UNIVERSITY of NEW HAMPSHIRE

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

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Northeast Asphalt User/Producer Group Meeting

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Research Team

University of New Hampshire

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Dr. Y. Richard Kim, PE

Current Participants

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

Project Objectives

- Evaluate the performance of plant-produced RAP mixtures (in the laboratory and field) in terms of low temperature cracking, fatigue cracking and moisture sensitivity.

- Provide further understanding of the blending that occurs between RAP and virgin binder in plant-produced mixtures.

- Refine fatigue failure criteria for RAP mixtures that can be used in the Simplified Viscoelastic Continuum Damage (S-VECD) model.

High RAP Pooled Fund Study

- Contractors have volunteered to produce mixtures at different RAP contents
- Mixtures sampled and taken to lab for testing
- SGC specimens compacted at time of production
- Data collected on plant operations, raw material info, placement location & conditions (field cores if possible)

Testing

- Recovered Binder
  - PG grade
  - CCT
  - ABCD
  - 4 mm diameter DSR
- Mixture
  - Dynamic Modulus
  - Hamburg & TSR
  - Low Temperature Creep & Strength
  - Fatigue (AMPT S-VECD protocol): crack initiation
  - Overlay Tester: crack propagation
  - Beam Flexure

Project Timeline

- Year 1: Production of Phase I mixtures, laboratory testing and data analysis.

- Year 2: Phase II mixtures produced, continuation of testing, data analysis, monitoring and construction of field sections, and refinement of fatigue failure criterion.

- *Year 3: Final Phase II mixtures produced, completion of testing, monitoring field sections, data analysis and synthesis, and preparation of final report*.

Outline

- Summary of completed Phase I testing
  - Stiffness
  - Fatigue
  - Low Temperature
- Phase II Silo storage study
  - Extracted binder
  - Stiffness

Phase I Mixtures: 2010 Production

Plant	NMAS (mm)	PG Grade	RAP Content (%)			
			0	20	30	40
Callanan NY (drum)	12.5	64-22	x	x	x	x
		58-28			x	x
Pike VT (batch)	9.5	58-28	x	x	x	x
		52-34	x	x	x	x
Pike NH (drum)	12.5	64-28	x	x	x	x

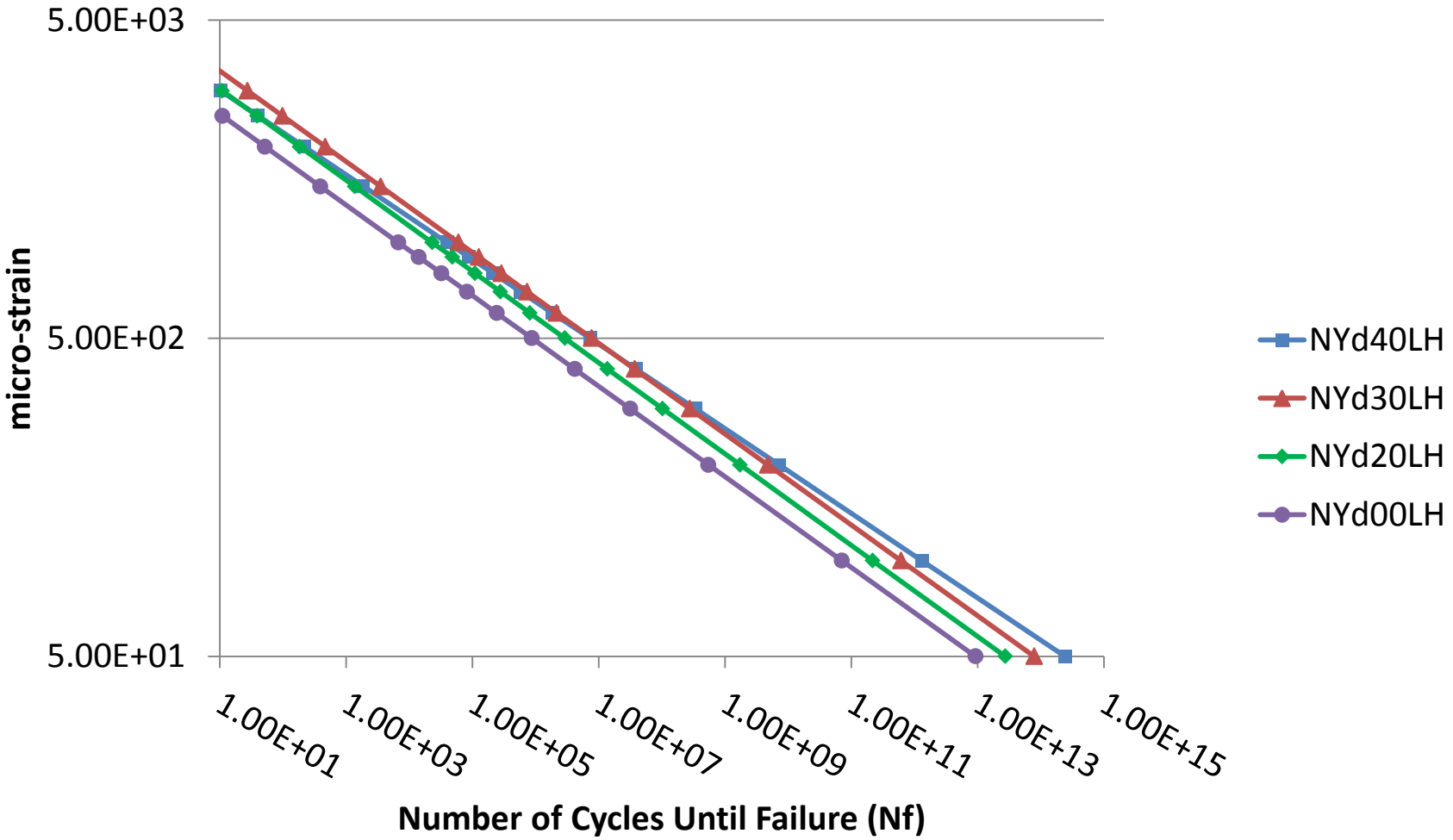
Phase I: Published Results Summary

- AAPT 2012 by Mogawer, et al.
- Increased RAP generally increased stiffness
- Increased RAP decreased resistance to crack propagation (OT)
- Softer binder grade effective in some cases for mitigating increase in stiffness and cracking (OT)
- Apparent effect of plant production (silo storage, temperature) on stiffness
- Reheated materials stiffer, effect of RAP and/or silo storage time

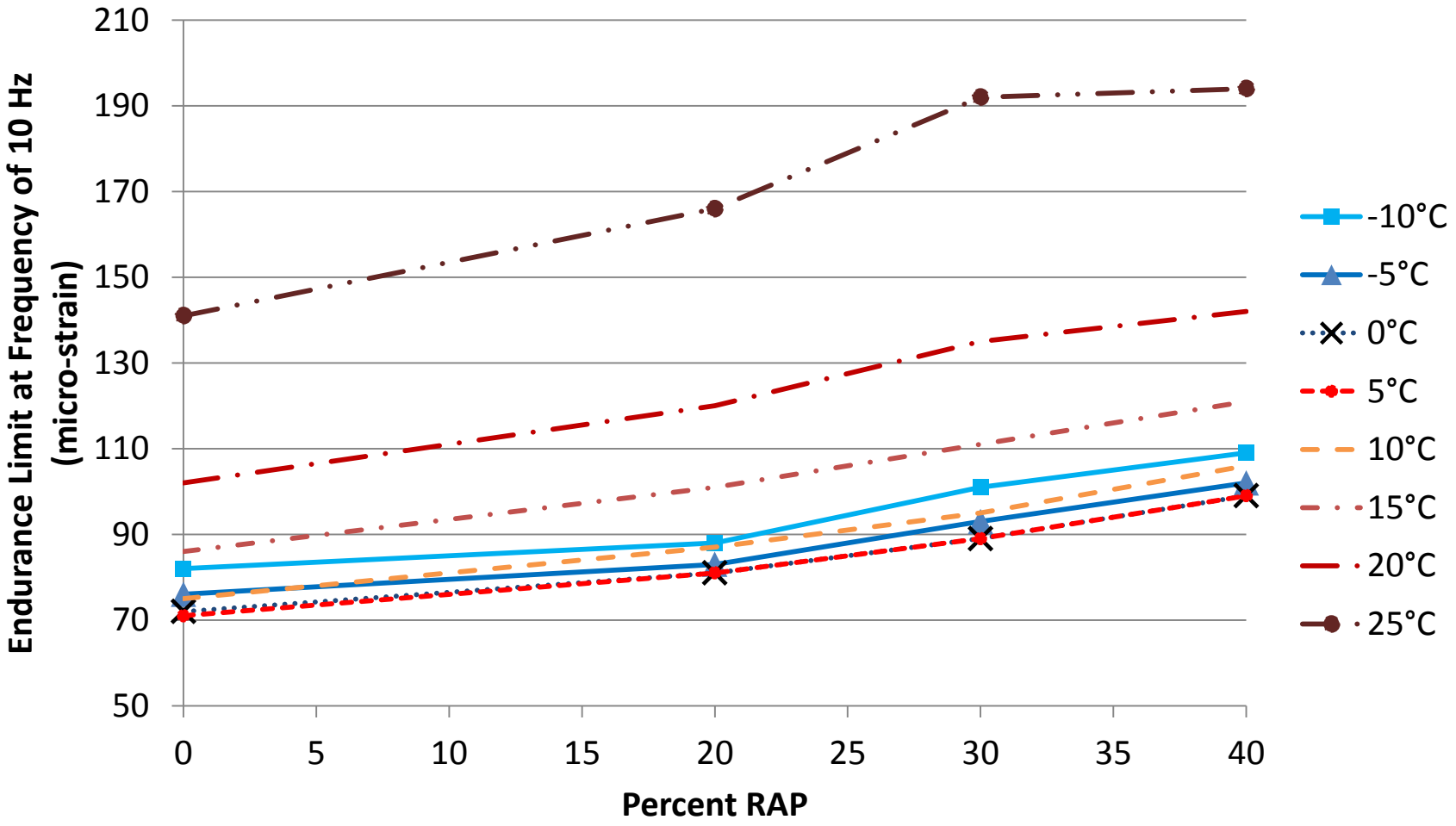
Phase I: Current Results Summary

- Fatigue (AMPT S-VECD): crack initiation
- Low Temperature
  - Extracted Binder
  - Low Temperature creep and strength
  - TSRST
- NY Mixtures shown

