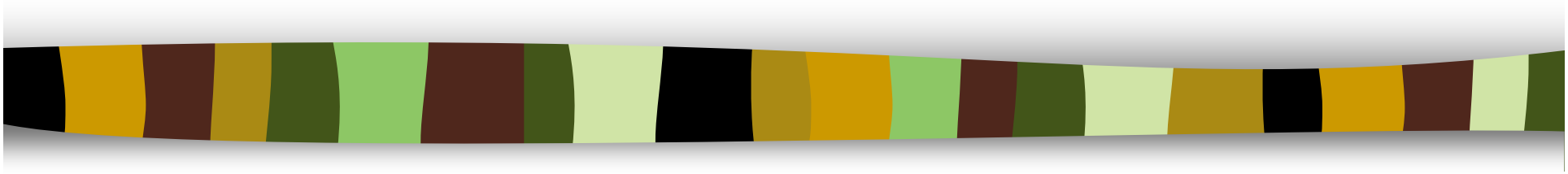
December 17, 2009



Investigation of Low and High Temperature Properties of Plant-Produced RAP Mixtures

Outline

- Review of Phase I
- Review of Work Plan
- Summary of Results
- Status

Phase 1

- *Low-Temperature Performance Properties of Hot Mix Asphalt Containing RAP*
  - Evaluated plant-produced mixes with up to 40% RAP and two virgin binder grades
  - Originally proposed to focus on effects of RAP on low temperature properties
    - Not strictly confined to low temps though

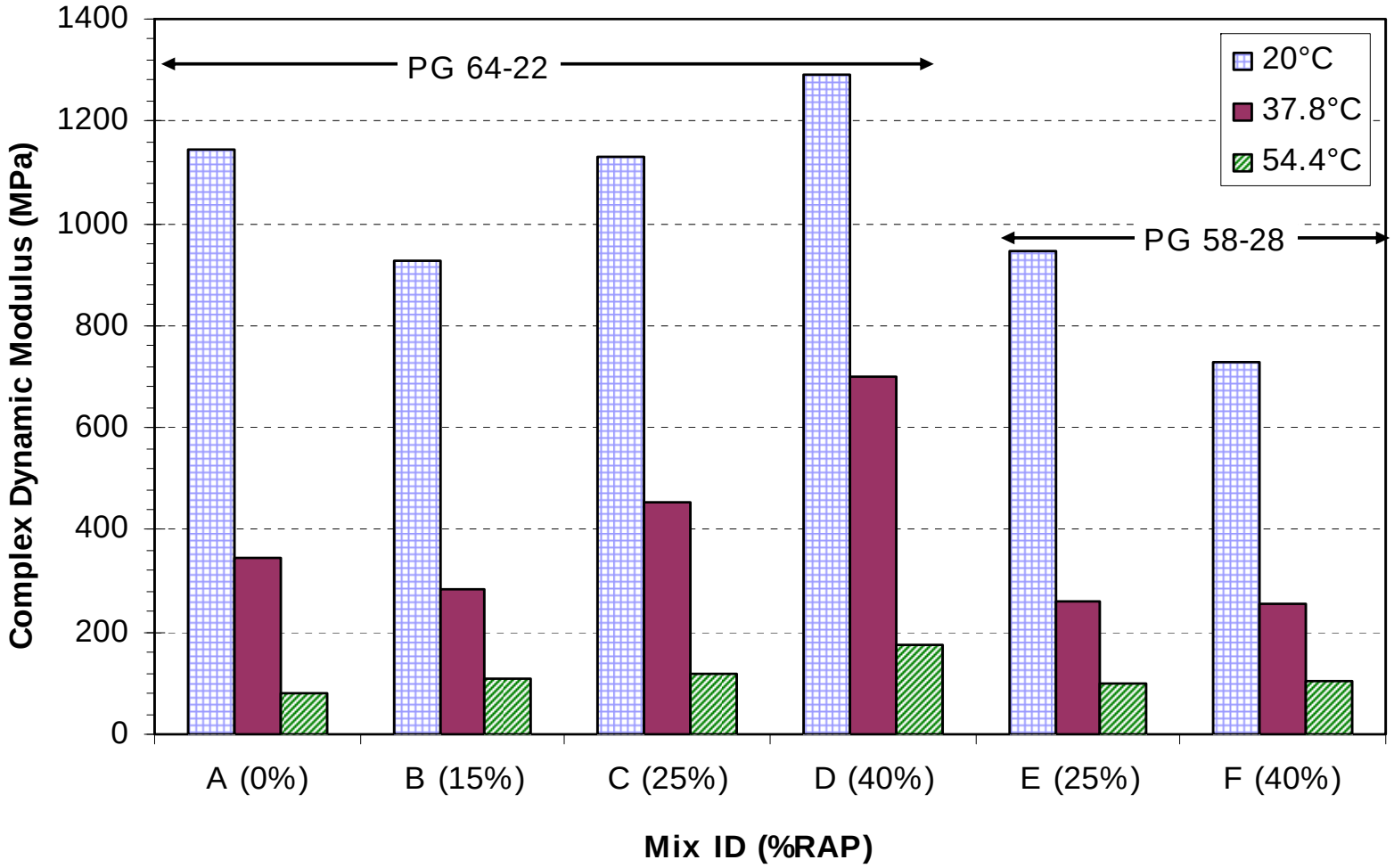
What We Did

- One contractor produced six mixes through one plant over two days.
- Heritage and NCSC tested RAP, virgin and mixture properties
  - Binder properties – PG binder tests
  - Mix properties – Indirect Tensile Strength, Dynamic Modulus, Shear Modulus

Experimental Design

	Reclaimed Asphalt Pavement			
Binder Grade	0%	15%	25%	40%
PG 58-28			X	X
PG 64-22	X	X	X	X

Phase 1 Data


1400
1200
1000
800
600
400
200
0
Complex Dynamic Modulus (MPa)
PG 64-22
PG 58-28
20°C
37.8°C
54.4°C
A (0%)
B (15%)
C (25%)
D (40%)
E (25%)
F (40%)
Mix ID (%RAP)

Critical Cracking Temperatures

Mix	RAP Content	Tc (°C)
A – PG64-22	0	-28.9
B – PG64-22	15	-23.3
C – PG64-22	25	-25.6
D – PG64-22	40	-22.8
E – PG58-28	25	-27.2
F – PG58-28	40	-23.9

2006 Results

- For these materials and this plant, the RAP mixes were not as stiff as expected.
- The binder did not stiffen linearly with increasing RAP content.
- In this case, dropping the virgin grade to PG58-28 for 25% RAP was not necessary.

Tests (being) Conducted

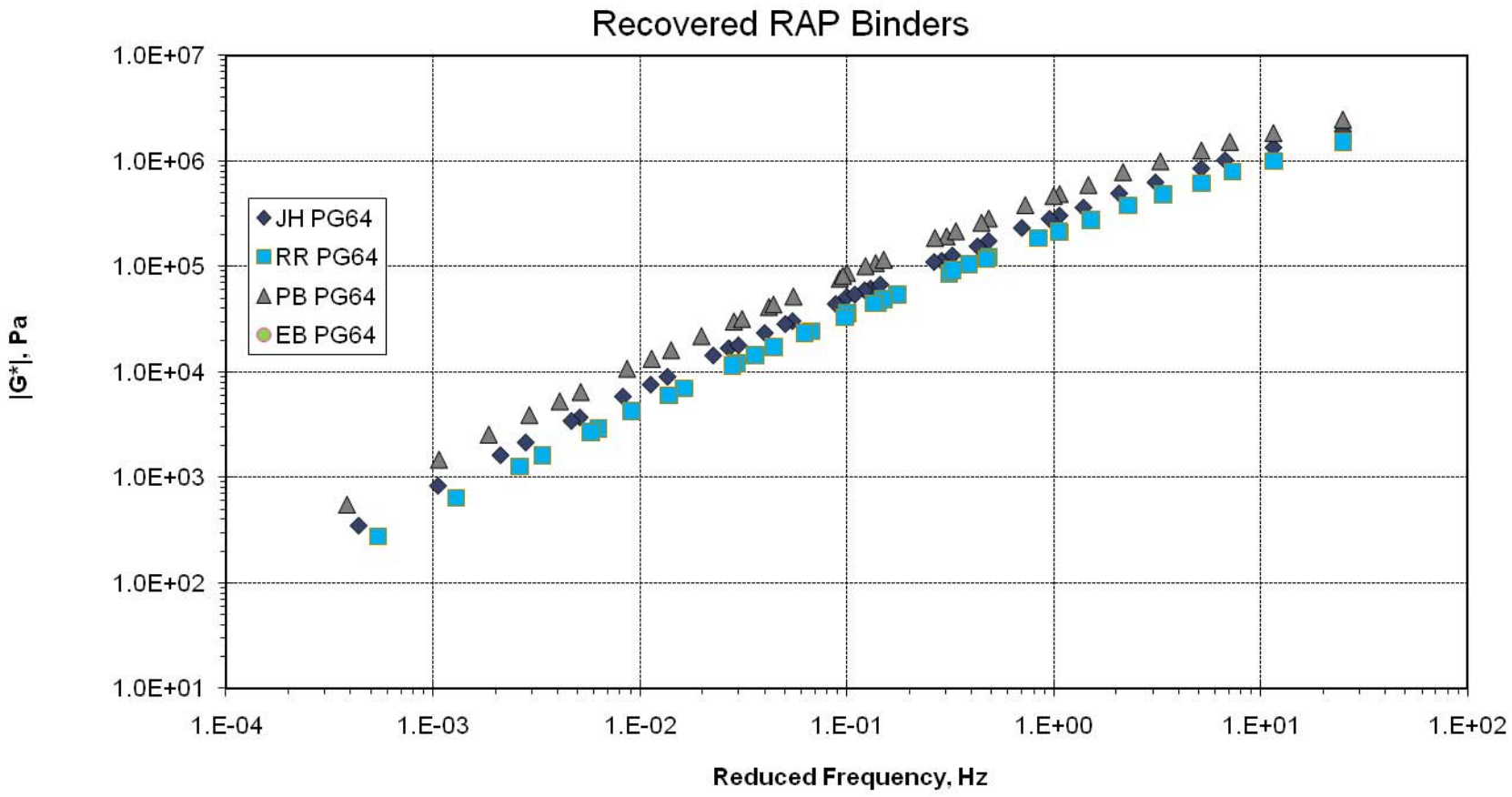
- Dynamic Modulus |E*|
  - High and intermediate modulus, blending
- Indirect Tension
  - Low temperature
- Binder extraction/recovery and PG grade
  - Blending analysis
- Fatigue Testing – at FHWA TFHRC
  - Samples delivered November 19, 2008

