Binder Aging and Durability Validation: The European Case

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AIF project: Presentation overview

1. **Experimental part (Hilde Soenen)**
    1. Objectives & Methodology
    2. Field sites
    3. Aging gradients
    4. Comparison field and lab aging
    5. Pavement damage versus properties of recovered binders

2. **Modelling part (Hanyu Zhang)**
    1. Objectives
    2. Modelling Framework
    3. Model Validations
    4. Model Applications
    5. Summary

3. **Q & A session (All)**

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1. Objectives & Methodology

1. **Which binder property relates to (aging–induced) asphalt cracking?**

   What property on the bitumen should we test to determine the risk for (aging-induced) fracture? Can we set limiting levels?

   How is the aging penetrating through the asphalt surface layer?

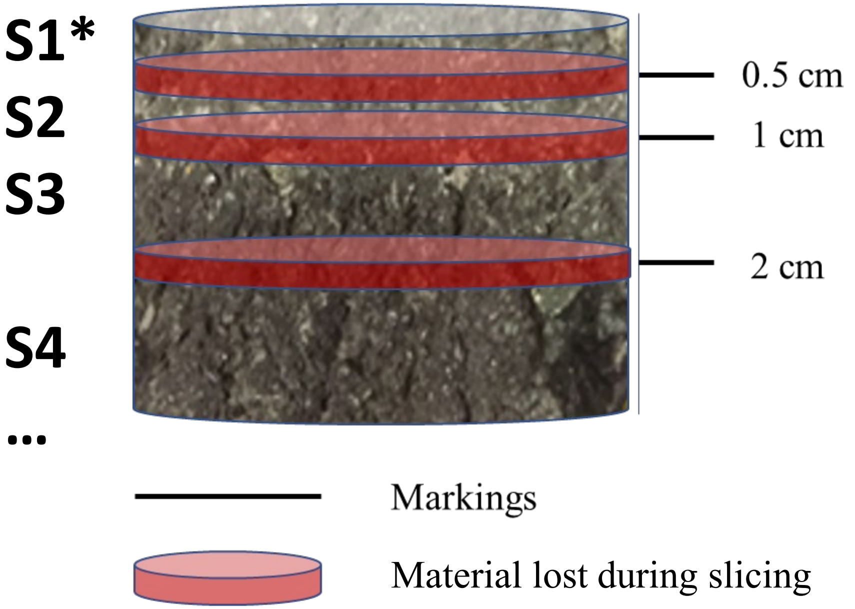
2. **Laboratory vs field aging.**

   Are the standard aging methods, currently used, representing the actual aging of bituminous binders in the field?

1. Objectives & Methodology

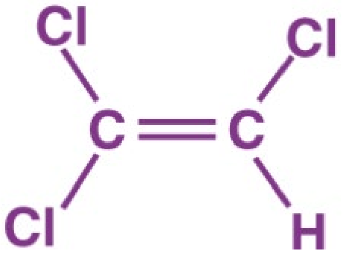
- Selected aged pavement sites (≥8y)
- Get info on the road surface condition
- Drilling the cores

- Density measurements on the cores
- Slicing of the cores and binder recovery
- Binder tests (DSR & FTIR)



Automated asphalt analyzer (EN 12697)

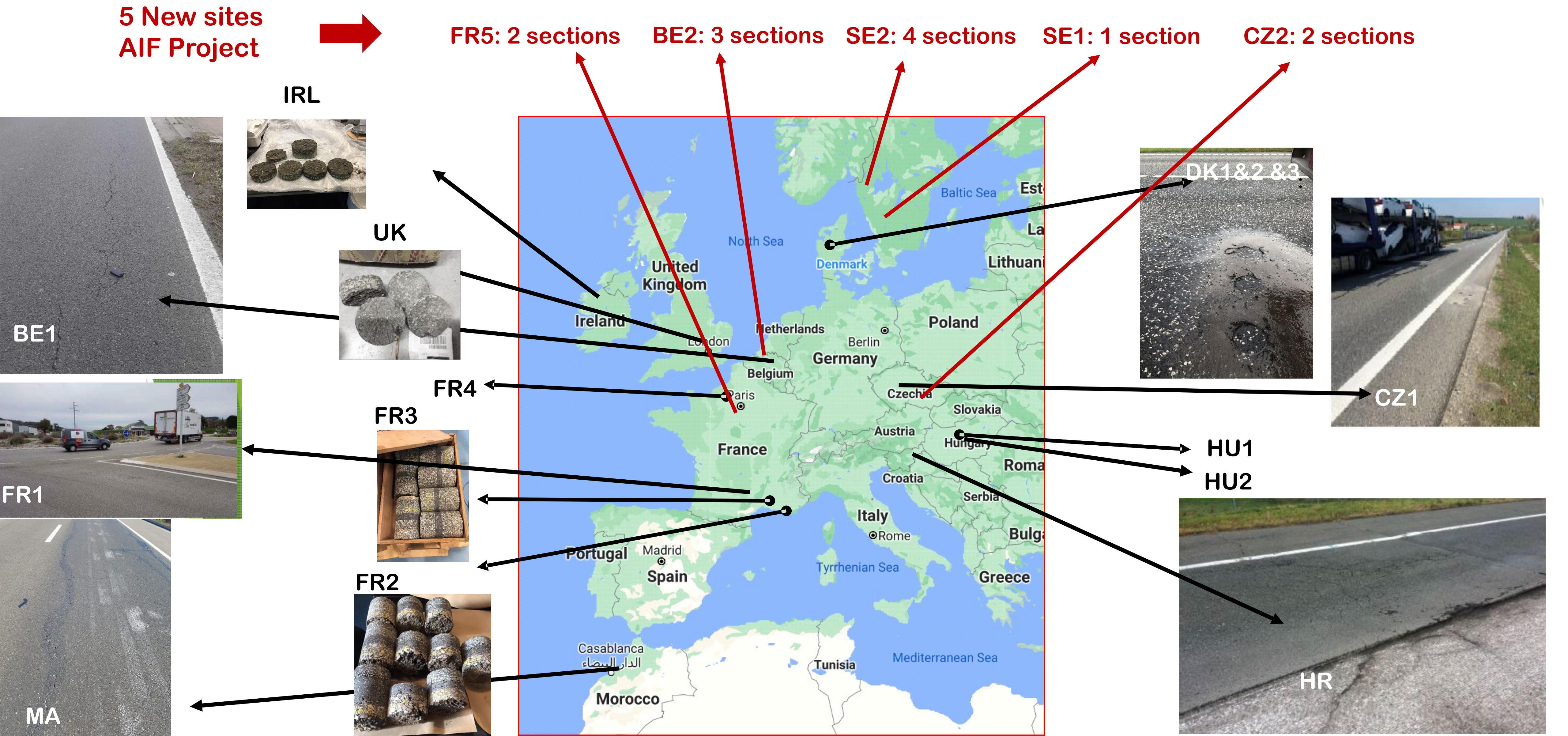
Solvent =



* *1cm top slice if large aggregates and/or very open mixes*

2. Field sites

12 sites were already investigated, 5 new sites were added



2. Field sites

France: FR5 A6 highway from Paris to Lyon, Two sections: 2004 & 2010

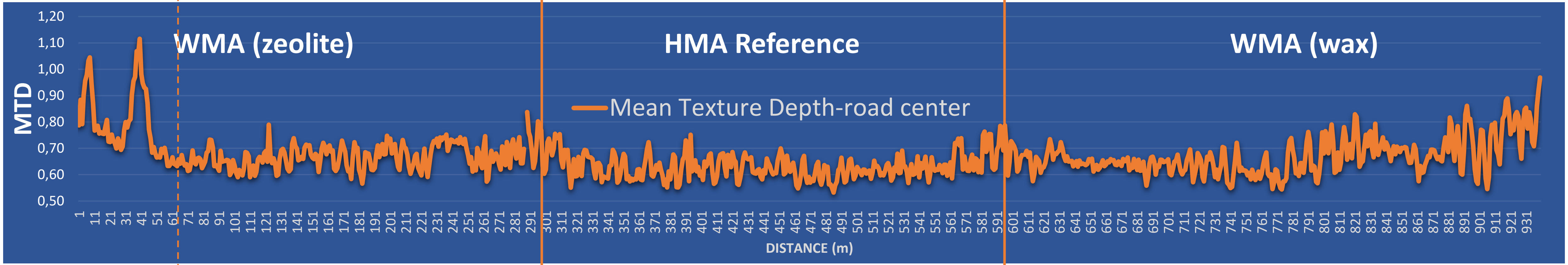
Zone homogènes structure Sens 2			État de dégradation*	
Zone	PR	Type structure (Voie lente) / Particularités	PR	Gravité selon l'inspection visuelle
Zone 1	PR 116+00 au PR 115+00	BAC 85	116+000 au 115+100	Gravité 2
	PR 115+00 au PR 110+00		115+100 au 111+200	Gravité 3


