A Project report on AASHTOWare Pavement Design

AASHTOWare Pavement ME Design

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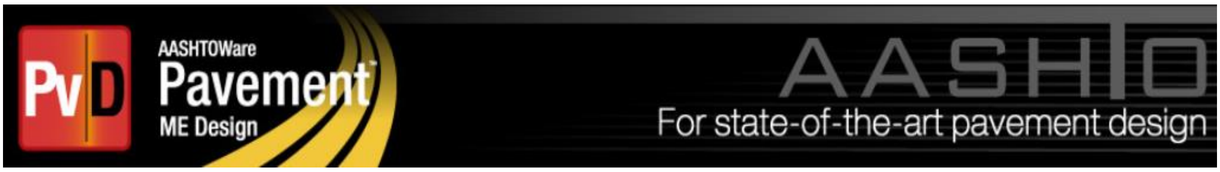
Contents

Abstract

Highways have played a key role in the development and sustainability of human civilization from ancient times to the present. Today, in the U.S. and throughout the world, highways continue to dominate the transportation system — providing critical access for the acquisition of natural resources, industrial production, retail marketing and population mobility. Designing Highways are real part of engineer's duty considering facts such as traffic data, climate data, soil condition, needs of contractor. AASHTO has set some limitations and specification for highway construction and AASHTOWare is smart software which is very useful to construct highways consuming less time and all parameters. In, this report I designed a new flexible pavement using AASHTOWare Pavement ME Design, considering all the inputs. Output report is attached in this report.

Introduction



AASHTOWare Pavement ME Design is the next generation of AASHTOWare pavement design software, which builds upon the mechanistic-empirical pavement design guide, and expands and improves the features in the accompanying prototype computational software. ME Design supports AASHTO's Mechanistic-Empirical Pavement Design Guide, ME Design is a production-ready software tool to support the day-to-day pavement design functions of public and private pavement engineers.

Background

AASHTO 1993 is largely based on the AASHO Road Test of 1958-59 (the T wasn't added to AASHTO until1973). In the Road Test, many different cross sections were built on closed loops. Trucks were driven on the loops and the performance of the different cross sections was observed periodically. This is known as an empirical method. Conversely, the mechanistic-empirical method utilizes the theories of mechanics to estimate the pavement response in the form of stresses and strains, to the applied loads of truck traffic (the mechanistic portion of ME). Damage is estimated from these stresses and strains, and accumulated over the pavement's design life. The damage is then converted to typical pavement distresses by way of transfer functions. These transfer functions are based on, and calibrated with, pavement distress information observed on in-service pavements (the empirical portion of ME).

Design specifications and Inputs

- ## Overview of pavement design process

1. Investigation and Collecting all the necessary data required for pavement construction
2. Obtain Design type, design life and performance criteria
3. Traffic data from DOT
4. Obtain climate data (EICM File from AASHTOWare website for different state)
5. Layer inputs and material properties
6. Special calibration factor
7. Review all the inputs
8. Run initial design
9. Review output and change if necessary

- ## Inputs

1. Location: wabaunsee, Kansas (Interstate-70 **CB1U73-** 4.7 miles E. of K 30 interchange (Maple hill))
2. Design type: New pavement
3. Pavement type: Flexible pavement
4. Design life: 20years
5. Performance criteria:

Performance criteria	Limit	Reliability
Initial IRI (in/mile)	60	90%
Terminal IRI (in/mile)	175	90%
AC Top-down fatigue cracking (ft./mile)	2000	90%
AC thermal cracking (ft./mile)	1000	90%
AC Bottom-up cracking	25%	90%
Pavement Deformation (Total Pavement) (inch)	0.75	90%
Pavement Deformation (AC only) (inch)	0.25	90%

6. Traffic:

From KDOT website:

- ✓ Annual average daily truck traffic: 3960 counts
- ✓ Two lanes in design direction
- ✓ 90% of truck traffic in design lane
- ✓ Truck traffic is equally distributed in both direction
- ✓ Operational speed: 60 mph
- ✓ Traffic growth rate: 2.0% (compounded annually)
- ✓ Vehicle class distribution: **TTC4** (2-3 axels)

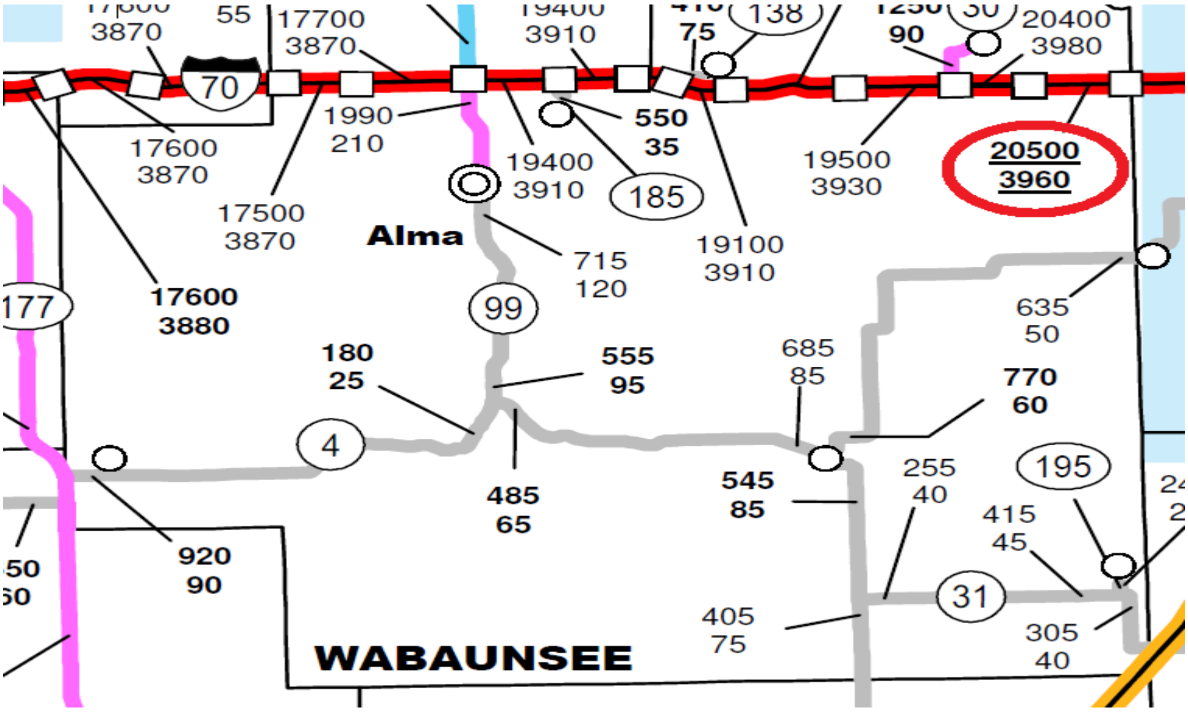


Figure 1:Traffic data

7. Climate data

Phoenix, AZ – lat/lon (33.68 -112.082): I have designed this pavement for Kansas state, but there was something wrong with software. It was not allowing me to do any change in directory. So, I took climate data of Arizona (already stored in computer) which is different than Kansas- it impacts a lot on results.

8. Pavement layer Inputs:

Layer 1	Flexible Default Asphalt layer
Thickness	12 inches
Binder grade	PG 58-28
Air voids	7%
Poisson's ration	0.35
Reference temperature (°F)	70

Layer 2	Sandwiched Granular
Thickness	10 inches
Resilient modulus (psi)	40000
Poisson's ratio	0.2

The granular base layer is directly below the pavement surface and acts as the load bearing and strengthening component of the pavement structure. The granular subbase forms the lowest (bottom) layer of the pavement structure, and acts as the principal foundation for the subsequent road profile, provides drainage for the pavement structure, and protects the structure from frost.

Granular bases are typically constructed by spreading the materials in thin layers of (6 in) to (8 in) and compacting each layer by rolling over it with heavy compaction equipment.

Layer 3	**Crushed stone**
Thickness	10 inches
Poisson’s ratio	0.35
Resilient modulus (psi)	30000

The test results show that engineered crushed-stone base sections having relatively thin asphalt surfacing can withstand large numbers of heavy loadings.

