TPF-5(230)
Evaluation of Plant-Produced High-Percentage RAP Mixtures in the Northeast

Technical Committee Project Closeout Meeting

April 19, 2016

Research Team

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Pooled Fund Participants

- New Hampshire (NHDOT) - Lead Agency
- Maryland (MDOT)
- New Jersey (NJDOT)
- New York (NYSDOT)
- Pennsylvania (PennDOT)
- Rhode Island (RIDOT)
- Virginia (VDOT)
- Federal Highway Administration (FHWA)

Project Objectives

- Evaluate the performance of plant-produced RAP mixtures in terms of low temperature and fatigue cracking
- Impact of plant production variables on material properties (temps, silo storage time)
- Produce better performing mixtures while also using higher RAP contents

Project Phases

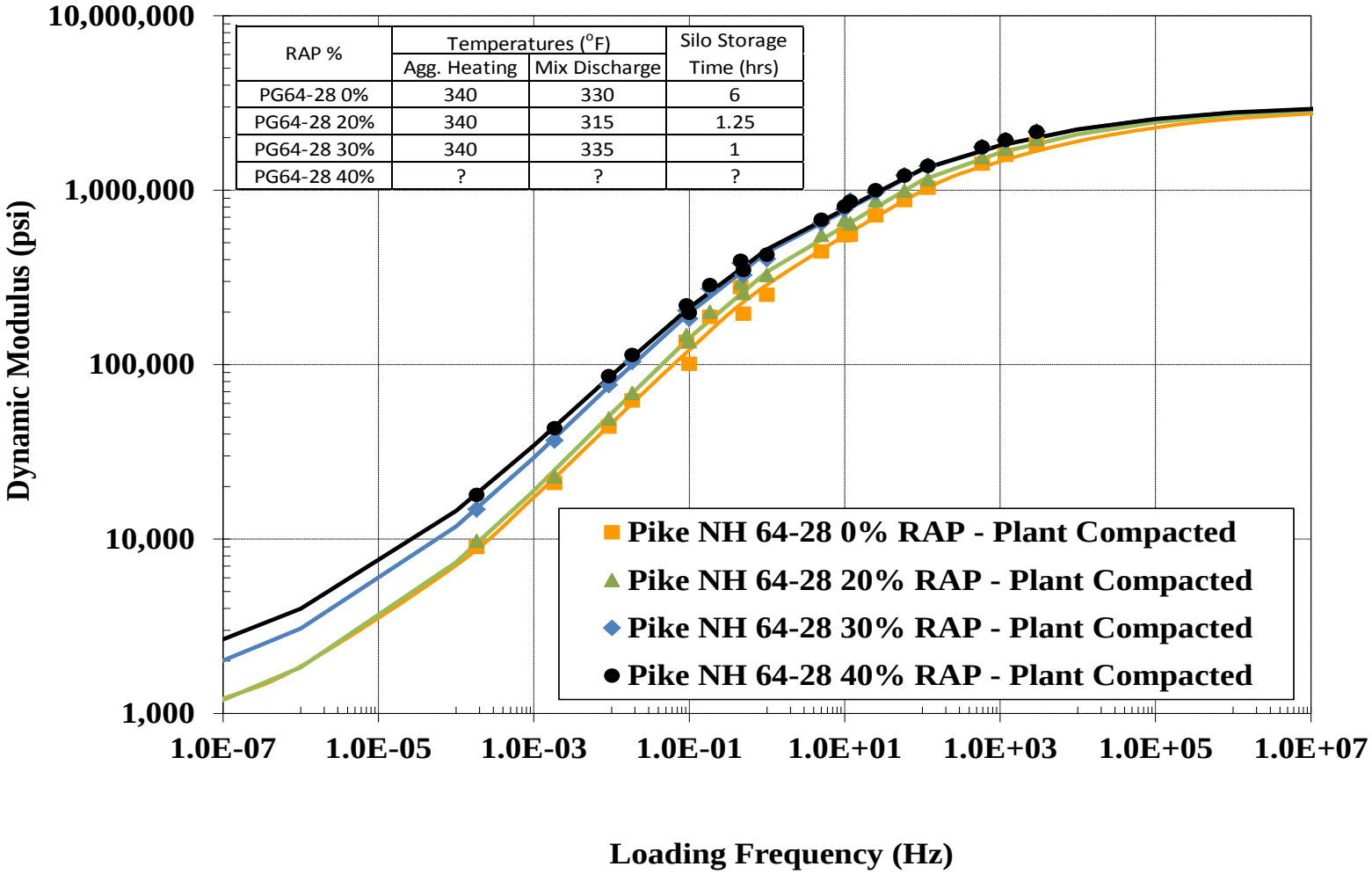
- Phase I (2010): 18 mixtures, 3 plants: NH, NY, VT, up to 40% RAP, different virgin PG grades
- Phase II (2011): 10 additional mixtures from NH and VA, 25% RAP silo storage study mixtures
- Phase III (2013): Controlled laboratory study with 20% & 40% RAP, two binder grades, range of binder contents
- Silo Storage Study Task (2014): virgin & 25% RAP mixture sampled at multiple storage times up to 10 hours

Testing

- Virgin & Recovered Binder
  - PG grade and DSR master curve
  - CCT
  - ABCD
  - 4 mm diameter DSR
- Mixture
  - Dynamic Modulus
  - Hamburg & TSR
  - Low Temperature
    - Creep & Strength
    - TSRST
  - Fatigue
    - AMPT S-VECD protocol
    - Overlay Tester
    - Beam Flexure
  - AMPT Triaxial Stress Sweep (rutting)

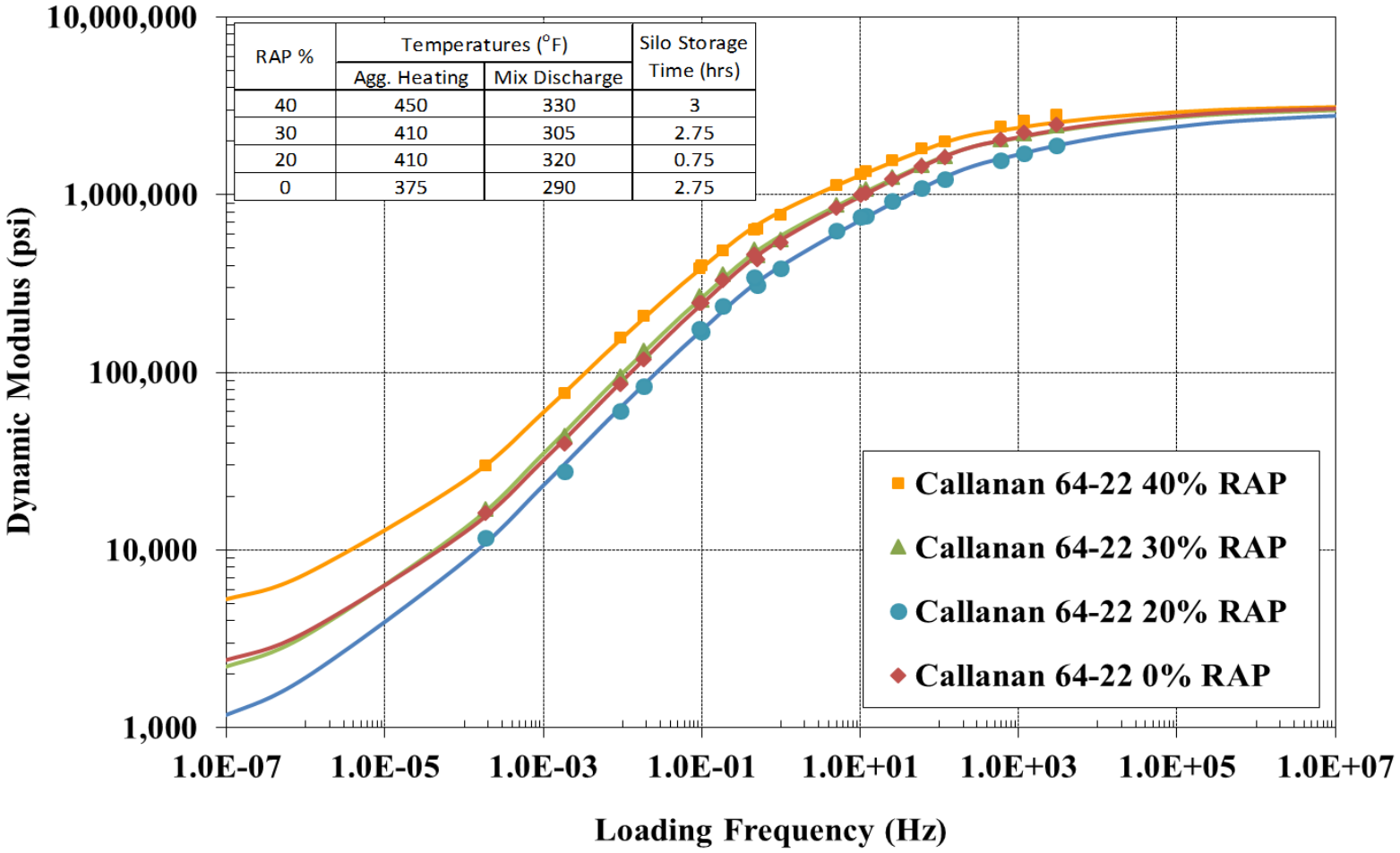
PHASE I & PHASE II
RAP CONTENT AND PG GRADE

Phase I: NH PMPC

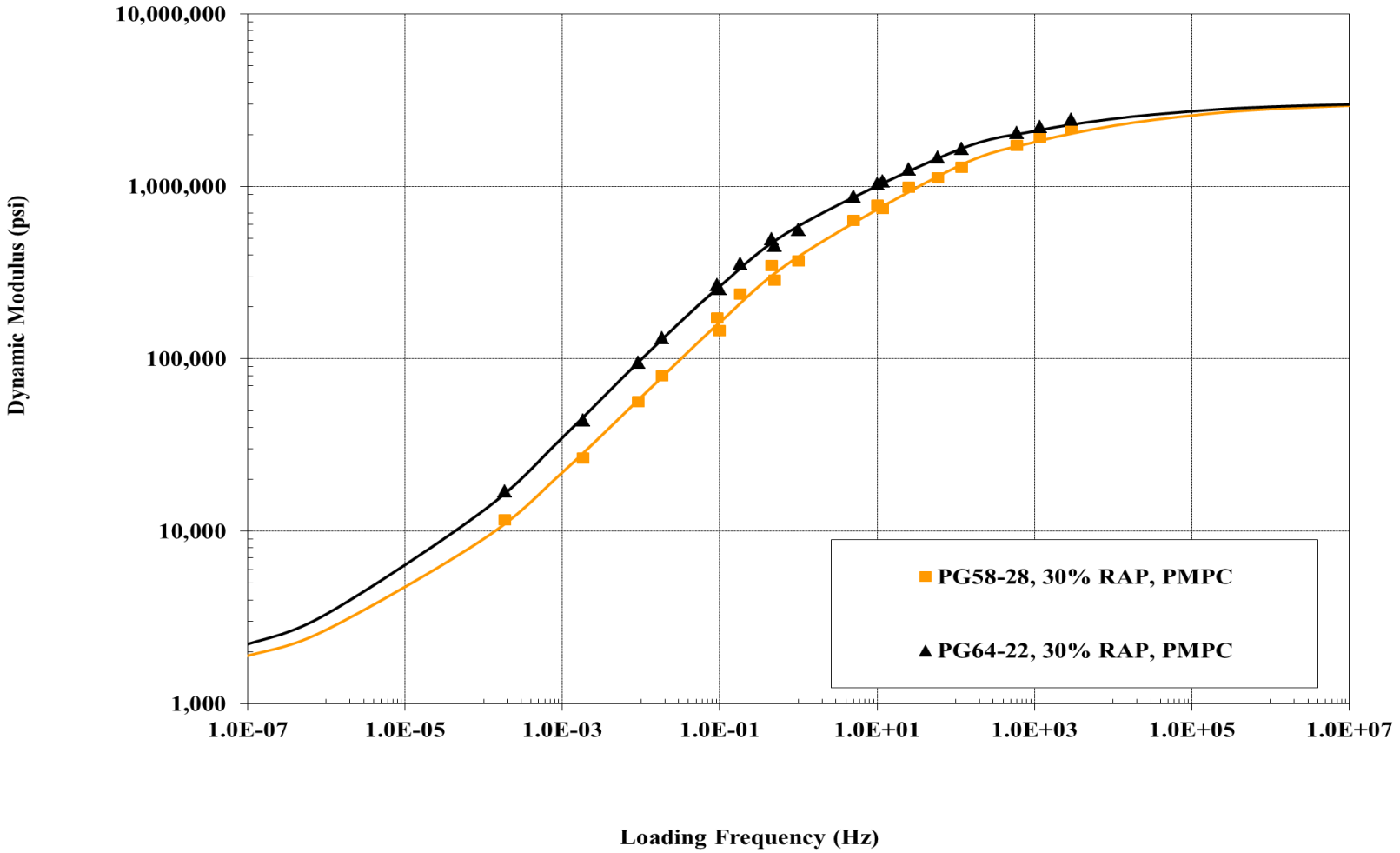


RAP %	Temperatures (°F)		Silo Storage Time (hrs)
	Agg. Heating	Mix Discharge	
PG64-28 0%	340	330	6
PG64-28 20%	340	315	1.25
PG64-28 30%	340	335	1
PG64-28 40%	?	?	?