FR5-A6 2004


FR5-A6 2010

2. Field sites

Belgium: local road 2009 (max. speed 70 km/h), Three sections, original binder available



2. Field sites

Czech Republic (CZ2): local road

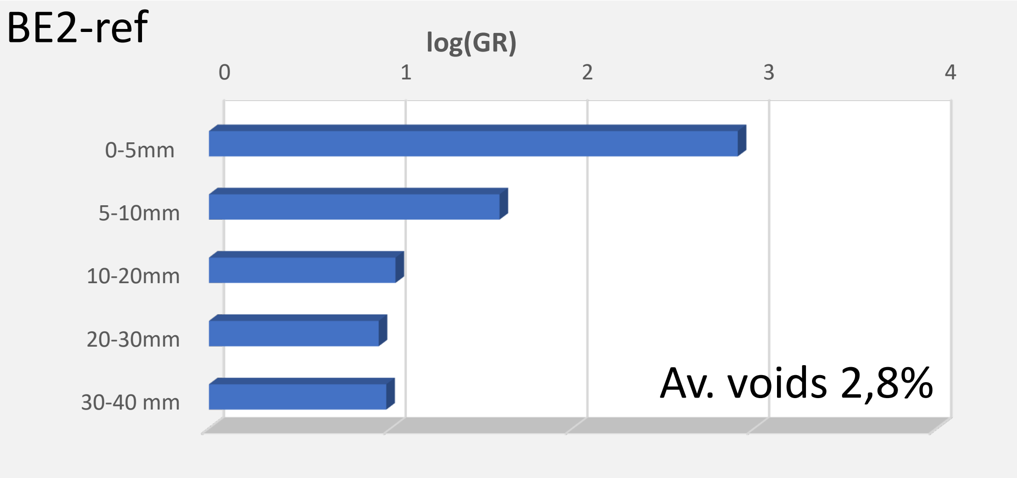
Podhradi (unmodified binder) (2014)

Clasification level (% of damaged area)				
1 -excelent	2 - good	3 - sufficient	4 - poor	5 - critical

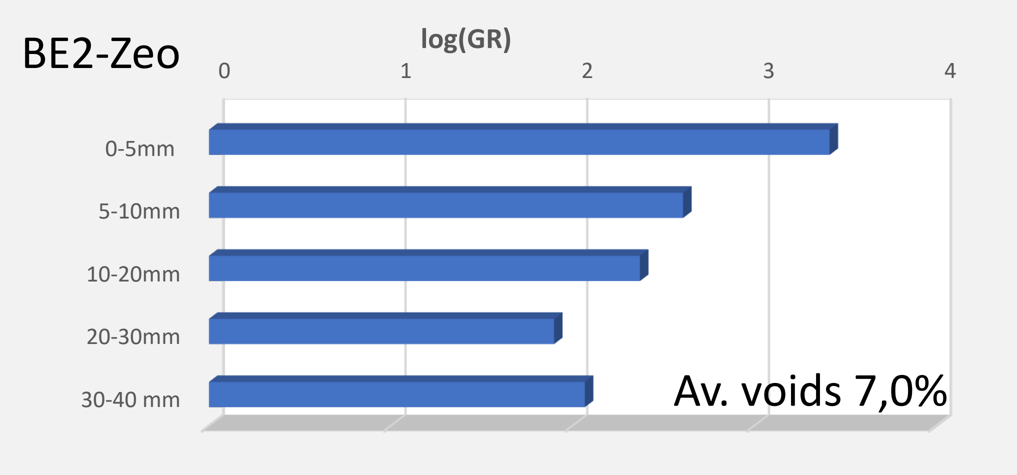
Classification	Clasification by damages									
	Thin cracks	Wide cracks	Mesh fatigue	Ravelling	Potholes	Settlements	Rutting	Los of	Loss of	Patching
2	2	1	2	2	1	2	1	1	1	1

3. Aging gradients

BE2-AIF site, reference & zeolite, 10.5 years in service.

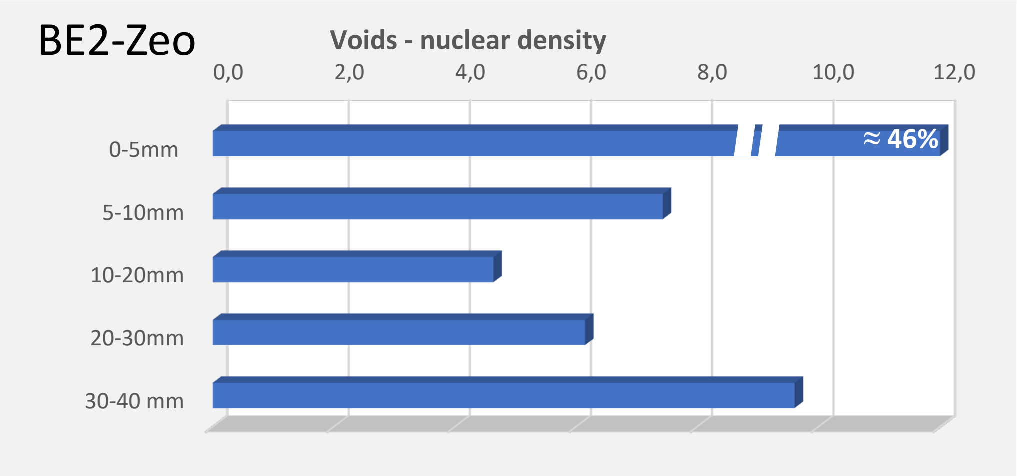


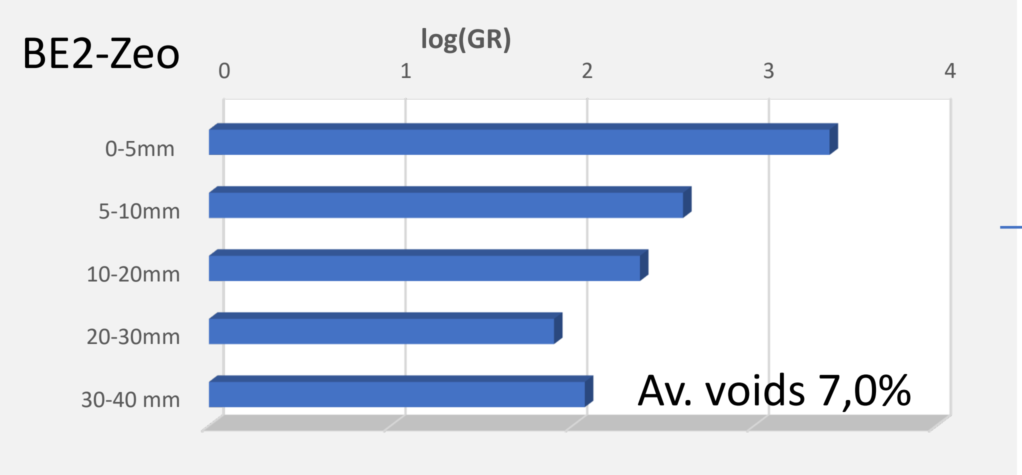
- Glover-Rowe (GR) versus depth of the surface course same binder, same location, different voids
- Denser mixes = less average aging, but a clear gradient

