Correlation between Laboratory and Plant Produced High RAP/RAS Mixtures

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Motivation

- Specification limitation on using recycled material

- Asphalt Recycling Advantages
  - ✓ Economic
  - ✓ Environmentally friendly

- Lab vs. Plant
  - ✓ Performance- based design
  - ✓ Comparison of PMPC and LMLC mixtures performance

Project Overview

- Project No. 15680R, funded by NHDOT
- **Objectives:**
  - To evaluate the properties of mixtures with RAP and RAS in HMA
  - To revise NHDOT existing specification
  - **To compare laboratory and plant produced mixes**
- Lab produced specimens, and binder extraction and recovery by NHDOT
- Plant produced specimens by Pike Industries, Inc.

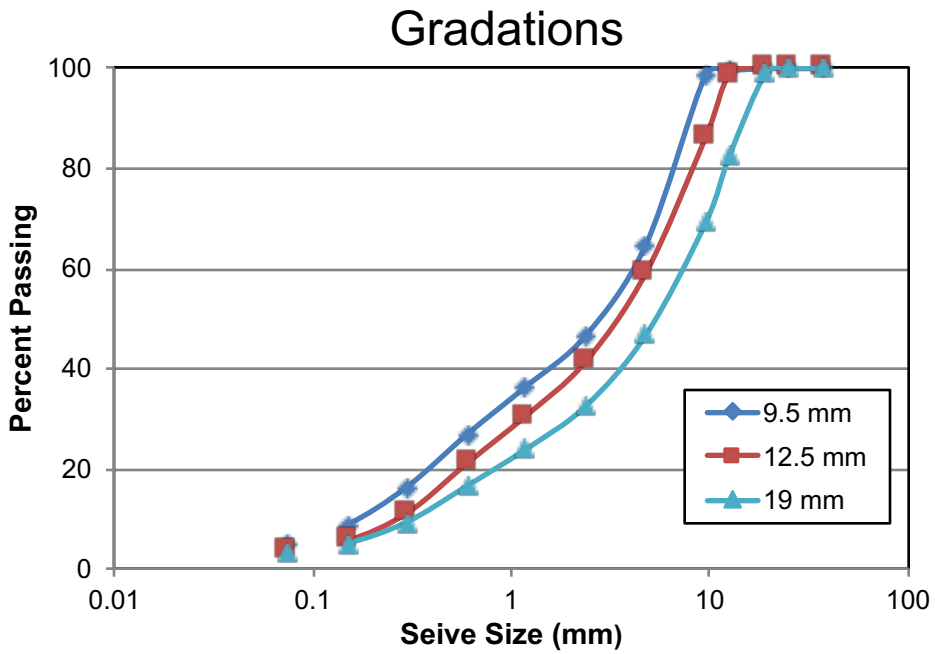
Summary of Mixtures

- Lebanon
  - ✓ 11 Mixtures (Plant), 8 Mixtures (Lab)
  - ✓ Binder PG Grade (PG 58-28, PG 52-34)
  - ✓ Two sources for each binder grade
  - ✓ NMAS (12.5 and 19 mm)
  - ✓ Recycled Material (20% RAP, 20% RAP/RAS, 30% RAP)
- Hooksett
  - ✓ 4 Mixtures (Plant)
  - ✓ Binder PG Grade (PG 58-28, PG 64-28)
  - ✓ NMAS (9.5 and 12.5 mm)
  - ✓ Recycled Material (20% RAP, 25% RAP)

Mixture Properties

- Target Air Void (test specimen): 6% ± 0.5
- RAP Binder Grade: 81.3-19.3
- Tear off Shingles

Mixture NMAS (mm)	%AC Design Total
19.0	4.7- 4.8
12.5	5.3
9.5	5.8- 6.0



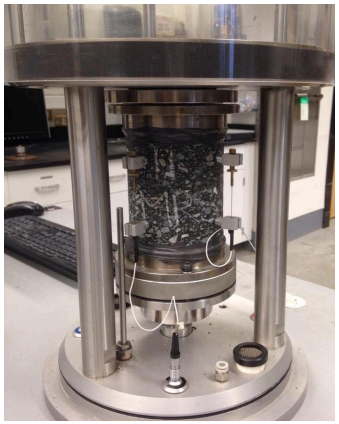
Testing

- Binder Testing (by NHDOT)
  - ✓ Extraction and Recovery
  - ✓ PG Grading
  - ✓ 4mm DSR (by Gerry Reinke, Mathy Construction)
- Mixture Testing (by UNH)
  - ✓ Complex Modulus
  - ✓ SVECD Fatigue
  - ✓ DCT testing

Testing

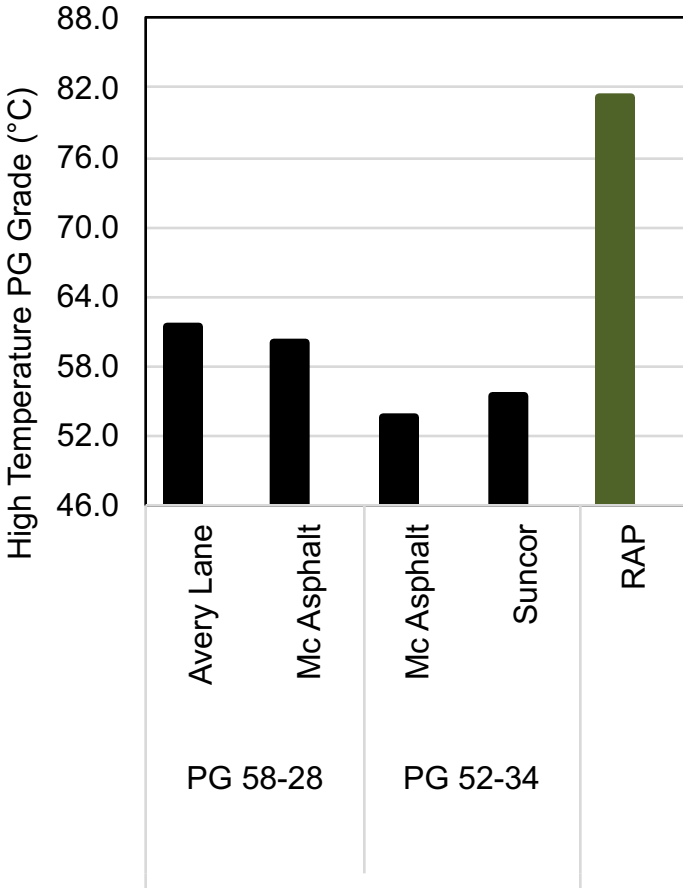
- Complex Modulus (AASHTO TP-62)
  - ✓ 3 replicates
  - ✓ Different Temperatures and Frequencies
  - ✓ Dynamic Modulus and Phase Angle Mastercurves

- SVECD Fatigue Testing (AASHTO TP-107)
  - ✓ 4 replicates
  - ✓ C-S and G^R-N_f
  - ✓ Simplified Viscoelastic Continuum Damage Approach

