Upping the RAP: Putting Research into Practice

NAPA Webinar

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

- Study funded by FHWA
- Thanks to participating contractors, Audrey Copeland, Gerry Huber.

- http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11058/

North Central Superpave Center

Growing Interest/Changing Practices

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

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

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 (mostly lab mixes).
- Many states have modified these.

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?

Approach

- Evaluated 5 sets of plant-produced mixes with up to 40% RAP and 2 virgin binders
- Compared mix properties:
  - 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

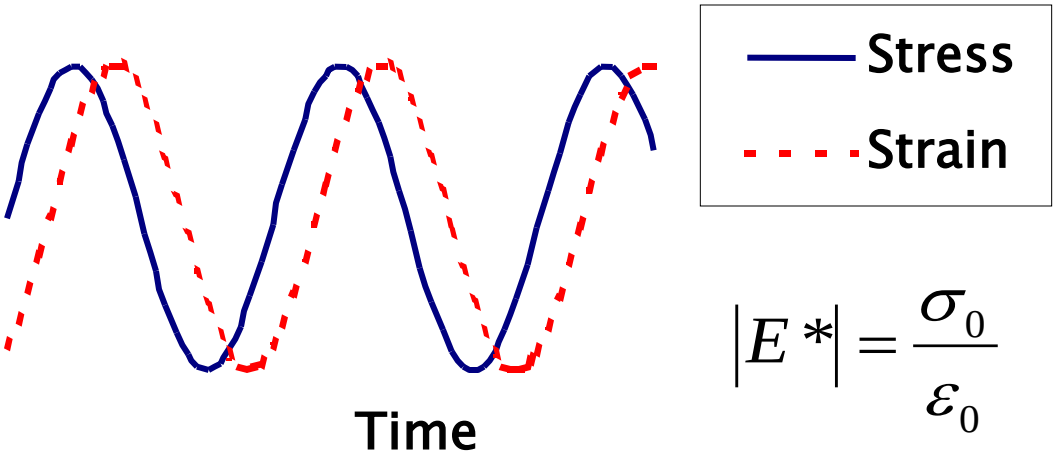
Mix Designs

- Contractors designed 9.5 mm mixes
  - Two coarse, three fine
- Full mix design on one mixture
- Adjust for changes in RAP content
- Keep gradations consistent while using existing stockpiles
  - Generally within 3% on any sieve
- Typically one point verification
  - Substantial spec compliance

Mix Production

- Routine processing and production
- RAP crushed and screened
  - Four used 12.5 mm screen
  - One used 15.9 mm (5/8 in.) screen
- Plant types – parallel and counter-flow drums, double drum, and aggregate dryer with separate mixing drum
- Sampled from one truck at plant – loose mix and gyratory samples

