



Laboratory Evaluation: Wax Additives in Warm-Mix Asphalt Binder

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Objective

Evaluate the effect of wax additives on physical properties and characteristics of asphalt binders and their subsequent performance in mixtures.

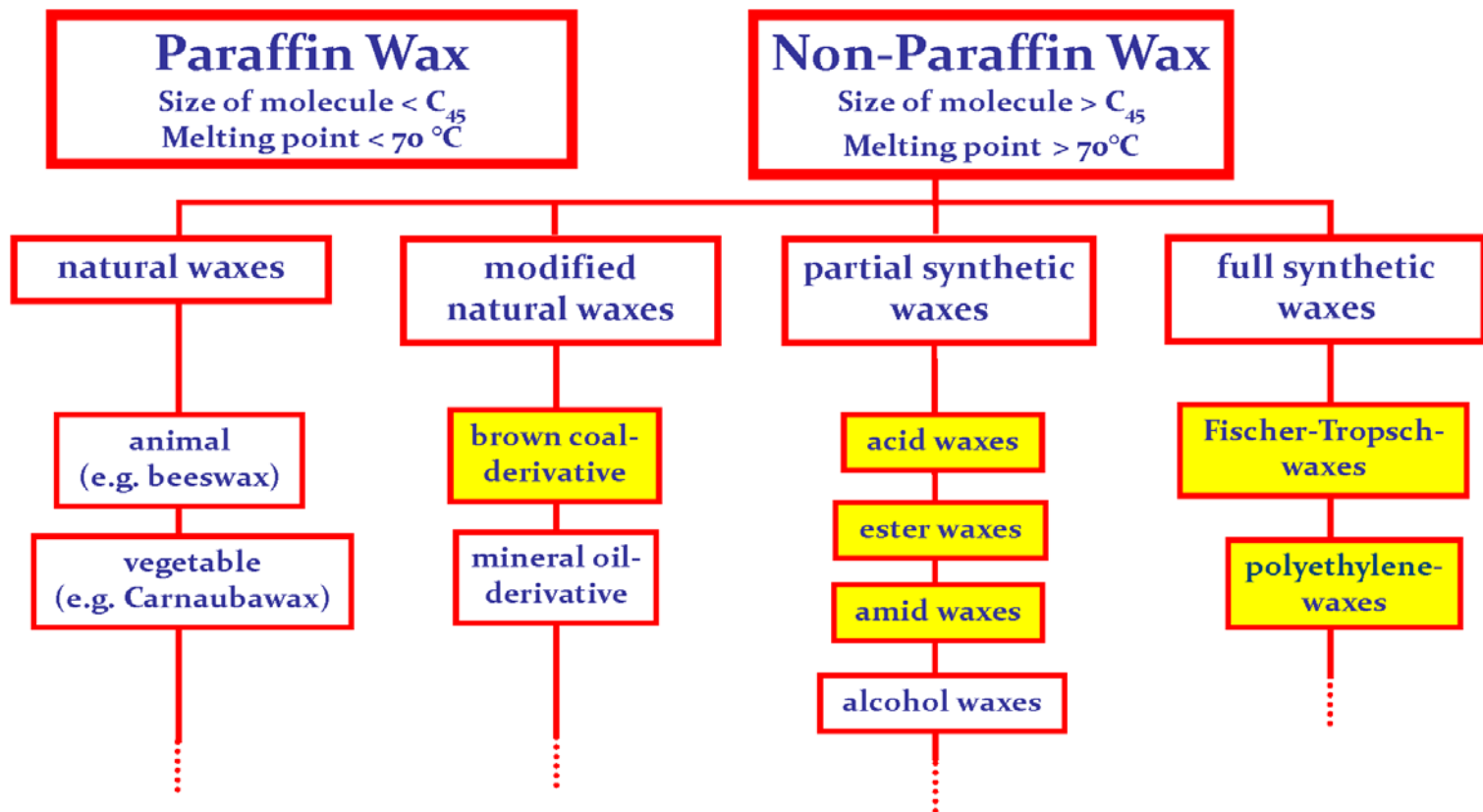
Can specifications distinguish between beneficial additives versus those that might have a negative impact on the performance of hot mix asphalt (HMA)?



Materials

- **Asphalt** – One (1)
 - Lion Oil PG64-22 Eldorado, AR Refinery (Saudi)
- **Wax Additives** – Nine (9)
 - Non-Paraffin Wax Additives
- **Aggregates**
 - Vulcan Barin Quarry Granite, Columbus, GA (Aggregate used on the NCAT Test Track)
- **Mix Design**
 - 12.5mm Dense Graded SuperPave™ Gyratory
 - ~5.5% Binder
 - ~7.0% Air Voids

Targeted a range of waxes





Materials tested

9 - Waxes

- 0 Lion Oil PG 64-22
- 1 Romanta Normal Montan
- 2 Romanta Asphaltan A
- 3 Romanta Asphaltan B
- 4 Licomont BS 100
- 5 Sasobit
- 6 Luxco Pitch # 2
- 7 Alphamin GHP
- 8 Strohmeier and Arpe Montan LGE
- 9 Astra Wax 3816D Microcrystalline



Test program

■ **Binder**

- M320 – Table 1 and 2
- Binder master curves – BBR and DSR
- BBR tests at different aging conditions (0, 2, 4, 8, 16 and 32 days)
- MSCR

■ **Mixture**

- Mix BBR tests – 2 temperatures for limited mastercurves
- Repeated creep tests
- Fatigue – monotonic tests and repeated load
- Master curves



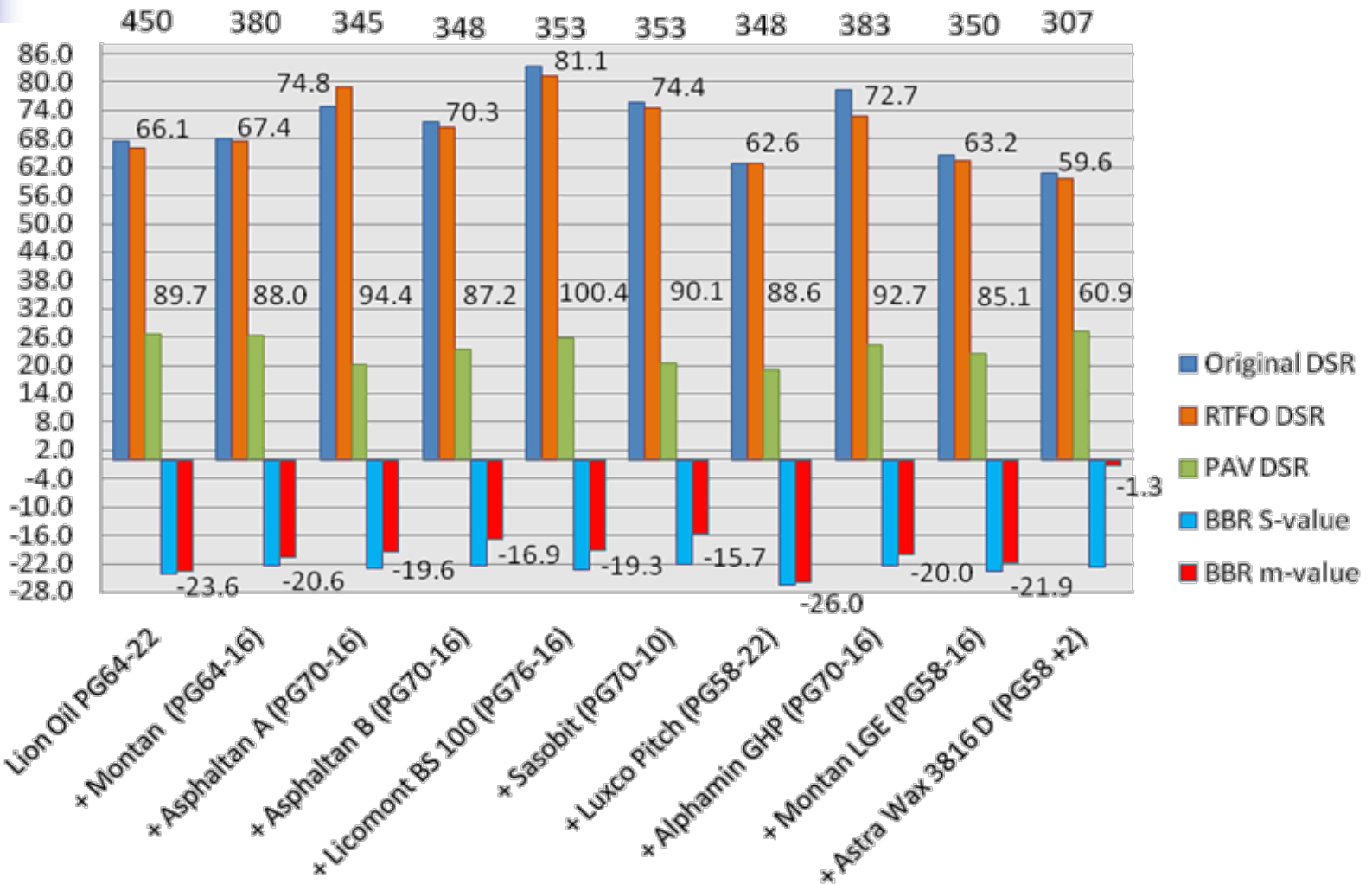
Mix stiffness in BBR

- Tested BBR beams at varying ageing
- Analysis extended to use 1000 second data
- Removed early part of test data to avoid effects of non-instantaneous startup

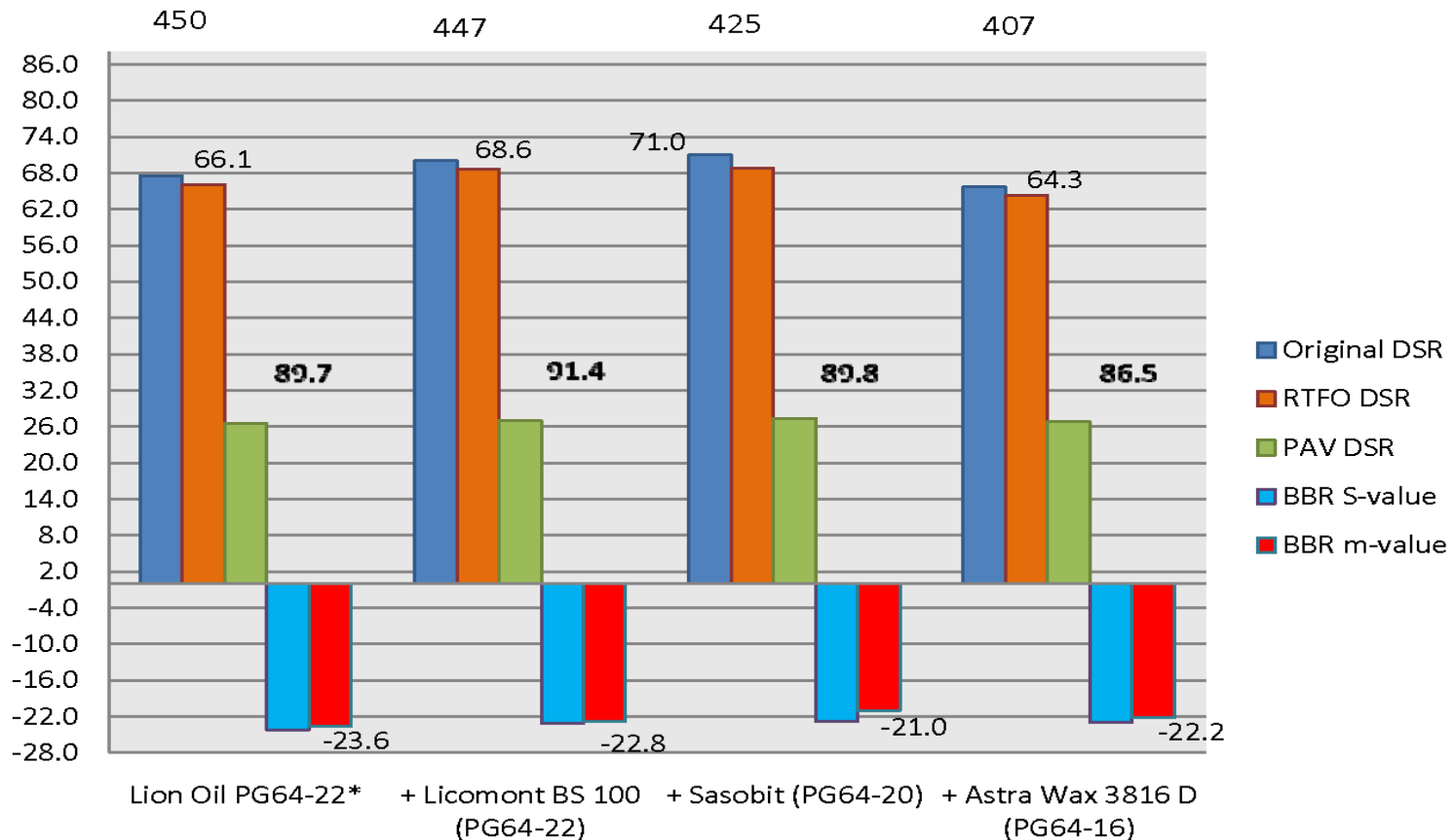


Binder test data

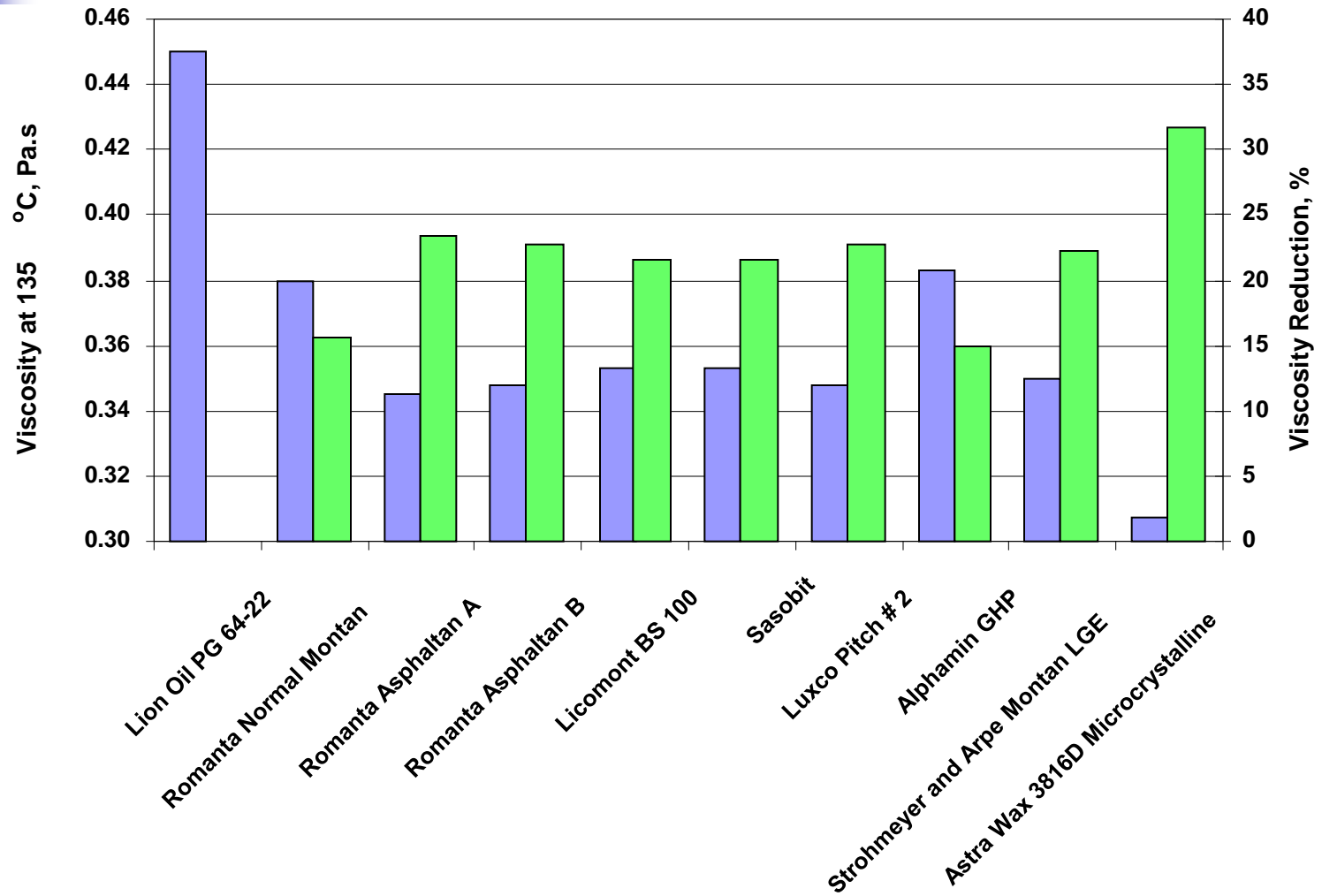
PG grading – AASHTO M320 (3% Wax Modified Binders)



PG grading – AASHTO M320 (1% Wax Modified Binders)



Viscosity Changes (3%)

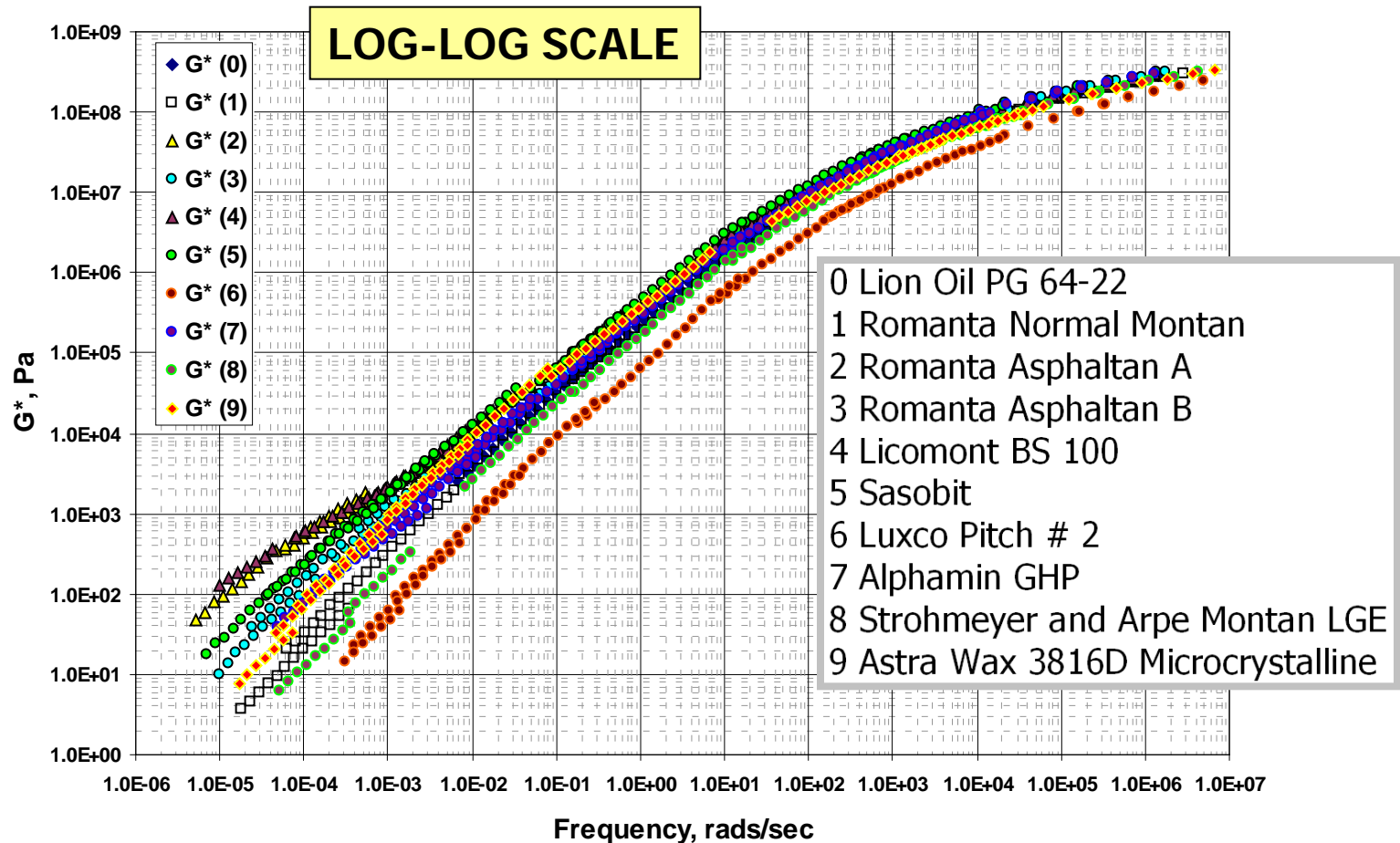




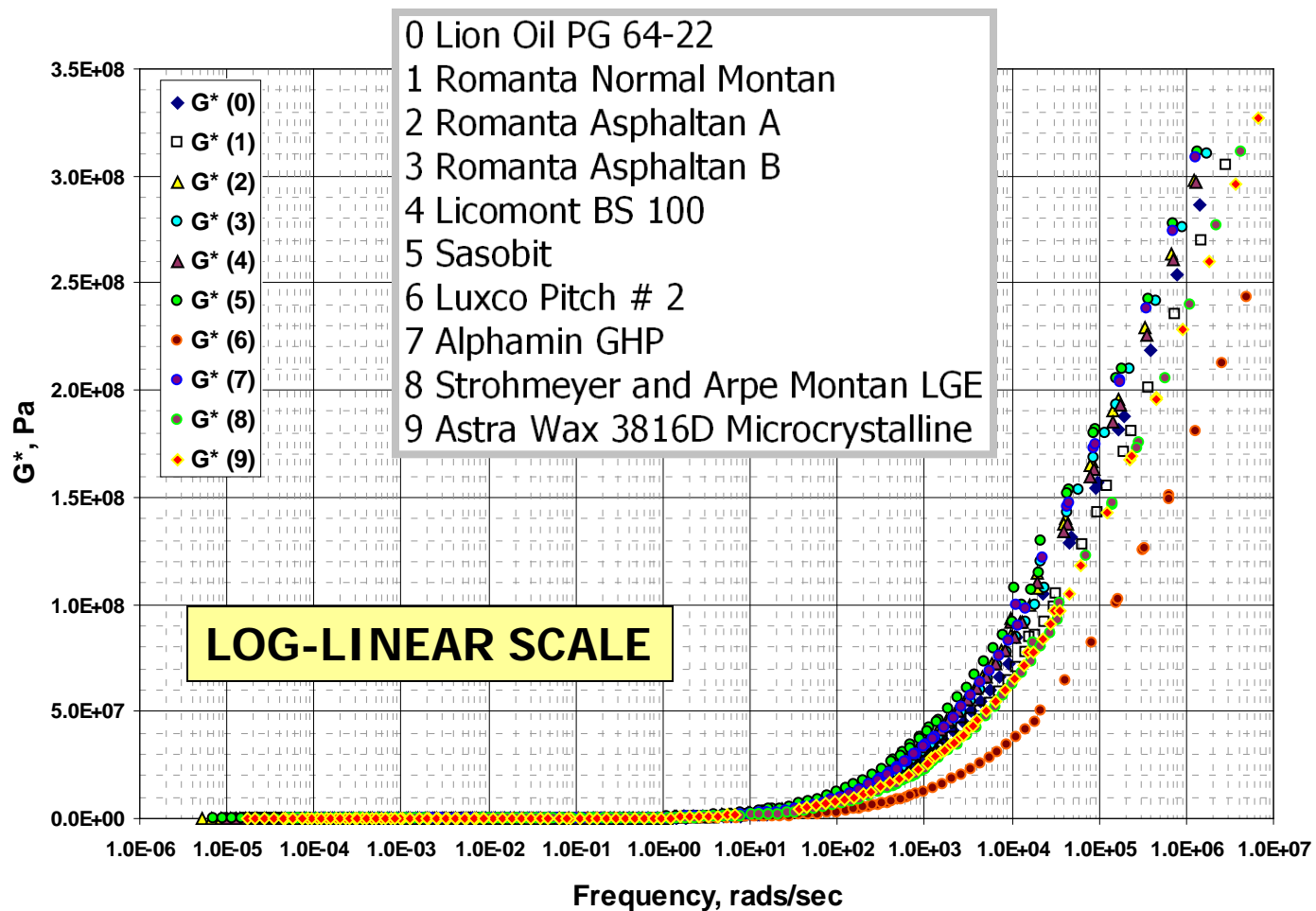
Binder – 0 day tests

- **RHEOLOGY ANALYSIS** in Abatech RHEA Software
- RHEOLOGY OBSERVATIONS
 - 6 (Luxco Pitch # 2)– has lower G^* mastercurve
 - Significant difference in G^* at lower end of frequency range
 - δ with various binders show some type of network at low frequencies, more significant in 2 (Romanta Asphaltan A), 3 (Romanta Asphaltan B), 4 (Licomont BS 100), 5 (Sasobit) and 7 (Alphamin GHP)
 - Judging from δ (*at low temp/high freq.*)
 - 6 (Luxco Pitch # 2) appears to have best relaxation properties
 - 9 (Astra Wax 3816D Microcrystalline) has worse relaxation properties

