Effect of RAP on Binder Grade

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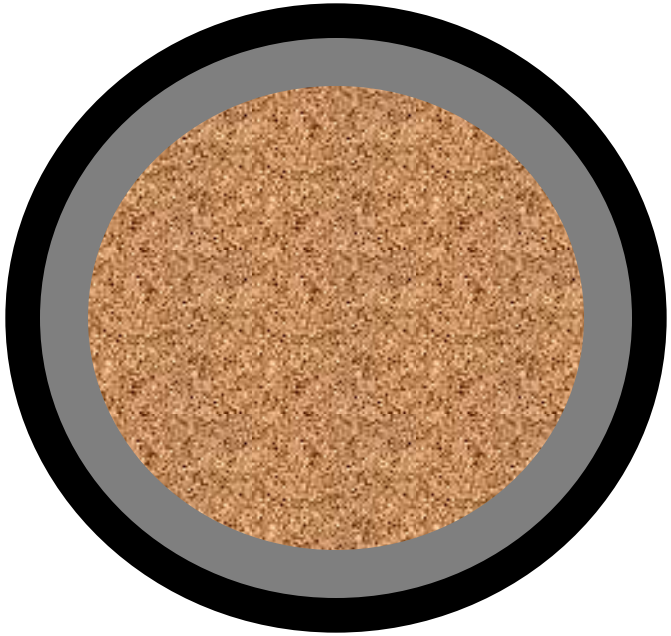
Conventional Wisdom

- RAP contains old, hardened binder that will stiffen the mix
- This will help reduce rutting
- May increase cracking tendencies
- There is research and experience to support conventional wisdom
  - And some that doesn't.

Possible Effects of RAP Binder

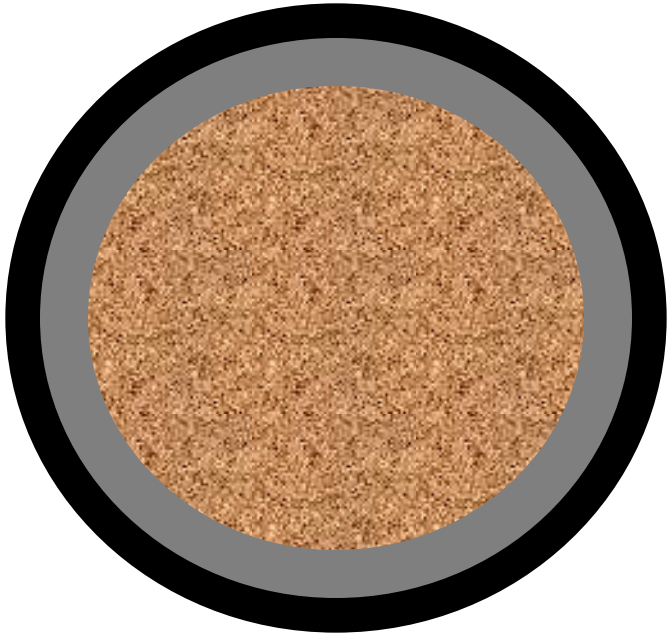
RAP aggregate with oxidized binder film

Possible Effects of RAP Binder



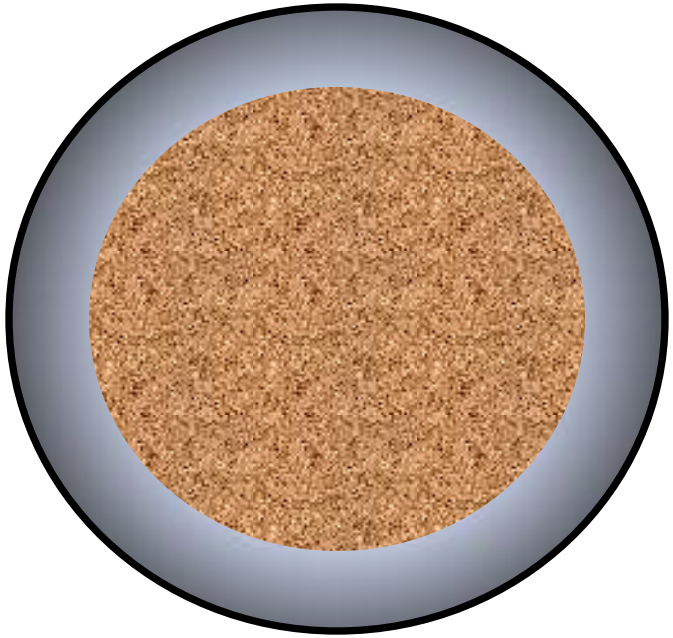
RAP aggregate with oxidized binder film plus virgin binder film

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.

