Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

AIA IMAA IGV

ASSOCIATION INTERNATIONALE DE L'ASPHALTE AIA
INTERNATIONAL MASTIC ASPHALT ASSOCIATION IMAA
INTERNATIONALE GUSSASPHALT-VEREINIGUNG IGV
SEILERSTR. 22 BOX 5853 CH 3001 BERN
PHONE +41 (0)31 310 20 32 FAX +41 (0)31 310 20 35
INFO@MASTIC-ASPHALT.EU WWW.MASTIC-ASPHALT.EU

Impact of Binder And Additives On Mastic Asphalt Quality

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Dr. Aybike Öngel | Bern University of Applied Sciences

Introduction

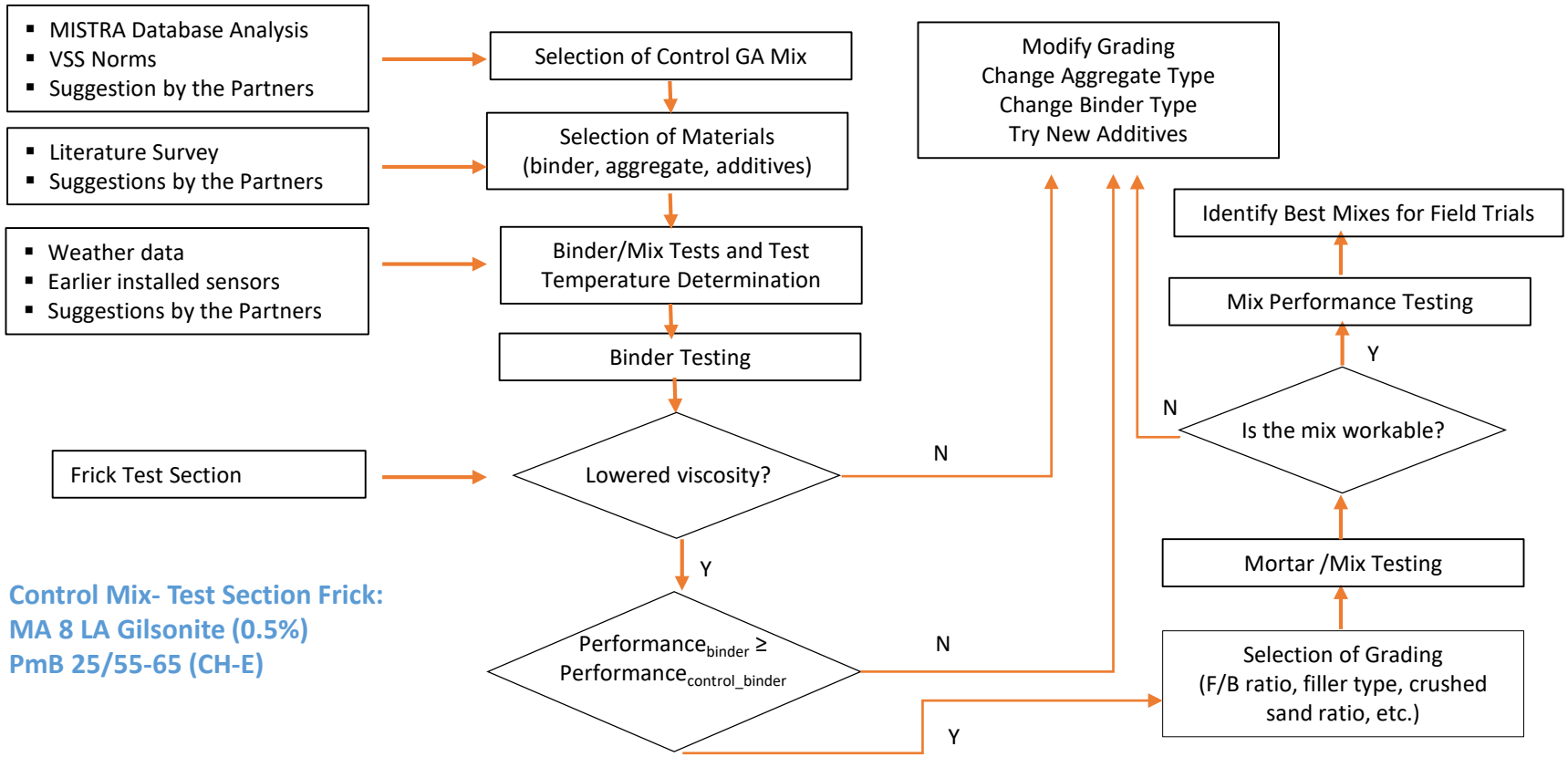
- Mastic Asphalt or Gussasphalt (GA) is a bituminous mixture composed of
  - relatively hard bitumen
  - relatively high bitumen content
  - relatively high mineral filler content
  - aggregates
- Ease of application
- Excellent water-proofing properties- near zero void content
- Avoid pavement distresses caused by moisture or air
- Various applications including tunnels, bridges, buildings, and parking lots

Goal and Objectives

➢ To bring GA more to the highway pavements

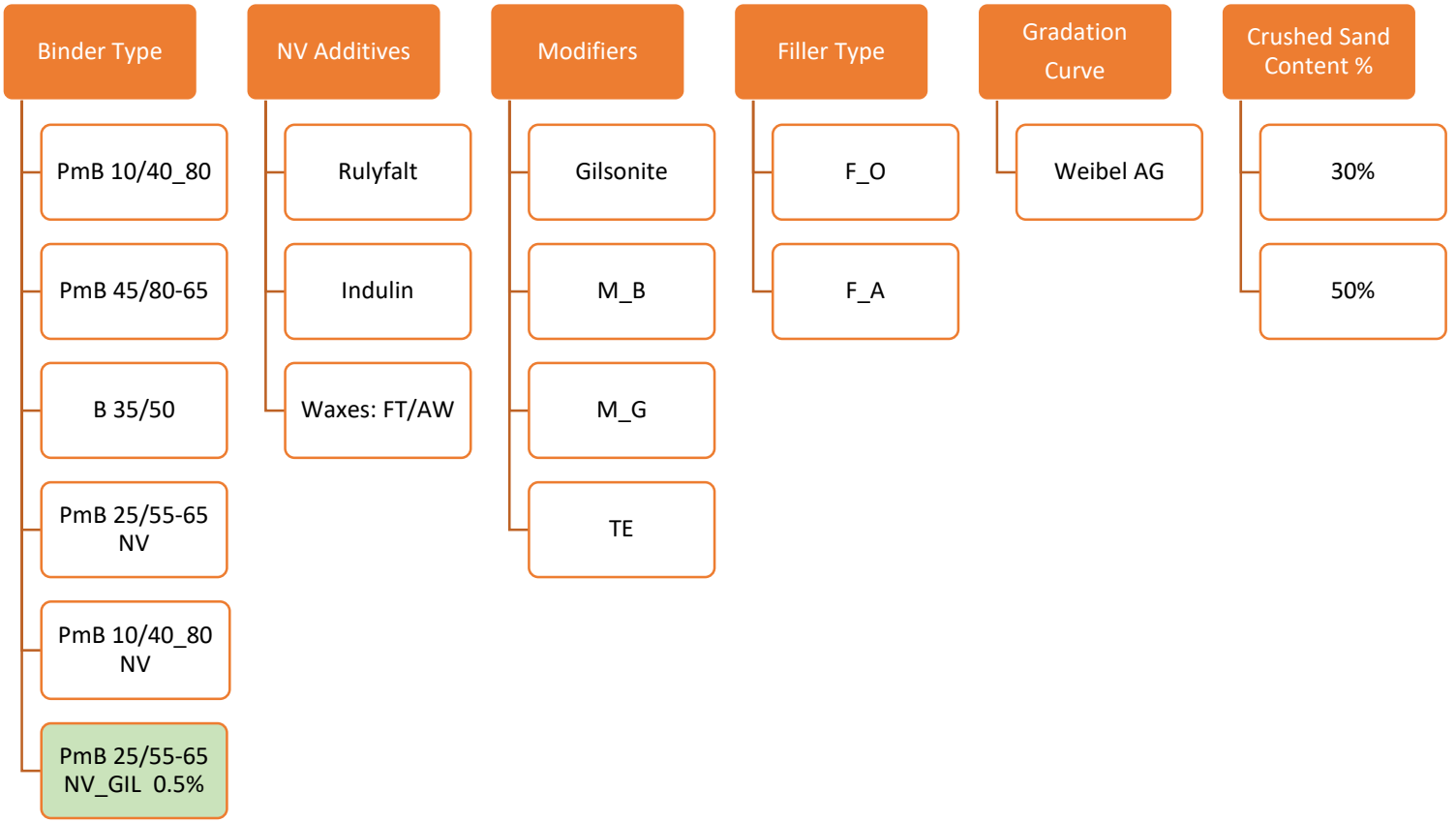
- Evaluate and optimize the GA mix for heavy traffic loads on road pavements
- Optimize the surface treatments for GA mixes to reduce noise and provide sufficient grip
- Optimize the construction methods
- Long term monitoring of GA mixes in the field

Proposed Testing Plan



Control Mix- Test Section Frick:
MA 8 LA Gilsonite (0.5%)
PmB 25/55-65 (CH-E)

Experimental Design



Modifier and NV Additive Evaluation

Bitumen \ Modif.	None	M_B	GiL	M_G	TE
PmB 25/55-65 NV	+	1.5%	0.5% REF 2%	1.5%	2%
B 35/50	+	1.5%	2%	1.5%	2%

Bitumen \ Modif.	None	Sasobit	Deurex
PmB 25/55-65	+	3%	3%

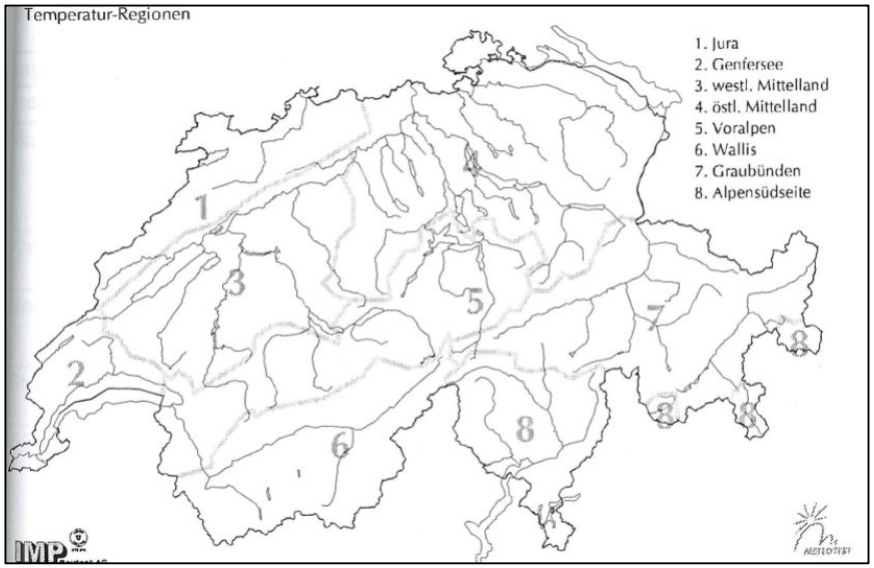
Test Temperature Determination

High temperature grades:

- PG 58
- PG 64

Low temperature grades:

- PG -16
- PG -22
- PG -28



IMP Bautest, 1999

Performance Grade Specifications (AASHTO M 332-20)