Layer 4	**Unbound Subgrade**
Thickness	Semi-infinite
Poisson’s ratio	0.35
Resilient modulus (psi)	12000 (Level 2)

The unbound granular layers (UGM’s) and the subgrade of a pavement structure provide a significant support for the structure. Hence the mechanical properties of these materials are important for the overall performance of the structure. These materials exhibit both non-linear stress dependency and their mechanical properties are highly affected by their moisture content.

Output

Project1

File Name: C:\Users\ssatani\Documents\Project1.dgpx

Design Inputs

Design Life:	20 years	Base construction:	May, 2019	Climate Data Sources (Lat/Lon)	33.688, -112.082
Design Type:	FLEXIBLE	Pavement construction:	June, 2020		
		Traffic opening:	September, 2020		

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Default asphalt concrete	12.0
Sandwich/Fractured	Sandwich Granular	10.0
NonStabilized	Crushed stone	10.0
Subgrade	A-2-7	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

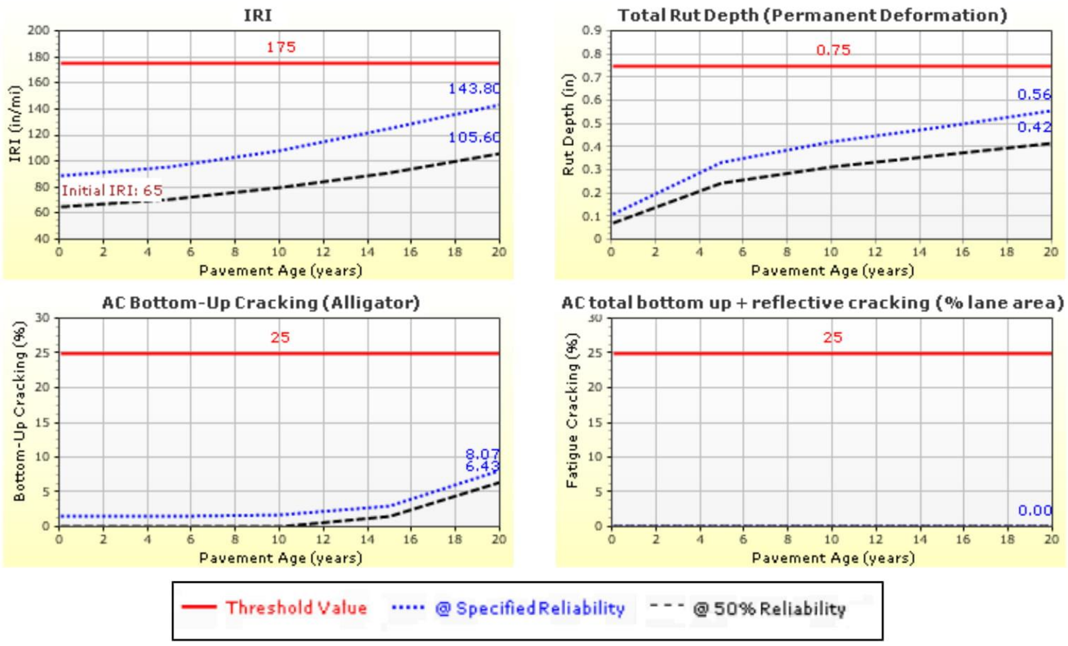
Age (year)	Heavy Trucks (cumulative)
2020 (initial)	3,960
2030 (10 years)	7,126,910
2040 (20 years)	15,814,600

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	175.00	143.79	90.00	99.01	Pass
Permanent deformation - total pavement (in)	0.75	0.56	90.00	99.89	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	8.07	90.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	25.00	0.00	90.00	0.00	Pass
AC thermal cracking (ft/mile)	1000.00	27.17	90.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	3752.62	90.00	68.38	Fail
Permanent deformation - AC only (in)	0.25	0.47	90.00	18.77	Fail

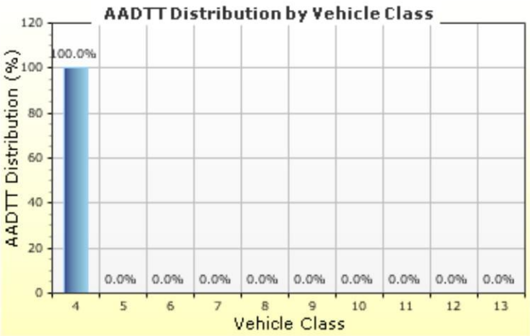
Distress Charts

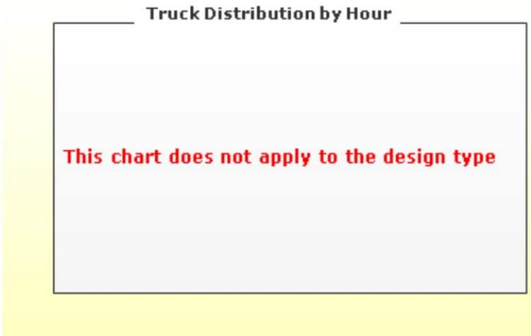


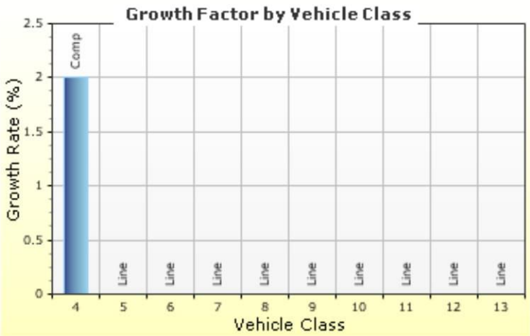
Traffic Inputs

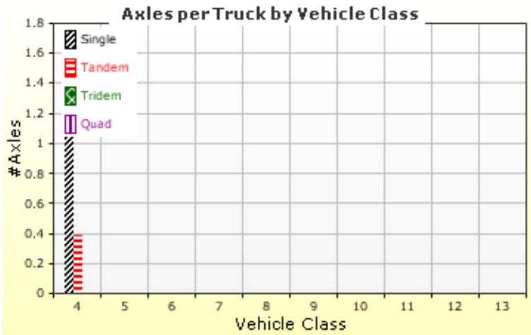
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	3,960	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	90.0
		Operational speed (mph)	60.0

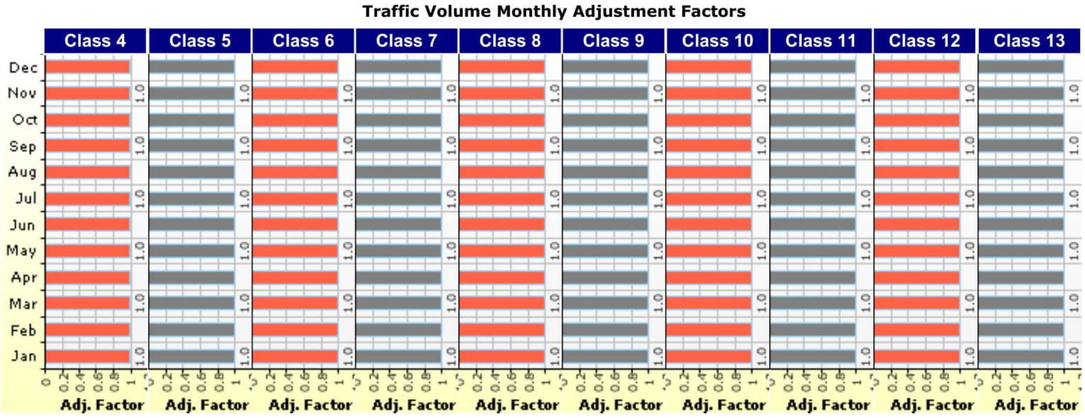








Traffic Volume Monthly Adjustment Factors



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	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	100%	2%	Compound
Class 5	0%	0%	Linear
Class 6	0%	0%	Linear
Class 7	0%	0%	Linear
Class 8	0%	0%	Linear
Class 9	0%	0%	Linear
Class 10	0%	0%	Linear
Class 11	0%	0%	Linear
Class 12	0%	0%	Linear
Class 13	0%	0%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

