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

Rebecca McDaniel

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Approach

- Evaluated 5 sets of plant-produced mixes with up to 40% RAP and 2 virgin binders
- Compared
  - Modulus
  - Low temperature properties and cracking
  - Estimated blending
  - Fatigue (TFHRC) (not presented today)
- Also tested extracted/recovered binders (not discussed today)

Five Contractors

	RAP Content*			
Binder Grade	**0%**	**15%**	**25%**	**40%**
PG 58-28			X	X
PG 64-22	X	X	X	X

*By mass of mix

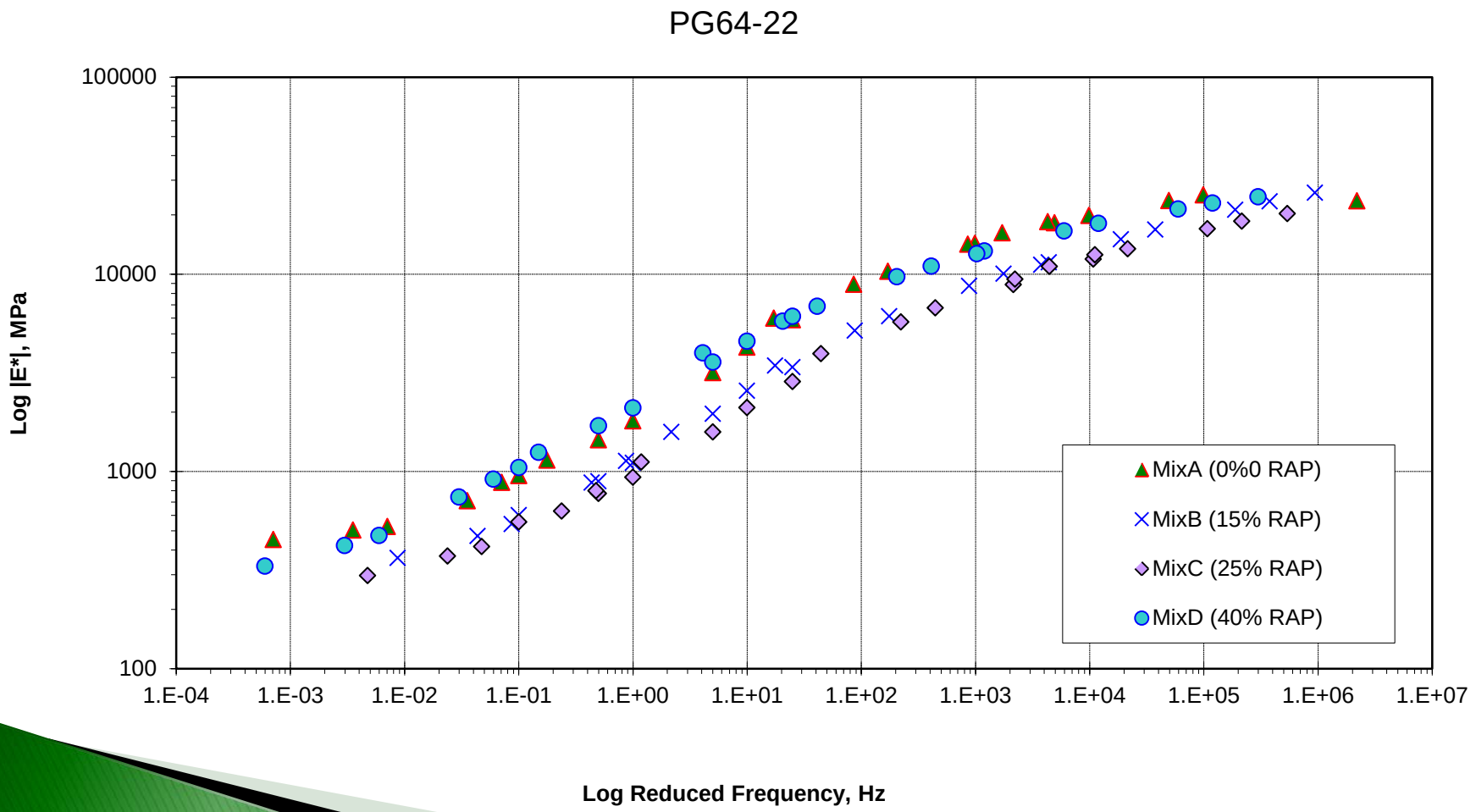
Conventional Wisdom

- RAP will stiffen mix
- More RAP will stiffen mix more
- Improves rut resistance at high temperatures
- May reduce fatigue resistance
- May worsen thermal cracking
- Need softer virgin binder to compensate

Dynamic Modulus – PG64-22

- In general, as RAP content increased, mix modulus, |E*|, did increase
- But, in most cases, modulus was not substantially greater than control for up to 25% RAP
- 40% RAP mixes tended to be stiffer than or comparable to control