Fatigue Life Prediction NY PG 64-22



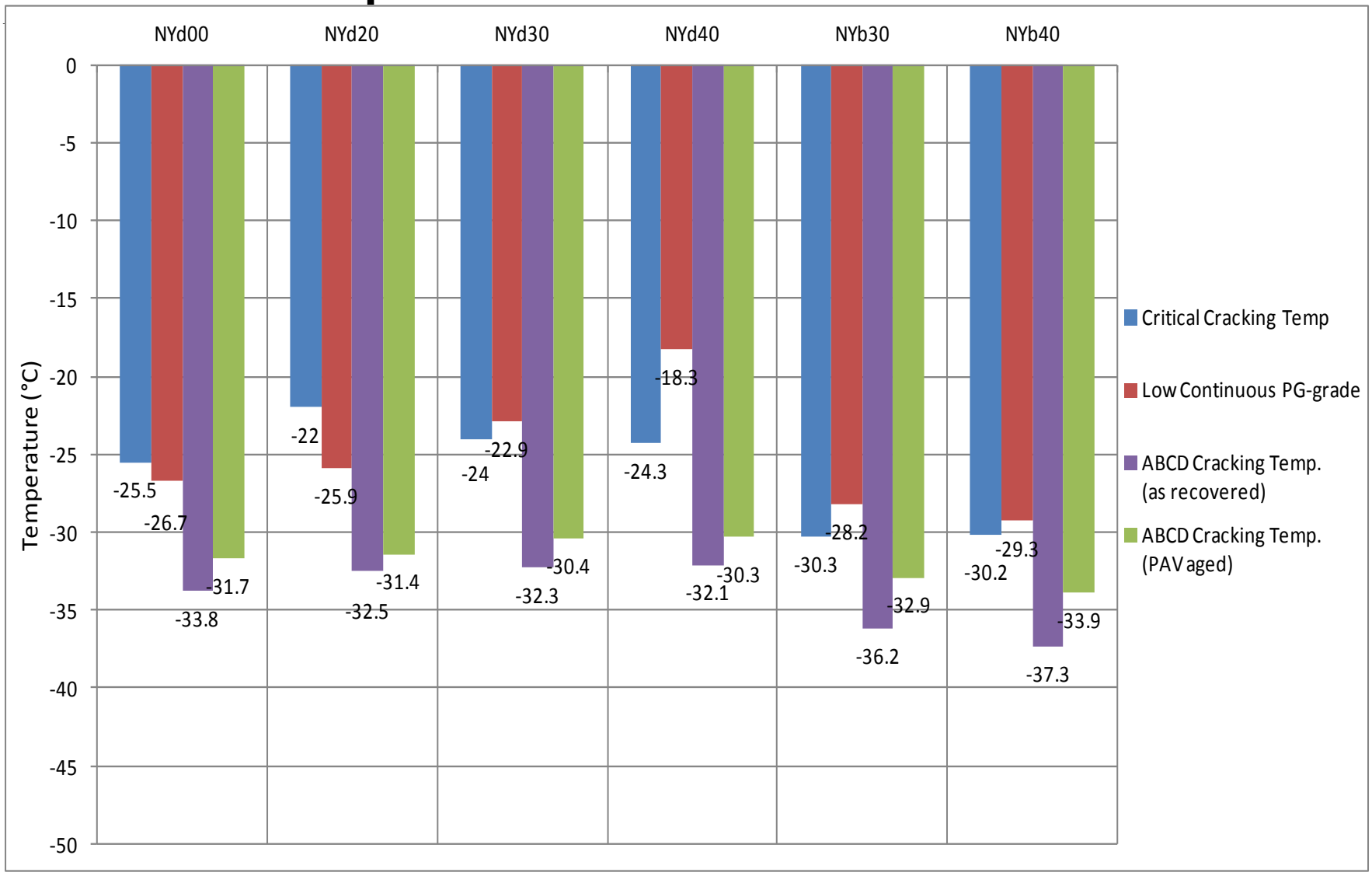
Endurance Limit for NY Mixtures PG 64-22



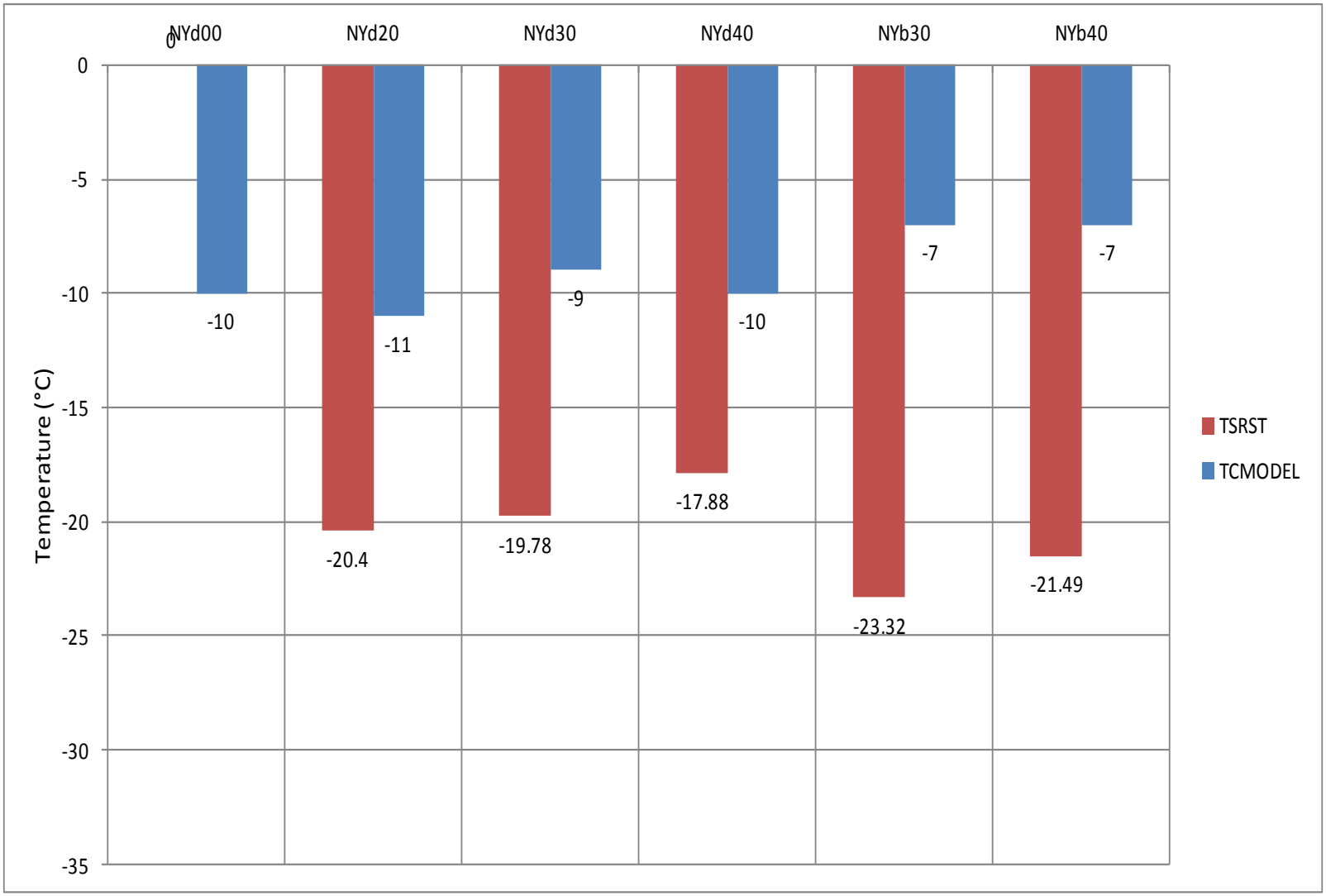
SVECD Fatigue Summary

- Rankings change depending on strain level. Higher RAP better at low strains
- Softer binder grade decreases slope of N_f curve
- Higher RAP contents increase endurance limit

