Documenting
Performance Related Specifications
Shadow Projects

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Outline

- Background on FHWA Performance Related Specifications Contract and Shadow Projects
- Audience for the Shadow Project Reports
- Outline for the Shadow Project Reports
- Content of Selected Sections

Develop and Deploy Performance-Related Specifications (PRS) for Pavement Construction

FHWA DTFH61-13-C-00025

U.S. Department of Transportation
Federal Highway Administration

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Jason Weiss (rigid)

Objective and Scope

- Further the advancement and deployment of PRS for pavements
  - Viable option for use during pavement construction
  - Agencies can confidently use them for acceptance purposes for a wide variety of construction projects.
- Addresses both flexible and rigid pavements

“Someday we are going to have to raise the bar”
– Dale Decker 9/20/2017

Develop and Deploy Performance-Related Specifications (PRS) for Pavement Construction

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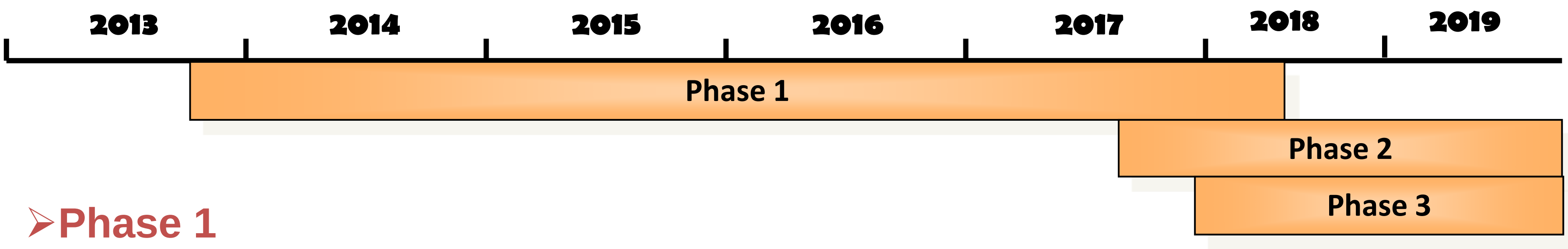


- **Phase 1**
  - **Development of PRS models and software**
    - **Asphalt and Jointed Plain Concrete Pavements**
  - **Guidelines development**
  - **Deployment projects and PRS validation**
- **Phase 2**
  - **Sensitivity analysis**
  - **Software integration**
  - **Inspection and material testing program optimization**
  - **PRS refinements**
- **Phase 3**
  - **Pay factor weighting evaluation**
  - **Risk evaluation**
  - **PRS final refinements**

What Are Shadow PRS Projects?

- Paving projects selected by the participating agency
  - Data for PRS are being collected in addition to the agency's normal acceptance data
- Shadow Project Benefits
  - Training in PRS testing and analysis
  - Demonstrates how would project have been accepted, if PRS were used
  - Understand ways that PRS may impact normal testing and acceptance operations
  - Collect data for PRS improvement

Shadow PRS Status

- Maryland SHA – Underway (10 projects)
- Maine DOT – Underway
- Missouri DOT – Underway (3 projects)
- Ontario MOT – Underway
- Western Federal Lands – 1st Project Complete, 2nd in 2018

Shadow Project Report Audience

- Agency and contractor personnel responsible for PRS implementation
  - Experienced engineers
    - Construction
    - Specifications
    - Asphalt Materials
    - Testing
    - Pavement design
  - Probably not familiar with viscoelastic continuum damage theory

Shadow Project Report Outline

- Introduction
  - Benefits of using PRS
  - Available assistance
- Overview of PRS for Asphalt
  - Supporting software
  - Concise description of the major steps
- Project description
- Performance volumetric relationships and life differences
- PRS pay tables
- Acceptance data and payment
  - PRS compared to agency practice
- Lessons Learned

Steps in PRS for Asphalt

Preliminary Research

- Step 1: Material database development

PRS Project

- Step 2: Pavement design
- Step 3: Predict pavement life for various mix volumetric conditions
- Step 4: Develop pay tables
- Step 5: Write the PRS specification
- Step 6: Send the contract out for bid and award
- Step 7: Mix design and approval*
- Step 8: Construction: monitoring through AQC's
- Step 9: Pay based on pay tables

Step 1 Material Database Example

NCDOT Superpave Mixtures

Layer Type	Mix Type	Loading Range (Million ESALs)	% Asphalt Binder	Asphalt Binder PG Grade
Surface	**S9.5A**	Less than 0.3	6.5	PG 64-22
	S9.5B	Less than 3	6.5	PG 64-22
	S9.5C	3 to 10	6.5	PG 70-22
	S12.5B	Less than 3	5.5	PG 64-22
	S12.5C	3 to 30	5.5	PG 70-22
	S12.5D	Over 30	5.5	PG 76-22
Intermediate	**I19.0B**	Less than 3	4.7	PG 64-22
	I19.0C	3 to 30	4.7	PG 64-22
	I19.0D	Over 30	4.7	PG 70-22
Base	**B25.0B**	Less than 3	4.3	PG 64-22
	B25.0C	3 or Greater	4.3	PG 64-22
	B37.5C	3 or Greater	4.3	PG 64-22

