Investigation of Low and High Temperature Properties of Plant-Produced RAP Mixtures

RAP ETG
December 17, 2009

North Central Superpave Center

What We Did

- Five contractors (4 IN, 1 MI)
- Six plant-produced mixes
  - Binder properties – PG binder tests
  - Mix properties – Indirect Tensile Strength, Dynamic Modulus, Blending analysis
  - 3 to 4 samples tested
  - Compacted to 7 ± 1% air voids
  - Samples provided to TFHRC, UW

North Central Superpave Center

Experimental Design

	Reclaimed Asphalt Pavement			
Asphalt Binder Grade	0%	15%	25%	40%
PG 64-22	X Mix A	X Mix B	X Mix C	X Mix D
PG 58-28			X Mix E	X Mix F

North Central Superpave Center

Mixture Info

- RAPs were all screened or crushed/screened over ½ or 5/8 in sieves
- Plants were counterflow, double drum and parallel flow
- Contractors did designs -- typically one complete and others were one point verifications
- Not all mixtures met all volumetric requirements during production

North Central Superpave Center

Recovered Binder

- Determined true grade of virgin and recovered binders
- Estimated critical cracking temperature from BBR and DT results

North Central Superpave Center

Example Binder Data

ID	Grade	HT Grade (DSR)	LT Grade (BBR)	True Grade	T_{crit} (TSAR)
Virgin Binders	PG64-22	67.4	-24.2	67-24	
	PG58-28	60.7	-28.3	60-28	
4A	PG64-22	73.7	-20.5	73-20	-22.6
4B		72.8	-20.8	72-20	-22.5
4C		74.4	-20.5	74-20	-20.1
4D		75.0	-19.6	75-19	-20.2
4E	PG58-28	67.8	-24.2	67-24	-26.2
4F		70.0	-23.3	70-23	-23.4

