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UNITED Consulting

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I-65 SOUTHEAST INDIANA PROJECT

INDIANA DEPARTMENT OF TRANSPORTATION INDOT

INTERSTATE 65

TECHNICAL PROPOSAL

Volume 2

APPENDICES

- KEY PERSONNEL RESUMES
- TECHNICAL/DESIGN DRAWINGS, GRAPHS, AND DATA

E&B PAVING, INC

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APRIL 27, 2017

SUMMARY & ORDER OF PROPOSAL CONTENTS

Exhibit E

SUMMARY AND ORDER OF PROPOSAL CONTENTS

Technical Proposal – Volumes 1 and 2		
Technical Proposal Component	Form (if any)	ITP Section Cross-Reference
Volume 1		
A. Executive Summary		
Executive Summary **(Exclude price information)**	No forms are provided	Exhibit B, Section 3.1
B. Proposer Information, Certifications and Documents		
Proposal Letter	Form A	Exhibit B, Section 3.2.1
Authorization Documents	No forms are provided	Exhibit B, Section 3.2.1
Identification of Proposer and Equity Members	Form B-1	Exhibit B, Section 3.2.2
Information About Proposer Organization	Form B-2	Exhibit B, Section 3.2.2
Information About Major Participants and Identified Contractors	Form B-3	Exhibit B, Section 3.2.2
Letter accepting joint and several liability, if applicable	No forms are provided	Exhibit B, Section 3.2.2
Responsible Proposer and Major Participant Questionnaire	Form C	Exhibit B, Section 3.2.3
Industrial Safety Record for Proposer, Equity Members and Major Participants	Form D (as applicable)	Exhibit B, Section 3.2.4
Personnel Work Assignment Form and Commitment of Availability	Form E	Exhibit B, Section 3.2.5
Letter(s) Regarding Pre-Proposal Submittals	No forms are provided	Exhibit B, Section 3.2.6
Non-Collusion Affidavit	Form F	Exhibit B, Section 3.2.7
DBE Certification	Form G No forms are provided for the DBE Performance Plan or Job Training Plan	Exhibit B, Section 3.2.8

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Surety/Financial Institution Information	No forms are provided	Exhibit B, Section 3.2.9
Conflict of Interest Disclosure	Form H	Exhibit B, Section 3.2.10
Certification regarding Buy America	Form R	Exhibit B, Section 3.2.11
Certification regarding Equal Employment Opportunity	Form S	Exhibit B, Section 3.2.12
Use of Contract Funds for Lobbying Certification	Form T	Exhibit B, Section 3.2.13
Debarment and Suspension Certification	Form U	Exhibit B, Section 3.2.14
Insurance	No forms are provided	Exhibit B, Section 3.2.15
Confidential Contents Index	No forms are provided	Exhibit B, Section 3.2.16
C. Proposal		
Stipend Agreement	Form O	Exhibit B, Section 3.3
D. Proposal Security (Proposal Bond)		
Proposal Security	Form J (if in the form of a bond); no forms provided for certified check	Exhibit B, Section 3.4
Volume 2		
E. Scope Package(s)	Form K	Exhibit B, Section 4.0
F. Preliminary Performance Plans		
Preliminary Project Management Plan	No forms are provided	Exhibit B, Section 5.1
Preliminary Project Baseline Schedule for Design and Construction	No forms are provided	Exhibit B, Section 5.1.2
Completion Deadlines	Form L	Exhibit B, Section 5.1.2
Preliminary Design-Build Plan	No forms are provided	Exhibit B, Section 5.2

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G. Volume 1 Appendices		
Copies of Organizational Documents	No forms are provided	Exhibit B, Section 3.2.2
Proposer Teaming Agreement or Key Terms	No forms are provided	Exhibit B, Section 3.2.2
Executed Contracts or Term Sheets/Heads of Terms	No forms are provided	Exhibit B, Section 3.2.2
H. Volume 2 Appendices		
Key Personnel Resumes	No forms are provided	Exhibit B, Section 3.2.5
Technical/Design Drawings, Graphs and Data	No forms are provided	Exhibit B, Section 5.2

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Price Proposal – Volume 3
Proposers shall follow the order of the Price Proposal Checklist in their submissions. A referenced copy of this document shall be submitted with the Price Proposal.

Price Proposal Component	Form (if any)	ITP Section Cross-Reference
Price Form	Form I	Exhibit C, Section 2.0
Summary Cost Table Form	Form M	Exhibit C, Section 2.0
Scope Package	Form K	Exhibit C, Section 4.0

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Scott O'Neil, PE

Project Manager and Public Involvement Manager

Education: Rose-Hulman Institute of Technology (1993)
BS Civil Engineering (1993)

Years Relevant Experience: 23

Licenses/Certifications:

- Professional Engineer (PE 10809522)
- OSHA 30 Certified
- CPR and First Aid Certified
- INDOT Level 1 Storm Water Manager Certified

Availability: 100%

Scott will be the Project Manager and the Public Involvement Manager. He will be designated as the single point of contact for purposes of overall administration of the project. Scott will be authorized to act with respect to contractual matters and for resolving any issues that arise during progress of the work. He will also be responsible for identifying public information issues and for formulating and implementing strategies to address issues relative to the public, public resource agencies, emergency service providers, businesses, media and other interested parties. Scott will work with INDOT to respond to the communication needs of the project with availability by telephone and email, and he will be available as needed during critical construction activities and emergencies.

Scott has 23 years of relative experience with the majority of the last 8 years being spent managing projects on I-69 between Evansville and Bloomington. Since graduating from Rose-Hulman Institute of Technology, he has been employed by INDOT, a consulting engineering firm, and now a contractor. Scott has been in his current position for the last 9 years. He is a good communicator and able to find common ground and present perspectives clearly to resolve project issues fairly. Scott is currently the industry side Co-Chairman for the ICI/INDOT Southern Region Joint Cooperative Committee which has allowed him to gain an appreciation of INDOT positions on current issues.

Relevant Experience

I-69 Design Build I-64 to SR 68

Scott was project manager on this project which included two overpass bridges and several box structures. He coordinated with Indiana State Police and INDOT when this segment of I-69 was opened in phases moving traffic from SR 57 to I-69. This project involved moving 450,000 cys of dirt, and placing 107,700 sys of PCCP and 9,000 tons of HMA on 123,260 sys of Subgrade Treatment. Scott coordinated with the design build team and INDOT to implement a scope change and cost reduction incentive which saved the project approximately $100,000.

I-69 Design Build I-64 to SR 68

I-69 Design Build Norfolk Southern Railroad to Patoka River

Scott was the project manager on this project which included several bridges and two overpasses structures. He was responsible for coordinating with the design build team and INDOT to implement changes to project drainage and replacing a bridge with a three sided box over Buck Creek. The project included 1.3 million cys of common excavation and placing 125,000 ton of HMA on 214,000 sys of Subgrade Treatment.

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Franz Hardesty
Construction Manager

Education: New Albany High School

Years Relevant Experience: 21

Licenses/Certifications:
- OSHA 30 Certified
- Traffic Control Superintendent Certified
- INDOT HMA Field Supervisor Certified
- CPR and First Aid Certified

Availability: 100%

Franz will be the Construction Manager responsible for oversight and management of all construction and field activities.

Over the last 21 years Franz has been involved with numerous high profile highway projects in Indiana and Kentucky. Franz has been the recipient of NAPA awards for several projects in Kentucky, and he has managed several projects on I-65 and I-265 in Indiana with great success. Franz is a great communicator allowing him to manage multiple crews and operations with extreme effectiveness. He thrives on the challenge of fast track projects and takes great personal pride in exceeding expectations.

Relevant Experience

I-65 Ohio River Bridge Section 3
Franz managed the HMA paving operations coordinating with bridge construction. He was able to place approximately 300,000 tons of HMA while accommodating the construction of the new Lincoln Bridge and several other bridge structures. Taking into account mix designs, pavement types, and typical sections, this project had 38 different HMA mix designs, and Franz was always able to stay organized to optimize efficiency and meet deadlines and exceed expectations.

Ohio River Bridge Section 3

I-65 Design Build Sellersburg to Memphis
This project is ongoing and scheduled for completion in 2018. This project is very similar to the currently proposed project, and Franz is demonstrating his ability to excel in the design build environment. Franz is able to manage the tight schedules, and traffic configurations while coordinating with bridge construction to stay on track. This project is approximately 8 miles long and scheduled for 385,000 ton of HMA on 496,500 sys of Subgrade Treatment Type 1-B. Franz's duties will be transitioned to make him available for this project.

Steve Parr
Construction Superintendent

Education: Crawford County High School

Years Relevant Experience: 21

Licenses/Certifications:

- IOSHA 30 Certified
- Traffic Control Superintendent Certified
- CPR and First Aid Certified
- INDOT Level 1 Storm Water Manager Certified
- Hazardous Waste Operations and Emergency Response Certified - HAZWOPE

Availability: 100%

Steve will be the Construction Superintendent responsible for supervising all construction and field activities. Steve will report to the Construction Manager Franz Hardesty.

Steve has been in the heavy highway construction industry for 21 years working on various projects in Southern Indiana. Most notably Steve has supervised crews at the I-65 Sellersburg Interchange, I-65 Hamburg and US 60 Interchanges, and at the I-64 Lynnville area resurface. Steve has spent the majority of his time for the last six years on I-69 new corridor construction between Evansville and Bloomington supervising multiple crews on multiple operations. He is highly organized and multitasks well. Steve has excelled and demonstrated this skill when supervising mass excavation, riprap placement, and structure installation simultaneously. Additionally, he is efficient coordinating concurrent operations including subgrade, subbase, and paving.

Relevant Experience

I-69 Patoka River to Petersburg

Steve was the construction superintendent on this 8 mile new corridor project from the Patoka River to the SR 61 Interchange. Steve supervised and helped coordinate all field operation. This project included several bridges and overpasses and moving approximately 3 million cys of dirt/rock while 226,000 sys of PCCP and 87,000 tons of HMA were placed on 405,000 sys of Subgrade Treatment. Steve played a critical role in a successful project being delivered on time.

I-69 Section 4 Segment 6 and 7

I-69 Section 4 Segment 6 and 7

Steve was the construction superintendent on the south section of segment 6 of this project. Steve successfully implemented a Cost Reduction Incentive which altered the grade at the SR 445 interchange and supervised and helped coordinate all field activities. This project included several bridges and overpasses and approximately 5 million cys of unclassified excavation. 215,800 cys of PCCP and 45,000 ton of HMA were placed on 365,000 cys of Subgrade Treatment. Steve was instrumental in this project finishing on time.

Brian Pierson, PE

Lead Engineer

Education: Valparaiso University (2003)
BS Civil Engineering

Years Relevant Experience: 13

Licenses/Certifications:

- Indiana Professional Engineer No. PE10809010

Availability: 75%

Brian Pierson will be the Lead Engineer and primary point of contact for design services. He has been involved in numerous facets of projects including **I-65 Added Travel Lanes from Southport Road to Main Street in Greenwood**, where he led the road design services.

Brian specializes in managing high profile accelerated projects of significant importance. He takes pride in exceeding clients' expectations for project delivery and providing excellent communication through the project development process.

Relevant Experience

I-65 Added Travel Lanes, Southport Road to Main Street (Greenwood)
United Road Design Manager
Brian led the overall development of the United Roadway Design Services. He successfully delivered the first Major Moves 2020 project on an extremely aggressive schedule. The added travel lane project also traversed three interchanges at Southport Road, County Line Road, and Main Street.

Operation Indy Commute

Operation Indy Commute, I-69 from I-465 to SR 37
Lead Project Engineer
Added travel lanes and interchange modification including a new flyover ramp from I-69 to SR 37 to minimize "weaving" and reduce bottleneck on one of the most heavily used sections of roadway in the state. Prepared lane closure waiver, traffic management plan, Level One Design Exceptions, and multi-phase maintenance of traffic plans to minimize impact on daily traffic. Designed horizontal alignments, vertical profiles, super-elevations, spot grading, surface drainage, underdrains, erosion control, guardrail, signing, and pavement markings. Prepared quantity calculations and cost estimate.

Indianapolis Cultural Trail

Indianapolis Cultural Trail, City of Indianapolis
Project Manager
Brian developed and oversaw the design of projects constructing nearly 6.5 miles of new shared use paths and sidewalks in and around downtown Indianapolis highlighting adjacent cultural districts, incorporating art into public spaces, and emphasizing green and context sensitive design. Detailed grading plans to reconstruct the urban streets and sidewalks within the limits of the existing conditions consisted of over 13,000 individual spot elevations. The project was a collaborative effort by the City of Indianapolis Department of Public Works and Central Indiana Community Foundation. The $40M construction cost has improved the city's infrastructure using a combination of private funding and Federal grant money.

Lambda Mort
Storm Water Quality Control Manager

Education: Purdue University (1986)
BS Natural Resources and Environmental Science

Years Relevant Experience: 24

Licenses/Certifications:

- CESSWI
- INDOT Level 1 Storm Water Manager Certified
- CPR and First Aid Certified

Availability: 75%

Lambda will be the Storm Water Quality Manager responsible for installation, inspection, maintenance, and removal of all required storm water quality management measures. She will be focusing on the implementation of our Storm Water Quality Control Plan.

Lambda is the owner of Mort Environmental LLC and has made application for her DBE status. She is a highly recommended former INDOT employee with extensive experience and expertise in inspecting construction projects for environmental compliance. Lambda has shown excellent communication skills while being a part of the I-69 Section 4 Environmental Team. She successfully worked with regulatory agencies, contractors, consultants, and INDOT personnel to implement solutions in extremely challenging conditions.

Relevant Experience

I-69 Section 4

Lambda was responsible for a variety of different assignments during the evolution of the I-69 Section 4 Project. Each task provided her with valuable experience working in extreme terrain and new corridor construction. Weekly Erosion and Sediment Control Reports, Rain Event Reports, analysis of failed features, evaluation of drainage areas, and inspections of offsite waste/borrow areas were some of her responsibilities. She was able to work professionally and coordinate with INDOT, contractors, and regulatory agencies to achieve environmental compliance.

I-69 Section 4

Chris Hammond, PE

Design Quality Manager

Education: Rose Hulman Institute of Technology (1992)
BS Civil Engineering

Years Relevant Experience: 24

Licenses/Certifications:

- Indiana Professional Engineer No. PE19800239
- INDOT Certified Utility Coordinator

Availability: 50%

Chris will be the Design Quality Manager of all design work performed for the project. He will ensure that all quality control procedures are followed and assure and certify compliance. Chris has completed such services on multiple high profile interstate projects over the last ten year. Currently, he provides such services for three different design teams including our Lead Engineer's team.

Chris is a great leader and communicator. These intangible skills, coupled with his sound technical expertise in all aspects of Road Design, have propelled him to be the Road Department Manager at United, where he daily guides, directs, and mentors the engineers and CAD designers. He is passionate about quality and reviews every document—from a complex set of Final Plans to a Transmittal Letter—that leaves the United Road Department. Chris has a special interest in Utility Coordination, where he has been certified through INDOT and serves as one of the presenters at the INDOT Certification Training sessions.

Relevant Experience

I-69 Sections 2/3, Gibson, Pike, Daviess, & Greene County
Deputy Project Manager

Oversaw multiple Design Teams including the utility coordination manager and lead the Practical Design Workshop on this 55-mile long corridor. Design was started and completed in just 14 months. Delivery included both Design/Build and traditional Design/Bid/Build. Although Chris manages the Transportation Department, he dedicated the majority of his time to make this project successful. During the delivery, Chris was responsible for the Quality Control of United's design.

I-69 2/3 Gibson,Pike Daviess, & Greene

I-74 Ronald Reagan Parkway, US 136 & Hendricks CR 600 N
Project Manager

Chris served as the Project Manager and was teamed with Kenny Franklin on his first project assignment as an INDOT Project Manager. Chris worked with Kenny to deliver a new interchange as a Fast-Track project with design completed for letting in six months. He led the accelerated design while obtaining the necessary permits and completed the utility coordination. During the delivery, Chris was responsible for the Quality Control of the design and assurance that all procedures were followed.

I-74 Ronald Reagan Parkway

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Lori Pelleman
Maintenance of Traffic Manager

Education: Indiana University, New Albany, IN
BS Computer Science

Years Relevant Experience: 16

Licenses/Certifications:

- OSHA 30 Certified
- Traffic Control Superintendent Certified
- Flagger Certified
- CPR and First Aid Certified
- INDOT Level 1 Storm Water Manager Certified

Availability: 100%

Lori will be the Maintenance of Traffic MOT Manager responsible for coordinating all MOT activities with INDOT. Lori will implement traffic management strategies, and provide MOT reports to INDOT with each change in traffic phasing. These reports shall include expected queue lengths/delays and a summary of expected operations and MOT durations. Lori will be continually available during construction until final acceptance and removal of all temporary traffic control. Lori will supervise the Construction Worksite Traffic Supervisor and she will report to the Construction Superintendent, Steve Parr.

Lori has 16 years of experience in highway construction and a computer science degree from Indiana University. Lori has always gravitated toward the more challenging aspects of the trade. With her technical background she excels at checking grade and verifying critical setups are completed correctly. She has specialized in traffic control for the last couple of years on various projects on I-65, I-264, I-71, and I-64 in Southern Indiana and Kentucky. Lori's responsibilities on other projects will be transitioned to other qualified staff to be the Maintenance of Traffic Manager on I-65 Southeast, if successful.

Relevant Experience

I-65 Design Build Sellersburg to Memphis

The project has significant similarities to I-65 Southeast project. The project is being completed through a Design-Build process and is adding travel lanes to the existing four lane interstate. Lori is demonstrating her traffic control expertise and is coordinating the Construction Worksite Traffic Supervisor. Lori is able to manage the tight schedules, and complex traffic configurations in the congested high speed traffic of I-65. This project is approximately 8 miles long and has 385,000 ton of HMA on 496,500 sys of Subgrade Treatment Type 1-B.

I-65 Resurface Scottsburg to Henryville

This project included extensive pavement patching and placing 50,000 tons of HMA. Temporary median crossovers were utilized to replace bridge decks and multiple traffic control setups were required to accommodate the patching operations. Lori managed the traffic control and was critical to the success of this 10 mile long project.

Steve Passey, PE, MS

Certified INDOT Utility Coordinator

Education: University of Southern California (1985)
BS: Civil Engineering

University of Missouri Rolla (1995)
MS: Engineering Management

Years Relevant Experience: 29

Licenses/Certifications:

- Indiana Professional Engineer No. PE19700124
- INDOT Certified Utility Coordinator

Availability: 75%

Steve is an extremely experienced designer who has worked in urban and rural interstate environments and understands their unique challenges. Additionally, he successfully completed INDOT's Utility Coordinator Training and will coordinate all utilities throughout the design into construction to alleviate conflicts with the project delivery.

Steve's strengths are flexibility and common sense in solving engineering problems. As an Army Engineer Officer for 28 years, Steve had to quickly assess a situation, identify resources, and analyze alternatives before deciding on the appropriate engineering response. This skill is critical in road projects, whether to minimize utility conflicts with proposed construction in the planning stage, adapt schedules to keep projects on track, develop cost-effective engineering alternatives, or revise plans in the field based on unforeseen conditions.

Relevant Experience

SR 25 Hoosier Heartland Project, Segment 4
Project Manager and Utility Coordinator

This project consisted of final design services for a new, four-lane divided highway for 4.1 mile segment of SR 25, also known as "Hoosier Heartland". Our project, Segment 4, extended from just north of Clymers, IN to US 24, providing a by-pass of Logansport along its southside. Seven new bridges were required over roadways, railroads, and waterways. Mechanically Stabilized Earth Walls were required to avoid railroad right-of-way located on either side of the new roadway. The project traversed new terrain and required evaluation of how the new embankments and cuts would be integrated into the existing geology. This evaluation was a proactive approach to ensuring that no geotechnical issues would arise. The project was also evaluated to ensure that the utility along the traversed existing roads minimized utility impacts. Steve managed the delivery and utility coordination for the project.

SR 25 Hoosier Heartland

I-70 Interchange Modification at US 27
Project Manager and Utility Coordinator

This consisted of the design and reconstruction of the existing interchange at I-70 and US 27. The selected interchange configuration was a single point. Steve managed the project delivery and worked with the other disciplines to deliver the project to and through construction. The maintenance of traffic extended on both I-70 and US 27 with extensive utility coordination required. The utility coordination involved extensive communication and coordination due to the urban US 27 roadway reconstruction.

I-70 Interchange Modification

Jeff Woodard

Environmental Compliance Manager

Education: New Albany High School 1977
Studied at the University of Alabama

Years Relevant Experience: 29

Licenses/Certifications:

- INDOT Level 1 Storm Water Manager Certified
- OSHA 30 Certified
- CPR and First Aid Certified

Availability: 100%

Jeff will be the Environmental Compliance Manager. Reporting directly to the Project Manager, he will be responsible for implementing all the designed features to satisfy the environmental and construction commitments identified in the final approved environmental documents and permits. Jeff will be committed to this project 100% of the time and work closely with the Storm Water Quality Manager to ensure permitting compliance. Jeff will supervise at least one crew whose highest priority will be environmental feature installation and maintenance and have the authority to increase resources if necessary to achieve permit compliance. Jeff will be INDOT's primary contact for compliance issues.

Jeff has worked in heavy highway construction since 1989. He has expertise in everything from finishing concrete to checking grade, and has the ability to supervise his crew while communicating with INDOT representatives. He has implemented Storm Water Pollution Prevention Plans, knows the Indiana Storm Water Quality manual, and installed features shown on erosion control plans. Jeff's application of these skills has been demonstrated on large earthwork projects with extensive riprap and large pipe structures.

Relevant Experience

I-69 Patoka River to Petersburg

Jeff was a foreman on this 8 mile new corridor project from the Patoka River to the SR 61 Interchange. This project included several bridges and overpasses and moving approximately 3 million cys of soil and rock while 226,000 sys of PCCP and 87,000 tons of HMA were placed on 405,000 sys of Subgrade Treatment. Jeff played a critical role in the success of this project in moving soil and maintaining environmental compliance.

I-69 Section 4 Segment 6 and 7

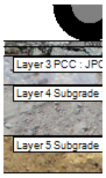
Jeff was a foreman on Segment 6 for this project. This project included several bridges and overpasses and approximately 5 million cys of unclassified excavation. 215,800 cys of PCCP and 45,000 ton of HMA were placed on 365,000 cys of Subgrade Treatment. Jeff was able to navigate the extreme terrain to implement the Storm Water Pollution Prevention Plan.

I-69 Section 4
Segment 6 and 7

Design Inputs

Design Life:	13 years	Existing construction:	May, 1960	Climate Data Sources (Lat/Lon)	39.144, -86.617
Design Type:	AC over JPCP	Pavement construction:	July, 2019		39.71, -86.272
		Traffic opening:	September, 2019		38.228, -85.664

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Seymour 9.5mm PG70-22	1.5
Flexible	Existing HMA	2.5
PCC	JPCP Default	8.0
Subgrade	A-4	14.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	8.0

Traffic

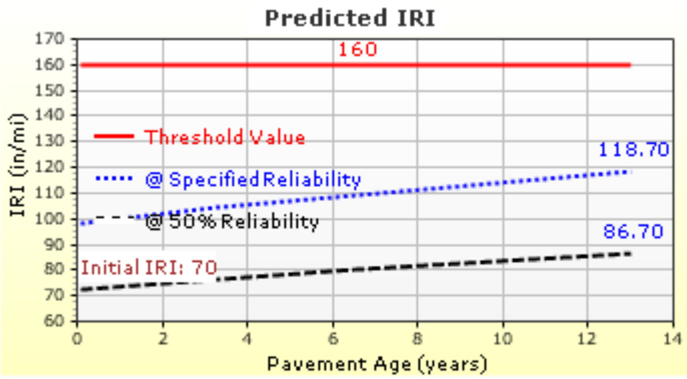
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	461
2025 (6 years)	1,211,860
2032 (13 years)	2,714,290

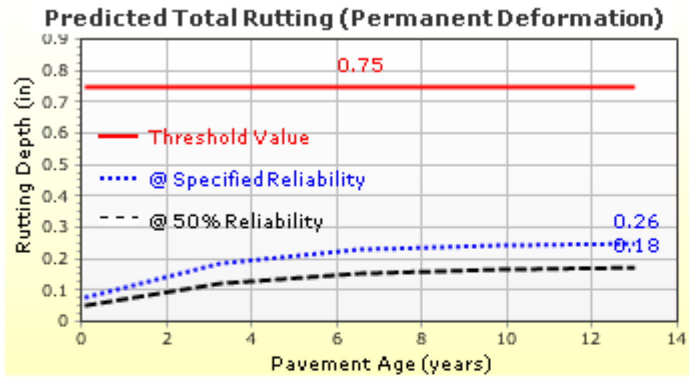
Design Outputs

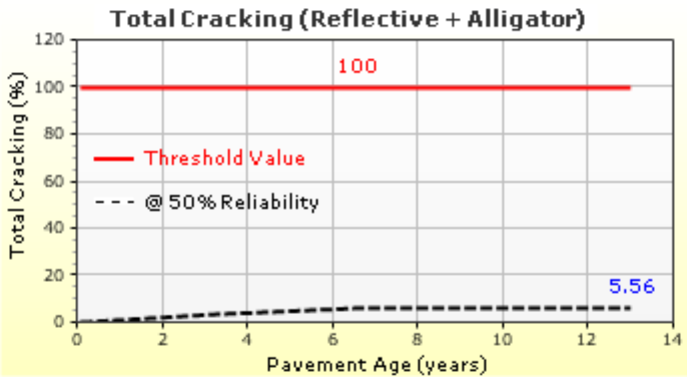
Distress Prediction Summary

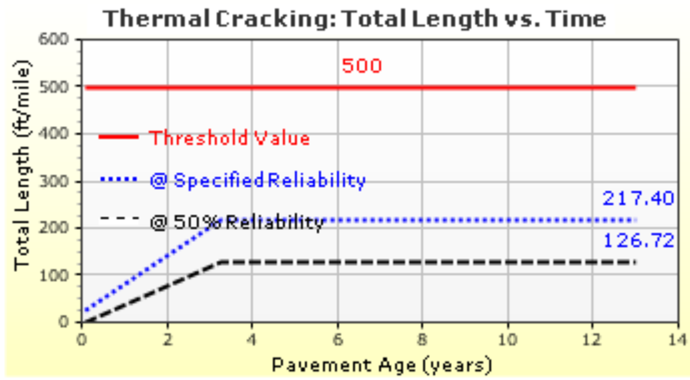
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	118.71	90.00	99.83	Pass
Permanent deformation - total pavement (in.)	0.75	0.26	90.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	100	5.56	-	-	Pass
AC thermal cracking (ft/mile)	500.00	217.40	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	4.39	90.00	99.83	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.45	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	304.59	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.26	90.00	99.99	Pass

Distress Charts





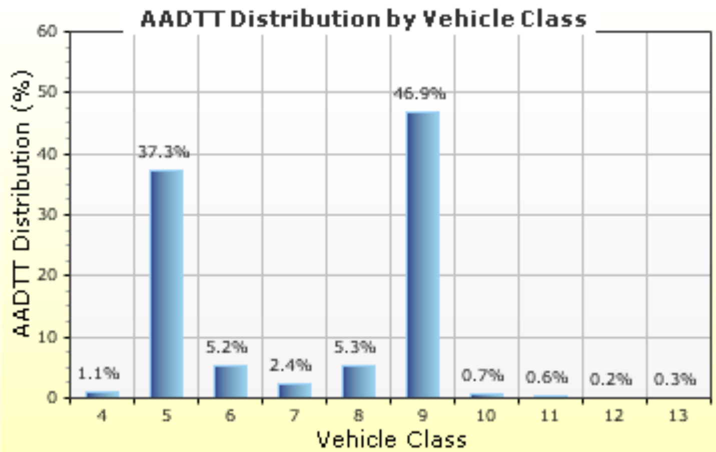


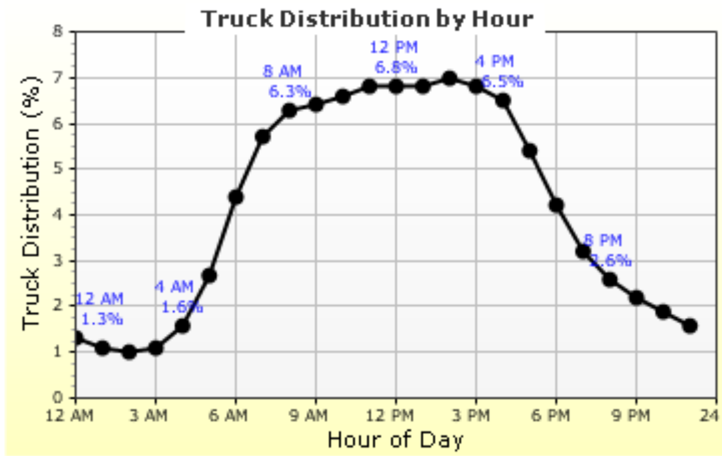


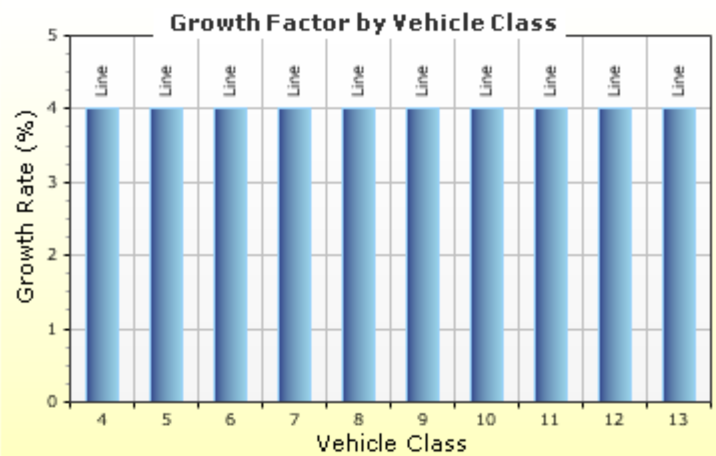
Traffic Inputs

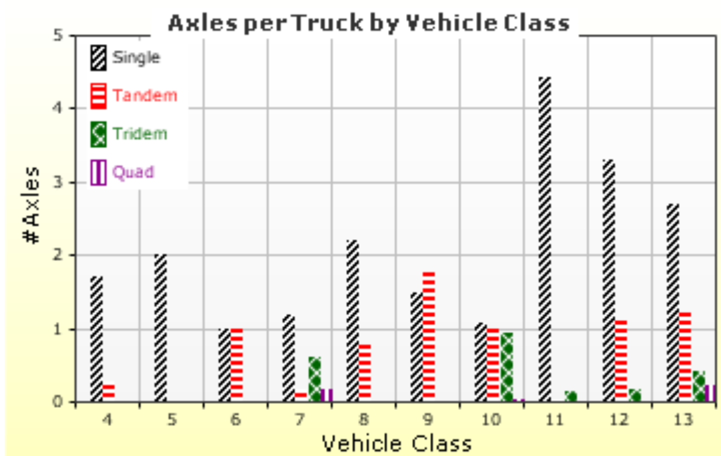
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	461	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)	55.0

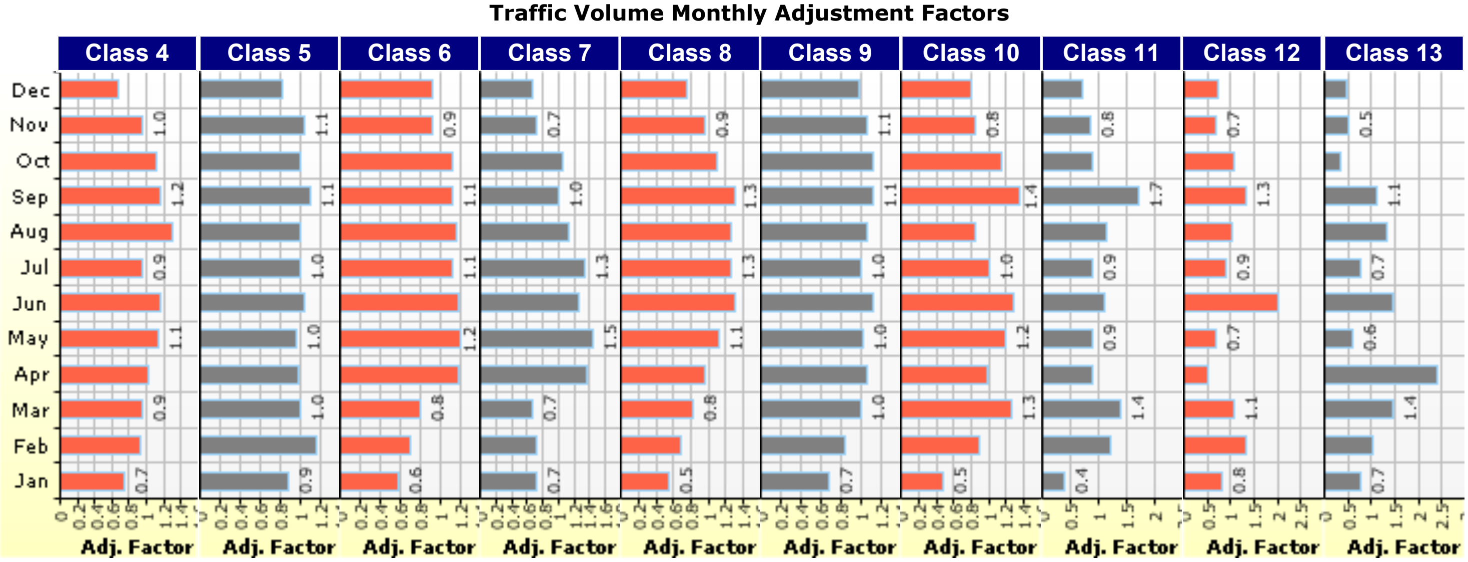








Traffic Volume Monthly Adjustment Factors



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	0.7	0.9	0.6	0.7	0.5	0.7	0.5	0.4	0.8	0.7
February	0.9	1.2	0.7	0.7	0.7	0.8	0.9	1.2	1.3	1.0
March	0.9	1.0	0.8	0.7	0.8	1.0	1.3	1.4	1.1	1.4
April	1.0	1.0	1.2	1.4	1.0	1.1	1.0	0.9	0.5	2.4
May	1.1	1.0	1.2	1.5	1.1	1.0	1.2	0.9	0.7	0.6
June	1.2	1.0	1.2	1.3	1.3	1.1	1.3	1.1	2.0	1.4
July	0.9	1.0	1.1	1.3	1.3	1.0	1.0	0.9	0.9	0.7
August	1.3	1.0	1.2	1.1	1.3	1.1	0.8	1.1	1.0	1.3
September	1.2	1.1	1.1	1.0	1.3	1.1	1.4	1.7	1.3	1.1
October	1.1	1.0	1.1	1.1	1.1	1.1	1.2	0.9	1.1	0.3
November	1.0	1.1	0.9	0.7	0.9	1.1	0.8	0.8	0.7	0.5
December	0.7	0.8	0.9	0.7	0.7	1.0	0.8	0.7	0.7	0.5

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.1%	4%	Linear
Class 5	37.3%	4%	Linear
Class 6	5.2%	4%	Linear
Class 7	2.4%	4%	Linear
Class 8	5.3%	4%	Linear
Class 9	46.9%	4%	Linear
Class 10	0.7%	4%	Linear
Class 11	0.6%	4%	Linear
Class 12	0.2%	4%	Linear
Class 13	0.3%	4%	Linear

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	1.3%	12 PM	6.8%
1 AM	1.1%	1 PM	6.8%
2 AM	1%	2 PM	7%
3 AM	1.1%	3 PM	6.8%
4 AM	1.6%	4 PM	6.5%
5 AM	2.7%	5 PM	5.4%
6 AM	4.4%	6 PM	4.2%
7 AM	5.7%	7 PM	3.2%
8 AM	6.3%	8 PM	2.6%
9 AM	6.4%	9 PM	2.2%
10 AM	6.6%	10 PM	1.9%
11 AM	6.8%	11 PM	1.6%
		Total	100%

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

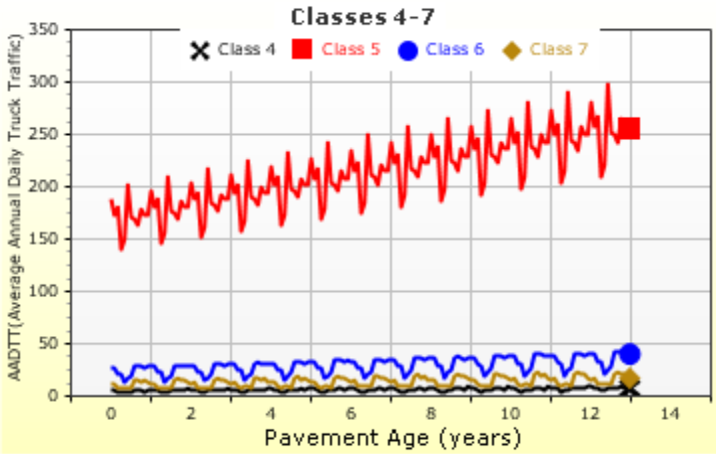
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12	15	18
Percent of Trucks (%)	33	33	34

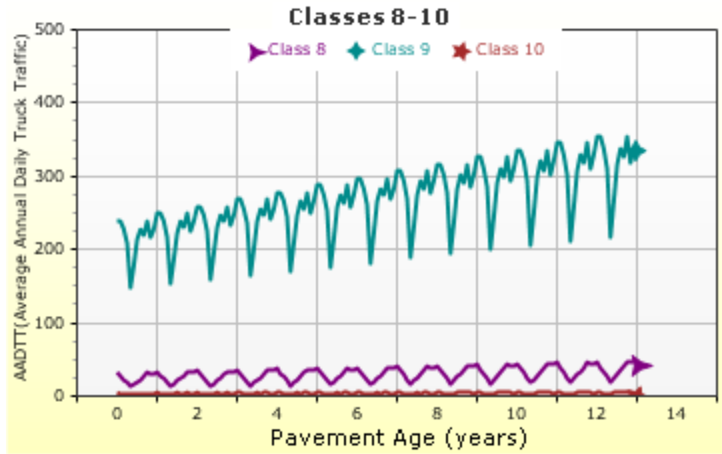
Number of Axles per Truck

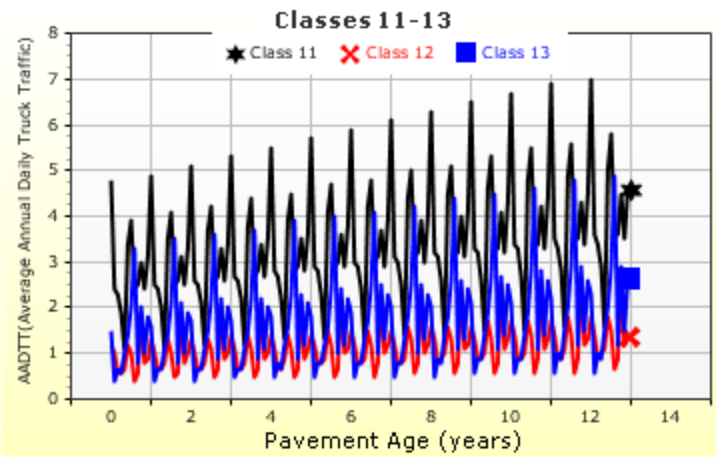
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.7	0.29	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.18	0.18	0.63	0.18
Class 8	2.21	0.78	0	0
Class 9	1.48	1.75	0	0
Class 10	1.08	0.99	0.94	0.03
Class 11	4.43	0.03	0.16	0
Class 12	3.29	1.09	0.17	0
Class 13	2.7	1.22	0.43	0.24

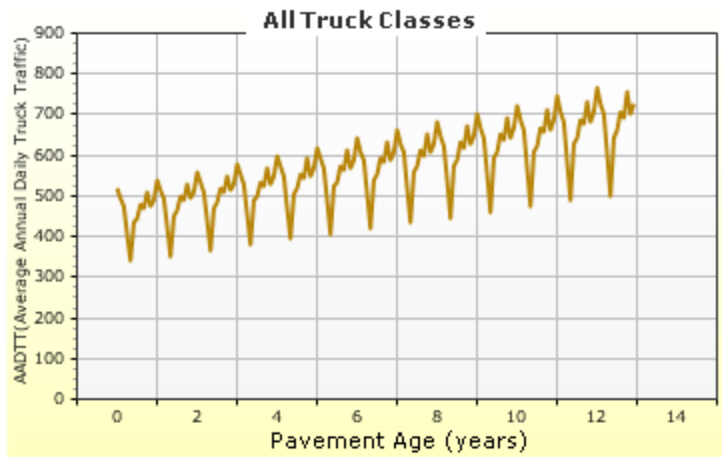
AADTT (Average Annual Daily Truck Traffic) Growth

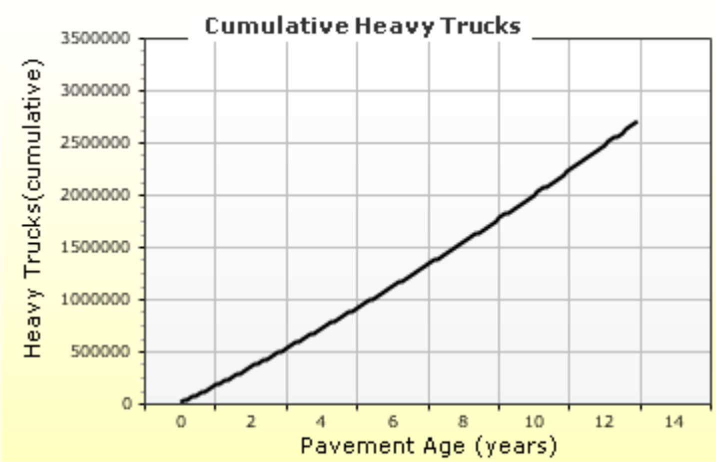
*** Traffic cap is not enforced**







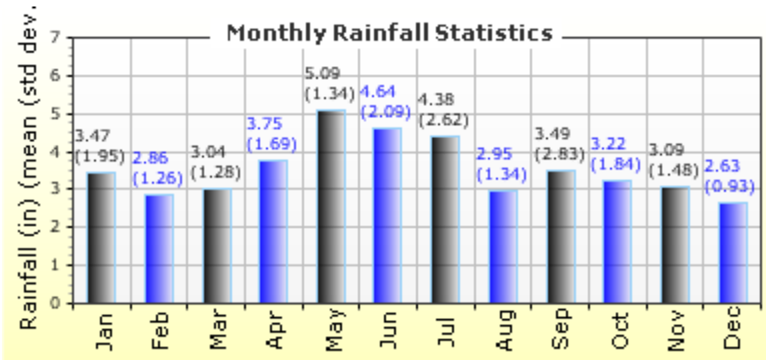




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

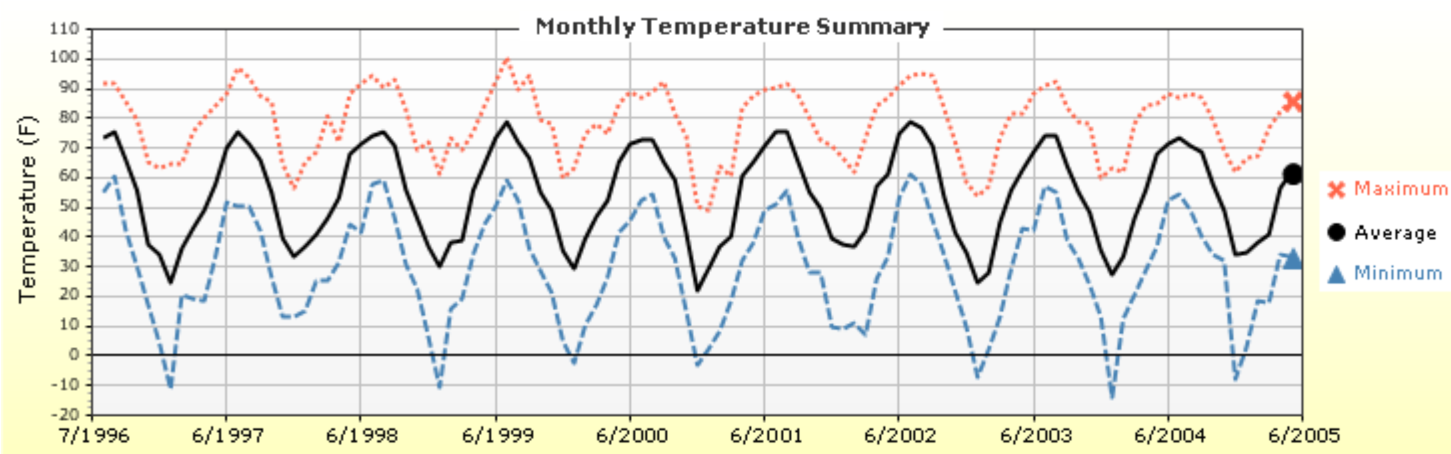


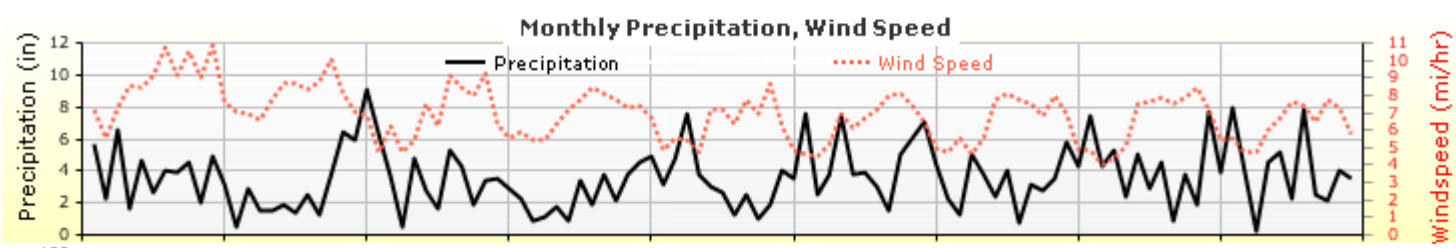
Annual Statistics:

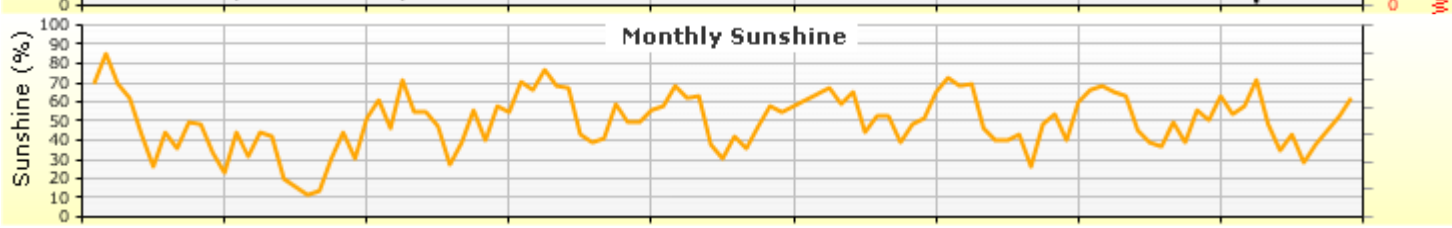
Mean annual air temperature (ºF)	54.41
Mean annual precipitation (in.)	42.59
Freezing index (ºF - days)	409.02
Average annual number of freeze/thaw cycles:	61.76

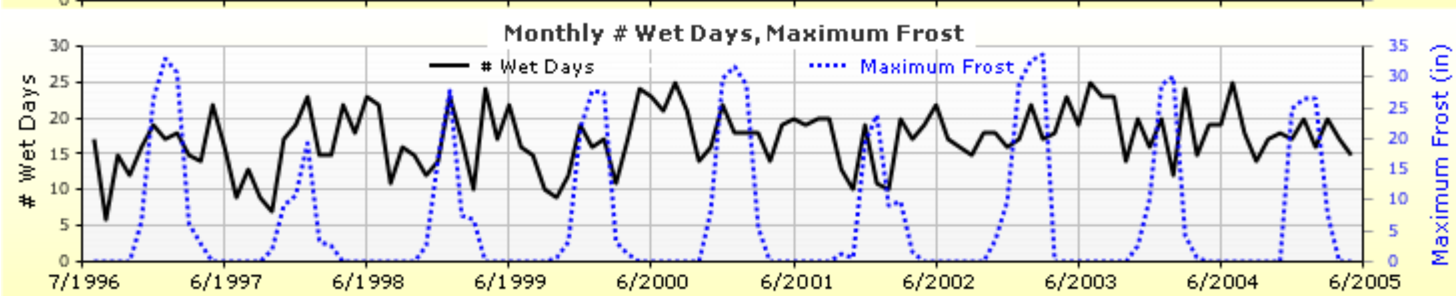
Water table depth (ft) 5.00

Monthly Climate Summary:

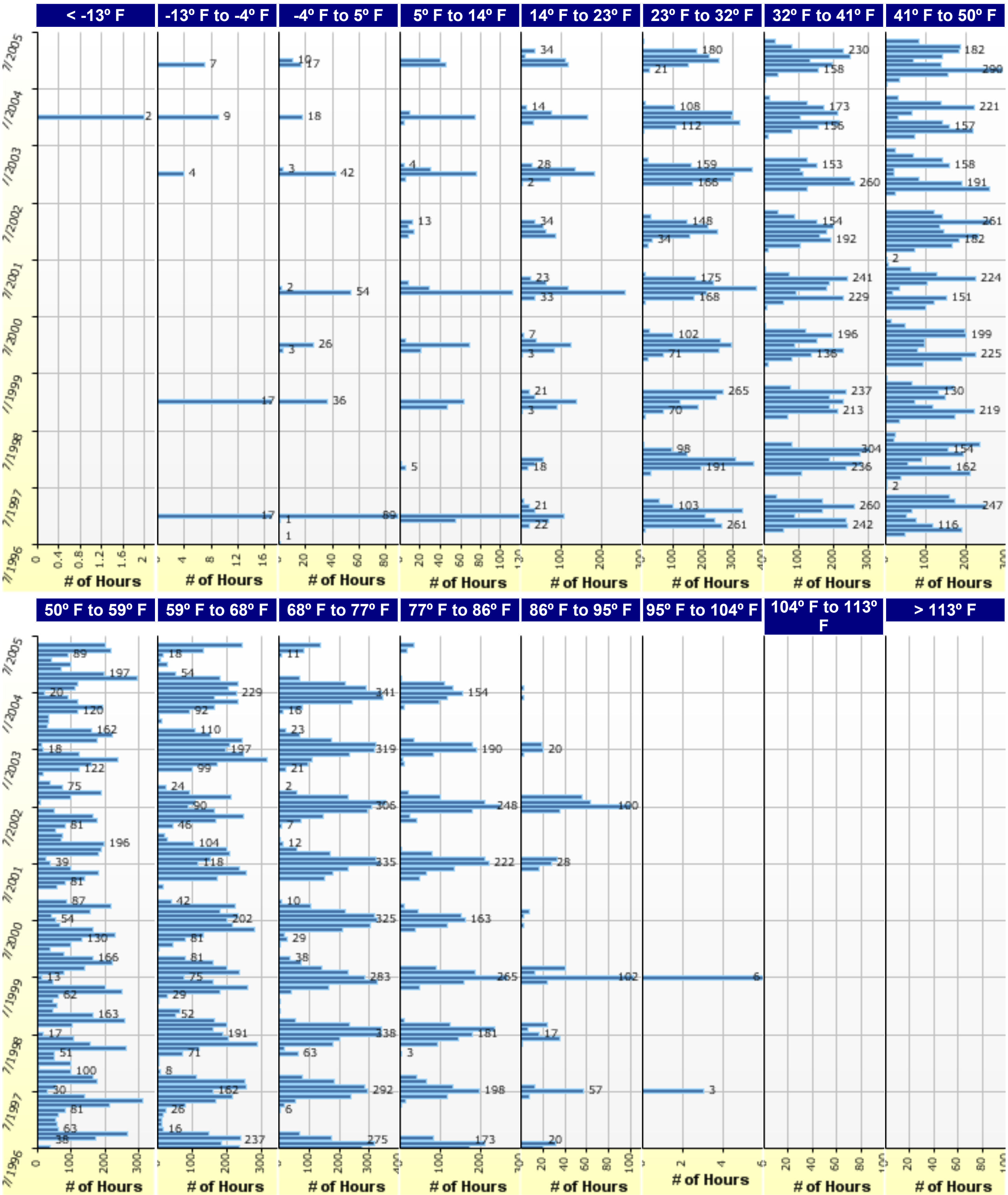








Hourly Air Temperature Distribution by Month:



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 : Seymour 9.5mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Existing HMA	Flexible (1)	1.00
Layer 3 PCC : JPCP Default	PCC (0)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

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	False
Load transfer efficiency (%)	-

PCC joint spacing (ft)	
Is joint spacing random ?	False
Joint spacing (ft)	18.00

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	600.00

Sealant type	Preformed

Erodibility index	2

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

JPCP Rehabilitation Properties

Slabs distressed/replaced before restoration (%)	0.00
Slabs repaired/replaced after restoration (%)	0.00

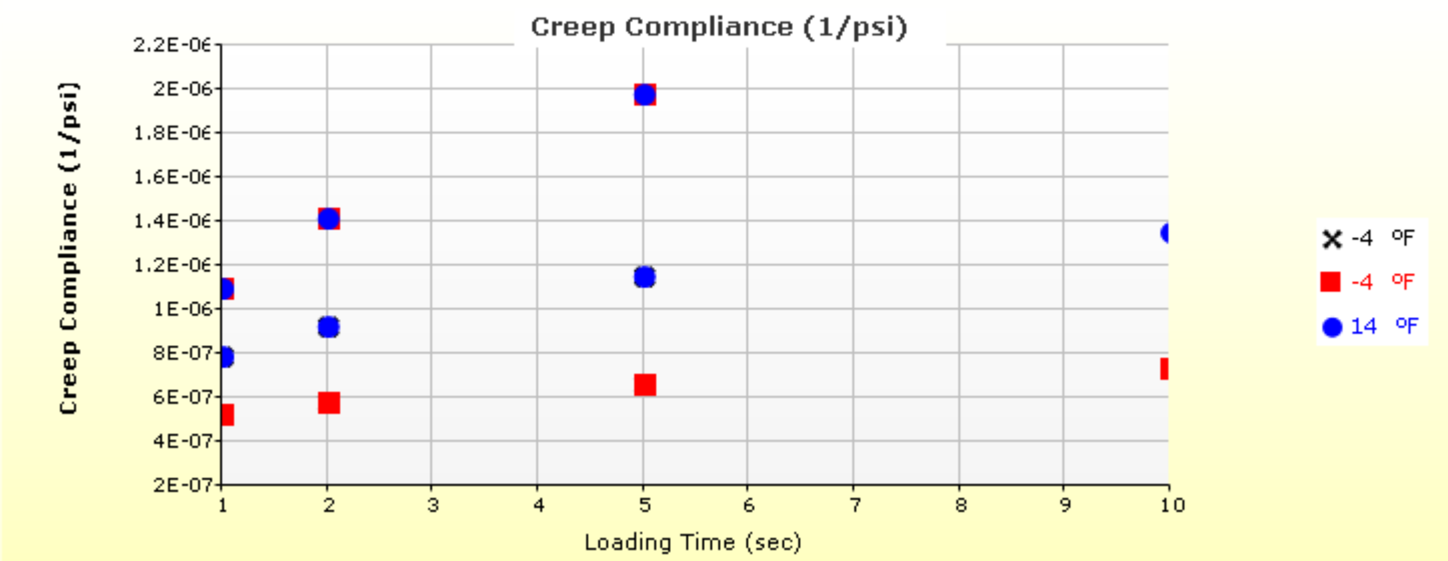
Modulus Subgrade Reaction	
Is modulus of subgrade reaction measured?	False
Month modulus of subgrade reaction measured	-
Dynamic modulus of subgrade reaction (psi/in.)	-

Thermal Cracking (Input Level: 3)

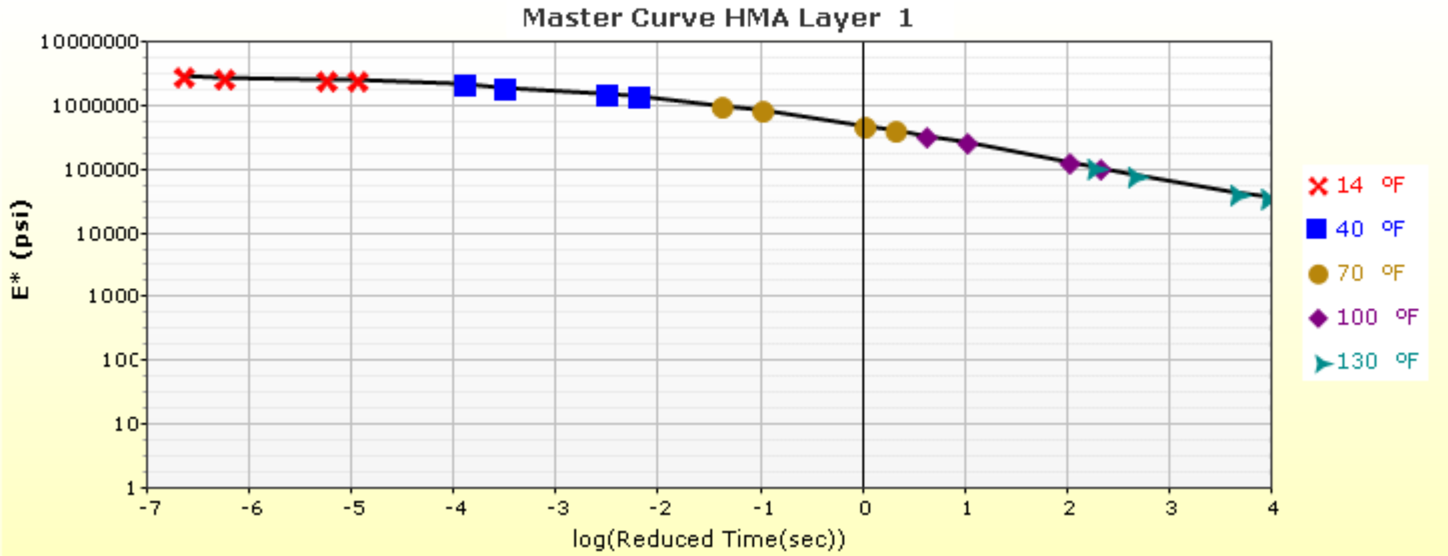
Indirect tensile strength at 14 ºF (psi)	444.45

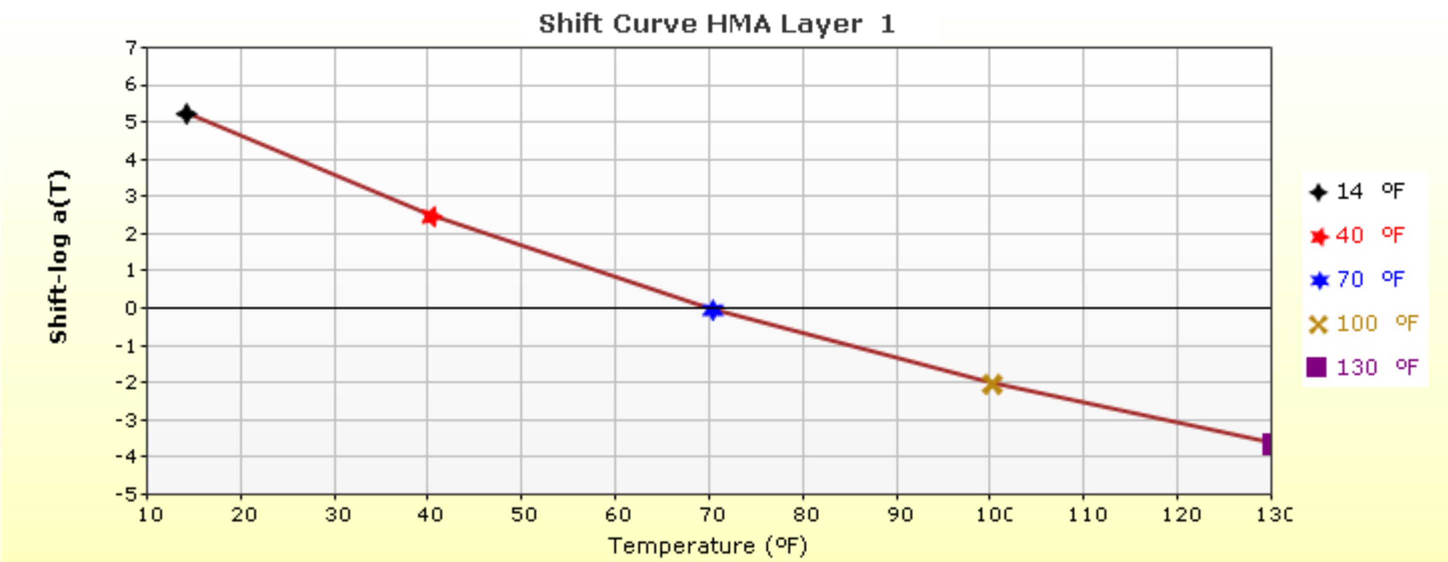
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

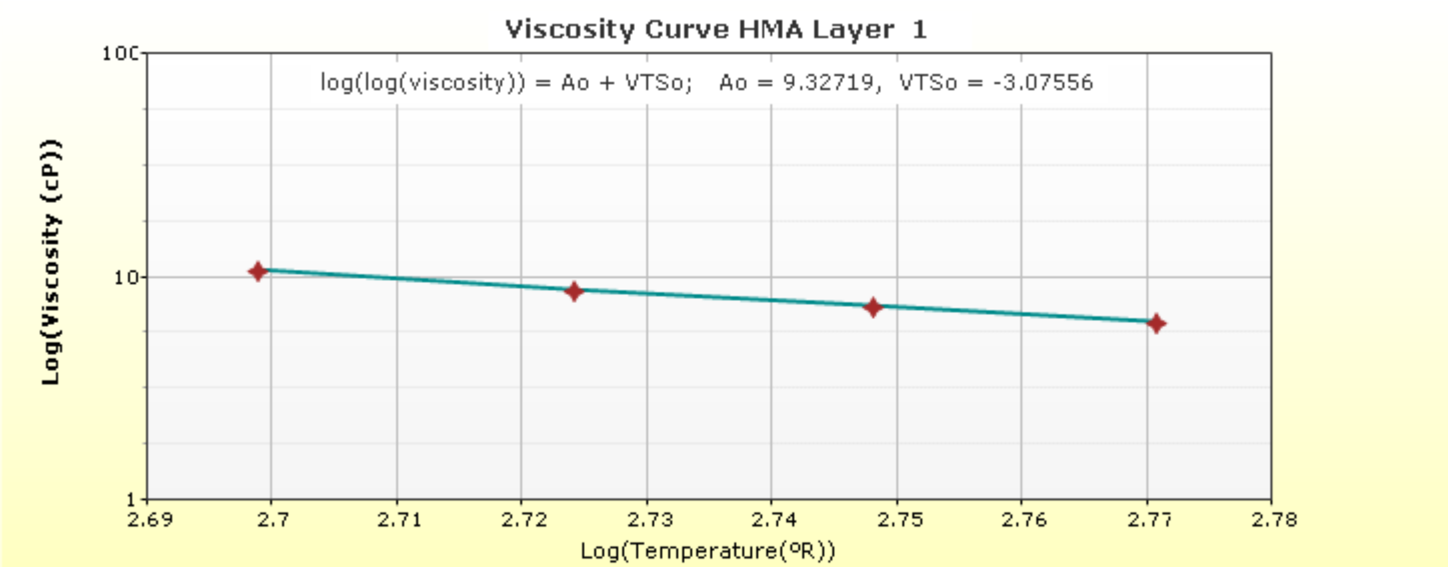
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	5.31e-007	5.31e-007	7.97e-007
1	7.97e-007	1.10e-006	1.10e-006
2	5.86e-007	5.86e-007	9.35e-007
2	9.35e-007	1.42e-006	1.42e-006
5	6.68e-007	6.68e-007	1.15e-006
5	1.15e-006	1.98e-006	1.98e-006
10	7.38e-007	7.38e-007	1.35e-006



