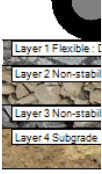


Design Inputs

Design Life: **20 years** Base construction: **May, 2016** Climate Data: **42.554, -92.401**
 Design Type: **Flexible Pavement** Pavement construction: **June, 2017** Sources (Lat/Lon)
 Traffic opening: **September, 2017**

Design Structure



Layer type	Material Type	Thickness (in.):
Flexible	Default asphalt concrete	6.5
NonStabilized	A-1-a	10.0
NonStabilized	Crushed stone	6.0
Subgrade	A-7-6	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

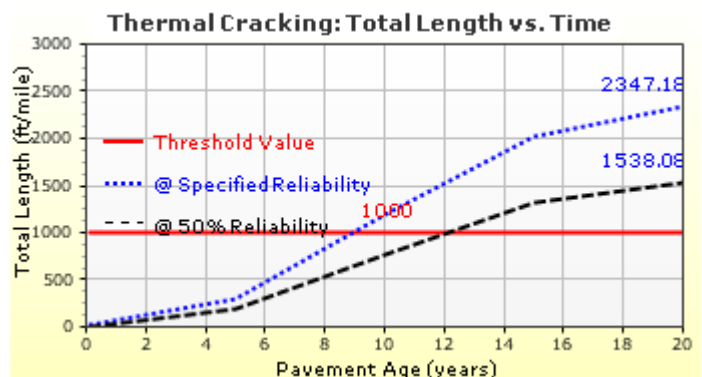
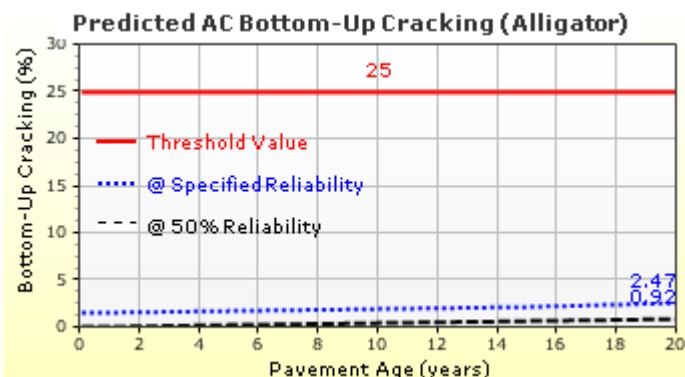
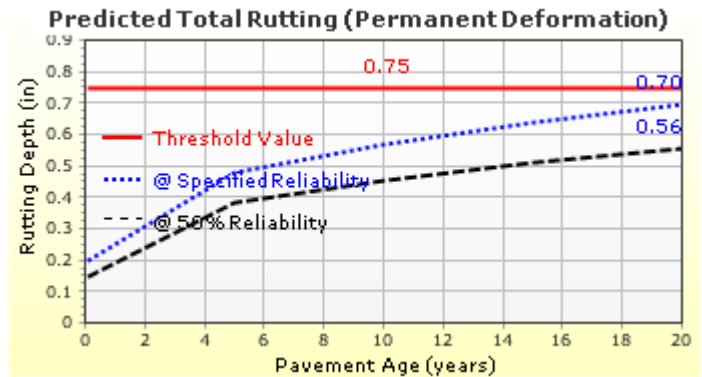
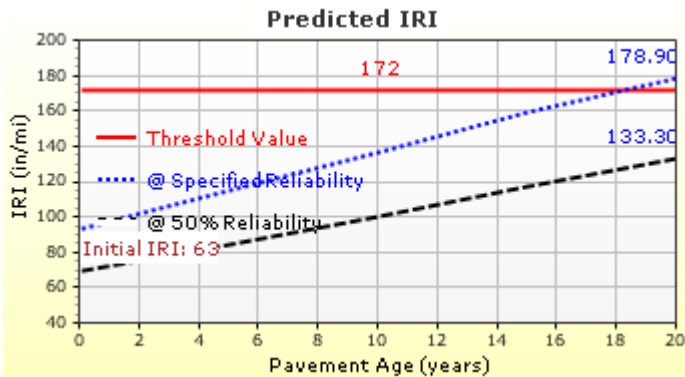
Age (year)	Heavy Trucks (cumulative)
2017 (initial)	14,150
2027 (10 years)	2,584,140
2037 (20 years)	5,168,290

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in./mile)	172.00	178.87	90.00	86.18	Fail
Permanent deformation - total pavement (in.)	0.75	0.70	90.00	96.40	Pass
AC bottom-up fatigue cracking (percent)	25.00	2.47	90.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	2347.18	90.00	19.70	Fail
AC top-down fatigue cracking (ft/mile)	2000.00	1729.01	90.00	93.17	Pass
Permanent deformation - AC only (in.)	0.25	0.37	90.00	45.03	Fail

Distress Charts

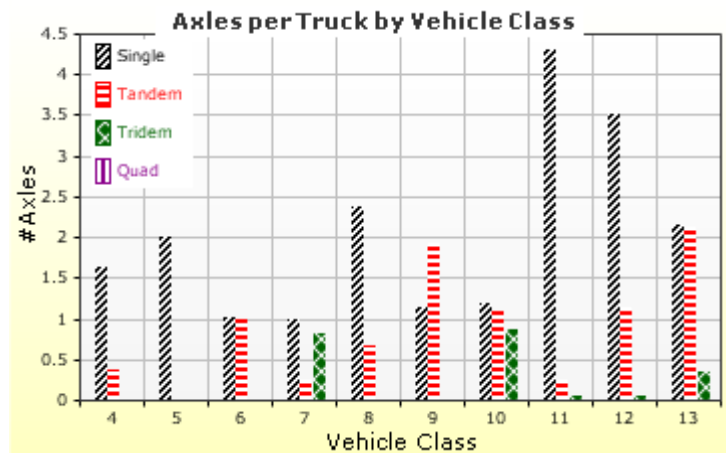
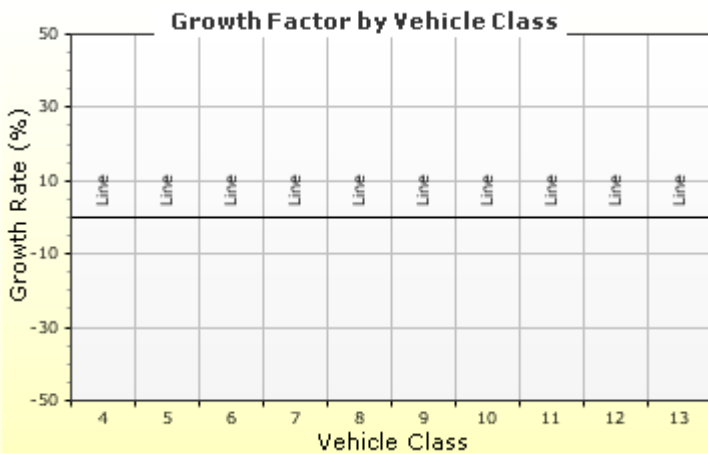
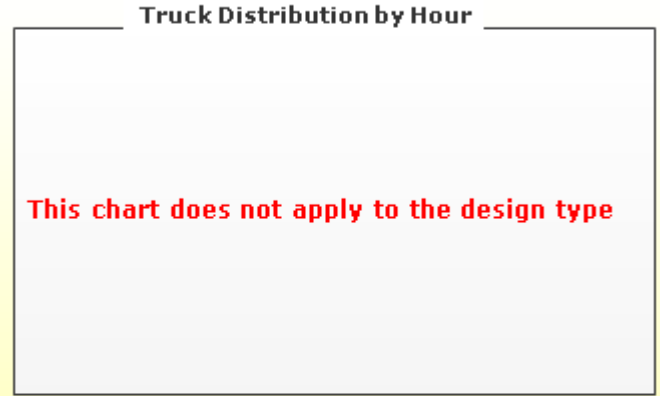
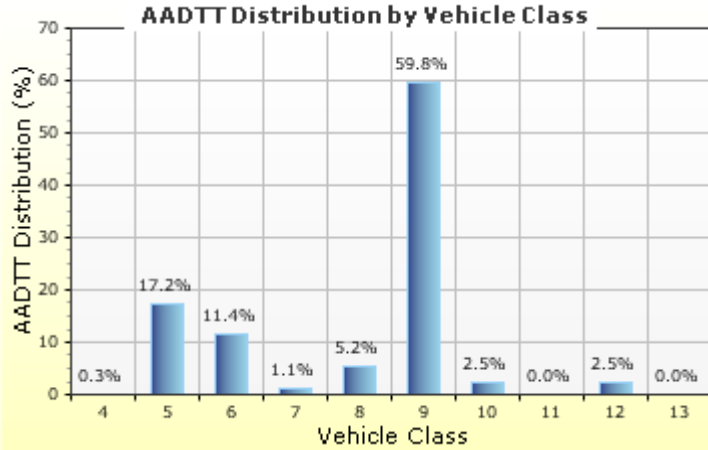


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: **14,150**
 Number of lanes in design direction: **2**

Percent of trucks in design direction (%): **50.0**
 Percent of trucks in design lane (%): **10.0**
 Operational speed (mph): **60.0**