Dynamic Modulus Test



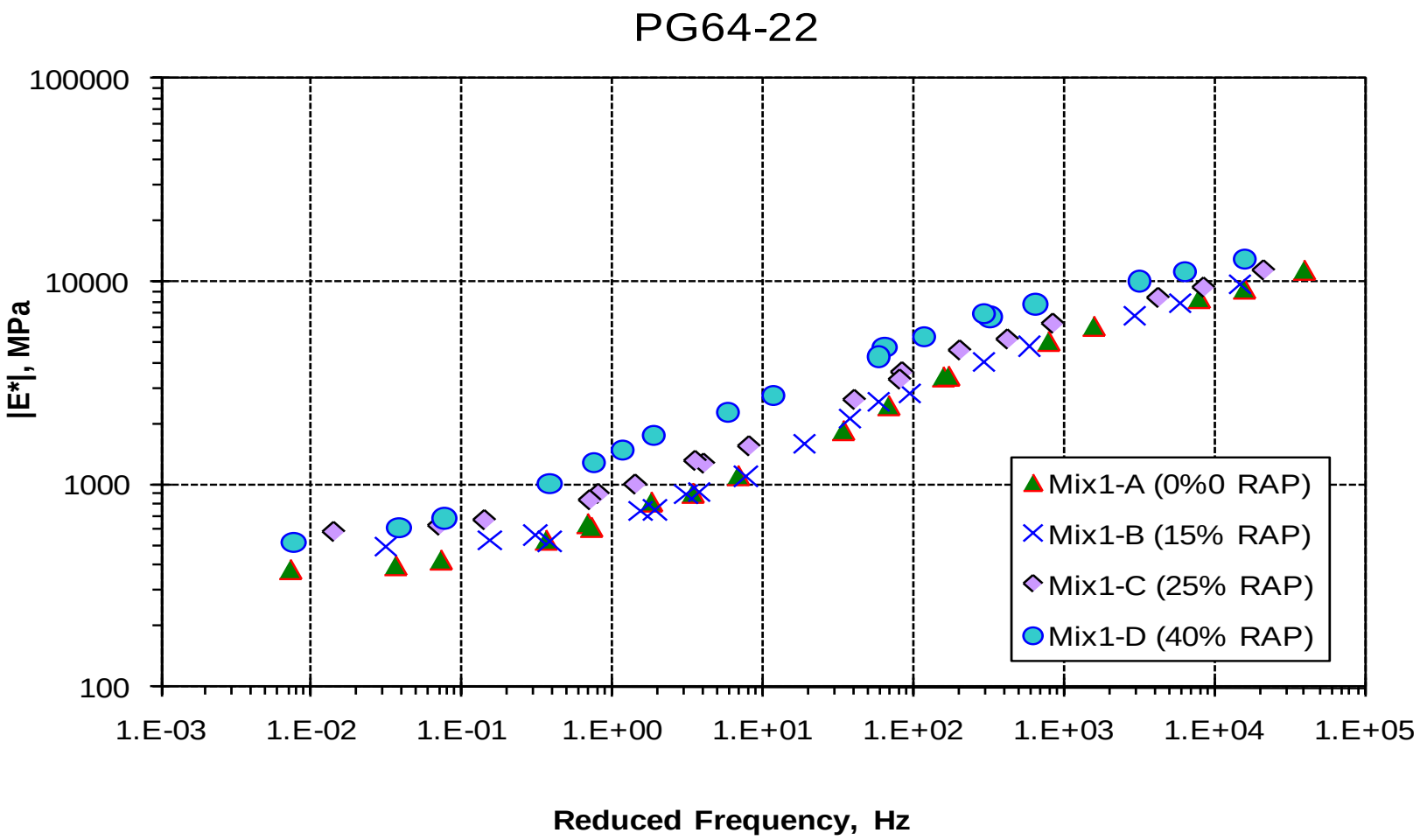
$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

