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# Advancements in Testing Roofing Asphalt Binder

Mike Anderson, Asphalt Institute

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# ASTM D 312

| Property | Type I Min | Type I Max | Type II Min | Type II Max | Type III Min | Type III Max | Type IV Min | Type IV Max |
|---|---|---|---|---|---|---|---|---|
| **Soft. Point, °C(°F)** | 57(135) | 66(151) | 70(158) | 80(176) | 85(185) | 96(205) | 99(210) | 107(225) |
| **Flashpoint, °C(°F)** | 260(500) | ... | 260(500) | ... | 260(500) | ... | 260(500) | ... |
| **Penetration, dmm at 0°C(32°F)** | 3 | ... | 6 | ... | 6 | ... | 6 | ... |
| **at 25°C(77°F)** | 18 | 60 | 18 | 40 | 15 | 35 | 12 | 25 |
| **at 46°C(115°F)** | 90 | 180 | ... | 100 | ... | 90 | ... | 75 |
| **Duct at 25°C(77°F),cm** | 10.0 | ... | 3.0 | ... | 2.5 | ... | 1.5 | ... |
| **Solubility in TCE, %** | 99 | ... | 99 | ... | 99 | ... | 99 | ... |

# Rheological Testing and Evaluation

- Rheology Task Force
  - Gaylon Baumgardner, Mike Franzen, Keith Stephens, Mike Anderson
  - Formed to evaluate rheological parameters of roofing asphalts for possible use in a specification

| | RPG 58 (Type I) | | RPG 70 (Type II) | | RPG 82 (Type III) | | RPG 94 (Type IV) | |
|---|---|---|---|---|---|---|---|---|
| **Property** | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| Flash Point, °C (°F) | 260(500) | --- | 260(500) | --- | 260(500) | --- | 260(500) | --- |
| Equi-viscous Temperature, °C | Report | | Report | | Report | | Report | |
| High Equi-stiffness Temperature, °C | 57 | 66 | 70 | 80 | 85 | 96 | 99 | 107 |
| Complex Viscosity @ 71.1°C, kPa-s | 0.2 | --- | 2.0 | --- | 20.0 | --- | 200.0 | --- |
| G*(0.4 Hz) @ 50°C, MPa | 0.02 | 0.10 | 0.04 | 0.20 | 0.05 | 0.30 | 0.07 | 0.40 |
| δ(0.4 Hz) @ 50°C, degrees | Report | | Report | | Report | | Report | |
| G*(0.4 Hz) @ 25°C, MPa | 0.3 | 1.8 | 0.6 | 3.2 | 0.8 | 4.9 | 1.1 | 7.1 |
| G*(0.4 Hz) @ 5°C, MPa | 3.6 | 16.0 | 17.0 | 28.0 | 23.0 | 42.0 | 32.0 | 62.0 |
| δ(0.4 Hz) @ 5°C, degrees | Report | | Report | | Report | | Report | |
| G*(15.9 Hz) @ 25°C, MPa | --- | 20 | --- | 30 | --- | 40 | --- | 50 |
| Solubility, % | 99.0 | --- | 99.0 | --- | 99.0 | --- | 99.0 | --- |

| | RPG 58 (Type I) | | RPG 70 (Type II) | | RPG 82 (Type III) | | RPG 94 (Type IV) | |
|---|---|---|---|---|---|---|---|---|
| **Property** | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Flash Point** | 260(500) | --- | 260(500) | --- | 260(500) | --- | 260(500) | --- |
| Equi-viscous Temperature, °C | Report | | Report | | Report | | Report | |
| **Softening Point** | 57 | 66 | 70 | 80 | 85 | 96 | 99 | 107 |
| Complex Viscosity @ 71.1°C, kPa-s | 0.2 | --- | 2.0 | --- | 20.0 | --- | 200.0 | --- |
| **Penetration @ 46C** | 0.02 | 0.10 | 0.04 | 0.20 | 0.05 | 0.30 | 0.07 | 0.40 |
| δ(0.4 Hz) @ 50°C, degrees | Report | | Report | | Report | | Report | |
| **Penetration @ 25C** | 0.3 | 1.8 | 0.6 | 3.2 | 0.8 | 4.9 | 1.1 | 7.1 |
| **Penetration @ 0C** | 3.6 | 16.0 | 17.0 | 28.0 | 23.0 | 42.0 | 32.0 | 62.0 |
| δ(0.4 Hz) @ 5°C, degrees | Report | | Report | | Report | | Report | |
| **Ductility** | --- | 20 | --- | 30 | --- | 40 | --- | 50 |
| **Solubility** | 99.0 | --- | 99.0 | --- | 99.0 | --- | 99.0 | --- |

# Rheological Testing and Evaluation

- Evaluation of Rheological Properties of Good/Bad Coatings
  - Start with 2 Good and 2 Bad Fluxes
    - Supplied by Owens Corning and GAF
  - Blow to 4 different Softening Points
  - Submit samples to AI and Paragon Technical Services for testing
    - Mastercurve determination
    - Compare data with conventional parameters

# Rheological Testing and Evaluation

- Asphalt Binders
  - Owens Corning
    - Two Asphalt Binders
      - OC-A
      - OC-B
    - Four Softening Points
      - Blown to R&B Softening Points of 200, 207, 214, and 220°F

# Rheological Testing and Evaluation

- Asphalt Binders
  - GAF
    - Two Asphalt Binders
      - F0965112
      - F106312
    - Blown to 3-4 Softening Points
      - F0965112
        - 3 softening points between 207 and 220°F
      - F106312
        - 4 softening points between 200 and 220°F

# Rheological Testing and Evaluation

- Testing
    - Conventional
        - R&B Softening Point
        - Penetration (25°C)

# Rheological Testing and Evaluation

- Testing
  - Rheological
    - Temperature-Frequency Sweep (High)
      - 0.1-10 rad/s (10 pts/decade)
      - 25-mm parallel plate geometry
      - 1-mm gap
      - 2% shear strain
      - 50-100°C (10°C increments)
    - Temperature-Frequency Sweep (Low)
      - 0.1-10 rad/s (10 pts/decade)
      - 8-mm parallel plate geometry
      - 2-mm gap
      - 1% shear strain
      - 10-40°C (5°C increments)

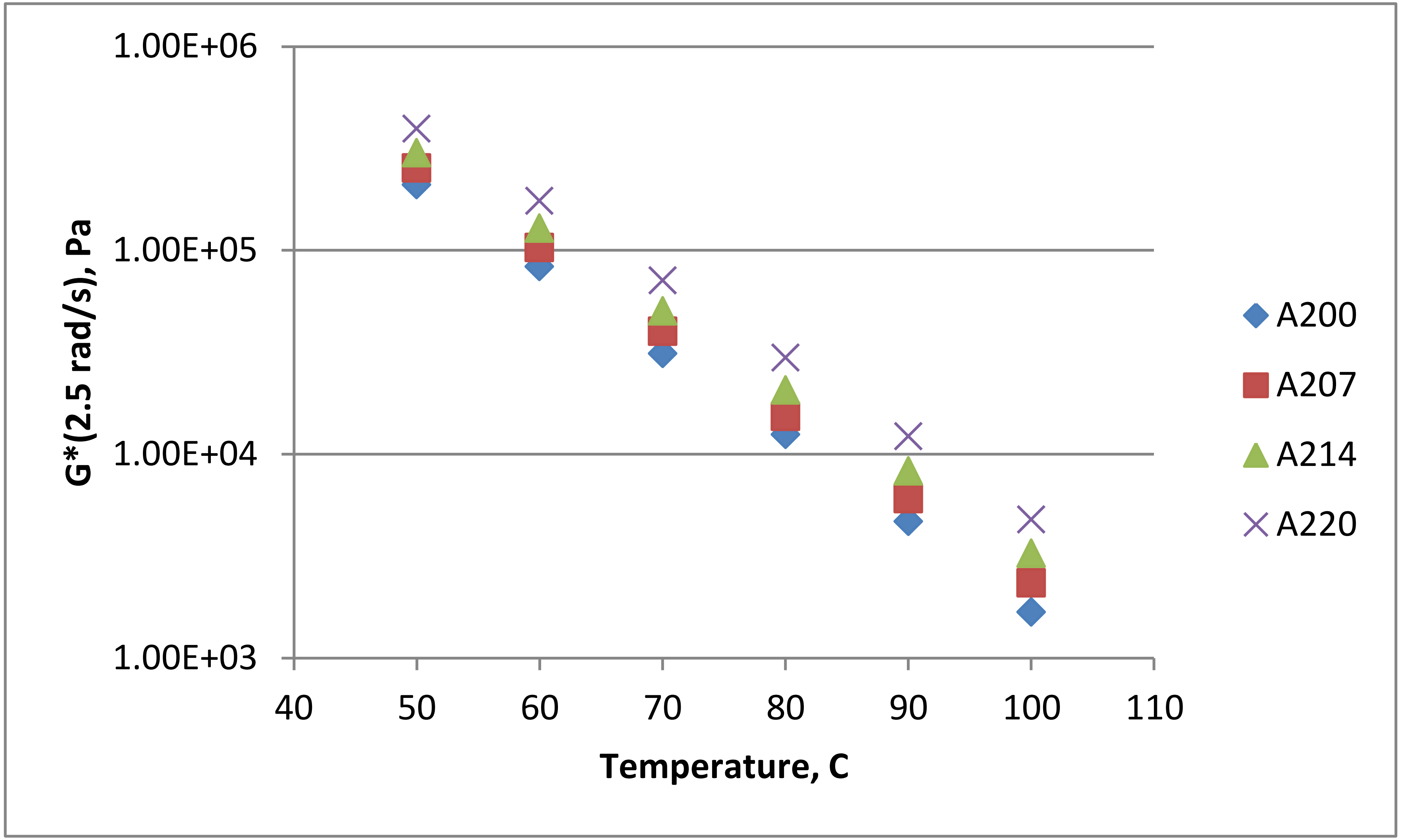
# Rheological Testing and Evaluation

- Testing
  - Rheological
    - Mastercurve development
      - Using high and low data sets separately
      - Can be combined
    - Derived parameters
      - $G^*$, $\delta$ at 2.5 rad/s
        - 5°C, 25°C, 50°C
      - $T_c$ at 2.5 rad/s
        - Determined where $G^* = 2000$ Pa
      - $G^*$, $\delta$ at 100 rad/s
        - 25°C
      - Complex Viscosity ($\eta^*$) at 71.1°C and 1 rad/s

# High Temperature (Paragon)

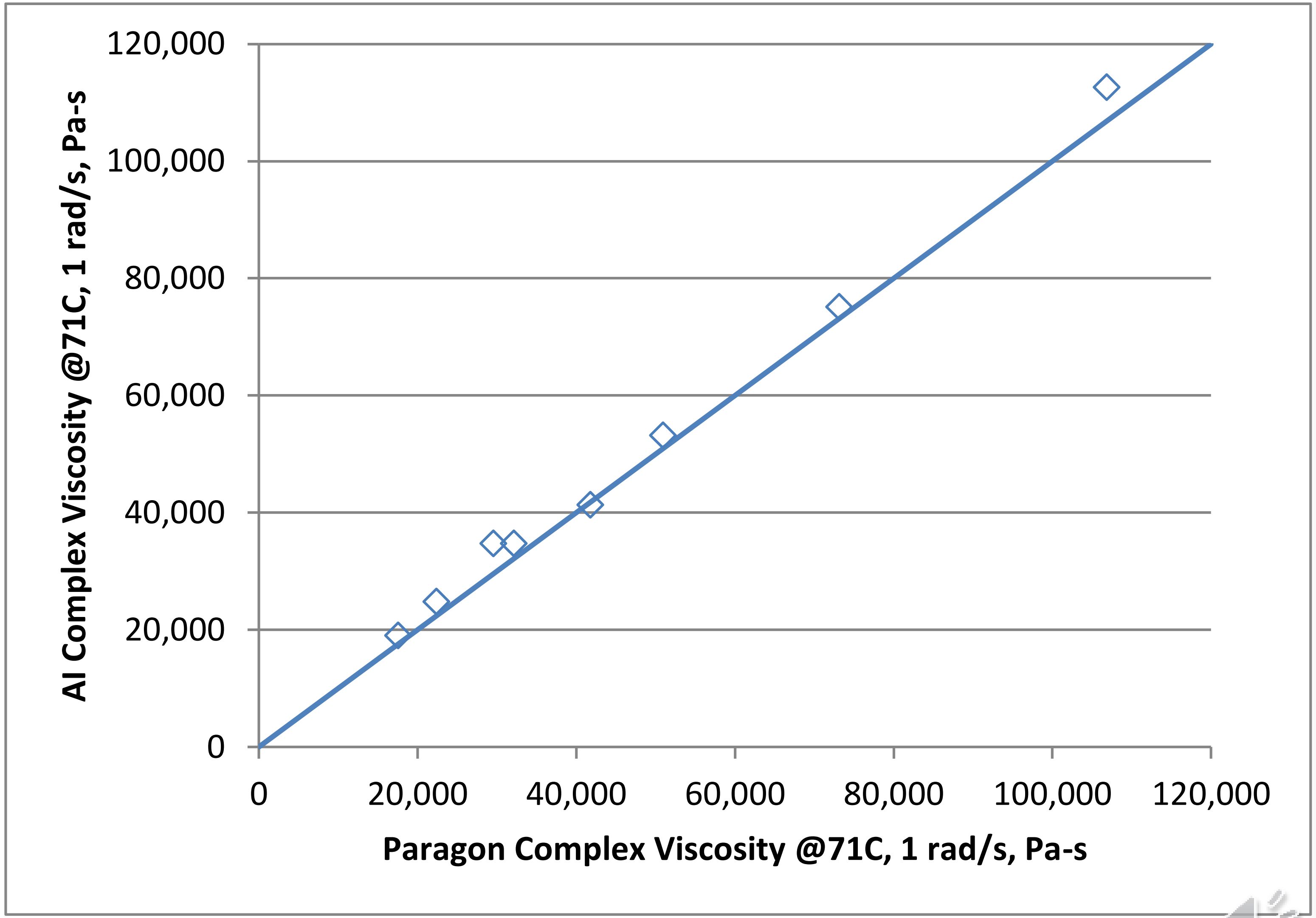
| Paragon | 50 | | 71.1 | | | | 50 | |
|---|---|---|---|---|---|---|---|---|
| | 2.5 rad/s | | 1 rad/s | 2.5 rad/s | log G* = Ax +B | | 2.5 rad/s | R&B |
| | G*, Pa | δ, deg. | η*, Pa-s | Tc, C | A | B | G(t), Pa | SP, C |
| A200 | 2.08E+05 | 37.8 | 17,604 | 98.6 | -0.0418 | 7.4235 | | 96.7 |
| A207 | 2.52E+05 | 36.5 | 22,417 | 101.6 | -0.0409 | 7.4565 | | 101.1 |
| A214 | 2.99E+05 | 35.6 | 29,625 | 105.5 | -0.0394 | 7.4588 | | 105.8 |
| A220 | 3.95E+05 | 33.1 | 41,846 | 110.2 | -0.0384 | 7.5345 | | 110.5 |
| | | | | | | | | |
| B200 | 6.11E+05 | 40.4 | 32,184 | 98.9 | -0.0518 | 8.4241 | | 93.7 |
| B207 | 8.33E+05 | 40.0 | 50,979 | 104.7 | -0.0481 | 8.3392 | | 104 |
| B214 | 1.07E+06 | 36.0 | 73,220 | 108.2 | -0.0476 | 8.451 | | 104.4 |
| B220 | 1.37E+06 | 33.8 | 106,931 | 113.4 | -0.0454 | 8.4478 | | 110 |