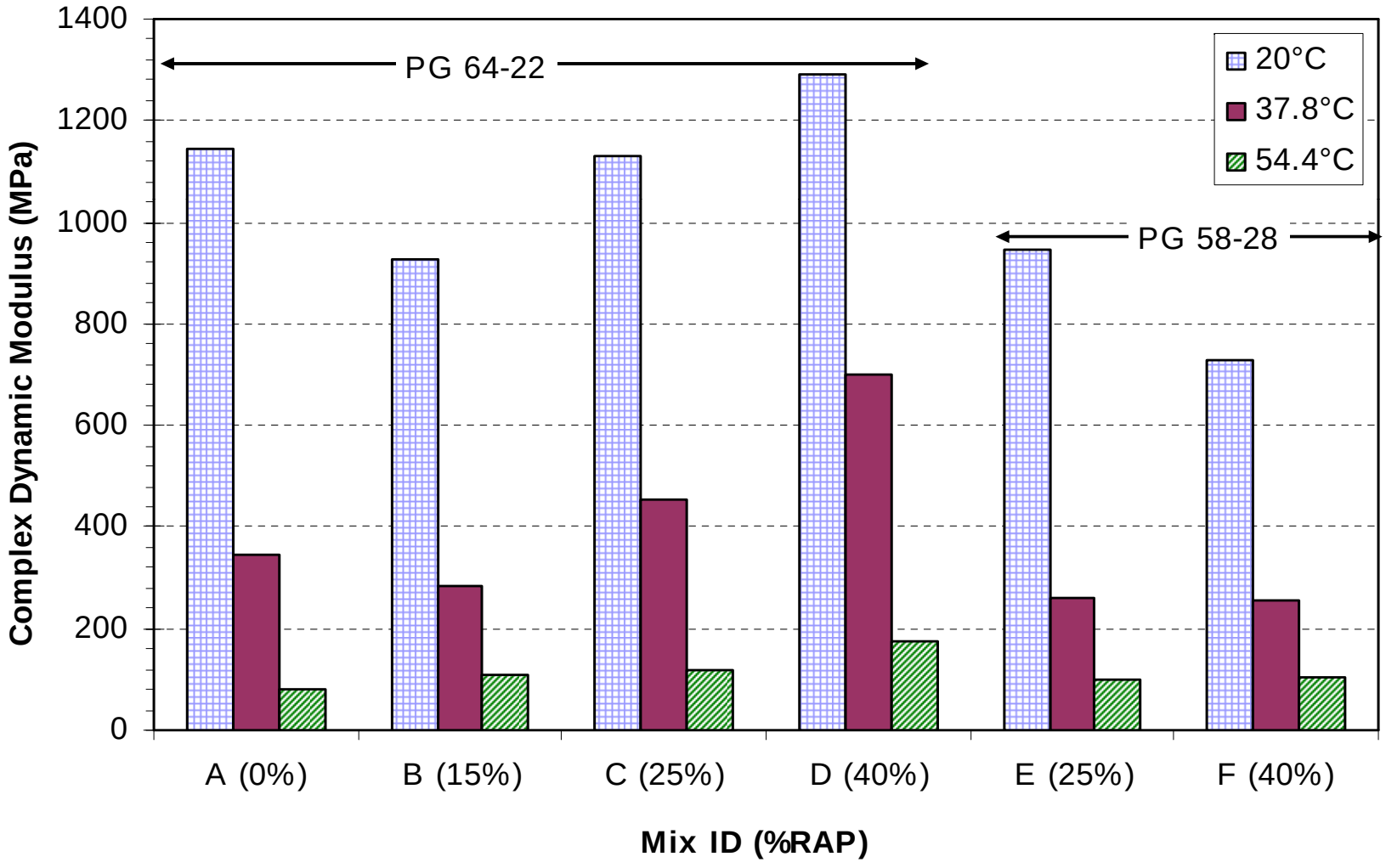
North Central Superpave Center

Binder Extraction/Recovery

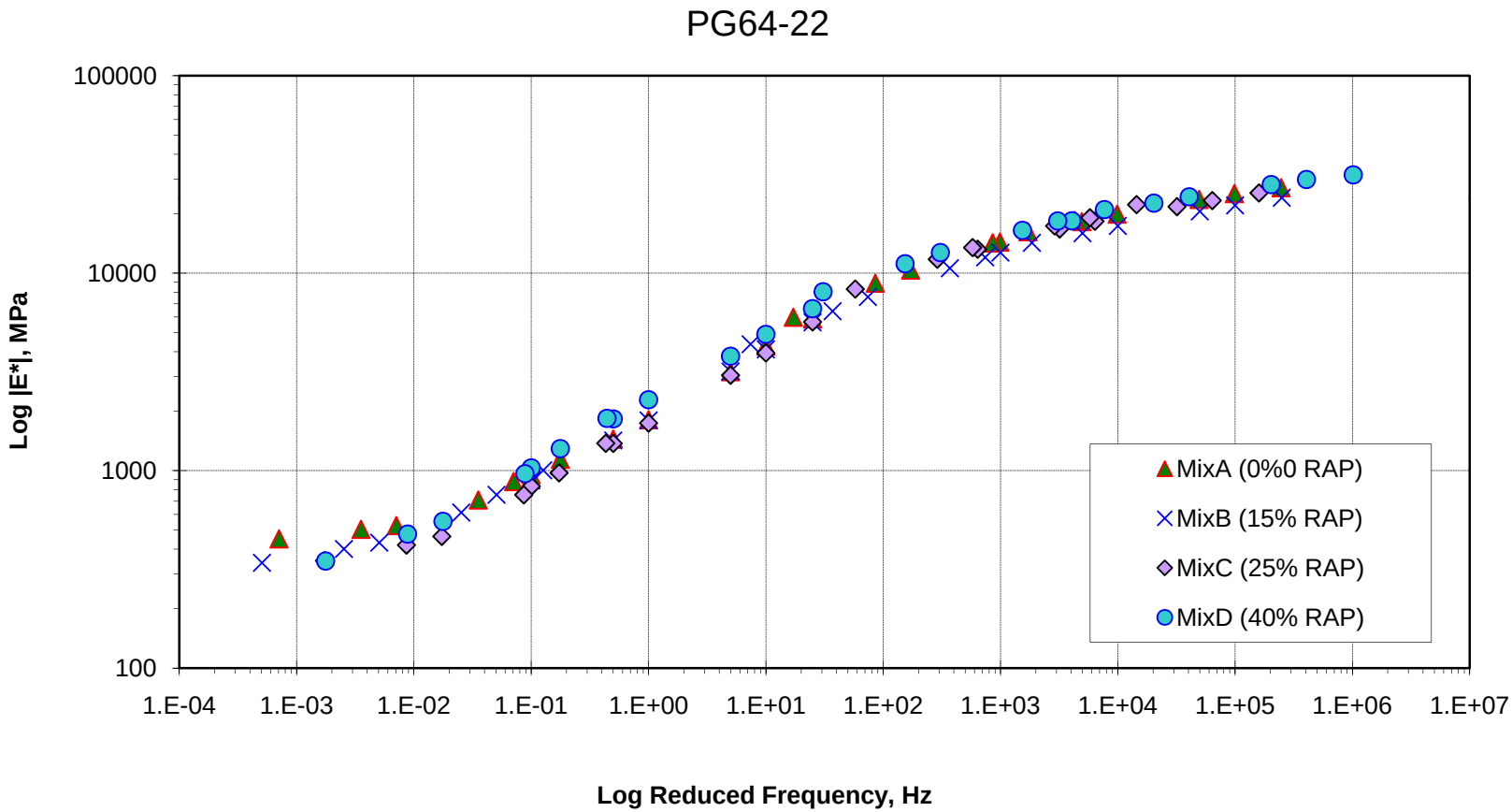
- Compared AASHTO T319 with nPB to Abson with reagent grade methylene chloride
  - T319 stiffer than Abson in Phase I
- One set of six mixes
- Master curves developed
- No consistent difference in stiffness of binders recovered with different techniques
- Little to no difference in most cases