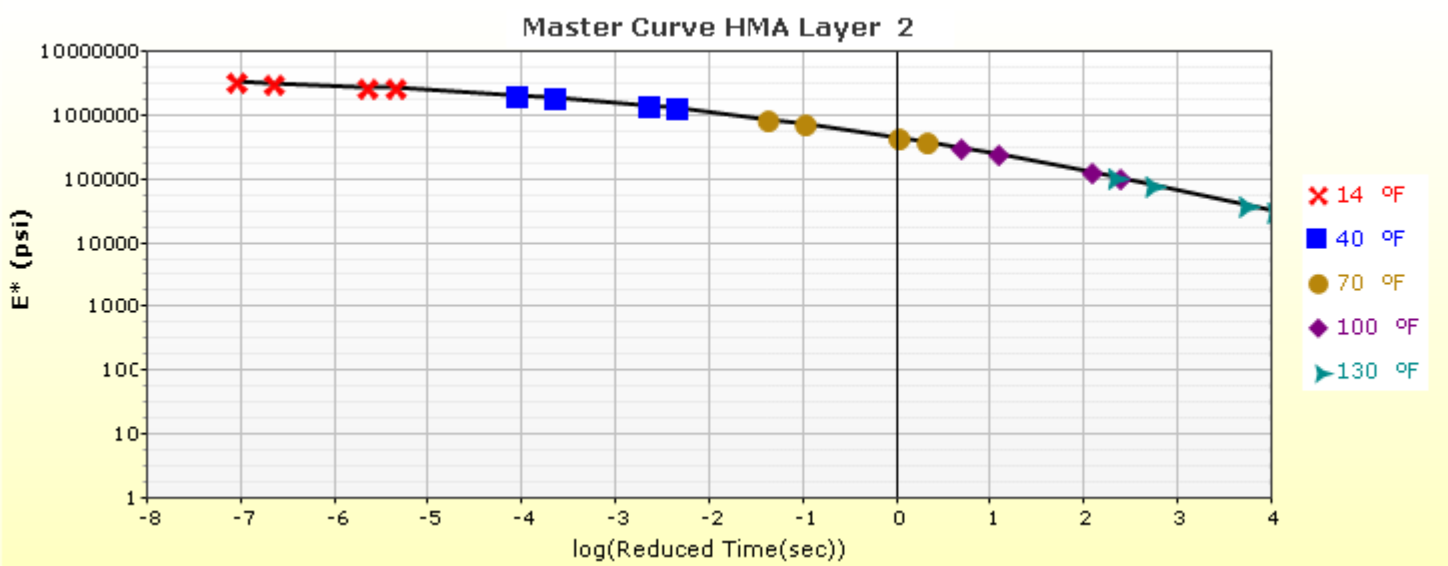
HMA Layer 1: Layer 1 Flexible : Seymour 9.5mm PG70-22

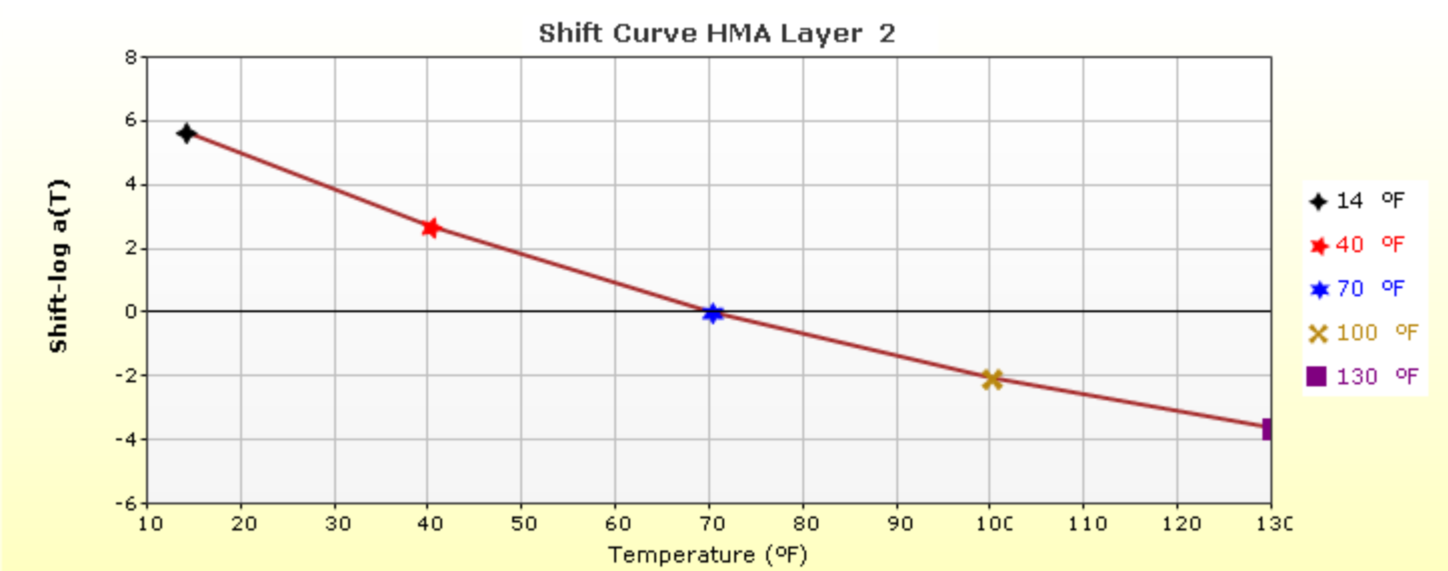


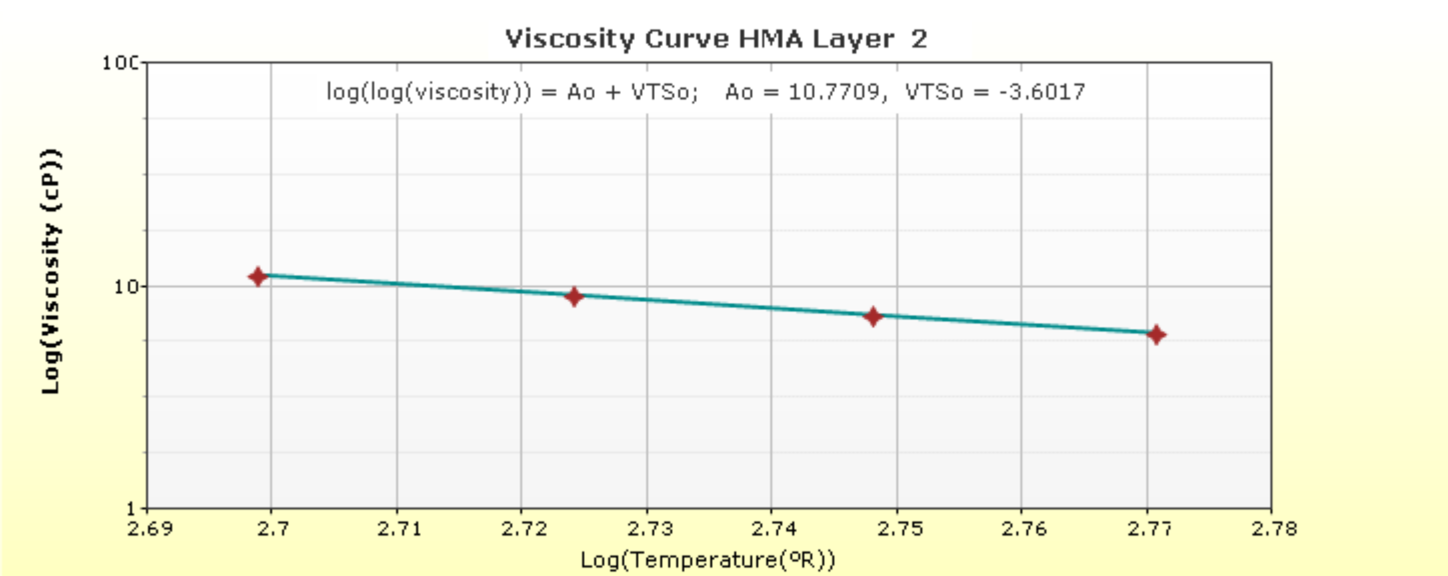




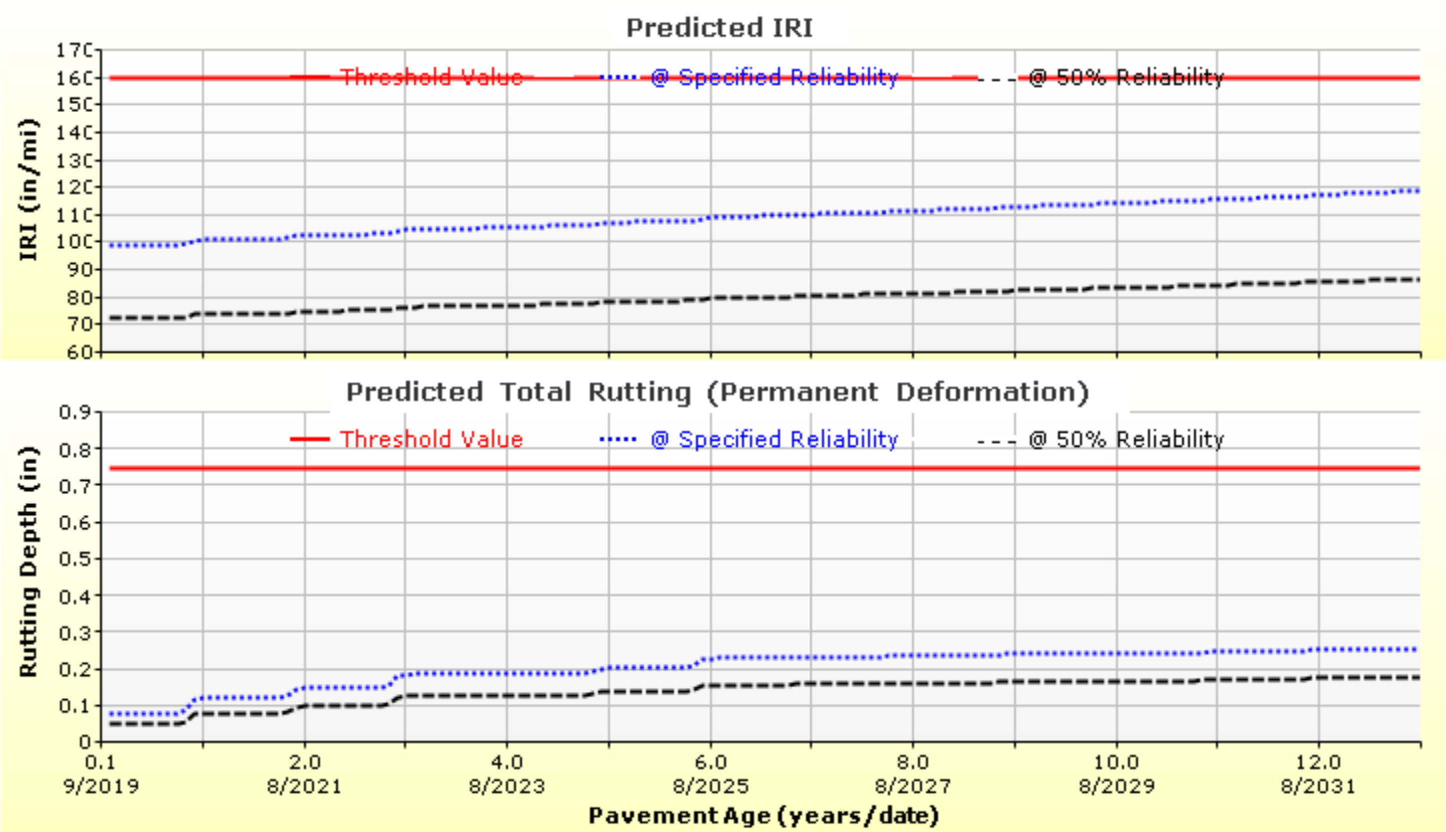
HMA Layer 2: Layer 2 Flexible : Existing HMA

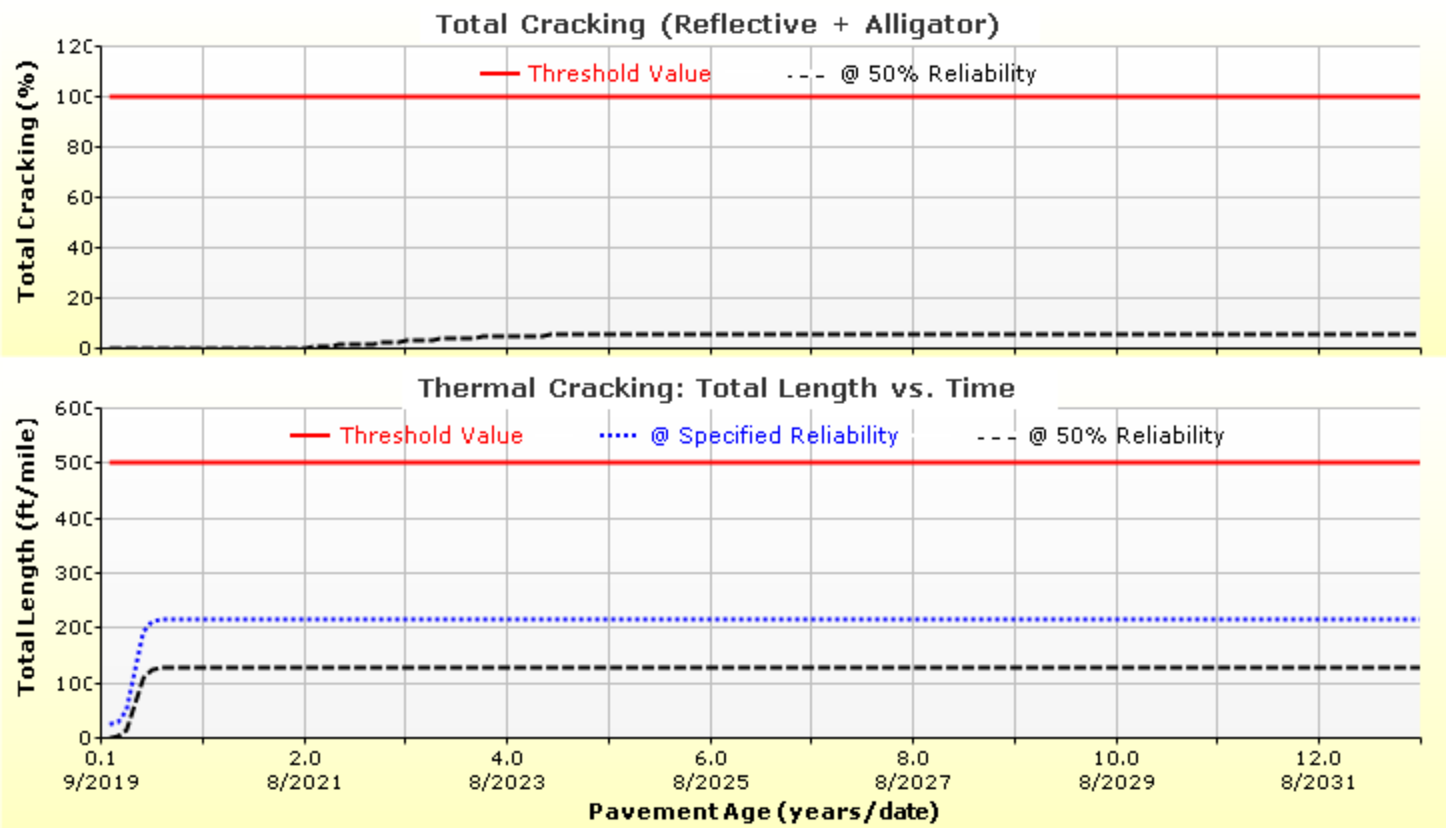


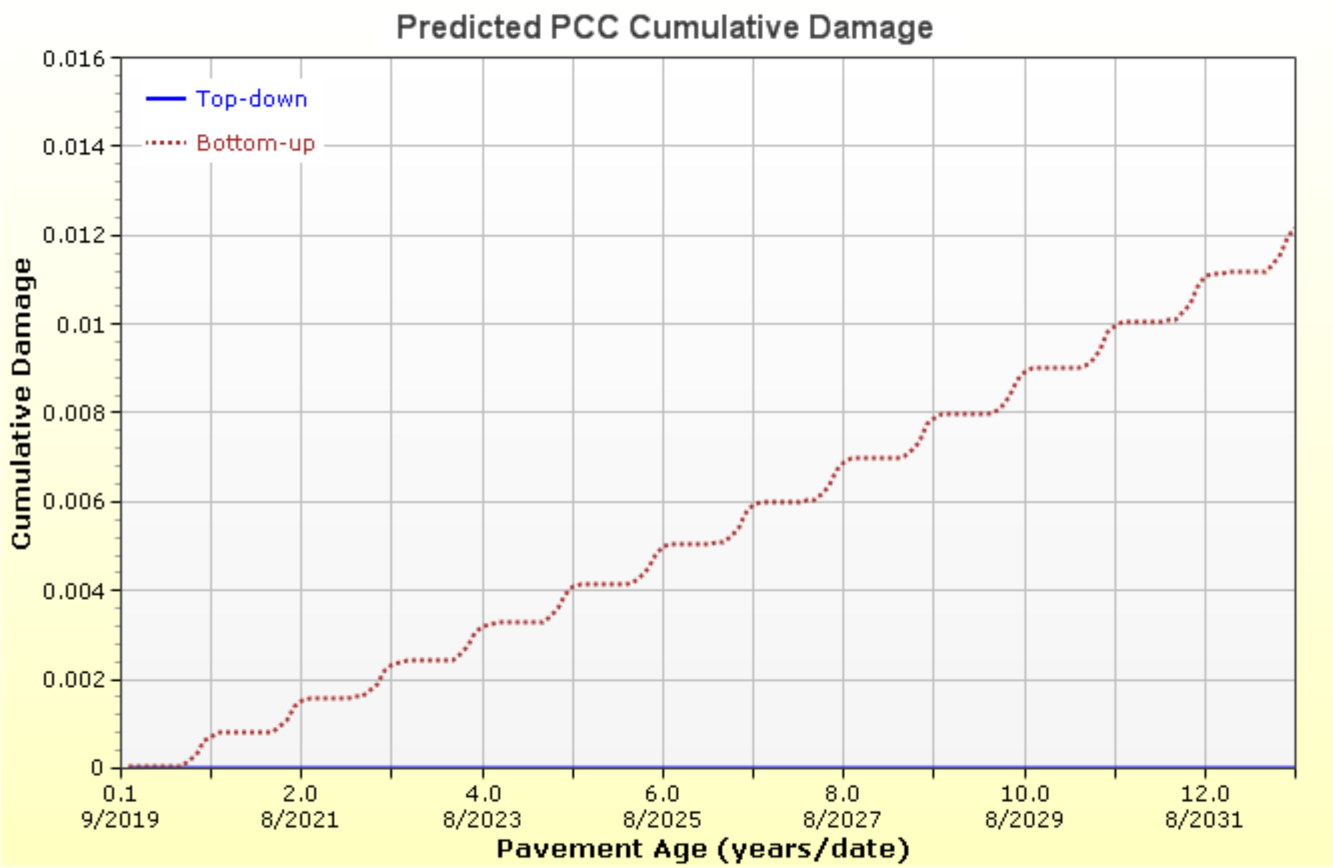




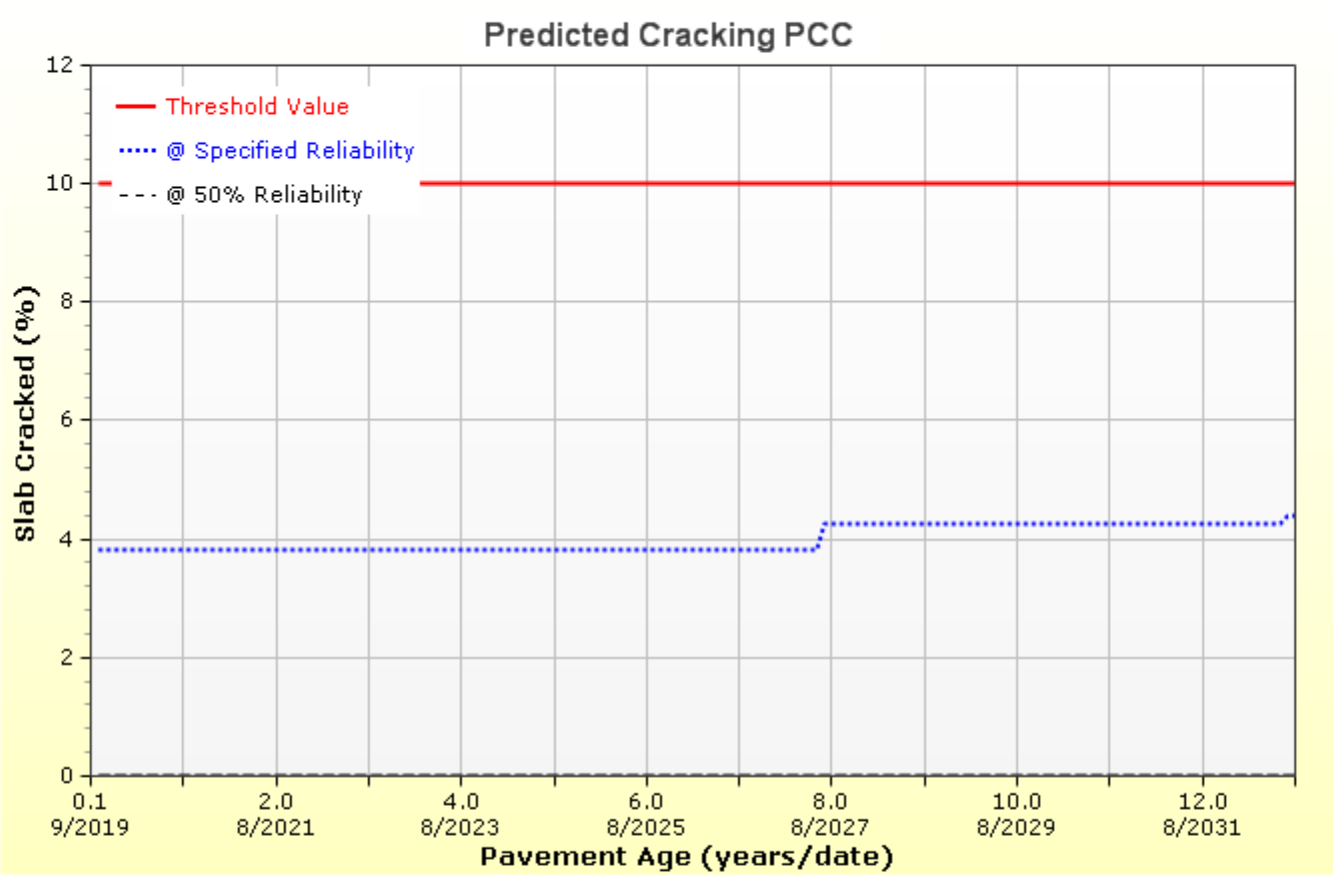
Analysis Output Charts



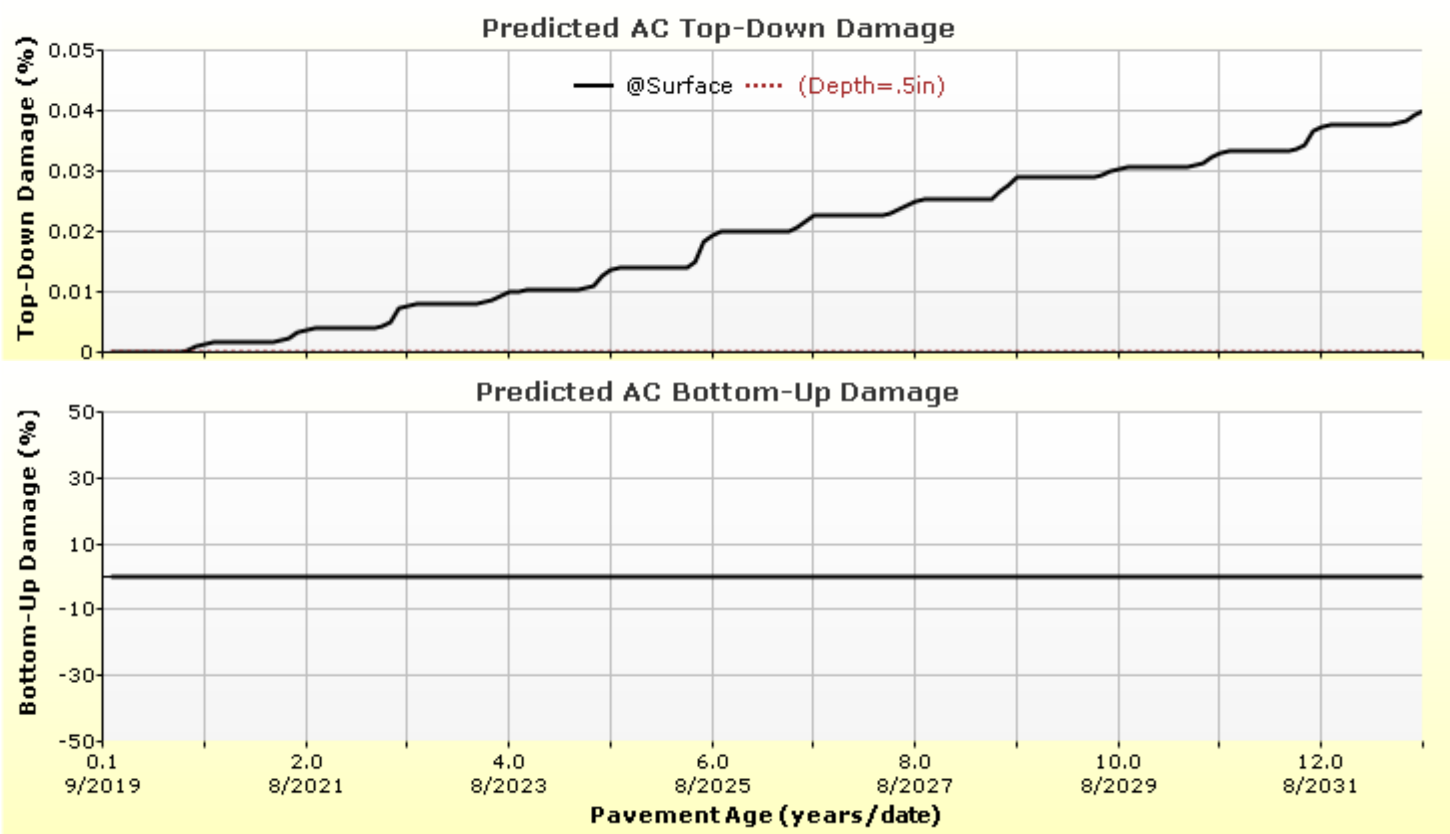




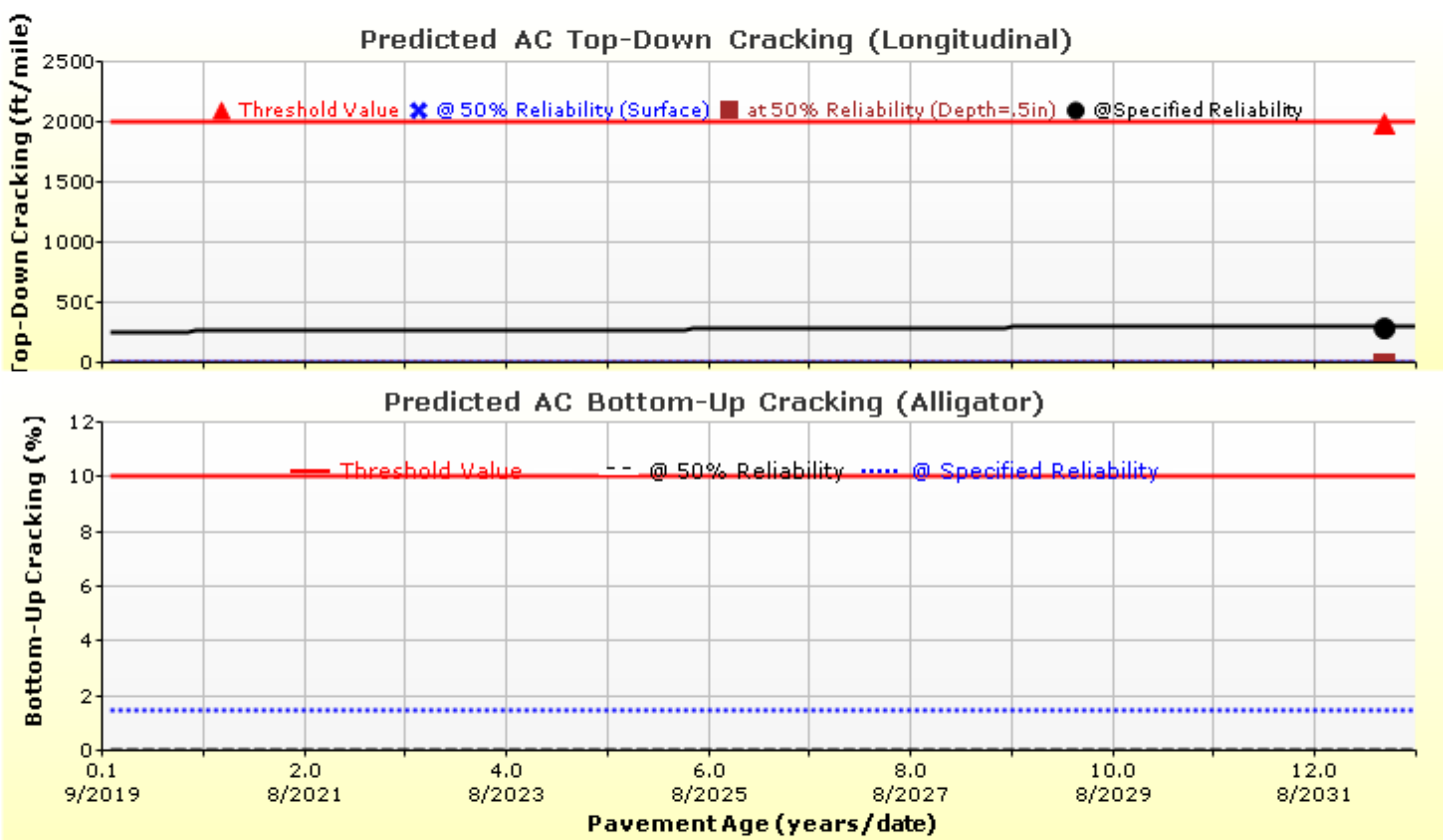
Predicted PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)



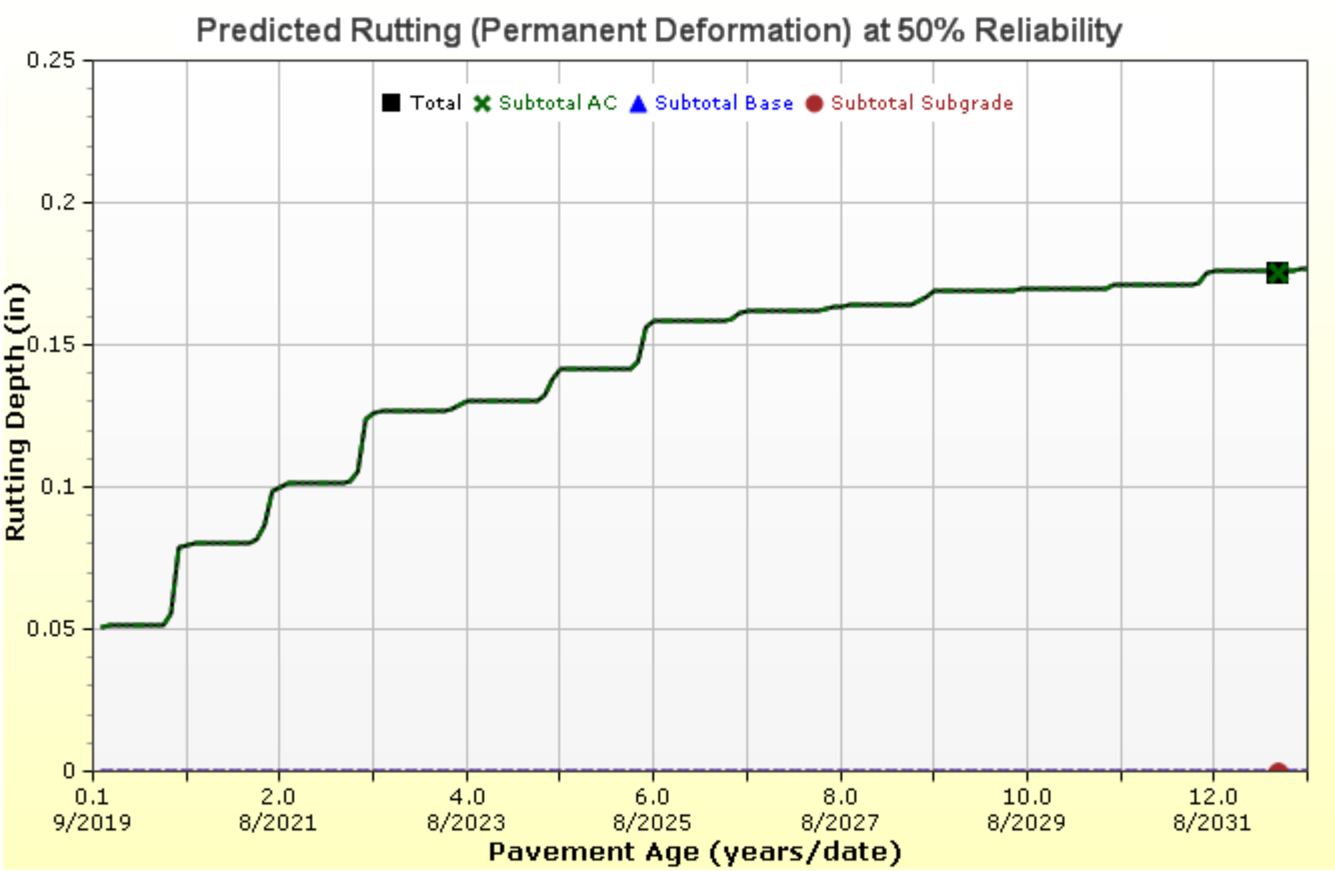
Predicted Cracking PCC
Threshold Value
@ Specified Reliability
@ 50% Reliability
Slab Cracked (%)
12
10
8
6
4
2
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)



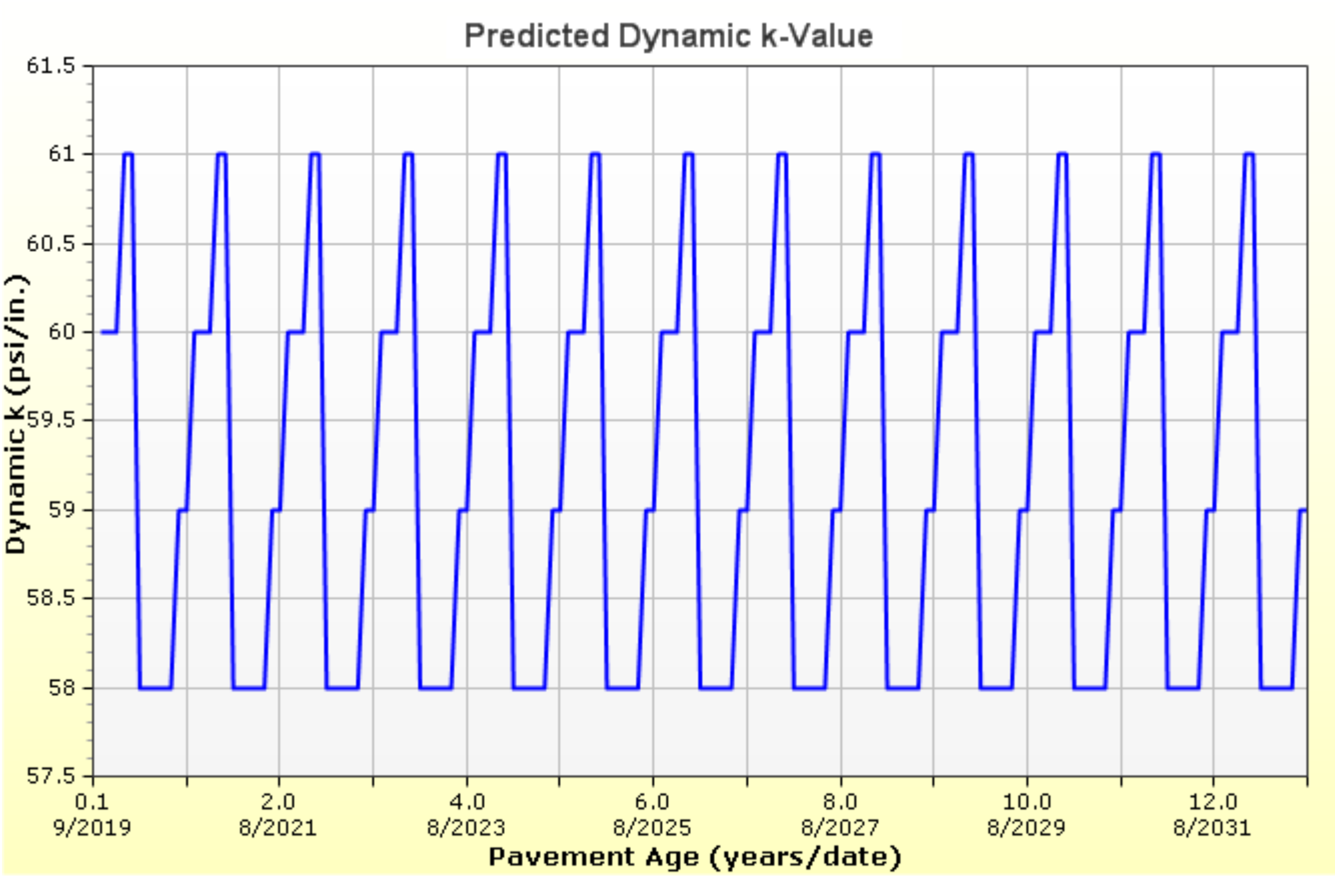
Predicted AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.05
0.04
0.03
0.02
0.01
0
Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
50
30
10
-10
-30
-50
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)



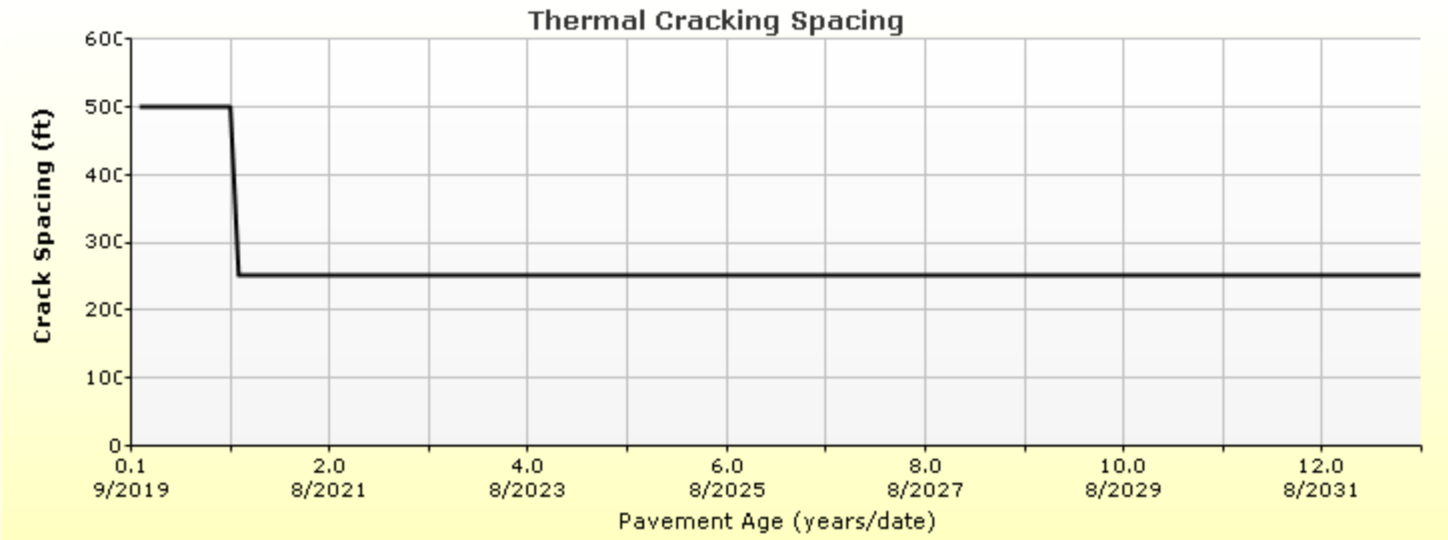
Predicted AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Predicted AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)

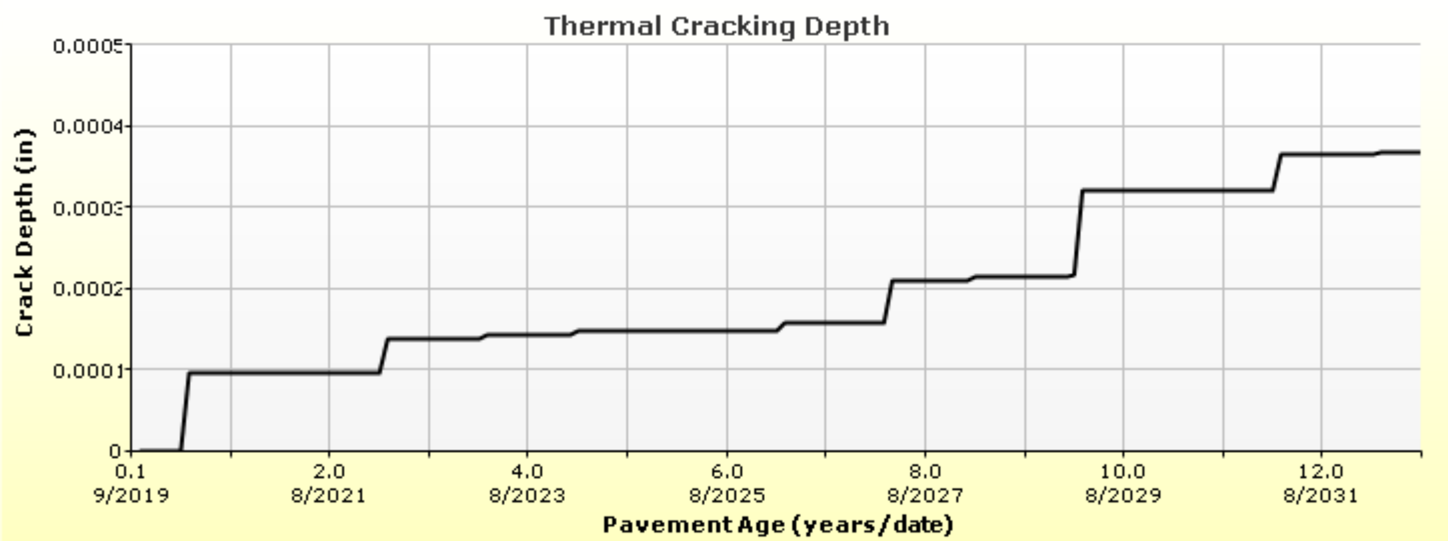


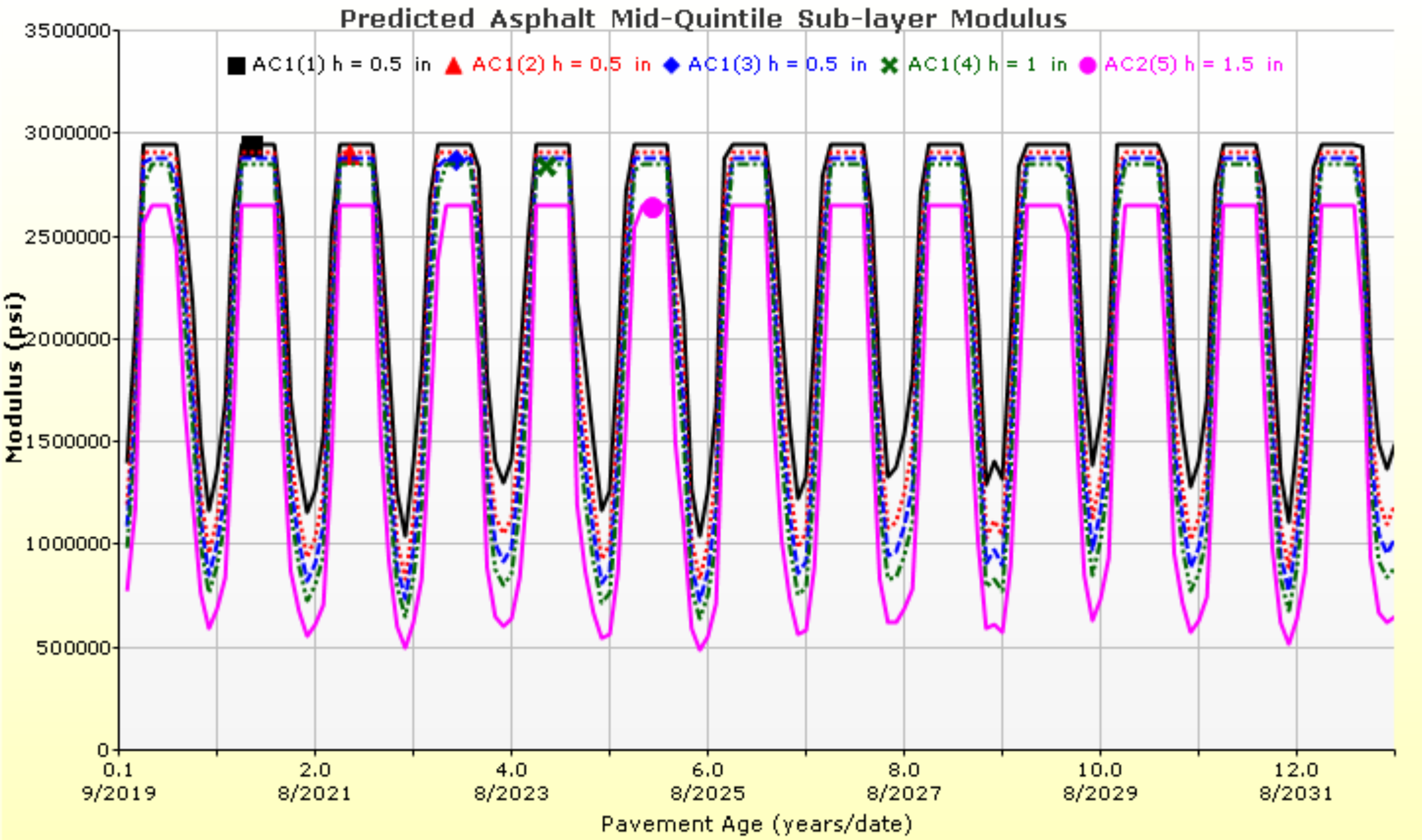
Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rutting Depth (in)
0.25
0.2
0.15
0.1
0.05
0
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)

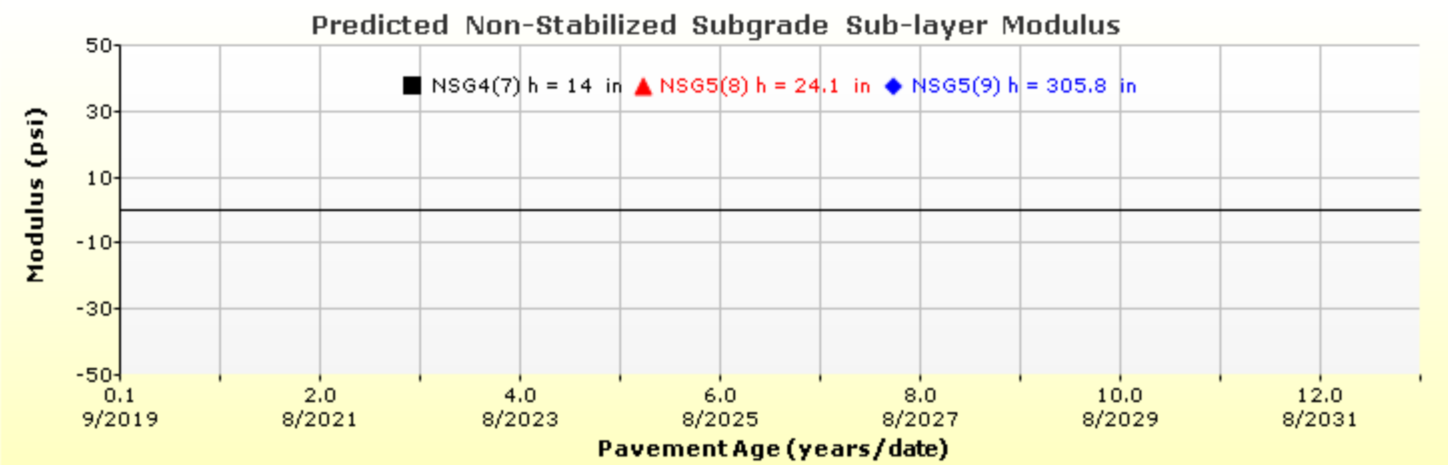


Predicted Dynamic k-Value
Dynamic k (psi/in.)
61.5
61
60.5
60
59.5
59
58.5
58
57.5
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)


Predicted Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 0.5 in
AC1(4) h = 1 in
AC2(5) h = 1.5 in
Modulus (psi)
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(7) h = 14 in
NSG5(8) h = 24.1 in
NSG5(9) h = 305.8 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Seymour 9.5mm PG70-22

Asphalt		
Thickness (in.)	1.5	
Unit weight (pcf)	142.6	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	1932546	2355005	2642382	3298195
40	1507676	1691777	1864079	2093353
70	262246	488012	733332	882731
100	55053	123973	246641	323256
130	24989	46973	96996	131550

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	22069340.66	33.76
55	9518271.99	44.39
70	2836317.75	52.87
85	765738.66	59.68
100	209102.28	65.17
115	60602.87	69.62
130	19021.84	73.24

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.61
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 9.5mm PG70-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : Existing HMA

Asphalt			
Thickness (in.)	2.5		
Unit weight (pcf)	143.8		
Poisson's ratio	Is Calculated?	False	
	Ratio	0.35	
	Parameter A	-	
	Parameter B	-	

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
3/4-inch sieve	97
3/8-inch sieve	69
No.4 sieve	43
No.200 sieve	2

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10
Air voids (%)	6
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Existing HMA
Description of object	Existing HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 3 PCC : JPCP Default

PCC	
Thickness (in.)	8.0
Unit weight (pcf)	150.0
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in./in./ºF x 10^-6)	5.5
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)		600
Water to cement ratio		0.42
Aggregate type		Dolomite (2)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	108.5
Ultimate shrinkage (microstrain)	Calculated Internally?	True
	User Value	-
	Calculated Value	632.3
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 3)

28-Day PCC modulus of rupture (psi)	690.0
28-Day PCC elastic modulus (psi)	-

Identifiers

Field	Value
Display name/identifier	JPCP Default
Description of object	
Author	
Date Created	4/24/2017 2:12:27 PM
Approver	
Date approved	4/24/2017 2:12:27 PM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in.)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

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

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

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

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:0.07 Br2:1.9 Br3:0.4

Thermal Fracture

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

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

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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: 1	k1: 1.35	Bs1: 0.12
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

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

AC Bottom Up Cracking

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

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

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

AC Top Down Cracking				AC Bottom Up Cracking		
c1: 7	c2: 3.5	c3: 0	c4: 1000	c1: 1	c2: 1	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))		

CSM Cracking

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

C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation			
CTB*11			

IRI Flexible over PCC

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40.8	C2: 0.575	C3: 0.0014	C4: 0.00825

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: 1	C5: -1.98
PCC Reliability Cracking Standard Deviation			
Pow(5.3116*CRACK,0.3903) + 2.99			

Reflective Cracking

$$RC = \frac{100}{1 + e^{c.a + d.b.t}}$$

RC = Percent of cracks reflected, %
t = Time, years
h_{ac} = Overlay thickness(in)
a = 3.5 + 0.75(Heff)
b = $-0.688584 - 3.37302(Heff)^{-0.915469}$
c = 1
d = Calibration parameter (user input)

	AC over AC	AC over Rigid, Good Load Transfer	AC over Rigid, Poor Load Transfer
Heff	h_{ac}	$h_{ac} - 1$	$h_{ac} - 3$

Heff	Recommended Calibration Parameter - d	
	Delay Cracking by 2 years	Accelerate Cracking by 2 years
< 4"	0.6	3
4 – 6"	0.7	1.7
> 6"	0.8	1.4

C: 1	D: 1

SR 58 Ramps

File Name: C:\My ME Design\Projects\MK16-465 SE BV\170313 TP-App No 3\SR 58 Ramps.dgpx

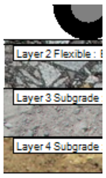
Design Inputs

Design Life: 13 years
Design Type: AC over AC

Existing construction: May, 2010
Pavement construction: July, 2019
Traffic opening: September, 2019

Climate Data Sources (Lat/Lon): 39.144, -86.617; 39.71, -86.272; 38.228, -85.664

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Seymour 9.5mm PG70-22	1.5
Flexible	Existing Asphalt Base	12.5
Subgrade	A-4	14.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	8.0

Traffic

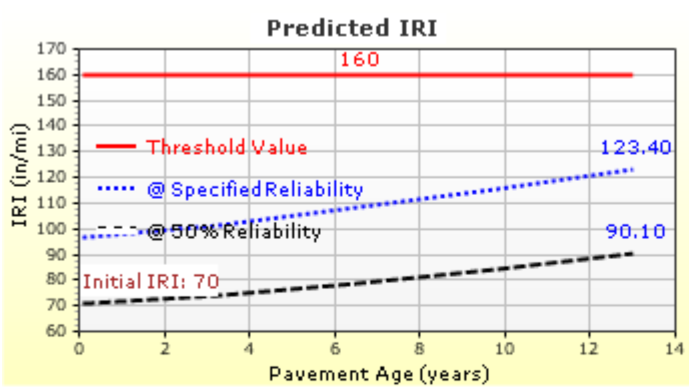
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	482
2025 (6 years)	1,204,070
2032 (13 years)	2,563,300

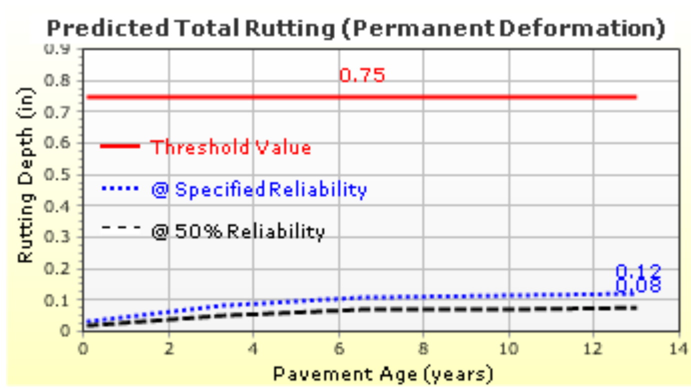
Design Outputs

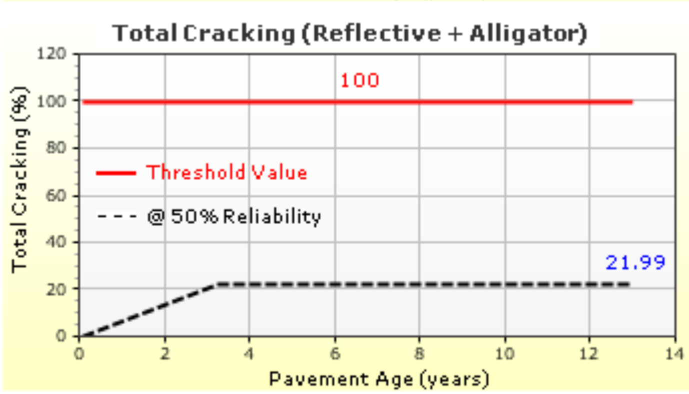
Distress Prediction Summary

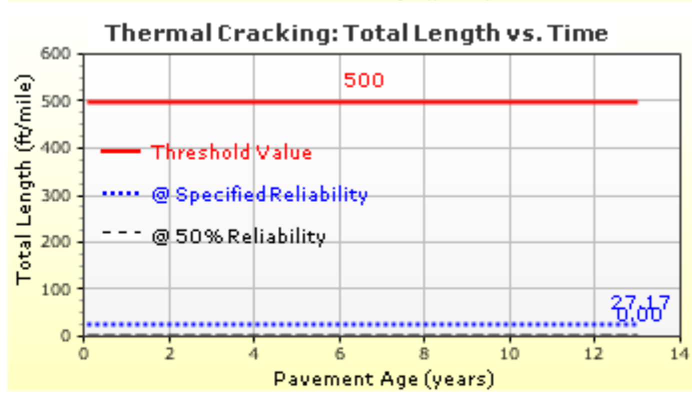
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	123.36	90.00	99.65	Pass
Permanent deformation - total pavement (in.)	0.75	0.12	90.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	100	21.99	-	-	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.45	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	256.72	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.12	90.00	100.00	Pass

Distress Charts





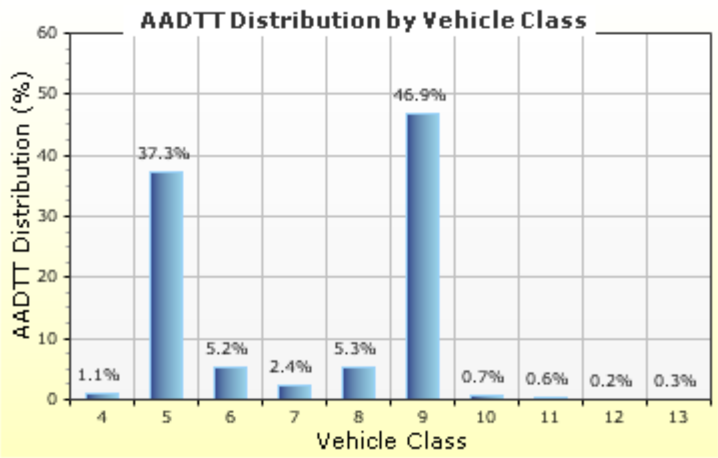


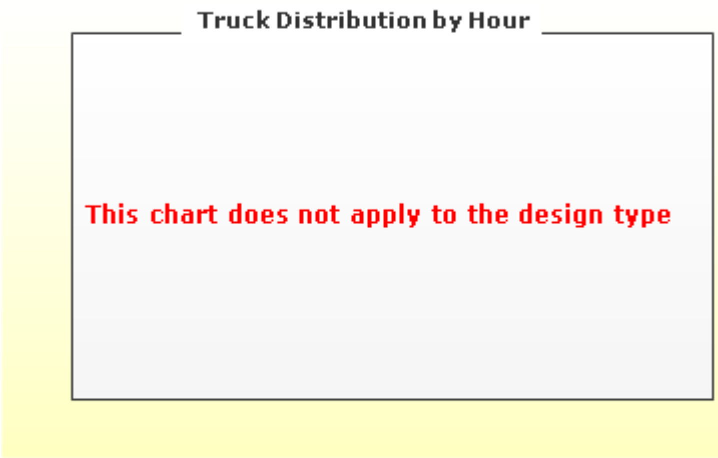


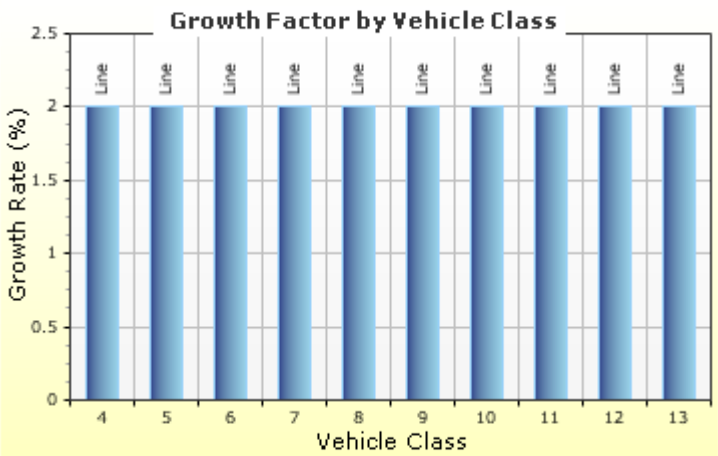
Traffic Inputs

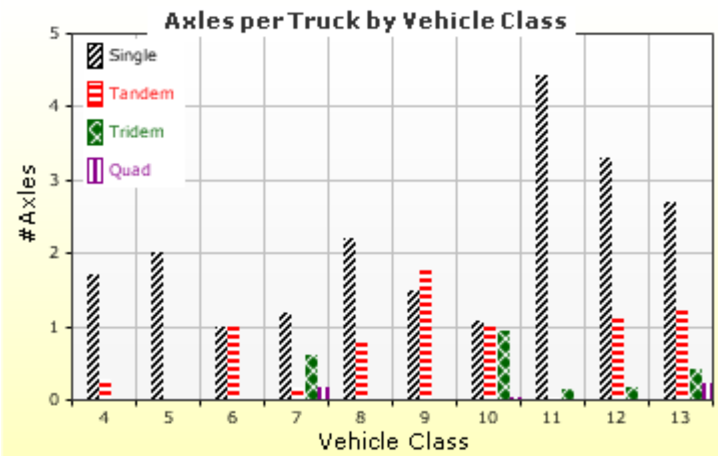
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	482	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)	55.0