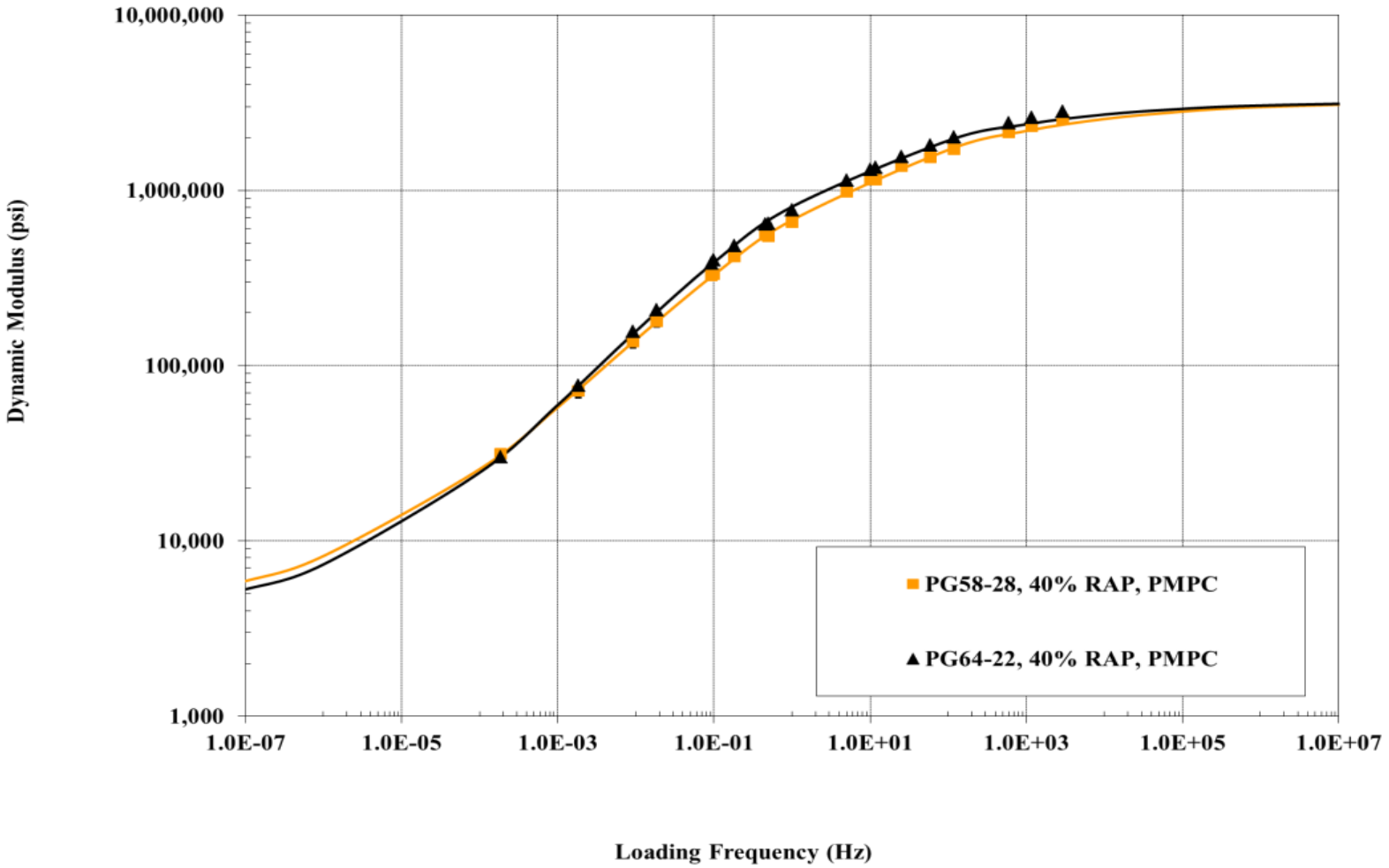
Phase I: NY PG 64-22 PMPC



NY 30% RAP Comparison

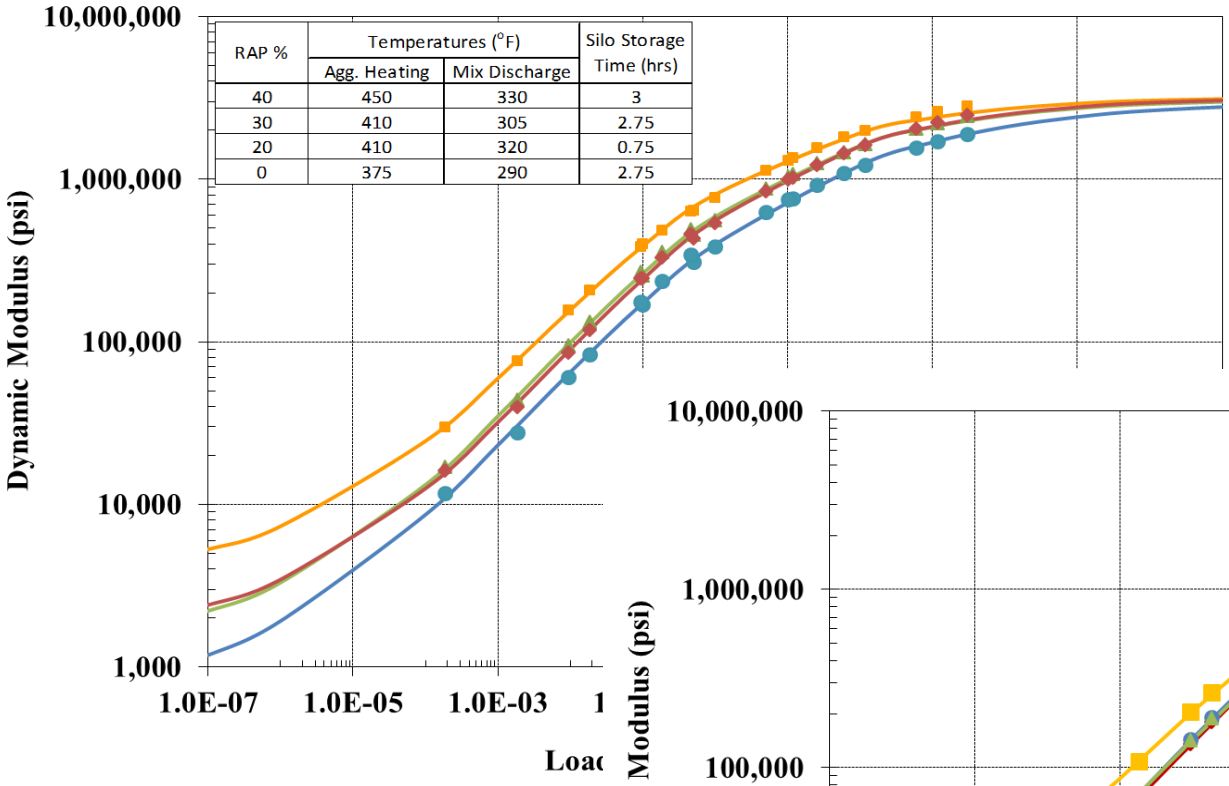


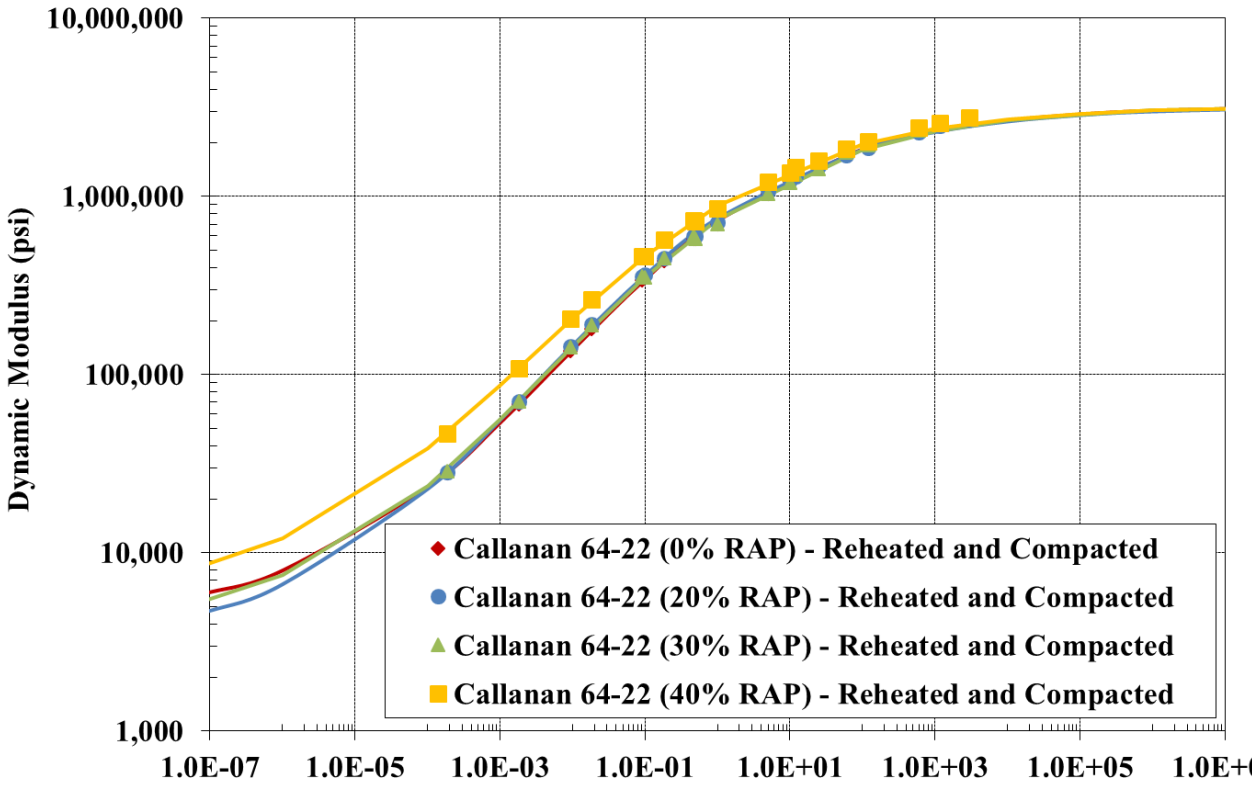
NY 40% RAP Comparison



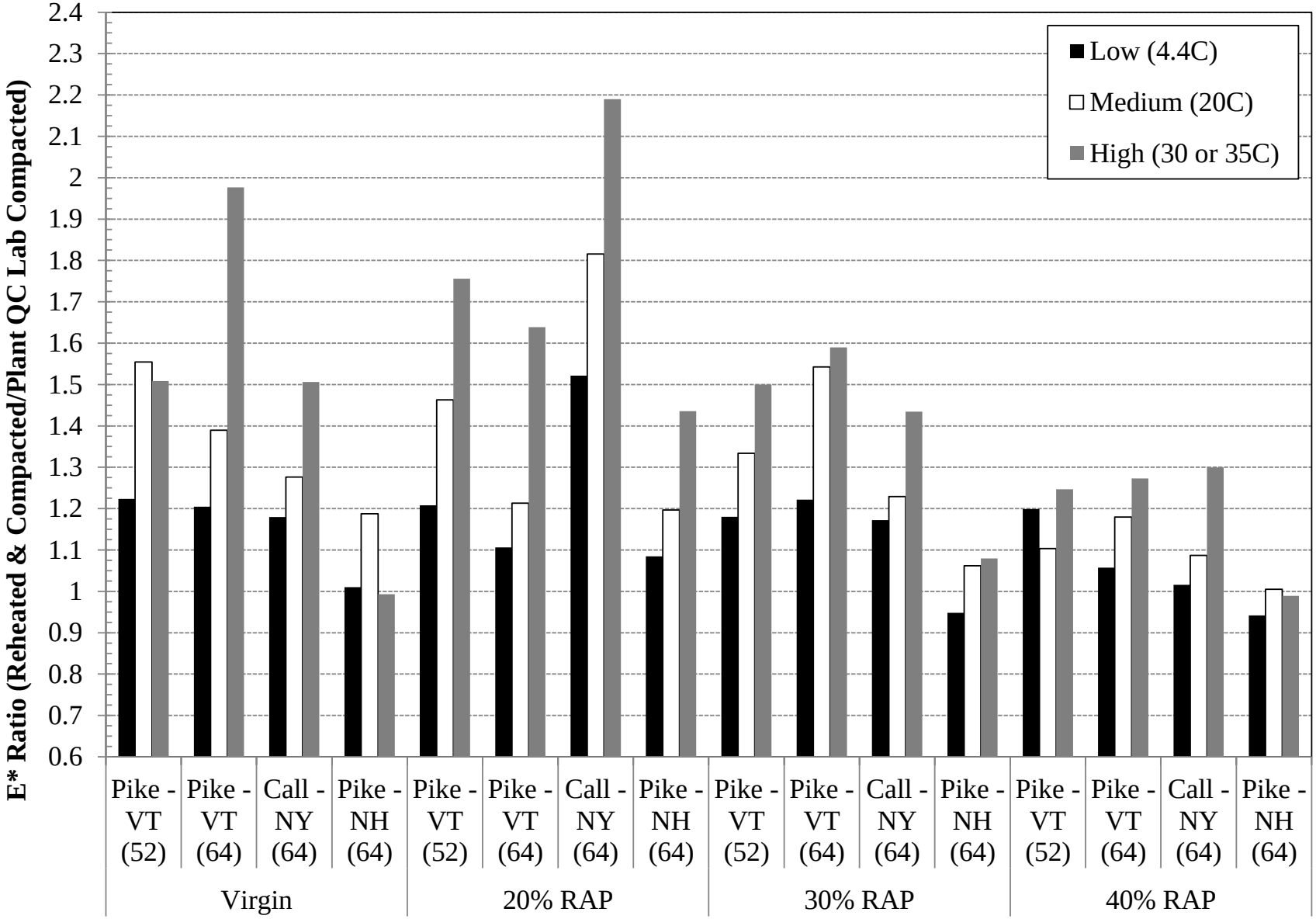
Impact of Reheating: |E*|

RAP %	Temperatures (°F)		Silo Storage Time (hrs)
	Agg. Heating	Mix Discharge	
40	450	330	3
30	410	305	2.75