Low Temp Extracted Binder Results



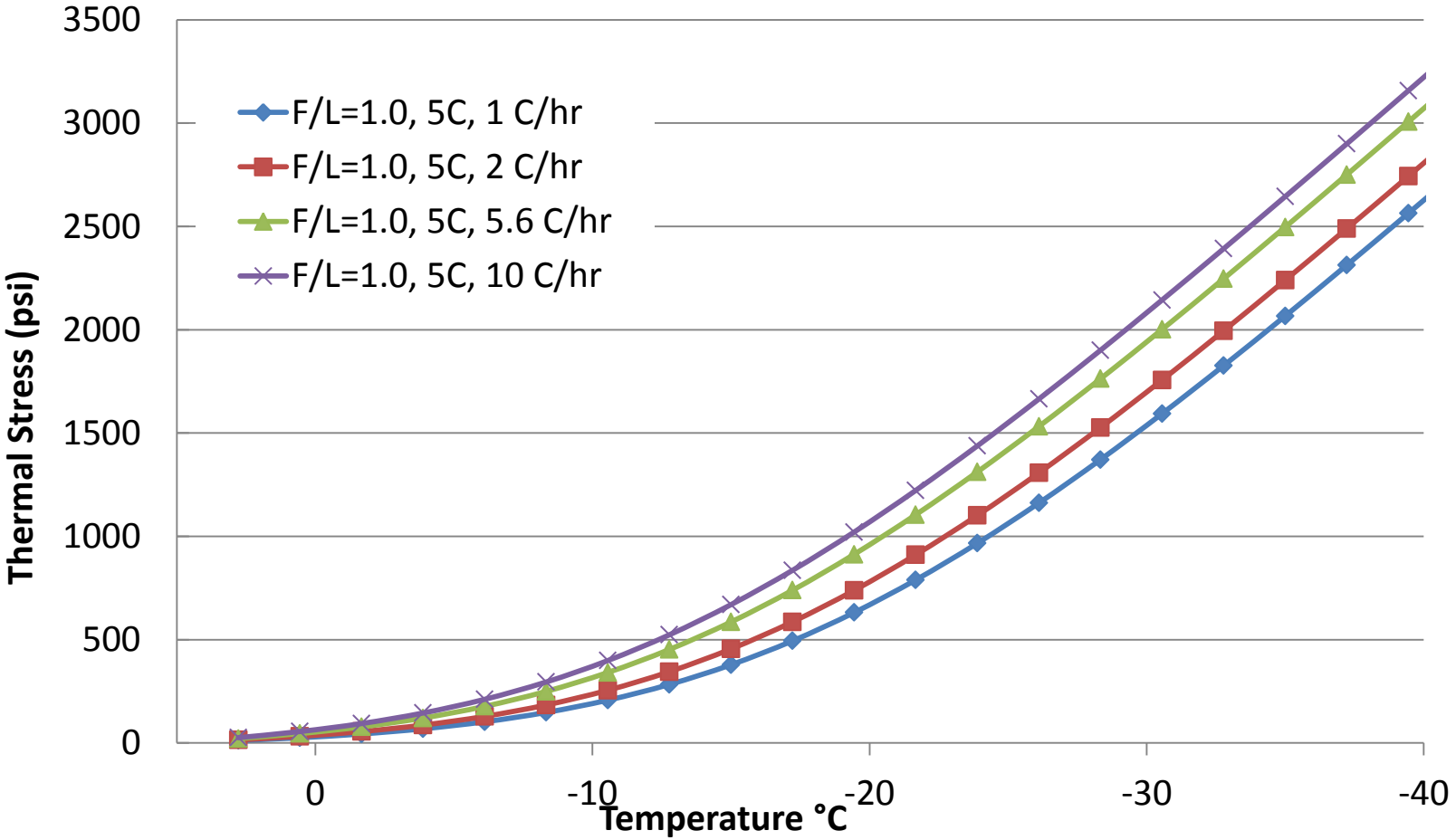
Low Temp Mixture Testing Results



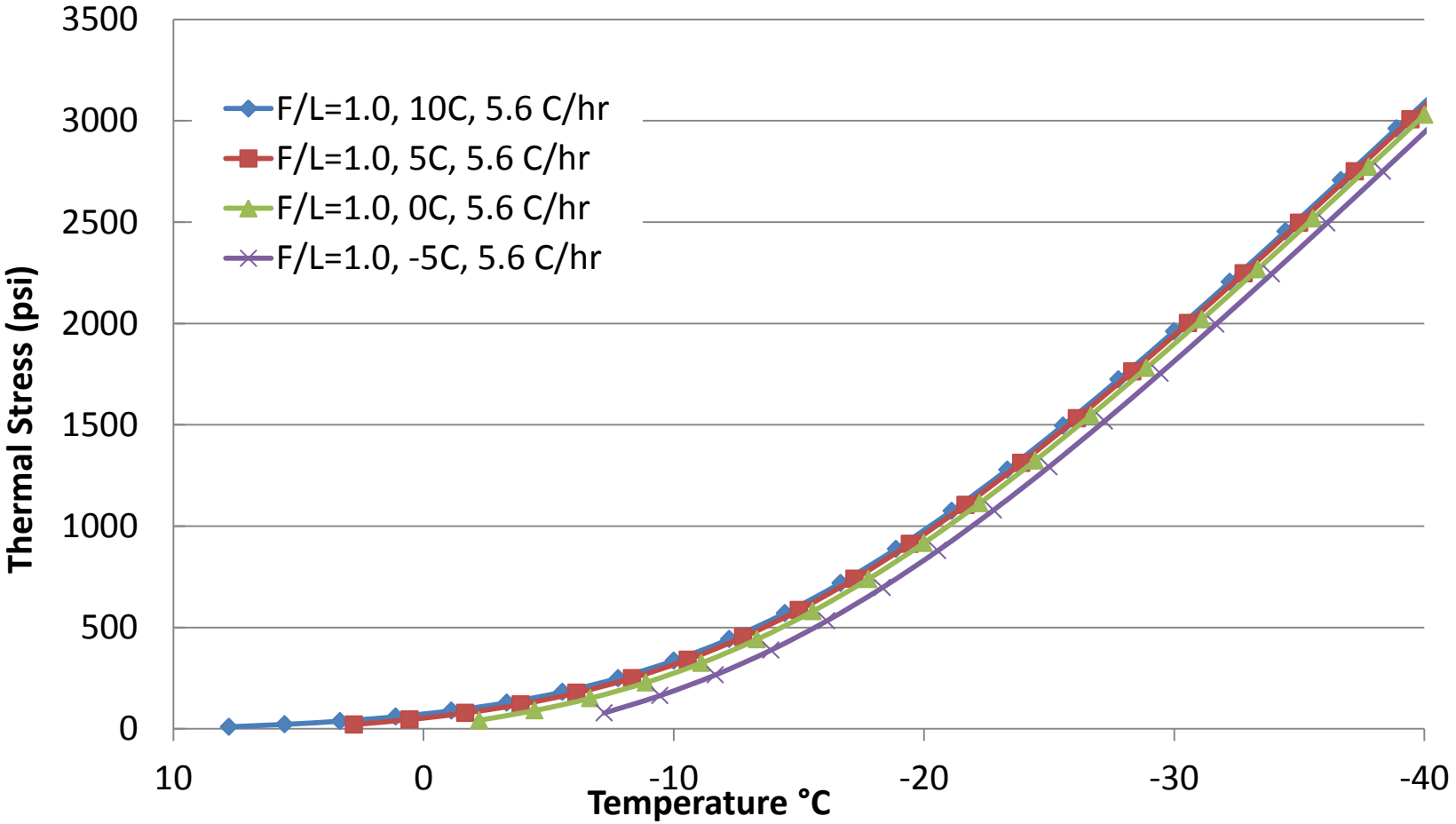
Testing and Analysis Parameters

Method	Initial Temp (C)	Cooling Rate (C/hr)
Binder CCT	0	10
ABCD	0	20
TCMODEL (mix)	10	5.6
TSRST	5	10

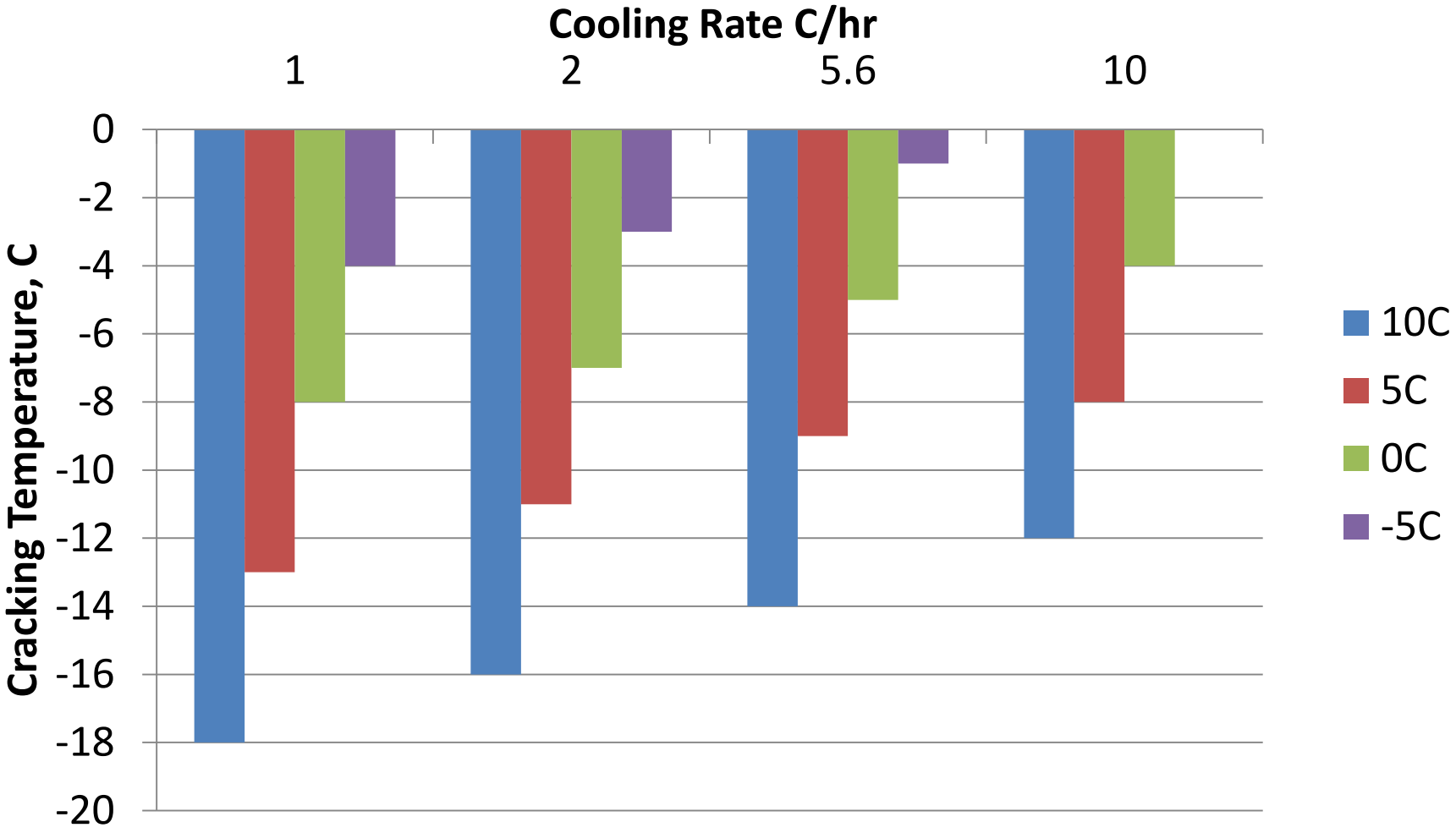
Impact of Cooling Rate TCMODEL: NY40% PG64-22