# OC-A-xxx Binders: G*(2.5 rad/s) = *f* (T) Paragon



# Complex Viscosity (η*): 71.1°C, 1 rad/s

| | AI | Paragon | |
|---|---|---|---|
| | 71.1 | 71.1 | |
| | 1 rad/s | 1 rad/s | |
| | η*, Pa-s | η*, Pa-s | **d2s%** |
| A200 | 19,015 | 17,604 | **8%** |
| A207 | 24,785 | 22,417 | **10%** |
| A214 | 34,753 | 29,625 | **16%** |
| A220 | 41,322 | 41,846 | **1%** |
| B200 | 34,754 | 32,184 | **8%** |
| B207 | 53,168 | 50,979 | **4%** |
| B214 | 75,140 | 73,220 | **3%** |
| B220 | 112,602 | 106,931 | **5%** |

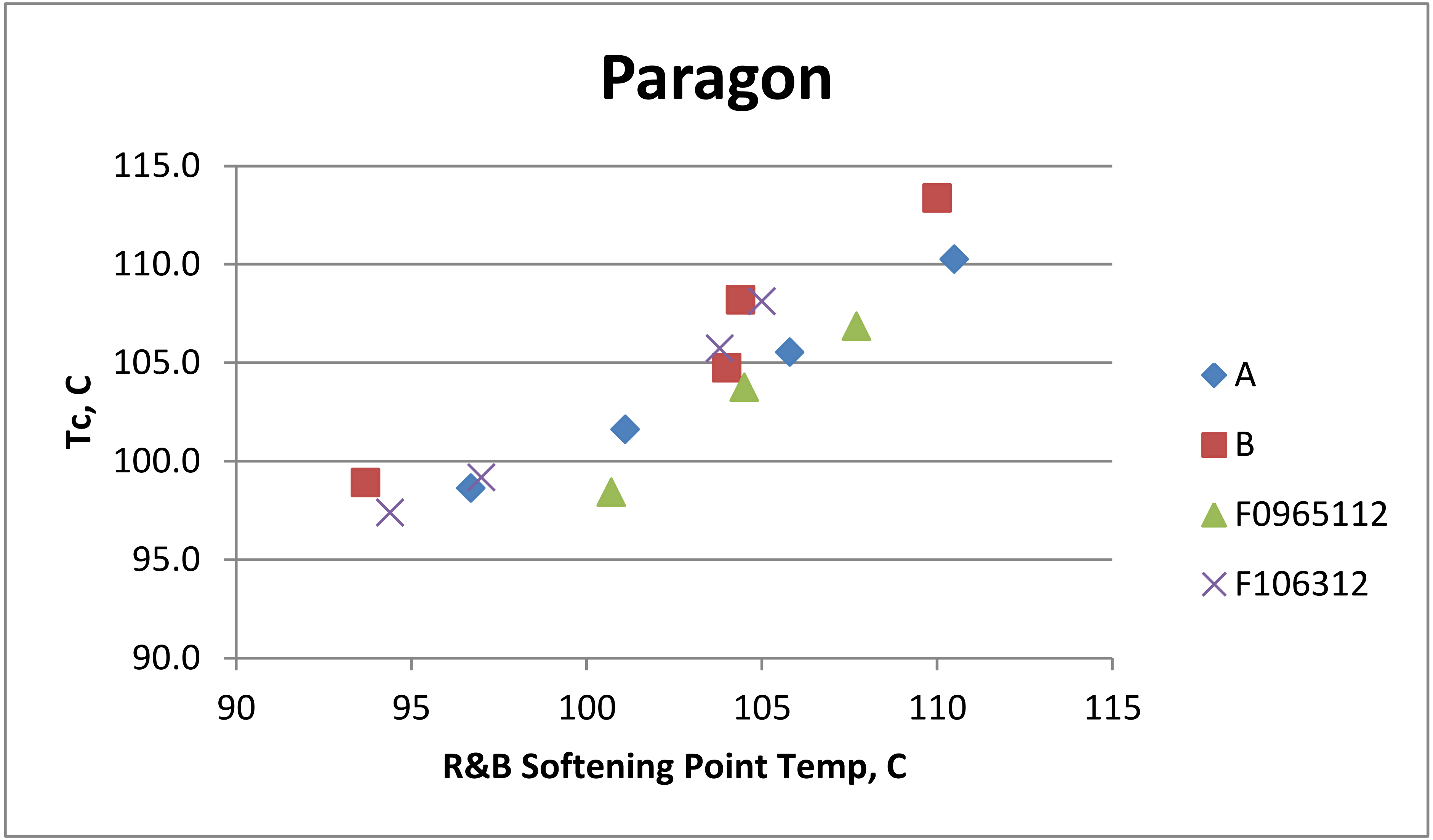



Multi-laboratory d2s% for rotational viscosity (AASHTO T316) = 12.1%

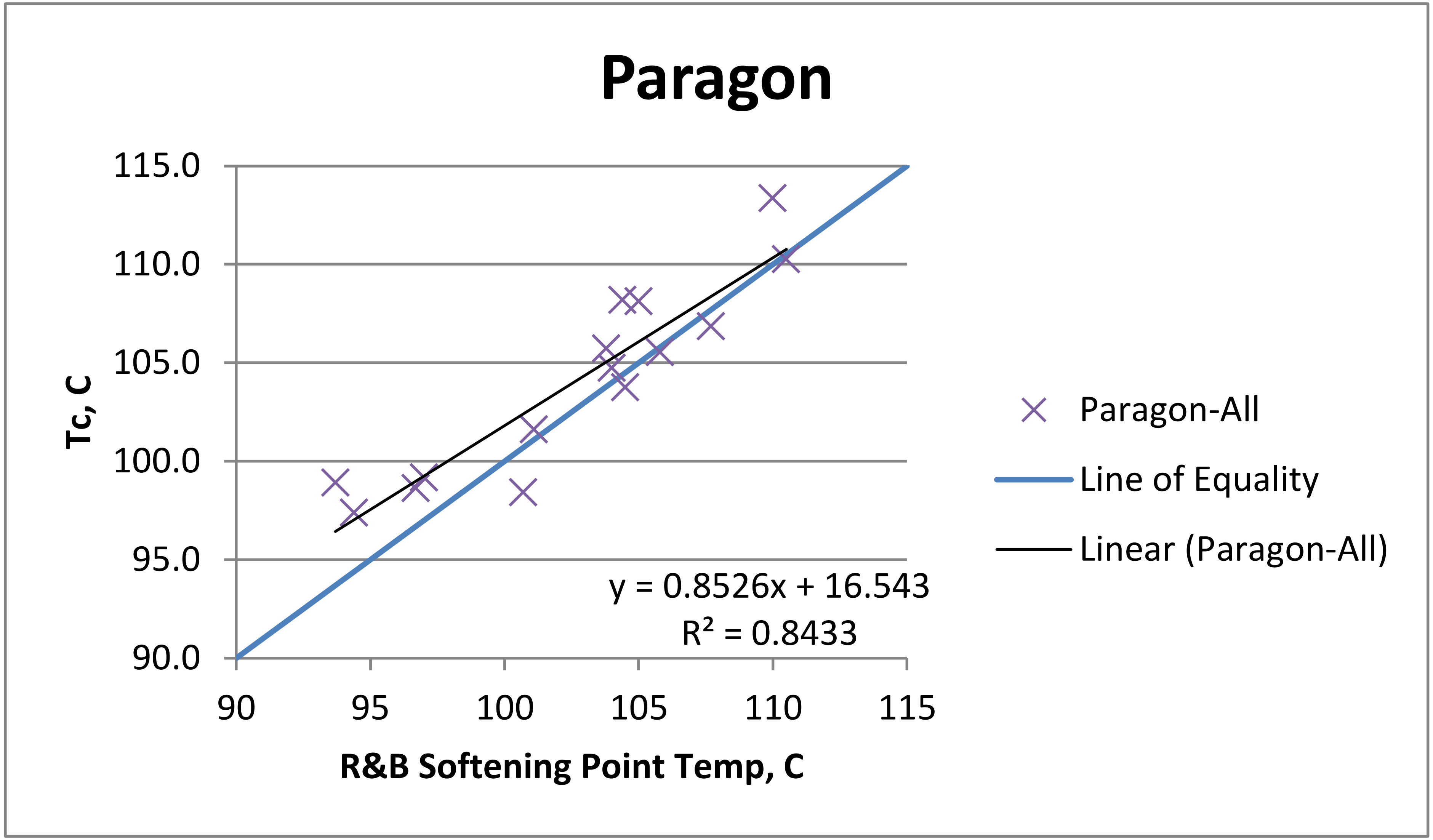
# High Temperature (Paragon)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50 | | 71.1 | | | | 50 | |
| | 2.5 rad/s | | 1 rad/s | 2.5 rad/s | log G* = Ax +B | | 2.5 rad/s | R&B |
| | G*, Pa | δ, deg. | η*, Pa-s | Tc, C | A | B | G(t), Pa | SP, C |
| F0965112-A | 2.37E+05 | 37.7 | 17,742 | 98.4 | -0.0429 | 7.5225 | | 100.7 |
| F0965112-B | 3.24E+05 | 35.9 | 26,651 | 103.7 | -0.0411 | 7.5649 | | 104.5 |
| F0965112-C | 3.92E+05 | 34.3 | 34,725 | 106.8 | -0.0403 | 7.6066 | | 107.7 |
| | | | | | | | | |
| | | | | | | | | |
| F106312-A | 2.37E+05 | 39.6 | 17,405 | 97.4 | -0.0443 | 7.6153 | | 94.4 |
| F106312-B | 2.62E+05 | 39.0 | 19,966 | 99.2 | -0.0435 | 7.6143 | | 97 |
| F106312-C | 3.73E+05 | 36.2 | 33,240 | 105.7 | -0.0411 | 7.6464 | | 103.8 |
| F106312-D | 4.11E+05 | 34.8 | 39,113 | 108.1 | -0.0402 | 7.6472 | | 105 |

# Calculated $T_c$ Compared to R&B Softening Point



# Calculated $T_c$ Compared to R&B Softening Point



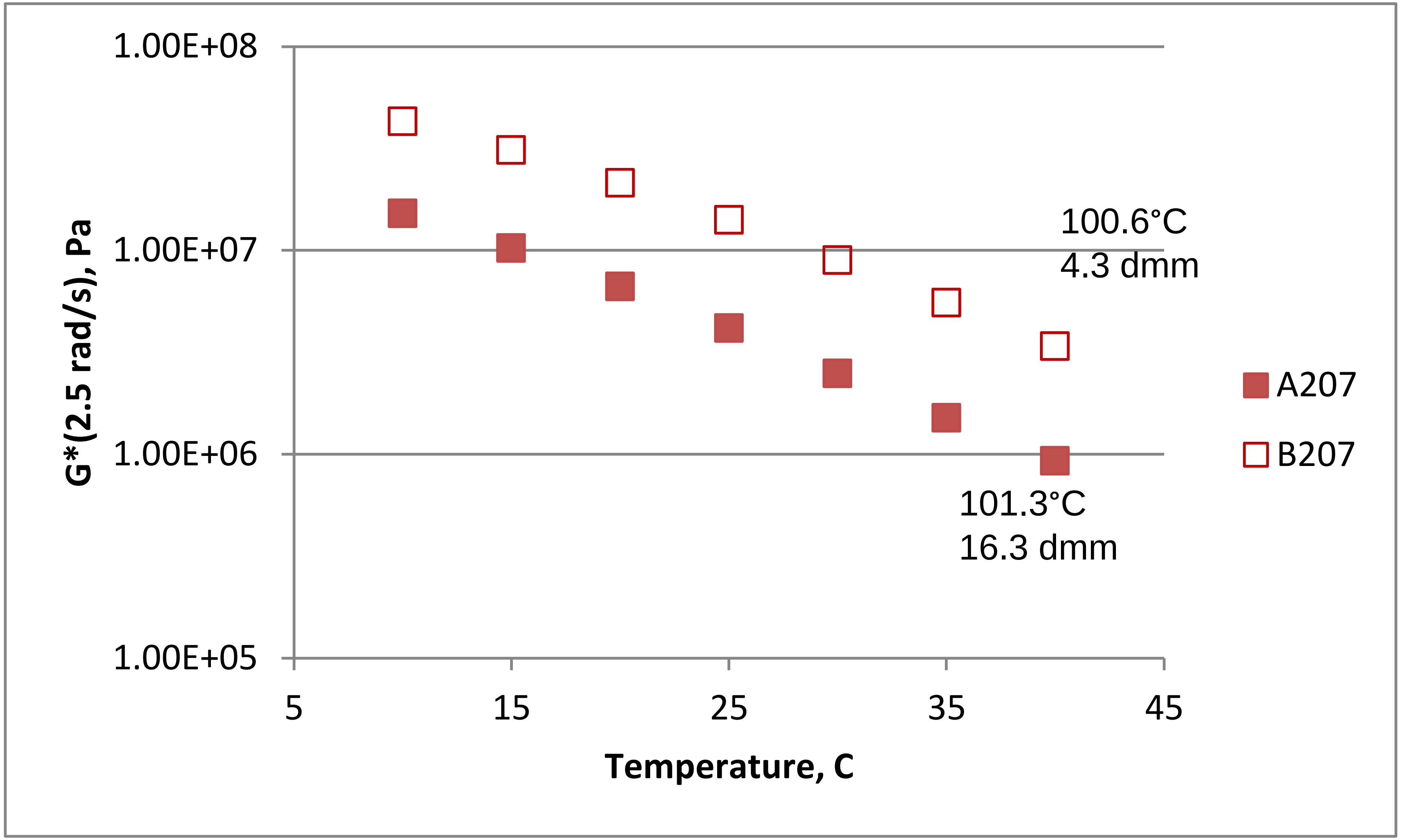
# Data Summary – Low/Intermediate Temperature