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

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

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

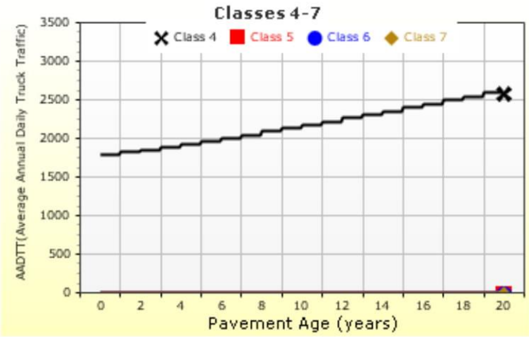
Wheelbase does not apply

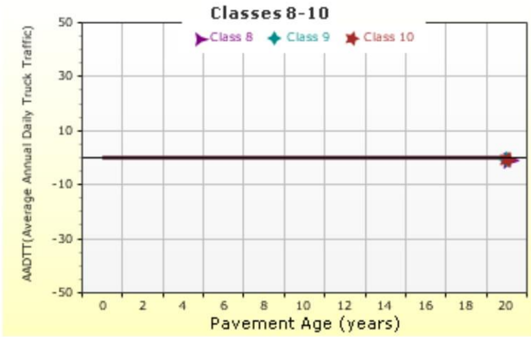
Number of Axles per Truck

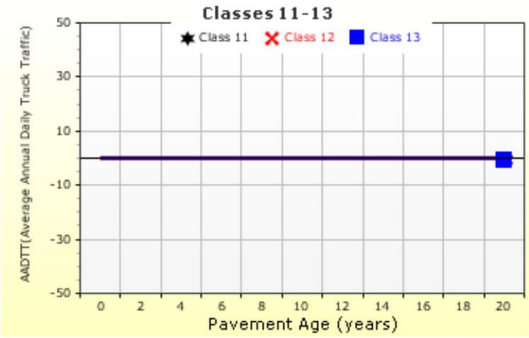
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	0	0	0	0
Class 6	0	0	0	0
Class 7	0	0	0	0
Class 8	0	0	0	0
Class 9	0	0	0	0
Class 10	0	0	0	0
Class 11	0	0	0	0
Class 12	0	0	0	0
Class 13	0	0	0	0

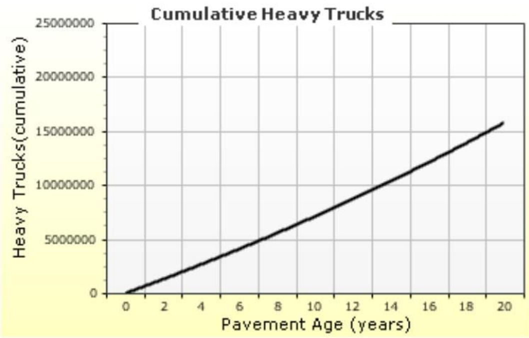
AADTT (Average Annual Daily Truck Traffic) Growth

*** Traffic cap is not enforced**





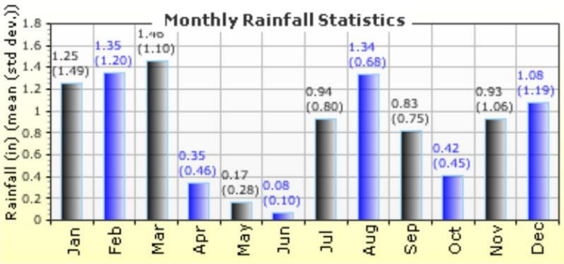




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
PHOENIX, AZ	33.68800 -112.08200 1485

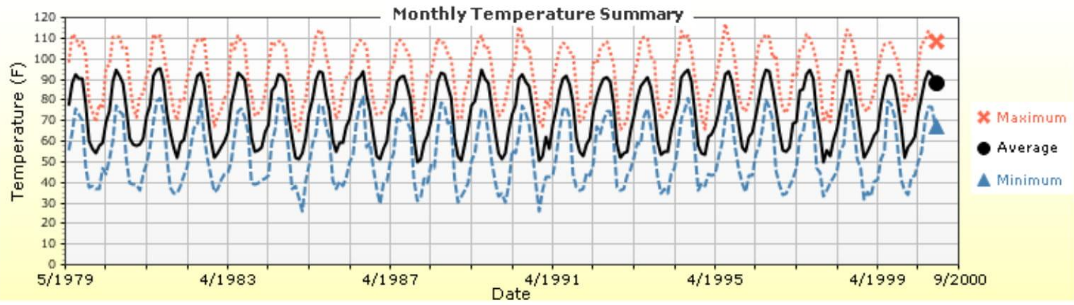


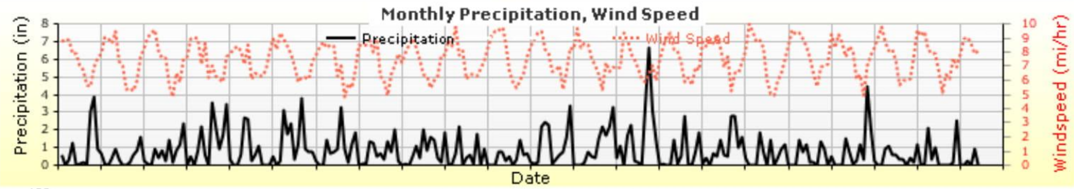
Annual Statistics:

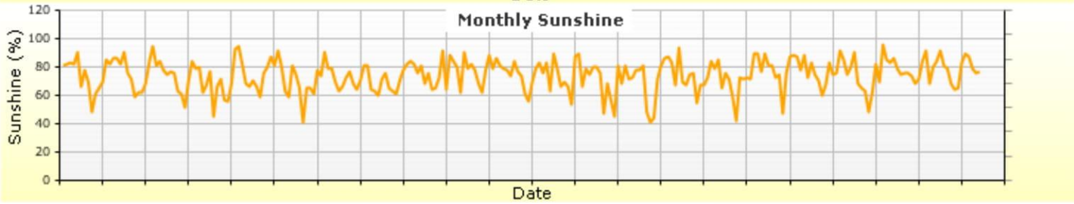
Mean annual air temperature (ºF)	73.41
Mean annual precipitation (in)	10.17
Freezing index (ºF - days)	0.09
Average annual number of freeze/thaw cycles:	0.83

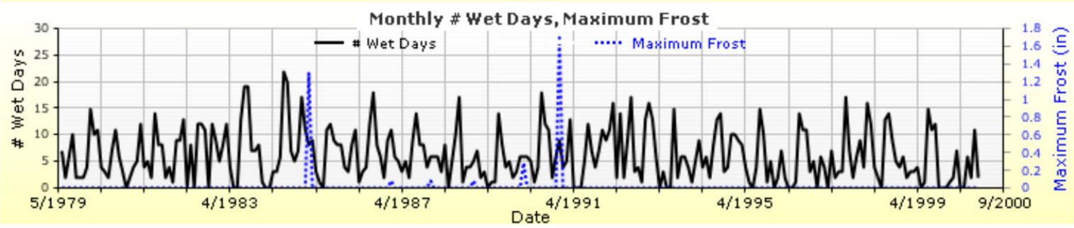
Water table depth (ft)	10.00

Monthly Climate Summary:

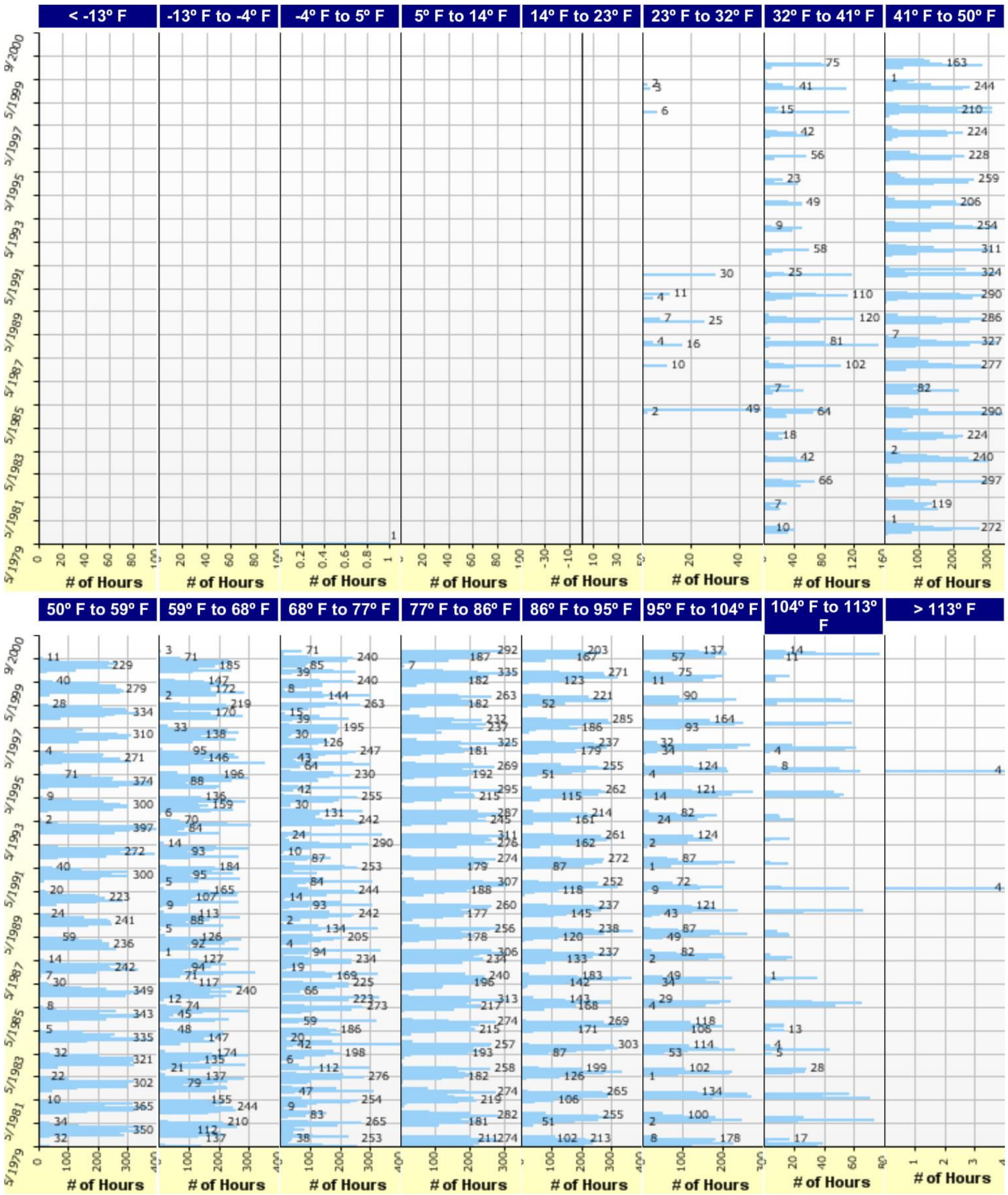








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

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

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

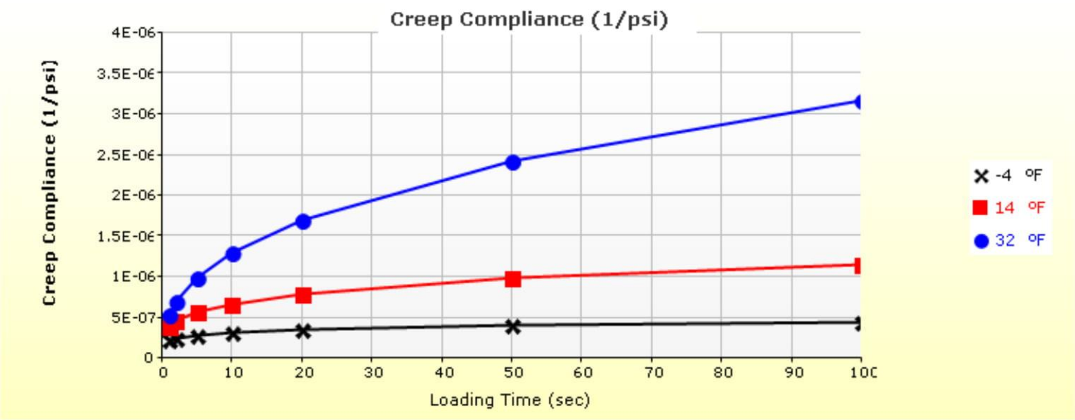
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Sandwich/Fractured : Sandwich Granular	Sandwiched Granular (3)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-2-7	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

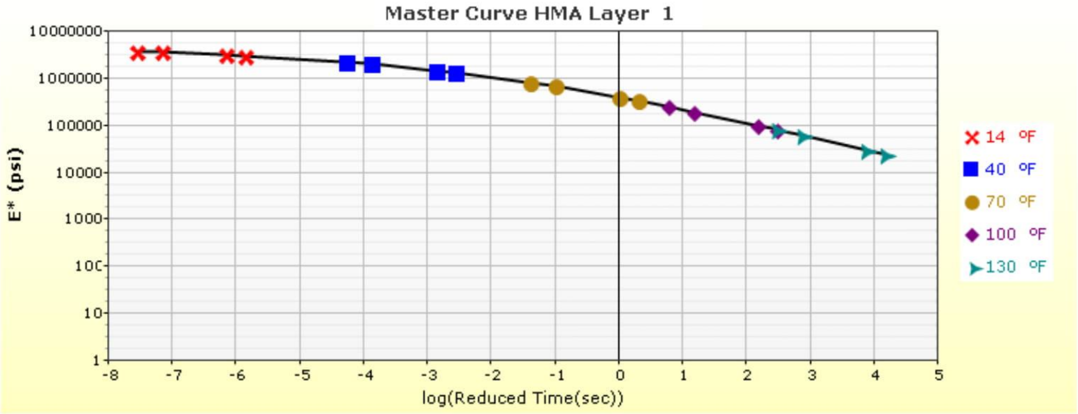
Indirect tensile strength at 14 ºF (psi)	345.78

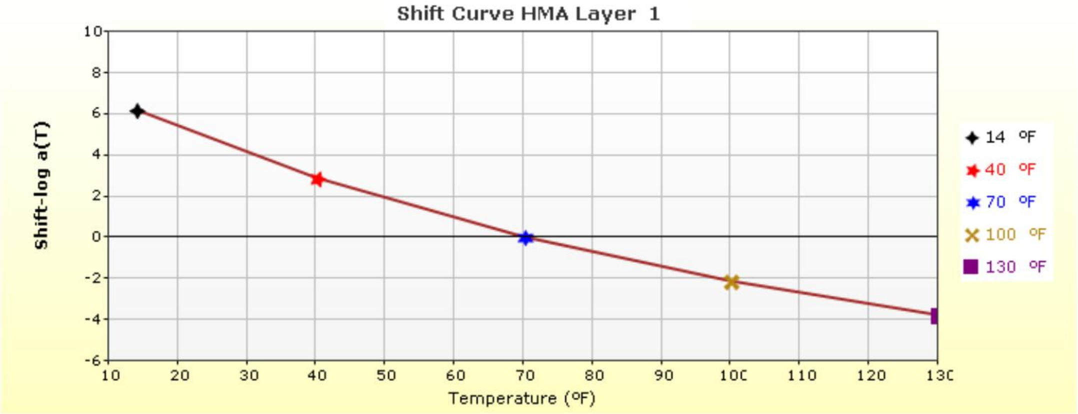
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (in/in/ºF)	-
Aggregate coefficient of thermal contraction (in/in/ºF)	5.0e-006
Voids in Mineral Aggregate (%)	18.6