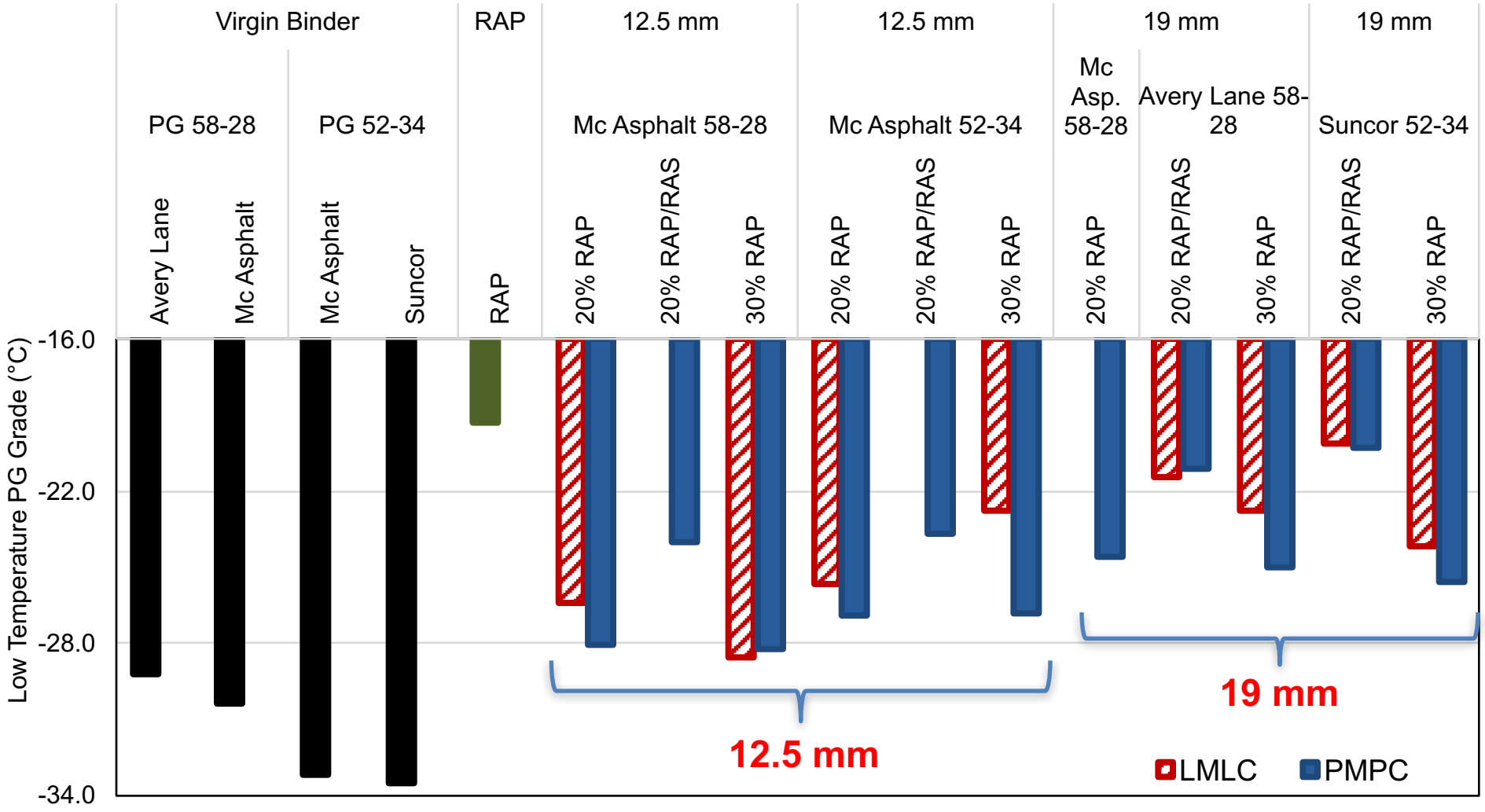


Summary of the Results

Binder Results



Binder Results



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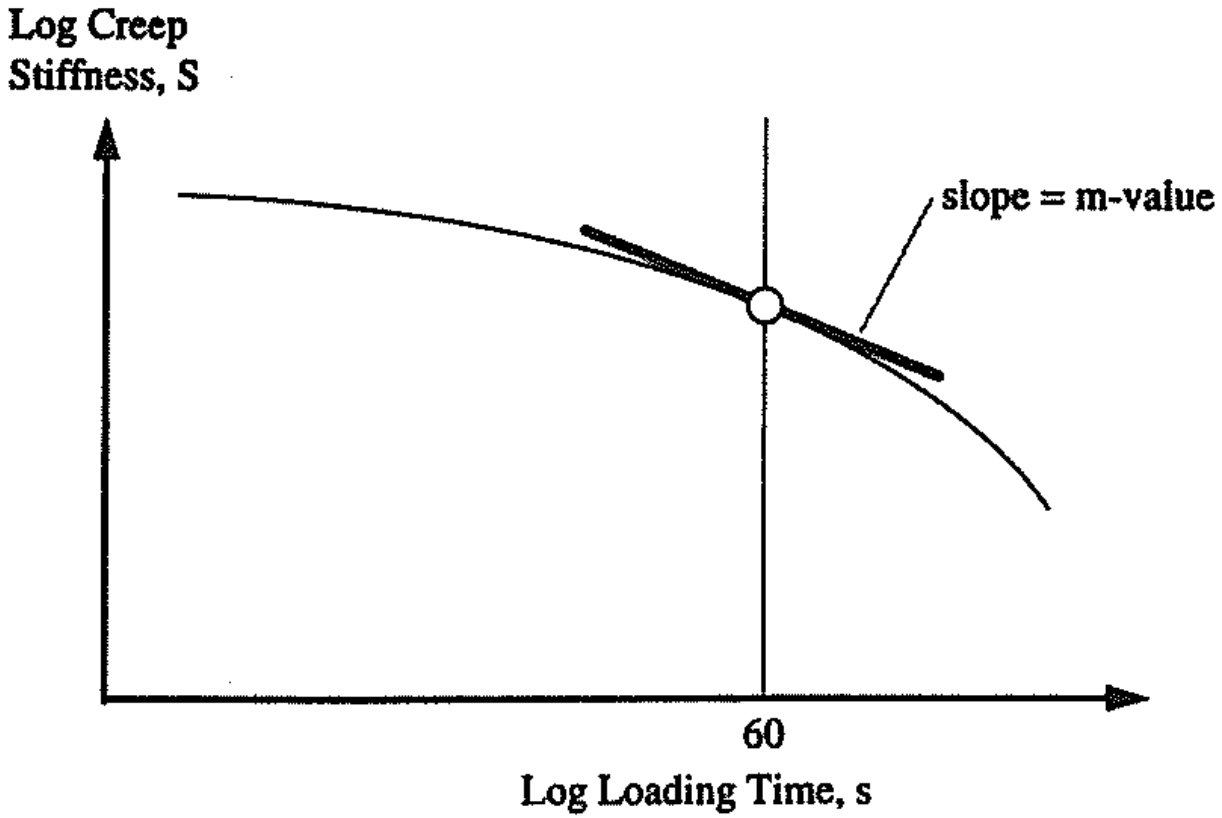
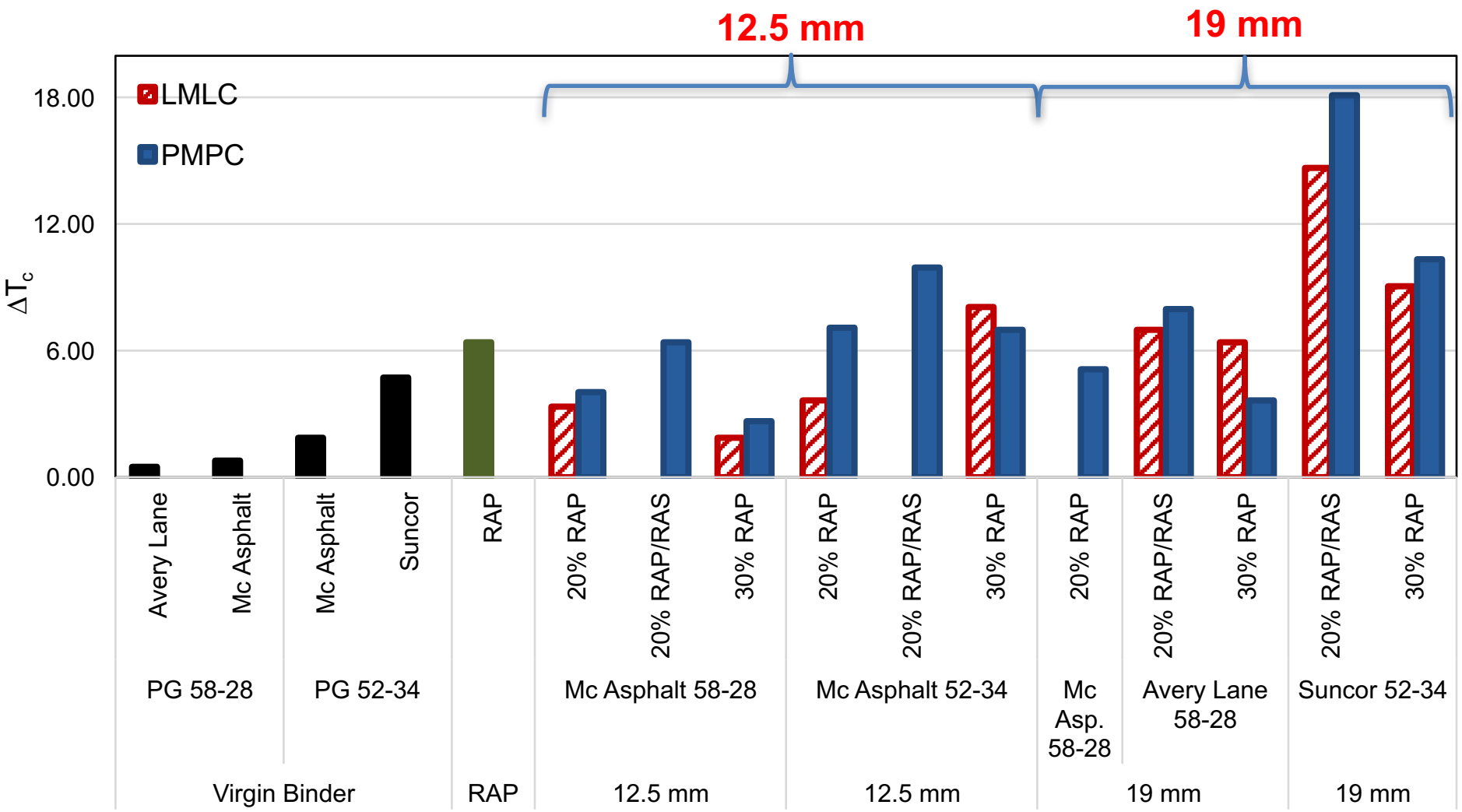
Binder Rheological Parameters



- $T_{cr\ (Stiffness)}$ = Critical low temp. where S(60) = 300
- $T_{cr\ (m\text{-}slope)}$ = Critical low temp. where m(60) = 0.3
- $\Delta T_{cr} = T_{cr\ (Stiffness)} - T_{cr\ (m\text{-}slope)}$

