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

DRAFT

GEOTECHNICAL AND PAVEMENT DESIGN REPORT

US 6 West Edwards Improvement Design

EAGLE COUNTY, CO

SHANNON & WILSON

April 2021

Shannon & Wilson No: 101726-200

PAGE INTENTIONALLY LEFT BLANK FOR DOUBLE-SIDED PRINTING

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

Subject: GEOTECHNICAL AND 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

Aaron L. Leopold, PE
Senior Geotechnical Engineer

Gregory R. Fischer, PhD, PE
Senior Vice President

ALL:GRF:DAA/

CONTENTS

CONTENTS

Exhibits

Figures

Appendix

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 geotechnical recommendations for construction. Our services were conducted in general accordance with our proposal to Felsburg Holt & Ullevig (FHU), dated July 30, 2019. Under this agreement we:

- Performed a subsurface investigation, including observation and logging of 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 geotechnical and pavement design aspects of the project; and
- Prepared this 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

The limits of the Project along US 6 extend from 1,000 feet west of the Hillcrest Drive intersection to 1,500 feet east of the 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. Alternatives will be considered to best accommodate vehicular, bicycle, and pedestrian movements at the intersection. 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 understand the proposed improvements may require roadway cuts up to 6 feet below existing grade. A cut retaining wall is proposed along the south side of the road, west of the proposed roundabout. The wall is anticipated to be a cast-in-place (CIP) concrete wall with a maximum exposed height of 4 feet.

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 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.

4.2 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.

4.3 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.

4.4 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 Seismic Hazards

Colorado is comprised of areas of low to moderate potential for damaging earthquakes. It is not possible to accurately estimate the timing or location of future earthquakes, because the occurrence of earthquakes is relatively infrequent and the historical earthquake record in Colorado is short (about 140 years). The nearest active fault to the site is the Frontal Fault, located approximately 25 miles east of Edwards. The Frontal Fault is north-northwest striking and primarily a high angle, normal fault located approximately 30 miles east of the Project. It forms the eastern margin of the Gore and Tenmile Ranges. Based on geomorphic features along the fault trace, this fault is suspected to have been active less than 130,000 years ago based on geomorphic features along the fault trace (Widmann, 1997). Because of the distance from the site to this fault, the potential for ground surface fault rupture along the alignment is low.

Liquefaction may occur in loose, saturated, cohesionless soils when subjected to earthquake ground shaking. Based on the blowcounts and the relatively low peak ground acceleration (PGA) for this area, it is our opinion that the risk of liquefaction is low. Design considerations for seismic design are discussion in Section 6.2.

5.2 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 and short retaining walls) 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.

5.3 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.

5.4 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.

5.5 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, 2019) 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 the proposed CIP wall.

6 GEOTECHNICAL AND PAVEMENT DESIGN

6.1 Design Criteria

We understand the selected wall will likely be a CIP retaining structure. All walls should be designed and constructed in accordance with AASHTO (2020) and the CDOT LRFD Bridge Design Manual (CDOT, 2020).

6.2 Design Ground Motion Parameters

Using the AASHTO (2020) criteria and based on subsurface conditions encountered in our borings along the proposed wall alignment (assuming that similar conditions are present from the maximum depth of our boring to a depth of 100 feet), Site Class D is recommended.

Ground motion parameters were determined for the project site using the USGS U.S. Seismic Design Map Web Application (USGS, 2020) and procedures recommended by AASHTO (2020). Recommended seismic design ground motion parameters are summarized below.

Exhibit 6-1: Recommended Seismic Design Parameters

Design Parameter	Recommended Value
Peak Ground Acceleration (PGA_B)[1]	0.085
Site Class	D
Short-period Spectral Acceleration, S_s	0.171
Long-period Spectral Acceleration, S_1	0.041
Site Factor, F_{pga}	1.6
Site Factor, F_a	1.6
Site Factor, F_v	2.4
Peak Design Spectral Acceleration, A_S	0.136
Short-period Design Spectral Acceleration, S_{DS}	0.274
Long-period Design Spectral Acceleration, S_{D1}	0.099
T_0	0.072
T_s	0.362
Seismic Zone	1

NOTES:

1 PGA_B refers to peak ground acceleration for a site underlain by Site Class B soil (soft rock).

g = gravity; sec. = seconds

6.3 Global Stability

The proposed wall will have a maximum exposed height of about 4 feet. Global stability analyses indicate that the wall will meet the minimum factor of safety (FS) specified in the CDOT Geotechnical Design Manual (GDM) (2017), assuming the recommendations herein are incorporated into the wall design. For walls not supporting structural elements, the GDM specifies a minimum FS of 1.3 for static long-term drained conditions, 1.1 for construction conditions, and 1.1 for pseudo-static seismic conditions.

6.4 Backfill Materials and Design Parameters

We recommend backfilling the selected retaining structure with CDOT Class 1 Structure Backfill in the 1H:1V (horizontal to vertical) zone extending from a point 1.5 feet behind the heel of the CIP wall. Recommended design parameters for CDOT Class 1 Structure Backfill are provided below. We assume the walls will be able to deflect 1/1000th the wall height (0.001H) to develop active earth pressure conditions. Based on a review of available documents, the backslope inclination angle is anticipated to vary between horizontal and 2H:1V across the wall alignment. Active earth pressure coefficients have been provided for varied backslope inclinations.

Exhibit 6-2: Recommended Parameters for Backfill Materials

Backfill Material	Design Parameter		Recommended Value
CDOT Class 1 Structure Backfill	Friction Angle, ϕ'		34 deg
	Cohesion, c'		0 psf
	Total Unit Weight, γ		135 pcf
	Static Active Earth Pressure Coefficient	Horizontal Backslope	0.28
		4H:1V Backslope	0.39
		3H:1V Backslope	0.43
		2H:1V Backslope	0.52

NOTES:
1 Earth Pressure coefficients calculated assuming no wall friction (δ = 0 deg.).
deg = degree; pcf = pounds per cubic foot; psf = pounds per square foot

6.5 Groundwater and Drainage

Based on conditions encountered in the subsurface explorations, we anticipate that groundwater will be located more than 10 feet below the base of the proposed wall. Nevertheless, surface water can make its way into the wall backfill, regardless of the permeability of the backfill. The provided earth pressures assume no water pressure.

Therefore, we recommend providing drainage measures that reduce the potential for water to accumulate in the backfill and for hydrostatic pressures to act on the wall face.

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 5.4, 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 regimes and inducing the collapse of soils.

6.6 Wall Embedment

AASHTO (2020) indicates that CIP wall footings be embedded below the frost depth. Based on requirements from Eagle County Building Codes (Town of Eagle 2020), we recommend an embedment of 4 feet below final grade for the CIP wall.

As an alternative to embedding the wall below the frost depth for frost protection, the wall could be embedded 18 inches and the wall subgrade over-excavated to 4 feet below surrounding grade and backfilled with non-frost susceptible (NFS) fill (granular fill with less than 5% fines, such as CDOT Filter Material). To prevent clogging of the NFS material with the native clay subgrade material, the NFS material should be wrapped with a geosynthetic separator fabric. Bearing and Sliding Resistance

We anticipate that the walls will be founded on medium dense, silty or clayey sand subgrade. We recommend a nominal bearing resistance of 7 ksf. AASHTO (2020) recommends a resistance factor 0.45 for CIP walls to be applied to the nominal bearing resistance for the Strength Limit State. For the extreme event, a nominal resistance factor of 1.0 should be used. The bearing resistance value assumes a footing embedment of at least 18 inches and a minimum footing width of 3 feet.

Sliding resistance of the selected wall type can be evaluated assuming a friction angle of 29 degrees for the native silty or clayey sand subgrade material. Per AASHTO (2020), a resistance factor of 0.85 should be applied for sliding analysis of CIP walls. For the extreme event, a resistance factor of 1.0 should be used.

6.7 Surcharge Loads

Surcharge loads such as traffic and construction equipment will induce lateral loads on retaining walls. While not anticipated for this project, lateral loads due to various types of surcharges may be calculated by using the loading diagrams provided in Figure 4 and the earth pressure coefficients provided in Section 6.4.

6.8 Pavement Design

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) (2019a) 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 Table 2.4 and 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 Table 2.4 and 2.6 do 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.

6.8.1 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. Appendix C contains our calculations and the assumptions made of how the below traffic loading was determined.

Exhibit 6-3: Pavement Analysis Design Traffic Loading

Roadway	2022 AADTT[1] (truck per day)	Growth[2] Rate (%)	Directional Distribution Factor (%)	No. Lanes in Design Direction	Lane Distribution Factor (%)	Traffic Speed (mph)
US 6	432	2.57	60	1	100	35
Roundabout	305	2.57	100	1	100	15
Hillcrest Drive	78	2.0	60	1	100	35

NOTE:

1 A paving date of 2022 is anticipated.

2 Annually compounded.

AADTT = Average Annual Daily Truck Traffic; mph = Miles Per Hour; No. = Number

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.

6.8.2 Pavement Subgrade Conditions

The subgrade strength for the Project was evaluated by using Hveem stabilometer (R-value) test results. A bulk sample from surficial, silty sand (AASHTO soil classification A-1-b) was tested from boring SW-03 and resulted in an R-value of 77. We understand portions of the roadway grades will be lowered and our explorations indicate a more cohesive soils such as clayey sand (AASHTO soil classifications A-2-6) and sandy lean clayey (AASHTO soil classifications A-6) could be exposed below the pavements. For our analysis, we assumed the majority of the exposed pavement subgrade will consist of A-2-6 soils.

The design subgrade strength was determined from a correlation from R-value to resilient modulus developed by CDOT and provided in the PDM, but the CDOT correlation limits the R-value to a value of 50. For design, we used this limiting R-value of 50 and the corresponding subgrade resilient modulus of 10,000 pounds per square inch in our pavement analysis. If lean clays are encountered during excavation, we recommend a minimum overexcavation of 24 inches and replacement with R-value of 50 sand. We recommend assuming overexcavation will be required over 20 percent of lowered grade areas for cost estimating purposes. For areas where the roadway will be raised, placed fill under the roadway section should meet the soil properties above.

6.8.3 Recommended Pavement Section

The recommended pavement are summarized below. Each proposed section exceeds performance criteria provided in Tables 2.4 and 2.5 of the PDM for minor arterials. 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	Alt. A	Alt. B	Alt. C[1]
US 6	5-1/2 in. HMA 6 in. Class 6 ABC	7 in. Full Depth HMA	7-1/2 in. PCC 6 in. Class 6 ABC
Roundabout	5-1/2 in. HMA 6 in. Class 6 ABC	8 in. Full Depth HMA	7-1/2 in. PCC 6 in. Class 6 ABC
Hillcrest Drive	4 in. HMA 6 in. Class 6 ABC	5 in. Full Depth HMA	-

NOTE:

1 PCC paving alternative assumes: (a) transverse joints with a 15 feet maximum length, (b) 1-inch 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

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.

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 in reduced bearing capacity, increased settlement, and 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 along the wall alignment. 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 Subgrade Preparation for Walls

Proper subgrade preparation is required for adequate performance of retaining wall foundations. In fill or at-grade areas, the exposed surface should be cleared, stripped, and proof-rolled in accordance with the CDOT Standard Specifications (CDOT, 2019b). Where proof rolling is not feasible (e.g., constrained excavations), the subgrade should be probed to evaluate its suitability. The exposed subgrade should then be scarified to a depth of 8 inches and compacted to a hard/dense and unyielding condition and to at least 95% of the maximum dry density, as determined by AASHTO T180 for granular soils or AASHTO T99 for cohesive soil.

Any areas that are delineated to be soft, loose, or yielding during proof-rolling should be removed and replaced with CDOT Class 1 Structure Backfill. These areas should be over-excavated and replaced with CDOT Class 1 Structure Backfill to achieve a passing proof roll. 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 BX1300, Tensar triaxial TX5, or equivalent) should be installed at the base of the over-excavation before backfilling.

7.4 Fill Materials, Placement, and Compaction

Wall backfill materials should consist of CDOT Class 1 Structure Backfill. All fill materials should be placed and compacted in accordance with the CDOT Standard Specifications (CDOT, 2019b). Compaction of backfill adjacent to walls can result in higher lateral earth pressures against the wall. Heavy equipment should stay behind a line extending upward from the base of the walls at 0.5H:1V, or 3 feet from the wall, whichever is greater. The backfill within this zone should be compacted with hand-operated equipment.

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 (2019b). Based on the binder selection procedure provided in the 2020 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.

We recommend using a Grade SX mix for upper-most lift and Grade S for lower lifts. For the Grade SX mix, CDOT recommends that lift thickness range between 1-1/2 and 3 inches; for the Grade S mix CDOT recommends a lift thickness between 2-1/4 and 3-1/2 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 (2019b).

7.5.3 Aggregate Base Course (ABC)

We recommend using CDOT Class 6 ABC from the most recent CDOT Standard Specification (2019b). 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

American Association of State Highway and Transportation Officials (AASHTO), 2013, AASHTOWare Pavement ME (Mechanistic-Empirical) Design, v. 2.3.1 (Revision 66): Washington, D.C., AASHTO.

AASHTO, 2020, AASHTO LRFD bridge design specifications, Customary U.S. units, 9th edition: Washington D.C., American Association of State Highway and Transportation Officials.

Colorado Department of Transportation (CDOT), 2017, CDOT Geotechnical Design Manual, dated April 24, available to download at https://www.codot.gov/business/designsupport/materials-and-geotechnical/programs/geotech/docs/cdot-gdm.

Colorado Department of Transportation (CDOT), 2020, CDOT Online Transportation Information System (OTIS), available at http://dtdapps.coloradodot.info/otis; accessed July 16, 2020.

CDOT, 2019a, 2020 M-E Pavement Design Manual, available at: https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/pdm.

CDOT, 2019b Standard Specifications for Road and Bridge Construction, available to download at https://www.codot.gov/business/designsupport/cdot-construction-specifications/2019-construction-specifications.

Federal Highway Administration (FHWA), 2020, LTPP InfoPave: Tools: LTPPBind Online, accessed July 21, 2020, available at: https://infopave.fhwa.dot.gov/Tools/LTPPBindOnline.

Felsburg Holt & Ullevig (FHU), 2019, US 6 West Edwards Preliminary Traffic Analysis, Hillcrest Drive to Arrow Grass, Edwards, Colorado, Final Report; FHU Reference No. 118339-01, dated March.

Lidke, D.J., 2008, Geologic map of the Wolcott Quadrangle, Eagle County, Colorado, US Geological Survey, Publication I-2656, scale 1:24,000.

Roberge, P.R., 2012, Handbook of Corrosion Engineering, Second Edition: McGraw-Hill, New York, New York.

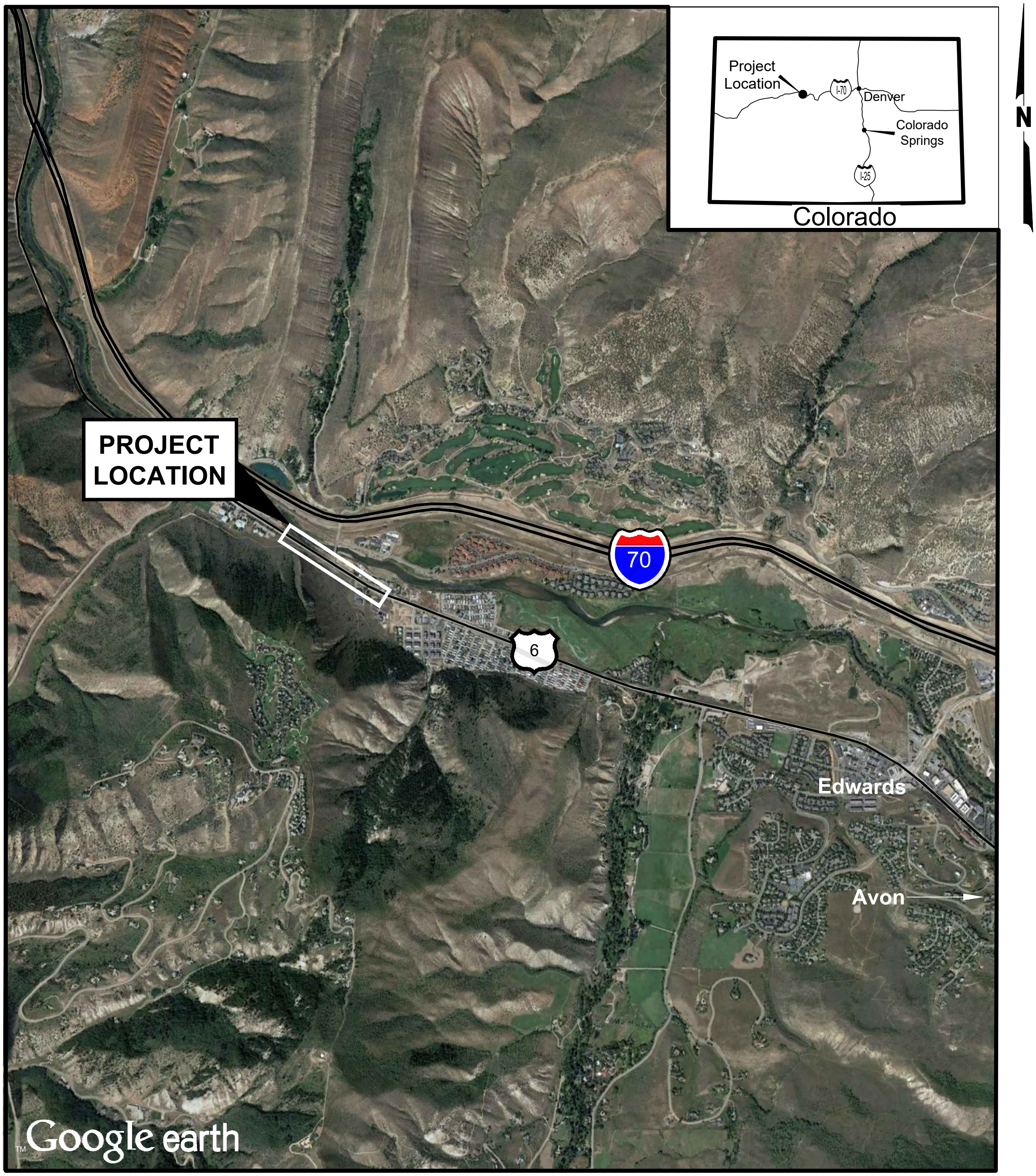
Town of Eagle, Building Code, Town of Eagle Website, https://www.townofeagle.org/138/Building, accessed 08/03/2020.

Tweto, Ogden, Moench, R.H., and Reed, J.C., 1978, Geologic map of the Leadville 1 degree x 2 degrees quadrangle, northwestern Colorado: U.S. Geological Survey, Miscellaneous Investigations Series Map I-999, scale 1:250,000.

White, J.L. and Greenman, J.L., 2008, Collapsible Soils in Colorado: Colorado Geological Survey Engineering Geology 14, 108p.

White, J.L., 2012, Colorado map of potential evaporite dissolution and evaporite karst subsidence hazards, Colorado Geologic Survey on-line publication, 24 p., GIS Data, scale 1:500,000.

Widmann, B.L., compiler, 1997, Fault number 2302, Frontal fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf, accessed 03/04/2020



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

April 2021 101726-200

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 1

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

LEGEND

SW-01 Boring Designation and Approximate Location

Approximate 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

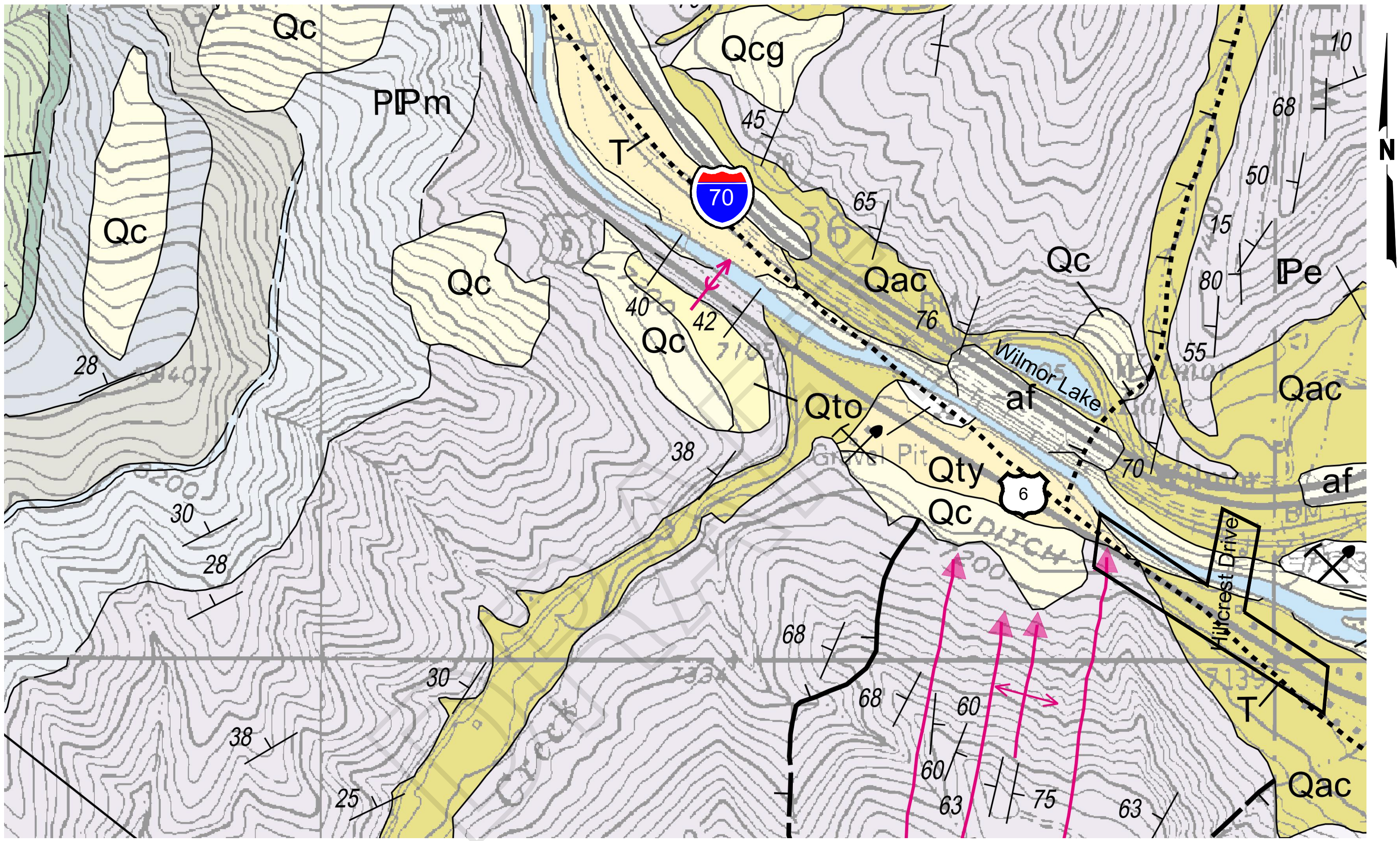
SITE AND EXPLORATION PLAN

April 2021 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: 09-01-2020 Login: all



Approximate Scale in Feet (0, 1,000, 2,000)

— Approximate 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

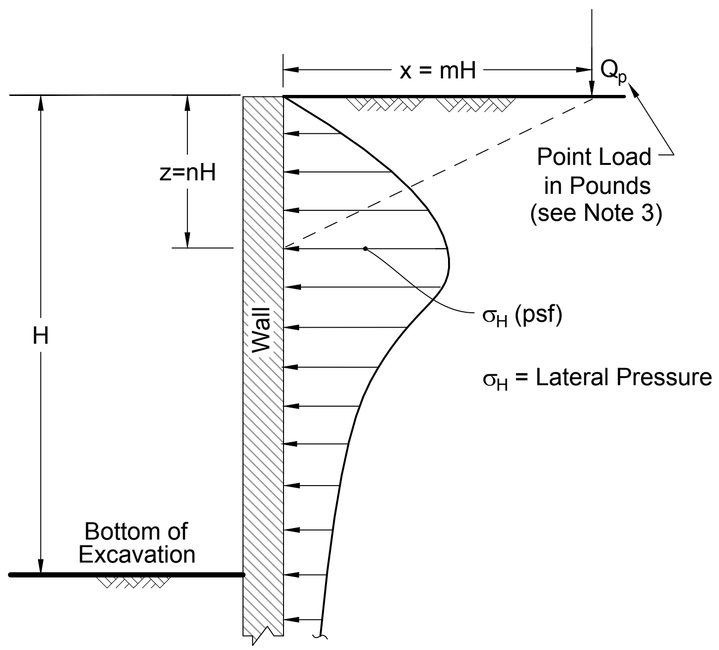
GEOLOGIC MAP

April 2021 | 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 3

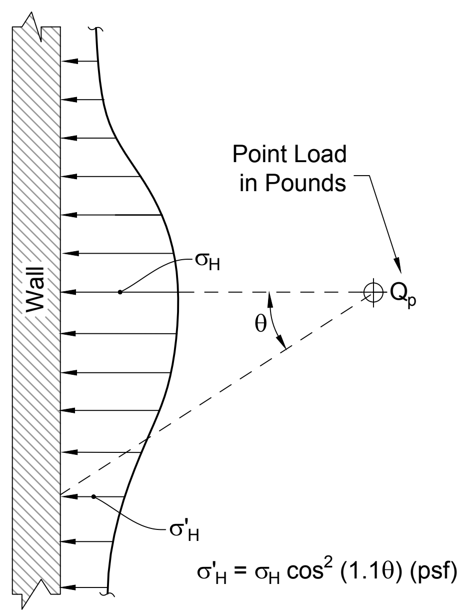
Filename: I:\EF\DEN\101000s\101726 US 6 West Edwar\100 PrelimDesign\Drafting\101726-100_F1.dwg Date: 09-01-2020 Login: all



ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.28 \frac{Q_p}{H^2} \frac{n^2}{(0.16 + n^2)^3}$ (psf) (see Note 3)

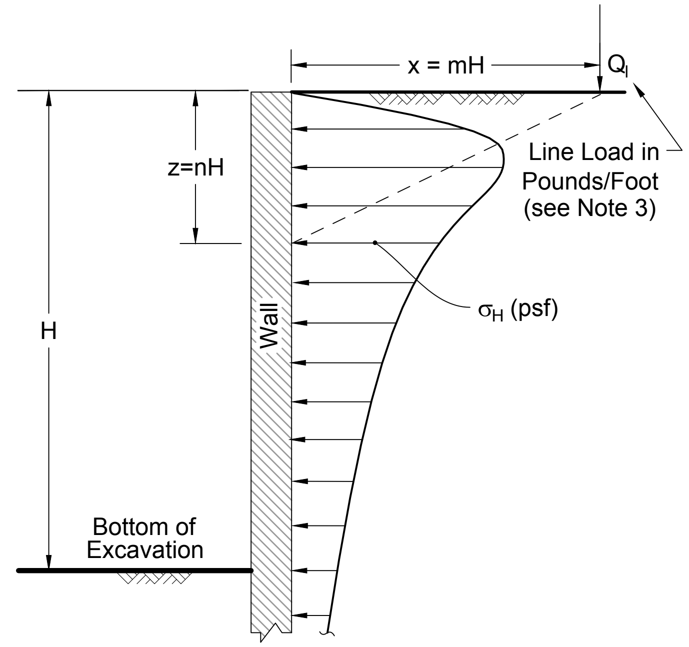
For m > 0.4: $\sigma_H = 1.77 \frac{Q_p}{H^2} \frac{m^2 n^2}{(m^2 + n^2)^3}$ (psf)



PLAN VIEW

A) LATERAL PRESSURE DUE TO POINT LOAD i.e. SMALL ISOLATED FOOTING OR WHEEL LOAD

(NAVFAC DM 7.02, 1986)



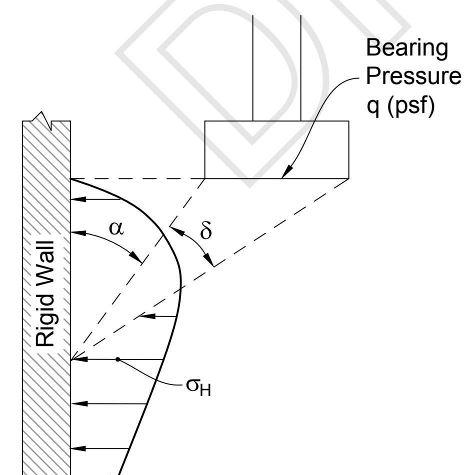
ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.20 \frac{Q_l}{H} \frac{n}{(0.16 + n^2)^2}$ (psf) (see Note 3)

For m > 0.4: $\sigma_H = 1.28 \frac{Q_l}{H} \frac{m^2 n}{(m^2 + n^2)^2}$ (psf)

B) LATERAL PRESSURE DUE TO LINE LOAD i.e. NARROW CONTINUOUS FOOTING PARALLEL TO WALL

(NAVFAC DM 7.02, 1986)

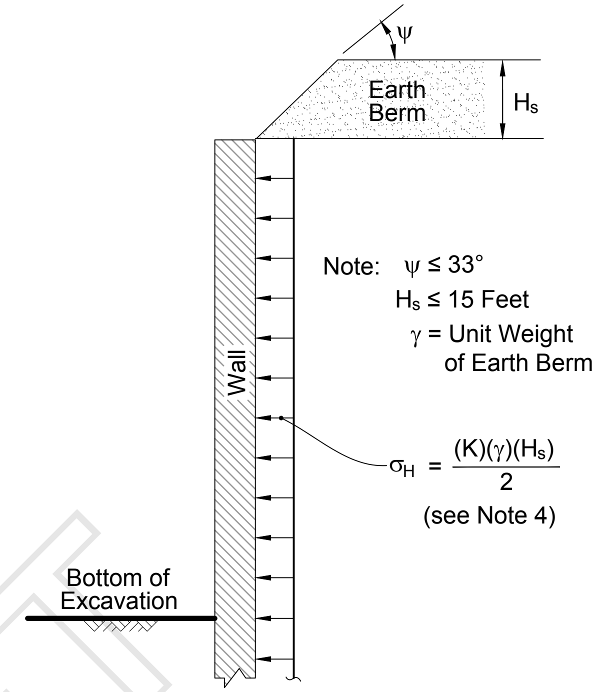


in radians

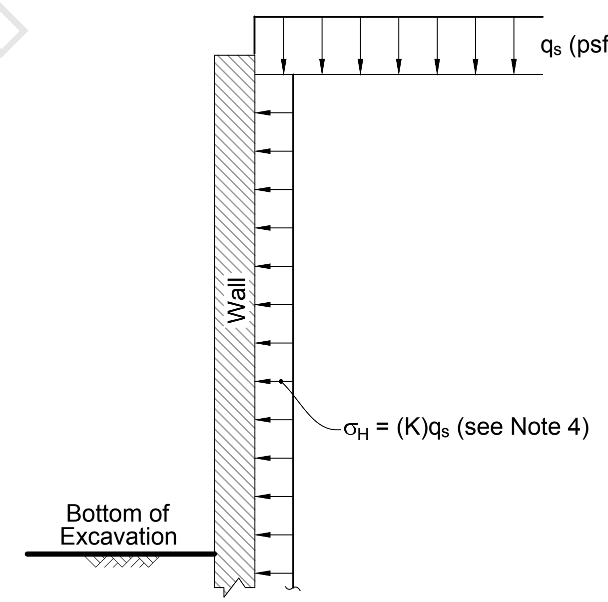
$\sigma_H = \frac{2q}{\pi}[\delta - \sin\delta\cos(\delta + 2\alpha)]$ (psf)

C) LATERAL PRESSURE DUE TO STRIP LOAD

(AASHTO LRFD Bridge Design Specifications, 2020)



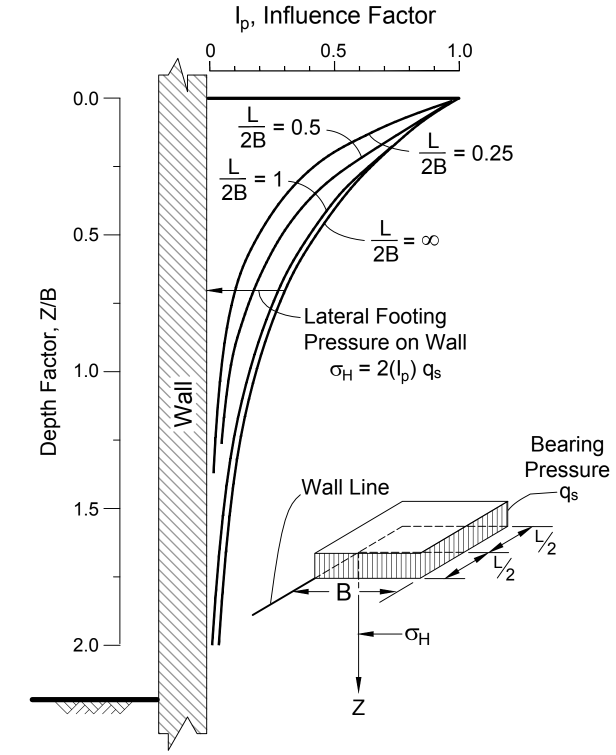
EARTH BERM



UNIFORM SURCHARGE

D) LATERAL PRESSURE DUE TO EARTH BERM OR UNIFORM SURCHARGE

(derived from Poulos and Davis, *Elastic Solutions for Soil and Rock Mechanics*, 1974; and Terzaghi and Peck, *Soil Mechanics in Engineering Practice*, 1967)



E) LATERAL PRESSURE DUE TO ADJACENT FOOTING

(see Notes 5 and 6)

(derived from NAVFAC DM 7.02, 1986; and Sandhu, *Earth Pressure on Walls Due to Surcharge*, 1974)

NOTES

1. Figures are not drawn to scale.
2. Applicable surcharge pressures should be added to appropriate permanent wall lateral earth and water pressure.
3. If point or line loads are close to the back of the wall such that m ≤ 0.4, it may be more appropriate to model the actual load distribution (i.e., Detail E) or use more rigorous analysis methods.
4. See text for recommended K values.
5. The stress is estimated on the back of the wall at the center of the length, L, of loading.
6. The estimated stress is based on a Poisson's ratio of 0.5.

US 6 West Edwards Improvement Design
Eagle County, Colorado

RECOMMENDED SURCHARGE LOADING FOR TEMPORARY AND PERMANENT WALLS

April 2021 | 101726-200

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 4

File: F:\J\Support\library_Standard Figures\Surcharge Loading Temp-Perm Wall_Tabloid_Updated.dwg Date: 08-18-2020 Author: SAC

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

April 2021 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 3

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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

SOIL CLASSIFICATION AND LOG KEY

April 2021 — 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

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.

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

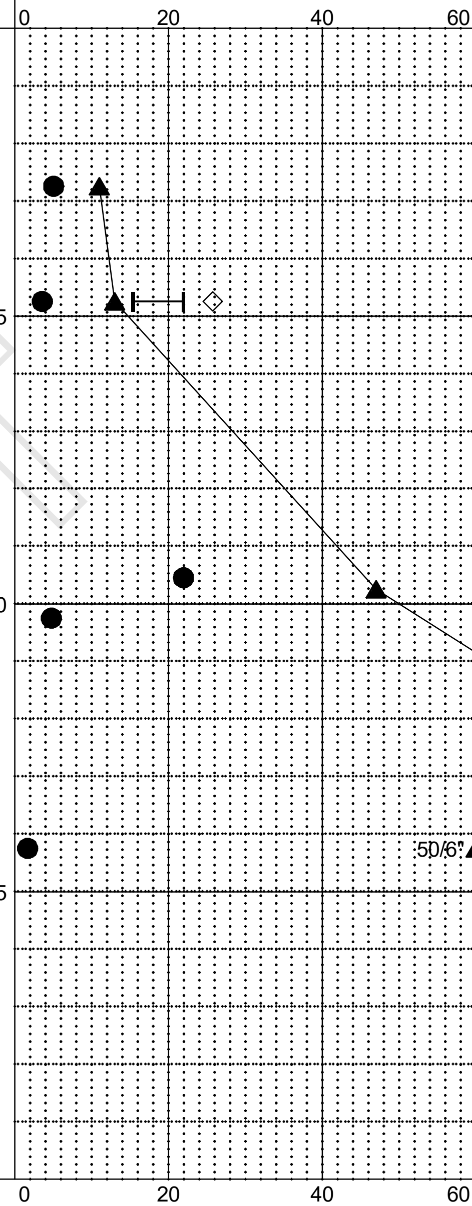
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples
Medium dense, red-brown, *Silty, Clayey Gravel with Sand (GC-GM);* moist. Fill A-2-4		S-1, S-2
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	

Ground Water: Groundwater not encountered in boring

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
Ⅰ 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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

LOG OF BORING SW-01

April 2021 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2

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:			

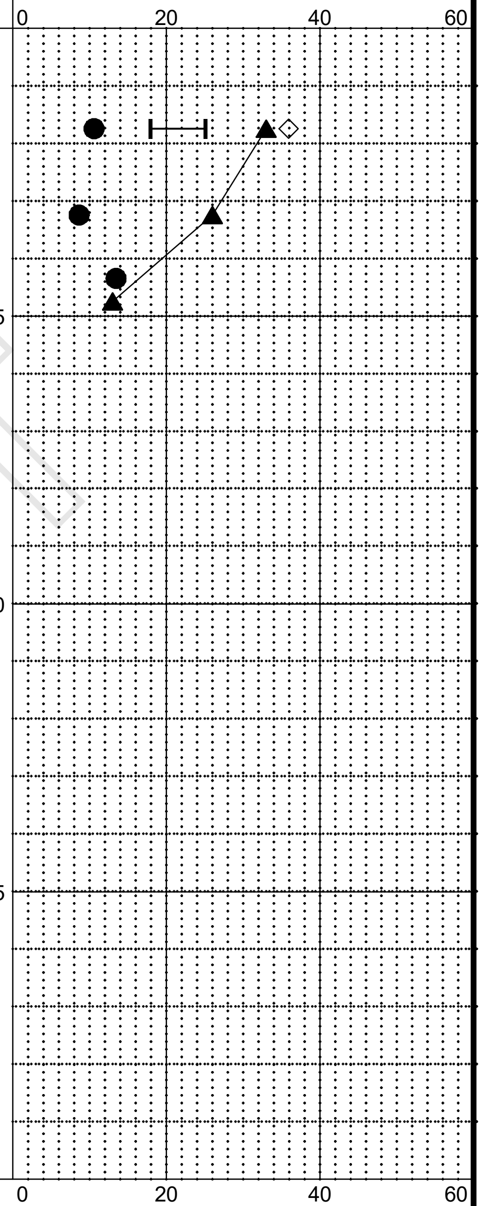
SOIL DESCRIPTION

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.			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.	0.8	S-1 S-2 S-3	
BOTTOM OF BORING COMPLETED ON 07/01/2020	5.5		

PENETRATION RESISTANCE (blows/foot)

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



LEGEND

* Sample Not Recovered

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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

LOG OF BORING SW-02

April 2021 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-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

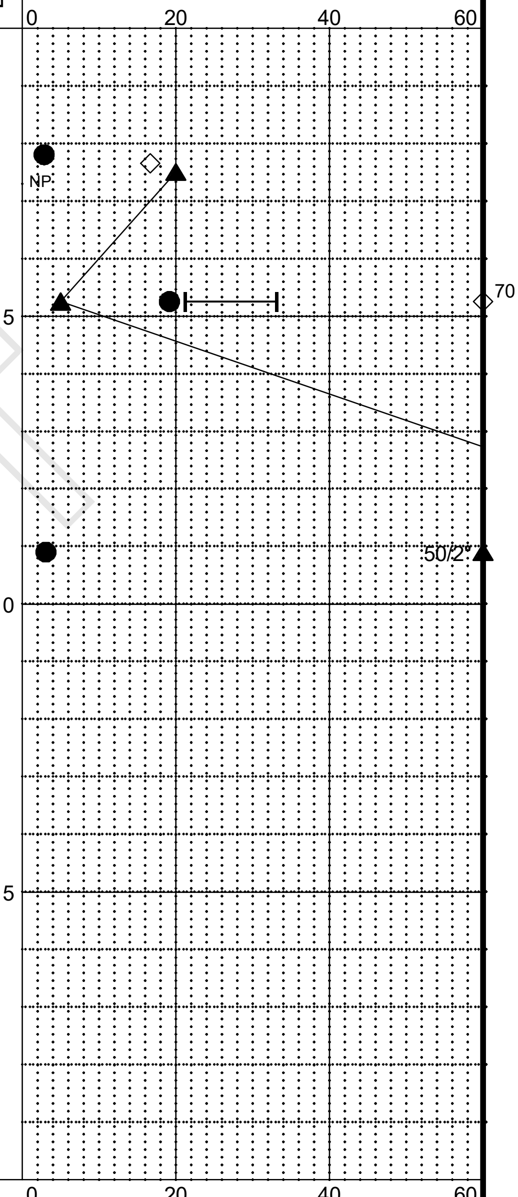
Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Soil Description	Depth, ft.	Samples	Ground Water
8 inches of Asphalt.	0.7		Groundwater not encountered in boring
Medium dense, red-brown, *Silty Sand with Gravel (SM);* moist. Fill A-1-b	4.0	B-1, S-1	
Medium stiff, red-brown, *Sandy Lean Clay (CL);* moist; few gravel. Undivided Alluvium and Colluvium A-6	7.0	S-2	
Very dense, red-brown, *Poorly Graded Gravel with Silt and Sand (GP-GM);* moist. Undivided Alluvium and Colluvium	9.2	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
- 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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

LOG OF BORING SW-03

April 2021 | 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-4

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:			

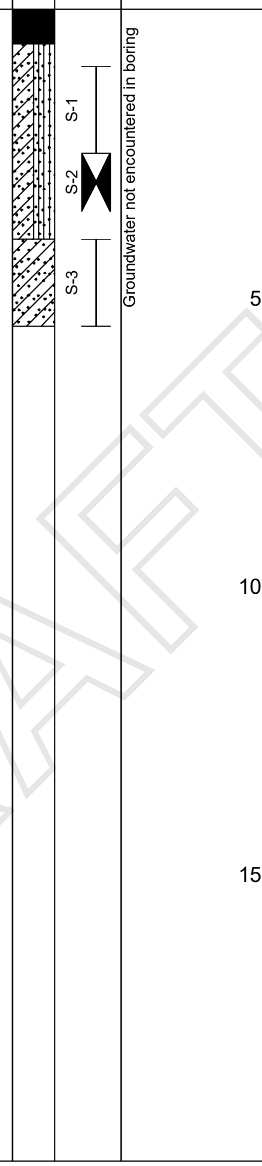
SOIL DESCRIPTION

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.
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
Loose, dark red-brown, *Clayey Sand (SC);* moist. Undivided Alluvium and Colluvium	5.5

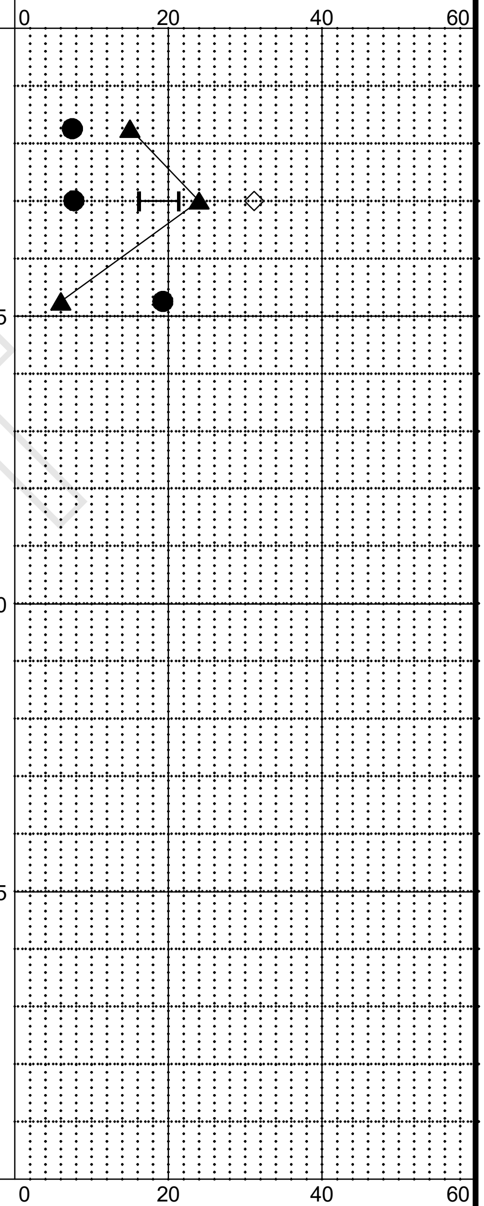
BOTTOM OF BORING
COMPLETED ON 07/01/2020

Symbol | Samples | Ground Water | Depth, ft.



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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

LOG OF BORING SW-04

April 2021 | 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-5

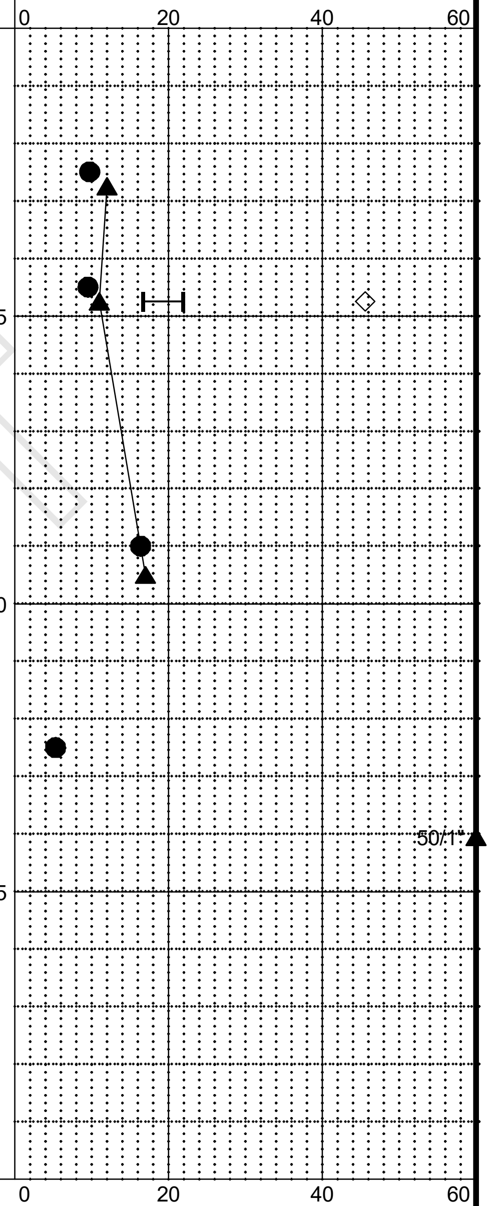
MASTER_LOG_E_POCKETPEN_LAT&LONG_US6_101726.GPJ 8/31/20

QCL 3

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.*	Depth, ft.	Symbol	Samples	Ground Water
Medium dense, red-brown *Silty, Clayey Sand with Gravel (SC-SM);* moist. Fill A-4			B-1, S-1, S-2	Groundwater not encountered in boring
Medium dense, red-brown, *Silty Sand (SM);* moist. Undivided Alluvium and Colluvium	7.0		S-3	
Very dense, red-brown, *Silty Gravel with Sand (GM);* moist. Undivided Alluvium and Colluvium	11.0		S-4, S-5*	
BOTTOM OF BORING COMPLETED ON 07/01/2020	14.1			

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
- Grab Sample
- 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.

US 6 West Edwards Improvement Design
Eagle County, Colorado

LOG OF BORING SW-05

April 2021 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-6

MASTER_LOG_E_POCKETPEN_LAT&LONG_US6_101726.GPJ 8/31/20

QCL 3

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

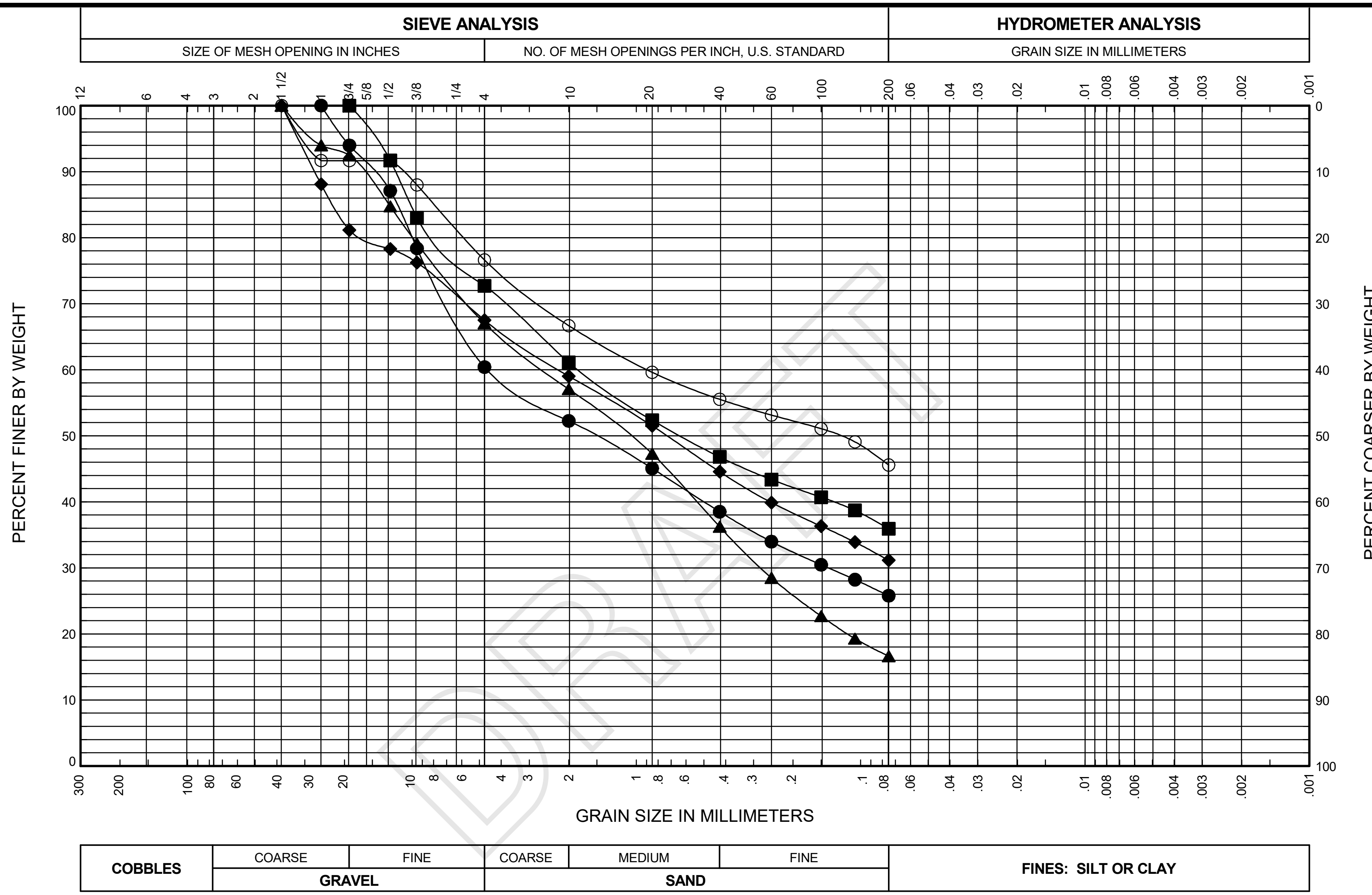
SAMPLE DATA						Natural Moisture Content (%)	GRAIN-SIZE ANALYSES[2]			ATTERBERG LIMITS[3]			CORROSIVITY				
Boring	Sample	Depth (feet) Top	Depth (feet) Bottom	USCS Symbol[1]	AASHTO Designation		Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	pH	Resistivity (ohm-cm)	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 sieve.

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

April 2021

101726-200

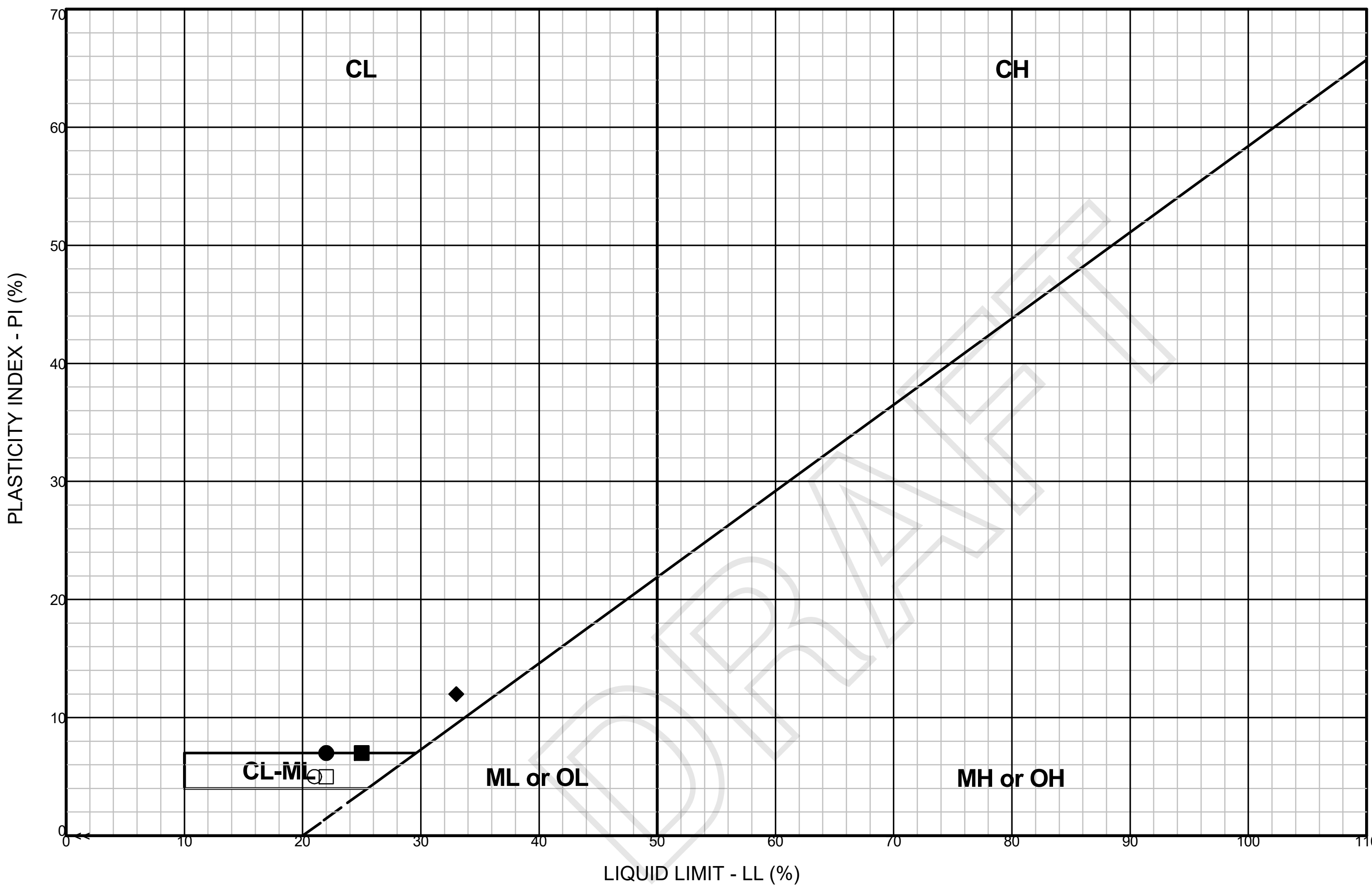
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-1

Felsburg Holt & Ullevig

GSA MAIN US6 101726.GPJ 8/19/20

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

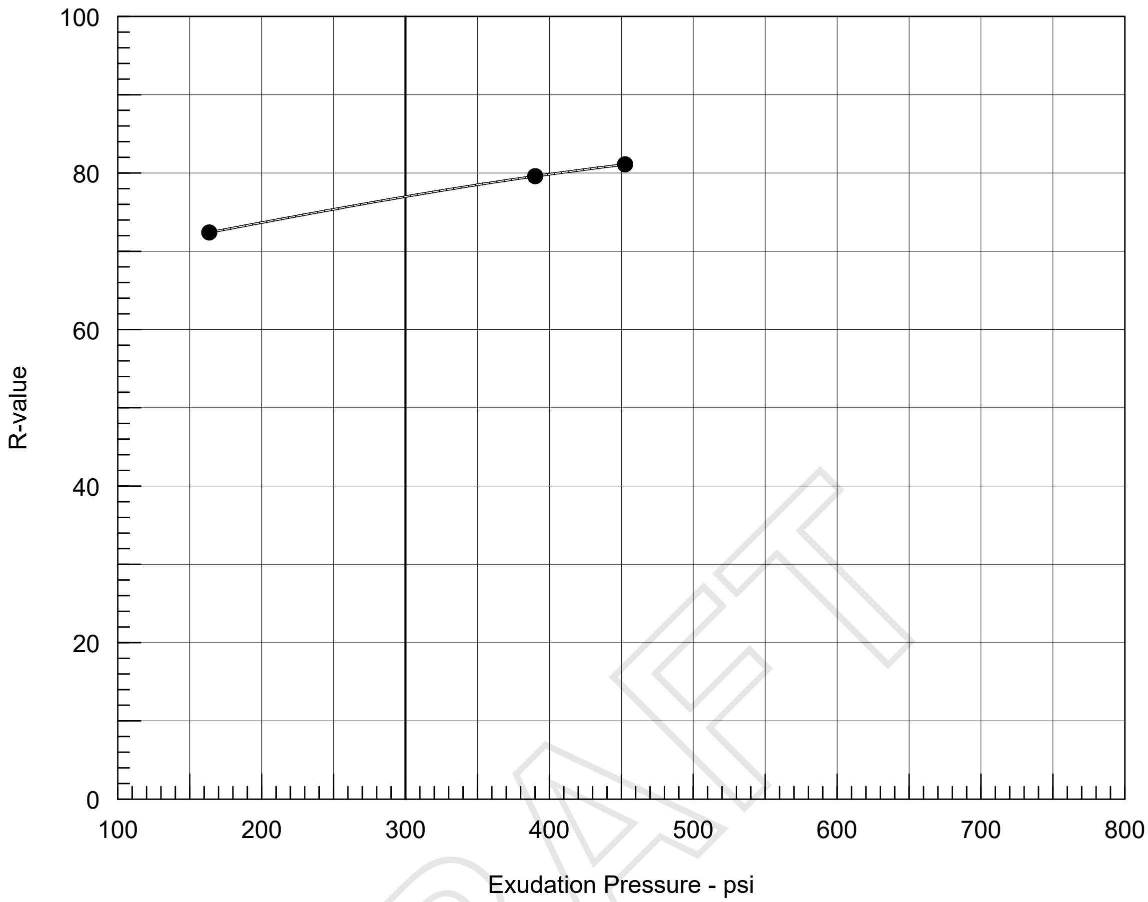
April 2021 101726-200

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-2

Felsburg Holt & Ullevig

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 Design Calculations

Exhibit

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Calculation No. 1

CALCULATION SUMMARY

Project:	US6 Edwards, CO	Job No:	101726-200
Feature and Subject::	Pavement Design		

Calculation Purpose

Design new flexible and rigid pavements for US-6, proposed roundabout, and Hillcrest Drive.

General Approach/Assumptions

Design Guidelines:

- 2020 CDOT M-E Pavement Design Manual (CDOT PDM)
- Assume a reliability of 90% for design (CDOT Table 2.3).

Analysis Approach:

- All pavements will be designed in accordance with CDOT design procedures using a mechanistic-empirical (M-E) design procedure.

Subsurface Information: S&W borings SW-01 through SW-05

- R-value test results from borings SW-03 was 77. A value of 50 is assumed due to subgrade variability.
- Assume A-2-6 subgrade soils for pavement design.

Traffic Information:

- Project traffic study: US 6 West Edwards Preliminary Traffic Analysis, Hillcrest Drive to Arrow Grass, Edwards, Colorado, Final Report dated March 2019 by FHU.
- Use 2019 traffic counts and 2045 projected traffic loading (Base Case Total Traffic Conditions; Figure 6).
- CDOT Online Transportation Information System (OTIS): https://dtdapps.coloradodot.info/otis
- 4.1% truck traffic for US 6.

Subgrade Strength: Correlations from R-value to resilient modulus (M_R) as specified by CDOT or Hudson:

- CDOT (Equation 4-1): $M_R = 3438.6\ R^{0.2753}$ where R = R-value
  For R = 50, M_R = 10,095 psi (Use 10,000 psi)

Climate Data (M-E Analysis): Use a composite weather station use Eagle Count Airport (~20 miles west of site, ~500 feet higher in elevation).

Sources of Data and Equations

M-E Design Software: V. 2.3.1 Pavement ME Design software developed by AASHTOWare

CDOT Database; online transportation information system (OTIS): http://dtdapps.coloradodot.info/otis

- Posted Speeds: 45 mph (assume a speed of 15 for in roundabout & 35 for US-6).
- Roadway Classification: Based on information provided in OTIS database: 5 Major Collector

HMA Binder Selection: LTPPBind web application. Available at: https://infopave.fhwa.dot.gov/Tools/LTPPBindOnline?mode=new

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Calculation No. 1

CALCULATION SUMMARY

M-E Design Pavement Performance Design Criteria: CDOT PDM Tables 2.4 & 2.6 using the major collector roadway classification for all roads. Per CDOT PDM Section 2.7, the initial construction IRI is 61 in/mi for asphalt pavement sections and 78 for rigid pavement sections.

CDOT Material Properties (M-E Analysis):

- HMA Material; CDOT PDM Appendix F, Top & lower lifts: Mix ID FS1958, R5 Level 1, SX(75) PG 58-34
- PCC Material; CDOT PDM Appendix G; Mix ID 2009092, R3 Level 1, Grand Jct Ready Mix

Summary and Conclusions

LTTP Bind Output:

- Top lift & lower of binder PG 58-34 binder

Design Traffic Loading: AADTT = Average Annual Daily Truck Traffic

- *US-6:* 2022 AADTT = 432 trucks/day, Growth Rate = 2.57% (compounded), Directional Distribution = 60%, Lane Distribution = 100%, Lanes = 2, Speed = 35 mph
- *Roundabout:* 2022 AADTT = 305 trucks/day, Growth Rate = 2.57% (compounded), Directional Distribution = 100%, Lane Distribution = 100%, Lane = 1, Speed = 15 mph
- *Hillcrest Drive:* 2022 AADTT = 78 trucks/day, Growth Rate = 2% (compounded), Directional Distribution = 60%, Lane Distribution = 100%, Lanes = 2, Speed = 35 mph

Recommended Pavement Sections:

US-6: i. 20 yr DL: 5.5" HMA / 6" Class 6 ABC
ii 20 yr DL: 7" Full Depth HMA
iii. 30 yr DL: 7.5" PCC /6" Class 6 ABC; requires tied shoulders & 1" doweled transverse joints.

Roundabout: i. 20 yr DL: 5.5" HMA / 6" Class 6 ABC
ii 20 yr DL: 8" Full Depth HMA
iii. 30 yr DL: 7.5" PCC /6" Class 6 ABC; req. tied shoulders & 1" doweled trans. joints.

Hillcrest Dr: i. 20 yr DL: 4" HMA / 6" Class 6 ABC
ii 20 yr DL: 5" Full Depth HMA

PM Check of Assumptions and Input Properties

Rev No.	Calculation By	Date	Checked By	Date
0	David Asunskis	7/24/2020	Joey Goode	7/24/2020
PM Review of Assumptions and Input Properties				
NOTES:				

TABLE 1
PREDICTED RIGID PAVEMENT PERFORMANCE

Location	Pavement Section	Analysis Period (years)	CDOT Performance Criteria [Calculated Reliability (%)]		
			Terminal IRI (in./mile)	PCC Transverse Cracking (%)	PCC Slab Faulting (in)
			≤ 200	≤ 7.0	≤ 0.20
US-6	7.5” PCC, 1” Dowels with tied shoulders, 15 ft max joints 6” Class 6 ABC	30	167 [98]	5.9 [94]	0.08 [100]
US-6 Roundabout	7.5” PCC, 1” Dowels with tied shoulders, 15 ft max joints 6” Class 6 ABC	30	173 [97]	6.4 [92]	0.09 [100]

TABLE 2
PREDICTED FLEXIBLE PAVEMENT PERFORMANCE

Location	Pavement Section	Analysis Period	CDOT Performance Criteria [Calculated Reliability (%)]					
			Terminal IRI (in./mile)	AC Bottom-Up Fatigue Cracking (%)	AC Thermal Cracking (ft/mile)	AC Top-Down Fatigue Cracking (ft/mile)	AC Permanent Deformation (in.)	Total Permanent Deformation (in.)
		Yrs	≤ 200	≤ 25	≤ 1,500	≤ 3,000	≤ 0.65	≤ 0.80
US 6	5.5” HMA (PG 58-34) 6” Class 6 ABC	20	172 [98]	19.3 [96]	194 [100]	1,300 [100]	0.39 [100]	0.58 [100]
	7” HMA (PG 58-34)	20	171 [98]	22.0 [94]	132 [100]	1,998 [97]	0.36 [100]	0.54 [100]
US 6 Roundabout	5.5” HMA (PG 58-34) 6” Class 6 ABC	20	183 [96]	24.0 [91]	194 [100]	1,578 [99]	0.53 [99]	0.74 [97]
	8” HMA (PG 58-34)	20	175 [98]	18.9 [96]	124 [100]	1,931 [98]	0.46 [100]	0.65 [100]
Hillcrest Dr.	4” HMA (PG 58-34) 6” Class 6 ABC	20	162 [99]	12.4 [100]	242 [100]	816 [100]	0.26 [100]	0.44 [100]
	5” HMA (PG 58-34)	20	164 [99]	19.7 [96]	156 [100]	1,831 [98]	0.26 [100]	0.44 [100]

Determine the approximate Design AADTT on
- US-6
- Roundabout
- Hillcrest Dr.

