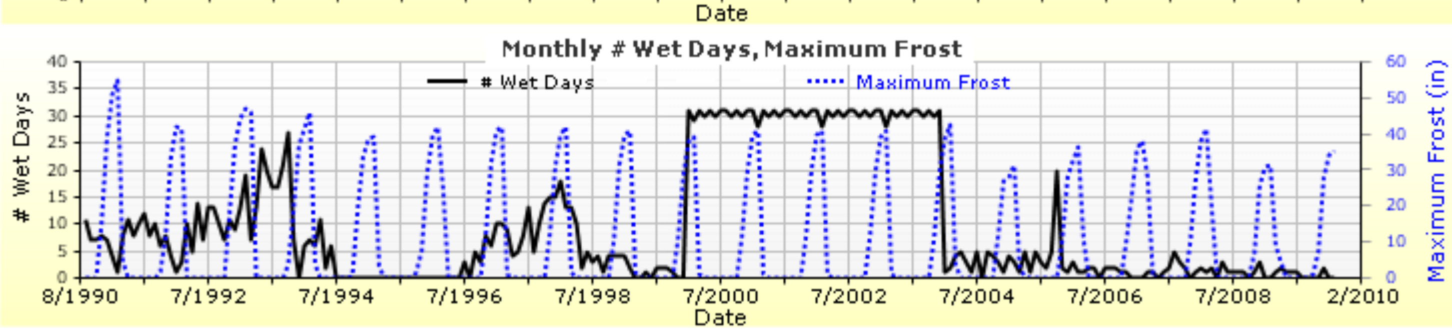
Water table depth (ft) 10.00

Monthly Climate Summary:

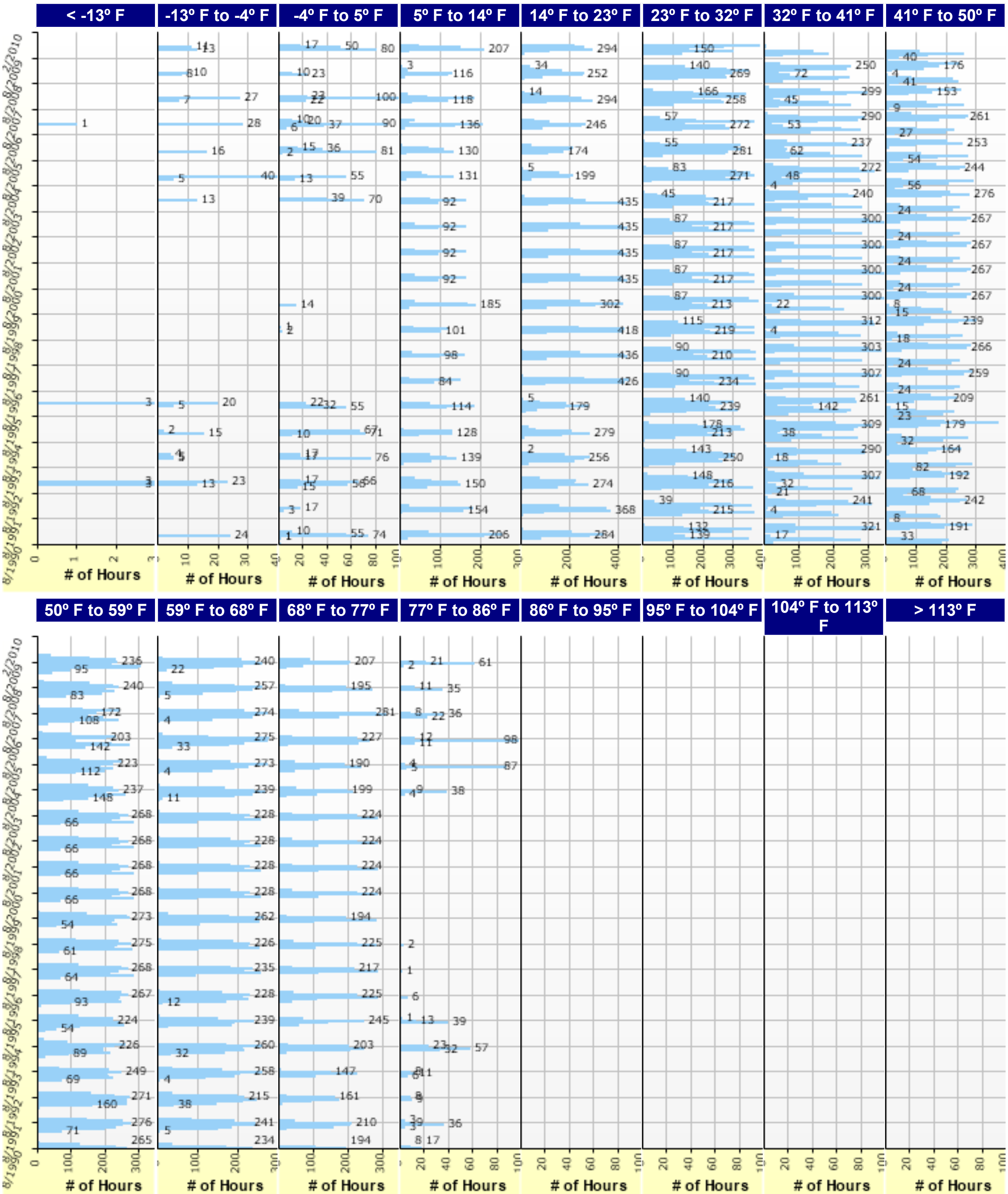








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	True
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