Binder Results



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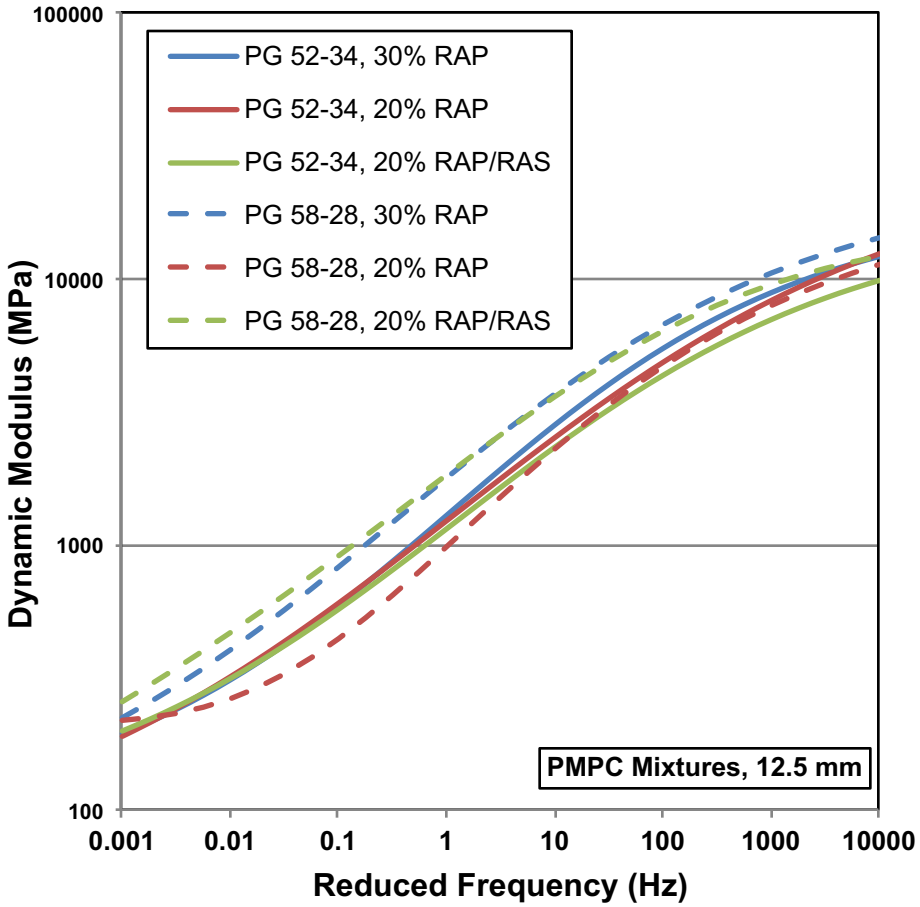
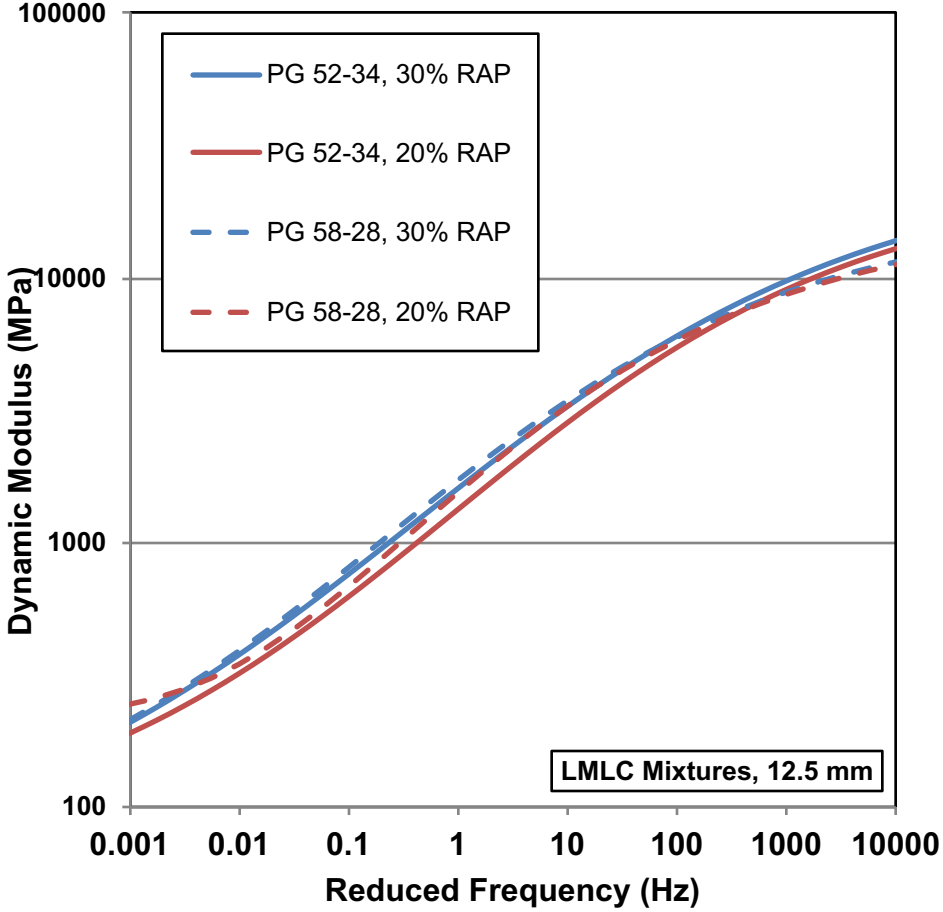
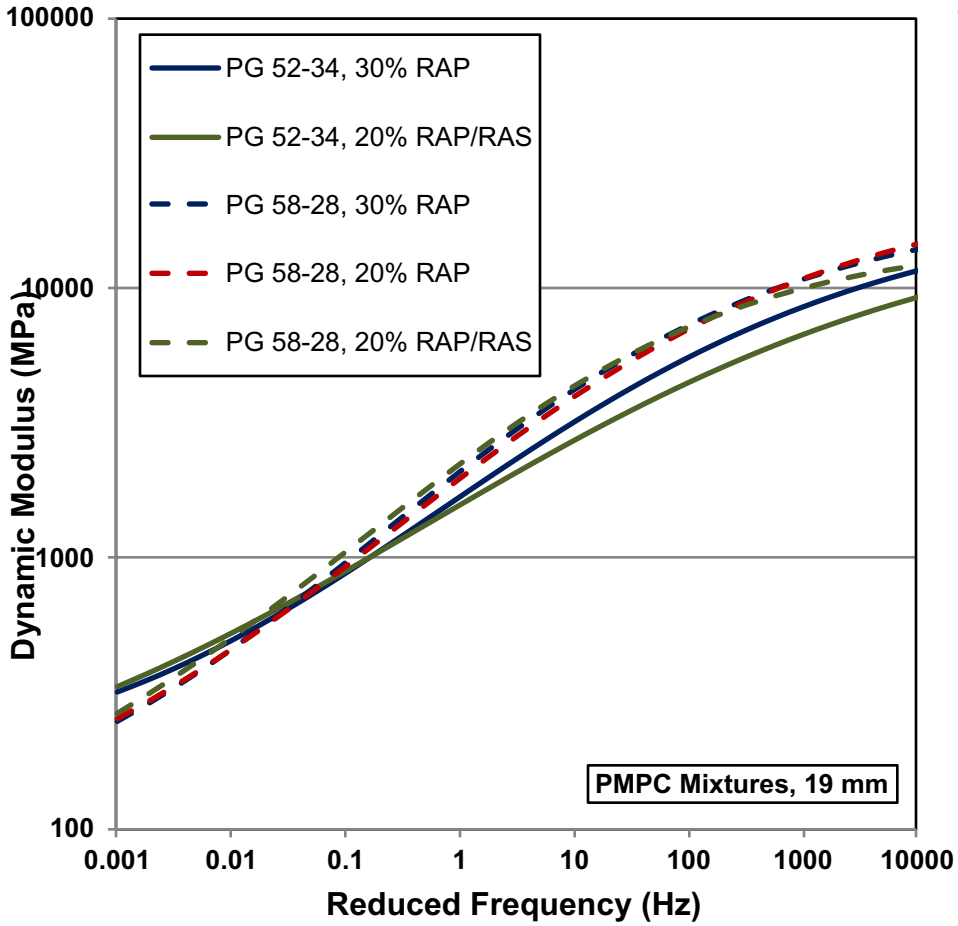
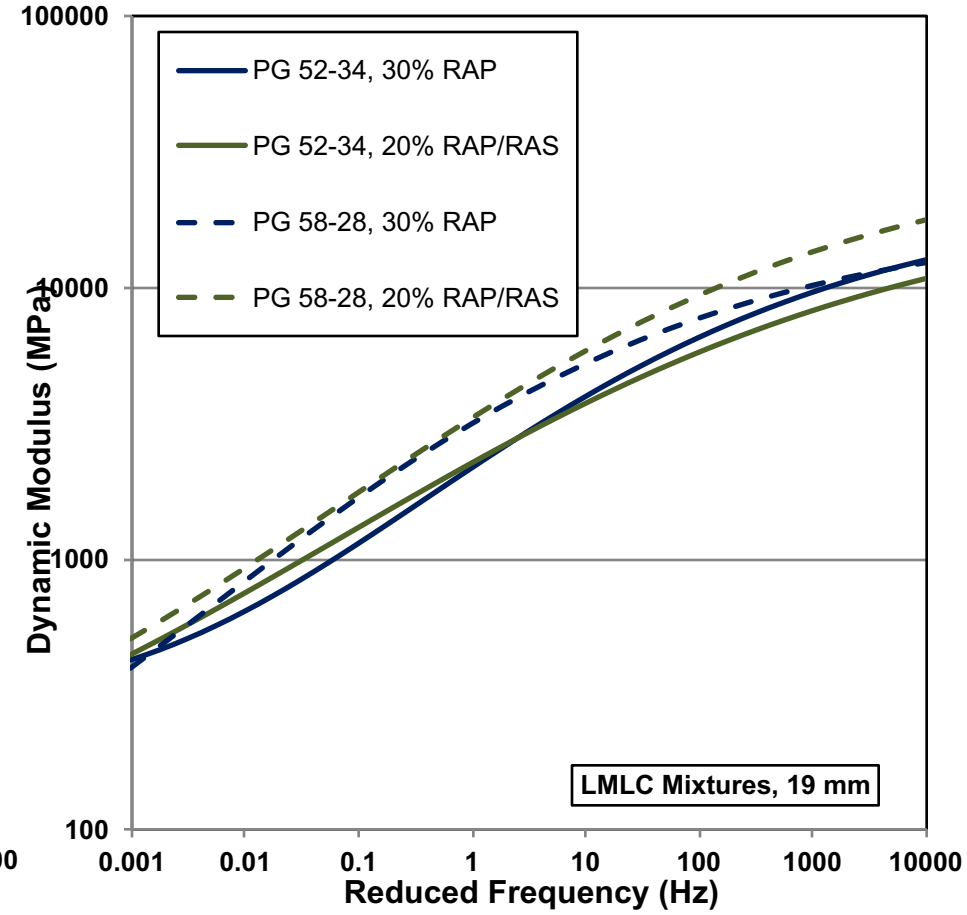
Dynamic Modulus (12.5 mm)



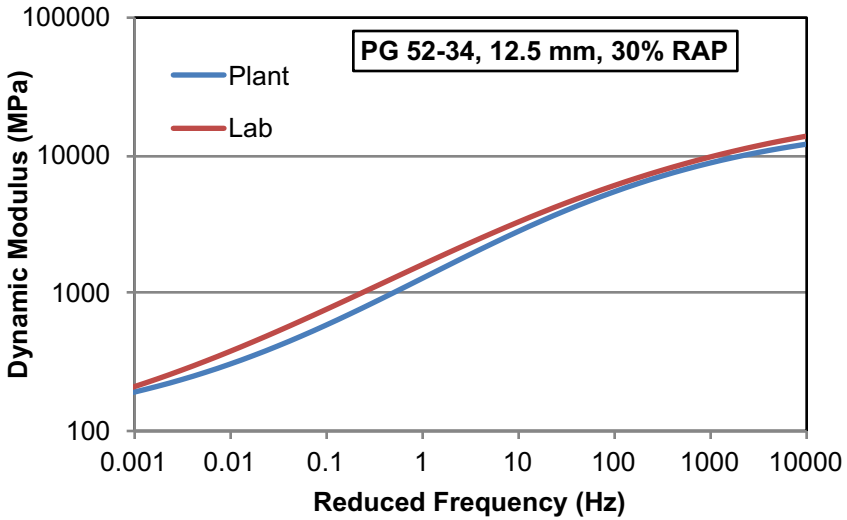


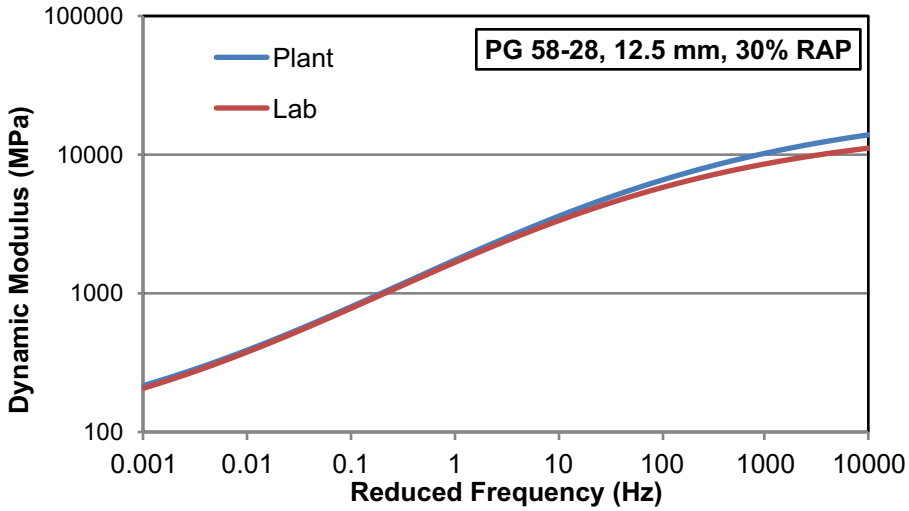
Dynamic Modulus (19 mm)