- Standard Designation “S” in most typical situations will be for traffic levels fewer than 10 million Equivalent Single Axle Loads (ESALs) and more than the standard traffic speed (>70 km/h)
- Heavy Designation “H” in most situations will be for traffic levels of 10 to 30 million ESALs or slow-moving traffic (20 to 70 km/h)
- Very Heavy Designation “V” in most situations will be for traffic levels of greater than 30 million ESALs or standing traffic (< 20 km/h)
- Extremely Heavy Designation “E” in most situations will be for traffic levels of greater than 30 million ESALs and standing traffic (< 20 km/h) such as toll plazas or port facilities

Binder Performance Tests

Tests on Original Binder	Tests on RTFO Aged Binder	Tests on PAV Aged Binder
Penetration Test (SN EN 1426)	Penetration Test (SN EN 1426)	DSR test
Softening Point, R&B (SN EN 1427)	Softening Point, R&B (SN EN 1427)	Temperature Sweep - max G*sin(delta)@10 rad/s, kPa from 10 °C to 40 °C
Viscosity at every 20°C between 130-230°C by Rotational Viscometer (ASTM D4402-06)	Mass loss, max %	BBR- Creep stiffness (low temp.) at -18 °C, -12 °C, -6°C (ASTM D6648 – 08)
Fraass Breaking Point (SN EN 12593)	DSR tests	
DSR Tests	Temperature Sweep – min G*/sin(delta)@10 rad/s at 58°C, 64 °C (FGSV Guidelines)	
Temperature Sweep – min G*/sin(delta)@10 rad/s at 58 °C, 64 °C (FGSV Guidelines)	Bitumen-Typisierungs-Schnell-Verfahren (BTSV) (DIN 52050)	
Bitumen-Typisierungs-Schnell-Verfahren (BTSV) (DIN 52050)	Multiple Stress Creep Recovery Test (SN EN 16659)	

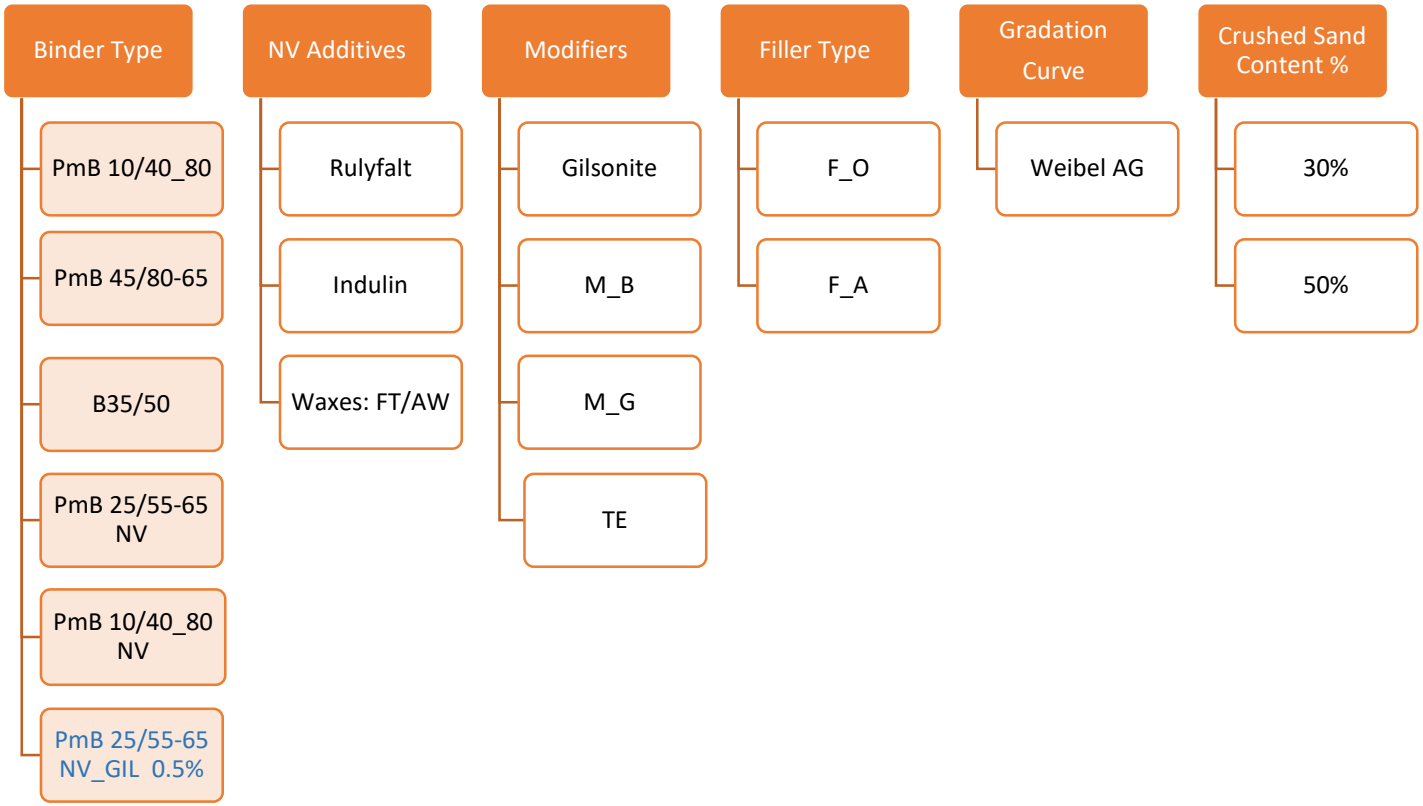
Filler Tests

Filler Tests
Rigden Voids (SN EN 1097-4)
Density (kg/m^3) (SN EN 1097-3, Annex A)
Size distribution- laser diffraction (ASTM D4464)
Bitumen Number (SN EN 13179-2)
Calcium carbonat content (SN 670116)
Water susceptibility (SN EN 1744-4)
Water solubility (SN EN 1744-1)
Organic Content- Loss on Ignition (Grobe Organische Verunreinigungen) (SN EN 1744-1:1998)
Methylene Blue Test (SN EN 933-9)
Kornverteilung von Füller (Luftstrahlsiebung) (SN EN 933-10)

Asphalt Mix Testing

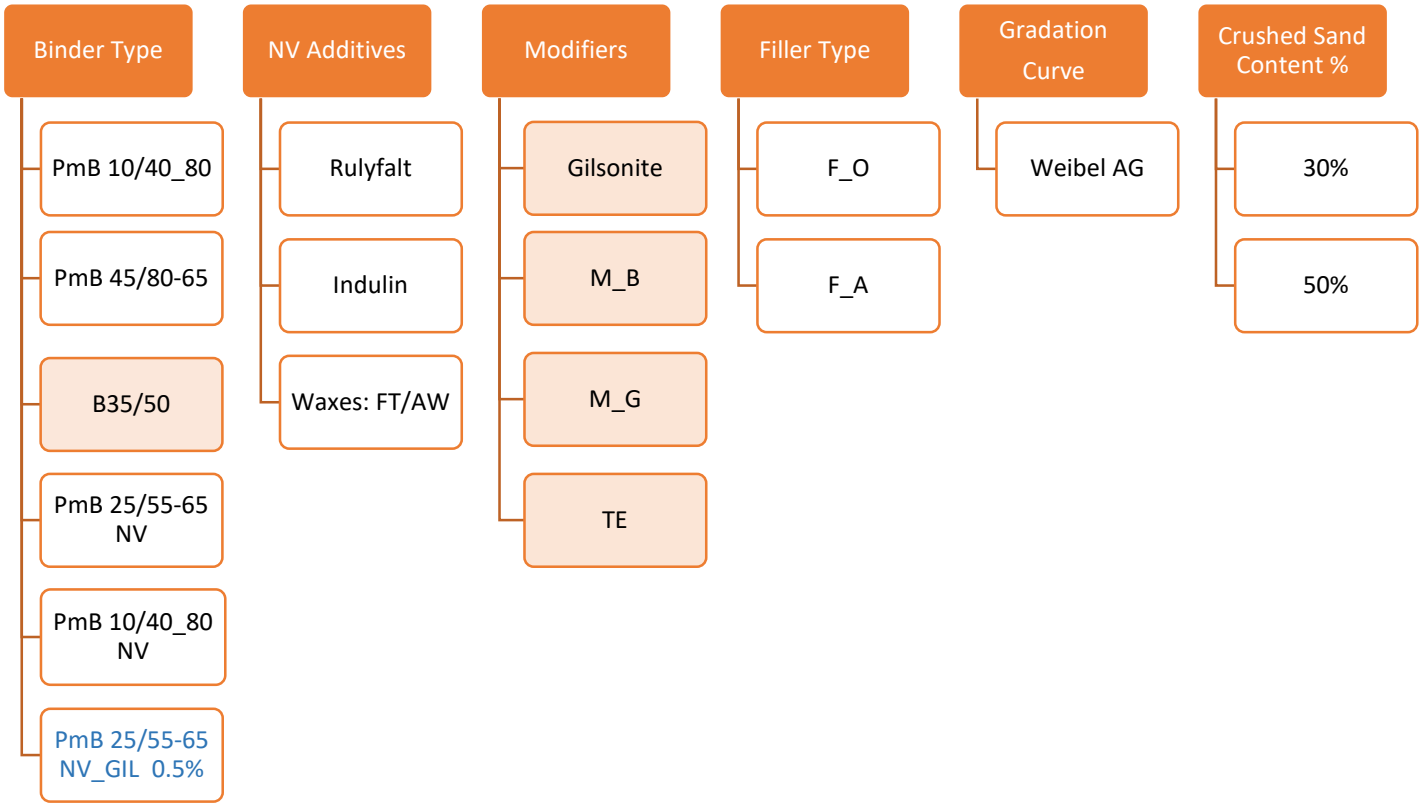
Tests on the Asphalt Mix
Bucket test
Indentation Tests
Static Indentation Test (modified method) at 55 ^{o}C and 650 N
Dynamic Indentation Test (SN EN 12697-25) at 50 ^{o}C, 60 ^{o}C
Free thermal shrinkage test – French method
Controlled thermal shrinkage cracking test– French method
Tensile Strength: Indirect Tension at -5 ^{o}C (EN 12697-23)
Low Temperature Cracking: SCB at -5 ^{o}C (AASHTO TP 394-21)
Intermediate Temperature Cracking: SCB at 25 ^{o}C (AASHTO TP 124-16)
Moisture Susceptibility: ITSR with freeze thaw conditioning (ASTM D4867/D4867M – 09)

Testing Scheme-I



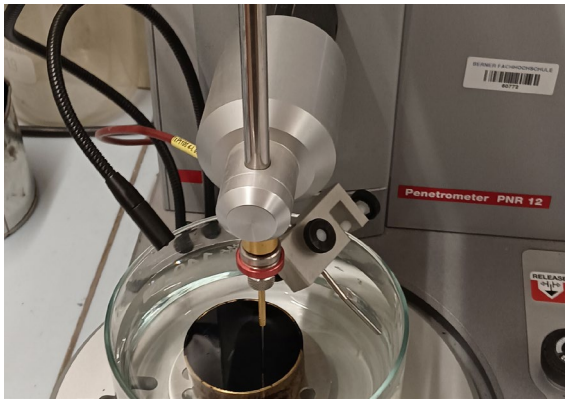
Bitumen Characterization → Additive Evaluation → Filler Characterization → Mix Characterization

Testing Scheme-II

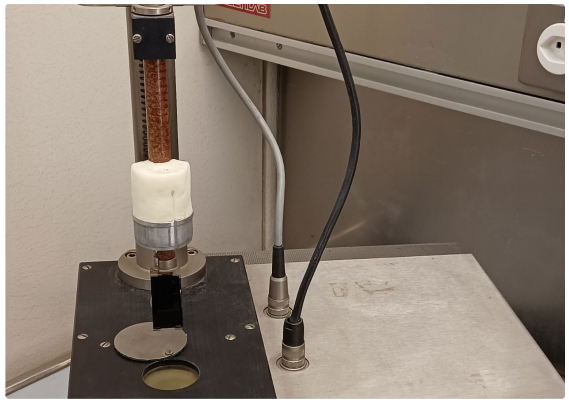


Bitumen Characterization → Additive Evaluation → Filler Characterization → Mix Characterization