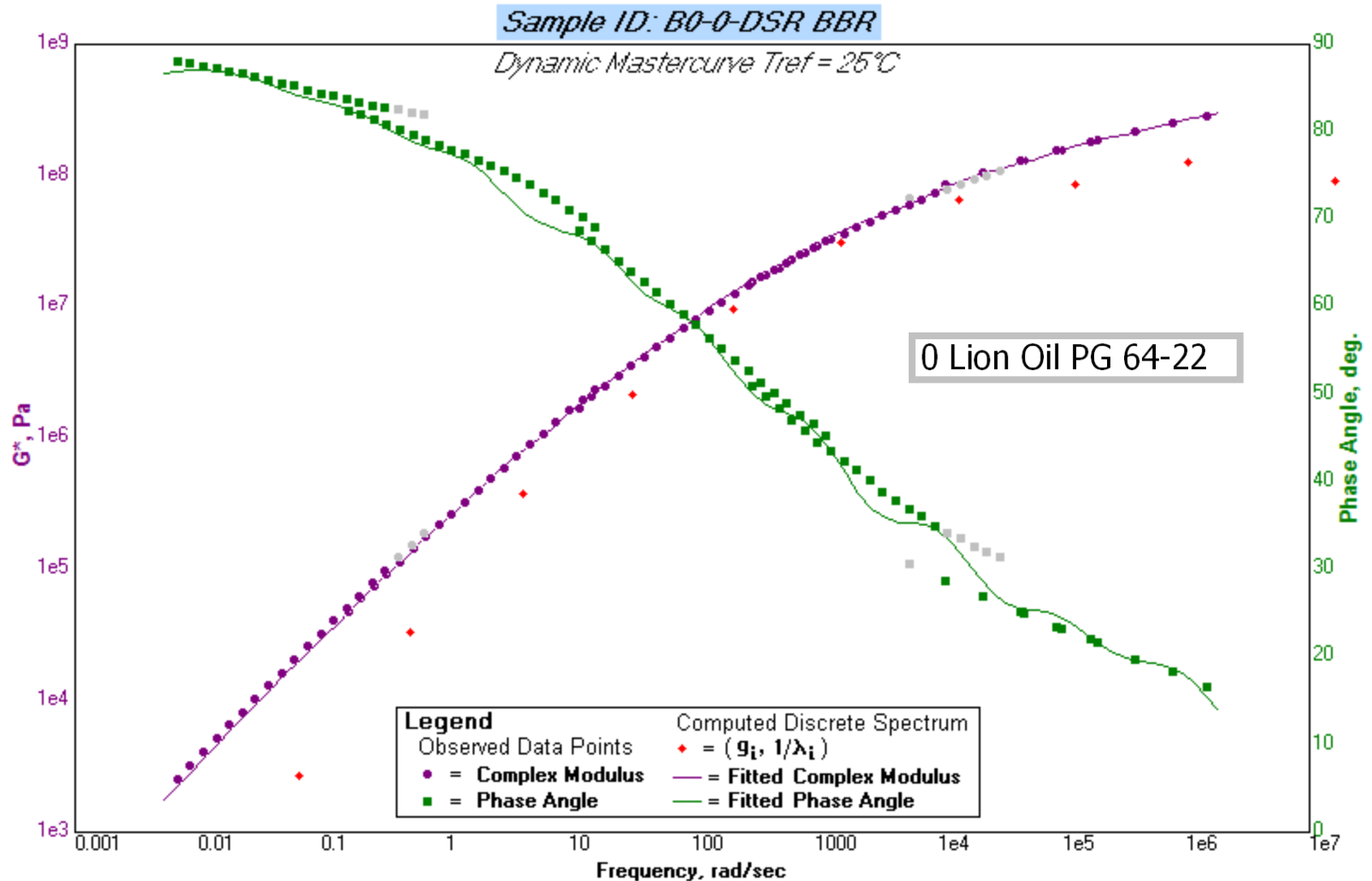
Master curve E^* , $T_{ref} = 25^\circ\text{C}$



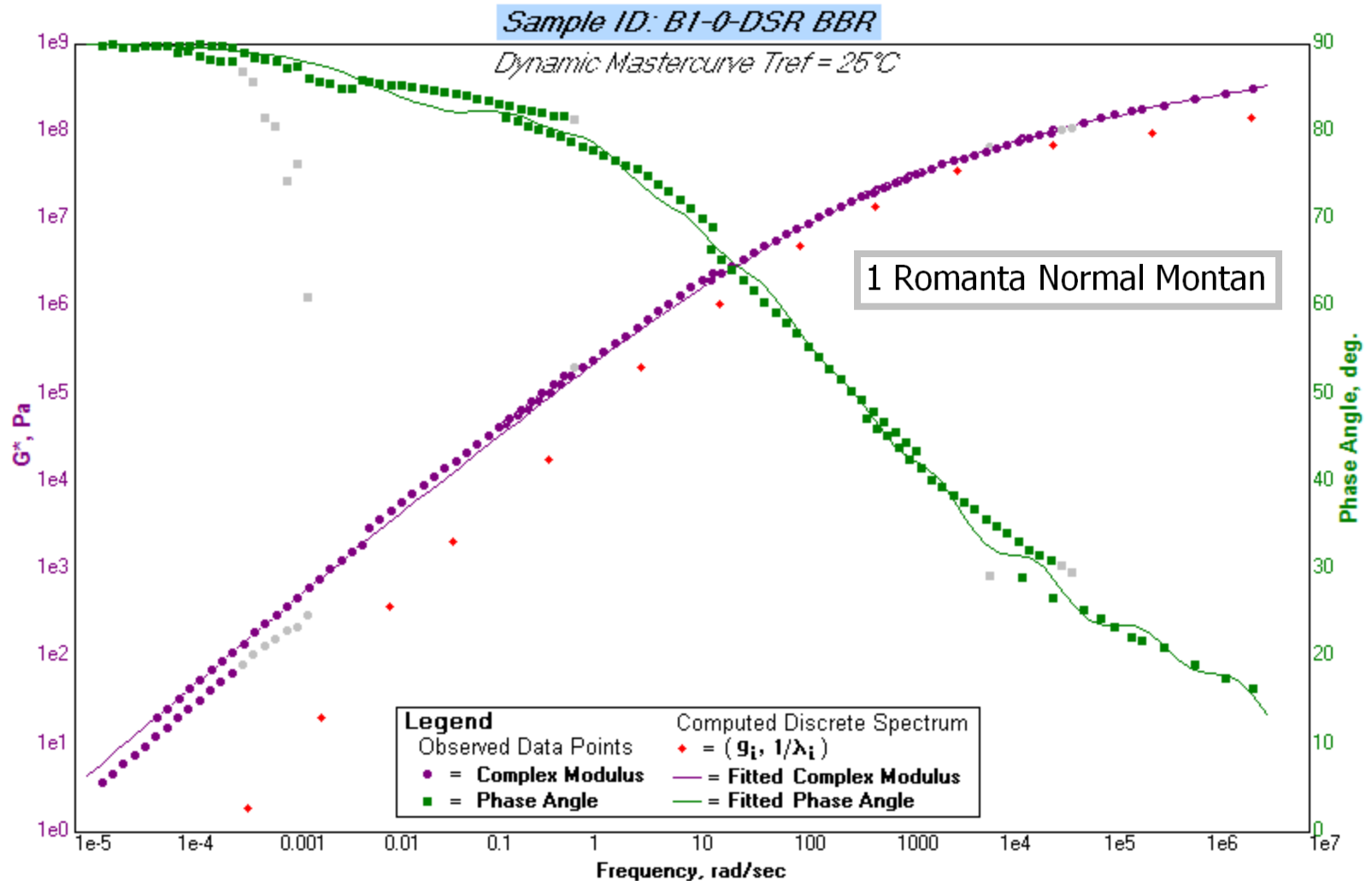
Master curve E^* , $T_{ref} = 25^\circ\text{C}$



