Proposing a Solvent-Free Approach to Evaluate the Properties of Blended Binders in Mixtures with High Amounts of Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS)

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OUTLINE

- INTRODUCTION
- OBJECTIVES
- EXPERIMENT DETAILS
- RESULTS & DISCUSSION
- CONCLUSIONS & ONGOING WORKS

INTRODUCTION
Advantages of Using RAP and RAS

Use of less non-renewable natural resources

Less dumping of materials in landfills

Potential reduction of GHG emissions

Production time and cost savings

More use of RAP and RAS in asphalt pavement construction

INTRODUCTION
Existing Studies

- Disadvantages of Binder Extraction & Recovery:
  - Potentially altering the chemistry of the binder
  - Forcing homogenized blending of binders
  - Creating hazardous material disposal issues
  - Labor intensive

INTRODUCTION
Existing Studies

- Asphalt Mortar Testing:
  - Two mortar samples are tested:
    - A) Virgin binder + fine RAP particles
    - B) Virgin binder + burned fine RAP aggregates
  - Single sized RAP material (typically passing #50 and retained on #100 sieve)
  - Disadvantages:
    - May not be representative of the actual fine aggregate proportion in a full mix
    - Often limited to low percentage

      of RAP or RAS due to workability concern.

INTRODUCTION
Existing Studies

- Fine Aggregate Matrix (FAM) Testing:
  - FAM: homogenous blend of asphalt binder and fine aggregates (i.e., passing #4, #8, or #16 sieve)
  - Can be tested with a solid torsion bar fixture in a dynamic shear rheometer (DSR)[DMA]
  - Commonly used to characterize fatigue damage, healing potential, and moisture susceptibility of asphalt mastics and FAM mixes

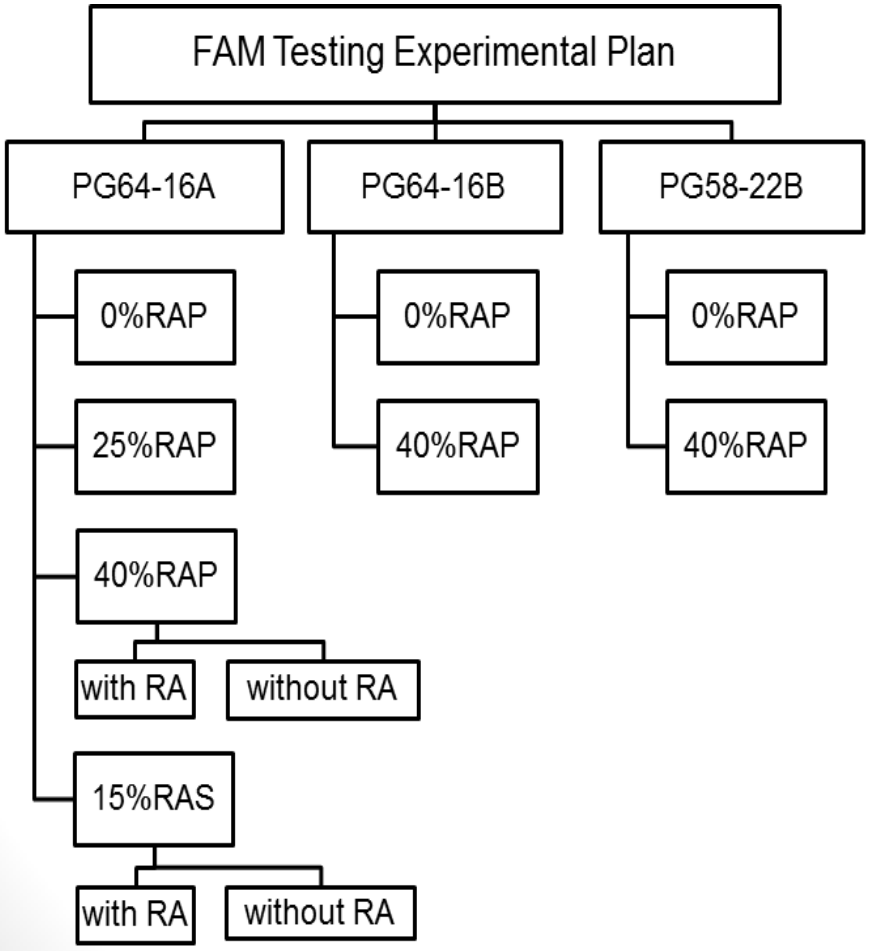
OBJECTIVES

Develop and assess an alternative approach to evaluate the properties of composite binders in mixes containing high RAP and RAS without extraction and recovery.

- Develop specifications and testing procedures for testing FAM mixes to be used in California.
- Assess sensitivity of FAM test to capture the influence of:
  - Asphalt binder grade,
  - Asphalt binder source,
  - Different percentages of RAP and/or RAS,
  - Presence of rejuvenator.