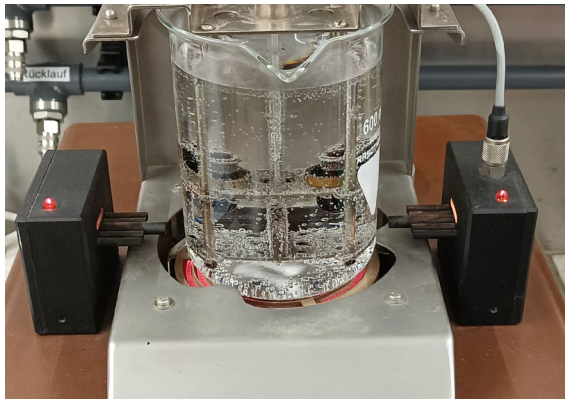
Binder Tests Conducted



Penetration Test
(SN EN 1426)



Fraass Breaking Point
(SN EN 12593)

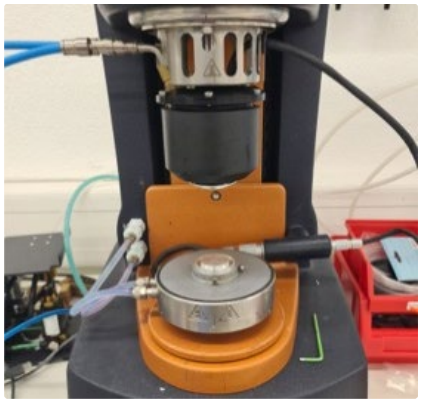


Ring and Ball Test
(SN EN 1427)

Binder Tests Conducted – cont`d

RTFO Aging
(SN EN 12607-1)

Short term aging



DSR
(SN EN 16659)
(FGSV Guidelines)

infraTest

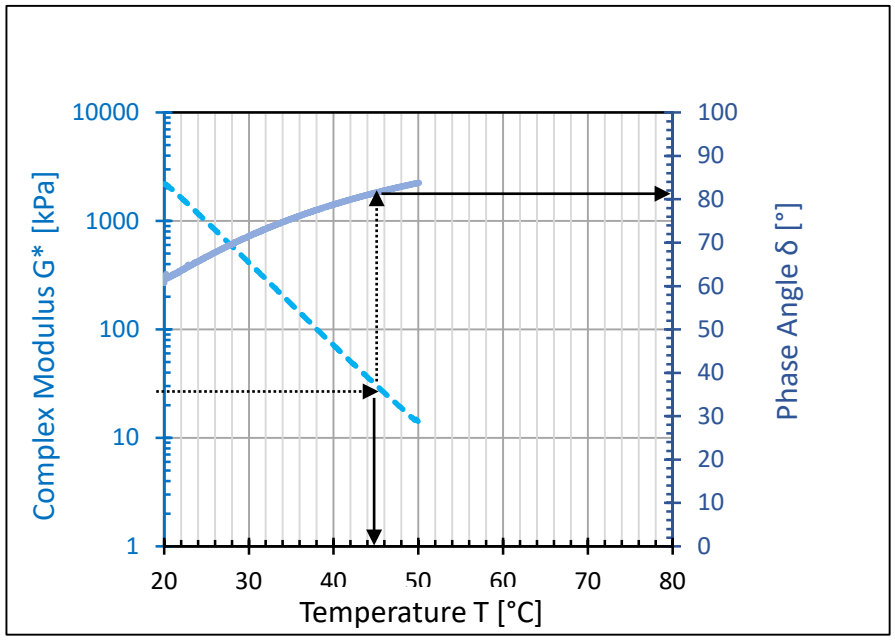
PAV Aging

Long term aging

Source: Labomat

Brookfield Rotational Viscometer

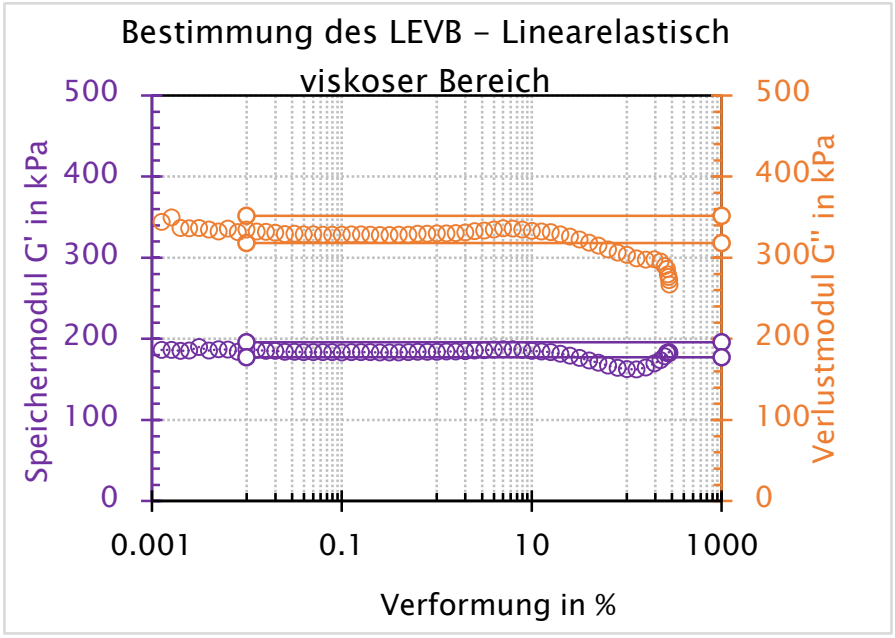
DSR Tests: BTSV Test



- Indicator of the softening point – equivalent to R&B softening point
- Parameters:
  - Equi-shear modulus temperature, is the temperature at G* = 15 kPa - indicator of softening point
  - Phase Angle at G* = 15 kPa characterizes the degree of modification
- All BTSV temperatures were estimated from T-Sweep Tests

DSR Tests: Temperature Sweep (T-Sweep)

Linear Viscoelastic (LVE) Region Determination



Temperature Sweep

- Strain controlled in the LVE region
- G*/sinδ between 30 °C and 90 °C on the original and RTFO conditioned samples
- PG requirement:

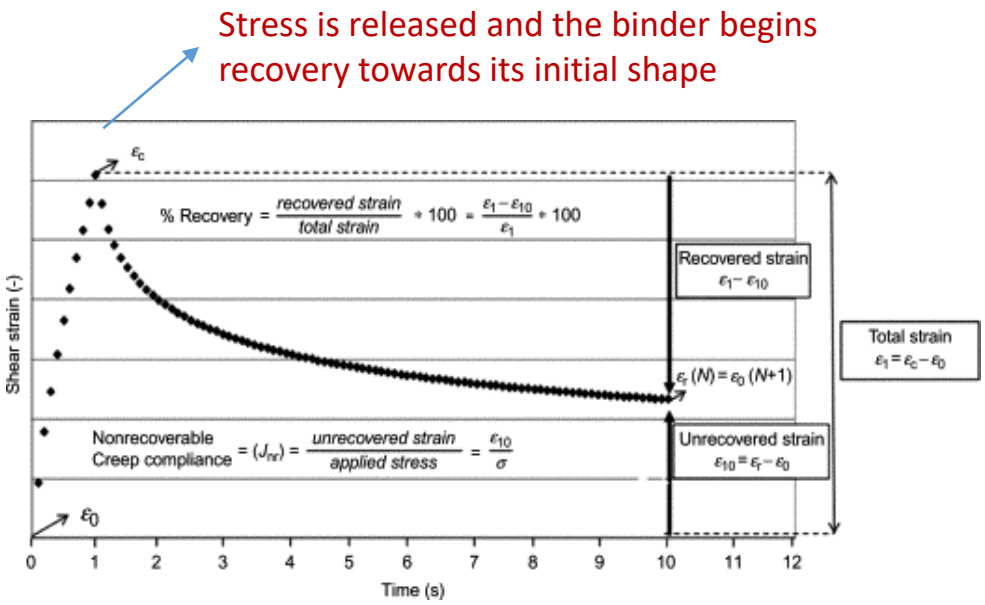
  G*/sinδ ≥ 1kPa @ 10 rad/s for original binder

  G*/sinδ ≥ 2.2kPa @ 10 rad/s for RTFOT aged binder (old criteria)
- G*sinδ between -10 °C and 40 °C on the PAV conditioned samples
- PG requirement:

  G*sinδ ≤ 5000kPa @ 10 rad/s for «S»

  G*sinδ ≤ 6000kPa @ 10 rad/s for «H, V, E»

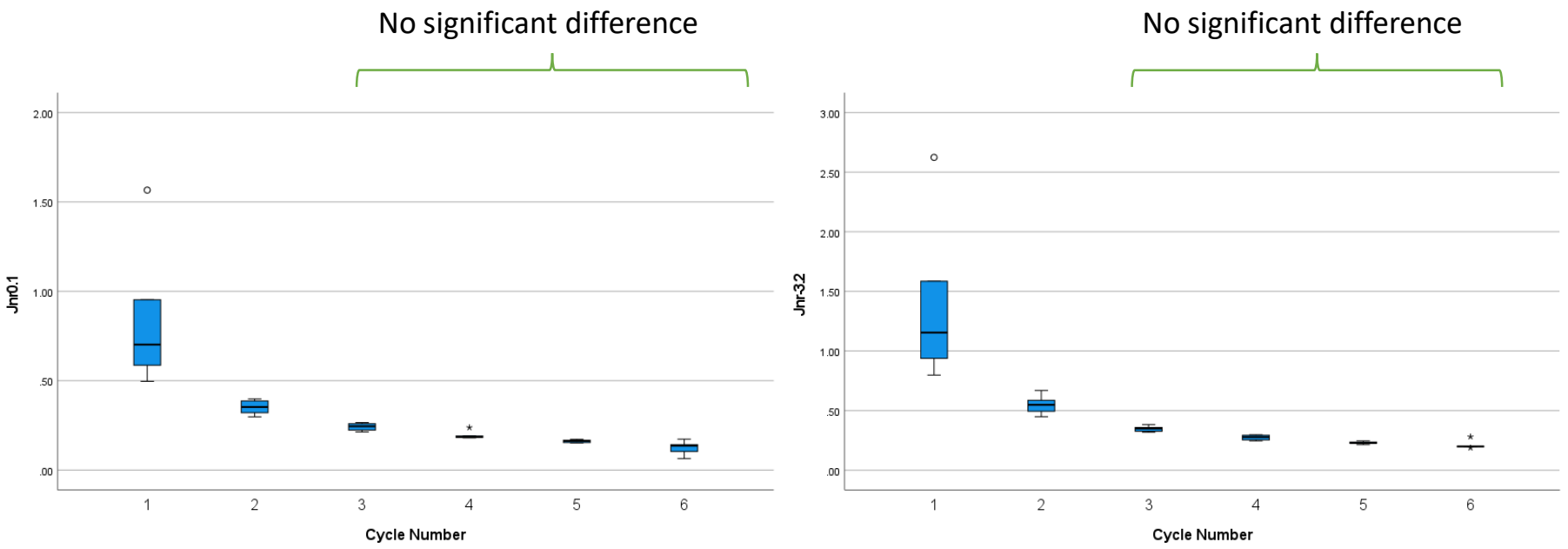
DSR Tests: Multiple Stress Creep Recovey (MSCR) Test



Source: Eco-Efficient Pavement Construction Materials, 2020

- Evaluates high-temperature behaviour
- Test conducted using DSR- applying 1-sec of creep stress followed by 9-sec recovery
- 10 cycles at 0.1 kPa and 10 cycles at 3.2 kPa shear stresses
- Parameters:
  - **Jnr**, non-recoverable creep compliance, is the unrecovered strain relative to the applied stress. Indicator of the capacity of asphalt binders to resist permanent deformation.
  - **Percent recovery (R%)** is how thoroughly the sample returns to its previous shape after being stretched (creep) and then relaxed (recovered). Indicator of how polymer works in the asphalt binder.