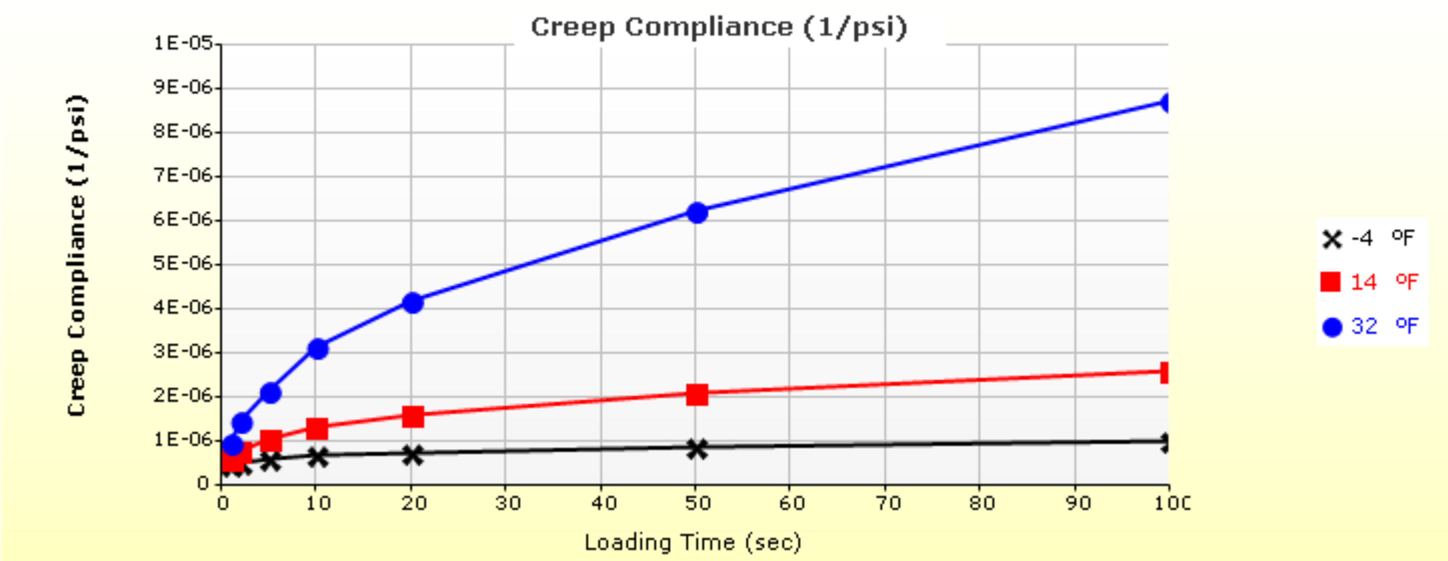
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Flexible : R3 Level 1 SX (75) PG 58-28 United	Flexible (1)	1.00
Layer 3 Non-stabilized Base : A-1-a	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 6 Subgrade : A-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

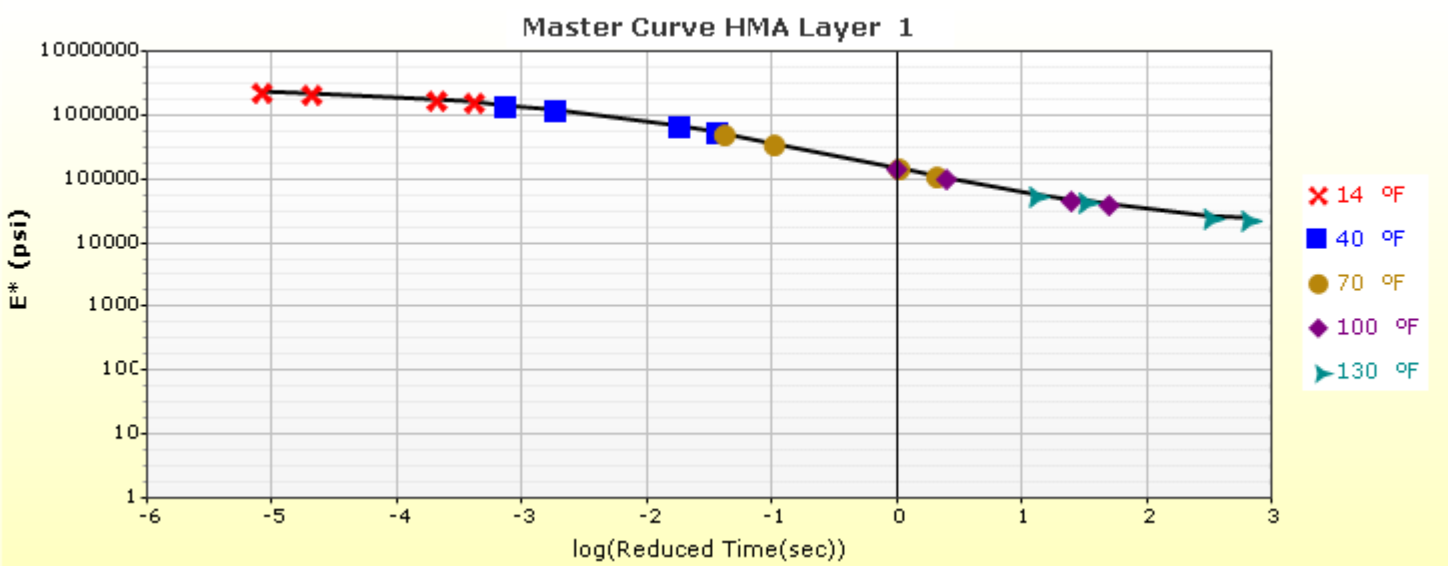
Indirect tensile strength at 14 ºF (psi)	446.00

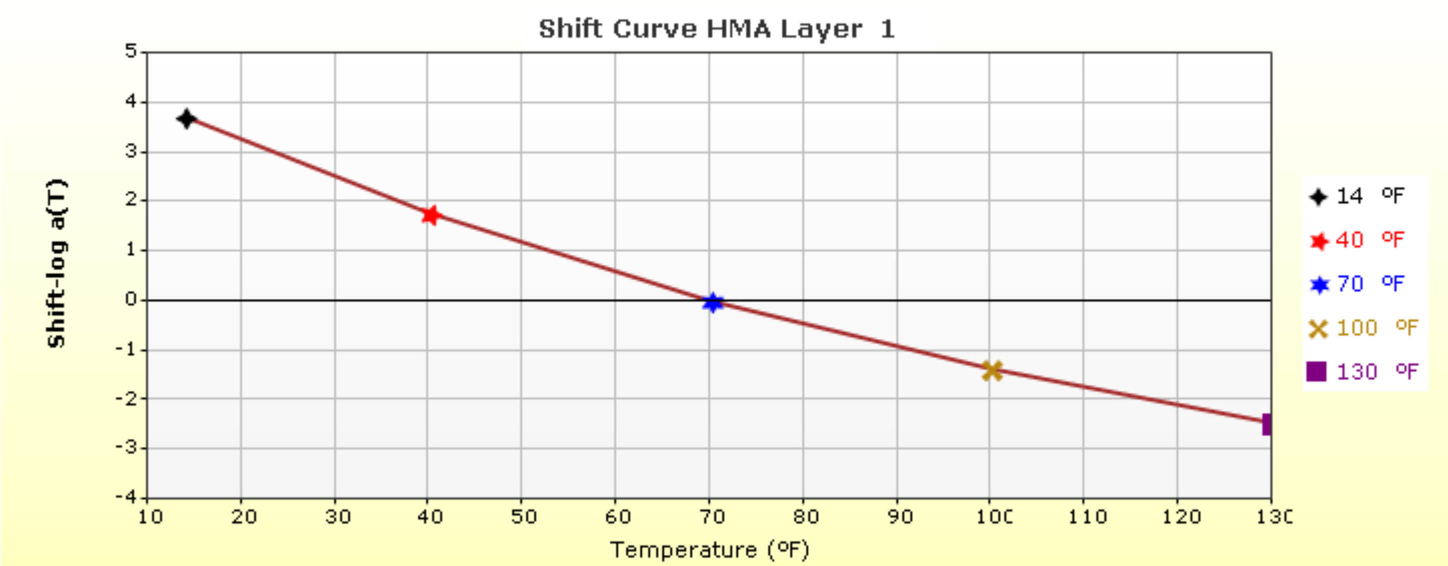
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	14.4

