PASSFlex for Integration of Asphalt Mix Design, Pavement Design, and Performance-Related Specifications

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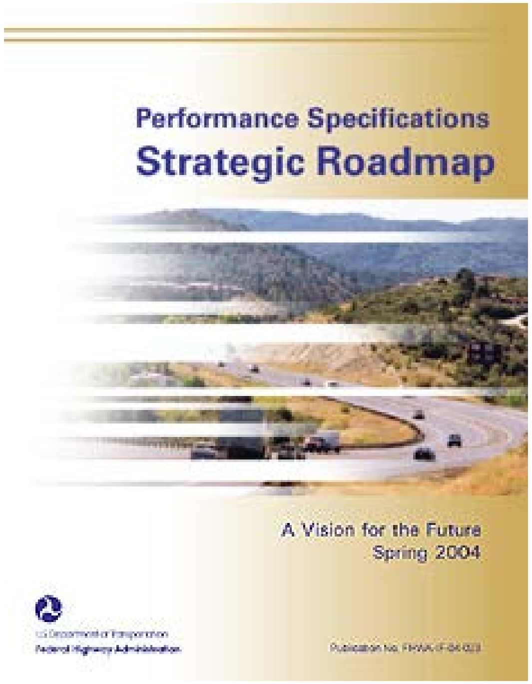
Outline

- What is PASSFlex?
- Test Methods, Models, and Software Programs
- Performance-Engineered Mix Design
- Performance-Related Specifications
- Concluding Remarks

Performance Specifications Strategic Roadmap: A Vision for the Future

Federal Highway Administration (2004)

- Vision: The performance of highway facilities will improve through **better translation of design intent and performance requirements into construction specifications.**
- Mission: To establish performance specifications as a viable contract option.
- *"**Freedom to innovate with accountability to deliver** is the driving force behind the performance specification movement."* - Ted Ferragut, TDC Partners, Ltd



What is PASSFlex?

- System of "tools" for asphalt mix design, pavement design, and performance-related specifications
  - Test methods using Asphalt Mixture Performance Tester (AMPT)
  - Mechanistic models
  - Software programs
- Based on fundamental engineering principles
  - Seamless integration of mix design, pavement design, and PRS
  - Efficient testing to cover a wide range of loading and environmental conditions

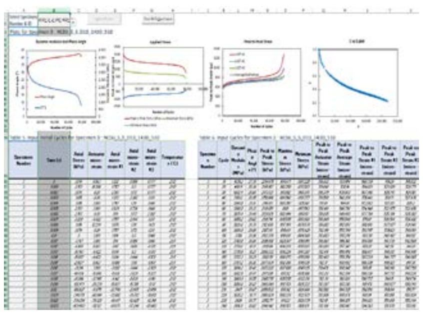
Distresses Covered

- Fatigue cracking (bottom-up and top-down)
- Thermal cracking
- Rutting
- Aging

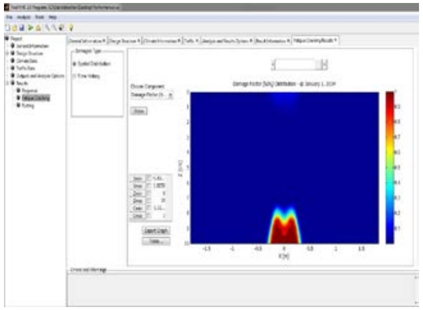
PASSFlex

AMPT → **FlexMAT^{TM}** → **FlexPAVE^{TM}** → **FlexMIX**

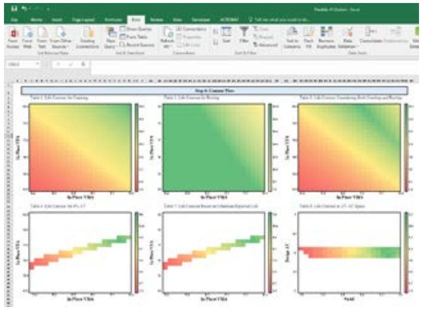
Mixture Testing System



Mixture Analysis Program



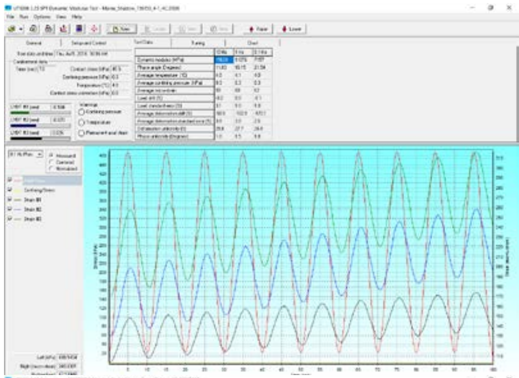
Pavement Performance Analysis Program

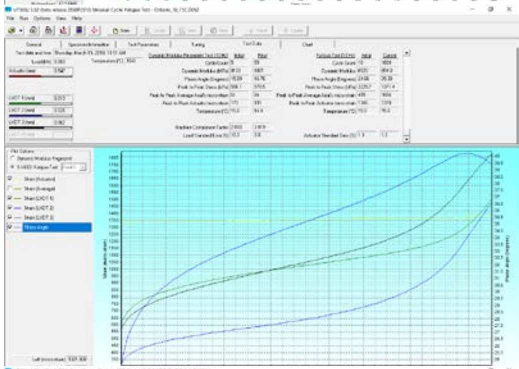


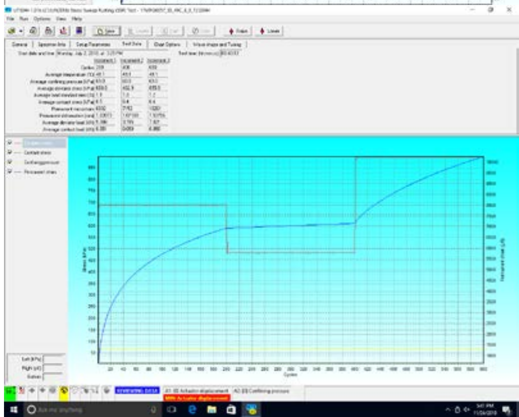
Performance Engineered Mix Design

AMPT Test Methods

Asphalt Mixture Performance Tester



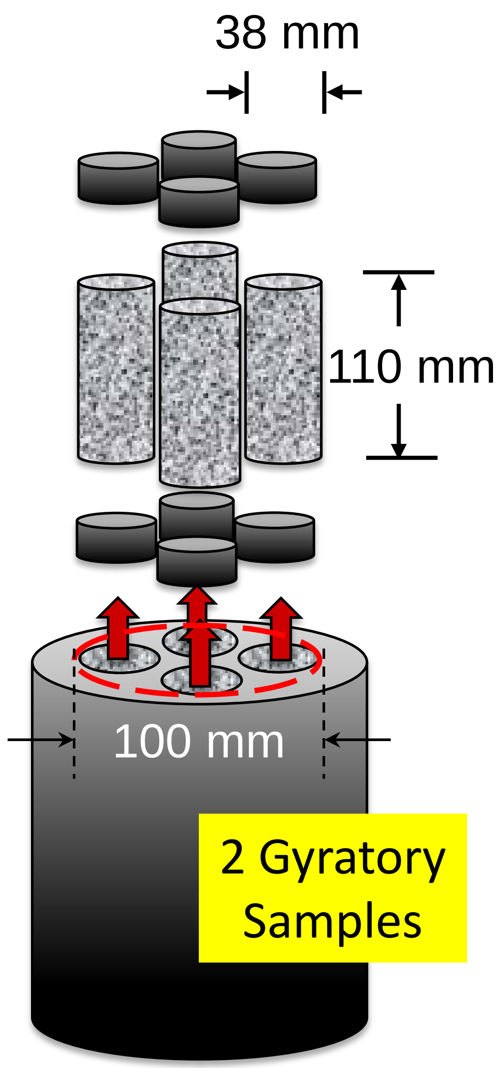




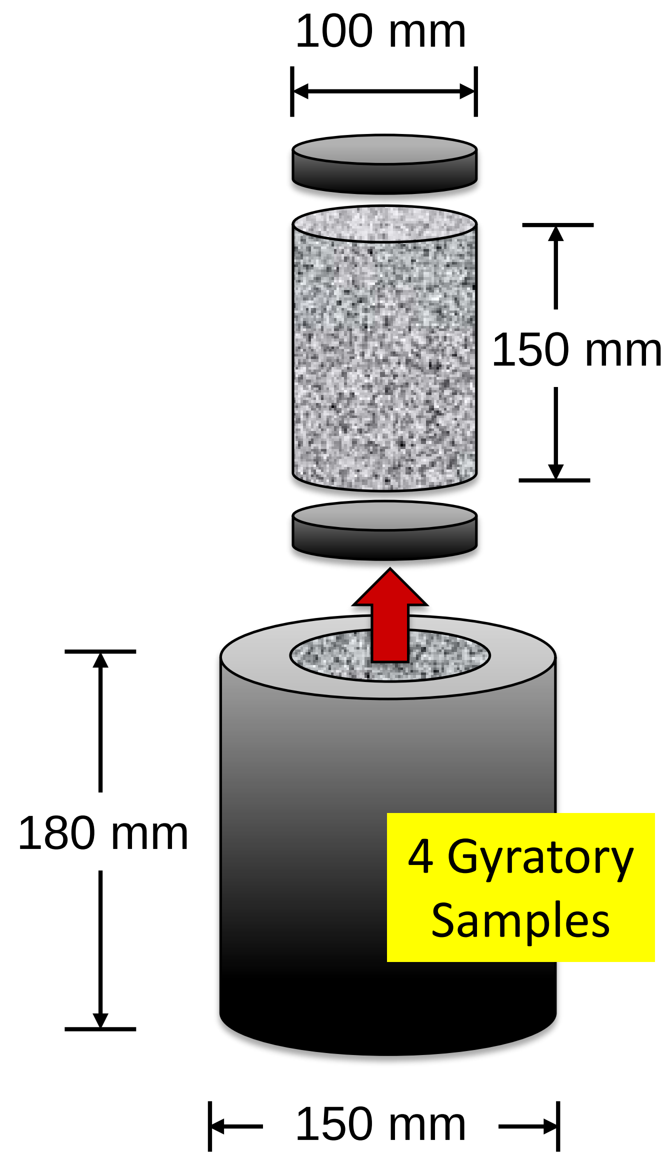
AMPT Performance Testing Suite

Test Method	AASHTO Spec.	Specimen Geometry	Material Properties	Index Parameter	Required Testing Time
Dynamic Modulus Test	PP 99/TP 132	38 mm D, 110 mm H	|E*|, phase angle, t-T shift factor	N/A	8 hrs
Cyclic Fatigue Test	PP 99/TP 133	38 mm D, 110 mm H	Damage characteristic curve, D^R failure criterion	S_{app}	5 hrs
Stress Sweep Rutting Test	TP 134	100 mm D, 150 mm H	Shift model coefficients	ATR	8 hrs