20	410	320	0.75
0	375	290	2.75



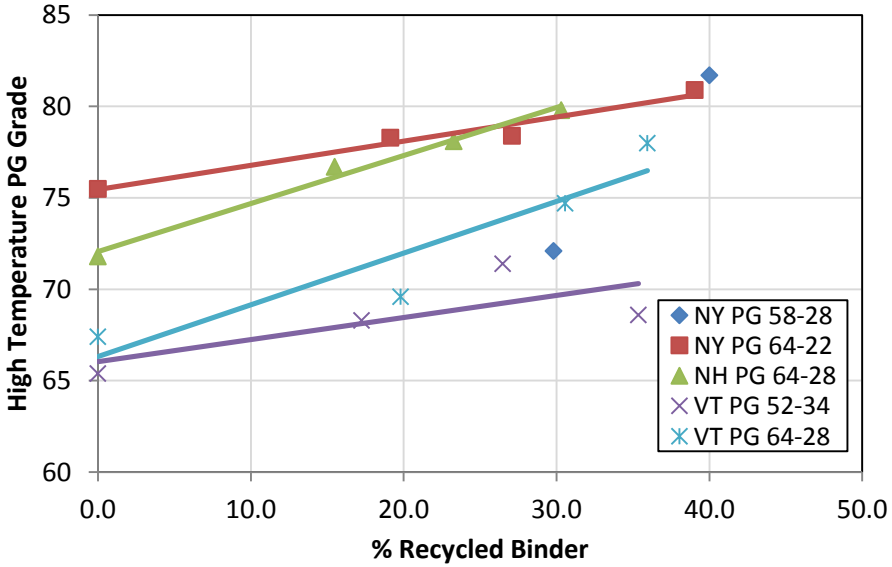


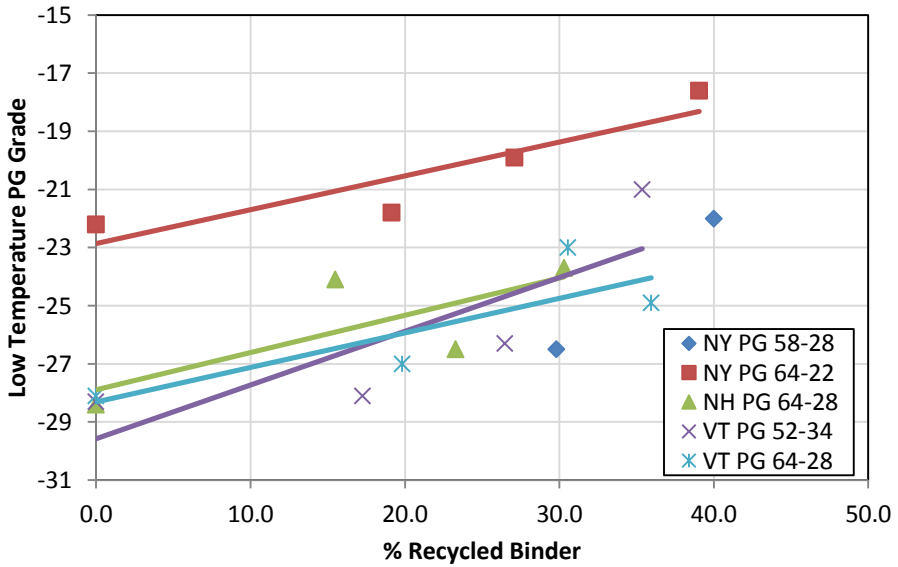
Impact of Reheating: |E*| Ratio



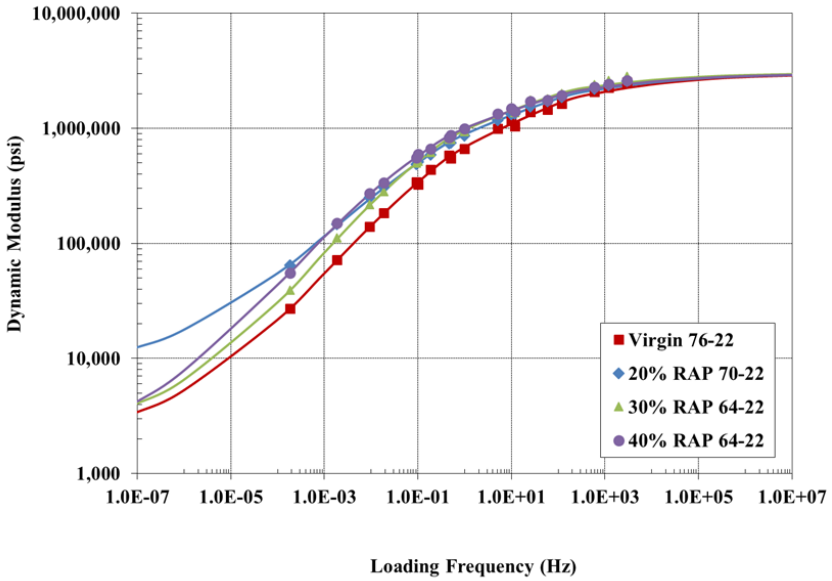
Recovered Binders

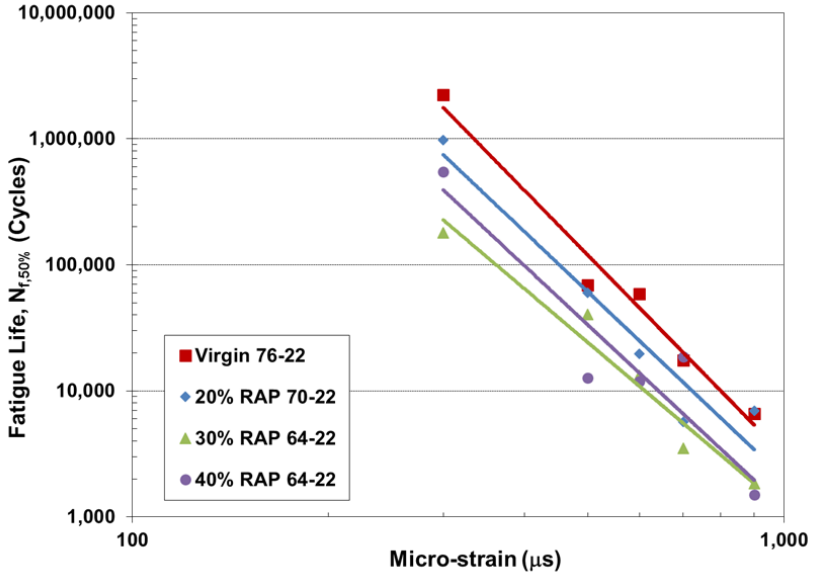
- RAP stiffens material
  - 1-3°C increase in high PG with each 10% RAP
  - 1-2°C increase in low PG with each 10% RAP

