NCHRP 9-54 Update

Selection of the Laboratory Aging Method and Aging Temperature

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Outline

- Overview
- Selection of most promising laboratory aging method
- Selection of laboratory aging temperature
- Interim findings

Overview

- NCHRP 9-54 objective
  - Develop a calibrated and validated procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction
- Progress to date
  - Selection of the most promising aging method
  - Selection of laboratory aging temperature

Selection of the Most Promising Laboratory Aging Method

Selection of the Most Promising Laboratory Aging Method

- Evaluation of loose mix versus compacted specimen aging
- Evaluation of laboratory aging with and without the application of pressure
- Selection of the most promising aging method for performance testing and prediction

Selection Criteria

- Specimen integrity
  - Compacted specimen
    - ✓ Geometric changes during aging
    - ✓ Air void changes during aging
    - ✓ Performance (Dynamic modulus and S-VECD functions)
    - ✓ Oxidation gradient
  - Loose mix
    - ✓ Compactability (number of gyrations, imaging analysis of aggregate structure)
    - ✓ Performance (Dynamic modulus and S-VECD functions)
- Efficiency
- Practicality and versatility

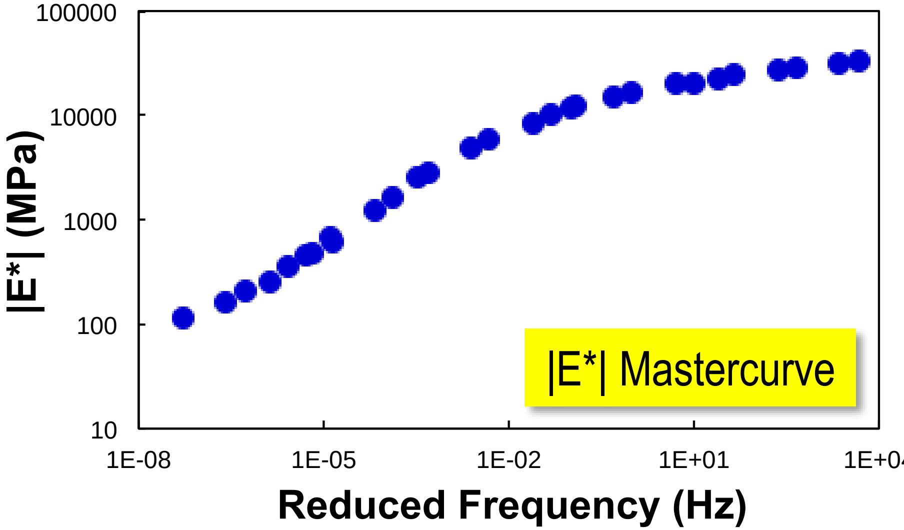
Experimental Factors

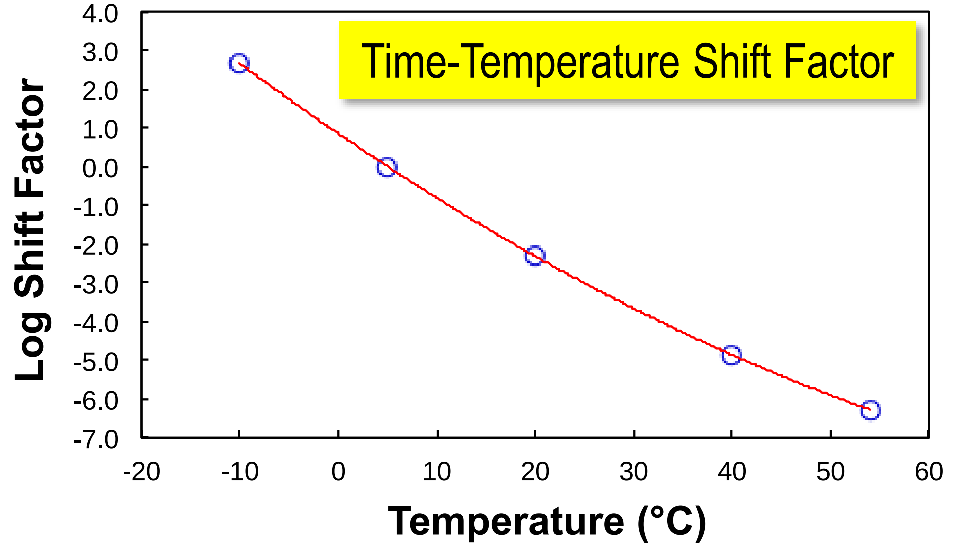
- Materials: NC S9.5B, FHWA ALF-SBS
- Material states
  - Binder: Standard RTFO, PAV
  - Loose mix, Compacted specimen: Oven, PAV
- Mix aging temperatures: 70° – 95°C
- Loose mix compaction temperatures: 144° and 157°C
- Mix aging durations
  - Oven: 8 – 35 days depending on aging temperature
  - PAV: 1 – 3 days
- Air pressures: 300 and 2,100 kPa

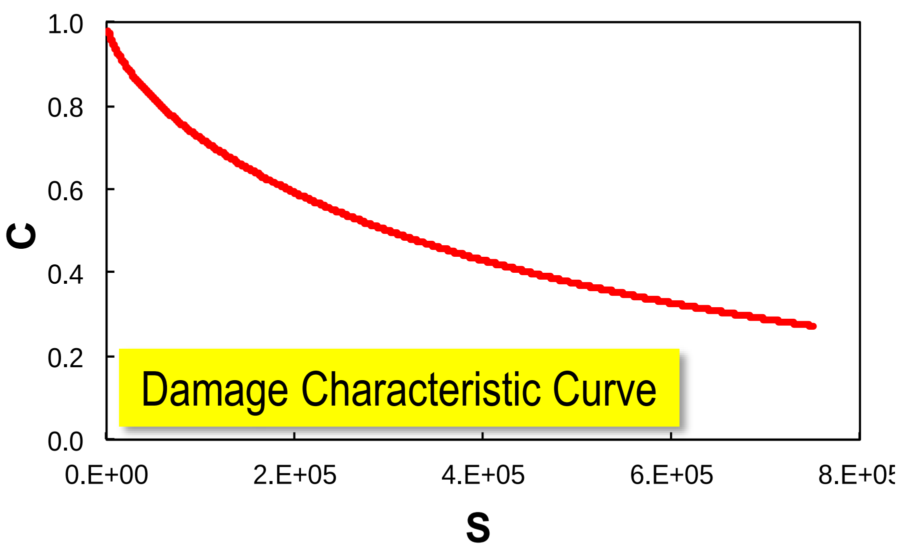
Binder Aging Index Properties

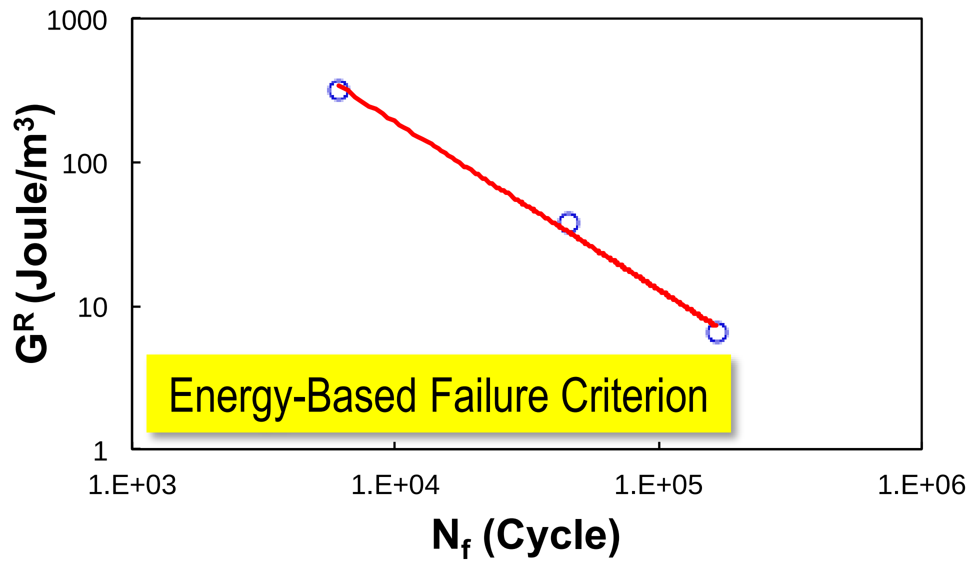
- Rheology
  - Cross over modulus, Zero shear viscosity, G* at 10 Hz and 64°C
- Chemistry
  - Carbonyl area, Carbonyl peak, Carbonyl + Sulfoxides area, Carbonyl + Sulfoxides peak
- Criteria
  - Sensitivity to oxidation levels
  - Variability
  - Sensitivity to characterization process

