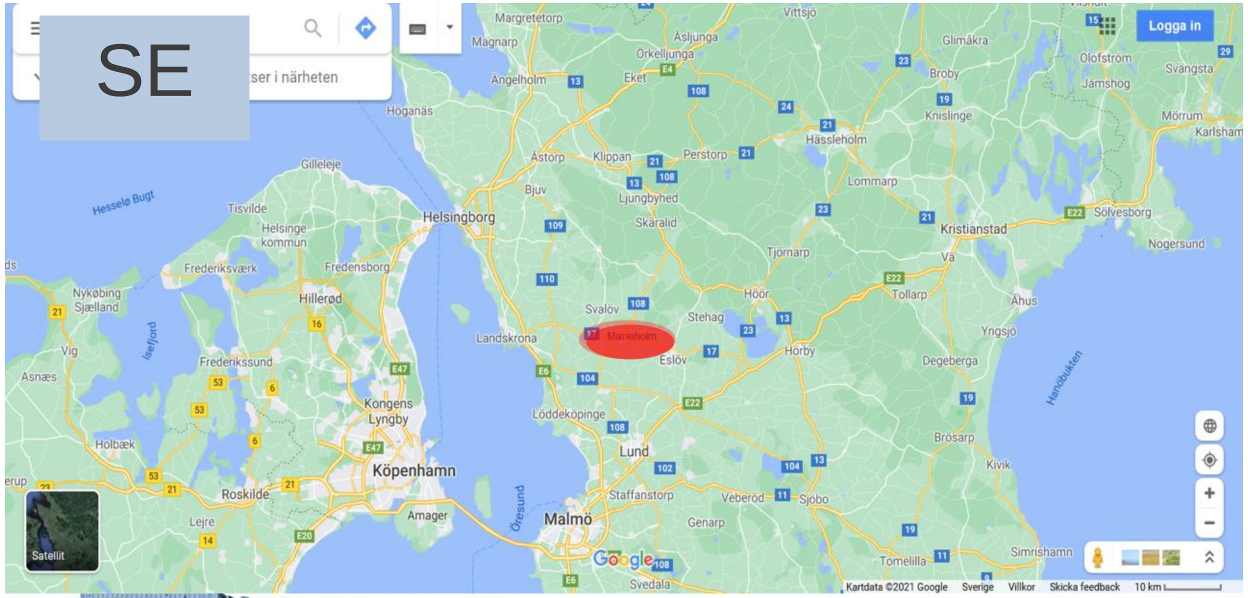
Binder Aging and Durability Validation

Comparison laboratory versus field aging for an unmodified bitumen

Project background

- Determine binder properties related to aging-induced damage, in field sections (WEARING course).
- Set or find limiting levels for these parameters
- Comparing field to laboratory aging

2 sections for which we have the original binder:



Overview

Field sections
- -information
- -sampling asphalt cores
- -nuclear density & void content

Slicing the cores horizontally & Binder recovery

original binder

Aging (RTFOT + PAV-100°C)

Extended aging RTFOT + 2x, 3x, 4x PAV

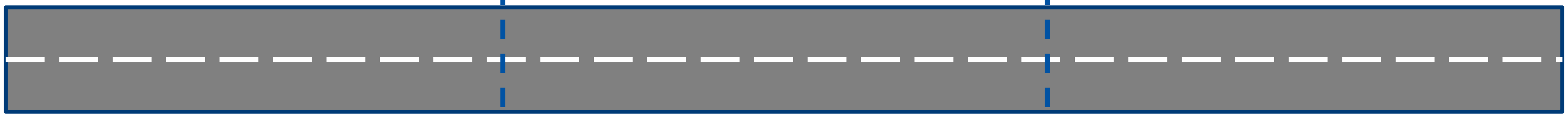
Evaluate the Binder recovery process

Binder testing

Belgium

Construction: 23-04-2009

Coring: 30-11-2020 **11 years**



Wax WMA:

Wax modified binder
Average voids: 5.3
Binder content: 6.1 (m% on aggregate)

Ref HMA:

B50/70
Average voids: 5.6
Binder content: 6.2 (m% on aggregate)

Zeolite WMA:

B50/70
Average voids: 5.9
Binder content: 6.2 (m% on aggregate)

Wax modified binder

50/70 PG 64-22

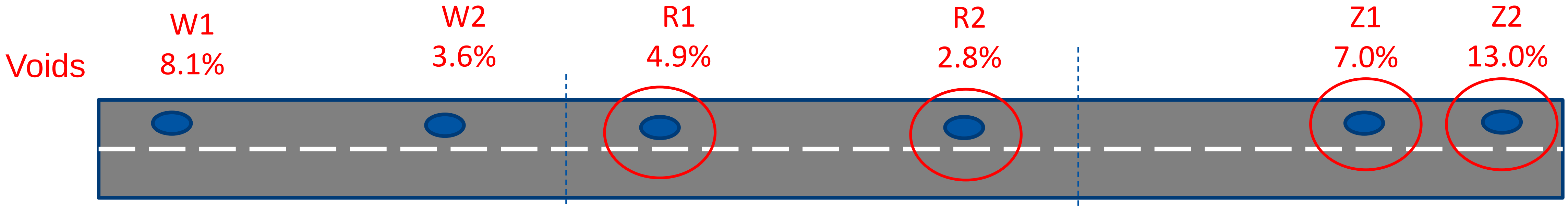
Original binders are still available

Belgium

NYNAS

Construction: 23-04-2009

Coring: 30-11-2020



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Zeolite WMA:

B50/70
Average voids: 5.9
Binder content: 6.2 (m% on aggregate)

Wax modified binder based on same crude origin as B50/70

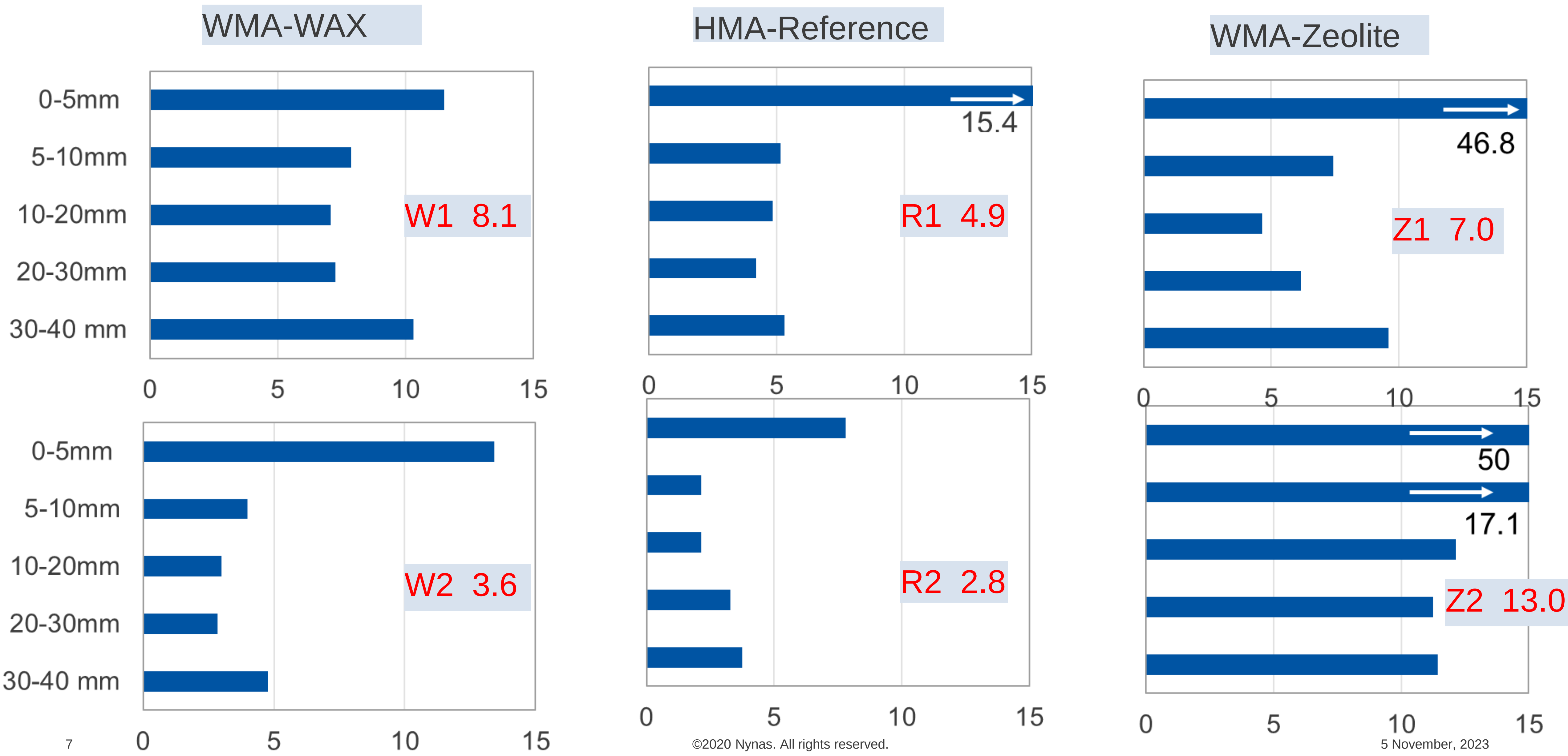
50/70 PG 64-22

Points for which the binder has been recovered and tested

Original binders are still avialable

Belgium

Nuclear density – wearing course – void %



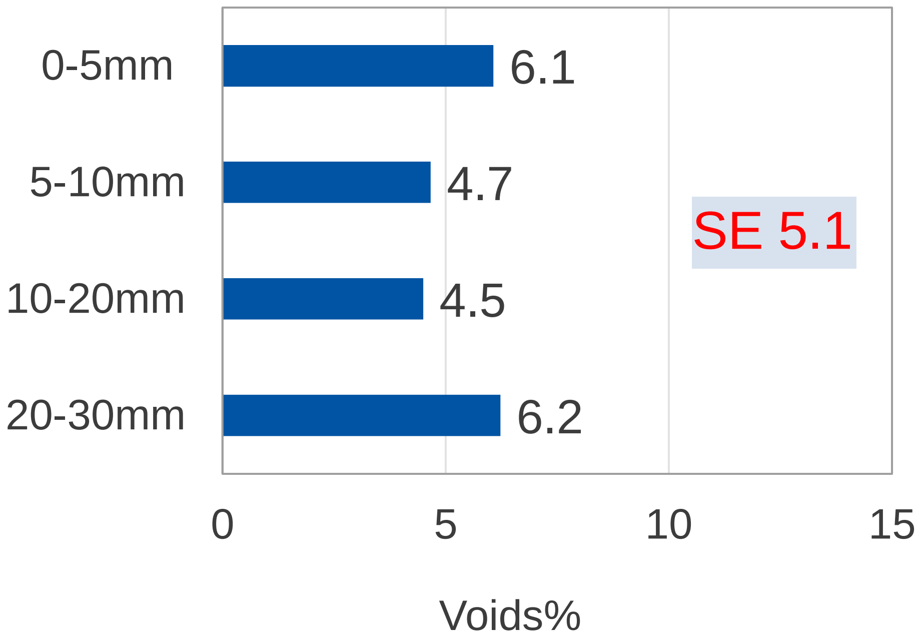
Sweden

RV-17: Field sampling 28-10-2020 **12 years**

Layer		Binder	Binder %	Air voids	Construction
Wearing	30 mm ABT16	70/100	6.0%	1.5 - 3.5%	2008
Binder	40 mm ABb16	70/100	5.0%	3.0 - 5.0%	2007
Base	50 mm AG22	160/220	4.2%	3.0 - 6.0%	2007

Sweden

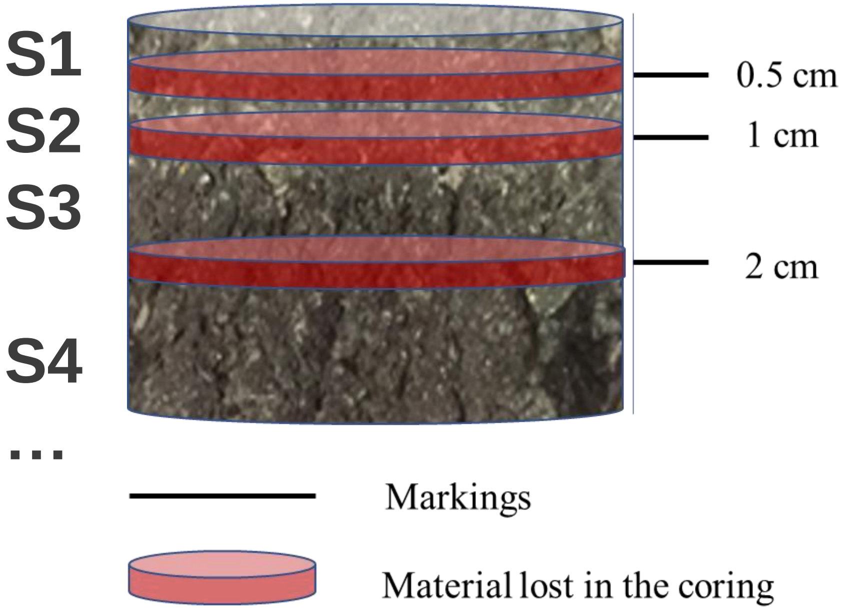
Nuclear density – wearing course – void %