From "US 6 West Edwards Preliminary Traffic Analysis, Hillcrest Drive to Arrow Grass, Edwards, Colorado, Final Report", dated March 2019 by FHU

- % Heavy Vehicles:
  - US-6: Use CDOT OTIS Data
  - Surface Streets (Hill Crest): 2%

- FHU Fig. 2 => 2019 Traffic Conditions
- FHU Fig. 6 => 2045 Base Case Total Traffic Conditions

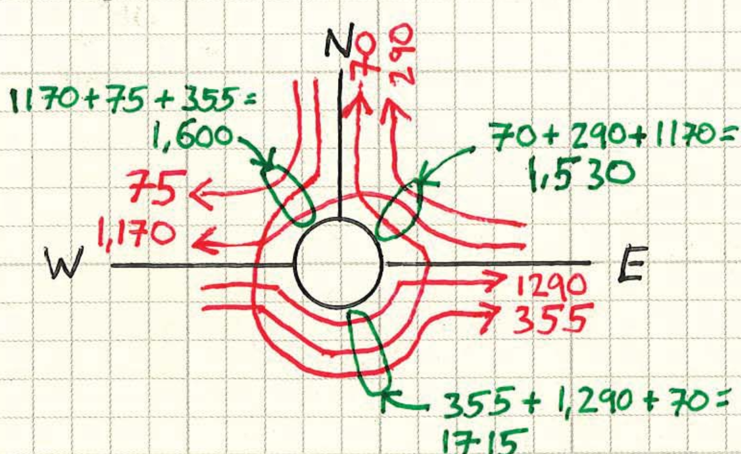
From CDOT OTIS Database:
- US 6 (SH06E) MP 164 to 165: • % Trucks = 4.1 %
  - Single Unit Trucks = 270 vpd
  - Combination Trucks = 120 vpd

From Discussions with FHU:
- 2022 Completion of Construction for the Roundabout
- Design Pavement based on projected traffic loading from Figure 6 of the 2019 FHU traffic report.
- A 4.1% truck traffic (from OTIS) was confirmed for Design

Design Approach:
- Use the 2045 Peak Hourly Volume (PHV) roundabout traffic distributions to estimate the 2045 average daily traffic (ADT) volumes:
- Use the sum of the AM & PM PHV to determine the roundabout traffic distribution

- From Fig 6:

AM + PM PHV: (2045)
SB to WB = 75
SB to EB = 355
EB to NB = 70
EB to EB = 1,290
WB to NB = 290
WB to WB = 1,170



2-way ADT at Roundabout:
North Leg = 3,900 vpd
West Leg = 12,500 vpd
East Leg = 14,690 vpd

i Calculate the 2-way PHV for each Leg

North Leg PHV = 355 + 75 + 70 + 290 = 790

West Leg PHV = 1,170 + 75 + 70 + 1,290 = 2,605

East Leg PHV = 350 + 1,290 + 290 + 1,170 = 3,100

ii Calculate the 2-way PHV distribution for each Leg

Total Traffic = 790 + 2,605 + 3,100 = 6,495

North Leg: 790/6,495 x 100% = 12.2%

West Leg: 2,605 / 6,495 x 100% = 40.1%

East Leg: 3,100 / 6,495 x 100% = 47.7%

iii Compare the 2-way PHV distributions w/ 2045 ADT distributions

Total ADT Traffic: 3,900 + 12,500 + 14,690 = 31,090

North Leg: 3900 / 31,090 x 100% = 12.5% (vs. 12.2%)

West Leg: 12,500 / 31,090 x 100% = 40.2% (vs. 40.1%)

East Leg: 14,690 / 31,090 x 100% = 47.3% (vs. 47.7%)

} Very close

Conclusion: ADT for each roundabout leg is very close to the PHV distributions. In our opinion, using the PHV distributions on the ADT to estimate the roundabout ADT is valid.

iv Calculate Directional Distribution Factors (DDF) Entering the Roundabout using PHV's:

North Leg (SB) = 75 + 355 = 430
North Leg (NB) = 70 + 290 = 360
North Leg (SB) DDF = 430 / [430 + 360] = 0.544

West Leg (WB) = 75 + 1170 = 1245
West Leg (EB) = 1,290 + 70 = 1,360
West Leg (EB) DDF = 1,360 / [1,360 + 1245] = 0.522

East Leg (WB) = 290 + 1170 = 1,460
East Leg (EB) = 1,290 + 355 = 1,645
East Leg (WB) DDF = 1,460 / [1,460 + 1,645] = 0.47

V. Determine 2045 Traffic Entering Roundabout:

North leg = 3,900 (0.544) = 2,122
West leg = 12,500 (0.522) = 6,525
East leg = 14,690 (0.470) = 6,904

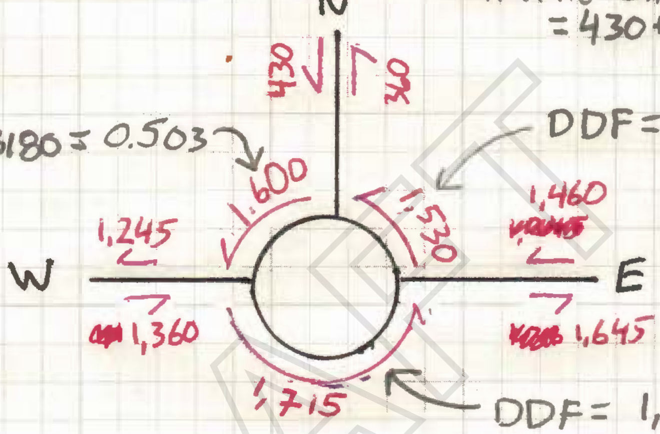
Σ = 15,551

vi Determine Roundabout DDF based on traff Entering Roundabout (using PHV)

Traffic Entering Roundabout = 430 + 1,460 + 1,360 = 3,180

DDF = 1,600/3180 = 0.503

DDF = 1,530/3180 = 0.481



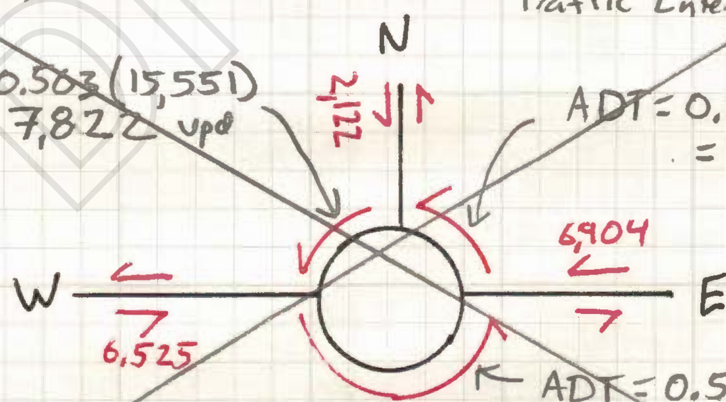
DDF = 1,715/3180 = 0.539

vii Determine Roundabout 2045 ADT

Traffic Entering Roundabout = 15,551

ADT = 0.503 (15,551) = 7,822 vpd

ADT = 0.481 (15,551) = 7,480 vpd



ADT = 0.539 (15,551) = 8,382 vpd

Not Required for Design DAA 7/24/2020

Determine Design Average Annual Daily Truck Traffic (AADTT) Volumes:

i Determine a design annually compounded growth rate (r):

* 2022 Paving

<u>2019 ADT's:</u>

North Leg: 3,900 vpd
West Leg: 5,400 vpd
East Leg: 7,900 vpd

North Leg: 2019 ADT = 2045 ADT ⇒ r = 0%

West Leg: Future ADT = Current ADT $(1+r)^N$

$12{,}500 = 5{,}400\,(1+r)^{(2045-2019)}$
r = 3.28 %

East Leg $14{,}690 = 7{,}600\,(1+r)^{26 \text{ years}}$
r = 2.57 %

Assume: r = 2.57% for roundabout (More conservative when 2022 ADT calculated)

ii Calculate 2022 AADTT

US-6 ⇒ % Trucks = 4.1 %
Hillcrest ⇒ % Trucks = 2.0 %
Roundabout: Assume % Trucks = 4.1 %

• US-6: 2045 ADT = 2022 ADT $(1+r)^{(2045-2022)}$
$14{,}690 = 2022 \text{ ADT}\,(1+0.0257)^{23 \text{ years}}$
2022 ADT = 8,195 vpd (2 way)

AADTT = % Trucks (ADT) = 0.041 (8,195)
2022 AADTT = 336 trucks/day

OTIS 2018 AADTT = 270 + 120 = 390 Trucks/day

OTIS 2022 AADTT = $390\,(1+0.0257)^{2022-2018}$
= 432 trucks/day

Use 432 trucks/day with r = 2.57 %

• Hillcrest: 2022 AADTT = 0.02 (3,900) = 78 trucks/day

Use a growth rate of 2%

- Roundabout:

Because 2022 2-way AADTT loading was increased from a 336 to 432 trucks per day (from Project traffic study to OTIS traffic Study), determine roundabout AADTT using OTIS AADTT

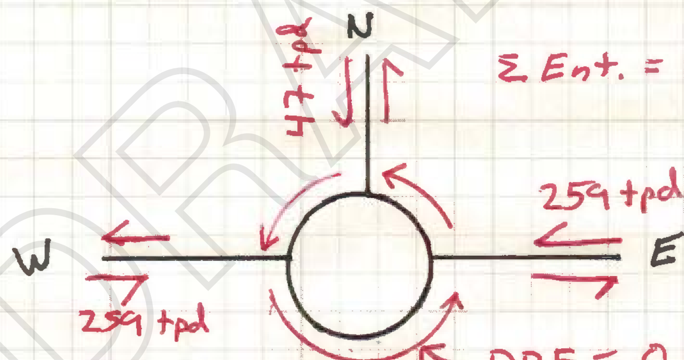
CDOT DDF for a 2-lane Road = 0.60

OTIS West Leg 2022 AADTT = 432 trucks/day
OTIS EB West Leg AADTT = 0.6(432) = 259 trucks/day

OTIS East Leg 2022 AADTT = 432 tpd
OTIS WB East Leg AADTT = 0.6(432) = 259 tpd

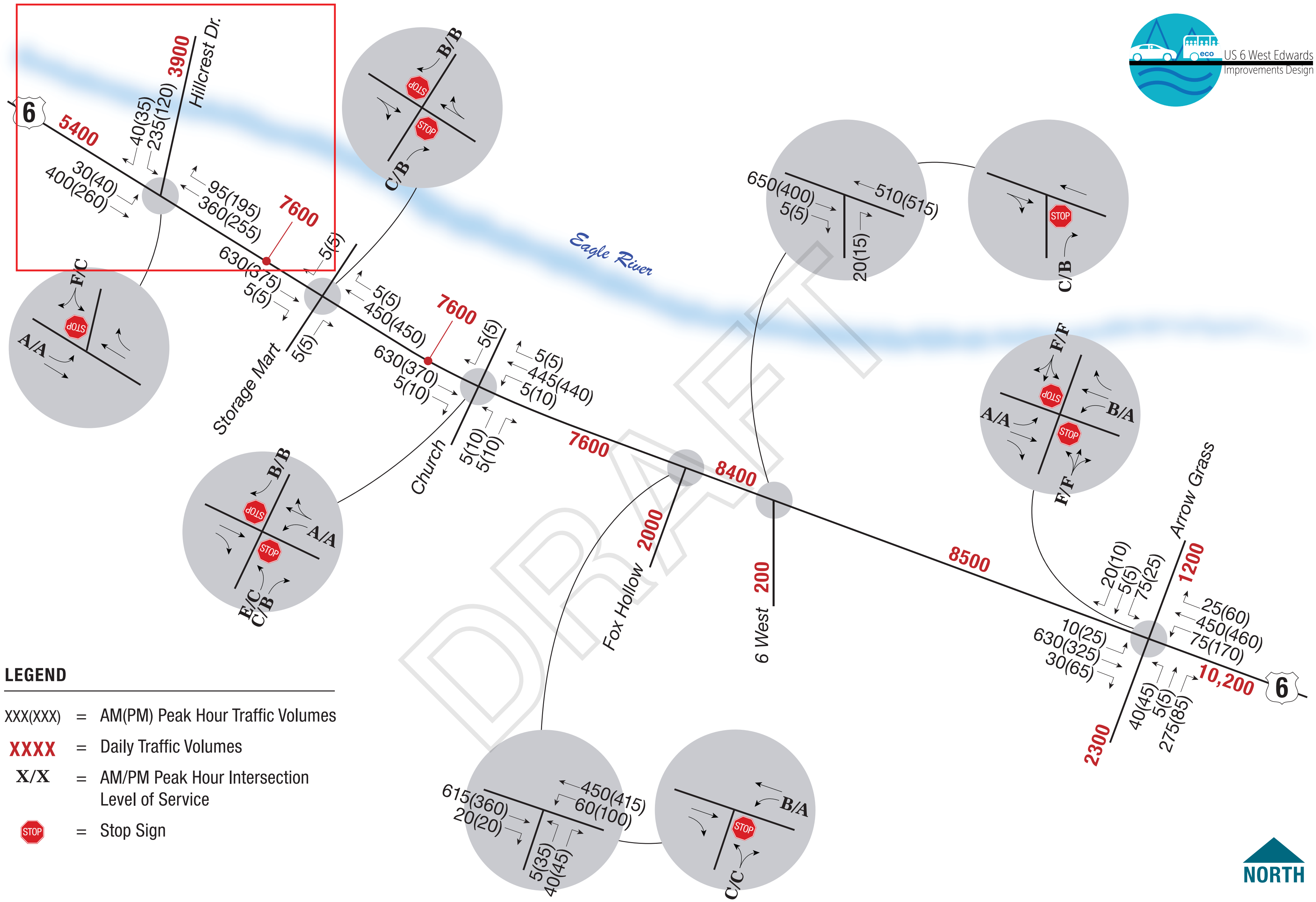
OTIS North Leg 2022 AADTT is Unknown.
Use 78 tpd
SB North Leg AADTT = 0.6(78) = 47 tpd

AADTT Entering Roundabout = 47 + 259 + 259
= 565 trucks/day



Σ Ent. = 565 tpd

DDF = 0.539
AADTT = 0.539(565) =
= 305 tpd



EAGLE COUNTY

FELSBURG HOLT & ULLEVIG

FIGURE 2

2019 Traffic Conditions

US 6 West Design - Traffic Analysis 18-339 11/7/19

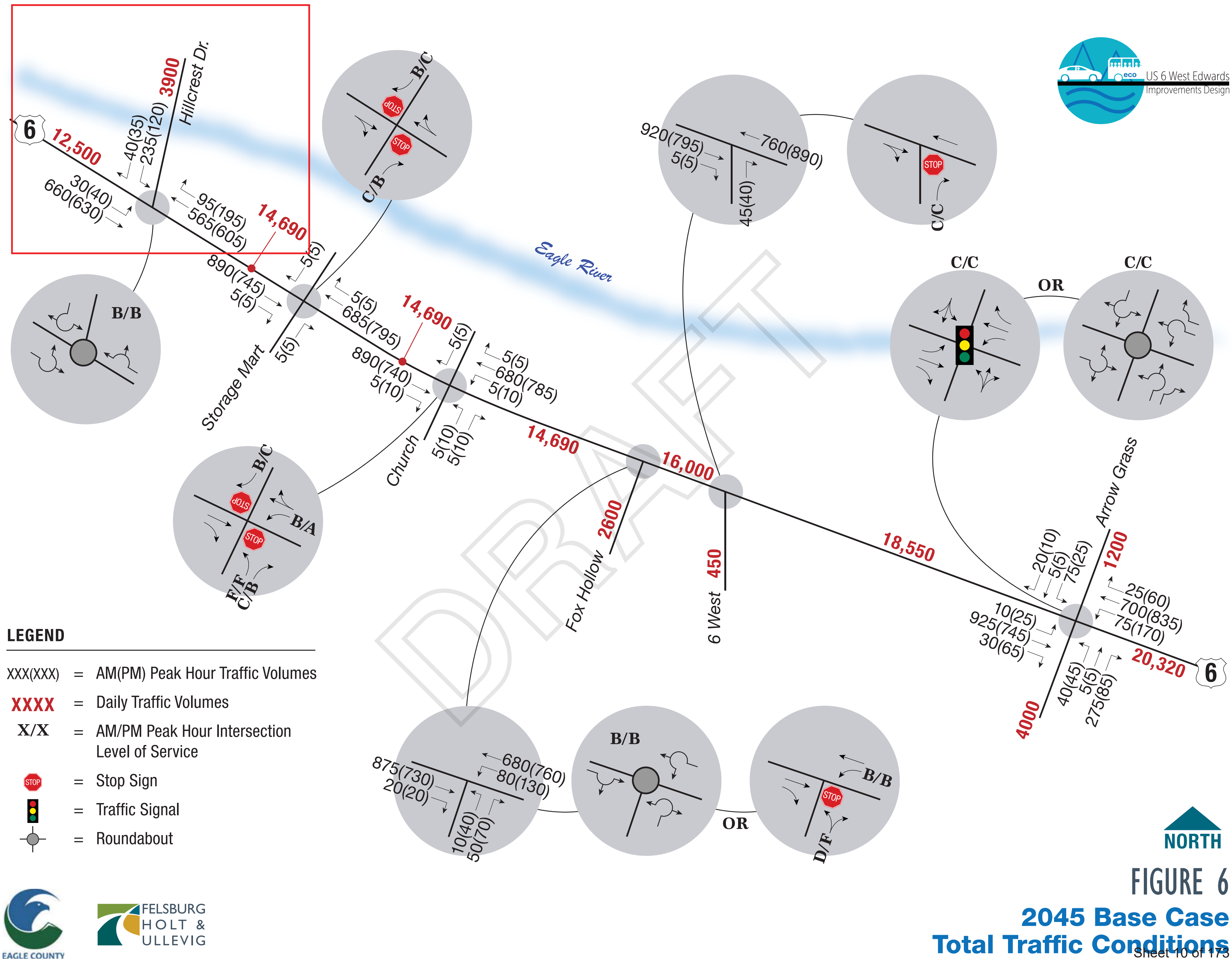


FIGURE 6

2045 Base Case Total Traffic Conditions

4. TRAFFIC OPERATIONS ANALYSIS

Operational analyses will be conducted for existing and year 2045 conditions based on procedures documented in the *Highway Capacity Manual* (HCM) 6th Edition (Transportation Research Board, 2016). It is anticipated that the following chapters of the HCM could be used to analyze specific operational conditions:

- Chapter 18 – Urban Street Segments
- Chapter 19 – Signalized Intersections
- Chapter 20 – Two-Way Stop Controlled Intersections
- Chapter 22 – Roundabouts
- Chapter 23 – Ramp Terminals and Alternative Intersections

Highway Capacity Software (HCS) and Synchro, will be used to conduct operational analyses. Roundabout analyses will also be conducted using Sidra and Rodel for comparison purposes.

HCM 6th Edition analysis procedures require the use of certain parameters, summarized in **Table 1.**

Table 1. HCM Analysis Parameters

Traffic Parameter		US 6	Surface Streets
% heavy vehicles	Trucks and buses	CDOT's OTIS Data	2%
	RV's	2%	0%
Existing Conditions Peak Hour Factor		Determined from existing intersection counts – calculated as the PHF average for the intersection	
Future Conditions Peak Hour Factor		0.92	
Saturation Flow Rate (vehicles per hour per lane) for two-way stop- controlled and signalized intersections		1800 vphpl	
Queue Length Percentile		95 percentile	

5. SAFETY ISSUES

Available CDOT crash data for the most recent five complete years will be analyzed to identify crash concentrations and trends within the study area. Locations showing elevated crash experience will be noted and reviewed to identify crash type and severity patterns within the study area and how to address them with project improvements.

OTIS Online Transportation Information System

Highway Data | Traffic Data | Data Catalog | Reports | Map View | Help

the pencil icon then click the map. You can enter the ref points into the text boxes or click the pencil icon then click the map.

Zoom to County (optional):

select a county

CDOT Route Number:

006E | Find by Name

Begin Reference: Min(149.718)

164

End Reference: Max(174.541)

165

Count type:

All

Search by traffic station

Stations | AADT | Future Traffic | ESAL

Found 1 Short Duration stations and 0 Continuous Count stations. Click the magnifying glass icon in front of a station to see count data below.

Export to Excel

	Station ID	Route	Start	End	Description	AADT	Year	Single Unit	Comb Trucks	% Trucks	20 Year Factor	DHV	DVMT	DD
🔍	100309	006E	163.344	165.294	ON SH 6 W/O LAKE CREEK RD, EDWARDS	9,500	2018	270	120	4.1	1.43	11	18,164	57

OTIS AADTT = 270+120 = 390 trucks/day

Daily | Monthly Summaries | Annual

View Entire Month | Export to Excel

Dir	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h

P = Primary direction S = Secondary direction C = Combined traffic counts

Click here to download current and historical CDOT traffic databases as either Excel (.xlsx) or compressed Access (.zip)

CDOT Tables & Figures

<u>Recommended Range for Reliability</u>

The reliability is a factor of safety to account for the inherent variations in construction, materials, traffic, climate, and other design inputs. **Table 2.3 Reliability (Risk)** provides the recommended values for the pavement structure to survive the design period traffic. Reliability values recommended for use in previous editions of the AASHTO Design Guide <u>should not</u> be used with M-E Design. Reliability is not dependent on either type of pavement or type of project.

Table 2.3 Reliability (Risk)

Functional Classification	Value for Reliability
Interstate	80-95
Principal Arterials (freeways and expressways)	75-95
Principal Arterials (other)	75-95
Minor Arterial	70-95
Major Collectors	70-90
Minor Collectors	50-90
Local	50-80

Assume 90%

Table 2.4 Recommended Threshold Values of Performance Criteria for New Construction or Reconstruction of Flexible Pavement Projects, Table 2.5 Recommended Threshold Values of Performance Criteria for New Construction or Reconstruction Projects of Rigid Pavement, Table 2.6 Recommended Threshold Values of Performance Criteria for Rehabilitation Projects of Flexible Pavements and **Table 2.7 Recommended Threshold Values of Performance Criteria for Rehabilitation Projects of Rigid Pavements** provide the threshold values recommended in M-E Design for pavements. M-E Design also requires the designer to enter the expected initial smoothness (IRI) at the time of construction. **<u>It is recommended to use an initial IRI value of 61 inches/mile for all HMA projects and 78 inches/mile for all PCC projects</u>** as they reflect targets that are documented using smoothness data from flexible and rigid pavements constructed between 2011 and 2016. **<u>It is recommended the same reliability value be used for all distresses; any changes should have Region Materials and Staff Materials approval.</u>**

Figure 2.1 Performance Criteria and Reliability in the M-E Design Software for a Sample Flexible Pavement Design presents the M-E Design software screenshot showing performance criteria and the corresponding design reliability values selected for the design/analysis of a sample flexible pavement design.

Figure 2.2 Performance Criteria and Reliability in the M-E Design Software for a Sample JCPC Design presents the M-E Design software screenshot showing performance criteria and the corresponding design reliability values selected for the design/analysis of a sample rigid pavement design.

Class 4-7: 62.9%

Table 3.6 Level 2 CDOT Vehicle Class Distribution Factors

Vehicle Class	Cluster 1 (Predominately Class 5)	Cluster 2 (Predominately Class 9)	Cluster 3 (Predominately Class 5 and 9)
	4-Lane Rural Principal Arterial (Non-Interstate)	4-Lane Rural Principal Arterial (Interstates and Highways)	2-Lane Rural Principal Arterial (other) 2-Lane Rural Major Collector 4-Lane Urban Principal Arterial
4	2.1	2.7	5.1
5	56.1	19.3	32.3
6	4.4	4.5	18
7	0.3	0.3	0.3
8	14.2	4.6	4.9
9	21.1	61.9	36.8
10	0.7	1.6	1.2
11	0.7	2.7	0.7
12	0.2	1.3	0.5
13	0.2	1.1	0.2

Class 8-13 37.1%

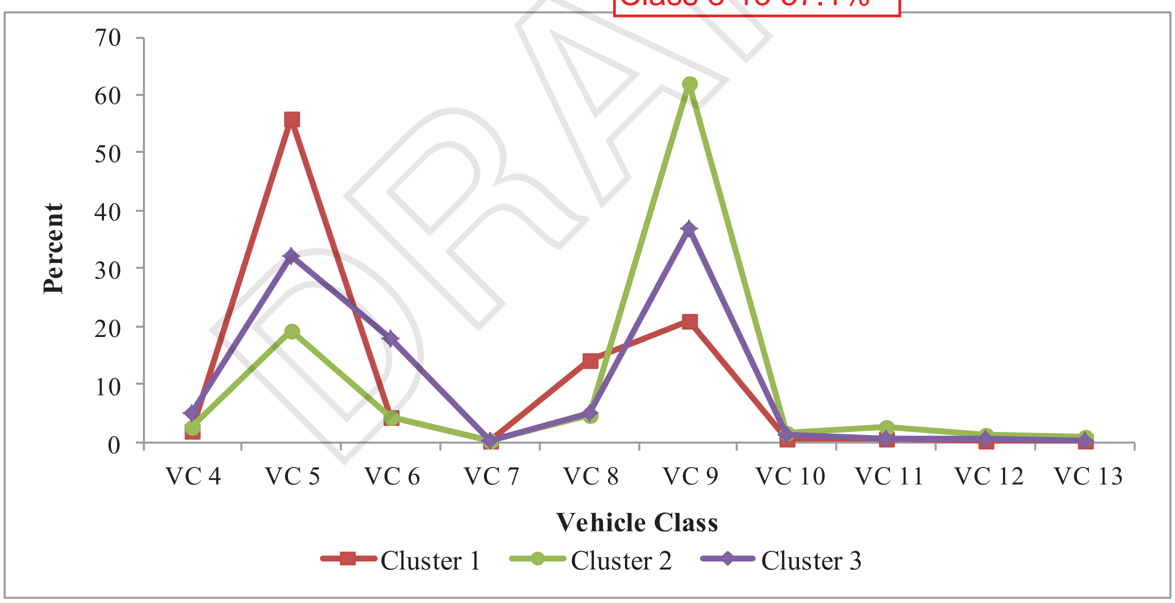


Figure 3.8 Vehicle Class Distribution Factors for CDOT Clusters

Table 2.4 Recommended Threshold Values of Performance Criteria for New Construction of Flexible Pavement

Flexible Pavement		
Performance Criteria	**Maximum Value at End of the Design Life**	**Determines the Years to First Rehabilitation (Minimum Age Shall be 14 Years)**
Terminal IRI (inches per mile)		Interstate – 160 Principal Arterial – 200 Minor Arterial – 200 Major Collector – 200 Minor Collector – 200* Local Roadway – 200*
AC Top-Down Fatigue Cracking (feet per mile)		Interstate – 2,000 Principal Arterial – 2,500 Minor Arterial – 3,000 Major Collector – 3,000 Minor Collector – 3,000* Local Roadway – 3,000*
AC Bottom-Up Fatigue Cracking (percent lane area)	Interstate – 10 Principal Arterial – 25 Minor Arterial – 25 Major Collector – 25 Minor Collector – 25* Local Roadway – 25*	
AC Thermal Cracking (feet per mile)	Interstate – 1,500 Principal Arterial – 1,500 Minor Arterial – 1,500 Major Collector – 1,500 Minor Collector – 1,500* Local Roadway – 1,500*	
Permanent Deformation (total inches)		Interstate – 0.55 Principal Arterial – 0.65 Minor Arterial – 0.80 Major Collector – 0.80 Minor Collector – 0.80* Local Roadway – 080*
Permanent Deformation AC Only (inches)		Interstate – 0.40 Principal Arterial – 0.50 Minor Arterial – 0.65 Major Collector – 0.65 Minor Collector – 0.65* Local Roadway – 0.65*
Additional Thresholds for Chemically Stabilized Layer		
Fatigue Fracture (percent lane area) (For semi-rigid base layer)		Interstate – 10 Principal Arterial – 25 Minor Arterial – 25 Major Collector – 25 Minor Collector – 25* Local Roadway – 25*
AC Total Fatigue Cracking Bottom Up + Reflective (percent lane area) (For semi-rigid base layer)		Interstate – 10 Principal Arterial – 25 Minor Arterial – 25 Major Collector – 25 Minor Collector – 25* Local Roadway – 25*
AC Total Transverse Cracking Thermal + Reflective (feet per mile) (For semi-rigid base layer)		Interstate – 1,500 Principal Arterial – 1,500 Minor Arterial – 1,500 Major Collector – 1,500 Minor Collector –1,500* Local Roadway – 1,500*

Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.

Table 2.6 Recommended Threshold Values of Performance Criteria for New Construction of Rigid Pavement

Rigid Pavement (JPCP)		
Performance Criteria	**Maximum Value at End of the Design Life**	**Determines the Year to First Rehabilitation (Minimum Age Shall Be 27 Years)**
Terminal IRI (inches per mile)		Interstate – 160 Principal Arterial – 200 Minor Arterial – 200 Major Collector – 200 Minor Collector – 200* Local Roadway – 200*
Transverse Slab Cracking (percent)		Interstate – 7.0 Principal Arterial – 7.0 Minor Arterial – 7.0 Major Collector – 7.0 Minor Collector – 7.0* Local Roadway – 7.0*
Mean Joint Faulting (inches)	Interstate – 0.12 Principal Arterial – 0.14 Minor Arterial – 0.20 Major Collector – 0.20 Minor Collector – 0.20* Local Roadway – 0.20*	
Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.		

Table 2.7 Recommended Threshold Values of Performance Criteria for Rehabilitation of Rigid Pavement Projects

Rigid Pavement (JPCP)	
Performance Criteria	**Maximum Value at End of the Design Life (Minimum Age Shall Be 20 Years)**
Terminal IRI (inches per mile)	Interstate – 160 Principal Arterial – 200 Minor Arterial – 200 Major Collector – 200 Minor Collector – 200* Local Roadway – 200*
Transverse Slab Cracking (percent)	Interstate – 7.0 Principal Arterial – 7.0 Minor Arterial – 7.0 Major Collector – 7.0 Minor Collector – 7.0* Local Roadway – 7.0*
Mean Joint Faulting (inches)	Interstate – 0.12 Principal Arterial – 0.14 Minor Arterial – 0.20 Major Collector – 0.20 Minor Collector – 0.20* Local Roadway – 0.20*
Note: * M-E Design has not been calibrated for minor collectors or local roadways. Exceptions to the threshold values may be approved by the RME.	

Table 3.15 Geographic Coordinates and Data Availability of Colorado Weather Stations

Station Number	Station	Latitude	Longitude	Elevation	Start Date	End Date	Years of Data
24015	Akron/Washington County	40.172	-103.232	4621	6/1/1973	3/31/2010	36.9
23061	Alamosa Muni(AWOS)	37.436	-105.866	7540.9	1/1/1973	3/31/2010	37.3
93073	Aspen Pitkin County SAR	39.223	-106.868	7742	1/1/1973	3/31/2010	37.3
23036	Aurora (Buckley AFB)	39.702	-104.752	5662	1/1/2000	3/31/2010	10.3
03065	Broomfield/Jefferson County	39.909	-105.117	5669.9	9/1/1984	3/31/2010	25.6
03026	Burlington	39.245	-102.284	4216.8	2/1/1999	3/31/2010	11.2
93067	Centennial	39.57	-104.849	5828	10/1/1983	3/31/2010	26.5
93037	Colorado Springs Municipal AP	38.812	-104.711	6169.9	1/1/1973	3/31/2010	37.3
03038	Copper Mountain Resort	39.467	-106.15	12074	8/1/2004	3/31/2010	5.7
93069	Cortez/Montezuma County	37.303	-108.628	5914	1/1/1973	3/31/2010	37.3
12341	Cottonwood Pass	38.783	-106.217	9826	7/1/2005	3/31/2010	4.8
24046	Craig-Moffat	40.495	-107.521	6192.8	9/1/1996	3/31/2010	13.6
03017	Denver (DIA) 03017	39.833	-104.658	5431	1/1/1995	3/31/2010	15.3
12342	Denver Nexrad 12342	39.783	-104.55	5606.9	5/1/2006	3/31/2010	3.9
93005	Durango/La Plata Airport	37.143	-107.76	6685	1/1/1973	3/31/2010	37.3
23063	Eagle County Airport	39.643	-106.918	6535	1/1/1973	3/31/2010	37.3
03040	Elbert County Airport	39.217	-104.633	7060	6/1/2004	3/31/2010	5.8
94015	Fort Carson/Butts	38.7	-104.767	5869.4	1/1/1969	3/31/2010	41.3
94062	Fort Collins Airport	40.452	-105.001	5016	5/1/1986	3/31/2010	23.9
12344	Glenwood Springs	39.433	-107.383	10603.5	7/1/2005	3/31/2010	4.7
23066	Grand Junction Airport	39.134	-108.538	4838.8	1/1/1973	3/31/2010	37.3
24051	Greeley/Weld County Airport	40.436	-104.618	4648.9	8/1/1991	3/31/2010	18.7
93007	Gunnison County Airport	38.452	-107.034	7673.8	4/1/1976	3/31/2010	34.0
94025	Hayden/Yampa (AWOS)	40.481	-107.217	6602	1/1/1973	5/31/2010	37.4
94076	Kremmling Airport	40.054	-106.368	7411	6/1/2004	3/31/2010	5.8
23067	La Junta Muni Airport	38.051	-103.527	4214.8	1/1/1961	3/31/2010	49.3
03042	La Veta Pass	37.5	-105.167	10216.7	7/1/2004	3/31/2010	5.8
03013	Lamar Muni Airport	38.07	-102.688	3070	1/1/1980	3/31/2010	30.3
93009	Leadville/Lake County Airport	39.228	-106.316	9926.7	7/1/1987	3/31/2010	22.8
93010	Limon Muni Airport	39.189	-103.716	5365.1	1/1/2004	3/31/2010	6.2
94050	Meeker	40.049	-107.885	6390	12/1/1978	3/31/2010	31.4
93013	Montrose Regional Airport	38.505	-107.898	5758.8	1/1/1973	3/31/2010	37.3
03039	Pagosa Springs	37.45	-106.8	11790.9	6/1/2004	3/31/2010	5.8
93058	Pueblo Airport	38.29	-104.498	4720.1	6/1/1954	3/31/2010	55.9
03016	Rifle/Garfield Airport	39.526	-107.726	5543.9	7/1/1987	3/31/2010	22.8
03069	Saguache Muni Airport	38.097	-106.169	7826	10/1/2004	3/31/2010	5.5
03041	Salida/Monarch Pass	38.483	-106.317	12030.7	6/1/2004	3/31/2010	5.8
12343	Steamboat Springs	40.467	-106.767	10633.1	4/1/2005	5/31/2010	5.2
03011	Telluride Regional Airport	37.954	-107.901	9078	12/1/2000	3/31/2010	9.3
23070	Trinidad/Animas County AP	37.259	-104.341	5743	1/1/1973	3/31/2010	37.3

Level 2 Inputs

The designer must input a single value of design M_r. Two approaches are available for Level 2 design subgrade M_r:

- **Laboratory Resilient Modulus**: The design M_r may be obtained through laboratory resilient modulus tests conducted in accordance with AASHTO T 307, Determining the Resilient Modulus of Soils and Aggregate Materials. Subgrade design M_r should reflect the range of stress states likely to be developed beneath flexible or rigid pavements subjected to moving wheel loads. Therefore, the laboratory measured M_r should be adjusted for the expected in-place stress state for use in M-E Design software. Stress state is determined based on the depth at which the material will be located within the pavement system (i.e., the stress states for specimens to be used as base or subbase or subgrade may differ considerably).

- **CDOT Resilient Modulus, R-value Correlation:** The design M_r may be obtained through correlations with other laboratory tested soil properties such as the R-value. Equation **Eq. 4-1** gives an approximate correlation of resistance value (R-value) to M_r. This equation is valid only for AASHTO T 190 procedure. If the R-value of the existing subgrade or embankment material is estimated to be greater than 50, a FWD analysis or resilient modulus by AASHTO T 307 should be performed. CDOT uses Hveem stabilometer equipment to measure strength properties of soils and bases. This equipment yields an index value called the R-value. The R-value is considered a static value and the M_r value is considered a dynamic value.

$$\mathbf{Mr = 3438.6 * R^{0.2753}} \qquad \textbf{Eq. 4-1}$$

Where:

M_r = resilient modulus (psi)
R = R-value obtained from the Hveem stabilometer

This equation **should be** used for R-values of 50 or less. Research is currently being done for soils with R-values greater than 50. The Hveem equipment does not directly provide resilient modulus values, rather, it provides the R-value which is then used to obtain an approximation of resilient modulus from correlation formulas.

The M-E Design software allows the designer to estimate M_r using other soil properties (see **Figure 4.5 M-E Design Software Screenshot for Level 2 Resilient Modulus Input**).

- California Bearing Ration (CBR)
- R-value
- Layer coefficient (a_i)
- Dynamic Cone Penetrometer (DCP) Penetration
- Plasticity Index (PI) and gradation (i.e., percent passing No. 200 sieve)

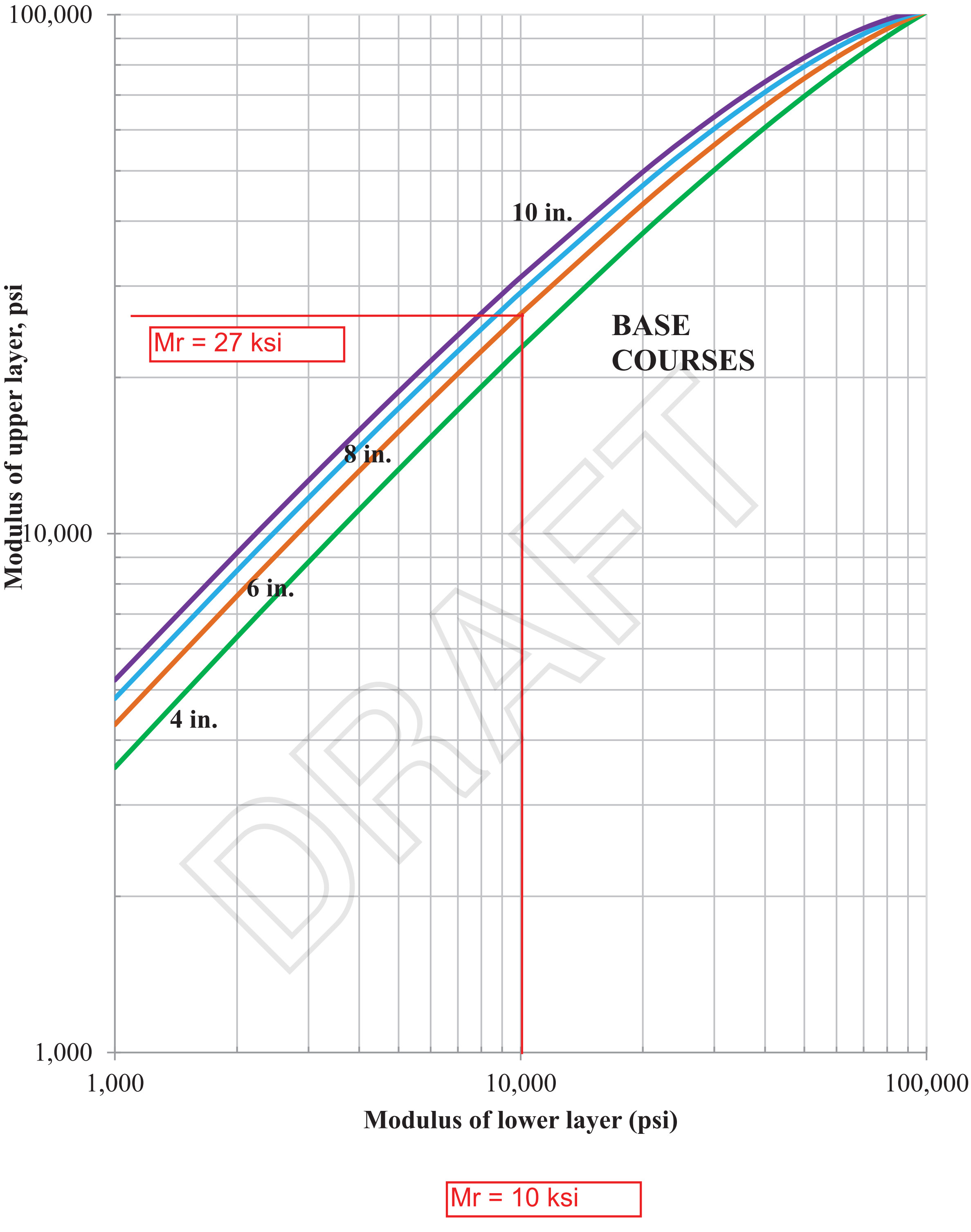


Figure 5.2 Limiting Modulus Criteria of Unbound Aggregate Base Layers

New Flexible Pavement-Calibration Settings

AC Cracking	
AC Cracking C1 Top	7
AC Cracking C2 Top	3.5
AC Cracking C3 Top	0
AC Cracking C4 Top	1000
AC Cracking Top Standard Deviation	200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))
AC Cracking C1 Bottom	0.021
AC Cracking C2 Bottom	2.35
AC Cracking C3 Bottom	6000
AC Cracking Bottom Standard Deviation	1+15/(1+exp(-3.1472-4.1349*LOG10(BOTTOM+0.0001)))
AC Fatigue	
AC Fatigue K1	0.007566
AC Fatigue K2	3.9492
AC Fatigue k3	1.281
AC Fatigue BF1	130.3674
AC Fatigue BF2	1
AC Fatigue BF3	1.217799
AC Rutting	
AC Rutting K1	-3.35412
AC Rutting K2	1.5606
AC Rutting K3	0.3791
AC Rutting BR1	4.3
AC Rutting BR2	1
AC Rutting BR3	1
AC Rutting Standard Deviation	0.1414*Pow(RUT,0.25)+0.001
CSM Cracking	
CSM Fatigue	
IRI	
IRI Flexible C1	50
IRI Flexible C2	0.55
IRI Flexible C3	0.0111
IRI Flexible C4	0.02
IRI Flexible Over PCCC1	40.8
IRI Flexible Over PCCC2	0.575
IRI Flexible Over PCCC3	0.0014
IRI Flexible Over PCCC4	0.00825
Subgrade Rutting	
Granular Subgrade Rutting K1	2.03
Granular Subgrade Rutting BS1	0.22
Granular Subgrade Rutting Standard Deviation	0.0104*Pow(BASERUT,0.67)+0.001
Fine Subgrade Rutting K1	1.35
Fine Subgrade Rutting BS1	0.37
Fine Subgrade Rutting Standard Deviation	0.0663*Pow(SUBRUT,0.5)+0.001
Thermal Fracture	
AC thermal cracking Level 1K	6.3
AC thermal cracking Level 1 Standard Deviation	0.1468 * THERMAL + 65.027
AC thermal cracking Level 2K	0.5
AC thermal cracking Level 2 Standard Deviation	0.2841 *THERMAL + 55.462
AC thermal cracking Level 3K	6.3
AC thermal cracking Level 3 Standard Deviation	0.3972 * THERMAL + 20.422
Identifiers	

Figure 6.7 Performance Prediction Model Coefficients for Flexible Pavement Designs (Polymer Modified Superpave Mix)

are shown in **Figure 7.4 Performance Prediction Model Coefficients for Rigid Pavement Designs.**

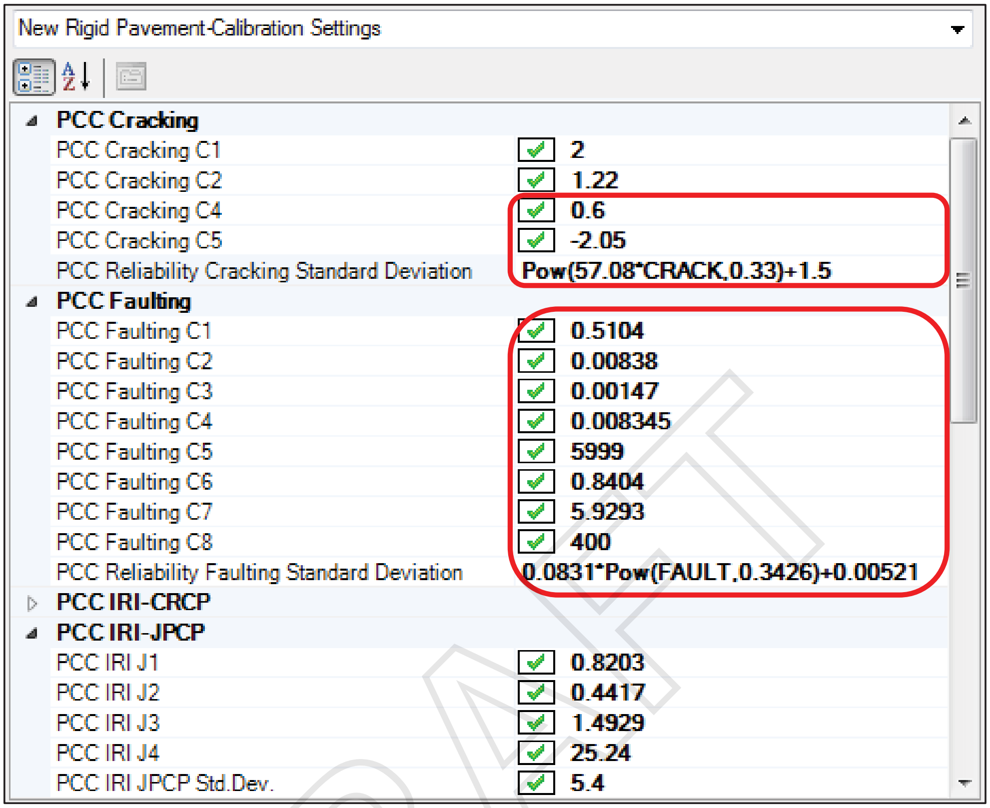


Figure 7.4 Performance Prediction Model Coefficients for Rigid Pavement Designs

7.5 Select the Appropriate Reliability Level for the Project

Table 2.3 Reliability (Risk) presents recommended reliability levels for rigid pavement designs. The designer should select an appropriate reliability level based on highway functional class and location (see **Figure 7.3 M-E Design Screenshot Showing General Information, Performance Criteria, and Reliability**).

7.6 Assemble the M-E Design Inputs

7.6.1 General Information

7.6.1.1 Design Period

The design period for new rigid pavement construction and reconstruction is 20 or 30 years. It is recommended a 30-year design period be used for rigid pavements. Selection of a design period other than 10, 20, or 30 years needs to be supported by a LCCA or other overriding considerations.

Pavement Calculations
(M-E Analysis)

US6-7.5inPCC_6inABC_30yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\US6-7.5inPCC_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	7.3
NonStabilized	A-1-a	6.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.00
Slab width (ft)	12.0

Traffic

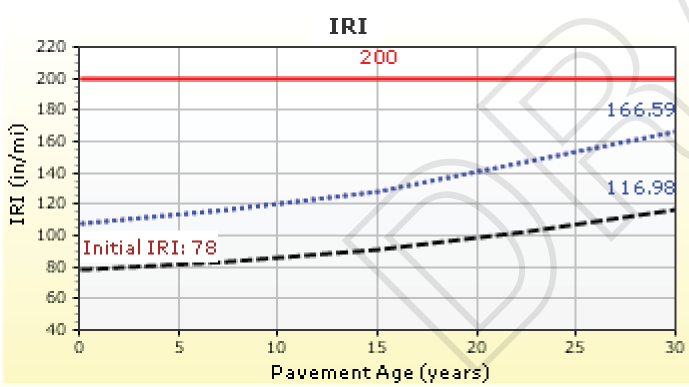
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2037 (15 years)	1,706,340
2052 (30 years)	4,203,070

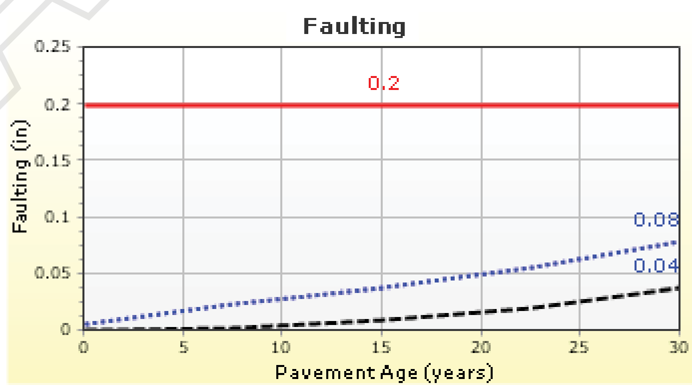
Design Outputs

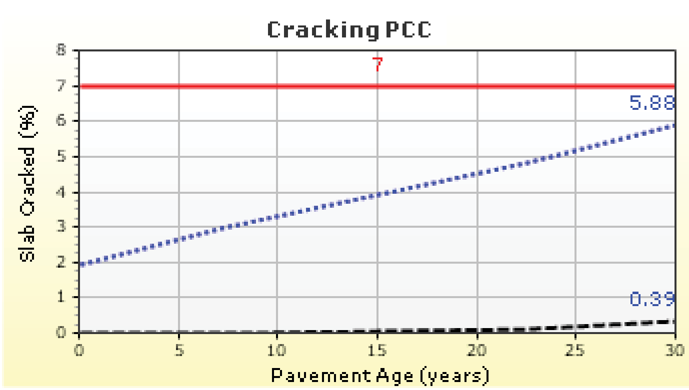
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	166.59	90.00	98.40	Pass
Mean joint faulting (in)	0.20	0.08	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	5.88	90.00	93.86	Pass

Distress Charts



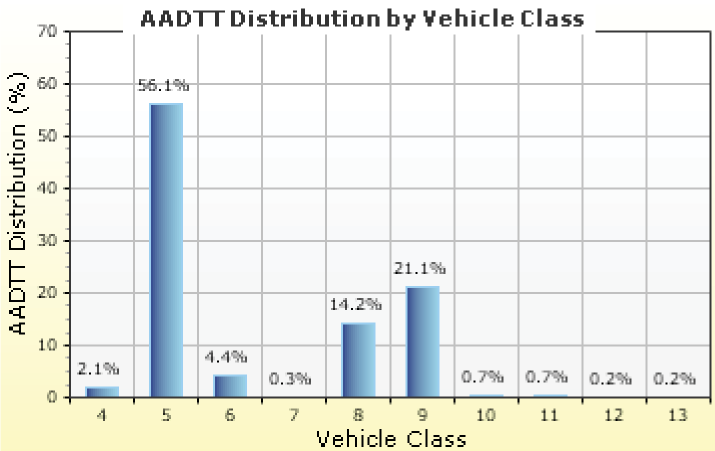


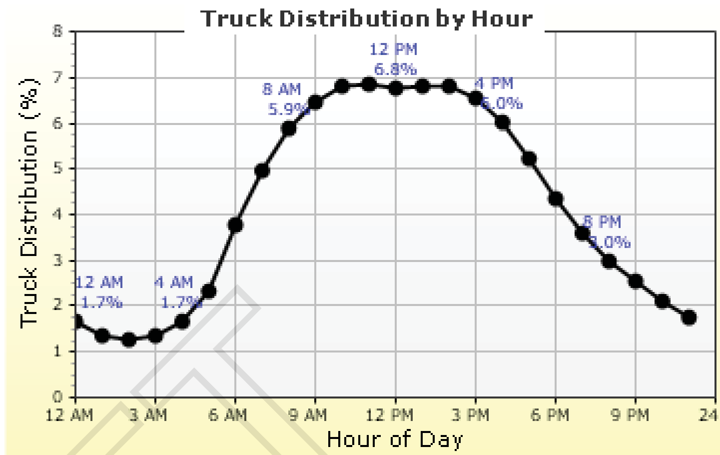


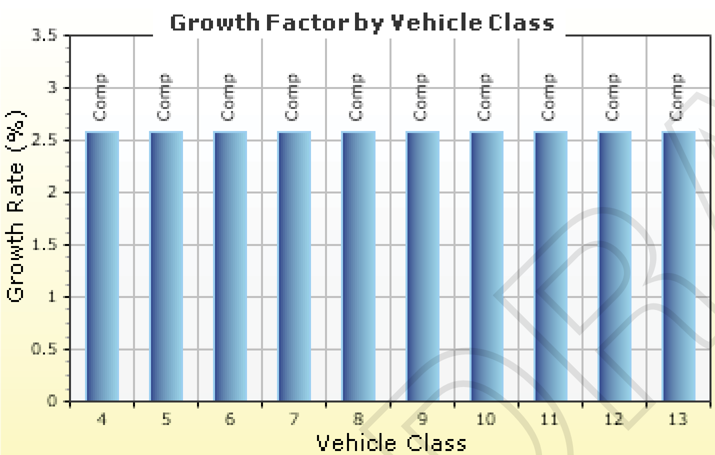
Traffic Inputs

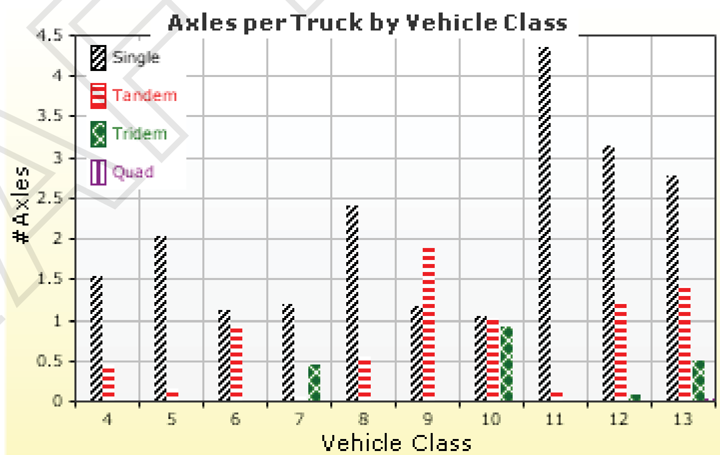
Graphical Representation of Traffic Inputs

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)	35.0

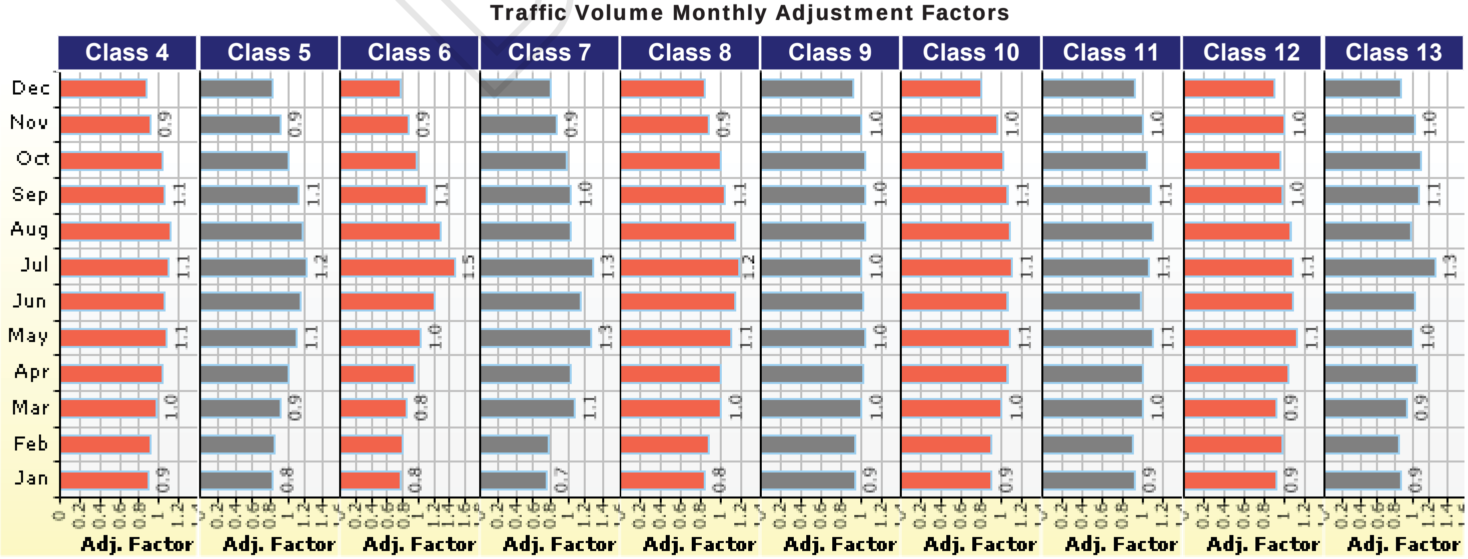








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

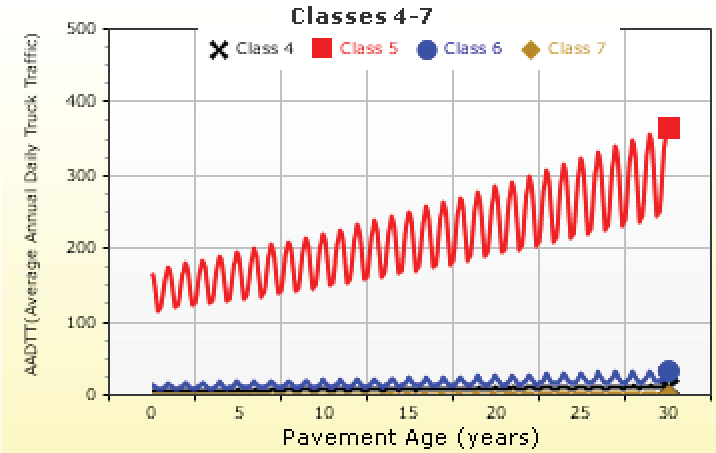
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12.0	15.0	18.0
Percent of Trucks (%)	17.0	22.0	61.0

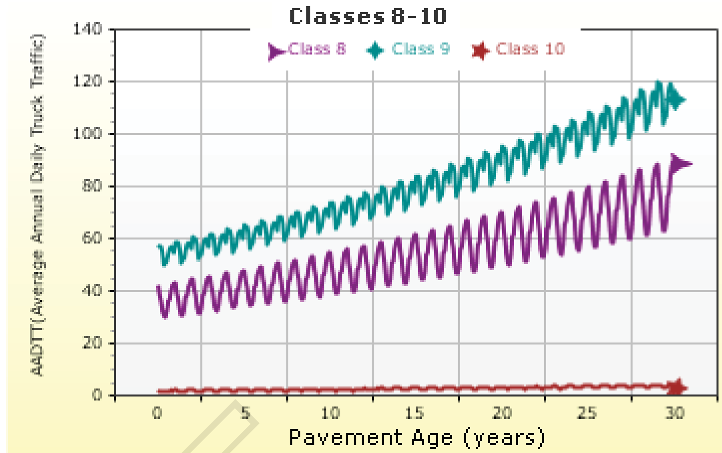
Number of Axles per Truck

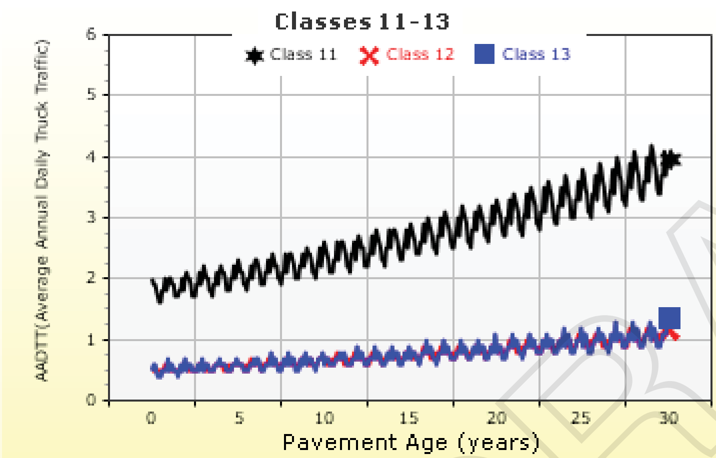
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

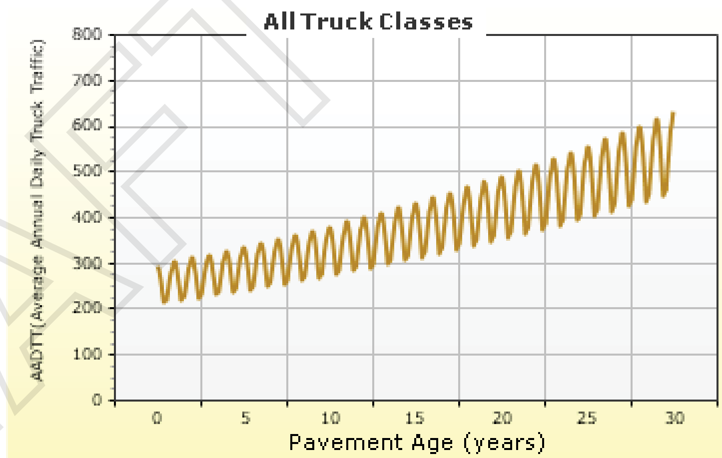
AADTT (Average Annual Daily Truck Traffic) Growth

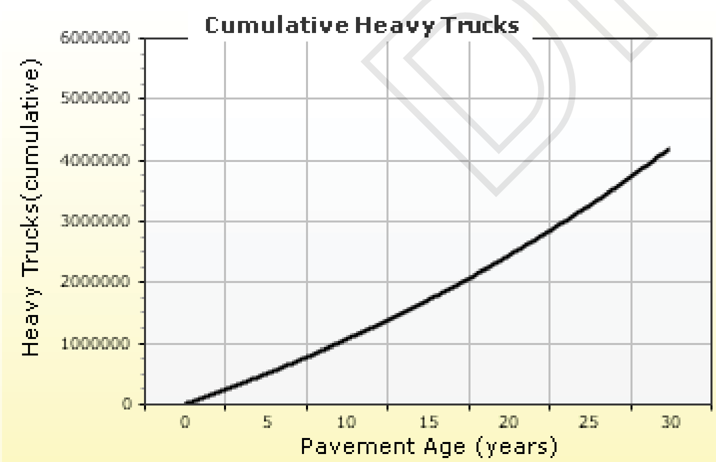
*** Traffic cap is not enforced**







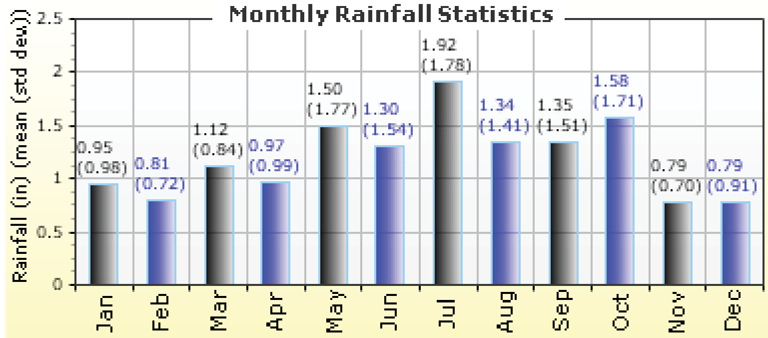




Climate Inputs

Climate Data Sources:

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

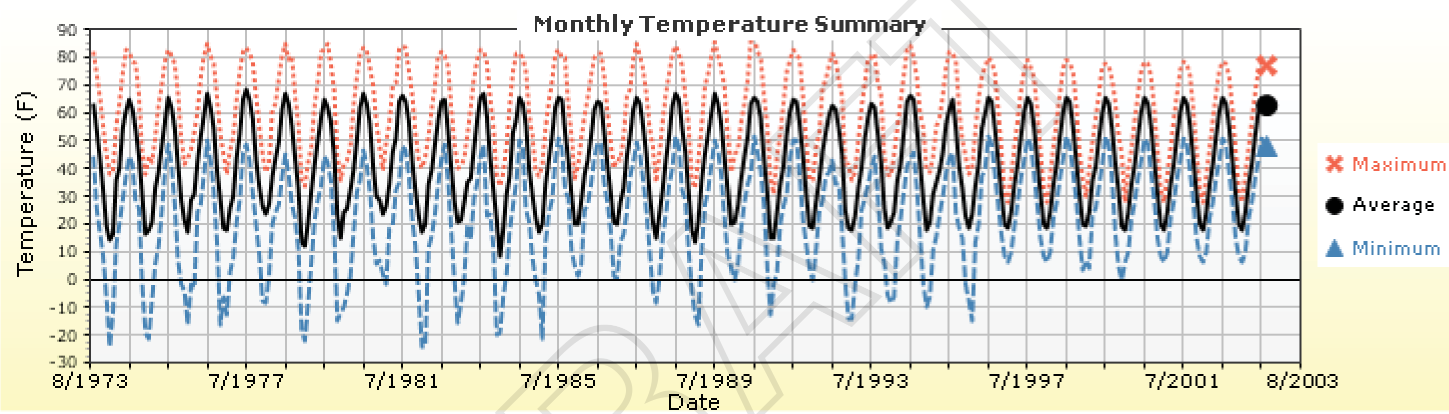


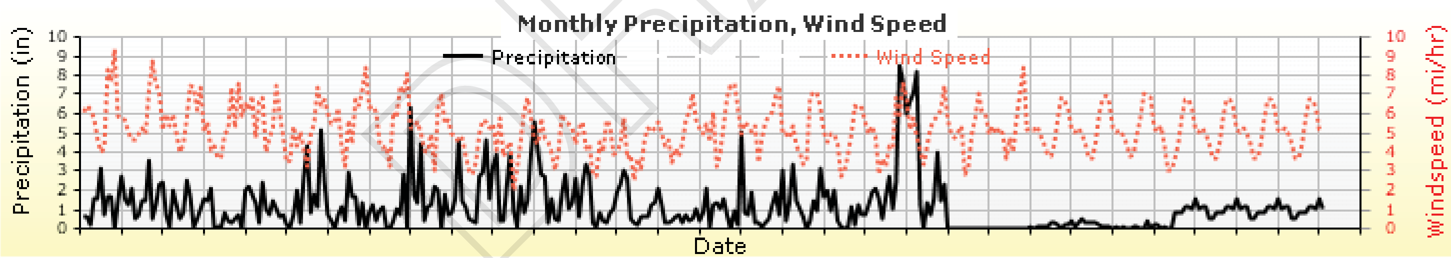
Annual Statistics:

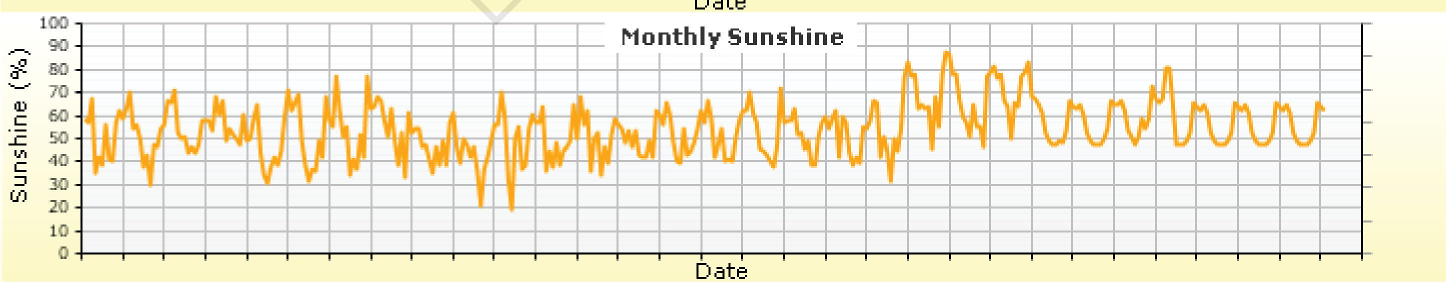
Mean annual air temperature (ºF)	42.70
Mean annual precipitation (in)	14.43
Freezing index (ºF - days)	1069.78
Average annual number of freeze/thaw cycles:	103.27

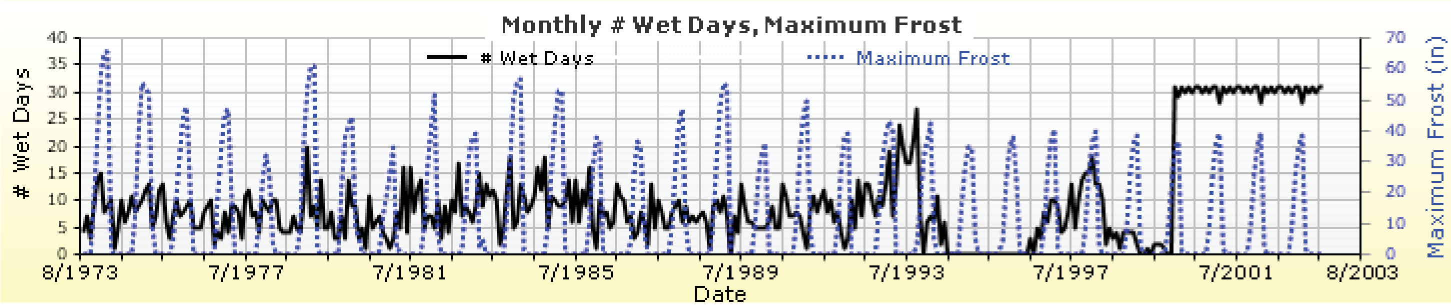
Water table depth (ft)	10.00

Monthly Climate Summary:

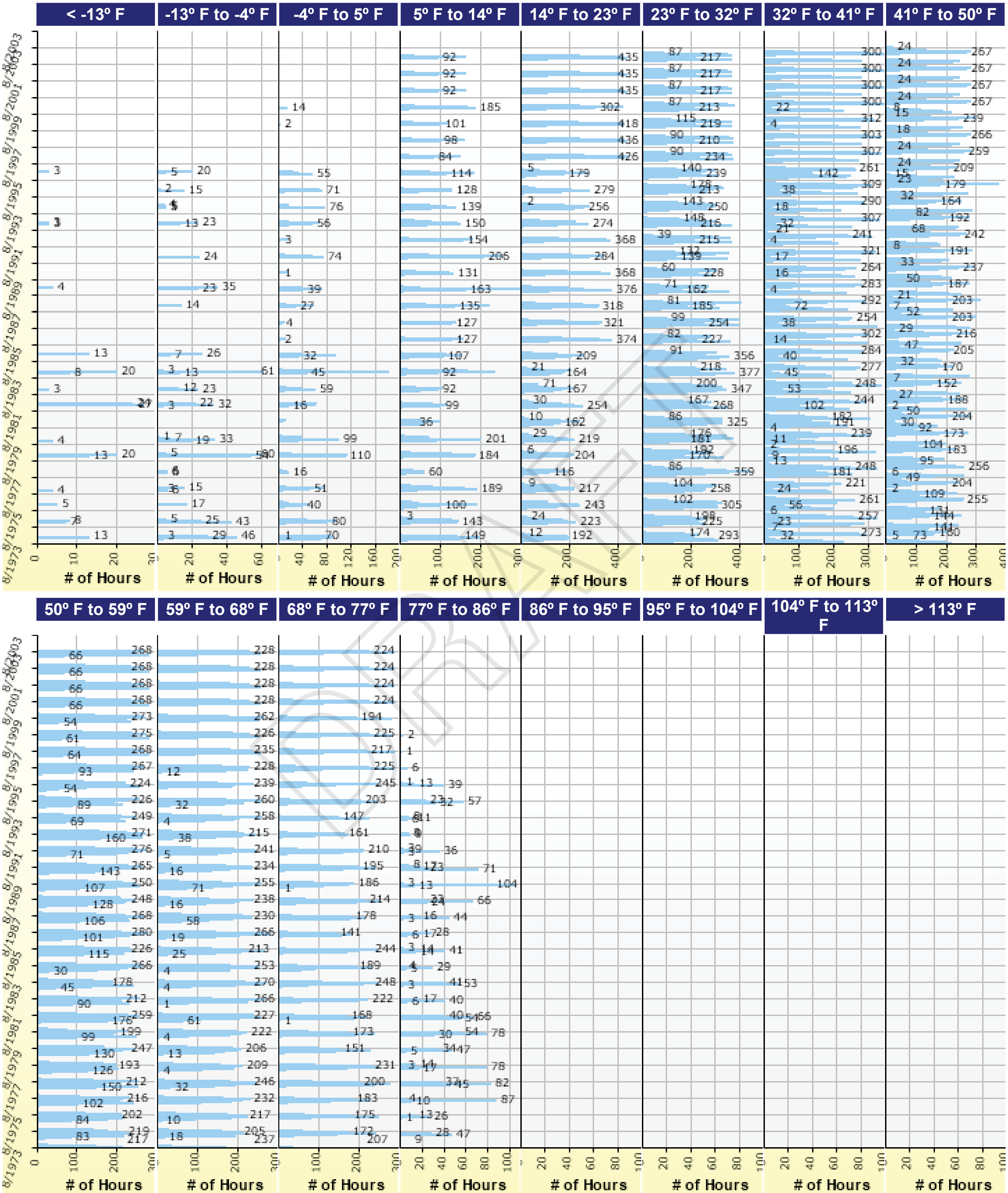








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in)	1.00
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

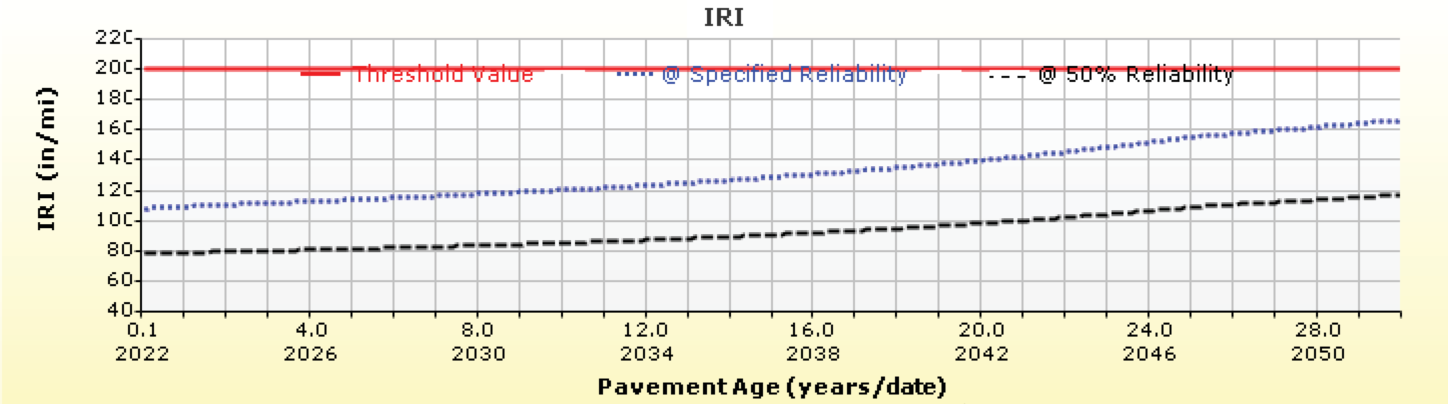
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

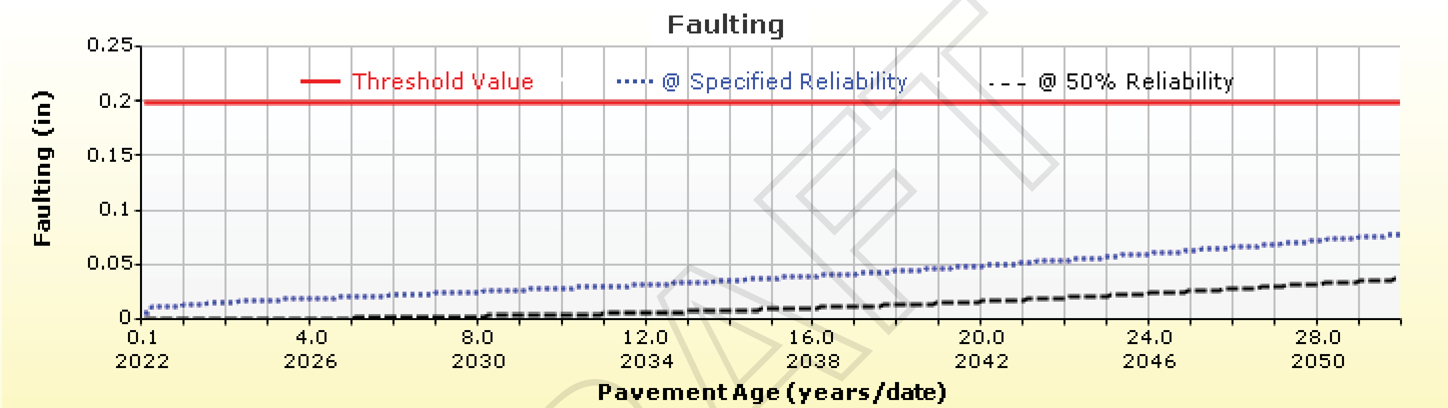
Sealant type	Other(Including No Sealant... Liquid... Silicone)

