Utilization of Post-Consumer Recycled Asphalt Shingles (RAS) and Fractionated RAP in HMA

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Introduction

- Illinois Tollway Authority undertaking unprecedented rehabilitation/expansion program
- Looking to new technologies to solve financial challenges
- Tollway sponsored 2007 study on increasing the percentage of RAP in HMA shoulders (FRAP)
- New 2009 research to study use of post-consumer RAS in HMA shoulders

Illinois Tollway Authority, Interstate 90

- Field demonstration conducted in July 2009
- Mixes containing RAS and FRAP were placed in the shoulder
- Iowa State obtained field samples for laboratory testing

Objectives

1. Characterize performance of HMA with RAS and varying percentages of FRAP

2. Can 5% RAS replace 5% FRAP in Tollway mixtures and maintain quality?

3. Performance difference between laboratory and field samples

Mix Design Experimental Plan

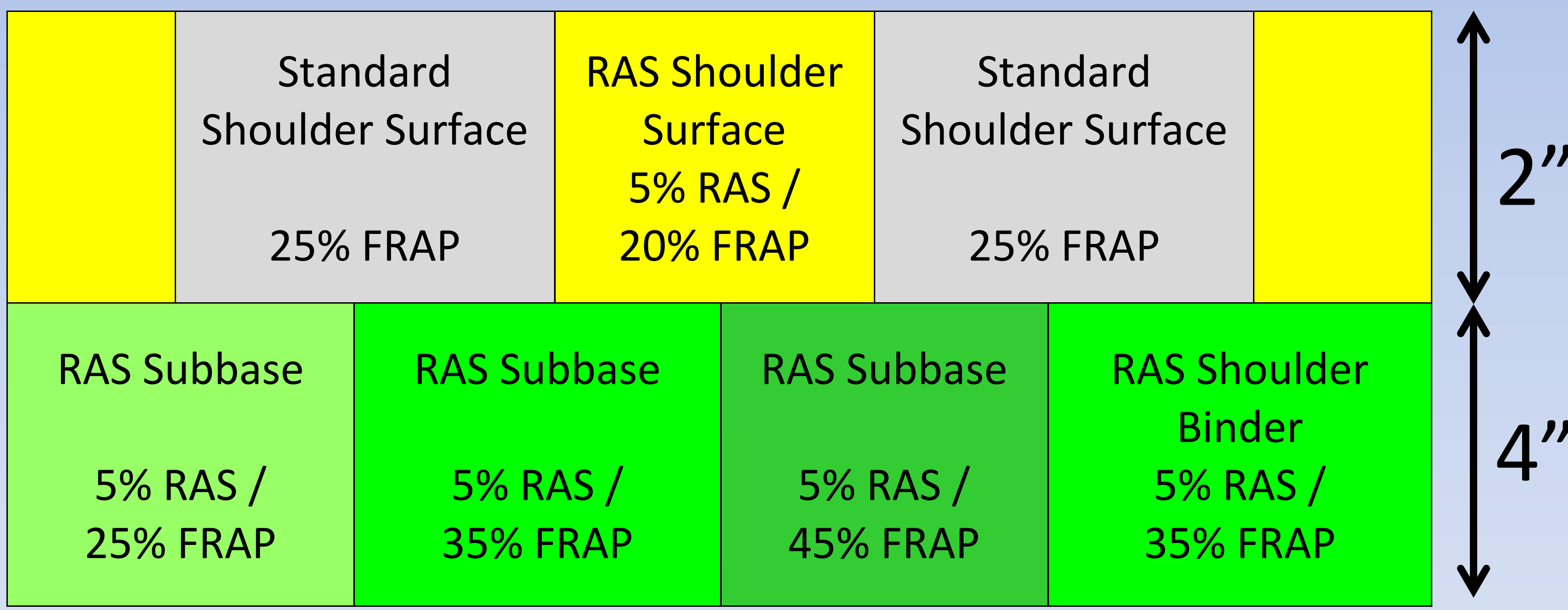
- Base mix designed at lower air voids to reduce permeability
- Binder mix designed as a “rich bottom layer” mix
- One grade bump in the high temperature Performance Grade

Mix Type	NMAS (mm)	Design Air Voids	N_{des}	Performance Grade
Base	19.0	2	50	58-22
Binder	19.0	3	50	58-22
Surface	9.5	4	70	58-22

Mix Design Experimental Plan

ID	Mix Type	FRAP	RAS	Experiment ID	Field Sample	Lab Sample
1	Base	25	5	Experimental	X	X
2	Base	35	5	Experimental	X	X
3	Base	45	5	Experimental	X	X
4	Base	50	0	Control	X	
5	Binder	35	5	Experimental		X
6	Binder	40	0	Control	X	X
7	Surface	20	5	Experimental	X	X
8	Surface	25	0	Control	X	

Shoulder Pavement Cross-Section



Laboratory Testing Plan

- Binder Characterization
  - Dynamic Shear Rheometer - Rutting
  - Bending Beam Rheometer - Thermal Cracking

- Mixture Characterization
  - Dynamic Modulus - Rutting
  - Flow Number - Rutting
  - Tensile Strength Ratio - Freeze Thaw Damage
  - Flexural Beam Test - Fatigue Life
  - Fracture Energy* - Thermal Cracking

    *By University of Illinois Urbana-Champaign

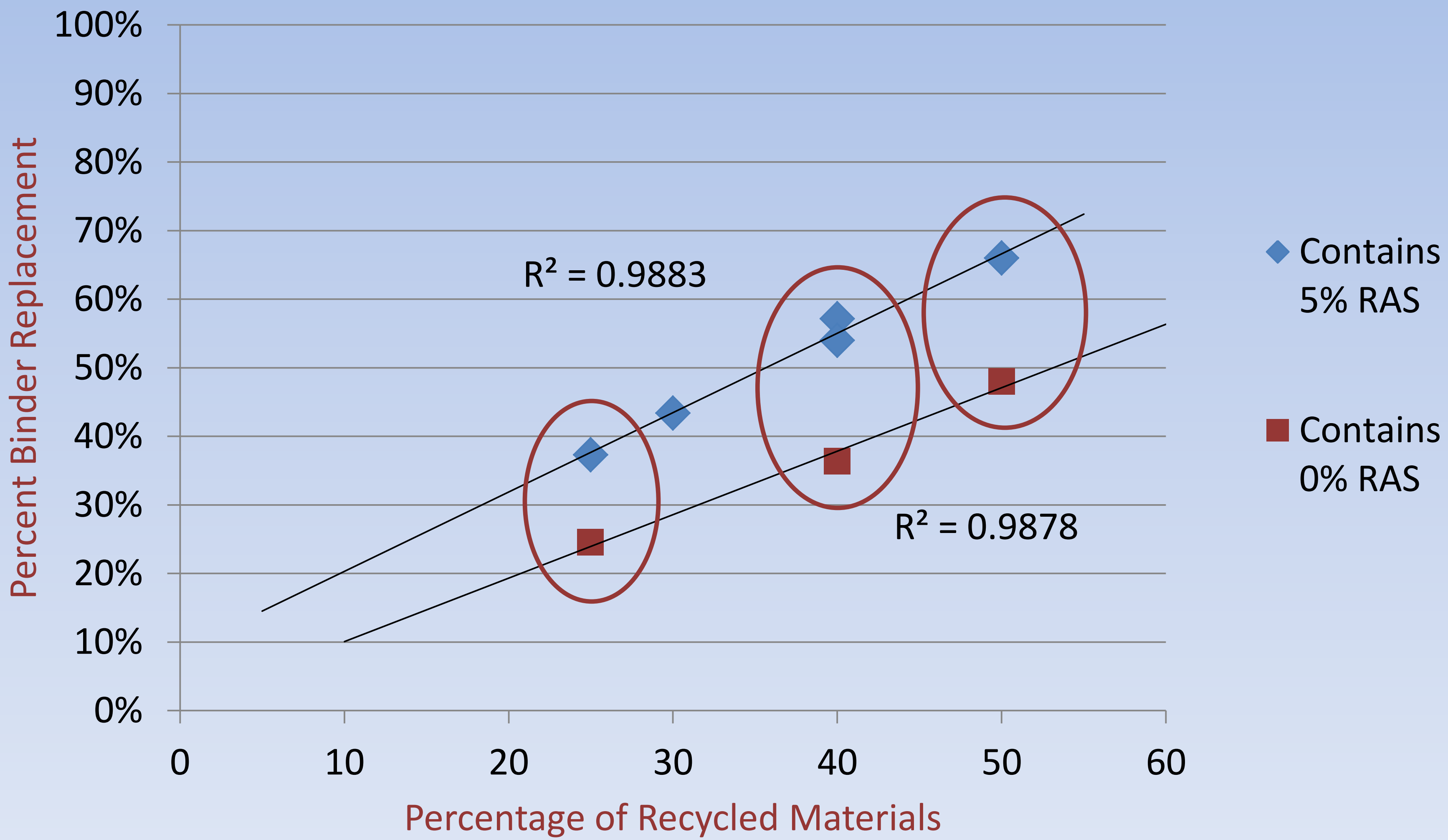
- Master Curves - Viscoelastic Behavior

Field Samples

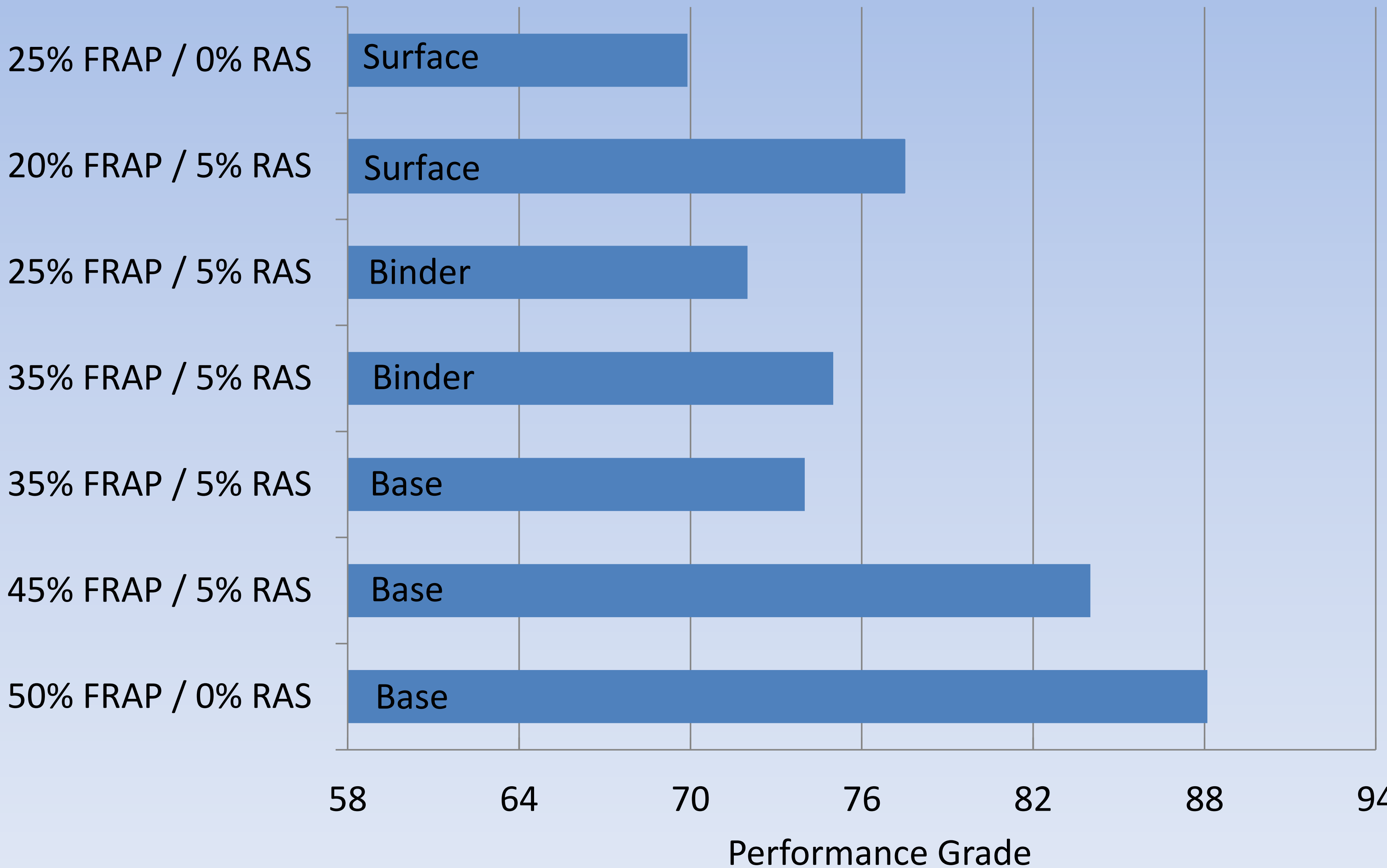
Laboratory Samples

- Samples Prepared by STATE Testing
- Aggregate heated to 325°F
- RAP heated separately until 300°F
- RAS carefully heated but no standard protocol
- Agg, RAP, and RAS added to mixing bucket individually
- No curing time
- Reheated in oven for 4-6 hours