Traffic Volume Monthly Adjustment Factors





Existing Condition 6.5 inch overlay1

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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	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	0.3%	0%	Linear
Class 5	17.2%	0%	Linear
Class 6	11.4%	0%	Linear
Class 7	1.1%	0%	Linear
Class 8	5.2%	0%	Linear
Class 9	59.8%	0%	Linear
Class 10	2.5%	0%	Linear
Class 11	0%	0%	Linear
Class 12	2.5%	0%	Linear
Class 13	0%	0%	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

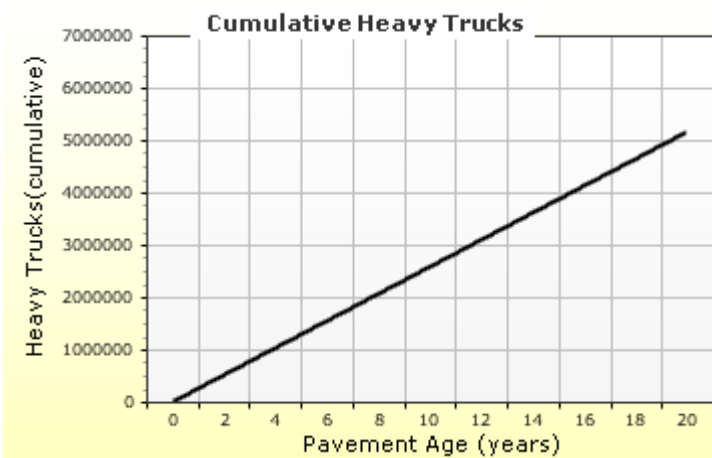
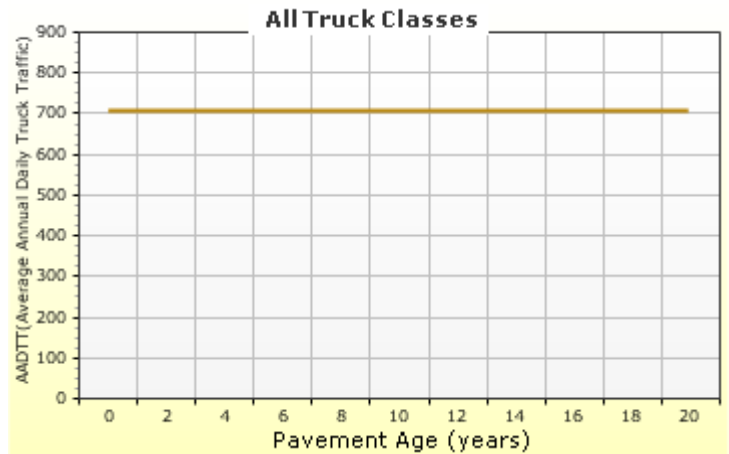
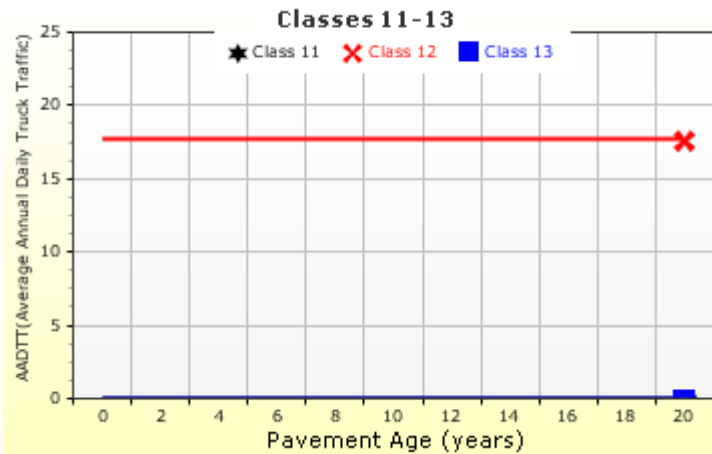
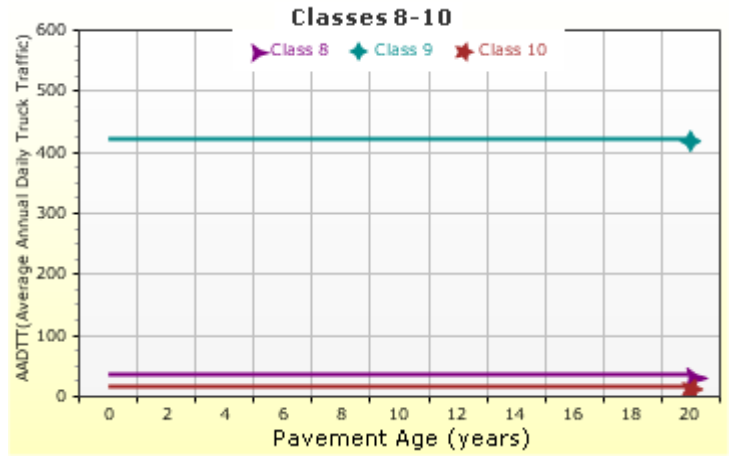
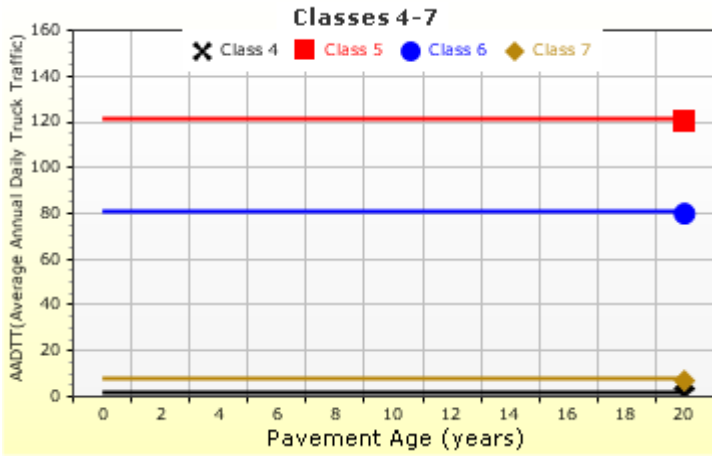
Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0



AADTT (Average Annual Daily Truck Traffic) Growth

* Traffic cap is not enforced





Existing Condition 6.5 inch overlay1

File Name: D:\My ME Design\FINAL REPORT\Existing Condition 6.5 inch overlay1.dgp



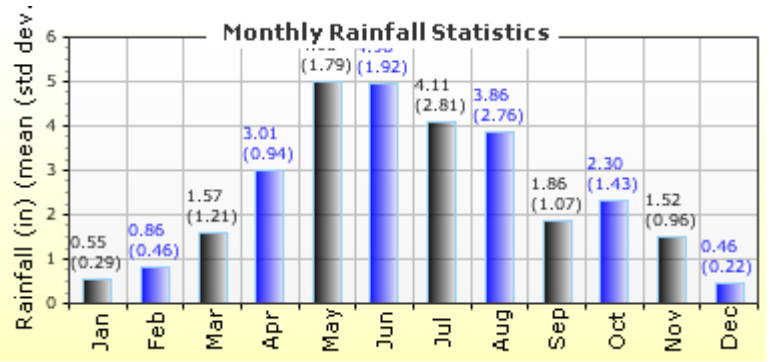
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(ft))
WATERLOO, IA 42.55400 -92.40100 865