Current Guidelines

- Current mix design recommendations assume that significant blending does occur
- But, they also assume there is a threshold level of RAP that can be added without affecting effective binder grade
  - 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)
- Based on non-fractionated mixes with about 5% binder in RAP and new mix.

Issues with Current Guidelines

- Does the RAP binder always blend?
- What about higher RAP content mixes?
- Guidelines call for virgin binders that may be more expensive, harder to get, harder to work with.
- Effects of plant/production largely unknown.
- Don't account for fractionated RAP.
- Testing RAP binder is a lot of work!

Impacts of Blending on Performance

- If we assume there is blending and there isn't, virgin binder grade may be softer than desired.
  - Increased chance for rutting
  - Decreased chance for cracking
- If we assume there is no blending and there is, effective binder grade may be stiffer than desired.
  - Decreased chance for rutting
  - Increased chance for cracking

Risks of False Assumptions

- Assuming there is blending may be more conservative.
  - Shouldn't rely on binder to control rutting
  - Increased cracking can have performance and economic impacts
- But, if the RAP binder does not blend and act like binder, mix could be under-asphalted.
- Current guidelines are a starting point, but not the definitive answer

Better options

- Know a reasonable threshold level for typical materials.
- Above threshold, know if blending is occurring or not.
- Contractors, know and manage RAP stockpiles to control the assumptions.
- But *how*?

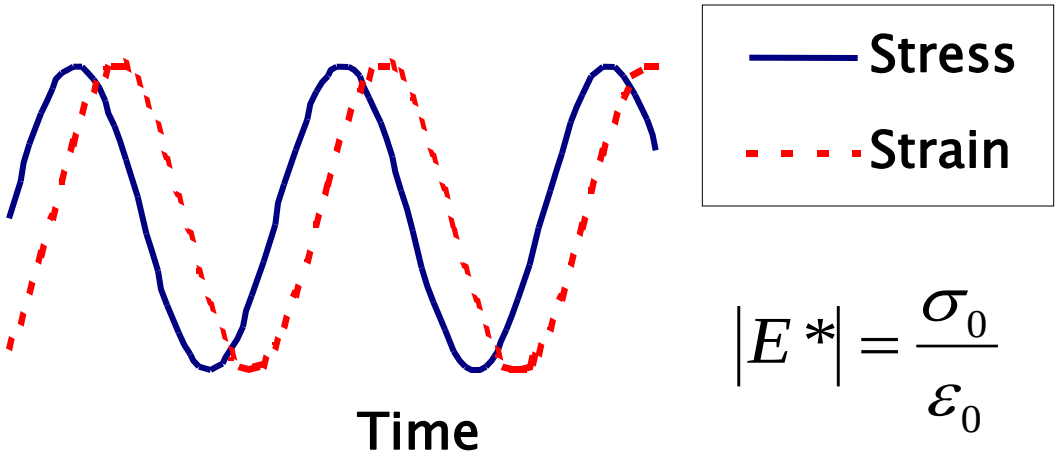
Threshold Values

- Test and know your typical RAP materials (recommended at state level)
  - What kinds of binder did you use?
  - How much aging is typical?
  - How stiff are typical RAP binders?
  - Extract and grade RAP binders, mixes
- Based on testing and experience, some states have changed the tiers
  - Say, up to 20% RAP without changing grade

Mixture Testing

- Test lab mixes at various RAP contents with different binder grades
- Test plant produced mixes
- Suggested mixture tests
  - Dynamic modulus
  - Indirect tensile strength
  - Other familiar tests