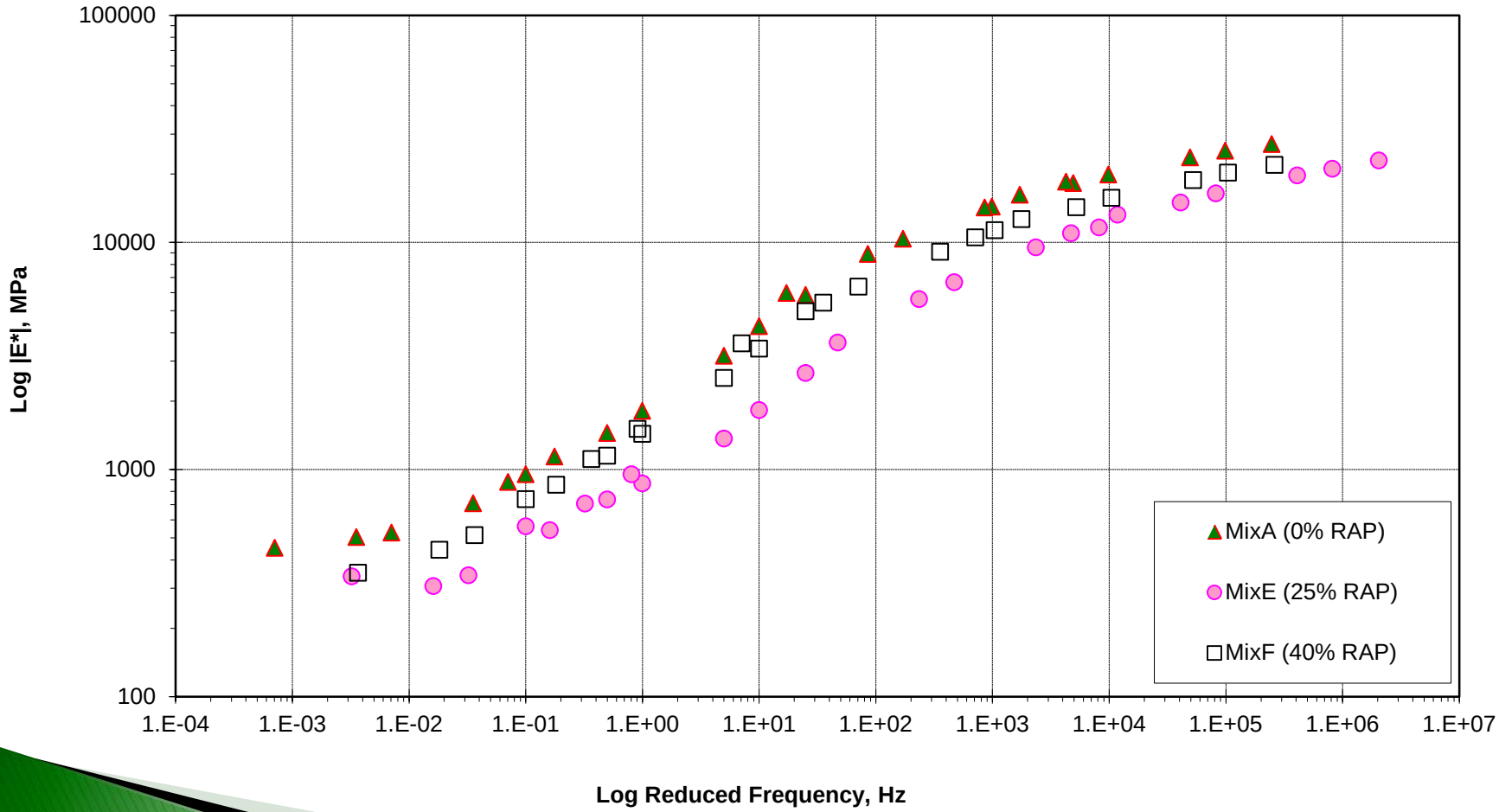
One Example – Mix |E*|



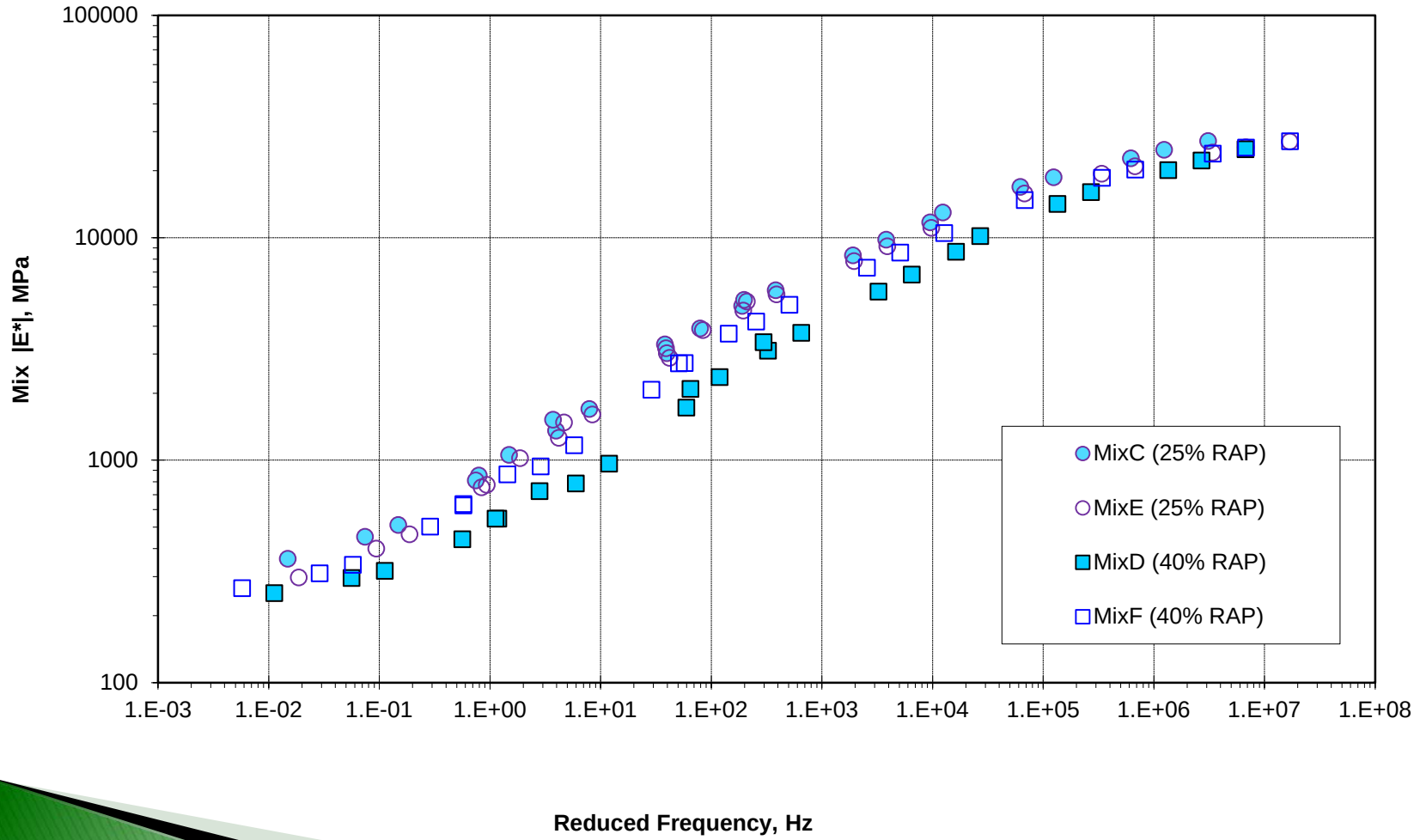
Modulus with PG58-28

- Use of PG58-28 generally reduced mix modulus
- Mixes with 40% RAP are much stiffer than with 25% RAP
- In some cases, mix with 25% RAP and PG58-28 was much less stiff than control