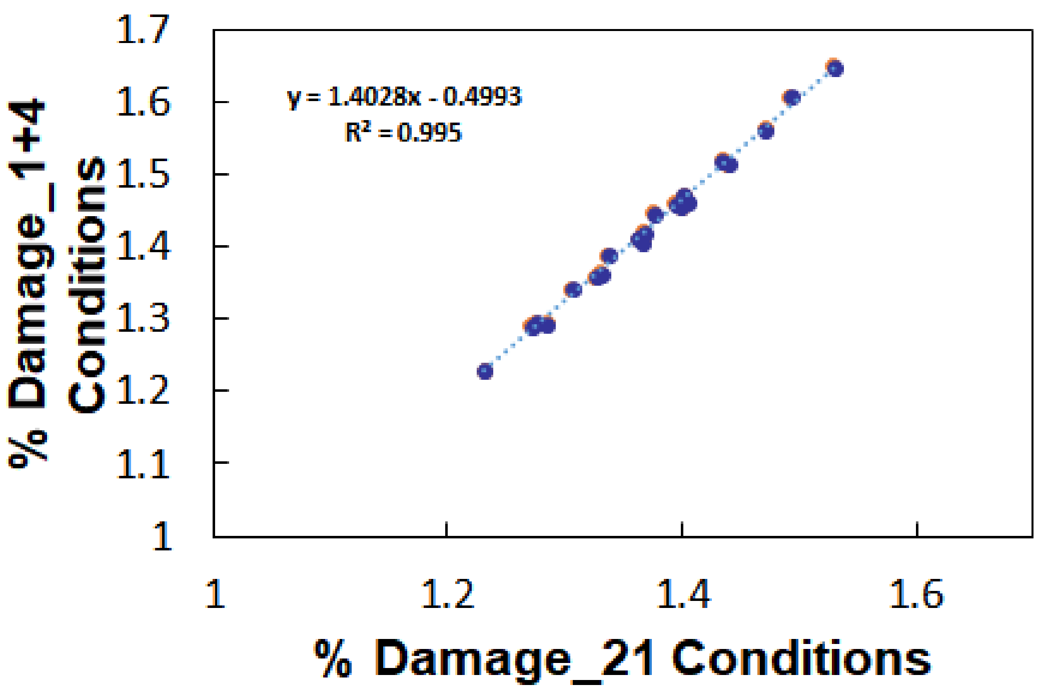
Step 1 Material Database Example

- Select a typical mix or two in each mixture classification
- Conduct AMPT performance tests on five volumetric conditions (mix design plus four extreme volumetric conditions)
- Store performance properties in the material database

1+4 Volumetric Conditions

Volumetrics	Cond #1	Cond #2	Cond #3	Cond #4	Cond #5
In-place VMA	Design	High	High	Low	Low
In-place VFA	Design	Low	High	Low	High

Predicting % damage for 21 different volumetric conditions from PVR calibrated by 1+4 conditions

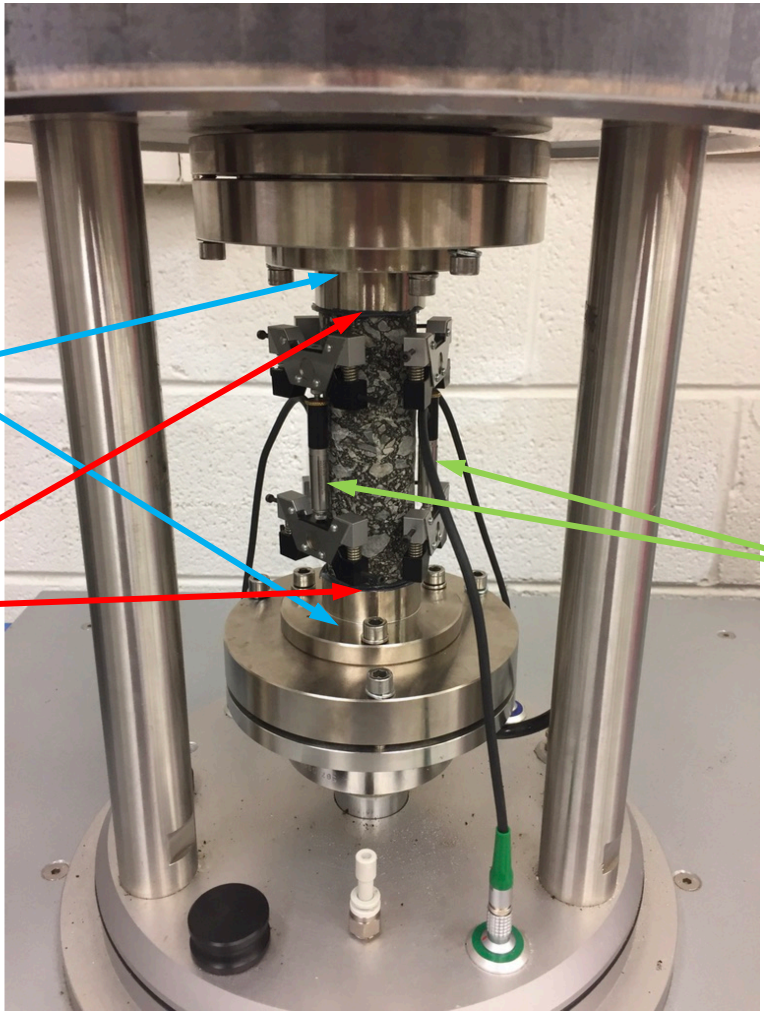


AMPT Performance Test Methods

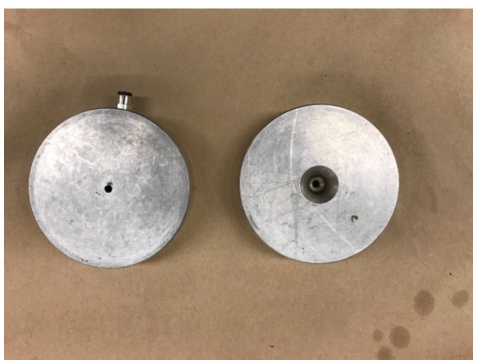
- Dynamic modulus test
  - AASHTO TP 79
- Cyclic fatigue test
  - AASHTO TP 107
- Stress sweep rutting (SSR) test
  - Draft AASHTO specification under review by the Mixture ETG