DSR Tests: MSCR Test - modified



30 reps at each stress level- 6 x 5 creep-recovery cycles

100% : First cycle was significantly different than the others

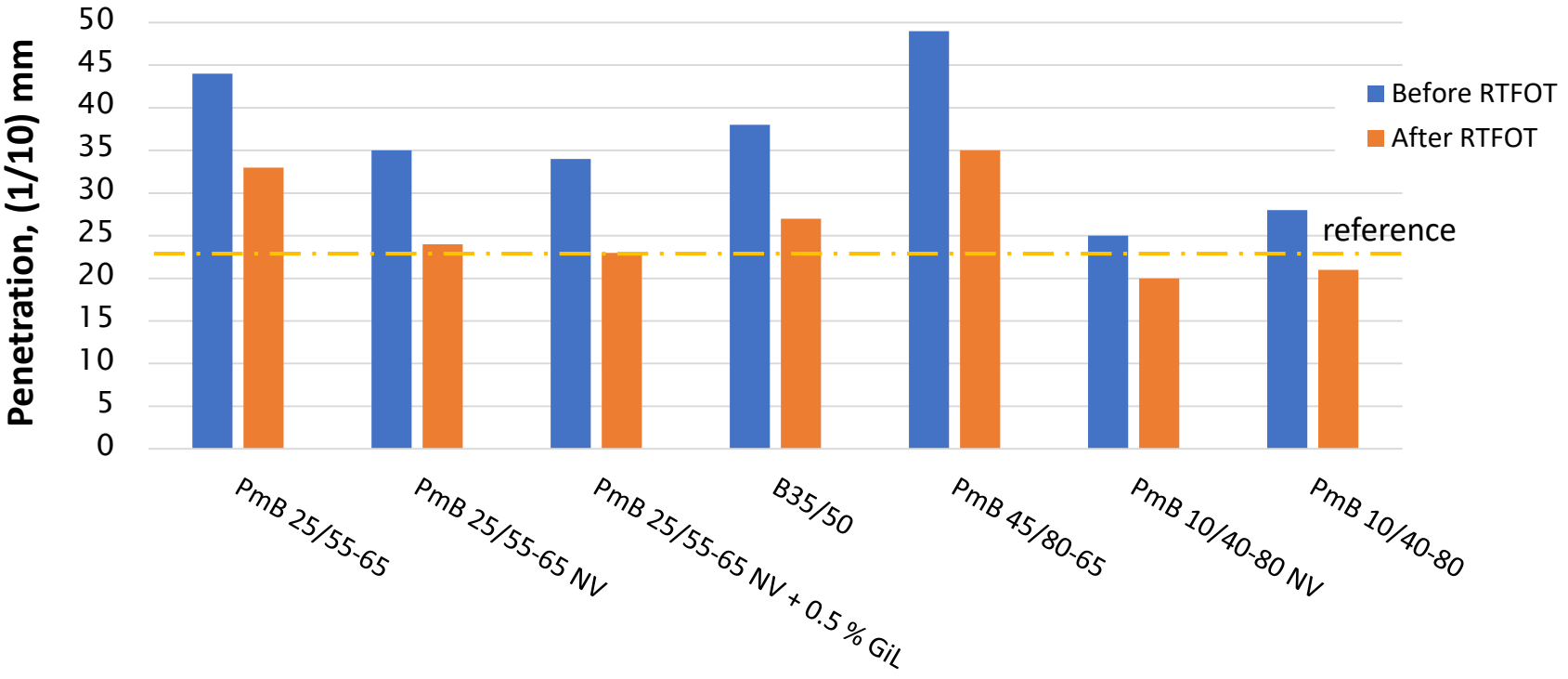
60% : First 2 cycles were significantly different than the others

Performance Grade Specifications for MSCR (AASHTO M 332-20)

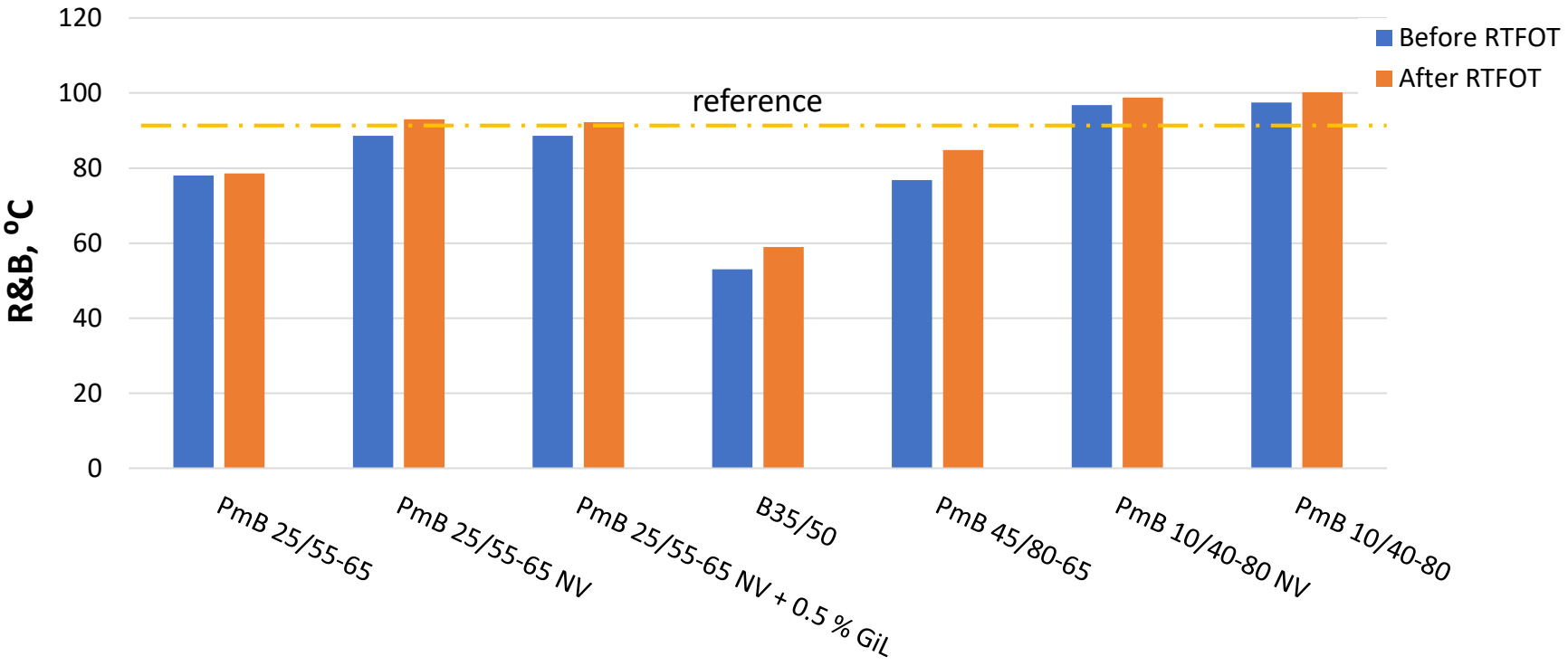
- Standard Designation “S” : $J_{nr3.2}$= max 4.5 kPa^{-1}
- Heavy Designation “H” : $J_{nr3.2}$= max 2.0 kPa^{-1}
- Very Heavy Designation “V” : $J_{nr3.2}$= max 1.0 kPa^{-1}
- Extremely Heavy Designation “E” : $J_{nr3.2}$= max 0.5 kPa^{-1}