5 cores used for binder recovery

(between wheel path)

Slicing and binder recovery



Automated asphalt analyzer (EN 12697)

Trichloro ethylene was the solvent

- **BE section: 40 mm wearing course** **5 slices** *(except for Z2, the location with 13.0% voids)*
- **SE section: 30 mm wearing** **4 slices**

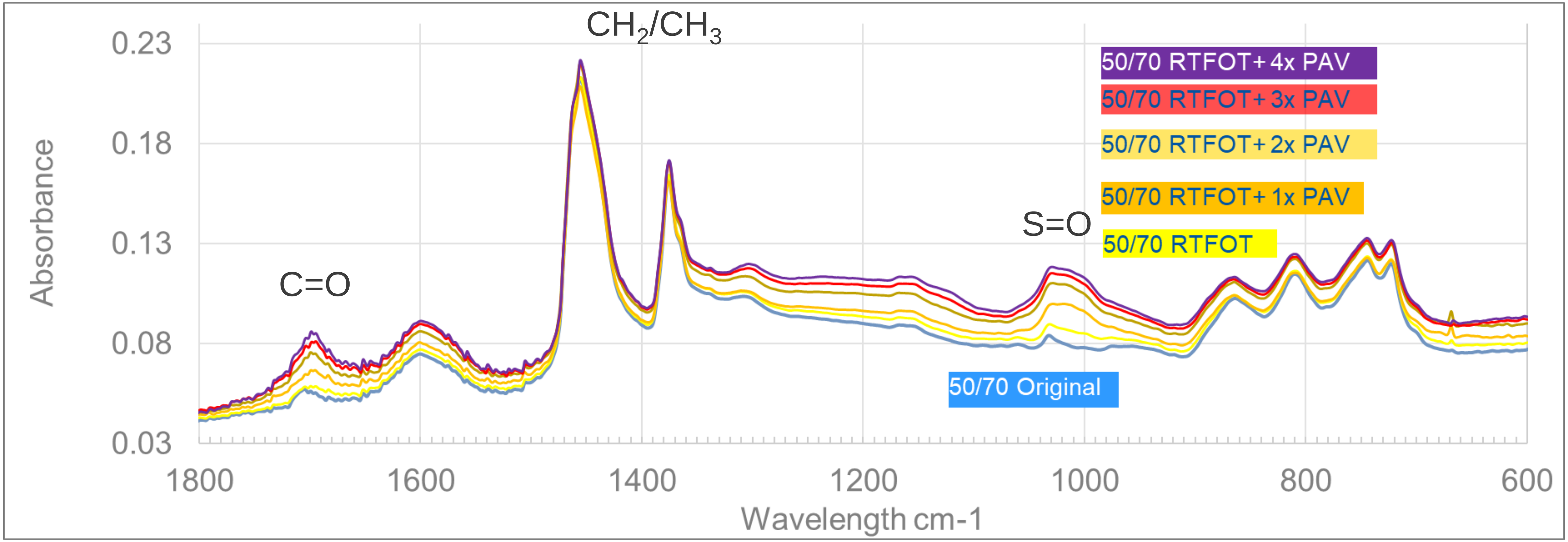
Binder tests

- **FIR** *(attenuated total reflection)* → C=O and S=O indices

- **DSR** *(plate-plate, plate diameter is indicated)* → Rheological parameters (Rhea software beta v.4)
  - Linear Visco Elastic range
    - 4 mm (10°C to -24°C) *(strain 0.02%)*
    - 8 mm (10°C to 50°C) *(strain 0.05%)*
    - 25 mm (50°C to 90°C) *(strain 1%)*
  - Non-linear → Brittle – ductile behavior
    - 4 mm stress-strain sweep at 10°C 10Hz

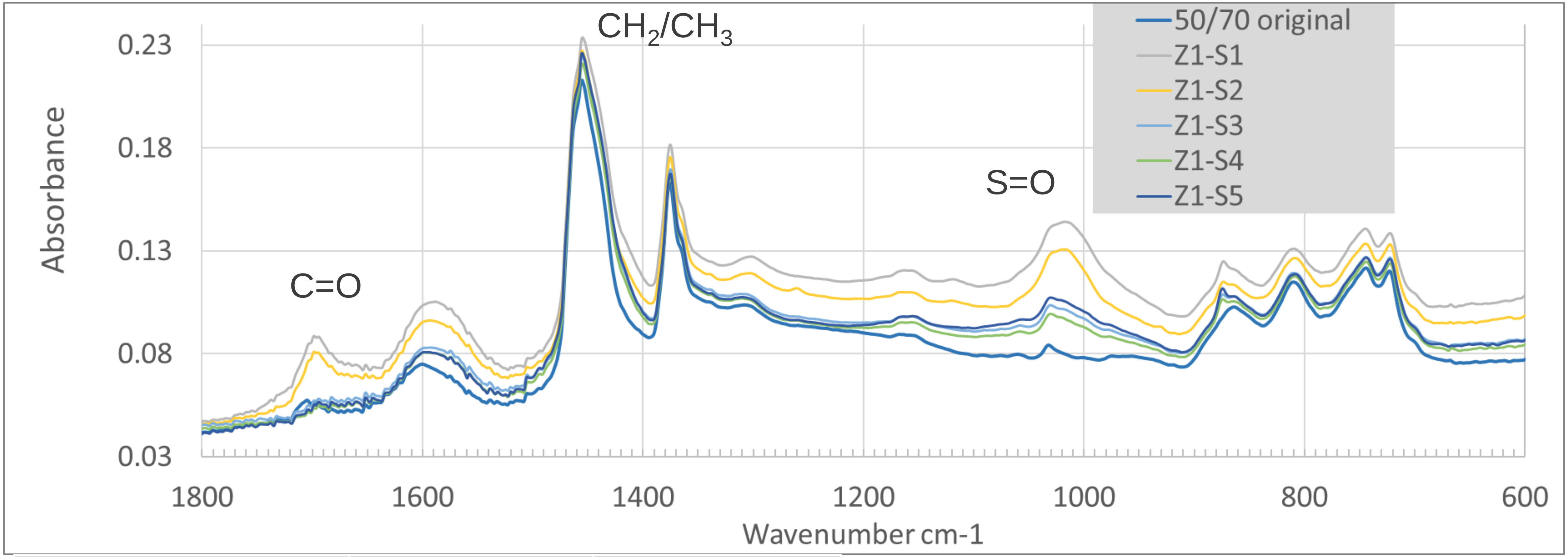
- **GPC on selected samples** → Molecular weight(s)

Binder tests: FTIR



Functional group	Wavenumber, cm^{-1}	Index
CH_2 and CH_3 (A_{ref})	1513-1326	A_{ref}
Carbonyl group ($A_{C=O}$)	1753-1635	$I_{C=O} = A_{C=O} / A_{ref}$
Sulfoxide group ($A_{S=O}$)	1082-980	$I_{S=O} = A_{S=O} / A_{ref}$

Binder tests: FTIR



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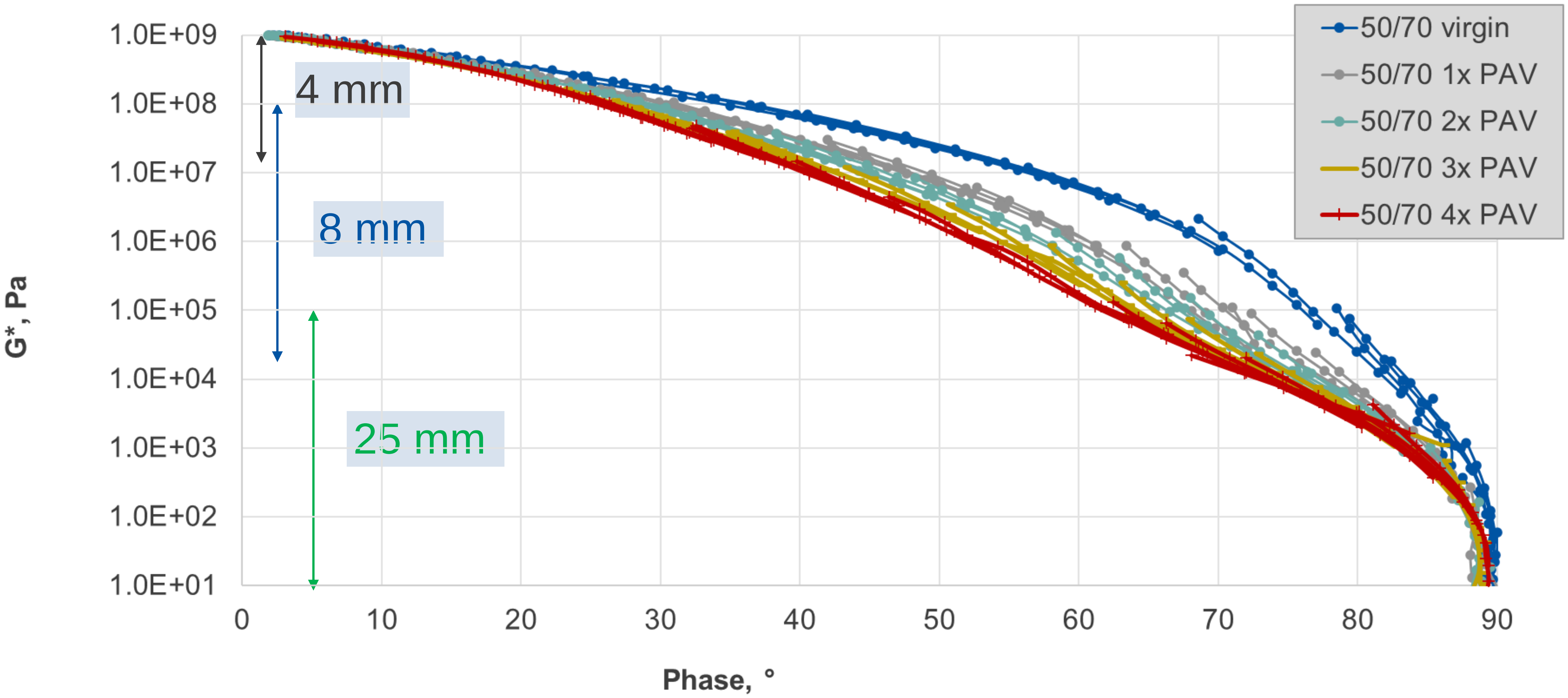
Binder tests: Rheology