S-VECD Material Functions

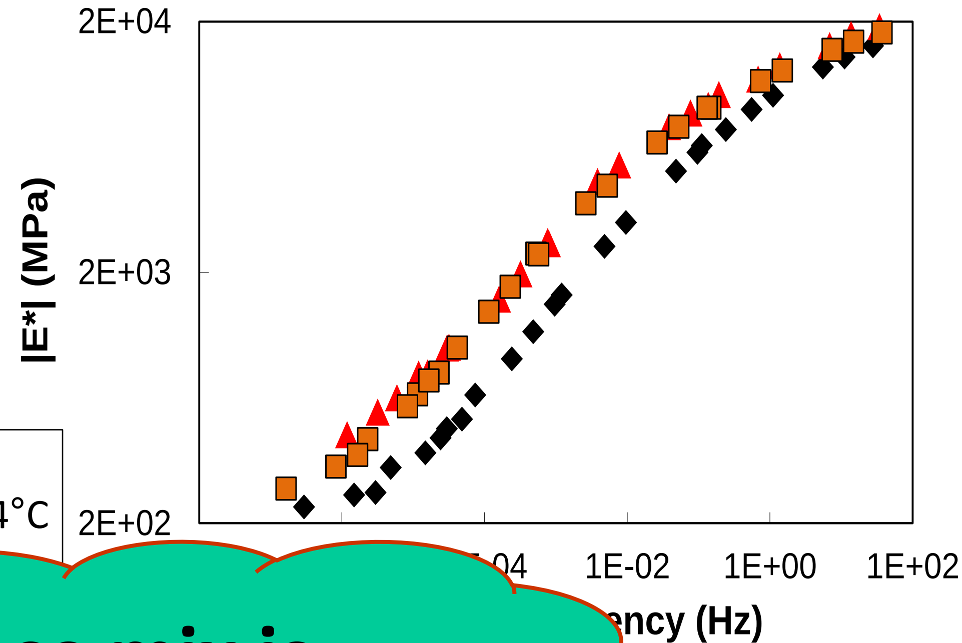






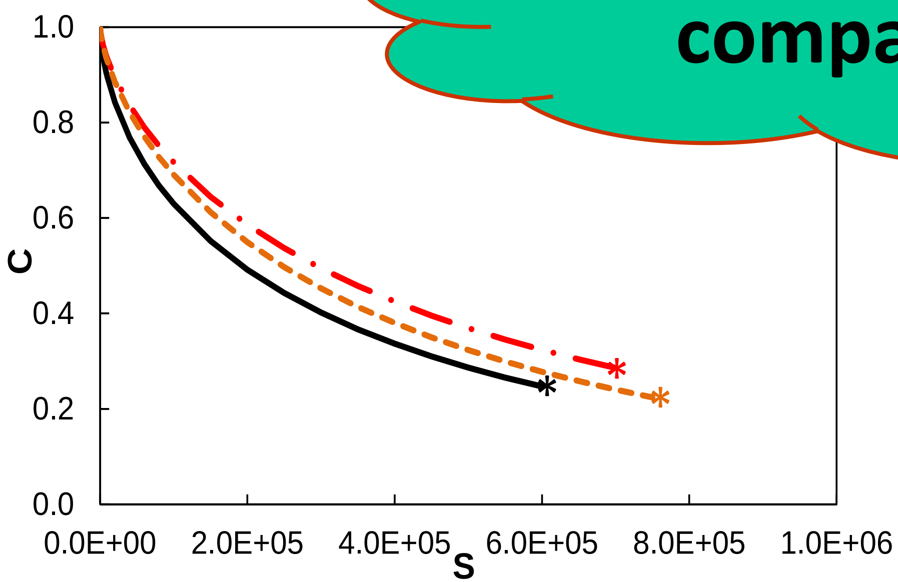


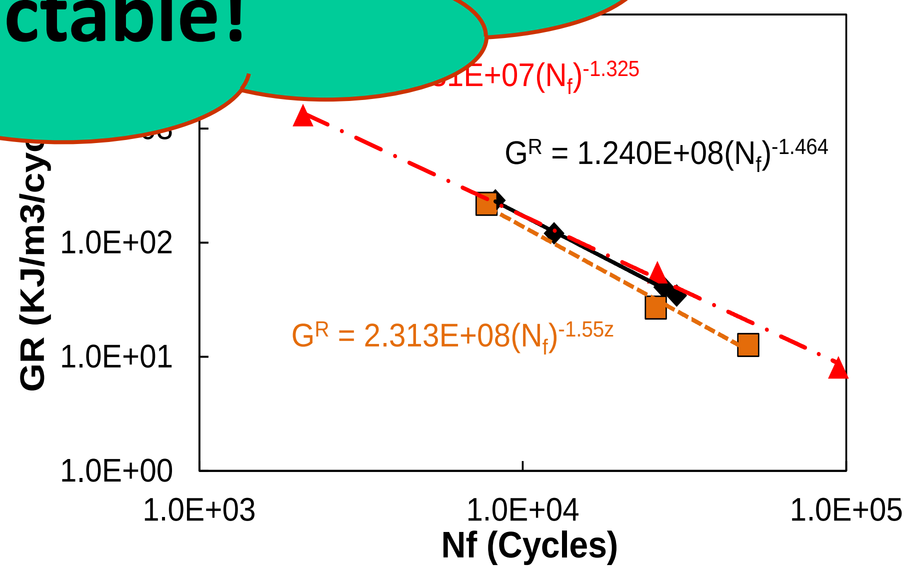
Loose Mix Vs. Compacted Spec.



◆ Short-term Aged – Compacted at 144°C
▲ Oven, Loose Mix, 85°C, 8 days – Compacted at 144°C
■ Oven, Compacted Spec., 85°C, 8 days

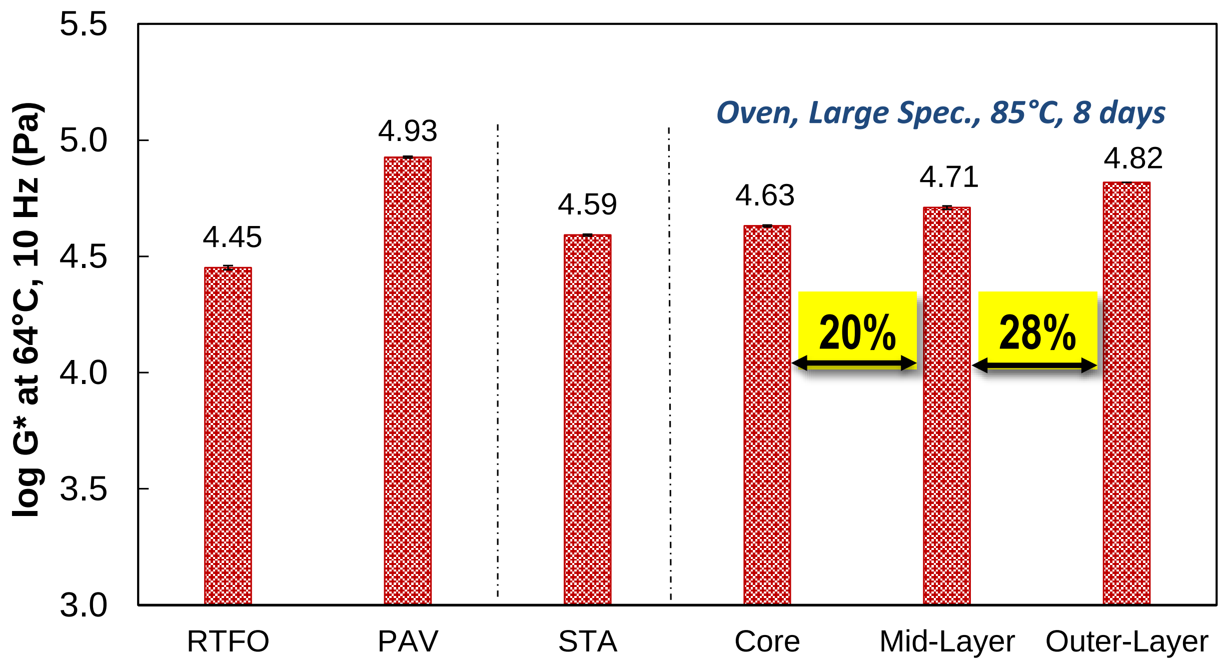
Aged loose mix is compactable!





Aging Gradient in Compacted Specimen

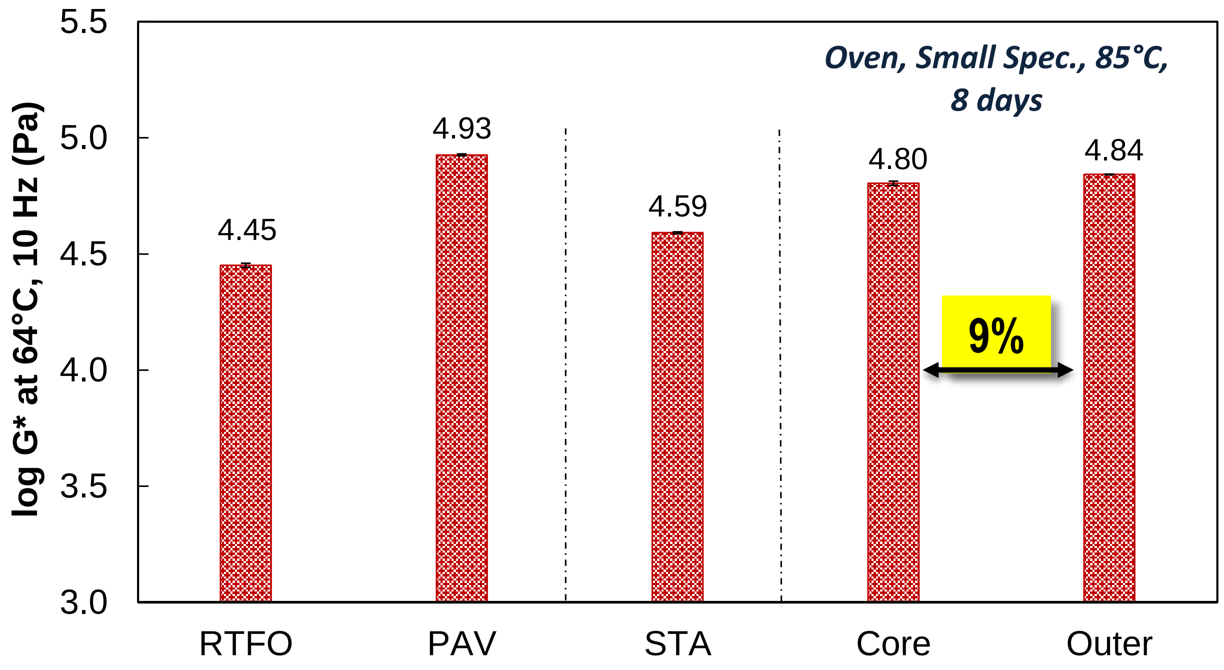
Oven Aging, Large Specimen

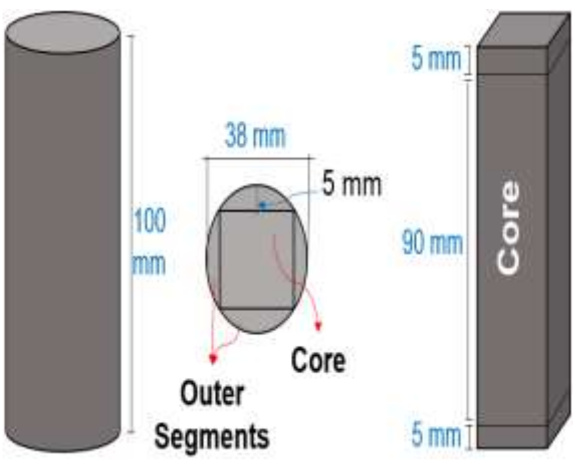


2% C+S ≈ 15% G* ≈ 10% E*

Aging Gradient in Compacted Specimen

Oven Aging, Small Specimen





2% C+S ≈ 15% G* ≈ 10% E*

Phase I Conclusions

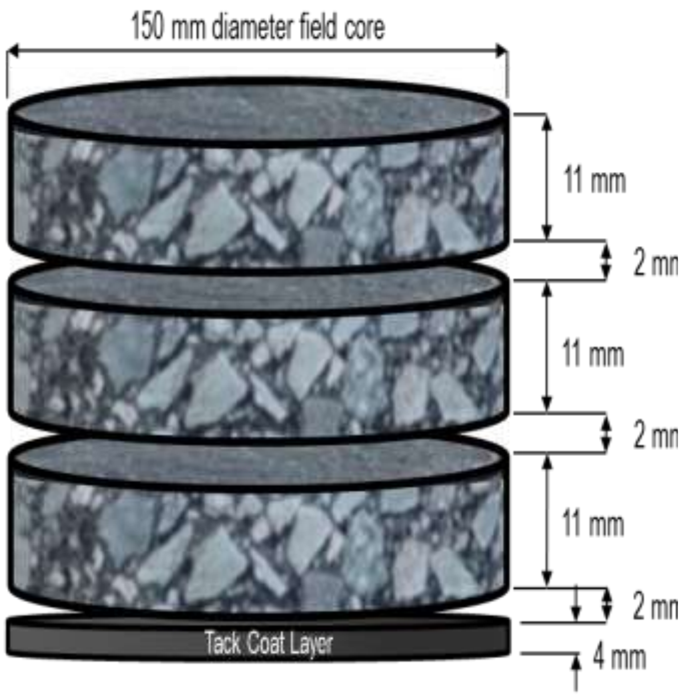
- Performance testing results indicate no problems of compacting loose mixtures after long-term aging.
- Oven aging of loose mix is the most promising method. Additionally, any specimen geometry (e.g., slabs and beams) can be produced using loose mix aging for performance testing.