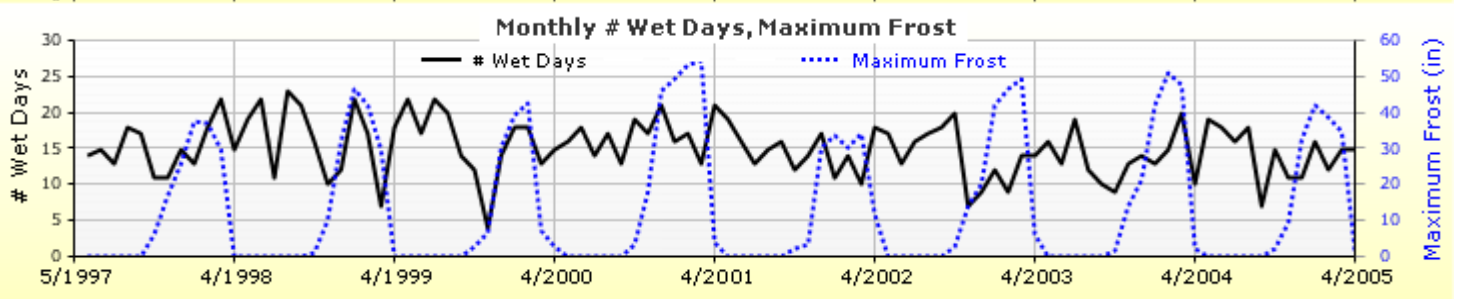
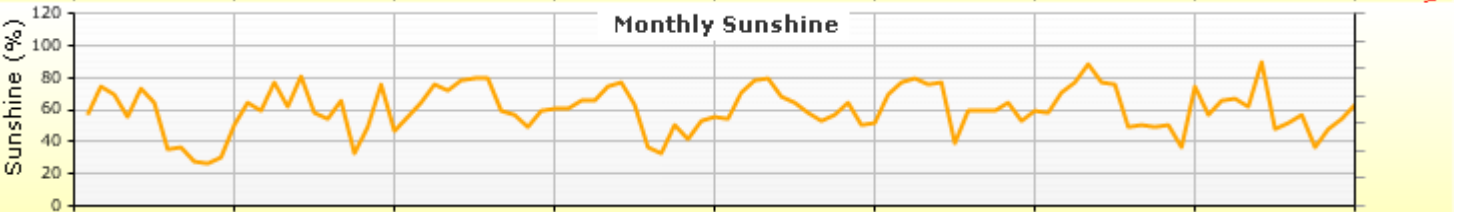
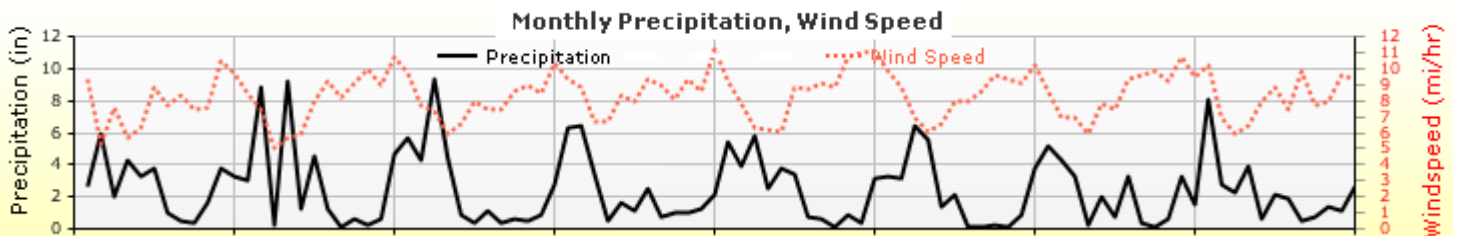
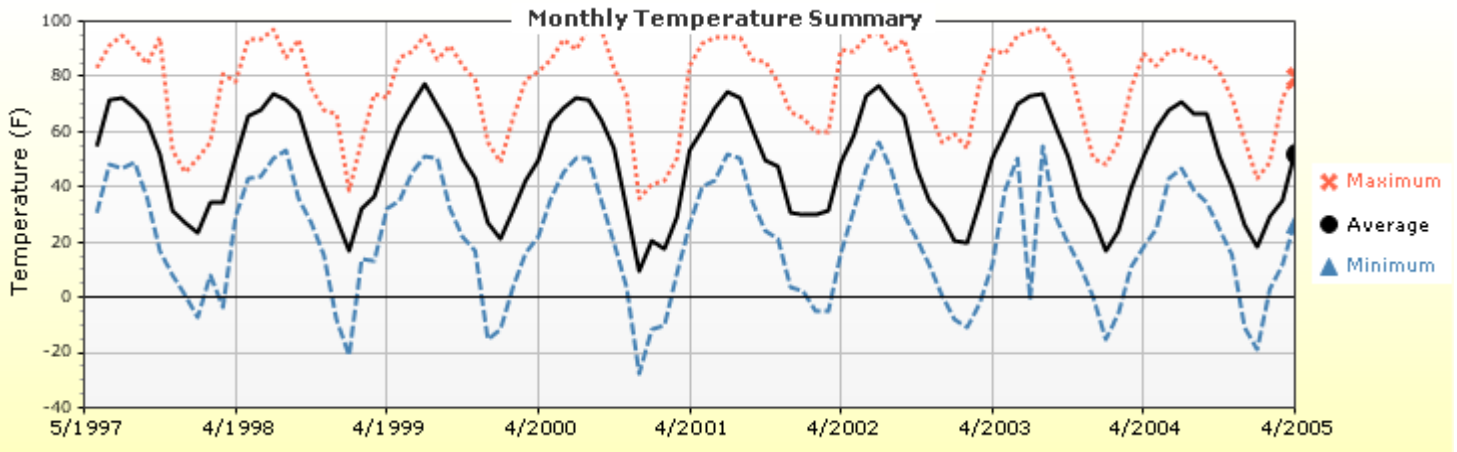
Annual Statistics:

Mean annual air temperature (°F) 48.98
Mean annual precipitation (in.) 30.04
Freezing index (°F - days) 1894.842
Average annual number of freeze/thaw cycles: 74.47



Water table depth (ft) 10.00

Monthly Climate Summary:



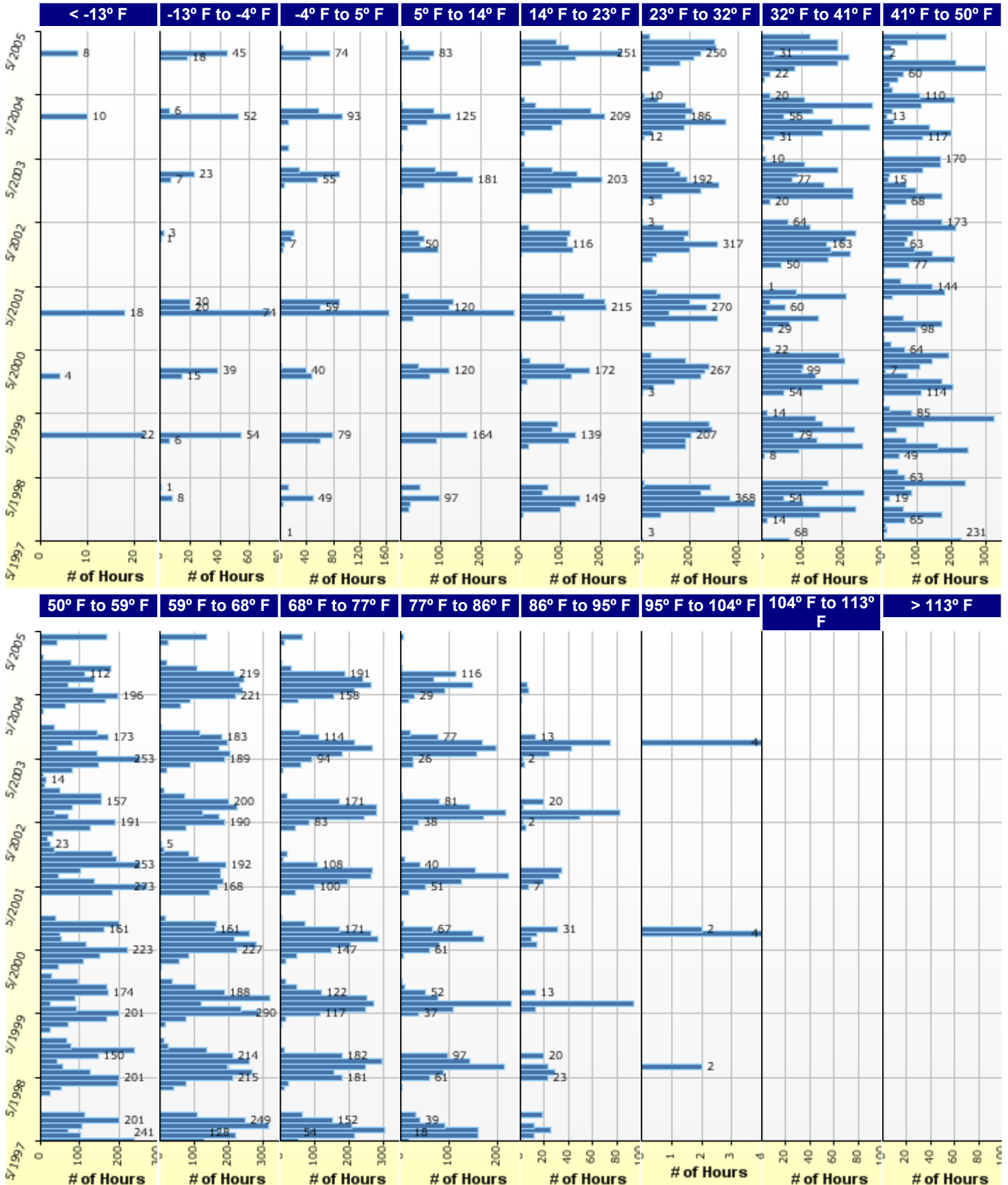


Existing Condition 6.5 inch overlay1

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Hourly Air Temperature Distribution by Month:





Existing Condition 6.5 inch overlay1

File Name: D:\My ME Design\FINAL REPORT\Existing Condition 6.5 inch overlay1.dgpx