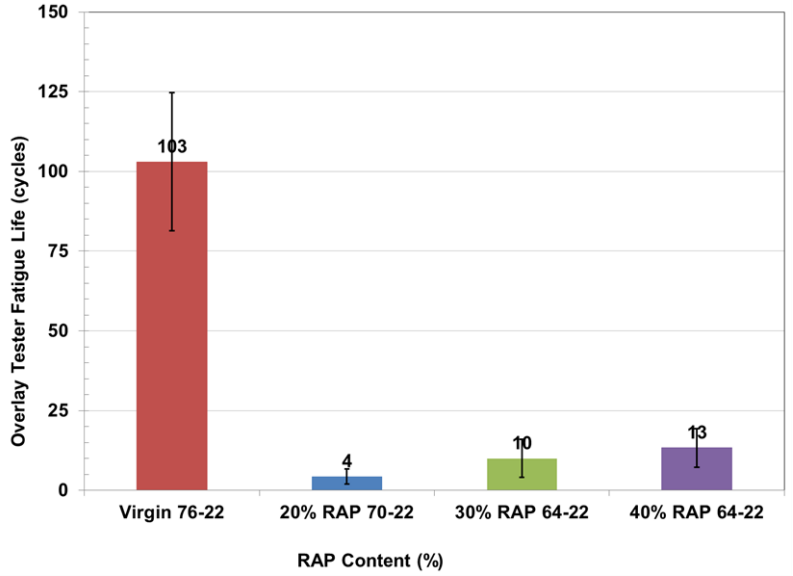


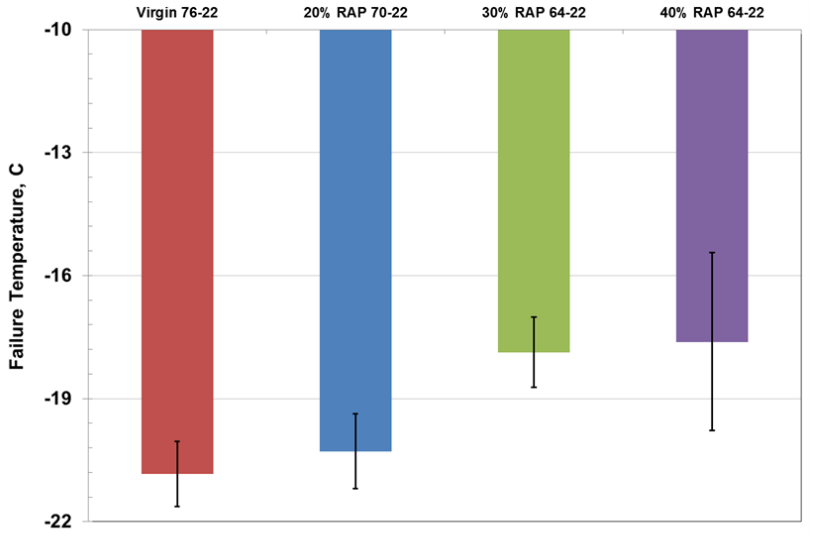


Virginia Mixtures

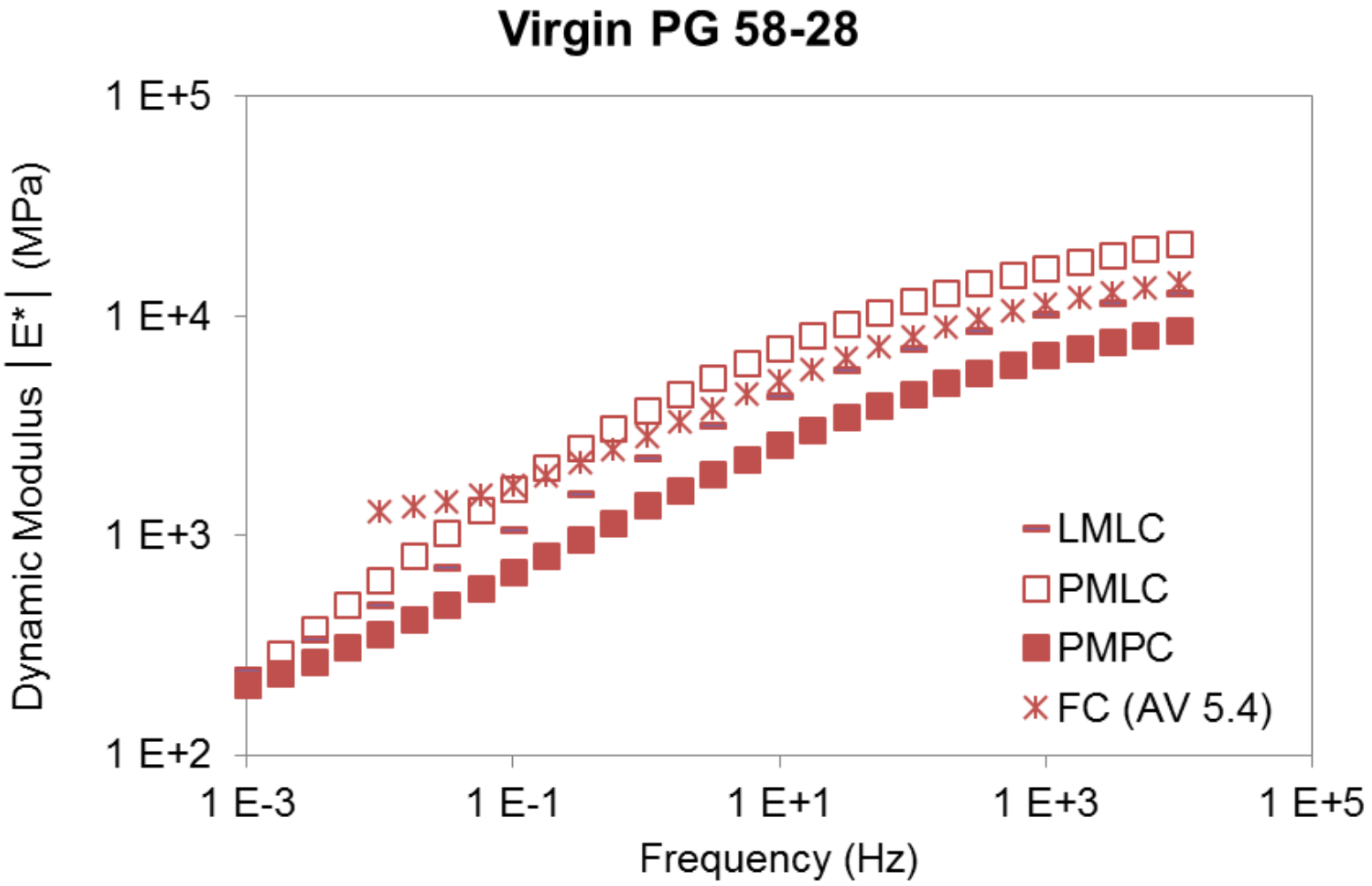


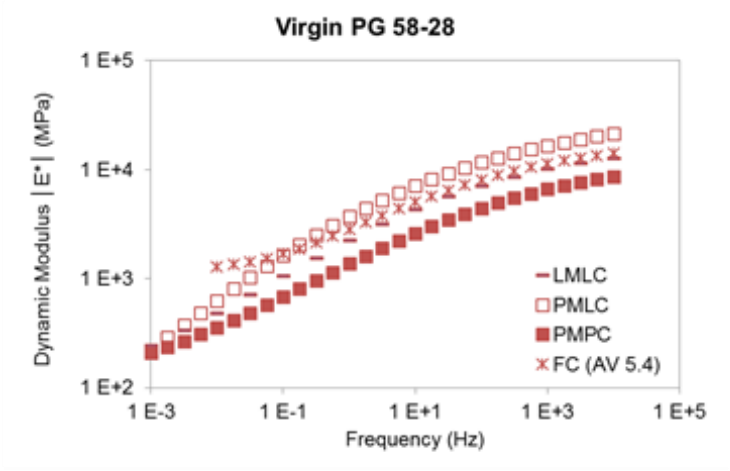


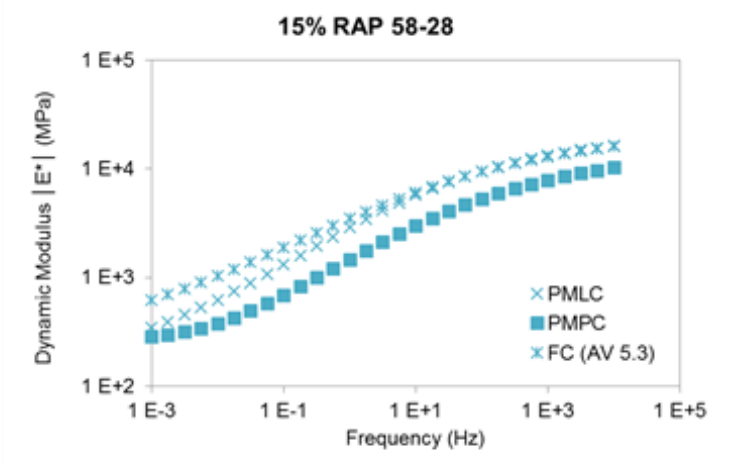


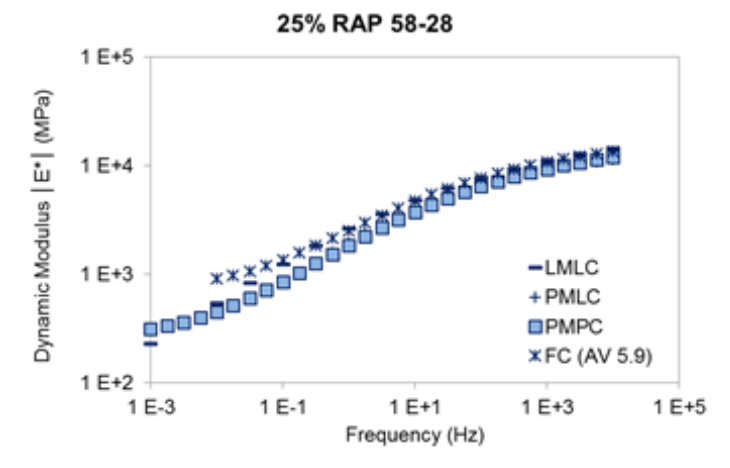


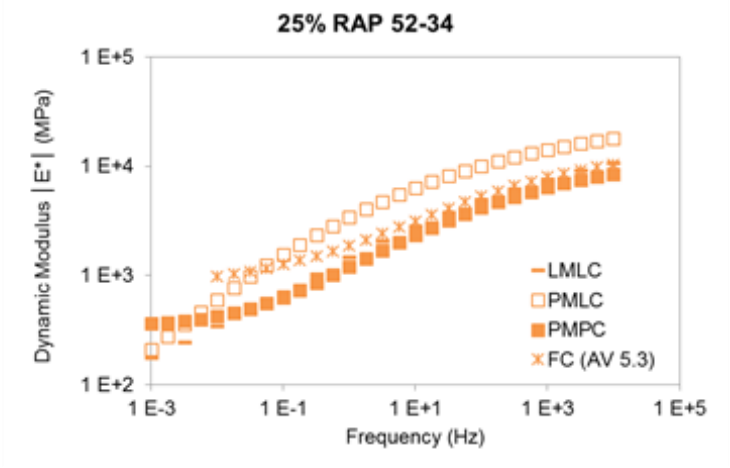
Plant vs Lab, Reheat and Field

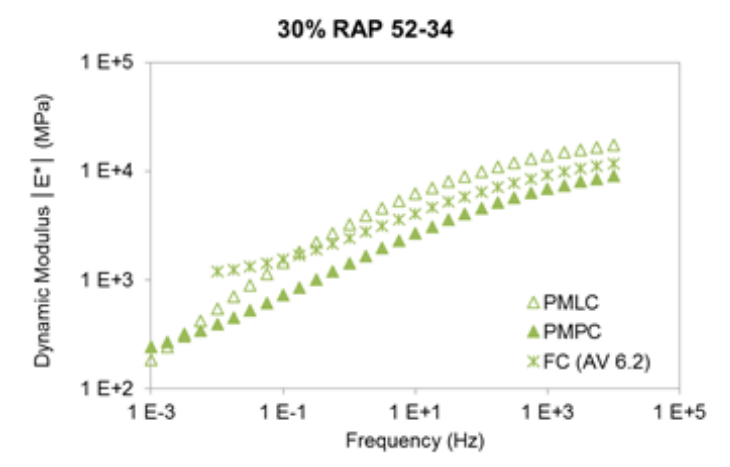


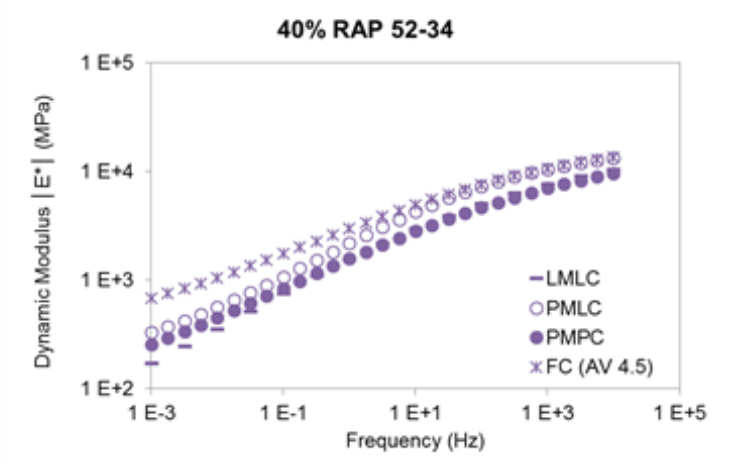

Virgin PG 58-28
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
LMLC
PMLC
PMPC
FC (AV 5.4)


15% RAP 58-28
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
PMLC
PMPC
FC (AV 5.3)


25% RAP 58-28
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
LMLC
PMLC
PMPC
FC (AV 5.9)


25% RAP 52-34
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
LMLC
PMLC
PMPC
FC (AV 5.3)


30% RAP 52-34
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
PMLC
PMPC
FC (AV 6.2)


40% RAP 52-34
Dynamic Modulus |E*| (MPa)
1 E+5
1 E+4
1 E+3
1 E+2
1 E-3
1 E-1
1 E+1
1 E+3
1 E+5
Frequency (Hz)
LMLC
PMLC
PMPC
FC (AV 4.5)