Impact of Initial Temperature TCMODEL: NY40% PG64-22



TCMODEL: NY Virgin PG 64-22

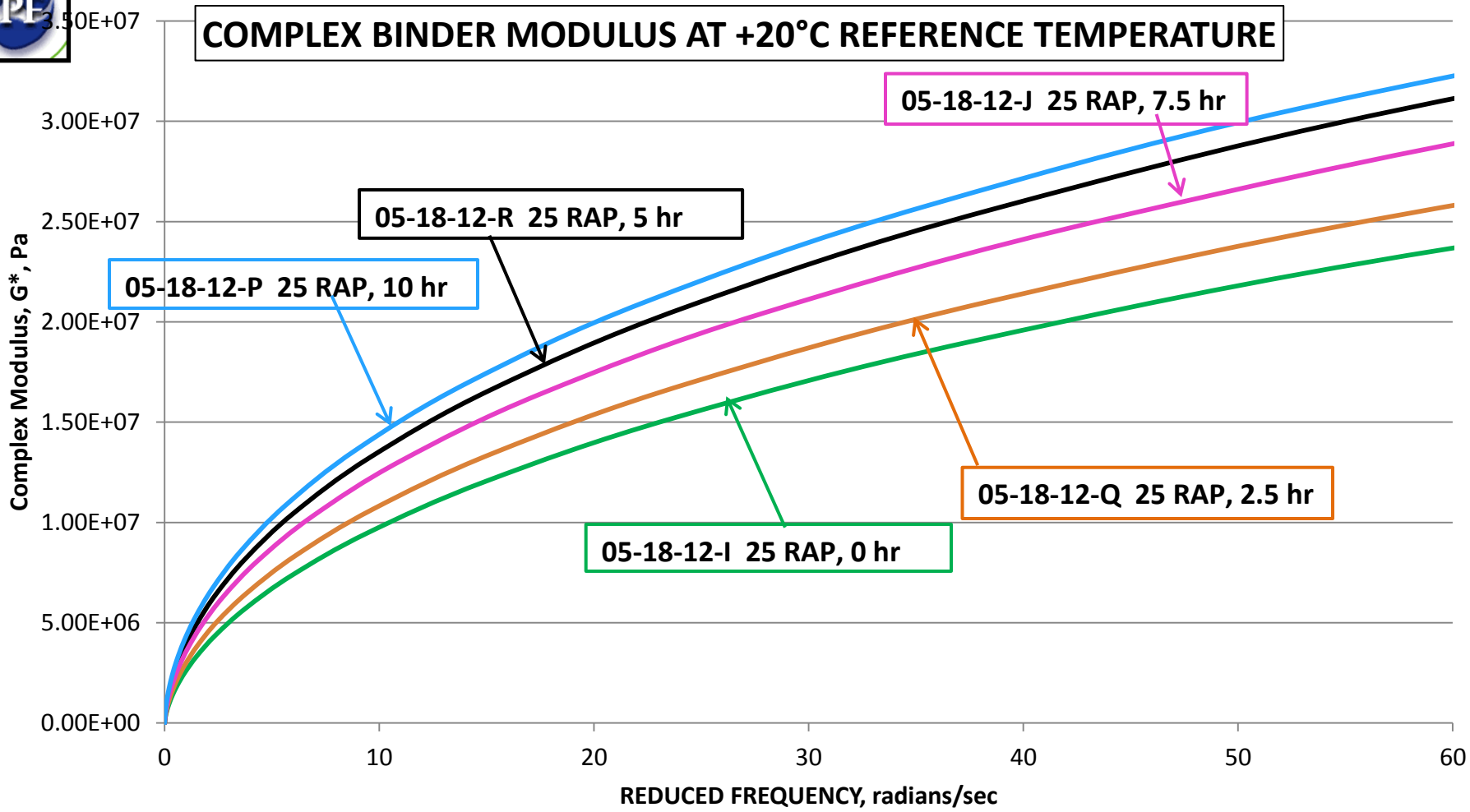


Low Temperature Summary

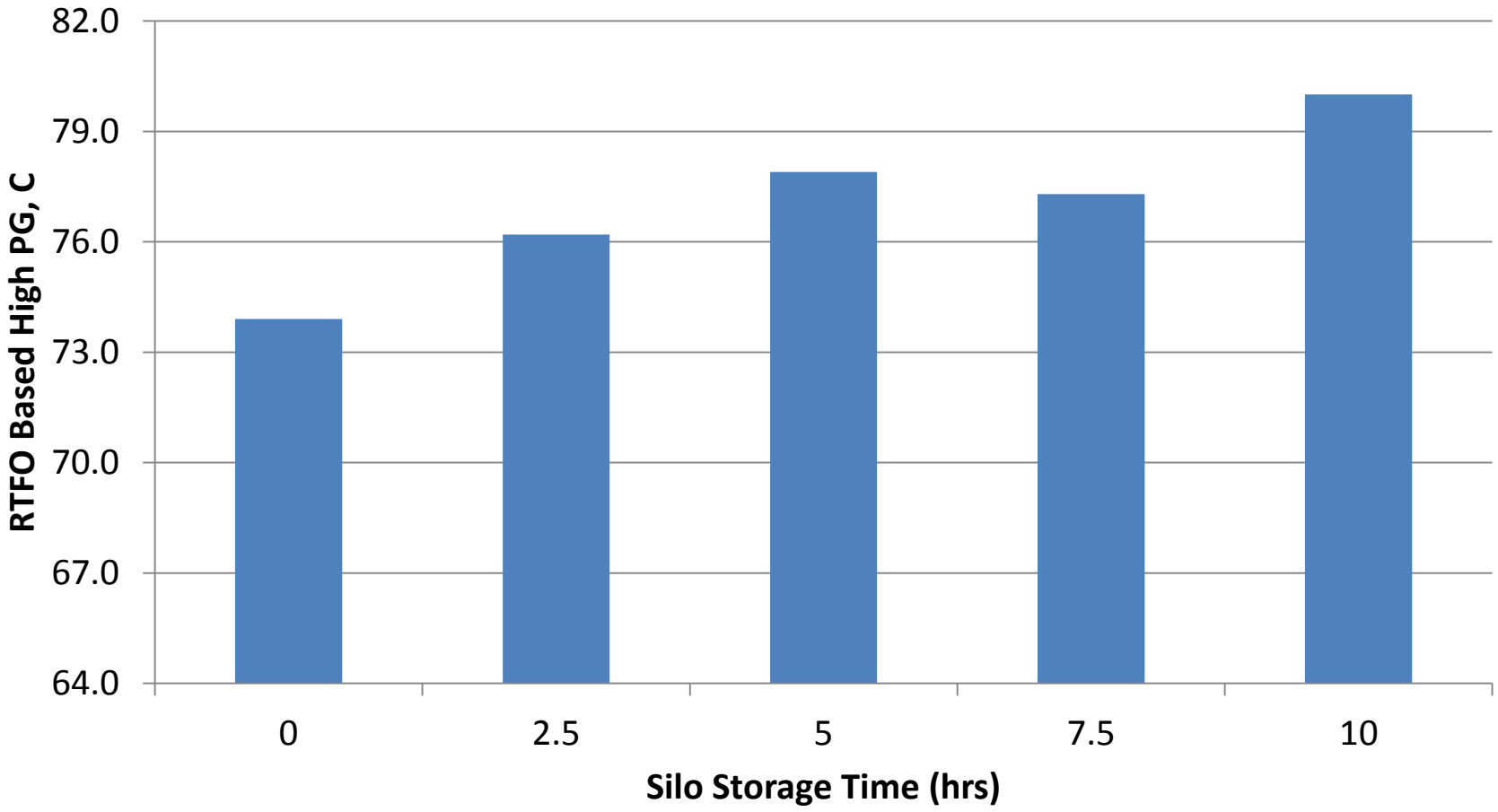
- Generally warmer cracking temperatures with increase in RAP content
- Softer virgin binder may help mitigate
- Impact of starting temperature and cooling rate used for testing and analysis
- Further investigation and analysis continuing

Silo Storage Study

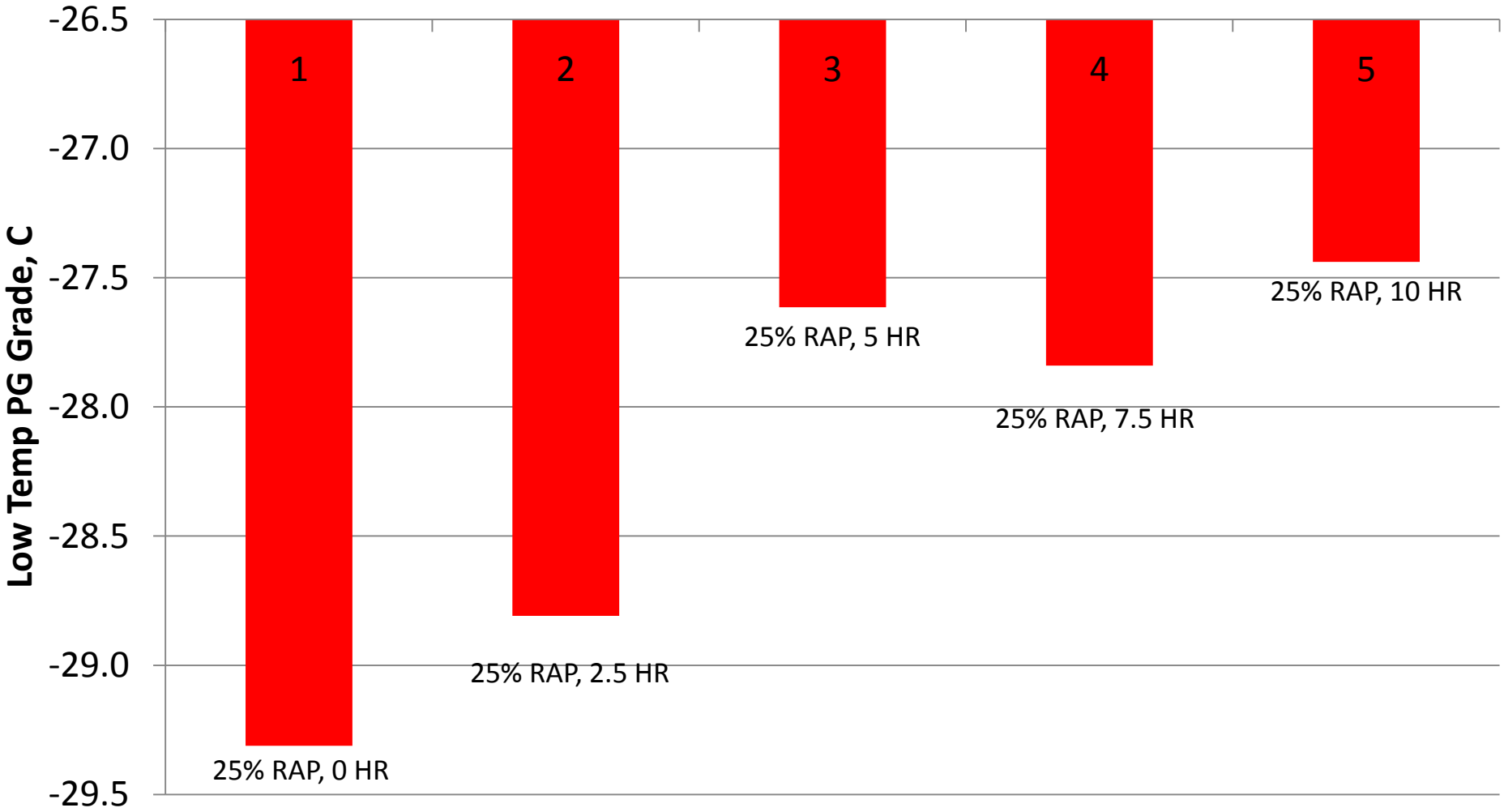
- Callanan 12.5 mm mixture with PG 64-22
  - Virgin: 0, 2.5, 5.0, 7.5 hours storage (~340 F)
  - 25% RAP: 0, 2.5, 5.0, 7.5, 10.0 hours storage (~340 F)
- Mix testing
  - Plant compacted specimens
  - Loose mix collected and compacted in lab
  - |E*|, fatigue, TSRST
- Binder extracted & recovered from plant compacted specimens
  - PG grading, 4 mm|G*|
  - Special thanks to Gerry Reinke


