Performance Modeling of a Highly Modified Asphalt Pavement

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Northeast Asphalt User Producer Group Meeting
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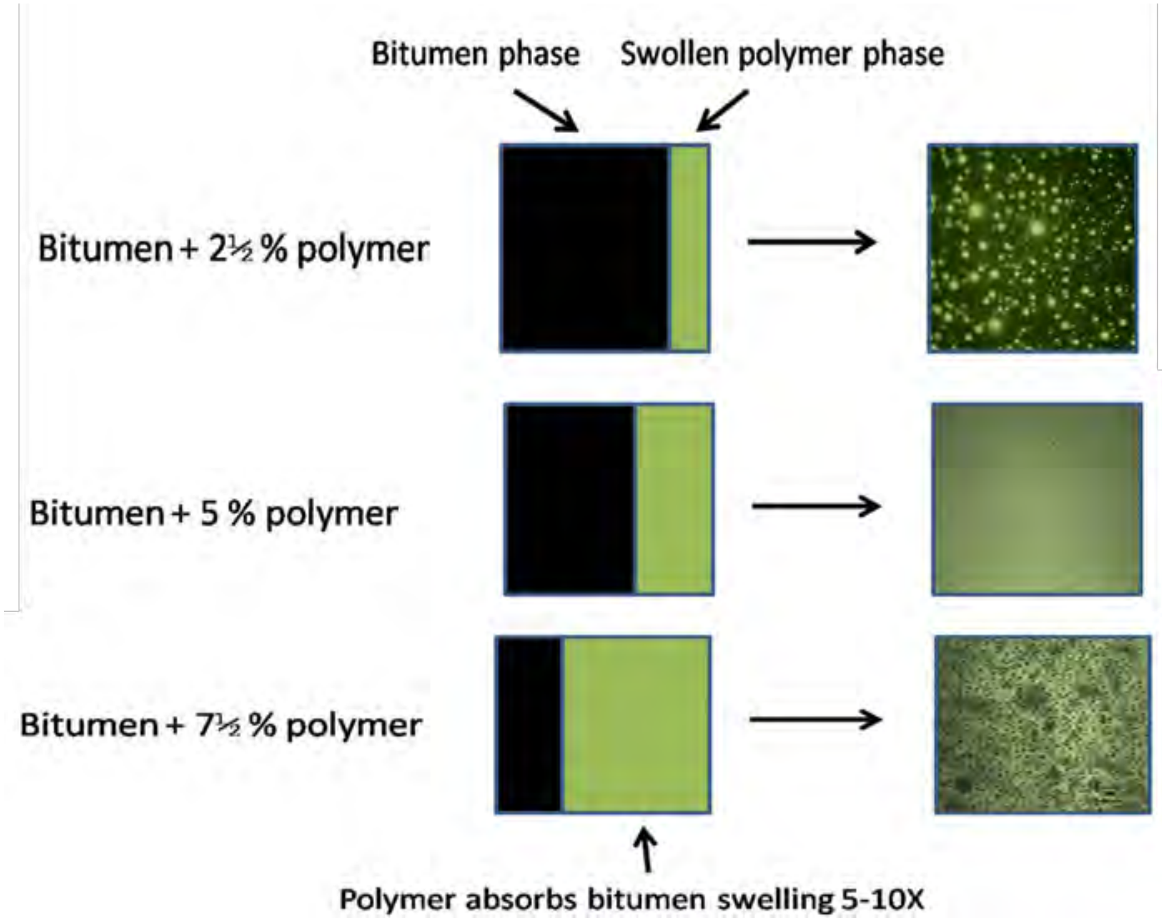
Outline

- What is highly modified asphalt?
- NCAT test track section performance
- AASHTOWare™ Pavement ME Design modeling
- FLEXPave™ software
- FLEXPave modeling
- Conclusions and where we go from here

What Is Highly Modified Asphalt?



Highly Modified Asphalt is exactly what it says, asphalt with double the normal amount of SBS polymer.

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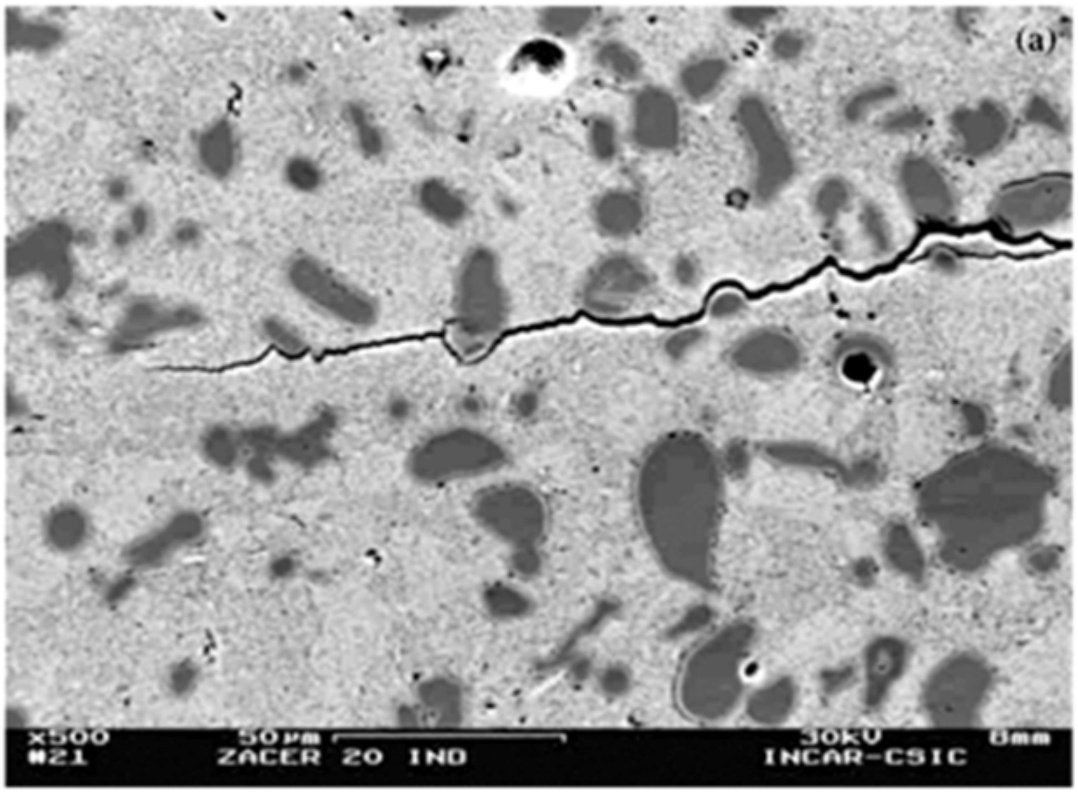
Cracking Behavior of Highly Modified Asphalt



This gives a much denser polymer network with up to 10X rutting **and** fatigue cracking resistance.

National Center for Asphalt Technology Test Track

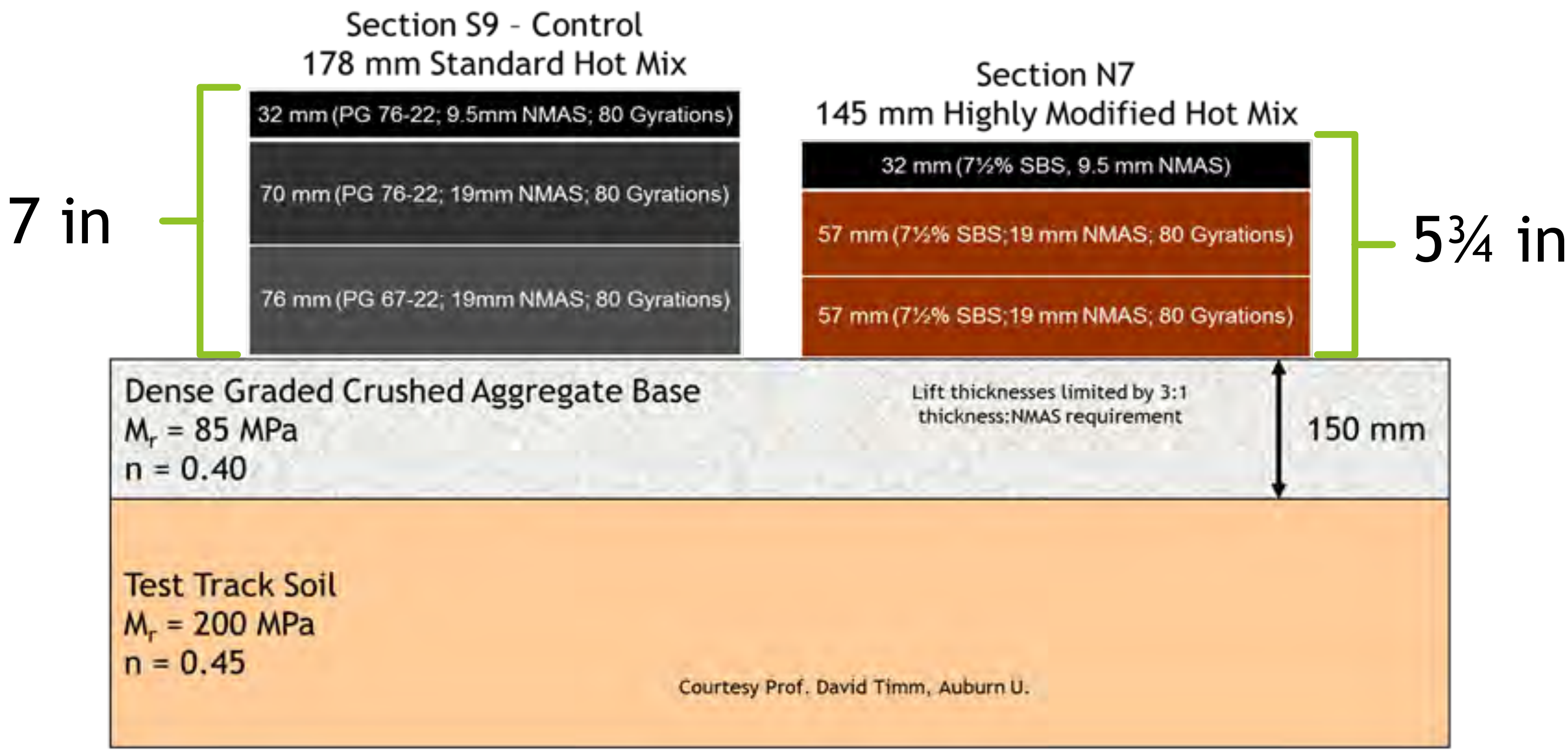
- 5 trucks, 16 h/day, 5 days/week
- Axle load: 18 kip
- Speed: 45 mph

National Center for Asphalt Technology Test Track

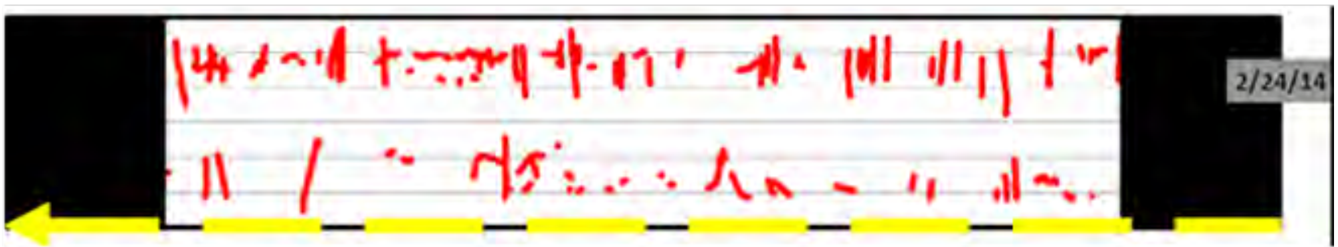
- Track cycle of 10 million ESALs simulates the design lifetime of damage in 2+ years
- ESAL = Equivalent Single Axle Load = 1 pass of 18 kip axle