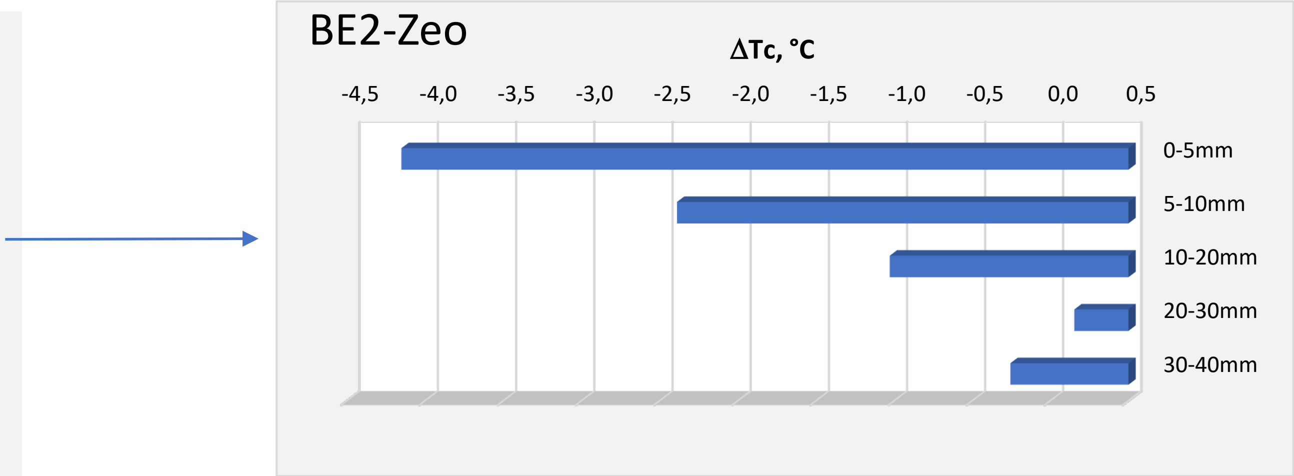


3. Aging gradients

- GR is plotted but all aging parameters change in a similar way (ΔTc, crossover parameters, R value, …)
- C-shape for aging-related parameters and for the void content

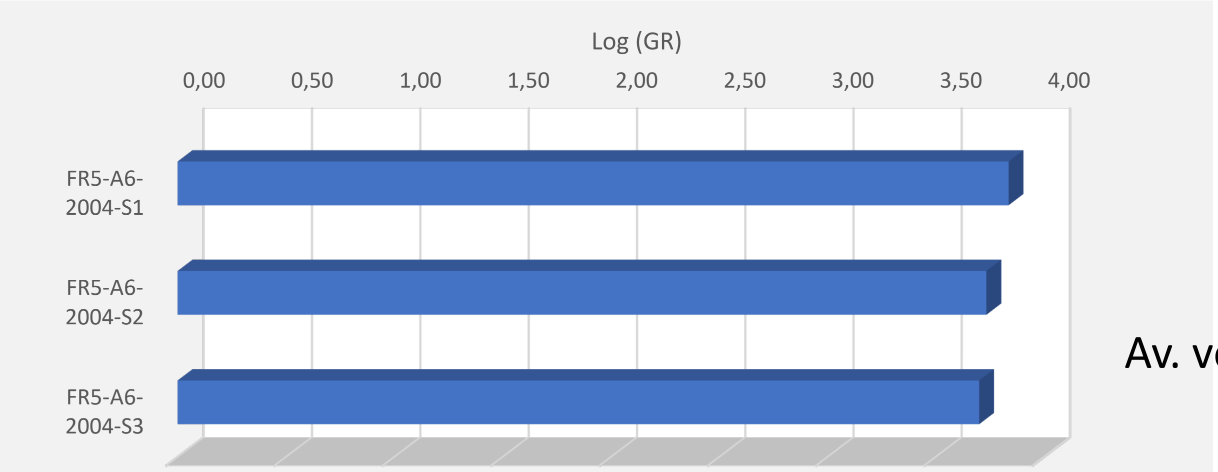




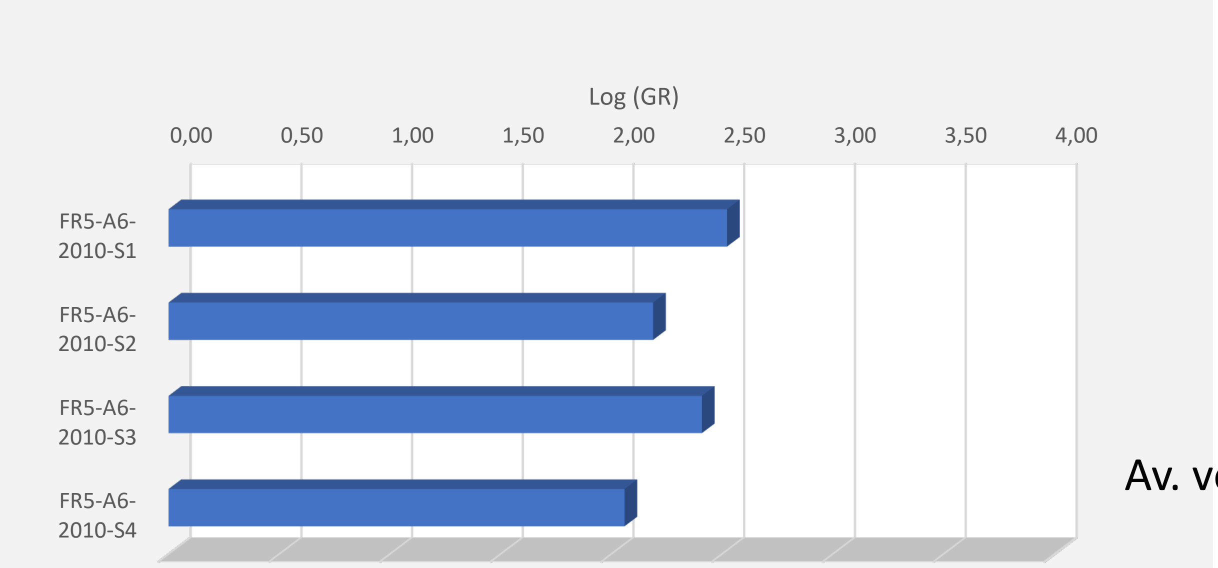


3. Aging gradients

FR5-AIF site, from 2004 & 2010



Av. voids 9,1%

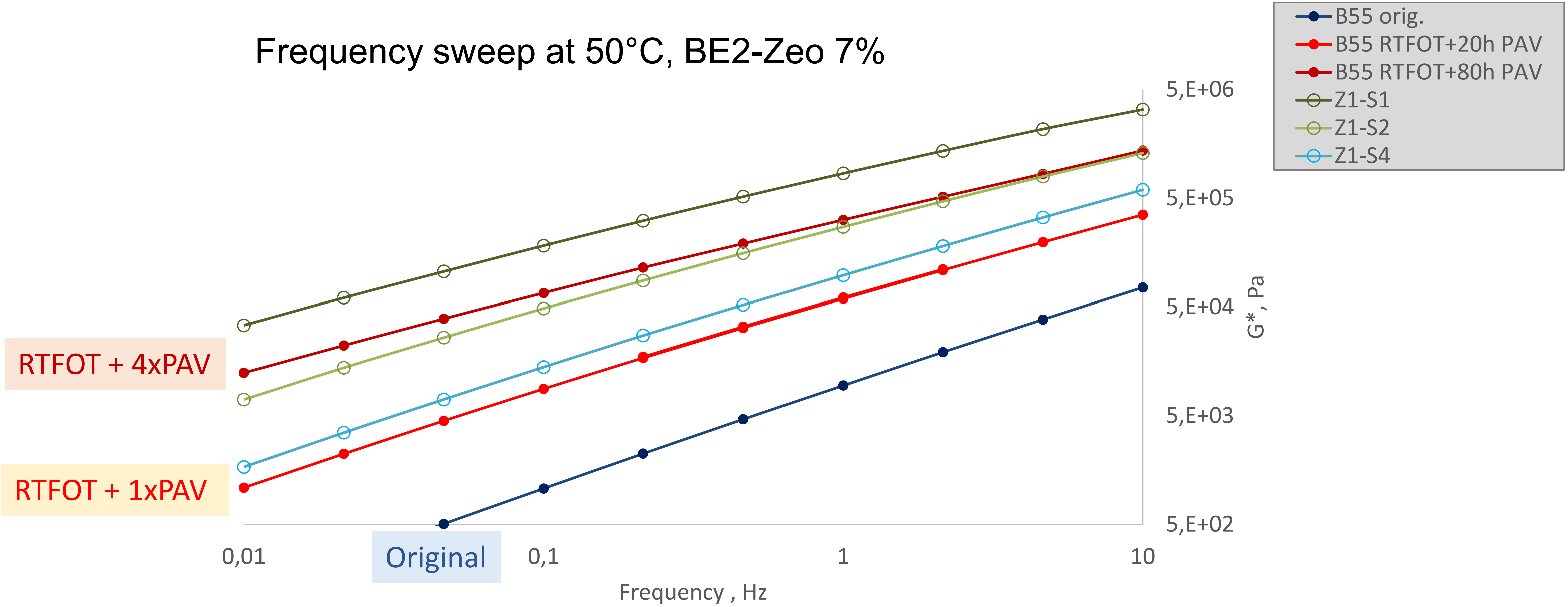


Av. voids 8,4%

- For open mixes the aging gradient is minimal.
- Measuring the binder properties in slices is only useful for denser mixes. For open mixes, (>8%) an average value could be used.

