



**COLORADO**  
**Department of Transportation**  
 Region 2

Region 2 Materials Unit  
 5615 Wills Blvd  
 Pueblo, CO 81008  
 (719) 562-5532

**PROJECT INFORMATION:**

PCN: 23558/23559  
 PRJ: FBR R200-266/FBR R200-267  
 LOC: US 350 & SH 239 Locations

December 18, 2020

TO: Patrick Vigil  
 FROM: Jeri Mero  
 SUBJECT: Pavement Justification Report

This report will consist of the replacement of 9 structures along US 350 in Otero and Las Animas Counties and one structure along SH 239 in Las Animas County. Improvements will consist of the replacement of the structure and associated roadway work. At this time, it is understood that it is not determined if a bridge or culvert will replace the existing structures. These recommendations contained herein will be suitable for each option.

Table 1 consists of a detailed list of structure locations and approximate milepost along SH 350 and SH 239. As this project will consist of approach work adjacent to existing Hot Mix Asphalt Pavement, a Life-Cycle Cost Analysis comparing Asphalt to Concrete was not performed. Instead, an alternate to utilize Hot Mix Asphalt (HMA) is being recommended. This is in accordance with the 2021 CDOT Pavement Design Manual, Section 13.2.

At this time, it is understood that the project will utilize the Design/Build alternative project delivery method. It is understood the CDOT Region 2 North and South Program will produce 30% plans for advertisement of the RFP. The recommendations supplied herein could be considered final if the project scope and assumptions above do not change significantly.

**Table 1: SH 350 & SH 239 Structure Replacement Locations**

R2B2 Phase I & II - SH 350 & SH 239 Locations					
Subaccount No./HWY Segment	Structure Name	Approximate MP	AADTT	Drivability Life	Pavement Distress
23558/SH 350	N-21-C	47.131	90	0	Severe Fatigue Cracking
23558/SH 350	N-21-F	48.744	90	0	Severe Fatigue Cracking
23558/SH 350	M-21-C	50.582	90	6	Moderate Transverse Cracking
23558/SH 350	M-21-B	51.682	90	9	Moderate Transverse Cracking
23558/SH 350	M-21-J	57.069	90	7	Moderate Transverse and Fatigue Cracking
23558/SH 350	M-22-Y	57.474	90	7	Moderate Transverse and Fatigue Cracking
23558/SH 350	M-22-U	69.817	40	12	Low Transverse Cracking
23559/SH 350	O-19-D	10.228	70	9	Moderate Transverse Cracking
23559/SH 350	M-21-I	56.445	90	7	Moderate Transverse and Fatigue Cracking
23559/SH 239	P-19-G (Minor)	1.74	13	5	Moderate Transverse Cracking

Traffic data used in the analysis is from the Division of Transportation Development based on 2019 published volumes. The soil classification used for design was obtained from geotechnical reports submitted to CDOT from Yeh and Associates, Inc. The preliminary soil survey consisted of coring through the existing pavement and retrieving bulk samples from auger cuttings. The pavement recommendations contained in this memorandum were made based on a component analysis of the materials encountered during the preliminary soil survey, as well as a visual survey of the existing roadway distresses. Table 2 details the soil survey information provided to CDOT from Yeh and Associates, Inc.

**Table 2: SH 350 & SH 239 Soil Profile Information**

R2B2 Phase I & II - SH 350 & SH 239 Soil Profile Data			
Subaccount No./HWY Segment	Structure Name	Soil Profile Classification	R-Value
23558/SH 350	N-21-C	A-6 (9)	18
23558/SH 350	N-21-F	A-6 (12)	10
23558/SH 350	M-21-C	A-6 (1)	20
23558/SH 350	M-21-B	A-6 (4)	16
23558/SH 350	M-21-J	A-6 (7)	13
23558/SH 350	M-22-Y	A-6 (11)	15
23558/SH 350	M-22-U	A-6 (11)	15
23559/SH 350	O-19-D	A-6 (12)	12
23559/SH 350	M-21-I	A-6 (9)	11
23559/SH 239	P-19-G (Minor)	A-6 (7)	11

### **Recommendations**

Based on the results of the pavement analysis, Region 2 Materials recommends the new construction for the approaches and/or the reconstruction of the roadway over the culvert consist of the following:

#### **New Pavement Section for Approaches and Reconstruction**

The new pavement section to be used for this project should consist of 6" HMA over 6" ABC Class 6. The entire pavement section should consist of HMA Grade SX (75) PG 58-28.

#### **Tie-In Pavement Section**

The tie-in pavement section to be used for the bridge replacements along SH 350 should consist of 1.5" mill and fill. The entire tie-in pavement section should consist of HMA Grade SX (75) PG 58-28. *Please note that for structure N-21-F and M-21-J, the mill and fill treatment will not satisfy the ten-year design life. If the budget allows, the entire project footprint should be rebuilt.*

Applicable project special provisions for use on this project will be provided. In addition, a copy of the index of standard special provisions with applicable materials specifications for this project highlighted will also be provided.

Jeri Mero

cc: Jody Pieper  
Jennifer Sparks  
Scott Dalton  
Cynthia Bailey

Pavement Stabilization Data  
(To be included in project plans)

SH 350 & SH 239				
Design Parameters				
	Tie-In		Rebuild	
Design Life (Years)	10		20	
Heavy Trucks (Initial)	100		100	
Heavy Trucks (Cumulative):	251,231		588,864	
Operational Speed (MPH):	65		65	
Subgrade Classification	A-6		A-6	
Subgrade Resilient Modulus (psi)	7,247		7,247	
Effective Binder Content (%):	10.7		10.7	
Voids (%):	5.5		5.5	
Re-Construction Total Pavement Thickness (in):	-		6	
Milling Thickness (in):	-		-	
Overlay Thickness (in):	1.5		-	
HMA Grading (Top/Bottom):	SX		SX	
HMA Design Gyration (Top/Bottom):	75		75	
HMA Grading (top lift)	PG 58-28		PG 58-28	
HMA Grading (bottom lift)	-		-	
Distress Prediction Summary				
	Target	Predicted	Target	Predicted
Terminal IRI (in/mile):	200	155.47	200	158.6
Reliability (%):	95	99.9	95	99.87
Permanent Deformation (in):	0.8	0.36	0.85	0.34
Reliability (%):	95	100	95	100
AC Total Fatigue Cracking(%)	35	36.16	-	-
Reliability (%):	50	49.69	-	-
AC Total Transverse Cracking (ft/mile):	2500	242.26	-	-
Reliability (%):	95	100	-	-
Permanent Deformation - AC Only (in):	0.65	0.19	0.8	0.2
Reliability (%):	95	100	95	100
AC Bottom-Up Fatigue Cracking (%)	25	0	25	10.32
Reliability (%):	50	100	95	100
AC Thermal Cracking (ft/mile)	1500	1	1500	109.79
Reliability (%):	50	100	95	100
AC Top-Down Fatigue Cracking (ft/mile):	3000	3333.23	3000	571.49
Reliability (%):	95	92.88	95	100

# New Pavement Thickness Design Output



# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Design Inputs

Design Life: **20 years**      Base construction: **May, 2021**      Climate Data **38.051, -103.527**  
 Design Type: **FLEXIBLE**      Pavement construction: **June, 2021**      Sources (Lat/Lon)  
 Traffic opening: **September, 2021**

### Design Structure

Layer type	Material Type	Thickness (in)
Flexible	R3 Level 1 SX(75) PG 58-28 United	6.0
NonStabilized	Crushed gravel	6.0
Subgrade	A-6	Semi-infinite

### Volumetric at Construction:

Effective binder content (%)	10.7
Air voids (%)	5.5

### Traffic

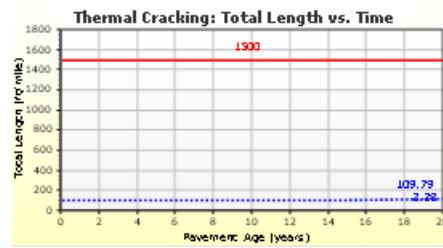
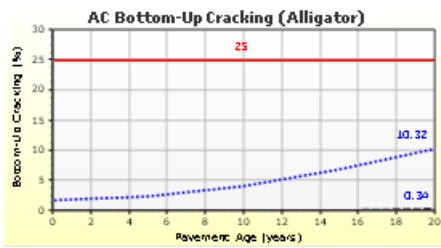
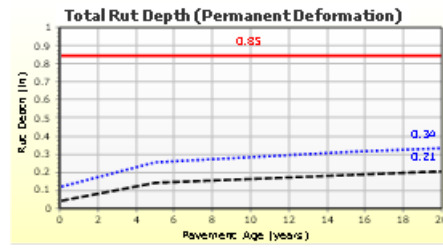
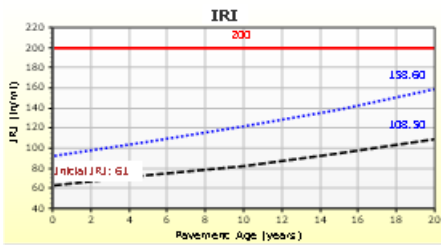
Age (year)	Heavy Trucks (cumulative)
2021 (initial)	100
2031 (10 years)	251,231
2041 (20 years)	588,864

## Design Outputs

### Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	158.60	95.00	99.87	Pass
Permanent deformation - total pavement (in)	0.85	0.34	95.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	10.32	95.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	109.79	95.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	571.49	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.80	0.20	95.00	100.00	Pass

## Distress Charts

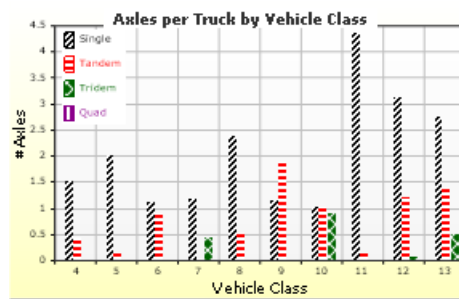
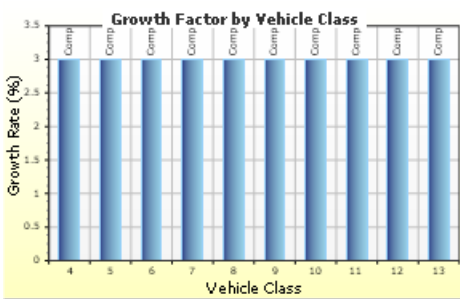
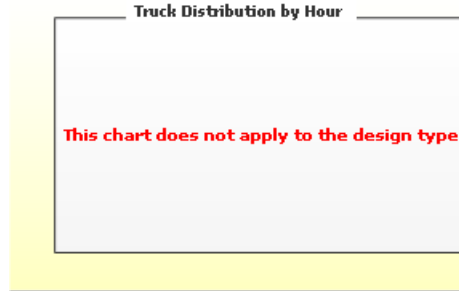
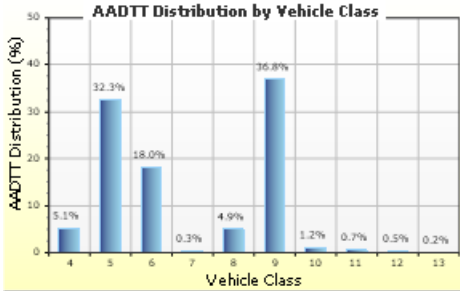


## Traffic Inputs

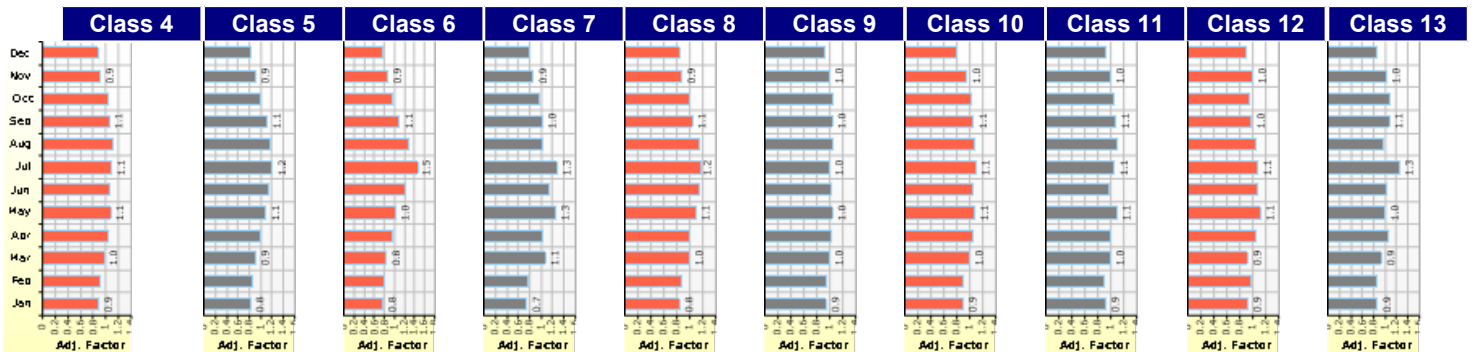
### Graphical Representation of Traffic Inputs

Initial two-way AADTT: **100**  
 Number of lanes in design direction: **1**

Percent of trucks in design direction (%): **60.0**  
 Percent of trucks in design lane (%): **100.0**  
 Operational speed (mph): **65.0**



### Traffic Volume Monthly Adjustment Factors





## Tabular Representation of Traffic Inputs

### Volume Monthly Adjustment Factors Level 3: Default MAF

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

### Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3%	Compound
Class 5	32.3%	3%	Compound
Class 6	18%	3%	Compound
Class 7	0.3%	3%	Compound
Class 8	4.9%	3%	Compound
Class 9	36.8%	3%	Compound
Class 10	1.2%	3%	Compound
Class 11	0.7%	3%	Compound
Class 12	0.5%	3%	Compound
Class 13	0.2%	3%	Compound