- Highly Modified Asphalt (HiMA) project started in 2009 cycle
- Part of Performance Group study—6 sections including control
- Continued in 2012 cycle
- Total 20 million ESALs

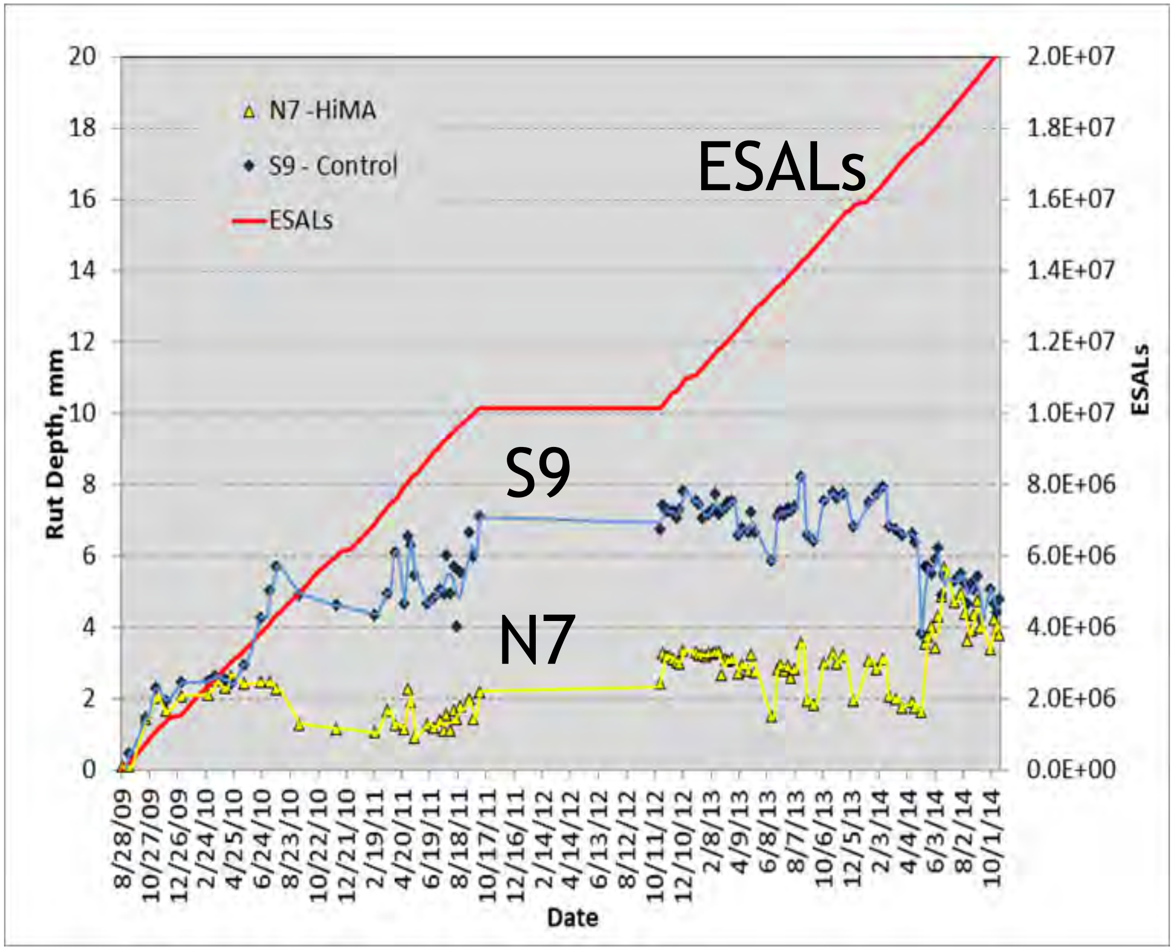
Control (S9) and HiMA (N7) Section Designs



Crack Maps at 17 Million ESALs

3/14 Rutting		2/14 Crack Maps
S9	6.0 mm	
		Lane - 9% Left wheel path - 12% Right wheel path - 21%
N7	1.6 mm	
		Lane - 0% Left wheel path - 0% Right wheel path - 0%

Rutting over 20 Million ESALs



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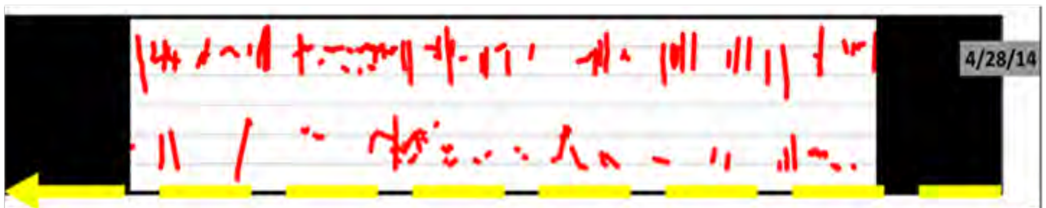
N7 Crack Map at 20 Million ESALs

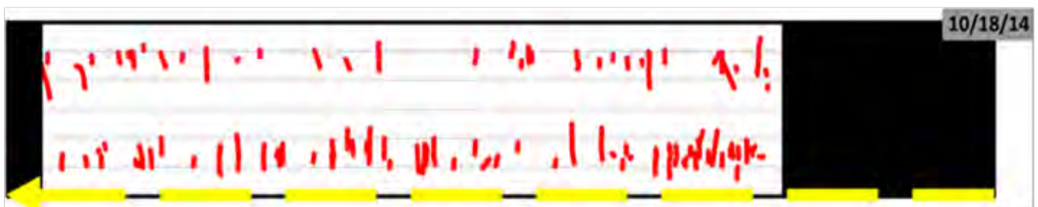
S9 resurfaced at
17 million ESALs

S9

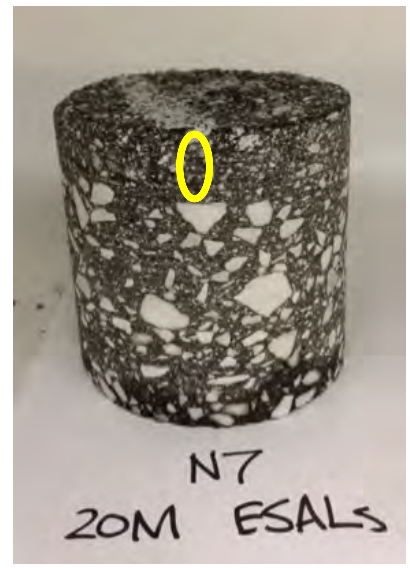


Lane - 10% Left wheel path - 13% Right wheel path - 21%

N7



Lane - 6% Left wheel path - 15% Right wheel path - 8%



N7 cracking is superficial top-down

AASHTOWare^{TM} Pavement ME Design

- Traditional layered elastic model
- Comprehensive input data

- Fatigue cracking model
- $N_{f\text{-}HMA} = k_{f1}(C)(C_H)b_{f1}(\varepsilon_t)^{kf2bf2}(E_{HMA})^{kf3bf3}$

- Permanent deformation model
- $D_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = b_{r1} k_z \varepsilon_{r(HMA)} 10^{kr1} \eta^{kr2br2} T^{kr3br3}$

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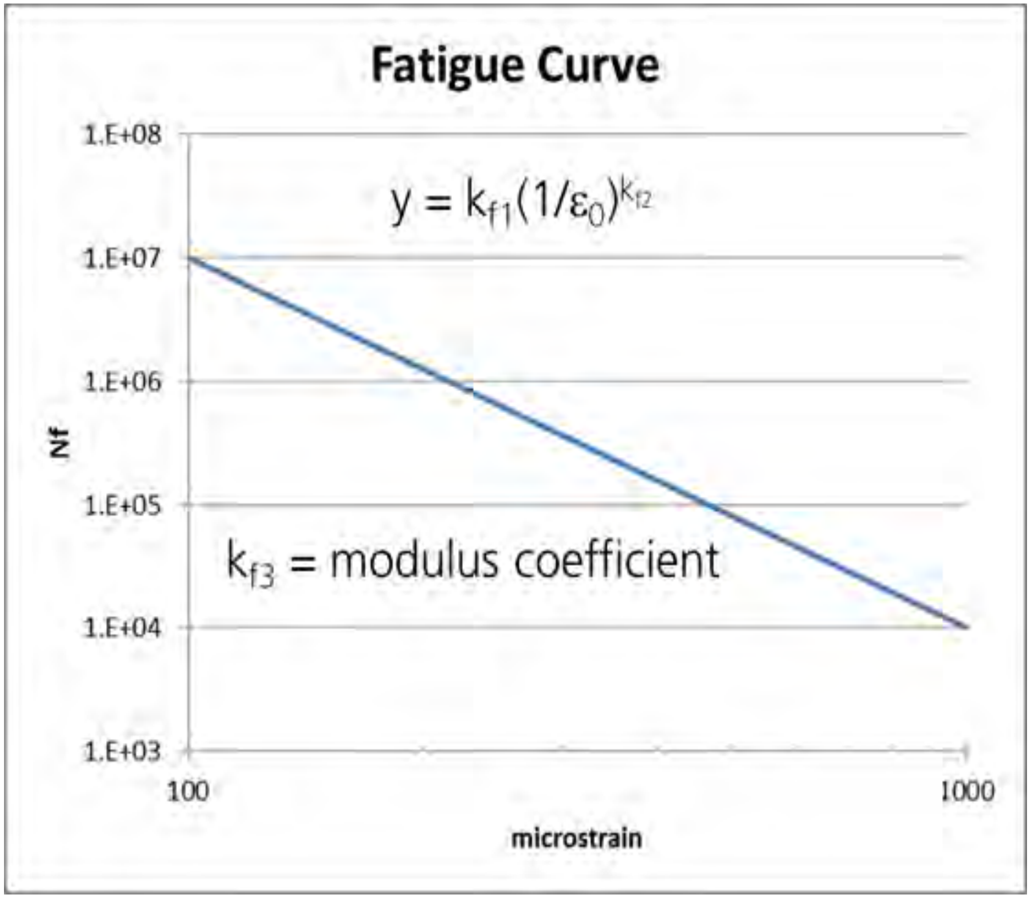
Fatigue Global Calibration Parameters