Dynamic Modulus

Cyclic Fatigue Test Setup

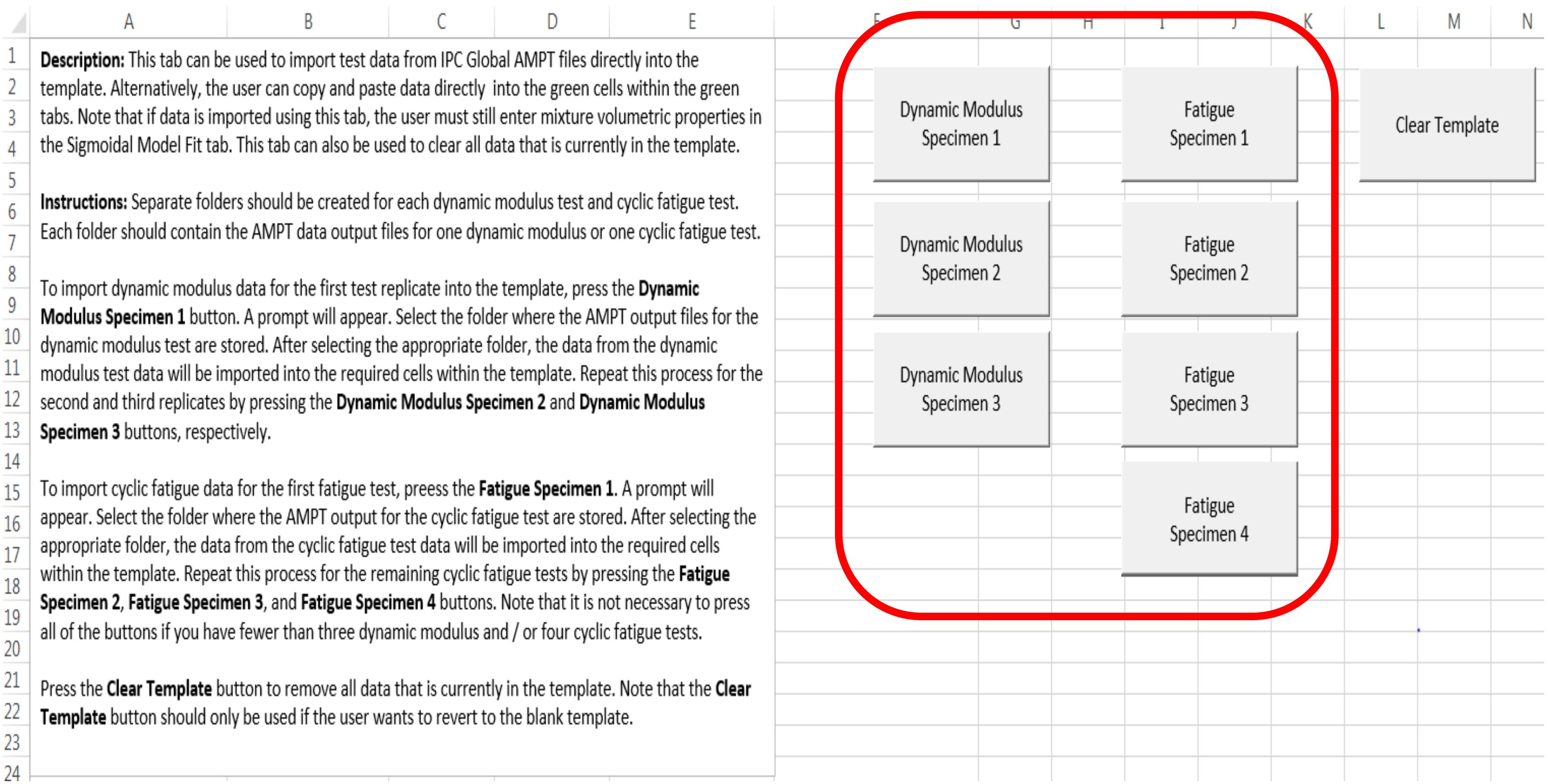


Stress Sweep Rutting Test Setup



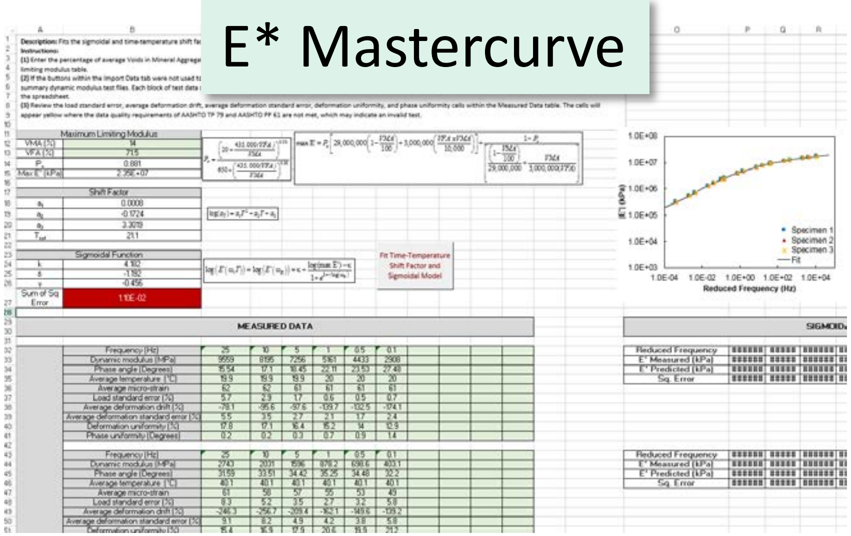
FlexMAT™ Program

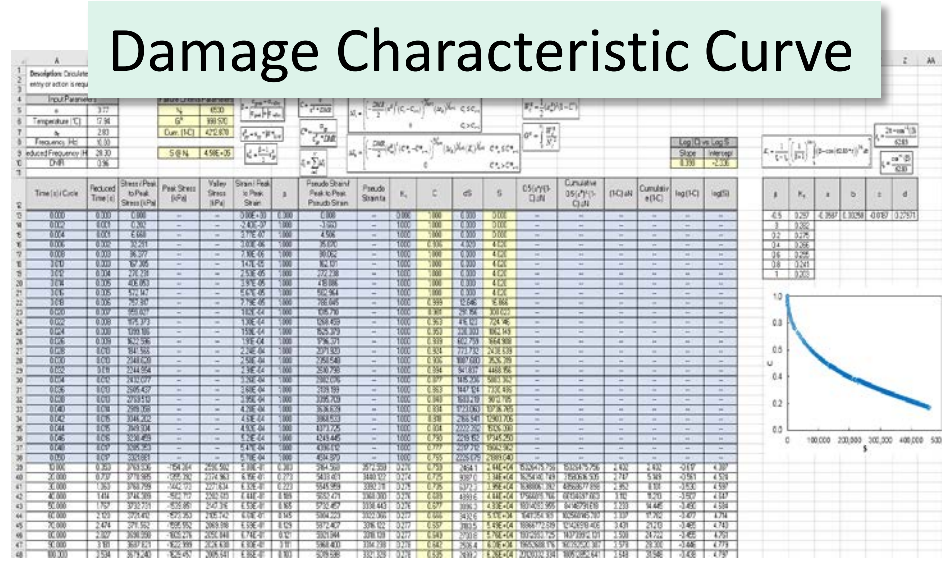
Import Data from AMPT

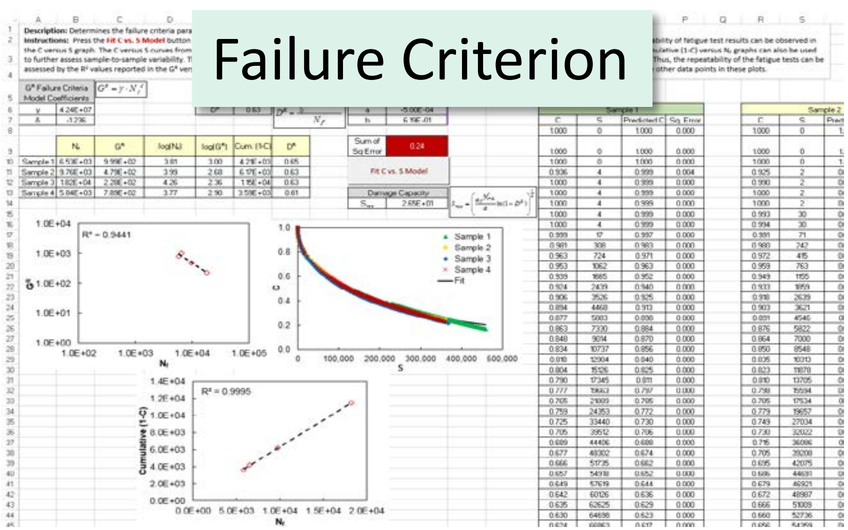


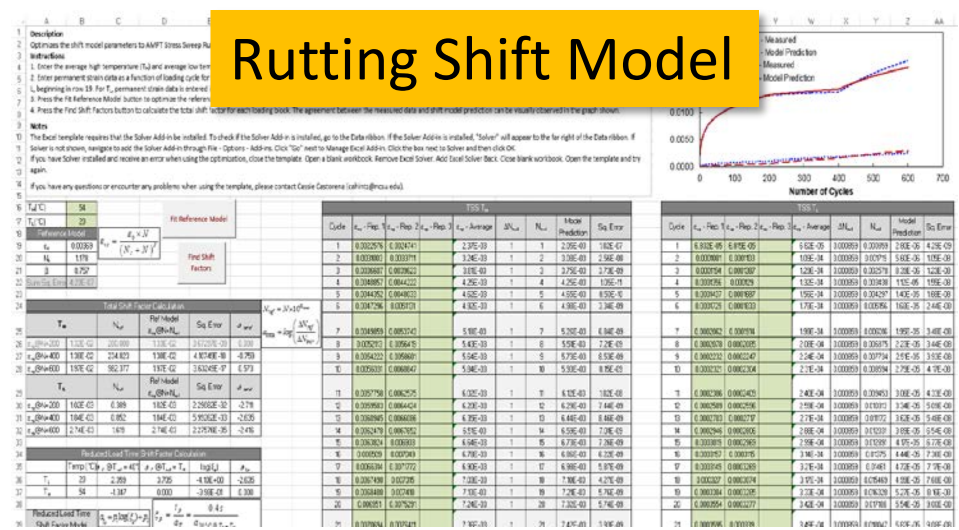
FlexMAT^{TM} Program

Analysis









FlexMAT™ Program

Export Data to FlexPAVE™

Description: Provides a summary of the linear viscoelastic and fatigue analysis results, which can be exported as input files to FlexPAVE. No data entry is required. Note that the use of this tab is optional.

Instructions: Press the **Export FlexPAVE Dynamic Modulus Inputs** button to export a dynamic modulus material input file for use in FlexPAVE. Press the **Export FlexPAVE Fatigue Inputs** button to export a fatigue material input file for use in FlexPAVE.

Linear Viscoelastic Properties	
E_∞	2.59E+04
T_{ref}	21.1