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | | 25 | | 25 | | | | 25 |
| | 2.5 rad/s | | 2.5 rad/s | | 100 rad/s | | log G* = Ax +B | | |
| | G*, Pa | δ, deg. | G*, Pa | δ, deg. | G*, Pa | δ, deg. | A | B | Pen, dmm |
| A200 | 2.40E+07 | 23.0 | 3.76E+06 | 28.5 | 1.12E+07 | 25.4 | -0.0413 | 7.5871 | 18 |
| A207 | 2.60E+07 | 21.8 | 4.17E+06 | 27.2 | 1.18E+07 | 23.9 | -0.041 | 7.6206 | 16.3 |
| A214 | 2.51E+07 | 22.0 | 4.31E+06 | 27.1 | 1.21E+07 | 24.0 | -0.0394 | 7.596 | 16 |
| A220 | 2.48E+07 | 21.4 | 4.53E+06 | 26.2 | 1.24E+07 | 23.3 | -0.038 | 7.5853 | 13.3 |
| | | | | | | | | | |
| B200 | 5.97E+07 | 19.8 | 1.05E+07 | 26.9 | 2.89E+07 | 22.9 | -0.0387 | 7.9698 | 6.3 |
| B207 | 7.24E+07 | 19.2 | 1.38E+07 | 25.8 | 3.61E+07 | 21.9 | -0.037 | 8.0446 | 4.3 |
| B214 | 6.58E+07 | 18.4 | 1.40E+07 | 24.1 | 3.45E+07 | 20.6 | -0.0346 | 7.9911 | 5 |
| B220 | 6.73E+07 | 18.3 | 1.48E+07 | 23.6 | 3.62E+07 | 20.5 | -0.0338 | 7.9969 | 4.3 |

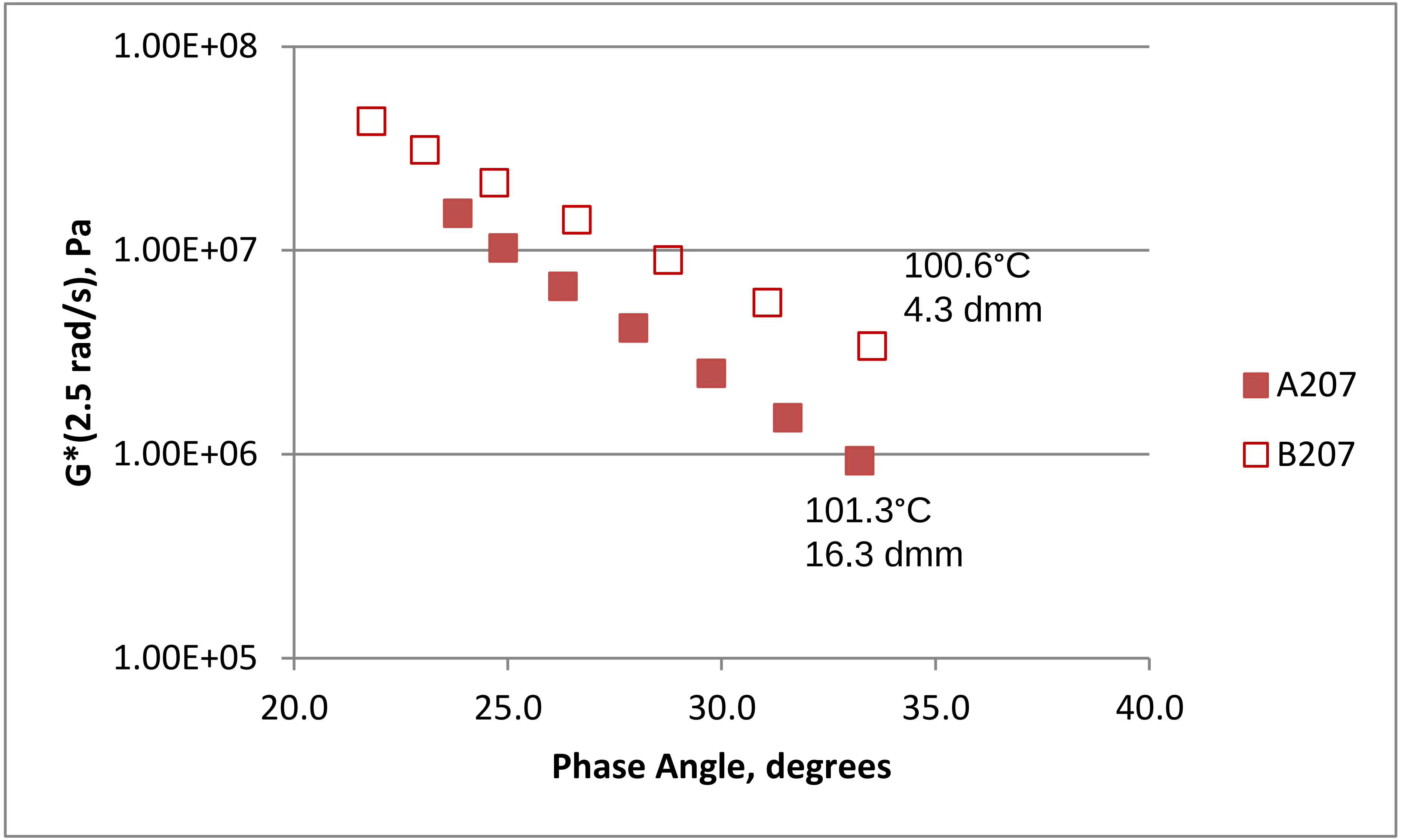
# Data Summary – Low/Intermediate Temperature

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | | 25 | | 25 | | | | 25 |
| | 2.5 rad/s | | 2.5 rad/s | | 100 rad/s | | log G* = Ax +B | | |
| | G*, Pa | δ, deg. | G*, Pa | δ, deg. | G*, Pa | δ, deg. | A | B | Pen, dmm |
| F0965112-A | 2.26E+07 | 24.0 | 3.55E+06 | 29.6 | 1.09E+07 | 25.8 | -0.0407 | 7.5573 | 21 |
| F0965112-B | 2.45E+07 | 23.0 | 4.13E+06 | 27.8 | 1.21E+07 | 24.7 | -0.0393 | 7.5861 | 20 |
| F0965112-C | 2.35E+07 | 22.6 | 4.24E+06 | 27.2 | 1.21E+07 | 24.1 | -0.0379 | 7.5599 | 20 |
| | | | | | | | | | |
| F106312-A | 3.18E+07 | 23.1 | 4.55E+06 | 29.6 | 1.41E+07 | 26.0 | -0.0429 | 7.7166 | 21 |
| F106312-B | 3.05E+07 | 22.8 | 4.57E+06 | 29.1 | 1.39E+07 | 25.7 | -0.0419 | 7.6939 | 19 |
| F106312-C | 3.44E+07 | 22.0 | 5.56E+06 | 27.6 | 1.61E+07 | 24.4 | -0.0402 | 7.7379 | 16 |
| F106312-D | 3.42E+07 | 21.6 | 5.82E+06 | 26.9 | 1.64E+07 | 23.9 | -0.0391 | 7.7291 | 16 |

# Similar Softening Point:
# G*(2.5 rad/s) = *f* (T)



# Similar Softening Point: G*(2.5 rad/s) = *f* (δ)



# Gershkoff (1995)

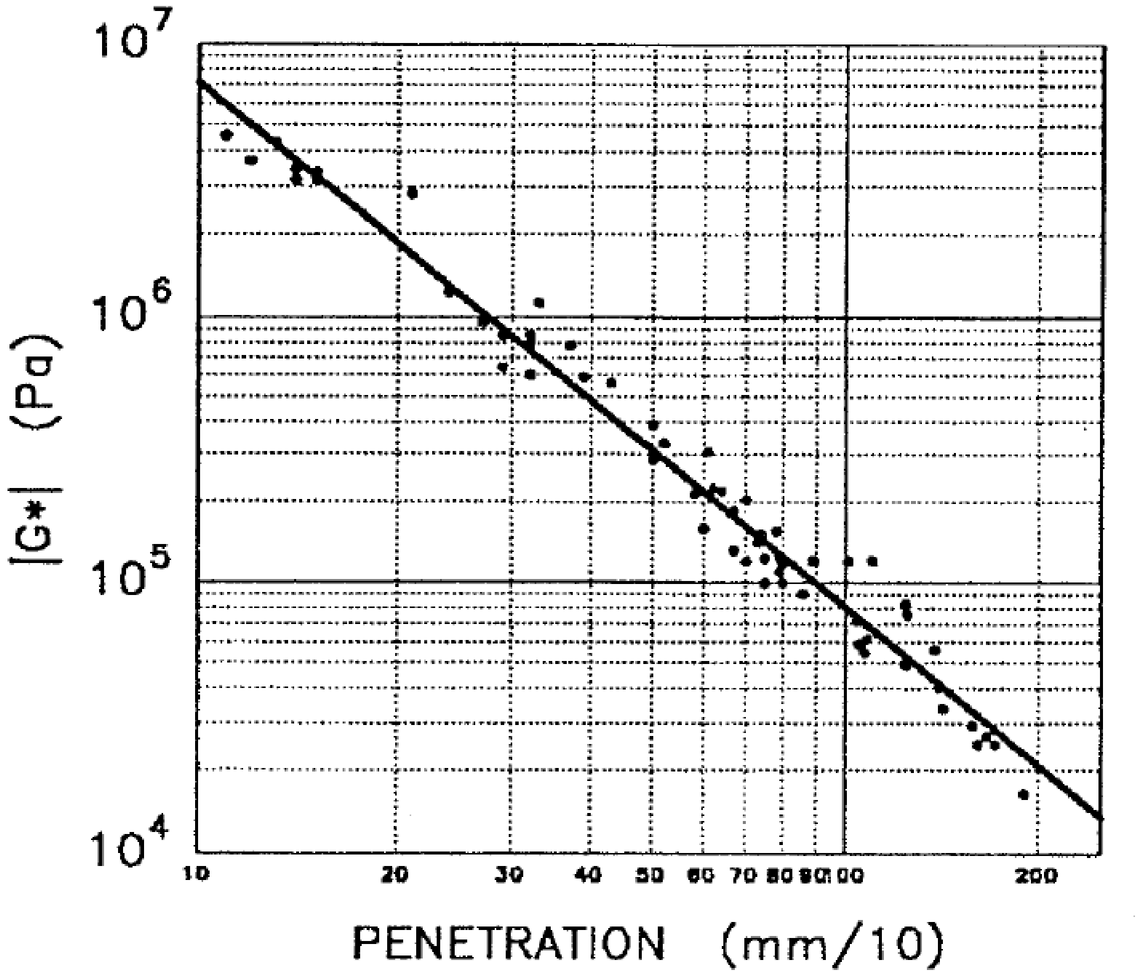
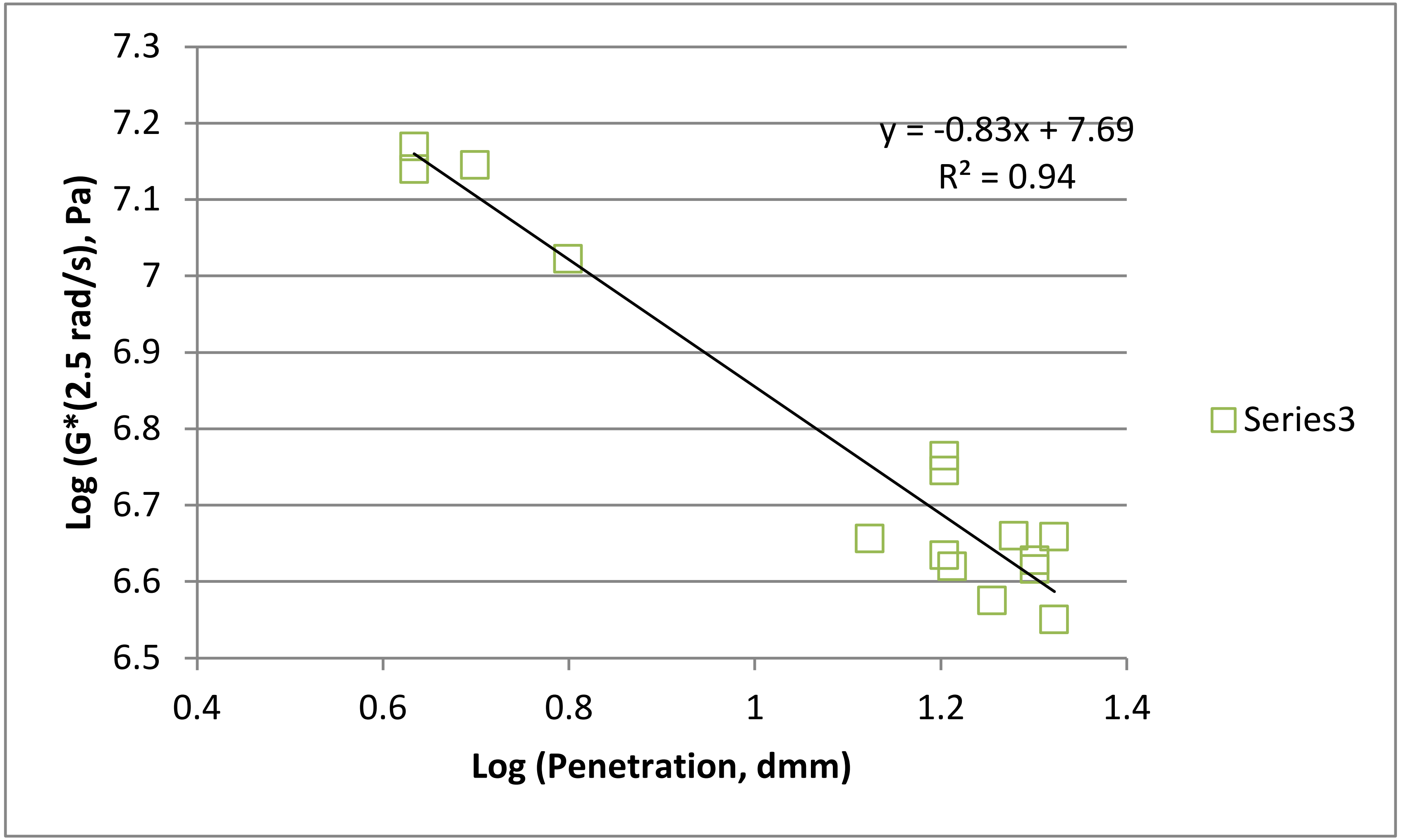