Test Results: GA Binders

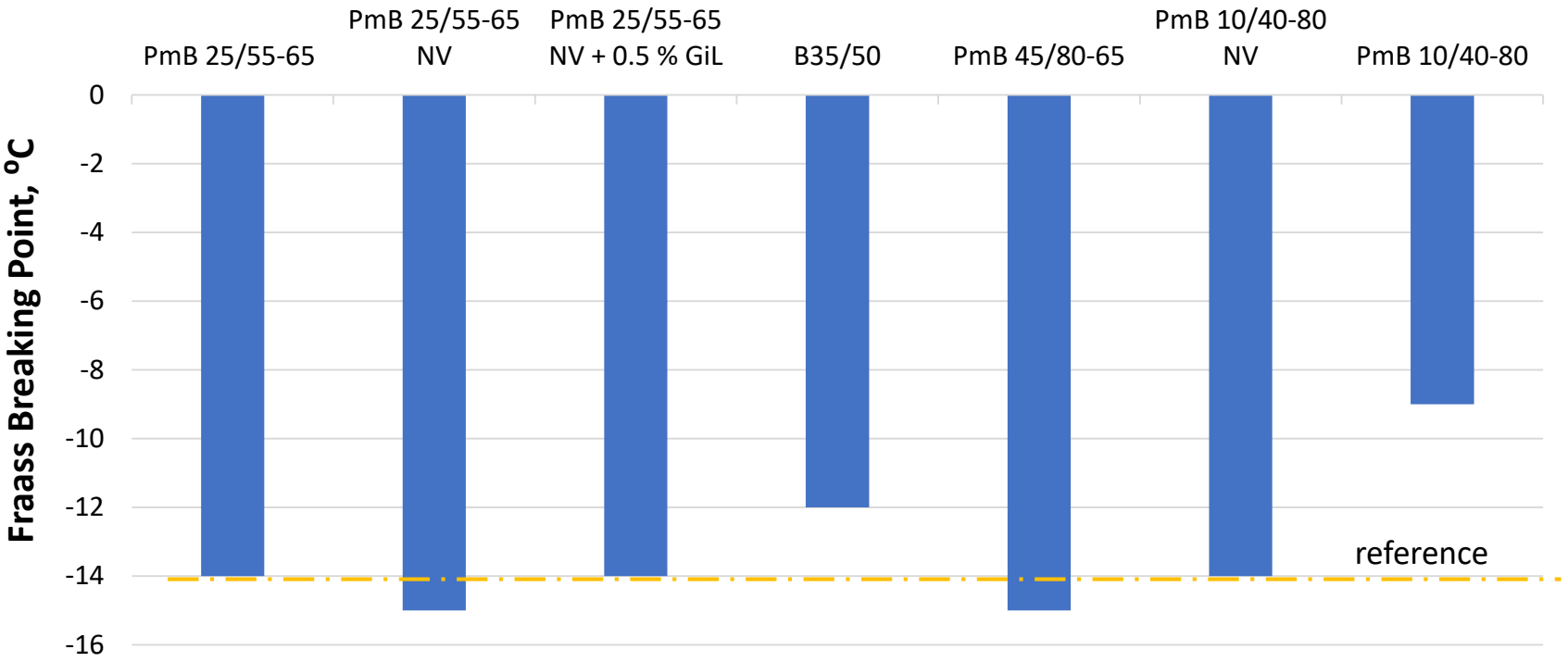
Penetration Value



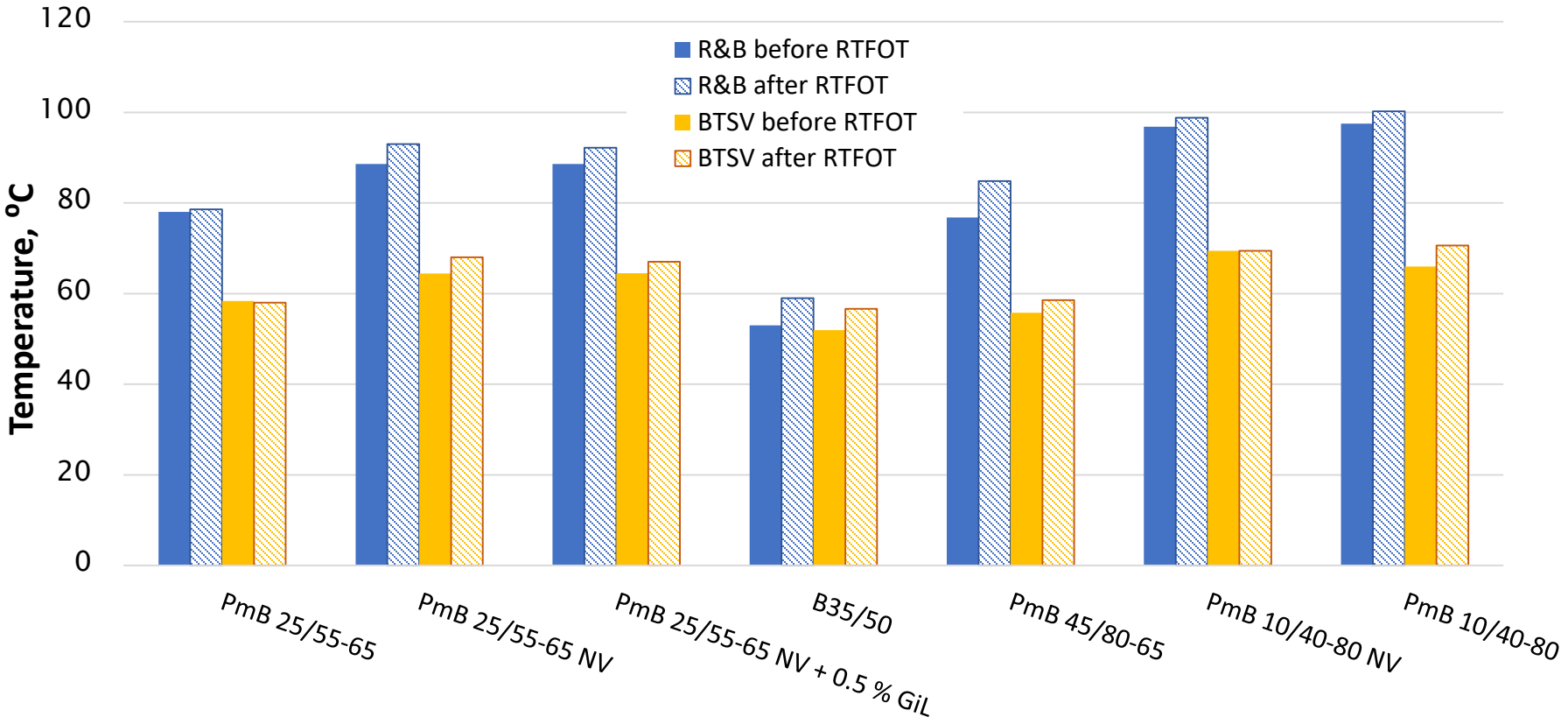
Softening Point



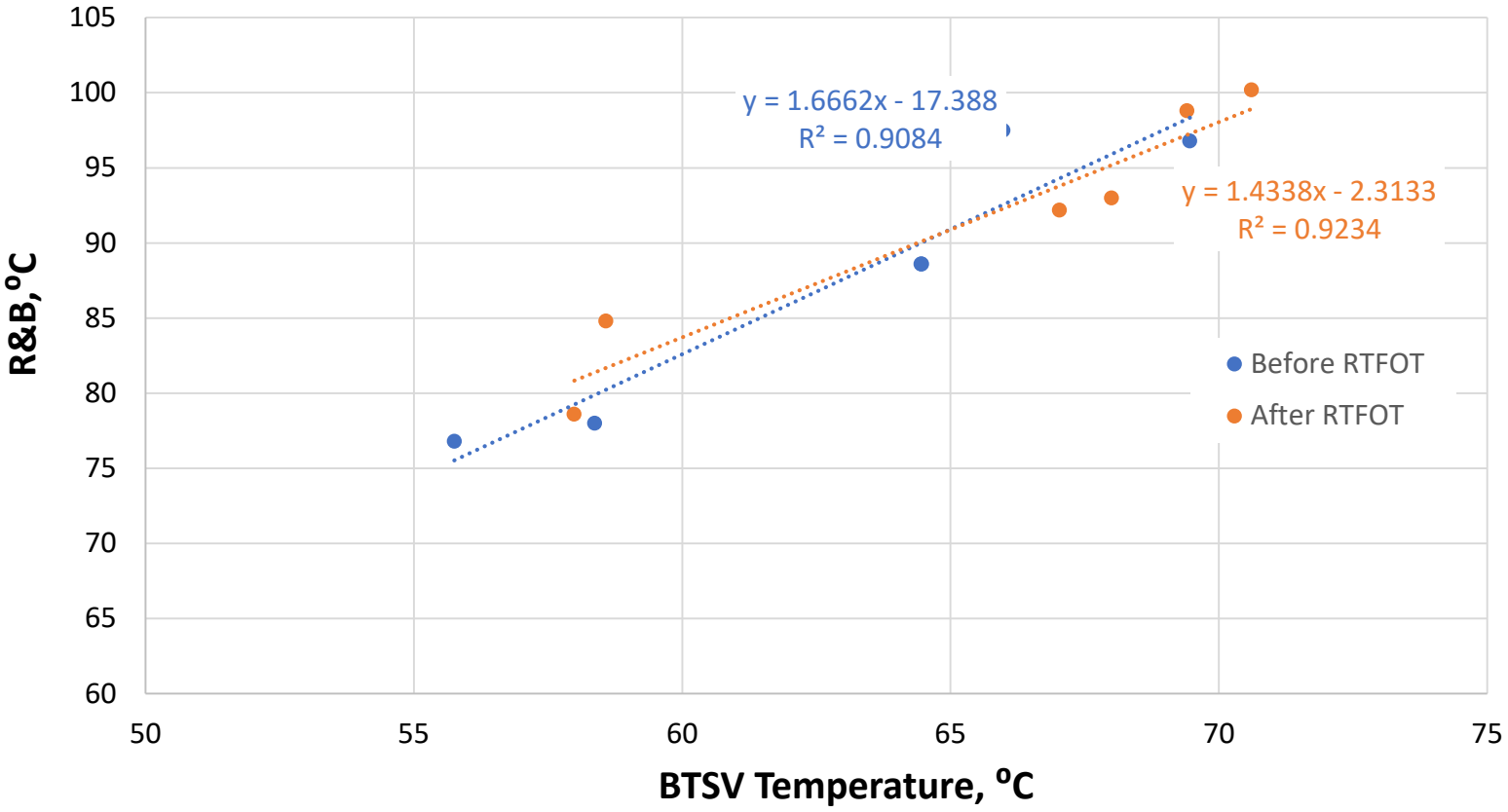
Fraass Breaking Point



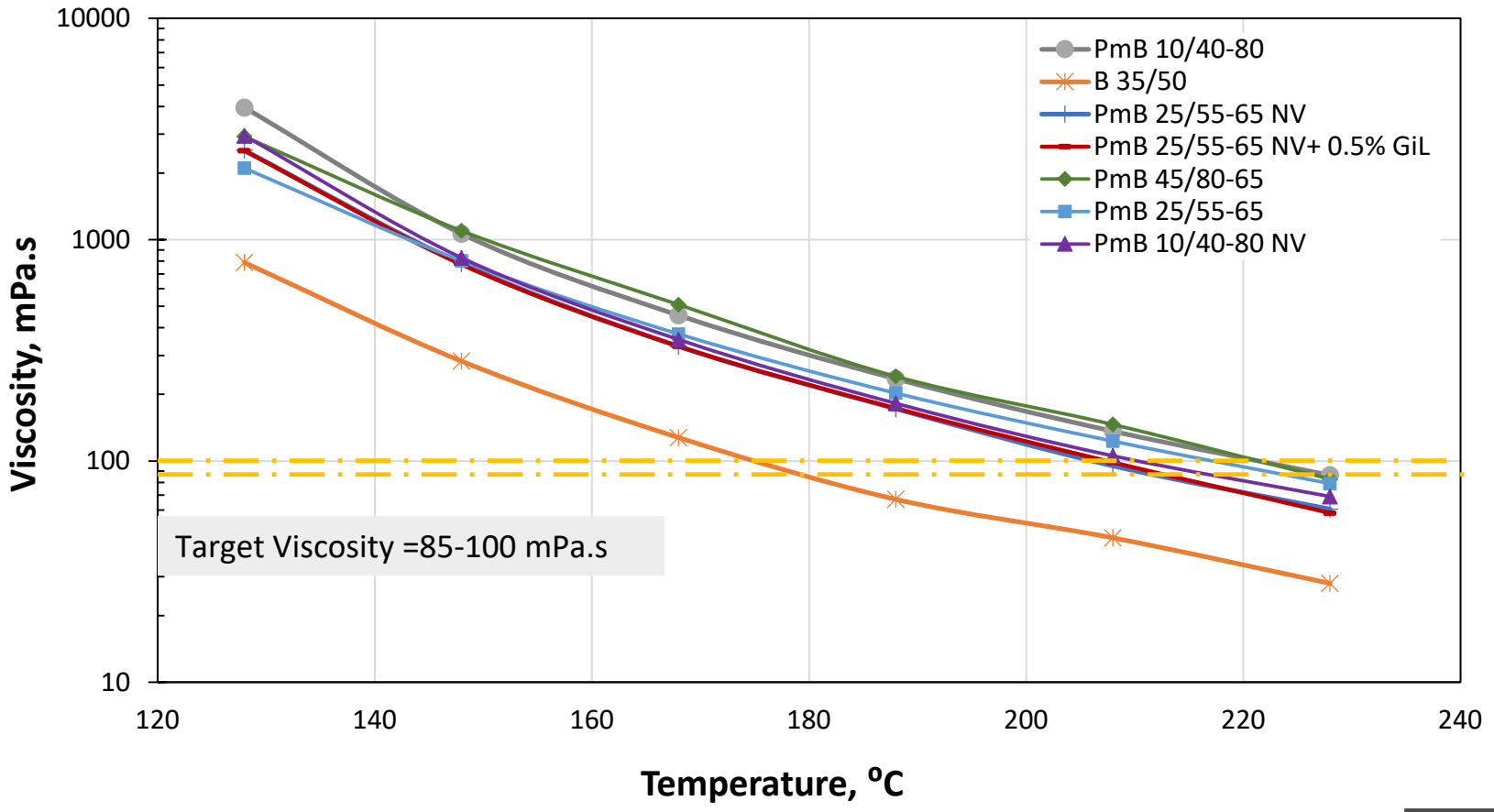
R&B vs. BTSV Values



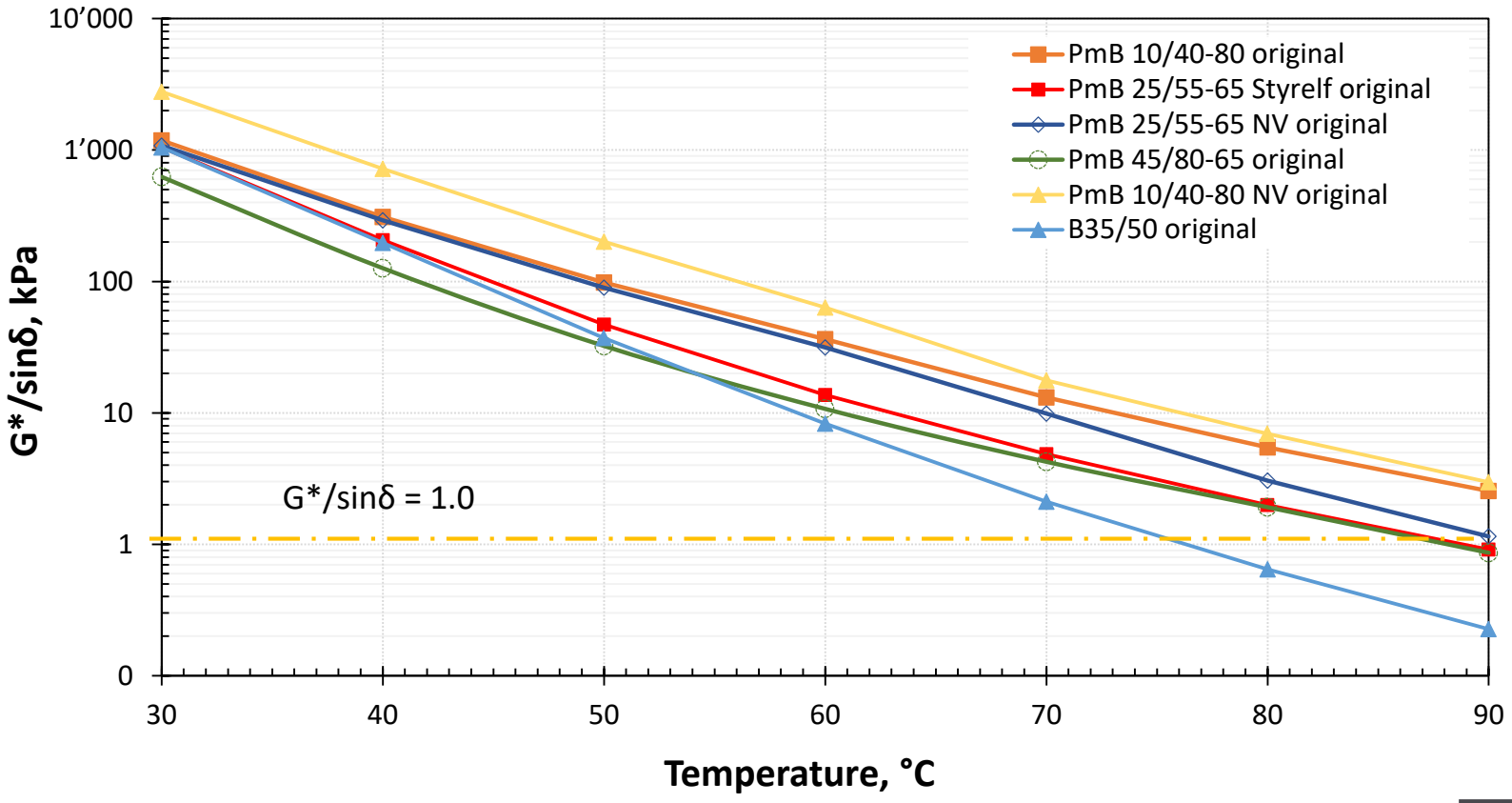
Correlation between R&B values and BTSV



Viscosity

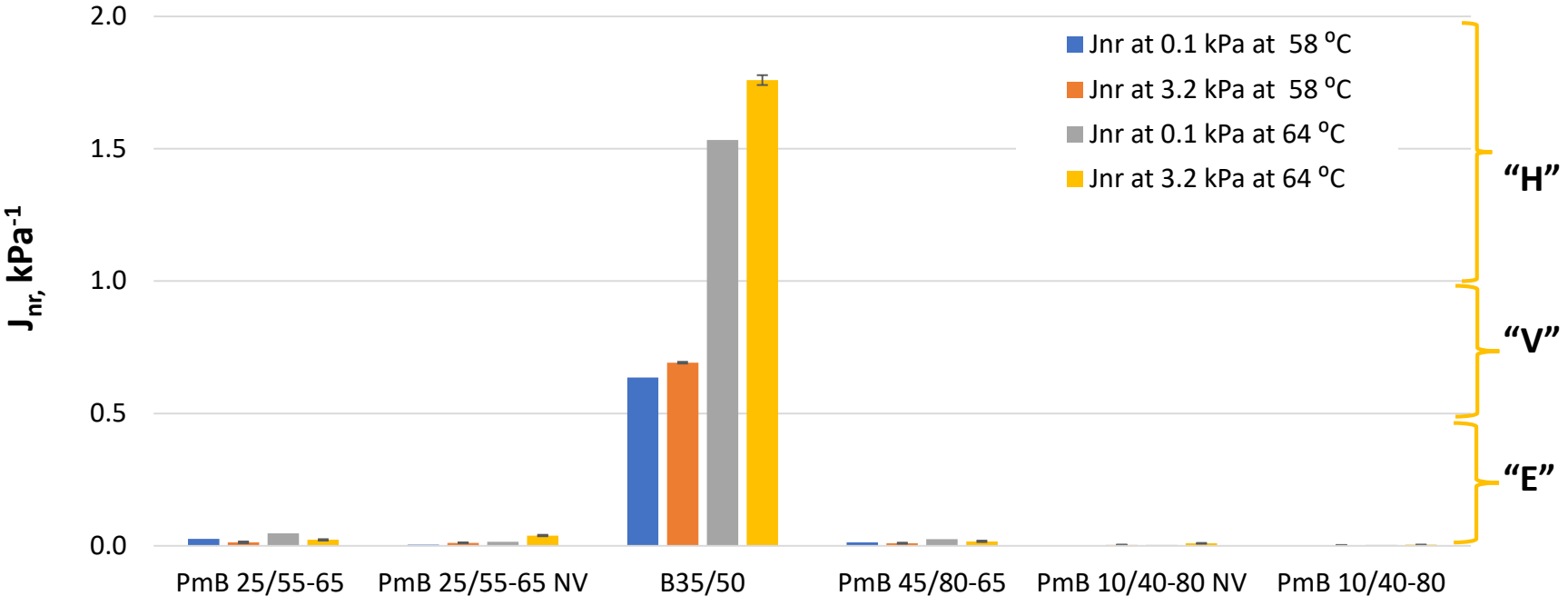

10000
1000
100
10
Viscosity, mPa.s
120
140
160
180
200
220
240
Temperature, °C
PmB 10/40-80
B 35/50
PmB 25/55-65 NV
PmB 25/55-65 NV+ 0.5% GiL
PmB 45/80-65
PmB 25/55-65
PmB 10/40-80 NV
