RAP Plant Mix Study

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Growing Interest/Changing Practices

- Higher RAP contents in more mixtures.
- More fractionating.
- More specs based on binder replacement.
- More interest in recycling asphalt shingles (high binder contents).

Previous RAP Research

- Often laboratory studies and some field performance evaluations
- Typically lower RAP contents and little comparison of RAP contents

➢ This study was intended to compare different RAP contents and binder grades in *plant produced* mixtures.

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

Questions

- At what RAP content do you need to change grades?
- Effect of RAP on low temperature cracking?
- Are things different when plant mixes are tested?

Current US Guidelines

- Adjust grade of binder added to account for the hard, oxidized binder in the RAP
  - 0 to 15% RAP, no binder grade change
  - 16-25% RAP, decrease virgin binder grade
  - Over 25% RAP, test RAP binder to determine appropriate virgin grade (or allowable RAP content)
- Percentage by weight of RAP in the mixture.
- Based on non-fractionated mixes with about 5% binder in RAP and new mix.
- Many states have modified these.

Approach

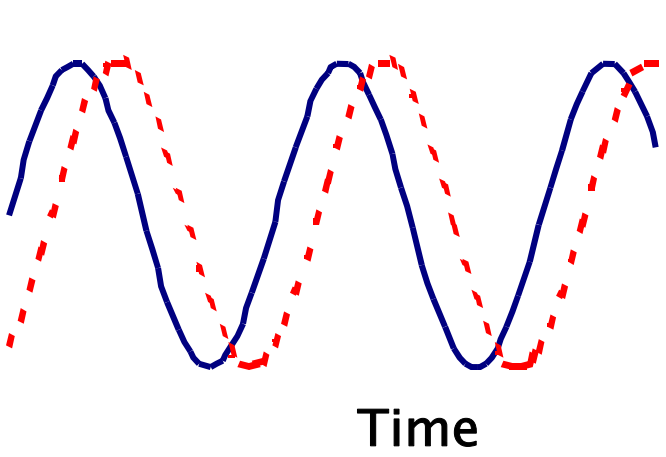
- Evaluated 5 sets of plant-produced mixes with up to 40% RAP and 2 virgin binders
- Compared
  - Dynamic modulus
  - Low temperature properties and cracking
  - Estimated blending
  - Fatigue (TFHRC) (not presented today)
- Also tested extracted/recovered binders (not discussed today)