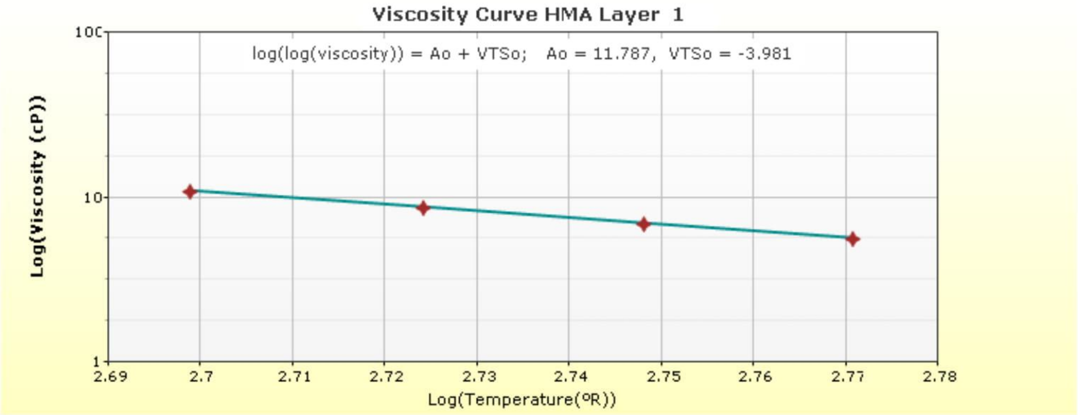
	Creep Compliance (1/psi)		
Loading time (sec)	**-4 ºF**	**14 ºF**	**32 ºF**
1	2.24e-007	3.87e-007	5.33e-007
2	2.49e-007	4.57e-007	6.97e-007
5	2.85e-007	5.68e-007	9.93e-007
10	3.16e-007	6.70e-007	1.30e-006
20	3.51e-007	7.91e-007	1.70e-006
50	4.03e-007	9.84e-007	2.42e-006
100	4.47e-007	1.16e-006	3.17e-006



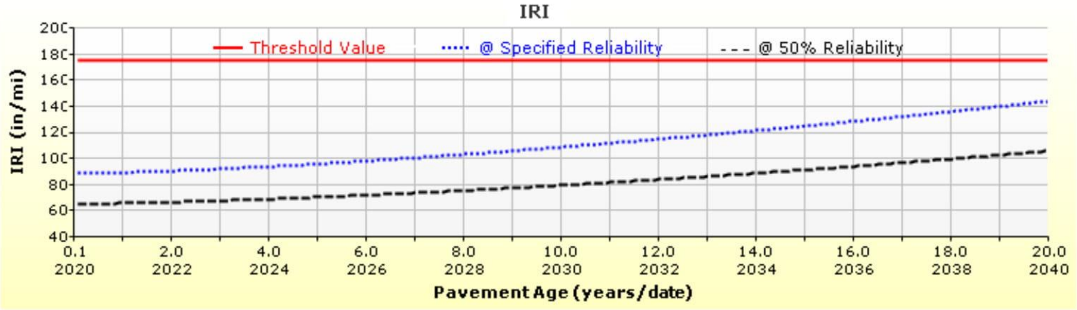
HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

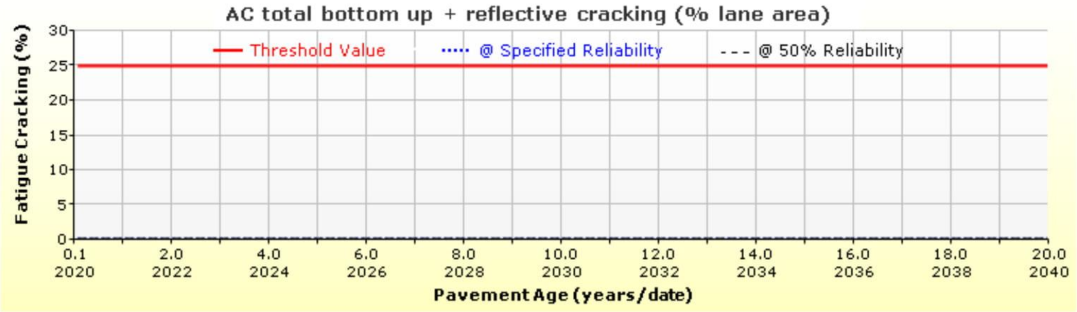






Analysis Output Charts





Project1

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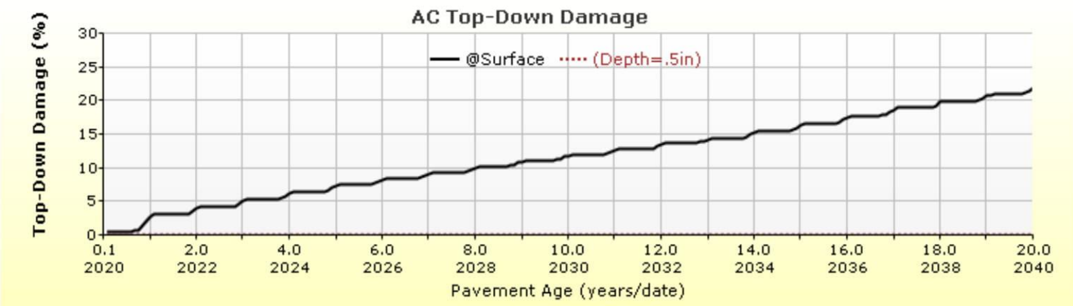