Example – Control vs PG58-28



Example – PG64-22 vs PG58-28



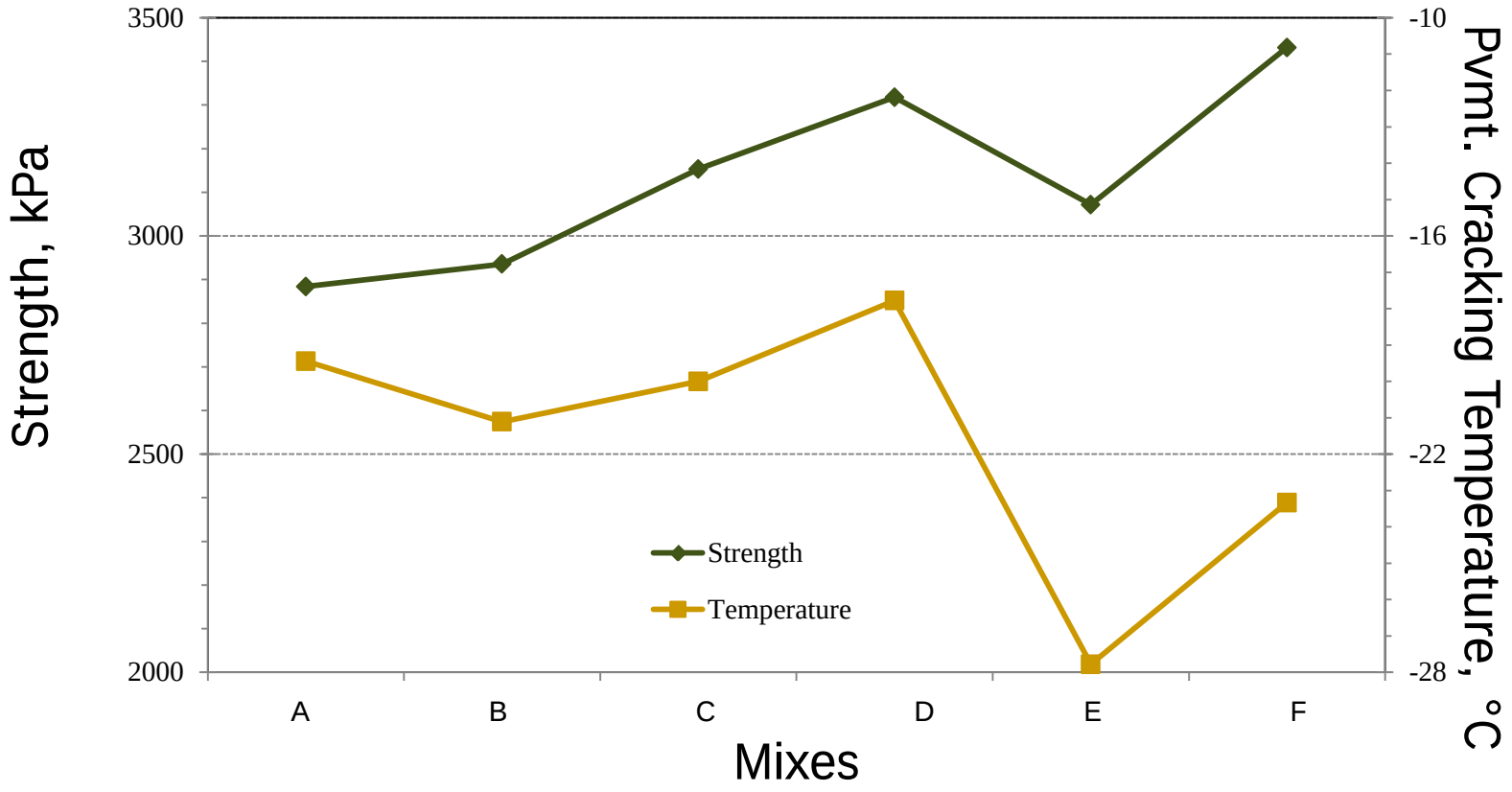
Statistical Analysis

- ANOVA and comparison of means test at different temperatures showed:
  - Mixes with PG64-22 either not significantly different OR
  - 40% RAP mix was different from the others
  - Mixes with PG58-28 were sometimes different from each other

Low Temperature Mix Tests

- With PG64-22
  - Addition of 15 to 25% RAP T_c by ~2°C (warmer)
  - 40% RAP changed T_c by ~4°C
- With PG58-28
  - 25% RAP comparable to control
  - 40% RAP mix was ~1°C warmer than control