Phase 2 Study

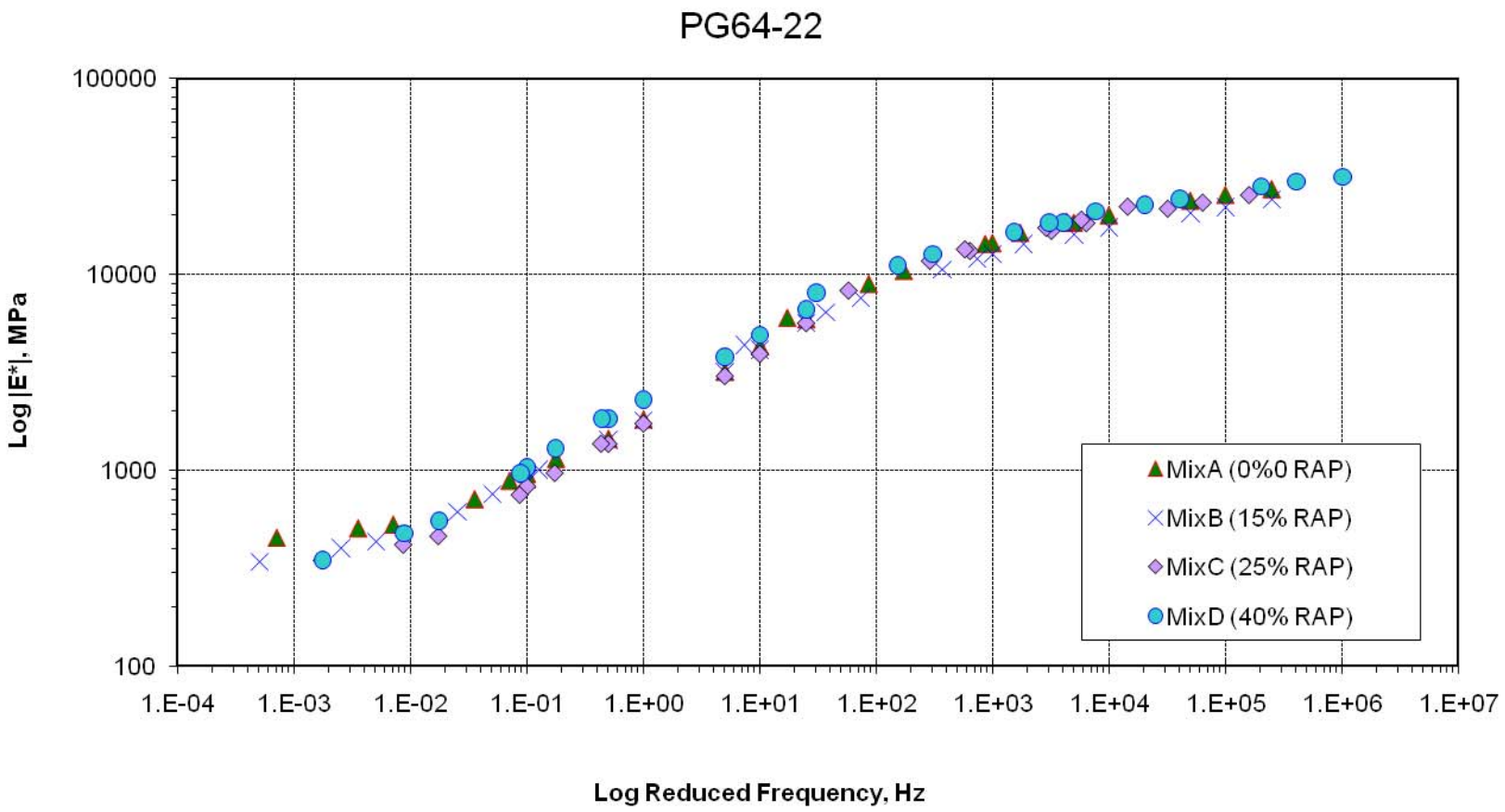
- High temperature properties added to title
- Four more contractors in two states (MI and IN – North, Central and South)
- Same experimental design