- 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

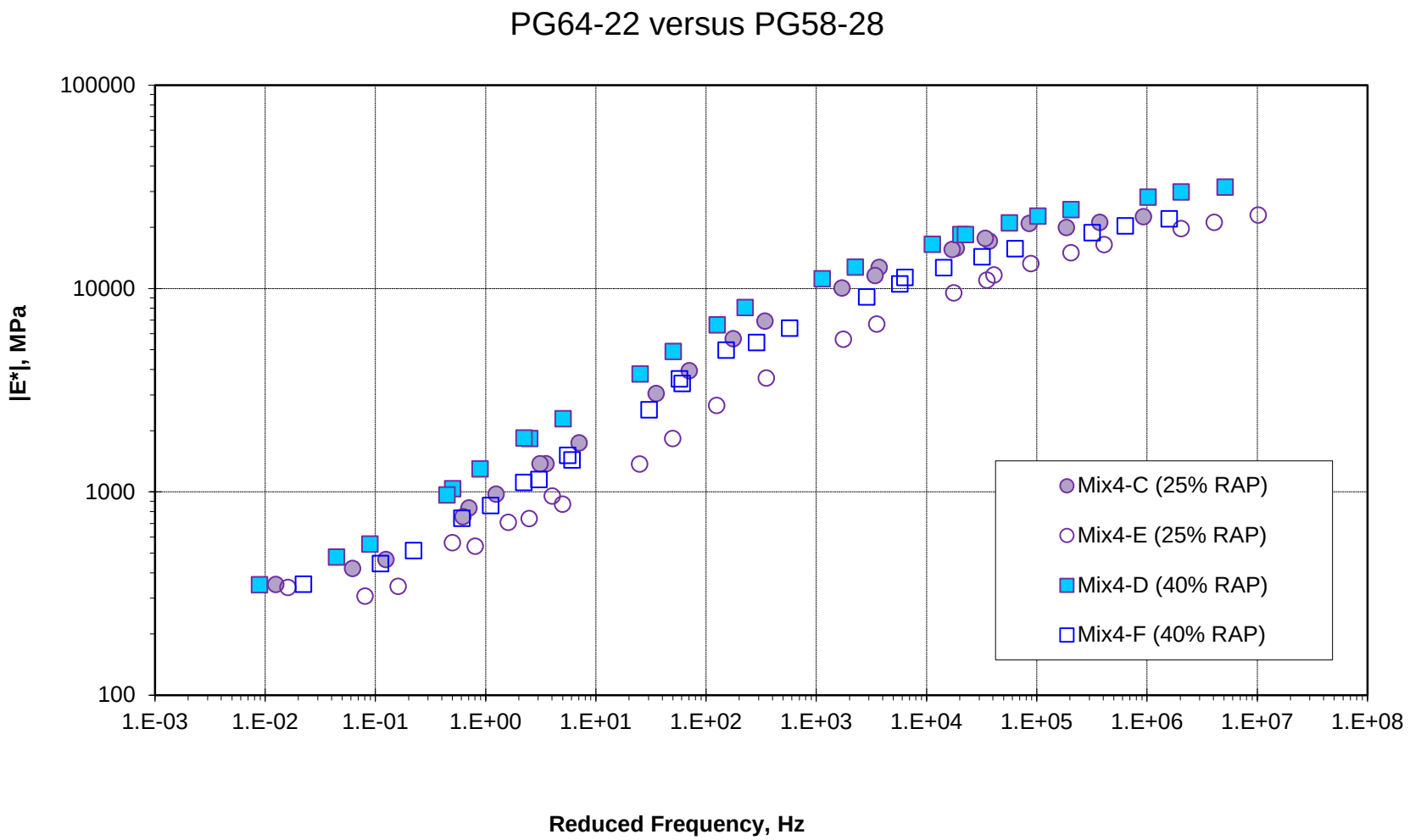
One Example - Mix |E*|



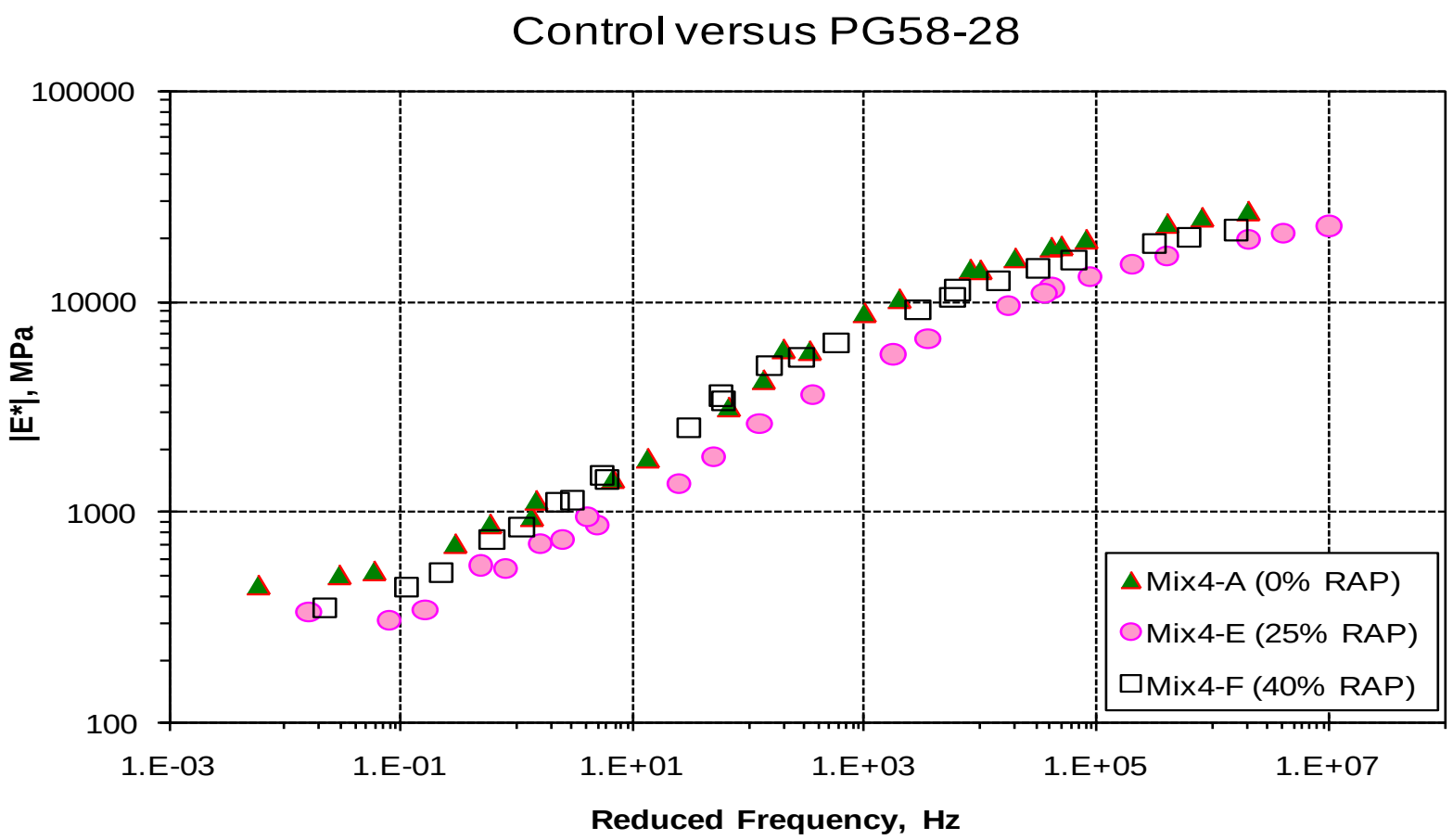
Modulus with PG58-28

