Indiana Finance Authority IFA

TECHNICAL PROPOSAL FOR THE I-69 MAJOR MOVES EXPANSION PROJECT

INTERSTATE 69 MajorMoves 2020

DUE DATE: SEPTEMBER 21, 2015

Milestone Contractors, L.P.

SAFETY BY CHOICE NOT BY CHANCE

PROPOSER:
MILESTONE CONTRACTORS, L.P.

5950 S. Belmont Ave.
Indianapolis, Indiana 46217
Office:(317) 788-6885
Fax:(317) 788-1098

UNITED Consulting

VOLUME 2

APPENDICES

KEY PERSONNEL RESUMES
TRAFFIC ANALYSIS OF CAMPUS PARKWAY
PAVEMENT DESIGN

Preliminary Performance Plans

VOLUME 2

SUMMARY AND ORDER OF PROPOSAL CONTENTS

Exhibit E

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 & 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 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

SUMMARY & ORDER OF PROPOSAL CONTENTS

EXHIBIT E

Technical Proposal – Volumes 1 and 2		
Technical Proposal Component	**Form (if any)**	**ITP Section Cross-Reference**
MWVBE Certification	Form G No forms are provided for the MWVBE Performance Plan or Job Training Plan	Exhibit B, Section 3.2.8
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
Insurance	No forms are provided	Exhibit B, Section 3.2.11
Confidential Contents Index	No forms are provided	Exhibit B, Section 3.2.12
C. **Proposal Security (Proposal Bond)**		
Proposal Security	Form J (if in the form of a bond); no forms provided for certified check	Exhibit B, Section 3.3
D. **Proposal**		
Stipend Agreement	Form O	Exhibit B, Section 3.4
Volume 2		
E. **Scope Package**	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

SUMMARY & ORDER OF PROPOSAL CONTENTS

EXHIBIT E

Technical Proposal – Volumes 1 and 2		
Technical Proposal Component	**Form (if any)**	**ITP Section Cross-Reference**
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

SUMMARY & ORDER OF PROPOSAL CONTENTS

EXHIBIT E

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
Additional Scope Pricing	Form Q	Exhibit C, Section 3.0
Scope Package	Form K	Exhibit C, Section 4.0

Executive Summary
Administrative Materials
Forms

VOLUME 2

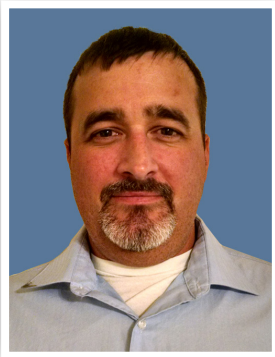
H. VOLUME 2 APPENDICES

Exhibit B, Section 3.2.5

Key Personnel Resumes

Ron Nagle

Project Manager



Education: Purdue University (2002)
BS Civil Engineering

Years Relevant Experience: 14

Years with Current Firm: 9

Licenses/Certifications:

- EIT
- 30 HR OSHA Training
- ATSSA Traffic Control Supervisor

Availability: 100%

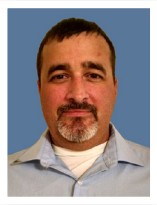
Reference:
I-65/I-70 South Split Reconstruction
Mike Wilmot, PE
Indiana Department of Transportation
Phone: (317) 474-4236
Email: mwilmot@indot.in.gov

For Ron's entire career he has managed construction projects. For the past two years, he has worked as a project manager for Milestone, prior to that he filled a dual role of project manager/project superintendent at Milestone. He has managed multiple projects per year, often several at any one time and with several different owners both public and private. He has coordinated between public and private entities to schedule work to be completed safely and on time while meeting their specific project goals and needs. He has provided solutions to INDOT to accelerate work without the addition of costs to the project. He has coordinated and led public information meetings for projects with high impact to the flow of traffic on major highways to help reduce the impact on the motorist. Ron's involvement with projects starts during the estimating of the bid to developing submittals and shop drawings and finally managing the construction of the project from start to completion.

Relevant Experience

Project Manager
R-35730-A: I-65/I-70 South Split Reconstruction
$14.5 Million, Marion County, IN
Owner: Indiana Department of Transportation

Ron was responsible for oversight of all aspects of construction activities and safety for this fast tracked, high public impact project. He was the point of contact for communication with INDOT to resolve unforeseen conditions and delays to keep the project ahead of schedule. He coordinated project activities between Milestone, INDOT, City of Indianapolis, subcontractors and trucking companies to complete this project ahead of schedule and reduce the impact on the customer. The project was a $14.5 Million reconstruction of 1 mile of I-65/I-70 at the South Split in Indianapolis, this work was completed with a complete closure of one of the busiest sections of road in the State. In order to reduce the impact on the public this work had to be completed in 59 days. Under Ron's leadership the project was completed in 44 day, 15 days ahead of schedule. The project was the first in 30 years for INDOT to use continuous reinforced concrete pavement and Milestone was able to plan and perform this work without delay to the progress of the project. The project was selected as one of the **TOP 10 ROAD PROJECTS IN THE US BY ROADS & BRIDGES MAGAZINE IN 2013**.



Ron Nagle

Project Manager

Relevant Experience Continued

Project Manager
RS-31502-A: I-74 Asphalt Resurface
$11.5 Million, Montgomery County, IN
Owner: Indiana Department of Transportation

Ron managed all of the scheduling and coordination of crews and subcontractors on the project. He was responsible for planning and directing safety efforts on the project. Upon INDOT's request to accelerate the project and add ramp construction and an additional mile of construction to the project in the first phase, Ron came up with a plan to achieve this goal without increasing the costs of the project. The project included HMA and PCCP patching of the existing pavement, full depth reclamation of the shoulders and asphalt resurface of 13.3 miles of I-74 in Montgomery County.

Chad Scott

Construction Manager & Superintendent

Education: Purdue University (2002)
BS Building Construction Management

Years Relevant Experience: 21

Years with Current Firm: 11

Licenses/Certifications:
- 30 HR OSHA Training
- ATSSA Traffic Control Supervisor

Availability: 100%

Reference:
I-70 Reconstruction
Lester Wagoner Jr., PS
Indiana Department of Transportation
Phone: (812)718-6142
Email: Lwagoner@indot.in.gov

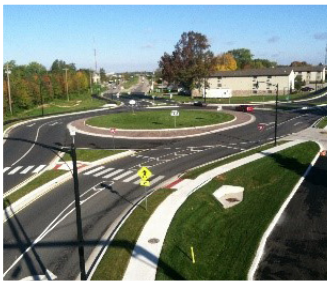
Chad will be responsible for managing all project field operations. His duties will include scheduling crews, materials, equipment, and subcontractors. He has served this role for the last 11 years, completing 11 projects. These projects ranged between $2 million and $ 16 million in value. Chad has worked with several INDOT personnel within the Crawfordsville and Greenfield districts. He has worked with INDOT to accelerate multiple projects through value engineering to save time and money. Chad has continuously maintained a safe work environment for both project personnel and the traveling public.

Relevant Experience

Project Superintendent – I-70 Reconstruction, Mt. Comfort Road to SR 9
$16M – Hancock County, Indiana
Owner: Indiana Department of Transportation

Chad managed all field operations which included scheduling crews, materials, equipment, subcontractors. Chad also provided and maintained the overall project schedules, erosion control, sign and barricade reports, and traffic worksite speed limit reports. The project was completed on time and under budget. The project also received the **INDIANA PARTNERSHIP FOR TRANSPORTATION QUALITY ACHIEVEMENT AWARD**.

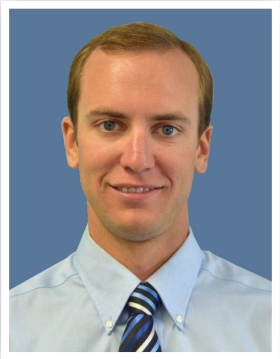
Project Superintendent – Northwestern Avenue and Yeager Road
$12M – Tippecanoe County, Indiana
Owner: City of West Lafayette



Chad managed all crews, materials, equipment, and subcontractors. He built and maintained the project schedule. Chad worked with the City of West Lafayette to alter the project MOT to combine phases, reducing the timeline of the contract and contract amount. The MOT change also reduced the amount of time the local businesses were affected by the project. The project received the **NAPA QUALITY IN CONSTRUCTION AWARD**.

Randy Wilkinson

Maintenance of Traffic Manager AND Erosion & Sediment Control Manager



Education: Purdue University
BS Civil Engineering

Years Relevant Experience: 5

Years with Current Firm: 4

Licenses/Certifications:

- EIT
- 30 HR OSHA Training
- ATSSA Traffic Control Supervisor
- INDOT Construction Storm Water Manager Certification (Pending 10/14/15 Training)

Availability: 100%

Reference:
I-65N to I-70W South Split Ramp Design Build
Mike Carver
Indiana Department of Transportation
Phone: (317) 474-4981
Email: D30Carv@indot.in.gov

Randy will serve on this project as both the Maintenance of Traffic Manager and the Erosion and Sediment Control Manager. Throughout his time with Milestone he has worked in both roles while managing primarily, but not limited to, bridge construction projects. Due to the nature of bridge work, Randy is accustomed to regularly working in close proximity to rivers, creeks, and wetlands as well as maintaining traffic whether it is above, below, or beside the work area. This naturally leads to more awareness and attention in the areas of erosion and sediment control and maintenance of traffic.

Relevant Experience

B-37019, I-65N to I-70W South Split Ramp Design Build
$3.5 Million- Marion County, IN
Owner: Indiana Department of Transportation

Randy was the project manager on this fast paced design build contract that included two bridges crossing multiple local streets and interstates. He coordinated subcontractors and suppliers and managed the project schedule. More importantly Randy coordinated the installation of all maintenance of traffic devices to completely shut down the I-65 North to I-70 West ramp as well as Morris & Prospect Streets all while safely maintaining pedestrian traffic along these local streets. The maintenance and inspection of these traffic control devices was performed by Randy and documented through sign and barricade reports submitted to the Owner. The demolition, superstructure work, and painting of these bridges required a considerable number of lane closures in an extremely high volume traffic area. Randy oversaw the setup and notification of all lane closures used on this project. This project required a very aggressive schedule to finish in the 57 days allotted by the Owner and was finished ahead of schedule.

Randy Wilkinson

Maintenance of Traffic Manager AND Erosion & Sediment Control Manager

Relevant Experience Continued

IB-31413-A, CSX Railroad Over I-65
$7 Million- Boone County, IN
Owner: Indiana Department of Transportation

During the course of this project Randy was responsible for inspecting daily the erosion control measures in place, coordinating subcontractors to install any erosion control necessary, and maintaining the existing erosion control measures. He filled out erosion control reports on a weekly basis and after every rainfall event that were submitted to the Owner. Randy also lead communications on this project to notify in advance INDOT, TMC, local police, and emergency response departments of all night time lane closures and stoppages required for the superstructure installation on this project. The majority of the lane closures were setup by Randy or overseen by him. All traffic control devices on this project were inspected and maintained by Randy. He was responsible for filling out sign and barricade reports that were turned into the Owner.

B-34291, US 40 Bridge & Road Rehabilitation
$9.75 Million- Vigo County, IN
Owner: Indiana Department of Transportation

Randy assisted in managing the installation of permanent and temporary erosion control measures on this project that included multiple creeks and wetlands. He also helped to revise erosion control plans at the Clear Creek bridge structures to include the use of temporary sandbag cofferdams, filter berms, and water pumps with sediment bags. These revisions reduced the planned in-channel cofferdam footprint and allowed for easier demolition which in turned created a savings for the Owner.

Matt Taylor, PE, MBA

Lead Engineer

Education: Purdue University (1998)
BS Civil Engineering

Butler University (2007)
MBA Business Administration

Years Relevant Experience: 17

Years With Current Firm: 5

Licenses/Certifications:

- Indiana Professional Engineer No. PE10200109

Availability: 75%

Matt Taylor will be the Lead Engineer and primary point of contact for design services. Matt has 17 years of experience in the transportation engineering field. He has been involved in numerous facets of project development including planning, design, permitting, and construction layout. His experience in fast track projects includes I-465 and Rockville Road interchange as a part of the Accelerate 465 project on the west side of Indianapolis, where he worked as member of the Accelerate 465 management team. Matt is a graduate of both the Purdue University School of Civil Engineering (BSCE) and the Butler University College of Business (MBA).

Matt specializes in managing fast track projects of significant local importance. He takes pride in exceeding clients' expectations for project delivery and providing excellent communication through the project development process.

Relevant Experience

US 31, Plymouth to Send Bend, United Project Manager

Matt led the overall development of the United Design Services. The delivery of US 31 contained design elements that spanned the spectrum of services including highway, local roads, culverts, signing, lighting, and signals. The project was accelerated several times and official ribbon cutting was completed the summer of 2014. United completed the design of multiple portions of the project including the single point interchange at Kern Road.

Interchange Modification, I-70 & Mount Comfort Road, Project Manager

Matt led and oversaw all Roadway, Hydraulic and Traffic Design, coordination with INDOT Central Office and Greenfield District, permitting and the preparation of contract documents. The project involved reconfiguration of a diamond interchange to a partial cloverleaf configuration. The new configuration eliminates left turns from Mt. Comfort Road which enables the signals to have shorter cycle times and thereby move more through traffic on Mt. Comfort Road, a developing arterial roadway. The project was delivered on schedule and within budget.

Chris Hammond, PE

Design Quality Manager

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

Years Relevant Experience: 23

Years With Current Firm: 10

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 following 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 the three different United road design teams.

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 Counties, Deputy Project Manager

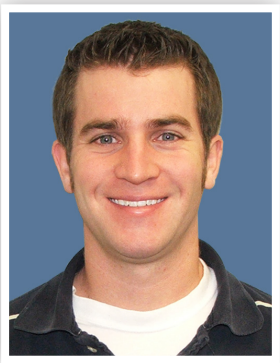
Oversaw multiple Design Teams including the utility coordination manager and lead the Practical Design Workshop on this 55-mile long corridor. Design was started and completed in just 14 months. Delivery included both Design/Build and traditional Design/Bid/Build. Although Chris manages the Transportation 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-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.

Ben Stenger, PE

Utility Coordinator



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

Years Relevant Experience: 6

Years With Current Firm: 4

Licenses/Certifications:

- Indiana Professional Engineer No. PE11500286
- INDOT Certified Utility Coordinator

Availability: 75%

Ben is a roadway engineer with experience through the multiple facets of a project's development. His background includes working as a contractor for Rieth-Riley and this experience has further developed his understanding of the elements necessary to successfully develop and coordinate all aspects of a project. Ben is a Design Engineer and INDOT Certified Utility Coordinator. He has been proactively coordinating with the utilities for all his design team's federally funded projects.

Relevant Experience

Covert Avenue Road Diet, Evansville, Indiana – Project Engineer and Utility Coordinator

Ben is coordinating the utility coordination efforts on this urban project. The project includes the conversion of four travel lanes of Covert Avenue from US 41 to I-164 in Evansville, Indiana to two travel lanes, a left turn lane, and two bike lanes, a process also known as a "Road Diet". Also a part of this Road Diet project is the addition of sidewalks on both sides of Covert Avenue, with ADA accessibility being implemented comprehensively throughout.

East 82nd Street Added Travel Lanes, Indianapolis, Indiana – Project Engineer

Ben assisted in the project development for the widening and rehabilitation of the roadway between Hague Road and Lantern Road and will complete the oversight of the project from Lantern Road to Fall Creek Road. The design included "practical design" components before the practice became a "named" pursuit in the Indiana civil engineering community. These components included overlay of the existing roadway with widening and also a design that incorporated five Level One Design Exceptions, which resulted in over $1,600,000 in cost savings to the project's construction cost. The project development included significant utility coordination and public information components. The entire project length was originally scoped as a single project, and was split to enable funding flexibility with other portions of the Department's program.

Executive Summary
Administrative Materials
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VOLUME 2

H. VOLUME 2 APPENDICES

Exhibit B, Section 3.2.5

Traffic Analysis of Campus Parkway

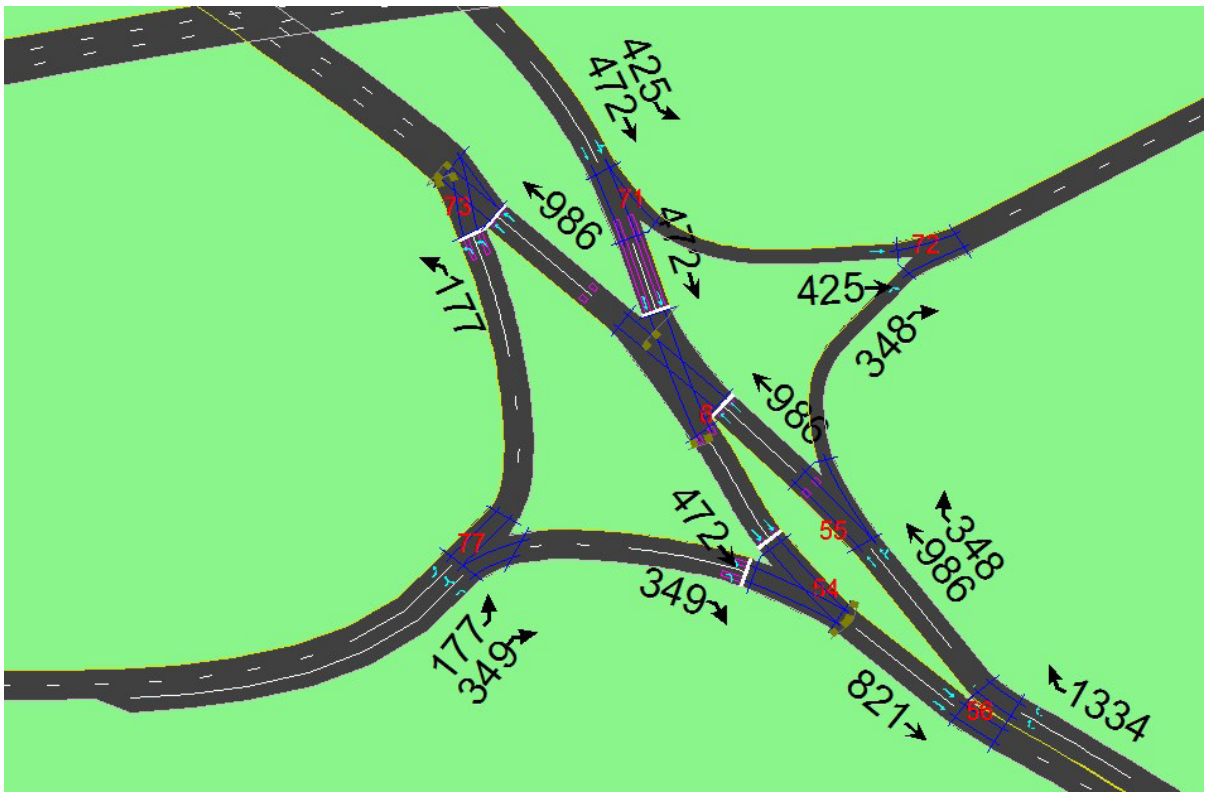
H. VOLUME 2 APPENDICES

AM Traffic Inputs

Southbound Ramp Terminal

H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2



Northbound Ramp Terminal

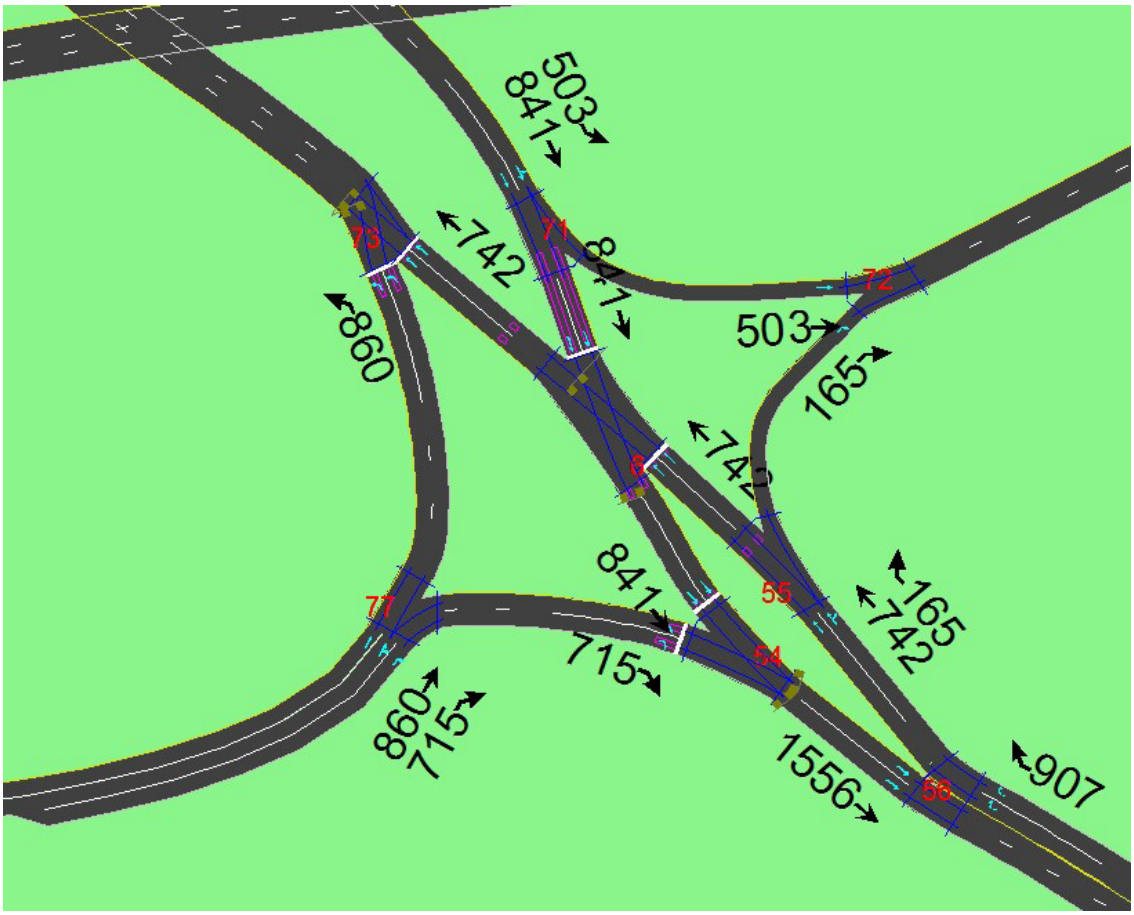
H. VOLUME 2 APPENDICES

PM Traffic Inputs

Southbound Ramp Terminal

H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2



Northbound Ramp Terminal

H. VOLUME 2 APPENDICES

PM Traffic Inputs with Special Event Loading Input

Southbound Ramp Terminal

H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2

Northbound Ramp Terminal

H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2

HCM Unsignalized Intersection Capacity Analysis
59: Campus Pkwy & I-69 SB Off-Ramp Left-Turn 9/4/2015

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (veh/h)	0	739	0	0	158	0
Sign Control		Free	Free		Yield	
Grade		0%	0%		0%	
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94
Hourly flow rate (vph)	0	786	0	0	168	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		215	737			
pX, platoon unblocked					0.81	
vC, conflicting volume	0				393	0
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	0				0	0
tC, single (s)	4.1				6.9	6.9
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	100				80	100
cM capacity (veh/h)	1622				829	1084

Direction, Lane #	EB 1	EB 2	SB 1
Volume Total	393	393	168
Volume Left	0	0	168
Volume Right	0	0	0
cSH	1700	1700	829
Volume to Capacity	0.23	0.23	0.20
Queue Length 95th (ft)	0	0	19
Control Delay (s)	0.0	0.0	10.4
Lane LOS			B
Approach Delay (s)	0.0		10.4
Approach LOS			B

Intersection Summary			
Average Delay	1.8		
Intersection Capacity Utilization	39.6%	ICU Level of Service	A
Analysis Period (min)	15		

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mat

Synchro 8 Report
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H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2

Queues
54: Campus Pkwy & I-69 NB Off-Ramp Right-Turn 9/4/2015

Lane Group	EBR	SET
Lane Group Flow (vph)	356	482
v/c Ratio	0.23	0.14
Control Delay	9.8	0.2
Queue Delay	0.0	0.0
Total Delay	9.8	0.2
Queue Length 50th (ft)	40	0
Queue Length 95th (ft)	64	0
Internal Link Dist (ft)		87
Turn Bay Length (ft)		
Base Capacity (vph)	1518	3471
Starvation Cap Reductn	0	0
Spillback Cap Reductn	0	0
Storage Cap Reductn	0	0
Reduced v/c Ratio	0.23	0.14

Intersection Summary

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mat

Synchro 8 Report
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H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2

HCM Unsignalized Intersection Capacity Analysis
59: Campus Pkwy & I-69 SB Off-Ramp Left-Turn 9/4/2015

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (veh/h)	0	1127	0	0	217	0
Sign Control		Free	Free		Yield	
Grade		0%	0%		0%	
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96
Hourly flow rate (vph)	0	1174	0	0	226	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		215	737			
pX, platoon unblocked					0.69	
vC, conflicting volume	0				587	0
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	0				0	0
tC, single (s)	4.1				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	100				68	100
cM capacity (veh/h)	1622				708	1084

Direction, Lane #	EB 1	EB 2	SB 1
Volume Total	587	587	226
Volume Left	0	0	226
Volume Right	0	0	0
cSH	1700	1700	708
Volume to Capacity	0.35	0.35	0.32
Queue Length 95th (ft)	0	0	34
Control Delay (s)	0.0	0.0	12.4
Lane LOS			B
Approach Delay (s)	0.0		12.4
Approach LOS			B

Intersection Summary			
Average Delay	2.0		
Intersection Capacity Utilization	53.1%	ICU Level of Service	A
Analysis Period (min)	15		

2/23/2015 2035 PM_DCD
mat

Synchro 8 Report
Page 1

Queues
54: Campus Pkwy & I-69 NB Off-Ramp Right-Turn 9/4/2015

Lane Group	EBR	SET
Lane Group Flow (vph)	761	895
v/c Ratio	0.58	0.25
Control Delay	19.7	0.2
Queue Delay	0.0	0.0
Total Delay	19.7	0.2
Queue Length 50th (ft)	149	0
Queue Length 95th (ft)	207	0
Internal Link Dist (ft)		87
Turn Bay Length (ft)		
Base Capacity (vph)	1310	3574
Starvation Cap Reductn	0	0
Spillback Cap Reductn	0	0
Storage Cap Reductn	0	0
Reduced v/c Ratio	0.58	0.25

Intersection Summary

H. VOLUME 2 APPENDICES

EXHIBIT B, SECTION 5.2

HCM Unsignalized Intersection Capacity Analysis
59: Campus Pkwy & I-69 SB Off-Ramp Left-Turn 9/4/2015

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Volume (veh/h)	0	1127	0	0	217	0
Sign Control		Free	Free		Yield	
Grade		0%	0%		0%	
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96
Hourly flow rate (vph)	0	1174	0	0	226	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		215	737			
pX, platoon unblocked					0.68	
vC, conflicting volume	0				587	0
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	0				0	0
tC, single (s)	4.1				6.8	6.9
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	100				67	100
cM capacity (veh/h)	1622				692	1084

Direction, Lane #	EB 1	EB 2	SB 1
Volume Total	587	587	226
Volume Left	0	0	226
Volume Right	0	0	0
cSH	1700	1700	692
Volume to Capacity	0.35	0.35	0.33
Queue Length 95th (ft)	0	0	35
Control Delay (s)	0.0	0.0	12.7
Lane LOS			B
Approach Delay (s)	0.0		12.7
Approach LOS			B

Intersection Summary			
Average Delay	2.1		
Intersection Capacity Utilization	55.3%	ICU Level of Service	B
Analysis Period (min)	15		

2/23/2015 2035 PM_DCD Klipsch
gtg

Synchro 8 Report
Page 1

Queues
54: Campus Pkwy & I-69 NB Off-Ramp Right-Turn 9/4/2015

Lane Group	EBR	SET
Lane Group Flow (vph)	761	895
v/c Ratio	0.59	0.25
Control Delay	20.3	0.1
Queue Delay	0.0	0.0
Total Delay	20.3	0.1
Queue Length 50th (ft)	151	0
Queue Length 95th (ft)	211	0
Internal Link Dist (ft)		87
Turn Bay Length (ft)		
Base Capacity (vph)	1282	3574
Starvation Cap Reductn	0	0
Spillback Cap Reductn	0	0
Storage Cap Reductn	0	0
Reduced v/c Ratio	0.59	0.25

Intersection Summary

2/23/2015 2035 PM_DCD Klipsch
gtg

Synchro 8 Report
Page 30

Executive Summary
Administrative Materials
Forms

VOLUME 2

H. VOLUME 2 APPENDICES

Exhibit B, Section 5.2

Pavement Design

August 24, 2015

VIA E-Mail

Milestone Contractors, L.P. ("Proposer")
Mr. Brad McCall
Director of Estimating
5950 South Belmont Ave.
Indianapolis, IN 46217
Brad.mccall@milestonelp.com

RE: I-69 Section Major Moves 2020 Expansion Project – Optional Pavement Design Submittal

Dear Mr. McCall:

Reference is made to that certain Request for Proposals to Design and Construct the I-69 Major Moves 2020 Expansion Project (the "Project"), issued by the Indiana Finance Authority ("IFA") on June 26, 2015 (as amended, the "RFP"). Initially capitalized terms not otherwise defined herein shall have the meanings set forth in the RFP.

IFA is in receipt of Proposer's optional pavement design submittal dated August 7, 2015, regarding Proposer's potential pavement designs. IFA understands Proposer's request to be for IFA's non-binding review Proposer's pavement designs pursuant to ITP Section 2.12.

See Attachment A for IFA's feedback concerning Proposer's optional pavement design submittal.

It is the Proposer's sole responsibility and risk to ensure that the pavement design complies with the requirements of the PPA Documents, including the Technical Provisions and any Addenda issued after the date of this letter, and nothing contained herein, including any statement or indication that a pavement design appears to be generally consistent to the requirements of the PPA Documents, including the Technical Provisions, shall be binding or dispositive on IFA or limit, modify or waive any of the requirements or rights of IFA herein or in the RFP and PPA Documents, including the right to issue Addenda. Nothing contained herein shall modify the terms of the RFP, and IFA reserves all rights thereunder.

Nothing contained herein shall modify the terms of the RFP, and IFA reserves all rights thereunder.Please let us know if you have any questions.

Sincerely,

Silvia Perez
Project Manager

Attachment

ATTACHMENT A

1. The following pavement designs appear to be generally responsive to the requirements of Addendum #1 of the PPA Documents and the RFP (note that titles of items below correspond to Proposer's submitted titles):

- I-69 Rehabilitation
- I-69 Full Depth Pavement including full-depth inside shoulders

2. IFA has no comment regarding the following proposed pavement designs, which did not provide the supporting documentation required in ITP Exhibit B, Section 5.2.2 (note that titles of items below correspond to Proposer's submitted titles):

- Partial Depth HMA Patching
- Full Depth CRCP Patching
- Full Depth JPCP Patching
- Mainline on I-69 Outside Shoulders (intended to be used for MOT)
- Profile Corrections along Mainline on I-69 (no change from PPD)
- Mainline Widening I-69 south of 116th Street (no change from PPD)
- Profile Corrections along Mainline on I-69 Outside Shoulders
- Campus Parkway Ramp Rehabilitation
- New Campus Parkway mainline, shoulders and ramps (no change from PPD)
- New SR 13 mainline. shoulders and ramps (no change from PPD)

3. Proposer is reminded that that the Proposer must include in its Proposal **complete submittals**, including all materials required pursuant to the RFP, including ITP Exhibit B, Section 5.2.2, **for all pavement designs** in order to be responsive to the Proposal requirements.

4. Proposer is also advised that IFA reserves the right to issue additional Addenda and Proposer shall be responsible for ensuring its pavement design complies with the final Addendum issued prior to the Proposal Due Date, without regard to any statements in this letter.

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

I-69 Overlay

Technical Proposal / I-69 Major Moves 2020 Expansion

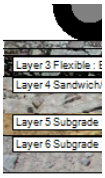
Mainline Overlay_4 25

File Name: C:\My ME Design\Projects\MK15-469\PrelimReport\Mainline Overlay_4 25.dgpx

Design Inputs

Design Life:	25 years	Base construction:	May, 1989	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	AC_FRAC_JPCP	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 12.5mm PG76-22	2.0
Flexible	Existing HMA	5.5
Stabilized	Fractured JPCP	10.0
Subgrade	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	12,700
2028 (12 years)	20,969,600
2041 (25 years)	46,030,000

Passes IRI at 16 years, consider as a PASSING section

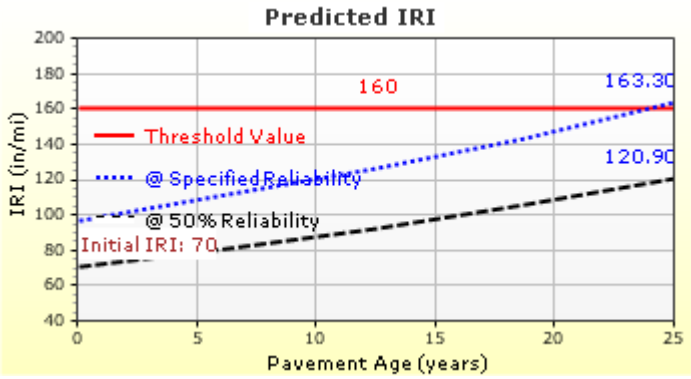
Design Outputs

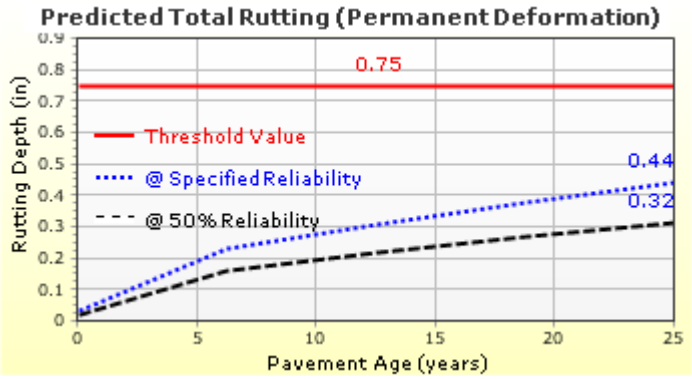
Distress Prediction Summary

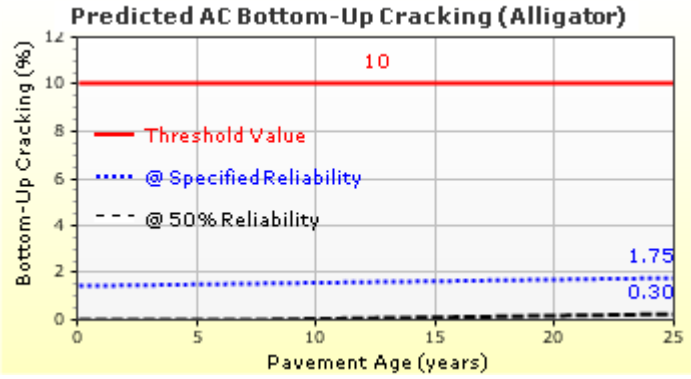
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	163.27	90.00	88.15	Fail
Permanent deformation - total pavement (in.)	0.75	0.44	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.75	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	478.22	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.43	90.00	83.28	Fail

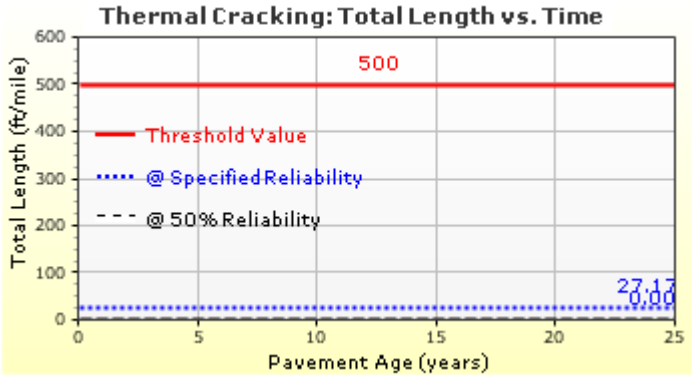
Passes Permanent Deformation - AC only at 16 years, consider as a PASSING section

Distress Charts





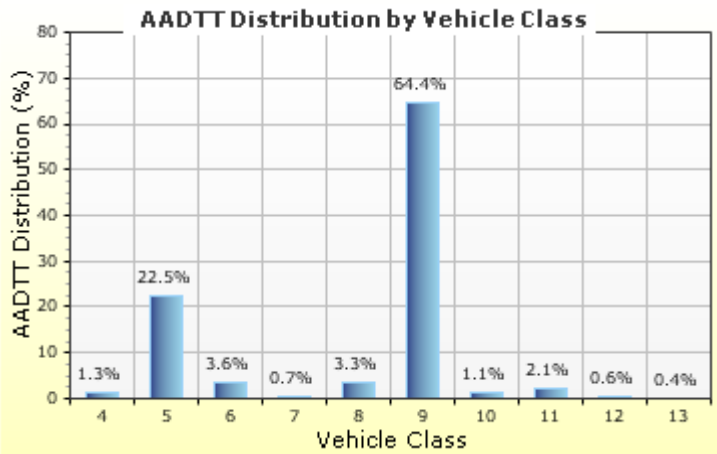


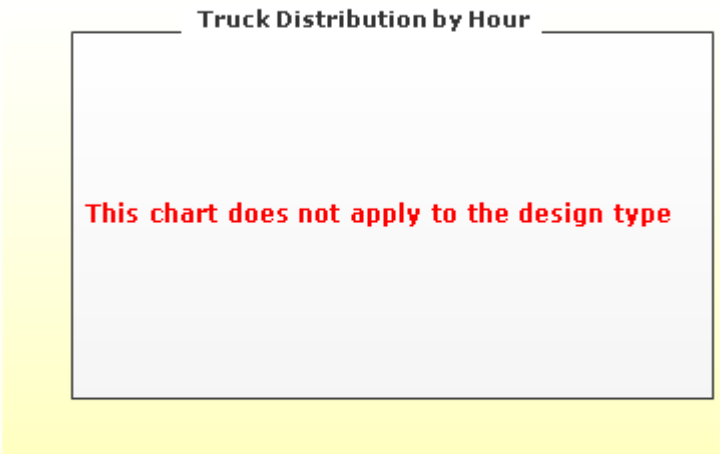


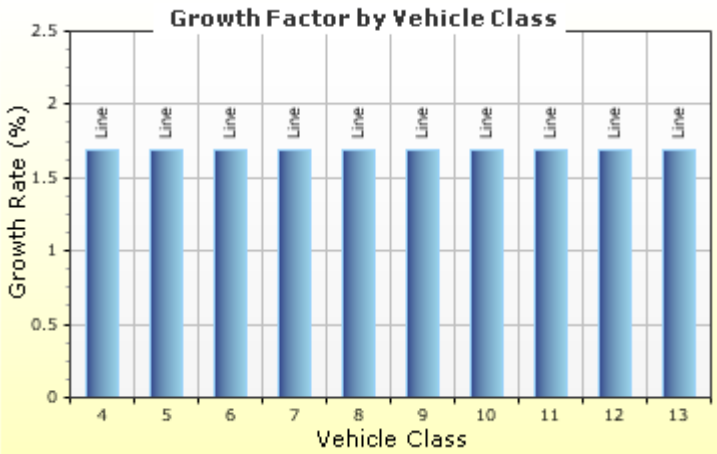
Traffic Inputs

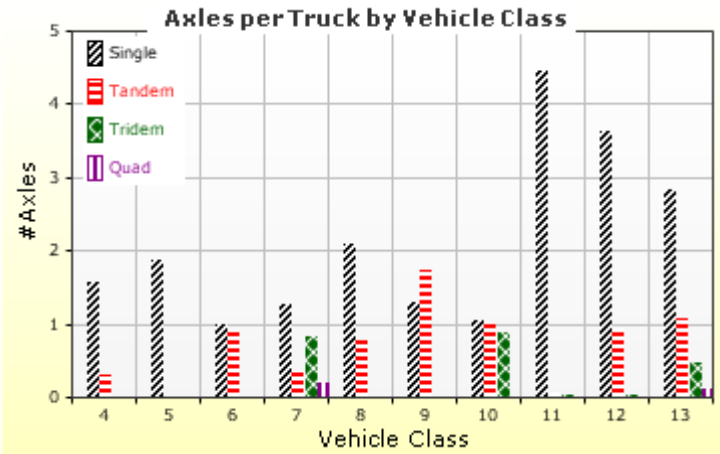
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	12,700	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	3	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

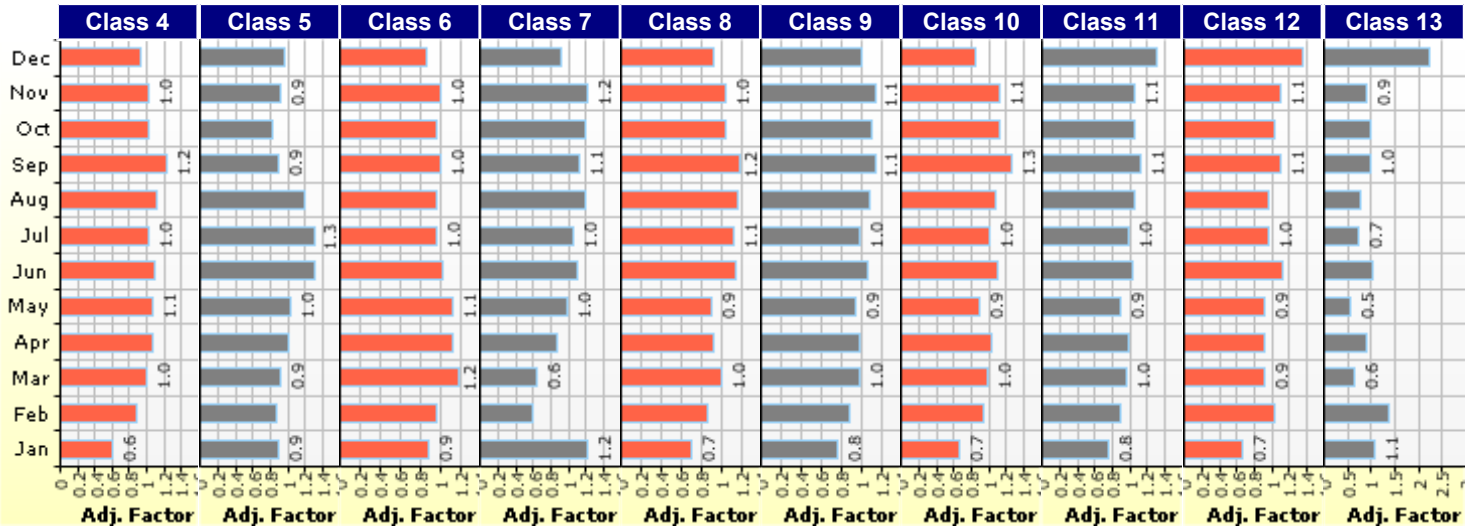








Traffic Volume Monthly Adjustment Factors



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	0.6	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%	1.69%	Linear
Class 5	22.5%	1.69%	Linear
Class 6	3.6%	1.69%	Linear
Class 7	0.7%	1.69%	Linear
Class 8	3.3%	1.69%	Linear
Class 9	64.4%	1.69%	Linear
Class 10	1.1%	1.69%	Linear
Class 11	2.1%	1.69%	Linear
Class 12	0.6%	1.69%	Linear
Class 13	0.4%	1.69%	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

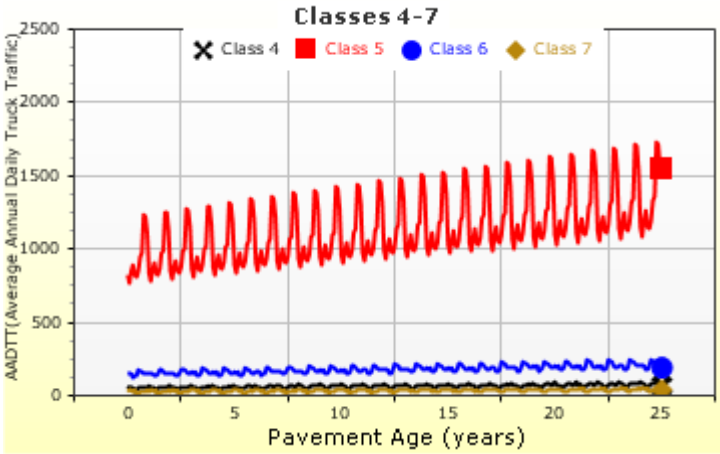
Wheelbase does not apply

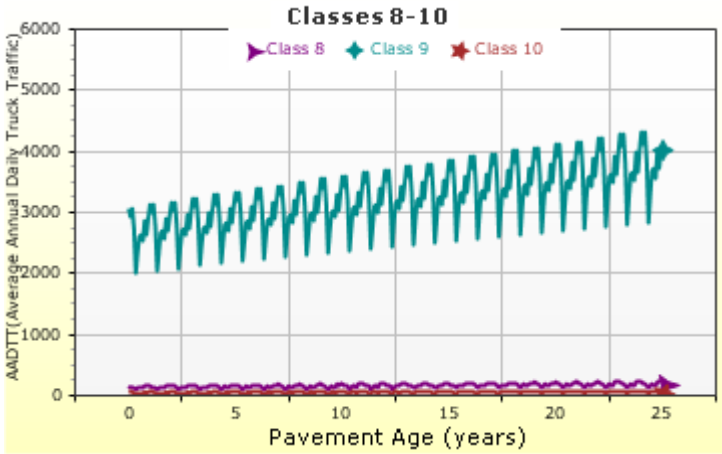
Number of Axles per Truck

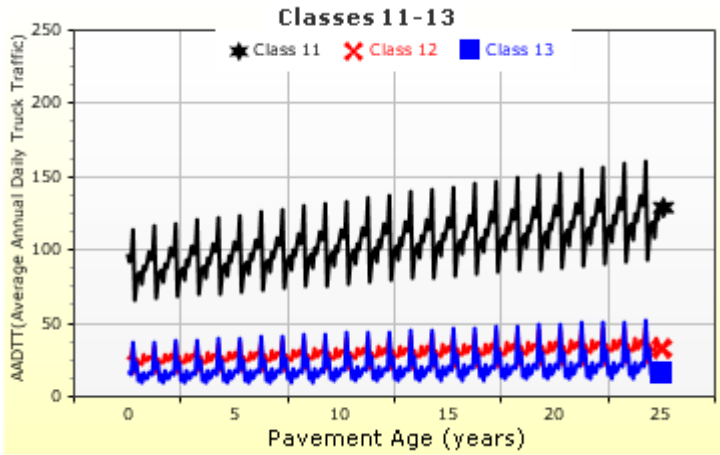
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

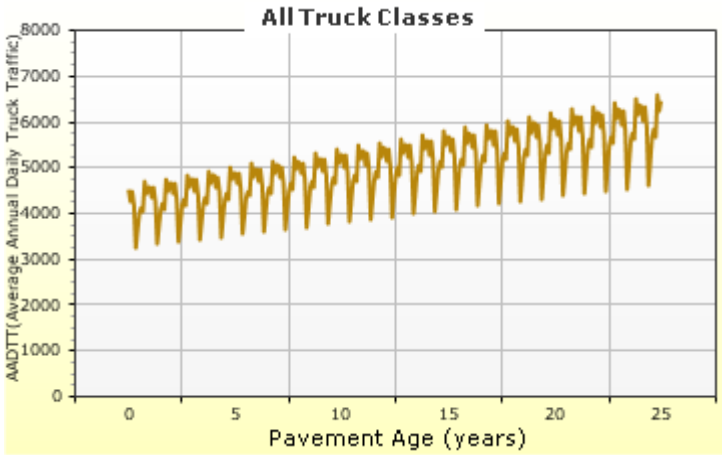
AADTT (Average Annual Daily Truck Traffic) Growth

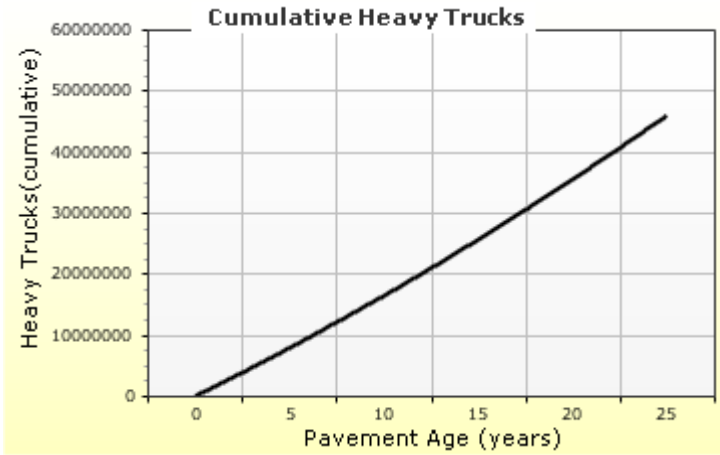
*** Traffic cap is not enforced**







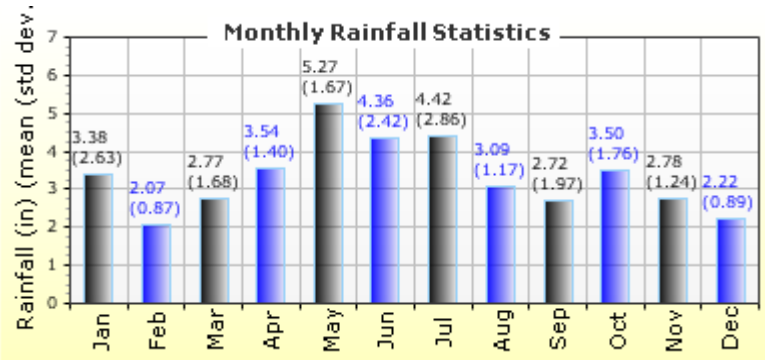




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

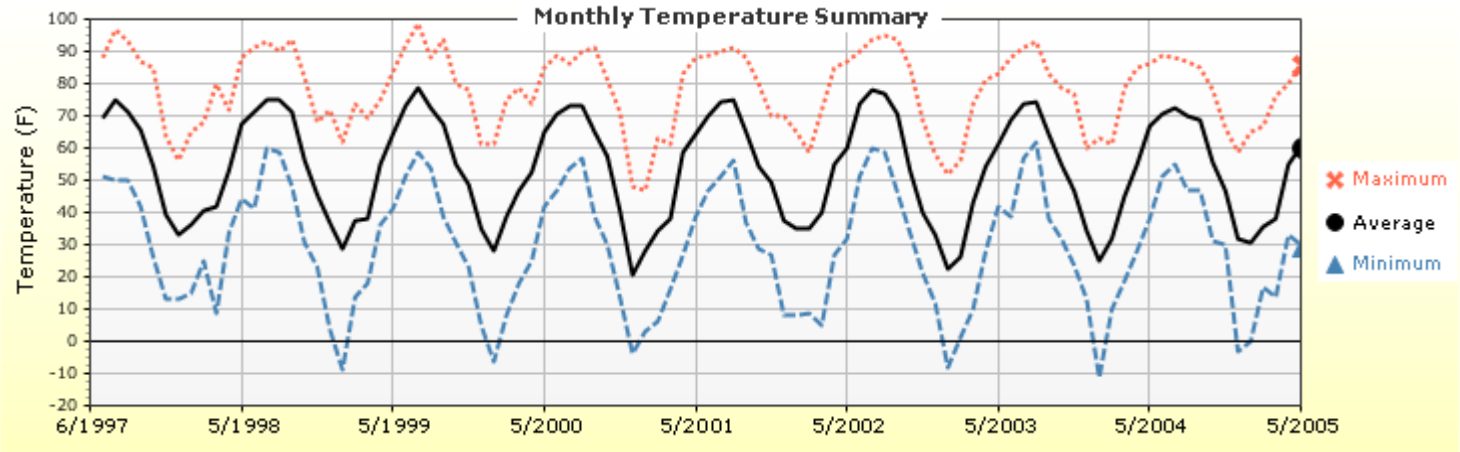


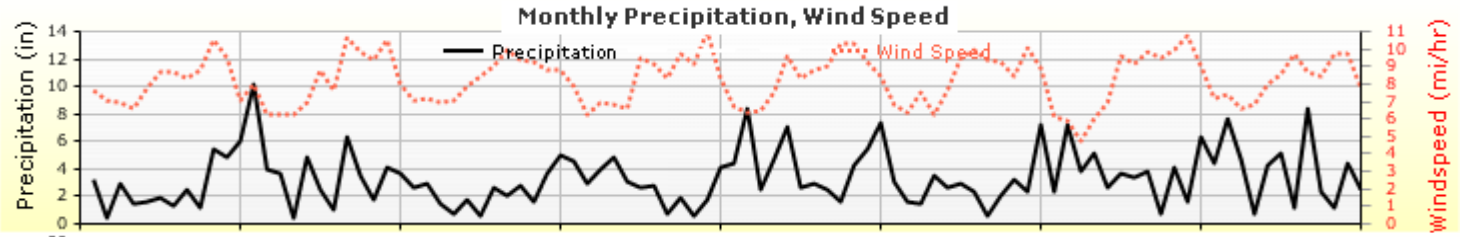
Annual Statistics:

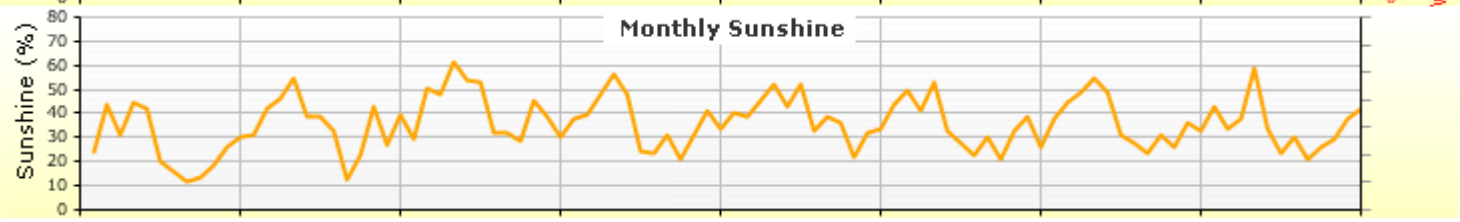
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in.)	40.11
Freezing index (ºF - days)	475.95
Average annual number of freeze/thaw cycles:	54.86

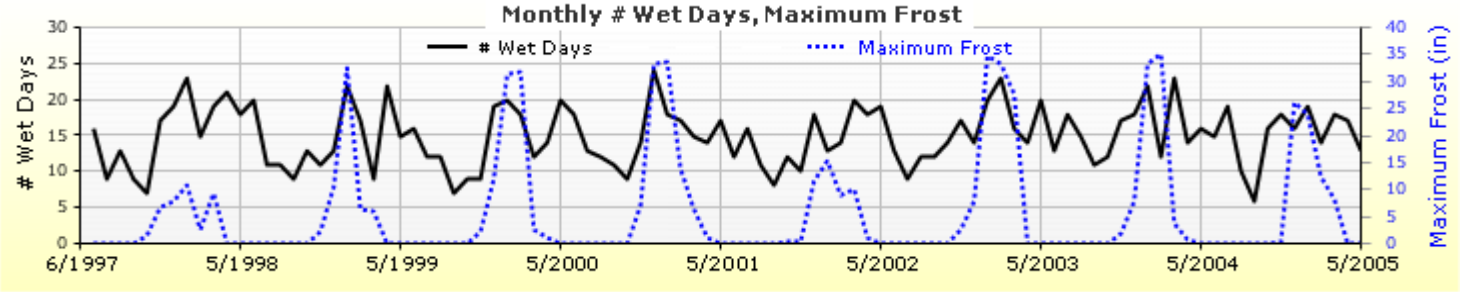
Water table depth (ft) 5.00

Monthly Climate Summary:

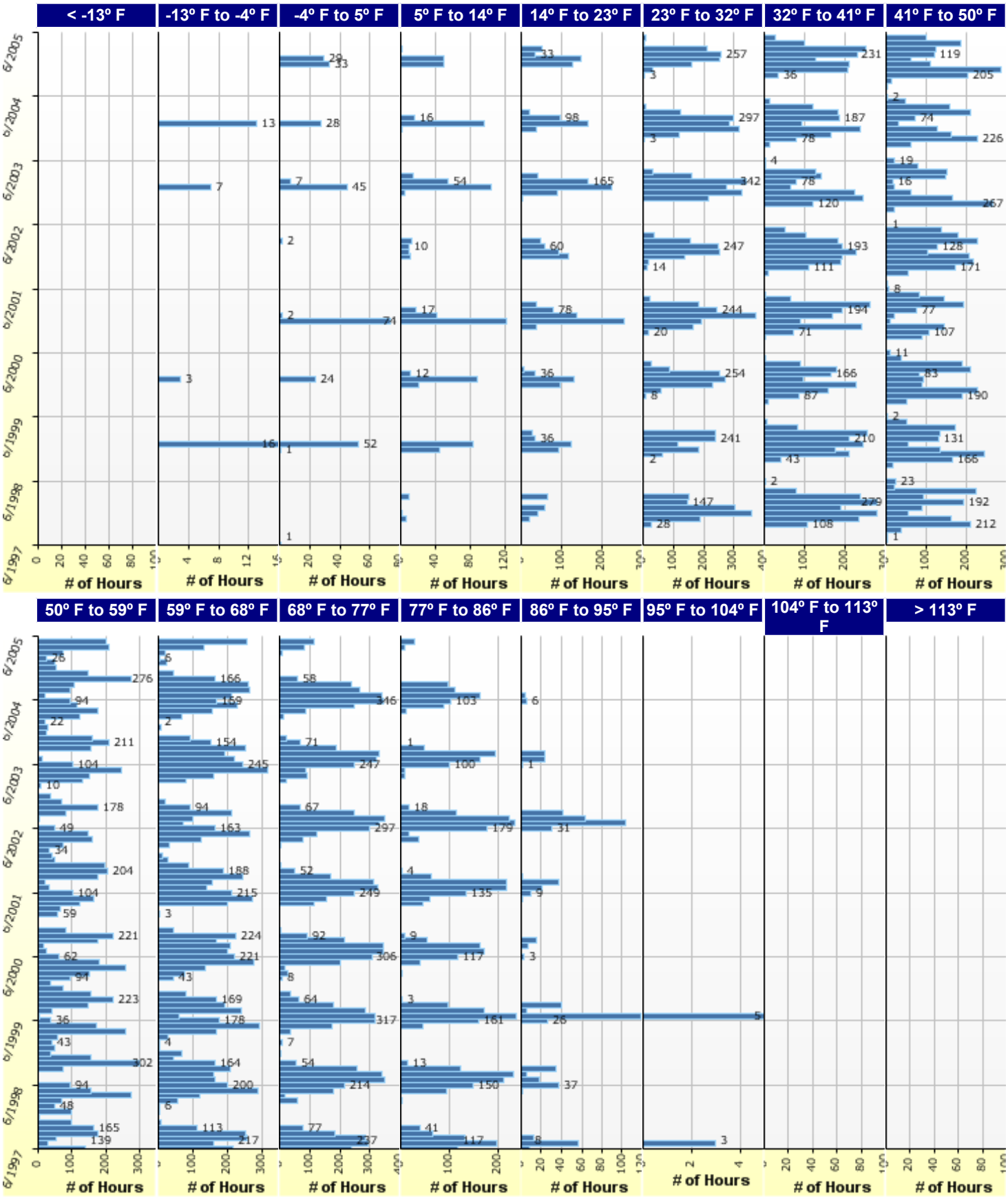








Hourly Air Temperature Distribution by Month:



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

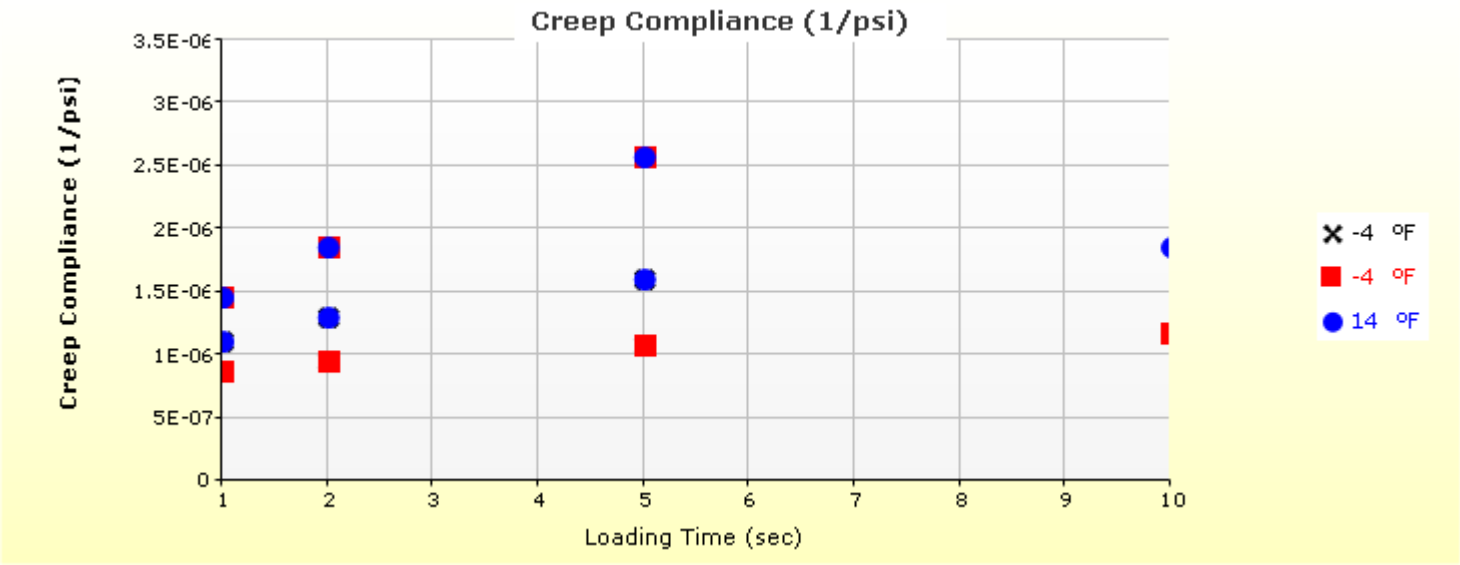
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield SMA PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 12.5mm PG76-22	Flexible (1)	1.00
Layer 3 Flexible : Existing HMA	Flexible (1)	1.00
Layer 4 Sandwich/Fractured : Fractured JPCP	Sandwiched Granular (3)	1.00
Layer 5 Subgrade : Crushed stone	Subgrade (5)	1.00
Layer 6 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

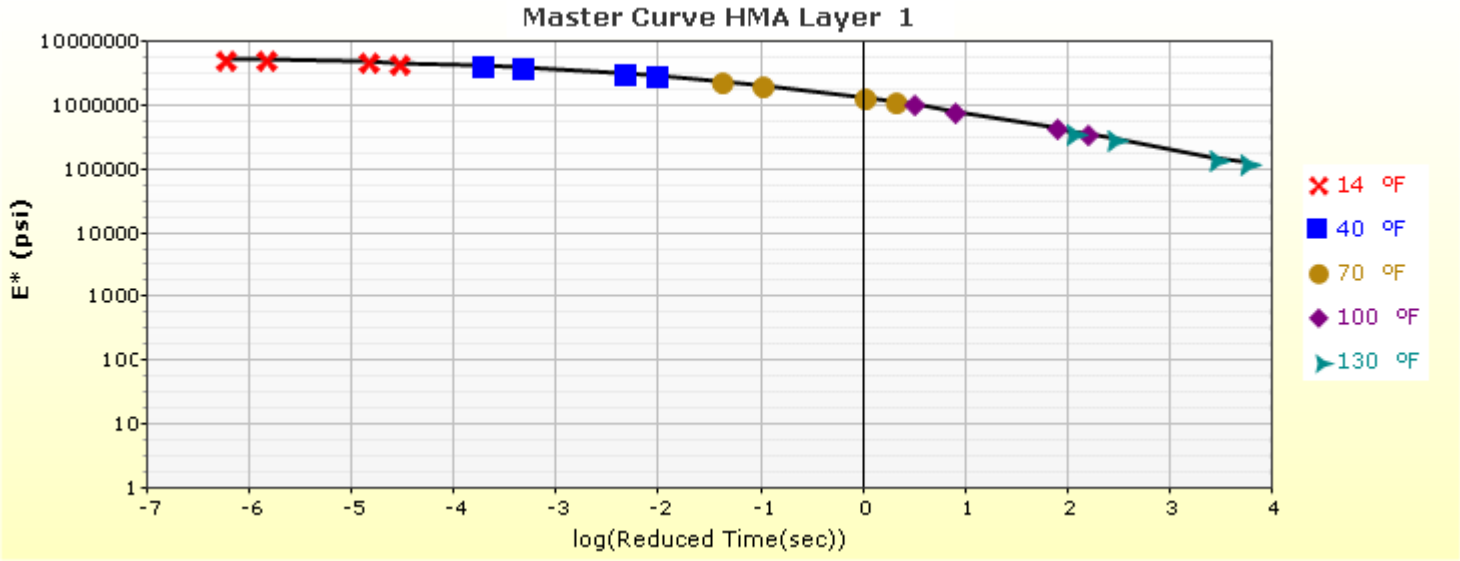
Indirect tensile strength at 14 ºF (psi)	404.62

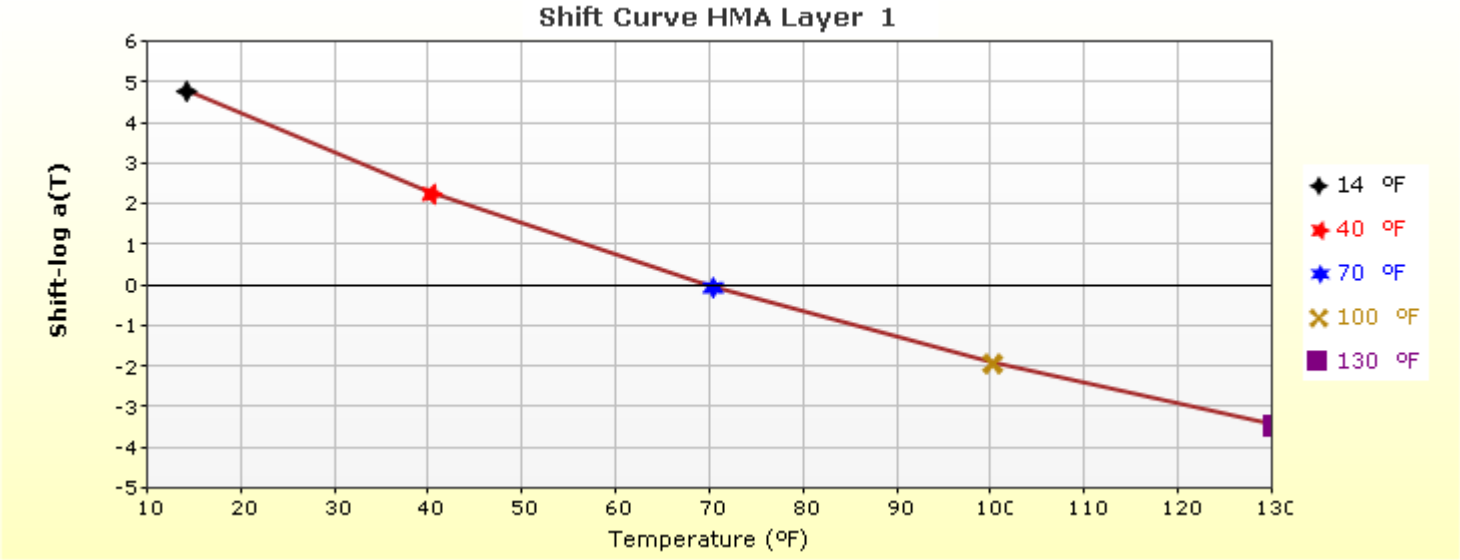
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	20.4

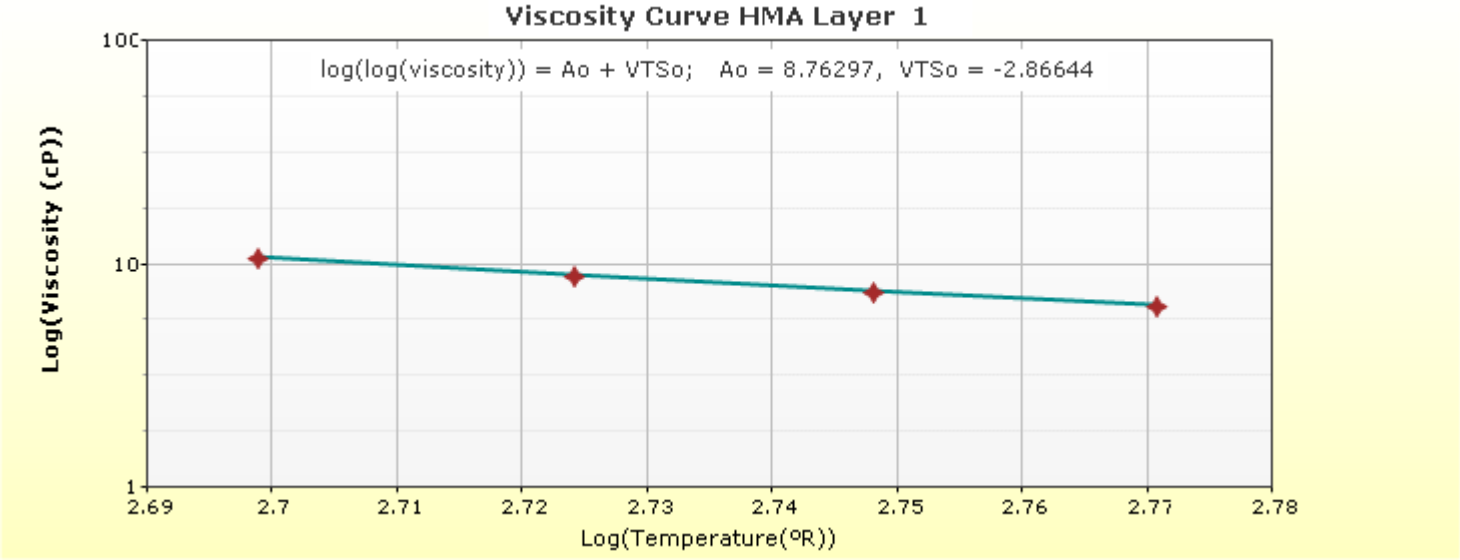
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	8.77e-007	8.77e-007	1.13e-006
1	1.13e-006	1.47e-006	1.47e-006
2	9.61e-007	9.61e-007	1.31e-006
2	1.31e-006	1.87e-006	1.87e-006
5	1.09e-006	1.09e-006	1.61e-006
5	1.61e-006	2.58e-006	2.58e-006
10	1.19e-006	1.19e-006	1.87e-006



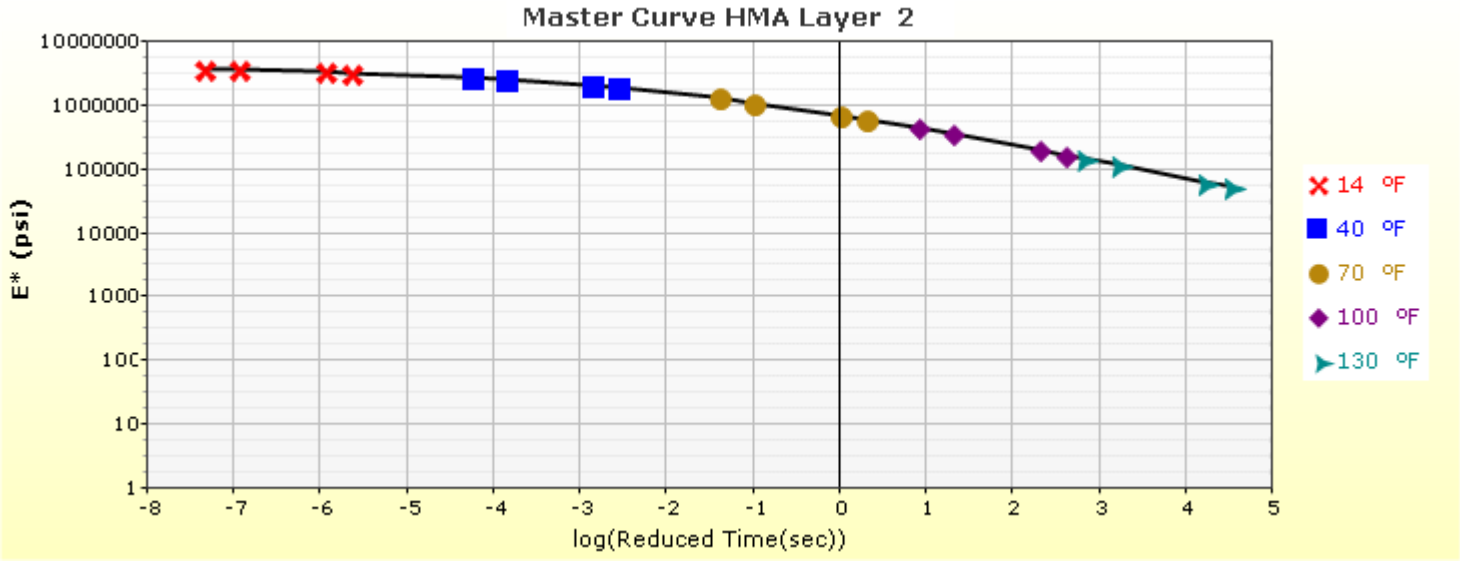
HMA Layer 1: Layer 1 Flexible : Greenfield SMA PG76-22

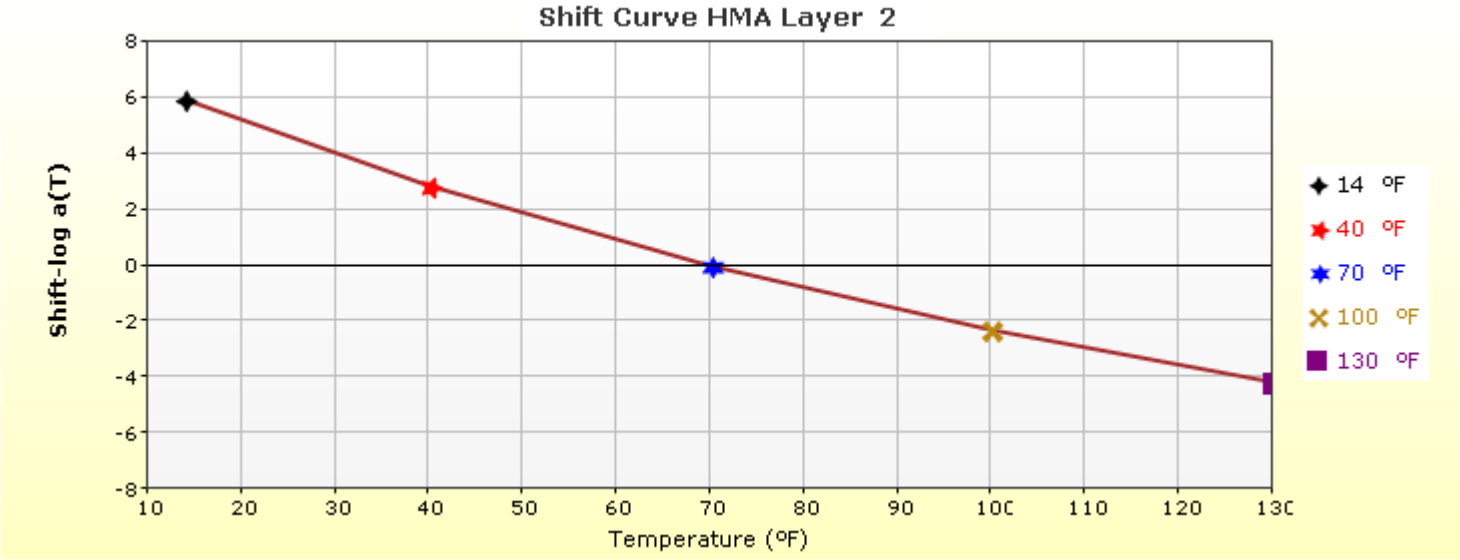


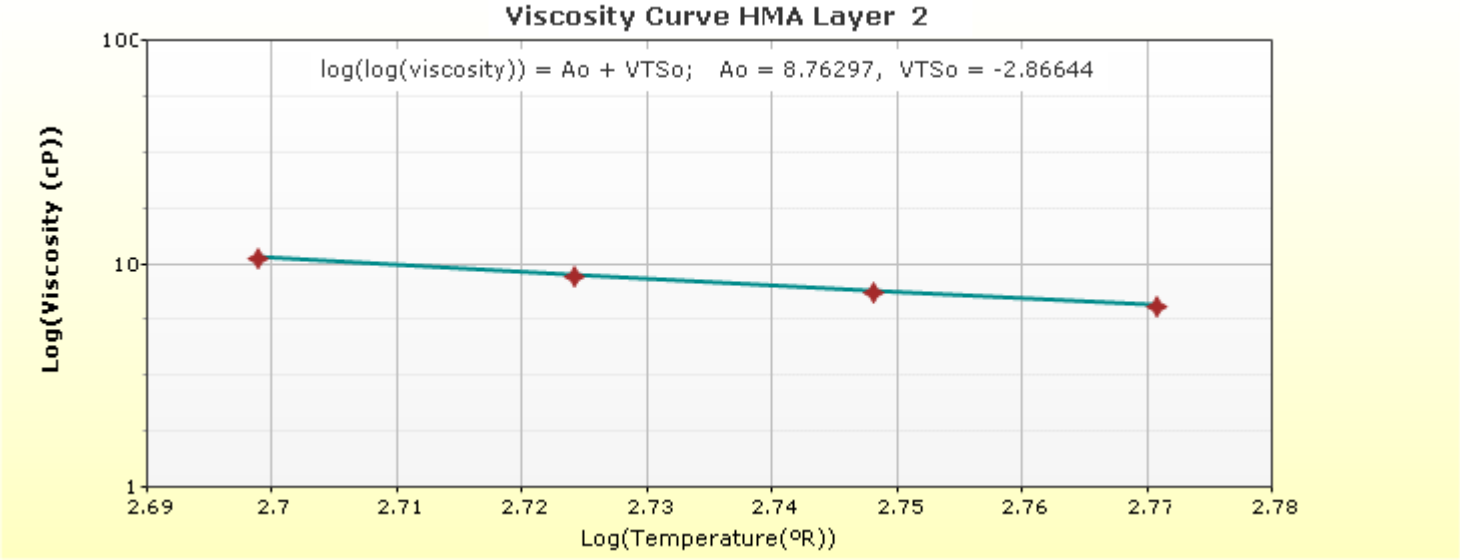




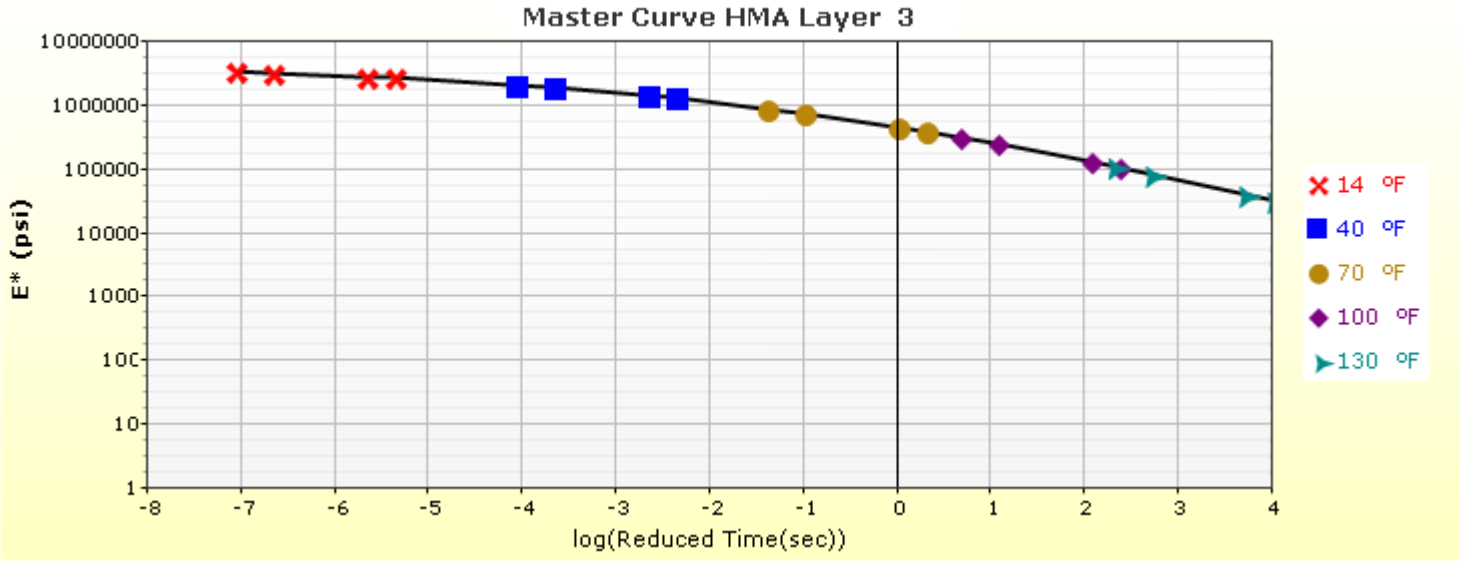
HMA Layer 2: Layer 2 Flexible : Greenfield 12.5mm PG76-22

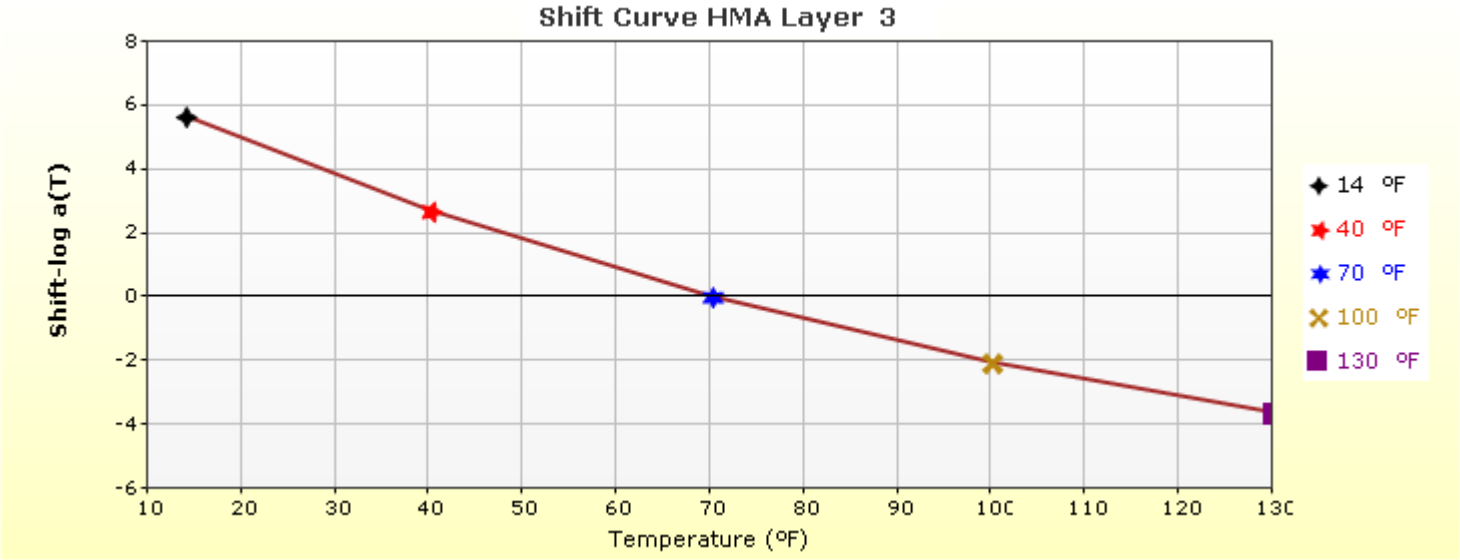


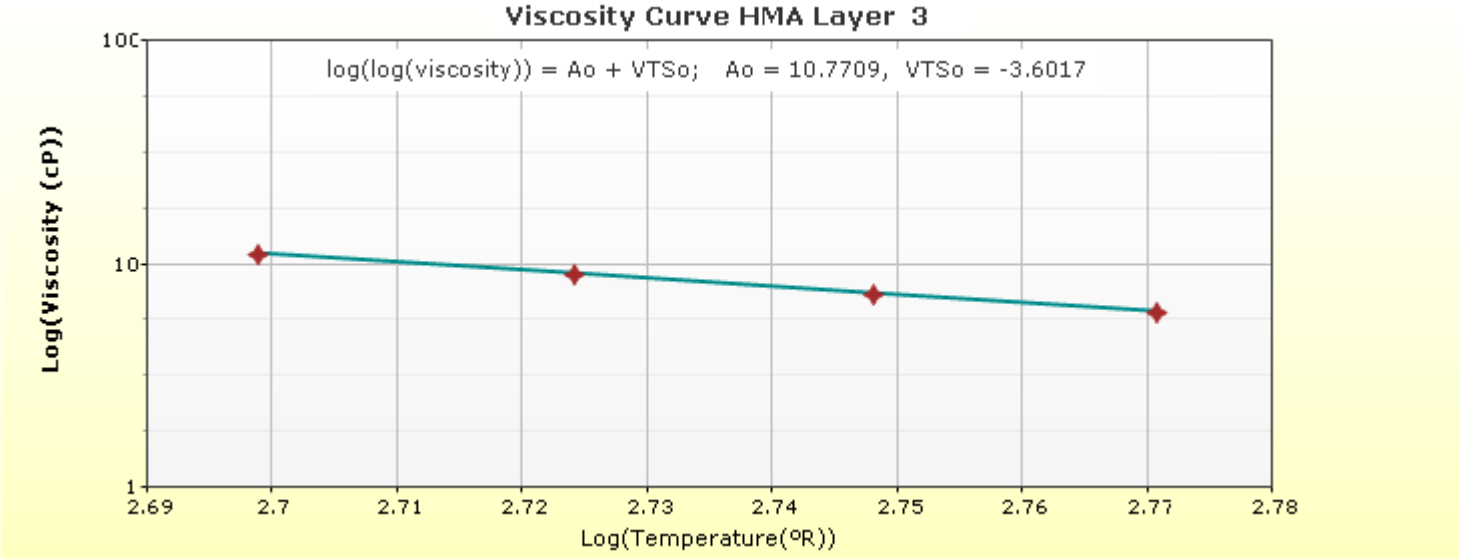




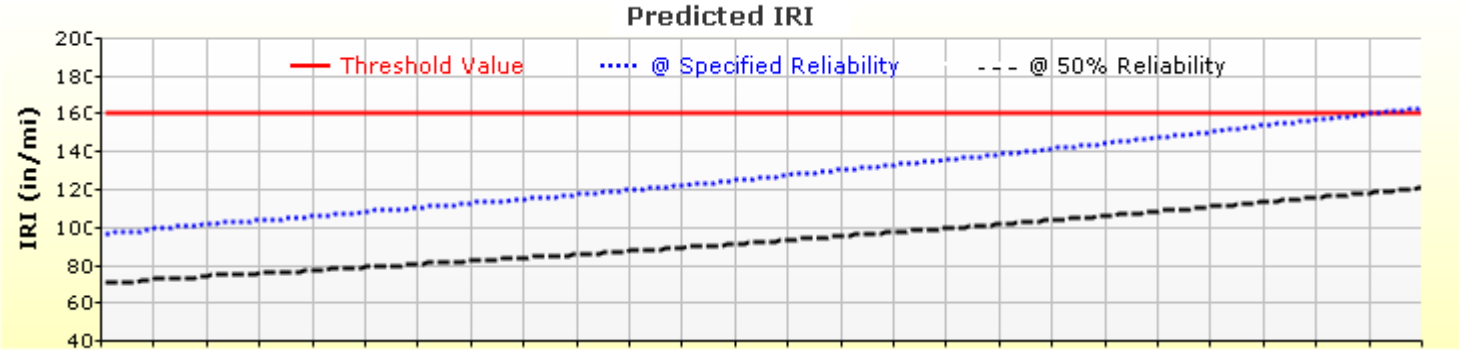
HMA Layer 3: Layer 3 Flexible : Existing HMA