4. Field versus long-term laboratory aging (PAV)

Comparison of stiffness data (LVE) in different temperature regions (50°C, 10°C and low temperatures)
Data from BE2 AIF site



Presented at the STAR meeting 2022, at Nabin 2023 and a speed poster presentation at E&E 2024

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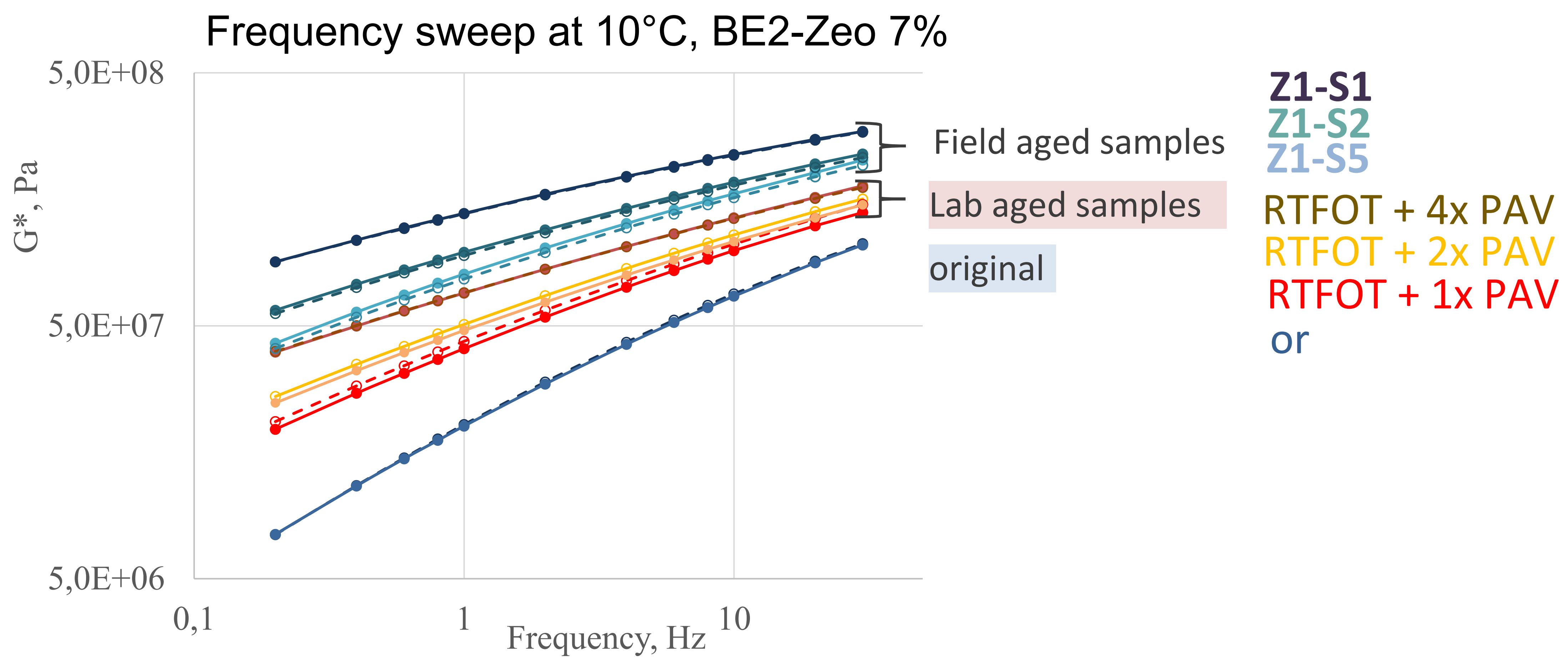

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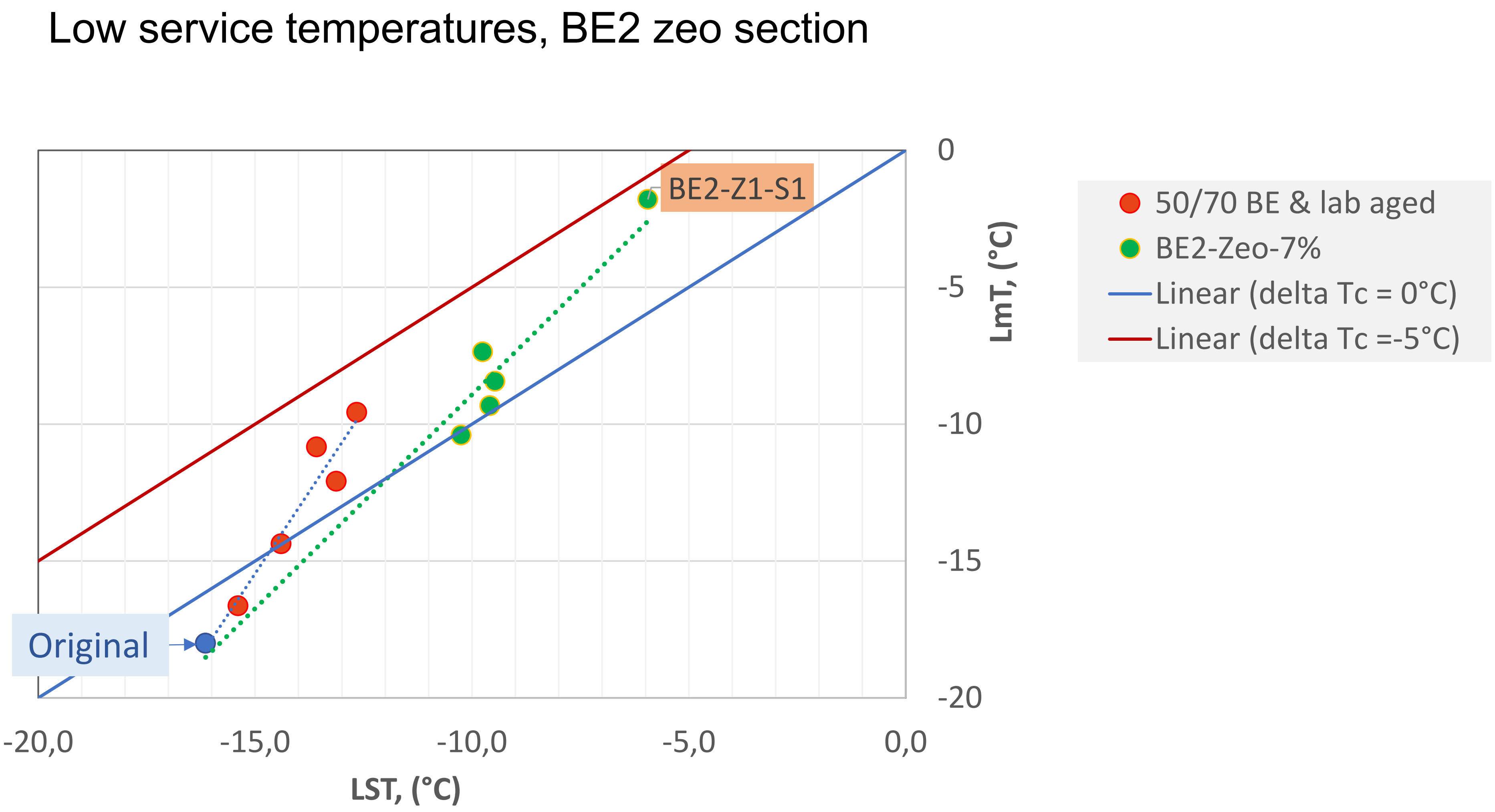

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4. Field versus long-term laboratory aging (PAV)

Rheological properties:

Trends are similar between field and PAV aging.