E* and Fatigue Test Specimen

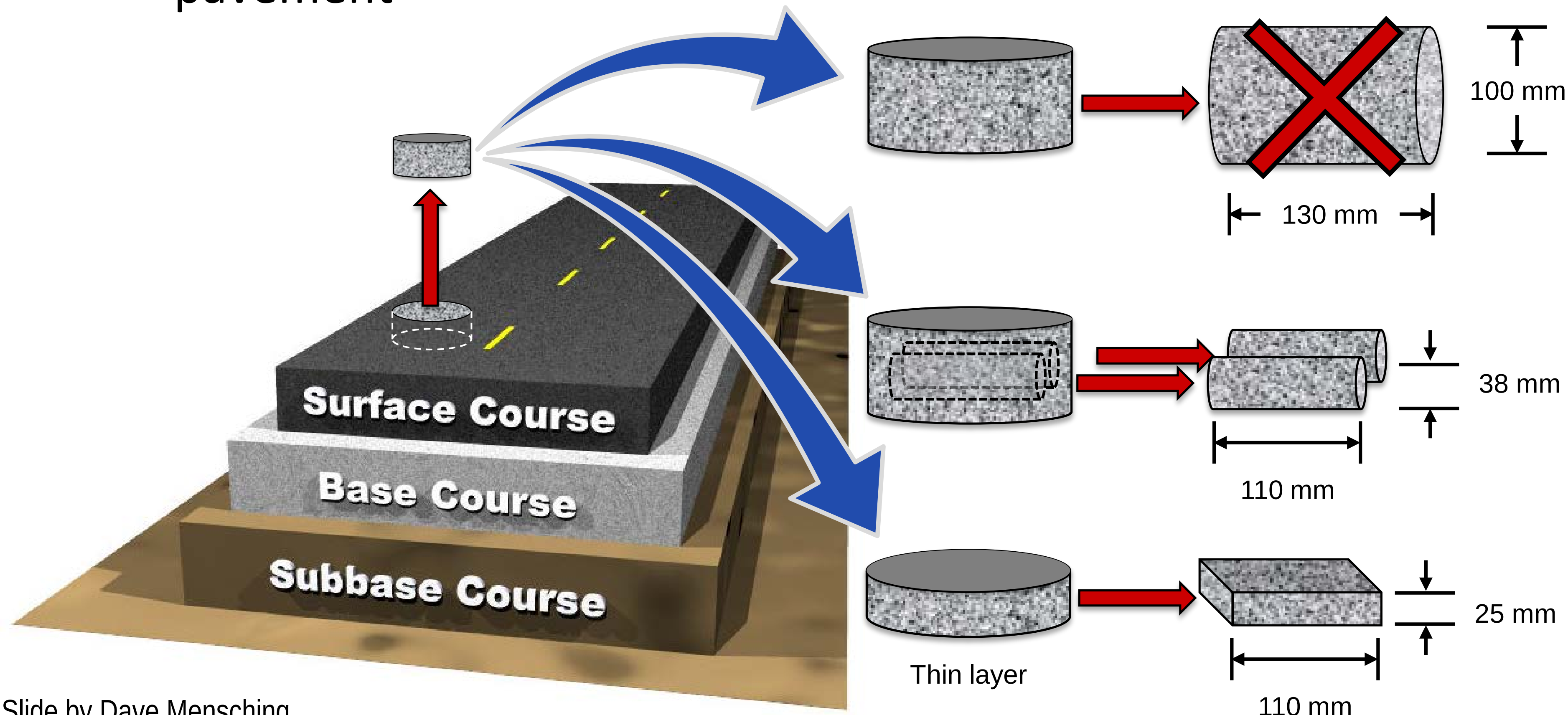


Rutting Test Specimen



38 mm Specimen from Field Cores

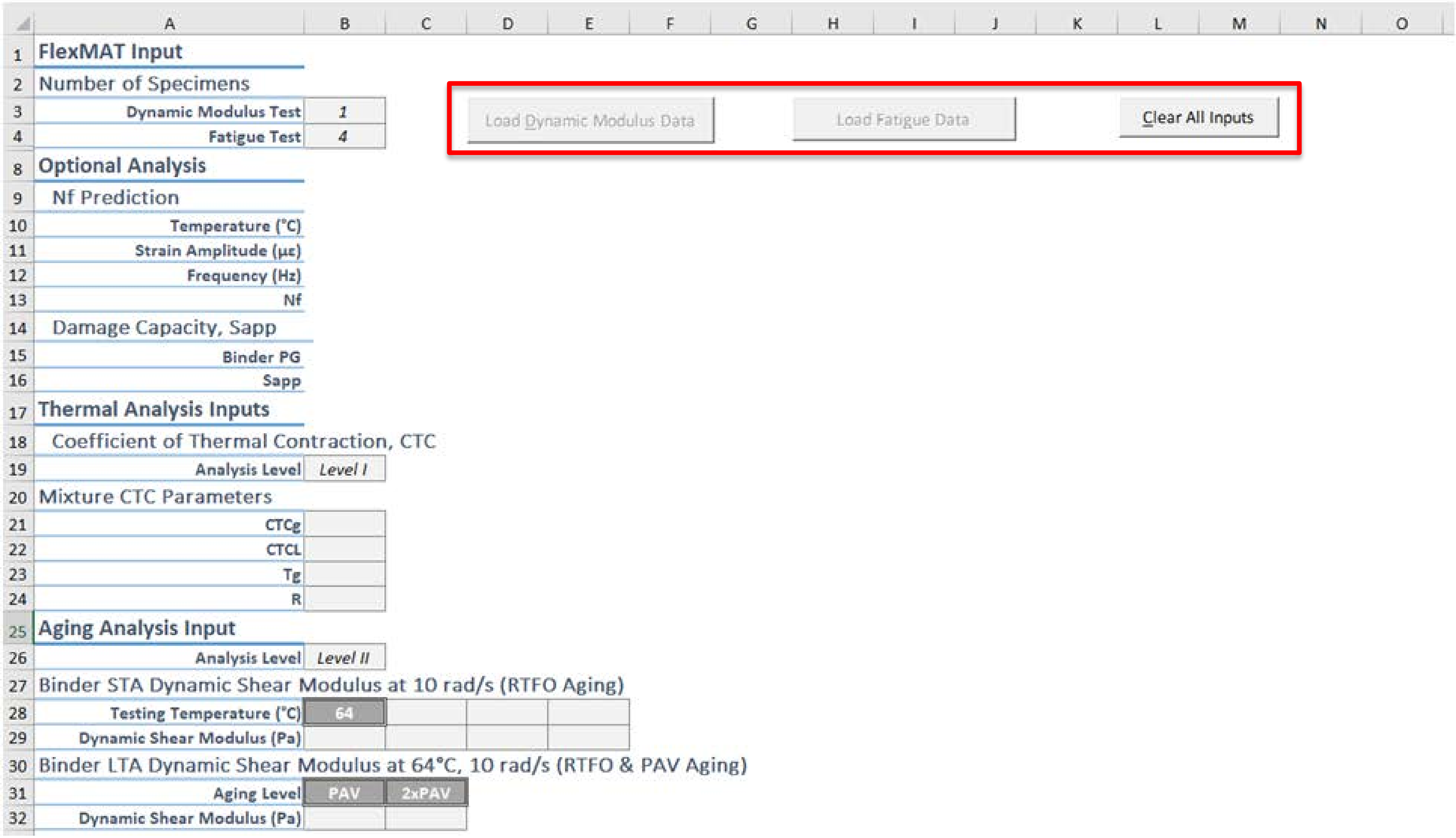
- Asphalt concrete layers are generally thinner than 100 mm
- Allow for performance testing individual layers of as-built pavement