Target Viscosity =85-100 mPa.s

G*/sinδ

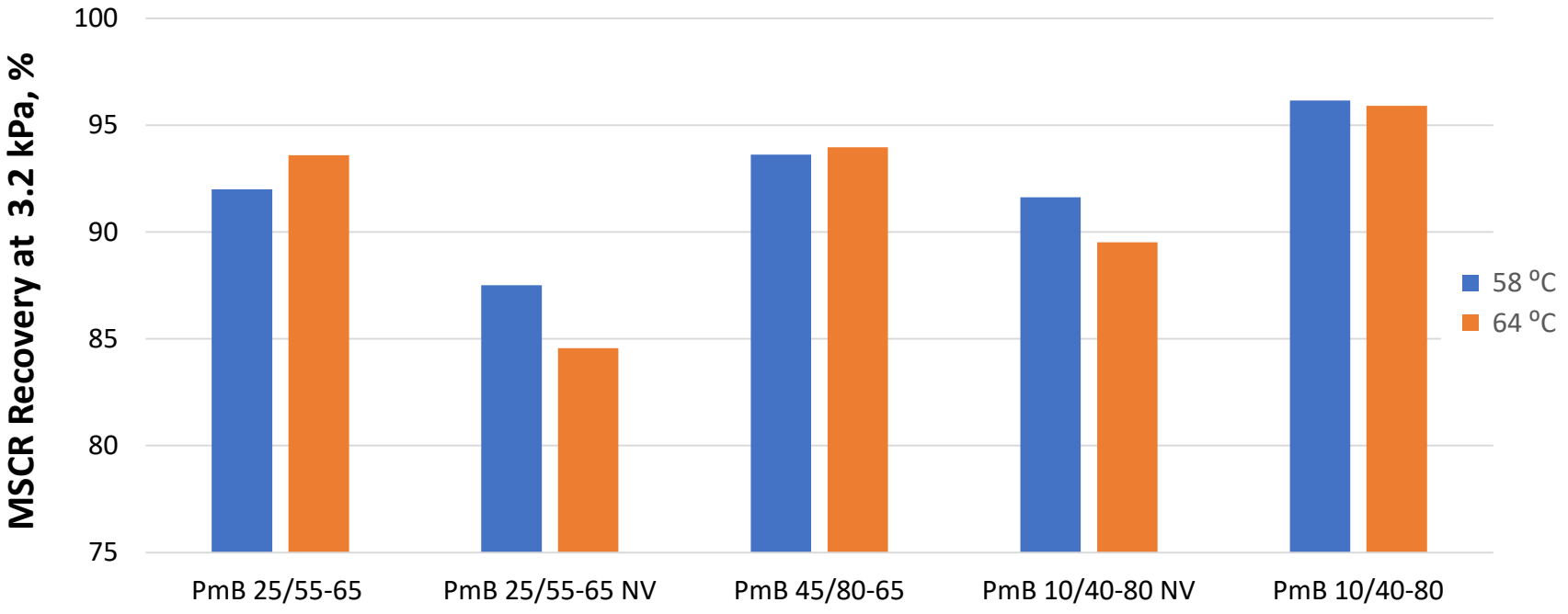

10’000
1’000
100
10
1
0
G*/sinδ, kPa
30
40
50
60
70
80
90
Temperature, °C
G*/sinδ = 1.0
PmB 10/40-80 original
PmB 25/55-65 Styrelf original
PmB 25/55-65 NV original
PmB 45/80-65 original
PmB 10/40-80 NV original
B35/50 original

J_{nr} Values

All PmBs can all handle (at 64 °C) Extremely heavy traffic - traffic levels of greater than 30 million ESALs and standing traffic (< 20 km/h). B35/50 can handle (at 64 °C) Heavy traffic “H” - traffic levels of 10 to 30 million ESALs or slow moving traffic (20 to 70 km/h).