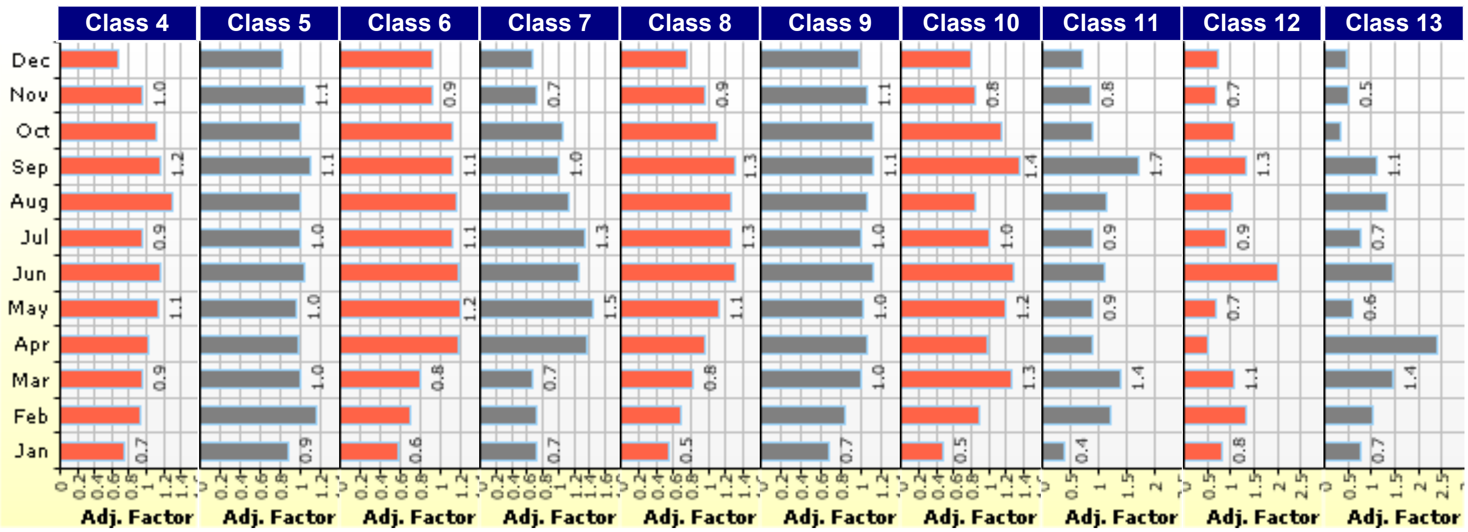








Traffic Volume Monthly Adjustment Factors



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	0.7	0.9	0.6	0.7	0.5	0.7	0.5	0.4	0.8	0.7
February	0.9	1.2	0.7	0.7	0.7	0.8	0.9	1.2	1.3	1.0
March	0.9	1.0	0.8	0.7	0.8	1.0	1.3	1.4	1.1	1.4
April	1.0	1.0	1.2	1.4	1.0	1.1	1.0	0.9	0.5	2.4
May	1.1	1.0	1.2	1.5	1.1	1.0	1.2	0.9	0.7	0.6
June	1.2	1.0	1.2	1.3	1.3	1.1	1.3	1.1	2.0	1.4
July	0.9	1.0	1.1	1.3	1.3	1.0	1.0	0.9	0.9	0.7
August	1.3	1.0	1.2	1.1	1.3	1.1	0.8	1.1	1.0	1.3
September	1.2	1.1	1.1	1.0	1.3	1.1	1.4	1.7	1.3	1.1
October	1.1	1.0	1.1	1.1	1.1	1.1	1.2	0.9	1.1	0.3
November	1.0	1.1	0.9	0.7	0.9	1.1	0.8	0.8	0.7	0.5
December	0.7	0.8	0.9	0.7	0.7	1.0	0.8	0.7	0.7	0.5

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.1%	2%	Linear
Class 5	37.3%	2%	Linear
Class 6	5.2%	2%	Linear
Class 7	2.4%	2%	Linear
Class 8	5.3%	2%	Linear
Class 9	46.9%	2%	Linear
Class 10	0.7%	2%	Linear
Class 11	0.6%	2%	Linear
Class 12	0.2%	2%	Linear
Class 13	0.3%	2%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

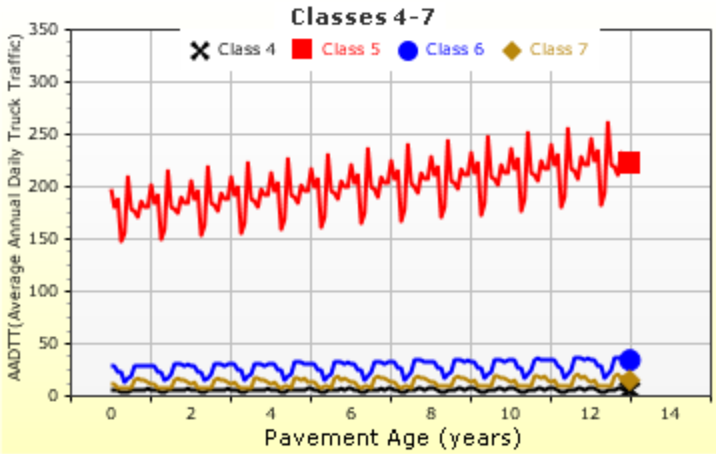
Wheelbase does not apply

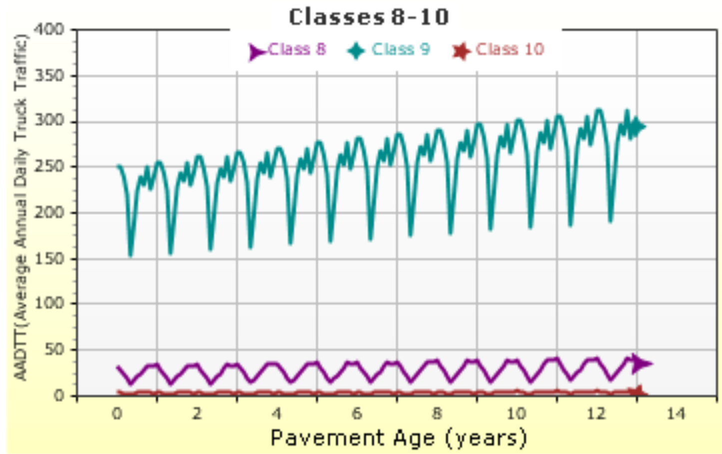
Number of Axles per Truck

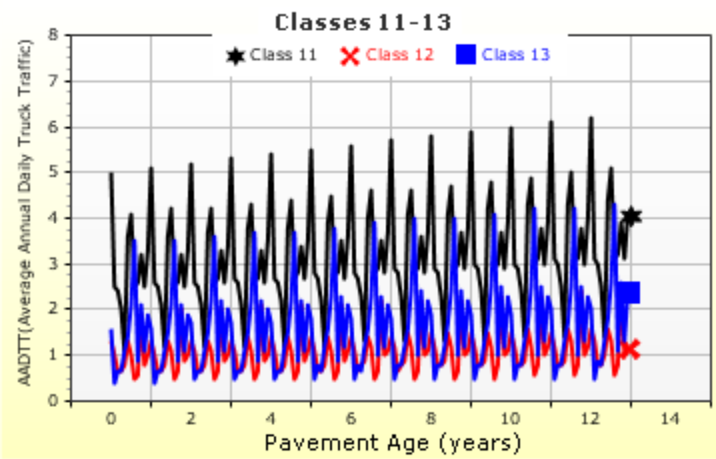
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.7	0.29	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.18	0.18	0.63	0.18
Class 8	2.21	0.78	0	0
Class 9	1.48	1.75	0	0
Class 10	1.08	0.99	0.94	0.03
Class 11	4.43	0.03	0.16	0
Class 12	3.29	1.09	0.17	0
Class 13	2.7	1.22	0.43	0.24

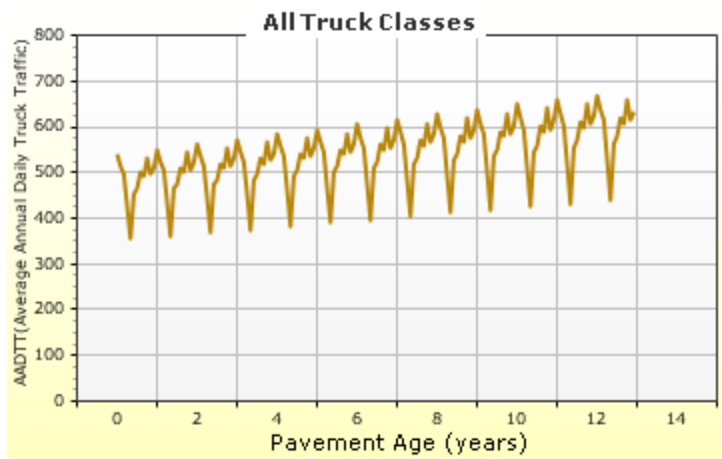
AADTT (Average Annual Daily Truck Traffic) Growth

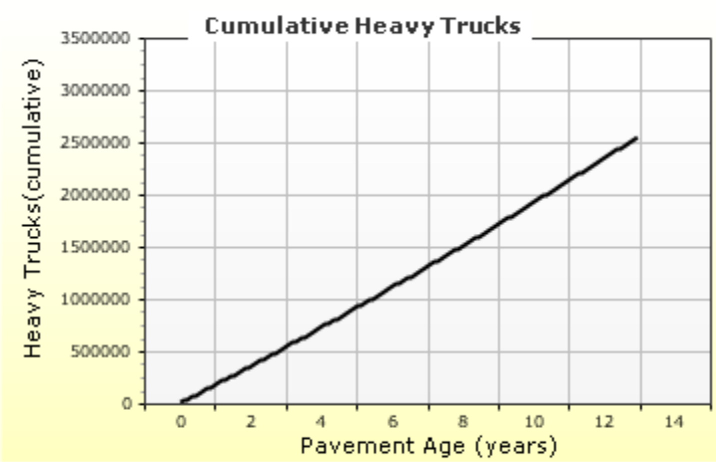
*** Traffic cap is not enforced**











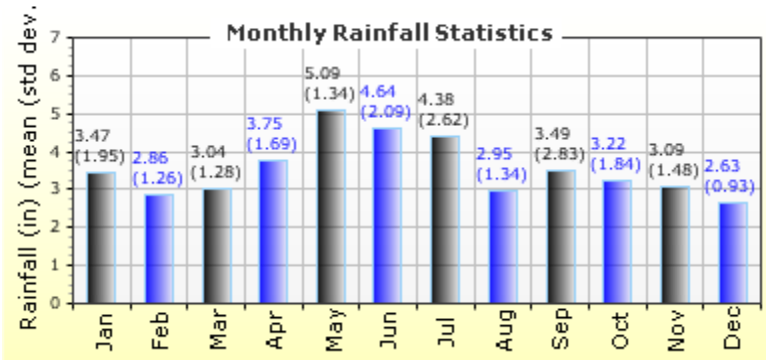
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

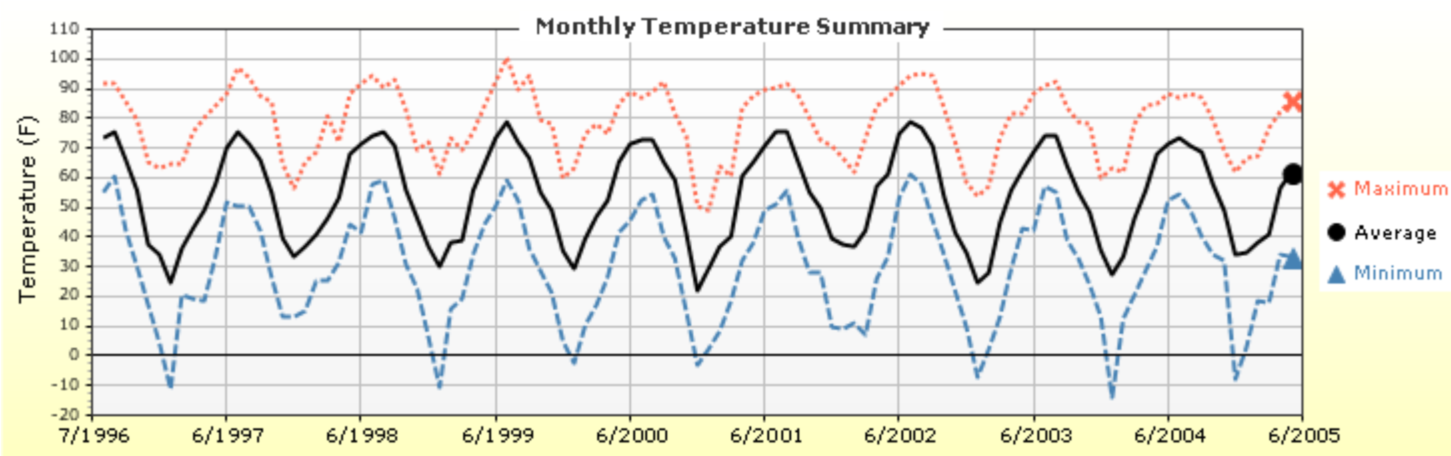
Annual Statistics:

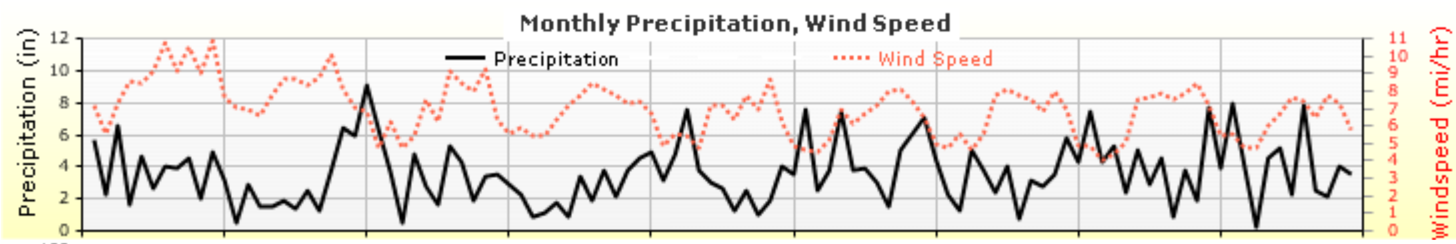
Mean annual air temperature (ºF)	54.41
Mean annual precipitation (in.)	42.59
Freezing index (ºF - days)	409.02
Average annual number of freeze/thaw cycles:	61.76

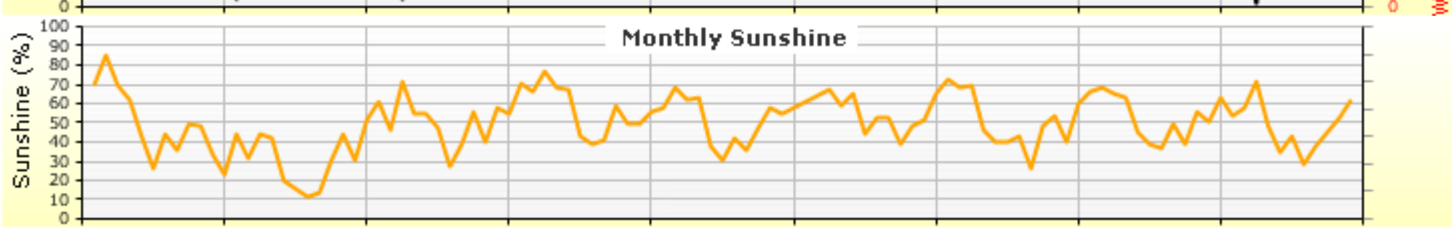


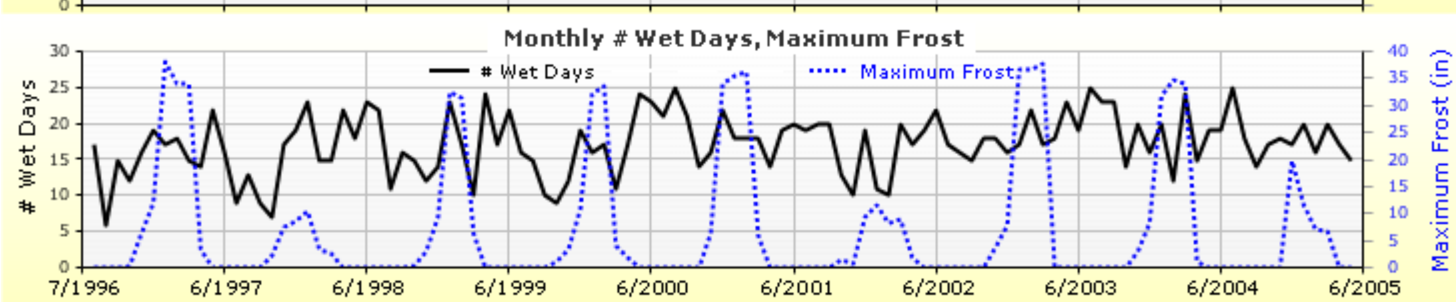
Water table depth (ft) 5.00

Monthly Climate Summary:

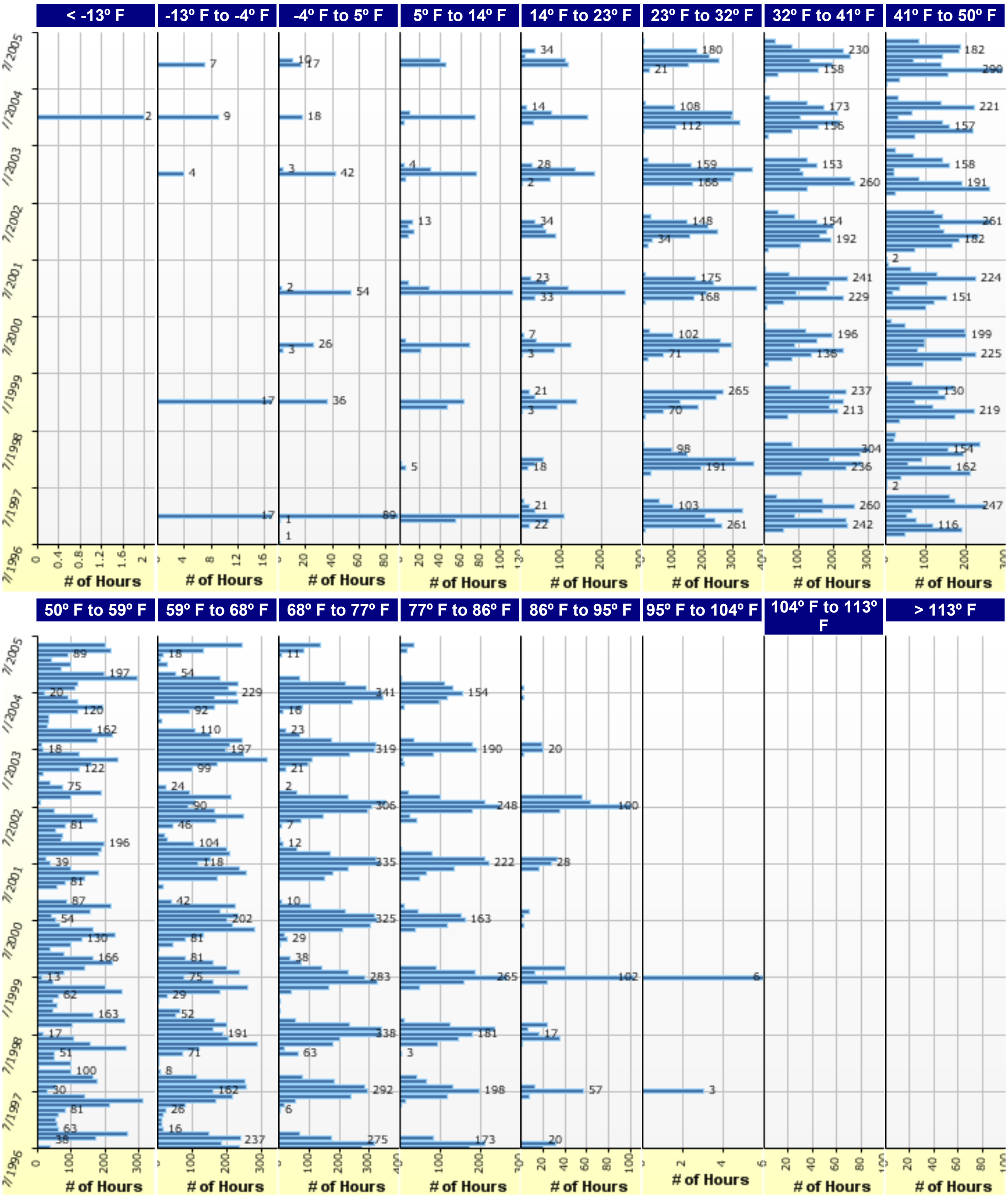








Hourly Air Temperature Distribution by Month:



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 : Seymour 9.5mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Existing Asphalt Base(existing)	Flexible (1)	1.00
Layer 3 Subgrade : A-4	Subgrade (5)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	-

HMA Rehabilitation (Input Level: 3)

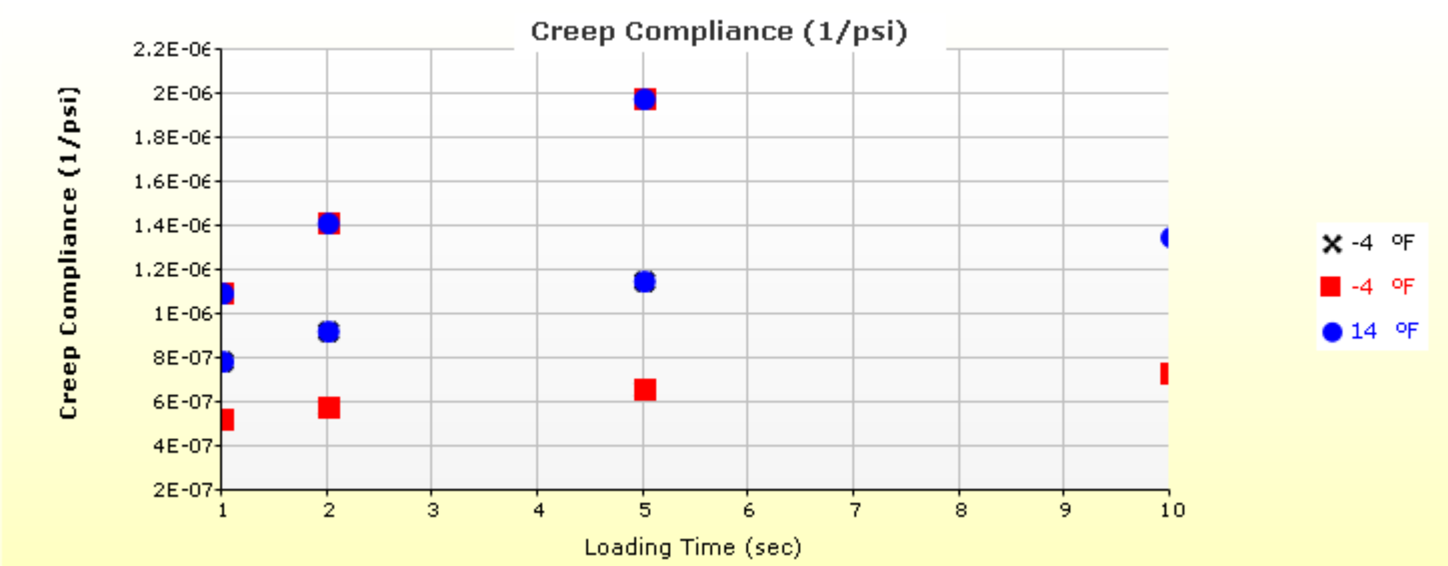
Milled thickness (in.)	-
Fatigue cracking (%)	-
Pavement rating	Good
Total rut depth (in.)	0.10

Thermal Cracking (Input Level: 3)

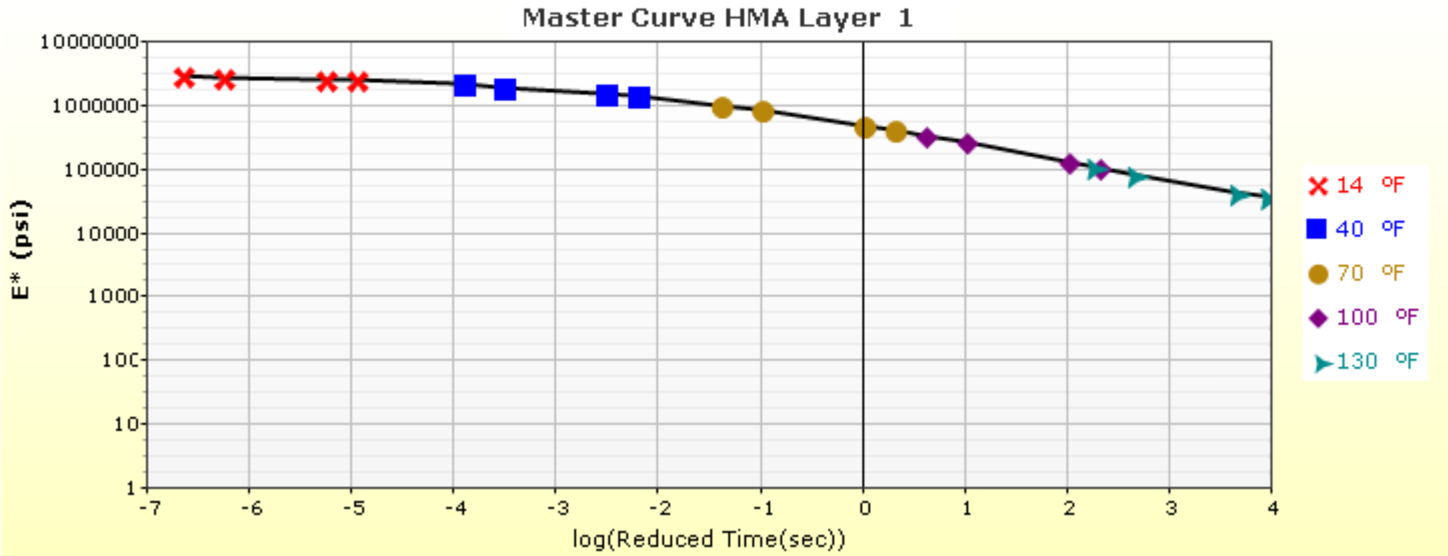
Indirect tensile strength at 14 ºF (psi)	444.45

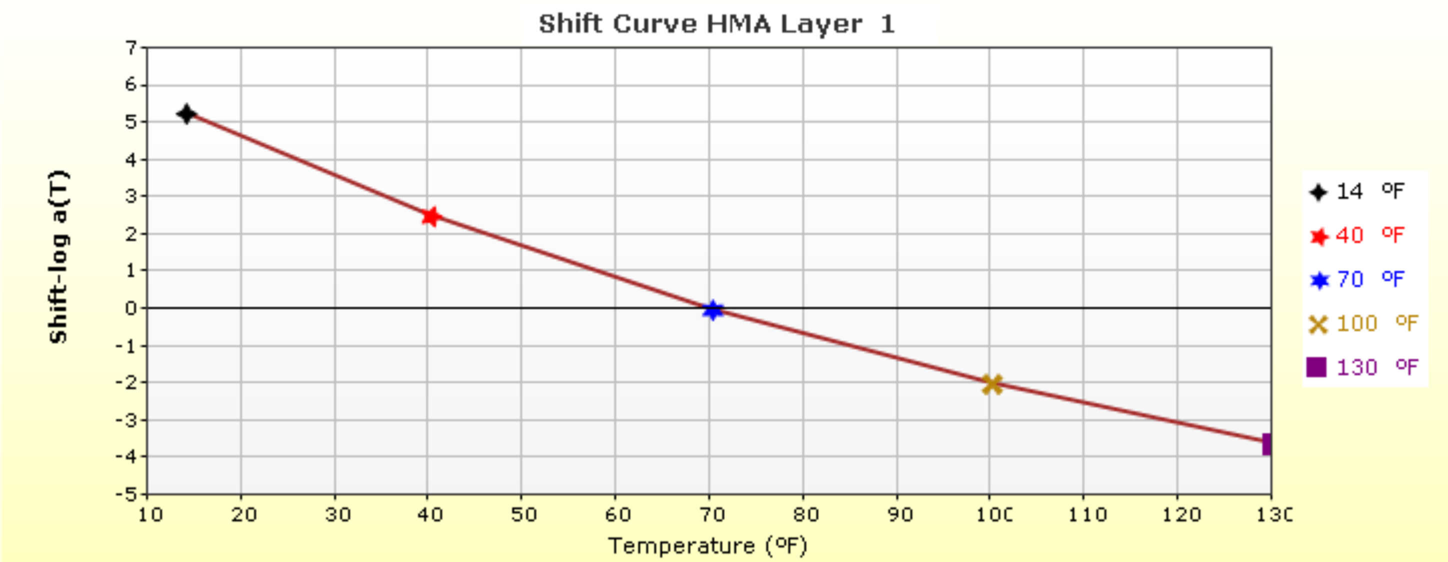
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

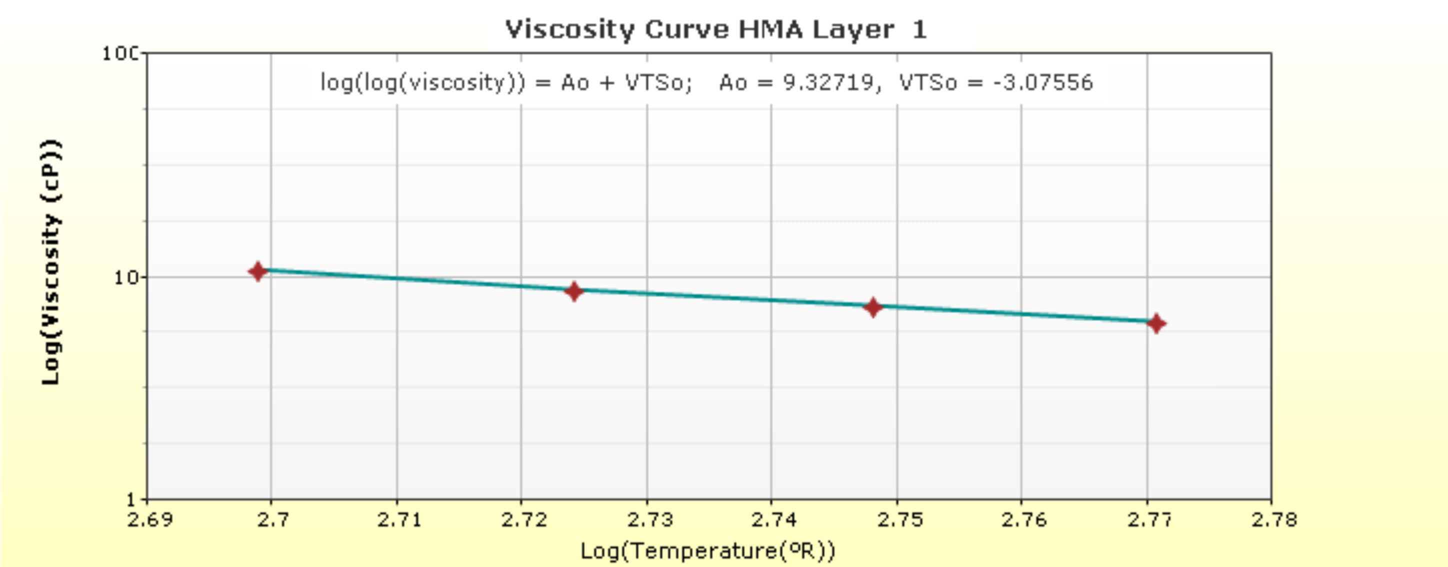
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	5.31e-007	5.31e-007	7.97e-007
1	7.97e-007	1.10e-006	1.10e-006
2	5.86e-007	5.86e-007	9.35e-007
2	9.35e-007	1.42e-006	1.42e-006
5	6.68e-007	6.68e-007	1.15e-006
5	1.15e-006	1.98e-006	1.98e-006
10	7.38e-007	7.38e-007	1.35e-006



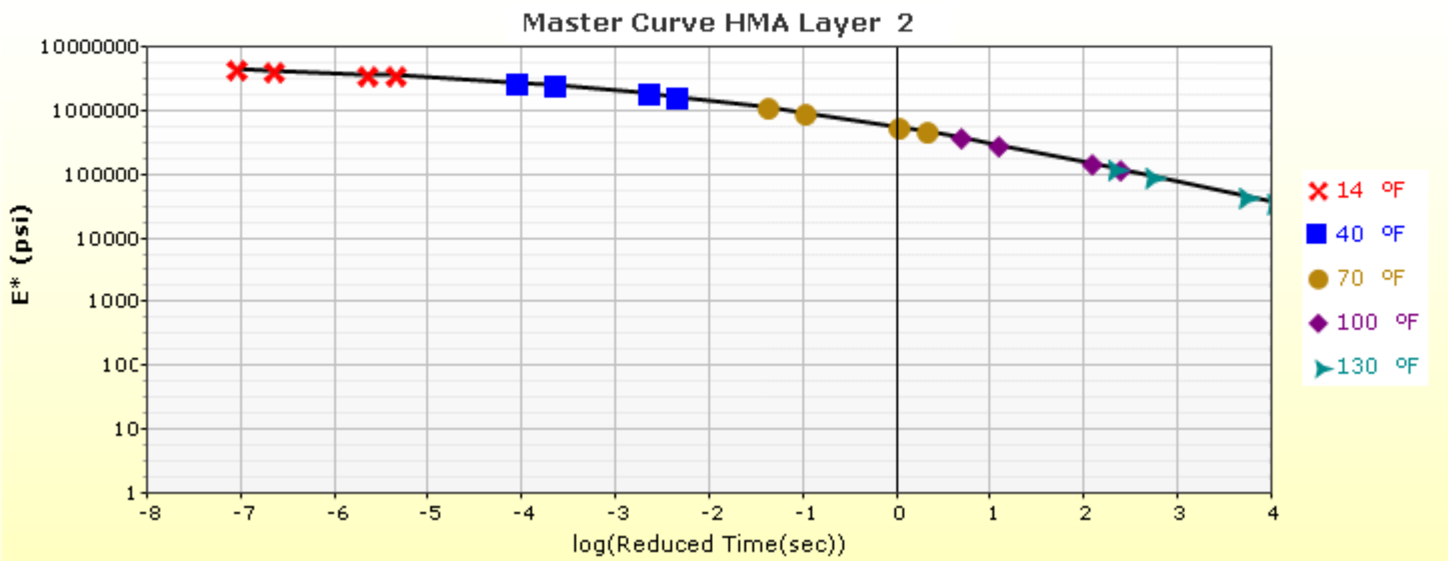
HMA Layer 1: Layer 1 Flexible : Seymour 9.5mm PG70-22

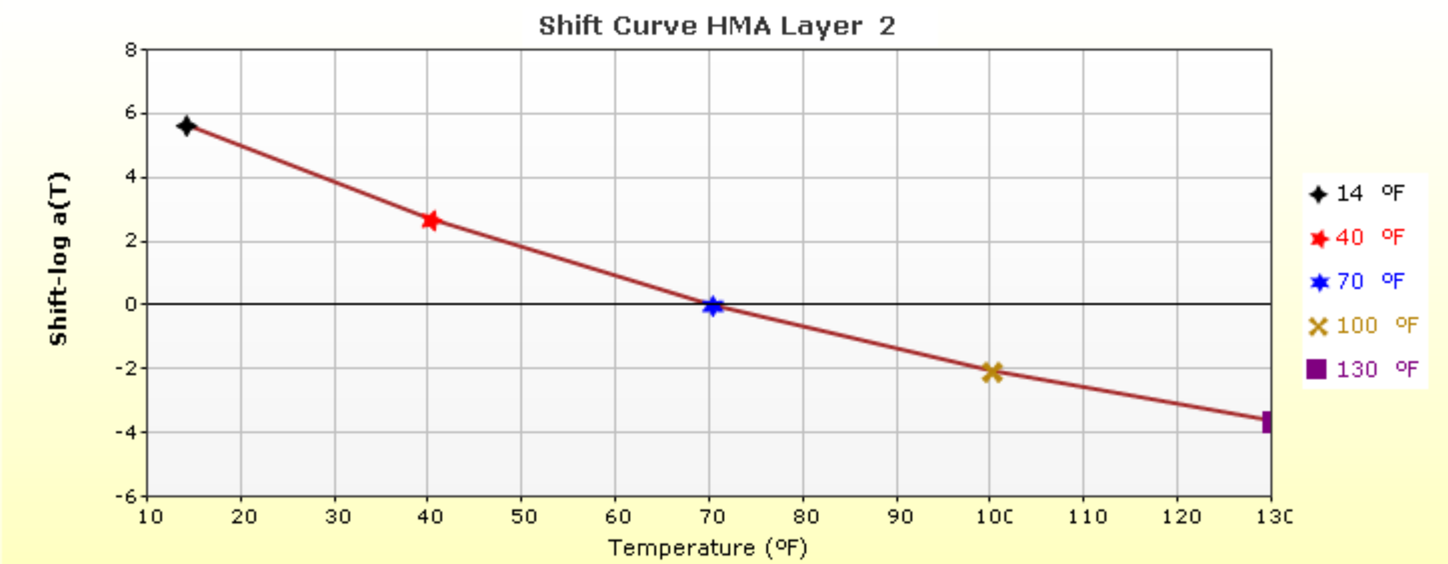


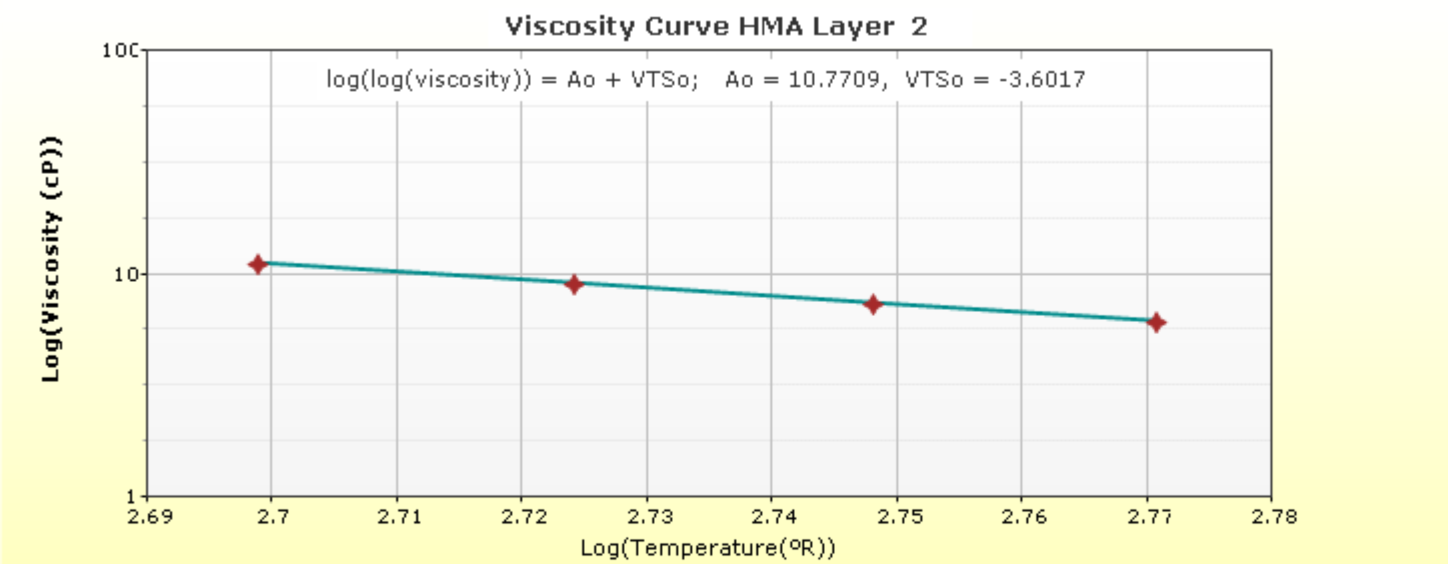




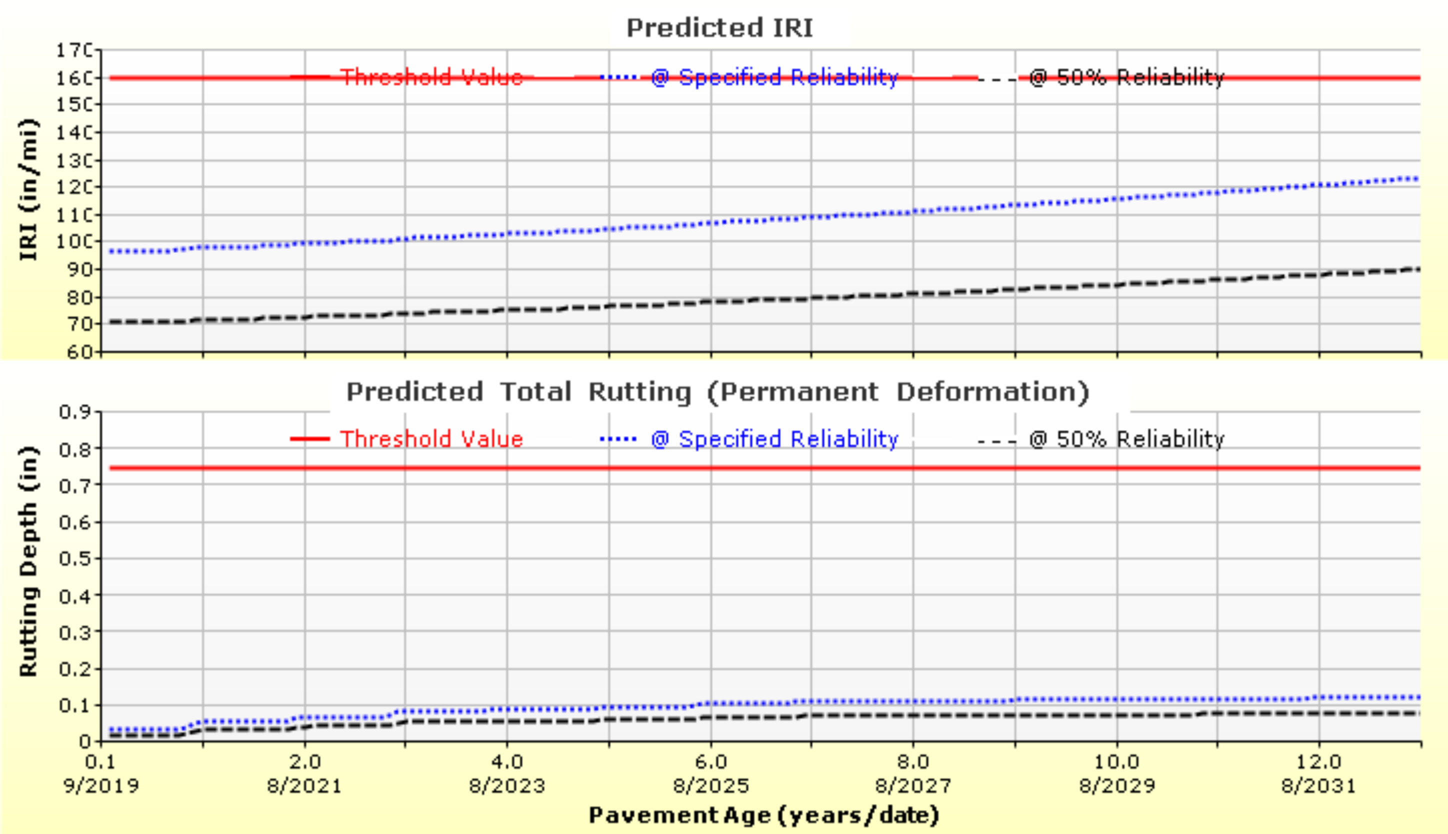
HMA Layer 2: Layer 2 Flexible : Existing Asphalt Base(existing)

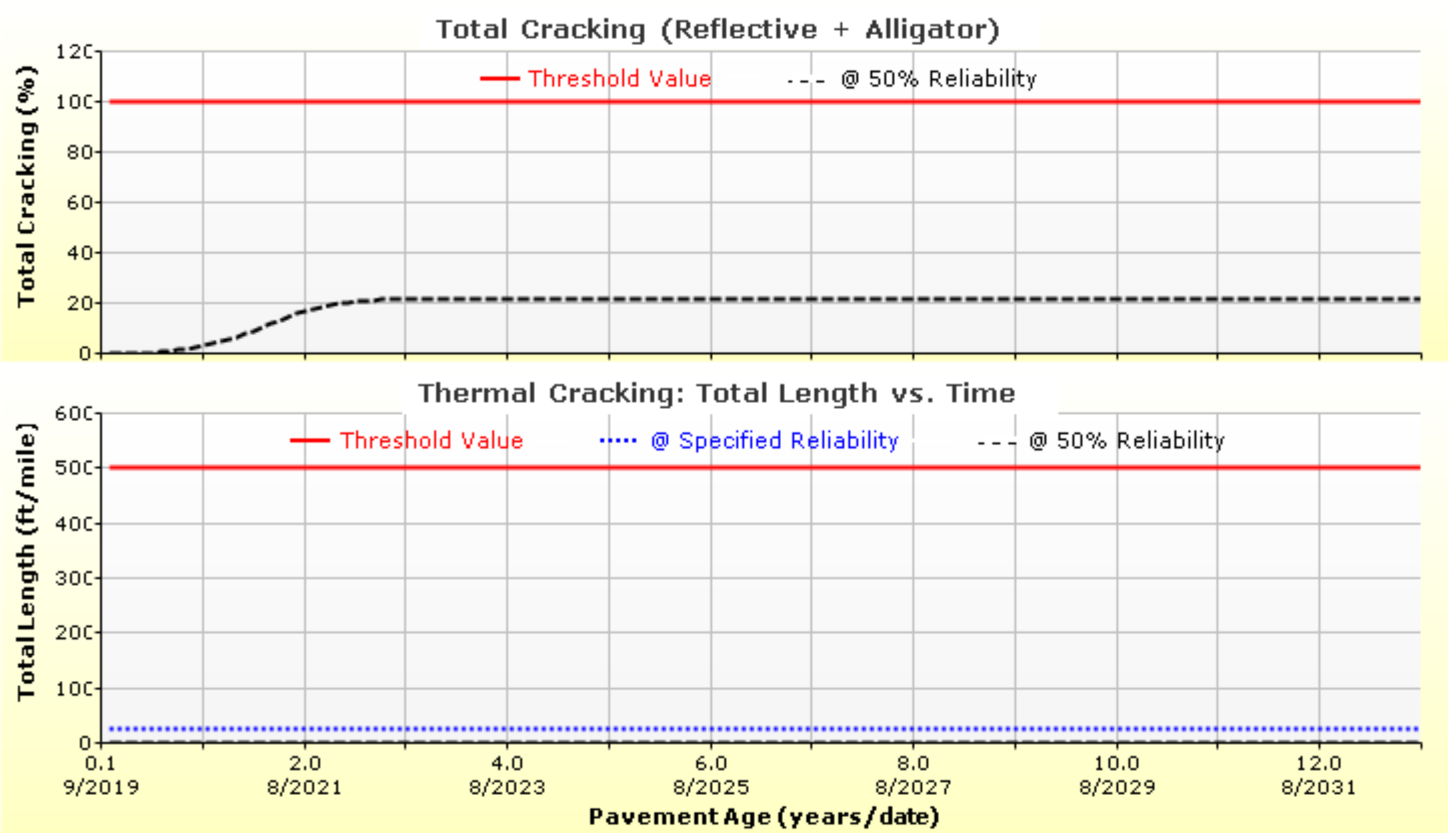


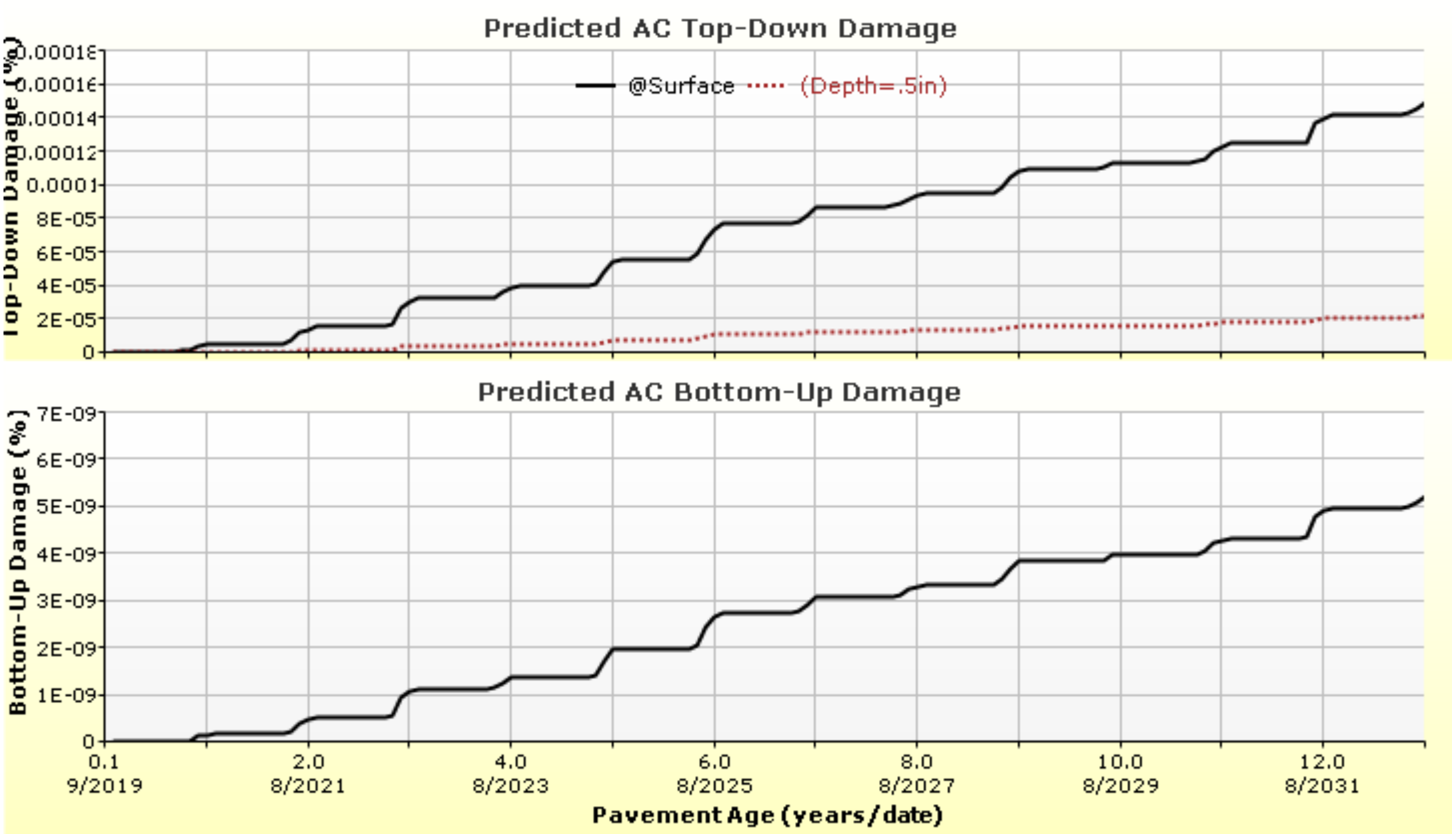


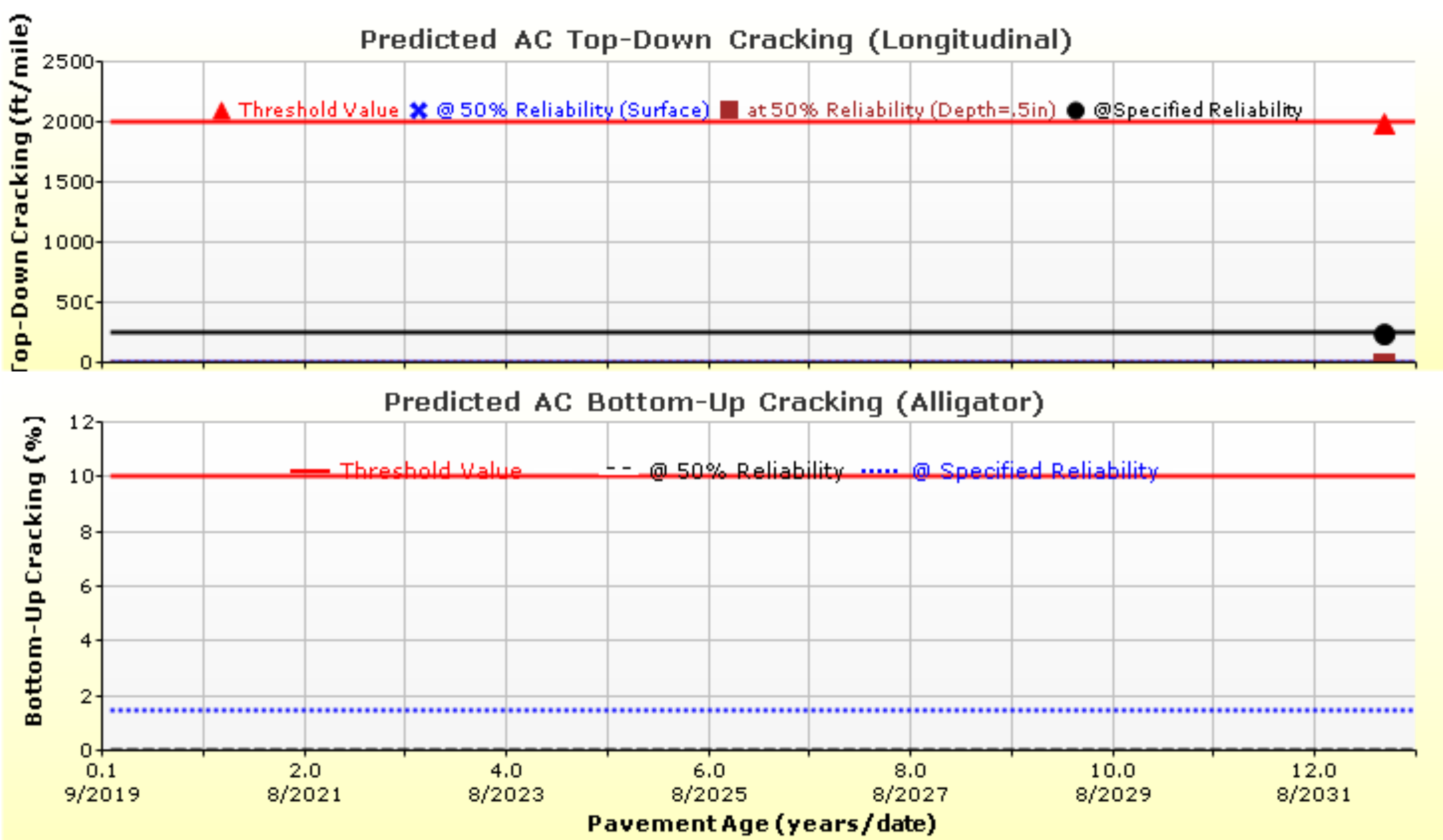


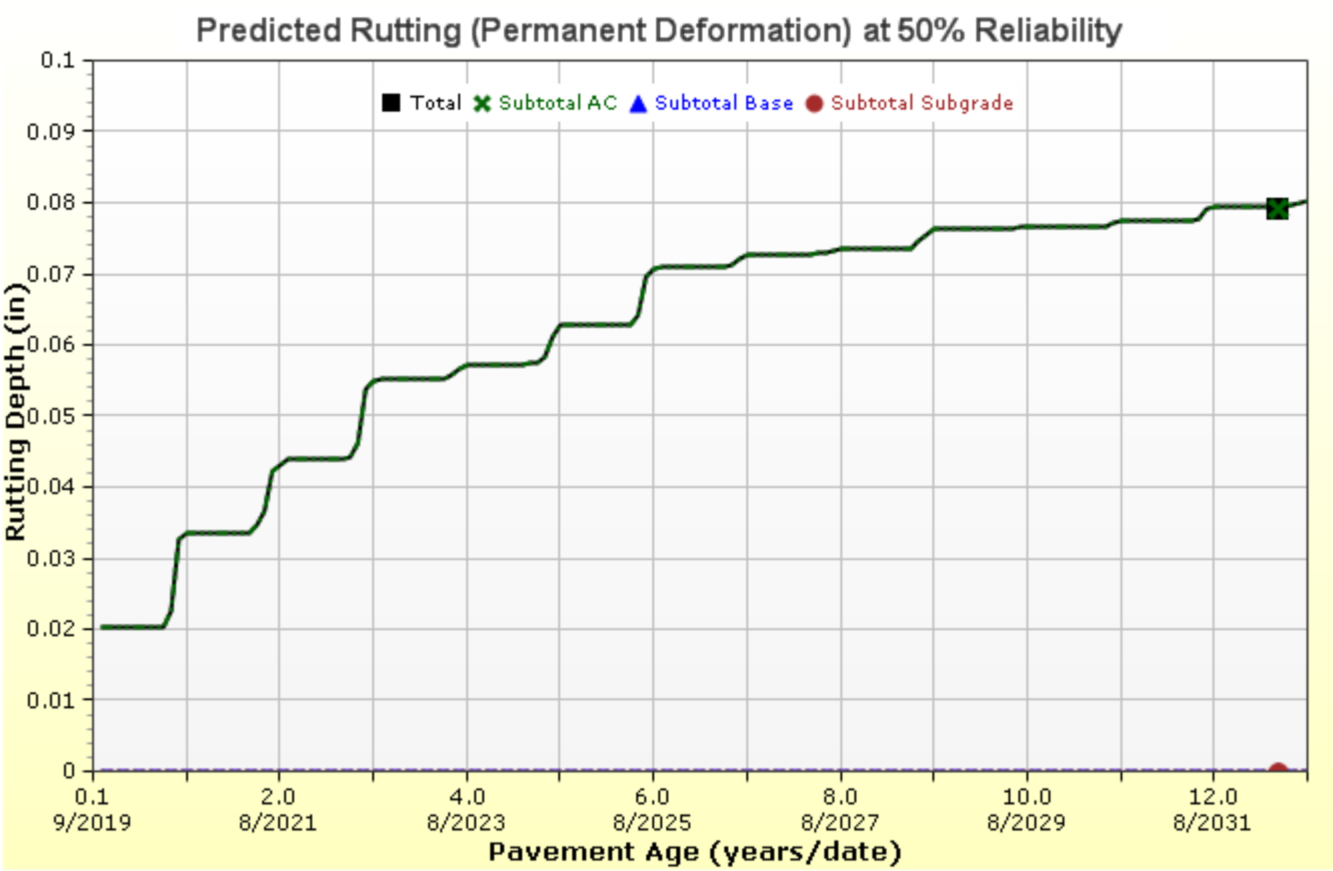
Analysis Output Charts

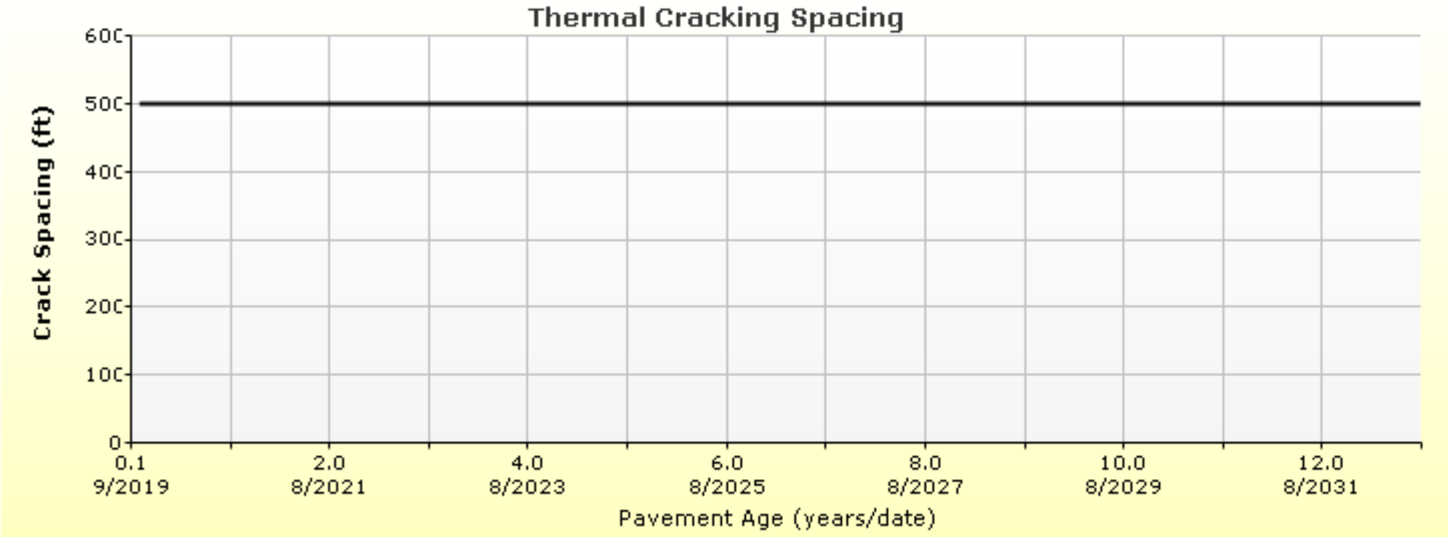


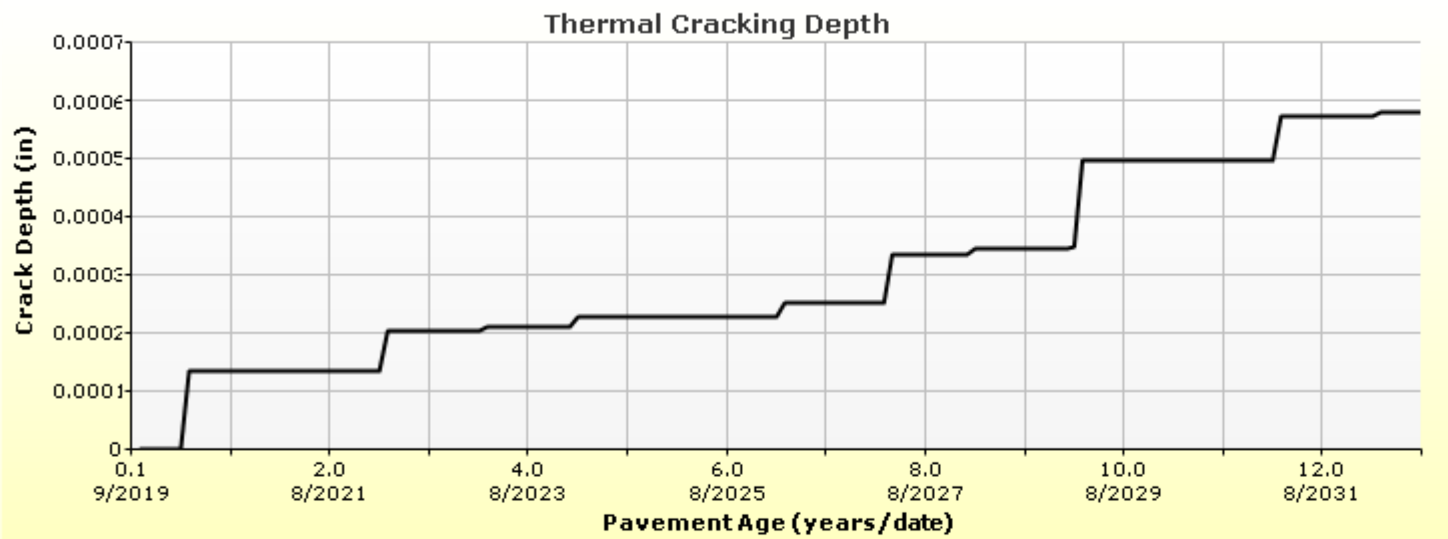


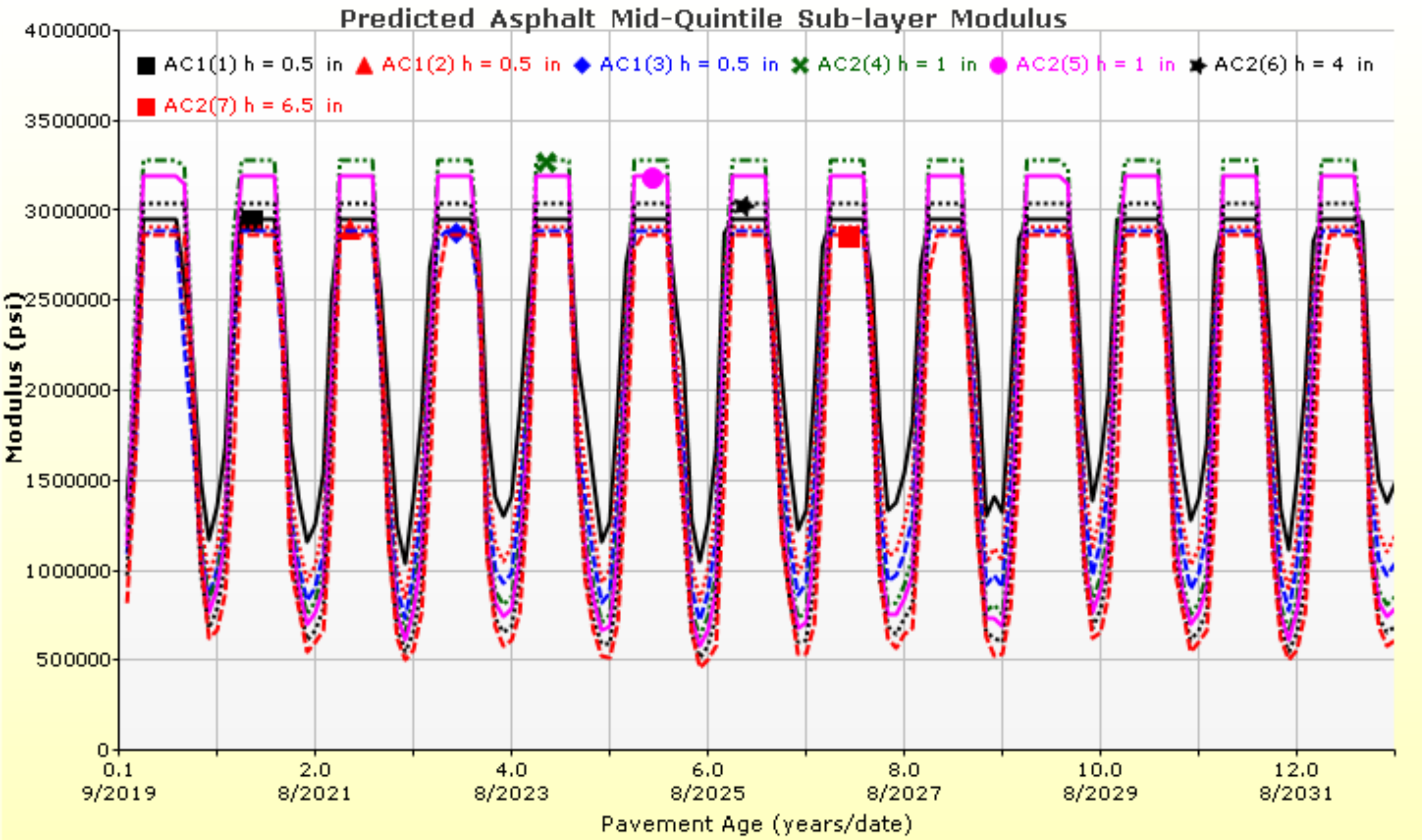

Predicted AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.00018
0.00016
0.00014
0.00012
0.0001
8E-05
6E-05
4E-05
2E-05
0
Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
7E-09
6E-09
5E-09
4E-09
3E-09
2E-09
1E-09
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)