EXPERIMENTAL DETAILS

- **Experimental plan**



- **Mix design**
  - Superpave mix design, dense-graded HMA
  - Two PG64-16 & one PG58-22 binders from Refinery A & B
  - Petroleum-based rejuvenating agent (RA)
  - Granitic virgin aggregate: North California
  - RAP: North California
  - RAS: Tear-off shingles

FAM Sample Preparation

- Passing #8 sieve & same gradation for all FAM mixes
- Key procedures for UCPRC method:
  - Prepare a full-graded mix
  - Sieve the loose mix to obtain 1.5kg of material passing #8
  - Determine the binder content of the fine mix by extraction
  - Sieve RAP/RAS to obtain 1.5kg of material passing #8
  - Determine the binder content and gradation of the fine RAP/RAS particles by ignition oven or extraction.
  - Prepare FAM mix with different percentages of RAP/RAS based on the required binder replacement rate
  - Determine the theoretical maximum gravity of the FAM mix

-Cont.

FAM Sample Preparation

- Short-term age the loose FAM mix and compact the FAM cores (150mm in D × 50mm in H, 10-13% target air-voids) using Superpave gyratory compactor (SGC)
- Core small cylindrical FAM specimens (12.5mm in D × 50mm in H) from the SGC FAM core
- Measure the air-voids of the FAM specimens
- Store FAM specimens in a sealed, undisturbed condition to prevent damage and excessive shelf-aging

a. Coring.

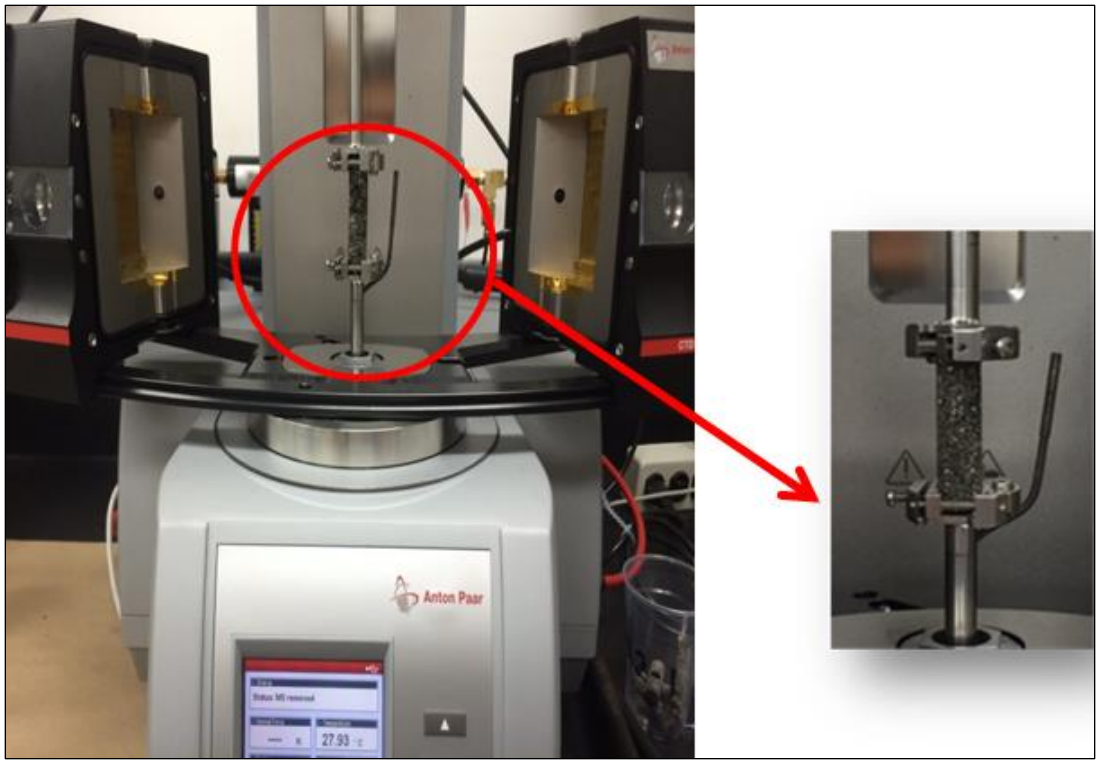
b. FAM specimens.

c. Weigh station to measure air voids.

d. Storage.