- 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 – PG64-22 vs PG58-28



Example – Control vs PG58-28



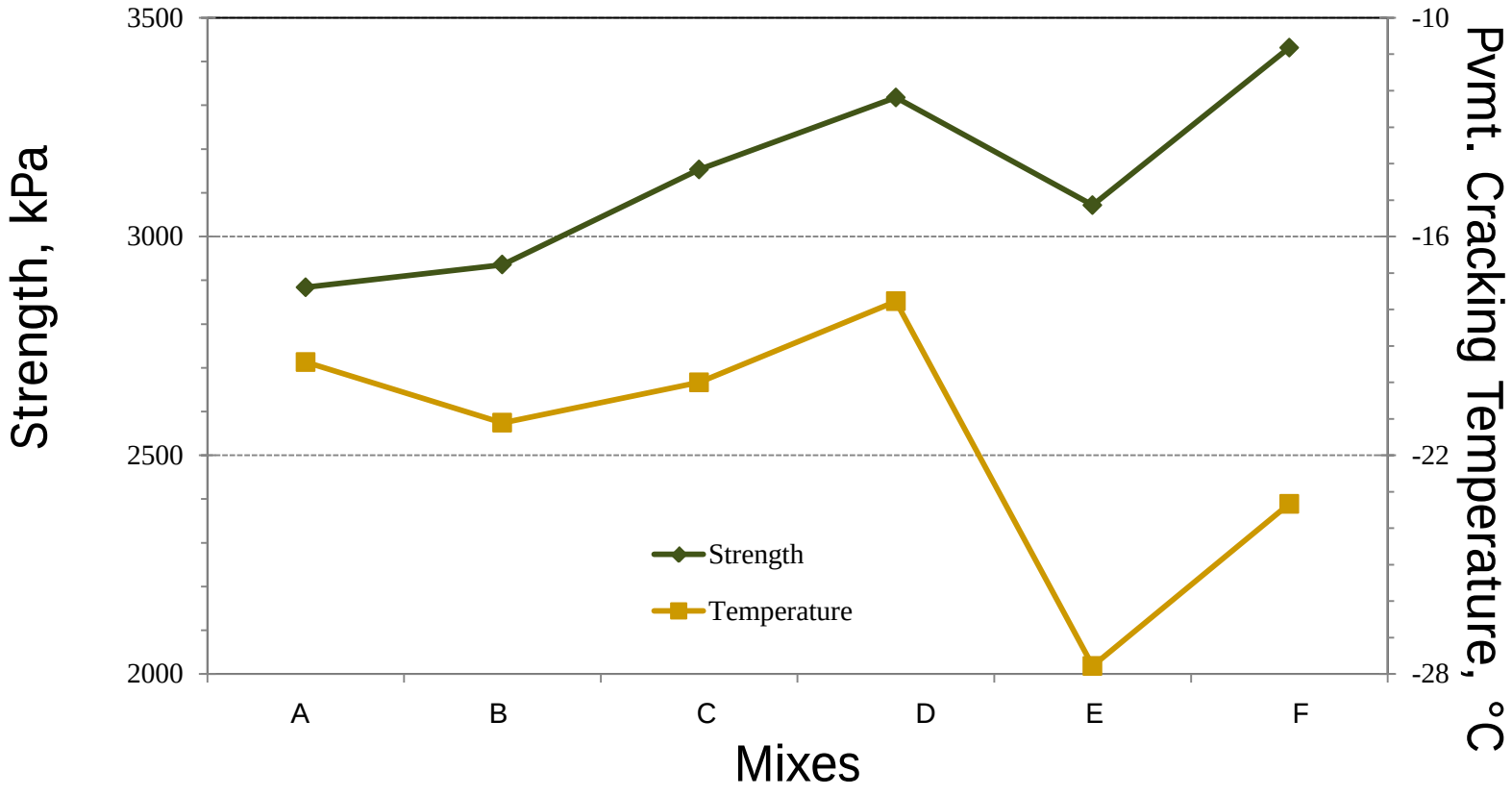
Statistical Analysis

- 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 (25% and 40% RAP)