RAS & FRAP Binder Contribution

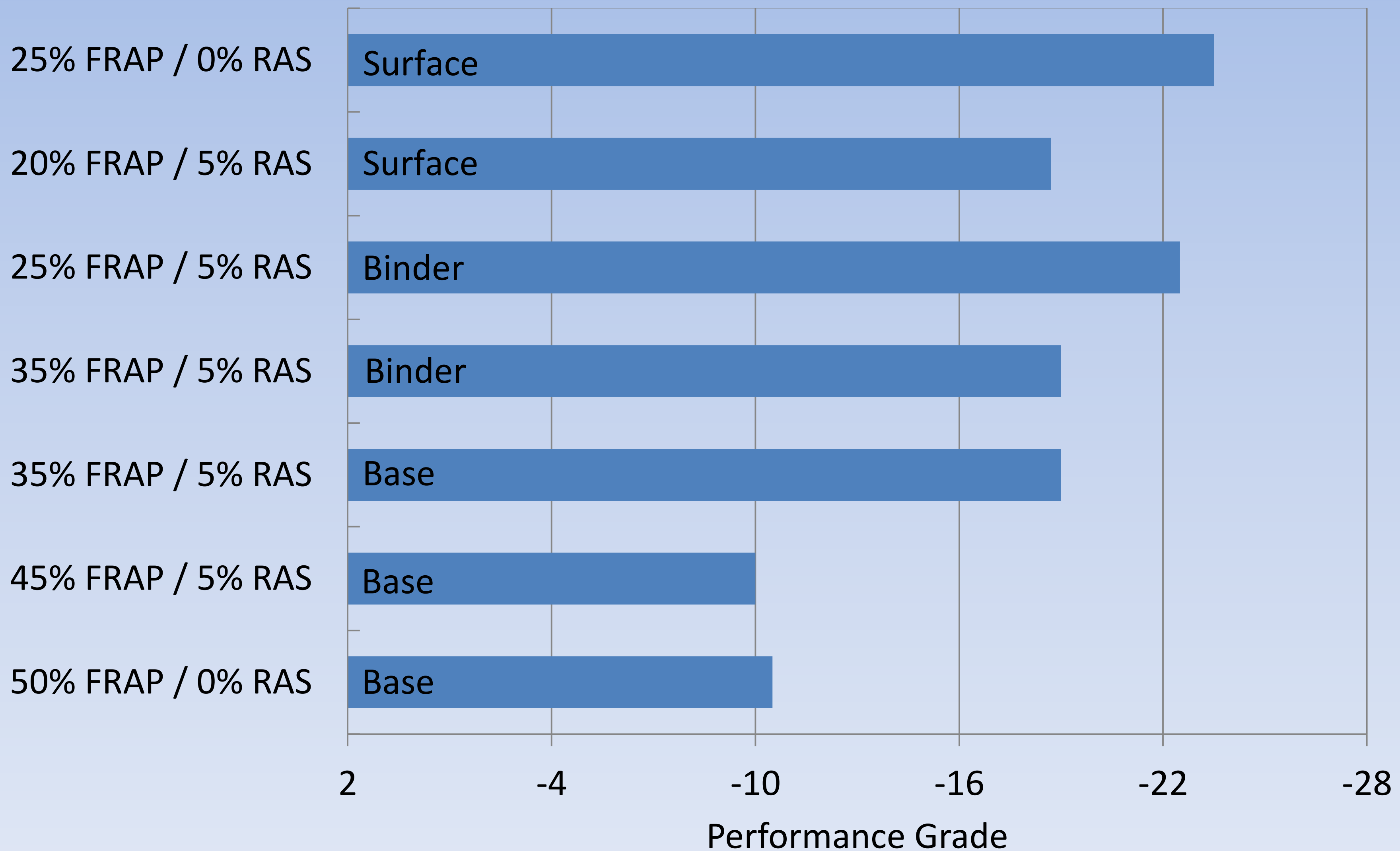


Field Binders - High Temperature Grades

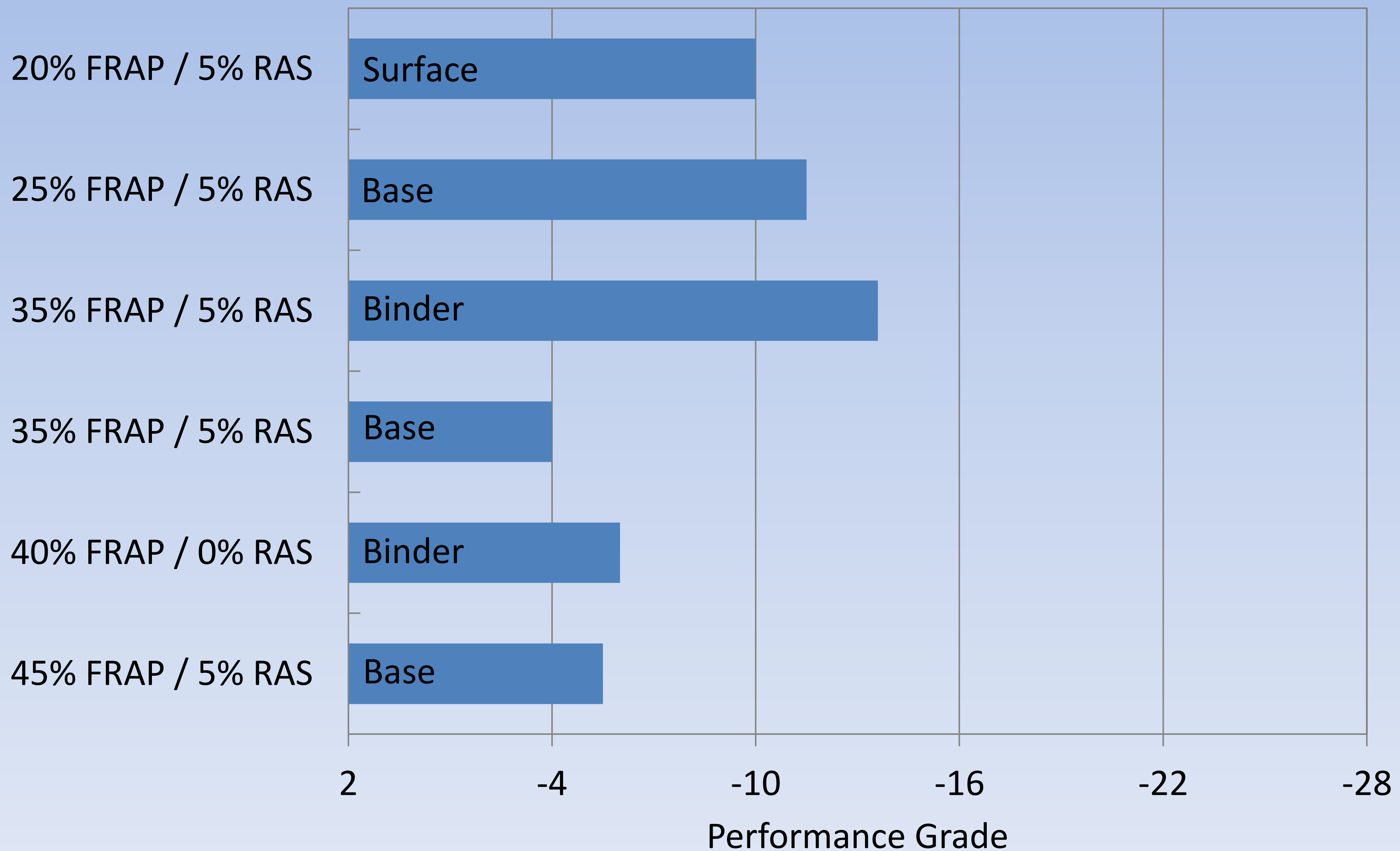


Lab Binders – High Temperature Grades

Field Binders – Low Temperature Grades



Lab Binders – Low Temperature Grades

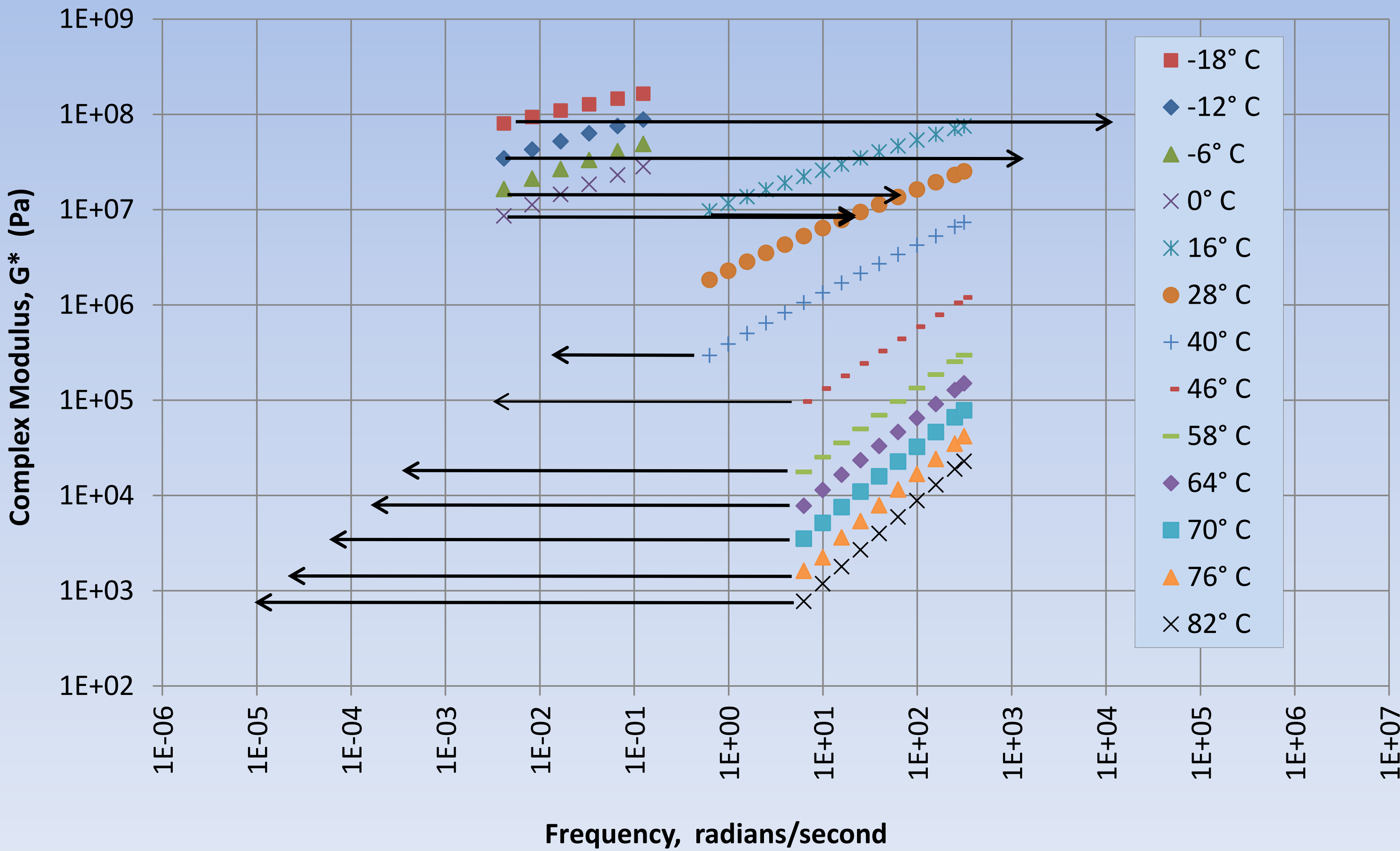


Binder Master Curves

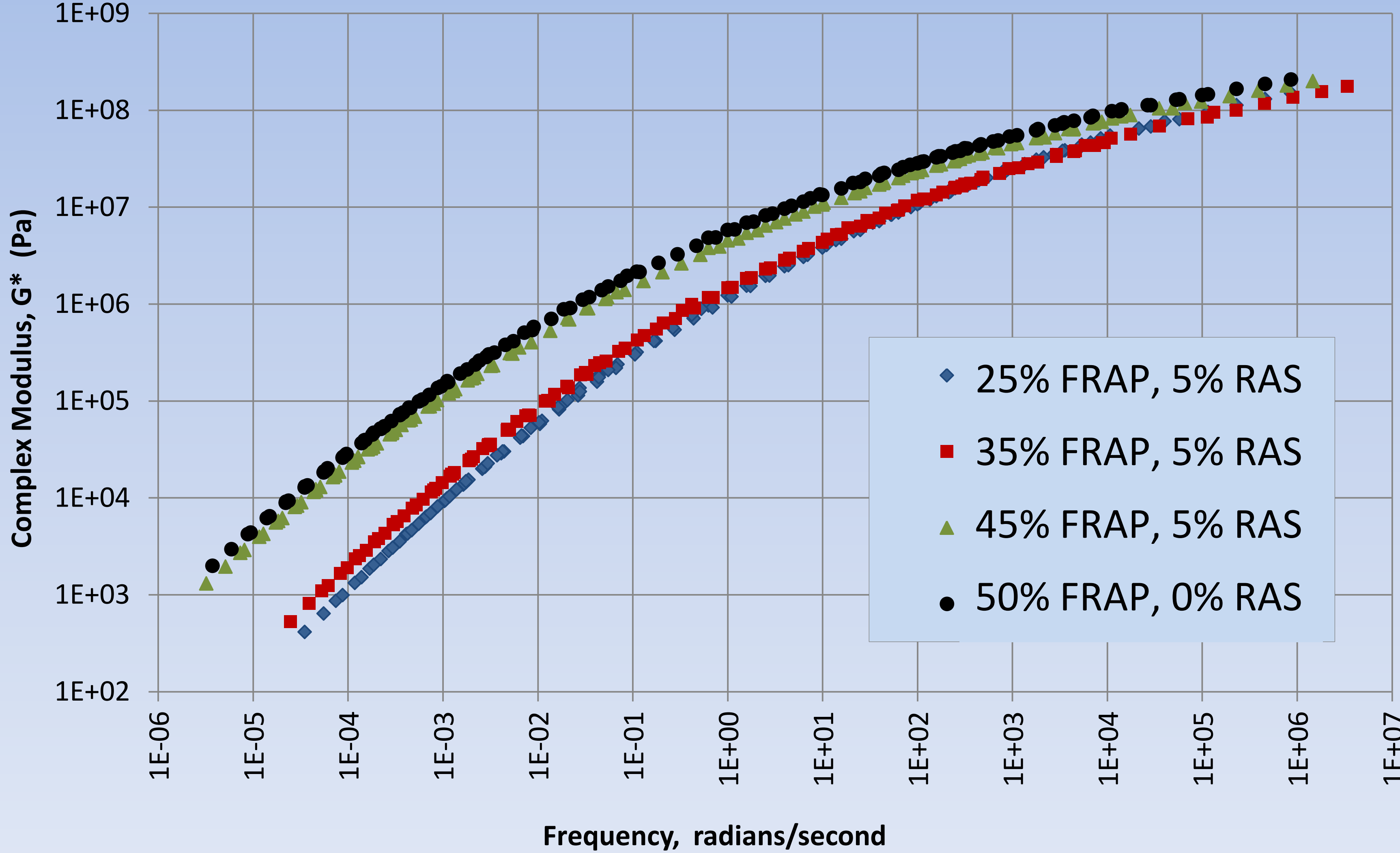
- Describes Shear Modulus G* as a function of temperature and rate of loading
- Frequency Sweeps in linear viscoelastic range in the DSR and BBR
- Converted Creep Stiffness to Shear Modulus values
- Frequency curves shifted horizontally with respect to 28°C
- CAM Model used to construction master curves