North Central Superpave Center

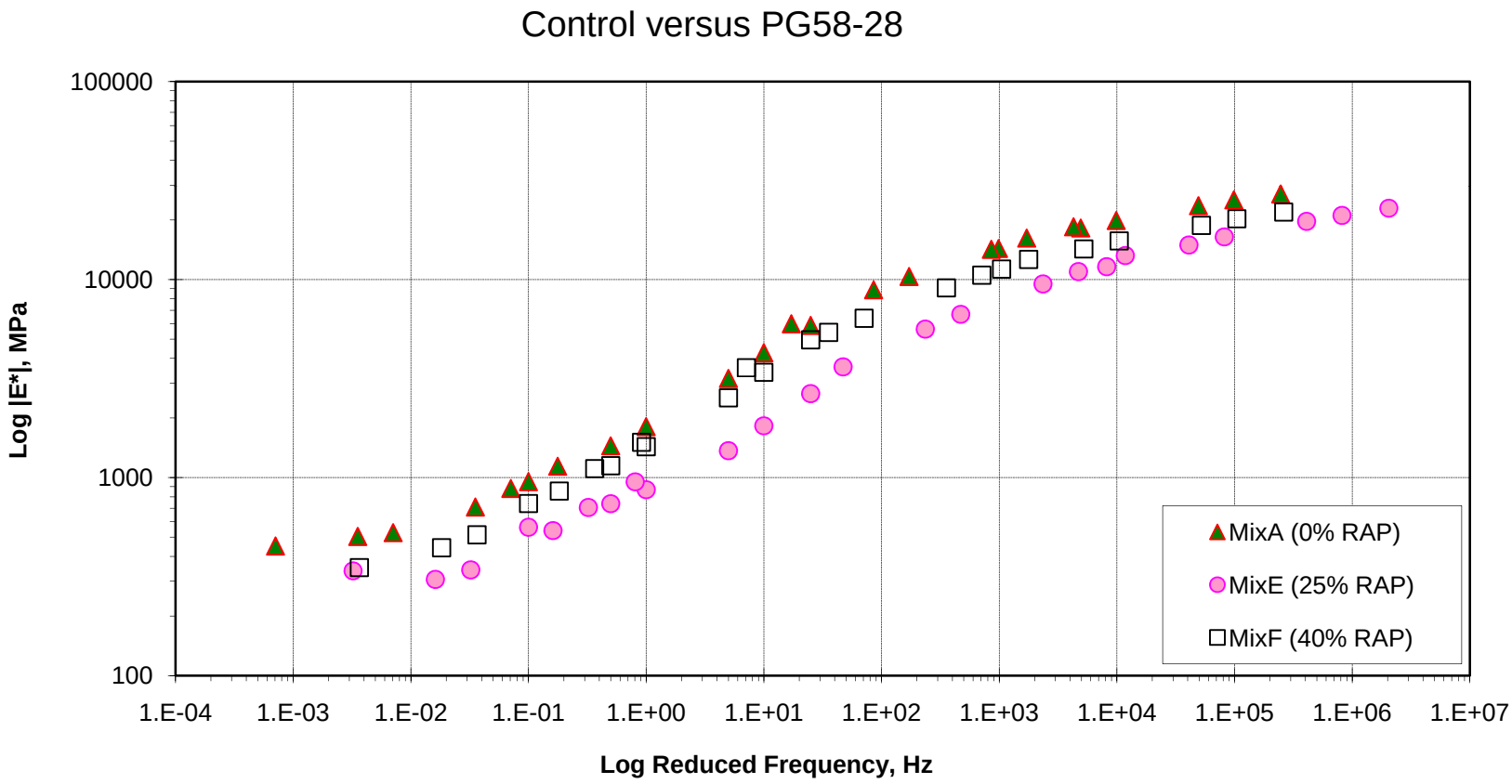
Phase 1 Data


1400
1200
1000
800
600
400
200
0
Complex Dynamic Modulus (MPa)
PG 64-22
PG 58-28
20°C
37.8°C
54.4°C
A (0%)
B (15%)
C (25%)
D (40%)
E (25%)
F (40%)
Mix ID (%RAP)