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

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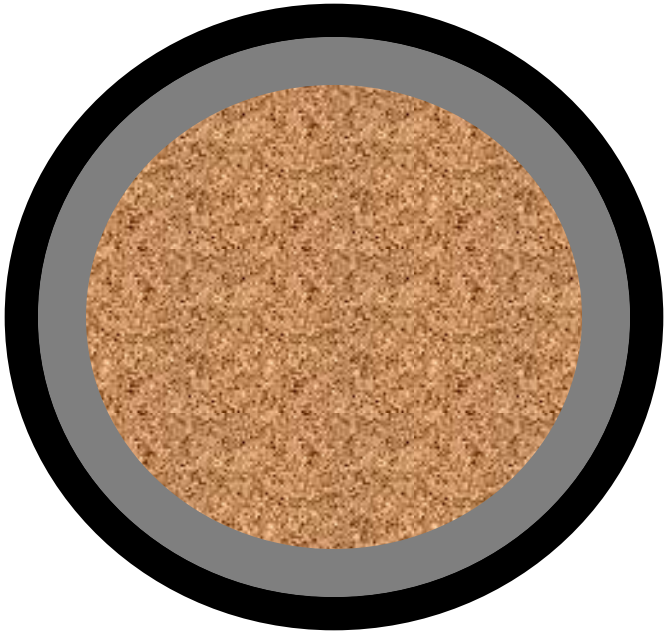
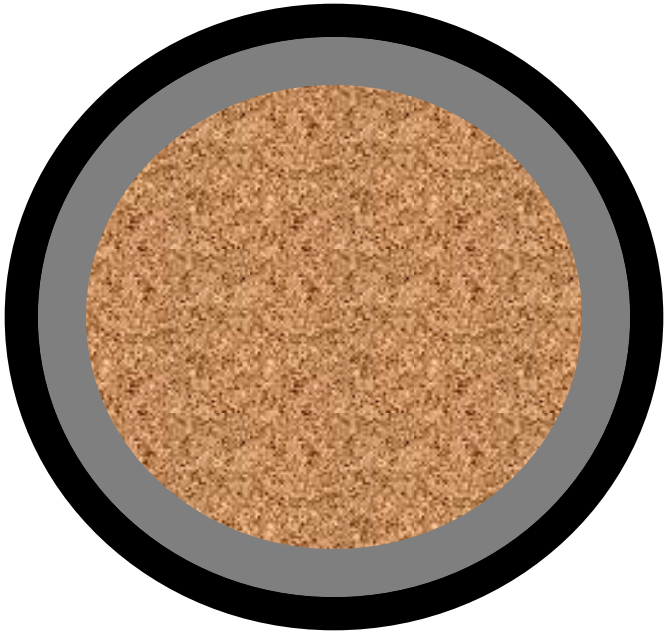


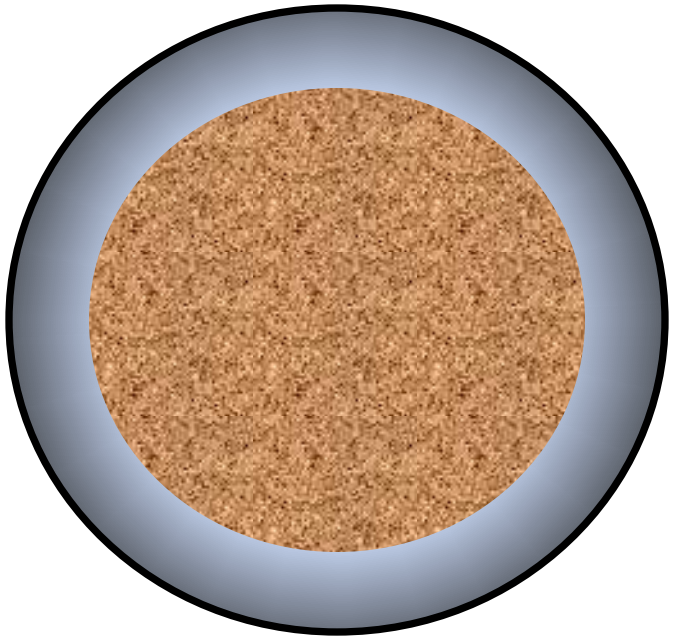
RAP aggregate with oxidized binder film plus virgin binder film