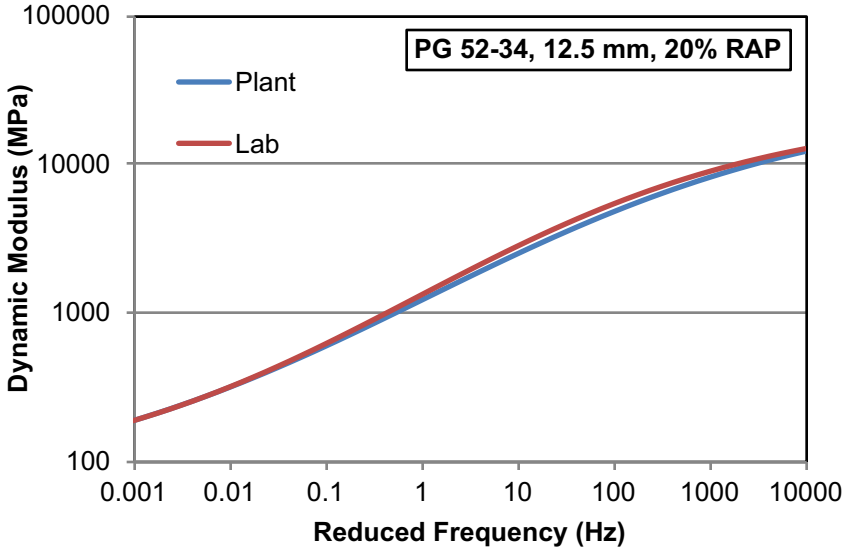


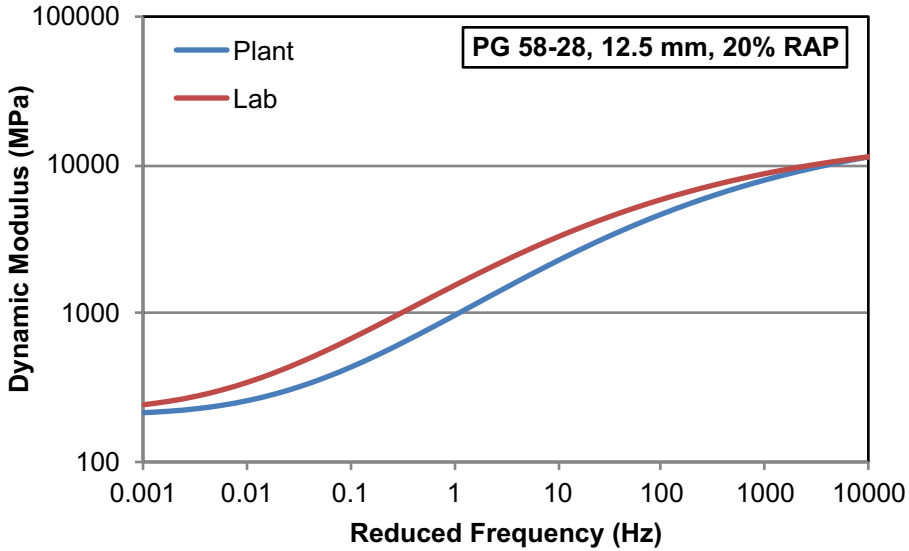


Dynamic Modulus, Plant vs. Lab, 12.5 mm

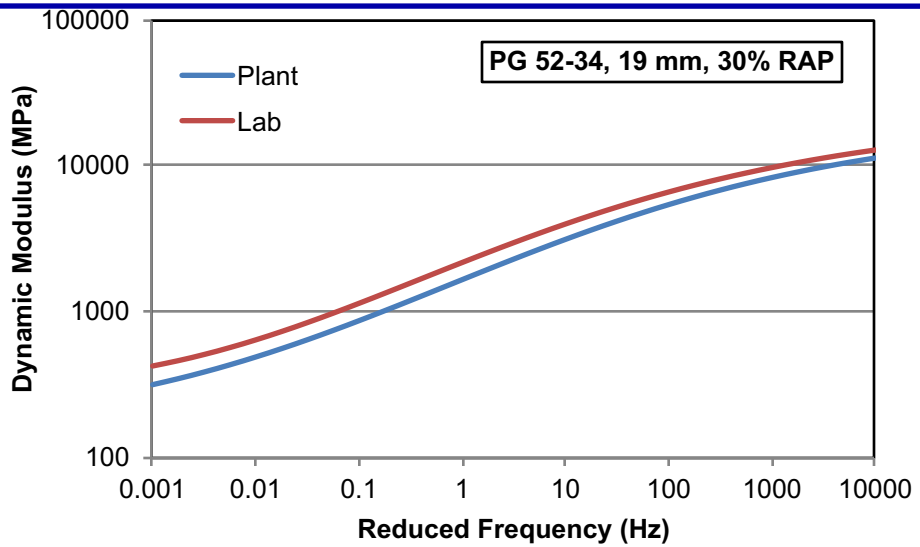


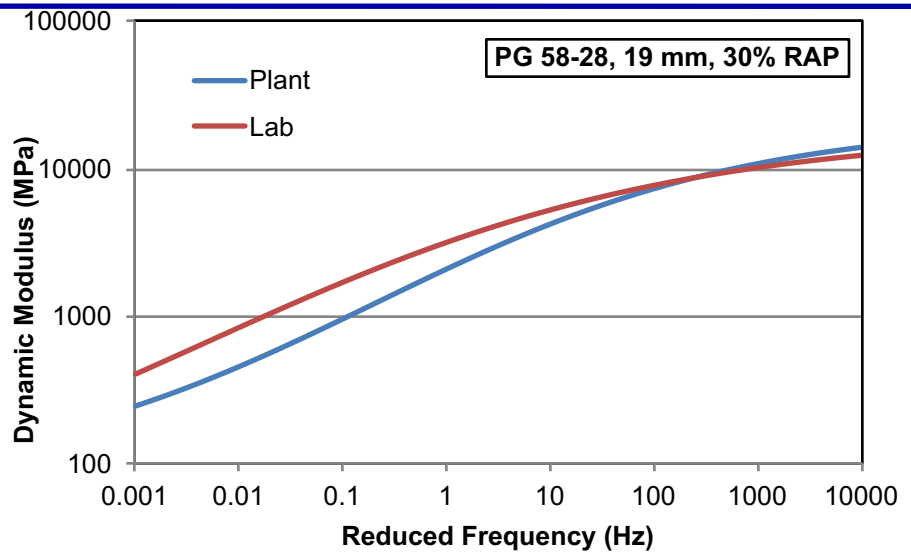


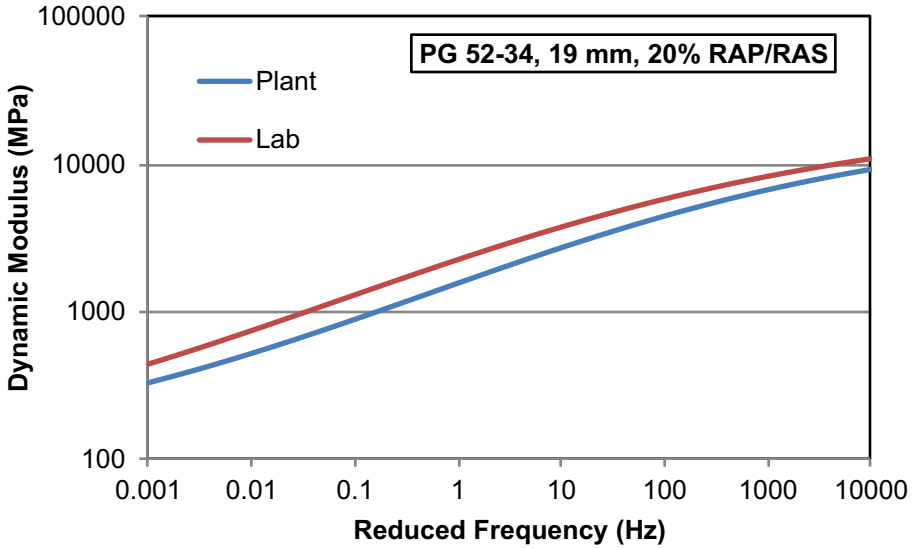


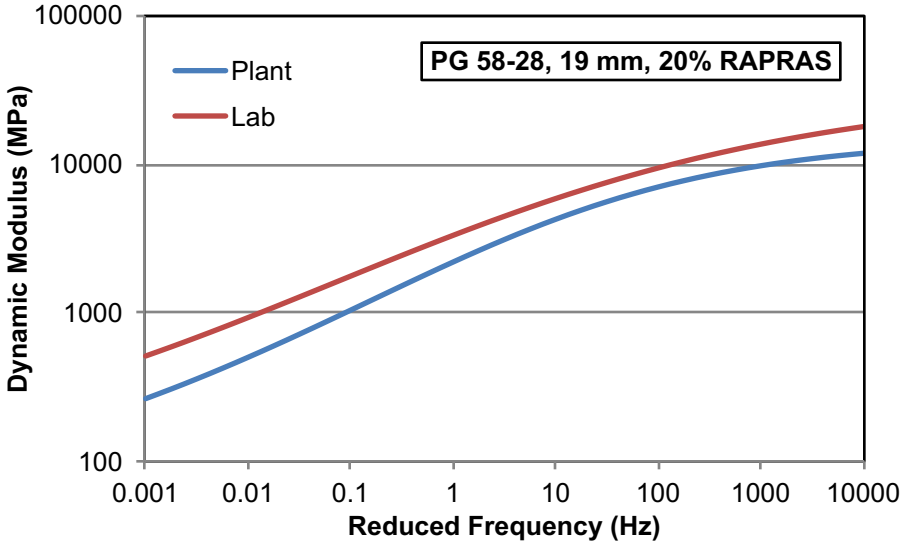


Dynamic Modulus, Plant vs. Lab, 19 mm









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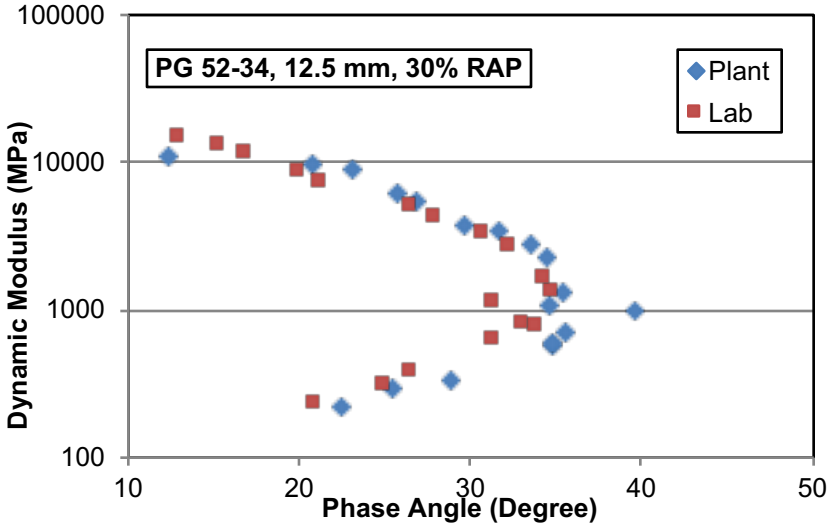
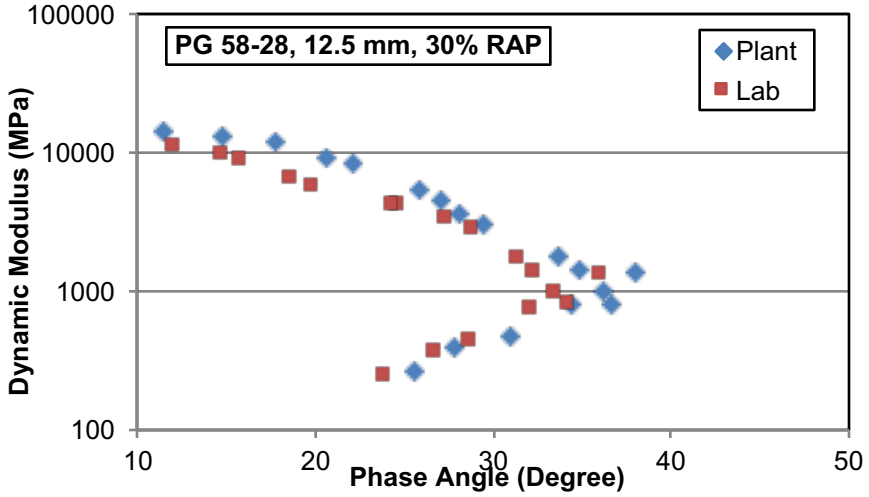
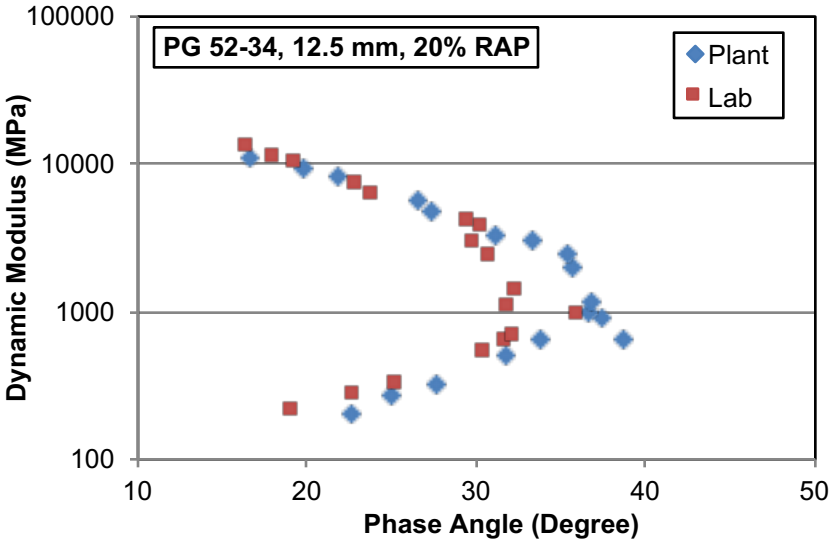
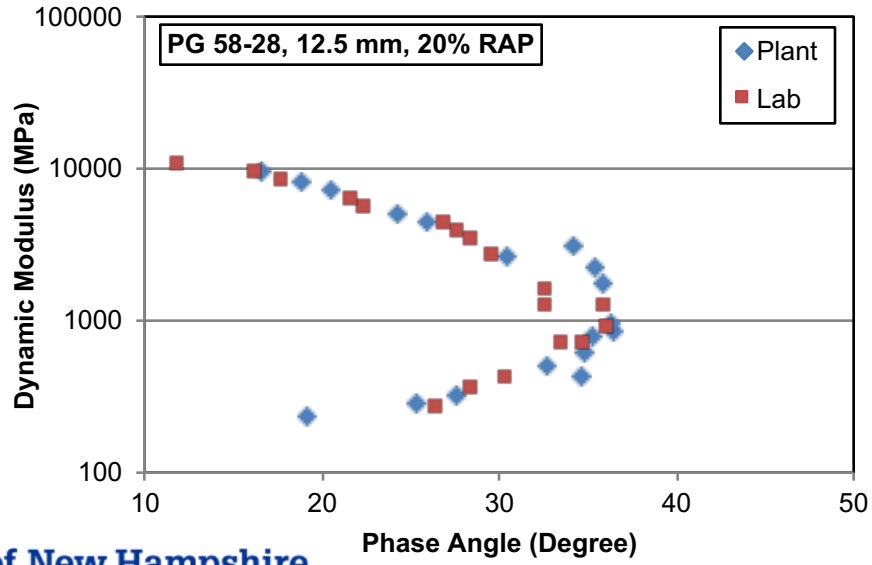
Black Space, Plant vs. Lab, (12.5 mm)