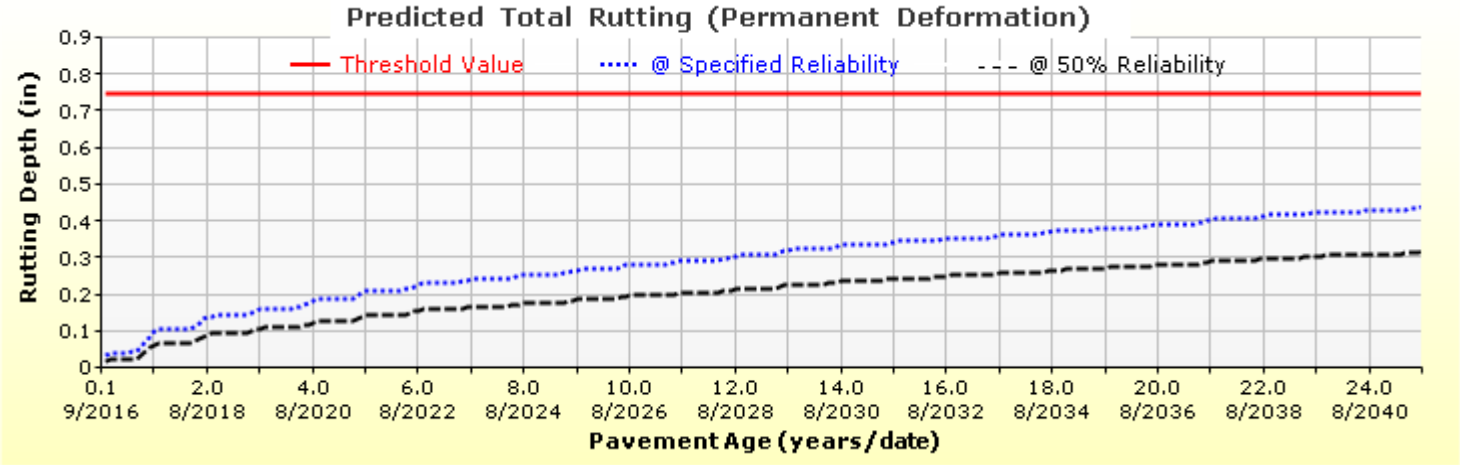


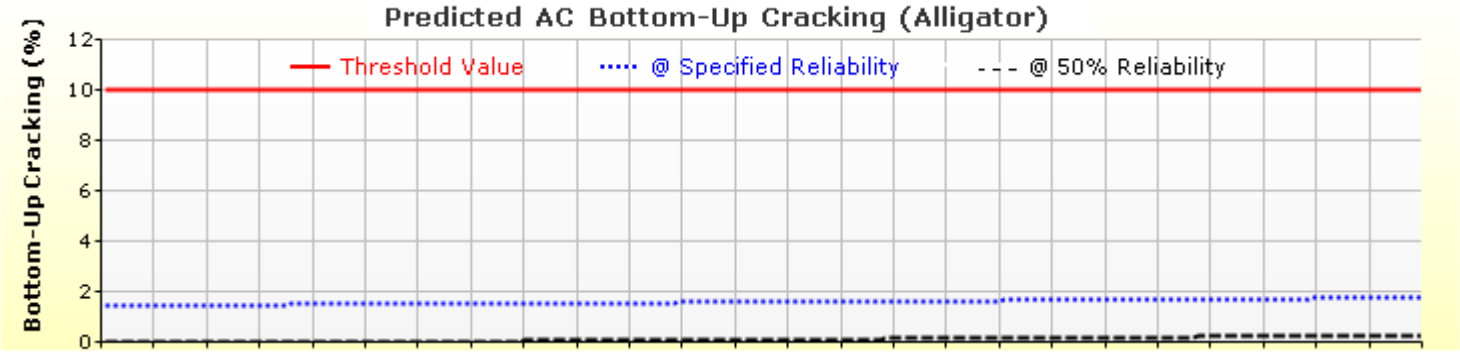


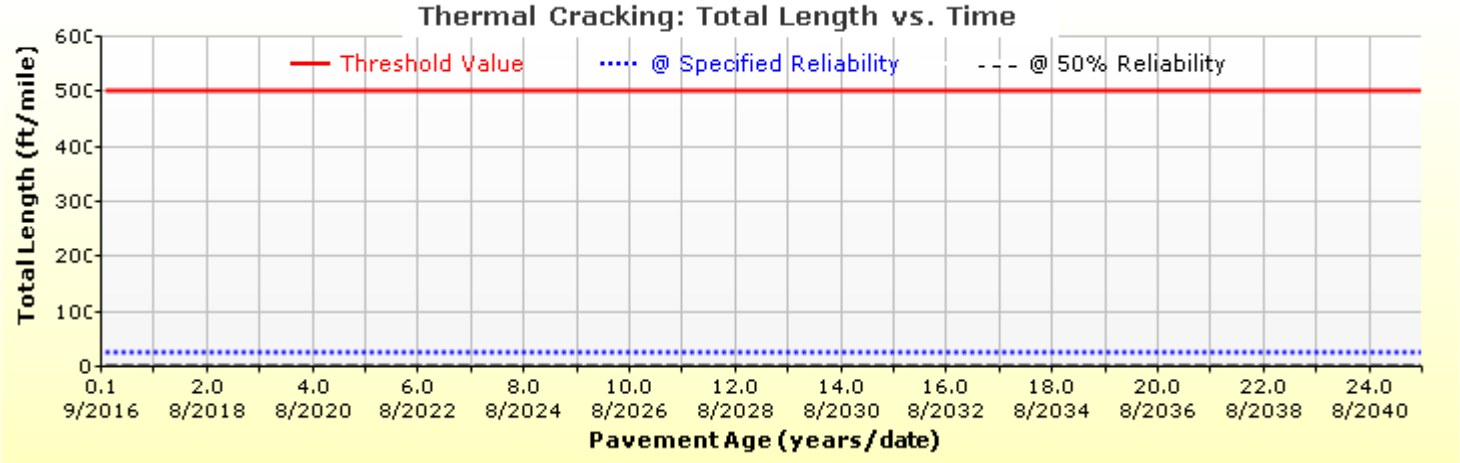


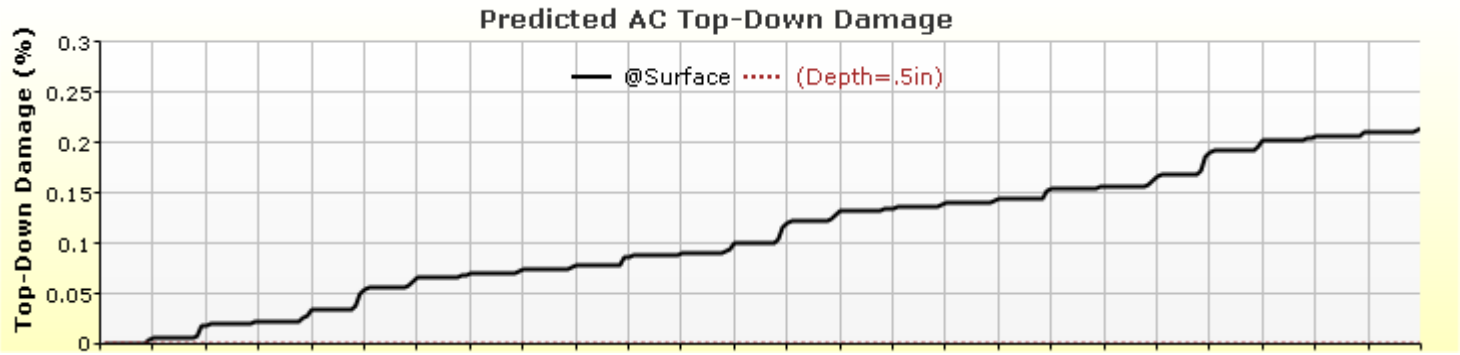
Analysis Output Charts

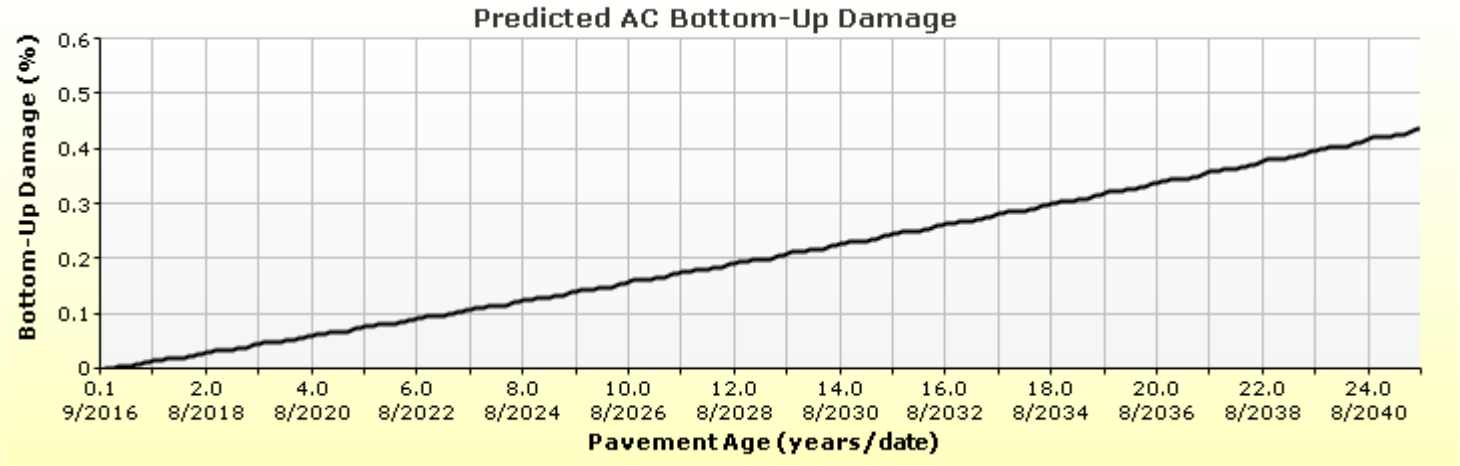


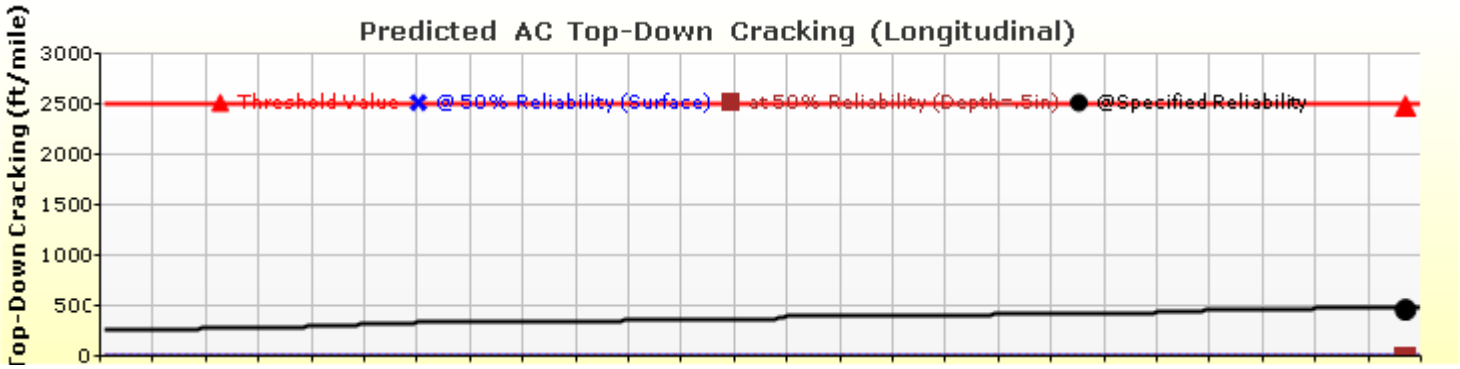


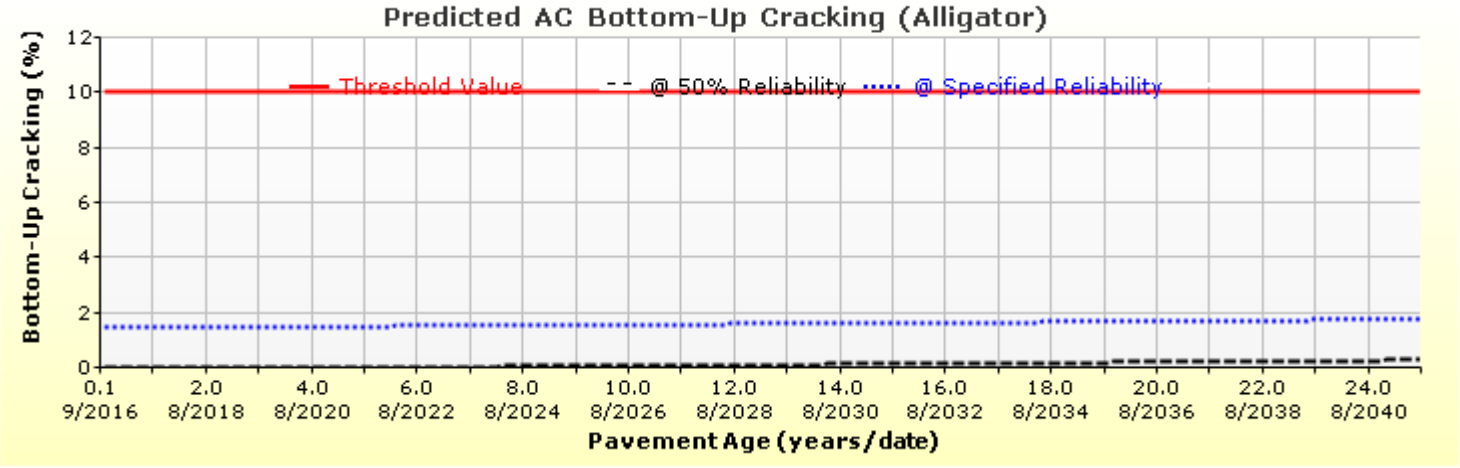


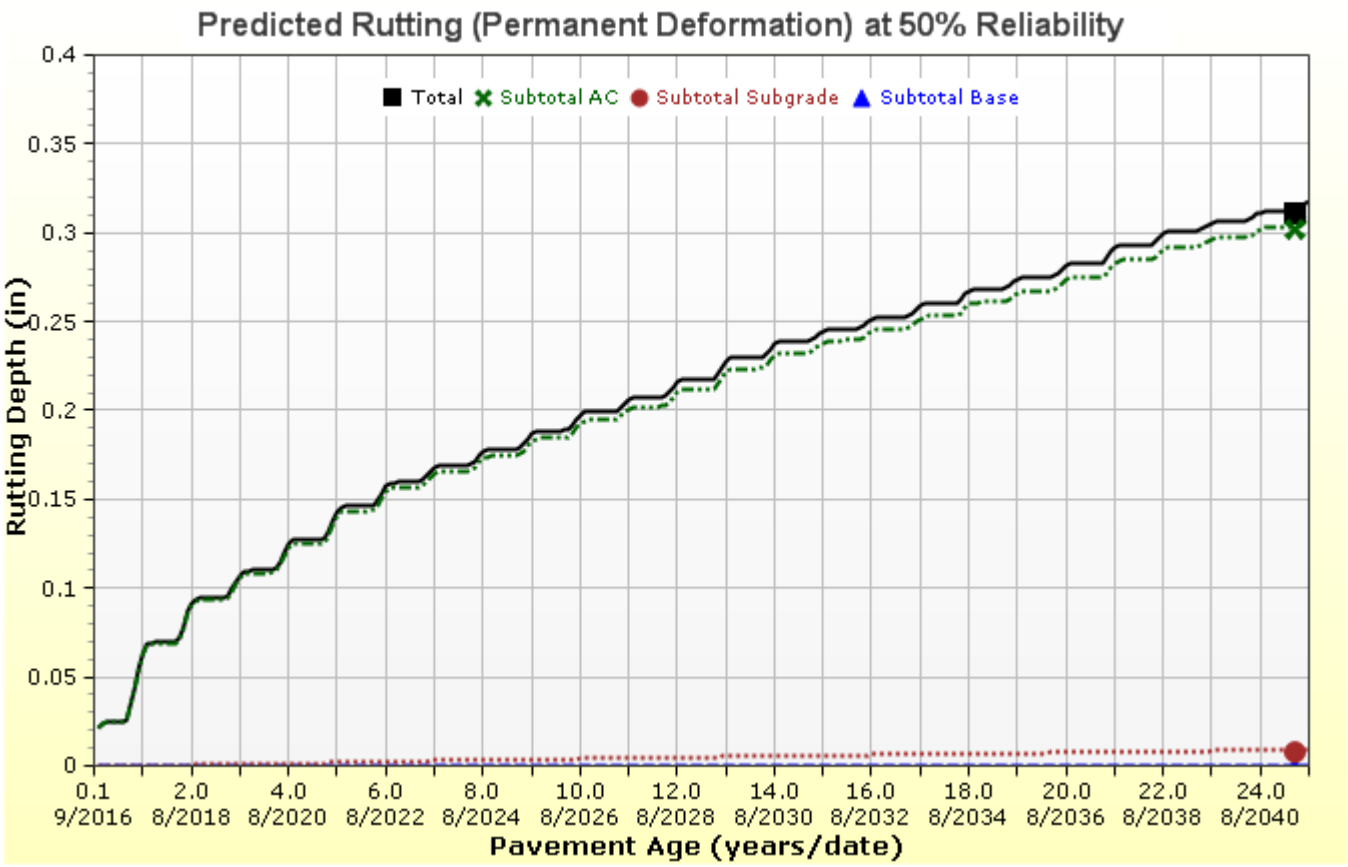


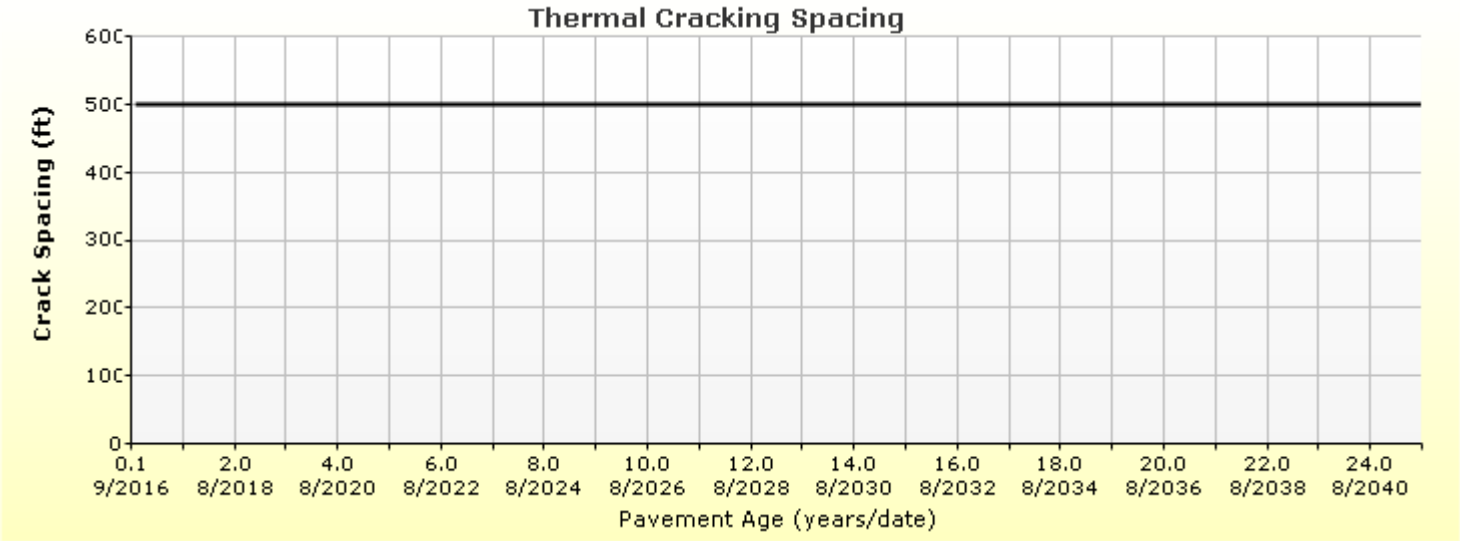

Predicted AC Top-Down Damage
Top-Down Damage (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
@Surface
(Depth=.5in)

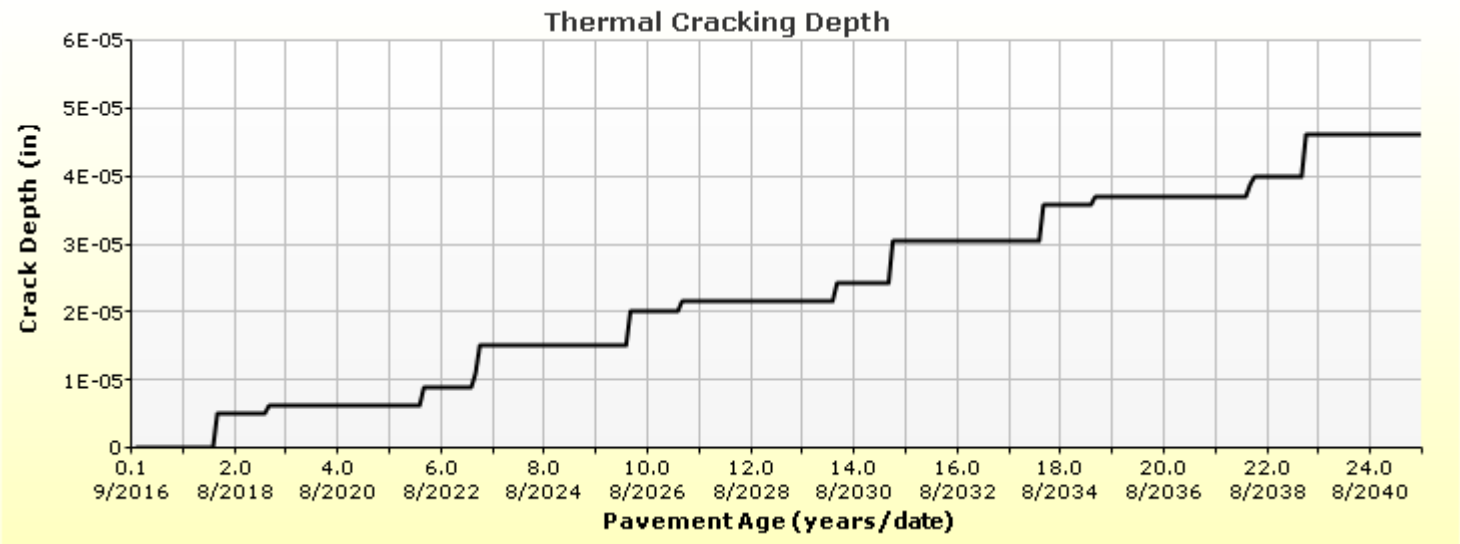

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

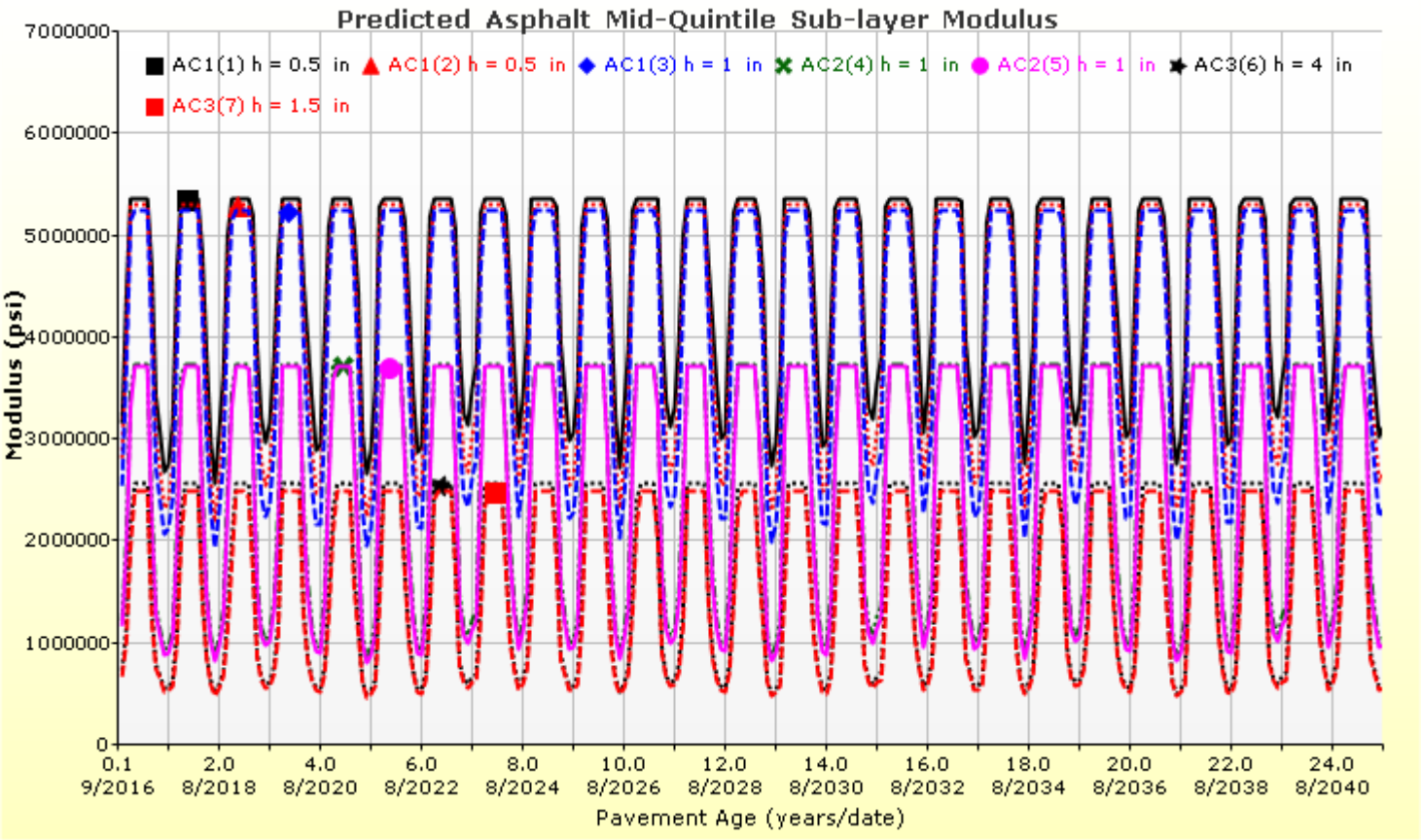

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
3000
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

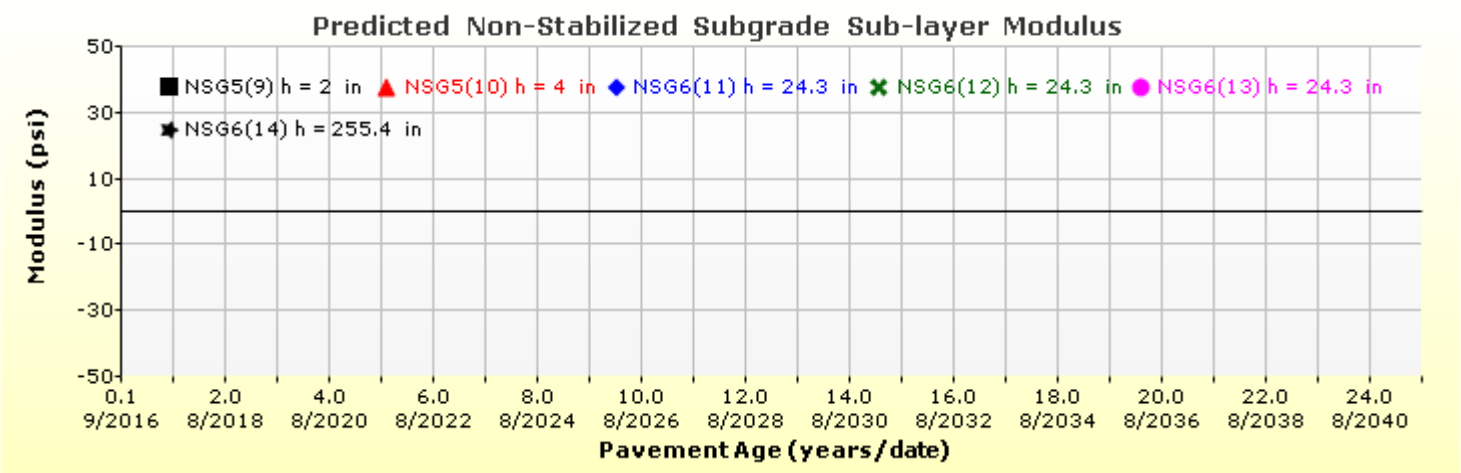

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rutting Depth (in)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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
AC2(4) h = 1 in
AC2(5) h = 1 in
AC3(6) h = 4 in
AC3(7) h = 1.5 in
Modulus (psi)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG5(9) h = 2 in
NSG5(10) h = 4 in
NSG6(11) h = 24.3 in
NSG6(12) h = 24.3 in
NSG6(13) h = 24.3 in
NSG6(14) h = 255.4 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield SMA PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	173.5	
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	3647648	4669504	5000000	5000000
40	2415742	3373281	4392981	4797248
70	763973	1296571	2030073	2372323
100	228891	438683	796159	989704
130	80754	159253	310900	401763

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	13.4
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield SMA PG76-22
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 : Greenfield 12.5mm PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	143.1	
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	2514388	3101384	3593791	4359236
40	2212131	2249168	2353738	2616932
70	452354	700875	948099	1117573
100	90946	186351	333771	425610
130	35731	68157	133871	177872

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.66
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield 12.5mm PG76-22
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 : Existing HMA

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: 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 4 Sandwich/Fractured : Fractured JPCP

Chemically Stabilized	
Layer thickness (in.)	10
Poisson's ratio	0.2
Unit weight (pcf)	150

Strength	
Elastic/resilient modulus (psi)	150000

Thermal	
Heat capacity (BTU/lb-ºF).	0.28
Thermal conductivity (BTU/hr-ft-ºF)	1.25

Identifiers

Field	Value
Display name/identifier	Fractured JPCP
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

Layer 5 Subgrade : Crushed stone

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)
9100.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 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 6 Subgrade : A-7-6

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)
9100.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 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

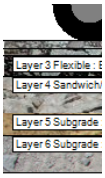
Mainline Overlay_4 16

File Name: C:\My ME Design\Projects\MK15-469\PrelimReport\Mainline Overlay_4 16.dgpx

Design Inputs

Design Life:	16 years	Base construction:	May, 1989	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	AC_FRAC_JPCP	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 12.5mm PG76-22	2.0
Flexible	Existing HMA	5.5
Stabilized	Fractured JPCP	10.0
Subgrade	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	12,700
2024 (8 years)	12,970,500
2032 (16 years)	27,596,600

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	135.94	90.00	98.34	Pass
Permanent deformation - total pavement (in.)	0.75	0.35	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.63	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	408.55	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.35	90.00	97.56	Pass

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

I-69 Full Depth Widening and Inside Shoulders

Technical Proposal / I-69 Major Moves 2020 Expansion

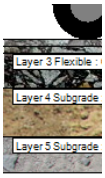
Mainline Widening 25

File Name: C:\My ME Design\Projects\MK15-469\PrelimReport\Mainline Widening 25.dgpx

Design Inputs

Design Life:	25 years	Base construction:	May, 2016	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	Flexible Pavement	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 12.5mm PG76-22	2.0
Flexible	Greenfield 19.0mm PG64-22	10.0
Subgrade	A-6	14.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	12,700
2028 (12 years)	20,969,600
2041 (25 years)	46,030,000

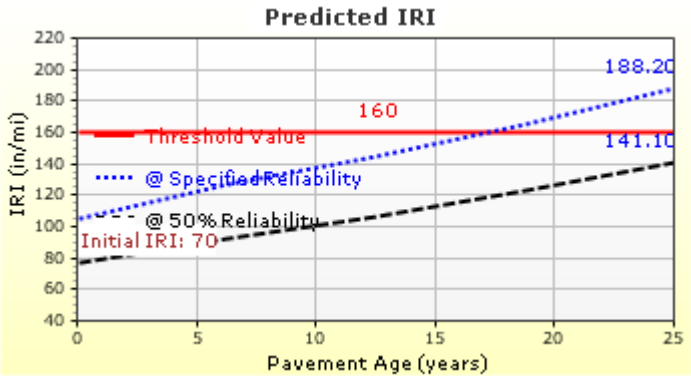
Passes IRI at 16 years, consider as a PASSING section

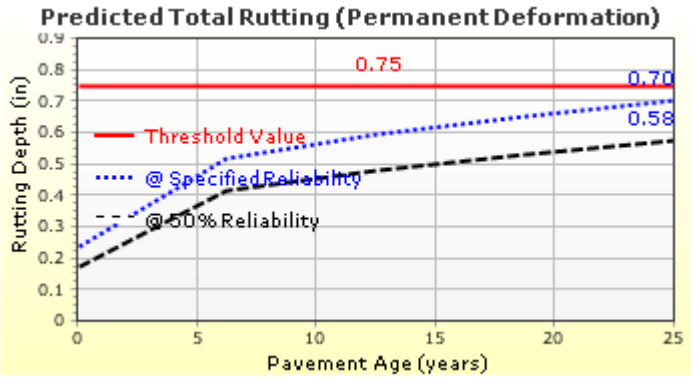
Design Outputs

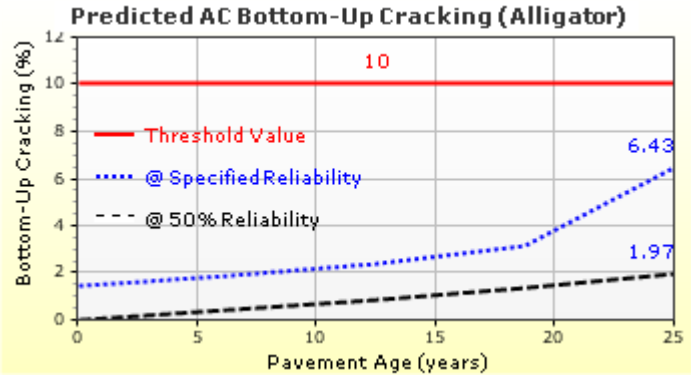
Distress Prediction Summary

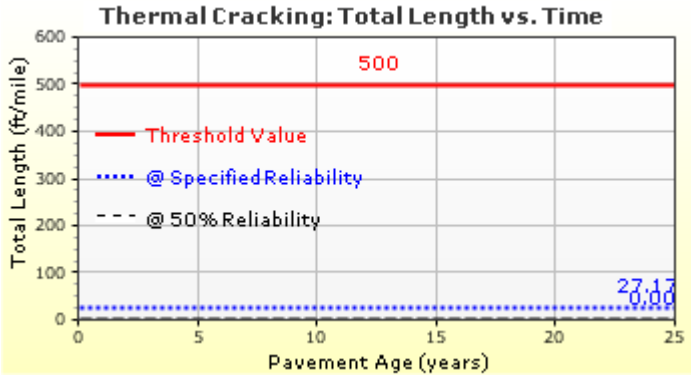
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	188.18	90.00	69.65	Fail
Permanent deformation - total pavement (in.)	0.75	0.70	90.00	96.05	Pass
AC bottom-up fatigue cracking (percent)	10.00	6.43	90.00	98.95	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	256.89	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.20	90.00	100.00	Pass

Distress Charts





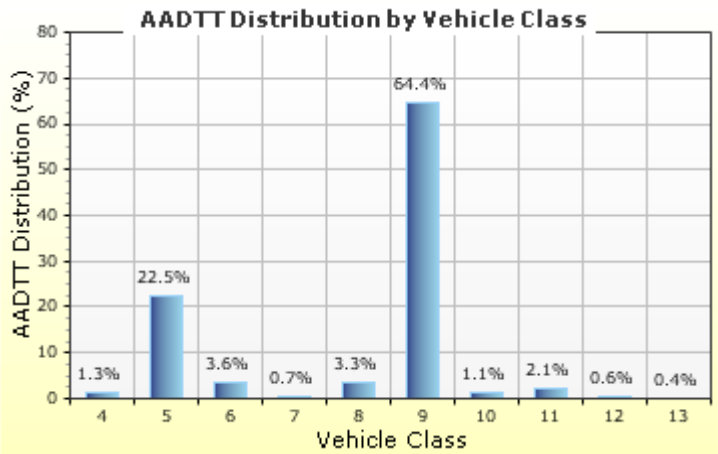


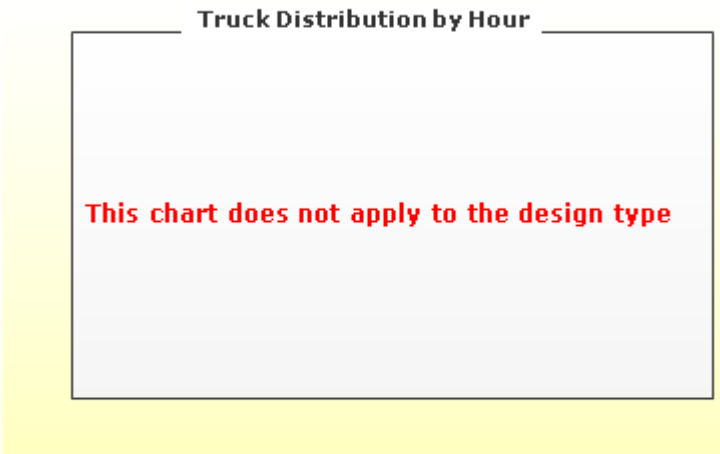


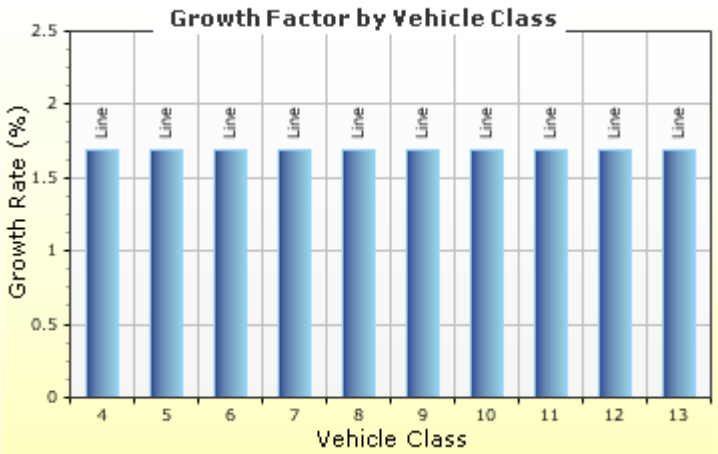
Traffic Inputs

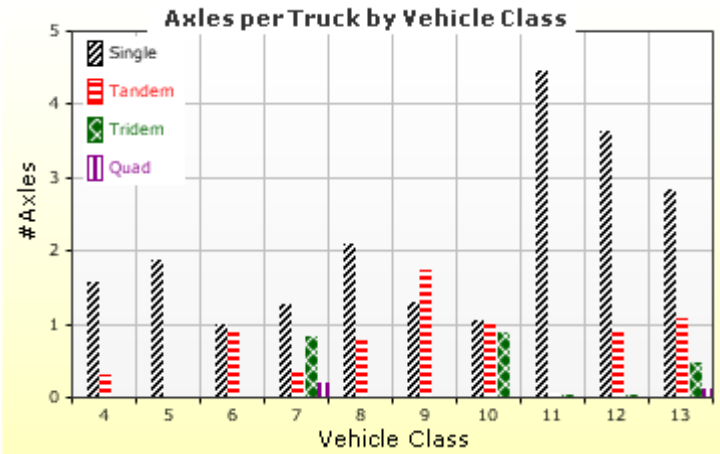
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	12,700	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	3	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

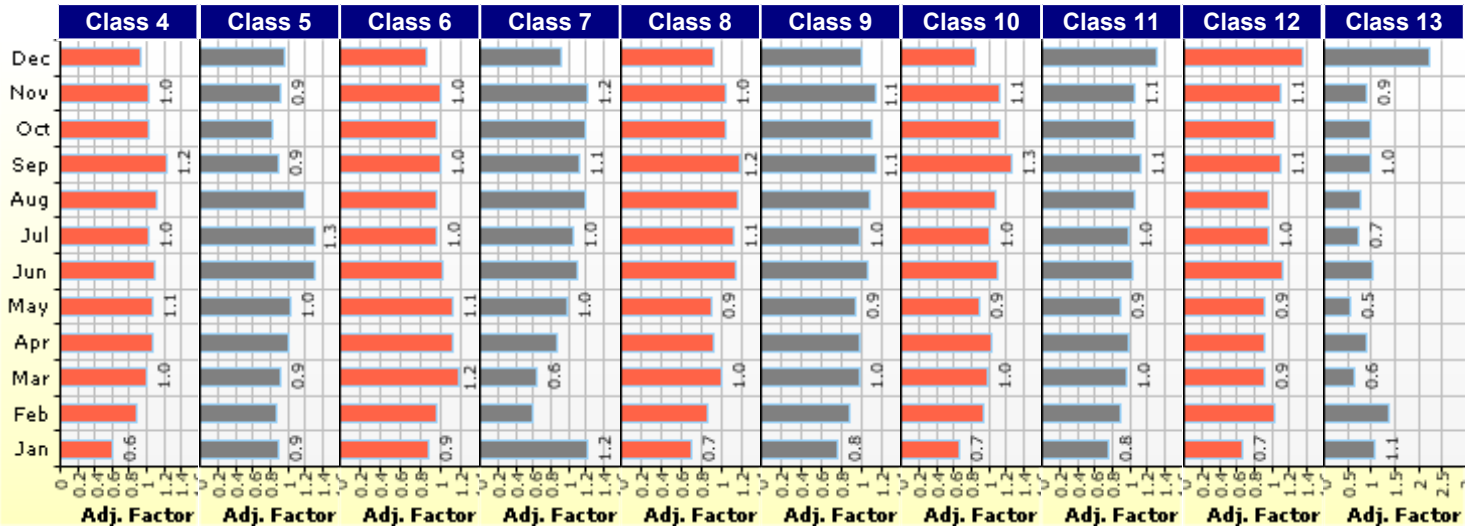








Traffic Volume Monthly Adjustment Factors



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	0.6	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%	1.69%	Linear
Class 5	22.5%	1.69%	Linear
Class 6	3.6%	1.69%	Linear
Class 7	0.7%	1.69%	Linear
Class 8	3.3%	1.69%	Linear
Class 9	64.4%	1.69%	Linear
Class 10	1.1%	1.69%	Linear
Class 11	2.1%	1.69%	Linear
Class 12	0.6%	1.69%	Linear
Class 13	0.4%	1.69%	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

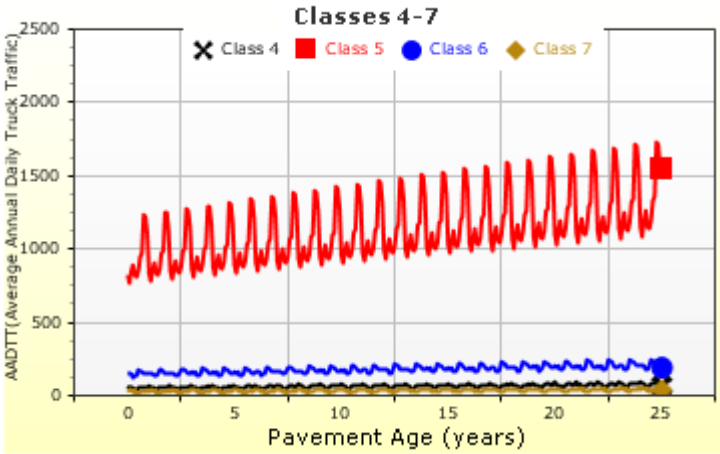
Wheelbase does not apply

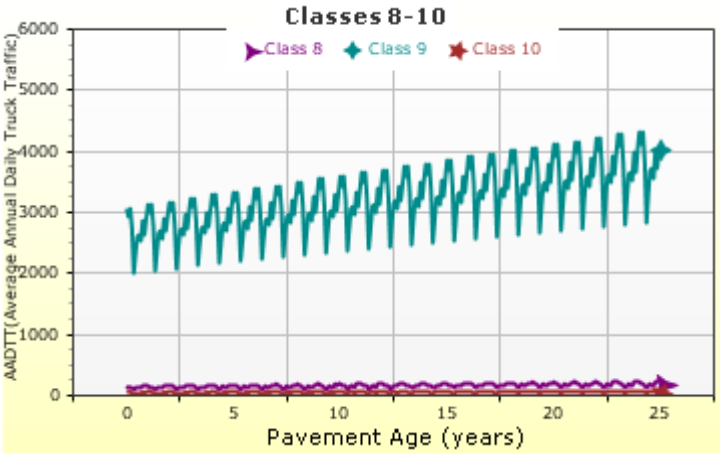
Number of Axles per Truck

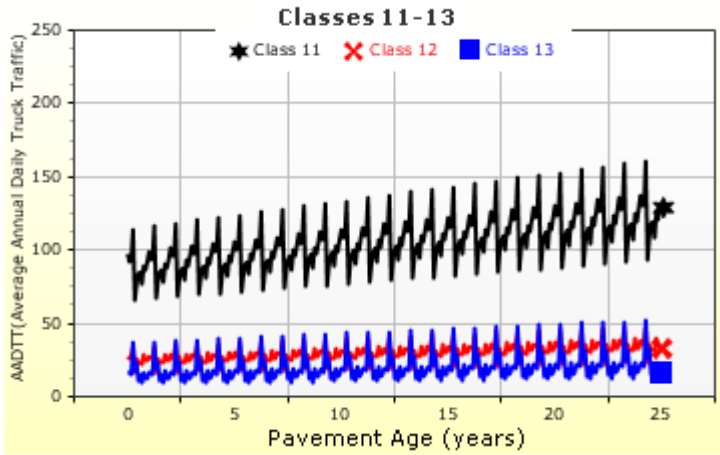
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

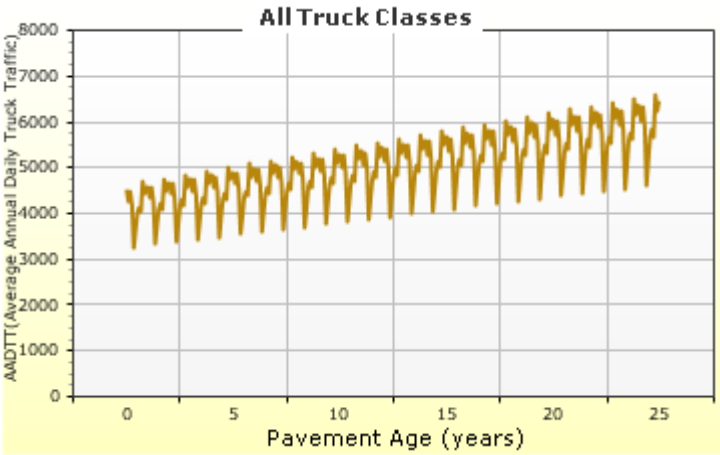
AADTT (Average Annual Daily Truck Traffic) Growth

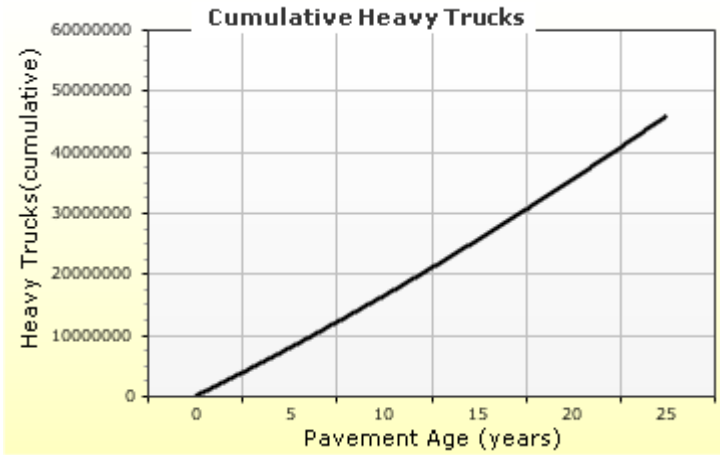
*** Traffic cap is not enforced**







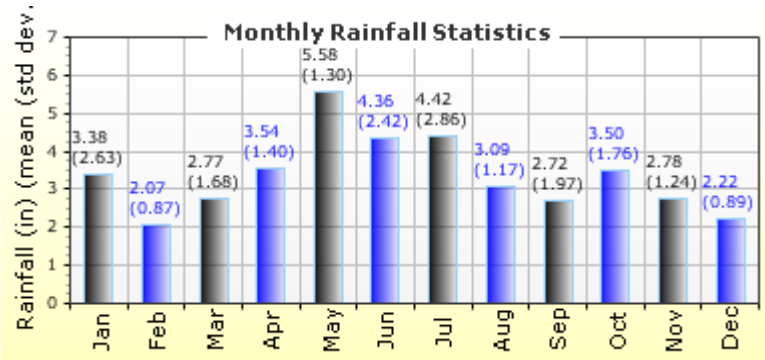




Climate Inputs

Climate Data Sources:

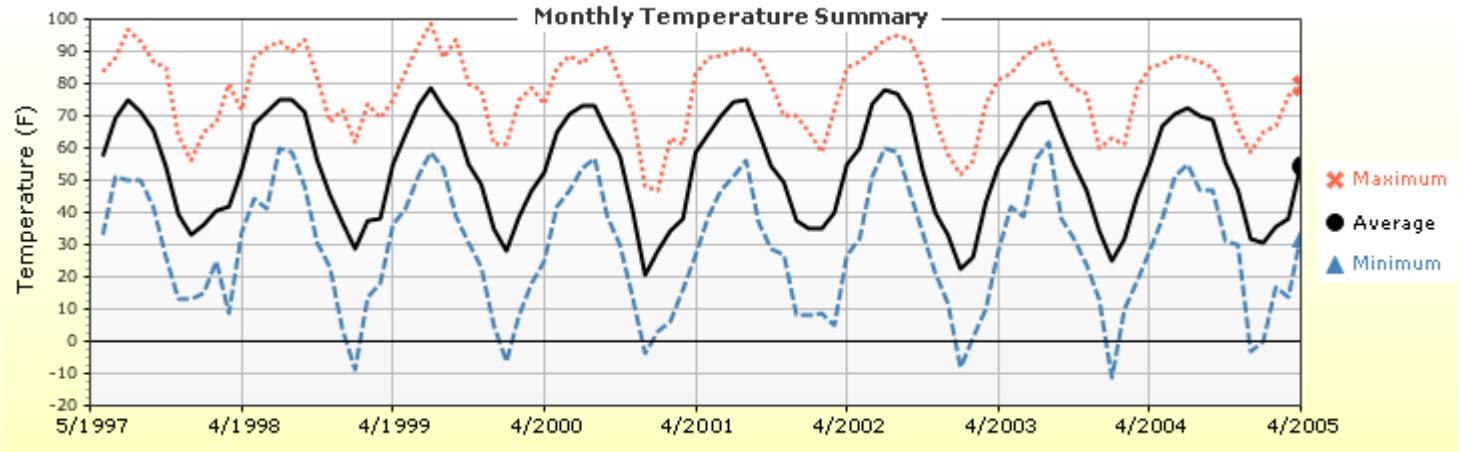
Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

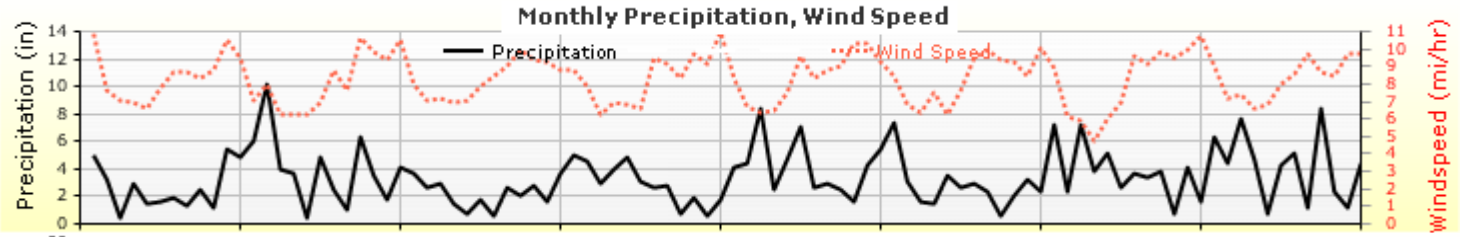


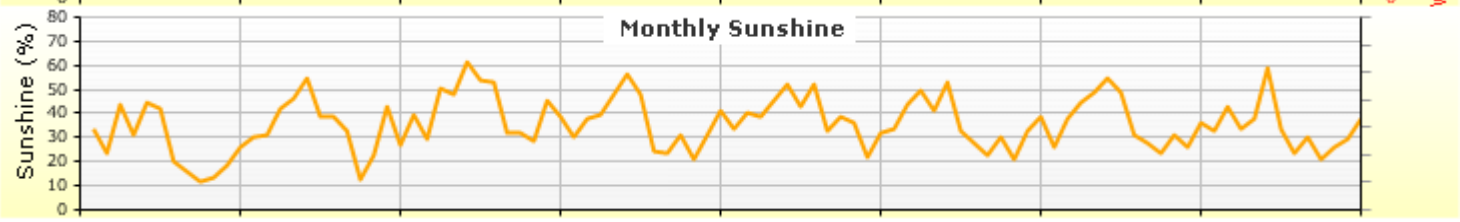
Annual Statistics:

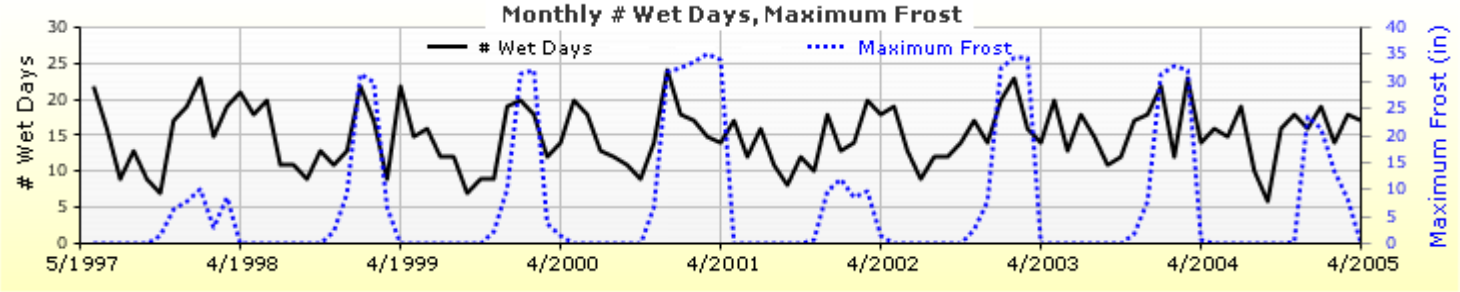
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in.)	40.41
Freezing index (ºF - days)	475.93
Average annual number of freeze/thaw cycles:	54.61
Water table depth (ft)	5.00

Monthly Climate Summary:

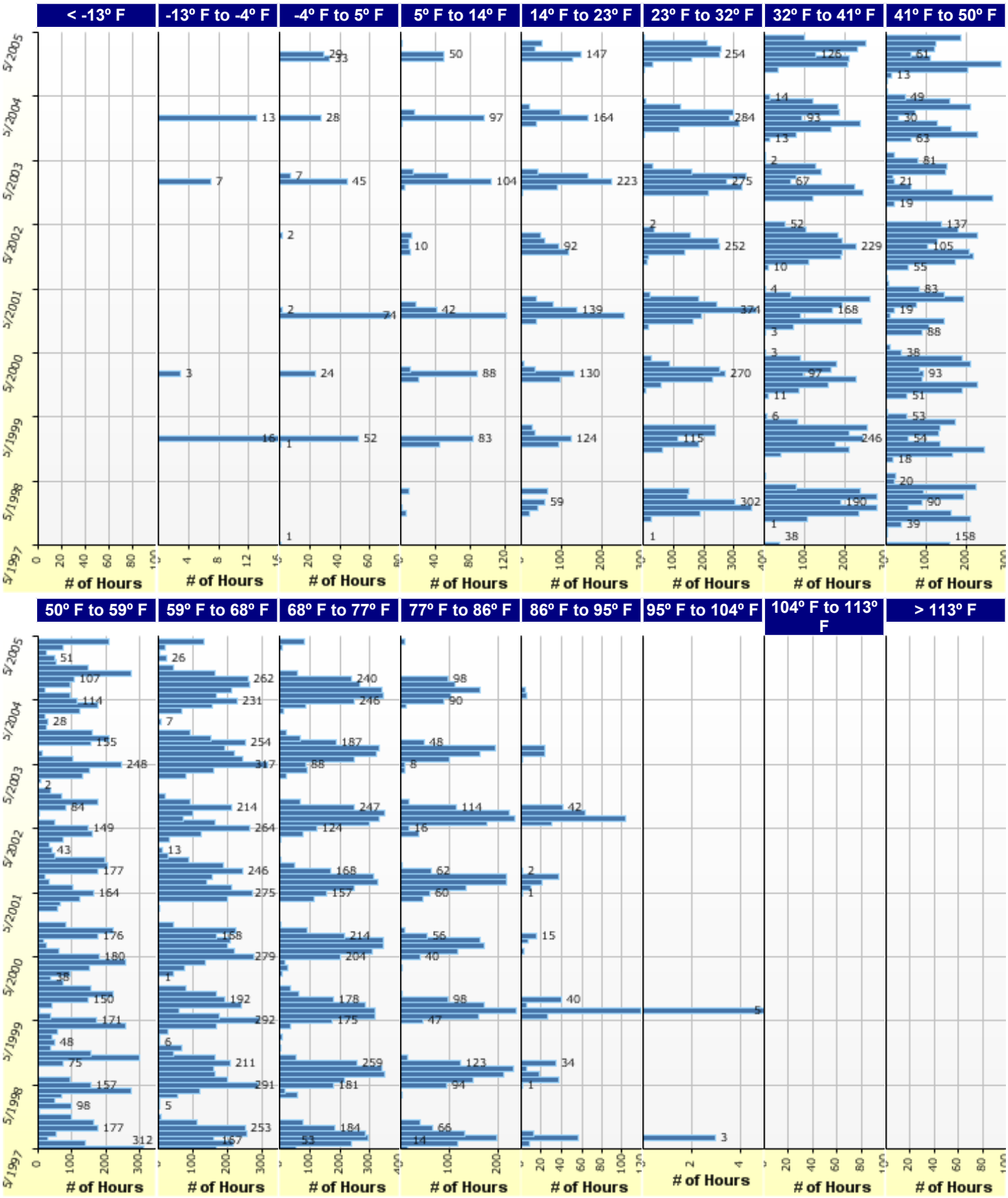








Hourly Air Temperature Distribution by Month:



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

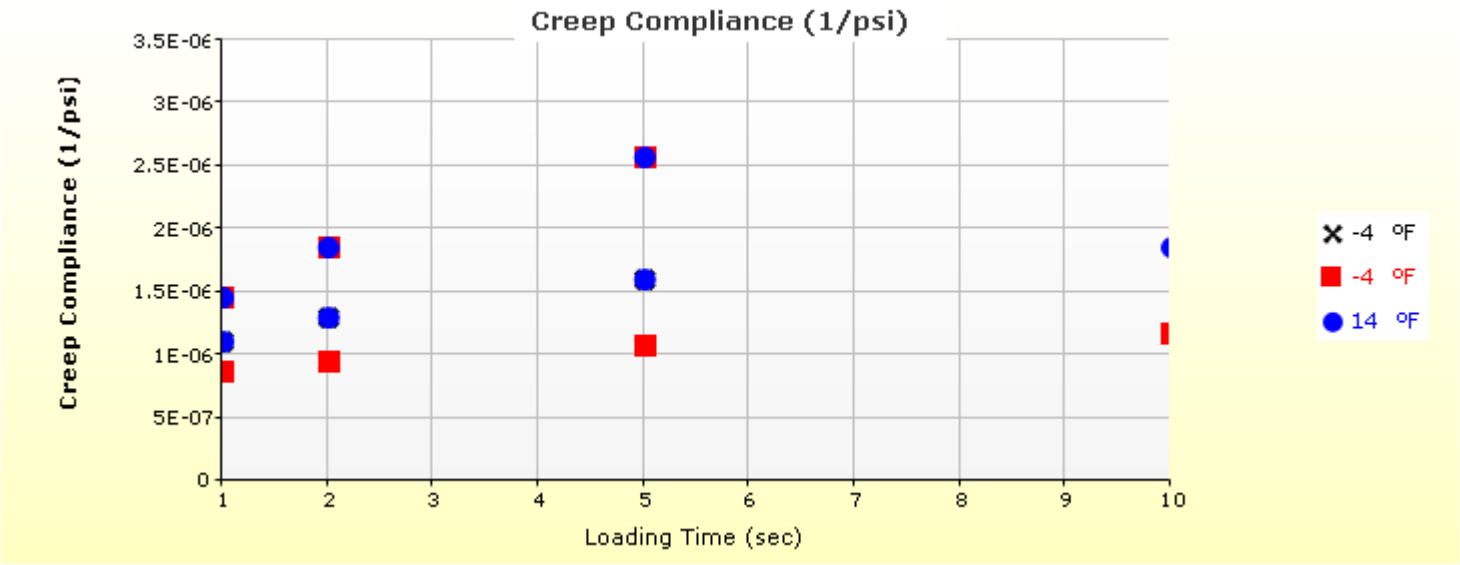
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield SMA PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 12.5mm PG76-22	Flexible (1)	1.00
Layer 3 Flexible : Greenfield 19.0mm PG64-22	Flexible (1)	1.00
Layer 4 Subgrade : A-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

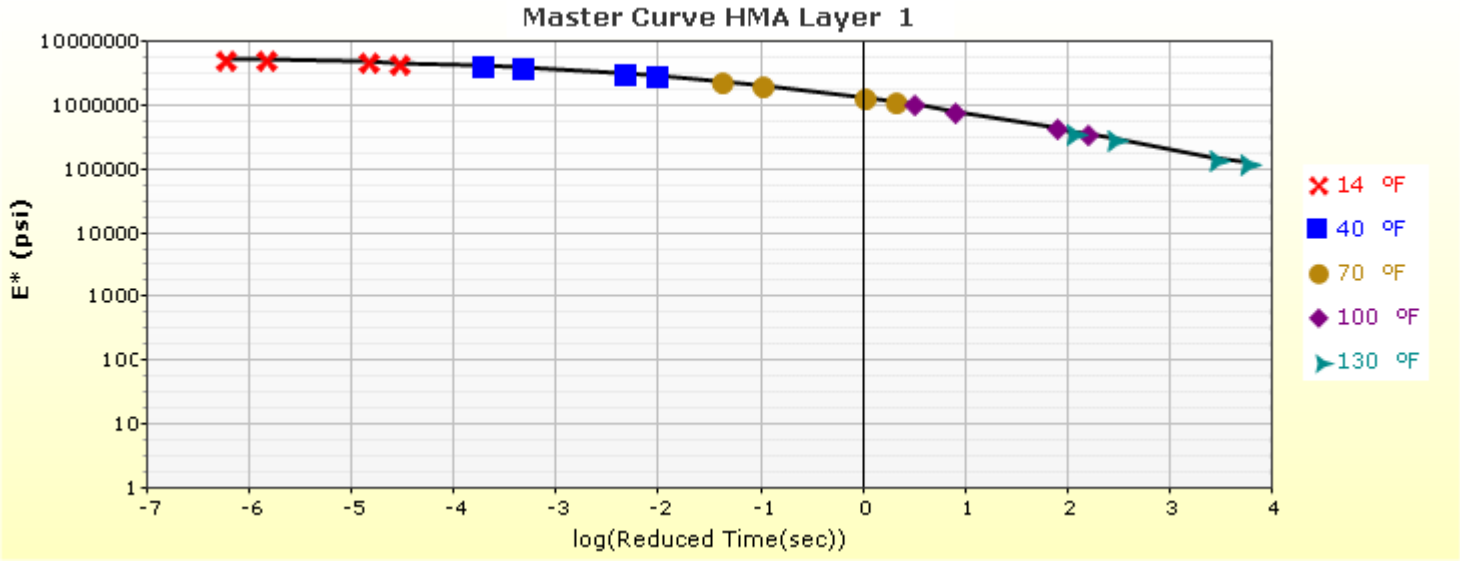
Indirect tensile strength at 14 ºF (psi)	404.62

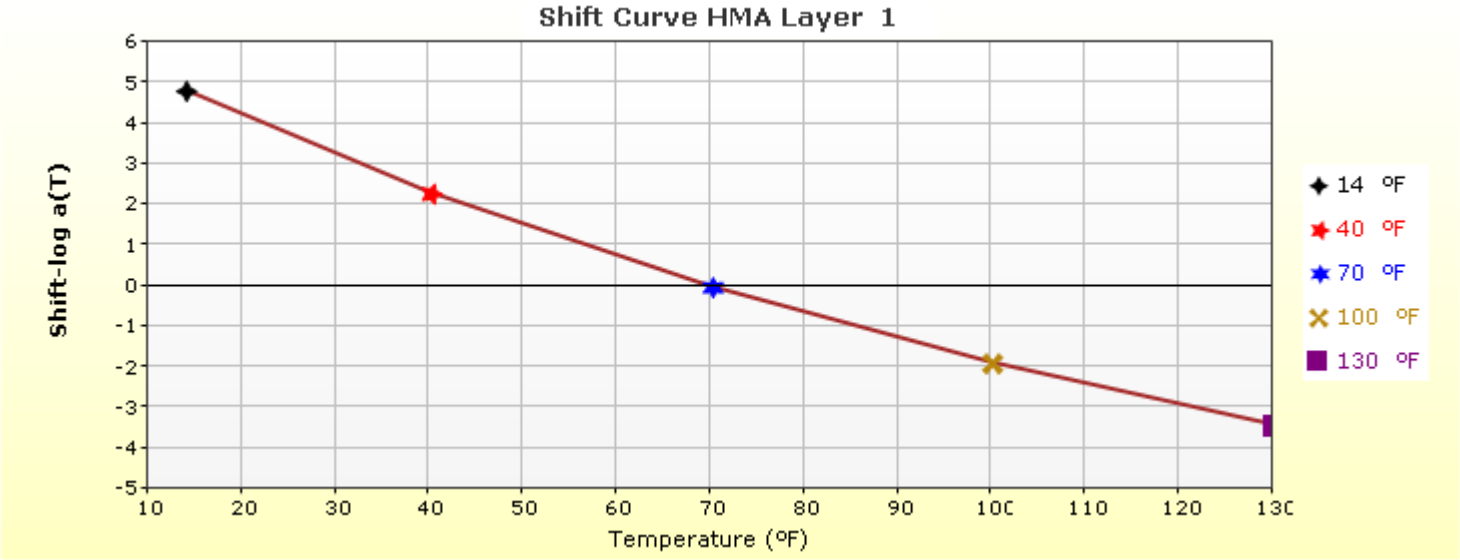
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	20.4

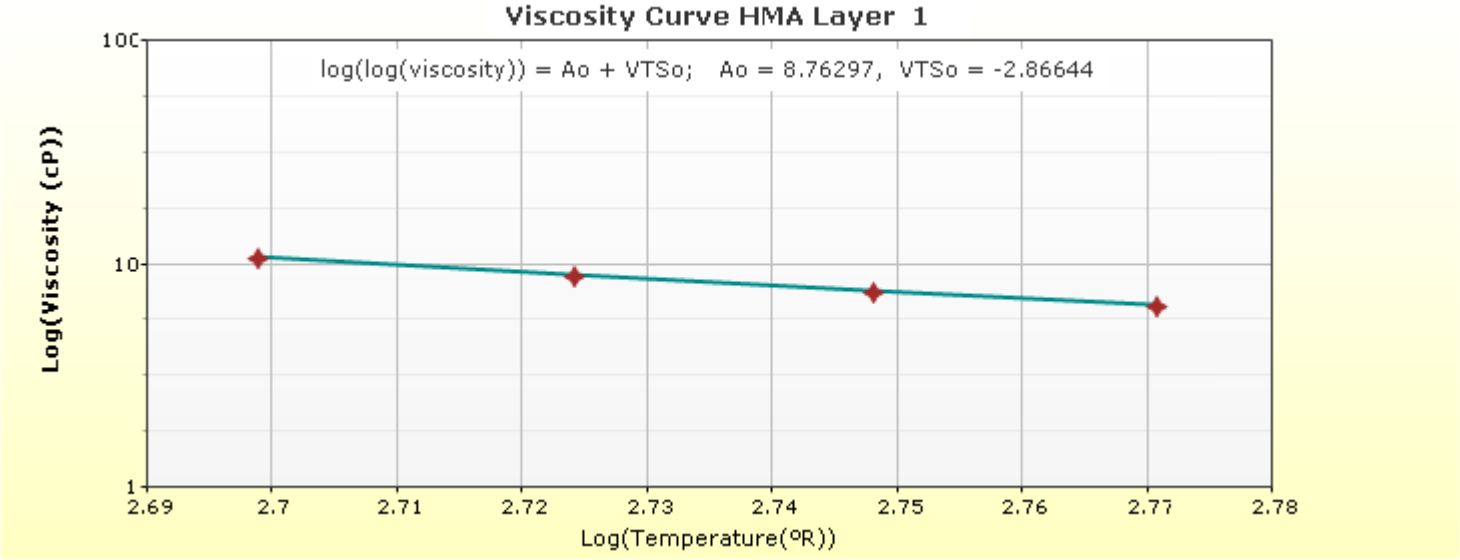
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	8.77e-007	8.77e-007	1.13e-006
1	1.13e-006	1.47e-006	1.47e-006
2	9.61e-007	9.61e-007	1.31e-006
2	1.31e-006	1.87e-006	1.87e-006
5	1.09e-006	1.09e-006	1.61e-006
5	1.61e-006	2.58e-006	2.58e-006
10	1.19e-006	1.19e-006	1.87e-006



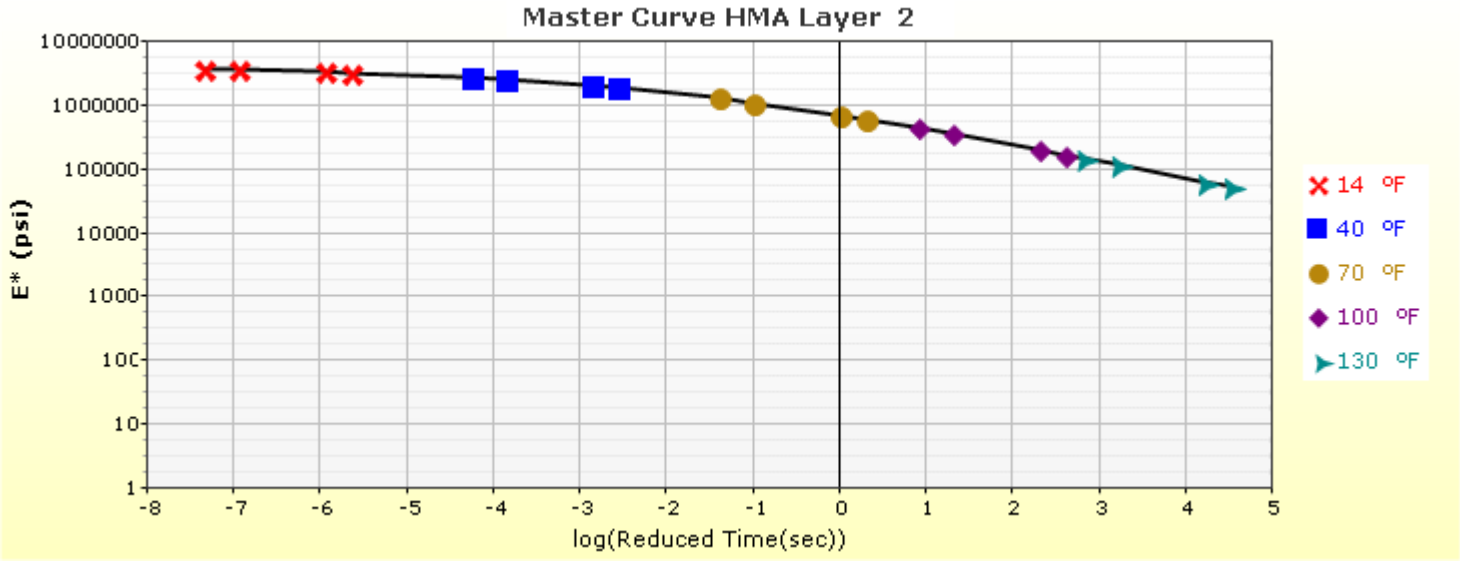
HMA Layer 1: Layer 1 Flexible : Greenfield SMA PG76-22

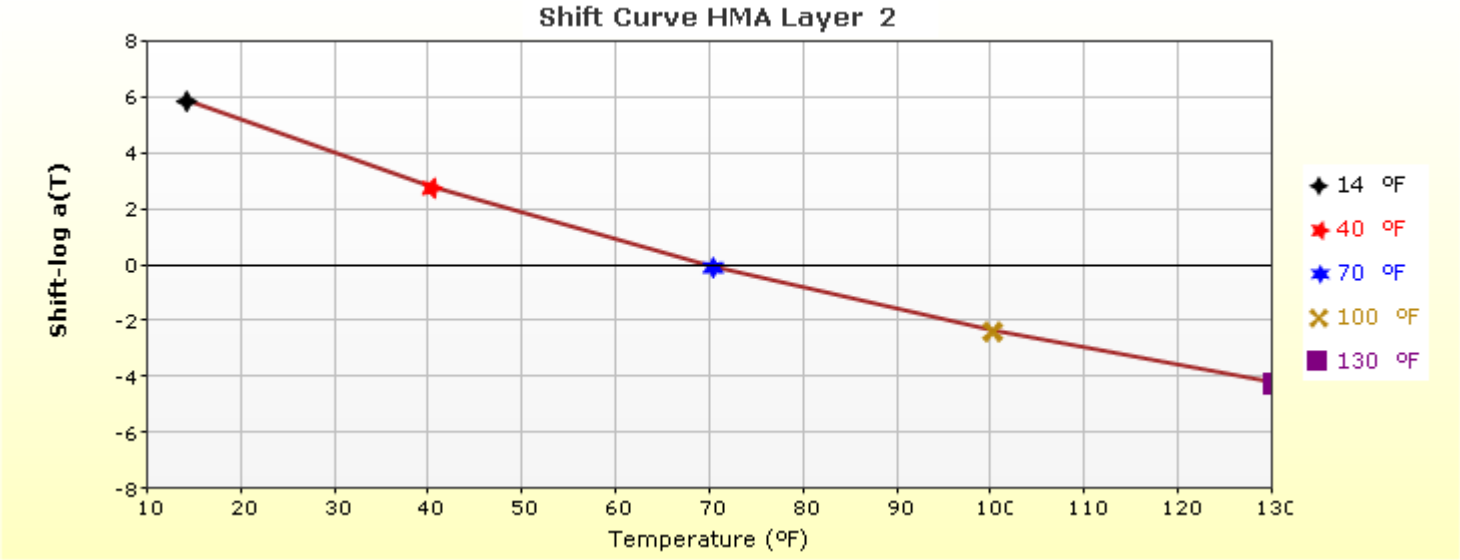


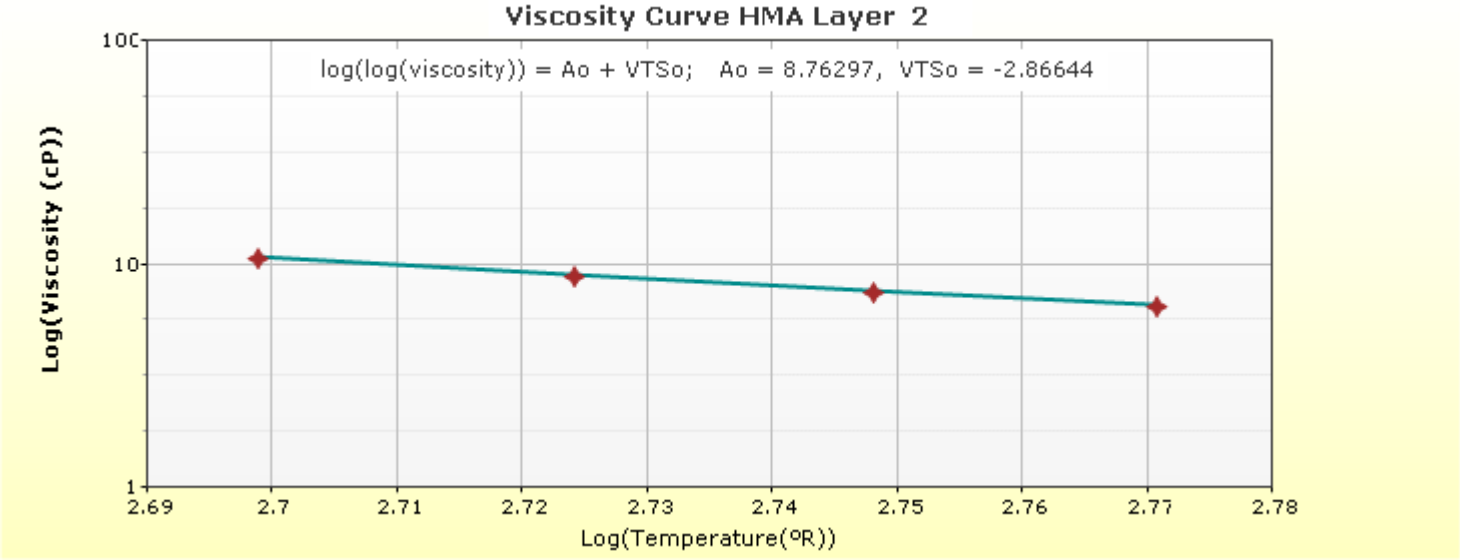




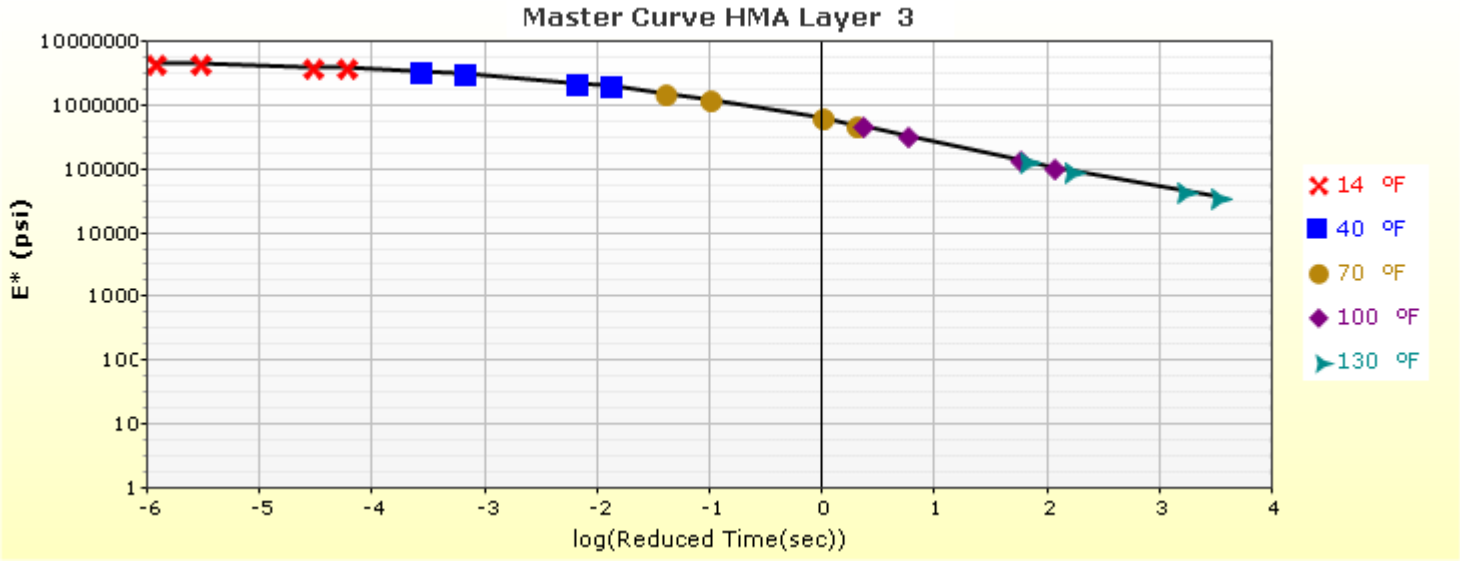
HMA Layer 2: Layer 2 Flexible : Greenfield 12.5mm PG76-22

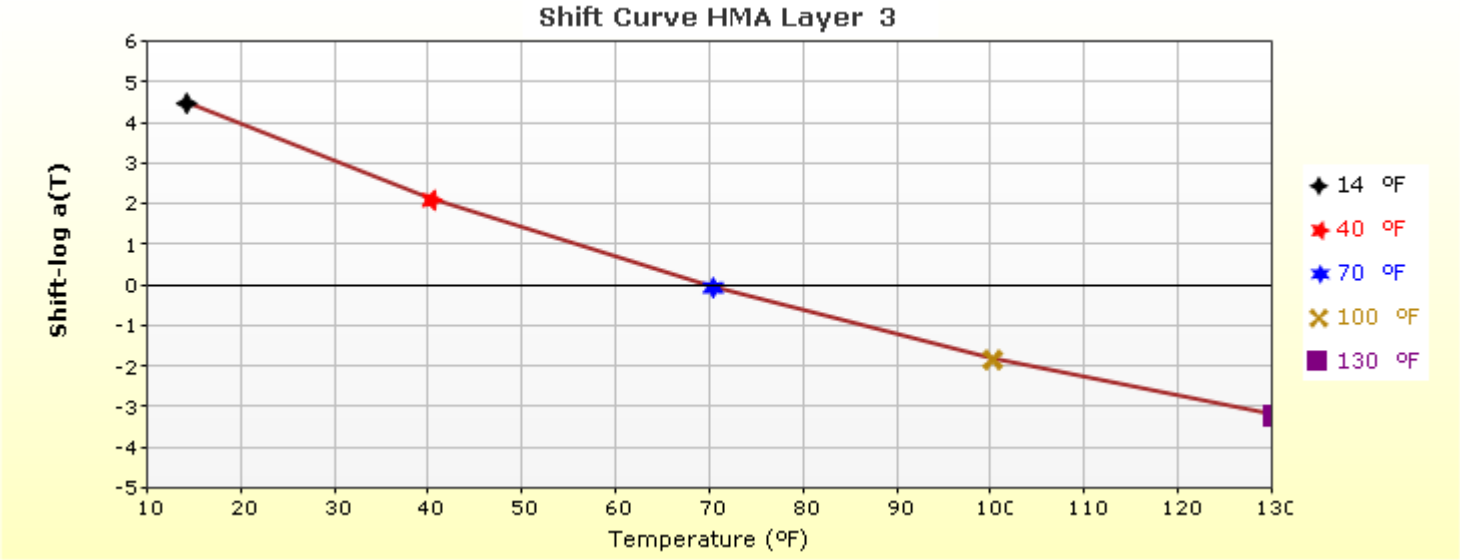


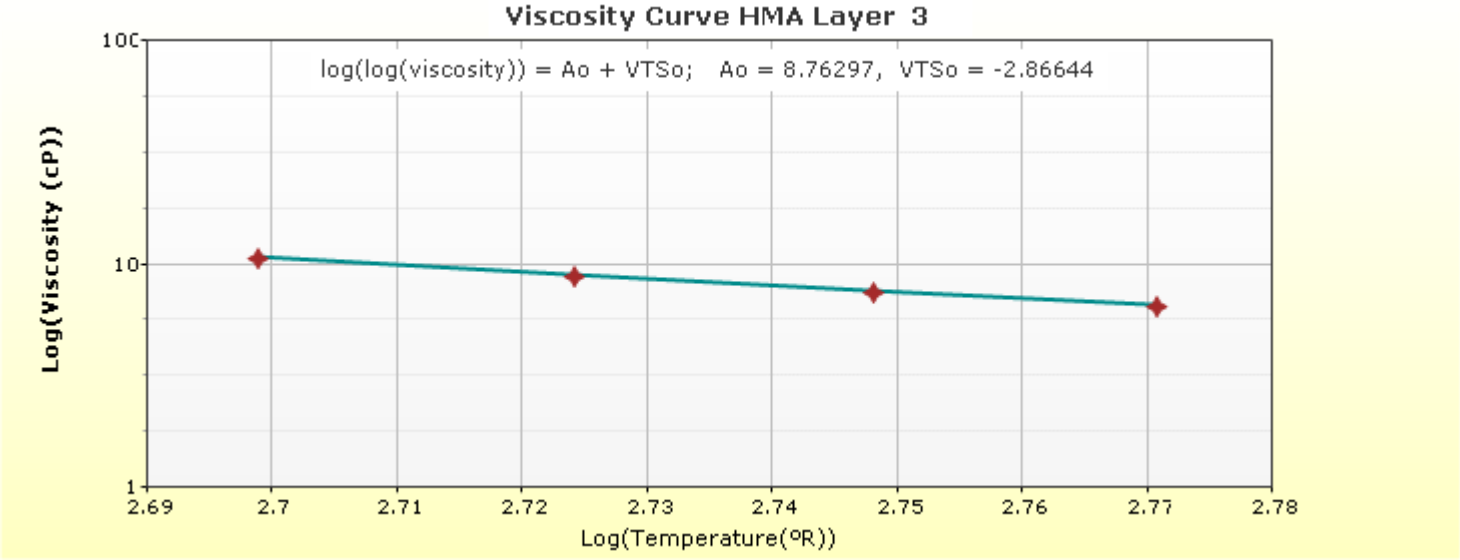




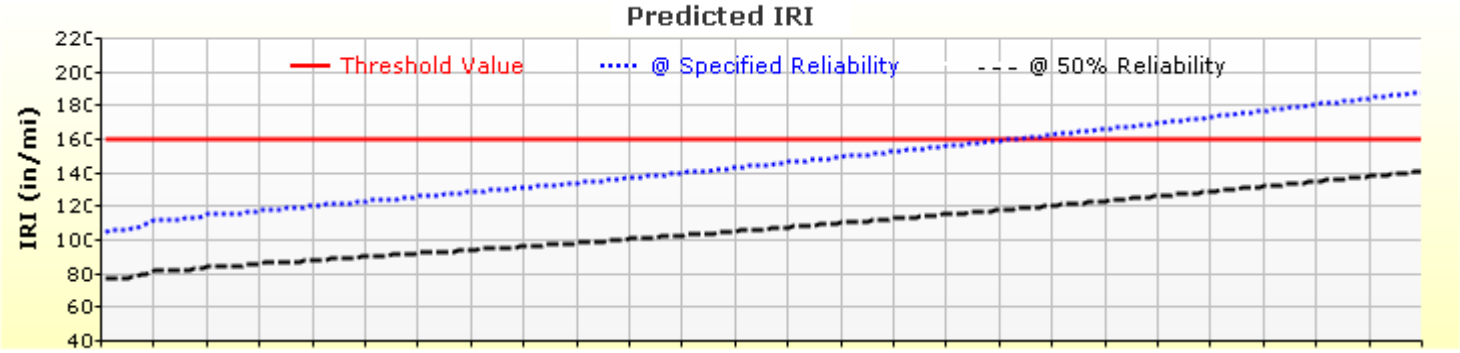
HMA Layer 3: Layer 3 Flexible : Greenfield 19.0mm PG64-22