$$|G^*(\omega)| = G_g\left[1 + \left(\frac{\omega_c}{\omega}\right)^v\right]^{-\frac{w}{v}}$$

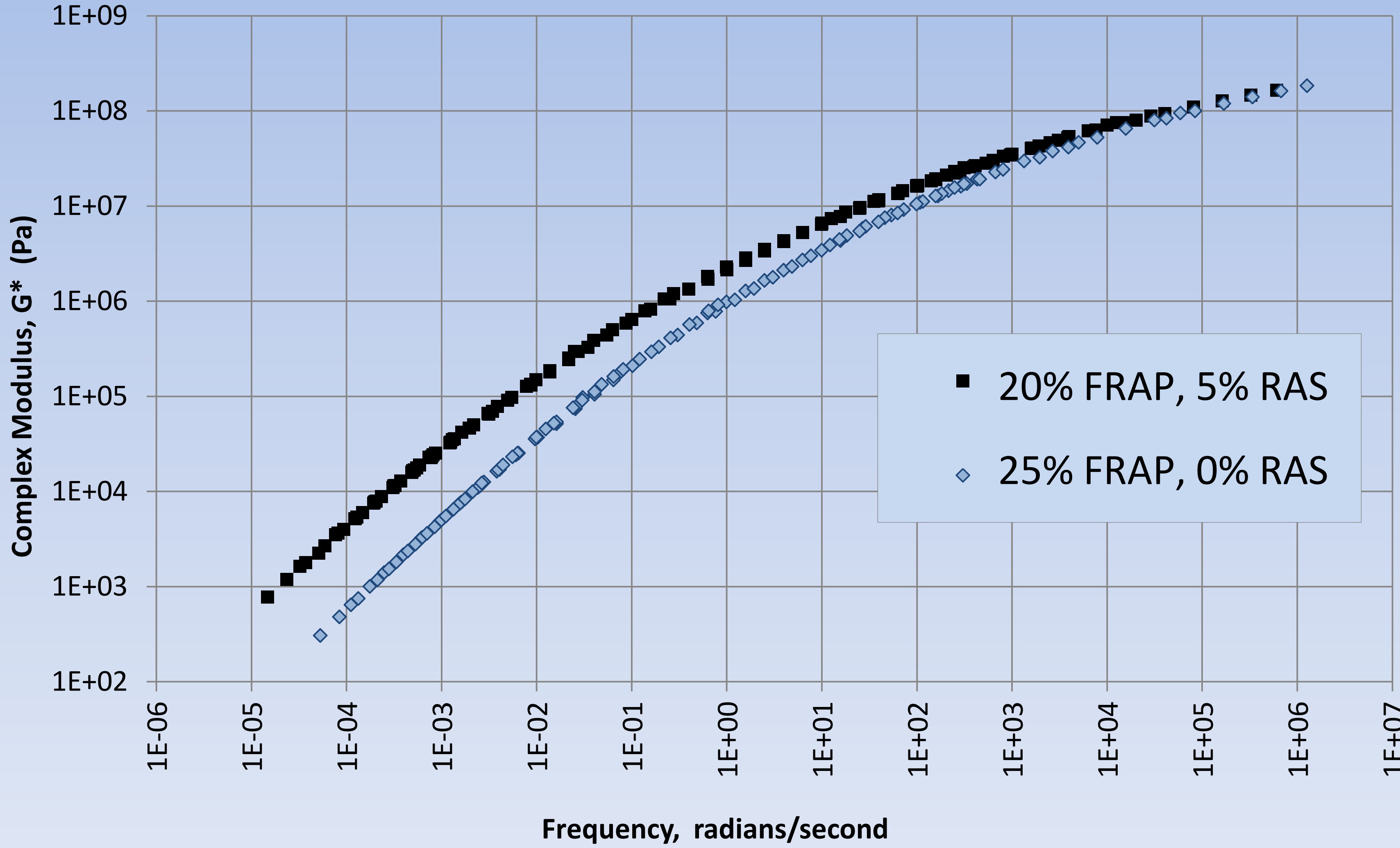
Master Curve Construction



Base Course Master Curves

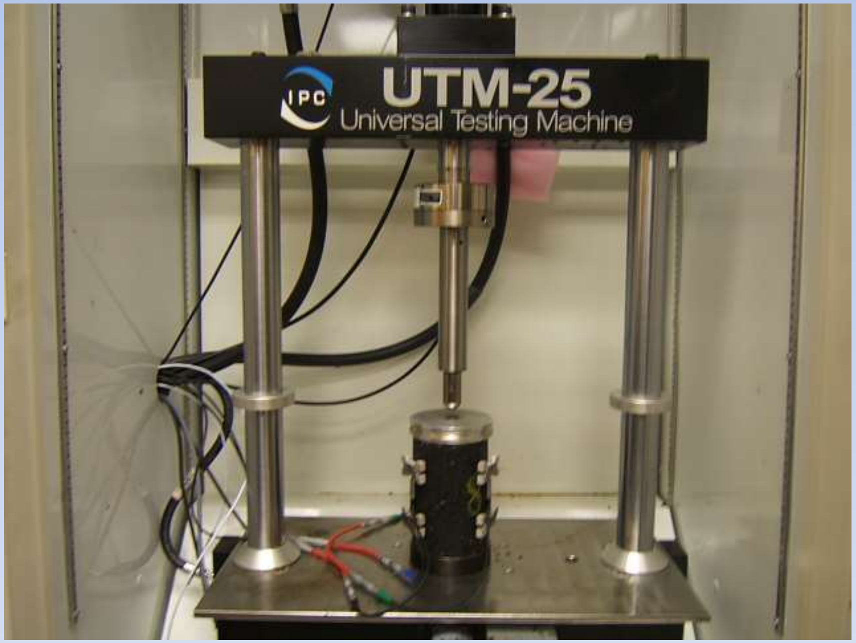


Surface Course



Dynamic Modulus, E*

- Five Replicate Samples
- 4” dia. by 6” height
- Axial Cyclical Load
- Constant Strain Mode
- Strain measured with three LVDTs
- Nine Frequencies
- 4, 21, and 37°C

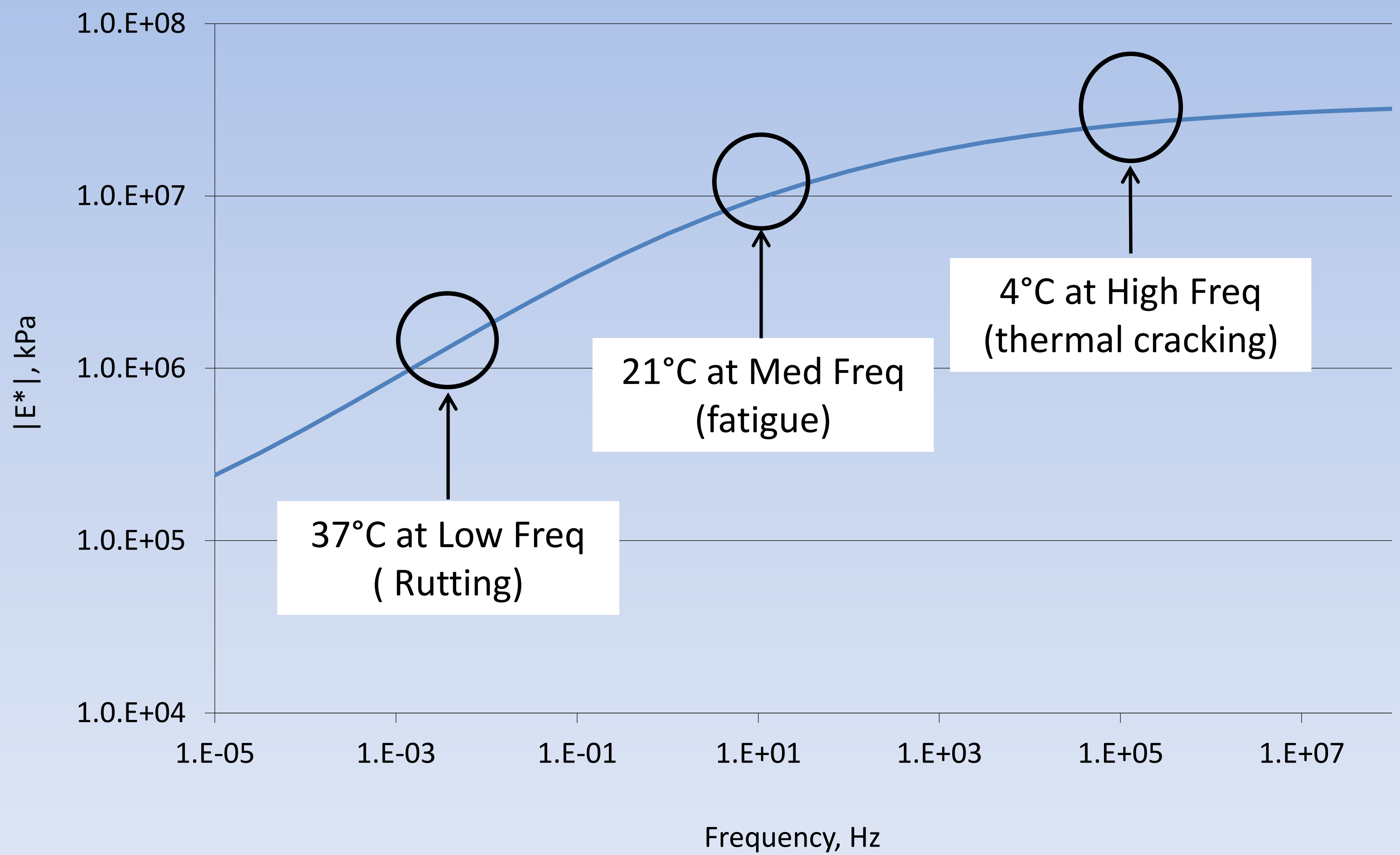


HMA Mixture Master Curves

- Describes Dynamic Modulus E* as a function of temperature and rate of loading
- Used for Mechanistic-Empirical Pavement Designs
- Frequency curves shifted horizontally with respect to 21°C
- Sigmoidal function used to construction master curves