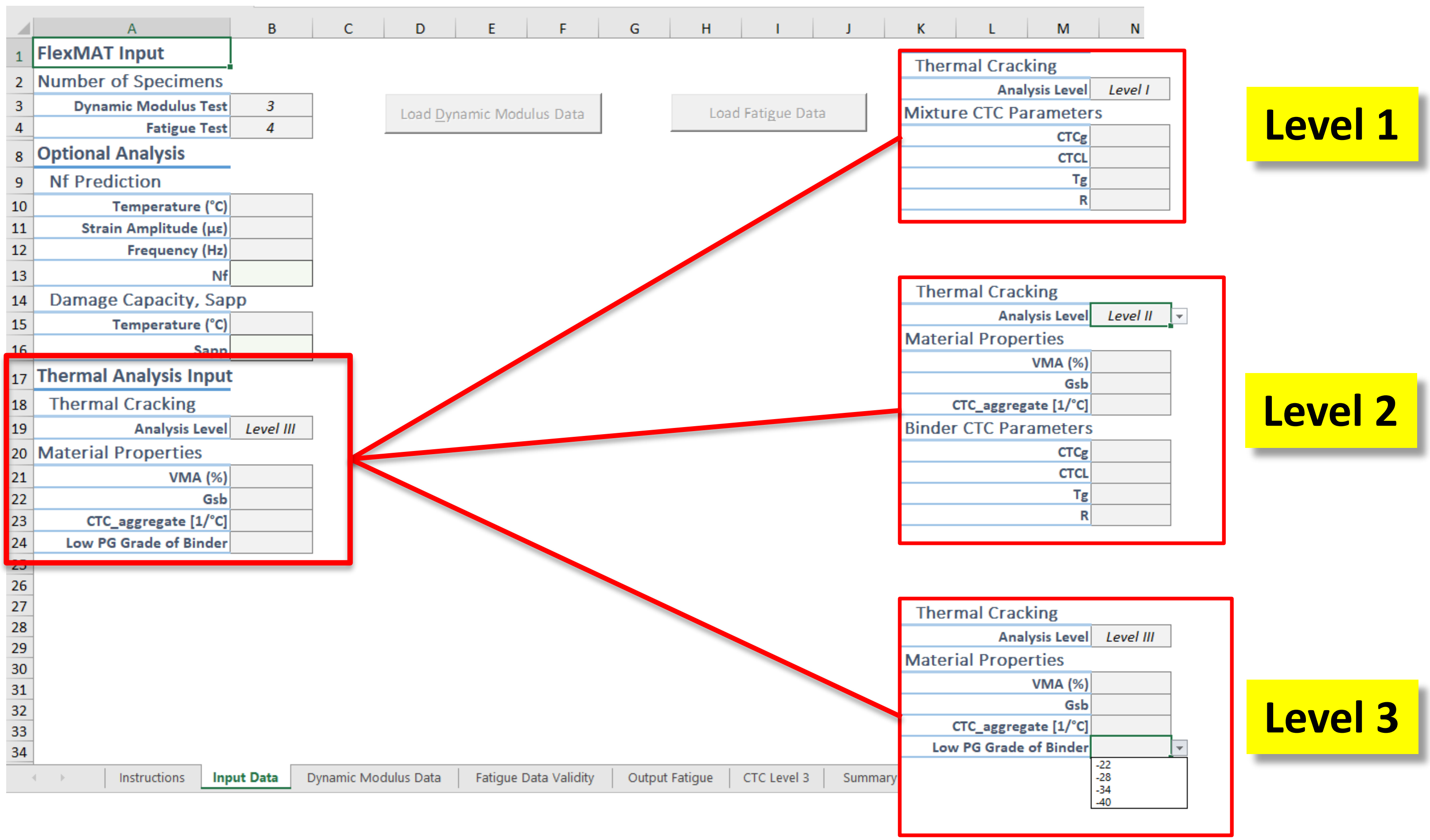
Slide by Dave Mensching

FlexMAT™

Single Click Data Loading/Clearing

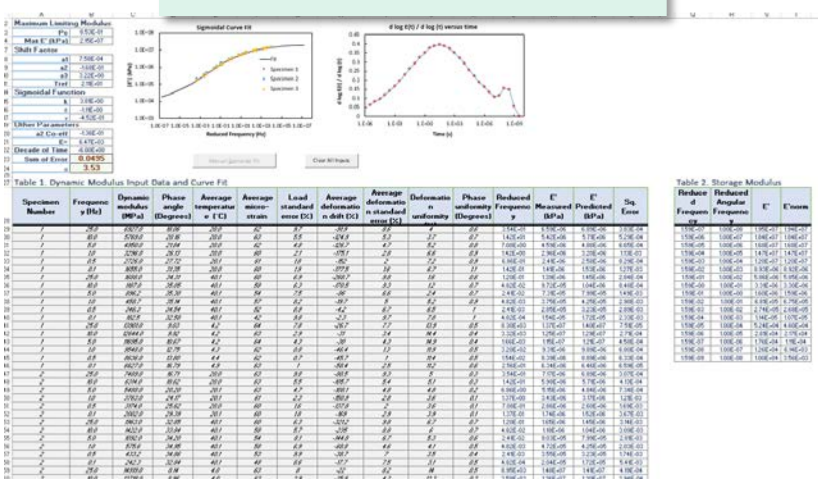


Hierarchical Input Structure

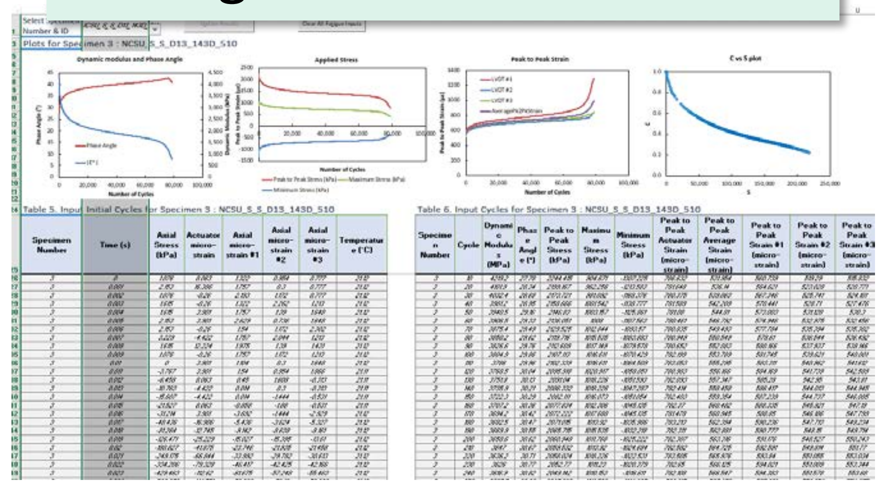


FlexMAT™ Analysis

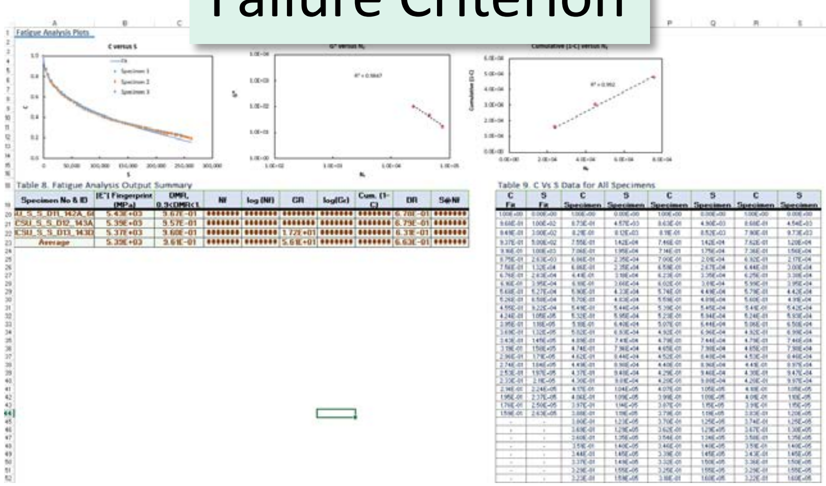
|E*| Mastercurve



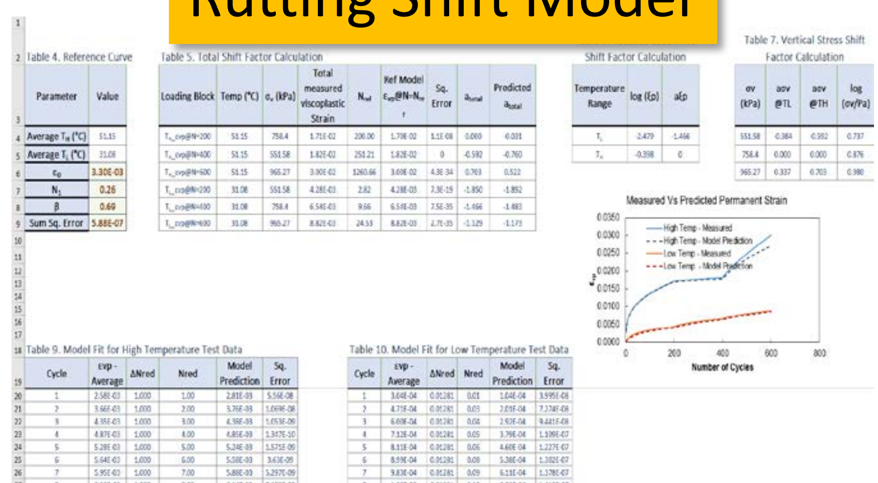
Damage Characteristic Curve



Failure Criterion



Rutting Shift Model



Analysis Summary and Outputs

FlexPAVE Dynamic Modulus Inputs

Table 15. Linear Viscoelastic Properties

E_{inf}	3.48E+04
Poisson's Ratio	0.30
T_{REF} (°C)	21.10
Shift Factor a1	1.07E-03
Shift Factor a2	-1.71E-01
Shift Factor a3	3.13E+00

Table 16. 2S2P1D coefficients

δ	1.61E+00
k	9.85E-02
h	4.07E-01
β	1.00E+12
E_{00} [MPa]	3.48E+01
E_0 [MPa]	4.00E+04
$\log(\tau_E)$	-3.17E+00

Table 18. S-VECD Properties

alpha	3.72
C11	2.63E-03
C12	4.65E-01
DR	0.59
Sapp	22.02

Table 19. Thermal Properties

CTC_g	9.23E-06
CTC_L	1.06E-05
T_g	-2.53E+01
R	4.70E+00

Table 20. Aging Properties

c	1.508
log|G*|,STA	0.37
M	0.84

Pavement ME Dynamic Modulus Data

Table 21. Pavement ME Table Size

Number of frequencies	Units	Values
6	Hz	Default
Number of Temperatures	Units	Values
8	Celsius	Default

Table 22. Dynamic Modulus (MPa)

Temperature (Celsius)	Frequency (Hz) 0.1	0.5	1	5	10	25
-30.0	2.74E+04	2.94E+04	2.99E+04	3.11E+04	3.15E+04	3.21E+04
-20.0	2.31E+04	2.48E+04	2.54E+04	2.70E+04	2.76E+04	2.83E+04
-10.0	1.73E+04	1.95E+04	2.04E+04	2.22E+04	2.30E+04	2.40E+04
4	7.83E+03	1.06E+04	1.18E+04	1.45E+04	1.56E+04	1.70E+04
10	4.59E+03	6.94E+03	8.08E+03	1.09E+04	1.21E+04	1.37E+04
20	1.66E+03	2.85E+03	3.54E+03	5.57E+03	6.62E+03	8.12E+03
40	2.82E+02	5.05E+02	6.50E+02	1.17E+03	1.49E+03	2.05E+03
54	1.32E+02	2.24E+02	2.86E+02	5.11E+02	6.59E+02	9.20E+02

Input to Pavement ME

Export to FlexPAVE 2.0

Export FlexPAVE Dyn. Modulus Inputs

Export FlexPAVE Fatigue Inputs

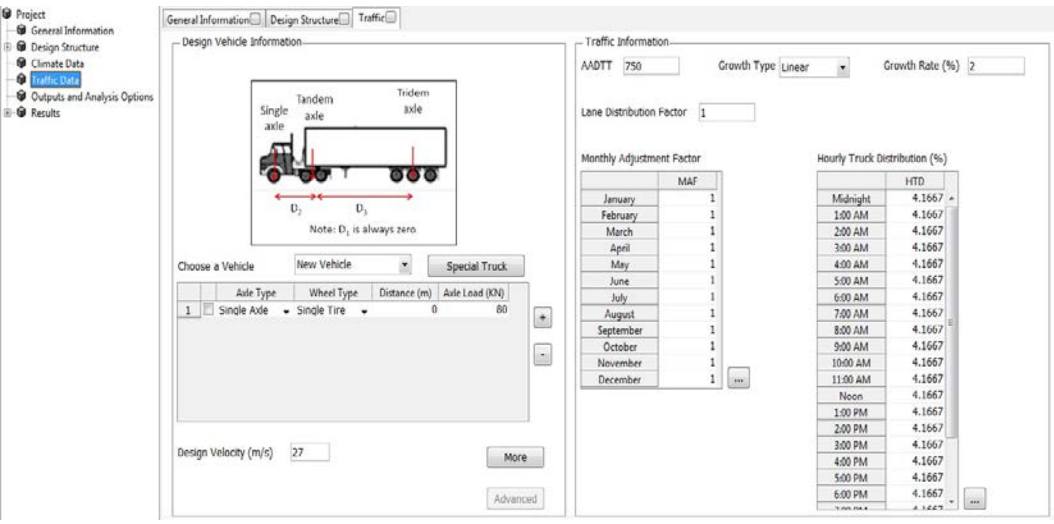
Export to FlexPAVE™

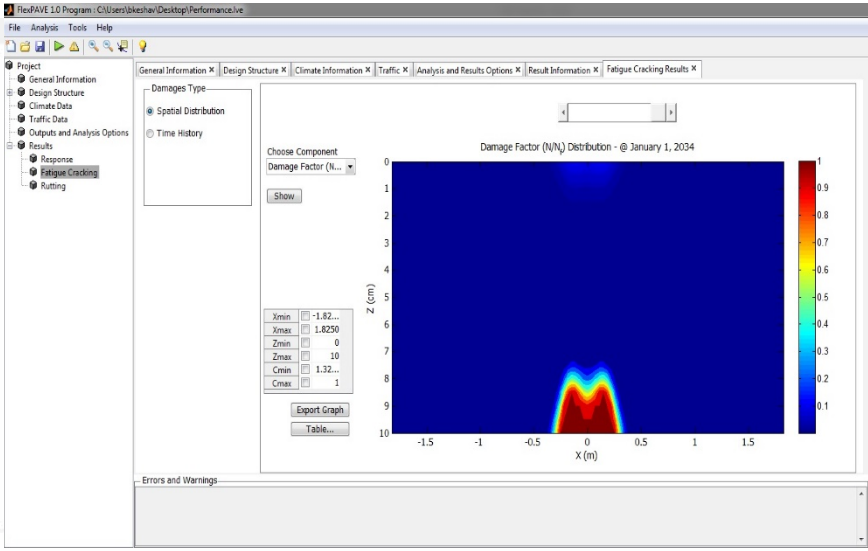
Index Parameter

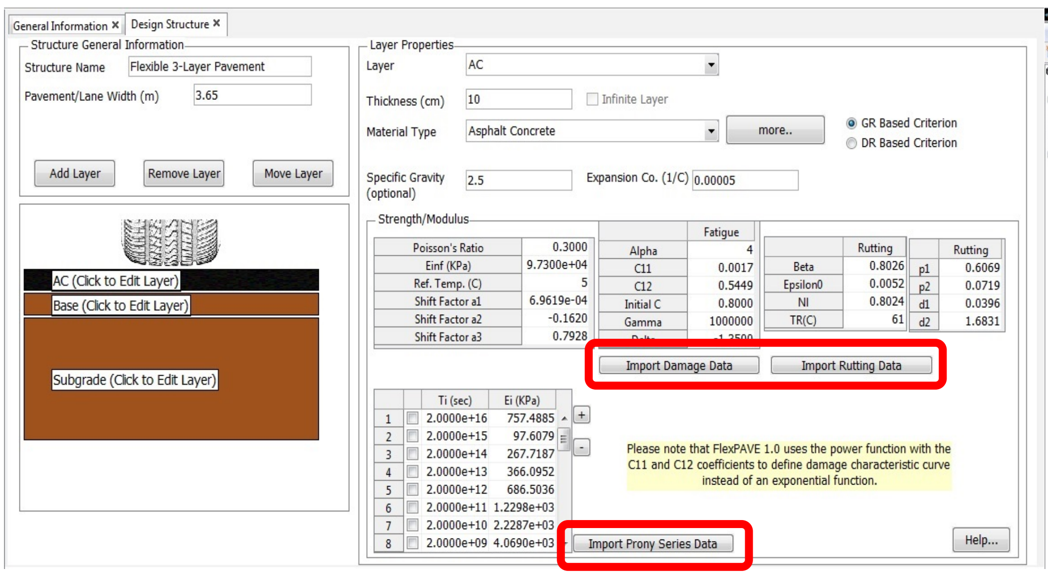
... Input Data | Dynamic Modulus Data | Fatigue Data Validity | Fatigue Analysis | CTC Analysis Level 2 | Aging Analysis Level 2 | Summary & Input to FlexPAVE