COMPLEX BINDER MODULUS AT +20°C REFERENCE TEMPERATURE
Complex Modulus, G*, Pa
3.50E+07
3.00E+07
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
0
10
20
30
40
50
60
REDUCED FREQUENCY, radians/sec
05-18-12-J 25 RAP, 7.5 hr
05-18-12-R 25 RAP, 5 hr
05-18-12-P 25 RAP, 10 hr
05-18-12-Q 25 RAP, 2.5 hr
05-18-12-I 25 RAP, 0 hr

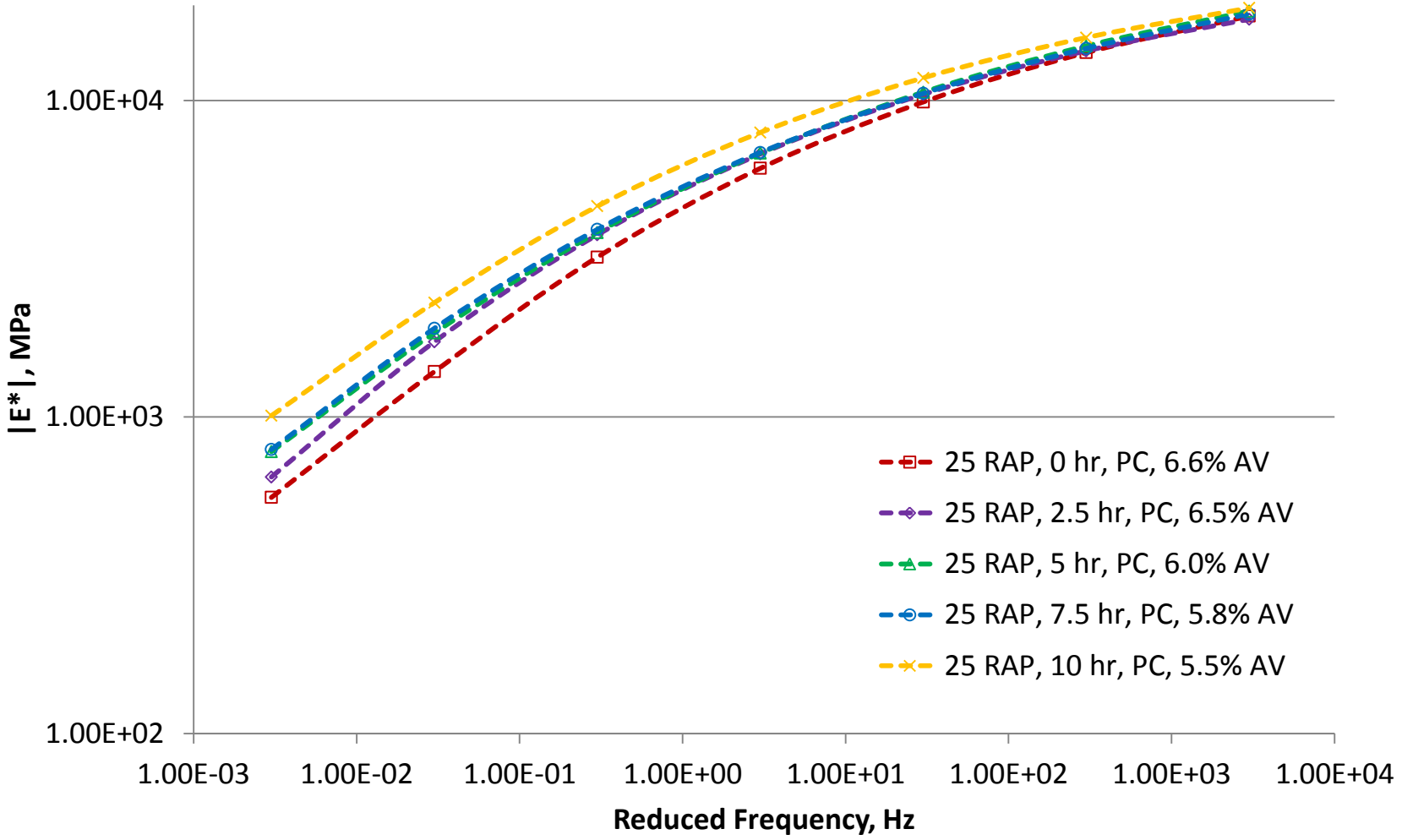
High Temp Grade 25% RAP Recovered



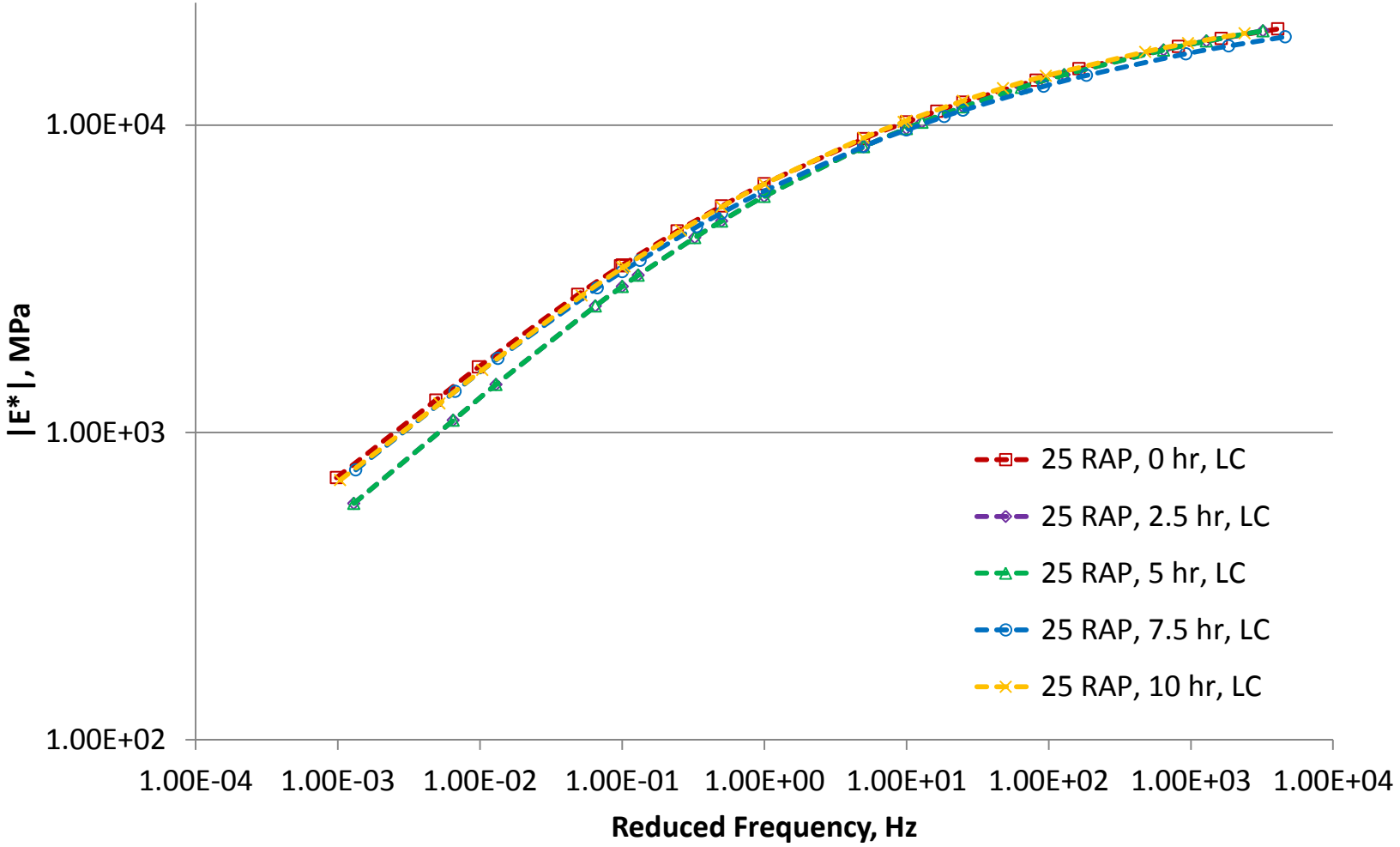
LOW TEMP GRADE 25% RAP RECOVERED BINDER



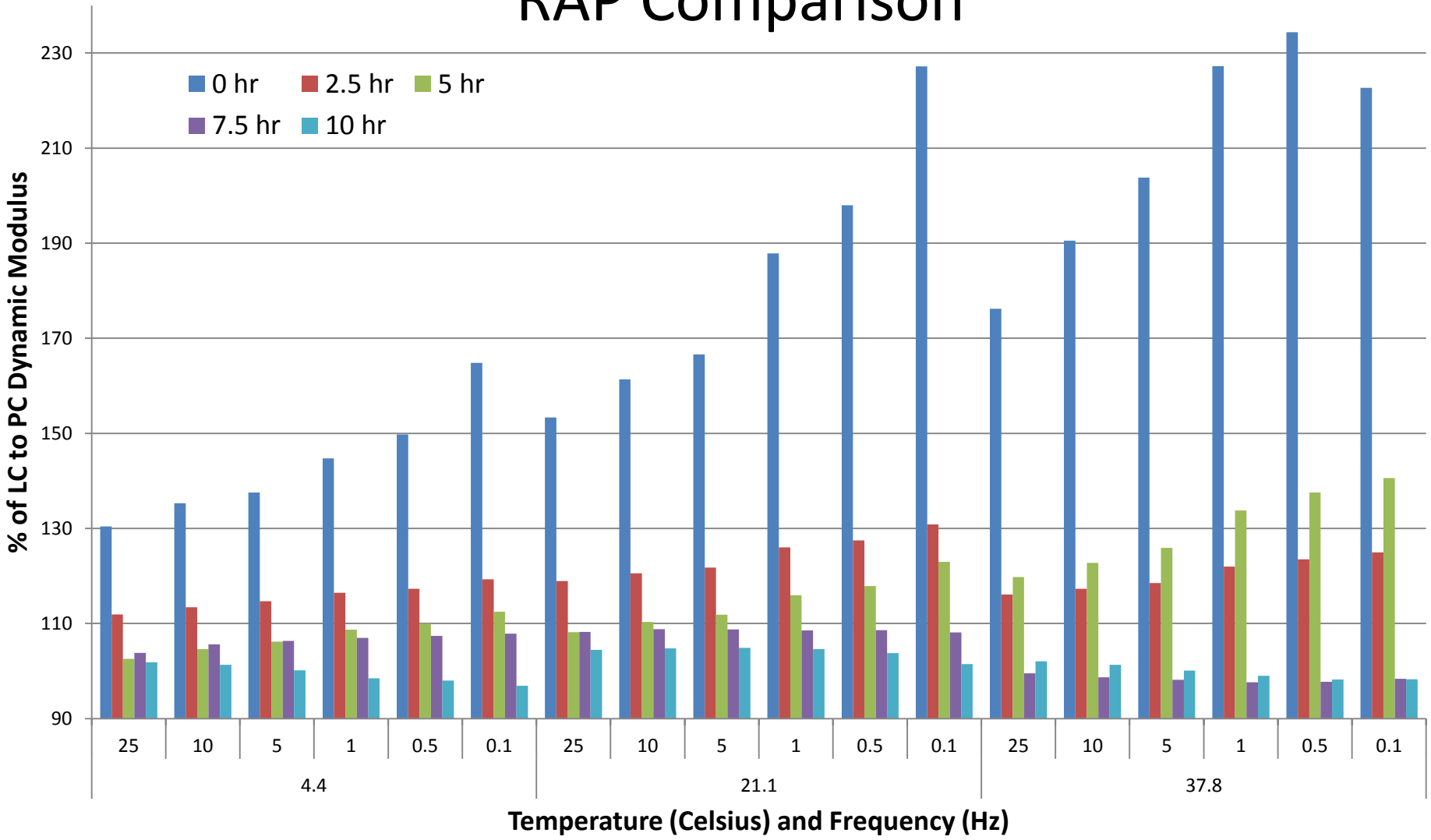
Plant Compacted Dynamic Modulus: 25% RAP