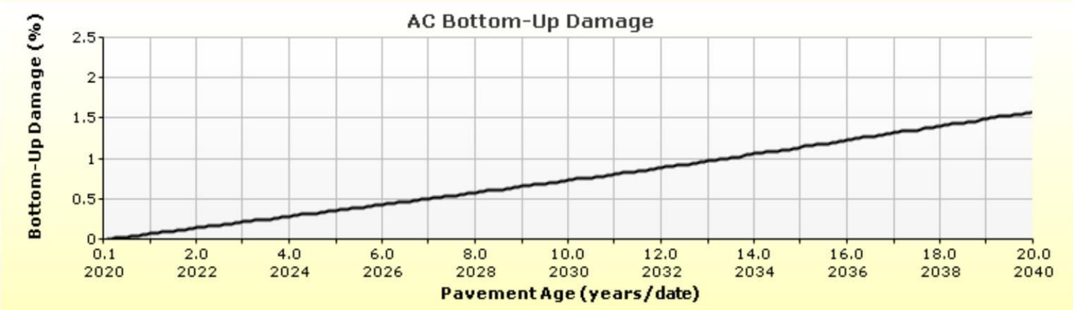

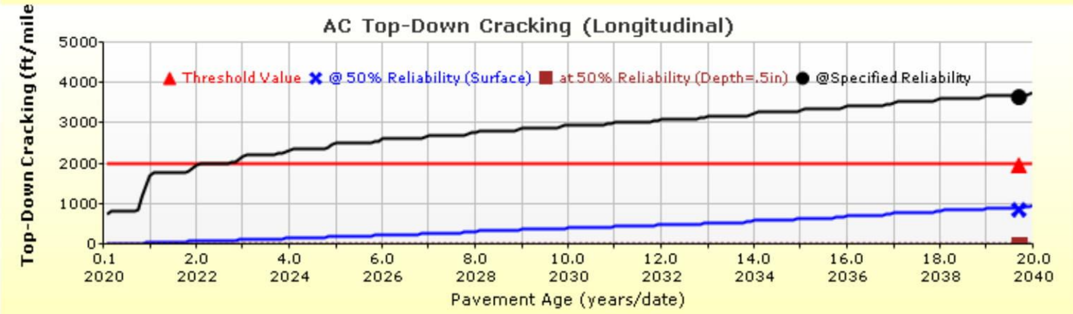

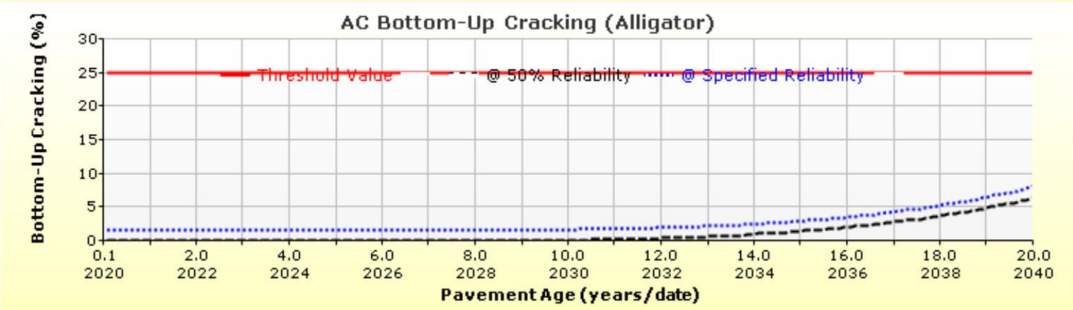

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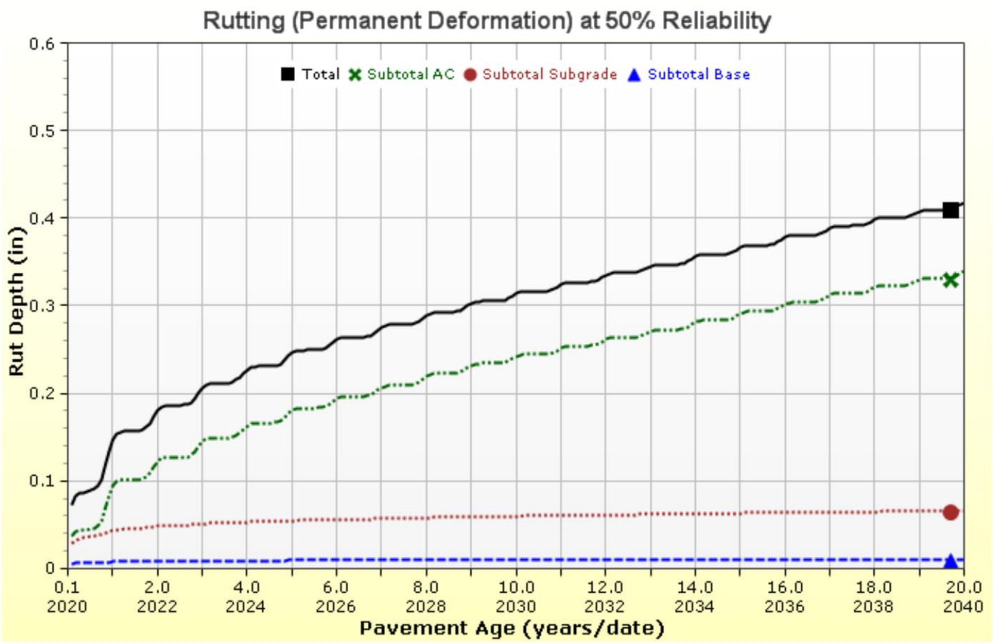
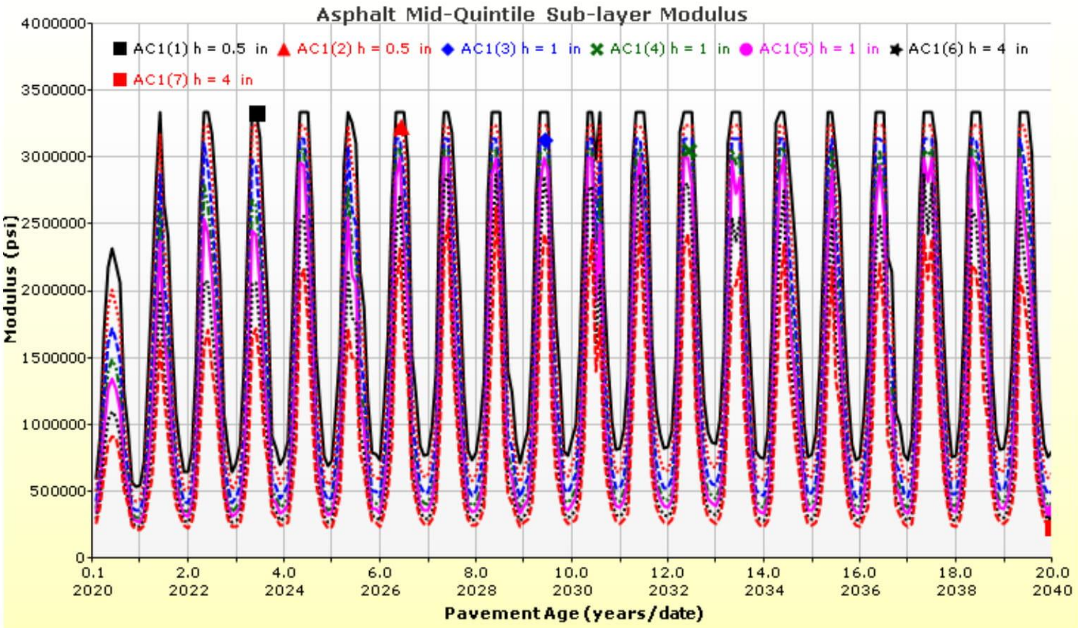
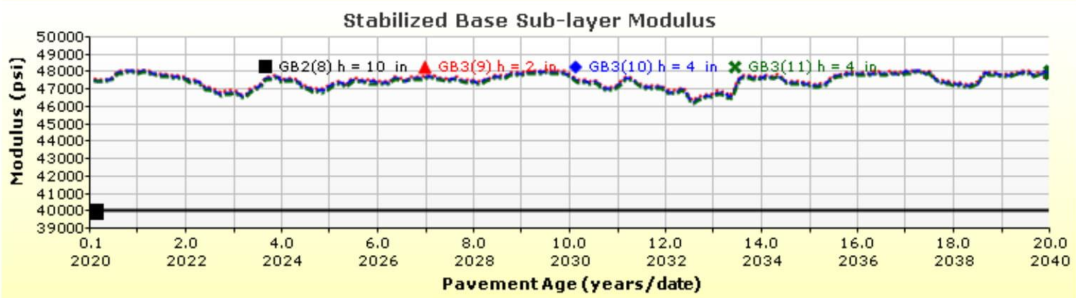
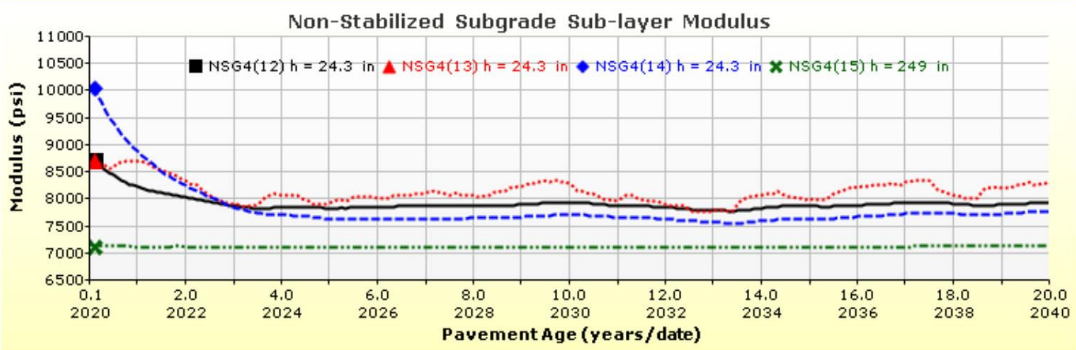

Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Subgrade
Subtotal Base
Rut Depth (in)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.1 2020
2.0 2022
4.0 2024
6.0 2026
8.0 2028
10.0 2030
12.0 2032
14.0 2034
16.0 2036
18.0 2038
20.0 2040
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 0.5 in
AC1(2) h = 0.5 in
AC1(3) h = 1 in
AC1(4) h = 1 in
AC1(5) h = 1 in
AC1(6) h = 4 in
AC1(7) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Stabilized Base Sub-layer Modulus
GB2(8) h = 10 in
GB3(9) h = 2 in
GB3(10) h = 4 in
GB3(11) h = 4 in
Modulus (psi)
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG4(12) h = 24.3 in
NSG4(13) h = 24.3 in
NSG4(14) h = 24.3 in
NSG4(15) h = 249 in
Modulus (psi)
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (in)	12.0	
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	58-22
A	11.787
VTS	-3.981

General Info

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

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	10/29/2010 10:00:00 PM
Approver	
Date approved	10/29/2010 10:00:00 PM
State	
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Sandwich/Fractured : Sandwich Granular

Sandwiched Granular	
Layer thickness (in)	10
Poisson's ratio	0.2
Unit weight (pcf)	150

Strength	
Elastic/resilient modulus (psi)	40000

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

Identifiers

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

Layer 3 Non-stabilized Base : Crushed stone

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)
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 1	
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
Water Content (%)	False	7.4