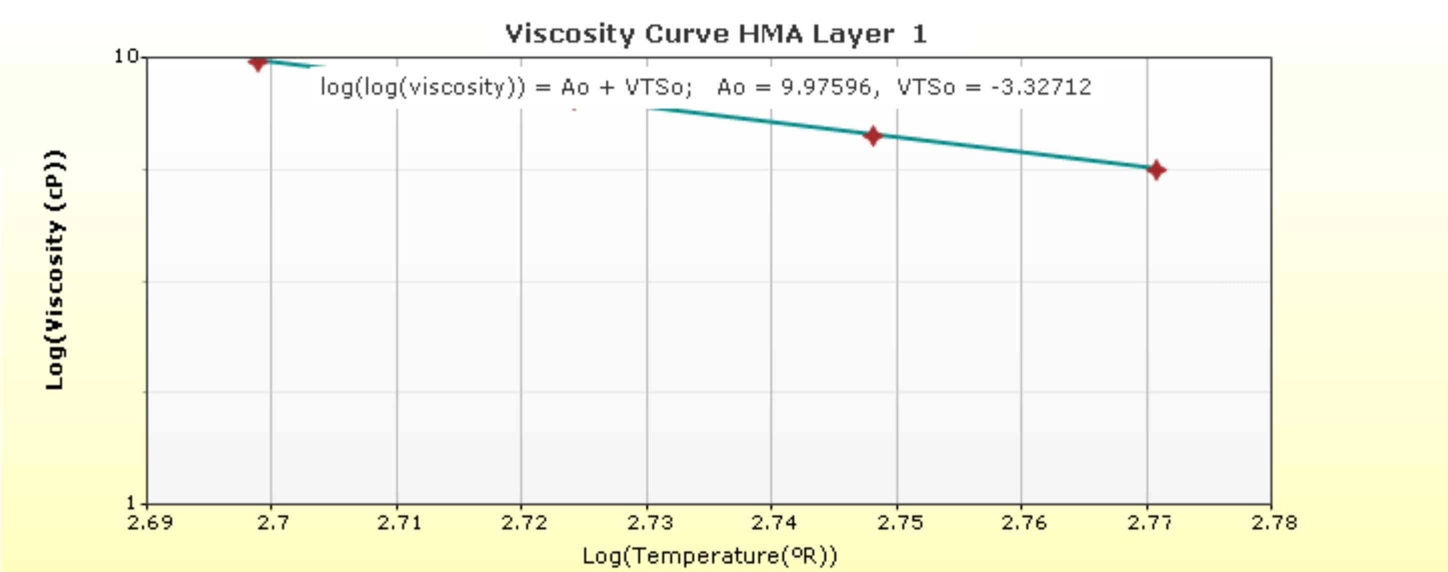
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



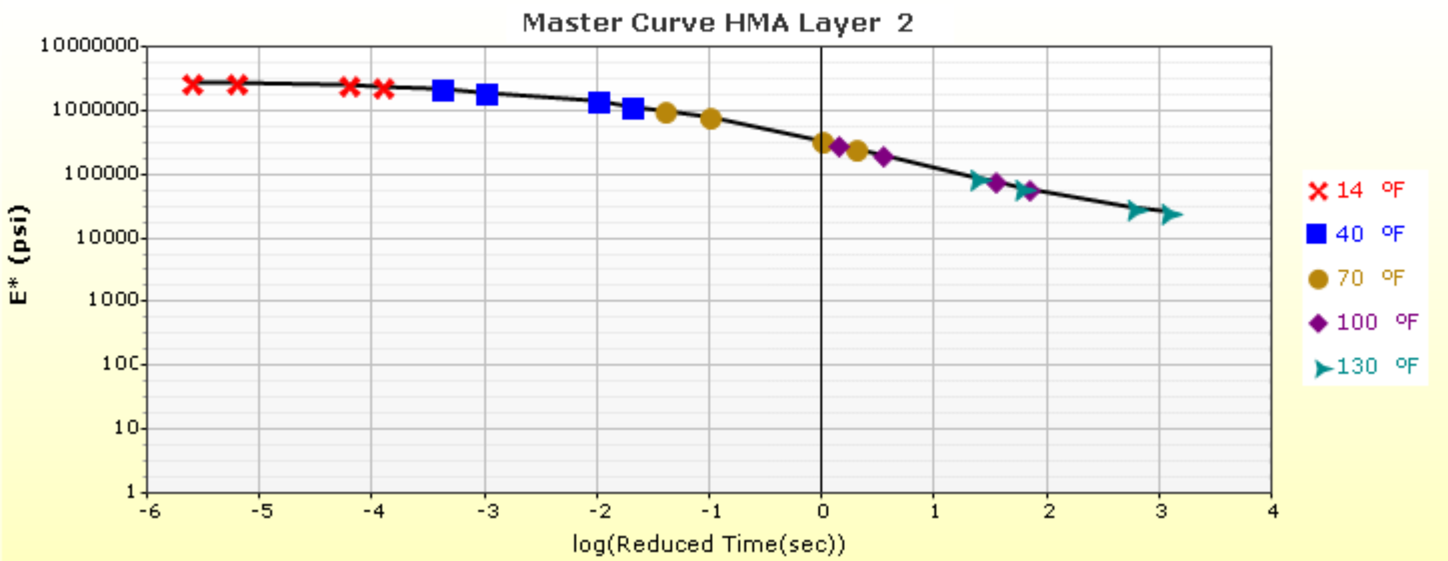
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