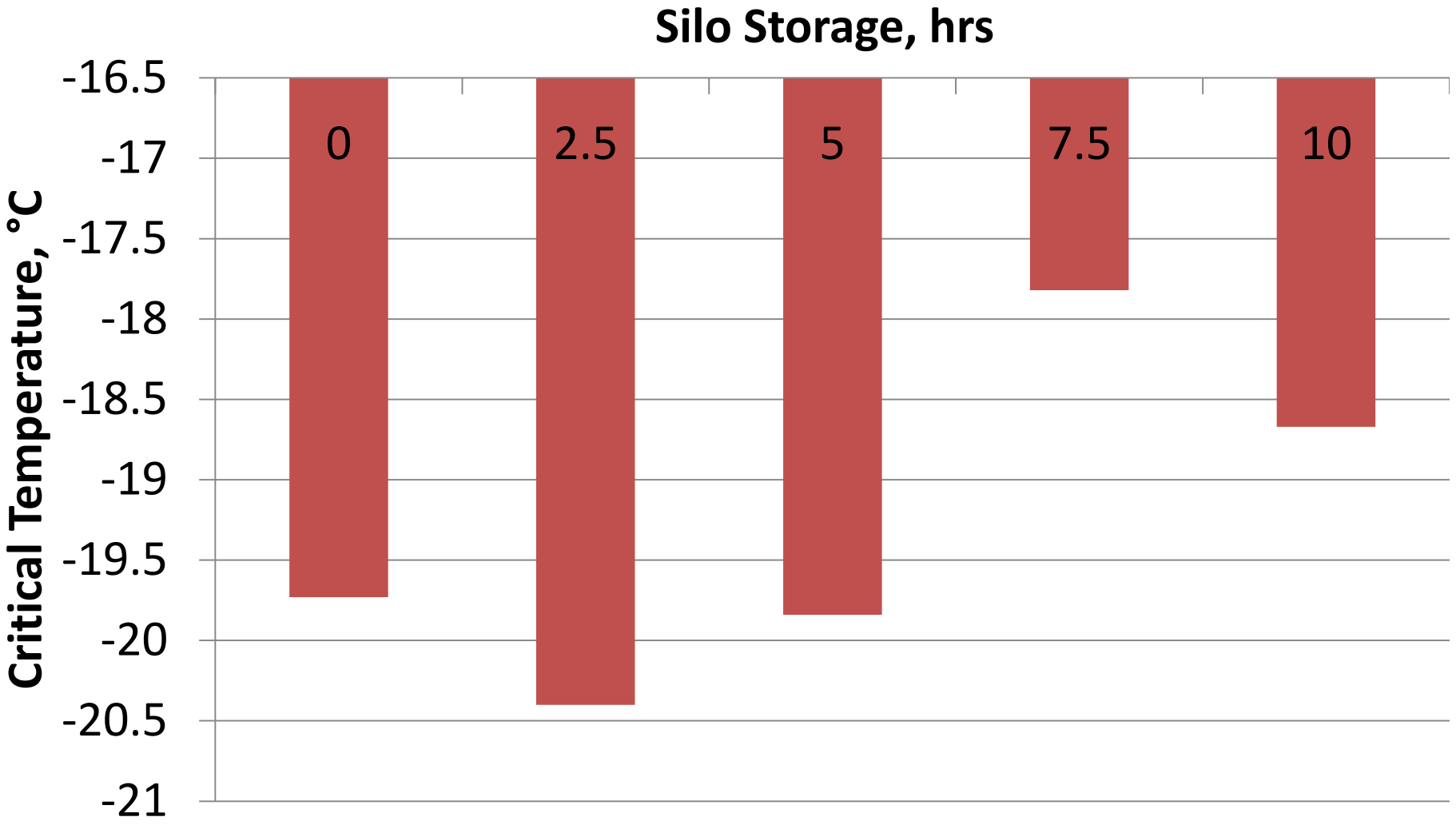
Lab Compacted Dynamic Modulus: 25% RAP



Lab- versus Plant-Compacted Dynamic Modulus RAP Comparison



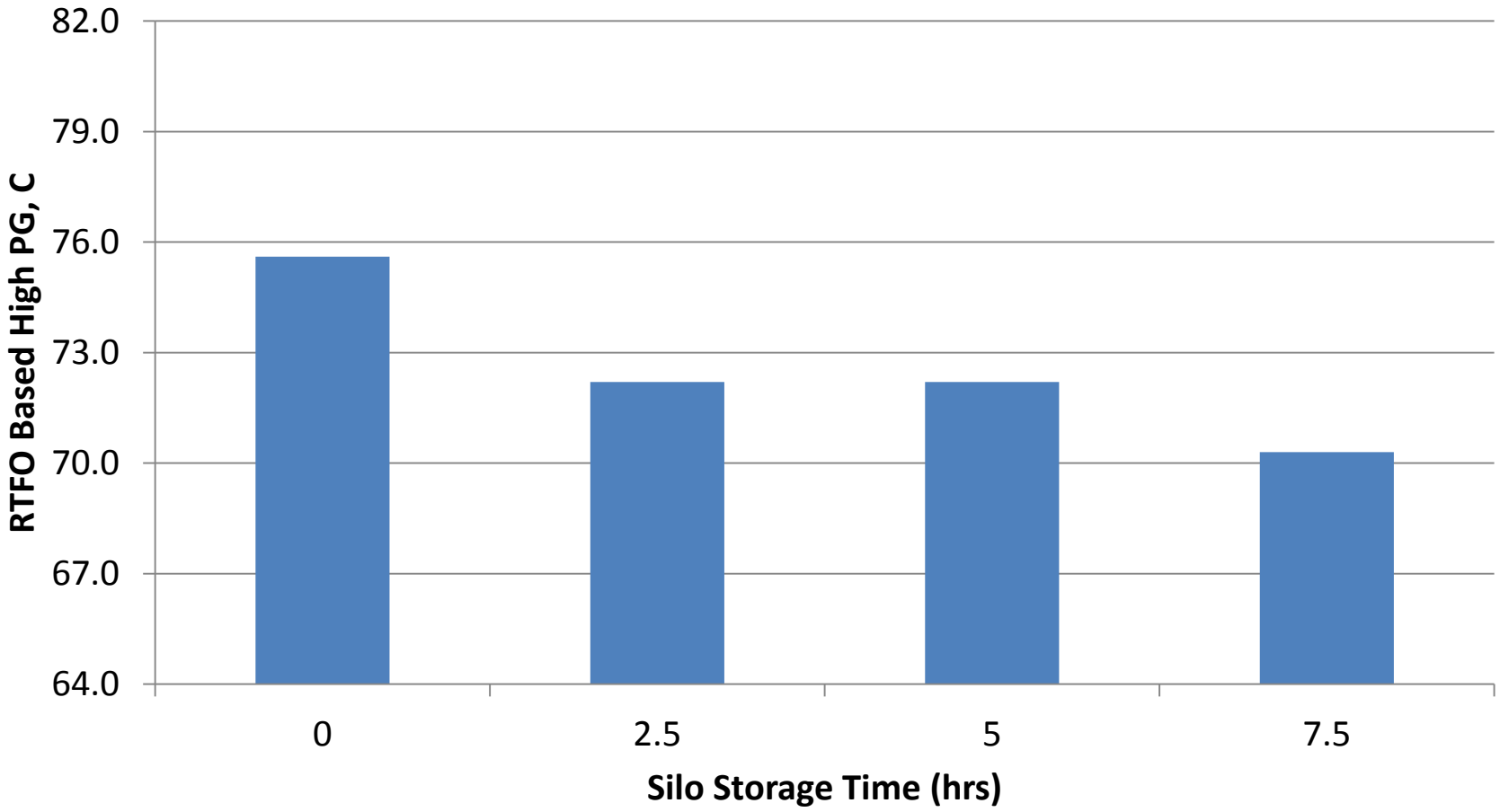
TSRST Results



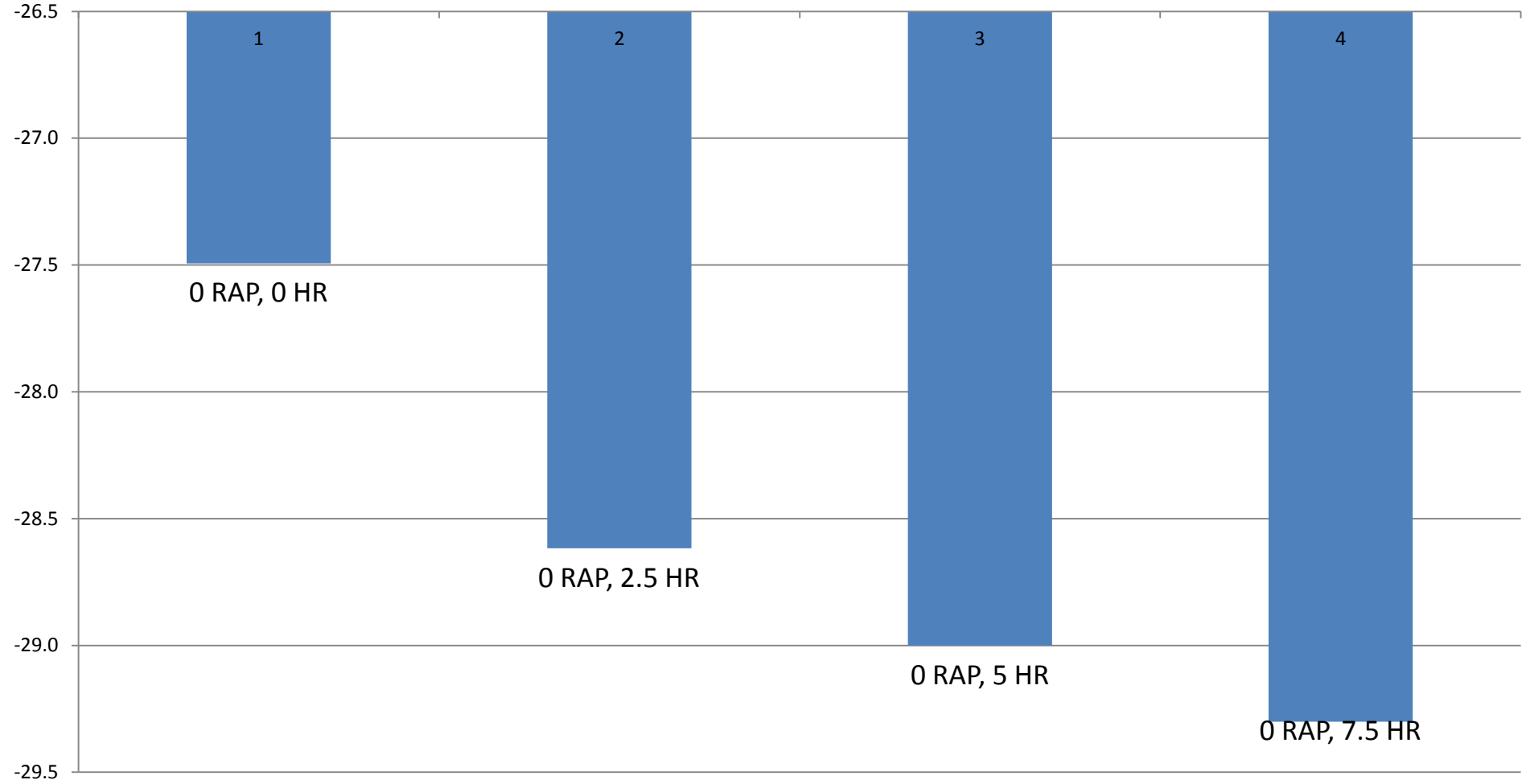
25% RAP Silo Storage Summary