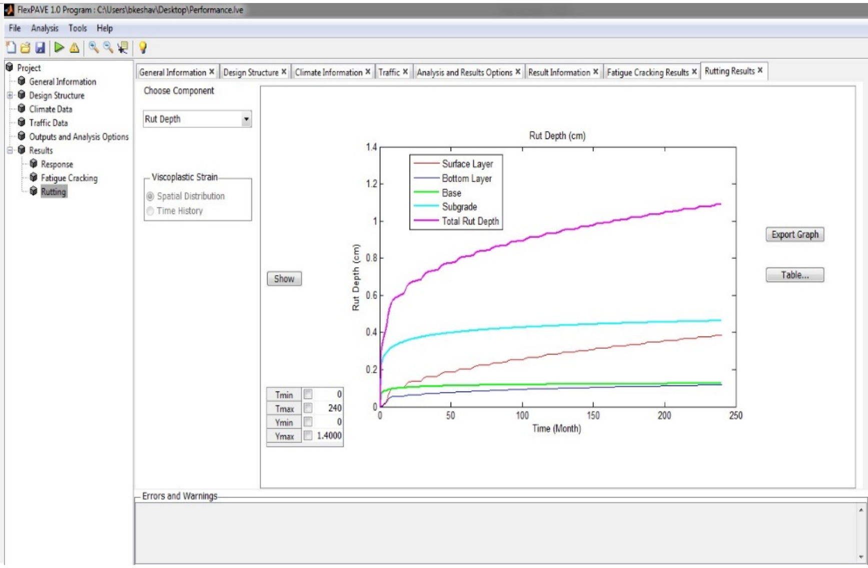
FlexPAVE^{TM}

FlexPAVE™ ver 1.1

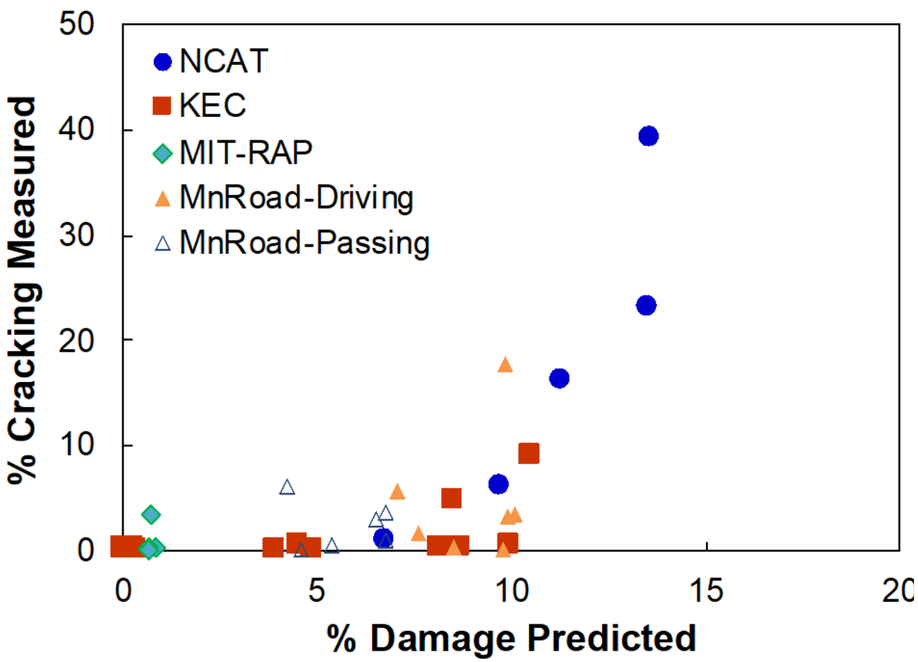


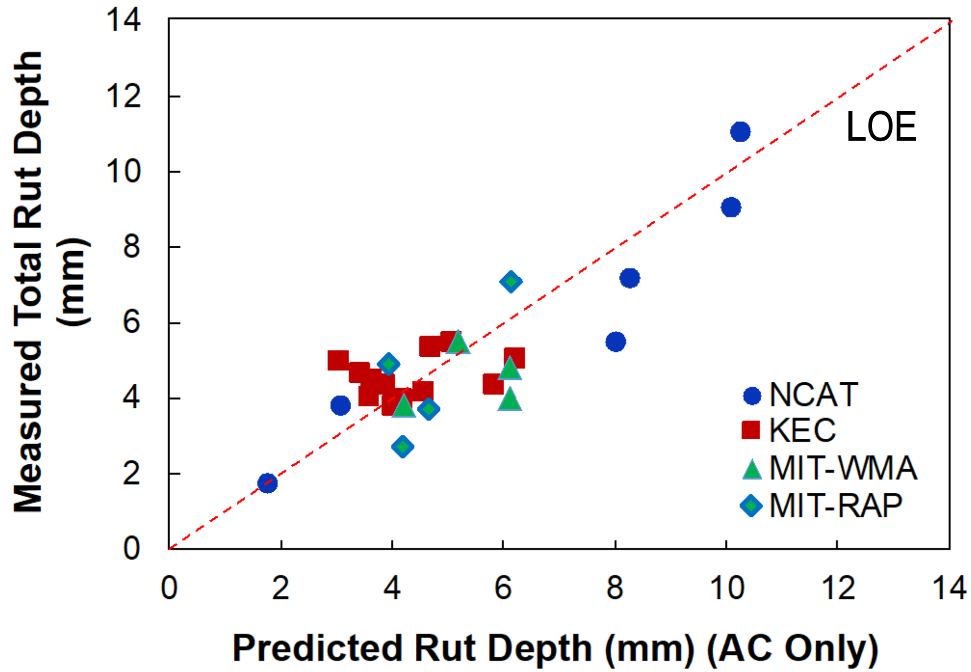






Field Validation





Performance-Engineered Mix Design

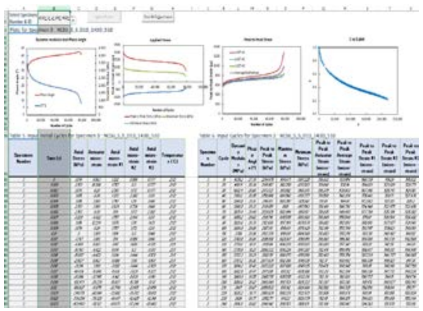
- Index-based PEMD
  - Use index parameters to pass/reject volumetric mix design
- Predictive PEMD
  - Use predicted life to optimize aggregate gradation and asphalt content for the design air voids
  - Use performance-volumetric relationship (PVR) developed from ‘four corners’ of volumetric space
  - Developed PVR can be used to develop pay tables in PRS.

Index Parameters

AMPT

Mixture Testing System

FlexMAT™



Mixture Analysis Program

S_{app}

Apparent Damage Capacity

ATR

Allowable Traffic for Rutting

Thresholds of S_{app}

Traffic (million ESALs)	S_{app} Limits	Tier	Designation
Less than 10	$S_{app} > 8$	Standard	S
Between 10 and 30	$S_{app} > 24$	Heavy	H
Greater than 30	$S_{app} > 30$	Very Heavy	V
Greater than 30 and slow traffic	$S_{app} > 36$	Extremely Heavy	E

Thresholds of ATR

Traffic (million ESALs)	Tier	Designation
Less than 2	Light	L
Between 2 and 10	Standard	S
Between 10 and 30	Heavy	H
Greater than 30	Very Heavy	V
Greater than 30 and slow traffic	Extremely Heavy	E

Project	Location	Mix	Rutting Allowable Traffic	Cracking Allowable Traffic	Allowable Traffic	Dominant Distress
ALF	Washington DC	Control	H	S	S	Cracking
		CR-TB	E	H	H	Cracking
		SBS	E	V	V	Cracking
Maine - PEMD	Maine	AC-0.5%	E	S	S	Cracking
		AC-Target	V	S	S	Cracking
		AC+0.5%	H	S	S	Cracking
		AC+1%	S	H	S	Rutting
MIT-RAP	Manitoba, Canada	50RSB	L	H	L	Rutting
		C	L	S	L	Rutting
		15R	L	H	L	Rutting
		50R	L	H	L	Rutting
MIT-WMA	Manitoba, Canada	Advera	L	S	L	Rutting
		Control	L	S	L	Rutting
		Evotherm	L	S	L	Rutting
		Sasobit	L	S	L	Rutting
NC DOT - ABC Project	North Carolina	RB25.0B	E	S	S	Cracking
		RI19.0B	S	L	L	Cracking
		RI19.0C	V	S	S	Cracking
		RS9.5B	L	S	L	Rutting
		RS9.5C	V	S	S	Cracking
KEC	Korea	ASTM	L	S	L	Rutting
		PMA	V	S	S	Cracking

Performance-Volumetric Relationship (PVR)

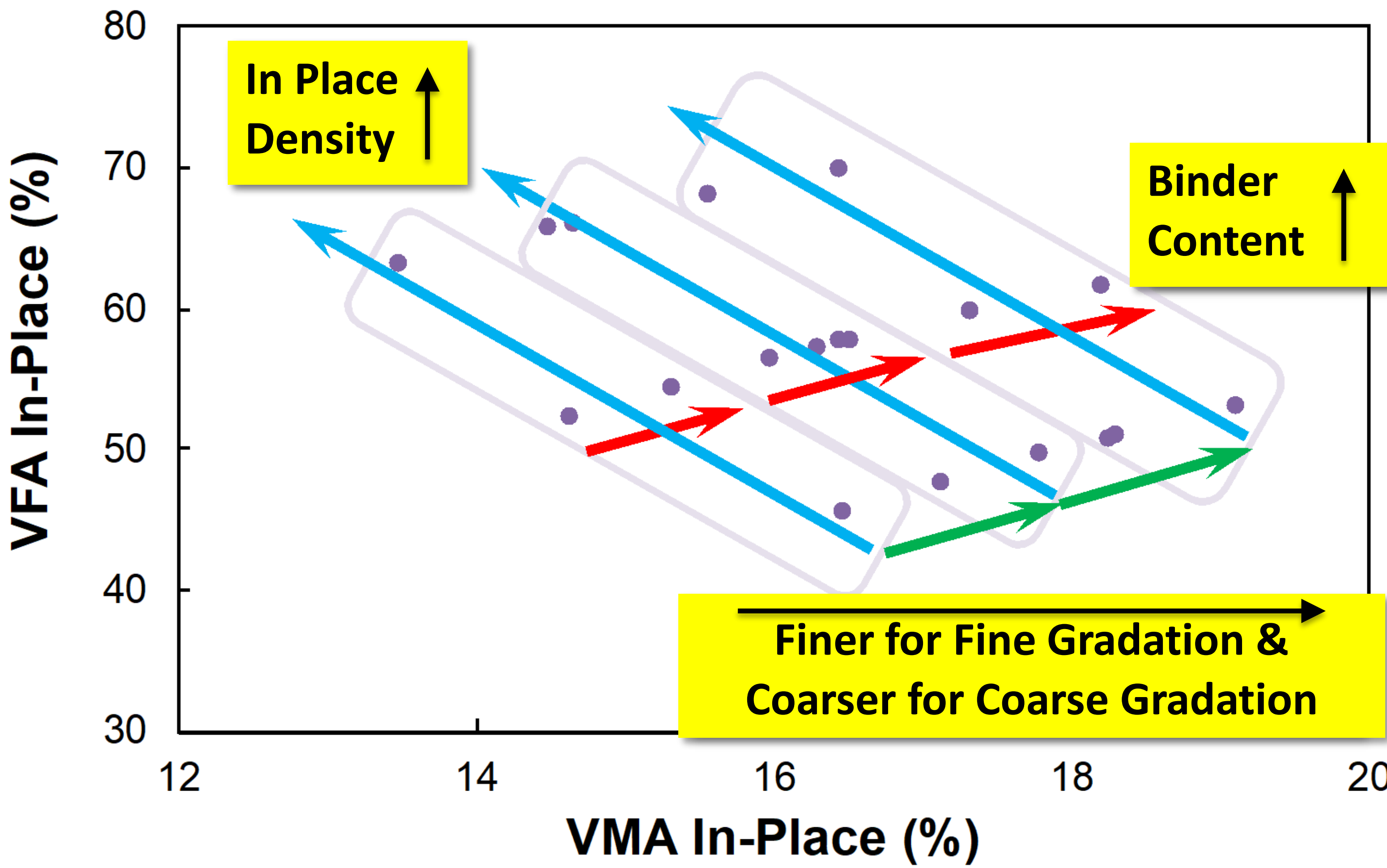
- Functions to predict the pavement performance using measurable Acceptance Quality Characteristics (AQC's).