Figure 1 - Modulus at 0.4 s and Penetration Value

# Relationship of G*(2.5 rad/s) to Penetration @ 25C




Gershkoff: Log(G*) = -1.95*Log(Pen) +8.80

# Coating Asphalt

- Proposed Procedure to Replace Penetration at 25°C
  - Perform single-point temperature test on DSR
    - 8-mm parallel plate, 1% strain, 2.5 rad/s, 25°C
    - Determine $G^*_{2.5}$ and compare to recommended specification value

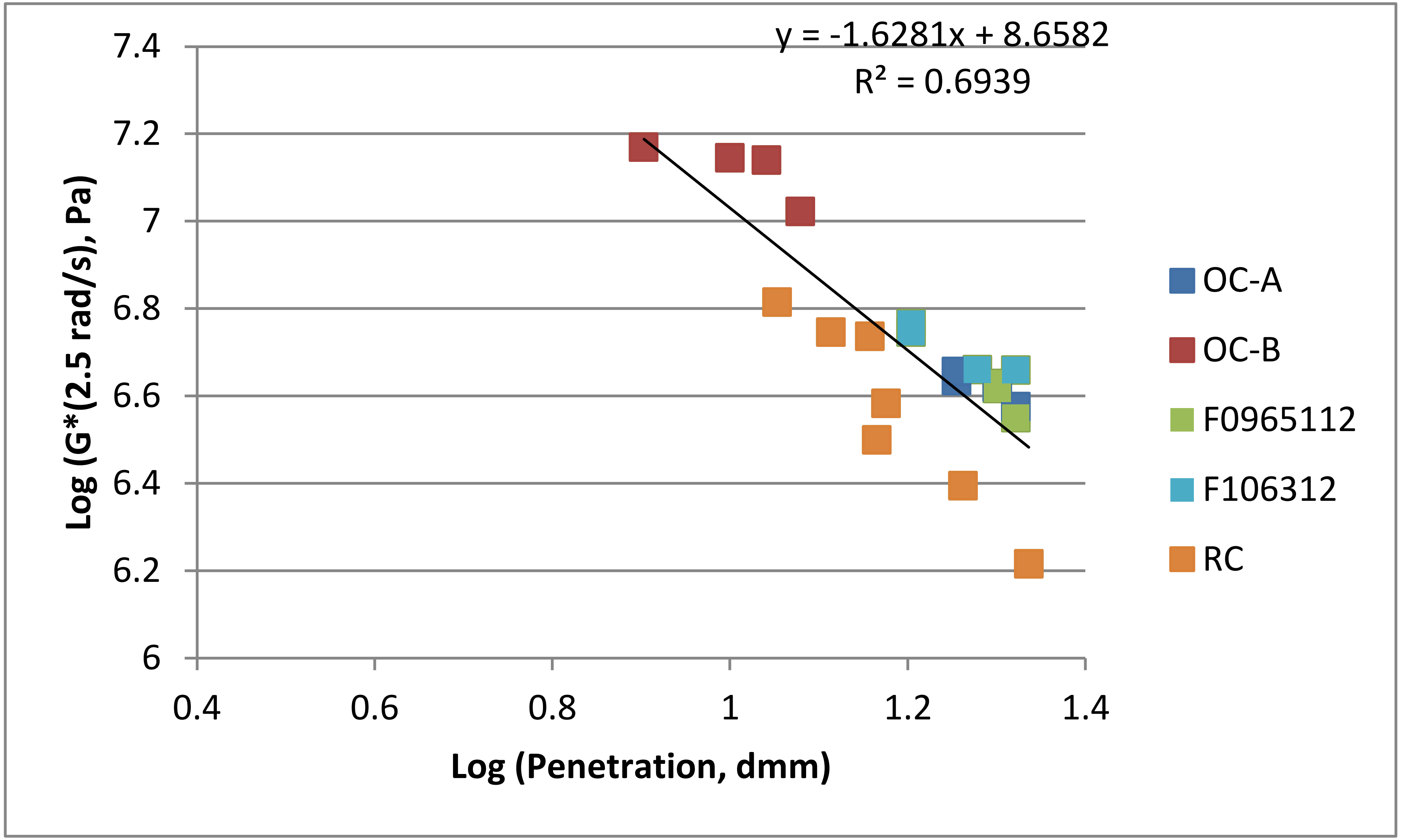
# Optional Rheological Testing

- Intermediate Temperature DSR – Determination of $G^*_{2.5}$ at 25°C
  - Generally follow the equipment and specimen preparation procedures as described in ASTM D7175, *Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer*.
  - Use 8-mm parallel plate geometry with a 2-mm gap.

# Optional Rheological Testing

- Intermediate Temperature DSR – Determination of $G^*_{2.5}$ at 25°C
  - Set the gap at 25°C. Increase the temperature to 75°C and load, trim the sample.  Lower the spindle to the testing gap (2 mm). Reduce the temperature to 25°C and allow the sample to achieve temperature equilibrium before testing.
  - Start testing at 25°C in oscillatory mode using 1% shear strain and a loading frequency of 2.5 rad/s. Determine the complex modulus, G*, in Pa.
  - Unload the sample and clean the DSR.

# Relationship Between $G^*_{2.5}$ and Penetration at 25°C



# Relationship Between $G^*_{2.5}$ and Penetration at 25°C

| | Penetration (25C), dmm | | | |
|---|---|---|---|---|
| Sample | >20 | 16-20 | 11-15 | ≤10 |
| A200 | 3.76E+06 | | | |
| A207 | | 4.17E+06 | | |
| A214 | | 4.31E+06 | | |
| A220 | | 4.53E+06 | | |
| B200 | | | 1.05E+07 | |
| B207 | | | 1.38E+07 | |
| B214 | | | | 1.40E+07 |
| B220 | | | | 1.48E+07 |
| F0965112-A | 3.55E+06 | | | |
| F0965112-B | | 4.13E+06 | | |
| F0965112-C | | 4.24E+06 | | |
| F106312-A | 4.55E+06 | | | |
| F106312-B | | 4.57E+06 | | |
| F106312-C | | 5.56E+06 | | |
| F106312-D | | 5.82E+06 | | |
| RC-01 | | | 5.56E+06 | |
| RC-02 | | | 6.53E+06 | |
| RC-03 | | | 3.82E+06 | |
| RC-04 | | | 3.15E+06 | |
| RC-05 | | 2.48E+06 | | |
| RC-06 | 1.64E+06 | | | |
| RC-07 | | | 5.45E+06 | |

# Relationship Between $G^*_{2.5}$ and Penetration at 25°C

| | >20 | 16-20 | 11-15 | ≤10 |
|---|---|---|---|---|
| Ave $G^*_{2.5}$(25°C) | 3.37E+06 | 4.42E+06 | 6.98E+06 | 1.44E+07 |
| Ave Pen (25°C) | 21 | 18 | 13 | 9 |
| # of Samples | 4 | 9 | 7 | 2 |

# Relationship Between $G^*_{2.5}$ and Penetration at 25°C

- Relationship from all data:
  - $\text{Log } G^*_{2.5} = -1.6281 * \text{Log(Pen)} + 8.6582$

- Penetration = 12 dmm
  - $G^*_{2.5}$ = 7.96E+06 Pa
- Penetration = 25 dmm
  - $G^*_{2.5}$ = 2.41E+06 Pa

# Relationship Between $G^*_{2.5}$ and Penetration at 25°C

- Proposed Specification Values

  $2.50E+06 \leq G^*_{2.5}(25°C) \leq 8.00E+06$

- Testing Variability for T315 (PAV DSR)
  - single-operator d2s% = 13.8%

- Acceptable range

  7.45E+06 to 8.55E+06 Pa

  2.33E+06 to 2.67E+06 Pa

# Relationship Between $G^*_{2.5}$ and Penetration at 25°C

- Acceptable range for variability

  7.45E+06 to 8.55E+06 Pa

  *12.5 to 11.5 dmm calculated Pen values*

  2.33E+06 to 2.67E+06 Pa

  *25.5 to 23.5 dmm calculated Pen values*

- Testing variability for Penetration
  - single-operator d2s = 2.3 dmm (Pen < 60)

# Coating Asphalt

- Proposed Procedure to Replace Softening Point
  - Perform temperature sweep on DSR
    - 25-mm parallel plate, 10% strain, 1 rad/s
    - Start at 90°C, increase to 110°C in 10°C increments
    - Plot η*(1 rad/s) versus temperature on semi-log graph
    - Calculate $T_c$ where η*(1 rad/s) = 1200 Pa-s

# Optional Rheological Testing

- High Temperature DSR – Determination of Tc where $\eta^*$ = 1200 Pa-s
  - Generally follow the equipment and specimen preparation procedures as described in ASTM D7175, *Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer*.
  - Use 25-mm parallel plate geometry with a 1-mm gap.
  - Load, trim the sample at 90°C. Allow the sample to achieve temperature equilibrium at 90°C before testing.

# Optional Rheological Testing

- High Temperature DSR – Determination of Tc where η* = 1200 Pa-s
  - Start testing at 90°C in oscillatory mode using 10% shear strain and a loading frequency of 1 rad/s. Determine the complex viscosity, η*, in Pa-s.
  - Without removing the sample, increase the temperature to 100°C. Allow the sample to achieve temperature equilibrium at 100°C before testing.
  - Start testing at 100°C in oscillatory mode using 10% shear strain and a loading frequency of 1 rad/s. Determine the complex viscosity, η*, in Pa-s.