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

Dynamic Modulus Test



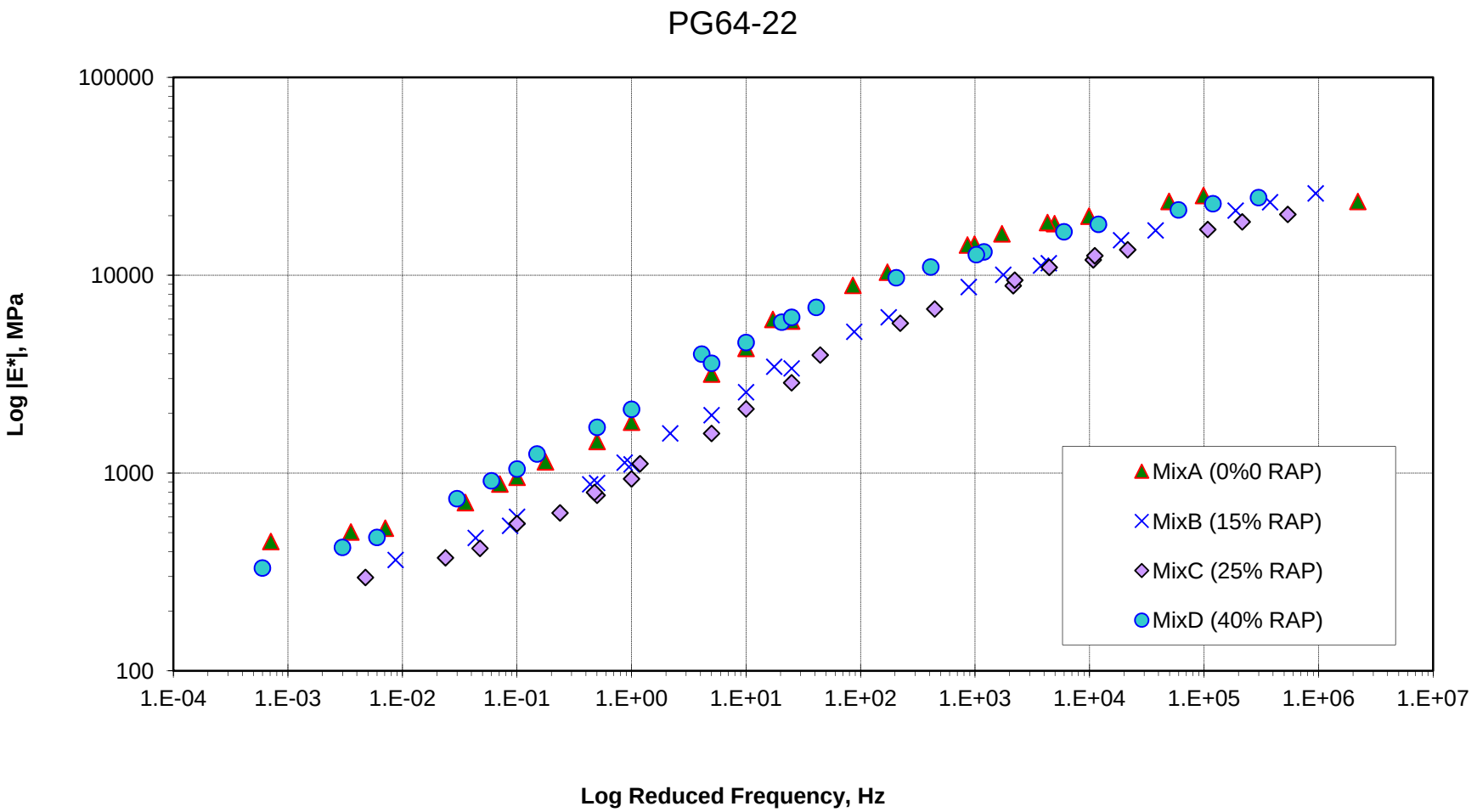
$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