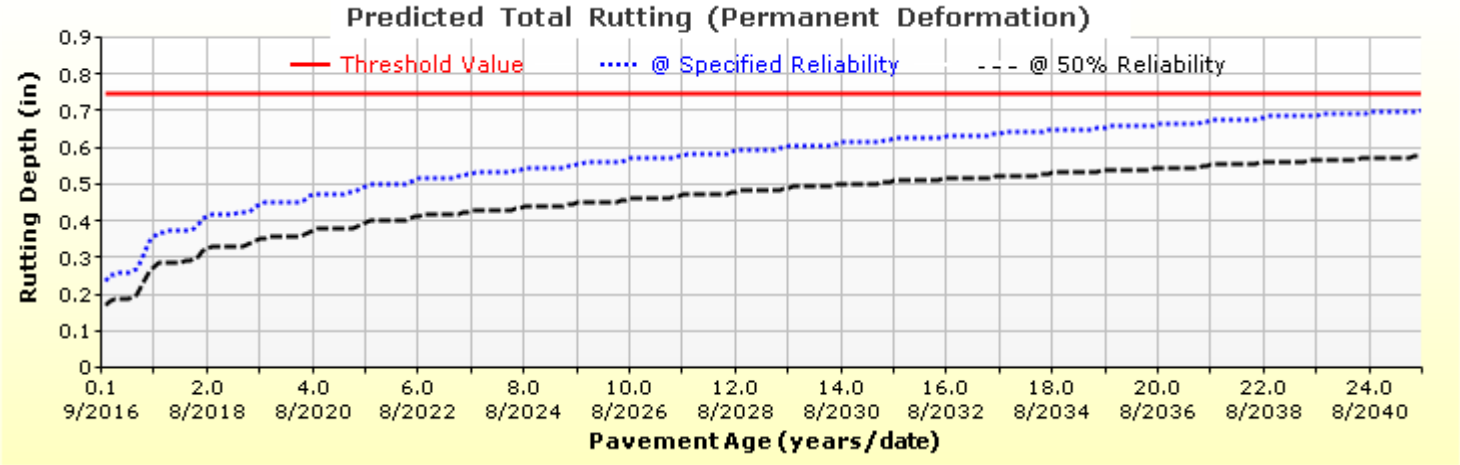


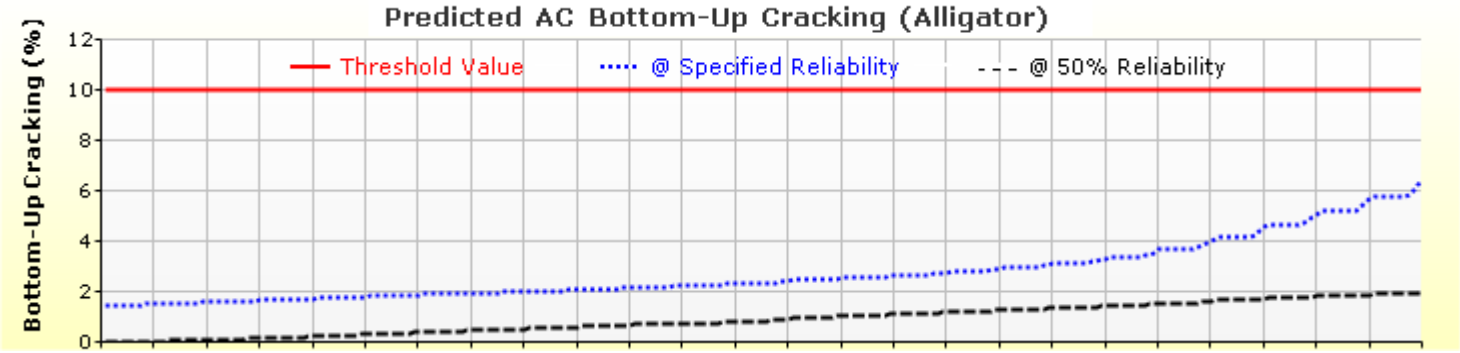


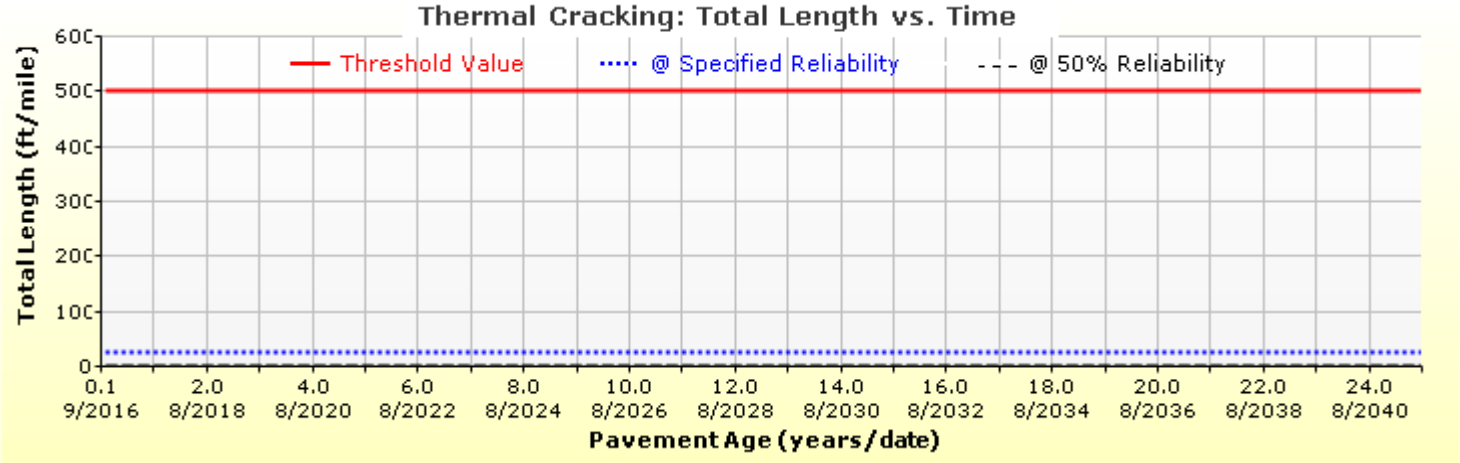


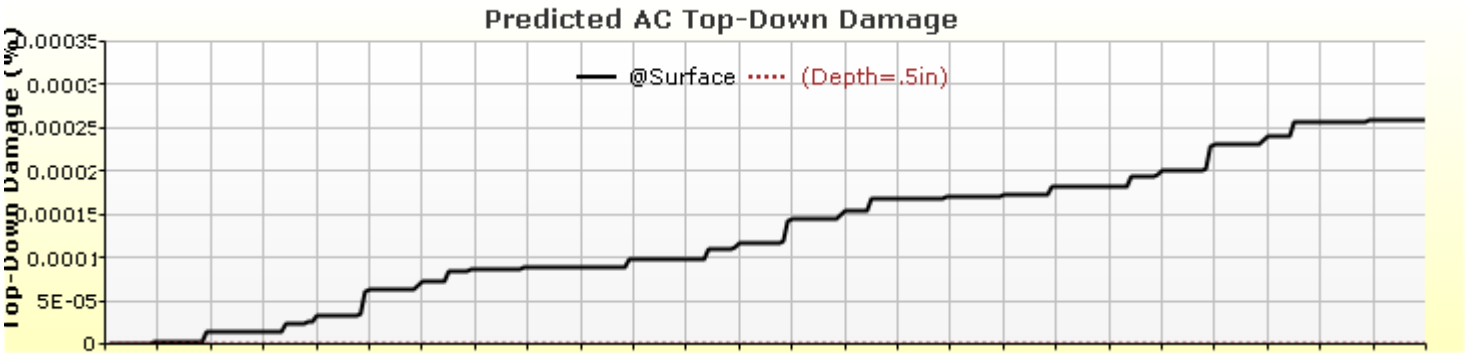
Analysis Output Charts

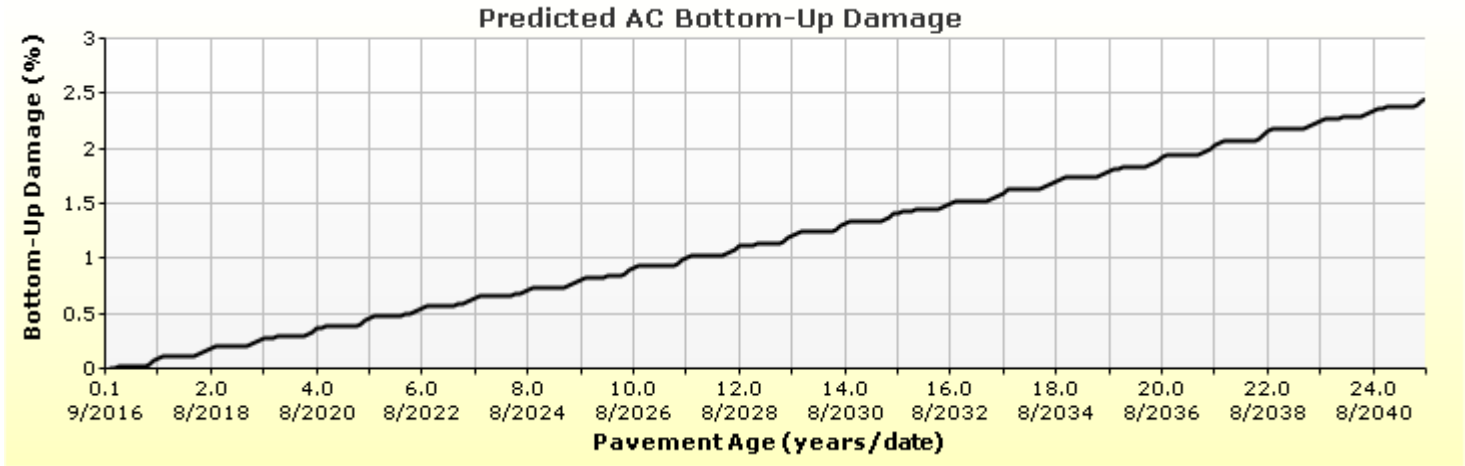


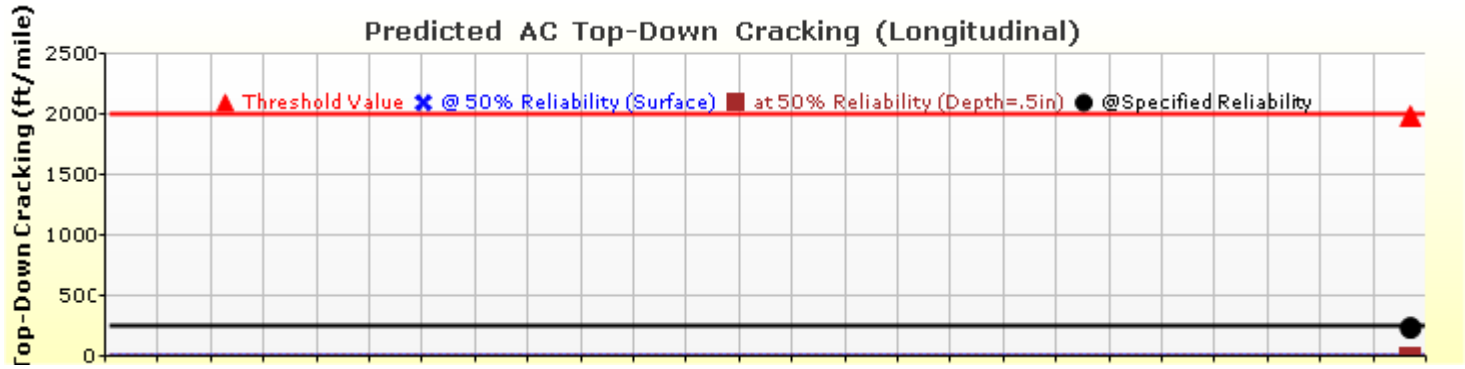


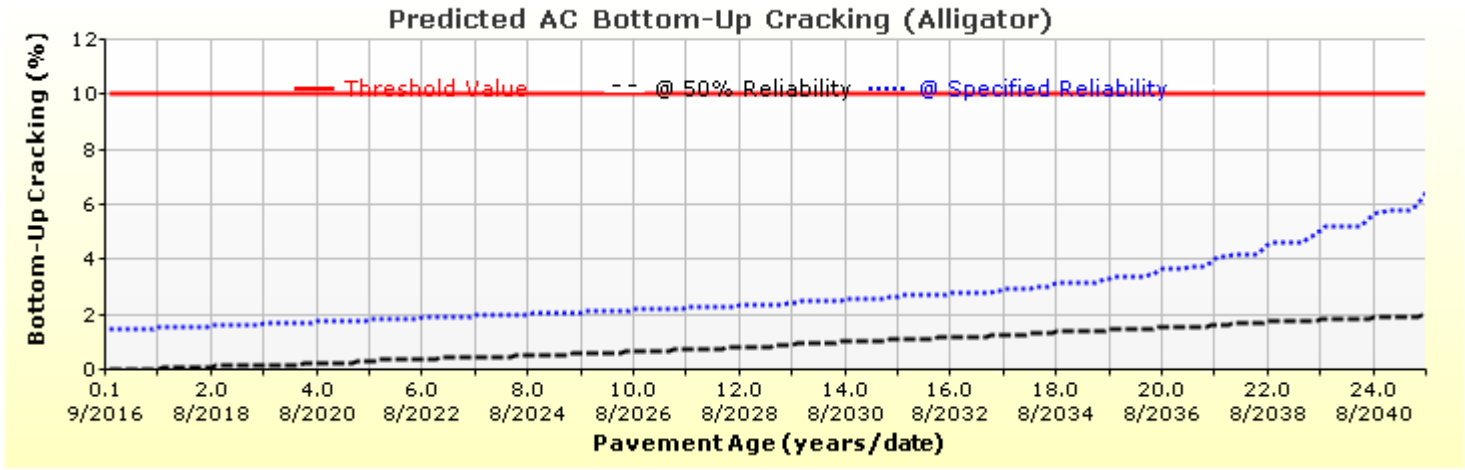


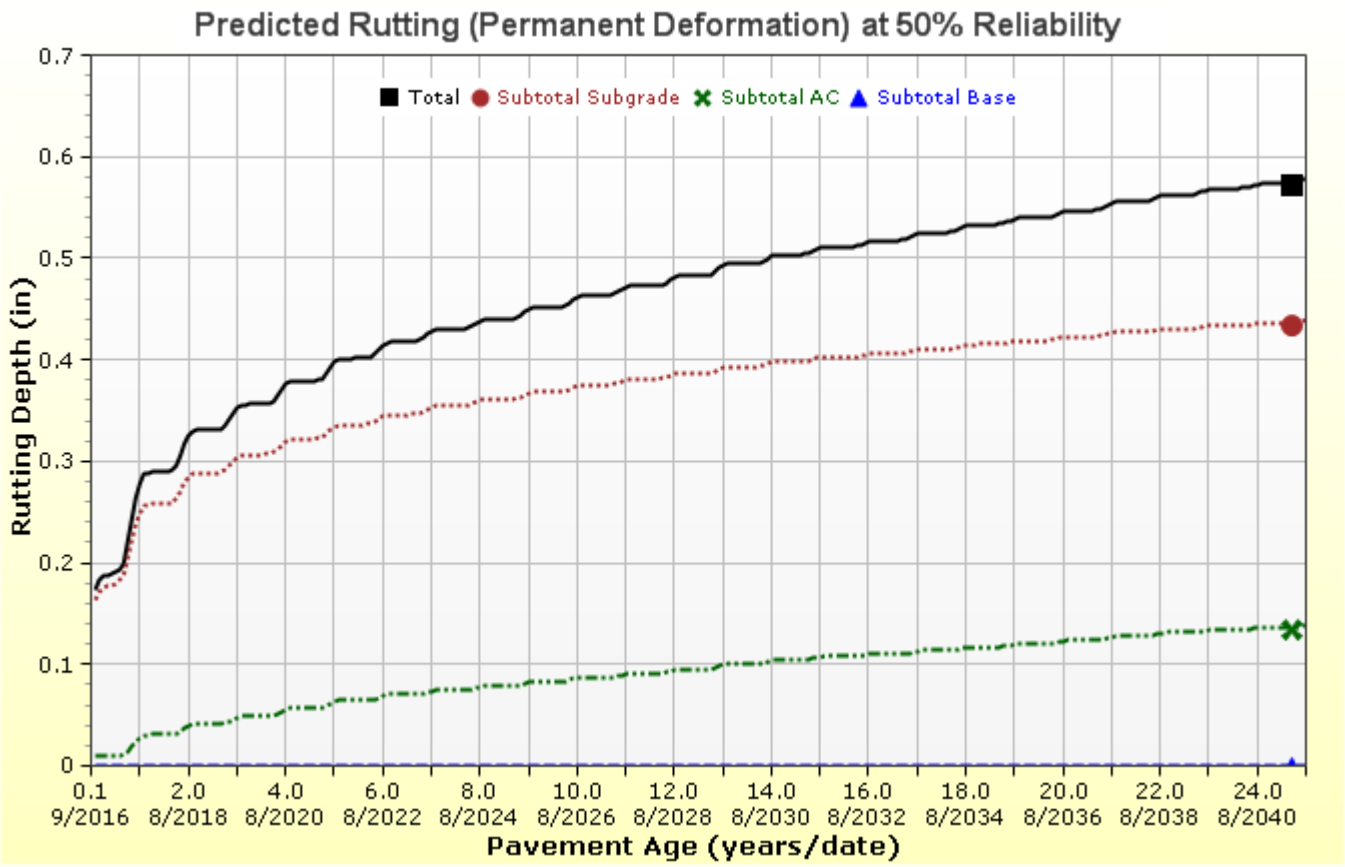


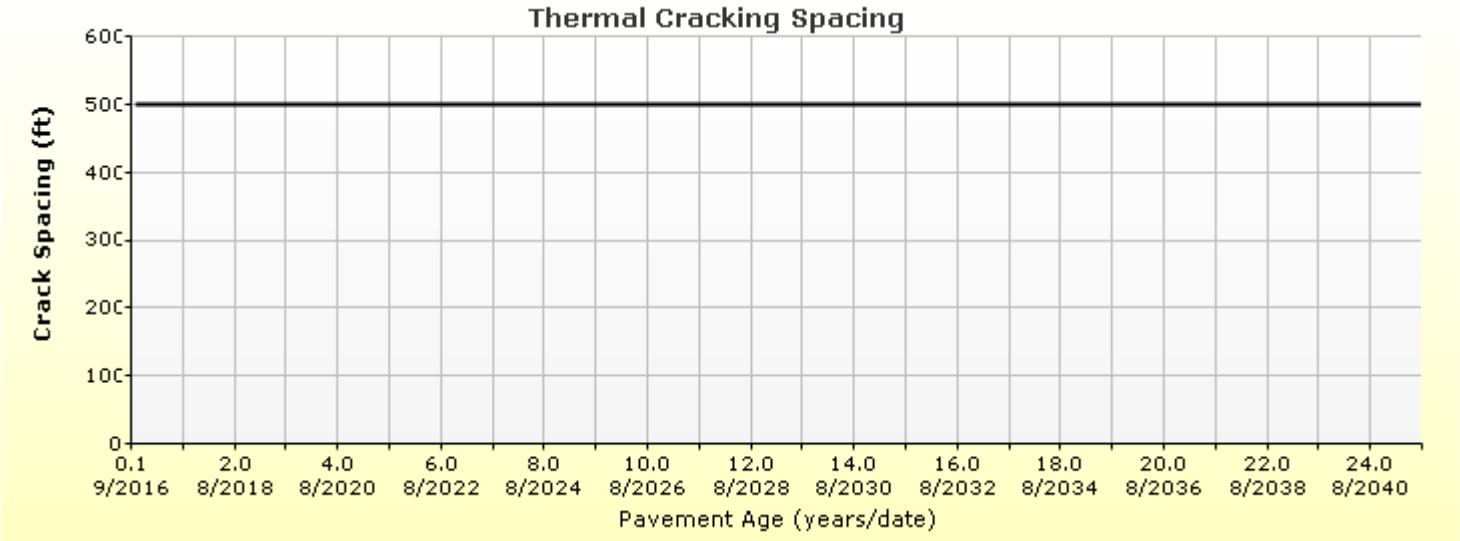

Predicted AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
5E-05
0

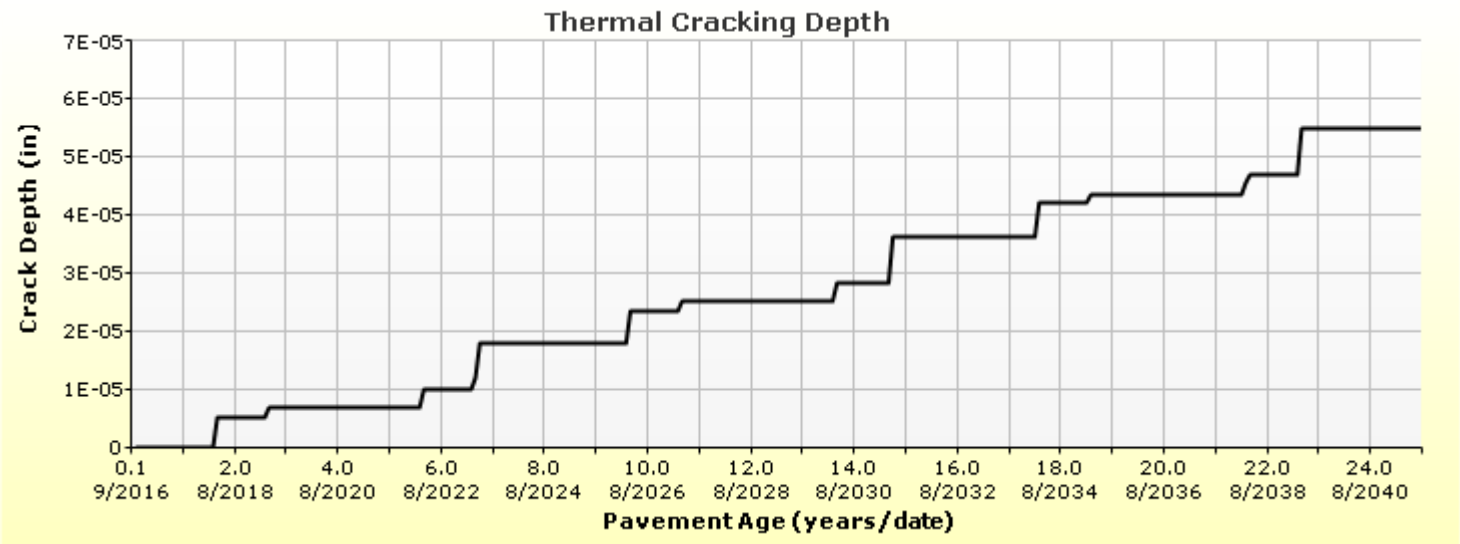

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
3
2.5
2
1.5
1
0.5
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

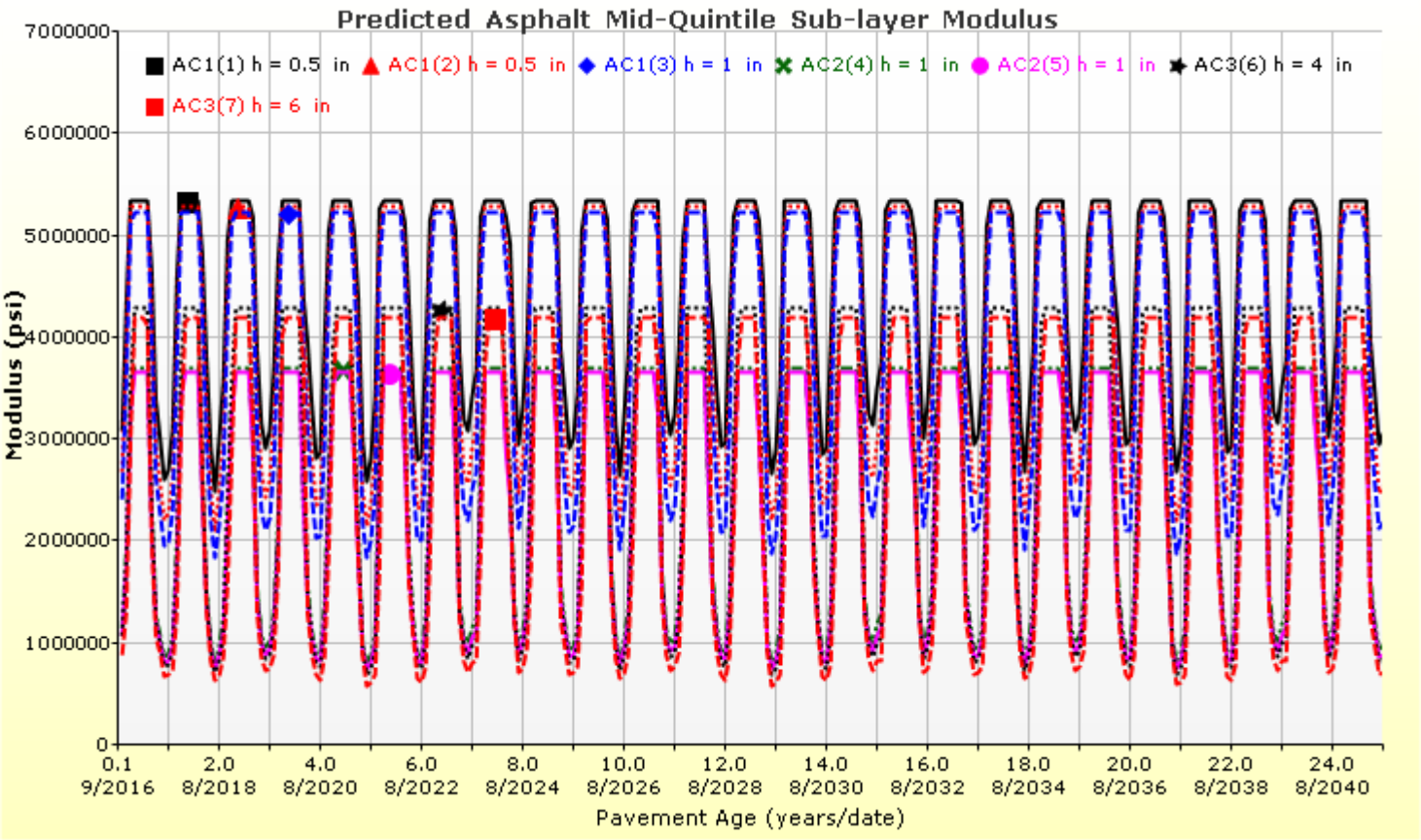

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability
2500
2000
1500
1000
500
0

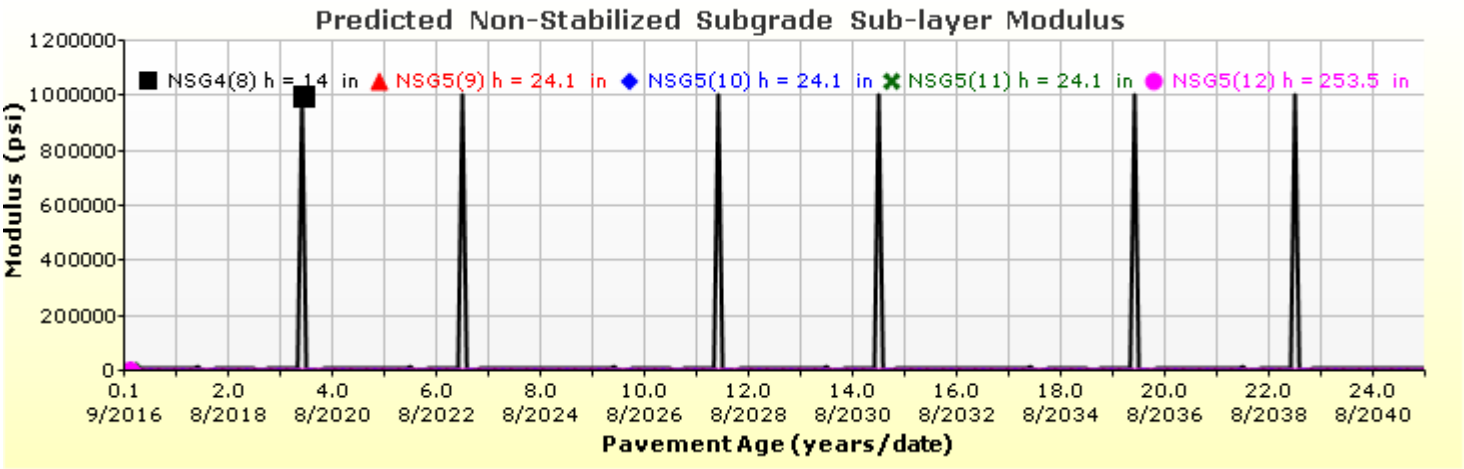

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
12
10
8
6
4
2
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rutting Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
7E-05
6E-05
5E-05
4E-05
3E-05
2E-05
1E-05
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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
AC2(4) h = 1 in
AC2(5) h = 1 in
AC3(6) h = 4 in
AC3(7) h = 6 in
Modulus (psi)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 14 in
NSG5(9) h = 24.1 in
NSG5(10) h = 24.1 in
NSG5(11) h = 24.1 in
NSG5(12) h = 253.5 in
Modulus (psi)
1200000
1000000
800000
600000
400000
200000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield SMA PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	173.5	
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	3647648	4669504	5000000	5000000
40	2415742	3373281	4392981	4797248
70	763973	1296571	2030073	2372323
100	228891	438683	796159	989704
130	80754	159253	310900	401763

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	13.4
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield SMA PG76-22
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 : Greenfield 12.5mm PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	143.1	
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	2514388	3101384	3593791	4359236
40	2212131	2249168	2353738	2616932
70	452354	700875	948099	1117573
100	90946	186351	333771	425610
130	35731	68157	133871	177872

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.66
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield 12.5mm PG76-22
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 : Greenfield 19.0mm PG64-22

Asphalt		
Thickness (in.)	10.0	
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	3042663	3715316	4113406	5000000
40	2000767	2583276	3039883	3481384
70	253862	614089	1083394	1357208
100	52156	133874	316005	437461
130	26313	49623	113020	160614

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 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 4 Subgrade : A-6

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

Resilient Modulus (psi)
7500.0

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

Identifiers

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

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Layer 5 Subgrade : A-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 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

Mainline Widening

File Name: C:\My ME Design\Projects\MK15-469\PrelimReport\Mainline Widening.dgpx

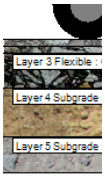
Design Inputs

Design Life: 16 years
Design Type: Flexible Pavement

Base construction: May, 2016
Pavement construction: June, 2016
Traffic opening: September, 2016

Climate Data Sources (Lat/Lon): 39.71, -86.272

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 12.5mm PG76-22	2.0
Flexible	Greenfield 19.0mm PG64-22	10.0
Subgrade	A-6	14.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

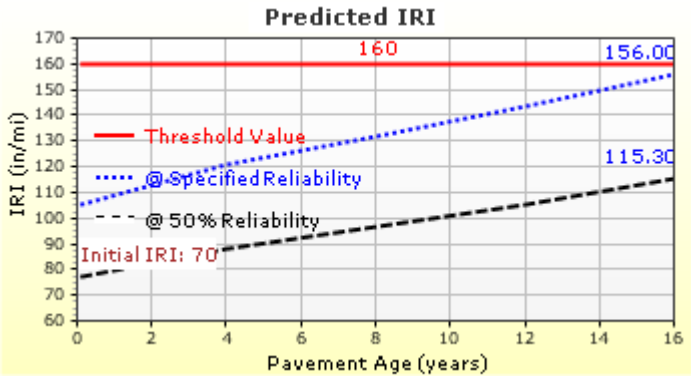
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	12,700
2024 (8 years)	12,970,500
2032 (16 years)	27,596,600

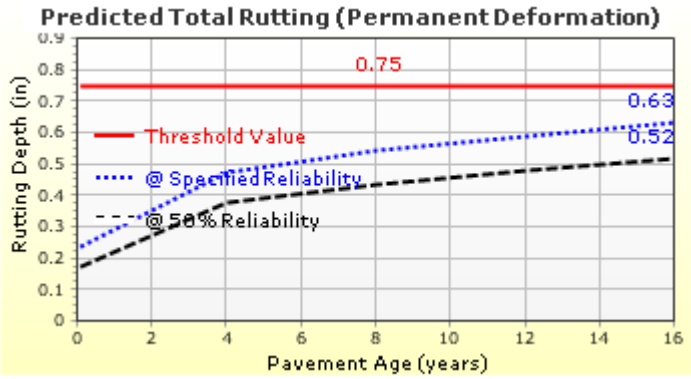
Design Outputs

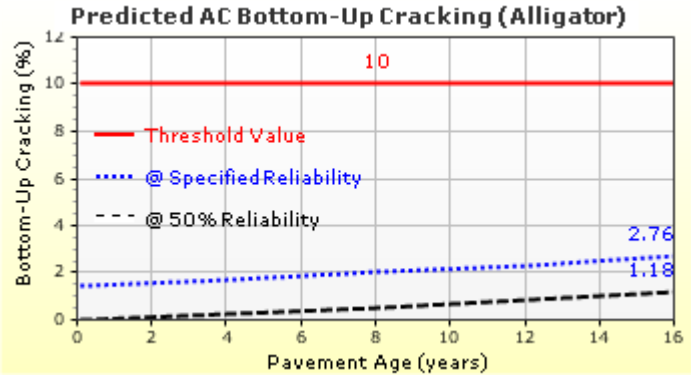
Distress Prediction Summary

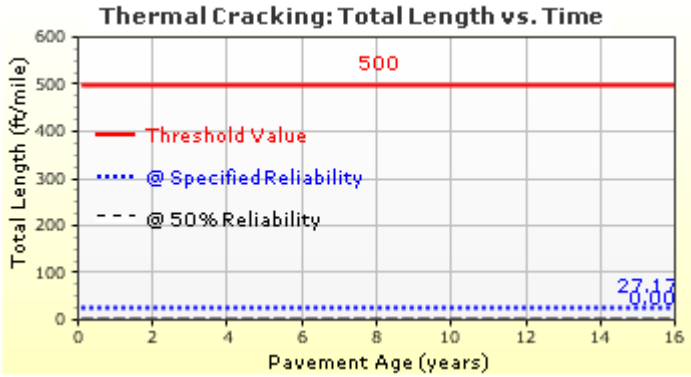
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	155.96	90.00	92.06	Pass
Permanent deformation - total pavement (in.)	0.75	0.63	90.00	99.51	Pass
AC bottom-up fatigue cracking (percent)	10.00	2.76	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	256.76	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.16	90.00	100.00	Pass

Distress Charts









Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

PATCHING DETAILS

Partial Depth HMA Patching

Full Depth CRCP Patching

Full Depth JPCP Patching

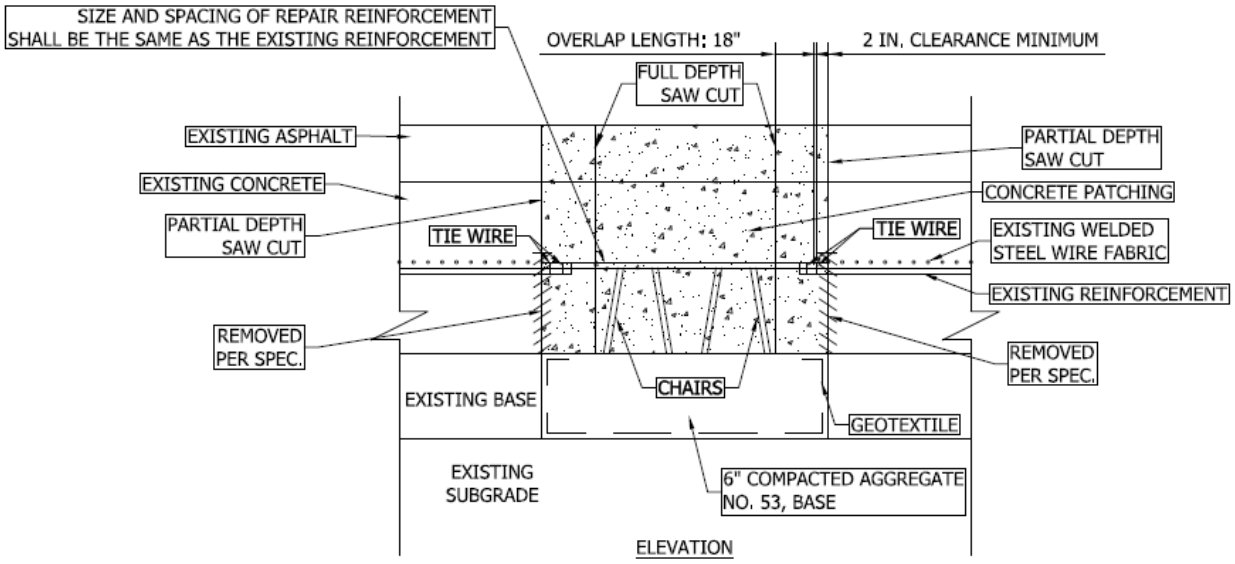
Partial Depth HMA Patching:
For use throughout the length of I-69

HMA Patching, Type D consisting of
Variable Depth Milling, (4 inch minimum or to existing concrete as directed), then
Variable depth HMA Type D, Intermediate (440#/sys minimum, 880#/sys maximum) on
Existing Pavement

Full Depth CRCP Patching (as described in TP 7.2.1, full depth concrete option):
For use from south end of project to Sand Creek Bridge

Saw cut existing pavement and remove, then
CRCP Patching, variable 10 in minimum (see detail below), on
Dense Graded Subbase for PCCP, on
Geotextiles, on
Subgrade Treatment, Type IC (as needed)

The full depth patching section for existing CRCP is detailed as follows:



Full Depth JPCP Patching:
For use from Sand Creek Bridge to north end of project

Saw cut existing pavement and remove, then
PCCP Patching, variable 10 in minimum (see IDM Figure 304-21DD, dowel bars shall be spaced at 1'), on
Dense Graded Subbase for PCCP, on
Geotextiles, on
Subgrade Treatment, Type IC (as needed)

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

Mainline on I-69 Outside Shoulders for MOT

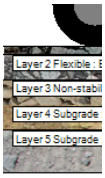
MOT Phase 1 Intermediate Overlay

File Name: C:\My ME Design\Projects\MK15-469\PostReport\MOT Phase 1 Intermediate Overlay.dgpx

Design Inputs

Design Life:	2 years	Existing construction:	May, 1983	Climate Data Sources (Lat/Lon)	39.825, -86.296
Design Type:	AC over AC	Pavement construction:	June, 2016		39.71, -86.272
		Traffic opening:	July, 2016		40.234, -85.394

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield 19.0mm PG76-22	2.0
Flexible	Existing HMA	6.0
NonStabilized	A-1-a	6.0
Subgrade	A-7-6	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

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

Traffic

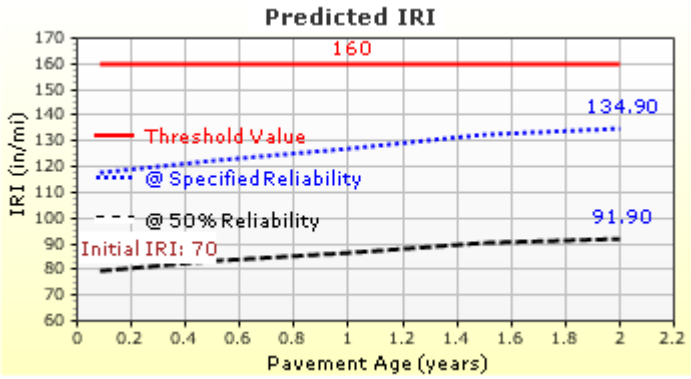
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	12,700
2017 (1 years)	765,381
2018 (2 years)	1,543,700

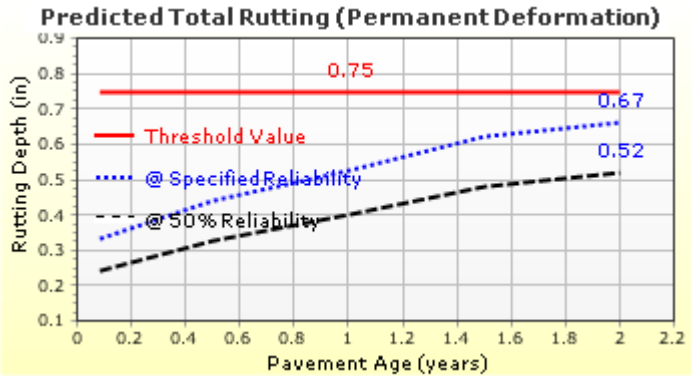
Design Outputs

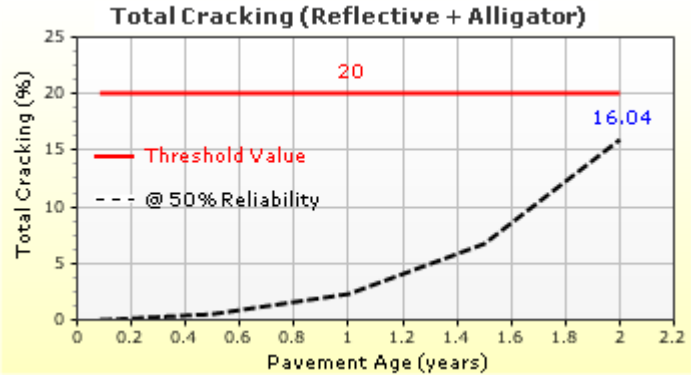
Distress Prediction Summary

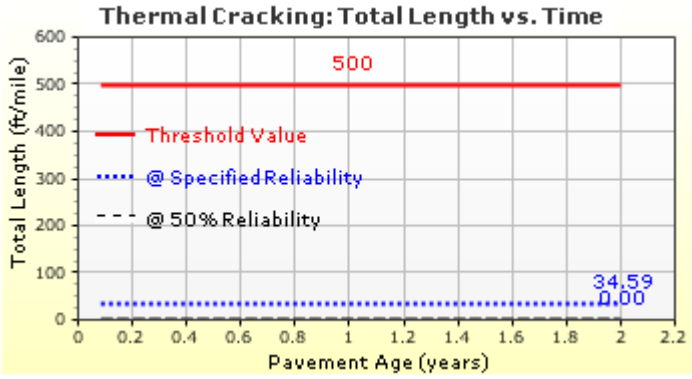
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	134.89	95.00	99.54	Pass
Permanent deformation - total pavement (in.)	0.75	0.67	95.00	99.53	Pass
Total Cracking (Reflective + Alligator) (percent)	20	16.04	-	-	Pass
AC thermal cracking (ft/mile)	500.00	34.59	95.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.86	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	2011.18	95.00	97.99	Pass
Permanent deformation - AC only (in.)	0.40	0.20	95.00	100.00	Pass

Distress Charts





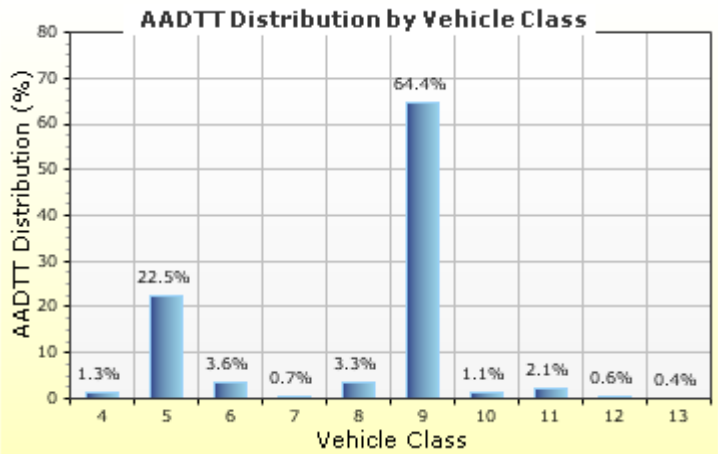


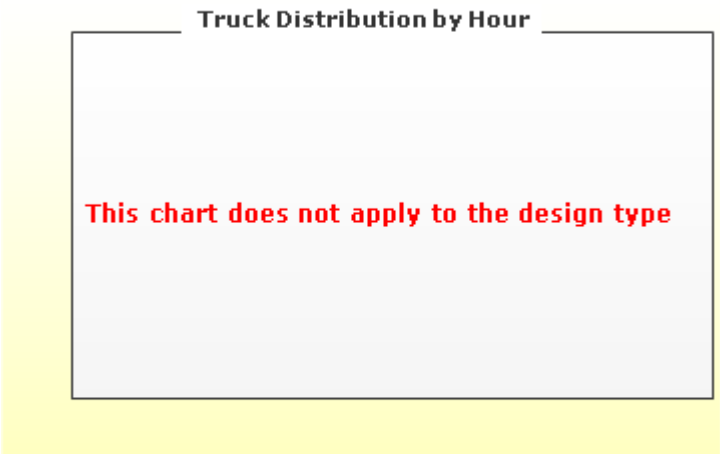


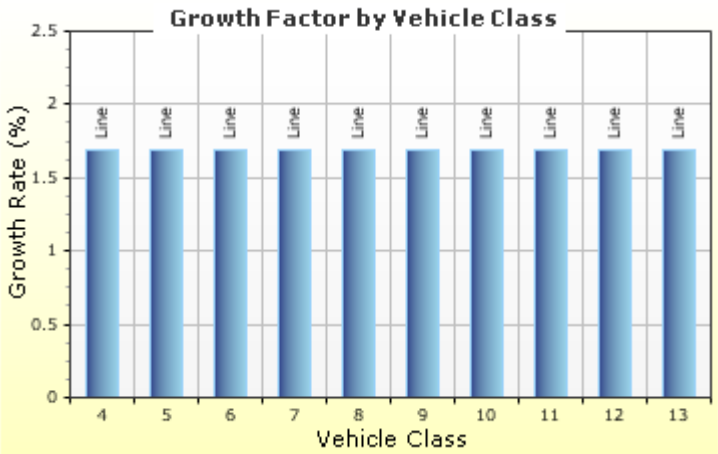
Traffic Inputs

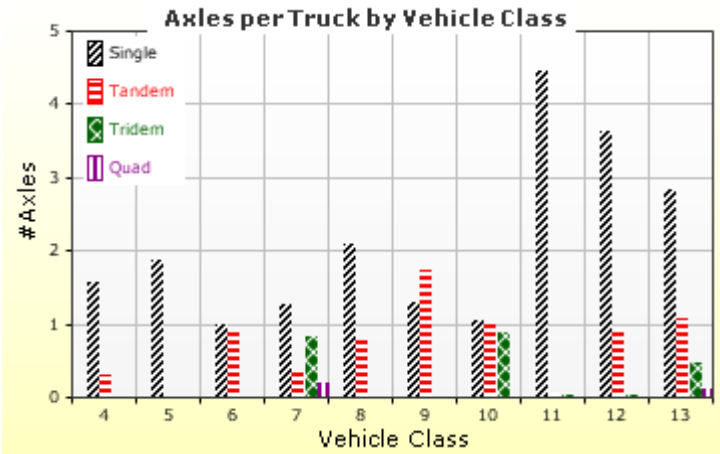
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	12,700	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	30.0
		Operational speed (mph)	45.0

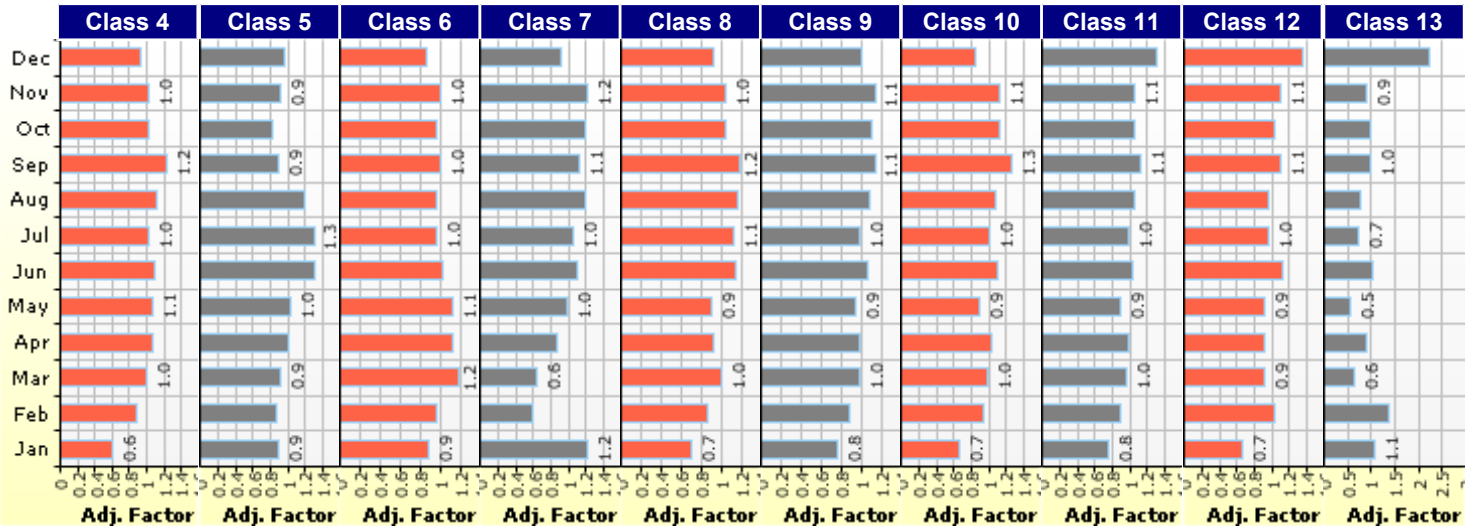








Traffic Volume Monthly Adjustment Factors



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	0.6	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%	1.69%	Linear
Class 5	22.5%	1.69%	Linear
Class 6	3.6%	1.69%	Linear
Class 7	0.7%	1.69%	Linear
Class 8	3.3%	1.69%	Linear
Class 9	64.4%	1.69%	Linear
Class 10	1.1%	1.69%	Linear
Class 11	2.1%	1.69%	Linear
Class 12	0.6%	1.69%	Linear
Class 13	0.4%	1.69%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (in.)	12
Traffic wander standard deviation (in.)	10
Design lane width (ft)	11

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

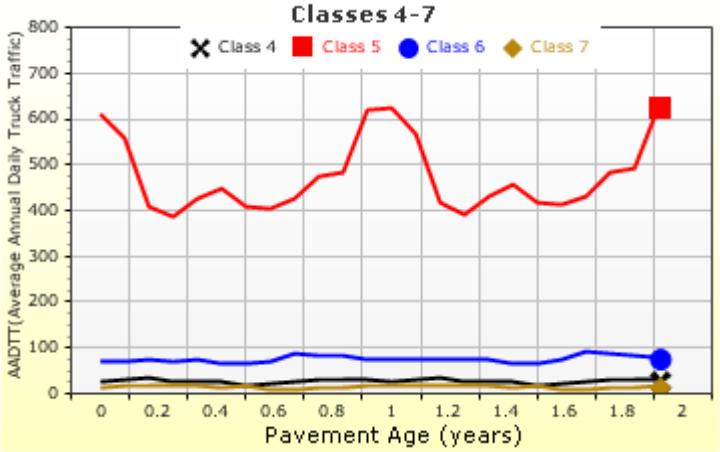
Wheelbase does not apply

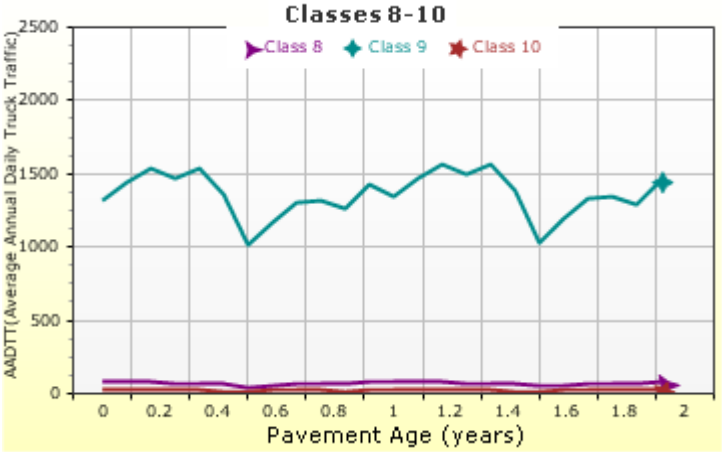
Number of Axles per Truck

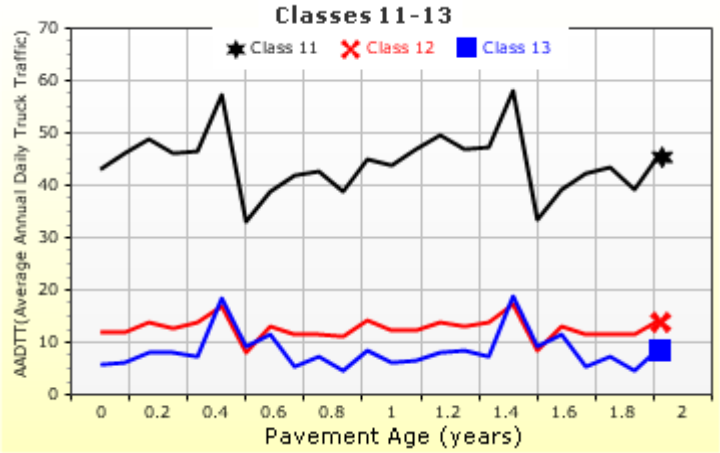
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

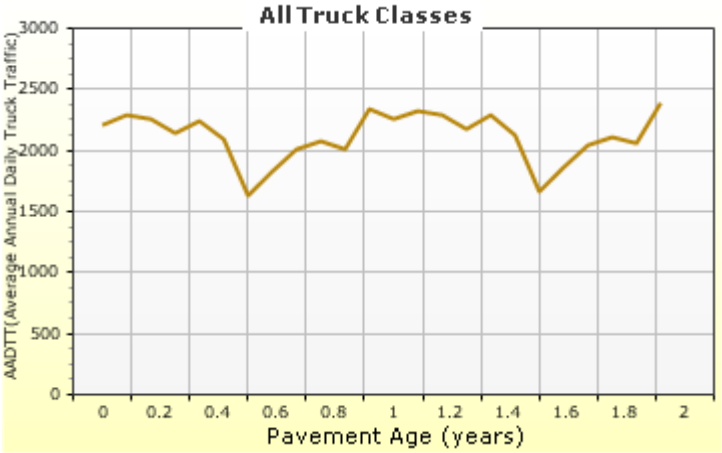
AADTT (Average Annual Daily Truck Traffic) Growth

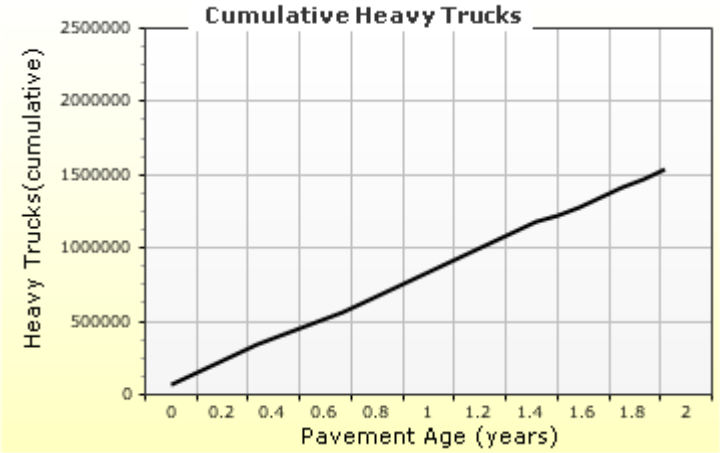
*** Traffic cap is not enforced**











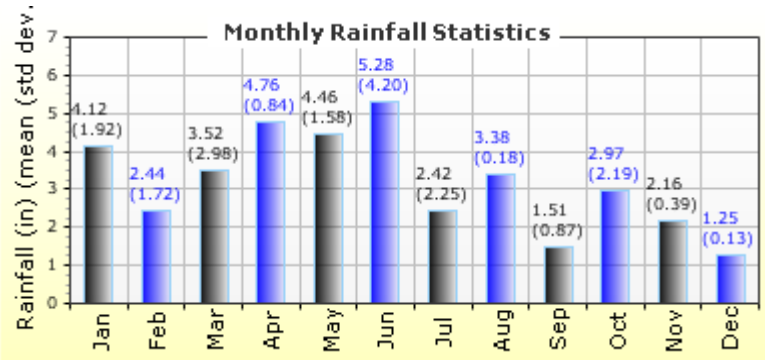
Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.82500 -86.29600 816
INDIANAPOLIS, IN	39.71000 -86.27200 790
MUNCIE, IN	40.23400 -85.39400 936

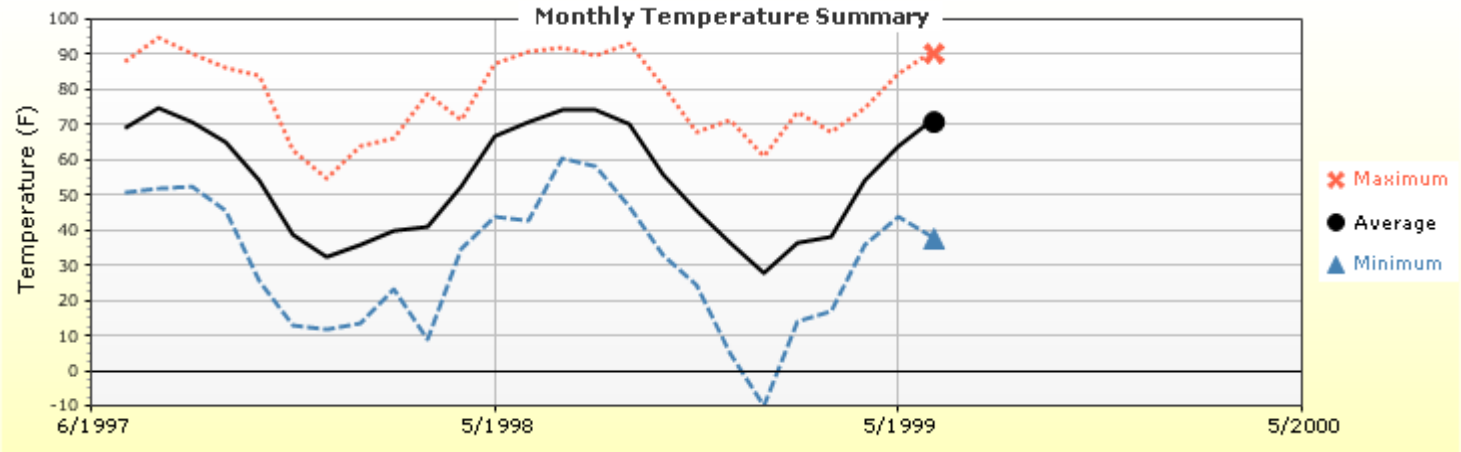
Annual Statistics:

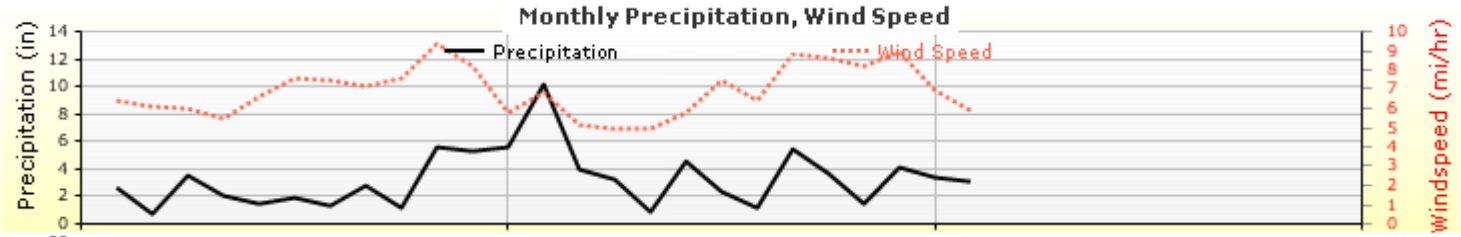
Mean annual air temperature (°F)	55.68
Mean annual precipitation (in.)	39.97
Freezing index (°F - days)	324.63
Average annual number of freeze/thaw cycles:	60.35

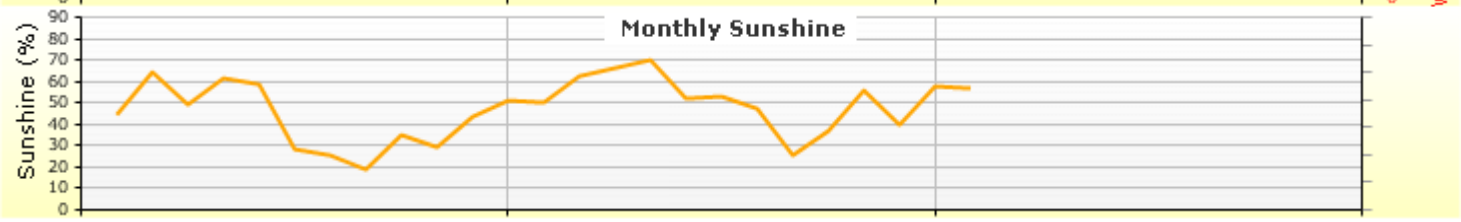


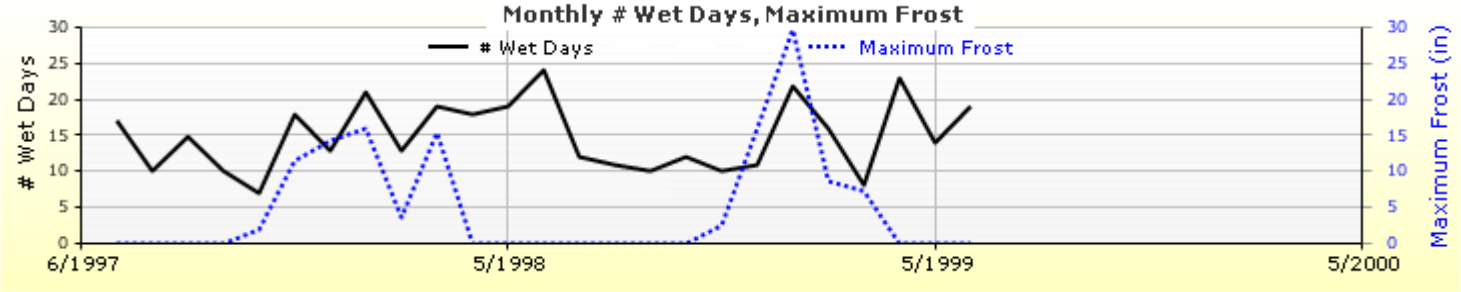
Water table depth (ft) 3.00

Monthly Climate Summary:

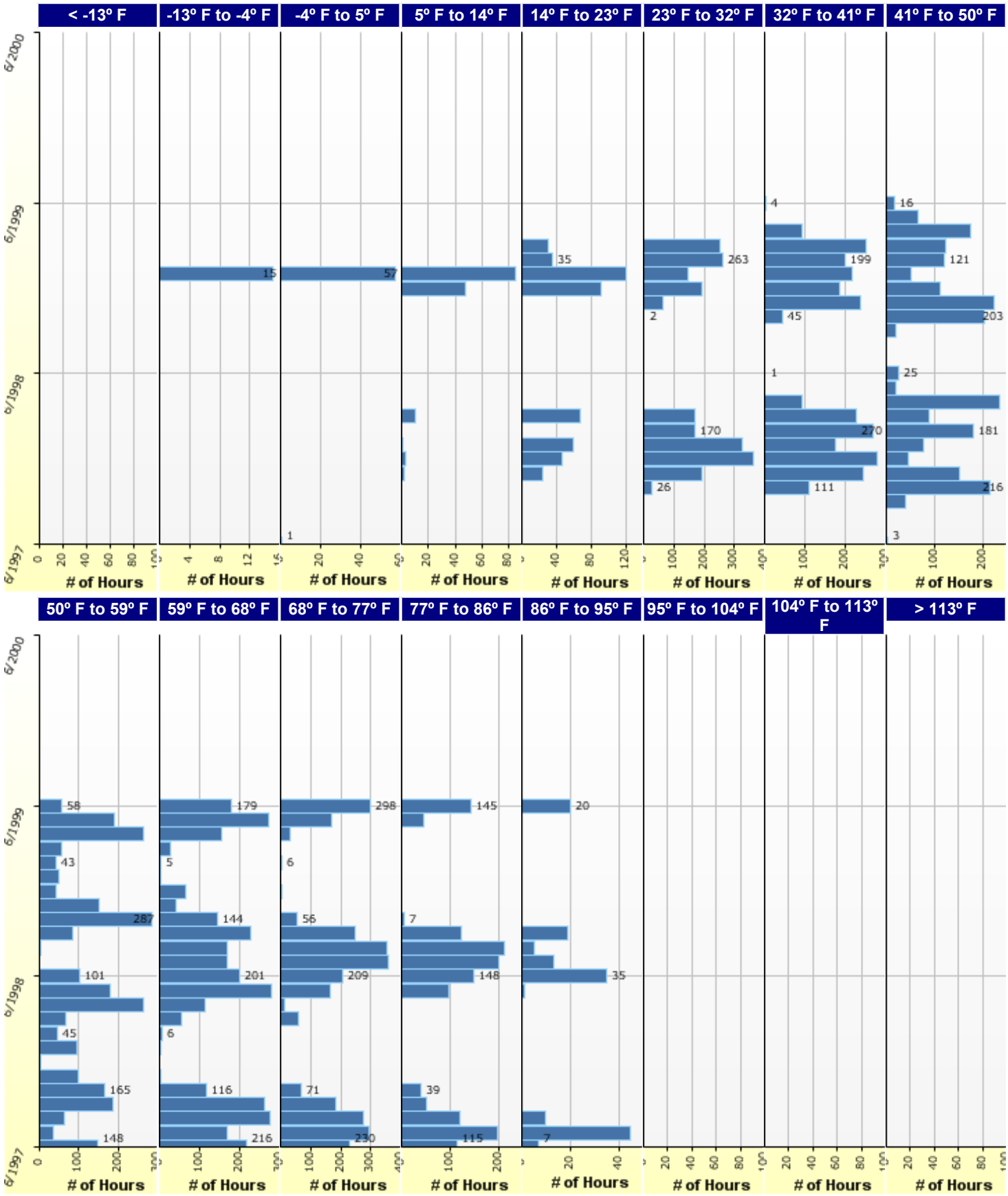








Hourly Air Temperature Distribution by Month:



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 : Greenfield 19.0mm PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Existing HMA (existing)	Flexible (1)	1.00
Layer 3 Non-stabilized Base : A-1 -a	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-7-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-7-6	Subgrade (5)	-

HMA Rehabilitation (Input Level: 3)

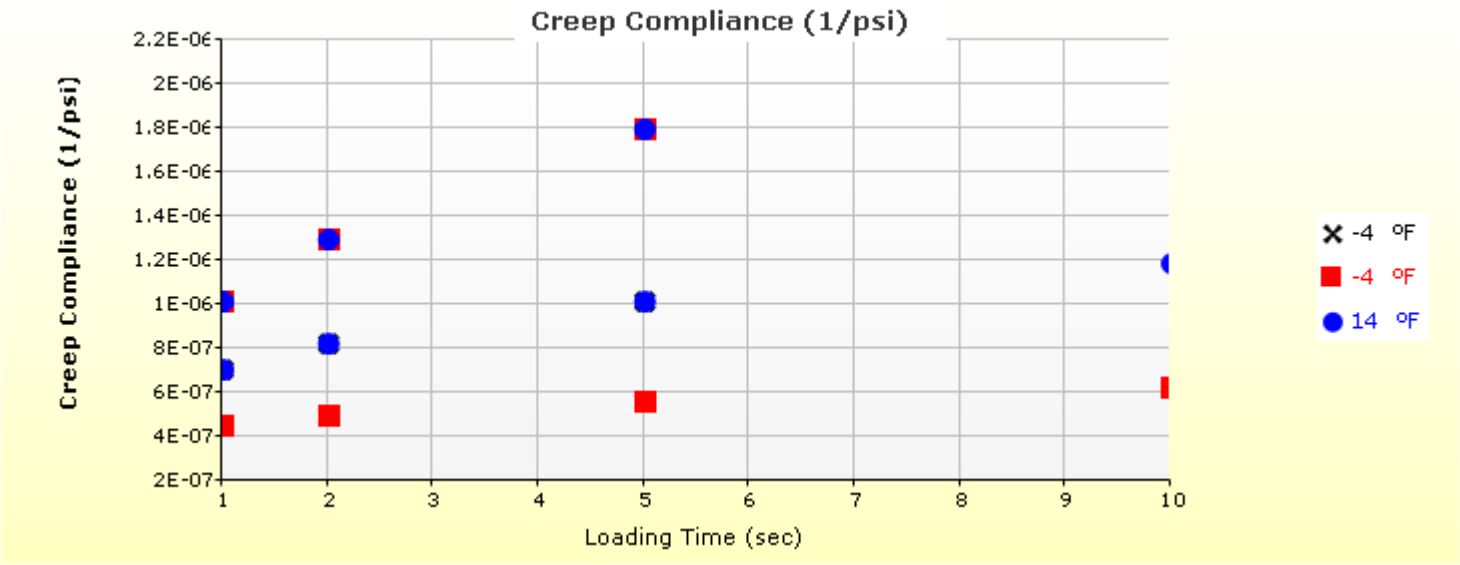
Milled thickness (in.)	-
Fatigue cracking (%)	-
Pavement rating	Fair
Total rut depth (in.)	0.10

Thermal Cracking (Input Level: 3)

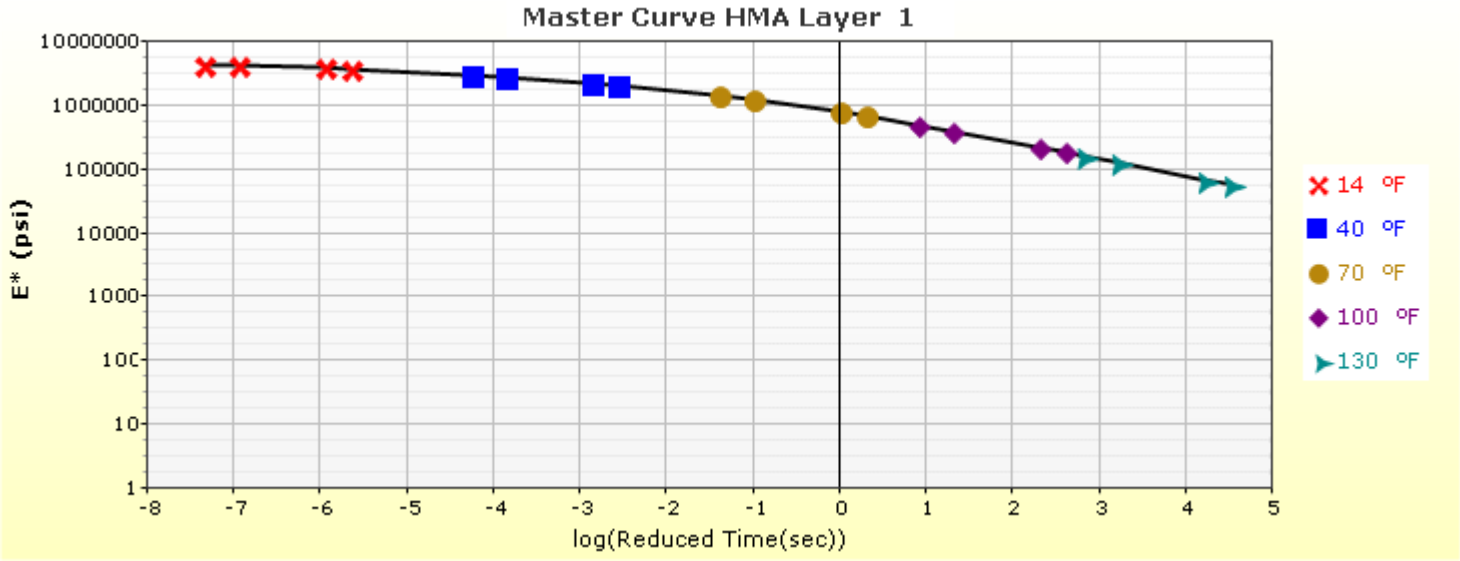
Indirect tensile strength at 14 ºF (psi)	601.83

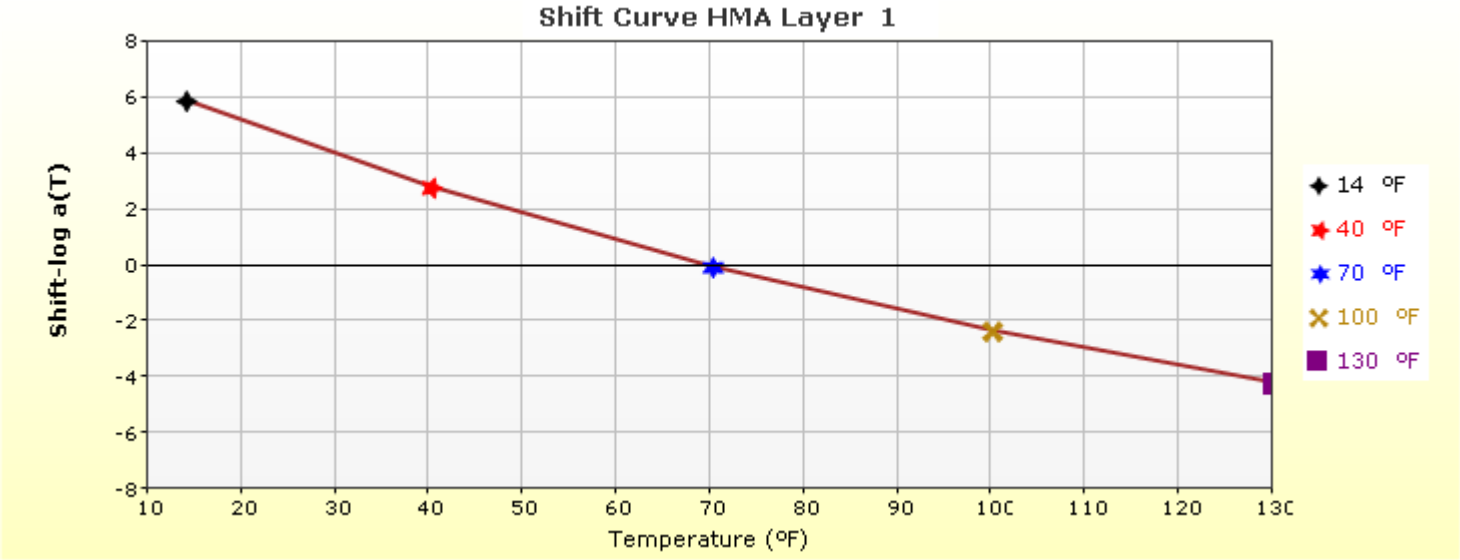
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	17.5

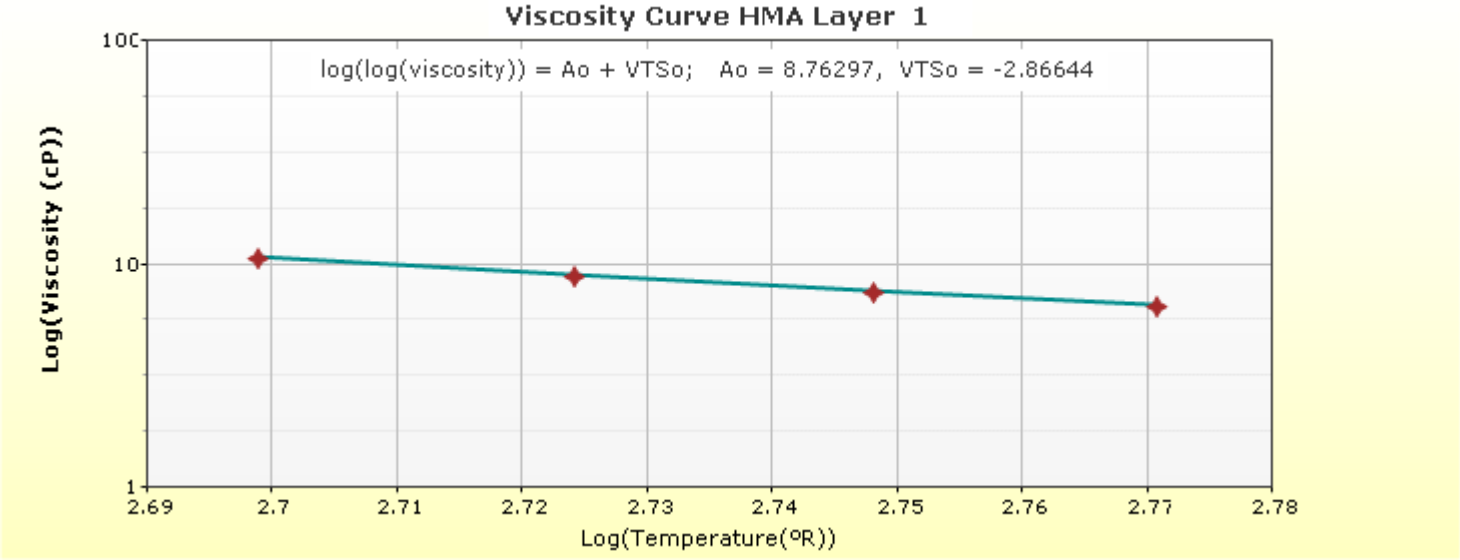
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	4.59e-007	4.59e-007	7.13e-007
1	7.13e-007	1.02e-006	1.02e-006
2	5.05e-007	5.05e-007	8.33e-007
2	8.33e-007	1.31e-006	1.31e-006
5	5.73e-007	5.73e-007	1.02e-006
5	1.02e-006	1.81e-006	1.81e-006
10	6.30e-007	6.30e-007	1.20e-006



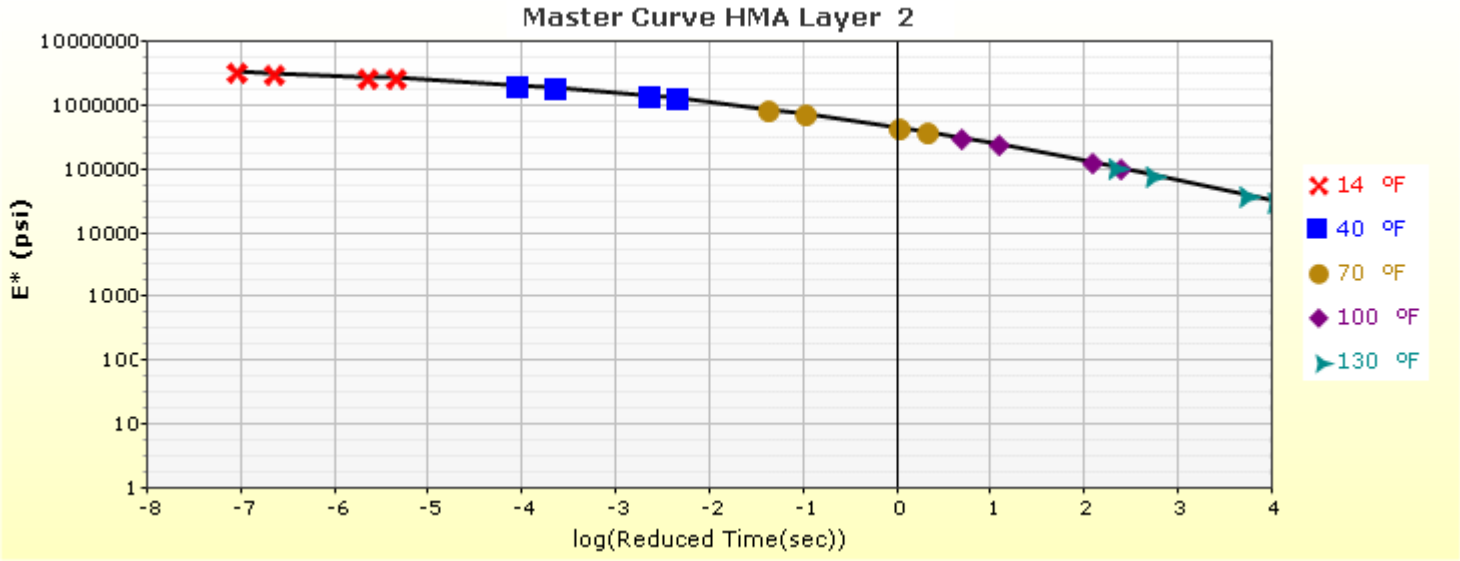
HMA Layer 1: Layer 1 Flexible : Greenfield 19.0mm PG76-22

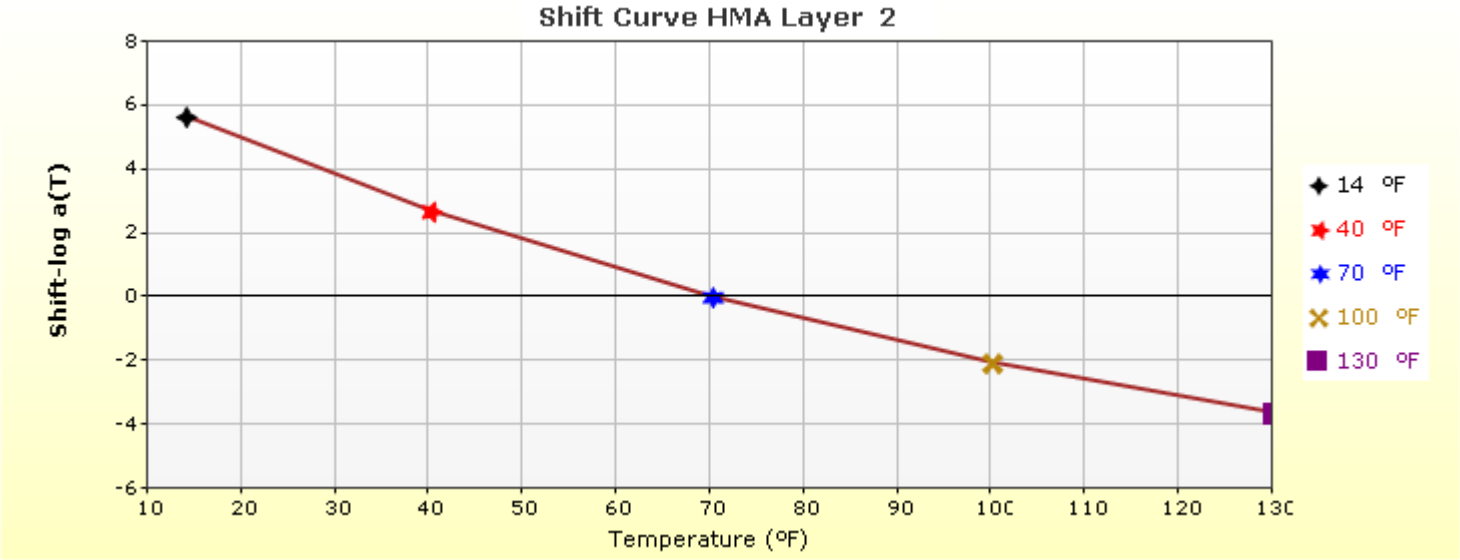


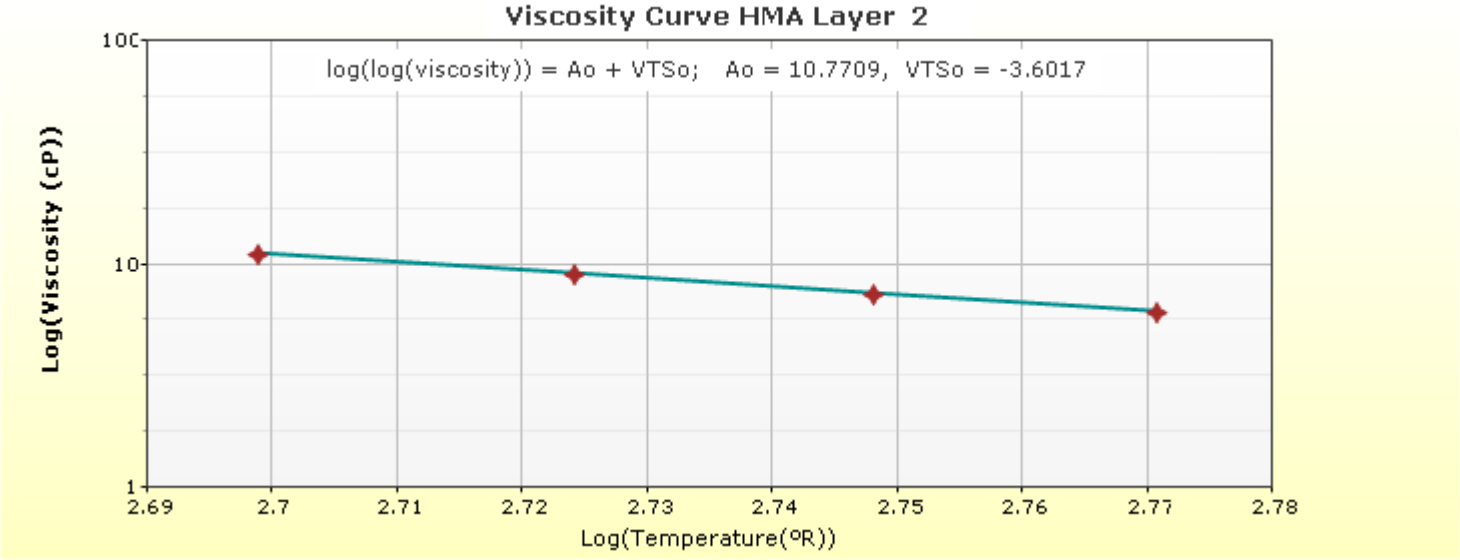




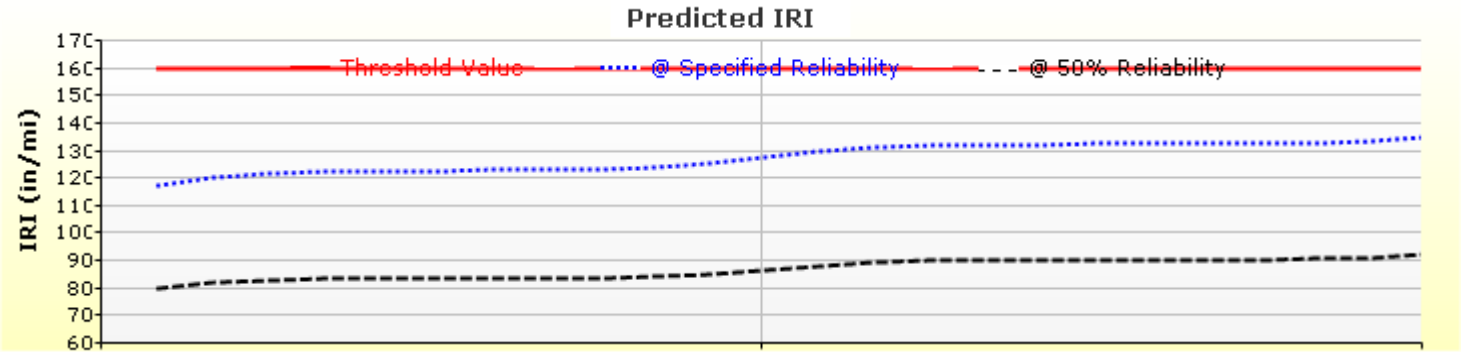
HMA Layer 2: Layer 2 Flexible : Existing HMA(existing)

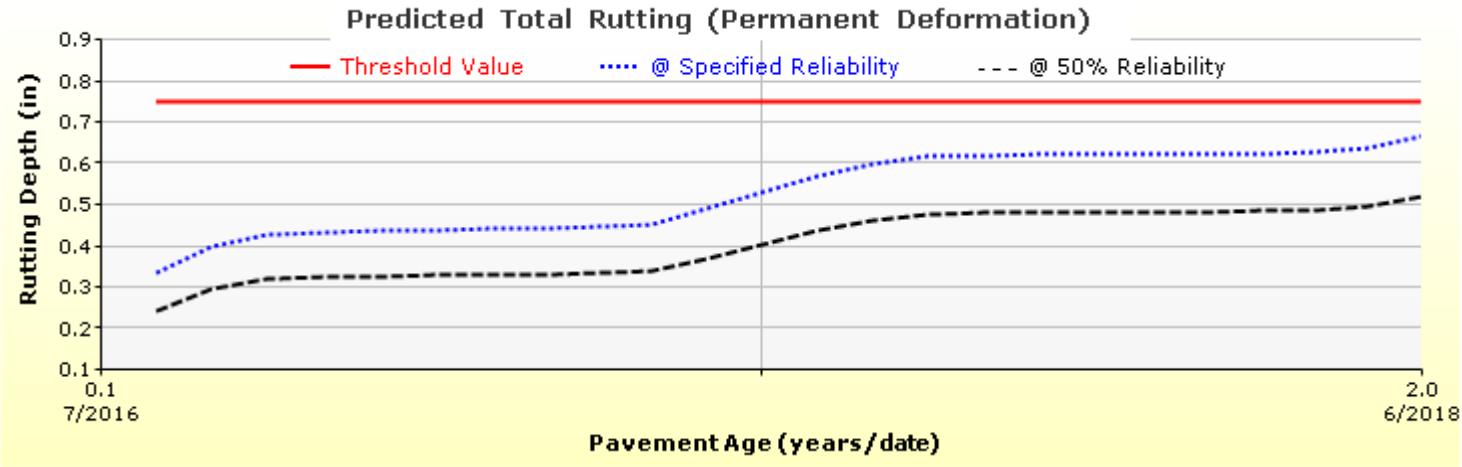


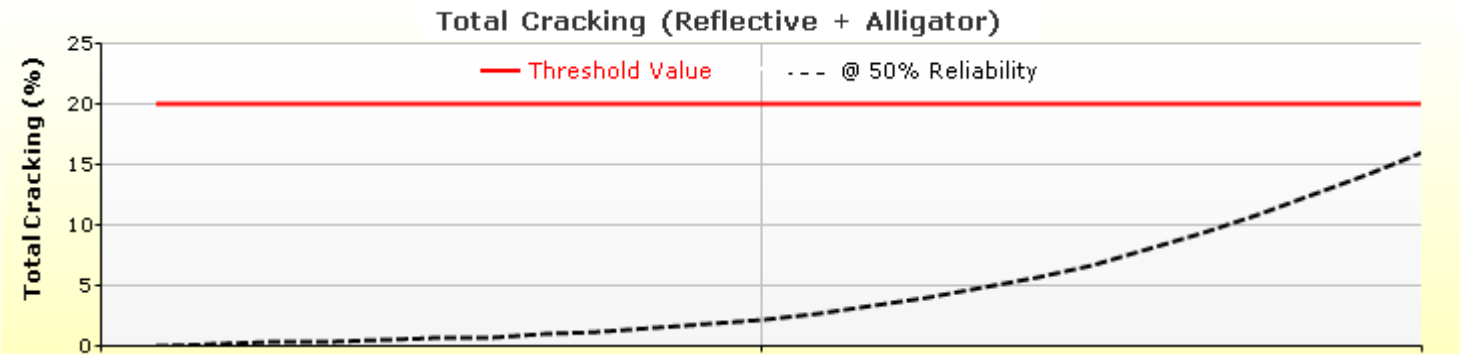


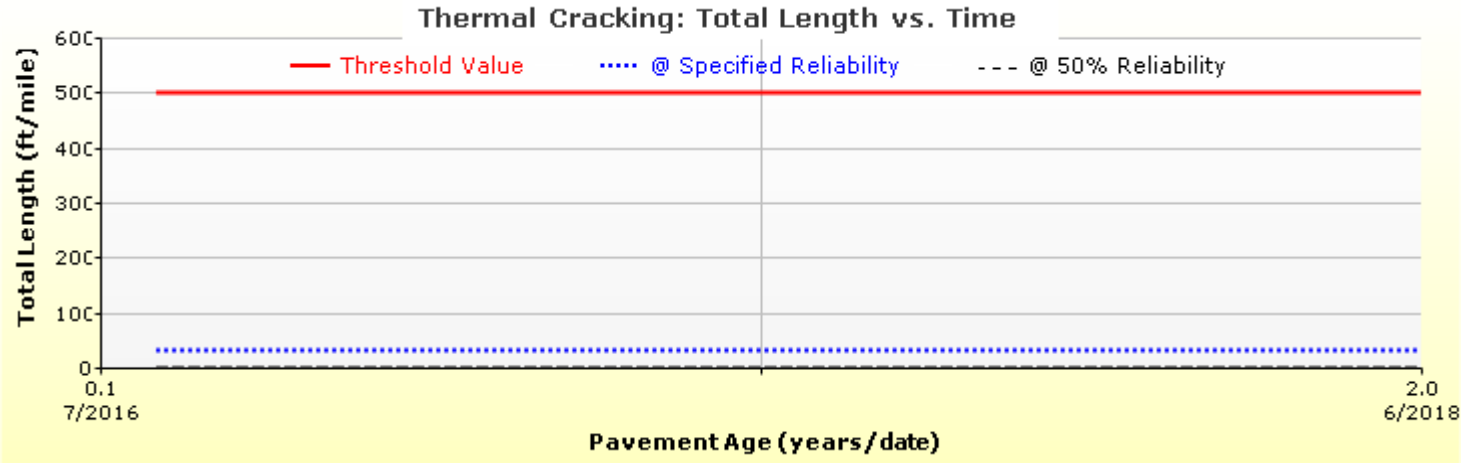


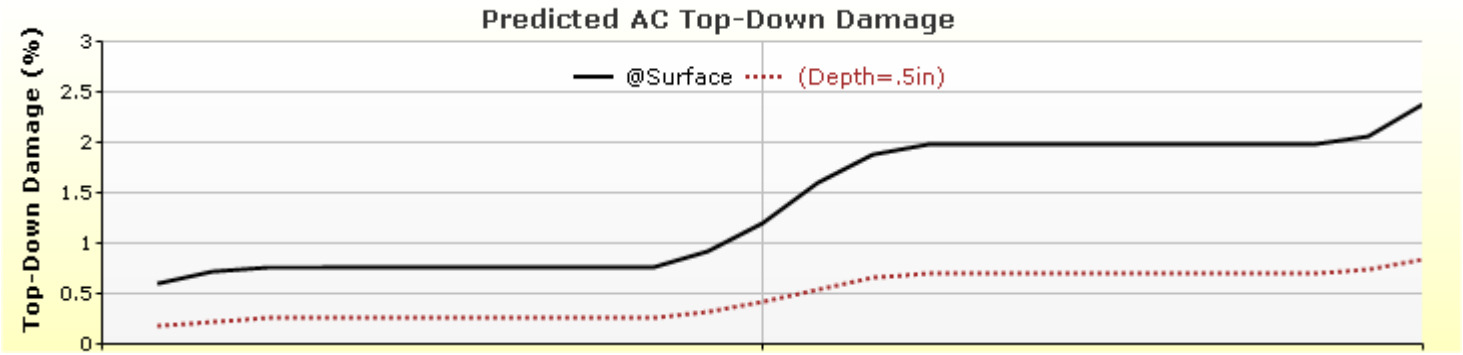
Analysis Output Charts

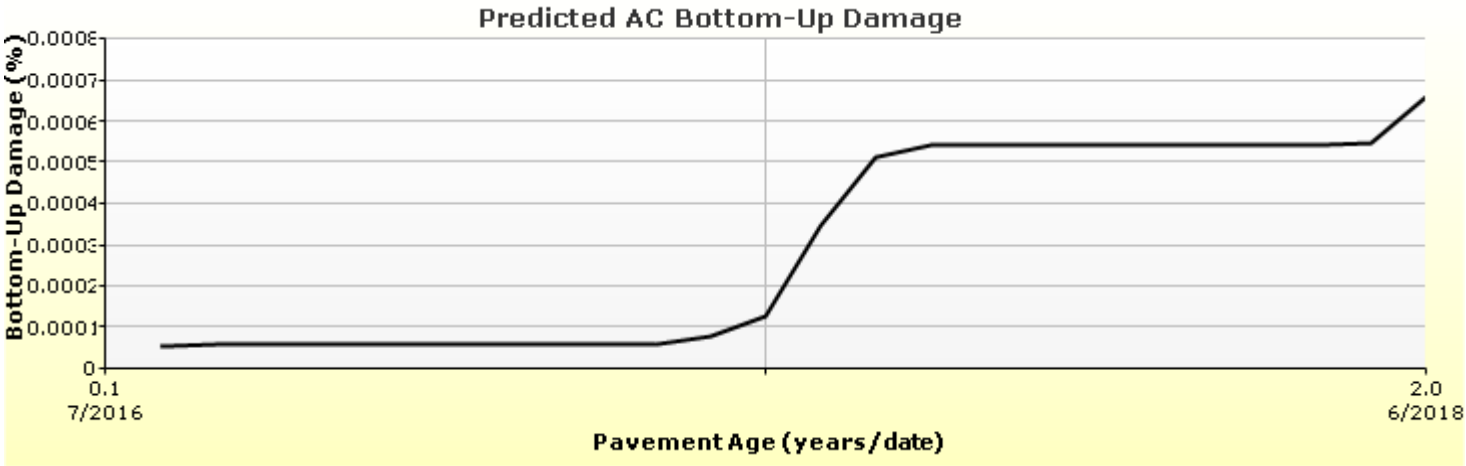


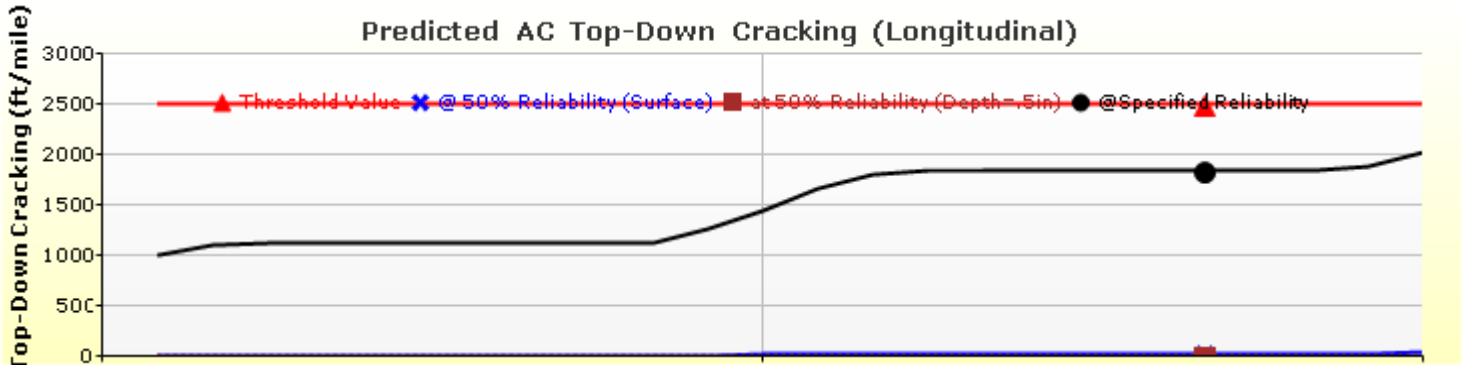


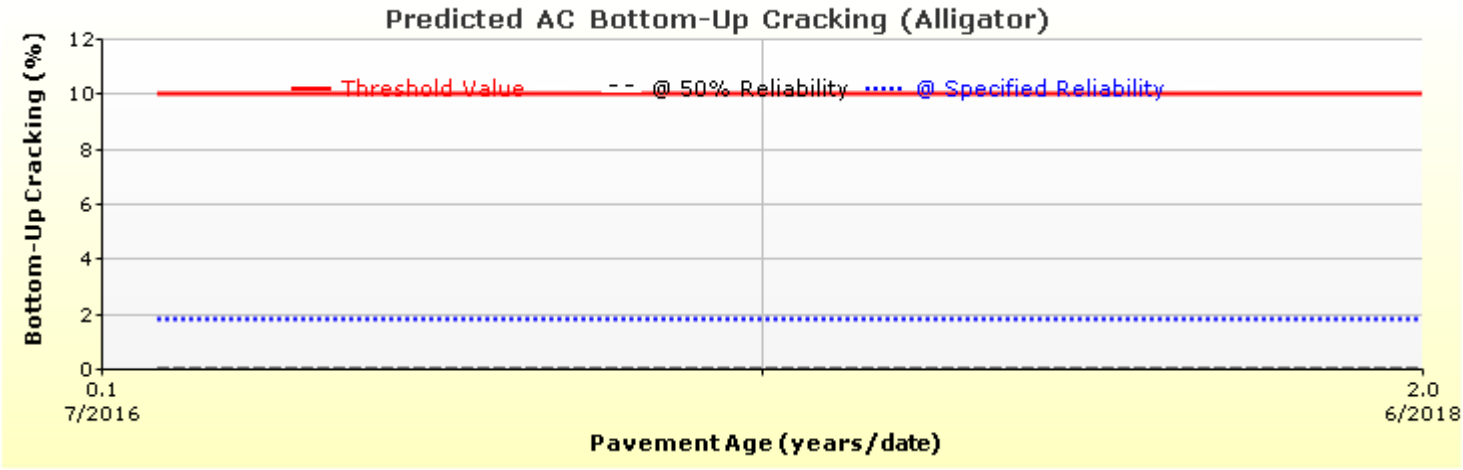


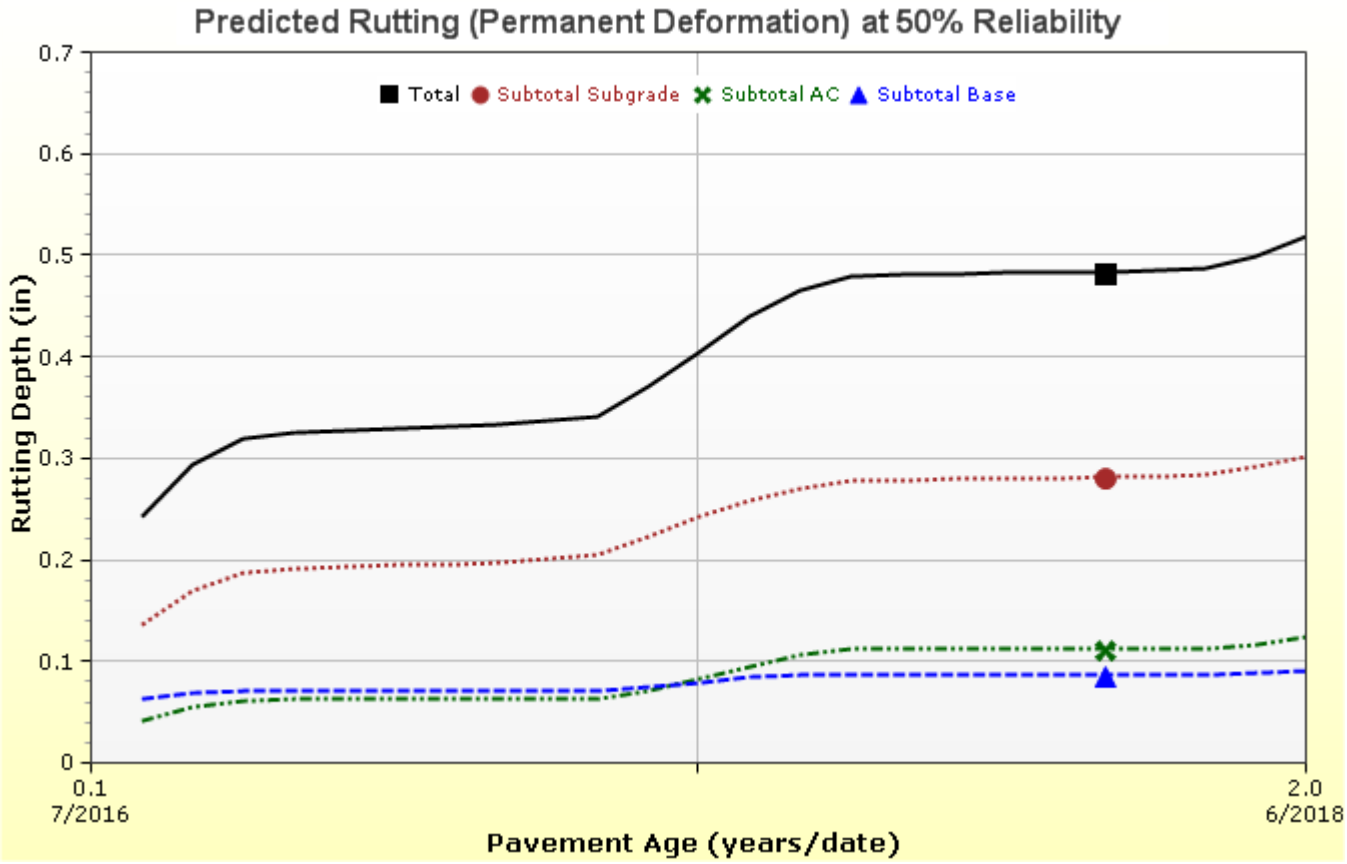


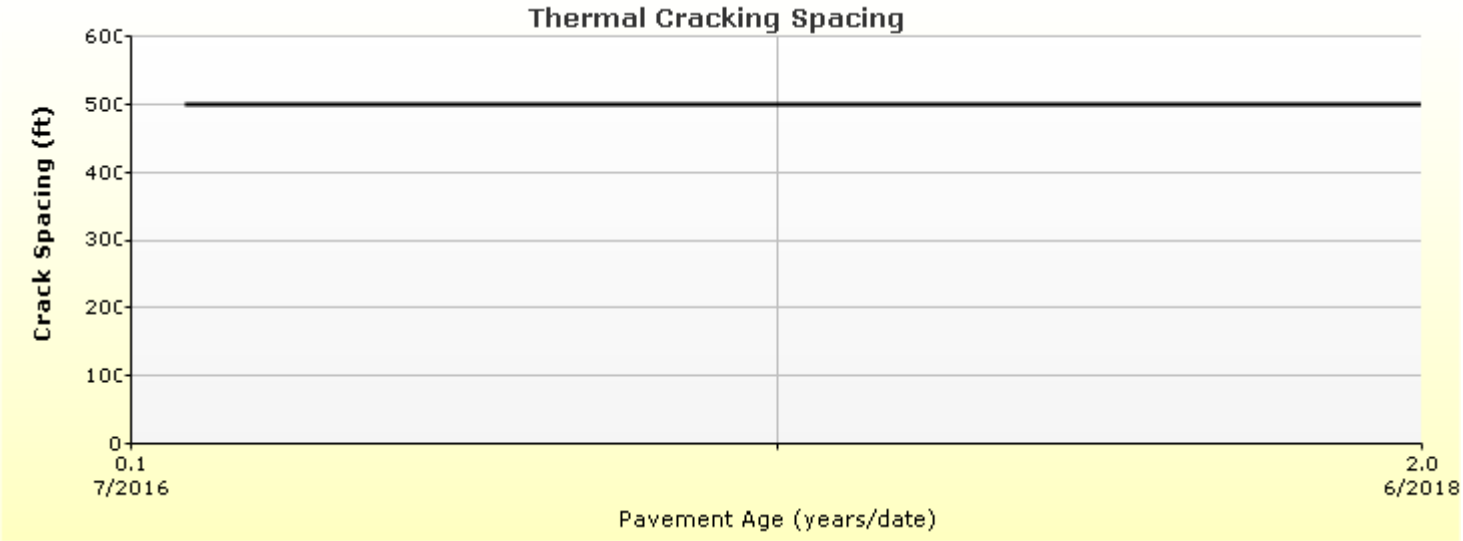

Predicted AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=.5in)
0
0.5
1
1.5
2
2.5
3