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

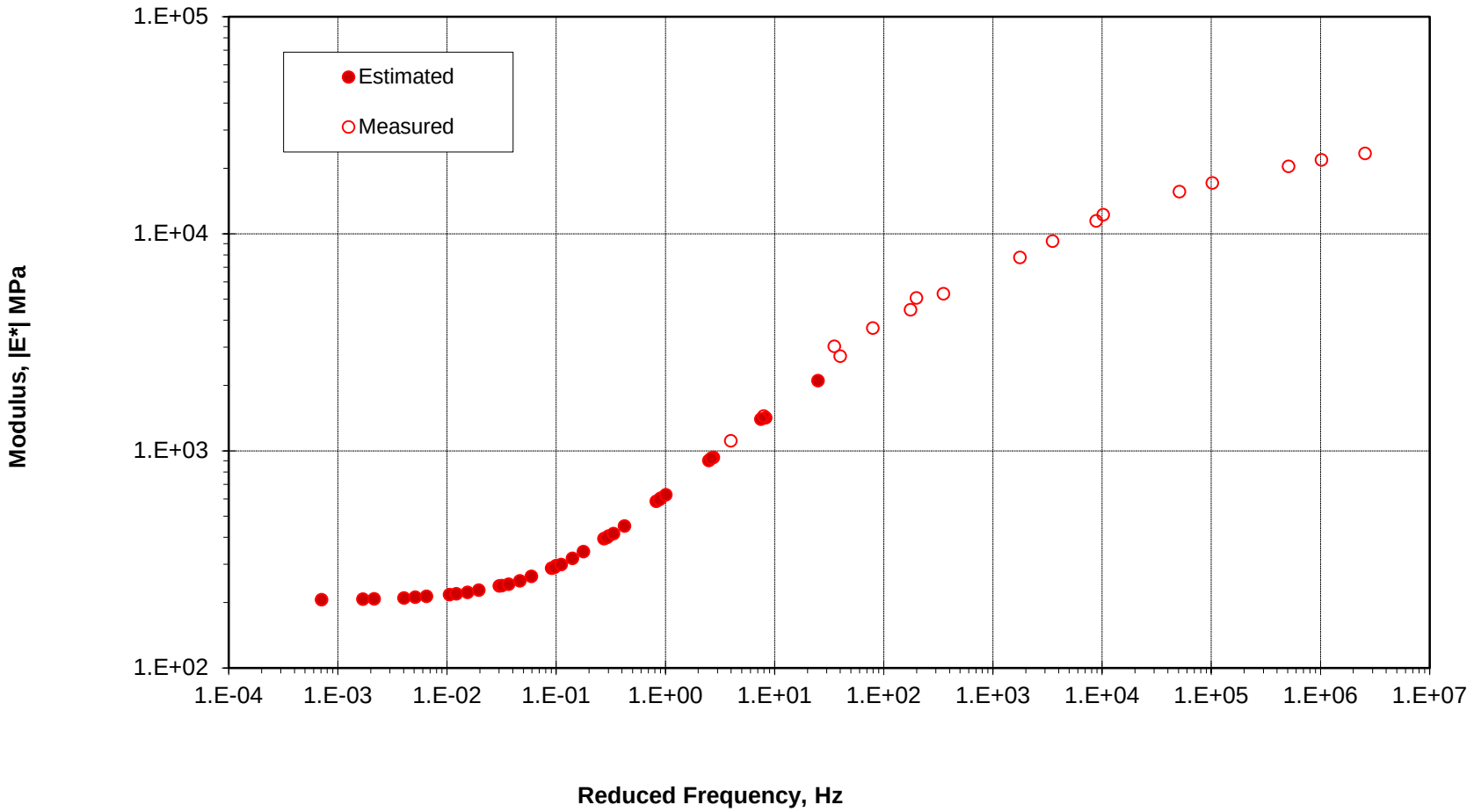


If RAP and virgin binders blend or merge, effective binder properties will be determined by the amount of blending that occurs.