Truck Distribution by Hour does not apply

### Axle Configuration

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

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

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

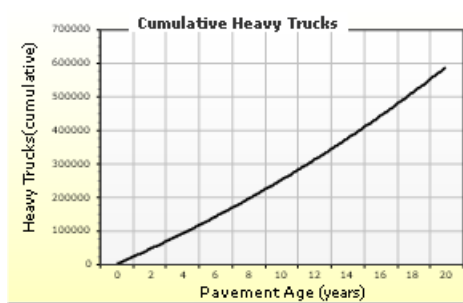
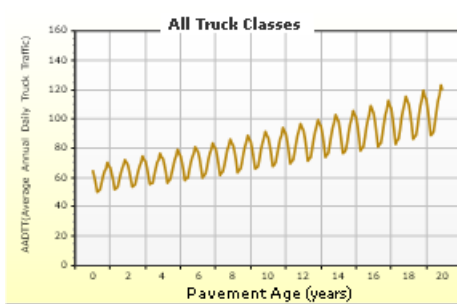
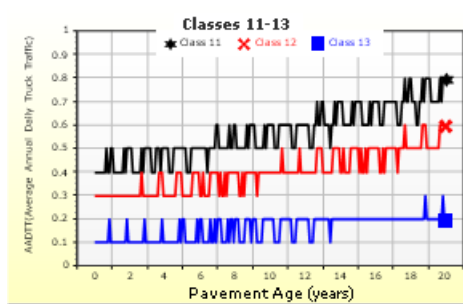
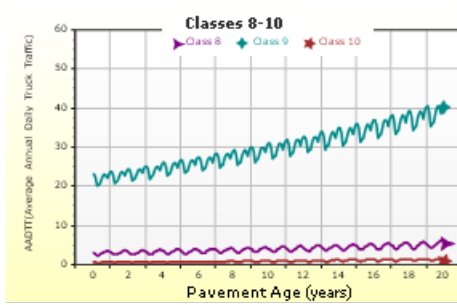
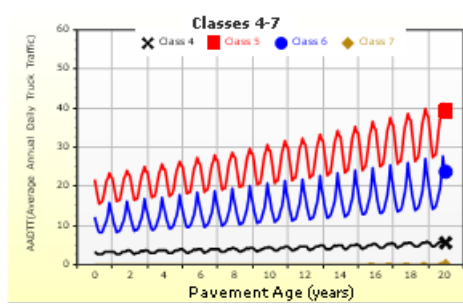
Wheelbase does not apply

### Number of Axles per Truck

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

## AADTT (Average Annual Daily Truck Traffic) Growth

\* Traffic cap is not enforced





# SH350\_New\_AC

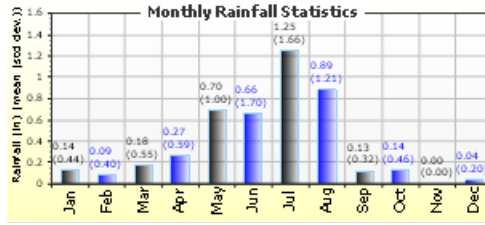
File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Climate Inputs

### Climate Data Sources:

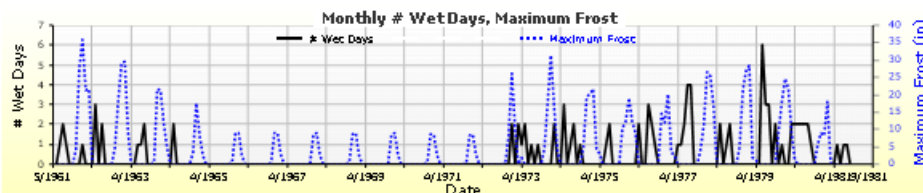
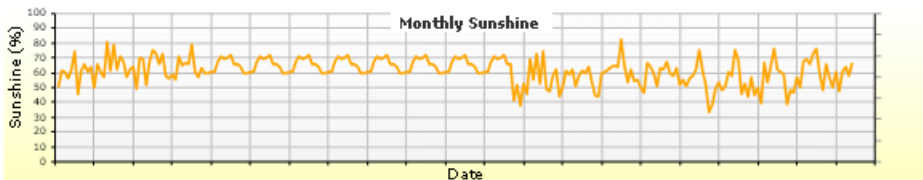
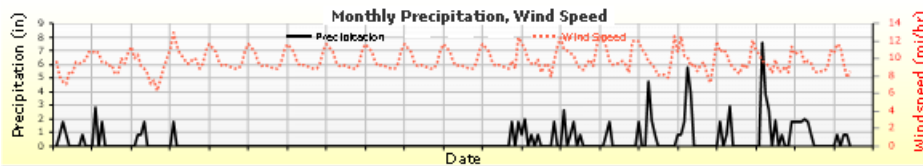
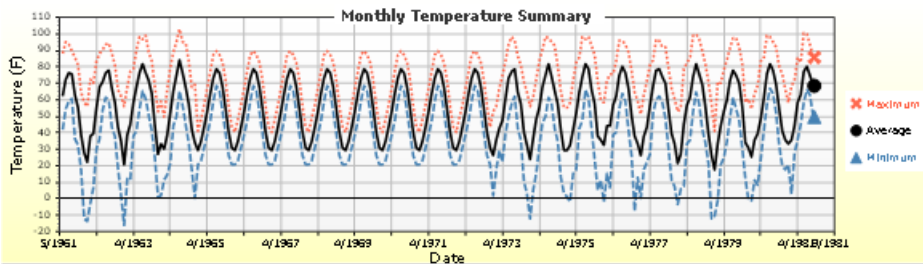
Climate Station Cities:                      Location (lat lon elevation(ft))  
 LA JUNTA, CO                                      38.05100 -103.52700 4215



### Annual Statistics:

Mean annual air temperature (°F)	54.12		
Mean annual precipitation (in)	4.57		
Freezing index (°F - days)	295.70		
Average annual number of freeze/thaw cycles:	81.93	Water table depth (ft)	10.00

### Monthly Climate Summary:



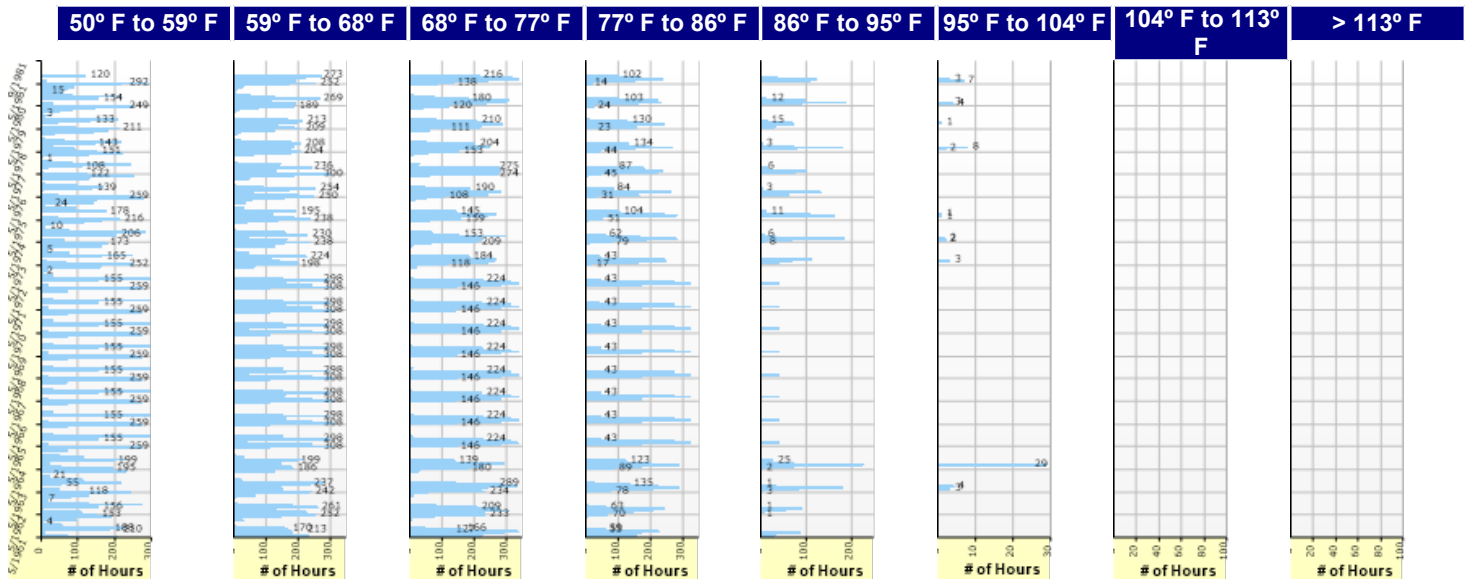
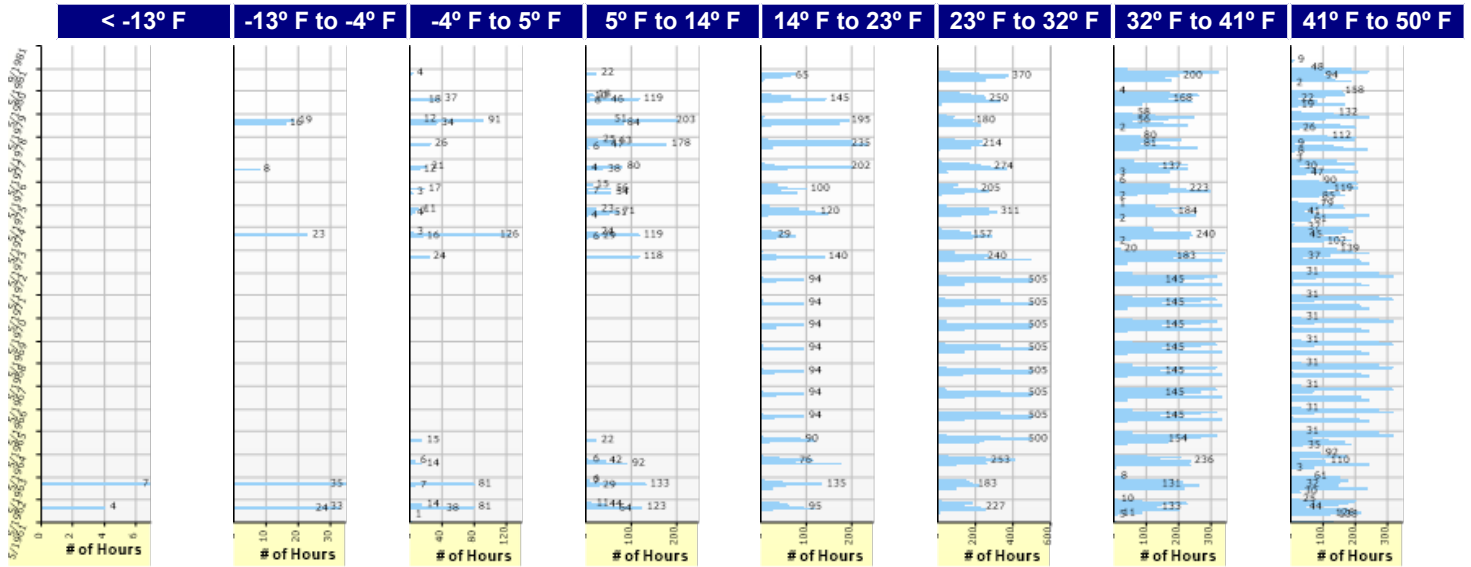


# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Hourly Air Temperature Distribution by Month:





# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Design Properties

### HMA Design Properties

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

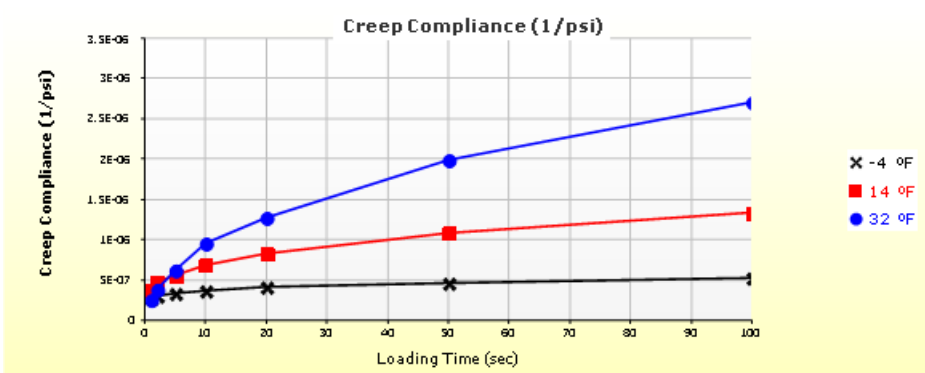
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : R3 Level 1 SX (75) PG 58-28 United	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed gravel	Non-stabilized Base (4)	1.00
Layer 3 Subgrade : A-6	Subgrade (5)	-