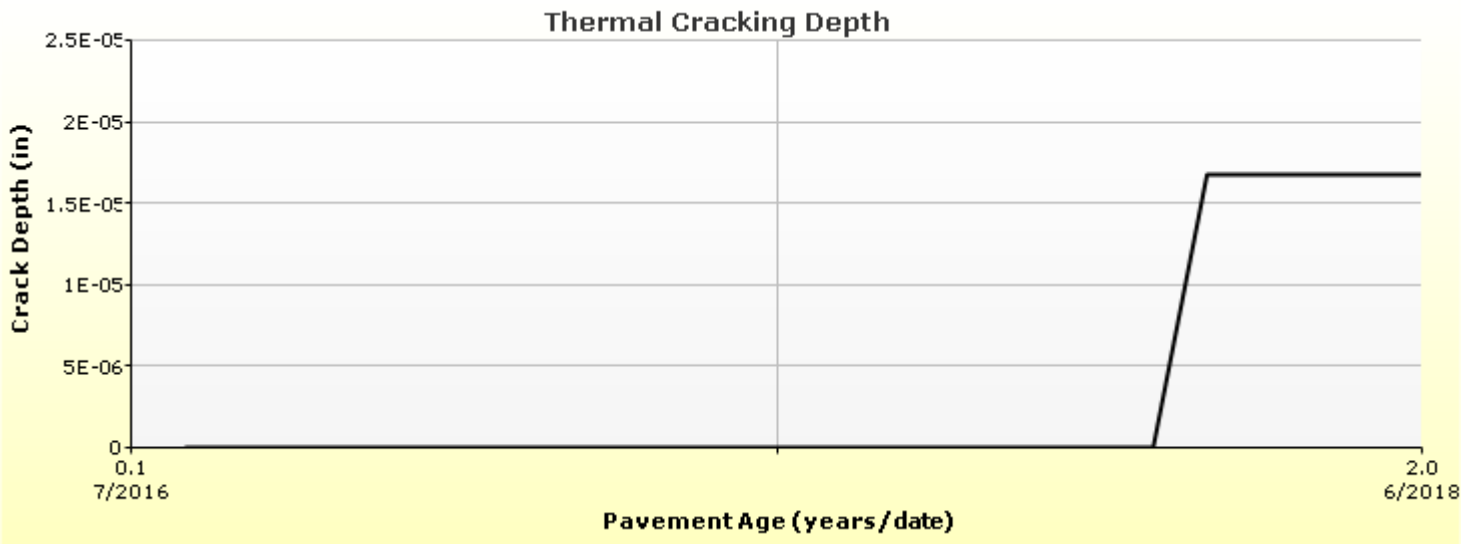

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)

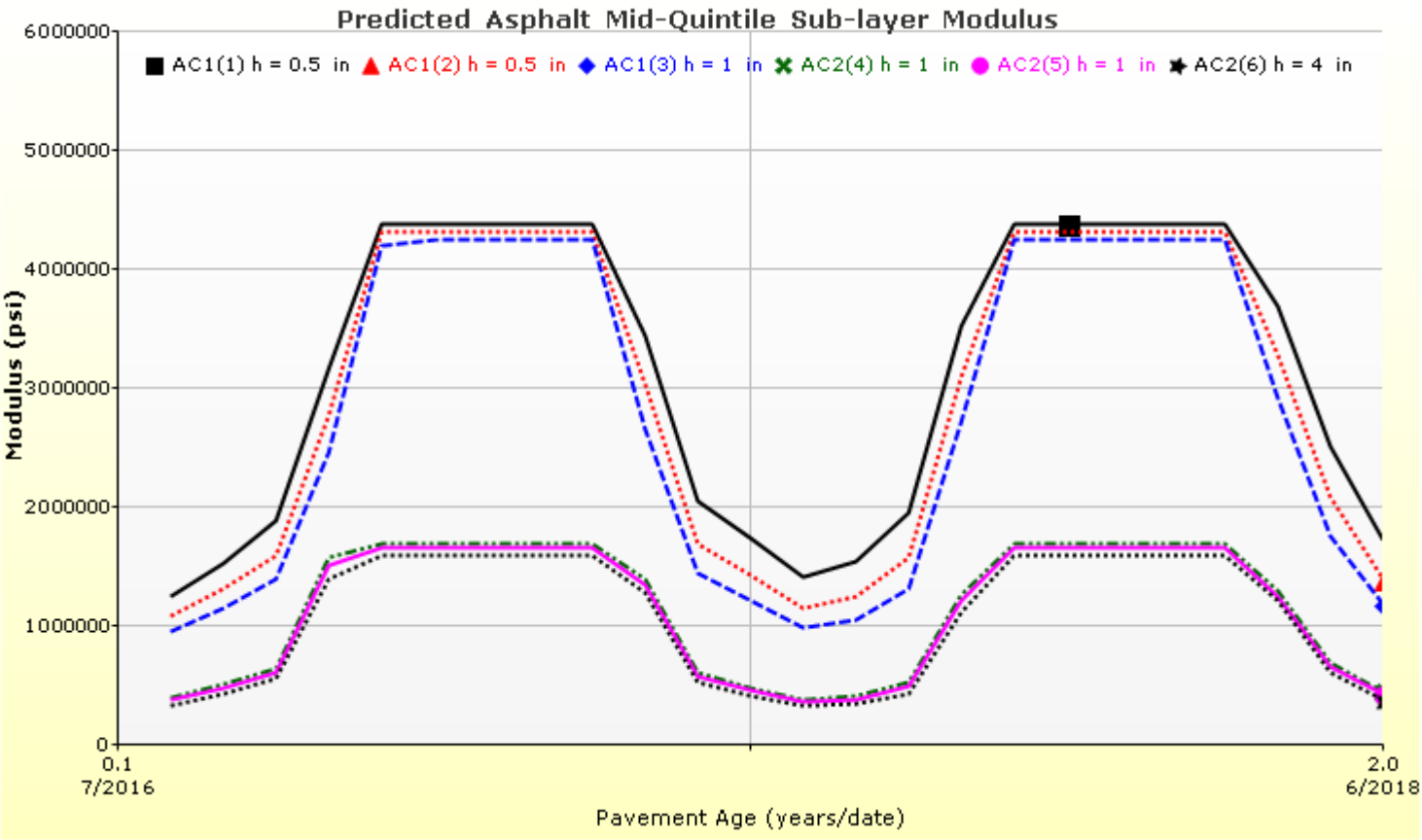

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
Threshold Value
@ 50% Reliability (Surface)
@ 50% Reliability (Depth=.5in)
@Specified Reliability
0
500
1000
1500
2000
2500
3000

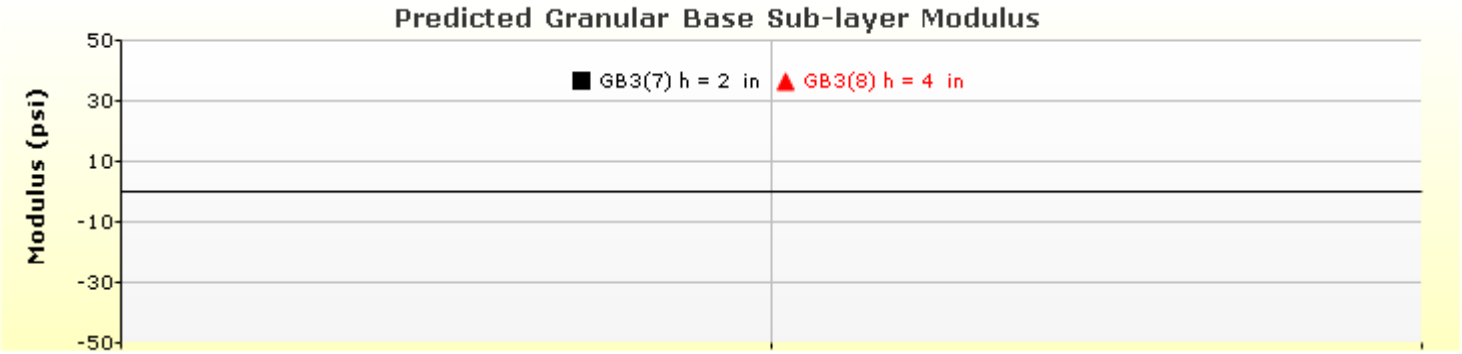

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
2
4
6
8
10
12
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)

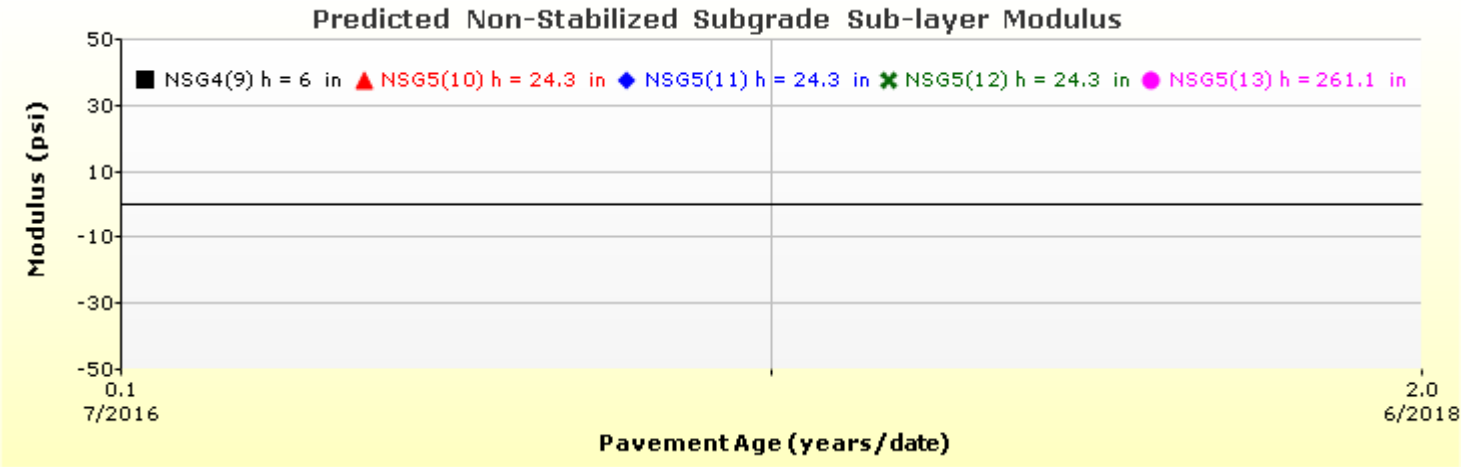

Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rutting Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
2.5E-05
2E-05
1.5E-05
1E-05
5E-06
0
0.1
7/2016
2.0
6/2018
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
AC2(4) h = 1 in
AC2(5) h = 1 in
AC2(6) h = 4 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)


Predicted Granular Base Sub-layer Modulus
GB3(7) h = 2 in
GB3(8) h = 4 in
Modulus (psi)
50
30
10
-10
-30
-50


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(9) h = 6 in
NSG5(10) h = 24.3 in
NSG5(11) h = 24.3 in
NSG5(12) h = 24.3 in
NSG5(13) h = 261.1 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1
7/2016
2.0
6/2018
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield 19.0mm PG76-22

Asphalt		
Thickness (in.)	2.0	
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	2844521	3518316	4084950	4969012
40	2498125	2540381	2660112	2962037
70	499696	778904	1058035	1250008
100	98245	203329	367124	469716
130	38083	73323	145389	193942

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 19.0mm PG76-22
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(existing)

Asphalt		
Thickness (in.)	6.0	
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 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)
5000.0

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

Identifiers

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

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	127.7
Saturated hydraulic conductivity (ft/hr)	False	5.054e-02
Specific gravity of solids	False	2.7
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-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 5 Subgrade : A-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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	Accelerate Cracking by 2 years
< 4"	0.6	3
4 – 6"	0.7	1.7
> 6"	0.8	1.4

C: 1	D: 1

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

Profile Corrections along Mainline I-69

Technical Proposal / I-69 Major Moves 2020 Expansion

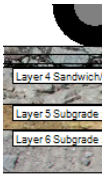
Mainline Overlay_Profile Correction

File Name: C:\My ME Design\Projects\MK15-469\PostReport\Mainline Overlay_Profile Correction.dgpx

Design Inputs

Design Life:	16 years	Base construction:	May, 1989	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	AC_FRAC_JPCP	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 12.5mm PG76-22	2.0
Flexible	Existing HMA	1.0
Stabilized	Fractured JPCP	8.7
Subgrade	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

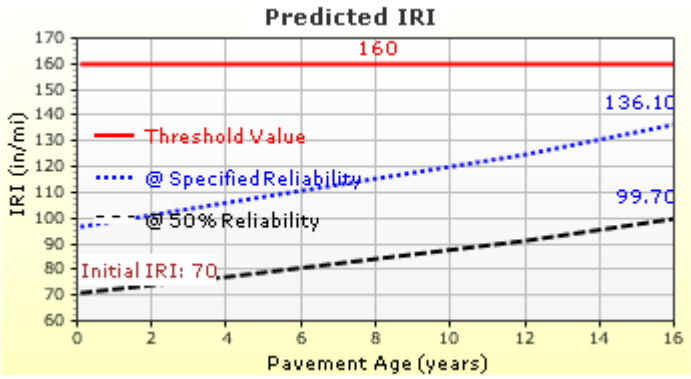
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	5,664
2024 (8 years)	5,631,700
2032 (16 years)	11,652,300

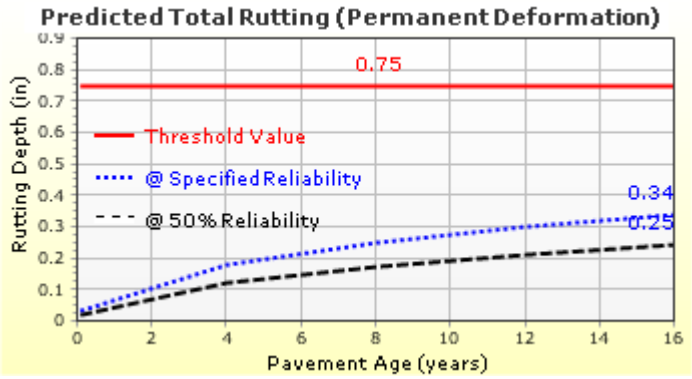
Design Outputs

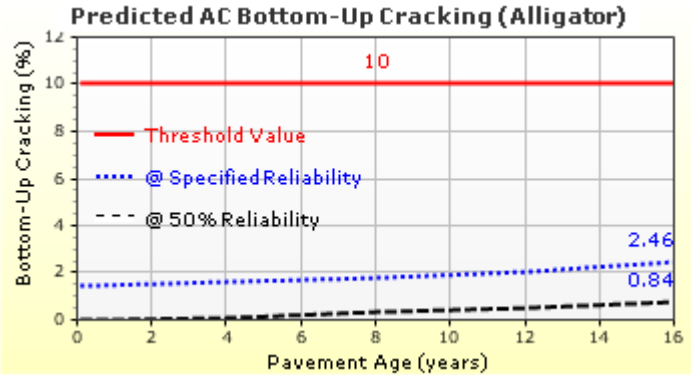
Distress Prediction Summary

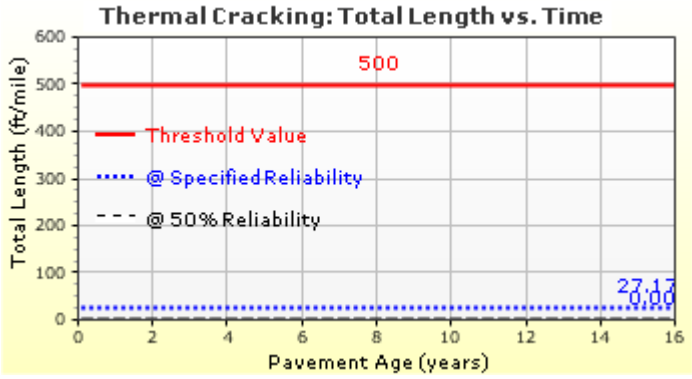
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	136.05	90.00	98.32	Pass
Permanent deformation - total pavement (in.)	0.75	0.34	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	2.46	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2500.00	521.21	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.31	90.00	99.41	Pass

Distress Charts





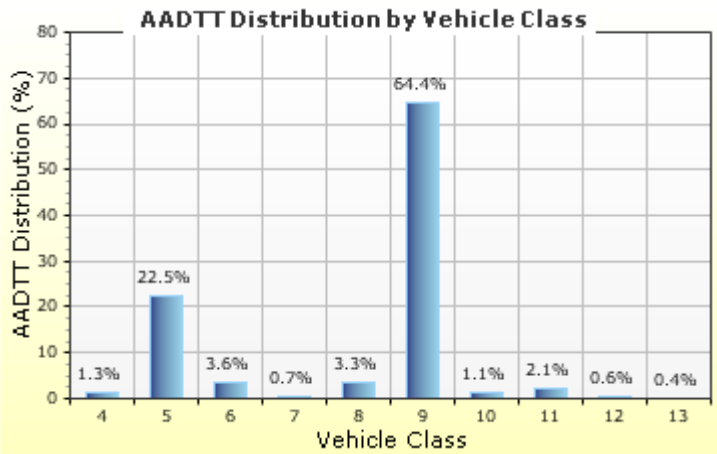


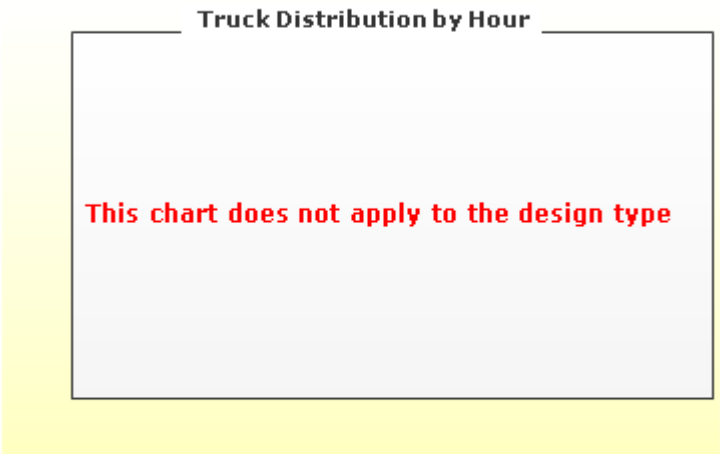


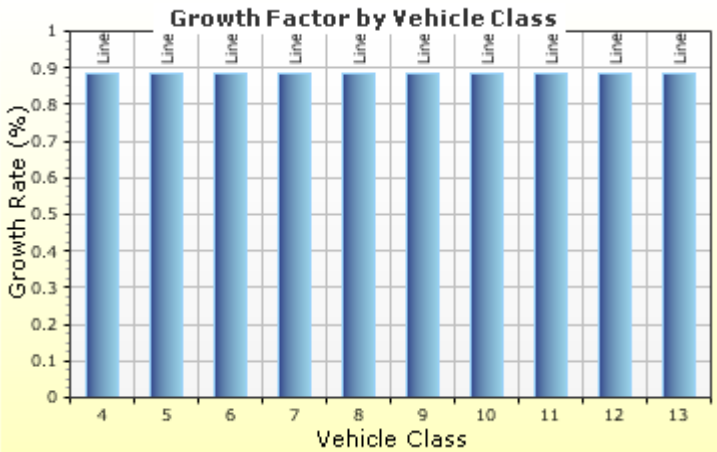
Traffic Inputs

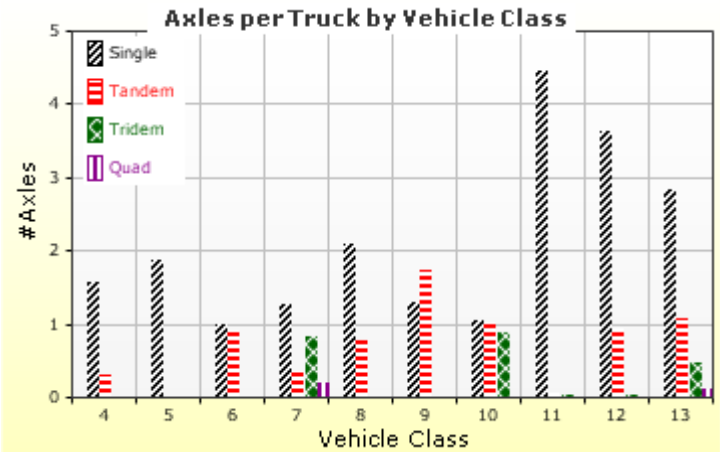
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,664	Percent of trucks in design direction (%):	55.0
Number of lanes in design direction:	3	Percent of trucks in design lane (%):	60.0
		Operational speed (mph)	55.0

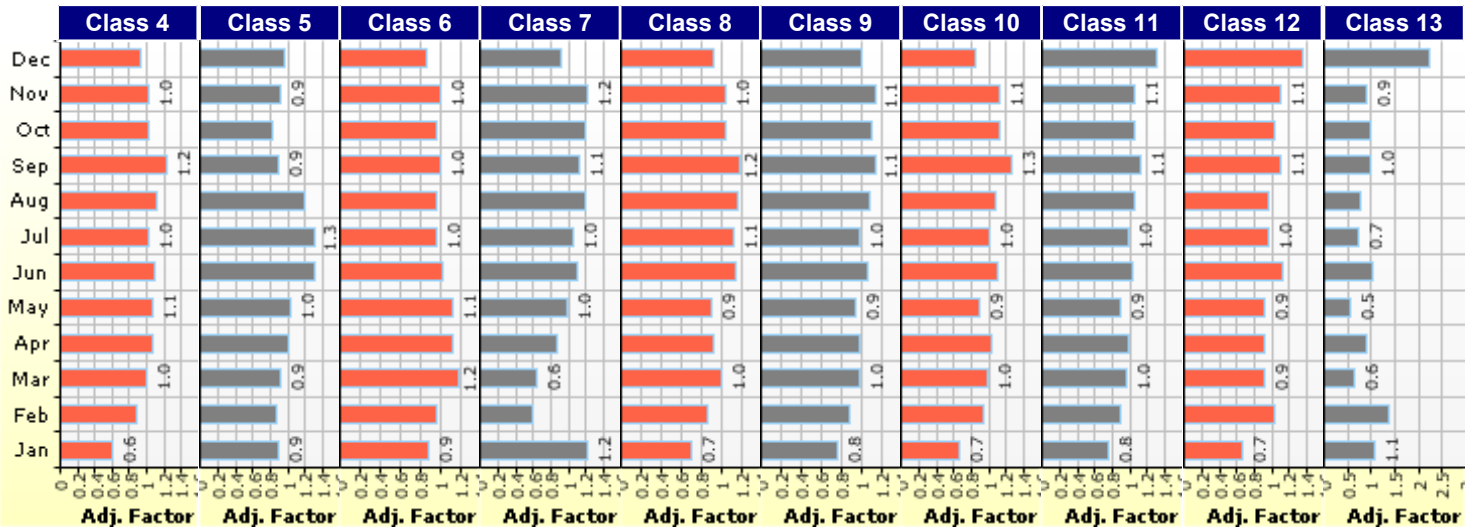








Traffic Volume Monthly Adjustment Factors



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	0.6	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%	0.89%	Linear
Class 5	22.5%	0.89%	Linear
Class 6	3.6%	0.89%	Linear
Class 7	0.7%	0.89%	Linear
Class 8	3.3%	0.89%	Linear
Class 9	64.4%	0.89%	Linear
Class 10	1.1%	0.89%	Linear
Class 11	2.1%	0.89%	Linear
Class 12	0.6%	0.89%	Linear
Class 13	0.4%	0.89%	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

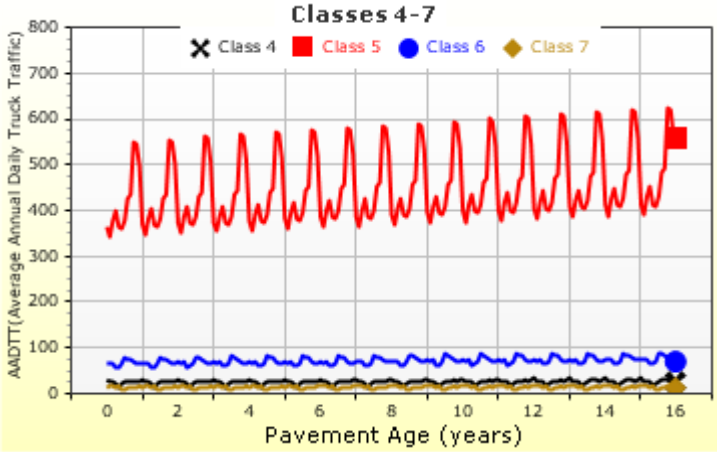
Wheelbase does not apply

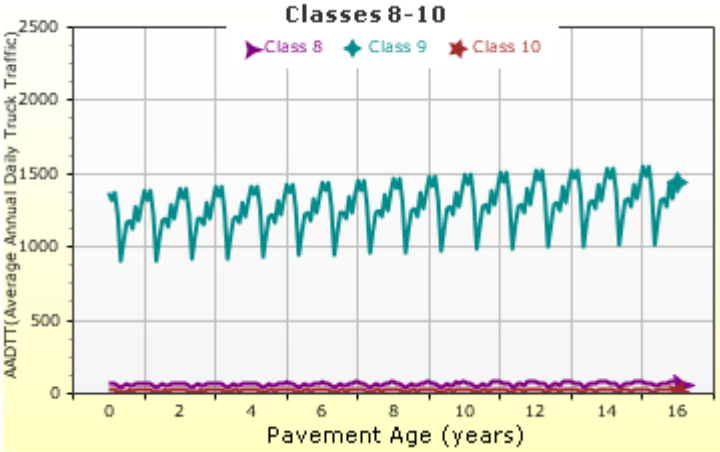
Number of Axles per Truck

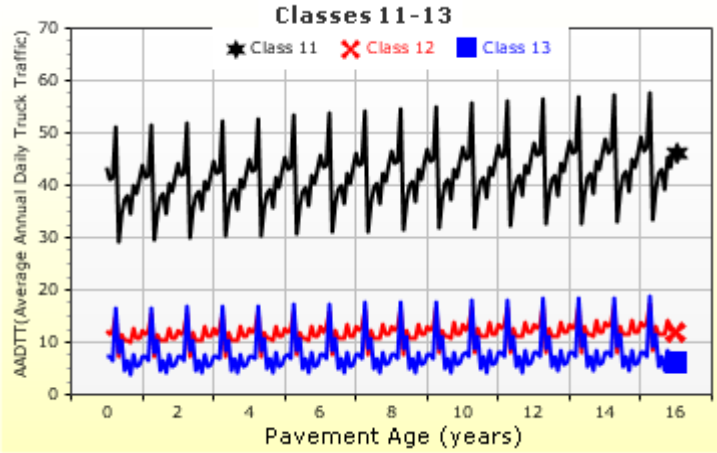
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

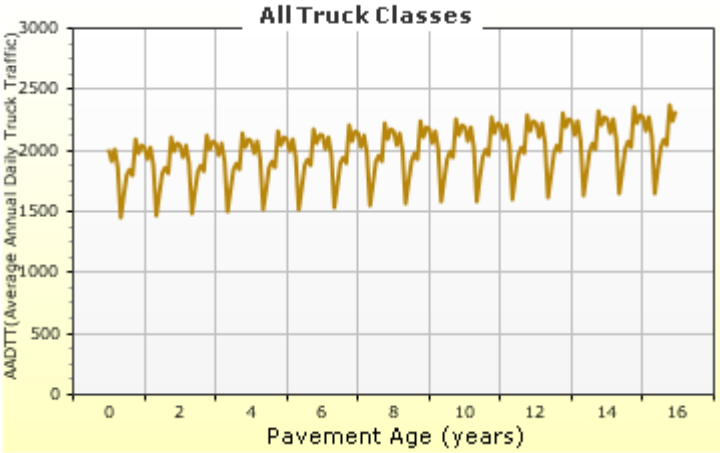
AADTT (Average Annual Daily Truck Traffic) Growth

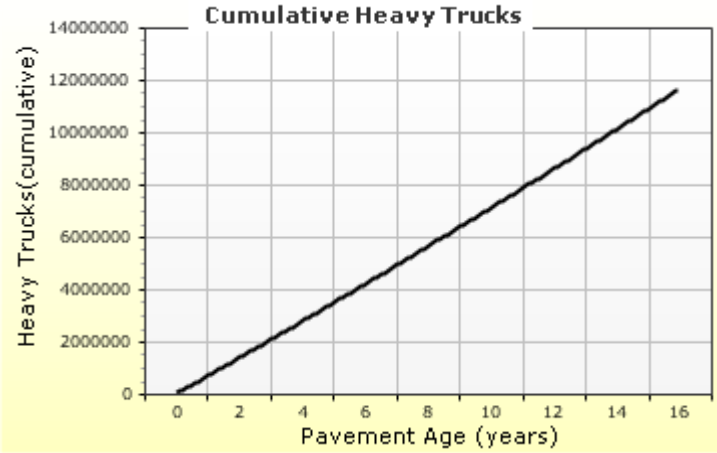
*** Traffic cap is not enforced**







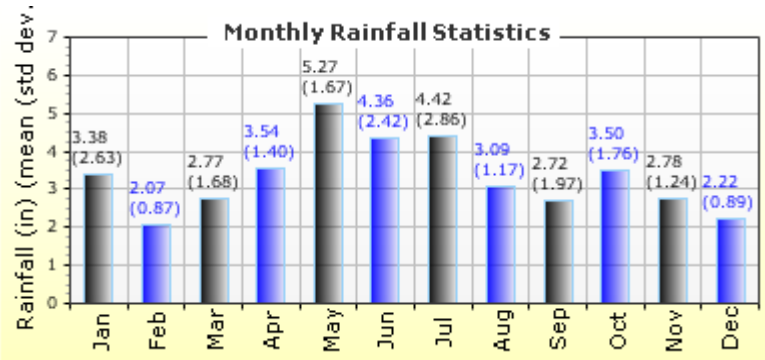




Climate Inputs

Climate Data Sources:

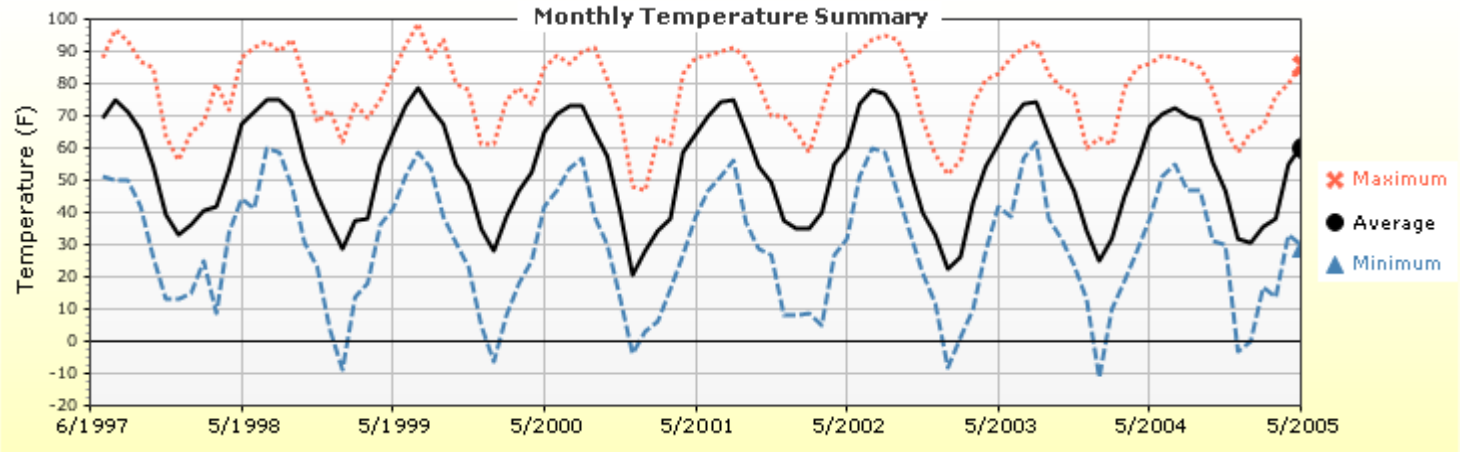
Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

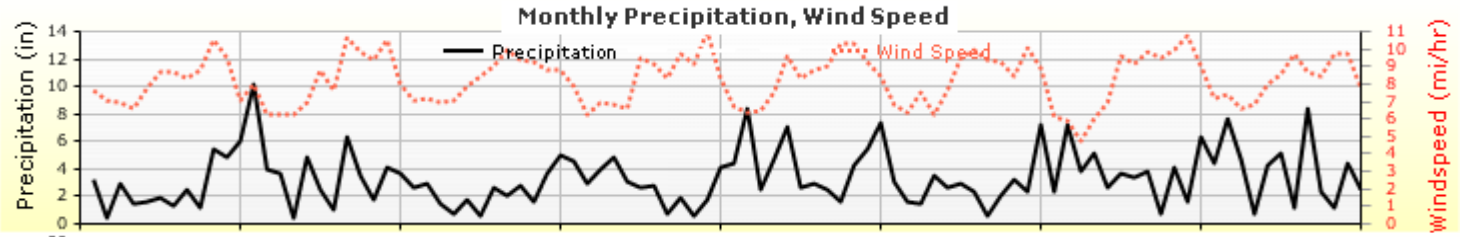


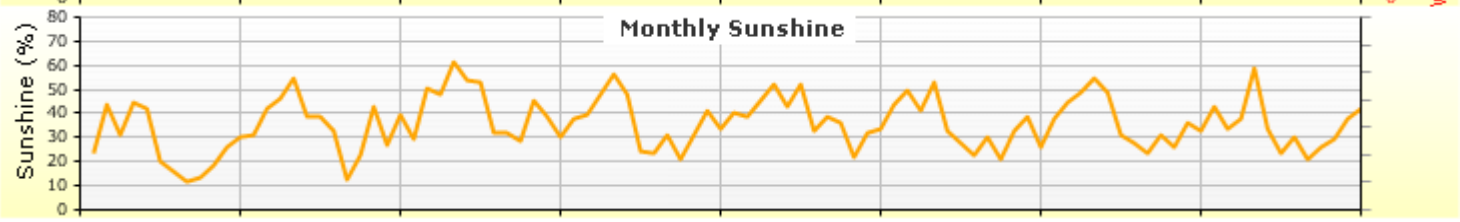
Annual Statistics:

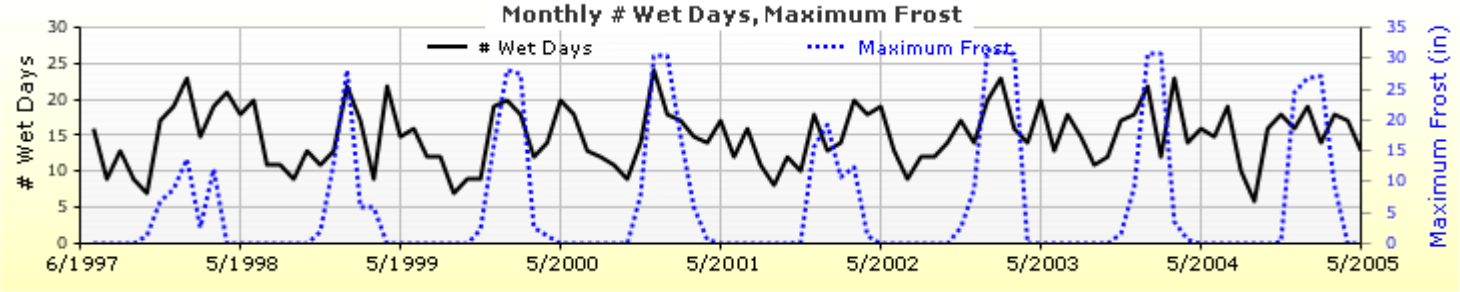
Mean annual air temperature (ºF)	53.75
Mean annual precipitation (in.)	40.11
Freezing index (ºF - days)	475.95
Average annual number of freeze/thaw cycles:	54.86
Water table depth (ft)	5.00

Monthly Climate Summary:

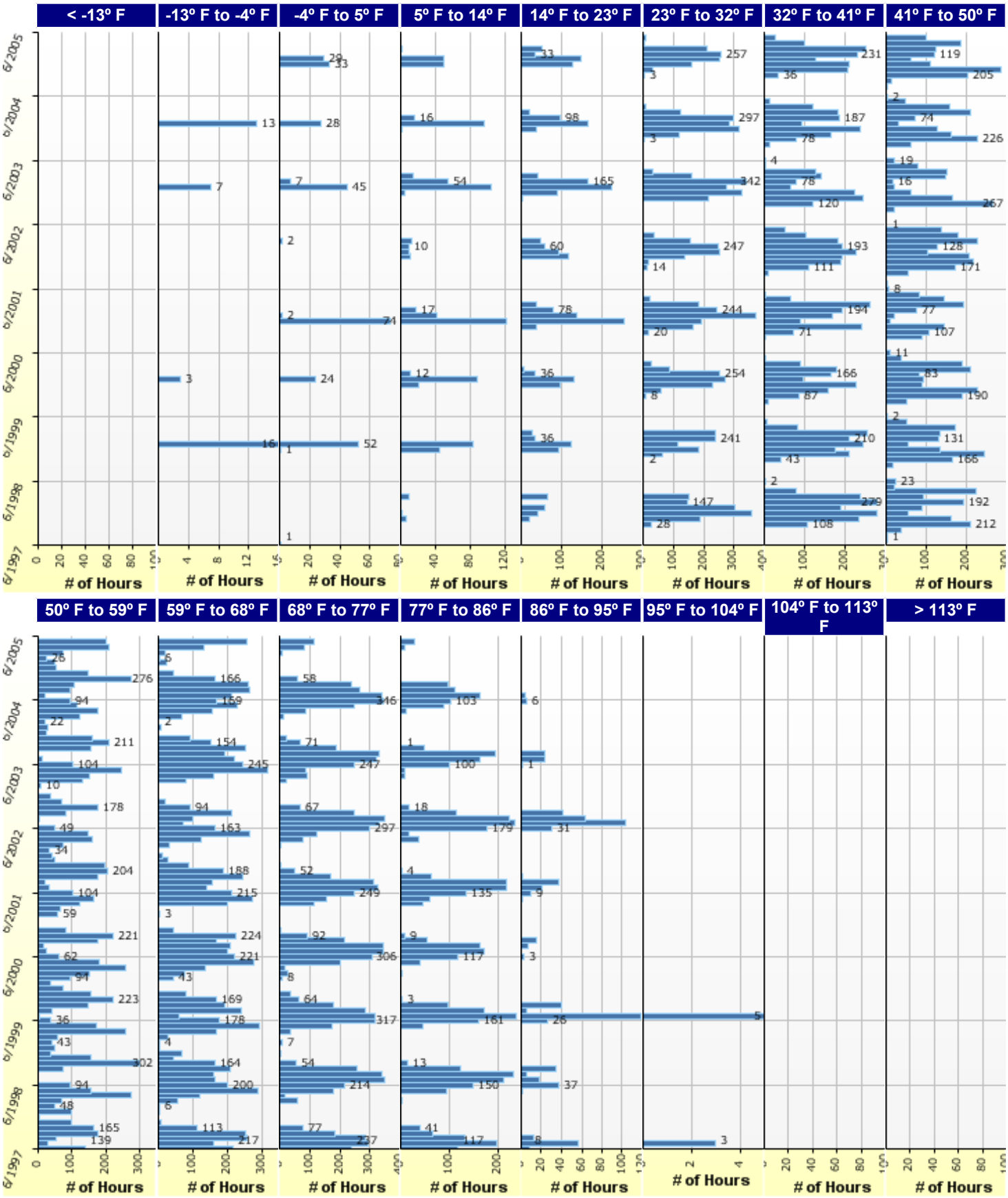








Hourly Air Temperature Distribution by Month:



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

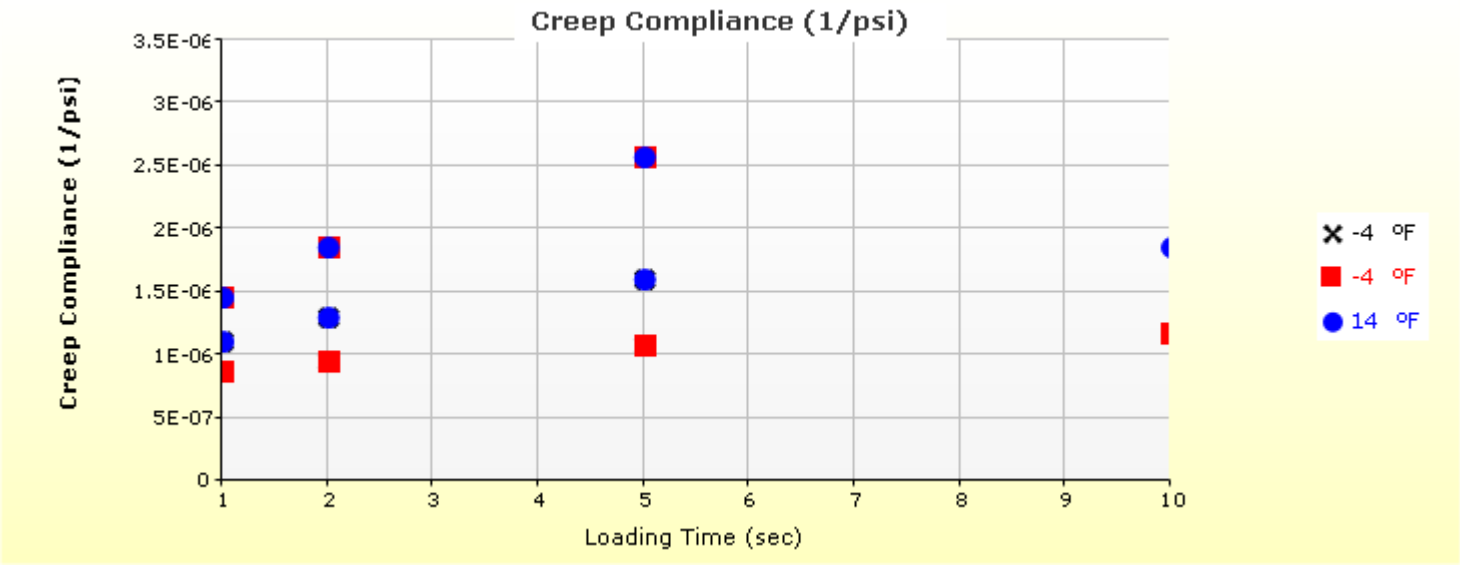
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield SMA PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 12.5mm PG76-22	Flexible (1)	1.00
Layer 3 Flexible : Existing HMA	Flexible (1)	1.00
Layer 4 Sandwich/Fractured : Fractured JPCP	Sandwiched Granular (3)	1.00
Layer 5 Subgrade : Crushed stone	Subgrade (5)	1.00
Layer 6 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

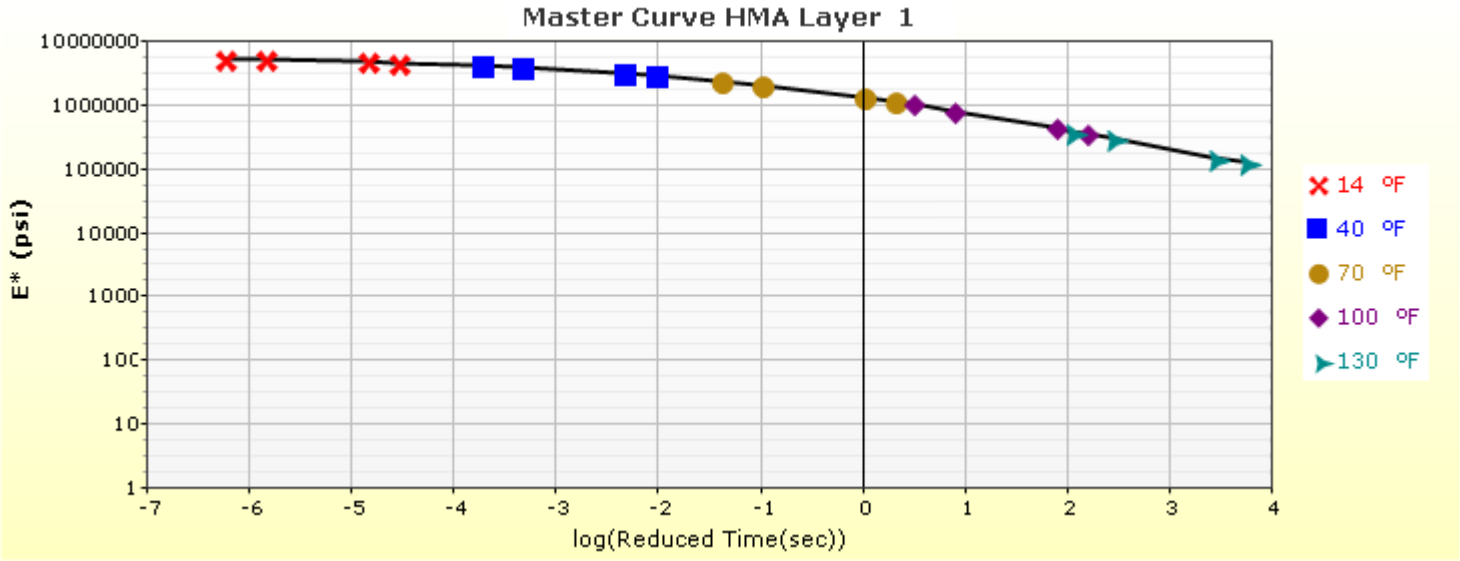
Indirect tensile strength at 14 ºF (psi)	404.62

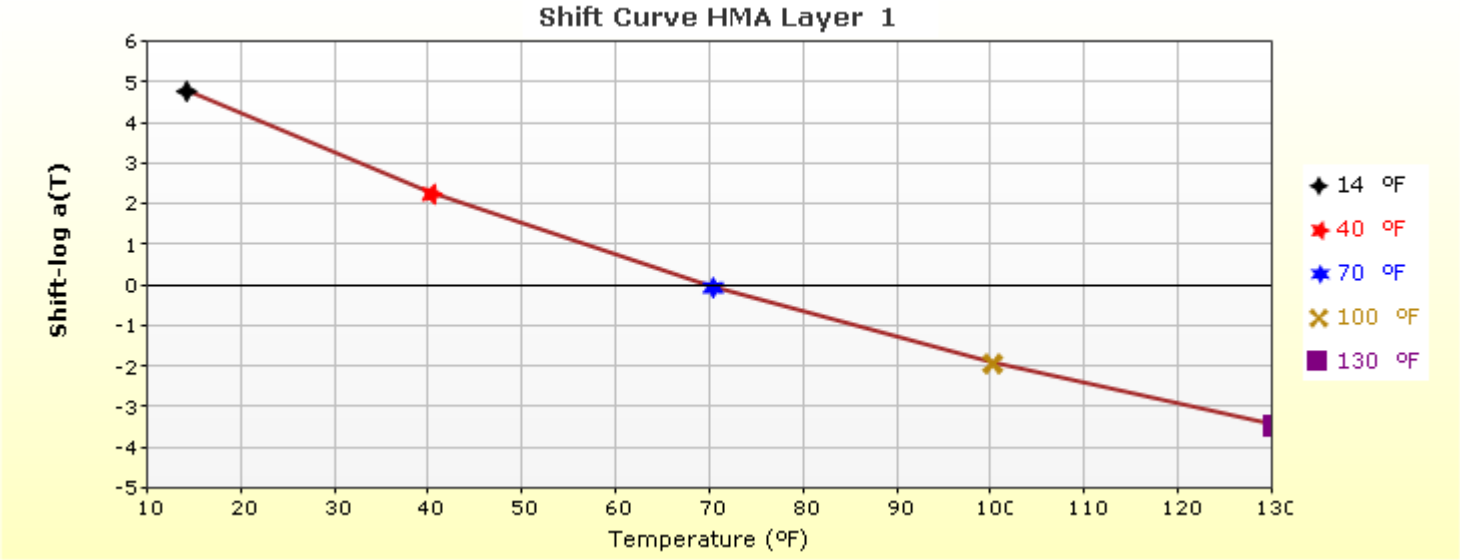
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	20.4

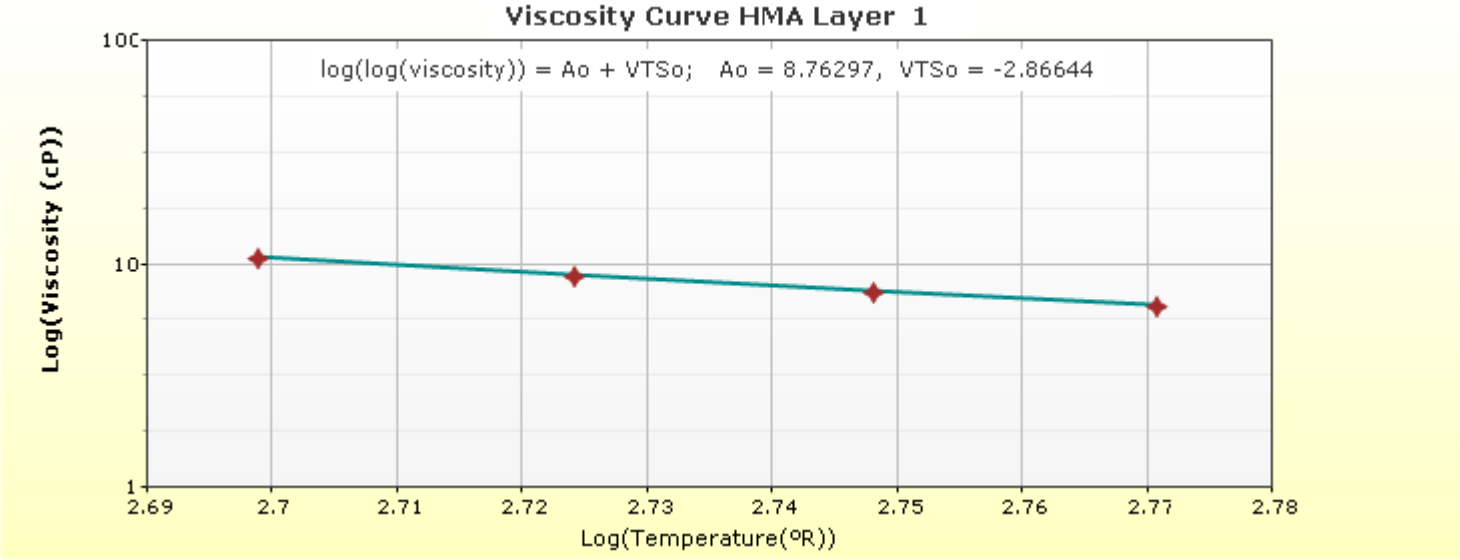
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	8.77e-007	8.77e-007	1.13e-006
1	1.13e-006	1.47e-006	1.47e-006
2	9.61e-007	9.61e-007	1.31e-006
2	1.31e-006	1.87e-006	1.87e-006
5	1.09e-006	1.09e-006	1.61e-006
5	1.61e-006	2.58e-006	2.58e-006
10	1.19e-006	1.19e-006	1.87e-006



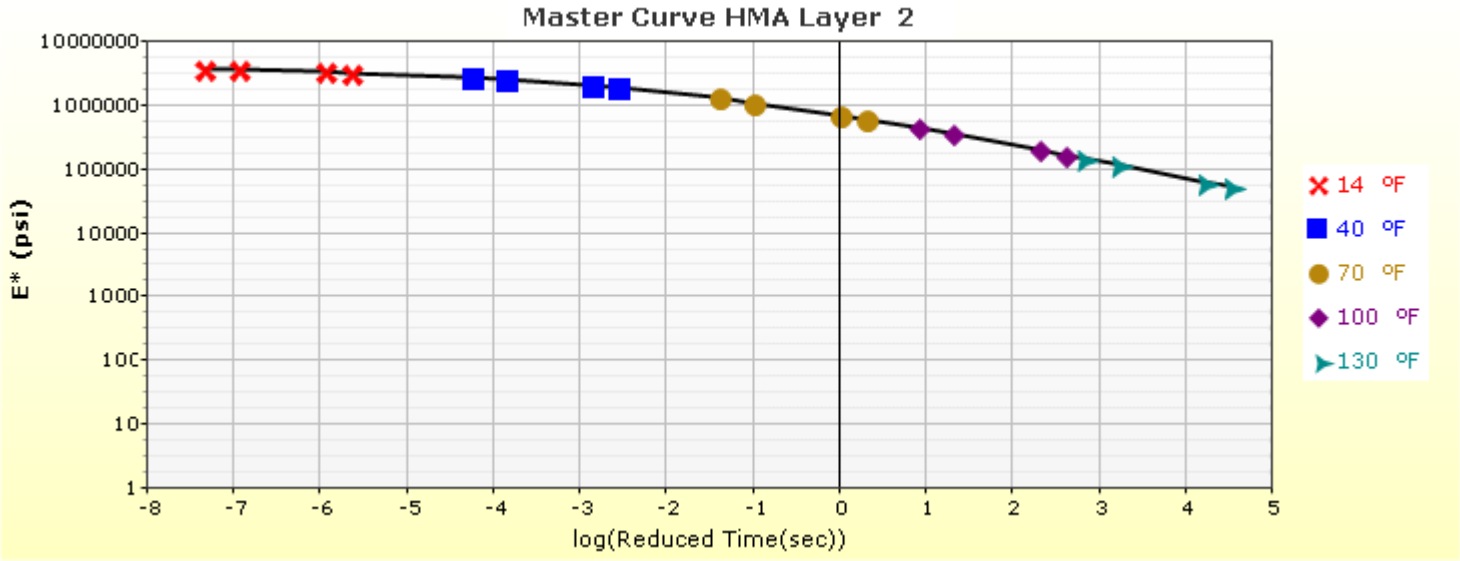
HMA Layer 1: Layer 1 Flexible : Greenfield SMA PG76-22

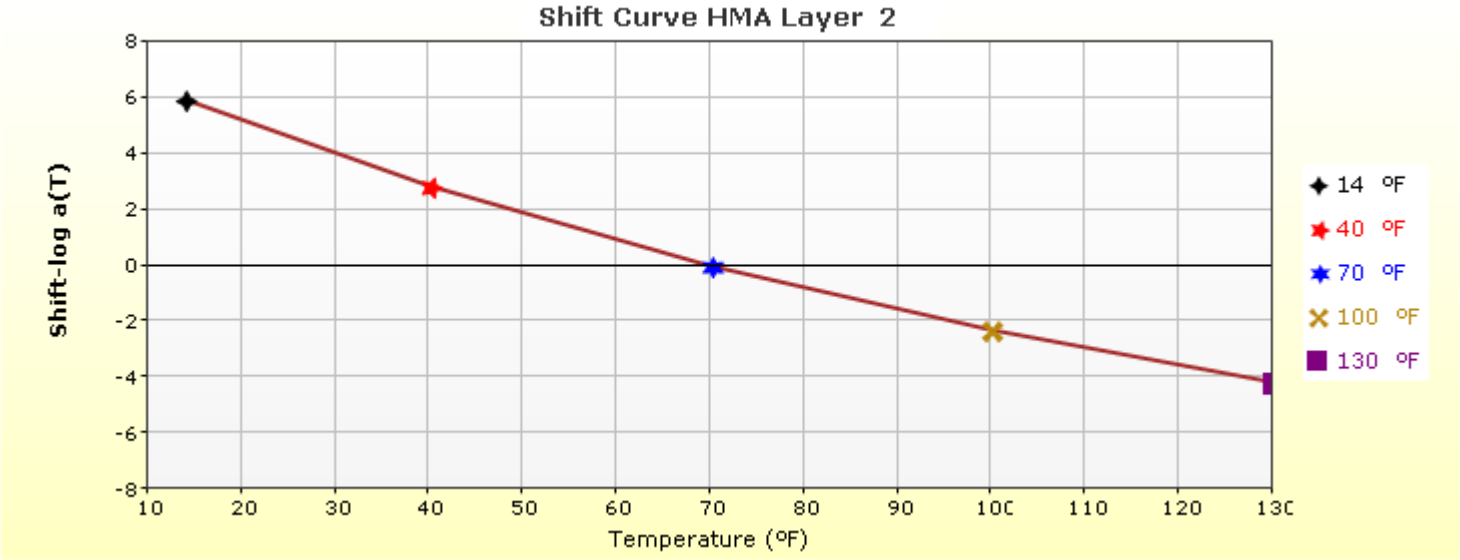


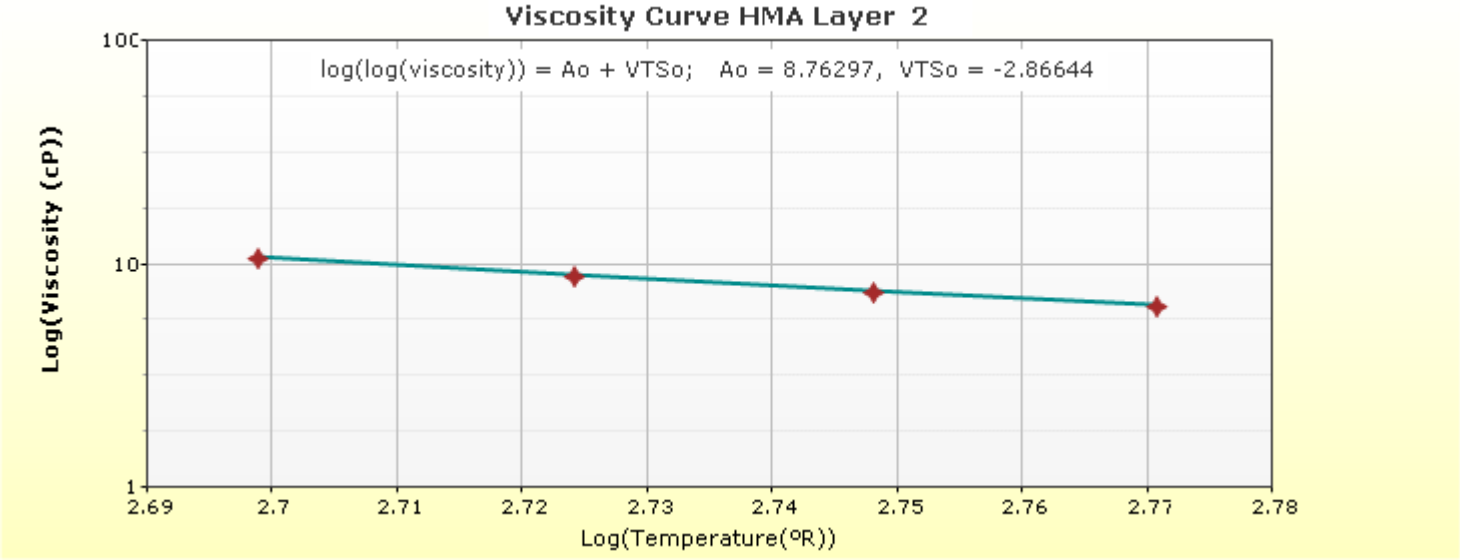




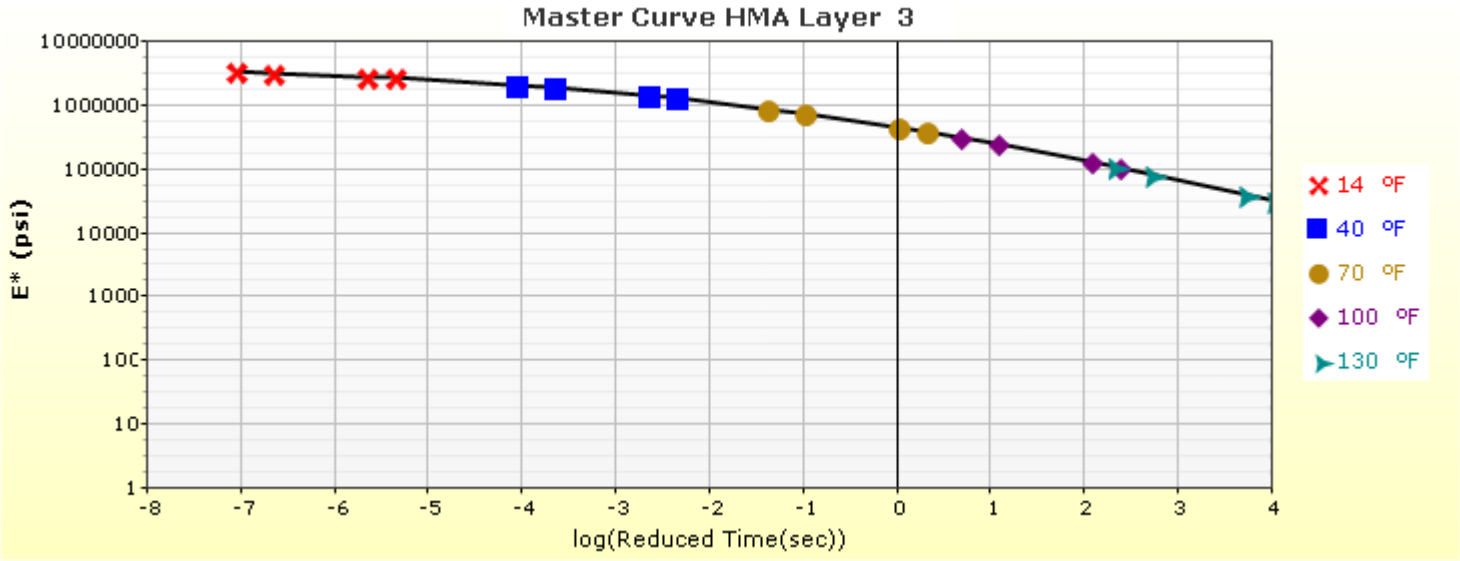
HMA Layer 2: Layer 2 Flexible : Greenfield 12.5mm PG76-22

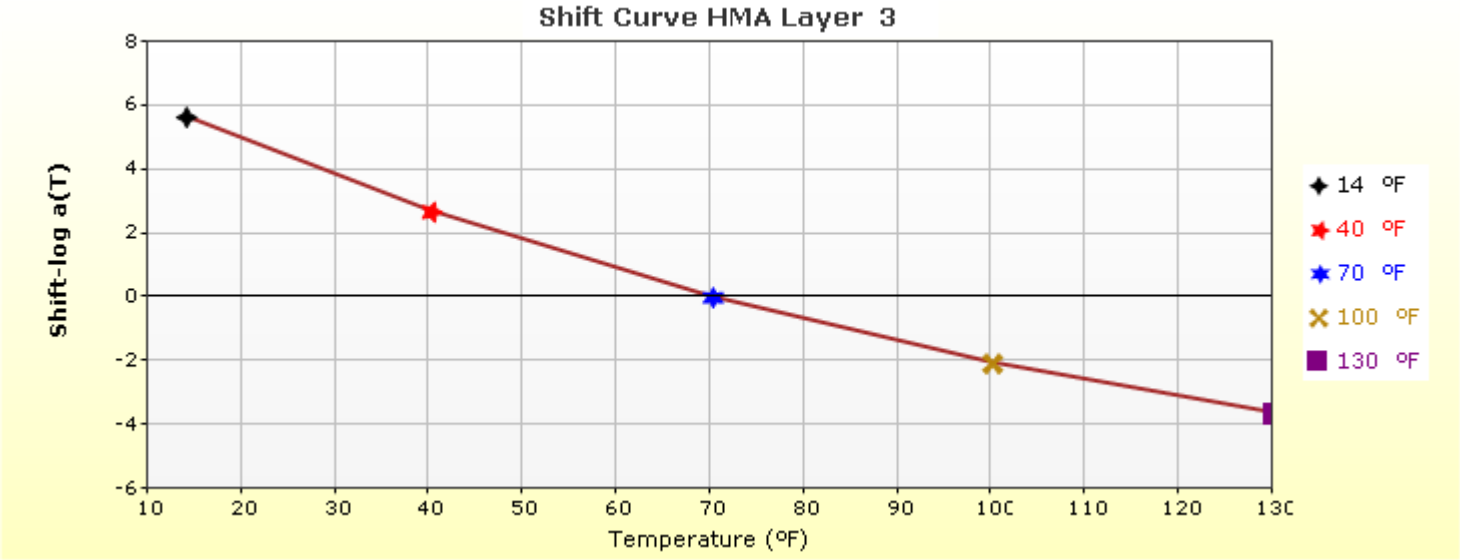


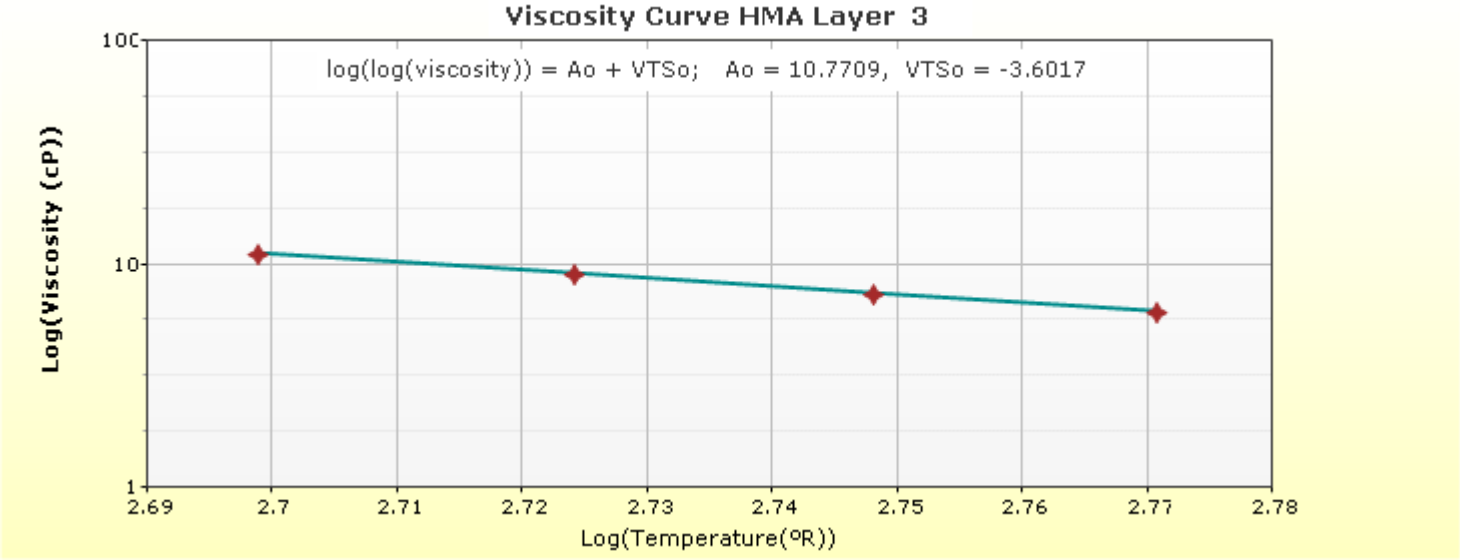




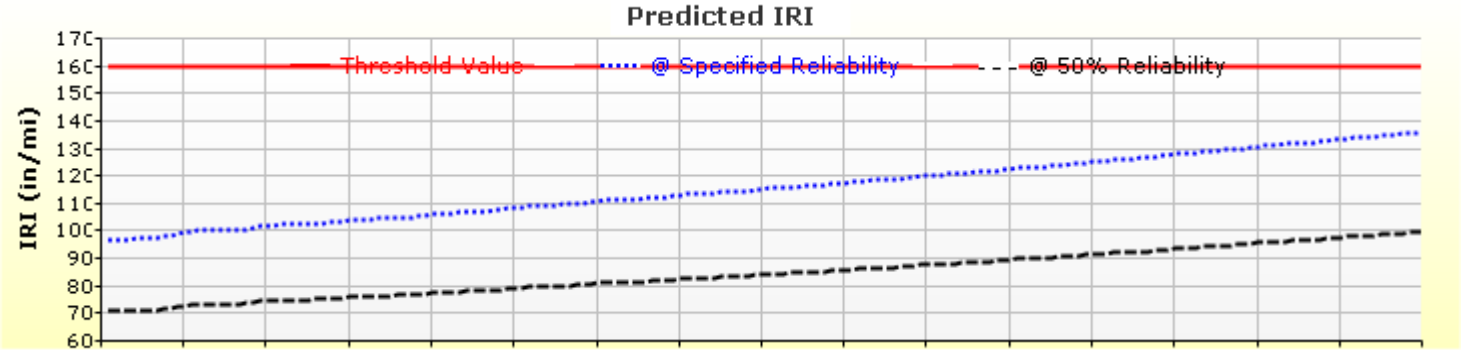
HMA Layer 3: Layer 3 Flexible : Existing HMA

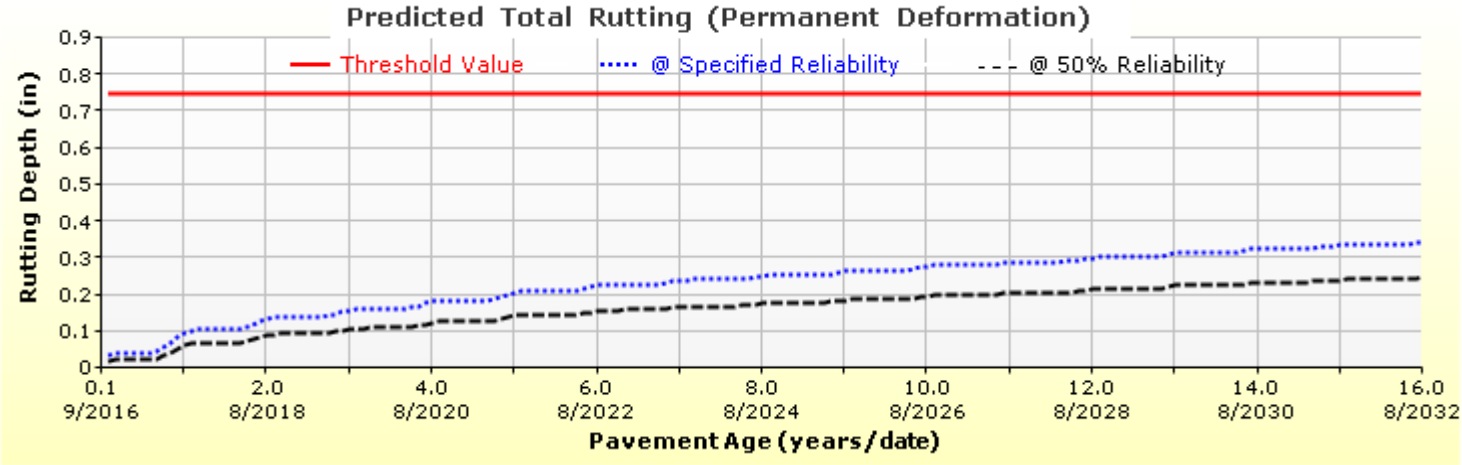


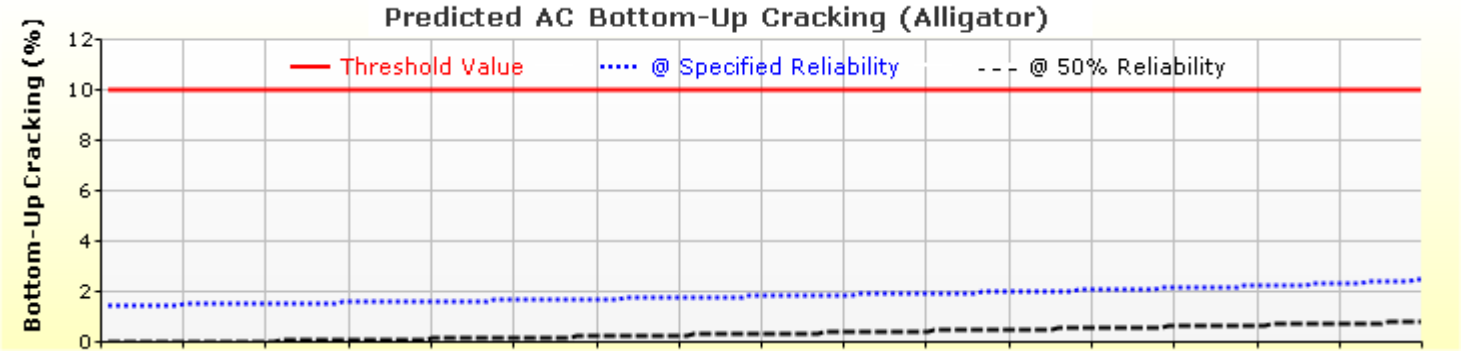


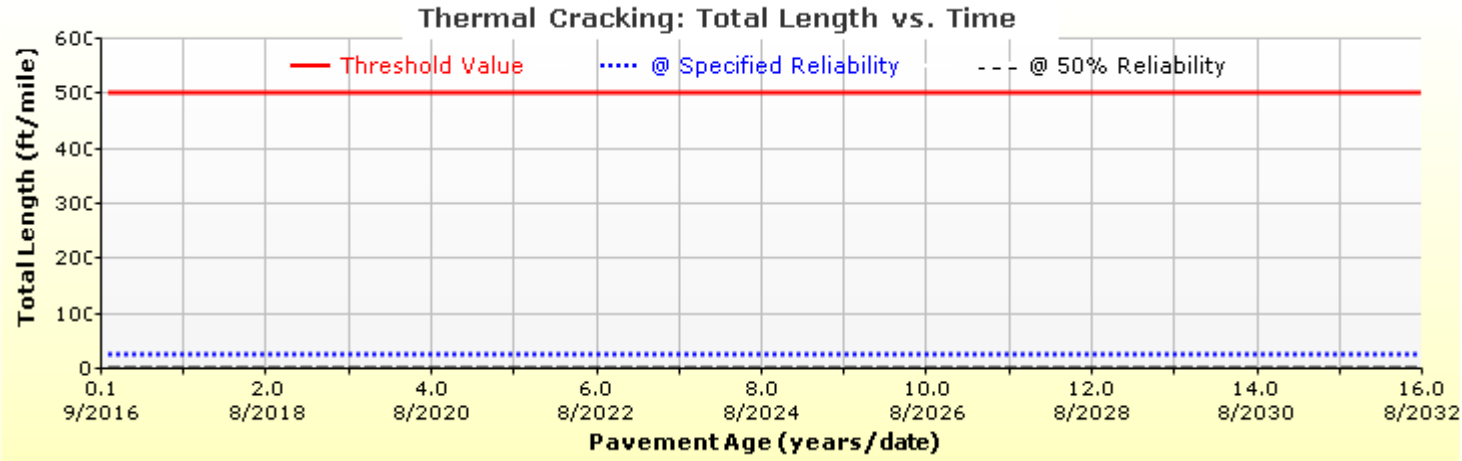


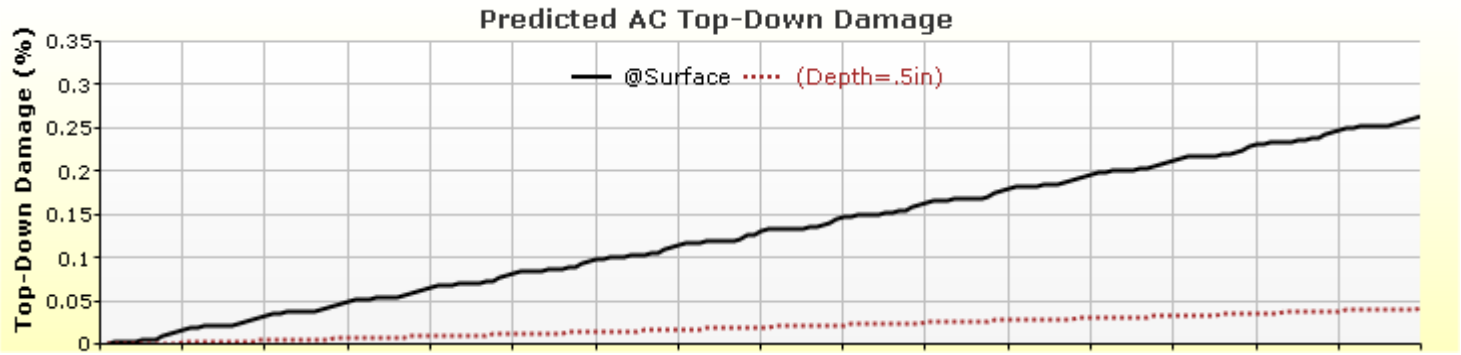
Analysis Output Charts

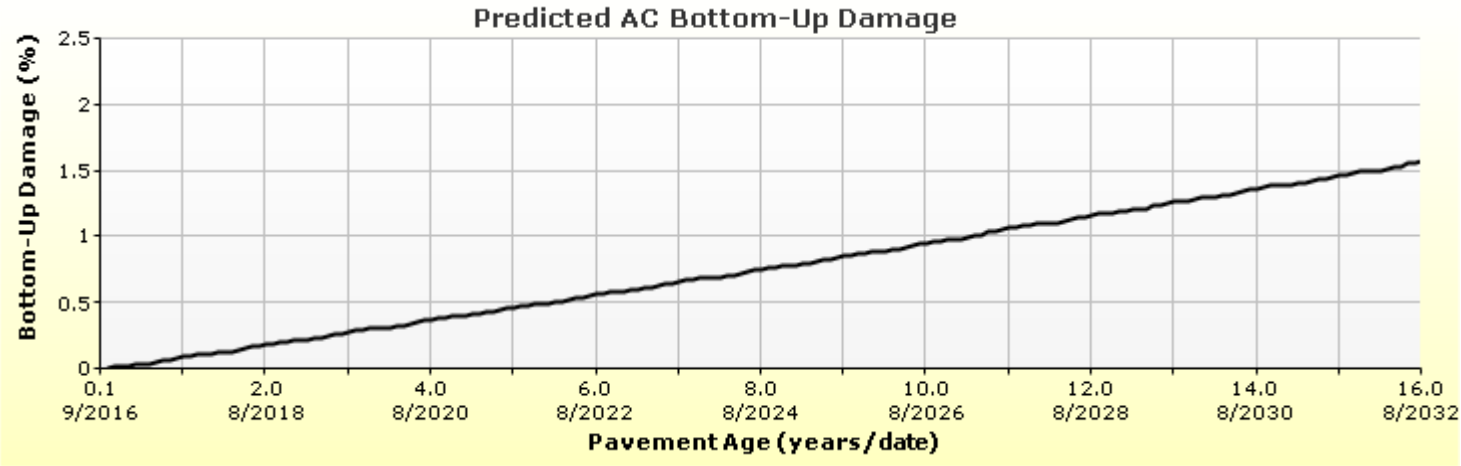


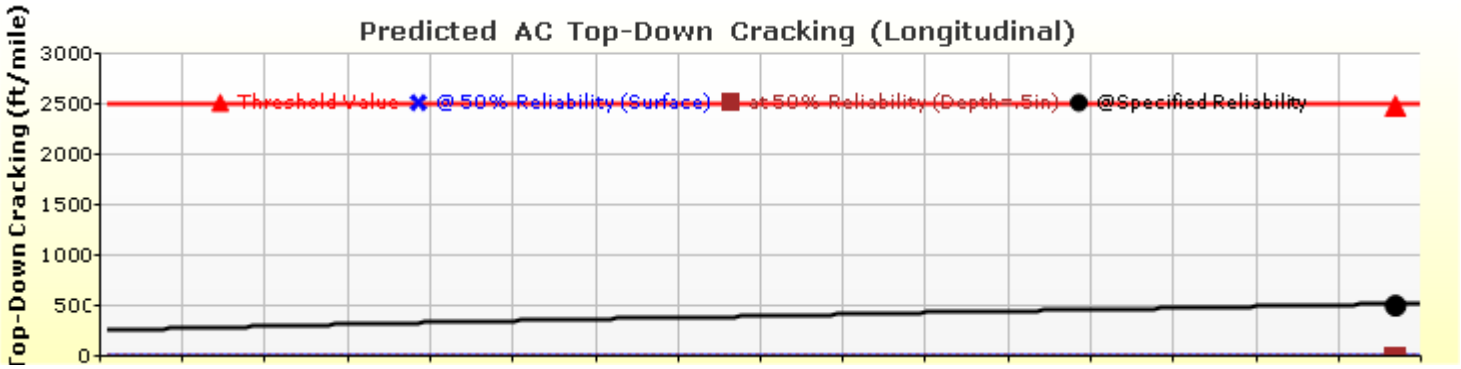


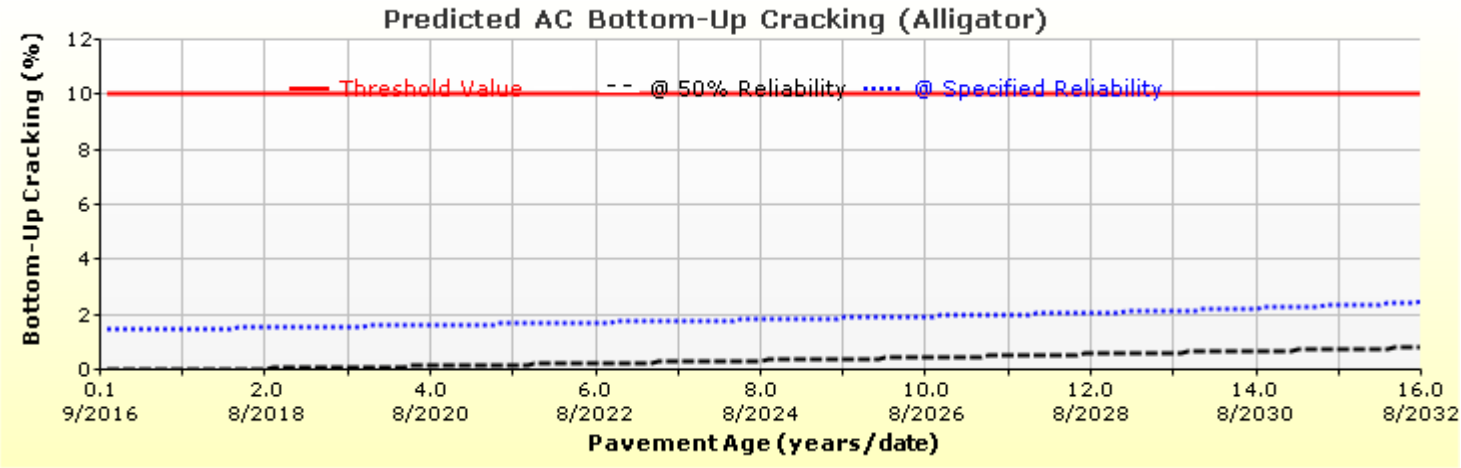


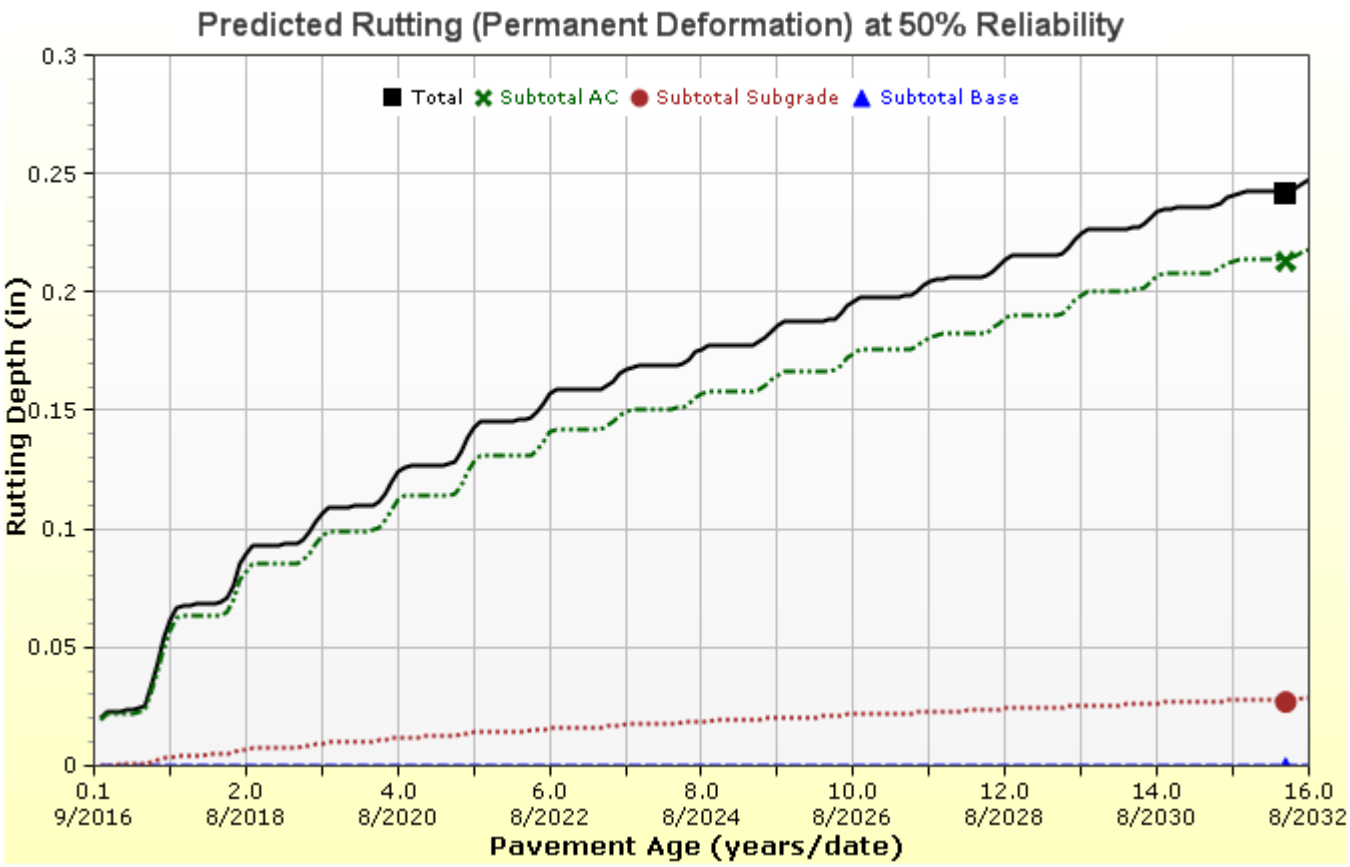


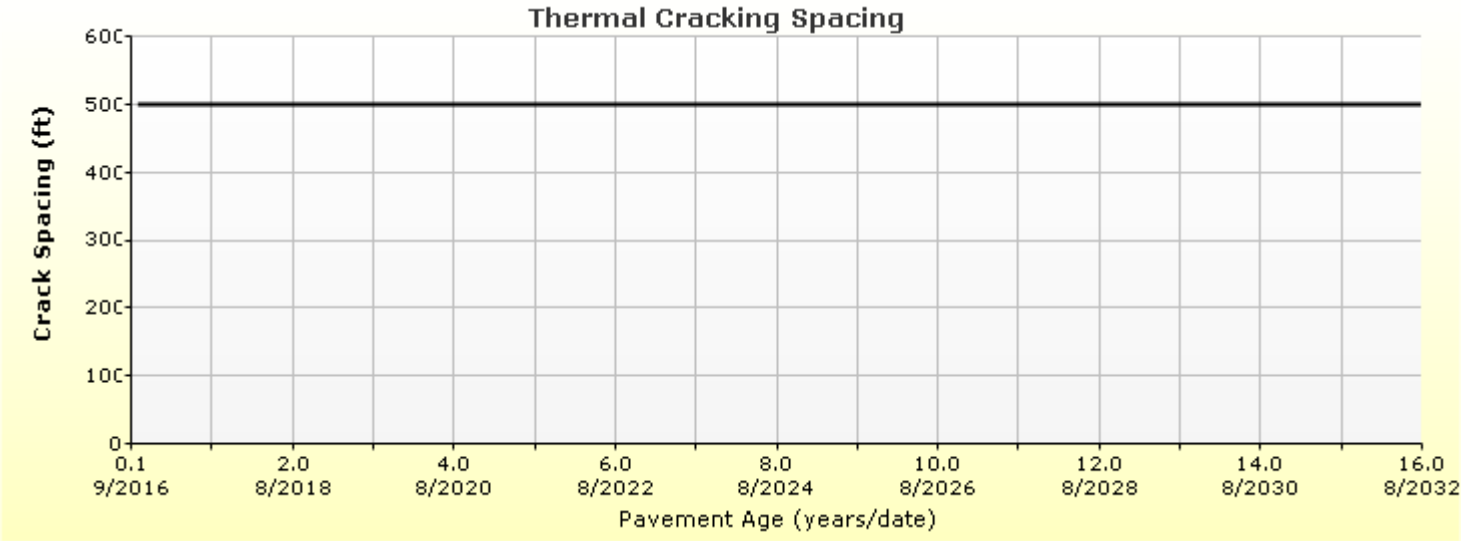

Predicted AC Top-Down Damage
Top-Down Damage (%)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
@Surface
(Depth=.5in)