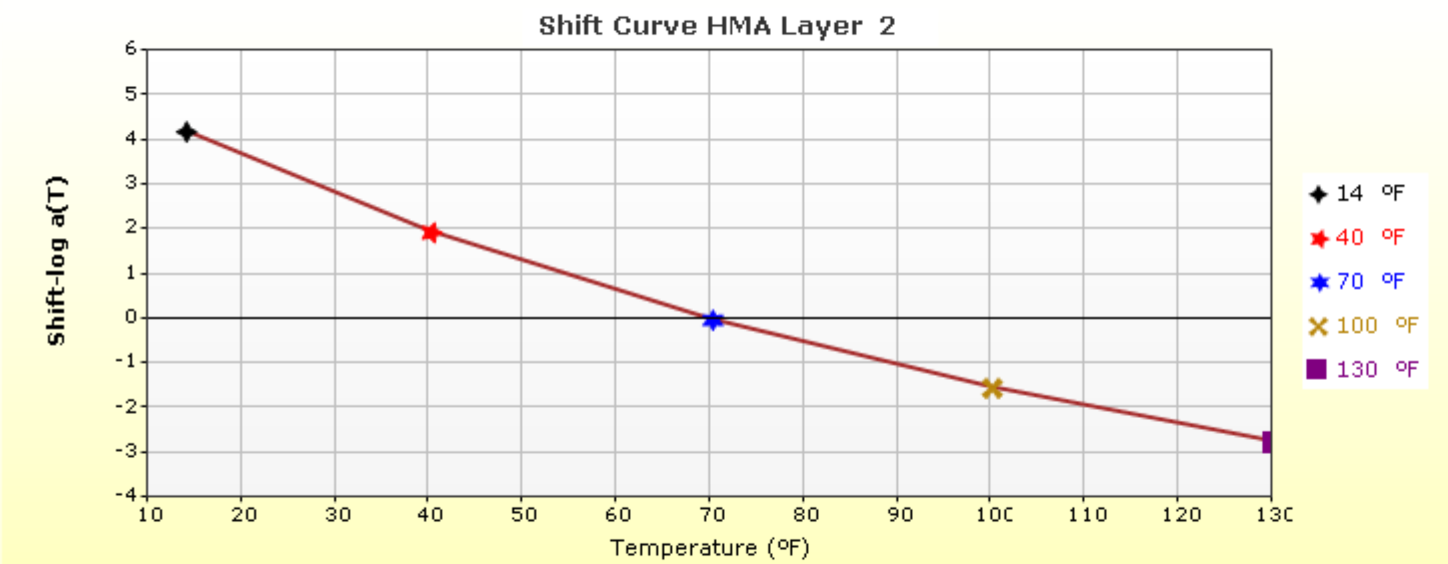


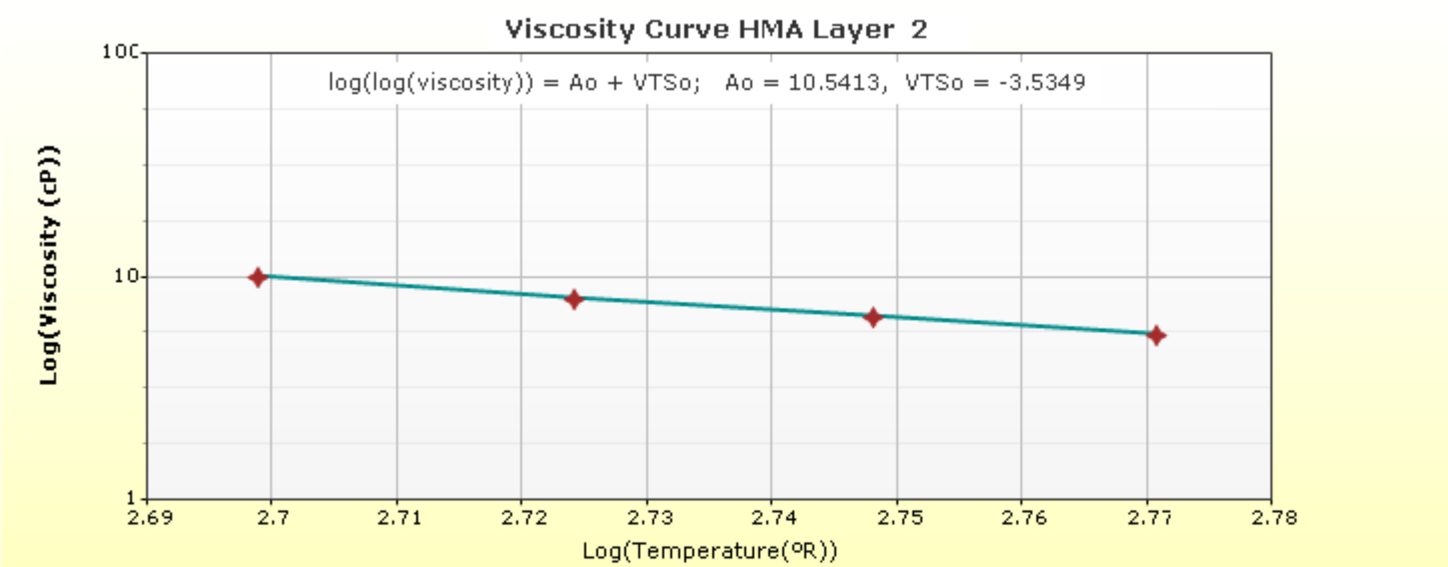




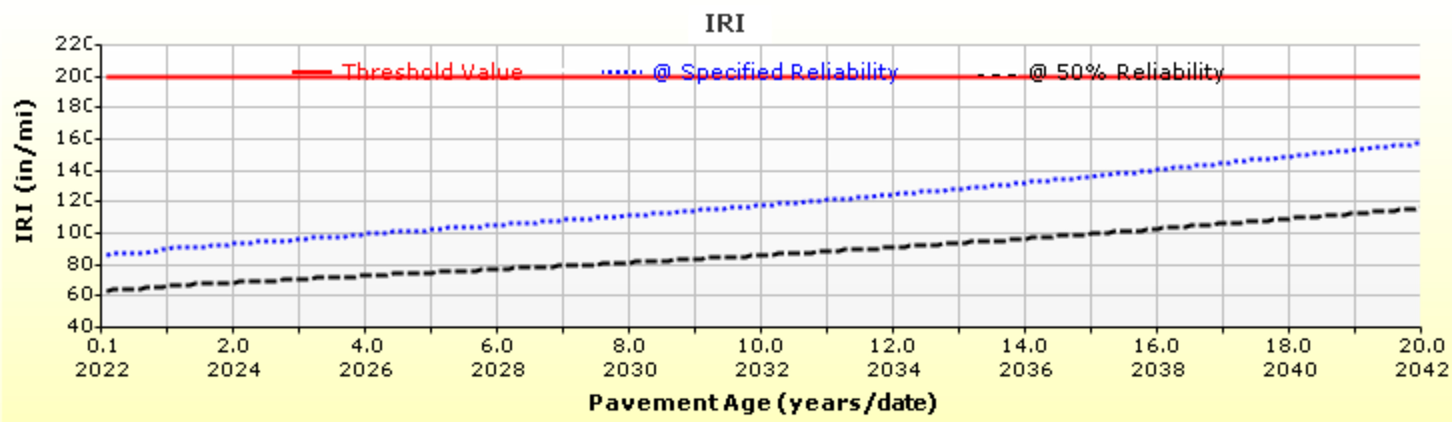
HMA Layer 2: Layer 2 Flexible : R3 Level 1 SX(75) PG 58-28 United