Shift Factor a_1	2.274E-03
Shift Factor a_2	-2.870E-01
Shift Factor a_3	5.044E+00
Prony Series	
Ti(s)	Ei (kPa)
2.00E+08	4.77E+03
2.00E+07	2.83E+03

$$\log(a_T) = a_1 T^2 + a_2 T + a_3$$

$$E(t) = E_\infty + \sum_{i=1}^{N} E_m e^{-t/\rho_m}$$

S-VECD Fatigue Properties	
α	3.37
C vs. S	
C_{11}	4.19E-03
C_{12}	4.10E-01
G^R Failure Criterion	
γ	2.18E+10
δ	-1.857
D^R Failure Criterion	
D^R	0.64

$$C = 1 - C_{11} \cdot S^{C_{12}}$$

$$G^R = \gamma \cdot N_f^{\delta}$$

$$D^R = \frac{\int_0^{N_f} (1-C)\,dN}{N_f}$$

$$\frac{\left(\frac{a_T^{\frac{C_{12}}{\alpha+1}}}{C_{11}} D^R \right)^{\frac{1}{C_{12}}}}{10{,}000}$$

Export FlexPAVE Dynamic Modulus Inputs

Export FlexPAVE Fatigue Inputs

Description: Provides a summary of the shift factor model coefficients, which can be exported as an input file to FlexPAVE. Not data entry is required.
Instructions: To export a FlexPAVE input file, press the **Export FlexPAVE Inputs** button.