Predicted AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Predicted AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)

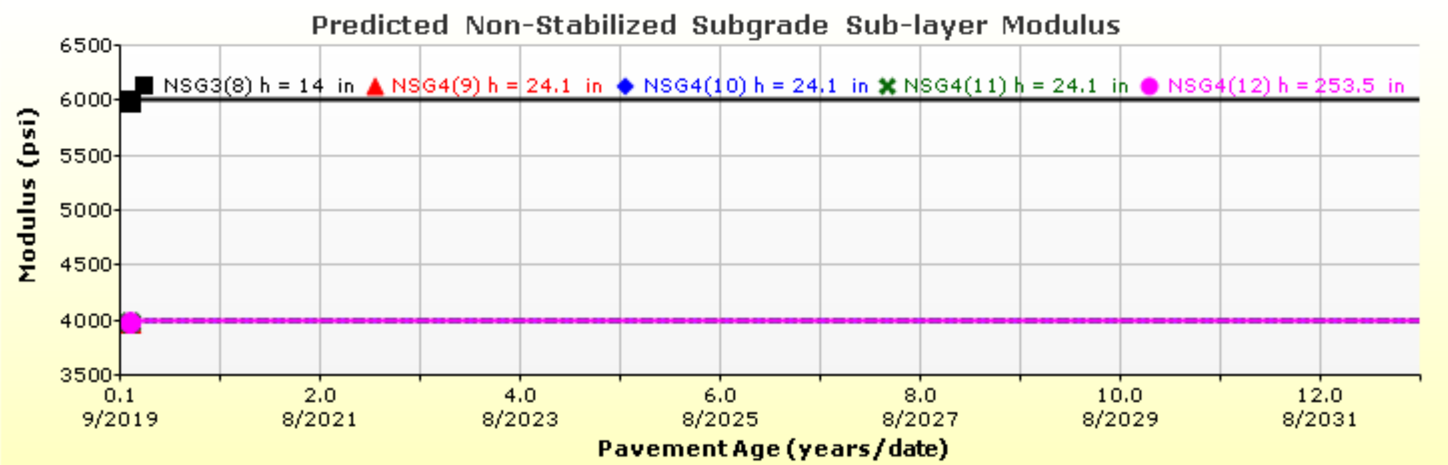

Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rutting Depth (in)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1
9/2019
2.0
8/2021
4.0
8/2023
6.0
8/2025
8.0
8/2027
10.0
8/2029
12.0
8/2031
Pavement Age (years/date)



Predicted Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 0.5 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
AC2(7) h = 6.5 in
Modulus (psi)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)



Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG3(8) h = 14 in
NSG4(9) h = 24.1 in
NSG4(10) h = 24.1 in
NSG4(11) h = 24.1 in
NSG4(12) h = 253.5 in
Modulus (psi)
6500
6000
5500
5000
4500
4000
3500
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Seymour 9.5mm PG70-22

Asphalt		
Thickness (in.)	1.5	
Unit weight (pcf)	142.6	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	1932546	2355005	2642382	3298195
40	1507676	1691777	1864079	2093353
70	262246	488012	733332	882731
100	55053	123973	246641	323256
130	24989	46973	96996	131550

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	22069340.66	33.76
55	9518271.99	44.39
70	2836317.75	52.87
85	765738.66	59.68
100	209102.28	65.17
115	60602.87	69.62
130	19021.84	73.24

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.61
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 9.5mm PG70-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : Existing Asphalt Base(existing)

Asphalt		
Thickness (in.)	12.5	
Unit weight (pcf)	144.4	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
3/4-inch sieve	80
3/8-inch sieve	45
No.4 sieve	35
No.200 sieve	2

Asphalt Binder

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

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	9
Air voids (%)	6
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Existing Asphalt Base
Description of object	Existing HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 3 Subgrade : A-4

Unbound	
Layer thickness (in.)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 4 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

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

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

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

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:0.07 Br2:1.9 Br3:0.4

Thermal Fracture

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

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

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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: 1	k1: 1.35	Bs1: 0.12
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

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

CSM Standard Deviation

CTB*11

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

Reflective Cracking

$$RC = \frac{100}{1 + e^{c.a + d.b.t}}$$

RC = Percent of cracks reflected, %
t = Time, years
h_{ac} = Overlay thickness(in)
a = 3.5 + 0.75(Heff)
b = -0.688584 – 3.37302(Heff)$^{-0.915469}$
c = 1
d = Calibration parameter (user input)

	AC over AC	AC over Rigid, Good Load Transfer	AC over Rigid, Poor Load Transfer
Heff	h_{ac}	$h_{ac} - 1$	$h_{ac} - 3$

Heff	Recommended Calibration Parameter - d: Delay Cracking by 2 years	Recommended Calibration Parameter - d: Accelerate Cracking by 2 years
< 4"	0.6	3
4 – 6"	0.7	1.7
> 6"	0.8	1.4

C: 1	D: 1

Design Inputs

Design Life:	20 years	Base construction:	May, 2019	Climate Data Sources (Lat/Lon)	39.144, -86.617
Design Type:	Flexible Pavement	Pavement construction:	July, 2019		39.71, -86.272
		Traffic opening:	September, 2019		38.228, -85.664

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Seymour 9.5mm PG70-22	1.5
Flexible	Seymour 19.0mm PG70-22	3.0
Flexible	Seymour 25.0mm PG64-22	5.5
Subgrade	A-4	14.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	8.0

Traffic

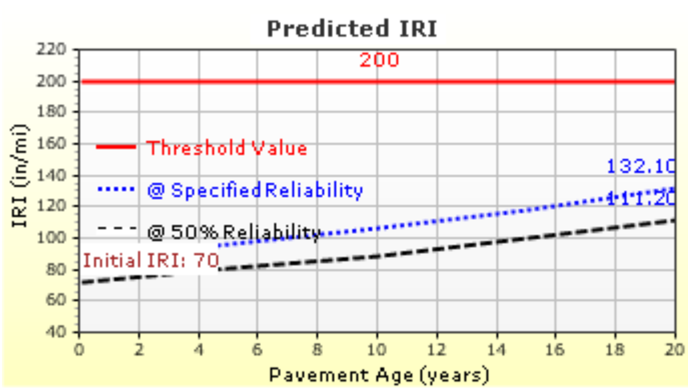
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	568
2029 (10 years)	1,196,770
2039 (20 years)	2,655,690

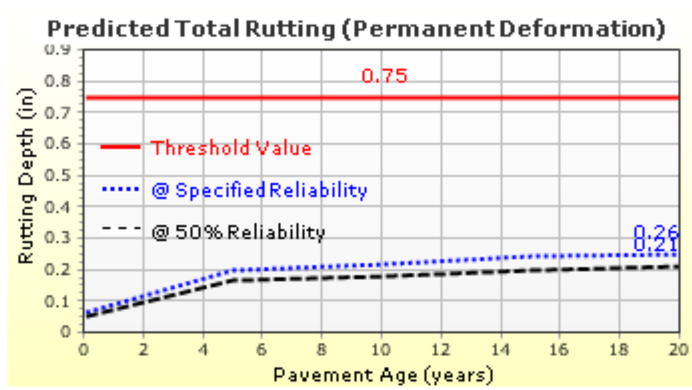
Design Outputs

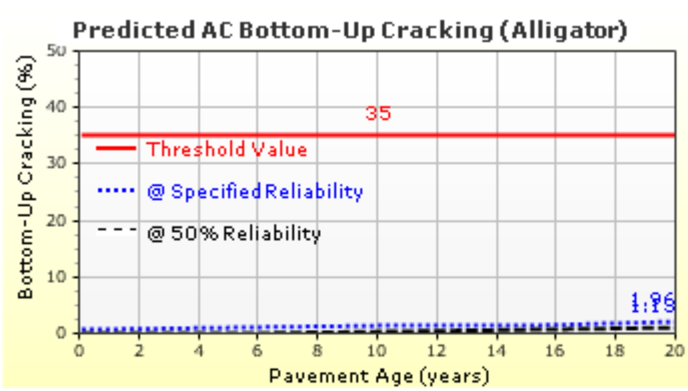
Distress Prediction Summary

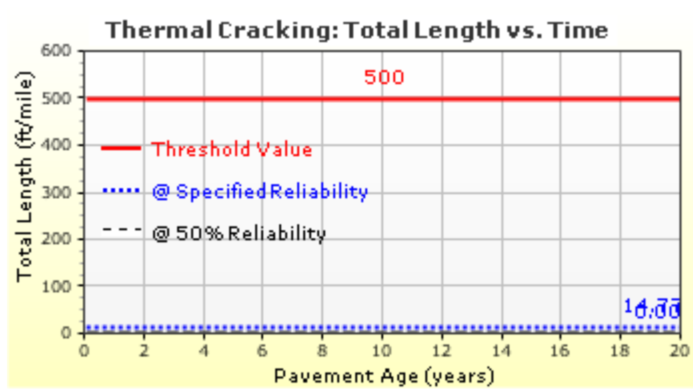
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	200.00	132.13	75.00	99.79	Pass
Permanent deformation - total pavement (in.)	0.75	0.26	75.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	35.00	1.96	75.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	14.77	75.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	185.05	75.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.19	75.00	100.00	Pass

Distress Charts





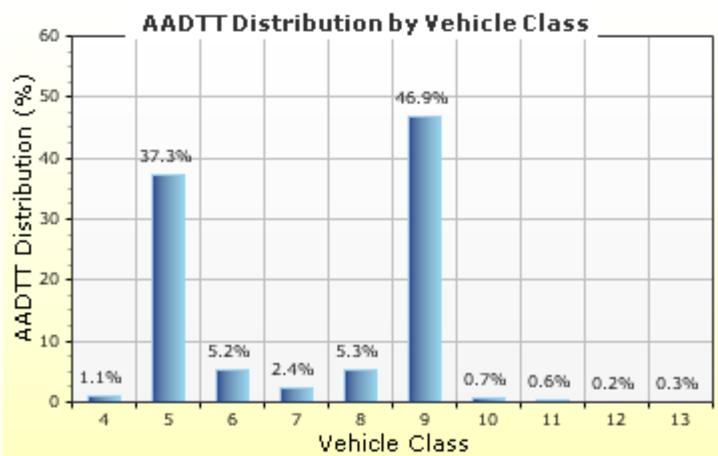


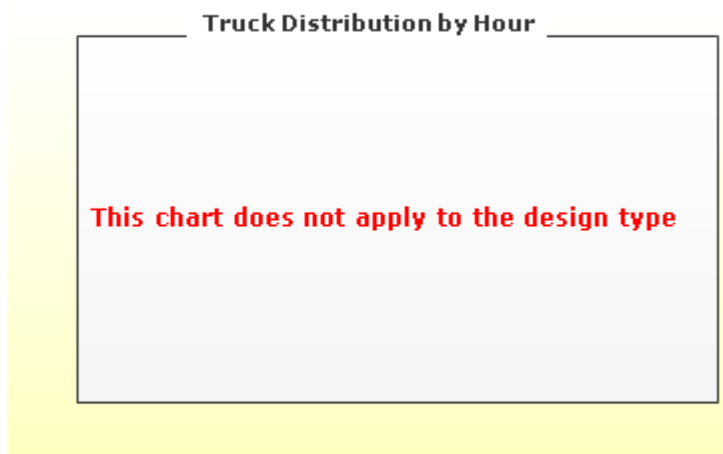


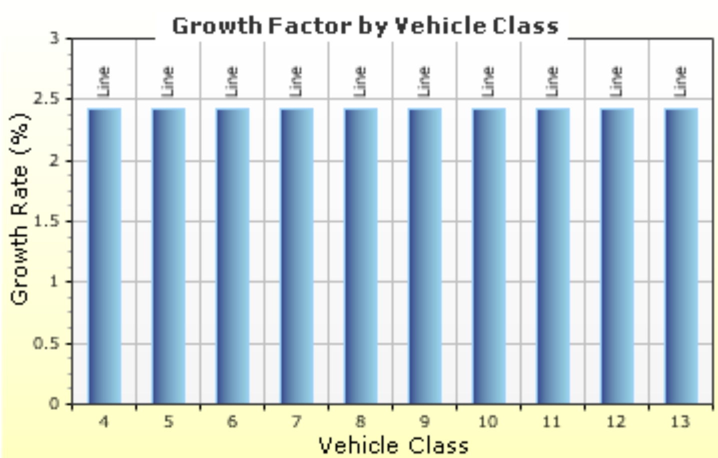
Traffic Inputs

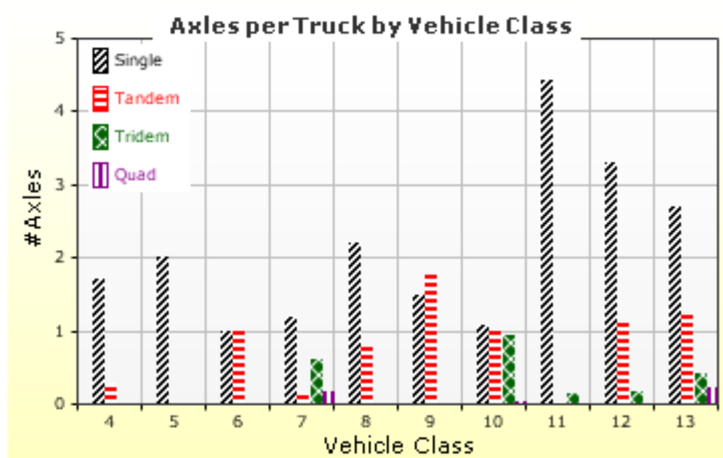
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	568	Percent of trucks in design direction (%):	52.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	100.0
		Operational speed (mph)	45.0

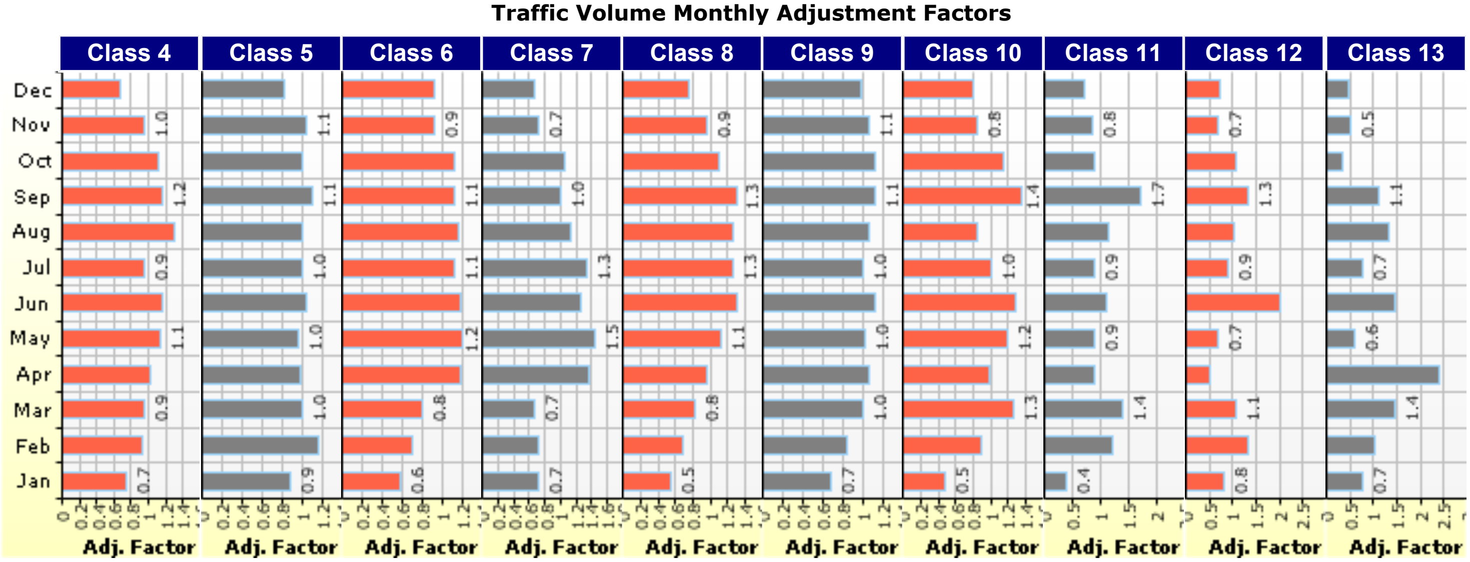








Traffic Volume Monthly Adjustment Factors



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	0.7	0.9	0.6	0.7	0.5	0.7	0.5	0.4	0.8	0.7
February	0.9	1.2	0.7	0.7	0.7	0.8	0.9	1.2	1.3	1.0
March	0.9	1.0	0.8	0.7	0.8	1.0	1.3	1.4	1.1	1.4
April	1.0	1.0	1.2	1.4	1.0	1.1	1.0	0.9	0.5	2.4
May	1.1	1.0	1.2	1.5	1.1	1.0	1.2	0.9	0.7	0.6
June	1.2	1.0	1.2	1.3	1.3	1.1	1.3	1.1	2.0	1.4
July	0.9	1.0	1.1	1.3	1.3	1.0	1.0	0.9	0.9	0.7
August	1.3	1.0	1.2	1.1	1.3	1.1	0.8	1.1	1.0	1.3
September	1.2	1.1	1.1	1.0	1.3	1.1	1.4	1.7	1.3	1.1
October	1.1	1.0	1.1	1.1	1.1	1.1	1.2	0.9	1.1	0.3
November	1.0	1.1	0.9	0.7	0.9	1.1	0.8	0.8	0.7	0.5
December	0.7	0.8	0.9	0.7	0.7	1.0	0.8	0.7	0.7	0.5

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.1%	2.43%	Linear
Class 5	37.3%	2.43%	Linear
Class 6	5.2%	2.43%	Linear
Class 7	2.4%	2.43%	Linear
Class 8	5.3%	2.43%	Linear
Class 9	46.9%	2.43%	Linear
Class 10	0.7%	2.43%	Linear
Class 11	0.6%	2.43%	Linear
Class 12	0.2%	2.43%	Linear
Class 13	0.3%	2.43%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

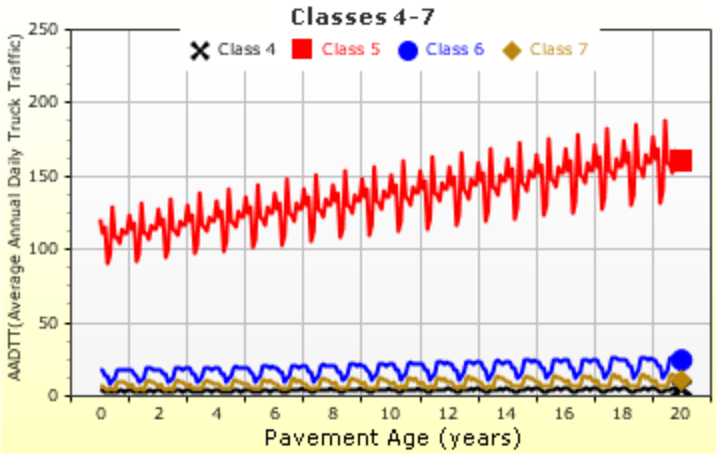
Wheelbase does not apply

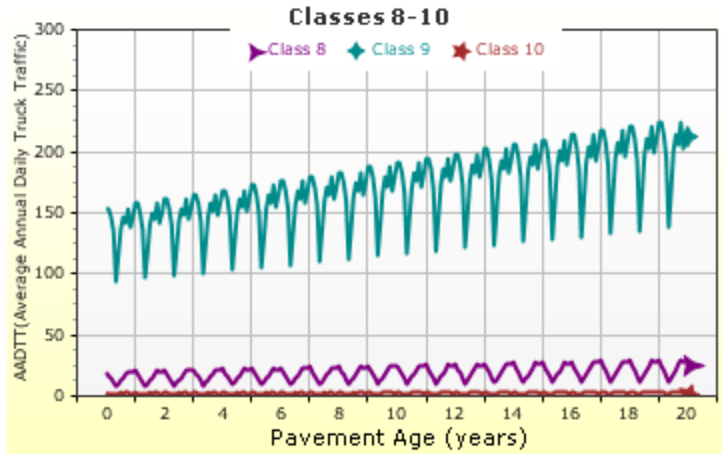
Number of Axles per Truck

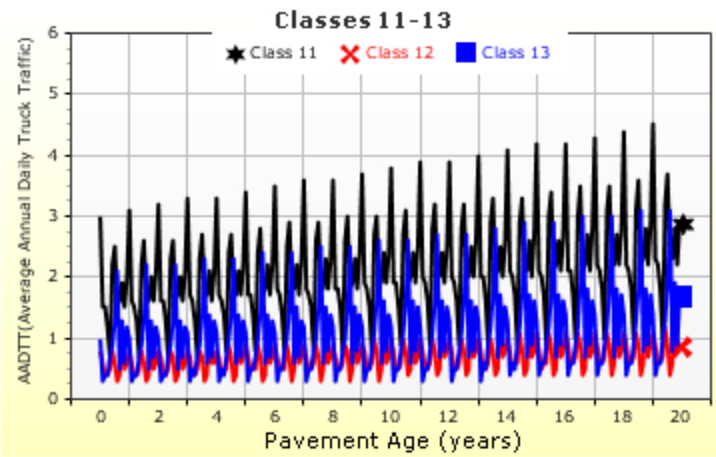
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.7	0.29	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.18	0.18	0.63	0.18
Class 8	2.21	0.78	0	0
Class 9	1.48	1.75	0	0
Class 10	1.08	0.99	0.94	0.03
Class 11	4.43	0.03	0.16	0
Class 12	3.29	1.09	0.17	0
Class 13	2.7	1.22	0.43	0.24

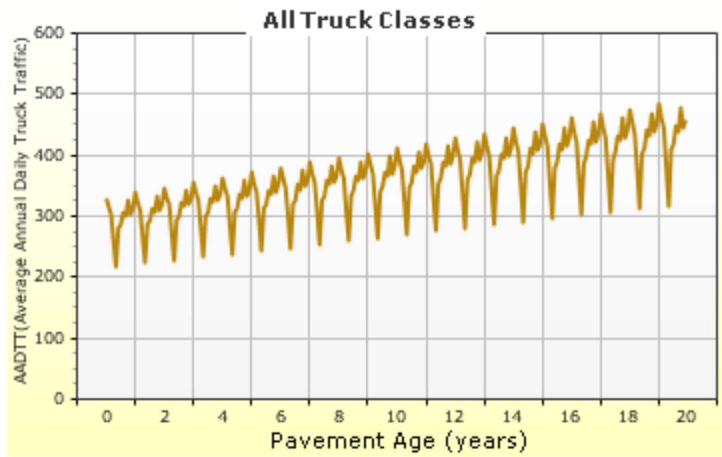
AADTT (Average Annual Daily Truck Traffic) Growth

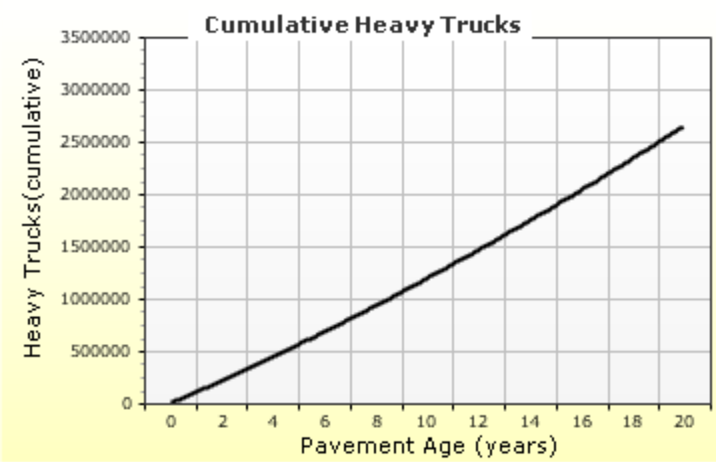
*** Traffic cap is not enforced**











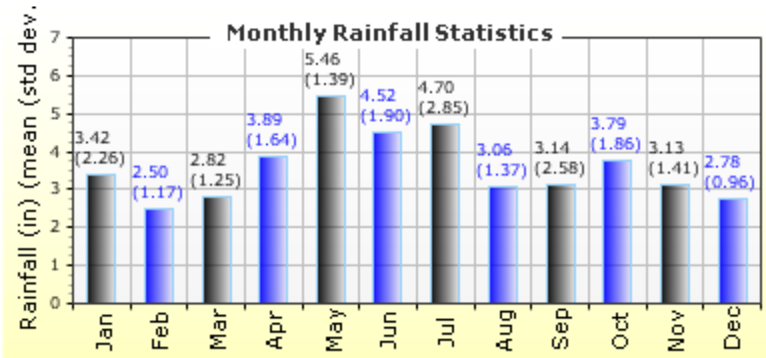
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

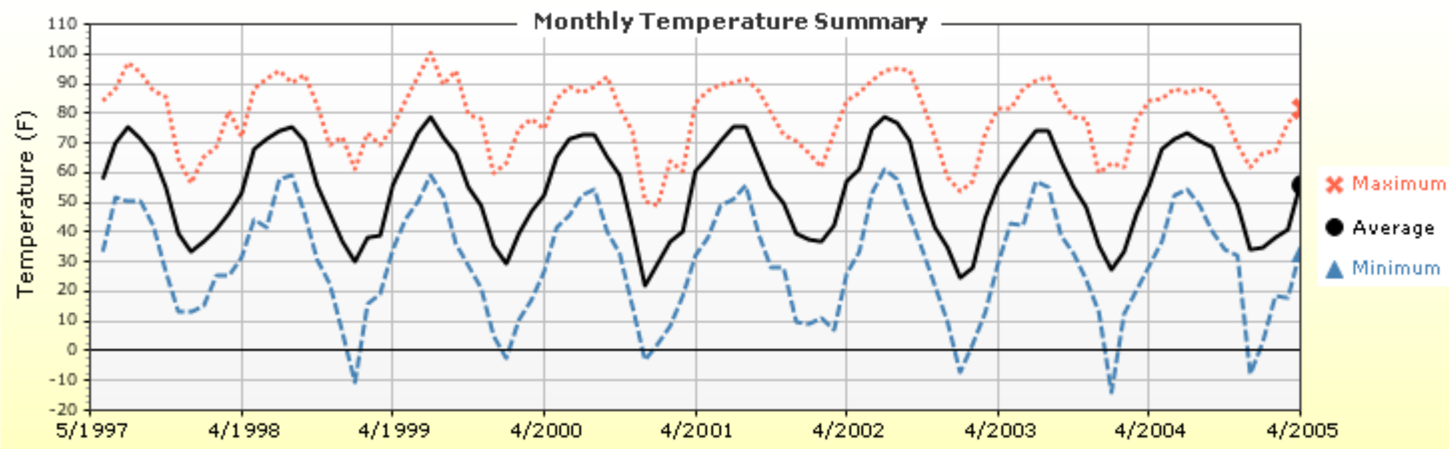
Annual Statistics:

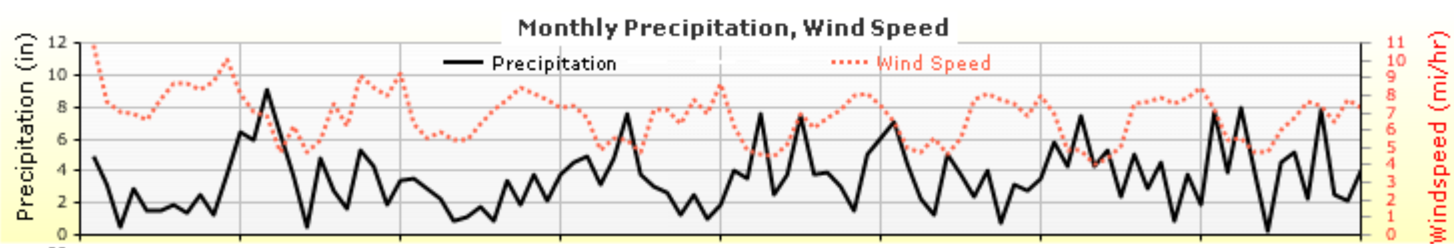
Mean annual air temperature (ºF)	54.34
Mean annual precipitation (in.)	43.19
Freezing index (ºF - days)	406.02
Average annual number of freeze/thaw cycles:	60.23

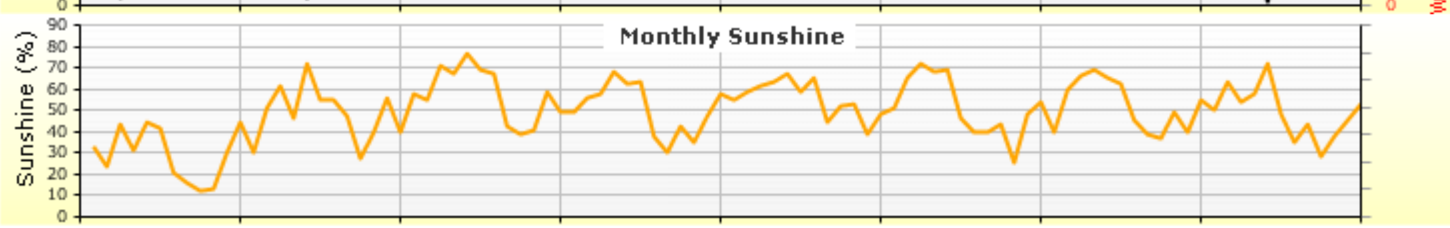


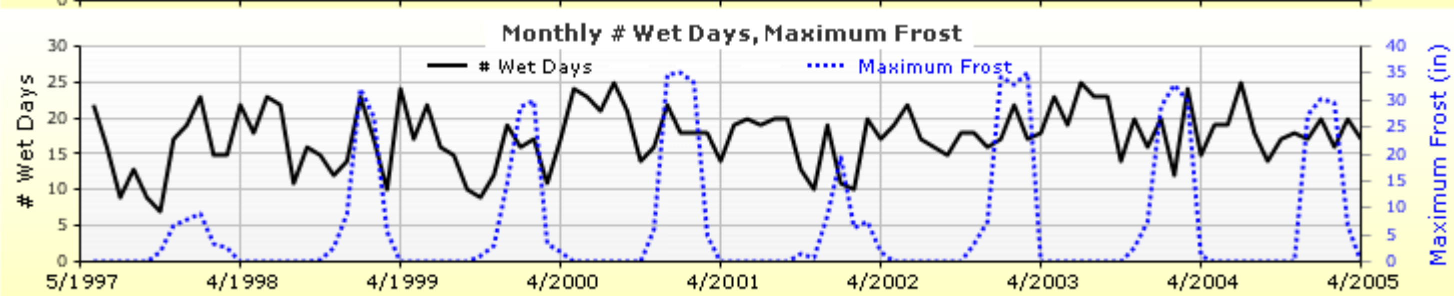
Water table depth (ft)	5.00

Monthly Climate Summary:

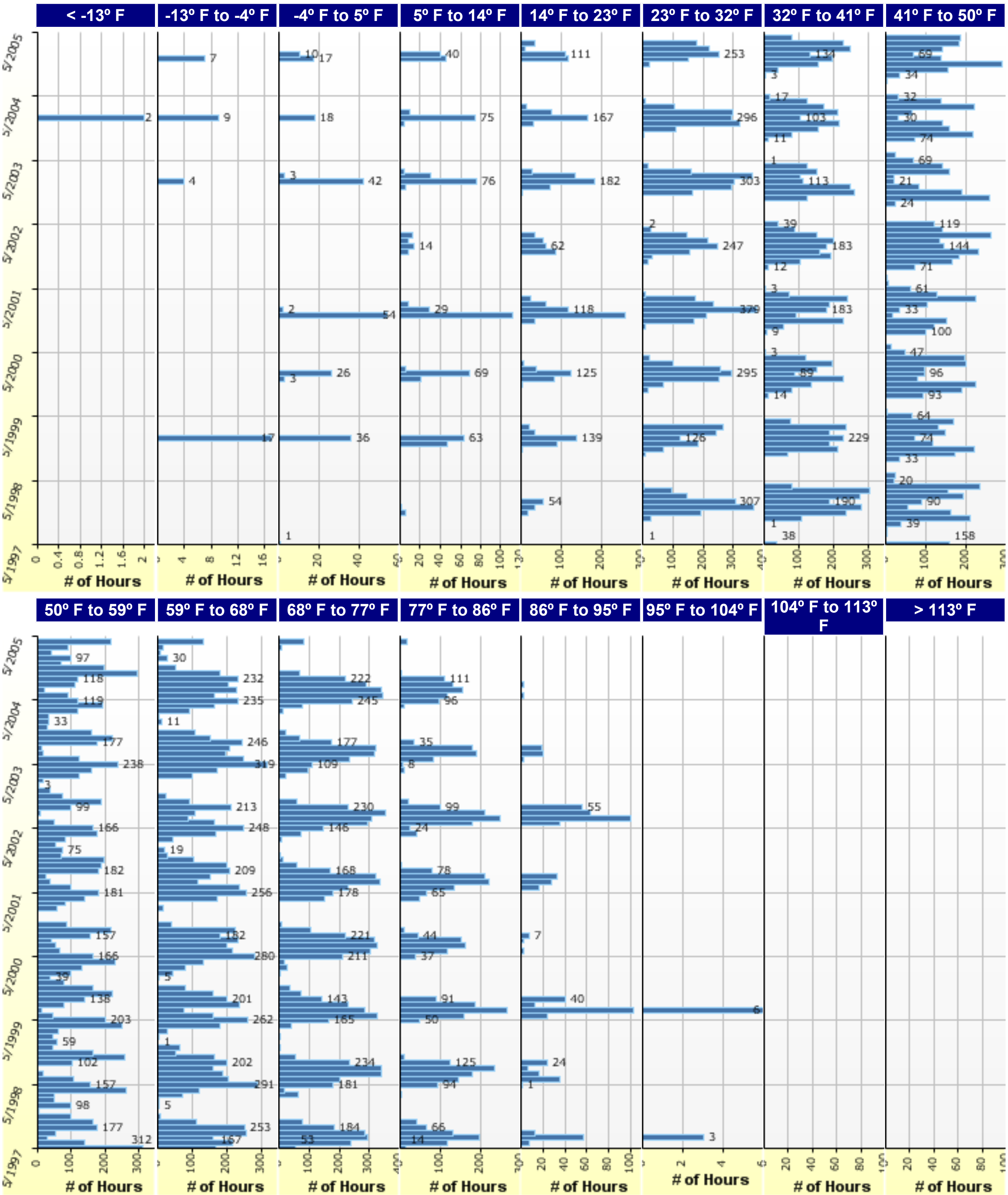








Hourly Air Temperature Distribution by Month:



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

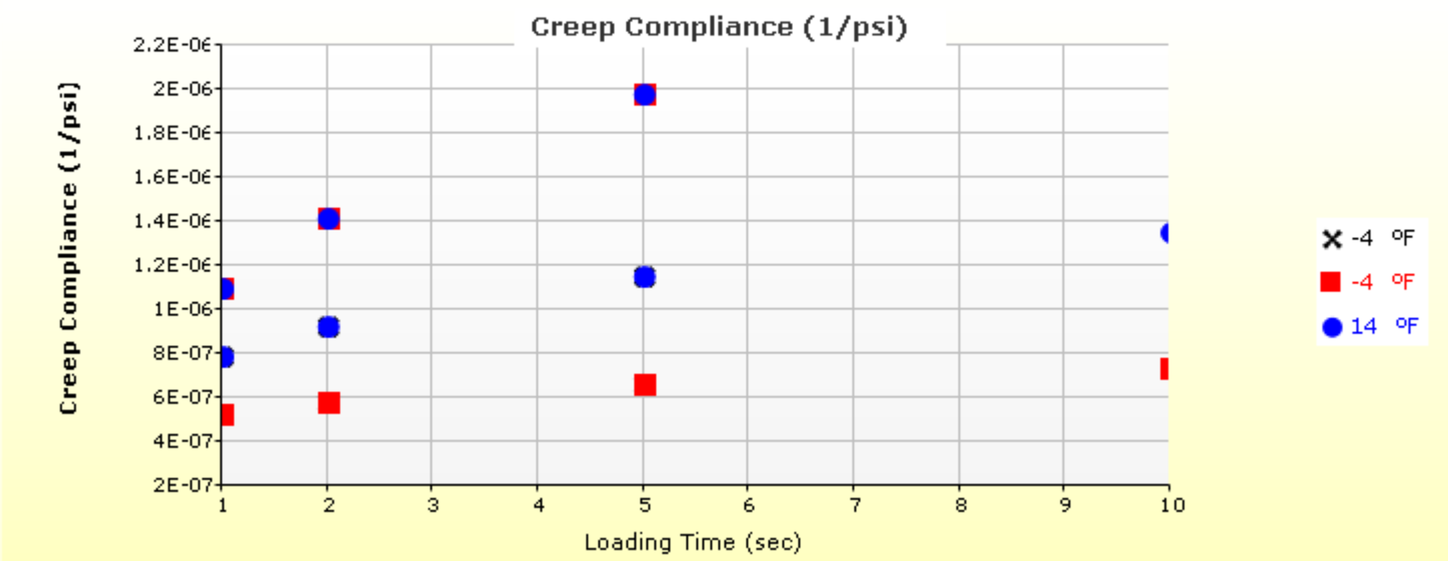
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Seymour 9.5mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Seymour 19.0mm PG70-22	Flexible (1)	1.00
Layer 3 Flexible : Seymour 25.0mm PG64-22	Flexible (1)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	1.00
Layer 5 Subgrade : A-4	Subgrade (5)	-

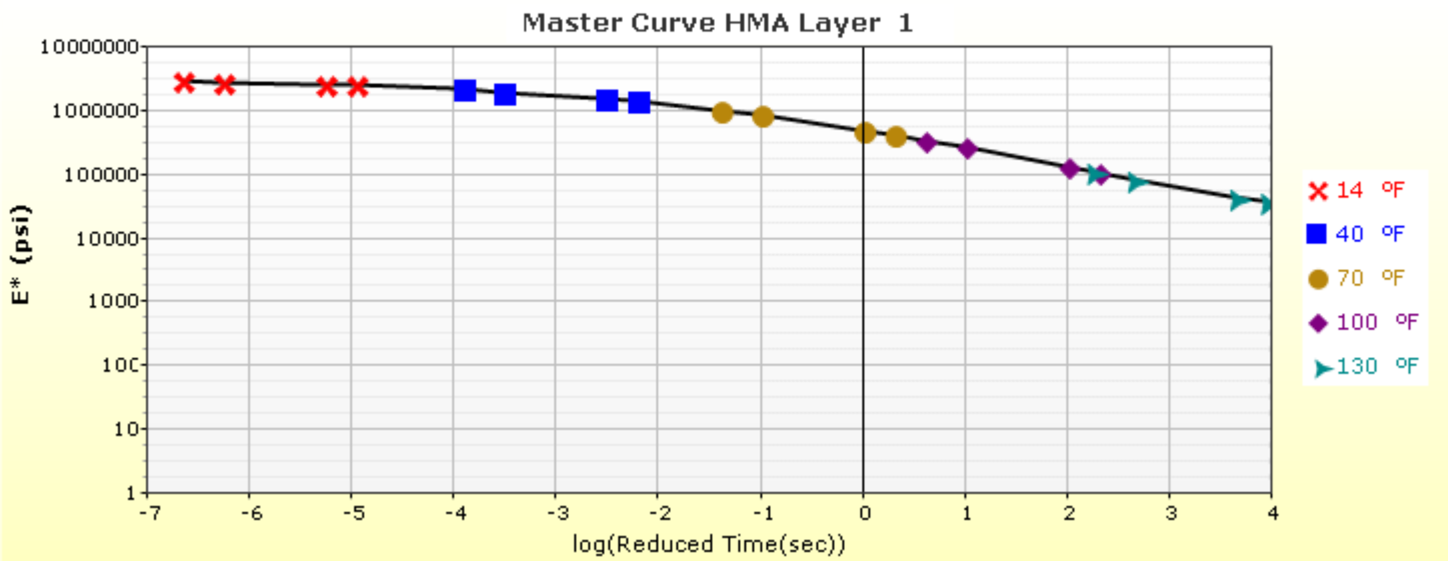
Thermal Cracking (Input Level: 3)

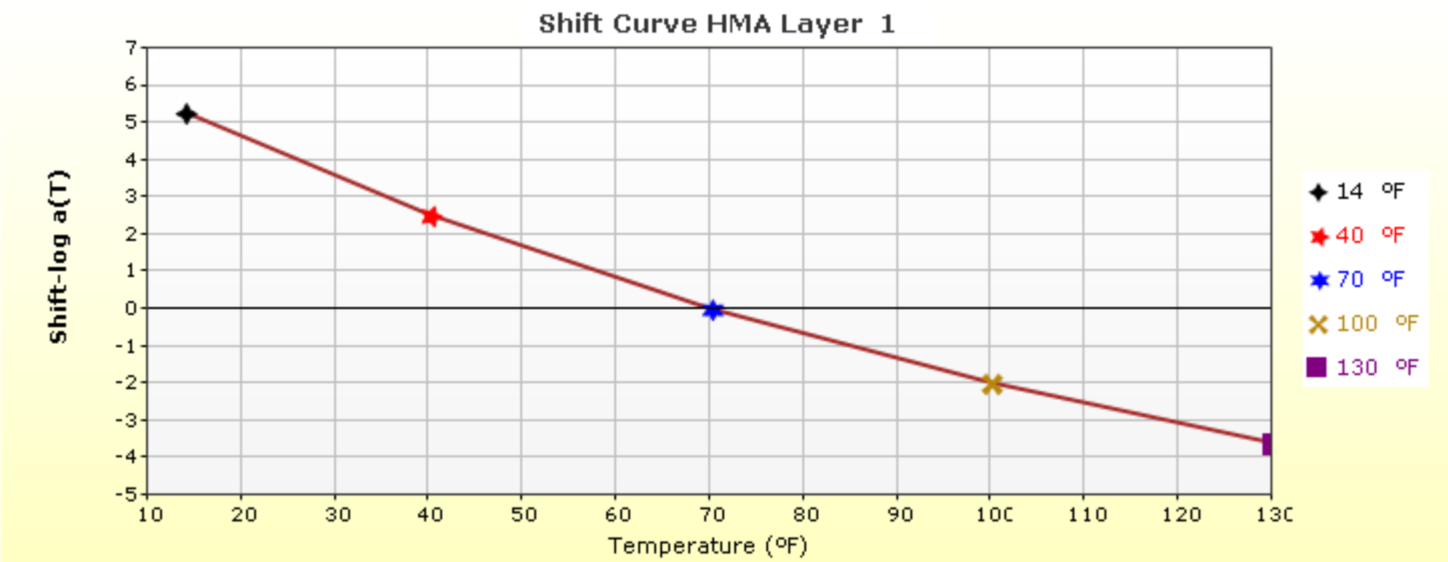
Indirect tensile strength at 14 ºF (psi)	444.45
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

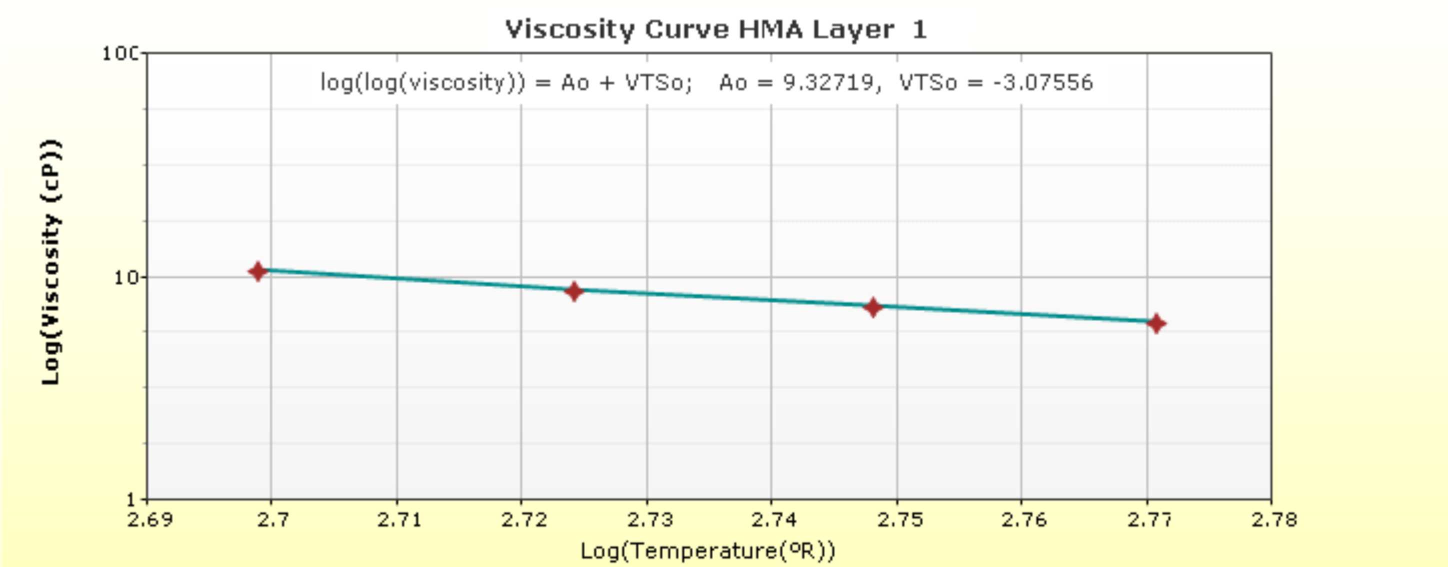
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	-4 ºF	14 ºF
1	5.31e-007	5.31e-007	7.97e-007
1	7.97e-007	1.10e-006	1.10e-006
2	5.86e-007	5.86e-007	9.35e-007
2	9.35e-007	1.42e-006	1.42e-006
5	6.68e-007	6.68e-007	1.15e-006
5	1.15e-006	1.98e-006	1.98e-006
10	7.38e-007	7.38e-007	1.35e-006



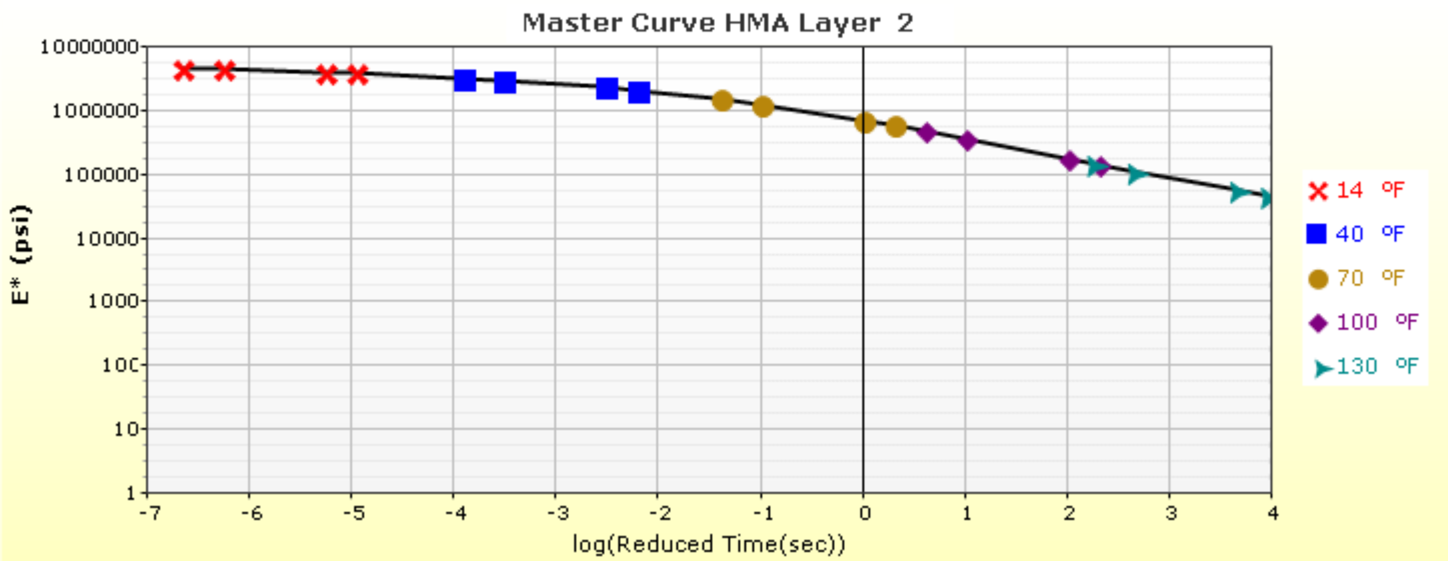
HMA Layer 1: Layer 1 Flexible : Seymour 9.5mm PG70-22

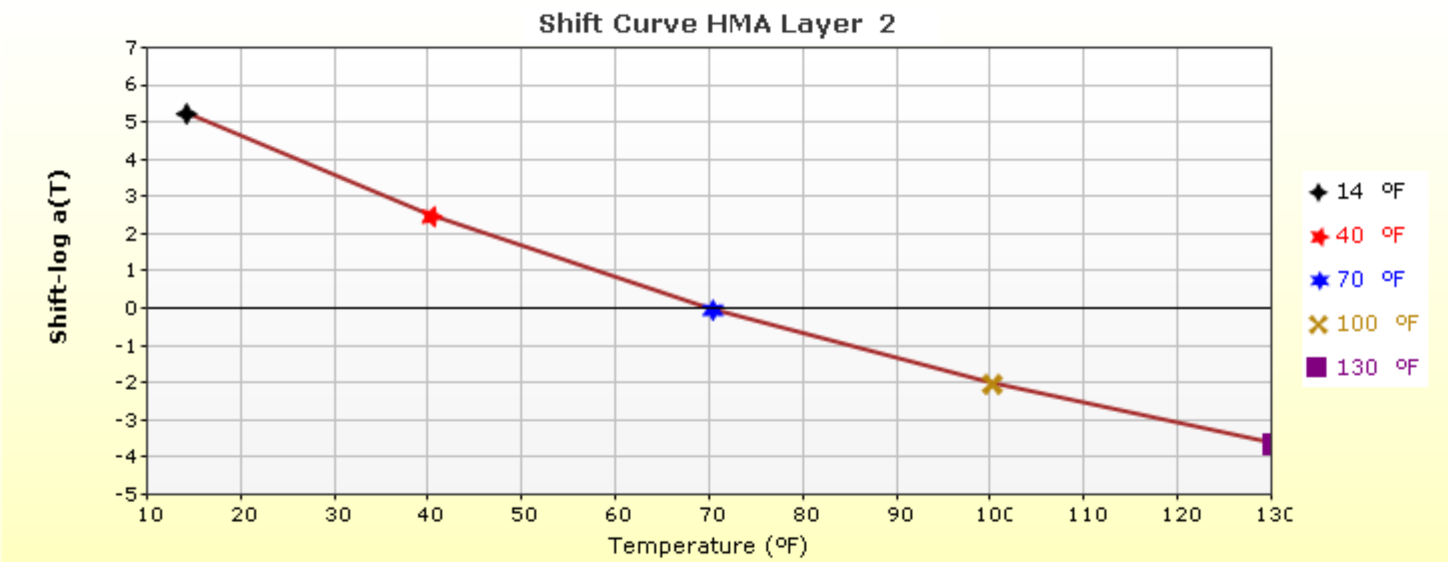


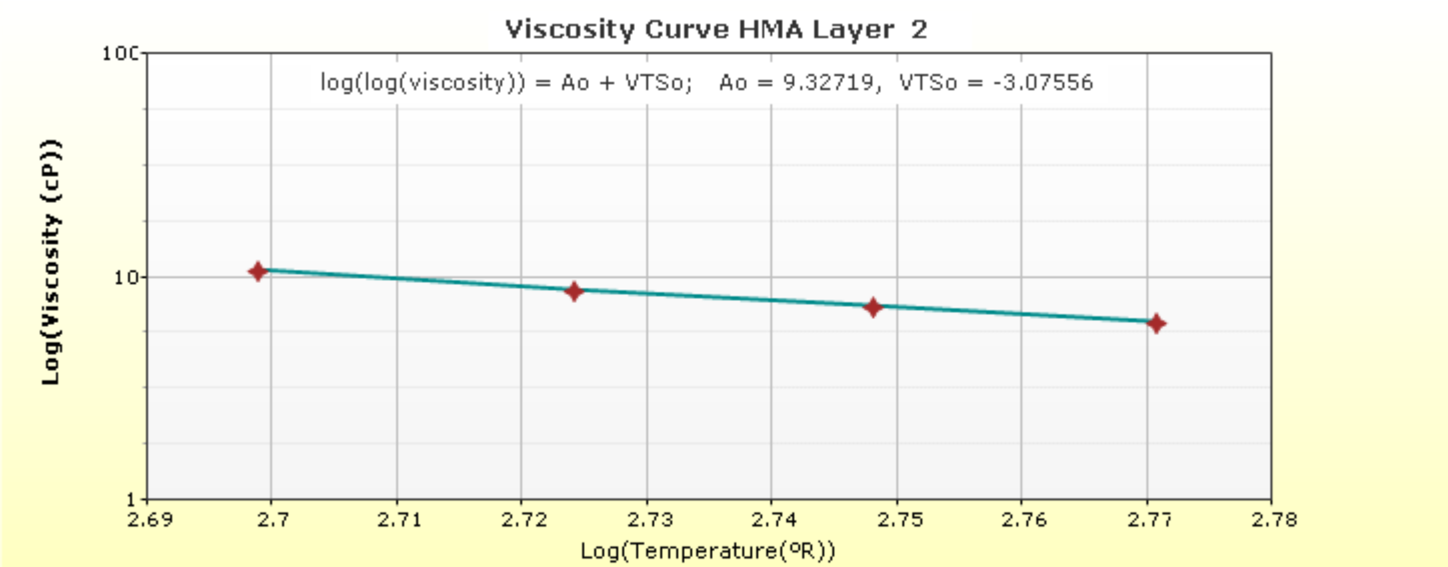




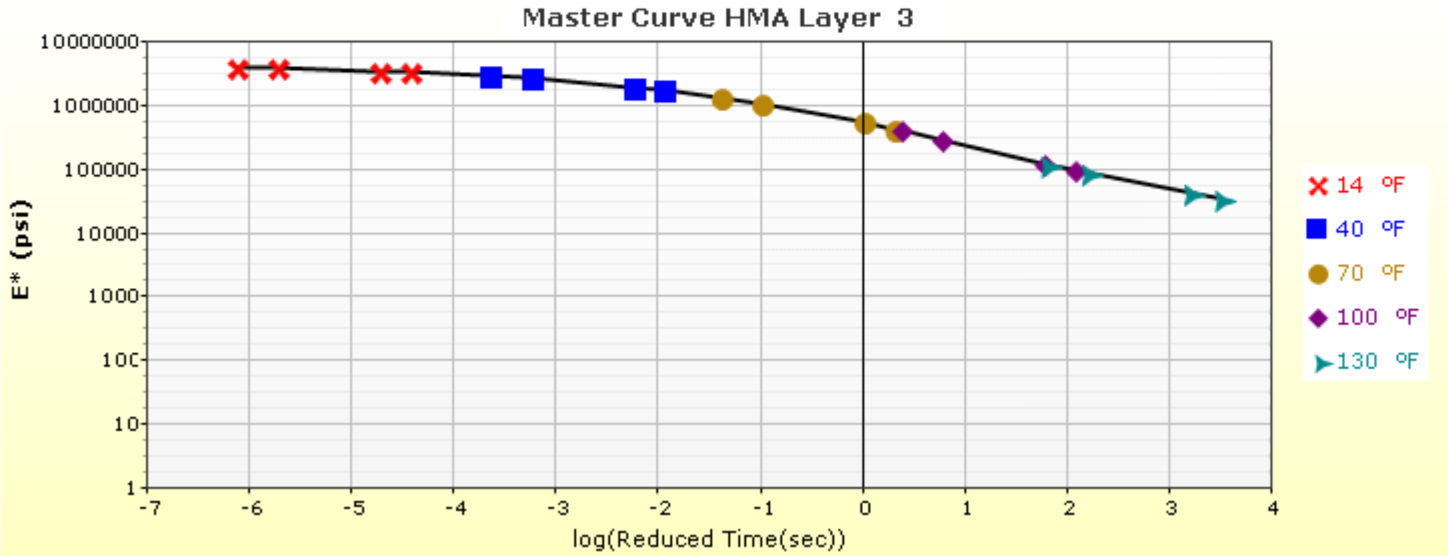
HMA Layer 2: Layer 2 Flexible : Seymour 19.0mm PG70-22

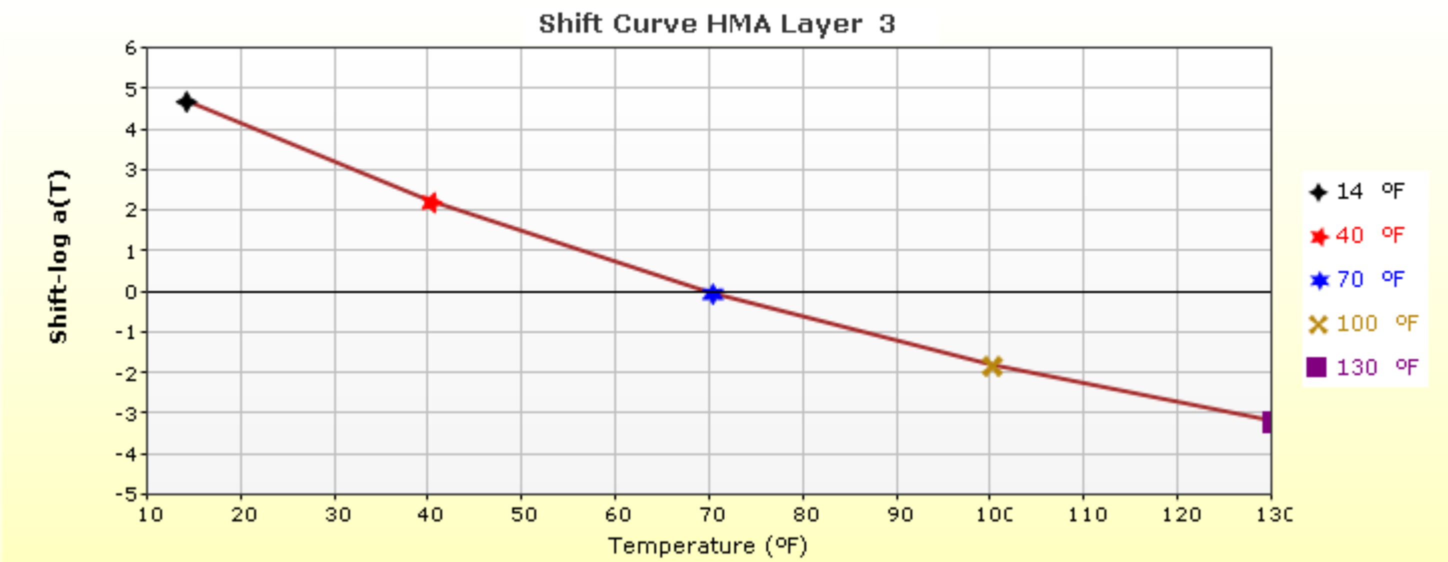


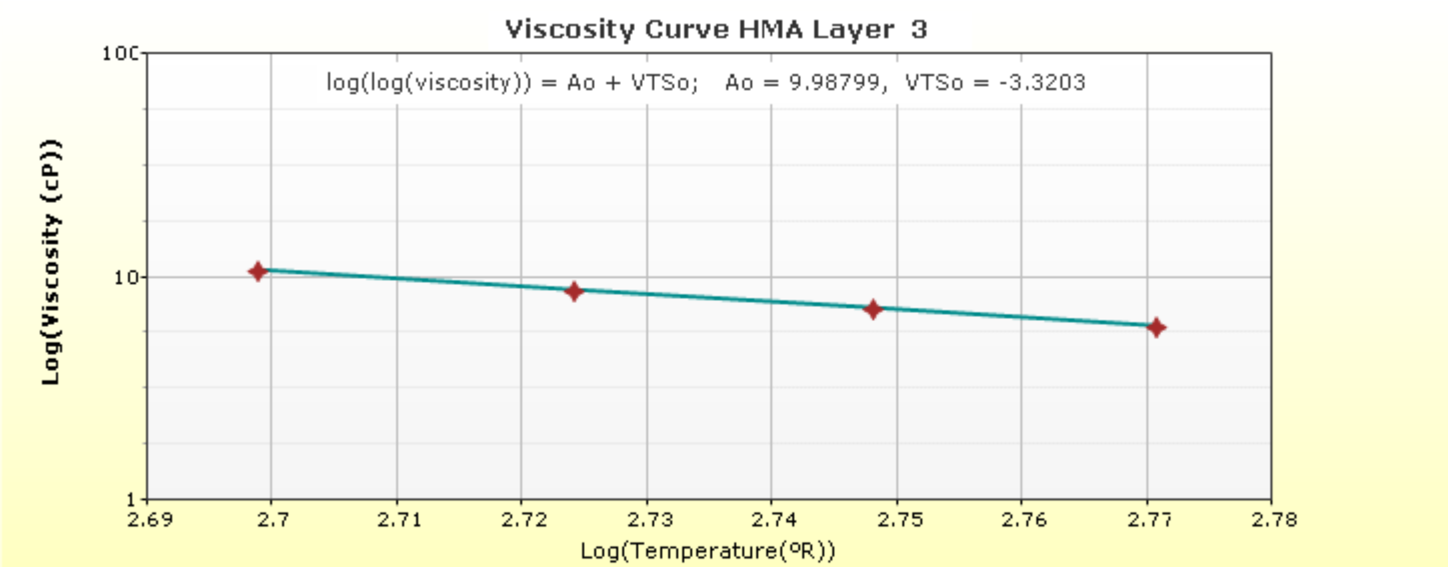




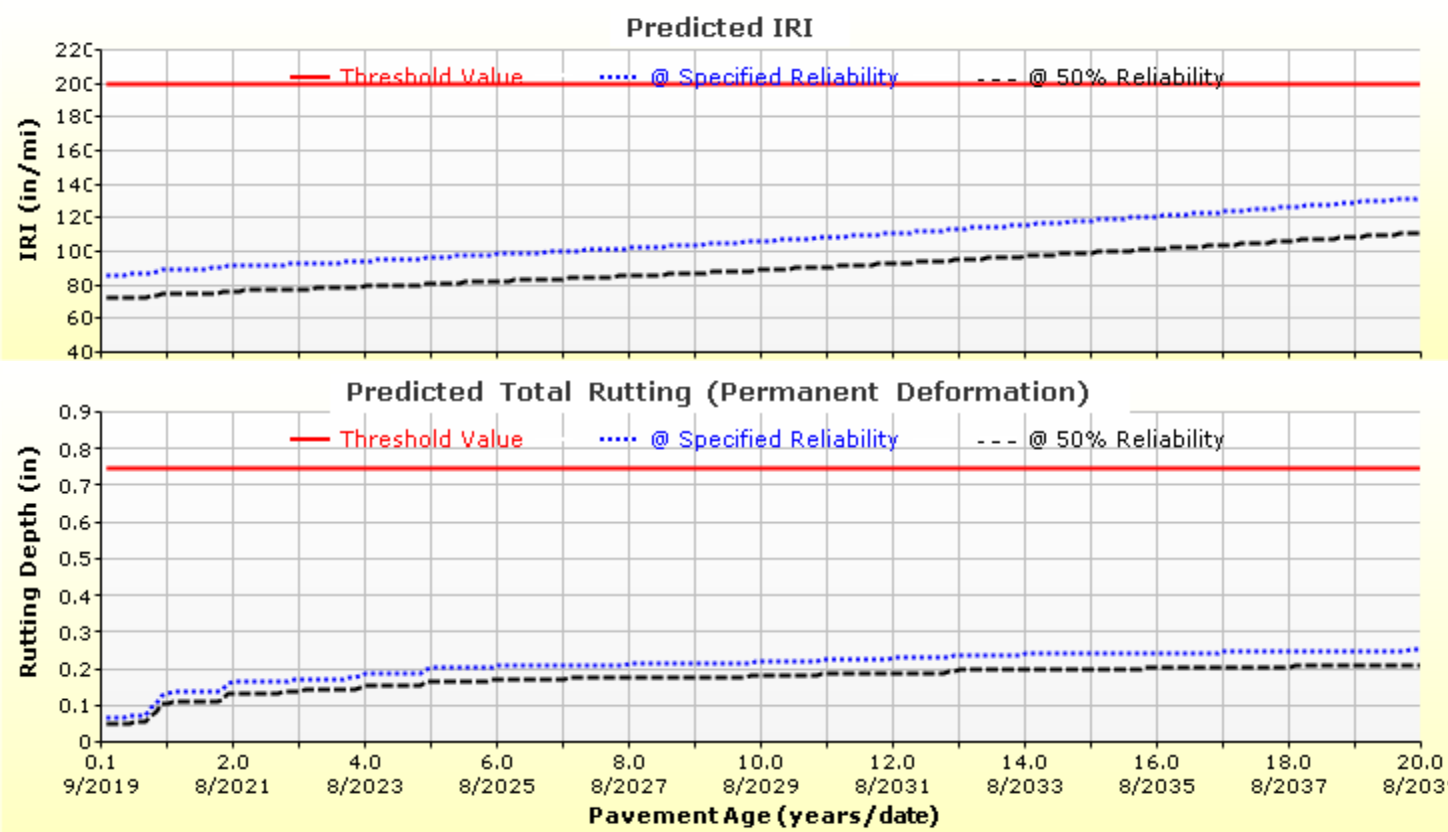
HMA Layer 3: Layer 3 Flexible : Seymour 25.0mm PG64-22