But, in field aging the stiffness increase is larger, especially at intermediate and low service temperatures, as compared to PAV aging.

Stress-strain sweeps 10°C & 10Hz: Brittle fracture after field aging, ductile after PAV aging.

Chemical properties:

Similar trends, but in field aging the sulfoxide index is higher compared to sulfoxides measured after the PAV aging.

Rankings:

PAV may still discriminate binders and give the same rankings as field tests.

Presented at the STAR meeting 2022, at Nabin 2023 and a speed poster presentation at E&E 2024

5. Damage versus binder parameters

<u>Damage: **qualitative, 5 levels:**</u>

0: no damage
1: very little & local
2: more, still local
3: a lot & connected levels
4: End of life

Damage: cracks are considered,
Cracks include all types, except reflective or due to base layer or support issues,
(HU1 was removed due to support issues)

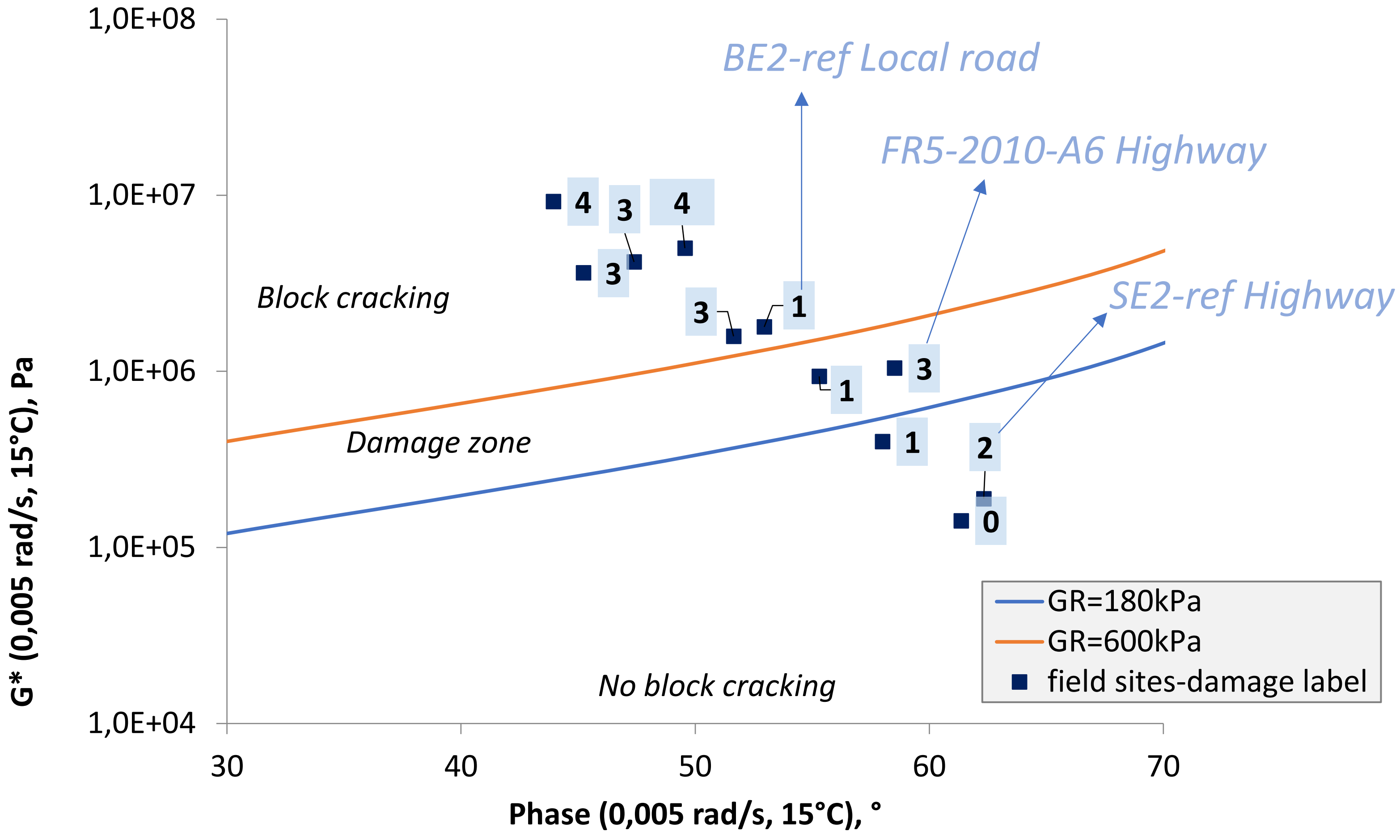
For the AIF-BE site raveling was included

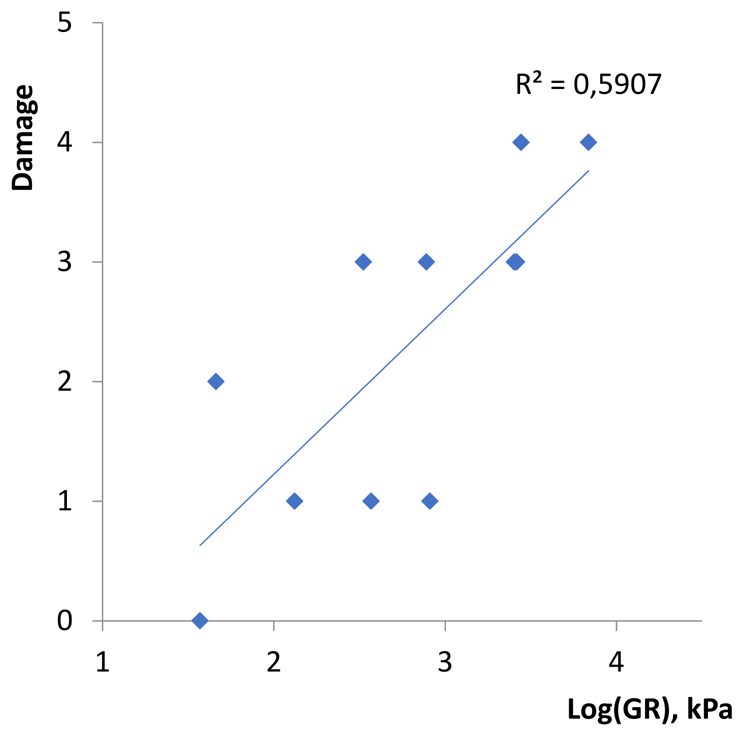
		unm.=0, PmB=1, HPmB=2	age, y	voids, %	[ ], %	road type	Damage	C=O	S=O	log (G-R), kPa	ΔT_c, °C	p c
	FR1											
	HR											
	DK2											
	DK3											
	IRL											
	MA											
AIF-BE	BE2-R2											
AIF-BE	BE2-Z1											
AIF-BE	BE2-Z2											
AIF-SE	SE1-R17											
AIF-CZ	CZ2: Podhradi											
AIF-E6	SE2 E6 ref											
	CZ1											
	FR2											
	DK1											
	BE1											
	UK											
	HU2											
	FR3											
AIF-FR	FR5-A6-2010											
AIF-FR	FR5-A6-2004											
AIF-CZ	CZ2: Ujezd											
AIF-E6	SE2 E6 SBS1											
AIF-E6	SE2 E6 SBS2											