<b>Structure - ICM Properties</b>	
AC surface shortwave absorptivity	0.85

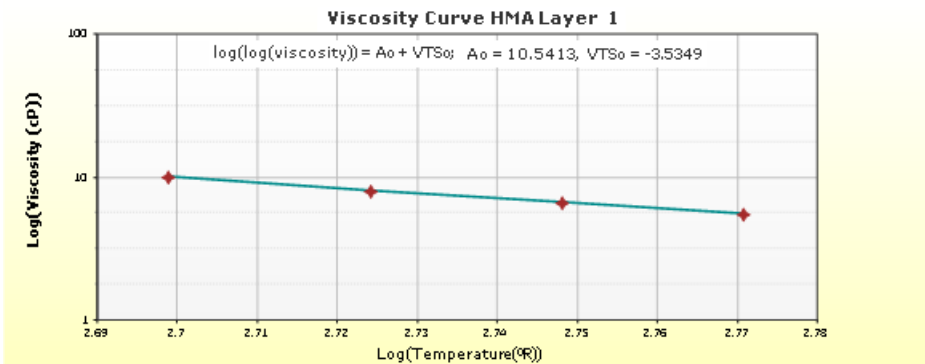
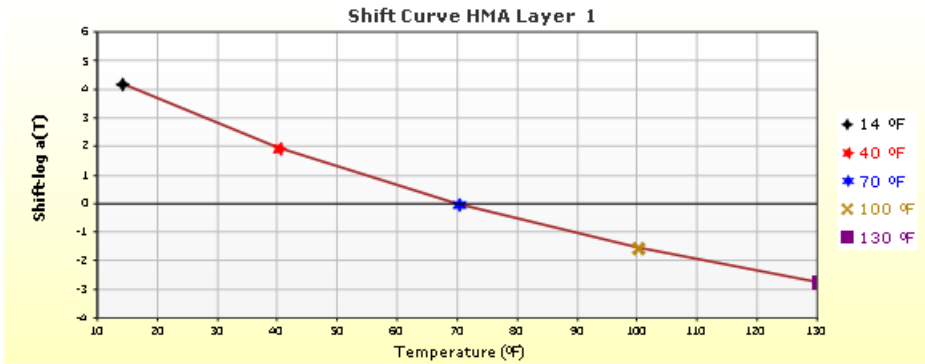
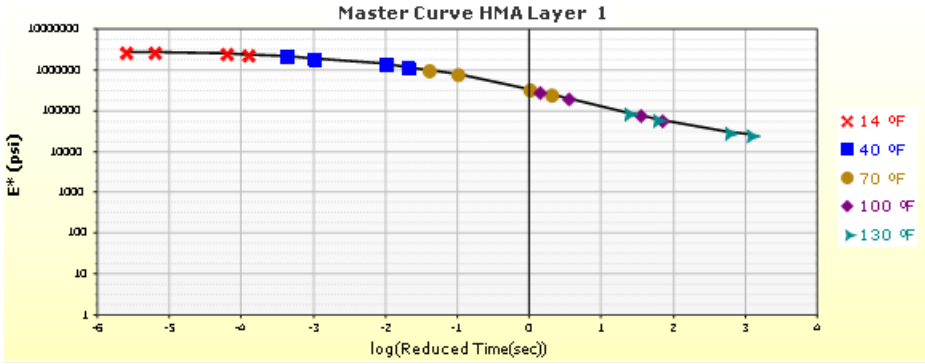
## Thermal Cracking (Input Level: 1)

Indirect tensile strength at 14 °F (psi)	555.90
<b>Thermal Contraction</b>	
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 (%)	16.2

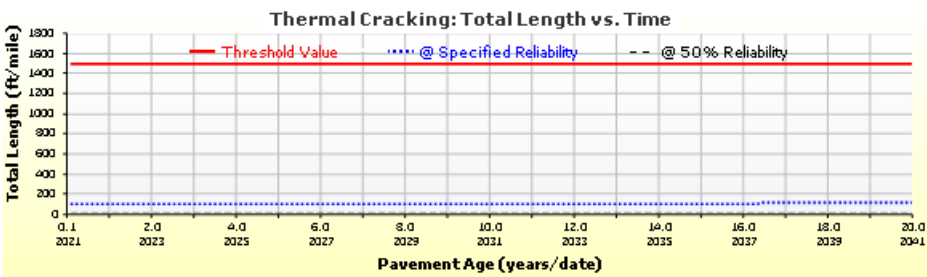
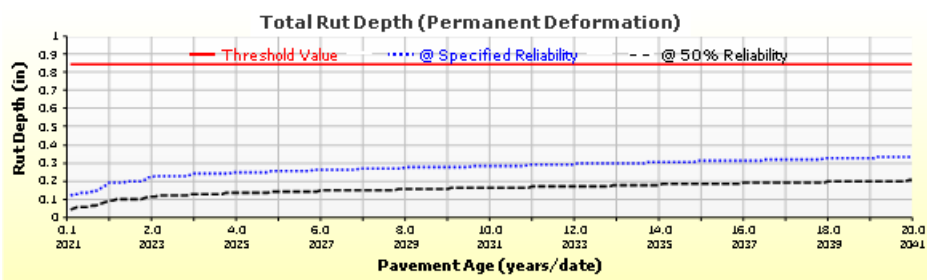
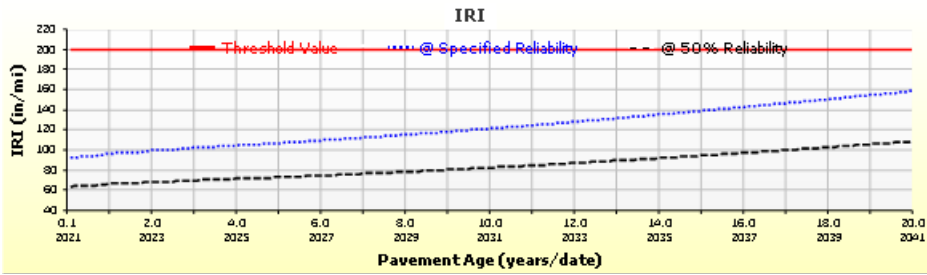
Loading time (sec)	Creep Compliance (1/psi)		
	-4 °F	14 °F	32 °F
1	2.78e-007	3.91e-007	2.65e-007
2	3.11e-007	4.79e-007	3.91e-007
5	3.48e-007	5.57e-007	6.33e-007
10	3.74e-007	6.94e-007	9.55e-007
20	4.22e-007	8.31e-007	1.28e-006
50	4.63e-007	1.08e-006	1.99e-006
100	5.28e-007	1.35e-006	2.72e-006



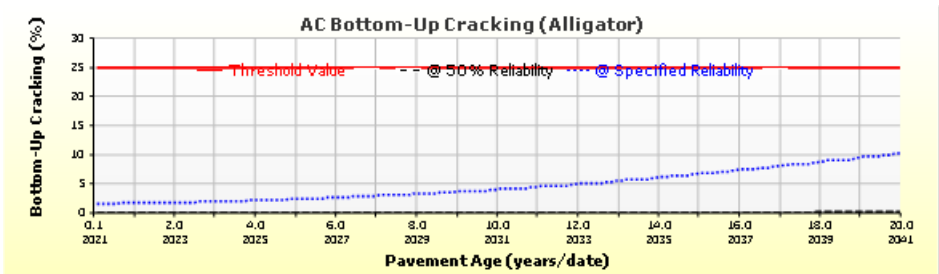
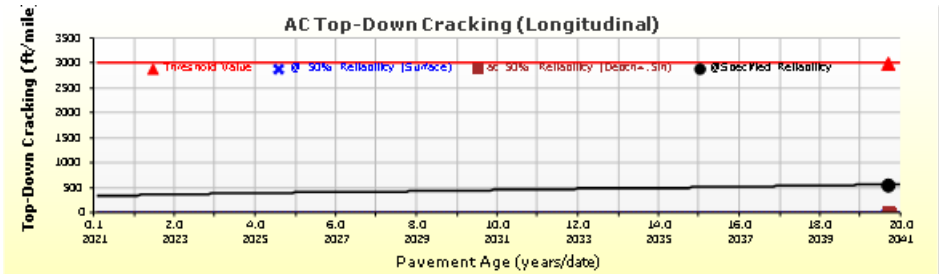
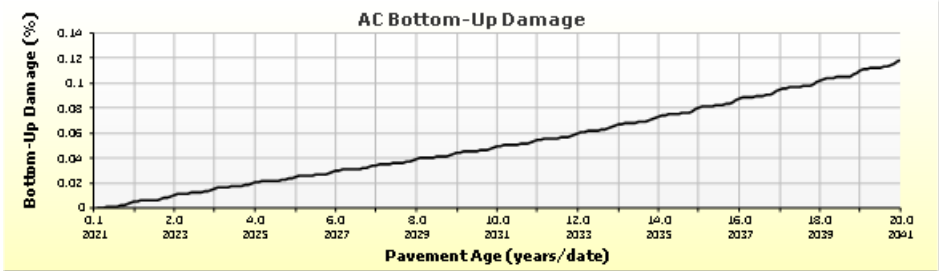
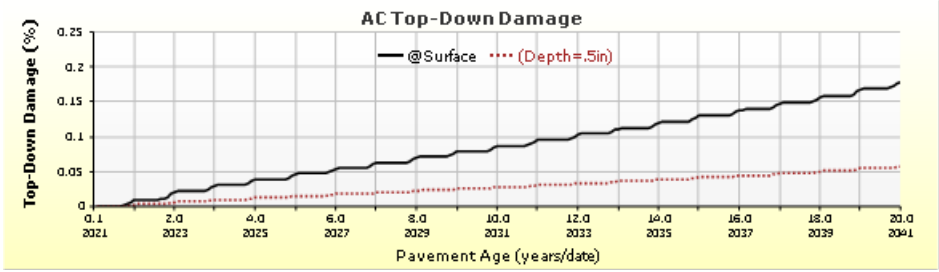
## HMA Layer 1: Layer 1 Flexible : R3 Level 1 SX(75) PG 58-28 United



## Analysis Output Charts



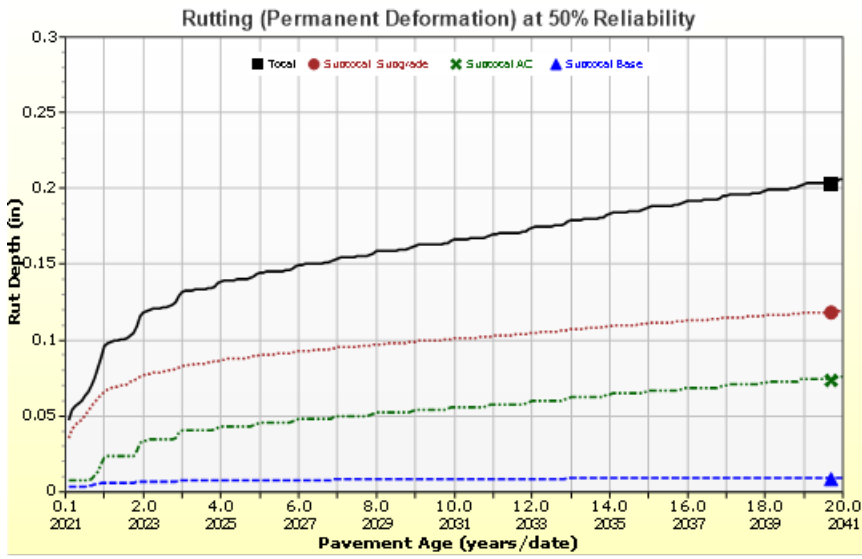


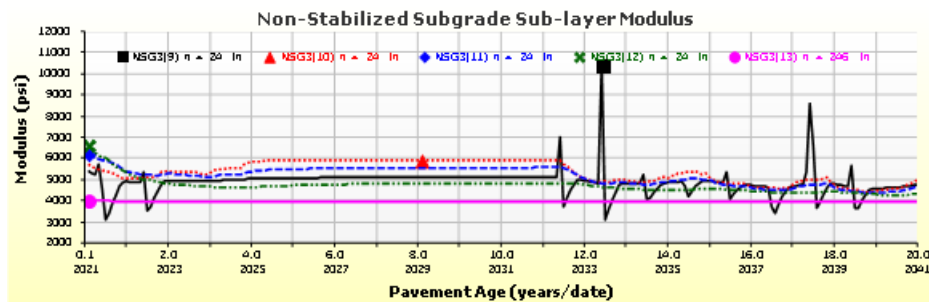
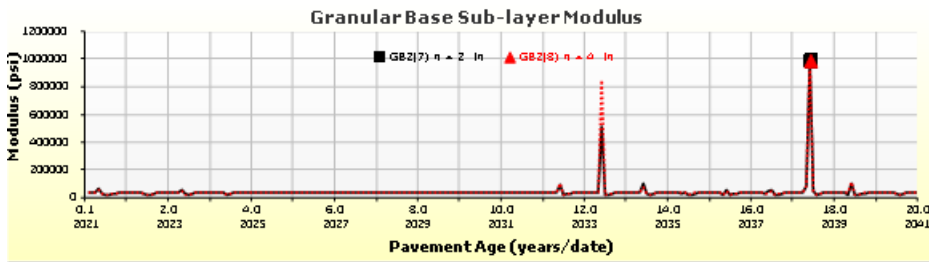
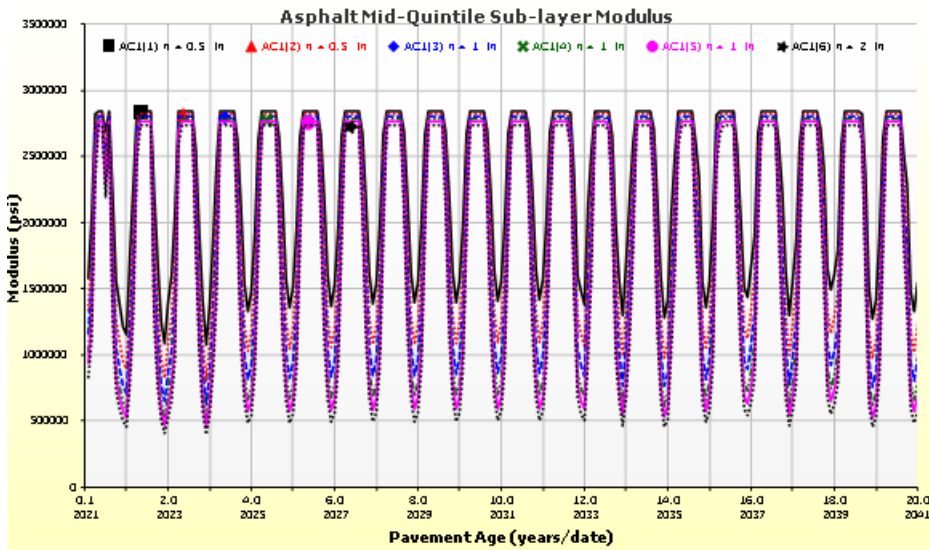




# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx







# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Layer Information

### Layer 1 Flexible : R3 Level 1 SX(75) PG 58-28 United

Asphalt		
Thickness (in)	6.0	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

### Asphalt Dynamic Modulus (Input Level: 1)

T (°F)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2067099	2488999	2785899	2873299
40	930800	1472800	2008399	2196999
70	207600	439600	838700	1039200
100	52500	101200	215300	291900
130	24100	35400	60900	78900

### Asphalt Binder

Temperature (°F)	Binder Gstar (Pa)	Phase angle (deg)
136.4	2227.6	80
147.2	1068.2	82
158	540.1	84

### General Info

Name	Value
Reference temperature (°F)	70
Effective binder content (%)	10.7
Air voids (%)	5.5
Thermal conductivity (BTU/hr-ft-°F)	0.67
Heat capacity (BTU/lb-°F)	0.23

### Identifiers

Field	Value
Display name/identifier	R3 Level 1 SX(75) PG 58-28
Description of object	Mix ID # FS1918
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	0



# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Layer 2 Non-stabilized Base : Crushed gravel

### Unbound

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

### Modulus (Input Level: 3)

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

### Resilient Modulus (psi)

25000.0
---------

<b>Use Correction factor for NDT modulus?</b>	-
<b>NDT Correction Factor:</b>	-

### Identifiers

Field	Value
Display name/identifier	Crushed gravel
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	45

### Sieve

<b>Liquid Limit</b>	6.0
<b>Plasticity Index</b>	1.0
<b>Is layer compacted?</b>	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)

<b>Is User Defined?</b>	False
<b>af</b>	7.2555
<b>bf</b>	1.3328
<b>cf</b>	0.8242
<b>hr</b>	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



# SH350\_New\_AC

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH350\_New\_AC.dgpx



## Layer 3 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: 3)

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

### Resilient Modulus (psi)

7247.0
--------

<b>Use Correction factor for NDT modulus?</b>	-
<b>NDT Correction Factor:</b>	-

### 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 1	
User defined field 2	
User defined field 3	
Revision Number	5

### Sieve

<b>Liquid Limit</b>	33.0
<b>Plasticity Index</b>	16.0
<b>Is layer compacted?</b>	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
Water Content (%)	False	17.1

### User-defined Soil Water Characteristic Curve (SWCC)

<b>Is User Defined?</b>	False
<b>af</b>	108.4091
<b>bf</b>	0.6801
<b>cf</b>	0.2161
<b>hr</b>	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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\epsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 130.3674
	Bf2: 1
	Bf3: 1.217799

### AC Rutting

$\frac{\epsilon_p}{\epsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$ $C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$ <p>Where:  <math>H_{ac}</math> = total AC thickness(in)</p>	$\epsilon_p$ = plastic strain(in/in) $\epsilon_r$ = resilient strain(in/in) $T$ = layer temperature(°F) $N$ = number of load repetitions
AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791 Br1:4.3 Br2:1 Br3:1

### Thermal Fracture

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma}\right)$ $\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f$ = observed amount of thermal cracking(ft/500ft) $k$ = refression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() $\sigma$ = 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: 6.3	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 * THERMAL + 55.462
Level 3 K: 6.3	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

### CSM Fatigue

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$	$N_f$ = number of repetitions to fatigue cracking $\sigma_s$ = Tensile stress(psi) $M_r$ = modulus of rupture(psi)		
k1: 1	k2: 1	Bc1: 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 $		$\delta_a$ = permanent deformation for the layer $N$ = number of repetitions $\varepsilon_v$ = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties $\varepsilon_r$ = resilient strain(in/in)	
Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking			
AC Top Down Cracking		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: 0.021	c2: 2.35	c3: 6000	
AC Cracking Top Standard Deviation		AC Cracking Bottom Standard Deviation	
200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))		1 + 15/(1+exp(-3.1472-4.1349*LOG10(BOTTOM+0.0001)))	

CSM Cracking				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: 0	C2: 75	C3: 5	C4: 3	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*1							



# Tie-In Pavement Thickness Design Output



# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Design Inputs

Design Life: 10 years  
 Existing construction: May, 2020  
 Climate Data 38.051, -103.527  
 Design Type: ACC\_ACC  
 Pavement construction: June, 2021  
 Sources (Lat/Lon)  
 Traffic opening: September, 2021

### Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	SX(75) PG 58-28	1.5
Flexible (existing)	Default asphalt concrete	1.5
Subgrade	A-6	12.0
Subgrade	A-6	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	10.7
Air voids (%)	5.5

### Traffic

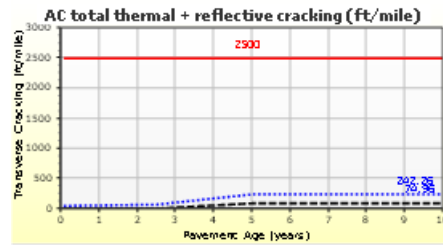
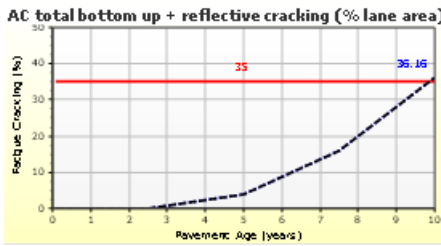
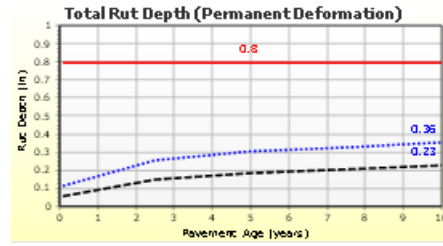
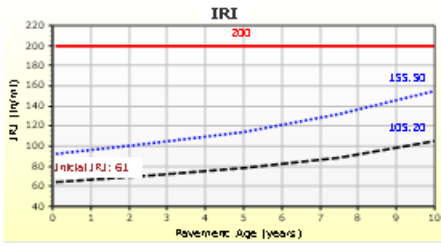
Age (year)	Heavy Trucks (cumulative)
2021 (initial)	100
2026 (5 years)	116,350
2031 (10 years)	251,231

## Design Outputs

### Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	155.47	95.00	99.90	Pass
Permanent deformation - total pavement (in)	0.80	0.36	95.00	100.00	Pass
AC total fatigue cracking: bottom up + reflective (% lane area)	35.00	36.16	50.00	46.69	Fail
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	242.26	95.00	100.00	Pass
Permanent deformation - AC only (in)	0.65	0.19	95.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	25.00	0.00	50.00	100.00	Pass
AC thermal cracking (ft/mile)	1500.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	3000.00	3333.23	95.00	92.88	Fail

## Distress Charts

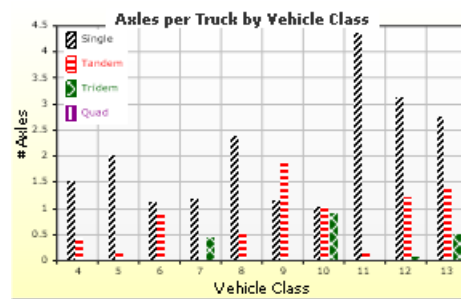
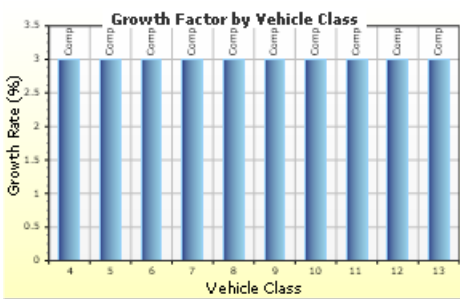
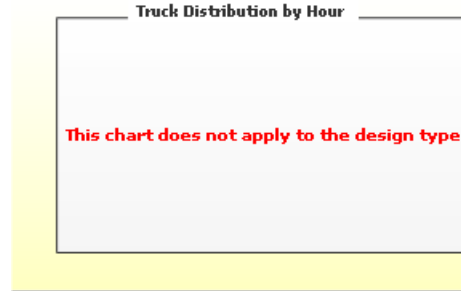
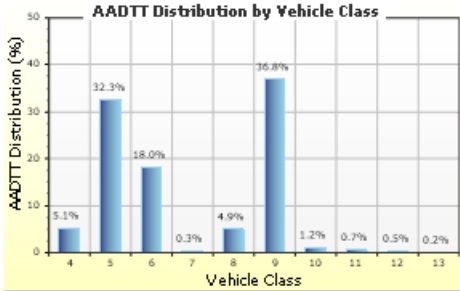


## Traffic Inputs

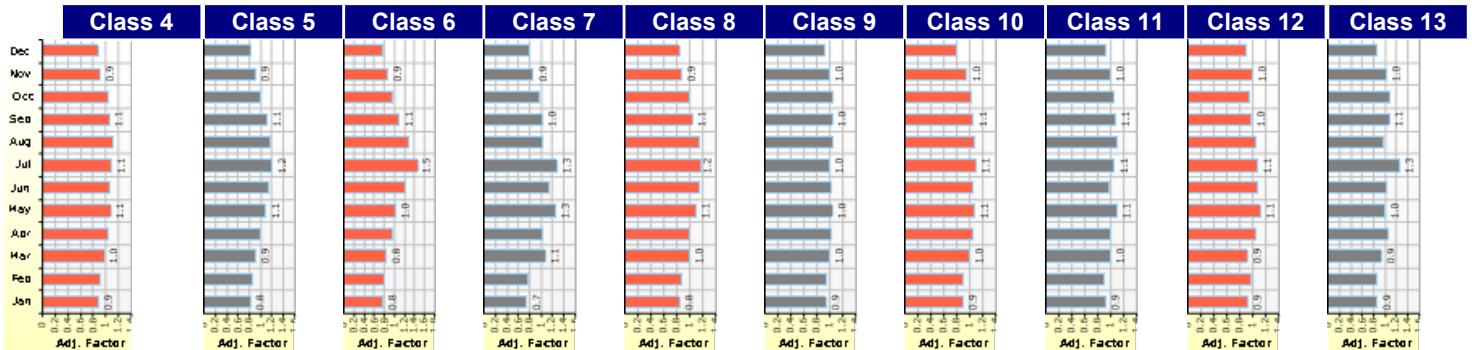
### Graphical Representation of Traffic Inputs

Initial two-way AADTT: **100**  
 Number of lanes in design direction: **1**

Percent of trucks in design direction (%): **60.0**  
 Percent of trucks in design lane (%): **100.0**  
 Operational speed (mph): **65.0**



### Traffic Volume Monthly Adjustment Factors



## Tabular Representation of Traffic Inputs

### Volume Monthly Adjustment Factors Level 3: Default MAF

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

### Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	5.1%	3%	Compound
Class 5	32.3%	3%	Compound
Class 6	18%	3%	Compound
Class 7	0.3%	3%	Compound
Class 8	4.9%	3%	Compound
Class 9	36.8%	3%	Compound
Class 10	1.2%	3%	Compound
Class 11	0.7%	3%	Compound
Class 12	0.5%	3%	Compound
Class 13	0.2%	3%	Compound

Truck Distribution by Hour does not apply

### Axle Configuration

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

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

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

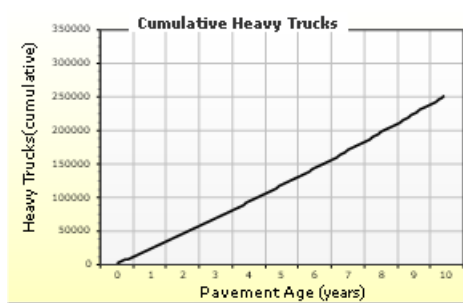
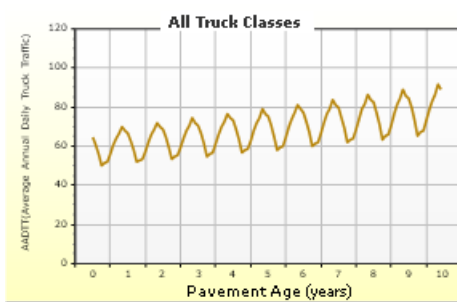
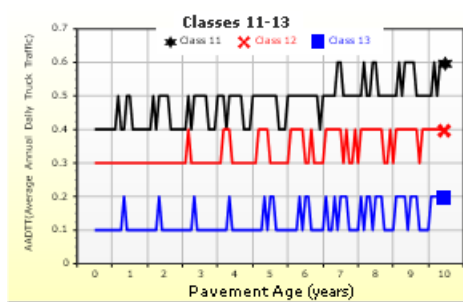
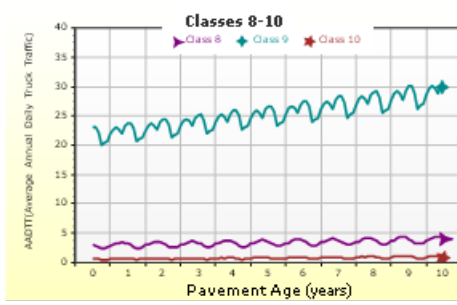
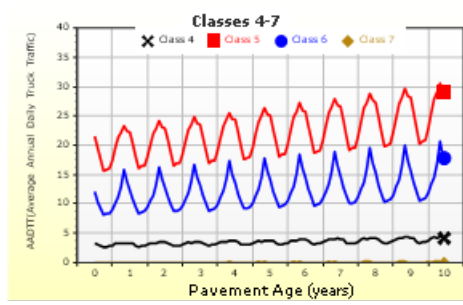
Wheelbase does not apply