Selection of Laboratory Aging Temperature

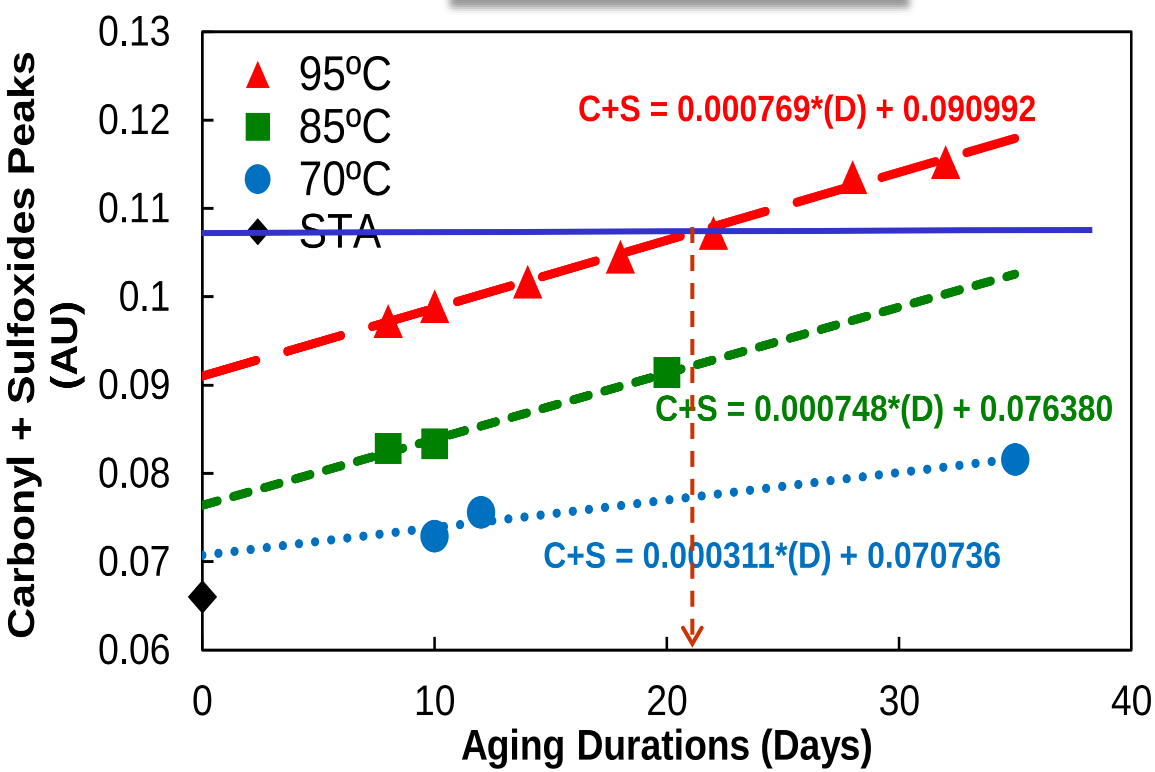
Loose Mix Aging Conditions to Match the Field Aging

FHWA ALF-SBS, 8 Year Field Core

Field

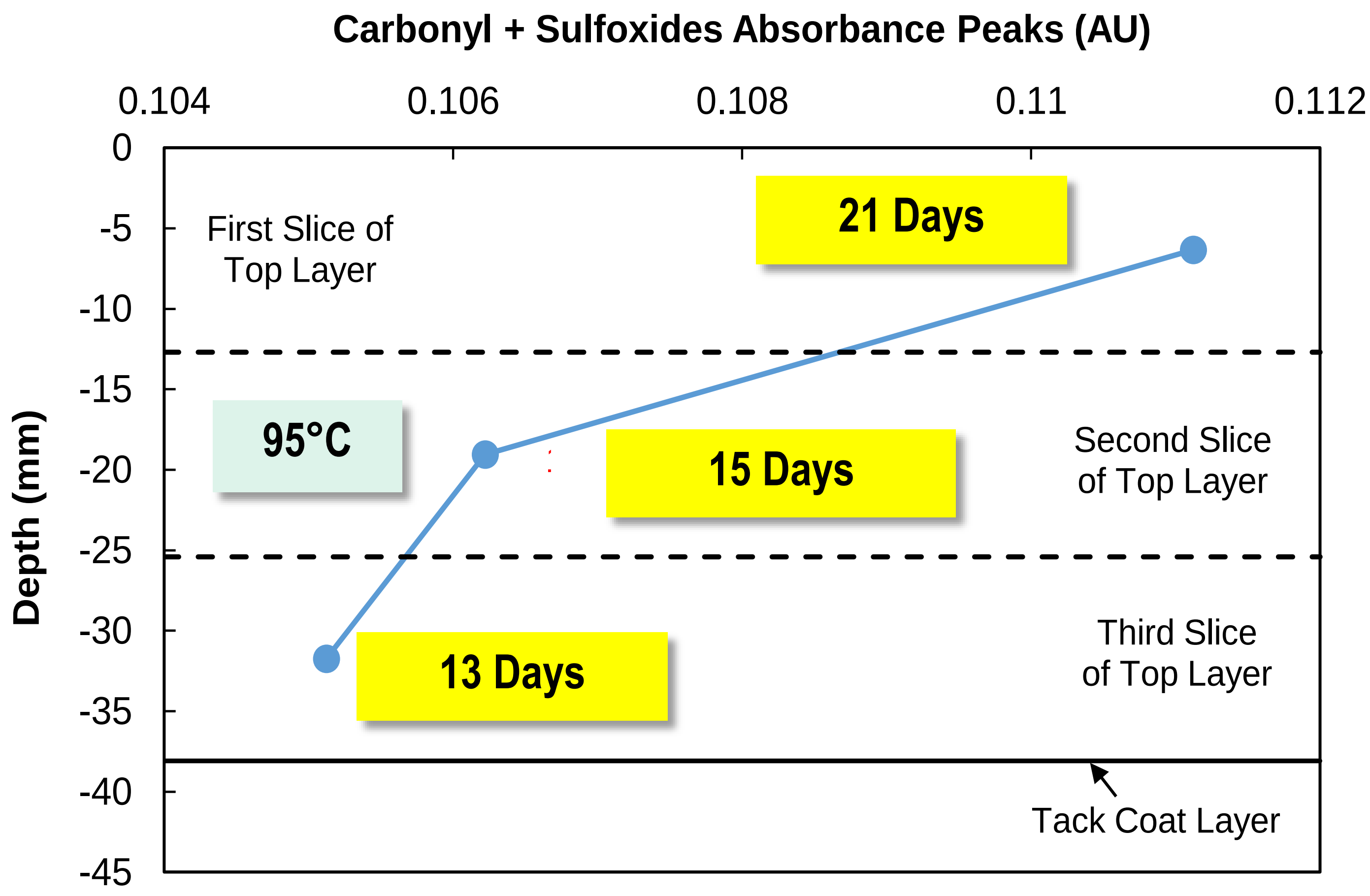


Loose Mix (Lab)



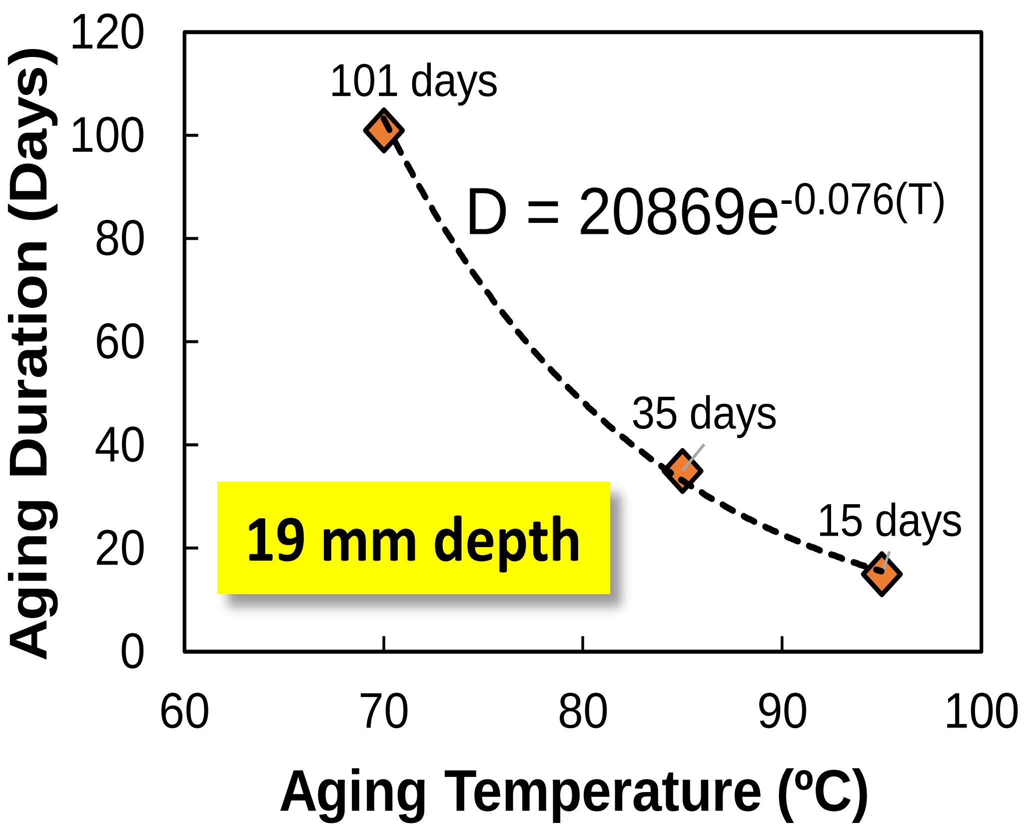
Matching the Field Aging at Diff. Depths