Phase 2 Results

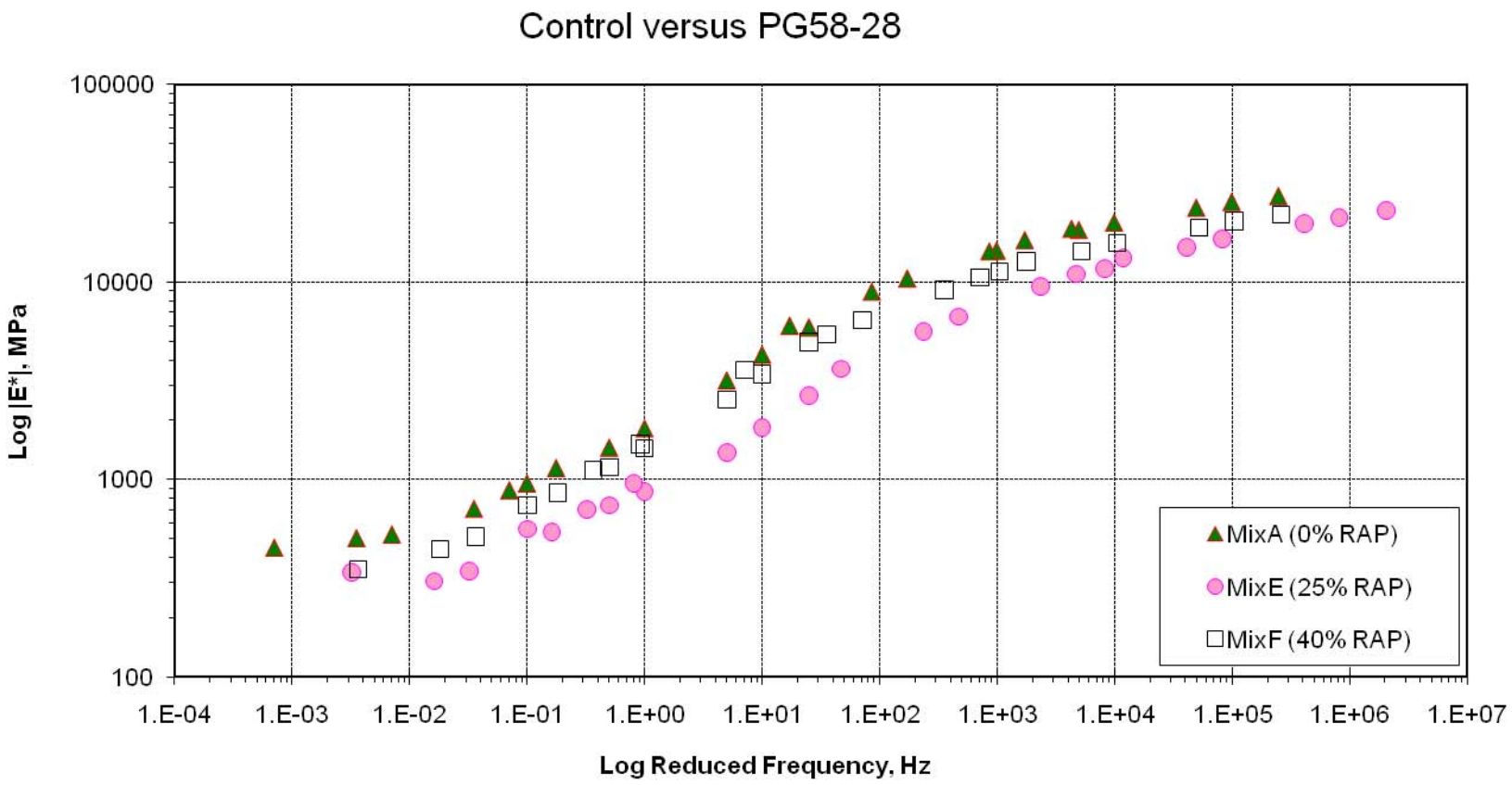
Recovered RAP Binder Comparison



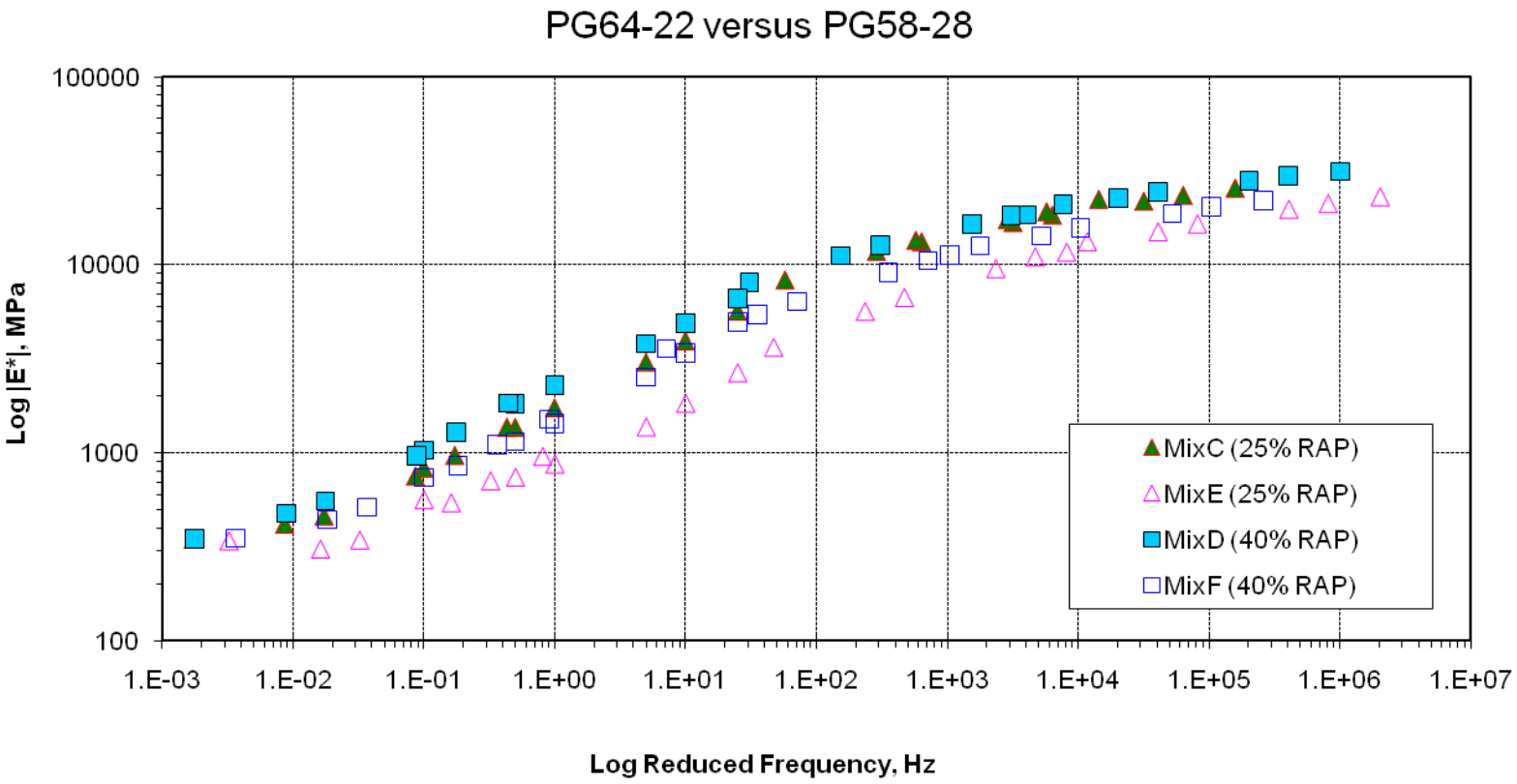
One Example - Mix |E*|



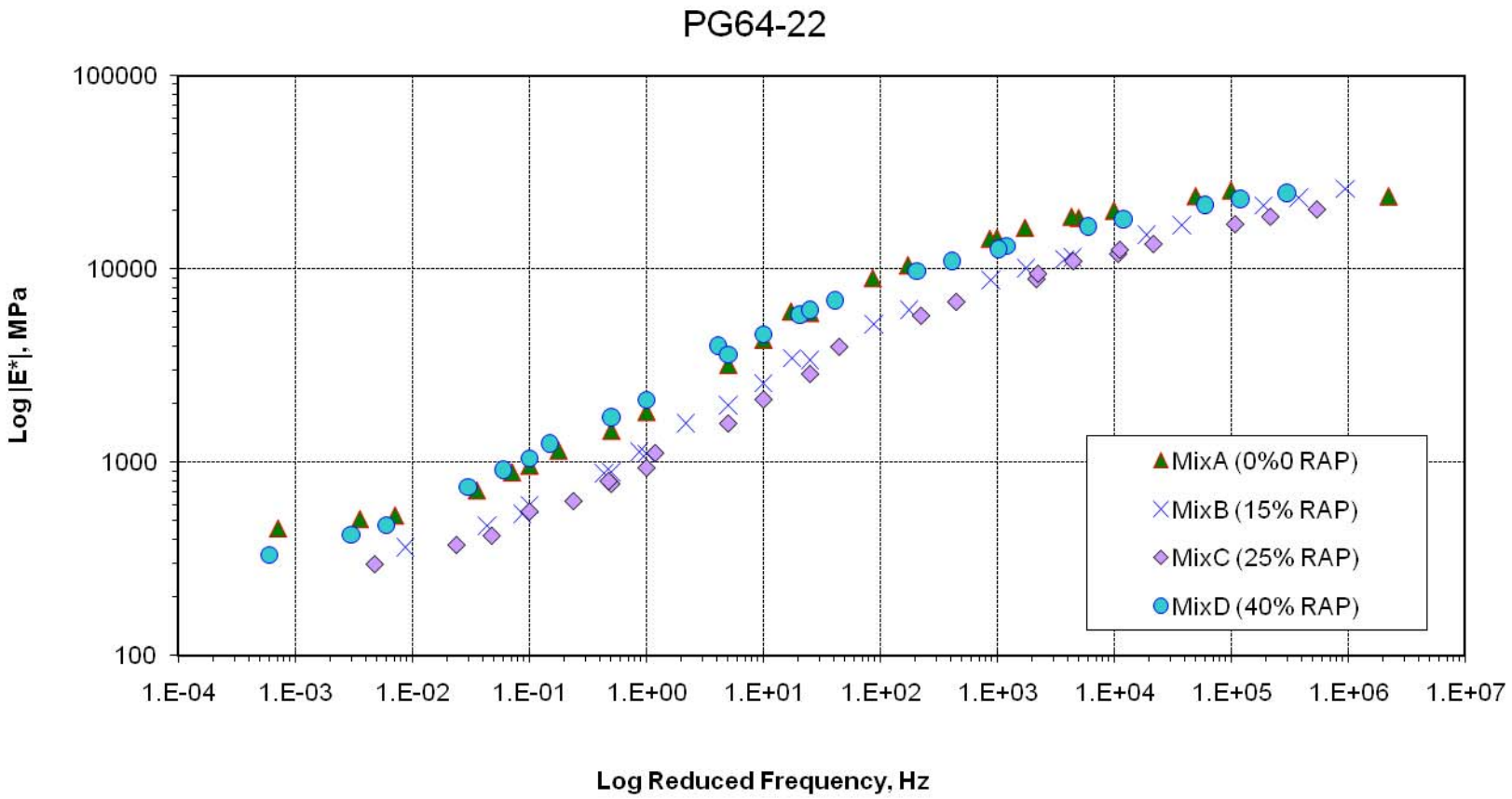
One Example - Mix |E*|



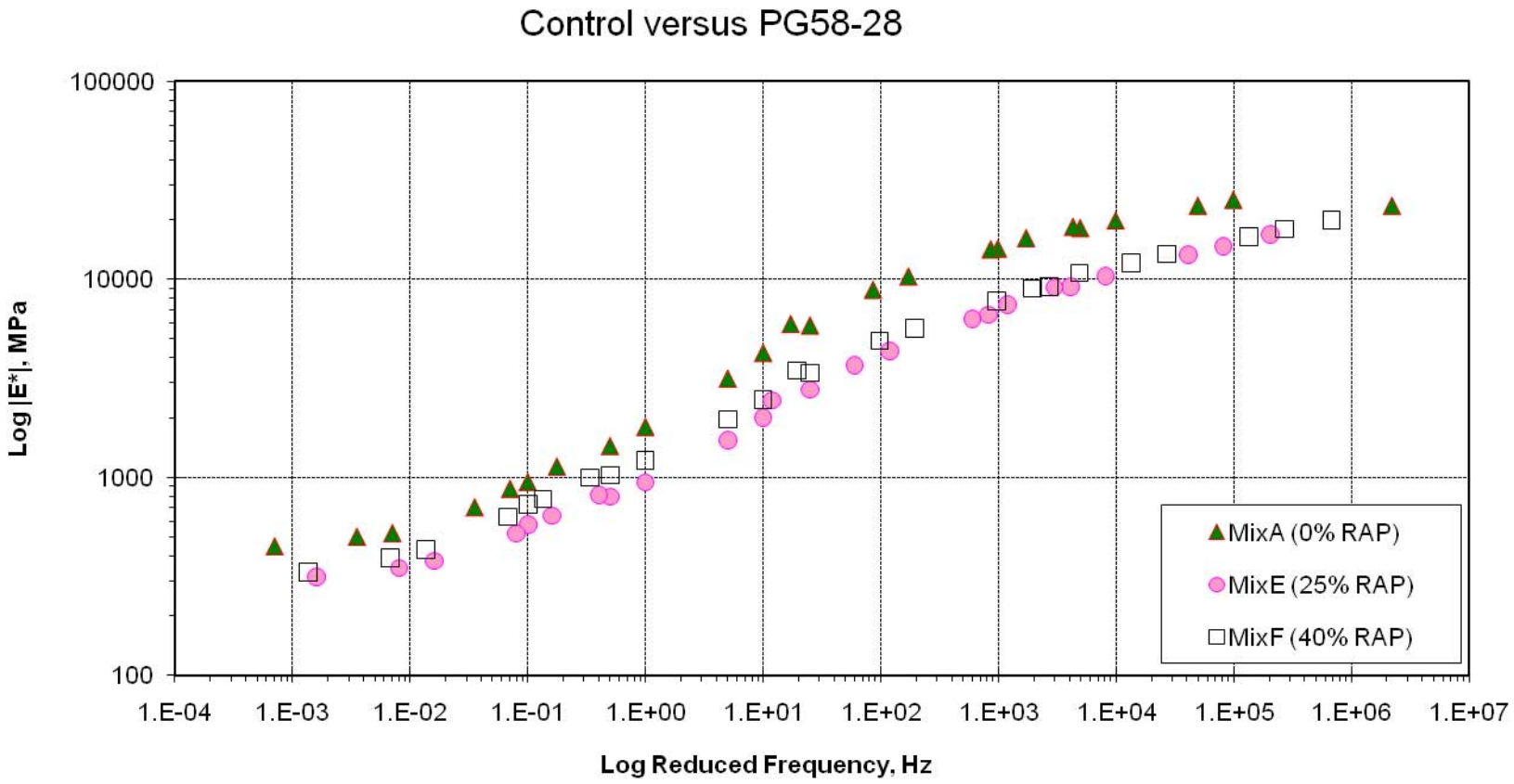
One Example - Mix |E*|