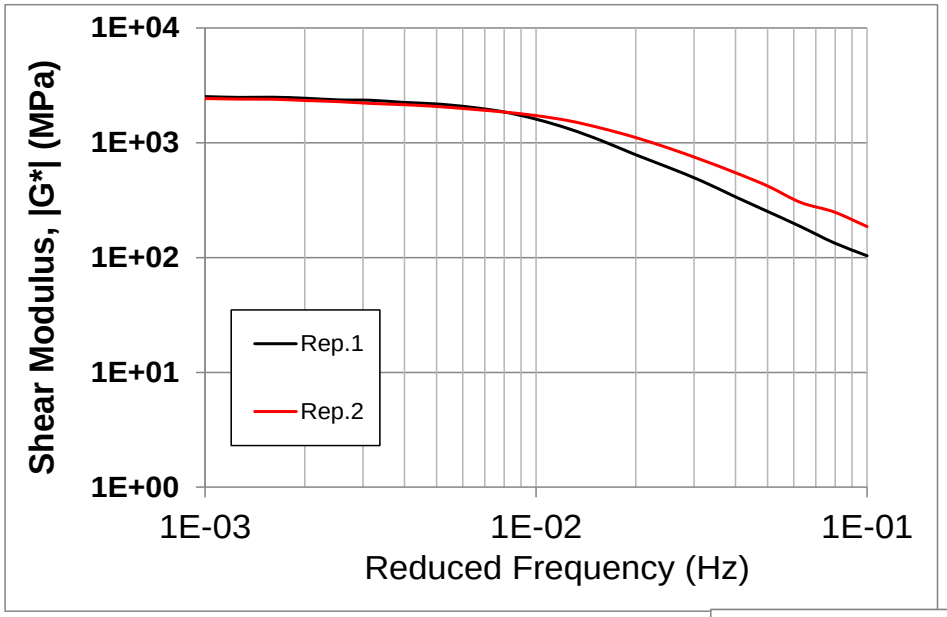
FAM Testing Setup and Procedure

Anton Paar MCR302 DSR



- Amplitude sweep strain test (4°C, 10Hz, shear strain 0.001 to 0.1%) to determine the linear viscoelastic (LVE) region
- Frequency (0.1 to 25Hz) and temperature sweep test (4, 20, 40°C) to develop shear modulus master curve

Sample Plots of FAM Test Results



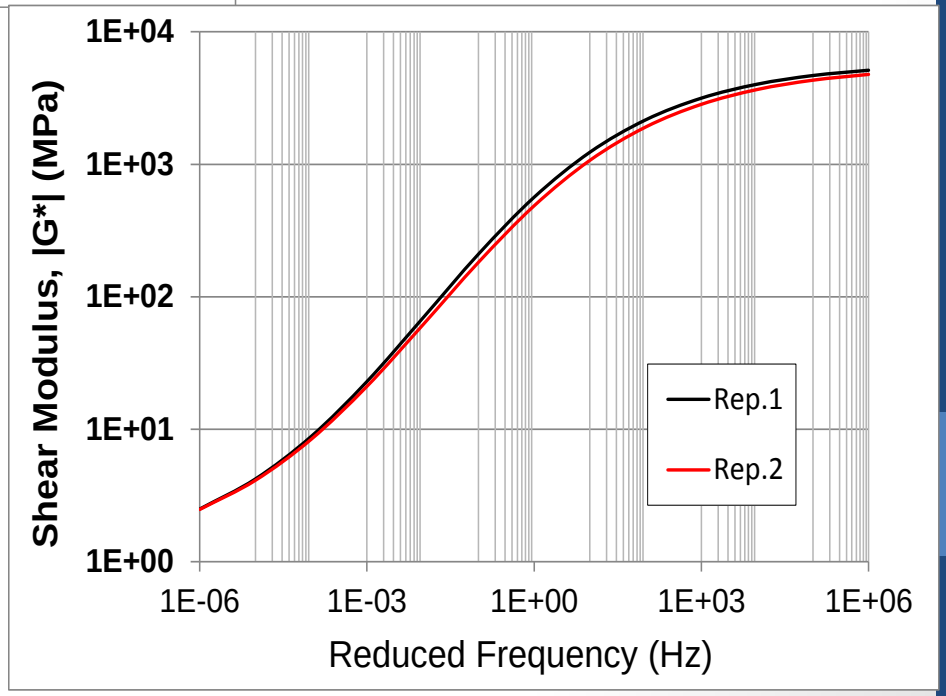
Amplitude sweep test

$$\log(|G^*(f_r)|) = \frac{\alpha}{1 + e^{\beta+\gamma\times\log(f_r)}}$$

$$\log(a_T(T)) = \frac{1}{\ln(10) \times R}\left(\frac{1}{T} - \frac{1}{T_r}\right)$$