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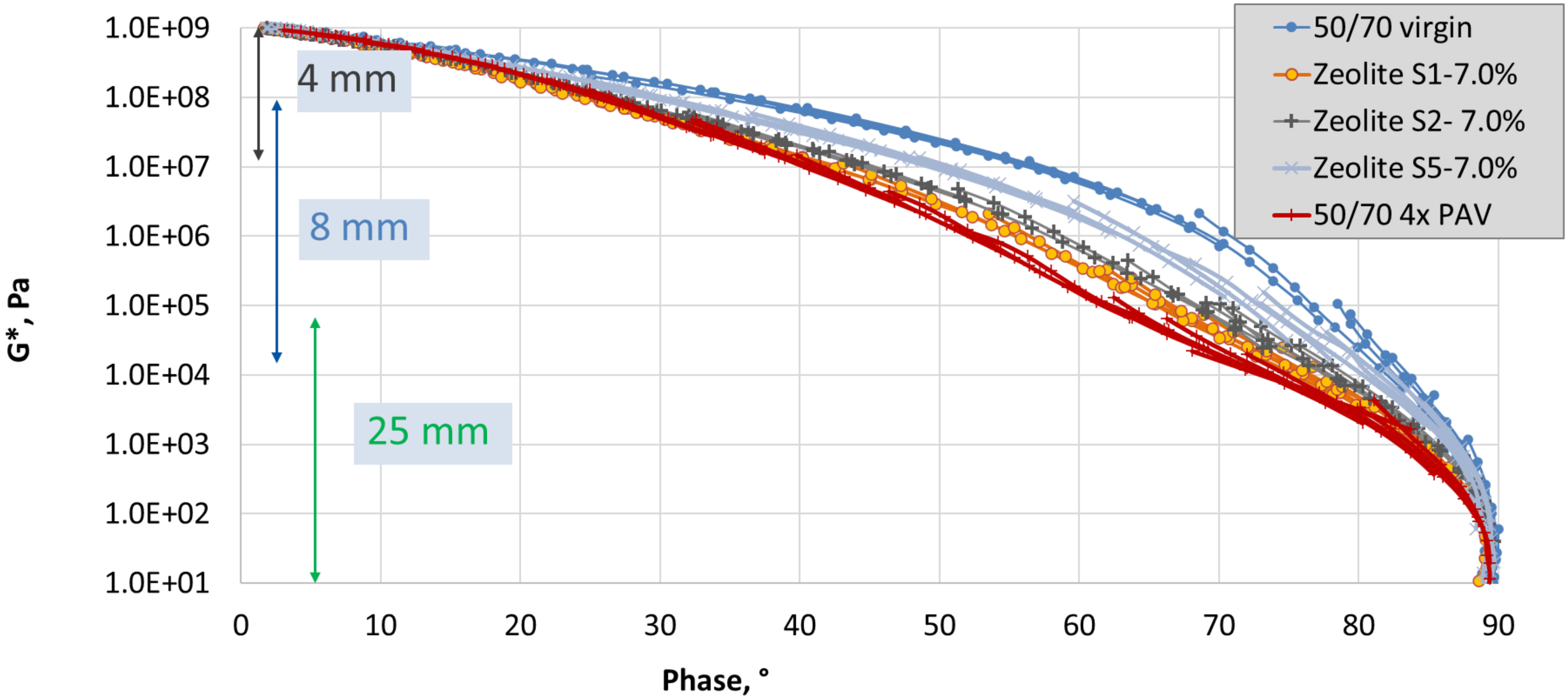
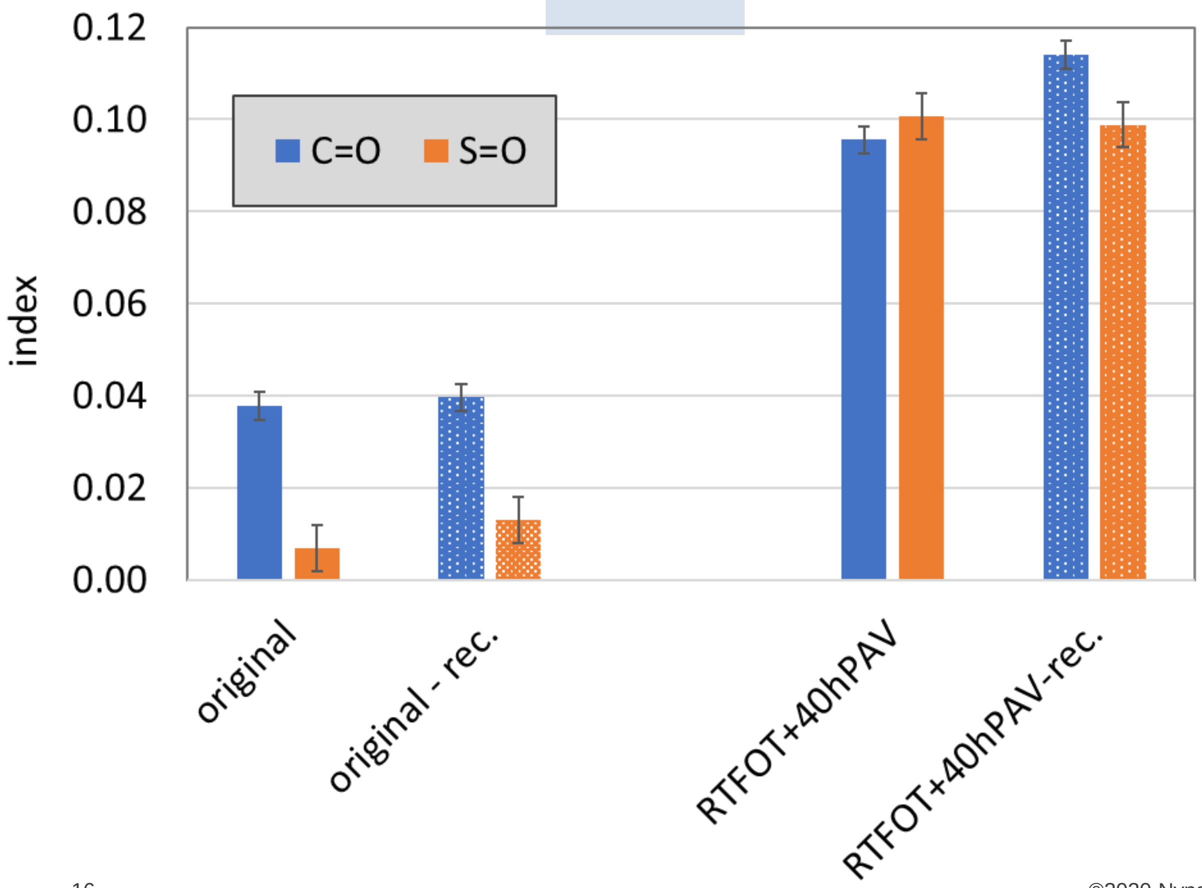


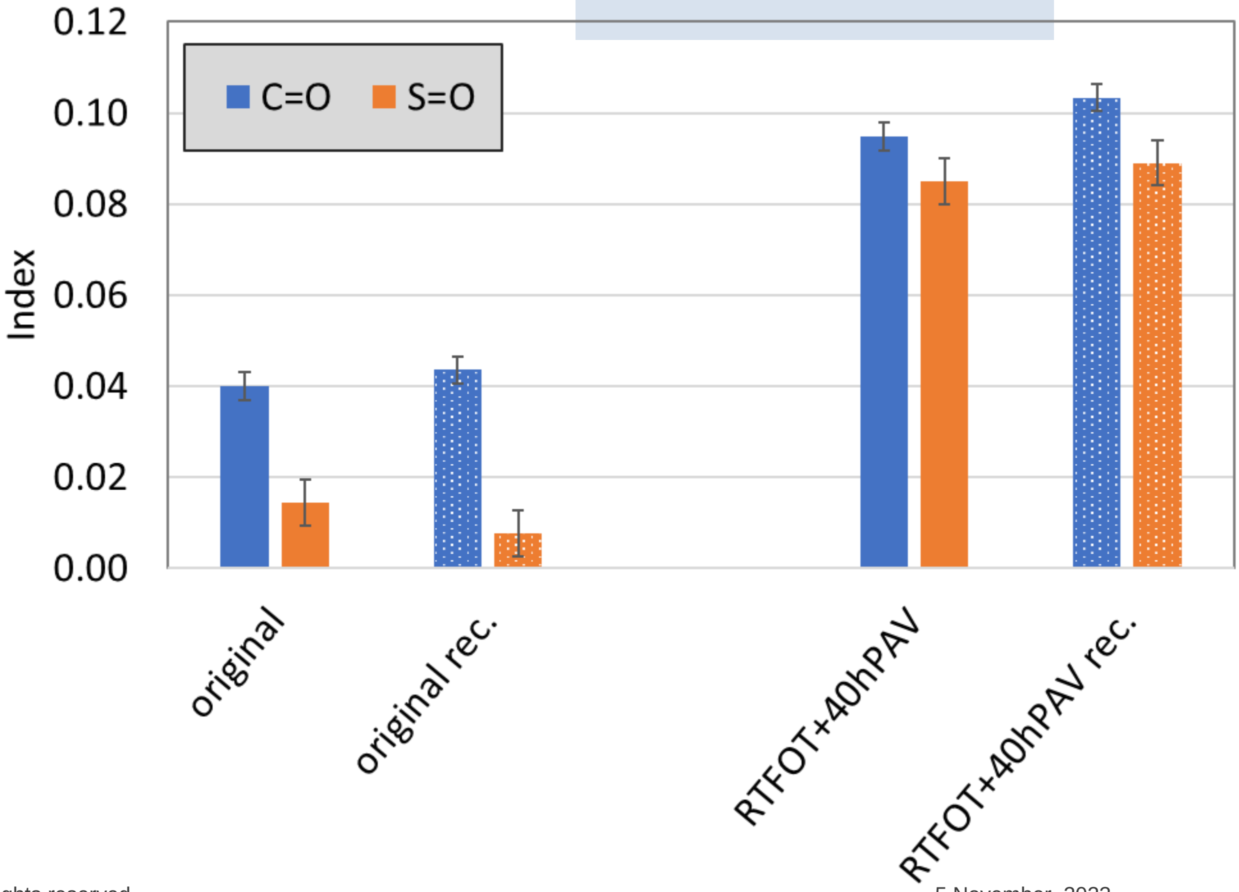
Recovery Check

- <u>4 binders were recovered (no asphalt mixing)</u>
  - The unmodified binder (50/70) (before and after aging)
  - The wax-modified binder (before and after aging)