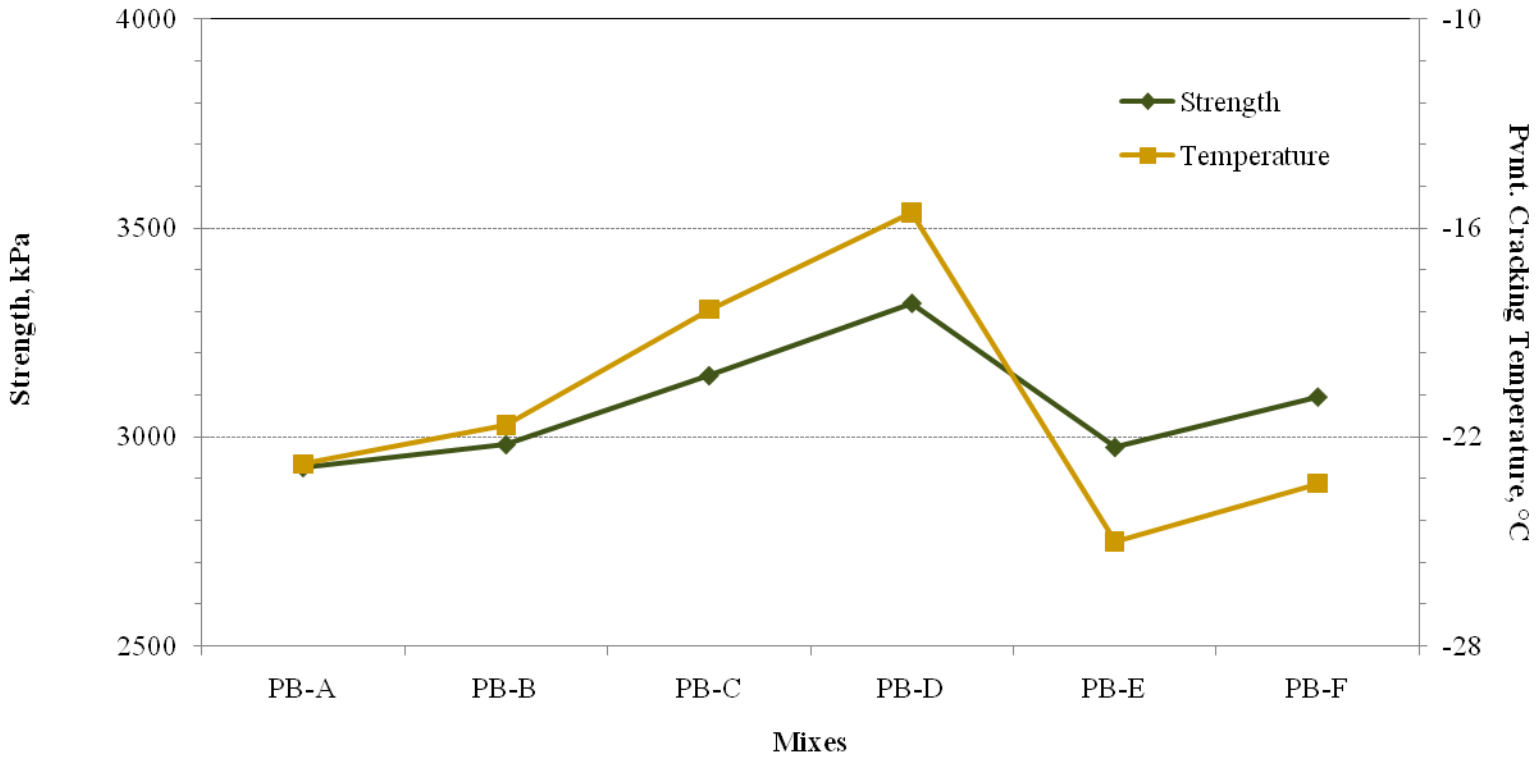
Second Example - Mix |E*|



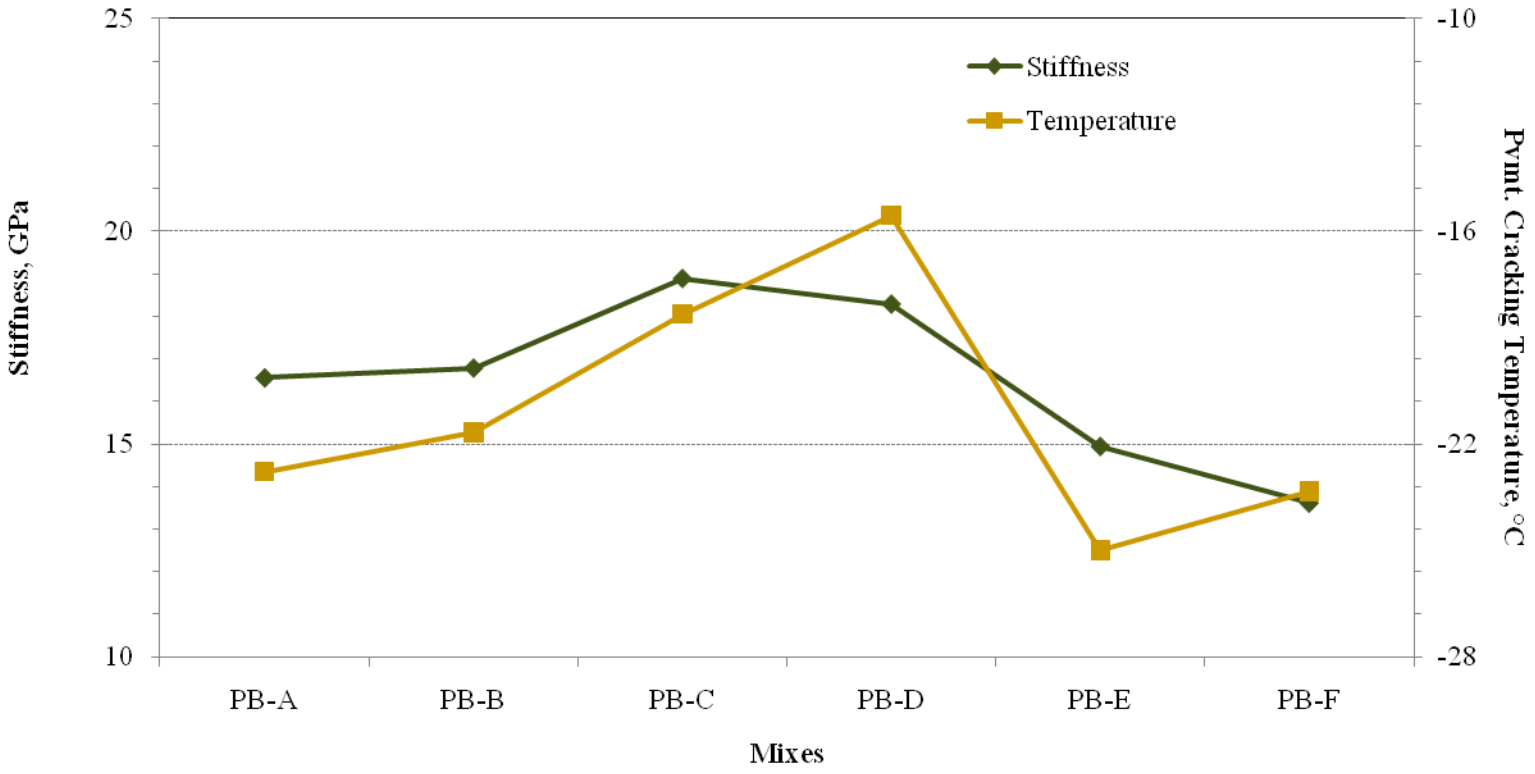
Second - Mix |E*|


Control versus PG58-28
100000
10000
1000
100
Log |E*|, MPa
1.E-04
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
Log Reduced Frequency, Hz
MixA (0% RAP)
MixE (25% RAP)
MixF (40% RAP)