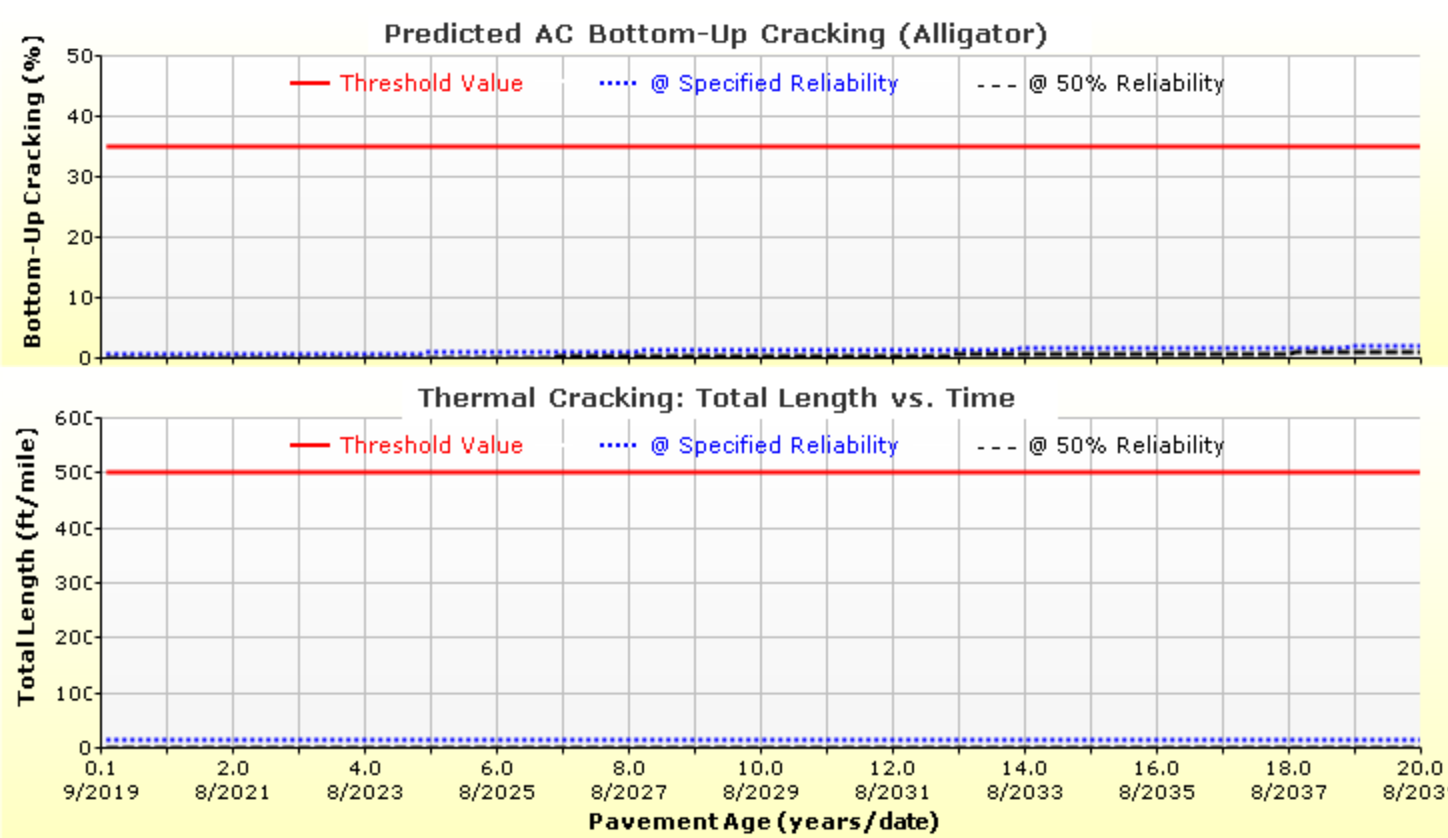


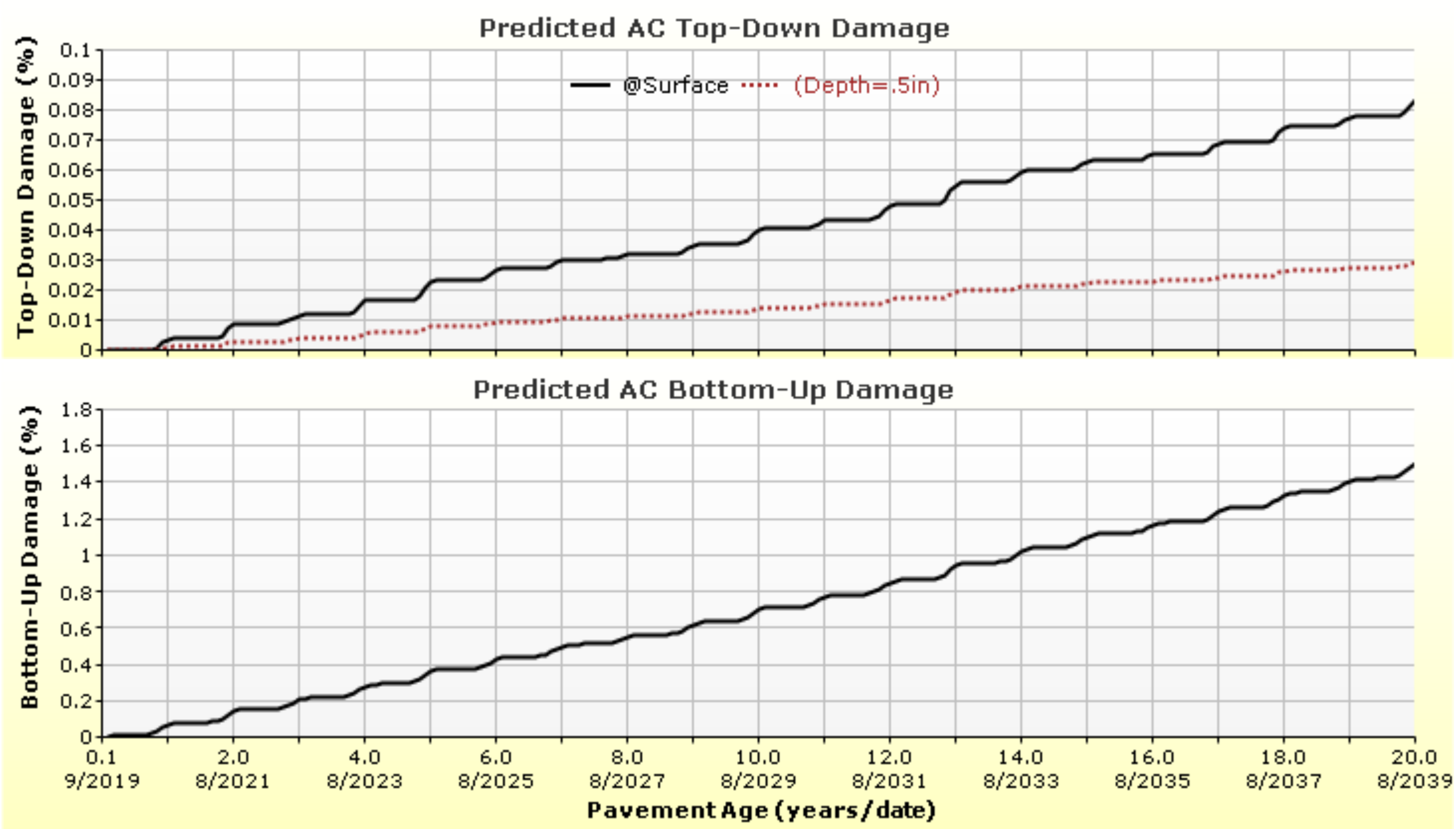




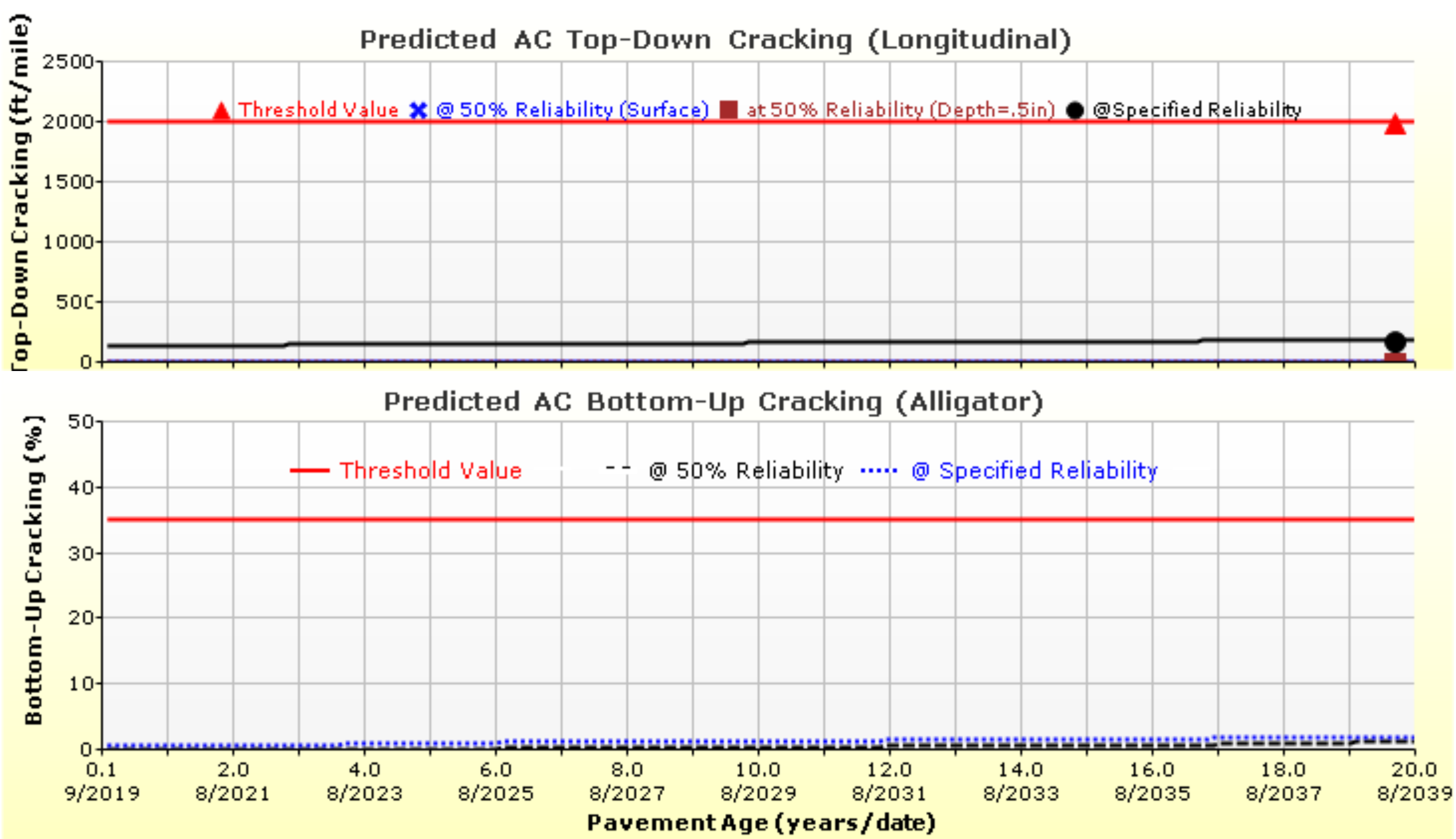
Analysis Output Charts



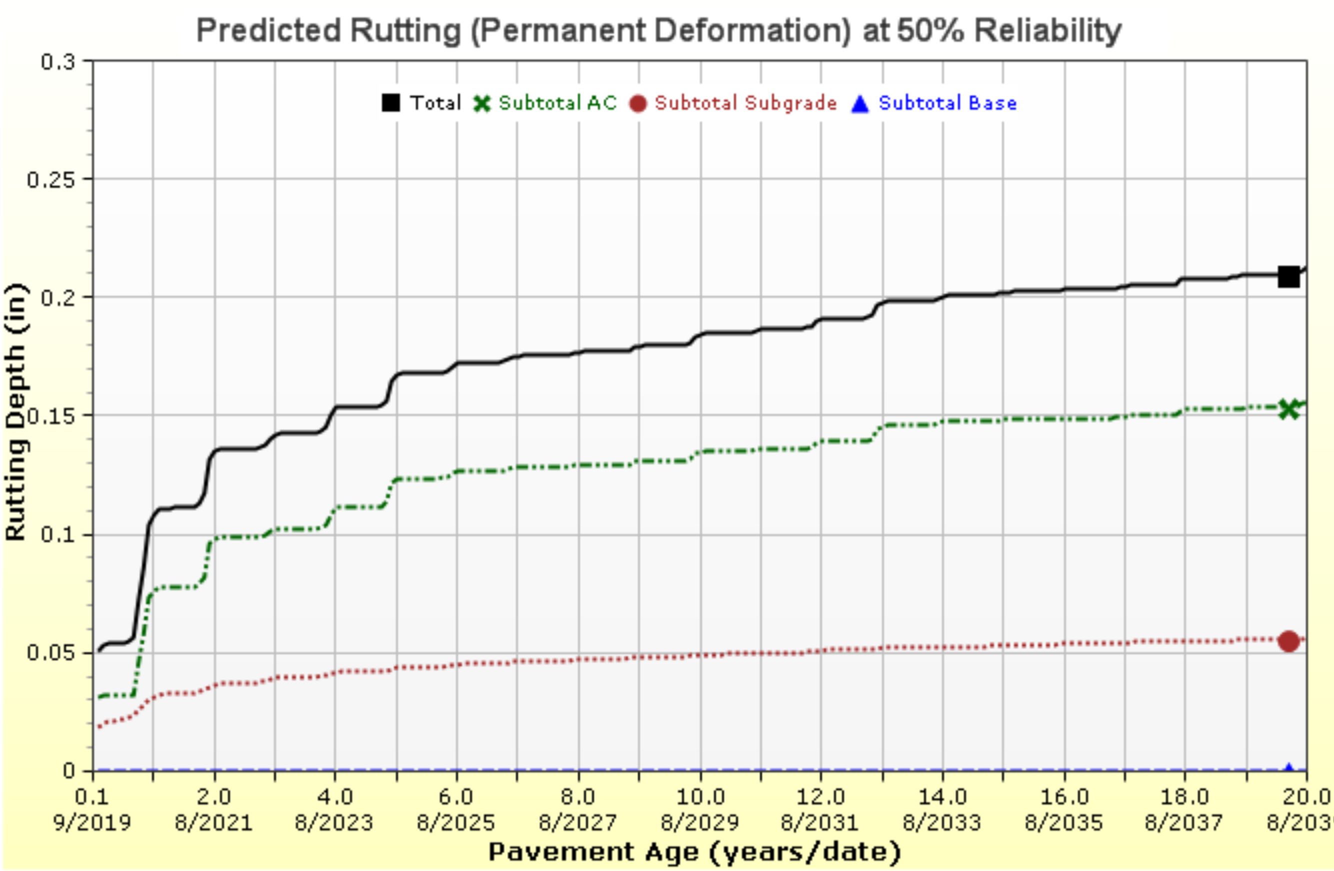


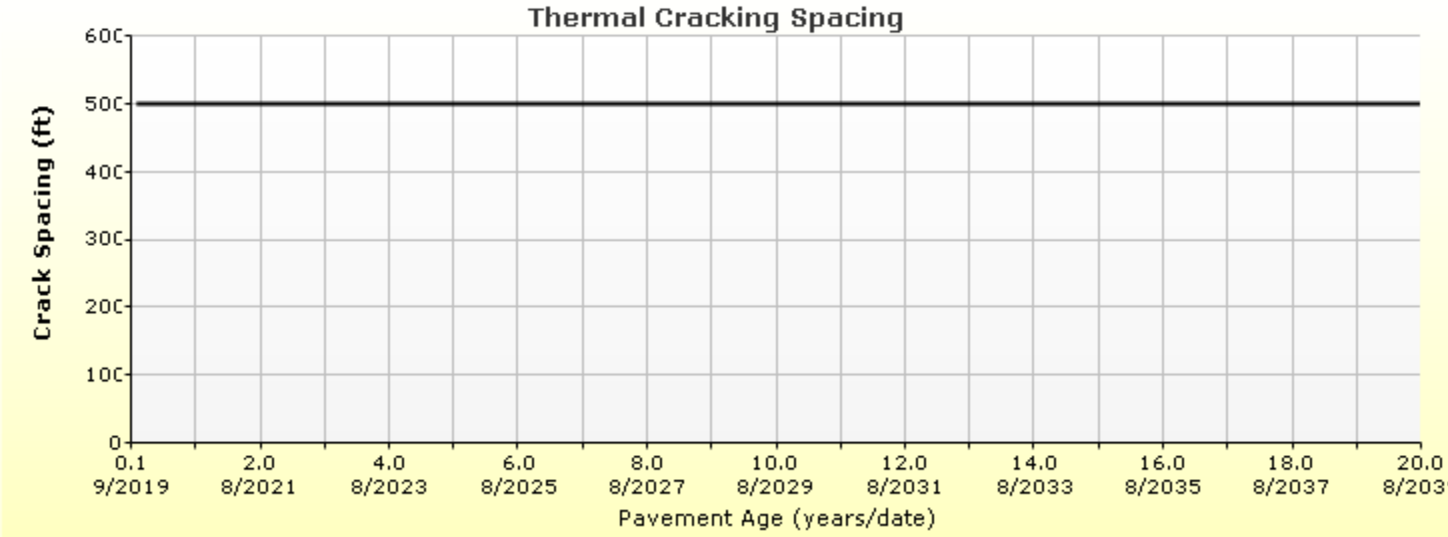


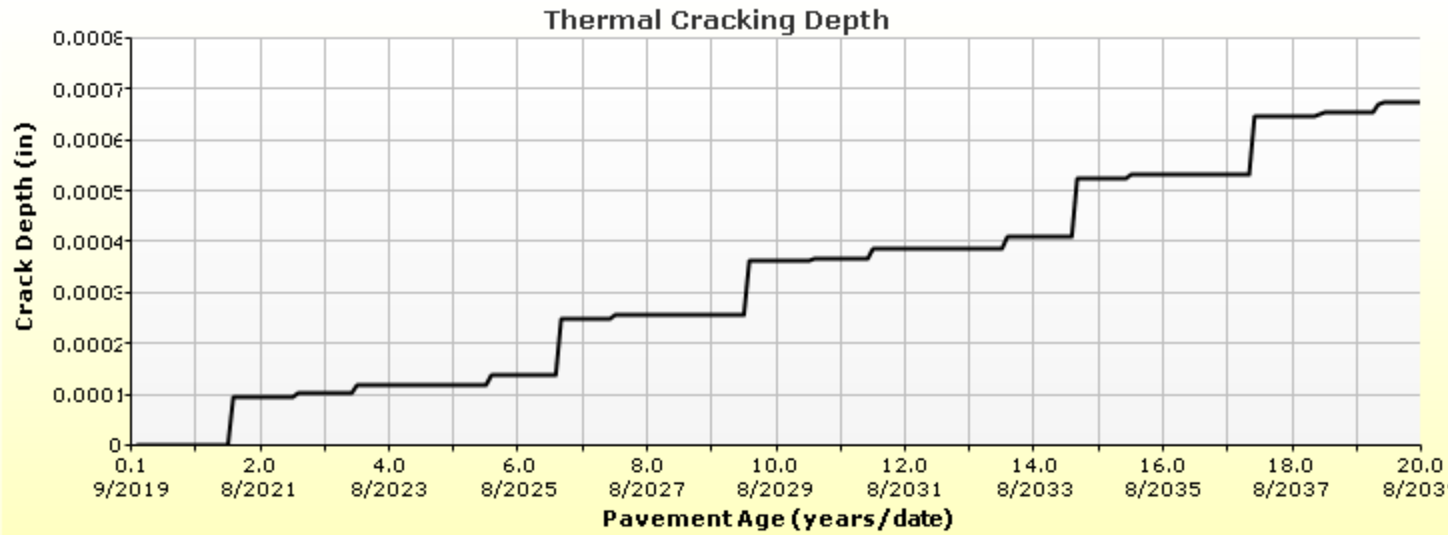
Predicted AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)

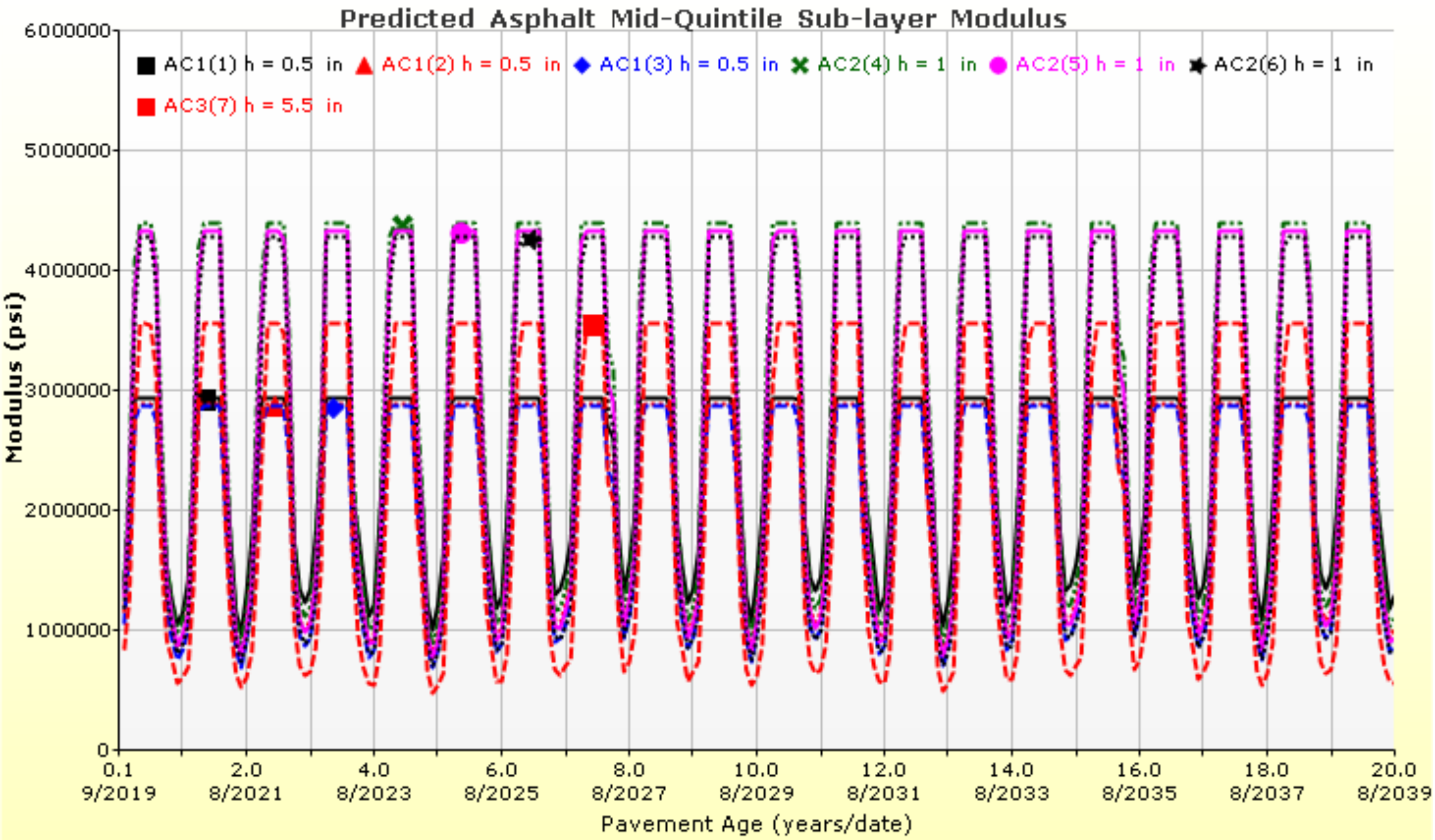


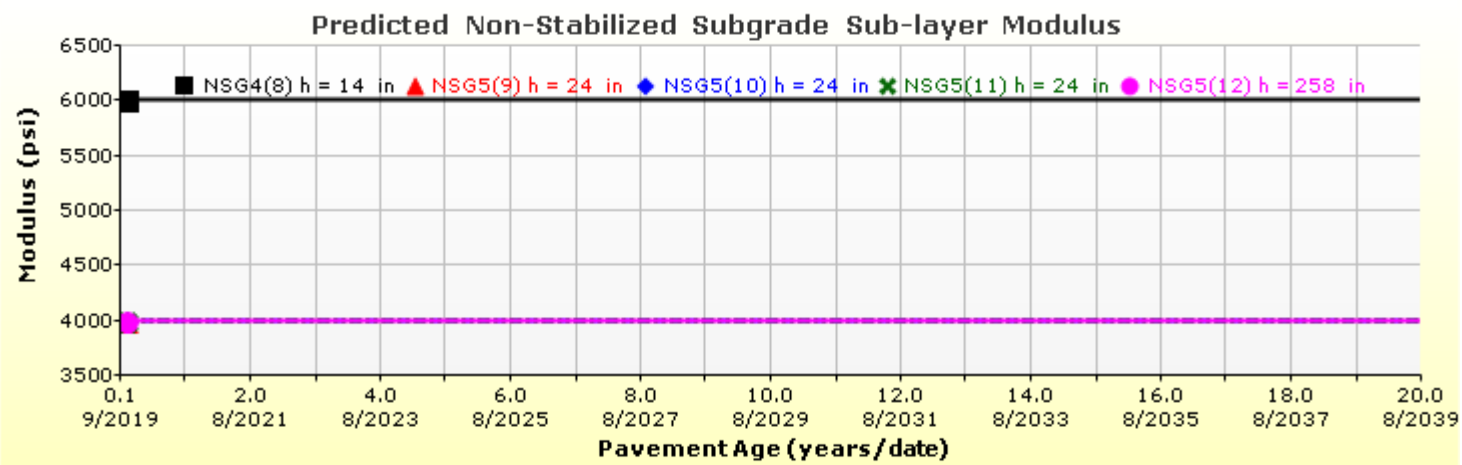
Predicted AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
0
500
1000
1500
2000
2500
Predicted AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
0
10
20
30
40
50
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rutting Depth (in)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)


Predicted Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 0.5 in
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 1 in
AC3(7) h = 5.5 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 14 in
NSG5(9) h = 24 in
NSG5(10) h = 24 in
NSG5(11) h = 24 in
NSG5(12) h = 258 in
Modulus (psi)
6500
6000
5500
5000
4500
4000
3500
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Seymour 9.5mm PG70-22

Asphalt		
Thickness (in.)	1.5	
Unit weight (pcf)	142.6	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	1932546	2355005	2642382	3298195
40	1507676	1691777	1864079	2093353
70	262246	488012	733332	882731
100	55053	123973	246641	323256
130	24989	46973	96996	131550

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	22069340.66	33.76
55	9518271.99	44.39
70	2836317.75	52.87
85	765738.66	59.68
100	209102.28	65.17
115	60602.87	69.62
130	19021.84	73.24

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	11.61
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 9.5mm PG70-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : Seymour 19.0mm PG70-22

Asphalt		
Thickness (in.)	3.0	
Unit weight (pcf)	143.8	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	2963030	3640294	4200283	5000000
40	2286934	2578608	2852971	3220280
70	368909	705010	1078041	1308064
100	72377	168834	345974	458741
130	31704	61317	130686	179591

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	22069340.66	33.76
55	9518271.99	44.39
70	2836317.75	52.87
85	765738.66	59.68
100	209102.28	65.17
115	60602.87	69.62
130	19021.84	73.24

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	9.53
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 19.0mm PG70-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 3 Flexible : Seymour 25.0mm PG64-22

Asphalt		
Thickness (in.)	5.5	
Unit weight (pcf)	144.4	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	2557822	3112035	3433058	4258578
40	1695559	2178666	2555866	2919290
70	223799	532345	929105	1158926
100	47413	119486	277451	381718
130	24261	45157	101209	142860

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	25339156.98	34.85
55	9930922.35	46.6
70	2585999.72	55.79
85	613653.8	63
100	149927.8	68.71
115	39662.01	73.23
130	11579.02	76.83

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	8.69
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 25.0mm PG64-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 4 Subgrade : A-4

Unbound	
Layer thickness (in.)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 5 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

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

AC Rutting

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

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

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

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:0.07 Br2:1.9 Br3:0.4

Thermal Fracture

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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: 0.12	k1: 1.35	Bs1: 0.12
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

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

AC Bottom Up Cracking

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

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

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

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

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

CSM Cracking

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

C1: 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: 40	C2: 0.4	C3: 0.008	C4: 0.015

PCCP Run(IRI) - 12

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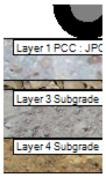
Design Inputs

Design Life:	26 years	Existing construction:	-	Climate Data Sources (Lat/Lon)	39.144, -86.617
Design Type:	Jointed Plain Concrete Pavement (JPCP)	Pavement construction:	July, 2019		39.71, -86.272
		Traffic opening:	September, 2019		38.228, -85.664

Design Structure



Layer type	Material Type	Thickness (in.):
PCC	JPCP	12.0
NonStabilized	Unbound Drainage Layer	3.0
Subgrade	A-4	14.0
Subgrade	A-4	Semi-infinite

Joint Design:

Joint spacing (ft)	15.0
Dowel diameter (in.)	1.50
Slab width (ft)	14.0 (w)

Traffic

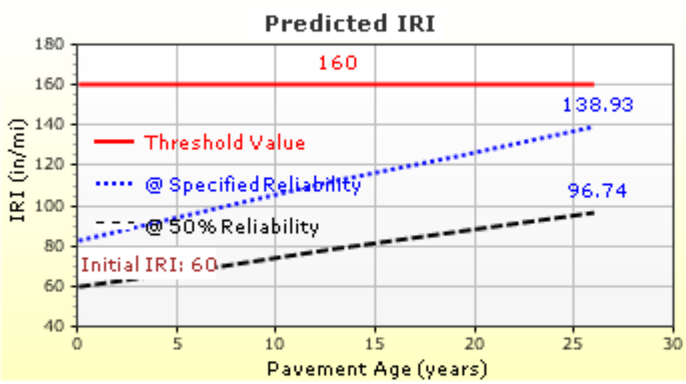
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	13,293
2032 (13 years)	33,324,500
2045 (26 years)	71,157,400

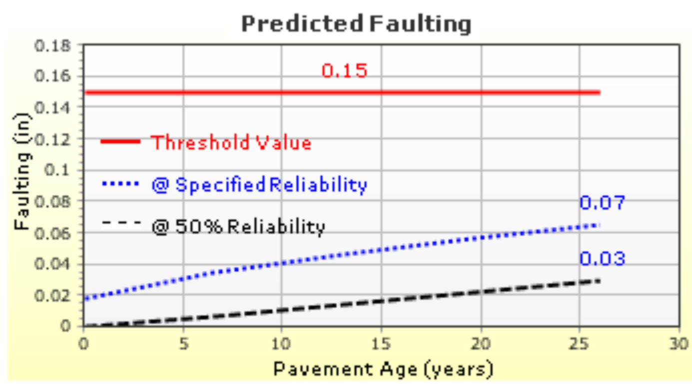
Design Outputs

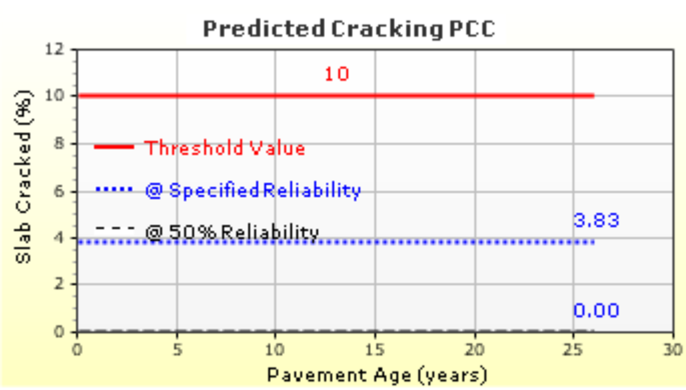
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	138.93	90.00	97.27	Pass
Mean joint faulting (in.)	0.15	0.07	90.00	100.00	Pass
JPCP transverse cracking (percent slabs)	10.00	3.83	90.00	99.96	Pass

Distress Charts



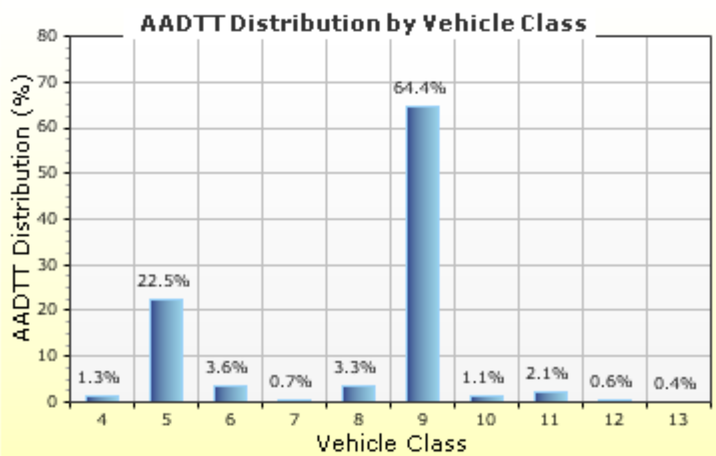


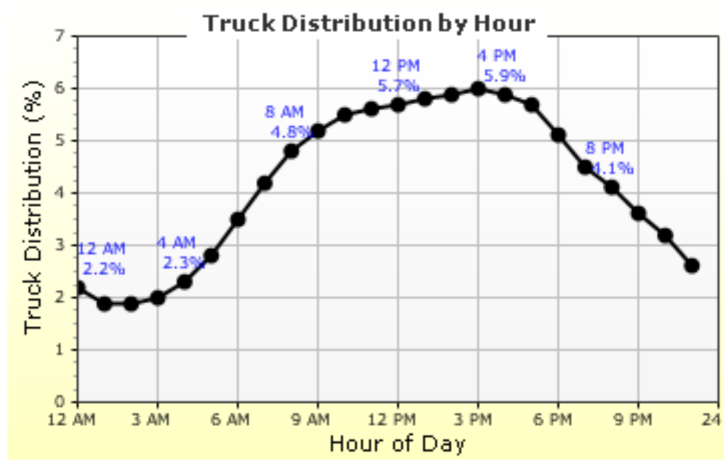


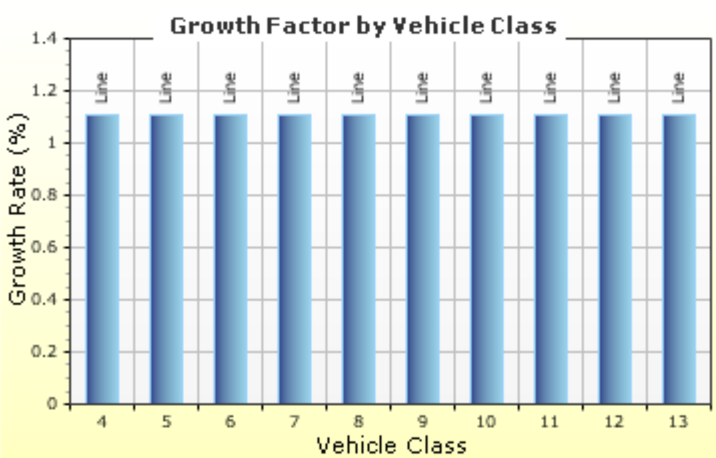
Traffic Inputs

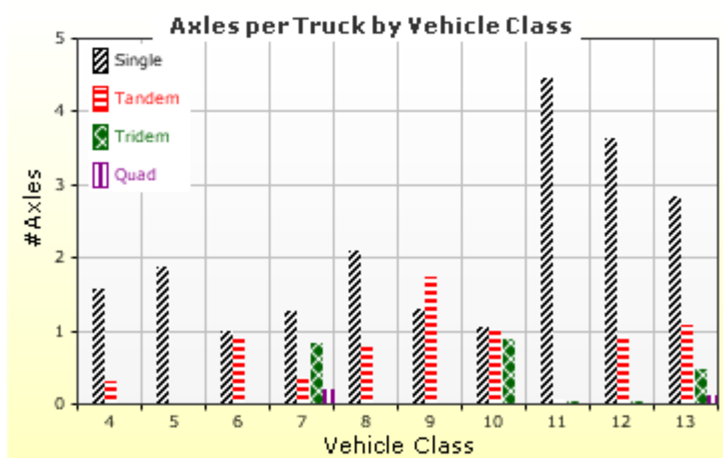
Graphical Representation of Traffic Inputs

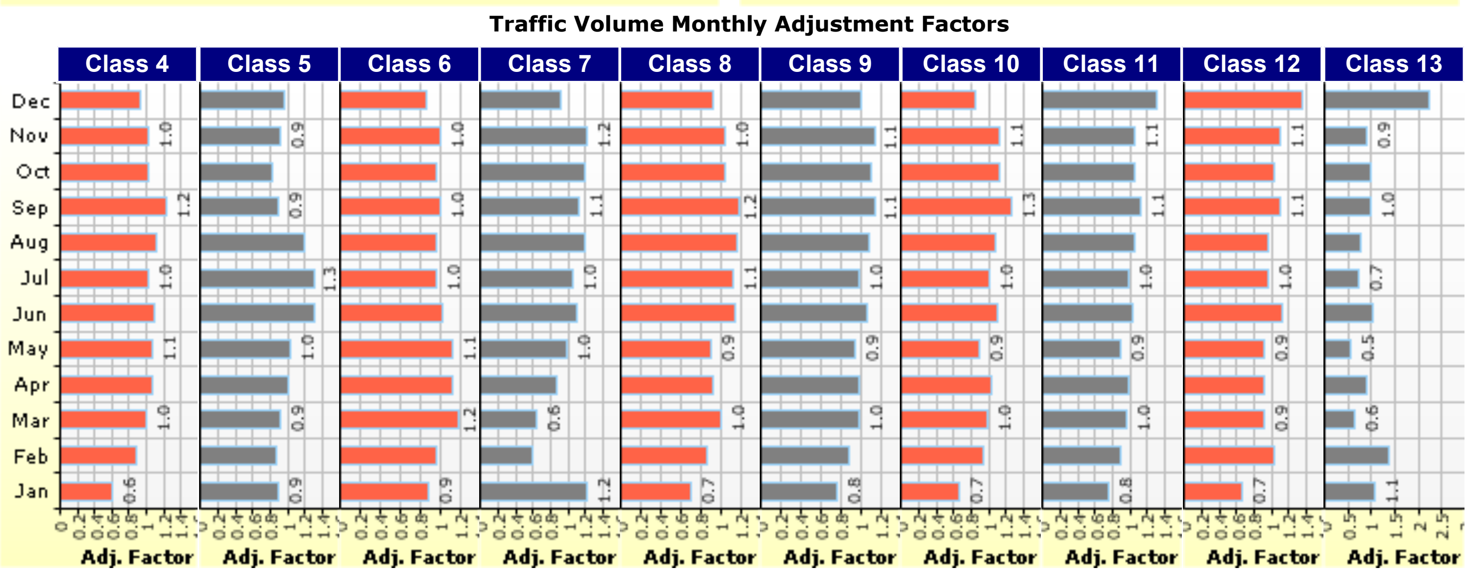
Initial two-way AADTT:	13,293	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	70.0











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	0.6	0.9	0.9	1.2	0.7	0.8	0.7	0.8	0.7	1.1
February	0.9	0.9	1.0	0.6	0.9	0.9	0.9	0.9	1.0	1.4
March	1.0	0.9	1.2	0.6	1.0	1.0	1.0	1.0	0.9	0.6
April	1.1	1.0	1.1	0.9	0.9	1.0	1.0	1.0	0.9	0.9
May	1.1	1.0	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.5
June	1.1	1.3	1.0	1.1	1.1	1.1	1.1	1.0	1.1	1.0
July	1.0	1.3	1.0	1.0	1.1	1.0	1.0	1.0	1.0	0.7
August	1.1	1.2	1.0	1.2	1.2	1.1	1.1	1.1	1.0	0.8
September	1.2	0.9	1.0	1.1	1.2	1.1	1.3	1.1	1.1	1.0
October	1.0	0.8	1.0	1.2	1.0	1.1	1.1	1.1	1.0	1.0
November	1.0	0.9	1.0	1.2	1.0	1.1	1.1	1.1	1.1	0.9
December	0.9	1.0	0.9	0.9	0.9	1.0	0.8	1.3	1.4	2.2

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.3%	1.11%	Linear
Class 5	22.5%	1.11%	Linear
Class 6	3.6%	1.11%	Linear
Class 7	0.7%	1.11%	Linear
Class 8	3.3%	1.11%	Linear
Class 9	64.4%	1.11%	Linear
Class 10	1.1%	1.11%	Linear
Class 11	2.1%	1.11%	Linear
Class 12	0.6%	1.11%	Linear
Class 13	0.4%	1.11%	Linear

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	2.2%	12 PM	5.7%
1 AM	1.9%	1 PM	5.8%
2 AM	1.9%	2 PM	5.9%
3 AM	2%	3 PM	6%
4 AM	2.3%	4 PM	5.9%
5 AM	2.8%	5 PM	5.7%
6 AM	3.5%	6 PM	5.1%
7 AM	4.2%	7 PM	4.5%
8 AM	4.8%	8 PM	4.1%
9 AM	5.2%	9 PM	3.6%
10 AM	5.5%	10 PM	3.2%
11 AM	5.6%	11 PM	2.6%
		Total	100%

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

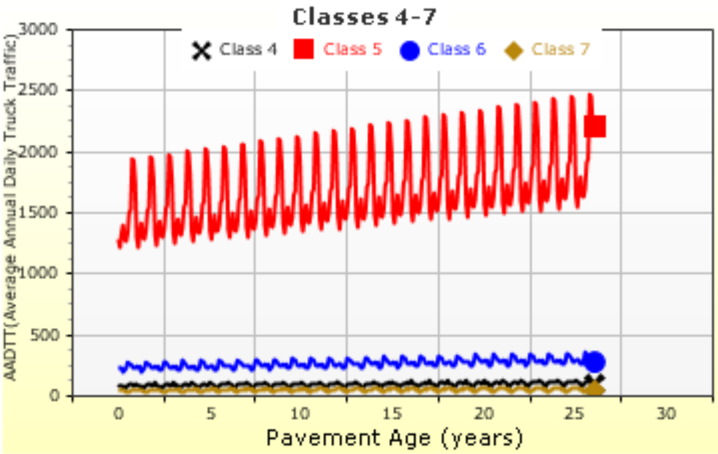
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12	15	18
Percent of Trucks (%)	33	33	34

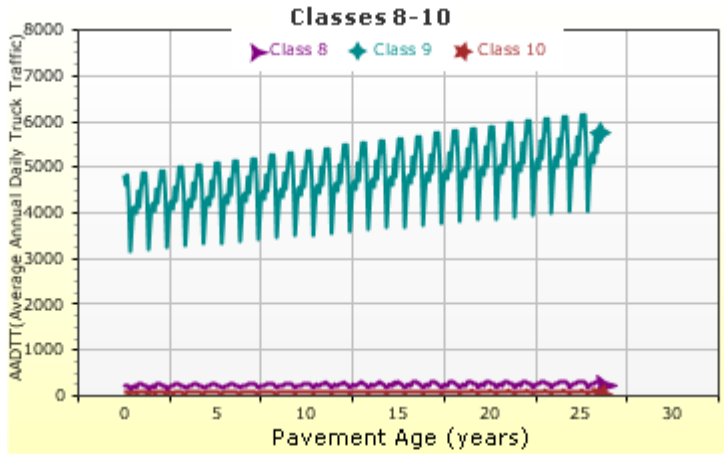
Number of Axles per Truck

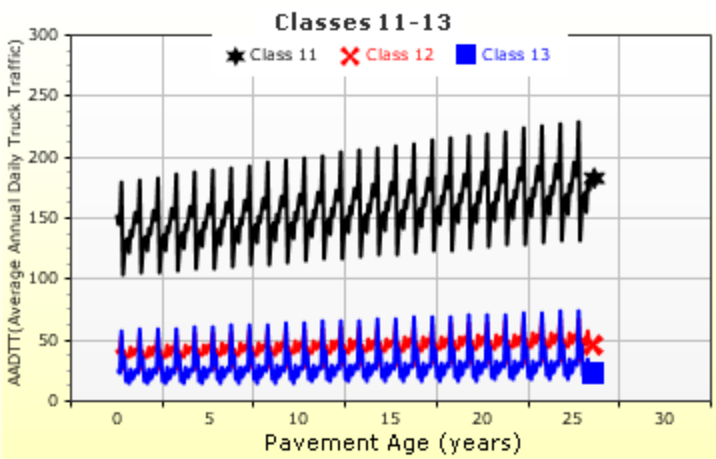
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

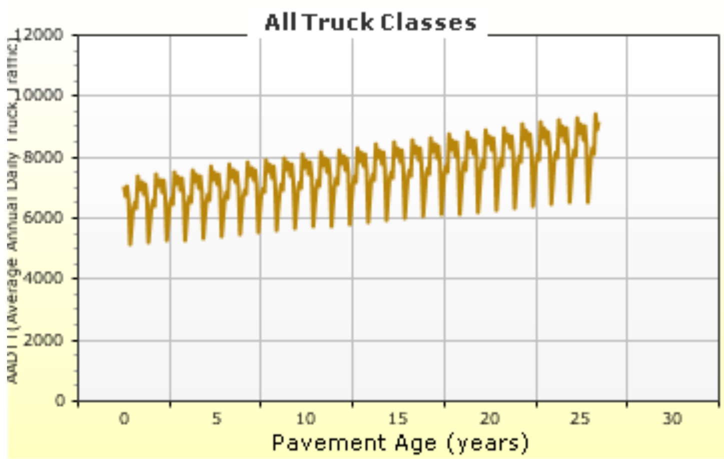
AADTT (Average Annual Daily Truck Traffic) Growth

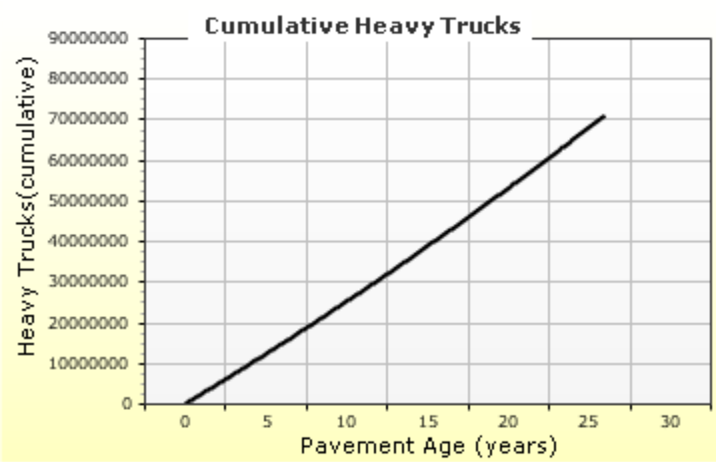
*** Traffic cap is not enforced**







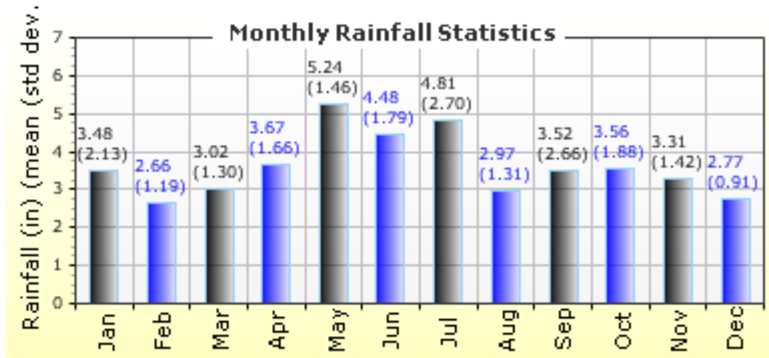




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

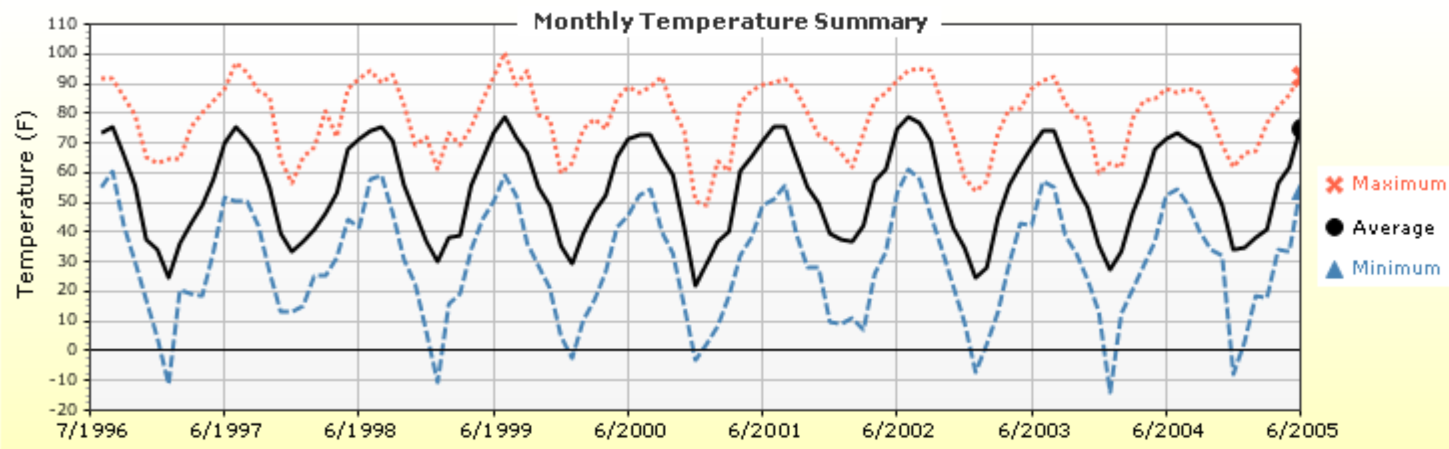


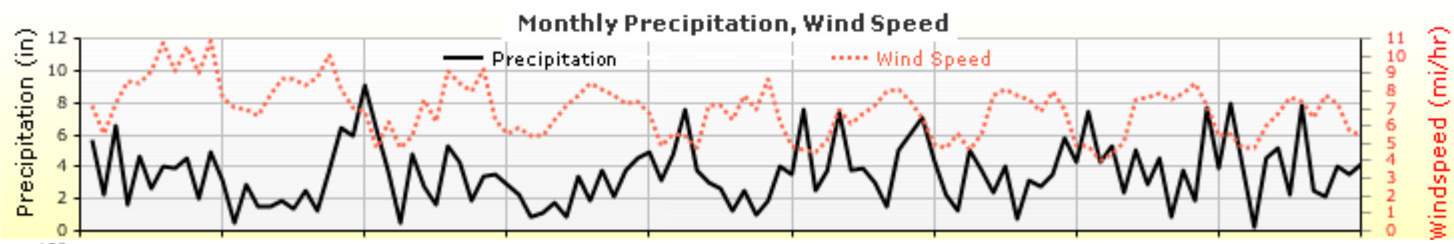
Annual Statistics:

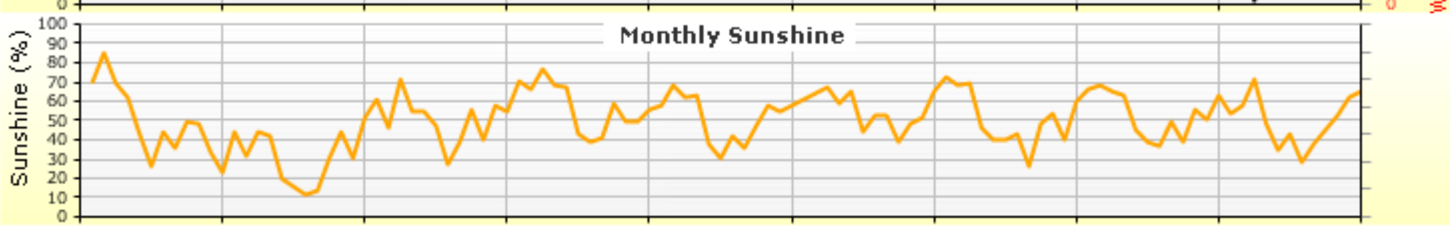
Mean annual air temperature (ºF)	54.14
Mean annual precipitation (in.)	43.47
Freezing index (ºF - days)	426.14
Average annual number of freeze/thaw cycles:	61.76

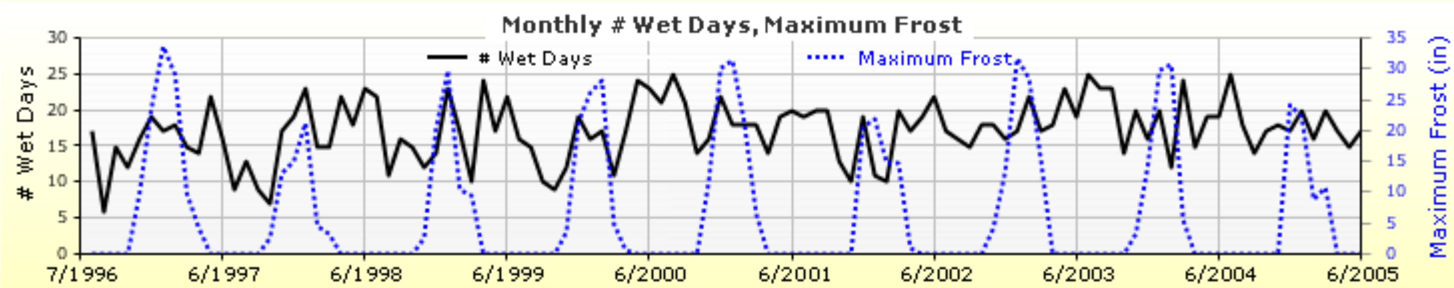
Water table depth (ft)	5.00

Monthly Climate Summary:

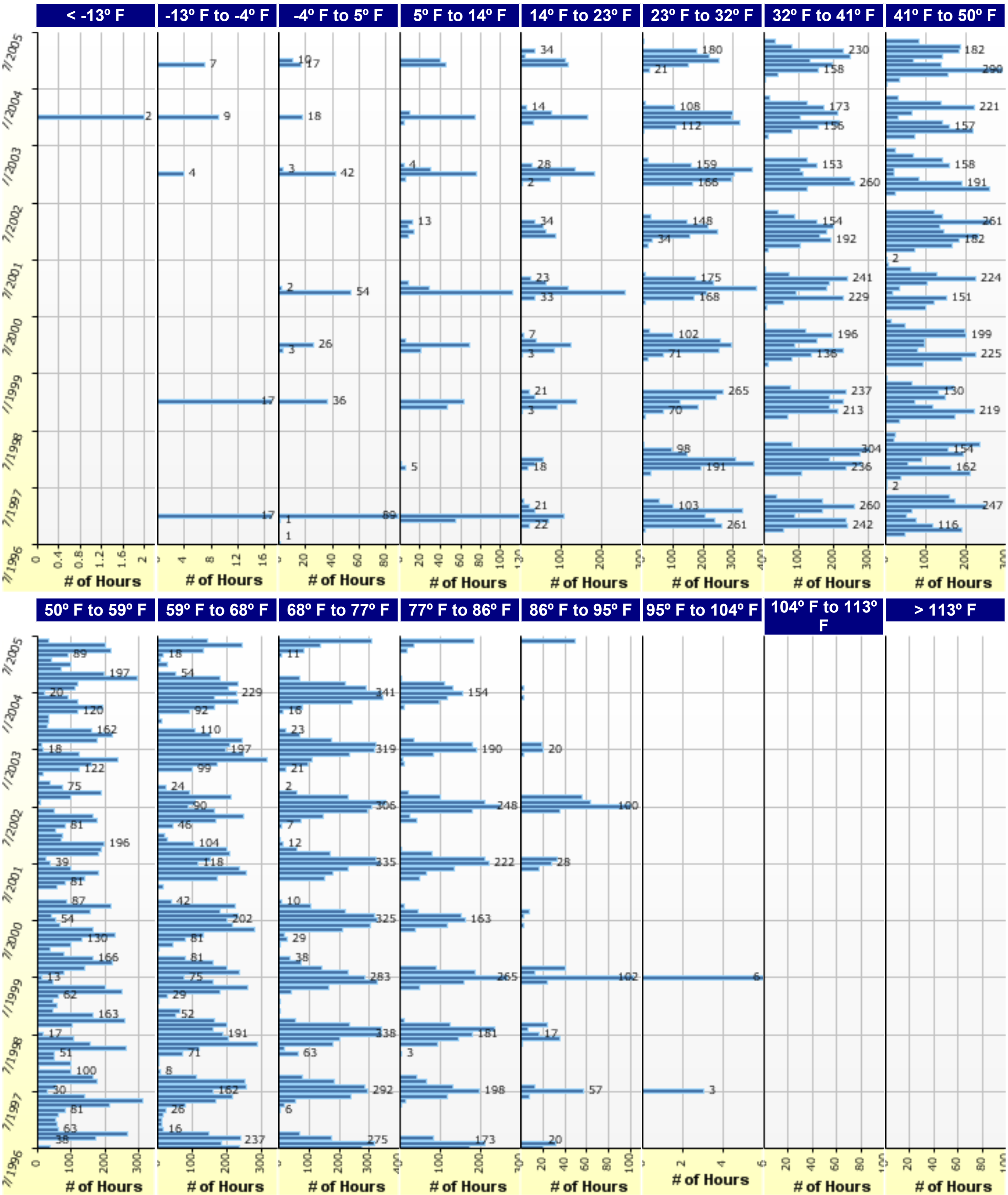








Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in.)	1.50
Dowel spacing (in.)	12.00

Tied Shoulders	
Tied shoulders	False
Load transfer efficiency (%)	-

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

Widened Slab	
Is slab widened ?	True
Slab width (ft)	14.00

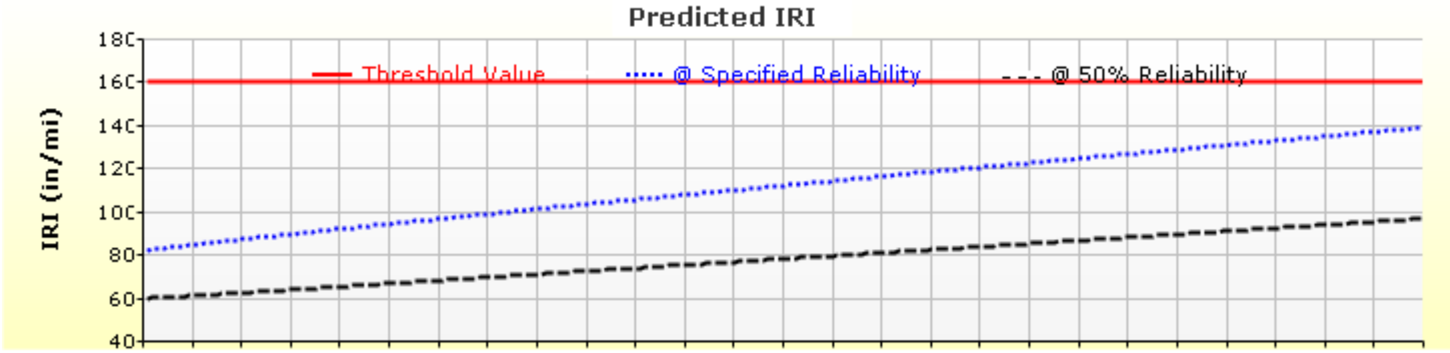
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	600.00