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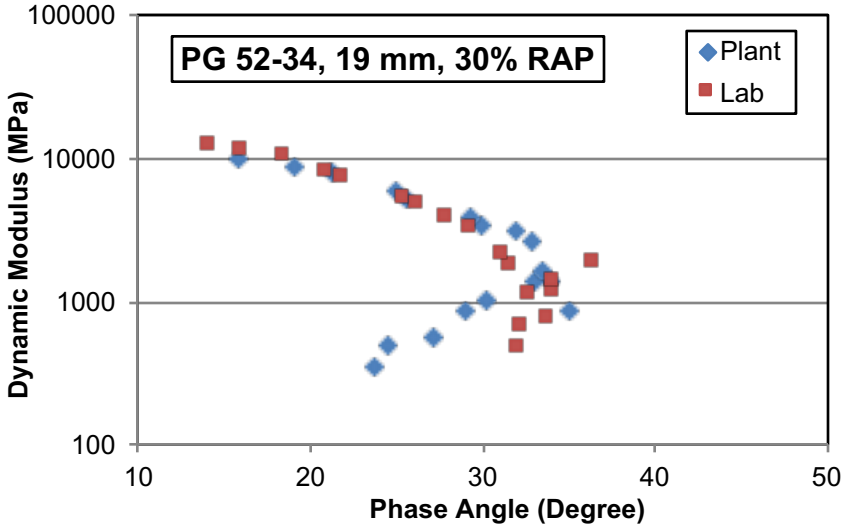
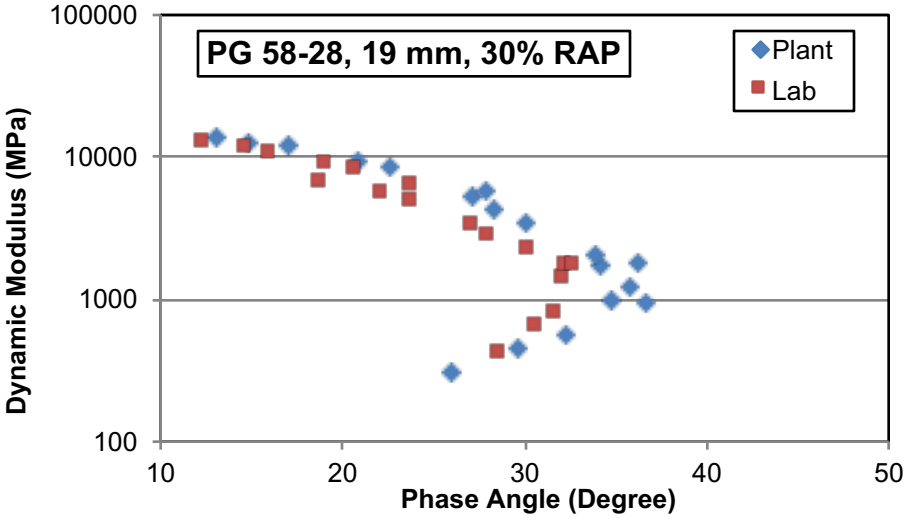
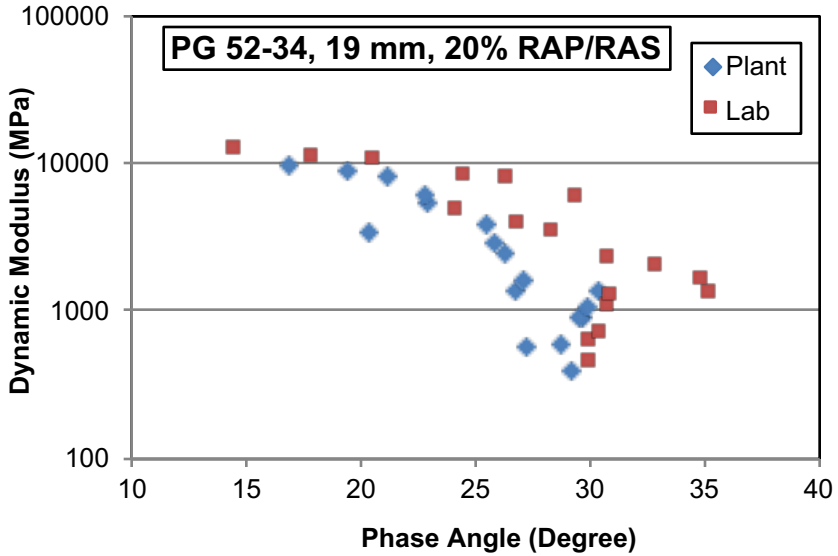
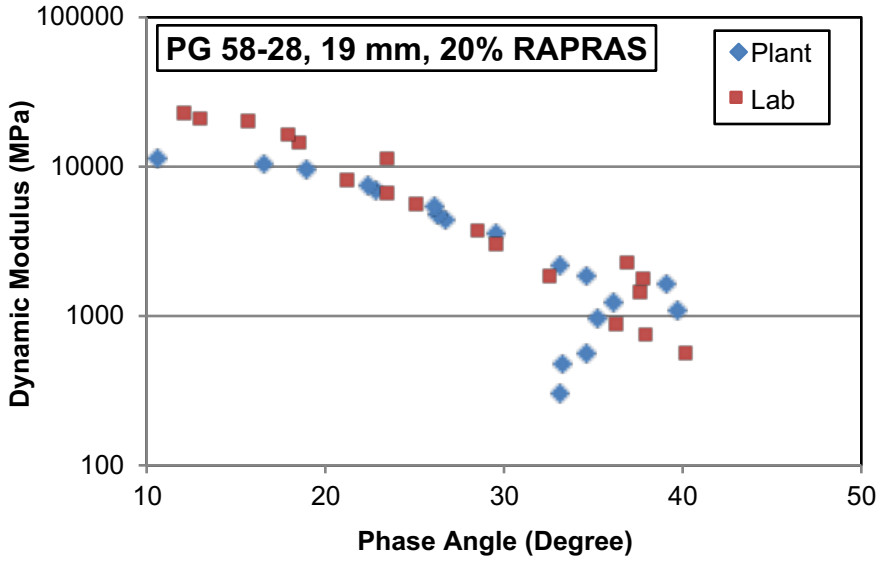
Black Space, Plant vs. Lab, (19 mm)