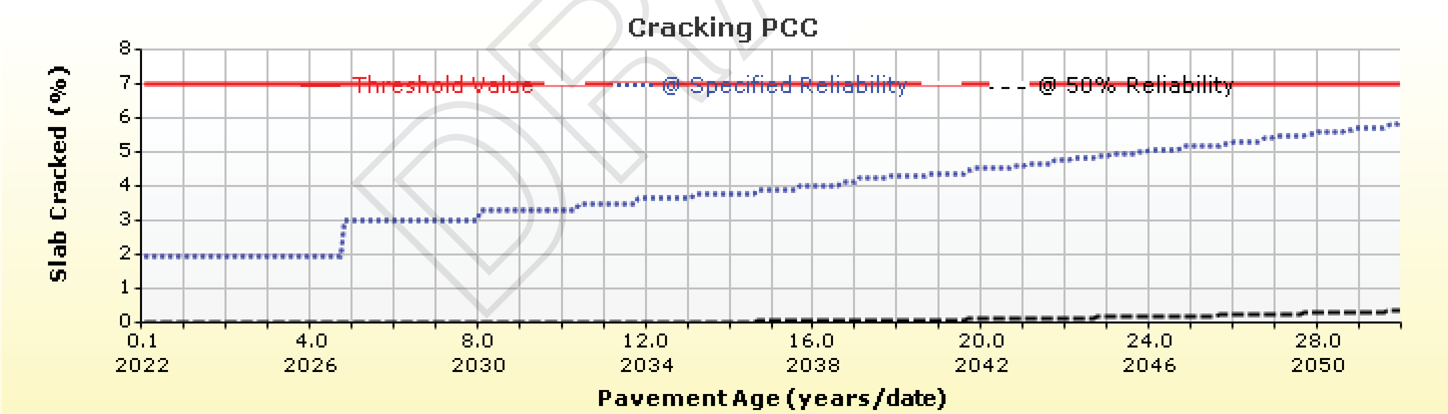
Erodibility index	4

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

Analysis Output Charts

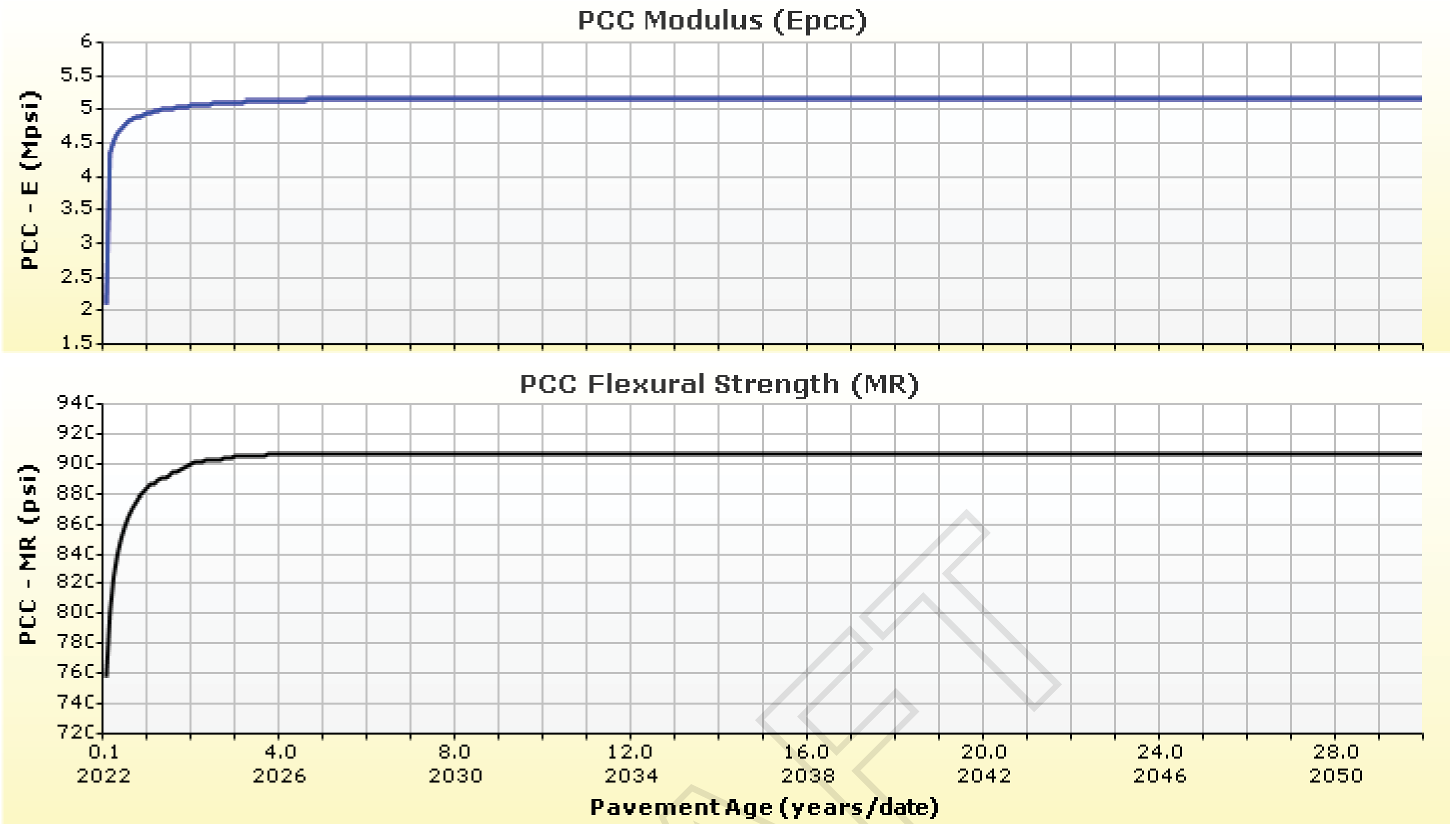


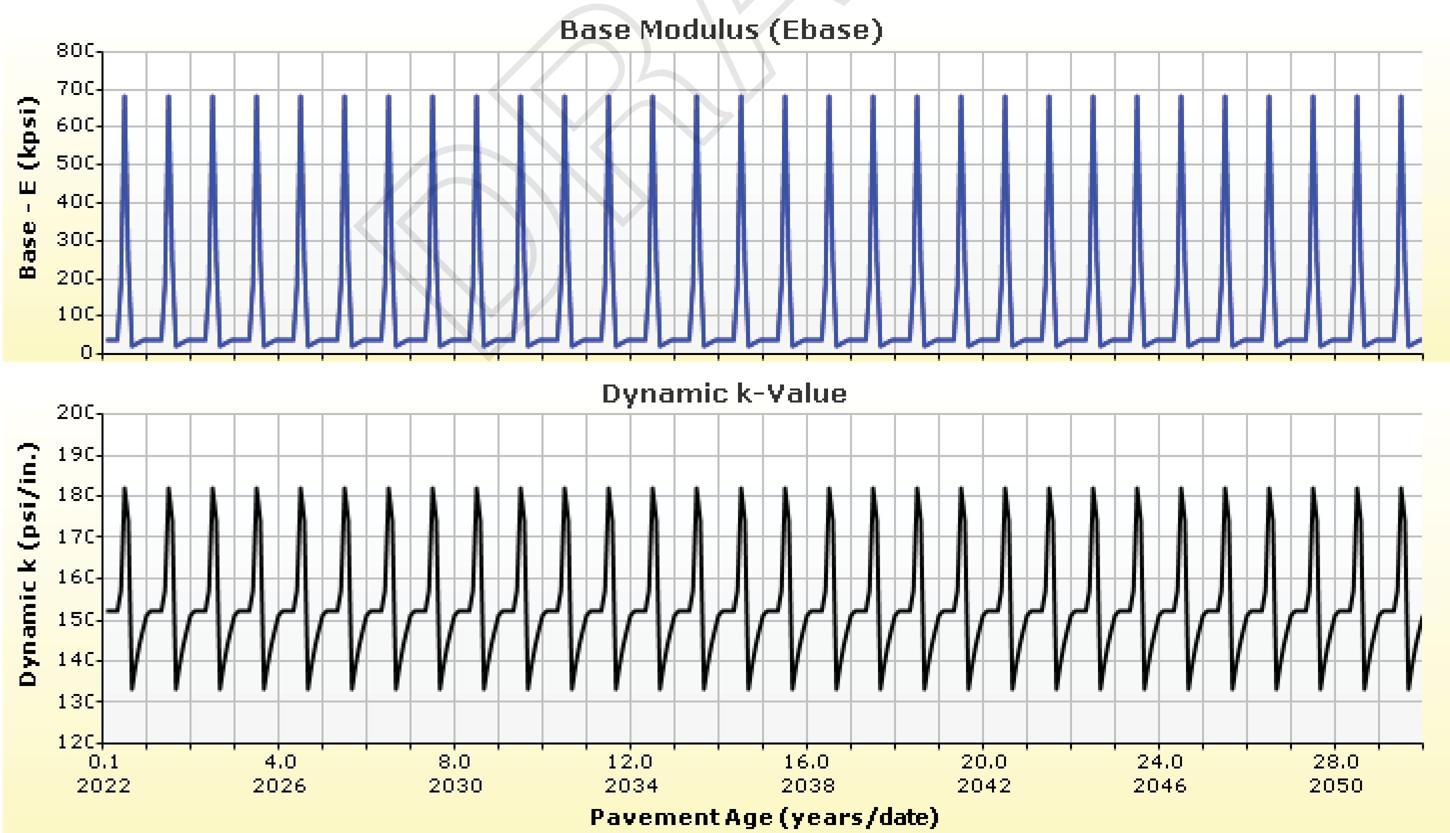


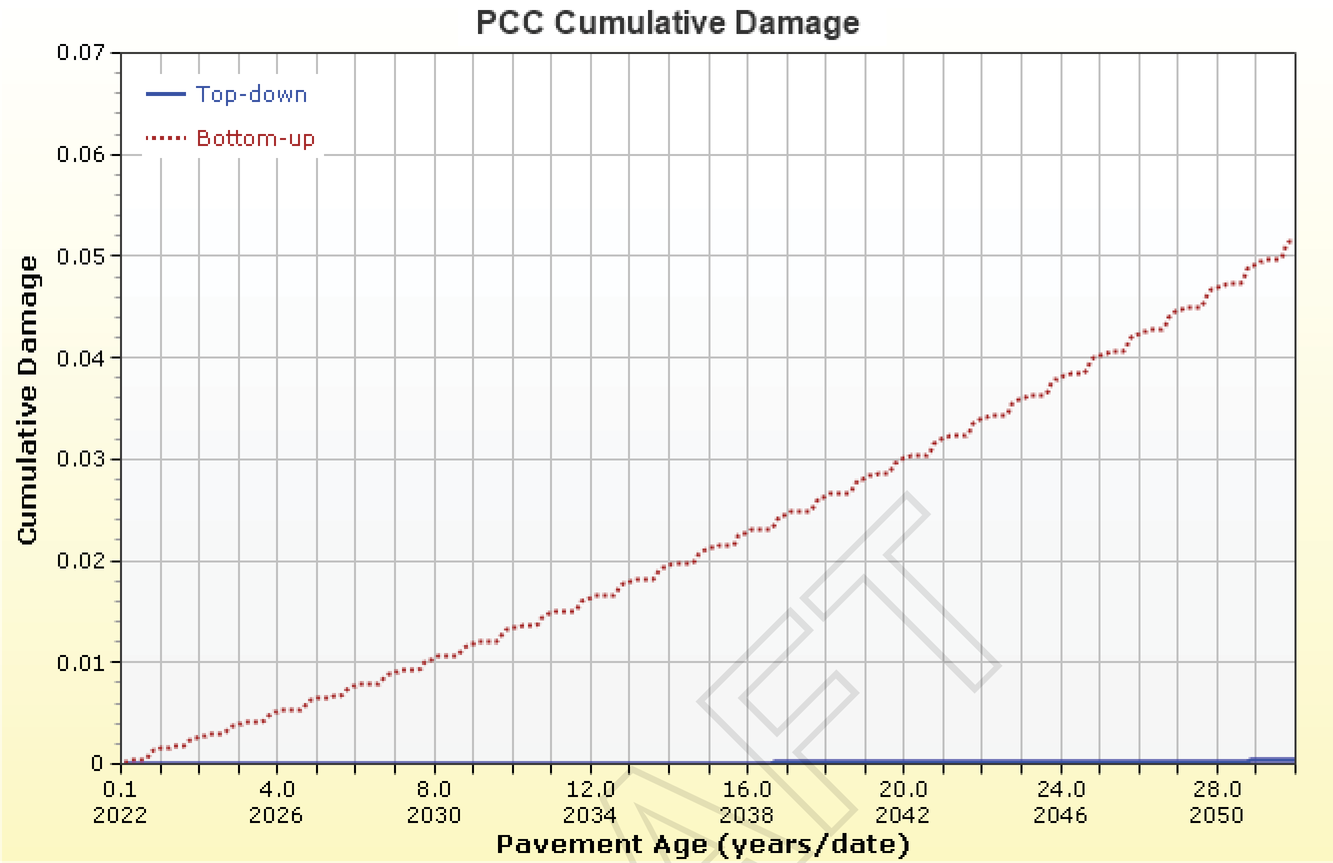


US6-7.5inPCC_6inABC_30yr

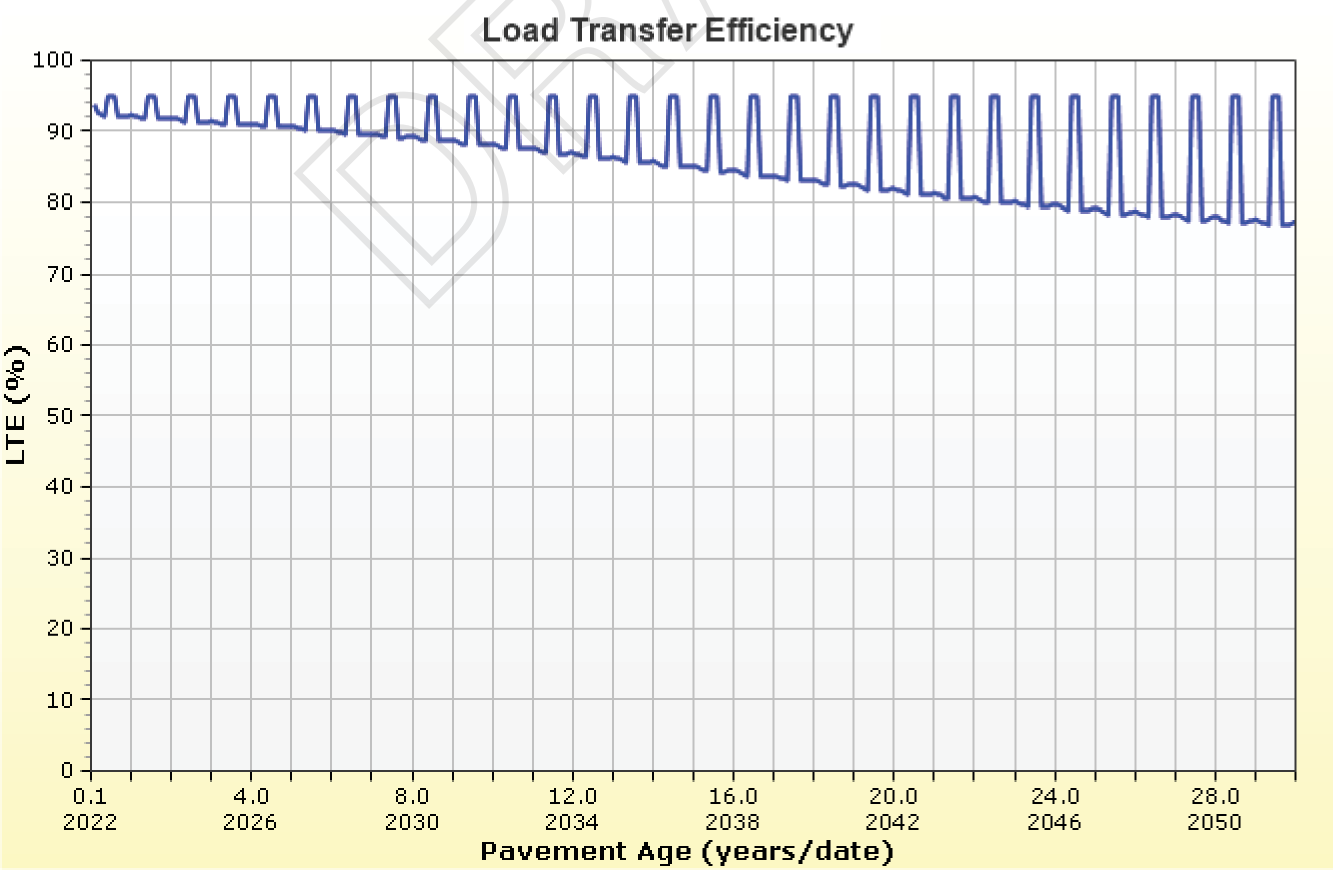
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\US6-7.5inPCC_6inABC_30yr.dgpx







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)	7.3
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	96.8
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)
27000.0

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-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)
10000.0

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-2-6

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)
10000.0

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

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

Roundabout-7.5inPCC_6inABC_30yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout-7.5inPCC_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	7.3
NonStabilized	A-1-a	6.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.00
Slab width (ft)	12.0

Traffic

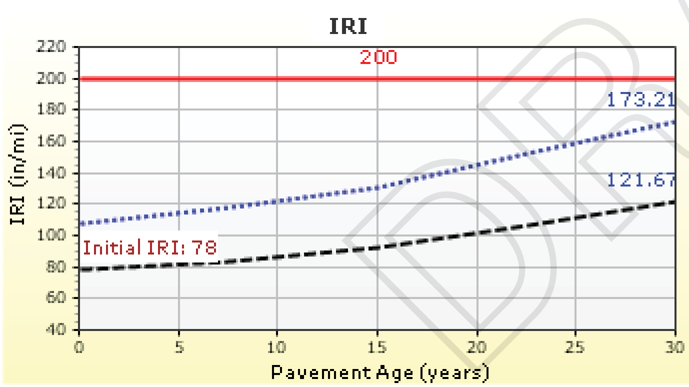
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	305
2037 (15 years)	2,007,850
2052 (30 years)	4,945,740

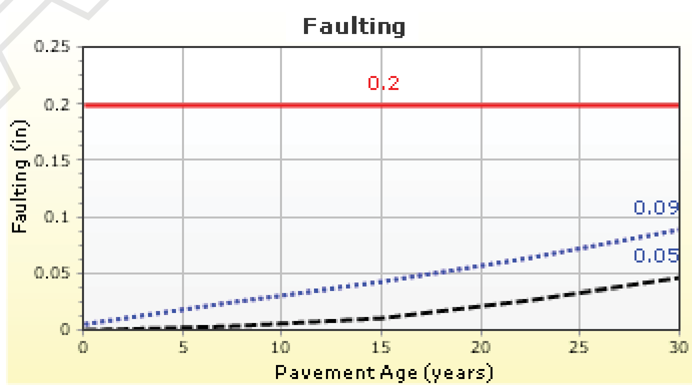
Design Outputs

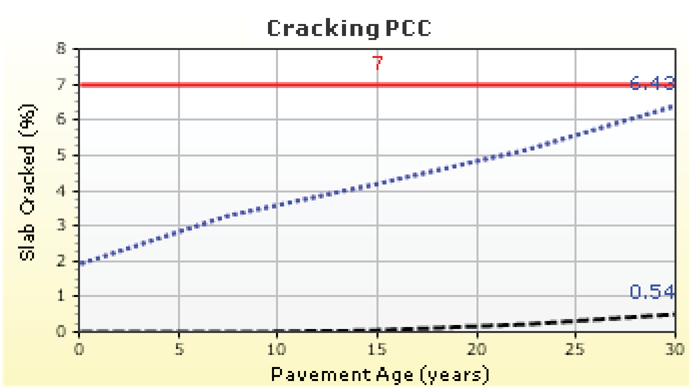
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	173.21	90.00	97.43	Pass
Mean joint faulting (in)	0.20	0.09	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	7.00	6.43	90.00	91.99	Pass

Distress Charts



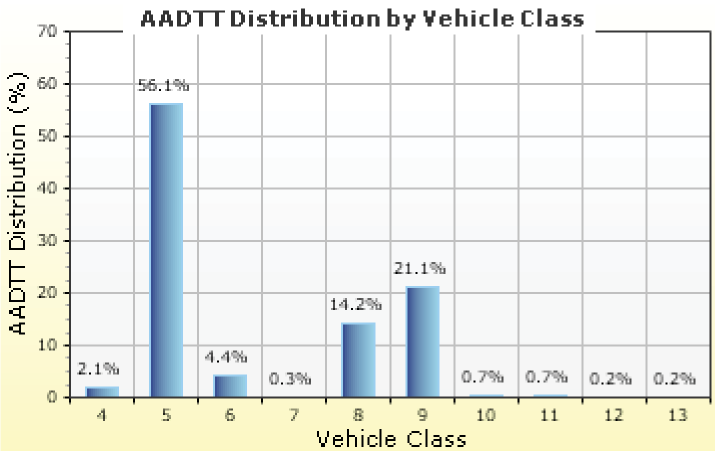


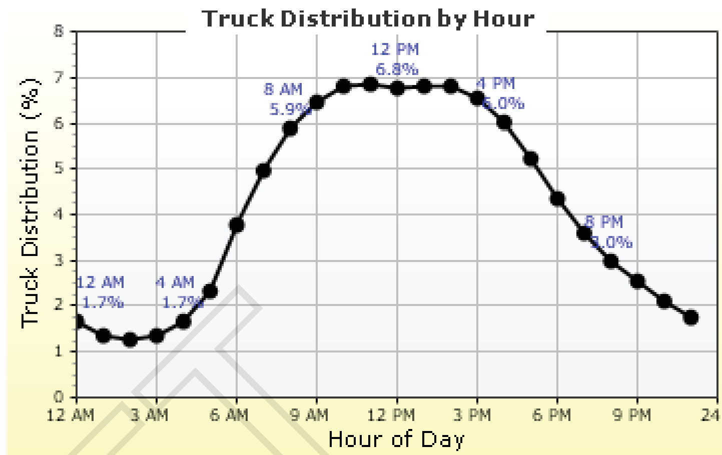


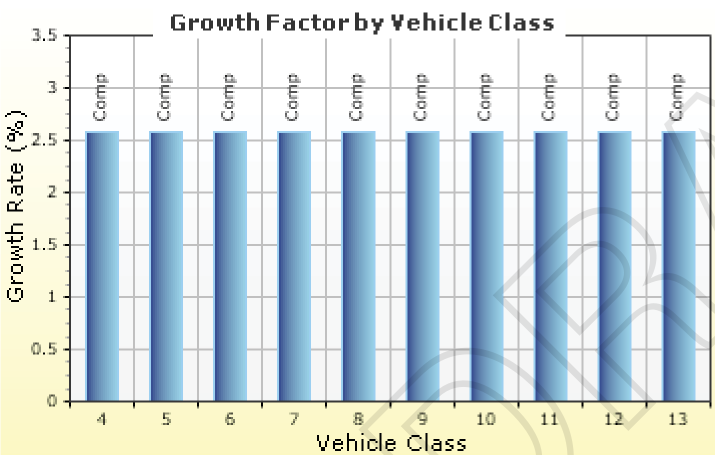
Traffic Inputs

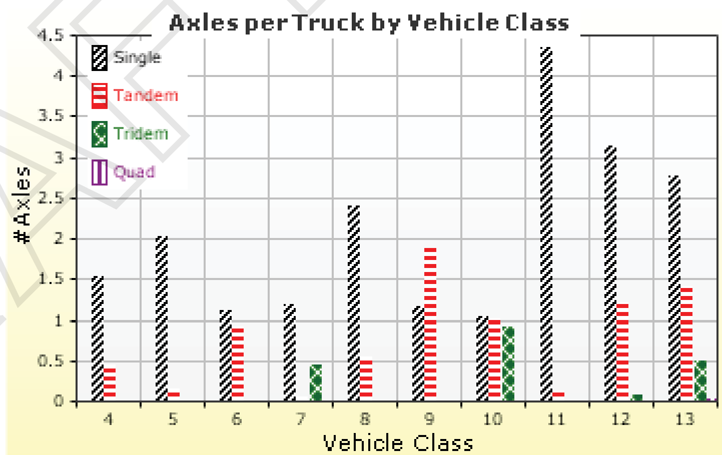
Graphical Representation of Traffic Inputs

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)	15.0

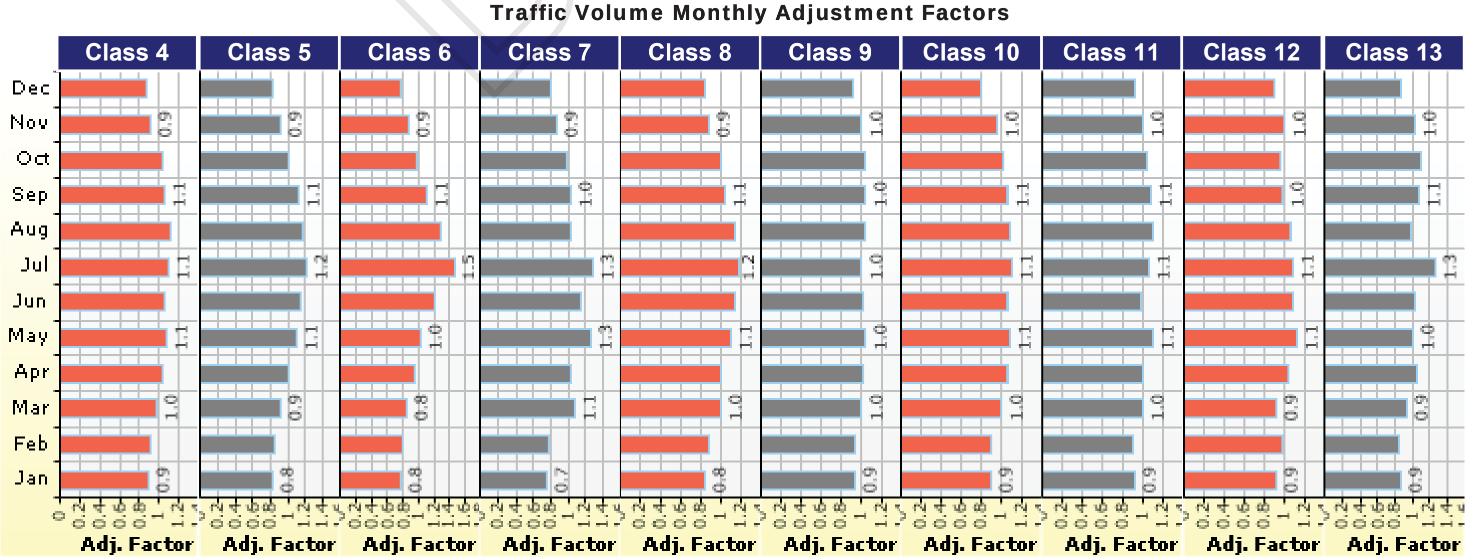








Traffic Volume Monthly Adjustment Factors



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%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

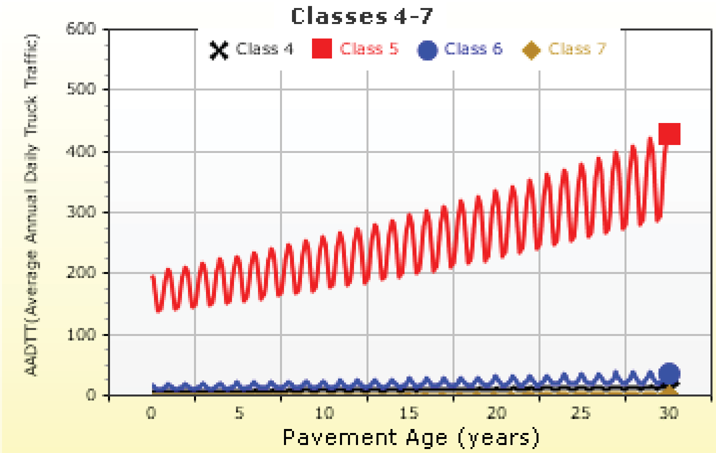
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

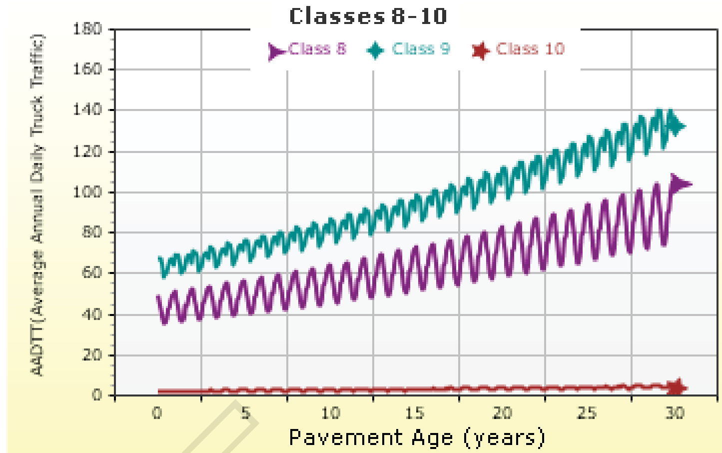
Roundabout-7.5inPCC_6inABC_30yr

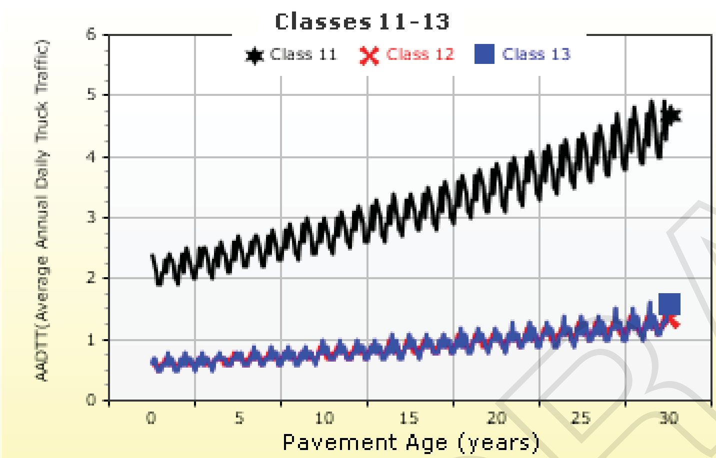
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout-7.5inPCC_6inABC_30yr.dgpx

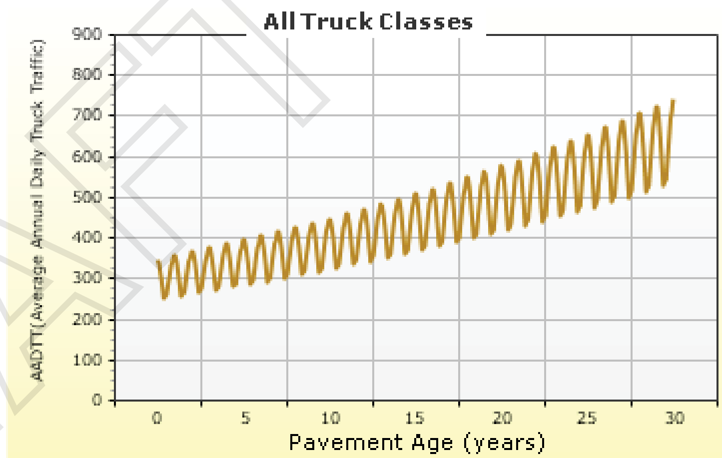
AADTT (Average Annual Daily Truck Traffic) Growth

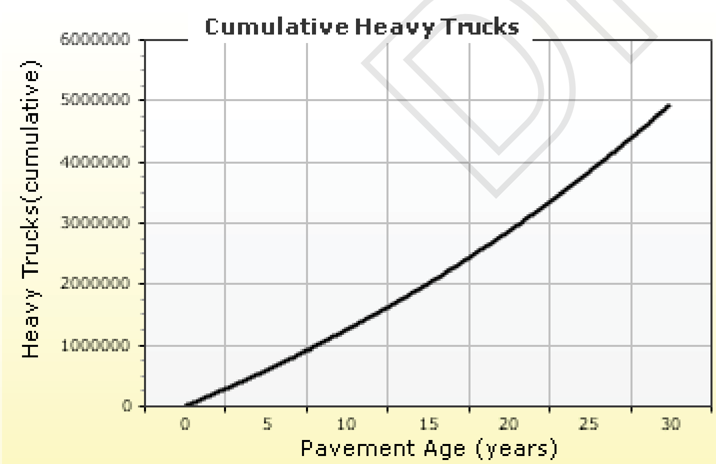
*** Traffic cap is not enforced**







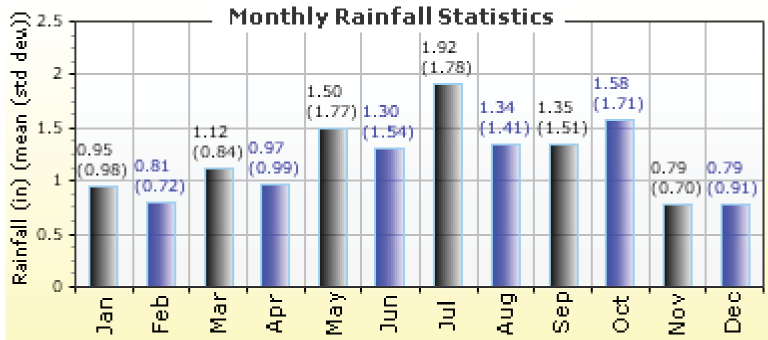




Climate Inputs

Climate Data Sources:

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

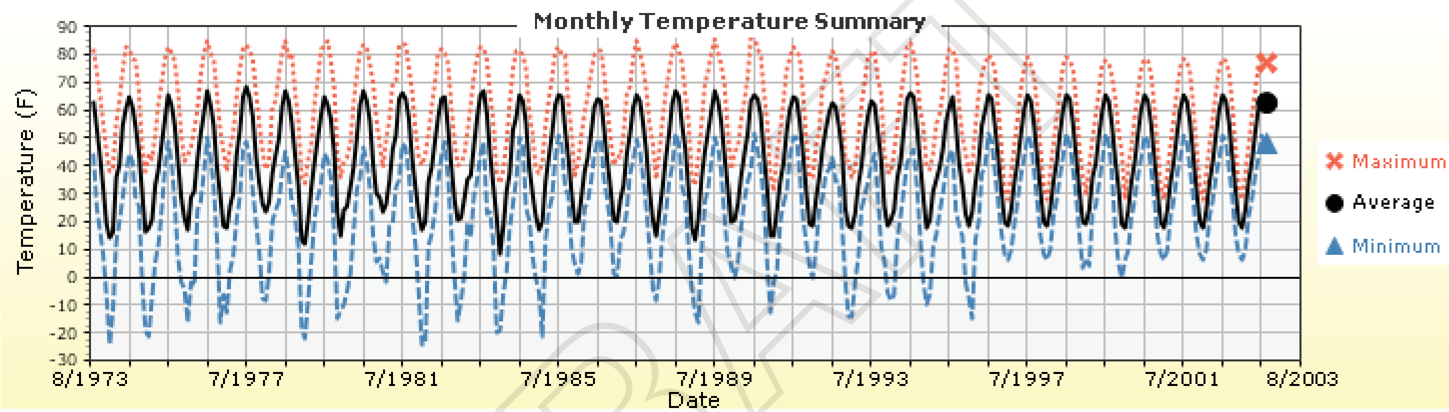


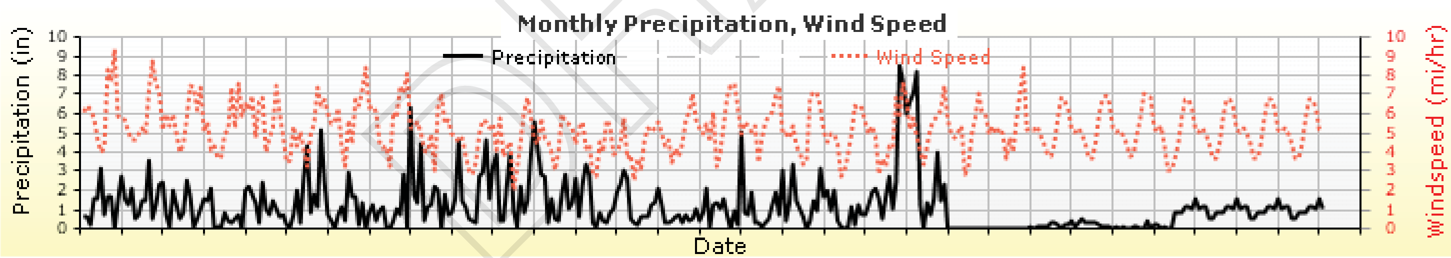
Annual Statistics:

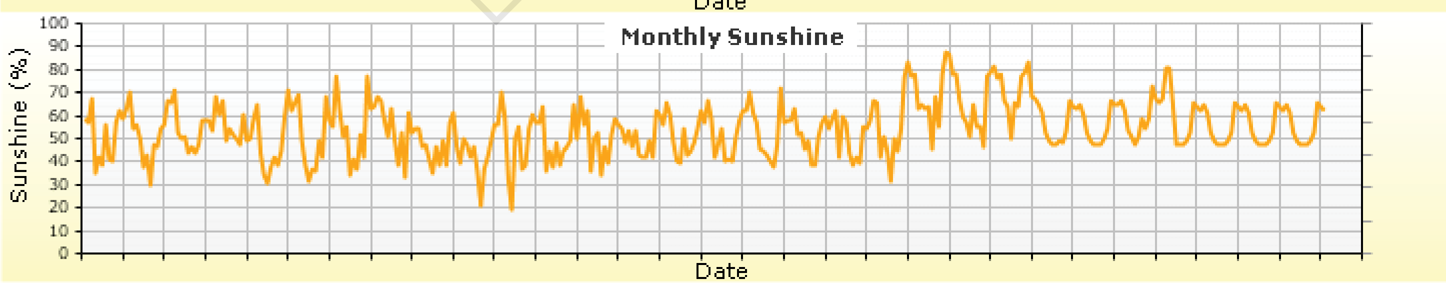
Mean annual air temperature (ºF)	42.70
Mean annual precipitation (in)	14.43
Freezing index (ºF - days)	1069.78
Average annual number of freeze/thaw cycles:	103.27

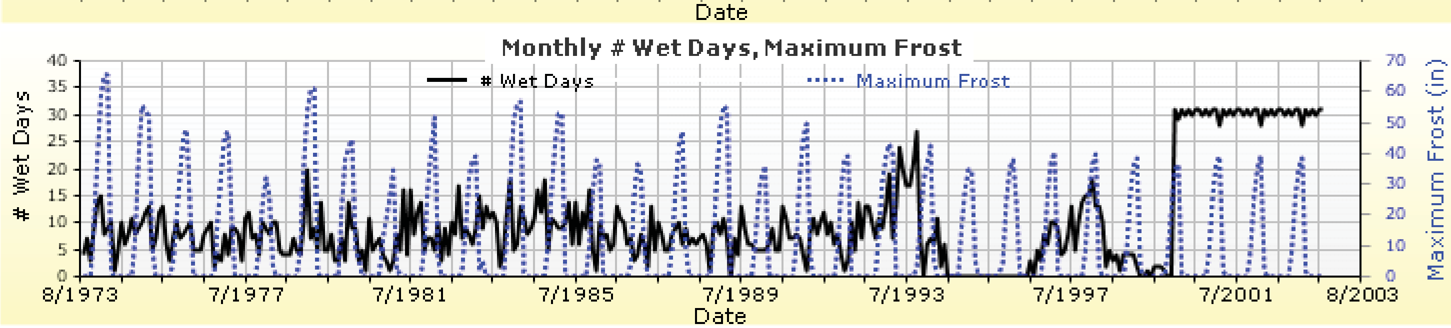
Water table depth (ft)	10.00

Monthly Climate Summary:

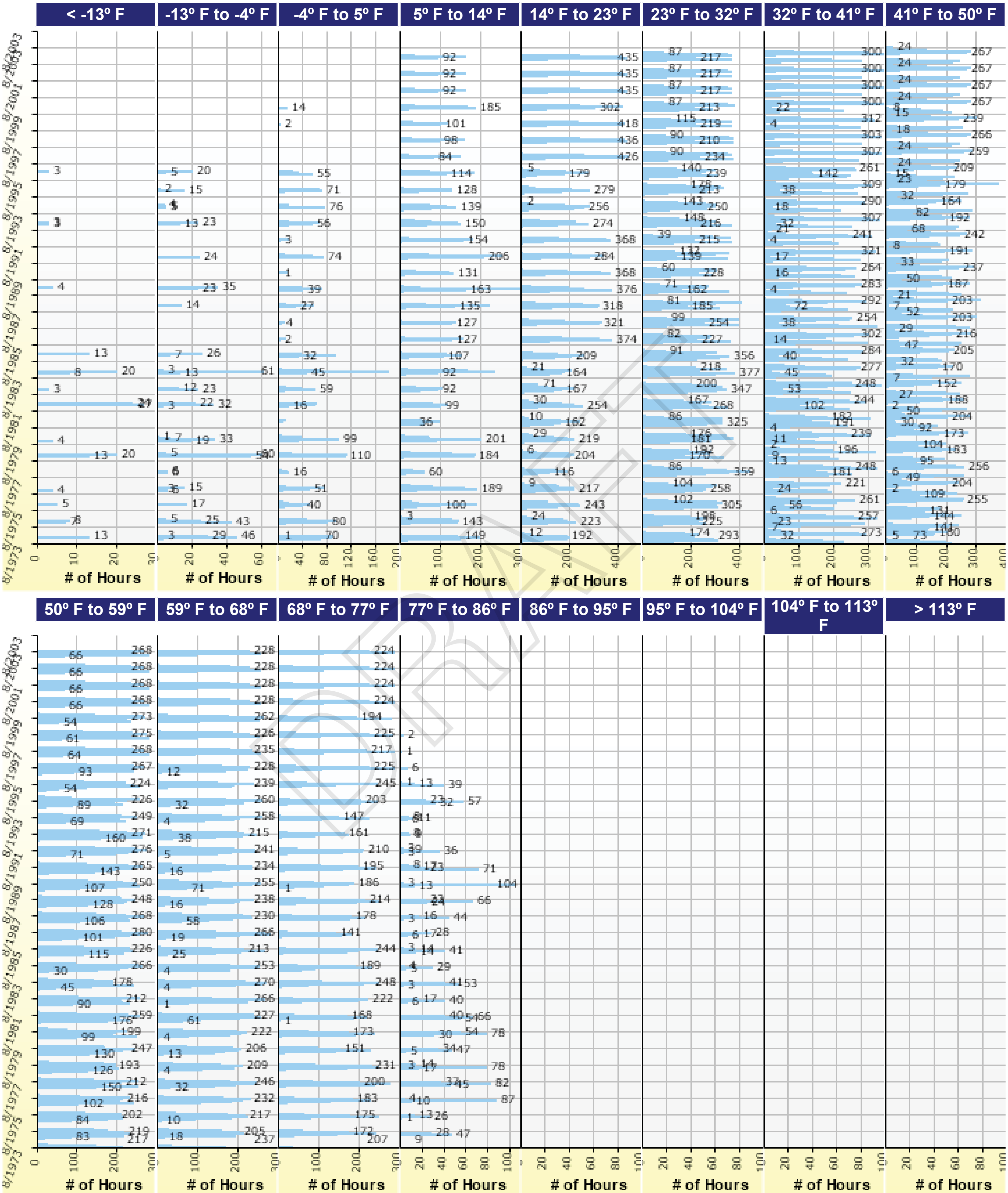








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in)	1.00
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

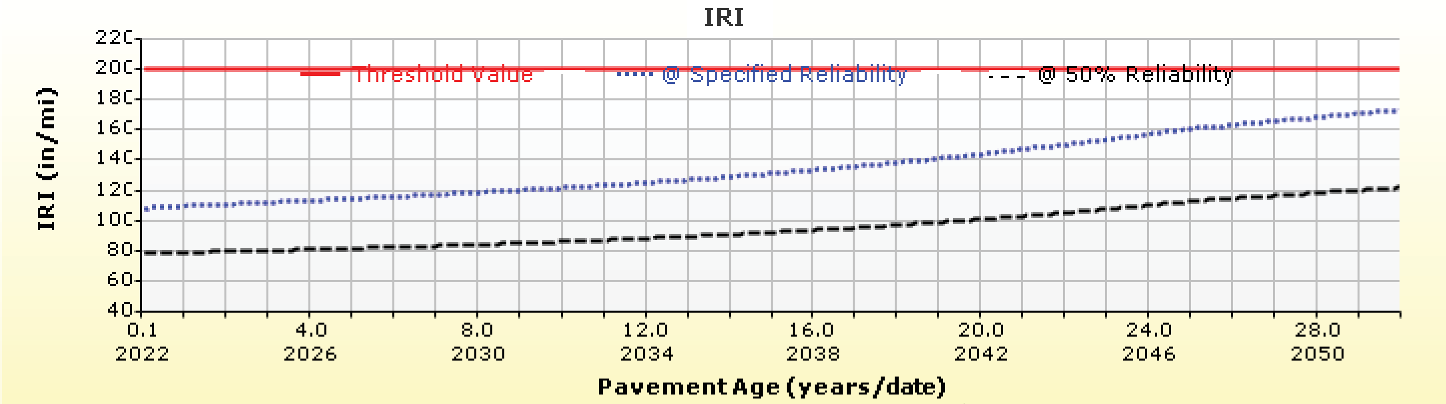
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	360.00

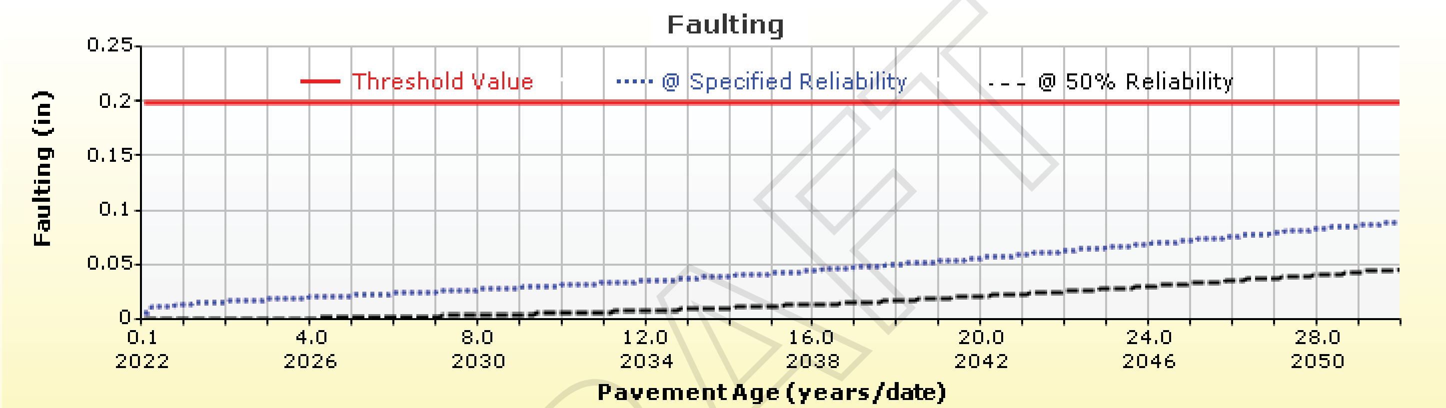
Sealant type	Other(Including No Sealant... Liquid... Silicone)

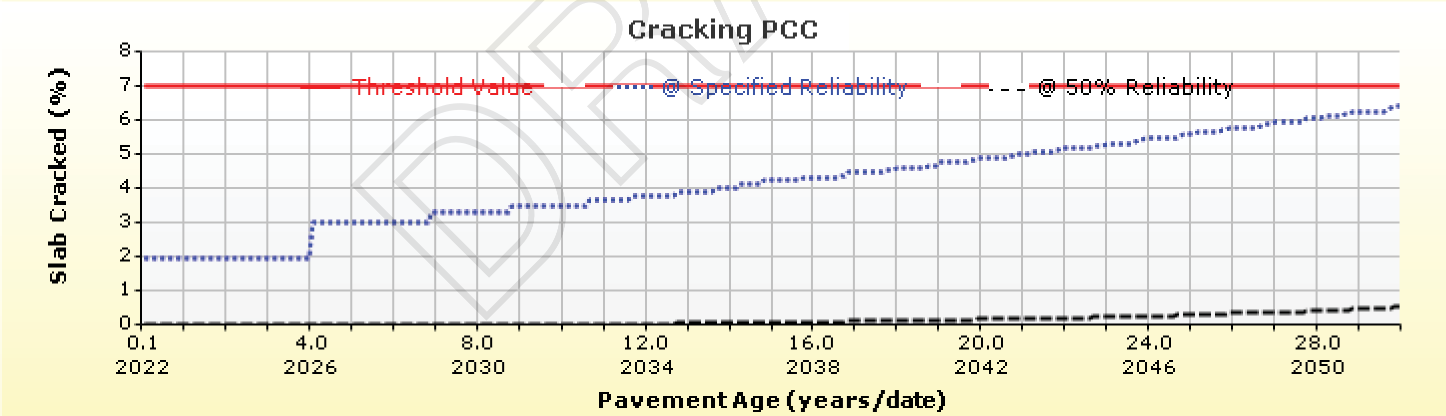
Erodibility index	4

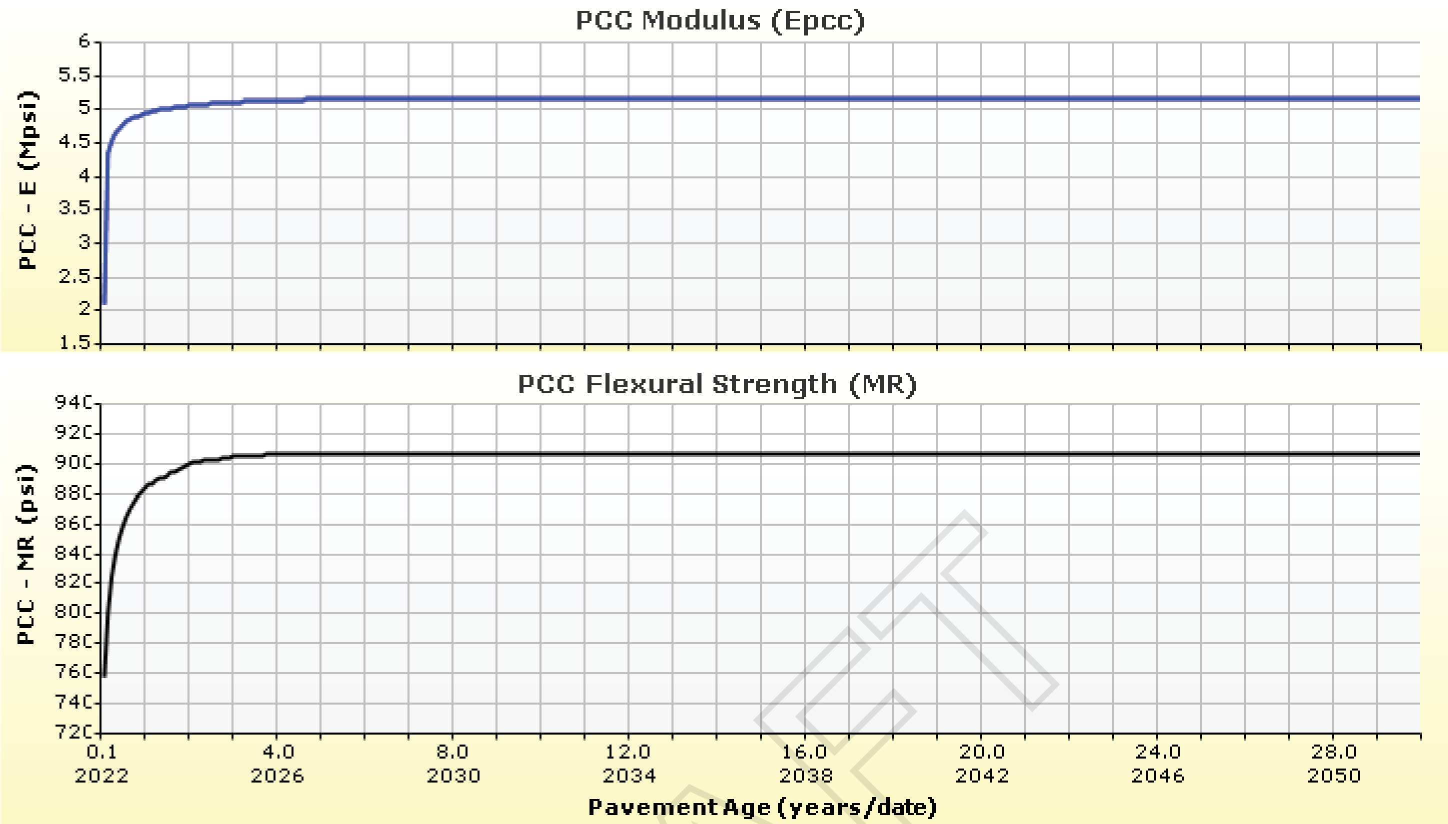
Permanent curl/warp effective temperature difference (ºF)	-10.00

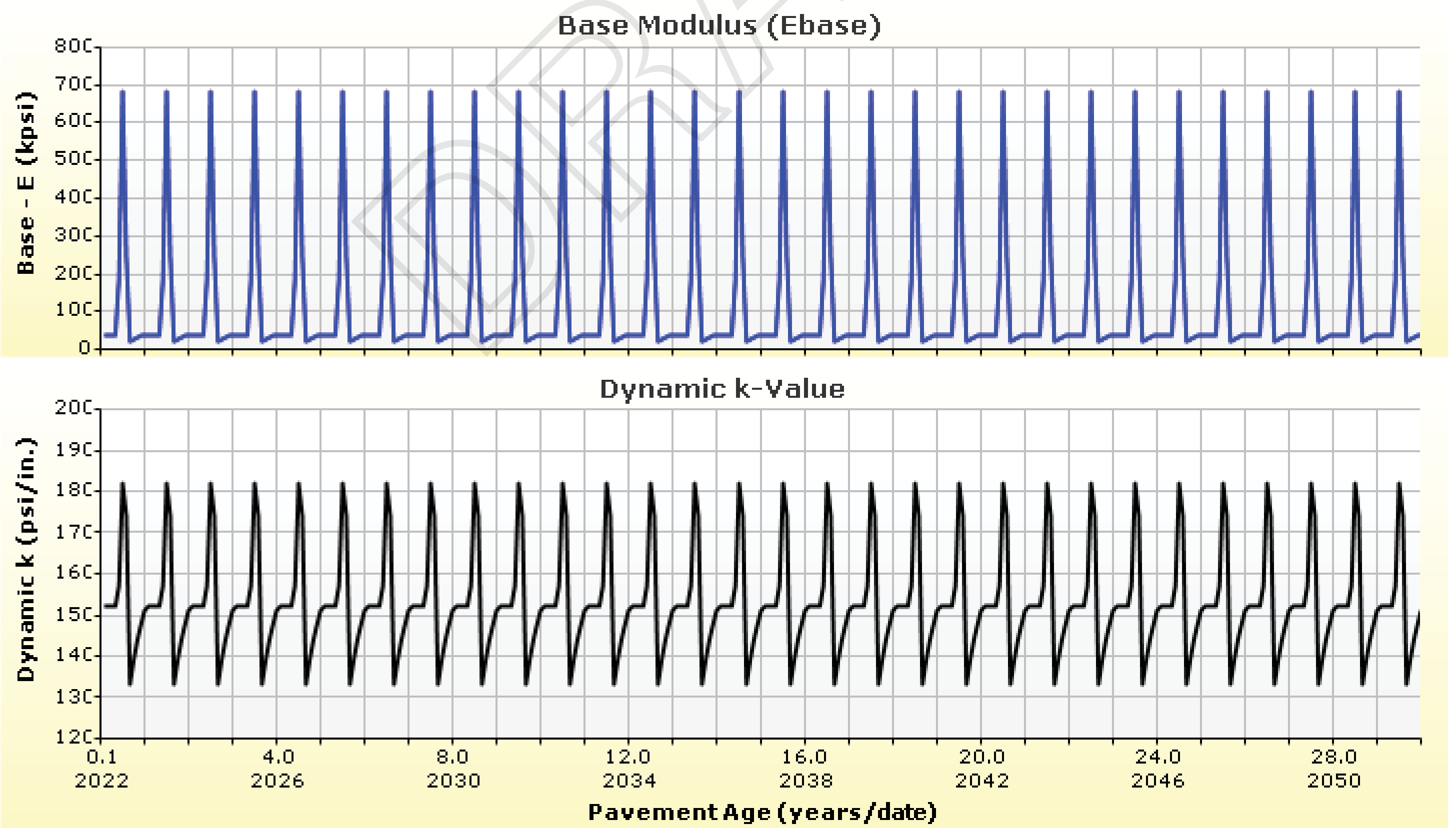
Analysis Output Charts

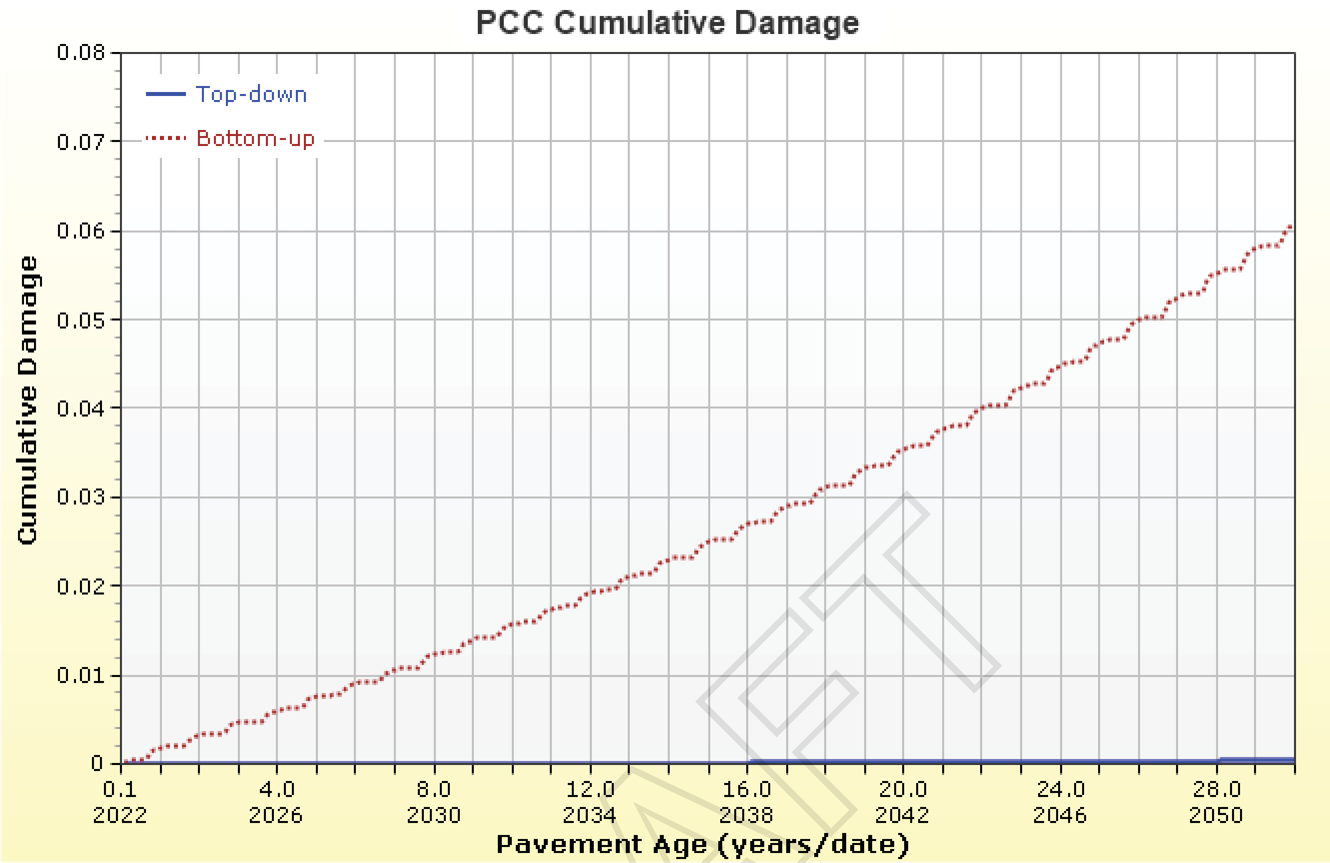


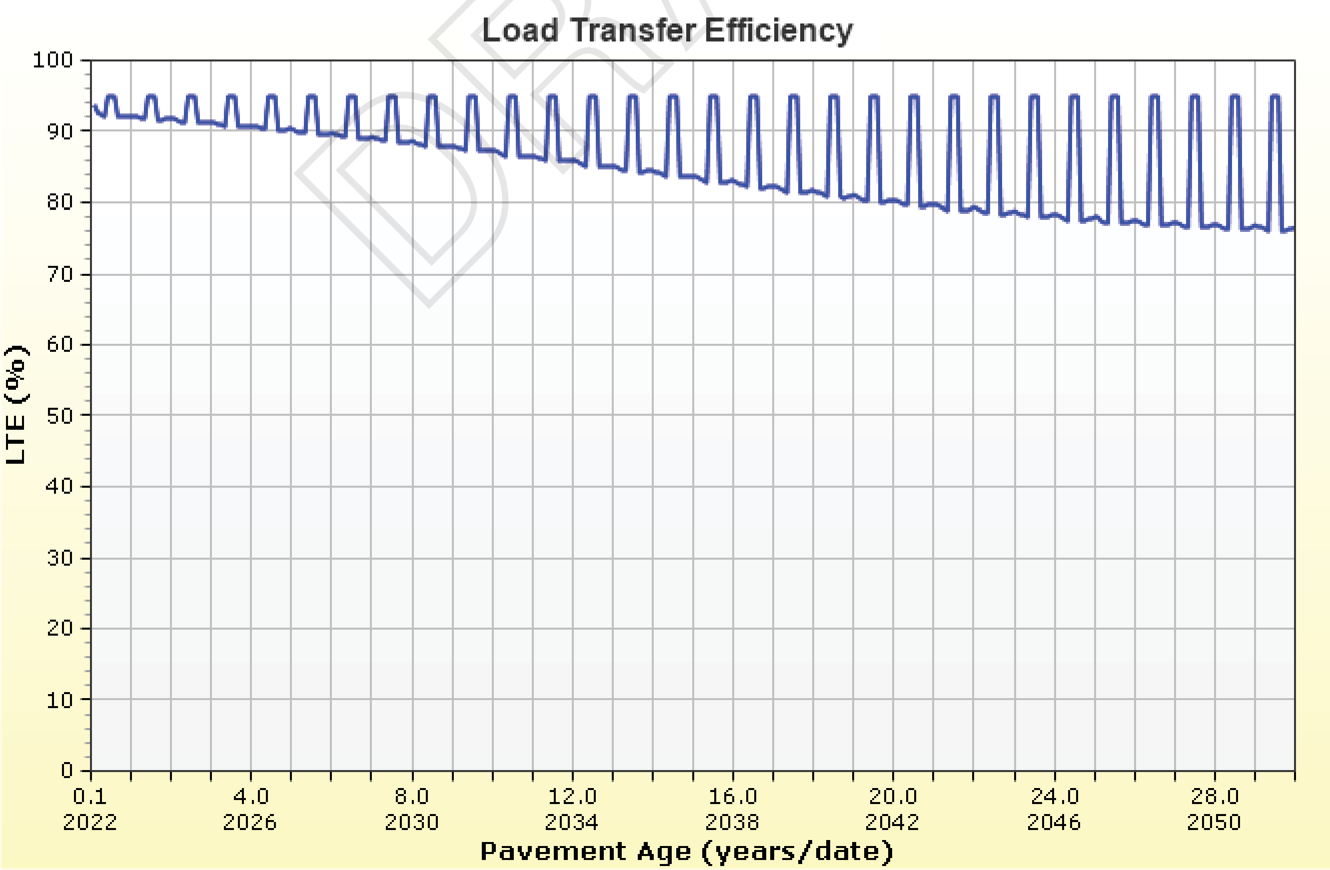





PCC Modulus (Epcc)
PCC - E (Mpsi)
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
PCC Flexural Strength (MR)
PCC - MR (psi)
720
740
760
780
800
820
840
860
880
900
920
940
0.1 2022
4.0 2026
8.0 2030
12.0 2034
16.0 2038
20.0 2042
24.0 2046
28.0 2050
Pavement Age (years/date)


Base Modulus (Ebase)
Base - E (kpsi)
0
100
200
300
400
500
600
700
800
Dynamic k-Value
Dynamic k (psi/in.)
120
130
140
150
160
170
180
190
200
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)	7.3
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	96.8
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)
27000.0

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-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)
10000.0

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-2-6

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)
10000.0

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

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

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	5.5
NonStabilized	A-1-a	6.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

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

Traffic

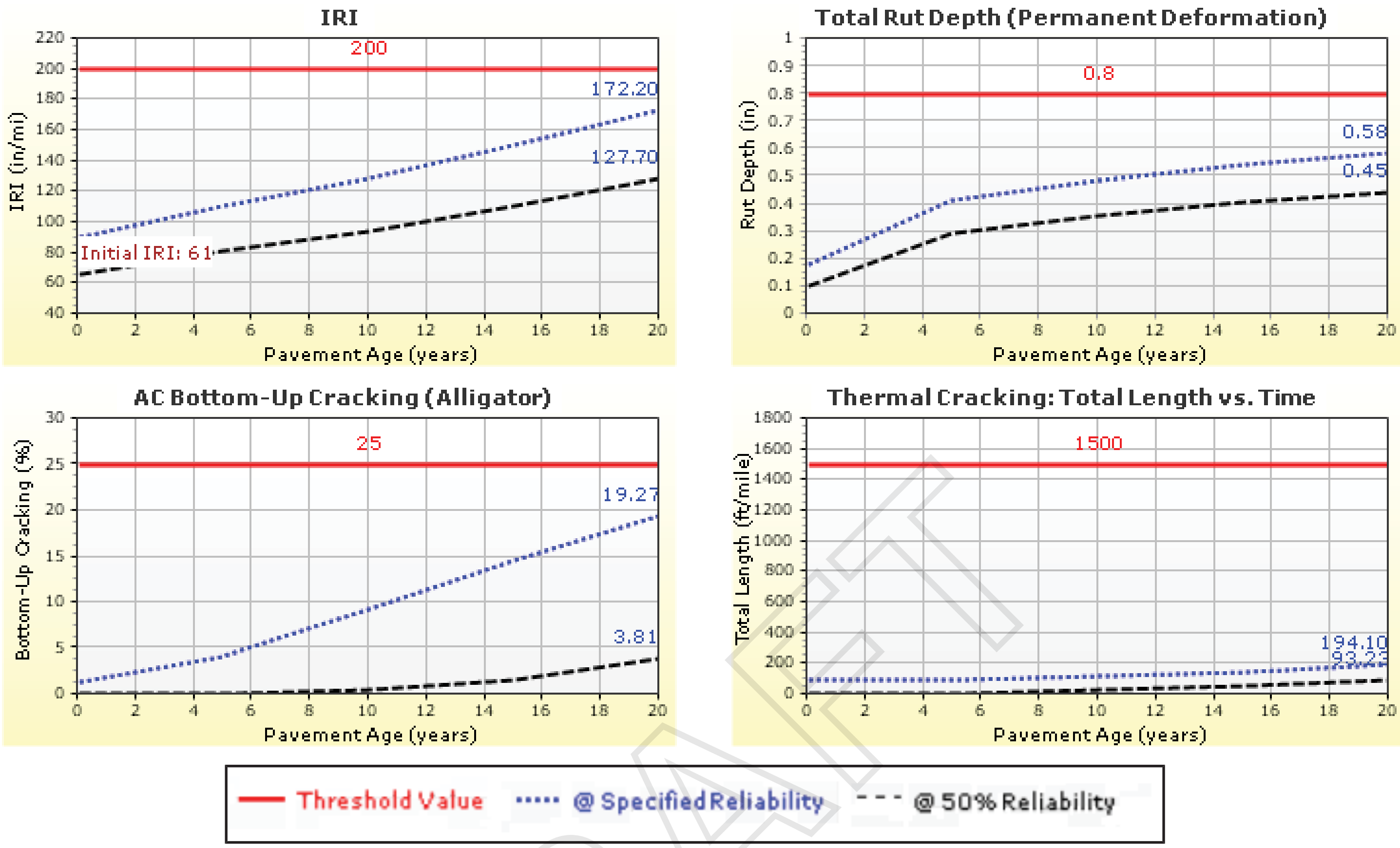
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2032 (10 years)	1,064,070
2042 (20 years)	2,435,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	172.25	90.00	98.12	Pass
Permanent deformation - total pavement (in)	0.80	0.58	90.00	99.96	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	19.27	90.00	96.05	Pass
AC thermal cracking (ft/mile)	1500.00	194.10	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1300.26	90.00	99.86	Pass
Permanent deformation - AC only (in)	0.65	0.39	90.00	99.99	Pass

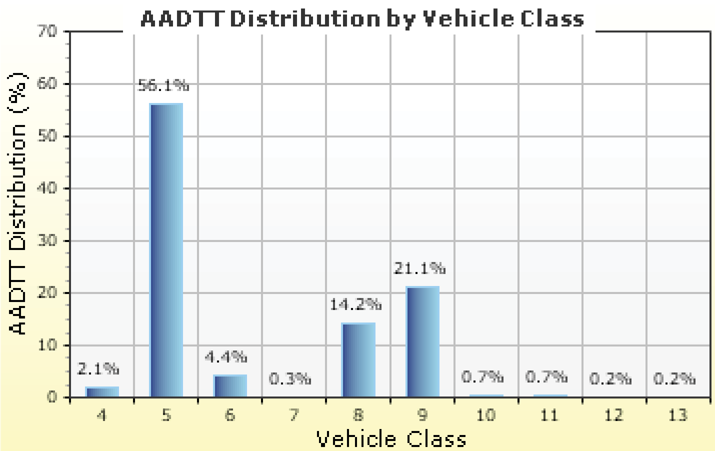
Distress Charts

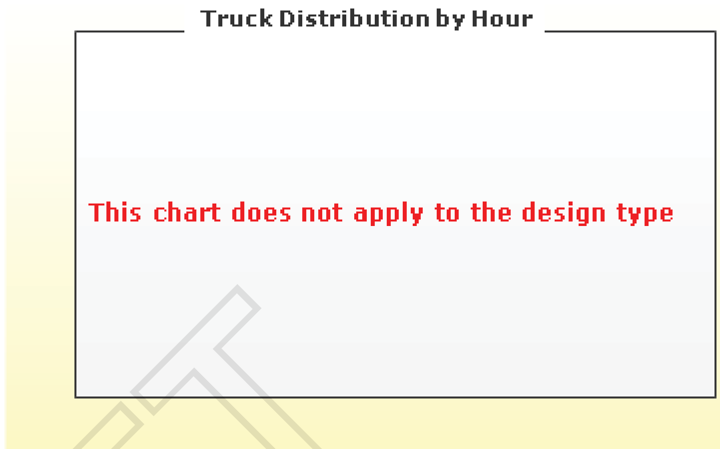


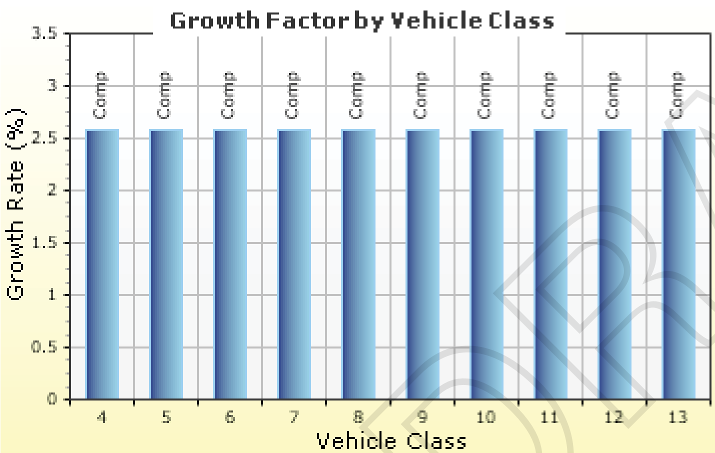
Traffic Inputs

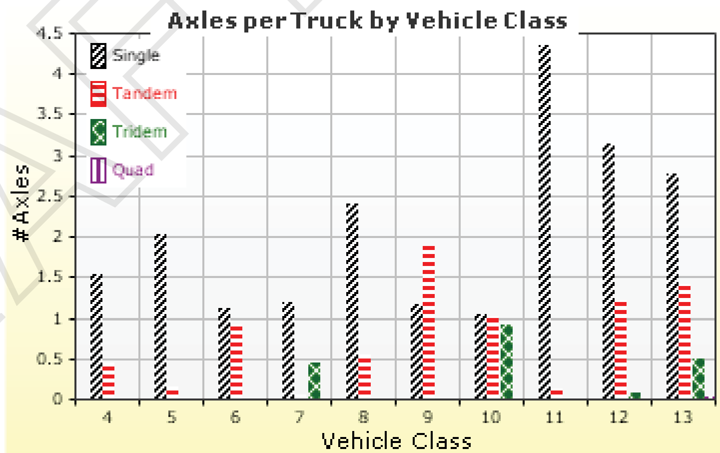
Graphical Representation of Traffic Inputs

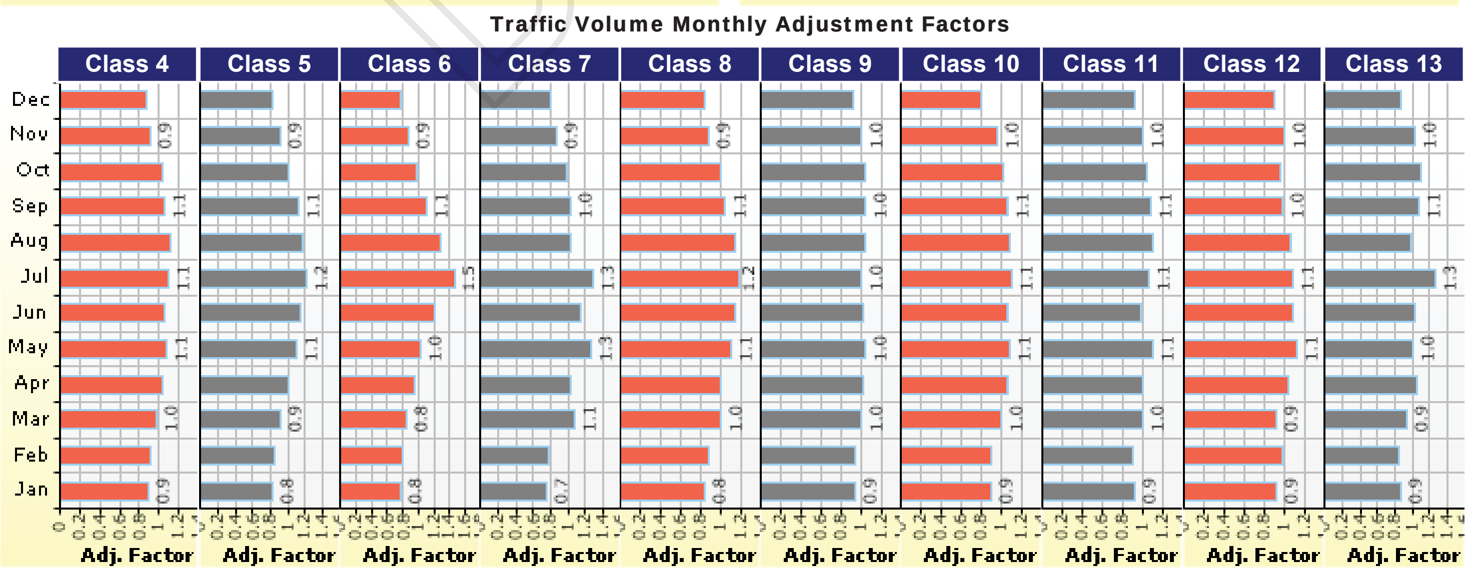
Initial two-way AADTT:	432	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0











Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

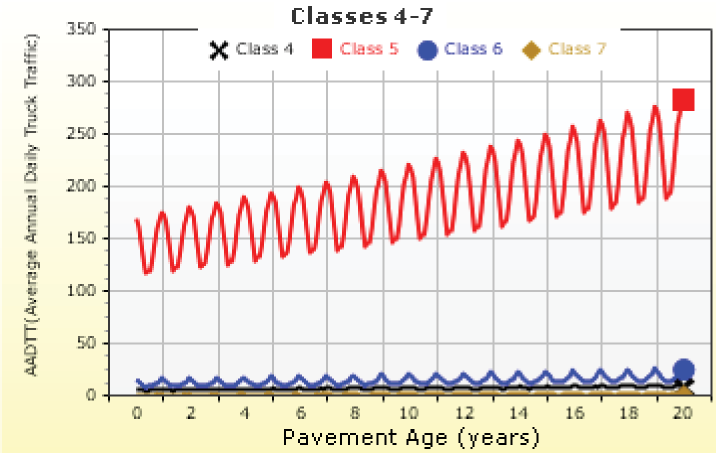
Wheelbase does not apply

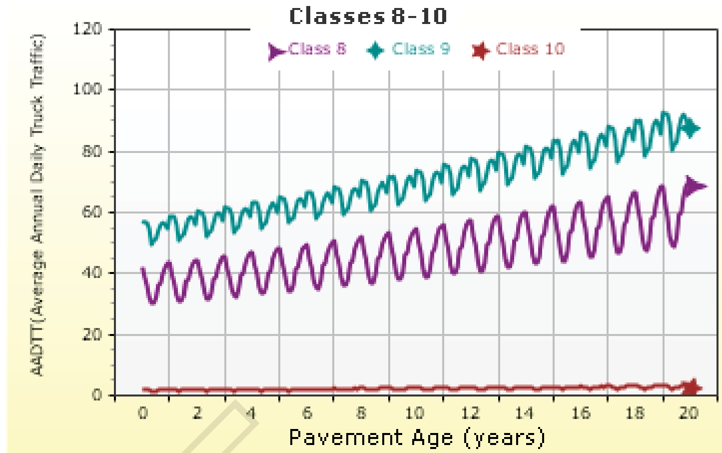
Number of Axles per Truck

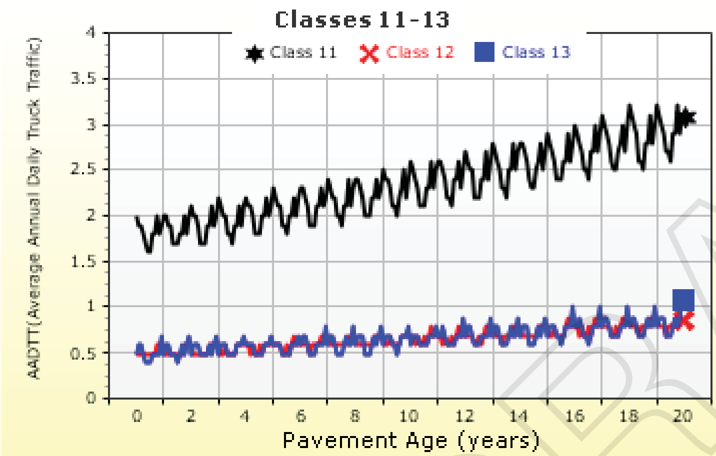
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

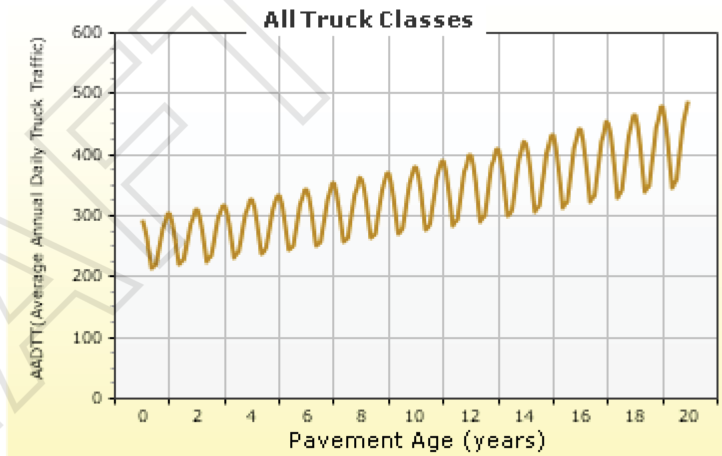
AADTT (Average Annual Daily Truck Traffic) Growth