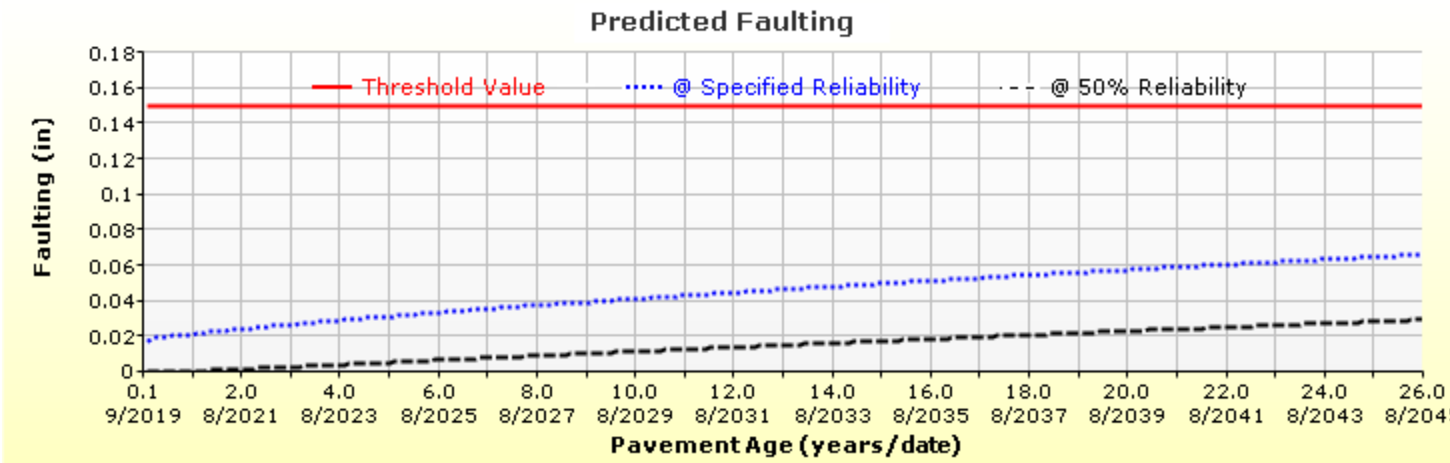
Sealant type	Other(Including No Sealant... Liquid... Silicone)

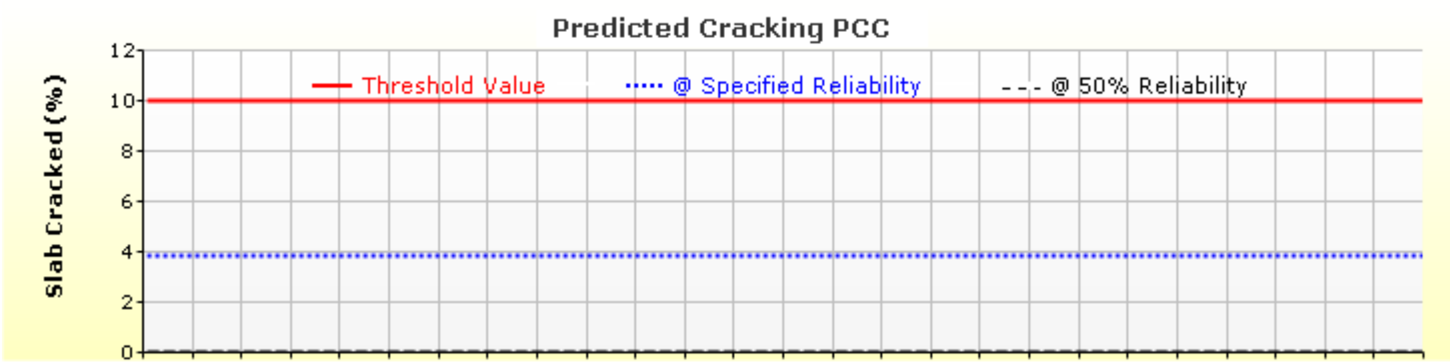
Erodibility index	2

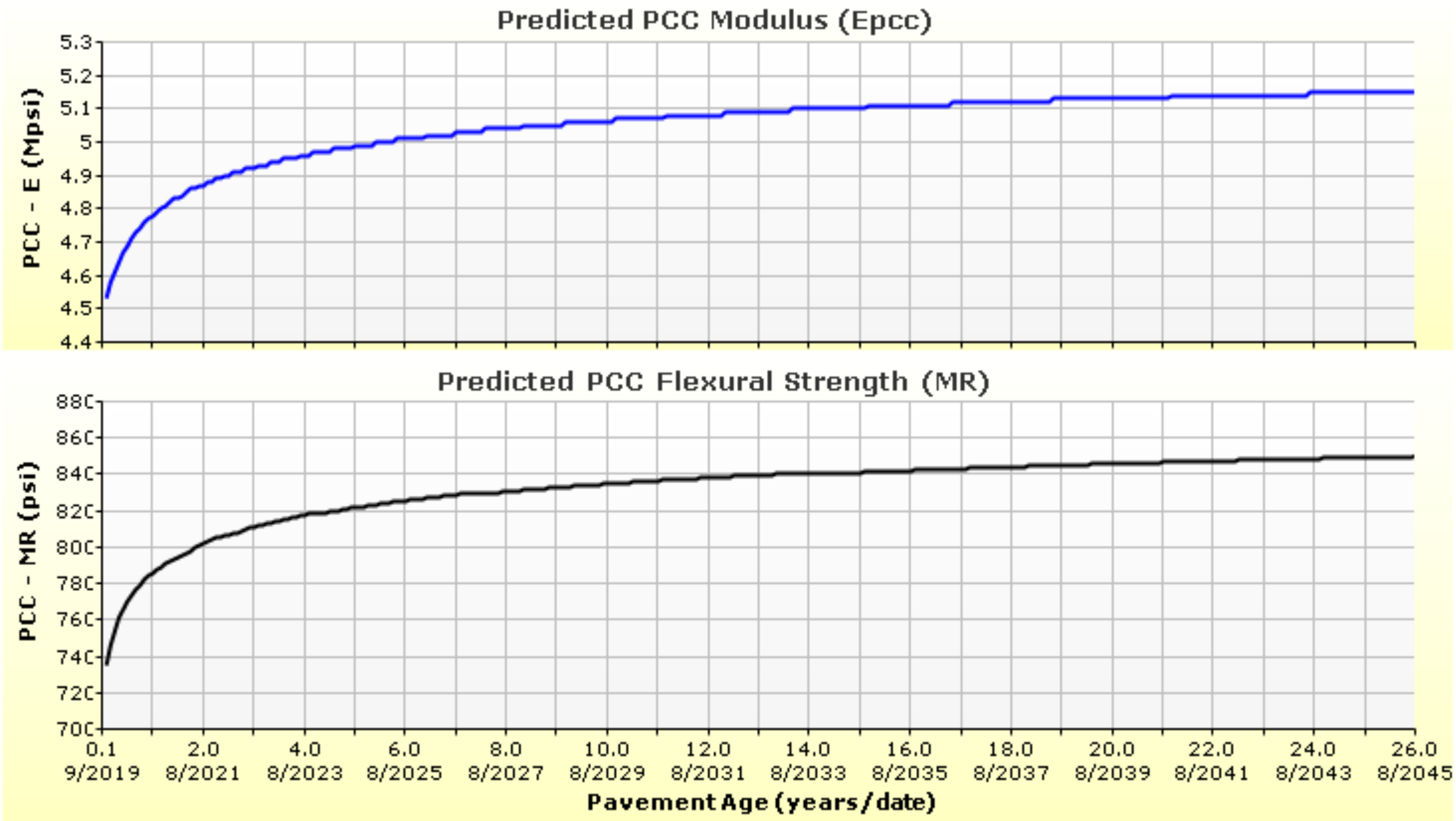
Permanent curl/warp effective temperature difference (ºF)	-10.00

Analysis Output Charts

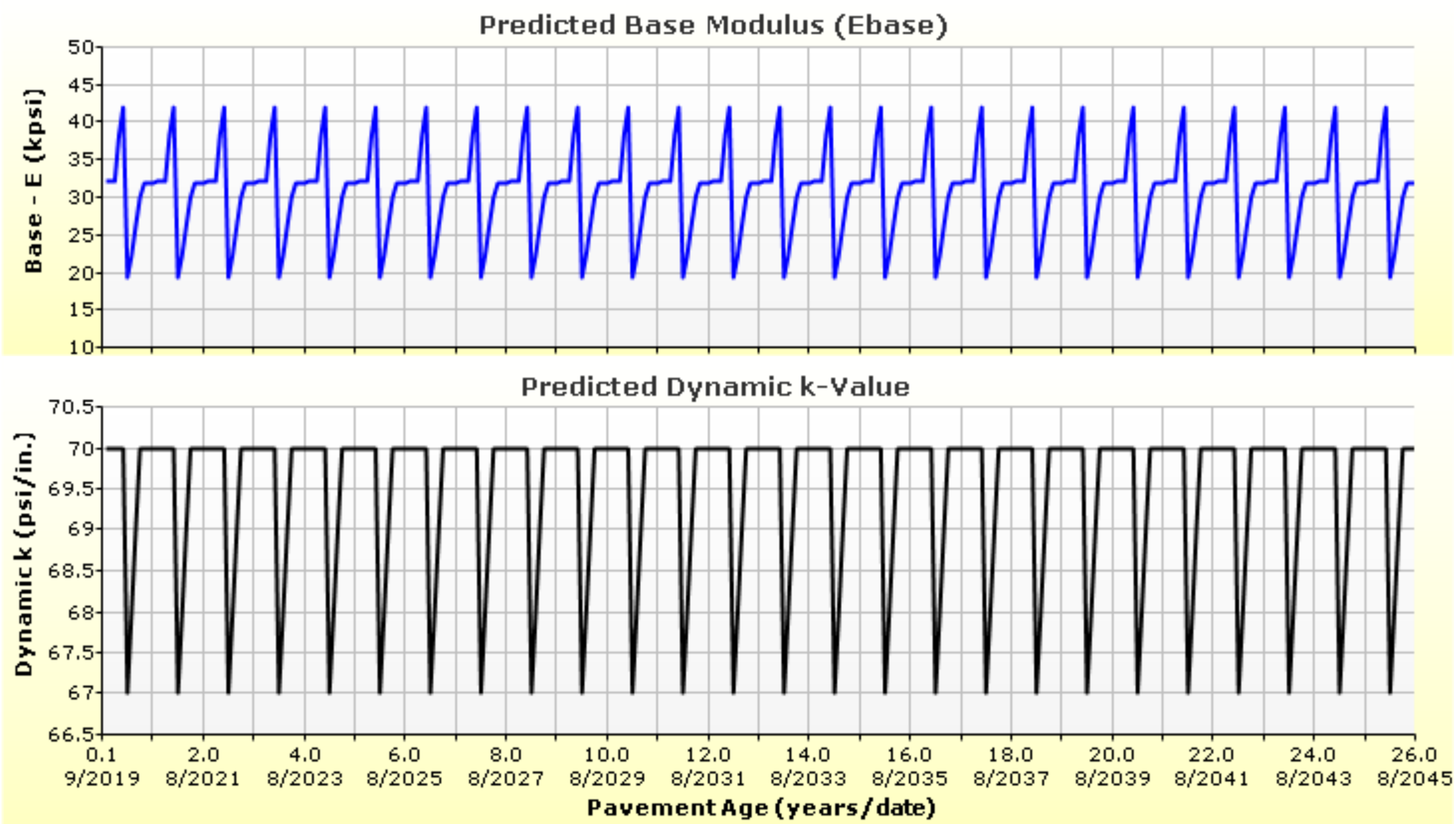




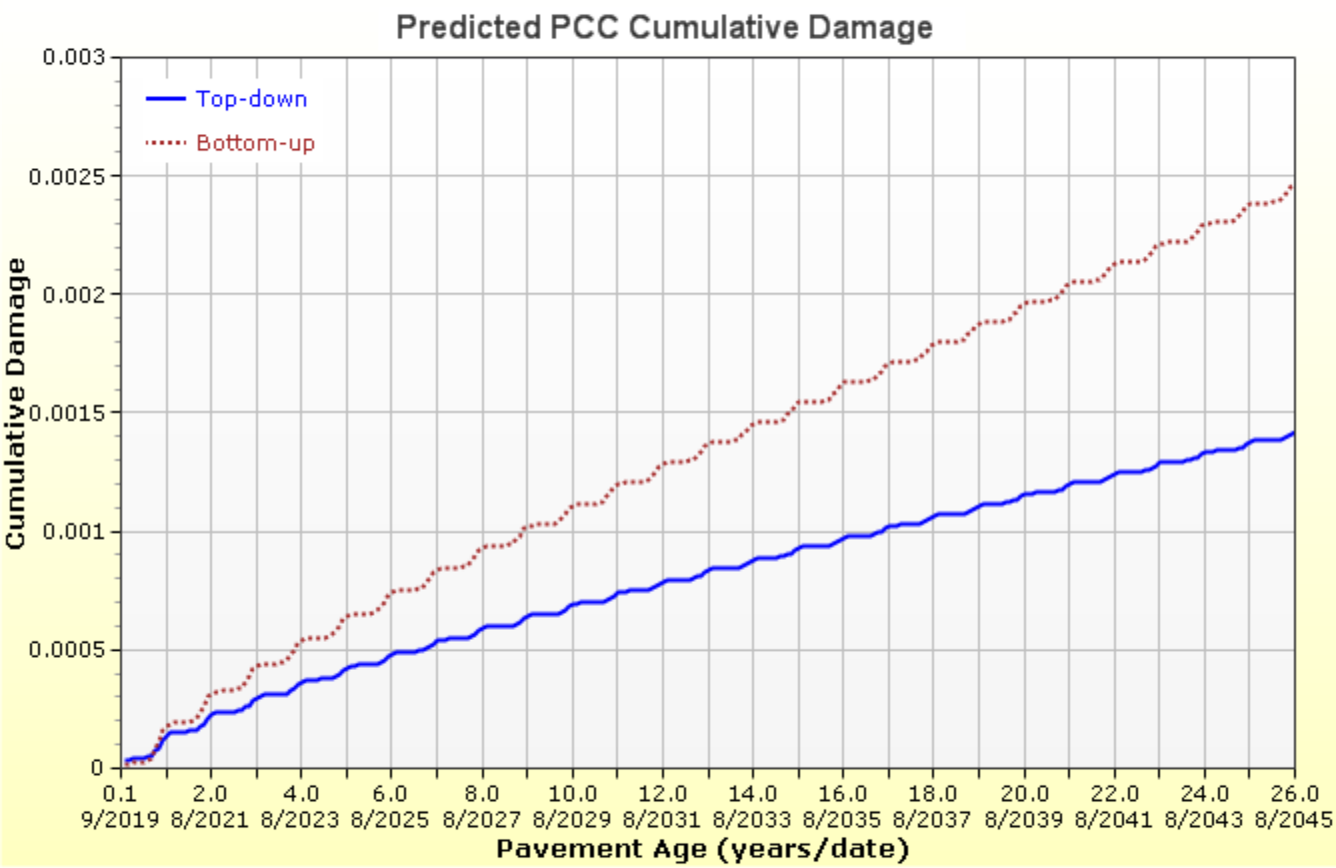




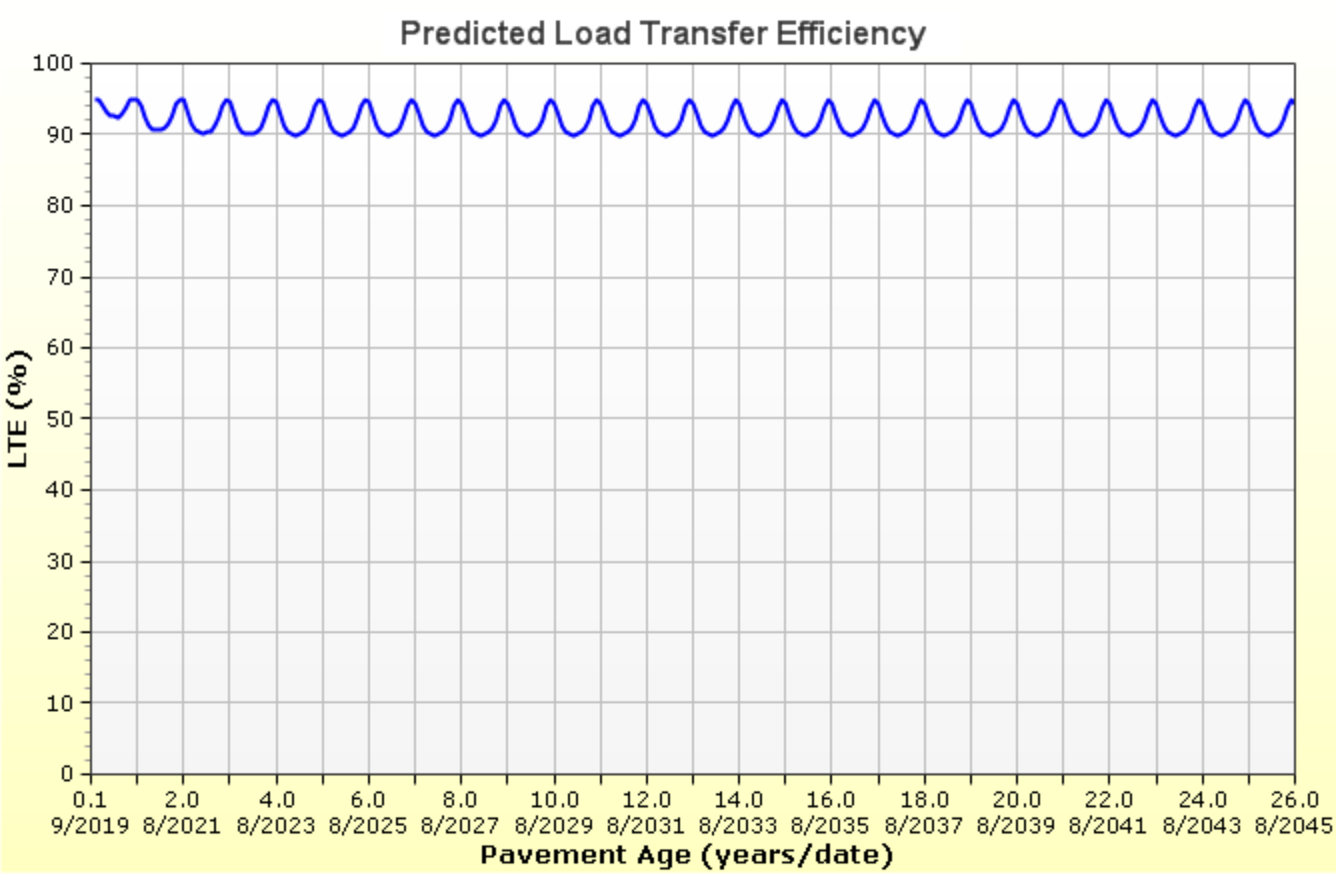
Predicted PCC Modulus (Epcc)
PCC - E (Mpsi)
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
Predicted PCC Flexural Strength (MR)
PCC - MR (psi)
880
860
840
820
800
780
760
740
720
700
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
22.0 8/2041
24.0 8/2043
26.0 8/2045
Pavement Age (years/date)



Predicted Base Modulus (Ebase)
Base - E (kpsi)
50
45
40
35
30
25
20
15
10
Predicted Dynamic k-Value
Dynamic k (psi/in.)
70.5
70
69.5
69
68.5
68
67.5
67
66.5
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
22.0 8/2041
24.0 8/2043
26.0 8/2045
Pavement Age (years/date)



Predicted PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
22.0 8/2041
24.0 8/2043
26.0 8/2045
Pavement Age (years/date)



Predicted Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
0.1 9/2019
2.0 8/2021
4.0 8/2023
6.0 8/2025
8.0 8/2027
10.0 8/2029
12.0 8/2031
14.0 8/2033
16.0 8/2035
18.0 8/2037
20.0 8/2039
22.0 8/2041
24.0 8/2043
26.0 8/2045
Pavement Age (years/date)

Layer Information

Layer 1 PCC : JPCP

PCC	
Thickness (in.)	12.0
Unit weight (pcf)	145.0
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in./in./ºF x 10^-6)	4.7
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)		510
Water to cement ratio		0.42
Aggregate type		Limestone (1)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	103.5
Ultimate shrinkage (microstrain)	Calculated Internally?	False
	User Value	483.0
	Calculated Value	-
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 3)

28-Day PCC modulus of rupture (psi)	700.0
28-Day PCC elastic modulus (psi)	-

Identifiers

Field	Value
Display name/identifier	JPCP
Description of object	
Author	
Date Created	12/18/2012 2:32:19 PM
Approver	
Date approved	12/18/2012 2:32:19 PM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Unbound Drainage Layer

Unbound	
Layer thickness (in.)	3.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Unbound Drainage Layer
Description of object	No. 8 Layer of Subbase for PCCP
Author	Matt Taylor
Date Created	1/31/2013 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 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

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

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

Layer 3 Subgrade : A-4

Unbound	
Layer thickness (in.)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 4 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

PCC Faulting

$$C_{12} = C_1 + (C_2 * FR^{0.25})$$

$$C_{34} = C_3 + (C_4 * FR^{0.25})$$

$$FaultMax_0 = C_{12} * \delta_{curling} * \left[\log(1 + C_5 * 5.0^{EROD}) * \log\left(P_{200} * \frac{WetDays}{p_s}\right)\right]^{C_6}$$

$$FaultMax_i = FaultMax_0 + C_7 * \sum_{j=1}^{m} DE_j * \log(1 + C_5 * 5.0^{EROD})^{C_6}$$

$$\Delta Fault_i = C_{34} * (FaultMax_{i-1} - Fault_{i-1})^2 * DE_i$$

$$C_8 = DowelDeterioration$$

C1: 1.0184	C2: 0.91656	C3: 0.0021848	C4: 0.000883739
C5: 250	C6: 0.4	C7: 1.83312	C8: 400
PCC Reliability Faulting Standard Deviation			
Pow(0.0097*FAULT,0.5178)+0.014			

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: 1	C5: -1.98
PCC Reliability Cracking Standard Deviation			
Pow(5.3116*CRACK,0.3903) + 2.99			

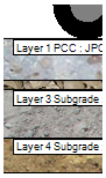
PCCP Run(Structural) - 12

File Name: C:\My ME Design\Projects\MK16-465 SE BV\170313 TP-App No 3\PCCP Run(Structural) - 12.dgpx

Design Inputs

Design Life:	98 years	Existing construction:	-	Climate Data Sources (Lat/Lon)	39.144, -86.617
Design Type:	Jointed Plain Concrete Pavement (JPCP)	Pavement construction:	July, 2019		39.71, -86.272
		Traffic opening:	September, 2019		38.228, -85.664

Design Structure



Layer type	Material Type	Thickness (in.):
PCC	JPCP	12.0
NonStabilized	Unbound Drainage Layer	3.0
Subgrade	A-4	14.0
Subgrade	A-4	Semi-infinite

Joint Design:

Joint spacing (ft)	15.0
Dowel diameter (in.)	1.50
Slab width (ft)	14.0 (w)

Traffic

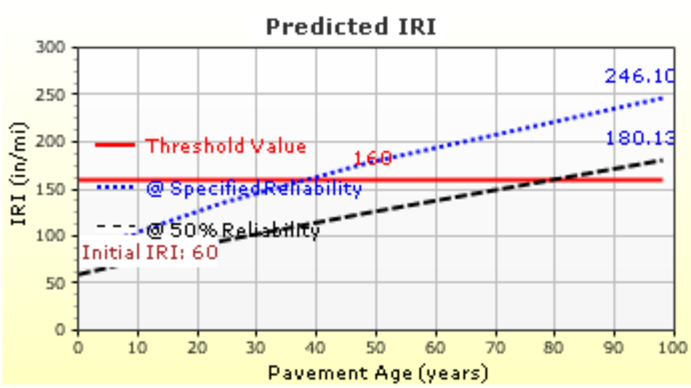
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	13,293
2068 (49 years)	149,137,000
2117 (98 years)	362,326,000

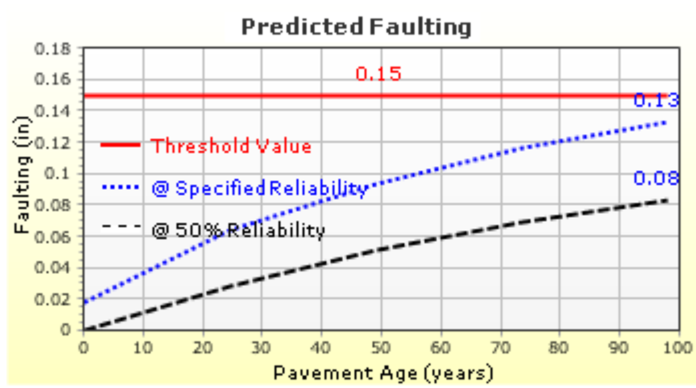
Design Outputs

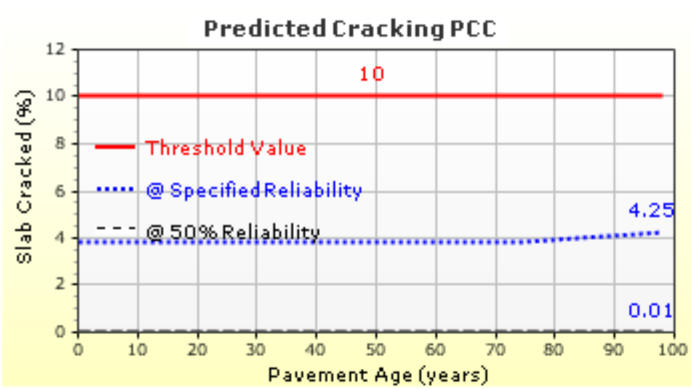
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	246.10	90.00	34.79	Fail
Mean joint faulting (in.)	0.15	0.13	90.00	95.50	Pass
JPCP transverse cracking (percent slabs)	10.00	4.25	90.00	99.87	Pass

Distress Charts



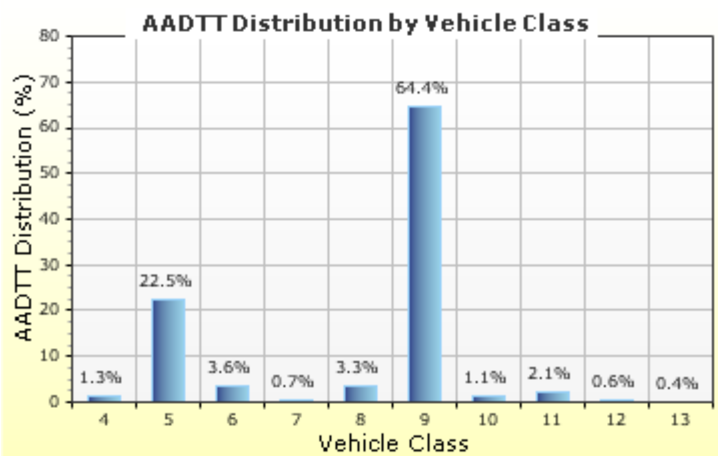


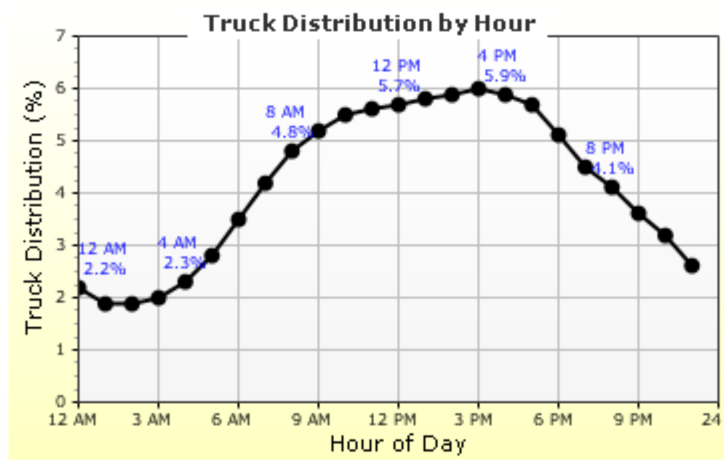


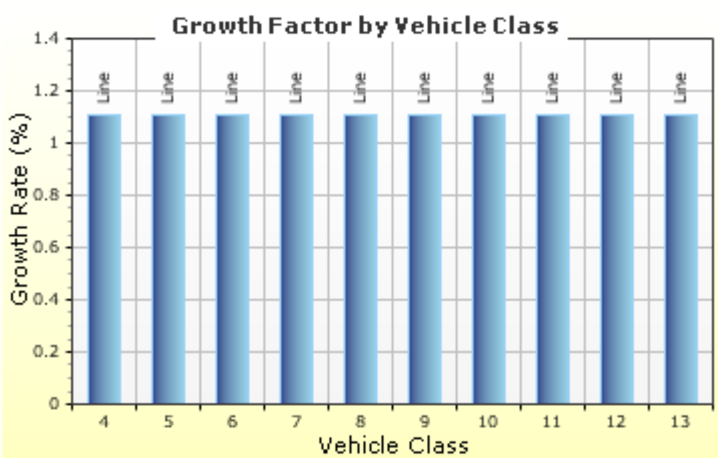
Traffic Inputs

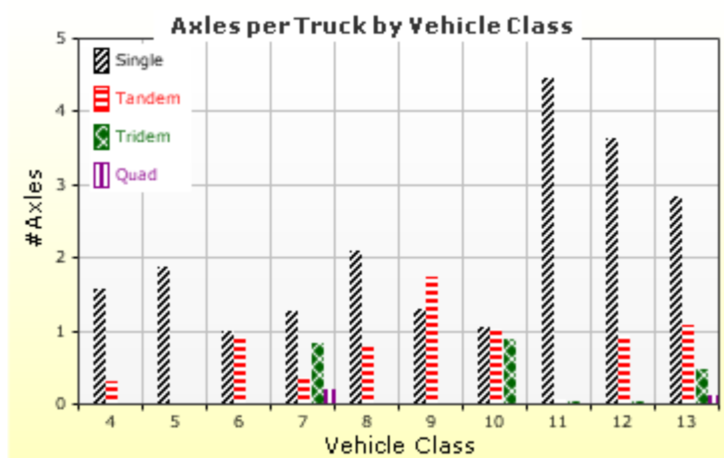
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	13,293	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	70.0

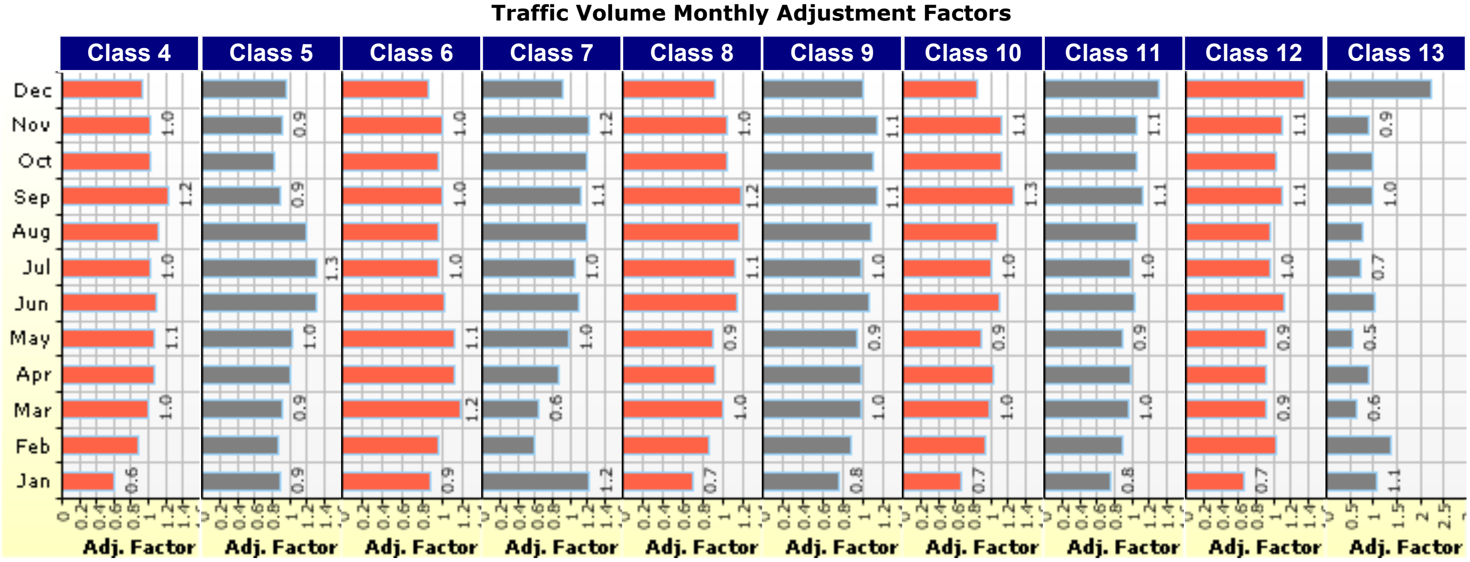








Traffic Volume Monthly Adjustment Factors



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	0.6	0.9	0.9	1.2	0.7	0.8	0.7	0.8	0.7	1.1
February	0.9	0.9	1.0	0.6	0.9	0.9	0.9	0.9	1.0	1.4
March	1.0	0.9	1.2	0.6	1.0	1.0	1.0	1.0	0.9	0.6
April	1.1	1.0	1.1	0.9	0.9	1.0	1.0	1.0	0.9	0.9
May	1.1	1.0	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.5
June	1.1	1.3	1.0	1.1	1.1	1.1	1.1	1.0	1.1	1.0
July	1.0	1.3	1.0	1.0	1.1	1.0	1.0	1.0	1.0	0.7
August	1.1	1.2	1.0	1.2	1.2	1.1	1.1	1.1	1.0	0.8
September	1.2	0.9	1.0	1.1	1.2	1.1	1.3	1.1	1.1	1.0
October	1.0	0.8	1.0	1.2	1.0	1.1	1.1	1.1	1.0	1.0
November	1.0	0.9	1.0	1.2	1.0	1.1	1.1	1.1	1.1	0.9
December	0.9	1.0	0.9	0.9	0.9	1.0	0.8	1.3	1.4	2.2

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.3%	1.11%	Linear
Class 5	22.5%	1.11%	Linear
Class 6	3.6%	1.11%	Linear
Class 7	0.7%	1.11%	Linear
Class 8	3.3%	1.11%	Linear
Class 9	64.4%	1.11%	Linear
Class 10	1.1%	1.11%	Linear
Class 11	2.1%	1.11%	Linear
Class 12	0.6%	1.11%	Linear
Class 13	0.4%	1.11%	Linear

Truck Distribution by Hour

Hour	Distribution (%)	Hour	Distribution (%)
12 AM	2.2%	12 PM	5.7%
1 AM	1.9%	1 PM	5.8%
2 AM	1.9%	2 PM	5.9%
3 AM	2%	3 PM	6%
4 AM	2.3%	4 PM	5.9%
5 AM	2.8%	5 PM	5.7%
6 AM	3.5%	6 PM	5.1%
7 AM	4.2%	7 PM	4.5%
8 AM	4.8%	8 PM	4.1%
9 AM	5.2%	9 PM	3.6%
10 AM	5.5%	10 PM	3.2%
11 AM	5.6%	11 PM	2.6%
		Total	100%

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

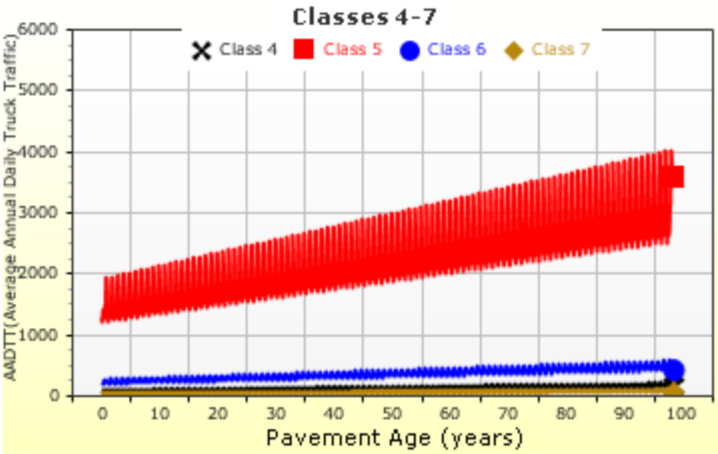
Wheelbase			
Value Type / Axle Type	Short	Medium	Long
Average spacing of axles (ft)	12	15	18
Percent of Trucks (%)	33	33	34

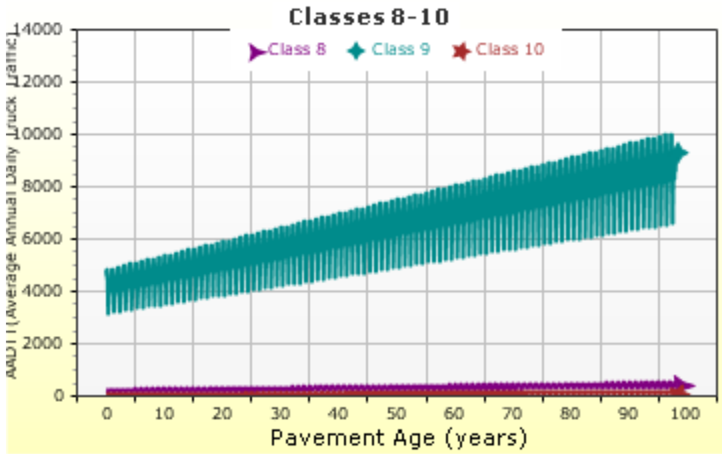
Number of Axles per Truck

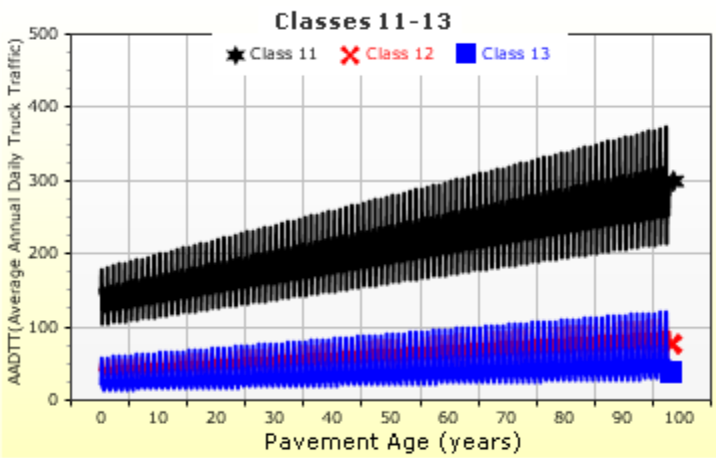
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

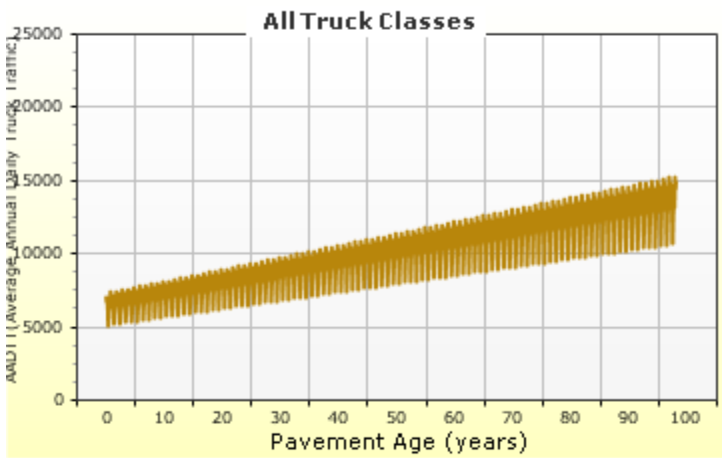
AADTT (Average Annual Daily Truck Traffic) Growth

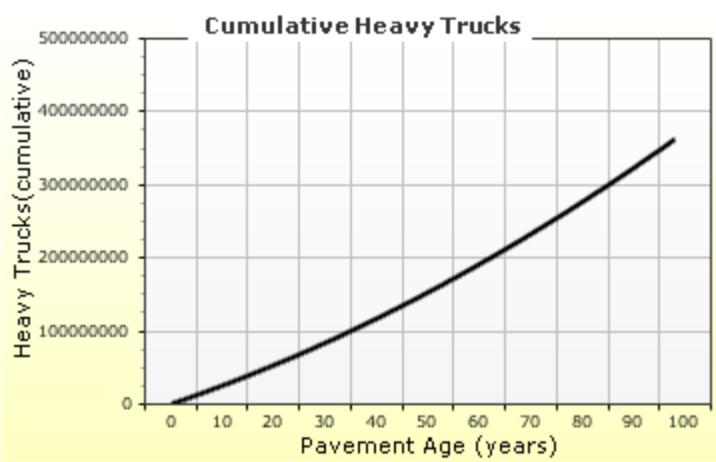
*** Traffic cap is not enforced**







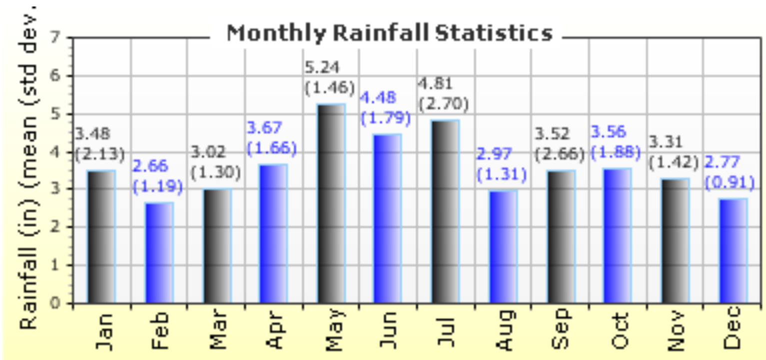




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

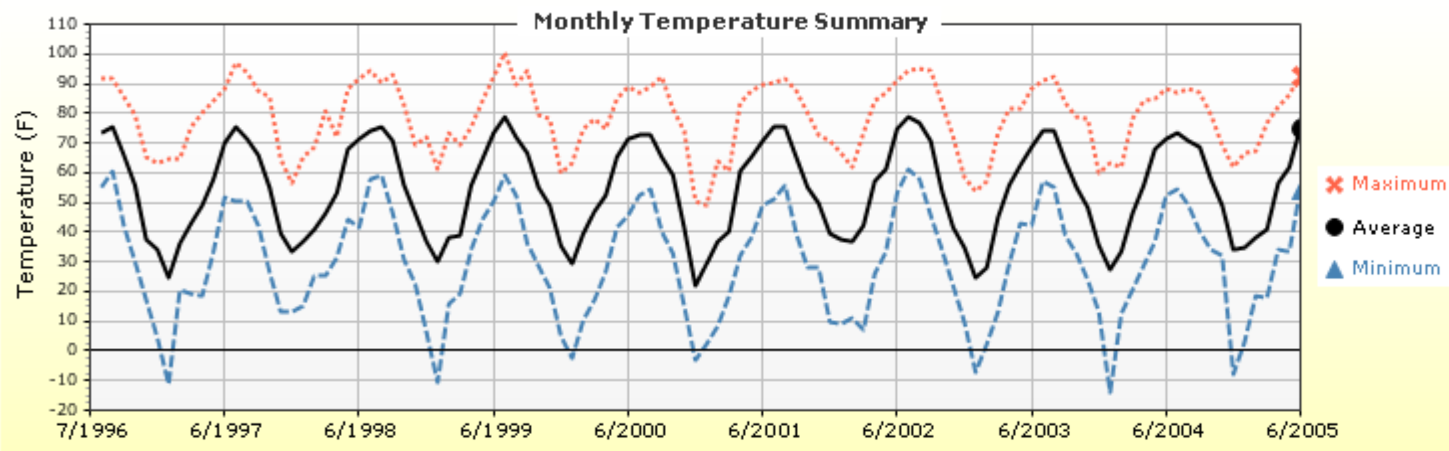


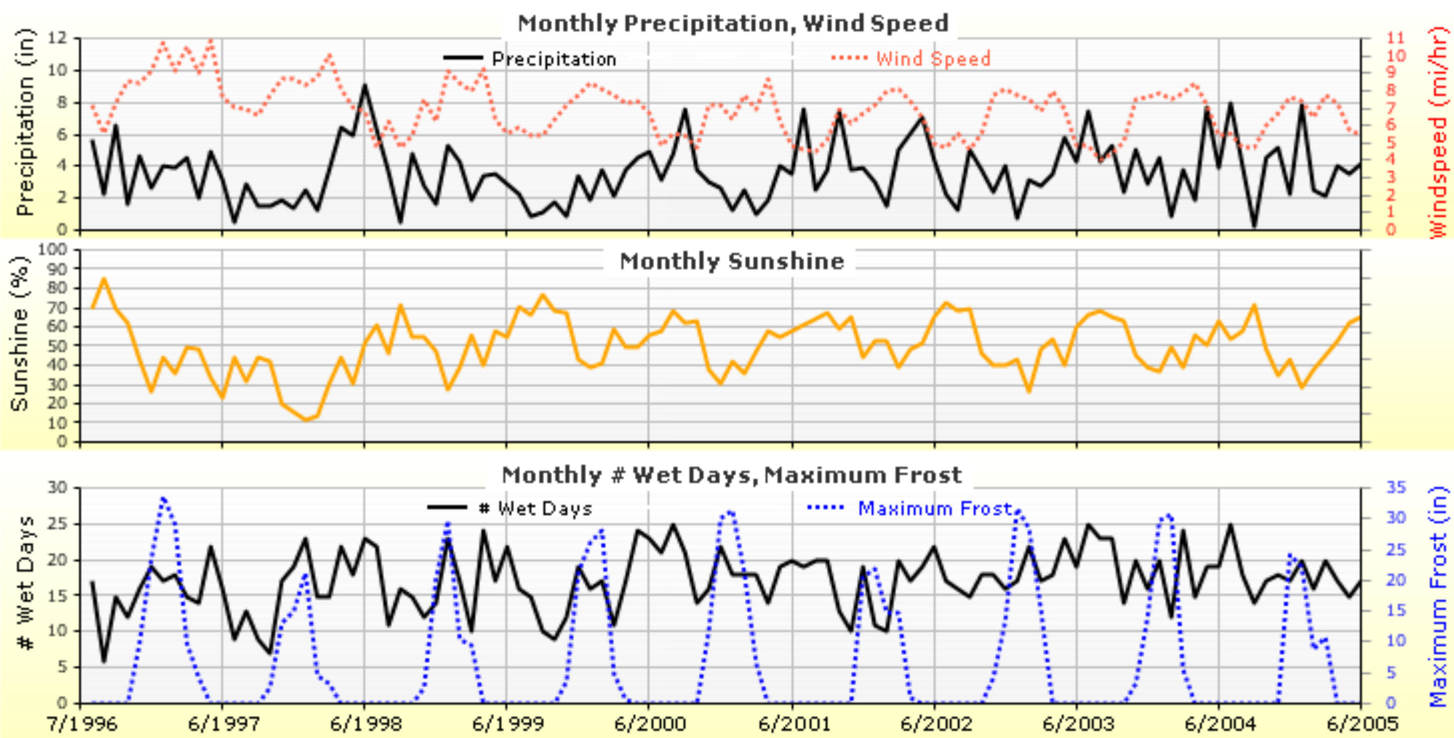
Annual Statistics:

Mean annual air temperature (ºF)	54.14
Mean annual precipitation (in.)	43.47
Freezing index (ºF - days)	426.14
Average annual number of freeze/thaw cycles:	61.76

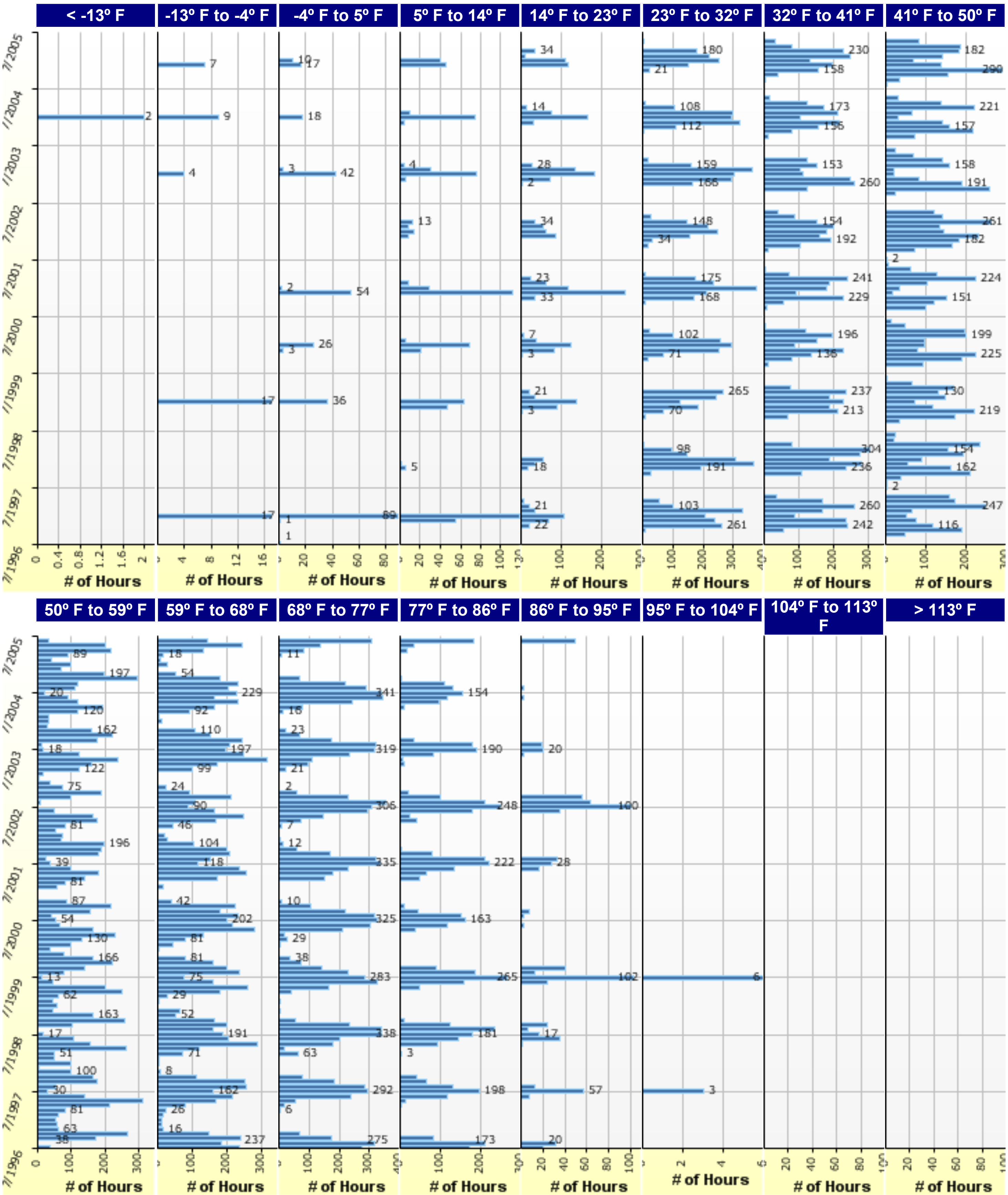
Water table depth (ft) 5.00

Monthly Climate Summary:





Hourly Air Temperature Distribution by Month:



Design Properties

JPCP Design Properties

Structure - ICM Properties	
PCC surface shortwave absorptivity	0.85

Doweled Joints	
Is joint doweled ?	True
Dowel diameter (in.)	1.50
Dowel spacing (in.)	12.00

Tied Shoulders	
Tied shoulders	False
Load transfer efficiency (%)	-

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

Widened Slab	
Is slab widened ?	True
Slab width (ft)	14.00

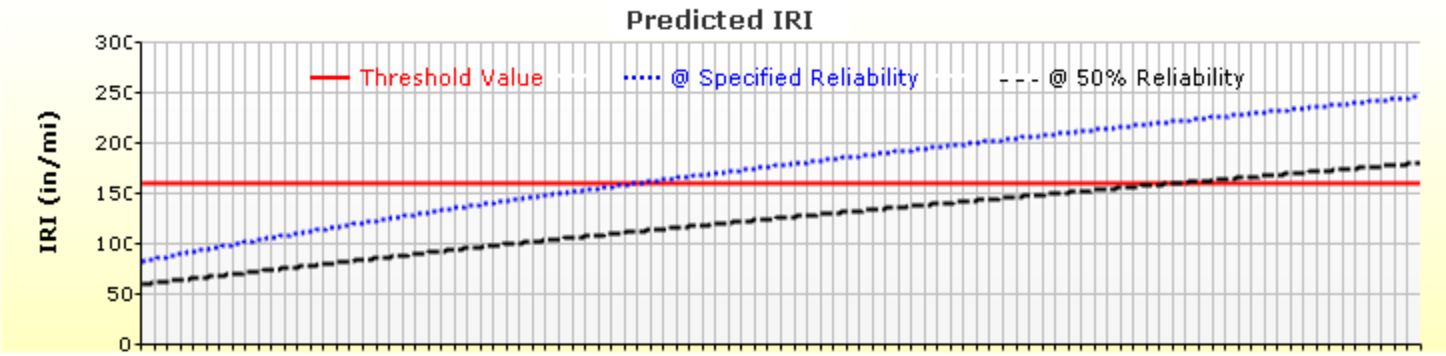
PCC-Base Contact Friction	
PCC-Base full friction contact	True
Months until friction loss	600.00

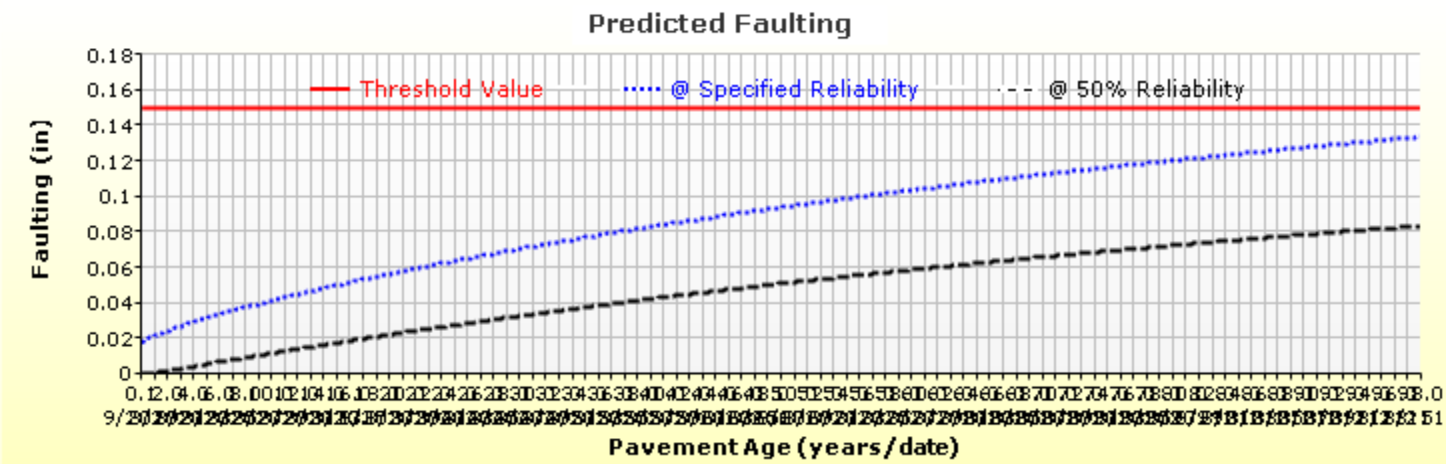
Sealant type	Other(Including No Sealant... Liquid... Silicone)