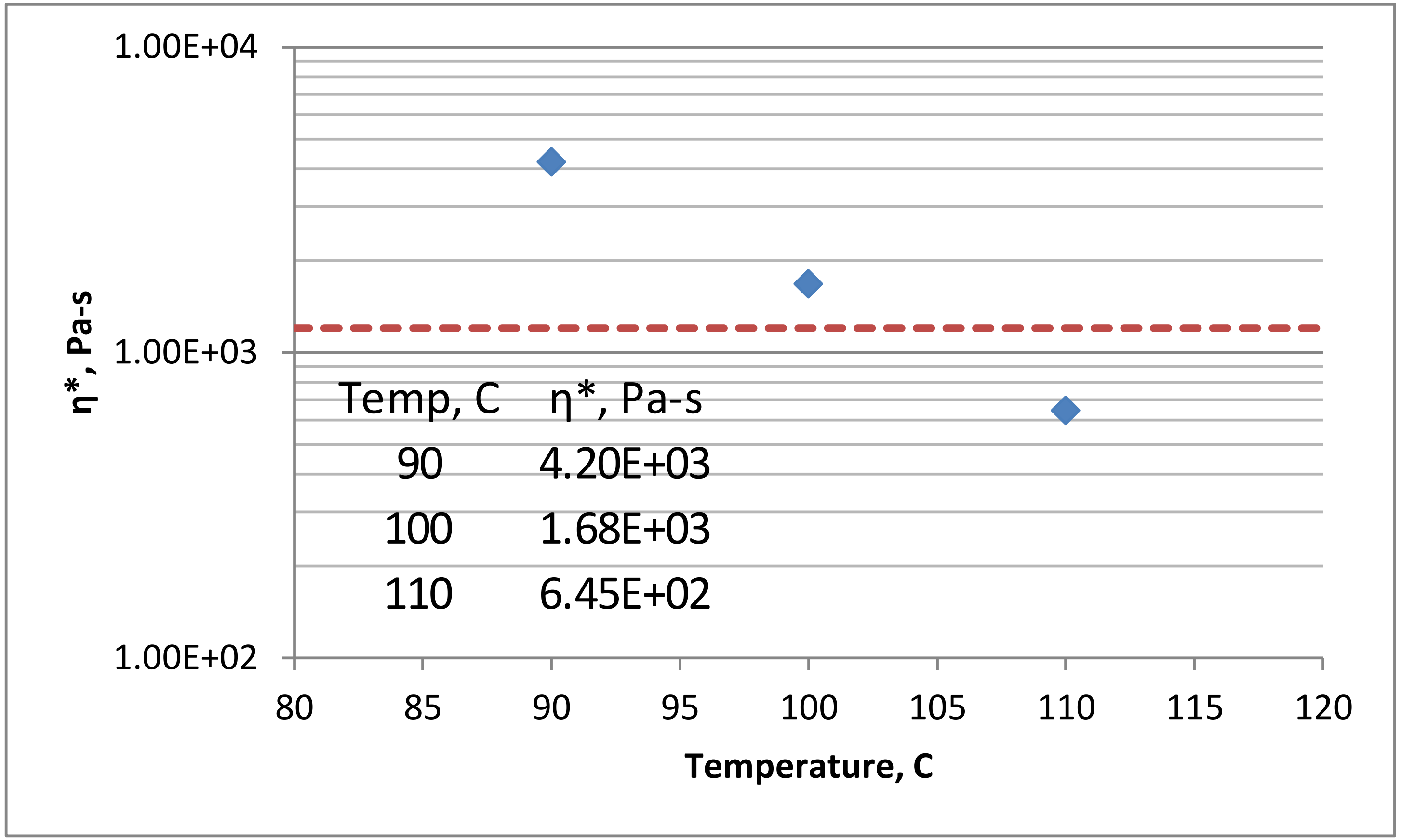
# Optional Rheological Testing

- High Temperature DSR – Determination of Tc where η* = 1200 Pa-s
  - Without removing the sample, increase the temperature to 110°C. Allow the sample to achieve temperature equilibrium at 110°C before testing.
  - Start testing at 110°C in oscillatory mode using 10% shear strain and a loading frequency of 1 rad/s. Determine the complex viscosity, η*, in Pa-s.
  - Unload the sample and clean the DSR.

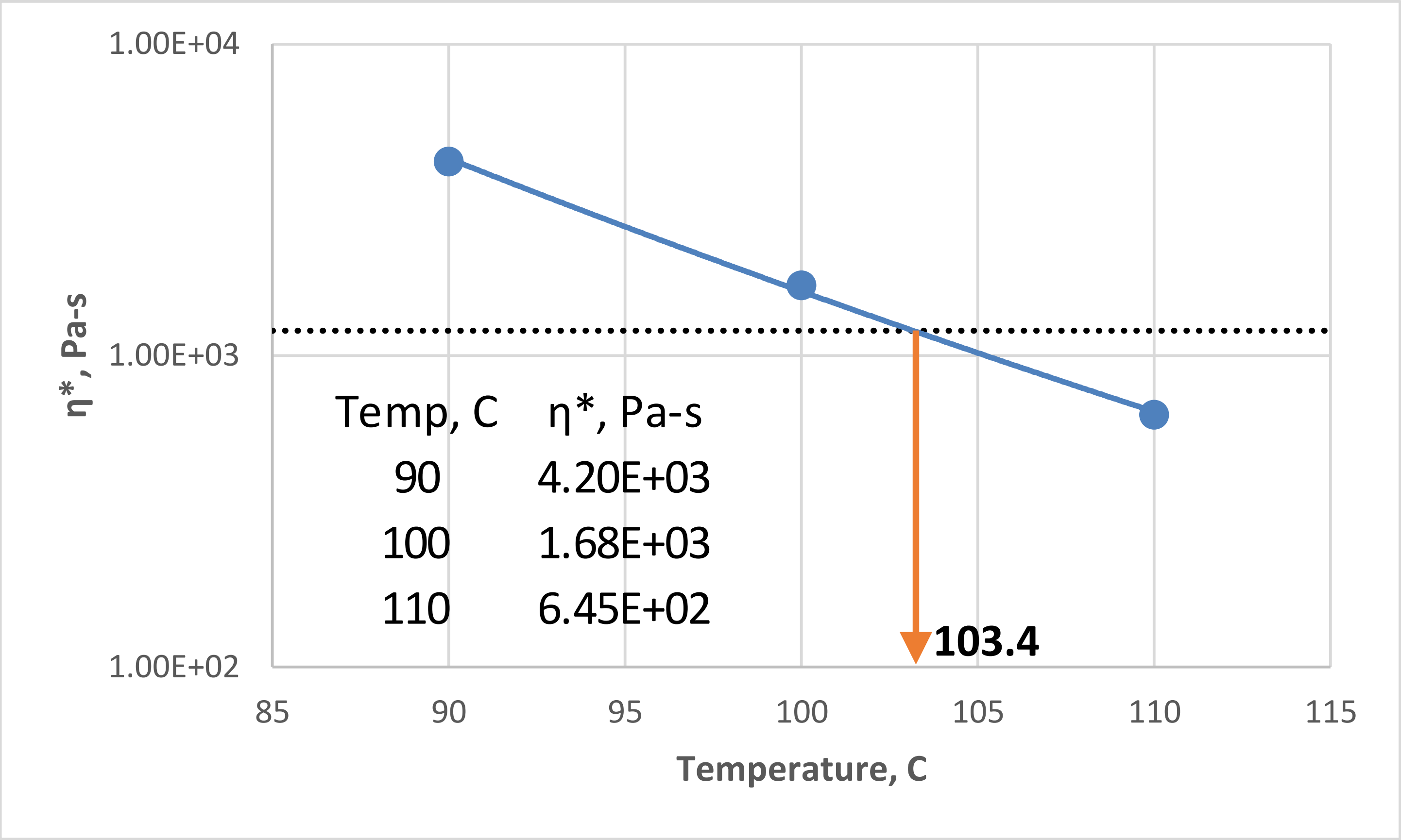
# Optional Rheological Testing

- High Temperature DSR – Determination of Tc where η* = 1200 Pa-s
  - Plot complex viscosity, η*, as a function of temperature. Determine the temperature, to the nearest 0.1°C, where η* is equal to 1200 Pa-s.  This temperature may be interpolated or extrapolated.

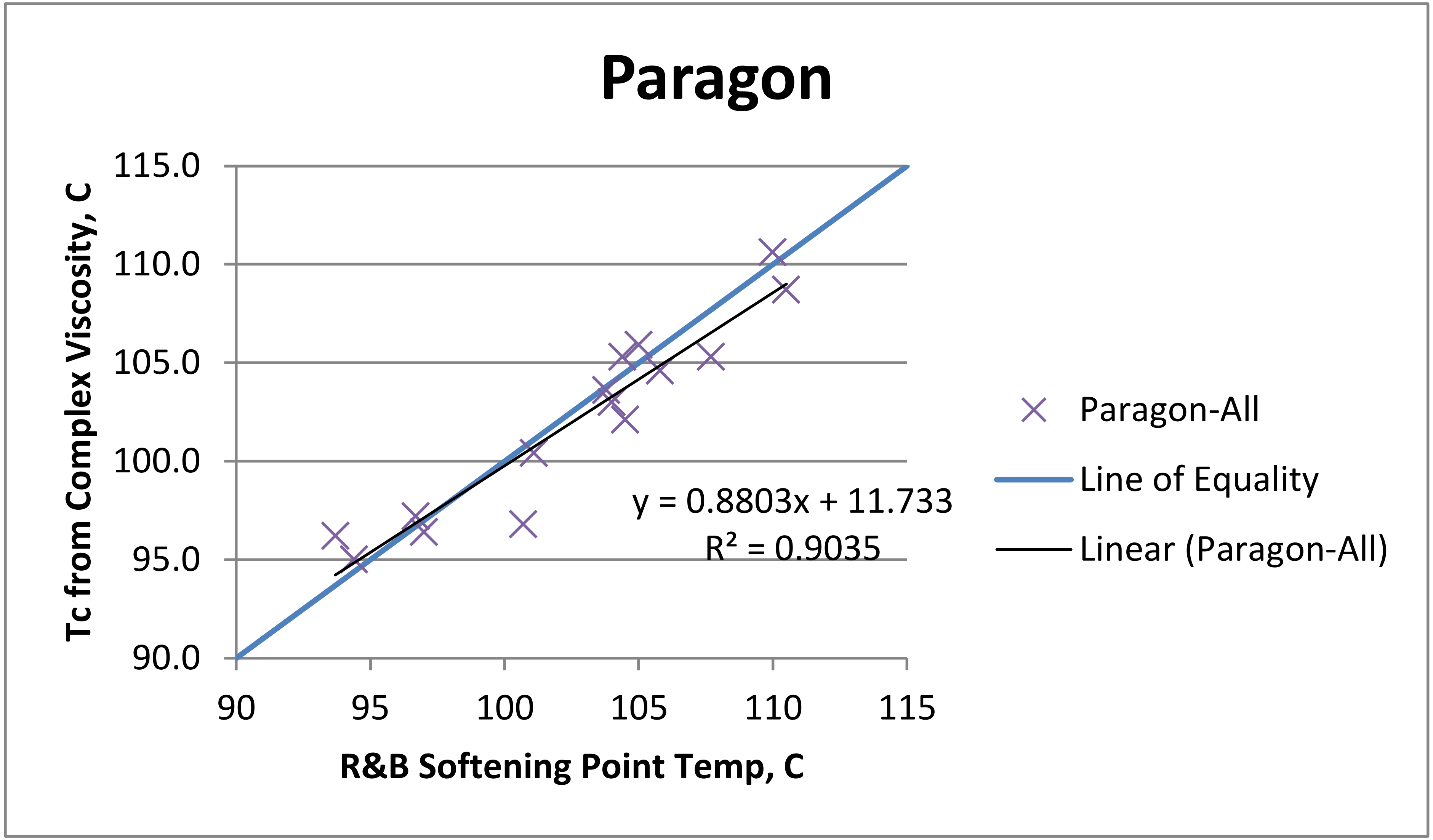
# Optional Rheological Testing (2014)



# Optional Rheological Testing (2014)



# Relationship Between Measured R&B Softening Point and $T_c$ (based on $\eta^*_1$ = 1200 Pa-s)



# Roofing PSP: Rheological Testing (2017)

| | Tc @ η*=1200 Pa-s, °C | R&B Softening Point, °C |
|---|---|---|
| Lab 2 | 107.7 | 110.0 |
| Lab 3 | 110.5 | 106.7 |
| Lab 4 | 108.4 | 109.4 |
| Lab 5 | 111.3 | 108.0 |
| Lab 6 | 108.8 | 107.8 |
| Lab 7 | 107.5 | 107.8 |
| Lab 9 | 110.0 | 112.2 |
| Lab 11 | 109.0 | 110.6 |
| Lab 13 | 111.4 | 110.0 |
| Lab 14 | 112.0 | 110.0 |
| Lab 15 | 108.7 | 109.9 |
| Lab 16 | 109.4 | 112.2 |

# Roofing PSP: Rheological Testing (2017)

| | Tc @ η*=1200 Pa-s, °C | R&B Softening Point, °C |
|---|---|---|
| Average | 109.6 | 109.5 |
| StDev | 1.4 | 1.6 |

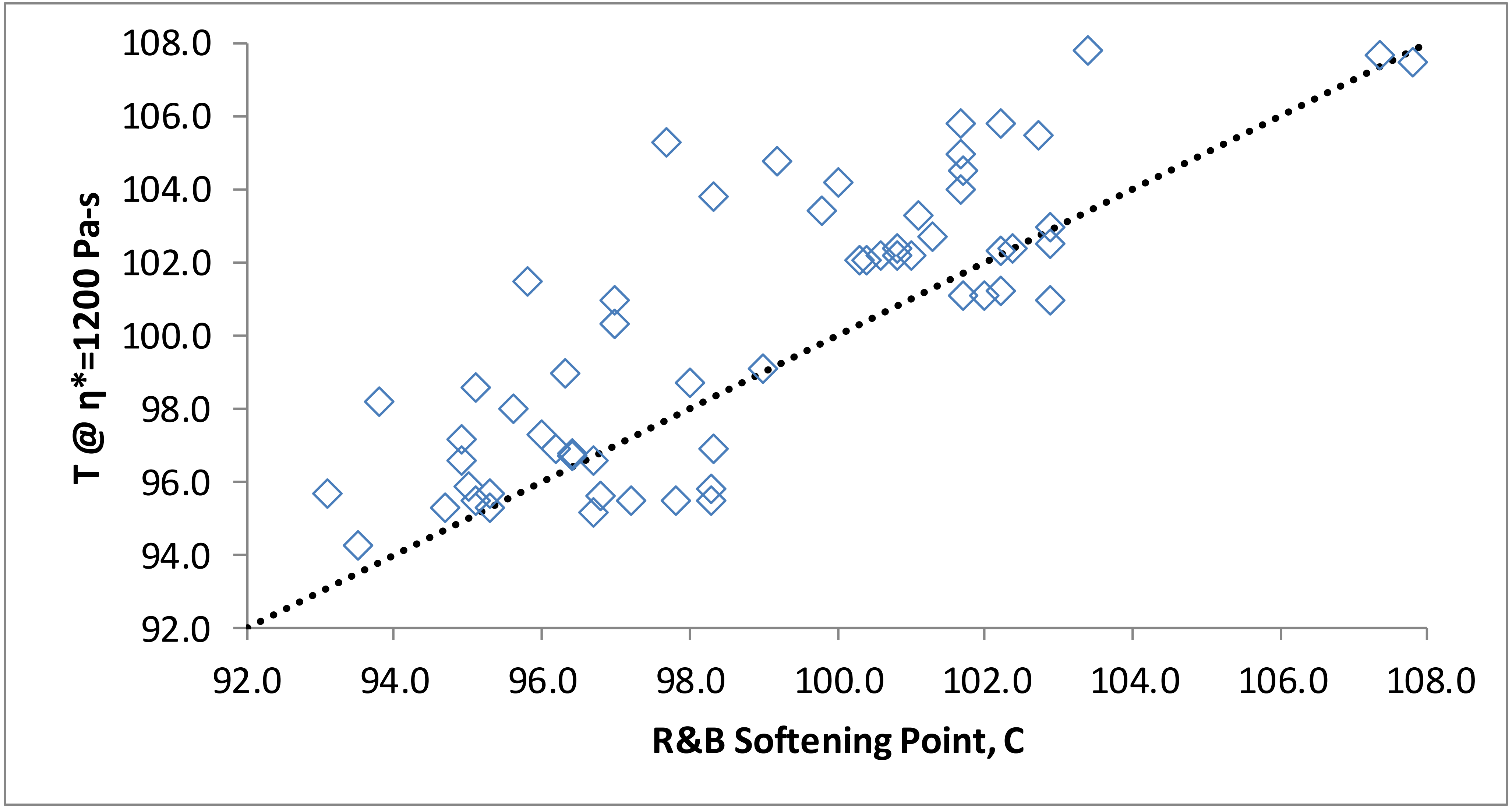
# Roofing PSP: Rheological Testing (2017)

| | Meas. $G^*_{2.5}$ @25°C, Pa | Penetration @ 25°C, dmm |
|---|---|---|
| Lab 2 | 4.81E+06 | 17 |
| Lab 3 | 3.24E+06 | 16 |
| Lab 4 | 4.72E+06 | 18 |
| Lab 5 | 3.64E+06 | 15 |
| Lab 6 | 4.50E+06 | 16.3 |
| Lab 7 | 4.53E+06 | 18 |
| Lab 11 | 4.21E+06 | 20 |
| Lab 13 | 4.64E+06 | 12 |
| Lab 14 | 5.12E+06 | 16 |
| Lab 15 | 3.52E+06 | 16.1 |
| Lab 16 | 4.60E+06 | 15 |