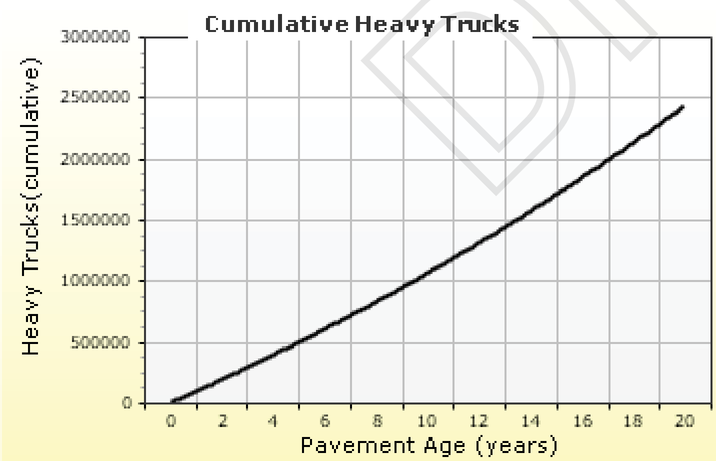
*** Traffic cap is not enforced**











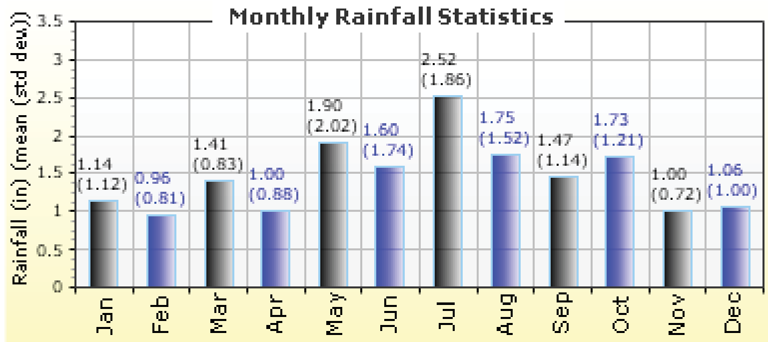
Climate Inputs

Climate Data Sources:

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

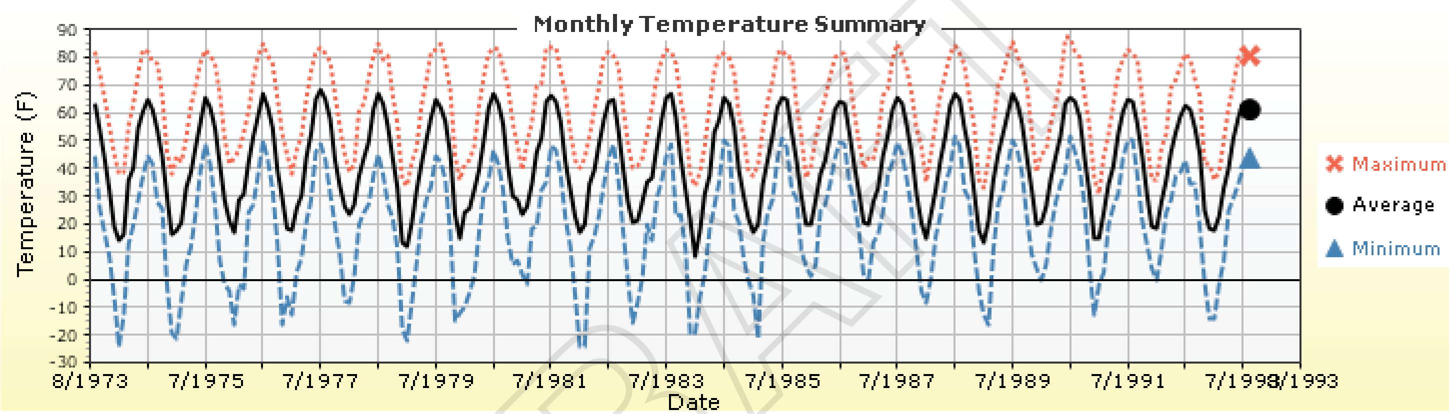
Annual Statistics:

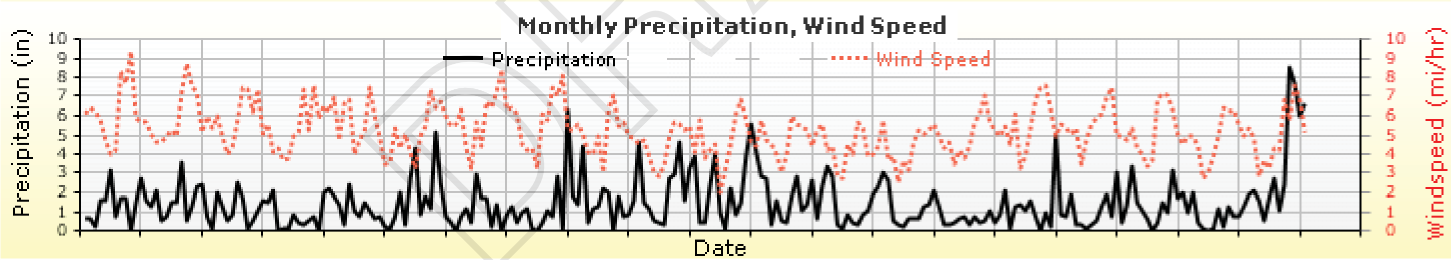
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

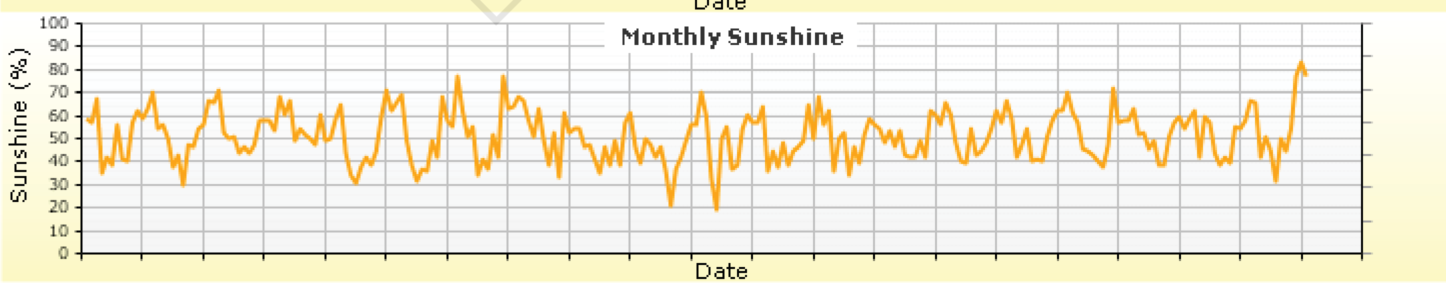


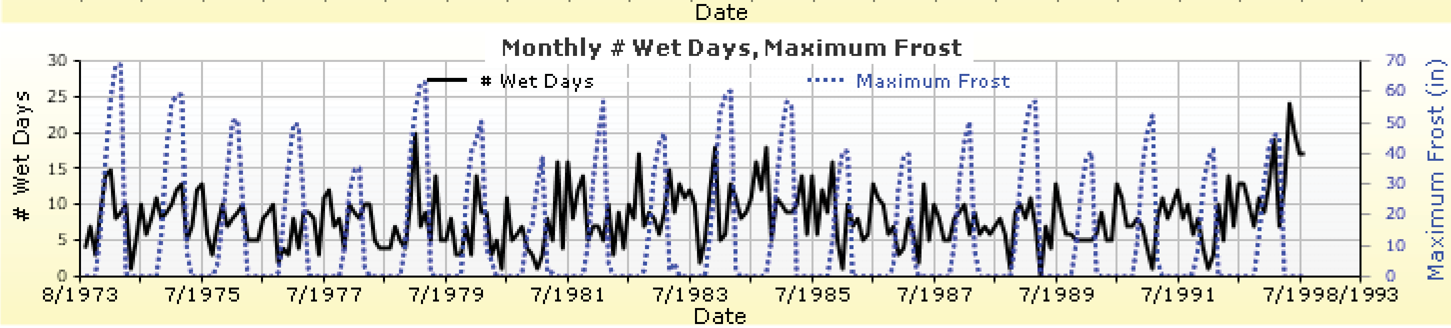
Water table depth (ft)	10.00

Monthly Climate Summary:

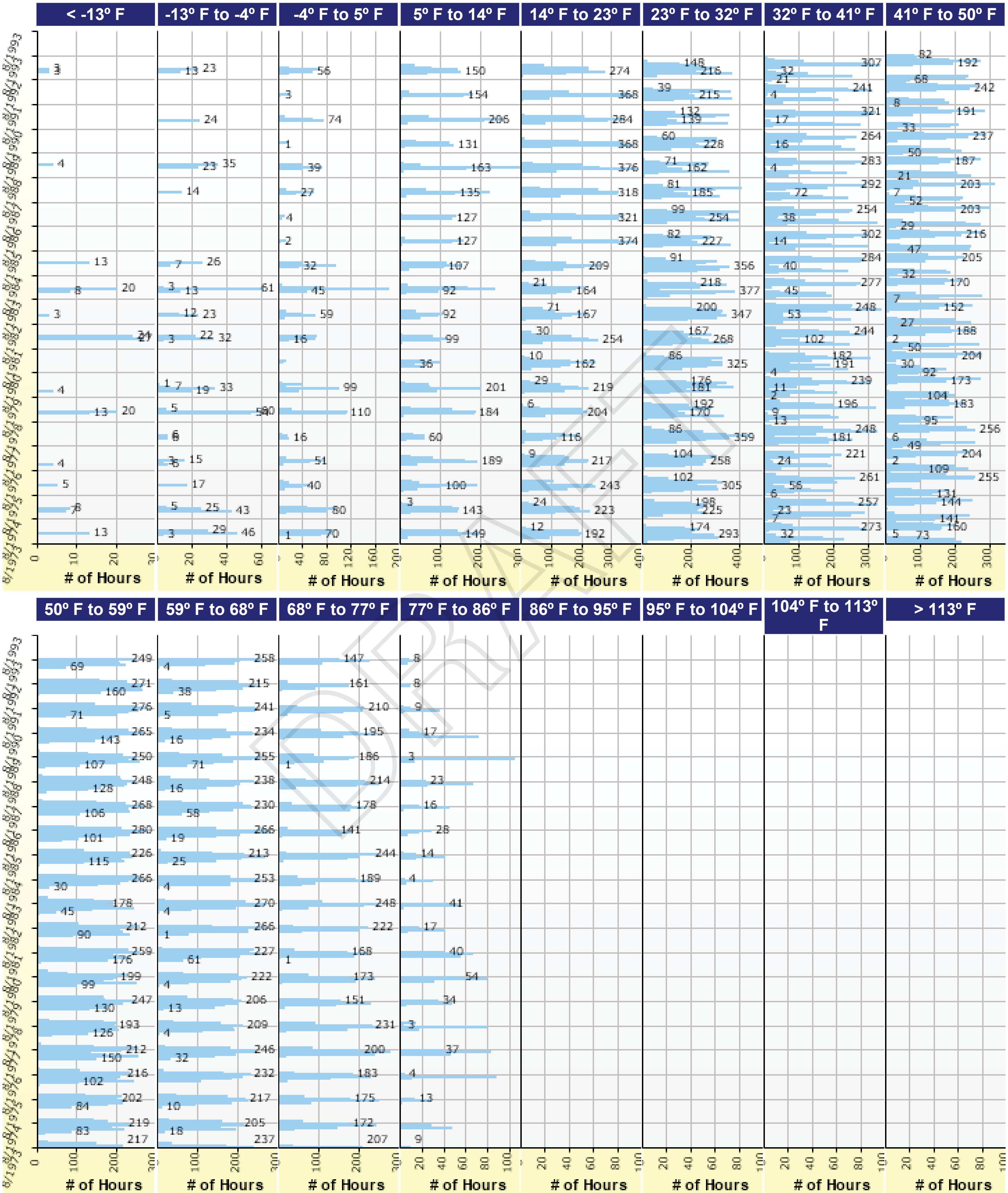








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

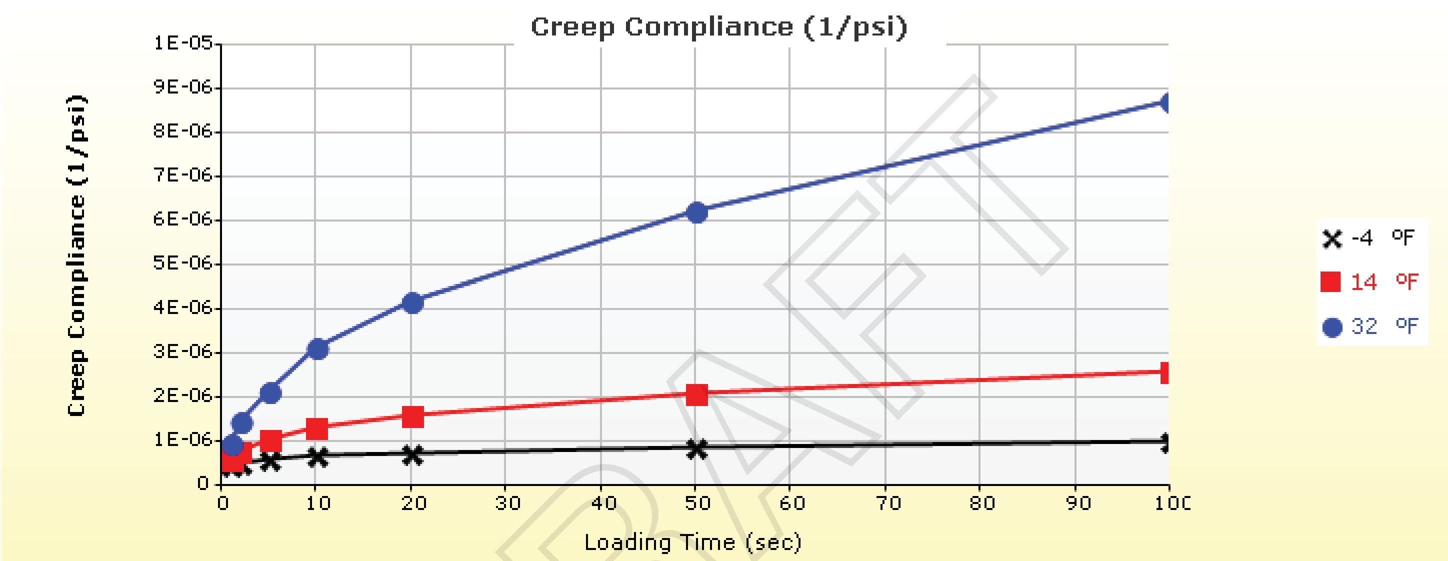
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

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

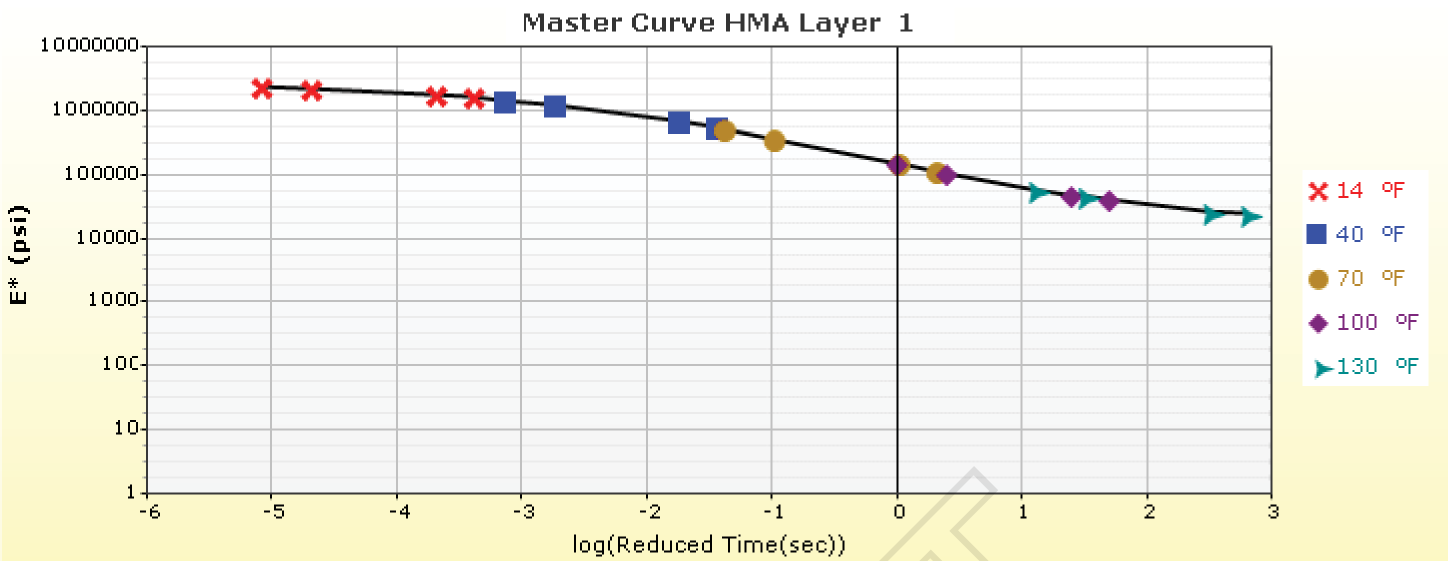
Thermal Cracking (Input Level: 1)

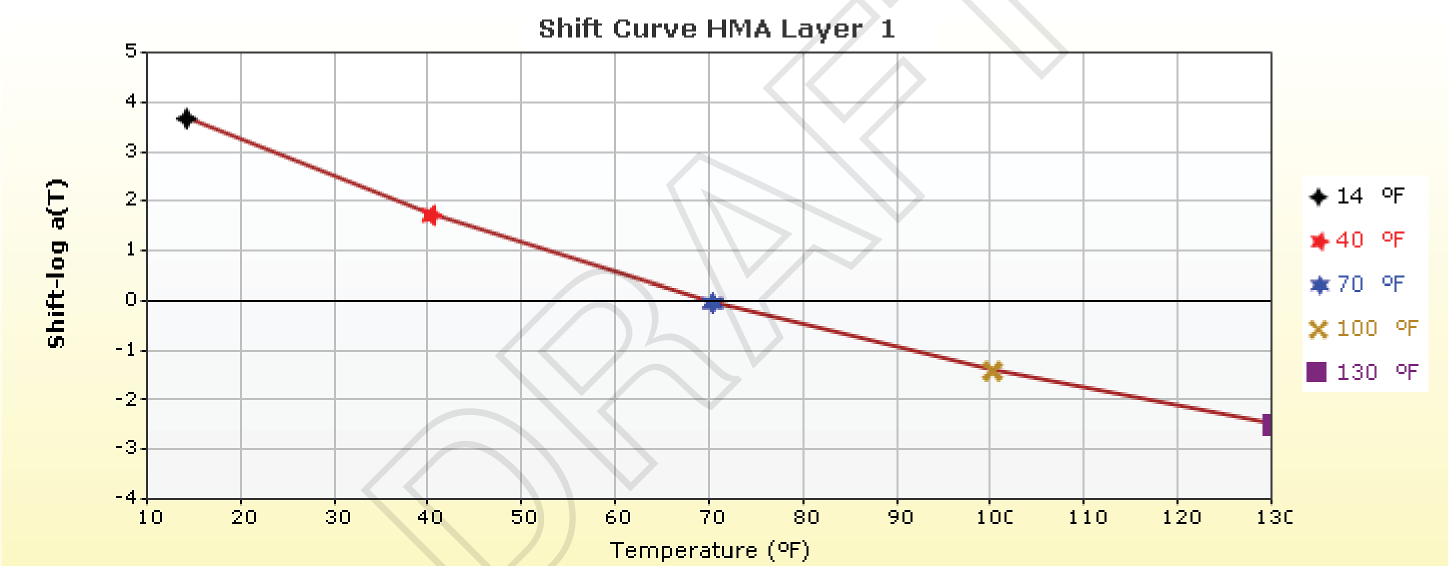
Indirect tensile strength at 14 ºF (psi)	446.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

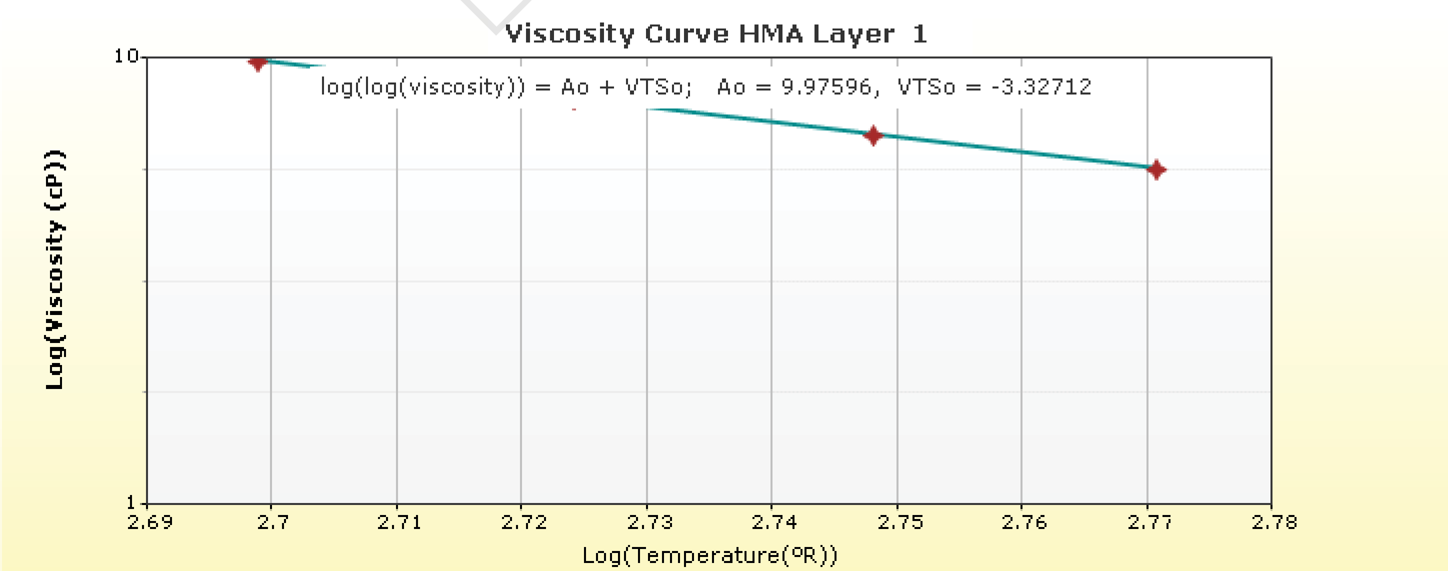
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



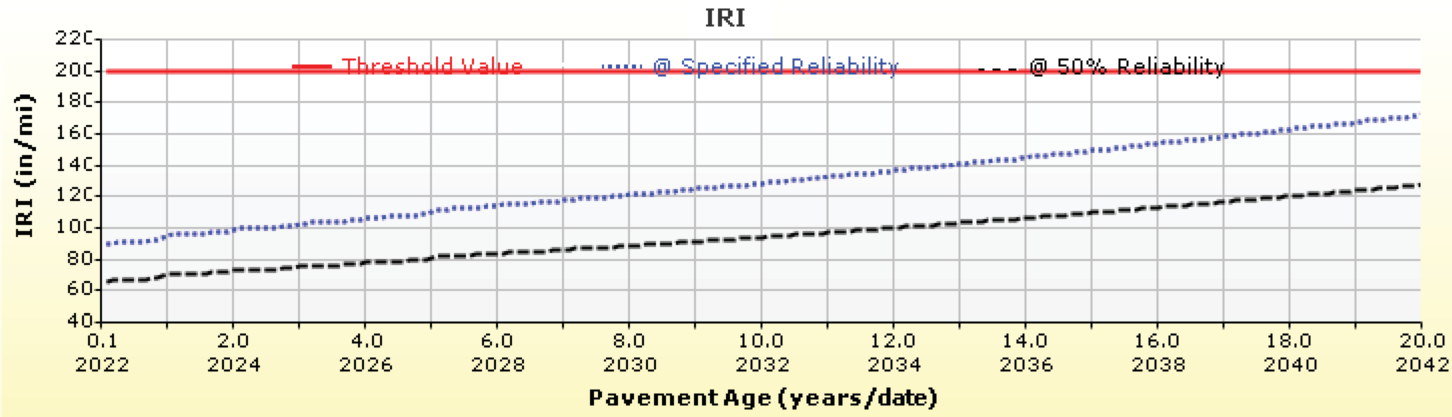
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

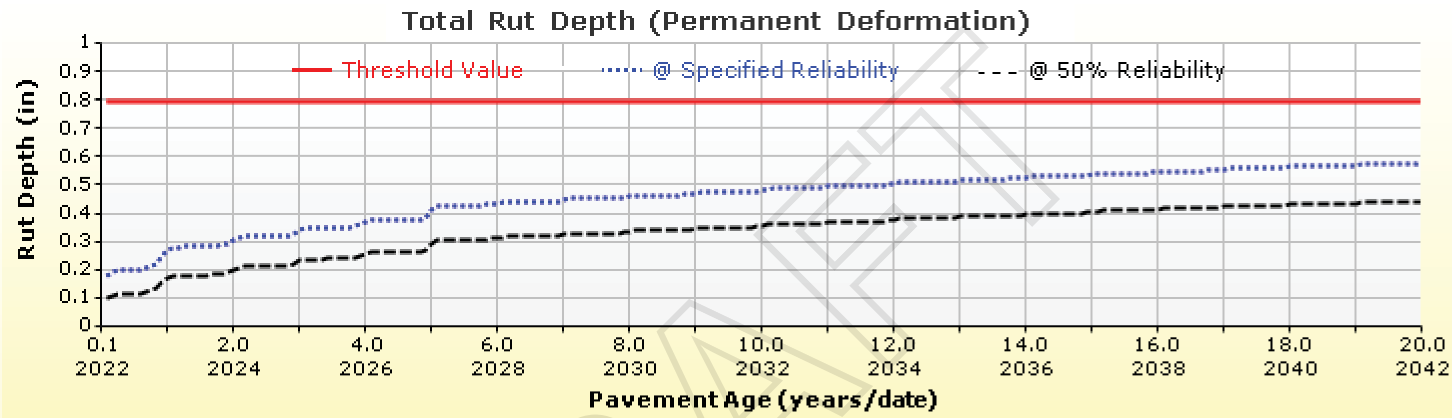


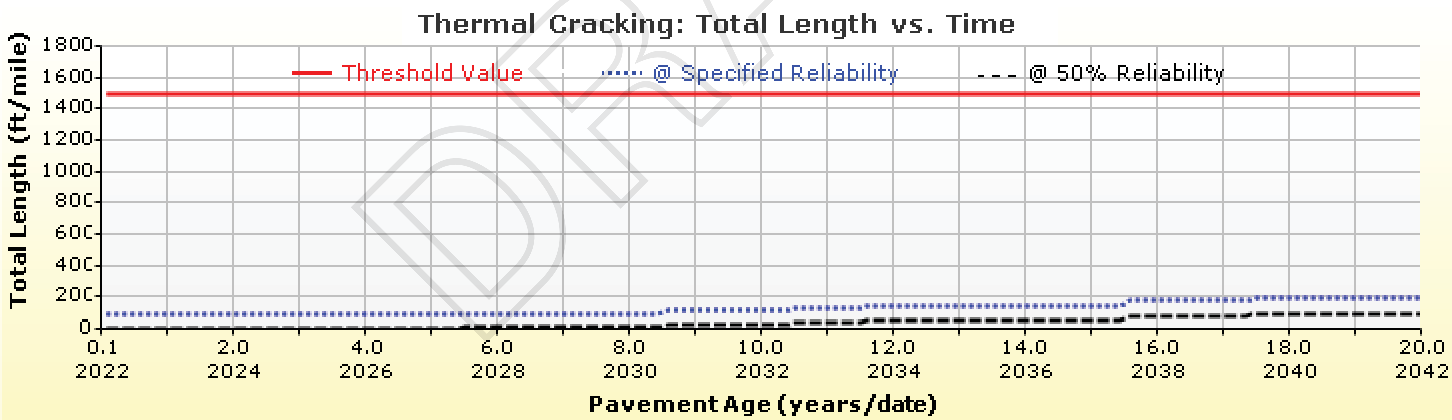




Analysis Output Charts

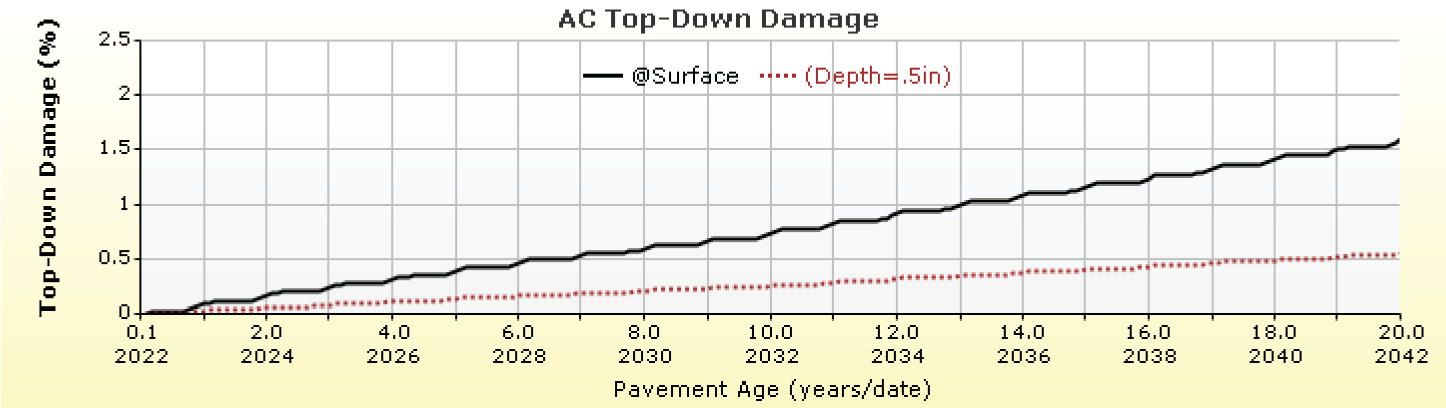


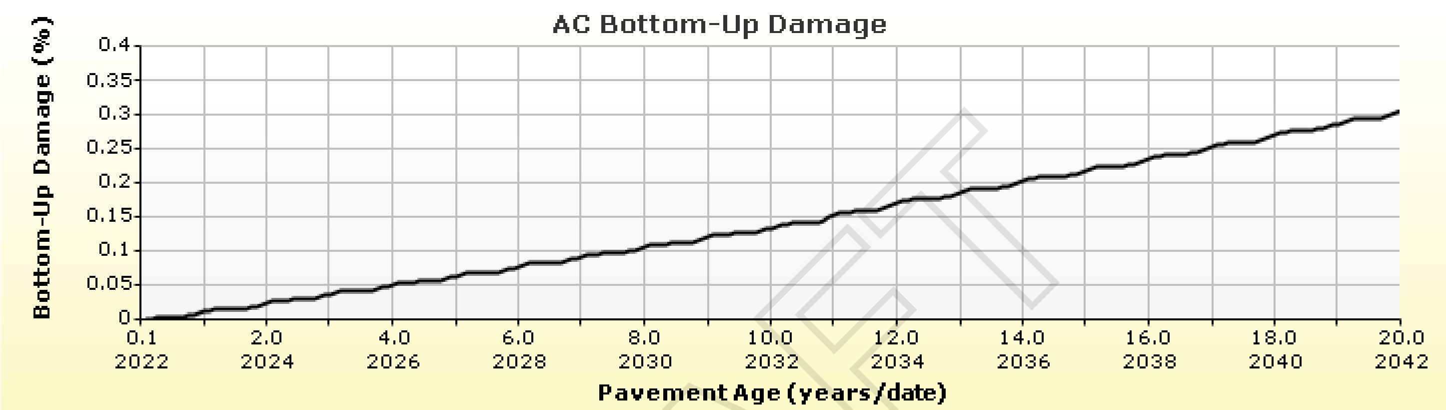


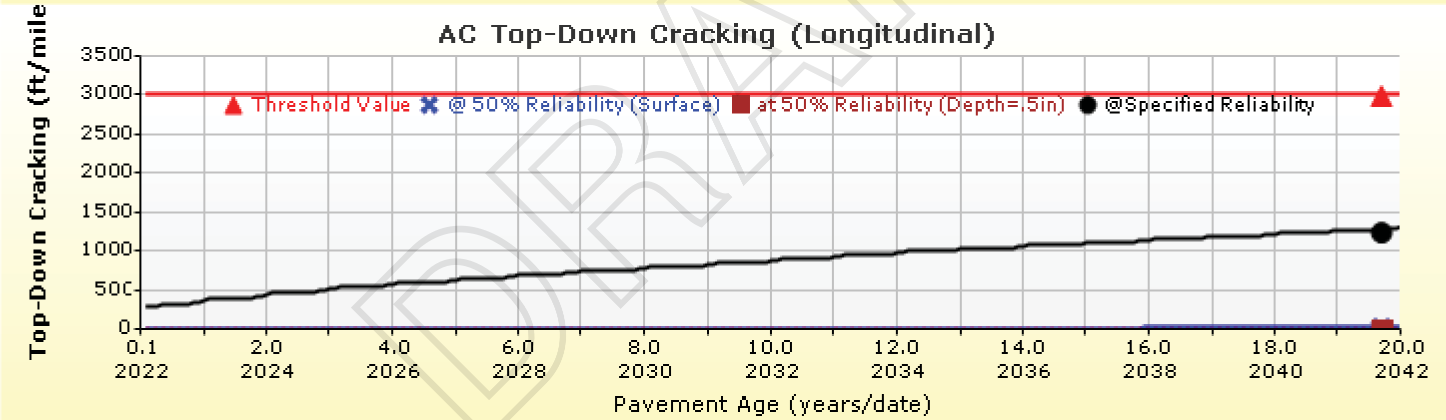


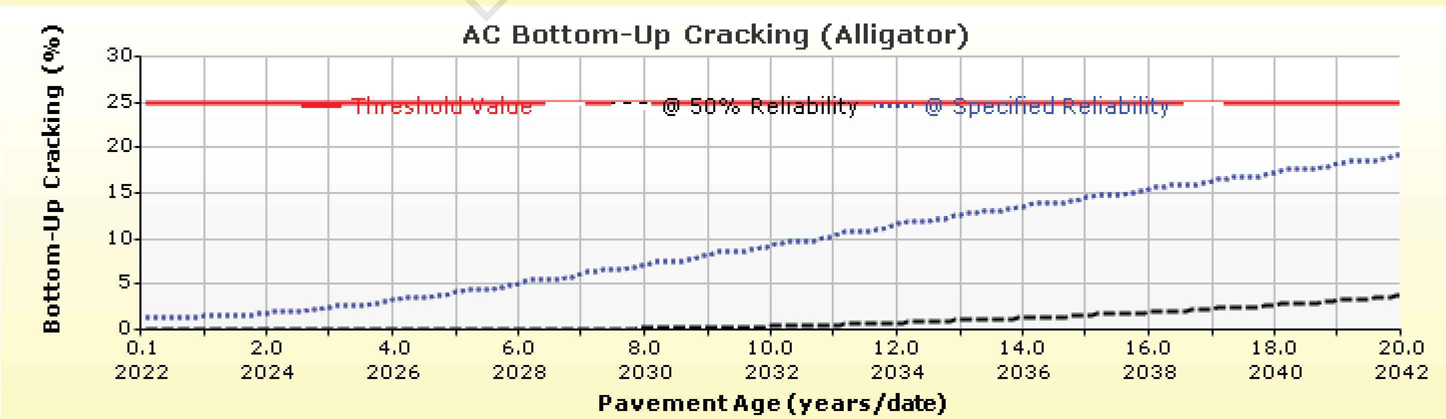
US6_5.5inHMA_6inABC_20yr

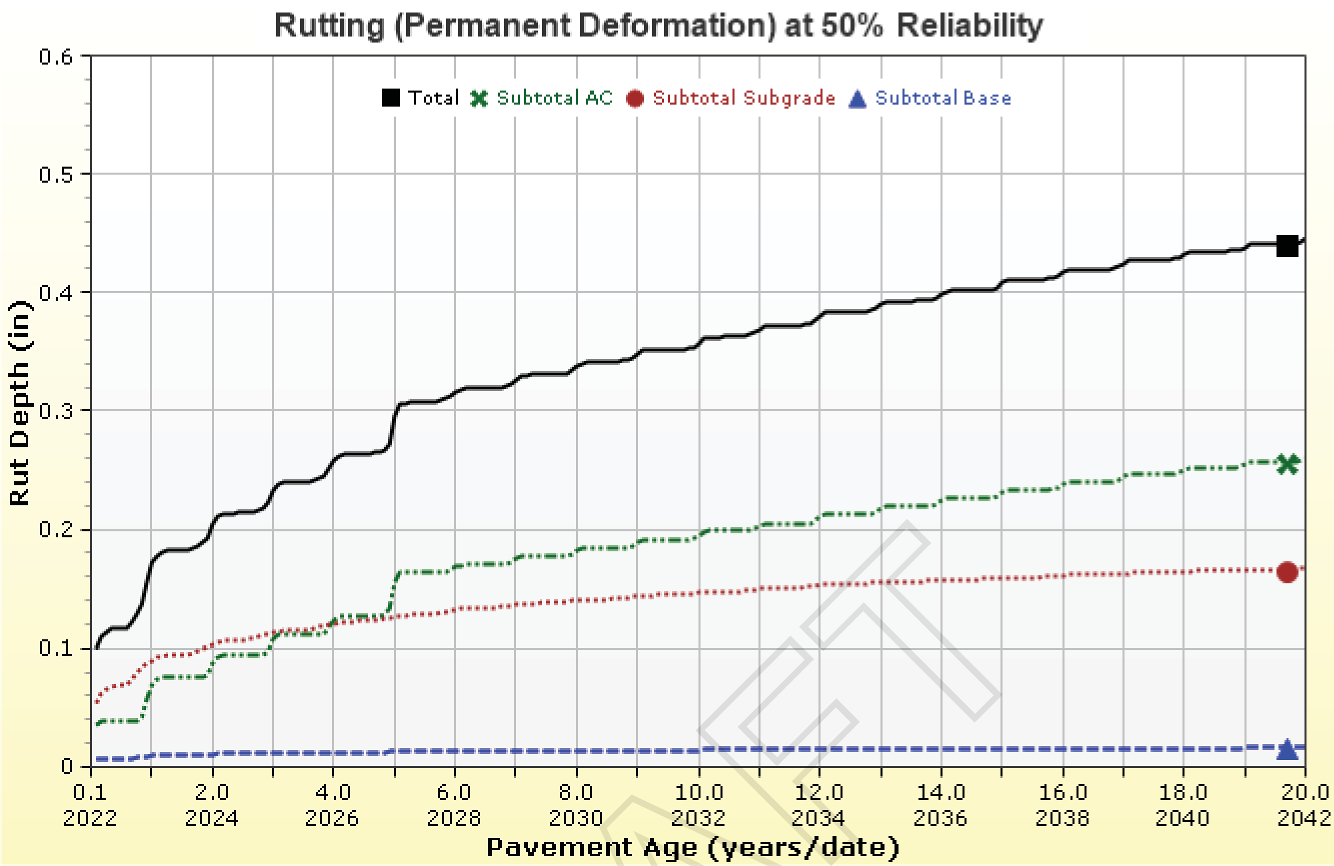
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\US6_5.5inHMA_6inABC_20yr.dgpx



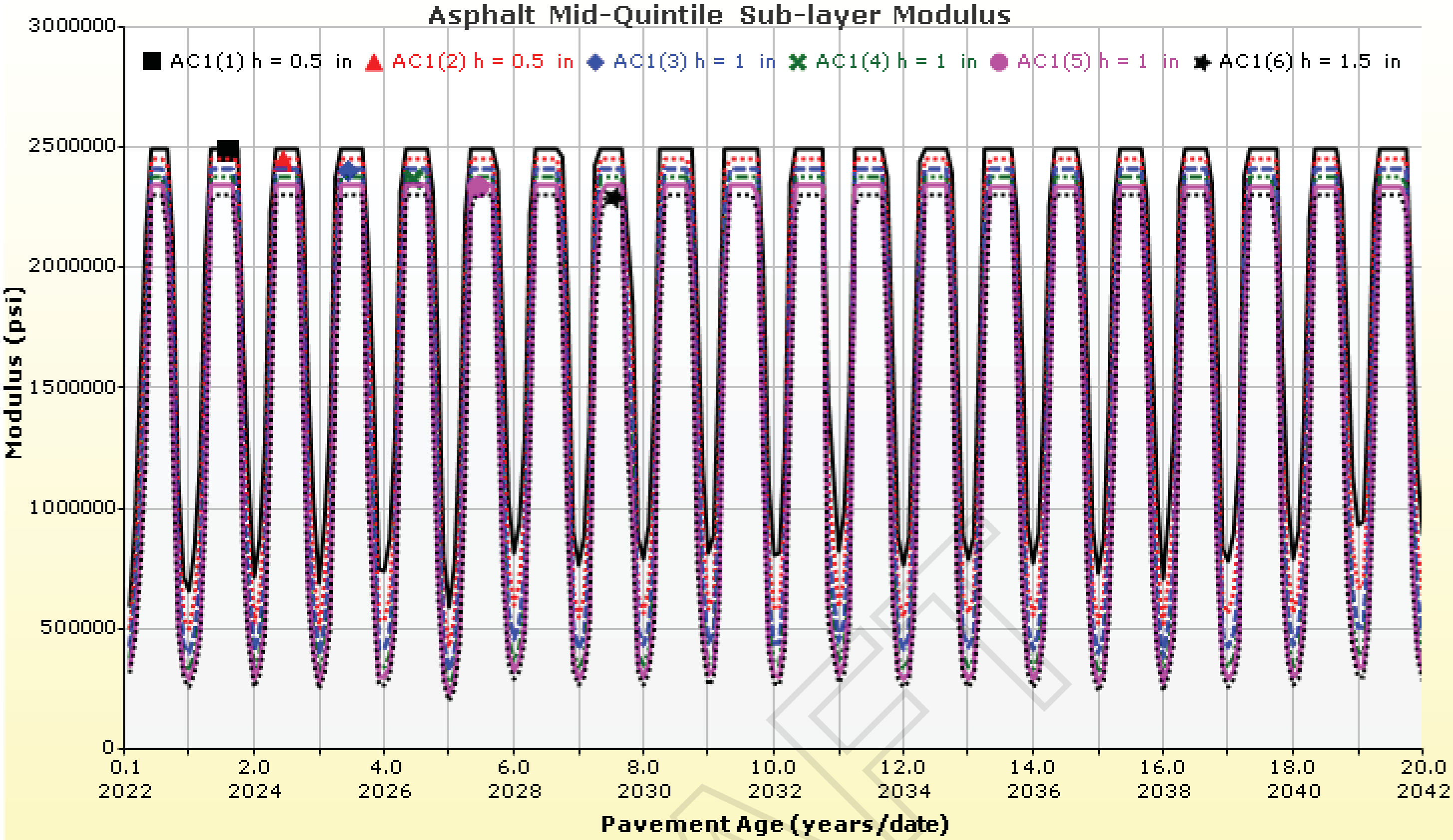




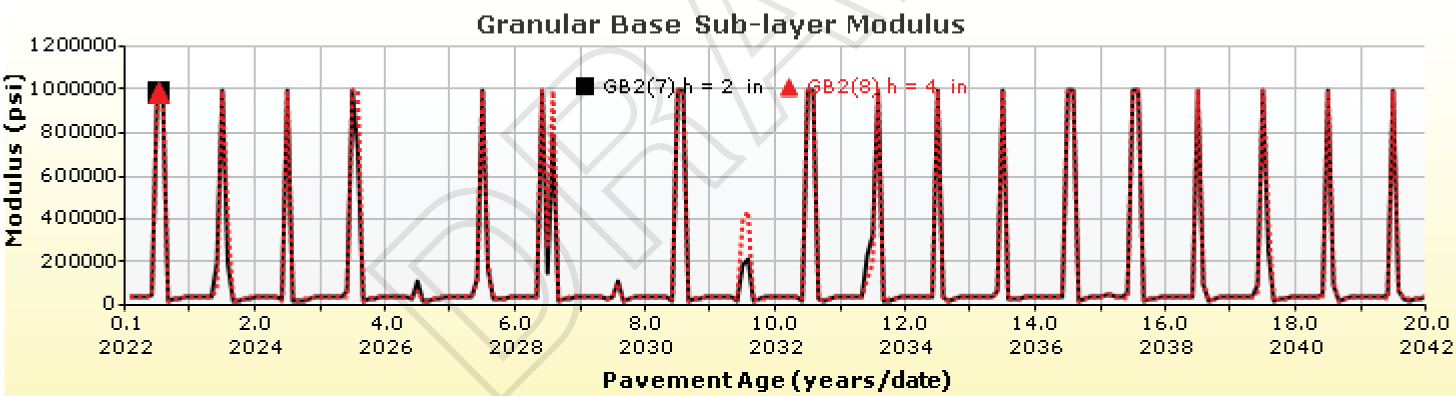




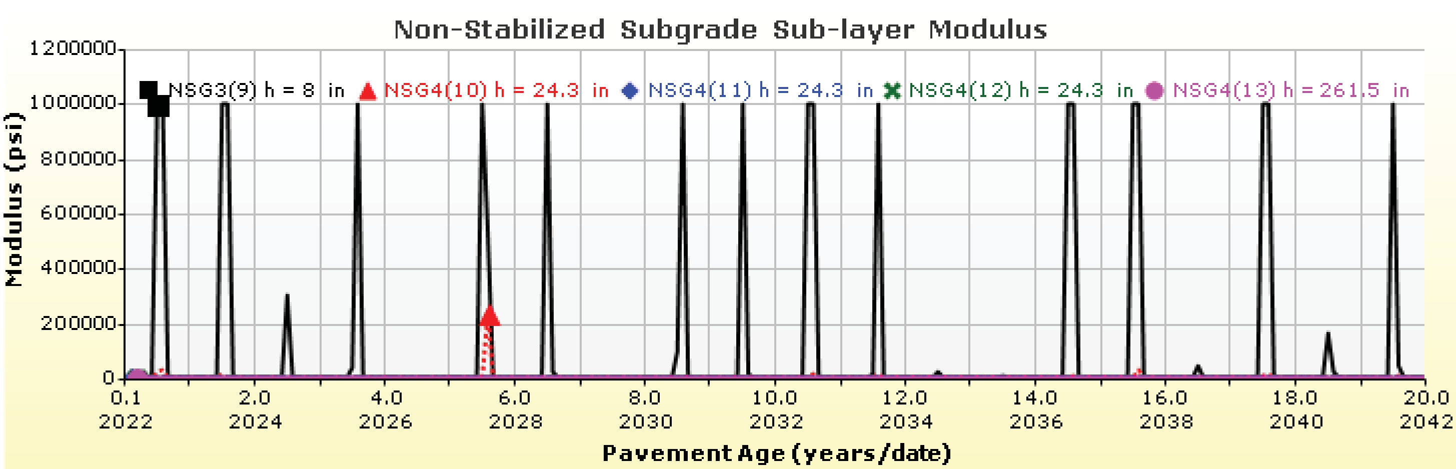
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
2022
2.0
2024
4.0
2026
6.0
2028
8.0
2030
10.0
2032
12.0
2034
14.0
2036
16.0
2038
18.0
2040
20.0
2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC1(4) h = 1 in
AC1(5) h = 1 in
AC1(6) h = 1.5 in
Modulus (psi)
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
GB2(7) h = 2 in
GB2(8) h = 4 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG3(9) h = 8 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
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	5.5	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

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 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)
27000.0

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-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)
10000.0

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-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

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

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))

CSM Cracking

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

C1: 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

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	7.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

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

Traffic

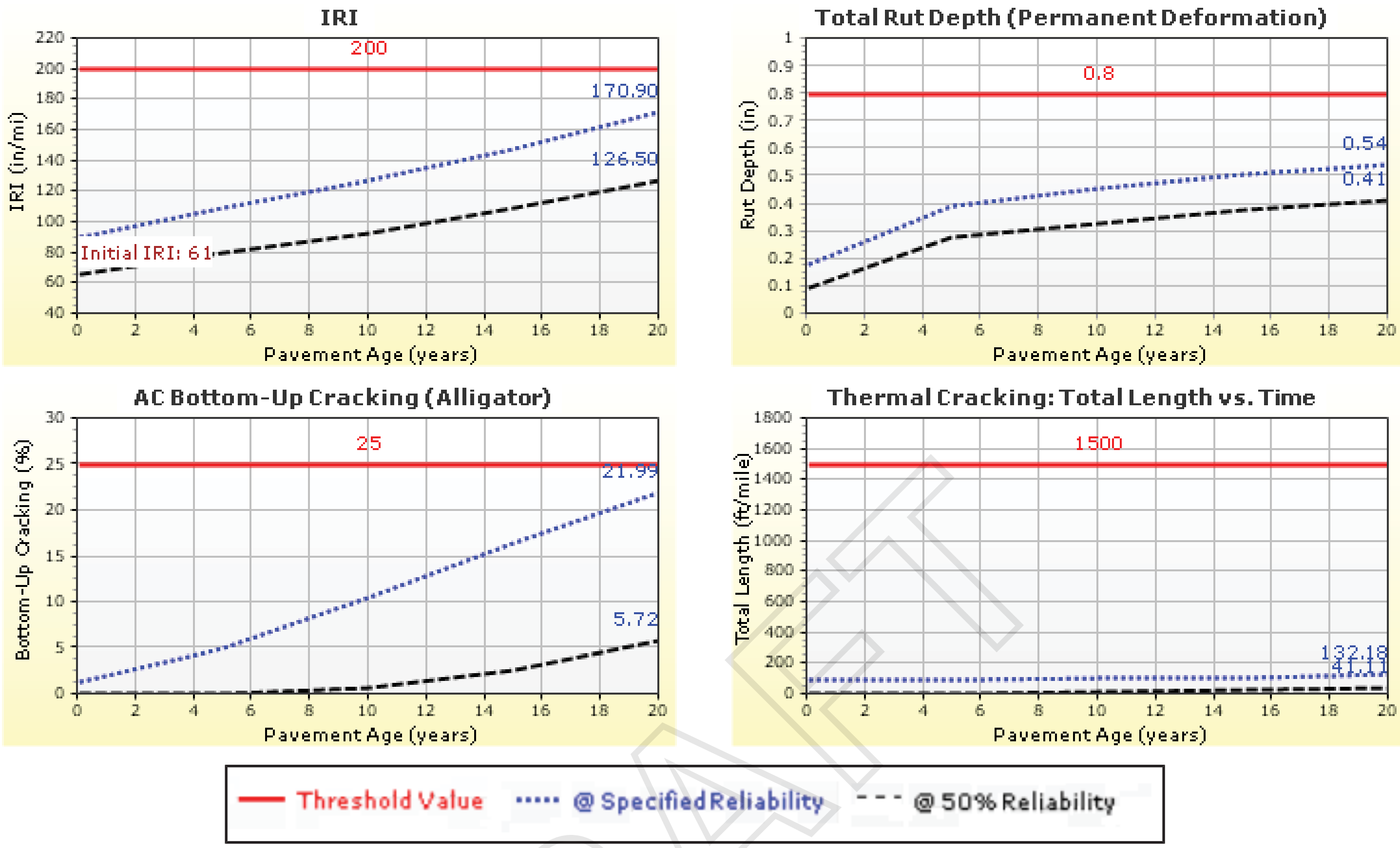
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	432
2032 (10 years)	1,064,070
2042 (20 years)	2,435,500

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	170.86	90.00	98.31	Pass
Permanent deformation - total pavement (in)	0.80	0.54	90.00	99.99	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	21.99	90.00	93.56	Pass
AC thermal cracking (ft/mile)	1500.00	132.18	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1998.45	90.00	97.45	Pass
Permanent deformation - AC only (in)	0.65	0.36	90.00	100.00	Pass

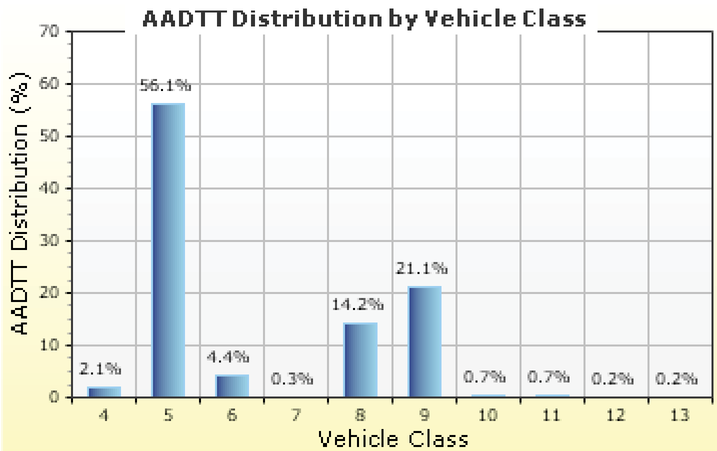
Distress Charts

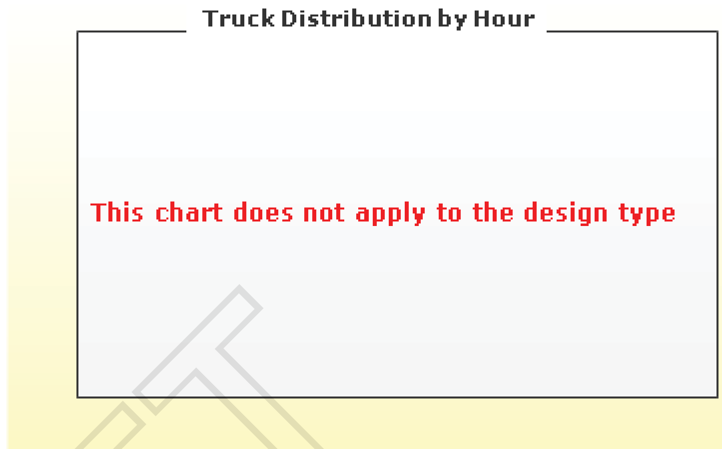


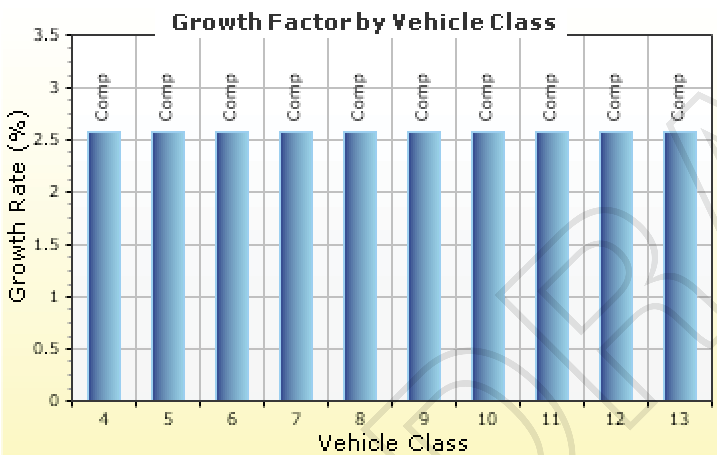
Traffic Inputs

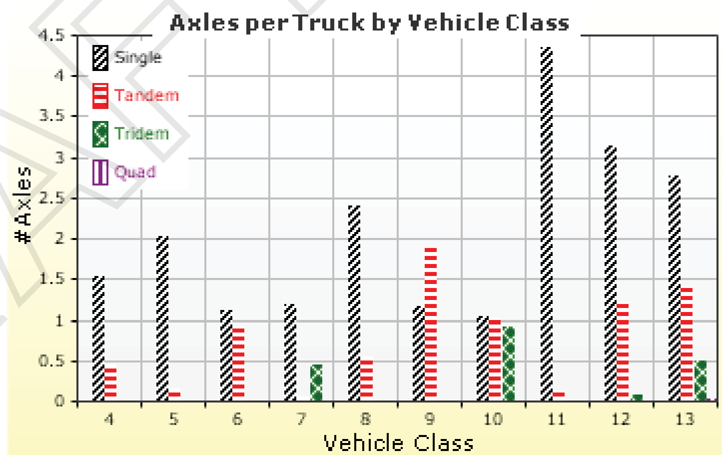
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	432	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

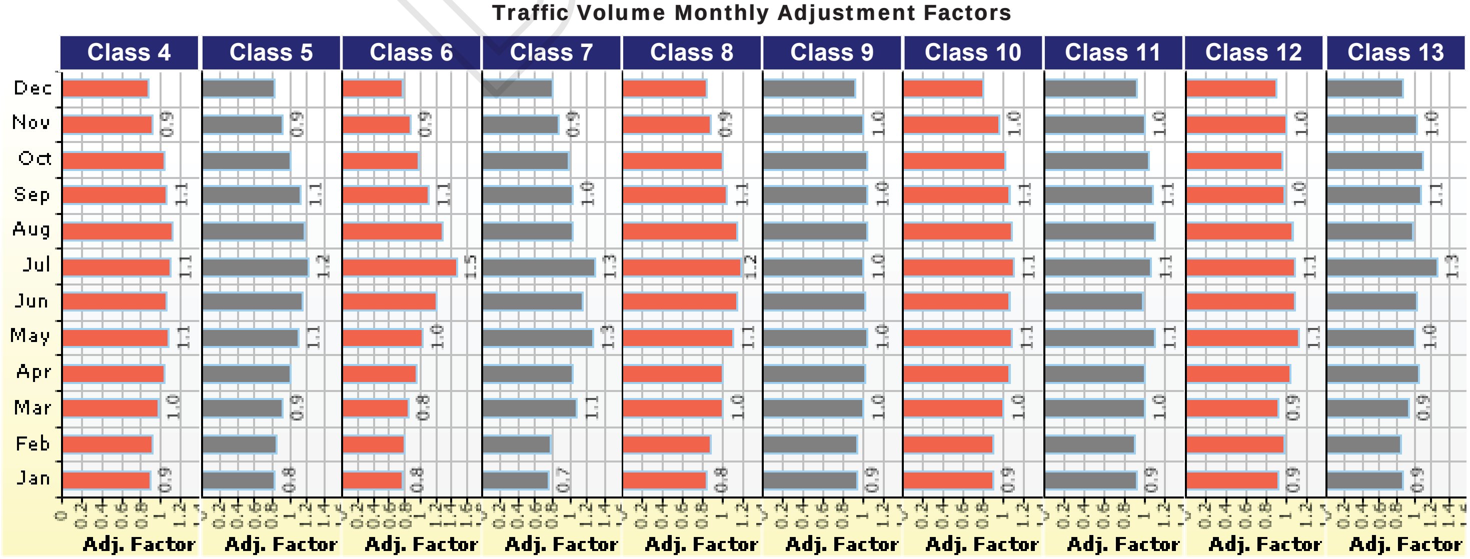








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

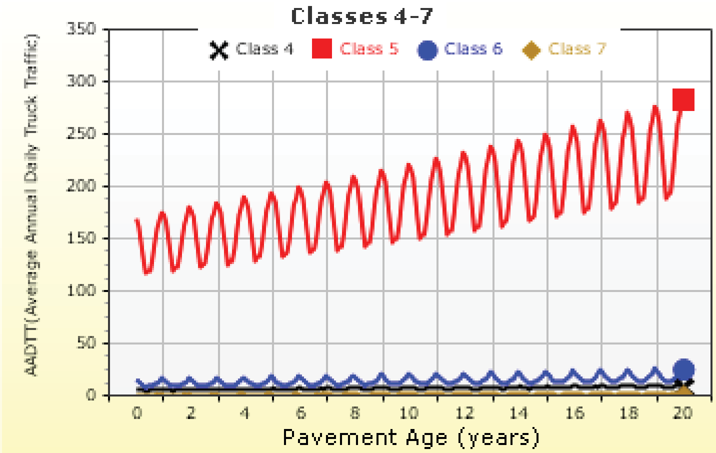
Wheelbase does not apply

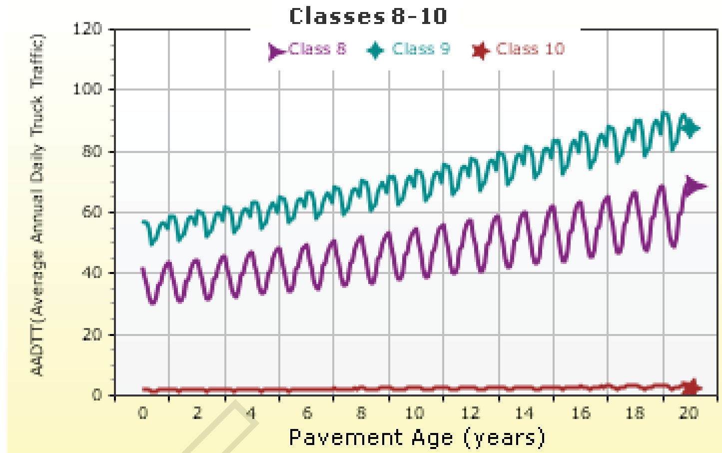
Number of Axles per Truck

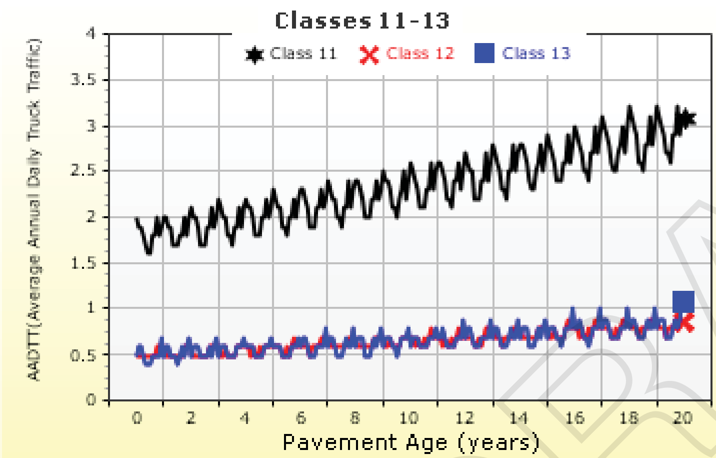
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

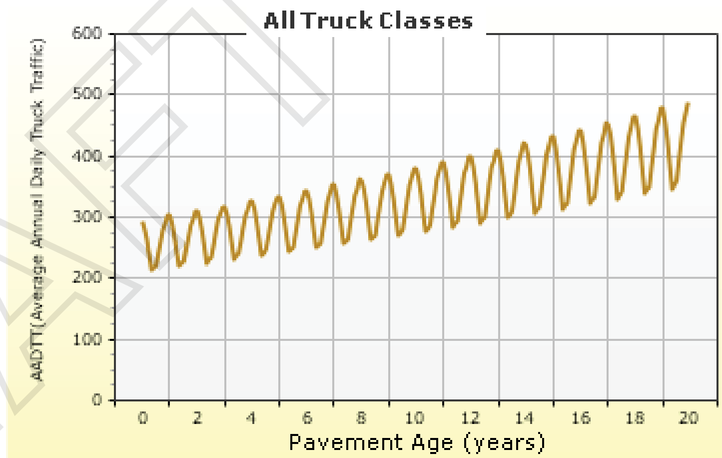
AADTT (Average Annual Daily Truck Traffic) Growth

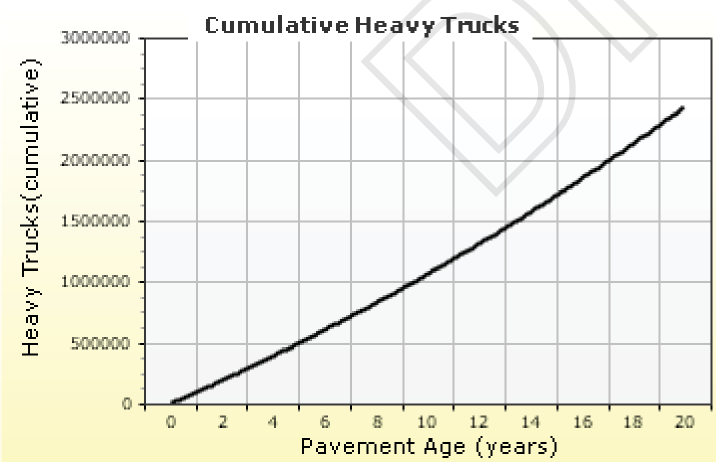
*** Traffic cap is not enforced**







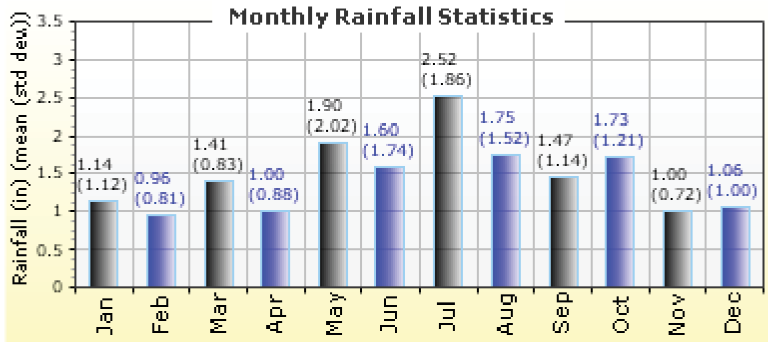




Climate Inputs

Climate Data Sources:

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

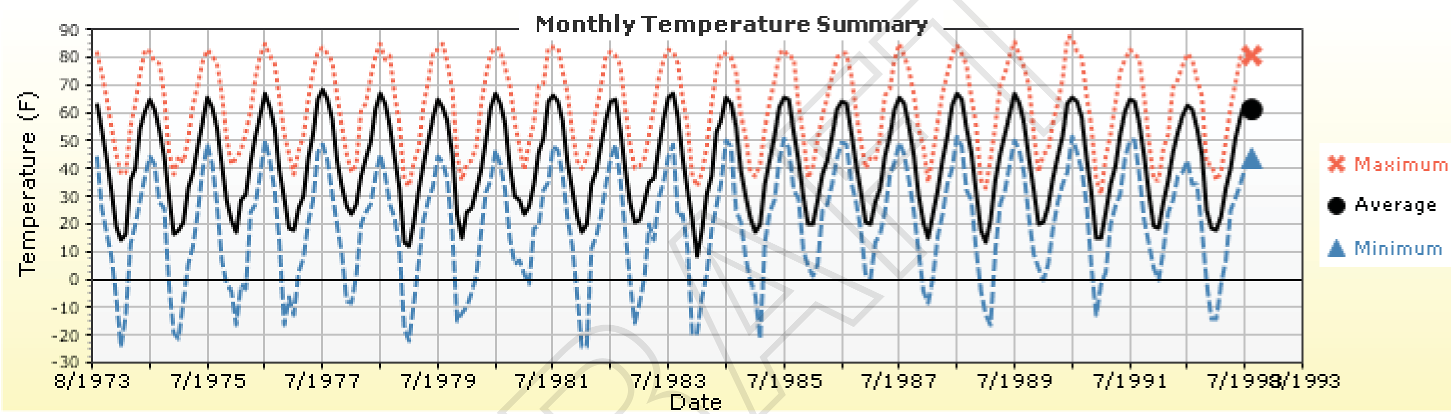


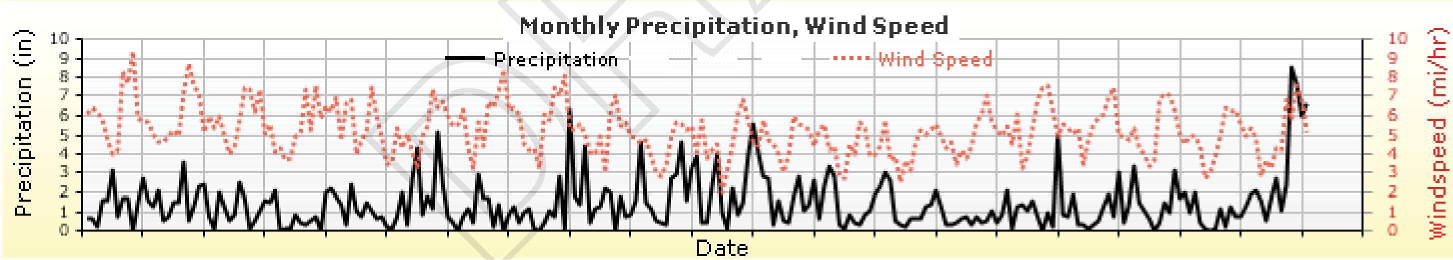
Annual Statistics:

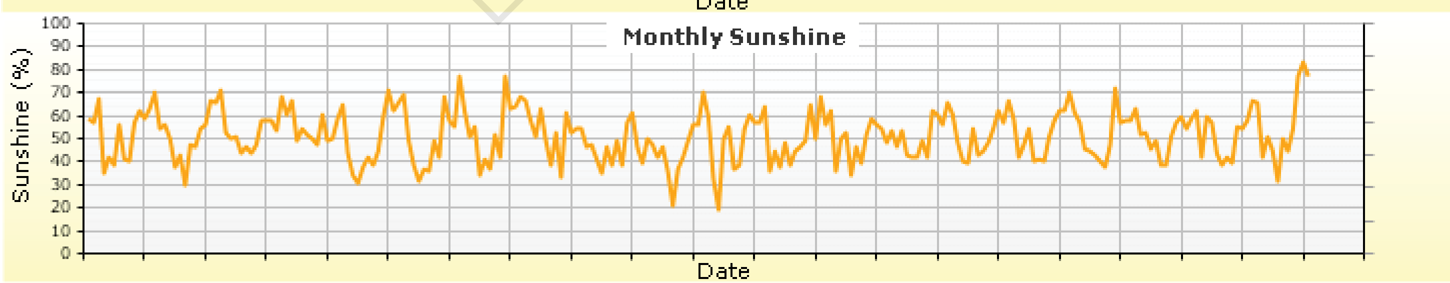
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

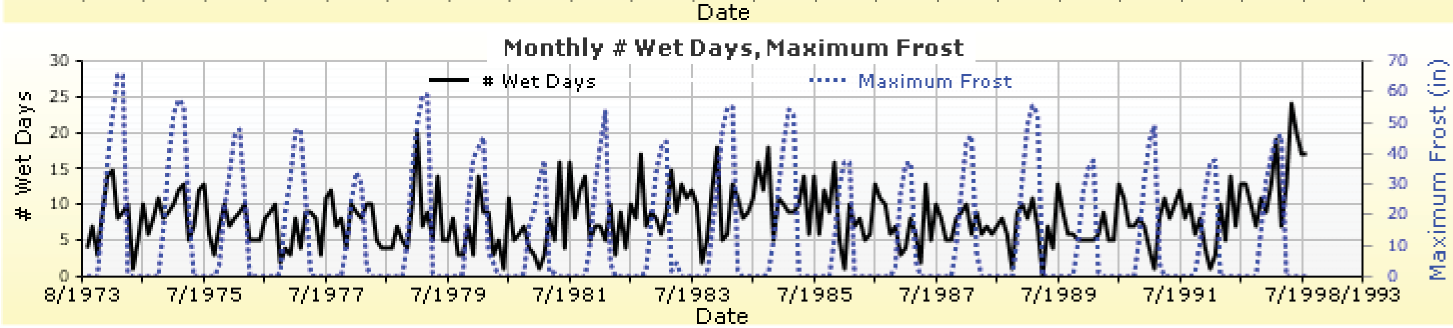
Water table depth (ft)	10.00

Monthly Climate Summary:

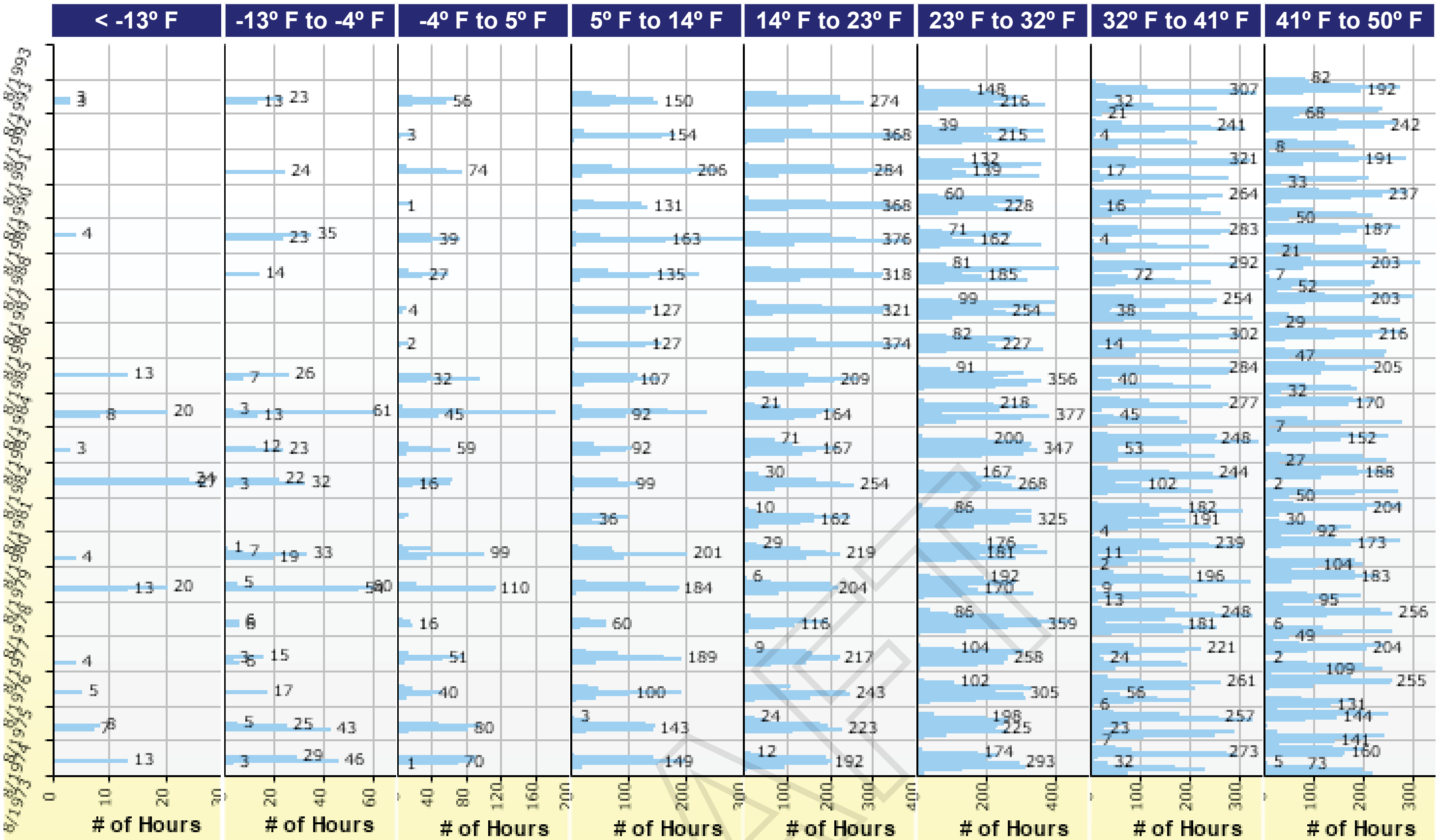


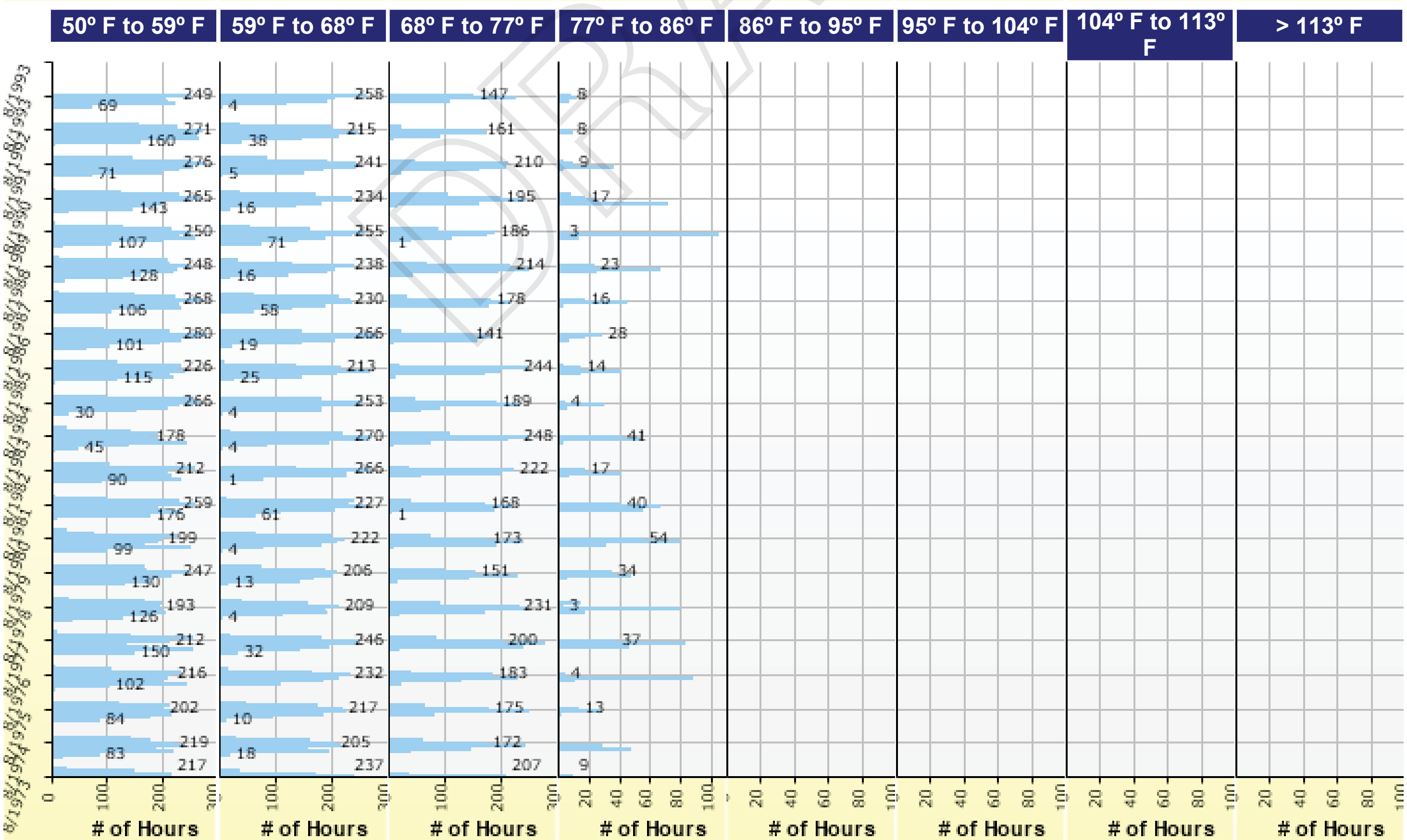






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

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

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	-

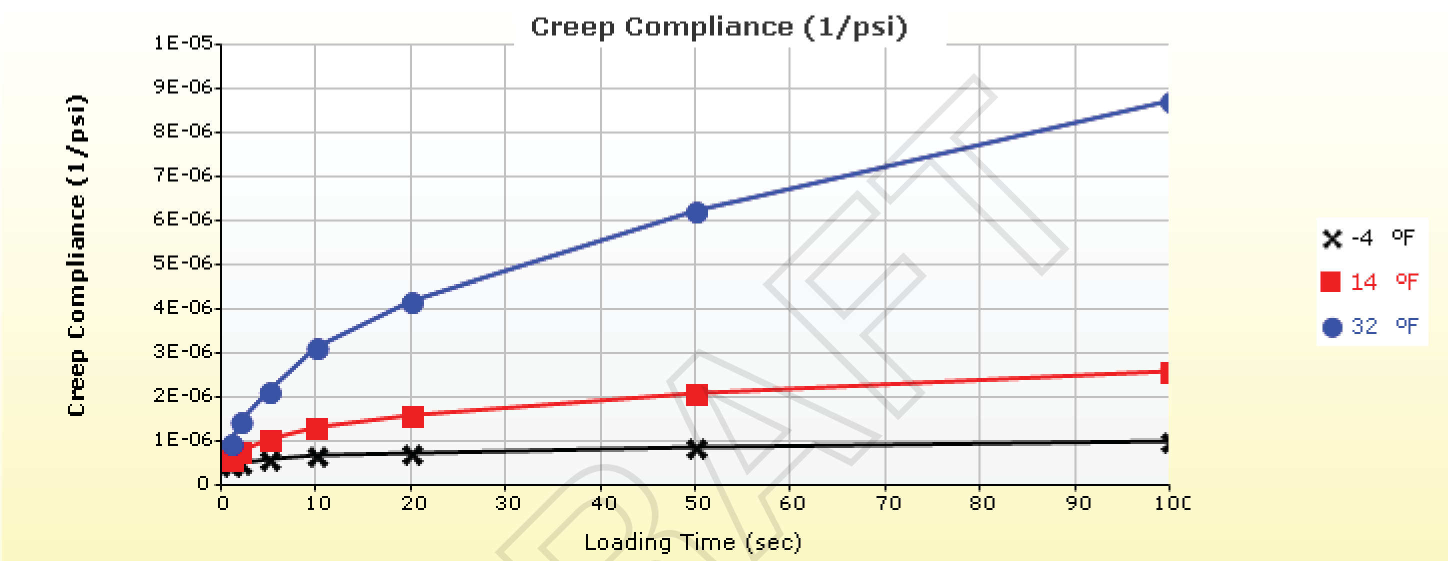
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Thermal Cracking (Input Level: 1)

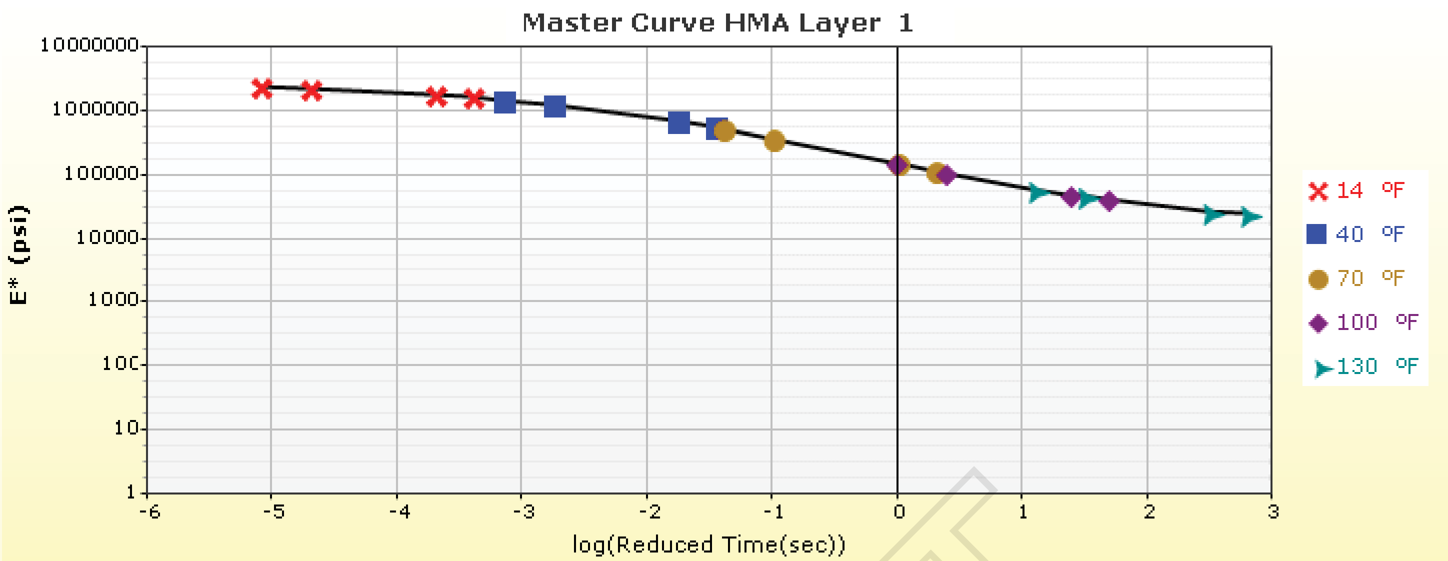
Indirect tensile strength at 14 ºF (psi)	446.00

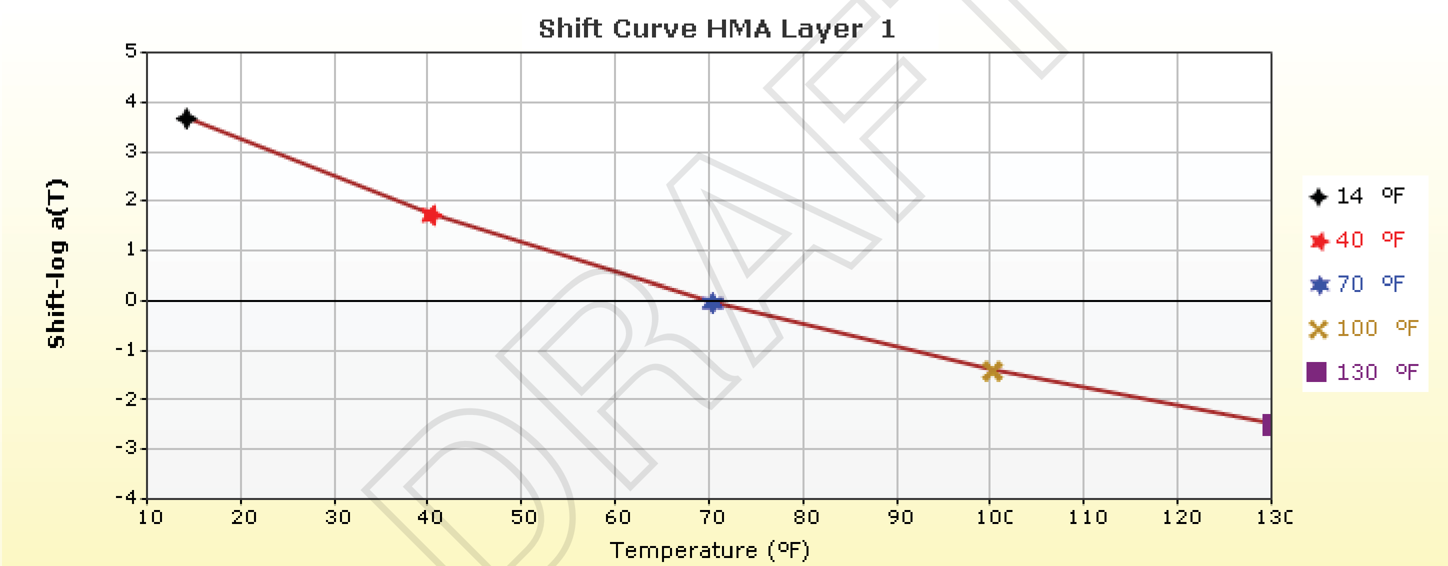
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

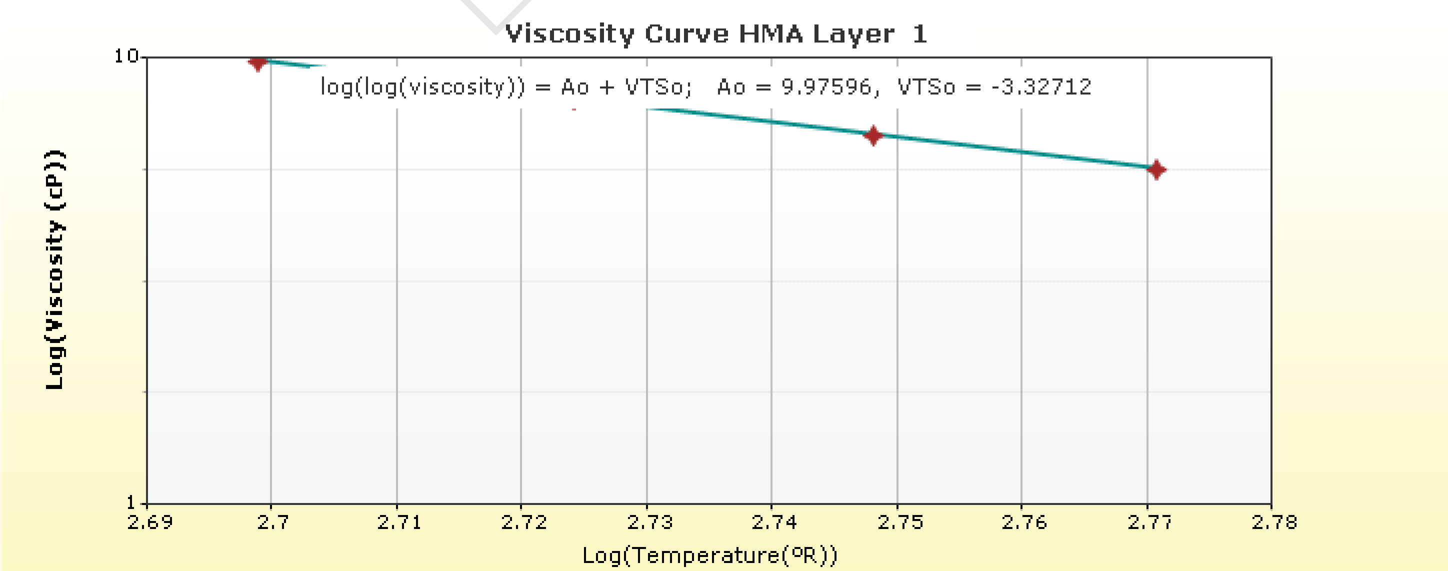
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



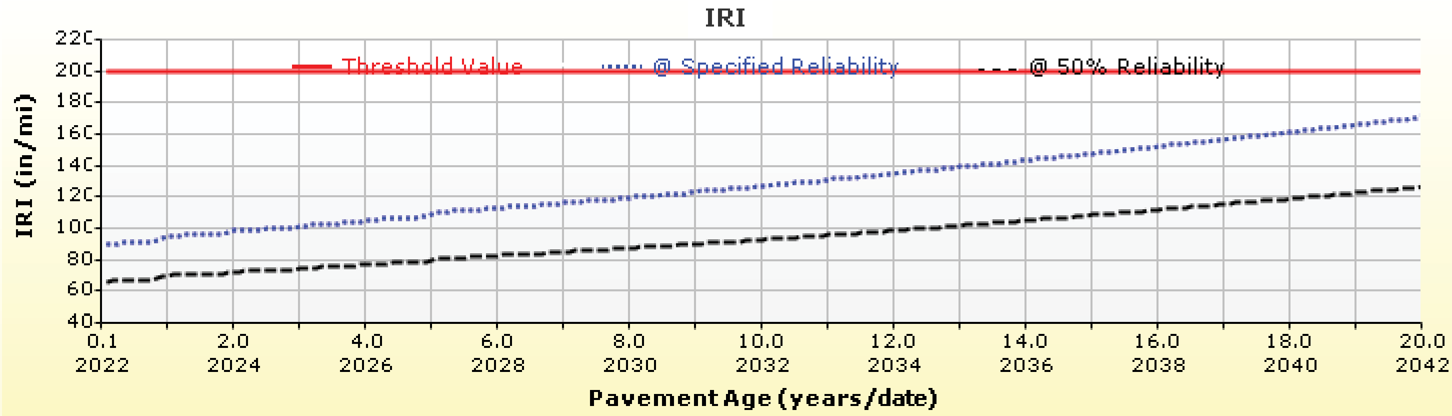
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

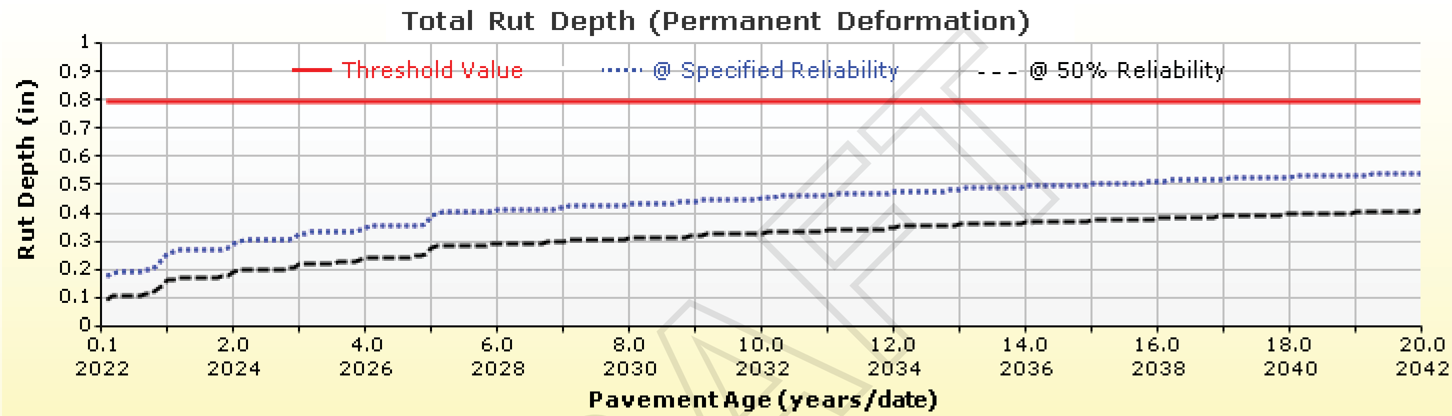


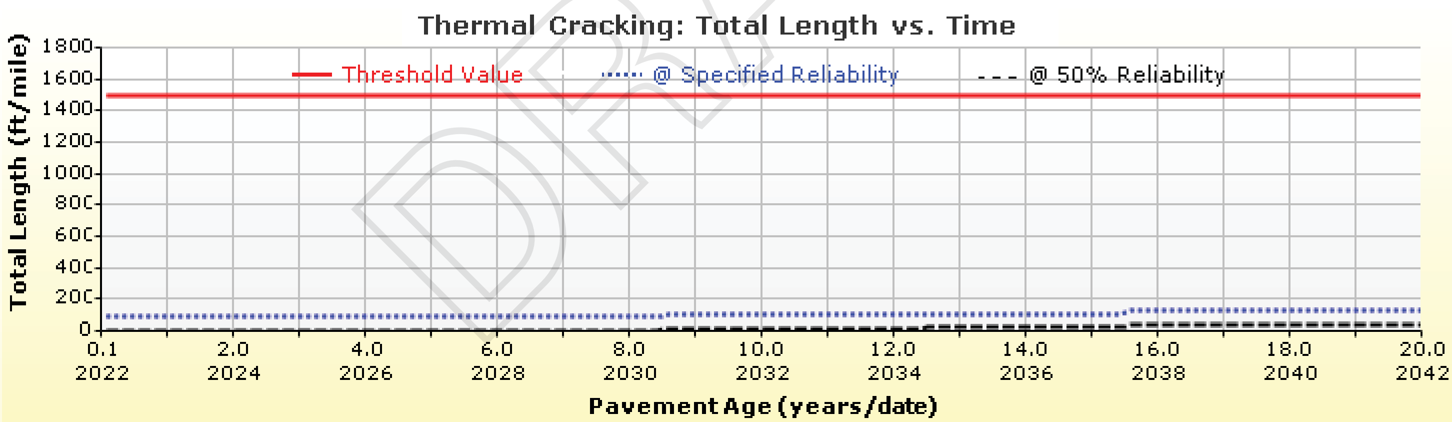


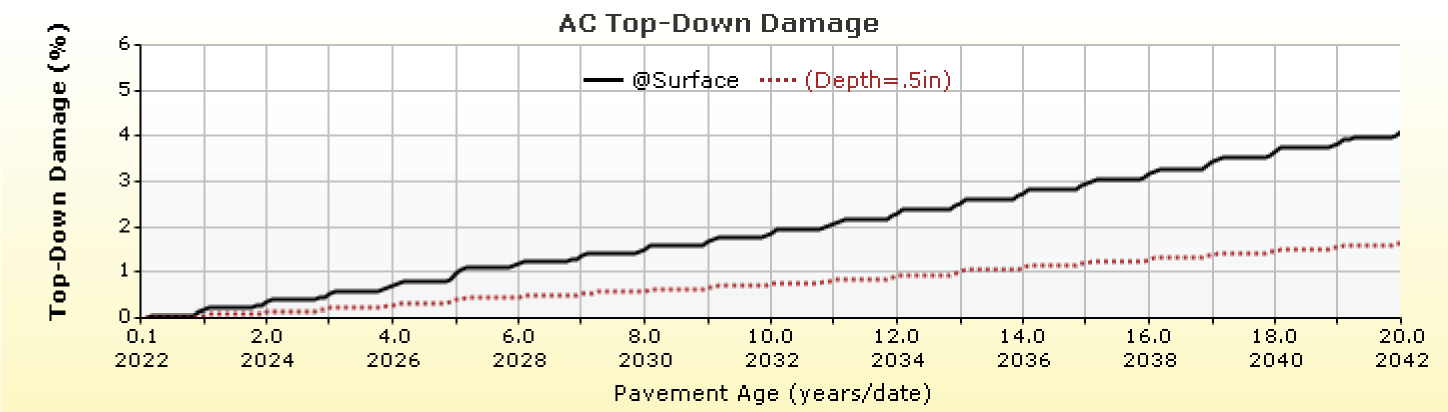


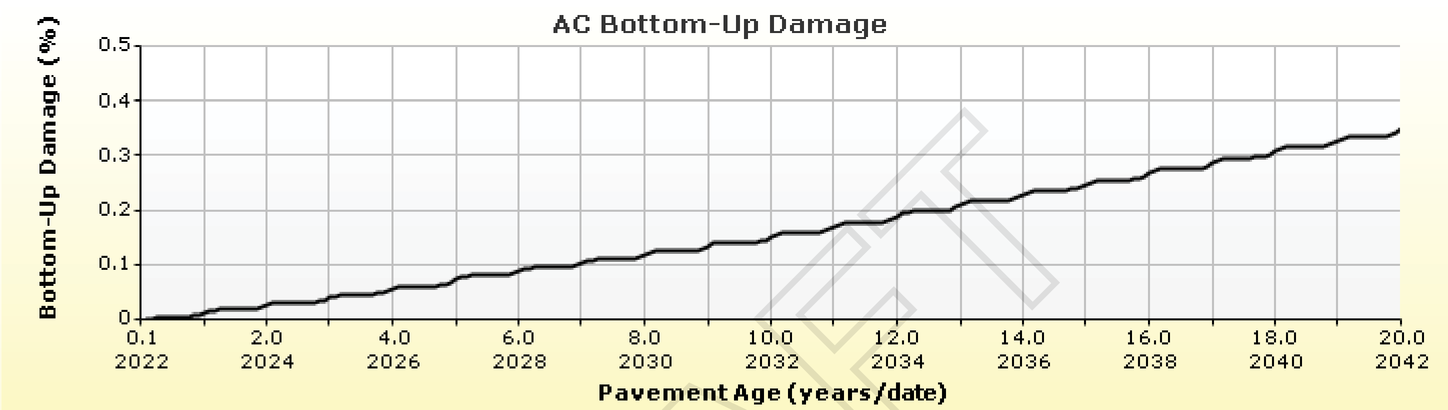
Analysis Output Charts

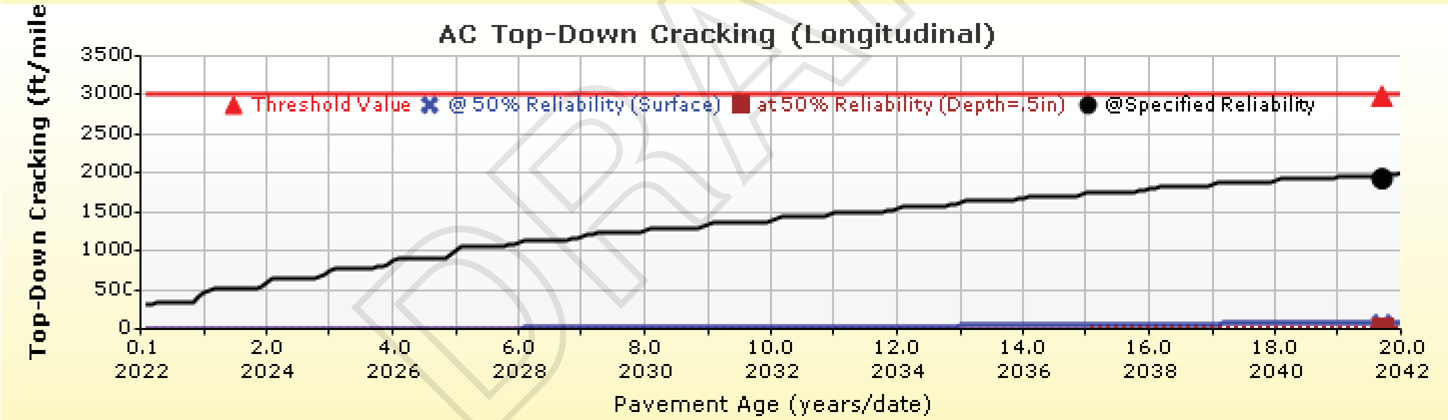


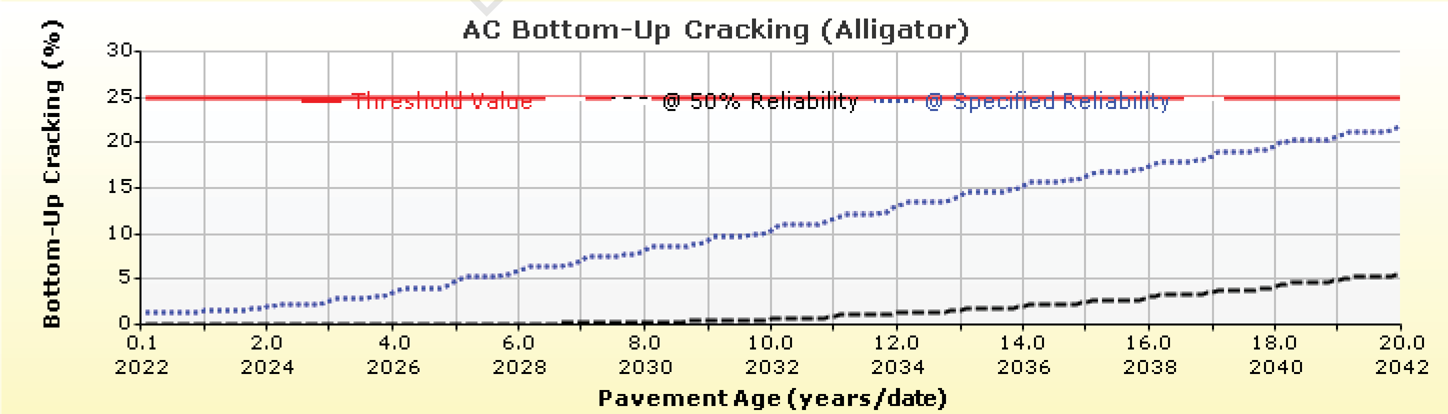


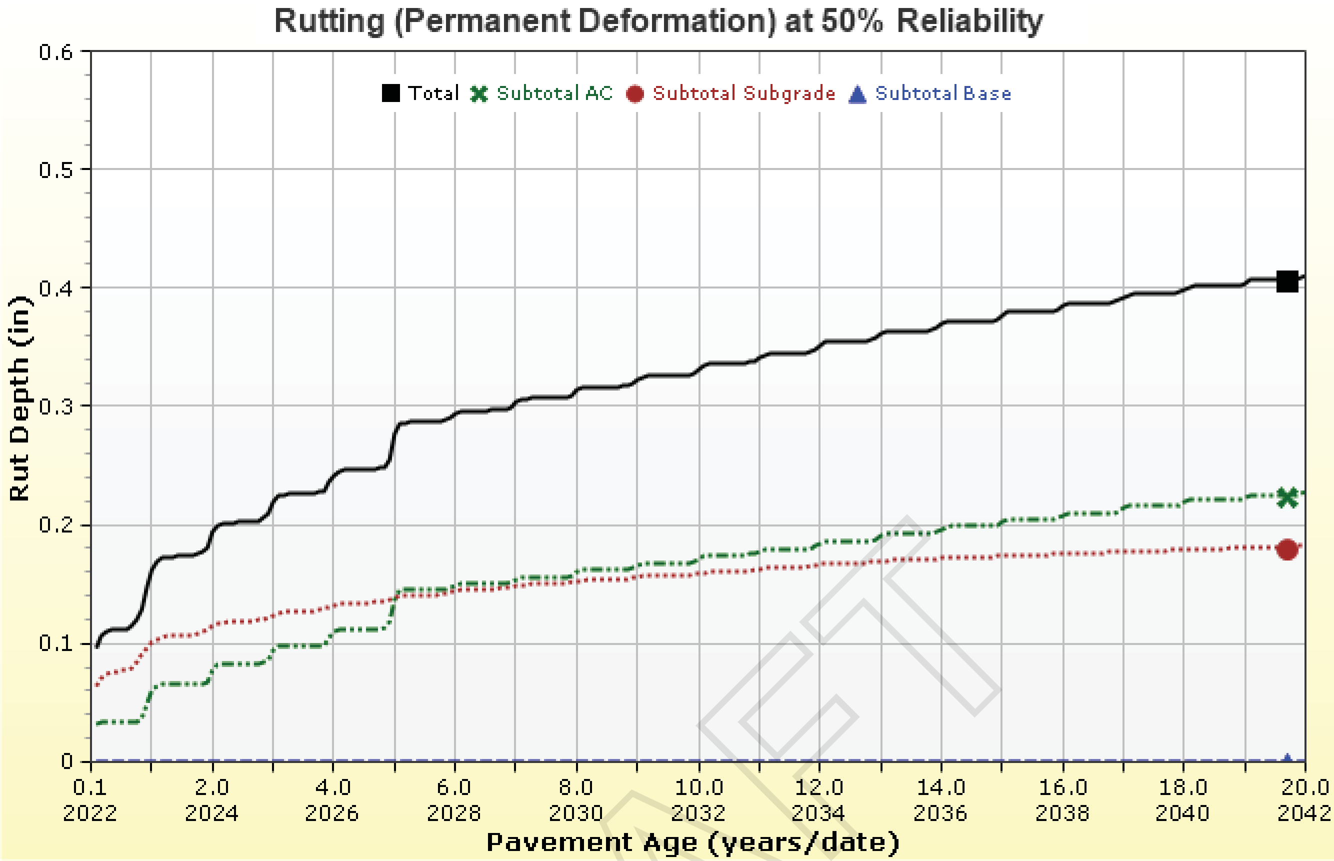


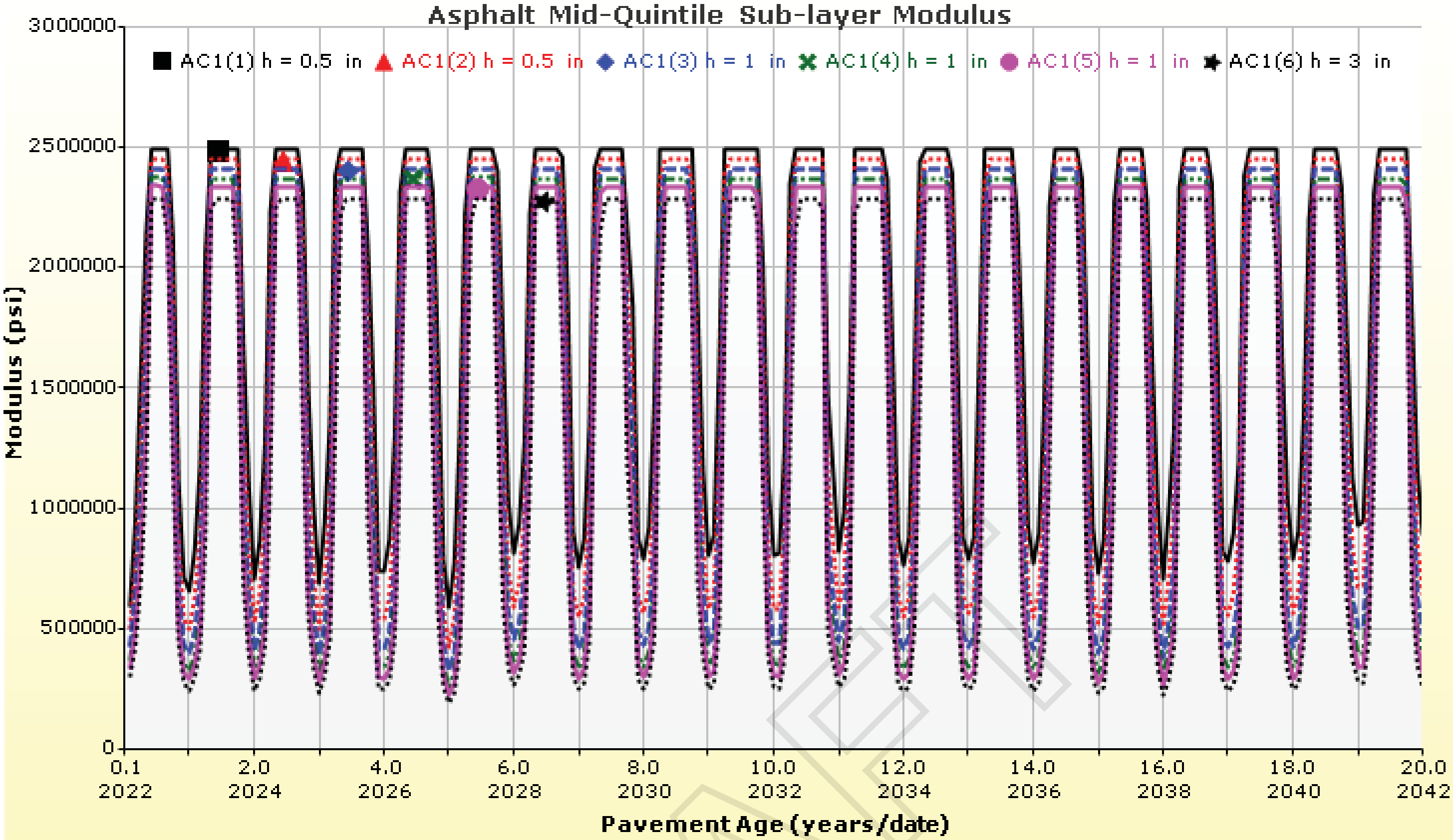

AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
Pavement Age (years/date)


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

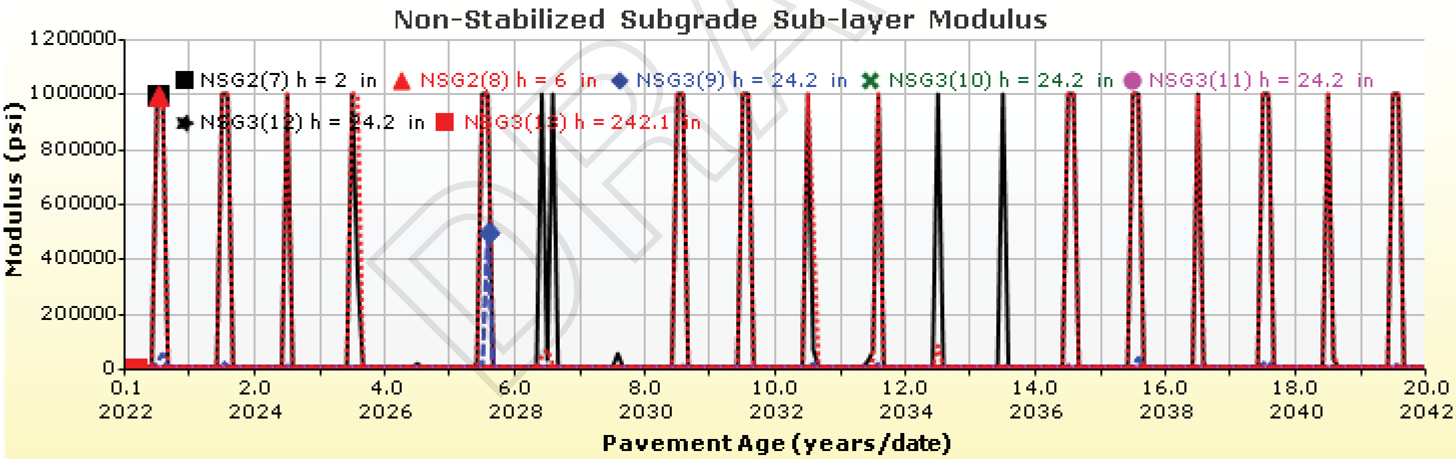

AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
Pavement Age (years/date)


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


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.6
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
AC1(4) h = 1 in
AC1(5) h = 1 in
AC1(6) h = 3 in
Modulus (psi)
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)



Non-Stabilized Subgrade Sub-layer Modulus
NSG2(7) h = 2 in
NSG2(8) h = 6 in
NSG3(9) h = 24.2 in
NSG3(10) h = 24.2 in
NSG3(11) h = 24.2 in
NSG3(12) h = 24.2 in
NSG3(13) h = 242.1 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	7.0	
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 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)
10000.0

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 3 Subgrade : A-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

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

Thermal Fracture

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

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

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 0.021	c2: 2.35	c3: 6000

AC Cracking Bottom Standard Deviation

1+15/(1+exp(-3.1472-4.1349*LOG10 (BOTTOM+0.0001)))

CSM Cracking

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

C1: 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

Roundabout_5.5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_5.5inHMA_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	5.5
NonStabilized	A-1-a	6.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

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

Traffic

Age (year)	Heavy Trucks (cumulative)
2022 (initial)	305
2032 (10 years)	1,252,090
2042 (20 years)	2,865,840

Design Outputs

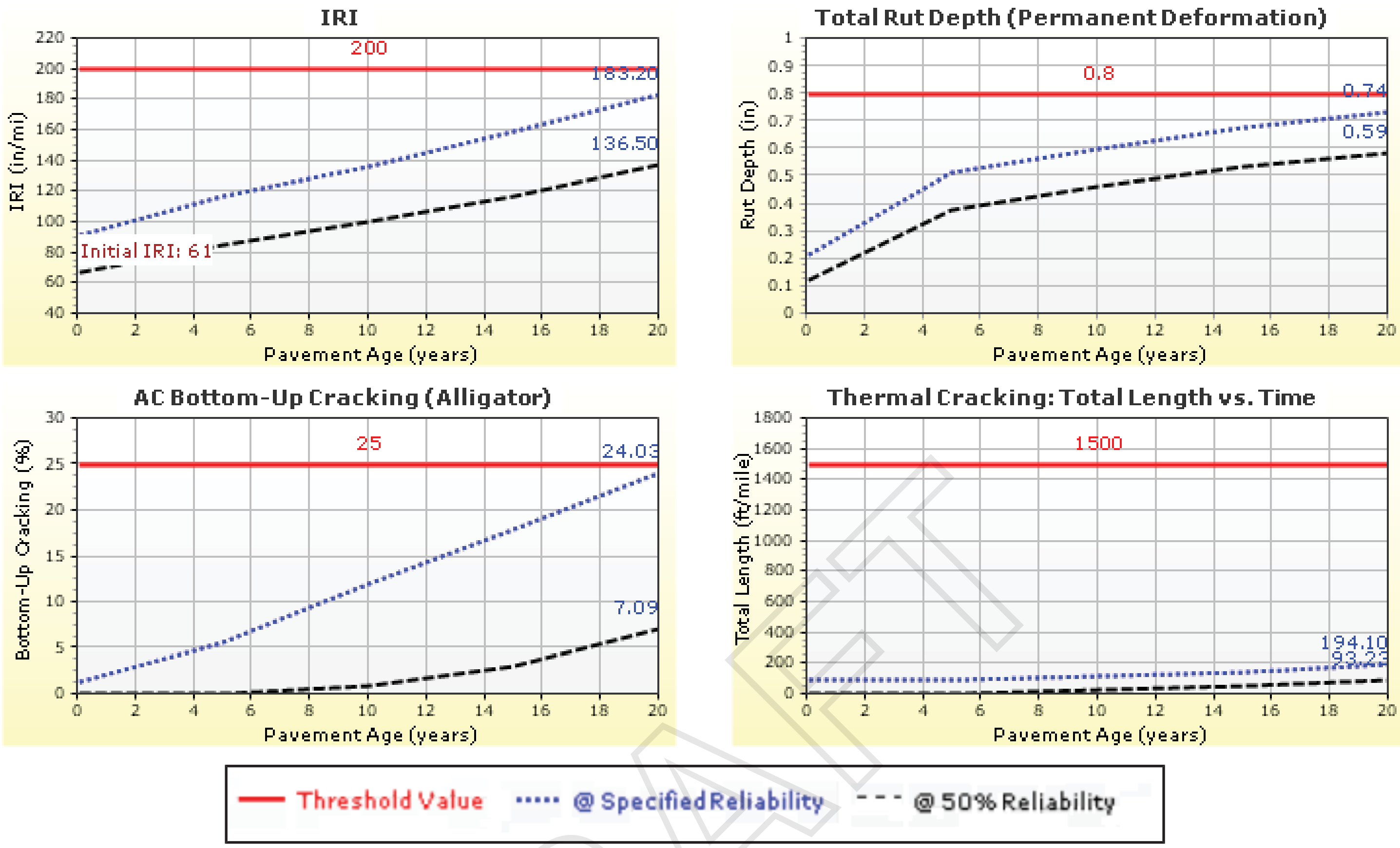
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	183.16	90.00	95.94	Pass
Permanent deformation - total pavement (in)	0.80	0.74	90.00	96.66	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	24.03	90.00	91.23	Pass
AC thermal cracking (ft/mile)	1500.00	194.10	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1577.90	90.00	99.31	Pass
Permanent deformation - AC only (in)	0.65	0.53	90.00	98.97	Pass

Roundabout_5.5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_5.5inHMA_6inABC_20yr.dgpx

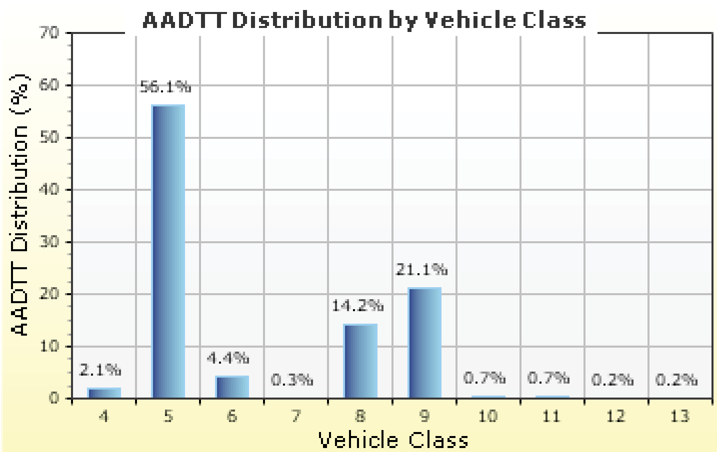
Distress Charts

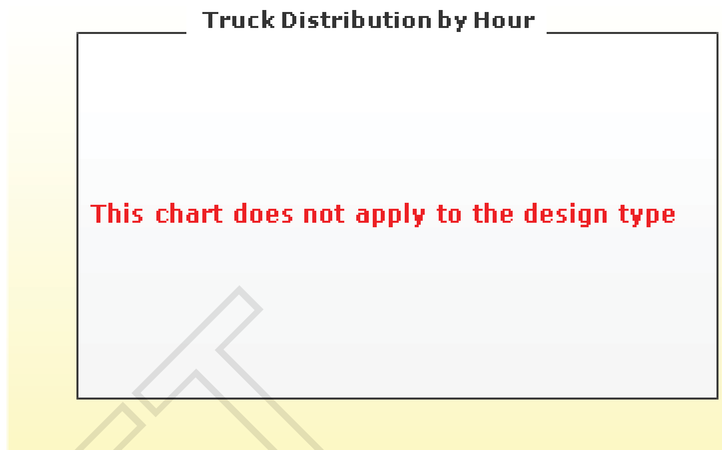


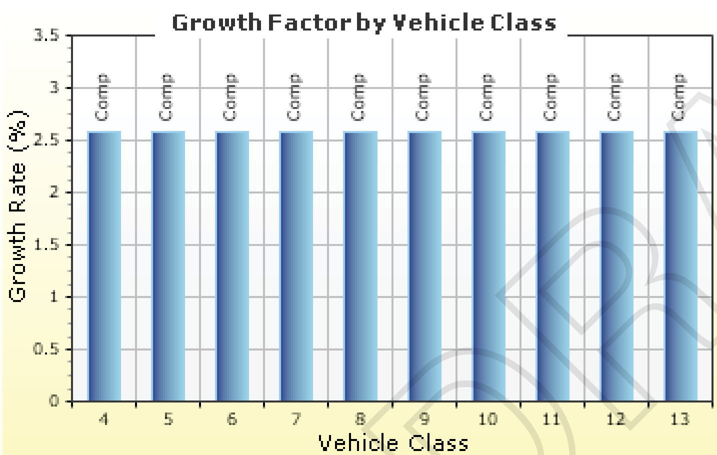
Traffic Inputs

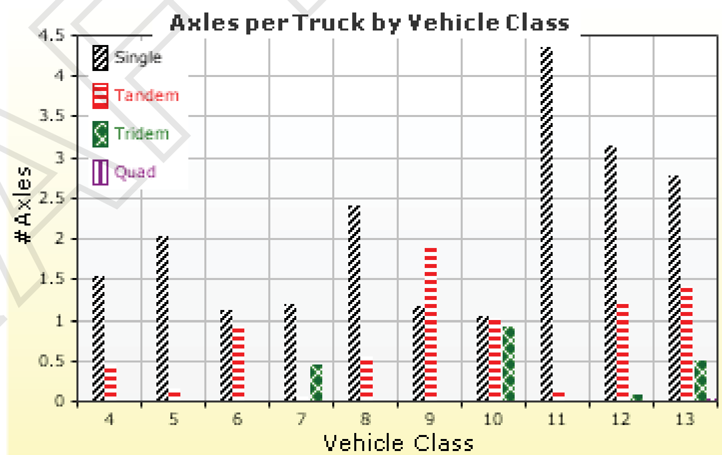
Graphical Representation of Traffic Inputs

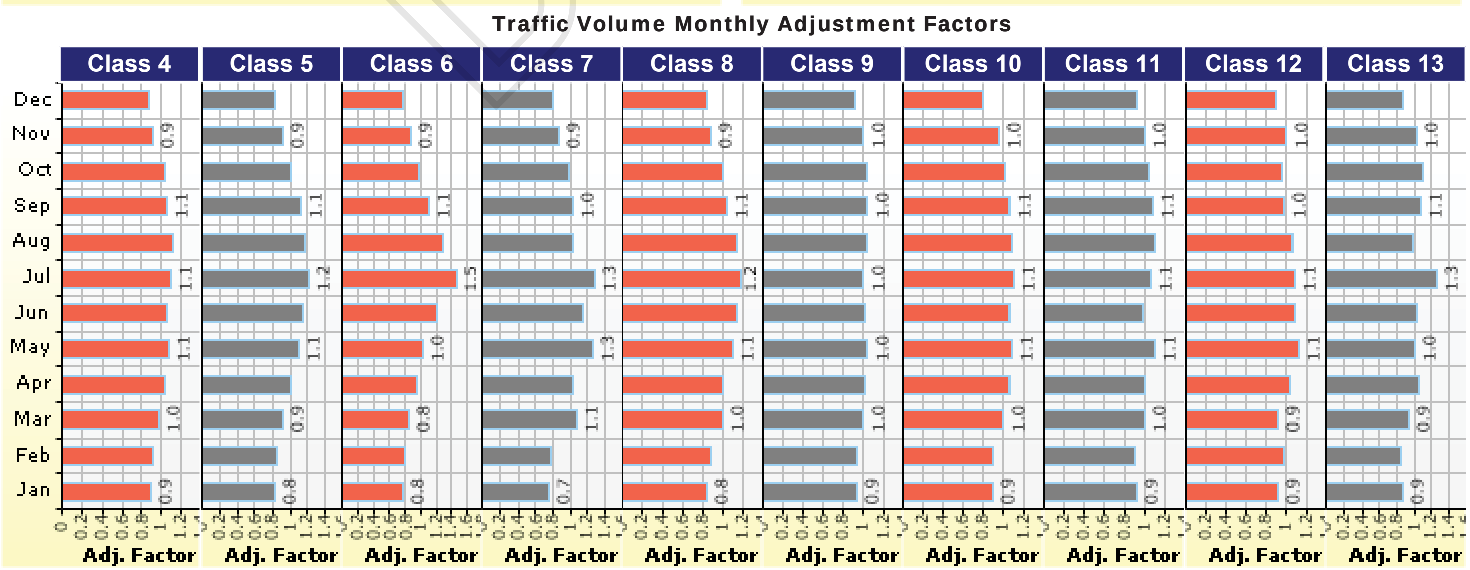
Initial two-way AADTT:	305	Percent of trucks in design direction (%):	100.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	15.0











Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	2.1%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

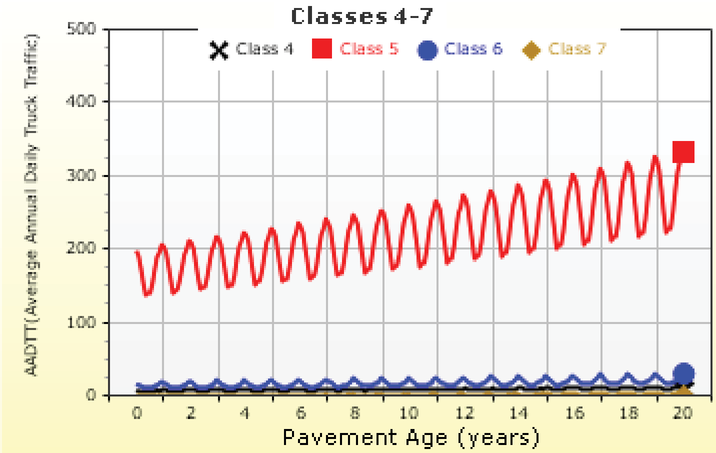
Wheelbase does not apply

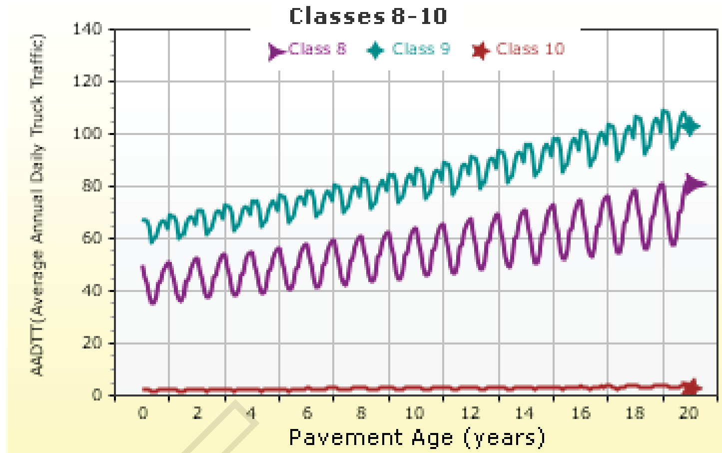
Number of Axles per Truck

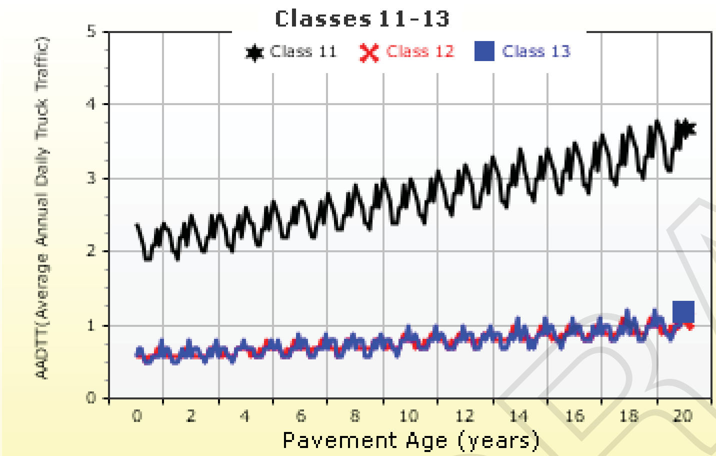
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

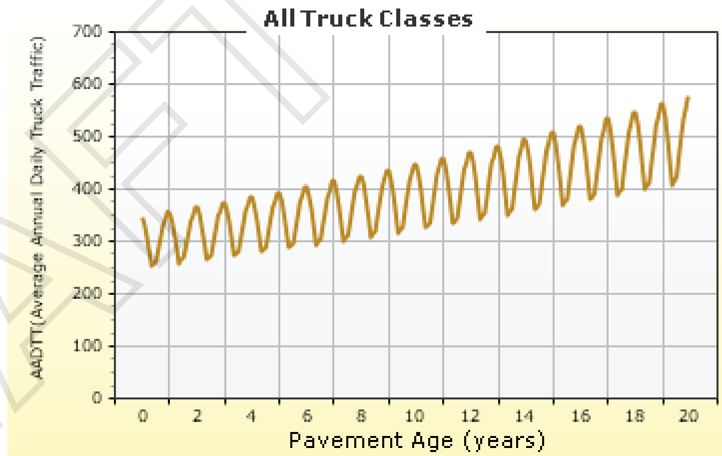
AADTT (Average Annual Daily Truck Traffic) Growth

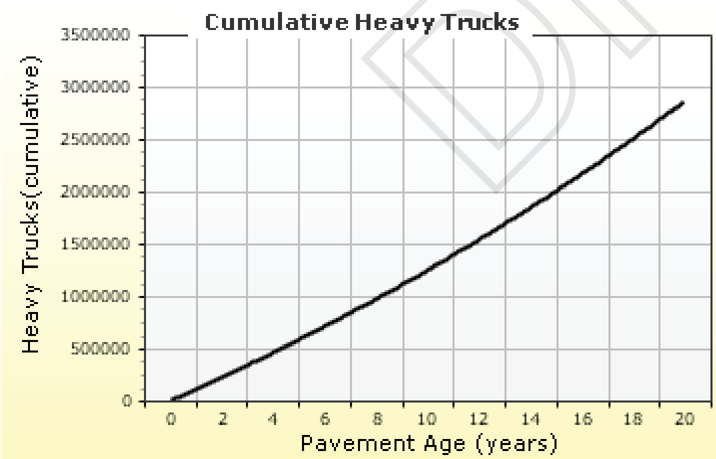
*** Traffic cap is not enforced**











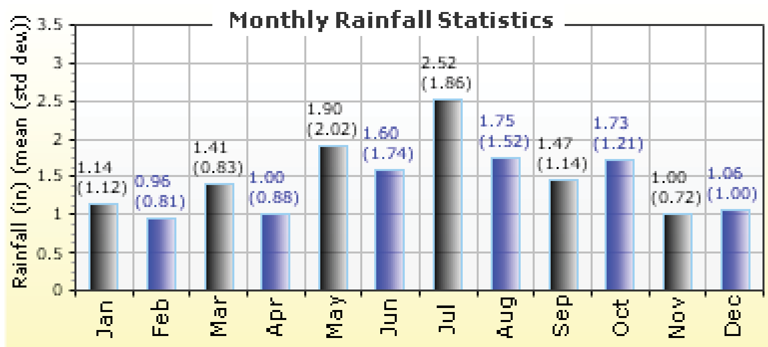
Roundabout_5.5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_5.5inHMA_6inABC_20yr.dgpx

Climate Inputs

Climate Data Sources:

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

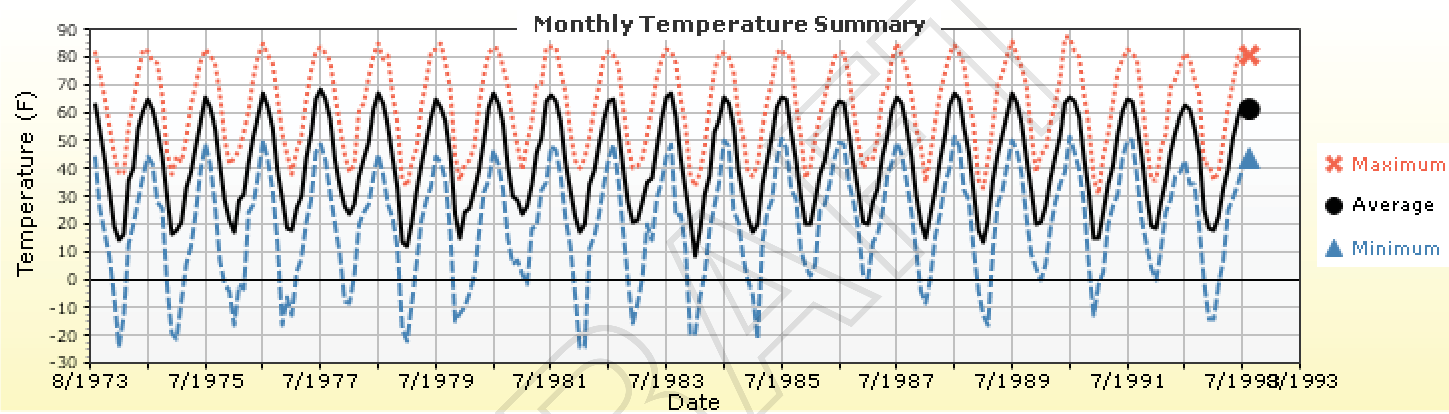


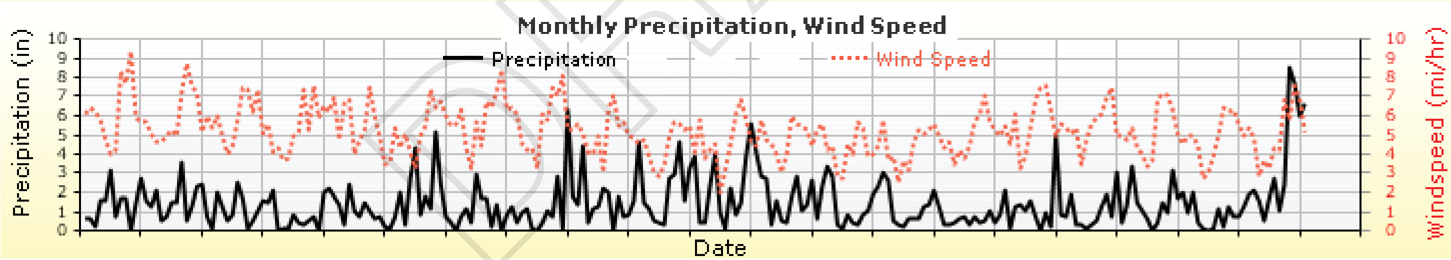
Annual Statistics:

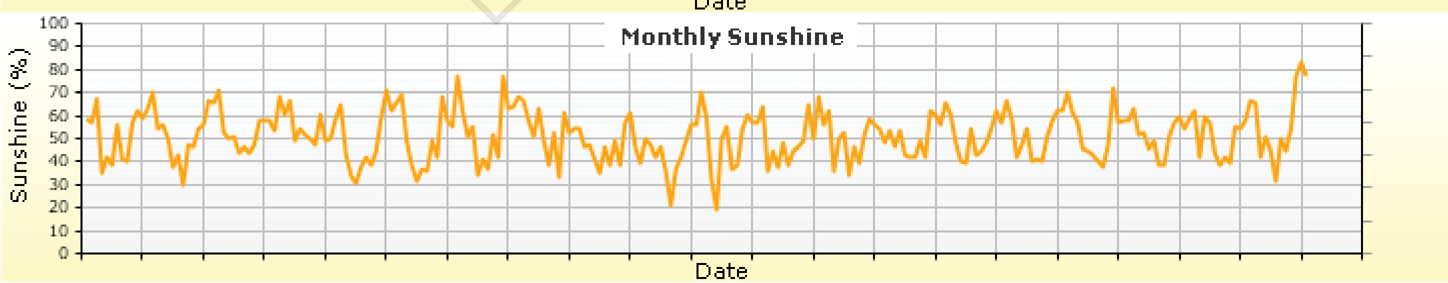
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

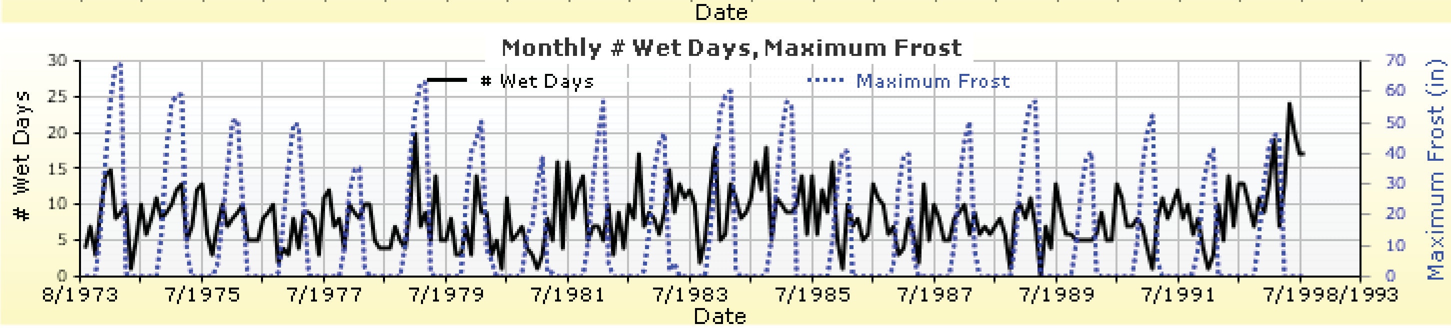
Water table depth (ft) 10.00

Monthly Climate Summary:





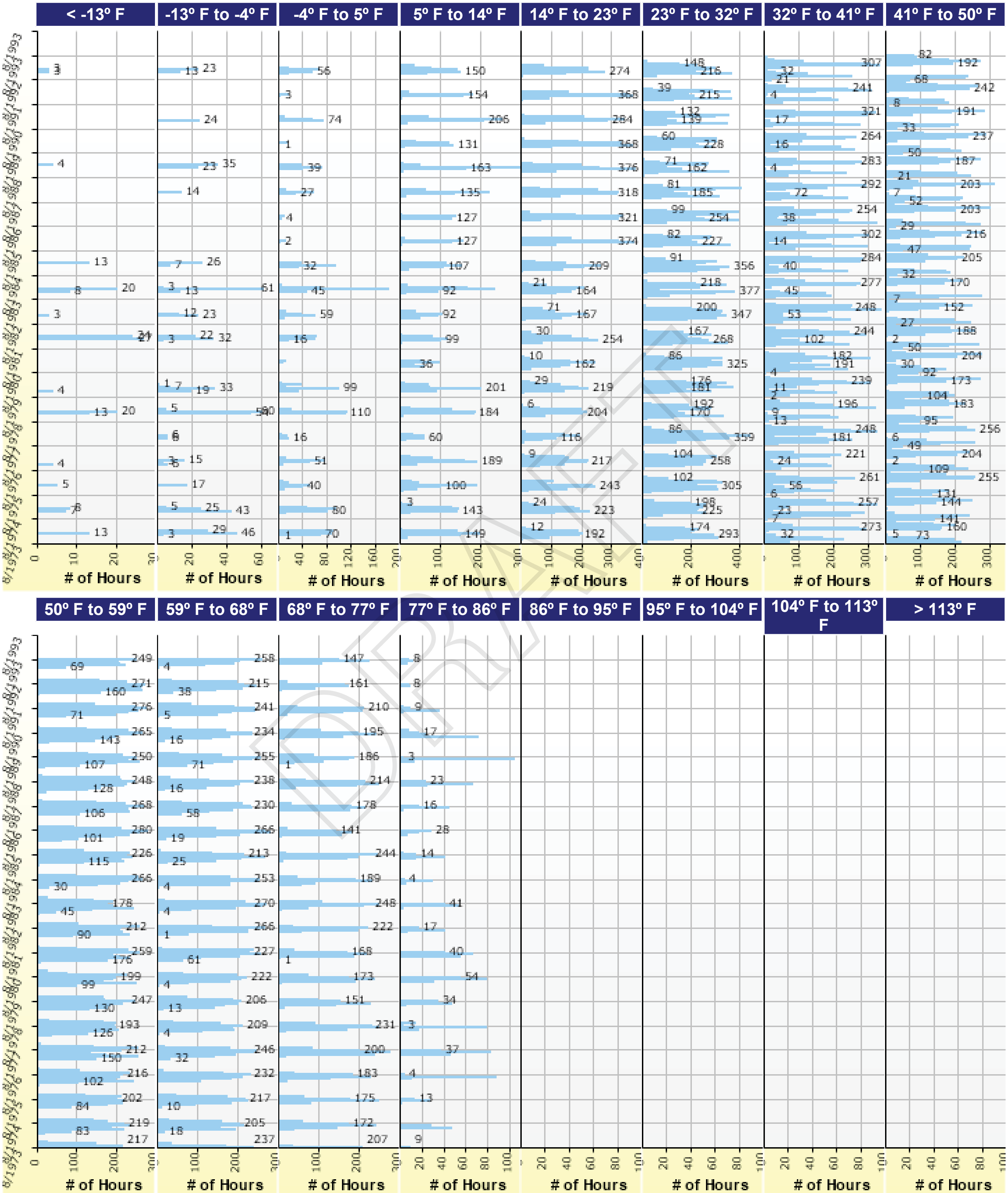




Roundabout_5.5inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_5.5inHMA_6inABC_20yr.dgpx

Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

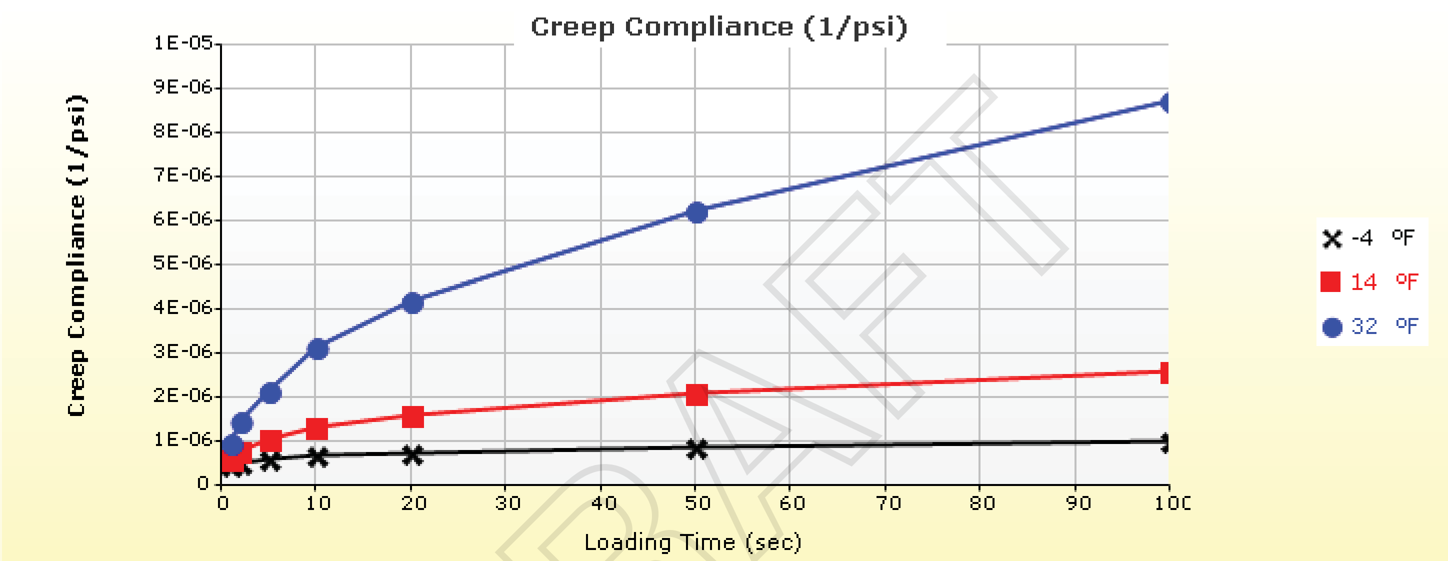
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Non-stabilized Base : A-1-a	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 4 Subgrade : A-2-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

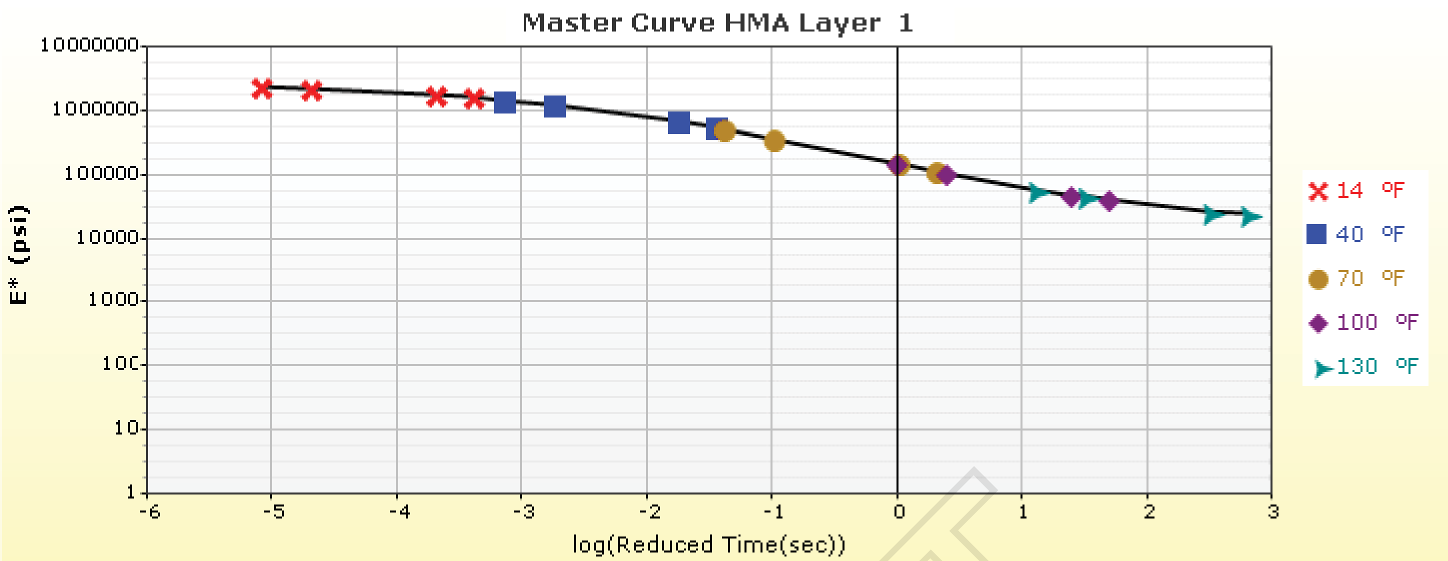
Indirect tensile strength at 14 ºF (psi)	446.00

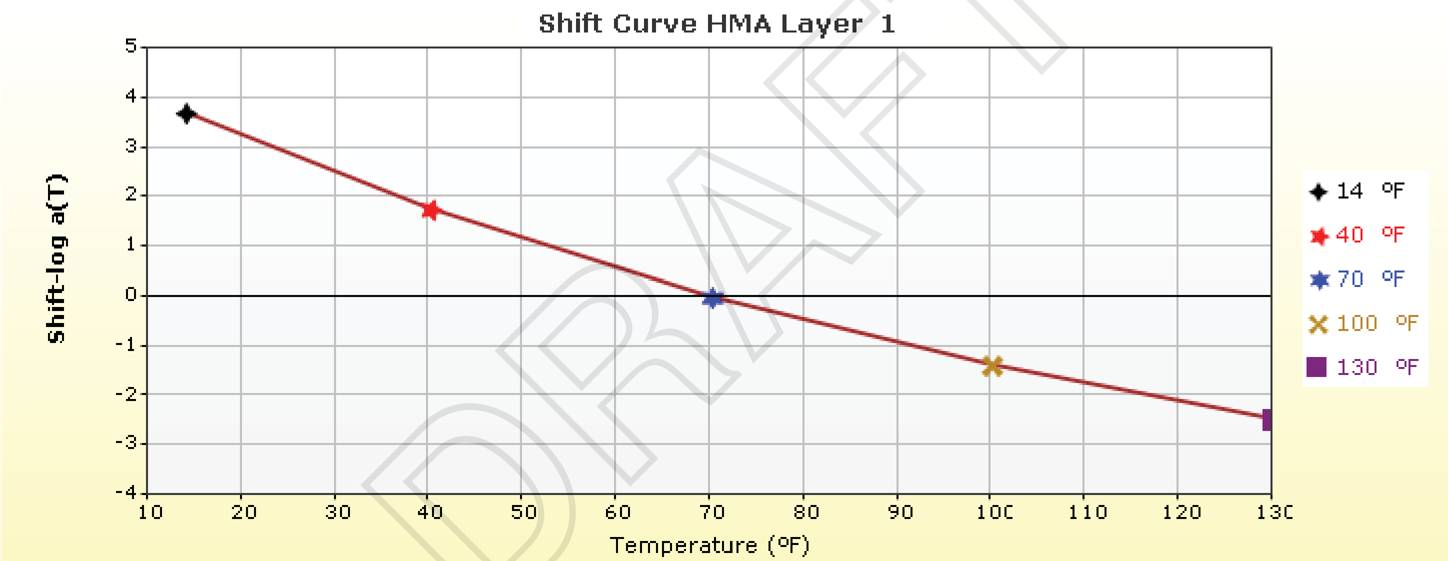
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