### Number of Axles per Truck

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

## AADTT (Average Annual Daily Truck Traffic) Growth

\* Traffic cap is not enforced





# SH 350\_Tie In

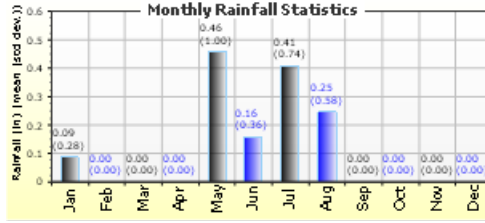
File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Climate Inputs

### Climate Data Sources:

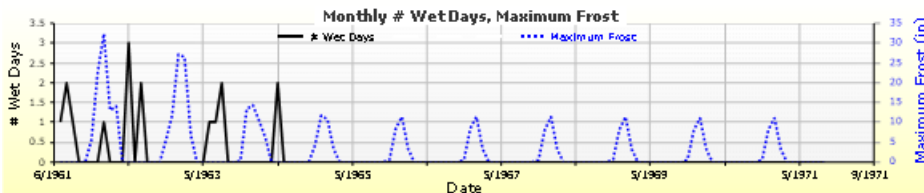
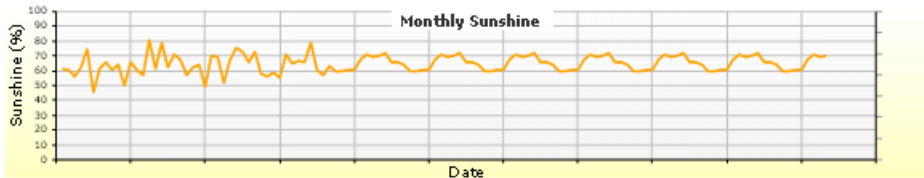
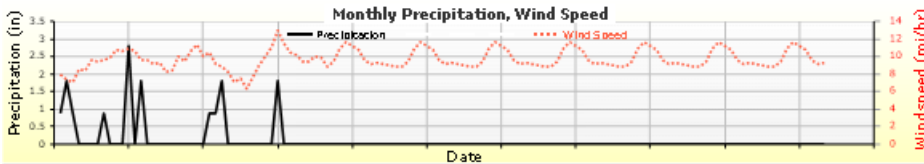
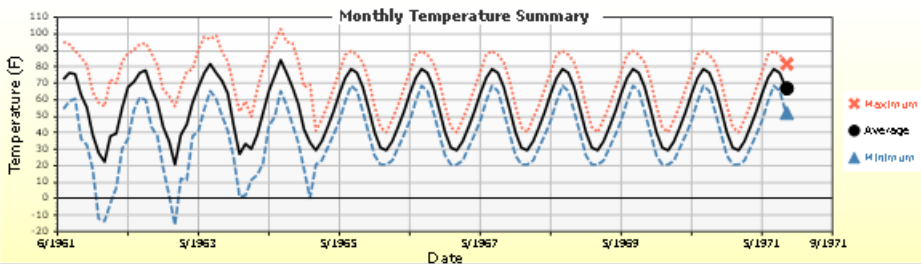
Climate Station Cities:                      Location (lat lon elevation(ft))  
 LA JUNTA, CO                                      38.05100 -103.52700 4215



### Annual Statistics:

Mean annual air temperature (°F)	54.48		
Mean annual precipitation (in)	1.40		
Freezing index (°F - days)	230.34		
Average annual number of freeze/thaw cycles:	81.93	Water table depth (ft)	10.00

### Monthly Climate Summary:



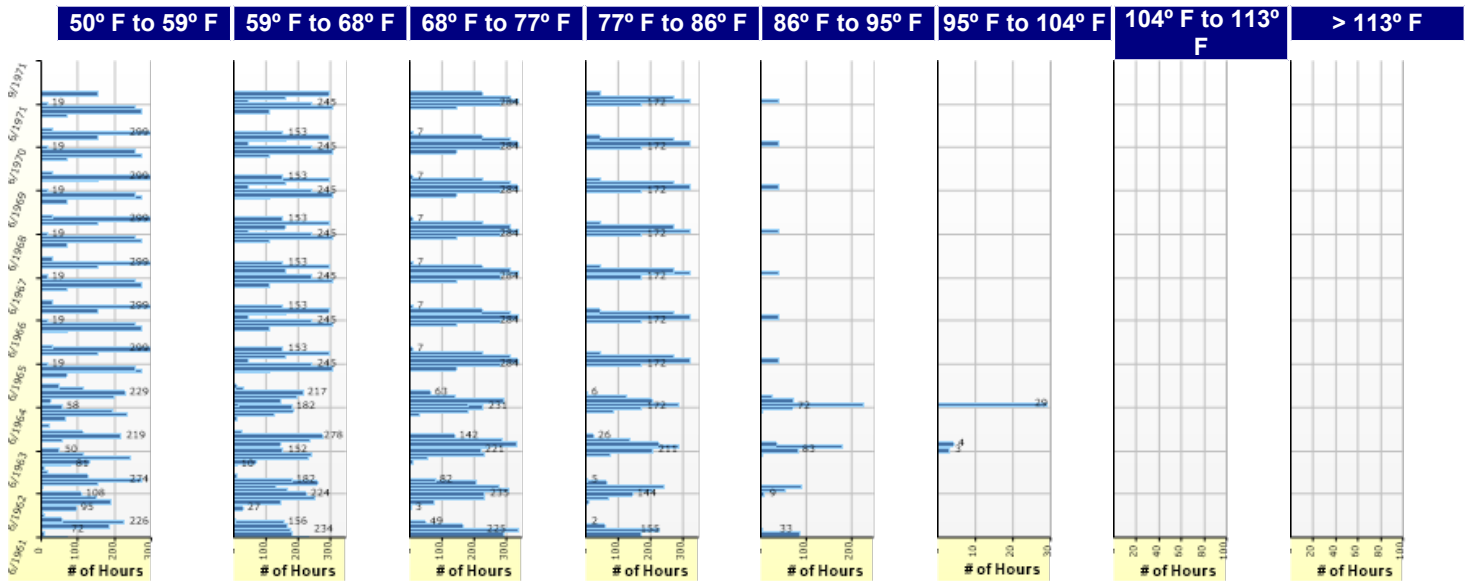
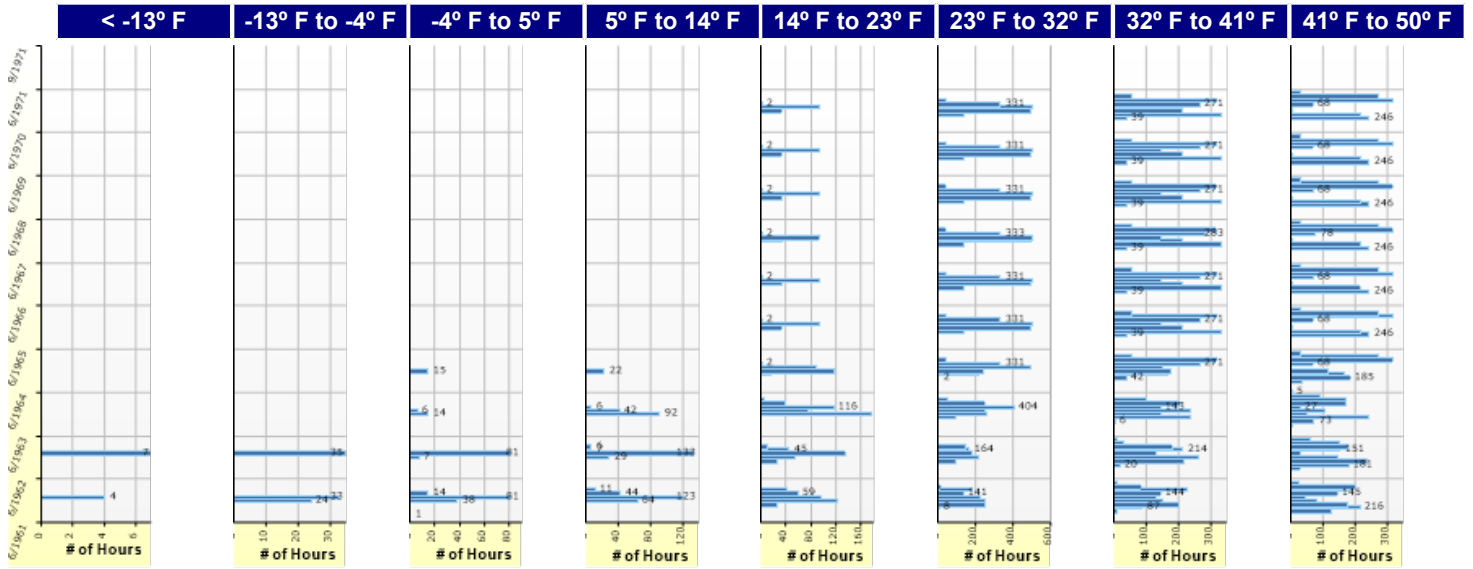


# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Hourly Air Temperature Distribution by Month:







# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.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

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : SX(75) PG 58-28	Flexible (1)	1.00
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	1.00
Layer 3 Subgrade : A-6	Subgrade (5)	1.00
Layer 4 Subgrade : A-6	Subgrade (5)	-

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

### HMA Rehabilitation (Input Level: 2)

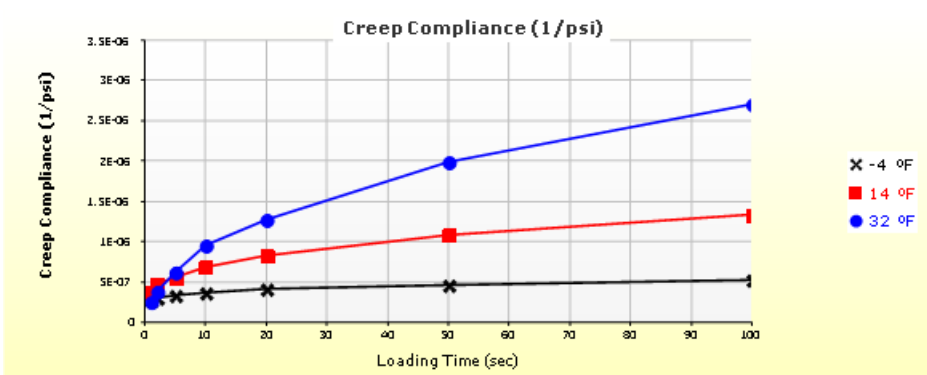
Milled thickness (in)	1.50
Fatigue cracking (%)	0.00 (Low)
Transverse cracking (ft/mile)	100.00 (Low)
Total rut depth (in)	-

Layer Name	Layer Type	Rut Depth (in)
Layer 1 Flexible : SX(75) PG 58-28	Flexible (1)	-
Layer 2 Flexible : Default asphalt concrete(existing)	Flexible (1)	0.10
Layer 3 Subgrade : A-6	Subgrade (5)	0.00
Layer 4 Subgrade : A-6	Subgrade (5)	0.00

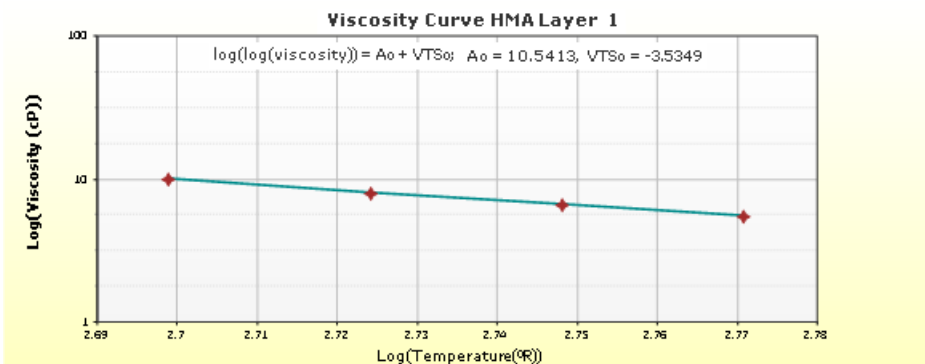
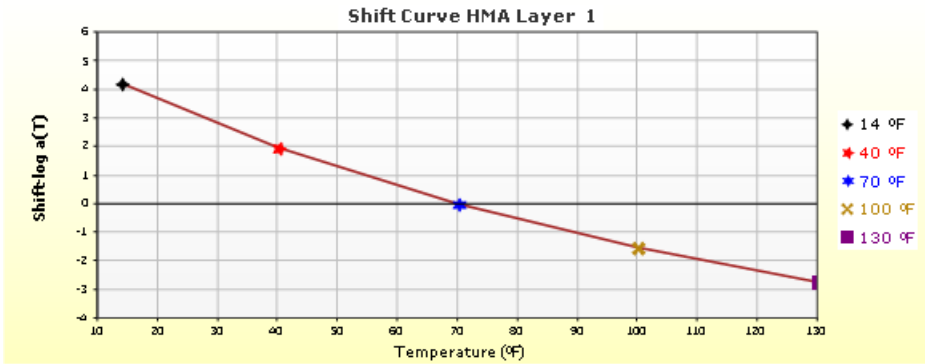
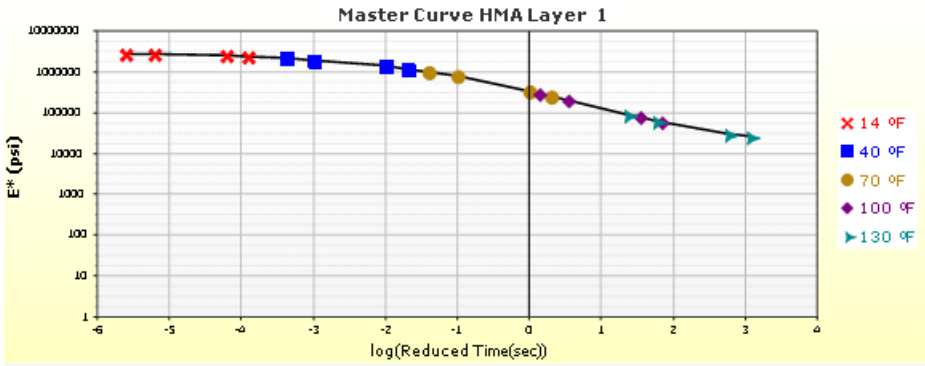
## Thermal Cracking (Input Level: 1)