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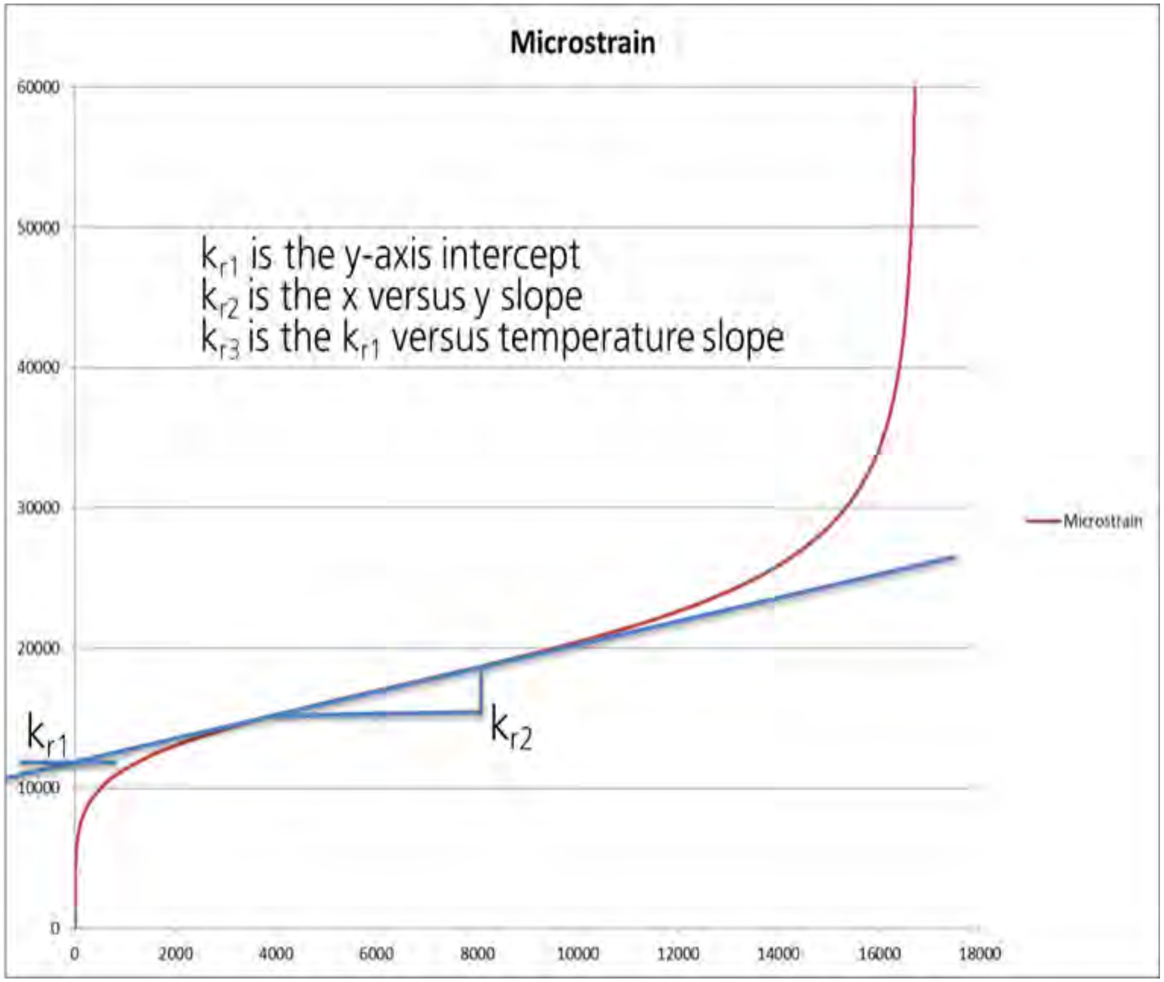
Fatigue Calibration Factors for Section N7

	k_{f1}	k_{f2}	k_{f3}
MEPDG Standard Values	7.566E-3	3.9492	1.2810
S9 Calculated Values	1.4964E-2	3.9492	1.2810
N7 Calculated Values	7.5721E-5	7.3135	2.3655
Ratios	0.9762	0.7595	0.0491
N7 Adjusted Values	7.386E-3	2.9994	0.0630

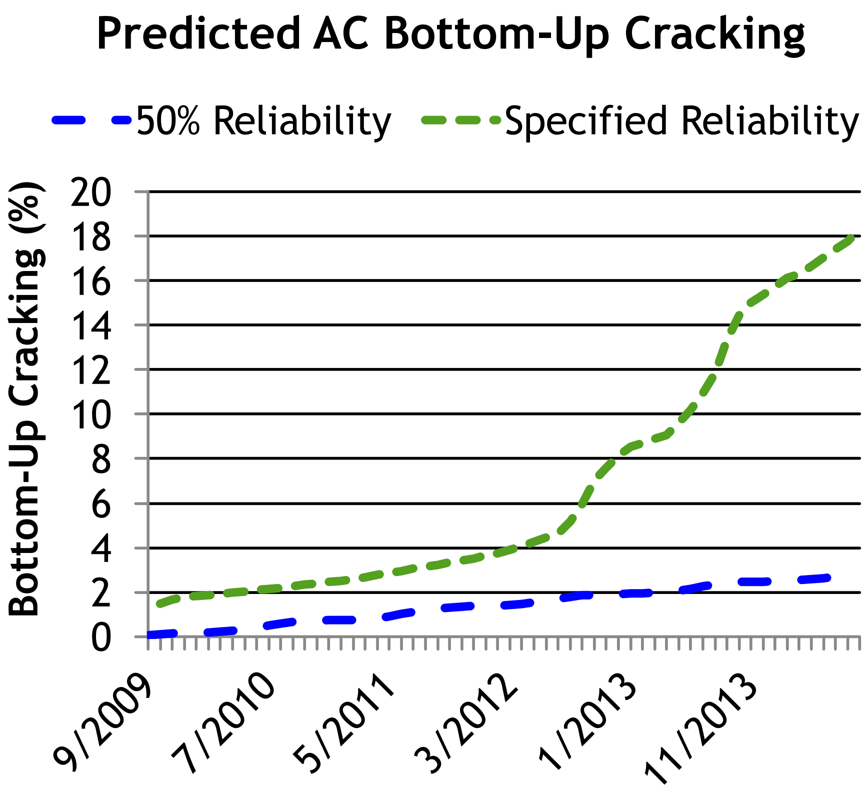
Rutting Global Calibration Parameters

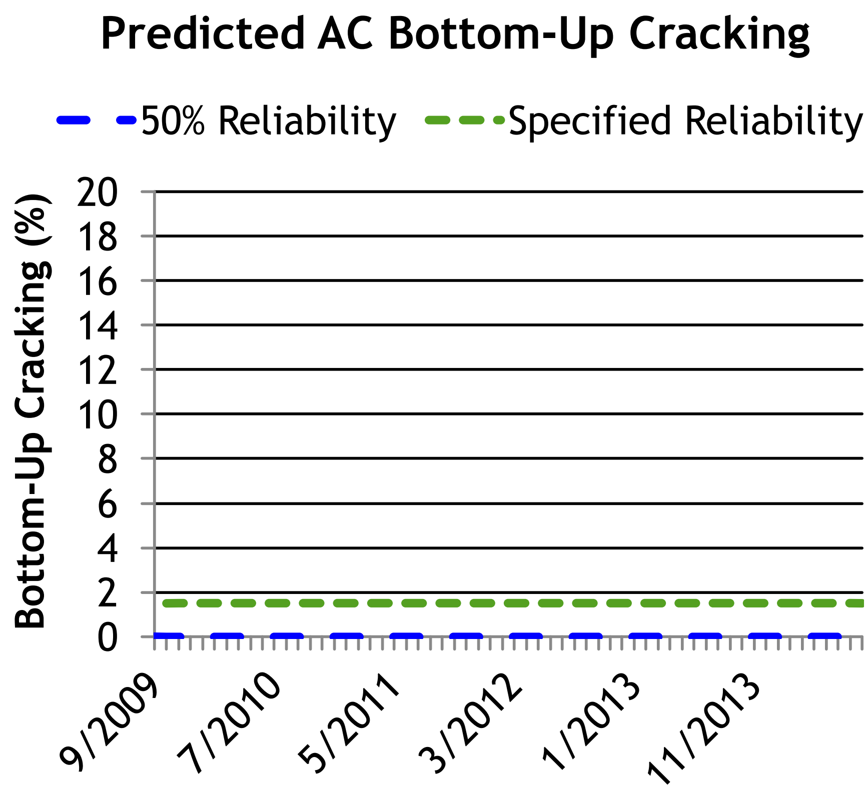


Rutting Calibration Factors for Section N7

	k_{r1}	k_{r2}	k_{r3}
MEPDG Standard Values	-3.3541	0.4719	1.5606
S9 Calculated Values	-3.7902	0.4719	1.5606
Ratios	0.8045	0.4791	1.0000
N7 Adjusted Values	-2.6985	0.2261	1.5606

S9 Predicted Cracking N7





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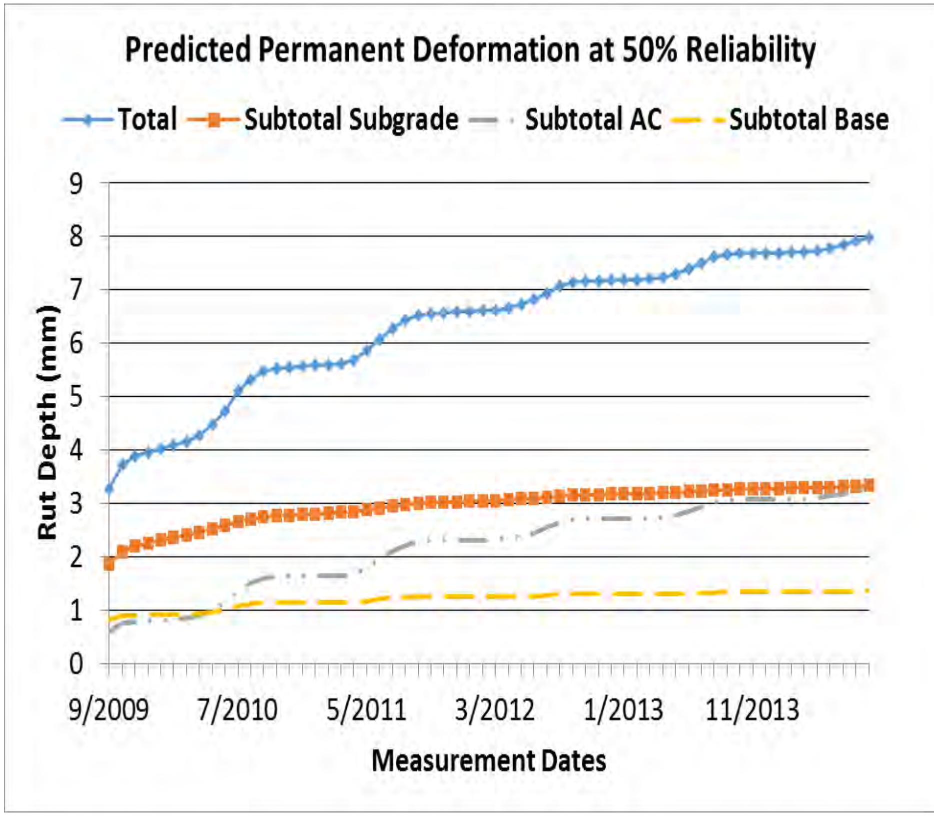
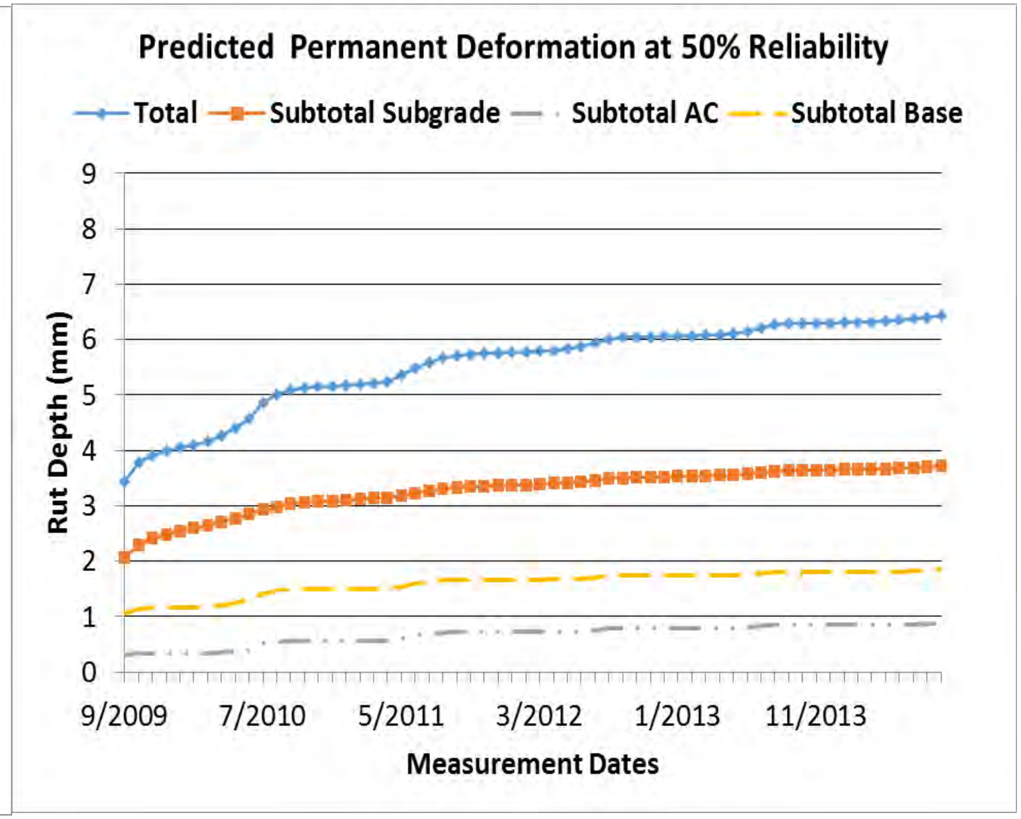
S9 Predicted Rutting N7