Dynamic Modulus Test



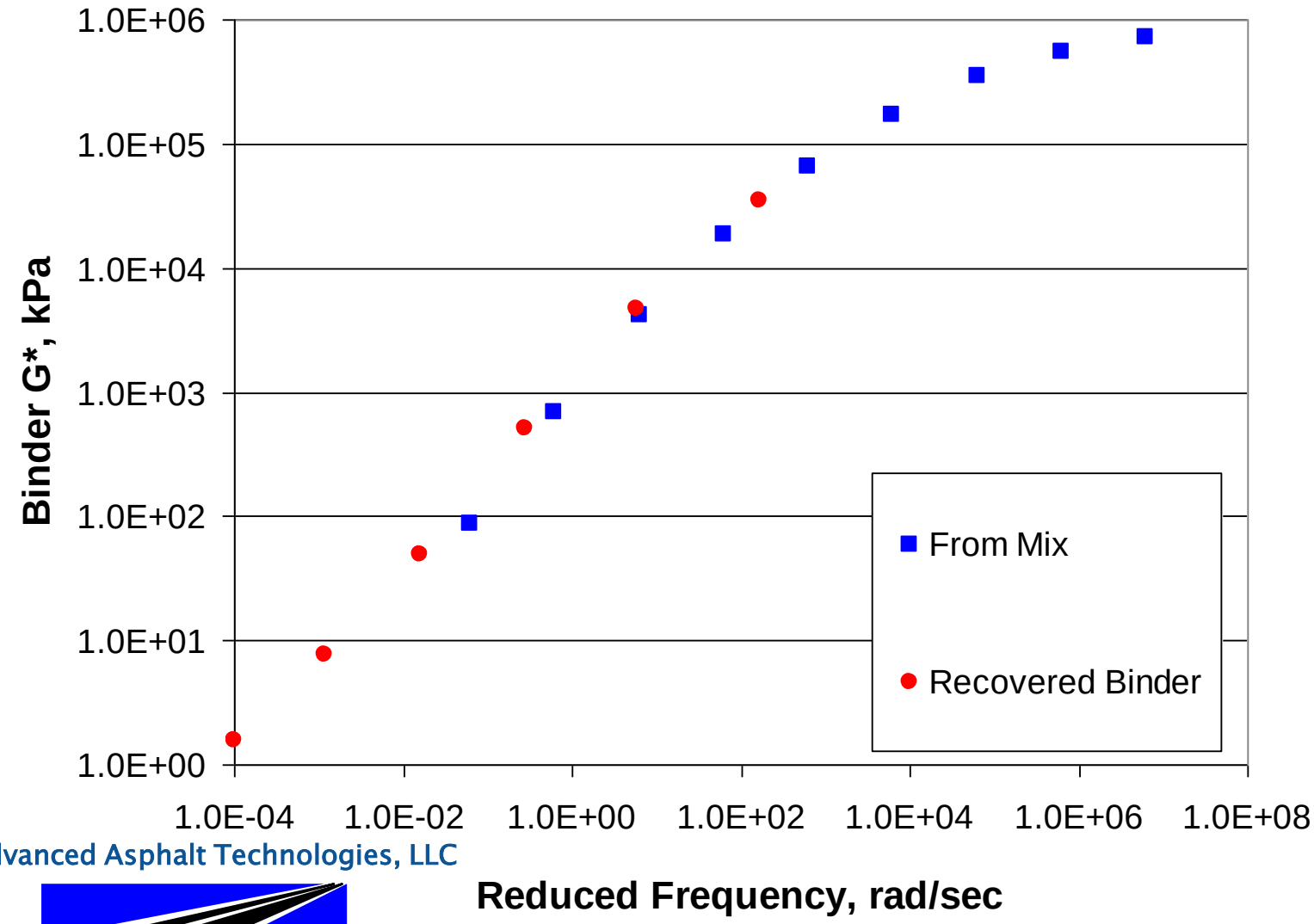
$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

- Rutting
- Fatigue Cracking

Blending – Bonaquist approach

- Measure mix dynamic modulus
- Develop master curve
  - Stiffness over range of temperatures and loading rates
- Estimate effective binder modulus in mix
  - Hirsch model uses binder shear modulus and mix volumetrics to estimate mix stiffness
- Extract and recover binder (total blending)
- Measure binder shear modulus
- Compare binder modulus and effective binder modulus from mix
  - Overlap indicates good mixing