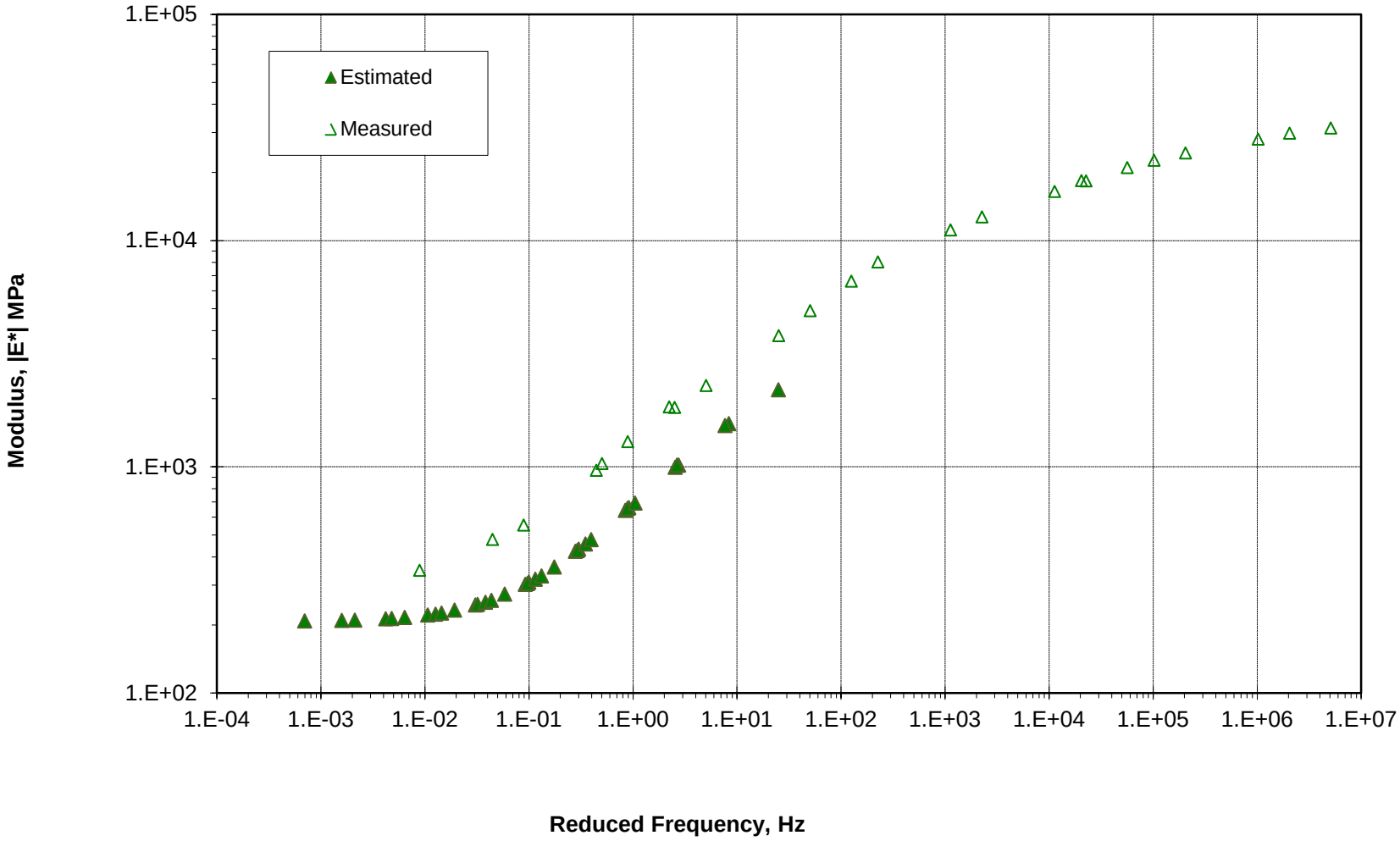
Bonaquist Approach

- 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



Summary of Blending

	Mix A	Mix B	Mix C	Mix D	Mix E	Mix F
RAP %	0	15	25	40	25	40
PG	64-22	64-22	64-22	64-22	58-28	58-28
Contractor 2	Good	Good	Good	Poor	Good	Good
Contractor 3	Good	Partial	Good	Good	Good	Good
Contractor 4	Good	Good	Poor	Poor	Good	Good
Contractor 5	Good	Good	Good	Good	Good	Good

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 differences between mix moduli with PG64-22 except for some mixes with 40% RAP
- Use of softer virgin binder did reduce modulus

Conclusions

- Significant blending of RAP and virgin binders was observed in most cases, especially up to 25%
- 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