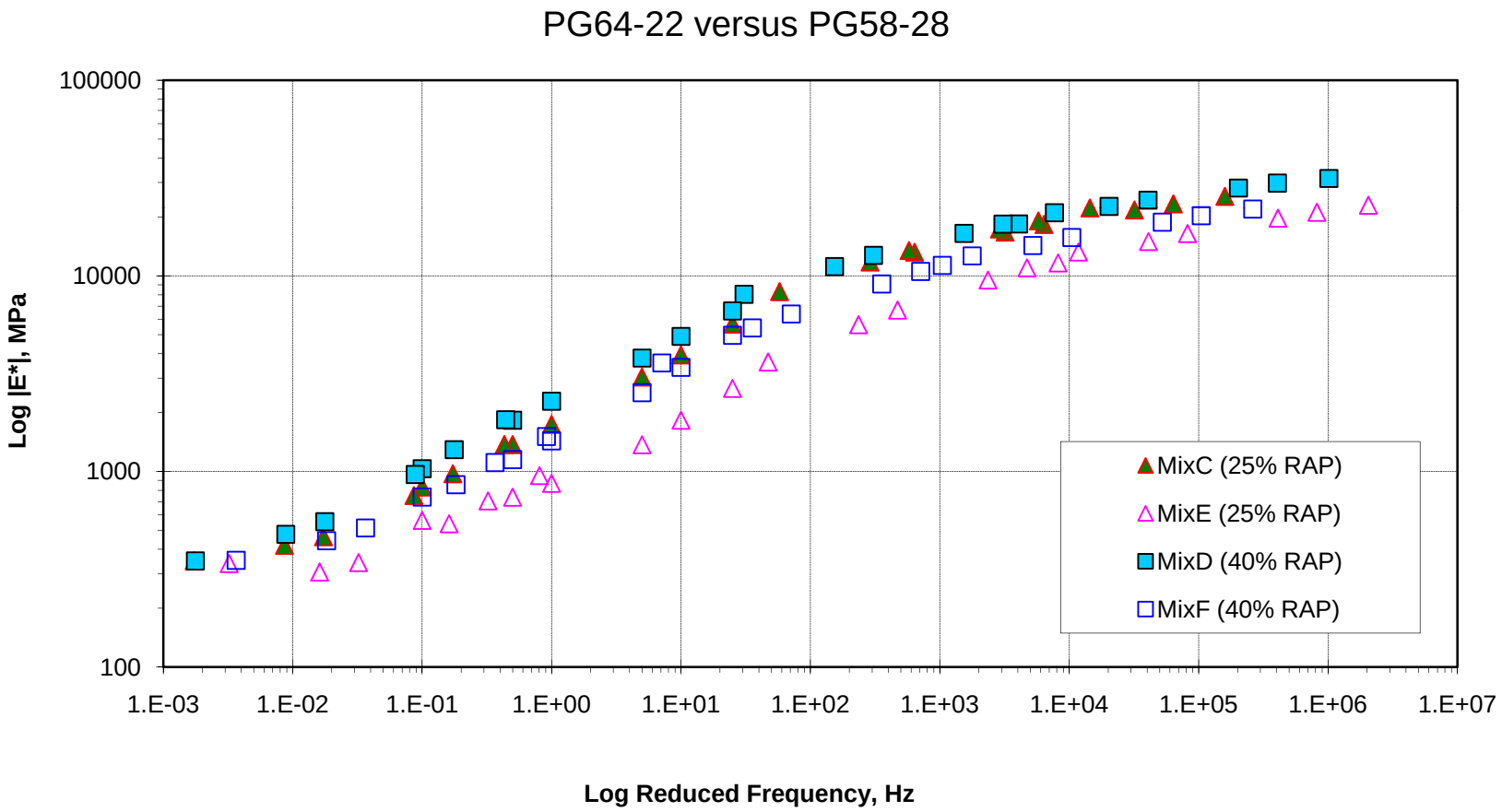
One Example - Mix |E*|



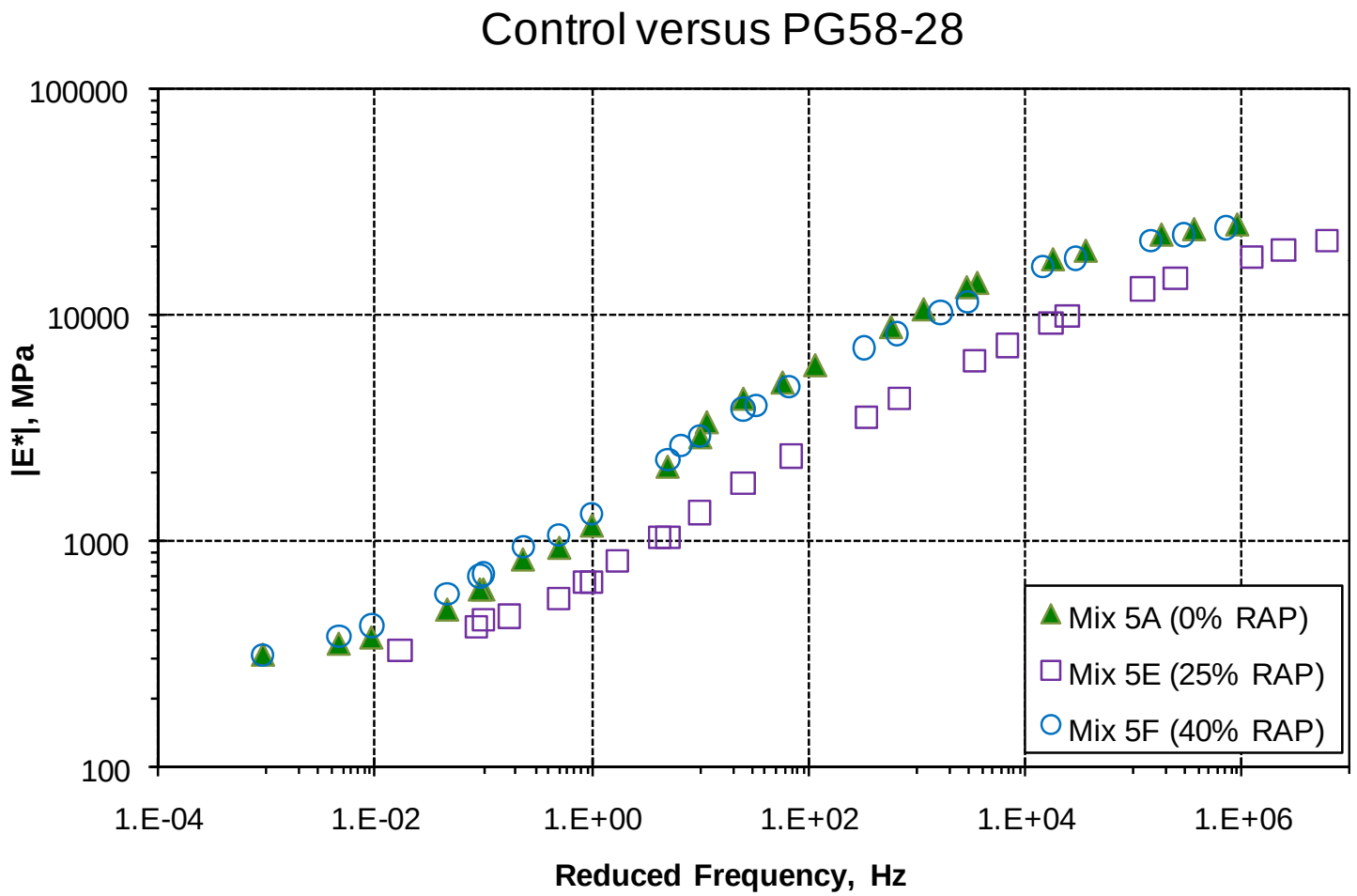
One Example - Mix |E*|



One Example - Mix |E*|



Second Example - Mix |E*|



Statistical Analysis

- |E*| at 25 Hz at 4, 20,37.8 and 54.4°C
- ANOVA and Comparison of Means
- Generally, either
  - No statistically significant difference, or
  - Mix D different from A, B and C
  - More difference with PG58-28 binder (E vs F)