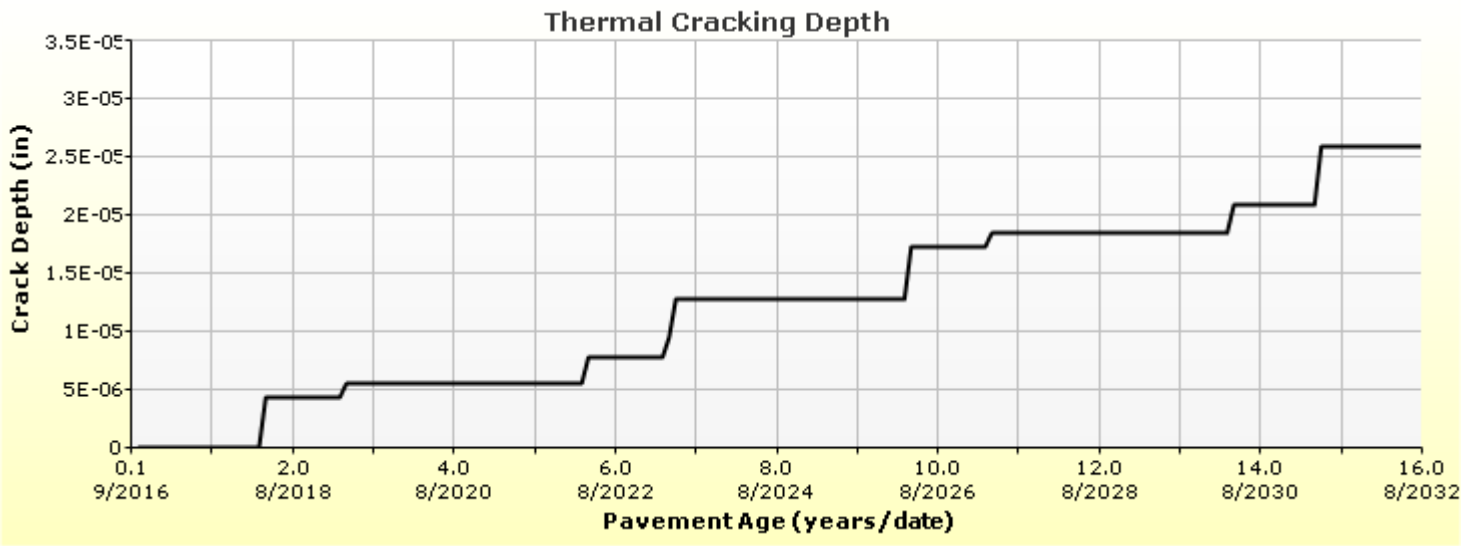

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
2.5
2
1.5
1
0.5
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
Pavement Age (years/date)

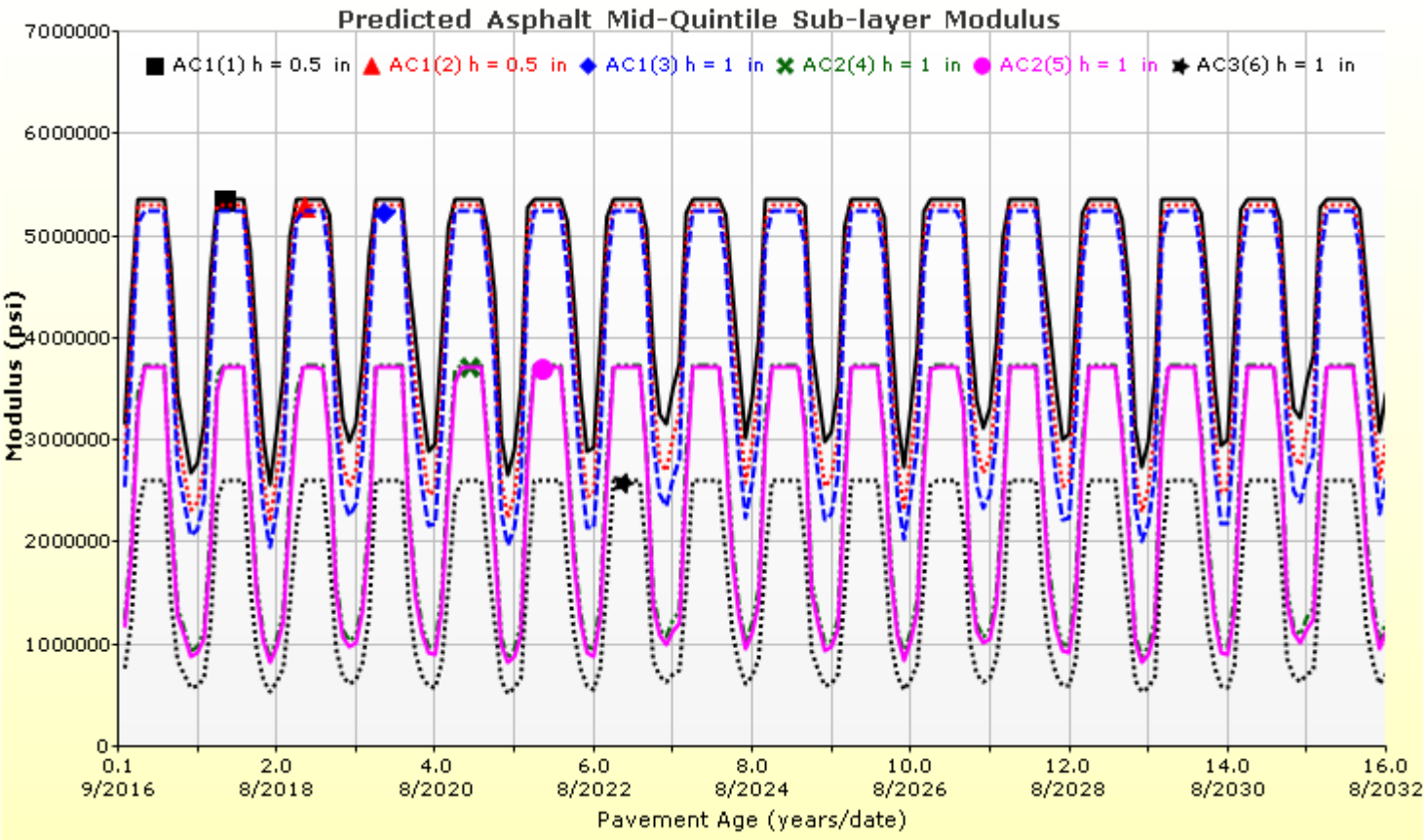

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
3000
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

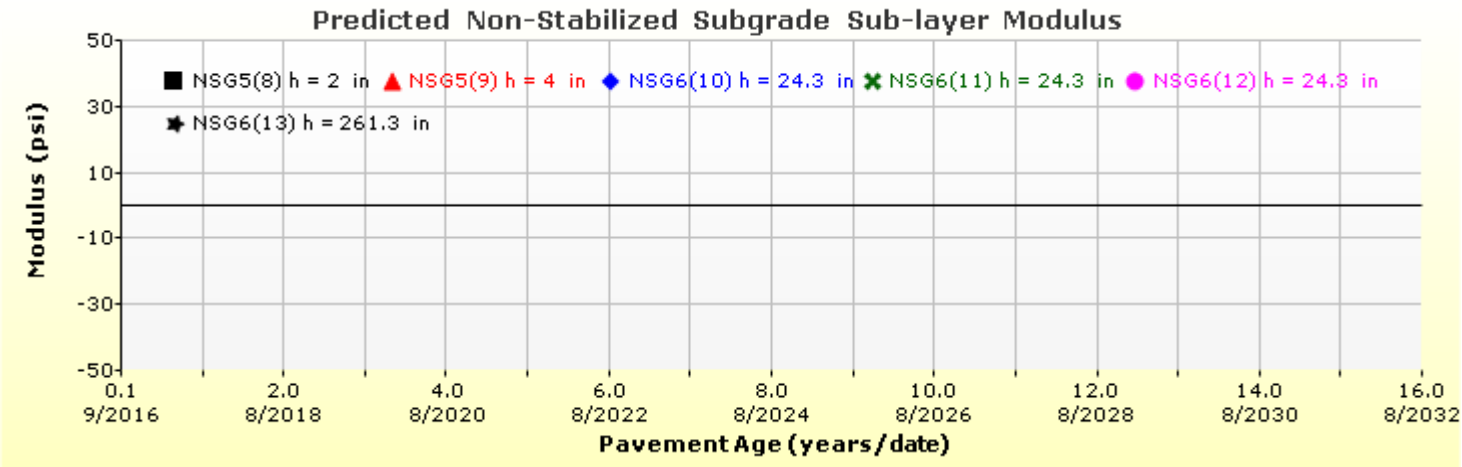

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
Pavement Age (years/date)


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
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
16.0
8/2032
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
16.0
8/2032
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
3.5E-05
3E-05
2.5E-05
2E-05
1.5E-05
1E-05
5E-06
0
0.1
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
16.0
8/2032
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
AC2(4) h = 1 in
AC2(5) h = 1 in
AC3(6) h = 1 in
Modulus (psi)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG5(8) h = 2 in
NSG5(9) h = 4 in
NSG6(10) h = 24.3 in
NSG6(11) h = 24.3 in
NSG6(12) h = 24.3 in
NSG6(13) h = 261.3 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield SMA PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	173.5	
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	3647648	4669504	5000000	5000000
40	2415742	3373281	4392981	4797248
70	763973	1296571	2030073	2372323
100	228891	438683	796159	989704
130	80754	159253	310900	401763

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	13.4
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield SMA PG76-22
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 : Greenfield 12.5mm PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	143.1	
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	2514388	3101384	3593791	4359236
40	2212131	2249168	2353738	2616932
70	452354	700875	948099	1117573
100	90946	186351	333771	425610
130	35731	68157	133871	177872

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	10.66
Air voids (%)	8
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield 12.5mm PG76-22
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 : Existing HMA

Asphalt		
Thickness (in.)	1.0	
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 4 Sandwich/Fractured : Fractured JPCP

Chemically Stabilized	
Layer thickness (in.)	8.7
Poisson's ratio	0.2
Unit weight (pcf)	150

Strength	
Elastic/resilient modulus (psi)	150000

Thermal	
Heat capacity (BTU/lb-ºF).	0.28
Thermal conductivity (BTU/hr-ft-ºF)	1.25

Identifiers

Field	Value
Display name/identifier	Fractured JPCP
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

Layer 5 Subgrade : Crushed stone

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)
9100.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 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 6 Subgrade : A-7-6

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)
9100.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

Mainline Widening along I-69 South of 116th Street

Technical Proposal / I-69 Major Moves 2020 Expansion

116th Ramp

File Name: C:\My ME Design\Projects\MK15-469\PostReport\116th Ramp.dgpx

Design Inputs

Design Life:	25 years	Base construction:	May, 2016	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	Flexible Pavement	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Greenfield 9.5mm PG76-22	1.5
Flexible	Greenfield 19.0mm PG76-22	3.0
Flexible	Greenfield 25.0mm PG64-22	11.0
Subgrade	A-7-6	14.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

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

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	618
2028 (12 years)	2,899,240
2041 (25 years)	5,981,700

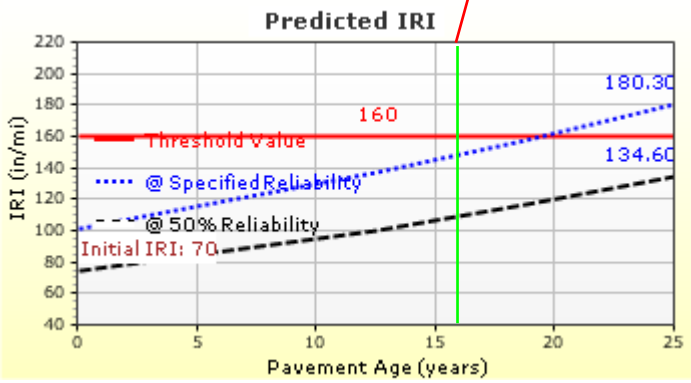
Passes IRI at 16 years, consider as a PASSING section

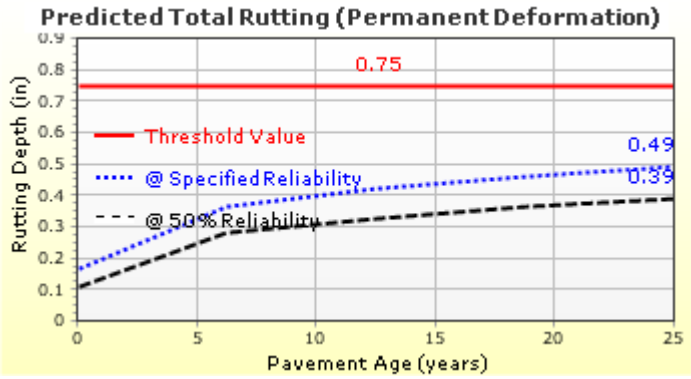
Design Outputs

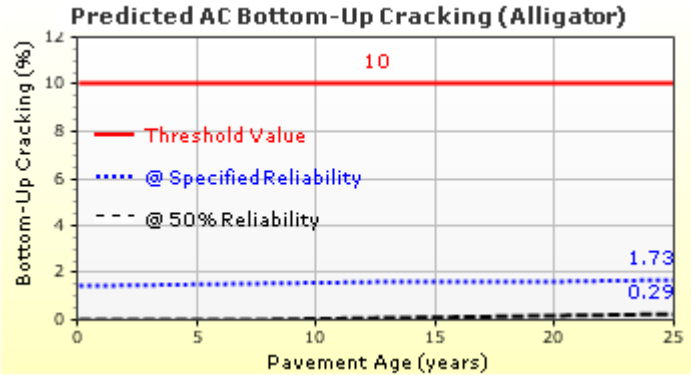
Distress Prediction Summary

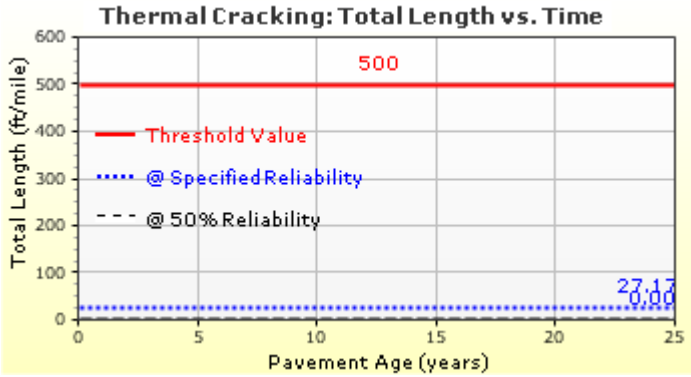
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	180.25	90.00	76.21	Fail
Permanent deformation - total pavement (in.)	0.75	0.49	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.73	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	256.55	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.13	90.00	100.00	Pass

Distress Charts





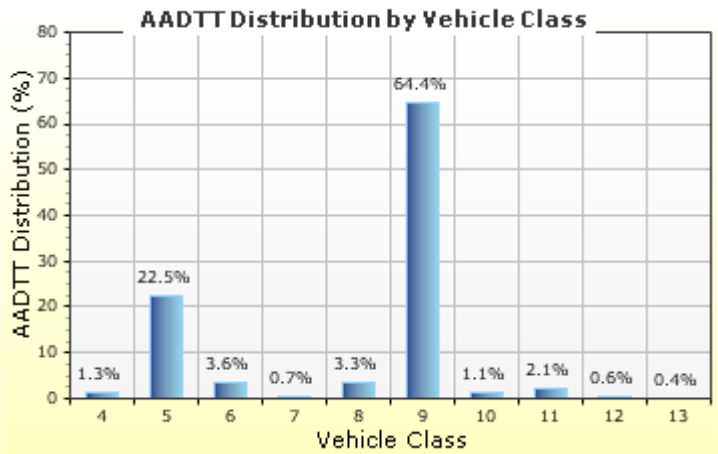


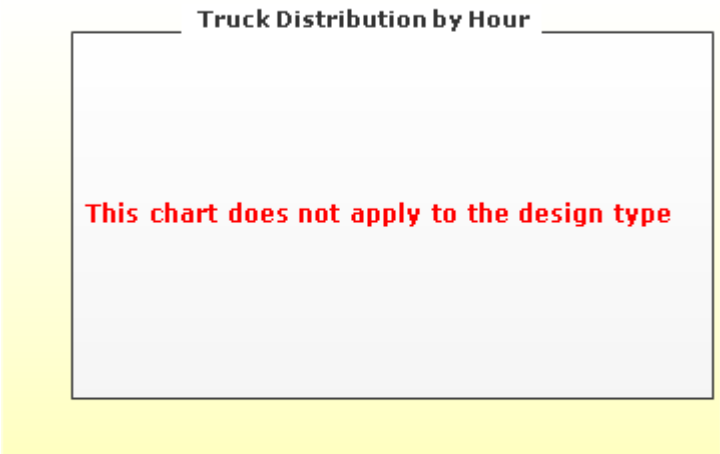


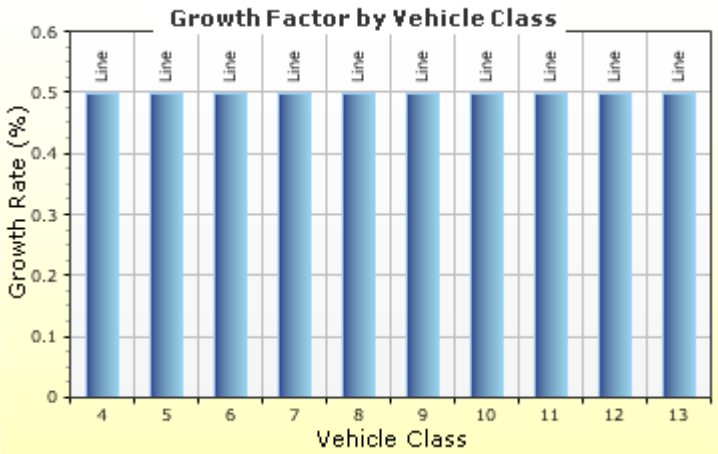
Traffic Inputs

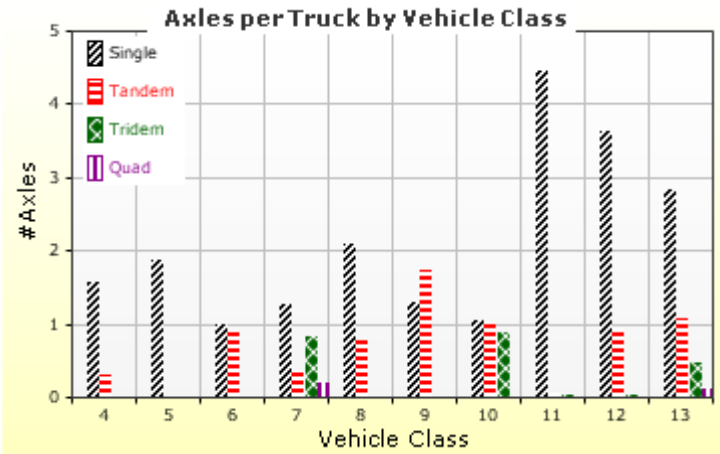
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	618	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)	30.0

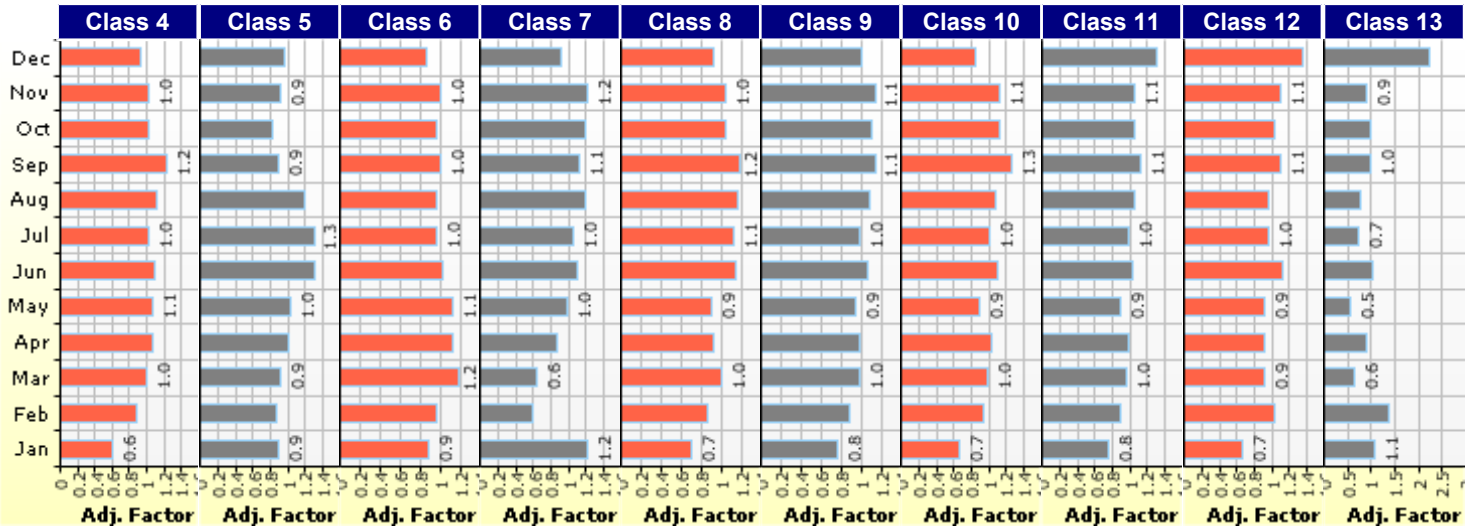








Traffic Volume Monthly Adjustment Factors



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%	0.5%	Linear
Class 5	22.5%	0.5%	Linear
Class 6	3.6%	0.5%	Linear
Class 7	0.7%	0.5%	Linear
Class 8	3.3%	0.5%	Linear
Class 9	64.4%	0.5%	Linear
Class 10	1.1%	0.5%	Linear
Class 11	2.1%	0.5%	Linear
Class 12	0.6%	0.5%	Linear
Class 13	0.4%	0.5%	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

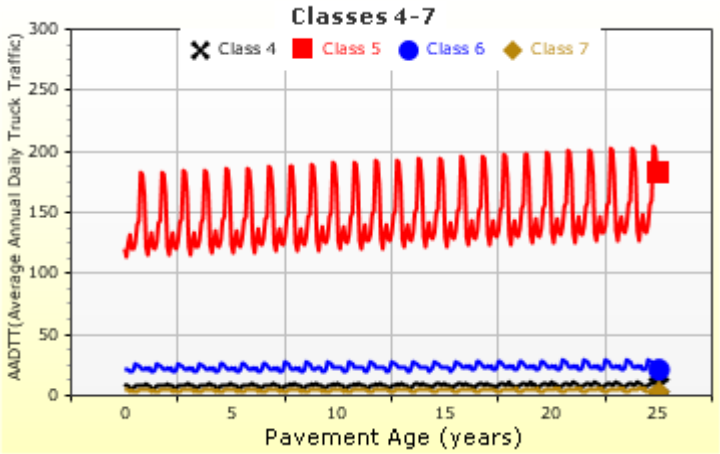
Wheelbase does not apply

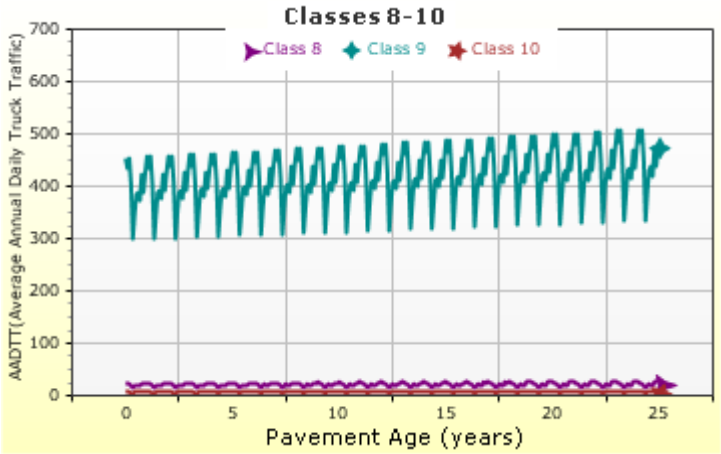
Number of Axles per Truck

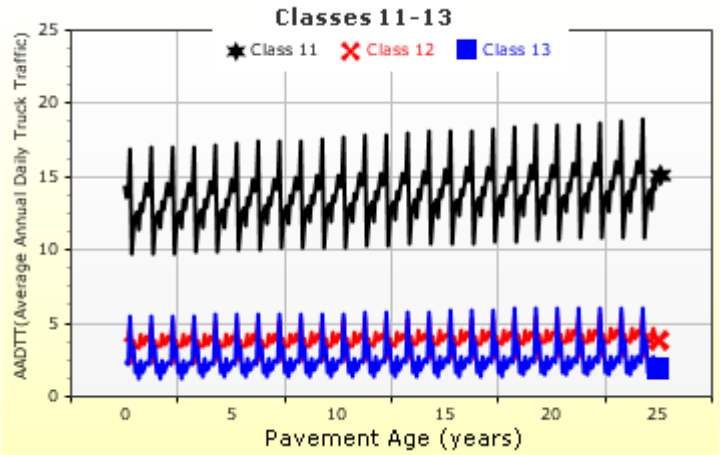
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.57	0.32	0	0
Class 5	1.87	0	0	0
Class 6	1	0.93	0	0
Class 7	1.27	0.38	0.83	0.2
Class 8	2.08	0.77	0	0
Class 9	1.3	1.73	0	0
Class 10	1.05	1.02	0.88	0.01
Class 11	4.45	0.06	0.03	0
Class 12	3.63	0.96	0.03	0
Class 13	2.82	1.07	0.48	0.13

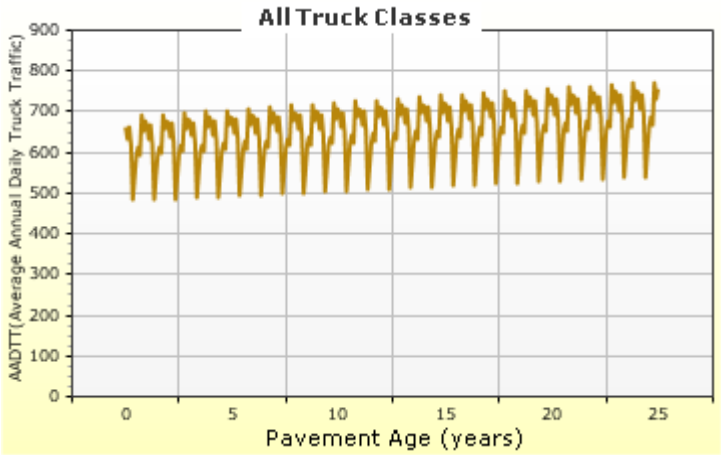
AADTT (Average Annual Daily Truck Traffic) Growth

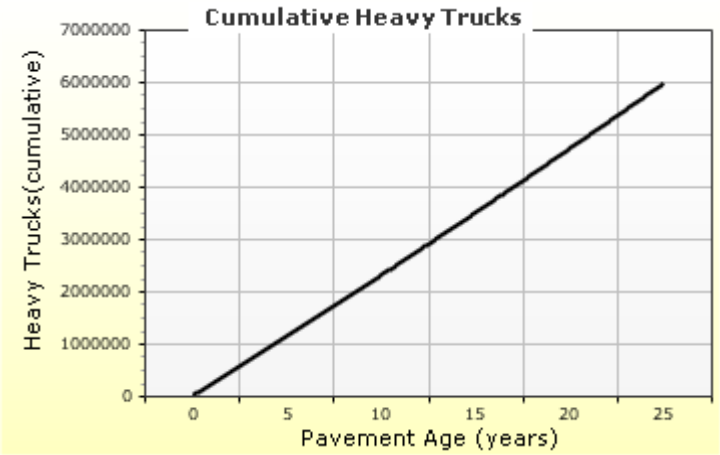
*** Traffic cap is not enforced**







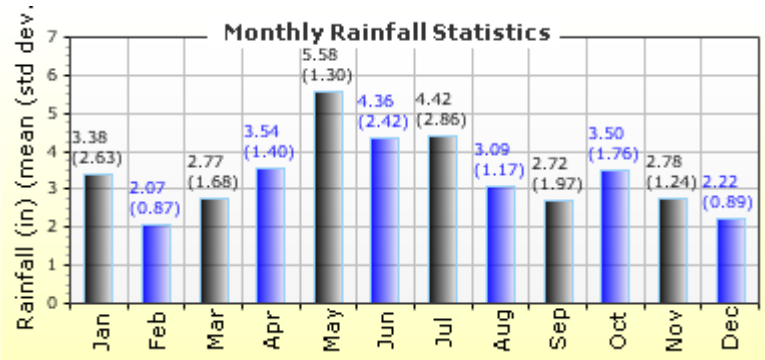




Climate Inputs

Climate Data Sources:

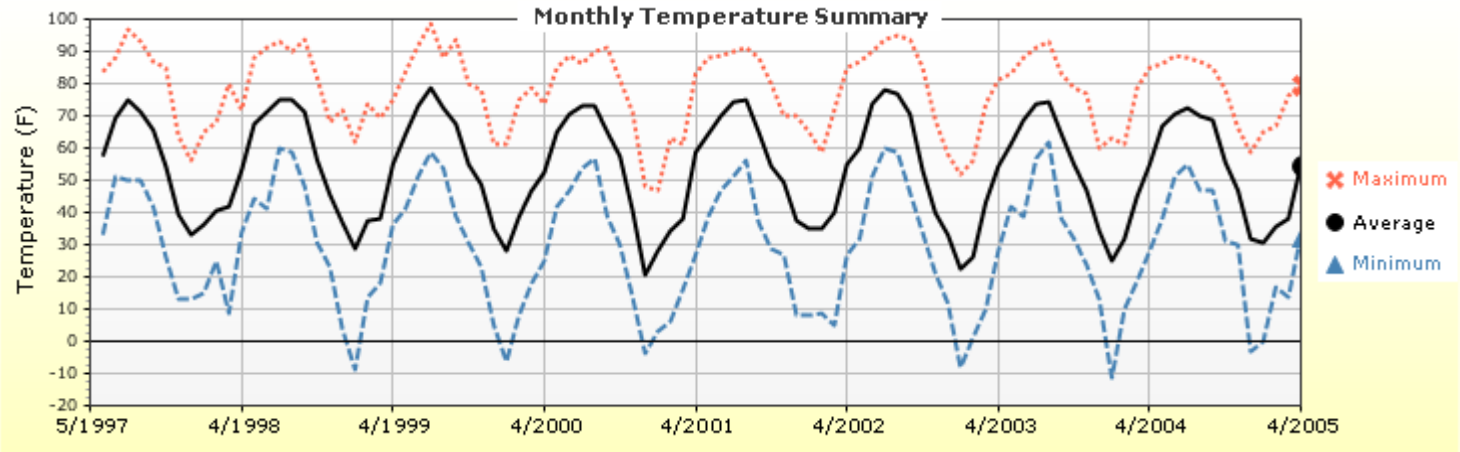
Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

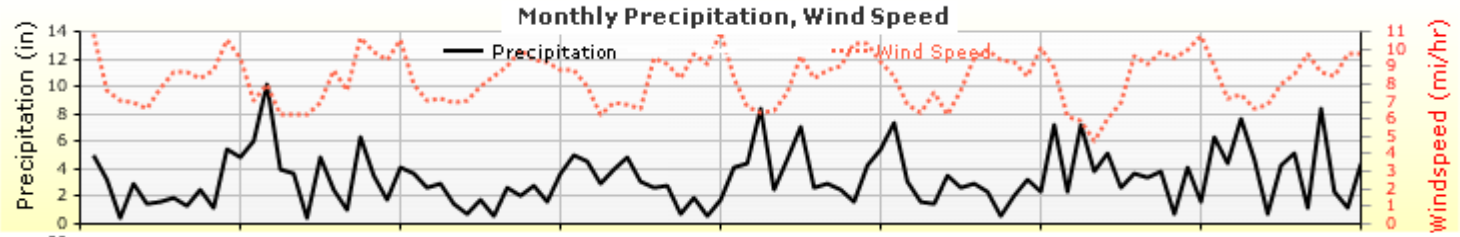


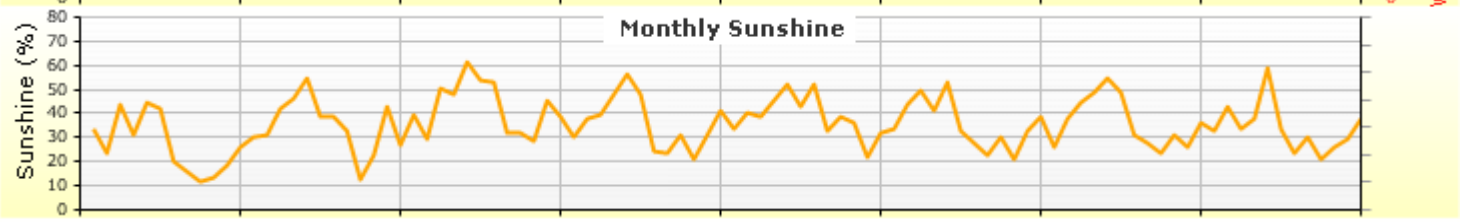
Annual Statistics:

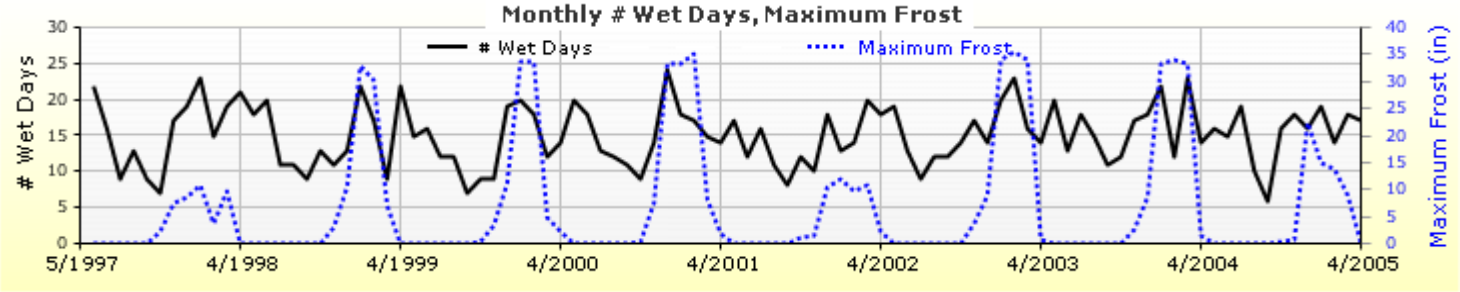
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in.)	40.41
Freezing index (ºF - days)	475.93
Average annual number of freeze/thaw cycles:	54.61
Water table depth (ft)	5.00

Monthly Climate Summary:

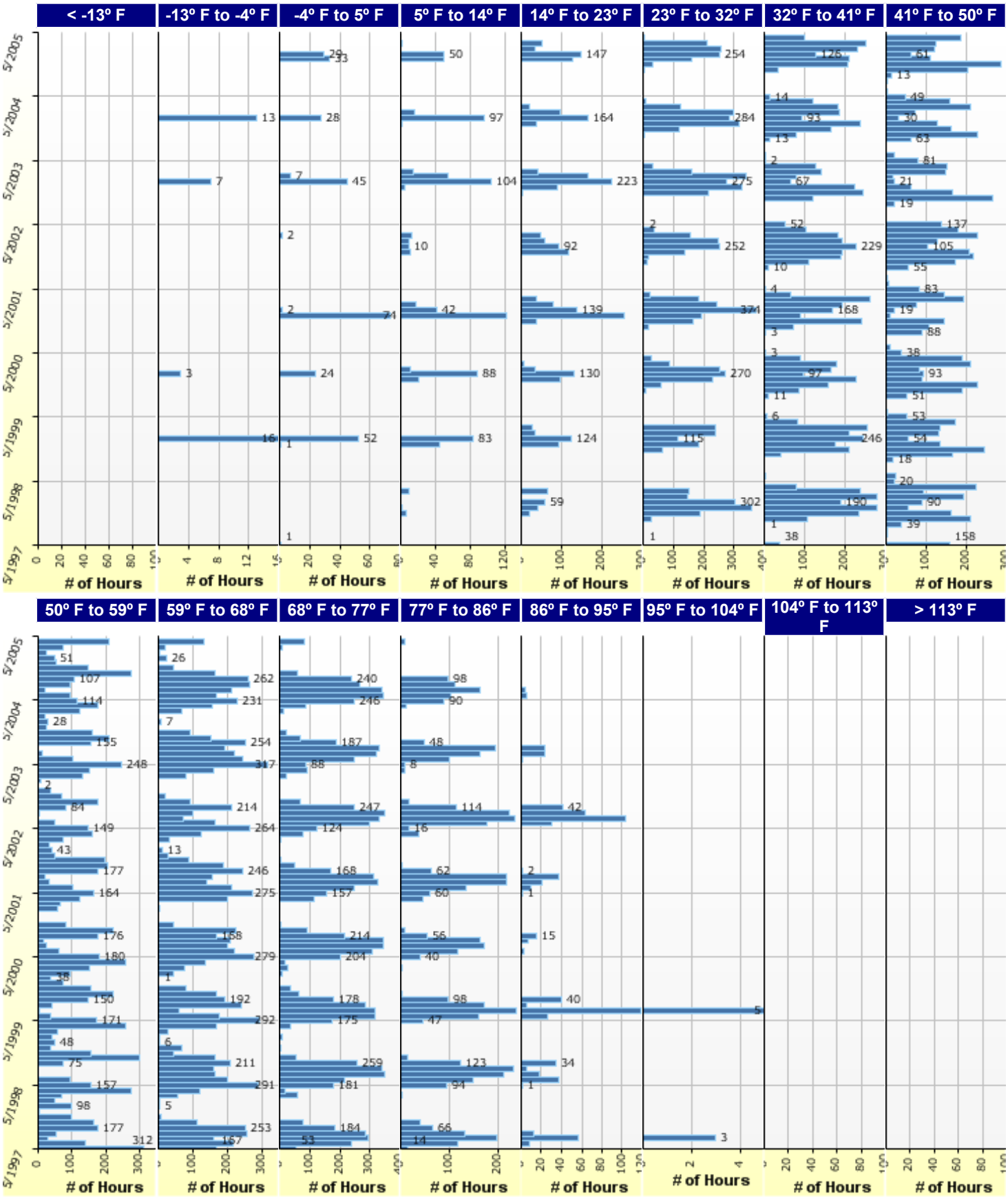








Hourly Air Temperature Distribution by Month:



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

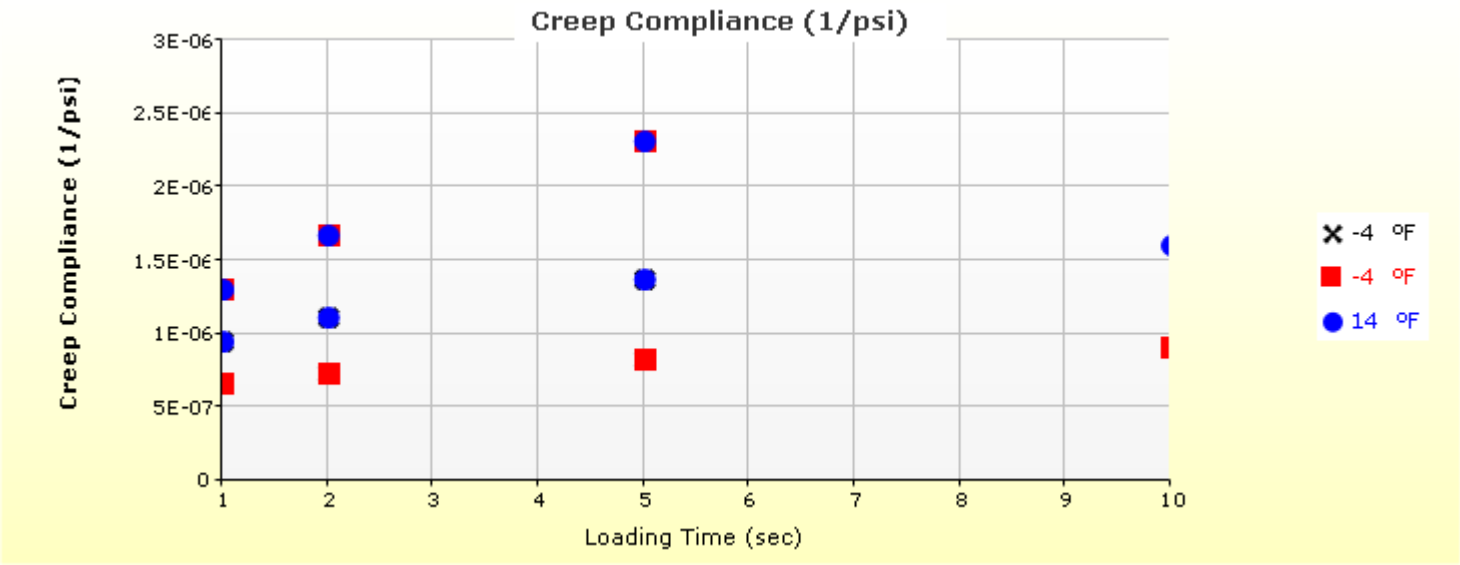
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield 9.5mm PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 19.0mm PG76-22	Flexible (1)	1.00
Layer 3 Flexible : Greenfield 25.0mm PG64-22	Flexible (1)	1.00
Layer 4 Subgrade : A-7-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

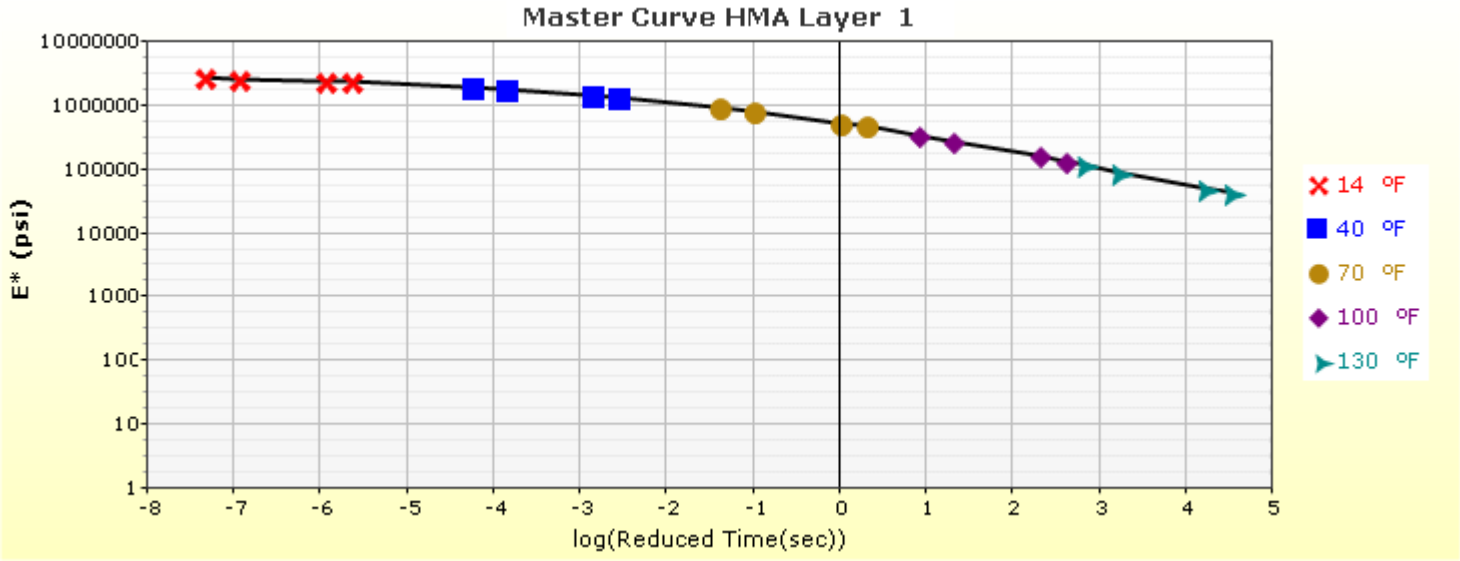
Indirect tensile strength at 14 ºF (psi)	467.26

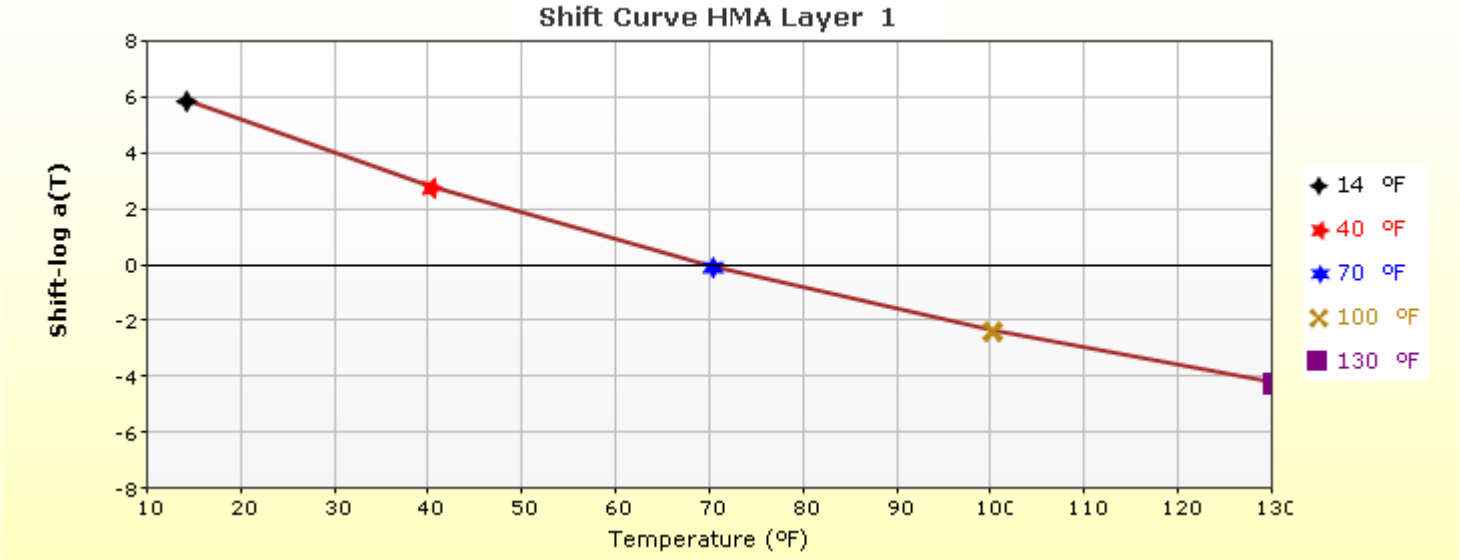
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

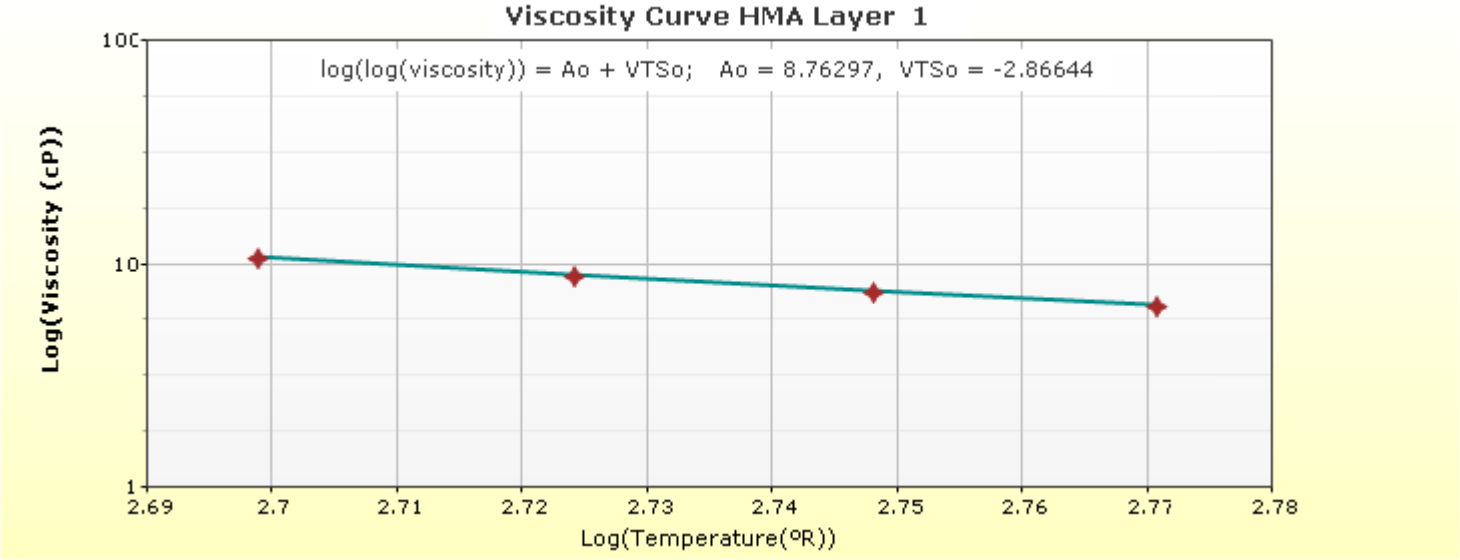
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	6.73e-007	6.73e-007	9.61e-007
1	9.61e-007	1.32e-006	1.32e-006
2	7.41e-007	7.41e-007	1.12e-006
2	1.12e-006	1.69e-006	1.69e-006
5	8.40e-007	8.40e-007	1.38e-006
5	1.38e-006	2.33e-006	2.33e-006
10	9.25e-007	9.25e-007	1.61e-006



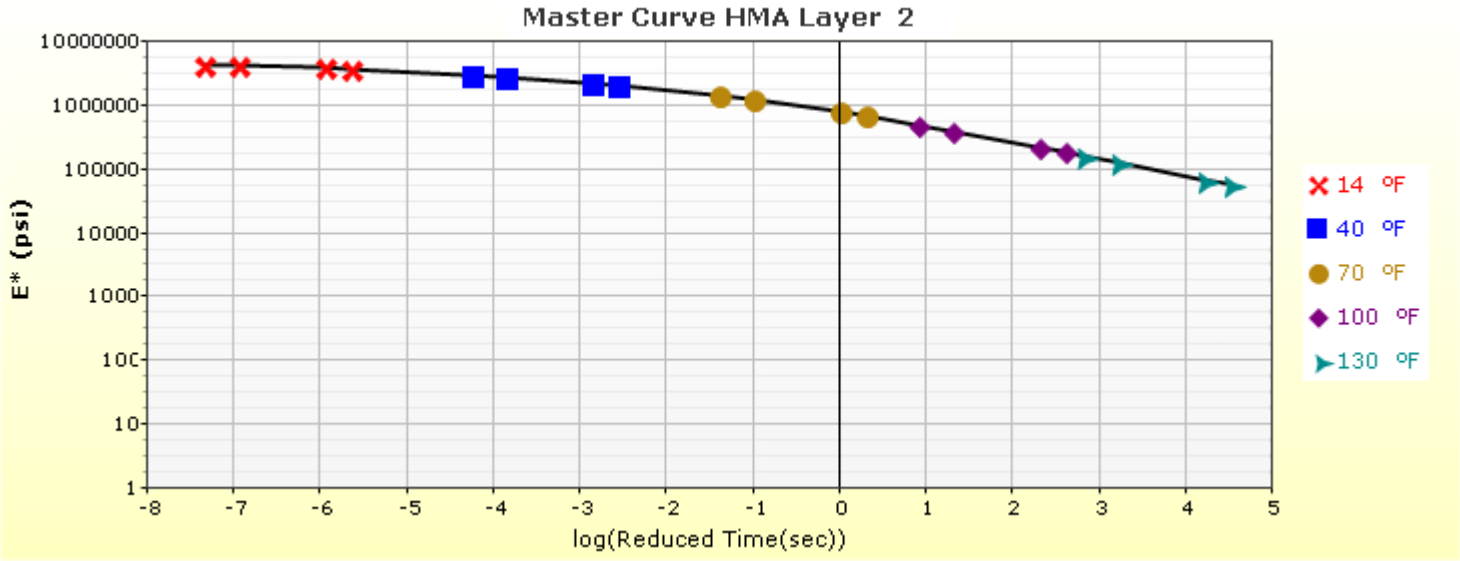
HMA Layer 1: Layer 1 Flexible : Greenfield 9.5mm PG76-22

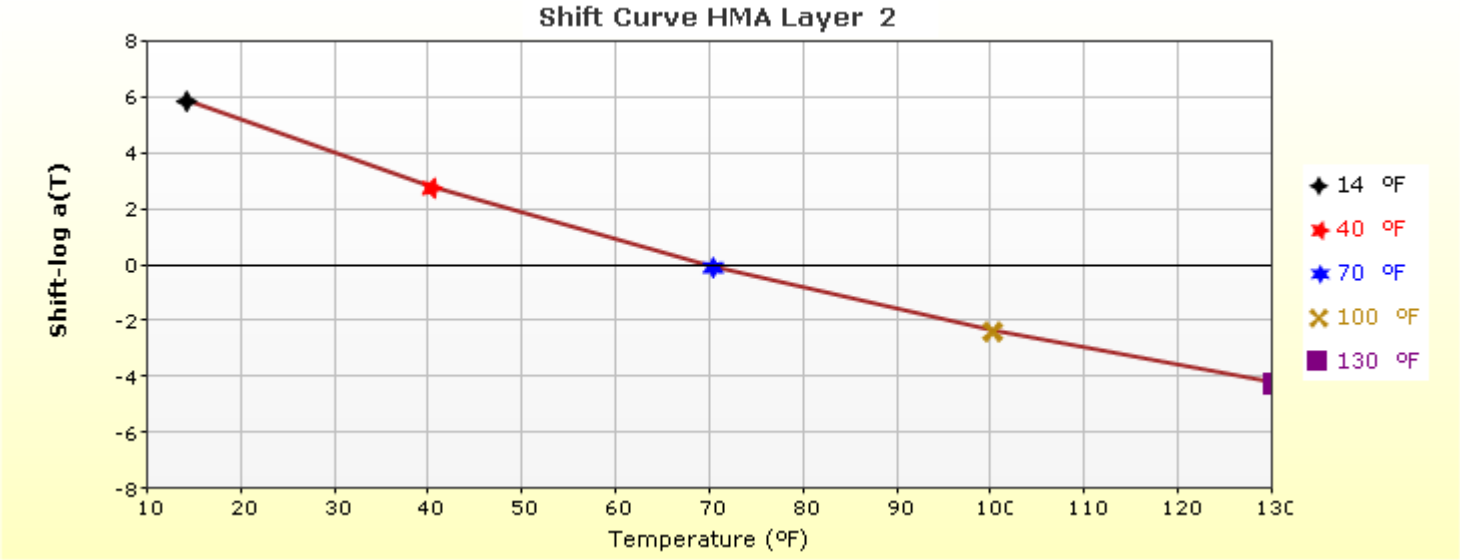


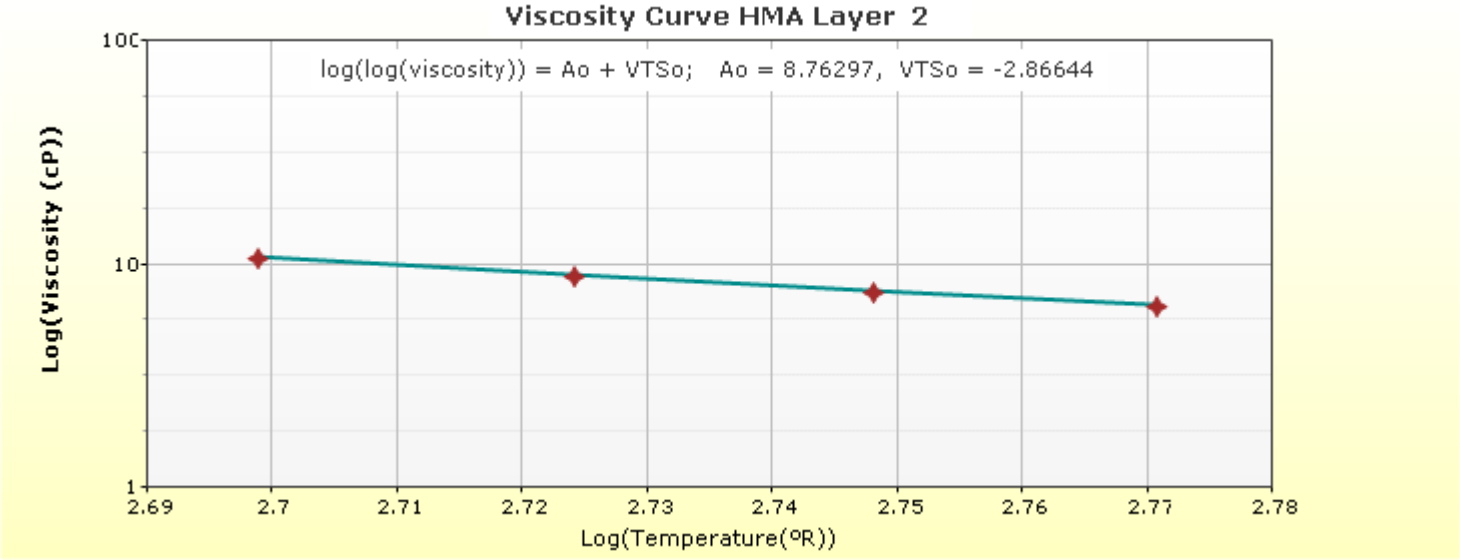




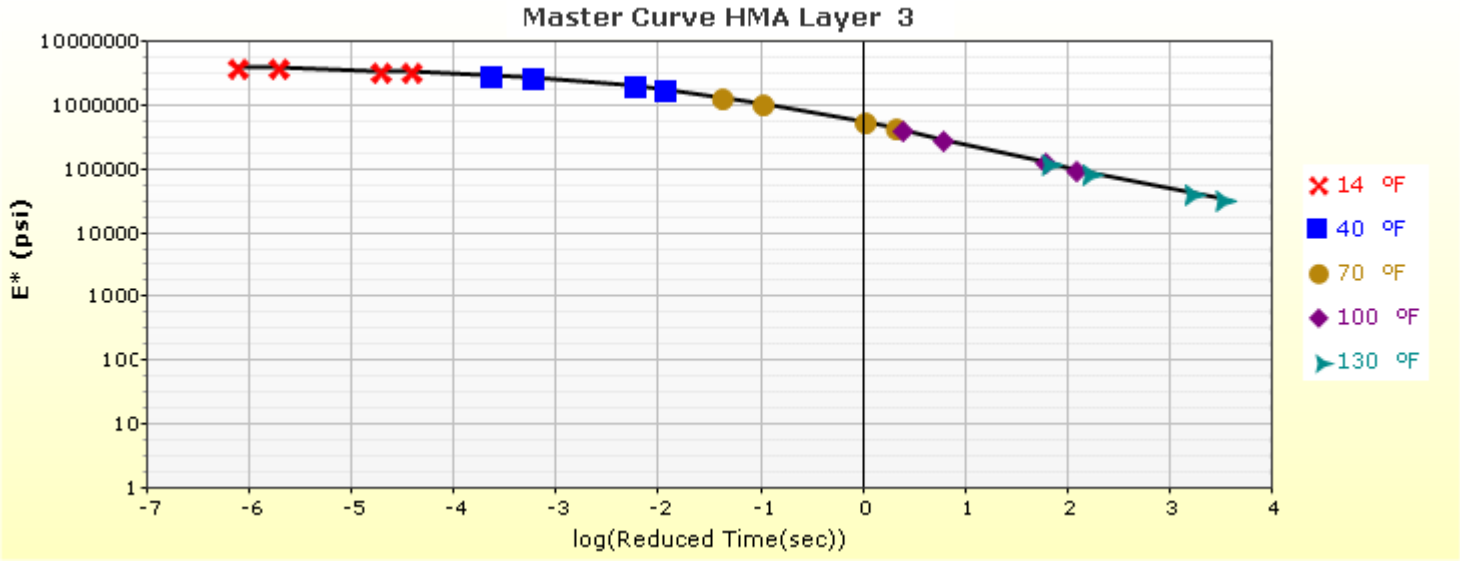
HMA Layer 2: Layer 2 Flexible : Greenfield 19.0mm PG76-22

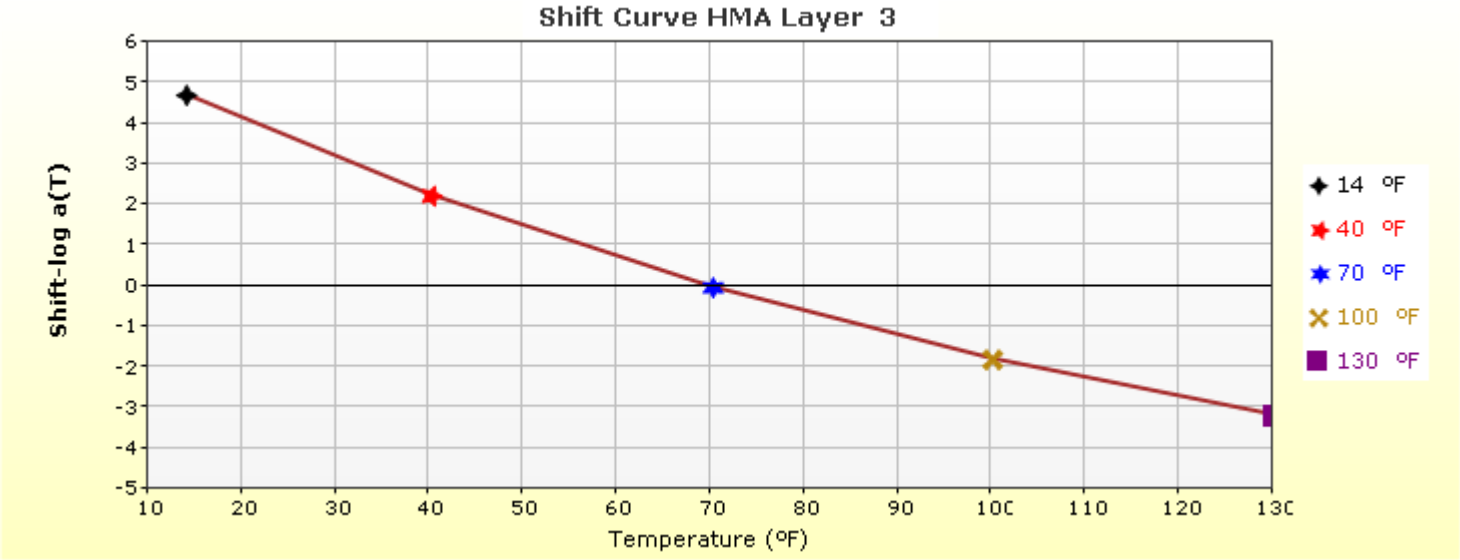


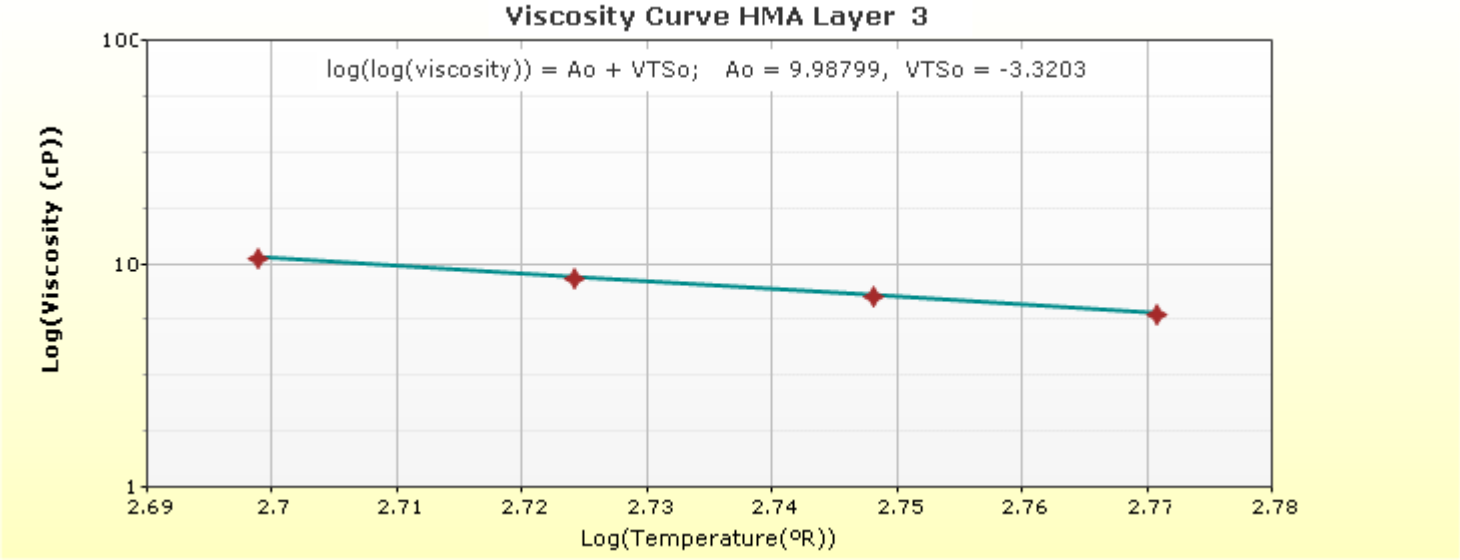




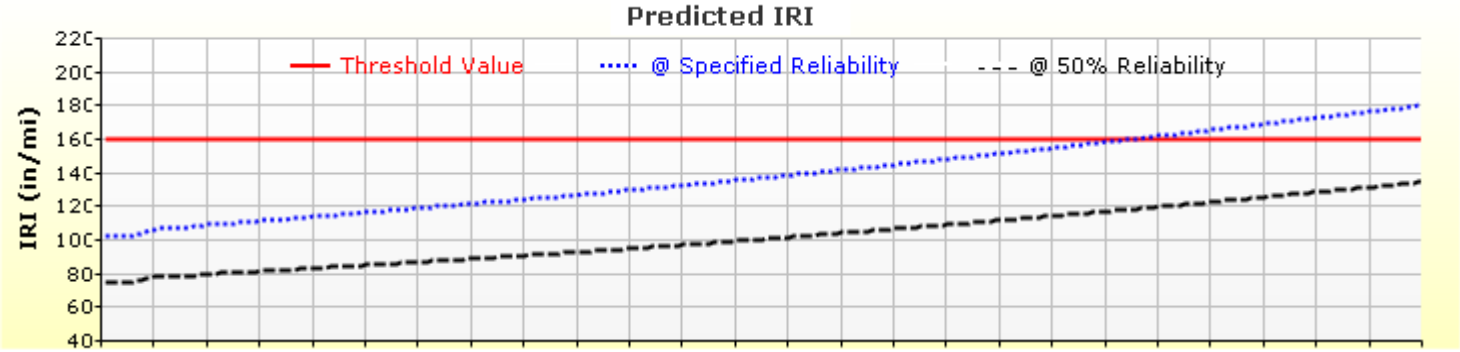
HMA Layer 3: Layer 3 Flexible : Greenfield 25.0mm PG64-22

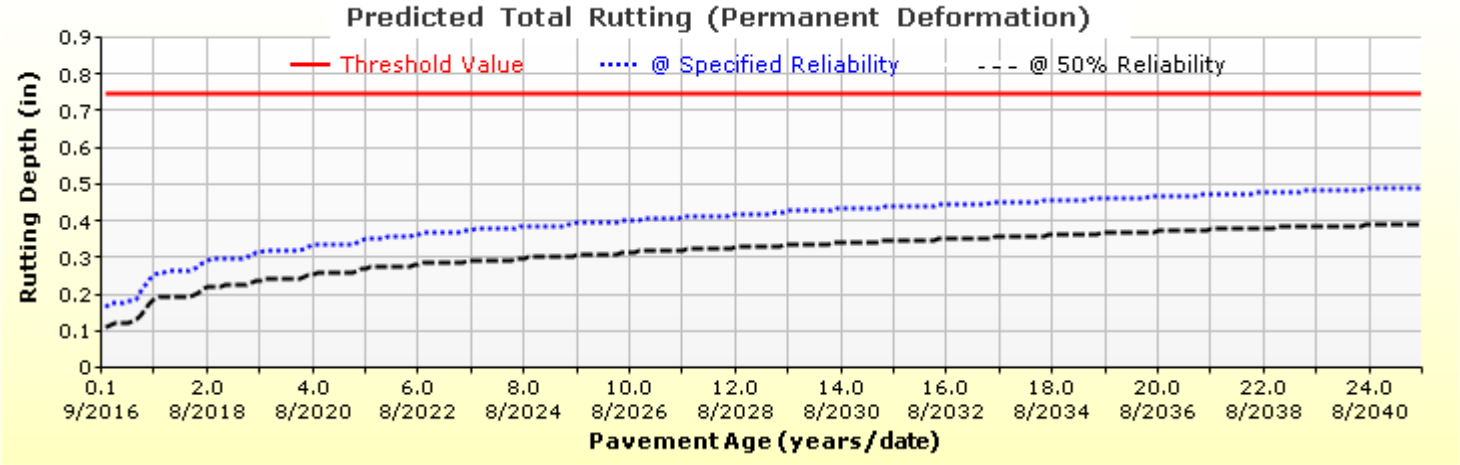


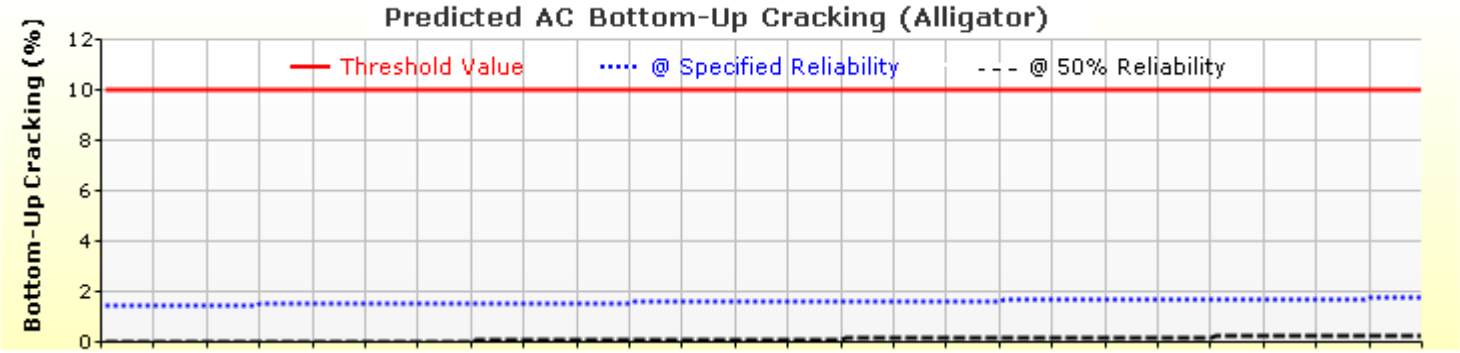


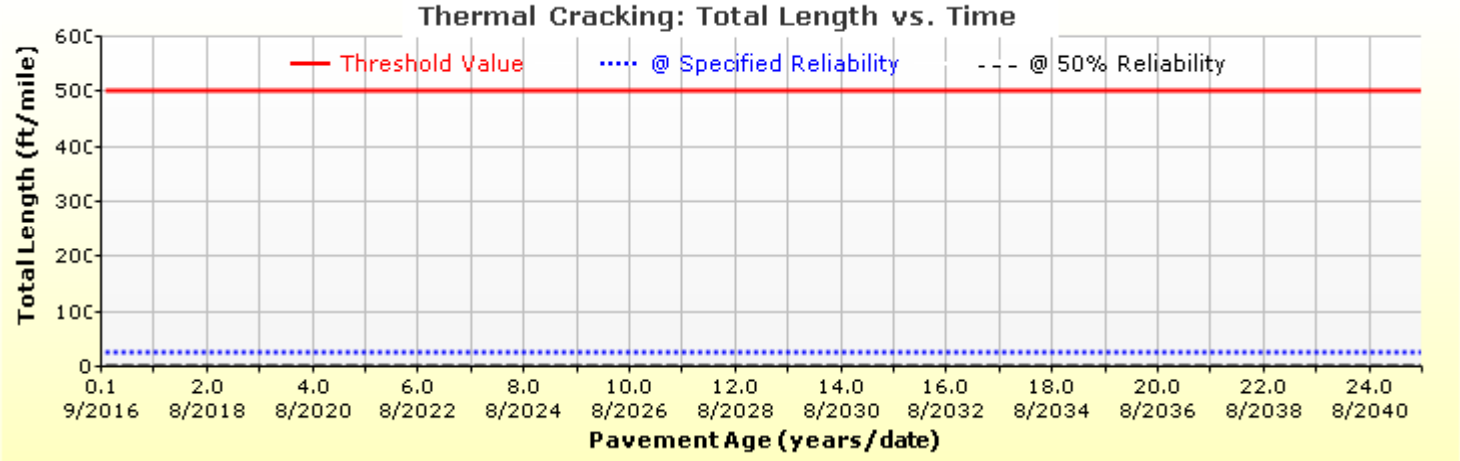


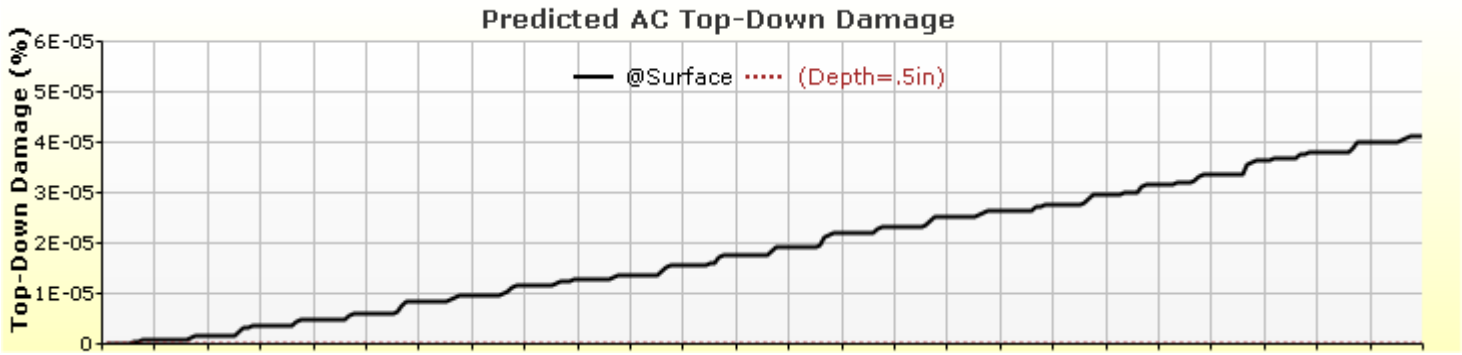
Analysis Output Charts

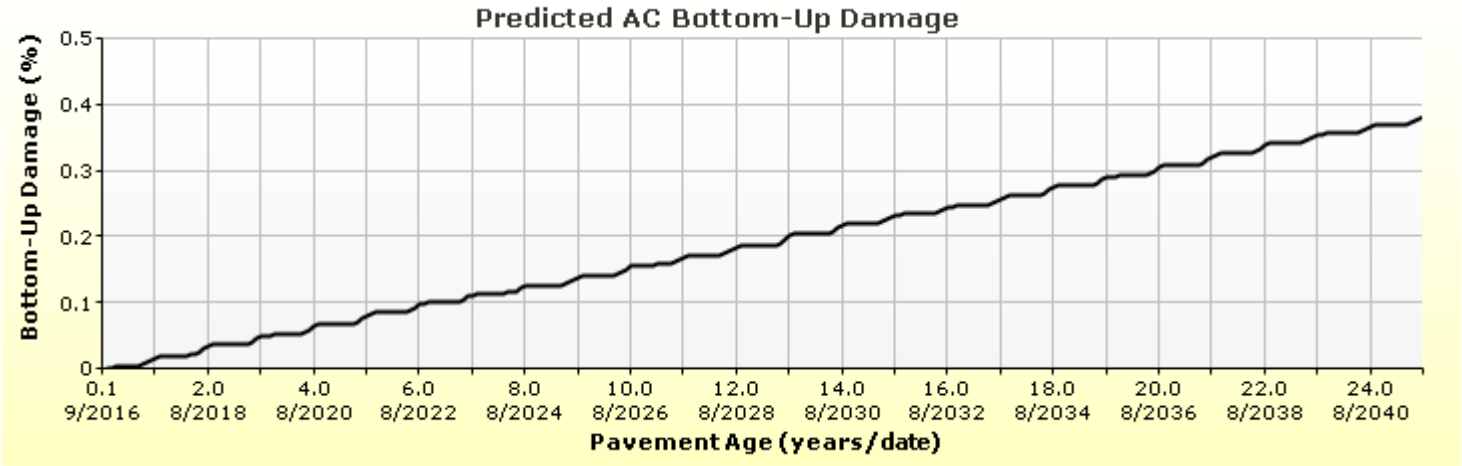


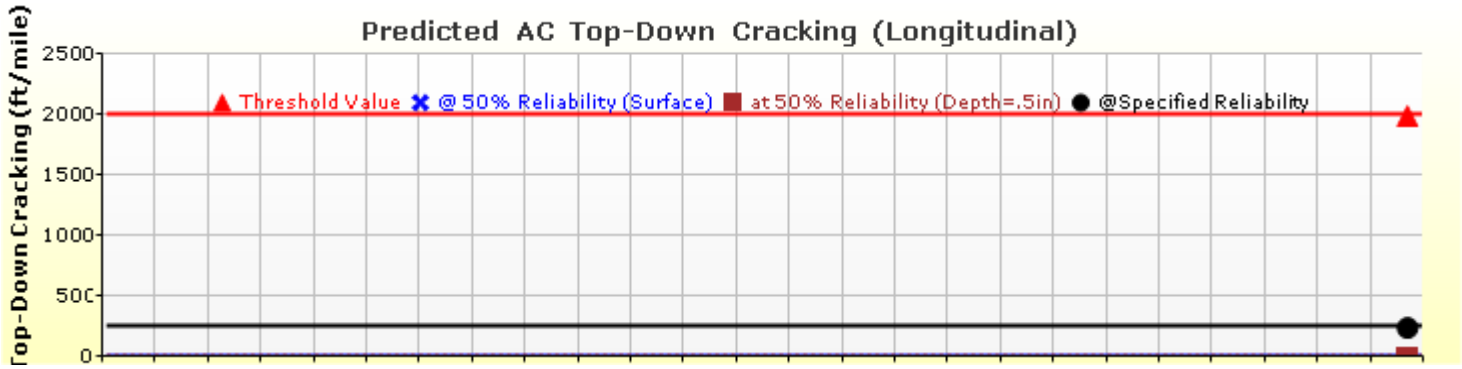


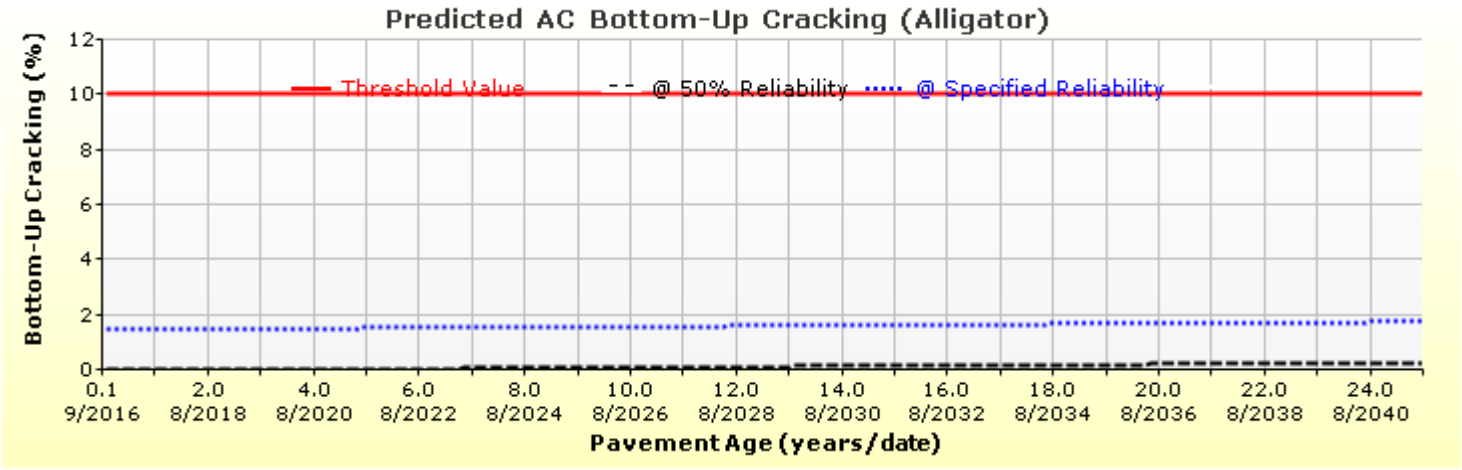


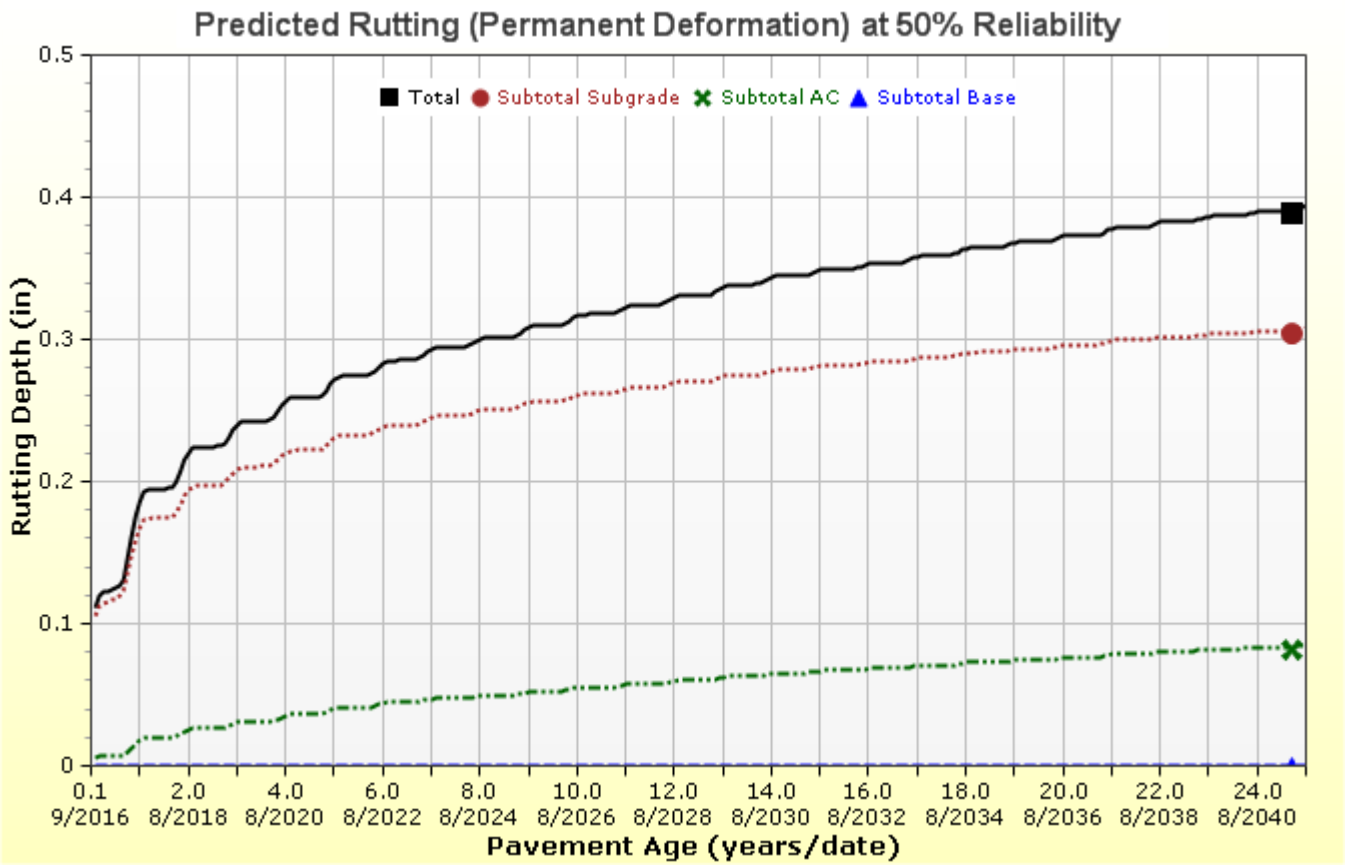


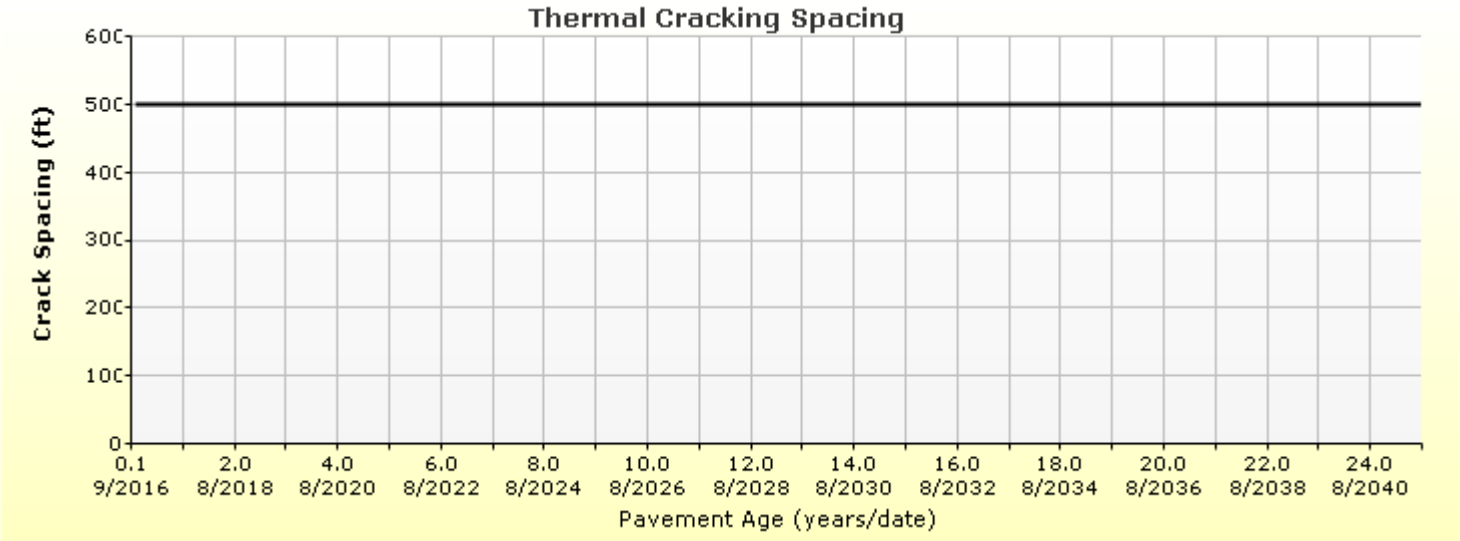

Predicted AC Top-Down Damage
Top-Down Damage (%)
6E-05
5E-05
4E-05
3E-05
2E-05
1E-05
0
@Surface
(Depth=.5in)