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

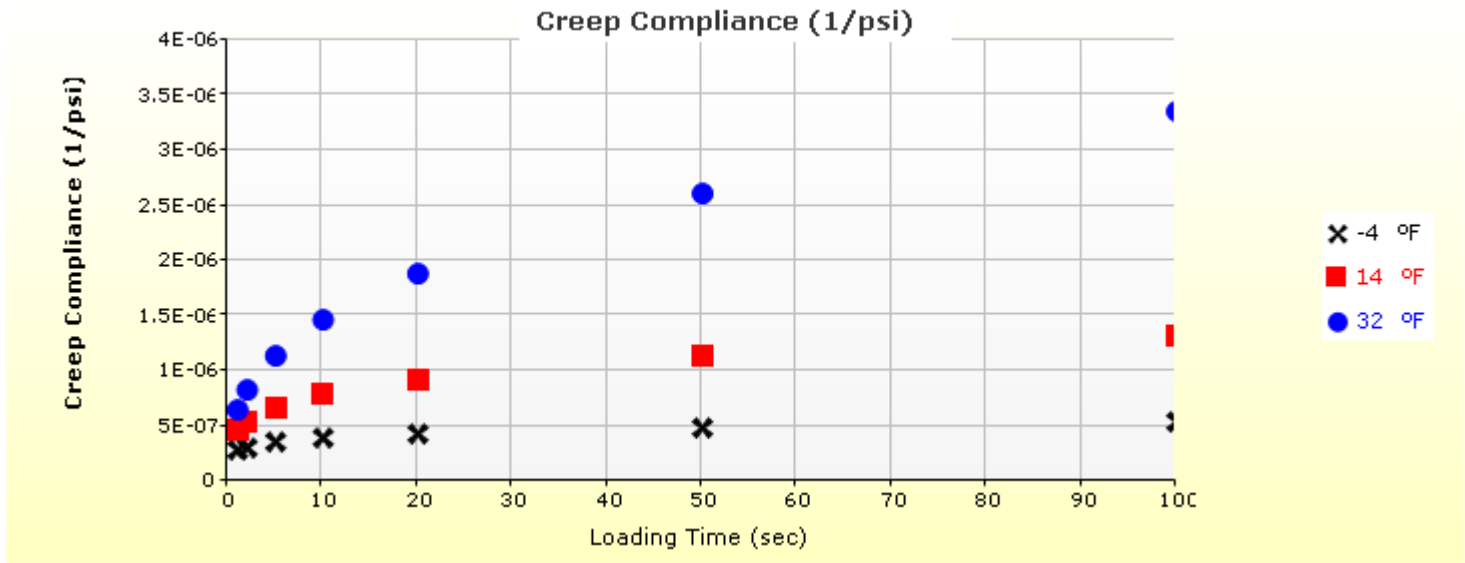
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : A-1-a	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-7-6	Subgrade (5)	-

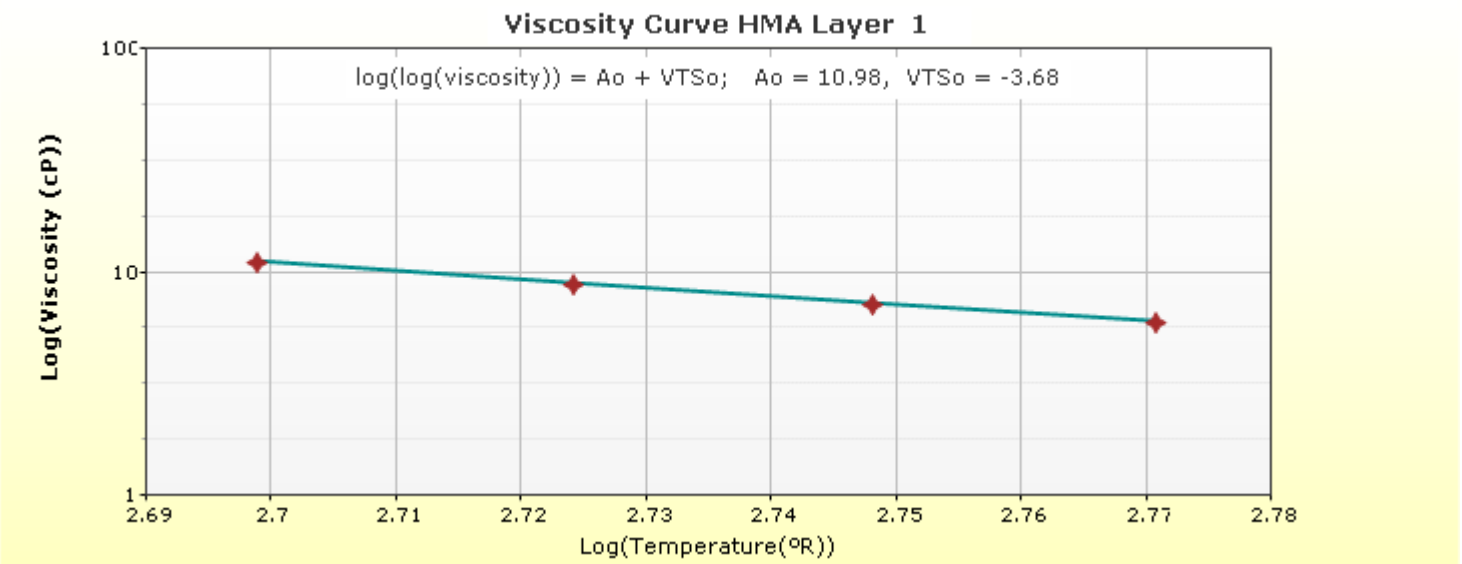
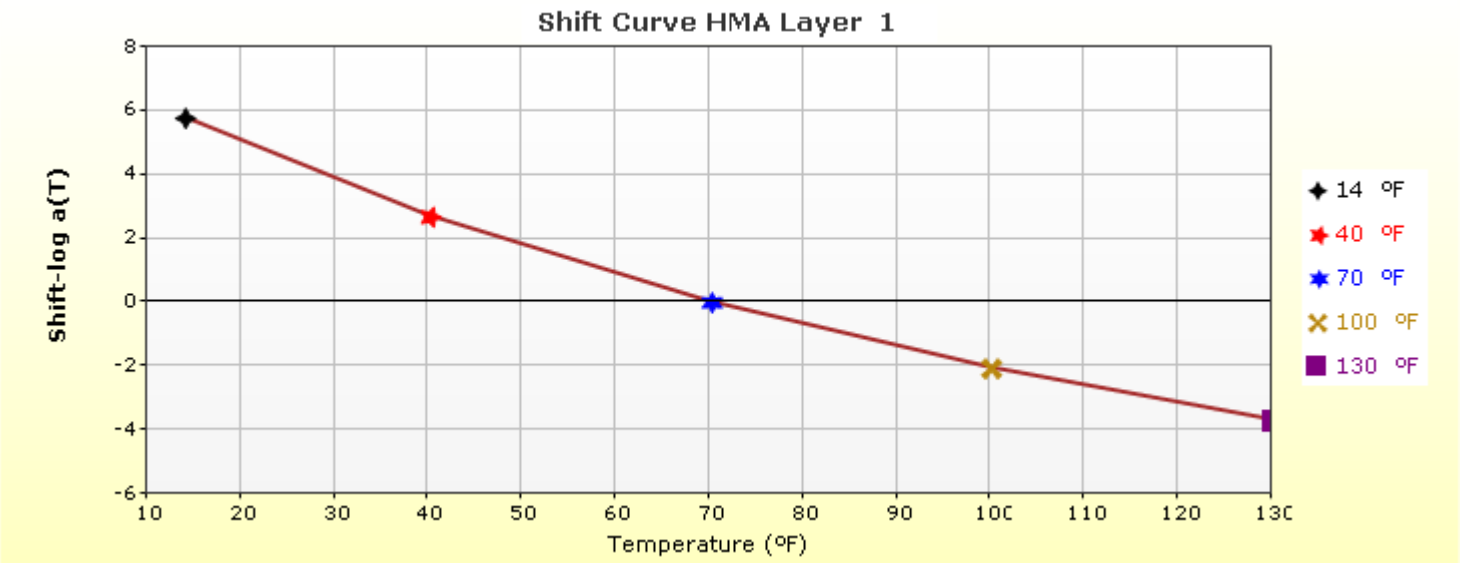
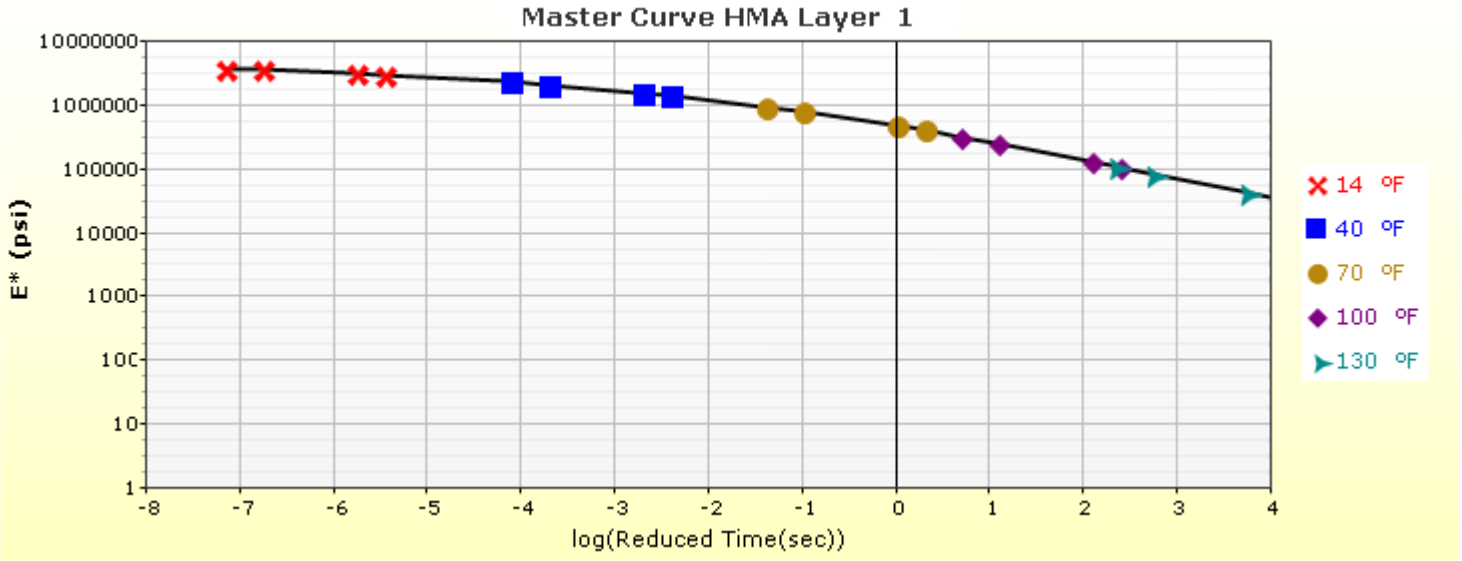
Thermal Cracking (Input Level: 3)