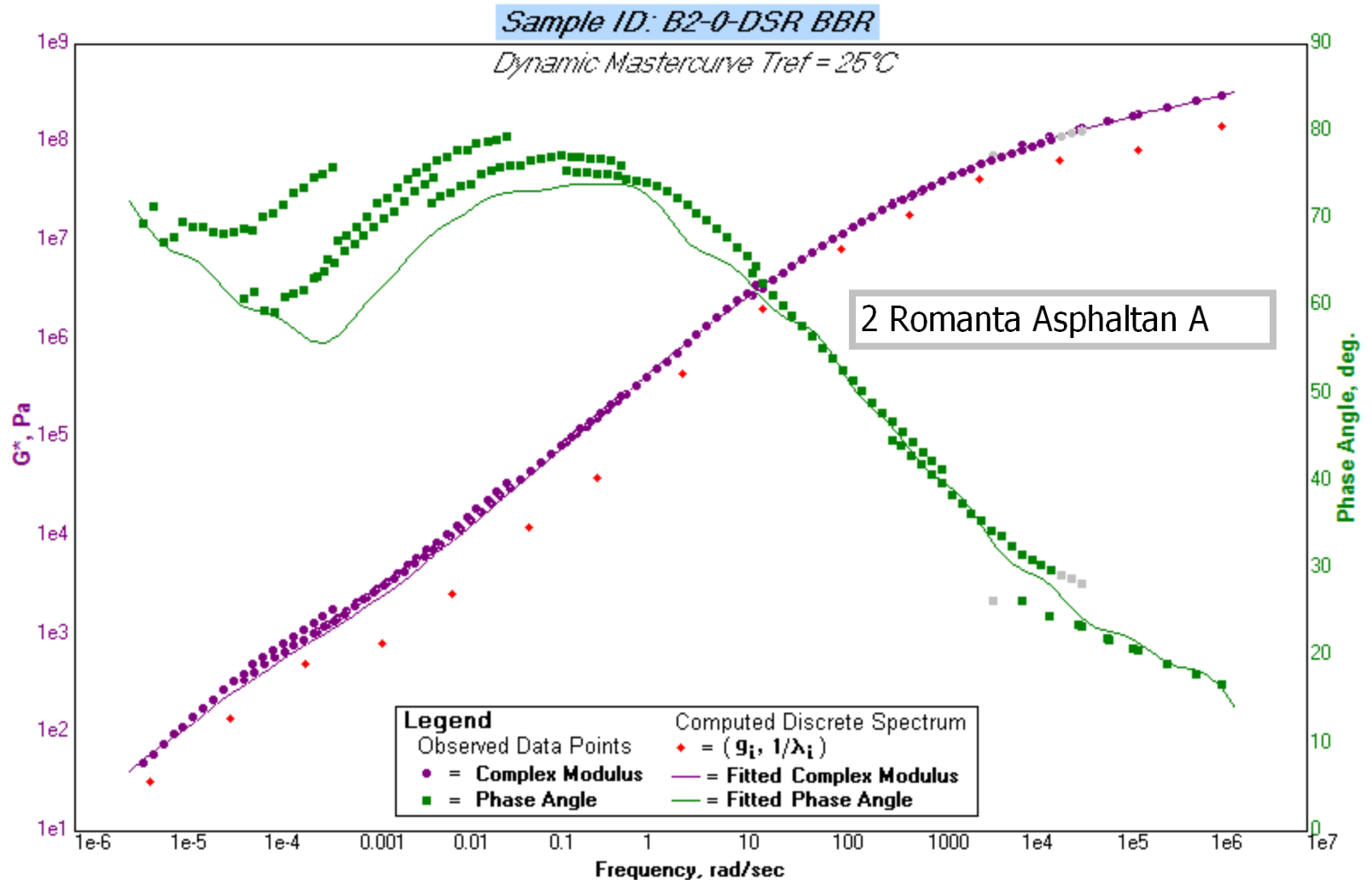
Binder 0 – 0 days



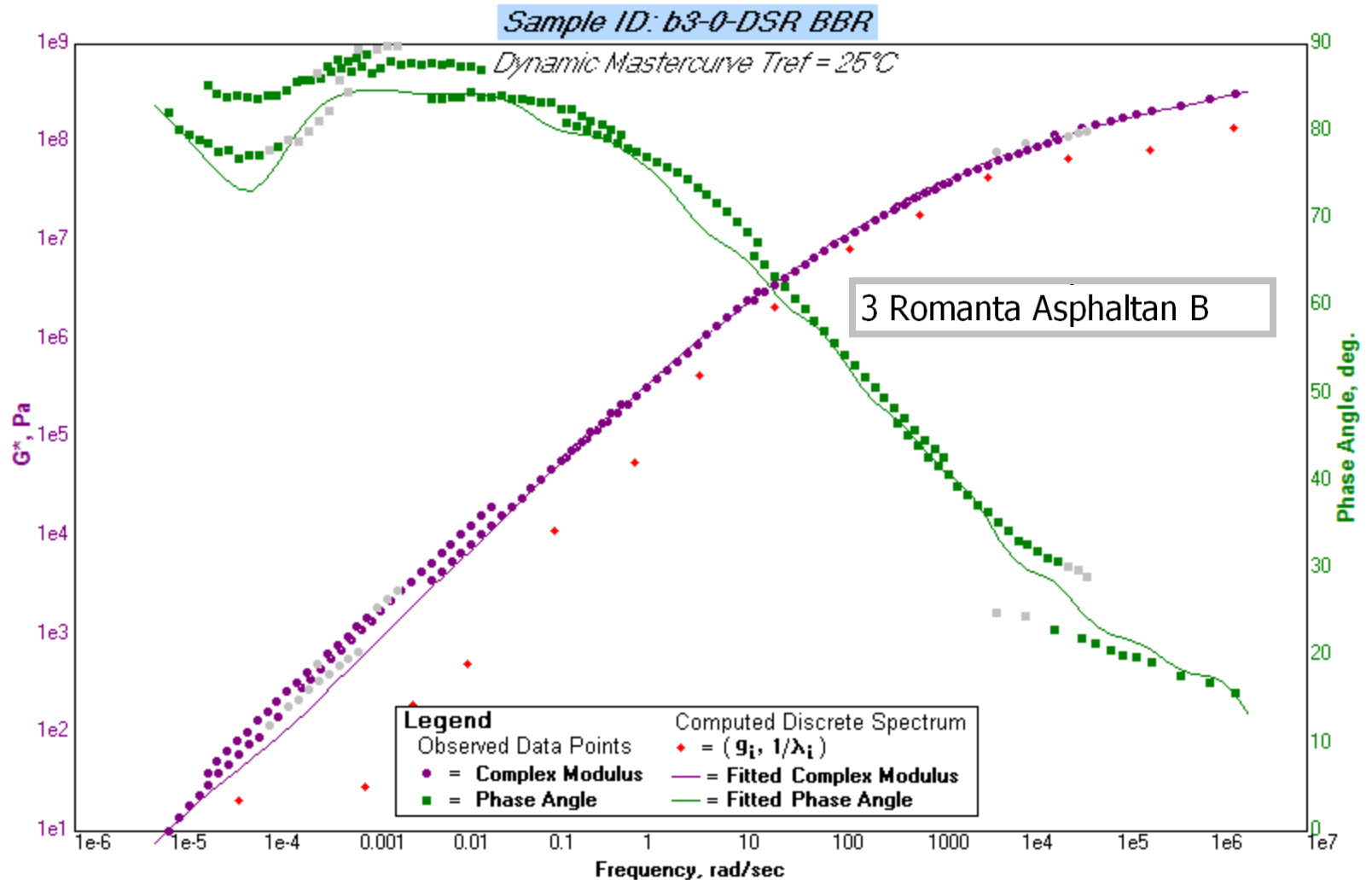
Binder 1 – 0 days



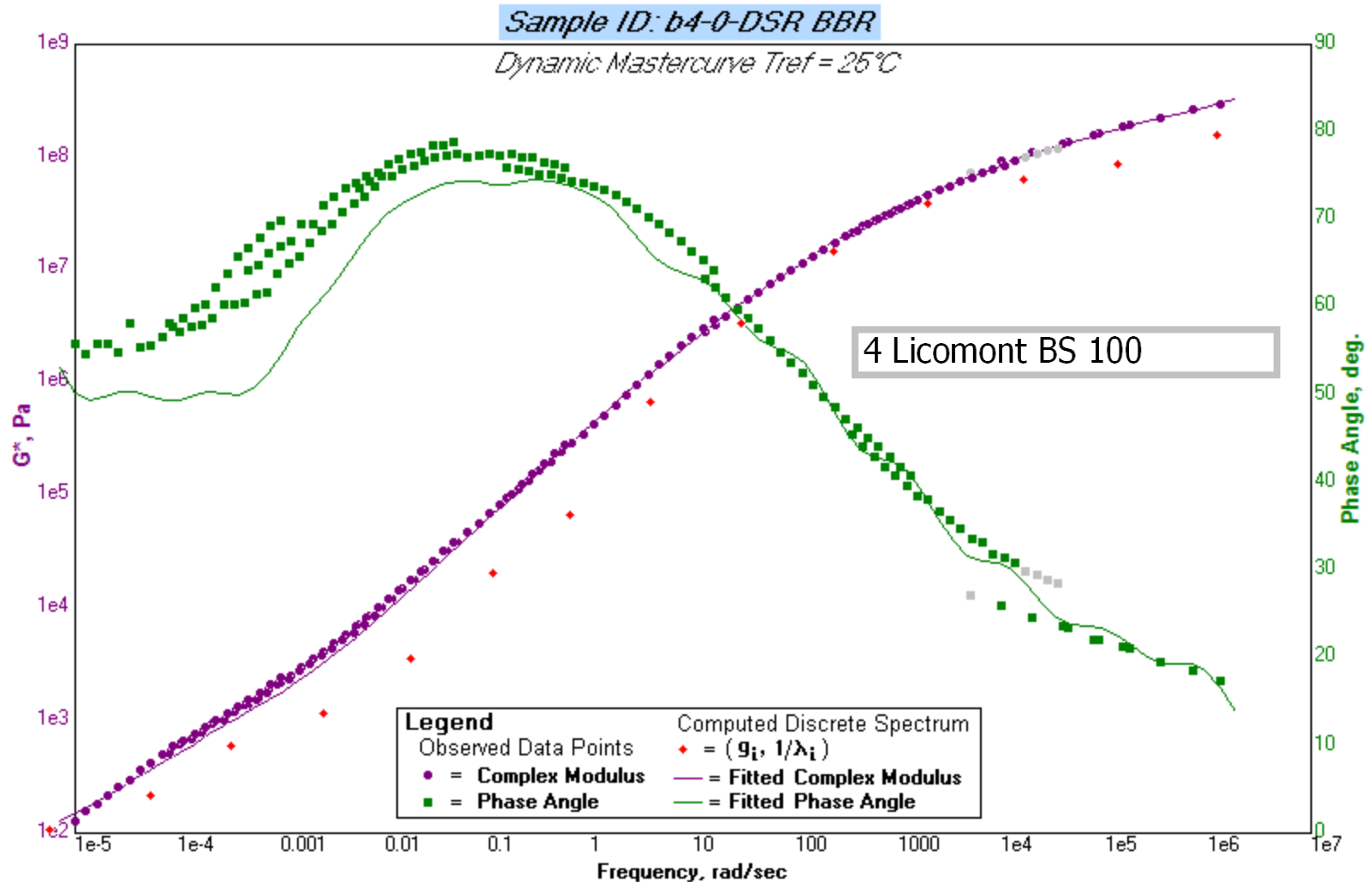
Binder 2 – 0 days



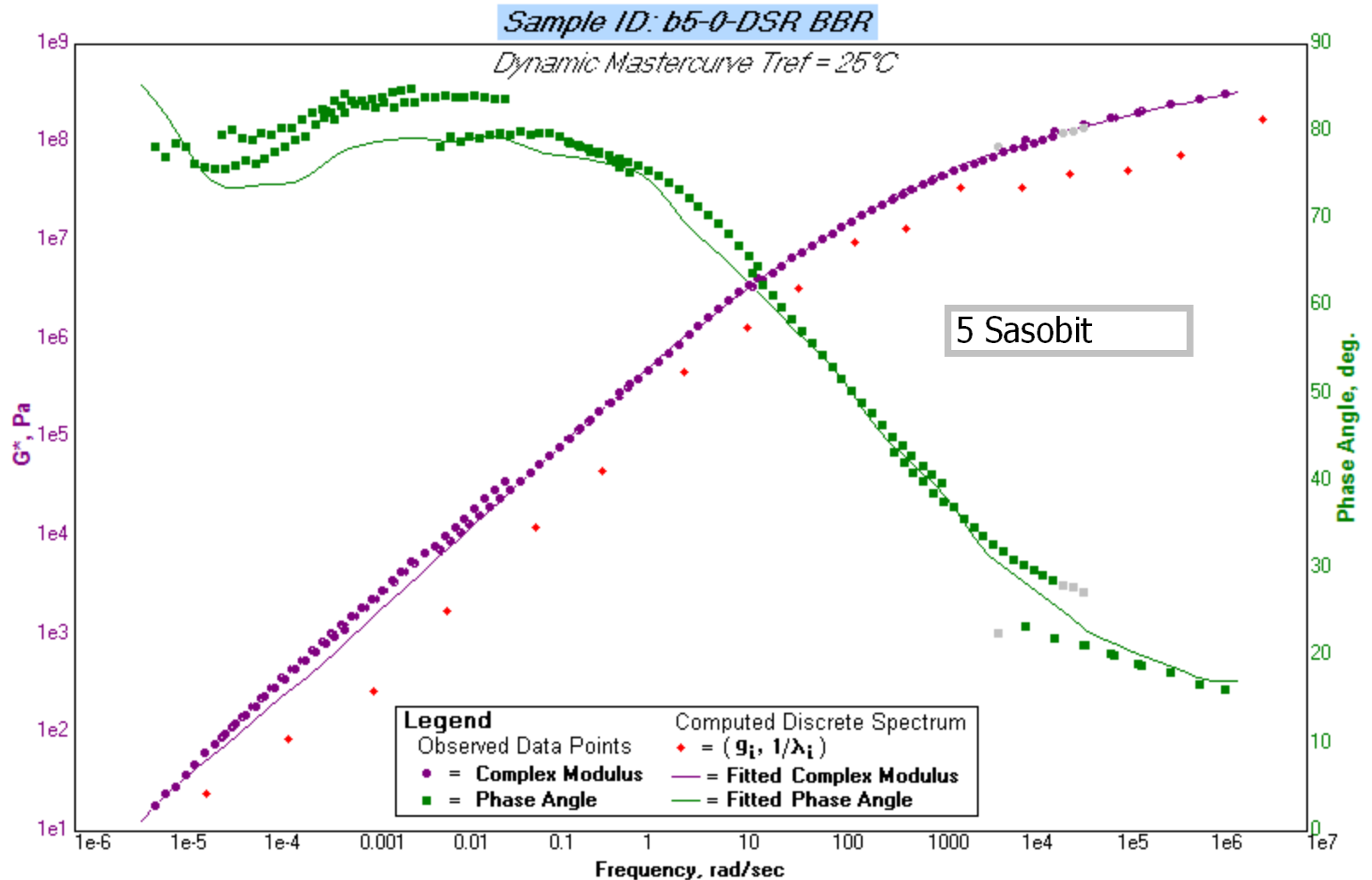
Binder 3 – 0 days



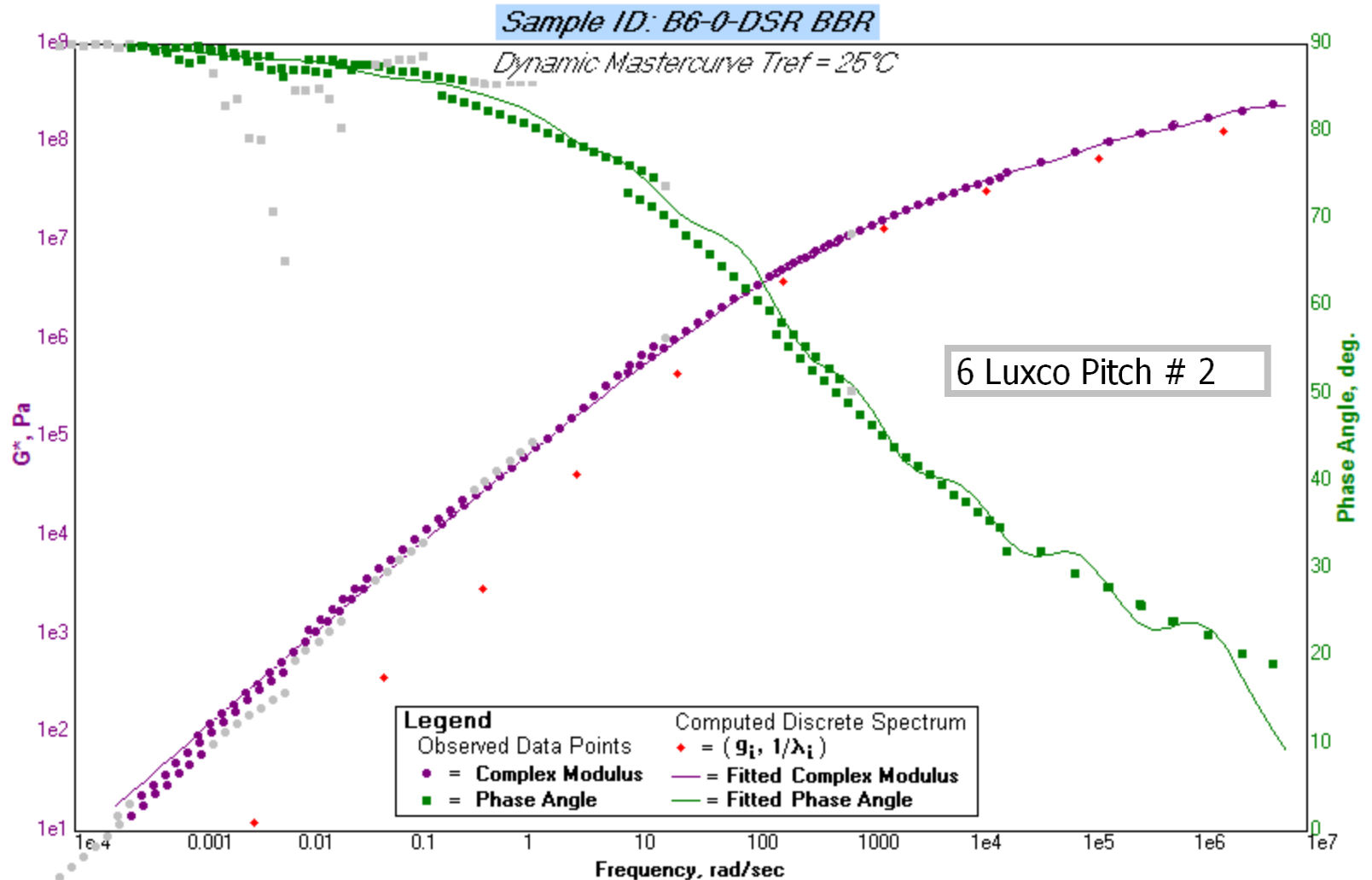
Binder 4 – 0 days



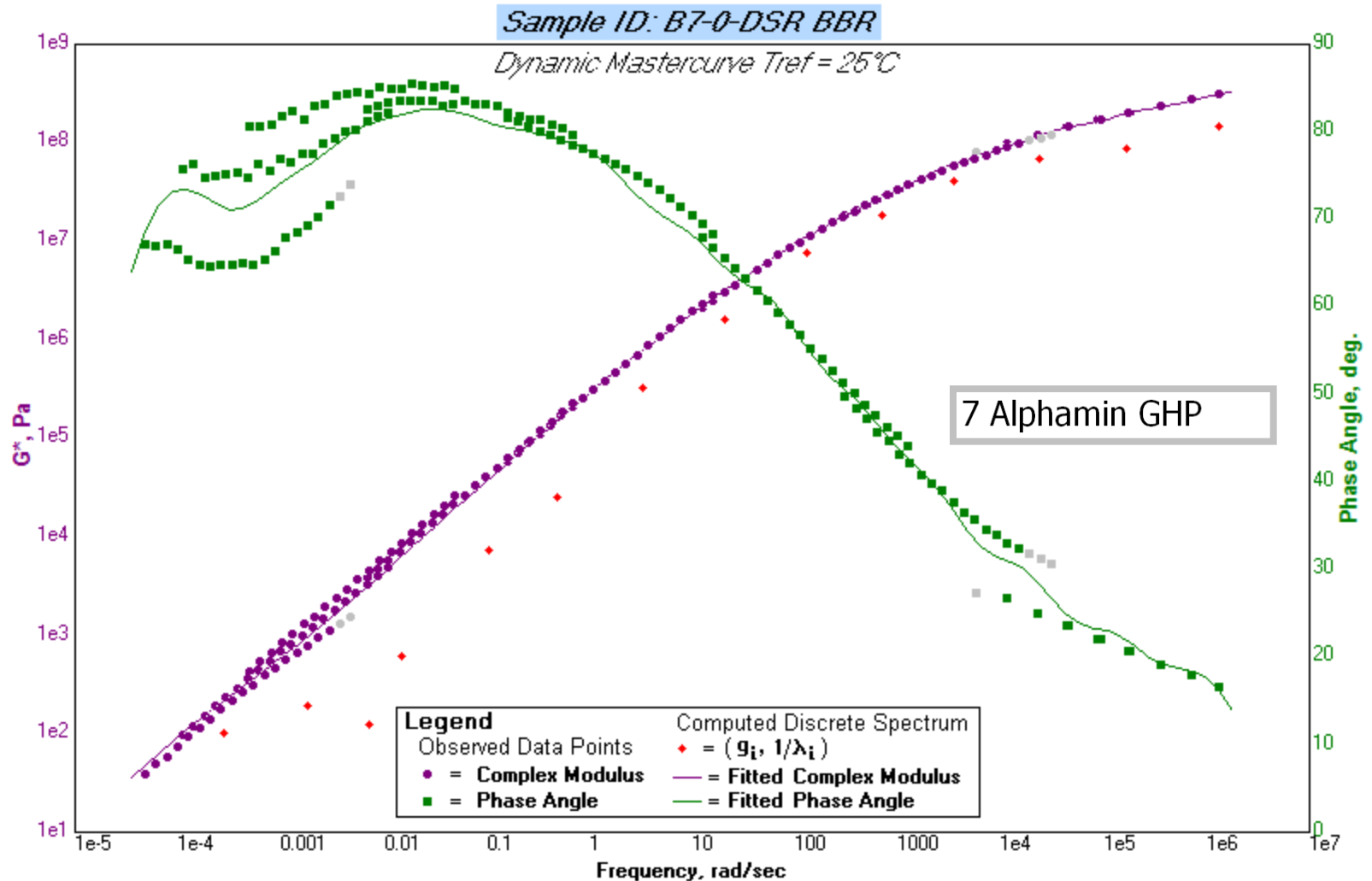
Binder 5 – 0 days



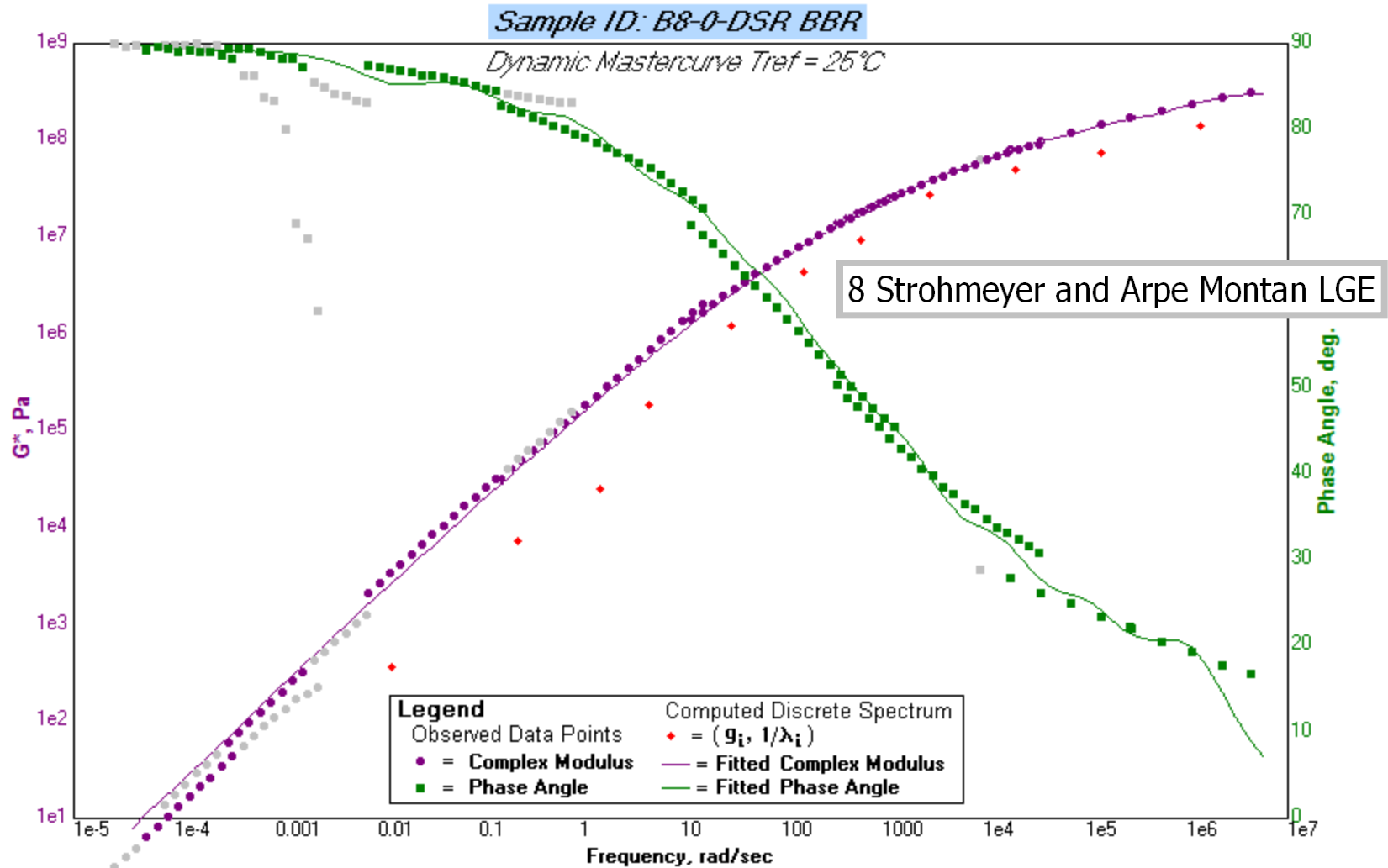
Binder 6 – 0 days



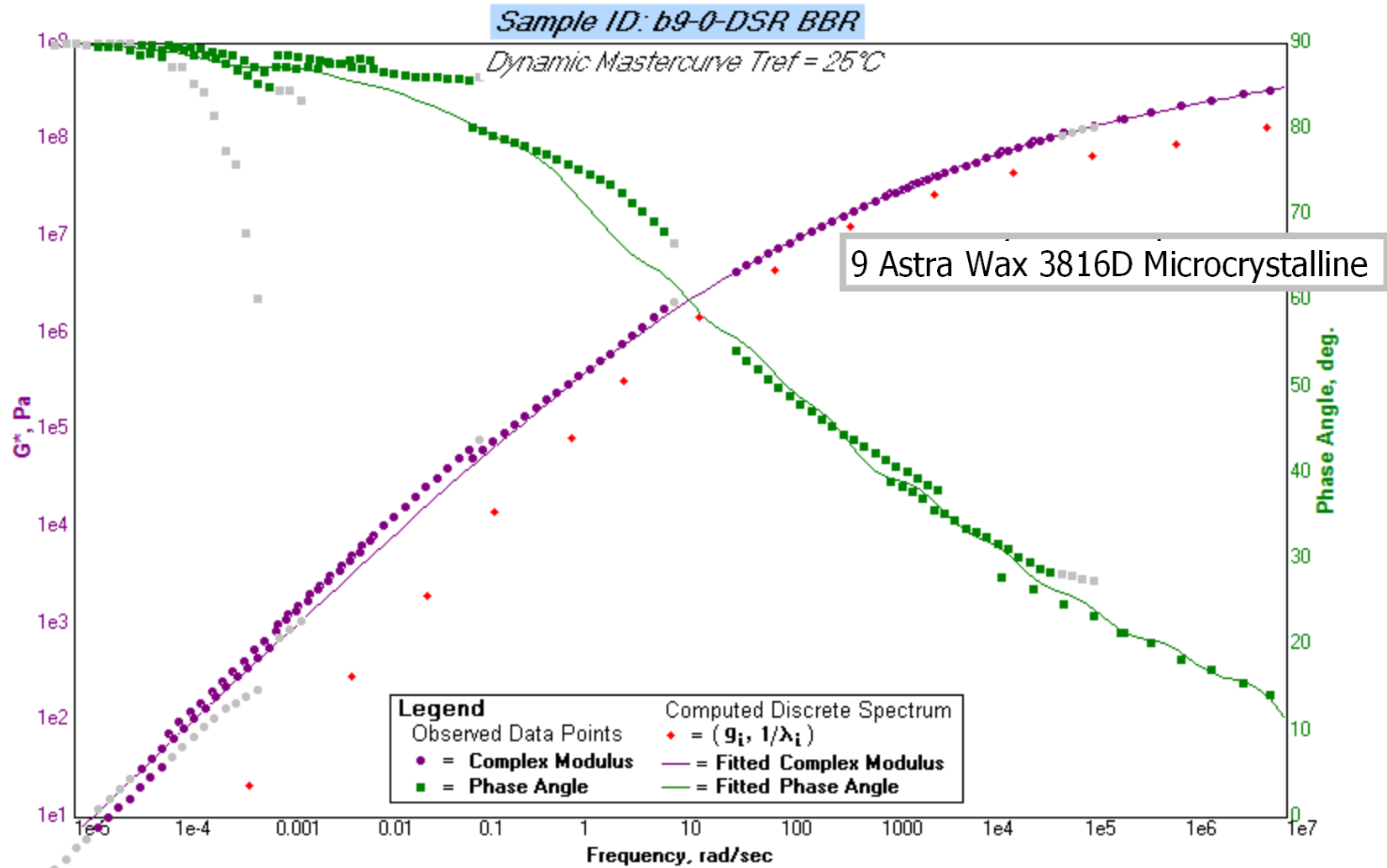
Binder 7 – 0 days



Binder 8 – 0 days



Binder 9 – 0 days

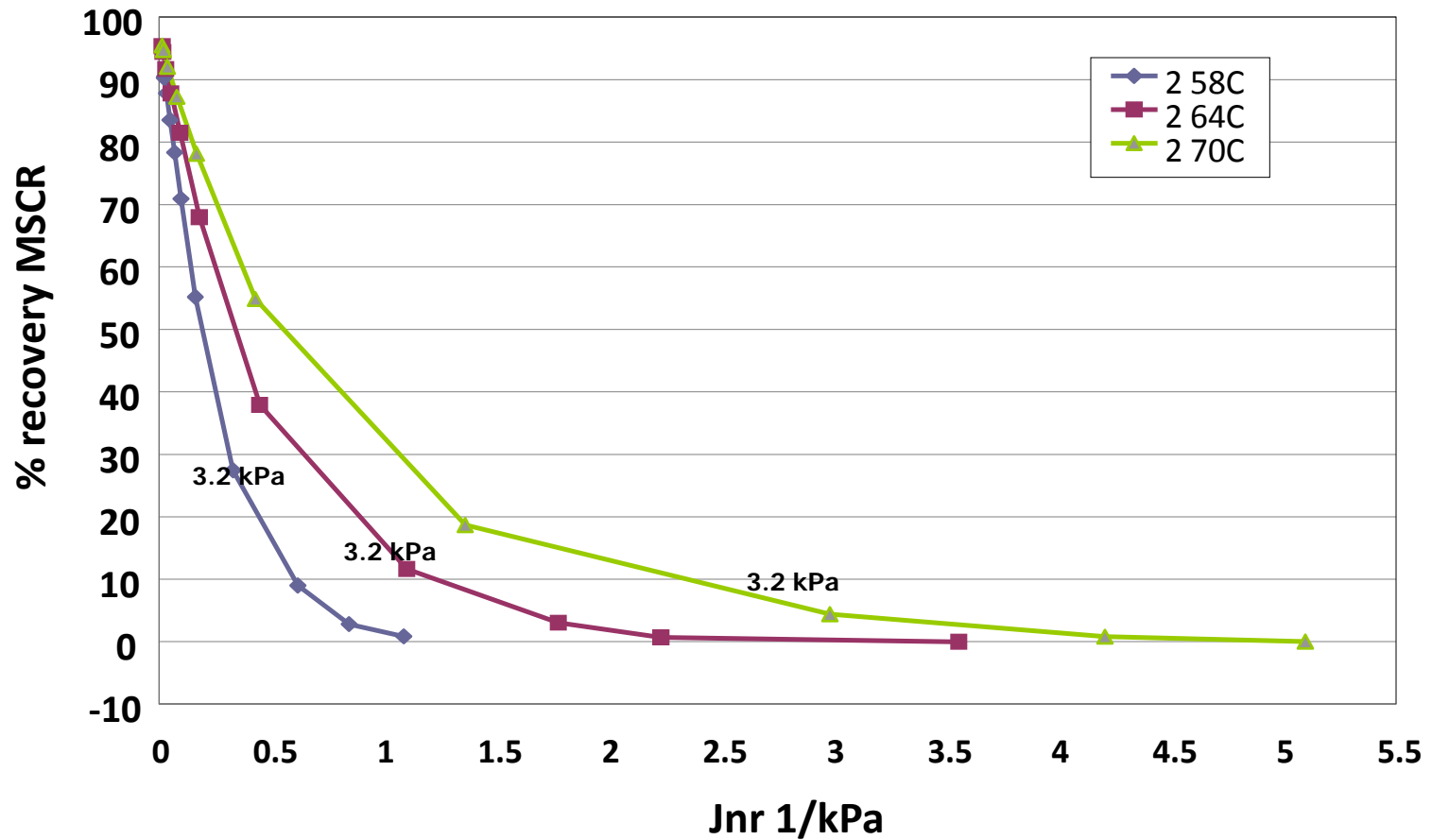




Jnr

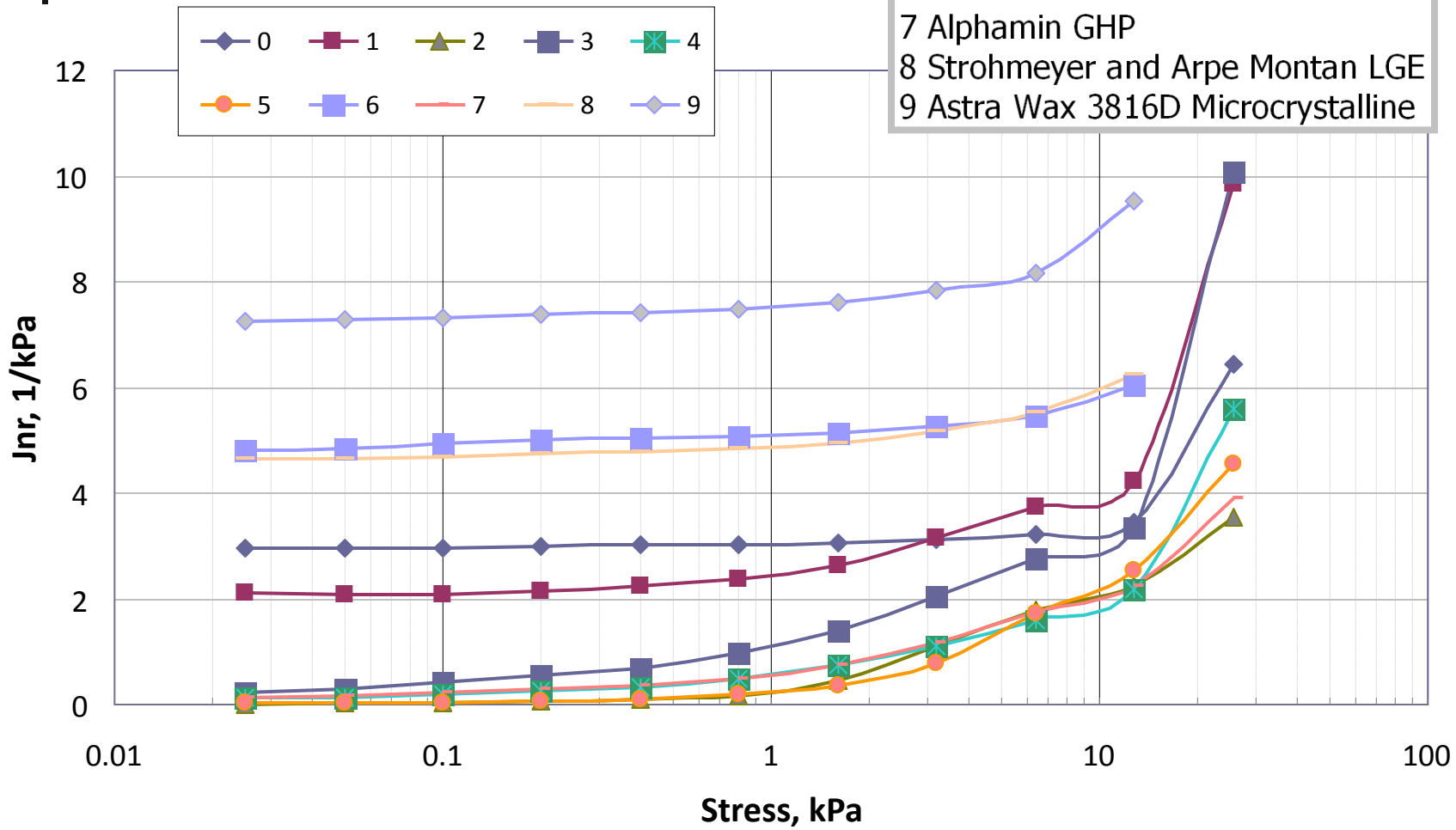
- Tests conducted at three temperatures
 - 58, 64, 70°C
- Jnr evaluated at 3.2 kPa and 4 (1/kPa)
- Elastic recovery – v. high for some products at low stress levels
- Certain products are more stress dependent than conventional binders