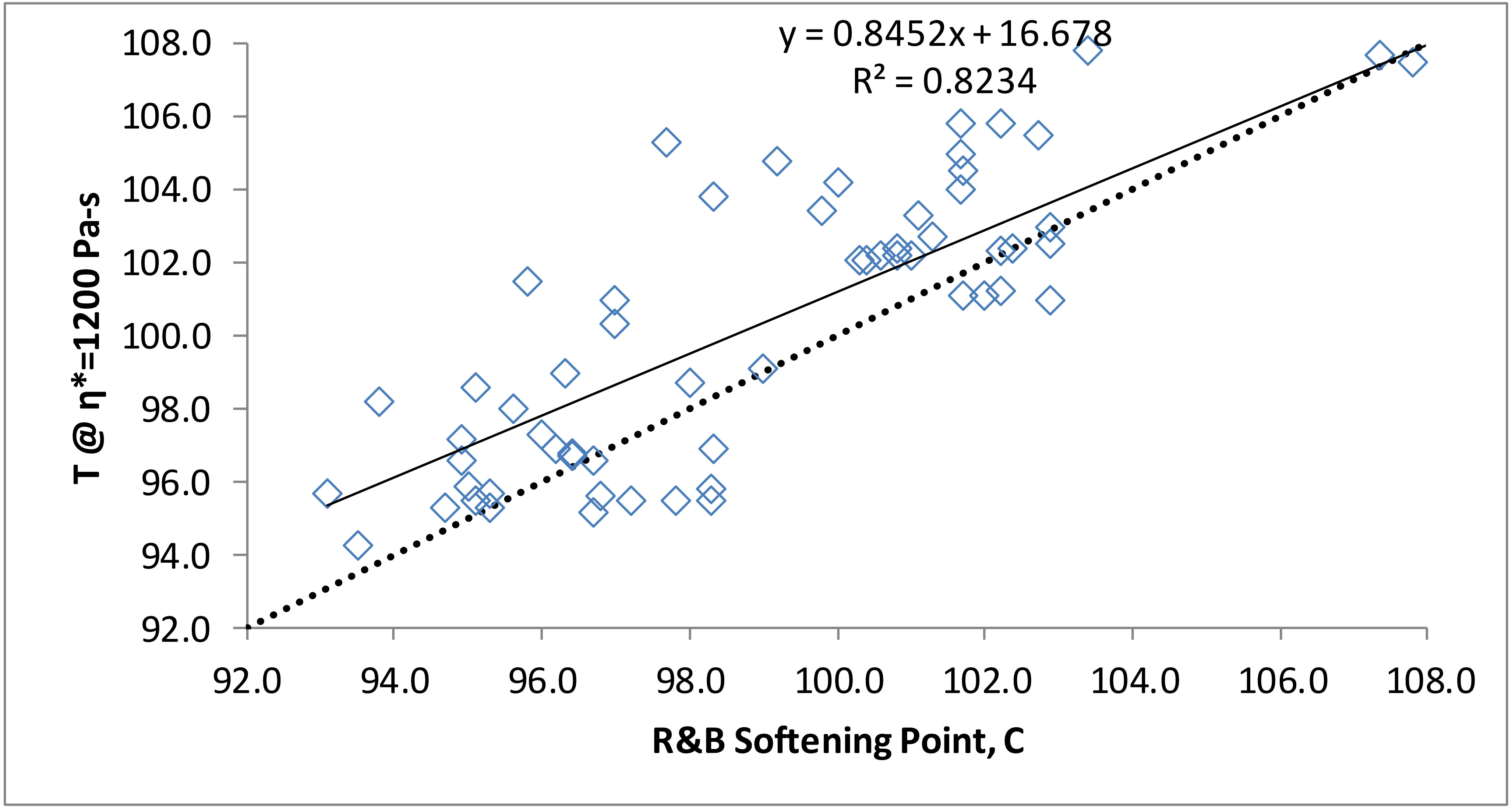
# Roofing PSP: Rheological Testing (2017)

| | Meas. $G^*_{2.5}$ @25°C, Pa | Penetration @ 25°C, dmm |
|---|---|---|
| Average | 4.32E+06 | 16.3 |
| StDev | 0.57E+06 | 2.0 |
| CV | 13.2% | 12.0% |

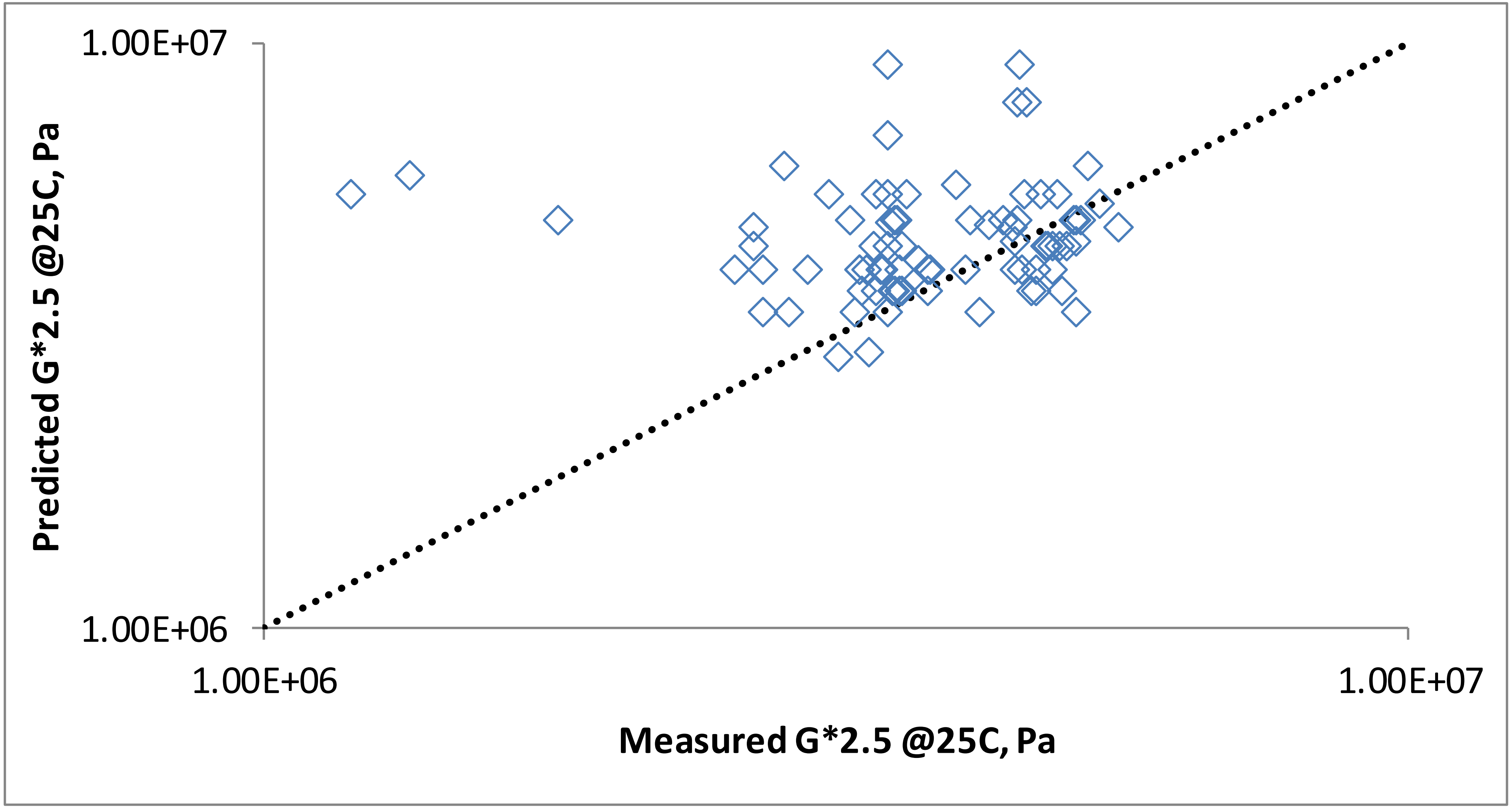
# Roofing PSP: Rheological Testing (2014-17)



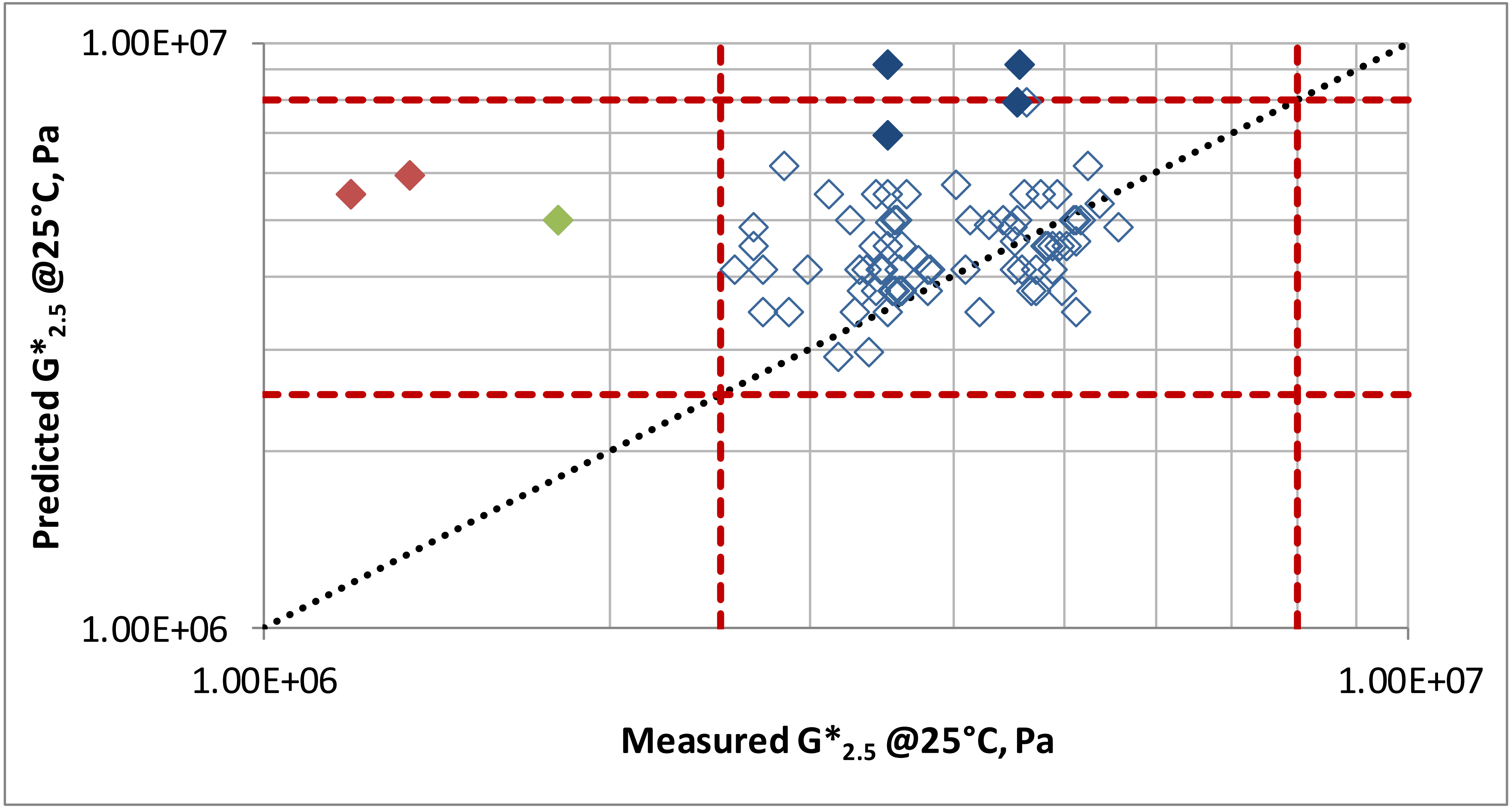
# Roofing PSP: Rheological Testing (2014-17)