Indirect tensile strength at 14 °F (psi)	361.14
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in./in./°F)	-
Aggregate coefficient of thermal contraction (in./in./°F)	5.0e-006
Voids in Mineral Aggregate (%)	18.6

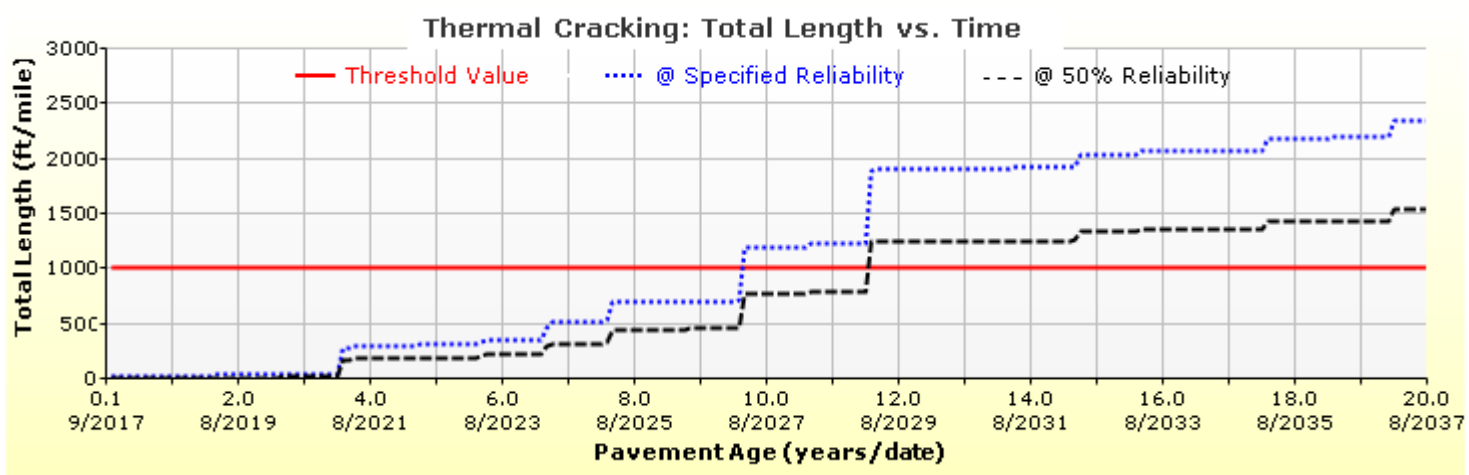
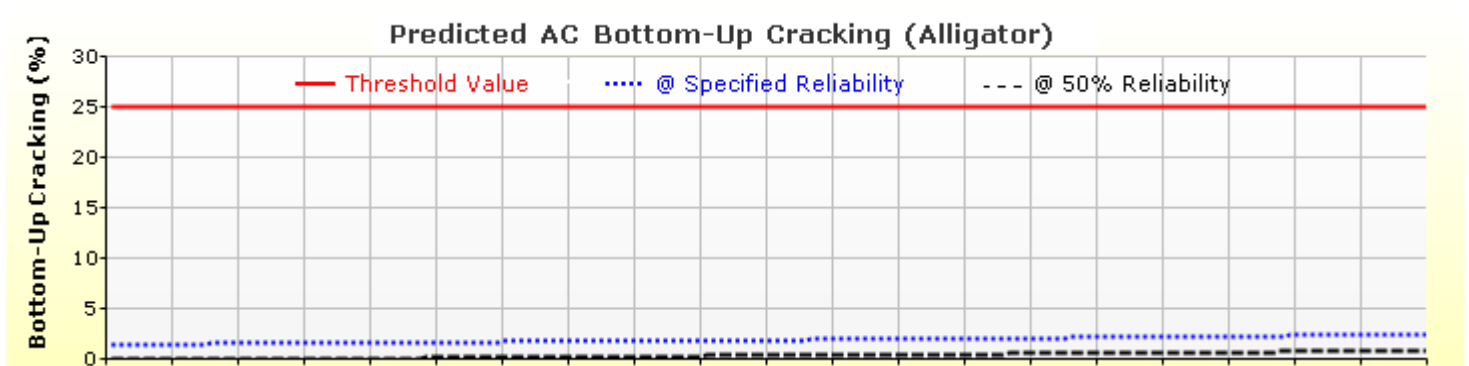
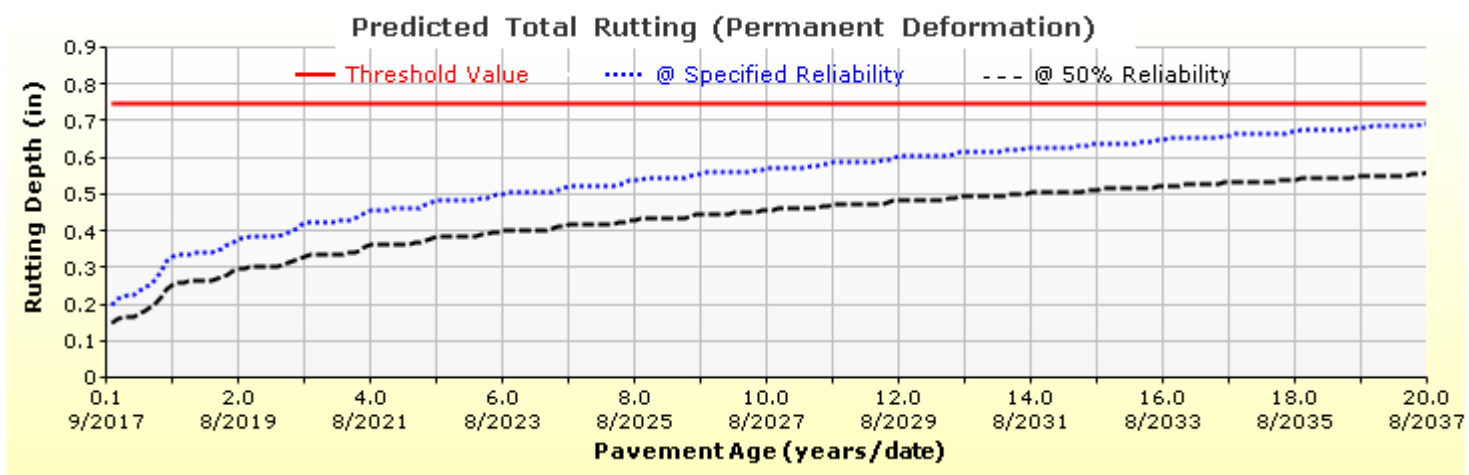
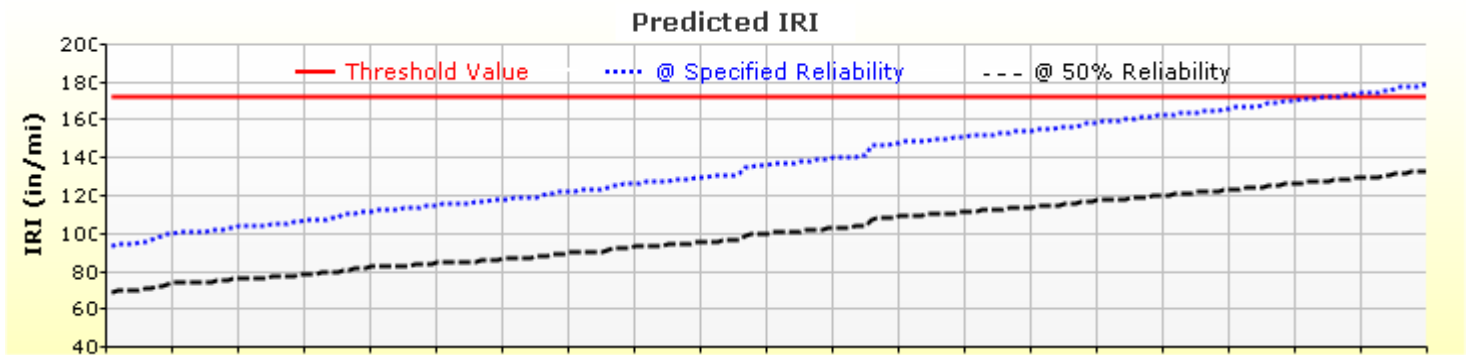
Loading time (sec)	Creep Compliance (1/psi)		
	-4 °F	14 °F	32 °F
1	2.94e-007	4.79e-007	6.55e-007
2	3.23e-007	5.59e-007	8.38e-007
5	3.66e-007	6.86e-007	1.16e-006
10	4.02e-007	8.00e-007	1.48e-006
20	4.41e-007	9.34e-007	1.90e-006
50	5.00e-007	1.15e-006	2.63e-006
100	5.49e-007	1.34e-006	3.37e-006