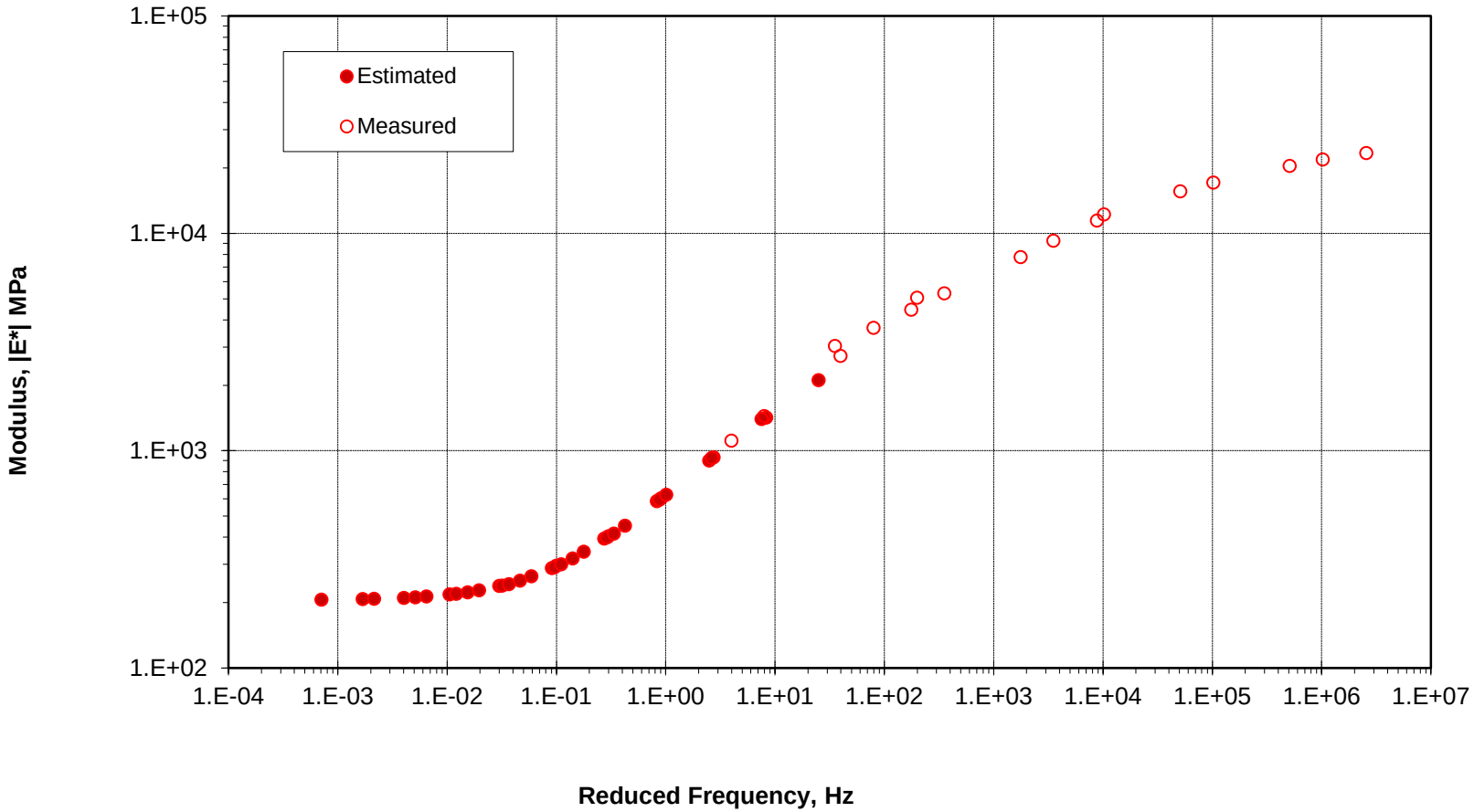
IDT Strength Example



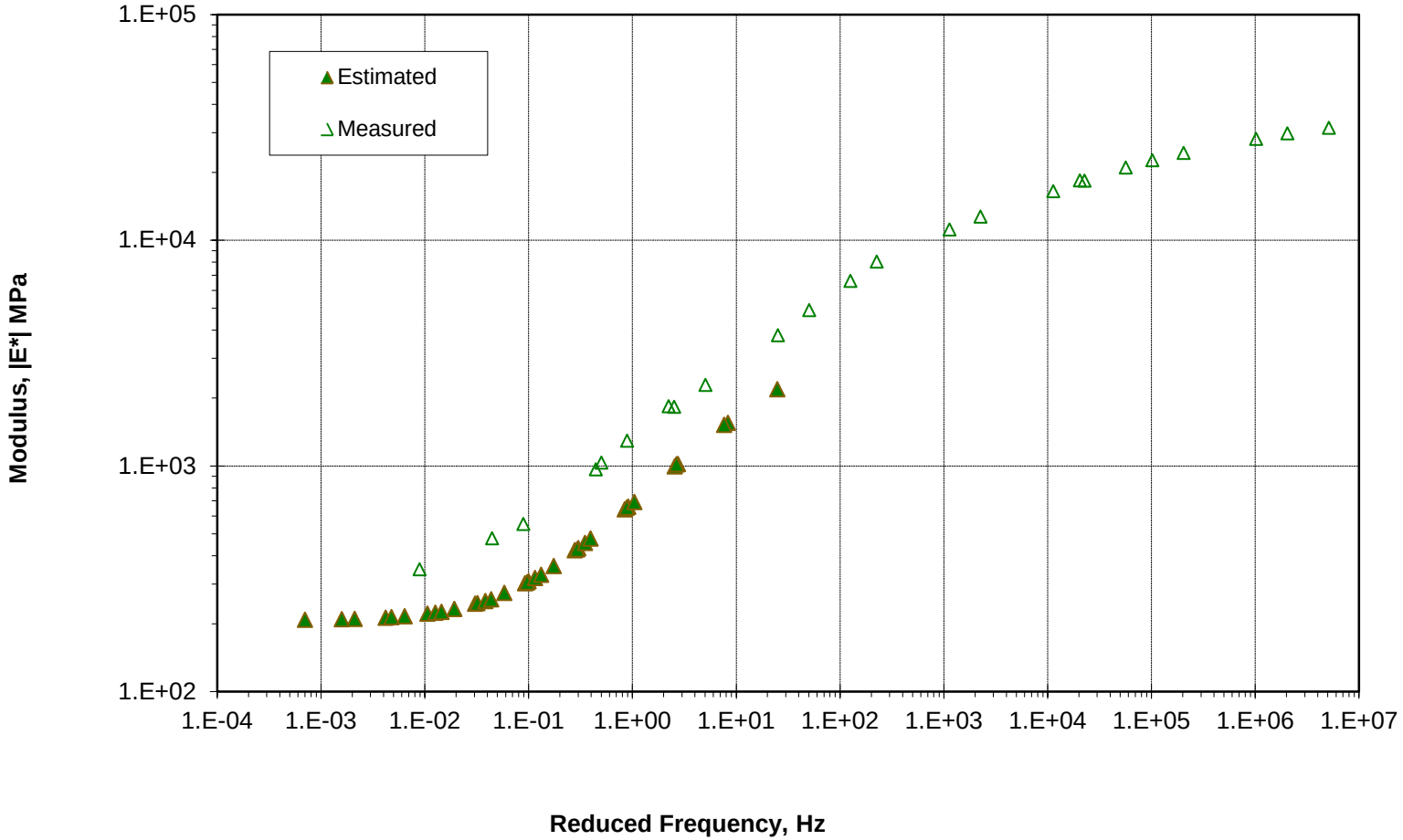
Bonaquist Blending Estimate

- Measure mix dynamic modulus
- Develop mix master curve
- Extract/recover binder (total blending)
- Measure binder shear modulus
- Estimate mix modulus for that binder (if totally blended) using Hirsch model
- Compare estimated (from binder) and measured mix moduli

Thorough Blending



Poor Blending



Blending Analysis

- Two cases indicated good blending for all RAP contents, two showed less for some mixes
- Relates to other comparisons
  - IDT indicated little effect of binder grade in the cases with questionable blending
- Results were not totally consistent
  - Not simple; many factors can affect blending and testing

Conclusions

- As RAP content increased, mix modulus generally increased