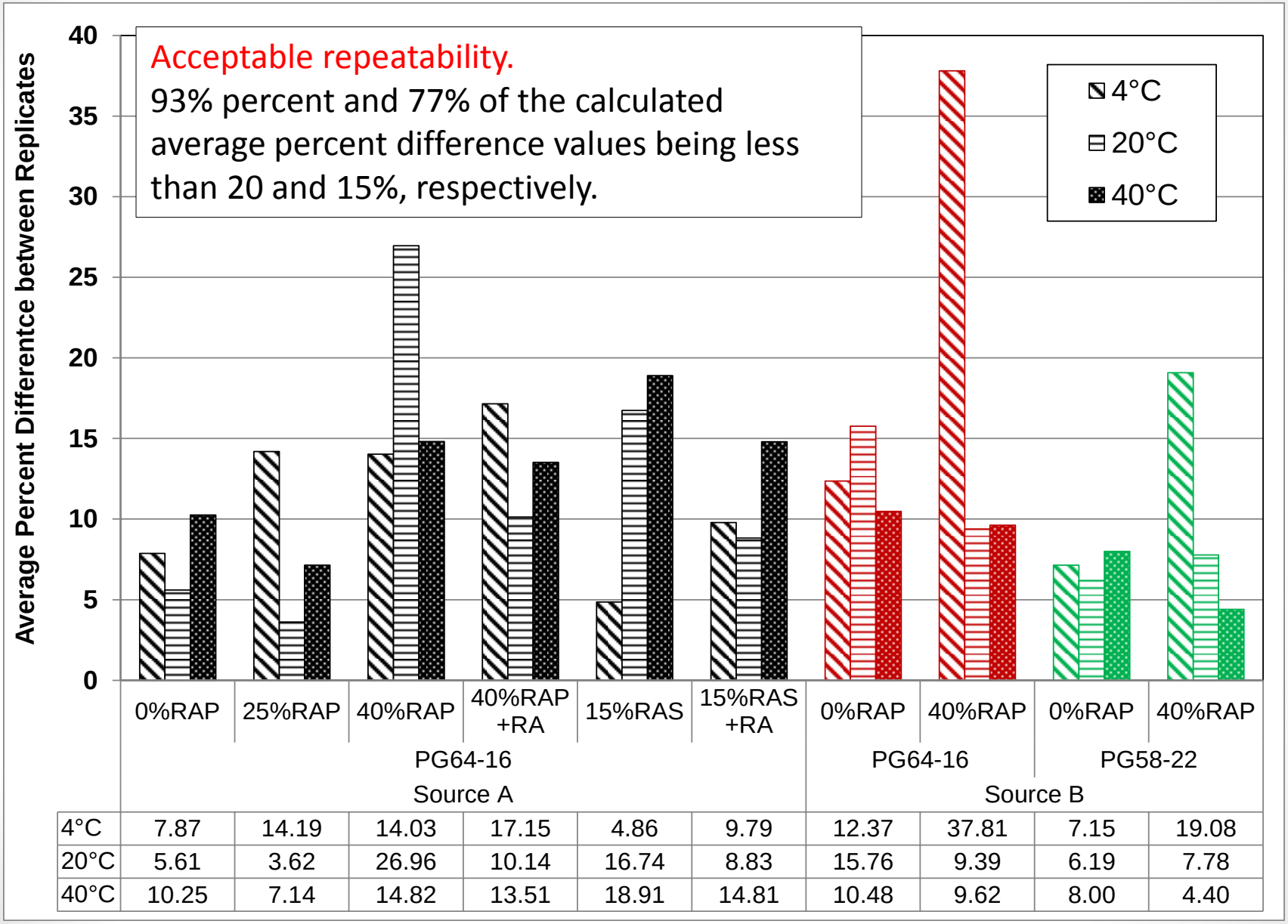
$$\log(f_r) = \log(a_T(T)) + \log(f)$$

Master curve



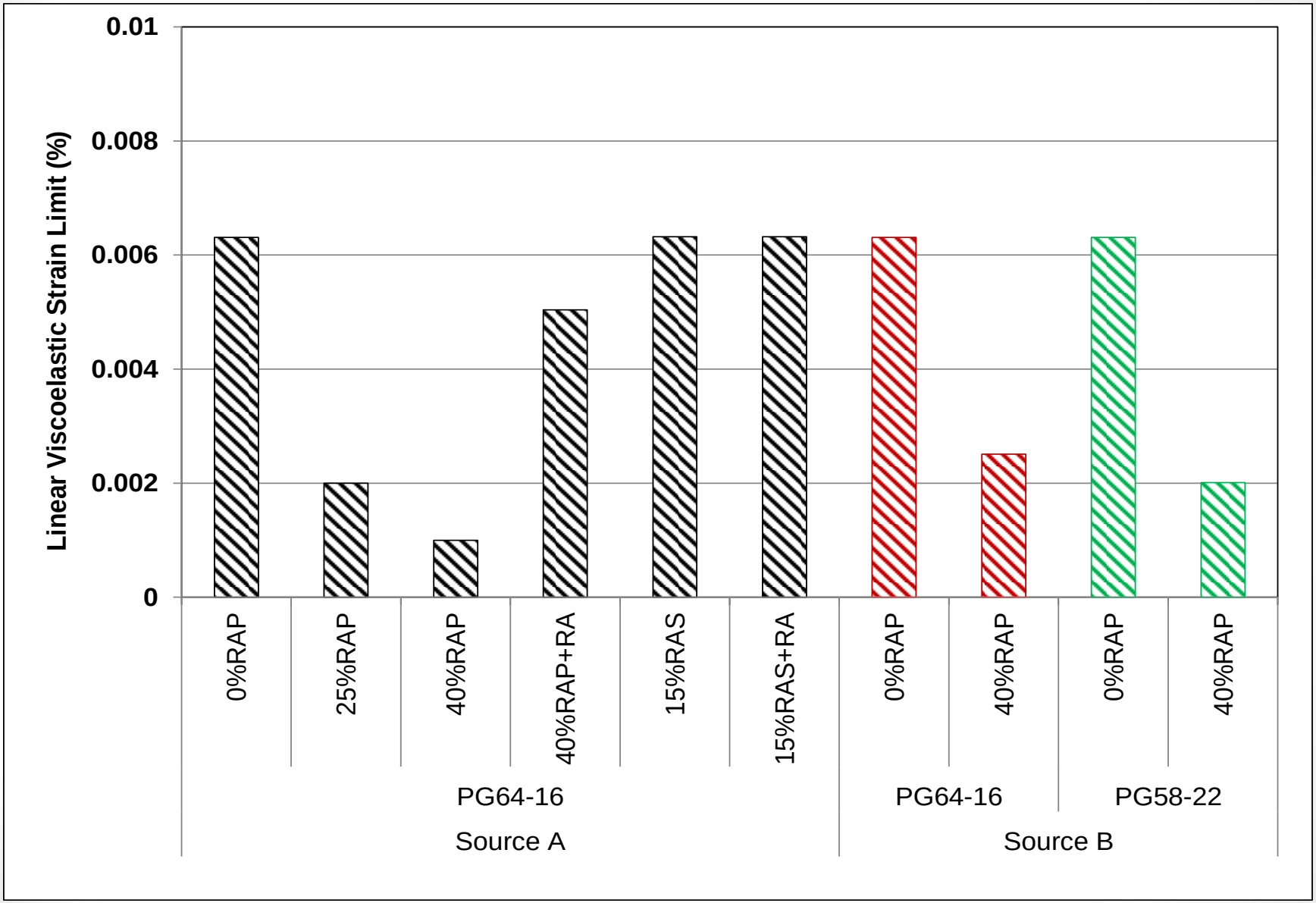
RESULTS
&
DISCUSSION

Analysis of repeatability of FAM specimen frequency sweep test

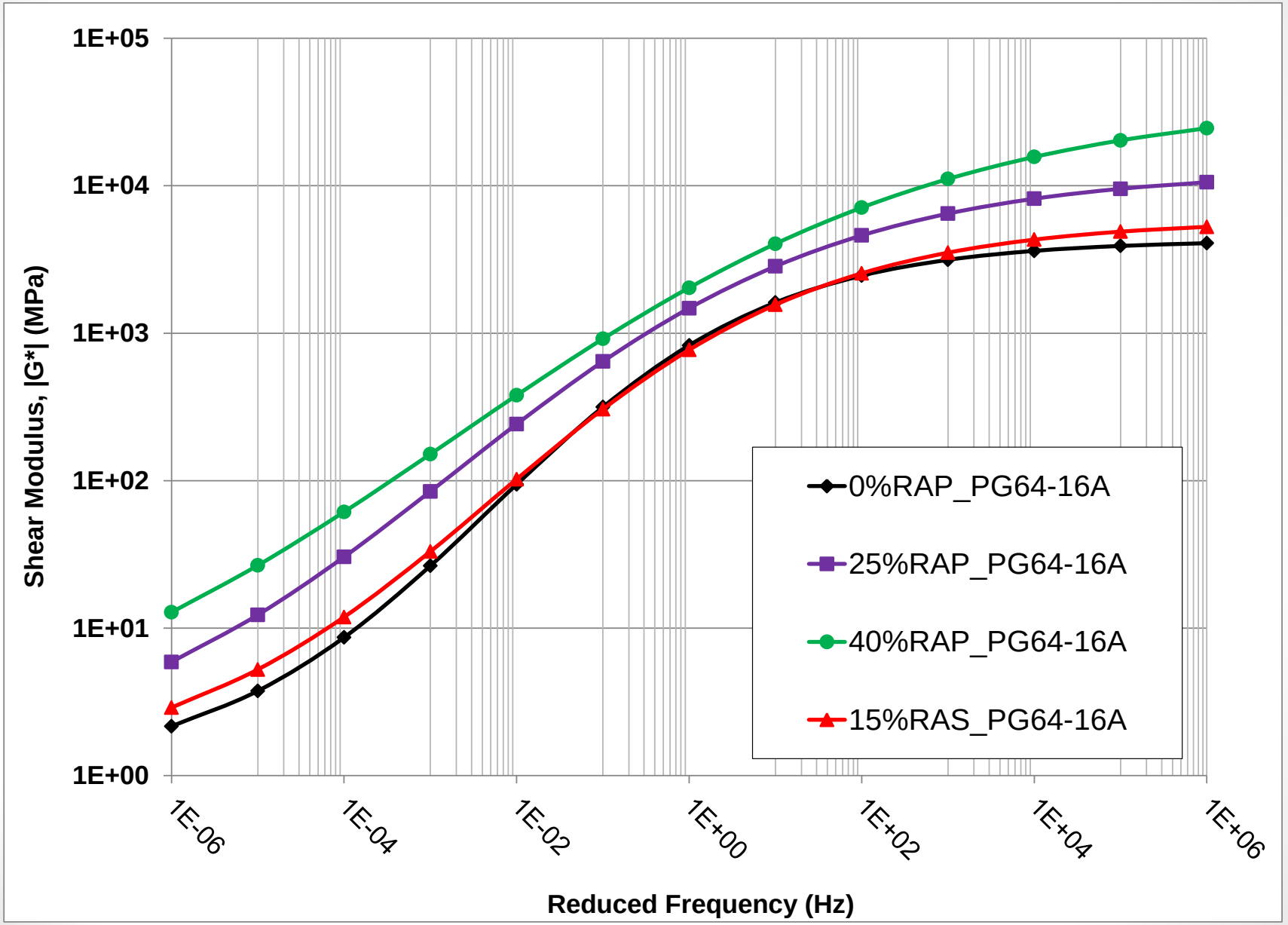


	0%RAP	25%RAP	40%RAP	40%RAP +RA	15%RAS	15%RAS +RA	0%RAP	40%RAP	0%RAP	40%RAP
	PG64-16 Source A						PG64-16 Source B		PG58-22 Source B	
4°C	7.87	14.19	14.03	17.15	4.86	9.79	12.37	37.81	7.15	19.08
20°C	5.61	3.62	26.96	10.14	16.74	8.83	15.76	9.39	6.19	7.78
40°C	10.25	7.14	14.82	13.51	18.91	14.81	10.48	9.62	8.00	4.40