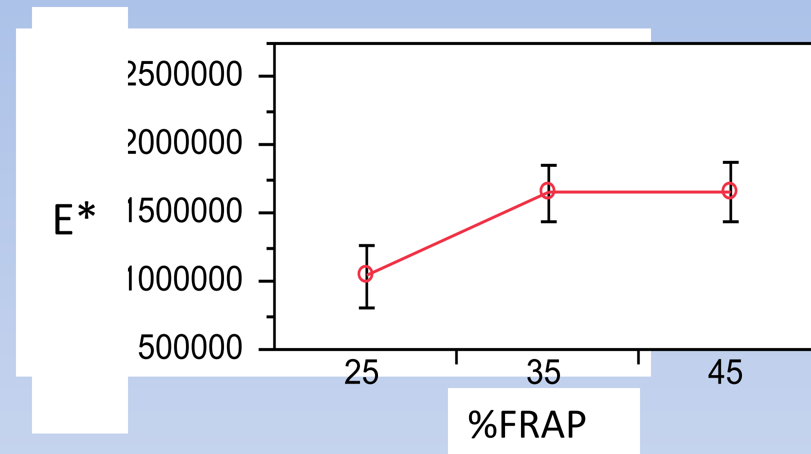
$$\text{Log}|E^*| = \delta + \frac{\alpha}{1 + e^{\beta+\gamma(logt_r)}}$$

Dynamic Modulus Master Curve

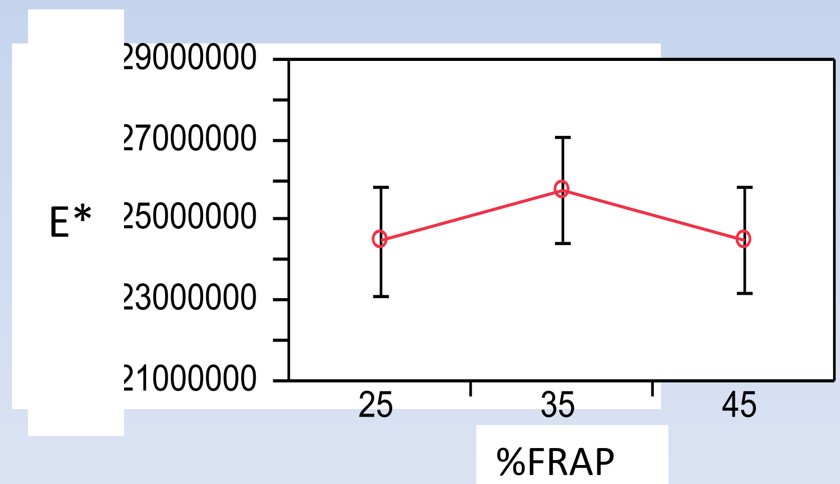


What effect does FRAP have on the Base Mix?

- High Temp/Low Freq E*
- 25 to 35% is Significant

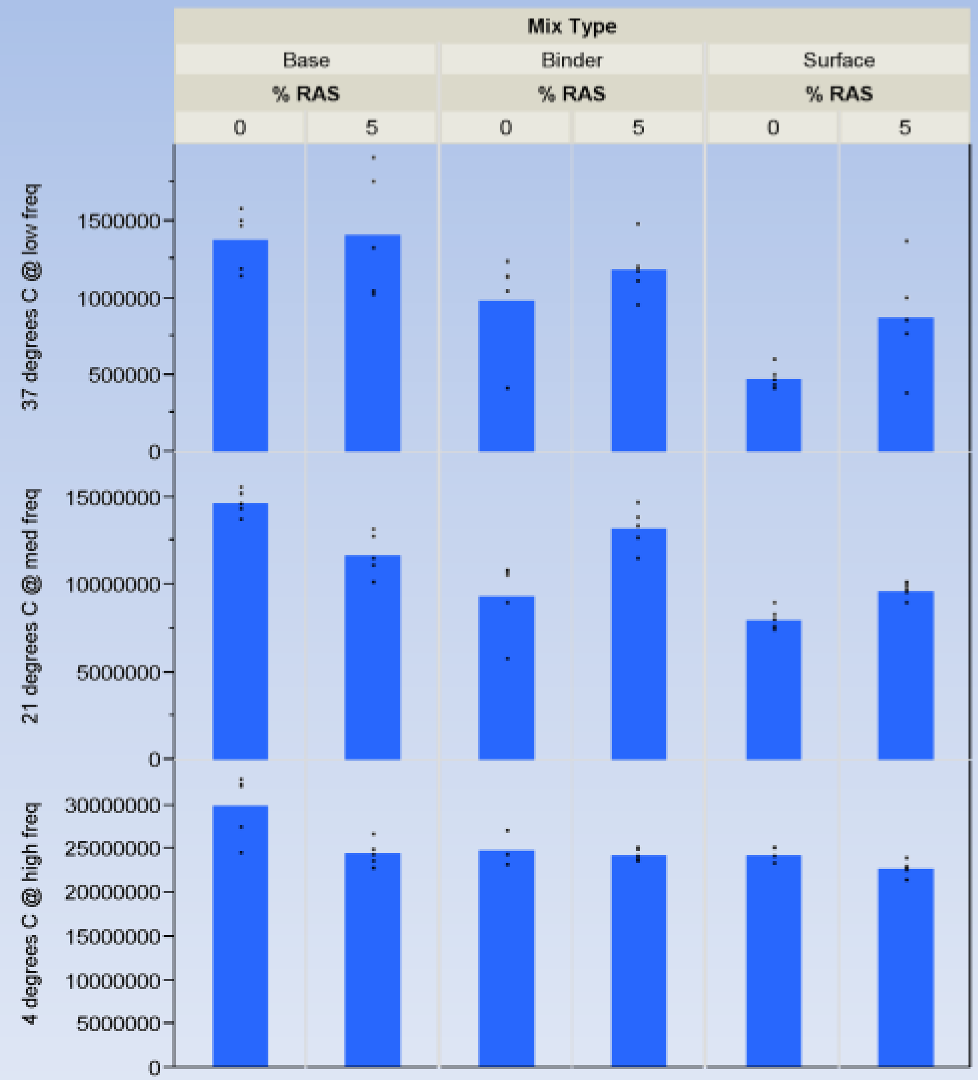


- Low Temp/High Freq E*
- No Significant Diff.



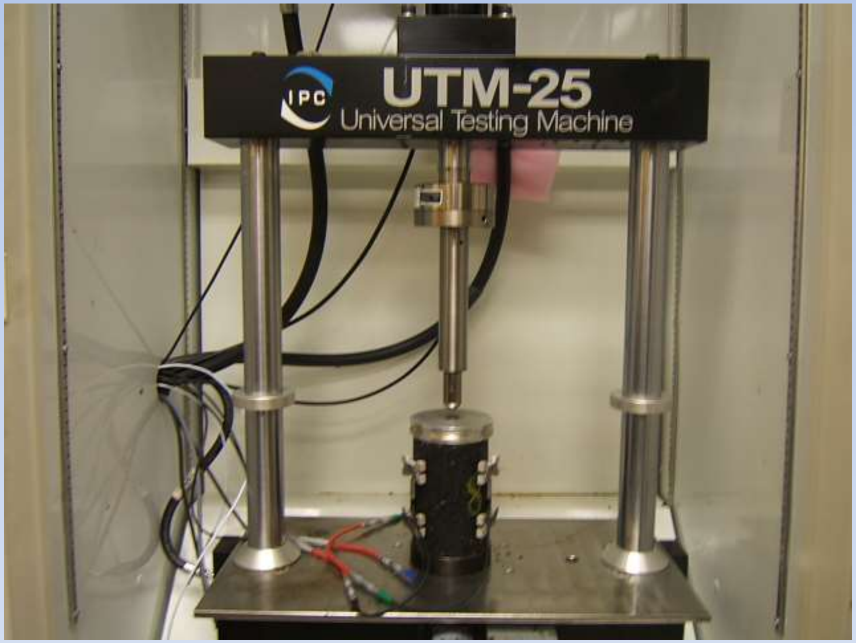
What effect does RAS have on the Dynamic Modulus?

- **High Temp/Low Freq E***
  - RAS increases E*
  - No Significant Diff.
- **Med Temp/Med Freq E***
  - Significant but no trend
- **Low Temp/High Freq E***
  - RAS decreases E*
  - Significant in the Base Course