FHWA ALF-SBS, 8 Year Field Core



Temperature Effect on Aging Time

FHWA ALF-SBS, 8 Year Field Core



Selection of Laboratory Aging Temperature

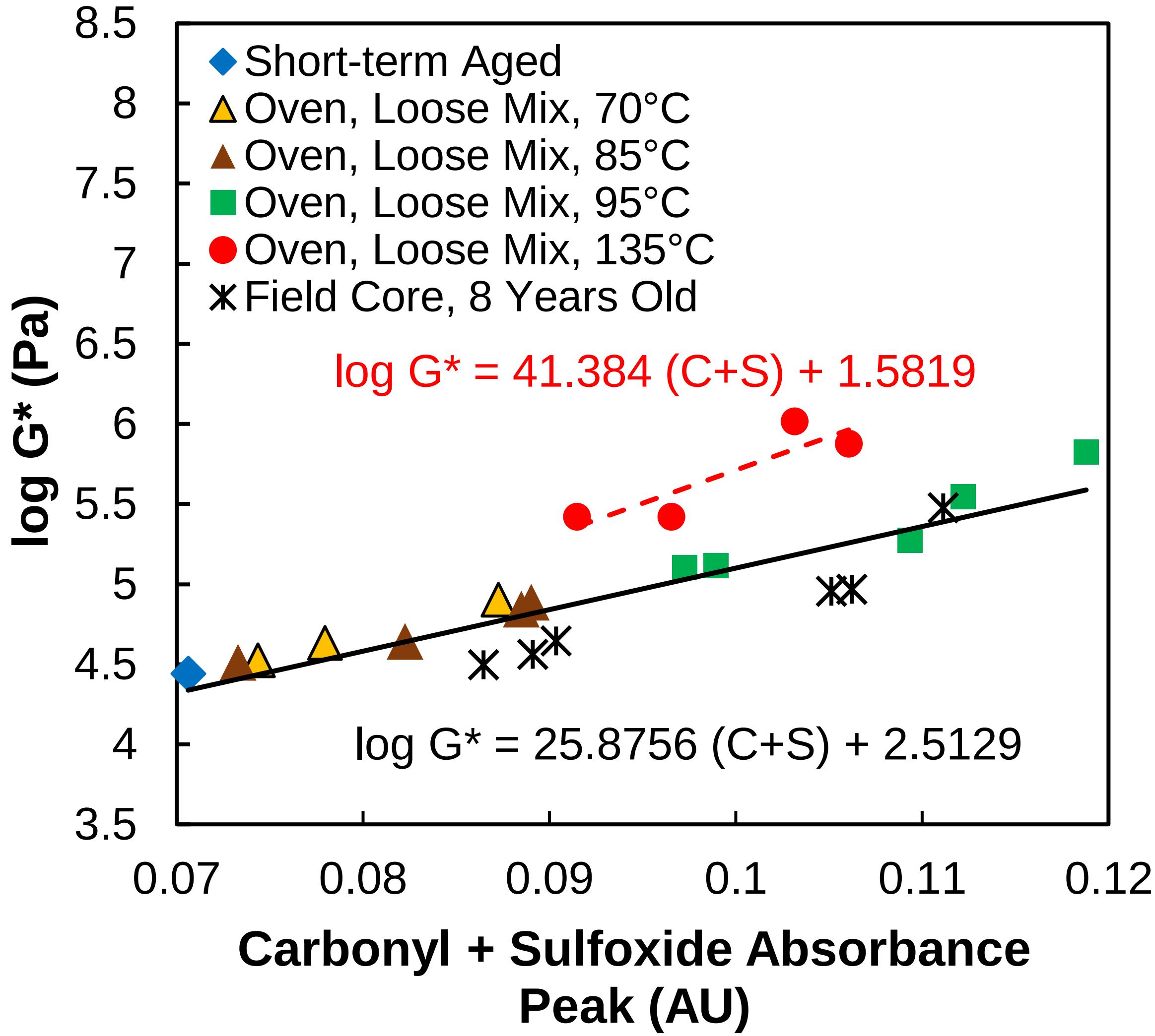
- Increasing temperature expedites oxidation
- Potential concerns when aging above 100°C
  - Chemical effects
    - ✓ Thermal Decomposition of Sulfoxides
    - ✓ Changes in relative amounts of functional groups
  - Physico-chemical effects
    - ✓ Disruption of binder microstructure
      - Increases the availability of molecules for oxidation
  - Binder/Mastic drain-down
- Performance implications of these effects unknown
  - If rheology of binders aged at 95°C and 135°C the same, does performance differ?

Experimental Factors

- Materials:
  - FHWA ALF aggregate
  - FHWA ALF-SBS (PG 70-28), SHRP AAD-1 (PG 58-28) and AAG-1 (PG 58-10) binders
- Aging Temperatures: 95°C and 135°C
- Aging Durations:
  - 95°C: 9 – 21 days
  - 135°C: 16.8 – 52 hours
- Binder Testing:
  - Frequency sweep test in the DSR and FTIR
- Mixture Performance Testing:
  - Dynamic modulus and cyclic direct tension (S-VECD)