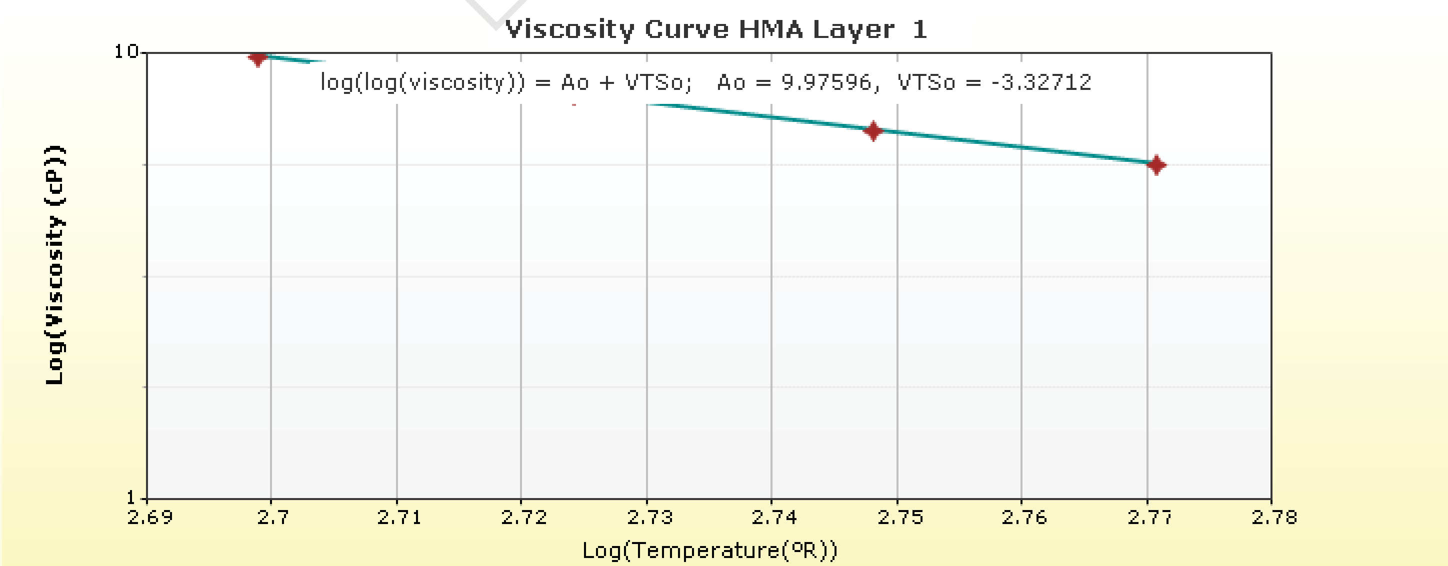
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	14 ºF	32 ºF
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



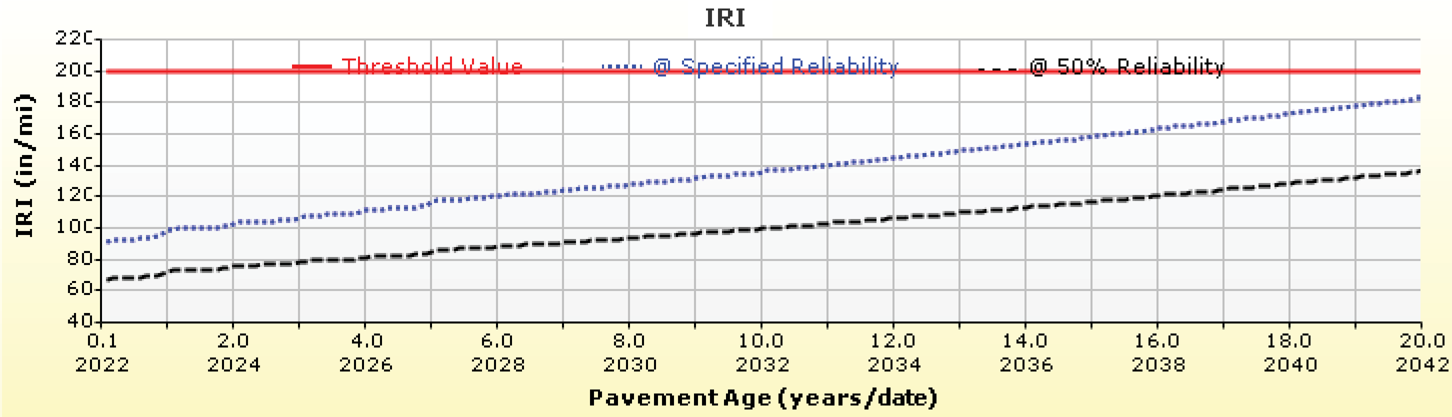
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

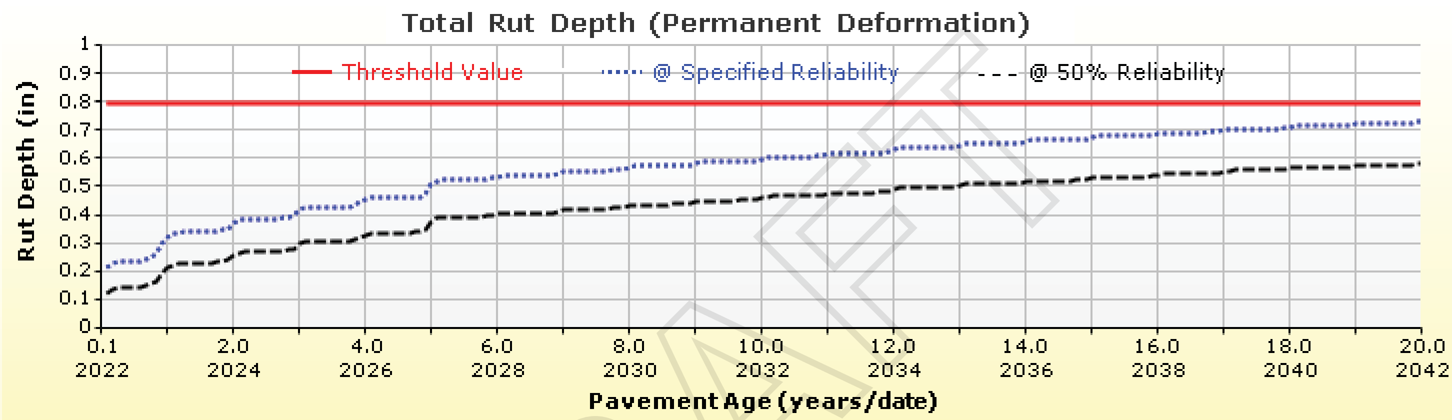


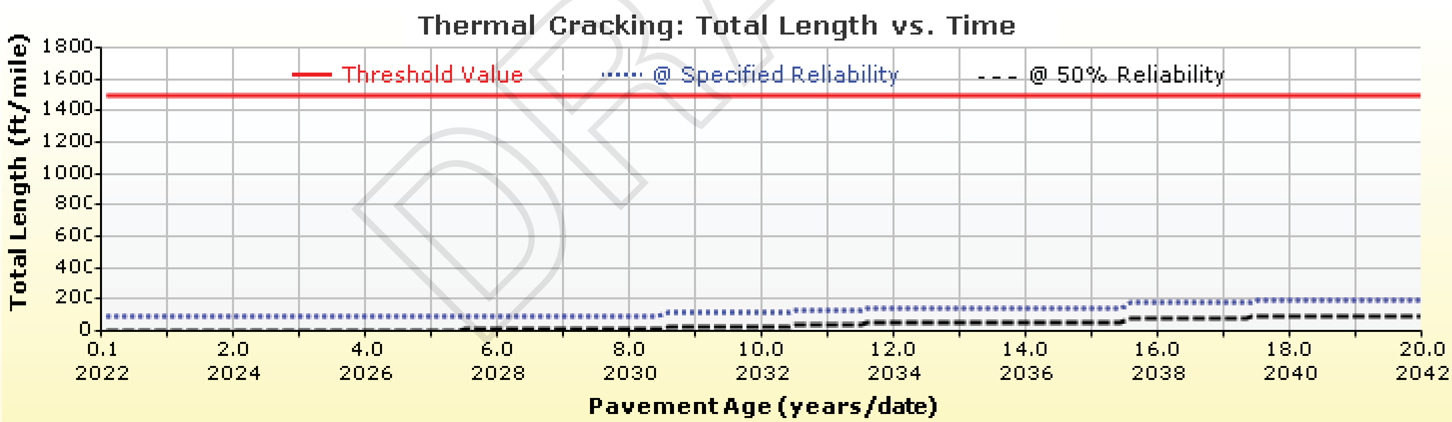




Analysis Output Charts

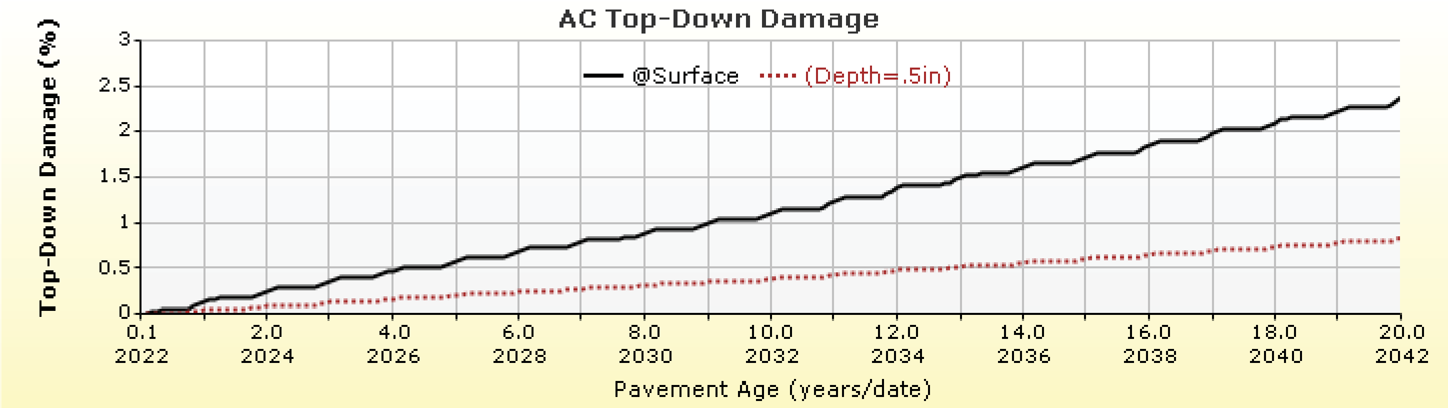


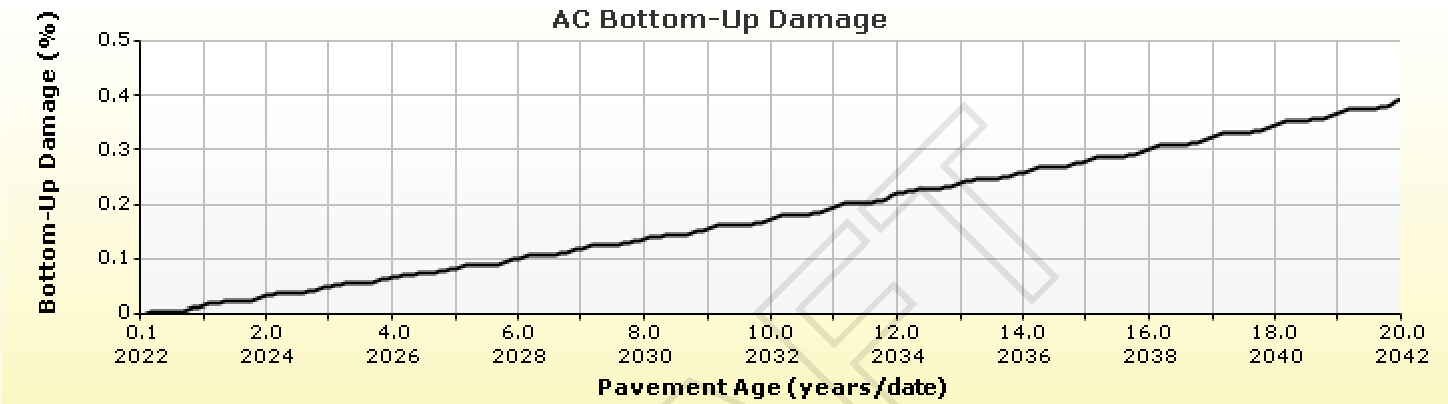


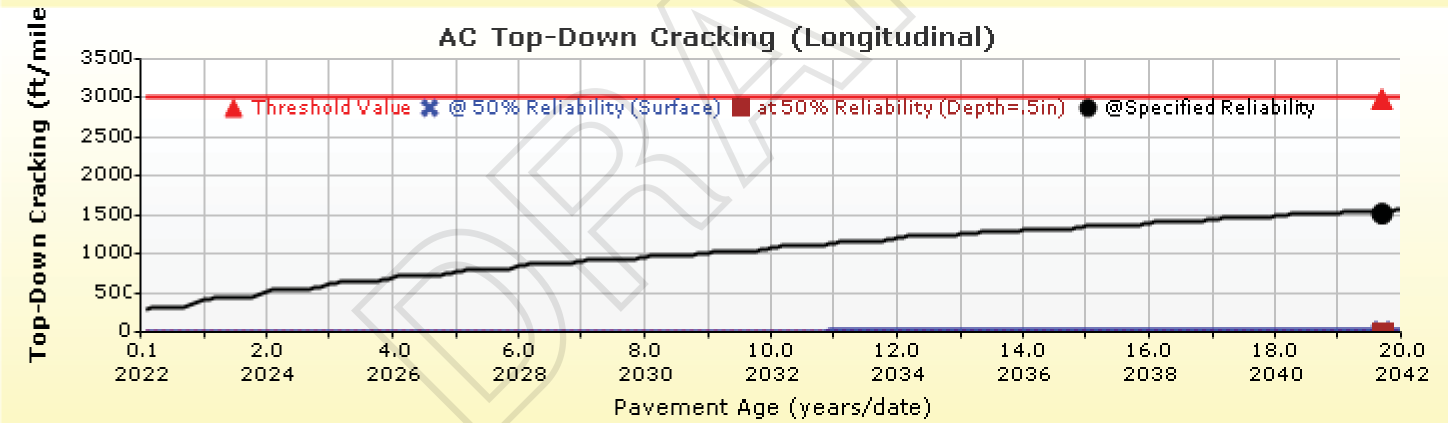


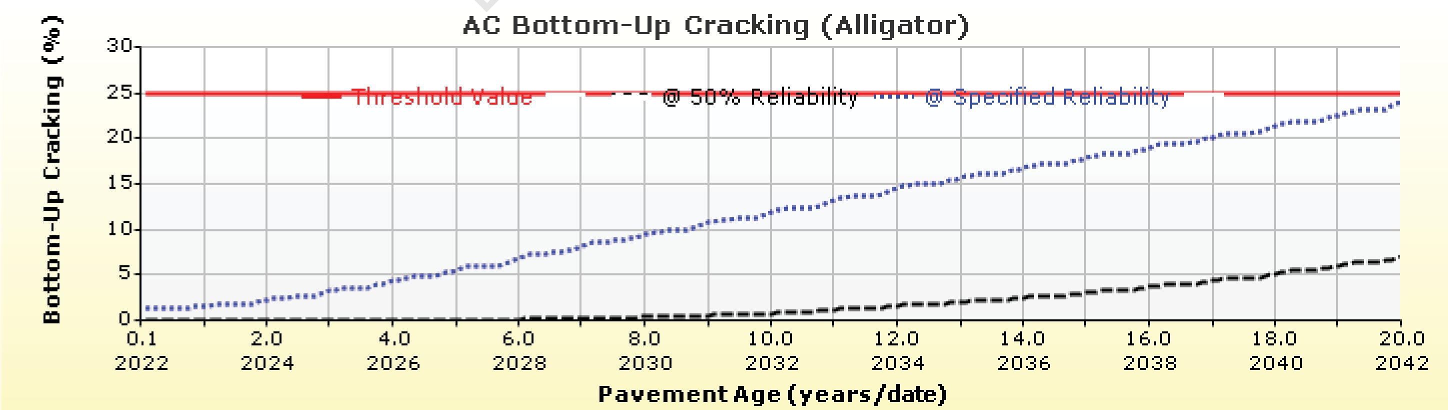
Roundabout_5.5inHMA_6inABC_20yr

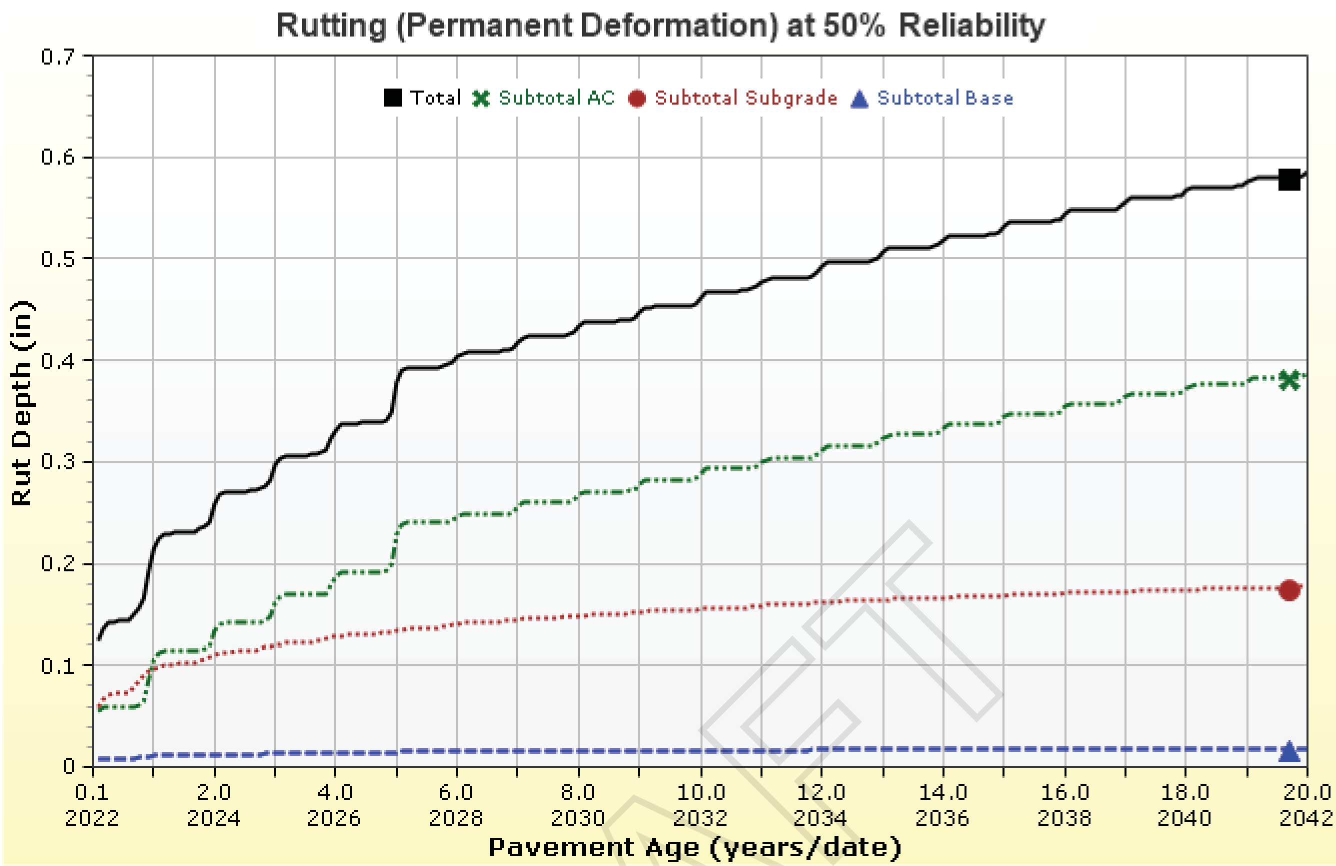
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_5.5inHMA_6inABC_20yr.dgpx



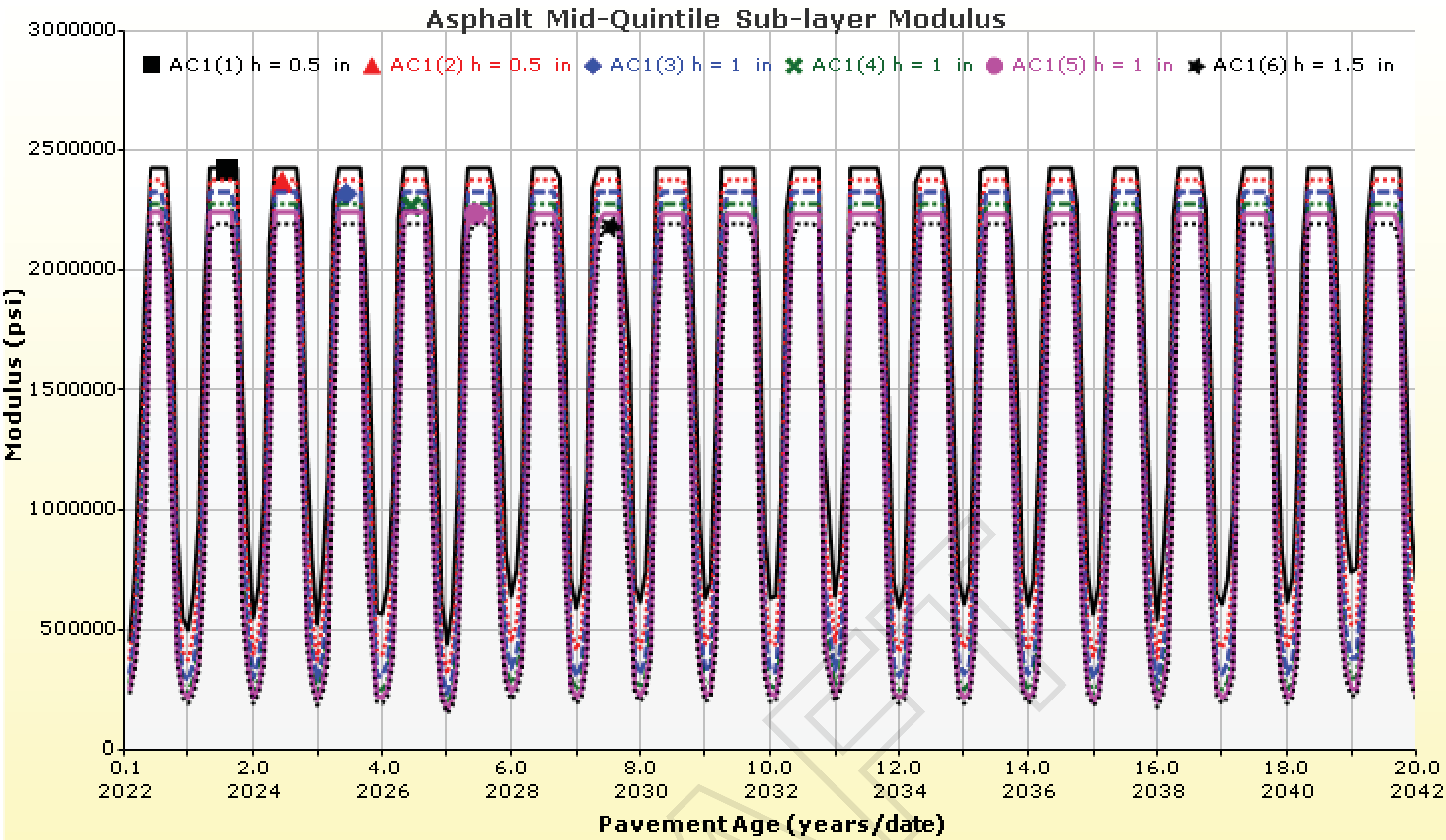




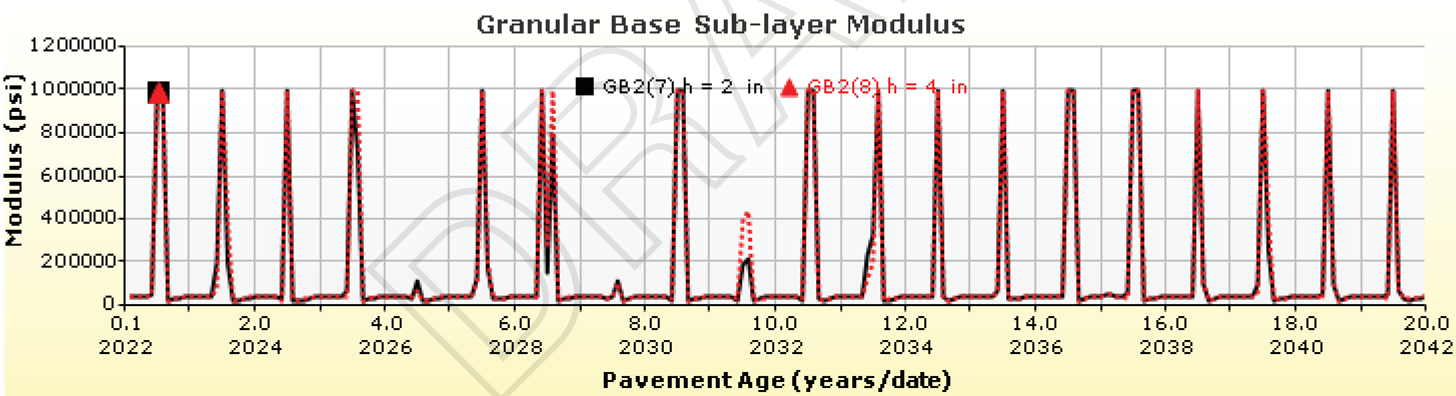




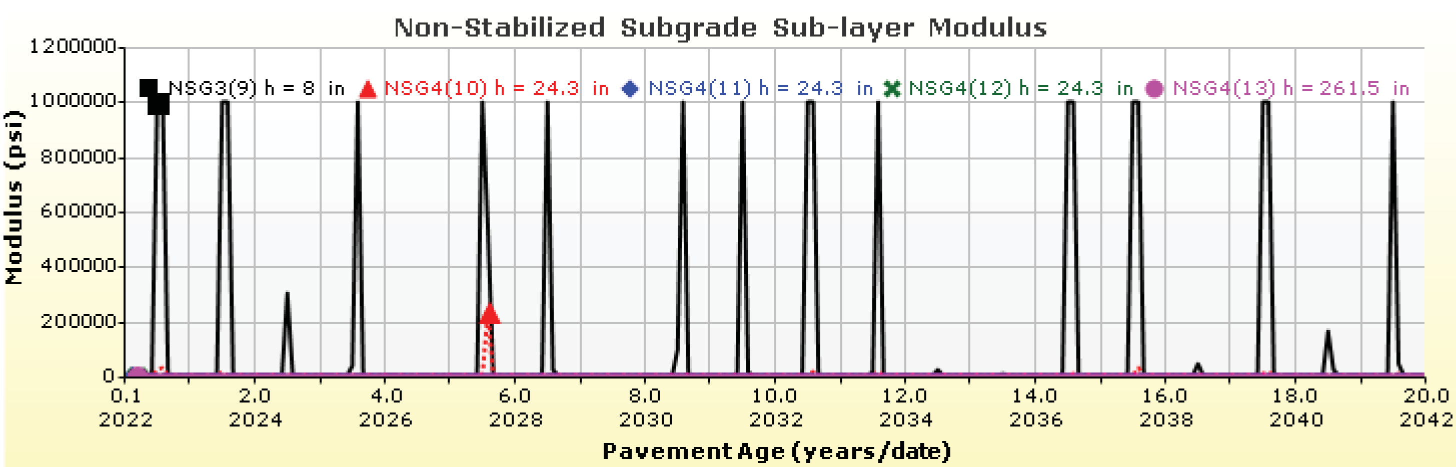
Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC1(4) h = 1 in
AC1(5) h = 1 in
AC1(6) h = 1.5 in
Modulus (psi)
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
GB2(7) h = 2 in
GB2(8) h = 4 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



Non-Stabilized Subgrade Sub-layer Modulus
NSG3(9) h = 8 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
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	5.5	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	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 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)
27000.0

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-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)
10000.0

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-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue	
$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 130.3674
	Bf2: 1
	Bf3: 1.217799

AC Rutting

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

Where:
H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

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

Thermal Fracture

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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

Roundabout_8inHMA_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_8inHMA_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	8.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

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

Traffic

Age (year)	Heavy Trucks (cumulative)
2022 (initial)	305
2032 (10 years)	1,252,090
2042 (20 years)	2,865,840

Design Outputs

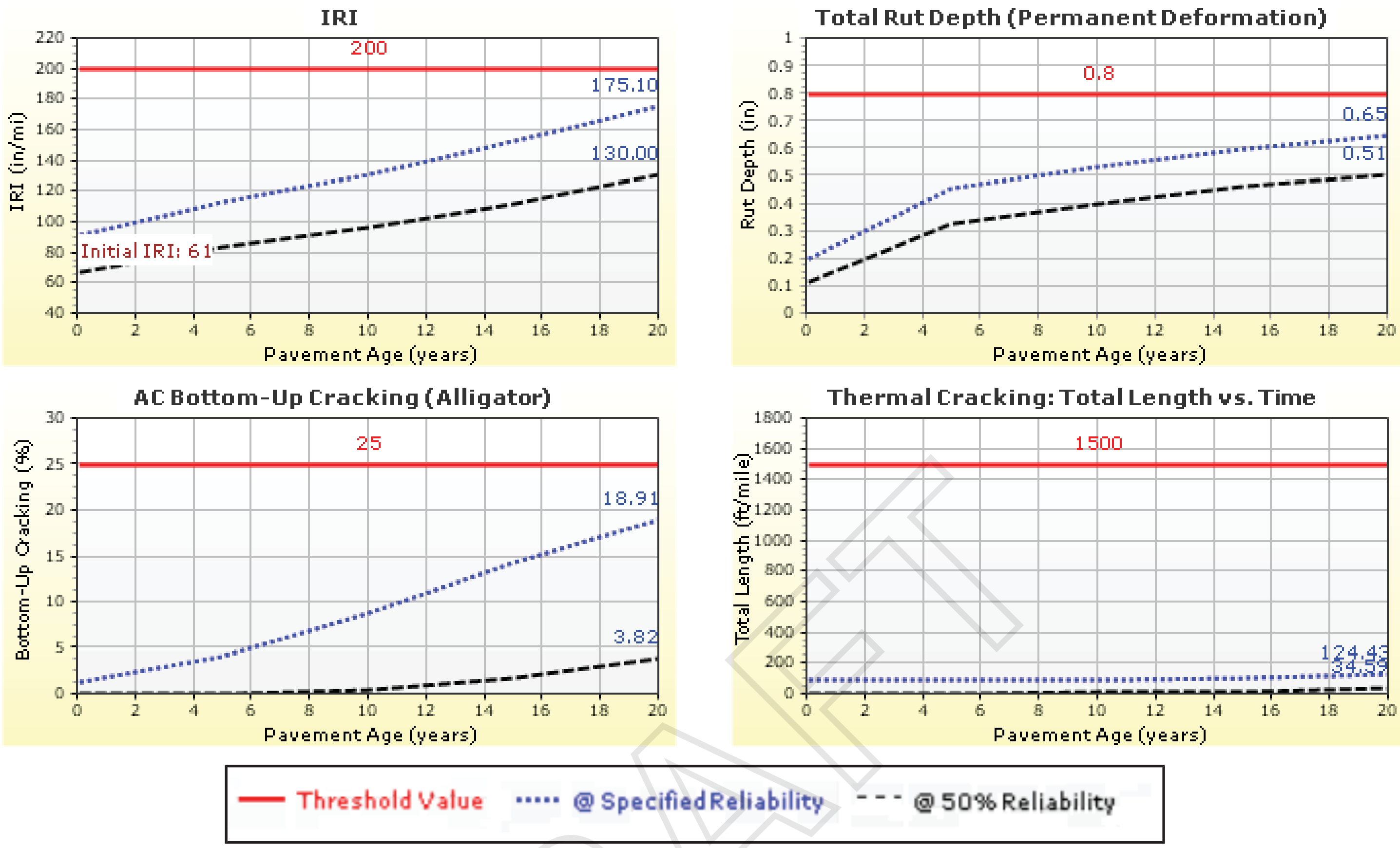
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	175.07	90.00	97.68	Pass
Permanent deformation - total pavement (in)	0.80	0.65	90.00	99.58	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	18.91	90.00	96.39	Pass
AC thermal cracking (ft/mile)	1500.00	124.43	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1931.28	90.00	97.82	Pass
Permanent deformation - AC only (in)	0.65	0.46	90.00	99.88	Pass

Roundabout_8inHMA_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_8inHMA_20yr.dgpx

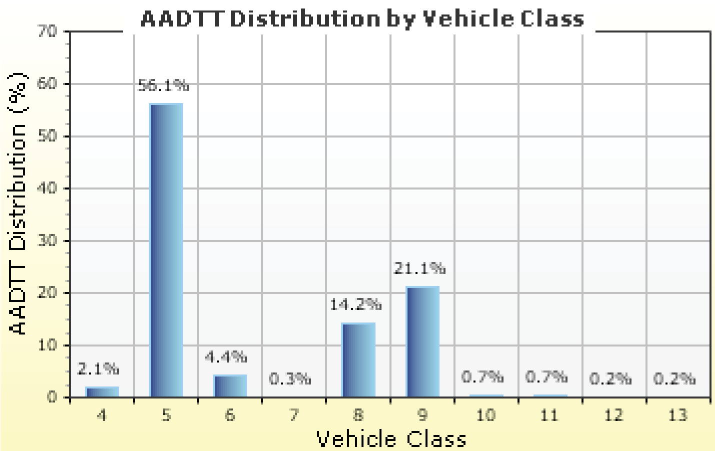
Distress Charts

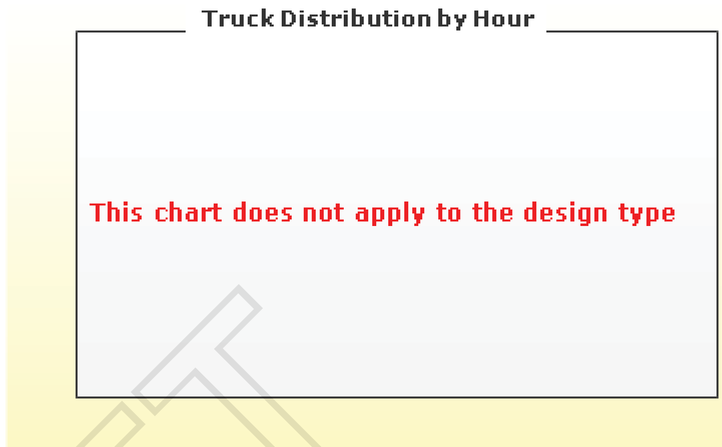


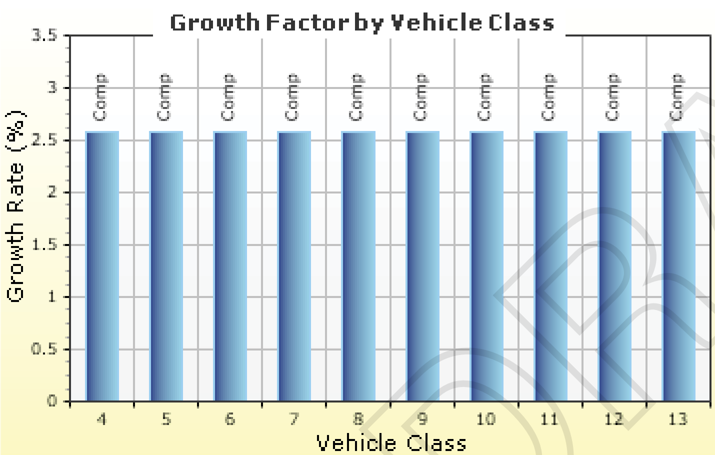
Traffic Inputs

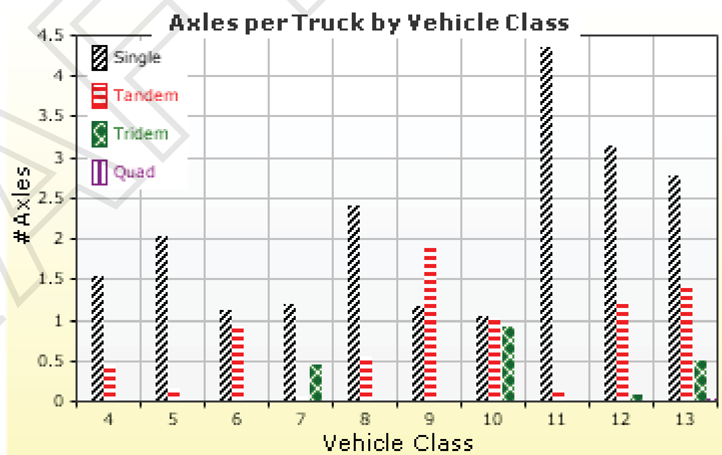
Graphical Representation of Traffic Inputs

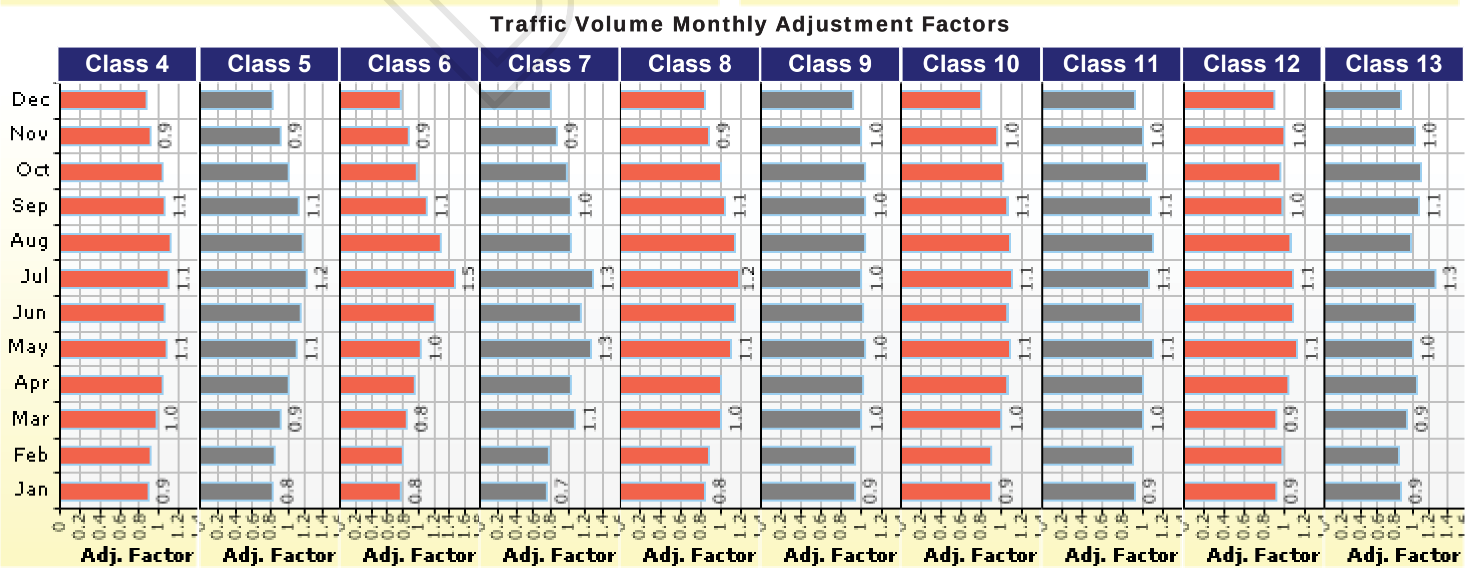
Initial two-way AADTT:	305	Percent of trucks in design direction (%):	100.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	15.0











Roundabout_8inHMA_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_8inHMA_20yr.dgpx

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%	2.57%	Compound
Class 5	56.1%	2.57%	Compound
Class 6	4.4%	2.57%	Compound
Class 7	0.3%	2.57%	Compound
Class 8	14.2%	2.57%	Compound
Class 9	21.1%	2.57%	Compound
Class 10	0.7%	2.57%	Compound
Class 11	0.7%	2.57%	Compound
Class 12	0.2%	2.57%	Compound
Class 13	0.2%	2.57%	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

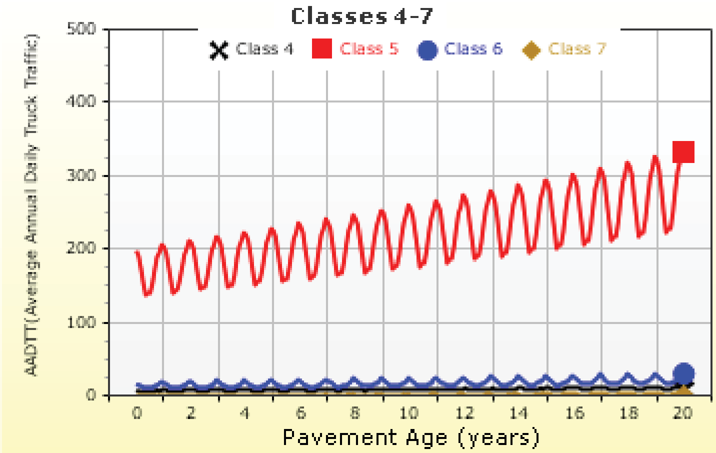
Wheelbase does not apply

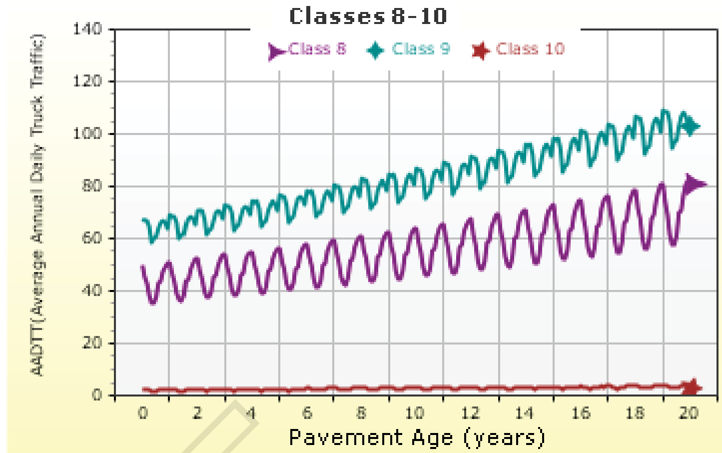
Number of Axles per Truck

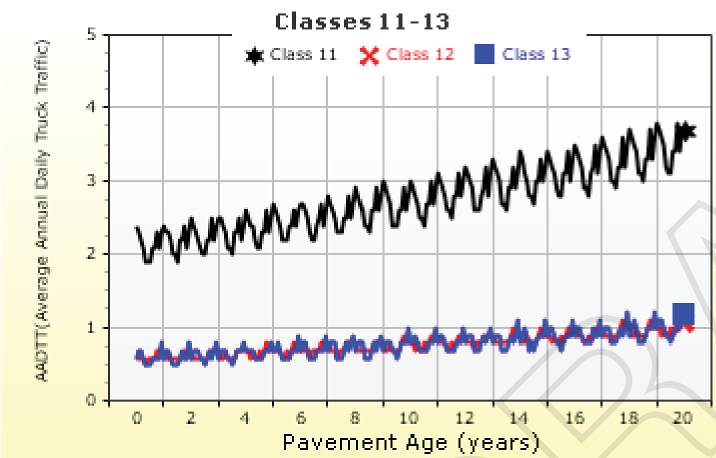
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

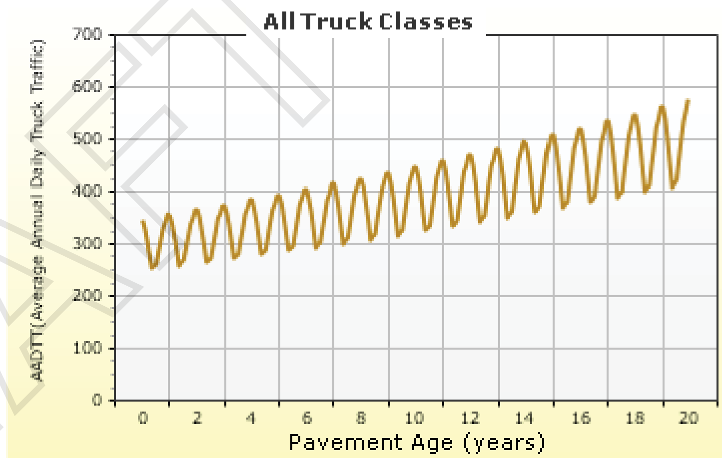
AADTT (Average Annual Daily Truck Traffic) Growth

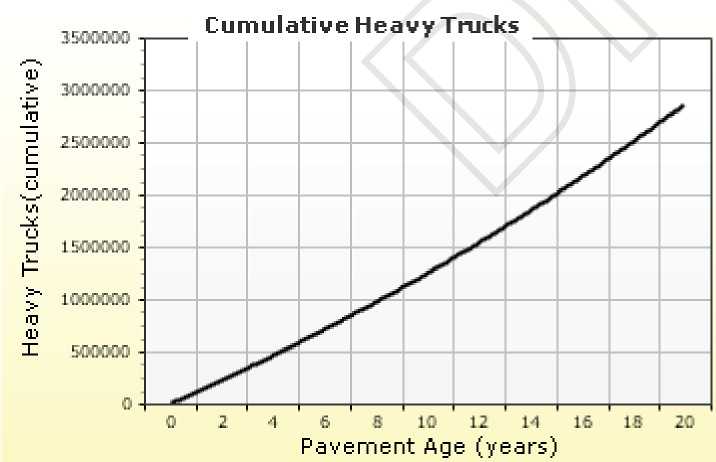
*** Traffic cap is not enforced**







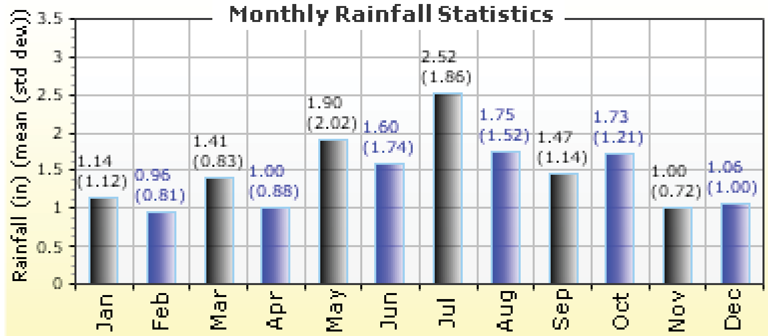




Climate Inputs

Climate Data Sources:

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

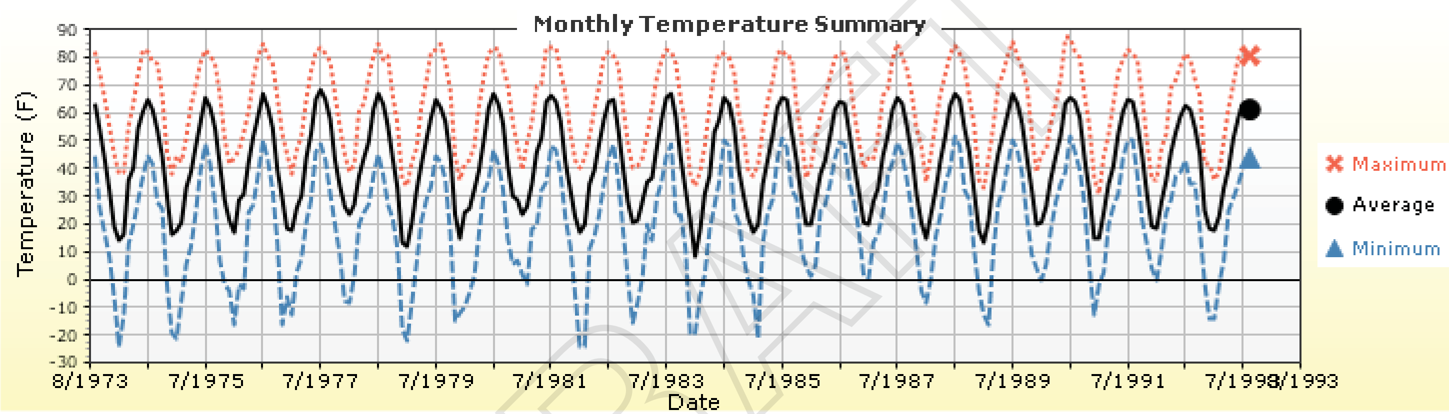


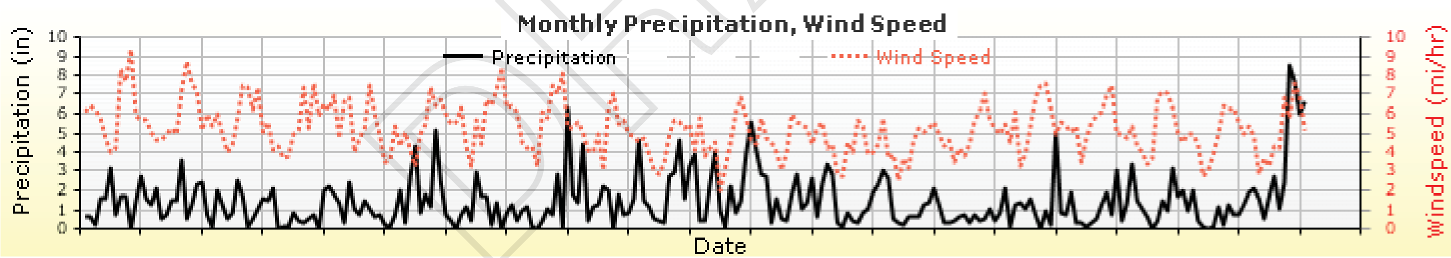
Annual Statistics:

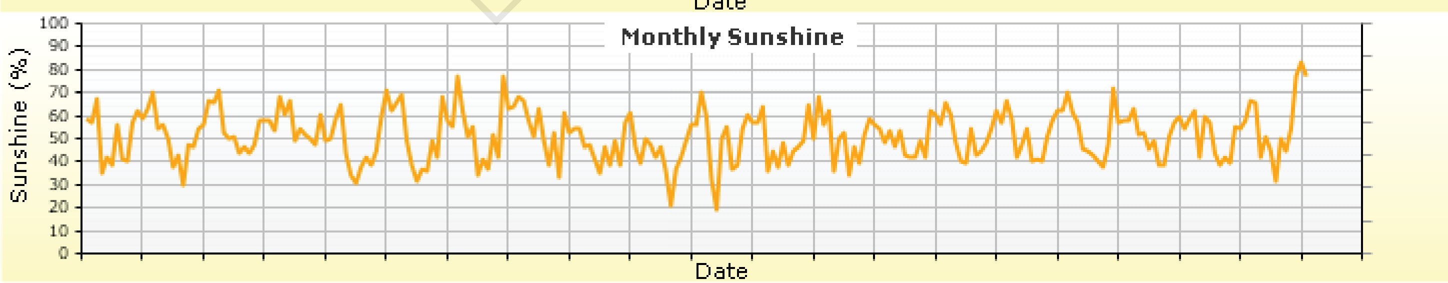
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

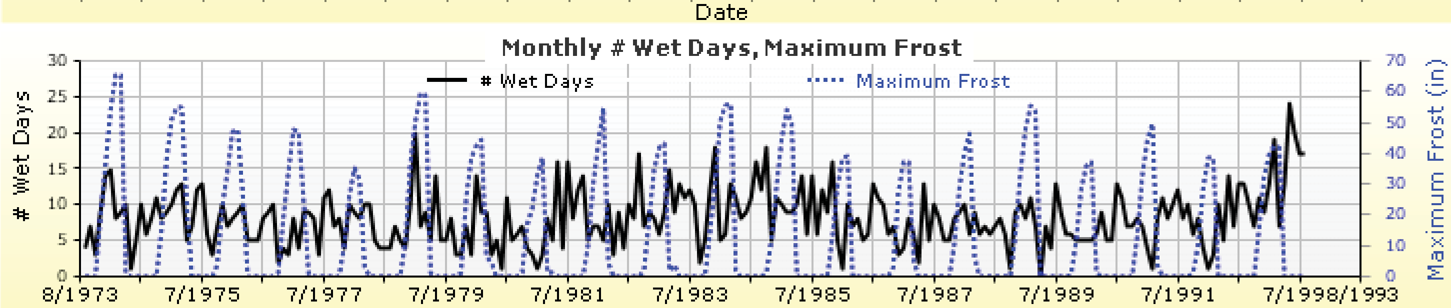
Water table depth (ft)	10.00

Monthly Climate Summary:





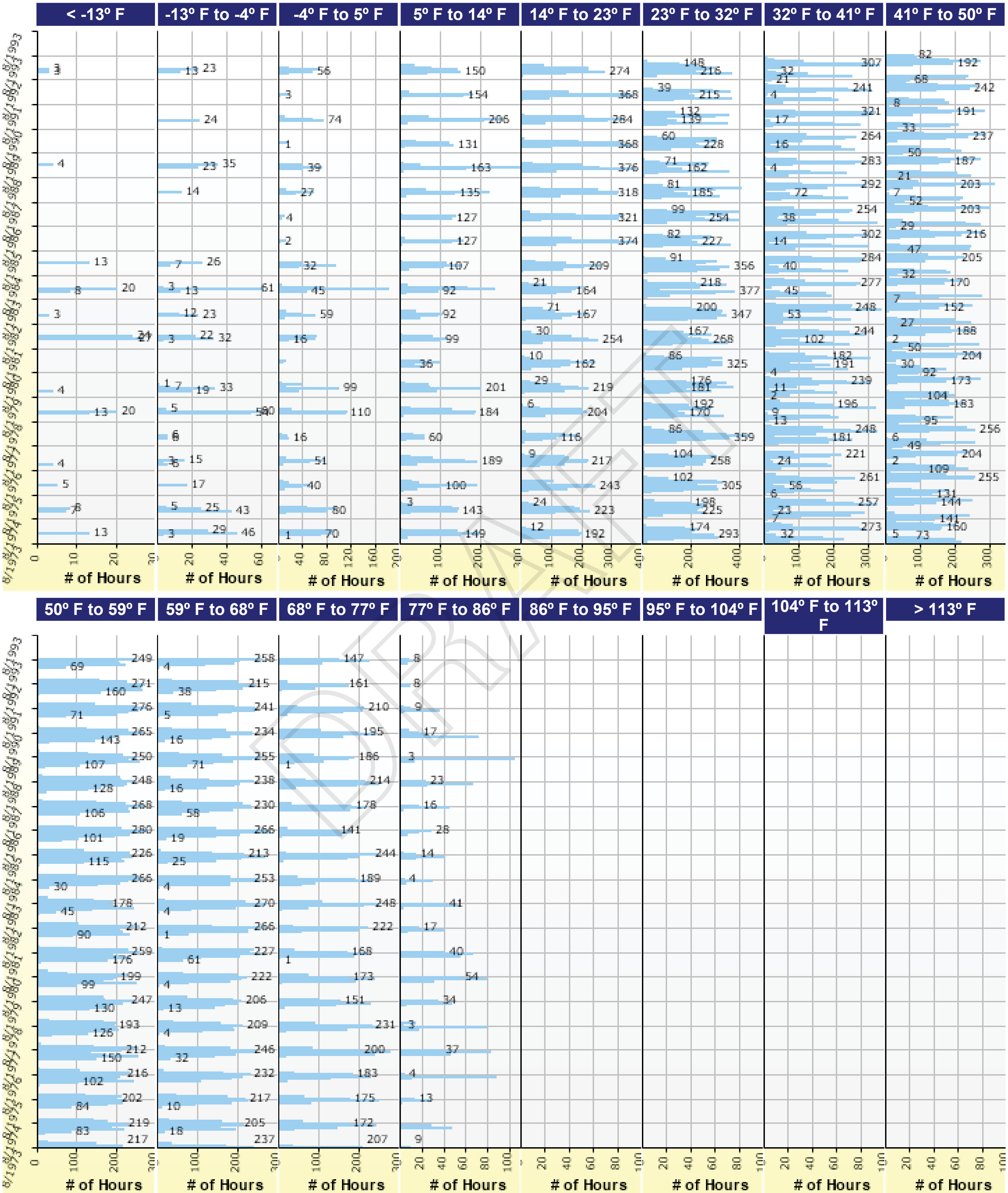




Roundabout_8inHMA_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_8inHMA_20yr.dgpx

Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

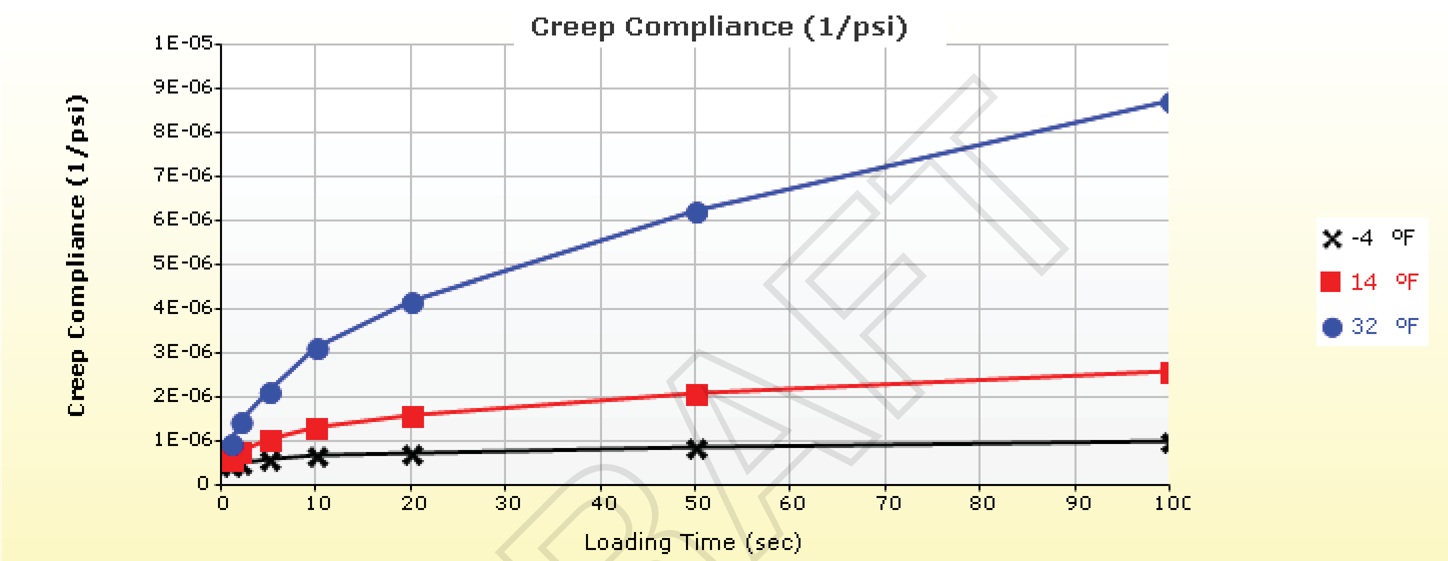
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

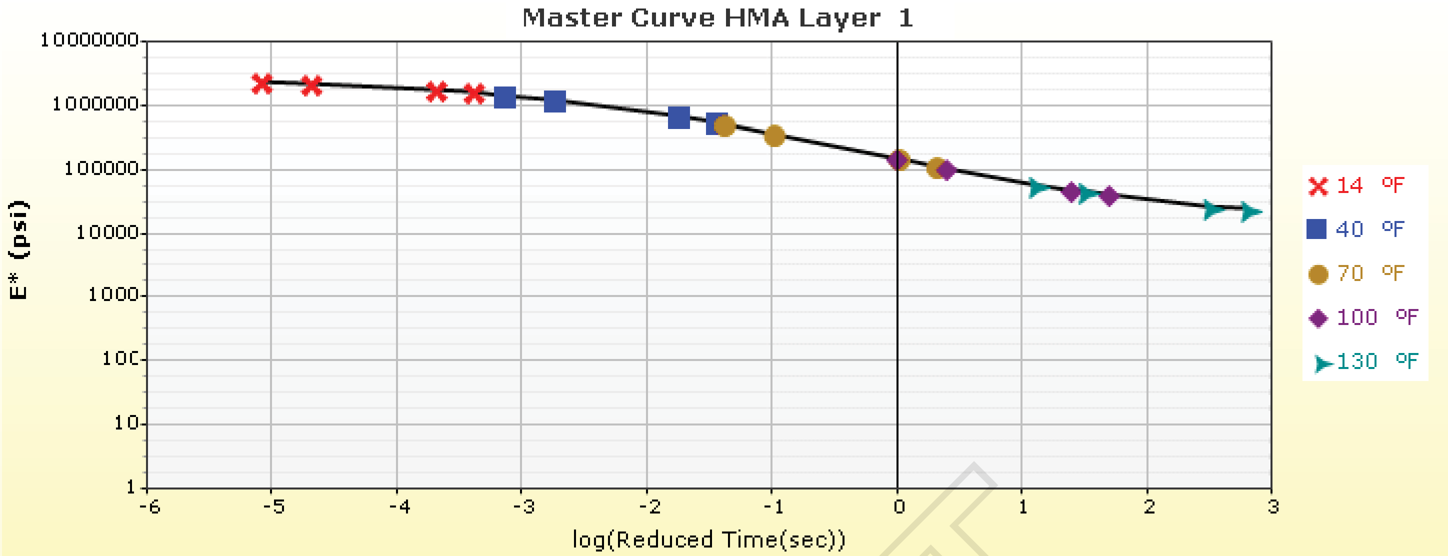
Indirect tensile strength at 14 ºF (psi)	446.00

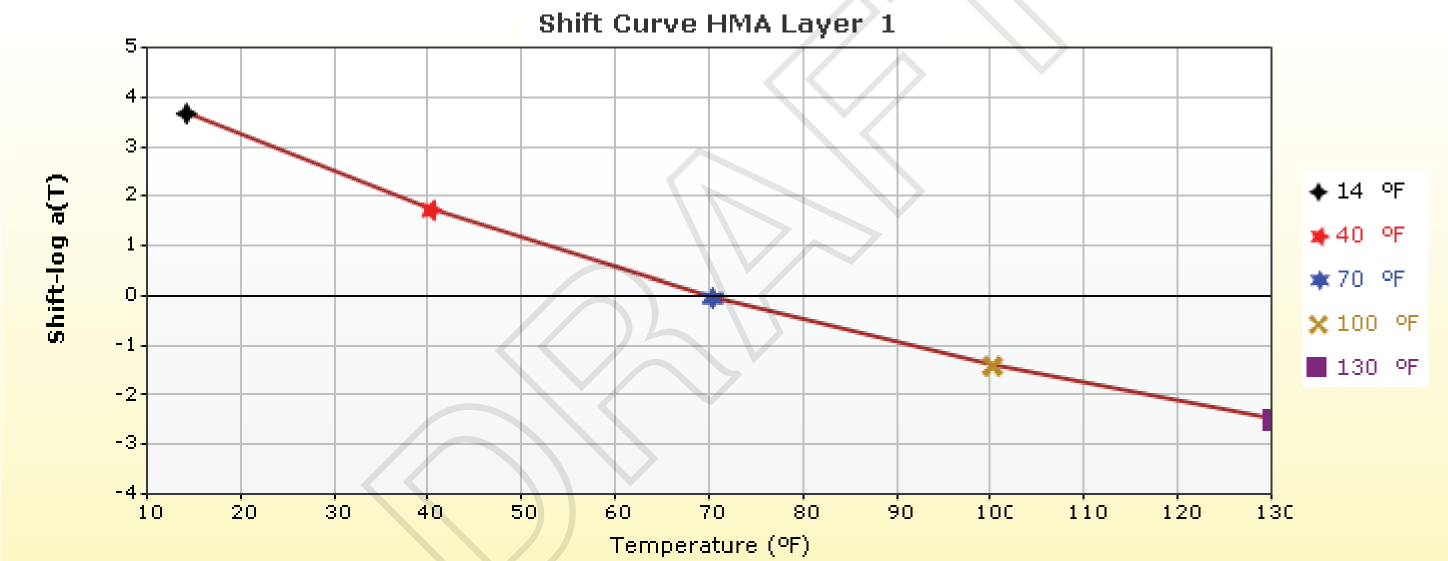
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

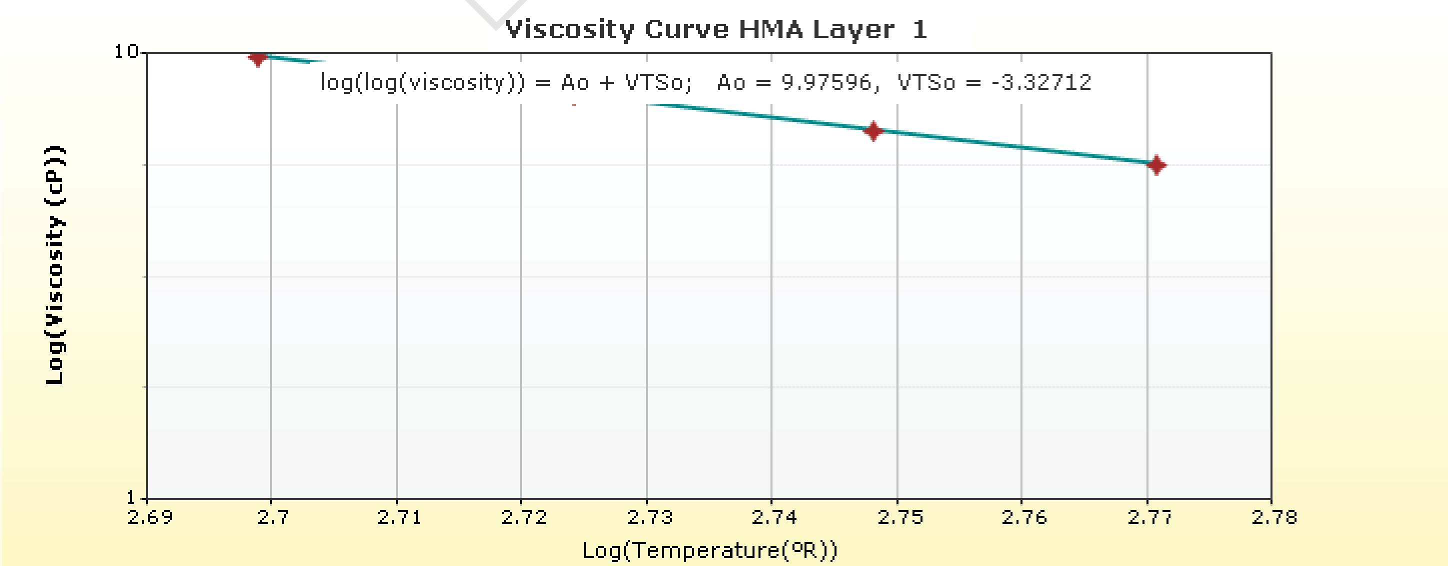
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



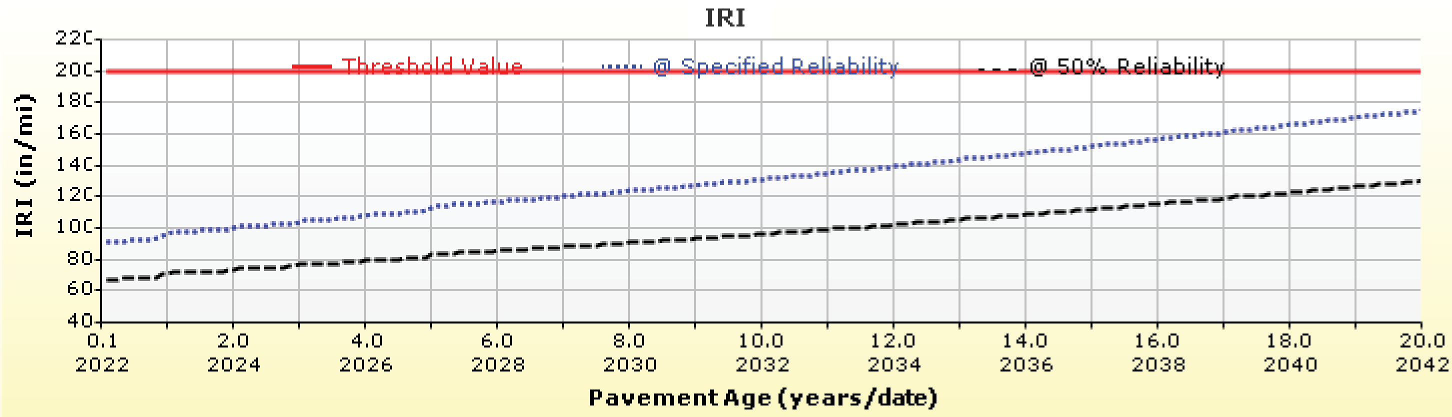
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