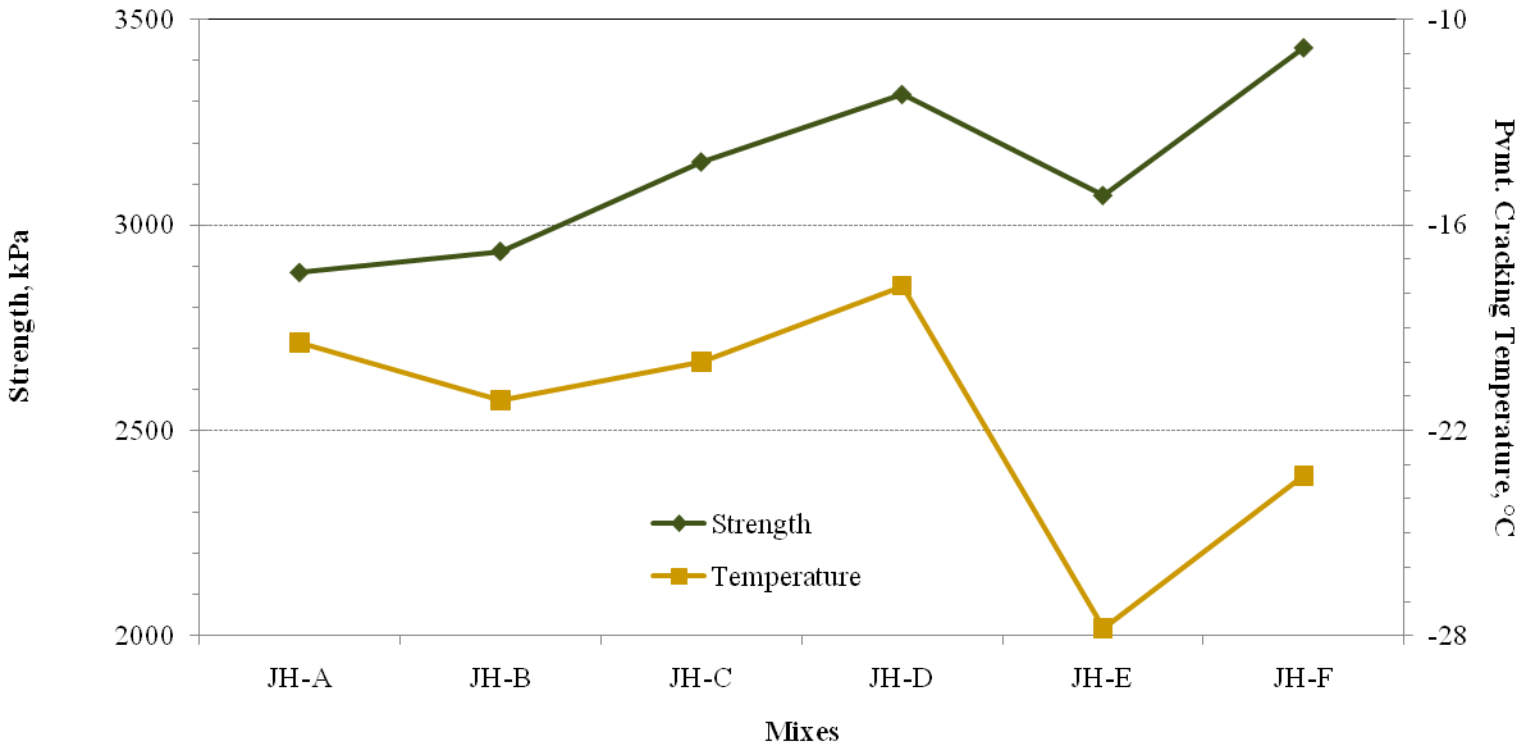
IDT Strength Example 1



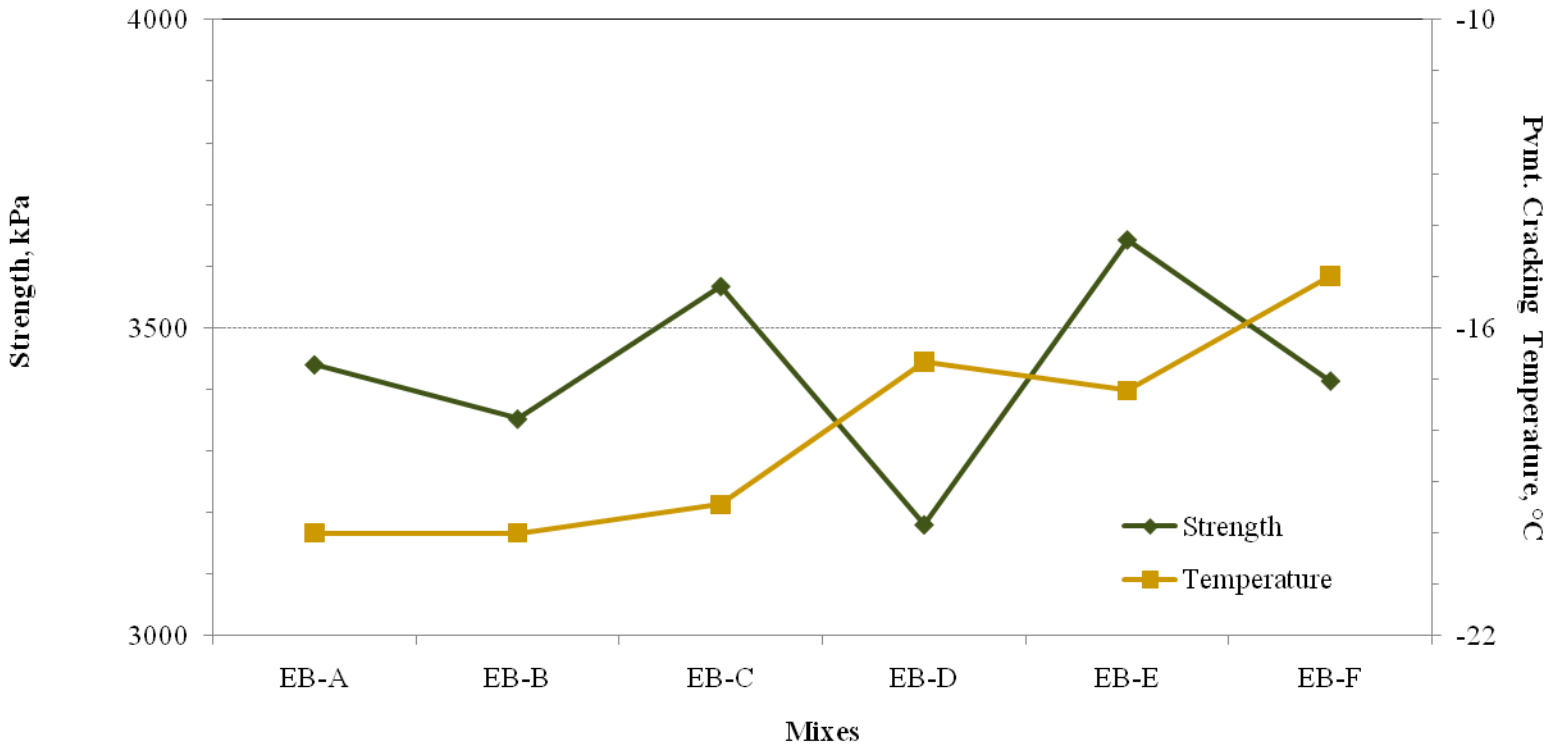
IDT Stiffness Example 1



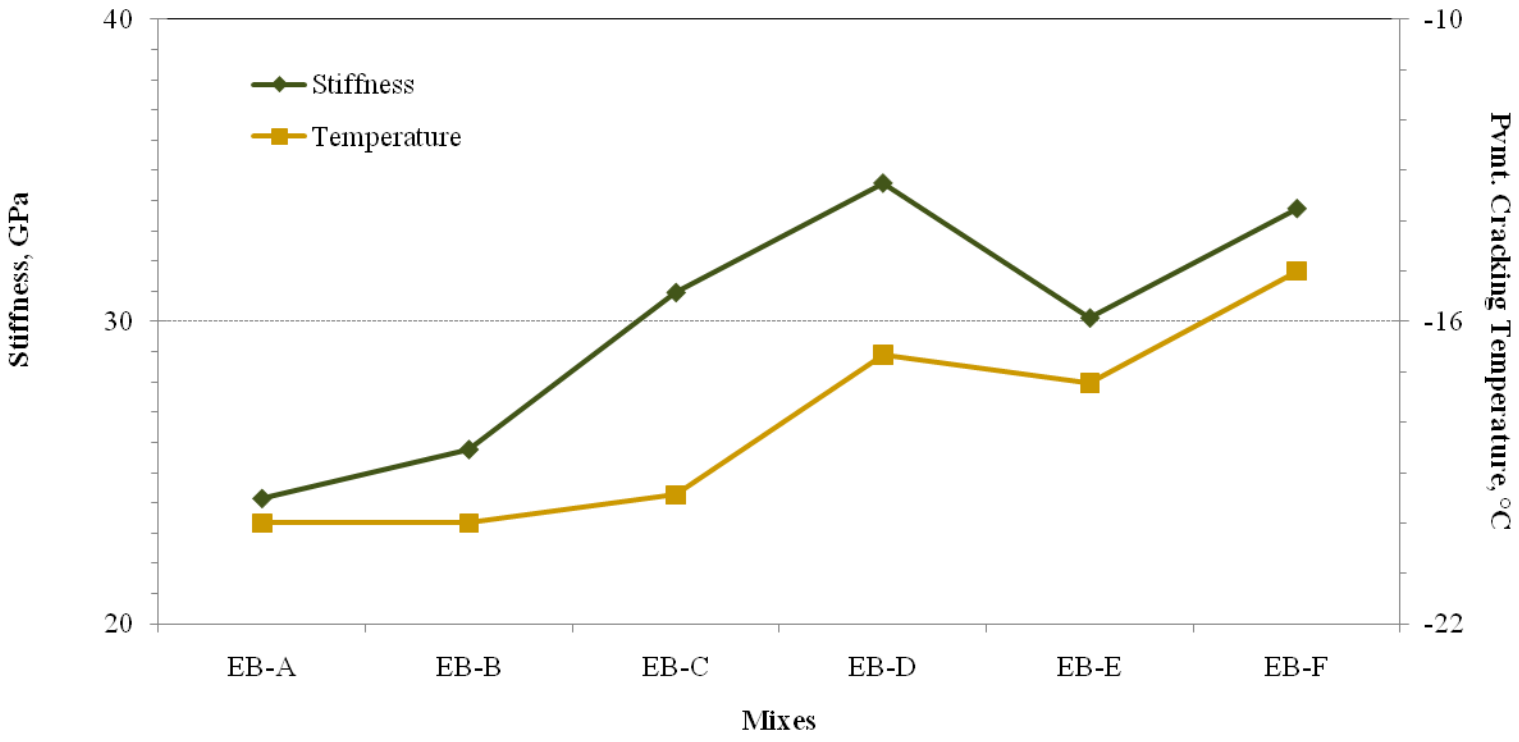
IDT Strength Example 2



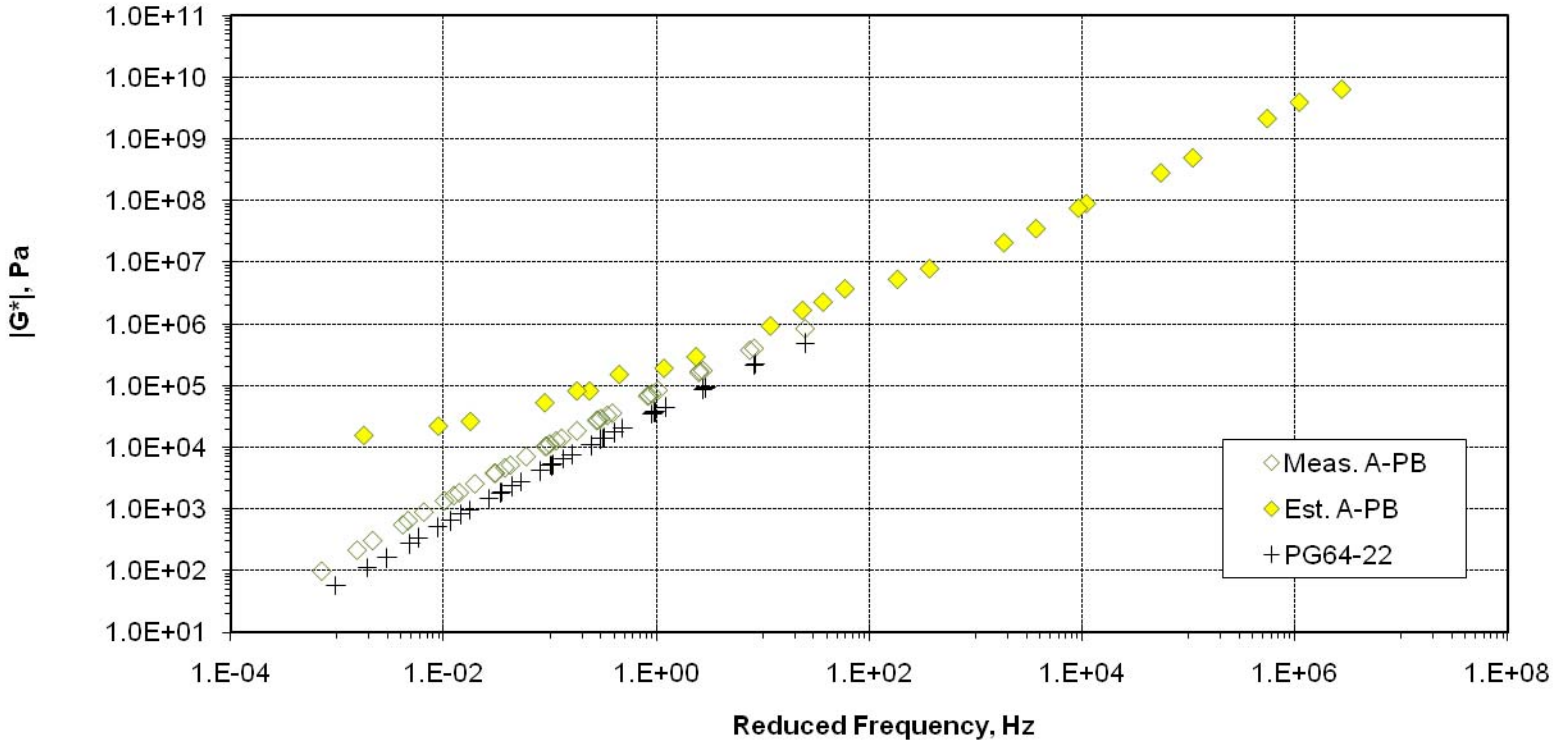
IDT Strength Example 3



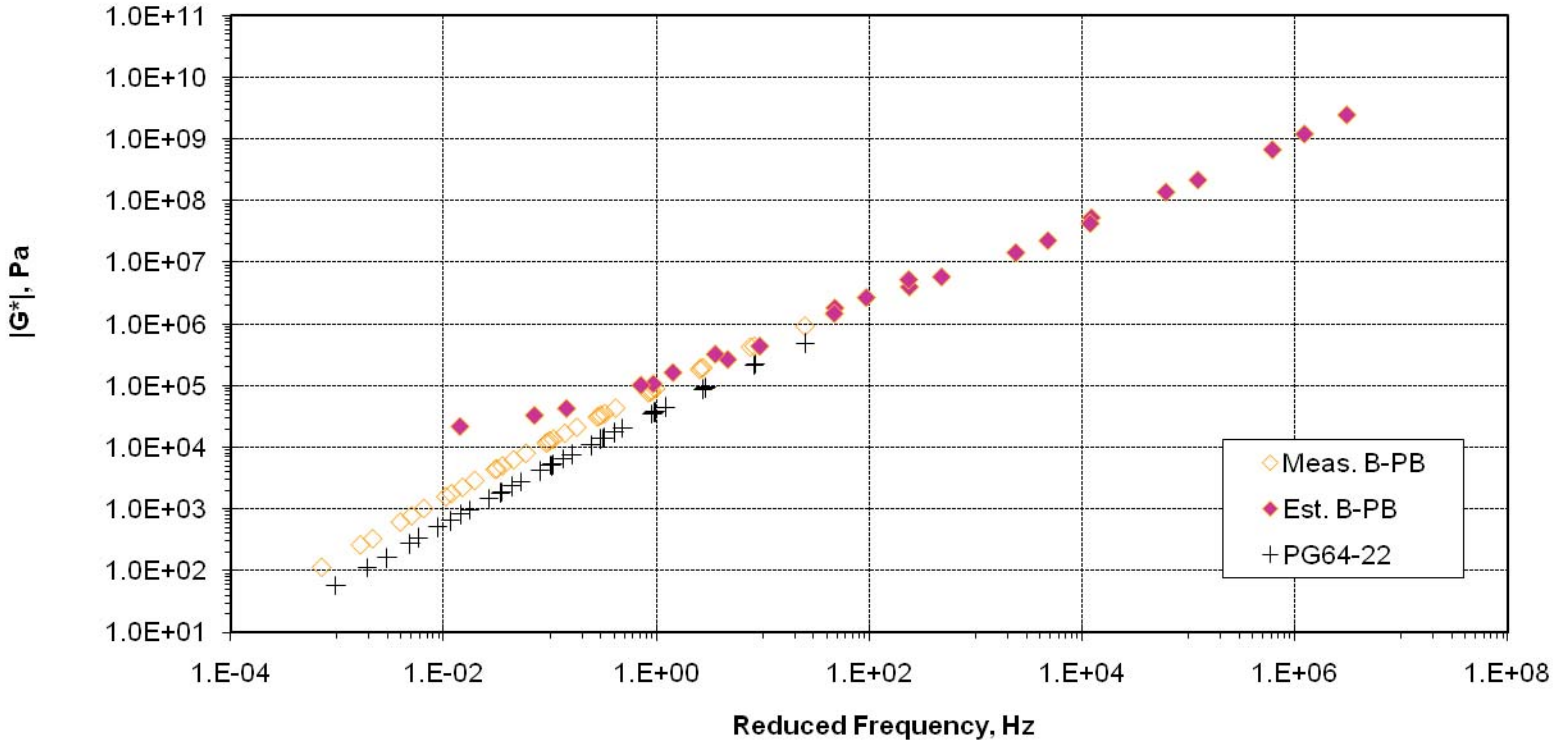
IDT Stiffness Example 3



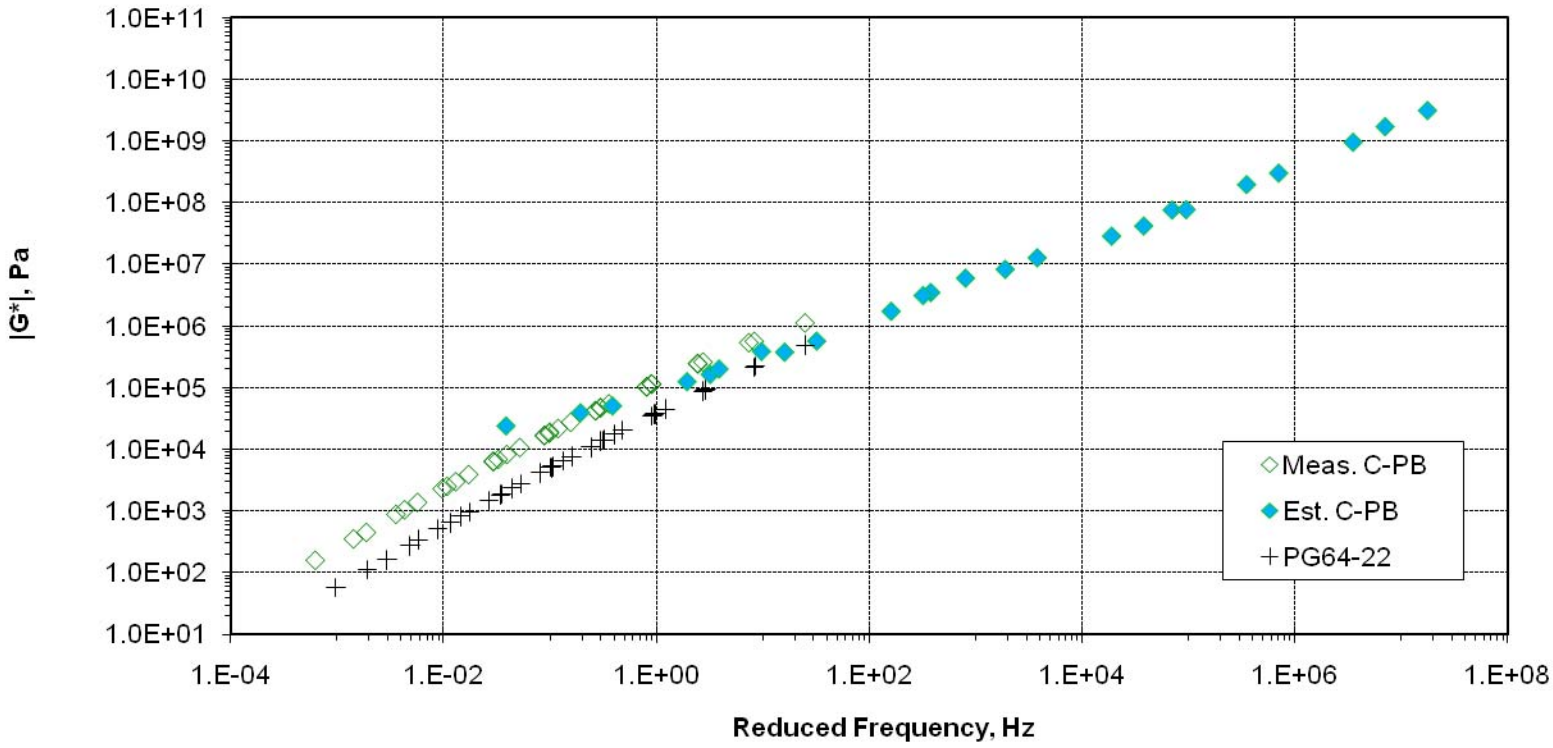
Mix A


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. A-PB
Est. A-PB
PG64-22

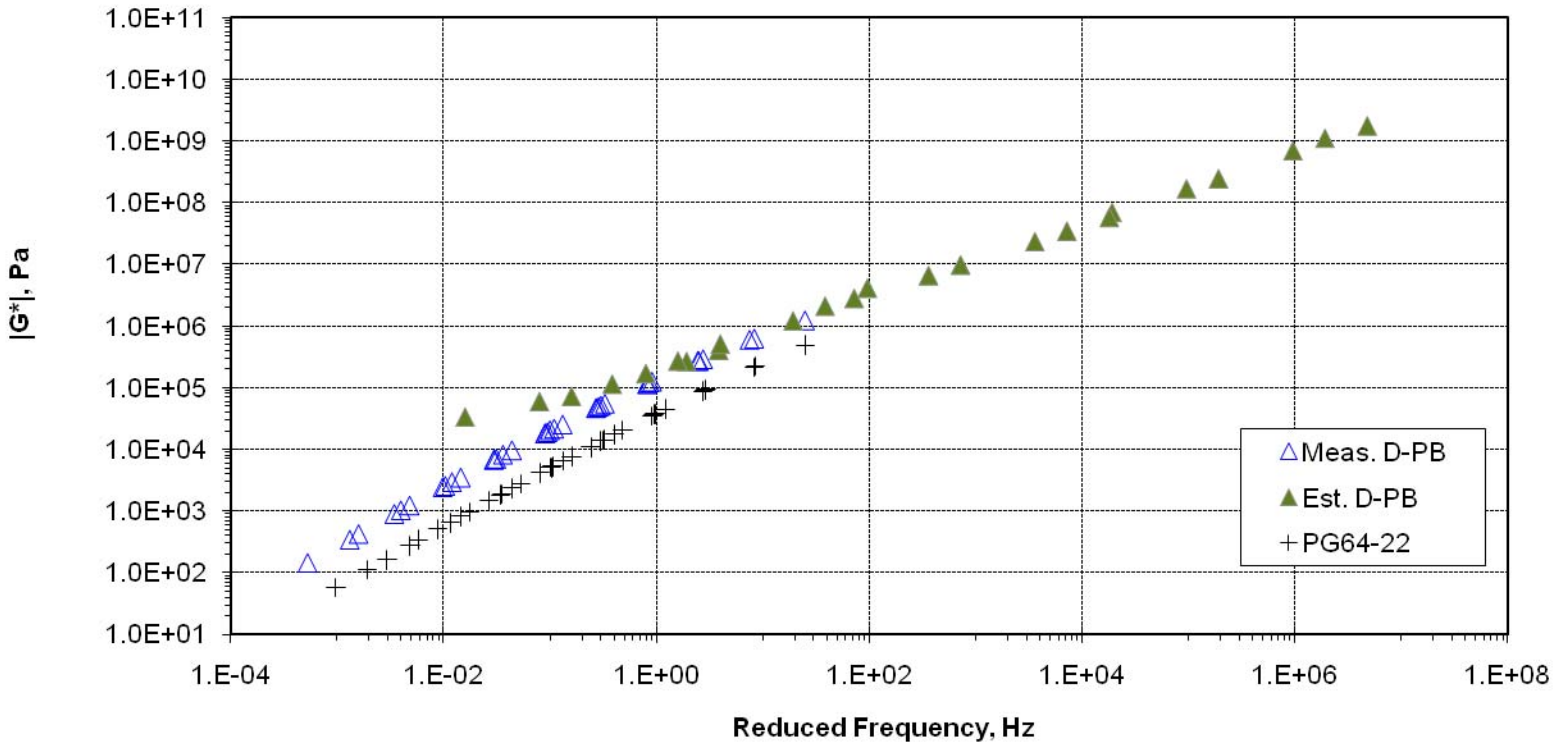
Mix B


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. B-PB
Est. B-PB
PG64-22

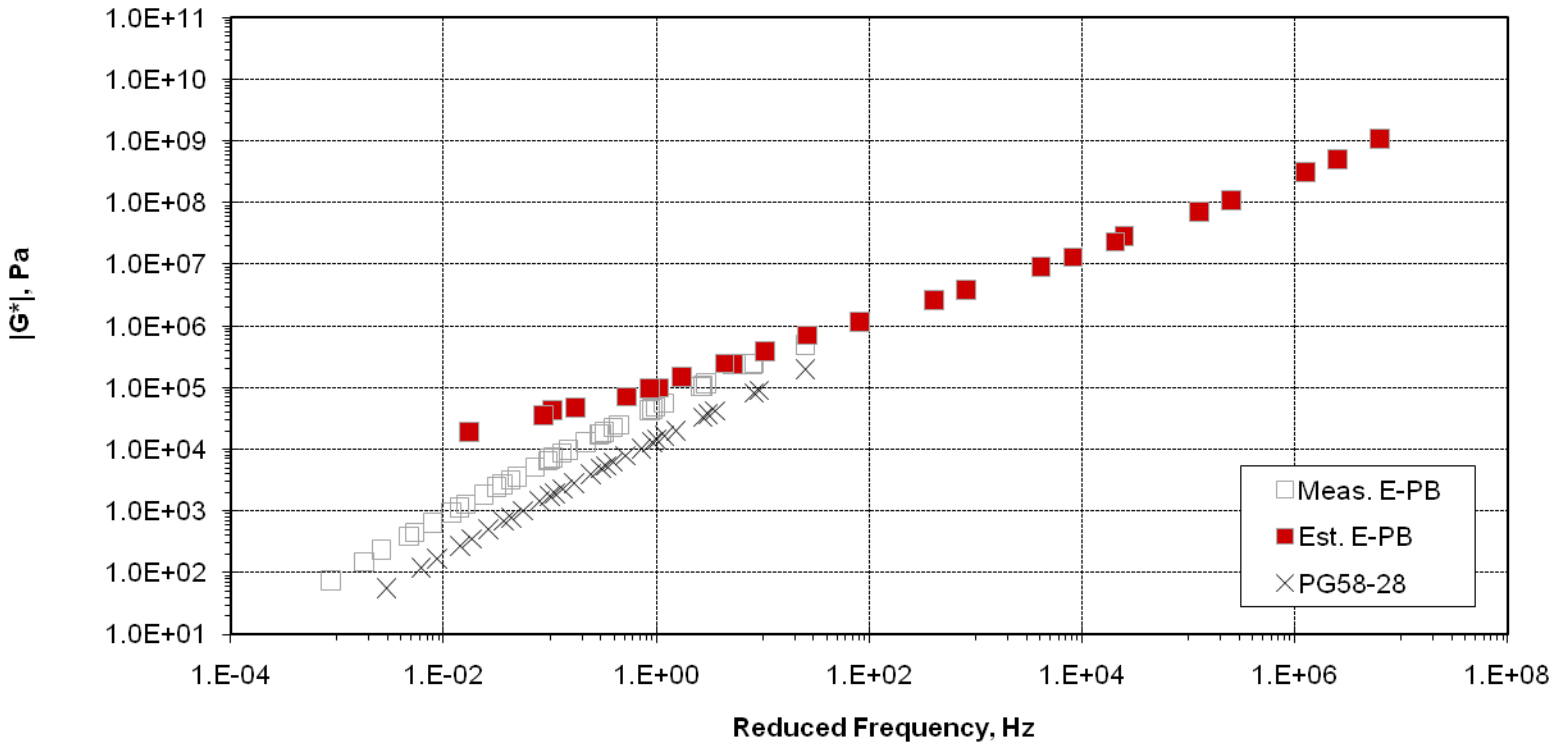
Mix C