HMA Layer 1: Layer 1 Flexible : Default asphalt concrete



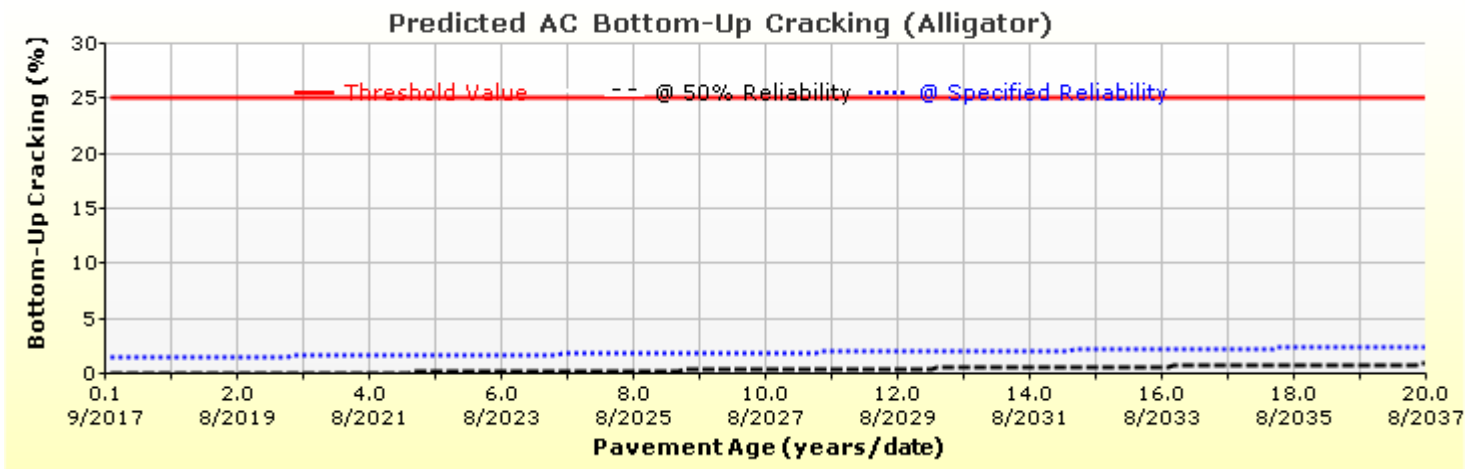
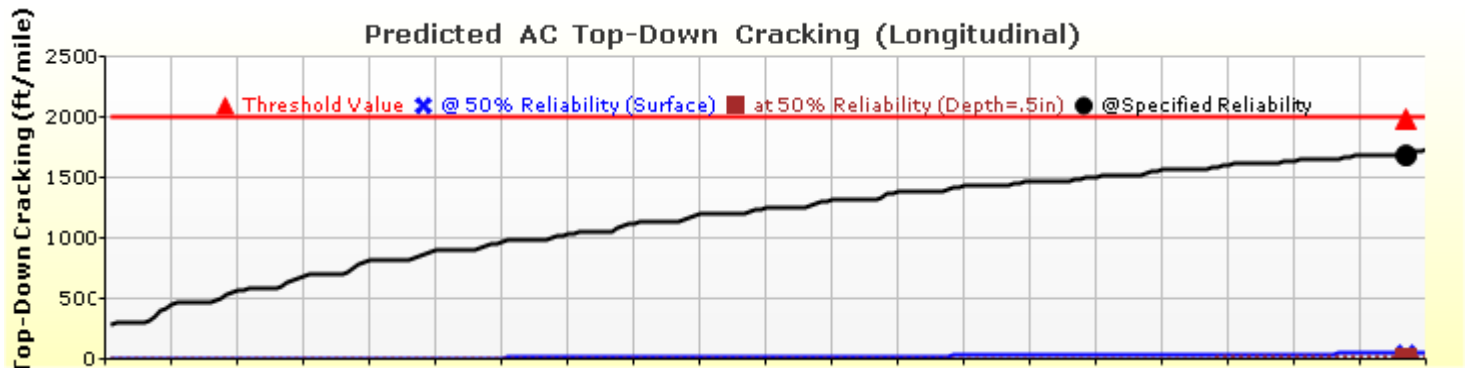
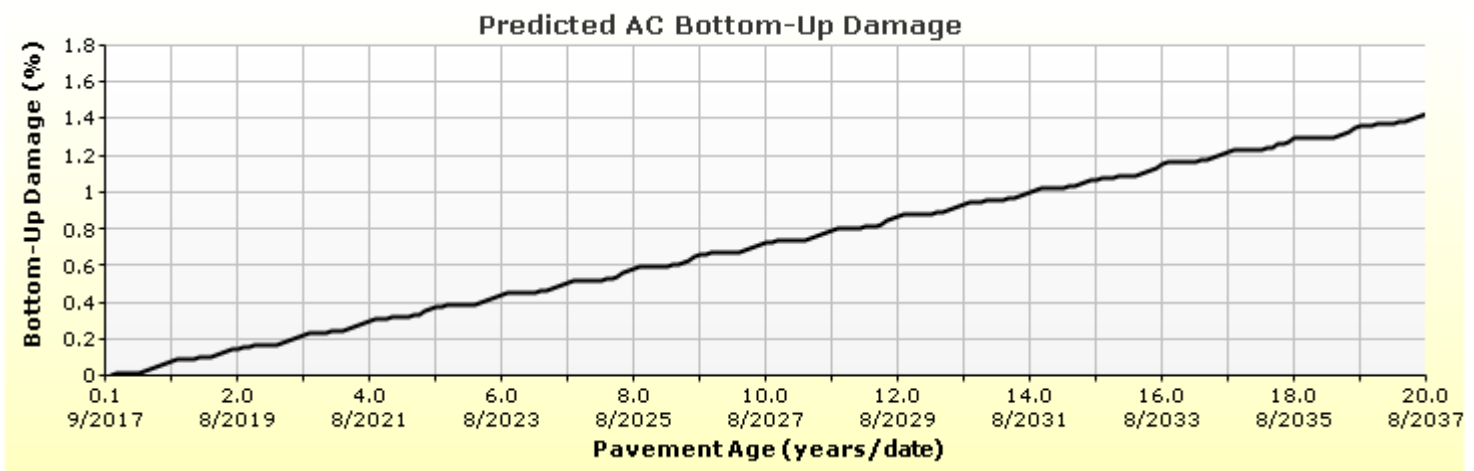
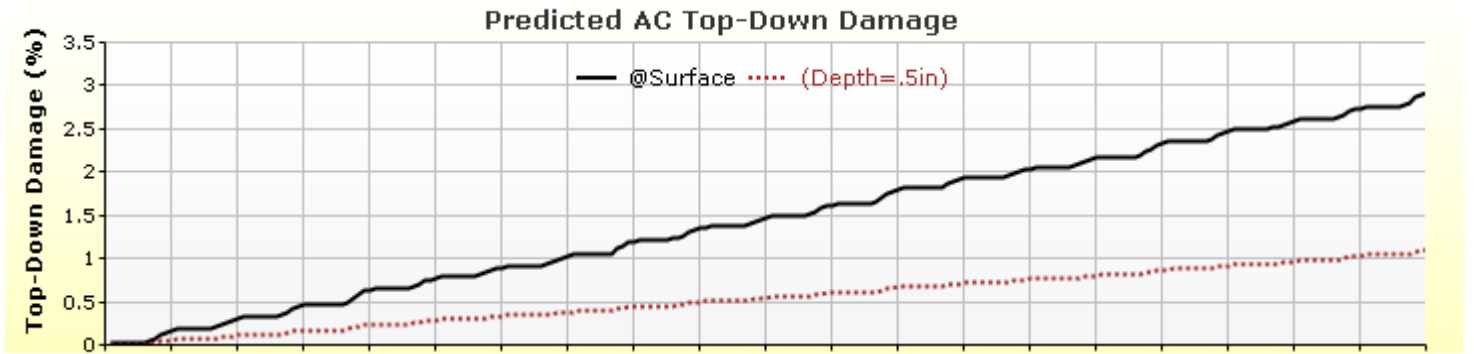
Analysis Output Charts