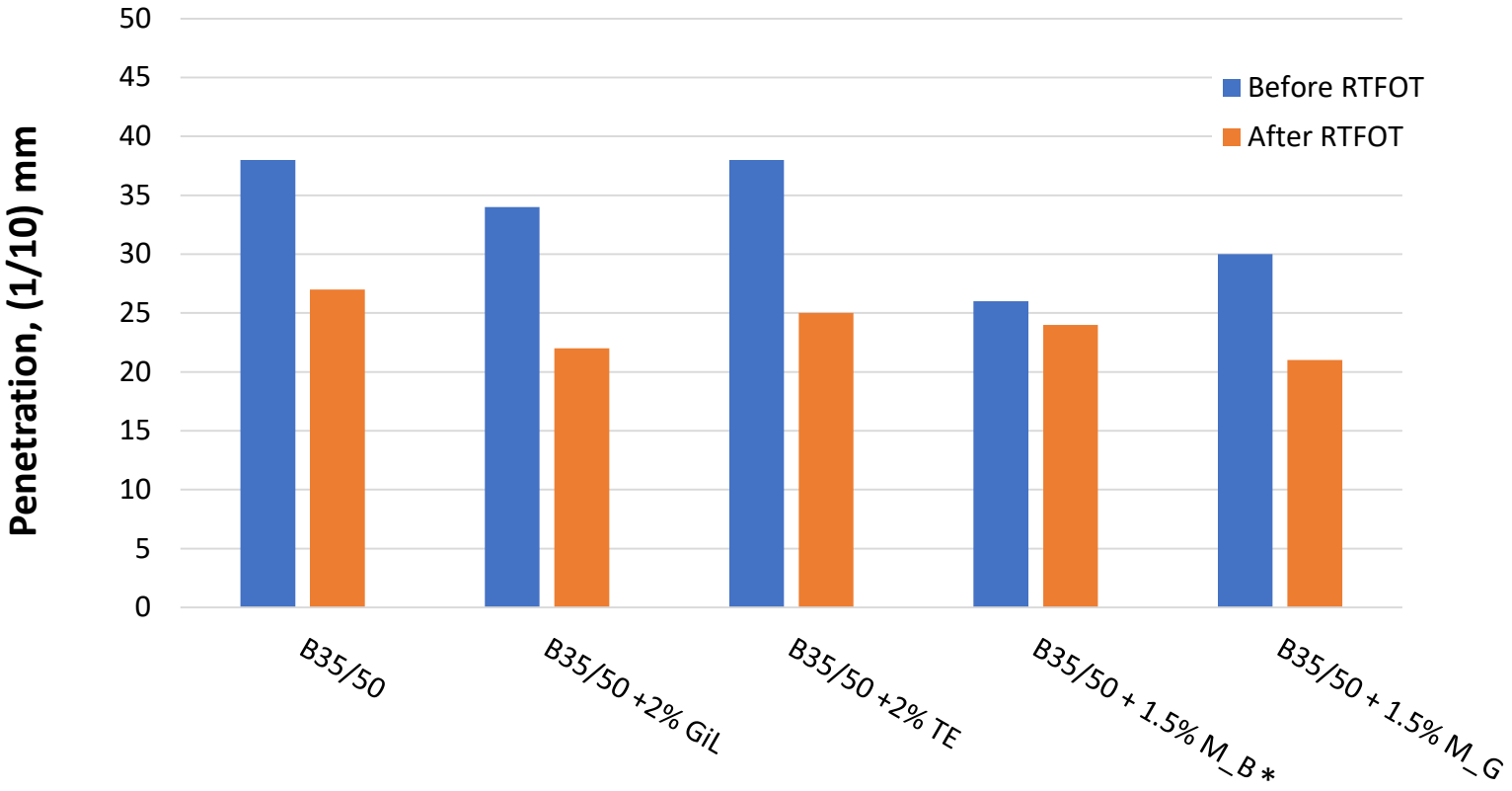


MSCR Recovery Values

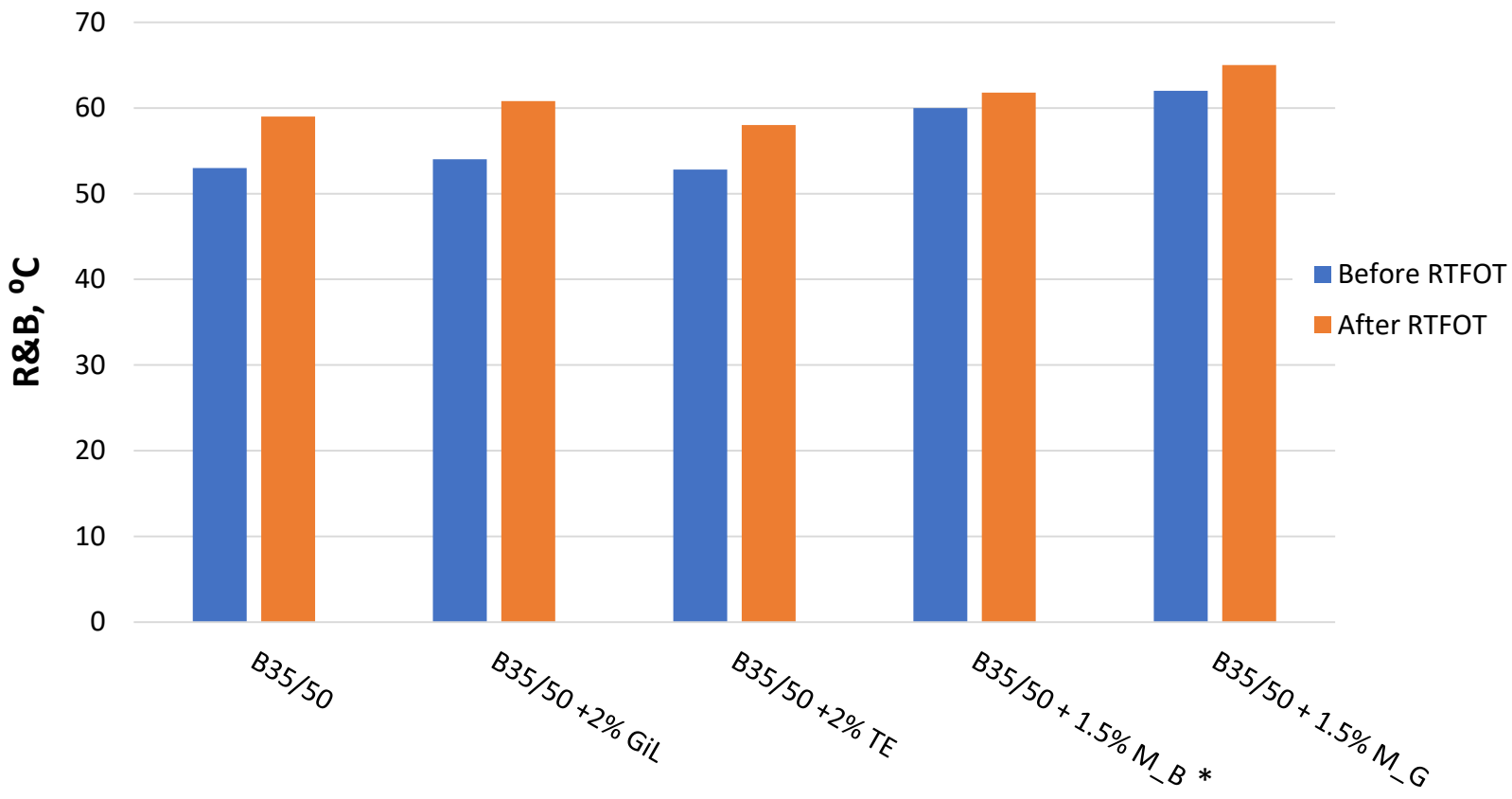


Test Results: B 35/50 + Modifiers

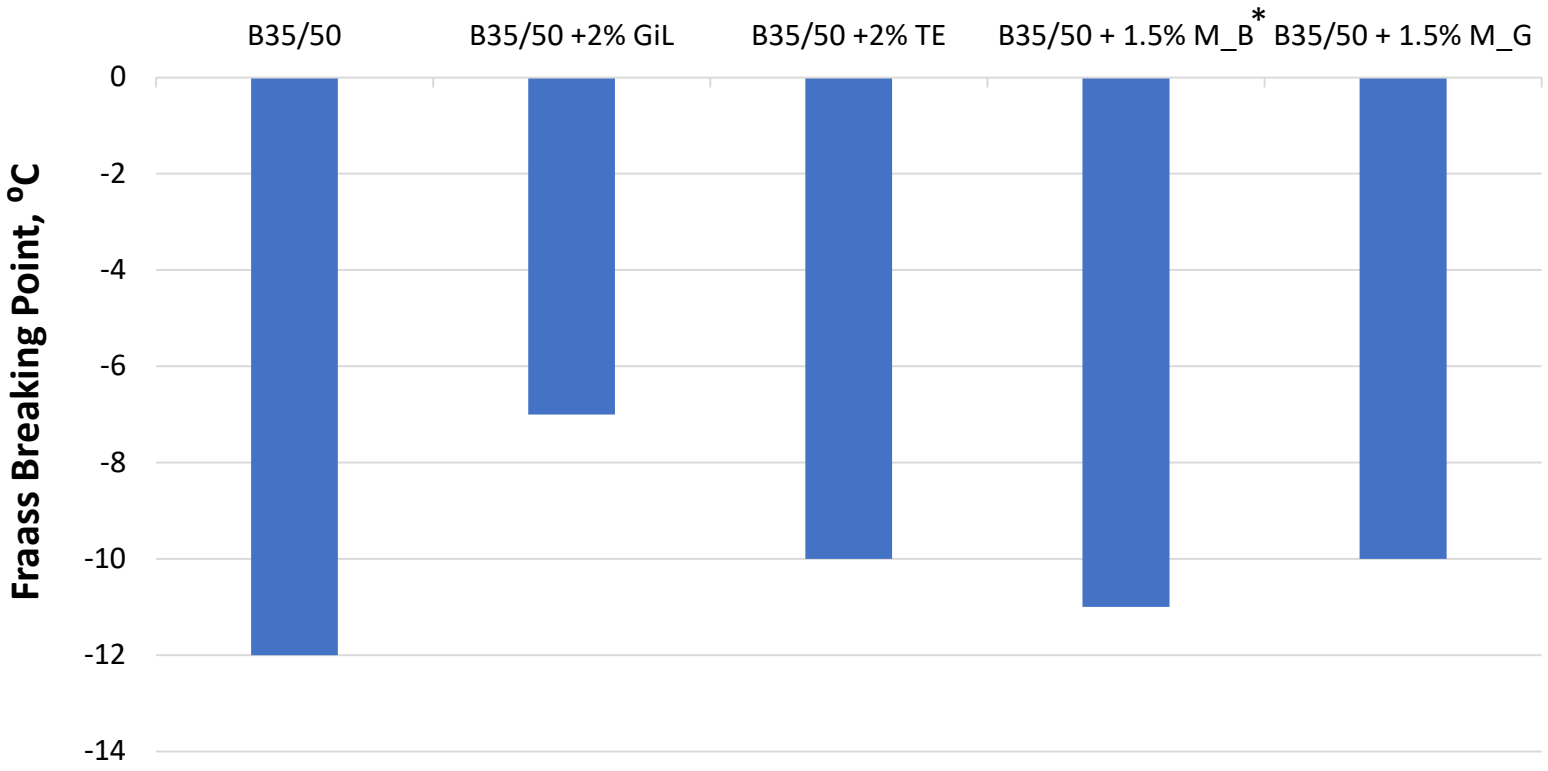
Penetration Values



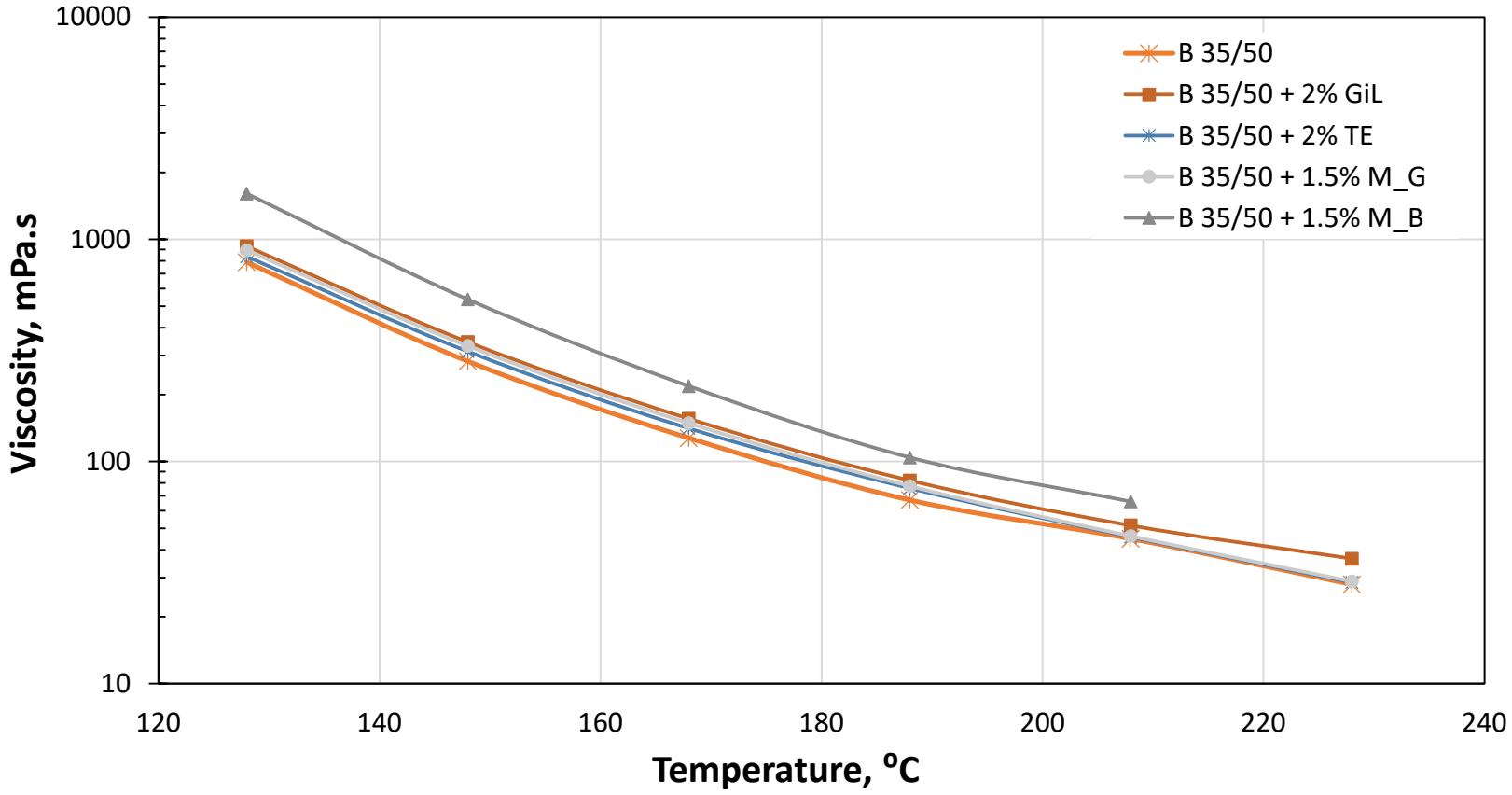
Softening Point



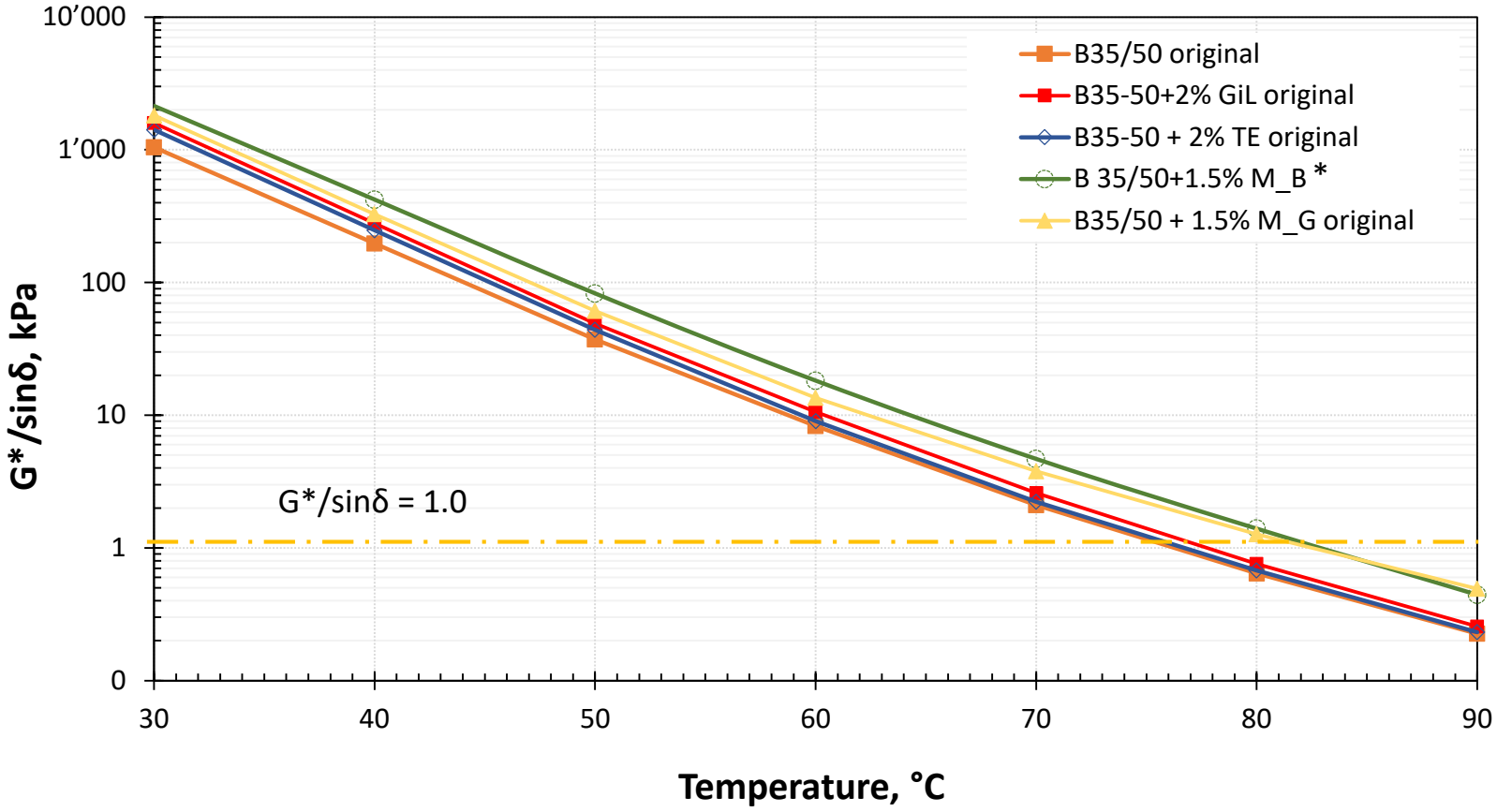
Fraass Breaking Point



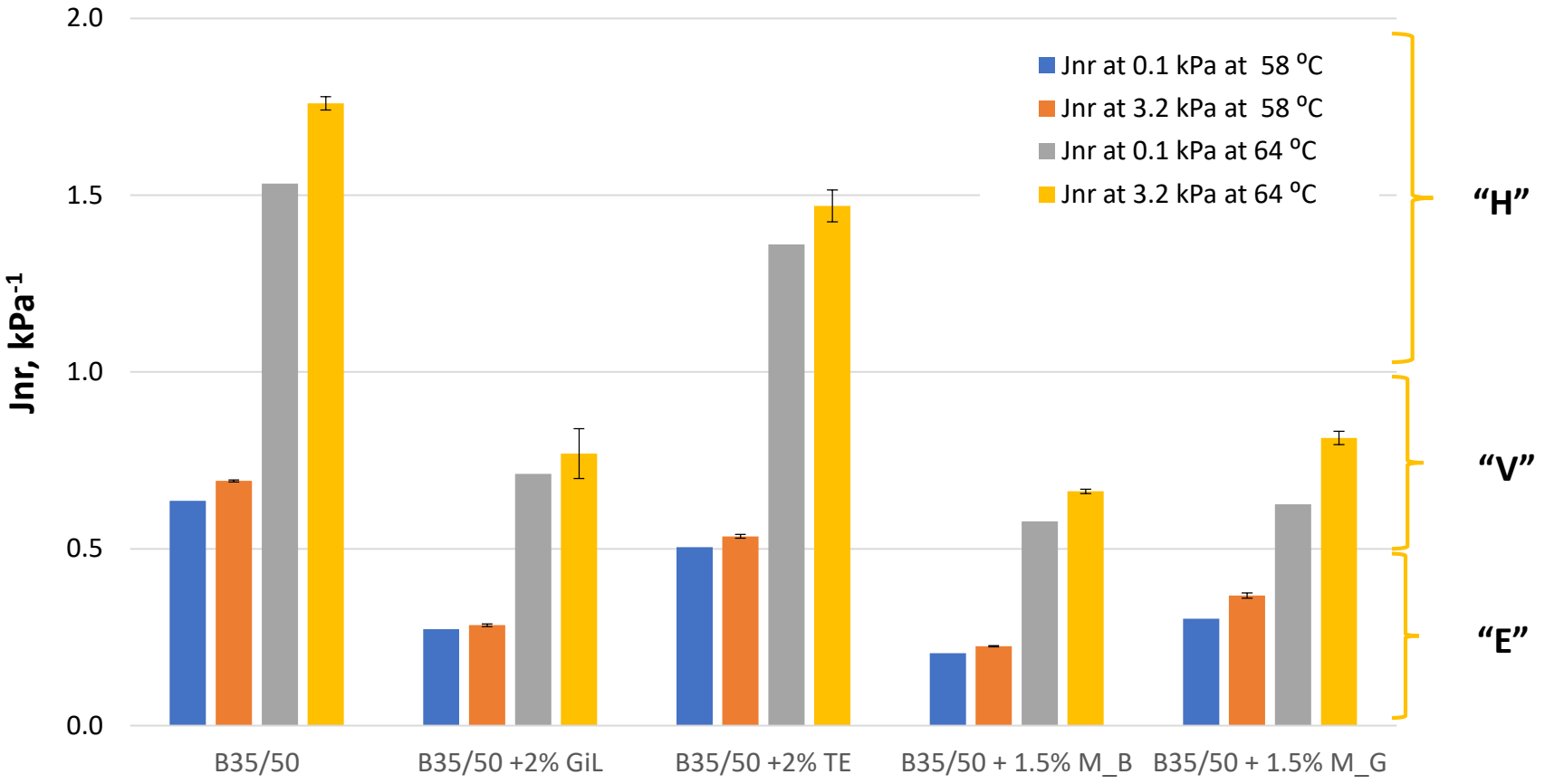
Viscosity - Brookfield



Phase Angle G*/sinδ



J_{nr} Values


2.0
1.5
1.0
0.5
0.0
Jnr, kPa-1
Jnr at 0.1 kPa at 58 °C
Jnr at 3.2 kPa at 58 °C
Jnr at 0.1 kPa at 64 °C
Jnr at 3.2 kPa at 64 °C
"H"
"V"
"E"
B35/50
B35/50 +2% GiL
B35/50 +2% TE
B35/50 + 1.5% M_B
B35/50 + 1.5% M_G

Conclusions

- All PmBs fulfill the original binder requirement of G*/sinδ ≥1.0 kPa at testing temperatures (even temperatures above 80 ^{o} C)
- According to PG specifications, all PmBs can perform well under heavy and slow traffic at 64 ^{o}C
- Rutting resistance in terms of G*/sinδ is the highest for the B35/50 + 2 % M_G and B35/50+ 1.5% M_B
- Rutting resistance in terms of J_{nr} has been improved one grade with the addition of 2% GiL, 1.5 % M_G, and 1.5% M_B
- M_B increases the viscosity significantly at high temperatures (>190^{o}C)
- Modifiers improve the high temperature performance, however they may reduce the low temperature resistance (except M_B) of asphalt binder. Further testing is required to see their low temperature behavior, i.e., BBR

Future Work and Discussion

- Binder testing at low temperatures
- Mix testing
- Correlation of binder tests with asphalt tests
- PG specifications are mainly for AC mixes with air void contents of 4% and above, further investigation is required to find out if these specifications can also apply to Gussasphalt
- MSCR J_{nr} values for hard binders require further investigation

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Thank you!

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