Indirect tensile strength at 14 °F (psi)	555.90
<b>Thermal Contraction</b>	
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 (%)	16.2

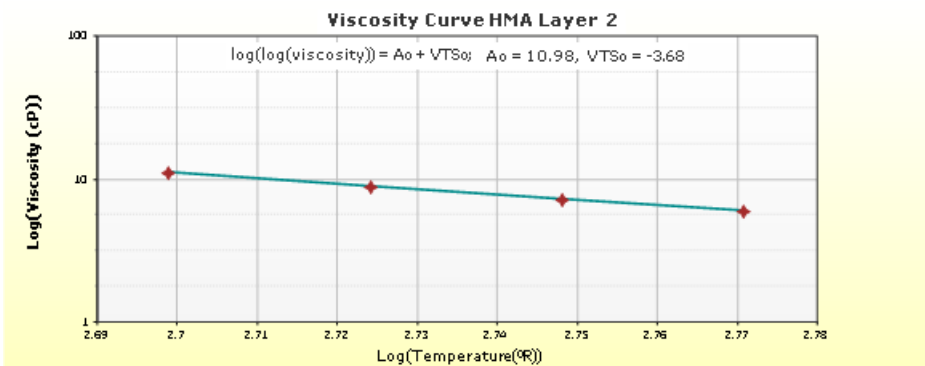
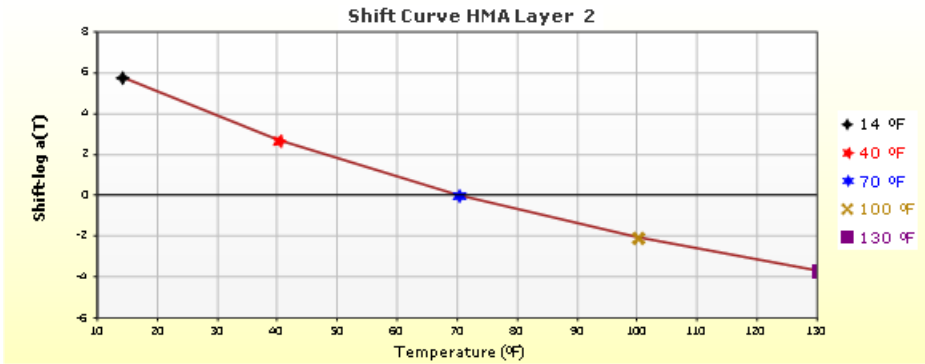
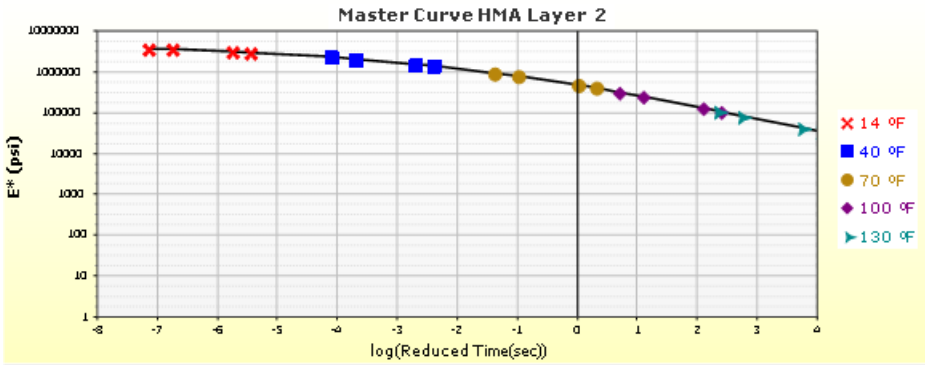
Loading time (sec)	Creep Compliance (1/psi)		
	-4 °F	14 °F	32 °F
1	2.78e-007	3.91e-007	2.65e-007
2	3.11e-007	4.79e-007	3.91e-007
5	3.48e-007	5.57e-007	6.33e-007
10	3.74e-007	6.94e-007	9.55e-007
20	4.22e-007	8.31e-007	1.28e-006
50	4.63e-007	1.08e-006	1.99e-006
100	5.28e-007	1.35e-006	2.72e-006



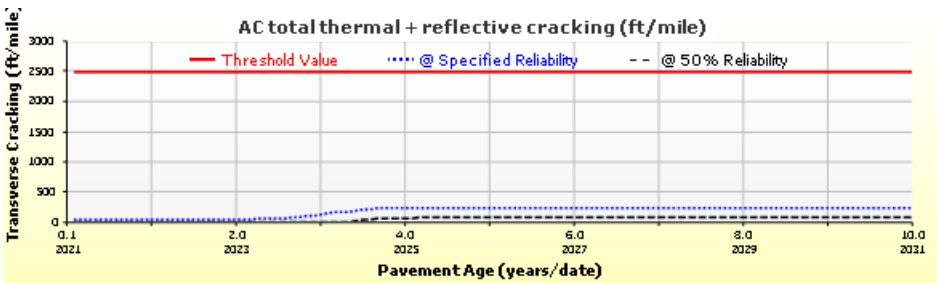
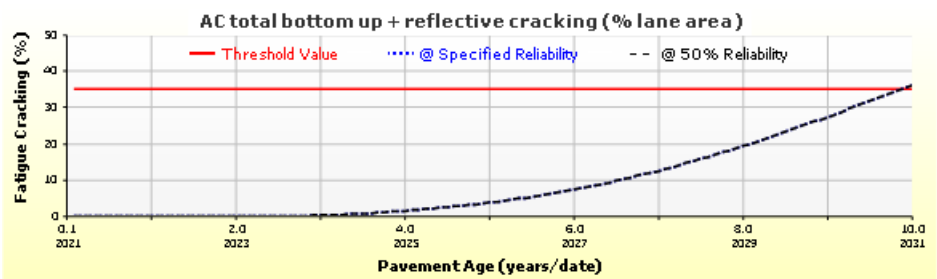
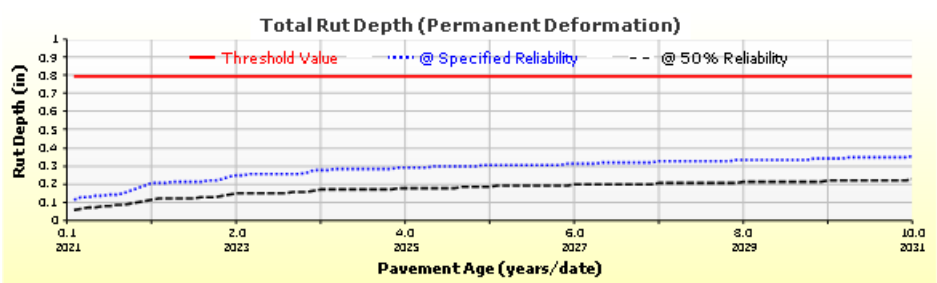
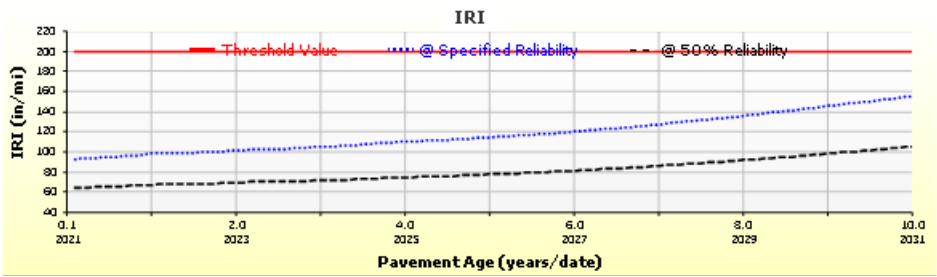
## HMA Layer 1: Layer 1 Flexible : SX(75) PG 58-28

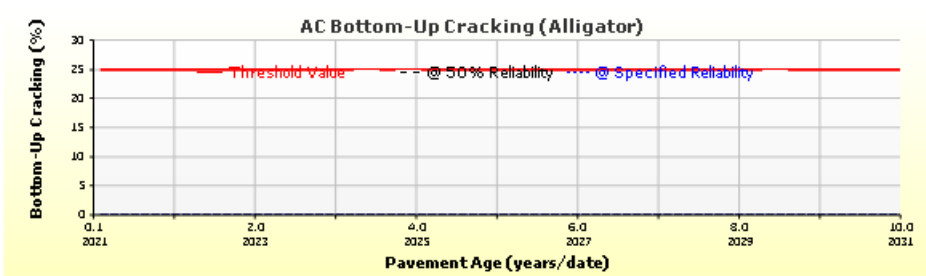
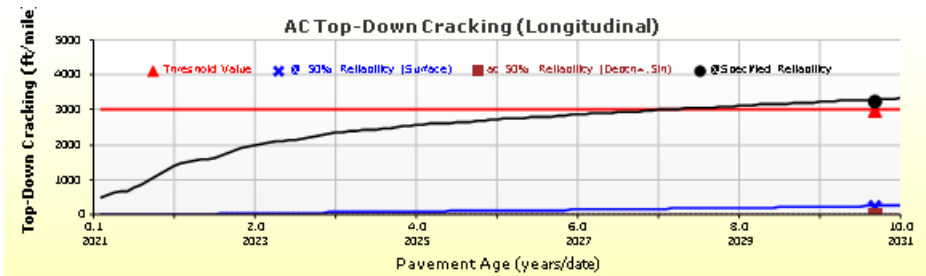
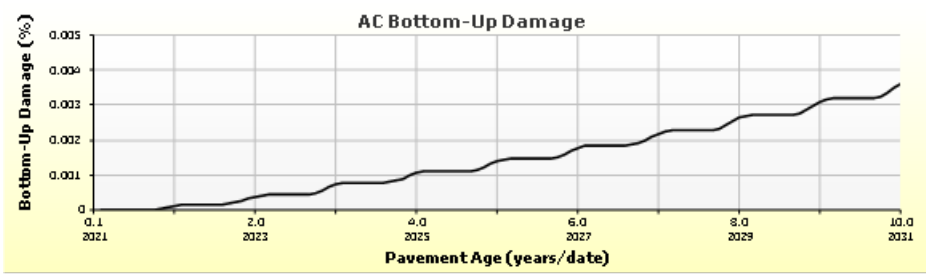
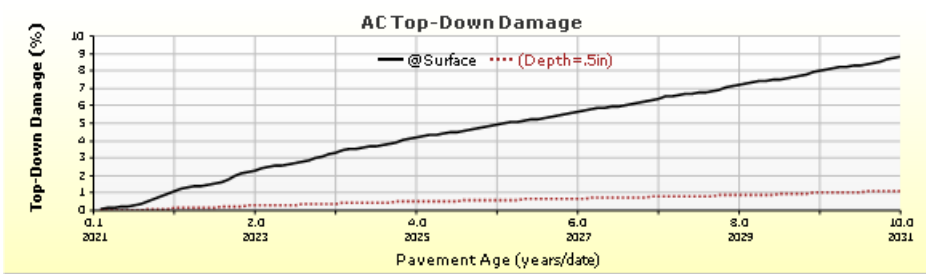