- Rutting
- Fatigue Cracking

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

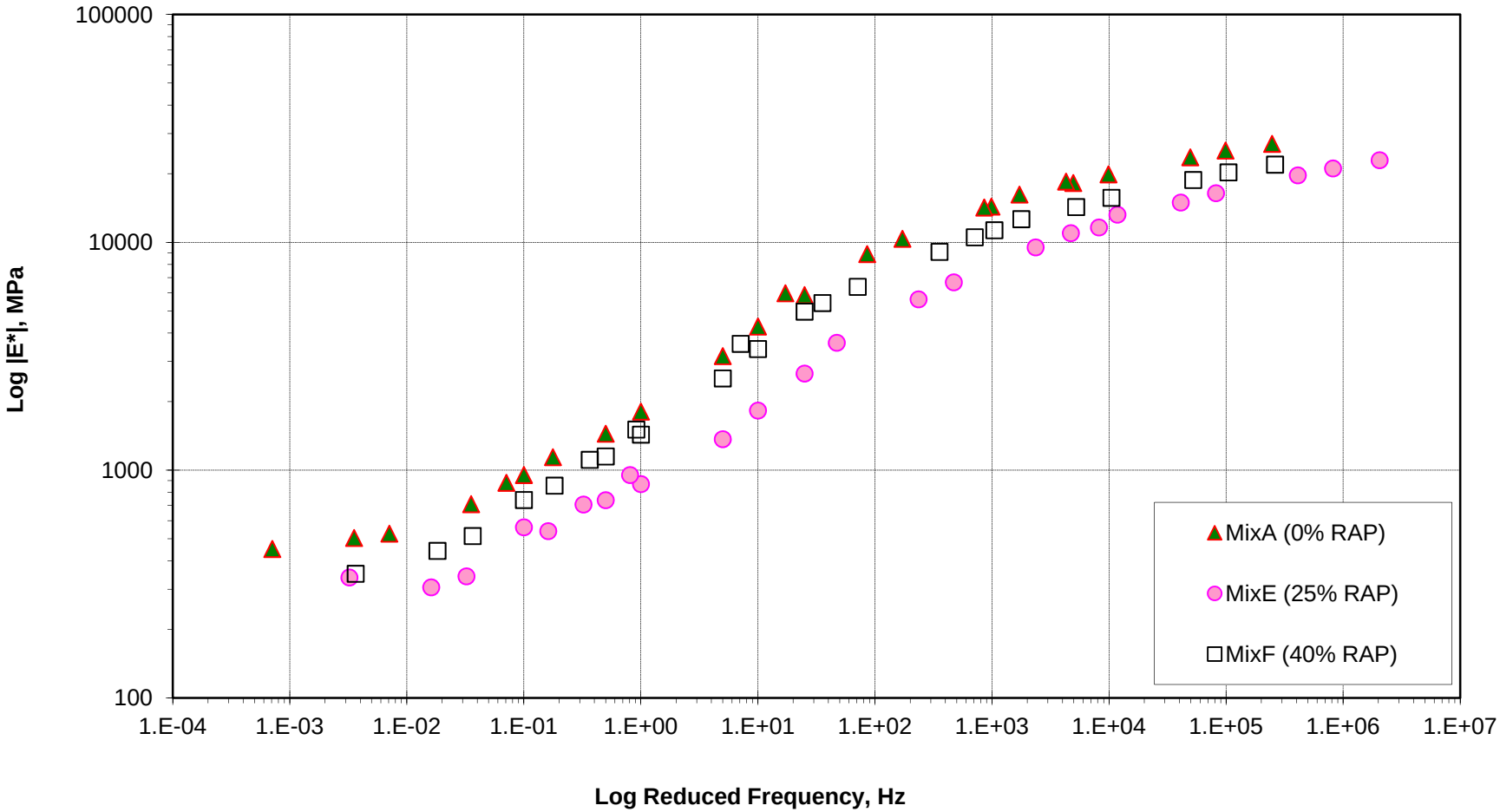
One Example - Mix |E*|