PVR

$$Performance = f\,(VMA_{IP},\, VFA_{IP},\, \%AC_{eff})$$

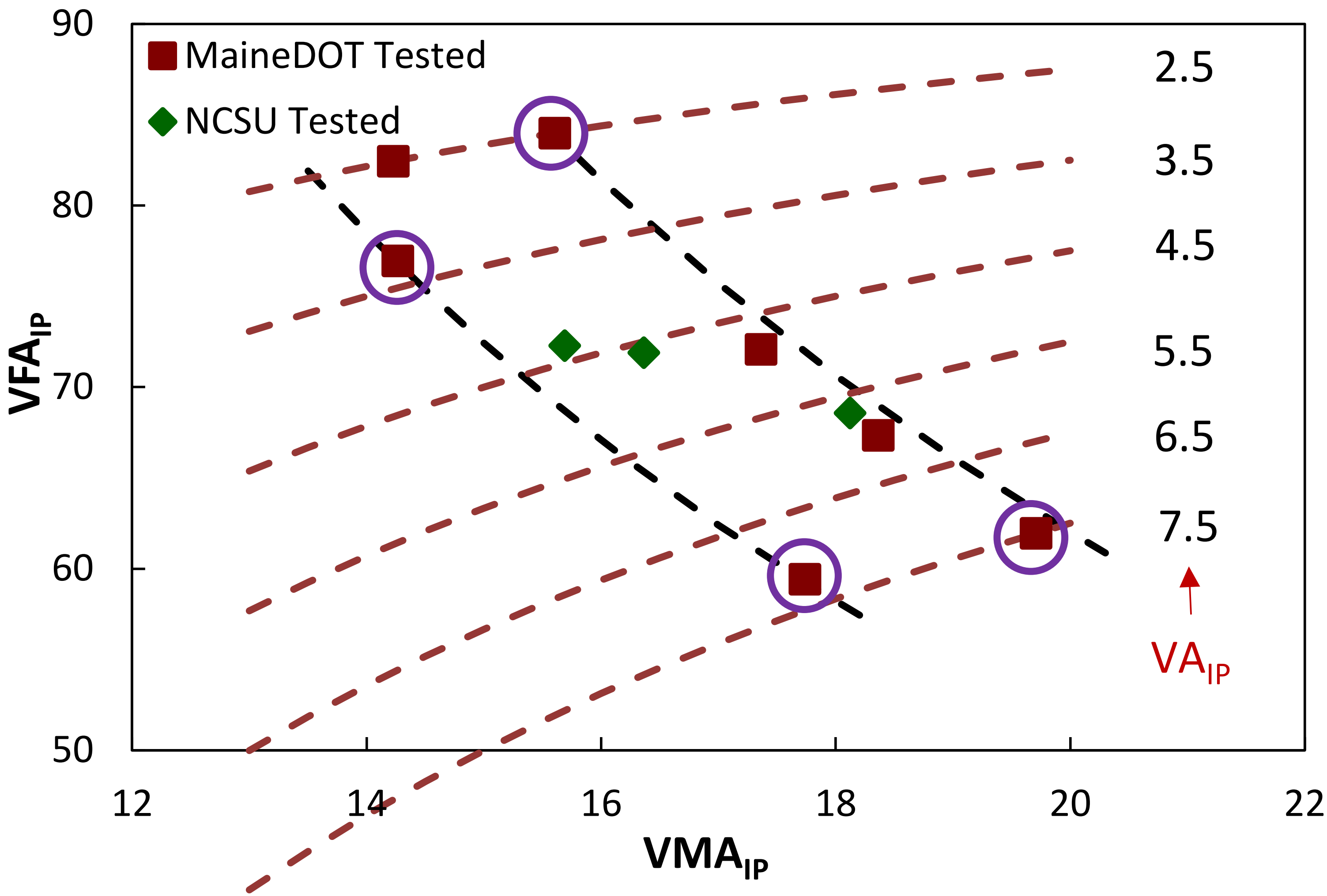
- Allows to use the current QA data collection methods in PRS applications

Analysis in Volumetric Space



Selection of PVR Calibration Conditions

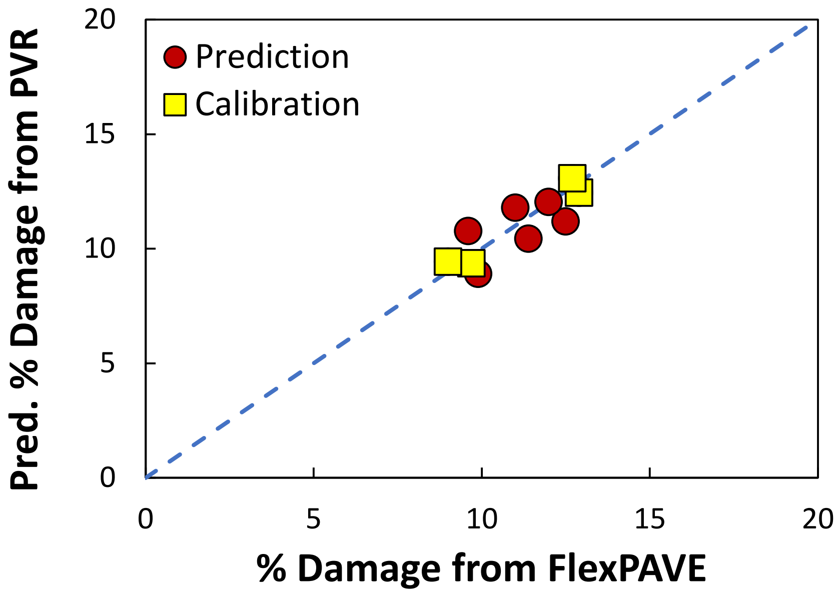
Findings with Maine Shadow Project Mixture