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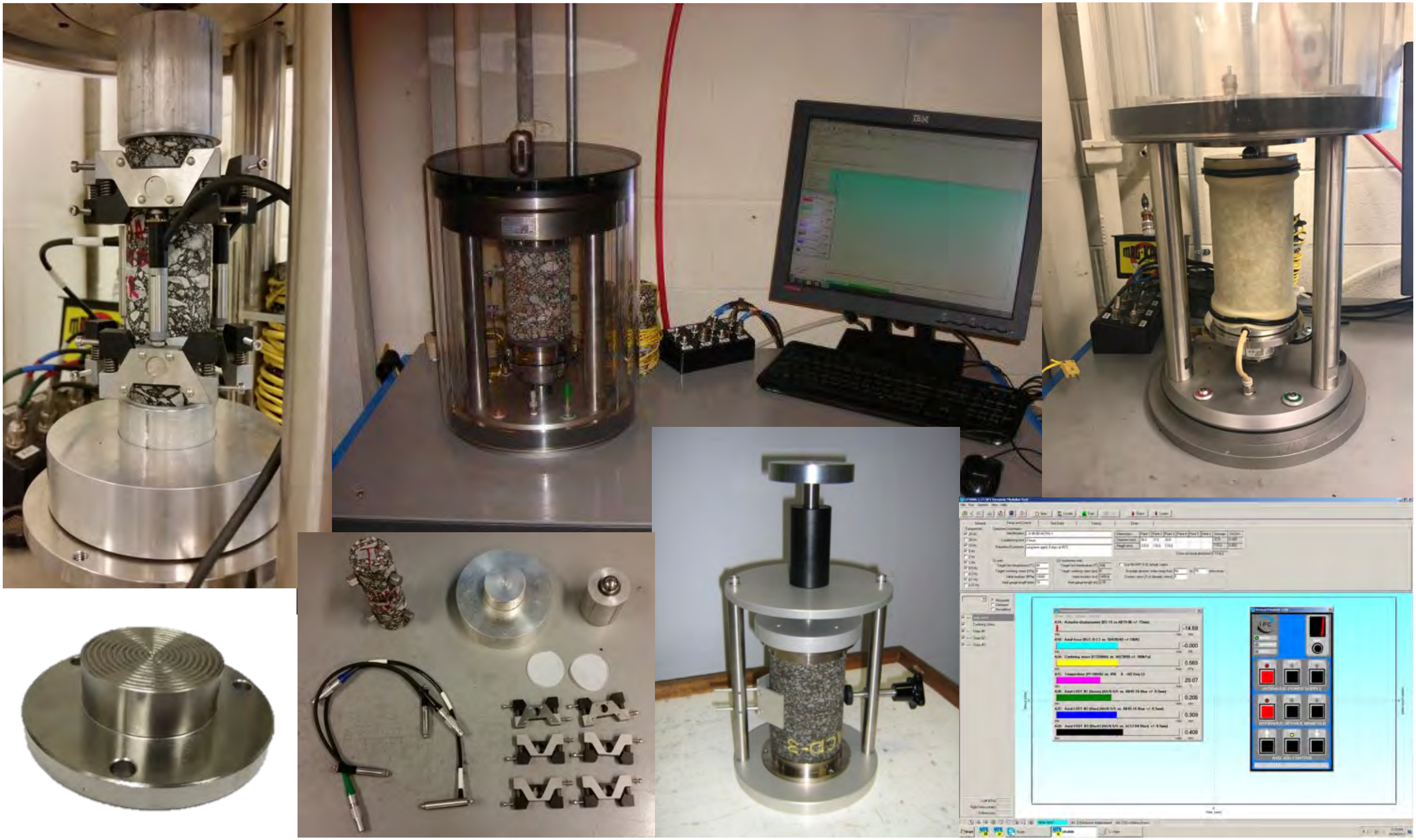
Predicted damage summary

Pavement Distress	S9	N7
Total Permanent Deformation, mm	10.2	8.4
AC Permanent Deformation, mm	6.4	1.5
Bottom-Up Cracking, % Area	18	1.5

Measured damage summary

Pavement Distress	S9	N7
Total Permanent Deformation, mm	6.0	1.6
AC Permanent Deformation, mm	6.0	1.6
Bottom-Up Cracking, % Area	10	0

Asphalt Mixture Performance Tester



AMPT Cracking Test Methods

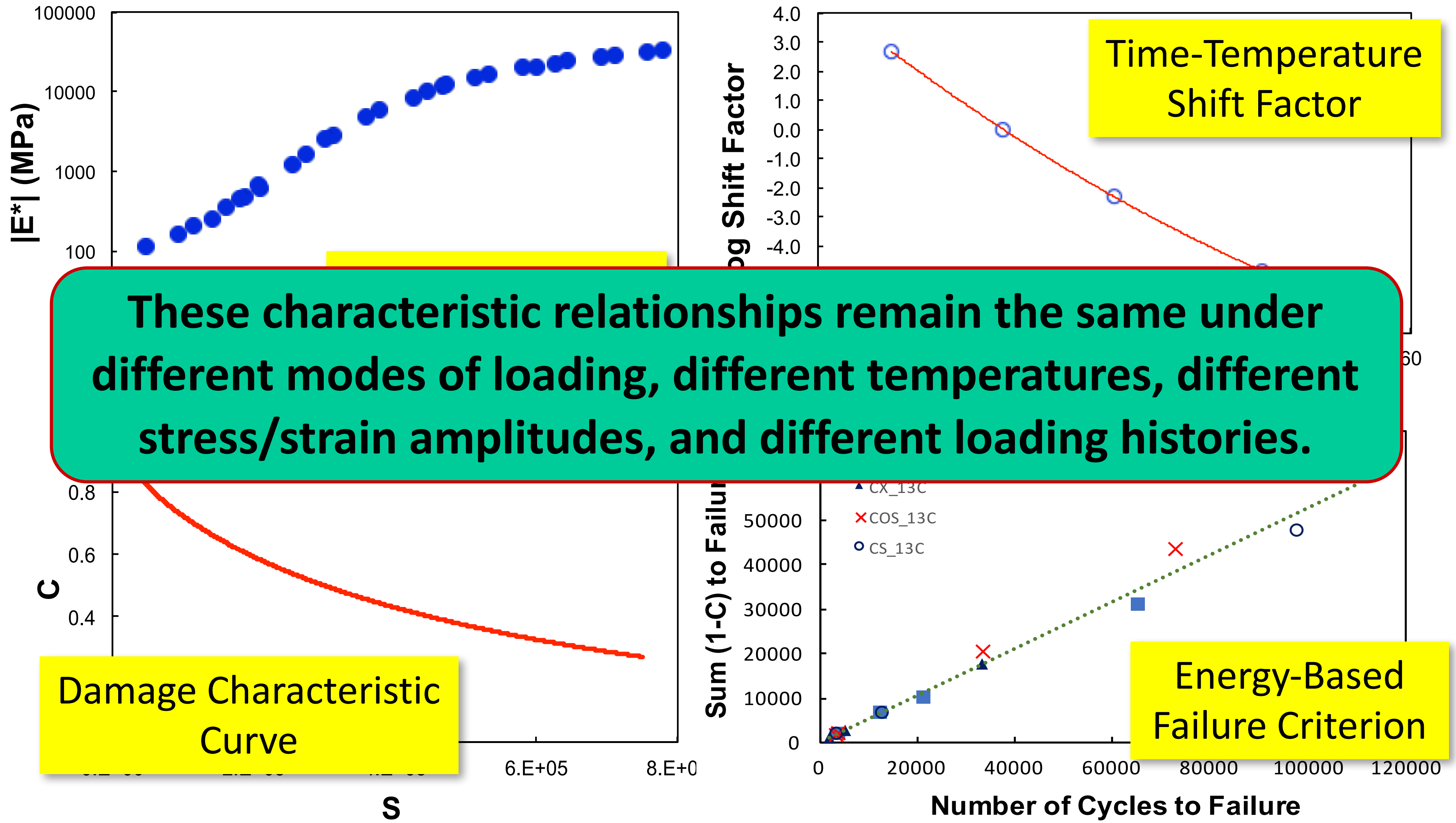
Modulus

- Axial compression dynamic modulus test (AASHTO T 378)
- Dynamic modulus mastercurve and time-temperature shift function

Cracking Resistance

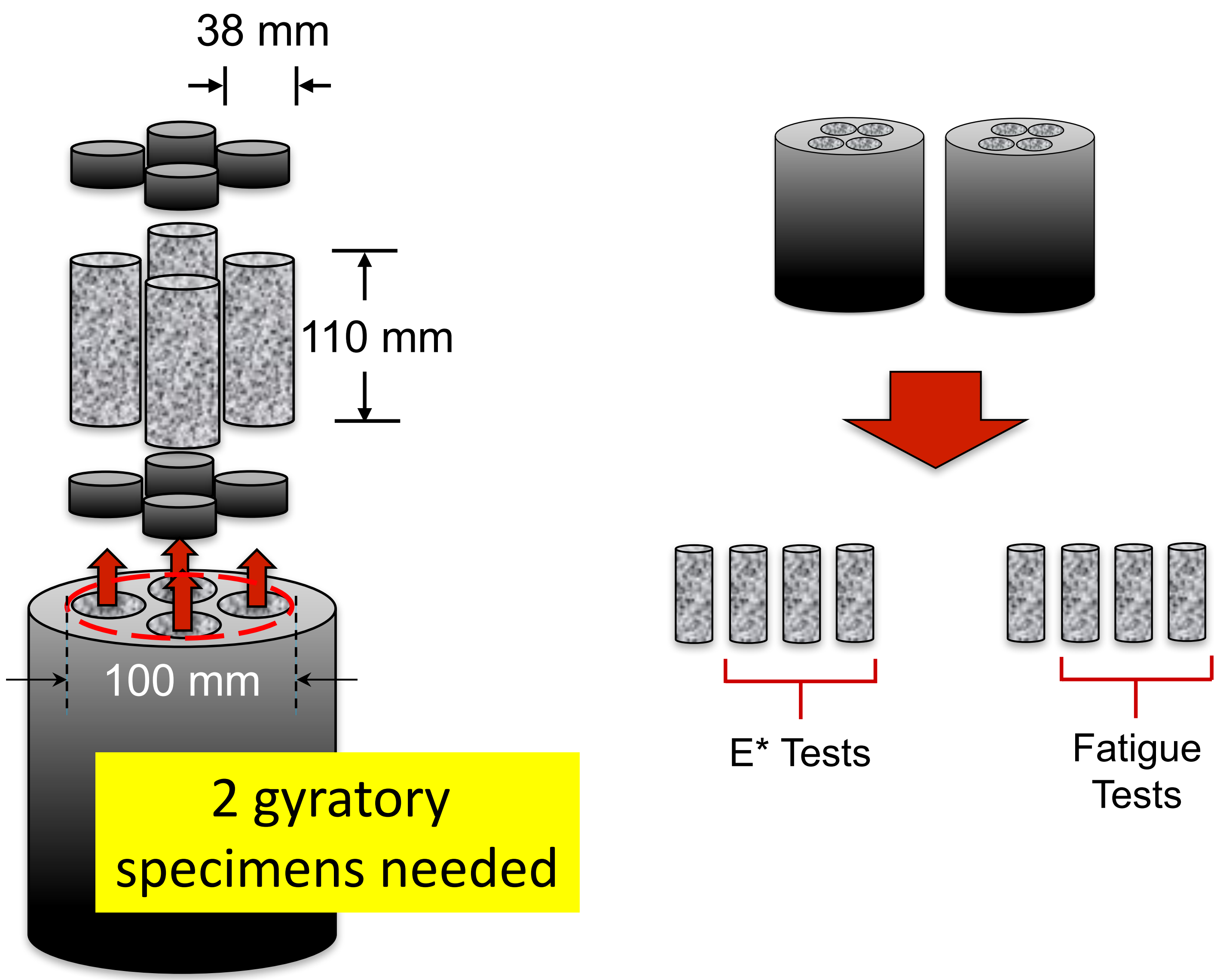
- AMPT cyclic fatigue test (AASHTO TP 107)
- C vs. S (damage characteristic curve)
- Energy-based failure criterion

S-VECD Model for Cracking



These characteristic relationships remain the same under different modes of loading, different temperatures, different stress/strain amplitudes, and different loading histories.