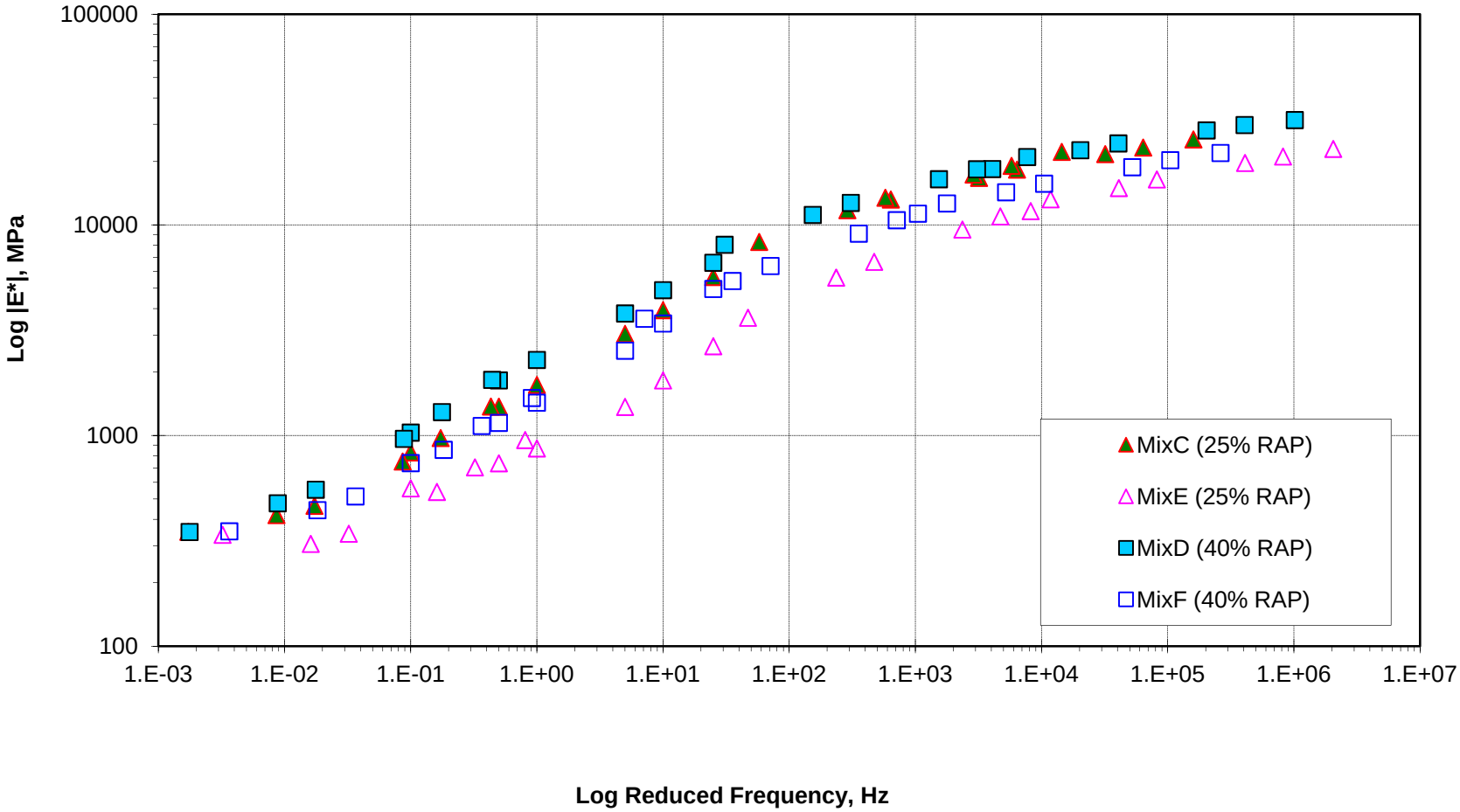
Modulus with PG58-28

- Use of PG58-28 generally reduced mix modulus
- Mixes with 40% RAP were 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