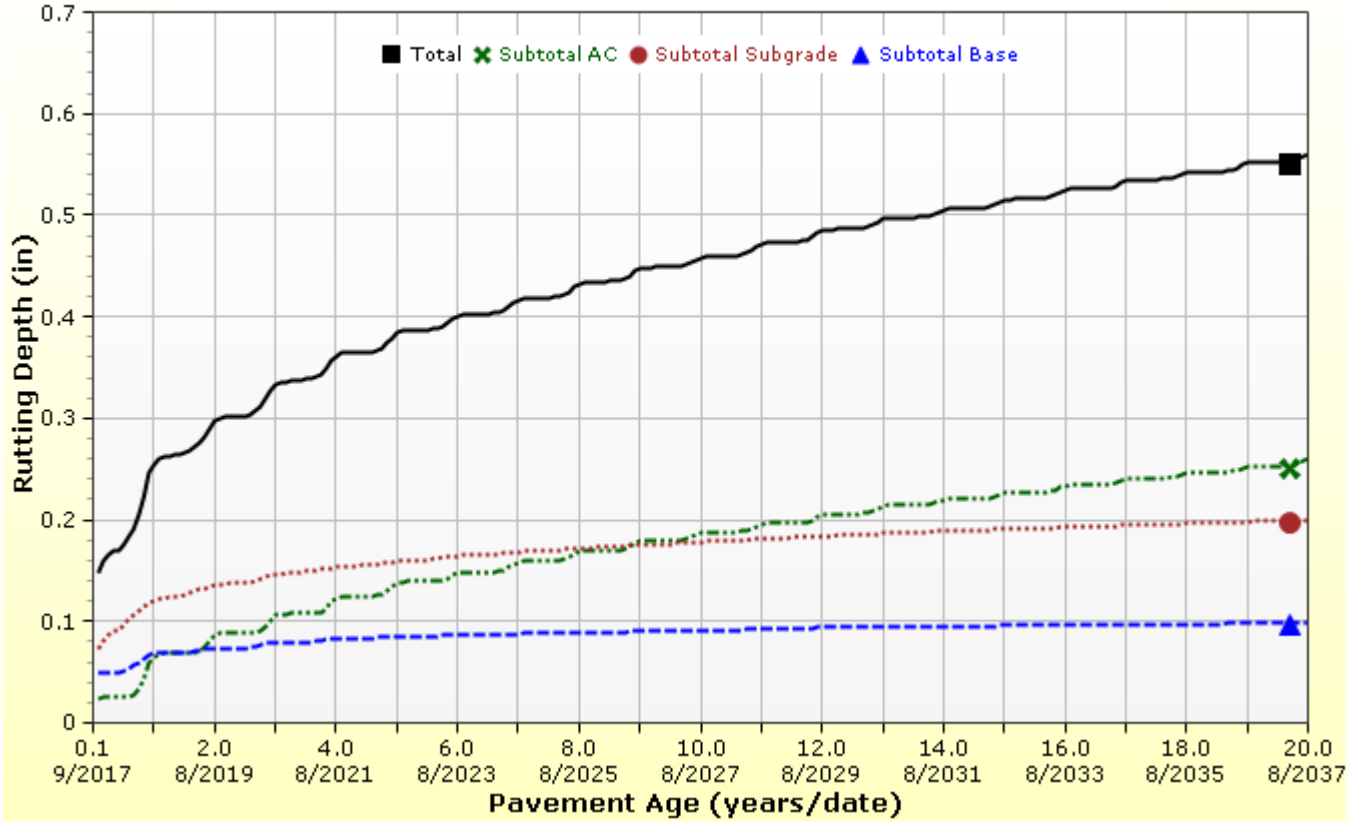


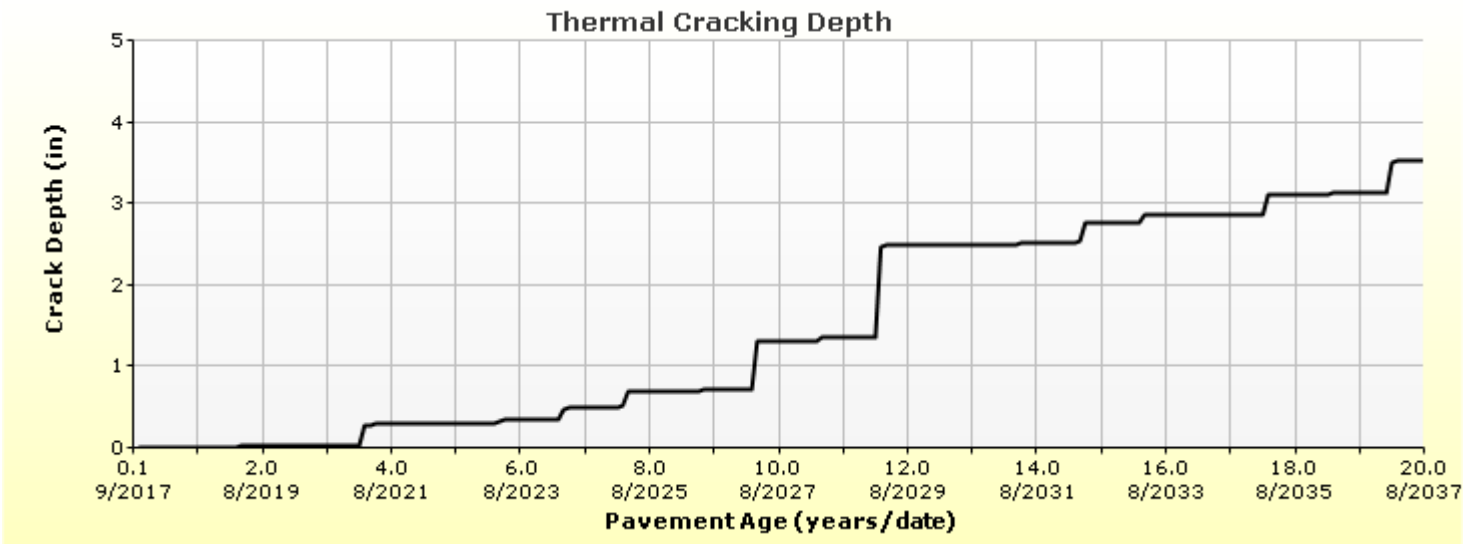
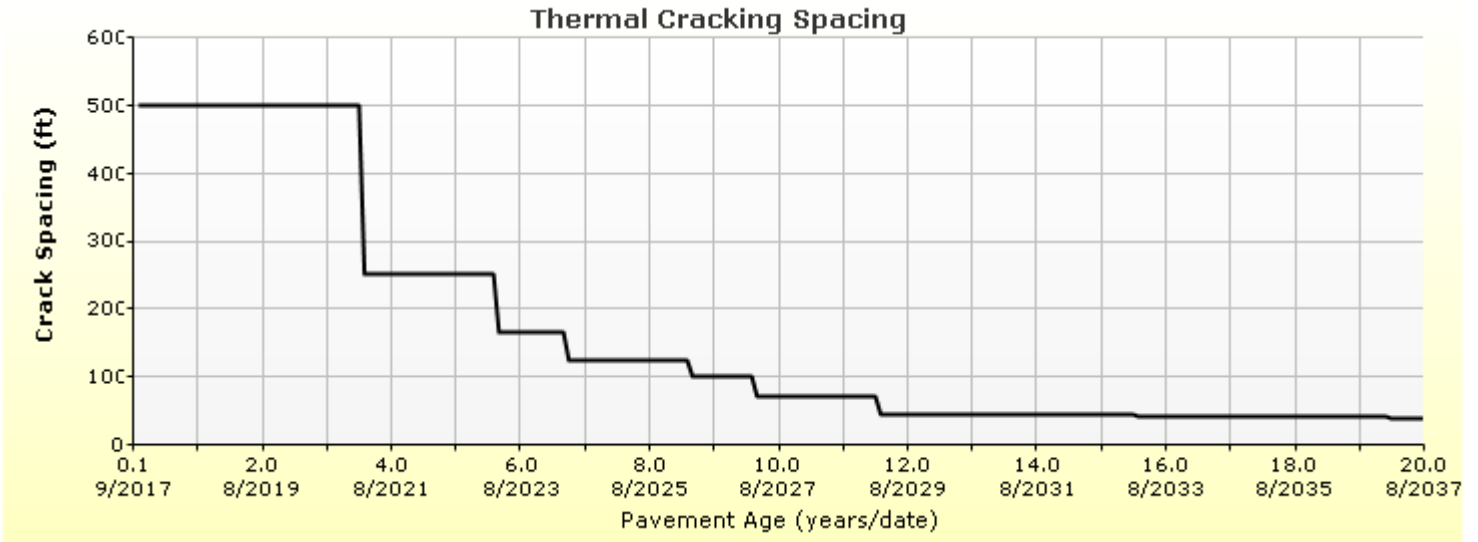
Existing Condition 6.5 inch overlay1