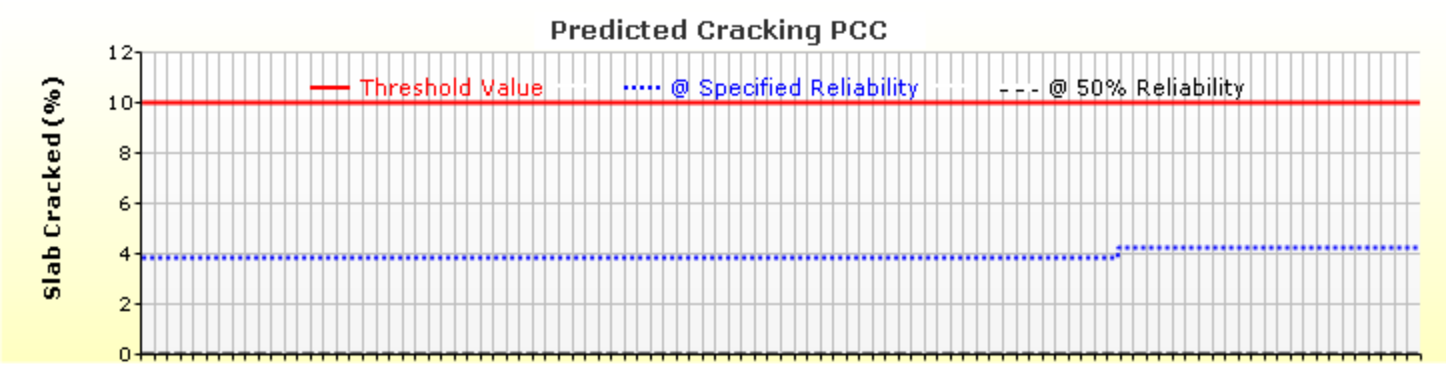
Erodibility index	2

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

Analysis Output Charts

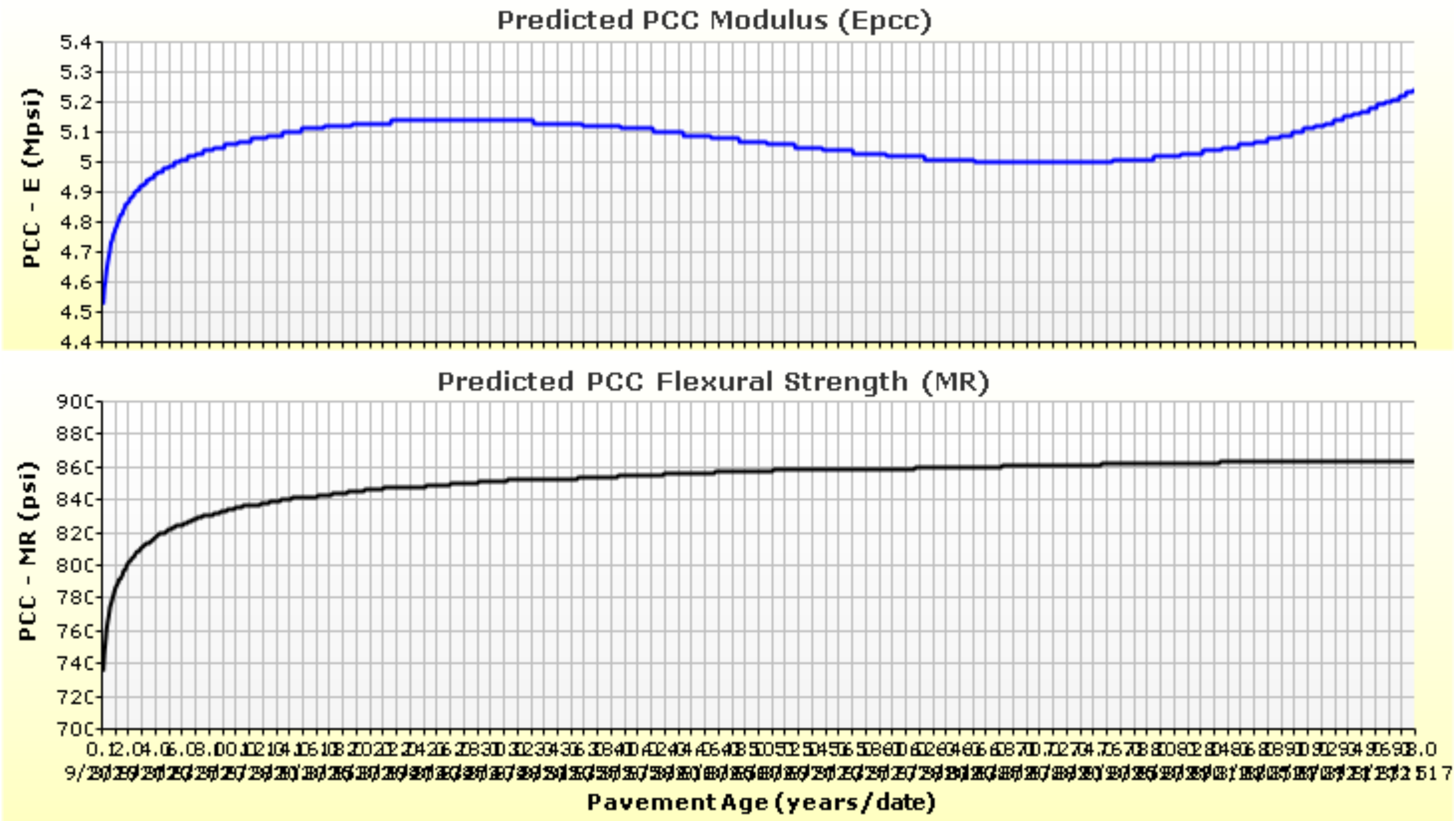


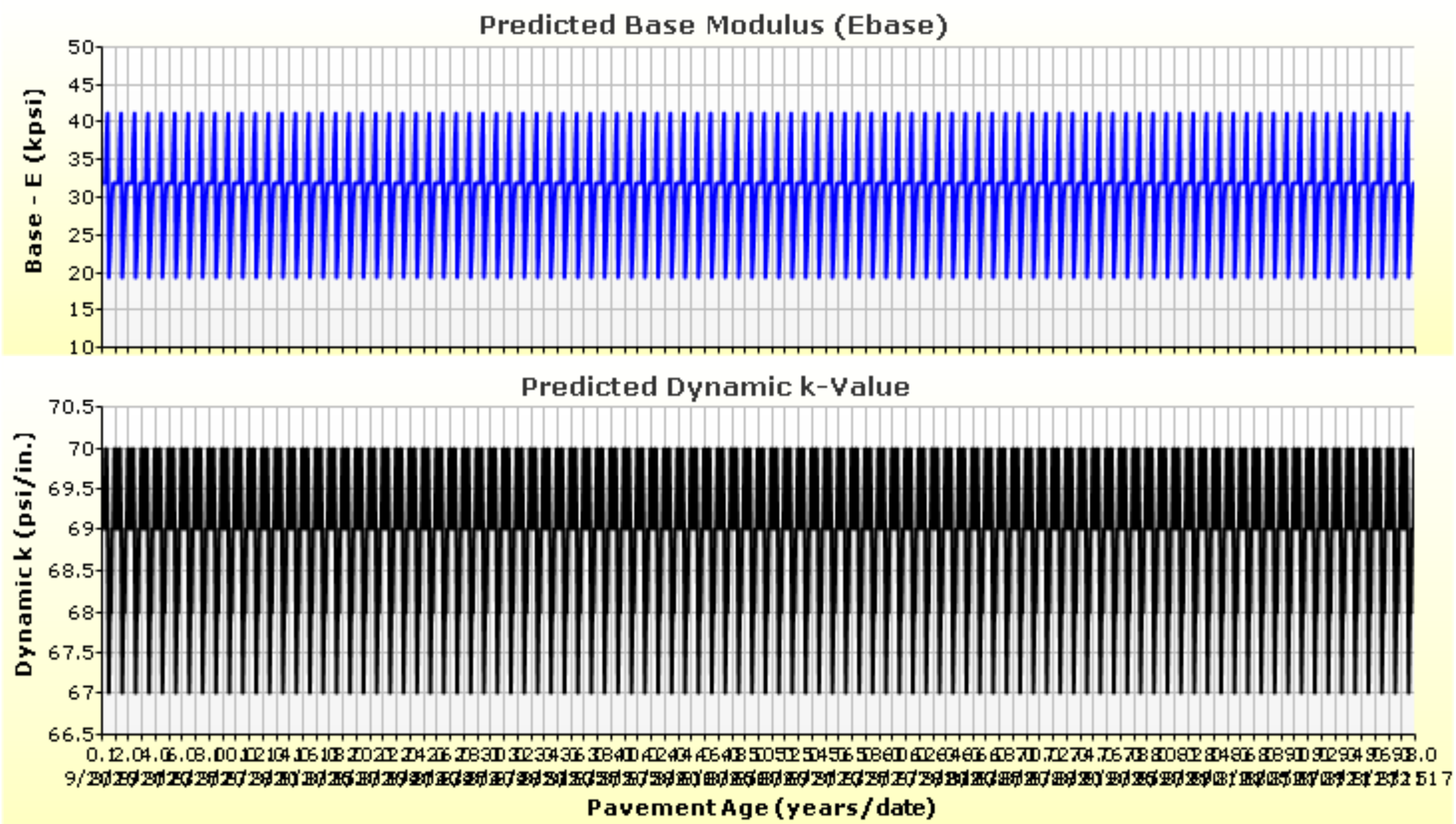


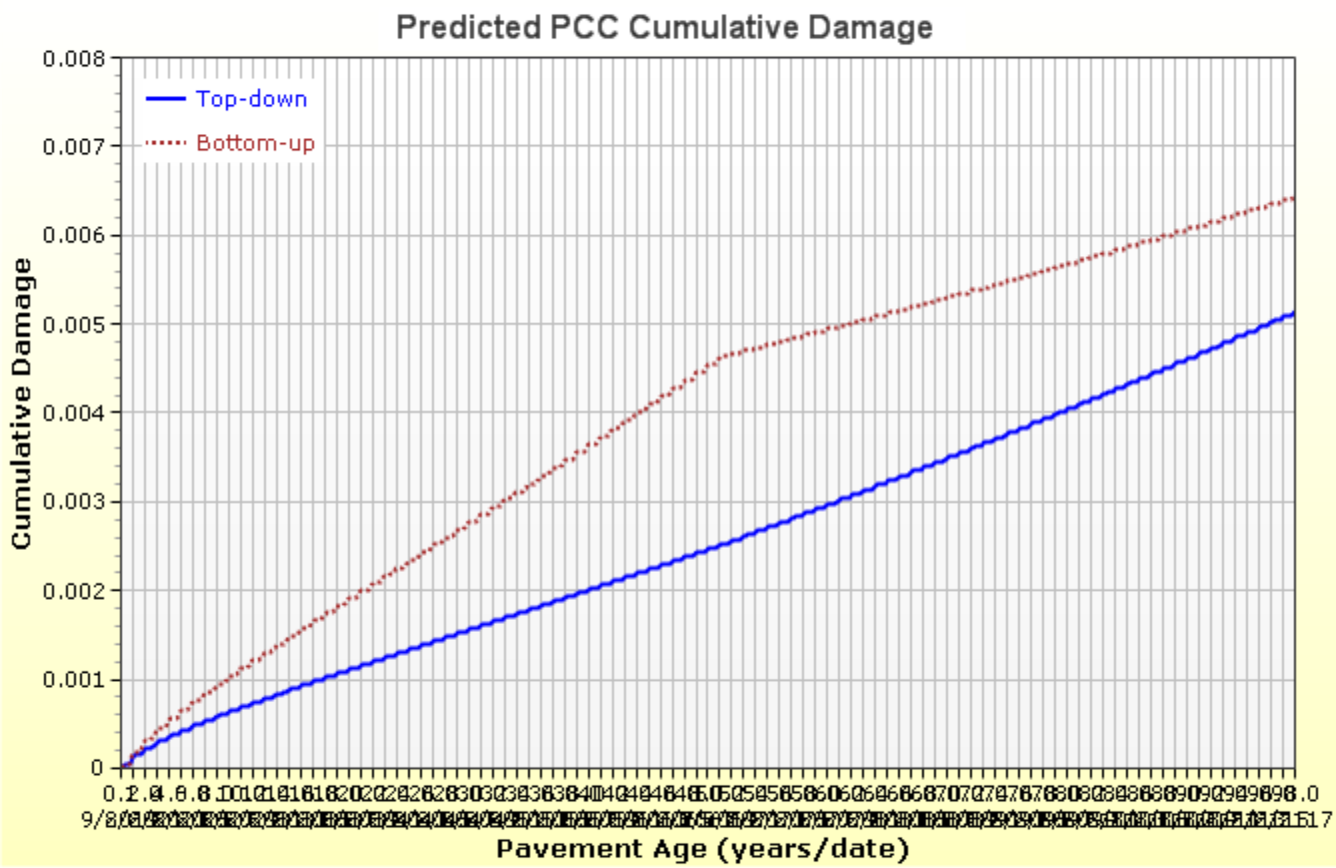


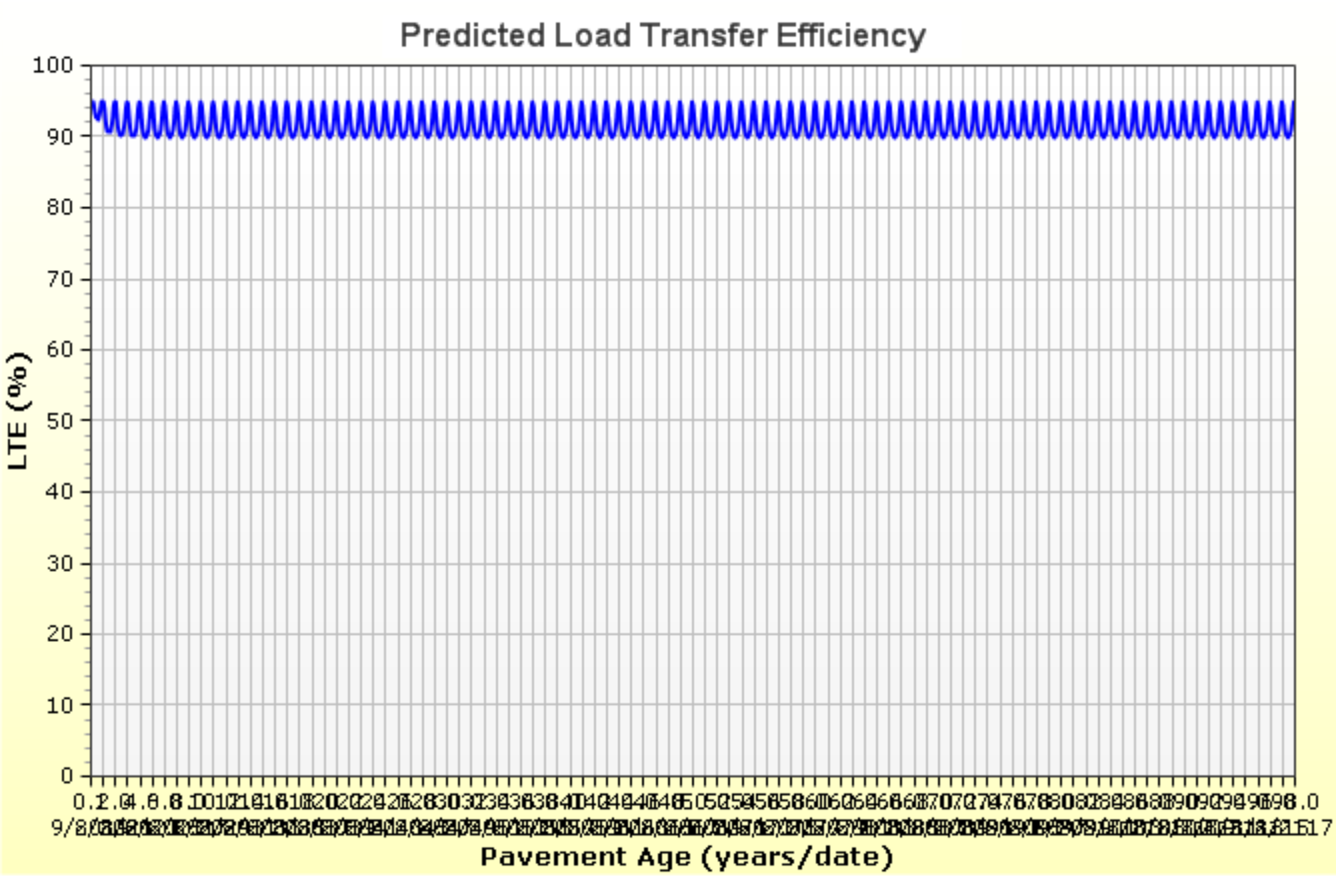
PCCP Run(Structural) - 12

File Name: C:\My ME Design\Projects\MK16-465 SE BV\170313 TP-App No 3\PCCP Run(Structural) - 12.dgpx






Predicted PCC Cumulative Damage
Top-down
Bottom-up
Cumulative Damage
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Pavement Age (years/date)


Predicted Load Transfer Efficiency
LTE (%)
100
90
80
70
60
50
40
30
20
10
0
Pavement Age (years/date)

Layer Information

Layer 1 PCC : JPCP

PCC	
Thickness (in.)	12.0
Unit weight (pcf)	145.0
Poisson's ratio	0.2

Thermal	
PCC coefficient of thermal expansion (in./in./ºF x 10^-6)	4.7
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)		510
Water to cement ratio		0.42
Aggregate type		Limestone (1)
PCC zero-stress temperature (ºF)	Calculated Internally?	True
	User Value	-
	Calculated Value	103.5
Ultimate shrinkage (microstrain)	Calculated Internally?	False
	User Value	483.0
	Calculated Value	-
Reversible shrinkage (%)		50
Time to develop 50% of ultimate shrinkage (days)		35
Curing method		Curing Compound

PCC strength and modulus (Input Level: 3)

28-Day PCC modulus of rupture (psi)	700.0
28-Day PCC elastic modulus (psi)	-

Identifiers

Field	Value
Display name/identifier	JPCP
Description of object	
Author	
Date Created	12/18/2012 2:32:19 PM
Approver	
Date approved	12/18/2012 2:32:19 PM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Unbound Drainage Layer

Unbound	
Layer thickness (in.)	3.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
25000.0

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

Identifiers

Field	Value
Display name/identifier	Unbound Drainage Layer
Description of object	No. 8 Layer of Subbase for PCCP
Author	Matt Taylor
Date Created	1/31/2013 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 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

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

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

Layer 3 Subgrade : A-4

Unbound	
Layer thickness (in.)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	True

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

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

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

Layer 4 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

PCC Faulting

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

C1: 1.0184	C2: 0.91656	C3: 0.0021848	C4: 0.000883739
C5: 250	C6: 0.4	C7: 1.83312	C8: 400

PCC Reliability Faulting Standard Deviation

Pow(0.0097*FAULT,0.5178)+0.014

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: 1	C5: -1.98

PCC Reliability Cracking Standard Deviation

Pow(5.3116*CRACK,0.3903) + 2.99

Design Inputs

Design Life: 2 years
Design Type: Flexible Pavement

Base construction: May, 2019
Pavement construction: July, 2019
Traffic opening: September, 2019

Climate Data Sources (Lat/Lon): 39.144, -86.617; 39.71, -86.272; 38.228, -85.664

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Seymour 19.0mm PG70-22	4.0
Flexible	Seymour 19.0mm PG64-22	5.5
NonStabilized	A-1-a	6.0
Subgrade	A-4	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	9.5
Air voids (%)	8.0

Traffic

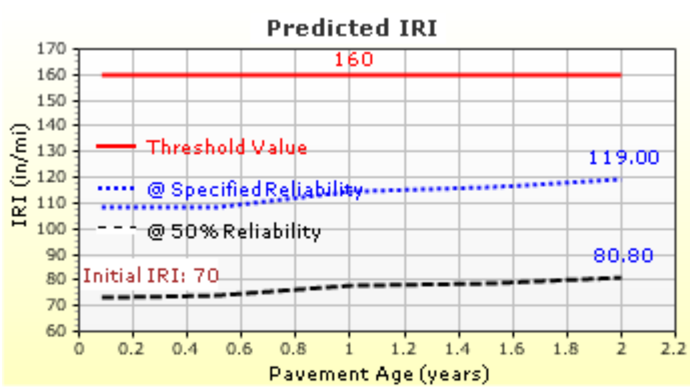
Age (year)	Heavy Trucks (cumulative)
2019 (initial)	13,293
2020 (1 years)	2,403,360
2021 (2 years)	4,833,390

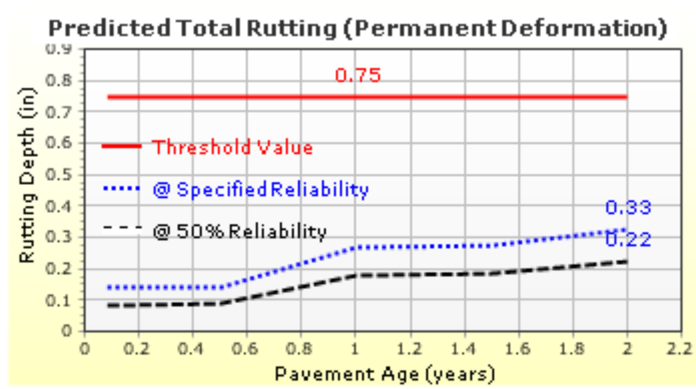
Design Outputs

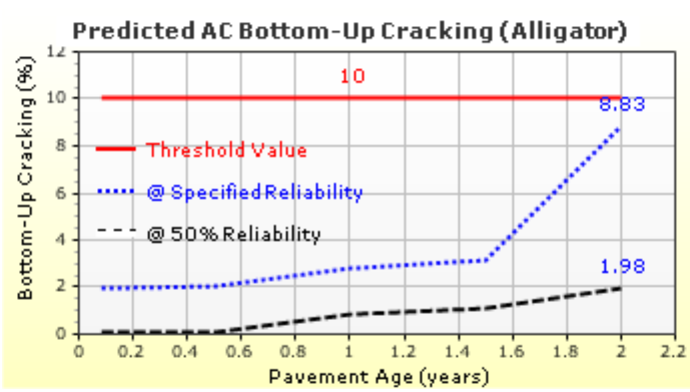
Distress Prediction Summary

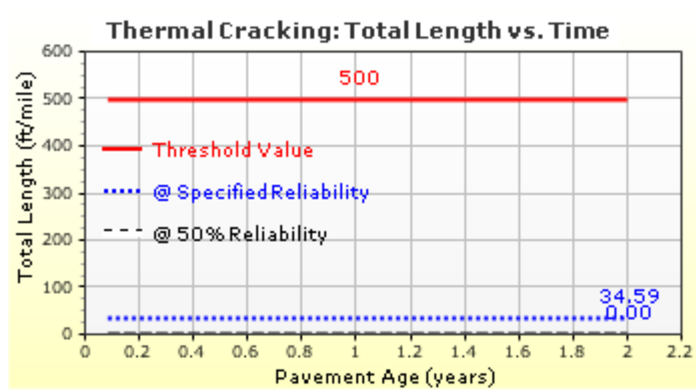
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	119.05	95.00	99.97	Pass
Permanent deformation - total pavement (in.)	0.75	0.33	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	8.83	95.00	97.30	Pass
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	638.55	95.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.24	95.00	100.00	Pass

Distress Charts





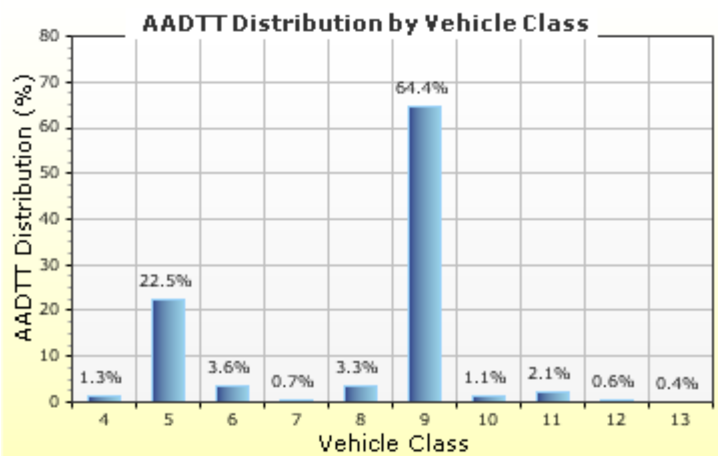


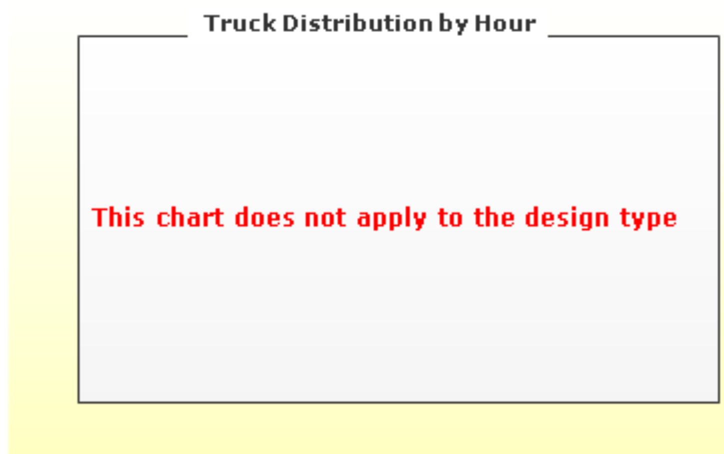


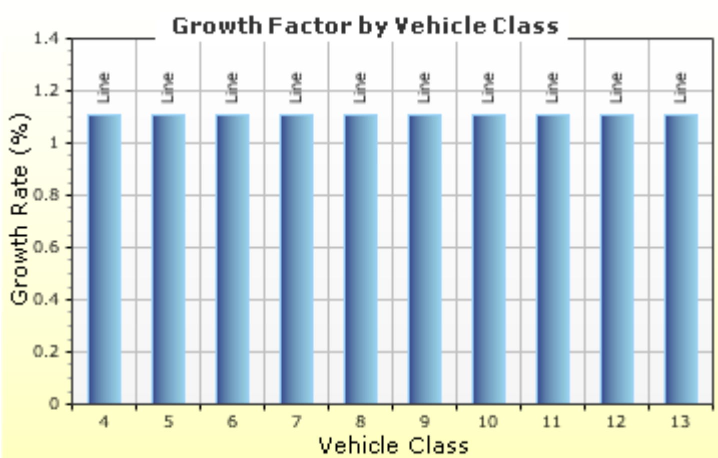
Traffic Inputs

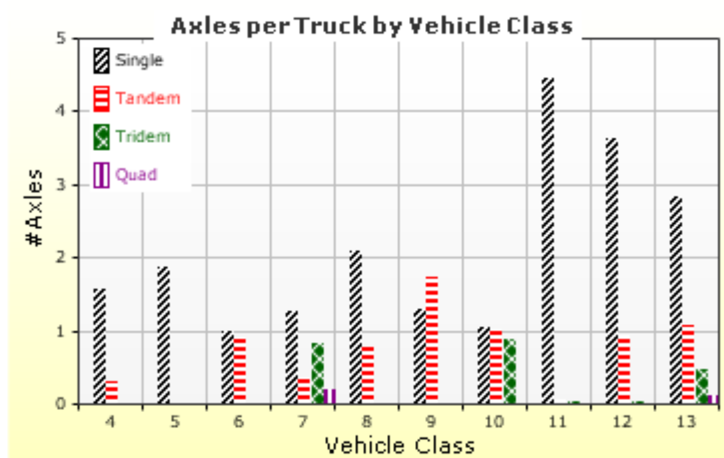
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	13,293	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	3	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	70.0

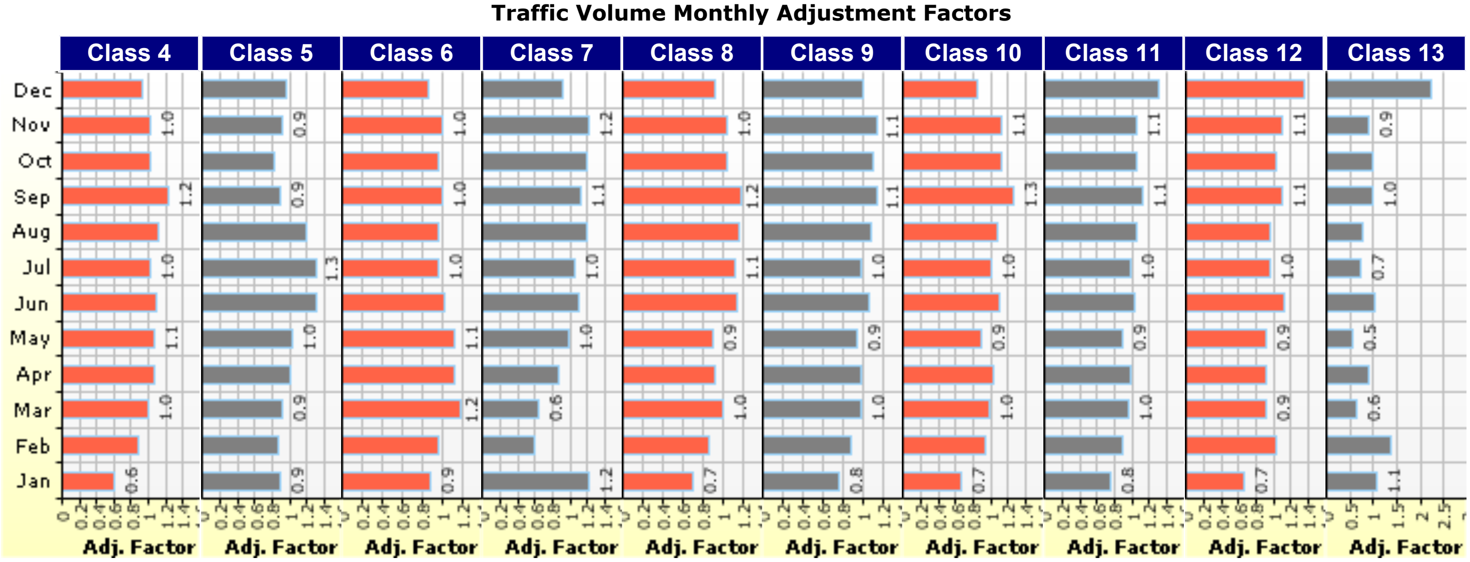








Traffic Volume Monthly Adjustment Factors



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	0.6	0.9	0.9	1.2	0.7	0.8	0.7	0.8	0.7	1.1
February	0.9	0.9	1.0	0.6	0.9	0.9	0.9	0.9	1.0	1.4
March	1.0	0.9	1.2	0.6	1.0	1.0	1.0	1.0	0.9	0.6
April	1.1	1.0	1.1	0.9	0.9	1.0	1.0	1.0	0.9	0.9
May	1.1	1.0	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.5
June	1.1	1.3	1.0	1.1	1.1	1.1	1.1	1.0	1.1	1.0
July	1.0	1.3	1.0	1.0	1.1	1.0	1.0	1.0	1.0	0.7
August	1.1	1.2	1.0	1.2	1.2	1.1	1.1	1.1	1.0	0.8
September	1.2	0.9	1.0	1.1	1.2	1.1	1.3	1.1	1.1	1.0
October	1.0	0.8	1.0	1.2	1.0	1.1	1.1	1.1	1.0	1.0
November	1.0	0.9	1.0	1.2	1.0	1.1	1.1	1.1	1.1	0.9
December	0.9	1.0	0.9	0.9	0.9	1.0	0.8	1.3	1.4	2.2

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.3%	1.11%	Linear
Class 5	22.5%	1.11%	Linear
Class 6	3.6%	1.11%	Linear
Class 7	0.7%	1.11%	Linear
Class 8	3.3%	1.11%	Linear
Class 9	64.4%	1.11%	Linear
Class 10	1.1%	1.11%	Linear
Class 11	2.1%	1.11%	Linear
Class 12	0.6%	1.11%	Linear
Class 13	0.4%	1.11%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	18
Traffic wander standard deviation (in.)	10
Design lane width (ft)	12

Axle Configuration	
Average axle width (ft)	8.5
Dual tire spacing (in.)	12
Tire pressure (psi)	120

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

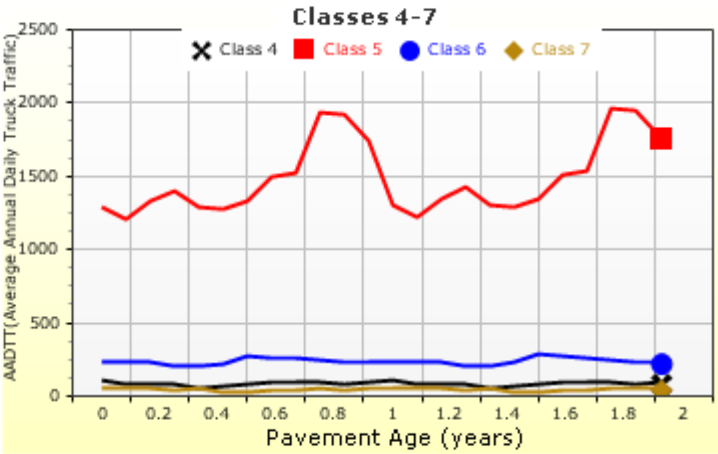
Wheelbase does not apply

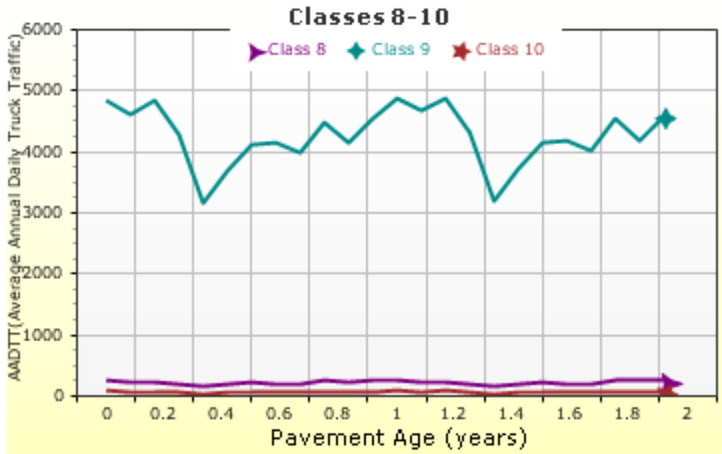
Number of Axles per Truck

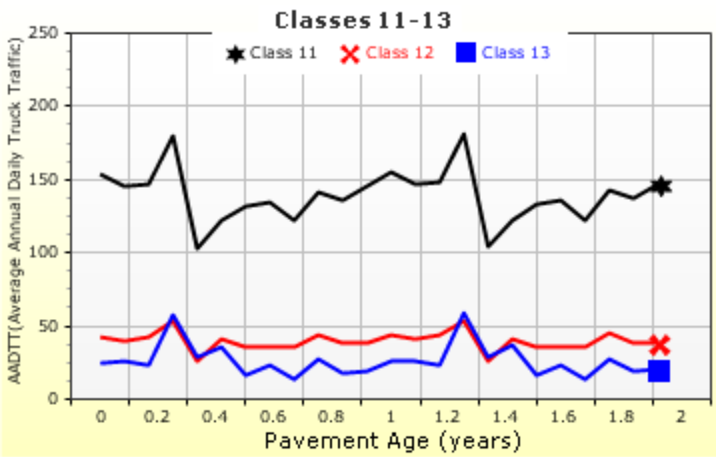
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

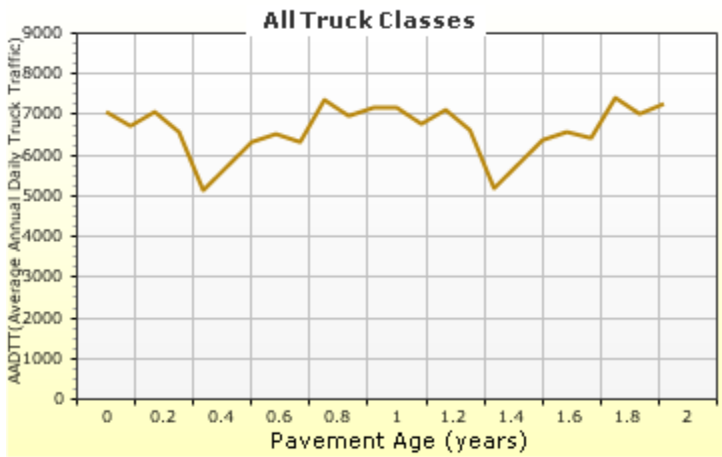
AADTT (Average Annual Daily Truck Traffic) Growth

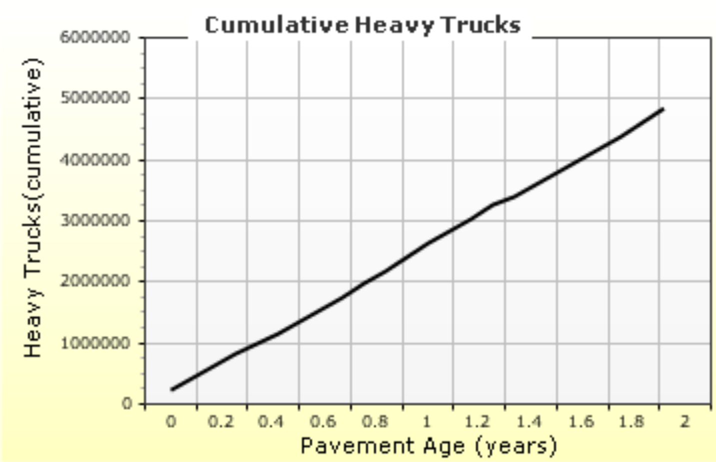
*** Traffic cap is not enforced**











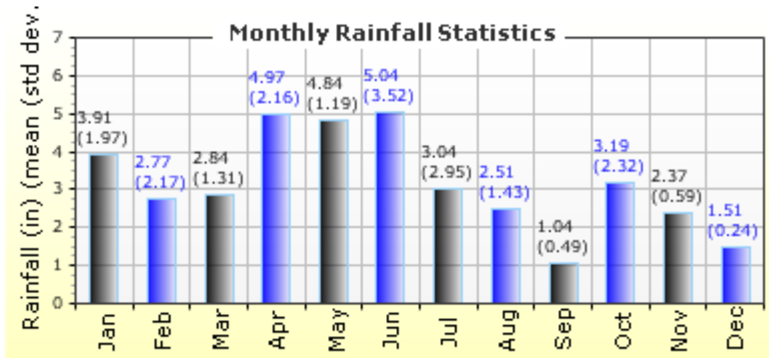
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
BLOOMINGTON, IN	39.14400 -86.61700 842
INDIANAPOLIS, IN	39.71000 -86.27200 790
LOUISVILLE, KY	38.22800 -85.66400 517

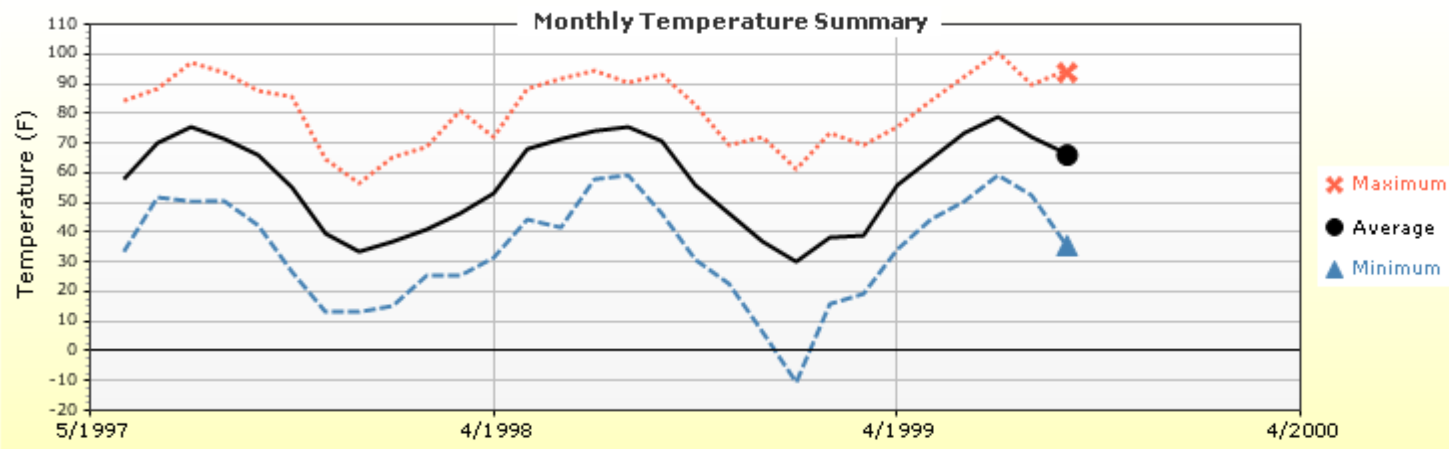
Annual Statistics:

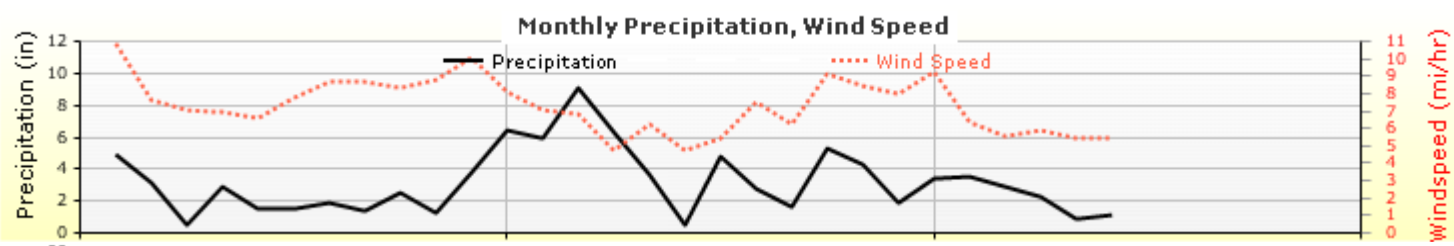
Mean annual air temperature (ºF)	57.17
Mean annual precipitation (in.)	38.22
Freezing index (ºF - days)	249.57
Average annual number of freeze/thaw cycles:	60.23

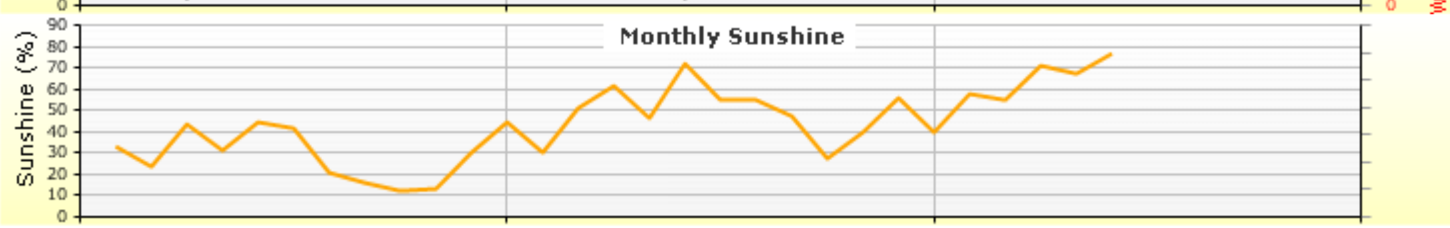


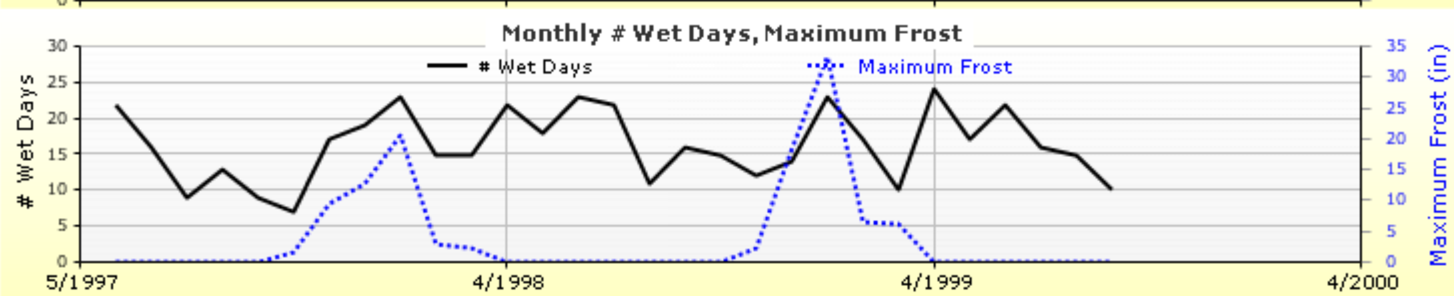
Water table depth (ft) 5.00

Monthly Climate Summary:

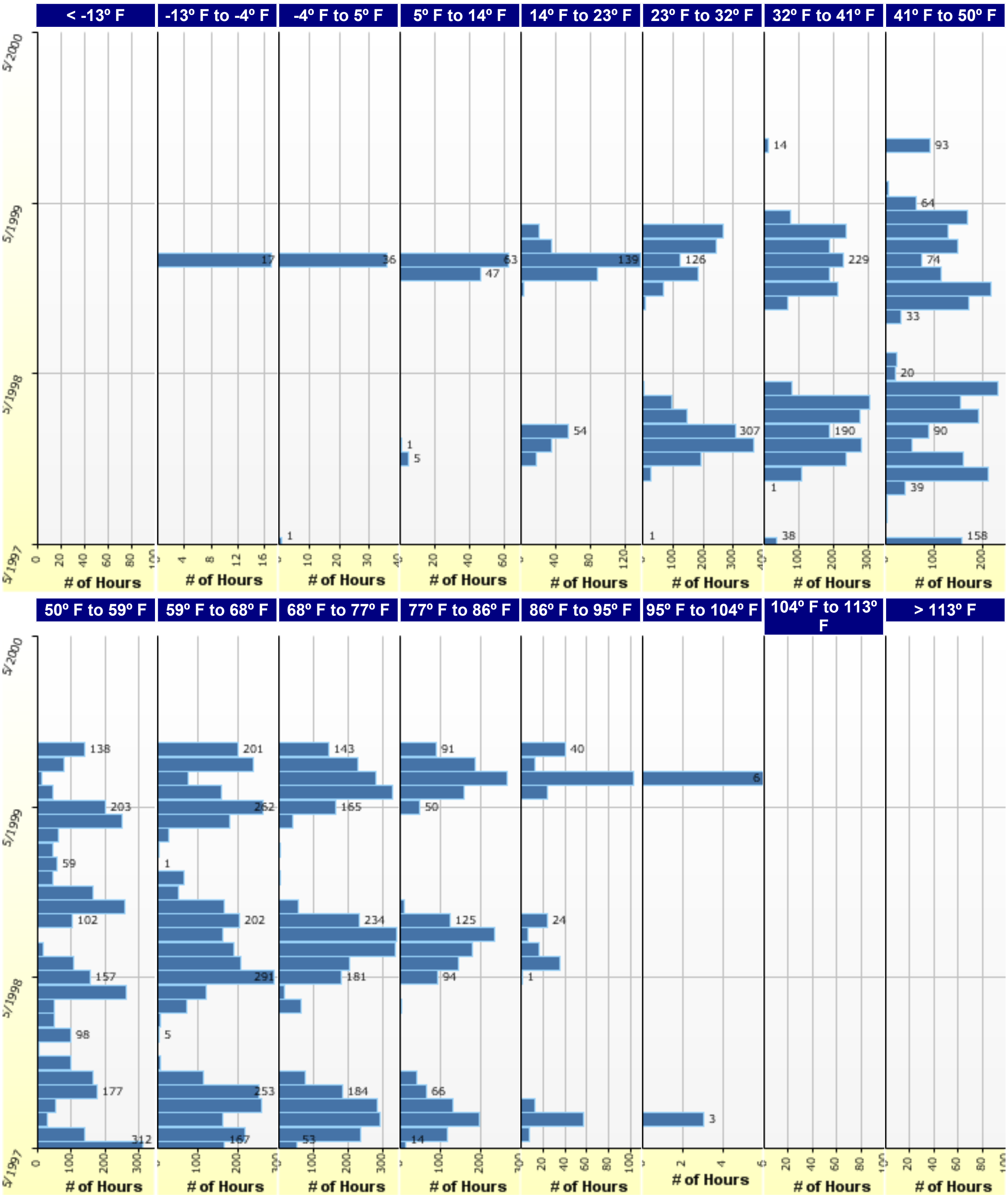








Hourly Air Temperature Distribution by Month:



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

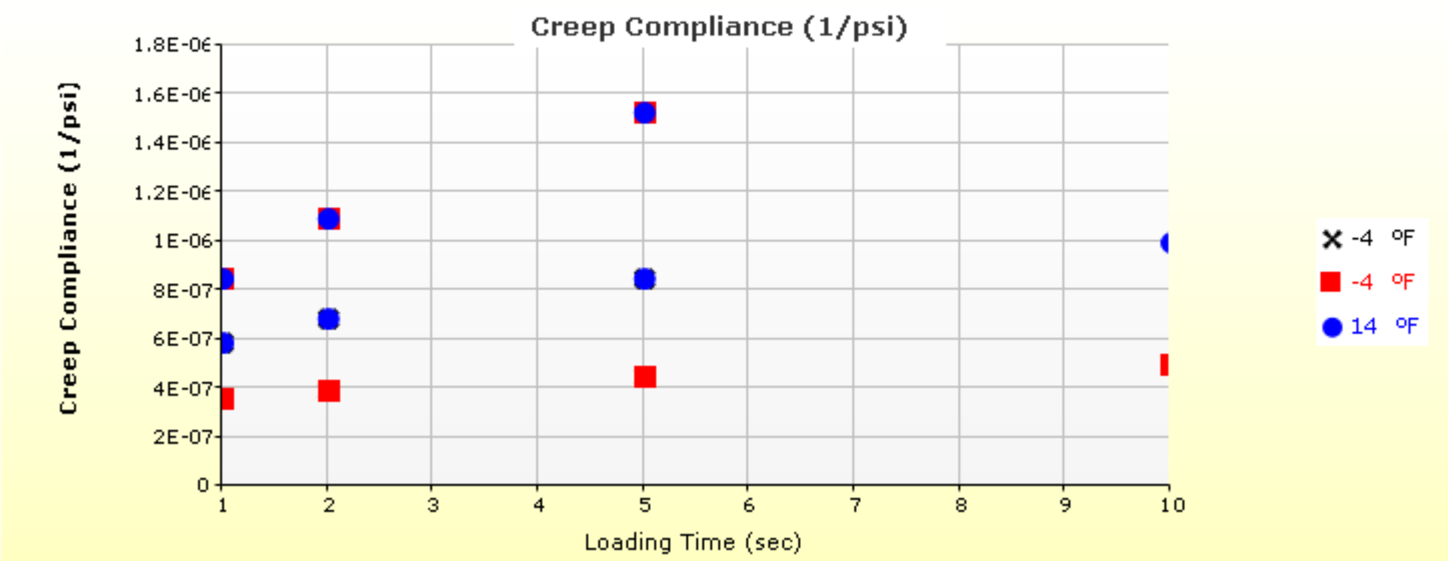
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Seymour 19.0mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Seymour 19.0mm PG64-22	Flexible (1)	1.00
Layer 3 Non-stabilized Base : A-1 -a	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-4	Subgrade (5)	-

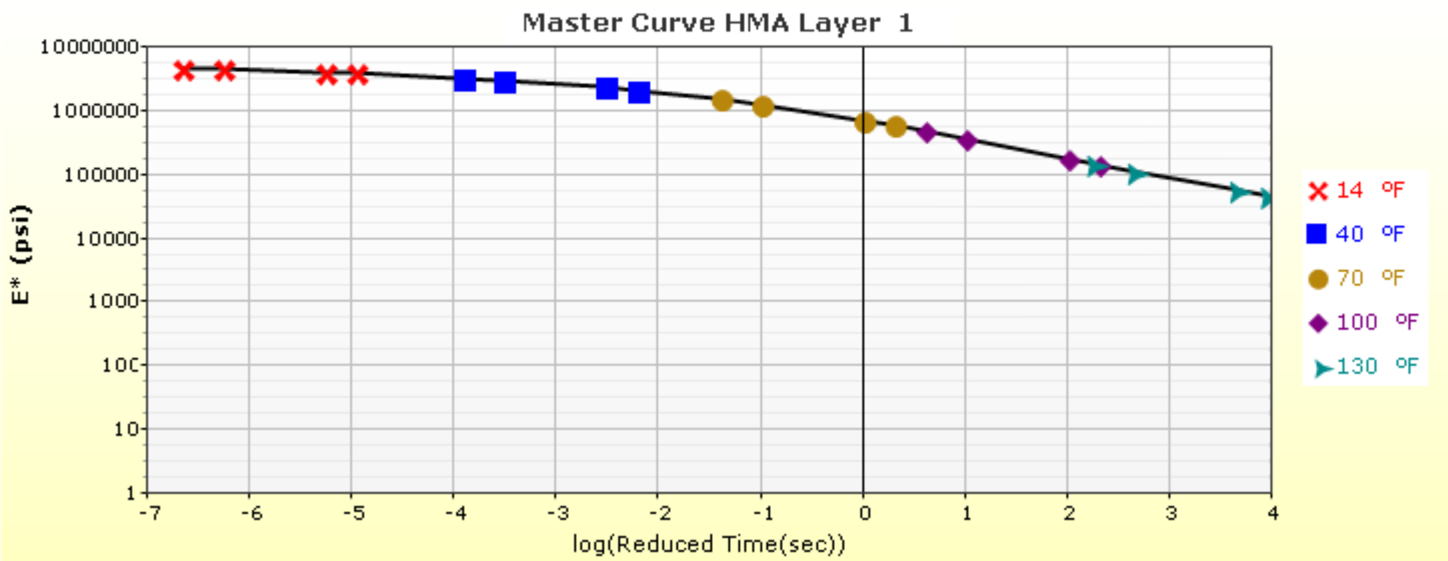
Thermal Cracking (Input Level: 3)

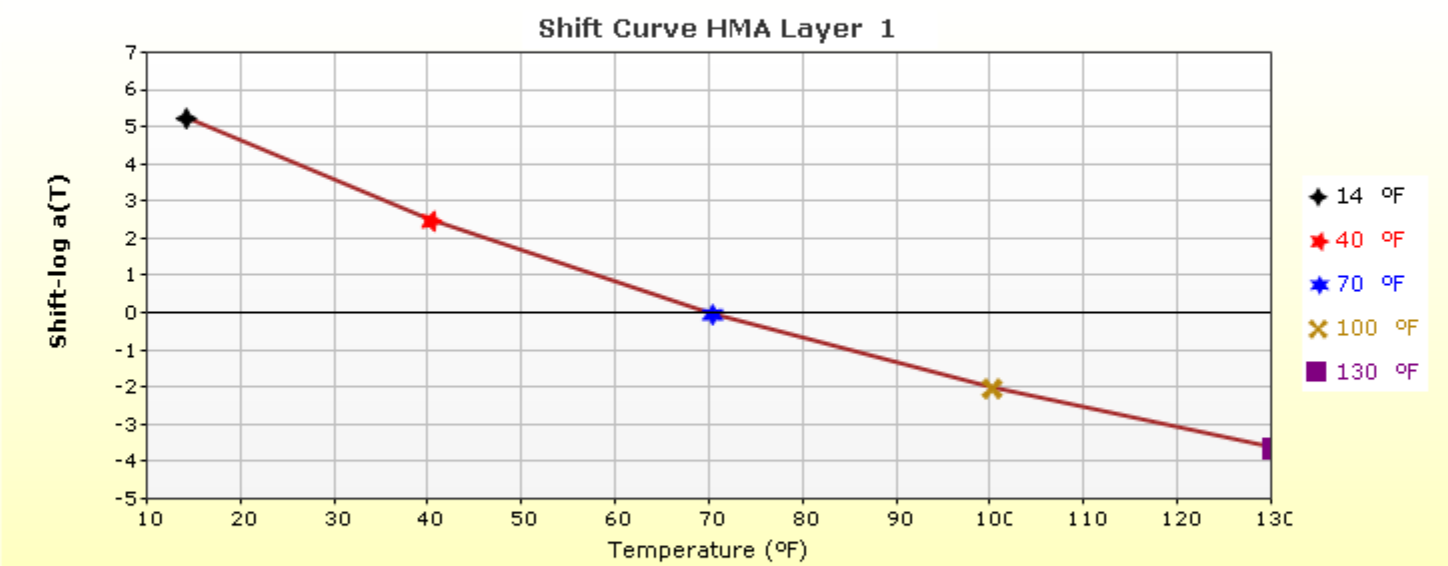
Indirect tensile strength at 14 ºF (psi)	579.02
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	17.5

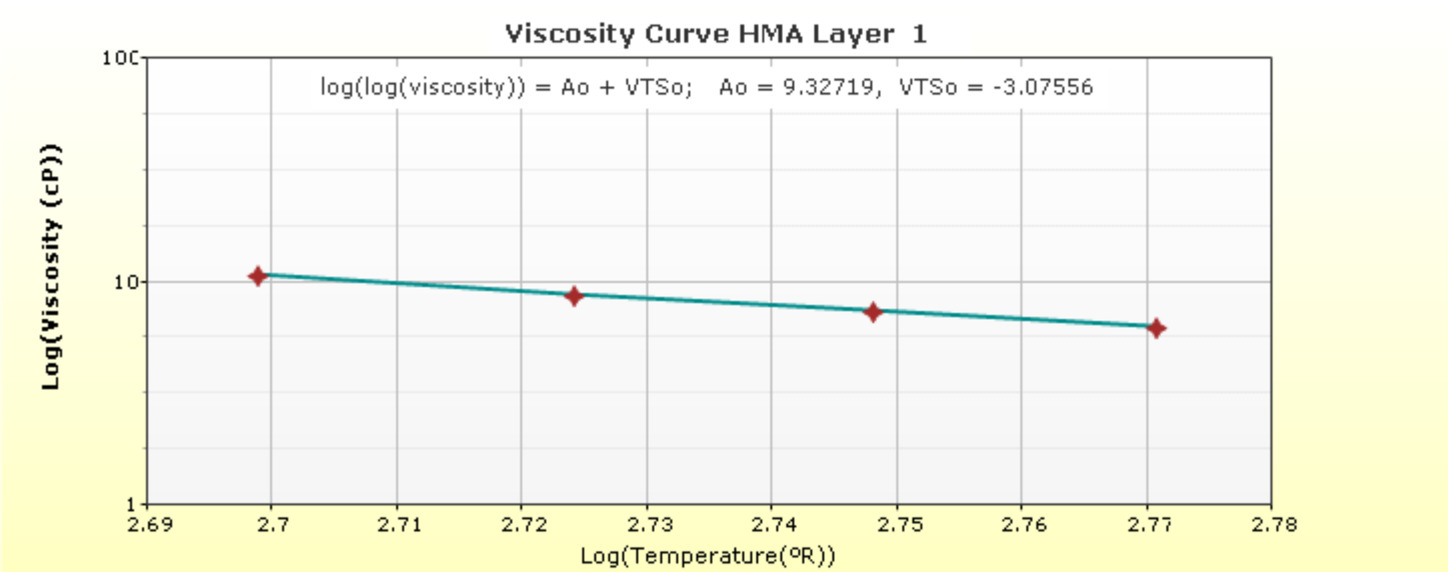
	Creep Compliance (1/psi)		
Loading time (sec)	-4 ºF	-4 ºF	14 ºF
1	3.61e-007	3.61e-007	5.92e-007
1	5.92e-007	8.53e-007	8.53e-007
2	3.99e-007	3.99e-007	6.94e-007
2	6.94e-007	1.10e-006	1.10e-006
5	4.55e-007	4.55e-007	8.57e-007
5	8.57e-007	1.54e-006	1.54e-006
10	5.03e-007	5.03e-007	1.00e-006



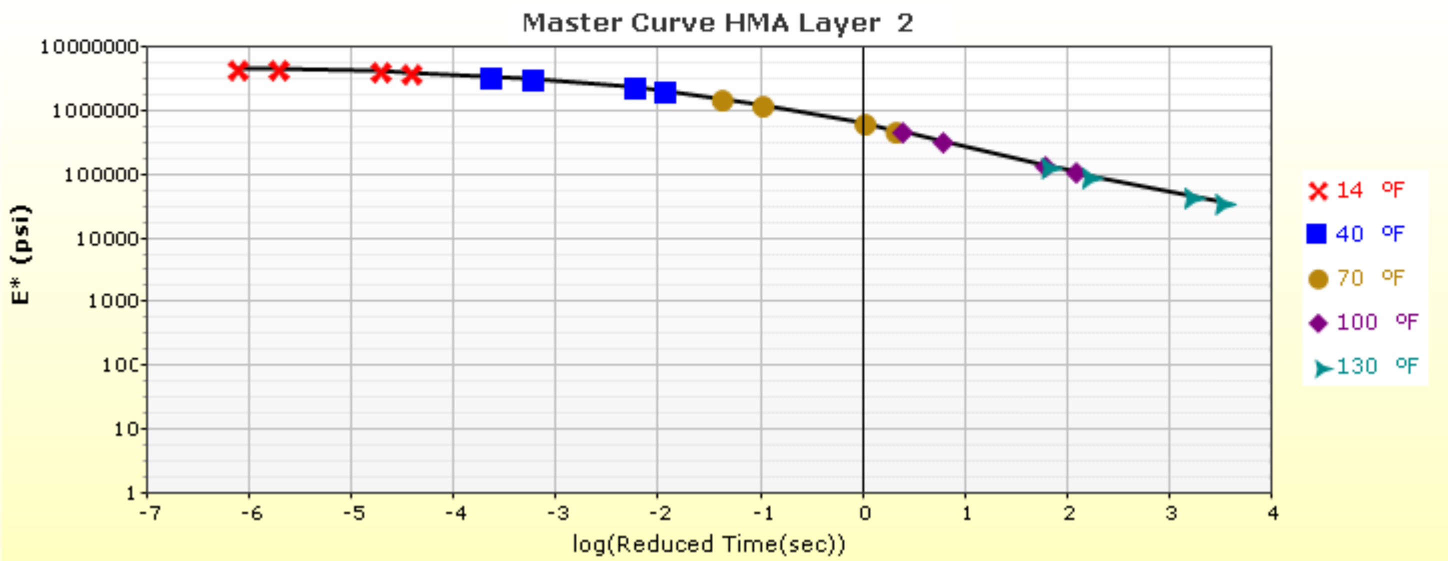
HMA Layer 1: Layer 1 Flexible : Seymour 19.0mm PG70-22

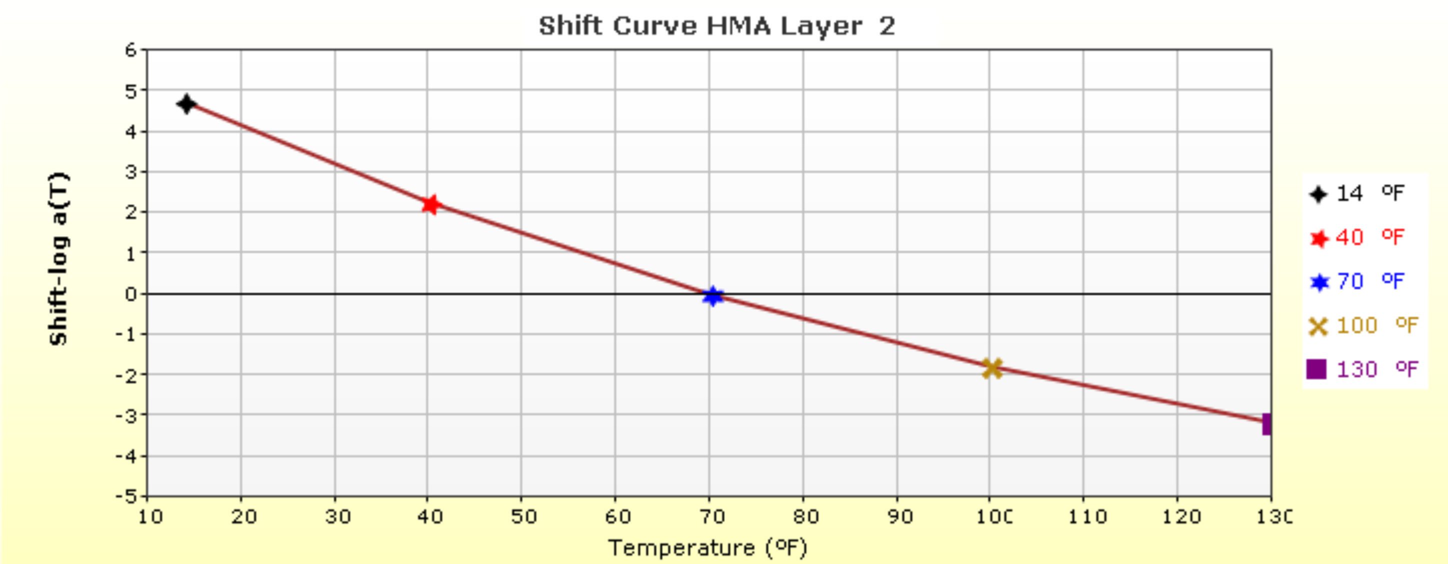


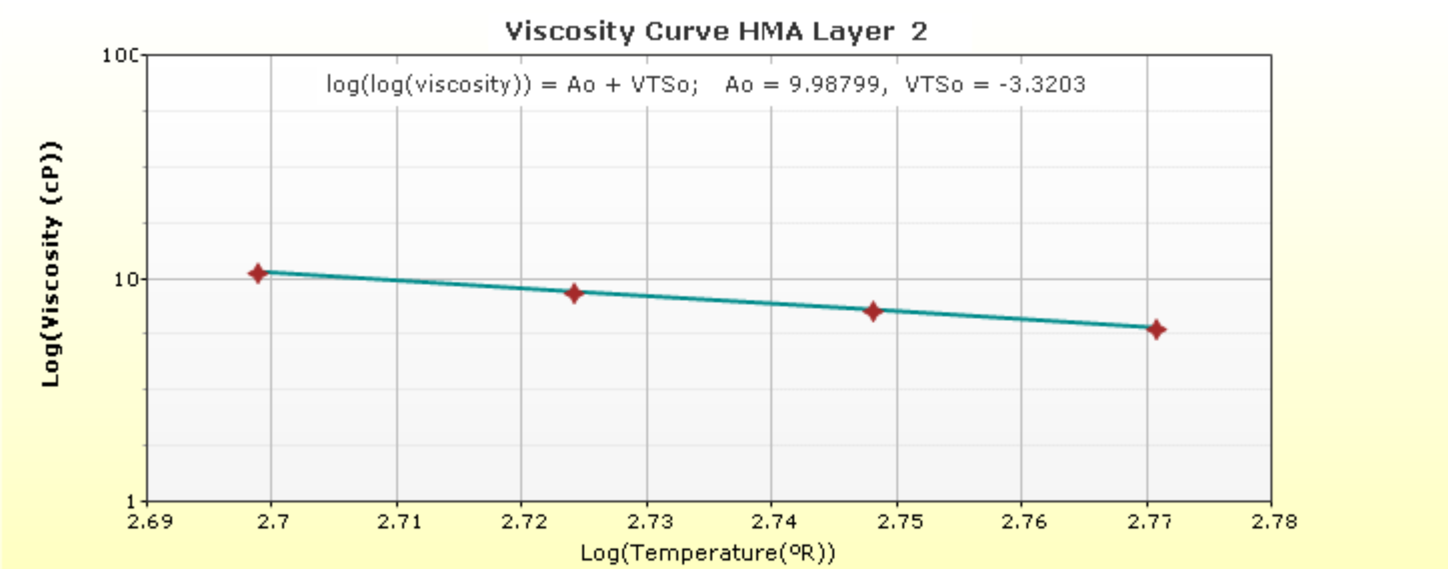




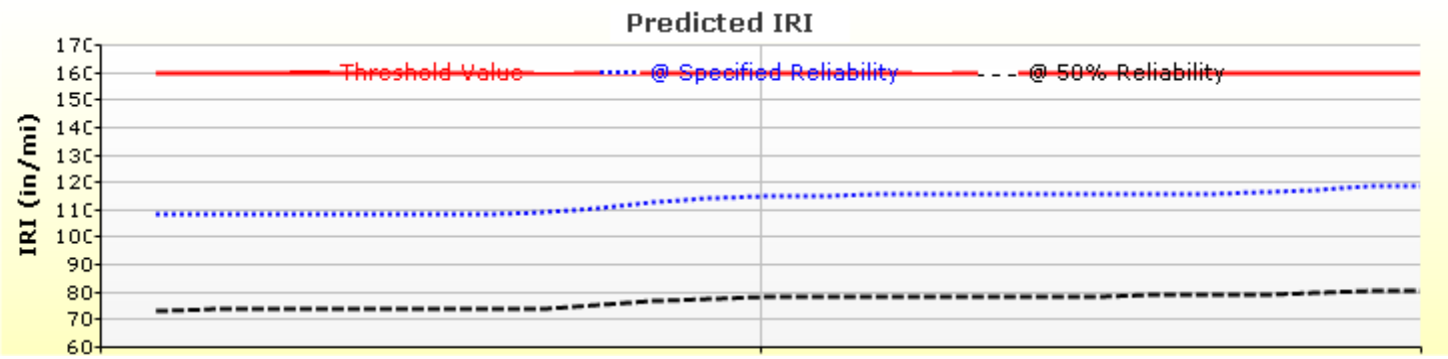
HMA Layer 2: Layer 2 Flexible : Seymour 19.0mm PG64-22