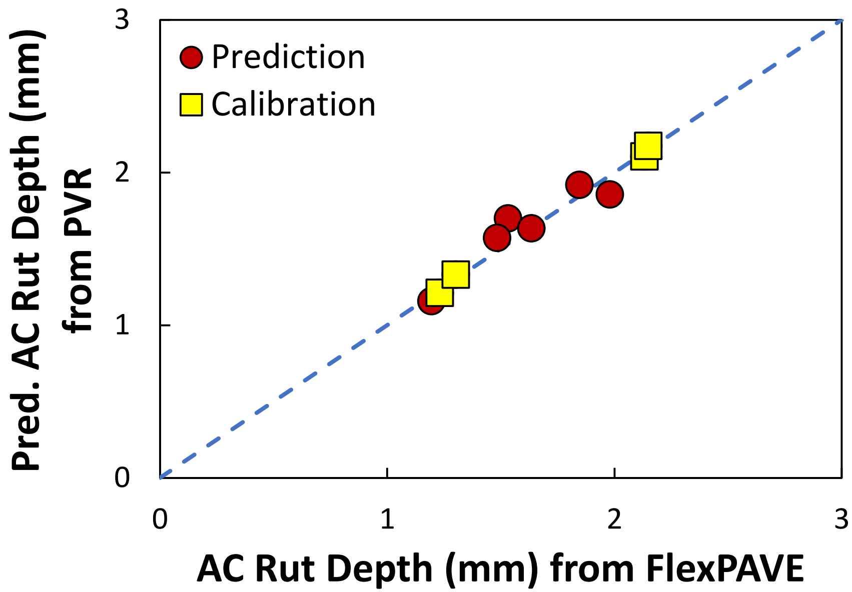
Selection of PVR Calibration Conditions

Findings with Maine Shadow Project Mixture

Cracking

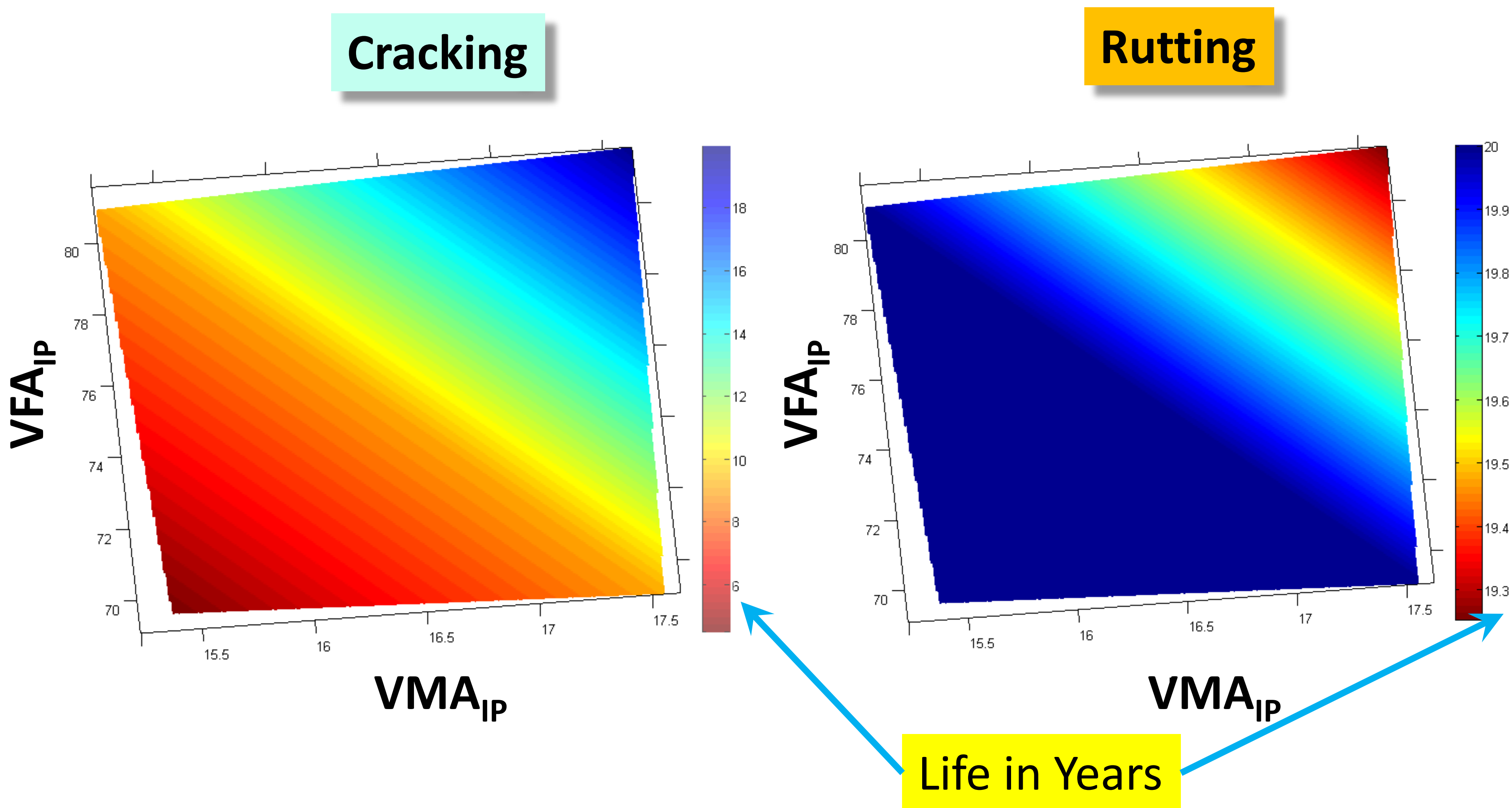


Rutting



Predictive PEMD

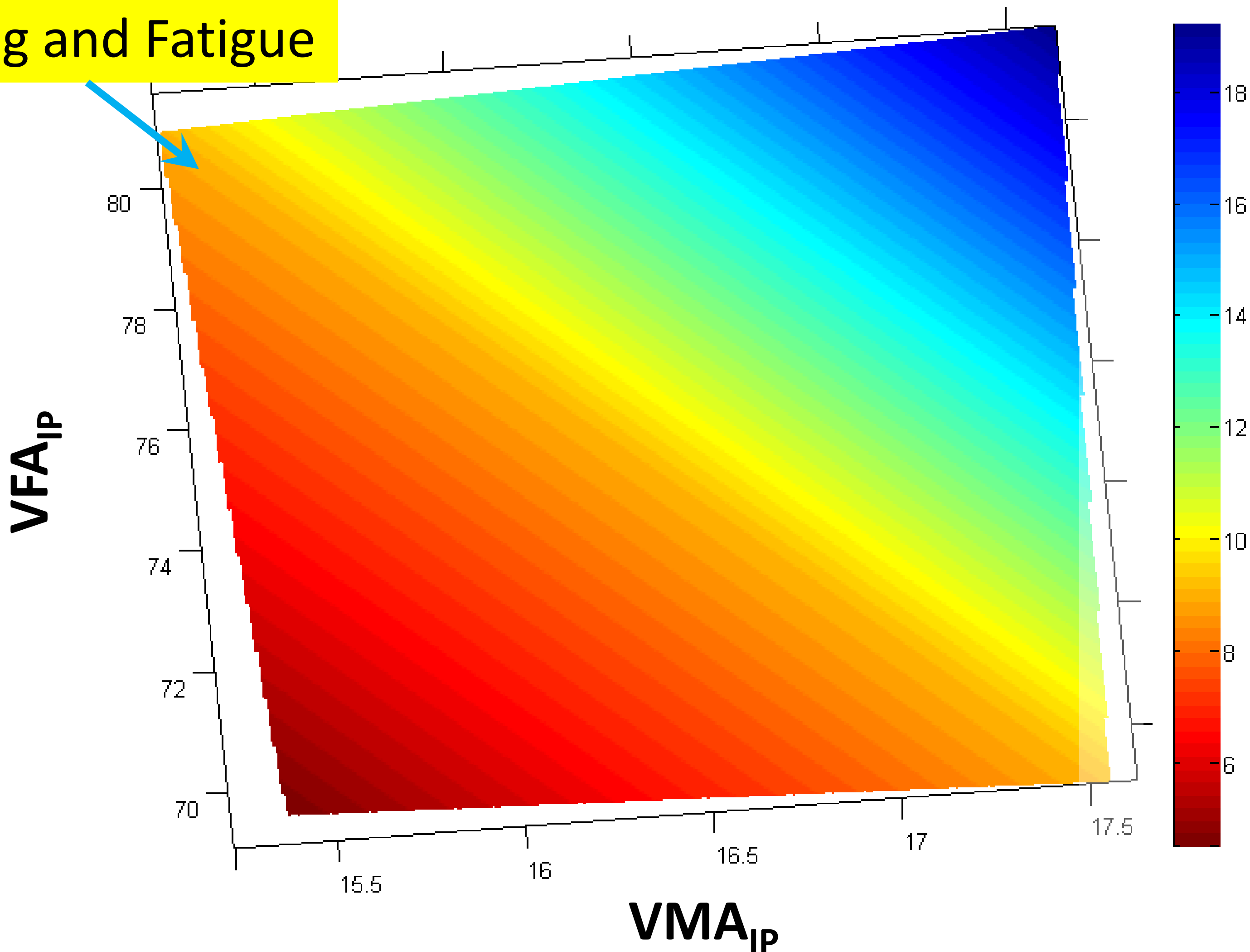
Example, PVR Function Predictions



Predictive PEMD

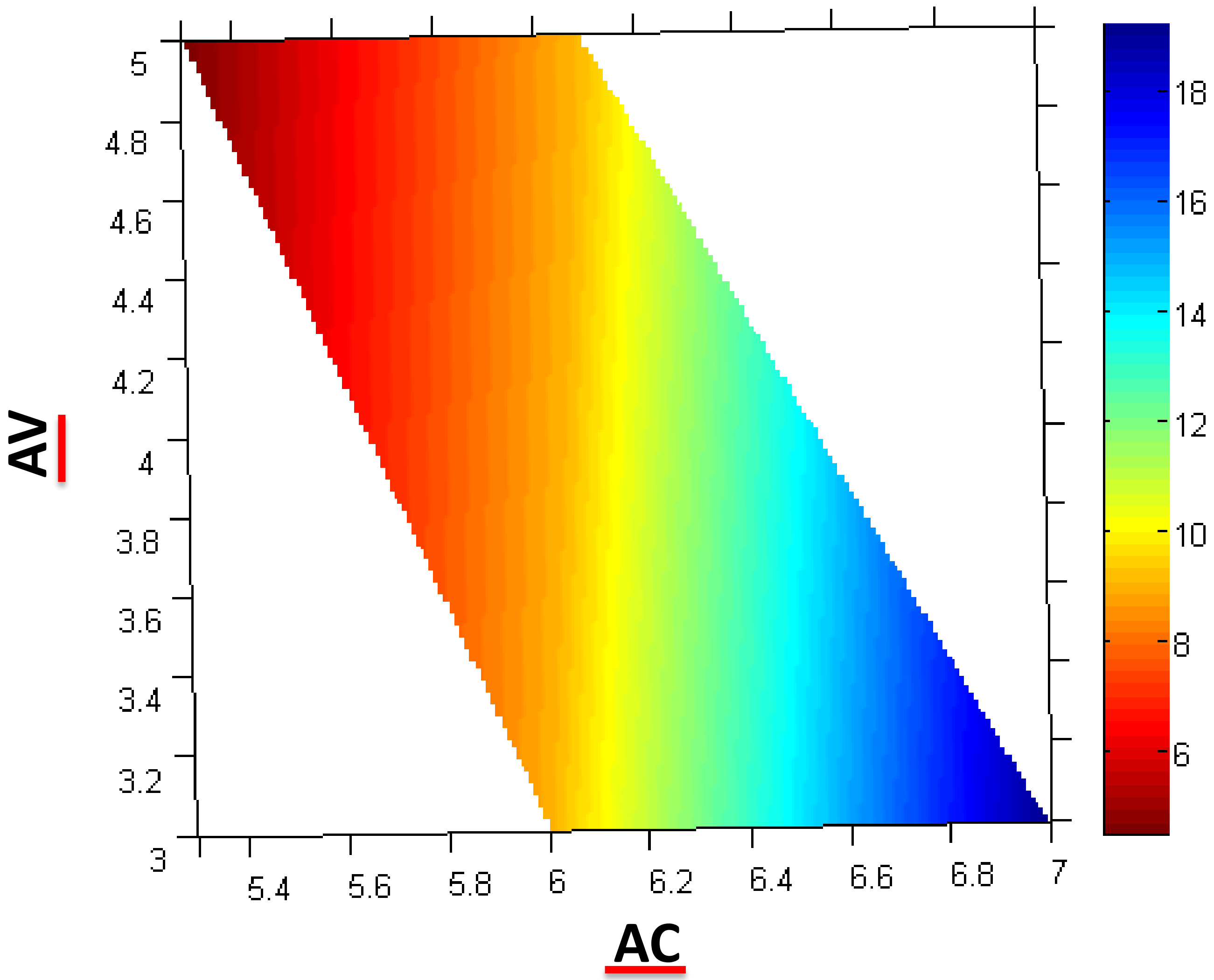
Example, Finding Mixture Design

Minimum of Rutting and Fatigue



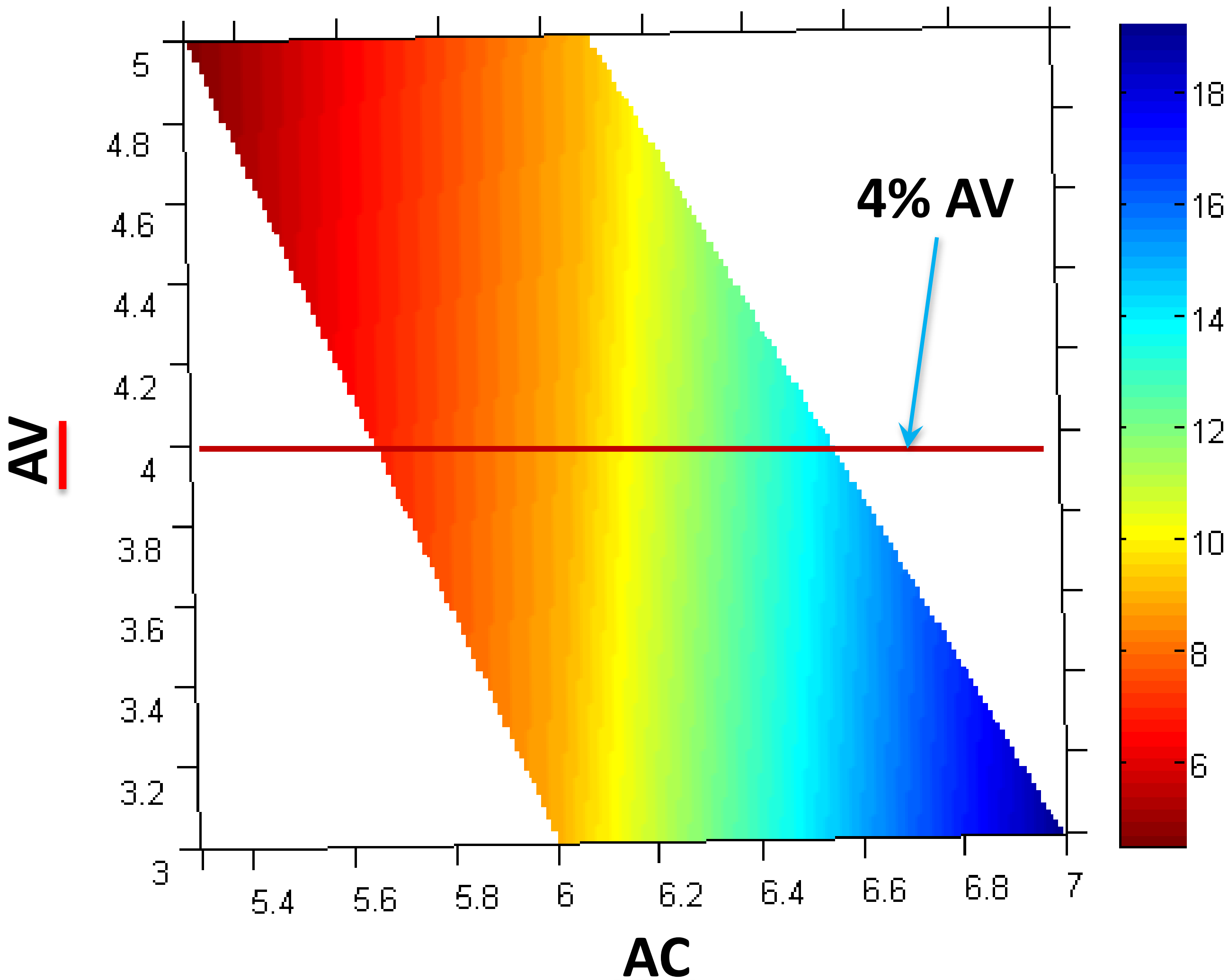
Predictive PEMD

Example, Finding Mixture Design



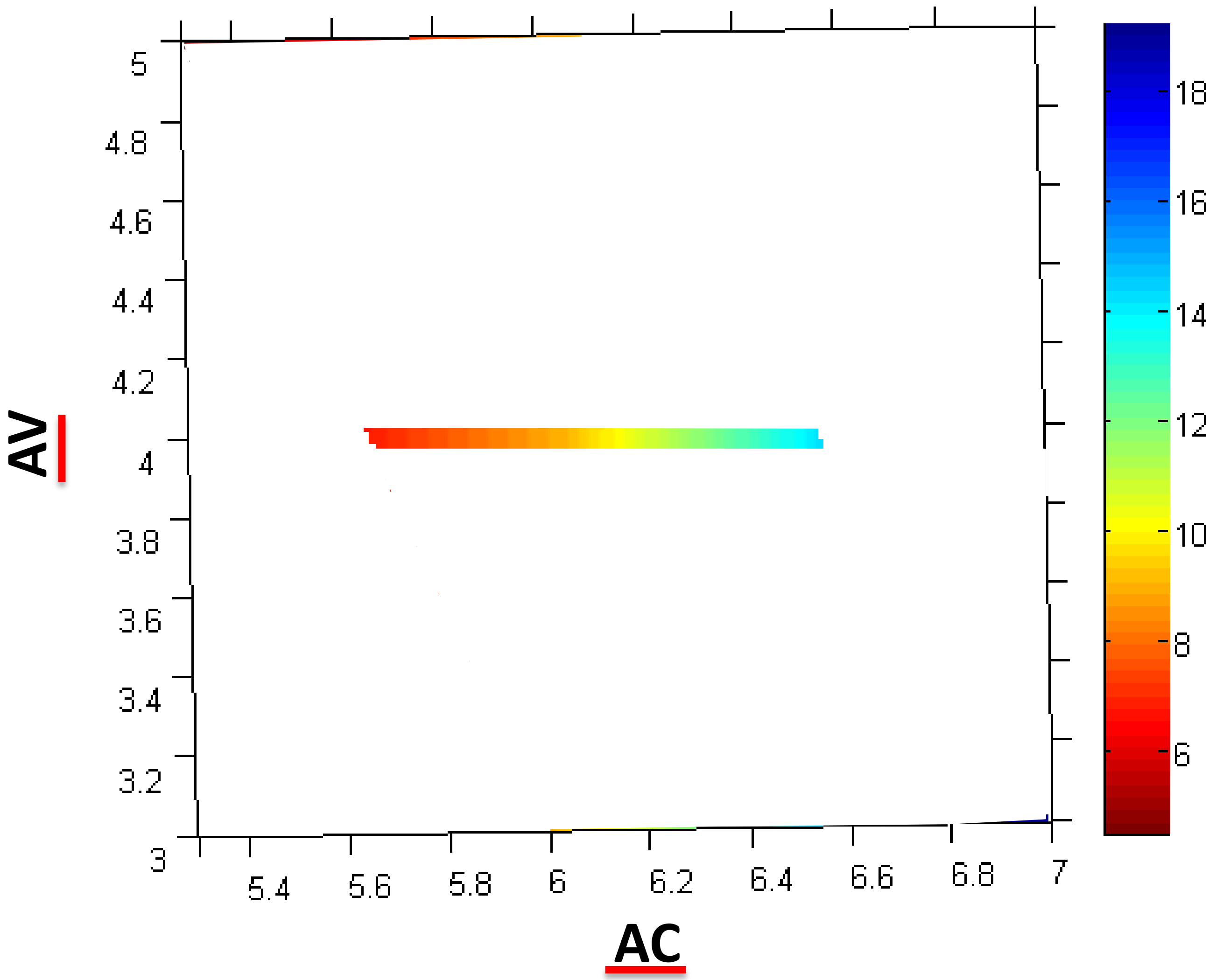
Predictive PEMD

Example, Finding Mixture Design



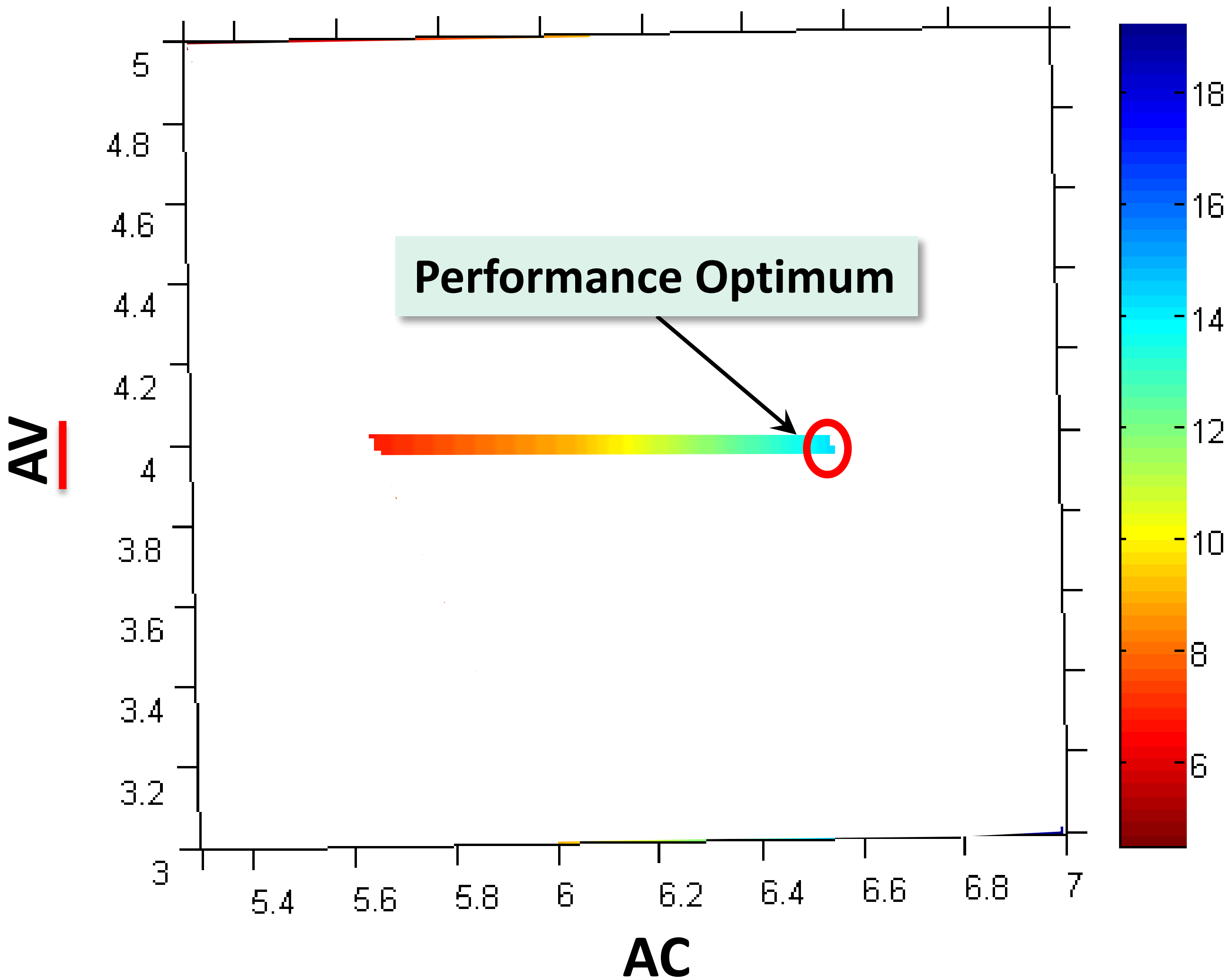
Predictive PEMD

Example, Finding Mixture Design



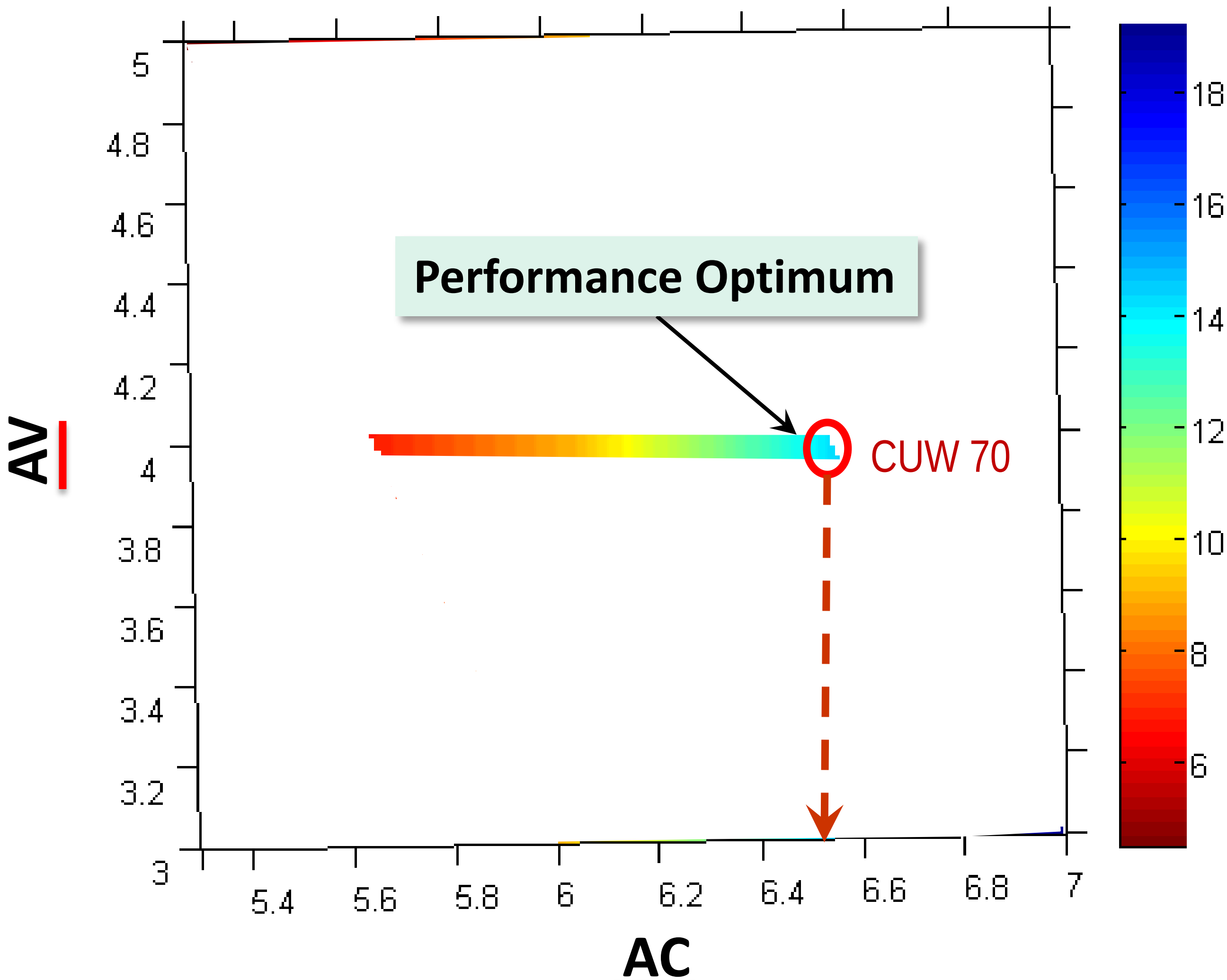
Predictive PEMD

Example, Finding Mixture Design



Predictive PEMD

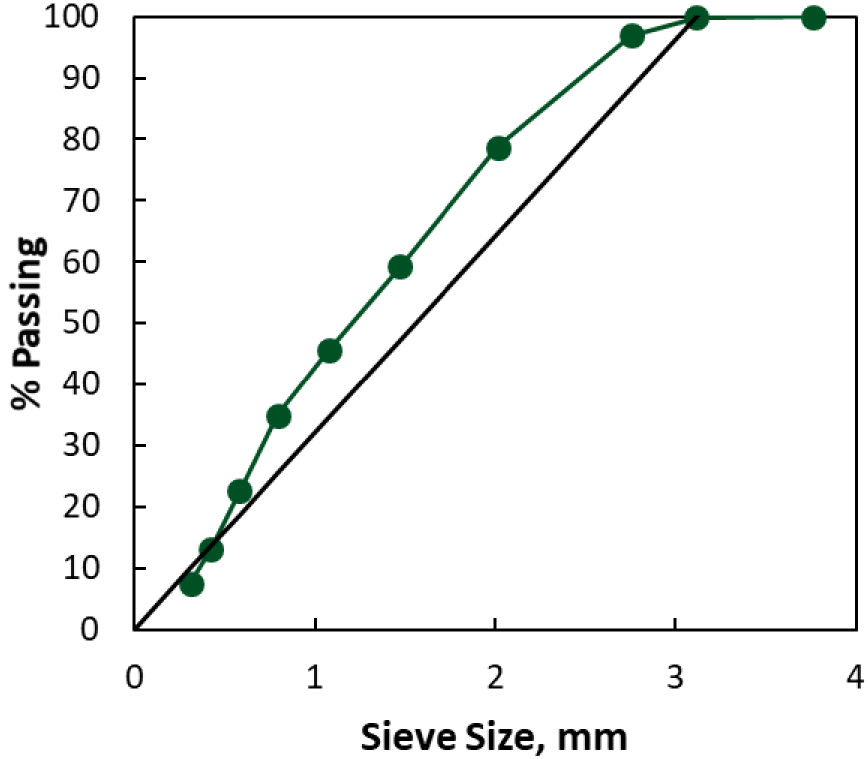
Example, Finding Mixture Design



Predictive PEMD

Example, Final Mixture Design

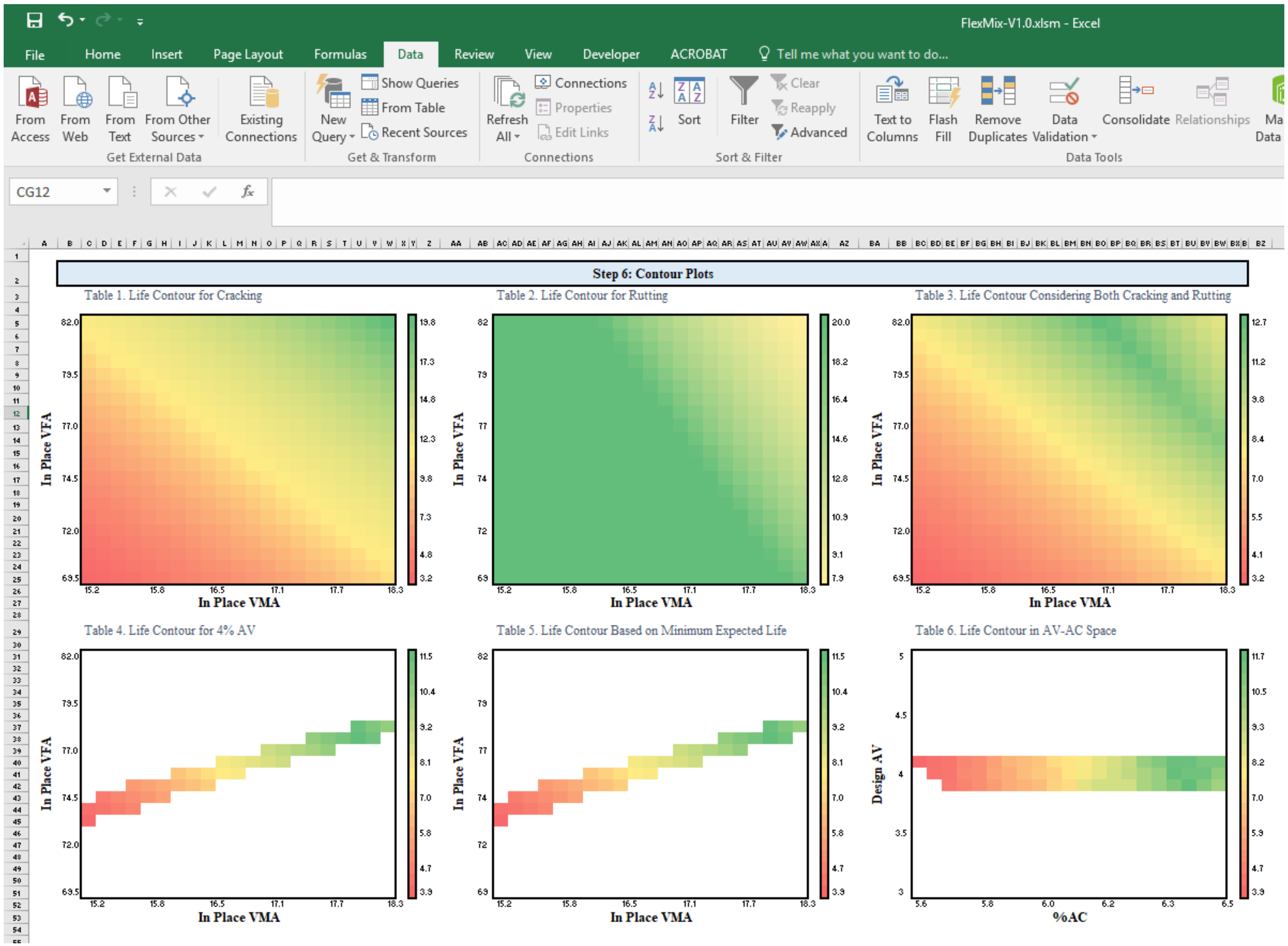
Gradation



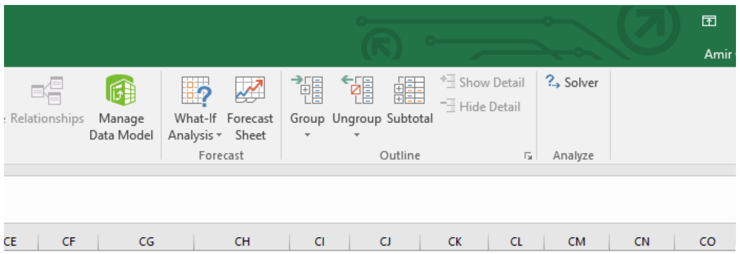
Asphalt Content and Stockpile Percentages

CUW	AC	Stockpile Contribution			
		#78	DS	WS	RAP
70	6.5	44	13	43	30

FlexMIX for PVR Analysis