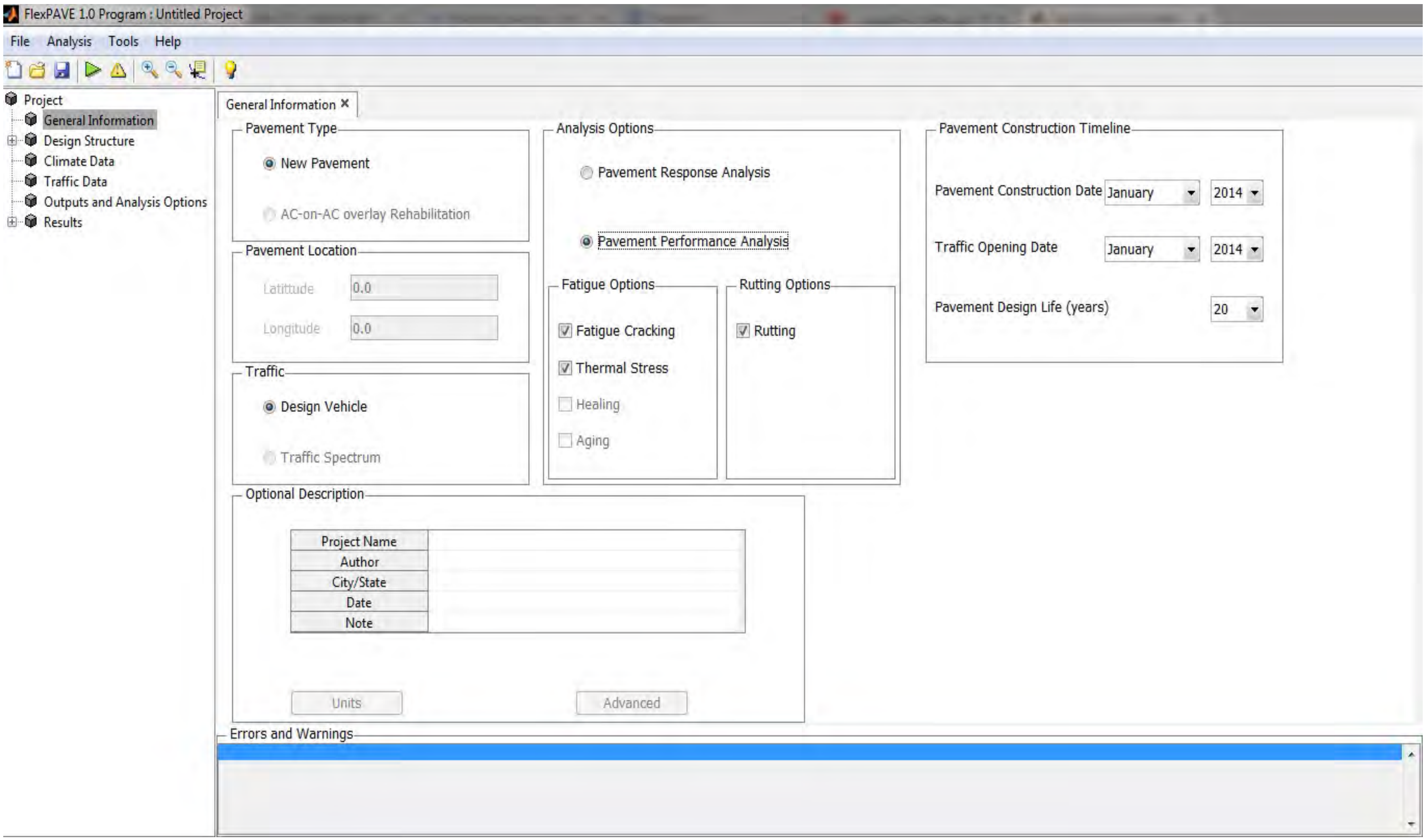
Specimen Geometry



FlexPAVE^{TM} 1.0

- Three dimensional layered viscoelastic analysis for moving loads and thermal stresses
- Fatigue performance analysis based on Viscoelastic Continuum Damage (VECD) Model
- Rutting performance analysis based on the shift model
- Support for multiple axle and multiple wheel loading
- Integrated with EICM software to capture temperature variation for thermal stress analysis and material properties
- Integrated GUI that includes pre and post processors

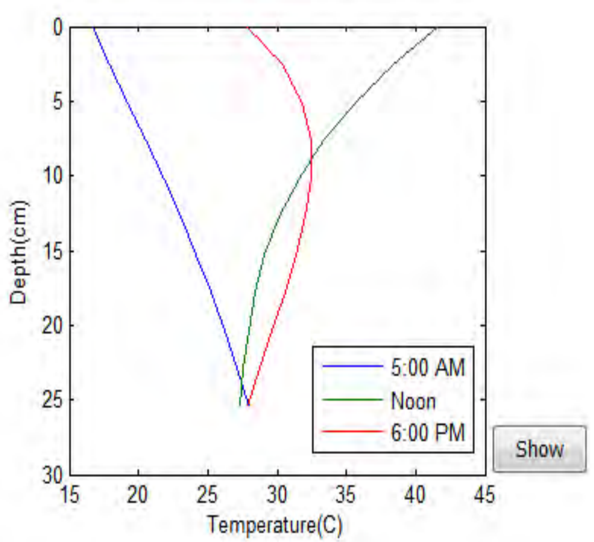
General Information



EICM in FlexPAVE™

Temperature Profile Input

- EICM
- EICM Text File
- Isothermal



Show

EICM DataBase Temperature

State: AL | Year: 2014 | Day: 6

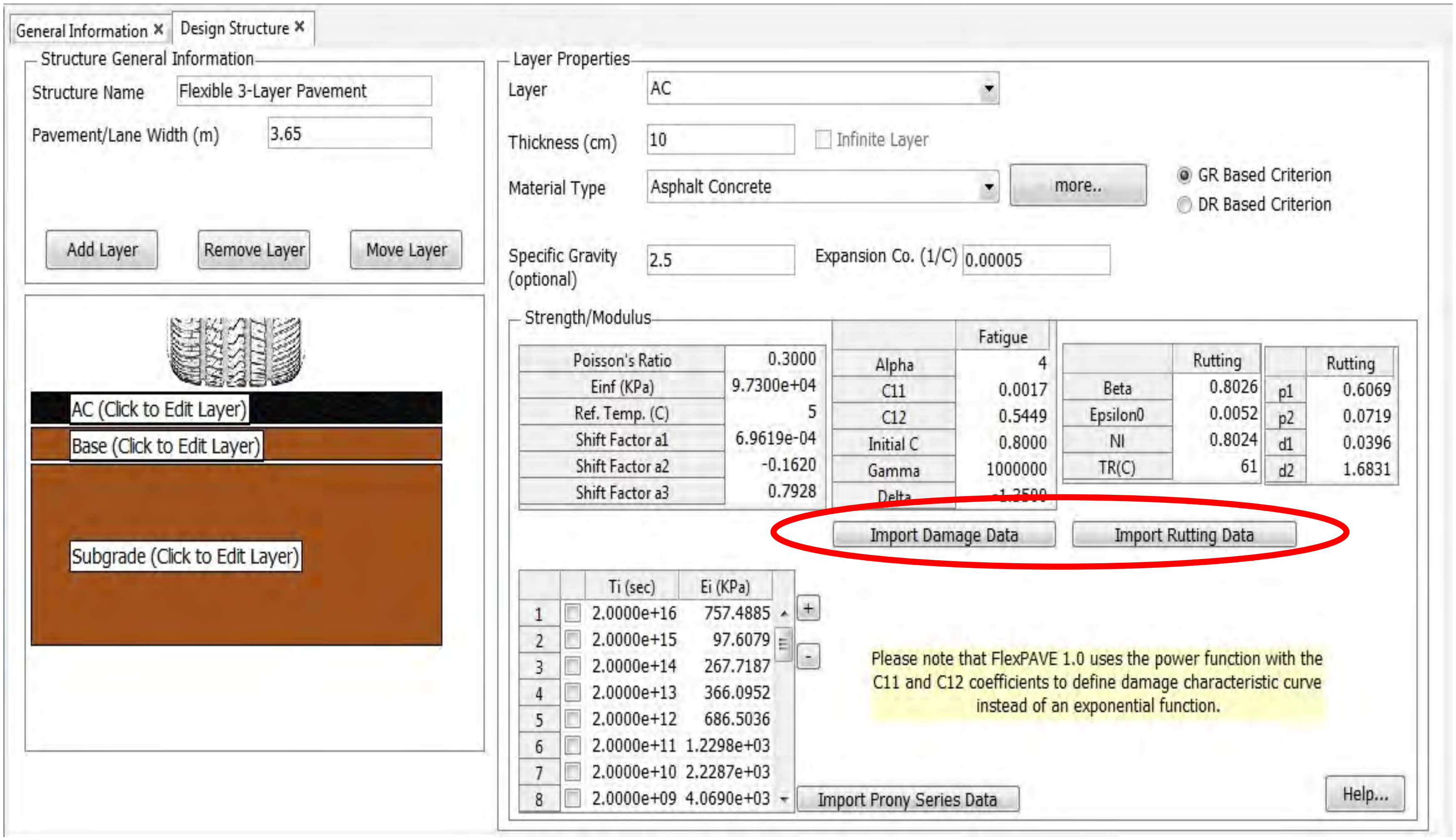
City: DECATUR | Month: Aug

Time\Depth (cm)	0	2.54	5.08	7.62	10.16	12.7
Midnight	17.17	19.56	21.56	23.22	24.56	25.67
1:00 AM	17.22	18.94	20.72	22.28	23.72	24.89
2:00 AM	16.11	18.22	20.06	21.67	23.06	24.28
3:00 AM	16.67	18.17	19.67	21.11	22.50	23.78
4:00 AM	16.11	17.78	19.33	20.78	22.11	23.39
5:00 AM	16.67	17.89	19.22	20.56	21.83	23.06
6:00 AM	19.44	19.33	19.89	20.78	21.78	22.89
7:00 AM	25.17	23.06	22.17	22.06	22.50	23.17
8:00 AM	30.56	27.39	25.39	24.33	24.00	24.11
9:00 AM	35.17	31.39	28.72	26.94	25.94	25.50
10:00 AM	38.28	34.83	31.83	29.61	28.11	27.17
11:00 AM	39.89	36.50	33.78	31.61	29.94	28.78
Noon	41.56	38.39	35.67	33.39	31.56	30.17
1:00 PM	41.94	39.33	36.89	34.72	32.89	31.39
2:00 PM	41.00	39.33	37.44	35.56	33.83	32.28
3:00 PM	39.00	38.11	36.94	35.61	34.17	32.83
4:00 PM	36.83	36.67	36.06	35.17	34.11	32.94
5:00 PM	33.06	34.17	34.44	34.17	33.56	32.72
6:00 PM	27.89	30.39	31.83	32.44	32.44	32.00