9.5 mm with PG 64-22, Batch Plant



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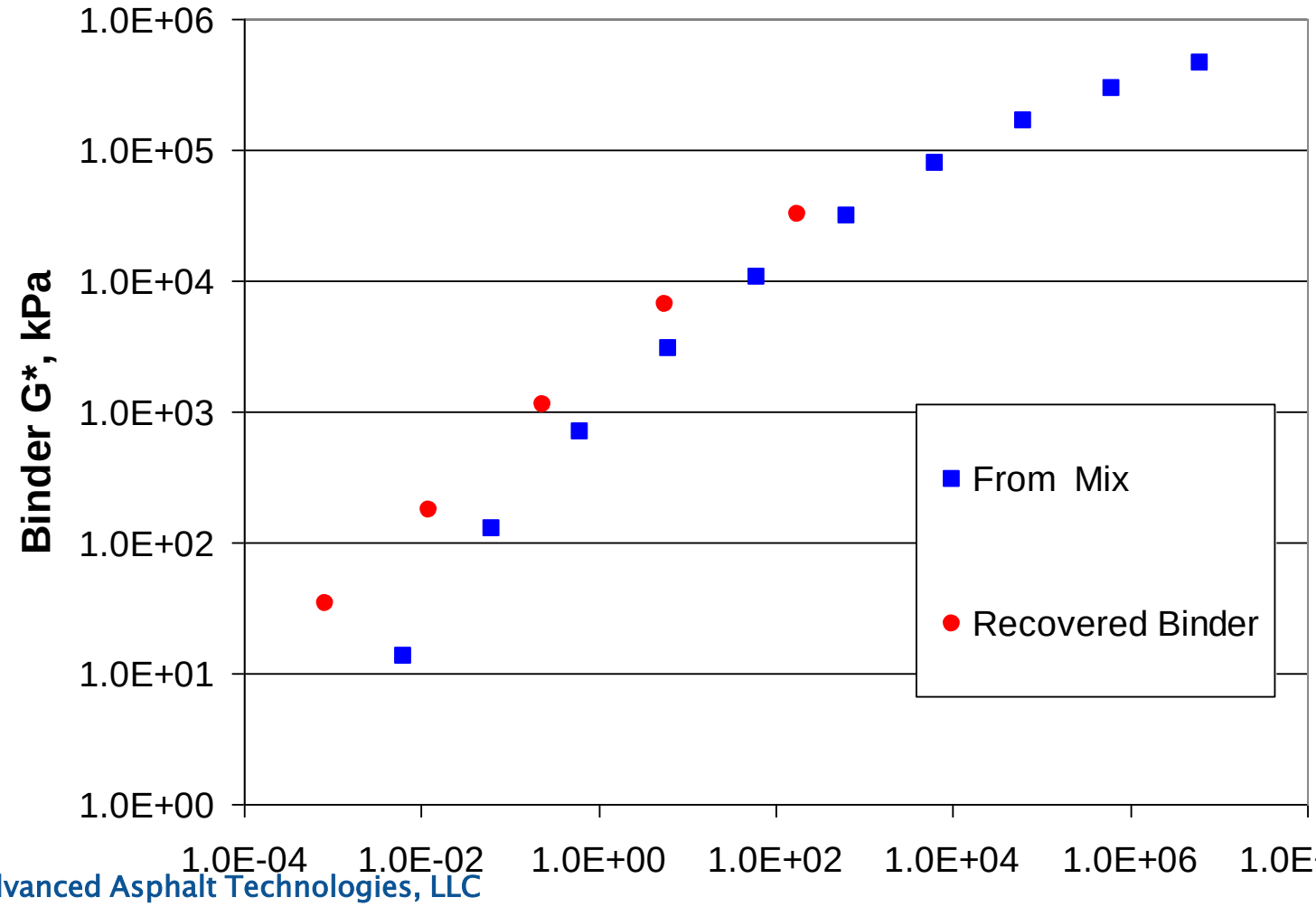
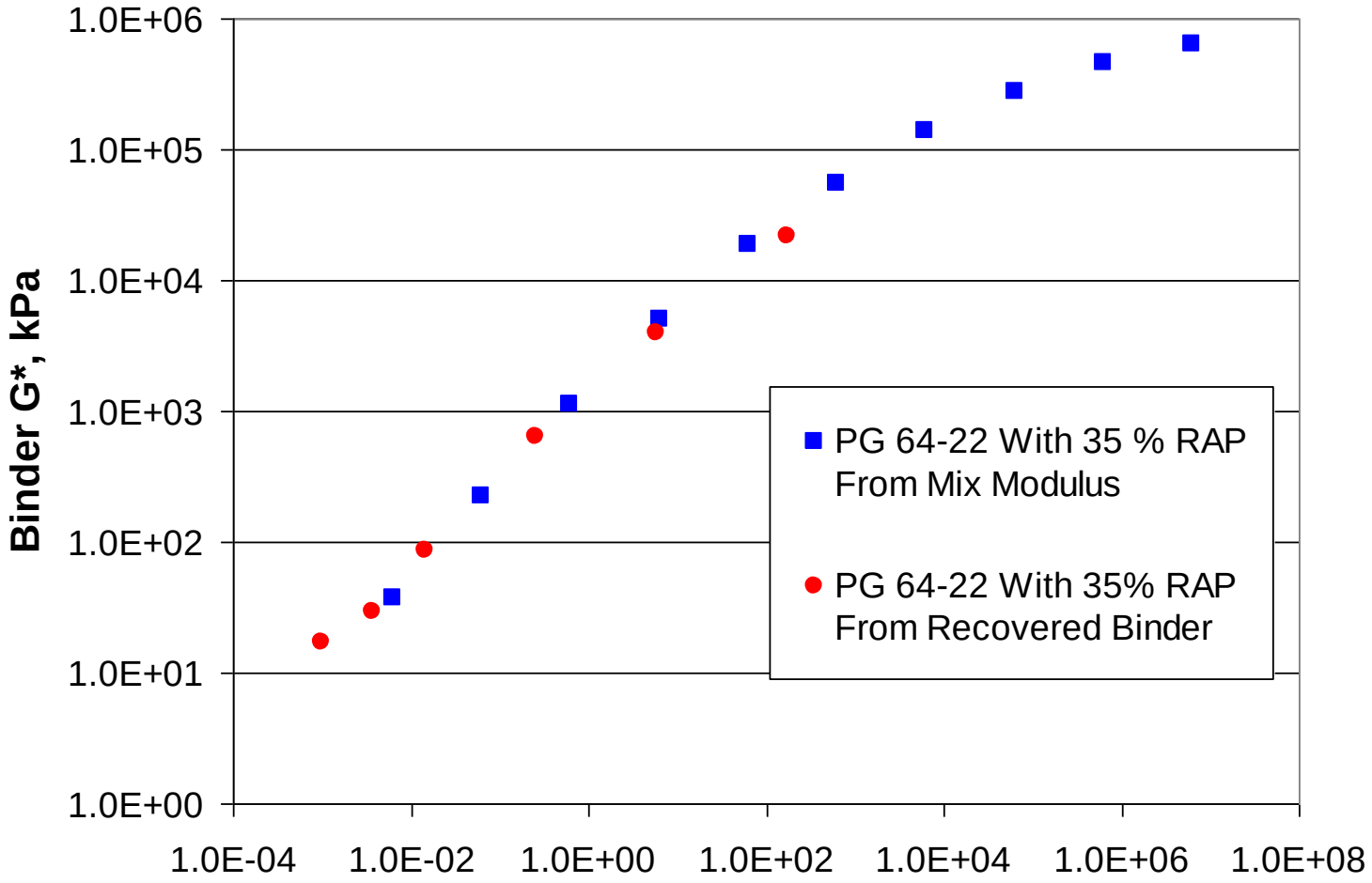
9.5 mm with PG 64-22 + 5% RAS, Batch Plant