Phase I & II Summary

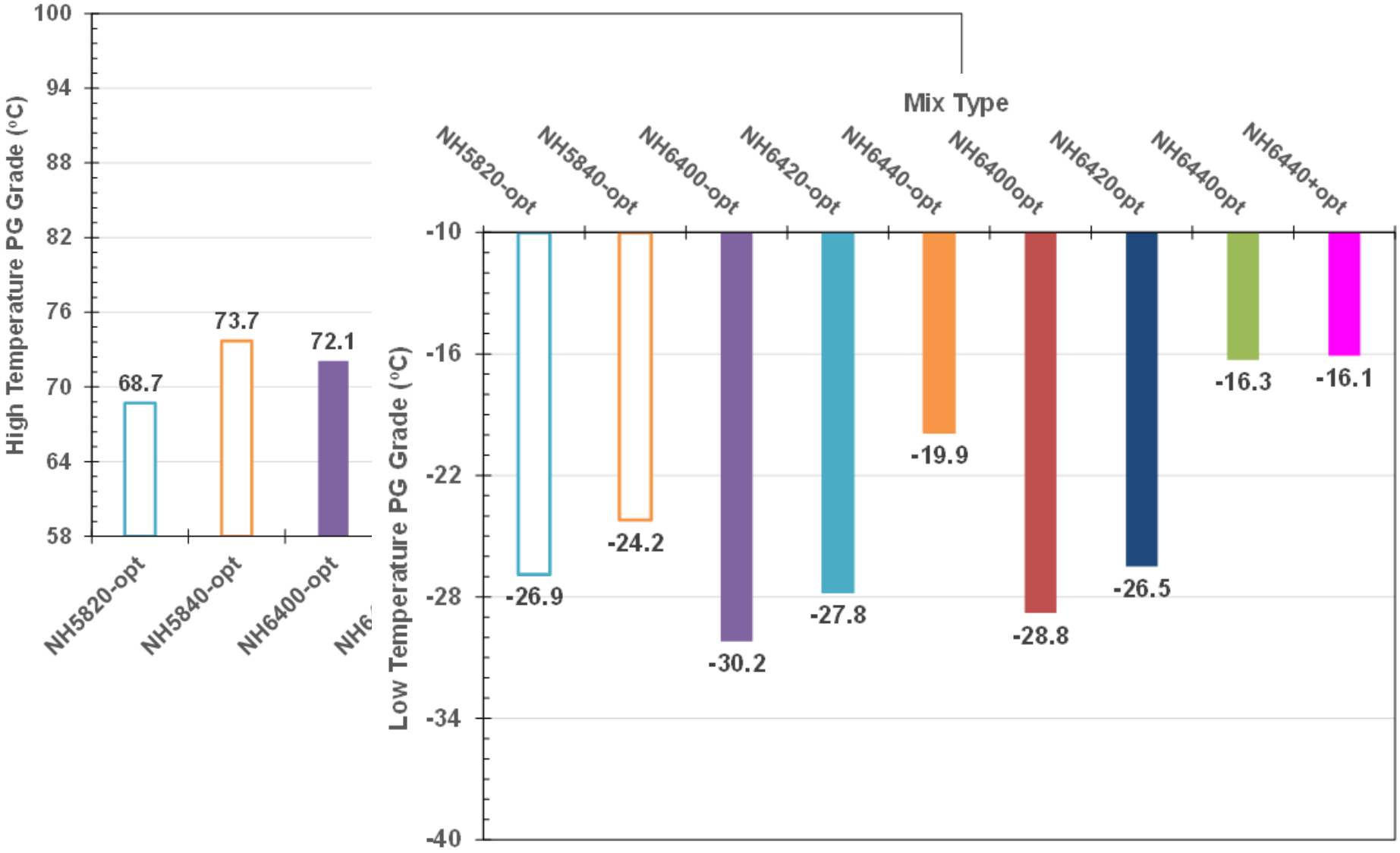
- Amount of stiffening impacted by:
  - Specimen preparation
  - RAP stiffness (soft VT RAP)
  - Virgin binder grade
  - Production parameters (temp, silo)
- Cracking resistance decreased, results mixed depending on test
- Dropping PG grade: mixed results

PHASE III LABORATORY STUDY

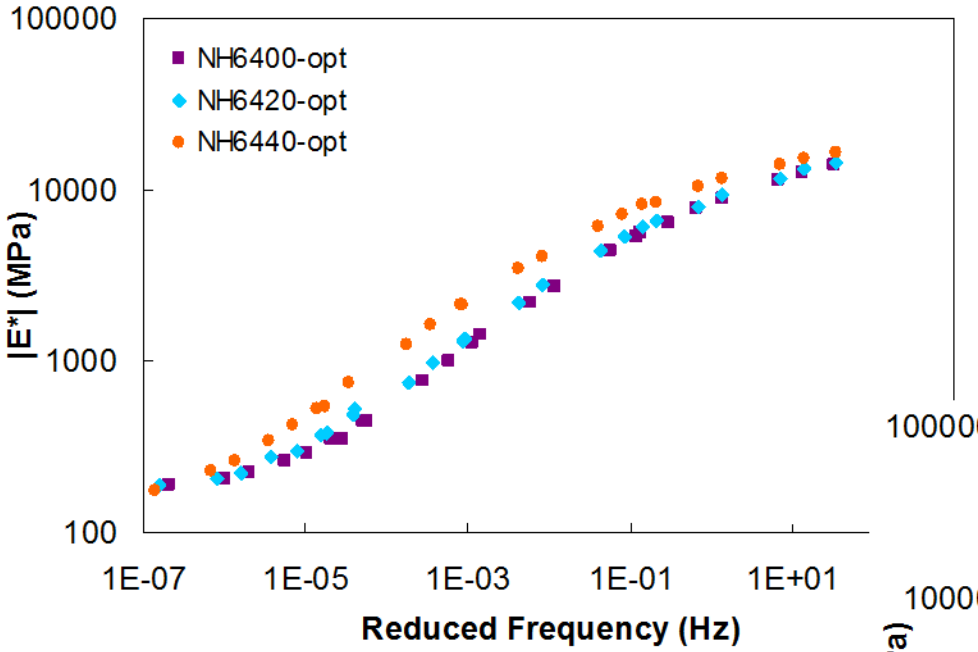
Phase III Testing Plan

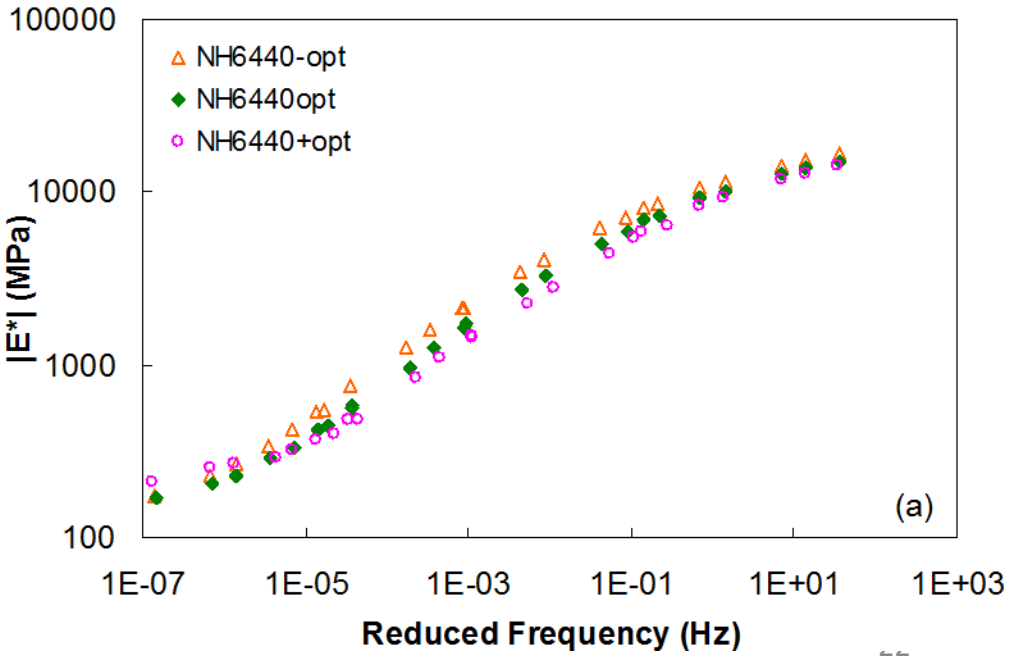
Mixture	Asphalt content	RAP Content (total weight)		
		0	**20**	**40**
NH Phase I	Opt-0.5%	PG 64-28	PG 64-28 PG58-28	PG 64-28 PG 58-28
	Opt	PG 64-28	PG 64-28	PG 64-28
	Opt+0.5%	-	-	PG 64-28