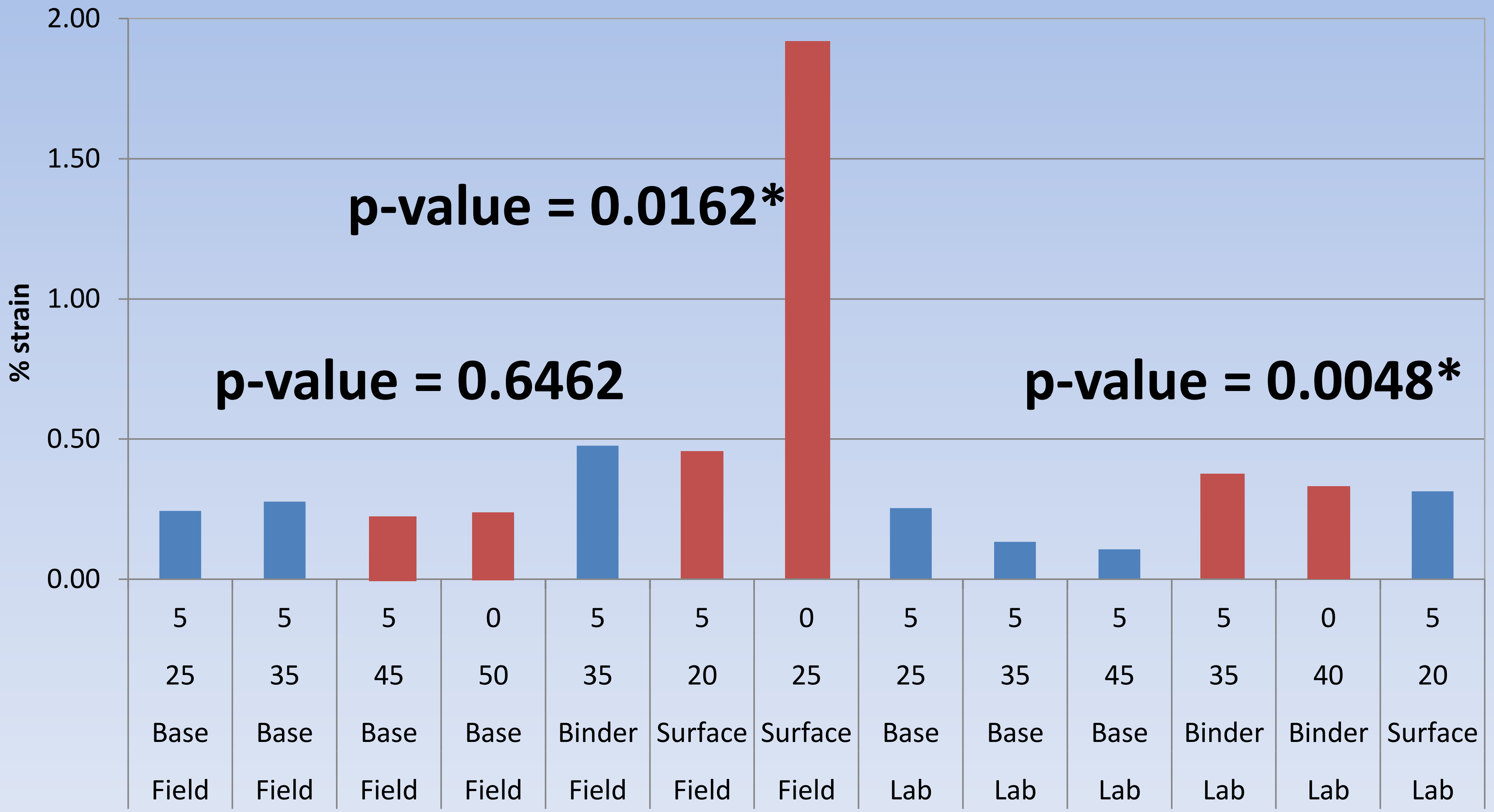


Flow Number

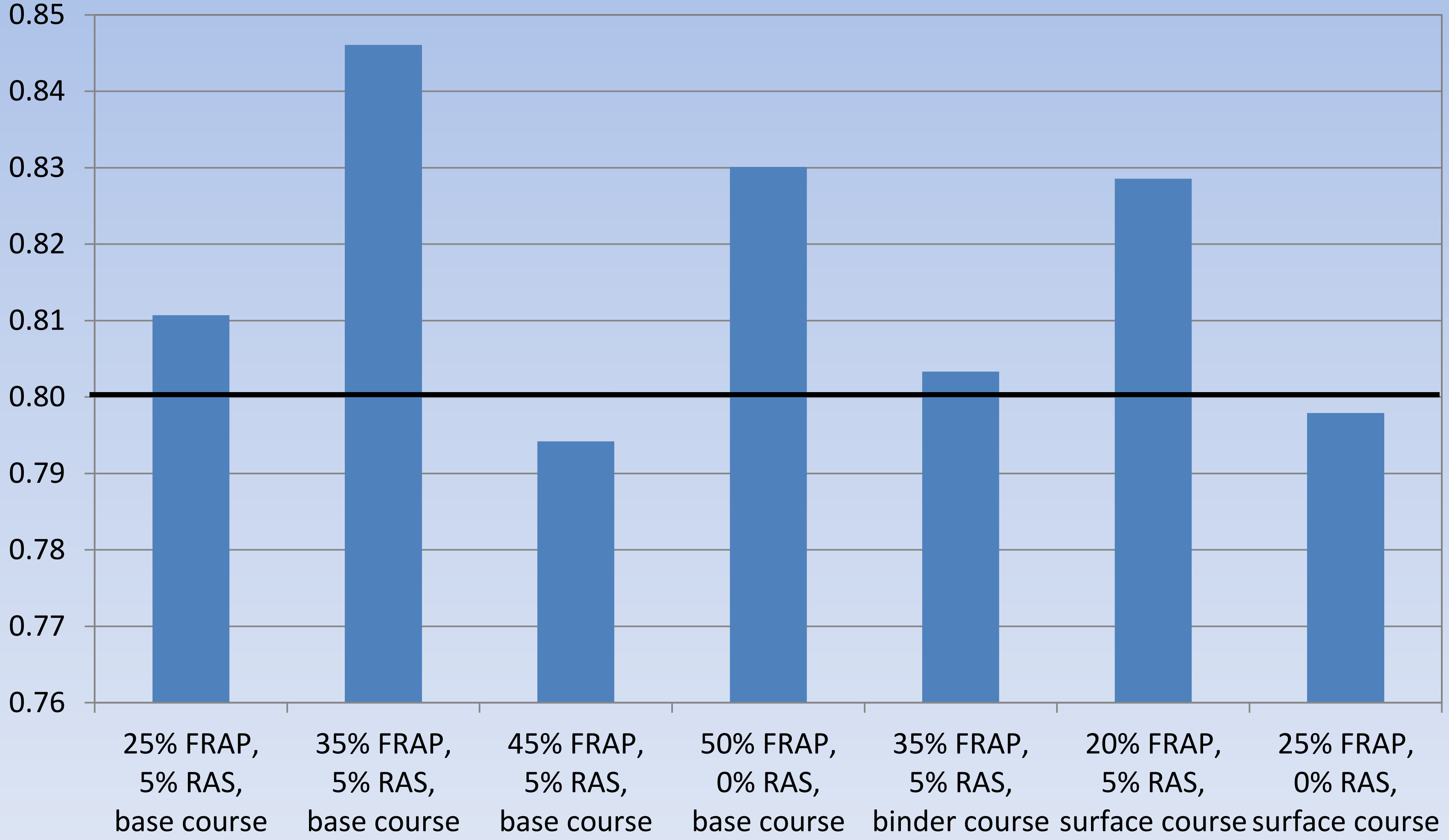
- Uses Dynamic Modulus Samples
- Test Temperature 37^{o}C
- Constant Stress
- Cyclic Repeated load
- 0.1s pulse and 0.9s rest
- Measured Accumulated Strain after 10,000 load cycles
- Indication of Rutting Resistance



Accumulated Strain in Flow Number Test

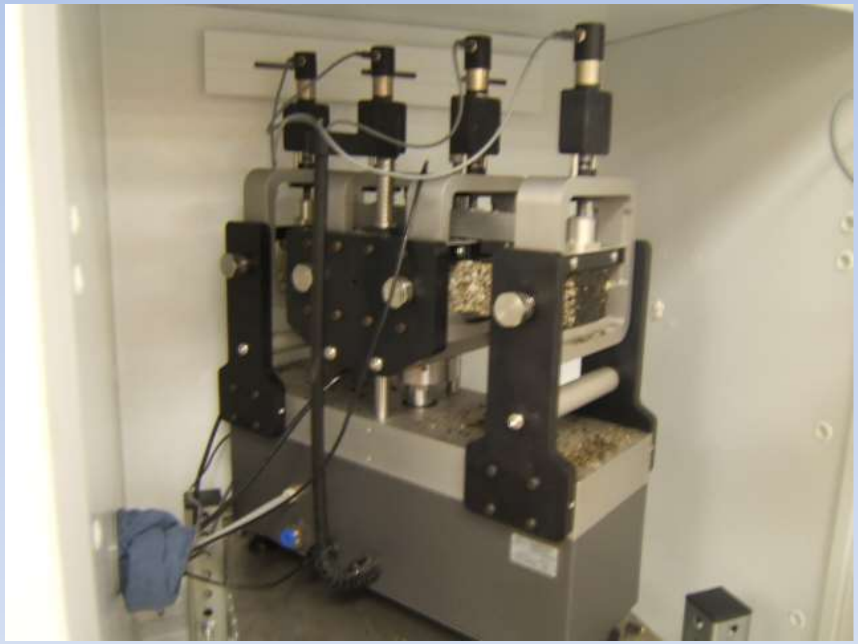


Tensile Strength Ratio (TSR)



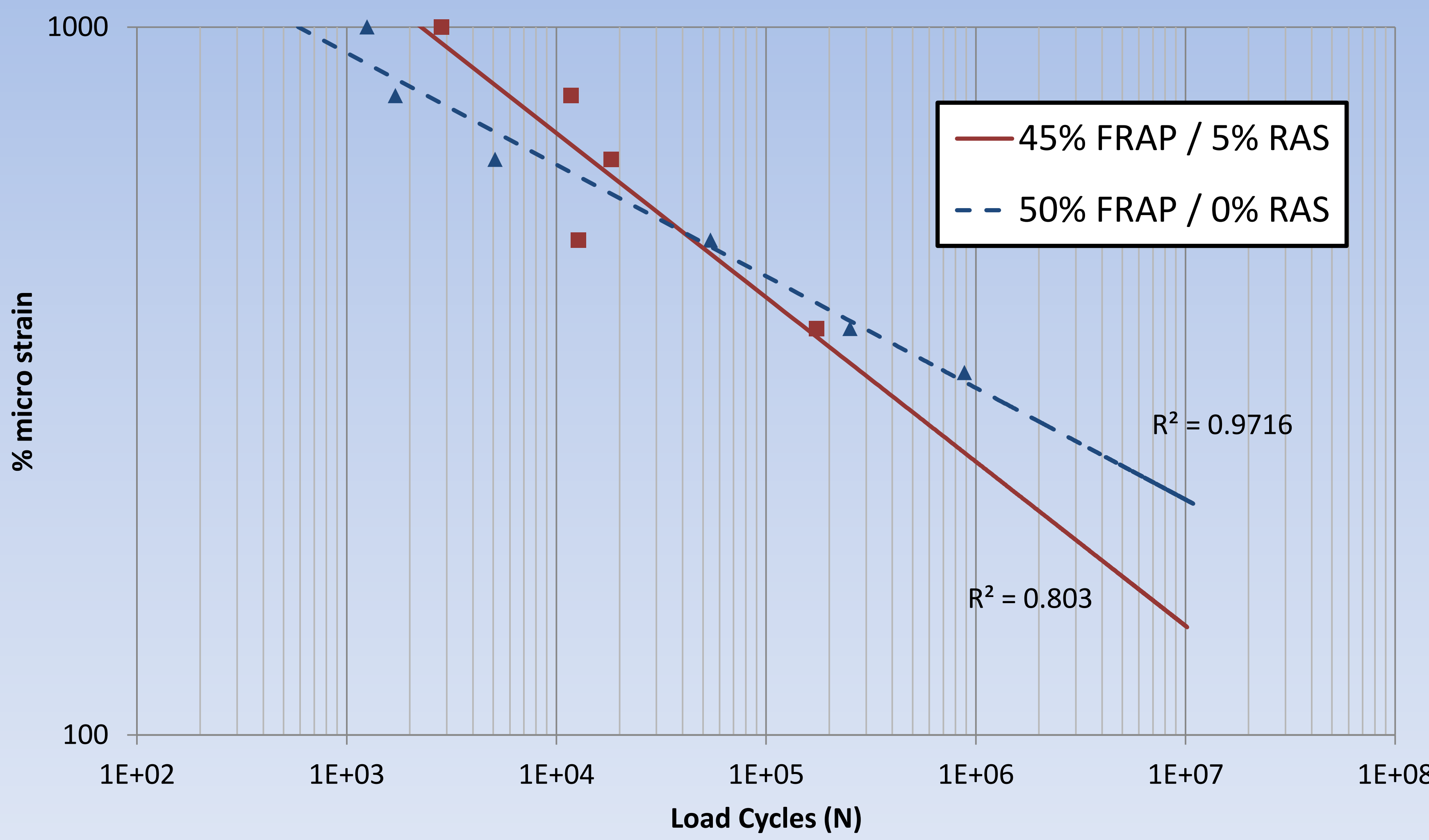
Beam Fatigue

- Repeated traffic loading
- Haversine loading at 10Hz
- Linear Kneading Compactor
- Six beams for each sample tested at a different constant strain level
- Test Temperature 20^{o}C
- Test is complete after a 50% reduction in flexural stiffness
- K2 indicates damage accumulation rate
- Above 3.5 is acceptable