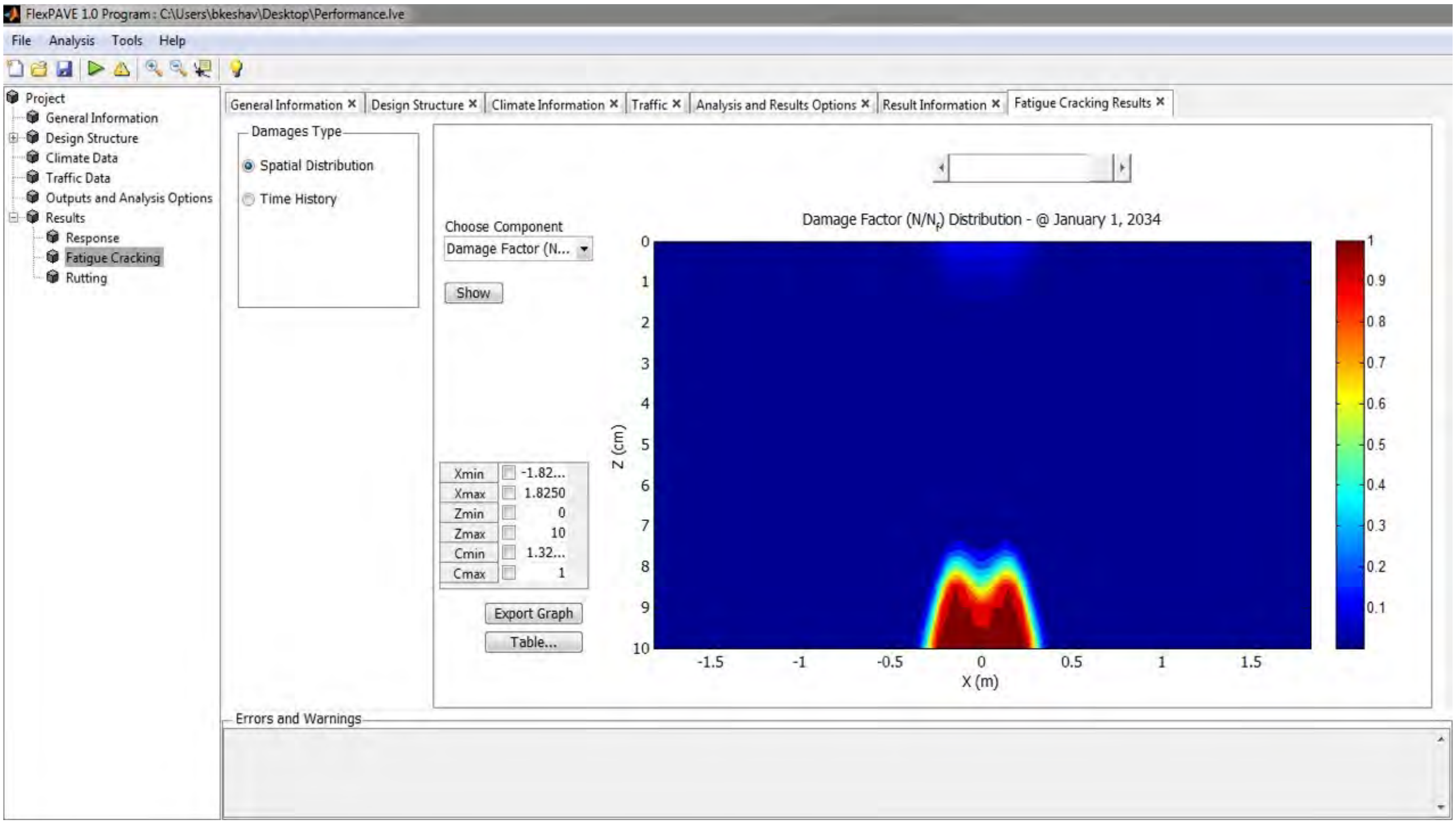
Refresh

Show

Material Properties

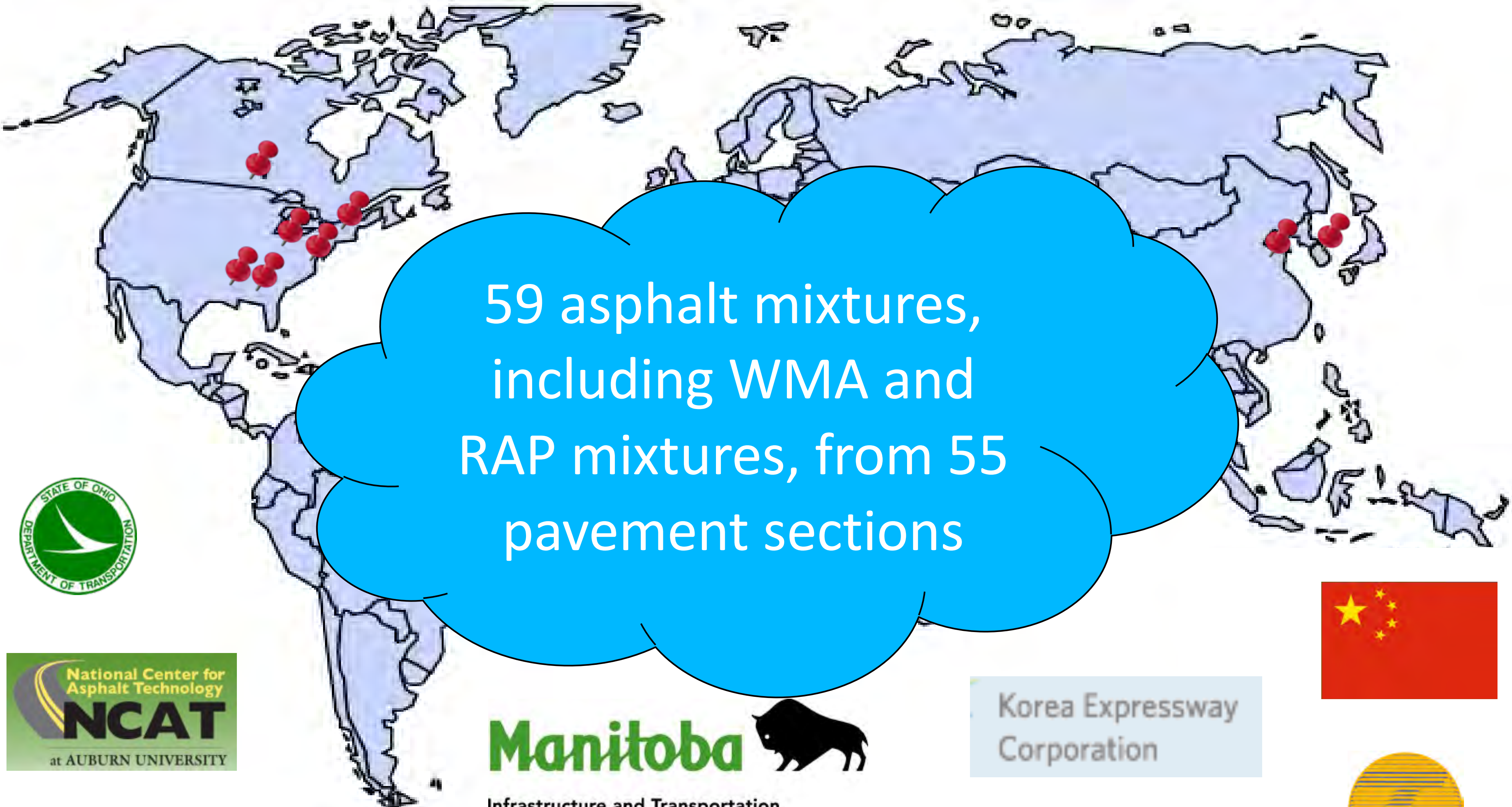


Damage Contour



Field Validation

Validation Sections



59 asphalt mixtures, including WMA and RAP mixtures, from 55 pavement sections

State of Ohio Department of Transportation

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Manitoba Infrastructure and Transportation