Recovered Binder Grades

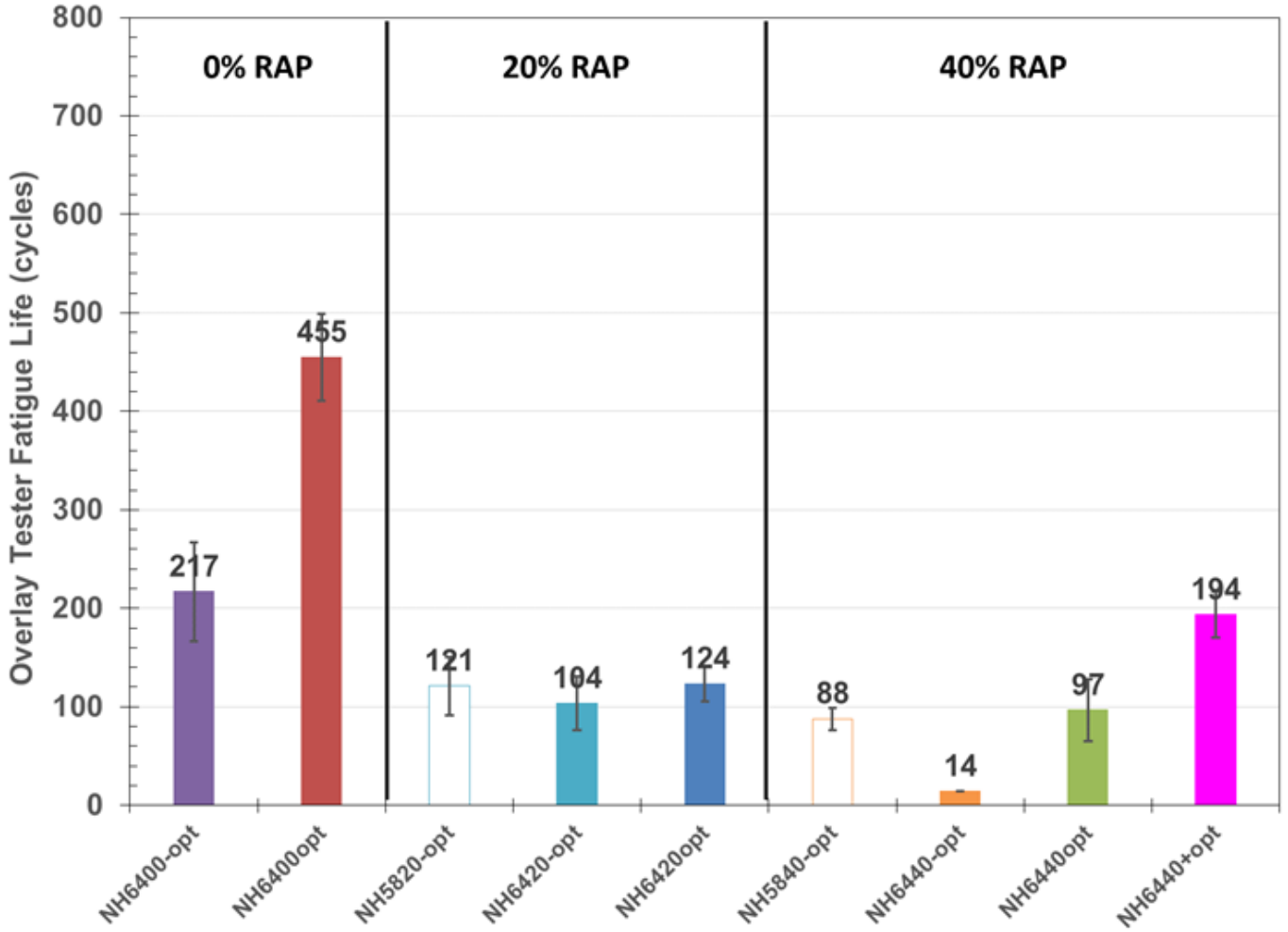


Dynamic Modulus

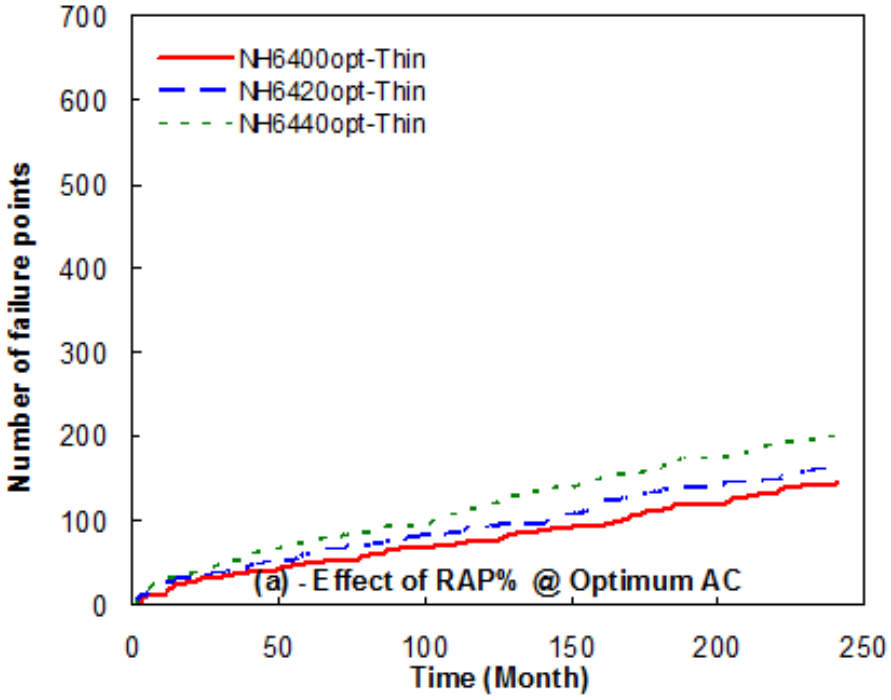


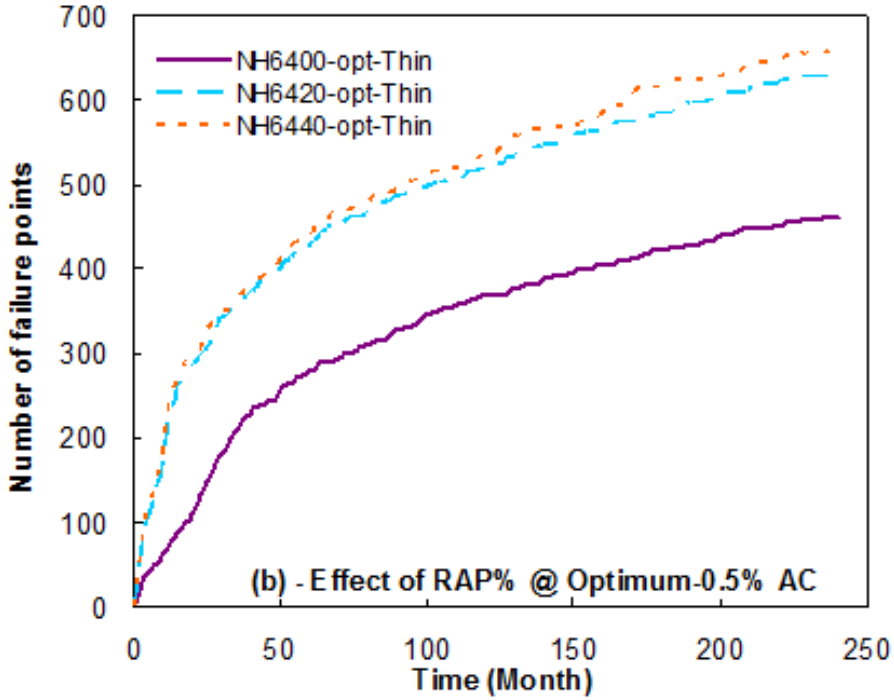


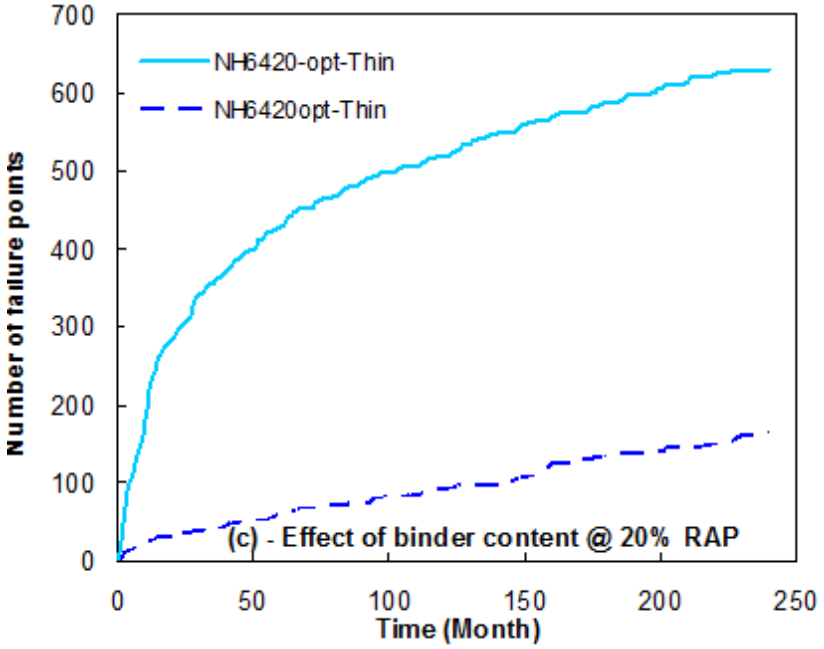
Overlay Tester

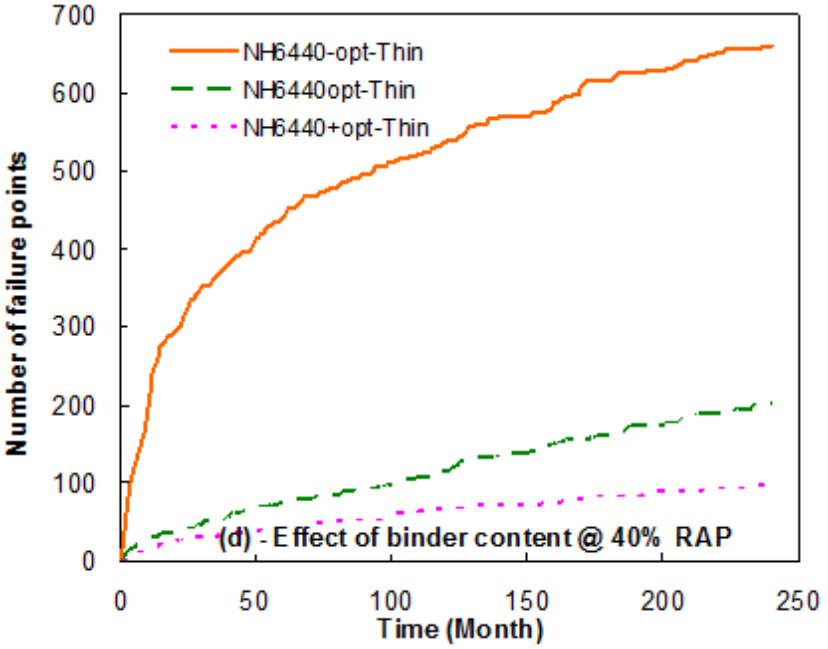


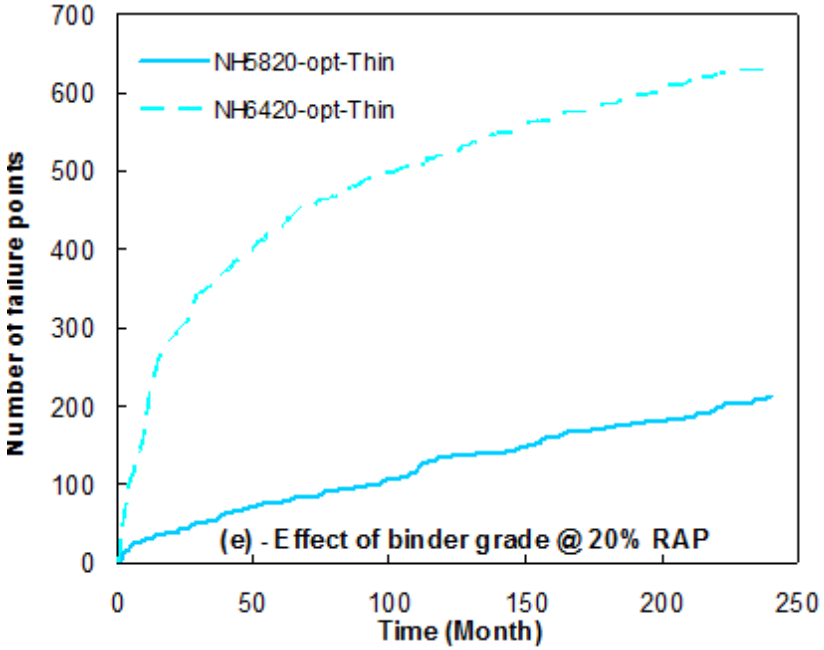
LVECD Fatigue Analysis

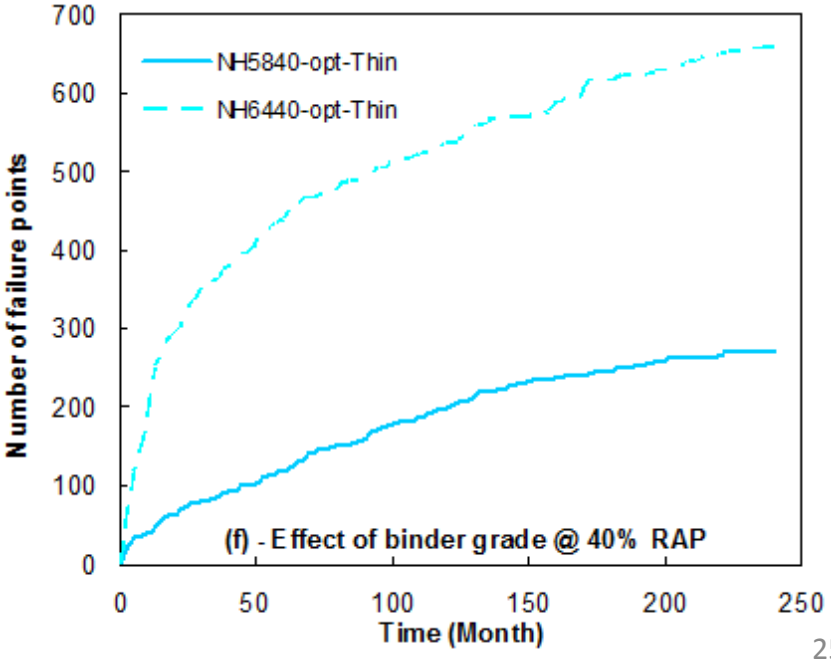




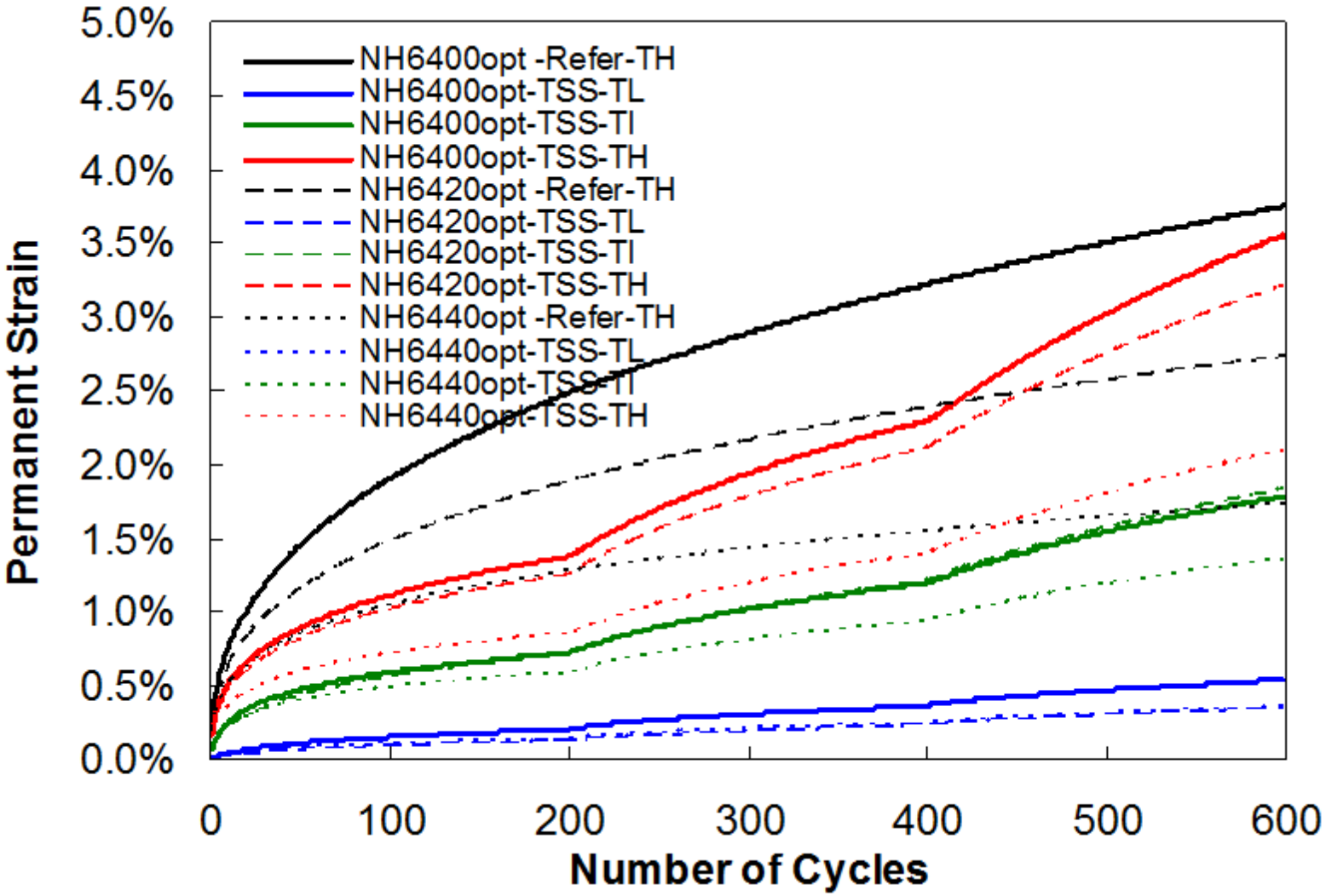

NH6420-opt-Thin
NH6420opt-Thin
Number of failure points
Time (Month)
(c) - Effect of binder content @ 20% RAP