## HMA Layer 2: Layer 2 Flexible : Default asphalt concrete(existing)



## Analysis Output Charts

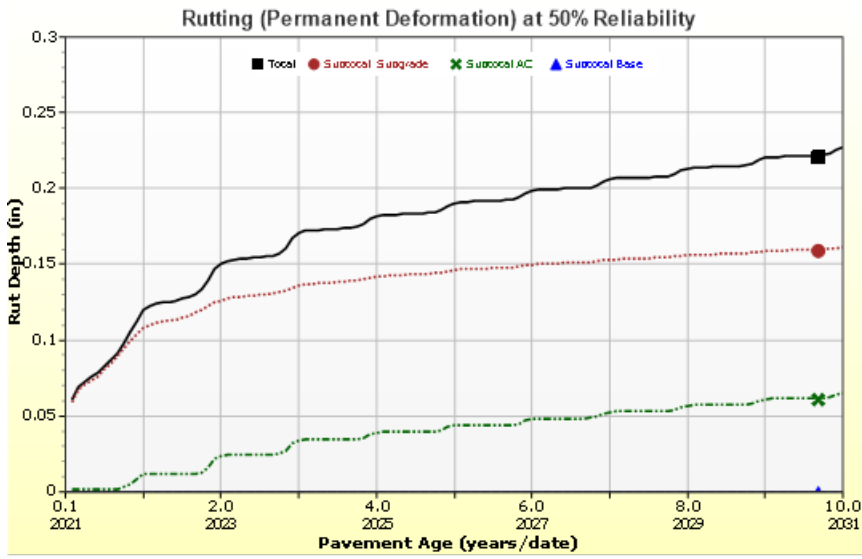


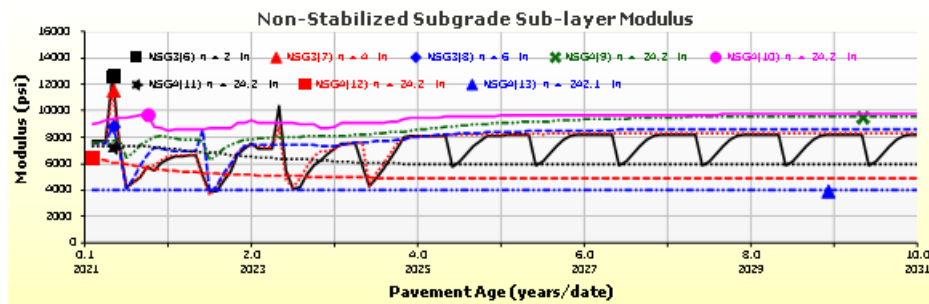
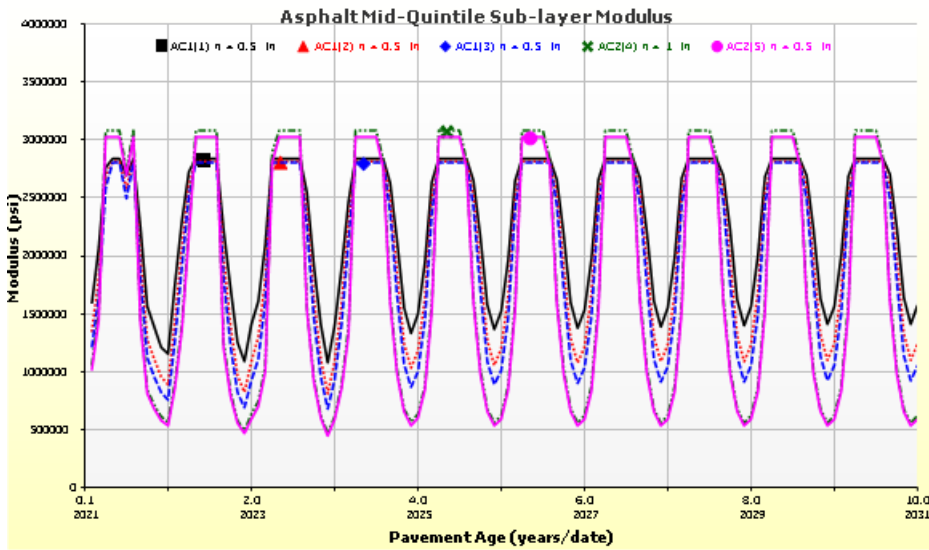




# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx









# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Layer Information

### Layer 1 Flexible : SX(75) PG 58-28

Asphalt		
Thickness (in)	1.5	
Unit weight (pcf)	145.0	
Poisson's ratio	Is Calculated?	True
	Ratio	-
	Parameter A	-1.63
	Parameter B	3.84E-06

### Asphalt Dynamic Modulus (Input Level: 1)

T (°F)	0.5 Hz	1 Hz	10 Hz	25 Hz
14	2067099	2488999	2785899	2873299
40	930800	1472800	2008399	2196999
70	207600	439600	838700	1039200
100	52500	101200	215300	291900
130	24100	35400	60900	78900

### Asphalt Binder

Temperature (°F)	Binder Gstar (Pa)	Phase angle (deg)
136.4	2227.6	80
147.2	1068.2	82
158	540.1	84

### General Info

Name	Value
Reference temperature (°F)	70
Effective binder content (%)	10.7
Air voids (%)	5.5
Thermal conductivity (BTU/hr-ft-°F)	0.67
Heat capacity (BTU/lb-°F)	0.23

### Identifiers

Field	Value
Display name/identifier	SX(75) PG 58-28
Description of object	Mix ID # FS1918
Author	CDOT
Date Created	4/3/2013 12:00:00 AM
Approver	CDOT
Date approved	4/3/2013 12:00:00 AM
State	Colorado
District	
County	
Highway	
Direction of Travel	
From station (miles)	
To station (miles)	
Province	
User defined field 1	SX
User defined field 2	
User defined field 3	
Revision Number	0



# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Layer 2 Flexible : Default asphalt concrete(existing)

Asphalt		
Thickness (in)	1.5	
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	10/29/2010 12:00:00 AM
Approver	
Date approved	10/29/2010 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	25

## Layer 3 Subgrade : A-6

### Unbound

Layer thickness (in)	12.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

### Modulus (Input Level: 3)

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

### Resilient Modulus (psi)

7247.0
--------

<b>Use Correction factor for NDT modulus?</b>	-
<b>NDT Correction Factor:</b>	-

### 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 1	
User defined field 2	
User defined field 3	
Revision Number	0

### Sieve

<b>Liquid Limit</b>	33.0
<b>Plasticity Index</b>	16.0
<b>Is layer compacted?</b>	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
Water Content (%)	False	17.1

### User-defined Soil Water Characteristic Curve (SWCC)

<b>Is User Defined?</b>	False
<b>af</b>	108.4091
<b>bf</b>	0.6801
<b>cf</b>	0.2161
<b>hr</b>	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



# SH 350\_Tie In

File Name: C:\Users\merojj\Documents\23558\_23559 - R2B2 Phase I and II\SH 350\SH 350\_Tie In.dgpx



## Layer 4 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: 3)

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

### Resilient Modulus (psi)

7247.0
--------

<b>Use Correction factor for NDT modulus?</b>	-
<b>NDT Correction Factor:</b>	-

### 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 1	
User defined field 2	
User defined field 3	
Revision Number	5

### Sieve

<b>Liquid Limit</b>	33.0
<b>Plasticity Index</b>	16.0
<b>Is layer compacted?</b>	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
Water Content (%)	False	17.1

### User-defined Soil Water Characteristic Curve (SWCC)

<b>Is User Defined?</b>	False
<b>af</b>	108.4091
<b>bf</b>	0.6801
<b>cf</b>	0.2161
<b>hr</b>	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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\epsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$ $C = 10^M$ $M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k1: 0.007566
	k2: 3.9492
	k3: 1.281
	Bf1: 130.3674
	Bf2: 1
	Bf3: 1.217799

### AC Rutting

$\frac{\epsilon_p}{\epsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3} B_{r3}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$ $C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$ <p>Where:  <math>H_{ac}</math> = total AC thickness(in)</p>	$\epsilon_p$ = plastic strain(in/in) $\epsilon_r$ = resilient strain(in/in) $T$ = layer temperature(°F) $N$ = number of load repetitions
AC Rutting Standard Deviation	0.1414 * Pow(RUT,0.25) + 0.001
AC Layer	K1:-3.35412 K2:1.5606 K3:0.3791 Br1:4.3 Br2:1 Br3:1

### Thermal Fracture

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma}\right)$ $\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f$ = observed amount of thermal cracking(ft/500ft) $k$ = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() $\sigma$ = standard deviation of the log of the depth of cracks in the pavements $C$ = 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 2 K: 0.5	
Level 3 K: 1.5	

### 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: 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 $		$\delta_a$ = permanent deformation for the layer $N$ = number of repetitions $\varepsilon_v$ = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties $\varepsilon_r$ = resilient strain(in/in)	
Granular		Fine	
k1: 2.03	Bs1: 0.22	k1: 1.35	Bs1: 0.37
Standard Deviation (BASERUT) 0.0104 * Pow(BASERUT,0.67) + 0.001		Standard Deviation (BASERUT) 0.0663 * Pow(SUBRUT,0.5) + 0.001	

AC Cracking			
AC Top Down Cracking		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: 0.021	c2: 2.35	c3: 6000	
AC Cracking Top Standard Deviation		AC Cracking Bottom Standard Deviation	
200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))		1+15/(1+exp(-3.1472-4.1349*LOG10(BOTTOM+0.0001)))	

CSM Cracking				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: 0	C2: 75	C3: 5	C4: 3	C1: 50	C2: 0.55	C3: 0.0111	C4: 0.02
CSM Standard Deviation							
CTB*11							

## Reflective Cracking

$$\Delta C = k_1 \Delta_{\text{bending}} + k_2 \Delta_{\text{shearing}} + k_3 \Delta_{\text{thermal}}$$

$$\Delta D = \frac{C_1 k_1 \Delta_{\text{bending}} + C_2 k_2 \Delta_{\text{shearing}} + C_3 k_3 \Delta_{\text{thermal}}}{h_{OL}}$$

$$\Delta_{\text{Bending}} = A(\text{SIF})_B^n$$

$$\Delta_{\text{Shearing}} = A(\text{SIF})_S^n$$

$$\Delta_{\text{Thermal}} = A(\text{SIF})_T^n$$

$$D = \sum_{i=1}^N \Delta D$$

$$\text{RCR} = \left( \frac{100}{C_4 + e^{C_5 \log D}} \right) * \text{EX\_CRK}$$

Where

- $\Delta C$  = Crack length increment, in
- $\Delta D$  = Incremental damage ratio
- $k_1, k_2, k_3, C_1, C_2, C_3, C_4, C_5$  = Calibration factors (local and global)
- $\Delta_{\text{bending}}, \Delta_{\text{shearing}}, \Delta_{\text{thermal}}$  = Crack length increments caused by bending, shearing, and thermal loading
- $A, n$  = HMA material fracture properties
- $N$  = Total number of days
- $(\text{SIF})_B, (\text{SIF})_S, (\text{SIF})_T$  = Stress intensity factors caused by bending, shearing, and thermal loading
- $D$  = Damage ratio
- $h_{OL}$  = Overlay thickness, in
- $\text{RCR}$  = Cracks in the underlying layers reflected, %
- $\text{EX\_CRK}$  = Transverse cracking in underlying pavement layers, ft/mile (transverse cracking)  
Alligator cracking in underlying pavement layers, % lane area (alligator cracking)

Pavement Type	Distress Type	k1	k2	k3	C1	C2	C3	C4	C5	Standard Deviation
AC over AC	Transverse	0.012	0.005	1	3.22	25.7	0.1	133.4	-72.4	70.98 * Pow (TRANSVERSE,0.2 994) + 30.12
AC over AC	Fatigue	0.012	0.005	1	0.38	1.66	2.72	105.4	-7.02	1.1097 * Pow (FATIGUE,0.6804) + 1.23

Preliminary Soil Survey Boring Logs  
(Provided by Yeh and Associates, Inc.)



# Legend for Symbols Used on Borehole Logs

## Sample Types



Bulk Sample of auger/odex cuttings



Rock core



Modified California Sampler (2.5 inch OD, 2.0 inch ID)



Standard Penetration Test (ASTM D1586)

## Drilling Methods



CORING



HOLLOW-STEM AUGER

## Lithology Symbols (see Boring Logs for complete descriptions)



Asphalt



Cobbles and gravel



USCS Fat/High Plasticity Clay



USCS Lean/Low Plasticity Clay



Fill with Clay as major soil



Fill with Gravel as major soil



USCS Clayey Gravel



USCS Silty, Clayey Gravel



USCS Poorly-graded Gravel



USCS Poorly-graded Gravel with Clay



Low Plasticity Gravelly Clay



USCS Silt



USCS Low Plasticity Organic silt or clay



High Plasticity Sandy Clay



Poorly-graded Sandy Gravel



Low Plasticity Sandy Clay



USCS Clayey Sand



USCS Silty Sand



USCS Poorly-graded Sand



USCS Poorly-graded Sand with Clay



Cobbles and gravel



Diorite



Gneiss



Granite



Limestone



Sandstone



Shale



Weathered Bedrock

## Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487
(Fines = % Passing #200 Sieve)	
Sand = % Passing #4 Sieve, but not passing #200 Sieve)	

## Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Collapse (ASTM D4546)
UCCS	Unconfined Compressive Strength (Soil - ASTM D2166, Rock - ASTM D7012)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

## Notes

1. Visual classifications are in general accordance with ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)".
2. "Penetration Resistance" on the Boring Logs refers to the uncorrected N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California (MC) sampler, drive depth is 12 inches, and "Penetration Resistance" refers to the sum of all blows. Where blow counts were > 50 for the 3rd increment (SPT) or 2nd increment (MC), "Penetration Resistance" combines the last and 2nd-to-last blows and lengths; for other increments with > 50 blows, the blows for the last increment are reported.
3. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.
4. "ER" for the hammer is the Reported Calibrated Energy Transfer Ratio for that specific hammer, as provided by the drilling company.