Reference Model	
ε_0	0.00224
N_I	1.78777
β	0.76643
Reduced Load Time	
p_1	0.705
p_2	0.281
Vertical Stress Shift	
d_1	3.191
d_2	-2.782
T_{ref} (°C)	54

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N}{(N_I + N)^{\beta}}$$

$$a_{\xi_p} = p_1 \log(\xi_p) + p_2$$

$$a_{\sigma_v} = d_1 \log(\sigma_v / P_a) + d_2$$

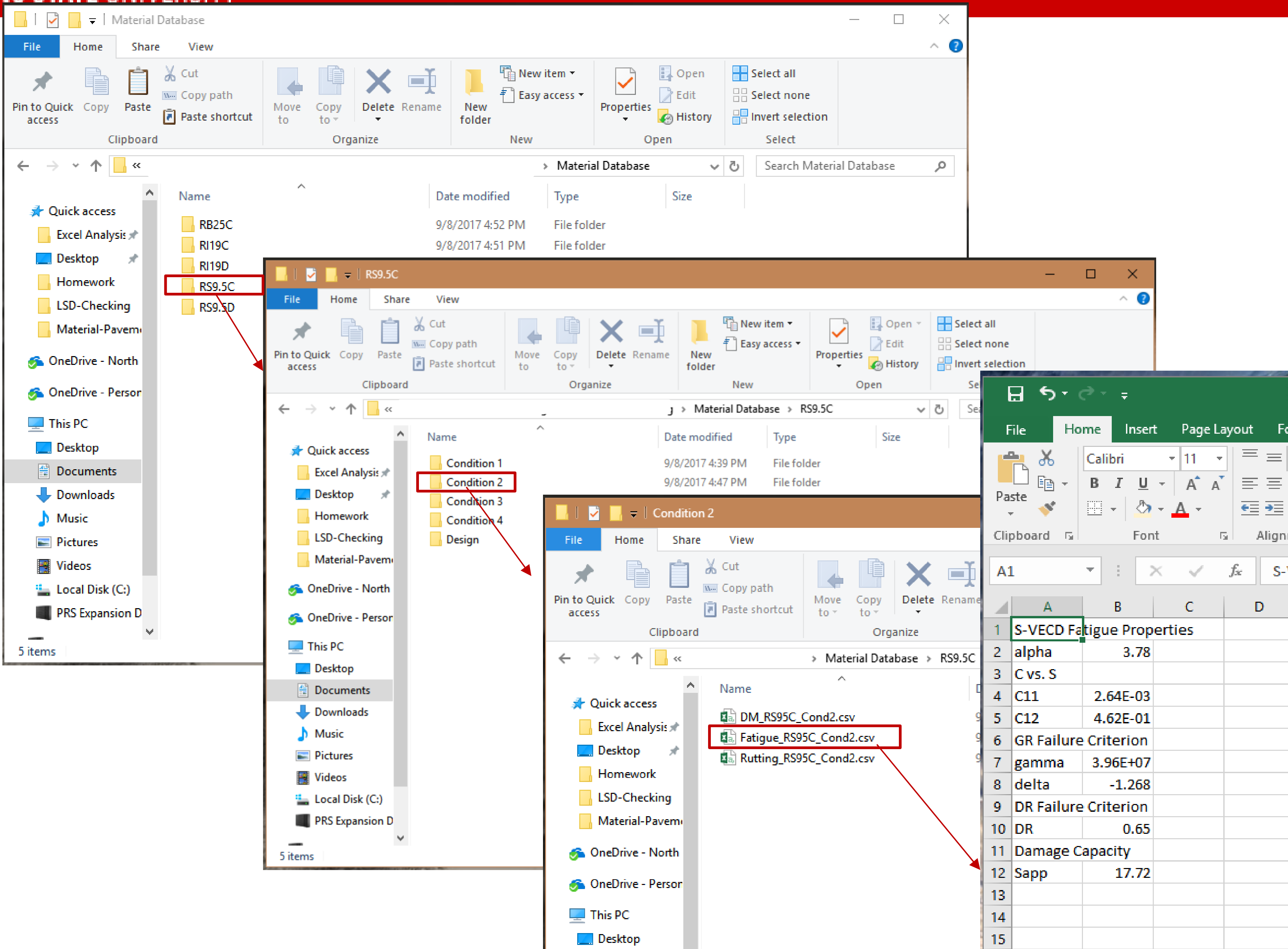
$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N_{red}}{(N_I + N_{red})^{\beta}}$$

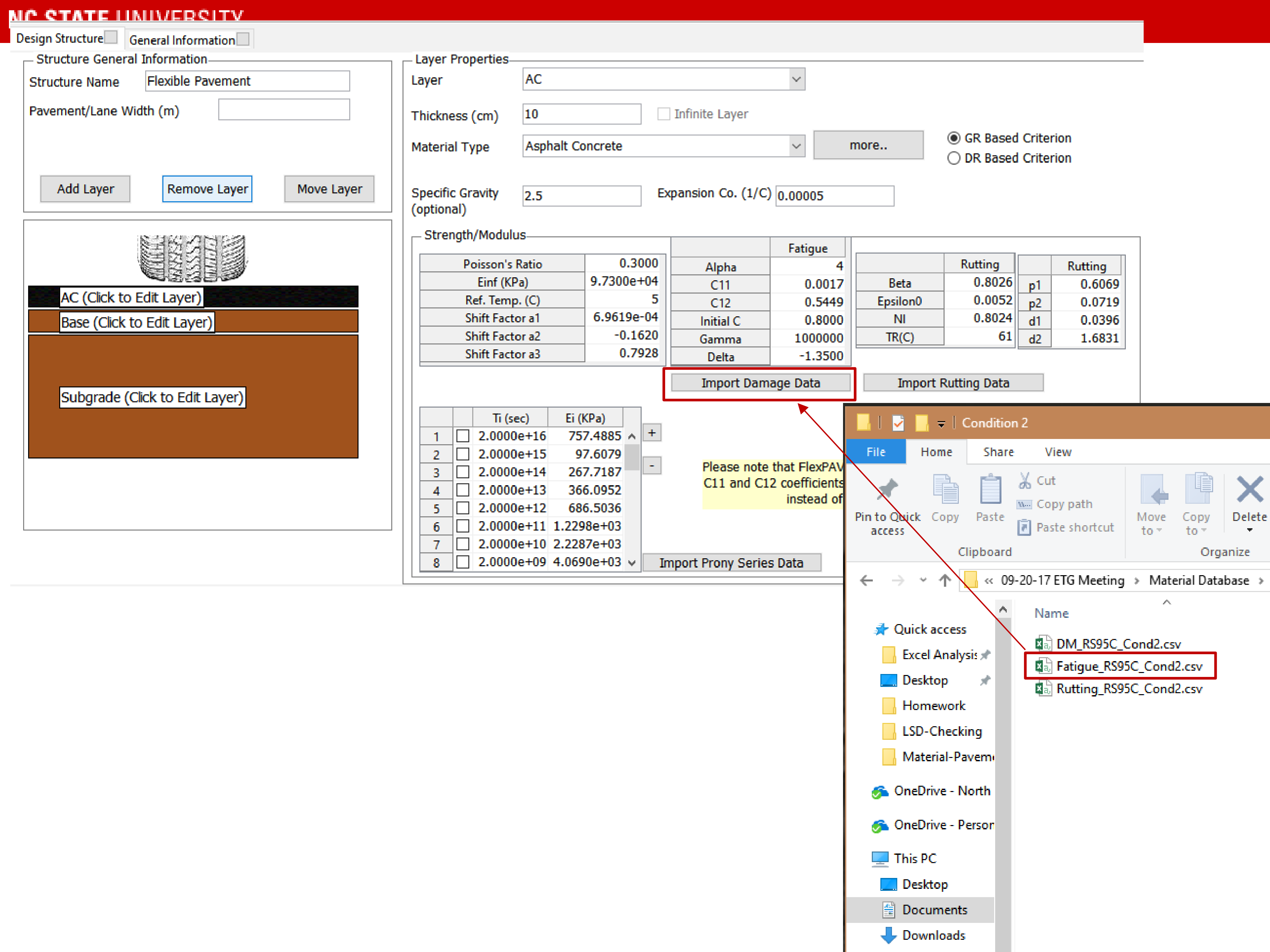
$$N_{red} = A \cdot N \left(\frac{\xi_p}{1} \right)^{p1} \left(\frac{\sigma_v}{P_a} \right)^{d1}$$