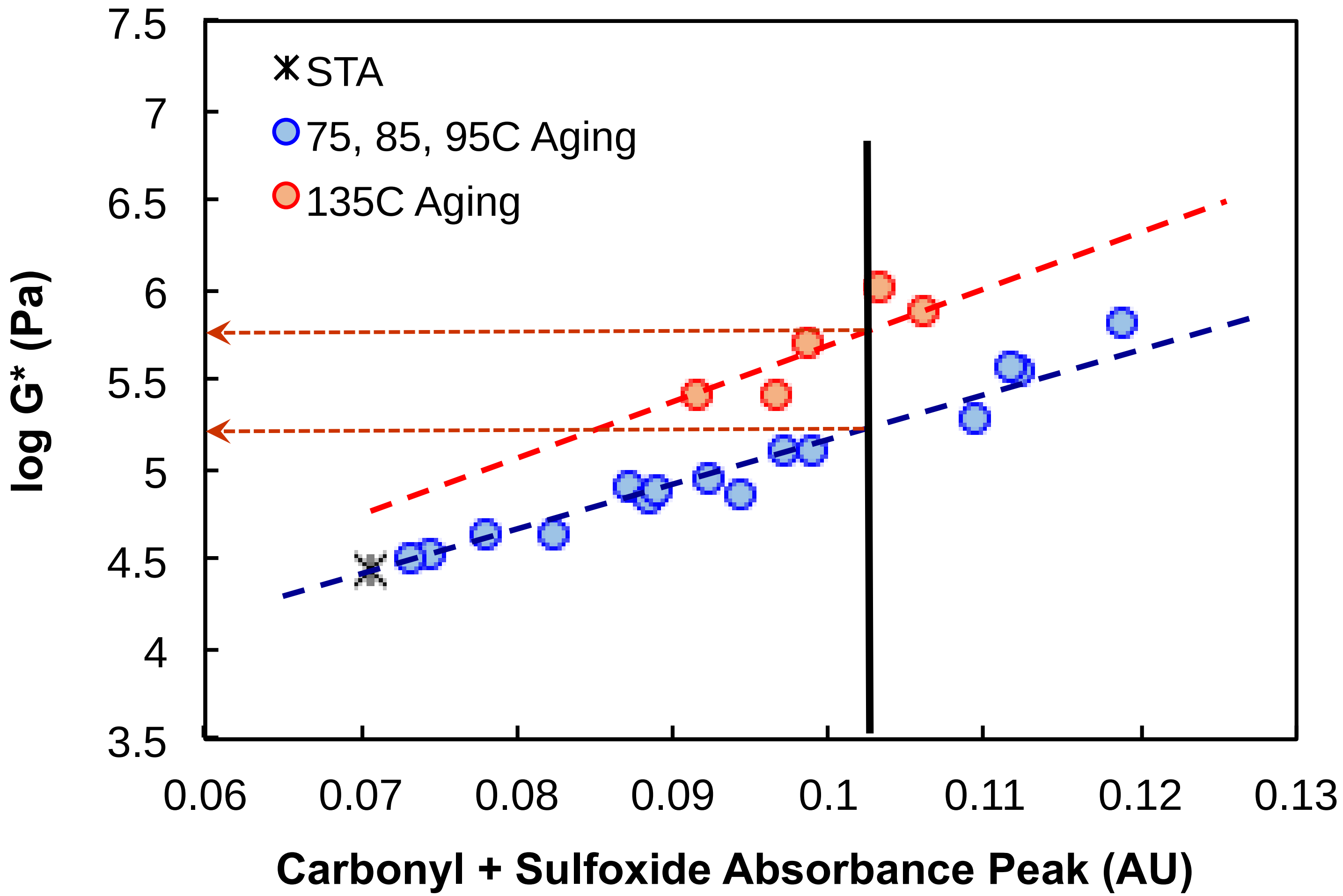
Chemistry vs. Rheology

FHWA ALF-SBS



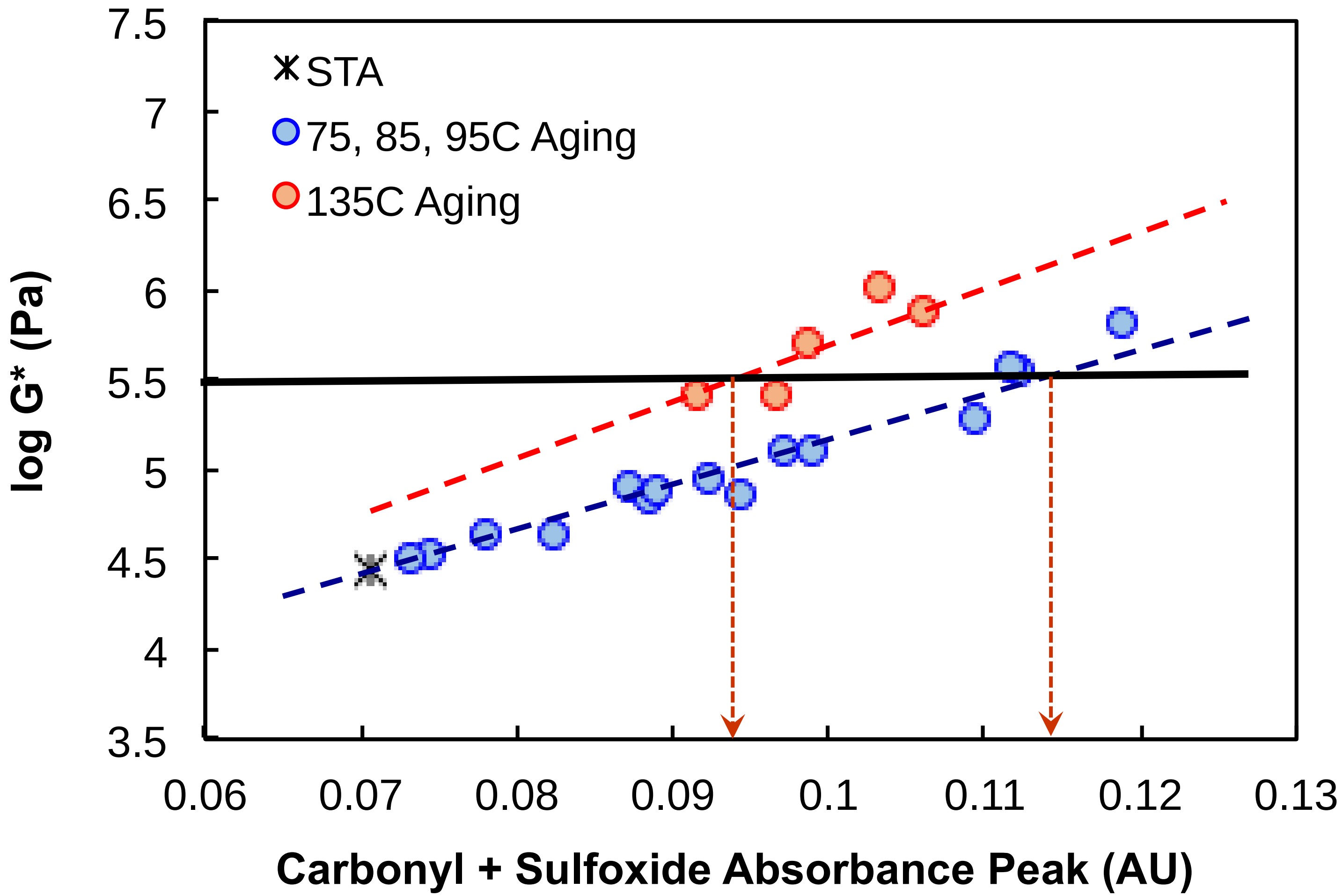
Testing Approach - I

Same Chemistry & Different Rheology



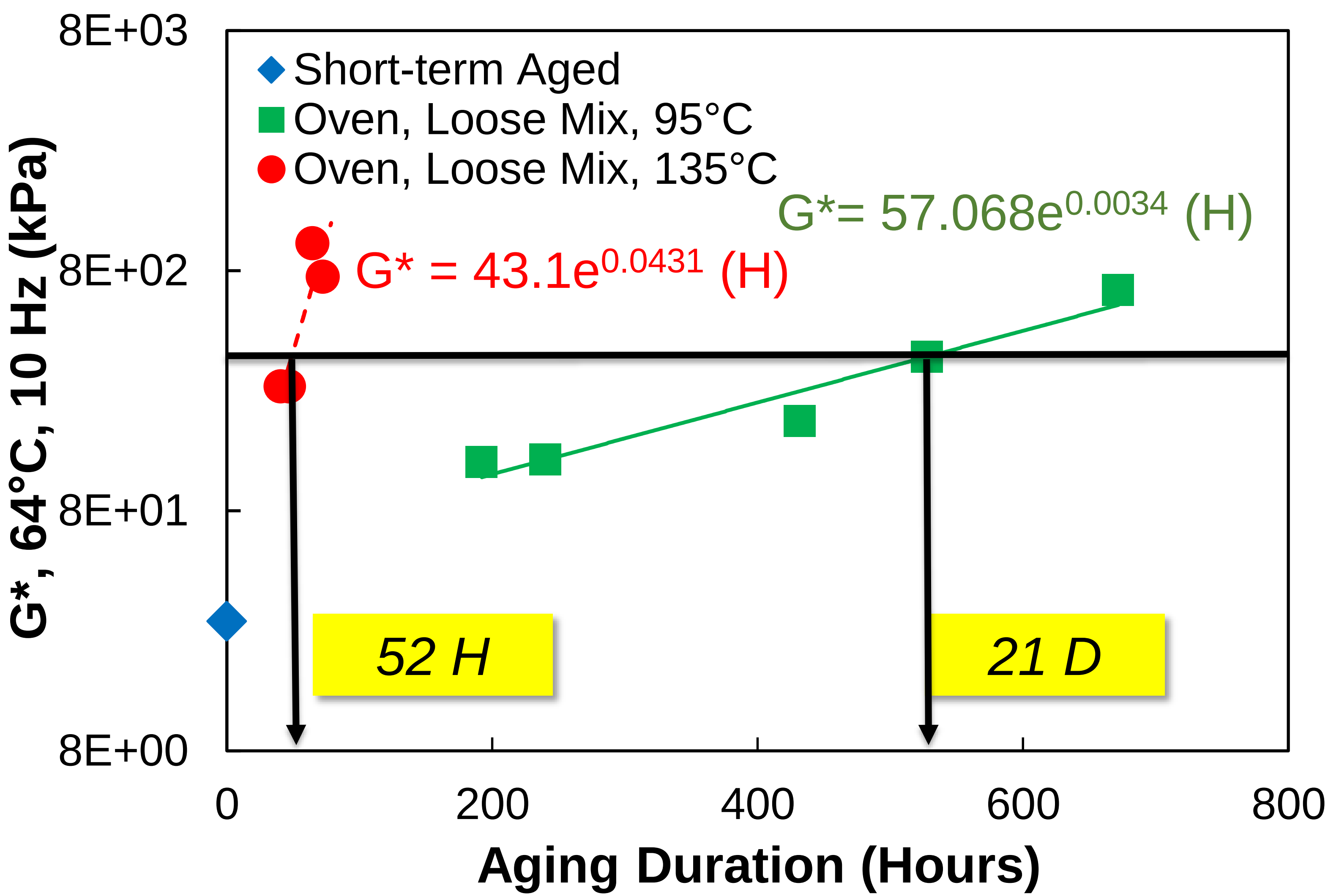
Testing Approach - II

Same Rheology & Different Chemistry



Determining Laboratory Aging Times

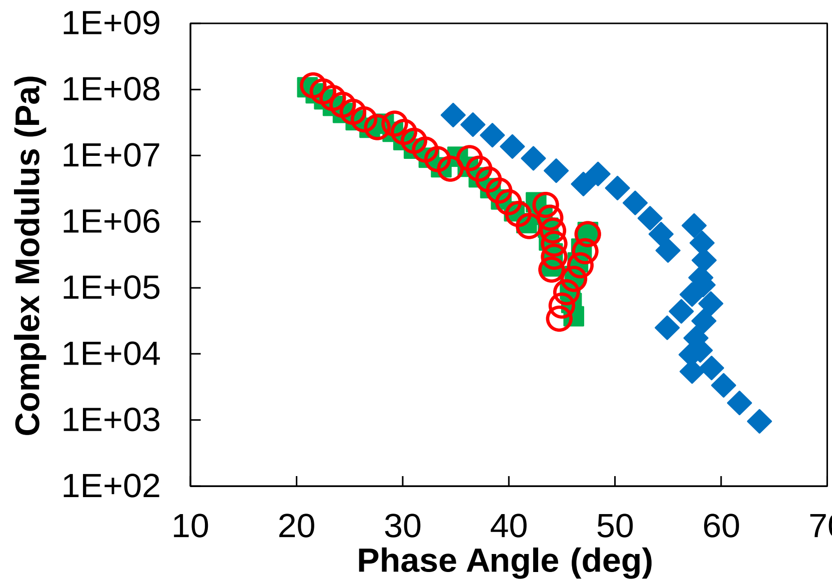
FHWA ALF-SBS (95°C and 135°C)

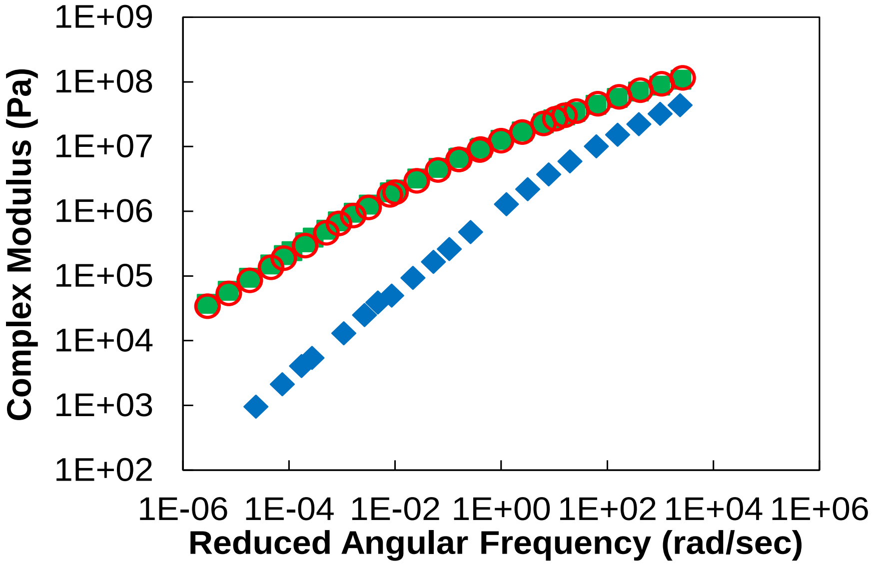


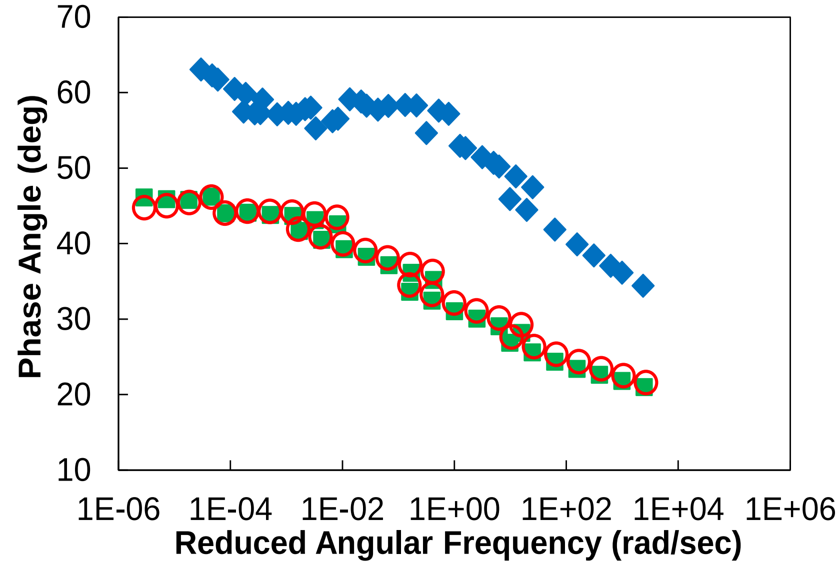
Rheology Comparison

FHWA ALF-SBS

- Short-term Aged
- Oven, Loose Mix, 95°C, 21 days
- Oven, Loose Mix, 135°C, 52 hours