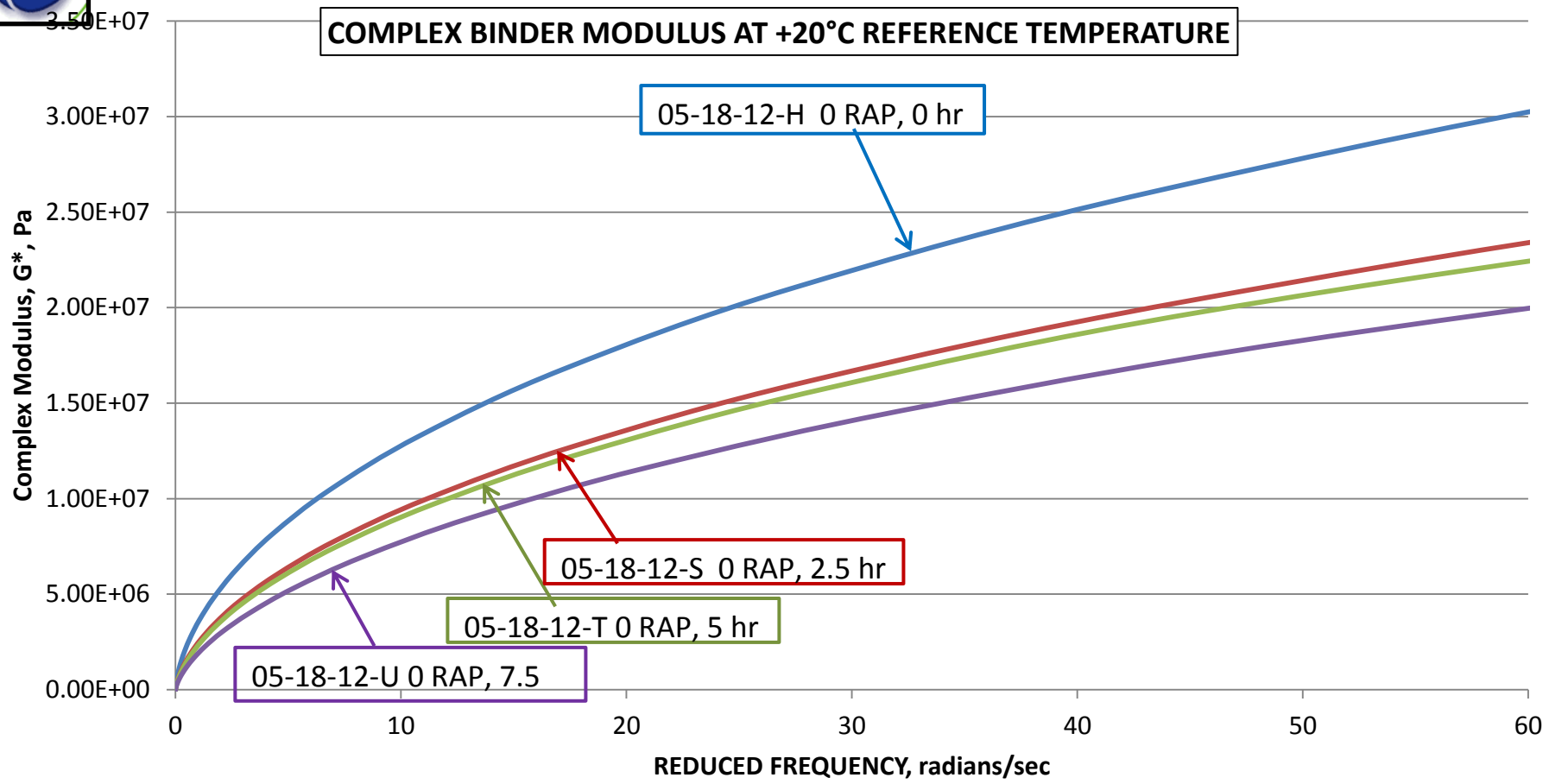
- Stiffening of binder with increase in storage time
- General stiffening trend with increase in storage time for mix
- Reheat mixtures stiffer than plant compacted but difference decreases with storage time