50/70



Wax modified



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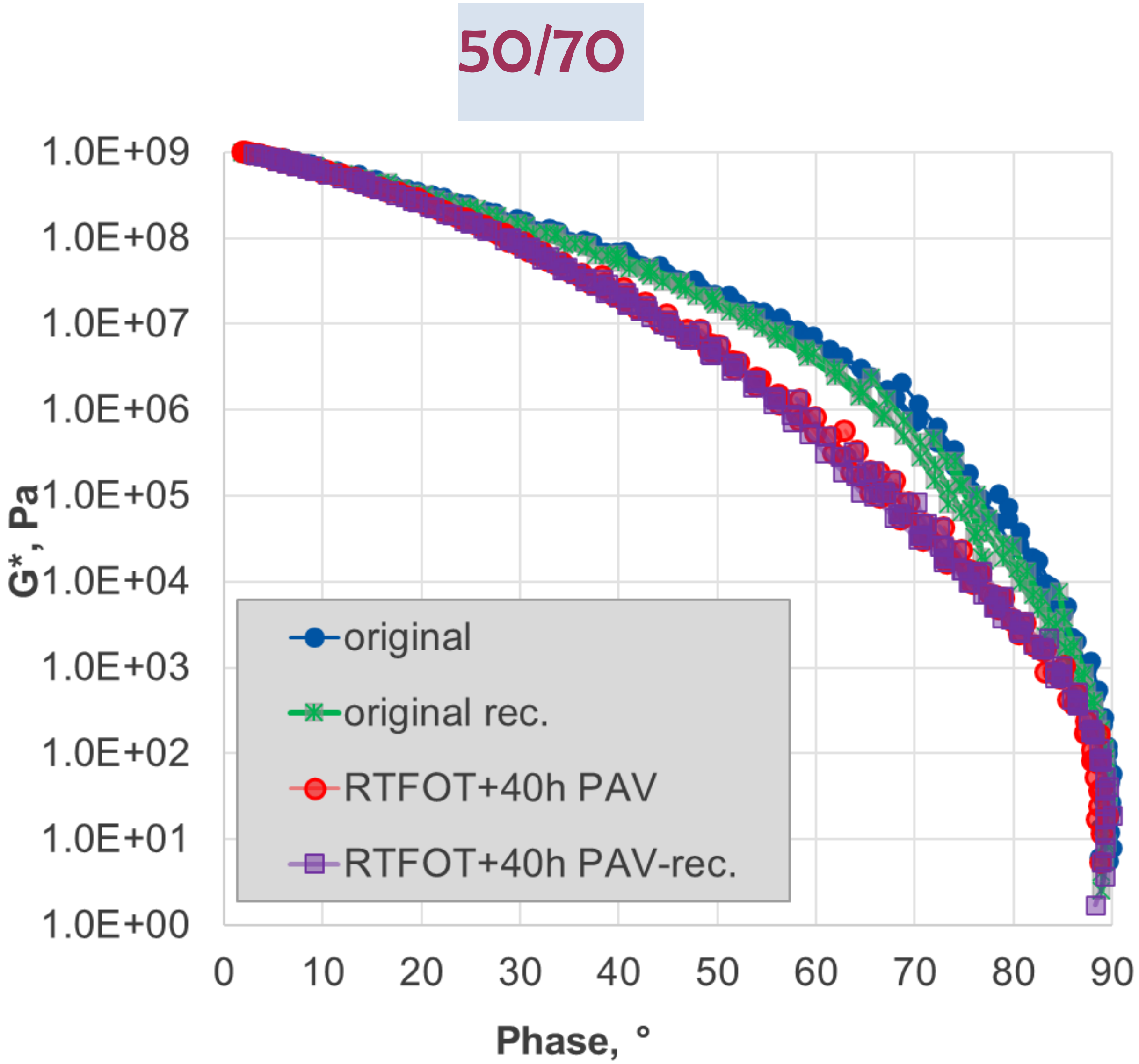
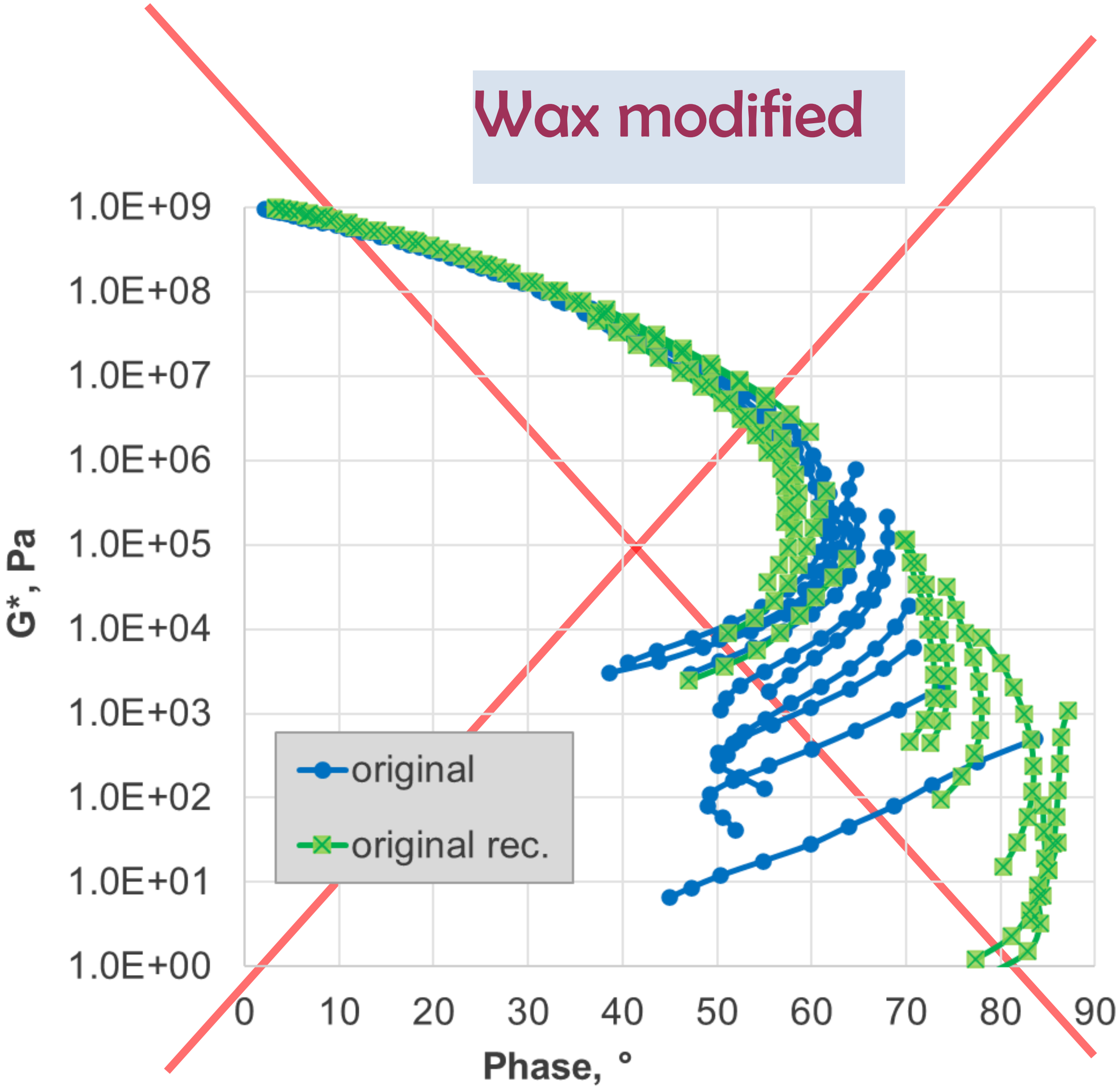
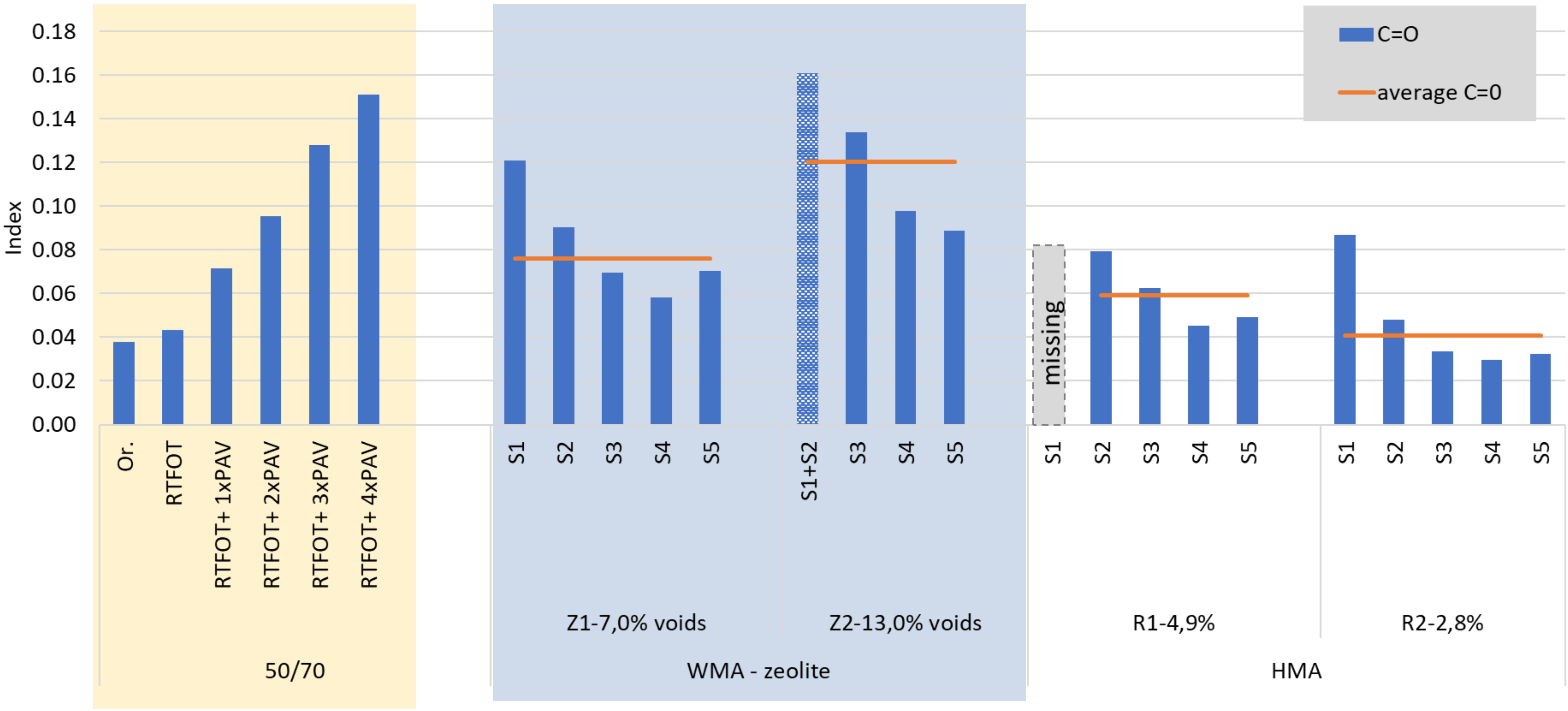




Comparison field and lab aging: FTIR

- BE section C=O



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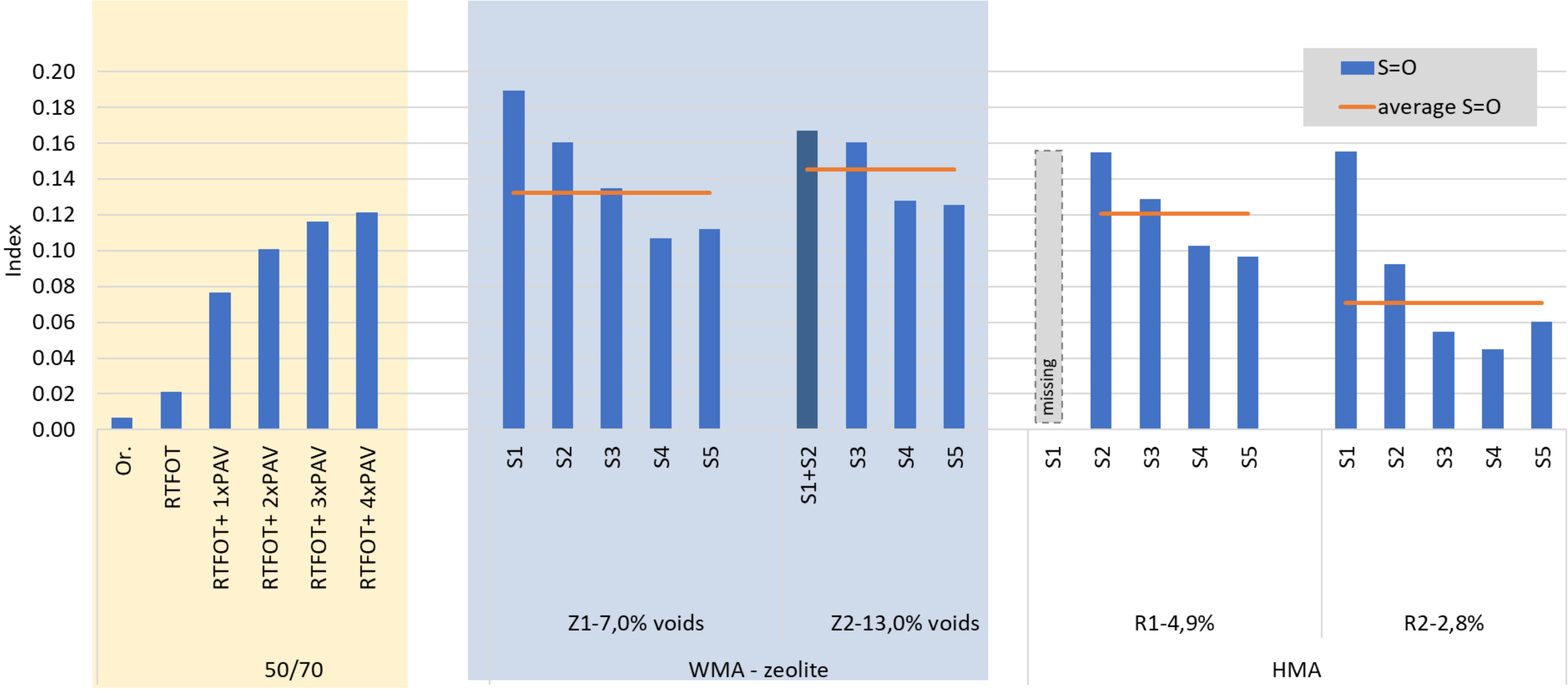
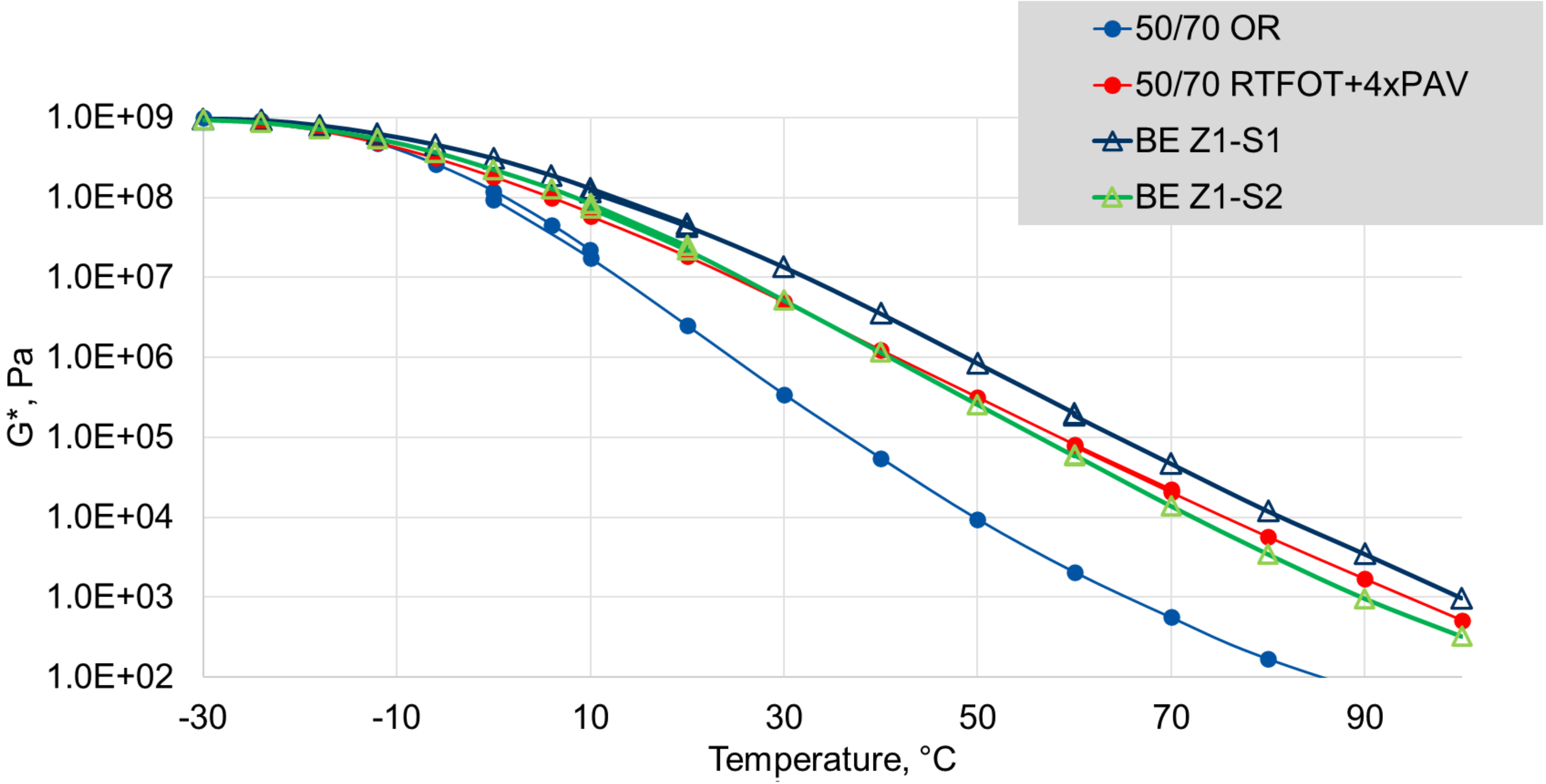