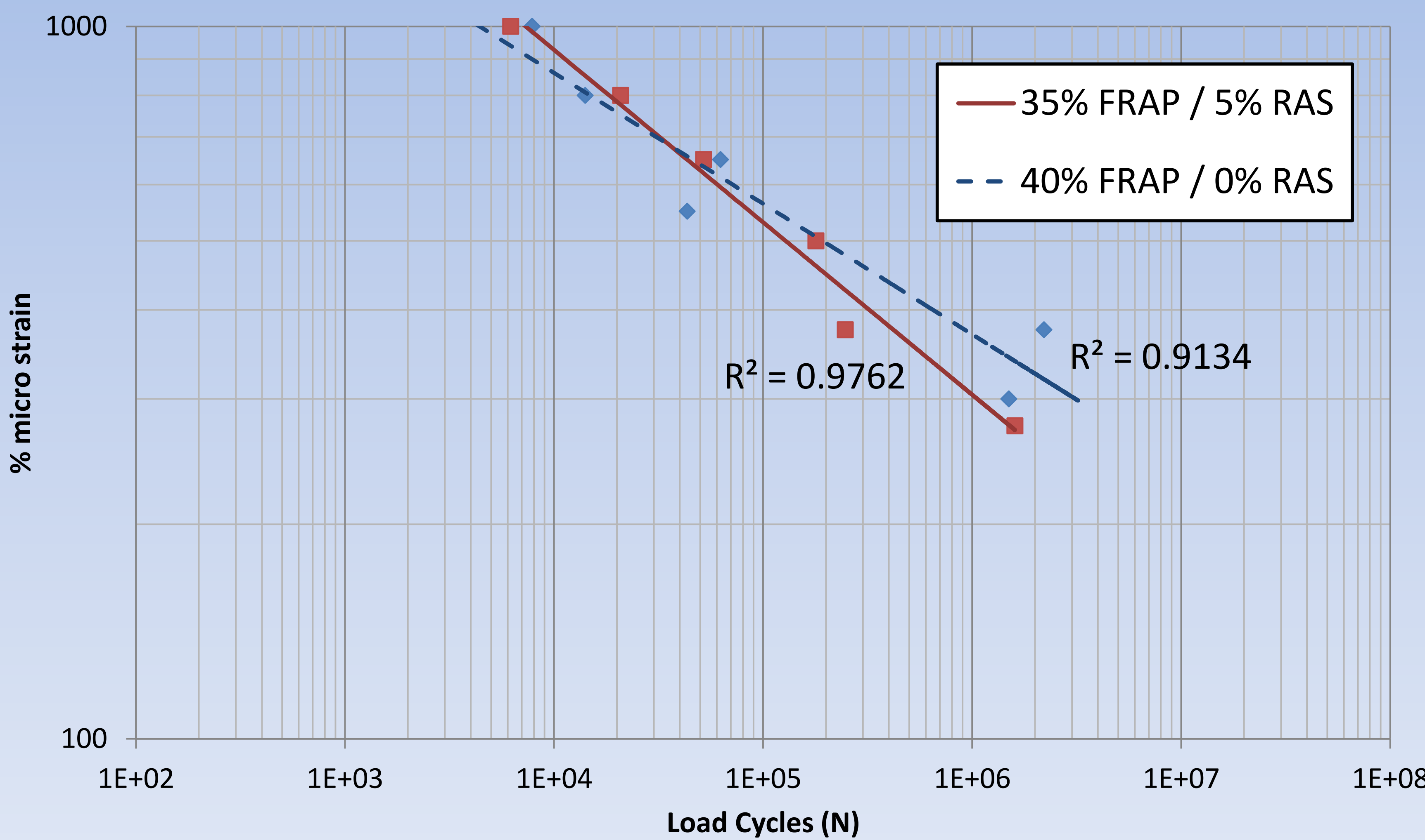


$$N_f = K1\left(\frac{1}{\varepsilon_o}\right)^{K2}$$

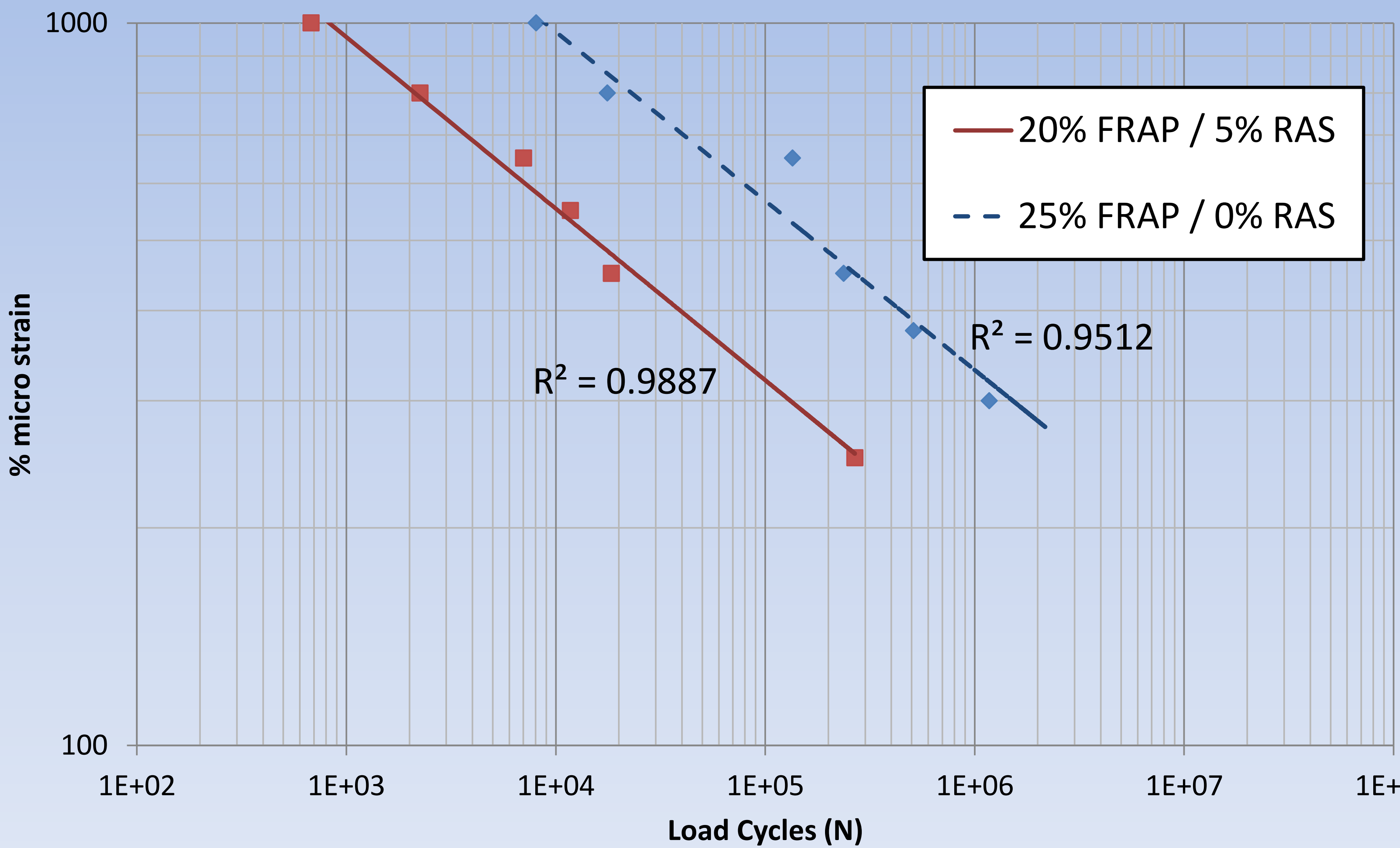
Base Course Mixes



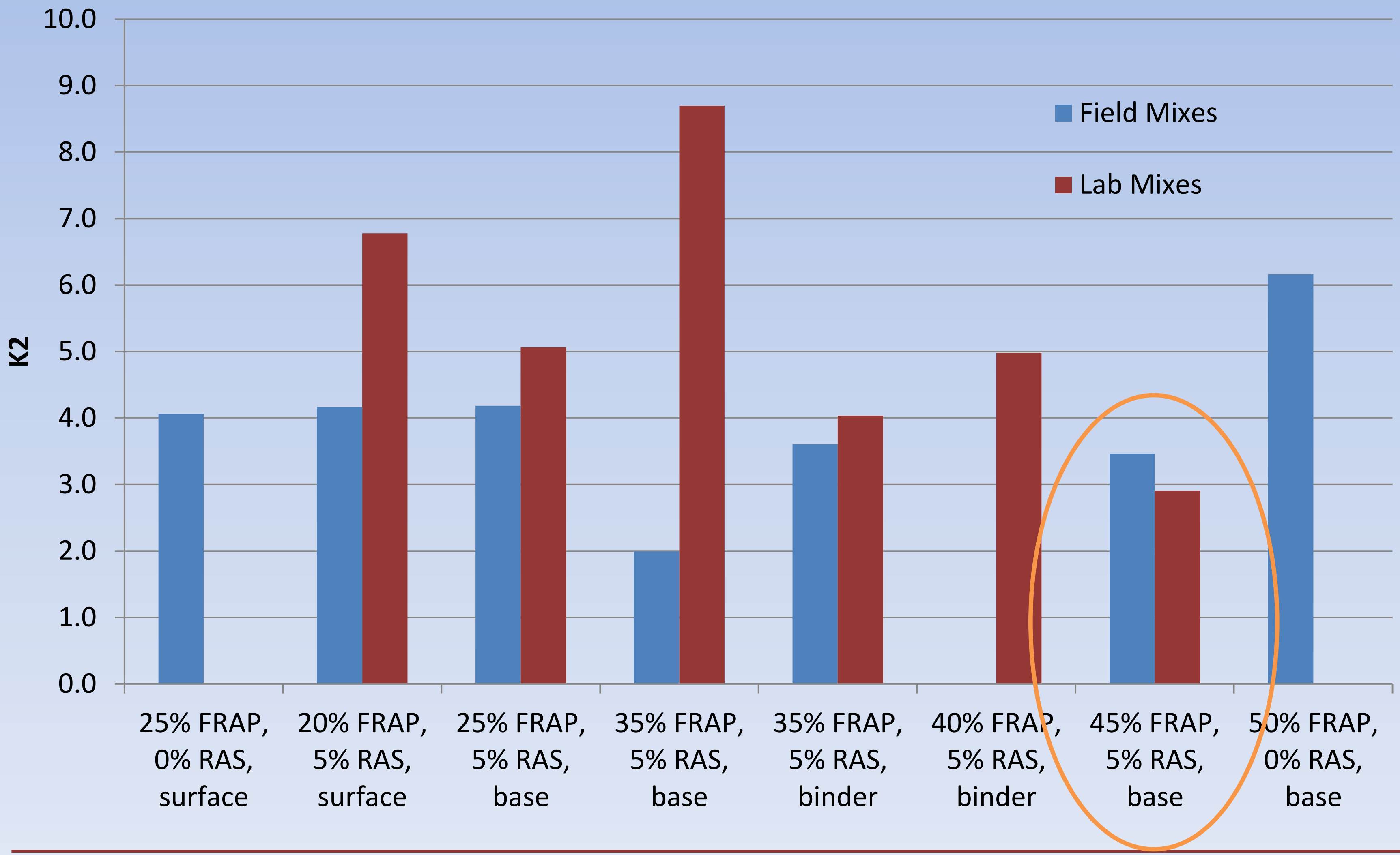
Binder Course Mixes



Surface Course Mixes

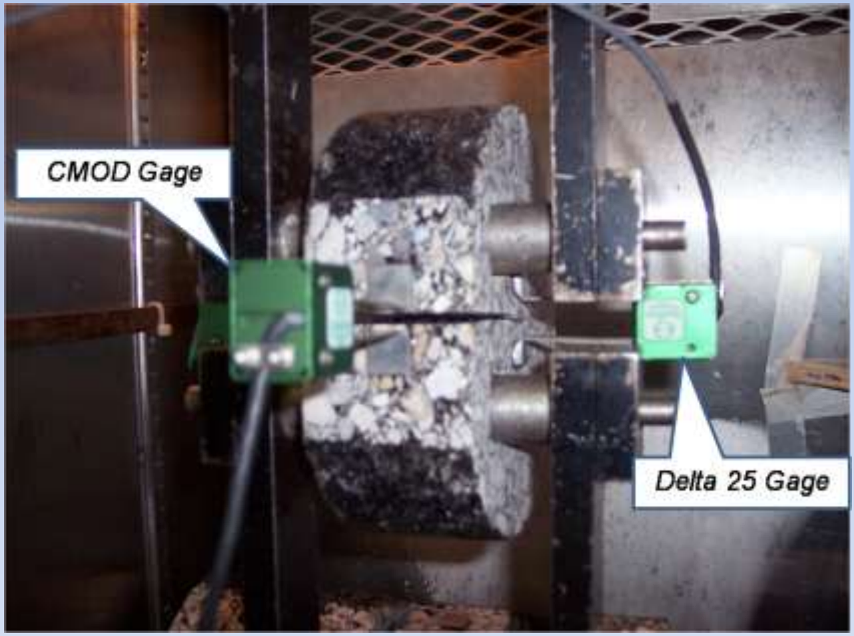


K2 Coefficients

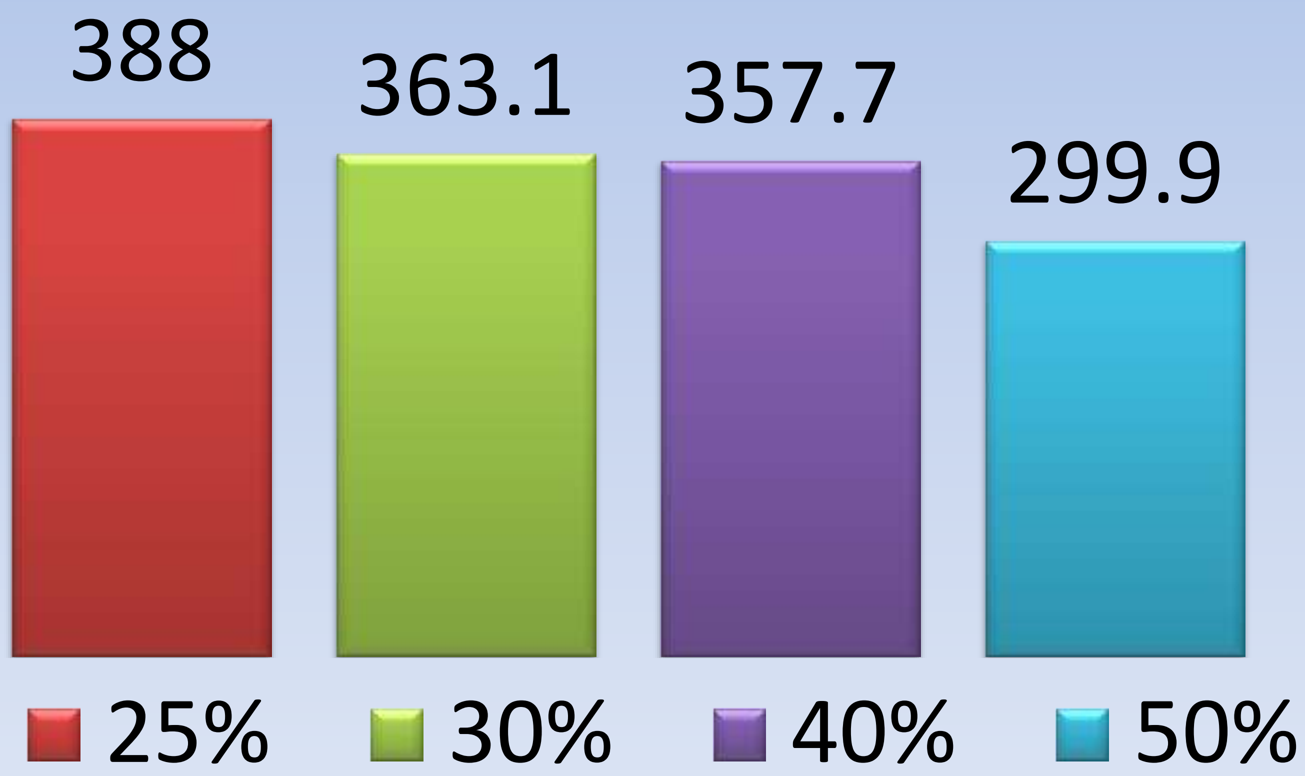


Compact Disk Tension

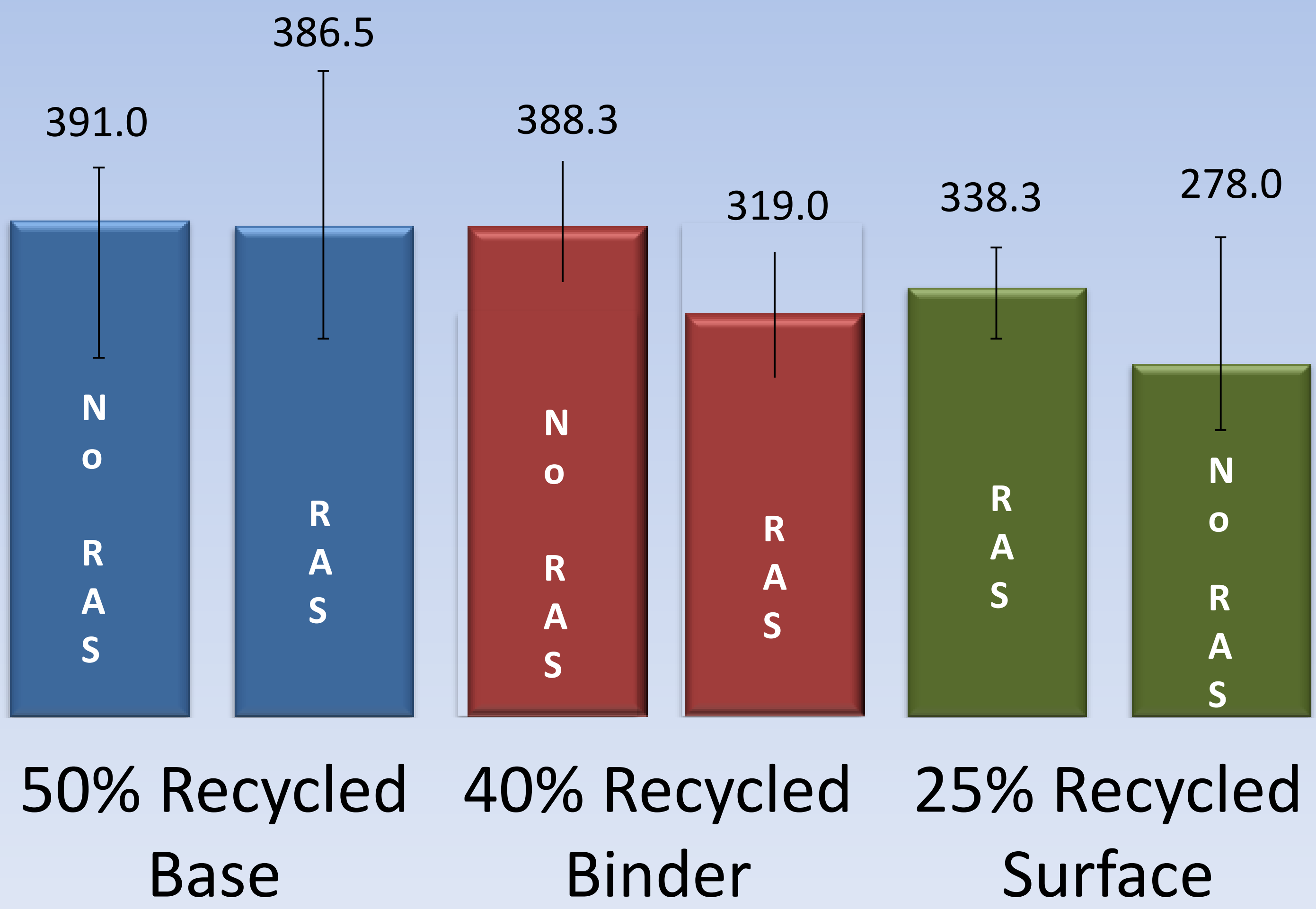
- Conducted by Univ. of Illinois Urbana-Champ.
- Test Temperature -12^{o}C
- 4 Specimens 120mm in height by 150mm in dia.
- Measures Fracture Energy
- Minimum recommended value is 350J/m^2



Average Fracture Energy by % recycled materials



Fracture Energy Comparison



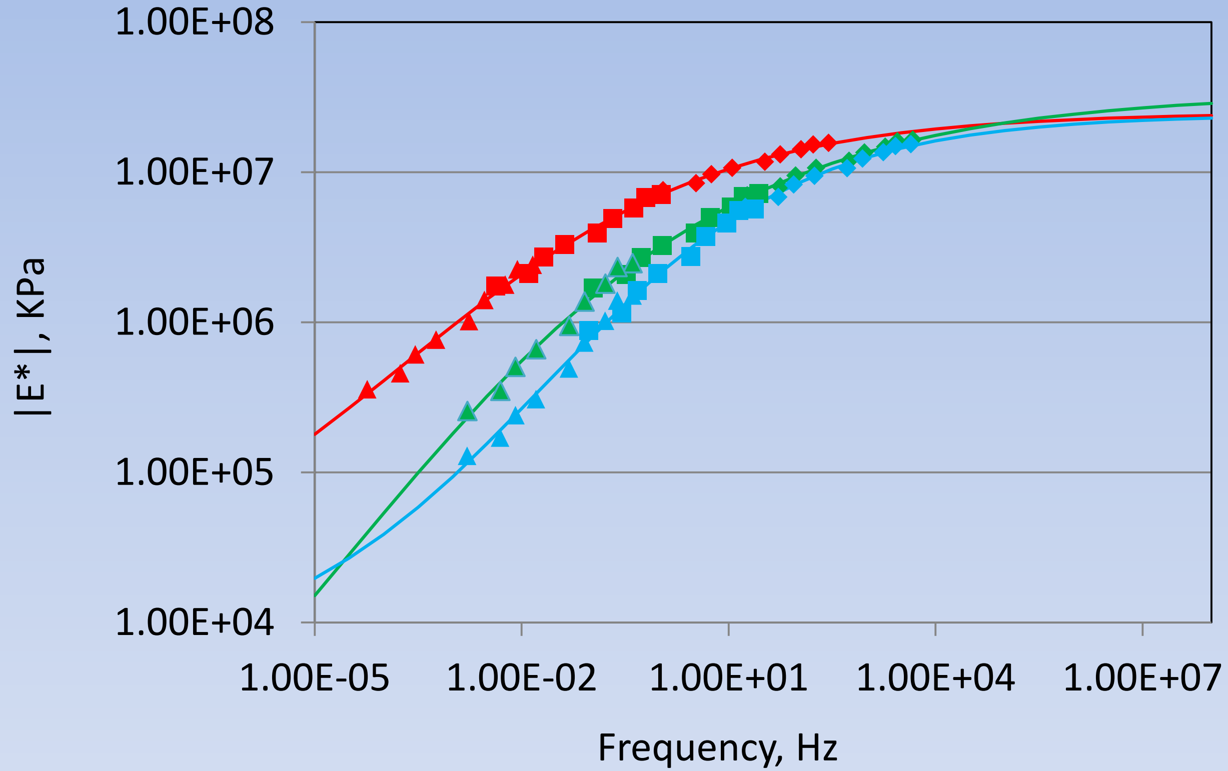