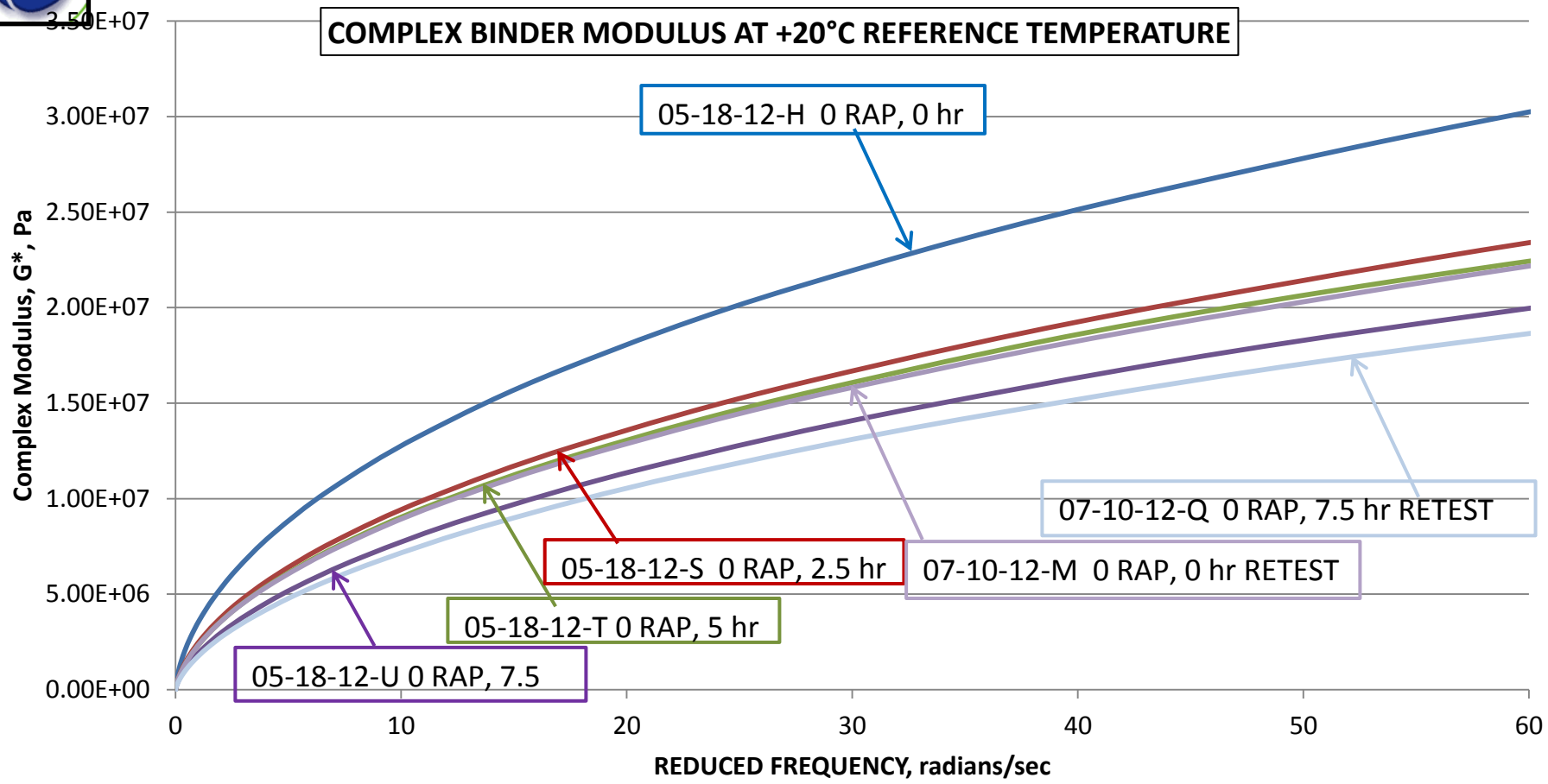
High Temp Grade Virgin Recovered



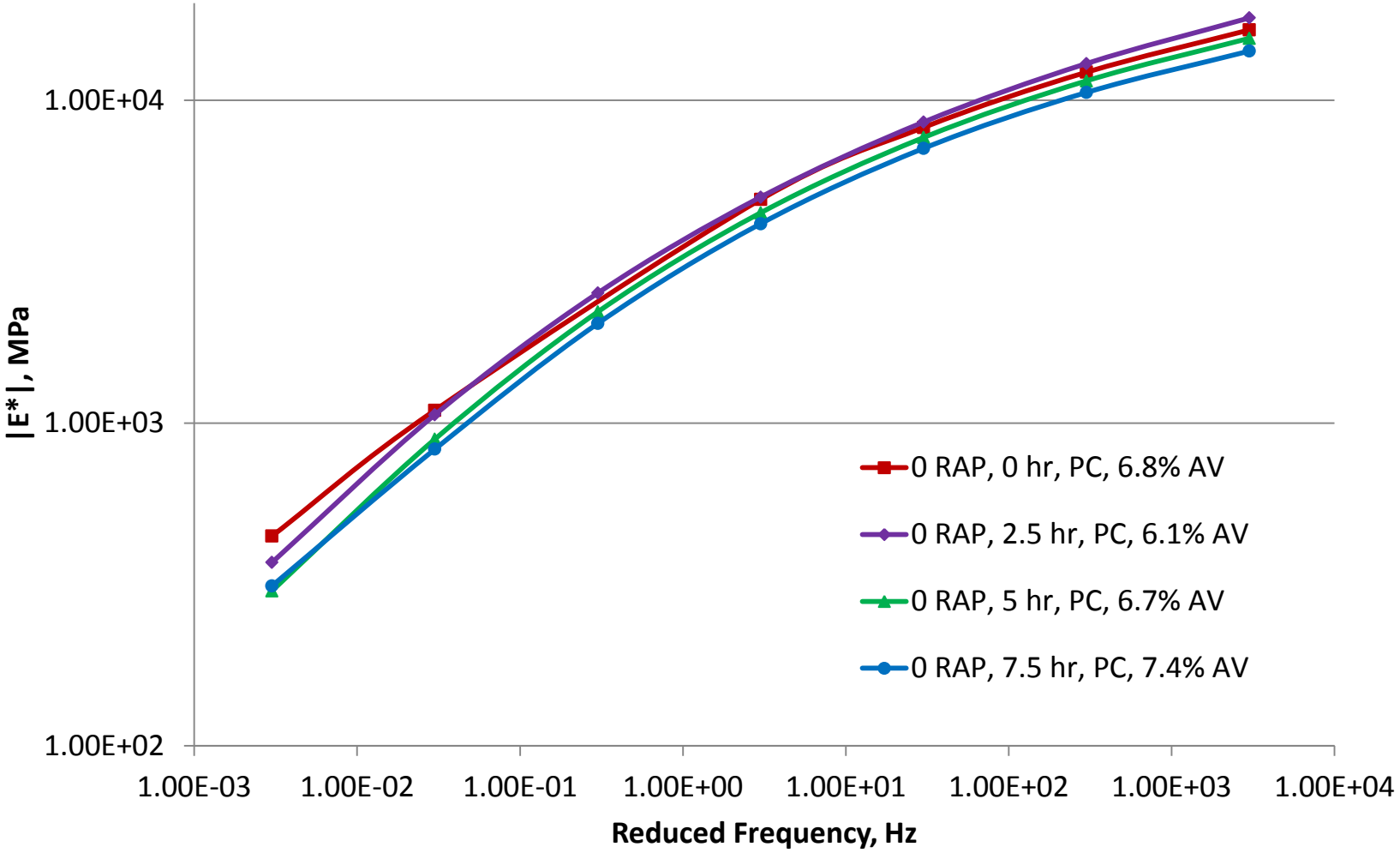
LOW TEMP GRADE VIRGIN MIX RECOVERED BINDER



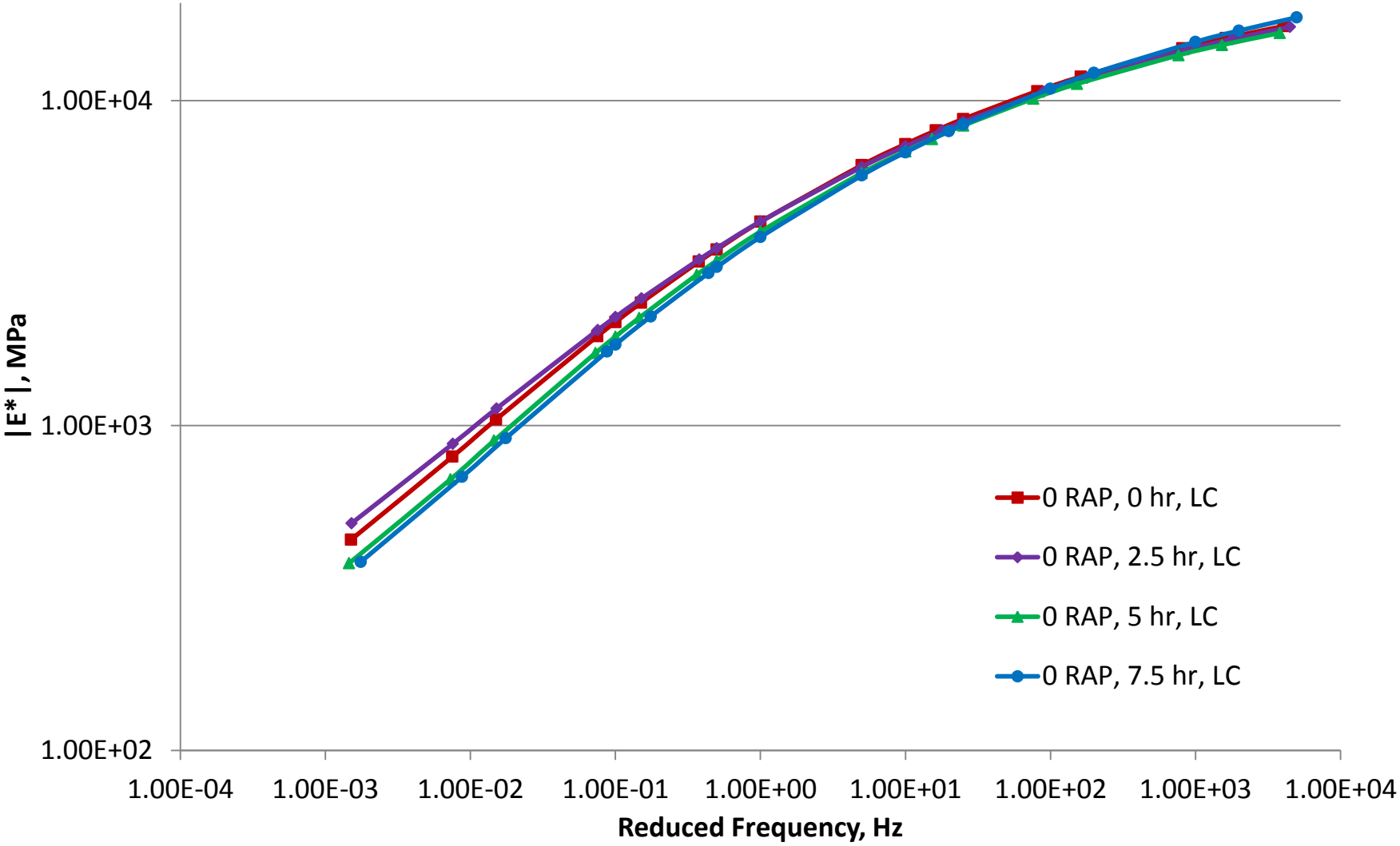

COMPLEX BINDER MODULUS AT +20°C REFERENCE TEMPERATURE
Complex Modulus, G*, Pa
3.50E+07
3.00E+07
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
0
10
20
30
40
50
60
REDUCED FREQUENCY, radians/sec
05-18-12-H 0 RAP, 0 hr
05-18-12-S 0 RAP, 2.5 hr
05-18-12-T 0 RAP, 5 hr
05-18-12-U 0 RAP, 7.5


COMPLEX BINDER MODULUS AT +20°C REFERENCE TEMPERATURE
Complex Modulus, G*, Pa
3.50E+07
3.00E+07
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
0
10
20
30
40
50
60
REDUCED FREQUENCY, radians/sec
05-18-12-H 0 RAP, 0 hr
05-18-12-S 0 RAP, 2.5 hr
05-18-12-T 0 RAP, 5 hr
05-18-12-U 0 RAP, 7.5
07-10-12-M 0 RAP, 0 hr RETEST
07-10-12-Q 0 RAP, 7.5 hr RETEST

Plant Compacted Dynamic Modulus: Virgin



Lab Compacted Dynamic Modulus: Virgin



So, what happened?

Continuing work

- Phase II mixtures
  - NH mixtures – field sections
  - VA mixtures (higher PG grades)
- New virgin silo storage study mixtures
- NCSU work refining fatigue criterion for RAP mixtures in SVECD approach
- Low temperature analysis, actual cooling rates and temperatures
- Additional mixtures: impact of asphalt content

Questions?