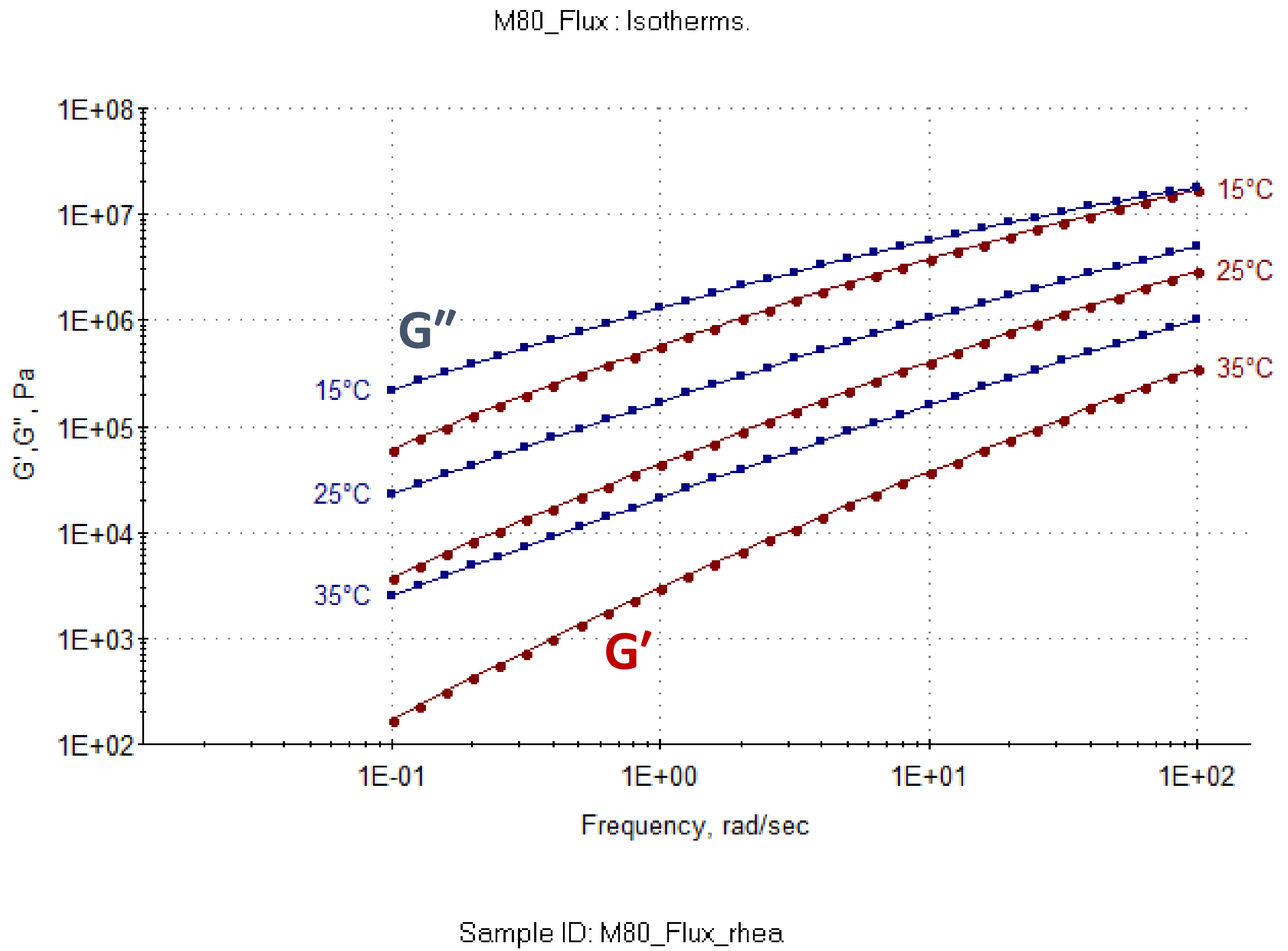
# Roofing PSP: Rheological Testing (2014-17)



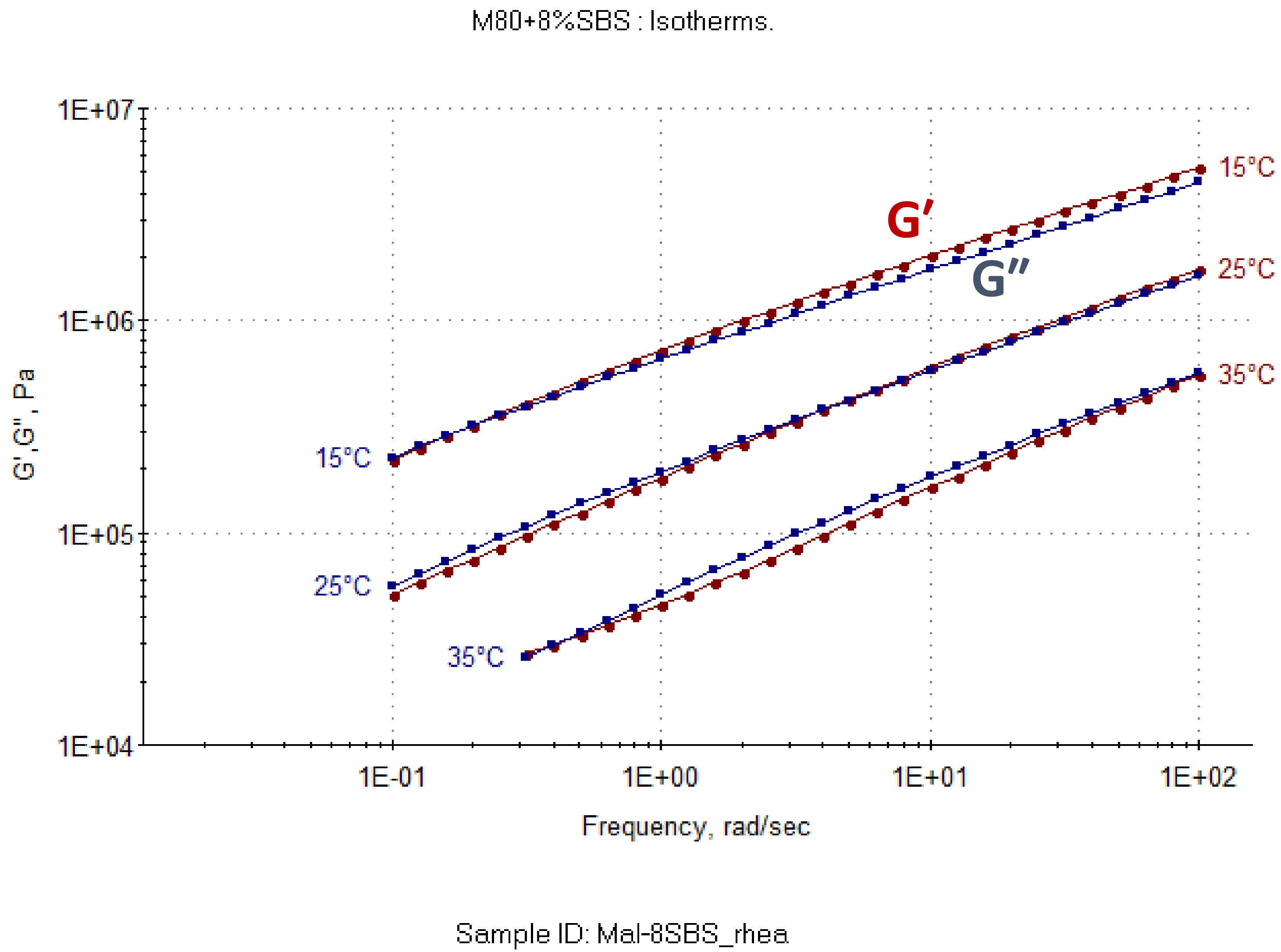
# Roofing PSP: Rheological Testing (2014-17)



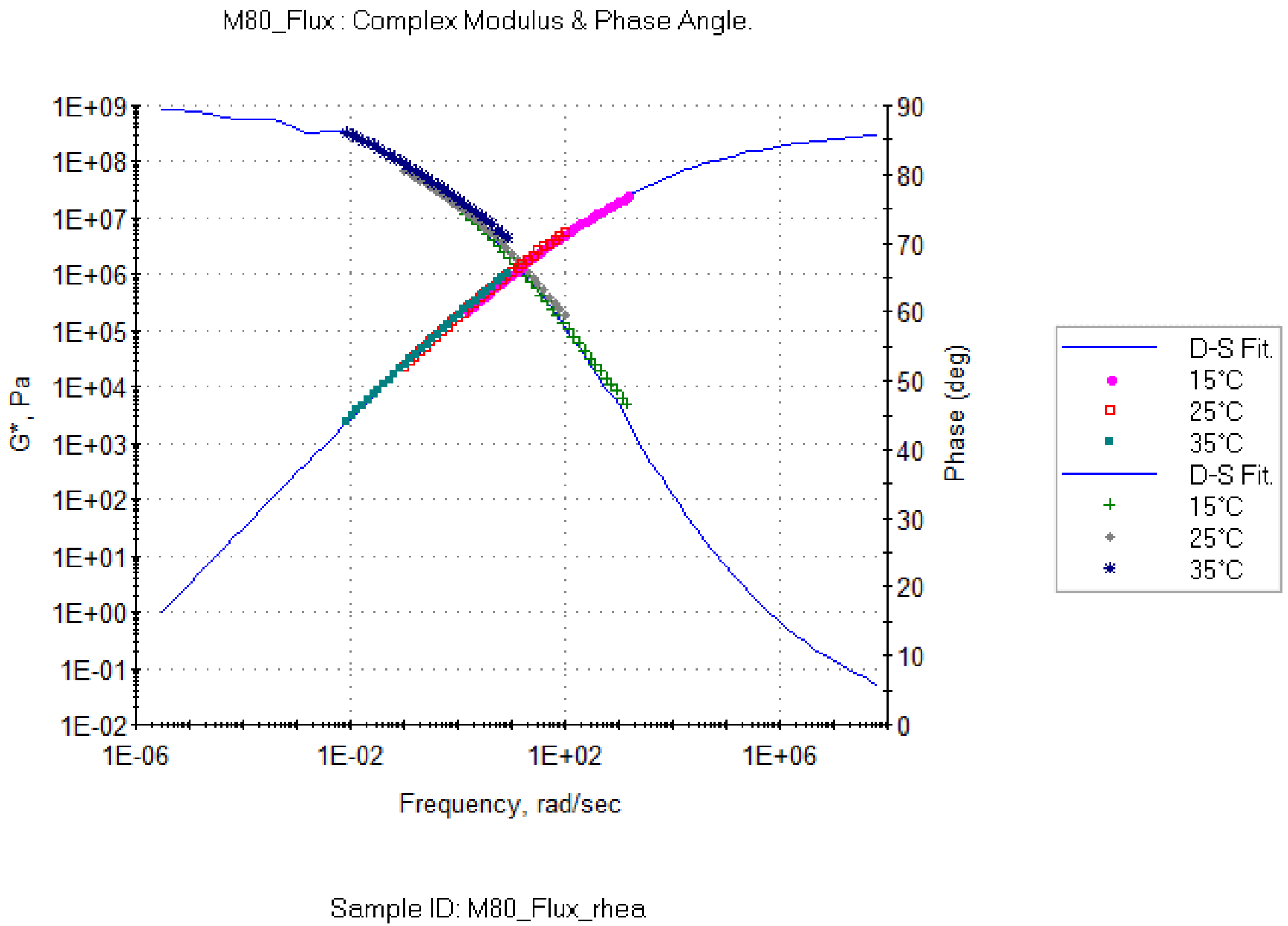
# Isotherms: Flux (80 PEN)