- No statistically significant difference between moduli of mixes with PG64-22 except with 40% RAP
- Use of softer virgin binder did reduce modulus
- Implies grade change is needed for 40% RAP

Conclusions

- Significant blending of RAP and virgin binders was observed in most cases
- Low temperature mix testing showed slight change in critical cracking temperature at up to 25% RAP with no grade change
- Critical cracking temperatures were lower with PG58-28, but -26 but may not be needed
- Fatigue results were unexpected; no clear effect of RAP content or binder grade

Outcome

- Presented to INDOT and industry
- INDOT OMM explored PG grading of 33 RAP sources across the state (PG90.1-11.1)
- Based on all these results, spec change was approved
  - 25% with no grade change, 40% max
  - Also changed to binder replacement
- *Reports coming in that some other states are verifying these results*

Final Report

- Published by FHWA earlier this week
- www.fhwa.dot.gov/publications/research/infrastructure/pavements/11058/index.cfm
- Paper at Association of Asphalt Paving Technologists, April 2-4, 2012 in Austin, TX

Upcoming Event!

- North Central Asphalt User Producer Group Technical Conference
- Hyatt Regency, Indianapolis
- February 15-16, 2012
- Details will be on the web -- Link from NCSC page

NCAUPG Topics

- RAP, RAS and WMA
- MSCR Test
- Mixing and Compaction Temperatures
- Plant Innovations
- QC and Continuous Plant Monitoring
- MEPDG
- Cold Temperature Study
- Intelligent Compaction and PaveIR
- Safety Edge
- Centerline Corrugations

Questions?

Rebecca S. McDaniel
Technical Director
North Central Superpave Center
Purdue University
West Lafayette, IN
765/463-2317 ext 226
rsmcdani@purdue.edu
https://engineering.purdue.edu/NCSC

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