9.5 MM WITH PG 64-22 + 35 % FRAP, DOUBLE BARREL



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Bonaquist Approach

- Advantage – allows assessment of production variables
  - RAP processing
  - Production rates and temperatures
  - Additives
  - Storage time, etc.

- More information *Hot Mix Asphalt Technology*, September/October 2007.

On-Going Study

Low-Temperature Performance Properties of Hot Mix Asphalt Containing RAP, Phase 2

- 2006 -- Evaluated plant-produced mixes with up to 40% RAP and two virgin binder grades
- Results suggested 25% RAP did not need grade change
- 2007 -- Expanded – four more contractors
- FHWA funded

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Experimental Design

	Reclaimed Asphalt Pavement			
Binder Grade	0%	15%	25%	40%
PG 58-28			X	X
PG 64-22	X	X	**X**	X

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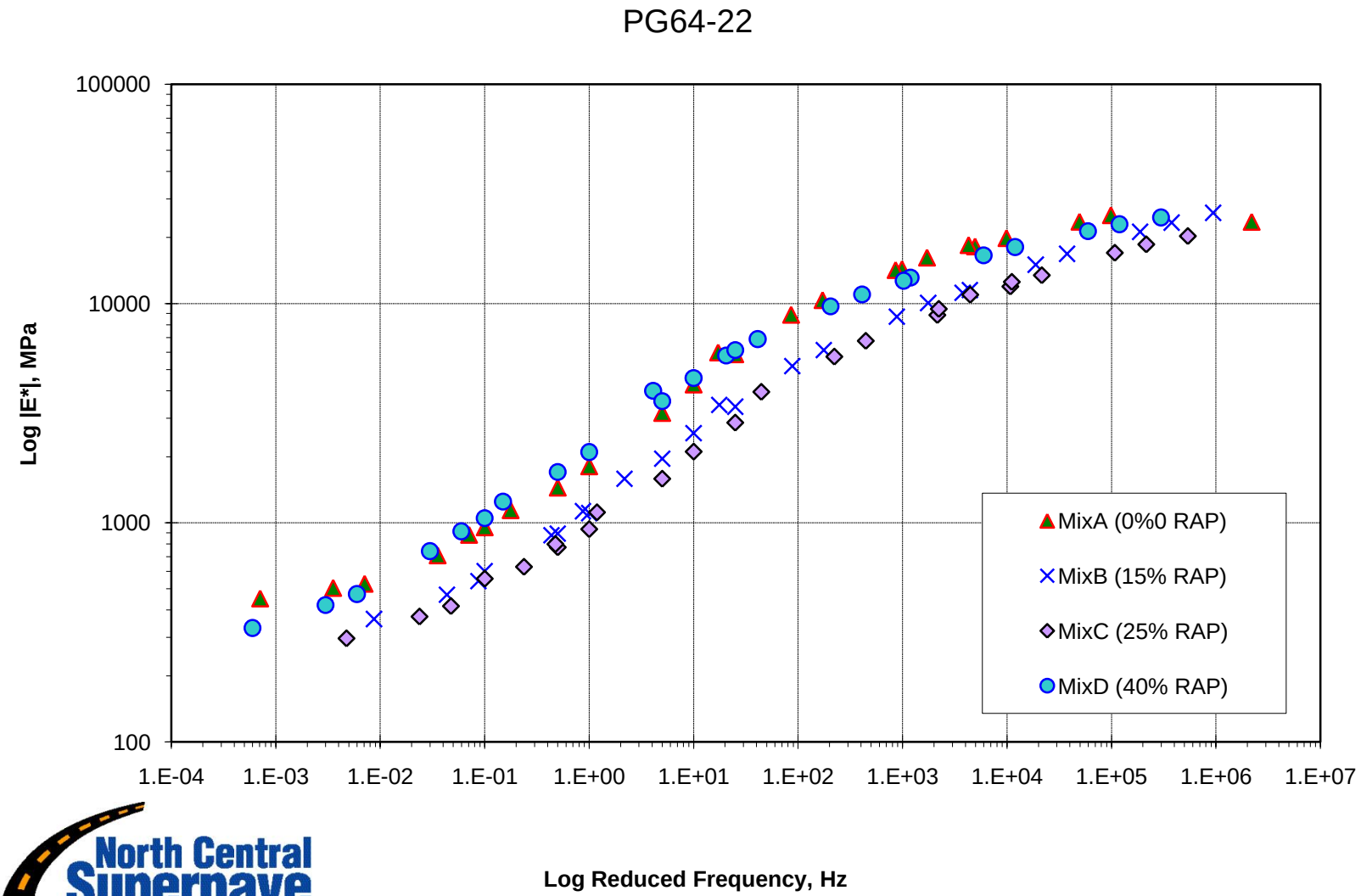
X = Replicated in 2006