Data mix type
Damage
Data top slices

5. Damage versus binder parameters

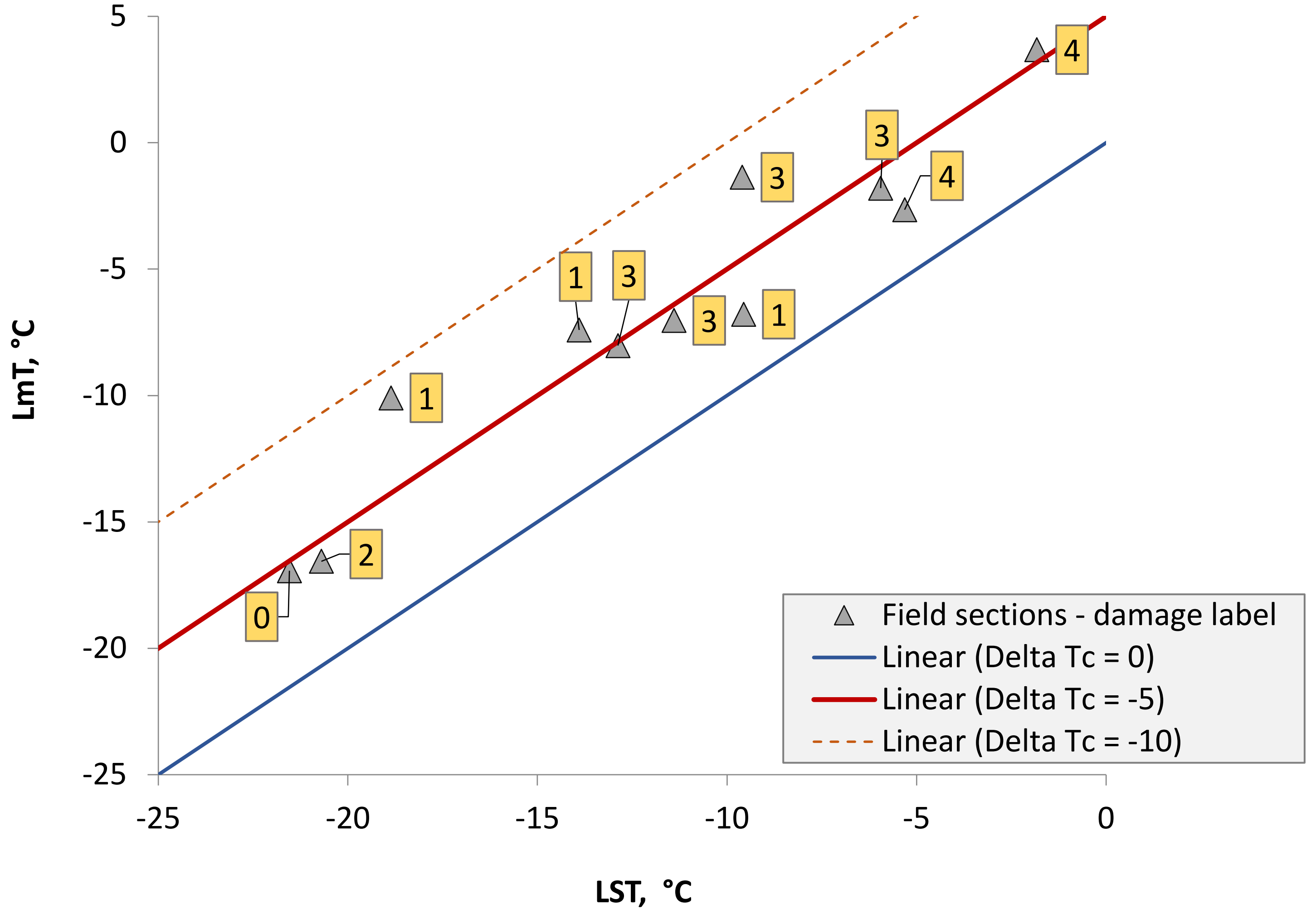
- **AIF sites** (top slices) Glover Rowe parameter (11sections)

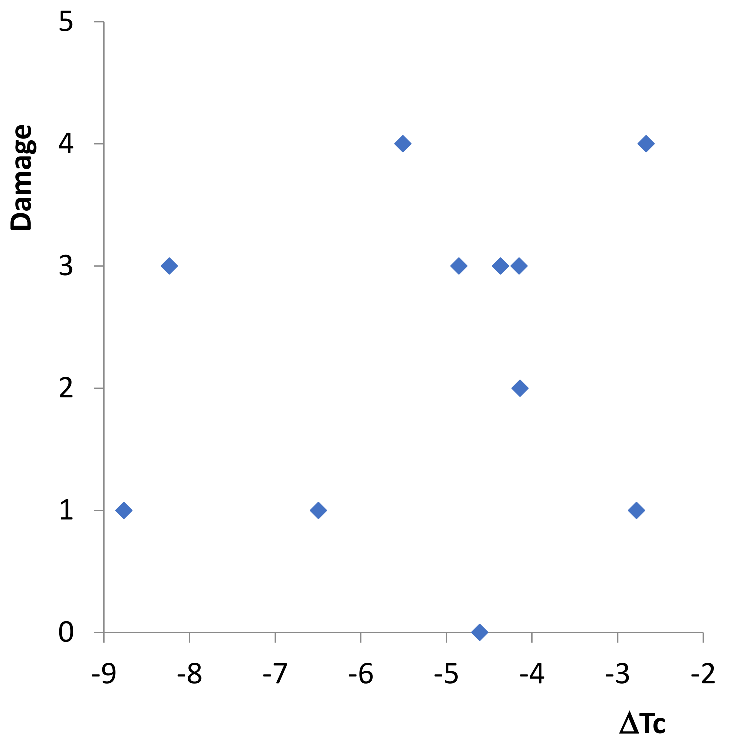




5. Damage versus binder parameters

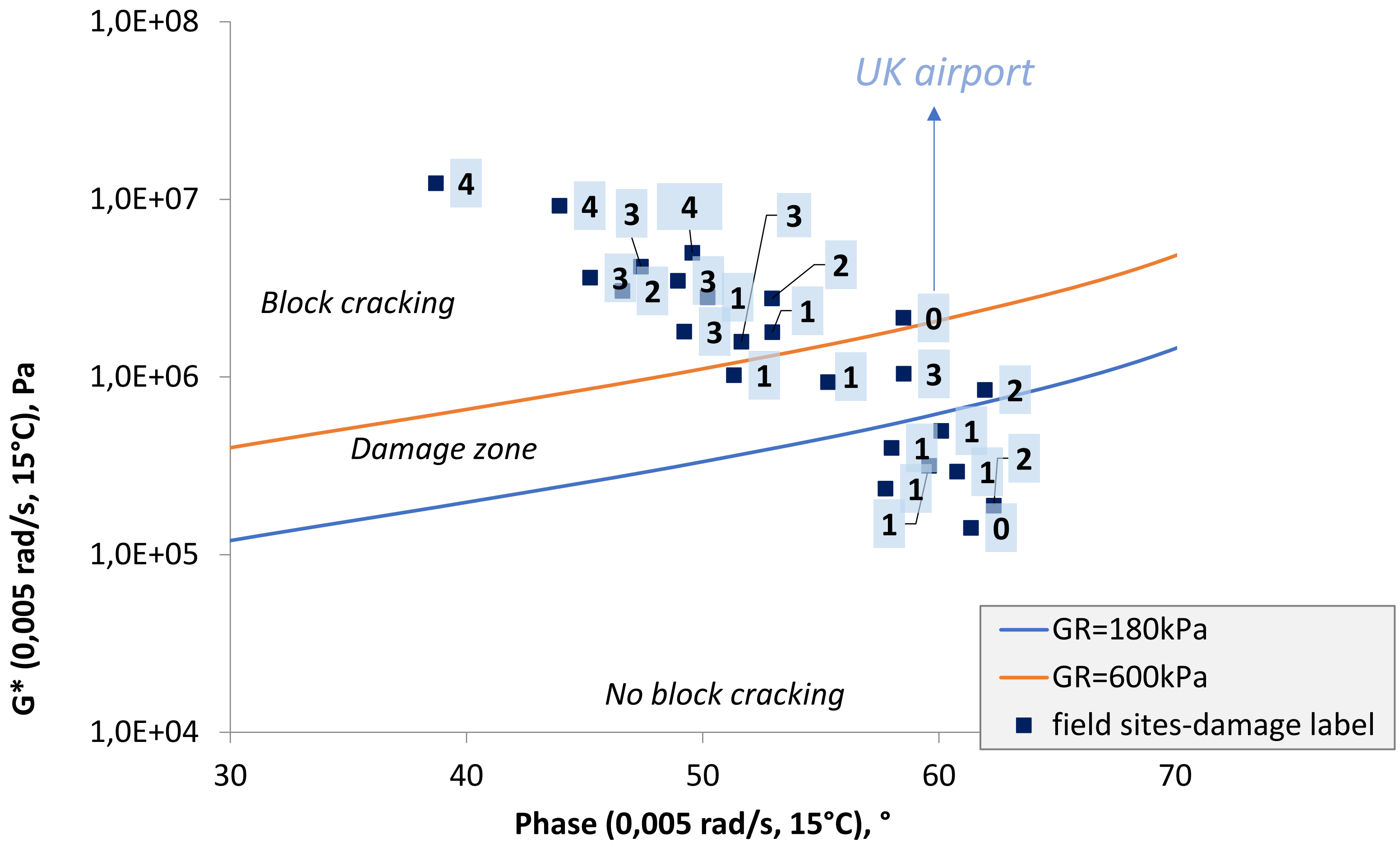
- **AIF sites** (top slices) Delta Tc (LST-LmT) (11 sections)