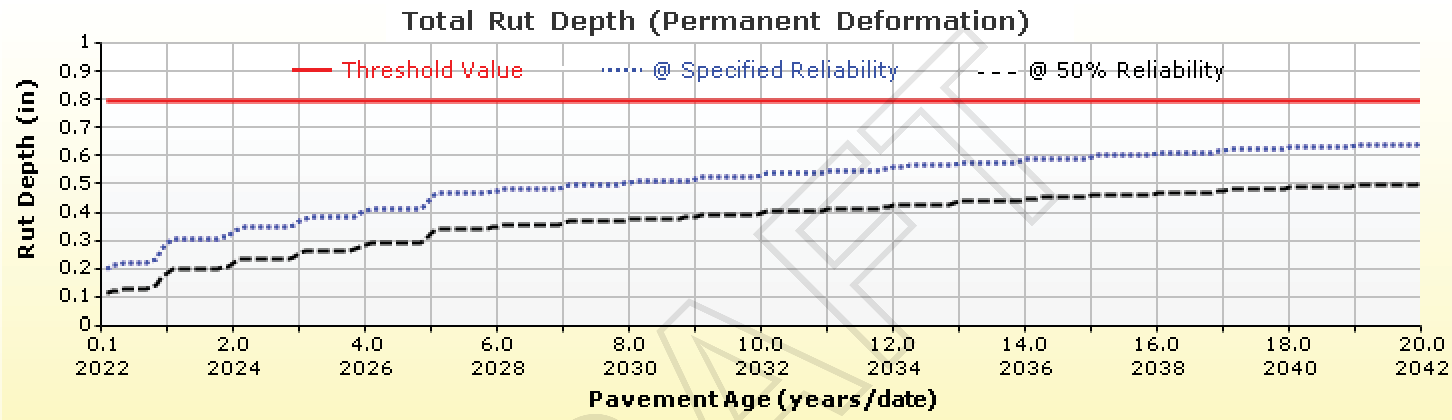


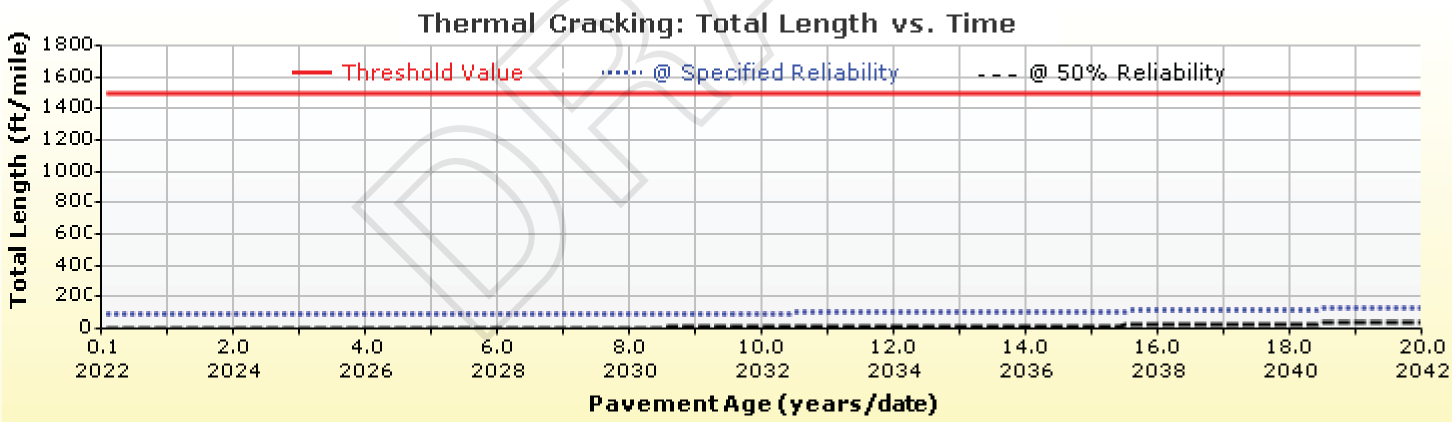




Analysis Output Charts

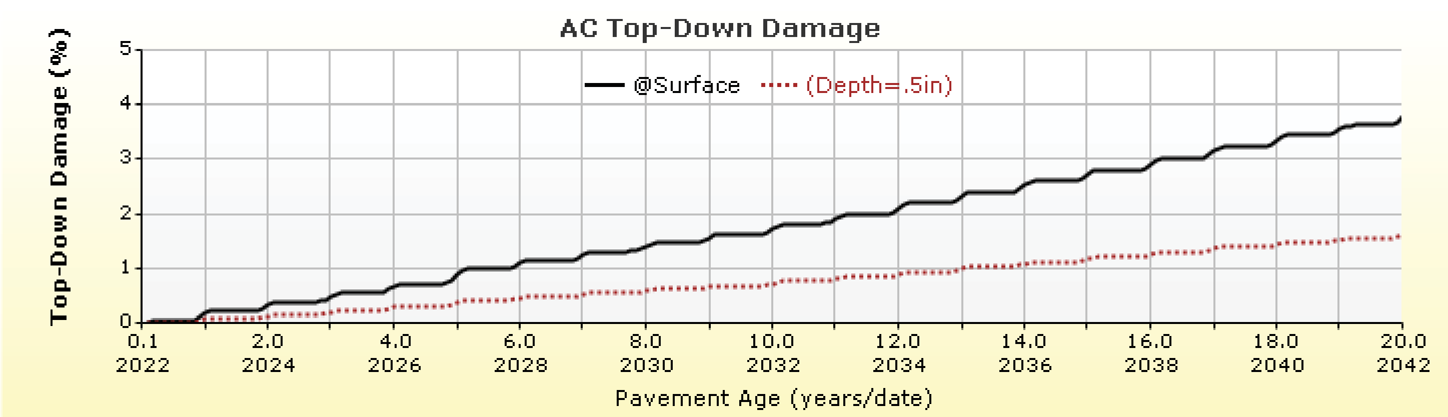


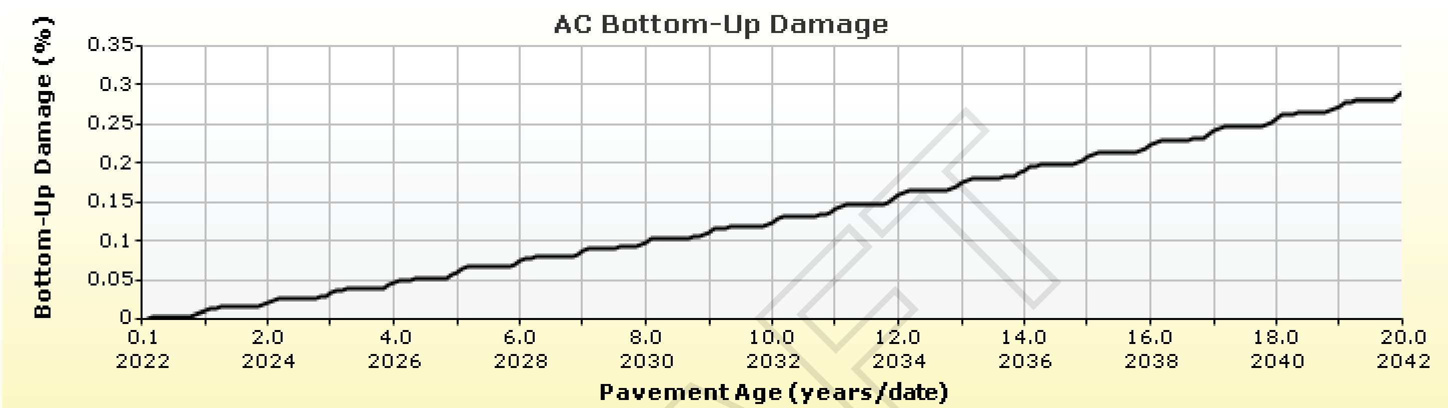


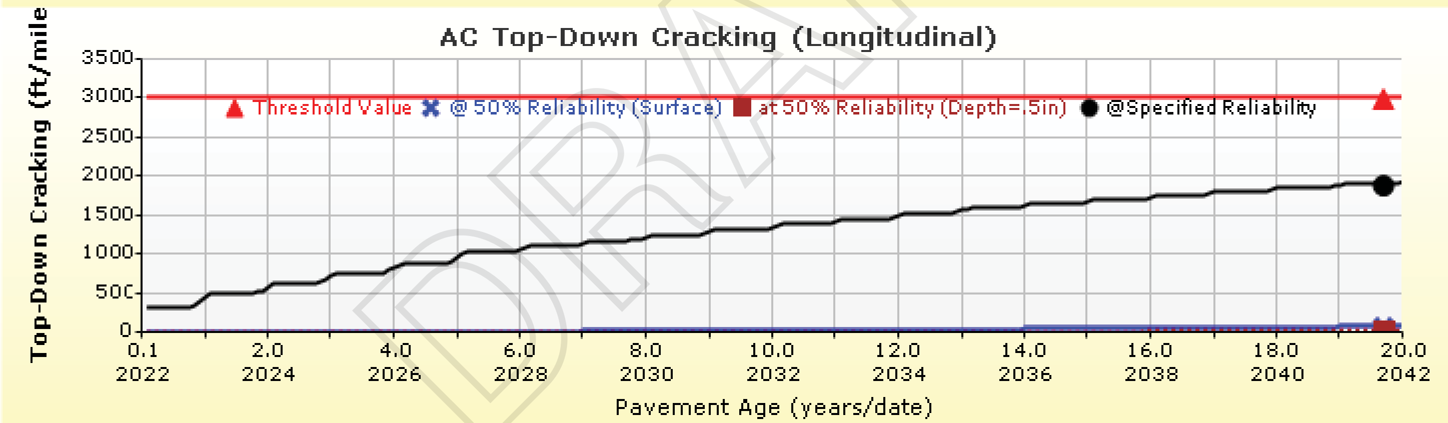


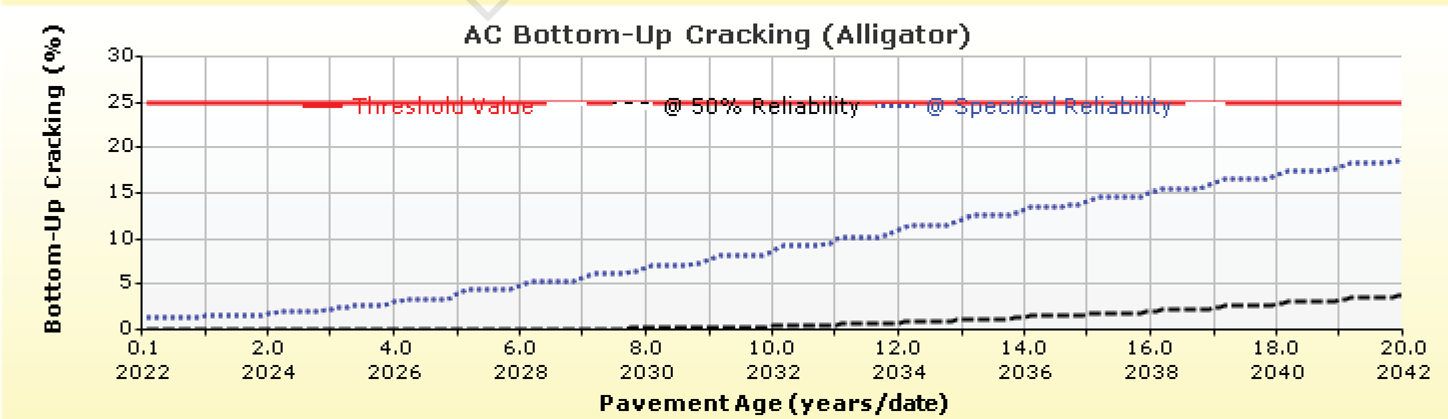
Roundabout_8inHMA_20yr

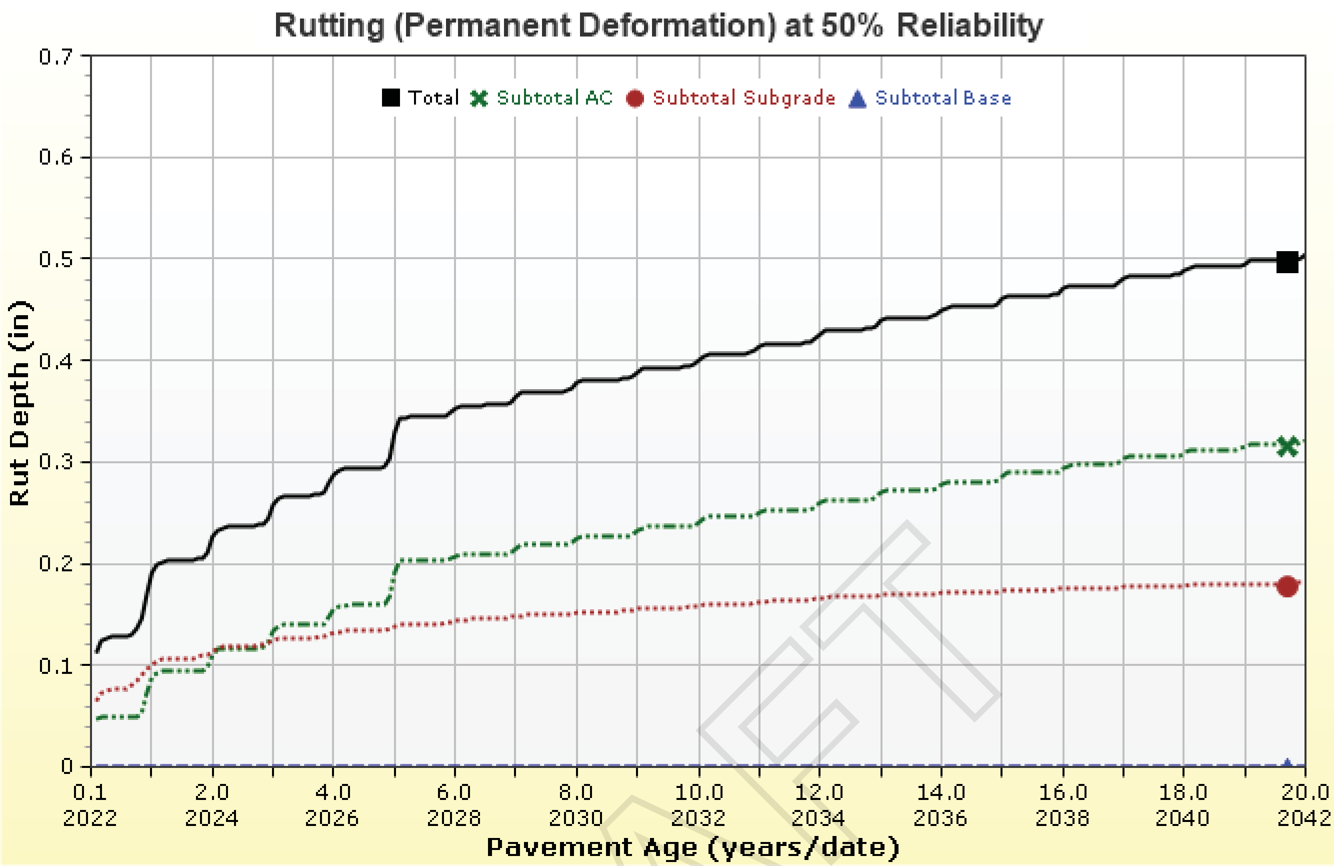
File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\Roundabout_8inHMA_20yr.dgpx



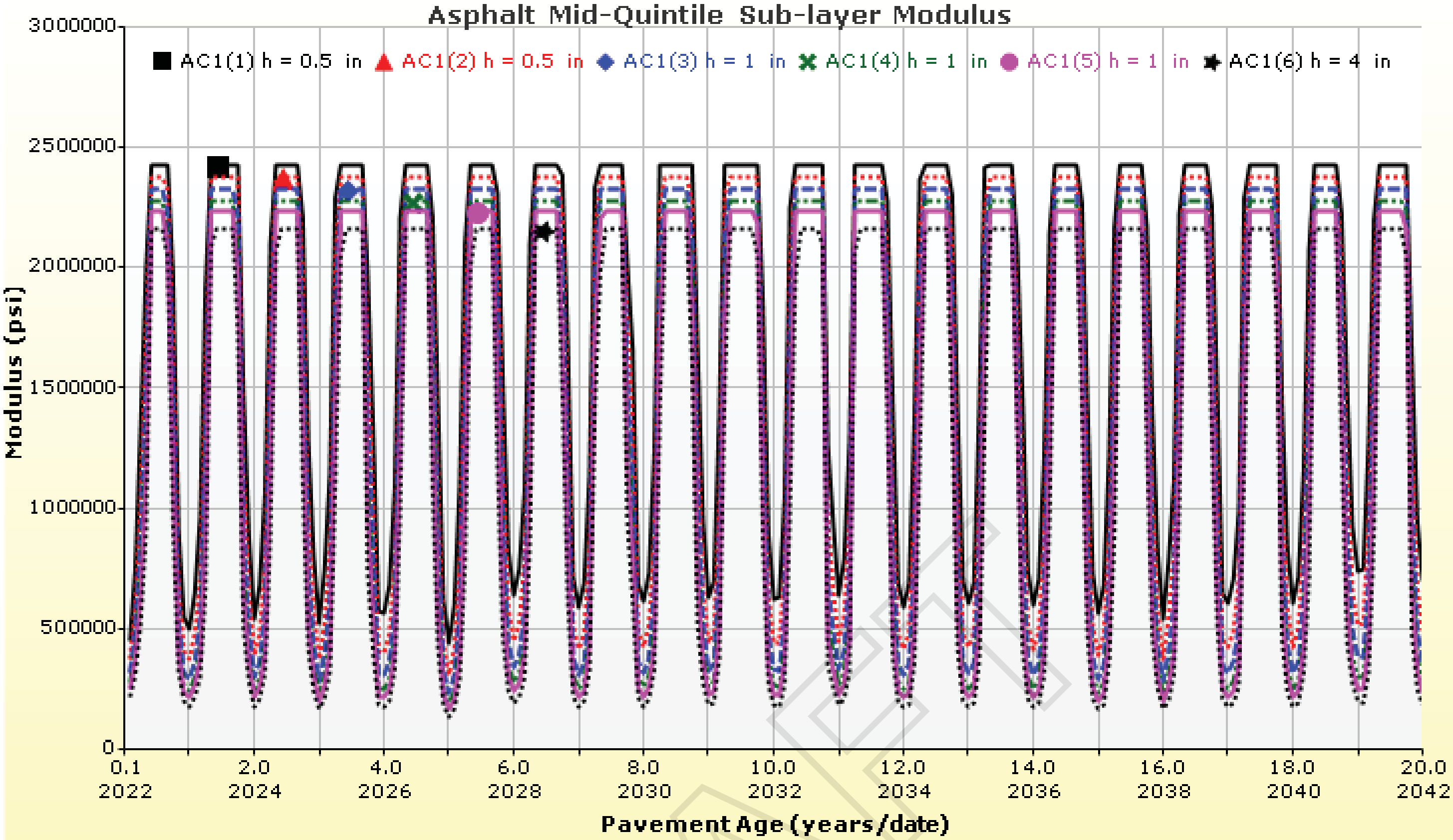




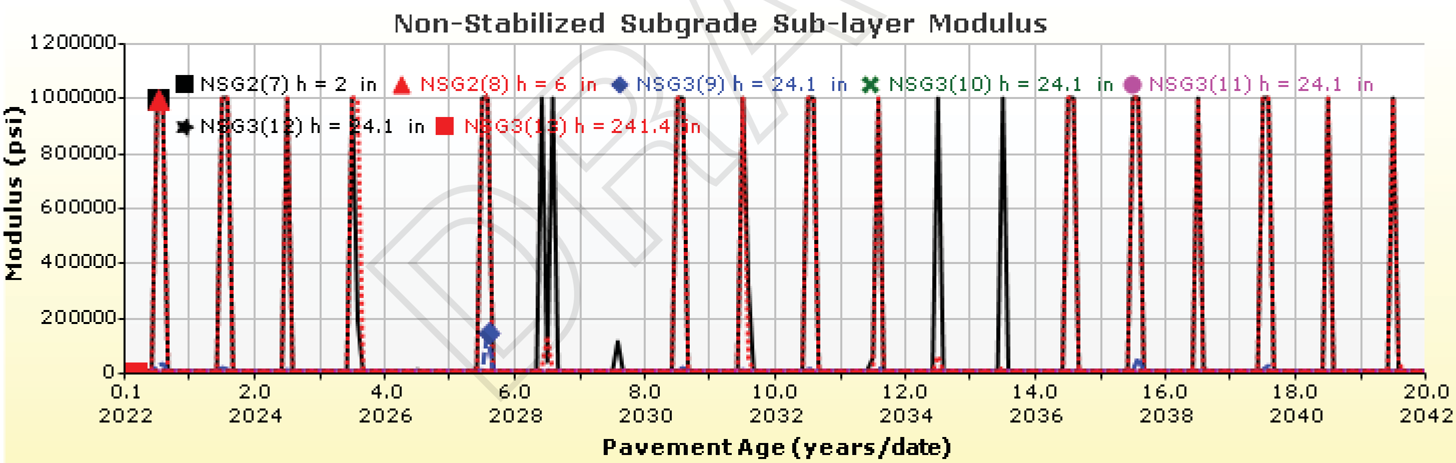




Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



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



Non-Stabilized Subgrade Sub-layer Modulus
NSG2(7) h = 2 in
NSG2(8) h = 6 in
NSG3(9) h = 24.1 in
NSG3(10) h = 24.1 in
NSG3(11) h = 24.1 in
NSG3(12) h = 24.1 in
NSG3(13) h = 241.4 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	8.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	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 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)
10000.0

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 3 Subgrade : A-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

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

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)

ε_r = resilient strain(in/in)

T = layer temperature(°F)

N = number of load repetitions

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

Thermal Fracture

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

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

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

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

k = refression coefficient determined through field calibration

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

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

C = crack depth(in)

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

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

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

A, n = Fracture parameters for the asphalt mixture

E = mixture stiffness

σ_M = Undamaged mixture tensile strength

β_t = Calibration parameter

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

CSM Fatigue

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

N_f = number of repetitions to fatigue cracking

σ_s = Tensile stress(psi)

M_r = modulus of rupture(psi)

k1: 1	k2: 1	Bc1: 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

HillcrestDr_4inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\HillcrestDr_4inHMA_6inABC_20yr.dgpx

Design Inputs

Design Life:	20 years	Base construction:	August, 2022	Climate Data Sources (Lat/Lon)	39.643, -106.918
Design Type:	FLEXIBLE	Pavement construction:	August, 2022		
		Traffic opening:	August, 2022		

Design Structure

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

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

Traffic

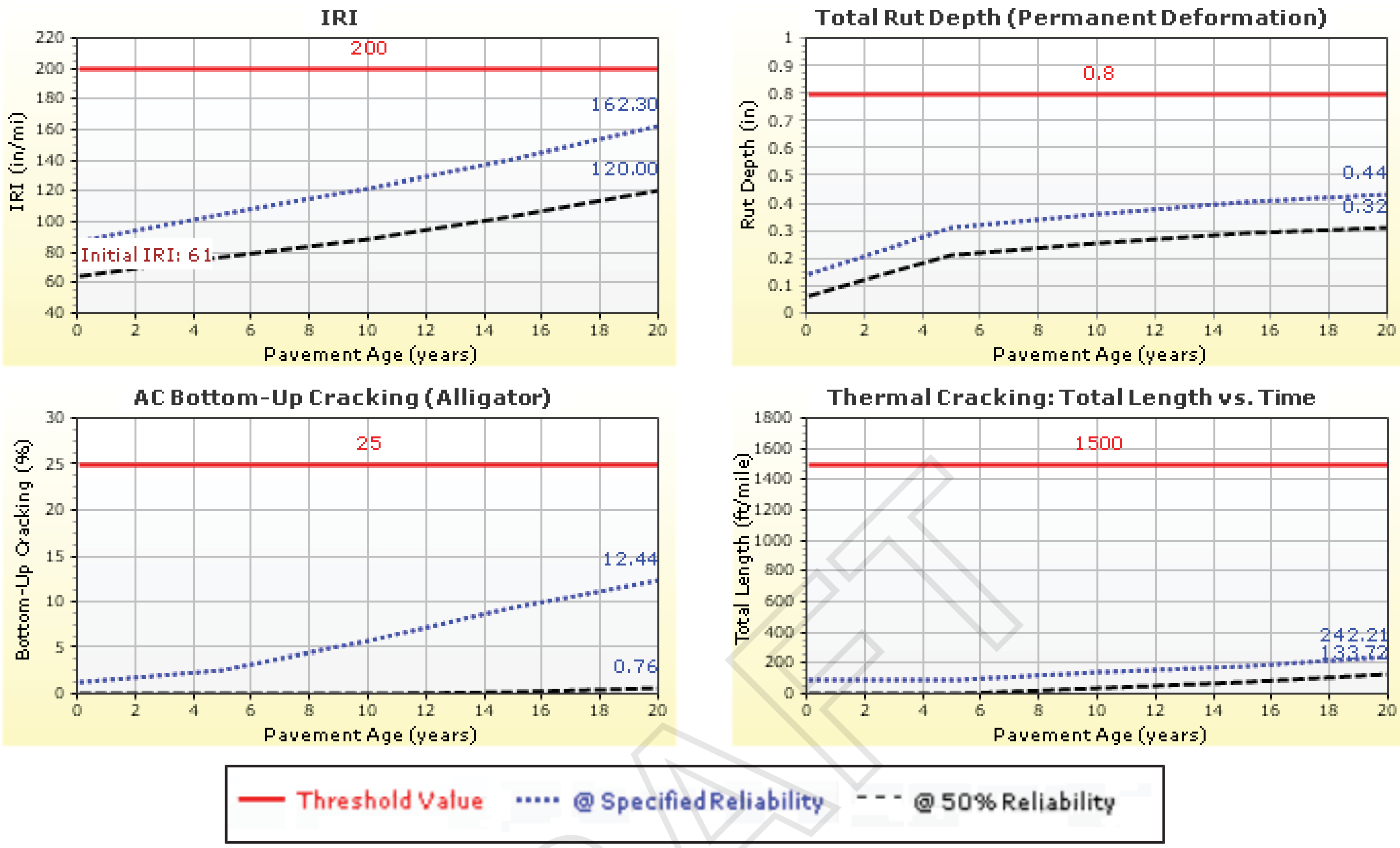
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	78
2032 (10 years)	187,171
2042 (20 years)	415,332

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	162.34	90.00	99.23	Pass
Permanent deformation - total pavement (in)	0.80	0.44	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	12.44	90.00	99.61	Pass
AC thermal cracking (ft/mile)	1500.00	242.21	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	815.77	90.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.26	90.00	100.00	Pass

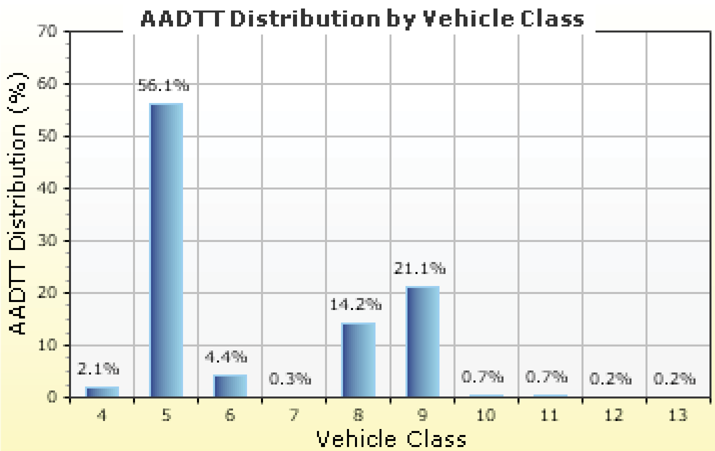
Distress Charts

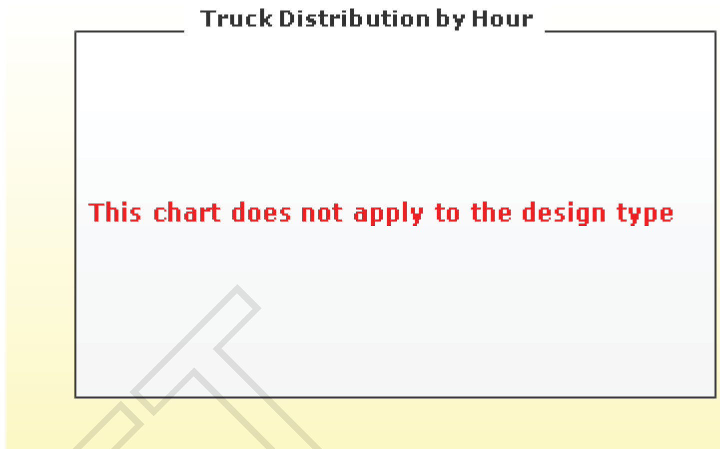


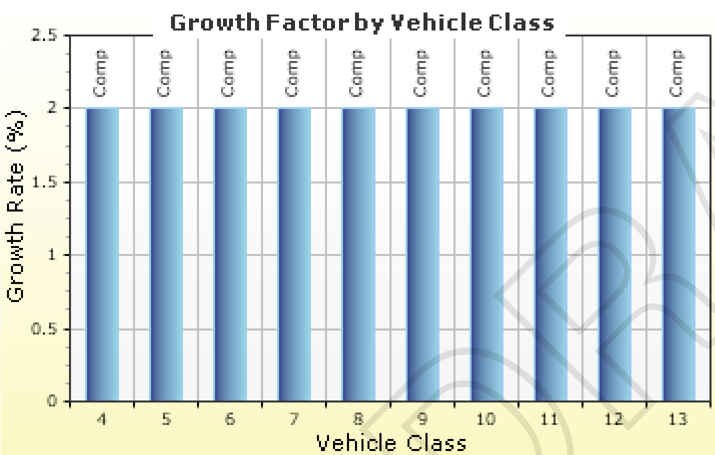
Traffic Inputs

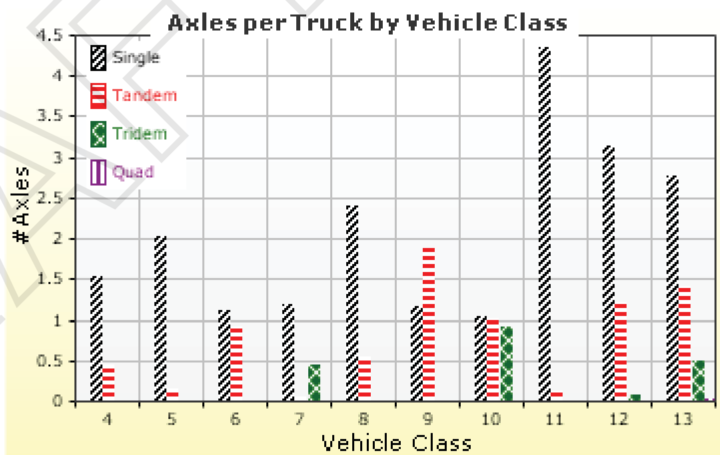
Graphical Representation of Traffic Inputs

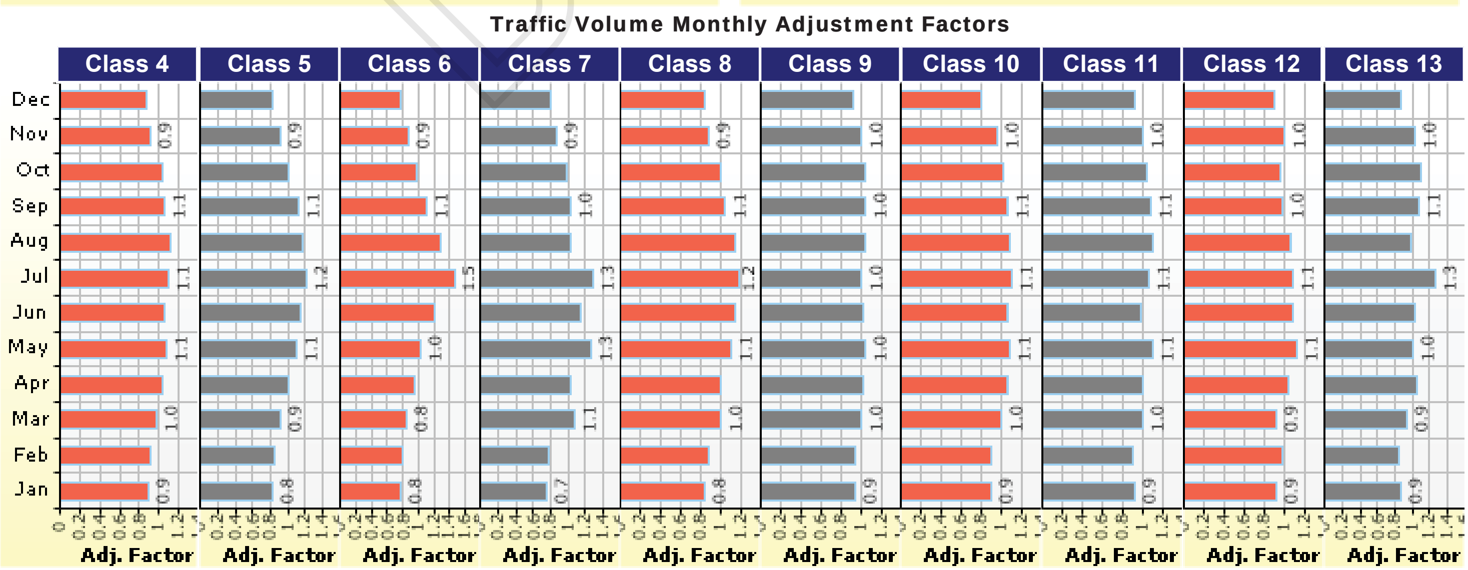
Initial two-way AADTT:	78	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0











Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

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

Truck Distribution by Hour does not apply

Axle Configuration

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

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

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

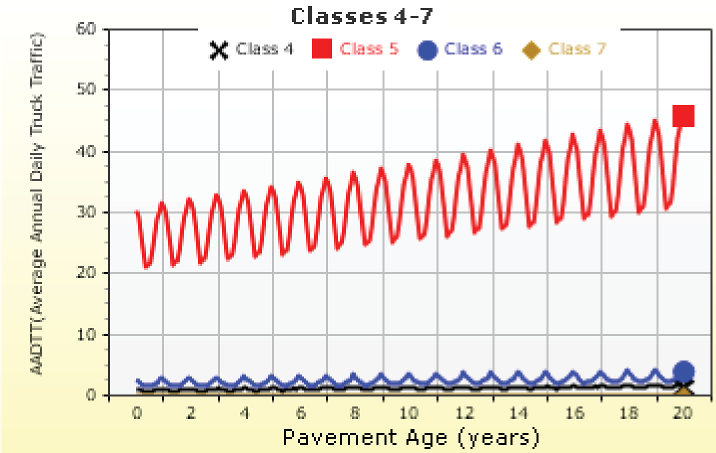
Wheelbase does not apply

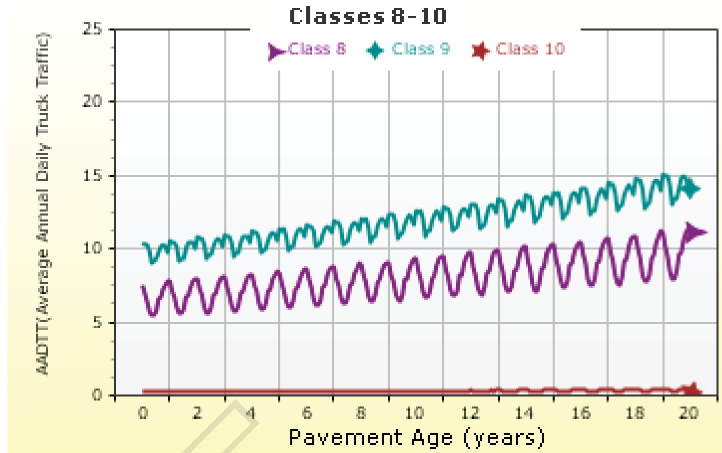
Number of Axles per Truck

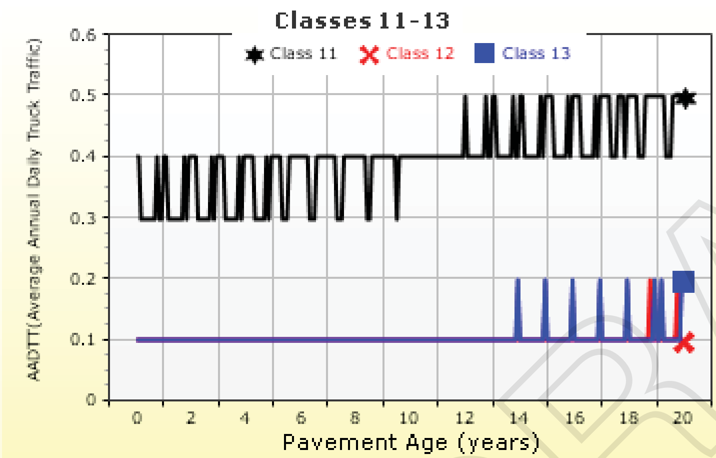
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

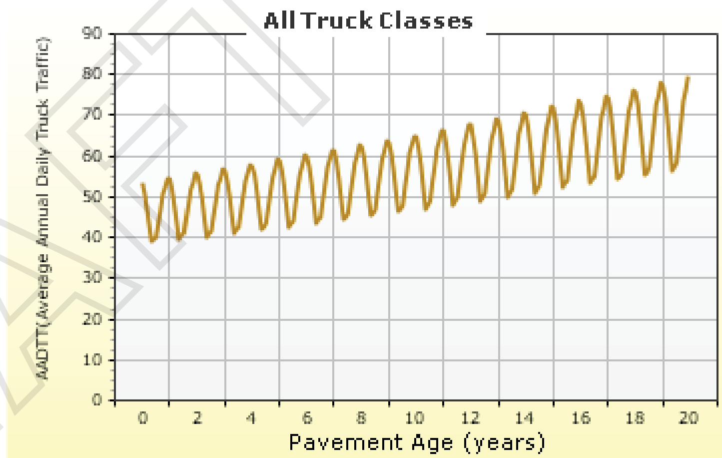
AADTT (Average Annual Daily Truck Traffic) Growth

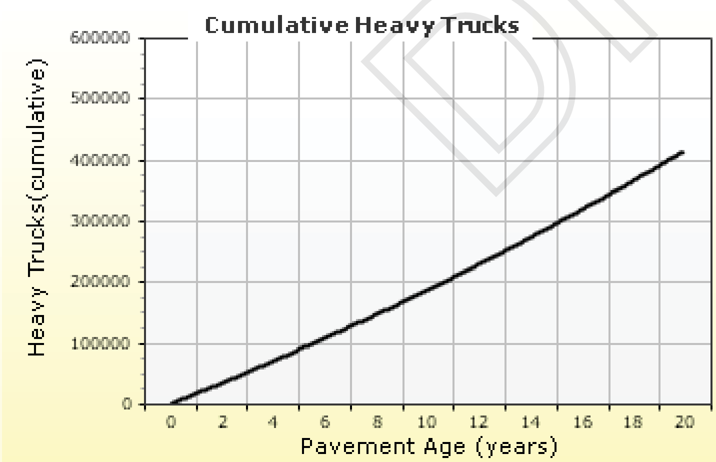
*** Traffic cap is not enforced**







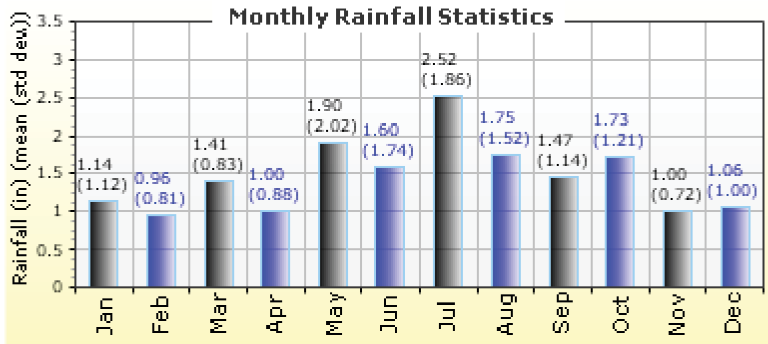




Climate Inputs

Climate Data Sources:

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

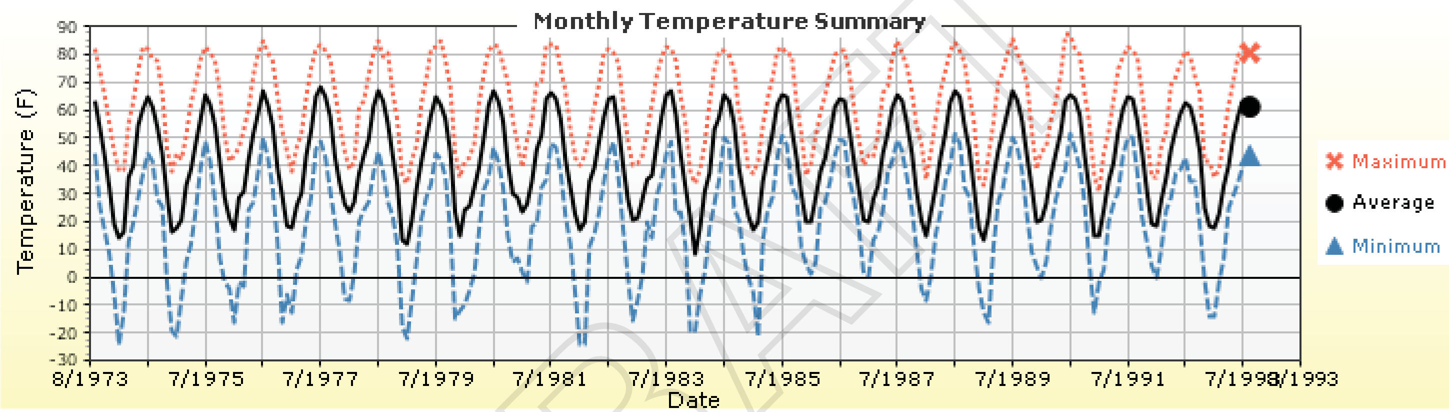


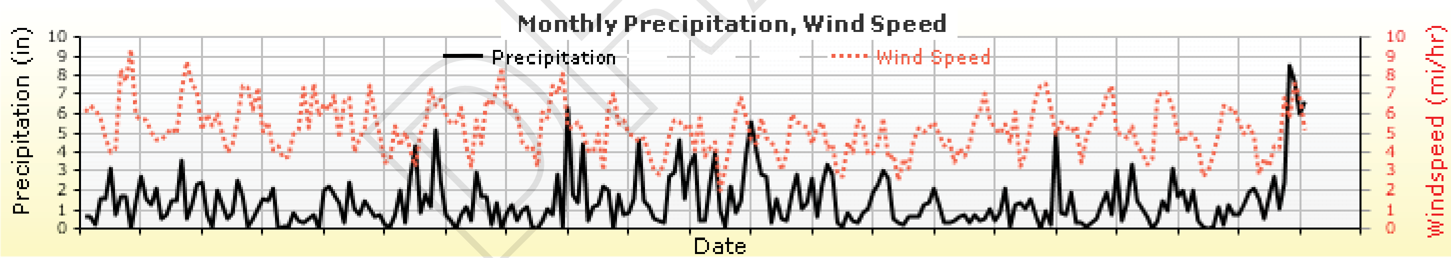
Annual Statistics:

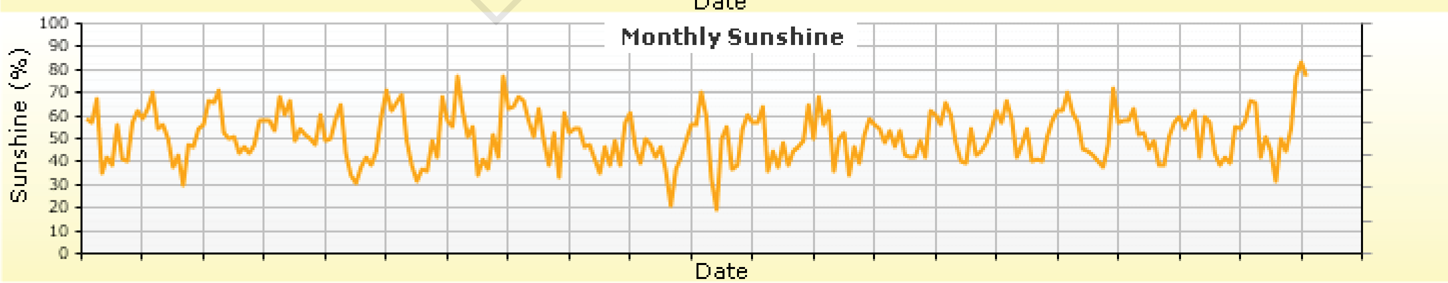
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

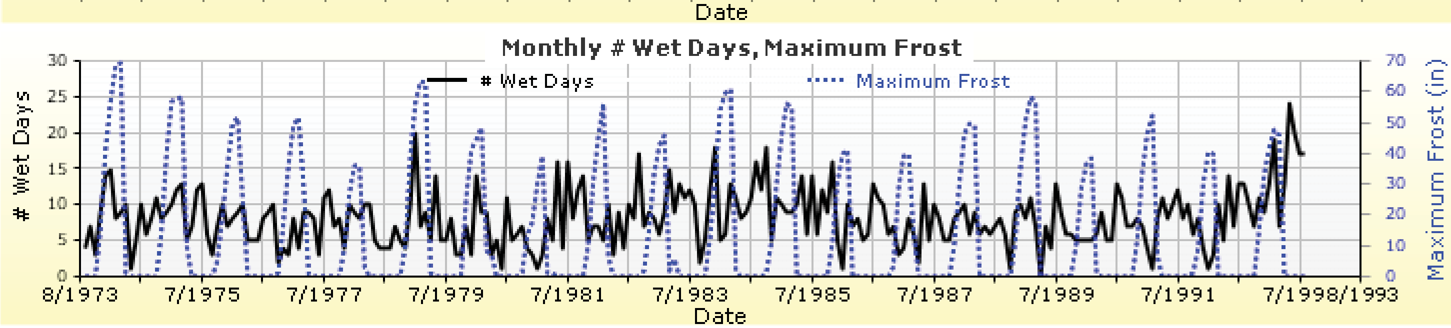
Water table depth (ft)	10.00

Monthly Climate Summary:

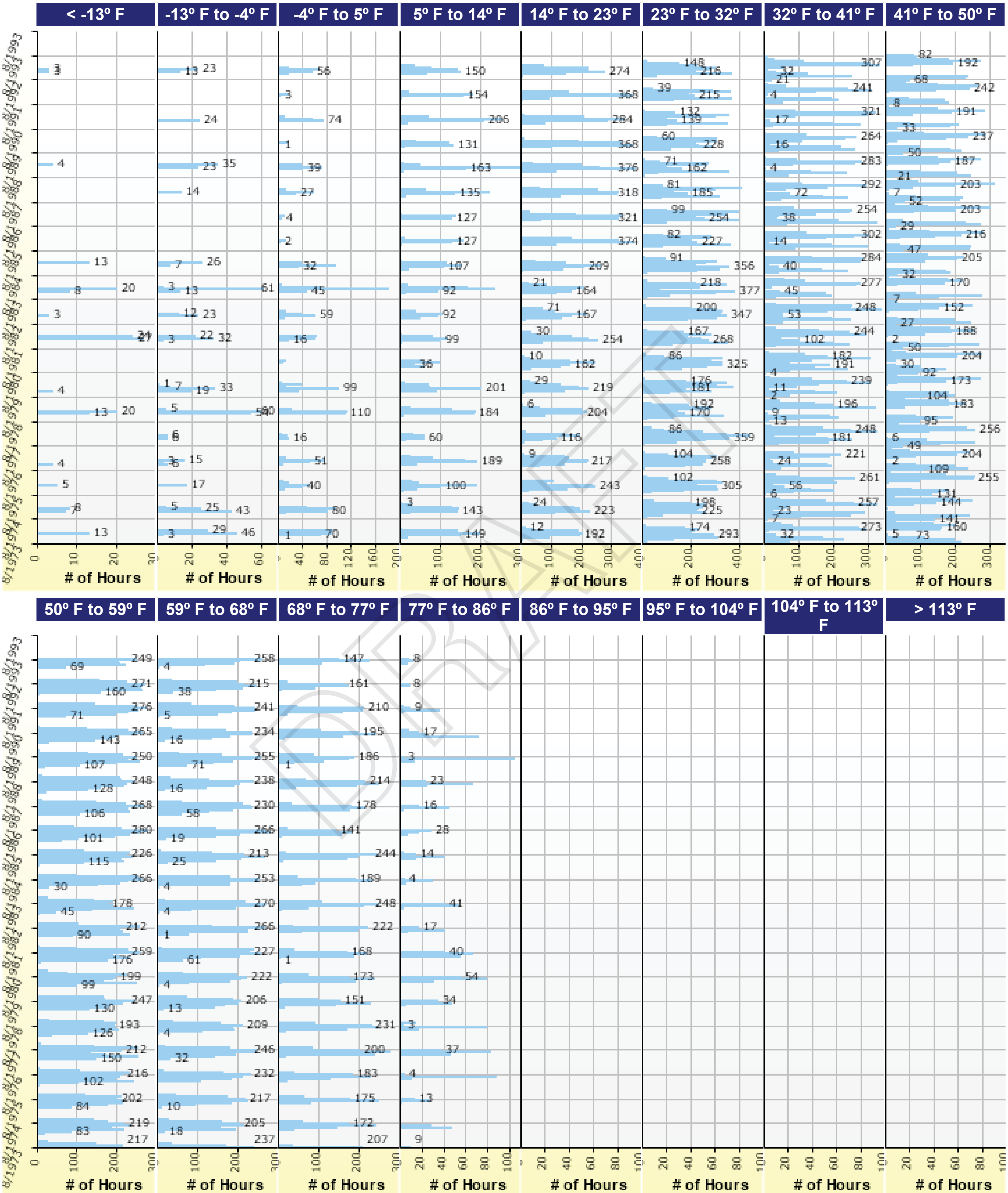








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

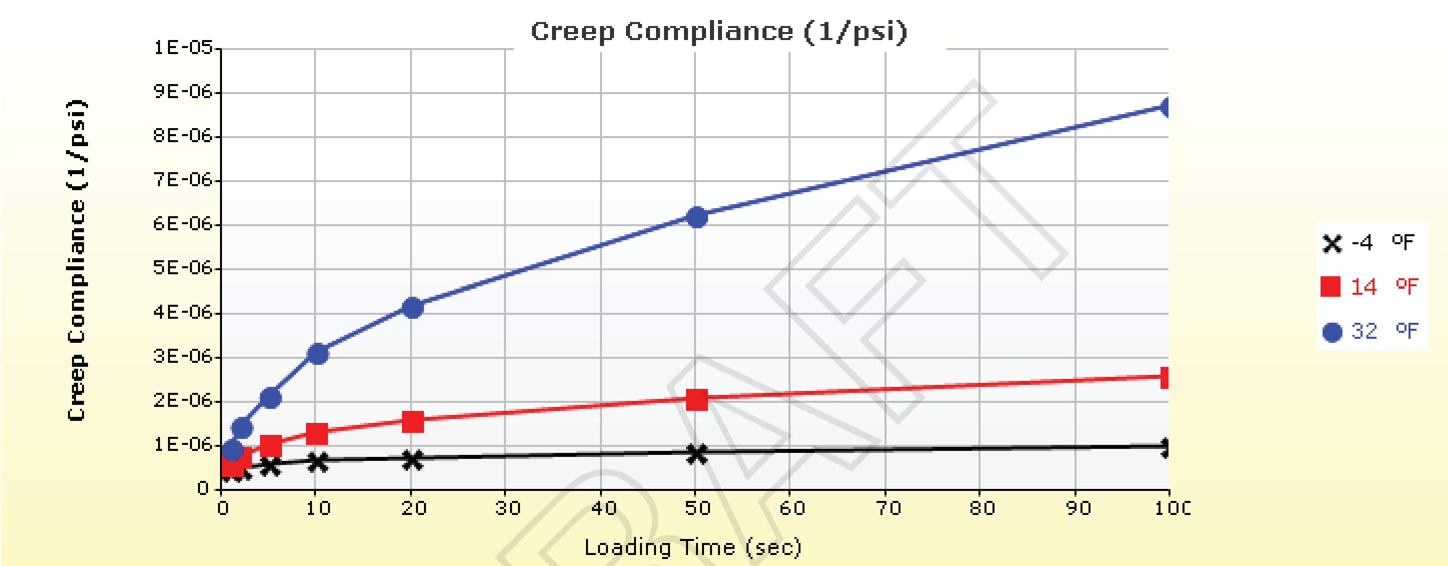
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Non-stabilized Base : A-1-a	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 4 Subgrade : A-2-6	Subgrade (5)	-

Thermal Cracking (Input Level: 1)

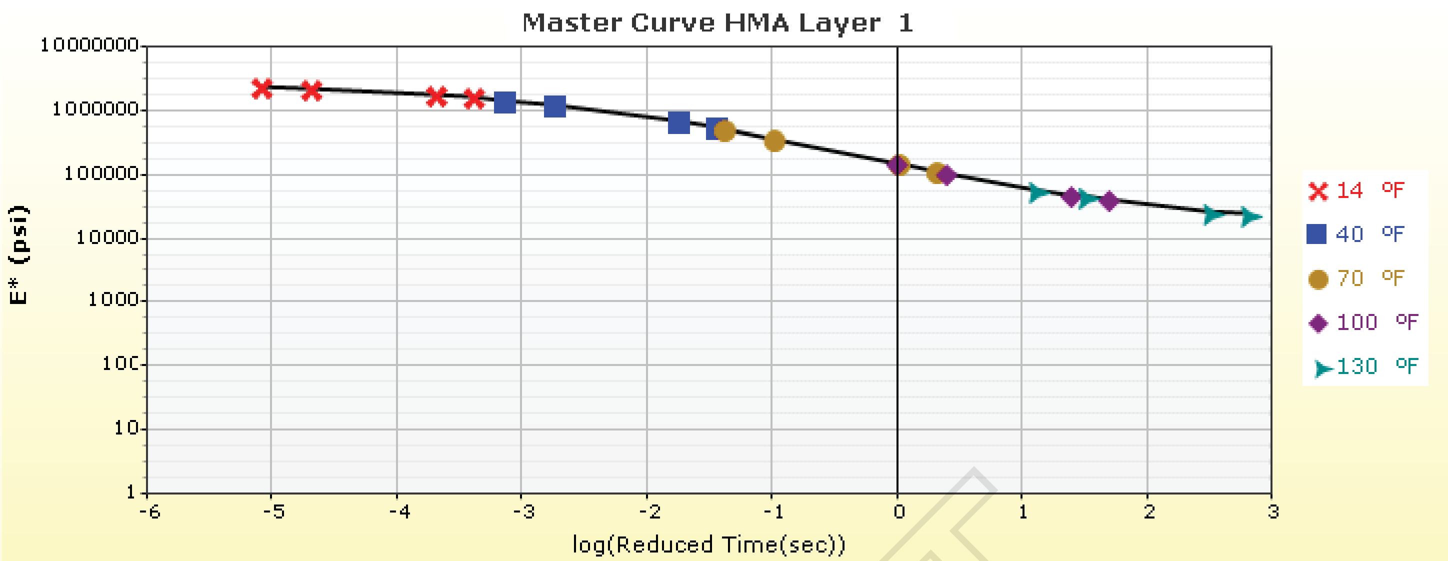
Indirect tensile strength at 14 ºF (psi)	446.00

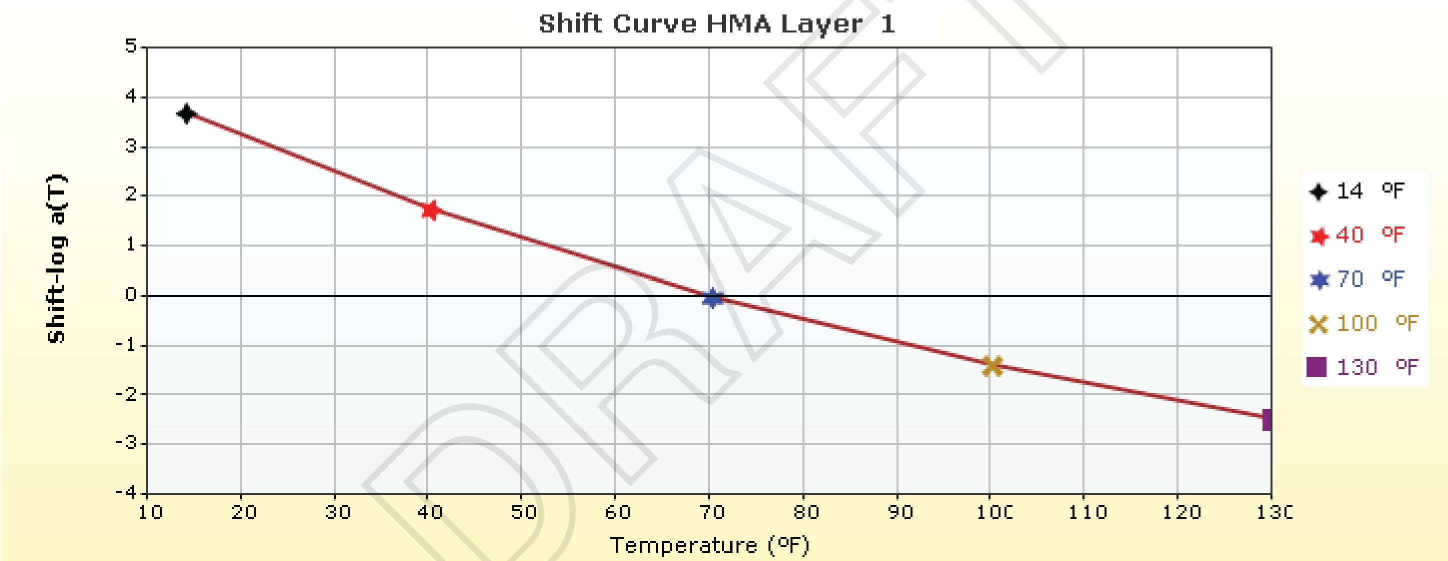
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

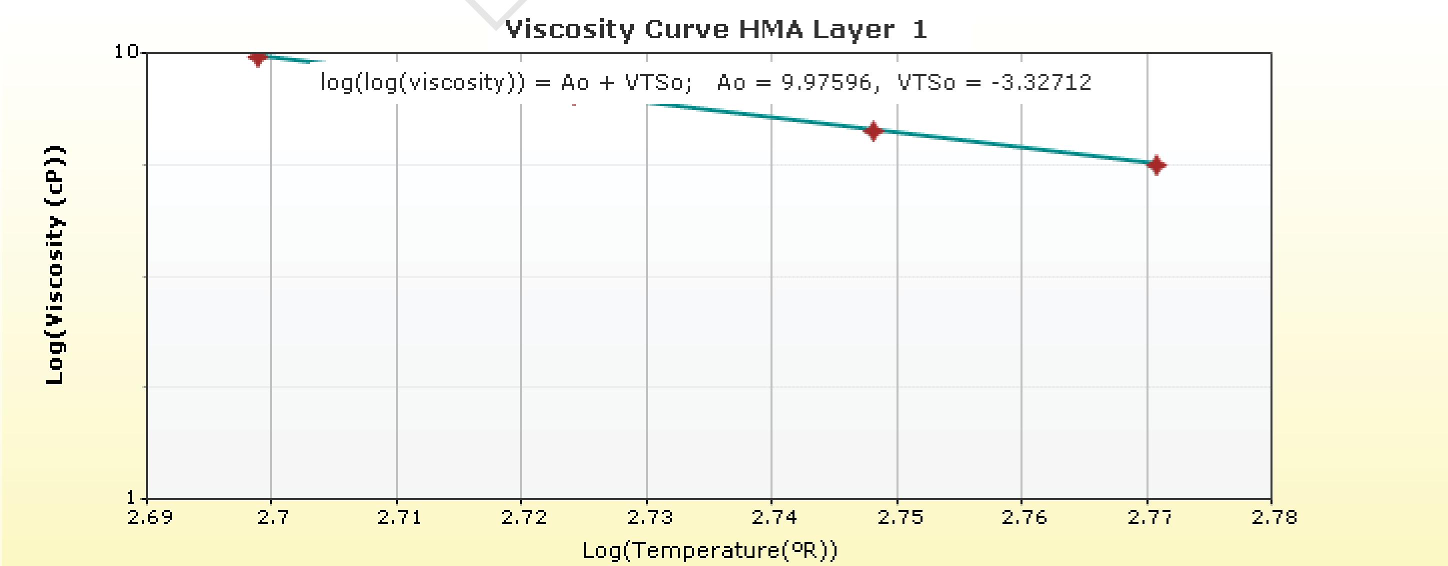
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



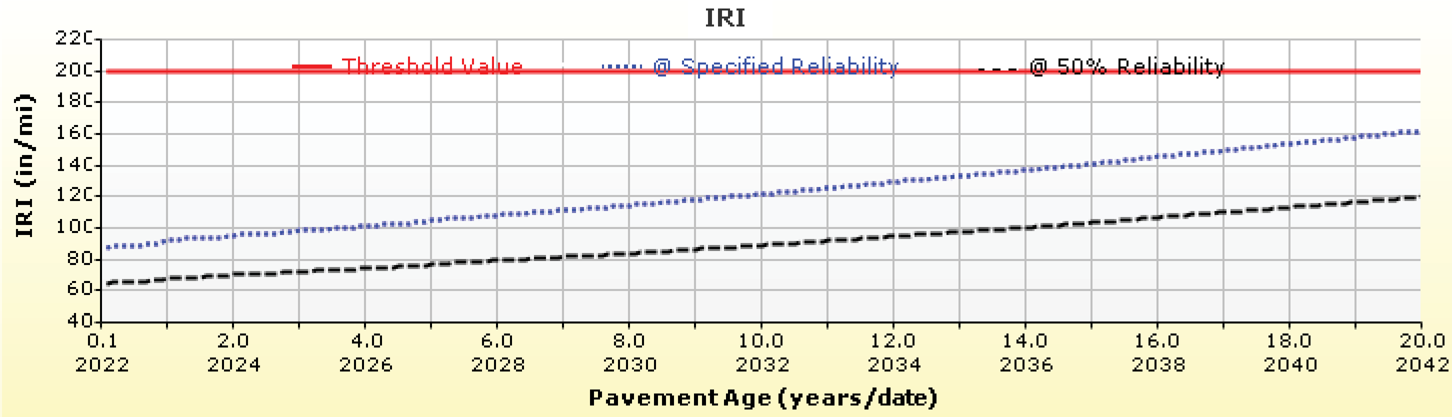
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

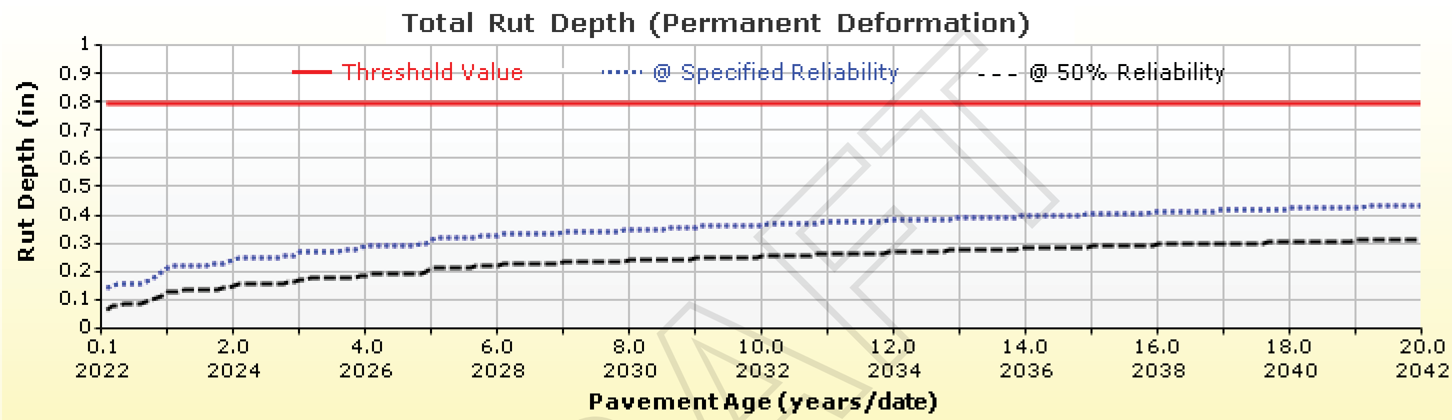


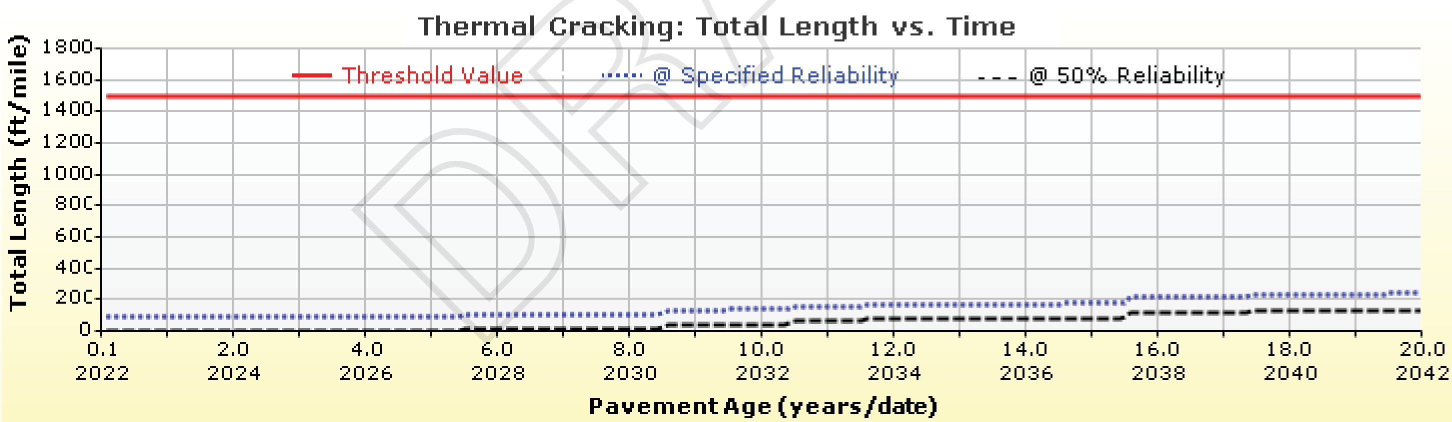


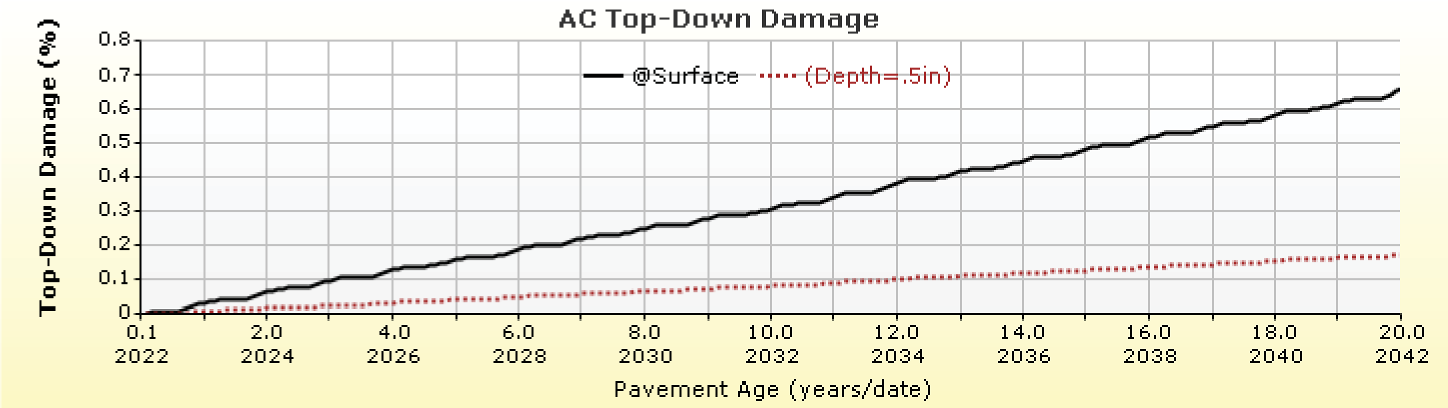


Analysis Output Charts

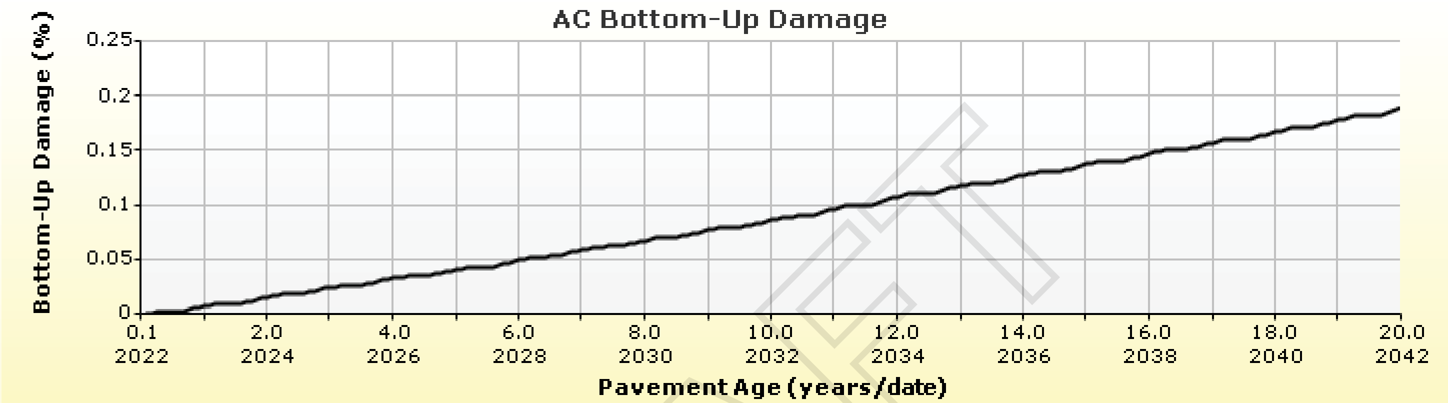




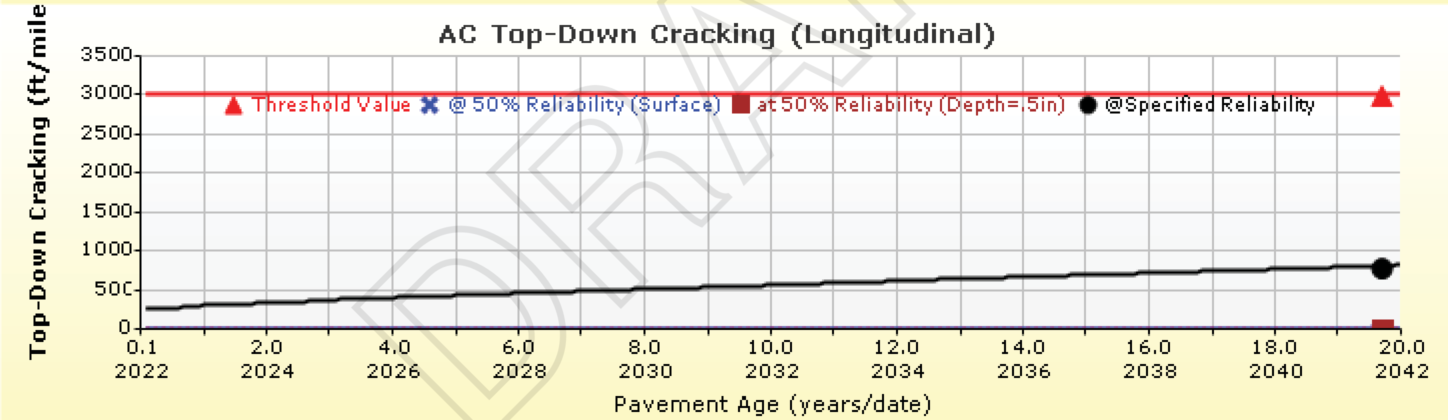




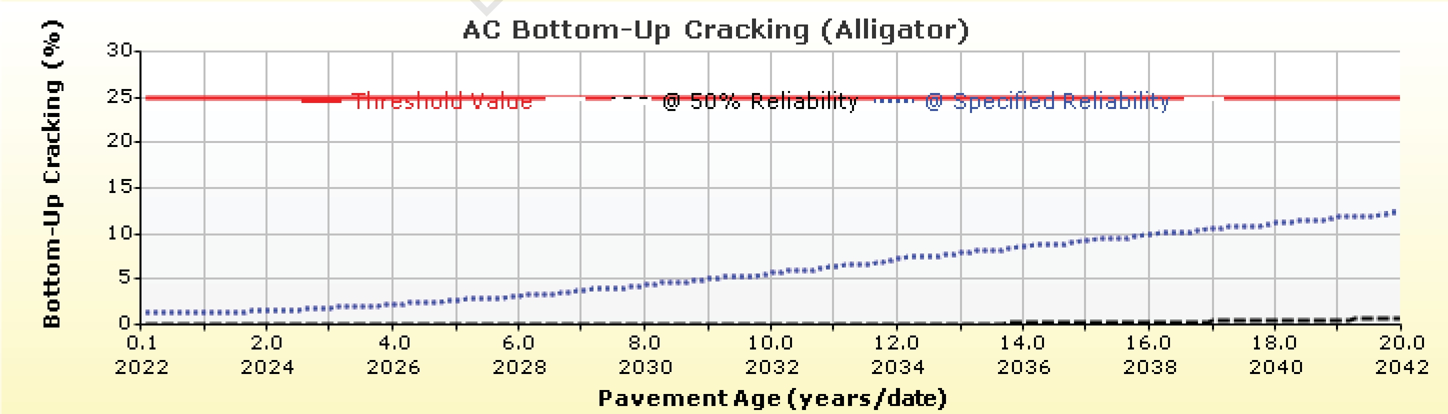
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



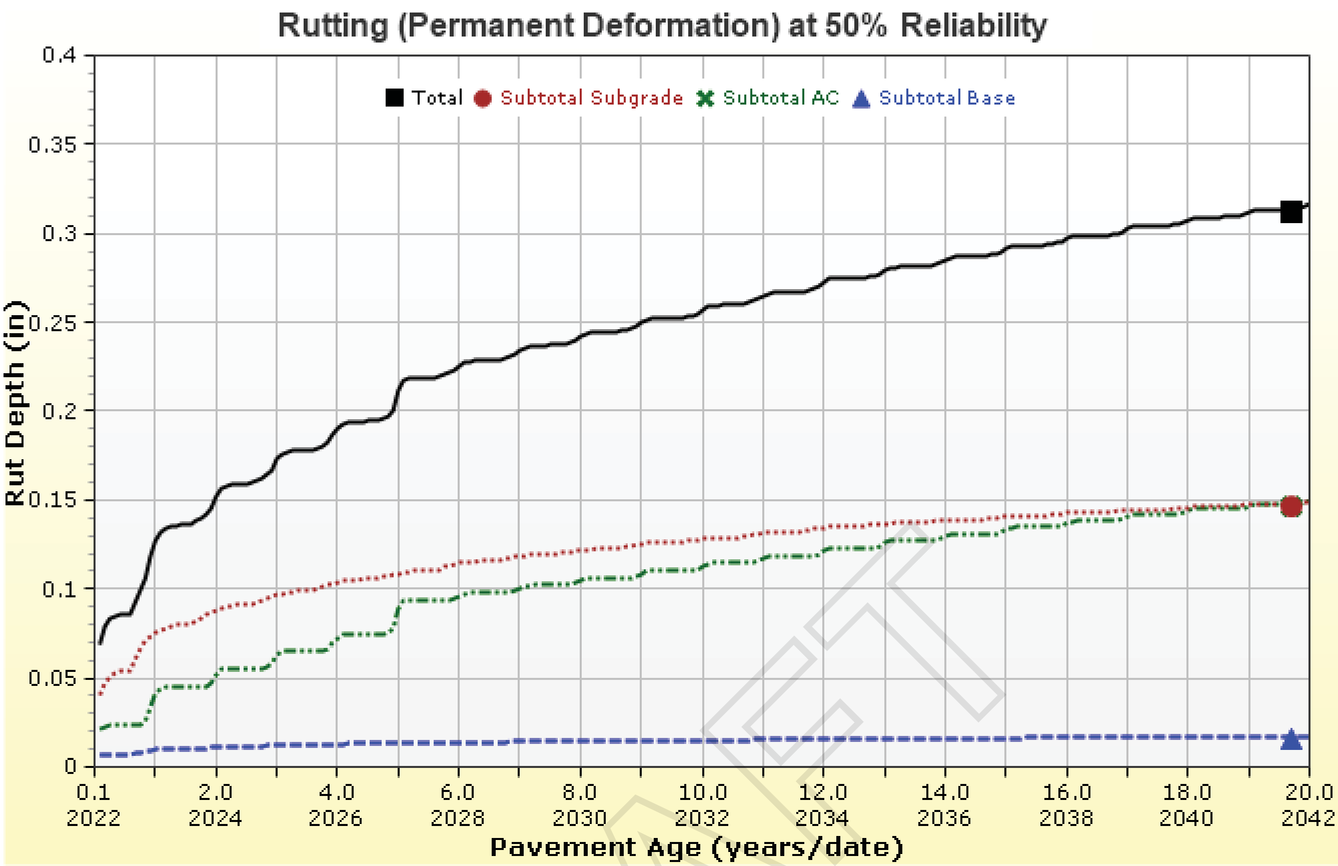
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.25
0.2
0.15
0.1
0.05
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)



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

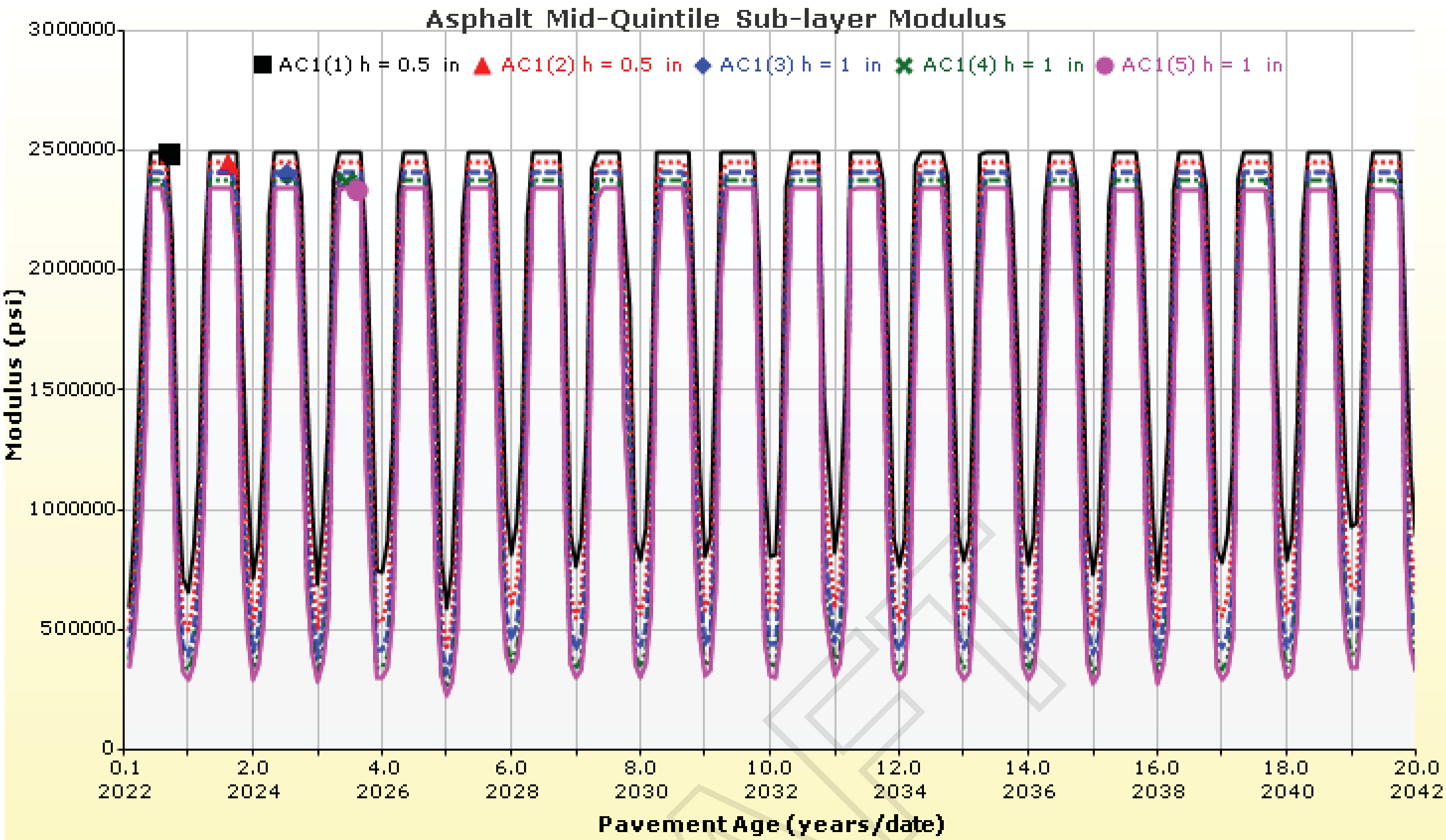


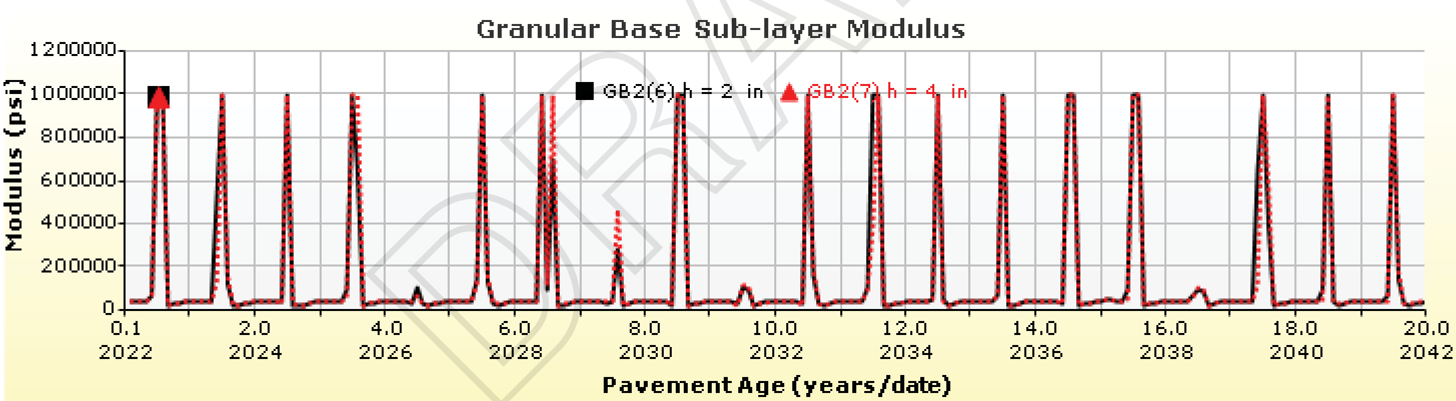
AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
2022 2024 2026 2028 2030 2032 2034 2036 2038 2040 2042
Pavement Age (years/date)