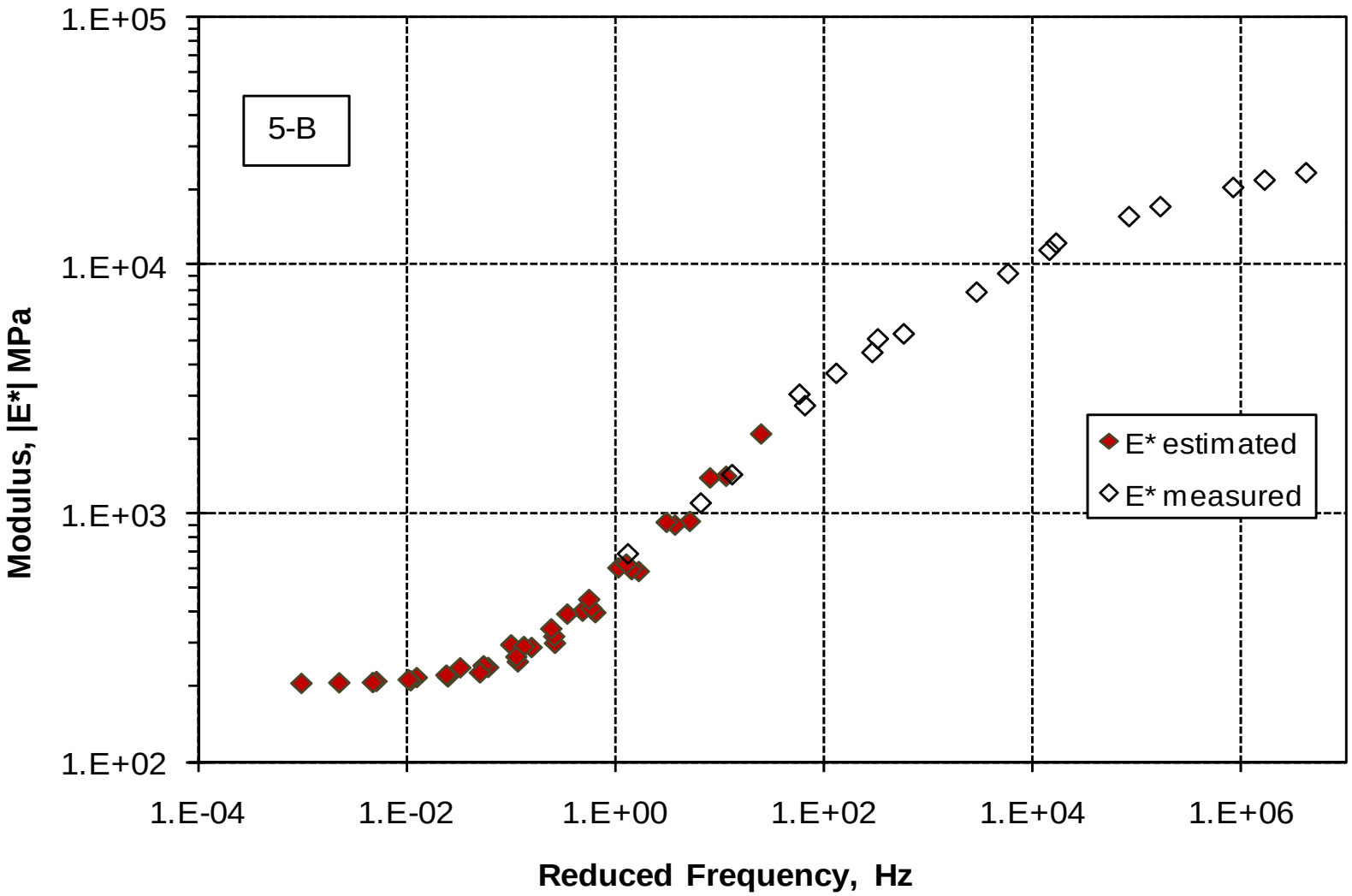
North Central Superpave Center

Blending Analysis

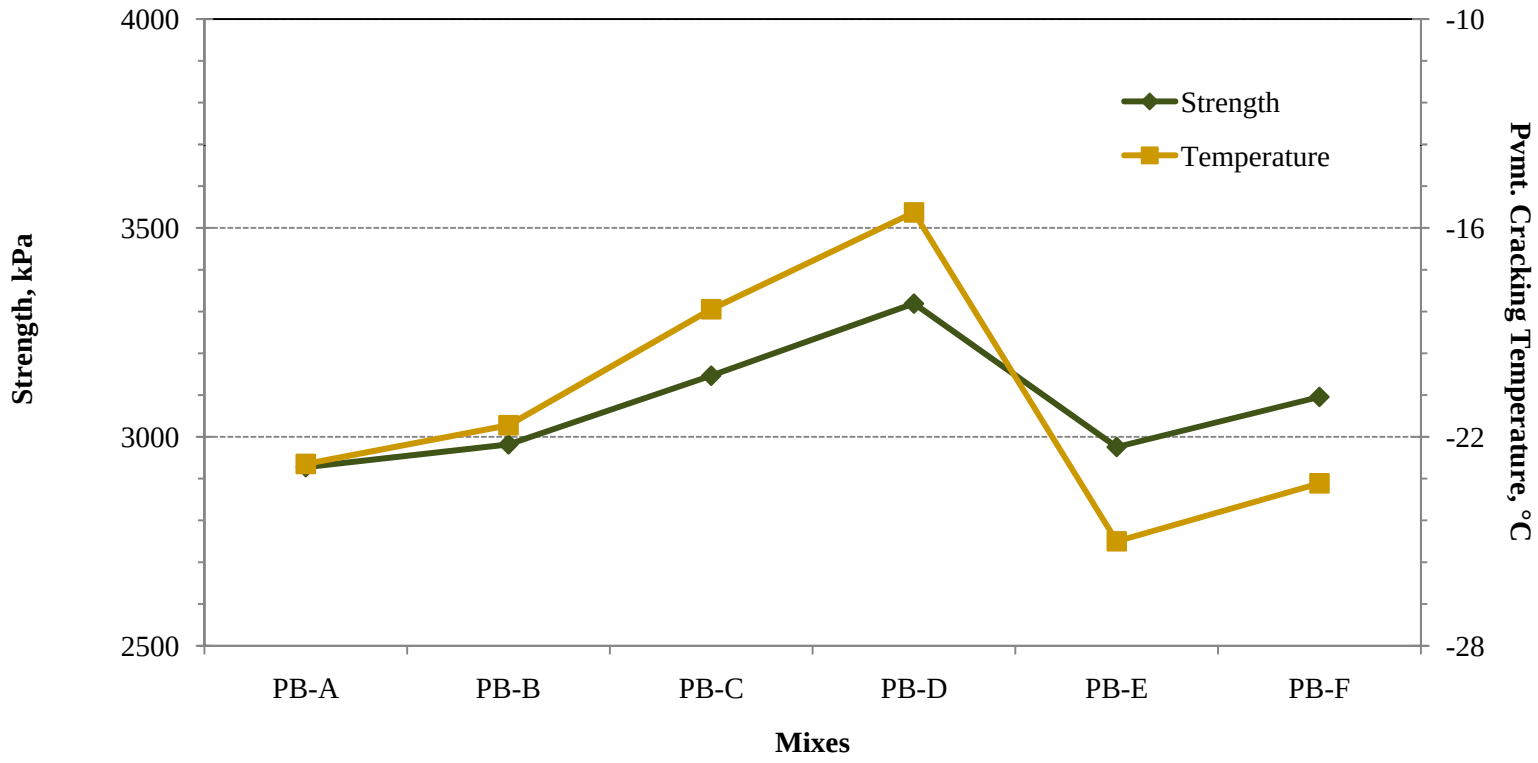
- Bonaquist approach
- Recovered binder test results and mix volumetrics used to estimate mix modulus using Hirsch model
- Compared to measured mix modulus
- Substantial overlap suggests good blending
- Three out of four data sets showed good blending, one is questionable
  - Control mix showed poor blending!