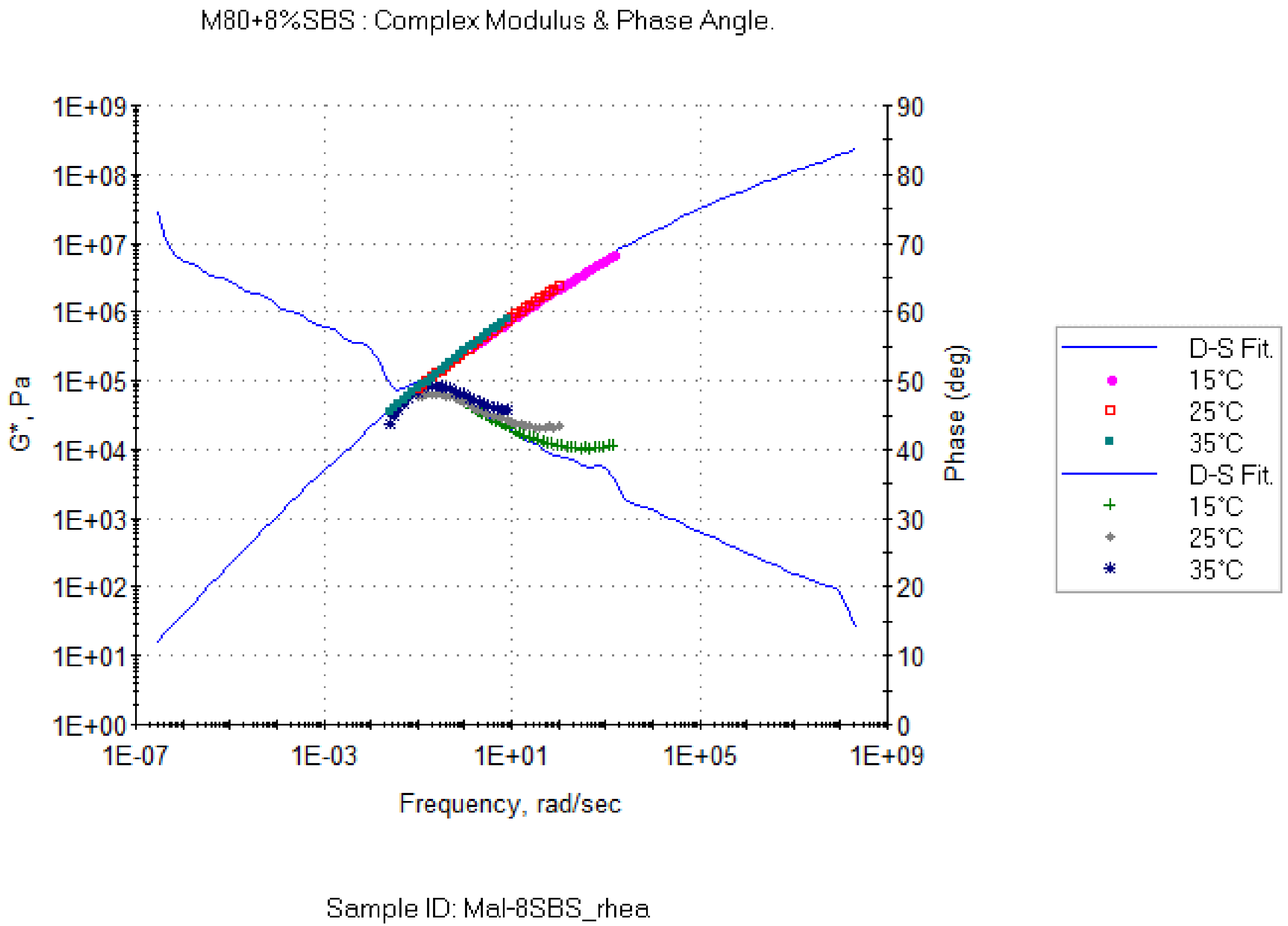
# Isotherms: Flux (80 PEN) + 8% SBS



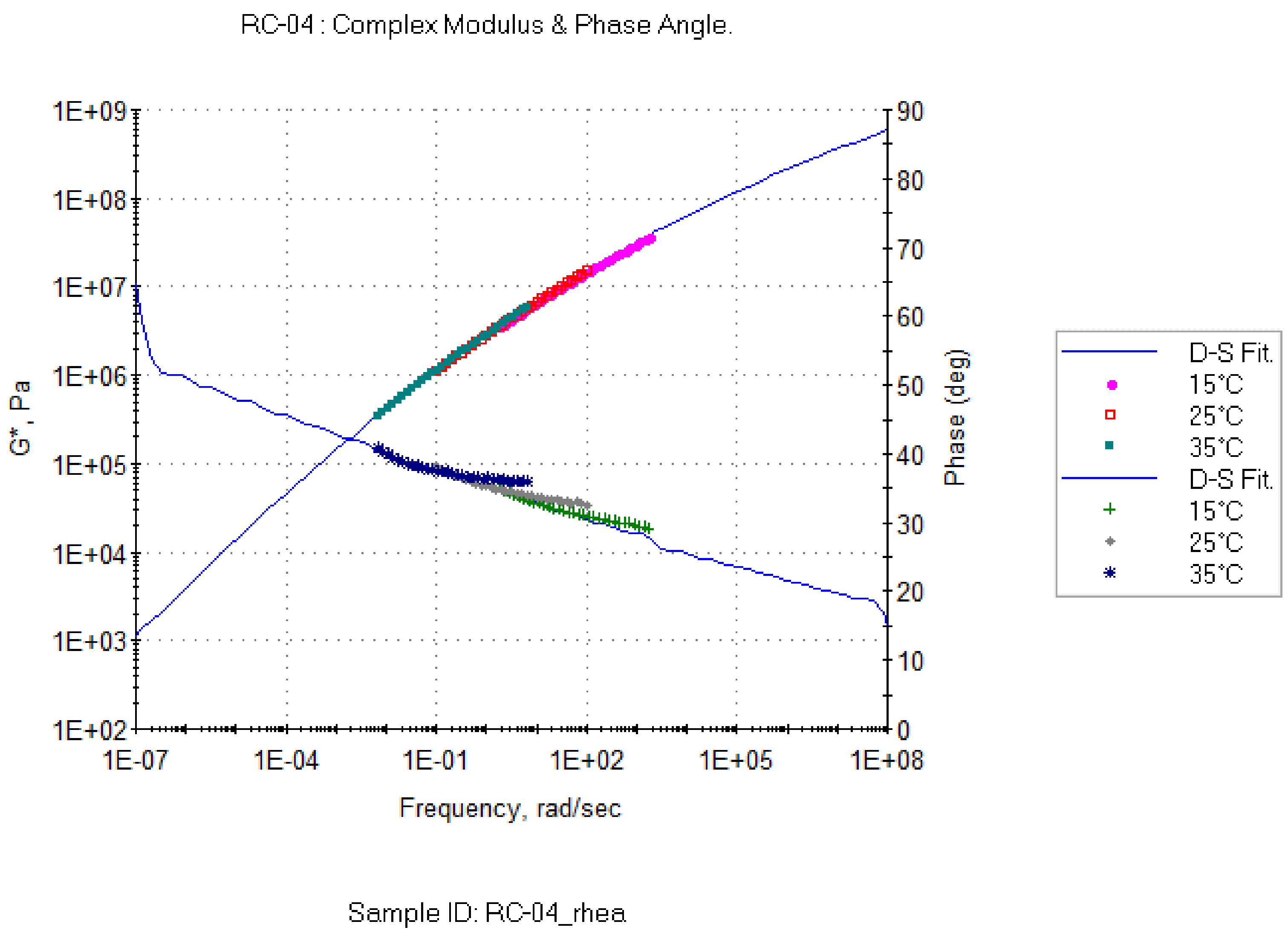
# Complex Modulus (G*) and Phase Angle (δ): Flux (80 PEN)



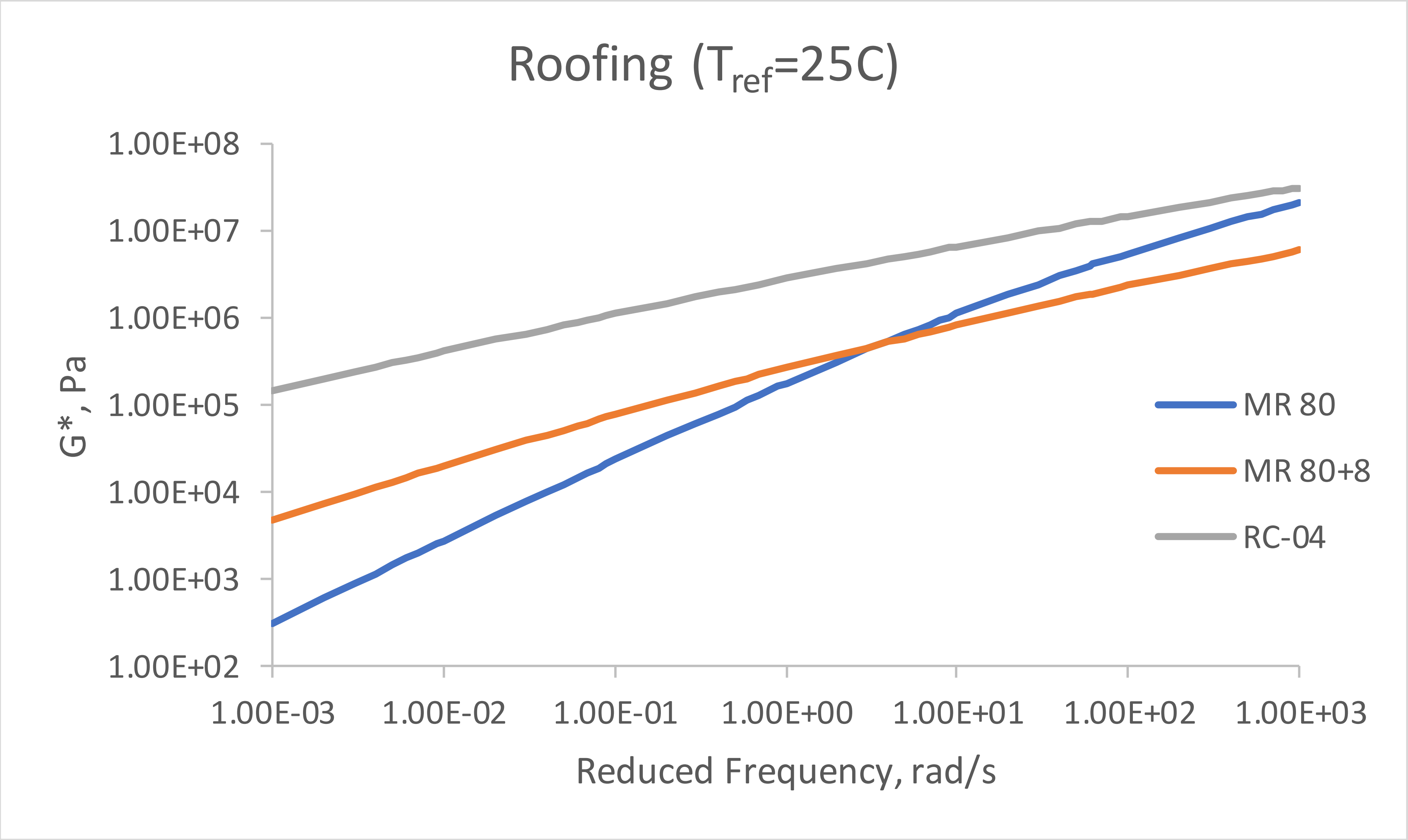
# Complex Modulus (G*) and Phase Angle (δ): Flux (80 PEN) + 8% SBS



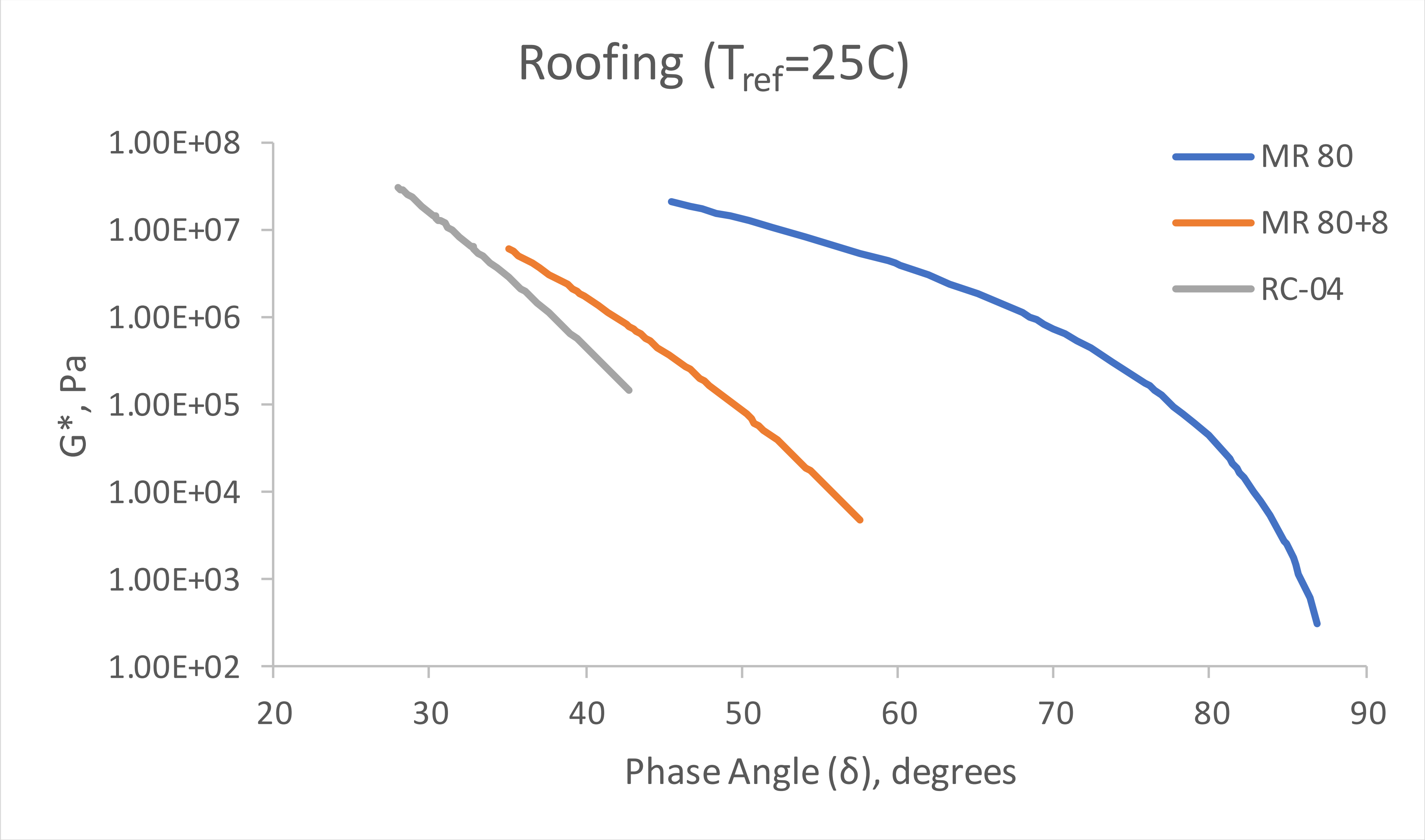
# Complex Modulus (G*) and Phase Angle (δ): Coating



# Mastercurves at 25°C (Frequency Dependence)



# Black Space at 25°C



# Summary: Rheological Testing of Roofing Asphalt

- Rheological Parameters
  - Respond rationally to changes in softening point and penetration
    - Effects of continued oxidation are readily seen in increased G* and δ decreased
  - Not a direct correlation
    - Shouldn't necessarily be expected since R&B Softening Point and Penetration are less fundamental (more empirical)
  - Variability appears reasonable compared to conventional tests
  - More information available from mastercurve analysis

# Thanks!

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