Comparison field and lab aging: RHEOLOGY

- Rheology temperature sweep – 1Hz



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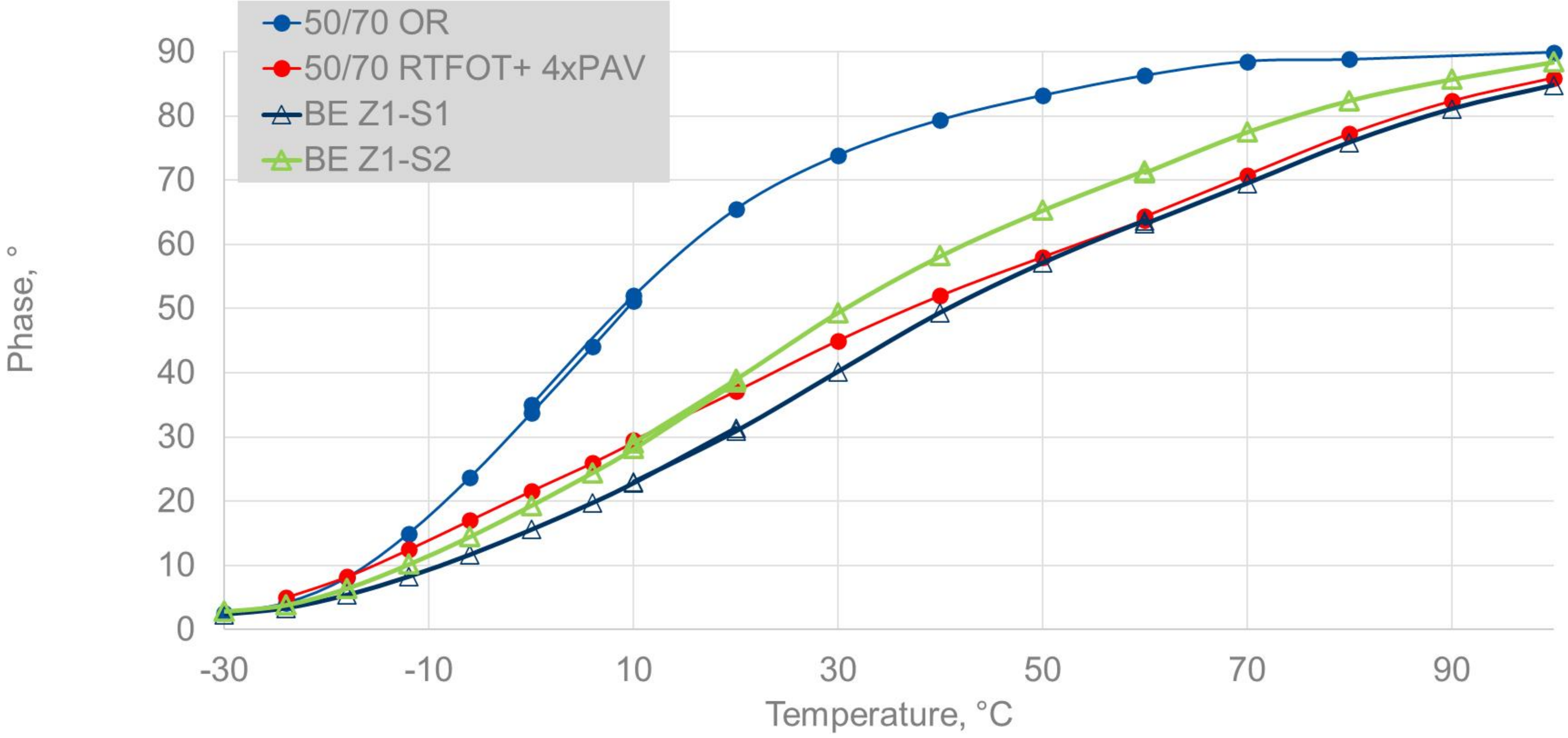
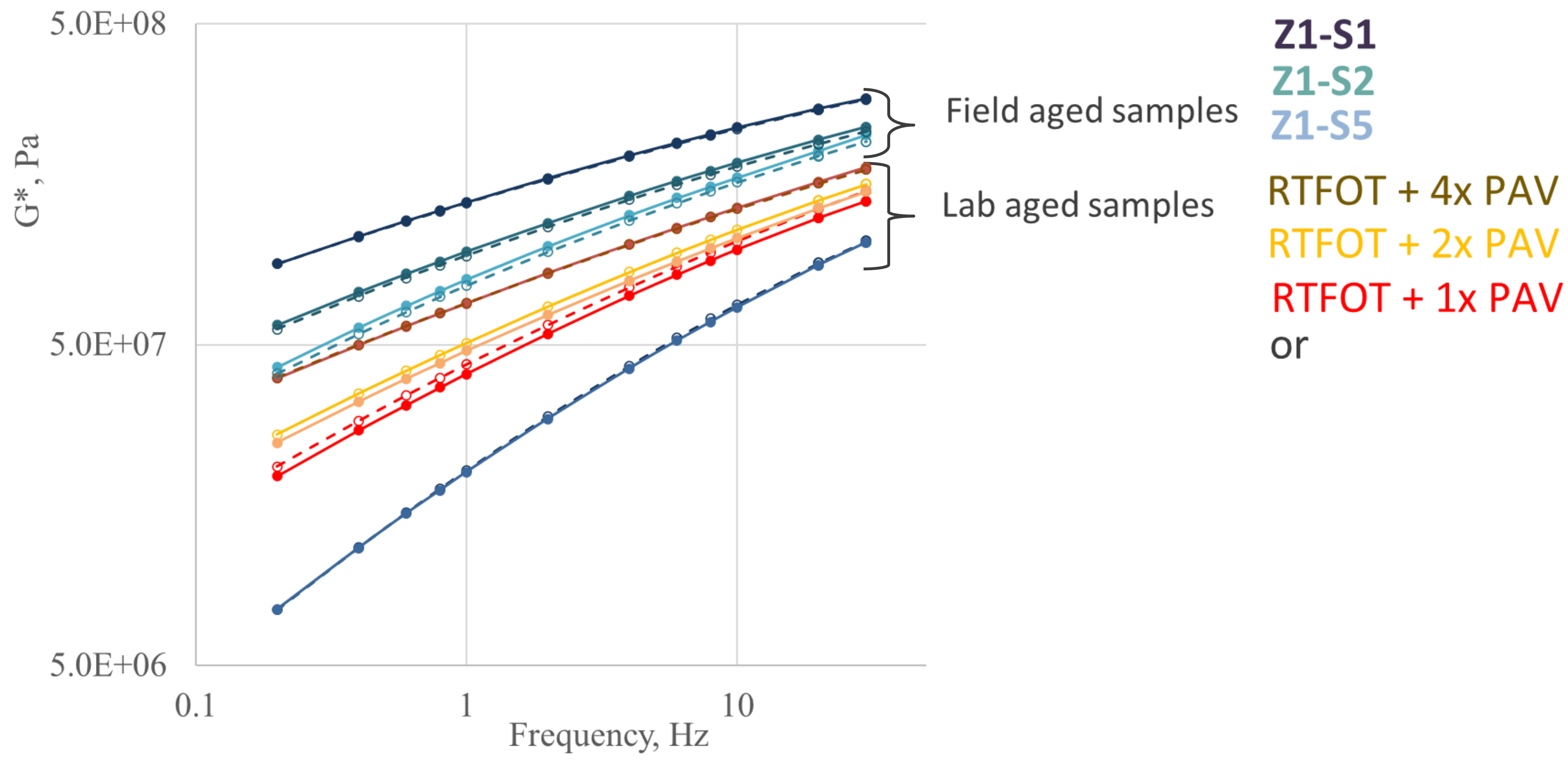


Comparison field and lab aging: RHEOLOGY

- Frequency sweep at 10°C BE-Z1 (7.0% voids)



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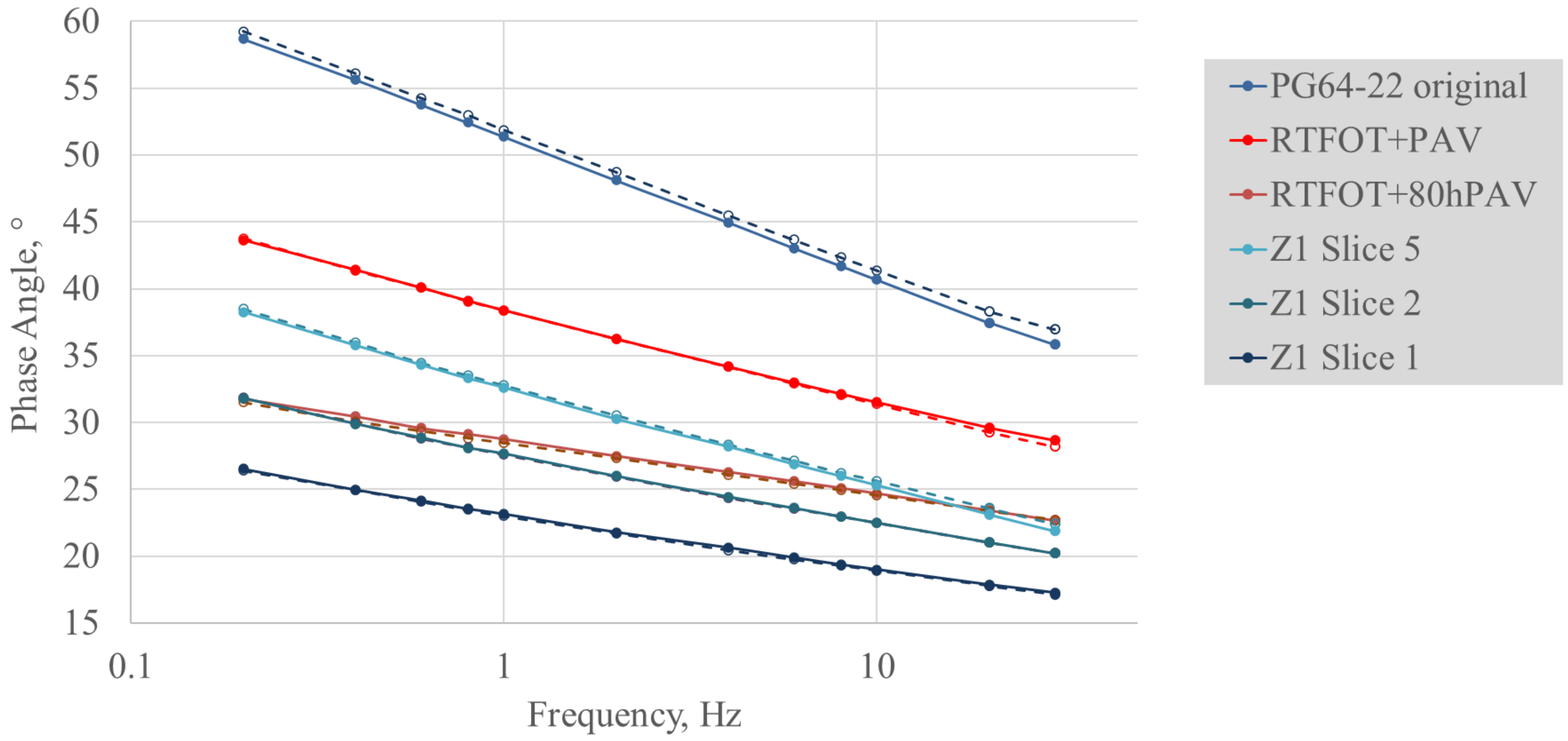
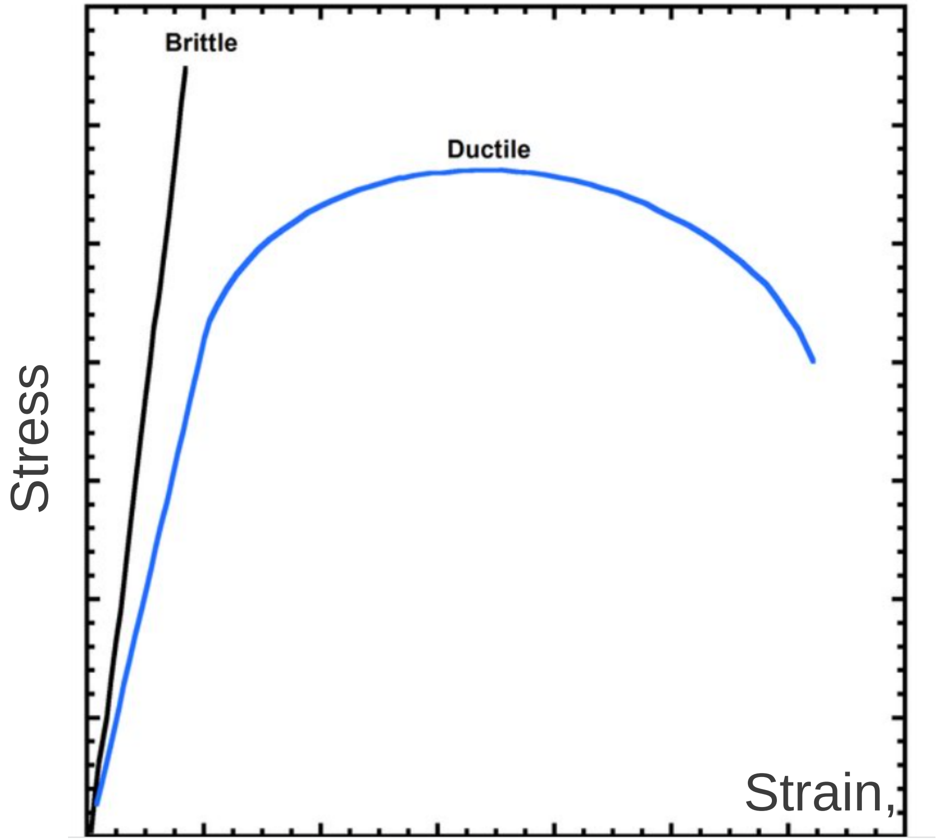