**Boring Began: 8/28/2020**

**Total Depth: 9.4 ft**

Weather Notes: Sunny, 91F

**Boring Completed: 8/28/2020**

Ground Elevation: 4577.75

Inclination from Horiz.: Vertical

Drilling Method(s): Coring /

Coordinates: N: 402628.5 E: 481096.6

Solid-Stem Auger

Location: US 350, southbound outside lane

Night Work:

Driller: Vine Laboratories

Logged By: B. Lykins

Drill Rig: CME 750X Buggy

Final By: J. McCall

Hammer: Automatic (hydraulic), ER: 80%

Groundwater Levels: Not Observed

Symbol	Depth	Date
-	-	-
-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							0.0 - 0.4 ft. ASPHALT (5 inches).										
				3-5	8		0.4 - 4.5 ft. Clayey GRAVEL with sand (GC), light brown to brown, moist, loose.	7.7		42.0	29.1	28.9	25	11	A-2-6 (0) GC		
4575	5			9-21	30		4.5 - 9.0 ft. DECOMPOSED SHALE, orange-brown with gray, predominantly decomposed, hard.	10.0		6.0	17.5	76.5	39	23	A-6 (16) CL	S=1.316% Ch=0.0012%	S/C=4.1%
4570				20-40	60												
				50:5"	50:5"		9.0 - 9.4 ft. SHALE, orange-brown with gray, moderately weathered, very hard.										
							Bottom of Hole at 9.4 ft.										
4565																	
4560																	
4555																	

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20





**Boring Began: 8/28/2020**

**Total Depth: 9.9 ft**

**Weather Notes: Sunny, 85F**

**Boring Completed: 8/28/2020**

**Ground Elevation: 4579.83**

**Inclination from Horiz.: Vertical**

**Drilling Method(s): Coring /**

**Coordinates: N: 402118.1 E: 480711.2**

**Solid-Stem Auger**

**Location: US 350, northbound outside lane**

**Night Work:**

**Driller: Vine Laboratories**

**Logged By: B. Lykins**

**Drill Rig: CME 750X Buggy**

**Final By: J. McCall**

**Hammer: Automatic (hydraulic), ER: 80%**

**Groundwater Levels: Not Observed**

Symbol	Depth	Date
-	-	-
-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							0.0 - 0.3 ft. ASPHALT (4 inches).										
				6-9	15		0.3 - 3.5 ft. Silty, clayey GRAVEL with sand (GC-GM), light brown with white, moist, medium dense.	10.0		35.0	30.8	34.2	25	7	A-2-4 (0) GC-GM		
4575	5			7-12-14	26		3.5 - 9.9 ft. DECOMPOSED SHALE, orange-brown with gray, predominantly decomposed, firm to hard.										S=1.316% Ch=0.0012%
				29-50:5"	79:11"												
4570				25-50:5"	50:5"												
Bottom of Hole at 9.9 ft.																	
4565																	
4560																	
4555																	

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20

Boring Began: 8/31/2020

Total Depth: 10.0 ft

Weather Notes: Clear, 80s

Boring Completed: 8/31/2020

Ground Elevation: 4539.68

Inclination from Horiz.: Vertical

Drilling Method(s): Coring /

Coordinates: N: 407206.9 E: 484695.9

Solid-Stem Auger

Location: US 350, southbound outside lane

Night Work:

Driller: Vine Laboratories

Logged By: C. Wallace

Drill Rig: CME 750X Buggy

Hammer: Automatic (hydraulic), ER: 80%

Final By: J. McCall

Groundwater Levels: Not Observed

Symbol	-	-	-
Depth	-	-	-
Date	-	-	-

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/12/20

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							0.0 - 0.5 ft. ASPHALT (6 inches).										
				5-5	10		0.5 - 8.0 ft. Lean CLAY with sand (CL) (Fill), light gray, dry, medium stiff to stiff.										
4535	5			4-5	9			14.3		7.0	29.0	64.0	34	15	A-6 (7) CL		
				3-2-2	4												
4530	10			3-4	7		8.0 - 10.0 ft. Sandy lean CLAY (CL), brown, moist, medium stiff.										
Bottom of Hole at 10.0 ft.																	







**Boring Began: 9/1/2020**

**Total Depth: 10.0 ft**

Weather Notes: Cloudy, 50s

**Boring Completed: 9/1/2020**

Ground Elevation: 4419.97

Inclination from Horiz.: Vertical

Drilling Method(s): Coring /

Coordinates: N: 425828.8 E: 500568.5

Solid-Stem Auger

Location:

Night Work:

Driller: Vine Laboratories

Logged By: C. Wallace

Drill Rig: CME 750X Buggy

Hammer: Automatic (hydraulic), ER: %

Final By: J. McCall

Groundwater Levels: Not Observed

Symbol	Depth	Date
-	-	-
-	-	-

BORING LOG 2019 - SPT CDOT STYLE - 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/12/20

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							<b>0.0 - 0.5 ft. ASPHALT (6 inches).</b>										
				3-3	6		<b>0.5 - 4.0 ft. Lean CLAY (CL) (Fill),</b> brown, moist, medium stiff.	17.8	106.9	1.0	11.0	88.0	36	21	A-6 (18) CL	S/C=0.9%	
4415	5			2-2	4		<b>4.0 - 7.5 ft. Silty SAND (SM),</b> brown, moist, very loose, very fine to fine sand.										
				2-2	4		<b>7.5 - 9.0 ft. Lean CLAY with sand (CL),</b> brown, moist, medium stiff, calcite.										
4410	10			4-6	10		<b>9.0 - 10.0 ft. Fat CLAY with sand (CH),</b> brown, moist, stiff.										

Bottom of Hole at 10.0 ft.







**Boring Began: 8/25/2020**

**Total Depth: 10.0 ft**

**Weather Notes: Clear, 80s**

**Boring Completed: 8/25/2020**

**Ground Elevation: 4410.47**

**Inclination from Horiz.: Vertical**

**Drilling Method(s): Coring /**

**Coordinates: N: 429926.2 E: 504691.5**

**Night Work:**

**Hollow-Stem Auger**

**Location: US 350, southbound outside lane**

**Driller: Vine Laboratories**

**Groundwater Levels: Not Observed**

**Drill Rig: CME 55 Truck**

**Logged By: C. Wallace**

**Hammer: Automatic (hydraulic), ER: 80%**

**Final By: J. McCall**

Symbol	Depth	Date
-	-	-
-	-	-

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
4410	0.0 - 0.4						0.0 - 0.4 ft. ASPHALT (4.5 inches).										
	0.4 - 1.4						0.4 - 1.4 ft. AGGREGATE BASE COURSE (12 inches).										
	1.4 - 5.0			3-5	8		1.4 - 5.0 ft. Lean CLAY with sand (CL) (Fill), light brown, moist, medium stiff.	16.5		0.0	19.1	80.9	39	22	A-6 (17) CL	S/C=0.8%	
	5.0 - 10.0			5-8	13		5.0 - 10.0 ft. Sandy lean CLAY (CL), light brown, moist, medium stiff.									S=0.041% ChI=0.0018% R-Value=13	
4405	3-4				7												
	4-4				8												
4400	Bottom of Hole at 10.0 ft.																







**Boring Began: 8/24/2020**

**Total Depth: 10.9 ft**

**Weather Notes: Clear, hot**

**Boring Completed: 8/24/2020**

**Ground Elevation: 4232.36**

**Inclination from Horiz.: Vertical**

**Drilling Method(s): Coring /**

**Coordinates: N: 475257.1 E: 551738.8**

**Hollow-Stem Auger**

**Location: US 350, northbound outside lane**

**Night Work:**

**Driller: Vine Laboratories**

**Logged By: R. Desterhouse**

**Drill Rig: CME 55 Truck**

**Hammer: Automatic (hydraulic), ER: 80%**

**Final By: J. McCall**

**Groundwater Levels: Not Observed**

Symbol	Depth	Date
-	-	-
-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							<b>0.0 - 0.7 ft. ASPHALT (8 inches).</b>										
4230	5			6-5	11		<b>0.7 - 7.0 ft. Lean CLAY with sand (CL) (Fill), brown, moist, very soft to stiff.</b>	9.5		6.0	22.8	71.2	32	16	A-6 (9) CL		
4225				2-0-1	1		<b>7.0 - 10.9 ft. LIMESTONE, light gray to light brown, slightly weathered, medium hard to very hard.</b>										
				31-12-34	46												
	10			45-50:5"	50:5"												
Bottom of Hole at 10.9 ft.																	
4220																	
4215																	
4210																	

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/17/20



**Boring Began: 8/27/2020**

**Total Depth: 9.3 ft**

**Weather Notes: Clear, 80s**

**Boring Completed: 8/27/2020**

**Ground Elevation: 4232.35**

**Inclination from Horiz.: Vertical**

**Drilling Method(s): Coring /**

**Coordinates: N: 474816.2 E: 551394.1**

**Hollow-Stem Auger**

**Location: US 350, southbound outside lane**

**Night Work:**

**Driller: Vine Laboratories**

**Logged By: C. Wallace**

**Groundwater Levels: Not Observed**

**Drill Rig: CME 55/300 Track**

**Hammer: Automatic (hydraulic), ER: 80%**

**Final By: J. McCall**

Symbol	Depth	Date
-	-	-
-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							<b>0.0 - 0.8 ft. ASPHALT</b> (10 inches).										
4230				2-3	5		<b>0.8 - 3.0 ft. Lean CLAY with sand (CL) (Fill)</b> , light brown to gray, moist, medium stiff.										
	5			3-2	5		<b>3.0 - 9.0 ft. Lean CLAY with sand (CL)</b> , light brown to light gray, moist, stiff, abundant calcite crystals, rock structure apparent (residuum).	16.5	104.5	0.0	20.1	79.9	36	21	A-6 (15) CL	S/C=0.4%	
4225				3-7	10												
				50:3"	50:3"		<b>9.0 - 9.3 ft. LIMESTONE</b> , light brown, slightly weathered, very hard. Bottom of Hole at 9.3 ft.										
4220																	
4215																	
4210																	

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/17/20



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
O-19-D-P-1	4.0	MC	18.5	109.2		2.8	97.2	32	16	16				1.7 @ 200			A-6 (15)	CL	
O-19-D-P-1/P-2	2.5	BULK	15.9		4.0	24.6	71.4	35	15	20		0.403	0.0162			12	A-6 (12)	CL	
O-19-D-P-2	7.0	MC	15.6	114.6	0.0	5.3	94.7	35	15	20				2.1 @ 200			A-6 (19)	CL	



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
N-21-C-P-1	1.0	MC	13.6	107.2	2.0	10.0	88.0	32	17	15								A-6 (12)	CL
N-21-C-P-1	4.0	MC	9.5	111.8										4 @ 200					
N-21-C-P-1/P-2	2.5	BULK	12.9		5.0	28.0	67.0	31	14	17		0.043	0.0051			18		A-6 (9)	CL
N-21-C-P-2	4.0	MC	15.3		0.0	20.0	80.0	35	16	19				2.1 @ 200				A-6 (14)	CL



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
N-21-F-P-1	4.0	MC	21.3	102.7		13.7	86.3	41	16	25				0.9 @ 200			A-7-6 (21)	CL	
N-21-F-P-1/P-2	2.5	BULK	15.8		10.0	21.5	68.5	36	14	22		0.731	0.0029			10	A-6 (12)	CL	
N-21-F-P-2	4.0	MC	19.4	105.5	0.0	1.3	98.7	38	16	22				2 @ 200			A-6 (22)	CL	



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-C-P-1	1.0	MC	7.7	123.0	42.0	29.1	28.9	25	14	11								A-2-6 (0)	GC
M-21-C-P-1	2.5	BULK									1.316	0.0012							
M-21-C-P-1	4.0	MC	10	122.9	6.0	17.5	76.5	39	16	23				4.1 @ 200				A-6 (16)	CL
M-21-C-P-1/P-2	2.5	BULK	7.4		17.0	46.1	36.9	25	13	12	1.316	0.0012				20		A-6 (1)	SC
M-21-C-P-2	1.0	MC	10	118.7	35.0	30.8	34.2	25	18	7								A-2-4 (0)	GC-GM
M-21-C-P-2	2.5	BULK									1.316	0.0012							



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-B-P-1	4.0	MC	14.3		7.0	29.0	64.0	34	19	15								A-6 (7)	CL
M-21-B-P-1/P-2	2.5	BULK	12		14.0	31.0	55.0	28	15	13		1.122	0.0024			16		A-6 (4)	CL
M-21-B-P-2	4.0	MC	5.1	108.0	6.0	25.0	69.0	33	15	18				0.5 @ 200				A-6 (10)	CL





## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-I-P-1	4.0	MC	11.6	116.8		13.0	87.0	33	13	20				3.5 @ 200			A-6 (16)	CL	
M-21-I-P-1	7.0	MC	11.6	116.8	0.0	5.0	95.0	45	17	28							A-7-6 (28)	CL	
M-21-I-P-1/P-2	2.5	BULK	11.3		13.0	27.0	60.0	34	14	20		0.053	0.0029			11	A-6 (9)	CL	
M-21-I-P-2	1.0	MC	17.8	106.9	1.0	11.0	88.0	36	15	21				0.9 @ 200			A-6 (18)	CL	



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-J-P-1	2.5	BULK									0.168	0.0012							
M-21-J-P-1	4.0	MC	19.4	106.3	2.0	2.6	95.4	40	17	23				0.5 @ 200			A-6 (22)	CL	
M-21-J-P-1/P-2	2.5	BULK	18.3		2.0	9.9	88.1	39	15	24	0.168	0.0012			11		A-6 (21)	CL	
M-21-J-P-2	1.0	MC	21.2	99.6	0.0	6.7	93.3	36	15	21				0.4 @ 200			A-6 (19)	CL	
M-21-J-P-2	2.5	BULK									0.168	0.0012							



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-22-Y-P-1	1.0	MC	16.5	110.2	0.0	19.1	80.9	39	17	22				0.8 @ 200			A-6 (17)	CL	
M-22-Y-P-1/P-2	2.5	BULK	10.9		16.0	24.4	59.6	31	14	17		0.041	0.0018			13	A-6 (7)	CL	
M-22-Y-P-2	4.0	MC	18.6	108.2	0.0	1.9	98.1	41	17	24				1.9 @ 200			A-7-6 (25)	CL	



## Summary of Laboratory Test Results

Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-16-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-22-U P-1/P-2	2.5	BULK	13.8		7.0	30.0	63.0	36	14	22		1.534	0.0026			15	A-6 (11)	CL	
M-22-U-P-1	2.0	BULK	9.5		6.0	22.8	71.2	32	16	16							A-6 (9)	CL	
M-22-U-P-2	4.0	MC	16.5	104.5	0.0	20.1	79.9	36	15	21				0.4 @ 200			A-6 (15)	CL	