North Central Superpave Center

Mix 5B

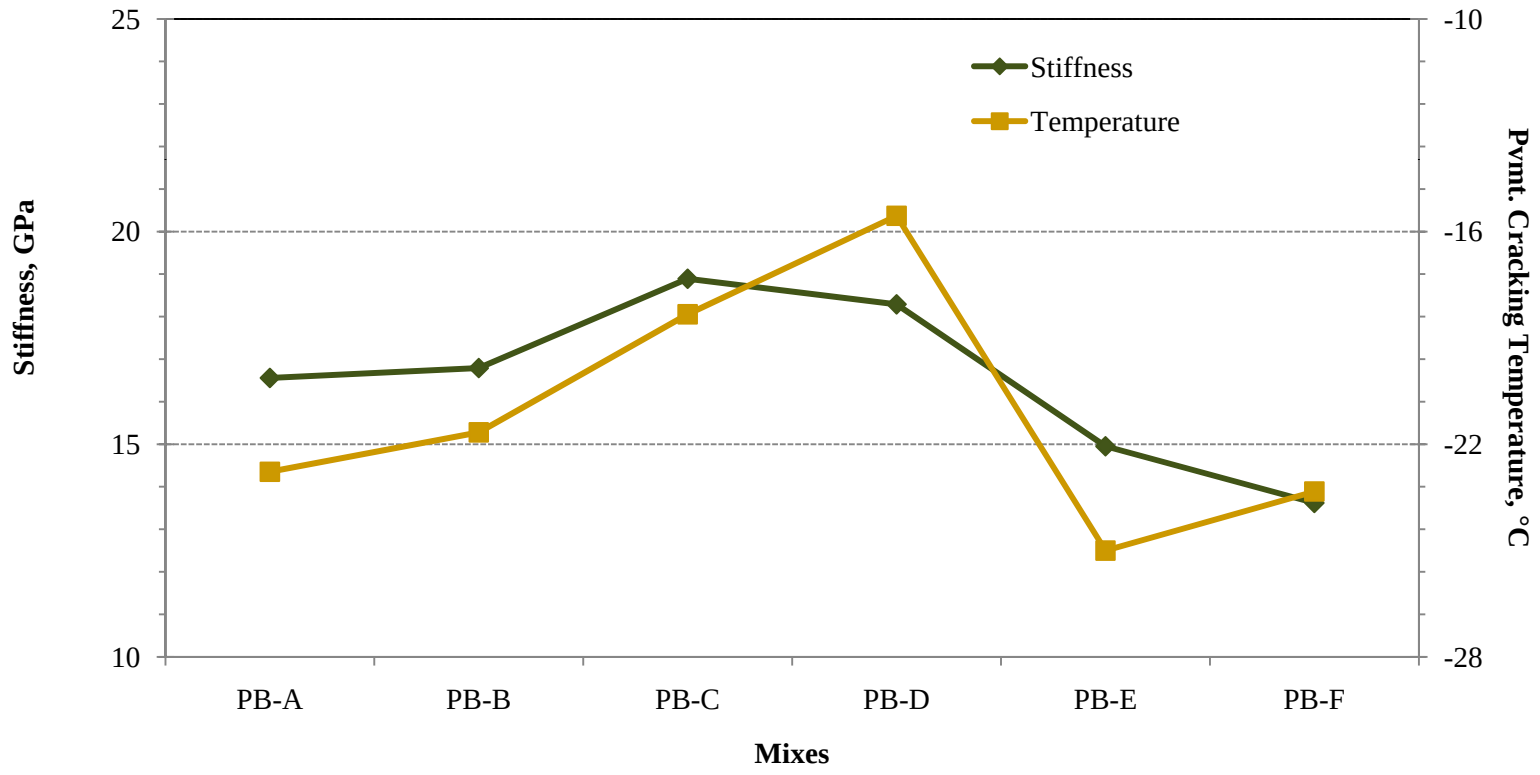

1.E+05
1.E+04
1.E+03
1.E+02
Modulus, |E*| MPa
5-B
E* estimated
E* measured
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
Reduced Frequency, Hz