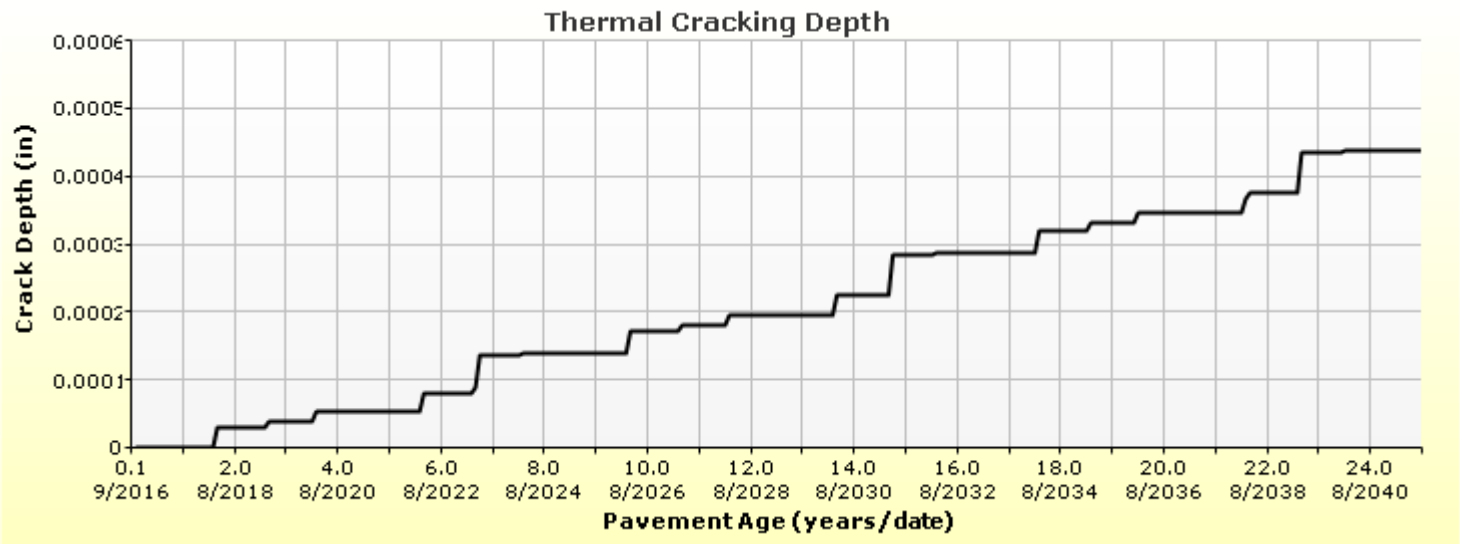

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

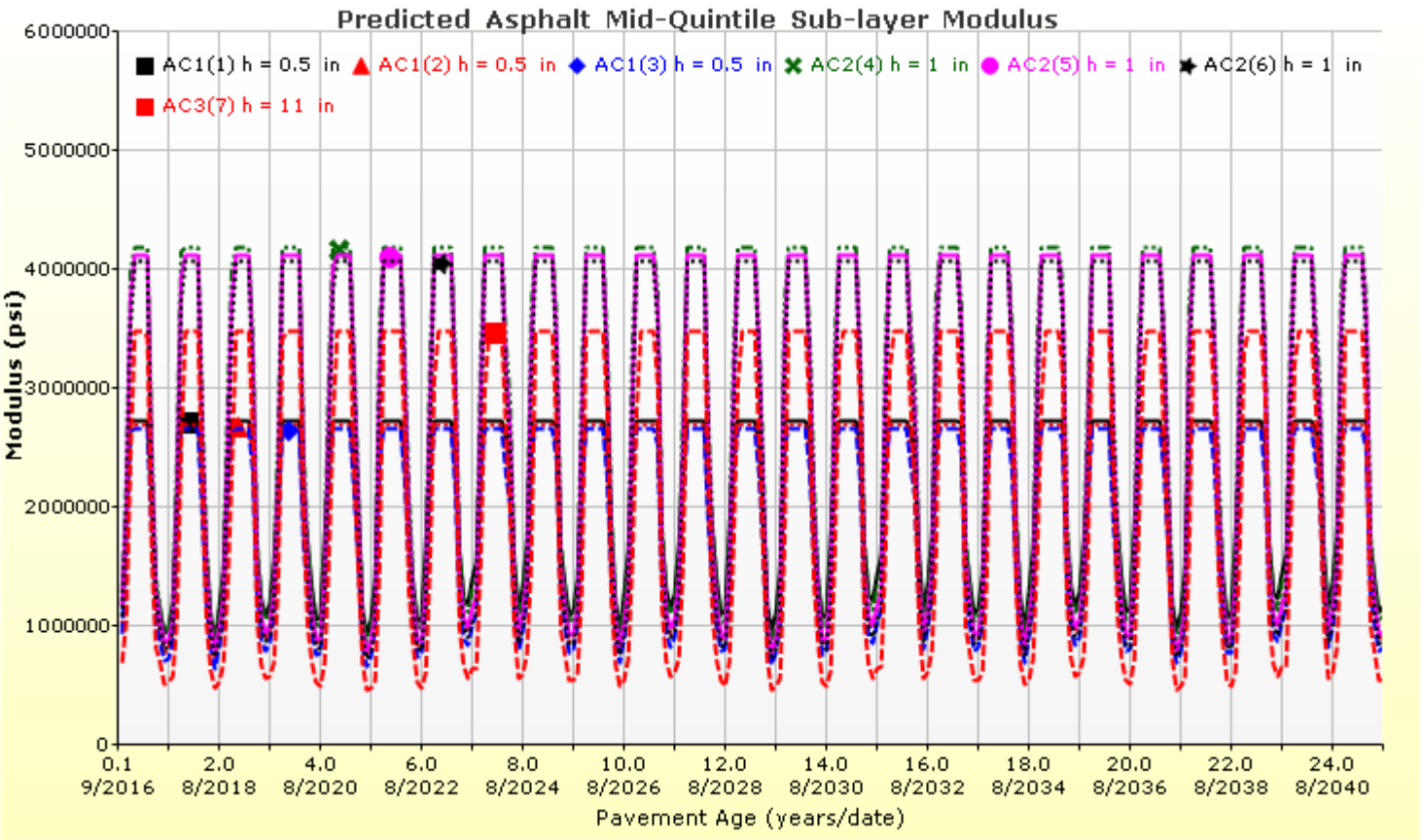

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

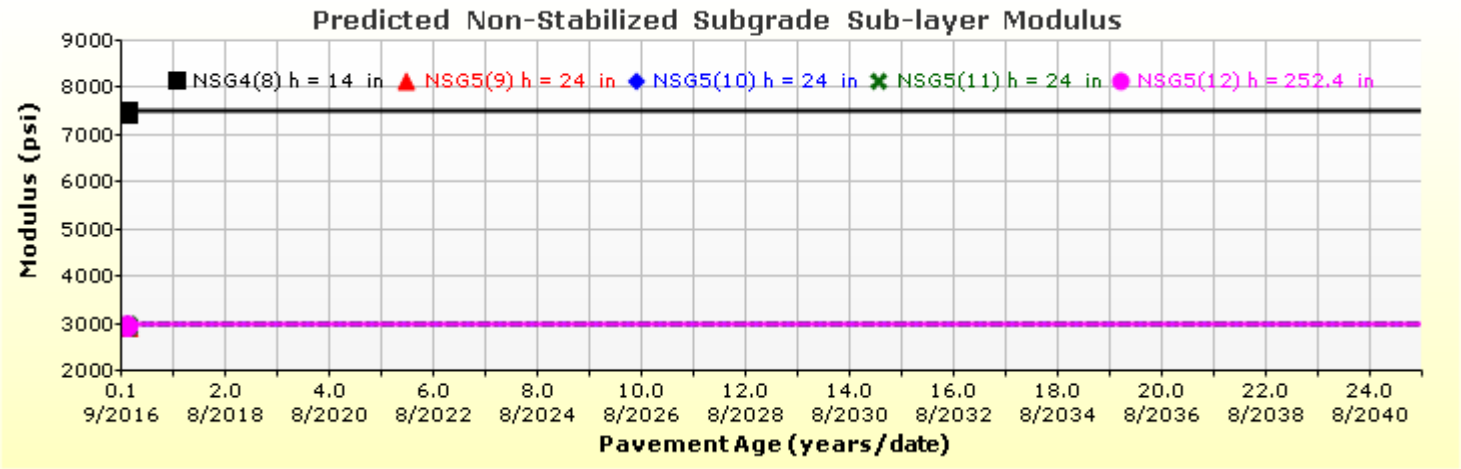

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rutting Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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 = 11 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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 = 252.4 in
Modulus (psi)
9000
8000
7000
6000
5000
4000
3000
2000
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield 9.5mm PG76-22

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	1815795	2225269	2582226	3093418
40	1604110	1630283	1703660	1887588
70	345178	527407	706612	828539
100	73077	146315	257222	325459
130	29611	55286	106243	139879

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 9.5mm PG76-22
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 : Greenfield 19.0mm PG76-22

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	2844521	3518316	4084950	4969012
40	2498125	2540381	2660112	2962037
70	499696	778904	1058035	1250008
100	98245	203329	367124	469716
130	38083	73323	145389	193942

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 19.0mm PG76-22
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 : Greenfield 25.0mm PG64-22

Asphalt		
Thickness (in.)	11.0	
Unit weight (pcf)	144.4	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

Asphalt Dynamic Modulus (Input Level: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	2598969	3160395	3486139	4321085
40	1725223	2215012	2597170	2965052
70	229249	543767	947325	1180792
100	48829	122657	284021	390350
130	25056	46516	103957	146568

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	Greenfield 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-7-6

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)
7500.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	98.6
Saturated hydraulic conductivity (ft/hr)	False	8.849e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 5 Subgrade : A-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 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

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

Campus Parkway Ramp Rehabilitation

Technical Proposal / I-69 Major Moves 2020 Expansion

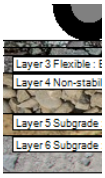
CampusPkwy Ramps

File Name: C:\My ME Design\Projects\MK15-469\PostReport\CampusPkwy Ramps.dgpx

Design Inputs

Design Life:	15 years	Existing construction:	May, 1967	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	AC over AC	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield SMA PG76-22	2.0
Flexible	Greenfield 9.5mm PG76-22	2.0
Flexible	Existing HMA	5.0
NonStabilized	Crushed stone	11.0
Subgrade	A-6	6.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	13.4
Air voids (%)	7.0

Traffic

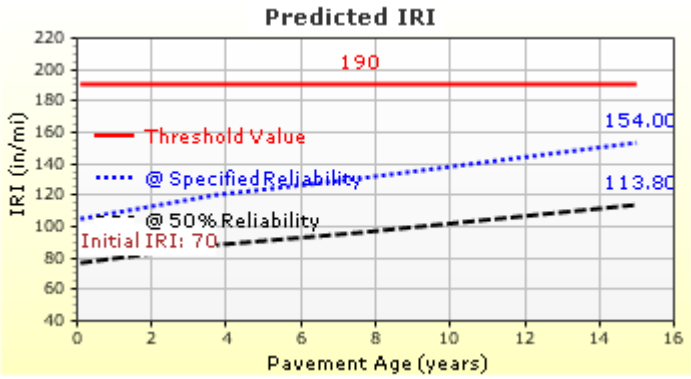
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	205
2023 (7 years)	528,644
2031 (15 years)	1,116,260

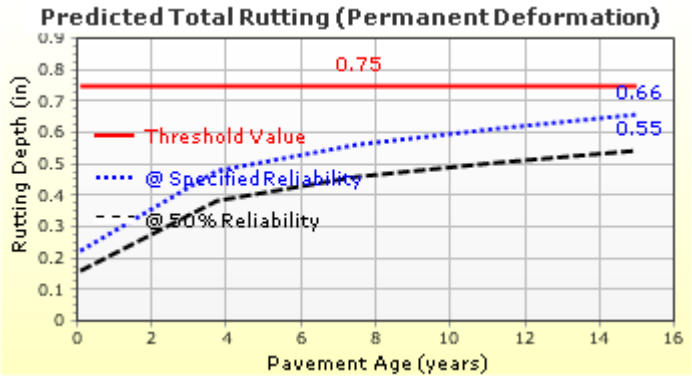
Design Outputs

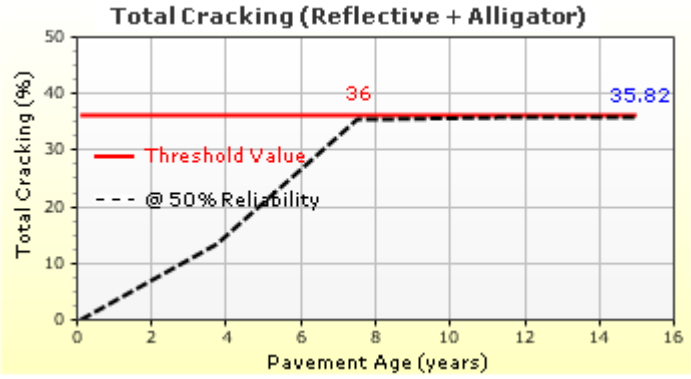
Distress Prediction Summary

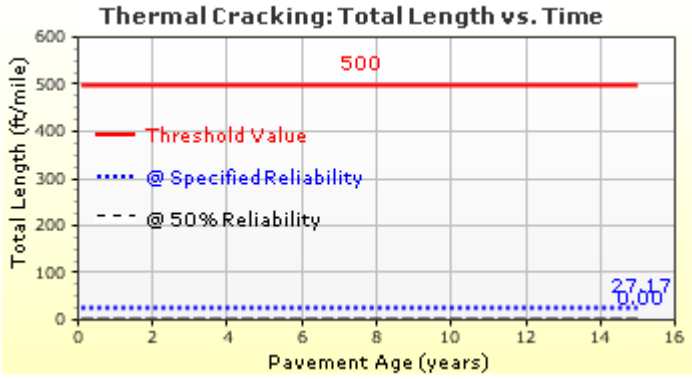
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	190.00	154.01	90.00	99.24	Pass
Permanent deformation - total pavement (in.)	0.75	0.66	90.00	98.84	Pass
Total Cracking (Reflective + Alligator) (percent)	36	35.82	-	-	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	1.45	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	274.67	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.11	90.00	100.00	Pass

Distress Charts





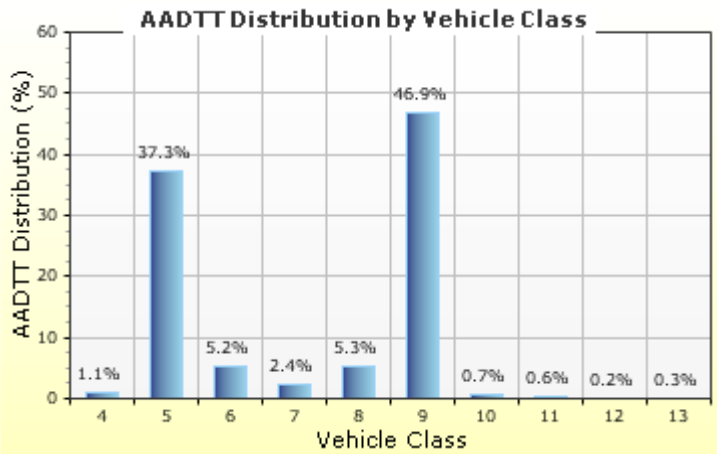


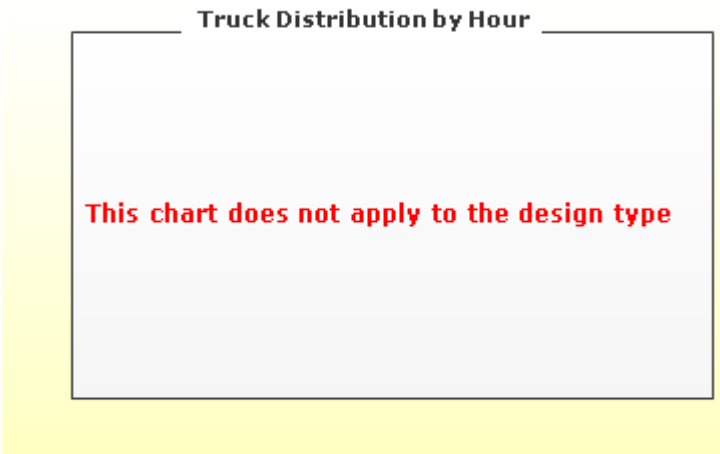


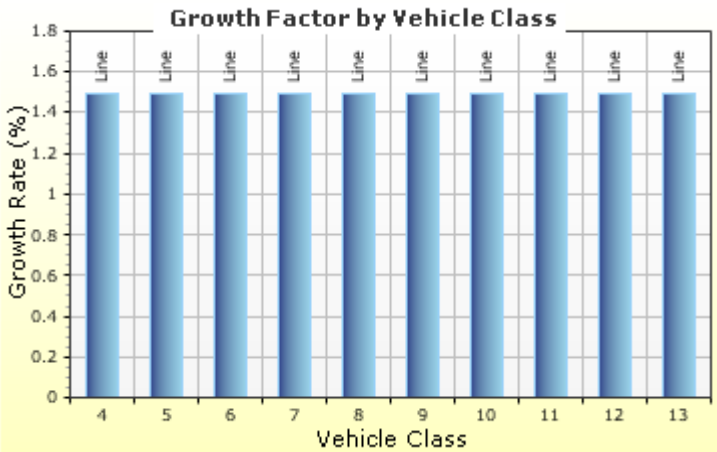
Traffic Inputs

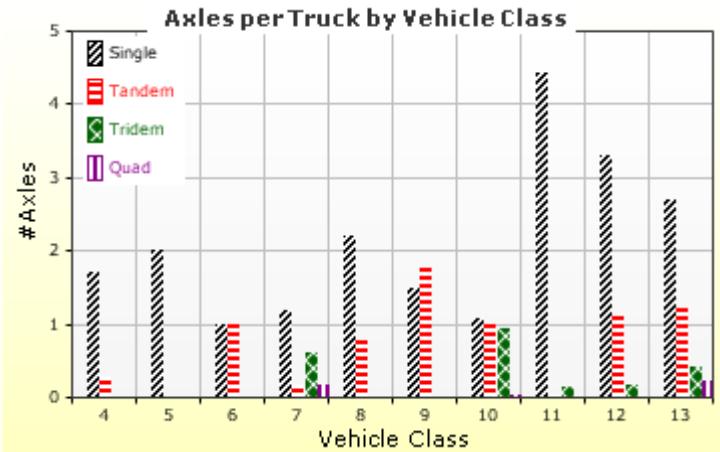
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	205	Percent of trucks in design direction (%):	100.0
Number of lanes in design direction:	1	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	25.0

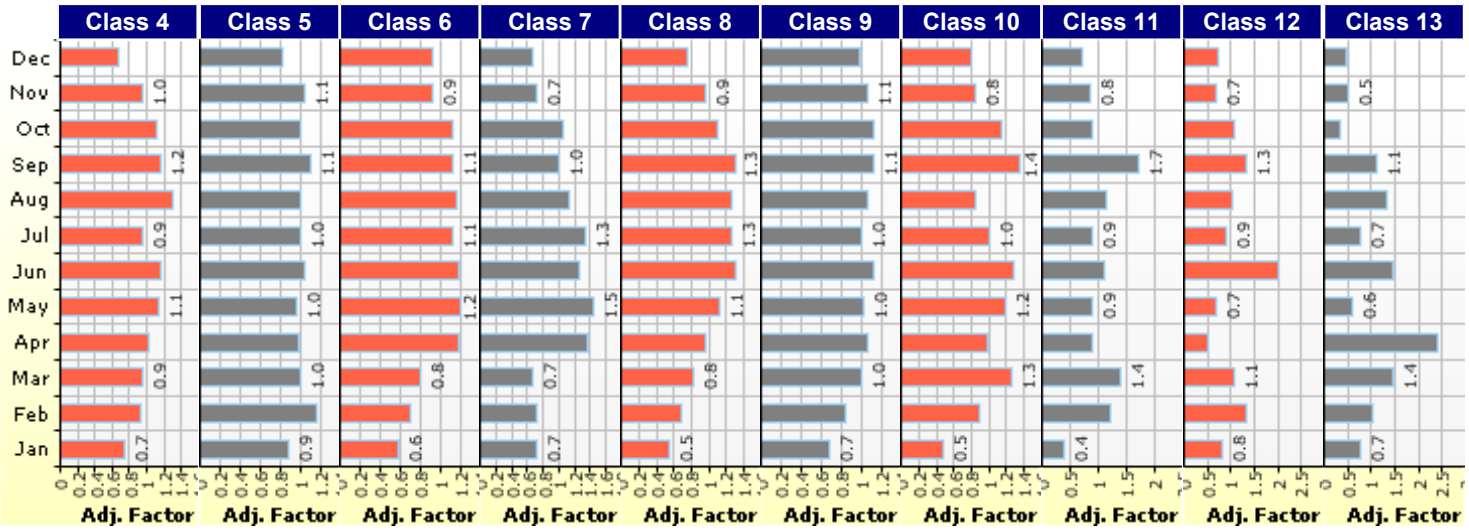








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.7	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%	1.49%	Linear
Class 5	37.3%	1.49%	Linear
Class 6	5.2%	1.49%	Linear
Class 7	2.4%	1.49%	Linear
Class 8	5.3%	1.49%	Linear
Class 9	46.9%	1.49%	Linear
Class 10	0.7%	1.49%	Linear
Class 11	0.6%	1.49%	Linear
Class 12	0.2%	1.49%	Linear
Class 13	0.3%	1.49%	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

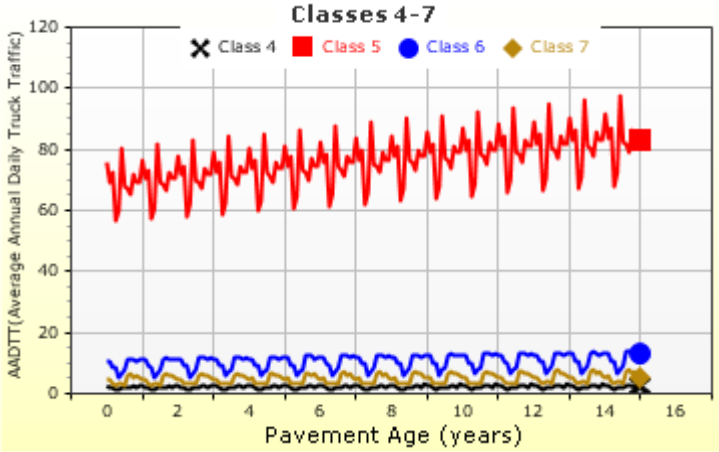
Wheelbase does not apply

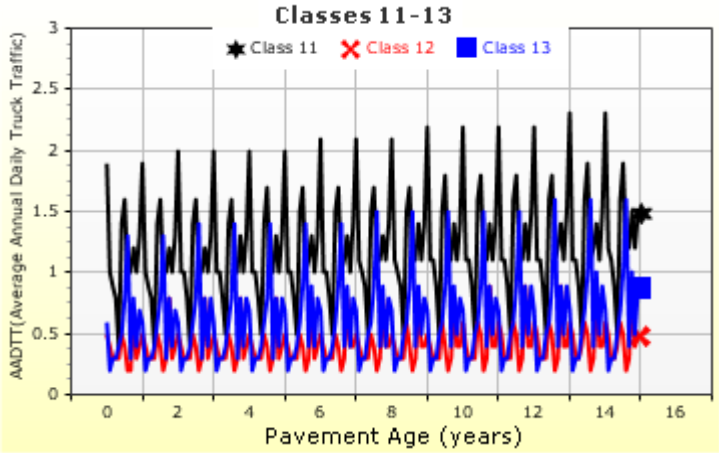
Number of Axles per Truck

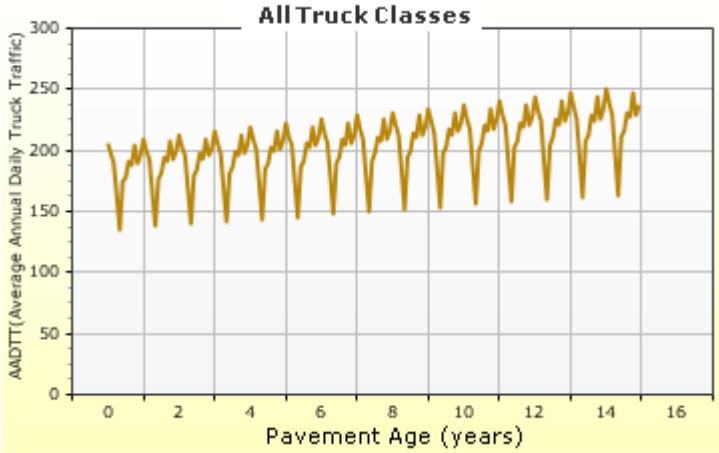
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.7	0.29	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.18	0.18	0.63	0.18
Class 8	2.21	0.78	0	0
Class 9	1.48	1.75	0	0
Class 10	1.08	0.99	0.94	0.03
Class 11	4.43	0.03	0.16	0
Class 12	3.29	1.09	0.17	0
Class 13	2.7	1.22	0.43	0.24

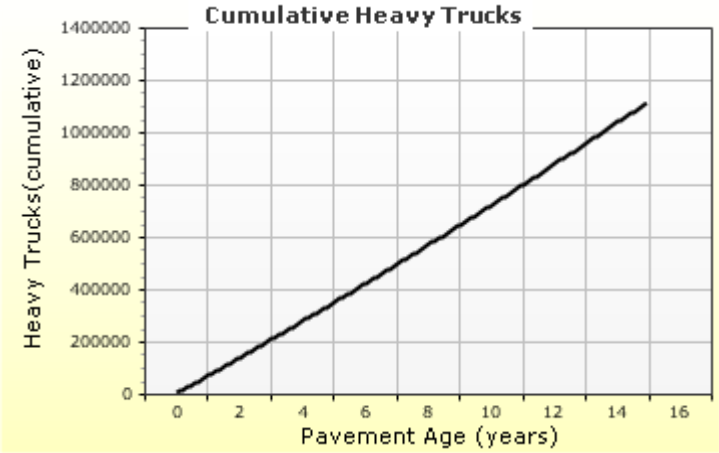
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





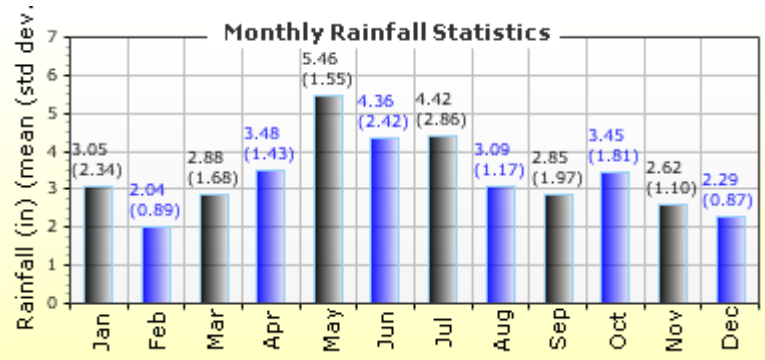




Climate Inputs

Climate Data Sources:

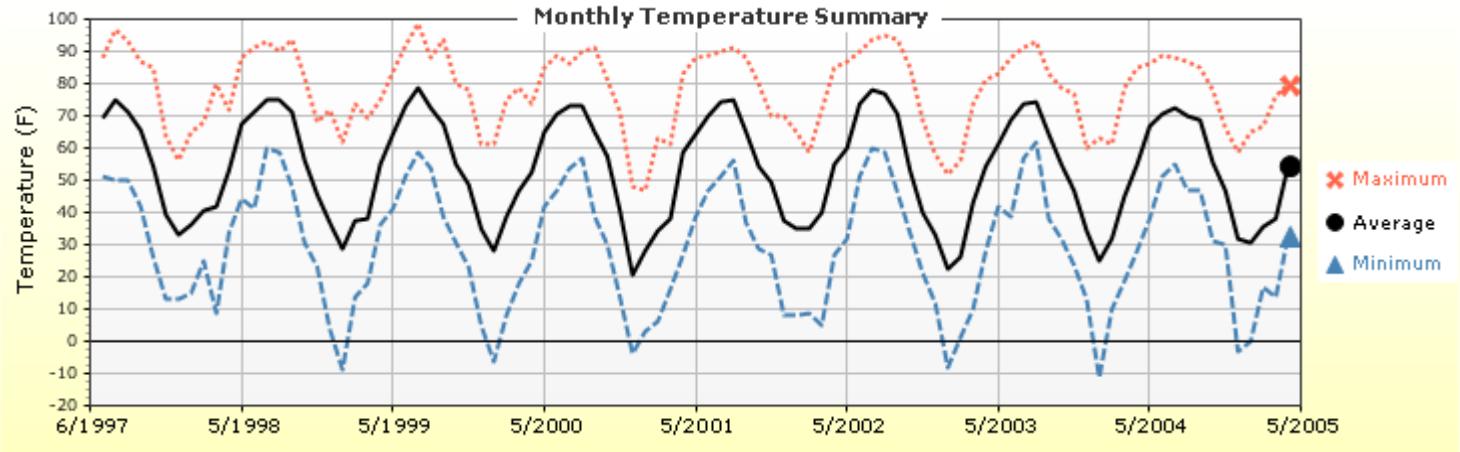
Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

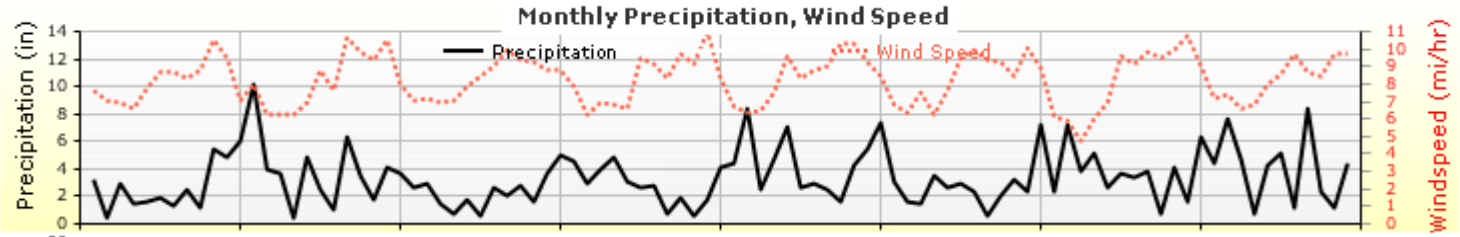


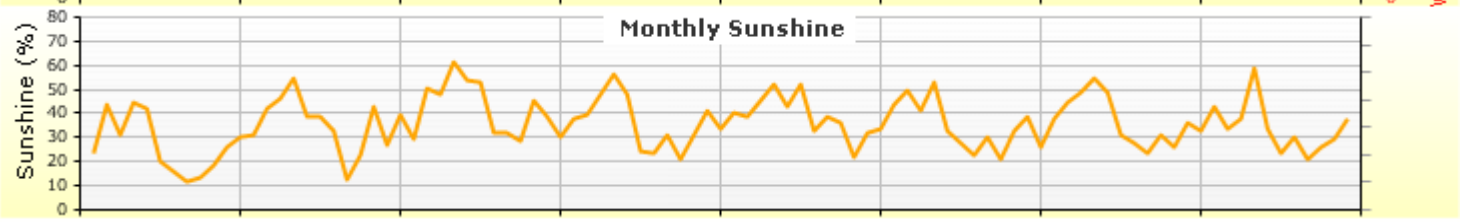
Annual Statistics:

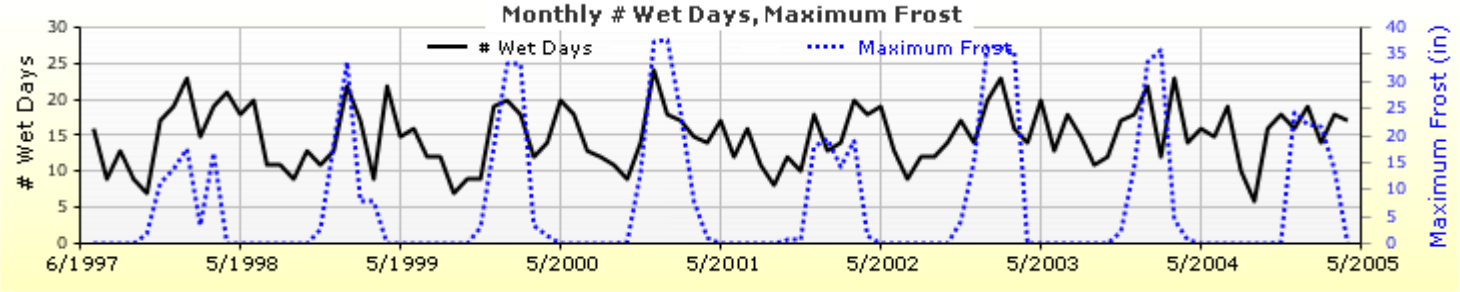
Mean annual air temperature (ºF)	54.16
Mean annual precipitation (in.)	39.93
Freezing index (ºF - days)	465.51
Average annual number of freeze/thaw cycles:	54.86
Water table depth (ft)	5.00

Monthly Climate Summary:

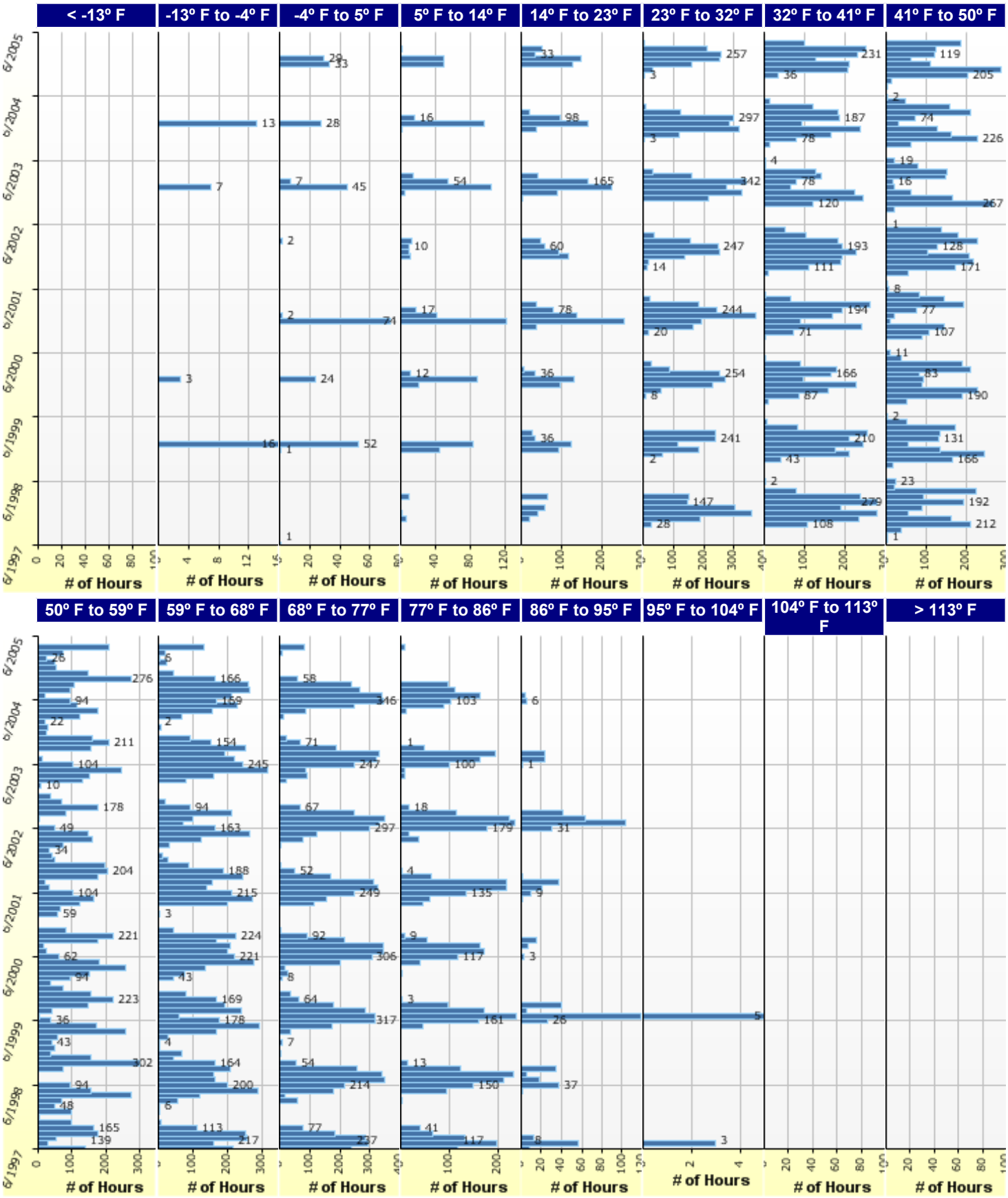








Hourly Air Temperature Distribution by Month:



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 : Greenfield SMA PG76-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 9.5mm PG76-22	Flexible (1)	1.00
Layer 3 Flexible : Existing HMA (existing)	Flexible (1)	1.00
Layer 4 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : A-6	Subgrade (5)	1.00
Layer 6 Subgrade : A-6	Subgrade (5)	-

HMA Rehabilitation (Input Level: 3)

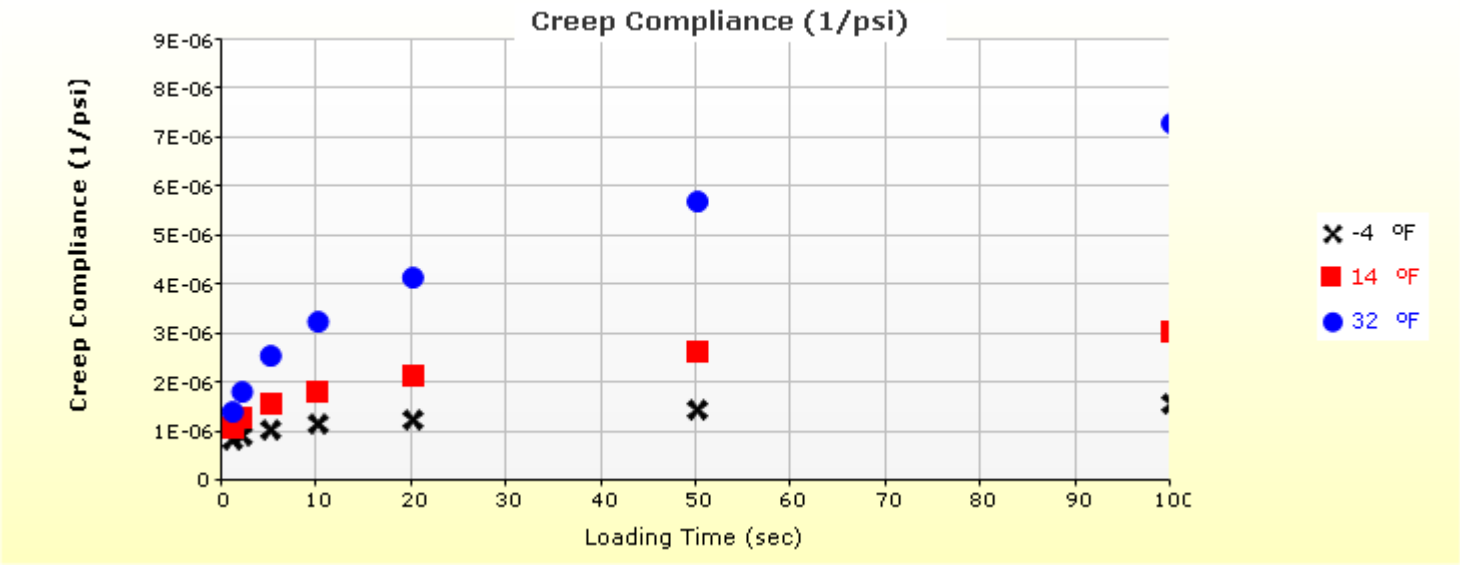
Milled thickness (in.)	-
Fatigue cracking (%)	-
Pavement rating	Fair
Total rut depth (in.)	0.00

Thermal Cracking (Input Level: 3)

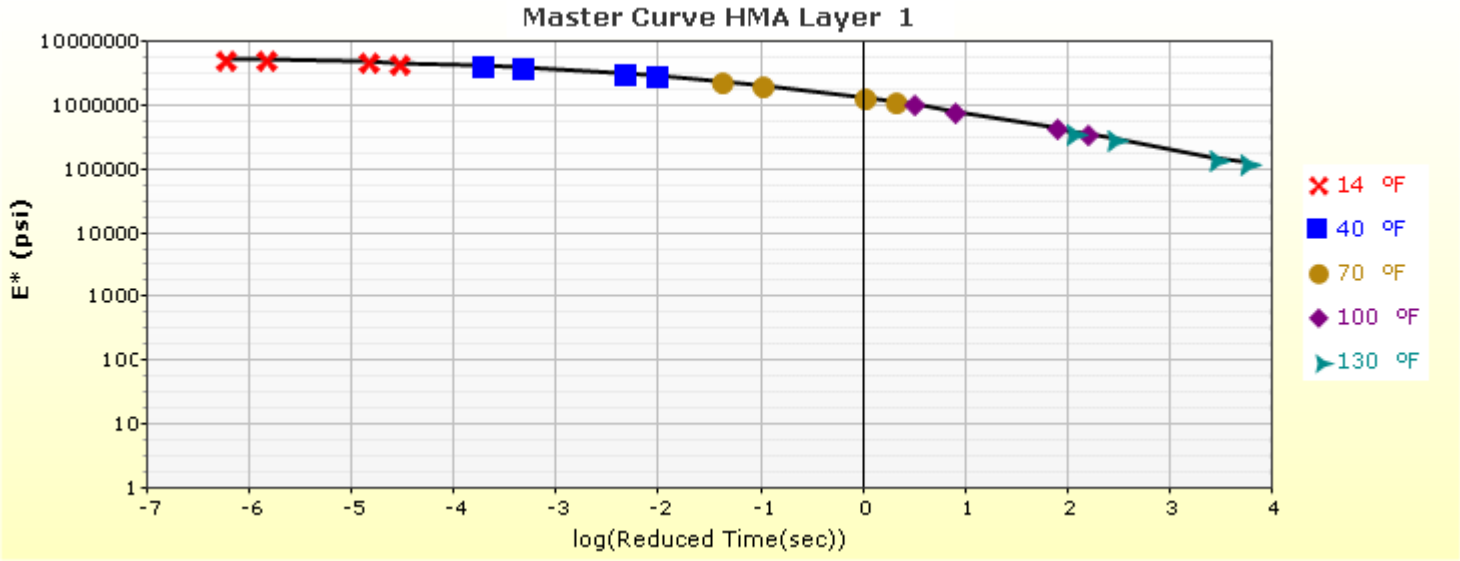
Indirect tensile strength at 14 ºF (psi)	404.62

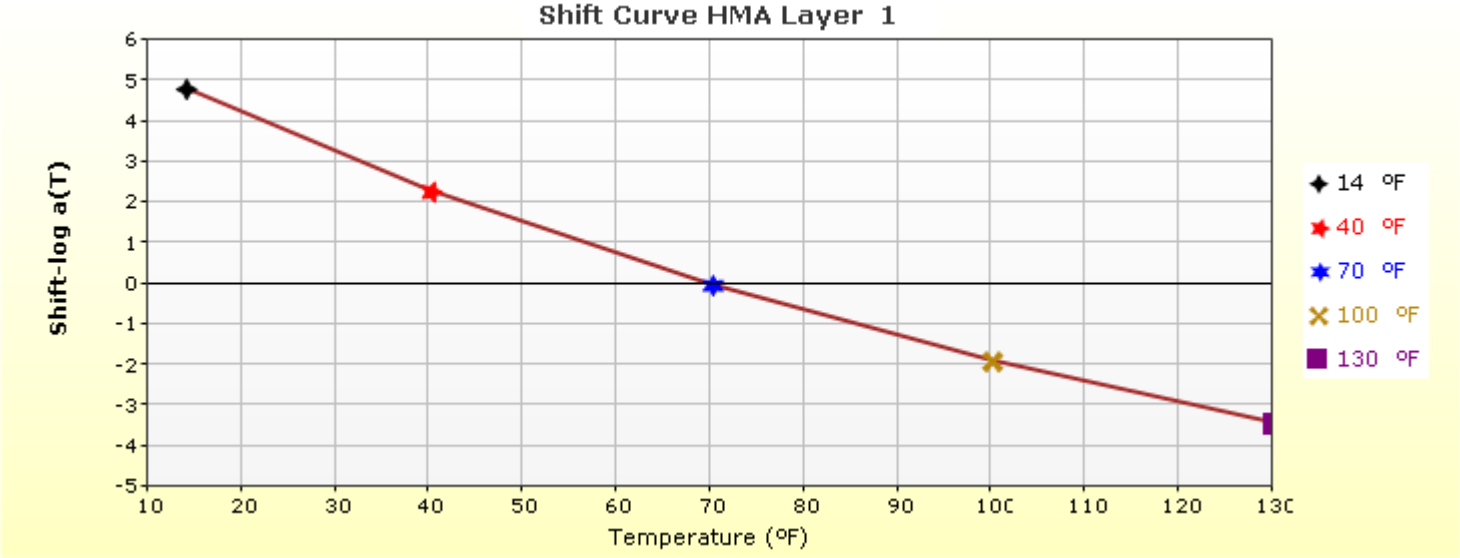
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	20.4

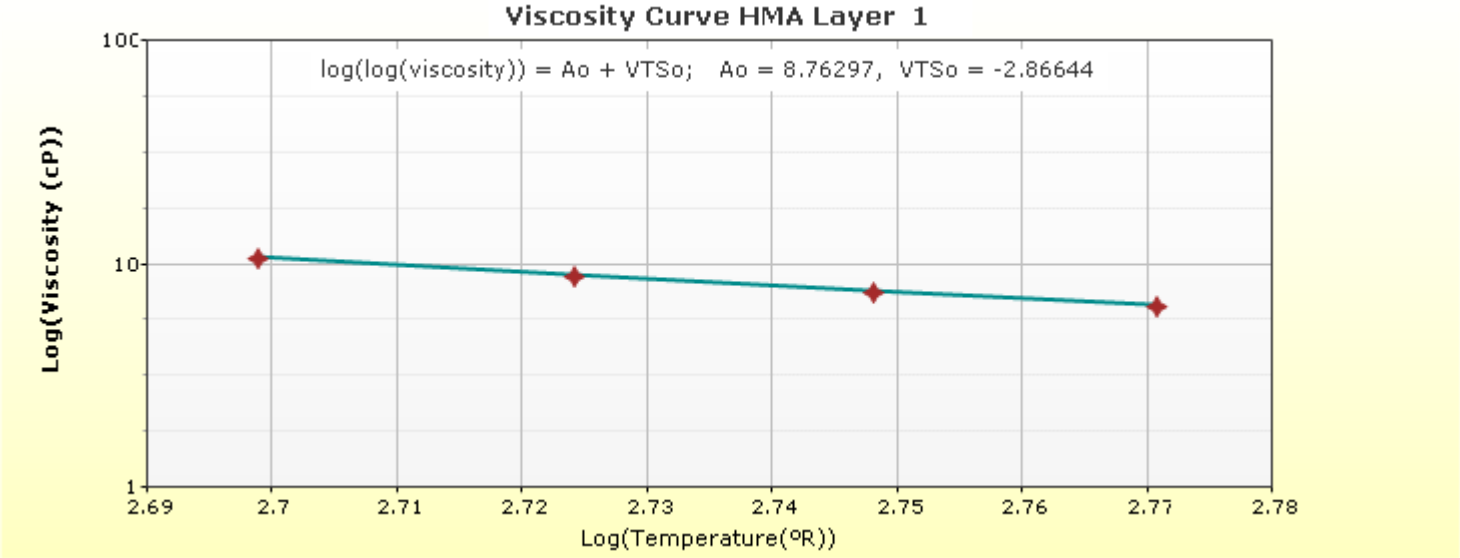
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	8.77e-007	1.13e-006	1.47e-006
2	9.61e-007	1.31e-006	1.87e-006
5	1.09e-006	1.61e-006	2.58e-006
10	1.19e-006	1.87e-006	3.28e-006
20	1.31e-006	2.18e-006	4.18e-006
50	1.47e-006	2.67e-006	5.75e-006
100	1.62e-006	3.11e-006	7.32e-006



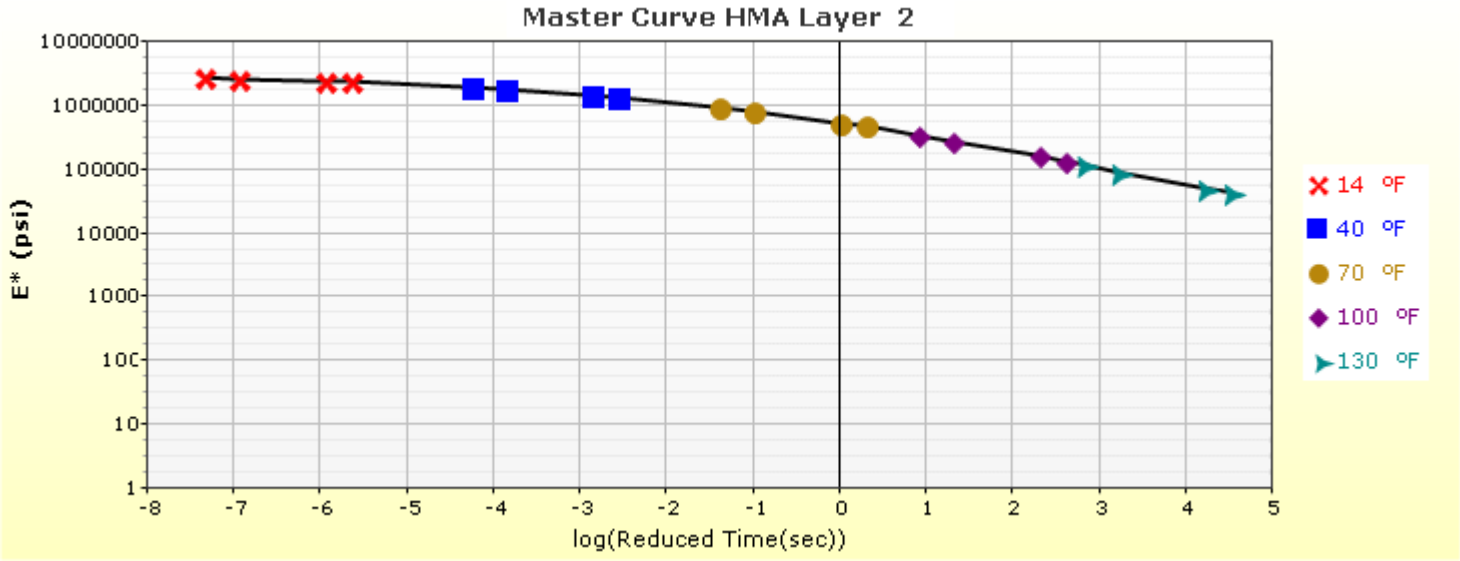
HMA Layer 1: Layer 1 Flexible : Greenfield SMA PG76-22

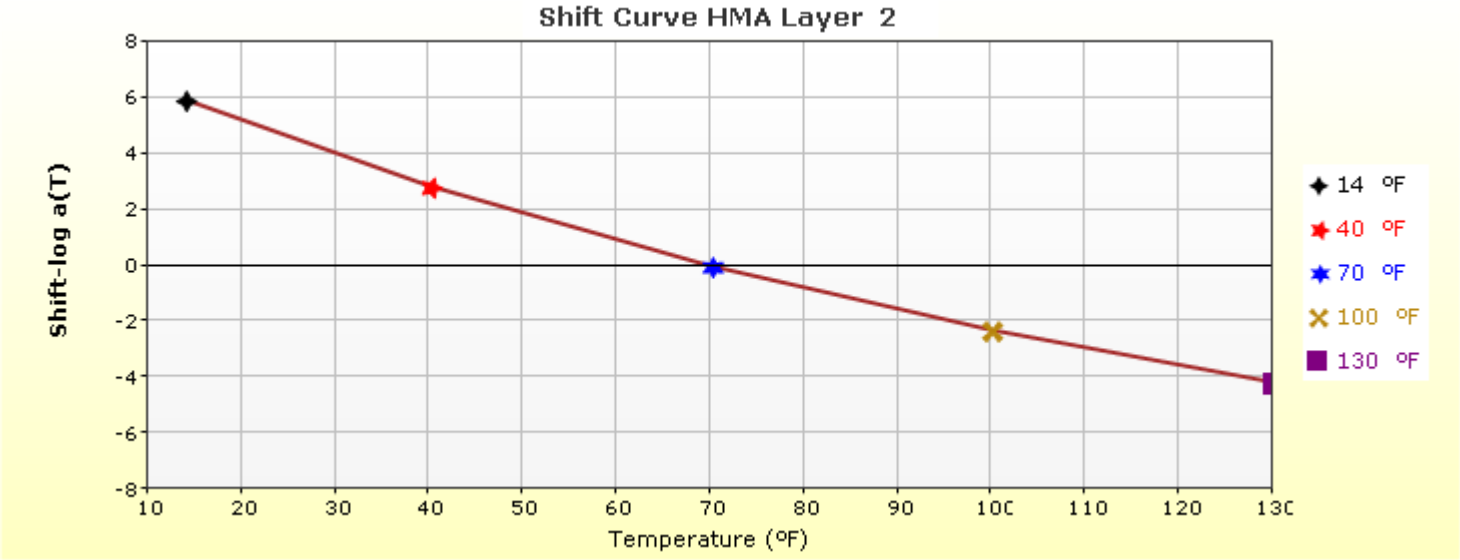


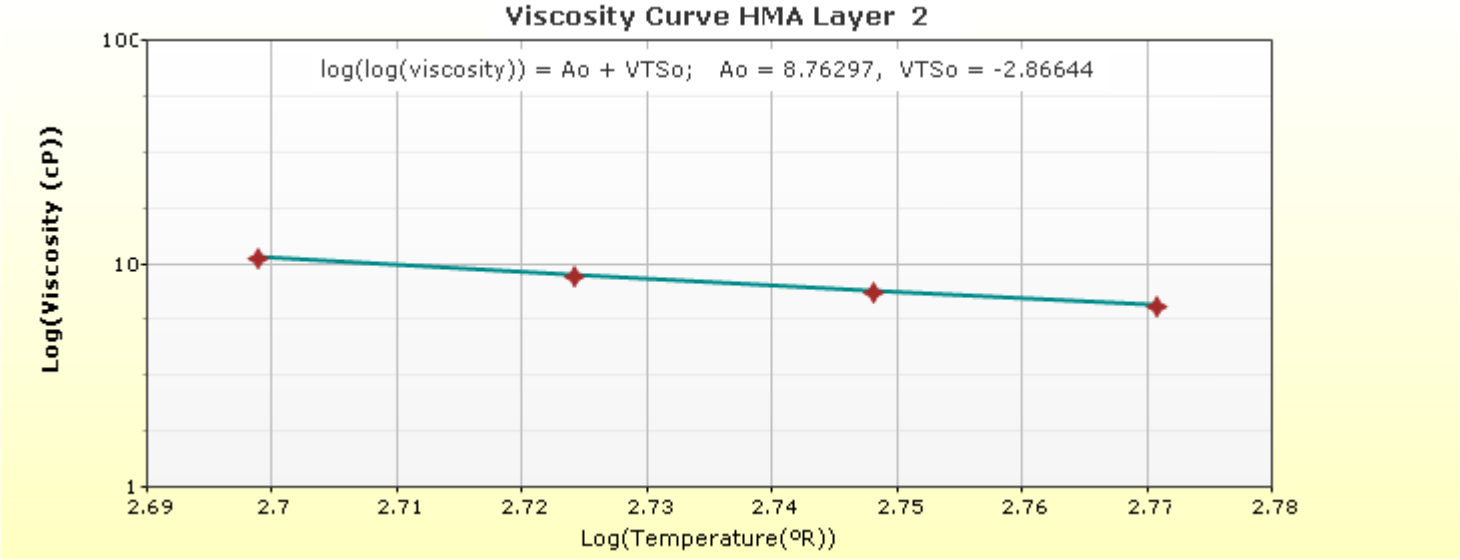




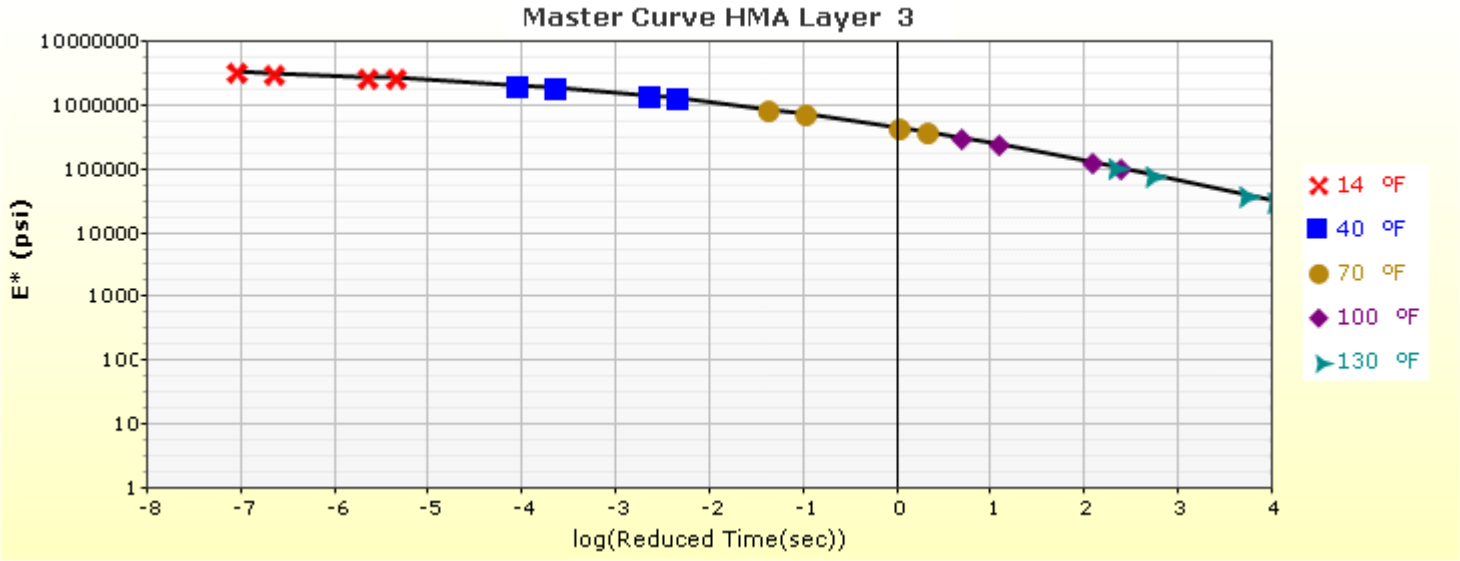
HMA Layer 2: Layer 2 Flexible : Greenfield 9.5mm PG76-22

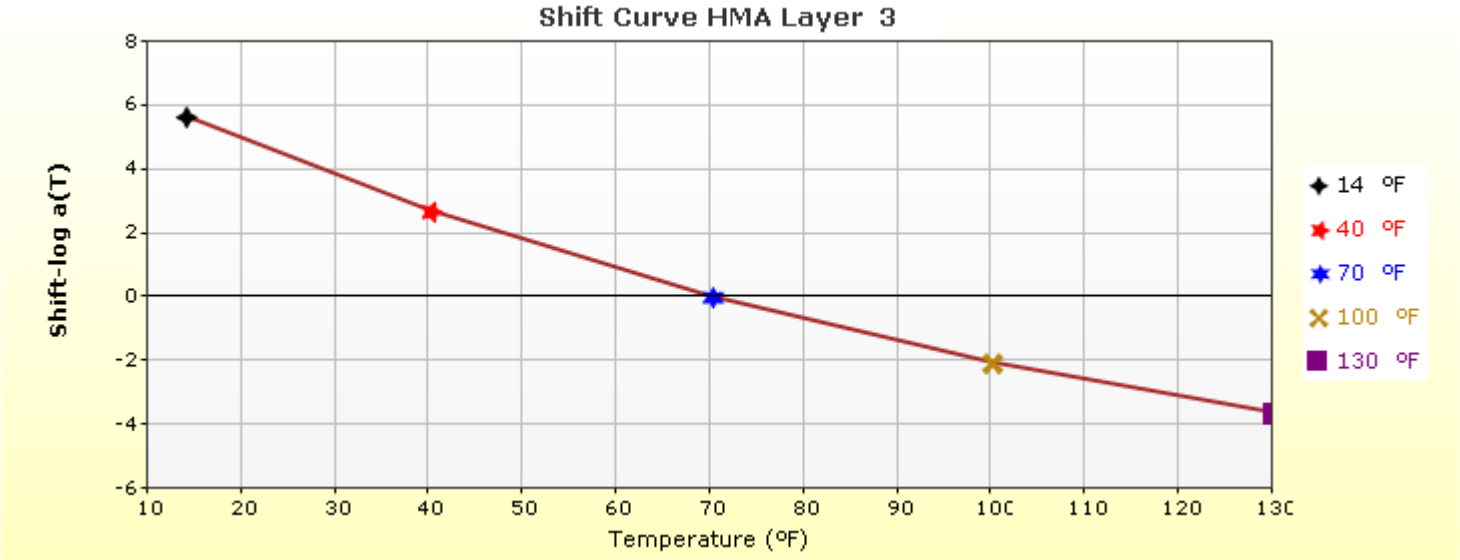


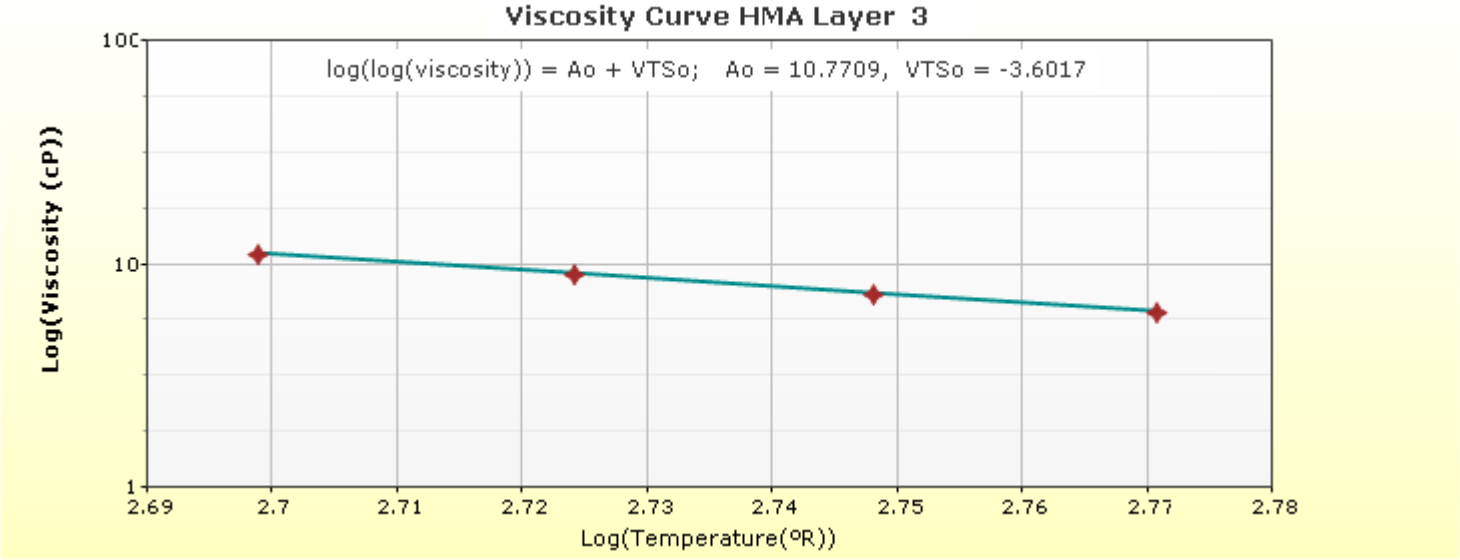




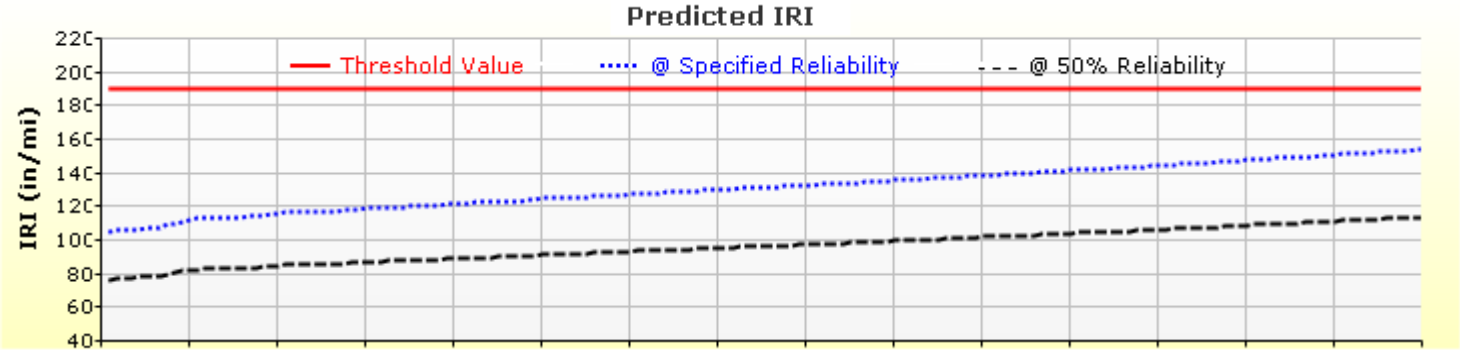
HMA Layer 3: Layer 3 Flexible : Existing HMA(existing)

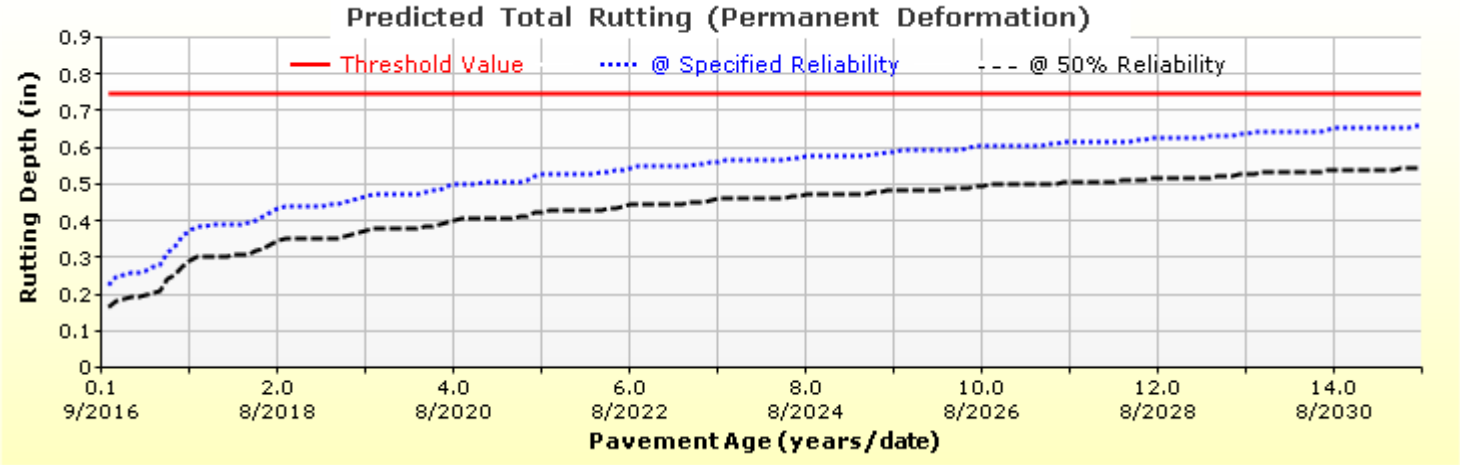


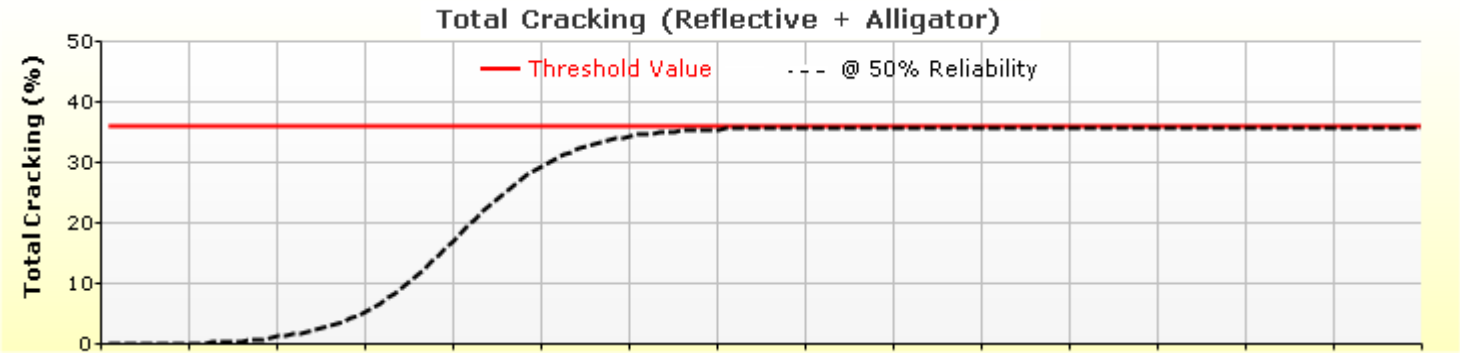


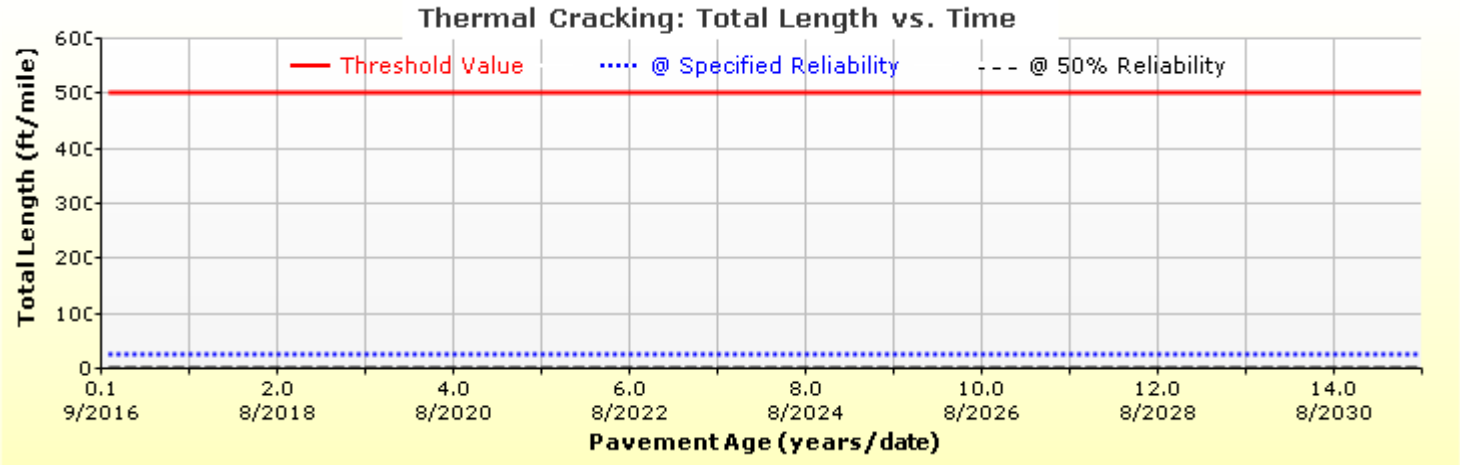


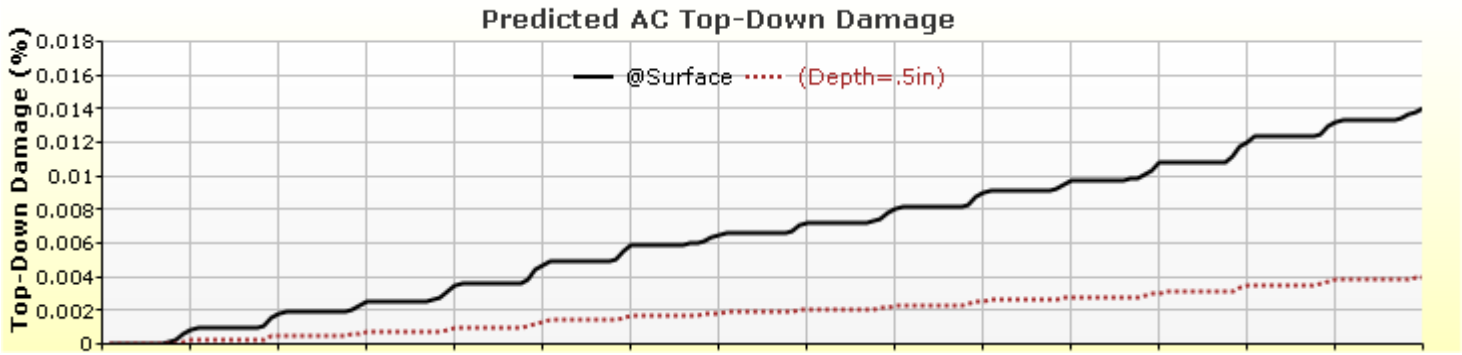
Analysis Output Charts

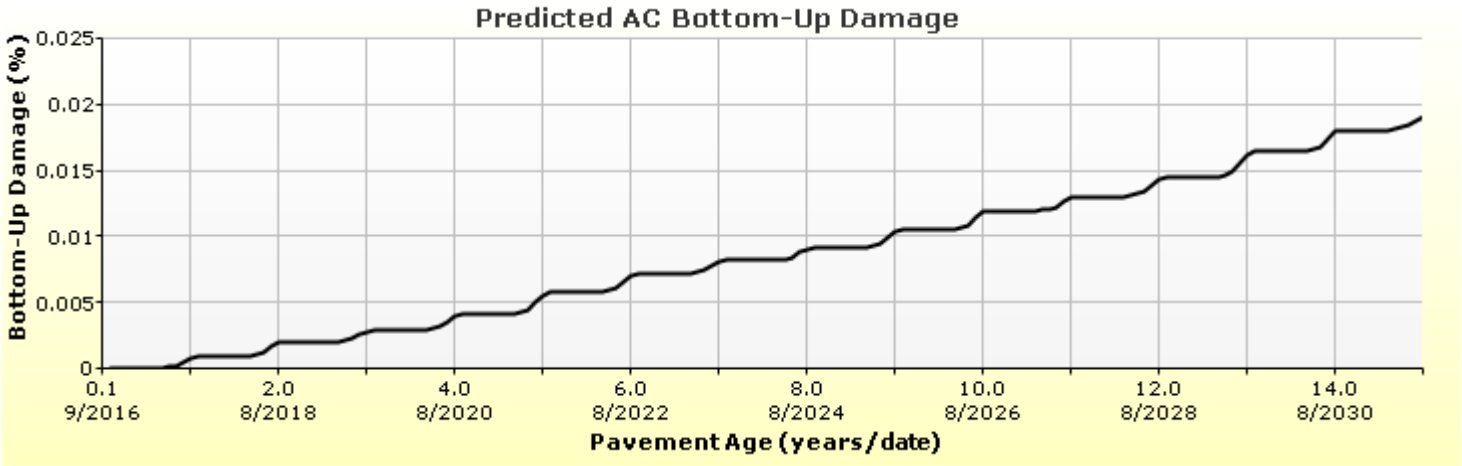


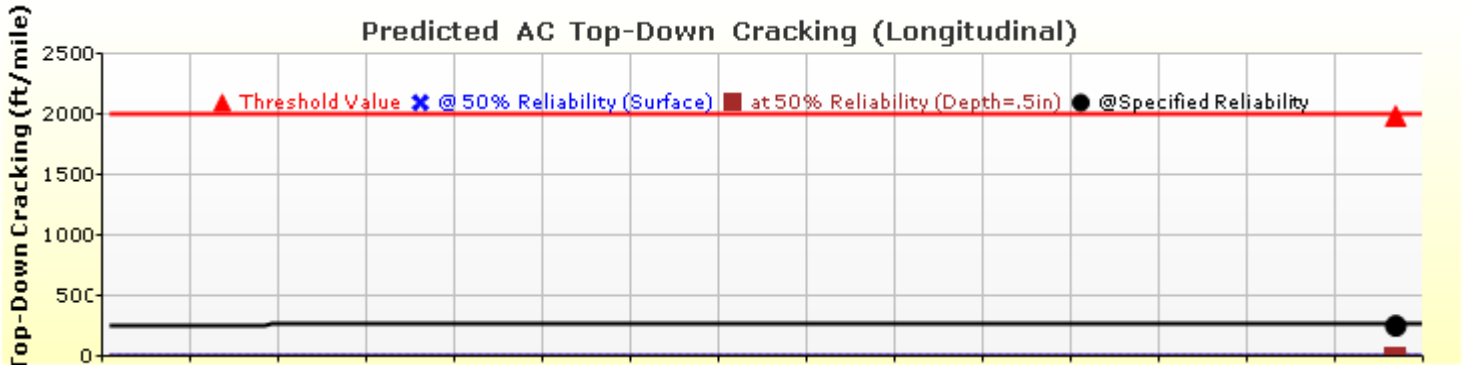


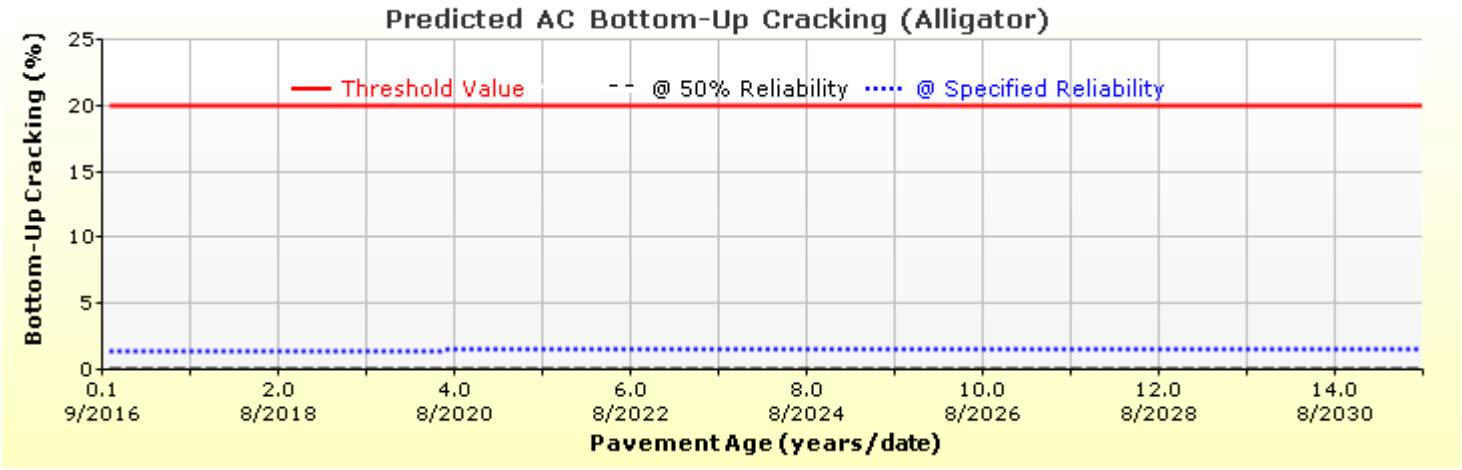


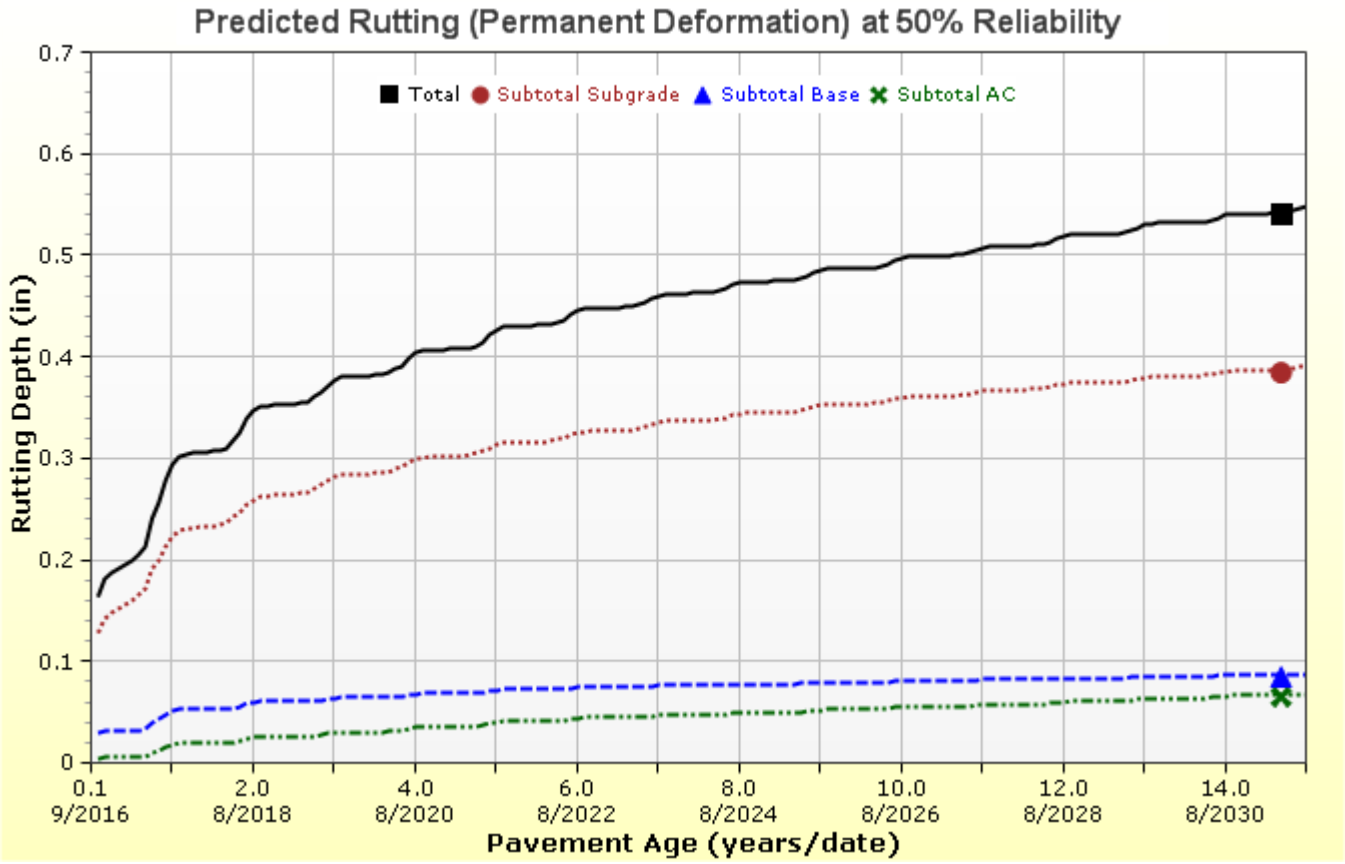


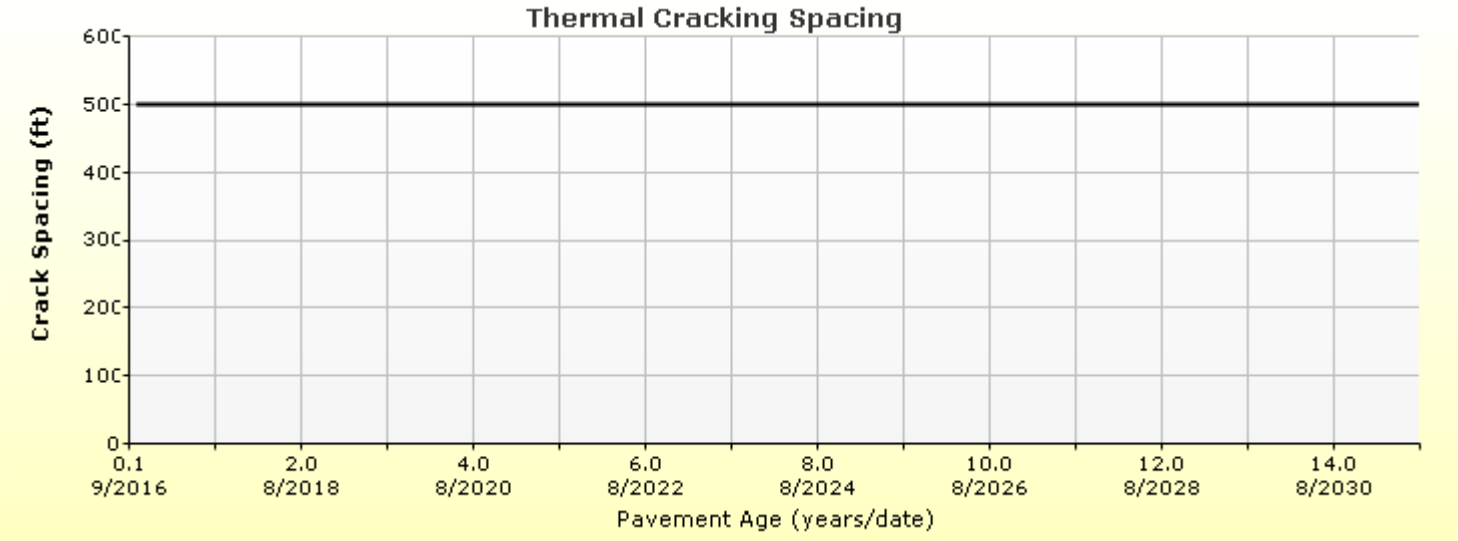

Predicted AC Top-Down Damage
Top-Down Damage (%)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
@Surface
(Depth=.5in)

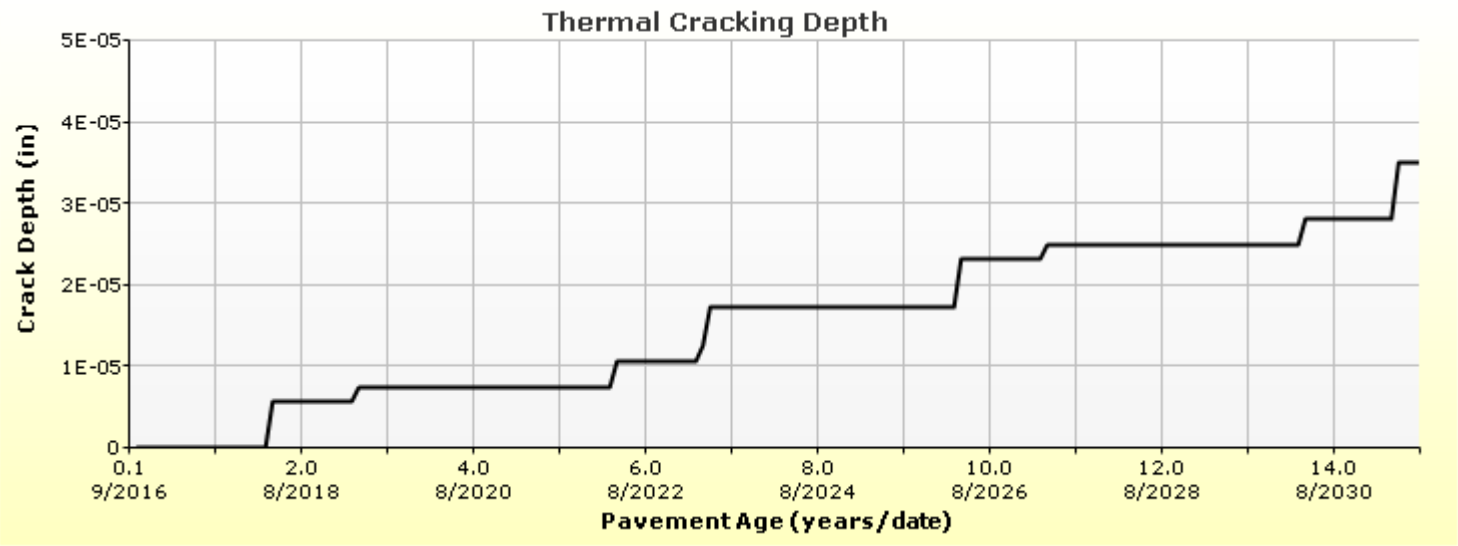

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0.025
0.02
0.015
0.01
0.005
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
Pavement Age (years/date)

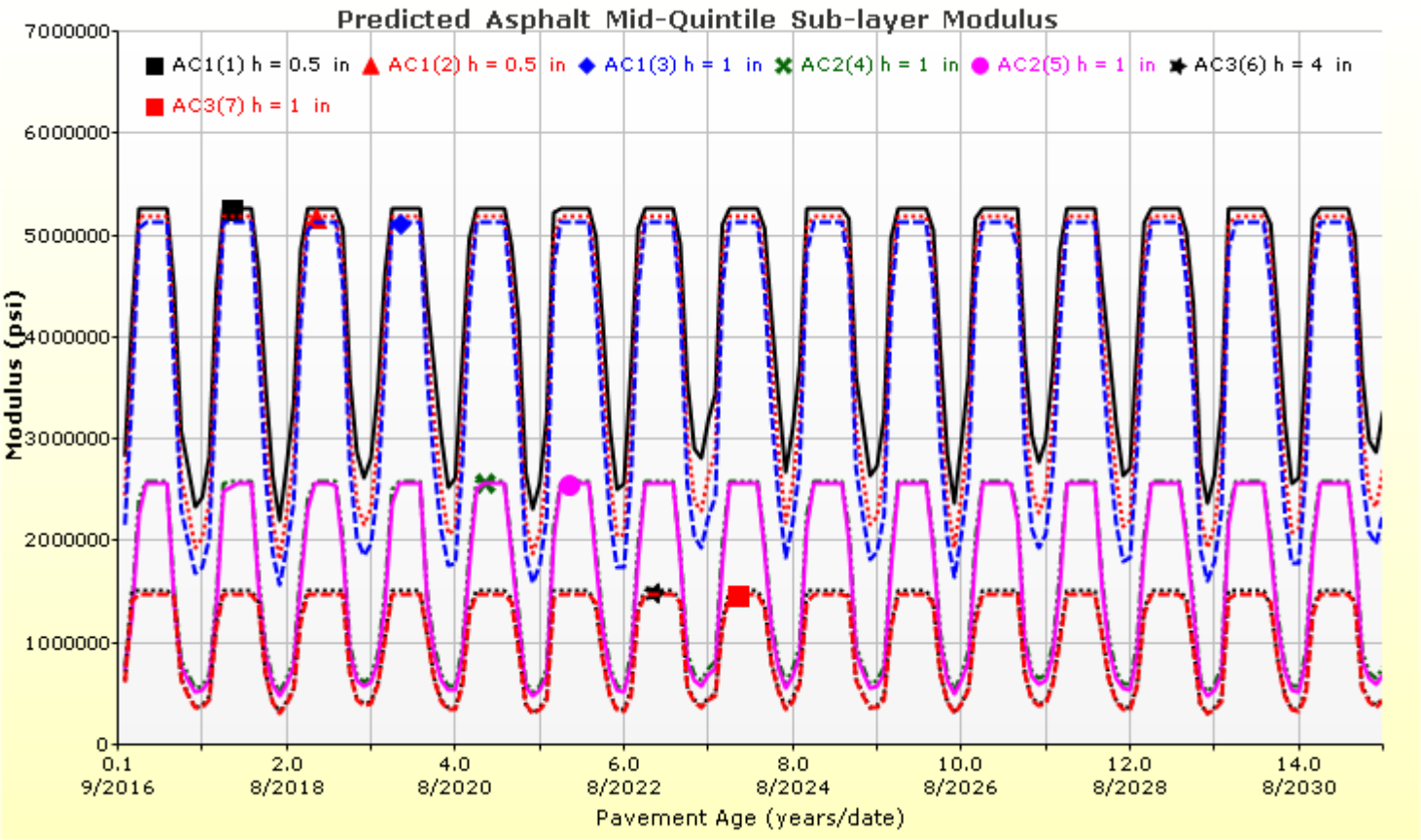

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

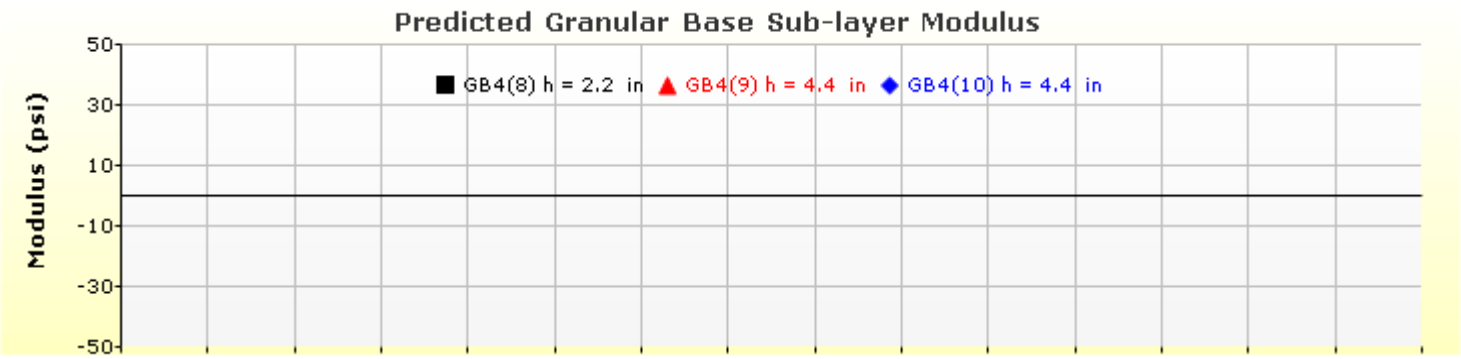

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
25
20
15
10
5
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
Pavement Age (years/date)