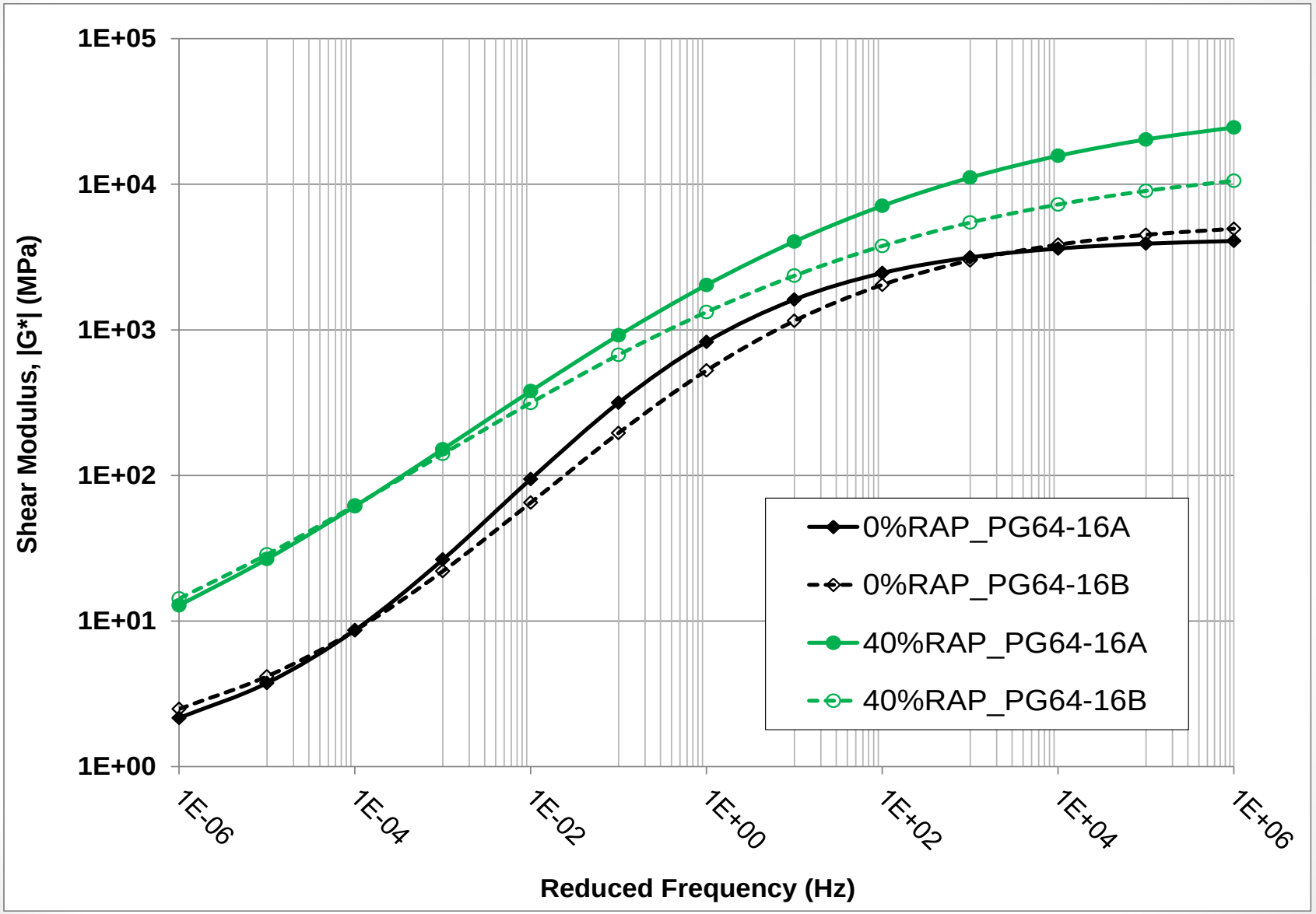
LVE range for FAM specimens by mix type



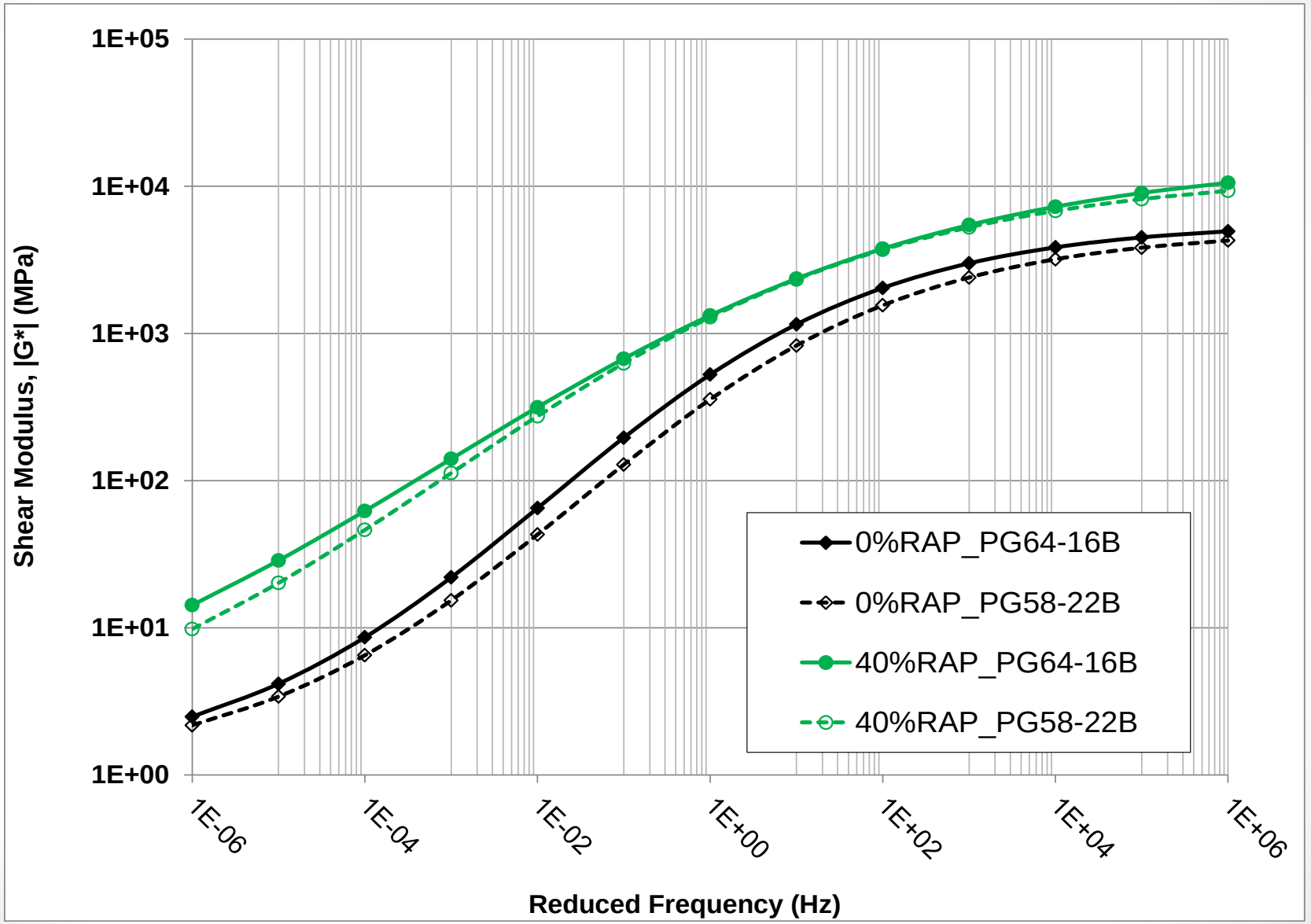
Effect of RAP and RAS



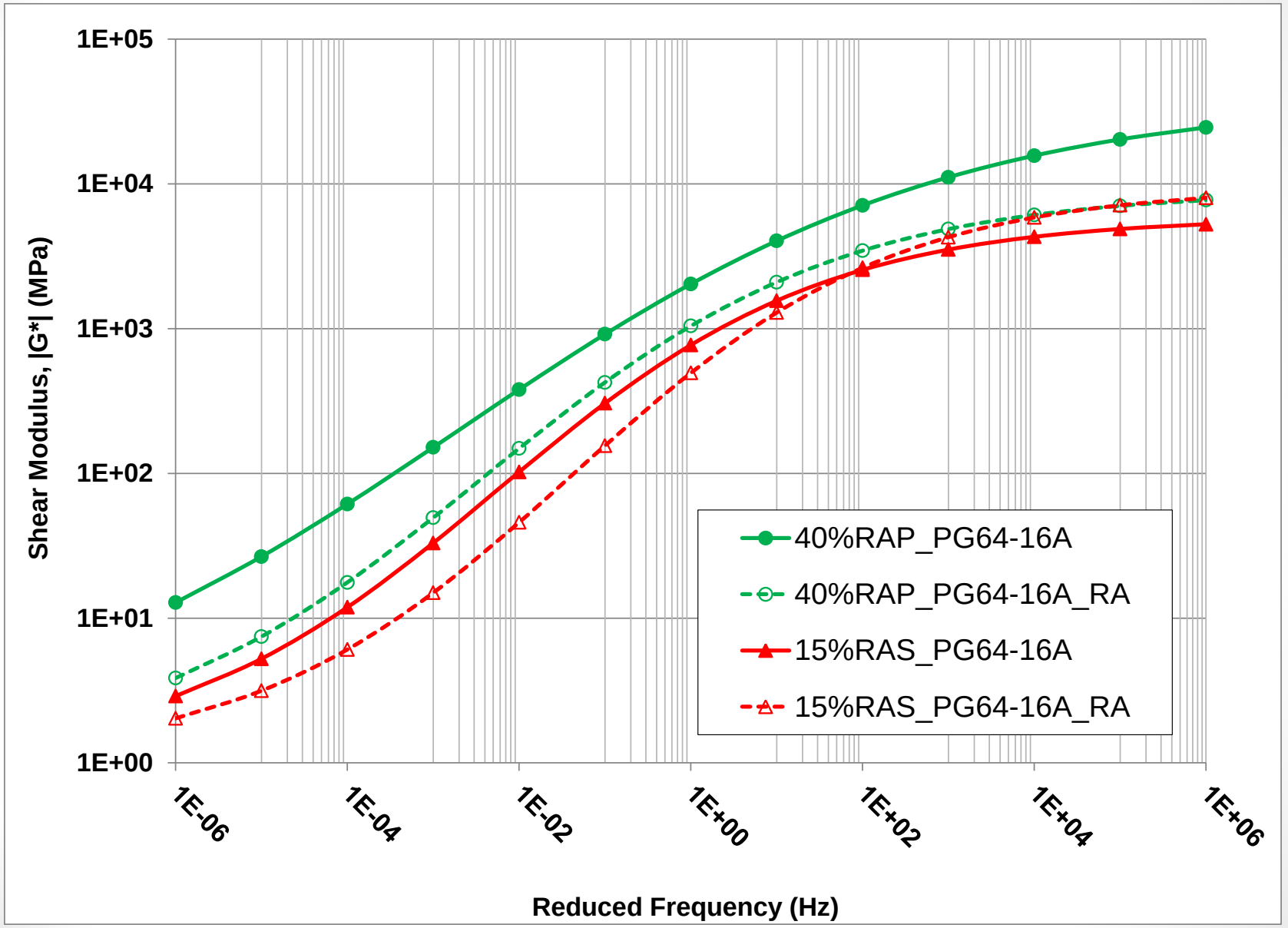
Effect of Virgin Binder Source



Effect of Virgin Binder Grade



Effect of Rejuvenating Agent



Statistical Analysis

- **ANOVA to identify the significance level of influential factors:**
  - Dependent variables: complex shear modulus (G*) values at 0.001, 1.0, and 1,000 Hz frequencies at the reference temperature of 20°C
  - Independent variables: percent binder replacement, binder source, binder grade, and use of the rejuvenating agent
  - Null hypothesis: mean shear modulus is the same for all independent variable categories
  - Significance level: 0.01

ANOVA Table