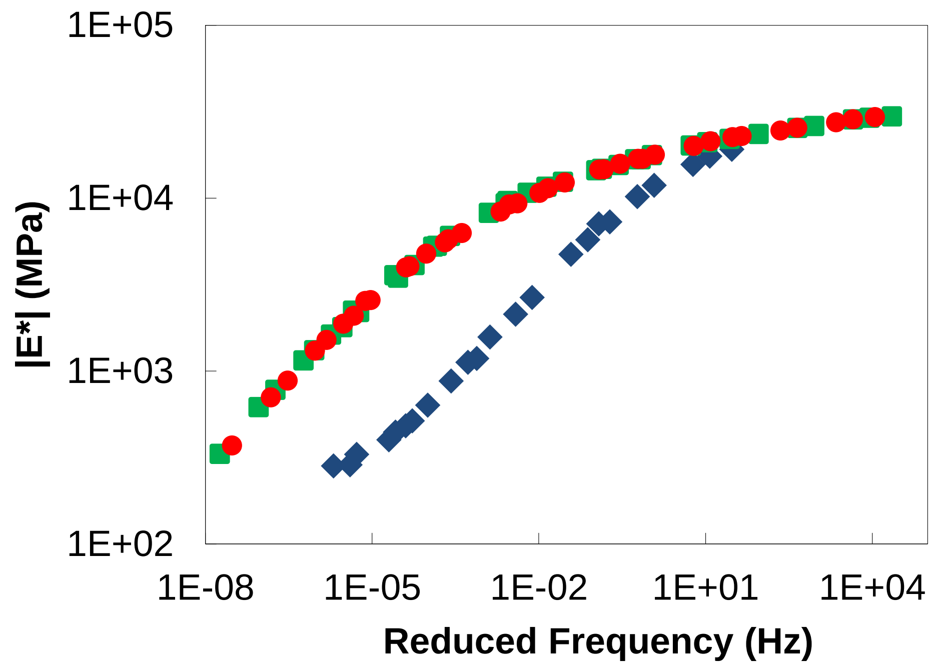


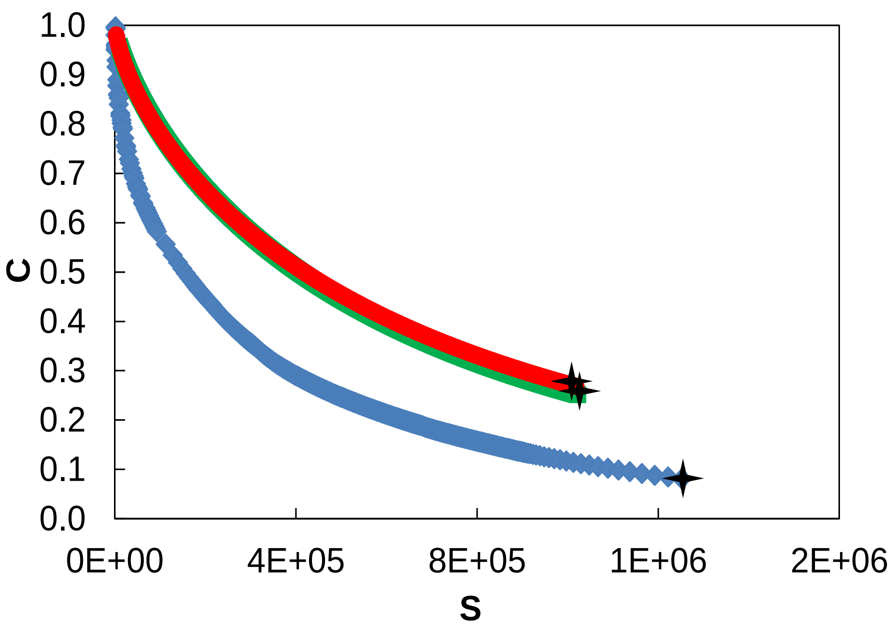


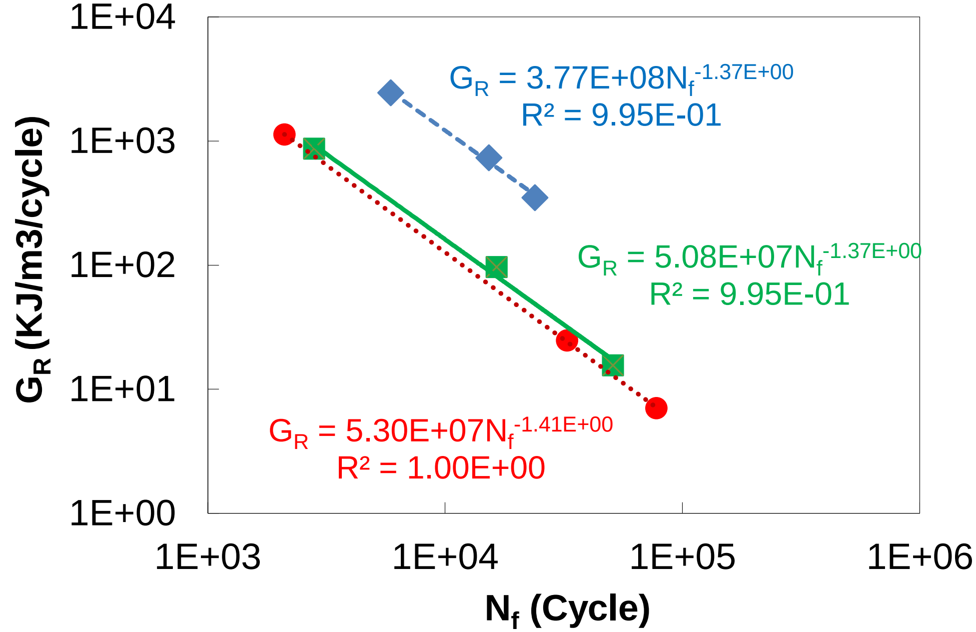
Performance Test Results

FHWA ALF-SBS Mix

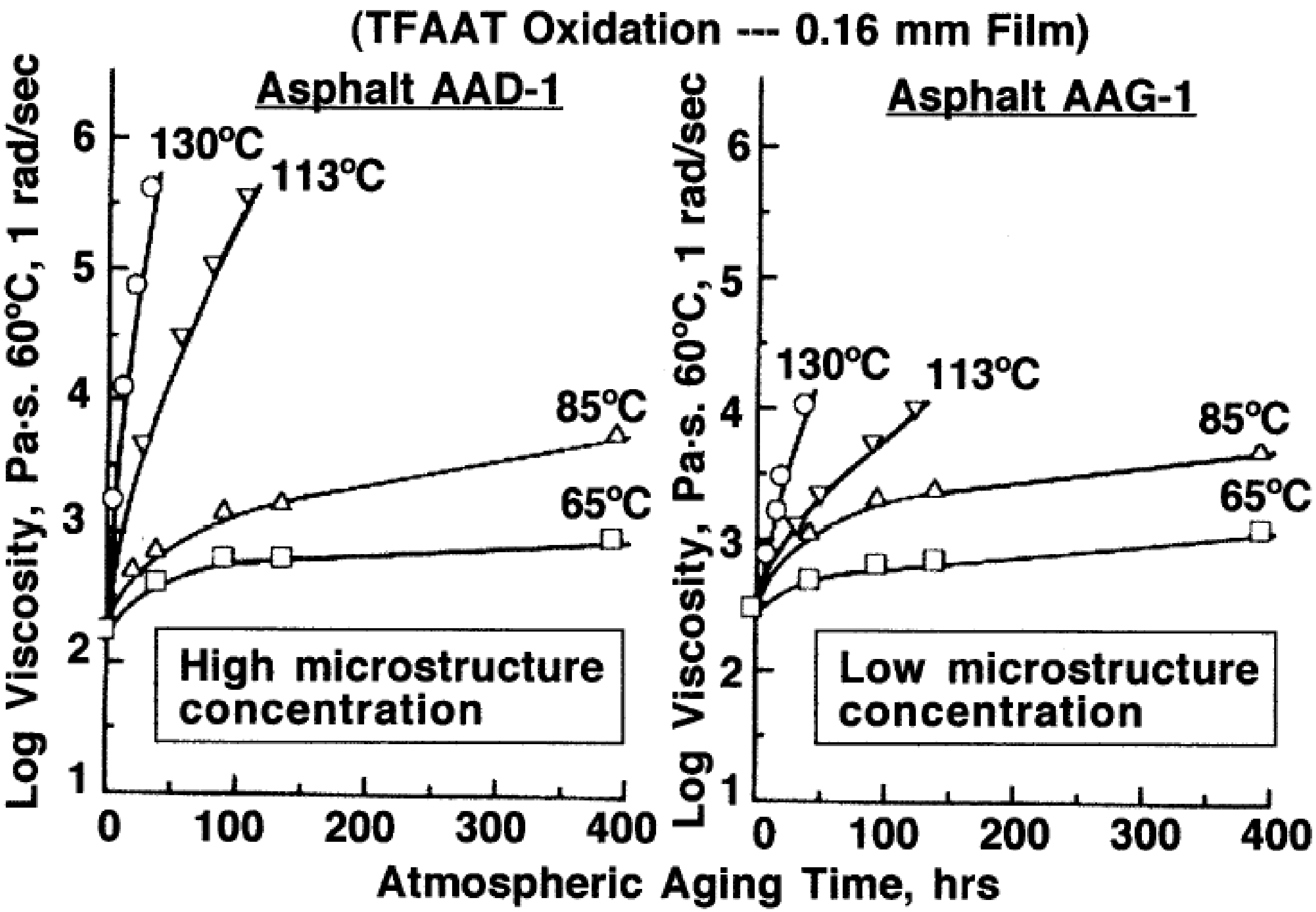
Short-term Aged
Oven, Loose Mix, 135°C, 52 hours
Oven, Loose Mix, 95°C, 21 days







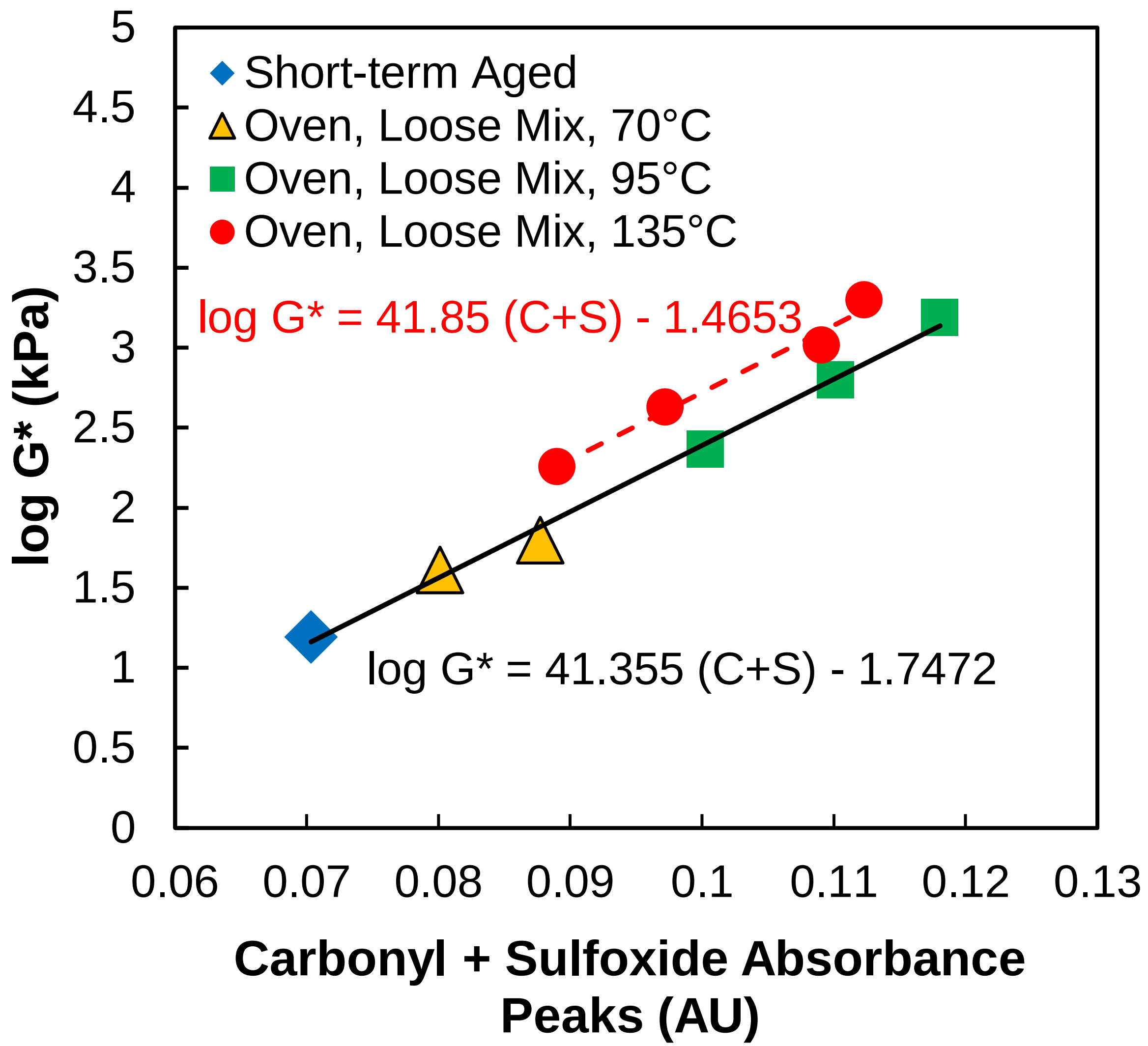
Motivation to Select AAD-1 Binder



(Petersen 2009)