NH6440-opt-Thin
NH6440opt-Thin
NH6440+opt-Thin
Number of failure points
Time (Month)
(d) - Effect of binder content @ 40% RAP

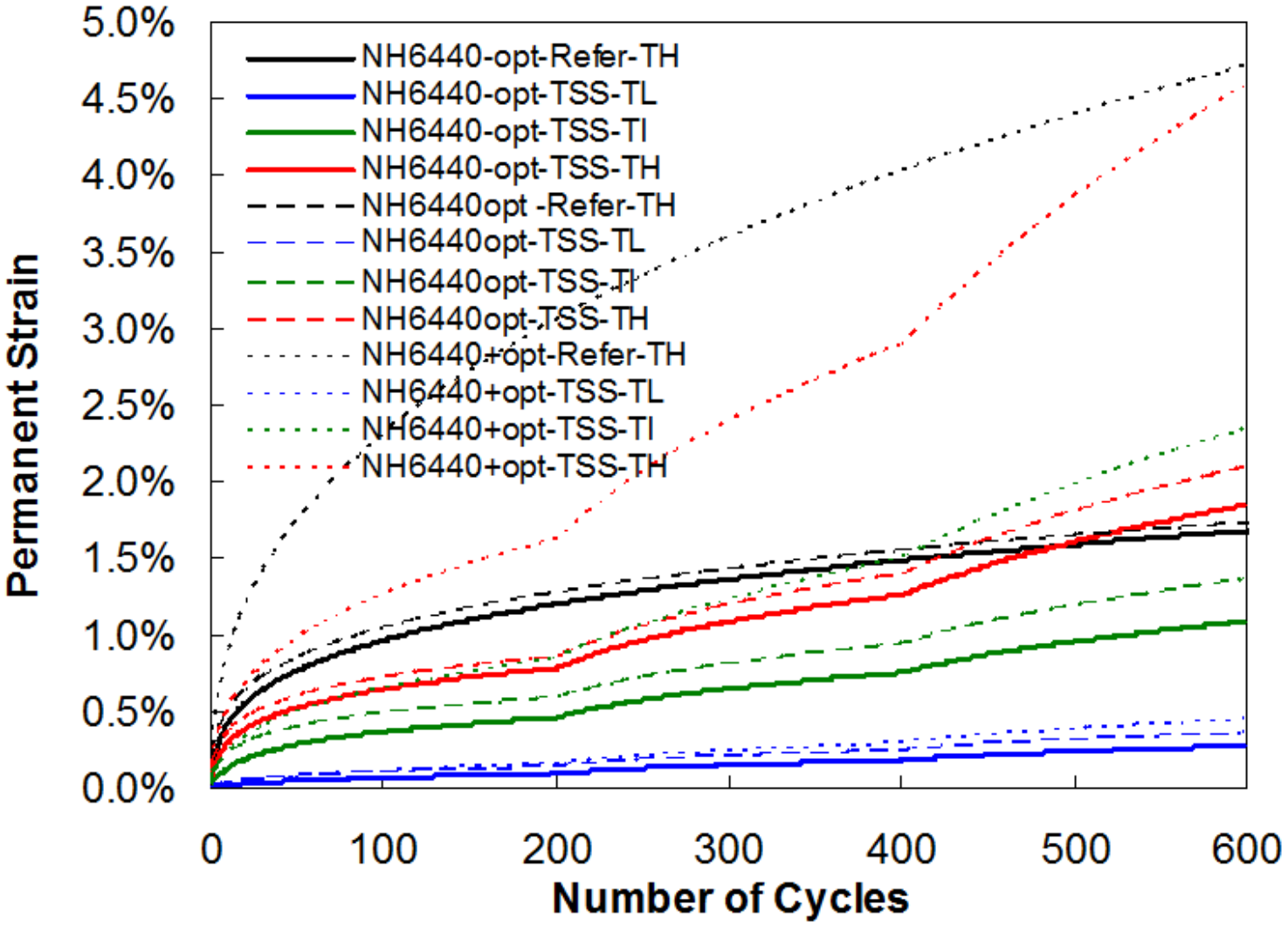

NH5820-opt-Thin
NH6420-opt-Thin
Number of failure points
Time (Month)
(e) - Effect of binder grade @ 20% RAP


NH5840-opt-Thin
NH6440-opt-Thin
Number of failure points
Time (Month)
(f) - Effect of binder grade @ 40% RAP

Permanent Deformation – RAP content



Permanent Deformation – % ac



Phase III Summary

- Better cracking performance
  - Softer PG, higher asphalt content, lower RAP content
  - Impacts of RAP greater at low asphalt content
- Better rutting performance
  - Harder PG, lower asphalt content, higher RAP content

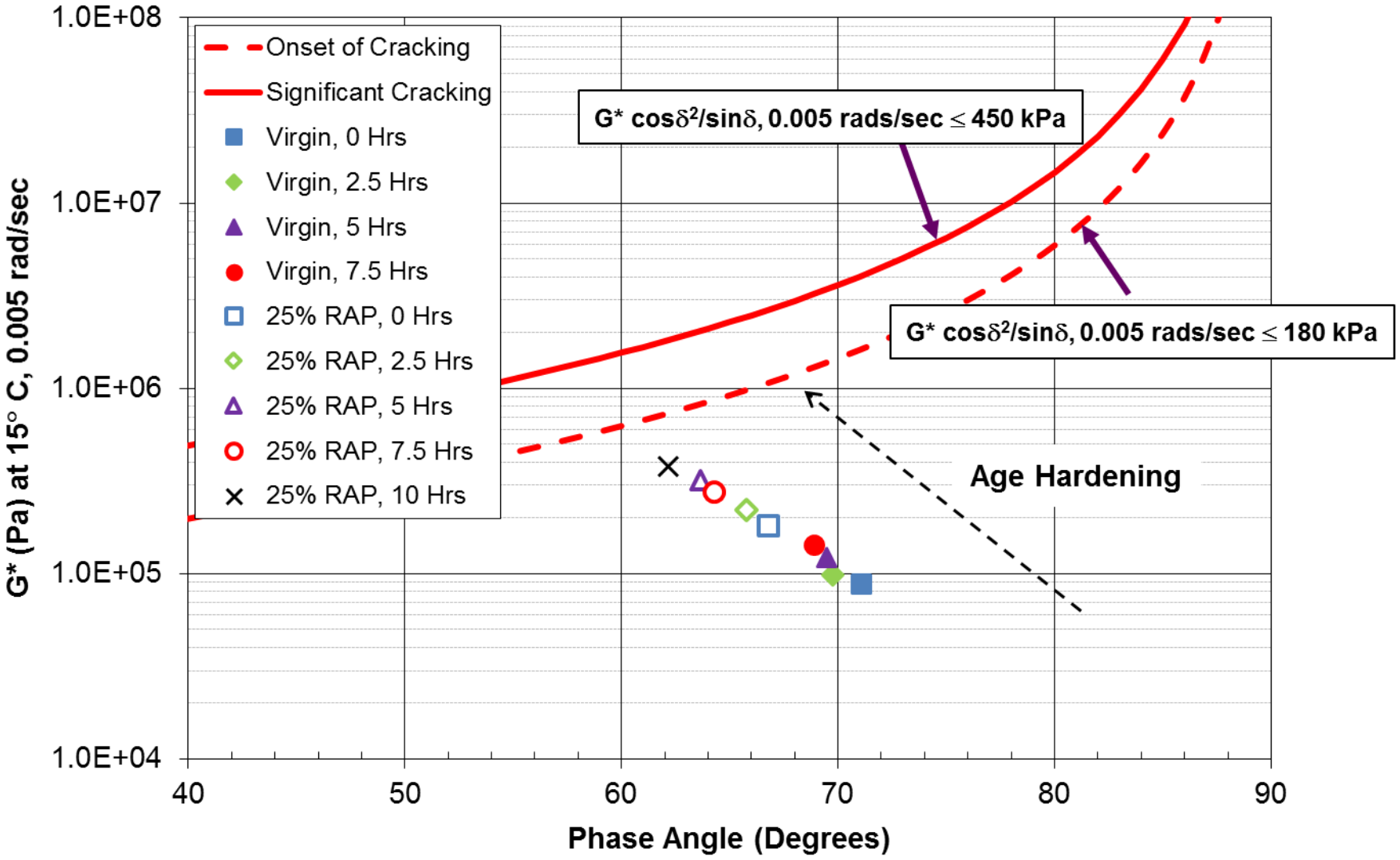
SILO STORAGE STUDY ADDITIONAL TASK

Silo Storage Study Task

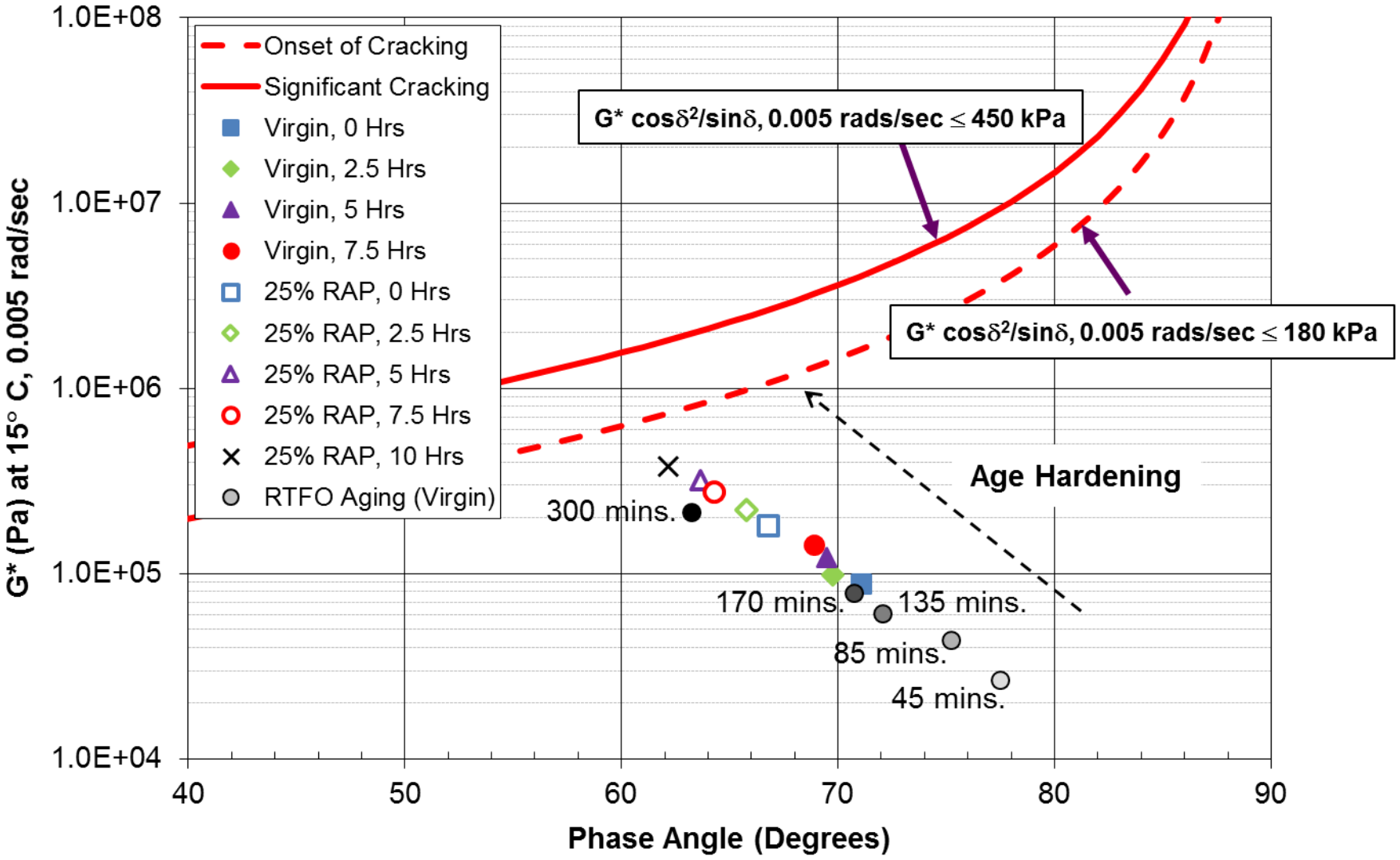
- Early phases indicated likely impact of silo storage time on measured properties
- Targeted study to evaluate storage time
- Materials
  - Virgin mixture
    - PG 64-22,12.5 mm NMAS
    - 0, 2.5, 5, 7.5 hours
  - 25% RAP mixture
    - PG 64-28,12.5 mm NMAS
    - 0, 2.5, 5, 7.5, 10 hours
- End of season
  - high production temperature