Variable	Type	Degrees of Freedom	$G^*_{0.001Hz}$		G^*_{1Hz}		G^*_{1000Hz}	
			F-value	p-value	F-value	p-value	F-value	p-value
% Reclaimed Material	0%RAP, 25%RAP, 40%RAP, 15%RAS	1	106.19	3.36E-08	65.75	7.29E-07	15.10	0.0015
Binder Source	Refinery A, B	1	5.20	0.037	3.10	0.099	1.90	0.19
Binder Grade	PG64-16, PG58-22	1	1.94	0.185	0.52	0.484	0.11	0.75
Rejuvenating Agent Effect	with/without rejuvenator	1	30.87	5.50E-05	30.05	6.32E-05	6.17	2.53E-02
Residuals		15						

CONCLUSIONS(1)

- In general, FAM testing was considered to be effective in distinguishing the performance properties between the different mixes.
- Adding RAP to the mix increased the stiffness of FAM mixes, as expected.
- The stiffness values of FAM mixes with no RAS and with 15 percent RAS by binder replacement were similar.
- Adding RA altered the properties of the aged binder, resulting in a drop in the mix stiffness. However, RA had limited effect on mixes containing RAS.

CONCLUSIONS(2)

- Blending between aged and new binders can be affected by the chemistry of the asphalt binder.
- FAM test can capture the difference between binder grades.
- RAP/RAS content and use of a rejuvenating agent were statistically significant factors that affect the shear stiffness of FAM mixes.

ONGOING WORK

Research is continuing to evaluate the sensitivity of the testing approach to:

- Aging level of the binder,
- Use of other additives and admixtures,
- Moisture content,
- Different combinations of RAP and RAS, and
- Characterizing low temperature properties.

Thanks!

QUESTIONS?