2 – % Recovery 58 to 64C

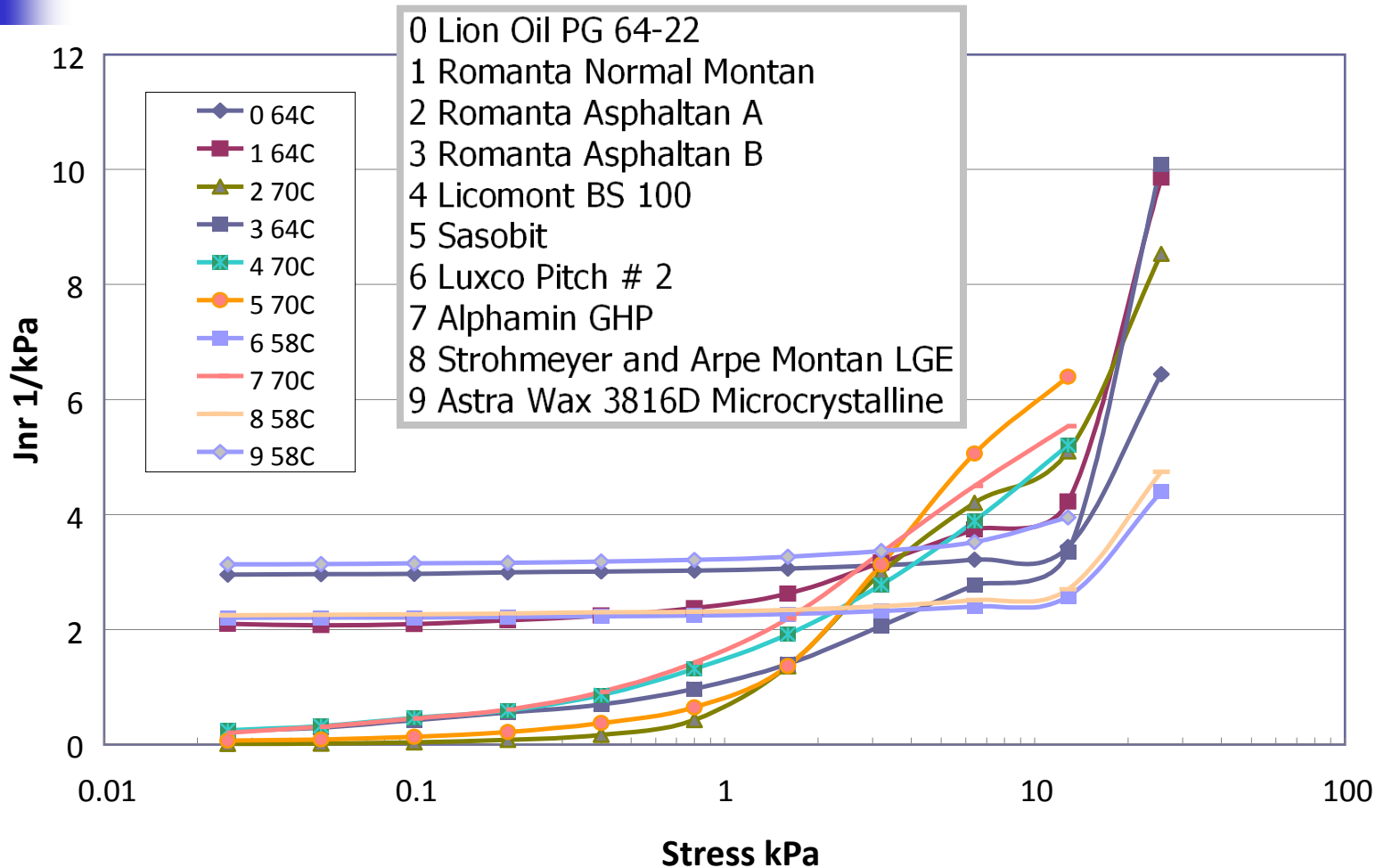


Jnr at 64°C

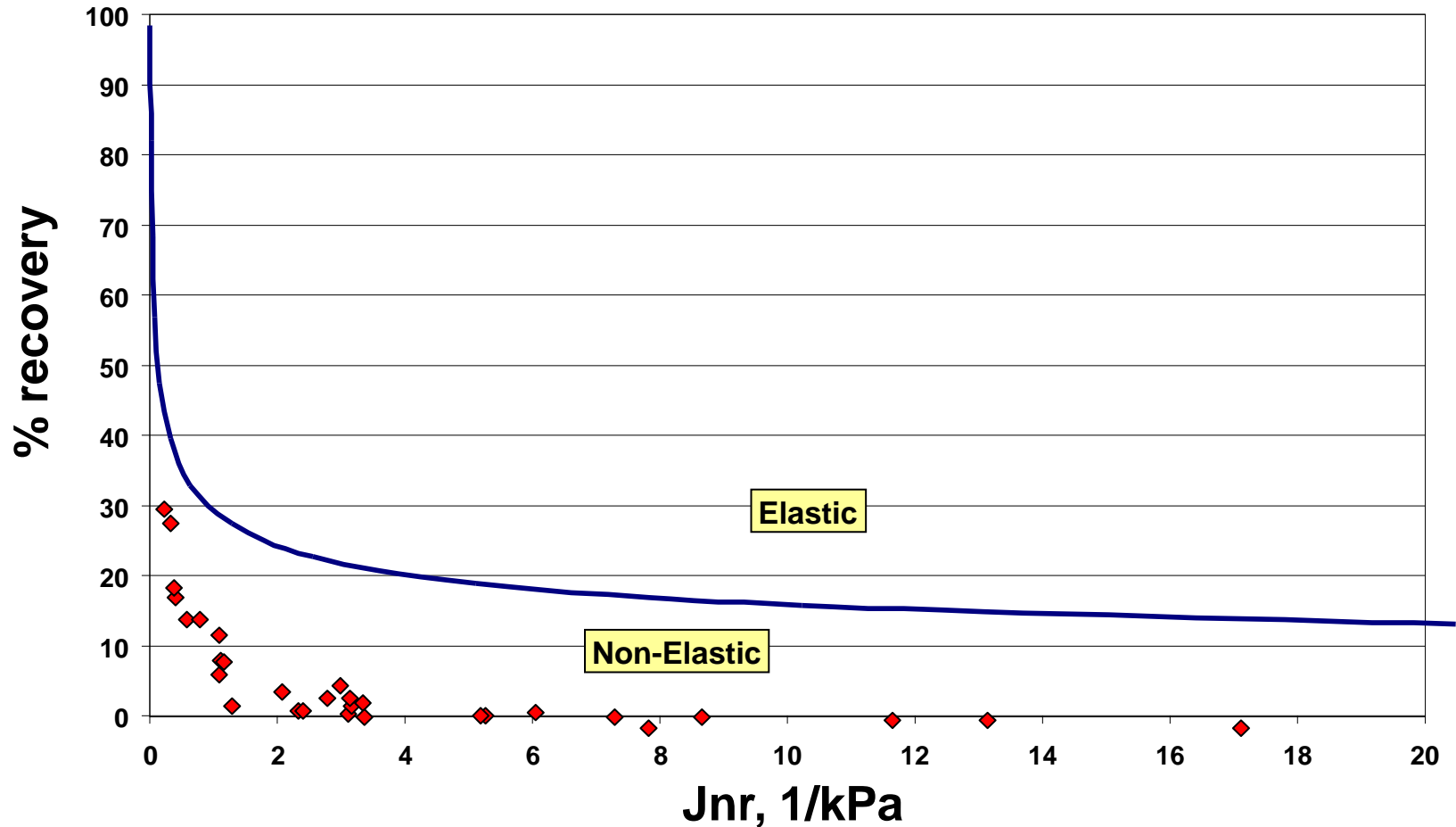
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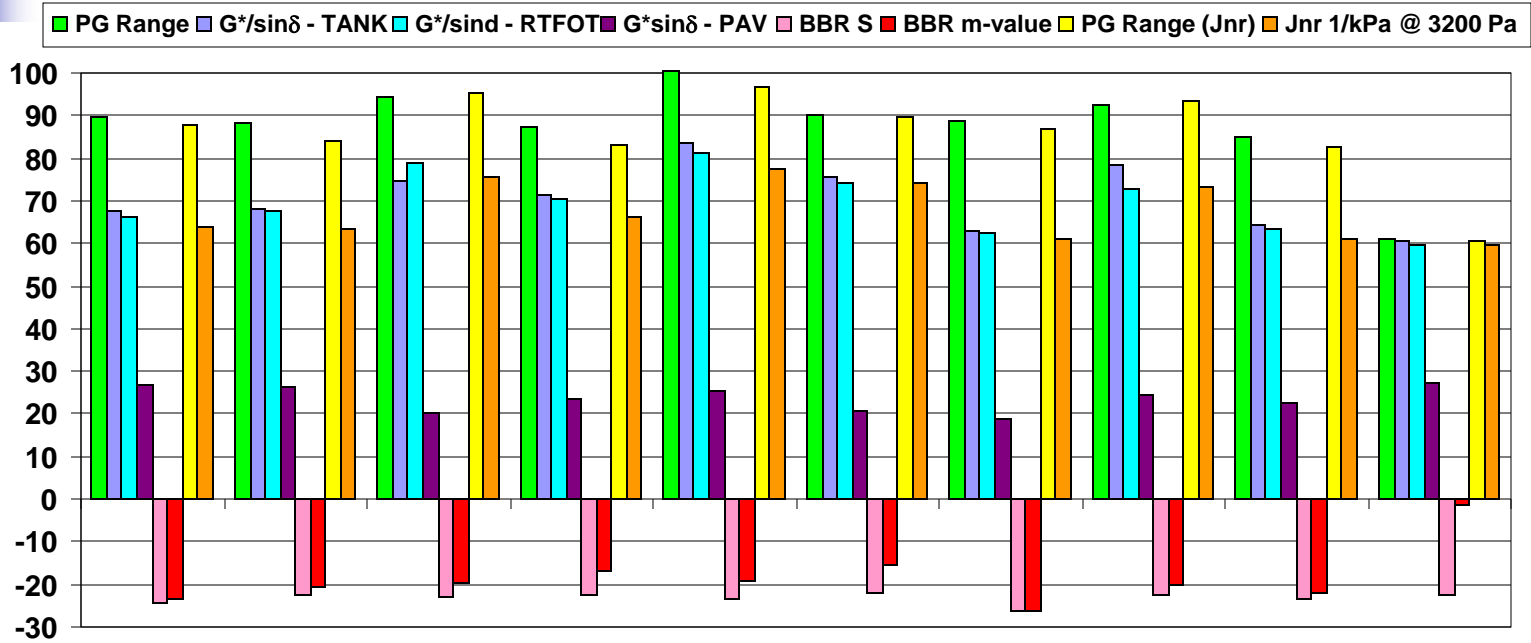
Jnr – near grade temperature



Jnr versus % recovery



PG grades – M320 Table 3



Lion Oil PG 64-22

Romanta Normal Montan

Romanta Asphaltan A

Romanta Asphaltan B

Licomont BS 100

Sasobit

Luxco Pitch # 2

Alphamin GHP

Strohmeier and Arpe Montan LGE

Astra Wax 3816D Microcrystalline



Difference in performance

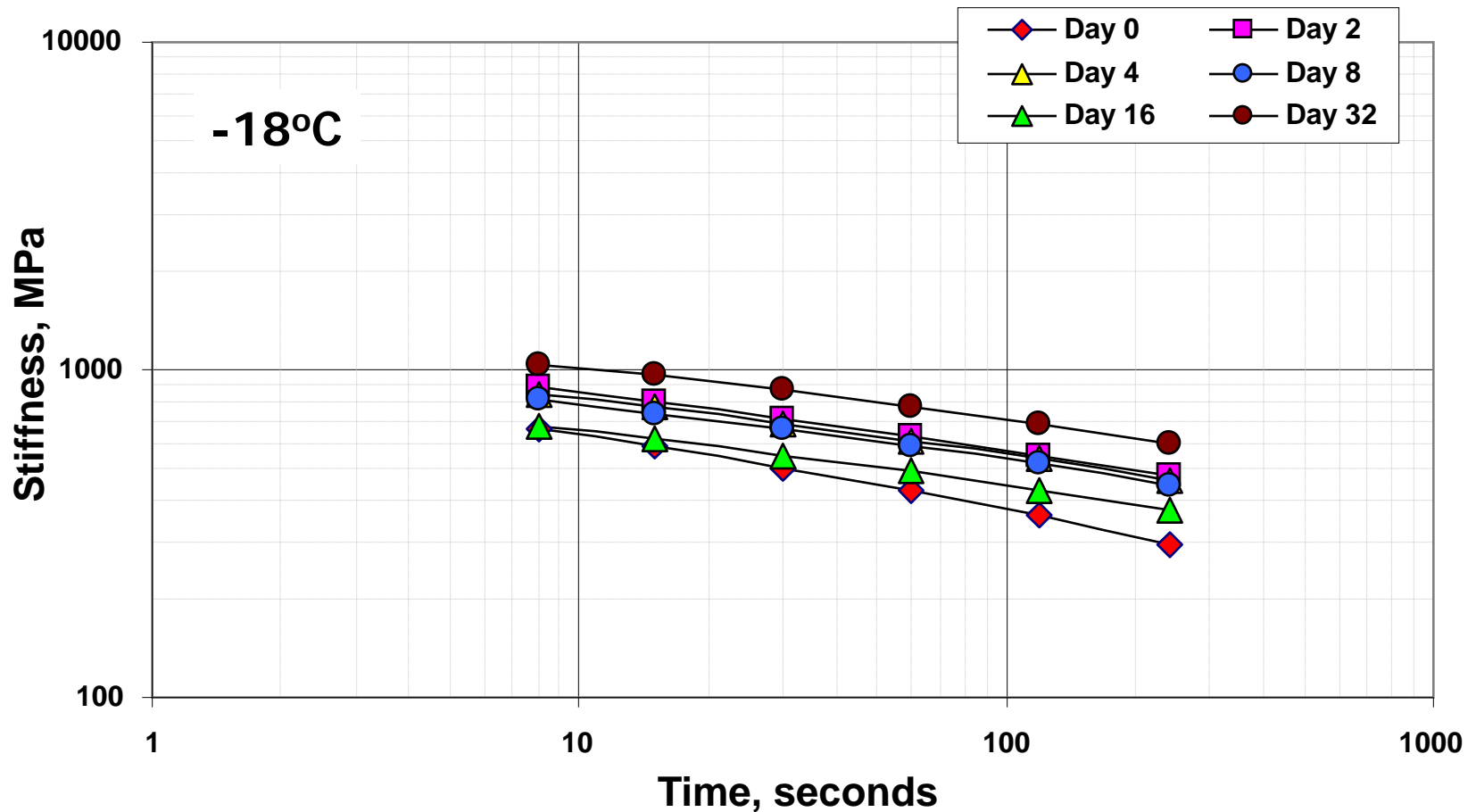
- Binders grade different in Jnr evaluation
- Can be as much ½ PG grade
- Early products that show network – 2 effected from 5
 - 2 (Romanta Asphaltan A)
 - 3 (Romanta Asphaltan B)
 - 4 (Licomont BS 100)
 - 5 (Sasobit)
 - 7 (Alphamin GHP)
- Suggests importance of Jnr evaluation

Ref	Diff
0	2.09
1	4.03
2	-0.71
3	4.22
4	3.80
5	0.33
6	1.67
7	-0.66
8	2.31
9	0.16



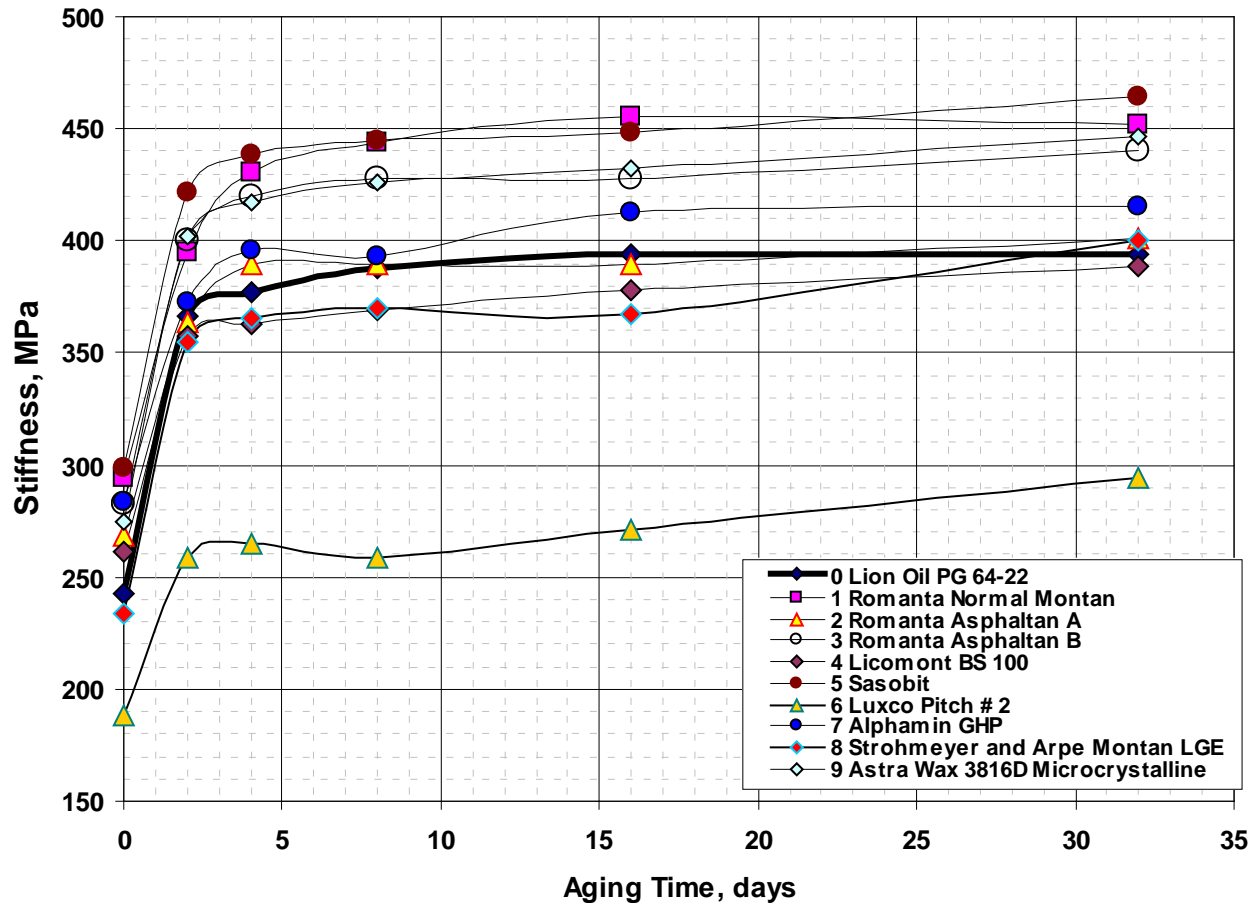
Aged tests - binder

PG64-22 – aging to 32 days



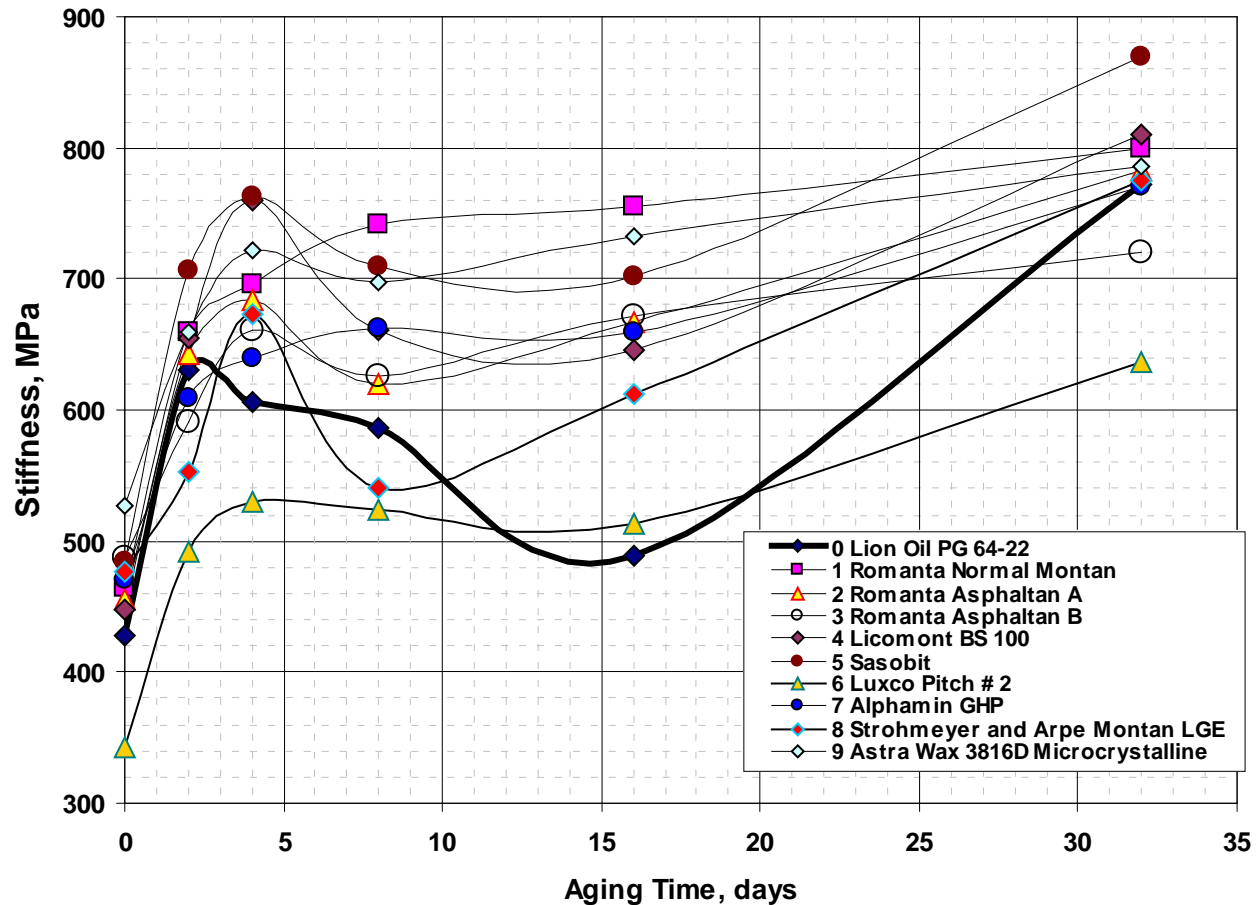
Binder BBR S(t) at -12°C

Binder BBR Stiffness, -12°C, t = 60 seconds



Binder BBR S(t) at -18°C

Binder BBR Stiffness, -18°C, t = 60 seconds





BBR data

- Aging data showed that the -18°C gave significantly more variability when compared to the -12°C data



Mix test data

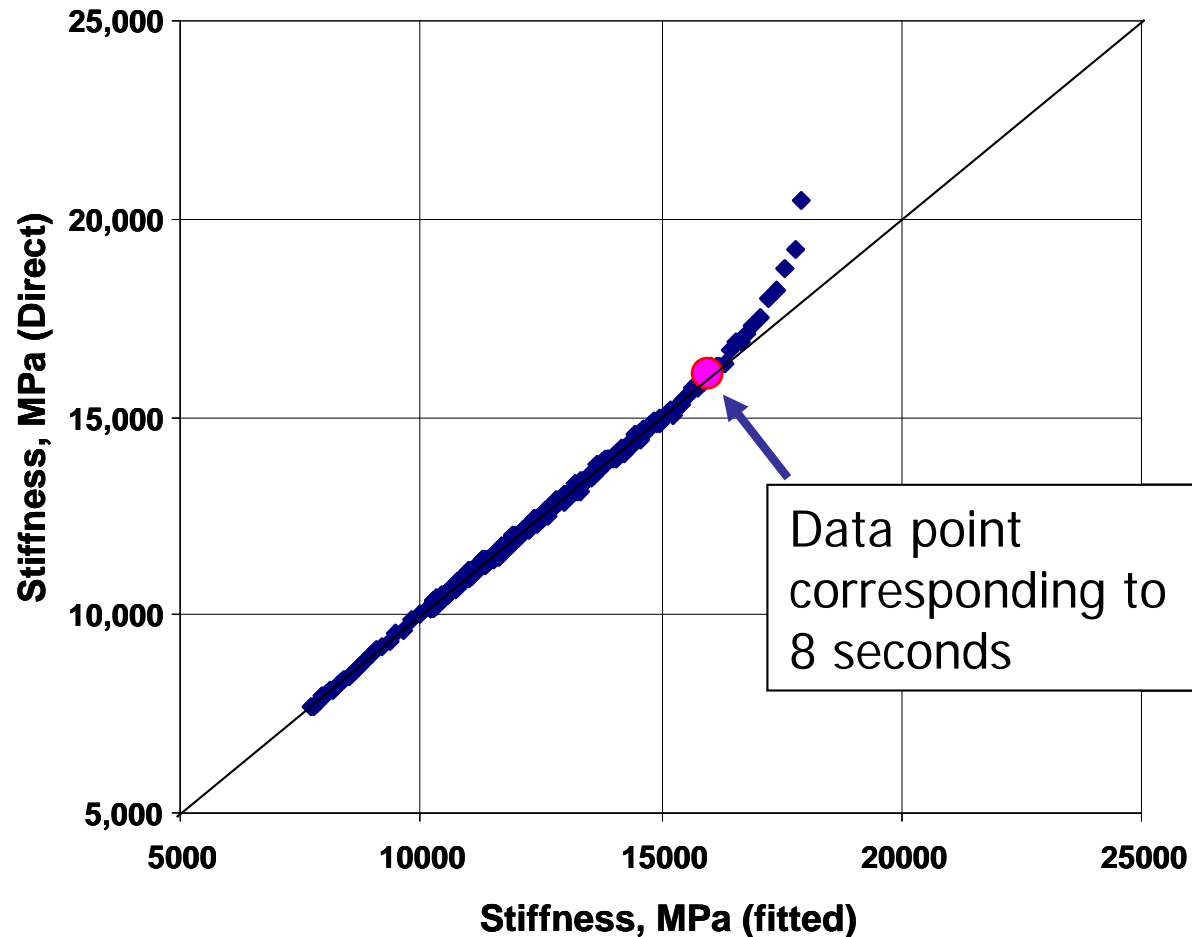


Mix BBR Data

- Data processed to produce equal-log scale representation with approximate linear double of scale
- Several cases exist which colder temperature is less stiff than matching warm temperature data