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

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

Layer 4 Subgrade : A-2-7

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

Resilient Modulus (psi)
12000.0

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

Identifiers

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

Sieve

Liquid Limit	50.0
Plasticity Index	29.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	120.8
Saturated hydraulic conductivity (ft/hr)	False	6.832e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	10.6

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	100.4941
bf	0.7343
cf	0.2680
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	27.4
#100	
#80	32.0
#60	
#50	
#40	37.1
#30	
#20	
#16	
#10	47.6
#8	
#4	55.4
3/8-in.	72.4
1/2-in.	78.1
3/4-in.	85.3
1-in.	89.1
1 1/2-in.	94.6
2-in.	97.0
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$	k1: 0.007566
	k2: 3.9492
$C = 10^M$	k3: 1.5
	Bf1: 249.00872
$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$	Bf2: 1
	Bf3: 1.23341

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:

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

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

AC Rutting Standard Deviation	0.24 * Pow(RUT,0.8026) + 0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:0.69 Br2:1 Br3:1

Thermal Fracture

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

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

Level 1 K: 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: 0.75	Bc2:1.1

Subgrade Rutting			
$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left\| e^{-\left(\frac{\rho}{N}\right)^\beta} \right\|$		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average veritcal strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_r = resilient strain(in/in)	
Granular		**Fine**	
k1: 2.03	Bs1: 0.14	k1: 1.35	Bs1: 0.37
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	c1: 1	c2: 4.5	c3: 6000
AC Cracking Top Standard Deviation				**AC Cracking Bottom Standard Deviation**		
200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))				1.13 + 13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))		

CSM Cracking				IRI Flexible Pavements			
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$				C1 - Rutting C2 - Fatigue Crack		C3 - Transverse Crack C4 - Site Factors	
C1: 0	C2: 75	C3: 5	C4: 3	C1: 1.2281	C2: 0.1175	C3: 0.008	C4: 0.028

CSM Standard Deviation
CTB*1

Review of an outputs

- Distress charts:

1. International Roughness Index:

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs.

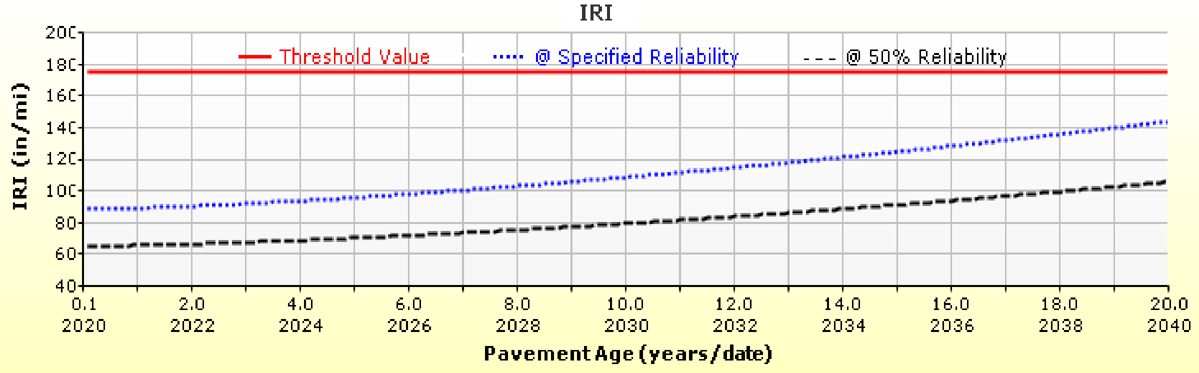


Figure 2:Chart of IRI vs. Pavement age

From this chart, I can conclude that value of IRI increase as Pavement age increase. Parameters such as pavement thickness, traffic level, environmental conditions, subgrade type affects roughness of pavement surface. Due to heavy traffic load as time passes roughness increases because of wear and tear of surface material. Dry and freeze environmental condition are most common reason of surface roughness. It can reduce by proper maintenance of pavement surface.

2. Rut depth:

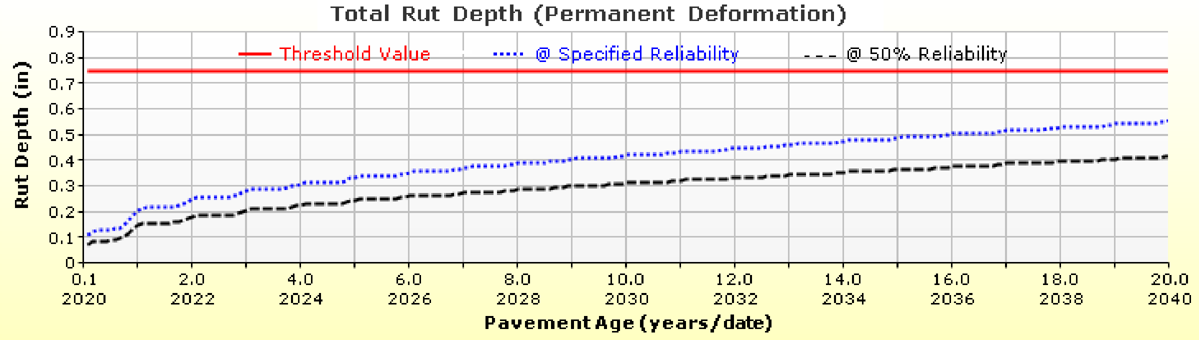


Figure 3: Rut depth vs. Pavement age

Ruts, related to shear deformations in the upper asphalt layer, are the most complicated and dangerous. The main cause of rut initiation is shear strains in asphalt. Another secondary cause of rut is high ambient temperature, improper components of asphalt mixture and heavy traffic loads. Rut depth increases as time passes, proper maintenance required to prevent this.

3. Fatigue cracking:

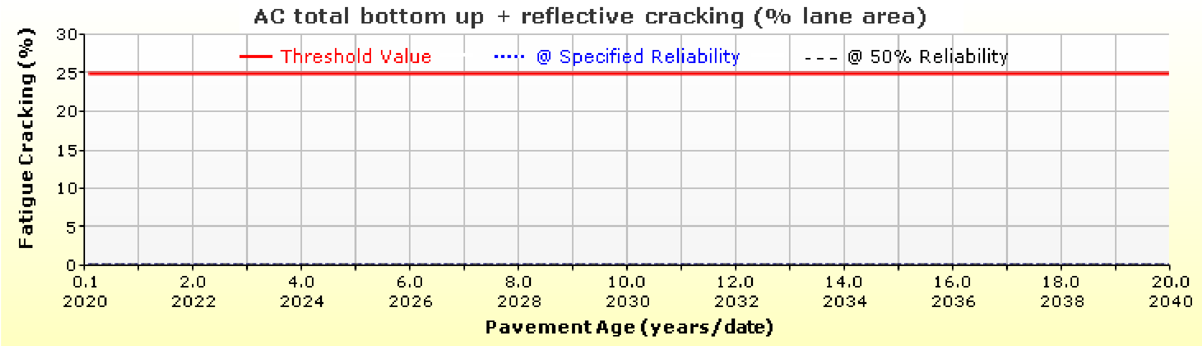


Figure 4: Fatigue cracking vs. pavement age

Repeat traffic loading eventually leads to the development of interconnected cracks known as fatigue cracking in pavement. These cracks are caused when fatigue failure impacts the HMA surface and stabilized base. Fatigue cracks originate as a minor issue but if repairs are not made in a timely fashion they can turn into larger and more costly problems.