IDT Strength Example 1

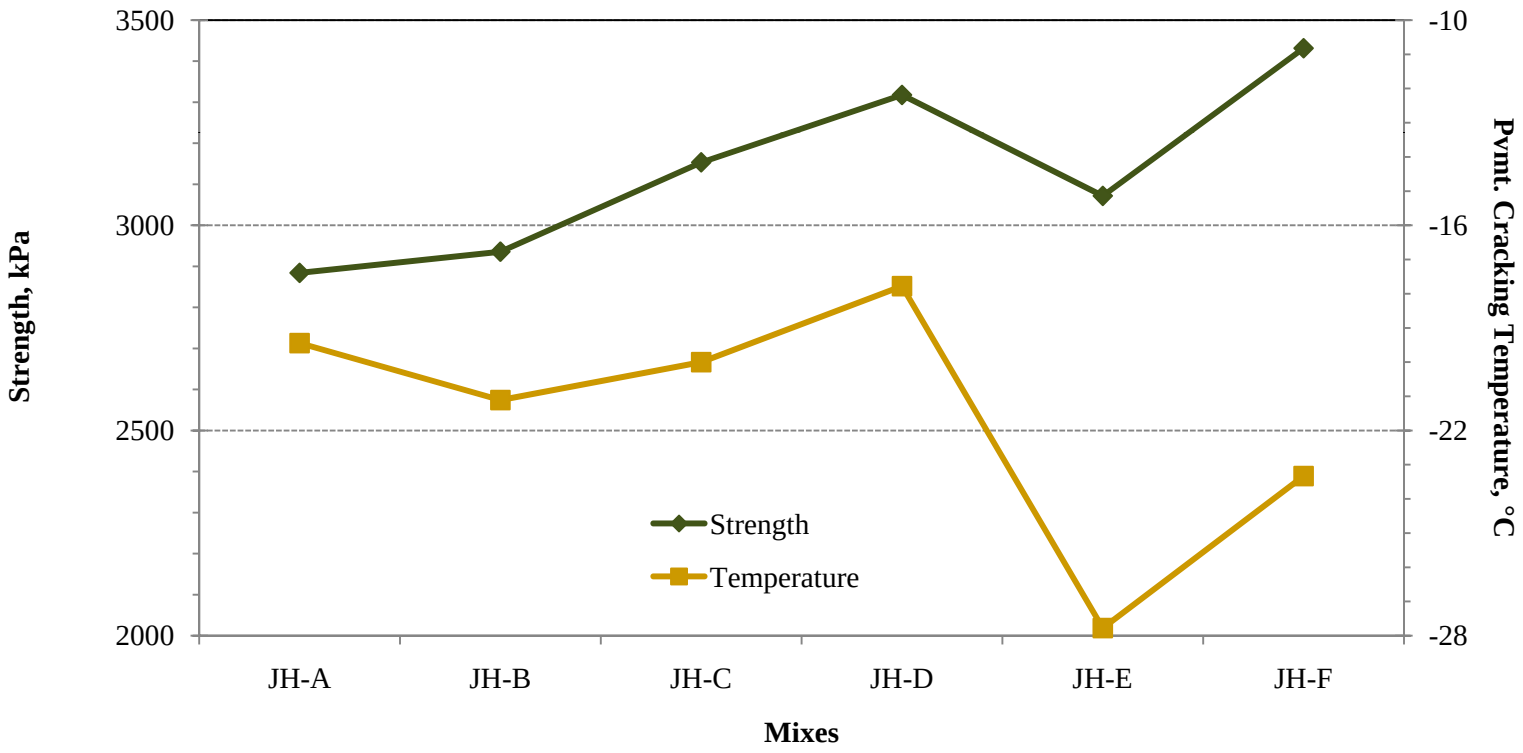


North Central Superpave Center

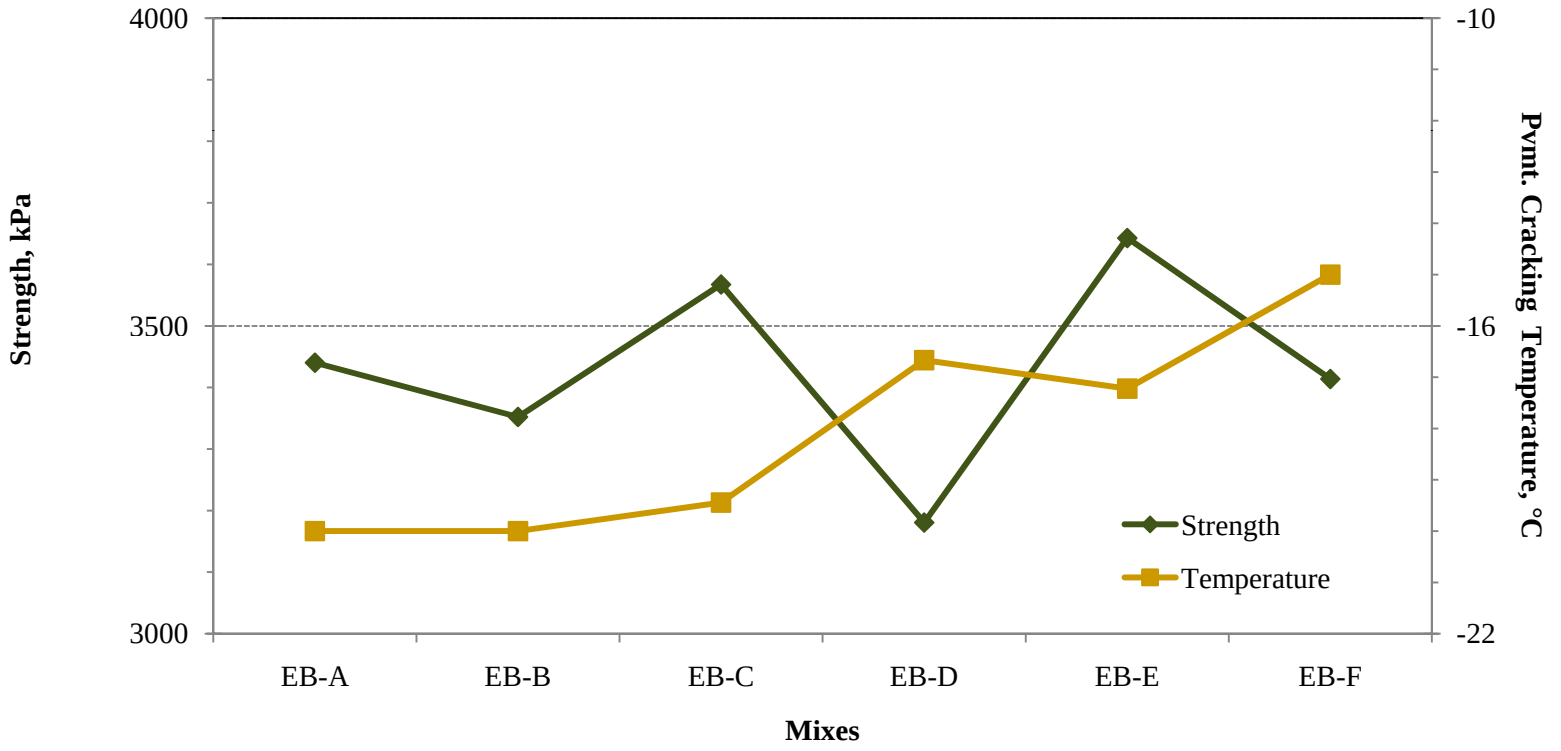
IDT Stiffness Example 1



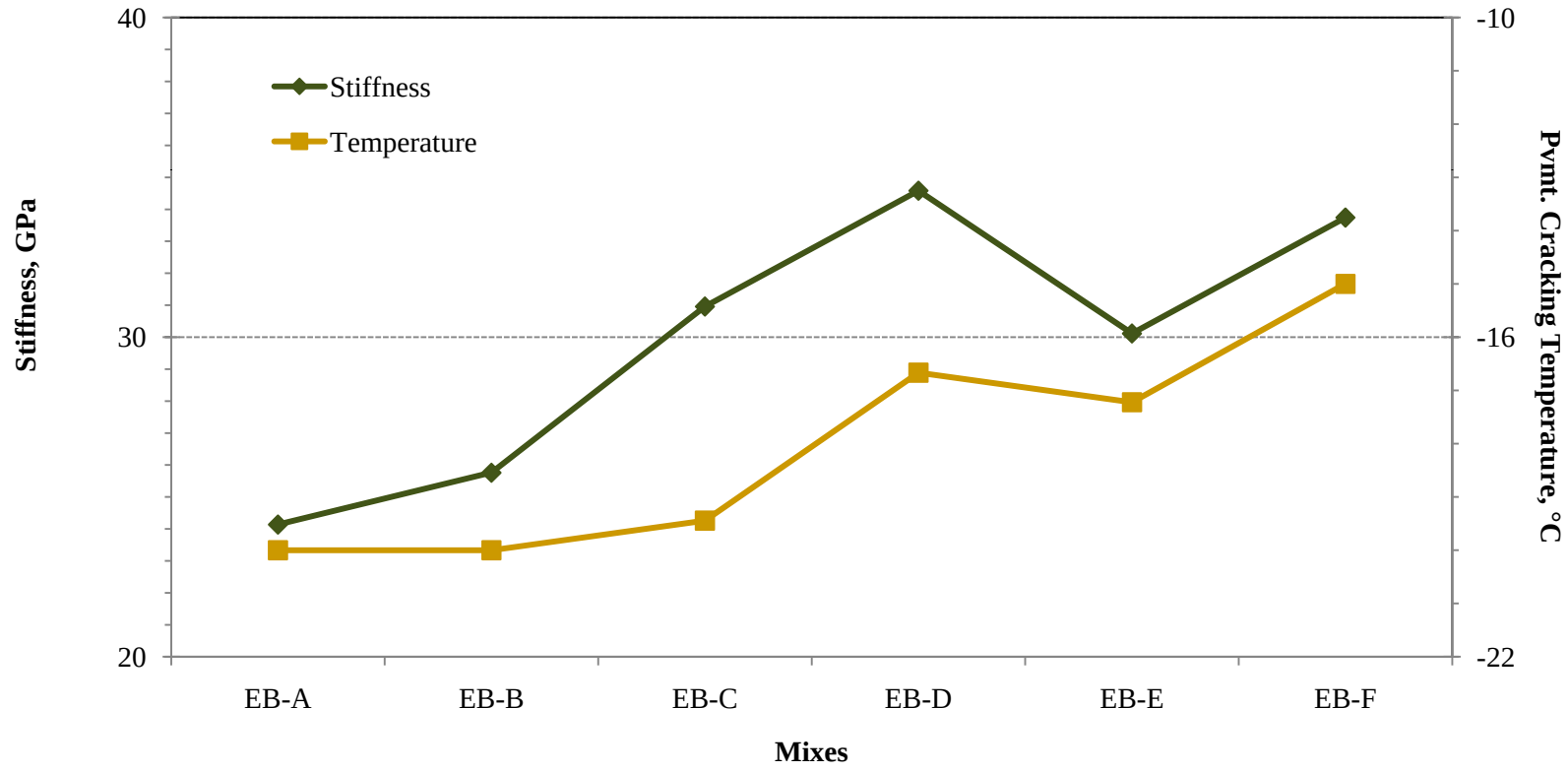
IDT Strength Example 2



IDT Strength Example 3



IDT Stiffness Example 3



Mixture Fatigue

- TFHRC testing
- Cyclic Pull-Pull test
- Most testing complete but data analysis pending
- Expected to be complete in three weeks
- Summary will be added to this report

North Central Superpave Center

General Conclusions

- Recovered binder tests
  - As RAP increases, high temp grade increases
  - As RAP increases, low temp grade increases but not as much as high temp grade
  - Softer binder decreased HT and LT by half a grade or more
  - Increasing RAP content to 25% changed critical cracking temperature no more than 2°
  - Extraction/recovery method did not appear to cause significant differences

North Central Superpave Center

General Conclusions

- Dynamic Modulus
  - Increase in RAP content caused increase in |E*|, especially at intermediate and high temps
  - Stats generally showed no significant difference in PG64-22 mixes; sometimes 40% RAP was significantly different
  - Softer virgin binder generally led to lower stiffness
  - Moduli of PG58-28 mixes with 25 and 40% RAP were often significantly different

North Central Superpave Center

General Conclusions

- Blending
  - Significant blending occurred in 3 of 4 cases
- Low Temperature Cracking (IDT)
  - Slight effects on critical cracking temp at up to 25% RAP with PG64-22
  - Critical cracking temp of 40% RAP with PG64-22 was slightly warmer but still around -22°C

North Central Superpave Center

General Conclusions

- Based on these results and extensive testing and characterization of RAP stockpiles, Indiana DOT changed specs
  - Allow up to 25% RAP before changing grade
  - Also changed to percent RAP binder

North Central Superpave Center

Status

- Putting finishing touches on final report
- Will add summary of TFHRC fatigue testing and resubmit to FHWA within three weeks

North Central Superpave Center

General Conclusions

- Low Temperature Cracking (IDT)
  - Slight effects on critical cracking temp at up to 25% RAP with PG64-22
  - Critical cracking temp of 40% RAP with PG64-22 was slightly warmer but still around -22°C

North Central Superpave Center

QUESTIONS?

COMMENTS?

North Central Superpave Center