Automatic Determination of Optimal Gradation and Binder Content



Step 7: Candidate for Optimum Design

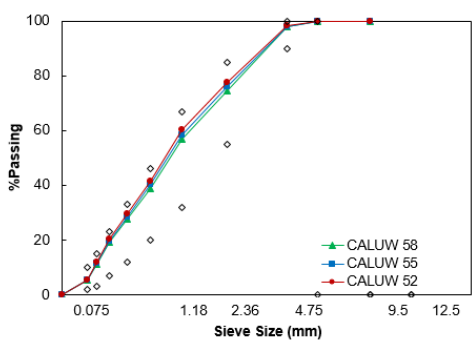
Minimum Expected Life (Year): **8.0**

%CALUW:	58	-	52
Pb:	6.0	-	6.4

	%AC	Life
CALUW 52	6.4	11.5
CALUW 55	6.2	9.8
CALUW 58	6.0	8.1

AV @ Ndes:	4.0	-	4.1
VMA @ Ndes:	18.0	-	17.2
VFA @ Ndes:	77.6	-	76.4

Design Airvoid	Tolerance
4	0.1



Sieve Size (mm)	Size ^ 0.45	%Passing CALUW 52	CALUW 55	CALUW 58
19.0	3.76	100.0	100.0	100.0
12.5	3.12	100.0	100.0	100.0
9.5	2.75	98.2	98.1	97.9
4.75	2.02	77.5	76	74.6
2.36	1.47	60.4	58.5	56.8
1.18	1.08	41.6	40.3	39
0.600	0.79	29.5	28.5	27.7
0.300	0.58	20.5	19.8	19.2
0.150	0.43	11.8	11.4	11.1
0.075	0.31	5.6	5.4	5.3

	#78	DS	WS
CALUW 52	32.2	26.7	41.1
CALUW 55	34.4	25.8	39.8
CALUW 58	36.5	25.0	38.5

Example Pay Tables in PRS

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

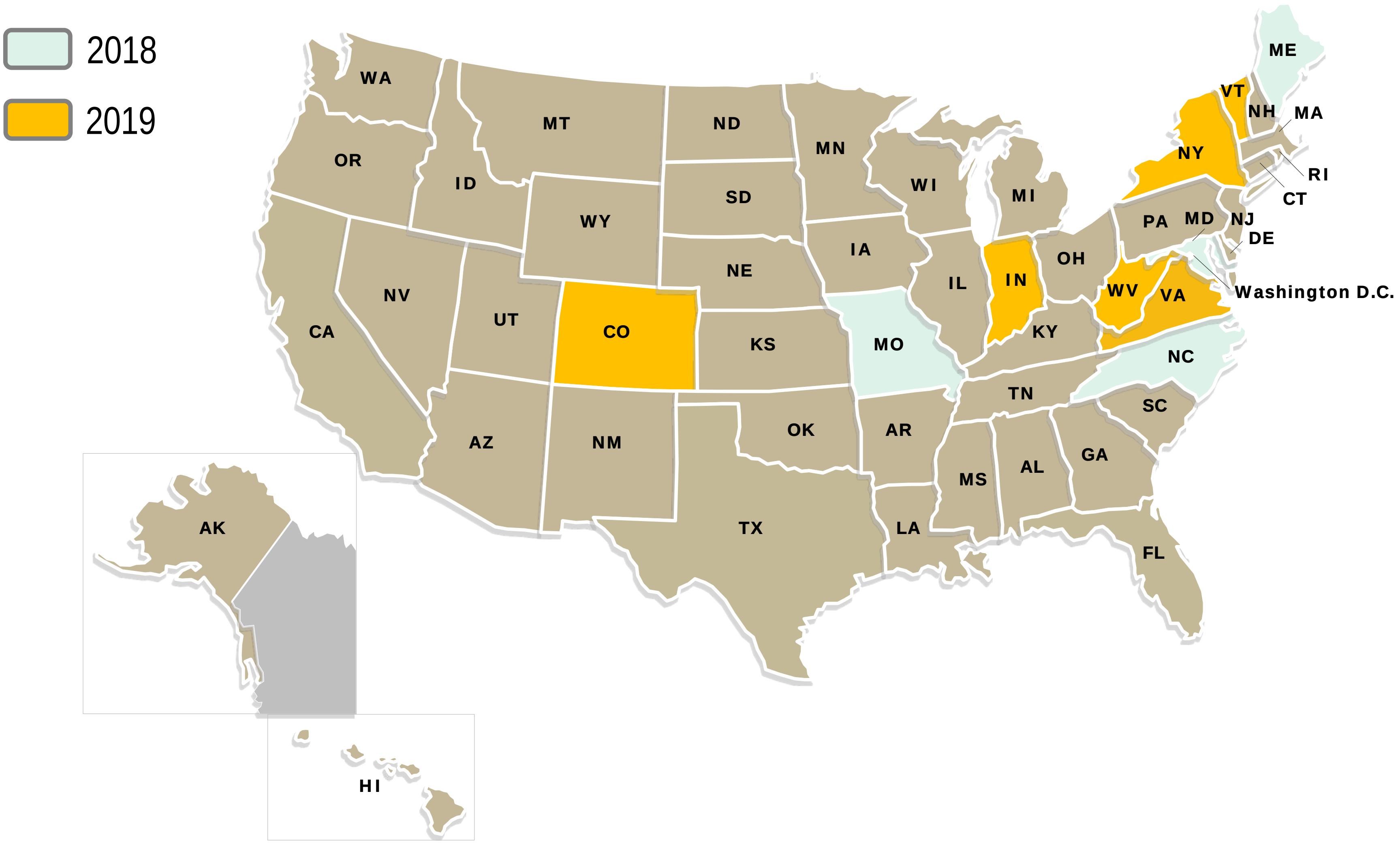
Pay Factor		QA VMA @ Ndes = 15%				
		QA Vbe @ Ndes				
		11	10	9	8	7
In-Place A.V.	4	101.6	102.4	102.6	102.0	100.2
	5	100.8	101.6	101.7	100.8	100.0
	6	100.0	100.7	100.6	100.0	100.0
	7	100.0	100.0	100.0	100.0	100.0
	8	100.0	100.0	100.0	100.0	98.1