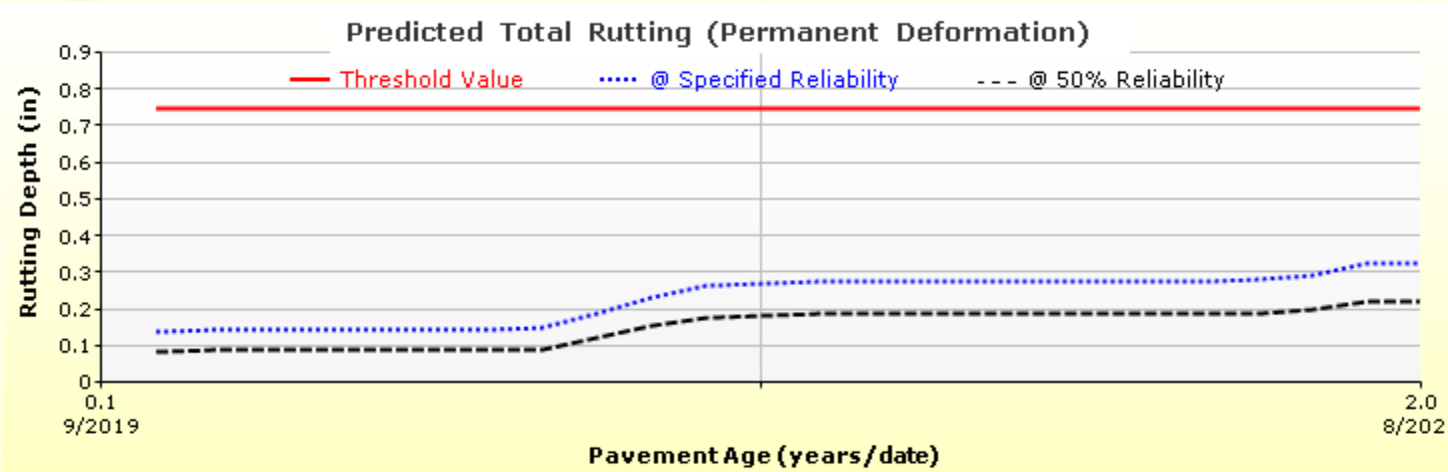


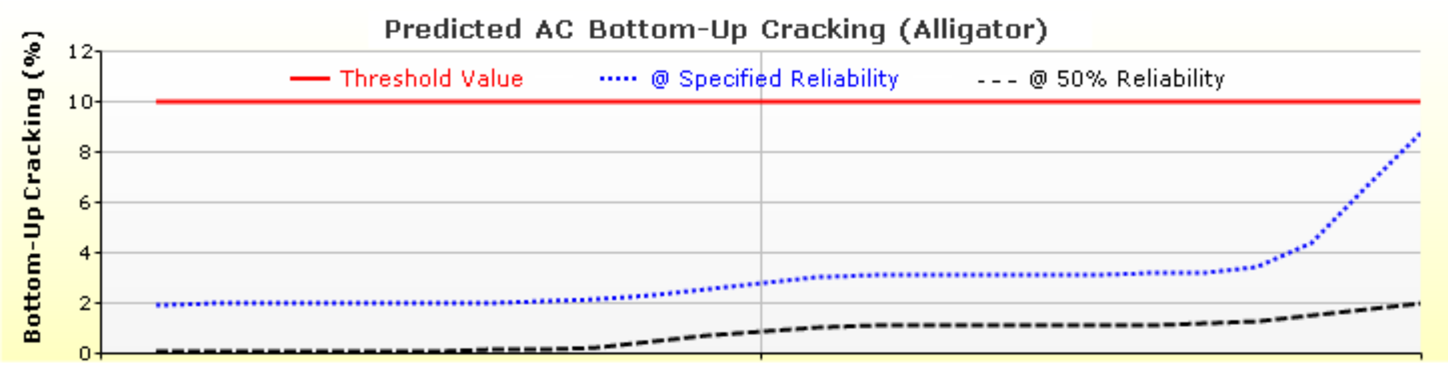


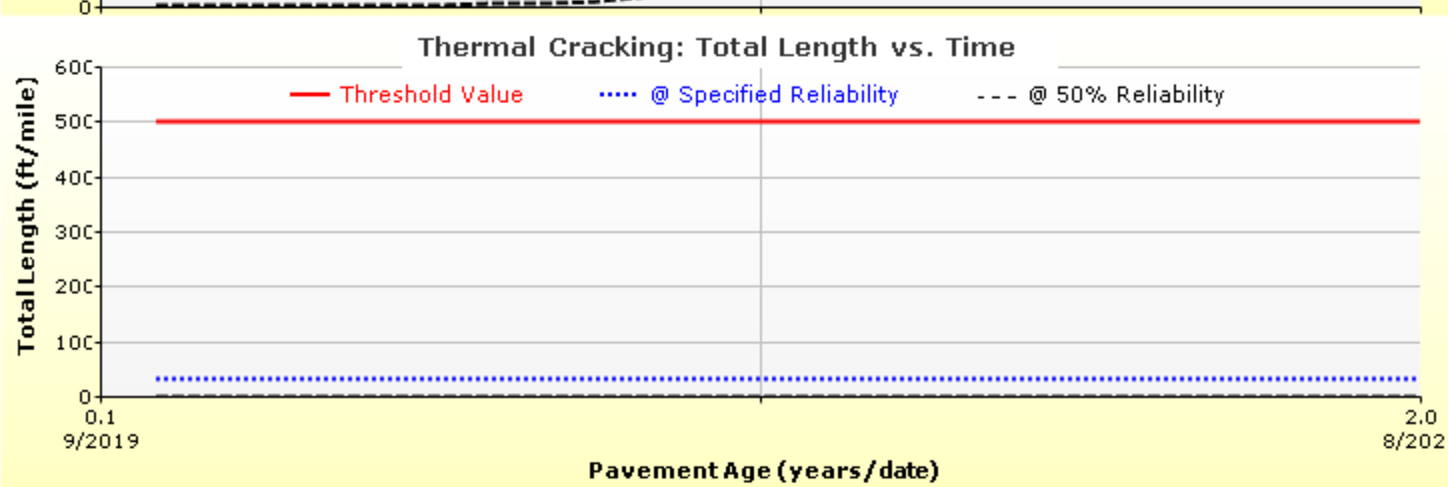


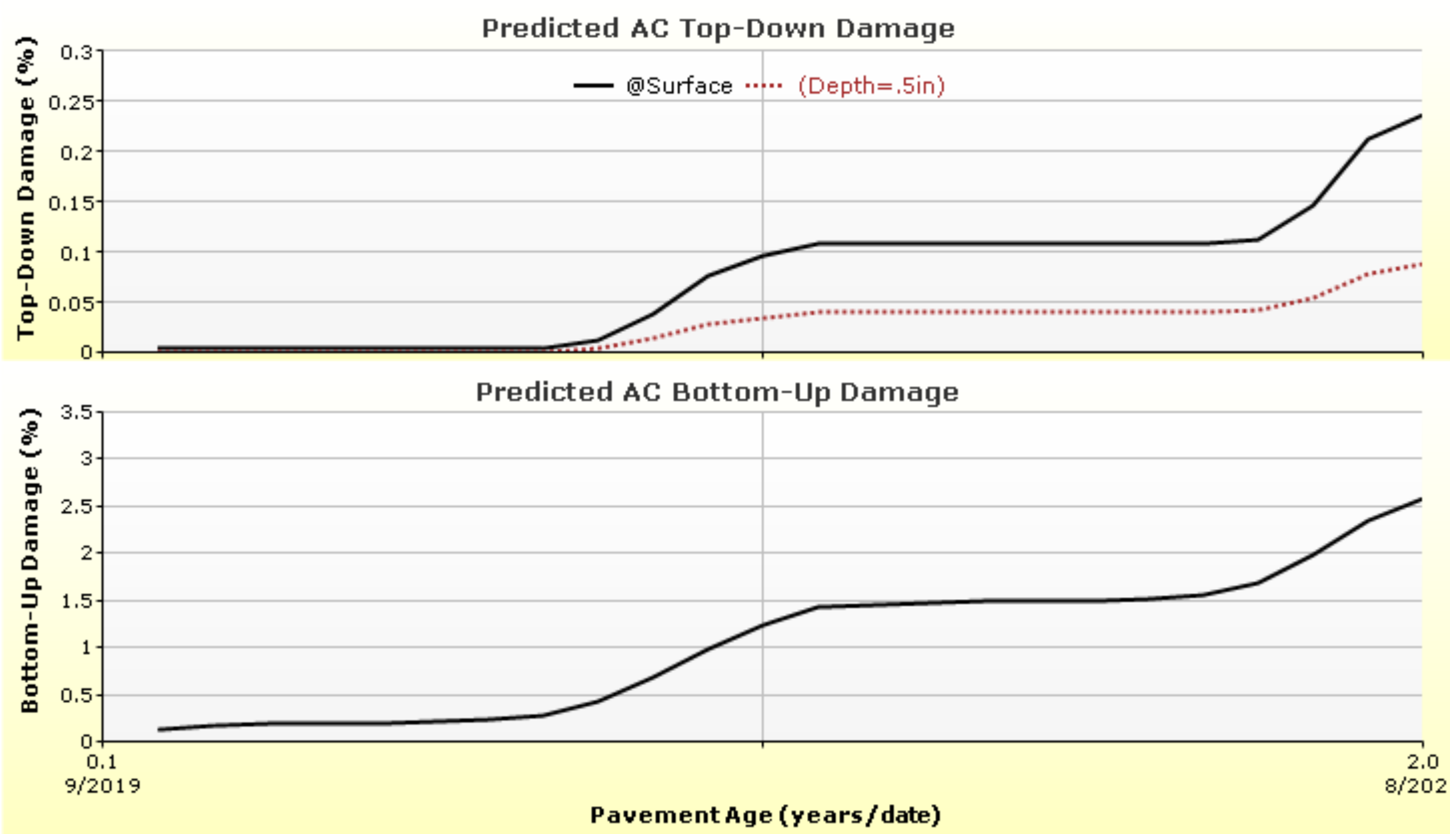
Analysis Output Charts



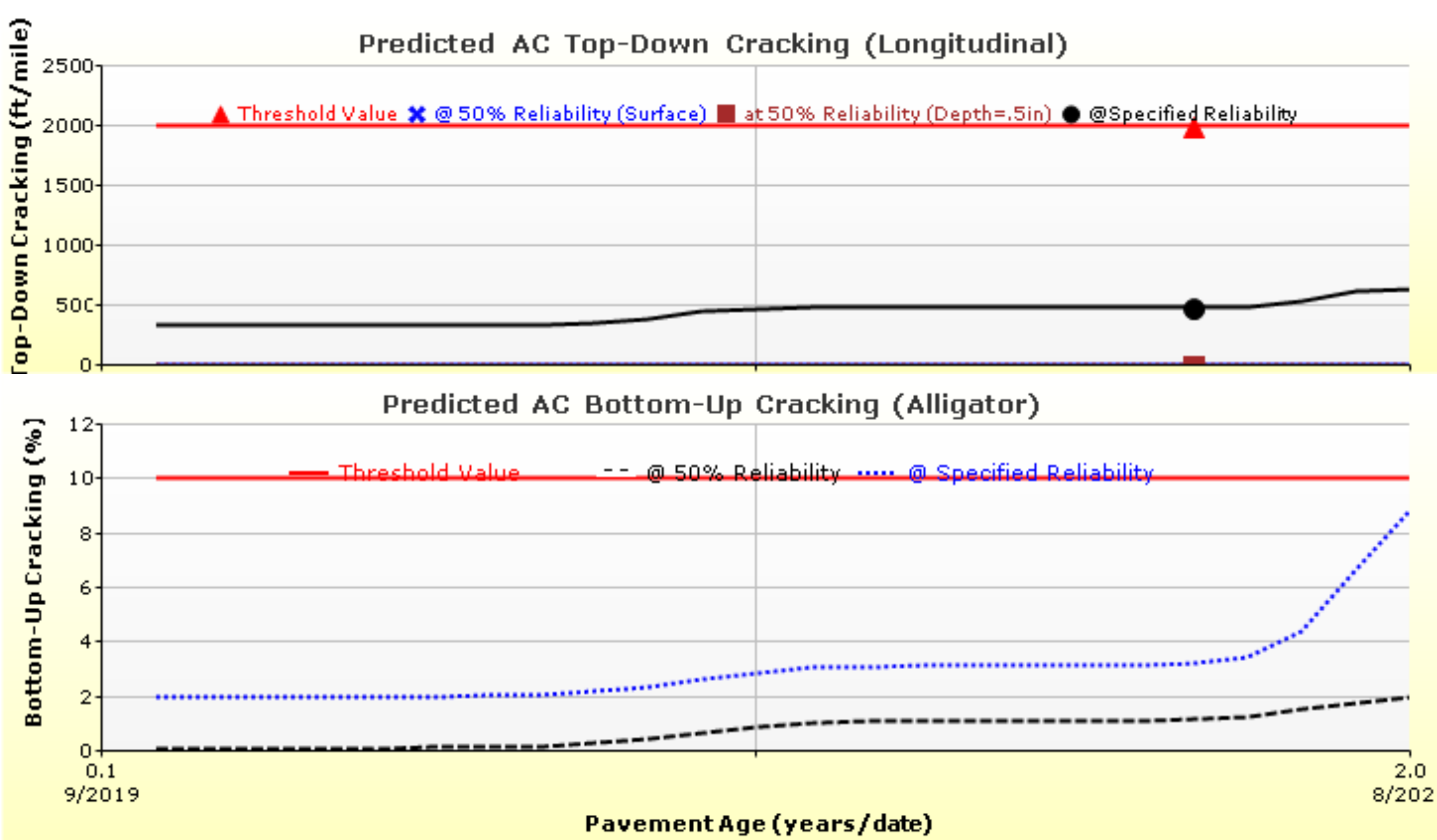




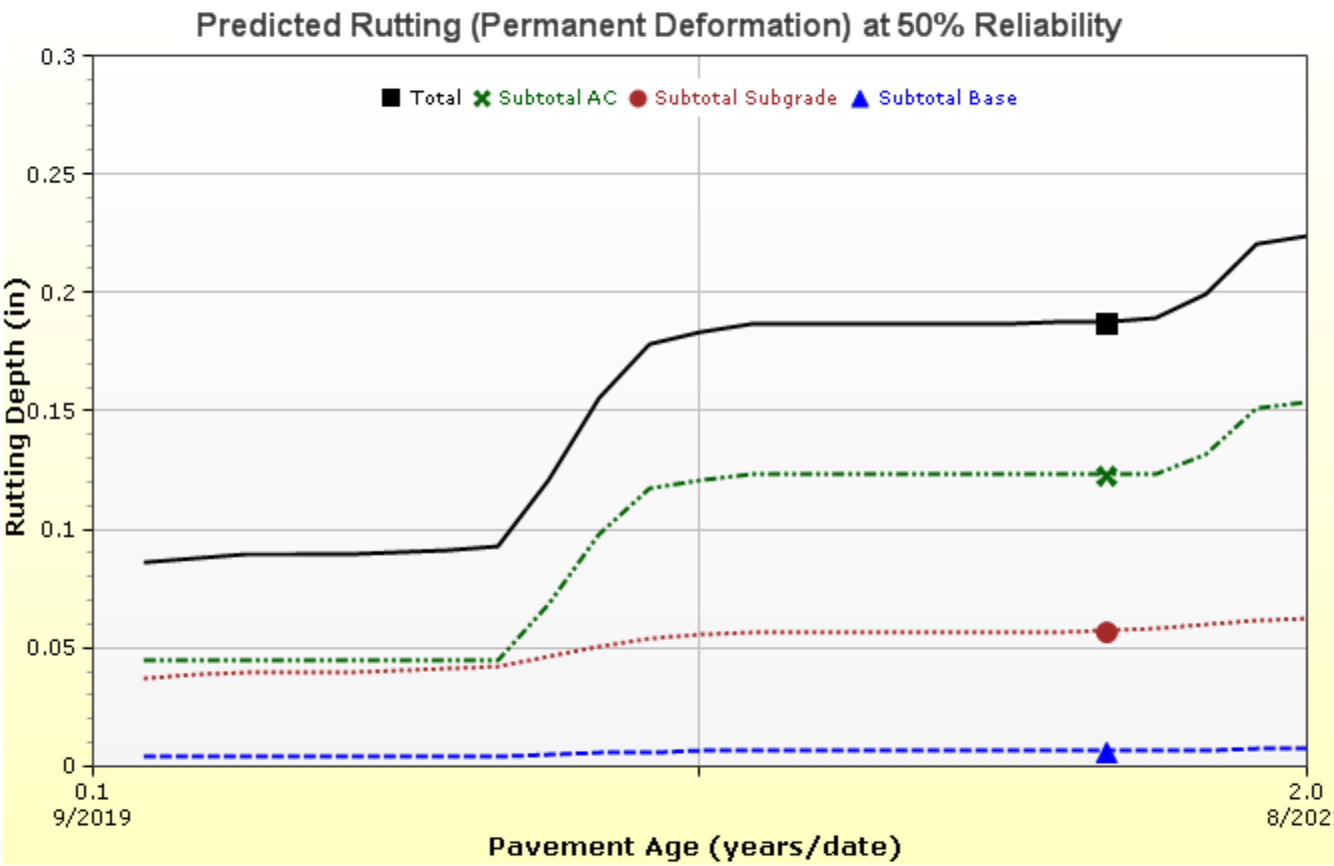




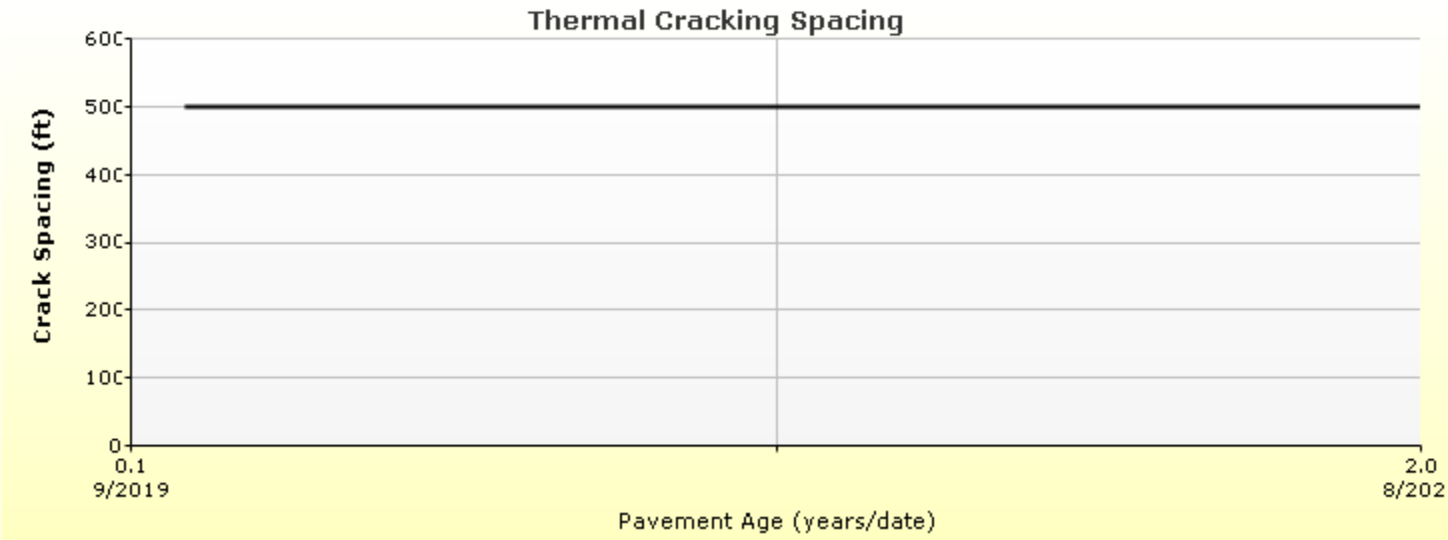
Predicted AC Top-Down Damage
@Surface
(Depth=.5in)
Top-Down Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
3.5
3
2.5
2
1.5
1
0.5
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)



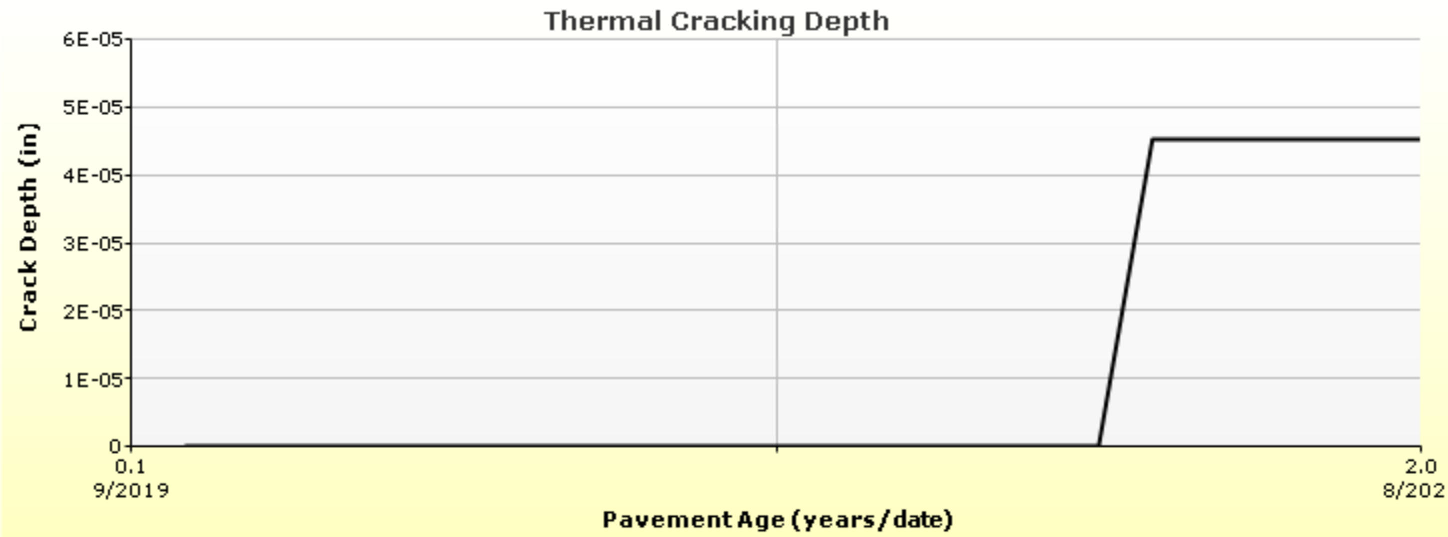
Predicted AC Top-Down Cracking (Longitudinal)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Predicted AC Bottom-Up Cracking (Alligator)
Threshold Value
@ 50% Reliability
@ Specified Reliability
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)



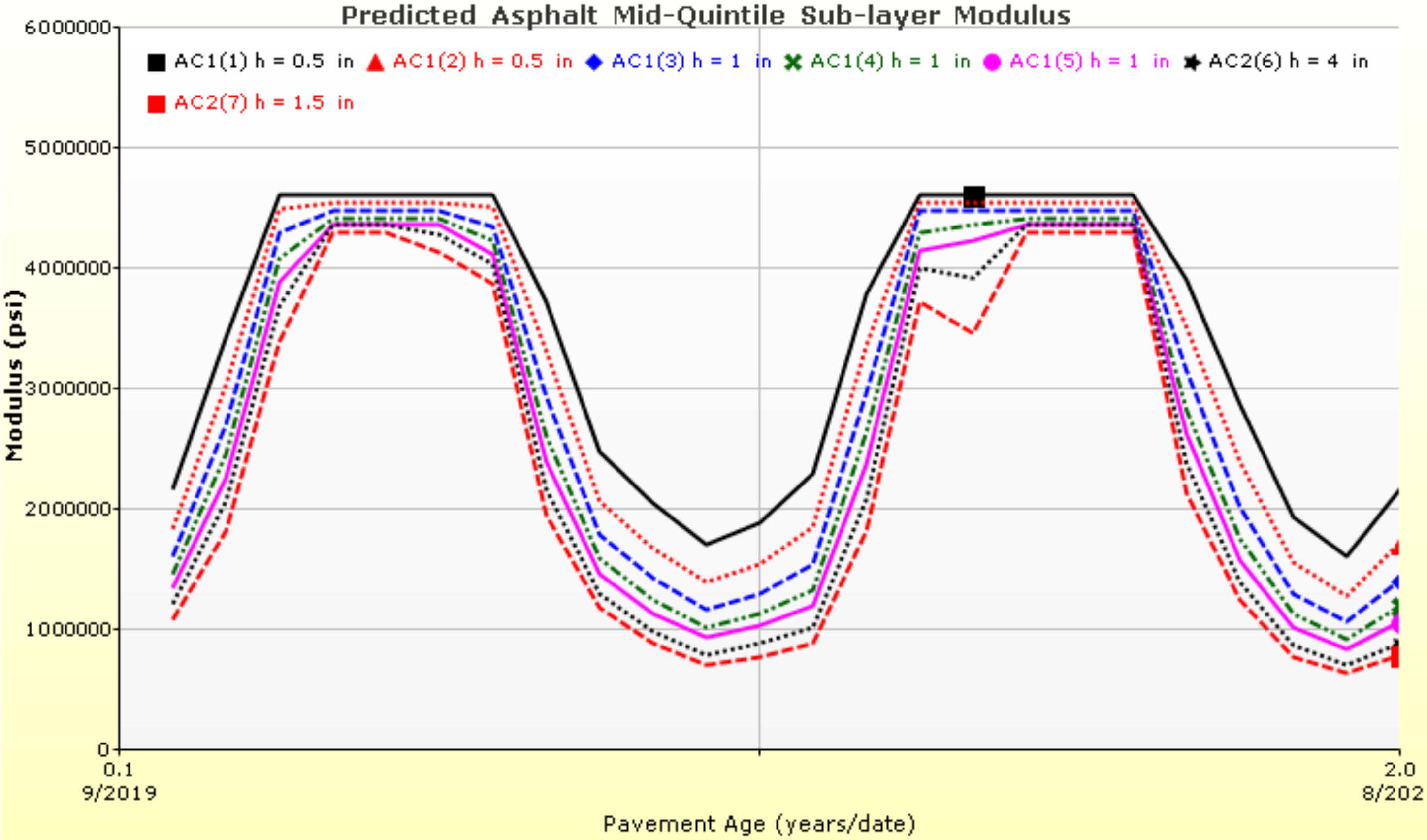
Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rutting Depth (in)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)

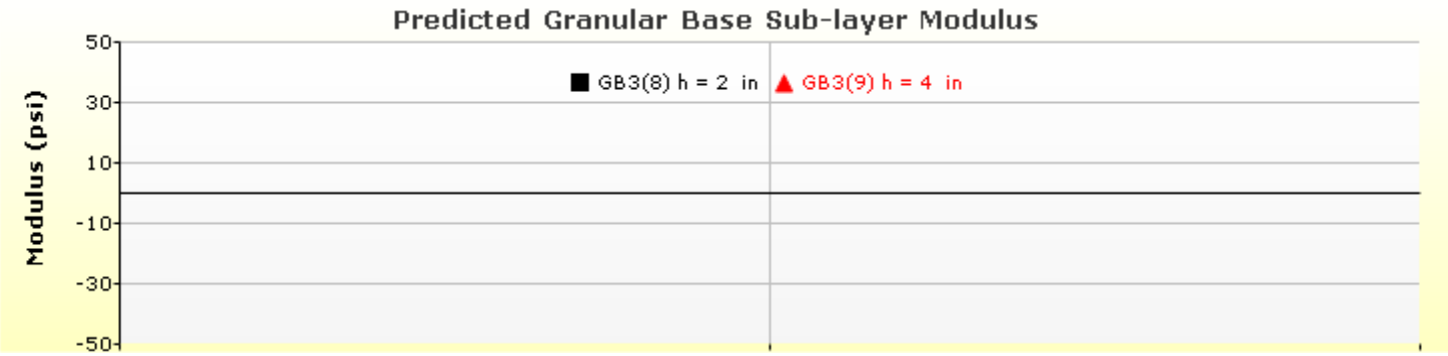


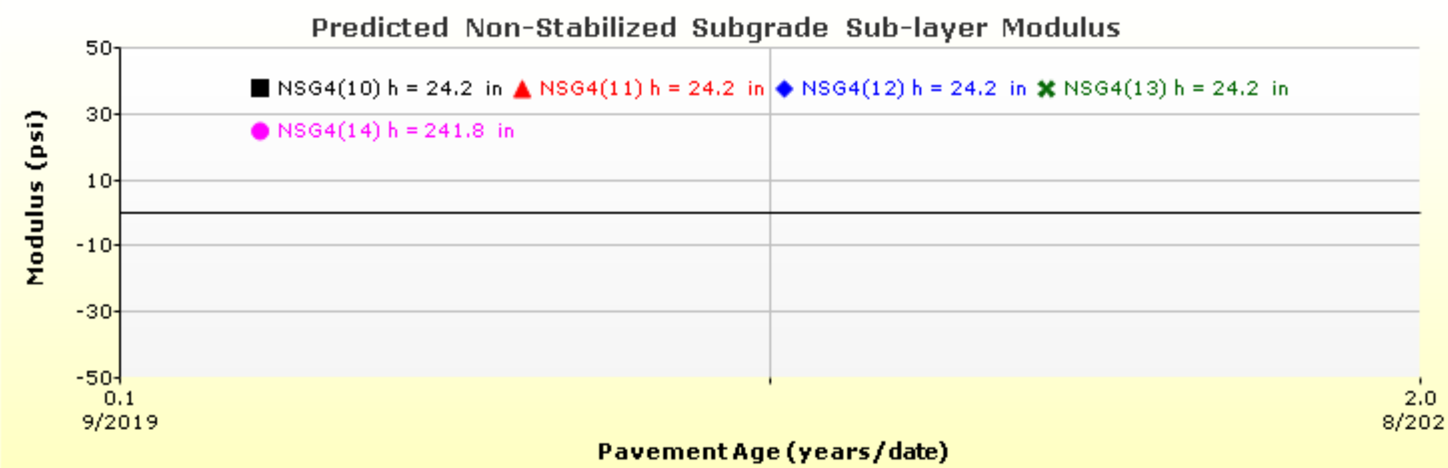
Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)



Thermal Cracking Depth
Crack Depth (in)
6E-05
5E-05
4E-05
3E-05
2E-05
1E-05
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)


Predicted 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
AC2(6) h = 4 in
AC2(7) h = 1.5 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)


Predicted Granular Base Sub-layer Modulus
GB3(8) h = 2 in
GB3(9) h = 4 in
Modulus (psi)
50
30
10
-10
-30
-50


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(10) h = 24.2 in
NSG4(11) h = 24.2 in
NSG4(12) h = 24.2 in
NSG4(13) h = 24.2 in
NSG4(14) h = 241.8 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1
9/2019
2.0
8/2021
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Seymour 19.0mm PG70-22

Asphalt		
Thickness (in.)	4.0	
Unit weight (pcf)	143.8	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	2963030	3640294	4200283	5000000
40	2286934	2578608	2852971	3220280
70	368909	705010	1078041	1308064
100	72377	168834	345974	458741
130	31704	61317	130686	179591

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	22069340.66	33.76
55	9518271.99	44.39
70	2836317.75	52.87
85	765738.66	59.68
100	209102.28	65.17
115	60602.87	69.62
130	19021.84	73.24

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	9.53
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 19.0mm PG70-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

Layer 2 Flexible : Seymour 19.0mm PG64-22

Asphalt		
Thickness (in.)	5.5	
Unit weight (pcf)	143.8	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	3068424	3745817	4147011	5000000
40	2019038	2605875	3065729	3510185
70	256999	620843	1094369	1370481
100	52936	135667	319812	442511
130	26742	50370	114566	162720

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	25339156.98	34.85
55	9930922.35	46.6
70	2585999.72	55.79
85	613653.8	63
100	149927.8	68.71
115	39662.01	73.23
130	11579.02	76.83

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	9.53
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Seymour 19.0mm PG64-22
Description of object	HMA
Author	
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 2	
User defined field 3	
Revision Number	0

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

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Subgrade Treatment, Type III
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 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.2
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

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

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

Layer 4 Subgrade : A-4

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

Modulus (Input Level: 2)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
4000.0

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

Identifiers

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

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.8

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

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

AC Rutting

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

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

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

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

Where:

H_{ac} = total AC thickness(in)

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

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:0.07 Br2:1.9 Br3:0.4

Thermal Fracture

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

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

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

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

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

CSM Fatigue

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

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

k1: 1	k2: 1	Bc1: 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: 0.12	k1: 1.35	Bs1: 0.12
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

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

CSM Cracking

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

C1: 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: 40	C2: 0.4	C3: 0.008	C4: 0.015

CTLGROUP

April 10, 2017

Gary McLeland
E & B Paving, Inc.
310 Blacketor Drive
Rochester, IN 46975

Cell: 765-744-1694
Gary.McLeland@EBPaving.com

Coefficient of Thermal Expansion Testing of Provided Concrete Cylinders (Two Sets)
I-65 Southern Indiana Interstate Highway, INDOT R-28940
CTLGroup Project No. 057622

Dear Gary:

As requested, CTLGroup has performed coefficient of thermal expansion testing of two sets of concrete samples (two cylinders per set) which were provided by you. The cylinders were received by CTLGroup personnel in Skokie, IL on March 29, 2017. The cylinders were labeled by others with the designation of "Hanson Scott" and "Ward". The cylinders are nominal 4-in. diameter.

The cylinders for this testing were received in the moist condition and transferred to a fully submerged limewater bath while still moist. The cylinders remained in this condition until the time of testing except for short periods of time to facilitate cutting, and taking length and weight measurements.

Testing was performed in general accordance with AASHTO T 336-15: *Standard Method of Test for Coefficient of Thermal Expansion of Hydraulic Cement Concrete*. The results of the referenced testing are attached to this letter. Note that thermal expansion is primarily based on the geology of the coarse aggregate and does not vary with age.

If you have any questions or comments, please call.

Sincerely,

CTLGROUP
An AASHTO Accredited Laboratory – Aggregates, Cement & Concrete

Jon Feld, PE (Indiana)
Materials Consulting
JFeld@CTLGroup.com
Phone: 920-980-7951

John Gajda, PE (Illinois)
Senior Principal Engineer
JGajda@CTLGroup.com
Phone: 847-922-1886

Attached: AASHTO T 336-15 Testing Results of the Provided Samples (2 pages)

CTLGroup

Client:	**E & B Paving, Inc.**	CTLGroup Project No.	**057622**
Project:	**I-65 Southern Indiana Interstate Highway**	CTLGroup Project Mgr.:	**J. Feld**
Contact:	**Gary McLeland**	Technician:	**W. Demharter**
Report Date:	**April 10, 2017**	Approved by:	**J. Gajda**

AASHTO T 336-15

Coefficient of Thermal Expansion of Hydraulic Cement Concrete

Specimen Identification and Information

CTLGroup Identification	Hanson Scott A	Hanson Scott B
Client Identification	Hanson Scott	
Casting Date	March 21, 2017	March 21, 2017
Test Date	April 8, 2017	April 8, 2017
Concrete Age at Test, days	18	18
Specimen Description	Nominal 4-in. dia. concrete cylinder provided by client	
Mixture Proportions and Aggregate Type	On file with client	

Specimen Dimensions

Length, mm	178.43	177.92
Diameter, mm	101.97	102.04

Measurements During Specimen Testing

Contraction Segment	Temperature 1, °C	49.98	49.98
	Temperature 2, °C	10.13	10.13
	Specimen Length Change, mm	-0.05349	-0.05297
	CTE of Contraction Segment, mm/mm/°C	7.521E-6	7.469E-6
Expansion Segment	Temperature 2, °C	10.13	10.13
	Temperature 3, °C	49.98	49.98
	Specimen Length Change, mm	0.05467	0.05440
	CTE of Expansion Segment, mm/mm/°C	7.688E-6	7.672E-6

Specimen Coefficient of Thermal Expansion

CTE_{avg}, mm/mm/°C	7.605E-6	7.571E-6
CTE_{avg}, in./in./°F	4.225E-6	4.206E-6
Average CTE, microstrain per °F	**4.215**	

Measurement Apparatus Information

Date of last calibration	12/17/2016	12/17/2016
Calibration specimen material	Titanium, Grade 2	Titanium, Grade 2
Date of last verification	3/29/2017	3/29/2017
Verification specimen material	Stainless Steel, Type 304	Stainless Steel, Type 304
Frame Serial No.	133721	128648
Frame C_f	19.223E-6	20.261E-6

Report Notes

1. This report may not be reproduced except in its entirety.
2. Samples reportedly fabricated on March 21, 2017 by others and received by CTLGroup on March 29, 2017.
3. Samples received by CTLGroup were fully submerged in a limewater bath in a controlled room at 73.5±3.5°F.
4. The full set of data (hundreds of data points) is available from CTLGroup upon request.
5. Note that "microstrain" designates $1x10^{-6}$ (or $1E^{-6}$).

CTLGroup

Client:	**E & B Paving, Inc.**	CTLGroup Project No.	**057622**
Project:	**I-65 Southern Indiana Interstate Highway**	CTLGroup Project Mgr.:	**J. Feld**
Contact:	**Gary McLeland**	Technician:	**W. Demharter**
Report Date:	**April 10, 2017**	Approved by:	**J. Gajda**

AASHTO T 336-15
Coefficient of Thermal Expansion of Hydraulic Cement Concrete

Specimen Identification and Information

CTLGroup Identification	Ward A	Ward B
Client Identification	Ward	
Casting Date	March 21, 2017	March 21, 2017
Test Date	April 7, 2017	April 7, 2017
Concrete Age at Test, days	17	17
Specimen Description	Nominal 4-in. dia. concrete cylinder provided by client	
Mixture Proportions and Aggregate Type	On file with client	

Specimen Dimensions

Length, mm	176.11	177.13
Diameter, mm	101.95	101.95

Measurements During Specimen Testing

Contraction Segment	Temperature 1, °C	49.99	49.99
	Temperature 2, °C	10.13	10.13
	Specimen Length Change, mm	-0.05966	-0.06070
	CTE of Contraction Segment, mm/mm/°C	8.499E-6	8.597E-6
Expansion Segment	Temperature 2, °C	10.13	10.13
	Temperature 3, °C	49.98	49.98
	Specimen Length Change, mm	0.06074	0.06136
	CTE of Expansion Segment, mm/mm/°C	8.654E-6	8.693E-6

Specimen Coefficient of Thermal Expansion

CTE_{avg}, mm/mm/°C	8.577E-6	8.645E-6
CTE_{avg}, in./in./°F	4.765E-6	4.803E-6
Average CTE, microstrain per °F	**4.784**	

Measurement Apparatus Information

Date of last calibration	12/17/2016	12/17/2016
Calibration specimen material	Titanium, Grade 2	Titanium, Grade 2
Date of last verification	3/29/2017	3/29/2017
Verification specimen material	Stainless Steel, Type 304	Stainless Steel, Type 304
Frame Serial No.	133721	128648
Frame C_f	19.223E-6	20.261E-6

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5. Note that "microstrain" designates $1x10^{-6}$ (or $1E^{-6}$).

April 5, 2017

Gary McLeland
E & B Paving, Inc.
310 Blacketor Drive
Rochester, IN 46975

Cell: 765-744-1694
Gary.McLeland@EBPaving.com

Coefficient of Thermal Expansion Testing of Provided Concrete Cylinders (Two Sets)
I-65 Southern Indiana Interstate Highway, INDOT R-28940
CTLGroup Project No. 057622

Dear Gary:

As requested, CTLGroup has performed coefficient of thermal expansion testing of two sets of concrete samples (two cylinders per set) which were provided by you. The cylinders were received by CTLGroup personnel in Skokie, IL on March 22, 2017. The cylinders were labeled by others with the designation of "HH" and "US AGG". The cylinders are nominal 4-in. diameter.

The cylinders for this testing were received in the moist condition and transferred to a fully submerged limewater bath while still moist. The cylinders remained in this condition until the time of testing except for short periods of time to facilitate cutting, and taking length and weight measurements.

Testing was performed in general accordance with AASHTO T 336-15: *Standard Method of Test for Coefficient of Thermal Expansion of Hydraulic Cement Concrete*. The results of the referenced testing are attached to this letter. Note that thermal expansion is primarily based on the geology of the coarse aggregate and does not vary with age.

If you have any questions or comments, please call.

Sincerely,

CTLGROUP
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J. Feld

Jon Feld, PE (Indiana)
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Phone: 920-980-7951

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Senior Principal Engineer
JGajda@CTLGroup.com
Phone: 847-922-1886

Attached: AASHTO T 336-15 Testing Results of the Provided Samples (2 pages)

CTLGroup

Client:	**E & B Paving, Inc.**	CTLGroup Project No.	**057622**
Project:	**I-65 Southern Indiana Interstate Highway**	CTLGroup Project Mgr.:	**J. Feld**
Contact:	**Gary McLeland**	Technician:	**W. Demharter**
Report Date:	**April 5, 2017**	Approved by:	**J. Gajda**

AASHTO T 336-15
Coefficient of Thermal Expansion of Hydraulic Cement Concrete

Specimen Identification and Information

CTLGroup Identification	Hanson Hayden A	Hanson Hayden B
Client Identification	Hanson Hayden (HH)	
Casting Date	March 14, 2017	March 14, 2017
Test Date	April 3, 2017	April 3, 2017
Concrete Age at Test, days	20	20
Specimen Description	Nominal 4-in. dia. concrete cylinder provided by client	
Mixture Proportions and Aggregate Type	On file with client	

Specimen Dimensions

Length, mm	177.31	177.85
Diameter, mm	101.97	102.03

Measurements During Specimen Testing

Contraction Segment	Temperature 1, °C	49.99	49.99
	Temperature 2, °C	10.13	10.13
	Specimen Length Change, mm	-0.05497	-0.05740
	CTE of Contraction Segment, mm/mm/°C	7.777E-6	8.096E-6
Expansion Segment	Temperature 2, °C	10.13	10.13
	Temperature 3, °C	49.98	49.98
	Specimen Length Change, mm	0.05573	0.05842
	CTE of Expansion Segment, mm/mm/°C	7.886E-6	8.242E-6

Specimen Coefficient of Thermal Expansion

CTE_{avg}, mm/mm/°C	7.831E-6	8.169E-6
CTE_{avg}, in./in./°F	4.351E-6	4.538E-6
Average CTE, microstrain per °F[5]	**4.444**	

Measurement Apparatus Information

Date of last calibration	12/17/2016	12/17/2016
Calibration specimen material	Titanium, Grade 2	Titanium, Grade 2
Date of last verification	3/29/2017	3/29/2017
Verification specimen material	Stainless Steel, Type 304	Stainless Steel, Type 304
Frame Serial No.	133721	128648
Frame C_f	19.223E-6	20.261E-6

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5. Note that "microstrain" designates $1x10^{-6}$ (or $1E^{-6}$).

CTLGroup

Client:	**E & B Paving, Inc.**	CTLGroup Project No.	**057622**
Project:	**I-65 Southern Indiana Interstate Highway**	CTLGroup Project Mgr.:	**J. Feld**
Contact:	**Gary McLeland**	Technician:	**W. Demharter**
Report Date:	**April 5, 2017**	Approved by:	**J. Gajda**

AASHTO T 336-15

Coefficient of Thermal Expansion of Hydraulic Cement Concrete

Specimen Identification and Information

CTLGroup Identification	US AGG A	US AGG B
Client Identification	US AGG	
Casting Date	March 14, 2017	March 14, 2017
Test Date	April 4, 2017	April 4, 2017
Concrete Age at Test, days	21	21
Specimen Description	Nominal 4-in. dia. concrete cylinder provided by client	
Mixture Proportions and Aggregate Type	On file with client	

Specimen Dimensions

Length, mm	176.14	177.88
Diameter, mm	101.98	102.03

Measurements During Specimen Testing

Contraction Segment	Temperature 1, °C	49.99	49.99
	Temperature 2, °C	10.13	10.13
	Specimen Length Change, mm	-0.05775	-0.05764
	CTE of Contraction Segment, mm/mm/°C	8.226E-6	8.130E-6
Expansion Segment	Temperature 2, °C	10.13	10.13
	Temperature 3, °C	49.98	49.98
	Specimen Length Change, mm	0.05833	0.05871
	CTE of Expansion Segment, mm/mm/°C	8.309E-6	8.282E-6

Specimen Coefficient of Thermal Expansion

CTE_{avg}, mm/mm/°C	8.268E-6	8.206E-6
CTE_{avg}, in./in./°F	4.593E-6	4.559E-6
Average CTE, microstrain per °F[5]	**4.576**	

Measurement Apparatus Information

Date of last calibration	12/17/2016	12/17/2016
Calibration specimen material	Titanium, Grade 2	Titanium, Grade 2
Date of last verification	3/29/2017	3/29/2017
Verification specimen material	Stainless Steel, Type 304	Stainless Steel, Type 304
Frame Serial No.	133721	128648
Frame C_f	19.223E-6	20.261E-6

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5. Note that "microstrain" designates $1x10^{-6}$ (or $1E^{-6}$).

Project Design and Utility Summary

Reporting Period:

INDOT DES NO: 0501212
Project Description: I-65 Pavement Replacement and Pavement Rehabilitation
Utility Coordinator: Greg Broz
INDOT Oversight Age Bill Read
INDOT Project Manag Whitney Carlin

INDOT Contract NO: R-28940
INDOT Letting Date: 4/27/17
Ready for Contract Date:
Design Consultant: United Consulting
Phone No: 317-895-2585

This color denotes that there is a small conflict chance or more info needed to determine
This color denotes that a conflict is probable
This color denotes that a conflict is likely
This color denotes a constructability issue

Utility Coordinator	Designer (collaboration with Utility Coordinator as needed)											Utility Coordinator			Project Team Collaboration
Utility Name & Contact Person	Utility Type	Material and Size	Description Of Design Conflict With Utility	Start Station	Start Offset	End Station	End Offset	Utility Investigation Level Needed	Designer's Justification To Impact The Utility	Design Around Alternative description*	Design Around Estimated Cost*	Utility Relocation Plan	Estimated Utility Relocation Cost	Utility Relocation Reimbursable	Additional Information/Recommended Resolution
AT&T Indiana; Troy Bishop	Communications	Copper and Fiber Optic	UTIL 1.35 Along SR 58 near I-65, AT&T appears to be outside the R/W. Easement?					Need confirmation of locations	Need to widen SR58 at I-65 ramps and place new signals in addition to new signal at SR 58 and International Dr	We anticipate designing the signal to avoid impacting utility facilities	$0				AT&T knows they are in a drainage and utility easement on E side of I-65, and are checking their records to see if they are in an easement along SR 58. They have fiber optic and copper on the N side of SR 58 at International Dr. They also state they have aerial and underground facilities along International, but UC cannot find aerial lines in 2014 dated streetview.
AT&T Indiana; Troy Bishop	Communications	Fiber Optic	UTIL 1.35 Fiber Optic line between Indy and Louisville in easement on E side US31					Need confirmation of locations and easement information	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				The fiber optic line is a connection between Louisville and Indy, size and depth unknown, easement info unknown, hopefully easement is east of existing pole on NE corner
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power	12.5kV	12.5 kV Aerial facilities cross I-65 725' north of SR58. Should be little to no impact, other than OSHA clearance for voltage.	2946+00 Line "A"				Need clearance above I-65.	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power	12.5kV??	12.5 kV? Aerial facilities along the north side of SR 58. Will likely conflict with signal pole locations at International Dr.					Signal needed at SR 58 and International Dr. Electric facilities are likely too close to road to set poles	Need to set poles for a new signal at SR 58 and International Dr.	Place signal poles less than 5 feet from edge of pavement and risk poles being hit by turning movements of trucks		N	Unknown	Yes, per INDOT	Poles may be at, or very close to, the R/W line. Any moving of the lines away from the road would result in the need for either the purchase of R/W or obtaining an easement. Having the line go underground may be another option, but there is already gas (E and S sides), 2 water lines (N and W sides), sewer (N side), at least 2 telecom lines (N and W sides), and an UG power line (SE to NW)at this intersection. In addition, if these overhead lines are considered transmission, the REMC may not be able to de-energize the lines and window for relocation could be very difficult to coordinate with.

Utility Coordinator	Designer (collaboration with Utility Coordinator as needed)											Utility Coordinator			Project Team Collaboration
Utility Name & Contact Person	Utility Type	Material and Size	Description Of Design Conflict With Utility	Start Station	Start Offset	End Station	End Offset	Utility Investigation Level Needed	Designer's Justification To Impact The Utility	Design Around Alternative description*	Design Around Estimated Cost*	Utility Relocation Plan	Estimated Utility Relocation Cost	Utility Relocation Reimbursable	Additional Information/Recommended Resolution
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power	7.2kV	7.2 kV line UG "at 700S"	Approx. 2795+00 Line "A"				Not located; need depths	Need to set drainage structures, and may need to re-grade ditches	No assessment can be made at this time					There is already a water line located in the area and if there is a need for median drainage, or changes to the grade of the ditch lines, there is concern that the line could be hit since both depth and location are unknown.
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power	7.2kV	7.2 kV Aerial Facilities at 800S	2735+00 Line "A"				"low" voltage, but also possible low clearance	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power	7.2kV	7.2 kV Aerial Facilities 1000' north of 1100N (Jack./Barth. Co line)	2566+40 Line "A"				"low" voltage, but also possible low clearance	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.
Bartholomew County REMC; Marvin Book mbook@bcremc.com	Power		UG facilities under and across SR 58 and International Dr. from SE quad to NW quad also appears that there is UG feed from pole on NE quad to switch gear in NW quad					Not located; need depths	Need to set poles for a new signal at SR 58 and International Dr.	We anticipate designing the signal to avoid impacting utility facilities	$0	N	Unknown	Yes, per INDOT	Underground power lines run from the SE corner to the NW corner according to Bartholomew Co REMC maps. The survey did not pick up this or several other utilities, but based on other utility information it is very probable that UG power crosses a gas line in the SE corner of the intersection. Placement of a pole in this corner without relocation will be very difficult. See 3c for explanation of this area.

Utility Coordinator	Designer (collaboration with Utility Coordinator as needed)											Utility Coordinator			Project Team Collaboration
Utility Name & Contact Person	Utility Type	Material and Size	Description Of Design Conflict With Utility	Start Station	Start Offset	End Station	End Offset	Utility Investigation Level Needed	Designer's Justification To Impact The Utility	Design Around Alternative description*	Design Around Estimated Cost*	Utility Relocation Plan	Estimated Utility Relocation Cost	Utility Relocation Reimbursable	Additional Information/Recommended Resolution
Columbus City Utilities Ed Bergsieker ebergsieker@columbusutilities.org	Water & Sewer	??	UTIL 1.34 Water line crosses SR 58 on west side of International Dr. Sewer line crosses under SR58 300 ft east of International Dr. Water line also parallel to SR 58 along the north side.					Need to determine depths and actual locations	Need to set poles for a new signal at SR 58 and International Dr.	We anticipate designing the signal to avoid impacting utility facilities	$0				Survey did not pick up sanitary sewer near intersection. Sewer may be out of the way, but any water line relocation on the north side would have to consider the proper buffer (>10') between a water supply line and a sanitary sewer line running parallel to each other. See 3c for explanation of this area. City is also planning on replacing/improving the water line along the north side of SR 58 (since we don't have proper survey information, I am going to assume this means there are 2 water lines ; 1 for SW Barth. CO and 1 for Columbus). Utility "would like to have a designated corridor for our water main improvements"
Comcast; Tom Davis Thomas_Davis3@cable.comcast.com	Communications	??	Comcast crosses under I-65 between Bode and 760E north of SR 11. This may become an issue when drainage is directed away from RR that is north of this location	2502+50 Line "A"				TH33 5.53', TH36 7.12'	required to direct drainage away from RR R/W	Proposed ditch elevations must maintain cover over existing facilities					
Comcast; Tom Davis Thomas_Davis3@cable.comcast.com	Communications	??	Comcast has several lines at International and SR 58. W side of International & N side of SR58					Need to determine depths and actual locations	Need to set poles for a new signal at SR 58 and International Dr.	We anticipate designing the signal to avoid impacting utility facilities	$0				This CATV was not picked up in the survey; but utility map shows them to be on the N and W sides of the intersection. Actual locations and depths unknown. See 3c for explanation of this area.
Duke Energy - Distribution Gabe Gibson	Power	12.5kV	12.5kV Aerial Facilities on east and west side of I-65 north of US 50.	2214+50 Line "A"				Possible low clearance	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.

Utility Coordinator	Designer (collaboration with Utility Coordinator as needed)											Utility Coordinator			Project Team Collaboration
Utility Name & Contact Person	Utility Type	Material and Size	Description Of Design Conflict With Utility	Start Station	Start Offset	End Station	End Offset	Utility Investigation Level Needed	Designer's Justification To Impact The Utility	Design Around Alternative description*	Design Around Estimated Cost*	Utility Relocation Plan	Estimated Utility Relocation Cost	Utility Relocation Reimbursable	Additional Information/Recommended Resolution
Duke Energy - Transmission Jason Keenan jason.keenan@duke-energy.com	Power	345kV	345 kV line crossing near 800S and 100W in Bartholomew Co. (34517) **OSHA >19.8' clear. Required NESC 24.8'**	2716+00 Line "A"	Lt	2718+75 Line "A"	Rt	NB clearance 36' **SB clearance 34'**	Need to work on I-65 under these power lines; NESC clearance means less than 10' from power line to buffer zone around power lines	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is more of a constructability and safety issue. Duke will not be willing to de-energize their transmission lines from previous experience. We have a situation where the line is only 34' above SB I-65 and NESC states a 24.8' buffer around the line is needed. Under OHSA, the buffer may be a small as 19.8'. This leaves 10'-15' to work under the lines
Duke Energy - Transmission Jason Keenan jason.keenan@duke-energy.com	Power	230kV x2	Twin 230kV lines crossing I-65 near Jackson/Barth. County line (23004 & 23005) **OSHA >16' clear. Required NESC 22.5'**	2611+00 Line "A"	Lt	2617+00 Line "A"	Rt	NB clearance 47' **SB clearance 27.5'**	Need to work on I-65 under these power lines; NESC clearance means only 5' from power line to buffer zone around power lines for SB lanes.	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is more of a constructability and safety issue. Duke will not be willing to de-energize their transmission lines from previous experience. We have a situation where the line is only 27.5' above SB I-65 and NESC states a 22.5' buffer around the line is needed. Under OHSA, the buffer may be a small as 16'. This leaves 5'-10' to work under the lines
Duke Energy - Transmission Jason Keenan jason.keenan@duke-energy.com	Power	138kV	138kV lines crossing I-65 between CSX tracks and weigh station (13851) **OHSA >12.9'**	2237+75 Line "A"	Lt	3338+25 Line "A"	Rt	NB clearance 38.5' **SB clearance 29'**	Required to work on I-65 under these power lines; NESC clearance means less than 10' from power line to	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning	$0				This is more of a constructability and safety issue. Duke will not be willing to de-energize their transmission lines from previous experience. We have a situation where the line is only 29' above SB I-65 and NESC states a 20.6' buffer around the line is needed. Under OHSA, the buffer may be a
Enterprise Products; Elisa Abraham or Scott Hawn	UG pipeline	16 in. and 20 in. steel pipe	Two lines cross I-65 at White River bridge "between 5th and 6th piers counting from north side"; north of river. Pipelines transport "highly volatile substances".	2426+75 Line "A"	Rt	2427+75 Line "A"	Lt	Need to notify when working near. Want rep on site while working near, at their expense. They also want "air bridges" built over each line; timber mats stacked on either side of the pipeline with a timber mat over the pipes. TH1,3,4,6 3.70' to 5.95'	Requitred to build widened bridges over White River	No design around; use timber mats to create a bridge over the individual pipelines for equipment	$0				Sister company to Texas Eastern/Spectra (#20 below) with shared R/W. UG pipelines run between 2 of the piers for both NB and SB I-65 and are not parallel to the piers. Temporary bridges of timber mats will need to be built over the pipelines in addition to the fact that monitoring will need to be in place at all times when there is work in the area.

Utility Coordinator	Designer (collaboration with Utility Coordinator as needed)											Utility Coordinator			Project Team Collaboration
Utility Name & Contact Person	Utility Type	Material and Size	Description Of Design Conflict With Utility	Start Station	Start Offset	End Station	End Offset	Utility Investigation Level Needed	Designer's Justification To Impact The Utility	Design Around Alternative description*	Design Around Estimated Cost*	Utility Relocation Plan	Estimated Utility Relocation Cost	Utility Relocation Reimbursable	Additional Information/Recommended Resolution
Frontier Communications; Mark Gibson	Communications	UG Copper	They suspect UG copper is on east side of 800E. Inactive per FTR	2503+50 Line "A"				Inactive line located on west side of 800E; Frontier admits old plans are inaccurate, so inactive line likely theirs	required to direct drainage away from RR R/W	Frontier has repeatedly stated this is abandoned and is not on their current maps. Should be ok to remove	$0				Contact Frontier and confirm removal of inactive/abandoned line is acceptable.
Frontier Communications; Mark Gibson	Communications	Copper and fiber optic lines; both UG and aerial	UG copper and F.O. at 1100N	2556+25 Line "A"				UG at 1100 N is possibly shallow (TH27 3.65', TH30 4.08')	for possible changes to proposed drainage	Profile will be adjusted as necessary to maintain clearance	$0				
Frontier Communications; Mark Gibson	Communications	Copper and fiber optic lines; both UG and aerial	UTIL 1.31 UG fiber on W side of US31 Aerial fiber S side SR250 Copper facilities in the area of US31 & SR250					need depths and locations if the existing signal equipment at SR250 and US31 cannot handle temp signal heads	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				This only becomes an issue if the existing poles and foundations will not be able to handle a switch from a flasher to a temp signal. UG fiber optic along the W side, and copper lines that are in the area but no information about whether or not they are UG or aerial.
Jackson County REMC; Mark Smallwood	Power	Single phase 7.2 kV 3 phase 15kV	Five aerial crossings; single phase @ 700N single phase @ 800N single phase @ 925N 3 phase 3100ft S of SR11 (this clearance over I-65 between 24' and 25') 3 phase 3900ft N of SR11	2281+90 2341+75 2378+55 2460+50 2531+50 all Line "A"				work within 20' of poles needs REMC approval. 3 phase crossing S of SR 11 could be impacted	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.
Jackson County REMC; Mark Smallwood	Power	Likely Single phase 7.2 kV 3 phase 15kV	Aerial trans. and dist. facilities on west side of US 31 and south side of SR250					need to confirm voltages and clearances.	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				This only becomes an issue if the existing poles and foundations will not be able to handle a switch from a flasher to a temp signal. Aerial power lines are on the W and S sides of the intersection.

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Jackson County Water Utility; Larry McIntosh manager@jacksoncountywater.com	Water	6 in. & 3 in.	UTIL 1.33 6" on W side of US31 3" on N side of SR250					need depths and locations if the existing signal equipment at SR250 and US31 cannot handle temp signal heads	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				This only becomes an issue if the existing poles and foundations will not be able to handle a switch from a flasher to a temp signal. Water lines are on the N and W sides of the intersection.
Smithville Communications; Joseph Bryniarski joe.bryniarski@smithville.com	Communications	fiber, in 1.25 in. duct plus empty duct	Crossing under SR 58 on west side of International Dr					Need to determine depths; location appears to be only telecom picked up in survey, only possible conflict if loops need to be placed for EB SR58	placing loop wire to run to the control cabinet	Wireless pucks					
Southwestern Bartholomew Water Corp.; Alan Ross aross@swbwc.com	Water	3 in. PVC	Water main along the north side of SR 58 at International Dr.					need depths and locations since all notes prior to Add. #4 stated they were not in the project.	Need to set poles for a new signal at SR 58 and International Dr.	We anticipate designing the signal to avoid impacting utility facilities	$0				This water company was not known about until after mid-March 2017. They state they are on the N side of SR 58. This utility was not picked up in the survey. Water line they comment on is likely different from the Columbus City Utility water line, meaning there are 2 water lines and a sanitary sewer line on N side of SR 58. See 3c for explanation of this area.
Texas Eastern Gas Pipeline (Spectra Energy); Doug Wessel pdwessel@spectraenergy	UG Pipeline	24 in. Steel	Similar location to Enterprise products; north of East Fork White River	2426+75 Line "A"	Rt	2427+75 Line "A"	Lt	Need to notify when working near. Want rep on site while working near, at their expense. They also want "air bridges" built over each line; timber mats stacked on either side of the pipeline with a timber mat over the pipes. *They are will be adding another pipeline by fall 2018* TH2&5 1.22'(#5)	Required to build widened bridges over White River	no design around; use timber mats to create a bridge over the individual pipelines for equipment	$0				Sister company to Enterprise at #11; pipelines are in a shared R/W with Enterprise. They will be adding another line in the middle of the 3 existing lines before the end of 2018. They will require the same timber mat temp bridging over their pipelines and monitoring that Enterprise is asking for.

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Vectren Energy; Sandra Buening and Holly Columbia	Gas	8" Steel 12"steel	Two HIGH PRESSURE lines on N side of SR11. With a 3rd line that is retired in place. This may become an issue when drainage is directed away from RR that is north of this location	2499+90 Line "A"		2503+25 Line "A"		Pothole depths for retired line are shallow, as is 8" line to north. Need to notify when working near TH34 2.23', TH35 4.27' TH31 4.81', TH37 4.86' TH32 2.93', TH38 3.28'	required to direct drainage away from RR R/W	Proposed ditch elevations must maintain cover over existing facilities					
Vectren Energy; Sandra Buening and Holly Columbia	Gas	6", 4", 2" plastic	6" line N of SR58, E side of International 4" line S of SR58, E side of International 2" line S side of SR58					Need to determine depths and actual locations	Need to set poles for a new signal at SR 58 and International Dr.	We anticipate designing the signal to avoid impacting utility facilities	$0				Gas lines on the south and east sides of the intersection of SR58 and International. Gas markers were picked up in the survey, but no line was surveyed, so no indication of accuracy of the gas markers in relation to the physical gas line. Gas lines very likely to cross UG power in SE corner. See 3c & 3g for explanation of this area.
"Unknown lines"	Power	4 in. metal	unknown owner, but based on plans for weigh stations, they appear to be NEW power feeds between weigh stations	2260+55 Line "A"		2260+75 Line "A"		TH39&40 (3.13' and 2.61') found in median	added travel lanes	Profile will be adjusted as necessary to maintain clearance	$0				These are new power feeds and must be preserved, but they are encased in a 4 inch steel casing.
Hoosier Energy; Tim Emmel	Power	?	Per UTIL 1.30, they cross over I-65 S of SR 58.	2929+90 Line "A"				Need to know what the voltage is as well as clearance over I-65	Height of electric wire over I-65 combined with required buffer around wire is a safety/constructability issue	Profile will be reviewed, and adjusted if necessary, in this location to avoid impacting facilities; warning signs will need to be placed near wires for safety	$0				This is a constructability and safety issue.

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Midwest Natural Gas Corporation; Phil Ross	Gas	3" PE x2 and 2" PE	3" on E side US31 3" N side of SR250 E of US31 2" S side SR250 across and W of US31					need depths and locations if the existing signal equipment at SR250 and US31 cannot handle temp signal heads	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				This only becomes an issue if the existing poles and foundations will not be able to handle a switch from a flasher to a temp signal. Gas lines are on the E and S sides of the intersection.
Zayo Bandwidth; Dan Jones	Communications	Fiber optic	UG facilities along W side of US31 around SR250					need depths and locations if the existing signal equipment at SR250 and US31 cannot handle temp signal heads	Need to change flasher to temp signal at SR 250 and US31	Use existing poles, no impact expected	$0				This only becomes an issue if the existing poles and foundations will not be able to handle a switch from a flasher to a temp signal. UG fiber optic along the W side, which is similar to Frontier (12f).

*Design around alternative and estimated construction cost level of detail should match the current plan development stage and level of known information of the conflict (i.e. initial assessment estimated costs should be similar to an engineering assessment estimation; SUE QL-A provided for Utility - higher level of known information, design alternative and estimate should be more refined.

Notes:

Direct coordination with the Utility Coordinator, Project Manager, and the rest of the project team will be the key to developing project specific needs and expectations.

March 16, 2017

RE: INDOT I-65 Southeast Project Design Build

Mr. Scott O'neil:

In 2009 two interstate widening projects were let by KYTC. I was the engineer in charge of both of these projects and have been asked about the construction access points for phased construction on an interstate. The design that I sent was approved and incorporated into the plans by FHWA. This design worked well on both projects and allowed for vehicles to enter and exit the workzone at free flow speed and did not hinder interstate traffic.

If you have any questions on this or other project matters, don't hesitate to contact this office. Thank you for your diligence in this matter.

Sincerely,

Ryan Gossom, PE
Division of Construction