Source: www.hellotrade.com

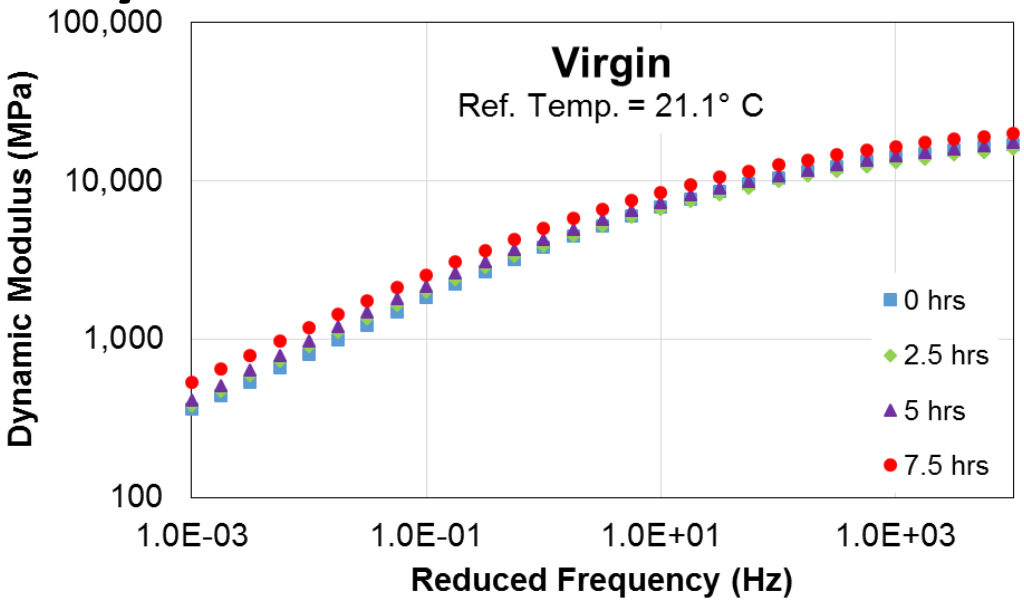
Binder: Glover-Rowe Parameter

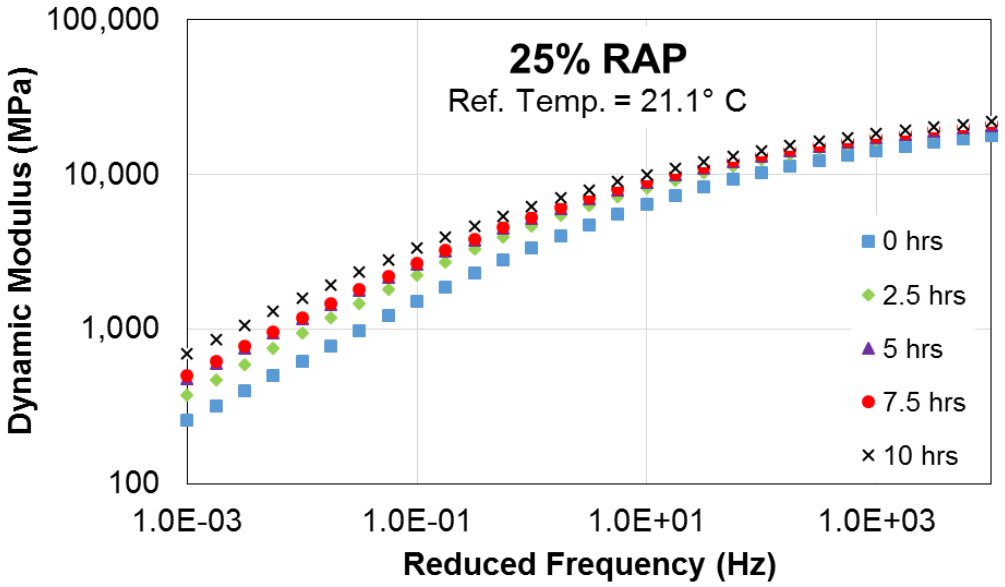


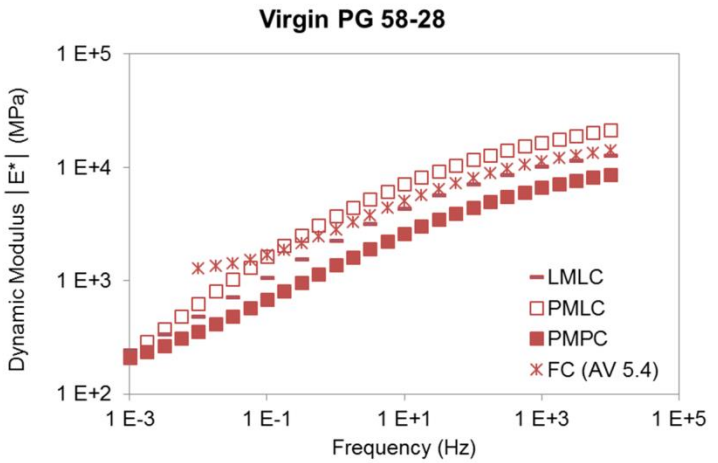
Binder: Glover-Rowe Parameter



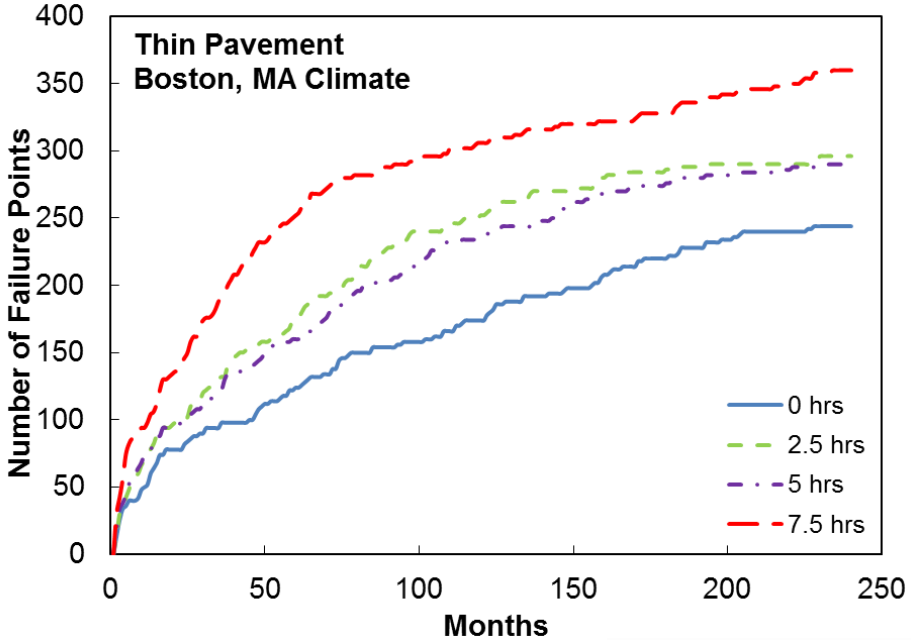
Dynamic Modulus Master Curves

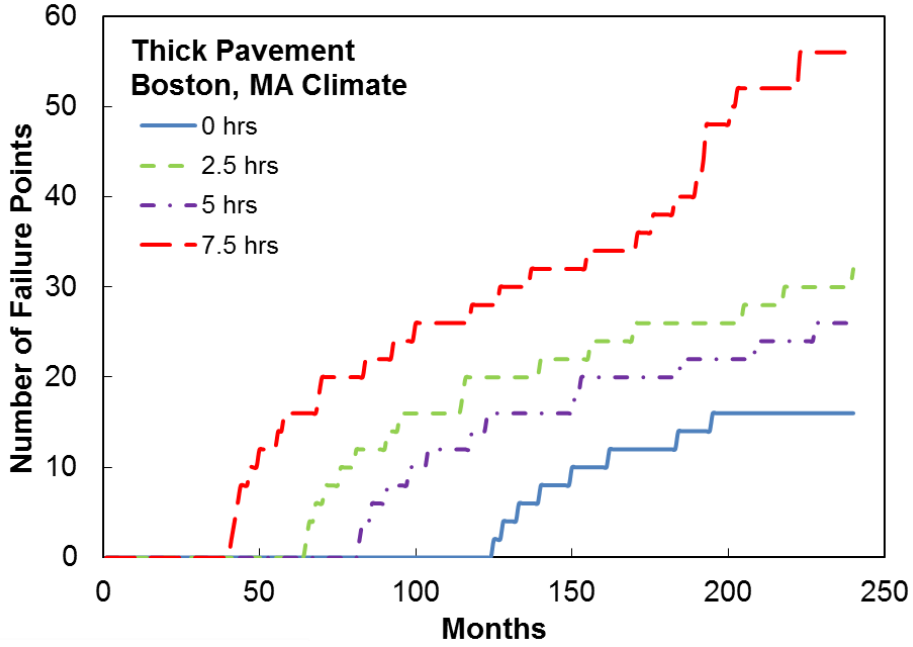


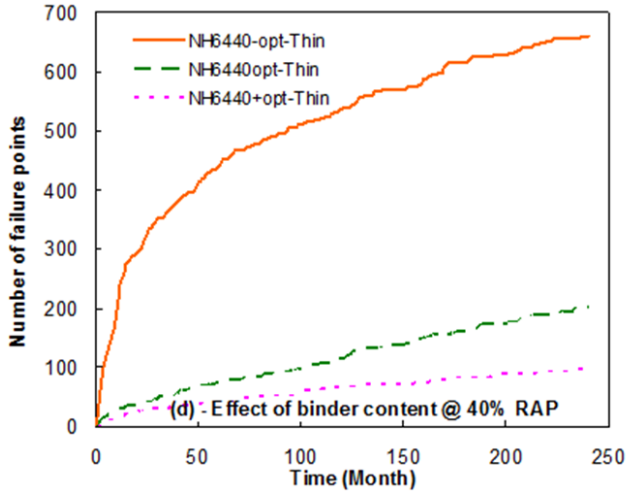




LVECD Pavement Life Evaluation







Summary of Observations

- Dropping PG grade not effective in all cases
- Virgin binder grade, RAP stiffness, and binder source important
- Plant conditions have impact on measured properties
  - Temperature, storage time
- Specimen fabrication technique matters
  - Reheating, Lab vs field
- Current laboratory protocols don’t always capture what happens in the plant
- Need to use engineering judgement

QUESTIONS & DISCUSSION