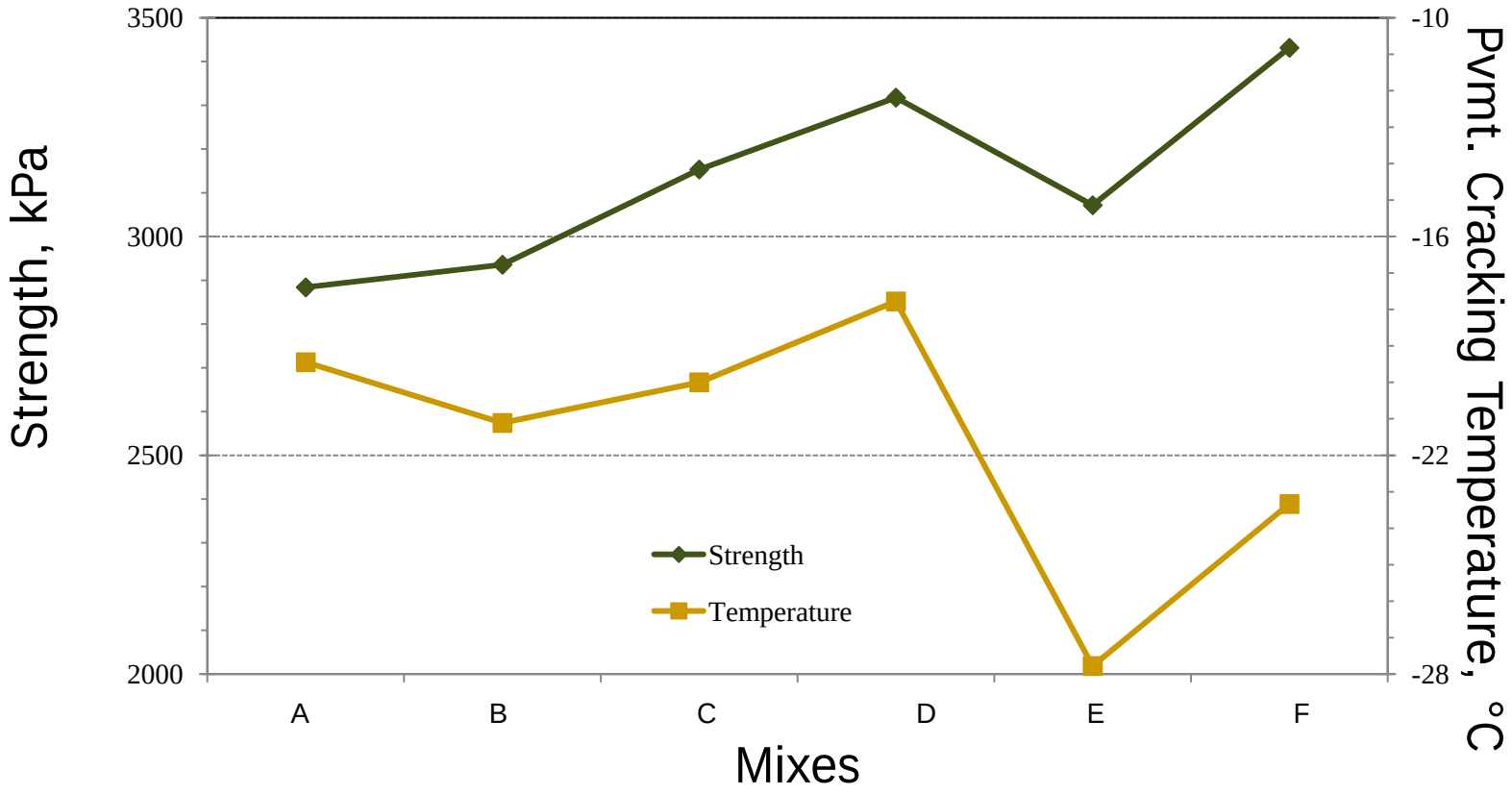
Statistical Analysis

- 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

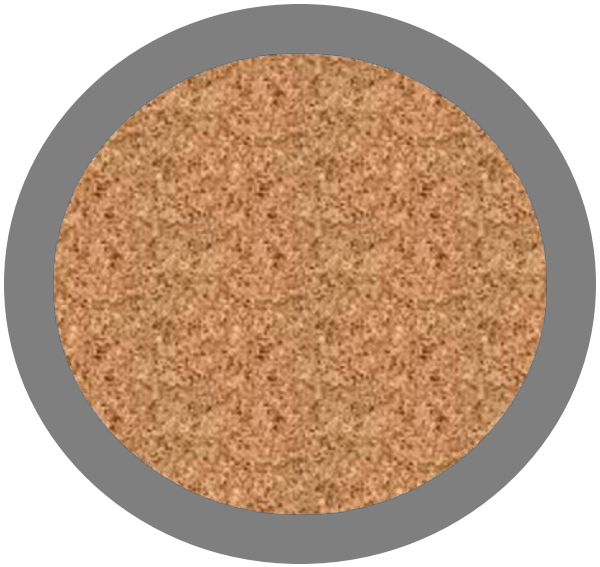
Low Temperature Mix Tests

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

IDT Strength Example

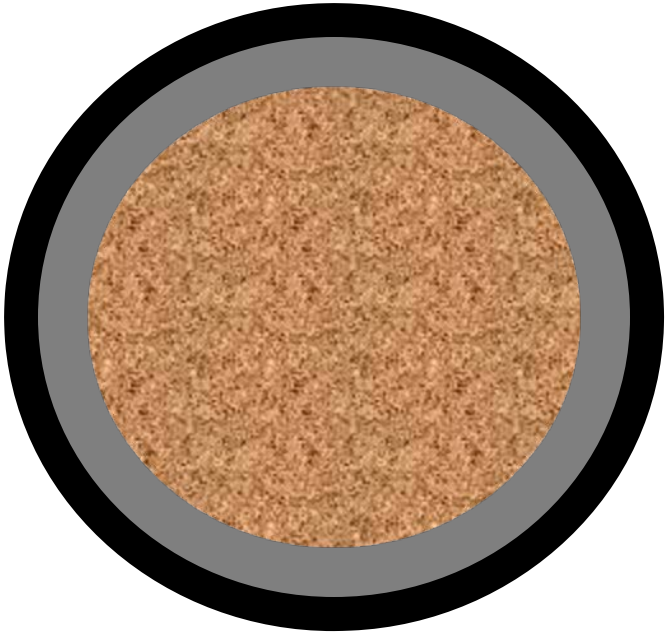


Possible Effects of RAP Binder