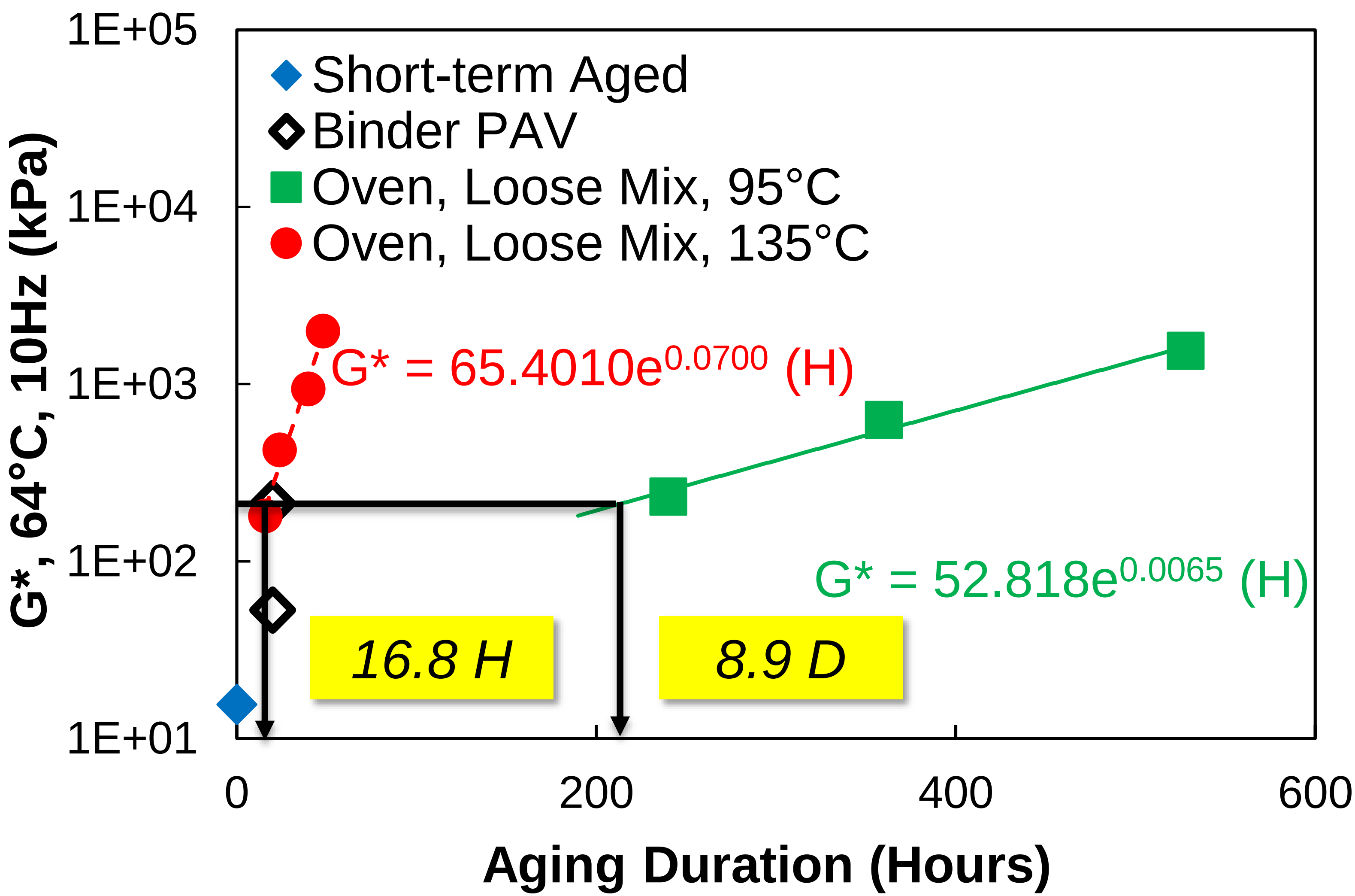
Chemistry vs. Rheology

SHRP AAD-1



Matching Rheological AIPs

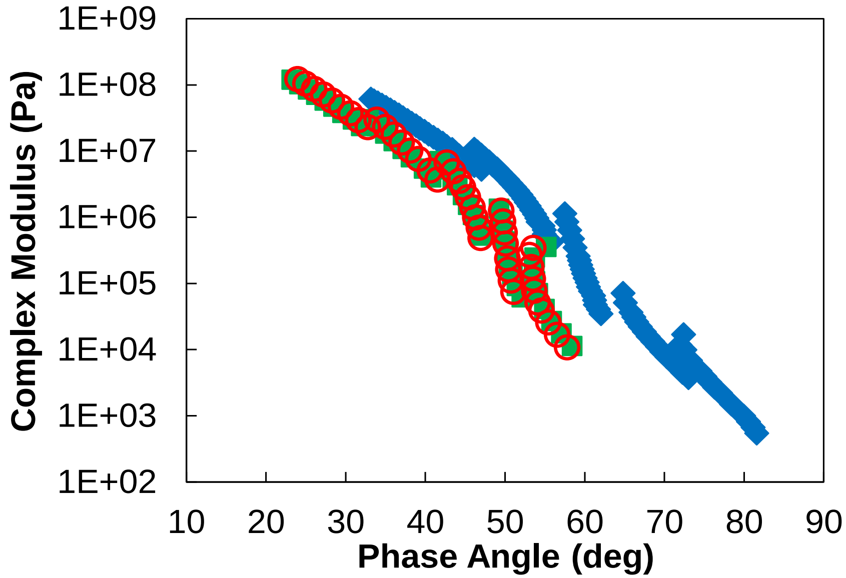
SHRP AAD-1 (95°C and 135°C)

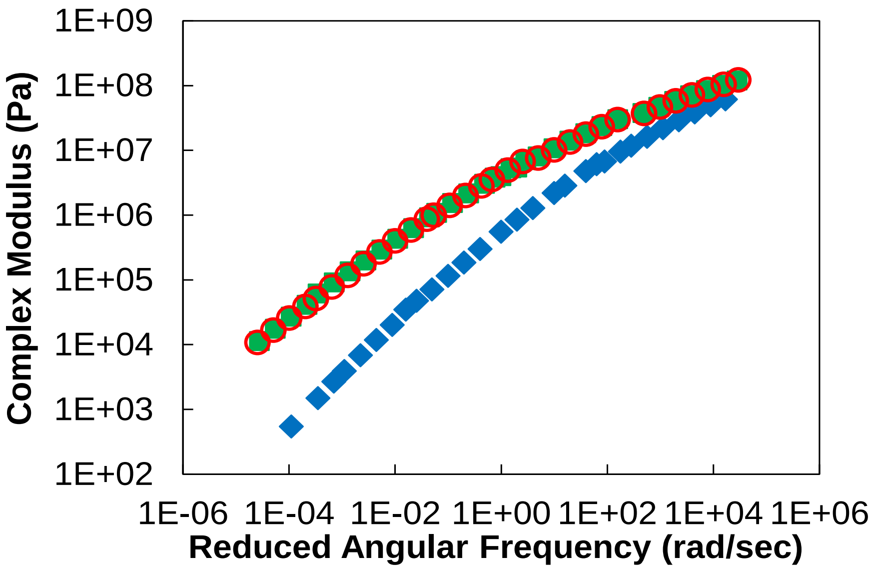


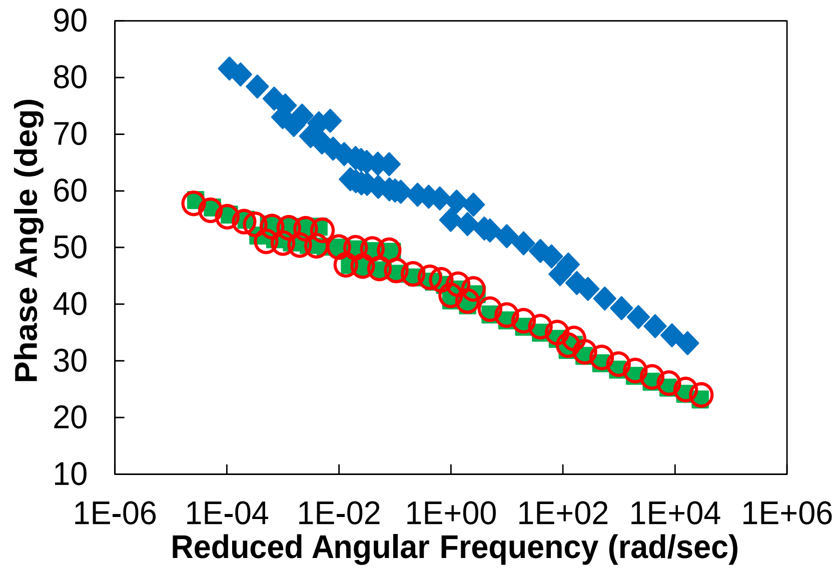
Rheology Comparison

SHRP AAD-1

- Short-term Aged
- Oven, Loose Mix, 95°C, 8.9 days
- Oven, Loose Mix, 135°C, 16.8 hours