Rheology – NON linear visco elastic range

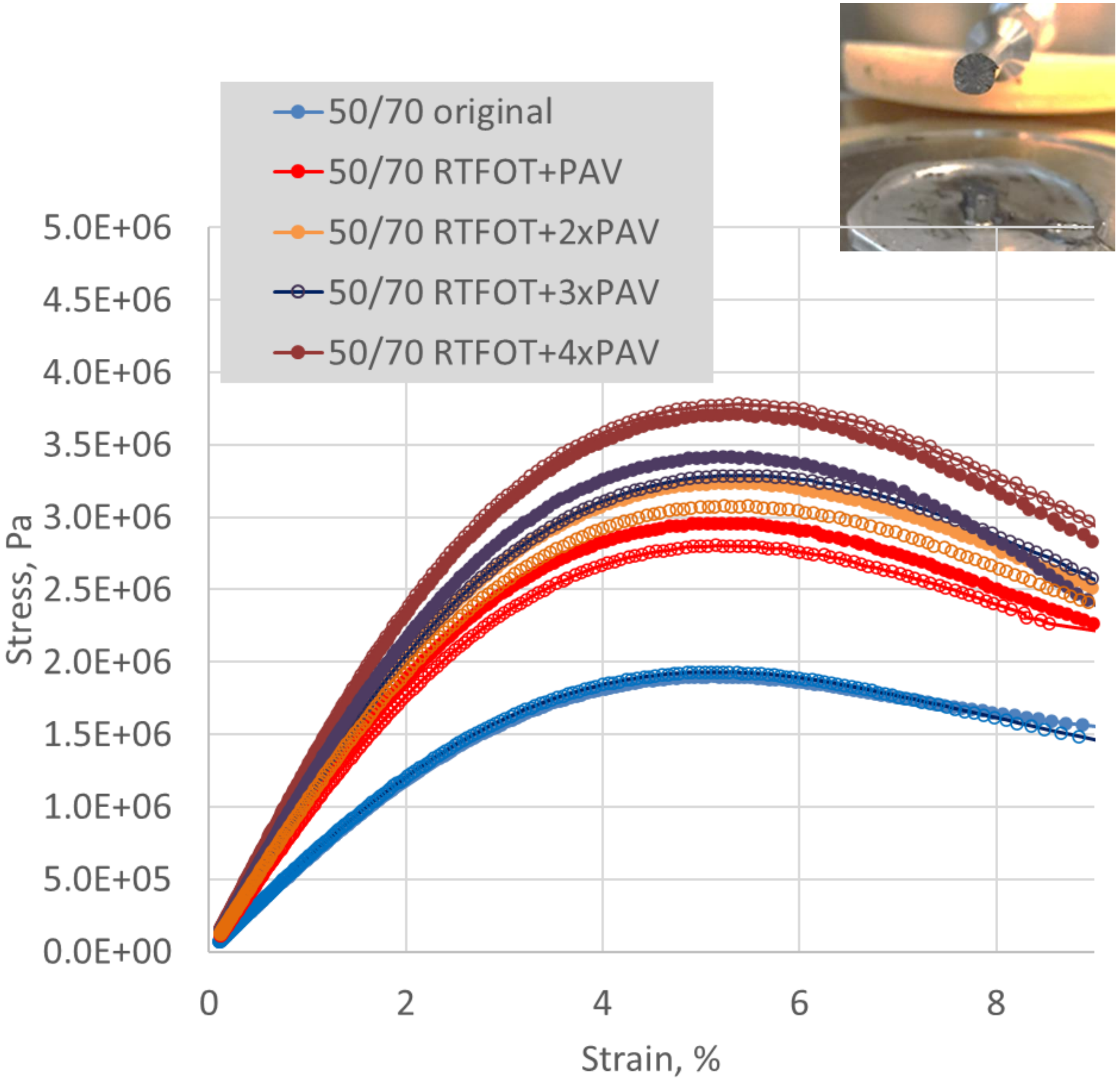
- Properties at large deformation - fracture
- Is there a relation to the LVE properties?
- Amplitude sweep from strain = 0,1 ... 30 % logarithmic at 10°C (10Hz)

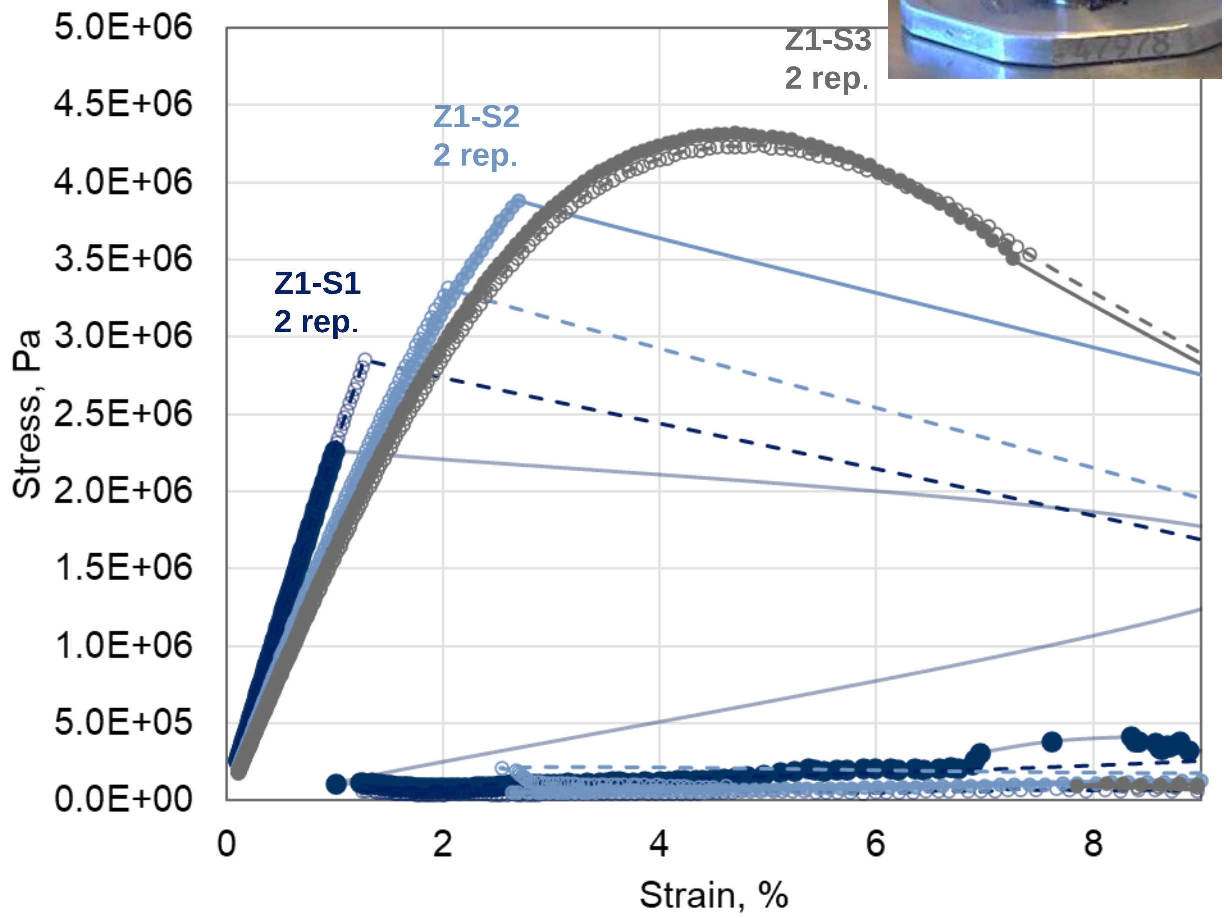


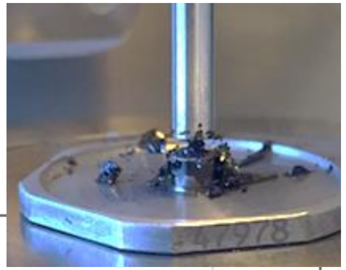
Brittle: failure before reaching a maximum in the stress strain curve

Ductile: failure after this maximum

Rheology – NON linear visco elastic range







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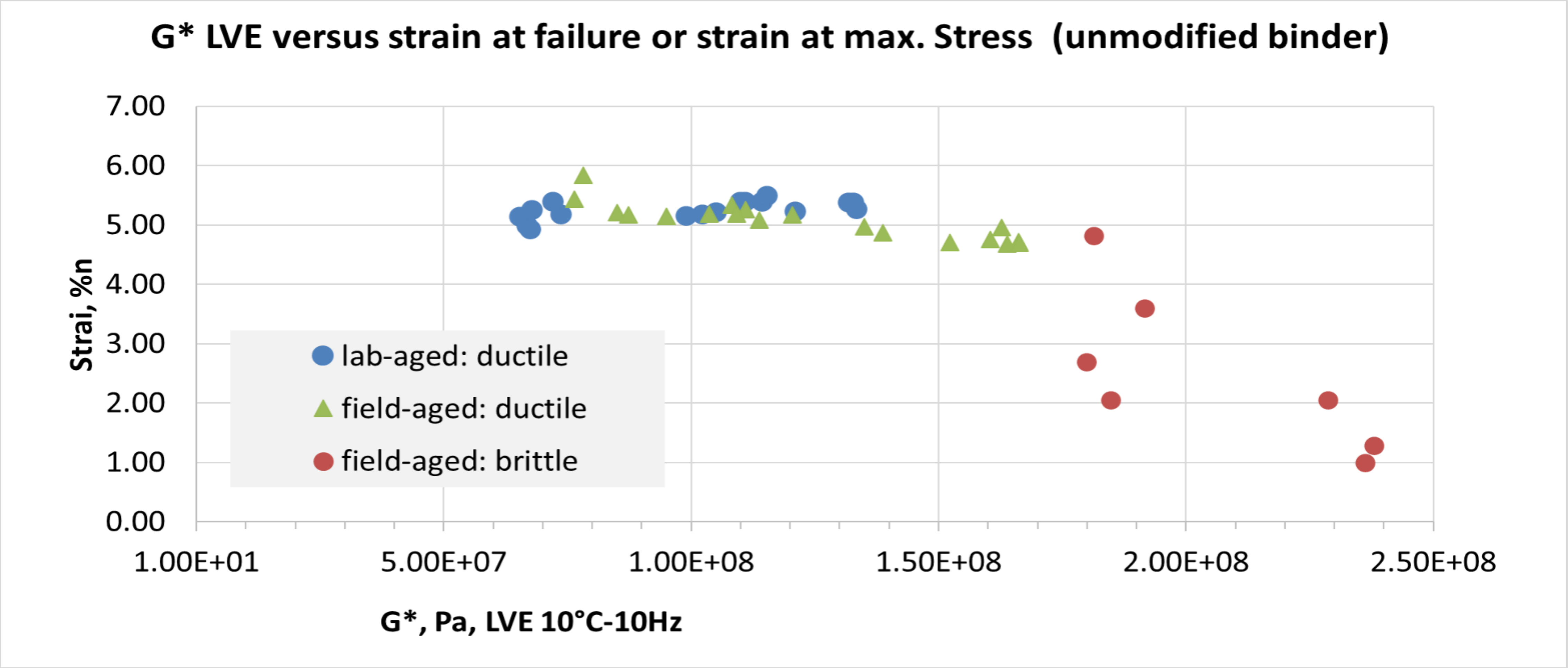