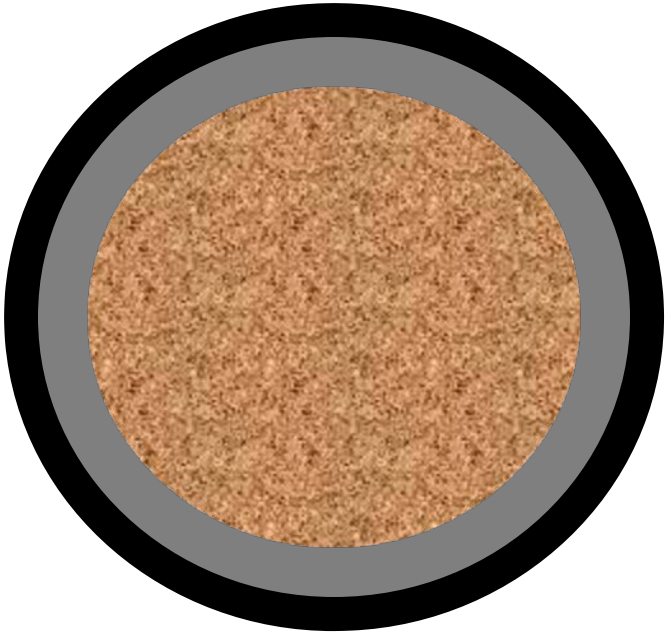
RAP aggregate with oxidized binder film

Possible Effects of RAP Binder



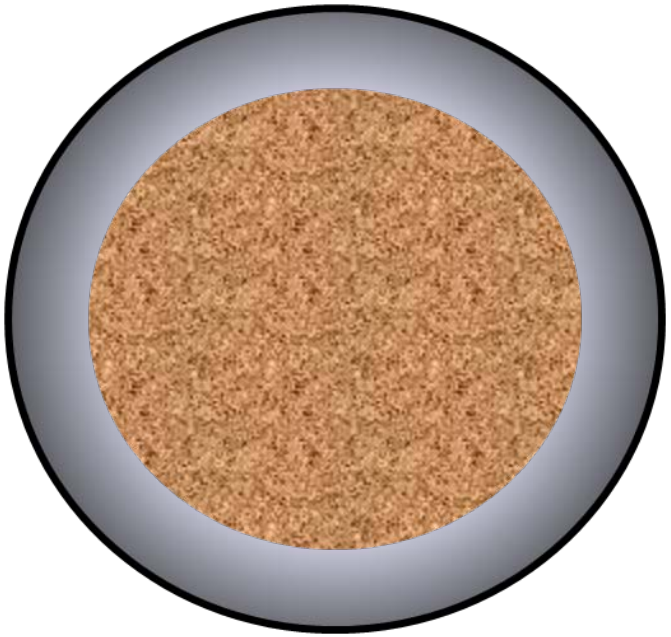
RAP aggregate with oxidized binder film plus virgin binder film

Possible Effects of RAP Binder



If RAP and virgin binders do not blend, effective binder properties will be those of the virgin binder only.