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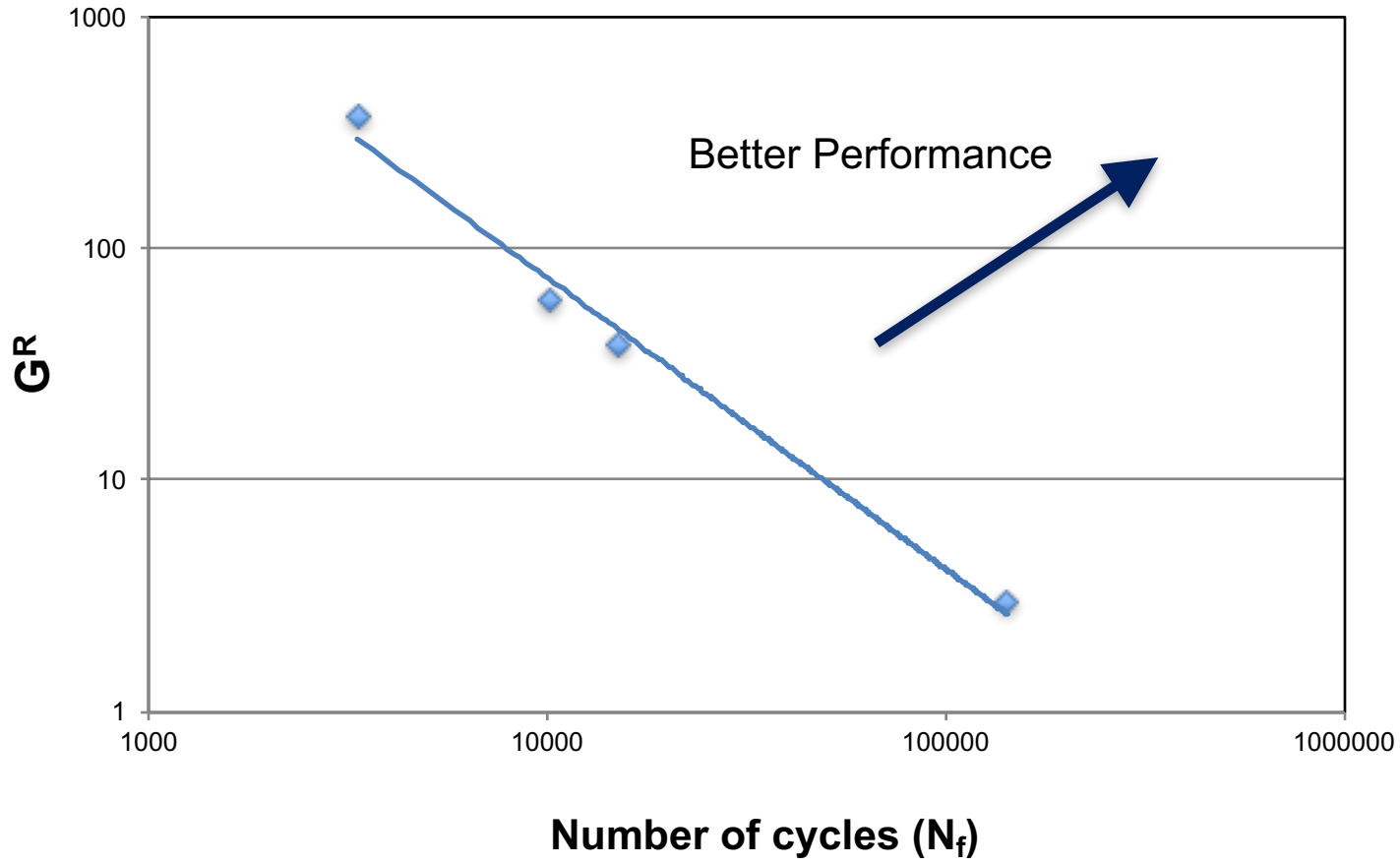
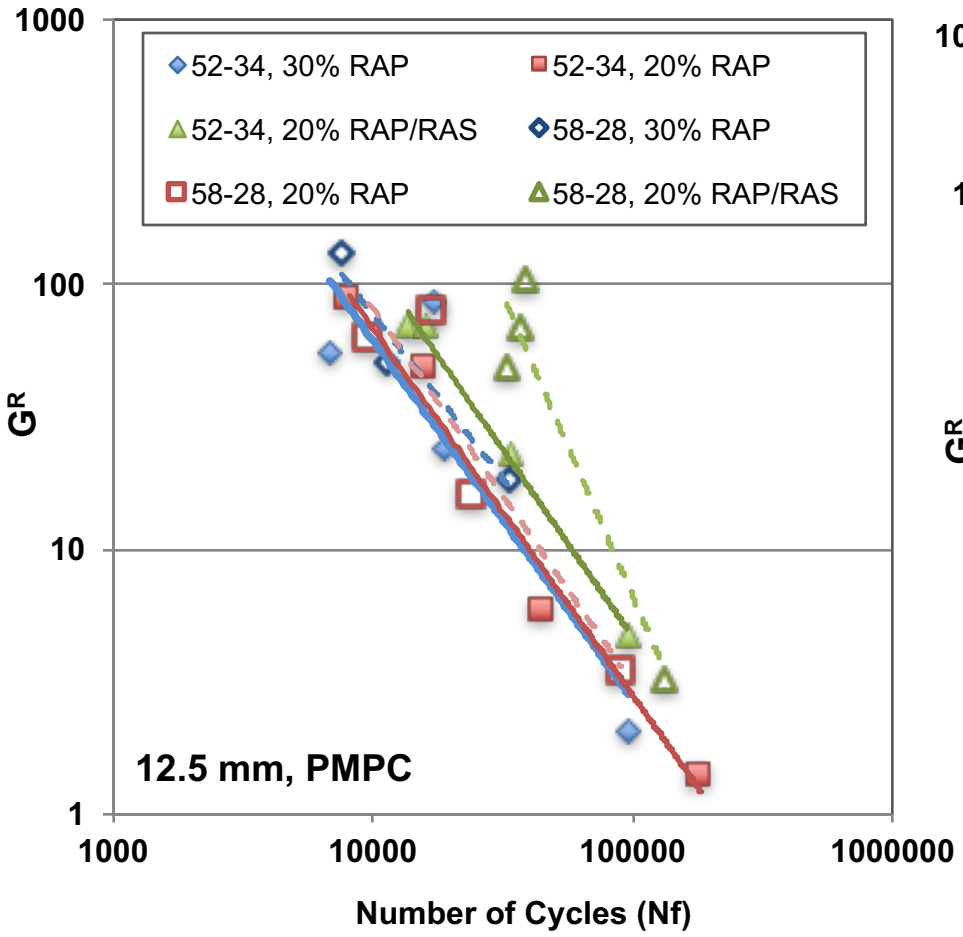
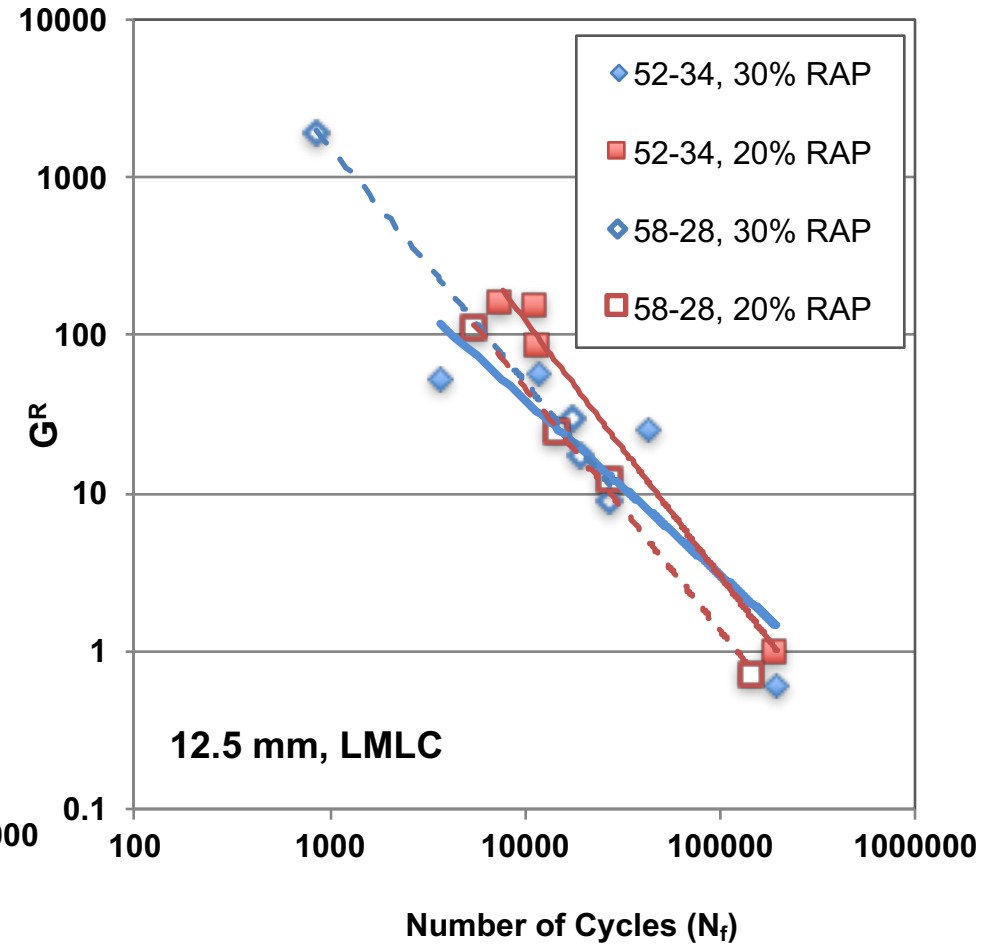
Fatigue Failure Criterion



Fatigue Failure (12.5 mm mixtures)





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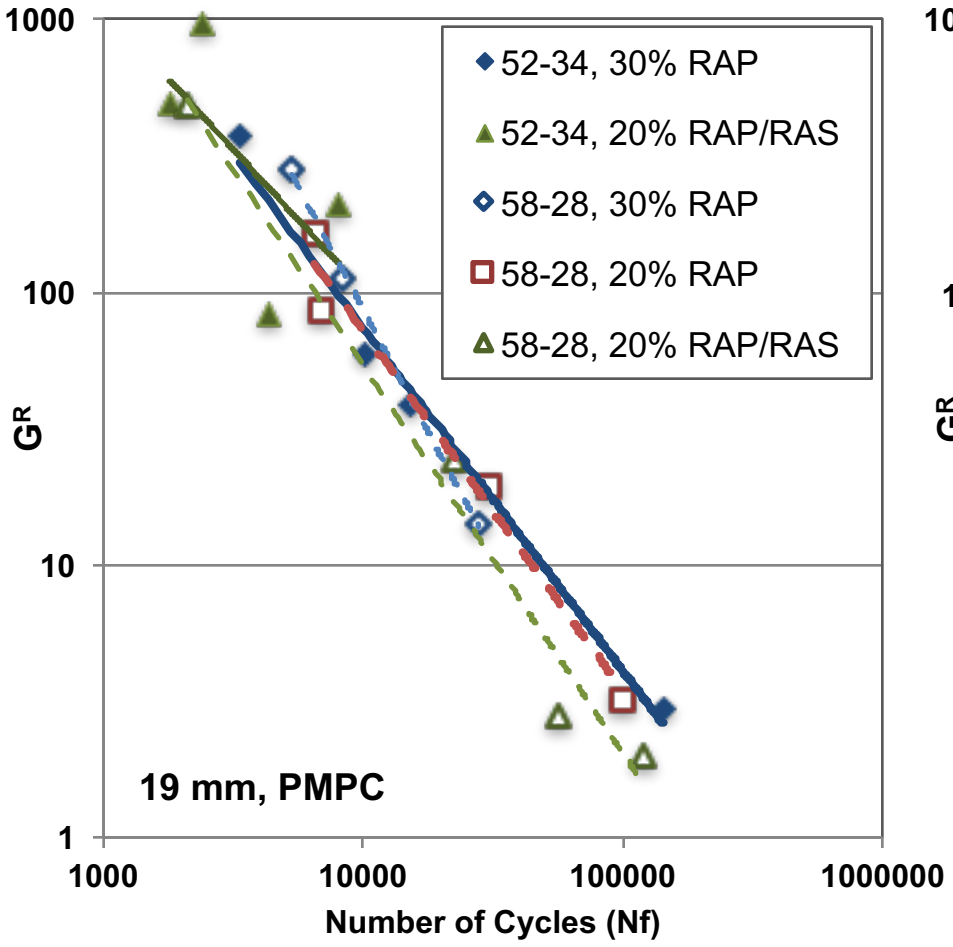
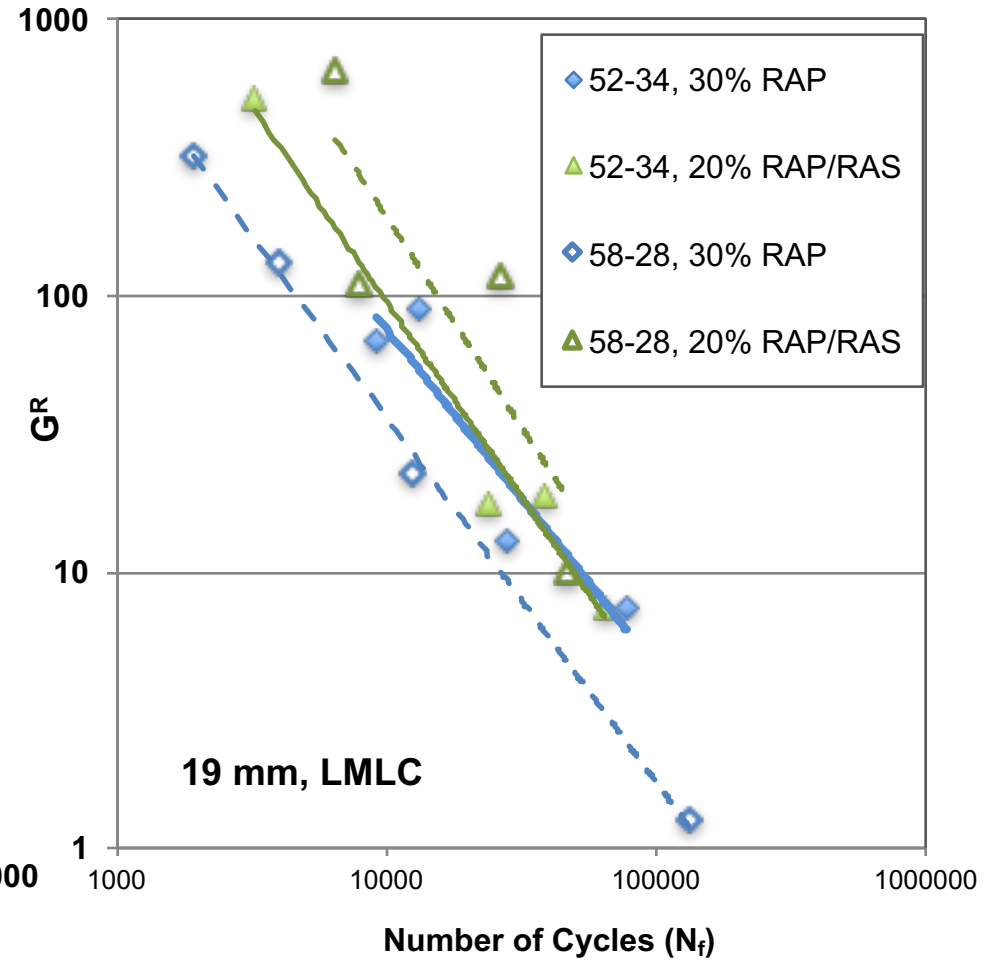
Fatigue Failure (19 mm mixtures)