Conclusions

- Tollway mixes exhibit good resistance to rutting
- 5% RAS is not detrimental to the fatigue performance of the Tollway mixes
- Mixtures may see some cracking due to lower fracture energies and higher low performance grade temperatures

Illinois Tollway Conclusions

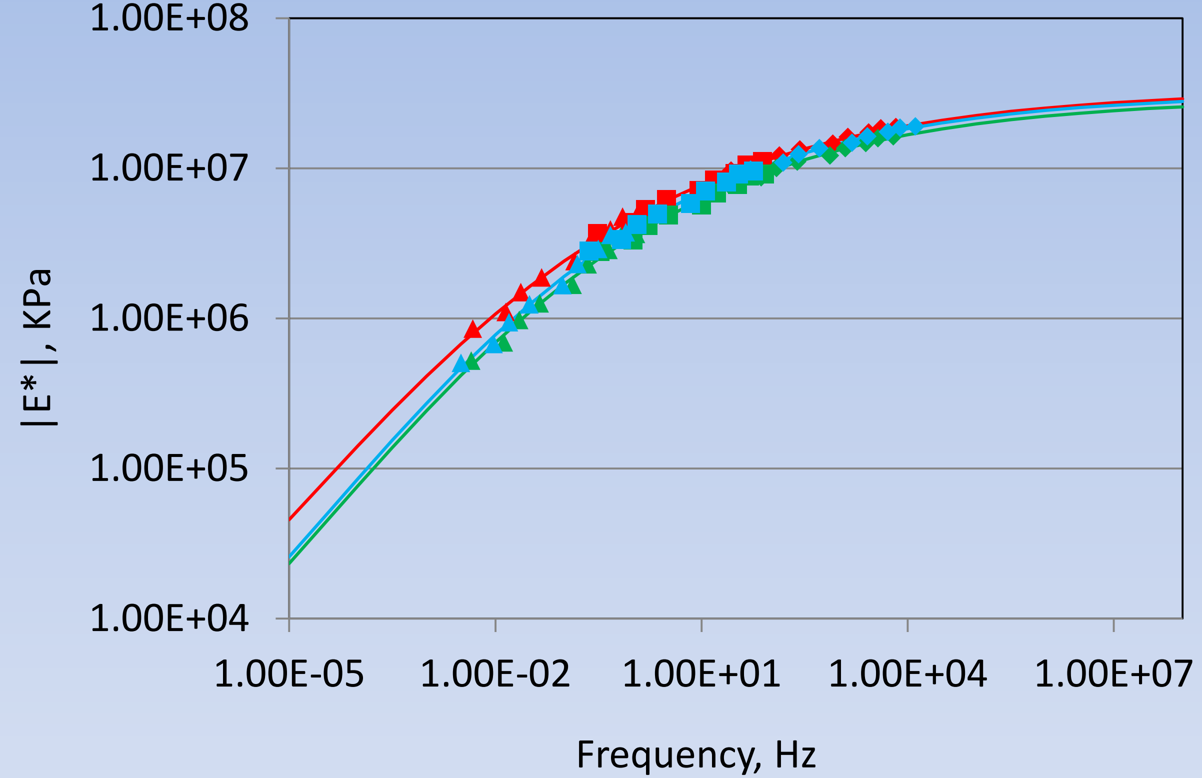
- Mixes with greater than 40% recycled will likely see the greatest amount of cracking
- Their performance may be improved by grade bumping the virgin binder from 58-22 to 58-28
- Fibers could be contributing to the performance of the mixtures
- Tollway mixes exhibit satisfactory freeze-thaw durability
- Laboratory RAS mix design procedures may need to be reevaluated