Possible Effects of RAP Binder

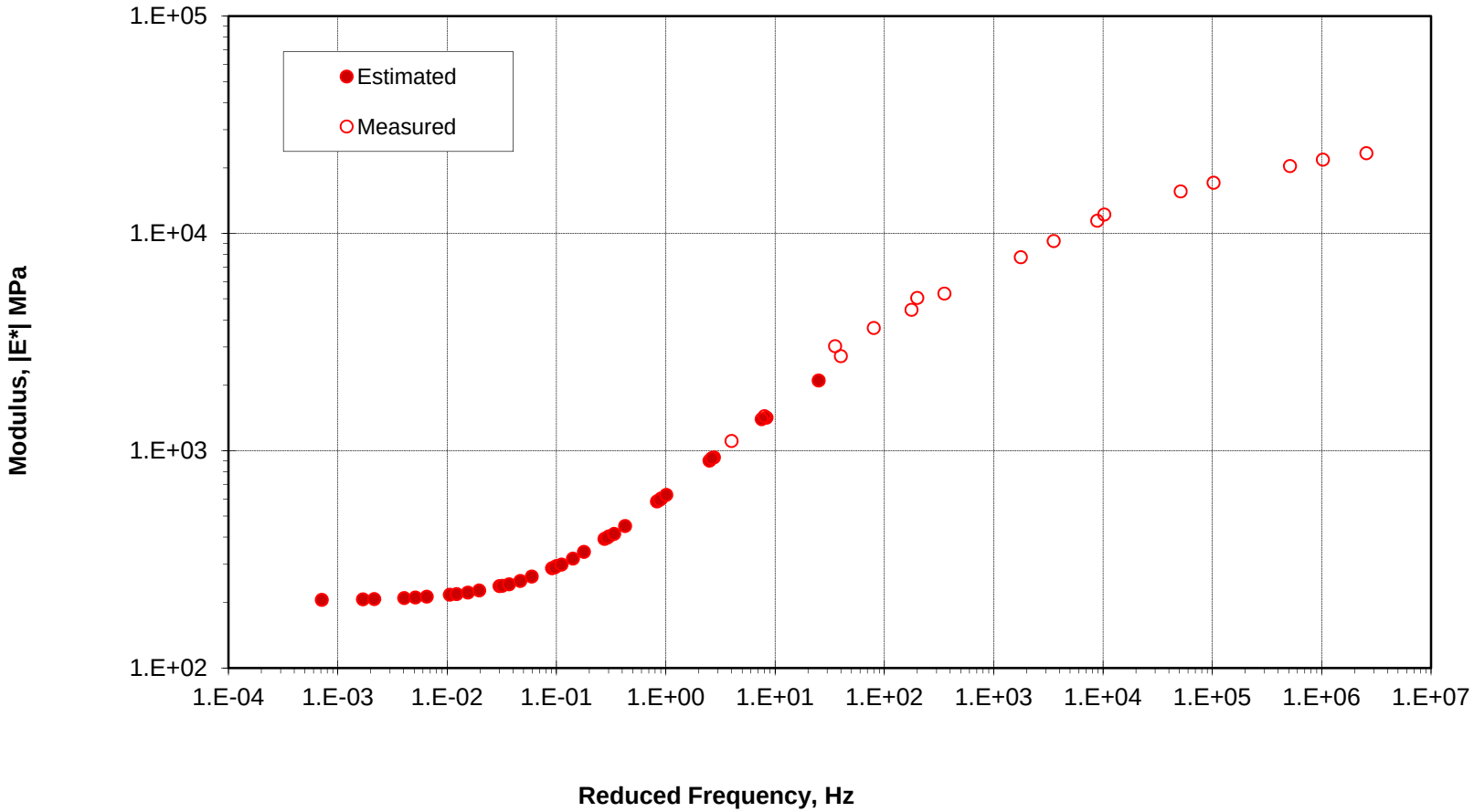


If RAP and virgin binders blend or merge, effective binder properties will be determined by the amount of blending that occurs.