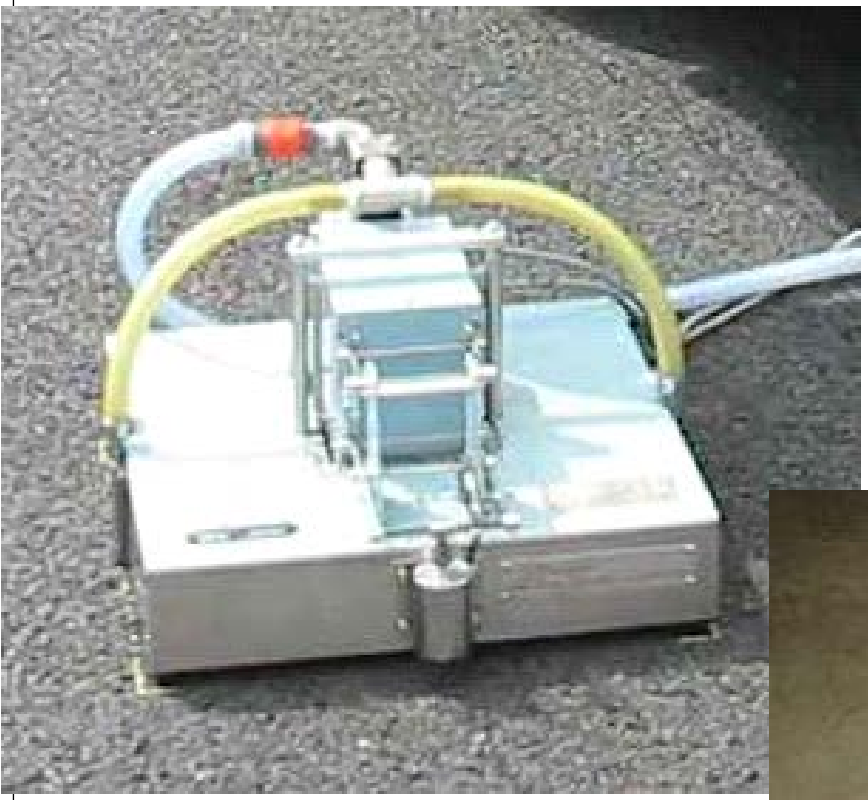
Overall Conclusions

- Findings suggest no grade change needed for RAP contents ≤25%
- Binder grade should be one grade softer for 40% RAP mixes
- Applicable to these materials and conditions; not necessarily true elsewhere
- Review your typical materials, especially typical RAPs, to explore applicability

RAP Effect on Frictional Properties

- Can you use RAP, with unknown agg properties, in surface mixes without compromising friction?
- Most Indiana aggregates are carbonates.
- INDOT-funded study.
- Fabricated RAP in lab with polish-prone agg.
  - Mixes with up to 40% RAP
  - Polished and tested in lab.
  - Tested low temperature mix properties
- Field tested some sites with RAP in surface.

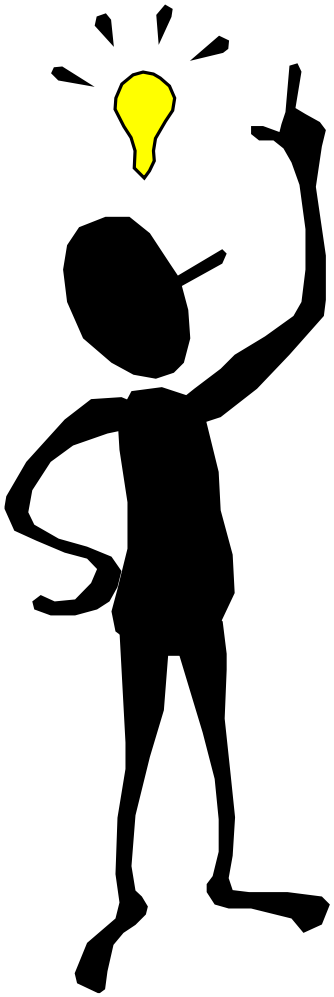
Surface Characteristics



Findings of Friction Study

- Up to 25% RAP in surface mixes can be allowed with no appreciable loss of friction.
- Finer RAP fractions are used (100% passing 9.5mm, 95% passing 4.75mm)
  - This may be relaxed in future based on another study.
- Field friction levels were acceptable on existing pavements.
- Mix testing confirmed minimal effect on low temperature properties up to 25%

http://docs.lib.purdue.edu/jtrp/1497/



Know Your Materials

- Here is what Indiana DOT did to evaluate their typical materials and revise their specifications for RAP mixes.