MNDOT MIXES



	Mix #1	5% Mfr RAS
	Mix #2	5% Tear-offs RAS
	Mis #3	30% RAP

INDOT MIXES

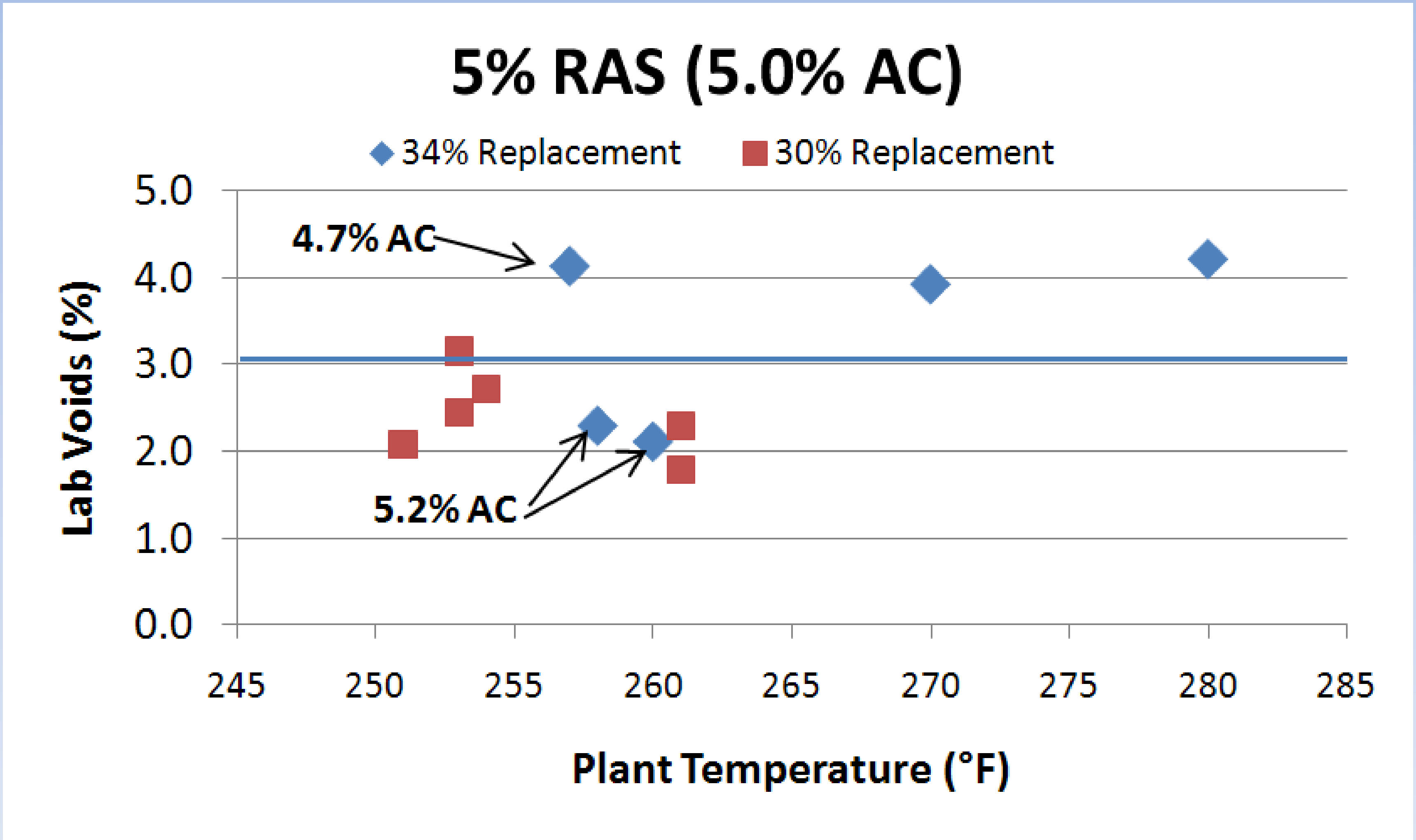


	Mix #11	HMA - 15% RAP
	Mix #12	HMA - 3% RAS
	Mix #13	WMA - 3% RAS

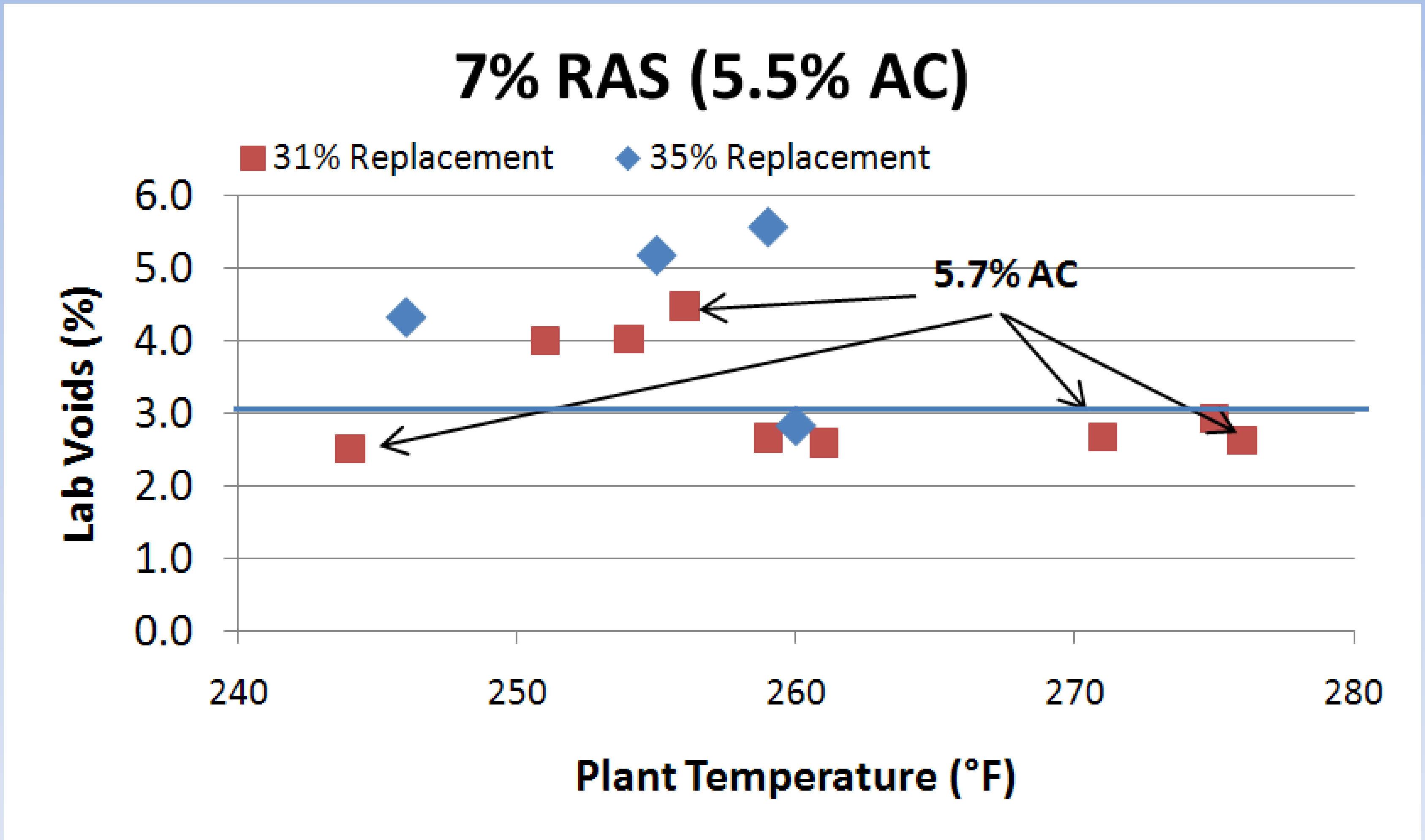
Iowa DOT: WMA+RAP+RAS

- Muscatine County (Hwy 61 Shoulders)
- Evotherm 3G (Plant Temp = 250F)
- 3 Test Sections
  - 20% RAP/0% RAS
    - 20% Binder Replacement
    - 4.6% Design AC
  - 15% RAP/5% RAS
    - 30% Binder Replacement
    - 5.0% Design AC
  - 8% RAP/7% RAS
    - 30% Binder Replacement
    - 5.5% Design AC

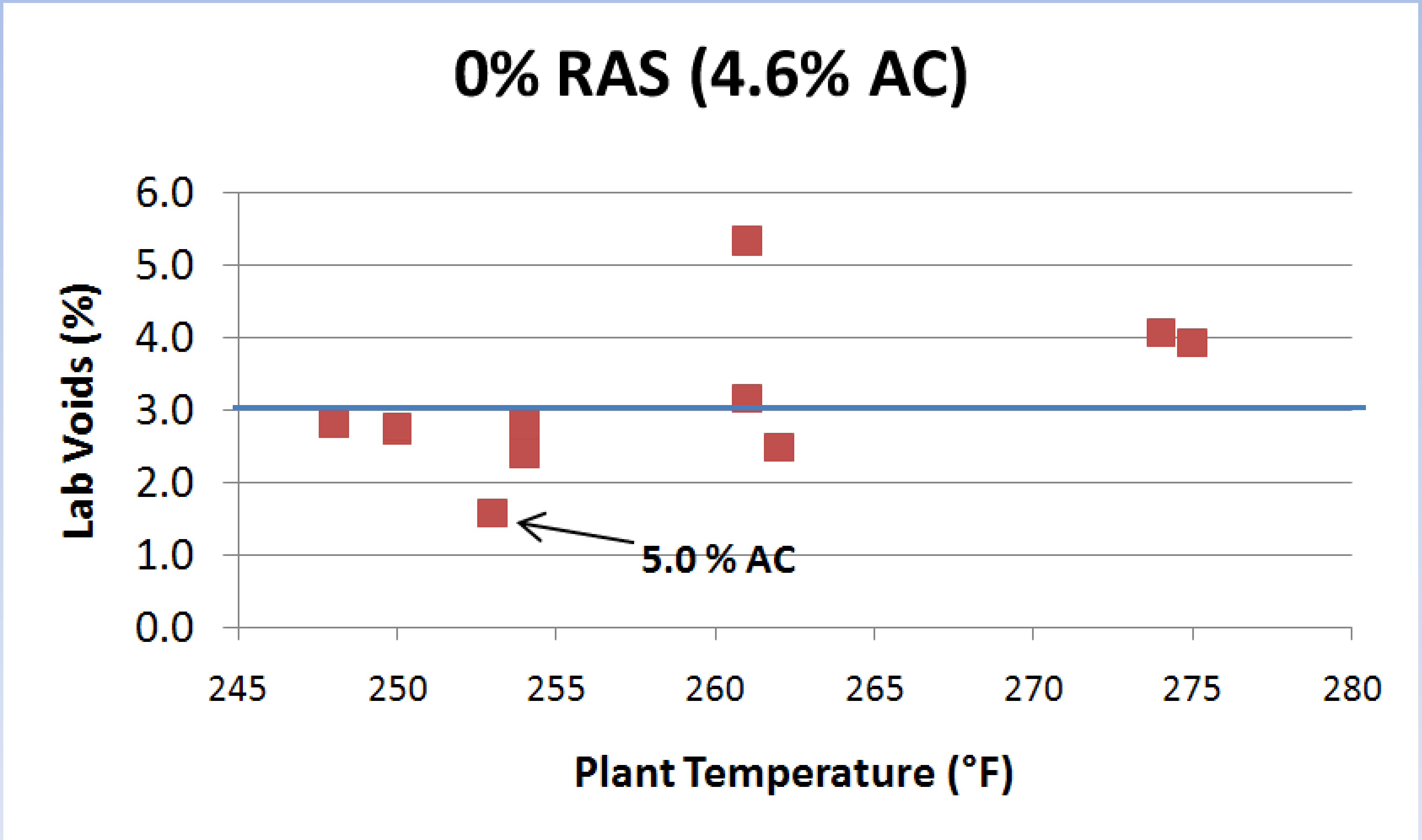
WMA + 5% RAS + 15% RAP



WMA + 7% RAS + 8% RAP



WMA Control + 20% RAP



WMA with RAS

- RAS contains much stiffer binder
- Not all RAS is activated
- 15-40% Acts like black rock = Requires more AC to coat
- May need to add oil
- May need to raise temperature
- HIGH RAS STOCKPILE MOISTURE
  - Reduce production rate
  - Increase plant temperature

Additional Demonstration Projects

- Iowa- 4%, 5%, 6% RAS
- Missouri- Coarse vs. Fine Grind
- Colorado- to be determined!
- Wisconsin- to be determined.
- California- to be determined.

Items Considered Best Practices

- Minimize water usage during grinding
- Store ground shingles under a covered roof
- Use multiple recycled cold feed bins- one that is dedicated to shingles
- Use a 2^{nd} recycle bin on drum plants closer to the hot zone for adding shingles

Thank You!

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Questions?