Removal of early BBR data

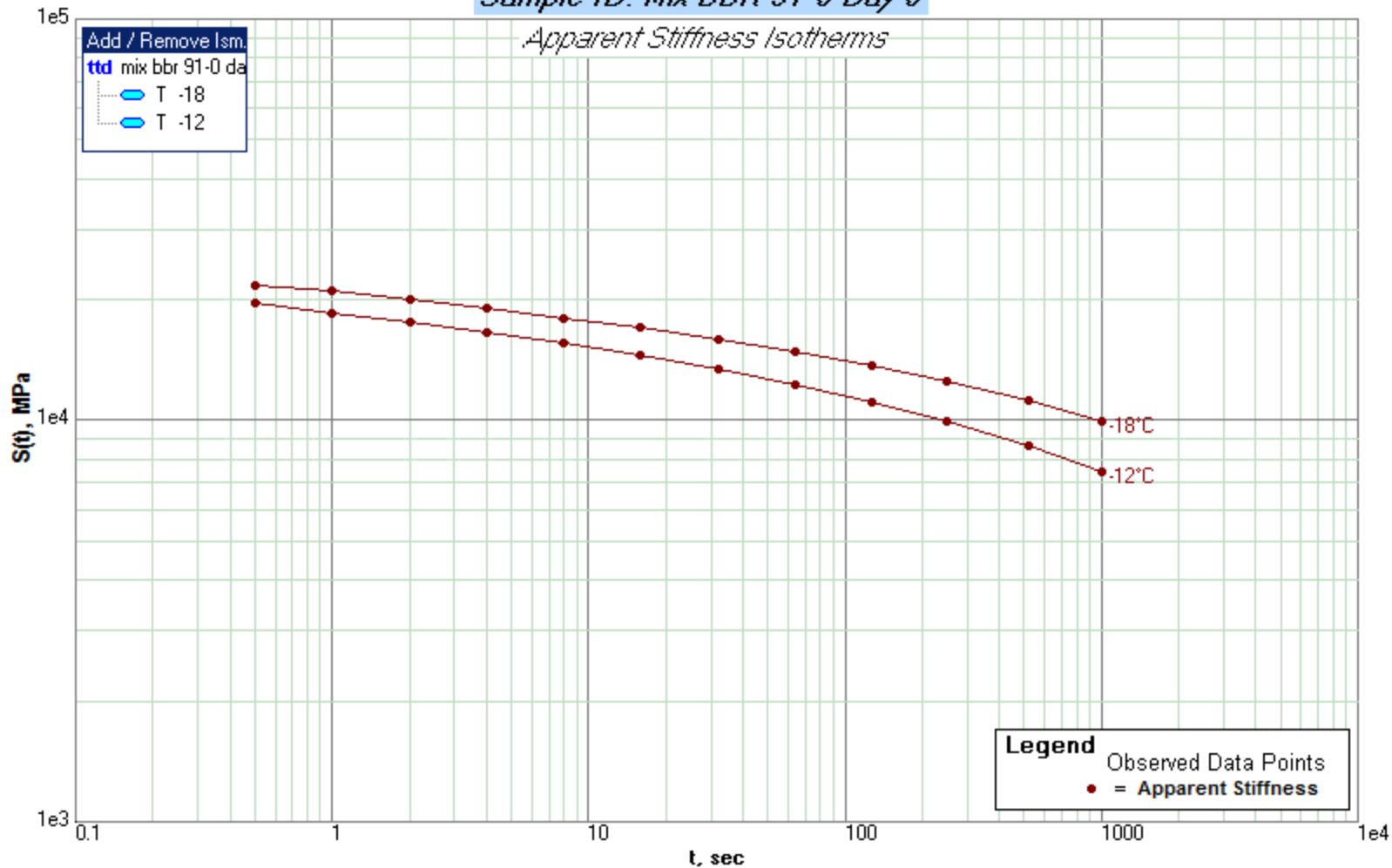
- Data before 8-seconds is removed from analysis in similar manner to binder BBR data
- Shows fitted (polynomial) approach versus direct calculation
- Data before $t=8$ seconds is less reliable