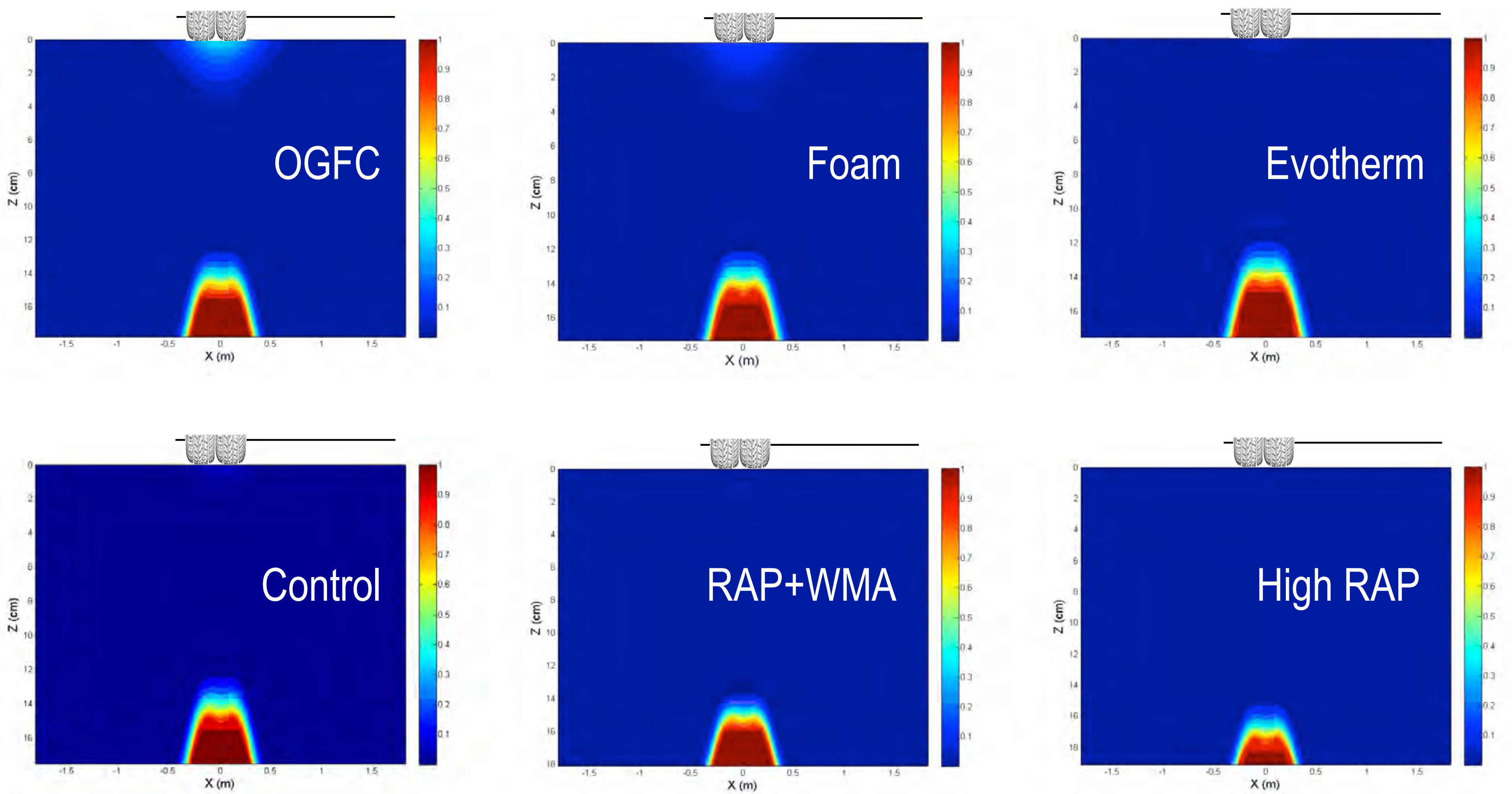
Korea Expressway Corporation

Western Research Institute

U.S. Department of Transportation Federal Highway Administration

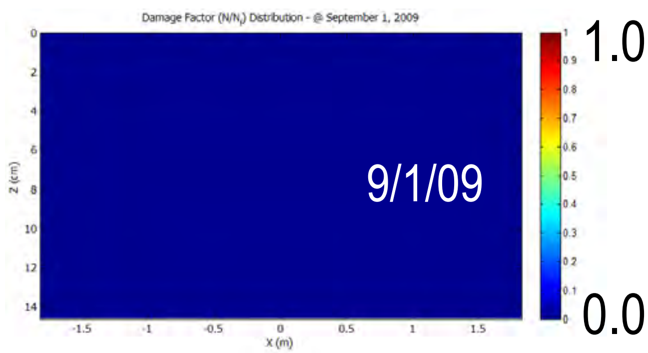
FlexPAVE^{TM} Simulation

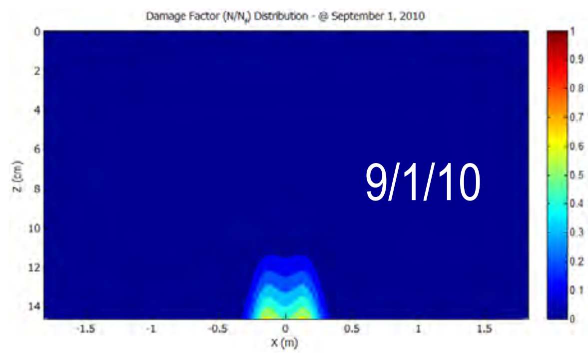
NCAT Test Track 2009 Performance Group

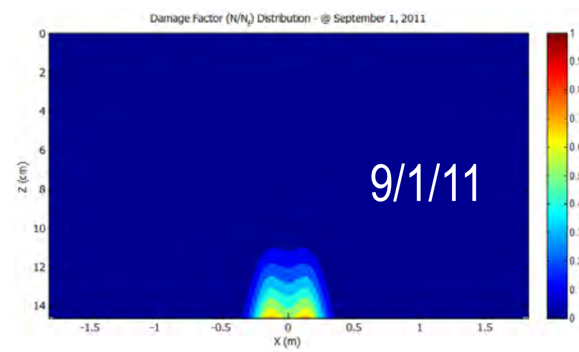


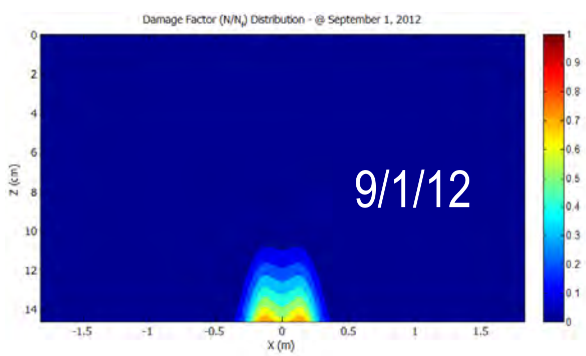
FlexPAVE^{TM} Simulation

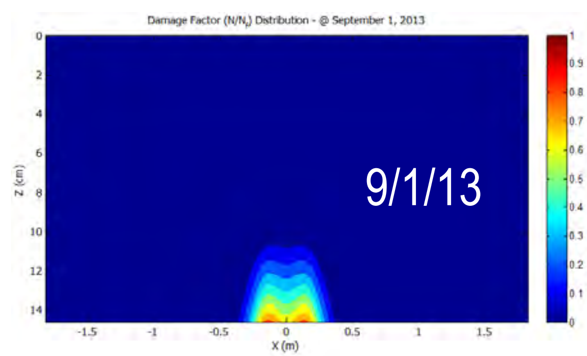
NCAT Test Track 2009 Section N7

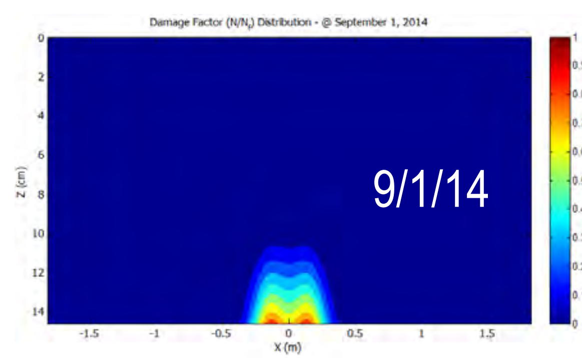


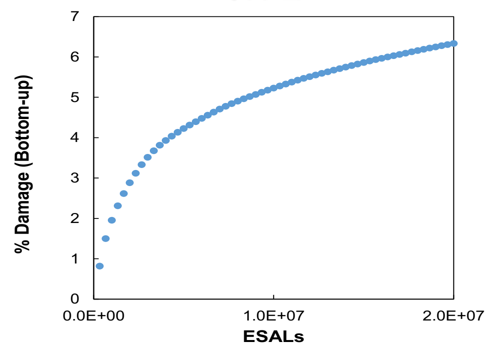






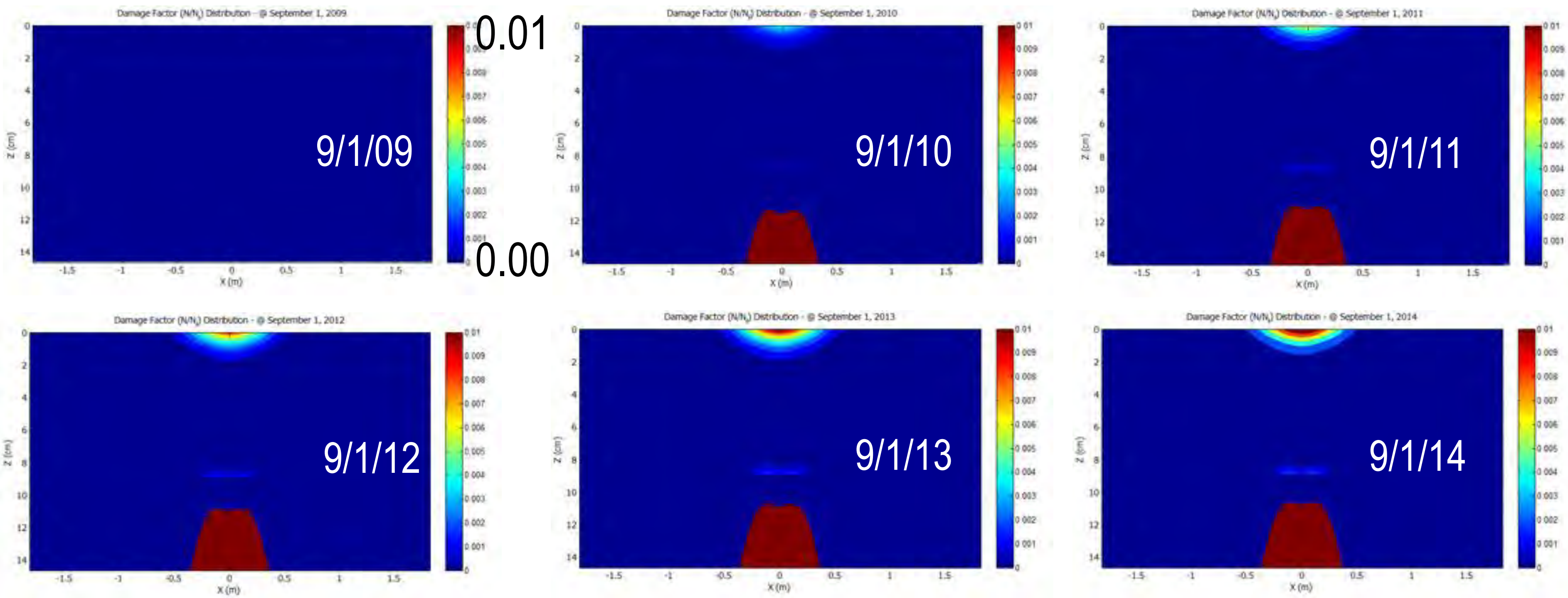


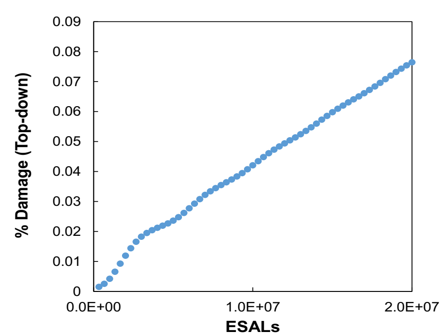




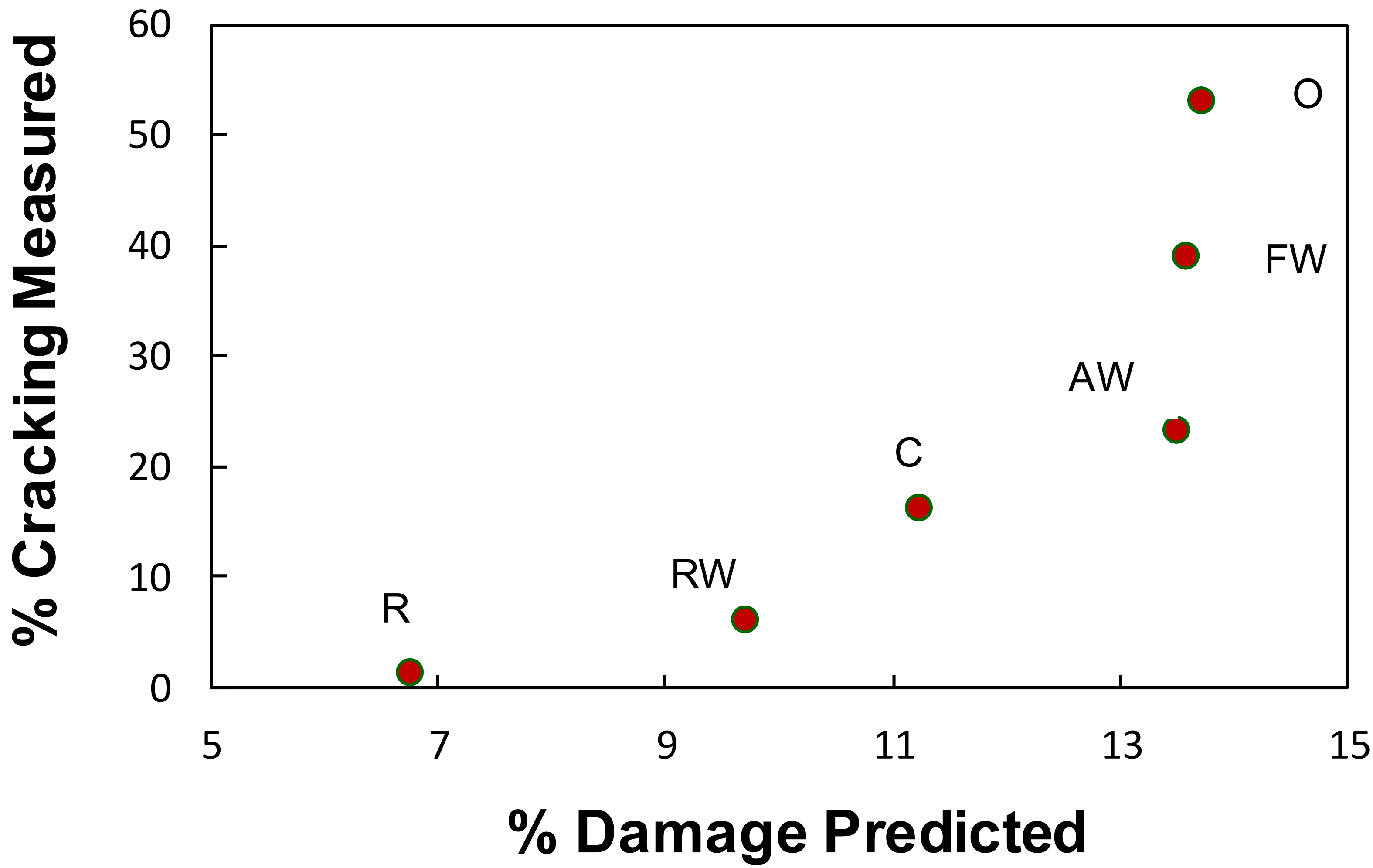
FlexPAVE™ Simulation

NCAT Test Track 2009 Section N7 Expanded Scale

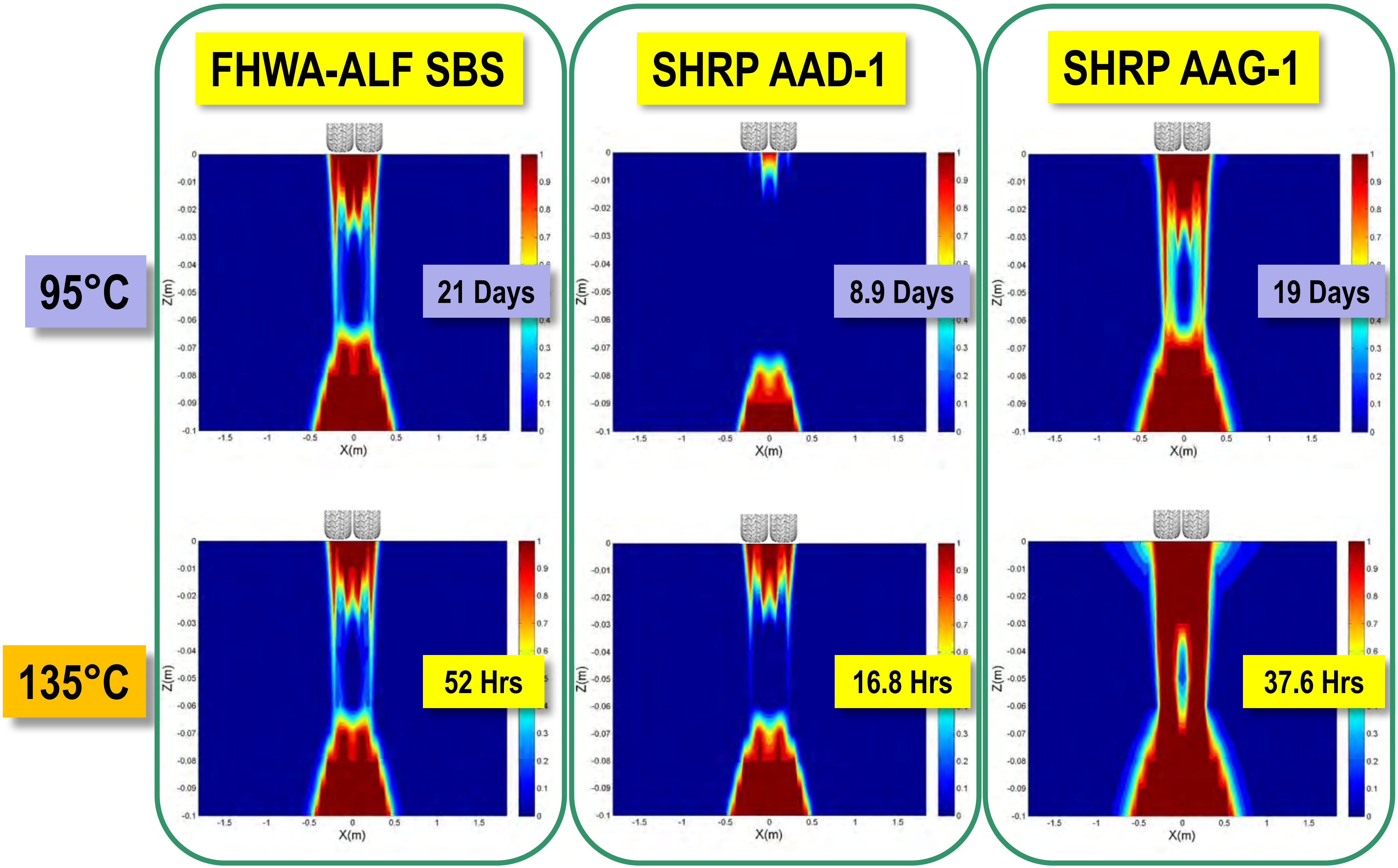




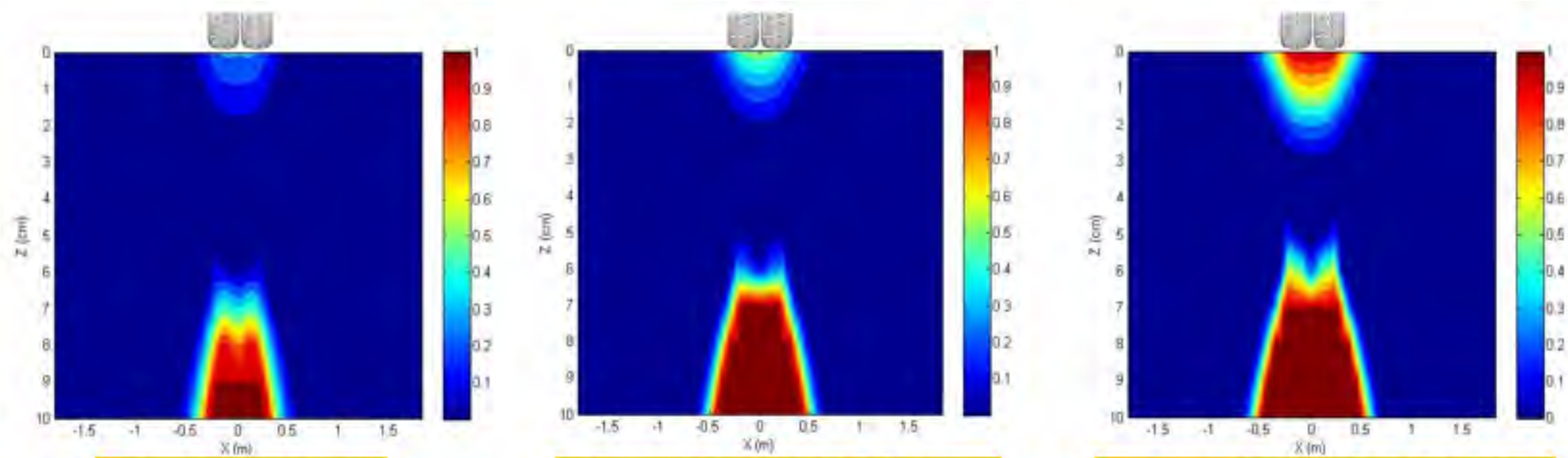
NCAT Test Track Prediction



Cracking Performance Simulation by FlexPAVE™



Effect of Aging on Cracking

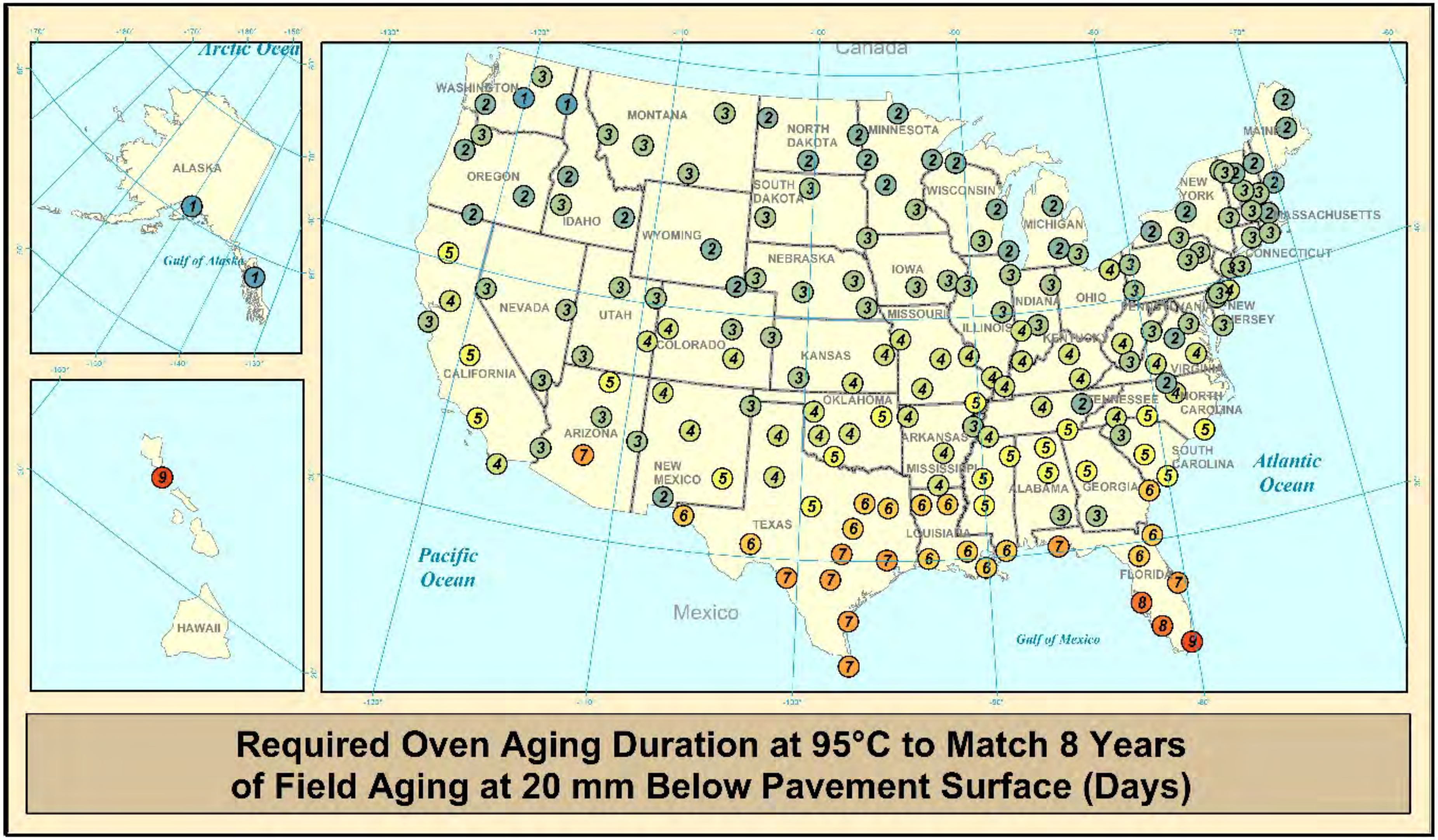


Short-Term Aged | Loose Mix, 95°C, 8.9 Days | Loose Mix, 135°C, 16.8 Hr

NCHRP 09-54 Aging Procedure

- Loose mixture aging in an oven at 95°C
- Use the climate aging index (CAI) map for laboratory aging durations for specific pavement depth and age of interest in the field

NCHRP 9-54 Aging Map



Required Oven Aging Duration at 95°C to Match 8 Years of Field Aging at 20 mm Below Pavement Surface (Days)

Conclusions

- NCAT section N7 developed fine surface cracking late in its life, but forensic analysis showed that the cracking was minor top down cracking not impacting the structural integrity of the pavement.
- Highly modified asphalt may be useful in perpetual pavement design.
- Demonstrated performance up to 20 million ESALs shows that the thickness of pavement structures may be reduced while retaining or even improving long term performance.

Conclusions

- AASHTO M332 specifications (plus elastic recovery) have been effective to specify HiMA binders for commercial applications.
- Standardized test methods in increasingly common use are adequate to characterize HiMA mixtures for the purpose of pavement design.
- The current Pavement ME Design protocol is suited to designing perpetual pavements with highly modified asphalts. Relative global calibration factor adjustment with Level 1 design gives performance predictions that agree well with actual field performance relative to known structures.

Conclusions

- Both AASHTOWare Pavement ME Design™ and FlexPAVE™ are effective design tools.
- ME Design currently lacks a validated model for top-down cracking.
- FlexPAVE currently lacks a built-in aging model and so required aged material properties.
- We will be doing follow up modeling with both to compare!

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