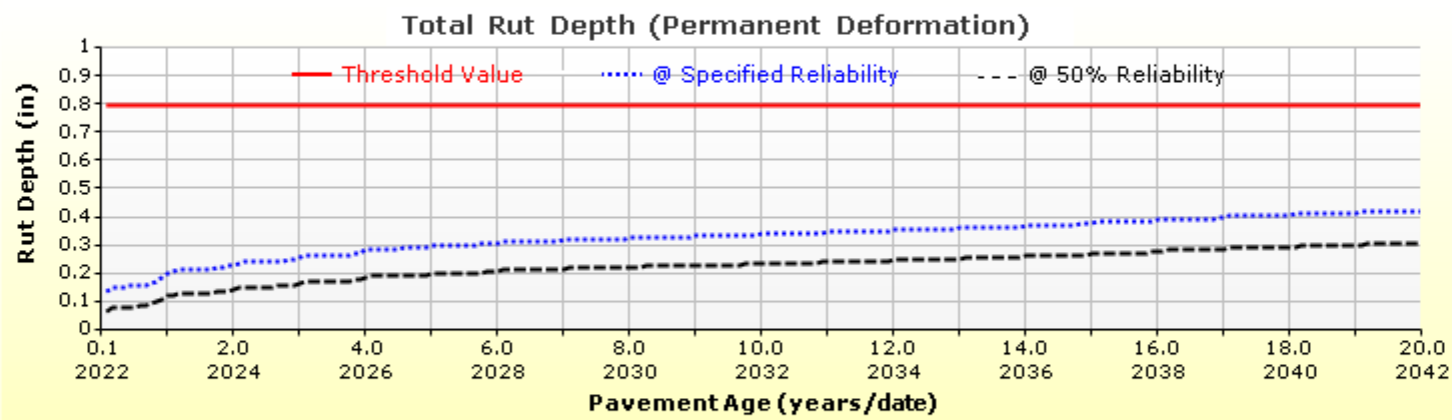


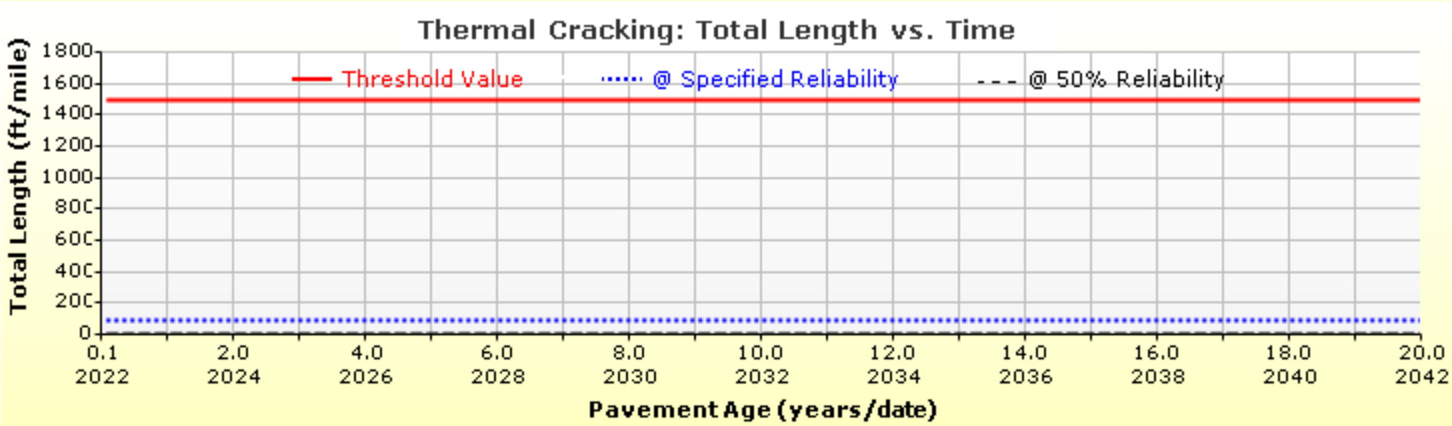


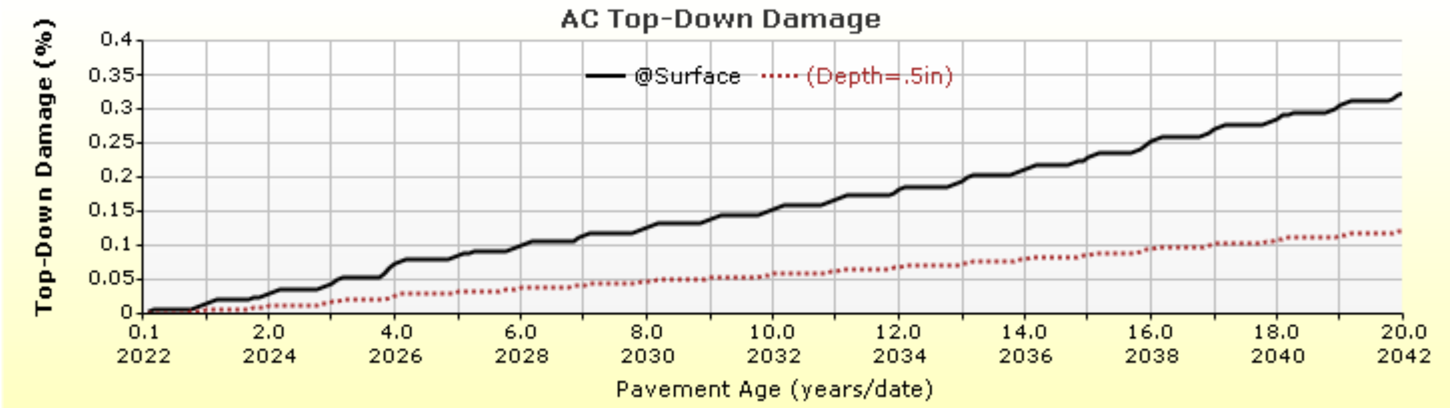


Analysis Output Charts