0-0

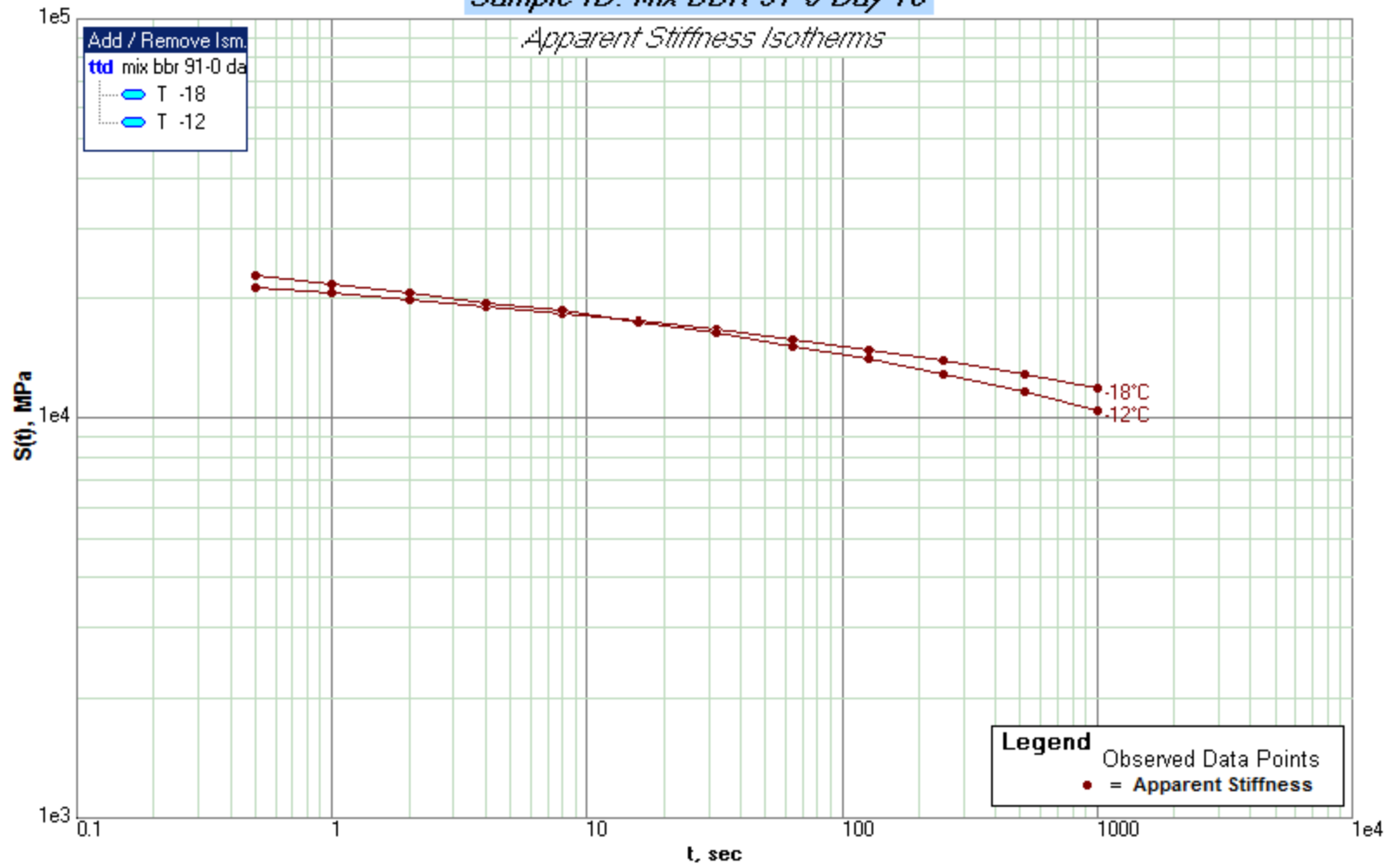
Sample ID: Mix BBR 91-0 Day 0

Apparent Stiffness Isotherms



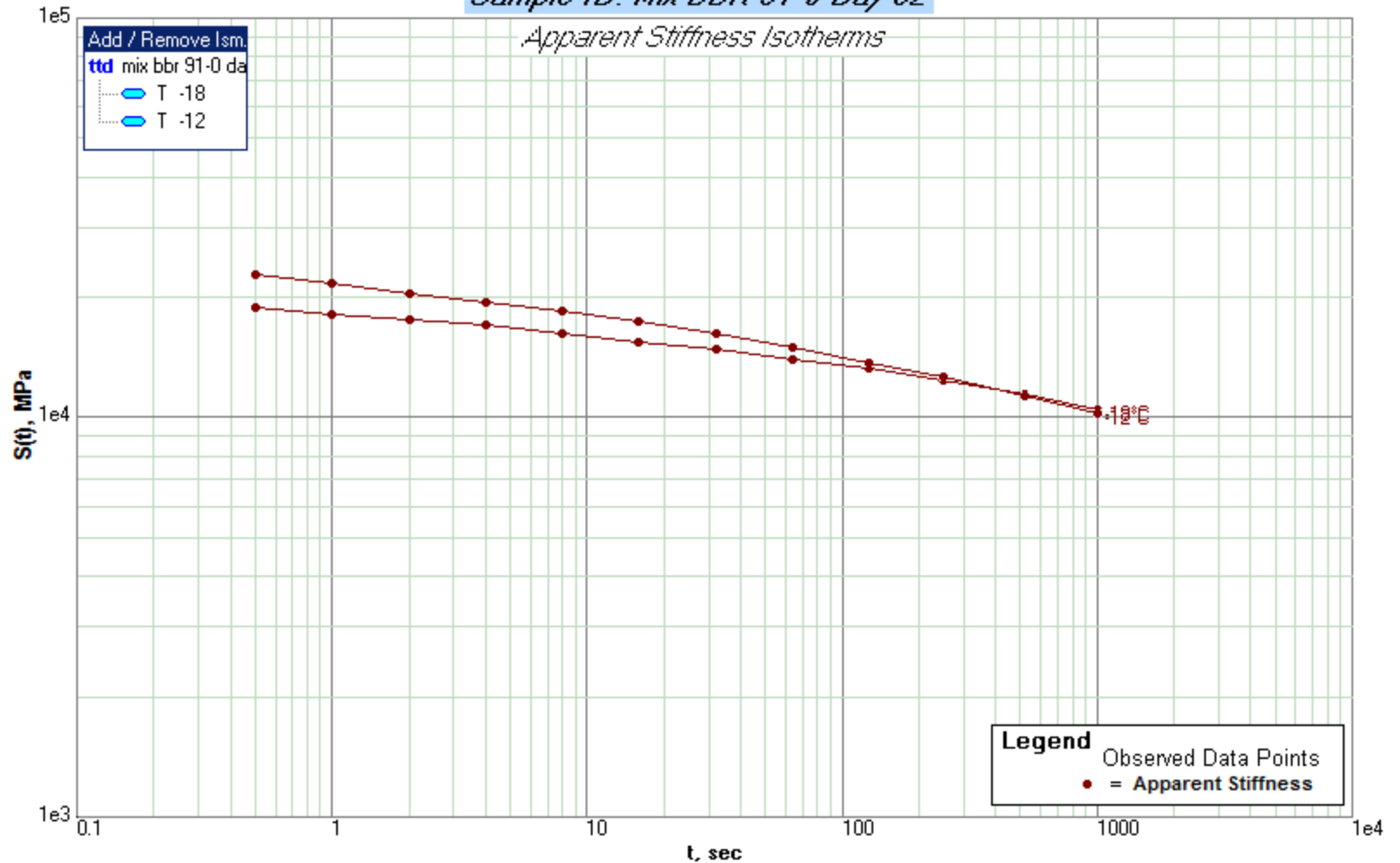
0-16

Sample ID: Mix BBR 91-0 Day 16



0-32

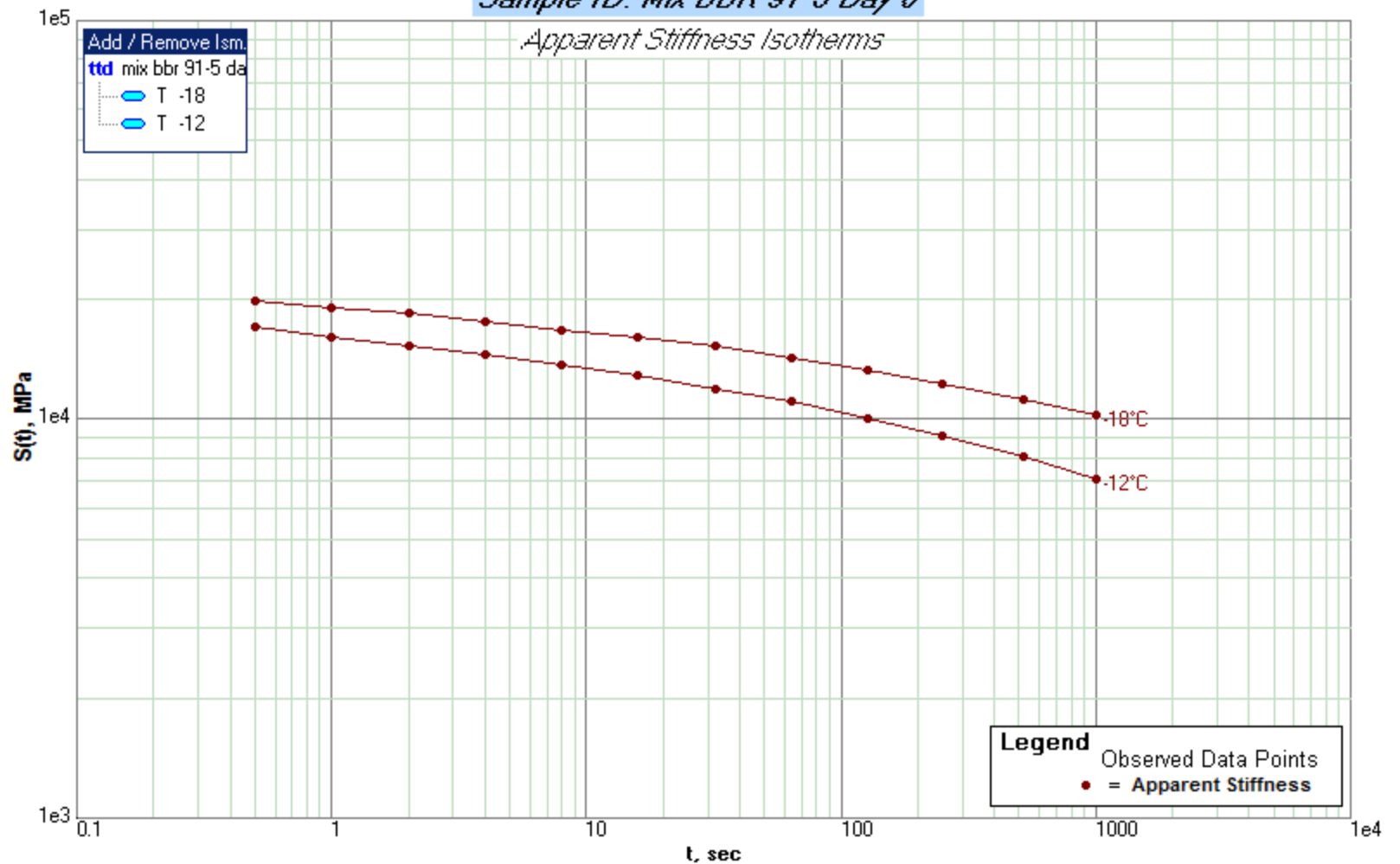
Sample ID: Mix BBR 91-0 Day 32



5-0

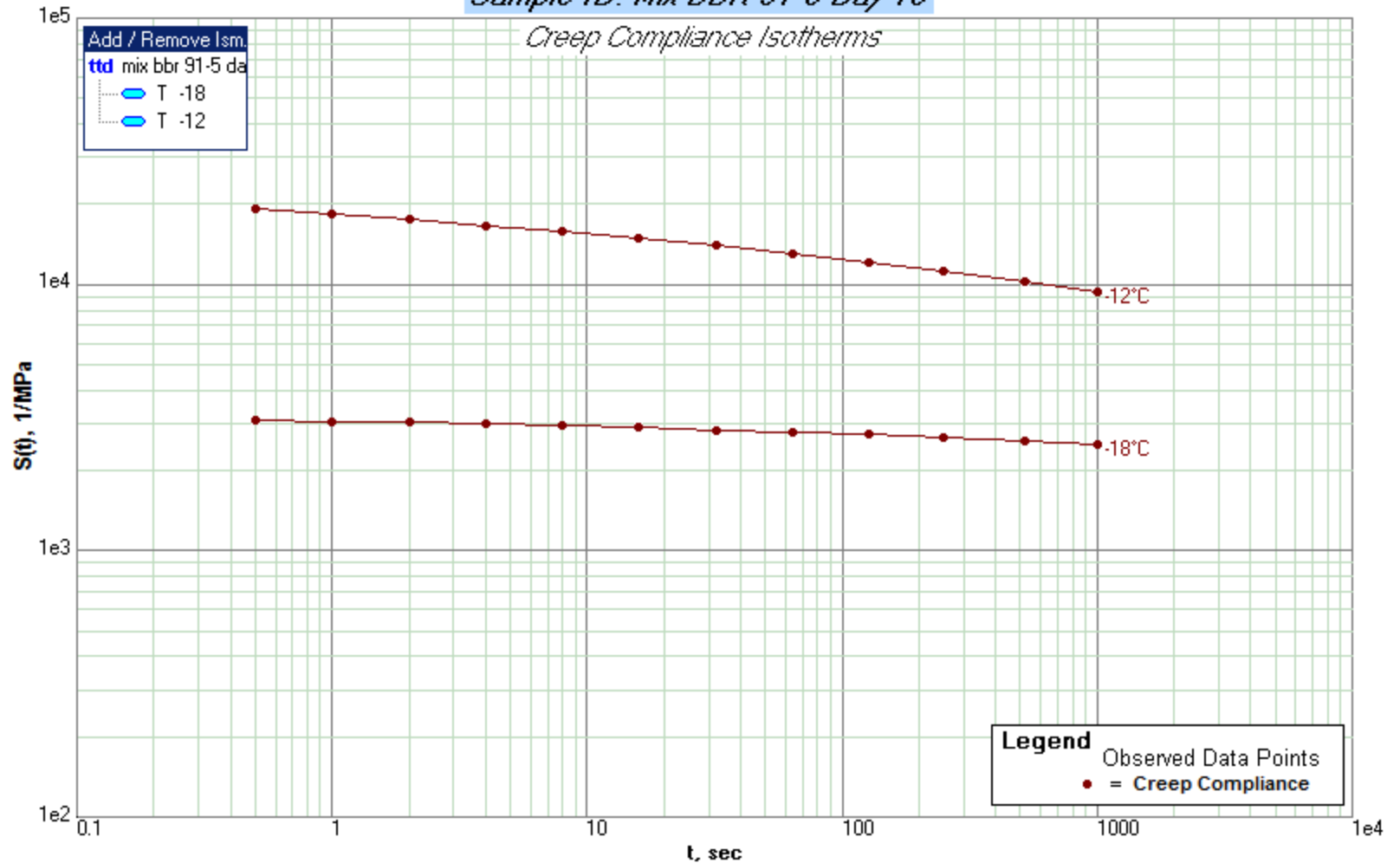
Sample ID: Mix BBR 91-5 Day 0

Apparent Stiffness Isotherms

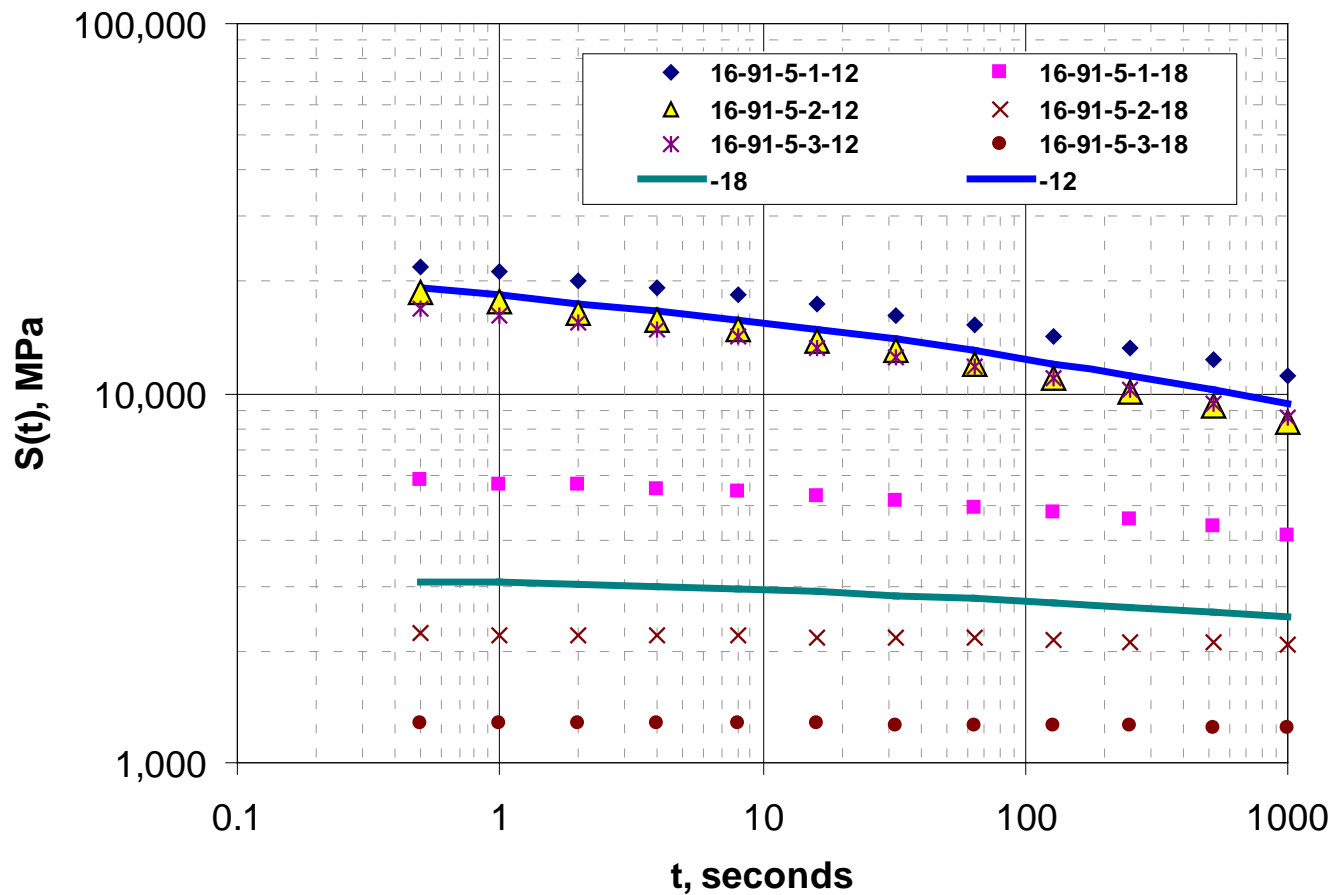


5-16

Sample ID: Mix BBR 91-5 Day 16



Material 5 - Day 16

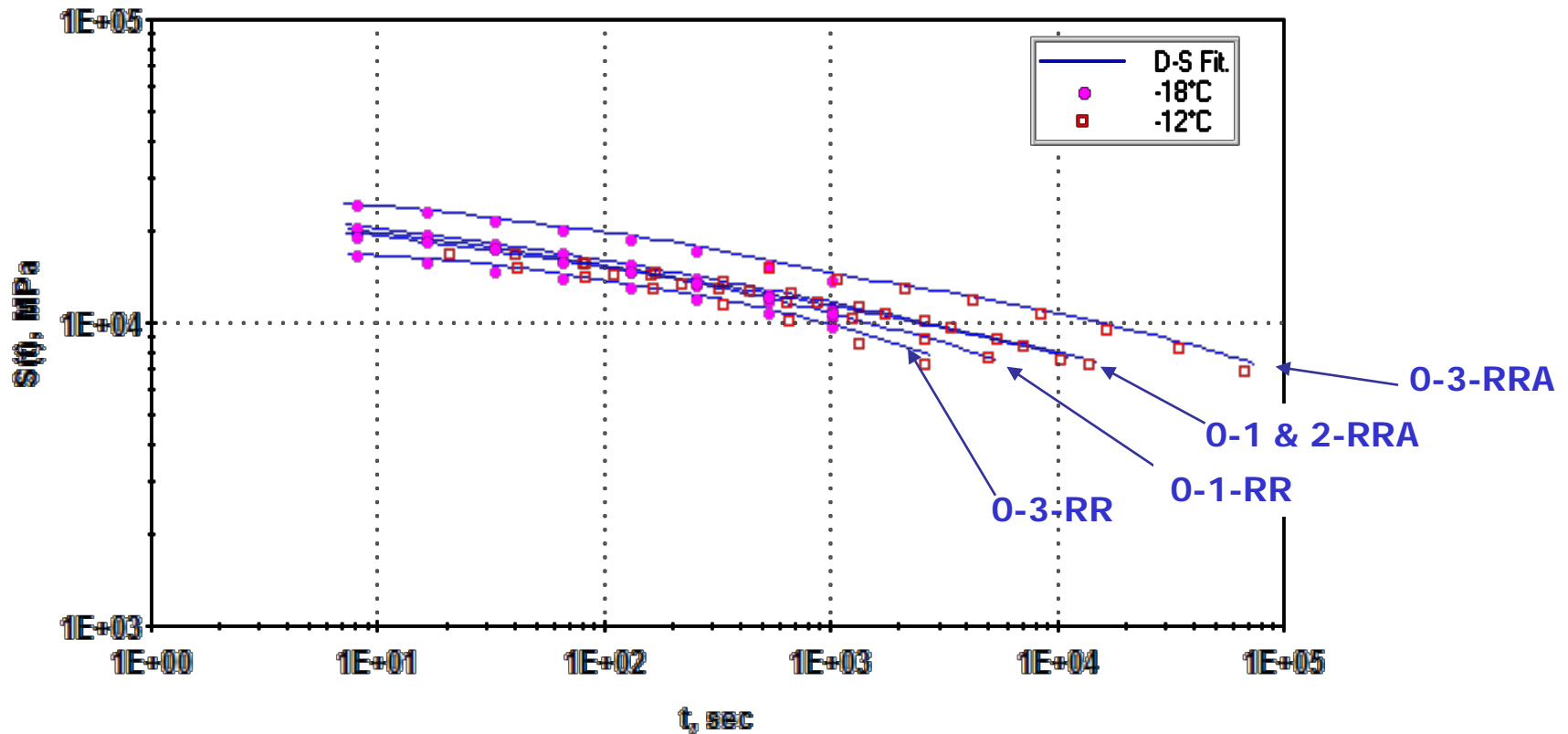




Re-tests of Mix Beams

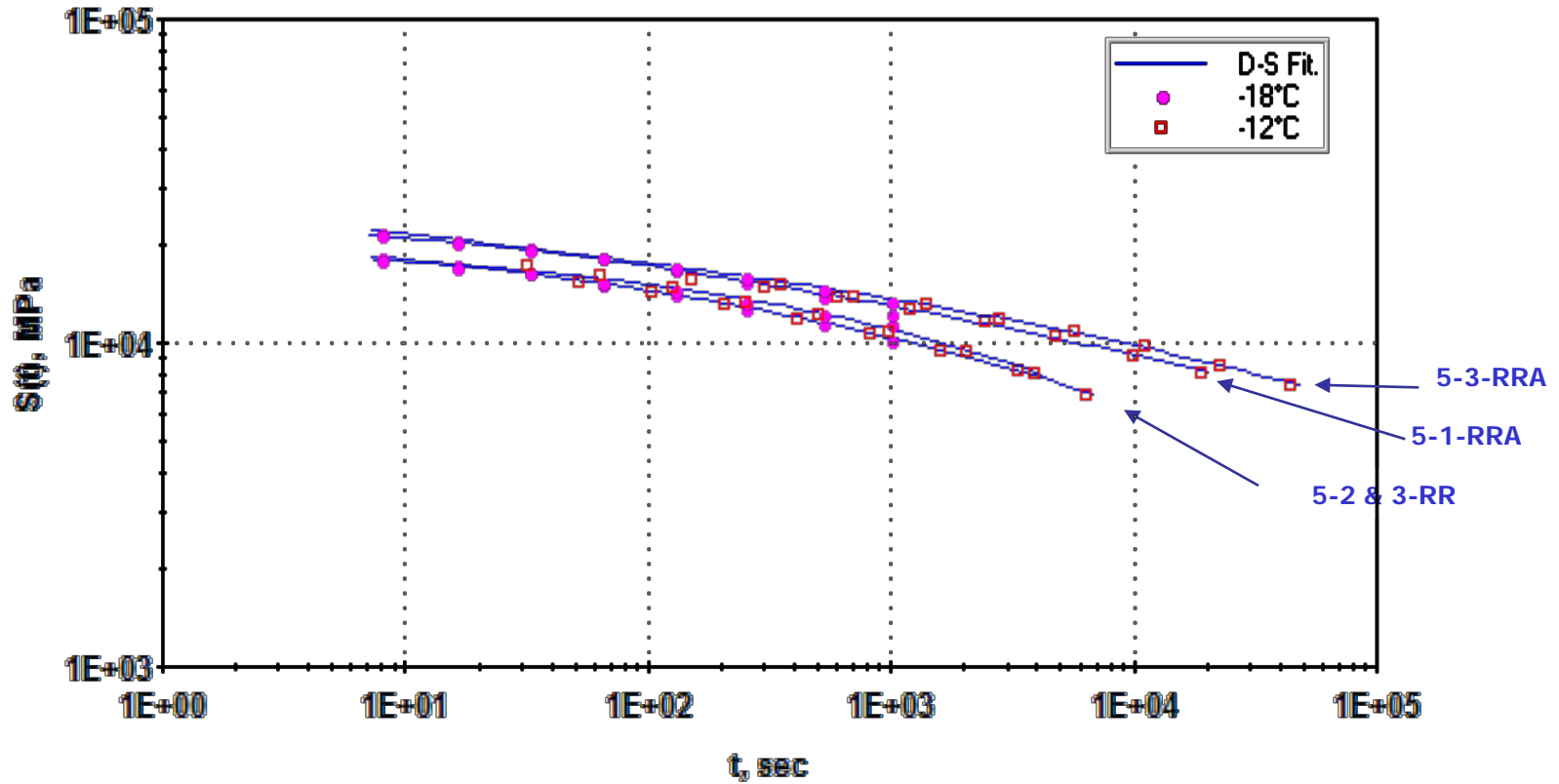
- Testing of beams before and after annealing
- Annealing conducted at 64°C overnight
- 64°C chosen since it represents day at likely high-pavement temperature

1 - PG64-22 - retests

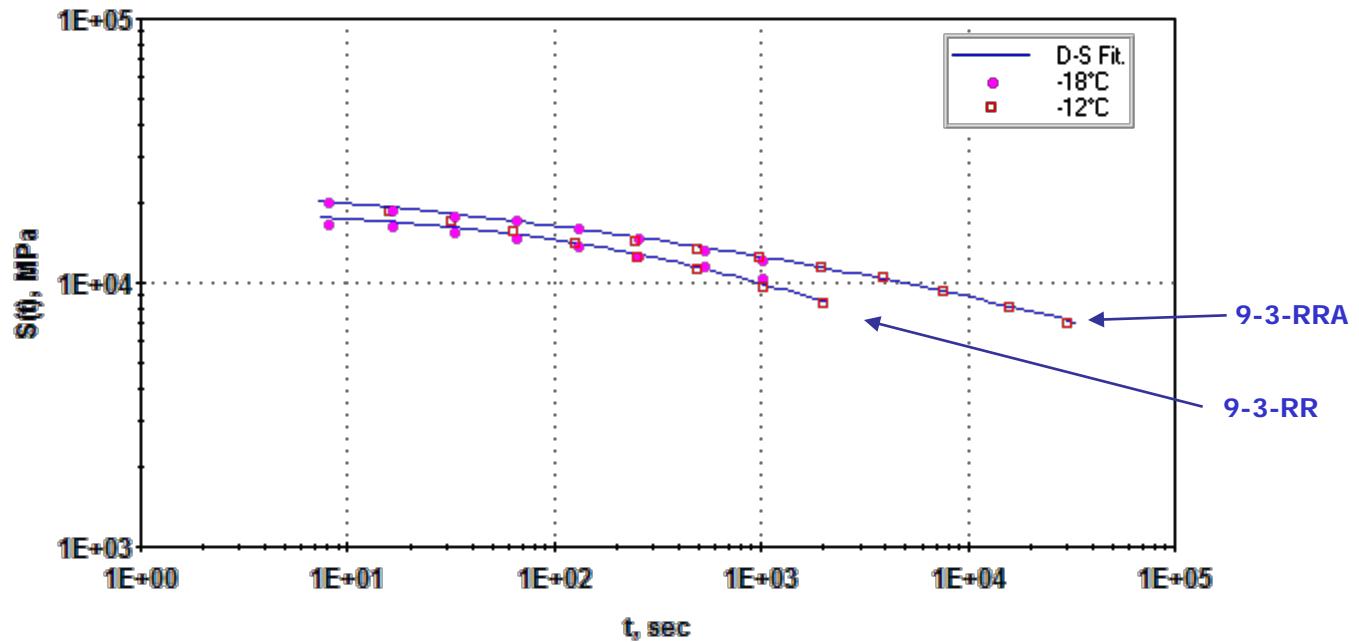


5 - Sasobit -retests

91-5-2 RR



9 - Astra Wax





Results from retesting

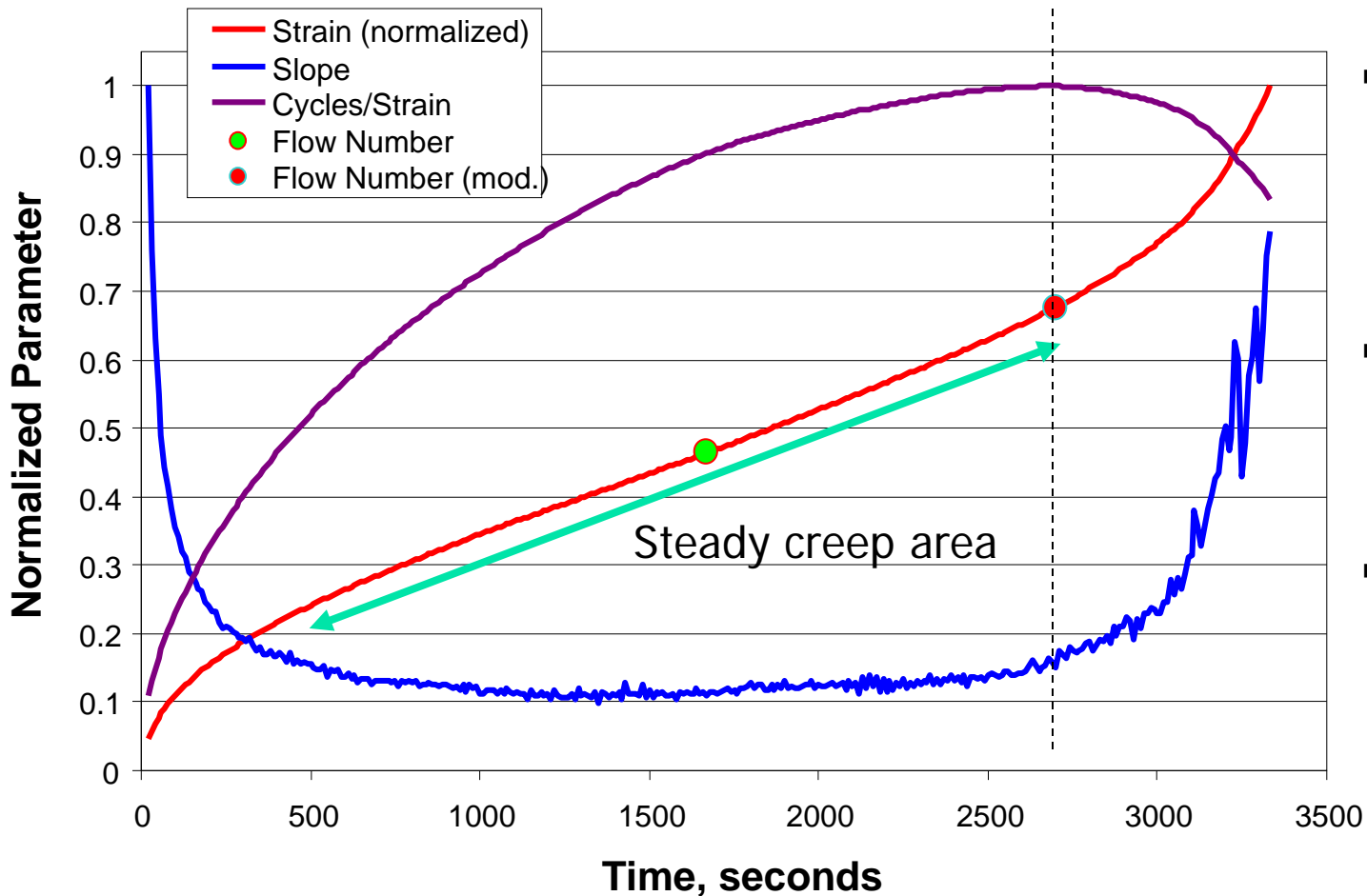
- In all cases healing overnight increased the stiffness of the mastercurve
- Most significantly – it resulted in the BBR stiffness of the -18°C isotherm being greater than the -12°C isotherm – as expected!
- The “healing” is more significant for the -18°C isotherm



Repeated creep torsion bar

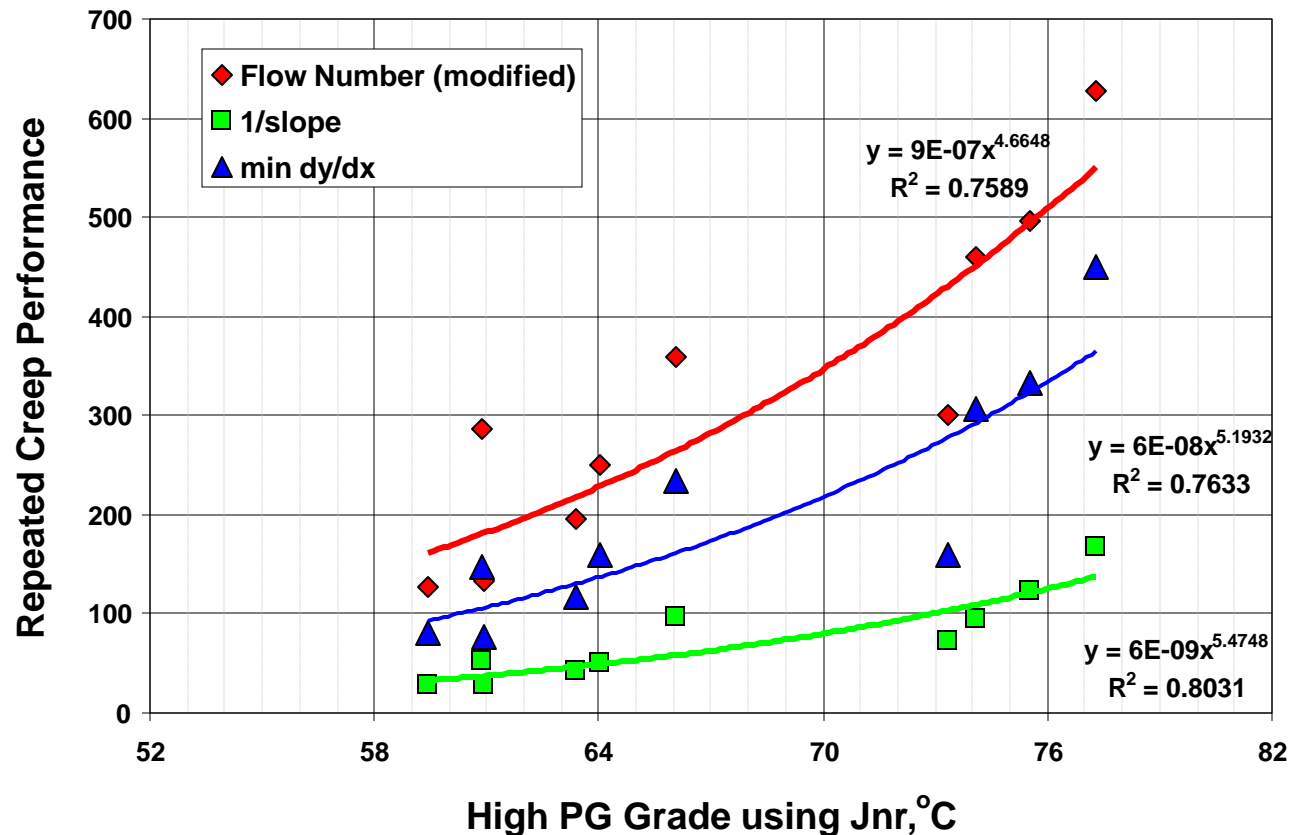
- Tests at two stress levels
 - 34 and 68 kPa
- Temperature = 64°C
- 5 replicates – used results of middle 3
- Analysis of various parameters

Repeated load tests

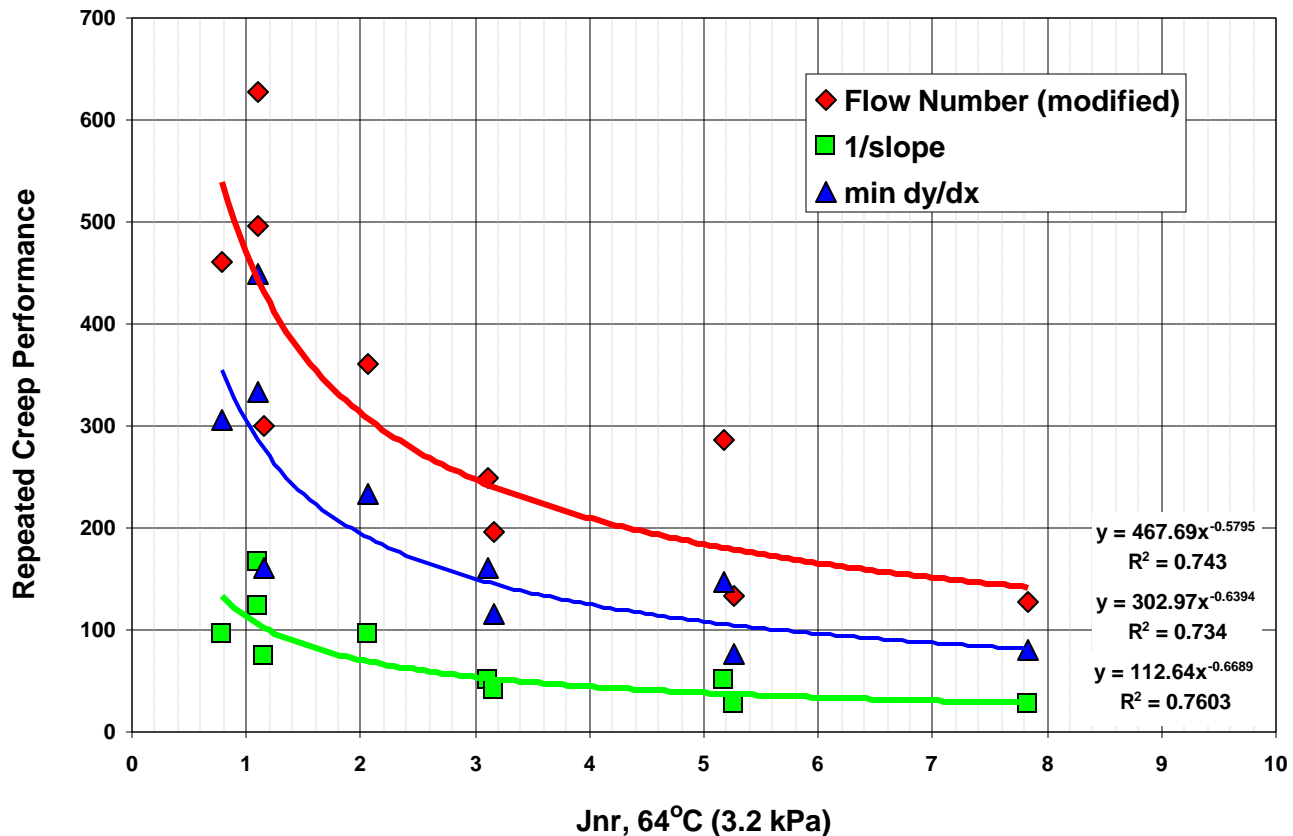


- Concept used in early 1990's with cyclic deformation tests
- Based on same concept as used for fatigue analysis
- Very easy to use to limit test time – stop test at say 5% less than max

Jnr Grade vs. Repeated Creep



Jnr at 64°C vs. Repeated Creep

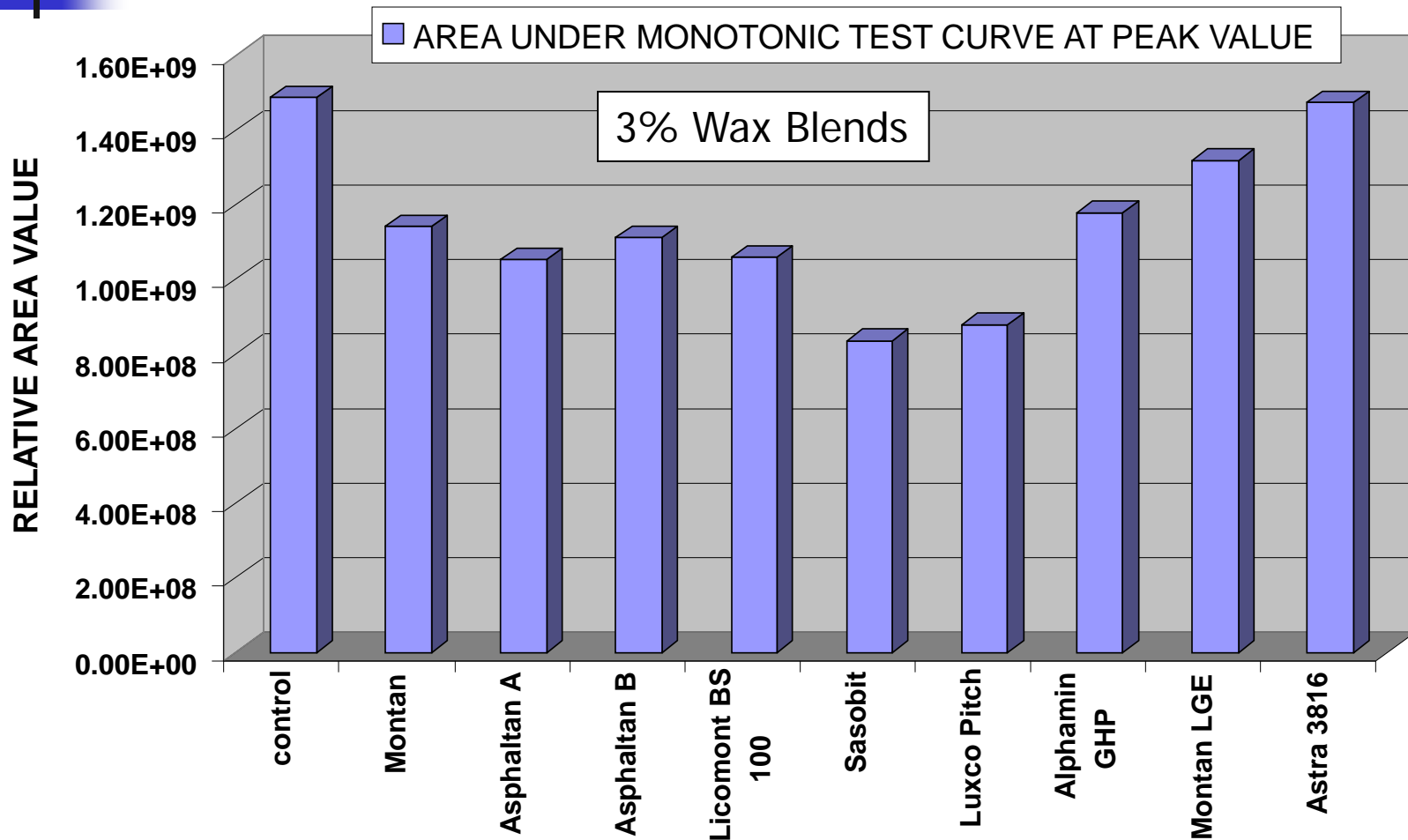


Fatigue

- Work conducted by MTE Services, Inc
- Monotonic loading test
- Sand cylinders repeated loading