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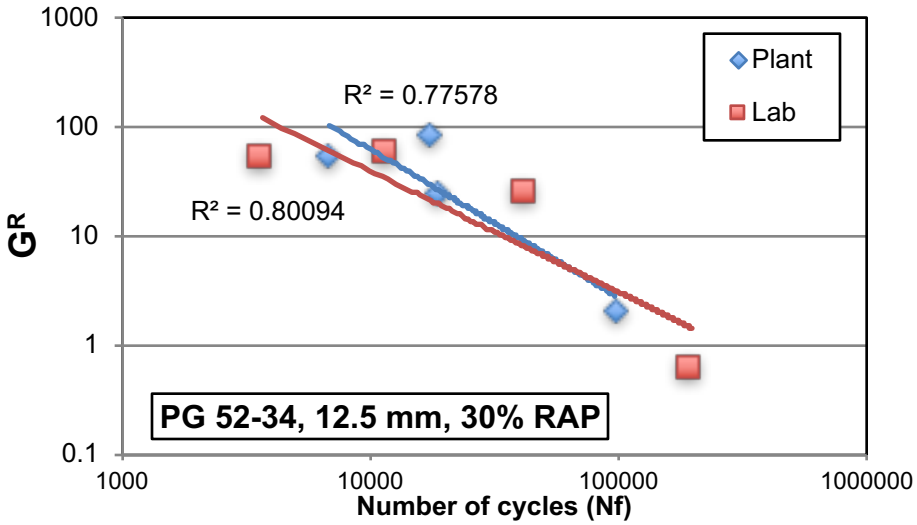
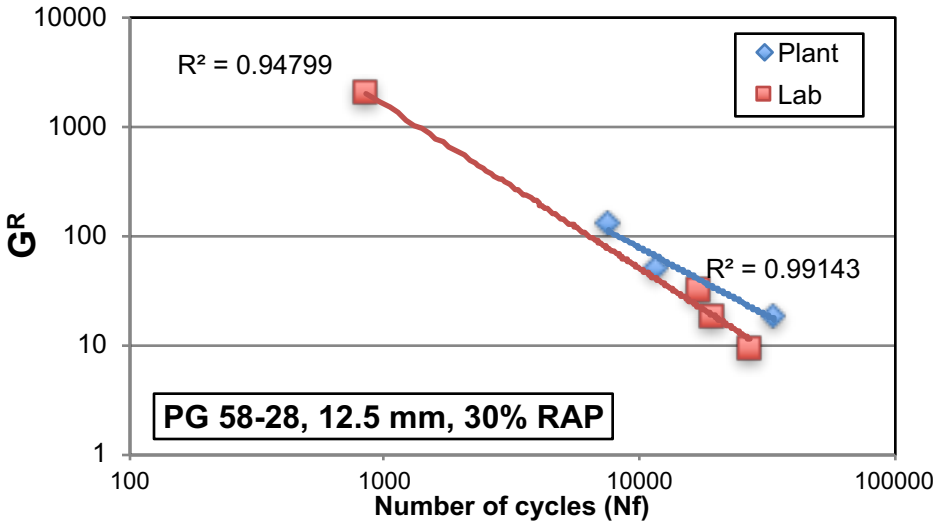
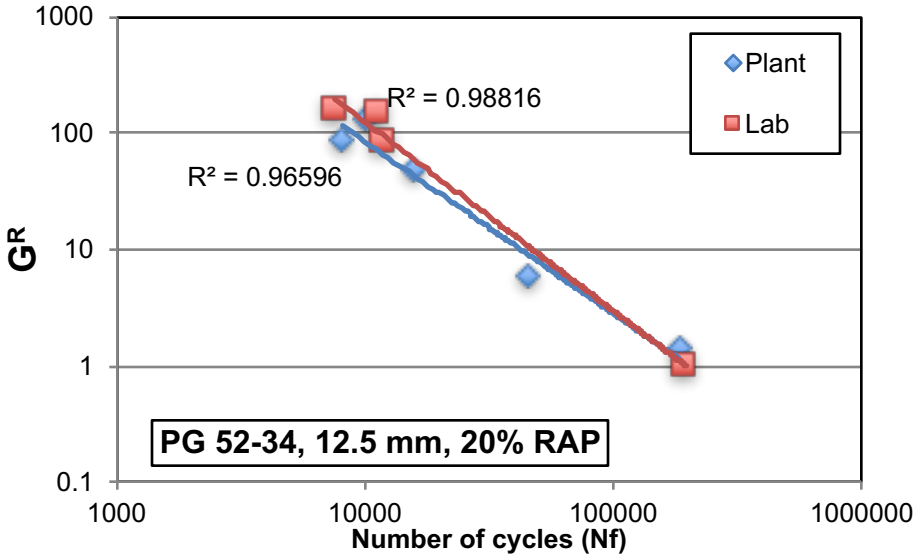
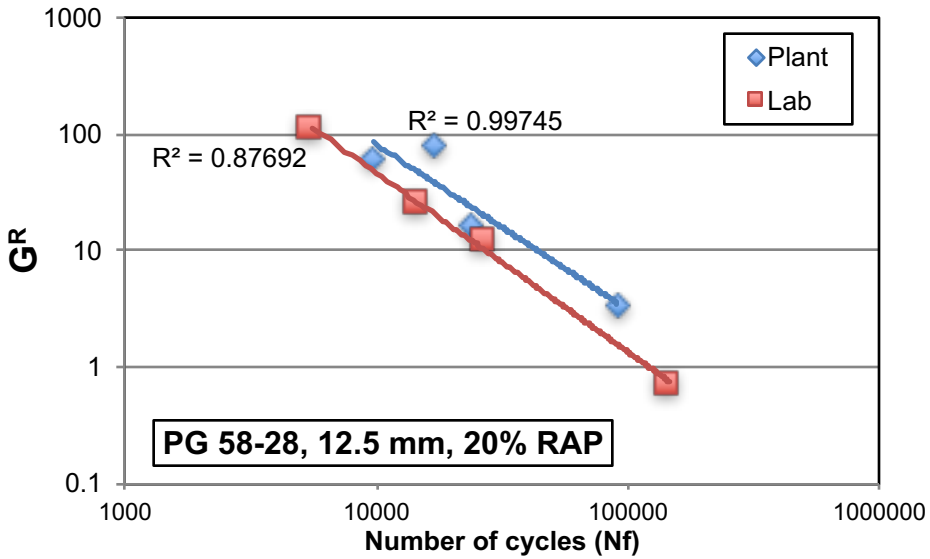
Fatigue Failure (Plant vs. Lab), 12.5 mm