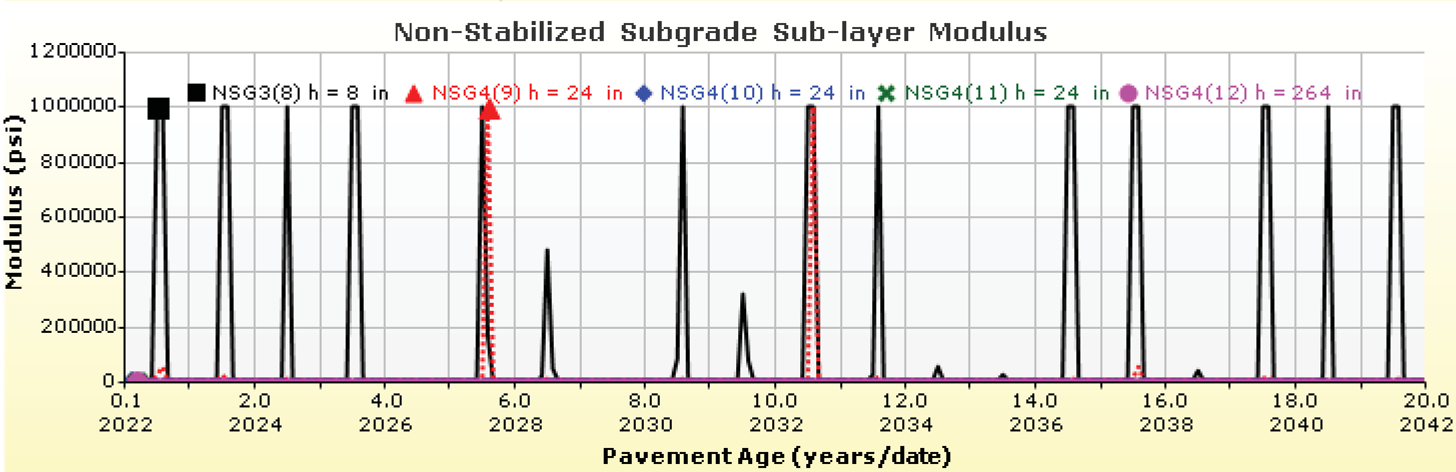

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rut Depth (in)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.1
2022
2.0
2024
4.0
2026
6.0
2028
8.0
2030
10.0
2032
12.0
2034
14.0
2036
16.0
2038
18.0
2040
20.0
2042
Pavement Age (years/date)

HillcrestDr_4inHMA_6inABC_20yr

File Name: C:\daa doc\PavM-E\US6-Edwards(101726)\HillcrestDr_4inHMA_6inABC_20yr.dgpx







Layer Information

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

Asphalt		
Thickness (in)	4.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	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 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)
27000.0

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-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)
10000.0

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-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.281
	Bf1: 130.3674
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.217799

AC Rutting

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

Where:

H_{ac} = total AC thickness(in)

ε_p = plastic strain(in/in)
ε_r = resilient strain(in/in)
T = layer temperature(°F)
N = number of load repetitions

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

Thermal Fracture

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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

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	5.0
Subgrade	A-2-6	8.0
Subgrade	A-2-6	Semi-infinite

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

Traffic

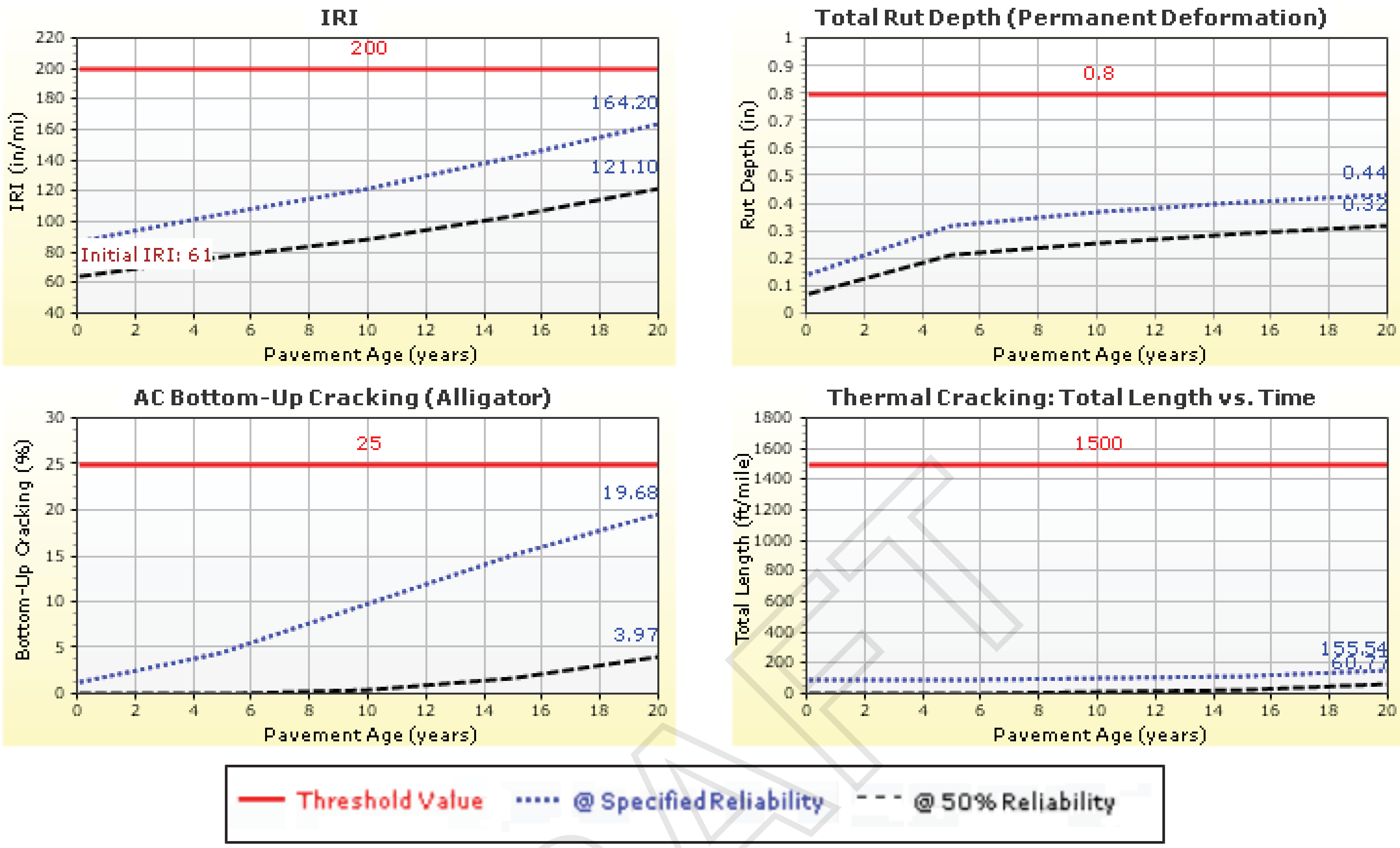
Age (year)	Heavy Trucks (cumulative)
2022 (initial)	78
2032 (10 years)	187,171
2042 (20 years)	415,332

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	164.17	90.00	99.06	Pass
Permanent deformation - total pavement (in)	0.80	0.44	90.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	19.68	90.00	95.69	Pass
AC thermal cracking (ft/mile)	1500.00	155.54	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	1831.02	90.00	98.33	Pass
Permanent deformation - AC only (in)	0.65	0.26	90.00	100.00	Pass

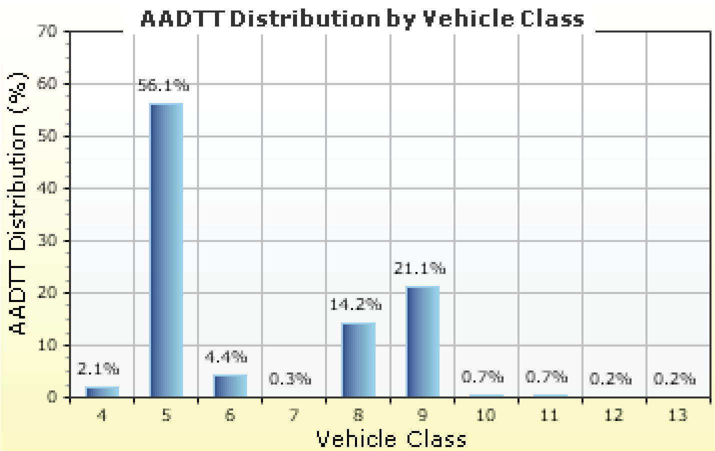
Distress Charts

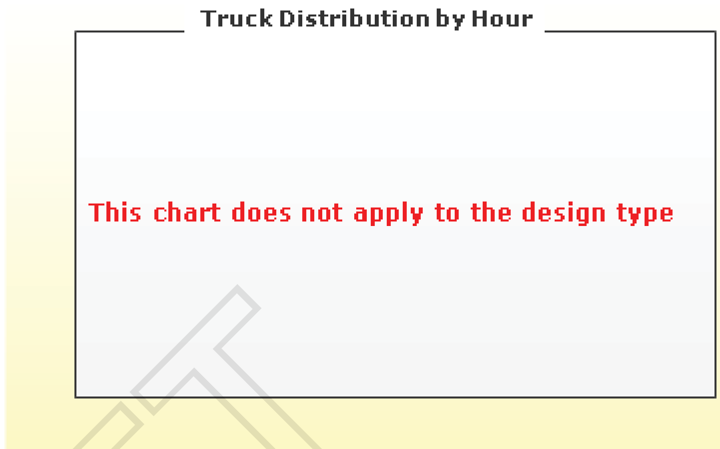


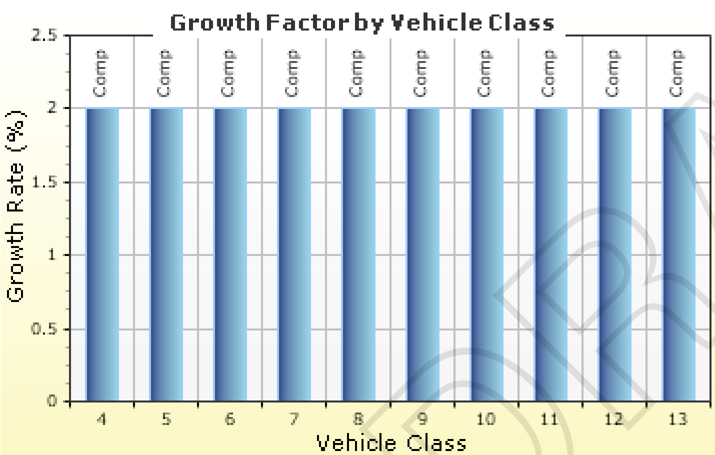
Traffic Inputs

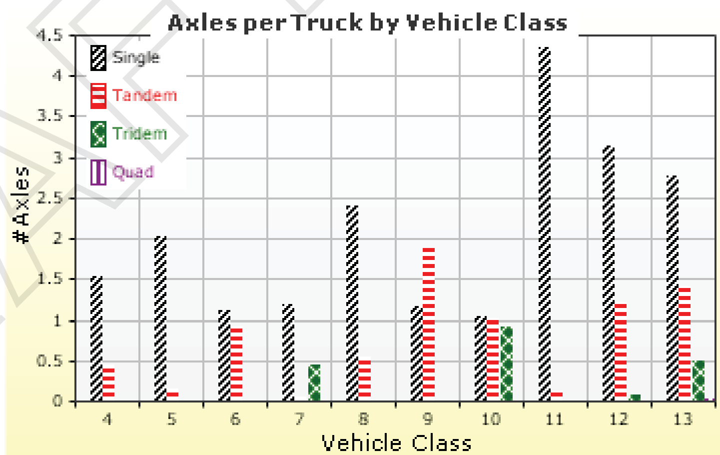
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	78	Percent of trucks in design direction (%):	60.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	35.0

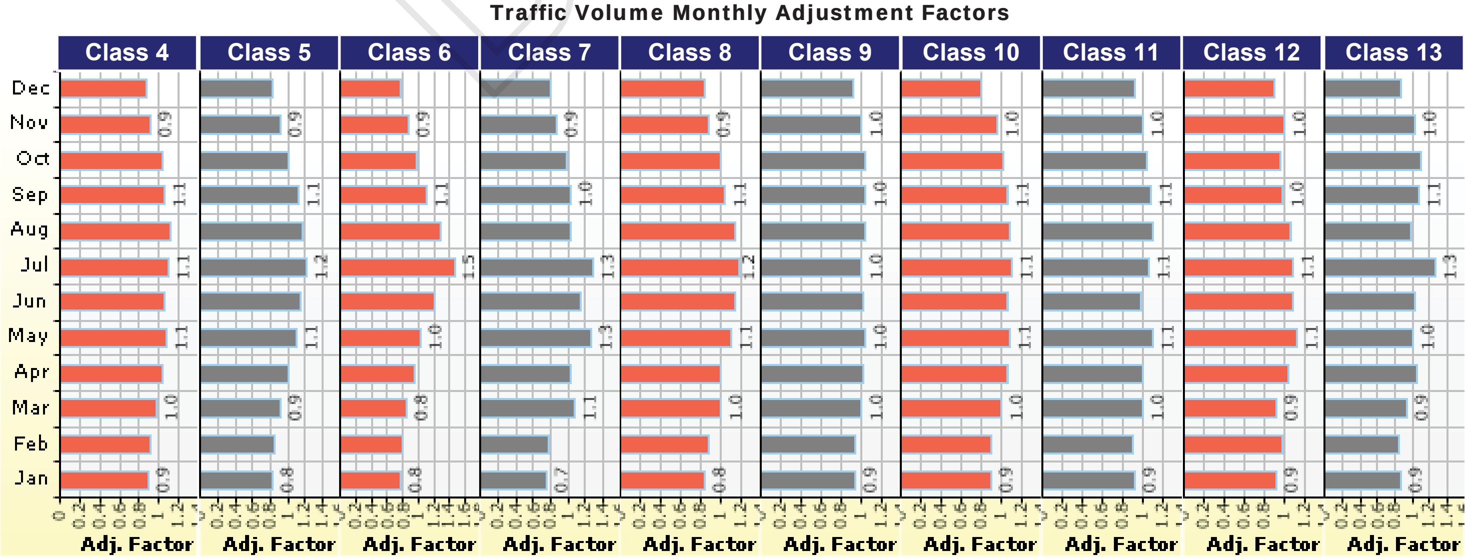








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

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

Distributions by Vehicle Class

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

Truck Distribution by Hour does not apply

Axle Configuration

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

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

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

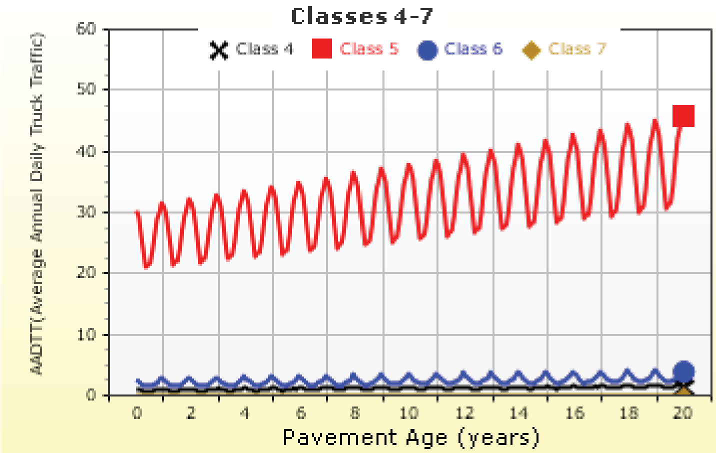
Wheelbase does not apply

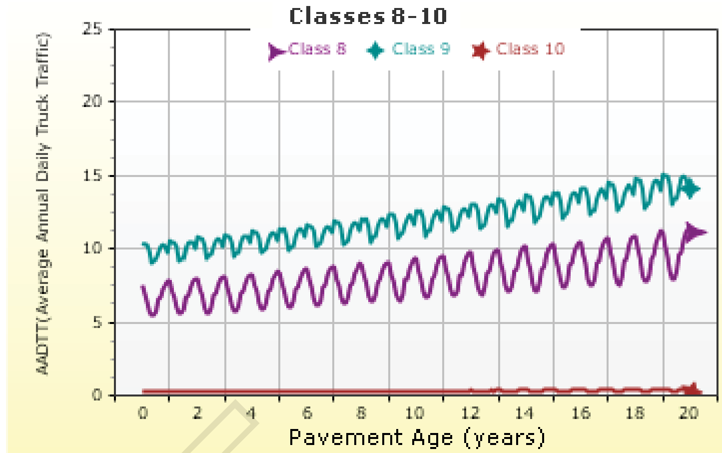
Number of Axles per Truck

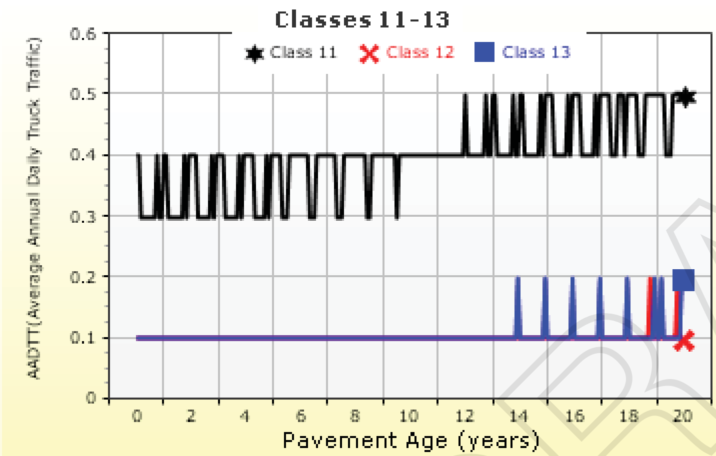
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.53	0.45	0	0
Class 5	2.02	0.16	0.02	0
Class 6	1.12	0.93	0	0
Class 7	1.19	0.07	0.45	0.02
Class 8	2.41	0.56	0.02	0
Class 9	1.16	1.88	0.01	0
Class 10	1.05	1.01	0.93	0.02
Class 11	4.35	0.13	0	0
Class 12	3.15	1.22	0.09	0
Class 13	2.77	1.4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

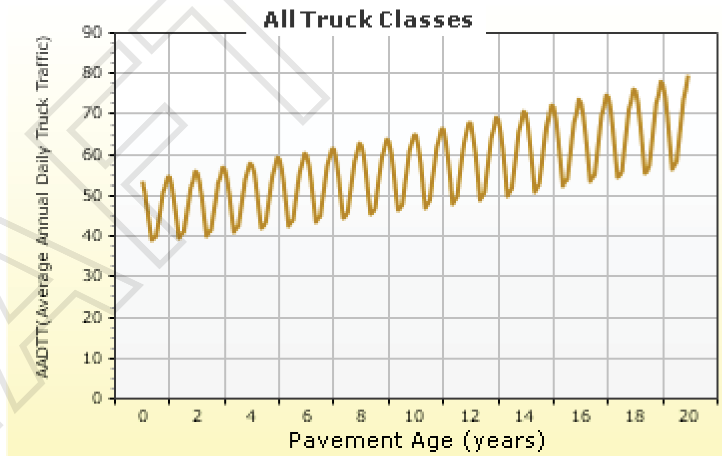
AADTT (Average Annual Daily Truck Traffic) Growth

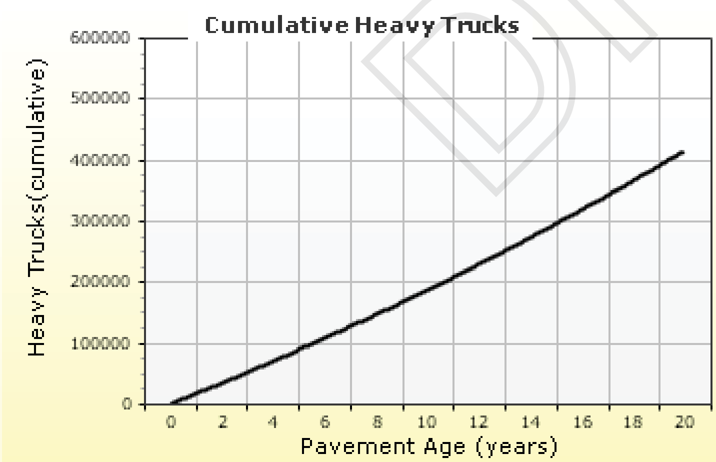
*** Traffic cap is not enforced**







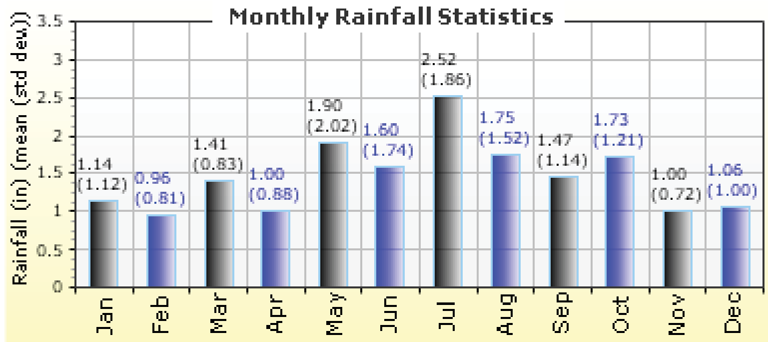




Climate Inputs

Climate Data Sources:

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

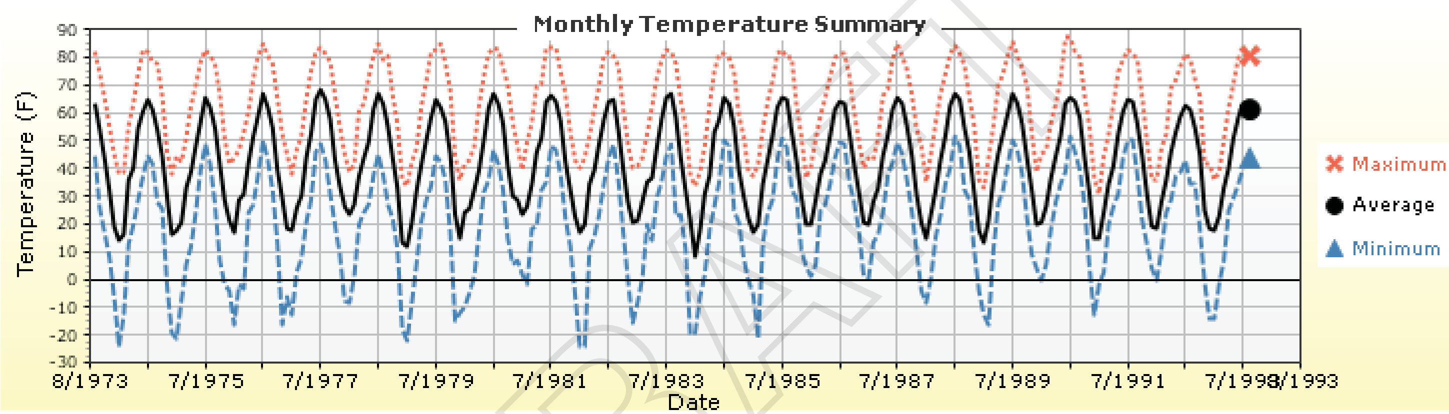


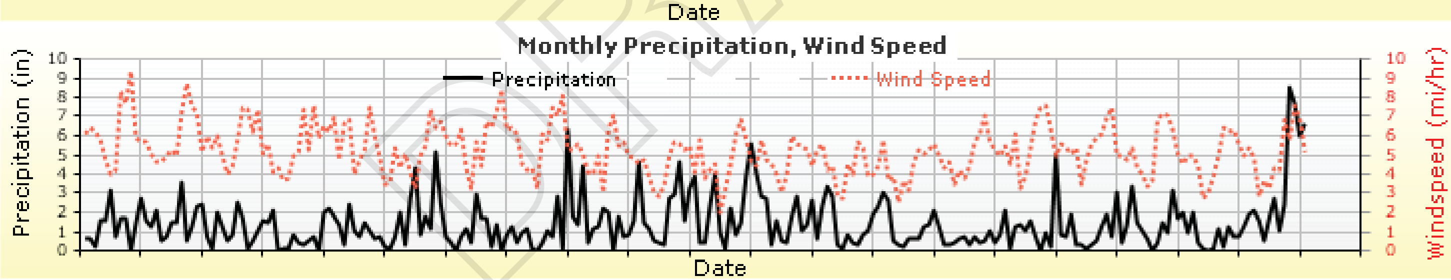
Annual Statistics:

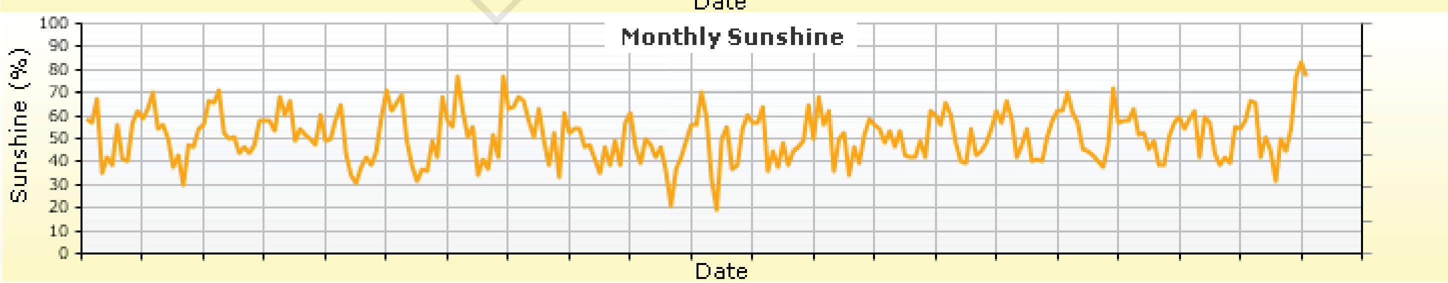
Mean annual air temperature (ºF)	42.71
Mean annual precipitation (in)	17.55
Freezing index (ºF - days)	1092.34
Average annual number of freeze/thaw cycles:	103.27

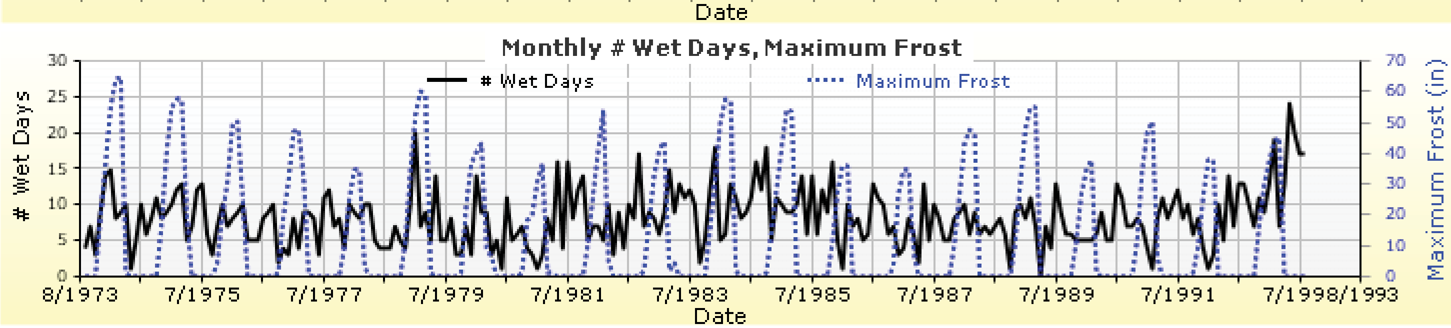
Water table depth (ft) 10.00

Monthly Climate Summary:

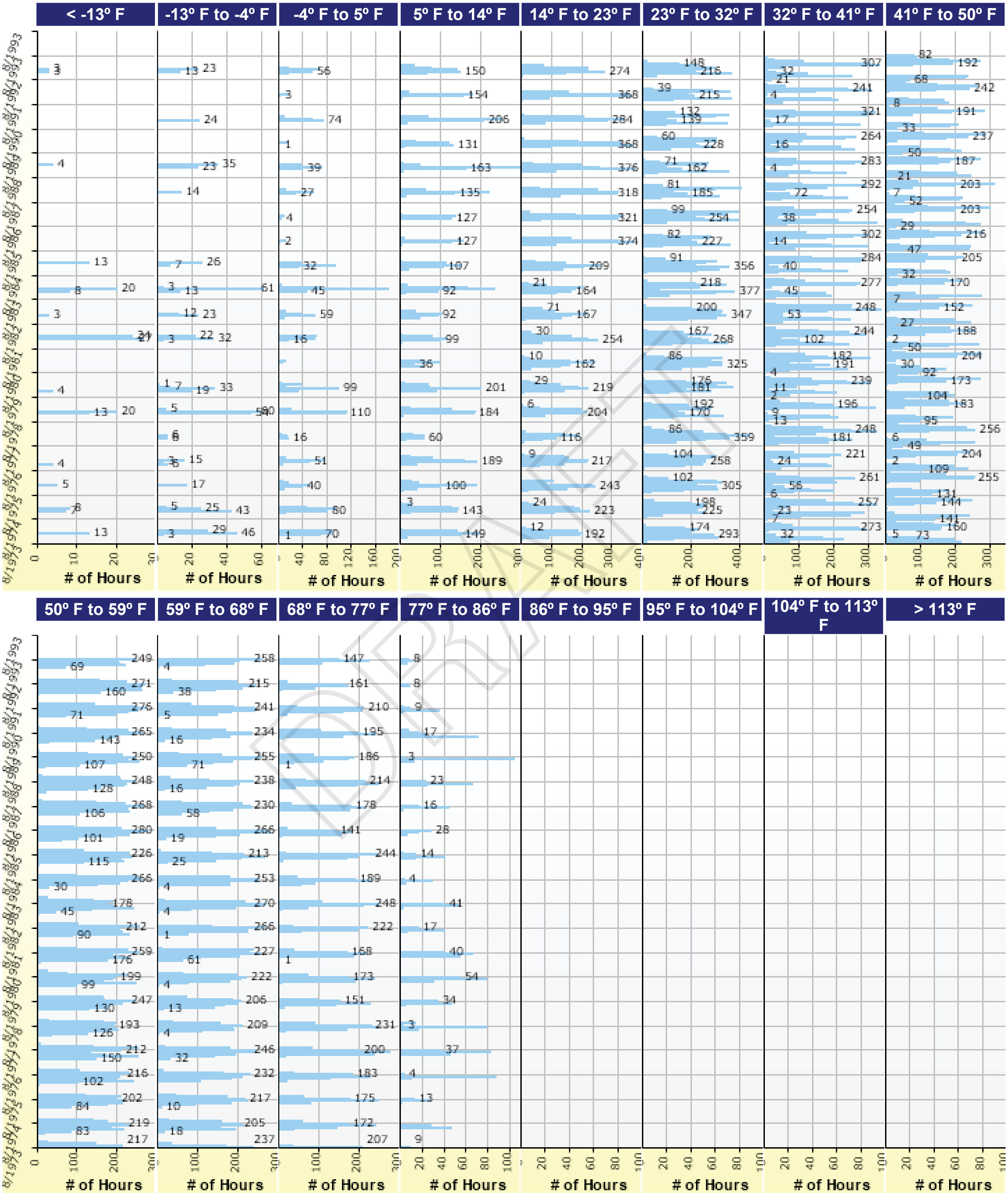








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

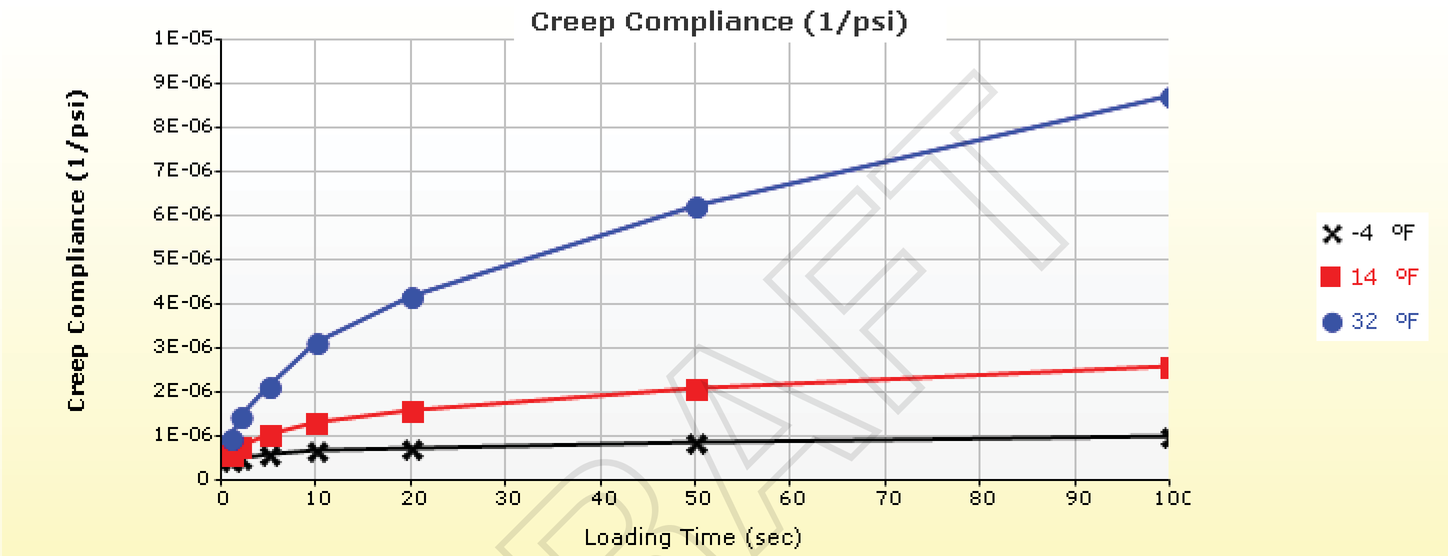
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R5 Level 1 SX (75) PG 58-34	Flexible (1)	1.00
Layer 2 Subgrade : A-2-6	Subgrade (5)	1.00
Layer 3 Subgrade : A-2-6	Subgrade (5)	-

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

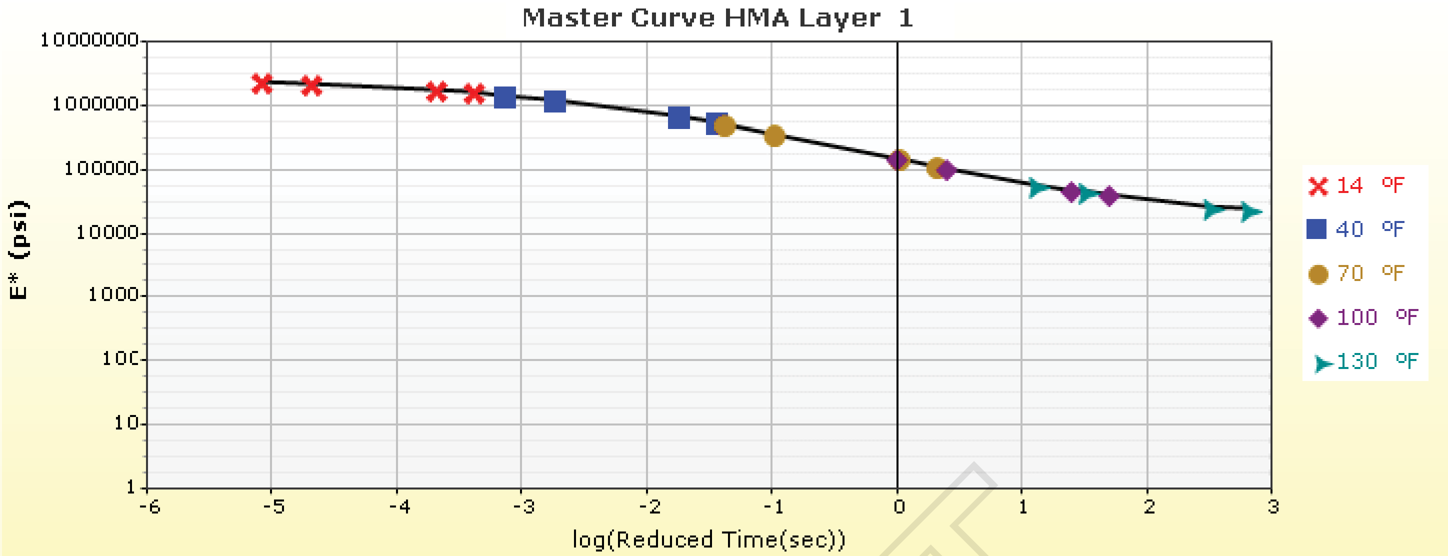
Thermal Cracking (Input Level: 1)

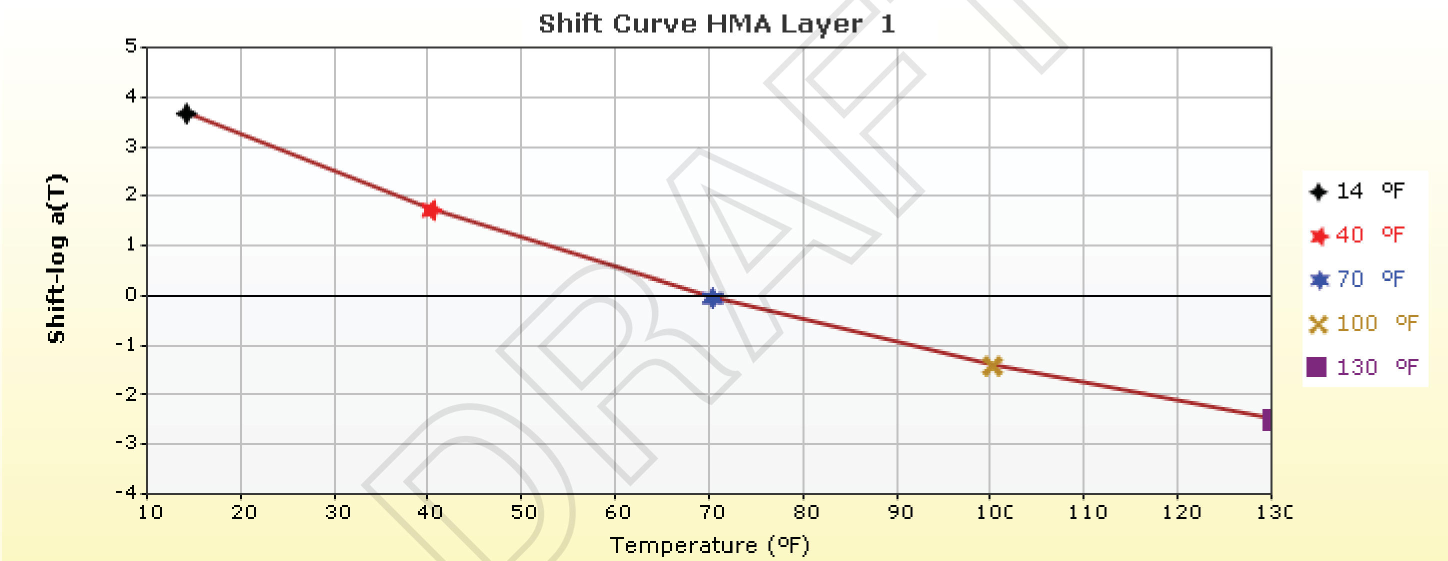
Indirect tensile strength at 14 ºF (psi)	446.00
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	19.6

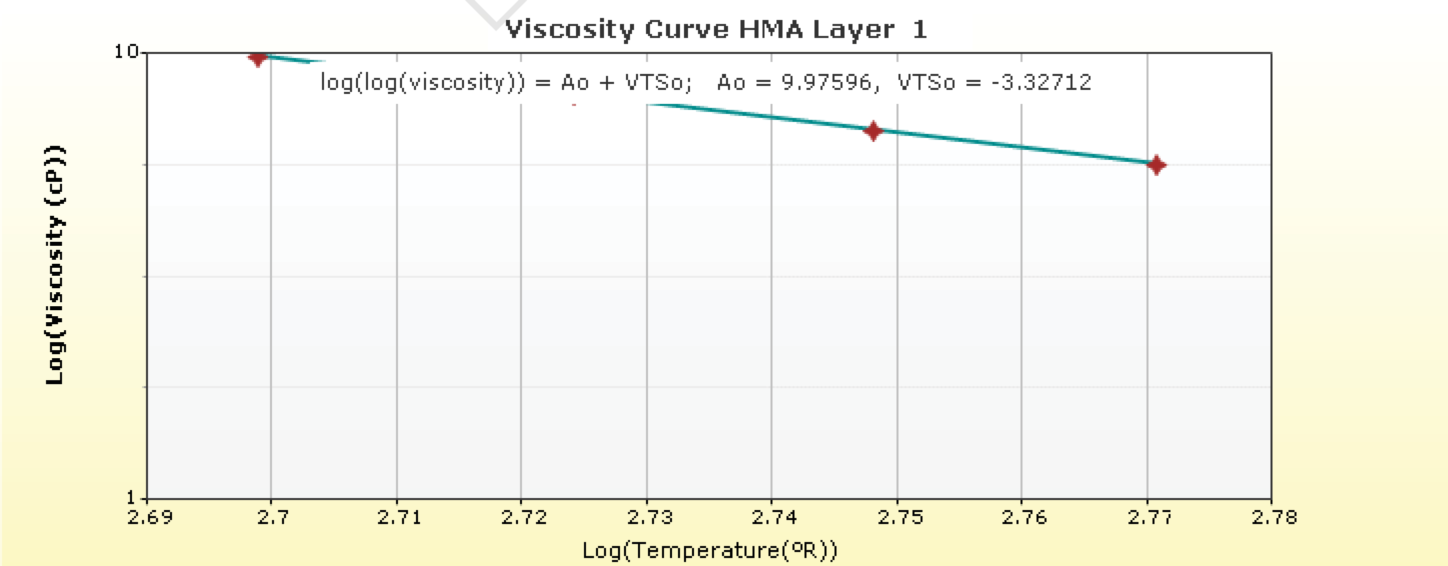
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	4.82e-007	5.95e-007	9.61e-007
2	5.30e-007	8.18e-007	1.48e-006
5	6.05e-007	1.05e-006	2.18e-006
10	6.85e-007	1.35e-006	3.14e-006
20	7.71e-007	1.62e-006	4.19e-006
50	8.72e-007	2.12e-006	6.23e-006
100	1.00e-006	2.63e-006	8.74e-006



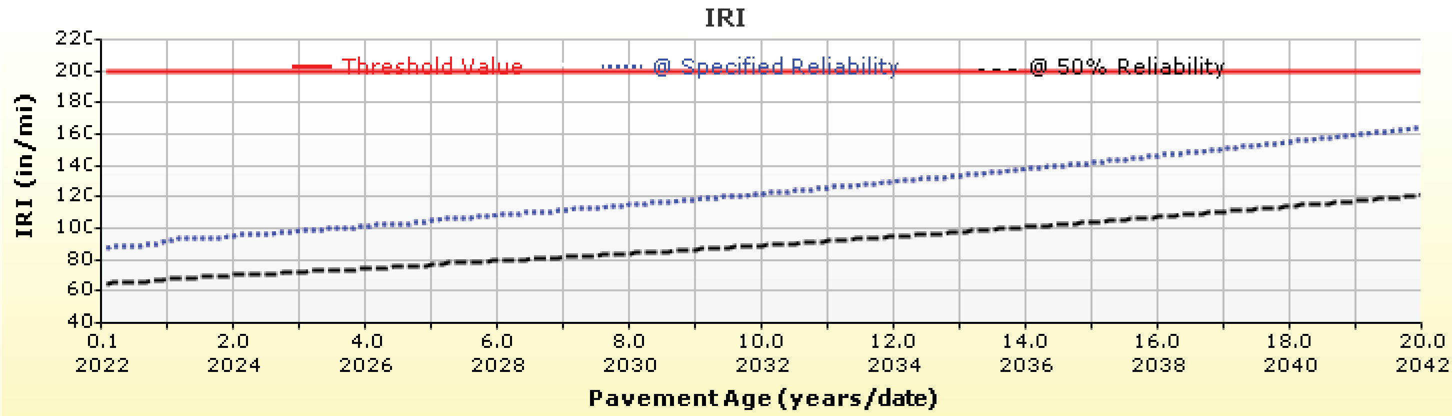
HMA Layer 1: Layer 1 Flexible : R5 Level 1 SX(75) PG 58-34

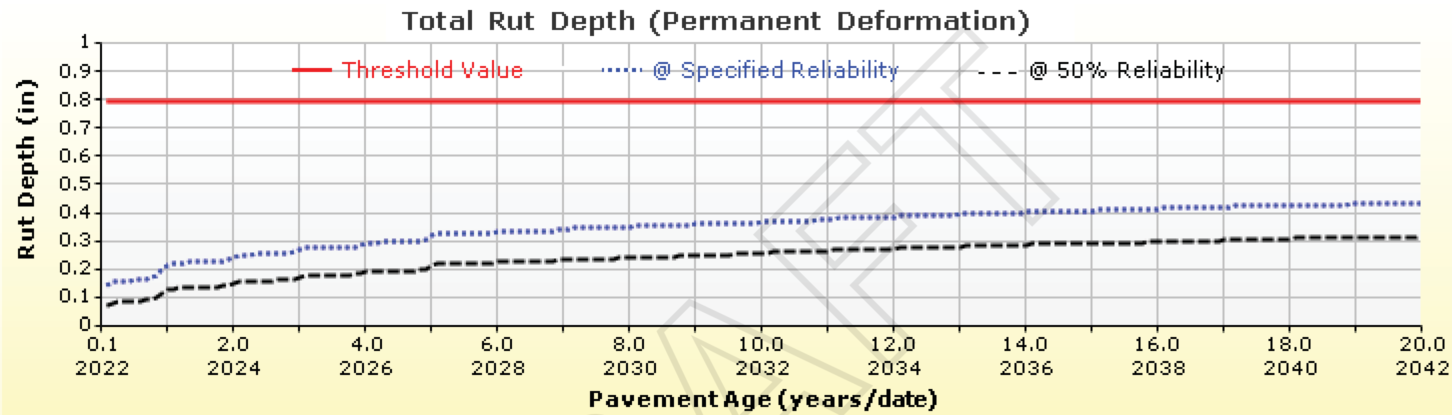


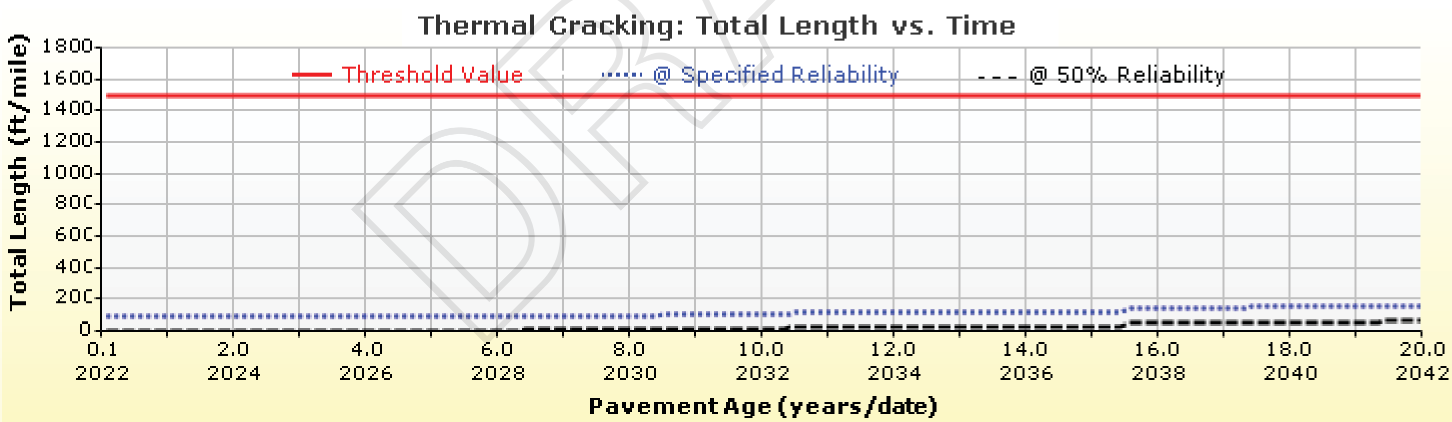


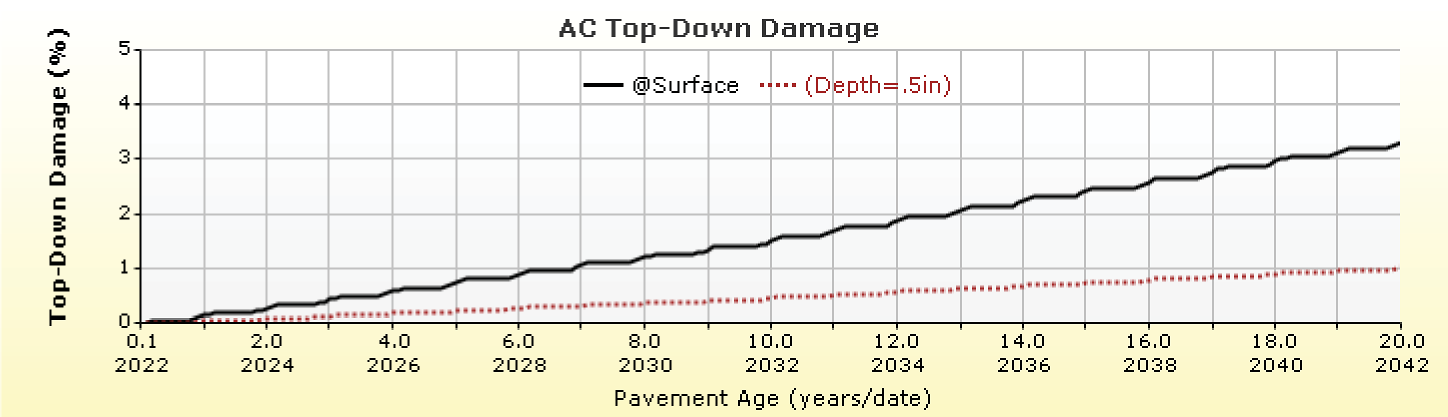


Analysis Output Charts

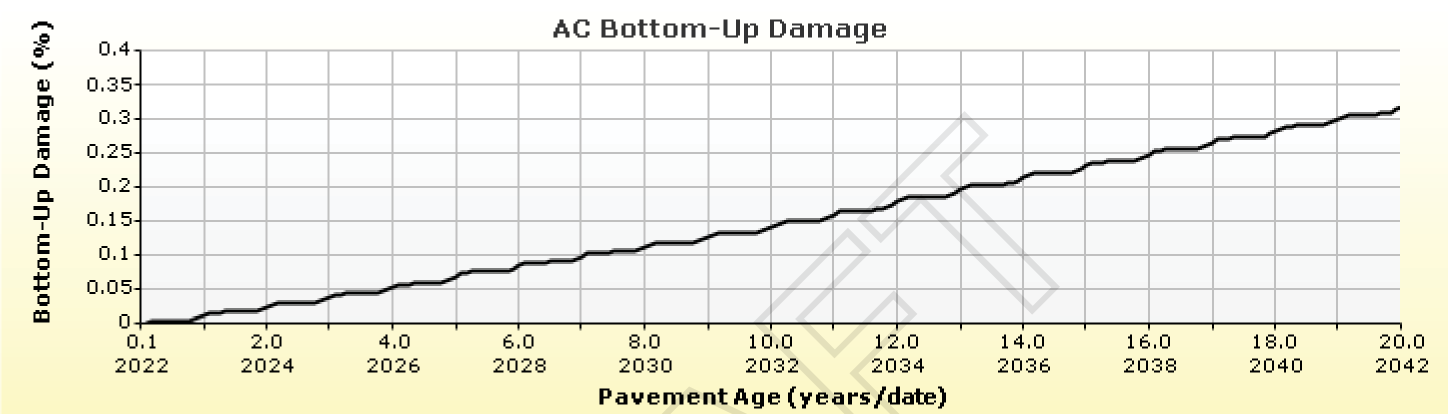




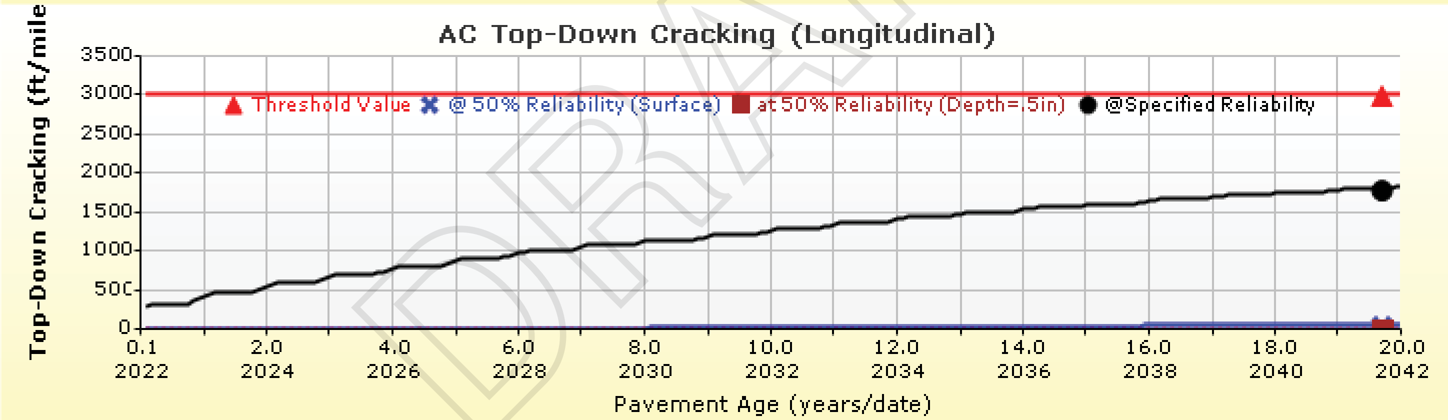




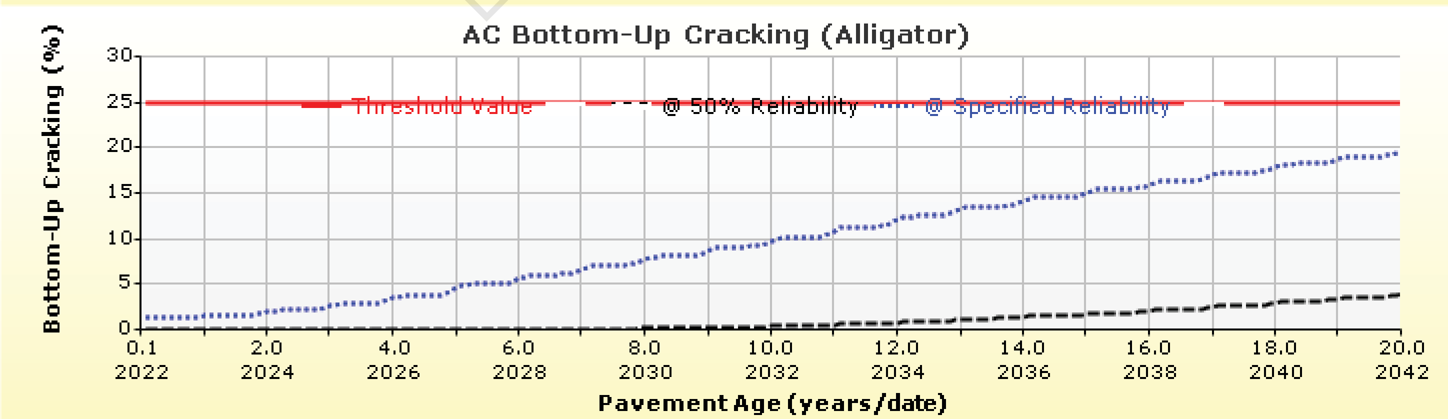
AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
5
4
3
2
1
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)



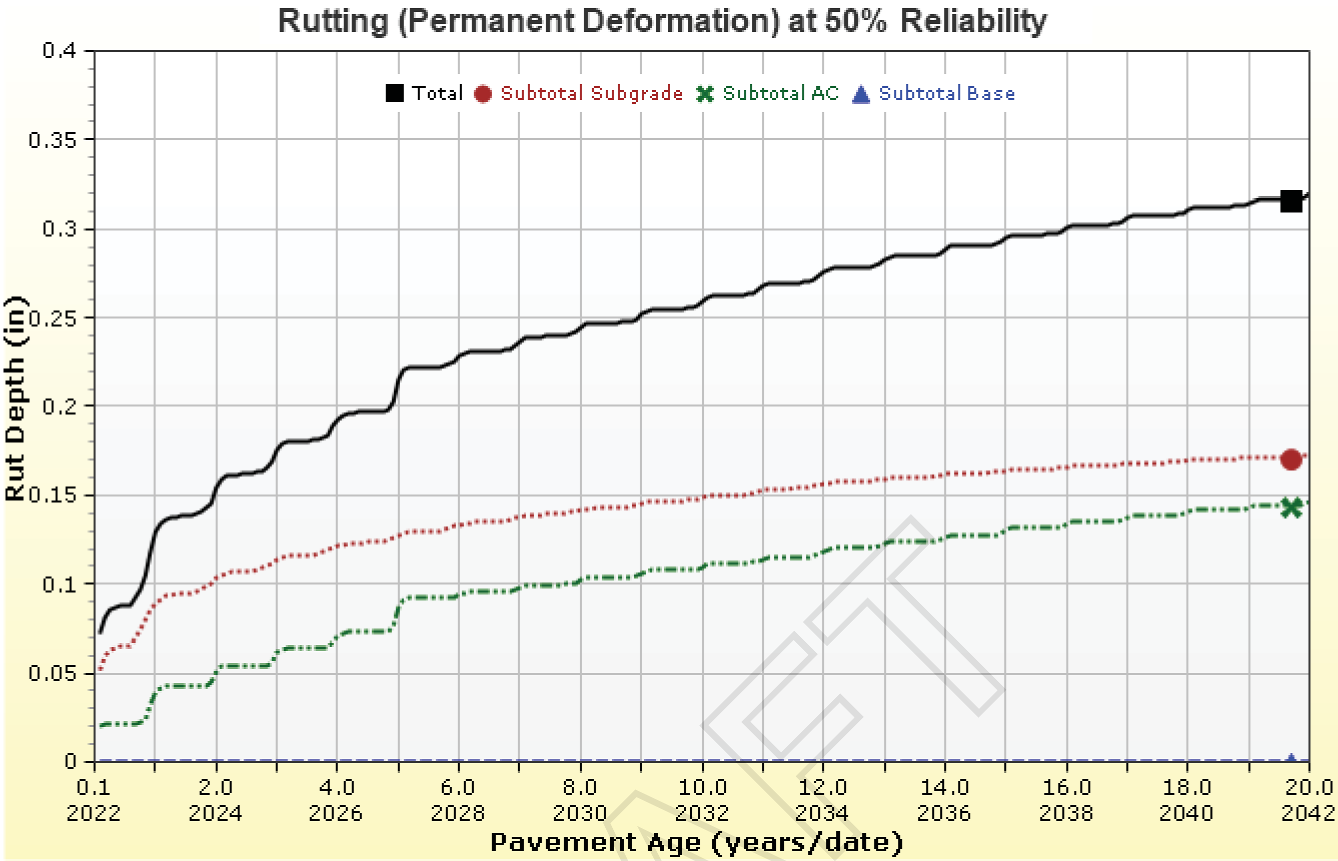
AC Bottom-Up Damage
Bottom-Up Damage (%)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

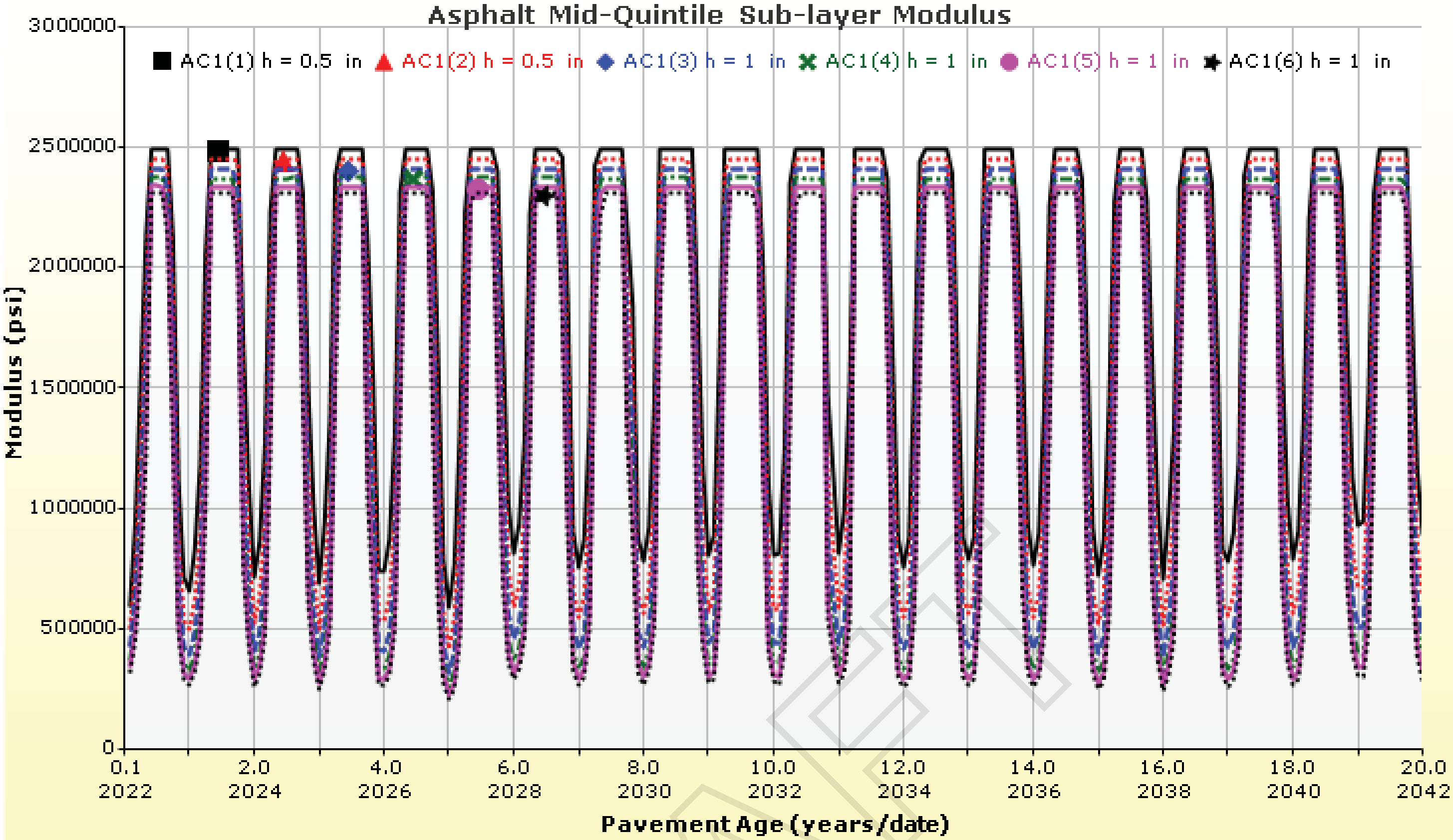


AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile
3500
3000
2500
2000
1500
1000
500
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042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

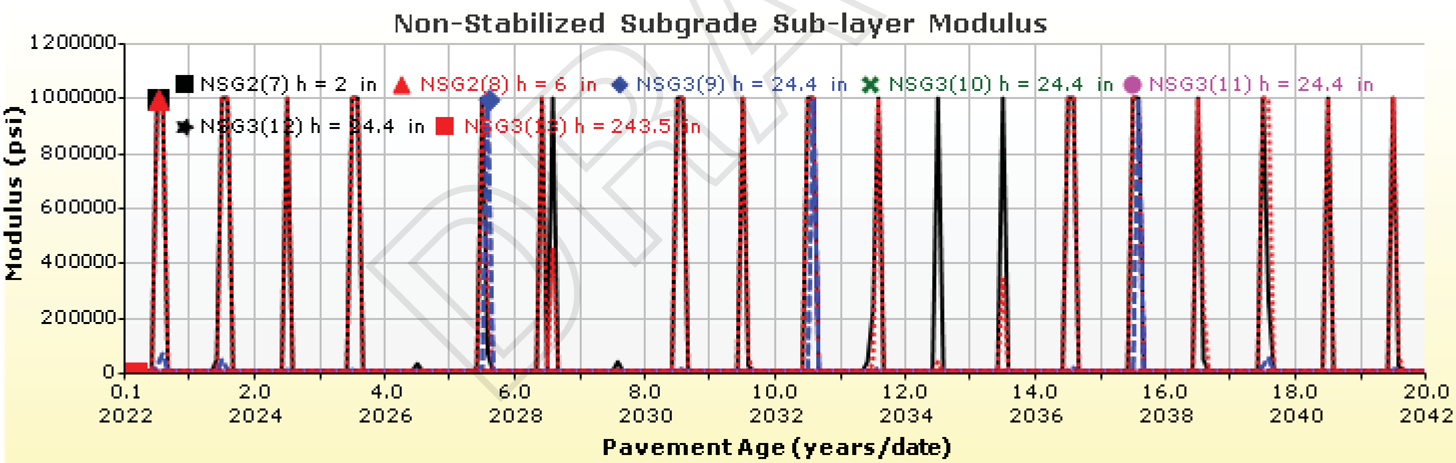


AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
30
25
20
15
10
5
0
0.1 2022
2.0 2024
4.0 2026
6.0 2028
8.0 2030
10.0 2032
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal 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
AC1(4) h = 1 in
AC1(5) h = 1 in
AC1(6) h = 1 in
Modulus (psi)
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)



Non-Stabilized Subgrade Sub-layer Modulus
NSG2(7) h = 2 in
NSG2(8) h = 6 in
NSG3(9) h = 24.4 in
NSG3(10) h = 24.4 in
NSG3(11) h = 24.4 in
NSG3(12) h = 24.4 in
NSG3(13) h = 243.5 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
12.0 2034
14.0 2036
16.0 2038
18.0 2040
20.0 2042
Pavement Age (years/date)

Layer Information

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

Asphalt		
Thickness (in)	5.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	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 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)
10000.0

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 3 Subgrade : A-2-6

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)
10000.0

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

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

AC Rutting

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

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

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

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

Where:

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

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

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

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

$N = number\ of\ load\ repetitions$

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

Thermal Fracture

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

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

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

C_f = observed amount of thermal cracking(ft/500ft)
k = refression coefficient determined through field calibration
$N()$ = standard normal distribution evaluated at()
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

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

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

$\sigma_s = Tensile\ stress(psi)$

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

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

LTPP Bind Output

General Project Information

Project Number: 0
Project Title: US6
Project Description:

Lower Lift

Climatic Data Source (MERRA)

Latitude, Degree: 39.65392
Longitude, Degree: -106.62921

Climatic Data

Lowest Yearly Air Temperature, ºC: -35.70
Low Air Temp Standard Deviation, ºC: 3.24
Yearly Degree-Days > 10 Deg. ºC: 1616.15
High Air Temperature of high 7 days: 28.57
Standard Dev. of the high 7 days: 1.48
Low Pavement Temperature 50%: -24.80
Low Pavement Temperature 98%: -31.30
High Avg Pavement Temperature of 7 Days 50%: 52.08
High Avg Pavement Temperature of 7 Days 98%: 55.98

Target Rut Depth

Target Rut Depth (mm): 12.5

Temperature Adjustments

Depth of Layer, mm: 50
Base HT PG: 58

Traffic Adjustments

Traffic loading Cumulative ESAL for the Design Period, Millions: 2
Traffic Speed (Fast: >70 km/h, Slow: 20-70 km/h, Standing: < 20 km/h): Slow

Performance Grade

AASHTO M323-13 Performance-Graded Asphalt Binder		
PG Temperature	**High**	**Low**
Performance Grade Temperature at 50% Reliability	43.3	-24.8
Performance Grade Temperature at 98% Reliability	44.9	-31.3
Adjustment for Traffic (AASHTO M323-13)	2.7	
Adjustment for Depth	-7.2	3.0
Adjusted Performance Grade Temperature	40.4	-28.3
Selected PG Grade	**52**	**-34**
PG Grade	**M323, PG 52-34**	

PG 58-34

AASHTO M 332-14 Performance-Grade Asphalt Binder using Multiple Stress Creep Recovery (MSCR) Test		
PG Temperature	**High**	**Low**
Performance Grade Temperature at 50% Reliability	43.3	-24.8
Performance Grade Temperature at 98% Reliability	44.9	-31.3
Designation for traffic loading	H	
Selected PG Grade	**46**	**-34**
PG Grade	**M332, PG 46H-34**	

Temperature Report	
Lowest Yearly Air Temperature, ºC:	-35.70
Low Air Temp Standard Deviation, ºC:	3.24
Yearly Degree-Days > 10 Deg. ºC:	1616.15
High Air Temperature of high 7 days:	28.57
Standard Dev. of the high 7 days:	1.48
Low Pavement Temperature 50%:	-24.80
Low Pavement Temperature 98%:	-31.30
High Avg Pavement Temperature of 7 Days 50%:	52.08
High Avg Pavement Temperature of 7 Days 98%:	55.98

Top Lift

General Project Information

Project Number: 0
Project Title: US6
Project Description:

Climatic Data Source (MERRA)

Latitude, Degree: 39.65392
Longitude, Degree: -106.62921

Climatic Data

Lowest Yearly Air Temperature, ºC: -35.70
Low Air Temp Standard Deviation, ºC: 3.24
Yearly Degree-Days > 10 Deg. ºC: 1616.15
High Air Temperature of high 7 days: 28.57
Standard Dev. of the high 7 days: 1.48
Low Pavement Temperature 50%: -24.80
Low Pavement Temperature 98%: -31.30
High Avg Pavement Temperature of 7 Days 50%: 52.08
High Avg Pavement Temperature of 7 Days 98%: 55.98

Target Rut Depth

Target Rut Depth (mm): 12.5

Temperature Adjustments

Depth of Layer, mm: 0
Base HT PG: 58

Traffic Adjustments

Traffic loading Cumulative ESAL for the Design Period, Millions: 2
Traffic Speed (Fast: >70 km/h, Slow: 20-70 km/h, Standing: < 20 km/h): Slow

Performance Grade

AASHTO M323-13 Performance-Graded Asphalt Binder		
PG Temperature	**High**	**Low**
Performance Grade Temperature at 50% Reliability	43.3	-24.8
Performance Grade Temperature at 98% Reliability	44.9	-31.3
Adjustment for Traffic (AASHTO M323-13)	2.7	
Adjustment for Depth	0.0	0.0
Adjusted Performance Grade Temperature	47.6	-31.3
Selected PG Grade	**52**	**-34**
PG Grade	**M323, PG 52-34**	

PG 58-34

AASHTO M 332-14 Performance-Grade Asphalt Binder using Multiple Stress Creep Recovery (MSCR) Test		
PG Temperature	**High**	**Low**
Performance Grade Temperature at 50% Reliability	43.3	-24.8
Performance Grade Temperature at 98% Reliability	44.9	-31.3
Designation for traffic loading	H	
Selected PG Grade	**46**	**-34**
PG Grade	**M332, PG 46H-34**	

Temperature Report	
Lowest Yearly Air Temperature, ºC:	-35.70
Low Air Temp Standard Deviation, ºC:	3.24
Yearly Degree-Days > 10 Deg. ºC:	1616.15
High Air Temperature of high 7 days:	28.57
Standard Dev. of the high 7 days:	1.48
Low Pavement Temperature 50%:	-24.80
Low Pavement Temperature 98%:	-31.30
High Avg Pavement Temperature of 7 Days 50%:	52.08
High Avg Pavement Temperature of 7 Days 98%:	55.98

IMPORTANT INFORMATION

Important Information

About Your Geotechnical Report

IMPORTANT INFORMATION

IMPORTANT INFO HEADING

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.

IMPORTANT INFORMATION

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.