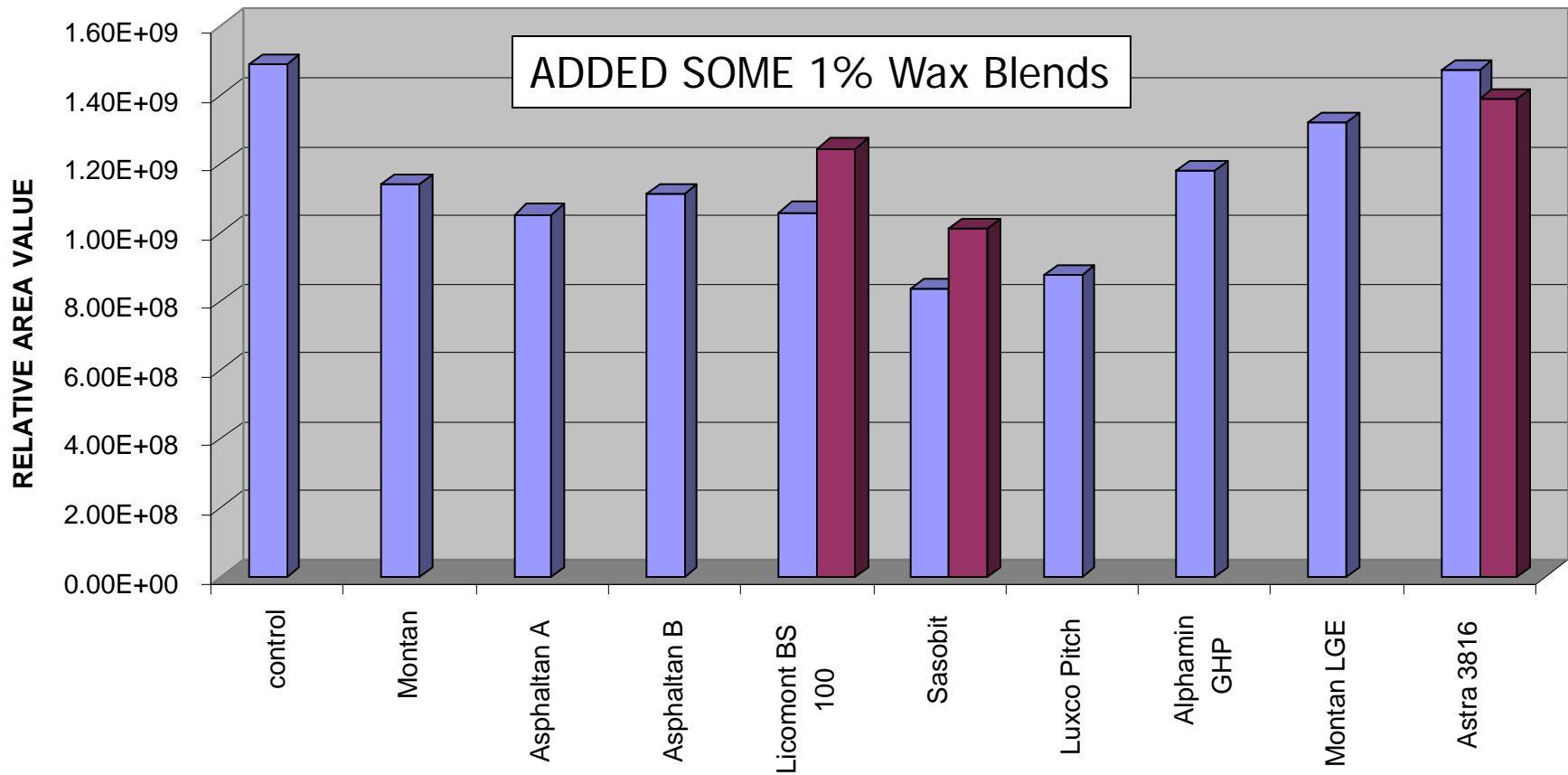


Monotonic tests

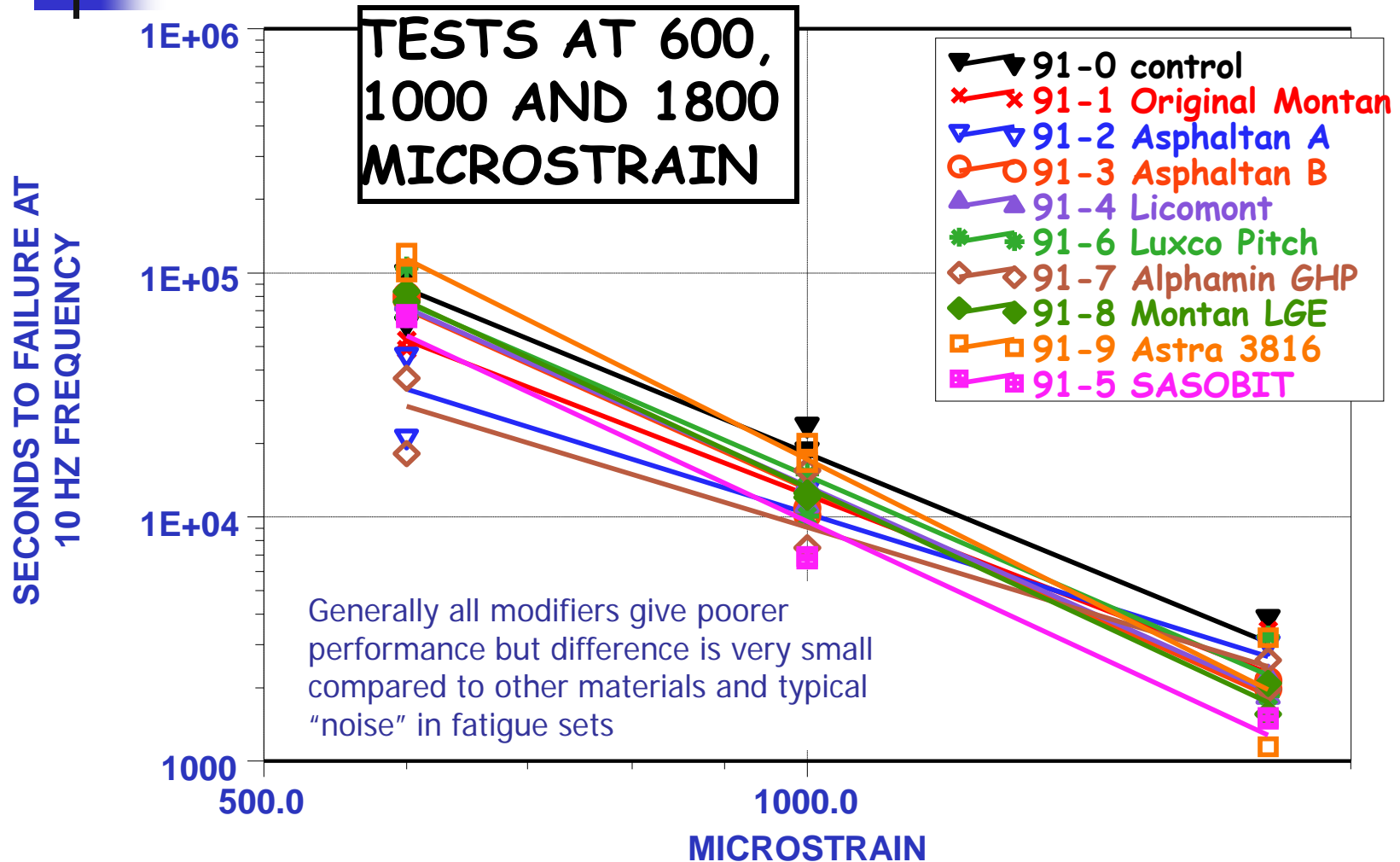


Monotonic tests

AREA UNDER MONOTONIC TEST CURVE AT PEAK VALUE AREA 1% BLENDS



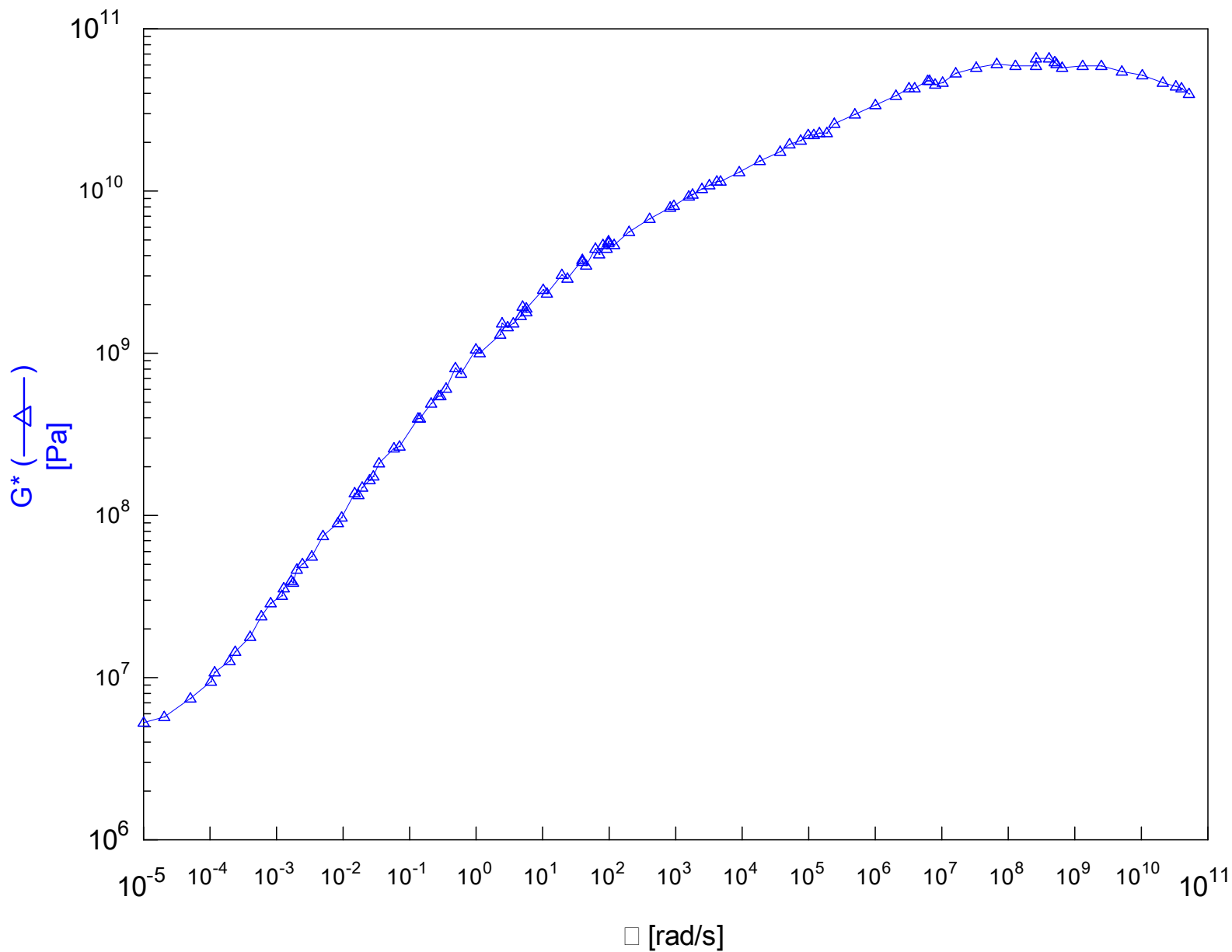
Sand Cylinder Fatigue



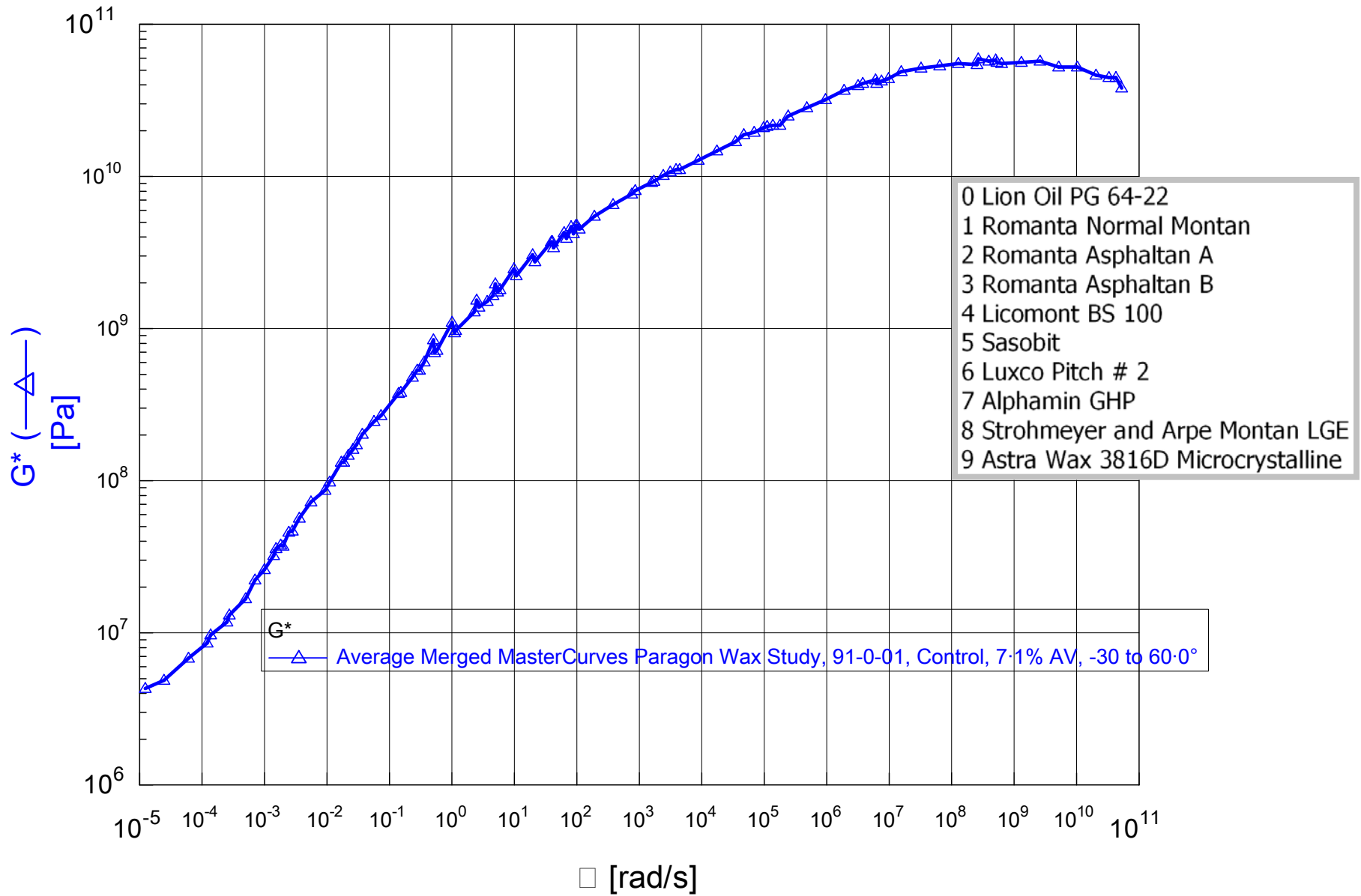


Master curves on sand-mix

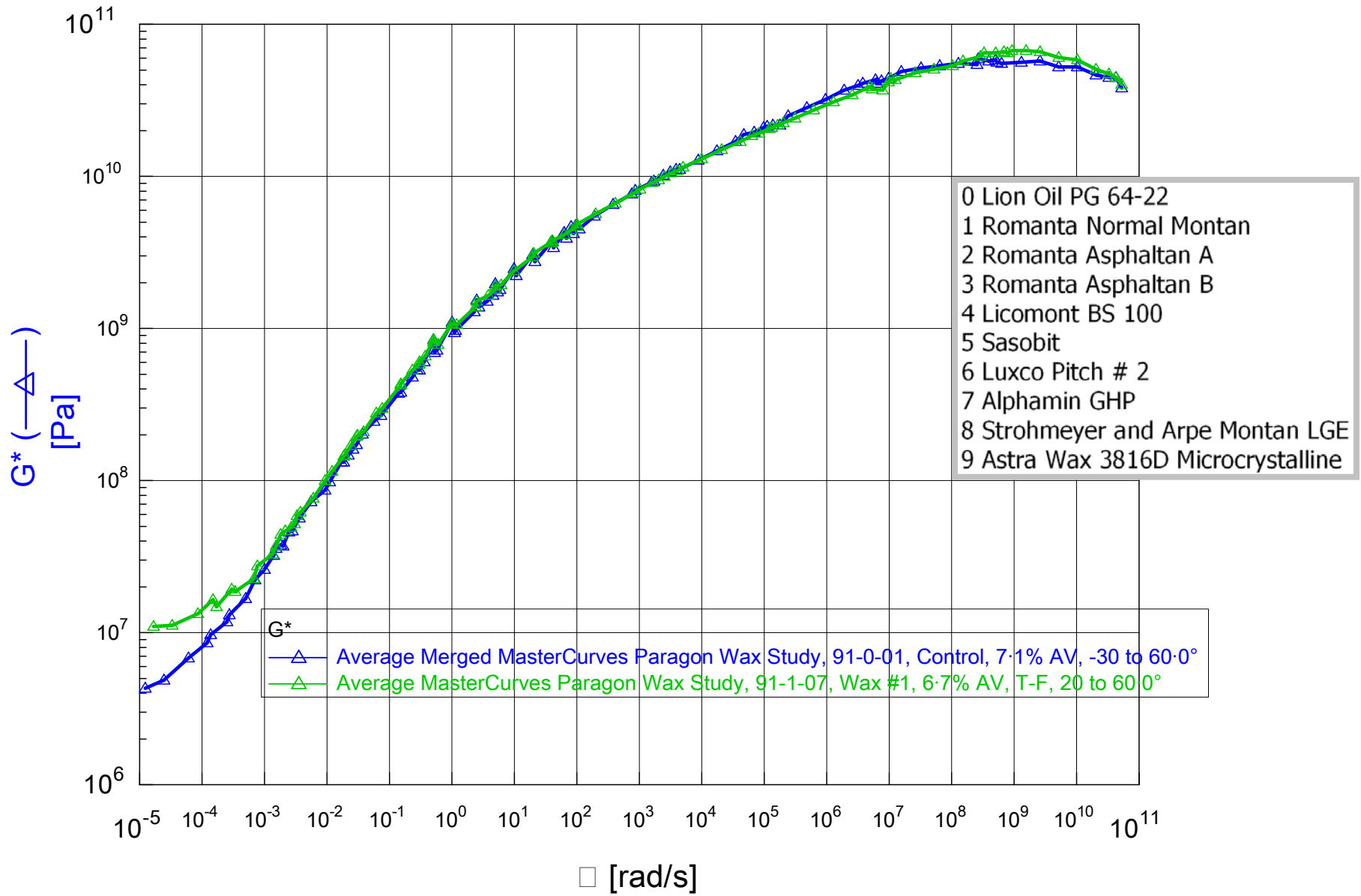
Merged MasterCurve Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0° #1



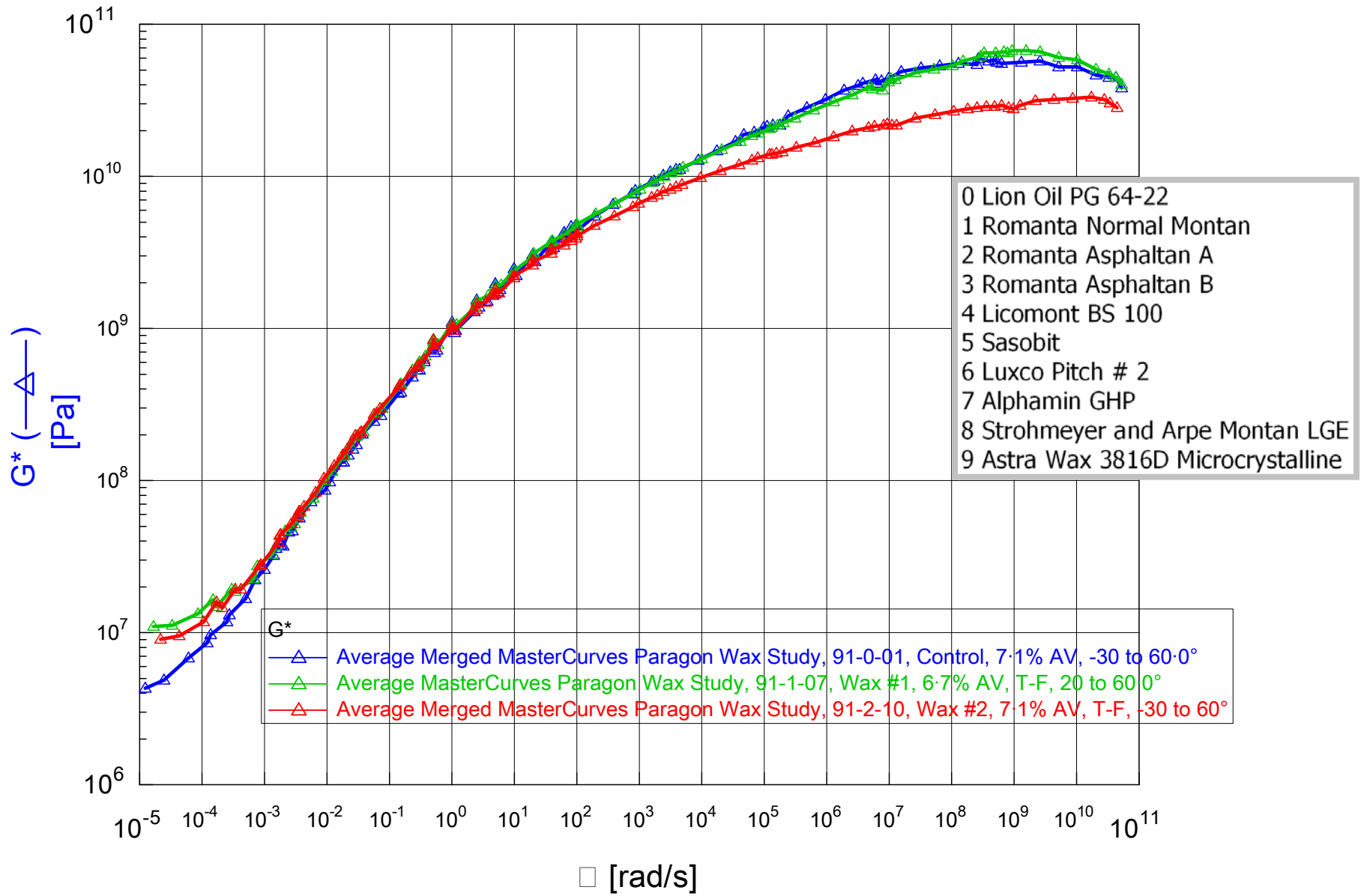
Average Merged MasterCurves Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0°