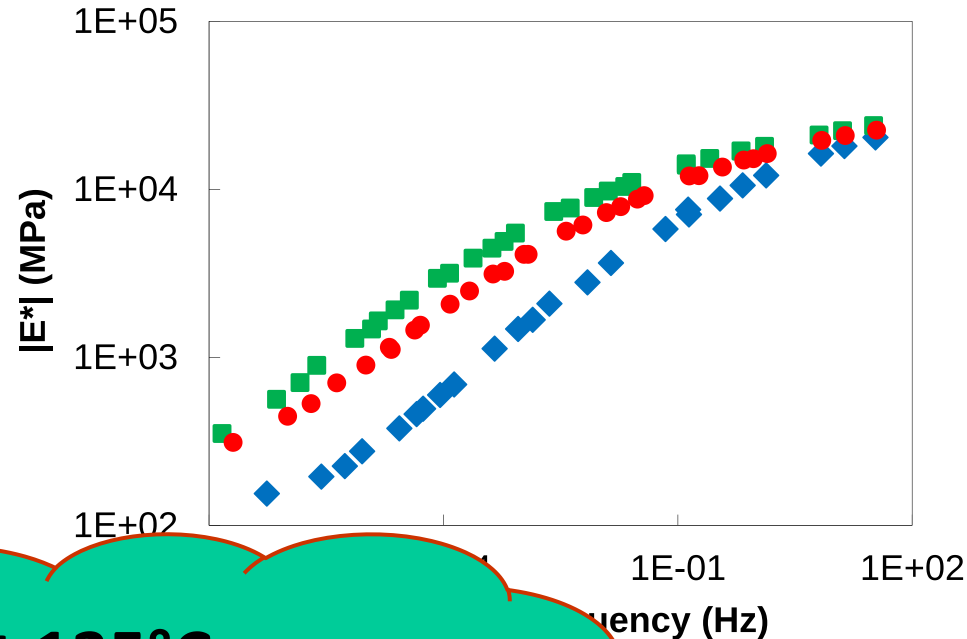


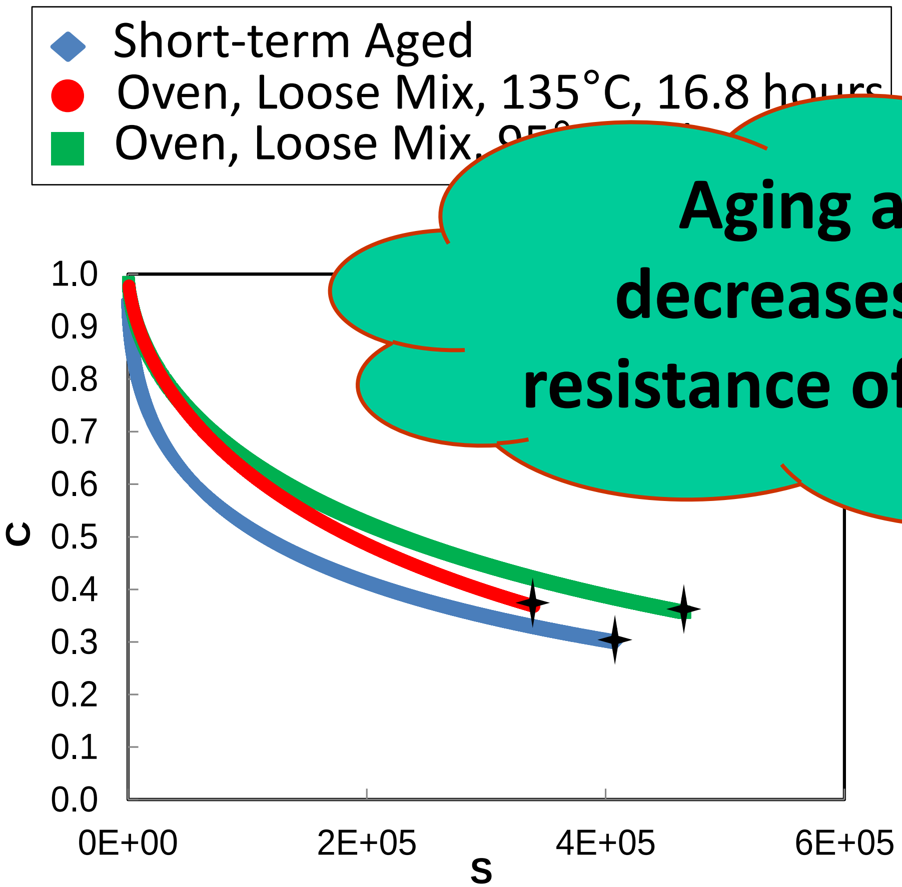


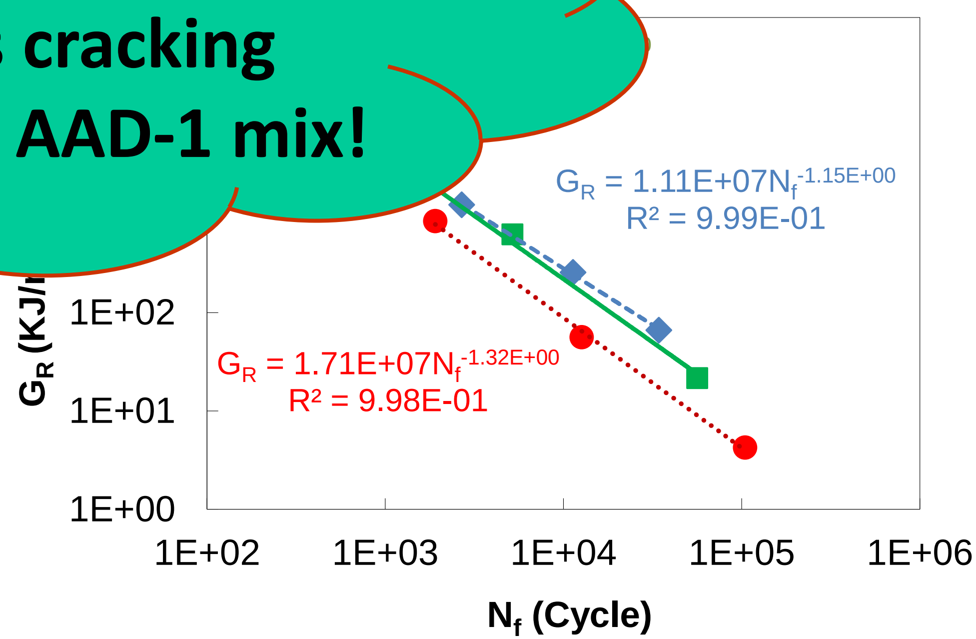


Performance Test Results

SHRP AAD-1 Mix

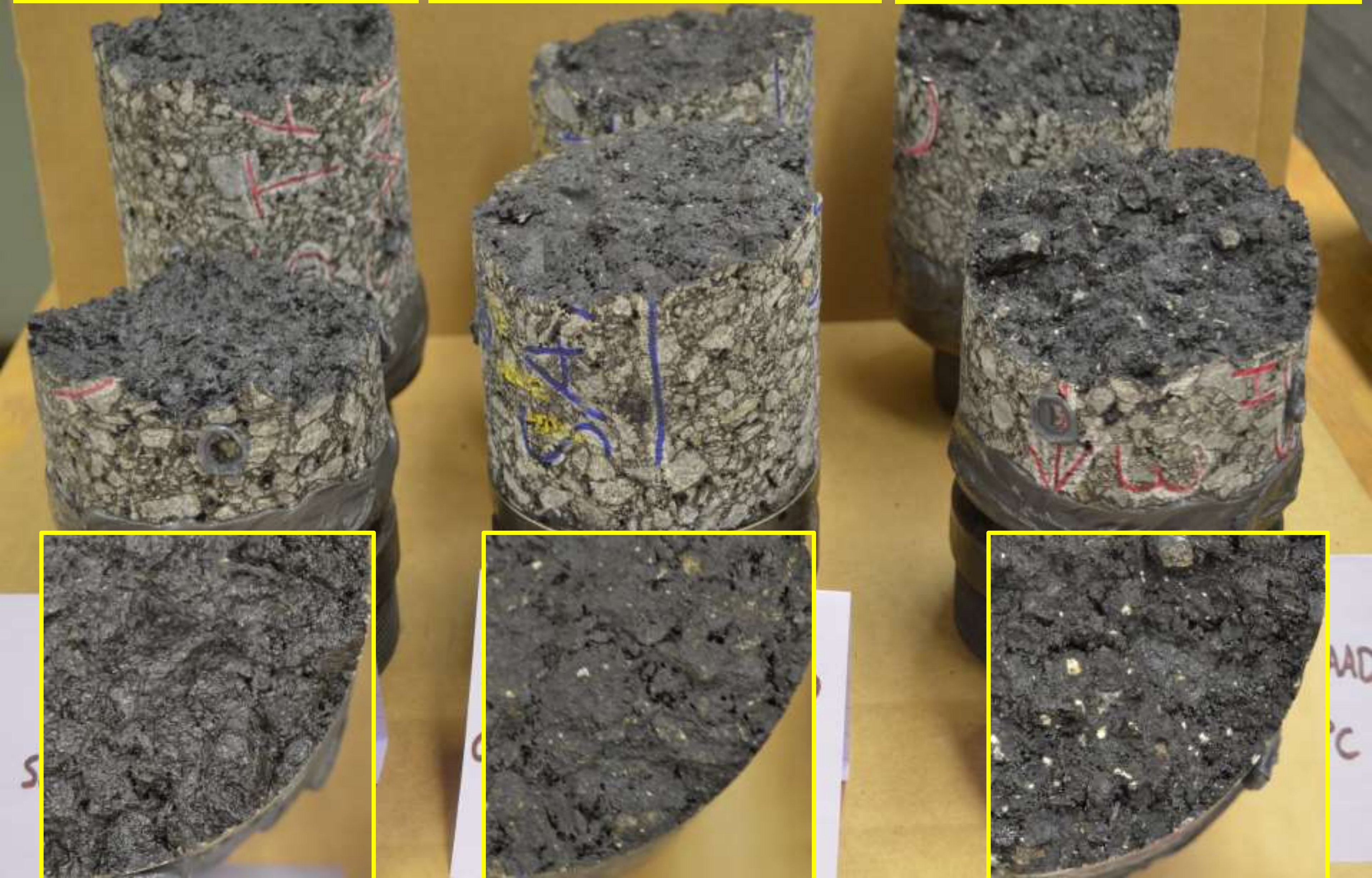






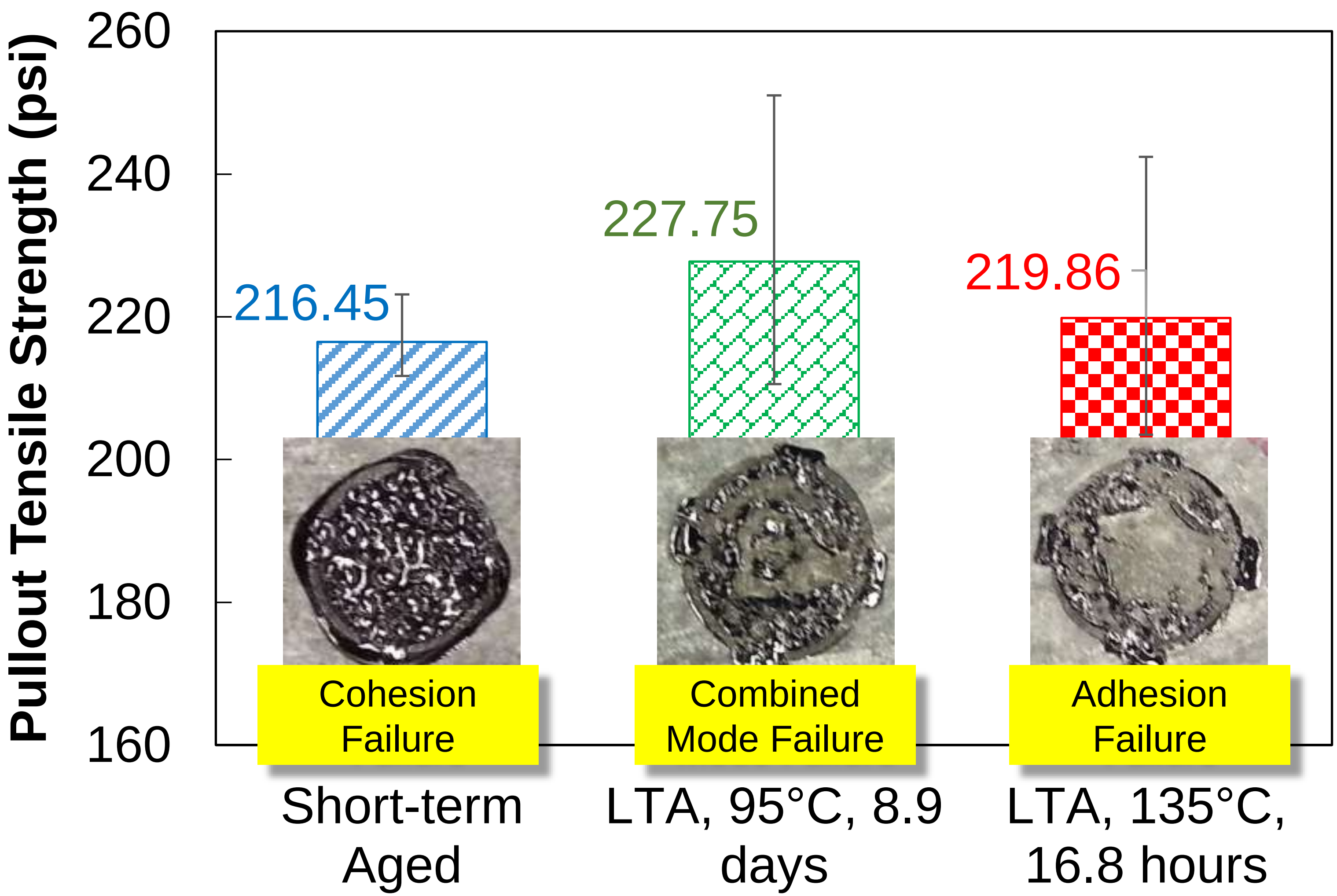
Aging at 135°C decreases cracking resistance of AAD-1 mix!

STA-SAAD Short-term aged	L-O-95-9D-SAAD Oven, 9 days aging at 95°C	L-O-135-16.8-SAAD Oven, 16.8 hours aging at 135°C



Asphalt Bond Strength

SHRP AAD-1 (95°C and 135°C)



Interim Findings

- Loose mix aging is the most promising aging method for performance test specimens.
- Aging at 135°C changes the binder chemistry, and this change is significant enough to decrease binder tackiness and cracking resistance in highly structured (less compatible) binders.
- The optimal temperature for long term aging of asphalt mixture for performance testing should be below 100°C, and 95°C is recommended from the efficiency point of view.

Questions?