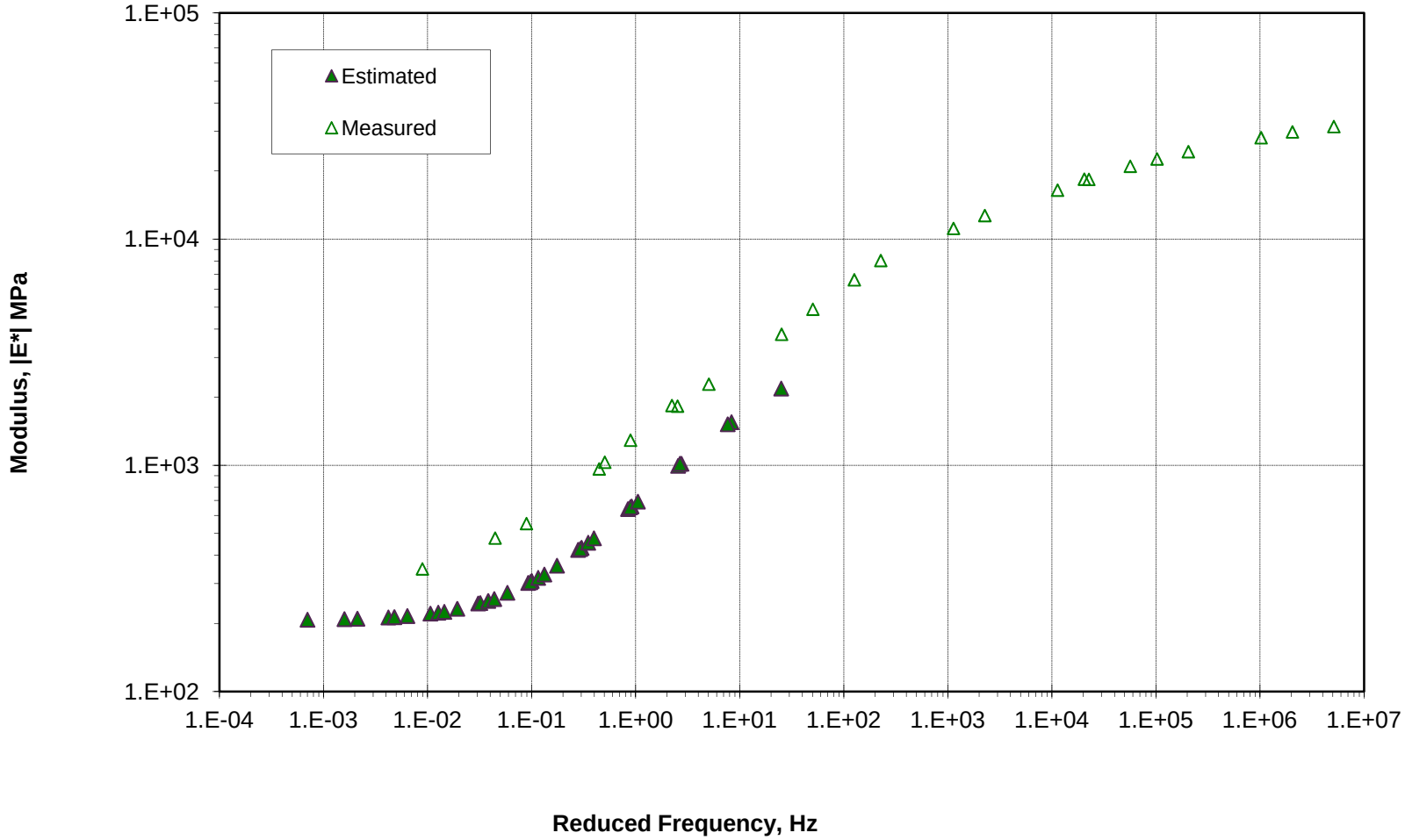
Bonaquist Approach

- Compare measured mix modulus to estimated modulus based on testing recovered binder and mix volumetrics
- Advantage – allows assessment of production variables
  - RAP processing
  - Production rates and temperatures
  - Additives
  - Storage time, etc.

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 mix moduli 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

Based on this research

- And testing RAP sources from across the state (average PG90.1–11.1)
- INDOT increased RAP contents to:
  - 25% with no change in grade
  - 40% with a grade change
  - Based on binder replacement
- Spec change has been adopted
- Reports are coming in that other states are verifying these findings

Final Report

- Published by FHWA in December
- 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

Questions?

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