$$A = 10^{p_2} \cdot 10^{d_2}$$

Export FlexPAVE Inputs

NC STATE UNIVERSITY




NC STATE UNIVERSITY
Design Structure
General Information
Structure General Information
Structure Name
Flexible Pavement
Pavement/Lane Width (m)
Add Layer
Remove Layer
Move Layer
AC (Click to Edit Layer)
Base (Click to Edit Layer)
Subgrade (Click to Edit Layer)
Layer Properties
Layer
AC
Thickness (cm)
10
Infinite Layer
Material Type
Asphalt Concrete
more..
GR Based Criterion
DR Based Criterion
Specific Gravity (optional)
2.5
Expansion Co. (1/C)
0.00005
Strength/Modulus
Poisson's Ratio 0.3000
Einf (KPa) 9.7300e+04
Ref. Temp. (C) 5
Shift Factor a1 6.9619e-04
Shift Factor a2 -0.1620
Shift Factor a3 0.7928
Fatigue
Alpha 4
C11 0.0017
C12 0.5449
Initial C 0.8000
Gamma 1000000
Delta -1.3500
Rutting
Beta 0.8026
Epsilon0 0.0052
NI 0.8024
TR(C) 61
Rutting
p1 0.6069
p2 0.0719
d1 0.0396
d2 1.6831
Import Damage Data
Import Rutting Data
Ti (sec)
Ei (KPa)
1 2.0000e+16 757.4885
2 2.0000e+15 97.6079
3 2.0000e+14 267.7187
4 2.0000e+13 366.0952
5 2.0000e+12 686.5036
6 2.0000e+11 1.2298e+03
7 2.0000e+10 2.2287e+03
8 2.0000e+09 4.0690e+03
Import Prony Series Data
Please note that FlexPAV
C11 and C12 coefficients
instead of
Condition 2
File
Home
Share
View
Pin to Quick access
Copy
Paste
Cut
Copy path
Paste shortcut
Clipboard
Move to
Copy to
Delete
Organize
09-20-17 ETG Meeting
Material Database
Quick access
Excel Analysis
Desktop
Homework
LSD-Checking
OneDrive - North
OneDrive - Persor
This PC
Desktop
Documents
Downloads
Name
DM_RS95C_Cond2.csv
Fatigue_RS95C_Cond2.csv
Rutting_RS95C_Cond2.csv

Steps in PRS for Asphalt

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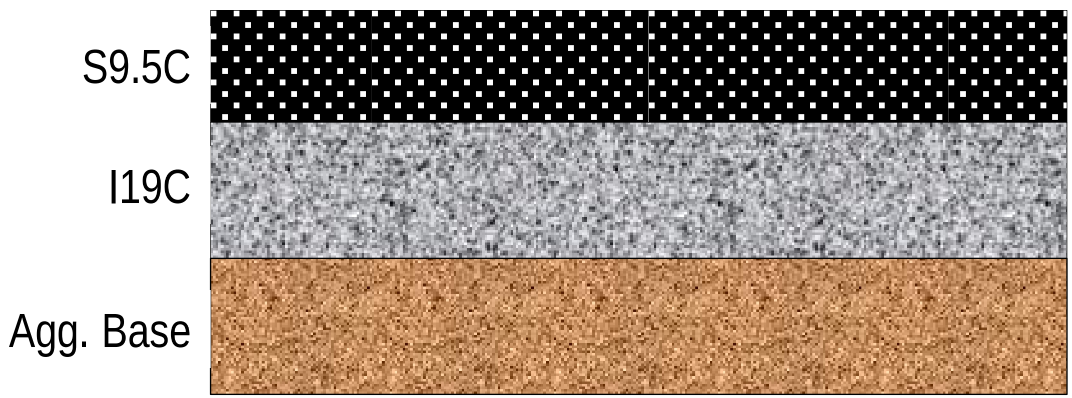
Step 2 Pavement Design

- Use current agency pavement design method

AASHTOWare Pavement ME Design

AASHTO® Guide for
Design of Pavement Structures
1993

AND MORE!