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. C-PB
Est. C-PB
PG64-22

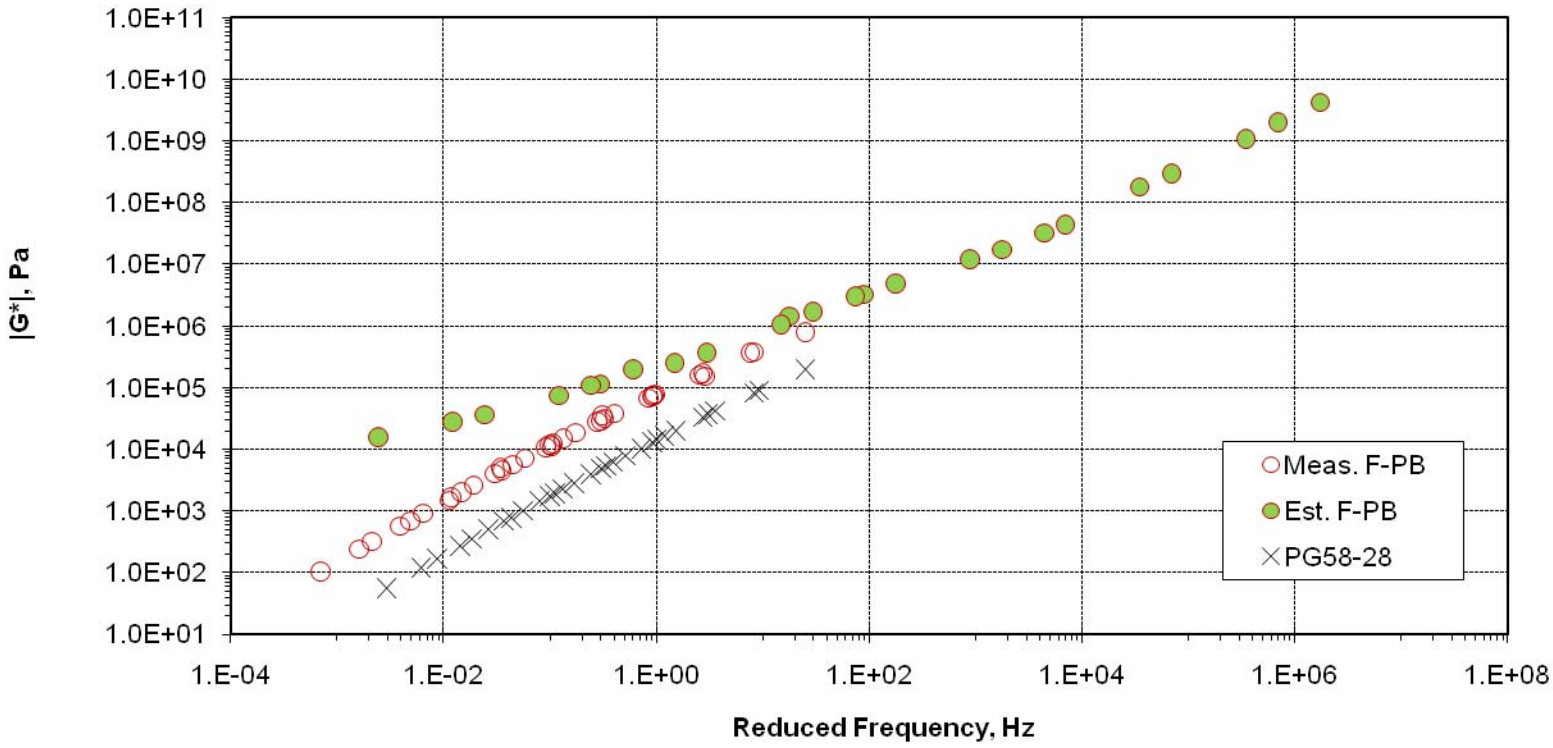
Mix D


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. D-PB
Est. D-PB
PG64-22

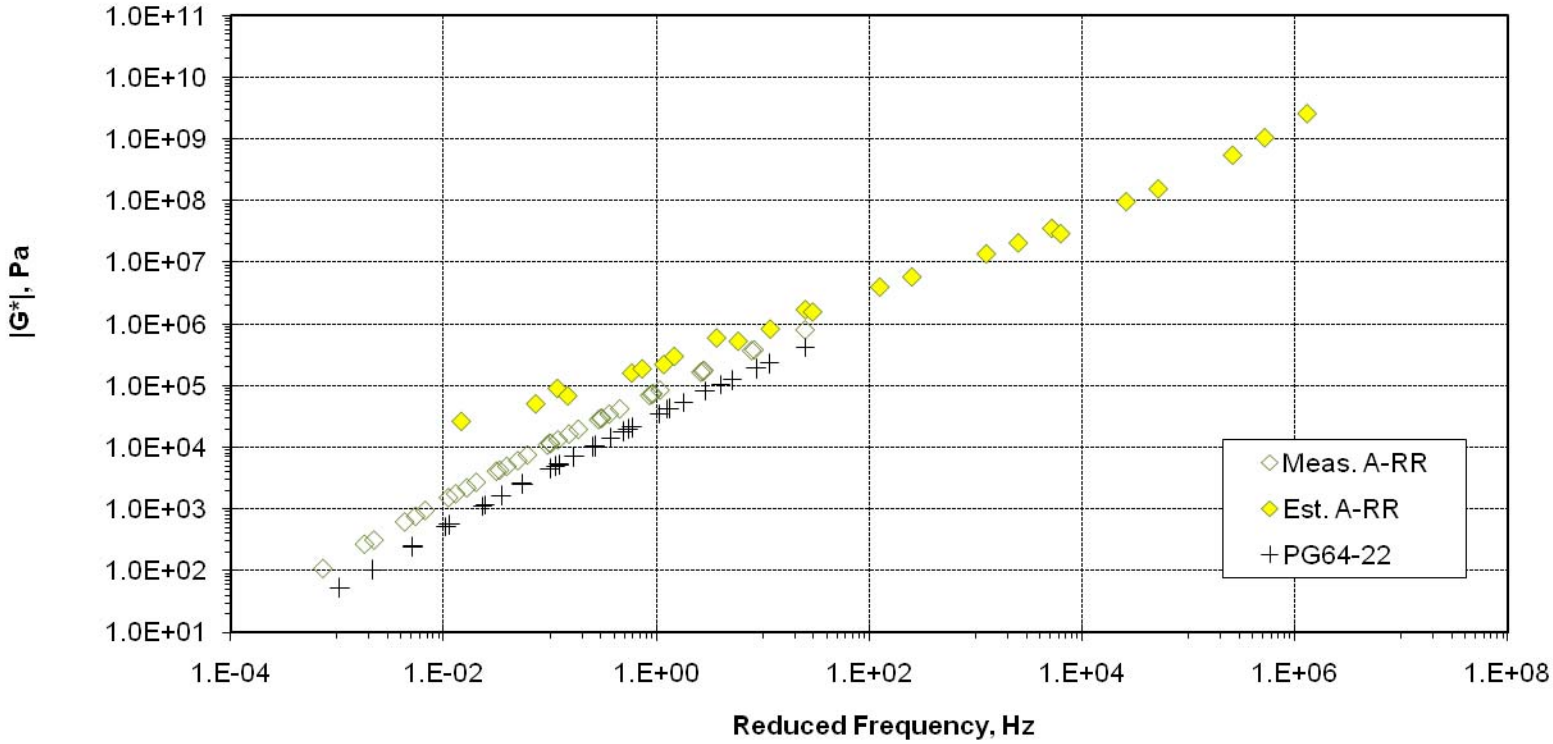
Mix E


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. E-PB
Est. E-PB
PG58-28

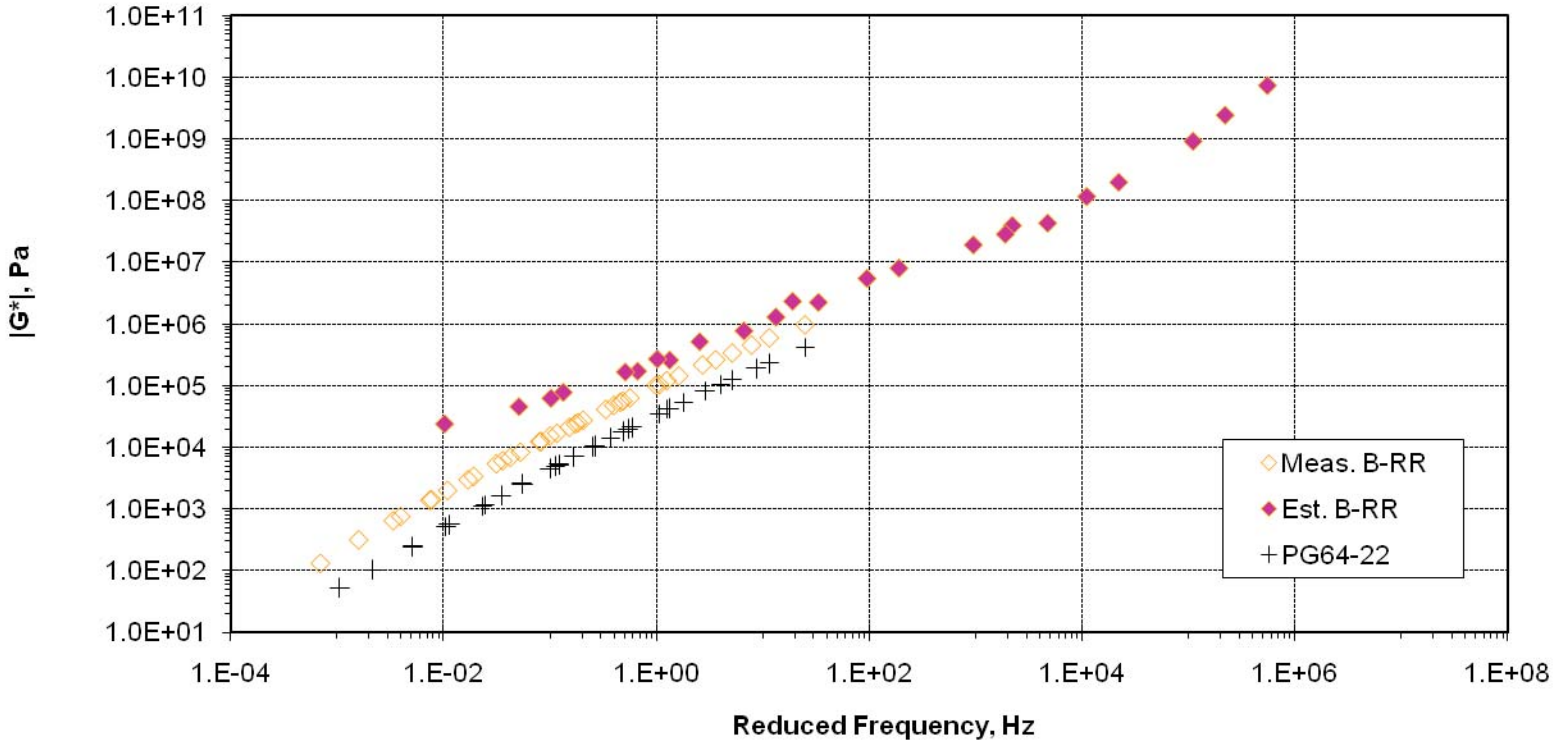
Mix F


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. F-PB
Est. F-PB
PG58-28

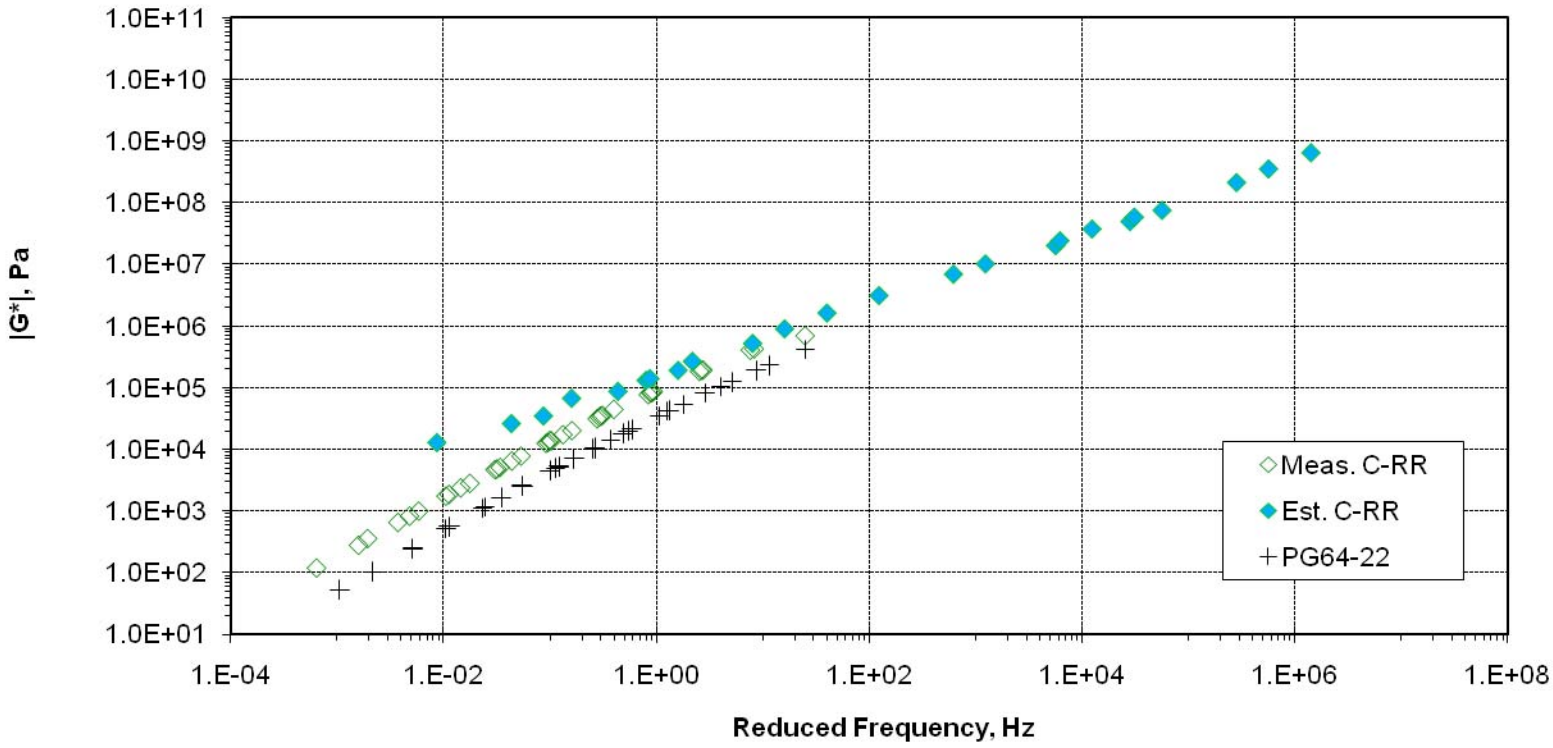
Mix A


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. A-RR
Est. A-RR
PG64-22

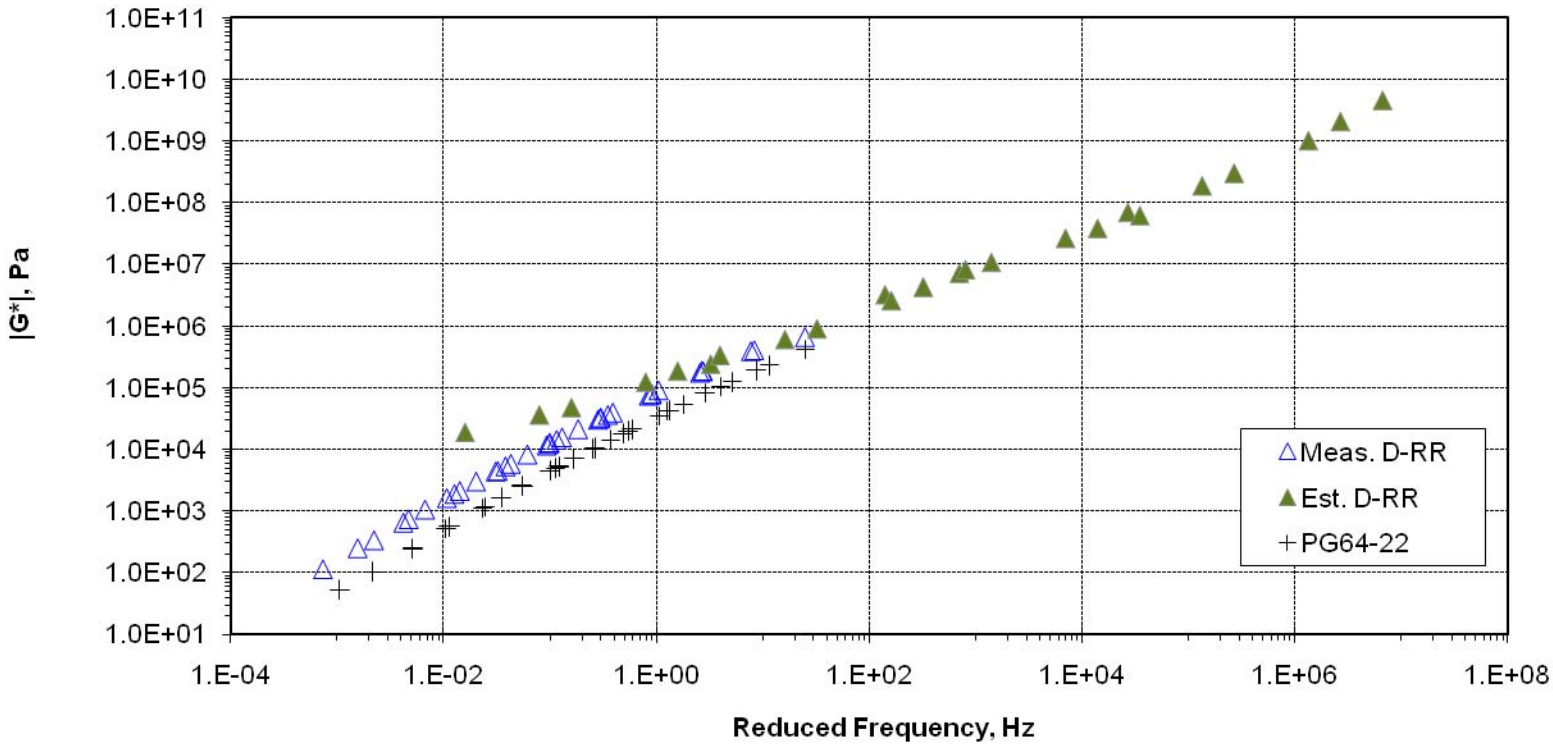
Mix B