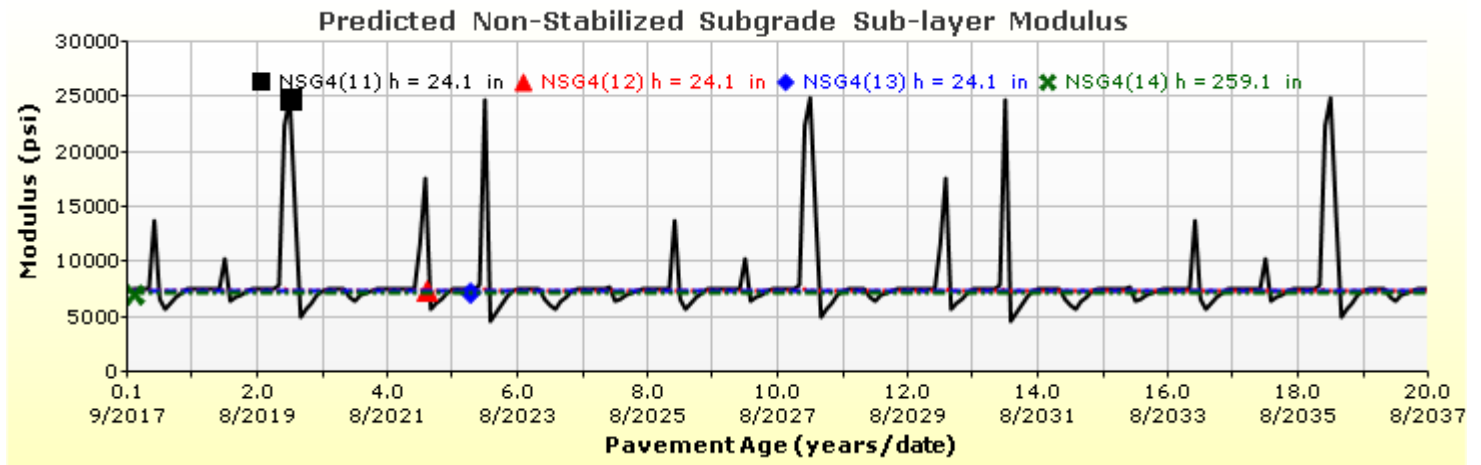
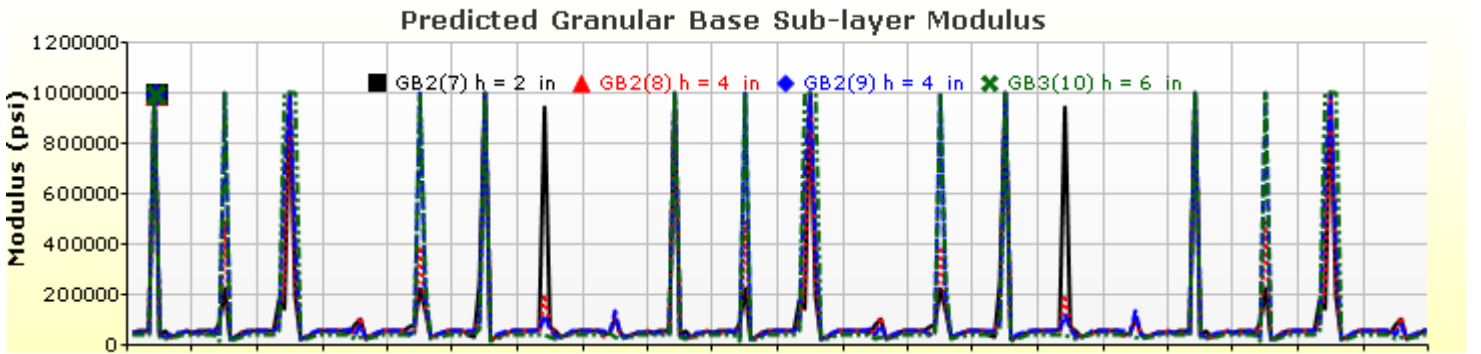
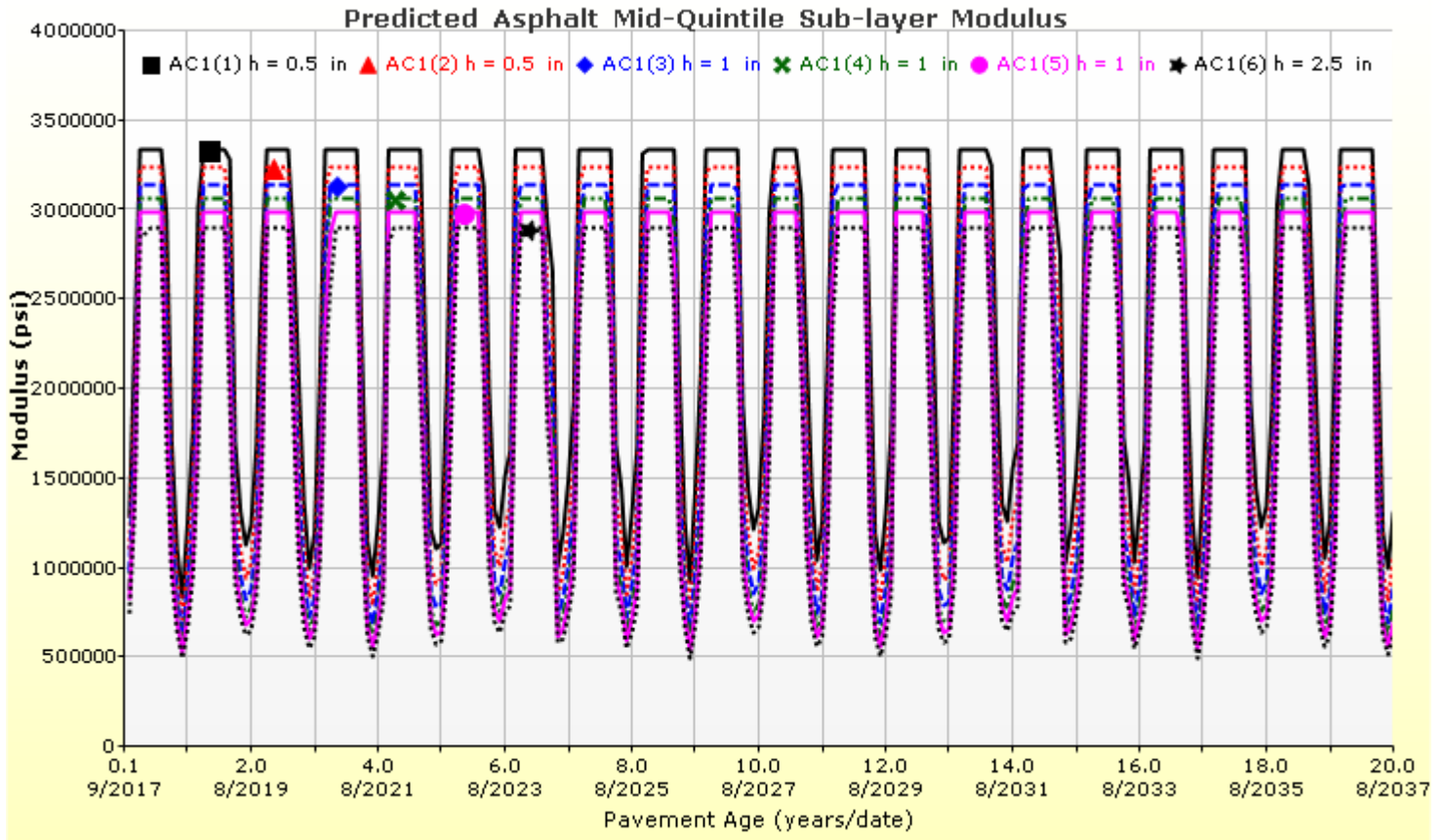
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Predicted Rutting (Permanent Deformation) at 50% Reliability









Existing Condition 6.5 inch overlay1

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Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (in.)	6.5	
Unit weight (pcf)	150.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

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

Asphalt Binder

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

General Info

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

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/30/2010 12:00:00 AM
Approver	
Date approved	10/30/2010 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



Existing Condition 6.5 inch overlay1

File Name: D:\My ME Design\FINAL REPORT\Existing Condition 6.5 inch overlay1.dgpx



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

Unbound	
Layer thickness (in.)	10.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
40000.0

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?	False

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

User-defined Soil Water Characteristic Curve (SWCC)

Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

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

Layer 3 Non-stabilized Base : Crushed stone

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

Modulus (Input Level: 3)

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

Resilient Modulus (psi)
30000.0

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



Existing Condition 6.5 inch overlay1

File Name: D:\My ME Design\FINAL REPORT\Existing Condition 6.5 inch overlay1.dgpx



Layer 4 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: 3)

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

Resilient Modulus (psi)

13000.0

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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\epsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\epsilon_p}{\epsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ <p>Where: H_{ac} = total AC thickness(in)</p>	ϵ_p = plastic strain(in/in) ϵ_r = resilient strain(in/in) T = layer temperature(°F) N = number of load repetitions
AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791 Br1:1 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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_t = Calibration parameter
Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$	N_f = number of repetitions to fatigue cracking σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)		
k1: 1	k2: 1	Bc1: 1	Bc2: 1

Subgrade Rutting			
$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r} \right) \left e^{-\left(\frac{\rho}{N}\right)^\beta} \right $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical 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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 7	c2: 3.5	c3: 0	c4: 1000
AC Cracking Top Standard Deviation 200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))		AC Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting	C3 - Transverse Crack
		C2 - Fatigue Crack	C4 - Site Factors
C1: 1	C2: 1	C3: 0	C4: 1000
C1: 40	C2: 0.4	C3: 0.008	C4: 0.015
CSM Standard Deviation			
CTB*1			