4. Top-down cracking:

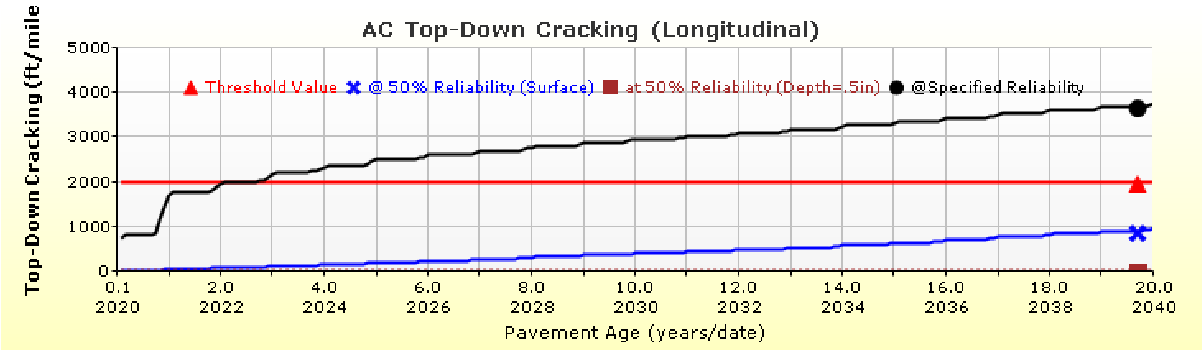


Figure 5: Top down cracking vs. pavement age

Top down cracking appears to be a common mode of HMA pavement distress in at least several states and countries. Traditionally, pavement cracking is thought to initiate at the bottom of the HMA layer where the tensile bending stresses are the greatest and then progress up to the surface (a bottom-up crack). Most traditional transfer functions used in mechanistic-empirical structural design is based on this concept.

In my design, this test is failed. As per my point of view it happens because of, I took traffic data of Kansas and considered climatic condition of Arizona state. Average Temperature in Arizona is much higher compare to Kansas and due to higher temperature, it will lower stiffness of upper layer.

5. Bottom-up cracking:

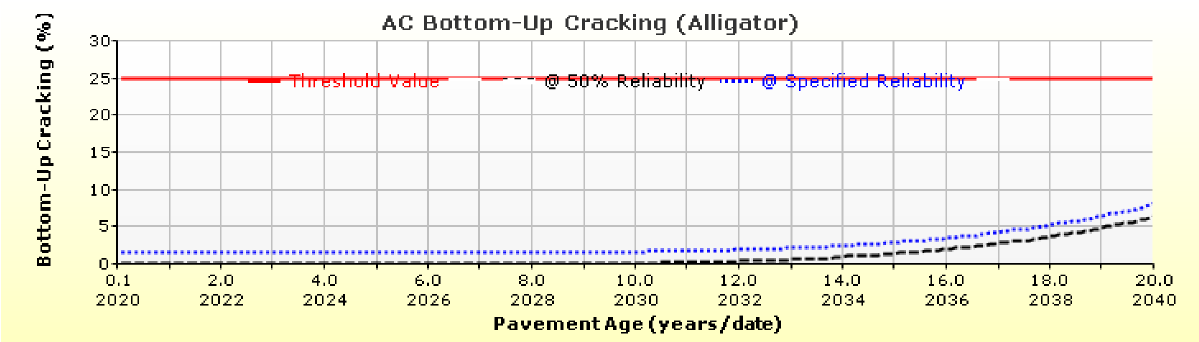


Figure 6: Bottom-up cracking vs. pavement age

the tensile strains at the bottom of the asphalt layer were so high that the crack development due to these strains dominated the cracking initiating at the pavement surface. From this chart I can conclude that this pavement has enough bottom-up capacity on specified reliability.

6. Permanent deformation (AC only):

Permanent deformation is a major distress in flexible pavements that leads to the development of rutting along the wheel path of heavily trafficked roads. Early detection of rutting is very important for preventive maintenance programs and design of rehabilitation strategies. If a poor quality HMA mixture is being used, increasing the thickness of this poor-quality layer will not decrease the rutting in the HMA layer. In fact, improving the material properties and mix characteristics will be significant in decreasing the rut depth (Kennedy. et al, 1996).

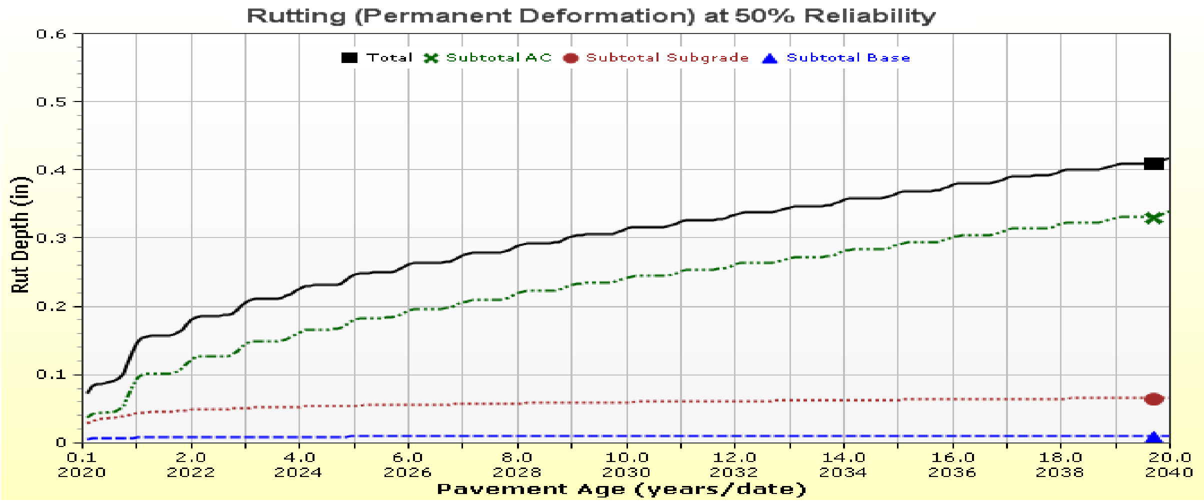


Figure 7: Permanent Deformation

7. Thermal cracking:

Transverse asphalt cracking usually occurs when the asphalt is exposed to cool or declining temperatures before it has completely hardened and while the hot asphalt mixture is still warm; therefore, it is also referred to as thermal cracking in asphalt pavement. When cold air intermingles with hot asphalt mix that is still wet, it can result in thermal cracking in the asphalt pavement.

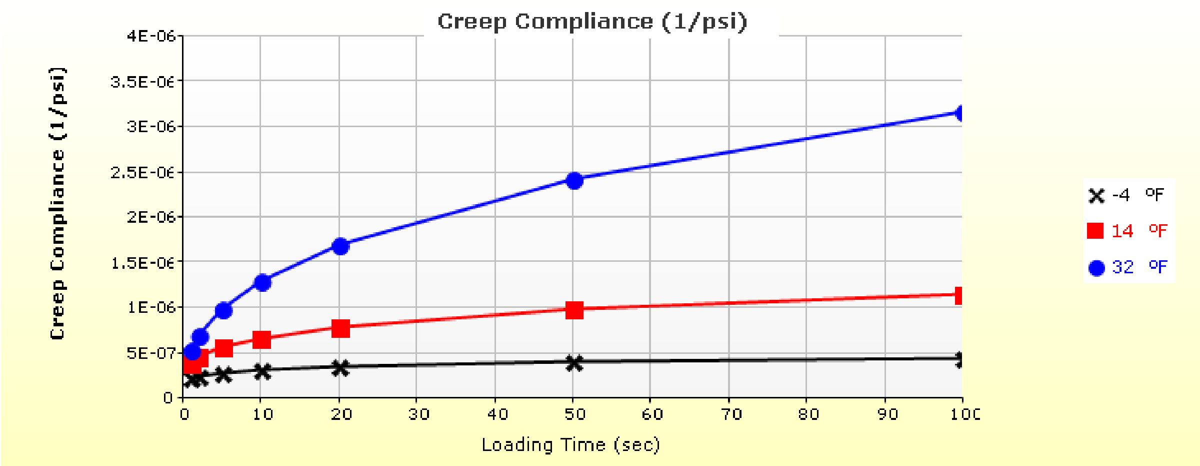


Figure 8: Creep compliance vs loading time.

Conclusion

Highway construction is very vital field. We cannot predict highway properties just considering any single parameter. AAHTOWare is very smart software, where we can input very different parameters such as design life, traffic data, climatic condition, layer and material properties, binder properties, overlay layers and it will gives a coinvent highway design. This software gives an output report containing different charts and calculations of calibration factors. I have designed new flexible pavement with 20 years design life. Output gave me terminal IRI, permanent deformation, AC bottom-up fatigue cracking, AC top-down fatigue cracking, AC thermal cracking considering Pavement age. Test result does not pass AC top-down fatigue cracking because of improper temperature consideration and does not satisfied permanent deformation because of very high thickness of HMA layer.

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