Comparison of RAP Contents



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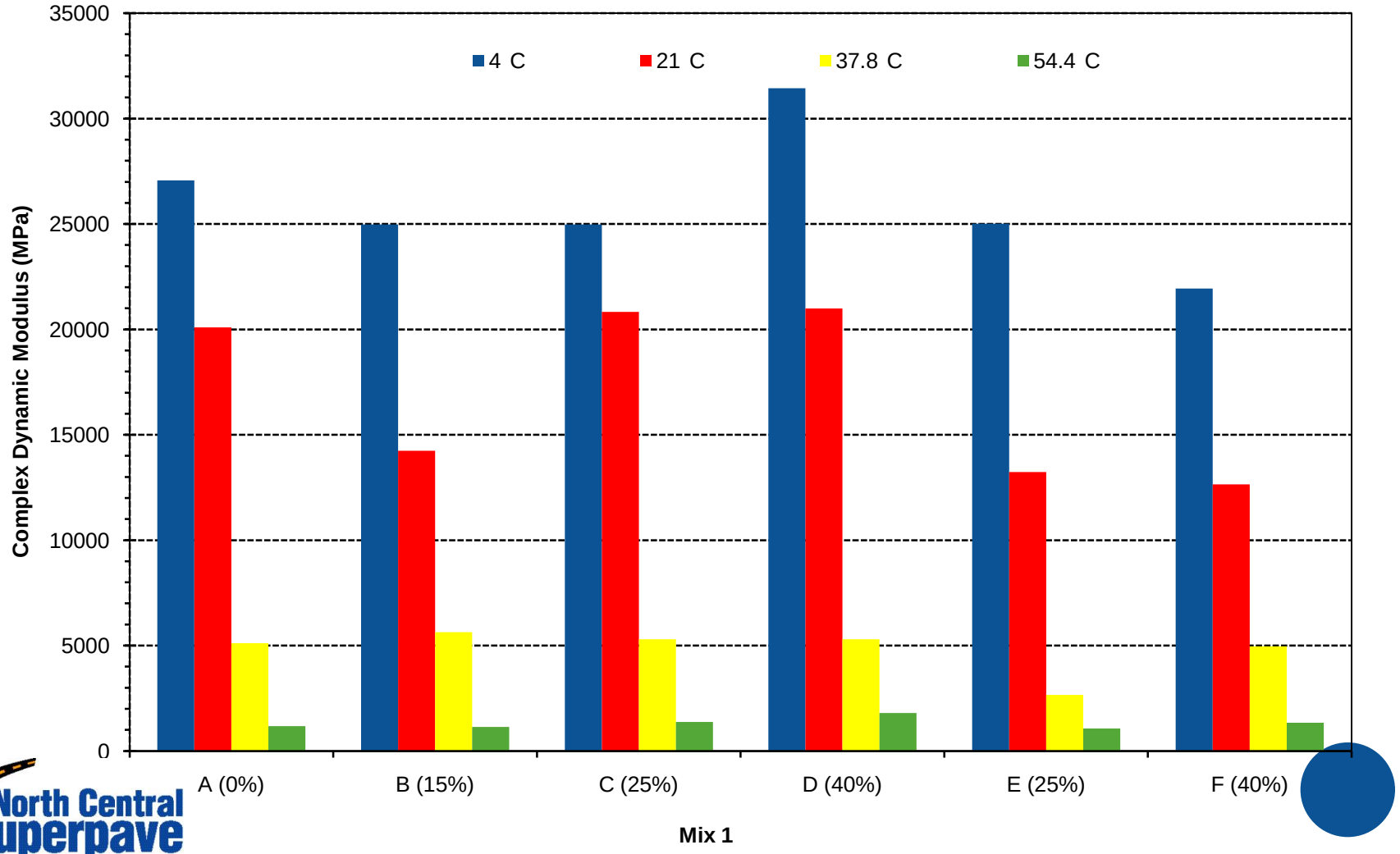
Draft, Unfiltered Data, Mix 1