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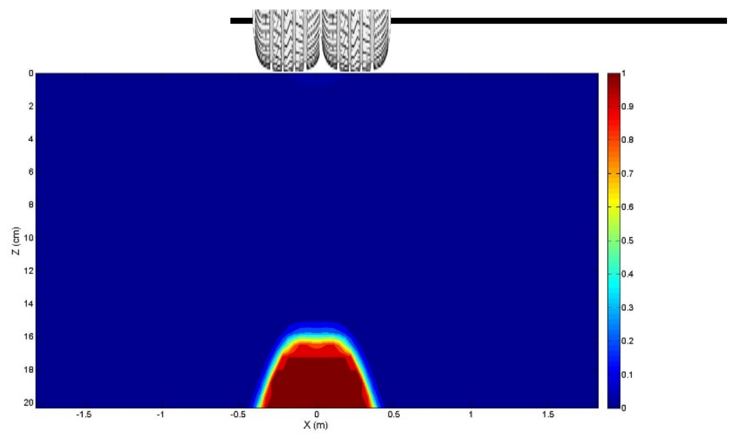
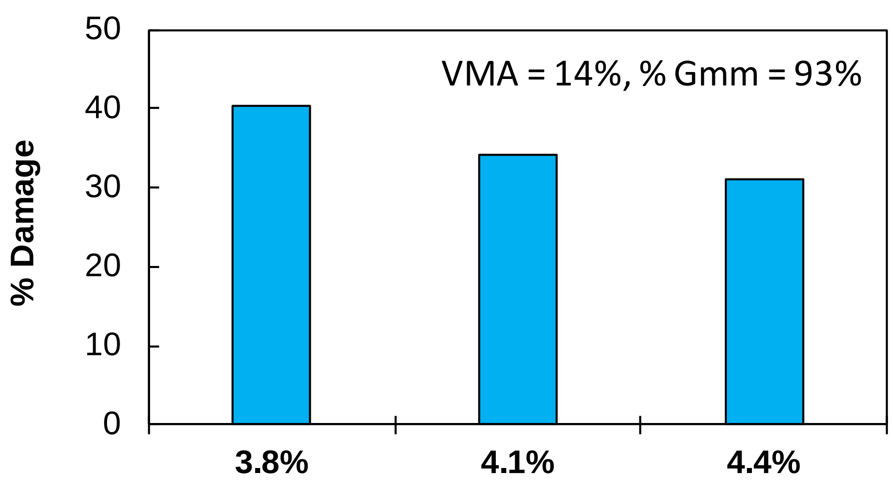
Step 3 Predict Pavement Performance for Various Volumetrics

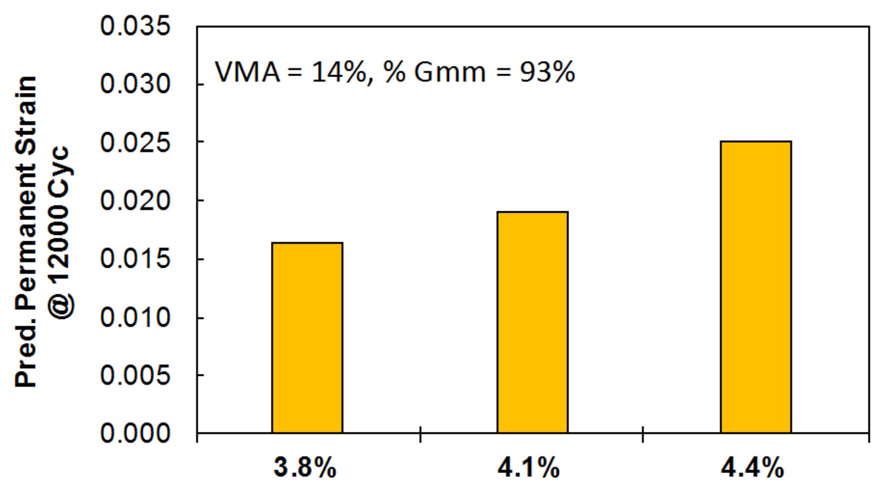
- Estimate the life of the design pavement structure via FlexPAVE™ for five volumetric conditions using performance properties in the material database
- Develop performance-volumetric relationships
- Determine life difference (i.e., as-designed vs. deviated) for a range of volumetric conditions

PASSFlex™ Software in development with a target completion date of mid 2018

Step 3 Predict Pavement Performance for Various Volumetrics







Step 3 Predict Pavement Life for Various Volumetrics

Life Change (years)*		Design VMA																			
		13	13	13	13	13	14	14	14	14	14	15	15	15	15	15	16	16	16	16	16
		Design A.V.																			
		2	3	4	5	6	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
In-Place A.V.	4	1.4	0.9	0.0	-1.8	-5.1	1.6	1.5	1.3	0.6	-0.7	1.4	1.6	1.6	1.5	1.0	1.0	1.4	1.6	1.7	1.7
	5	1.1	0.5	-0.7	-2.9	-7.1	1.3	1.3	0.9	0.1	-1.6	1.2	1.4	1.4	1.2	0.6	0.8	1.2	1.4	1.5	1.4
	6	0.7	0.0	-1.5	-4.3	-9.6	1.1	1.0	0.5	-0.6	-2.6	1.0	1.2	1.2	0.9	0.1	0.5	0.9	1.2	1.3	1.1
	7	0.3	-0.6	-2.5	-6.0	-12.8	0.8	0.6	0.0	-1.3	-3.9	0.7	0.9	0.9	0.5	-0.5	0.3	0.7	1.0	1.0	0.8
	8	-0.2	-1.4	-3.7	-8.2	-17.0	0.5	0.2	-0.6	-2.3	-5.6	0.5	0.6	0.5	0.0	-1.2	0.0	0.5	0.7	0.7	0.4
	9	-0.8	-2.3	-5.3	-11.0	-20.0	0.1	-0.3	-1.3	-3.5	-7.6	0.2	0.3	0.1	-0.6	-2.1	-0.2	0.2	0.4	0.4	-0.1
	10	-1.5	-3.4	-7.2	-14.6	-20.0	-0.3	-0.8	-2.2	-4.9	-10.2	-0.1	-0.1	-0.4	-1.3	-3.3	-0.5	0.1	0.1	-0.1	-0.7
	11	-2.3	-4.8	-9.6	-19.2	-20.0	-0.8	-1.5	-3.3	-6.7	-13.5	-0.5	-0.5	-0.9	-2.1	-4.6	-0.9	-0.5	-0.3	-0.5	-1.3
	12	-3.4	-6.5	-12.7	-20.0	-20.0	-1.3	-2.3	-4.6	-9.0	-17.7	-0.9	-1.0	-1.6	-3.2	-6.3	-1.2	-0.8	-0.7	-1.1	-2.1