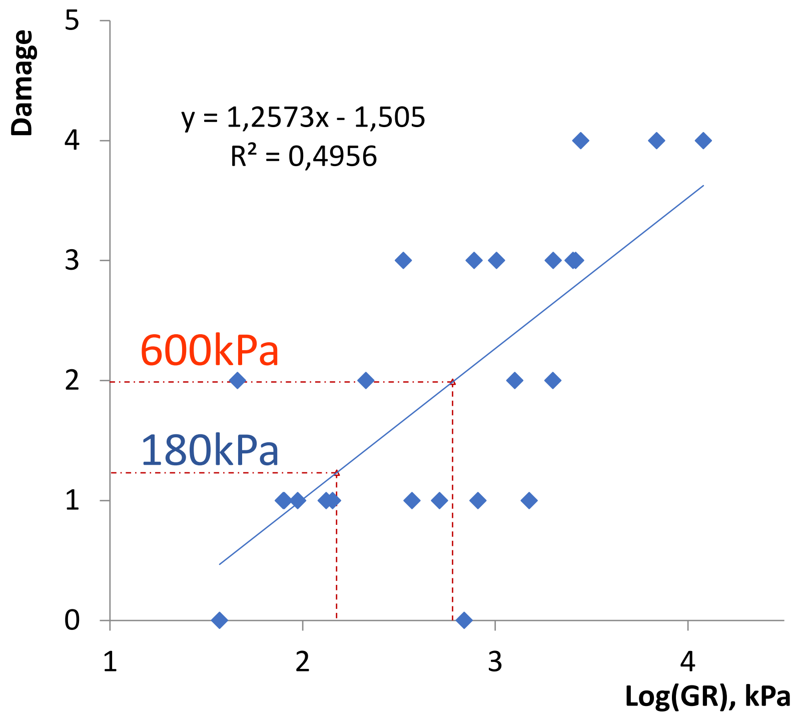




5. Damage versus binder parameters

- **All sites** (top slices) Glover-Rowe (24 sections)





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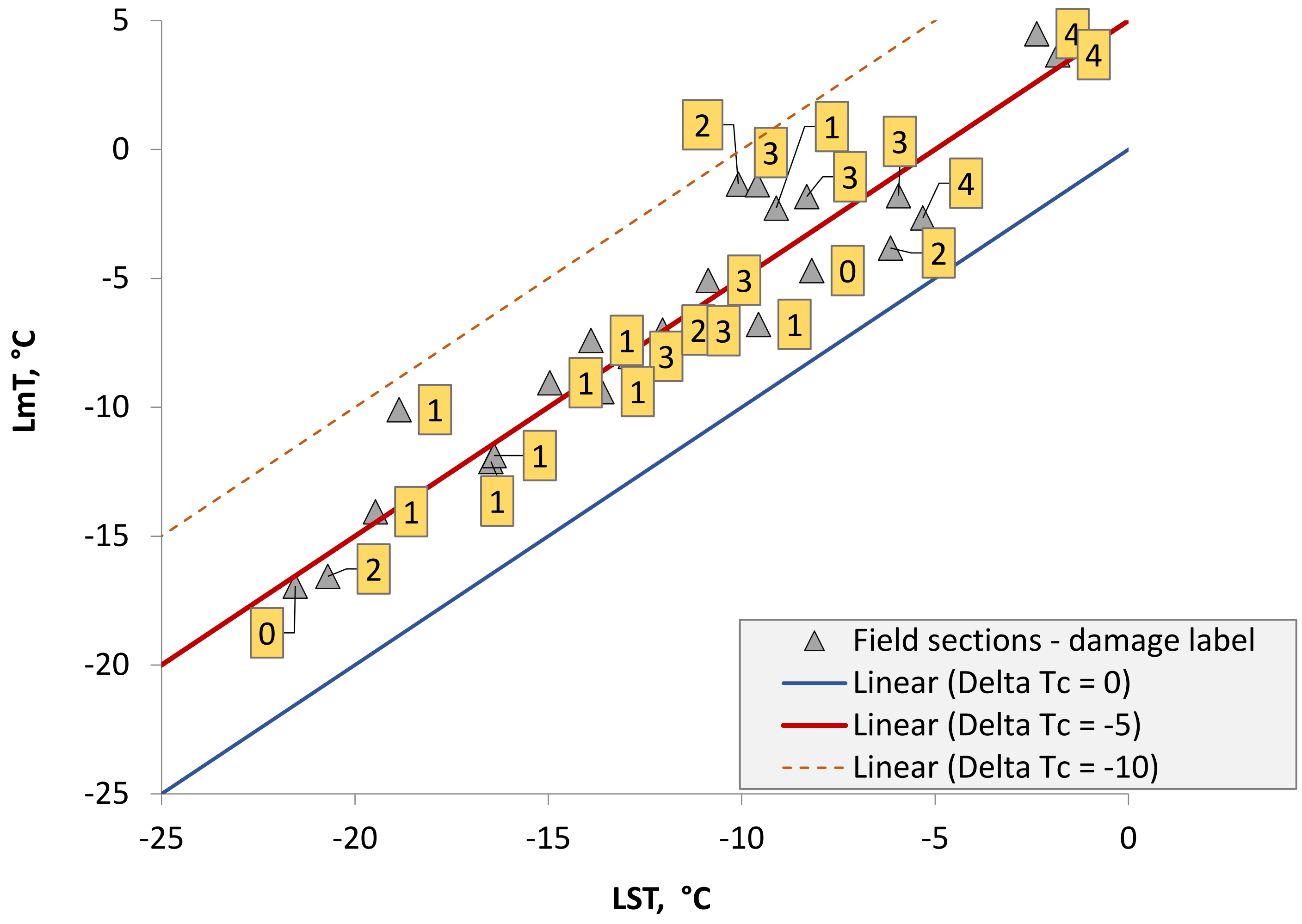
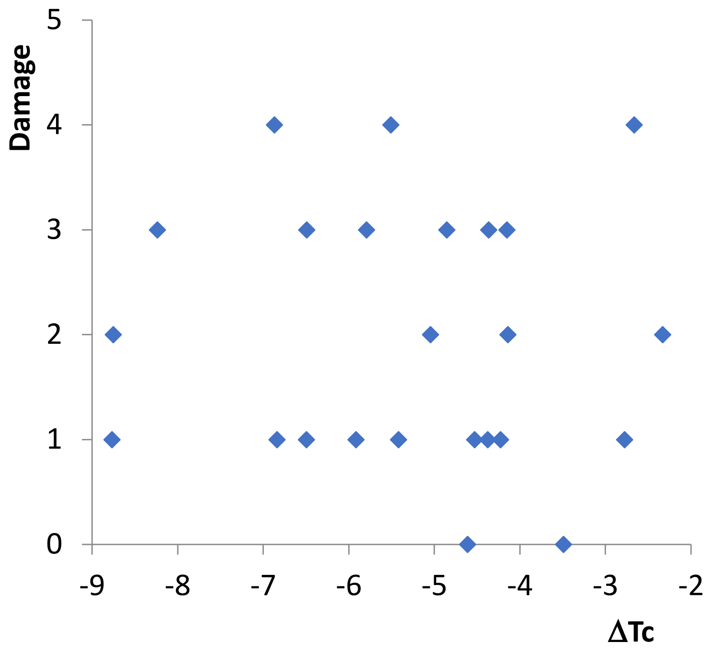
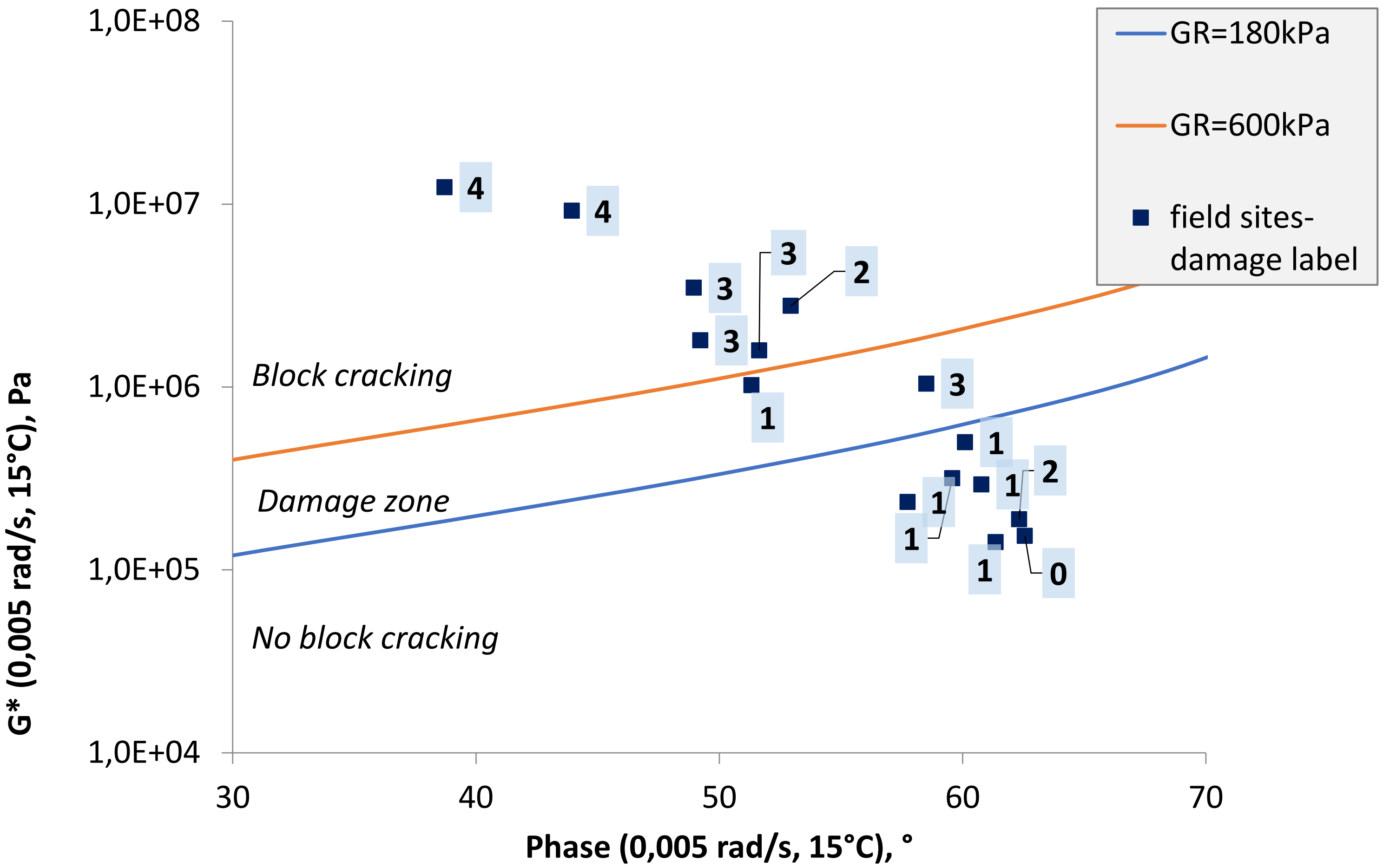
- **All sites** (top slices) Delta Tc (LST-LmT) (24 sections)