	9	100.0	100.0	100.0	100.0	90.9
	10	100.0	100.0	100.0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

Shadow Project

- Two-day AMPT hands-on training workshop at NCSU
- On-site training at the shadow agency's lab
- Proficiency testing
- Mix design using PEMD
- Development of life tables using PVR
- Collection of construction mix samples
- Comparison of PEMD-based PVR and PVR developed from construction samples
- Shadow PRS application

PRS Shadow Projects - USA



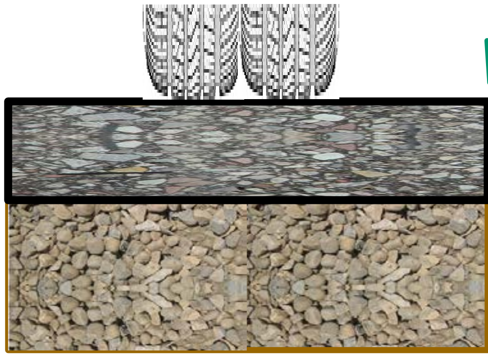
Concluding Remarks

- PASSFlex is a system of test methods, mechanistic models, and software programs.
- PASSFlex allows the integration of mix design, pavement design, and PRS.
- FlexMAT^{TM}, FlexPAVE^{TM}, and FlexMIX are available upon request.
- Southeastern states are welcome to participate in the shadow project!

Slide by Prof. Kevin Hall

PASSFlex

Structural Design
(materials/thickness)



Richard Kim

Pay Factor = $f(\Delta \text{life})$

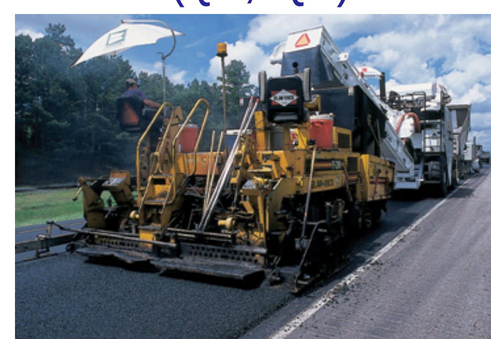
Mixture Design
Material Characterization

Rutting

gecan.ca

Cracking

Construction
(QA; QC)



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Thank you!