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. B-RR
Est. B-RR
PG64-22

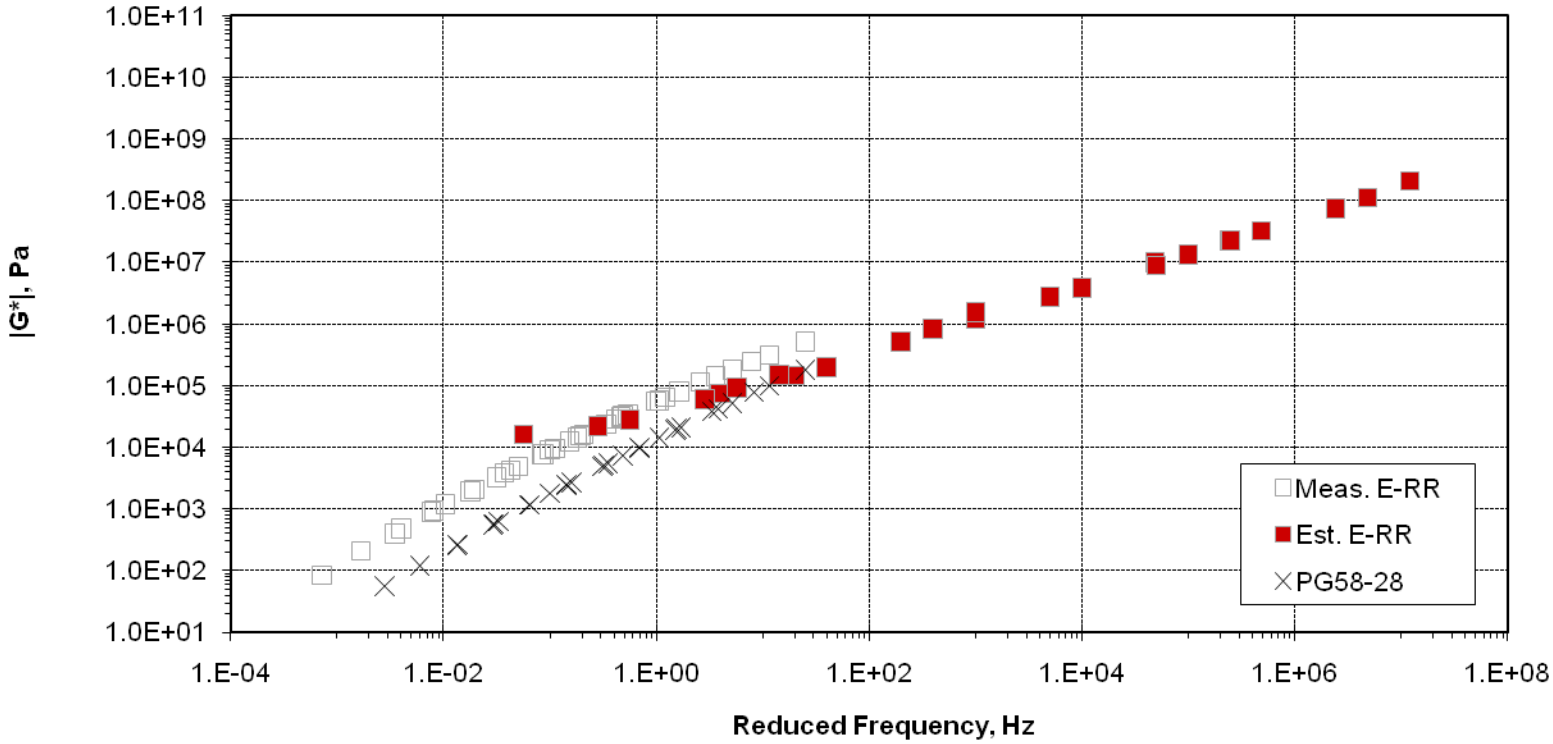
Mix C


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. C-RR
Est. C-RR
PG64-22

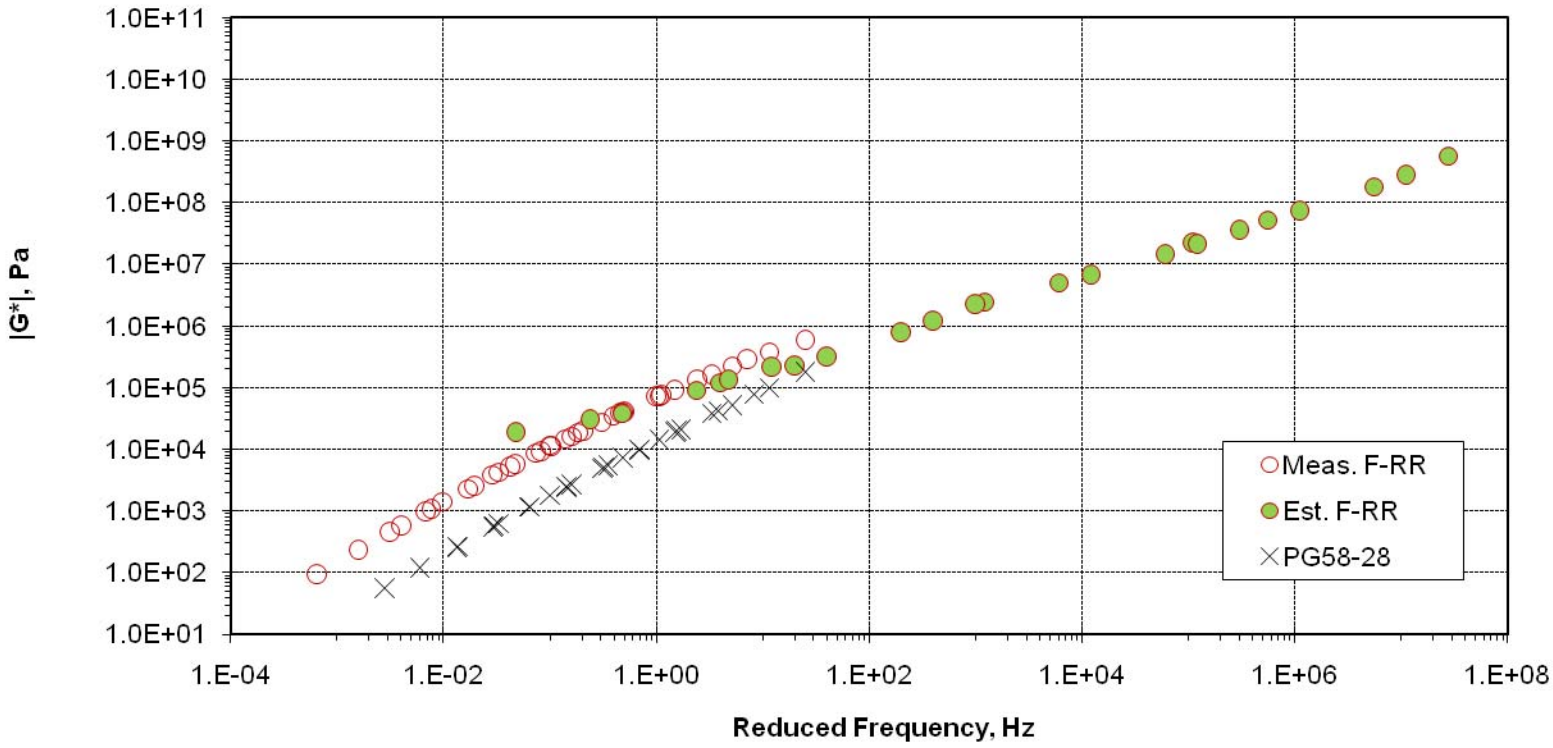
Mix D


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. D-RR
Est. D-RR
PG64-22

Mix E


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. E-RR
Est. E-RR
PG58-28

Mix F


1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
|G*|, Pa
1.E-04
1.E-02
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Reduced Frequency, Hz
Meas. F-RR
Est. F-RR
PG58-28

Overall

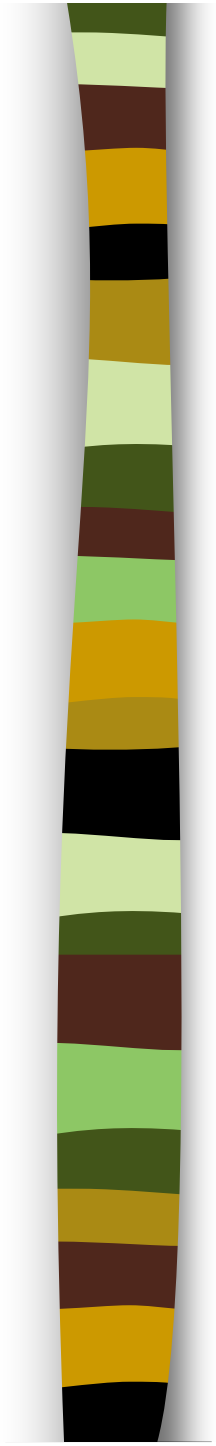
- Two cases indicated pretty good blending, two showed less
- Relates to other comparisons
  - IDT indicated little effect of binder grade in the cases with questionable blending
- Results were not totally consistent

Risks of False Assumptions

- Assuming there is blending may be more conservative.
  - Shouldn’t rely on binder to control rutting
  - Increased cracking can have performance and economic impacts

Status

- Presented to INDOT and industry
- INDOT OMM explored PG grading of RAP sources across the state
- Based on all these results, spec change in progress
  - 25% with no grade change, 40% max
- Report is 90-95% complete



QUESTIONS?