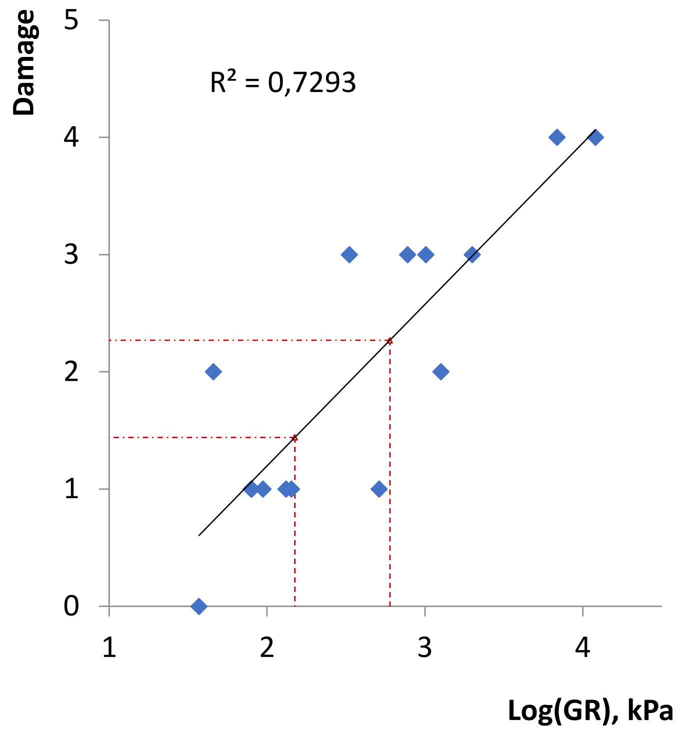




5. Damage versus binder parameters

- **Only highways** (top slices): Glover Rowe (15 sections)





5. Damage versus binder parameters

The significance of the linear regression of log (GR) was assessed using a Student's t-test (all 24 sections):

- t-test on the slope (assume the null hypothesis, slope = zero)
- If the probability (P) is below 0,05 the null hypothesis is rejected and there is a significant relation

Regression Statistics	
r	0,705
R Square	**0,496**
Standard Error Residuals, SER	0,895
Observations	24

Almost 50% of the variance in the damage is explained by log (GR).

	Slope, b1	*Standard Error on the slope, SE(b1)*	*t Stat*	*P-value*
log(GR)	1,257	0,270	4,649	**0,000124**

$$SE(b_1) = \frac{SER}{\sqrt{\sum(X_i - \bar{X})^2}}$$

$$t = \frac{\text{slope}}{SE(b_1)} = \frac{1.257}{0.270} \approx 4.65$$

5. Damage versus binder parameters

The significance of the linear regressions was assessed for more parameters (24 sections):

	log (GR)	LmT, °C	LST, °C	log (CR freq)	CR temp	ΔTc, °C	log (CR G*)	FTIR C=O + S=O
r	0,70	0,66	0,66	-0,71	0,69	-0,07	-0,07	0,78
R^2	0,50	0,44	0,43	0,51	0,47	0,01	0,01	0,61
p	0,0001	0,0004	0,0005	0,0001	0,0002	0,7334	0,7340	0,0000

CR *= cross-over: calculated using Rhea, ref temp = 0°C, between G* 1 GPa to 0,1 MPa*

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5. Field damage versus binder properties

- Qualitative damage levels indicate a significant trend with GR, while no relation to delta Tc. The proposed cracking limit GR= 600kPa fits the observations.

- Slicing; not needed for open mixes, for dense mixes slicing allows to capture the aging gradient. (the slicing thickness is still an open question)

- The pavement damage: Some observations
  - It is still QUALITATIVE: no unified method
  - The reasons for damage not always clear
  - Large differences in compaction for the same site, damage around the coring site?
  - Exclude places having extra shear forces (curves, traffic lights, crossings,…)?

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→ to the modelling