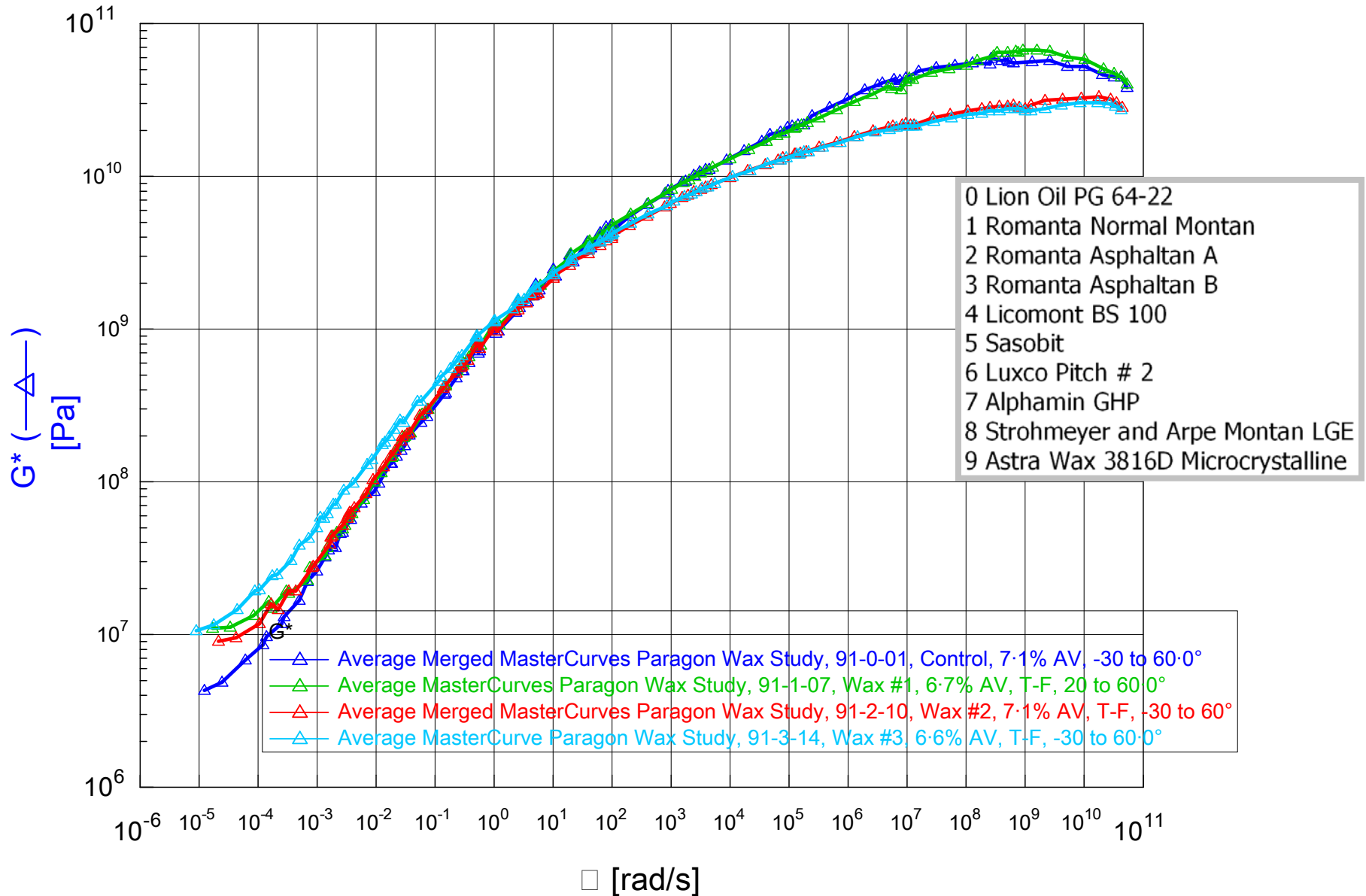
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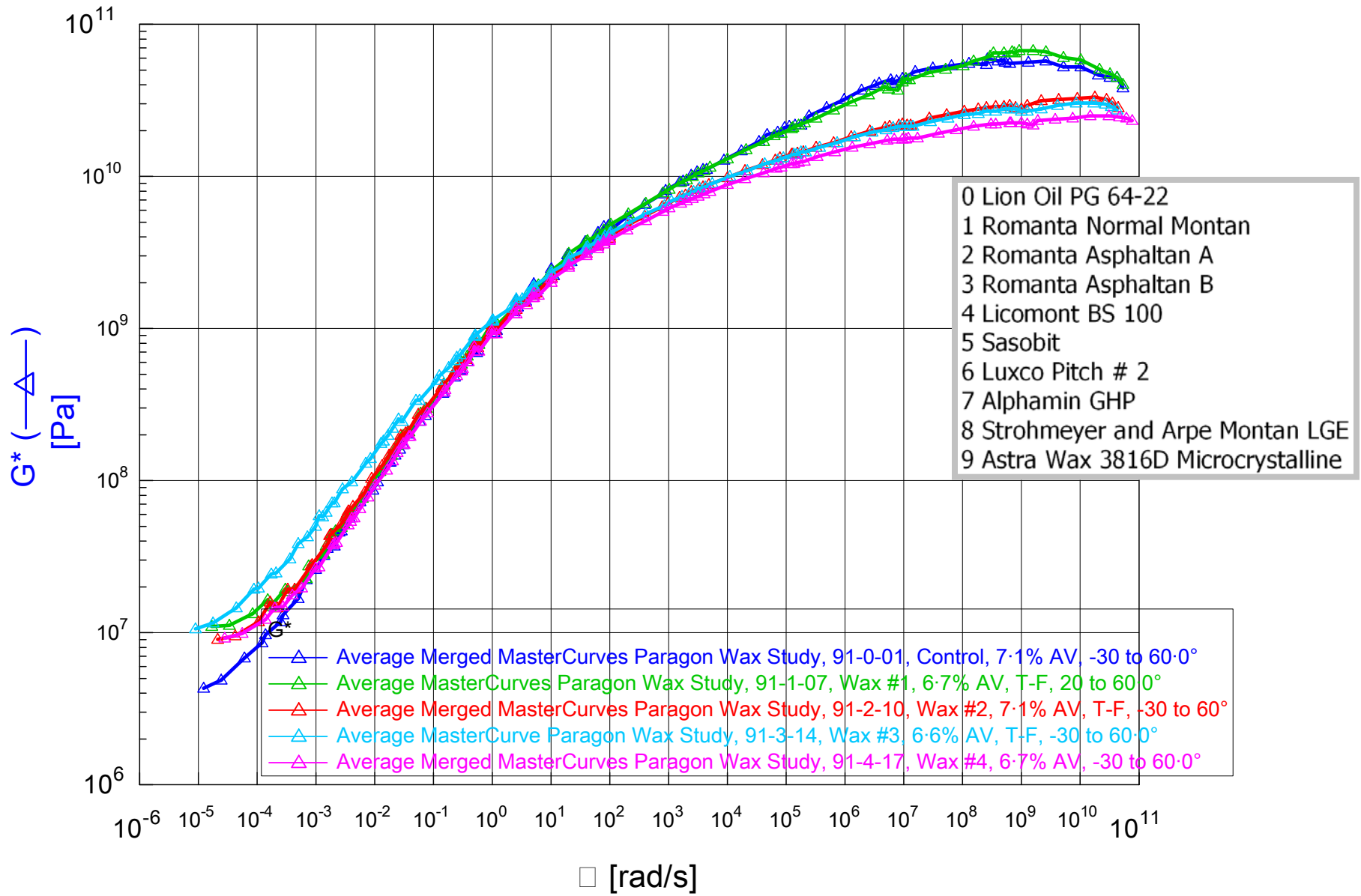
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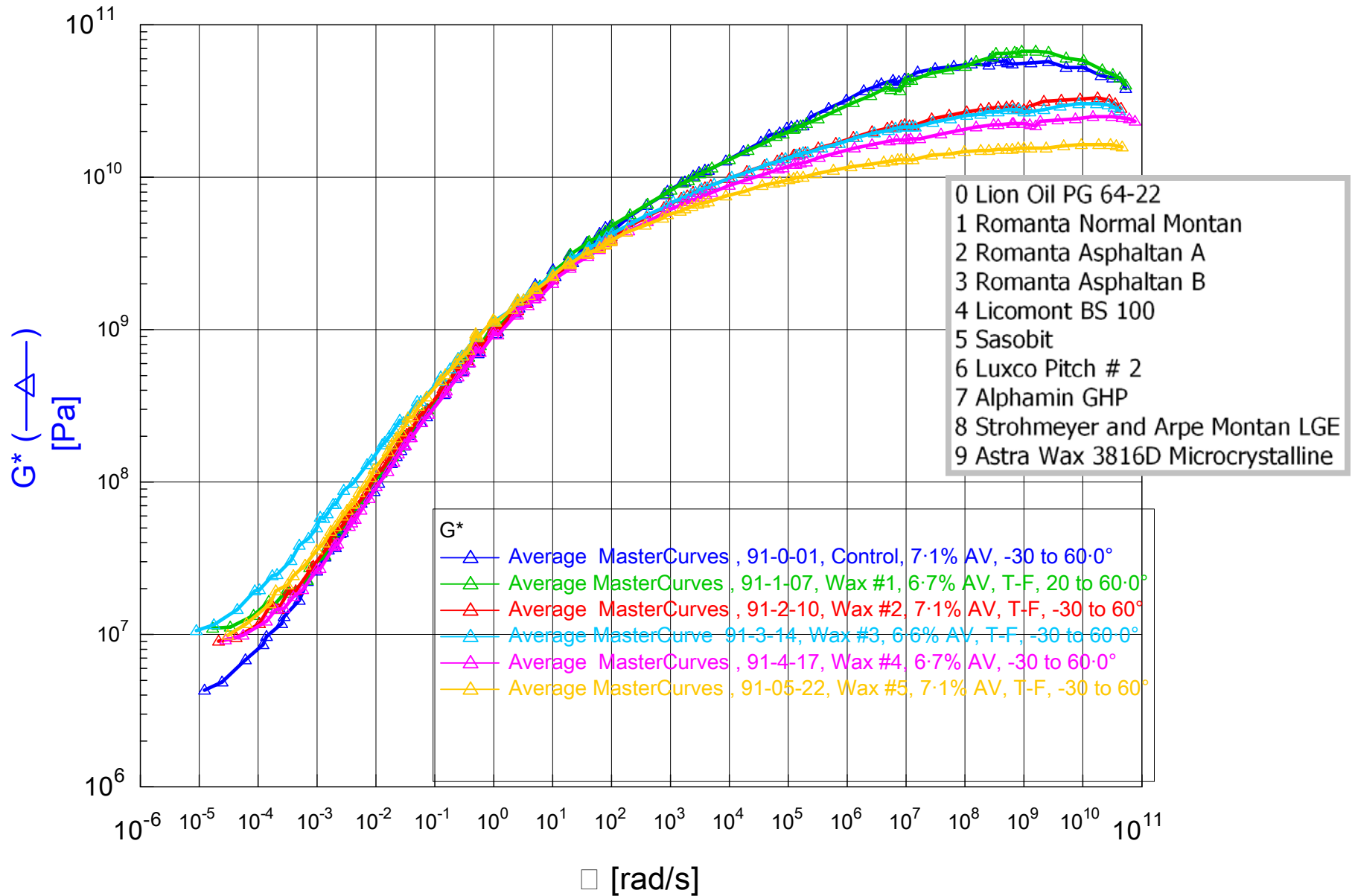
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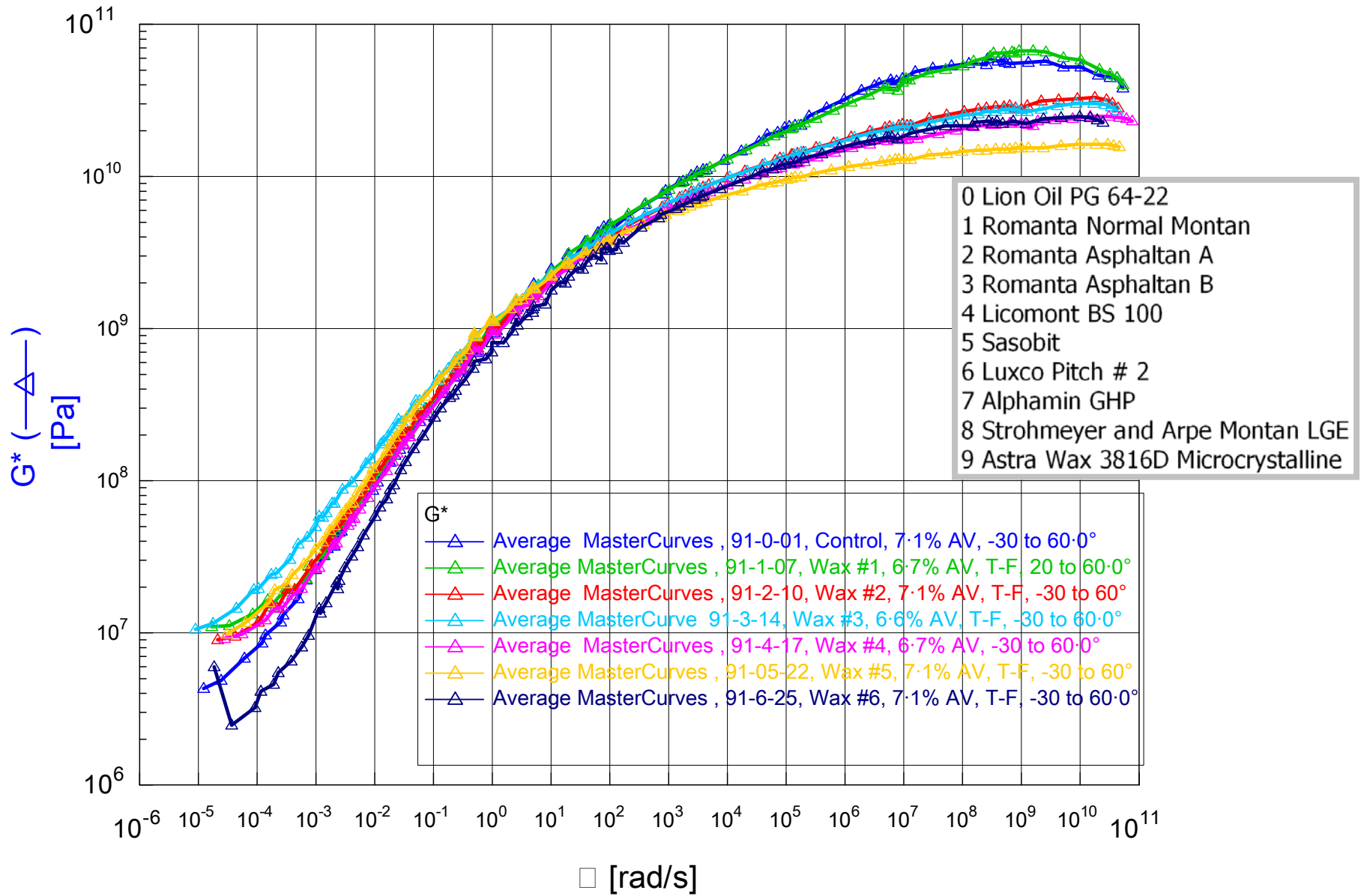
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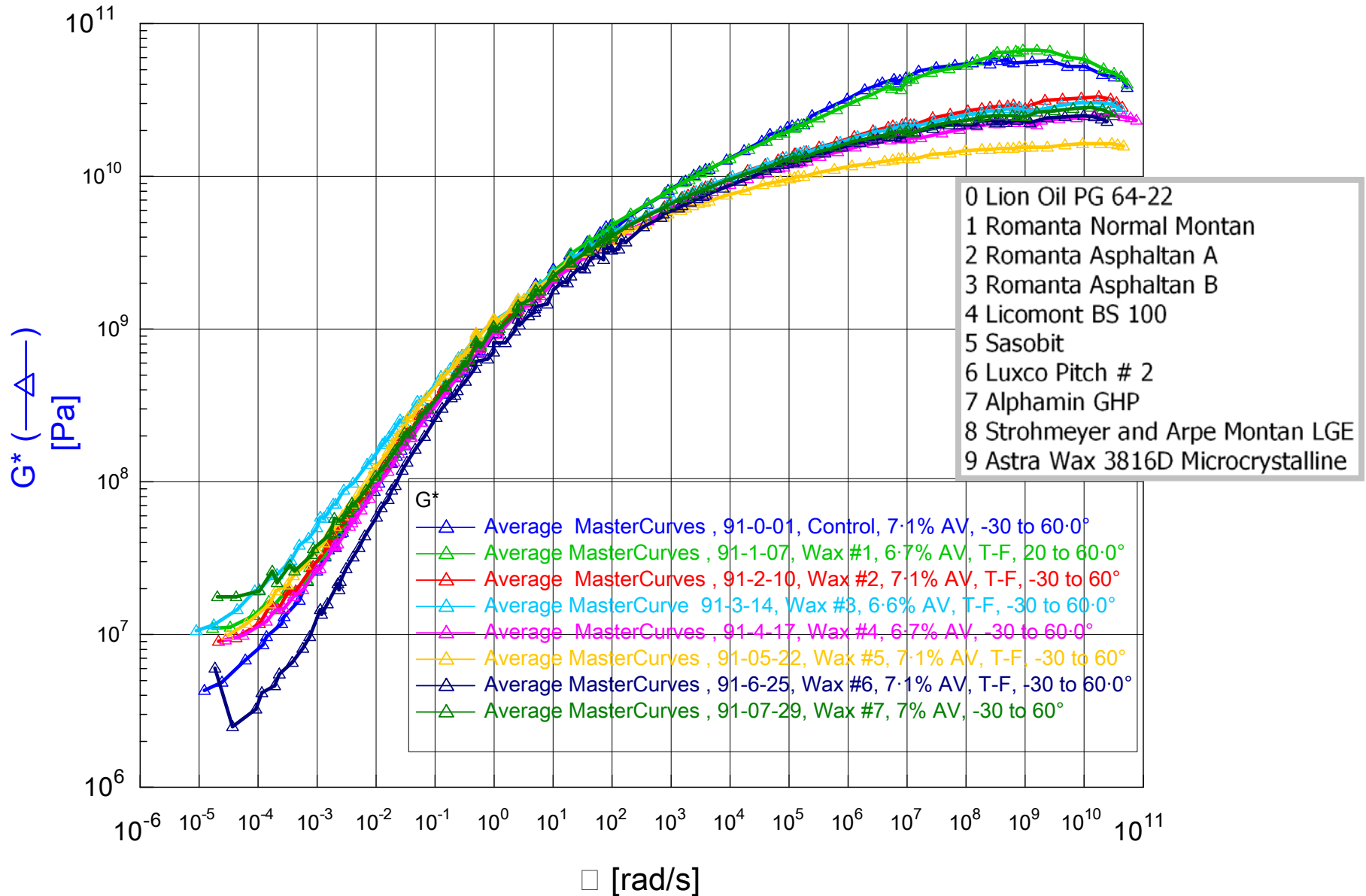
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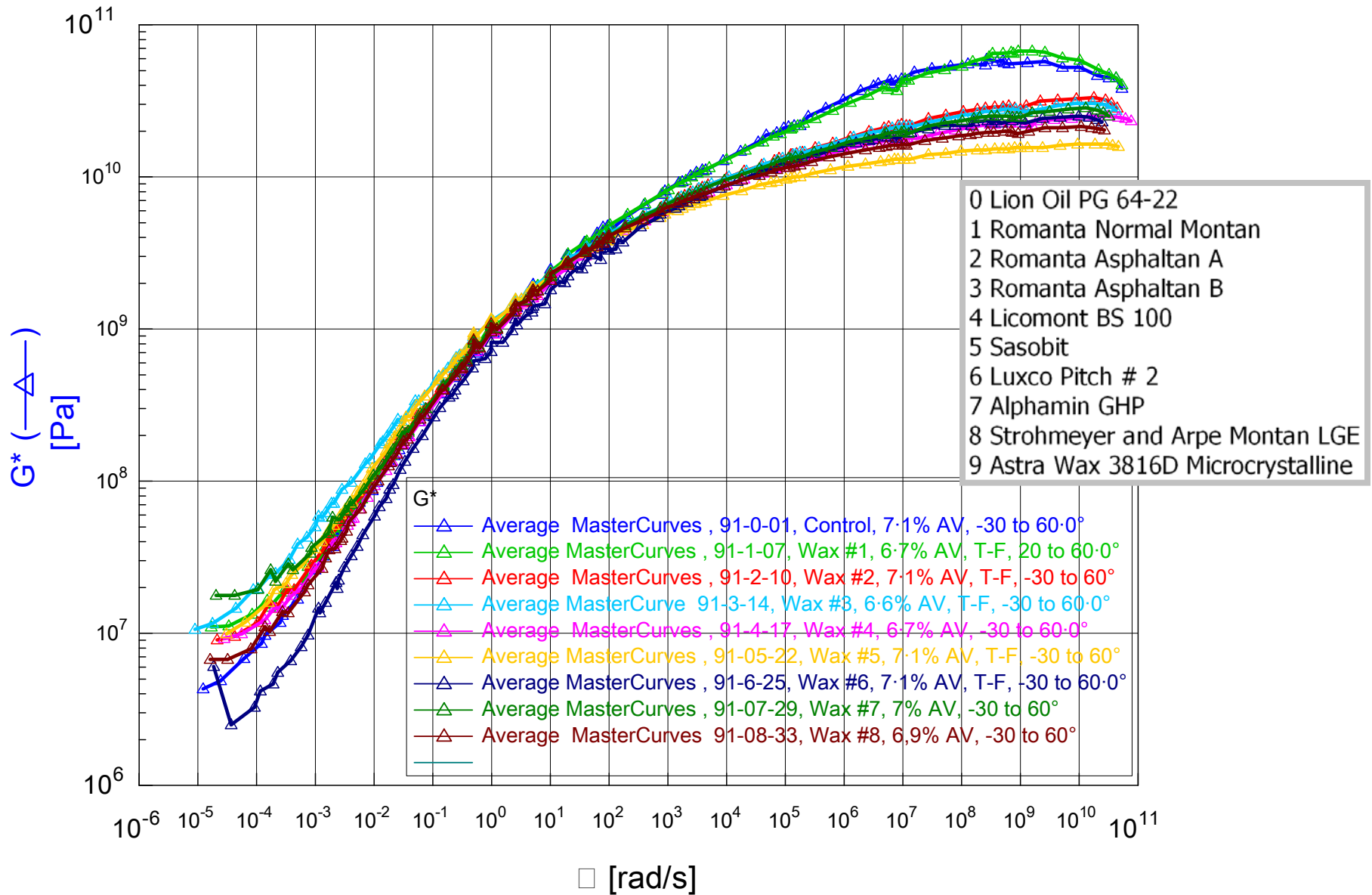
Average Merged MasterCurves Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0°



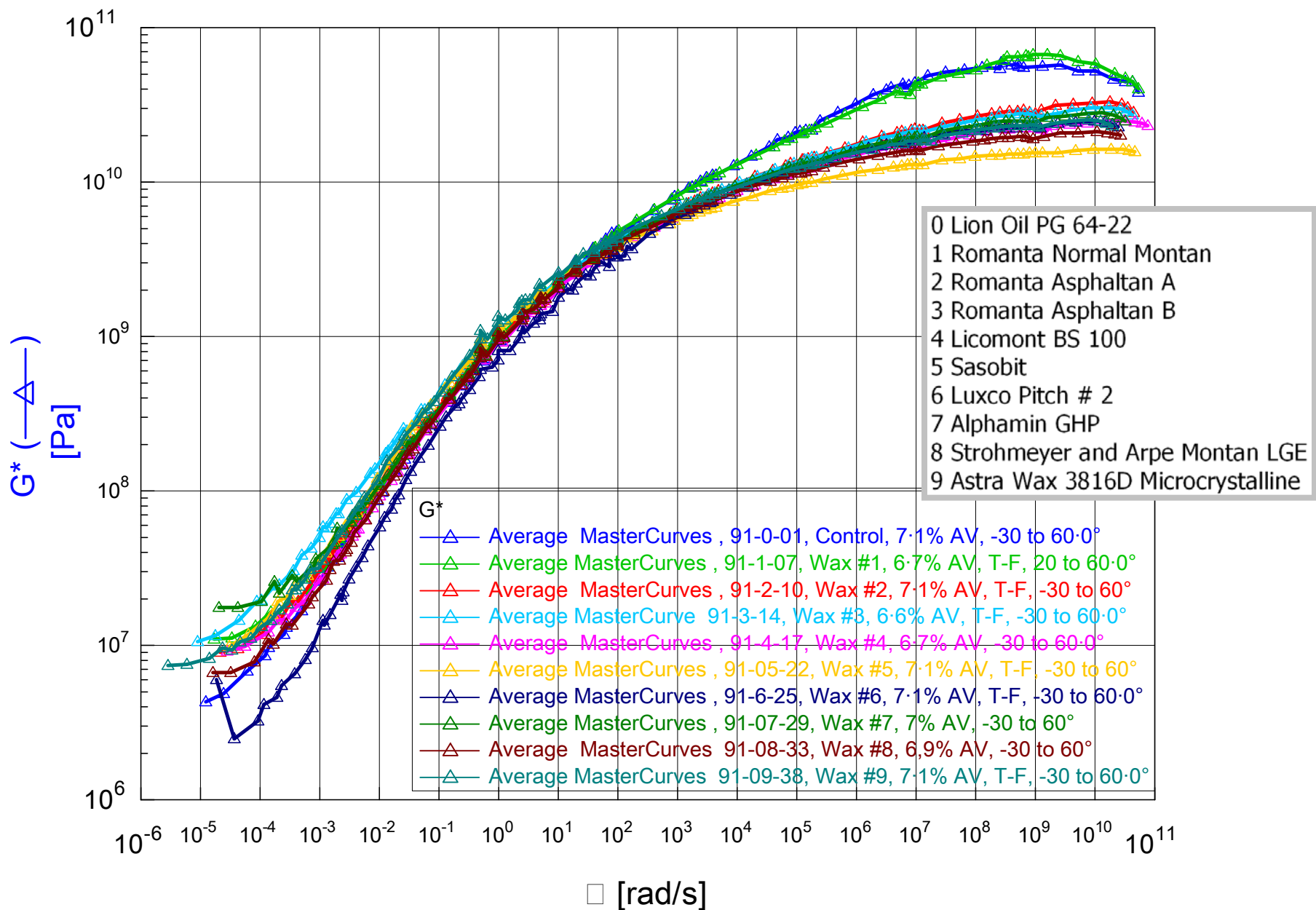
Average Merged MasterCurves Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0°

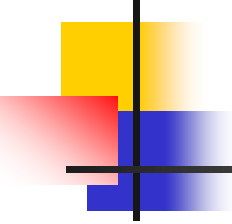


Average Merged MasterCurves Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0°



Average Merged MasterCurves Paragon Wax Study, 91-0-01, Control, 7.1% AV, -30 to 60.0°





Summary – Binder tests

- Significant differences in PG grades with different modifiers
 - All had some loss of performance at low end of specification
- Master curves show different structures in binder – note low strain level
- Jnr – results show that binder is stress sensitive
 - Wax products generally vary more with stress level
 - Have apparently good behavior at low stress levels
 - As stress level increases performance drops
 - The wax materials are a non-elastic modifier
 - Note δ can confuse the analysis such as used in some specifications
- Aging of BBR binder beams over extended time shows significant change in properties
 - Data at -12C was more in line with that expected
 - Data at -18C appears to be confounded



Summary – mix tests

- BBR
 - Avoid using early part of isotherm
 - Issues with -18C data after extended aging
 - Some damage/healing evident in data
 - Annealing at 64C showed that rankings could be restored to that expected
 - -18C is poorer than -12C data
- Repeated creep
 - Data lines up with Jnr results
 - Some suggestions for data analysis
- Fatigue
 - Monotonic tests show difference in performance
 - Preliminary – 1% and 3% wax show some different results
 - Repeated loading shows again significant differences – all waxes generally give lower performance but difference is small
- Master curves
 - Differences evident in G^* master curves
 - Should be able to look at these combined with BBR master curves



What to do

- More work with 1% wax content
- Some additional analysis of data
 - Maybe combine G^* and $S(t)$ master curves for mix to look at trends – do they match binder?
- DTT with notched specimens
- Develop report

Rio, Brazil 2009/5/10

Help ... I'm getting wet !!!

ANY QUESTIONS??