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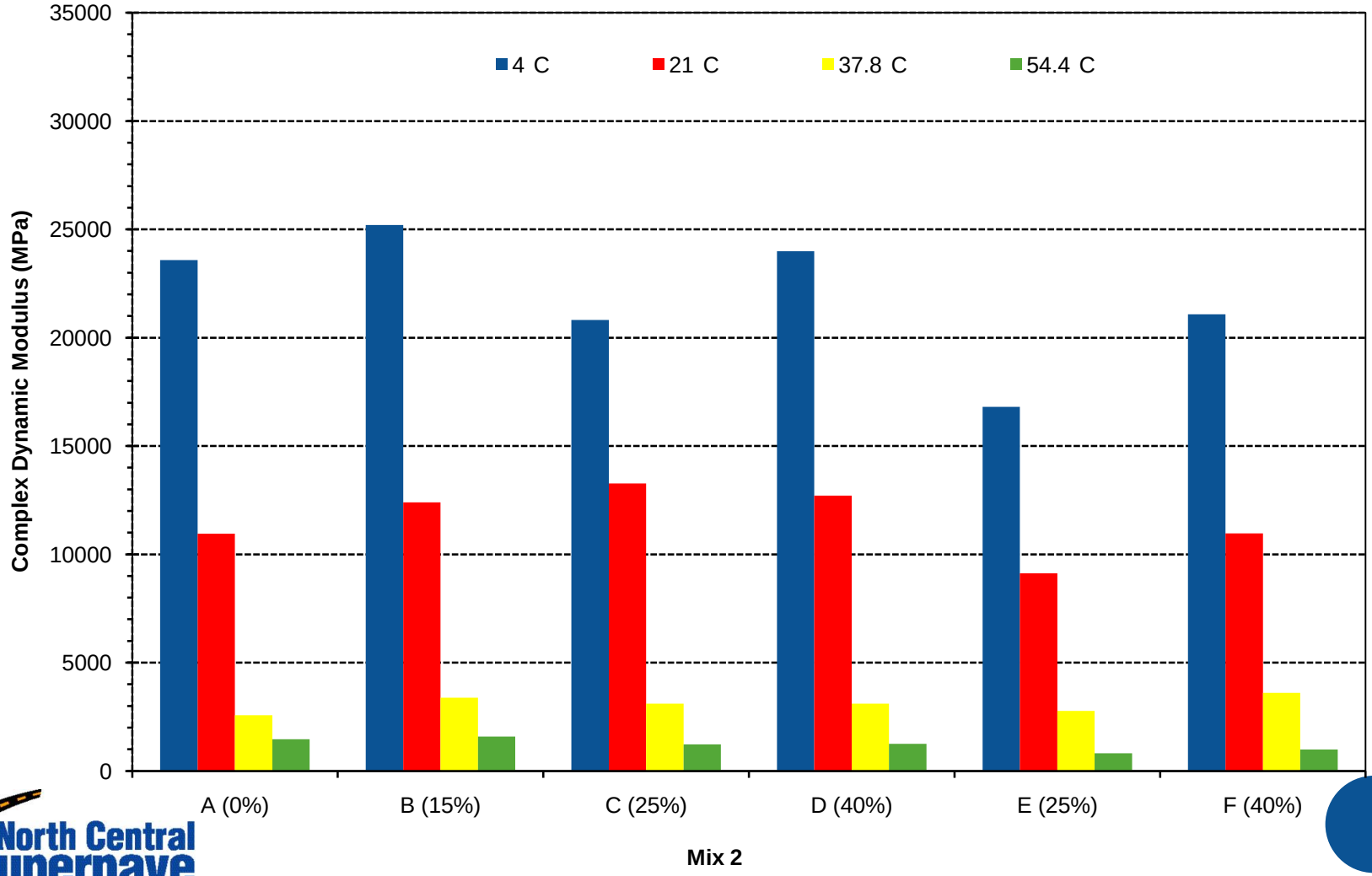
Draft, Unfiltered Data, Mix 2



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Observations

- *Still preliminary*
- Low temperature mixture testing is underway.
- It appears that there may be more evidence to support allowing higher RAP contents before changing grade.
- Mixes with 25% RAP appear to be comparable to control.
- Based on these results, we recommended INDOT consider allowing 20% RAP without changing grade.

RAP Stockpile Management

- Consistency is key to meeting specifications.
- RAP is not necessarily a variable material if properly handled.
  - Often less variable than virgin aggregates
- Watch out for “unusual” materials
  - Millings from temporary pavements that are not aged as much as usual
  - Materials from sources that might be highly variable or contain unconventional materials
  - Depending on amounts, either keep separate or disperse evenly into stockpile

Other work

- NCHRP 9-46, *Improved Mix Design, Evaluation and Materials Management of High RAP Content HMA (NCAT)* – completion 2010
- FHWA Funded, *Development of High RAP Content Mix Guidelines and Informational Documents* (NCAT/ NCSC/UNH) – completion early 2010
- FHWA HMA Recycling ETG – ongoing
- Other state studies ongoing

- All will offer more guidance.

Current State of Knowledge

- With many materials and plants, complete (or essentially complete) blending does occur.
- In other cases complete blending may not occur.
  - Temperature, Time, Binder Compatibility, Plant
- RAP mixes can perform as well as or better than virgin mixes.

More info:

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