Limiting low temperatures

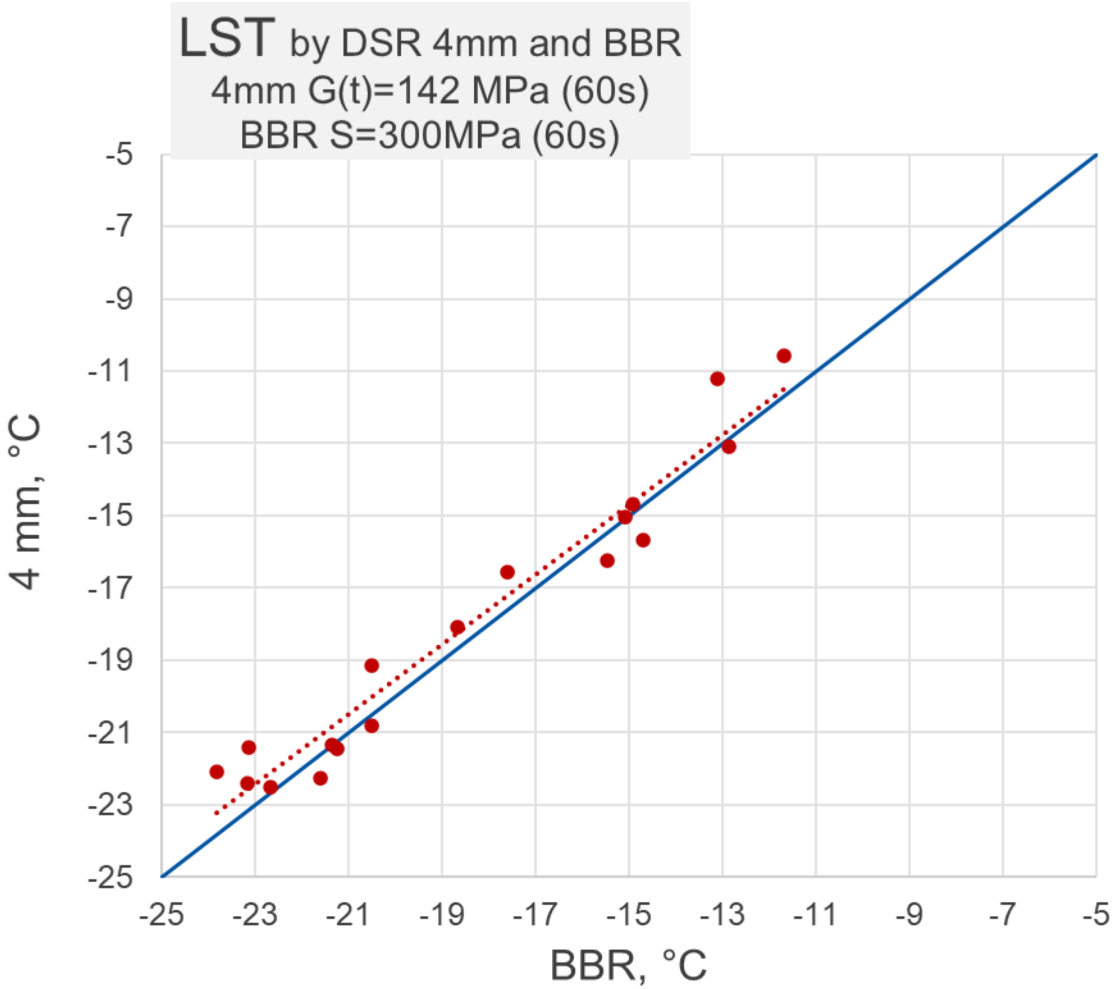
BBR = flexural creep test

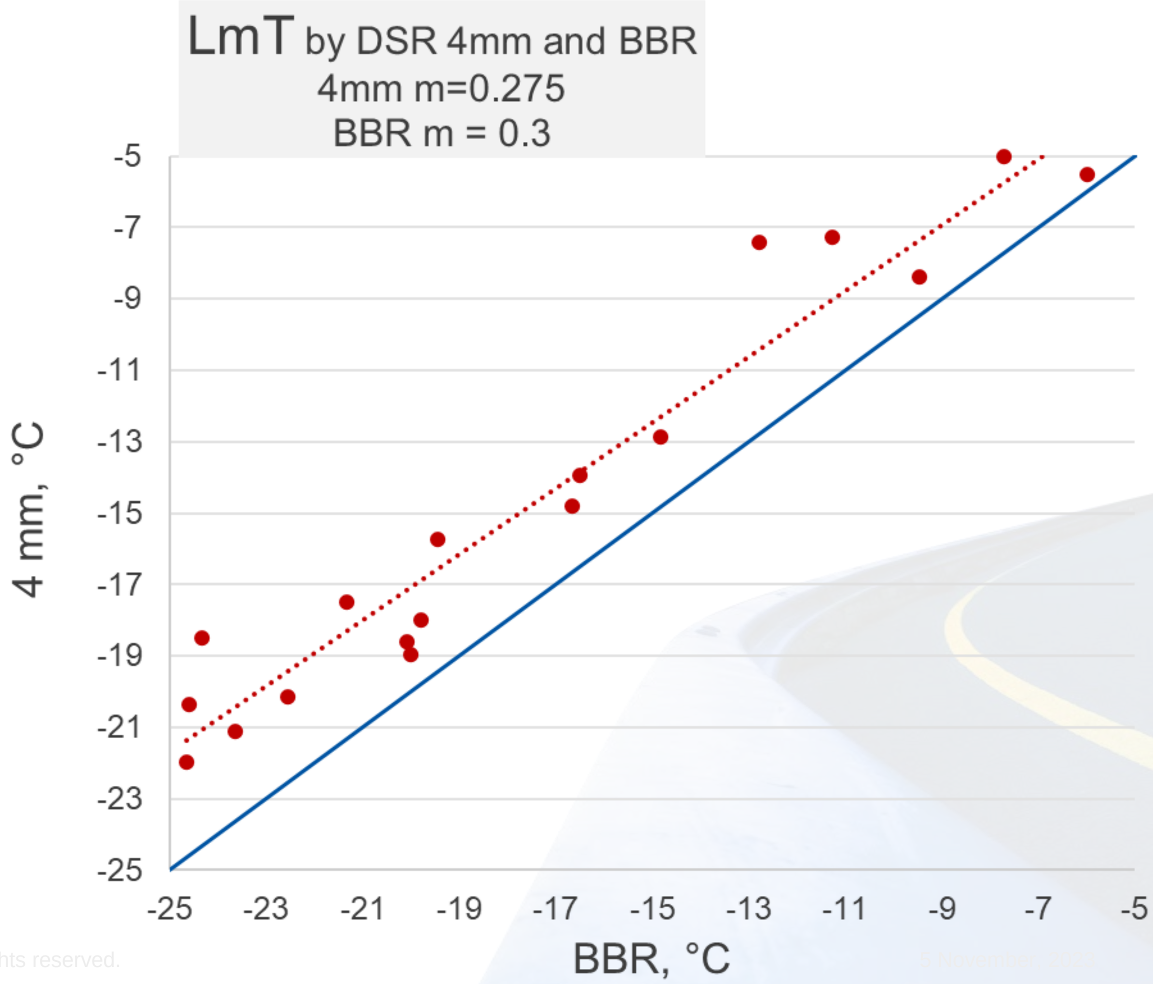
- LST_{BBR} = S(t) = 300MPa
- LmT_{BBR} = slope = 0.3

DSR = shear oscillation transformed to a creep test

LST_{DSR} = G(t) = 142 MPa (t= 60s loading time)

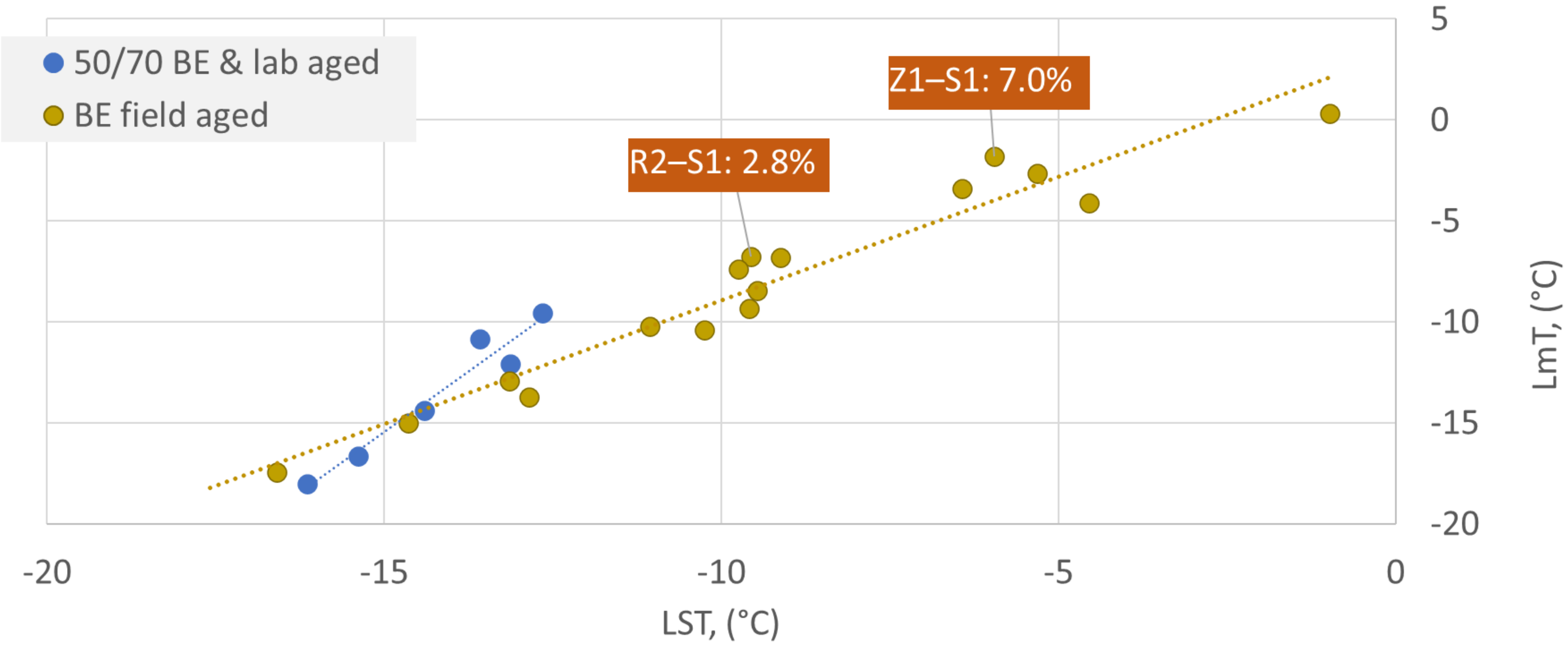
LmT_{DSR} = slope = 0.275 (t= 60s loading time)





Comparison field and lab aging: RHEOLOGY

- Limiting low temperatures: 4mm LST (142 MPa) and 4mm LmT (0.275)



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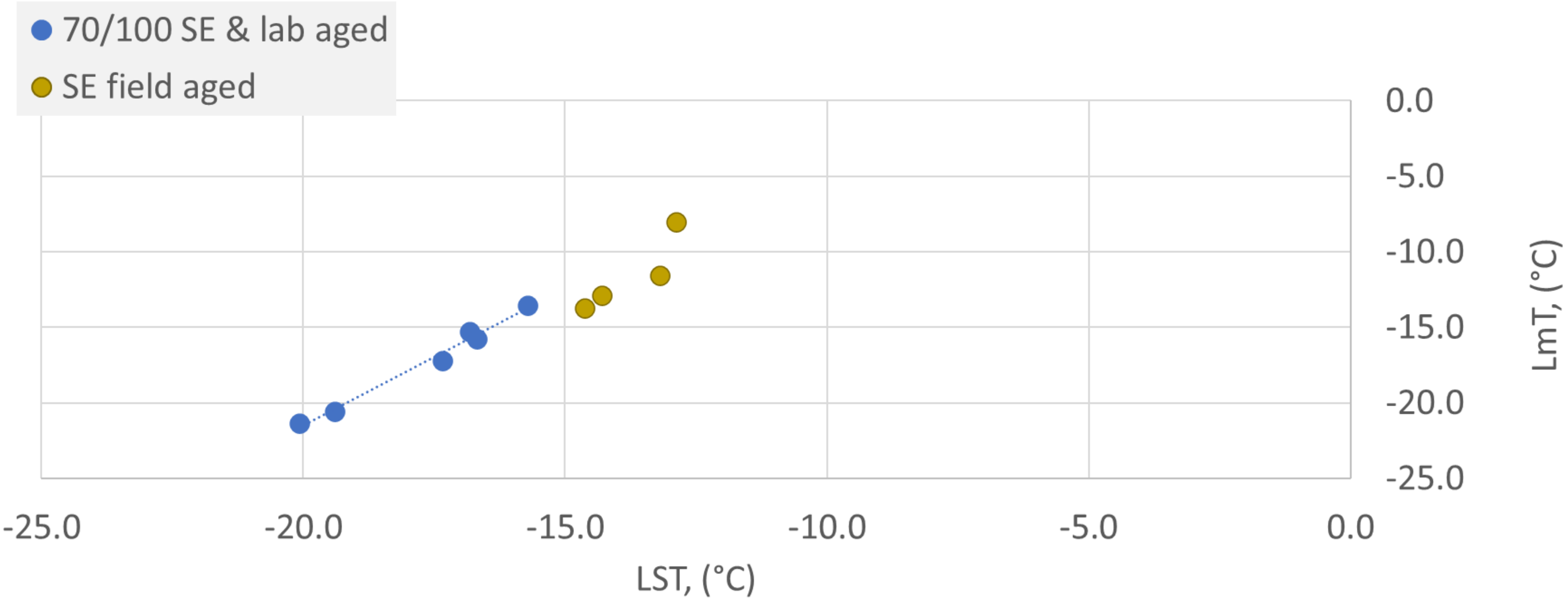
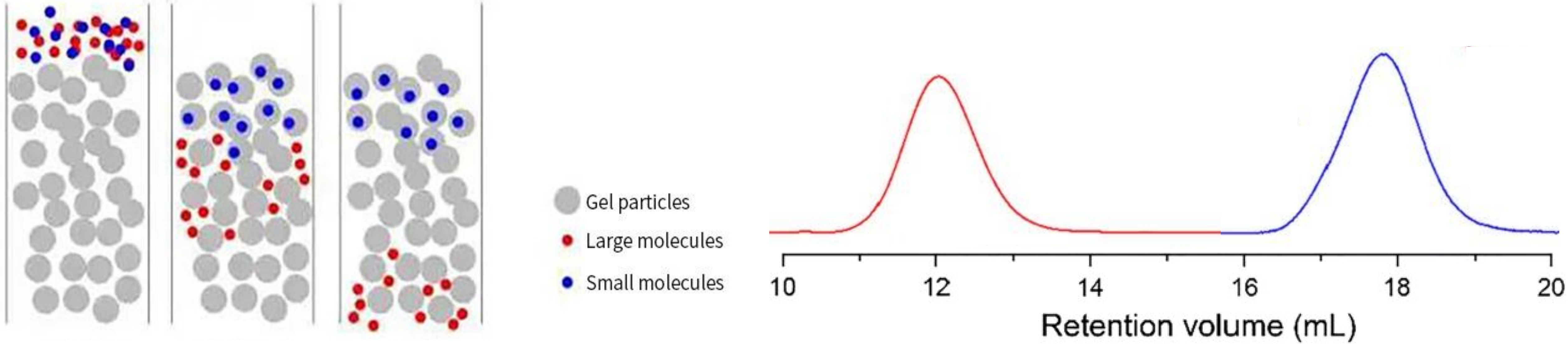