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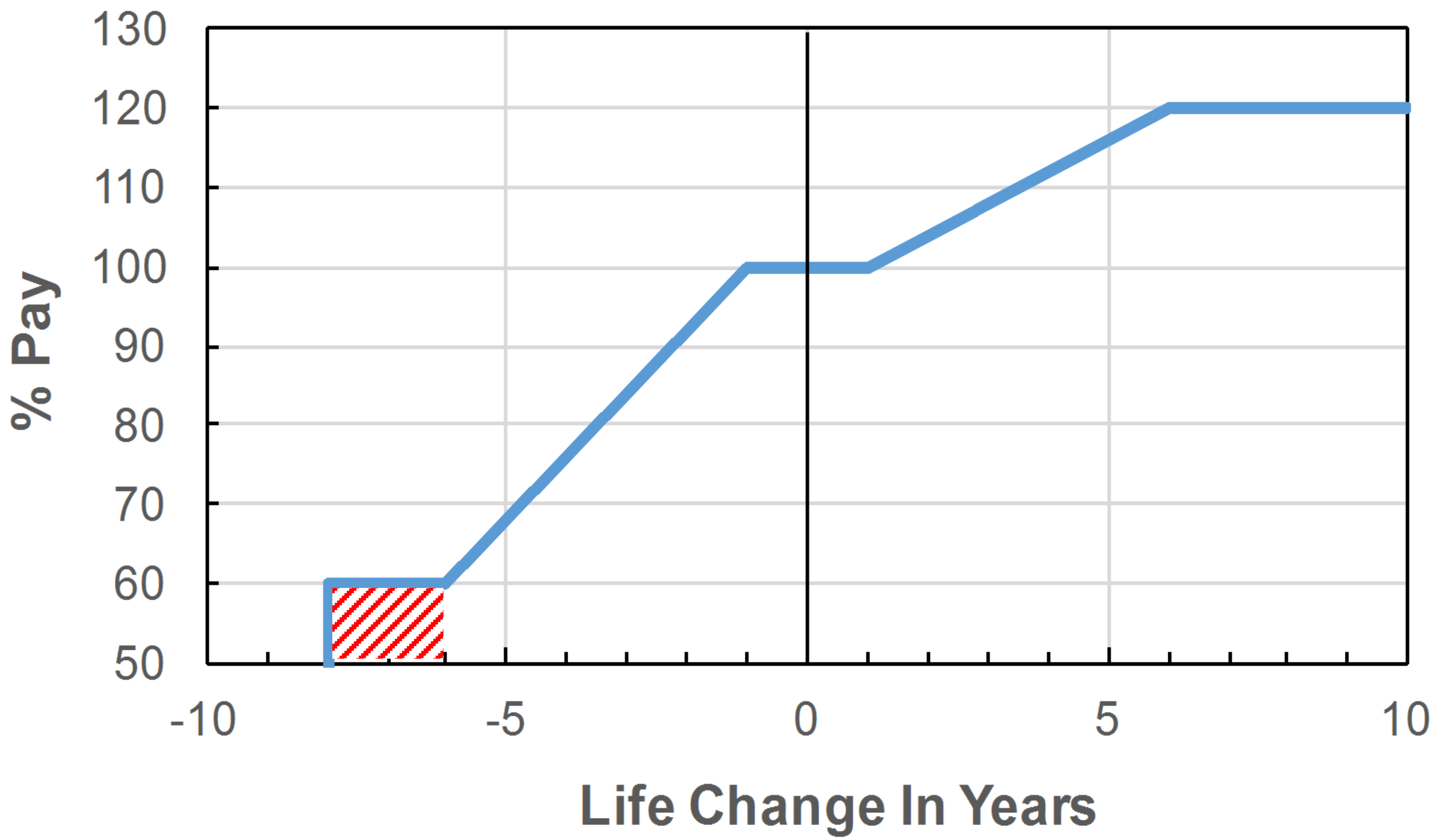
Step 4 Develop Pay Tables

Agency Specific Cost Model



Step 4 Develop Pay Tables

Pay Factor		QA VMA @ Ndes = 13%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	101.5	100.0	100.0	93.9	67.3
	5	100.3	100.0	100.0	84.9	60.0
	6	100.0	100.0	96.3	73.7	0.0
	7	100.0	100.0	88.2	60.0	0.0
	8	100.0	97.1	78.3	0.0	0.0
	9	100.0	89.8	65.9	0.0	0.0
	10	96.1	80.8	60.0	0.0	0.0
	11	89.3	69.7	0.0	0.0	0.0
	12	81.1	60.0	0.0	0.0	0.0

Pay Factor		QA VMA @ Ndes = 14%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	102.3	102.1	101.0	100.0	100.0
	5	101.4	101.1	100.0	100.0	95.5
	6	100.4	100.0	100.0	100.0	87.1
	7	100.0	100.0	100.0	97.3	76.6
	8	100.0	100.0	100.0	89.7	63.5
	9	100.0	100.0	97.5	80.3	60.0
	10	100.0	100.0	90.5	68.6	0.0
	11	100.0	95.8	81.9	60.0	0.0
	12	97.3	89.2	71.4	0.0	0.0

Pay Factor		QA VMA @ Ndes = 15%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	101.6	102.4	102.6	102.0	100.2
	5	100.8	101.6	101.7	100.8	100.0
	6	100.0	100.7	100.6	100.0	100.0
	7	100.0	100.0	100.0	100.0	100.0
	8	100.0	100.0	100.0	100.0	98.1
	9	100.0	100.0	100.0	100.0	90.9
	10	100.0	100.0	100.0	97.6	82.0
	11	100.0	100.0	100.0	90.9	70.9
	12	100.0	100.0	95.1	82.7	60.0

Pay Factor		QA VMA @ Ndes = 16%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	100.0	101.4	102.4	102.9	102.6
	5	100.0	100.6	101.6	102.0	101.6
	6	100.0	100.0	100.8	101.1	100.5
	7	100.0	100.0	100.0	100.0	100.0
	8	100.0	100.0	100.0	100.0	100.0
	9	100.0	100.0	100.0	100.0	100.0
	10	100.0	100.0	100.0	100.0	100.0
	11	100.0	100.0	100.0	100.0	97.4
	12	98.0	100.0	100.0	99.3	90.9

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Mix Design and Approval

- Two Options
  - Normal volumetric mix design based on pay tables
  - Performance Engineered Mix Design
    - ✓ Indices based on
      - Dynamic Modulus
      - Cyclic Fatigue
      - Stress Sweep Rutting Test

Questions/Discussion