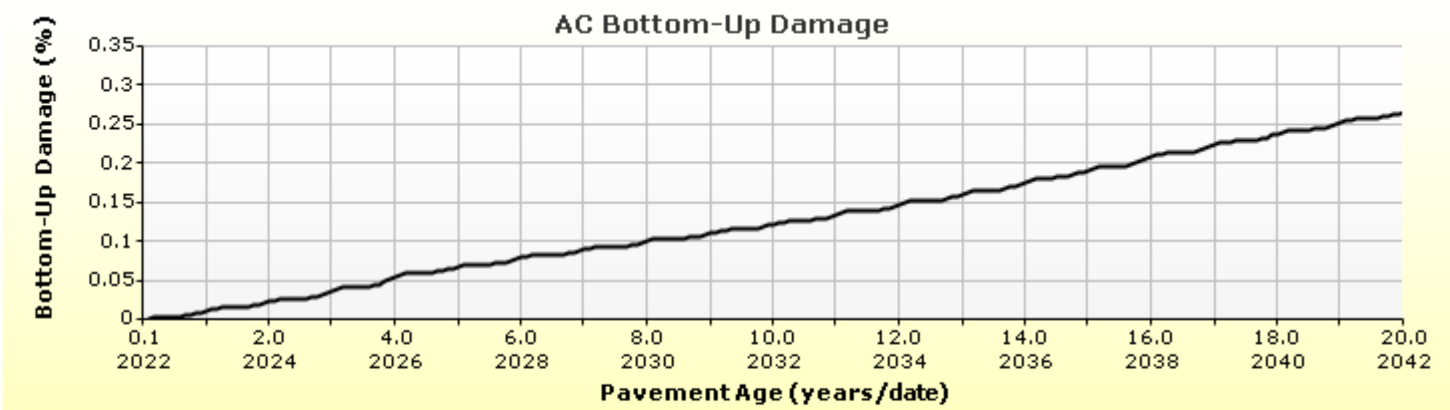




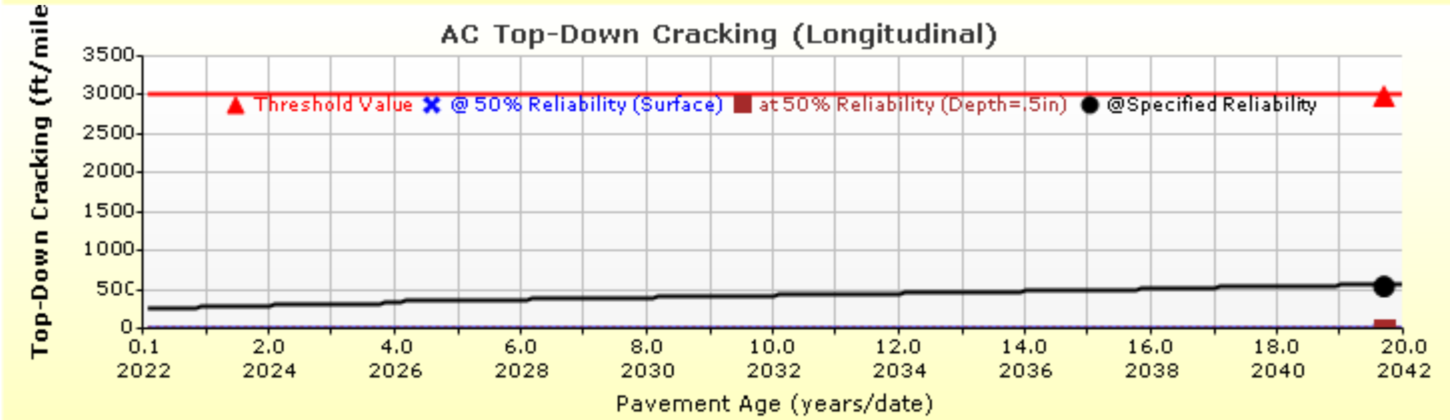




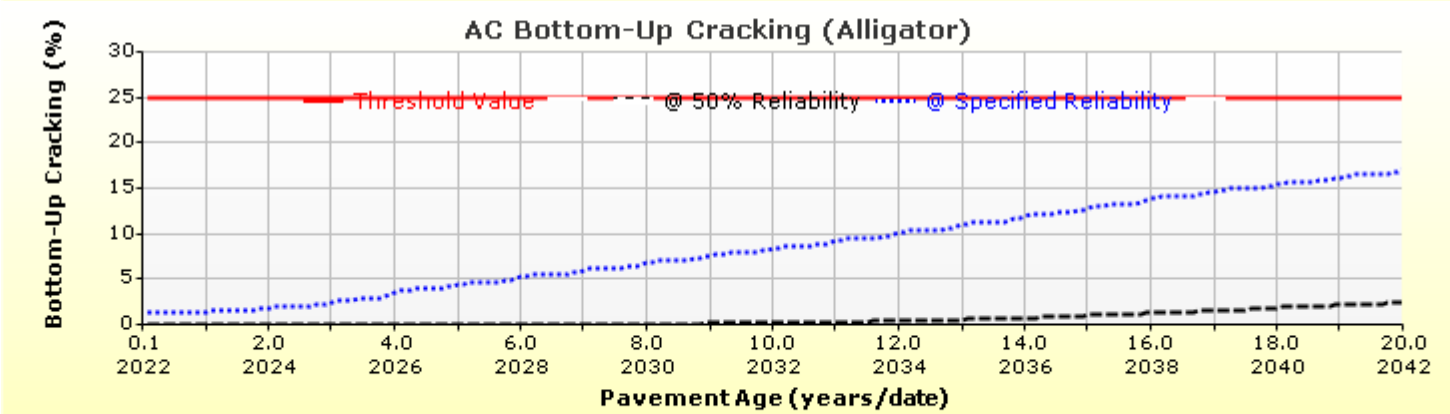
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)