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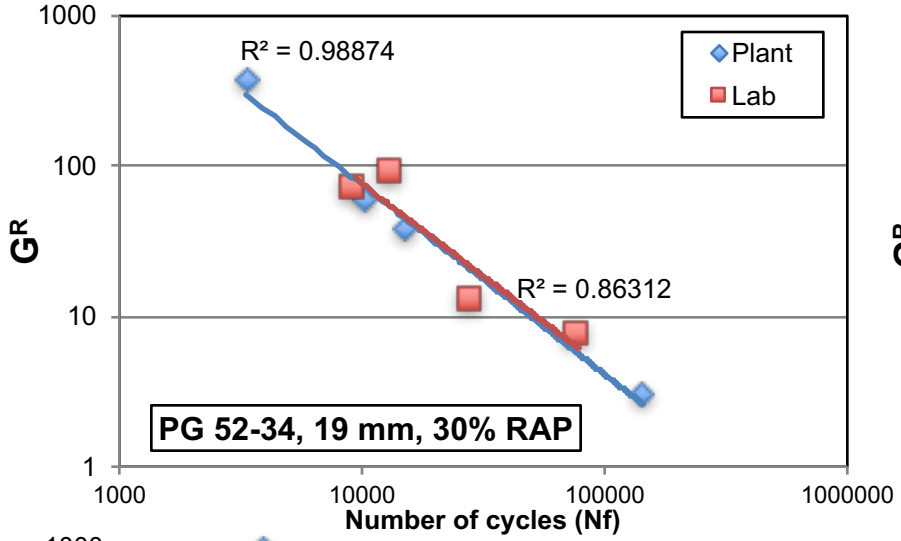
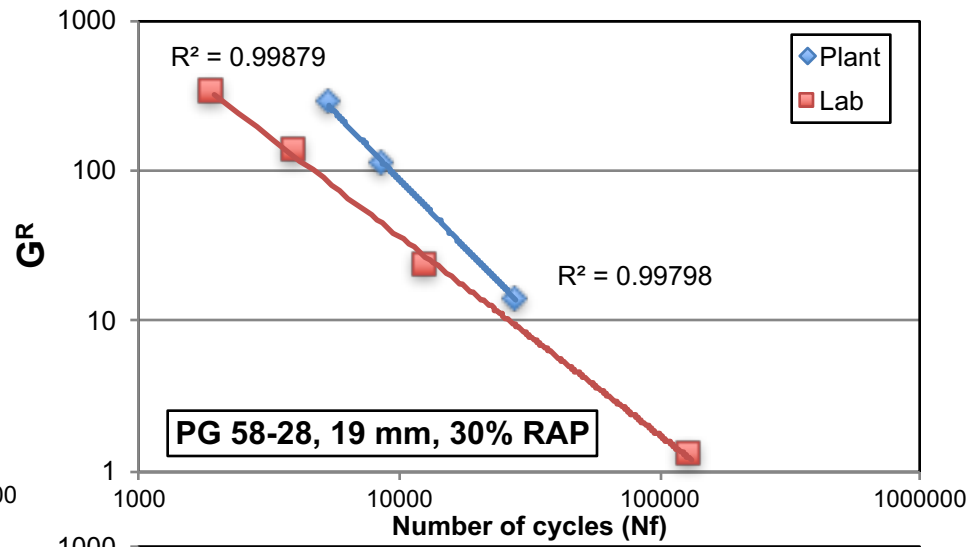
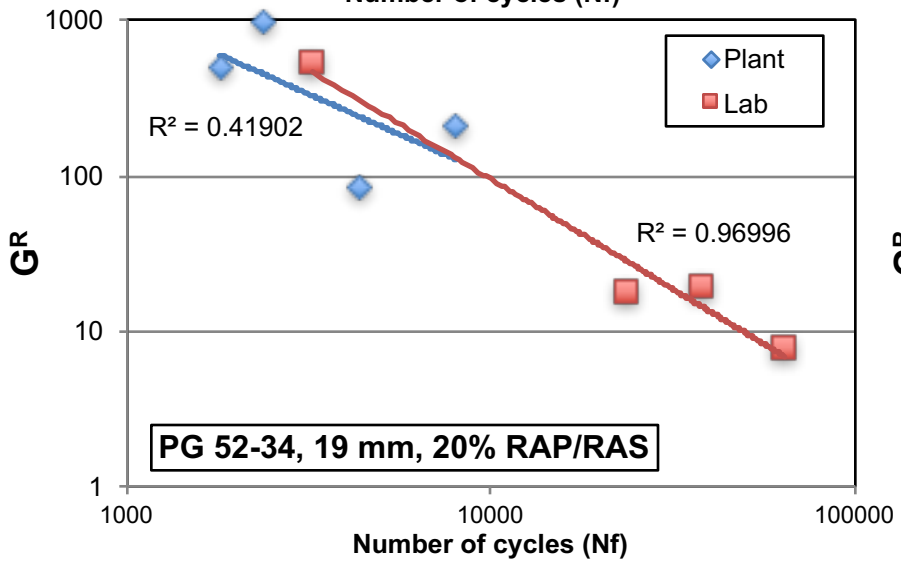
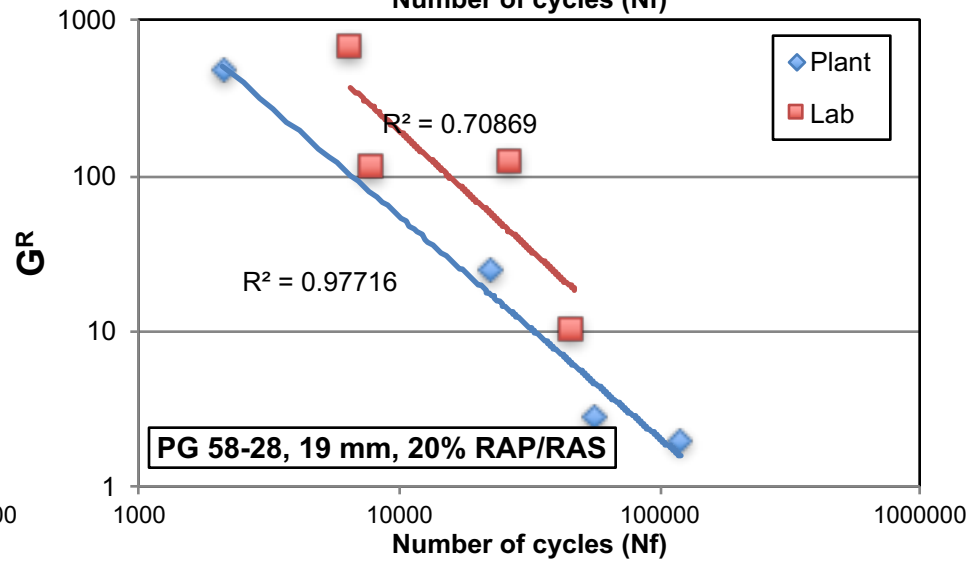
Fatigue Failure (Plant vs. Lab), 19 mm









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Conclusion

- **Binder results**
  - LMLC have warmer high and low PG temperature.
  - The binders extracted from the 19 mm mixtures have warmer temperatures than those extracted from 12.5 mm mixtures.
  - ΔT_{cr} of 19 mm and PG 52-34 mixtures are generally higher than 12.5 mm and PG 58-28, respectively.
  - Generally, ΔT_{cr} of the mixtures containing RAS are larger than those for the mixtures with RAP only.

Conclusion

- **Complex Modulus**
  - Dynamic Modulus of lab produced mixtures are higher than plant produced mixtures.
  - In most cases, lab produced mixtures show slightly more elastic behavior, less relaxation capability.
  - The variation of mixtures stiffness are as expected in terms of stiffer binder, higher recycled materials and coarser aggregate.
  - Inclusion of higher RAP increases dynamic modulus, while incorporating RAS does not follow a consistent trend.

Conclusion

- **Fatigue Cracking**
  - There is no consistent trend between Lab and plant produced mixtures, but:
    - There is larger difference between PG 58-28 plant and lab mixes than PG 52-34 mixes.
  - The fatigue performance (fatigue life) of 20% RAP and 30% RAP mixtures are similar.
  - Most 20% RAP/RAS mixes show higher G^R, but lower N_f.

Future Work

- Additional Testing and Mixtures
  - ✓ DCT testing
  - ✓ Binder test results
  - ✓ Hooksett mixtures
- Evaluate impact of long term aging

Acknowledgement

- Dr. J. Daniel,

  Professor, University of New Hampshire
- Dr. E. Dave,

  Assistant Professor, University of New Hampshire
- New Hampshire Department of Transportation
- Pike Industries, Inc.
- Asphalt Research Group, University of New Hampshire

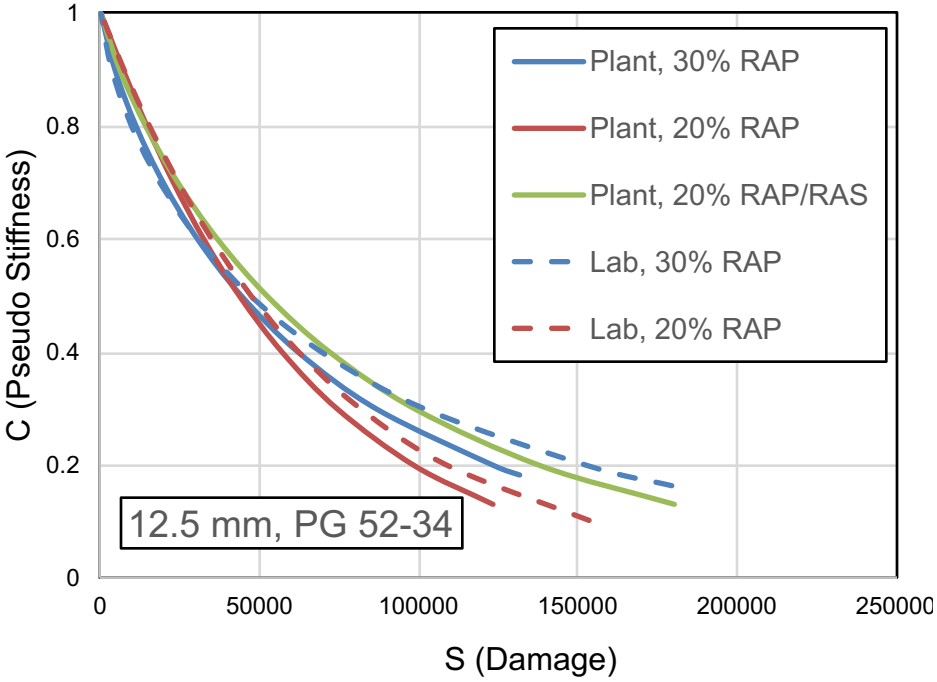
Thank You!

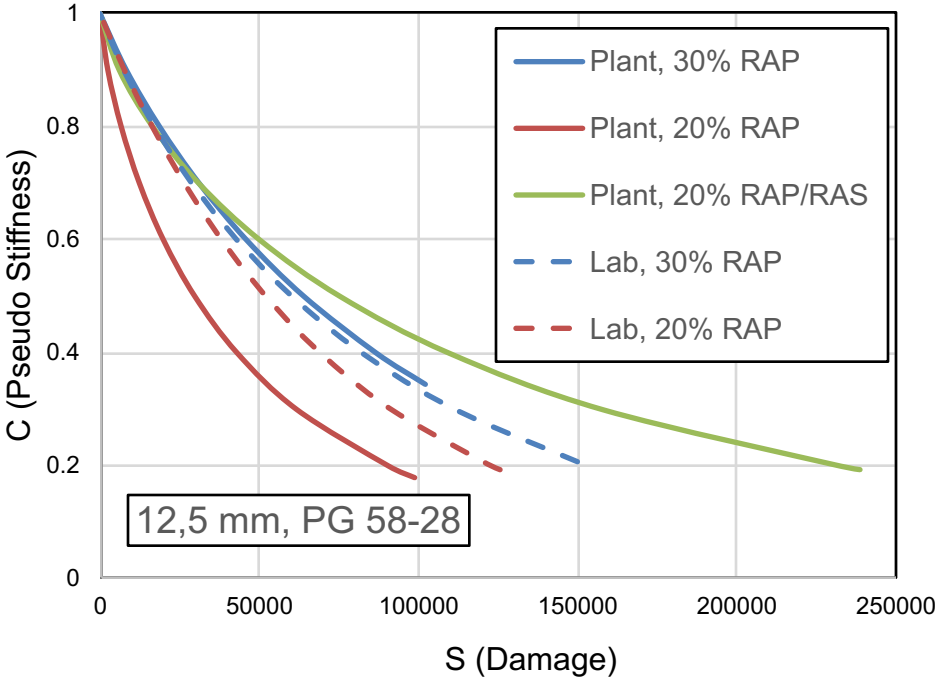
Questions?

Mixtures

Binder PG Grade	Binder Source (mm)	NMSA	%Total Binder Replacement	% RAP Binder	% RAS Binder	PMPC (Pike)	LMLC (NHDOT)
58-28 (2013)	McAsphalt	12.5	18.9	18.9	0		
	McAsphalt	12.5	18.5	7.4	11.1		-
	McAsphalt	12.5	28.3	28.3	0		
	McAsphalt	19	20.8	20.8	0		-
	Avery Lane	19	20.4	8.2	12.2		
	Avery Lane	19	31.3	31.3	0		
52-34 (2013)	McAsphalt	12.5	18.9	18.9	0		
	McAsphalt	12.5	18.5	7.4	11.1		-
	McAsphalt	12.5	28.3	28.3	0		
	Suncor	19	20.4	8.2	12.2		
	Suncor	19	31.3	31.3	0		
58-28 (2014)		9.5	21.3	21.3	0		
		12.5	21.3	21.3	0		
64-28 (2014)		9.5	16.4	16.4	0		
		12.5	-	-	0		

Damage Characteristic Curve (12.5 mm)





Damage Characteristic Curve (19 mm)