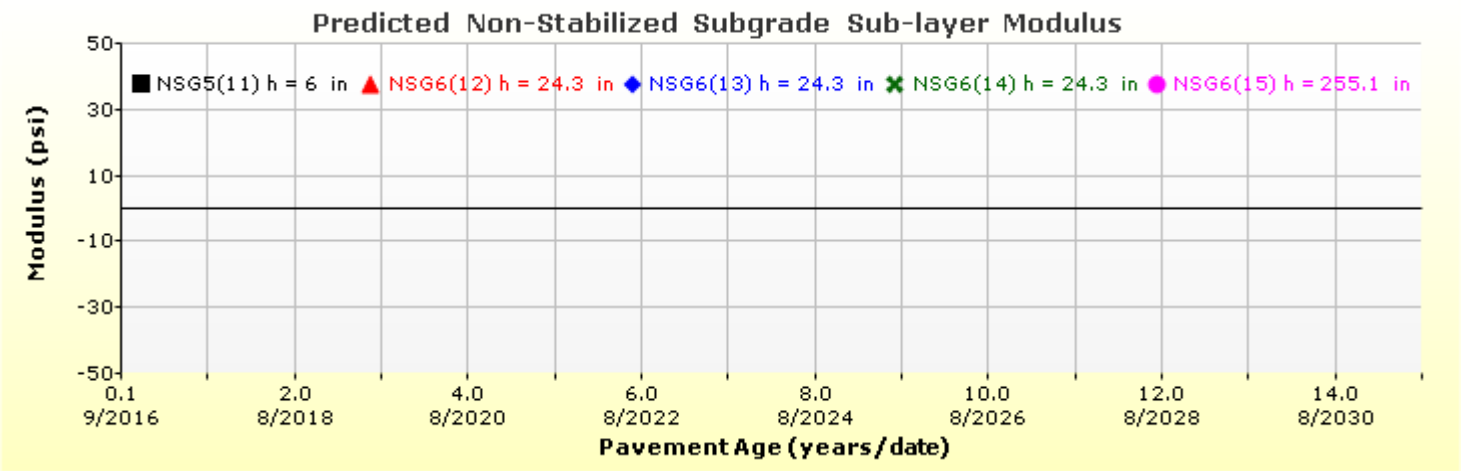

Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal Base
Subtotal AC
Rutting Depth (in)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
5E-05
4E-05
3E-05
2E-05
1E-05
0
0.1
9/2016
2.0
8/2018
4.0
8/2020
6.0
8/2022
8.0
8/2024
10.0
8/2026
12.0
8/2028
14.0
8/2030
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
AC2(4) h = 1 in
AC2(5) h = 1 in
AC3(6) h = 4 in
AC3(7) h = 1 in
Modulus (psi)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
Pavement Age (years/date)


Predicted Granular Base Sub-layer Modulus
GB4(8) h = 2.2 in
GB4(9) h = 4.4 in
GB4(10) h = 4.4 in
Modulus (psi)
50
30
10
-10
-30
-50


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG5(11) h = 6 in
NSG6(12) h = 24.3 in
NSG6(13) h = 24.3 in
NSG6(14) h = 24.3 in
NSG6(15) h = 255.1 in
Modulus (psi)
50
30
10
-10
-30
-50
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield SMA PG76-22

Asphalt		
Thickness (in.)	2.0	
Unit weight (pcf)	173.5	
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	3647648	4669504	5000000	5000000
40	2415742	3373281	4392981	4797248
70	763973	1296571	2030073	2372323
100	228891	438683	796159	989704
130	80754	159253	310900	401763

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

General Info

Name	Value
Reference temperature (ºF)	70
Effective binder content (%)	13.4
Air voids (%)	7
Thermal conductivity (BTU/hr-ft-ºF)	0.63
Heat capacity (BTU/lb-ºF)	0.31

Identifiers

Field	Value
Display name/identifier	Greenfield SMA PG76-22
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 : Greenfield 9.5mm PG76-22

Asphalt		
Thickness (in.)	2.0	
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	1815795	2225269	2582226	3093418
40	1604110	1630283	1703660	1887588
70	345178	527407	706612	828539
100	73077	146315	257222	325459
130	29611	55286	106243	139879

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 9.5mm PG76-22
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 : Existing HMA(existing)

Asphalt		
Thickness (in.)	5.0	
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 4 Non-stabilized Base : Crushed stone

Unbound	
Layer thickness (in.)	11.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
9100.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 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 5 Subgrade : A-6

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)
3000.0

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

Identifiers

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

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	True

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

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

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

Layer 6 Subgrade : A-6

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

Modulus (Input Level: 2)

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

Resilient Modulus (psi)
3000.0

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

Identifiers

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

Sieve

Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

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

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

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

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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	Accelerate Cracking by 2 years
< 4"	0.6	3
4 – 6"	0.7	1.7
> 6"	0.8	1.4

C: 1	D: 1

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

New Campus Parkway Mainline, Shoulders and Ramps

Technical Proposal / I-69 Major Moves 2020 Expansion

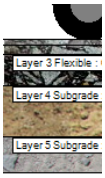
CampusPkwy

File Name: C:\My ME Design\Projects\MK15-469\PostReport\CampusPkwy.dgpx

Design Inputs

Design Life:	25 years	Base construction:	May, 2016	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	Flexible Pavement	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Greenfield 9.5mm PG70-22	1.5
Flexible	Greenfield 19.0mm PG70-22	2.5
Flexible	Greenfield 19.0mm PG64-22	9.0
Subgrade	A-7-6	14.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

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

Traffic

Age (year)	Heavy Trucks (cumulative)
2016 (initial)	670
2028 (12 years)	1,622,010
2041 (25 years)	3,489,900

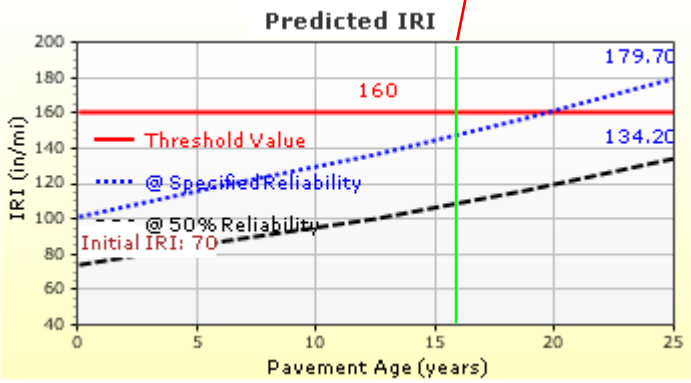
Passes IRI at 16 years, consider as a PASSING section

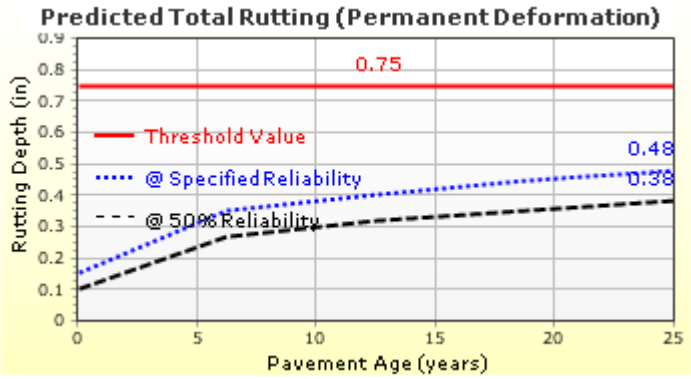
Design Outputs

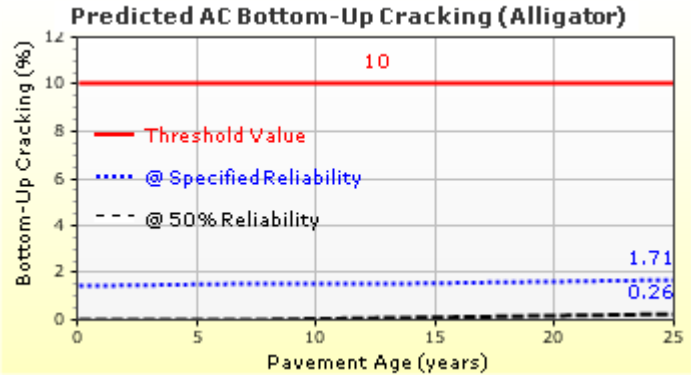
Distress Prediction Summary

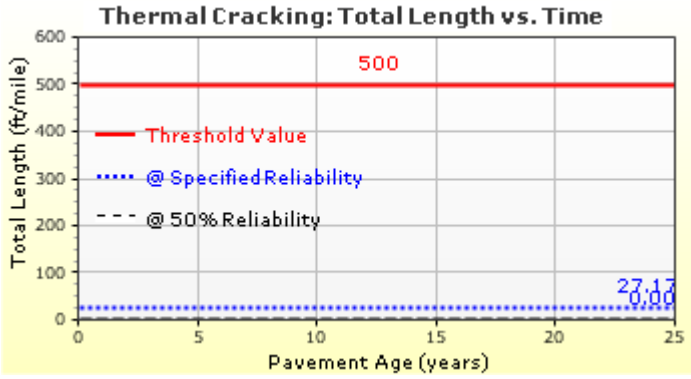
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	160.00	179.71	90.00	76.64	Fail
Permanent deformation - total pavement (in.)	0.75	0.48	90.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	10.00	1.71	90.00	100.00	Pass
AC thermal cracking (ft/mile)	500.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	257.21	90.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.11	90.00	100.00	Pass

Distress Charts





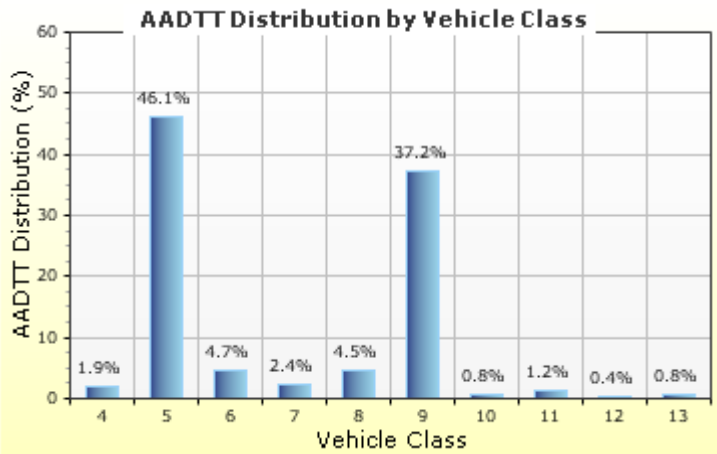


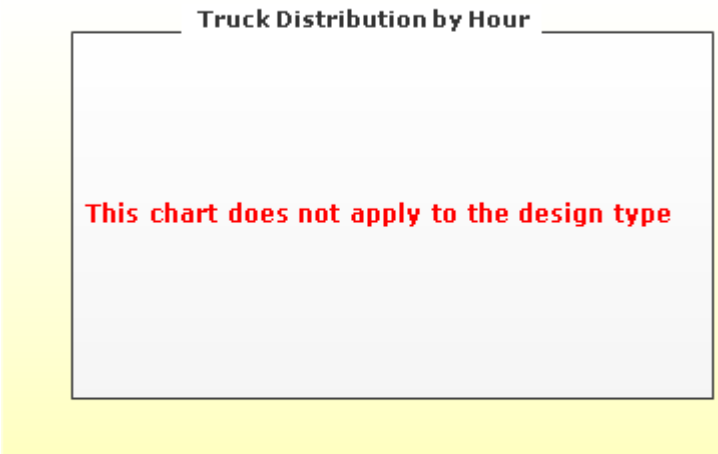


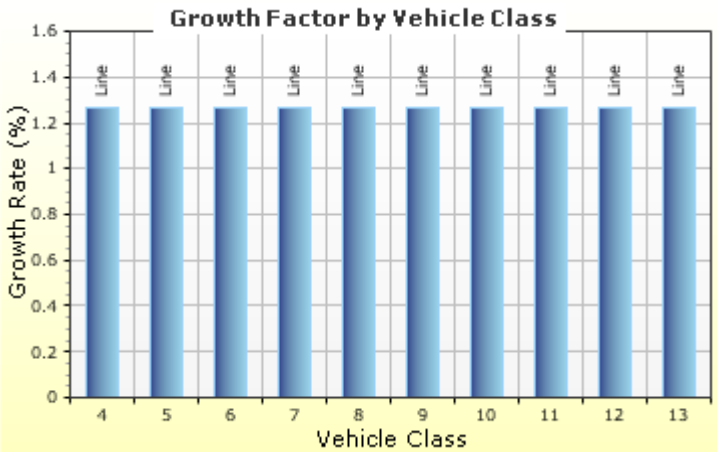
Traffic Inputs

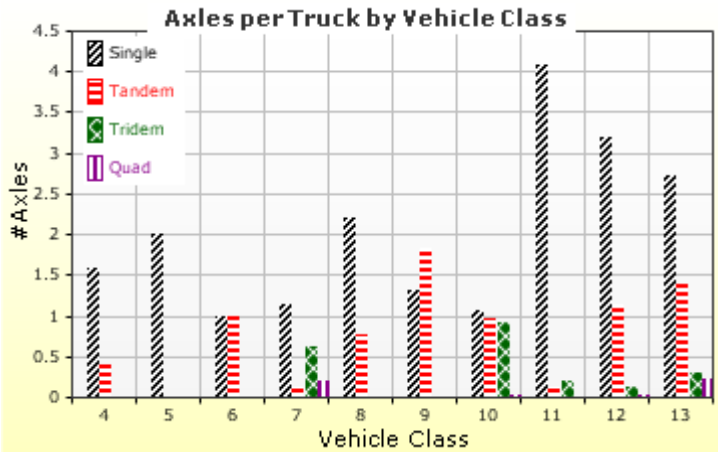
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	670	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)	25.0

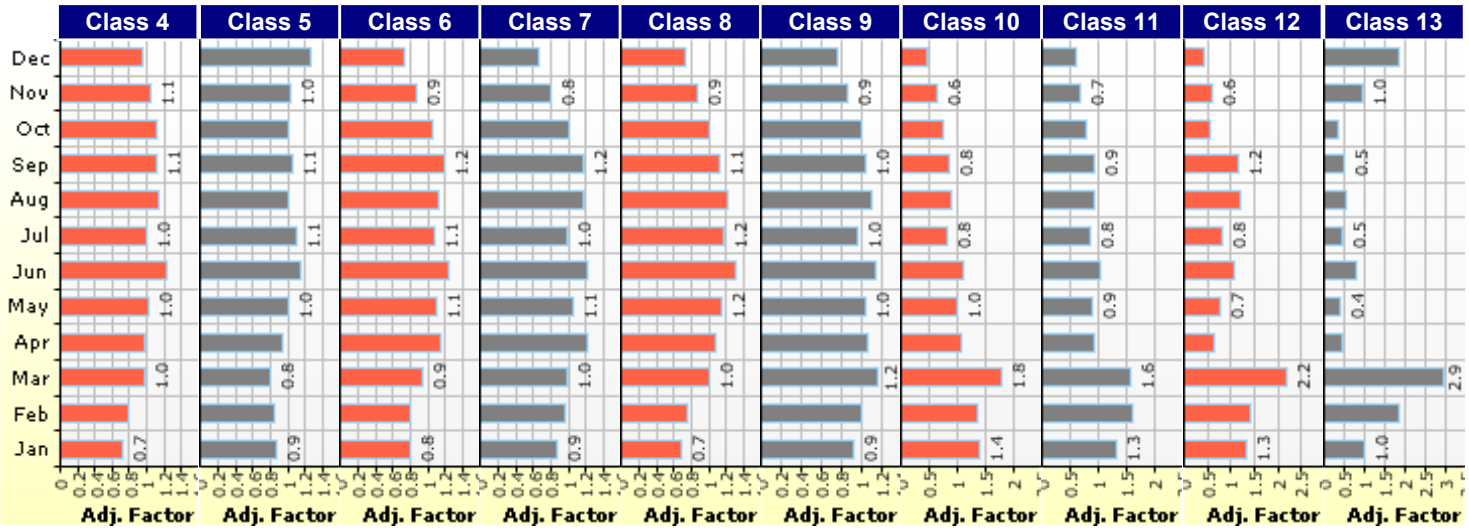








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	0.7	0.9	0.8	0.9	0.7	0.9	1.4	1.3	1.3	1.0
February	0.8	0.8	0.8	0.9	0.7	1.0	1.3	1.6	1.4	1.9
March	1.0	0.8	0.9	1.0	1.0	1.2	1.8	1.6	2.2	2.9
April	1.0	0.9	1.1	1.2	1.1	1.1	1.1	0.9	0.6	0.4
May	1.0	1.0	1.1	1.1	1.2	1.0	1.0	0.9	0.7	0.4
June	1.2	1.2	1.2	1.2	1.3	1.1	1.1	1.1	1.1	0.8
July	1.0	1.1	1.1	1.0	1.2	1.0	0.8	0.8	0.8	0.5
August	1.1	1.0	1.1	1.2	1.2	1.1	0.9	0.9	1.2	0.5
September	1.1	1.1	1.2	1.2	1.1	1.0	0.8	0.9	1.2	0.5
October	1.1	1.0	1.1	1.0	1.0	1.0	0.7	0.8	0.5	0.3
November	1.1	1.0	0.9	0.8	0.9	0.9	0.6	0.7	0.6	1.0
December	0.9	1.3	0.7	0.7	0.7	0.8	0.4	0.6	0.4	1.9

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	1.9%	1.27%	Linear
Class 5	46.1%	1.27%	Linear
Class 6	4.7%	1.27%	Linear
Class 7	2.4%	1.27%	Linear
Class 8	4.5%	1.27%	Linear
Class 9	37.2%	1.27%	Linear
Class 10	0.8%	1.27%	Linear
Class 11	1.2%	1.27%	Linear
Class 12	0.4%	1.27%	Linear
Class 13	0.8%	1.27%	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

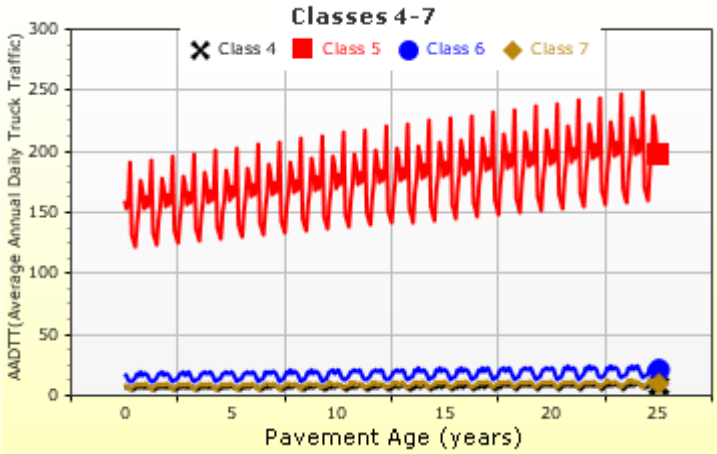
Wheelbase does not apply

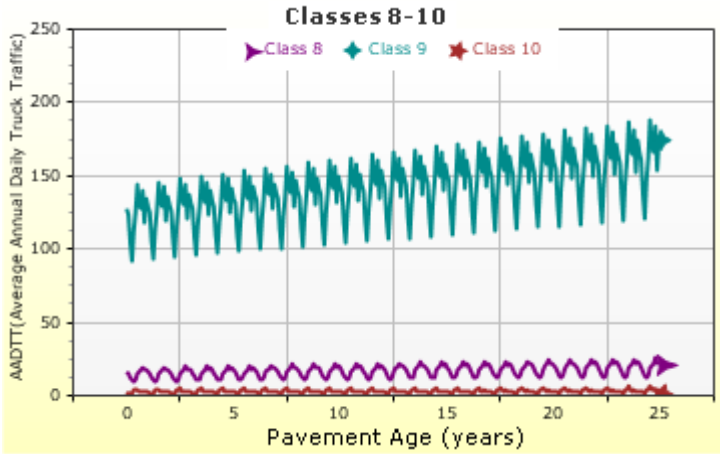
Number of Axles per Truck

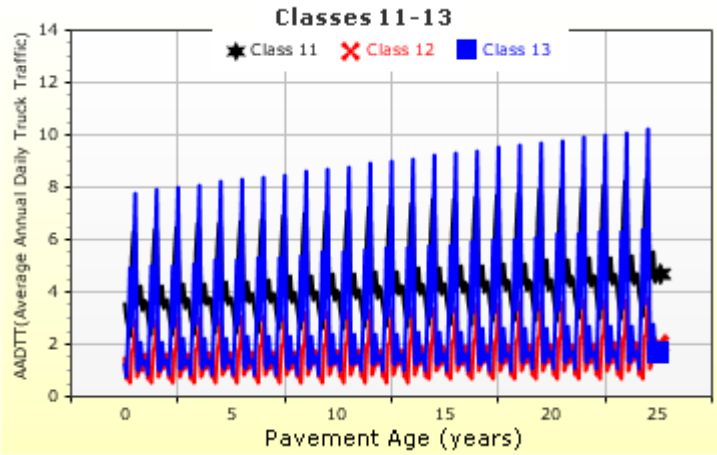
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.58	0.41	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.14	0.14	0.64	0.2
Class 8	2.21	0.78	0	0
Class 9	1.3	1.84	0	0
Class 10	1.07	0.98	0.93	0.03
Class 11	4.09	0.14	0.2	0
Class 12	3.18	1.14	0.13	0.03
Class 13	2.73	1.38	0.31	0.24

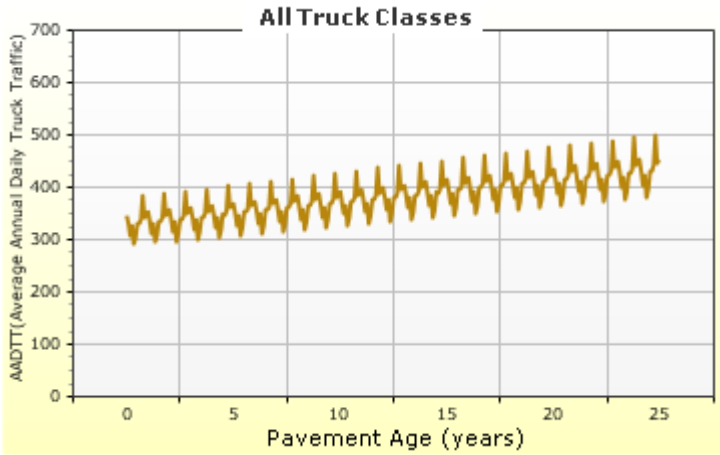
AADTT (Average Annual Daily Truck Traffic) Growth

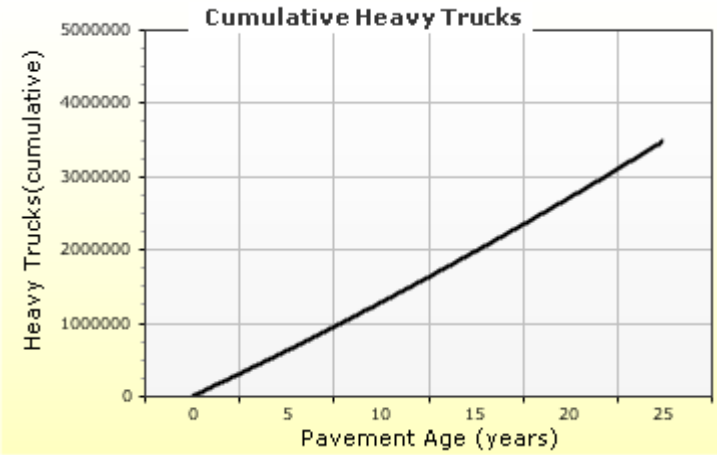
*** Traffic cap is not enforced**







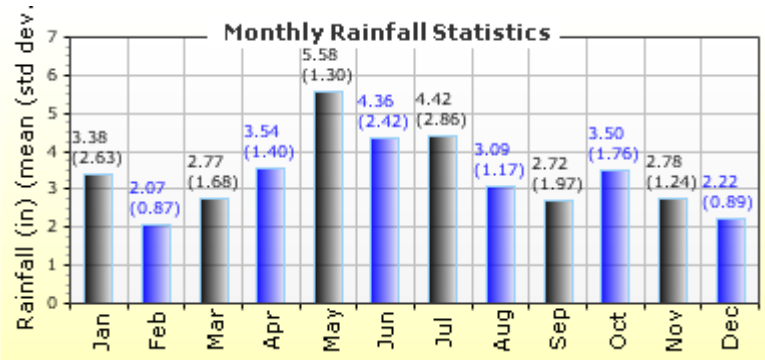




Climate Inputs

Climate Data Sources:

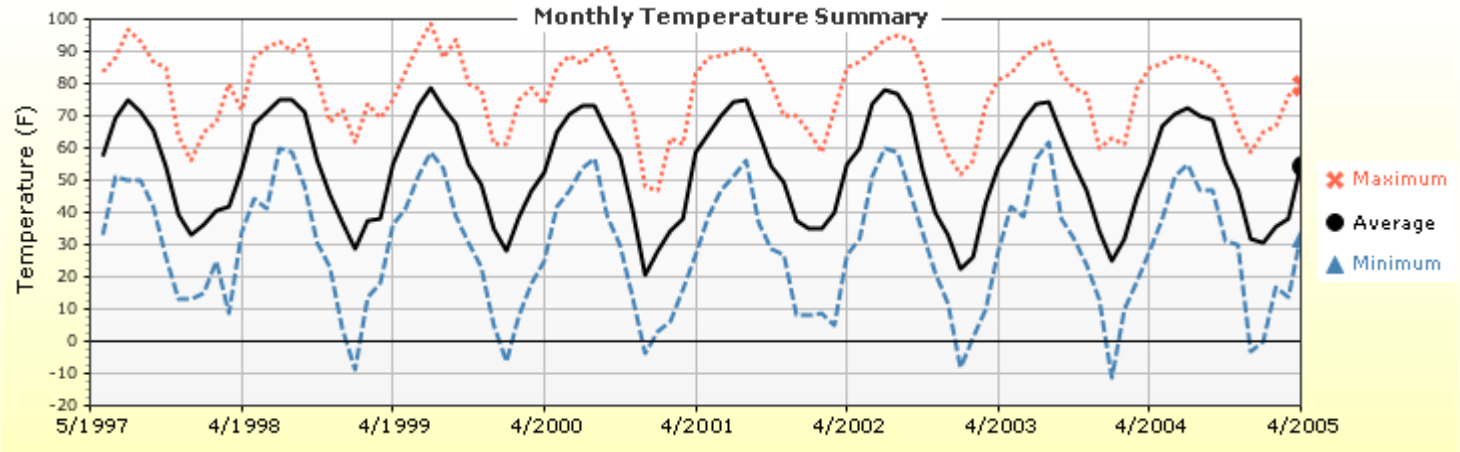
Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

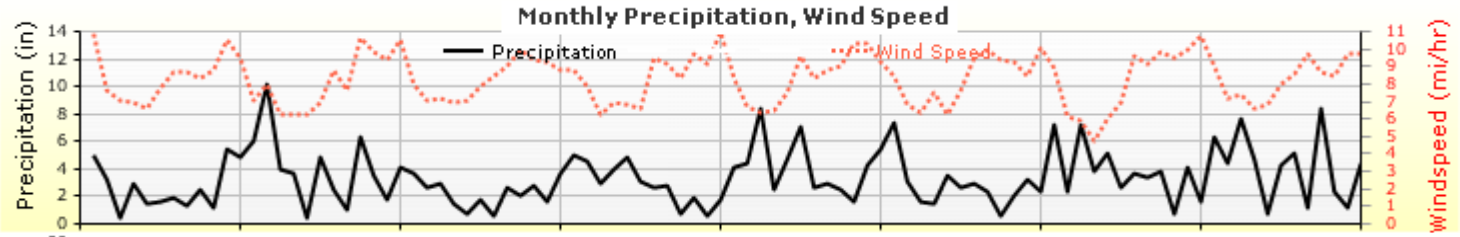


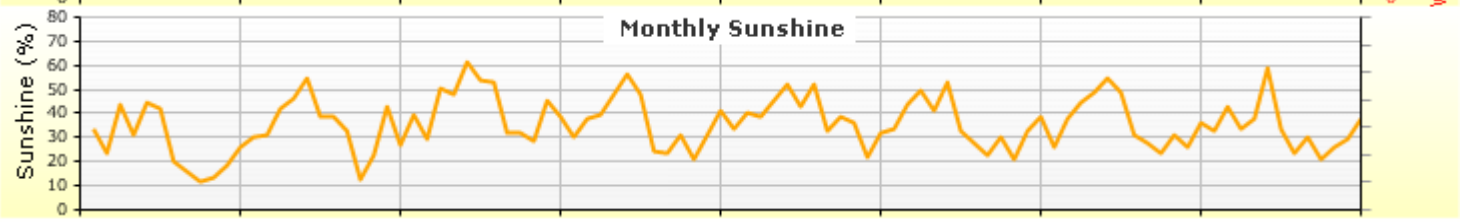
Annual Statistics:

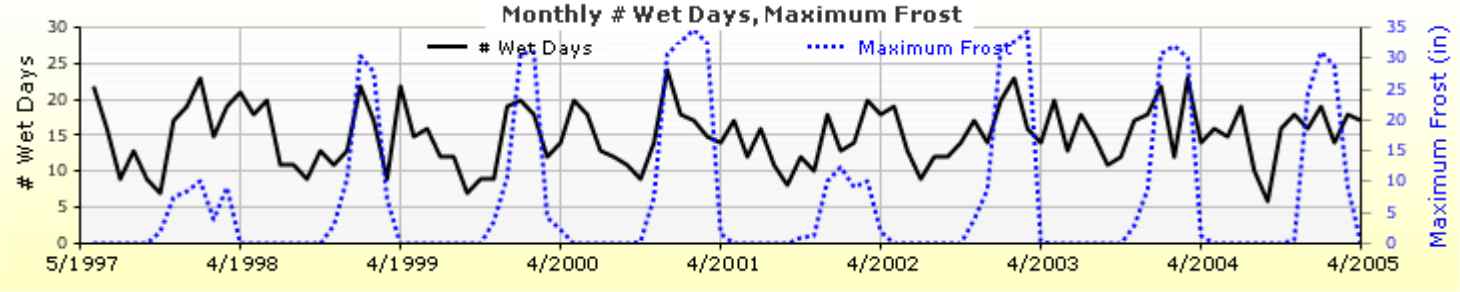
Mean annual air temperature (ºF)	53.71
Mean annual precipitation (in.)	40.41
Freezing index (ºF - days)	475.93
Average annual number of freeze/thaw cycles:	54.61
Water table depth (ft)	5.00

Monthly Climate Summary:

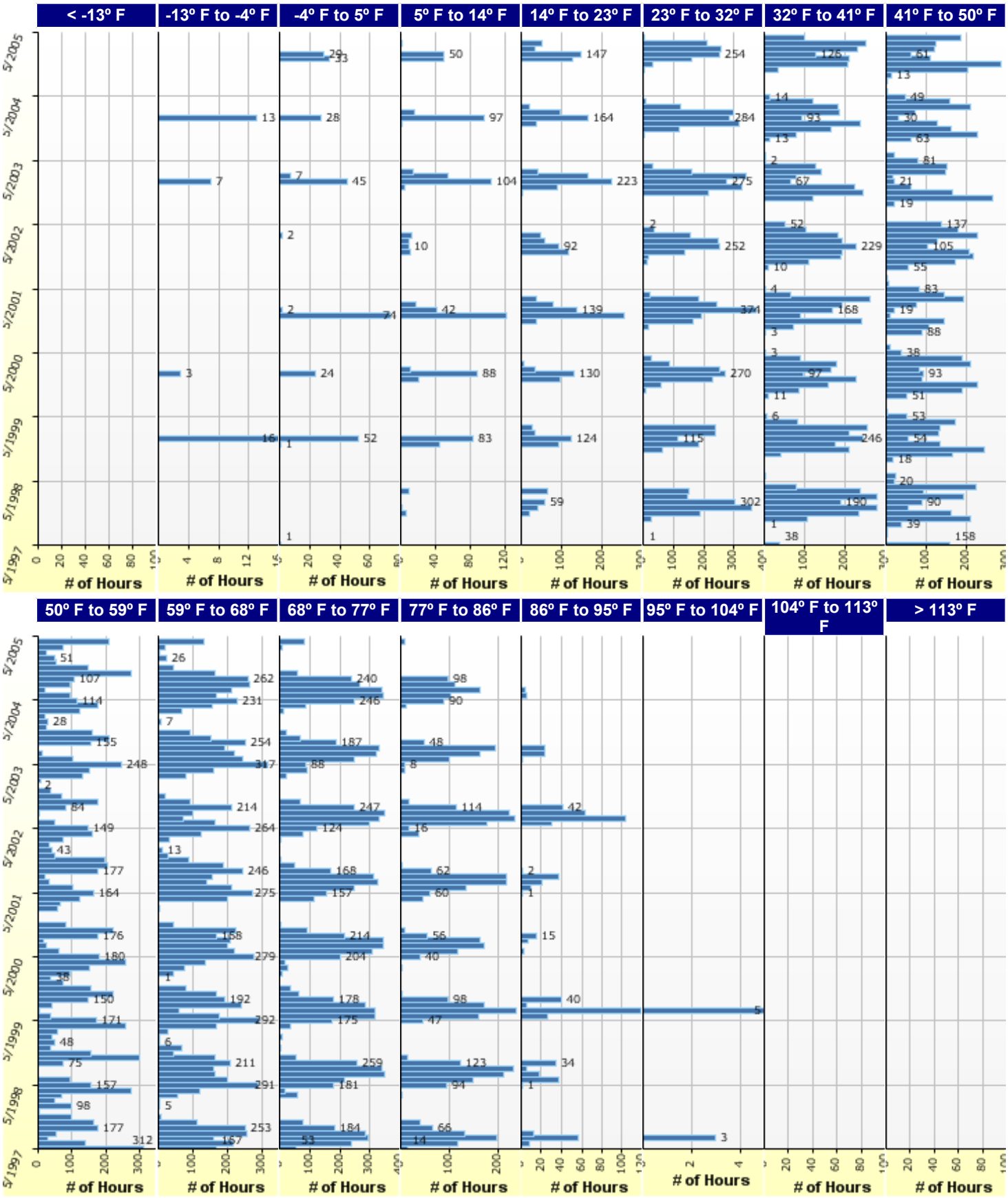








Hourly Air Temperature Distribution by Month:



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

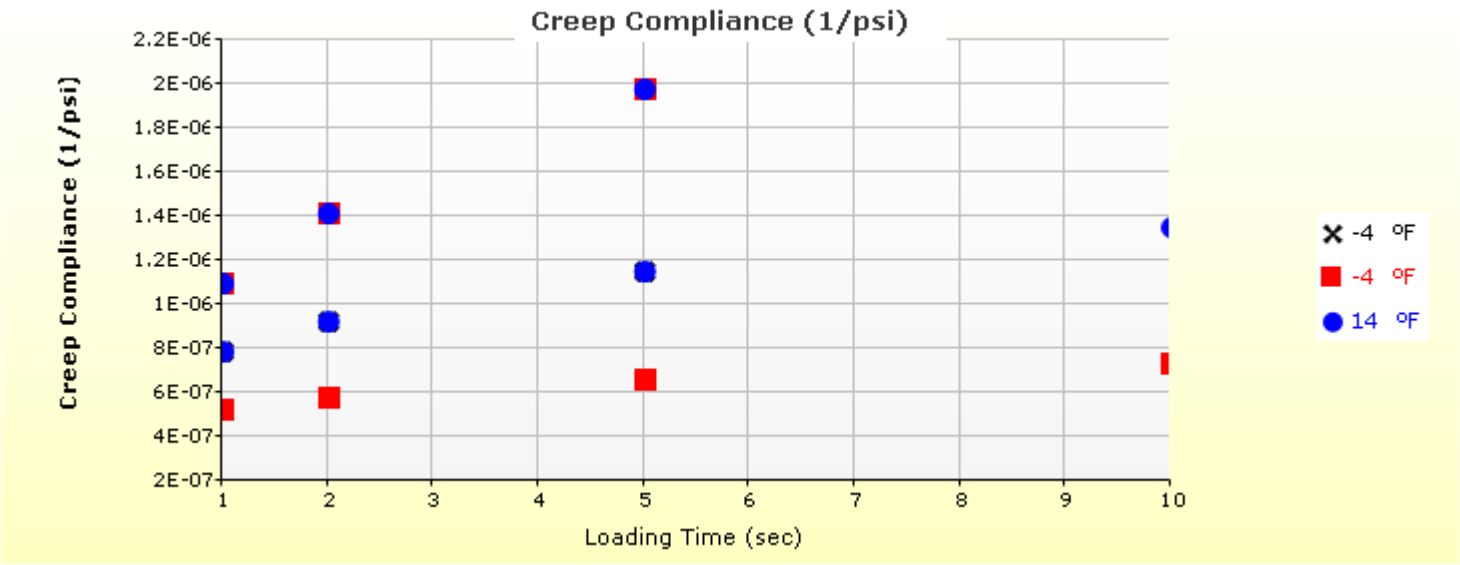
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield 9.5mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 19.0mm PG70-22	Flexible (1)	1.00
Layer 3 Flexible : Greenfield 19.0mm PG64-22	Flexible (1)	1.00
Layer 4 Subgrade : A-7-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

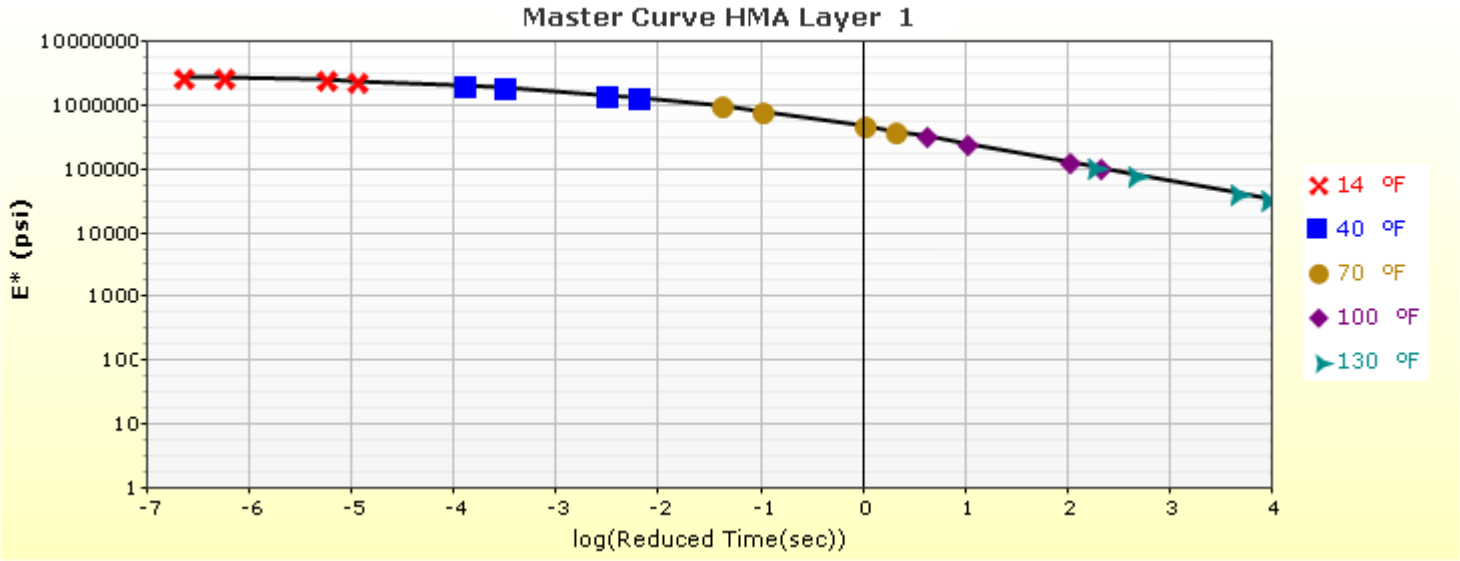
Indirect tensile strength at 14 ºF (psi)	444.45

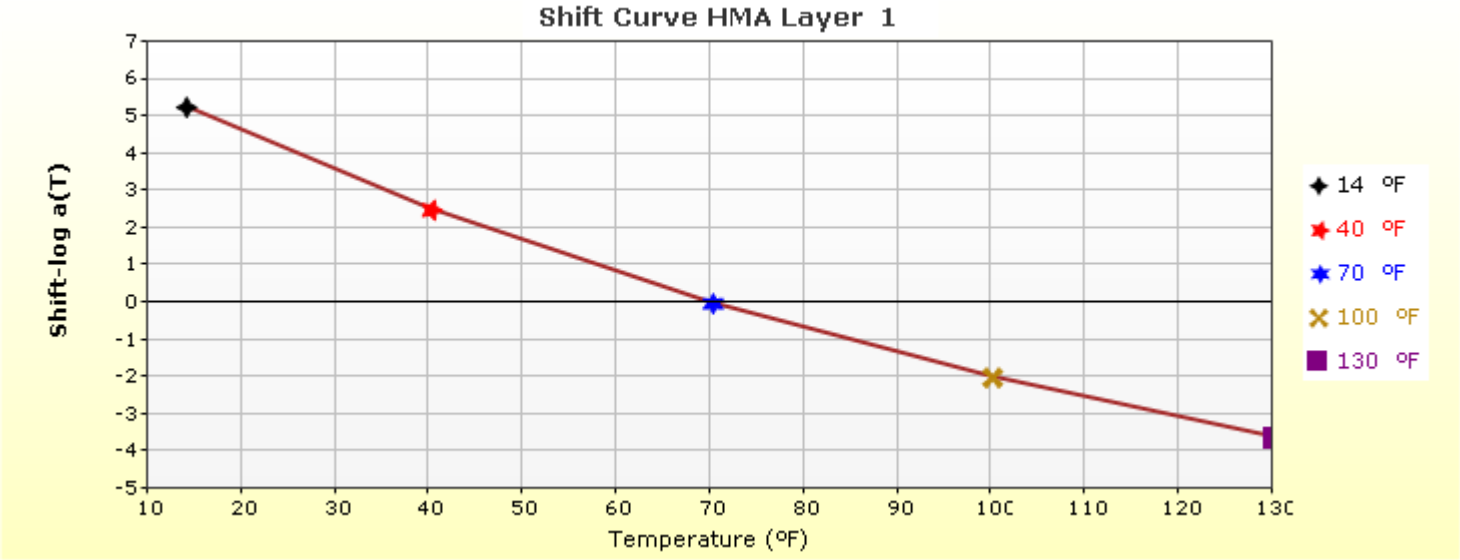
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

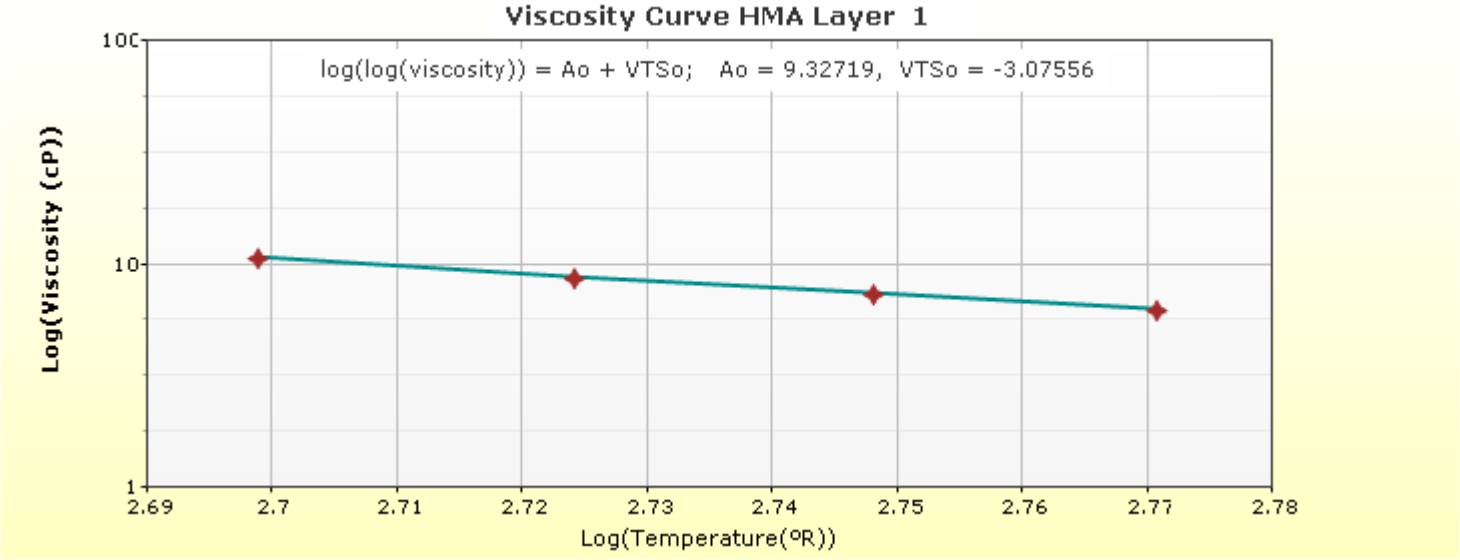
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	5.31e-007	5.31e-007	7.97e-007
1	7.97e-007	1.10e-006	1.10e-006
2	5.86e-007	5.86e-007	9.35e-007
2	9.35e-007	1.42e-006	1.42e-006
5	6.68e-007	6.68e-007	1.15e-006
5	1.15e-006	1.98e-006	1.98e-006
10	7.38e-007	7.38e-007	1.35e-006



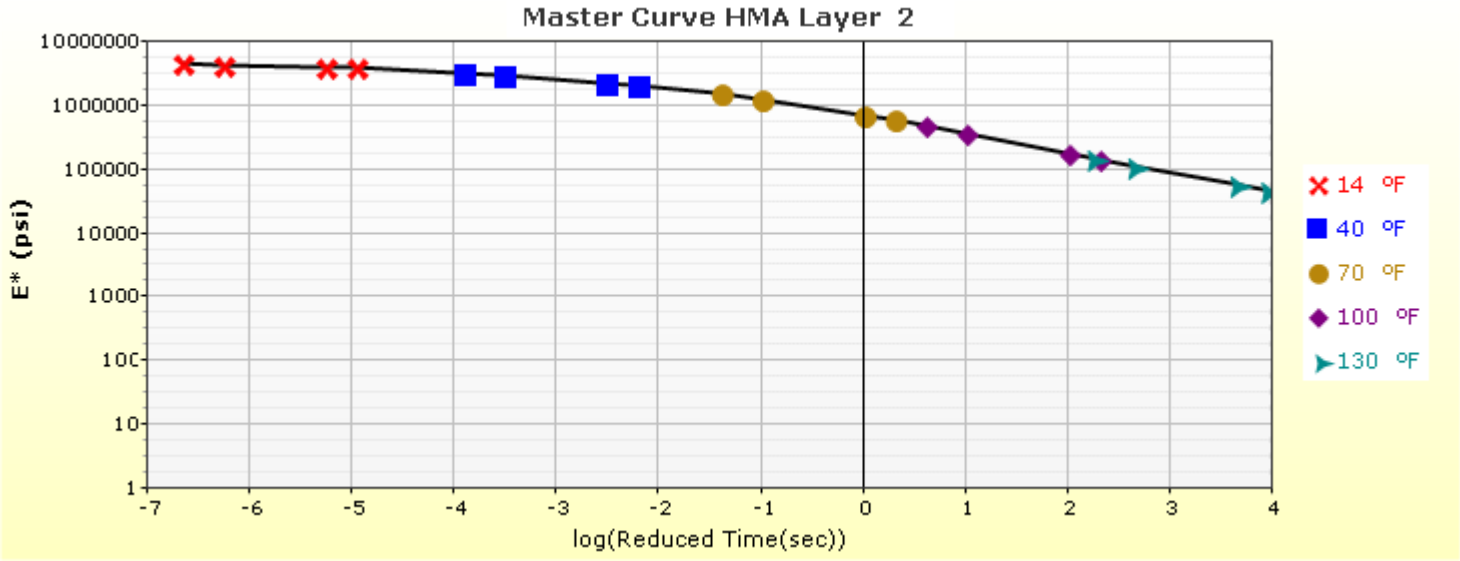
HMA Layer 1: Layer 1 Flexible : Greenfield 9.5mm PG70-22

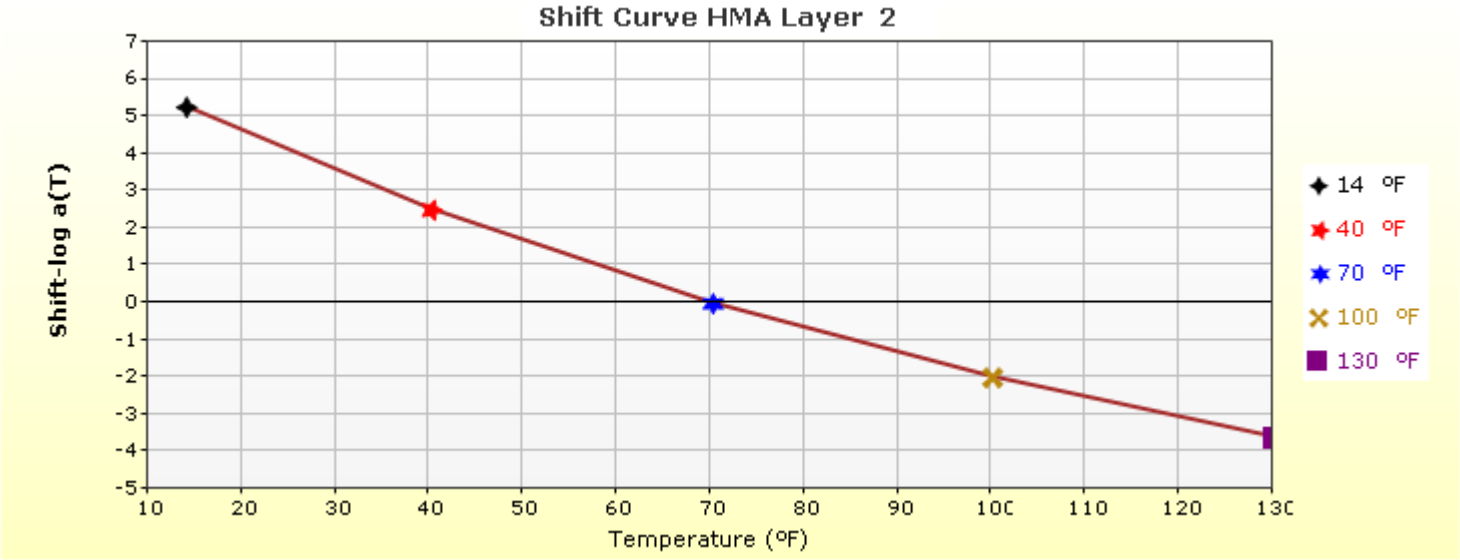


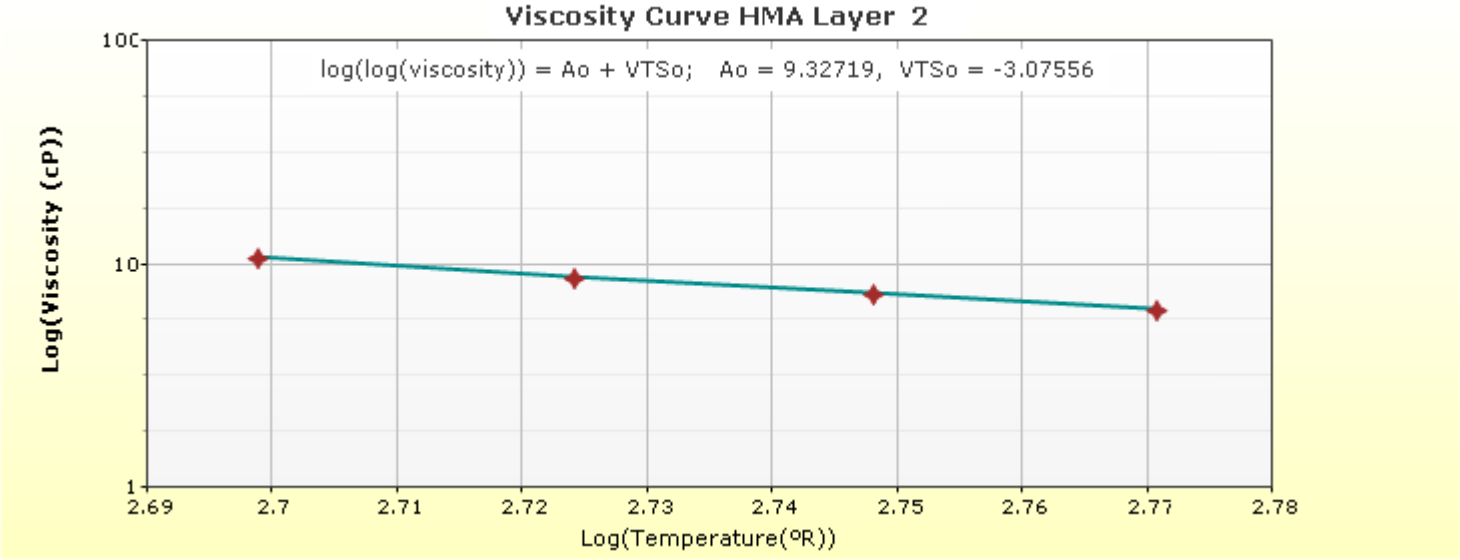




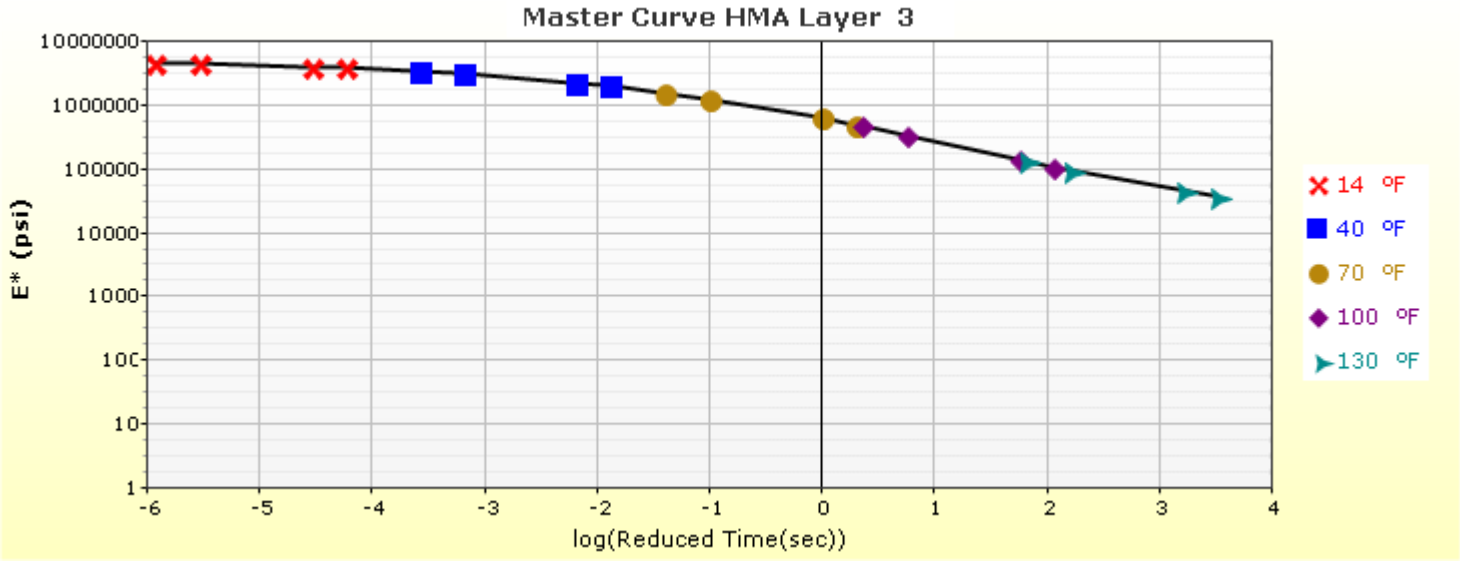
HMA Layer 2: Layer 2 Flexible : Greenfield 19.0mm PG70-22

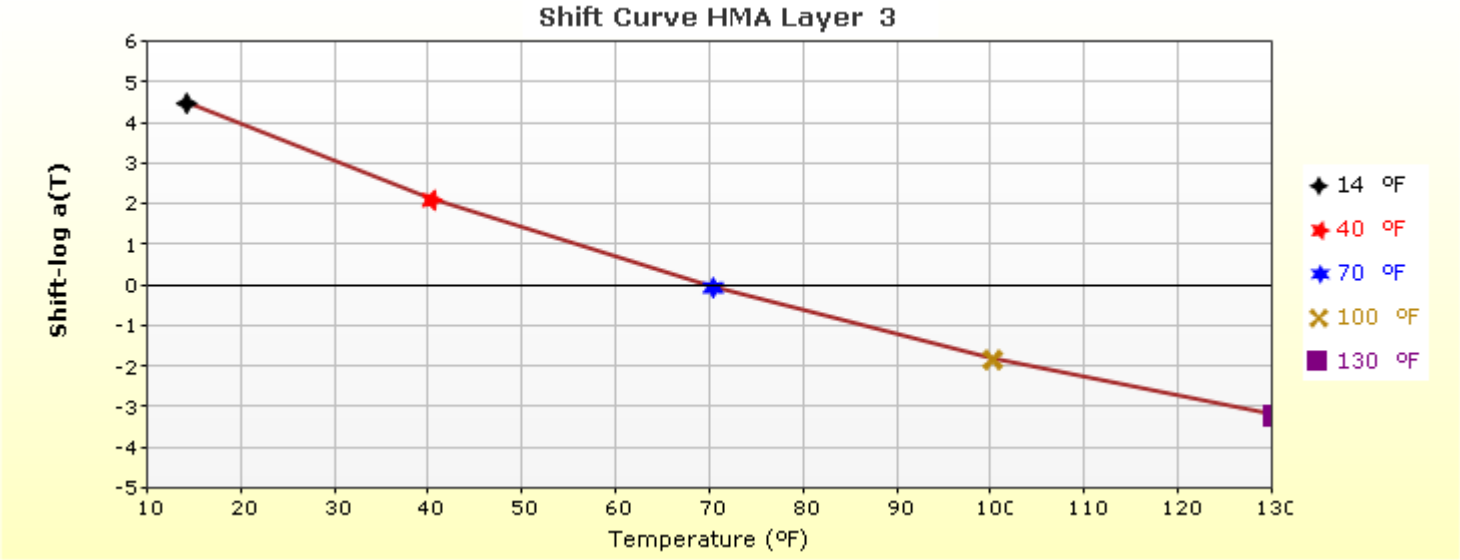


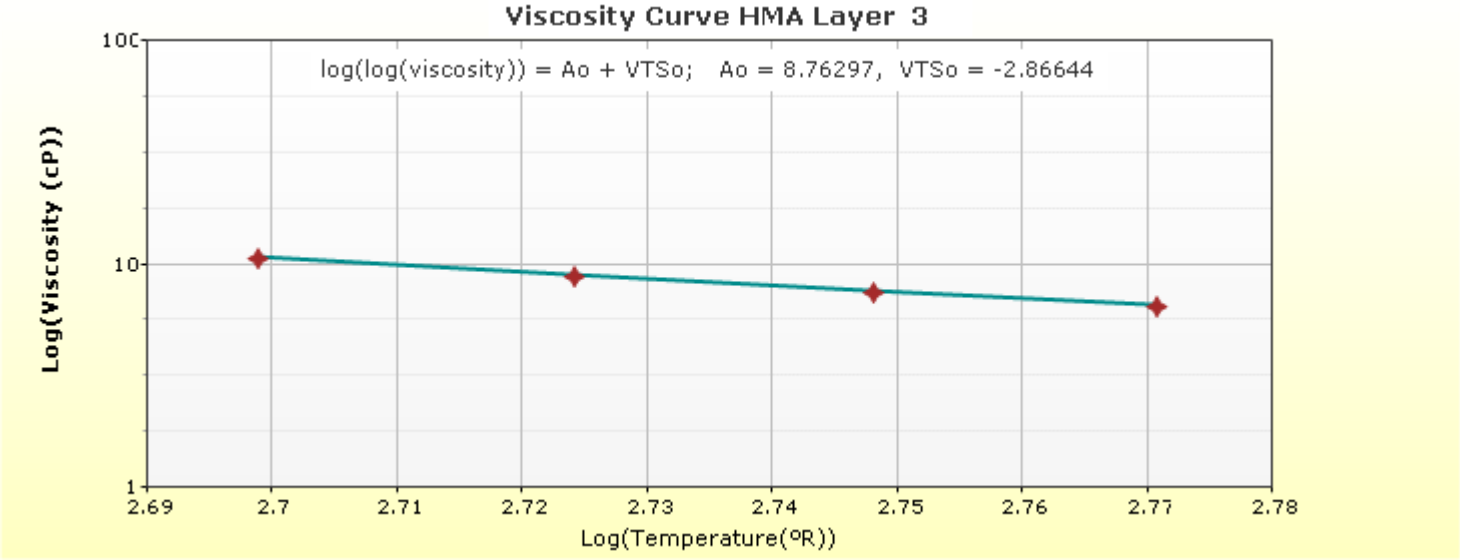




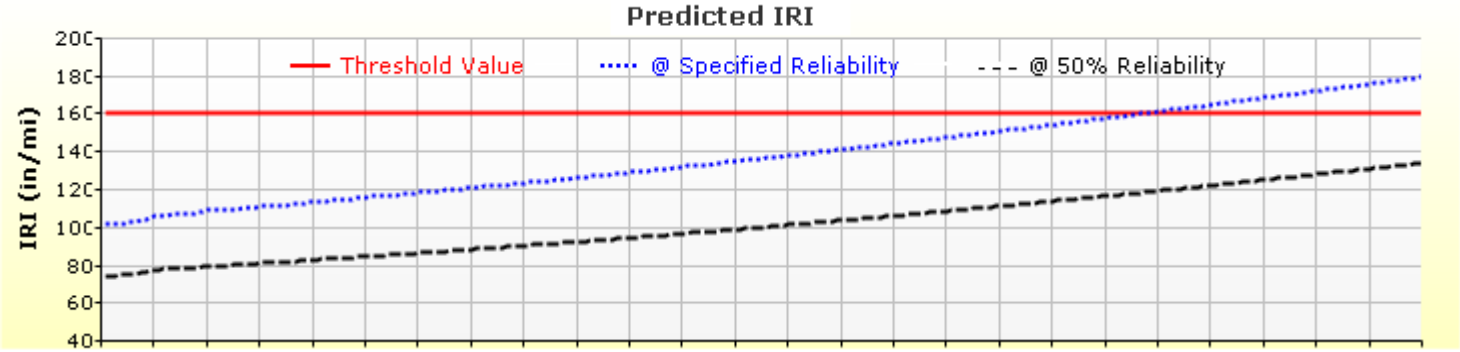
HMA Layer 3: Layer 3 Flexible : Greenfield 19.0mm PG64-22

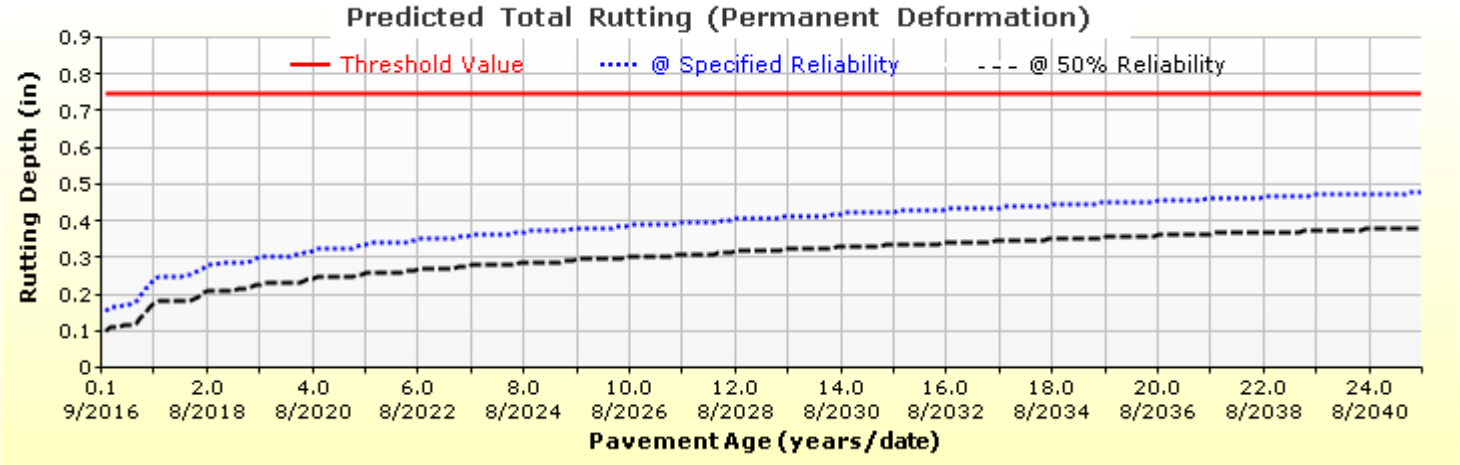


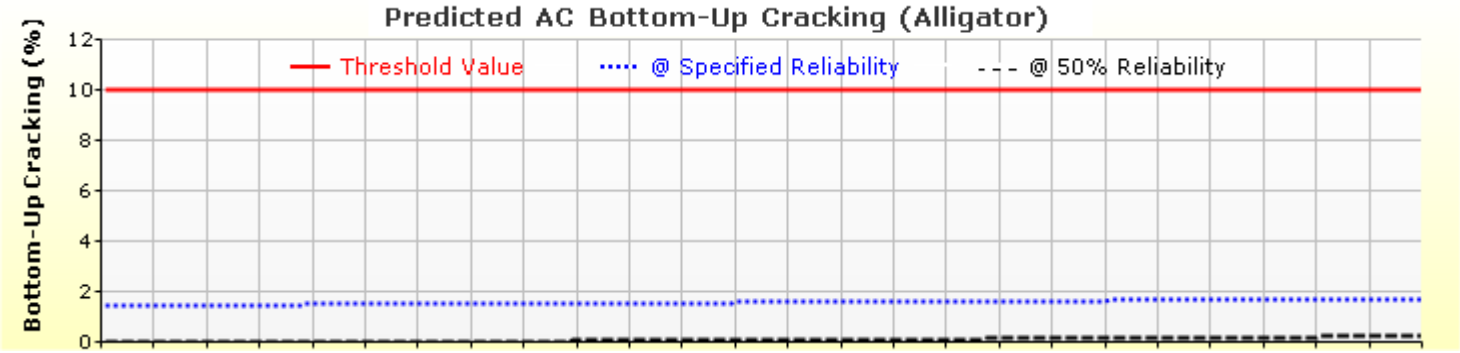


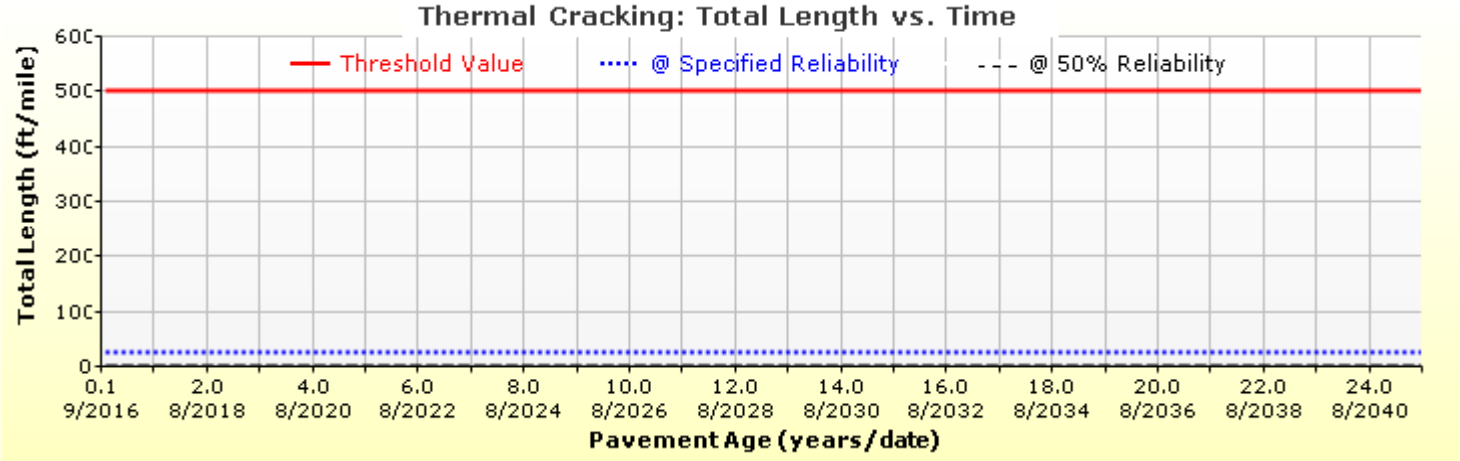


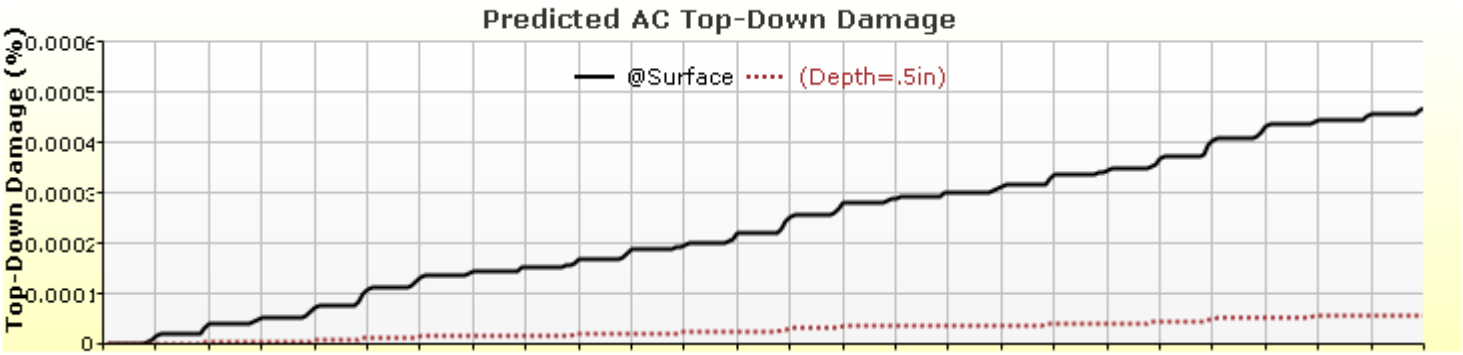
Analysis Output Charts

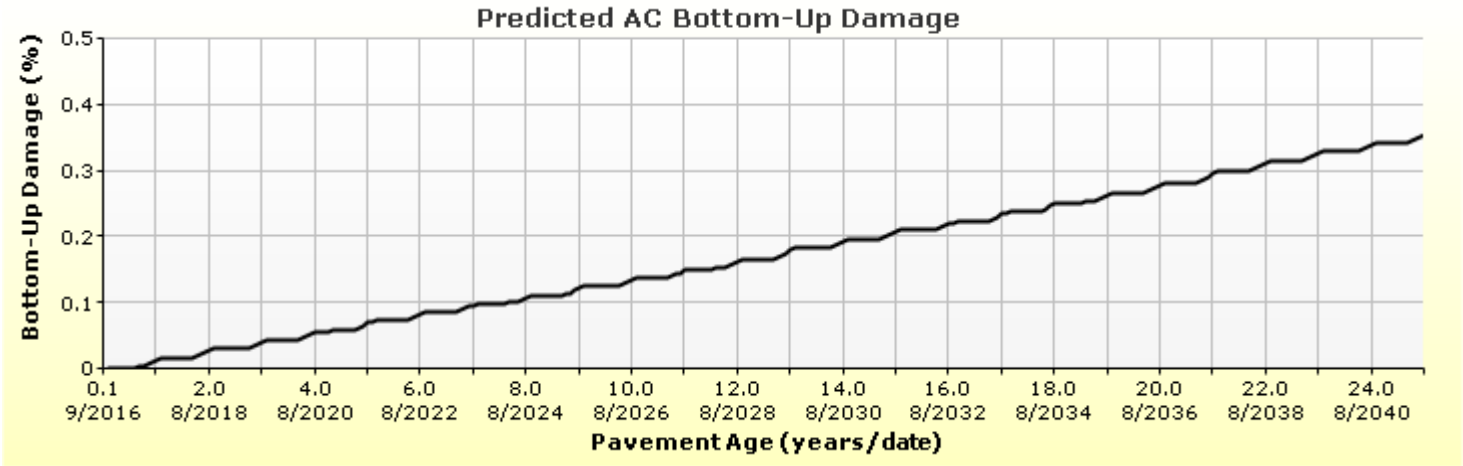


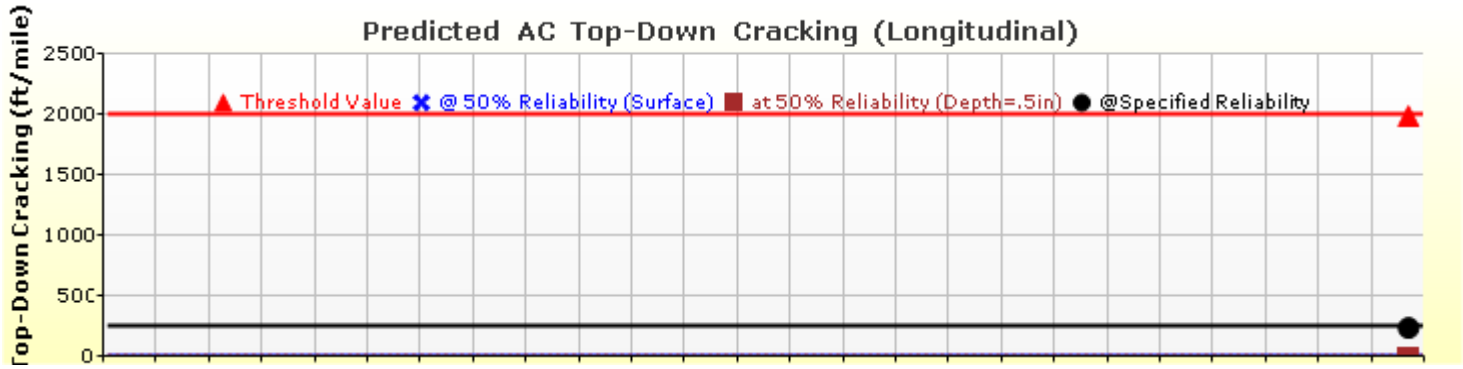


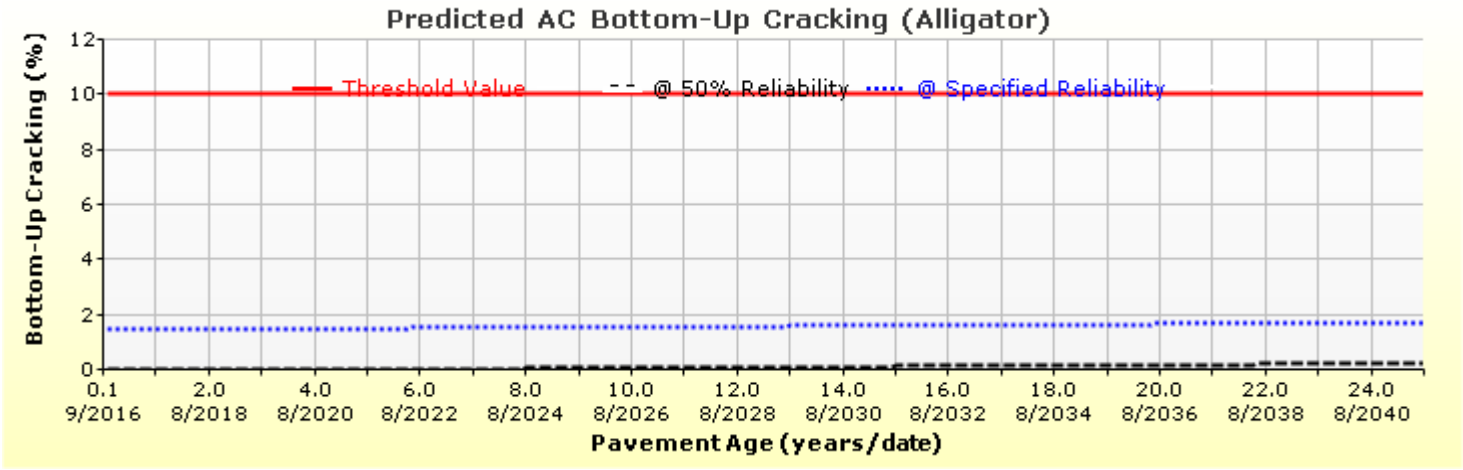


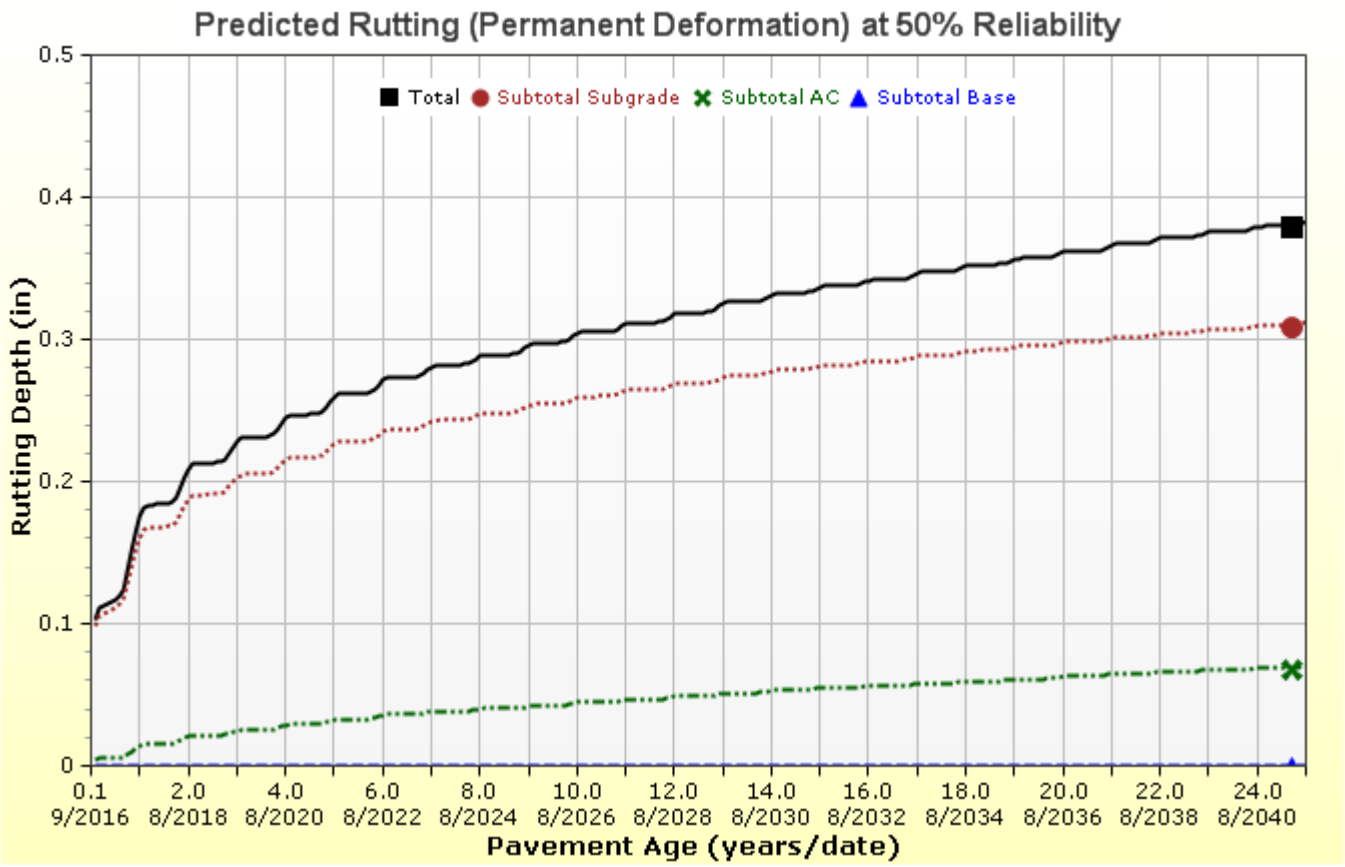


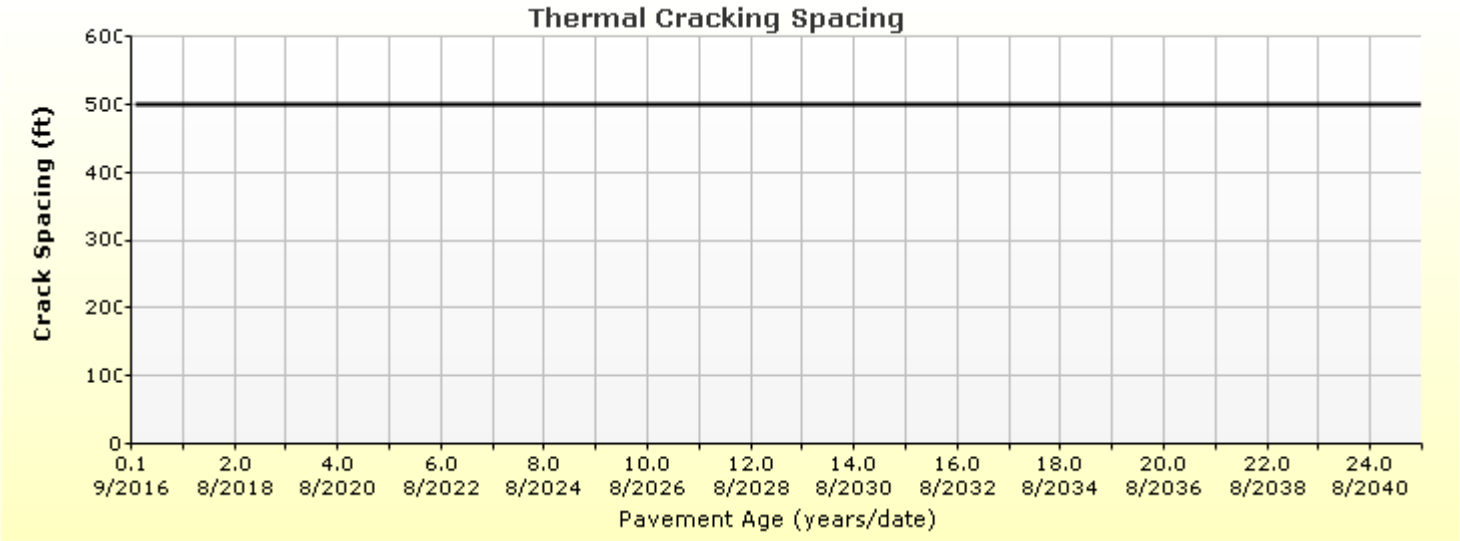

Predicted AC Top-Down Damage
Top-Down Damage (%)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
@Surface
(Depth=.5in)

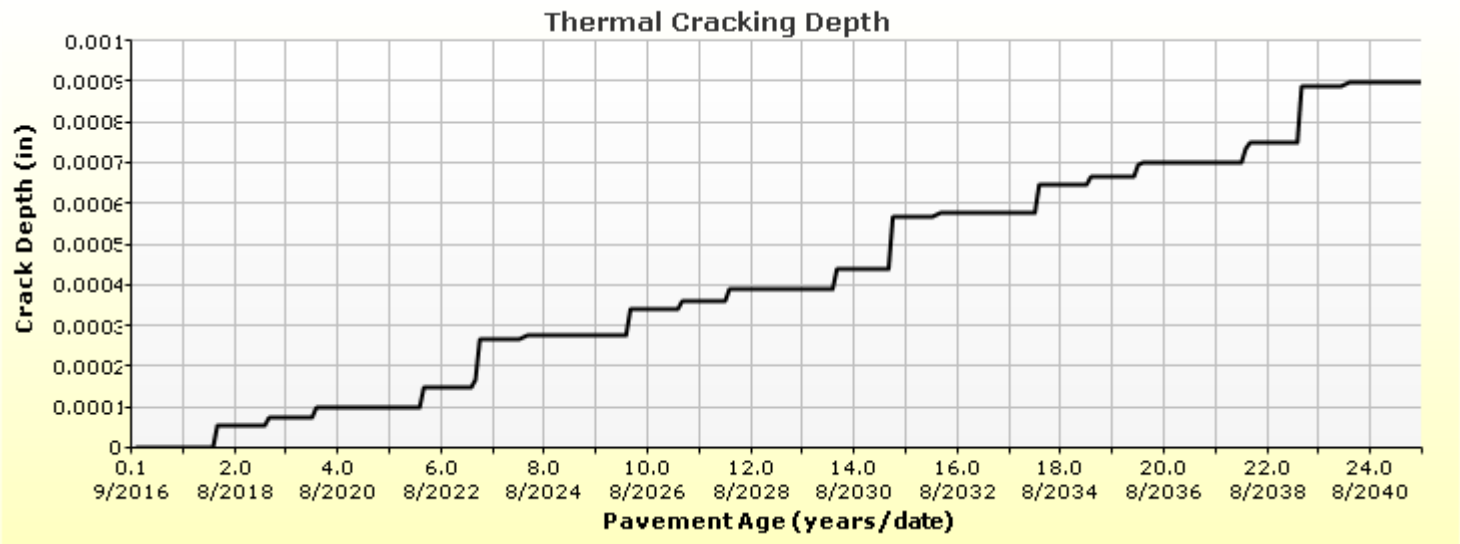

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

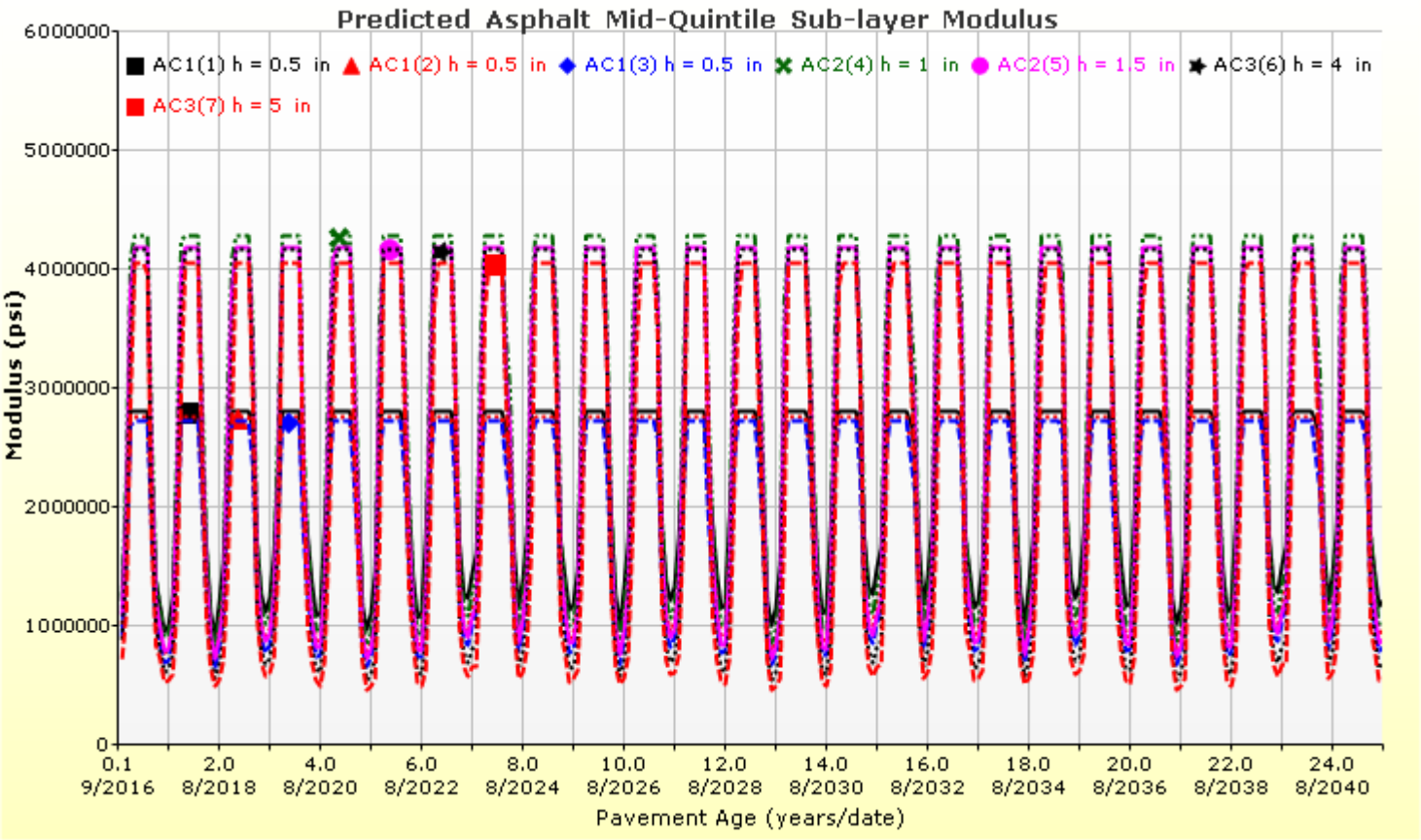

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

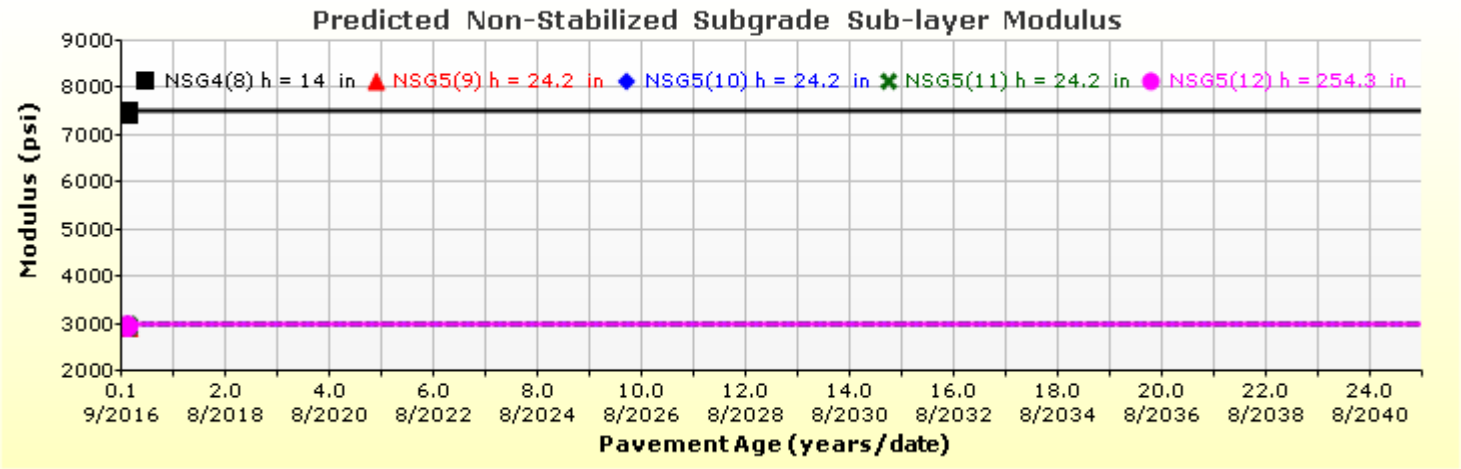

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
12
10
8
6
4
2
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rutting Depth (in)
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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 = 1.5 in
AC3(6) h = 4 in
AC3(7) h = 5 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Non-Stabilized Subgrade Sub-layer Modulus
NSG4(8) h = 14 in
NSG5(9) h = 24.2 in
NSG5(10) h = 24.2 in
NSG5(11) h = 24.2 in
NSG5(12) h = 254.3 in
Modulus (psi)
9000
8000
7000
6000
5000
4000
3000
2000
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield 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	1872495	2280649	2558243	3191179
40	1461806	1639806	1806348	2027879
70	255467	474605	712409	857118
100	53857	121012	240307	314726
130	24499	45972	94742	128388