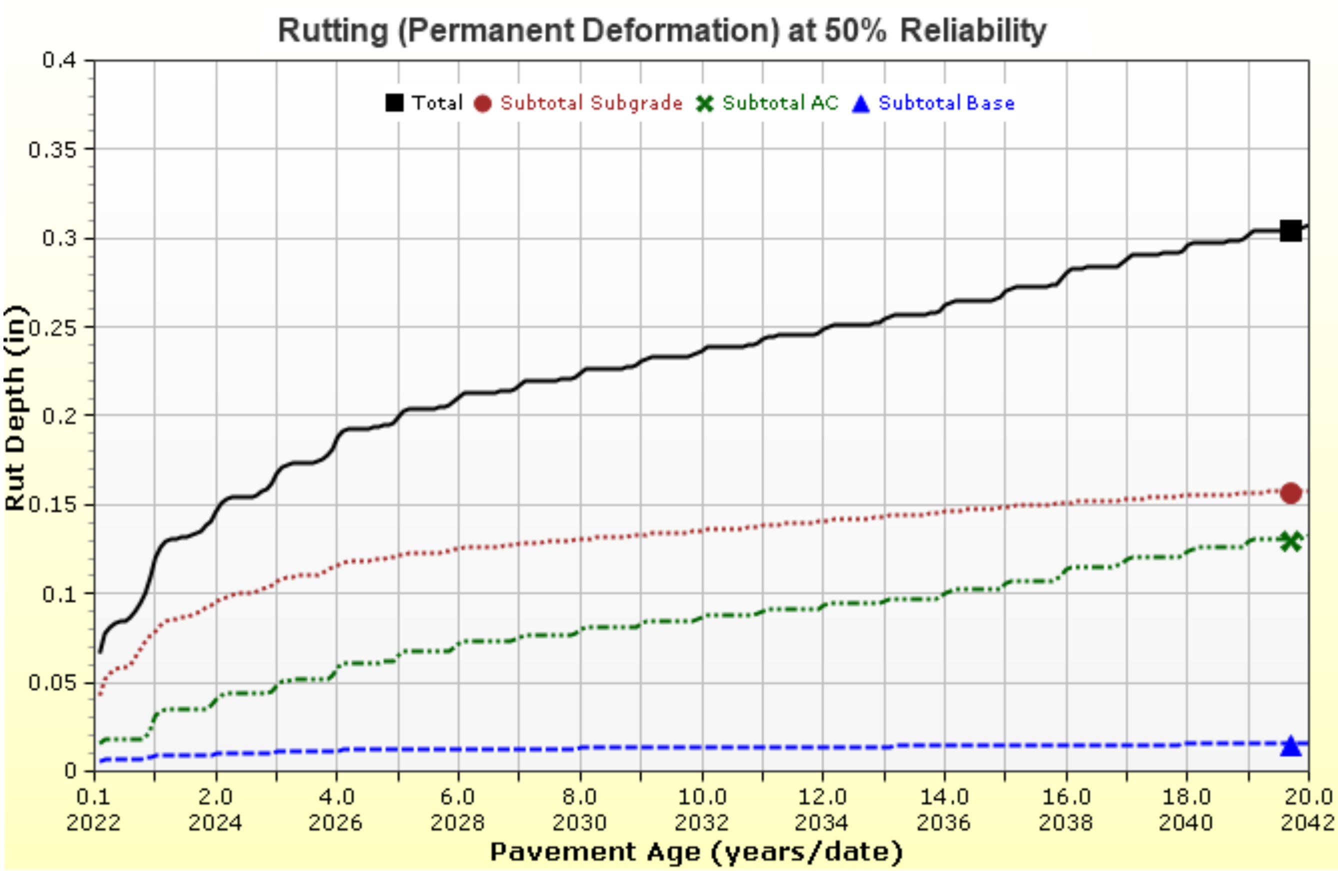
AC Bottom-Up Damage
Bottom-Up Damage (%)
Pavement Age (years/date)

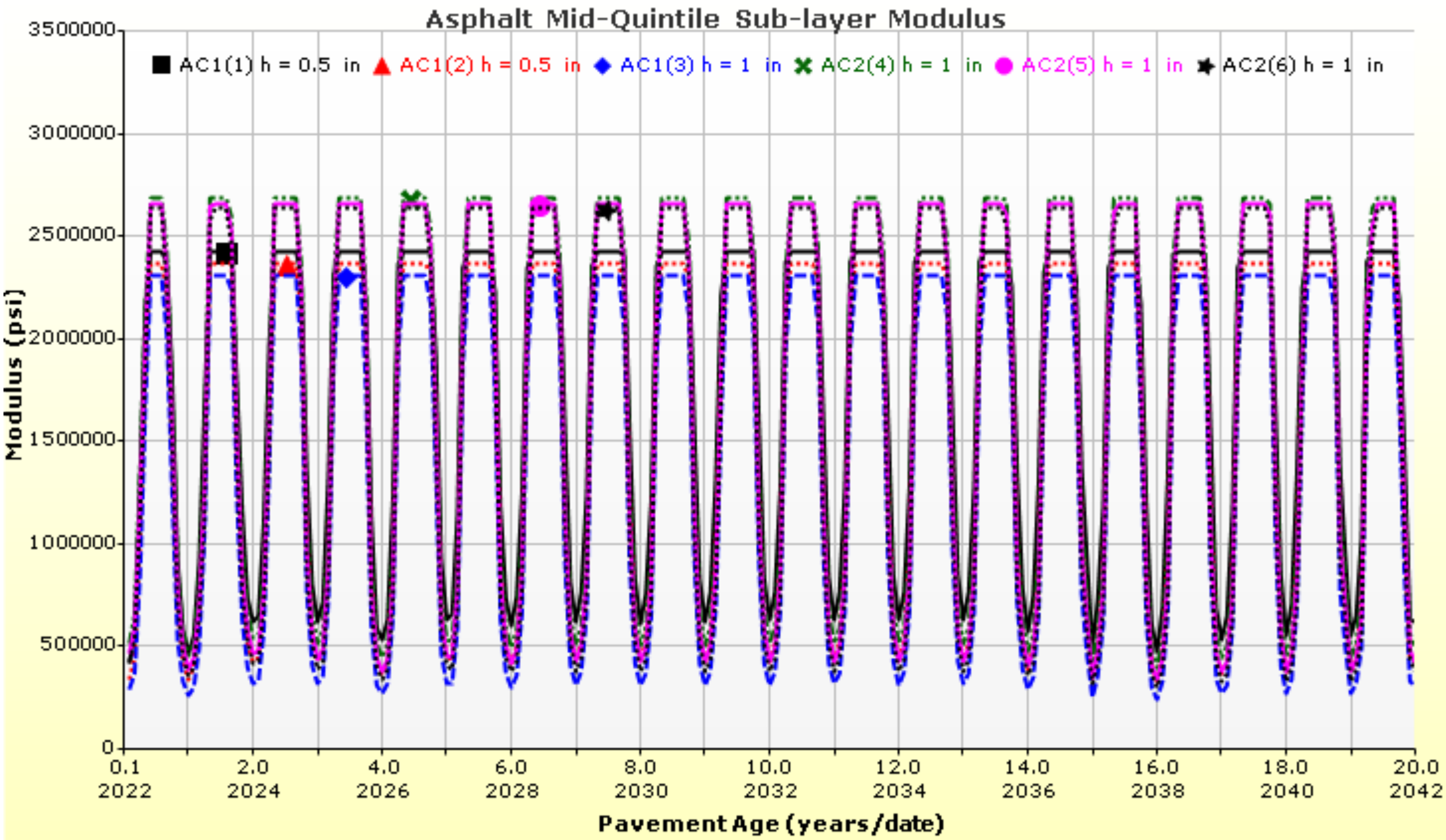


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)