GPC (gel permeation chromatography): molecular weight

- Dilute solution,
- Inject the sample on a porous column
- Follow elution time versus detector response (refractive index)



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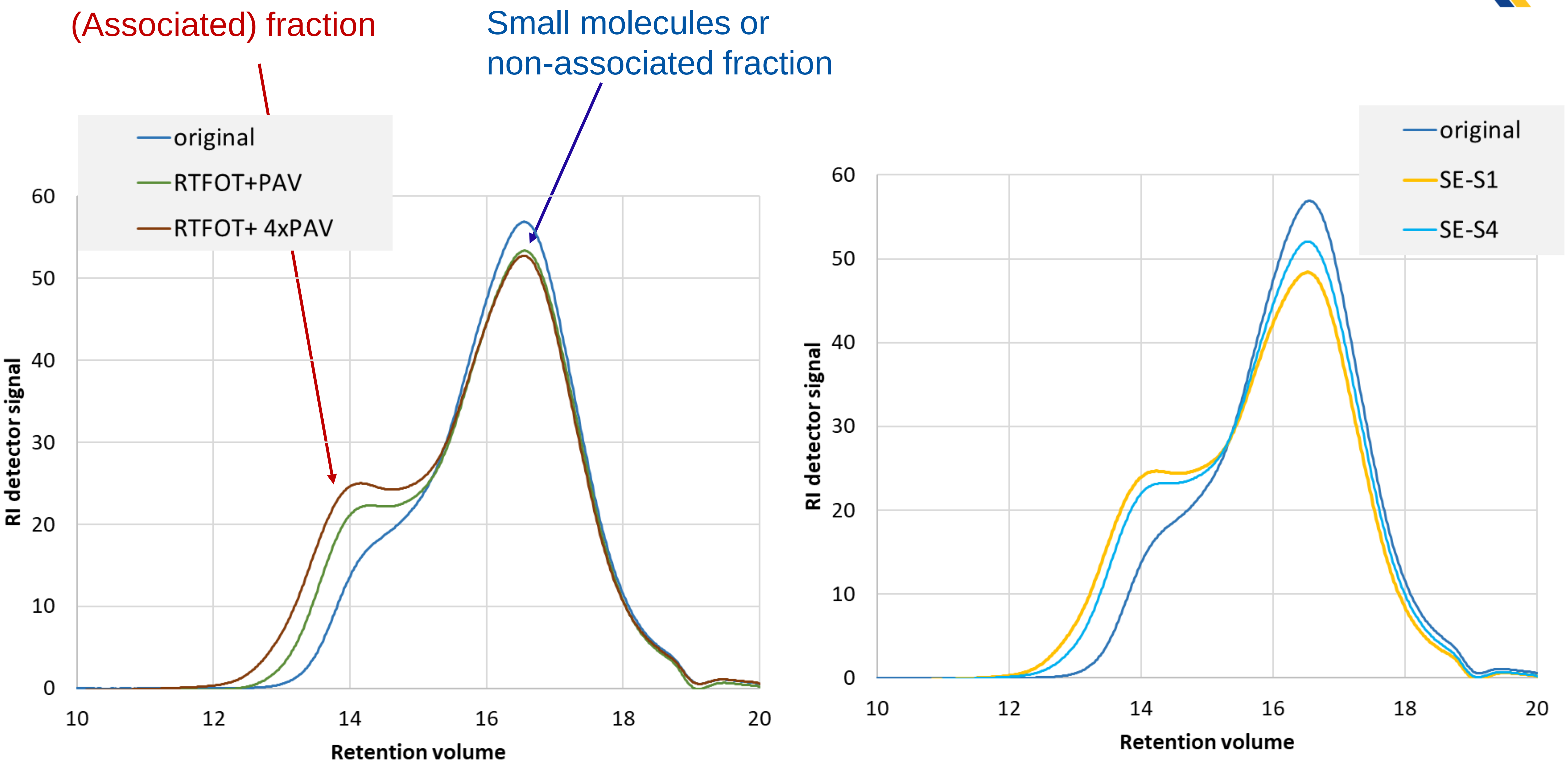
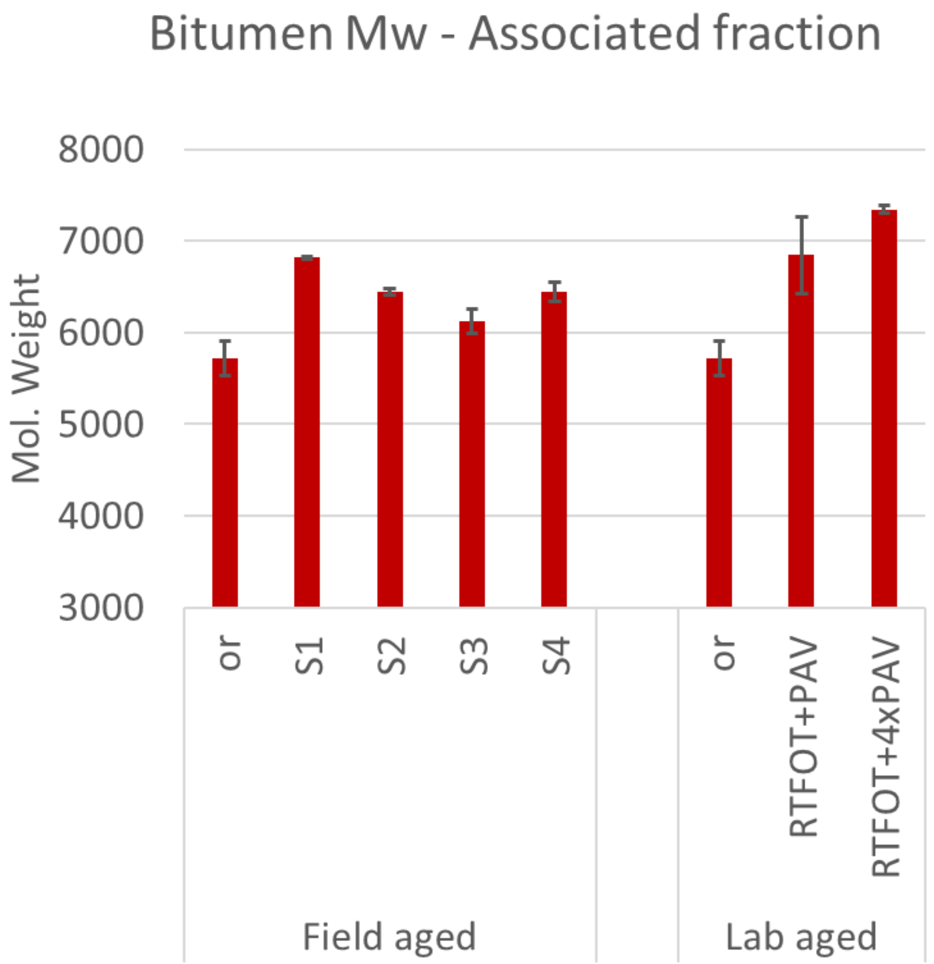
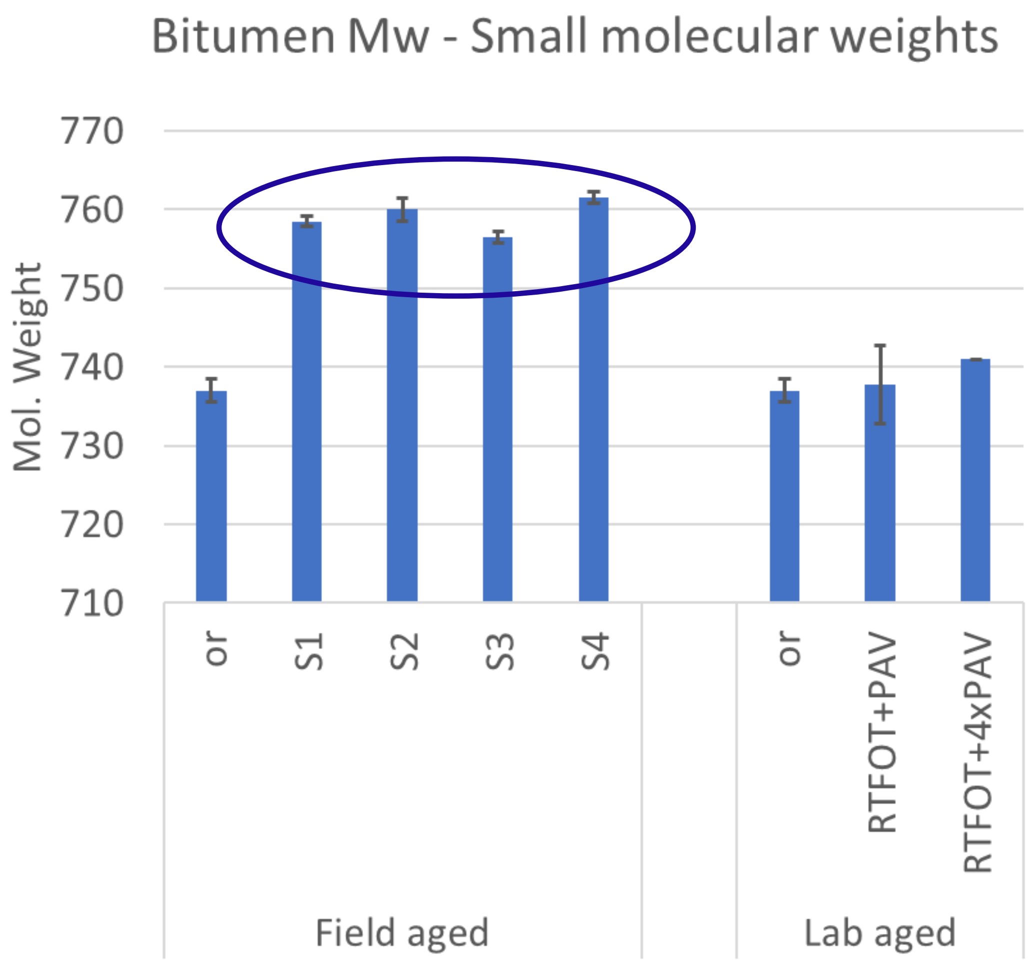


GPC (gel permeation chromatography): molecular weight

In field aging, the smallest molecules have reacted ~~(evaporated)~~ ?





Conclusions

- General conclusions:
  - (Large) variations in the degree of compaction, within one section
  - Dense mixes prevent aging in the asphalt layers, but the top slices still age considerably.
  - Density versus depth (wearing course) often showed a C-shape, which was also reflected in the aging.

- The comparison field versus standard lab aging:
  - Trends are similar
  - The comparison depends on the property that is investigated. For rheology, the comparison is dependent on the test conditions (frequency and temperature)
  - <u>At intermediate service temperatures:</u> field-aged binders become considerably more stiff and brittle as compared to lab-aged binders. Even after RTFOT+4x PAV binders were still ductile at 10°C-10Hz, while all top slices of field cores were brittle.
  - <u>At low service temperatures:</u> LmT and LST change more after field aging.
  - <u>Molecular level:</u> similar chemical reactions for field and lab aging, but there are indications that in lab aging larger molecules are involved compared to field aging.

Further Tests & Recommendations & Challenges

- Laboratory aging: (RTFOT + PAV)
  - Do we need an aging that exactly reflects field aging?
    *As long as **rankings are the same = No***
    If lab aged samples are used as a surrogate for field aged binders = Yes
  - How can we improve the comparison?
    Use a lower aging temperature – longer time window?
    Induce an acceleration by adding reactive radicals? Vienesse aging test (see literature)

- If taking field cores; take as many as possible

- Binder recovery:
  1. Binder aging due to the recovery process: very little
  2. Contaminations:
     Silicon grease – very clear in FTIR
     Rest solvent – clear when homogenizing the binders
     Rest filler – see anomalies in the stiffness / microscopy / FTIR
  3. Insufficient recovery: Yes, for the wax-modified binder

- *(Pavement performance – quantification of damage – cause of damage – data, data, data)*

Acknowledgments:

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