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	Greenfield 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 : Greenfield 19.0mm PG70-22

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: 1)

T (ºF)	0.1 Hz	1 Hz	10 Hz	25 Hz
10	2937952	3610444	4166515	5000000
40	2266657	2556171	2828567	3193383
70	364606	697471	1067196	1295291
100	71348	166660	341895	453527
130	31206	60428	128949	177293

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	Greenfield 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 : Greenfield 19.0mm PG64-22

Asphalt		
Thickness (in.)	9.0	
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	3042663	3715316	4113406	5000000
40	2000767	2583276	3039883	3481384
70	253862	614089	1083394	1357208
100	52156	133874	316005	437461
130	26313	49623	113020	160614

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 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 4 Subgrade : A-7-6

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)
7500.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	98.6
Saturated hydraulic conductivity (ft/hr)	False	8.849e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 5 Subgrade : A-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 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

Preliminary Performance Plans

VOLUME 2

H. VOLUME 2 APPENDIX PAVEMENT DESIGN

Exhibit B, Section 5.2

New SR 13 Mainline and Shoulders

Technical Proposal / I-69 Major Moves 2020 Expansion

SR13

File Name: C:\My ME Design\Projects\MK15-469\PostReport\SR13.dgpx

Design Inputs

Design Life:	25 years	Base construction:	May, 2016	Climate Data Sources (Lat/Lon)	39.71, -86.272
Design Type:	Flexible Pavement	Pavement construction:	June, 2016		
		Traffic opening:	September, 2016		

Design Structure

Layer type	Material Type	Thickness (in.):
Flexible	Greenfield 9.5mm PG70-22	1.5
Flexible	Greenfield 19.0mm PG70-22	3.5
Flexible	Greenfield 19.0mm PG64-22	5.0
Subgrade	A-7-6	14.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

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

Traffic

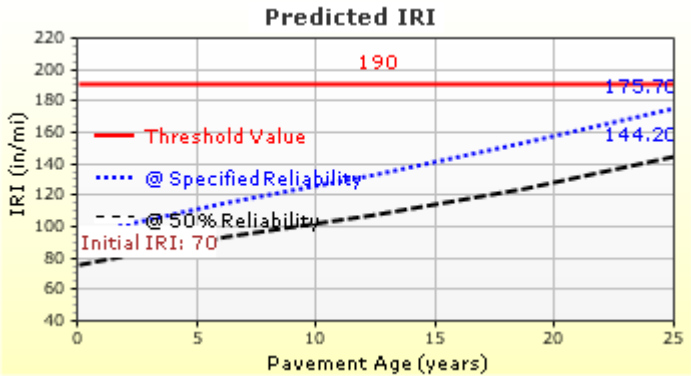
Age (year)	Heavy Trucks (cumulative)
2016 (initial)	1,530
2028 (12 years)	4,096,370
2041 (25 years)	9,226,320

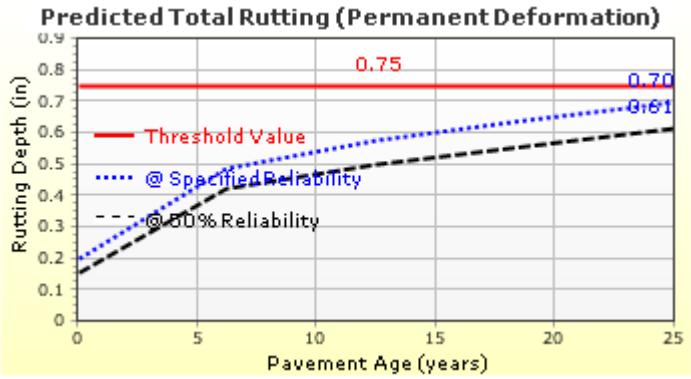
Design Outputs

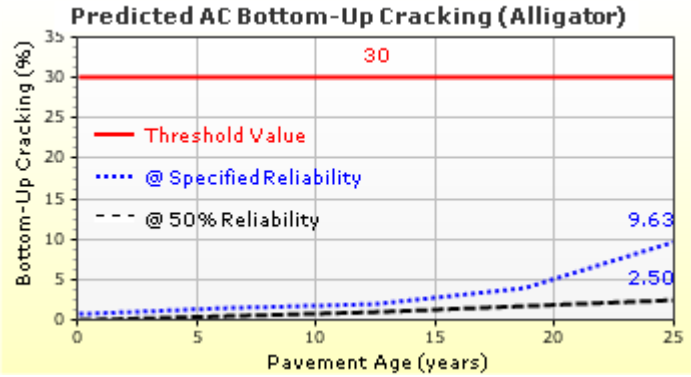
Distress Prediction Summary

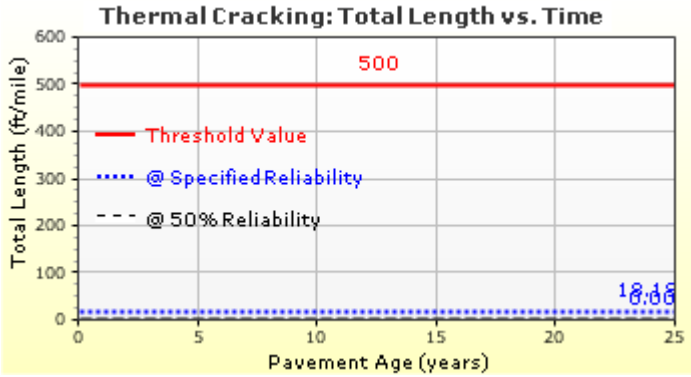
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	190.00	175.69	80.00	88.96	Pass
Permanent deformation - total pavement (in.)	0.75	0.70	80.00	91.20	Pass
AC bottom-up fatigue cracking (percent)	30.00	9.63	80.00	99.94	Pass
AC thermal cracking (ft/mile)	500.00	18.19	80.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	206.73	80.00	100.00	Pass
Permanent deformation - AC only (in.)	0.40	0.21	80.00	100.00	Pass

Distress Charts





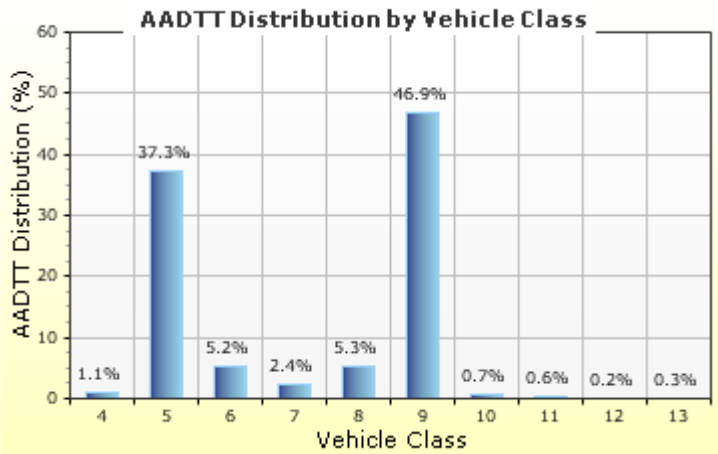


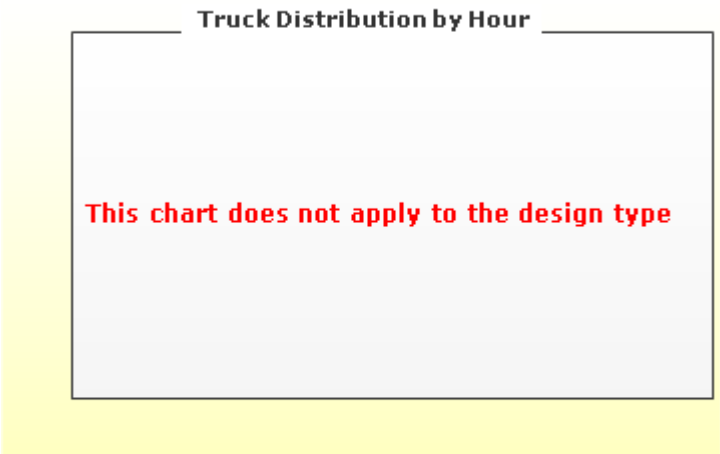


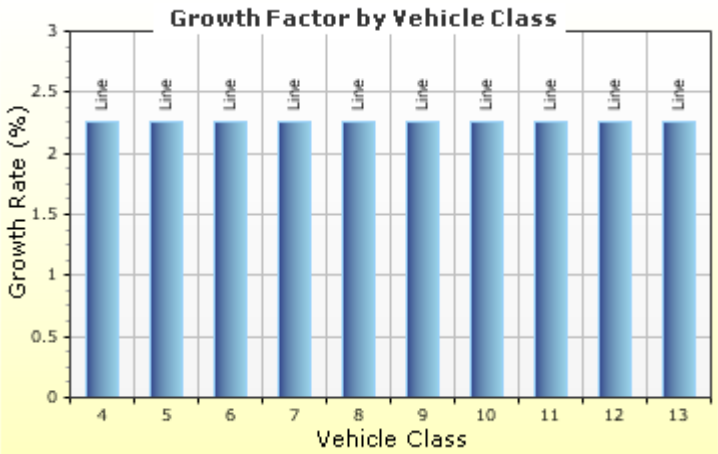
Traffic Inputs

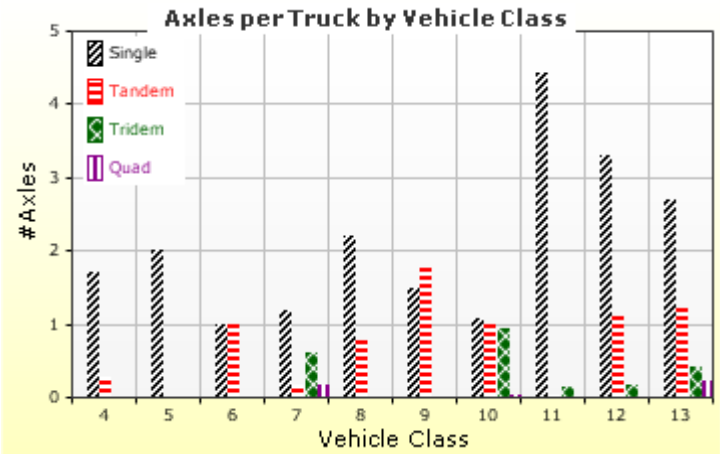
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	1,530	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)	55.0

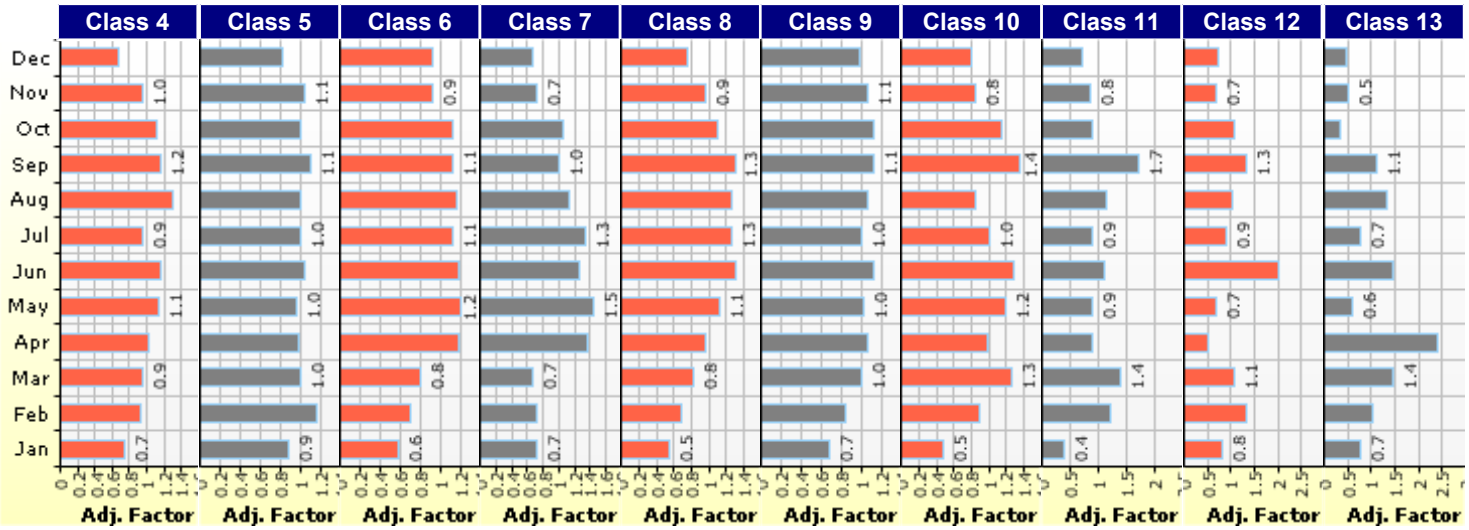








Traffic Volume Monthly Adjustment Factors



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%	2.25%	Linear
Class 5	37.3%	2.25%	Linear
Class 6	5.2%	2.25%	Linear
Class 7	2.4%	2.25%	Linear
Class 8	5.3%	2.25%	Linear
Class 9	46.9%	2.25%	Linear
Class 10	0.7%	2.25%	Linear
Class 11	0.6%	2.25%	Linear
Class 12	0.2%	2.25%	Linear
Class 13	0.3%	2.25%	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

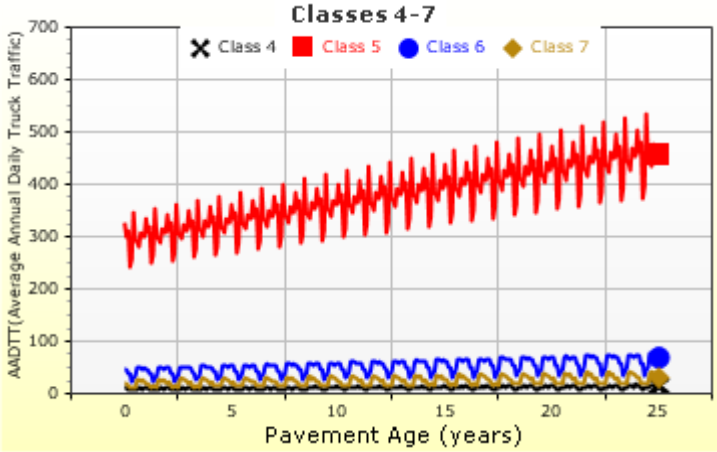
Wheelbase does not apply

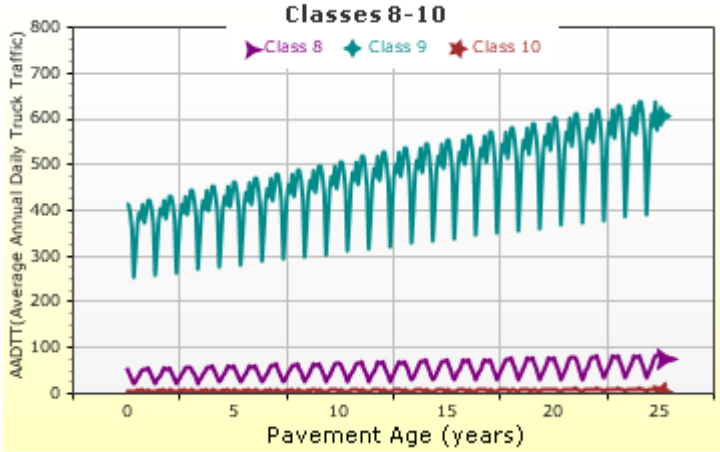
Number of Axles per Truck

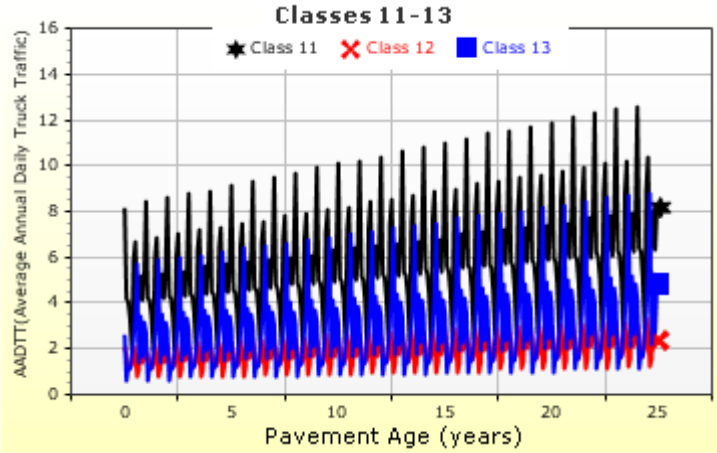
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.7	0.29	0	0
Class 5	2	0	0	0
Class 6	1	1	0	0
Class 7	1.18	0.18	0.63	0.18
Class 8	2.21	0.78	0	0
Class 9	1.48	1.75	0	0
Class 10	1.08	0.99	0.94	0.03
Class 11	4.43	0.03	0.16	0
Class 12	3.29	1.09	0.17	0
Class 13	2.7	1.22	0.43	0.24

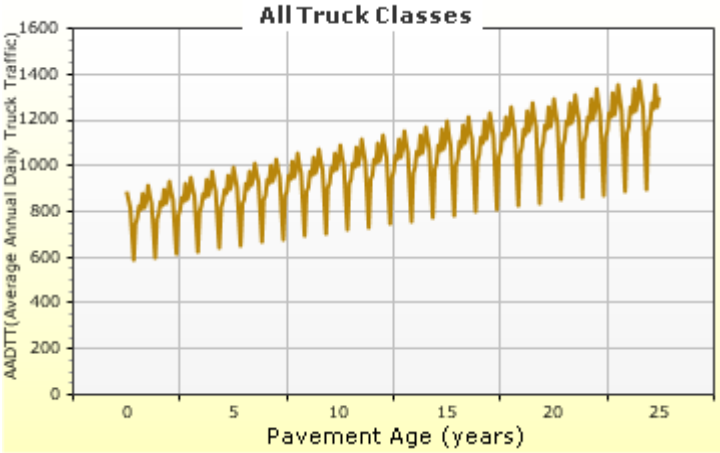
AADTT (Average Annual Daily Truck Traffic) Growth

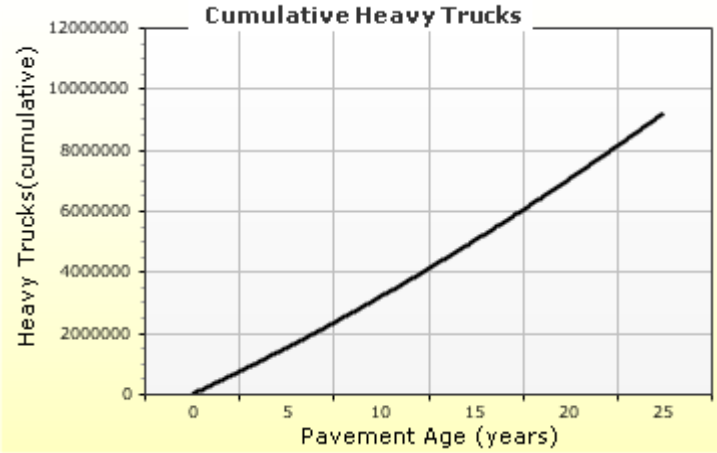
*** Traffic cap is not enforced**







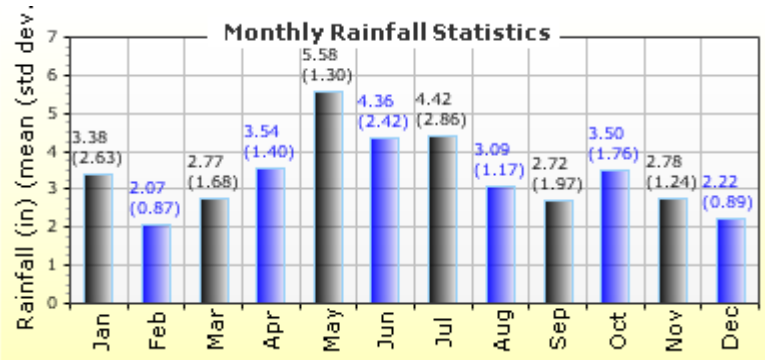




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790

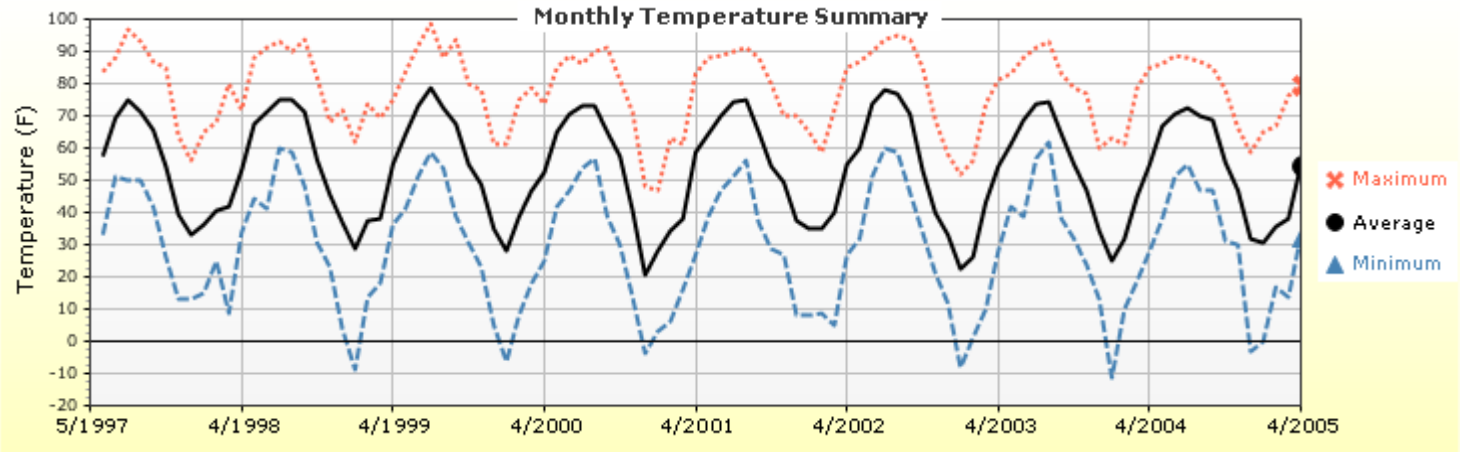


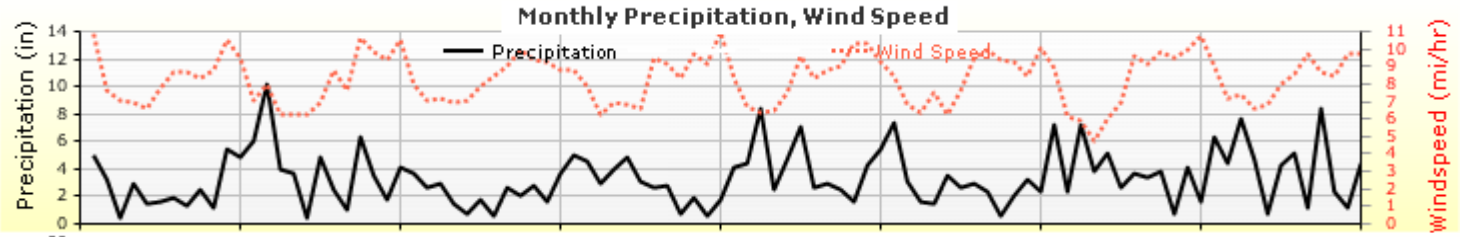
Annual Statistics:

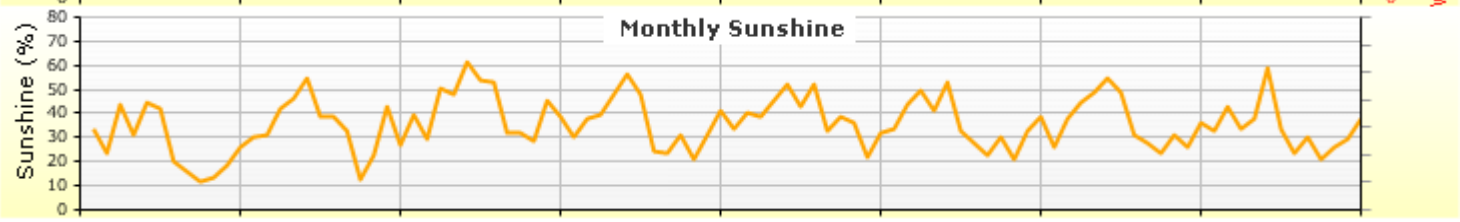
Mean annual air temperature (°F)	53.71
Mean annual precipitation (in.)	40.41
Freezing index (°F - days)	475.93
Average annual number of freeze/thaw cycles:	54.61

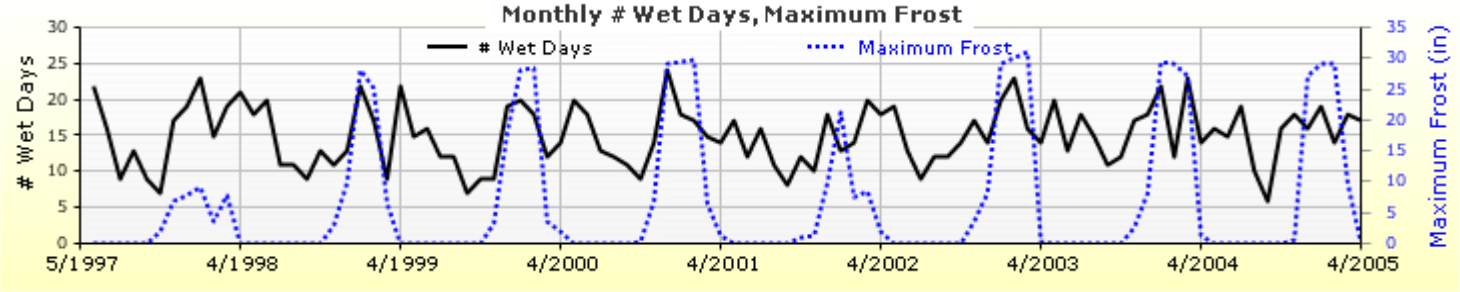
Water table depth (ft) 5.00

Monthly Climate Summary:

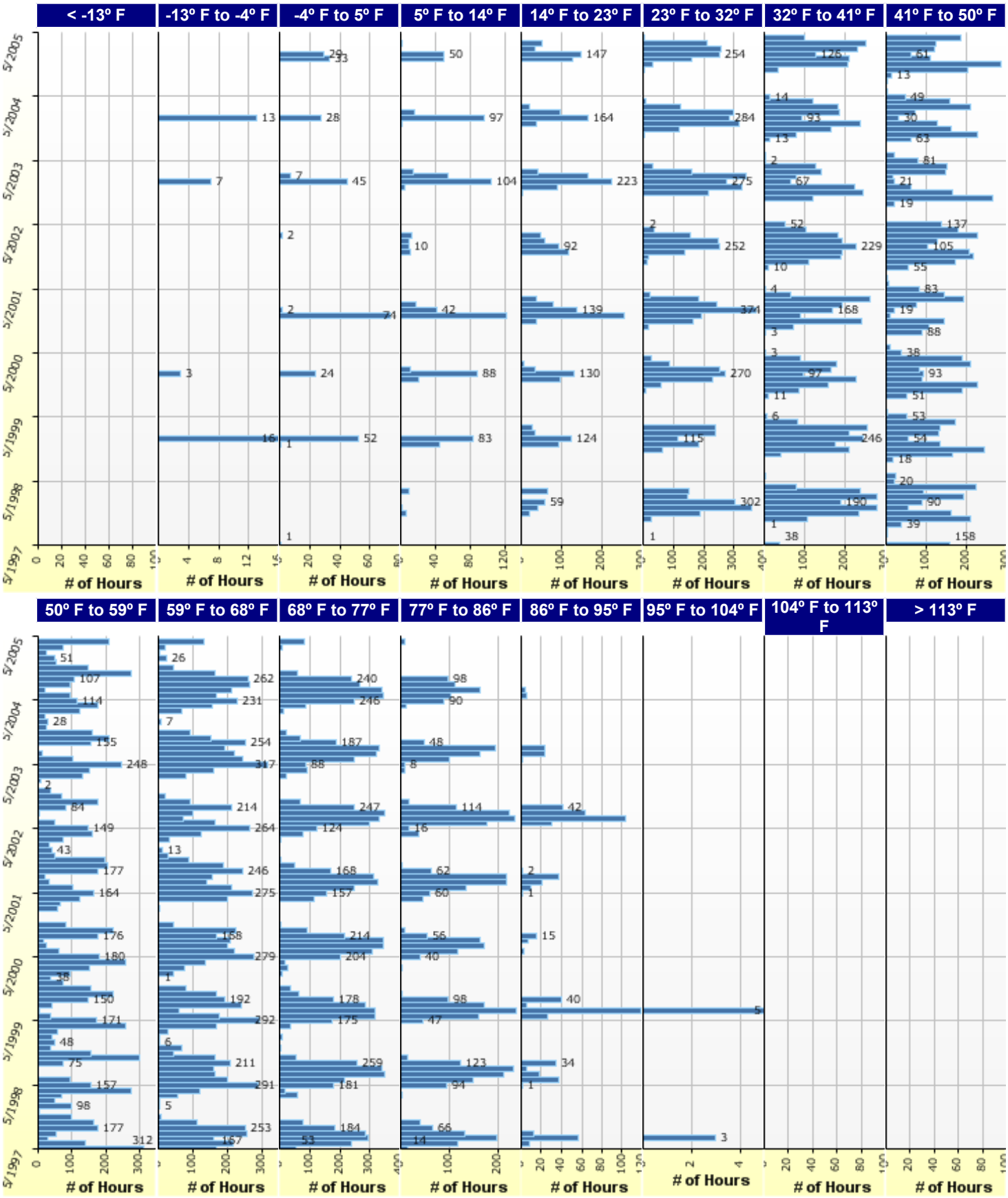








Hourly Air Temperature Distribution by Month:



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

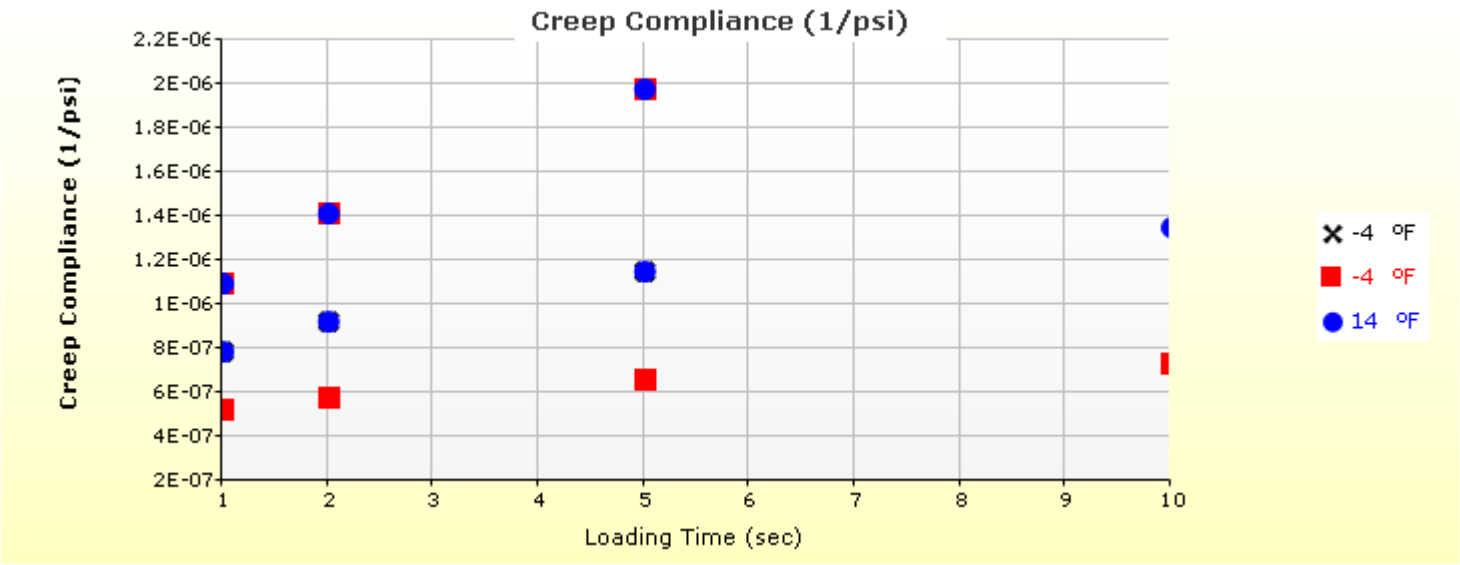
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Greenfield 9.5mm PG70-22	Flexible (1)	1.00
Layer 2 Flexible : Greenfield 19.0mm PG70-22	Flexible (1)	1.00
Layer 3 Flexible : Greenfield 19.0mm PG64-22	Flexible (1)	1.00
Layer 4 Subgrade : A-7-6	Subgrade (5)	1.00
Layer 5 Subgrade : A-7-6	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

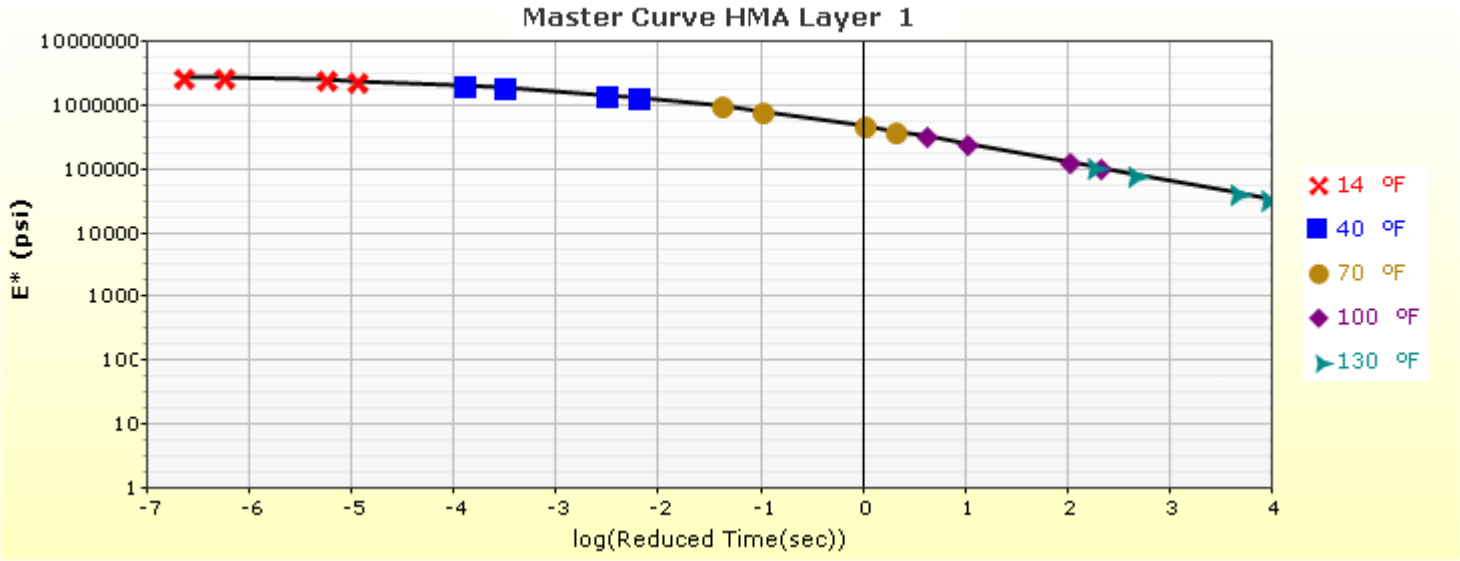
Indirect tensile strength at 14 ºF (psi)	444.45

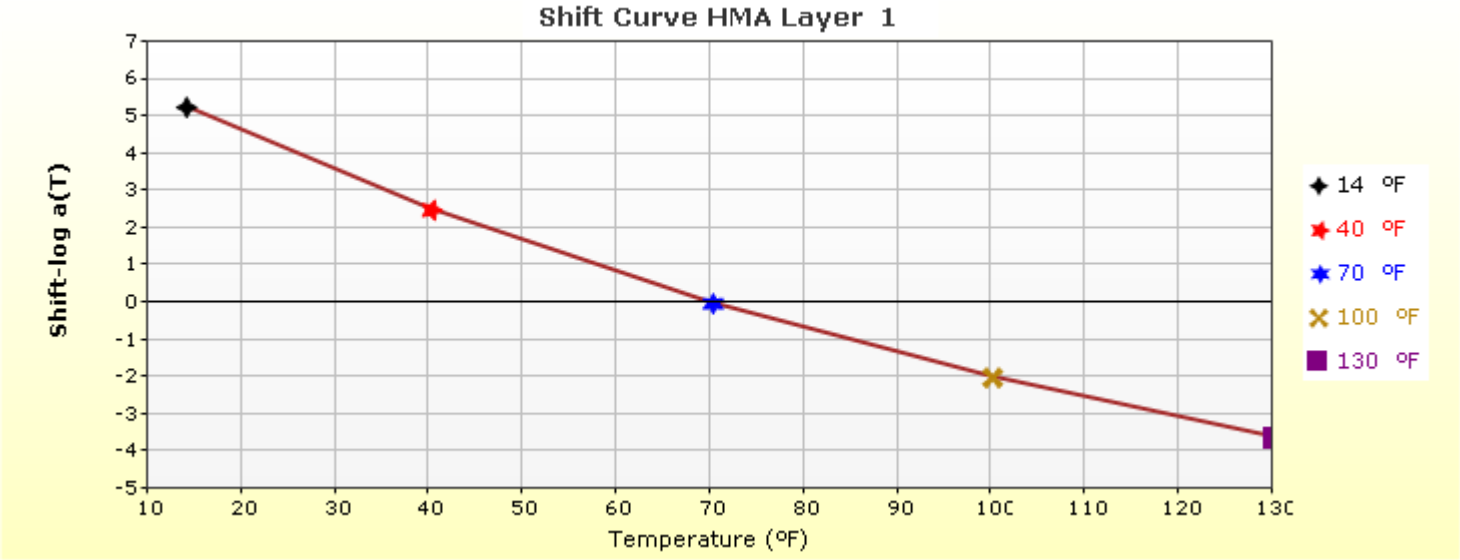
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./ºF)	-
Aggregate coefficient of thermal contraction (in./in./ºF)	6.1e-006
Voids in Mineral Aggregate (%)	19.6

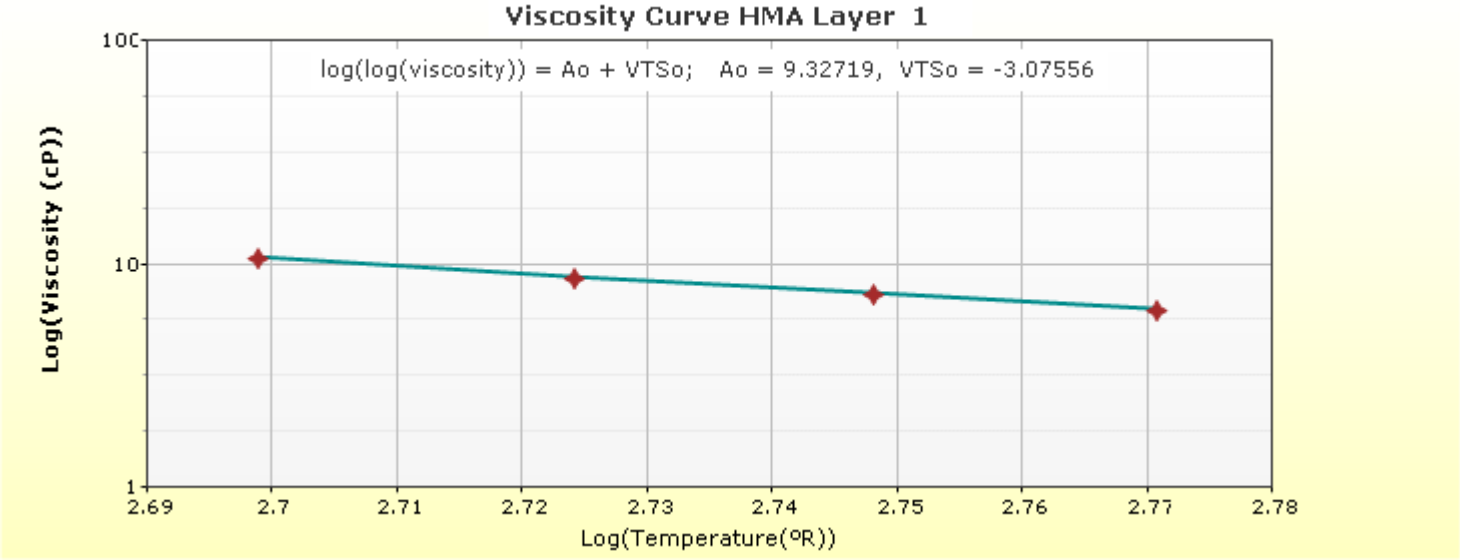
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**-4 ºF**	**14 ºF**
1	5.31e-007	5.31e-007	7.97e-007
1	7.97e-007	1.10e-006	1.10e-006
2	5.86e-007	5.86e-007	9.35e-007
2	9.35e-007	1.42e-006	1.42e-006
5	6.68e-007	6.68e-007	1.15e-006
5	1.15e-006	1.98e-006	1.98e-006
10	7.38e-007	7.38e-007	1.35e-006



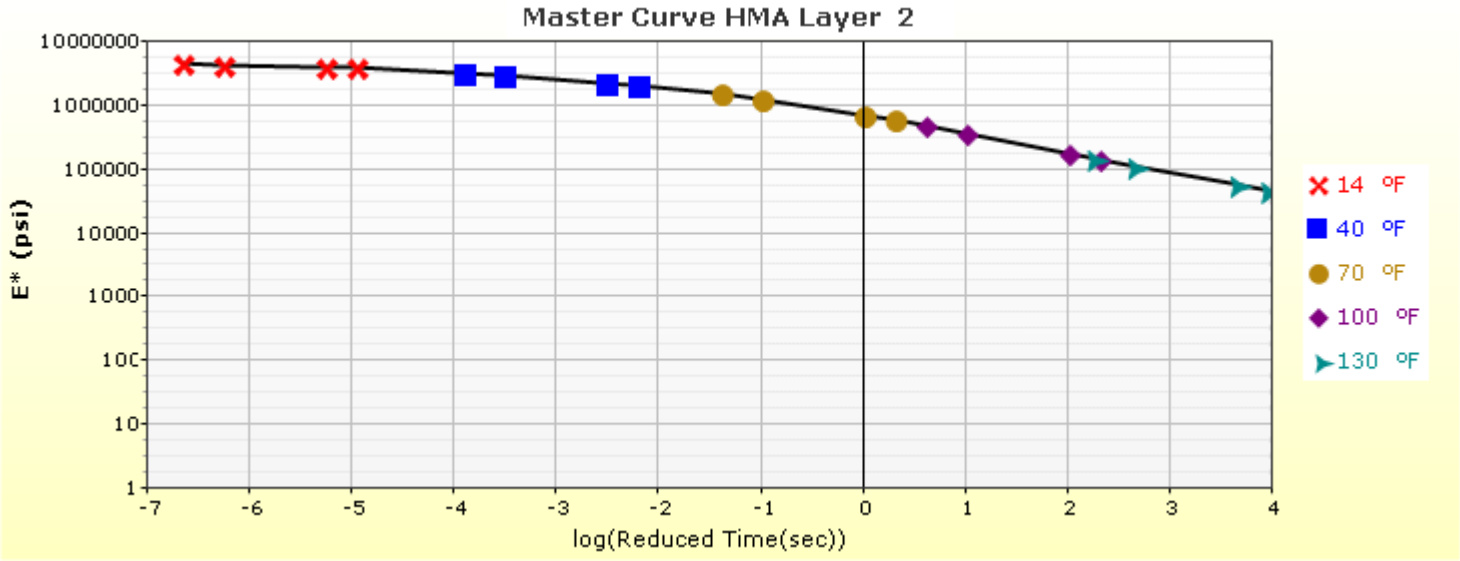
HMA Layer 1: Layer 1 Flexible : Greenfield 9.5mm PG70-22

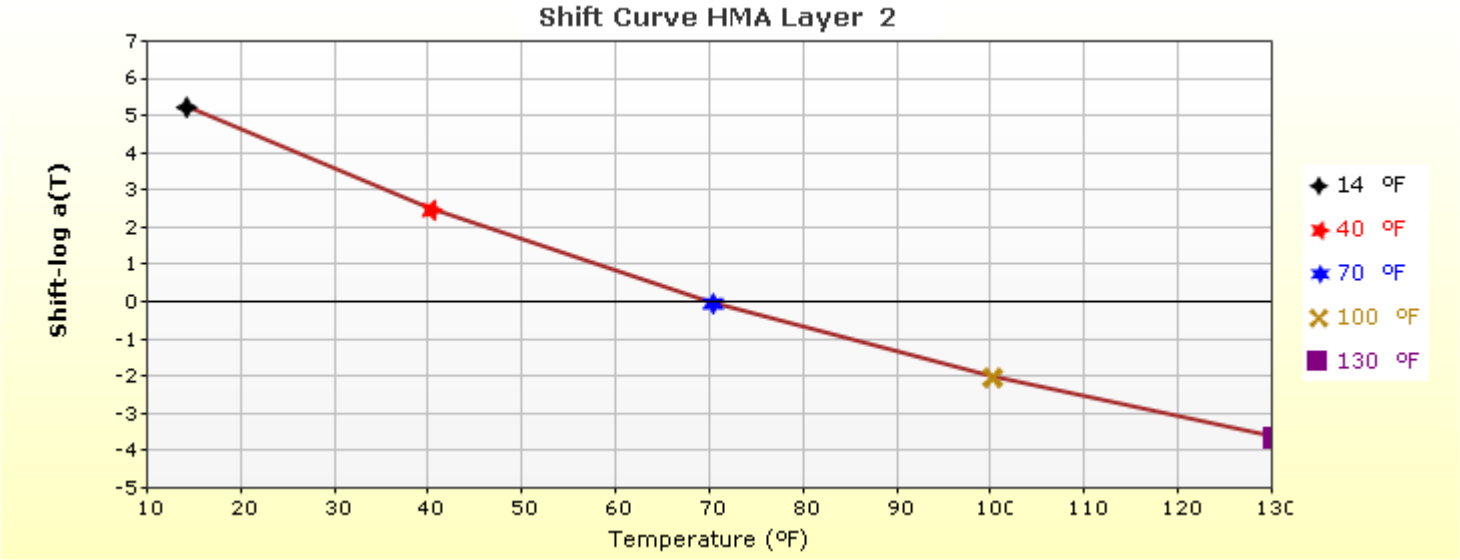


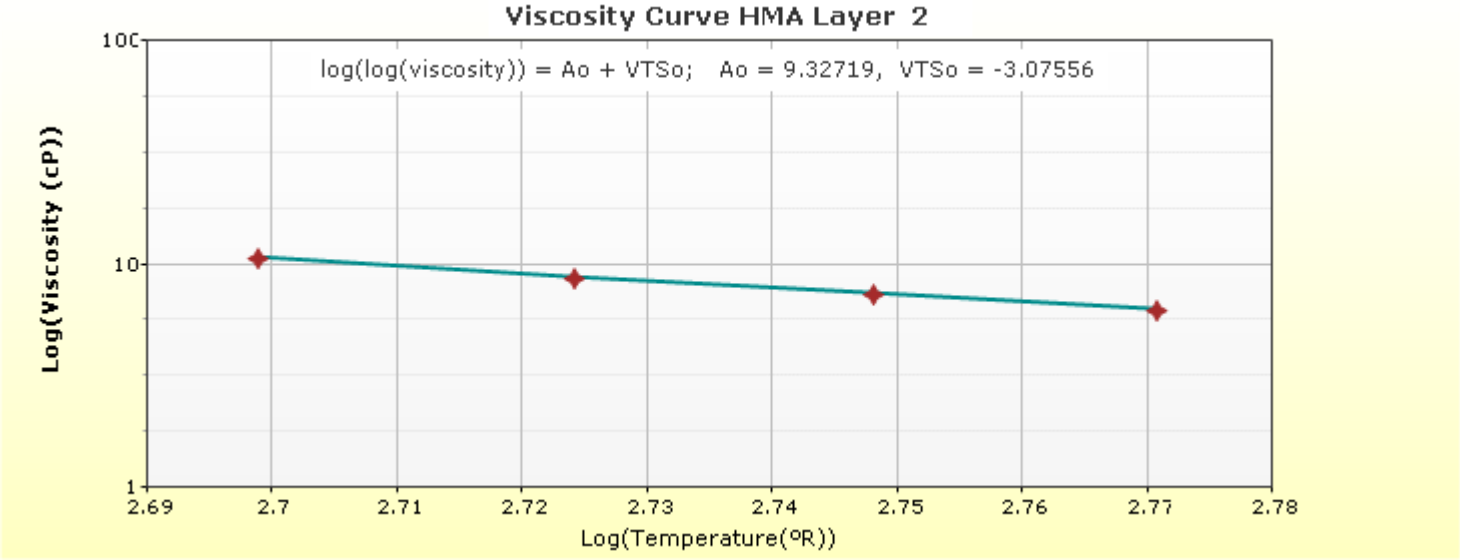




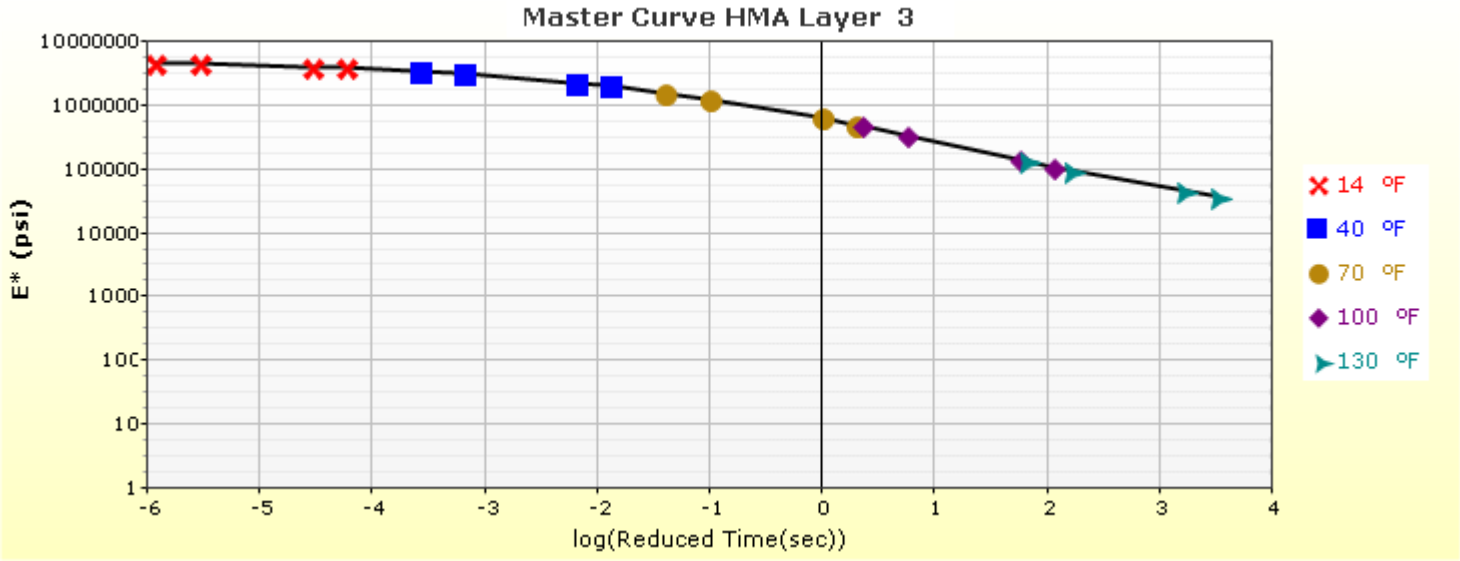
HMA Layer 2: Layer 2 Flexible : Greenfield 19.0mm PG70-22

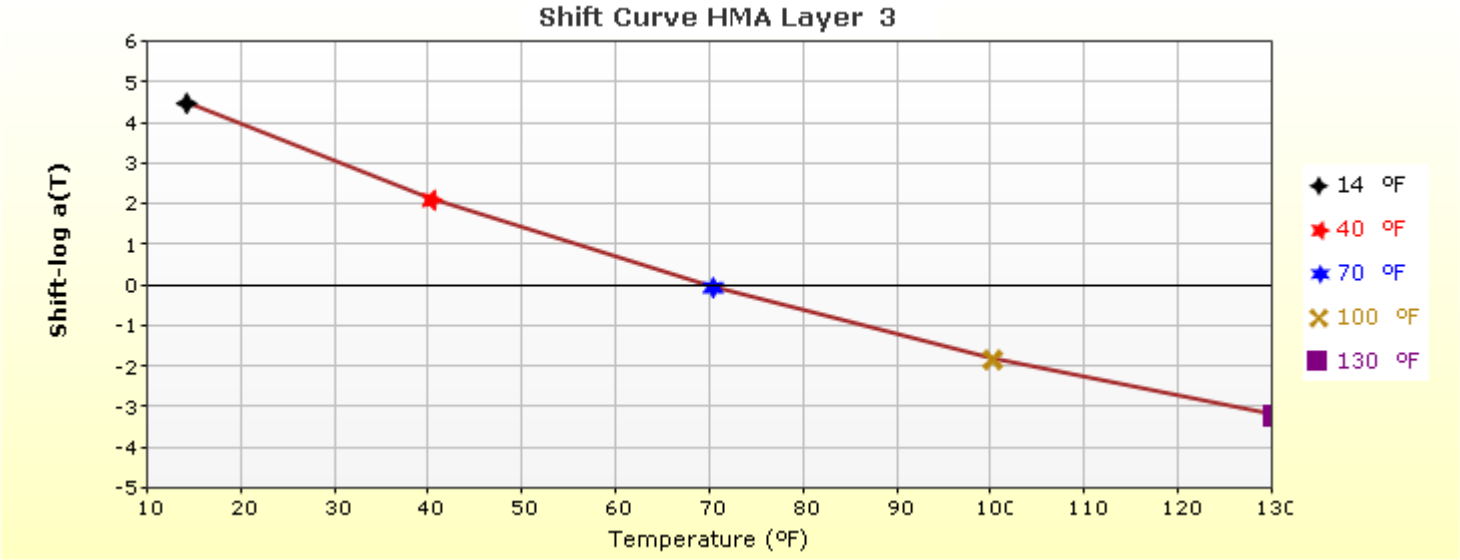


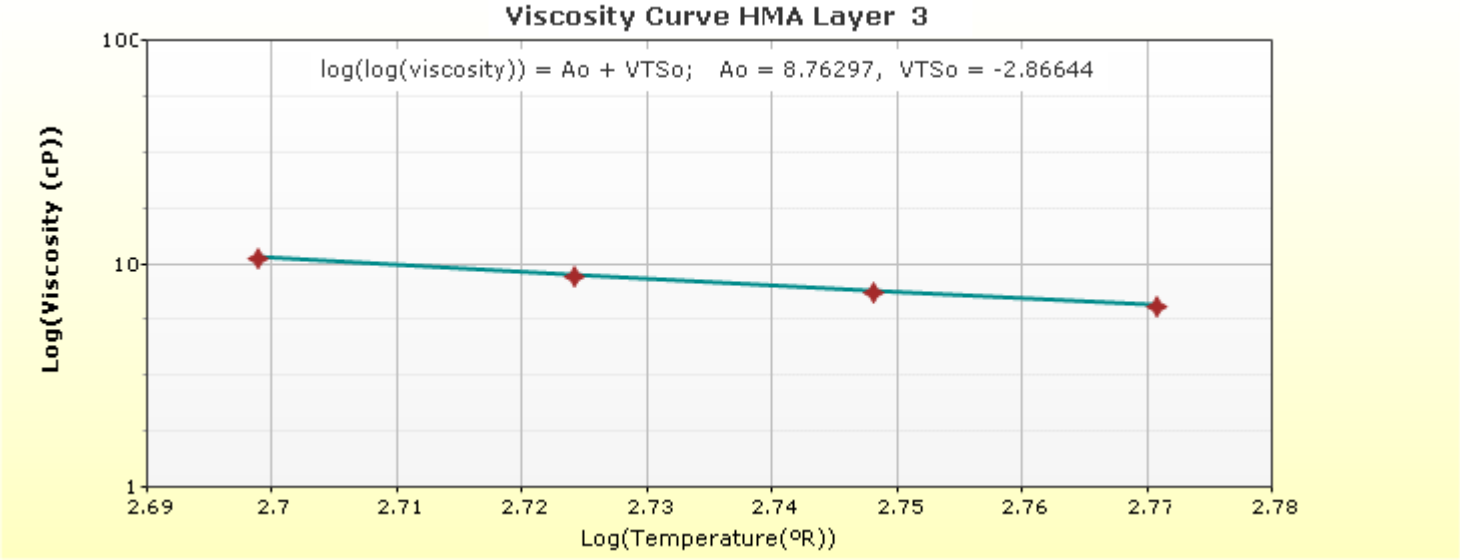




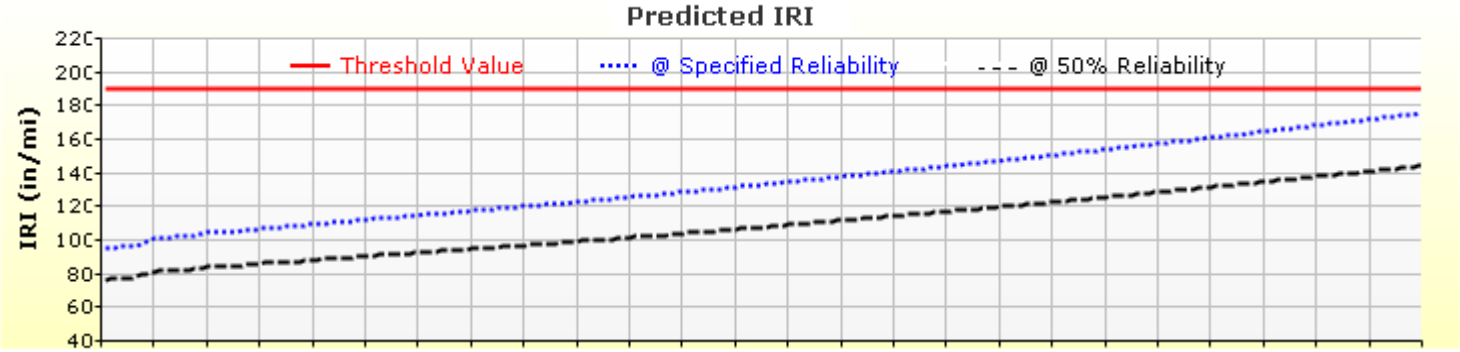
HMA Layer 3: Layer 3 Flexible : Greenfield 19.0mm PG64-22

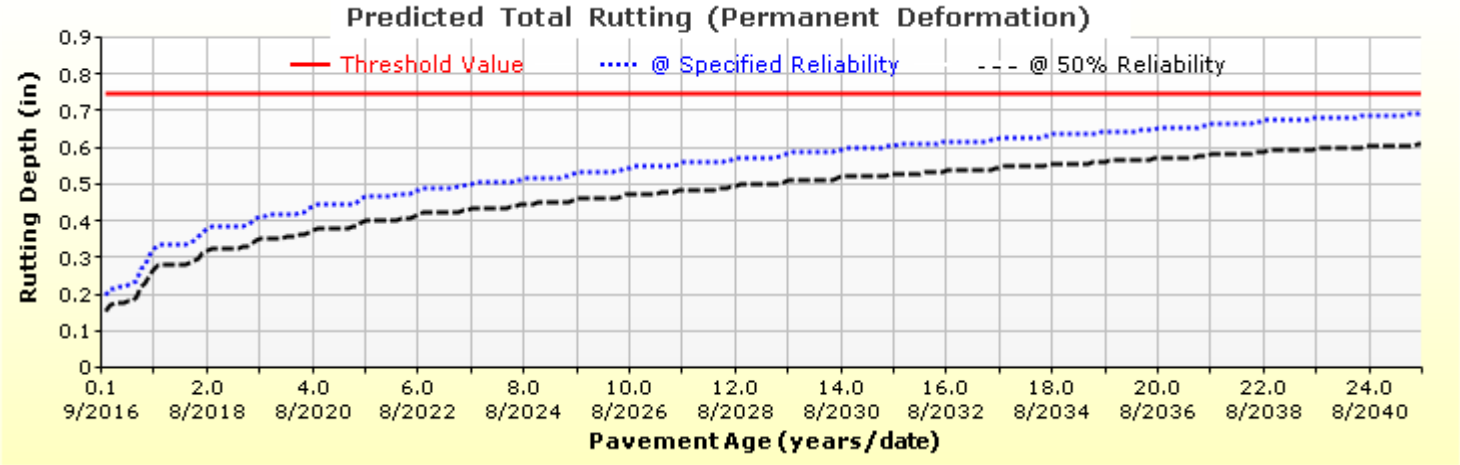


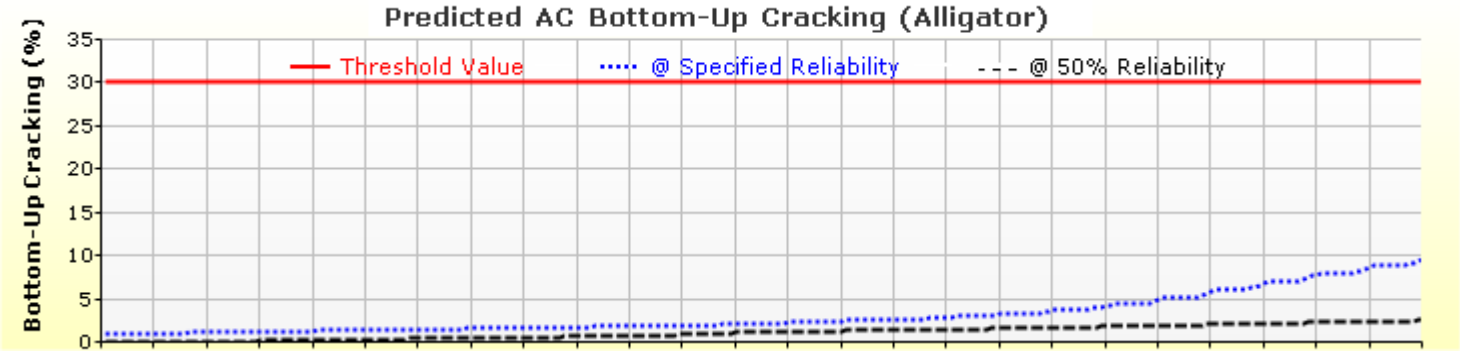


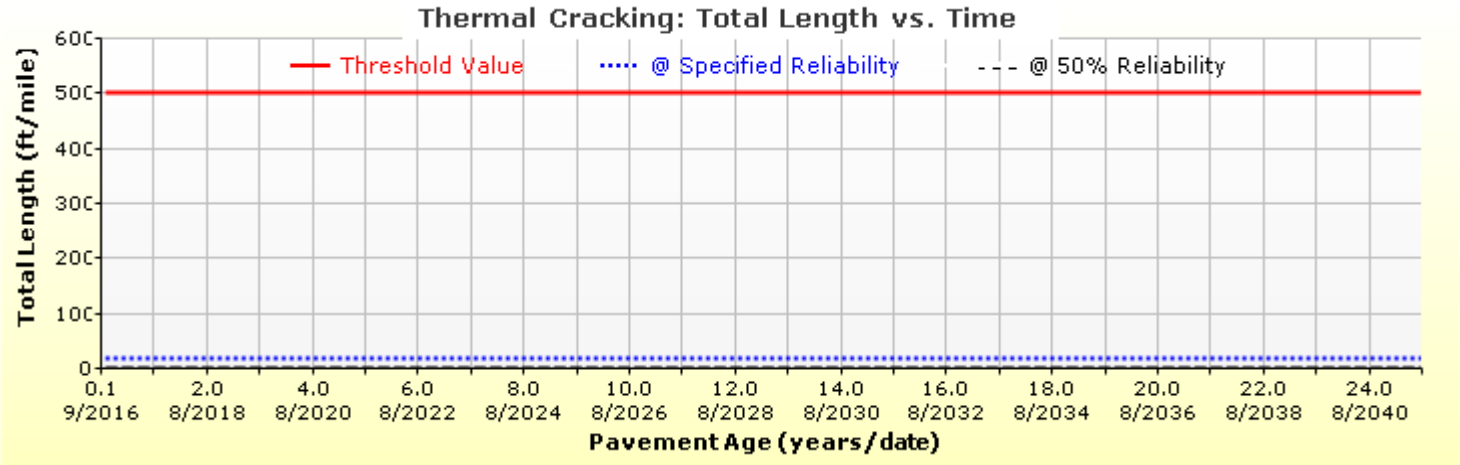


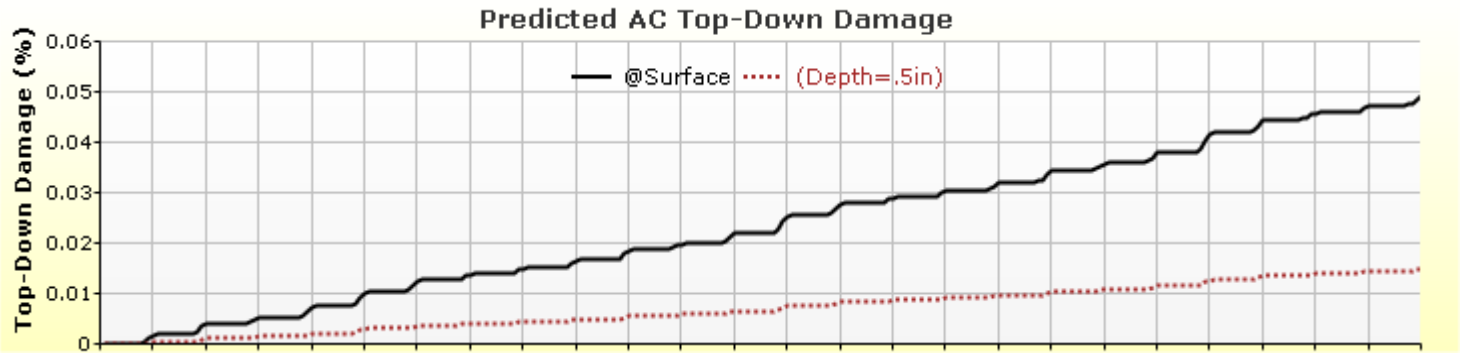
Analysis Output Charts

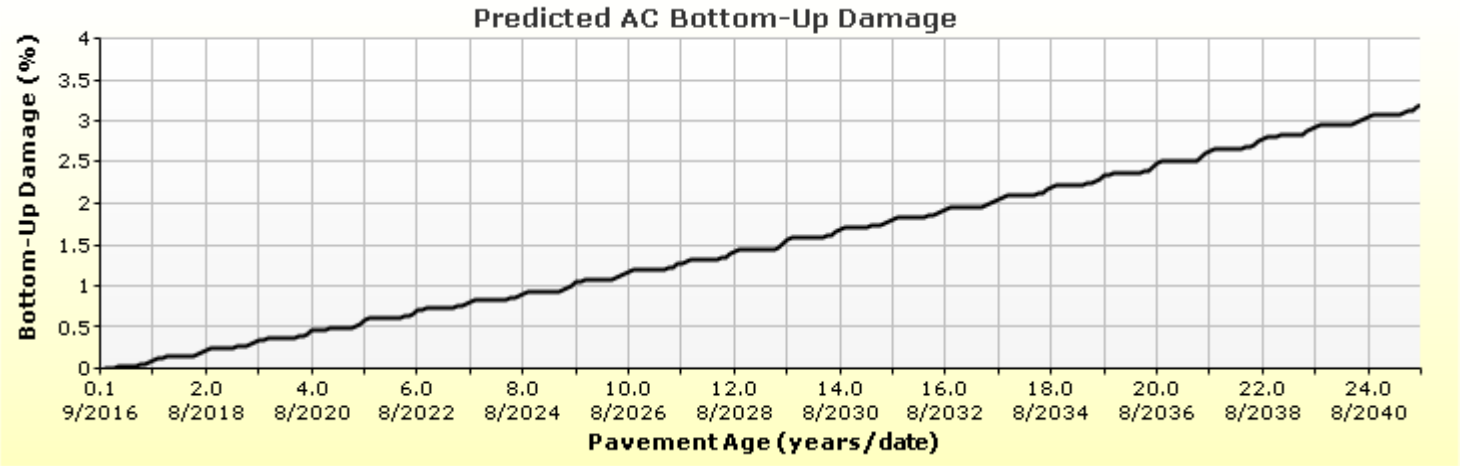


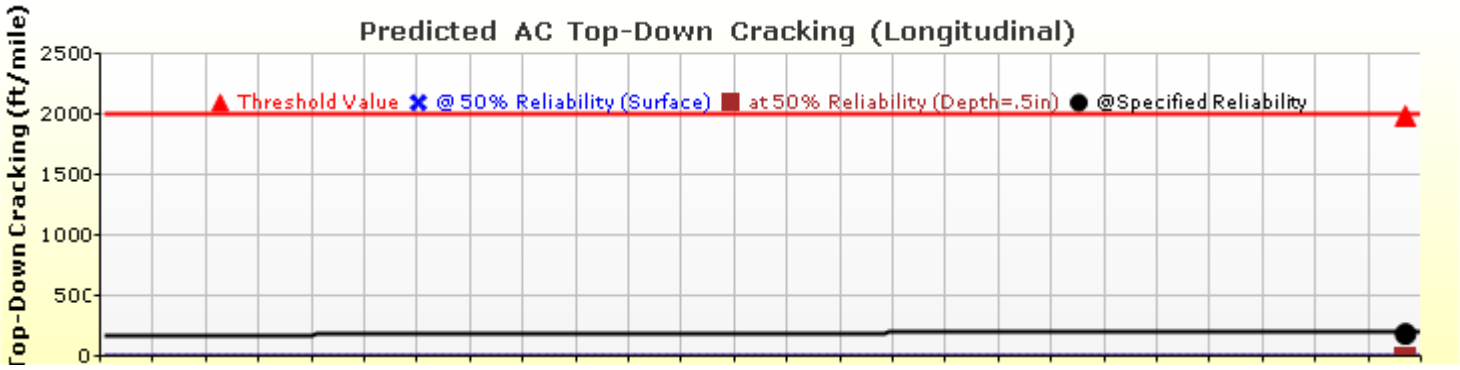


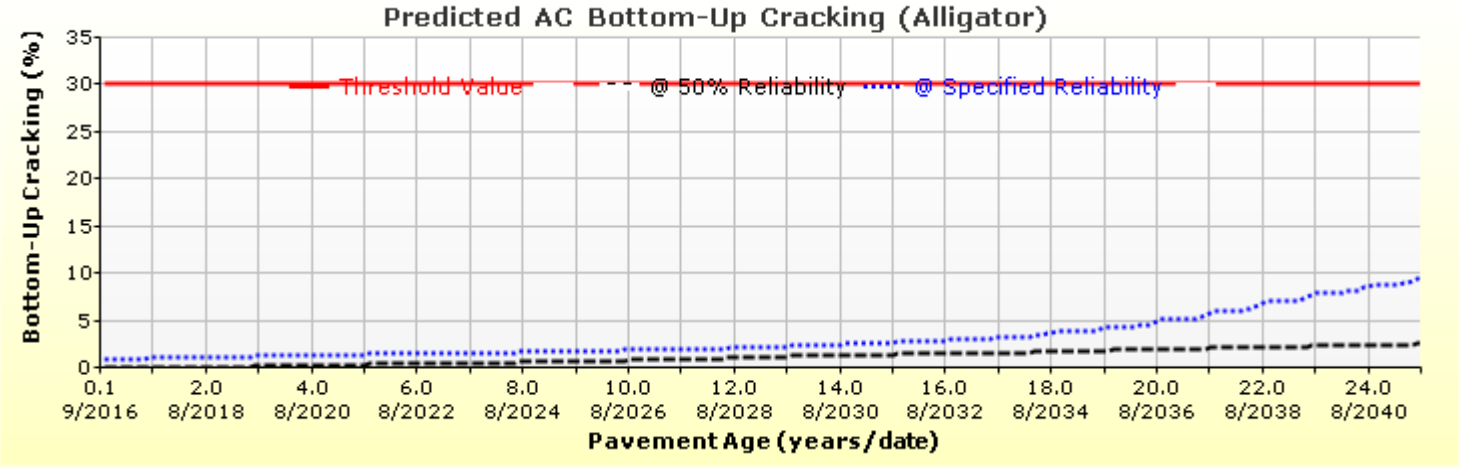


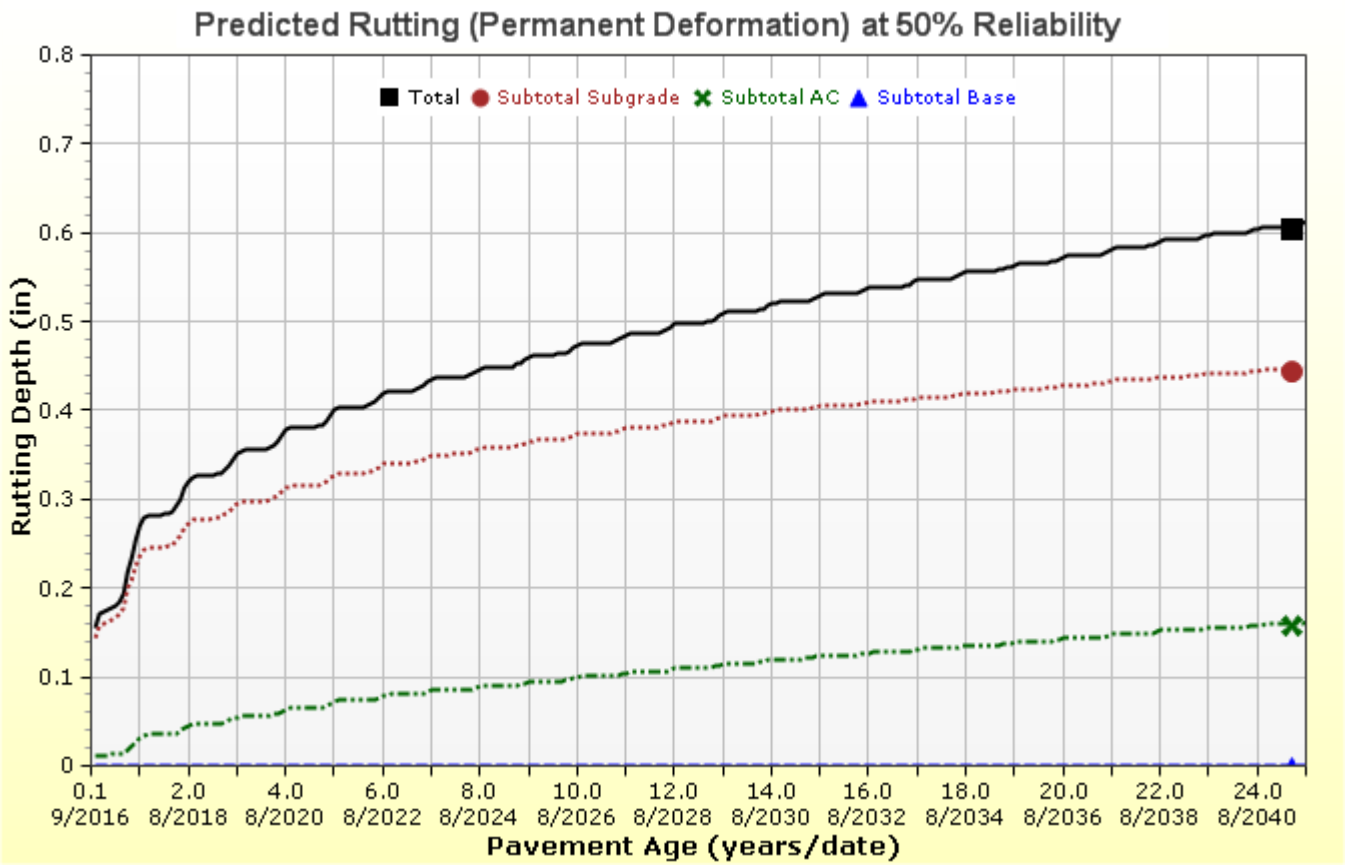


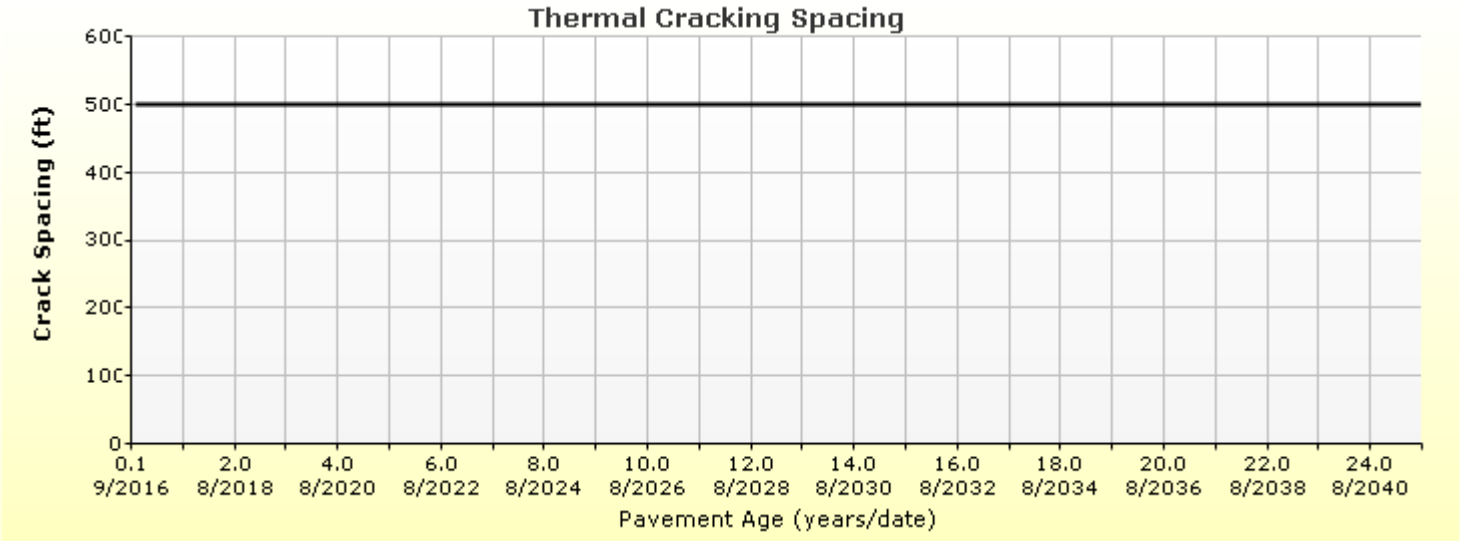

Predicted AC Top-Down Damage
Top-Down Damage (%)
0.06
0.05
0.04
0.03
0.02
0.01
0
@Surface
(Depth=.5in)

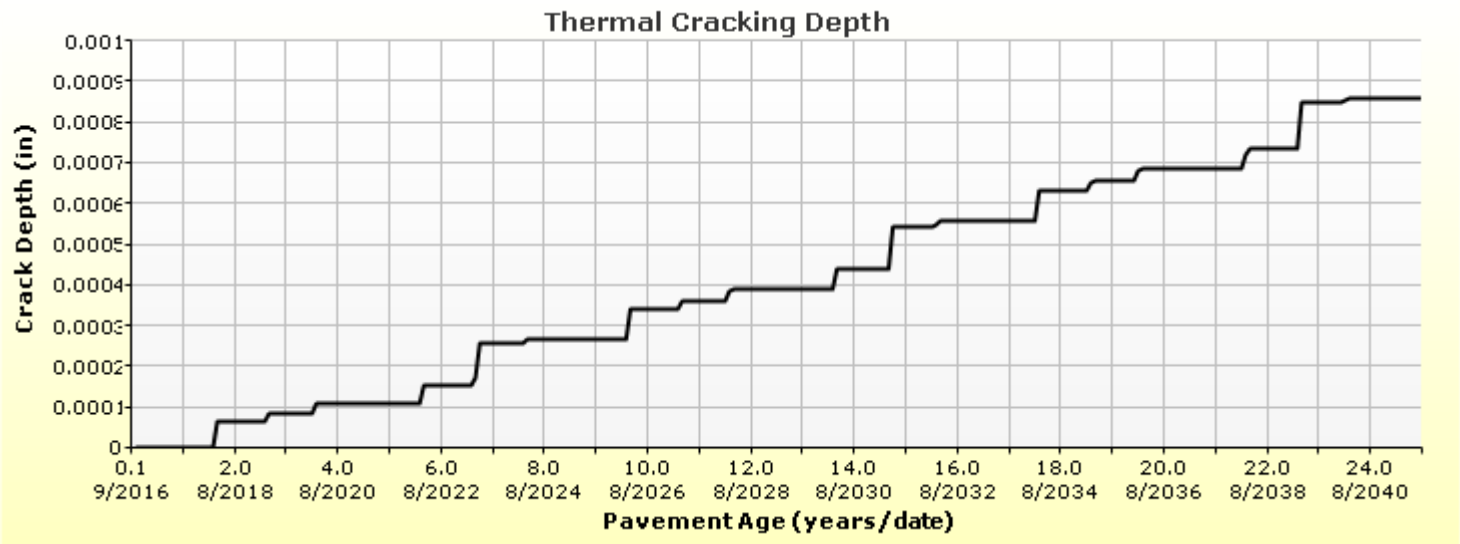

Predicted AC Bottom-Up Damage
Bottom-Up Damage (%)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

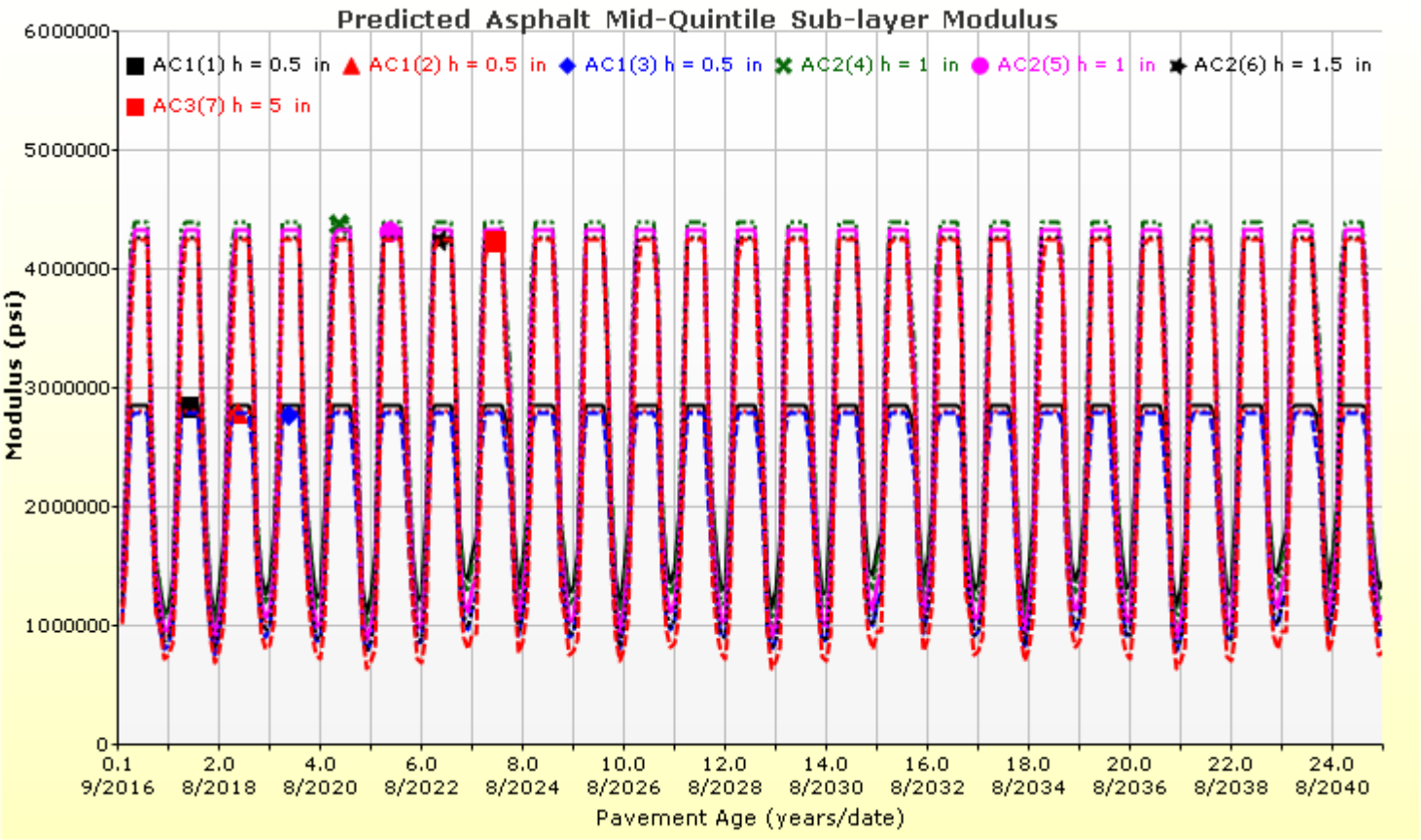

Predicted AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (ft/mile)
2500
2000
1500
1000
500
0
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=.5in)
@Specified Reliability

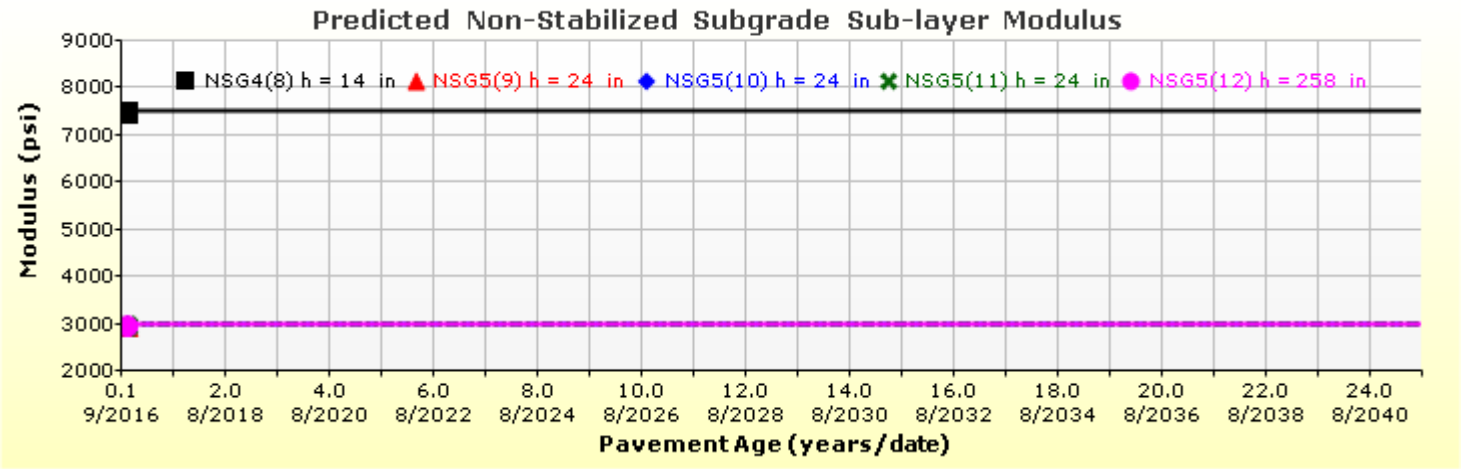

Predicted AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
35
30
25
20
15
10
5
0
Threshold Value
@ 50% Reliability
@ Specified Reliability
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Predicted Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Subgrade
Subtotal AC
Subtotal Base
Rutting Depth (in)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Spacing
Crack Spacing (ft)
600
500
400
300
200
100
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)


Thermal Cracking Depth
Crack Depth (in)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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 = 1.5 in
AC3(7) h = 5 in
Modulus (psi)
6000000
5000000
4000000
3000000
2000000
1000000
0
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
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)
9000
8000
7000
6000
5000
4000
3000
2000
0.1 9/2016
2.0 8/2018
4.0 8/2020
6.0 8/2022
8.0 8/2024
10.0 8/2026
12.0 8/2028
14.0 8/2030
16.0 8/2032
18.0 8/2034
20.0 8/2036
22.0 8/2038
24.0 8/2040
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Greenfield 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	1872495	2280649	2558243	3191179
40	1461806	1639806	1806348	2027879
70	255467	474605	712409	857118
100	53857	121012	240307	314726
130	24499	45972	94742	128388

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	Greenfield 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 : Greenfield 19.0mm PG70-22

Asphalt		
Thickness (in.)	3.5	
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	2937952	3610444	4166515	5000000
40	2266657	2556171	2828567	3193383
70	364606	697471	1067196	1295291
100	71348	166660	341895	453527
130	31206	60428	128949	177293

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	Greenfield 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 : Greenfield 19.0mm PG64-22

Asphalt		
Thickness (in.)	5.0	
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	3042663	3715316	4113406	5000000
40	2000767	2583276	3039883	3481384
70	253862	614089	1083394	1357208
100	52156	133874	316005	437461
130	26313	49623	113020	160614

Asphalt Binder

Temperature (ºF)	Binder Gstar (Pa)	Phase angle (deg)
40	19627632.35	32.71
55	9199787.41	42.43
70	3072091.94	50.32
85	926086.84	56.76
100	278615.81	62.04
115	87586.86	66.4
130	29373.15	70.01

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	Greenfield 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 4 Subgrade : A-7-6

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)
7500.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	98.6
Saturated hydraulic conductivity (ft/hr)	False	8.849e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Layer 5 Subgrade : A-7-6

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)
3000.0

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

Identifiers

Field	Value
Display name/identifier	A-7-6
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	51.0
Plasticity Index	30.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	97.7
Saturated hydraulic conductivity (ft/hr)	False	8.946e-06
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	22.2

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	136.4179
bf	0.5183
cf	0.0324
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	79.1
#100	
#80	84.9
#60	
#50	
#40	88.8
#30	
#20	
#16	
#10	93.0
#8	
#4	94.9
3/8-in.	96.9
1/2-in.	97.5
3/4-in.	98.3
1-in.	98.8
1 1/2-in.	99.3
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.9

Calibration Coefficients

AC Fatigue

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

$$C = 10^M$$

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

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 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:

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

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

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

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

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

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

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

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

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

Level 1 K: 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

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

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

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

Subgrade Rutting

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

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

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
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

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

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

AC Cracking Top Standard Deviation

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

AC Bottom Up Cracking

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

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

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

c1: 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