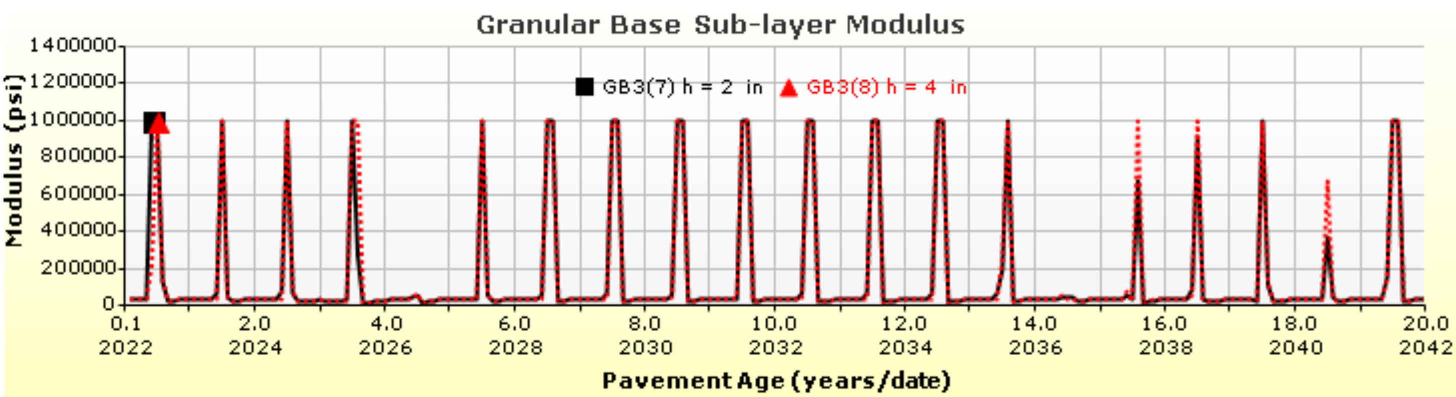


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
Pavement Age (years/date)

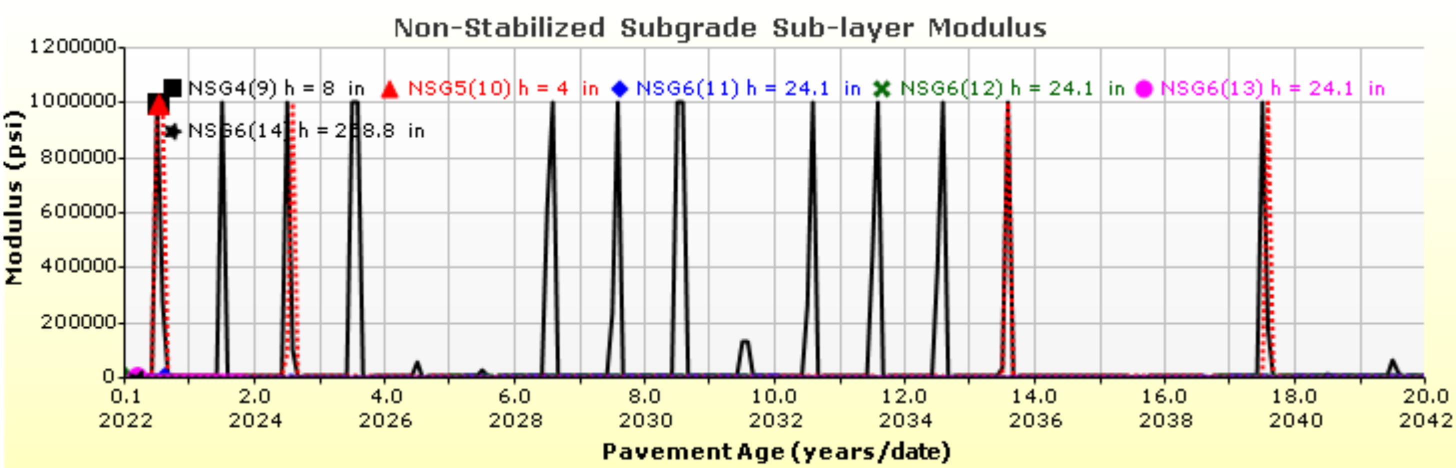

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 1 in
Modulus (psi)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 4 in
Modulus (psi)
1400000
1200000
1000000
800000
600000
400000
200000
0
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG4(9) h = 8 in
NSG5(10) h = 4 in
NSG6(11) h = 24.1 in
NSG6(12) h = 24.1 in
NSG6(13) h = 24.1 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

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 (%)	14.4
Air voids (%)	5.2
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	1291280	1808320	2249869	2393659
40	424726	794978	1289510	1499050
70	98659	198153	405545	529690
100	37405	59422	109288	143776
130	23504	29885	43077	51915

Identifiers

Field	Value
Display name/identifier	R5 Level 1 SX(75) PG 58-34
Description of object	Mix ID # FS1958
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)
136.4	3093	80
147.2	1519	82
158	784	84

Layer 2 Flexible : R3 Level 1 SX(75) PG 58-28 United

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	2067099	2488999	2785899	2873299
40	930800	1472800	2008399	2196999
70	207600	439600	838700	1039200
100	52500	101200	215300	291900
130	24100	35400	60900	78900

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
136.4	2227.6	80
147.2	1068.2	82
158	540.1	84

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.7
Air voids (%)	5.5
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(75) PG 58-28
Description of object	Mix ID # FS1918
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	0

Layer 3 Non-stabilized Base : A-1-a

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)
22000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
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 4 Subgrade : A-2-6

Unbound	
Layer thickness (in)	8.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
8770.0

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

Identifiers

Field	Value
Display name/identifier	A-2-6
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	32.0
Plasticity Index	15.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	122.5
Saturated hydraulic conductivity (ft/hr)	False	7.363e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	10

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	75.5741
bf	0.9351
cf	0.4315
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	24.8
#100	
#80	32.4
#60	
#50	
#40	43.5
#30	
#20	
#16	
#10	59.4
#8	
#4	67.2
3/8-in.	78.8
1/2-in.	83.3
3/4-in.	90.4
1-in.	94.5
1 1/2-in.	97.7
2-in.	99.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 5 Subgrade : A-2-6

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)
8770.0

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

Identifiers

Field	Value
Display name/identifier	A-2-6
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	32.0
Plasticity Index	15.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	121.9
Saturated hydraulic conductivity (ft/hr)	False	7.651e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	10

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	75.5741
bf	0.9351
cf	0.4315
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	24.8
#100	
#80	32.4
#60	
#50	
#40	43.5
#30	
#20	
#16	
#10	59.4
#8	
#4	67.2
3/8-in.	78.8
1/2-in.	83.3
3/4-in.	90.4
1-in.	94.5
1 1/2-in.	97.7
2-in.	99.4
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 6 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)
5350.0

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

Identifiers

Field	Value
Display name/identifier	A-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 130.3674
Bf2: 1
Bf3: 1.217799

AC Rutting (using Multilayer Calibration)

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

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

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

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

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: 1	Bc2:1

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

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 0.021	c2: 2.35	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))		

CSM Cracking

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

C1: 1	C2: 1	C3: 0	C4: 1000
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

Important Information

About Your Geotechnical Report

IMPORTANT INFORMATION

IMPORTANT INFORMATION

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors that were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas

IMPORTANT INFORMATION

not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary, because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

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READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland.