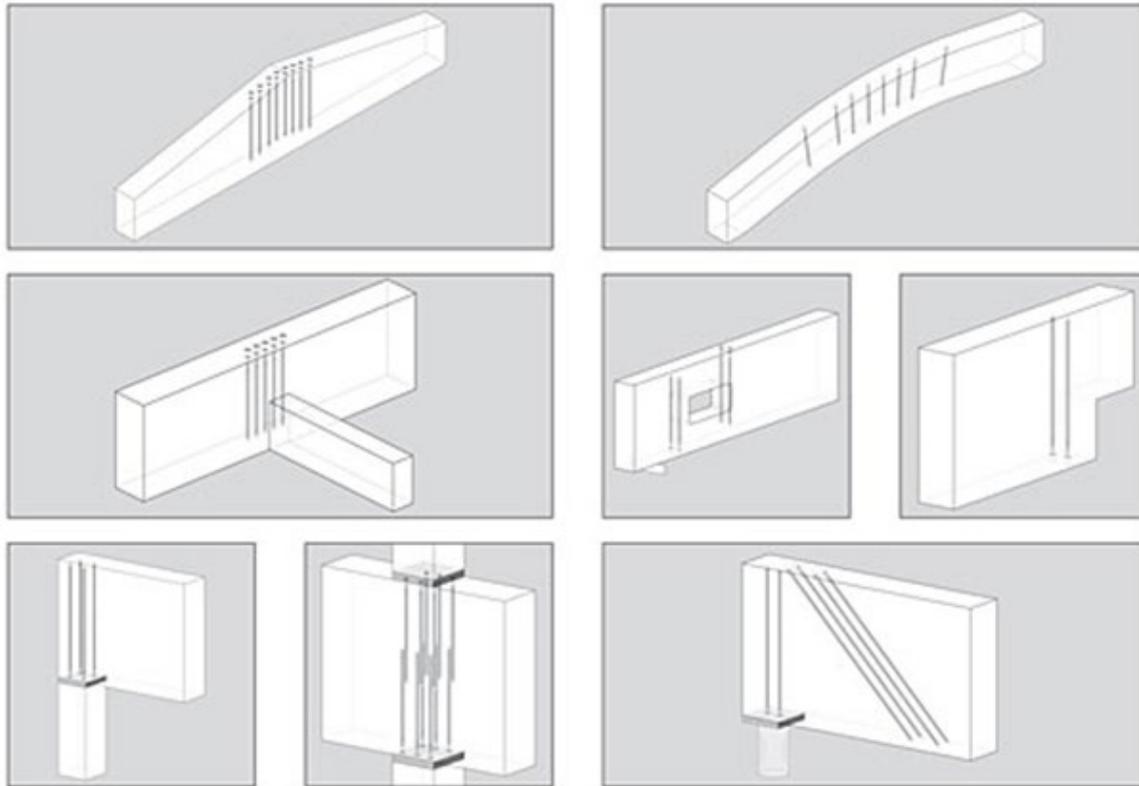# Climate impact on reinforcements in wood members

Dr. Bettina Franke, Prof. Dr. Steffen Franke, Marcus Schiere
Forum Wood Building Nordic (WBN) 28-30 September 2022

▸ Institute for Timber Construction, Structures and Architecture

Reinforcements for strengthening of cross sections

restrained swelling/shrinkage

www.SFS-intec.biz (12.09.2018)

Brüninghof (2007), Dietsch et al. (2017)

Moisture content of wood

▶ **Physical and mechanical behaviour of wood depends on the moisture content**

  ▶ Shrinkage and swelling

  ▶ Increasing moisture content leads to decreasing of strength and stiffness properties
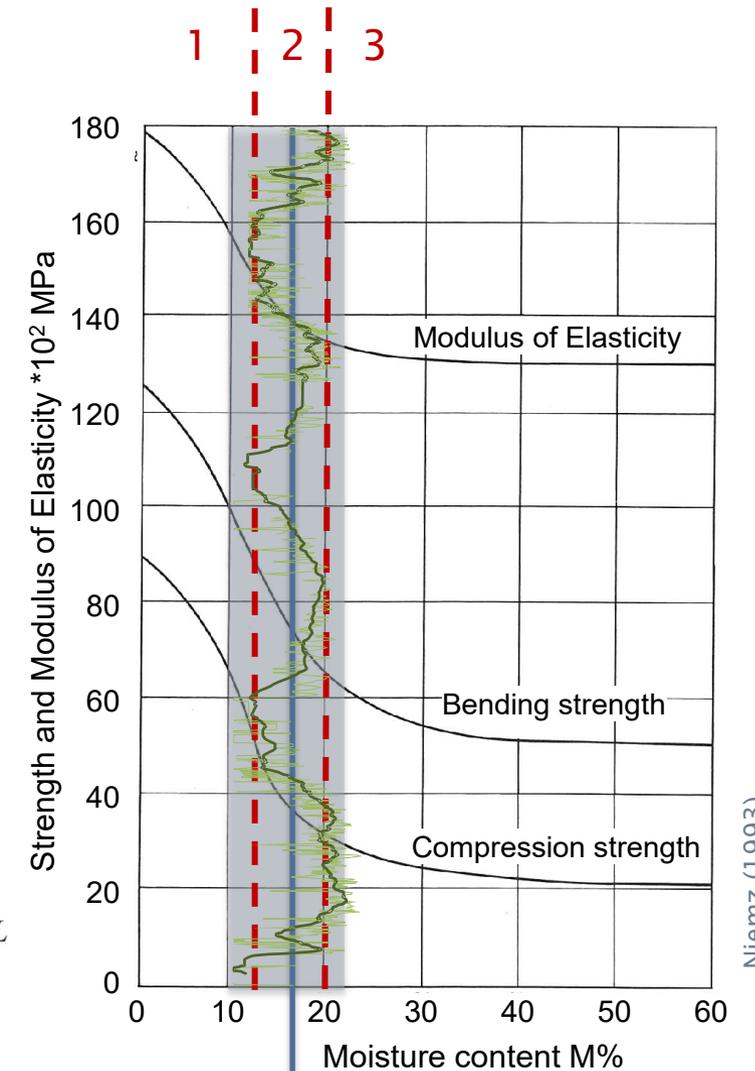
  ▶ Service classes according EN 1995-1-1:2004

  Reasons for structural damages
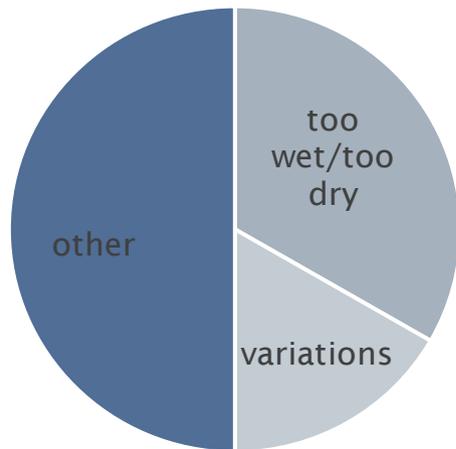
source: Frese & Blaß (2011), Dietsch & Winter (2018)
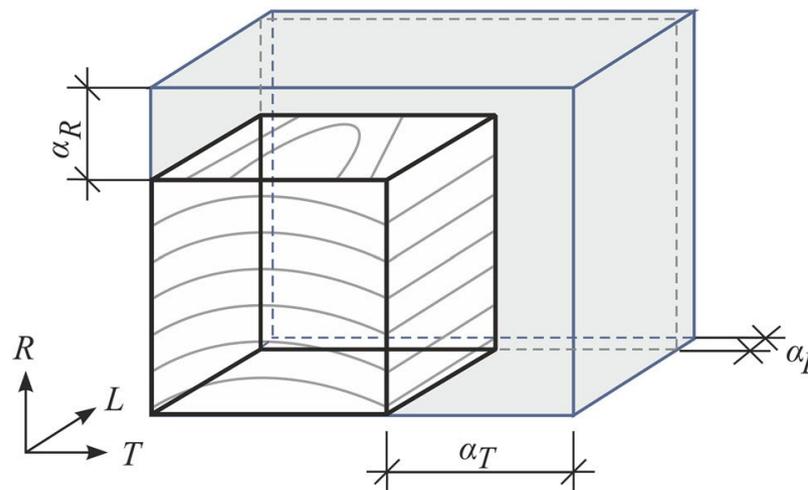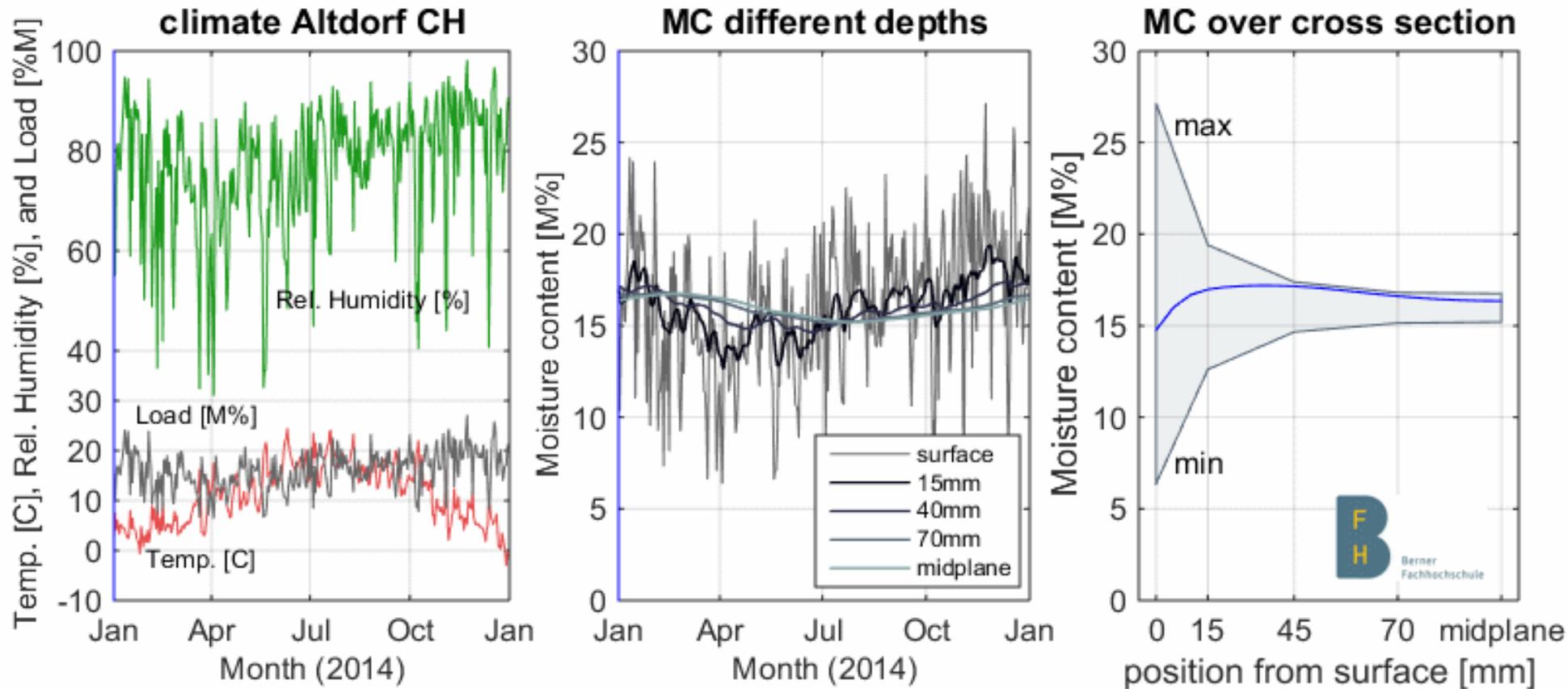
FE-Simulations – Moisture content, moisture induced stresses

▶ Simulation of seasonal climate changes for one year (meteorological station)
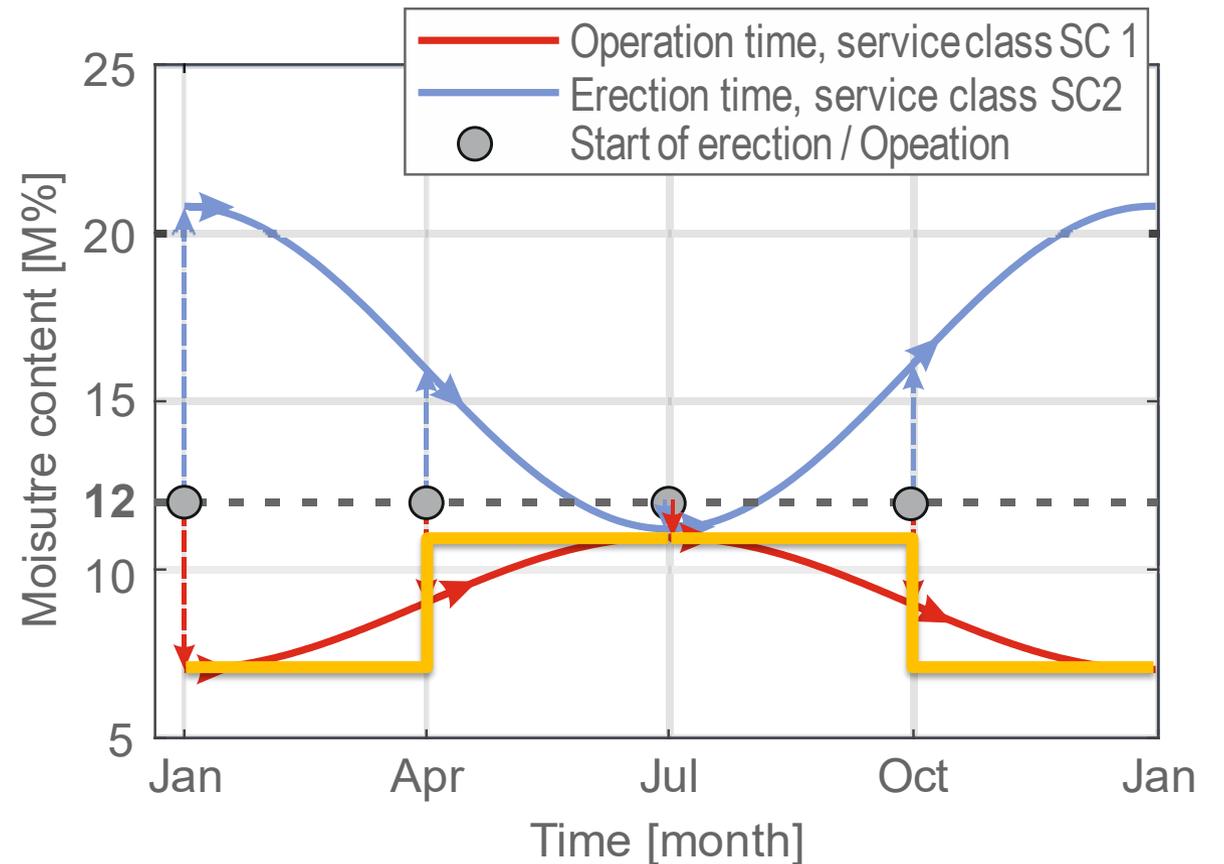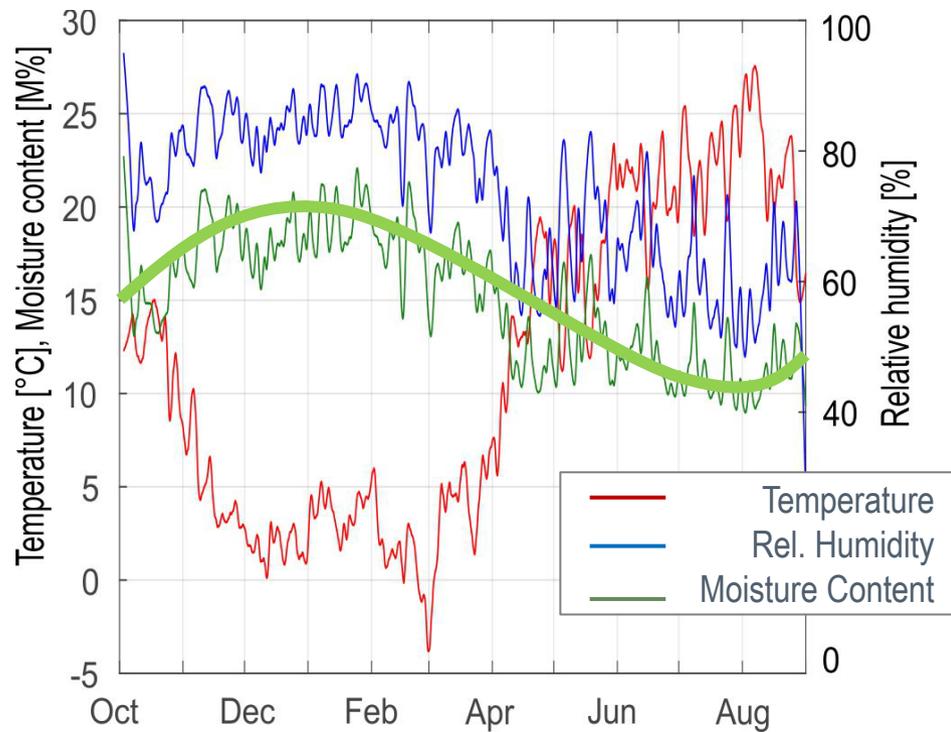▶ Cross section width of 200 mm

FE-Modell – Moisture content, moisture induced stresses

- ▸ Simulation of climate change for riding hall
- ▸ Envelopes over the year
  - ▸ Moisture content changes within 30 - 50 mm zone
  - ▸ Moisture induced stresses over complete cross section
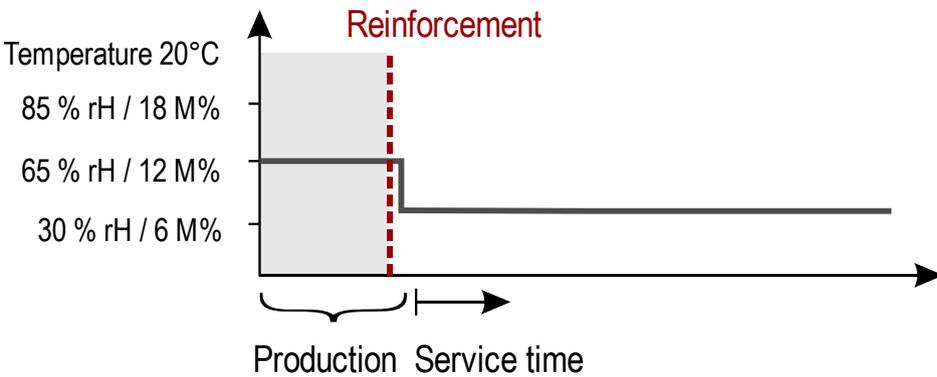 - ▸ What is the impact on a reinforcement?

Climate

Moisture content

Moisture induced stresses
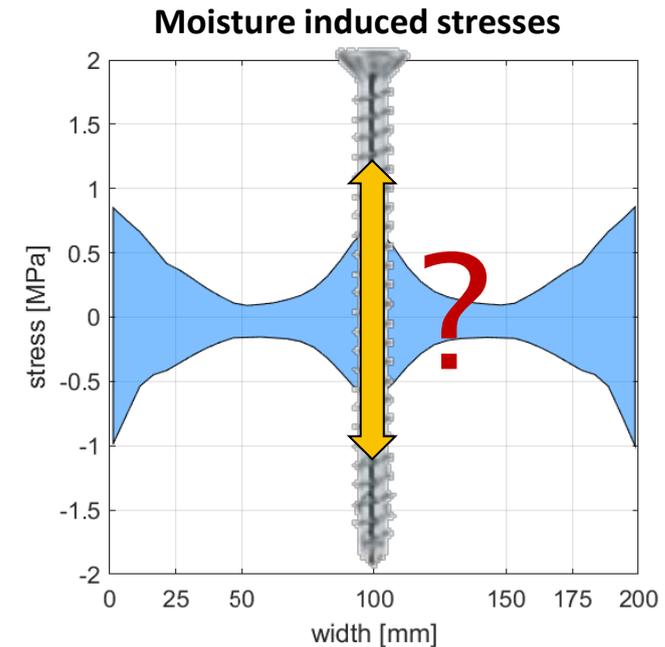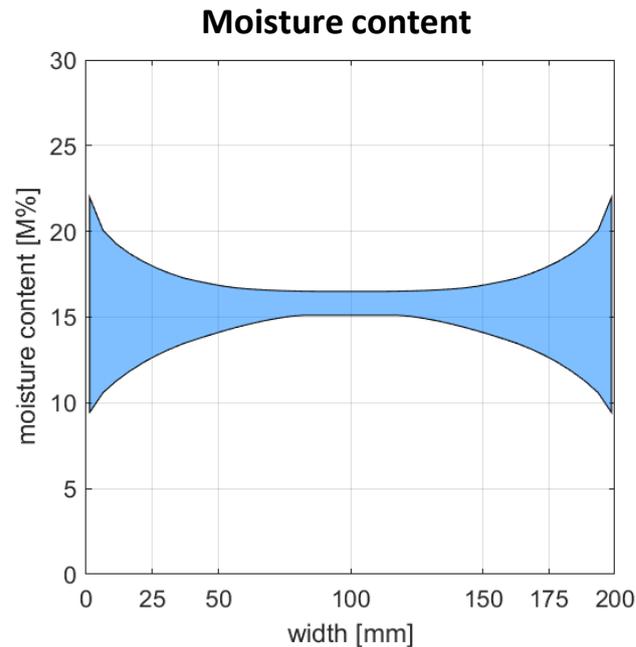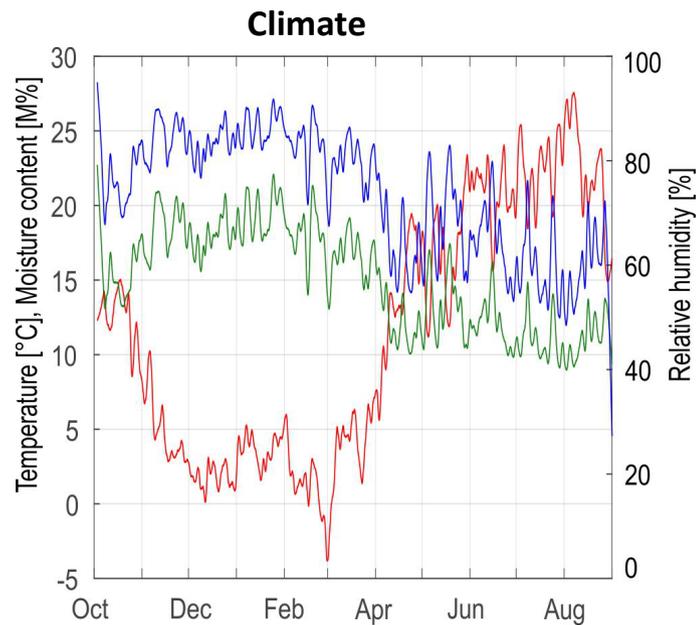
Climate scenarios

▶ Simplified cosinus shaped moisture variations per year, developed from measured values

Climate scenarios

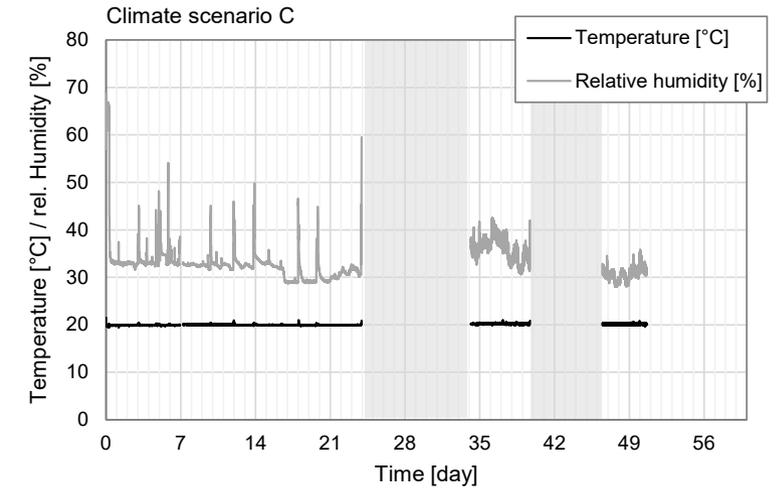# Experimental program
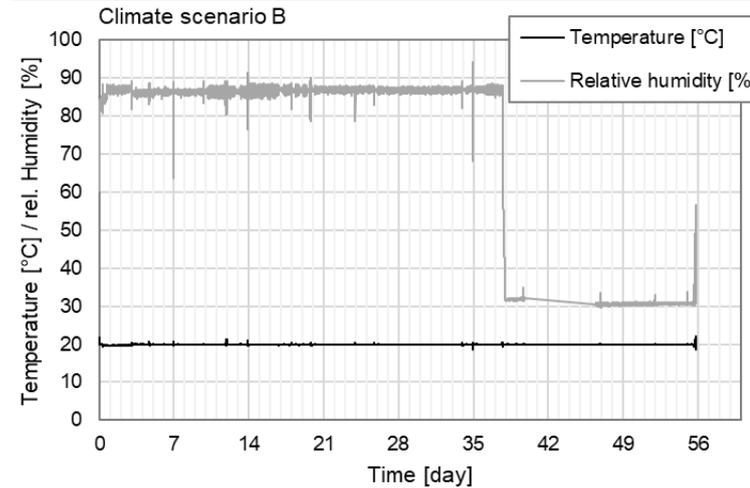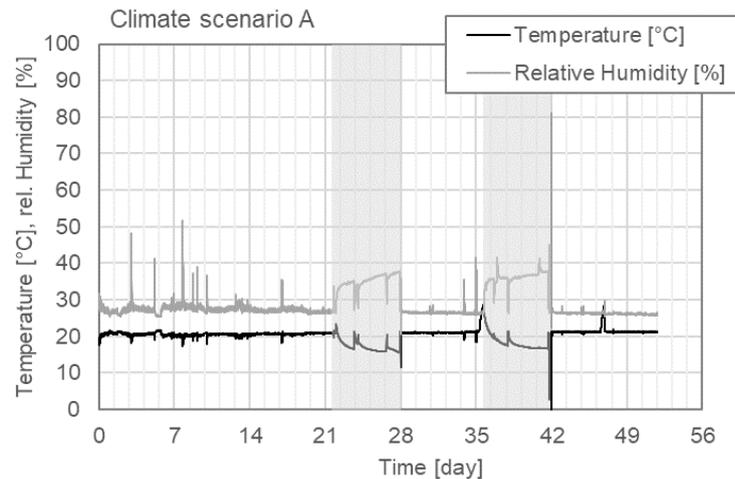
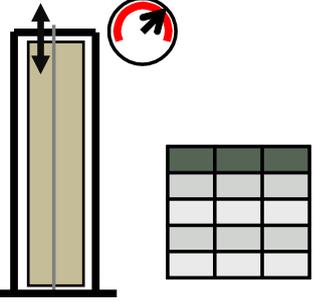| Climate scenario							
	DM MI	DM MI	DM MI	SH MI DM MI	SH MI DM OB / DM MI / DM UN	DM MI	
	unreinforced unsealed	unreinforced unsealed	unreinforced sealed	reinforced unsealed	reinforced unsealed	reinforced sealed	reinforced unsealed
[mm]	160/160/600	160/320/600	160/320/600	160/160/600	160/320/600	160/320/600	160/320/600
A	# P9	# P10	# P23	# P1	# P2[1]	# P3[1], P11[1], P12	# P4
B			# P25	-	-	# P15[2], P16	-
C			# P27	# P5	# P6[1]	# P7[1], P19[1], P20	# P8

[1] Measurment of moisture content in depths of 15 and 40 mm
[2] Measurment of moisture content in depths of 15, 25, and 40 mm

Measuring techniques
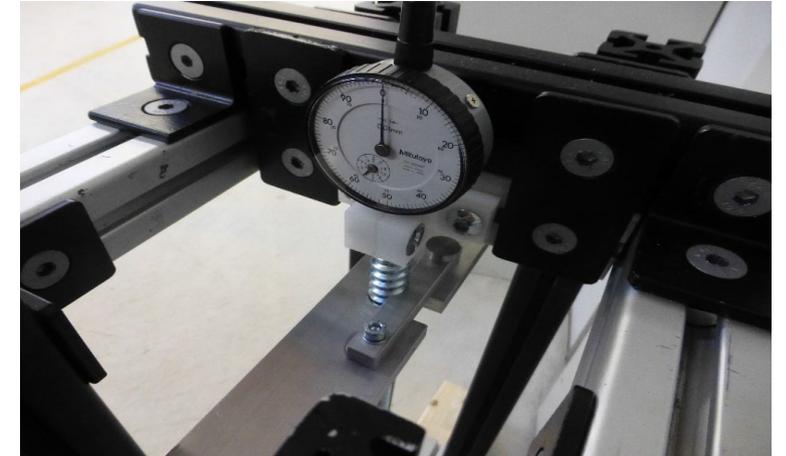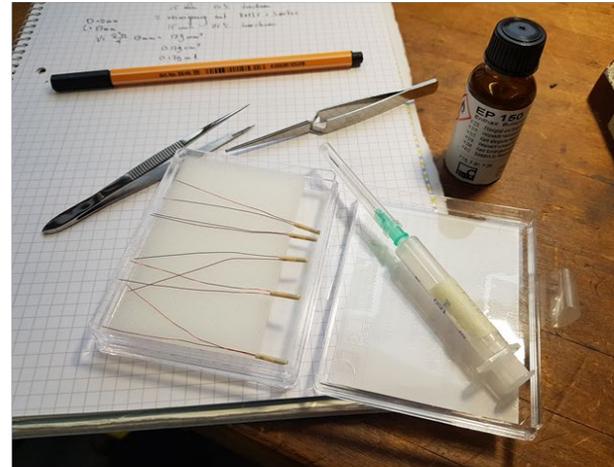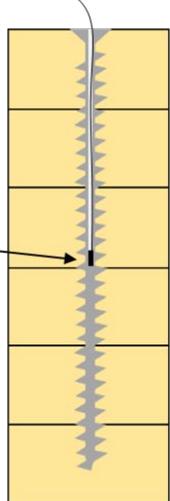
Measurand Methode Range/ Position Accuracy	Displacement (global) Dial gauge 670, 1070 mm 0.01 mm	Displacement (local) Deformeter 100, 200 mm 0.001 mm	Moisture content Electrical resistance 15, 25, 40 mm 1-2 M%	Strain (local) Strain gauges 290 mm depth Micro strain
Photo				
Principal Sketch				
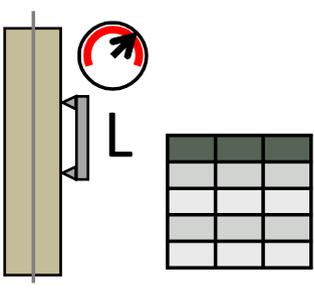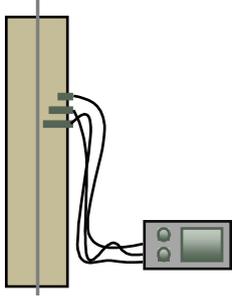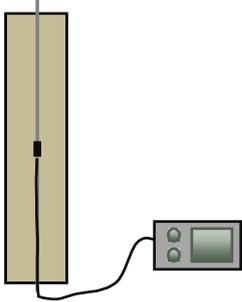
Preparation of test examples
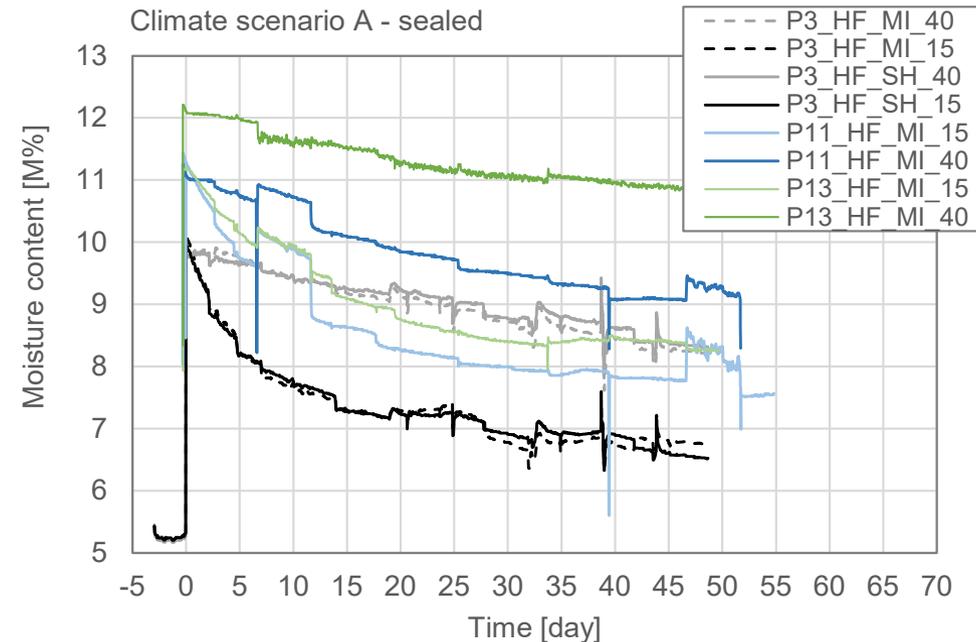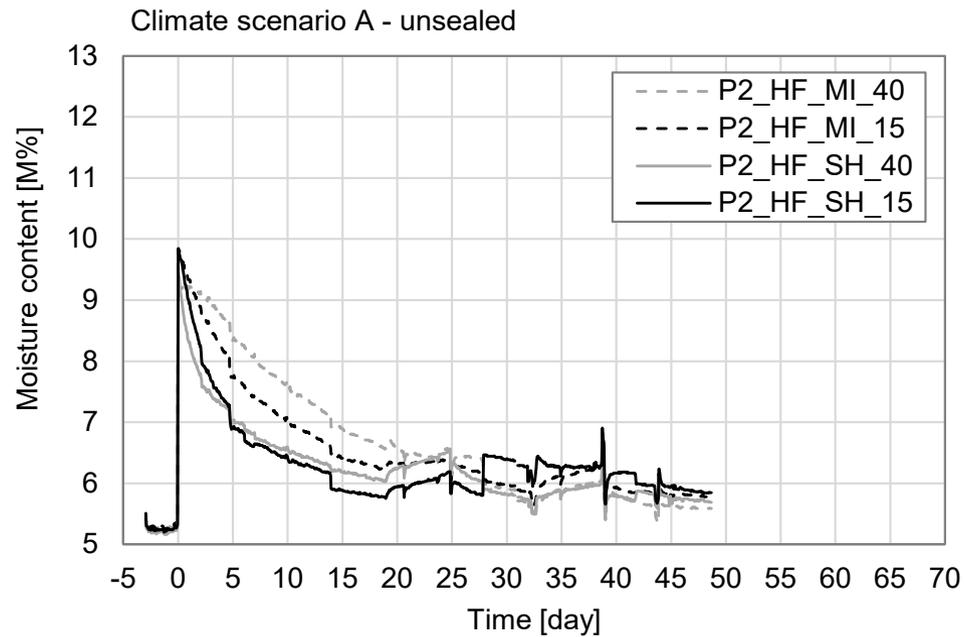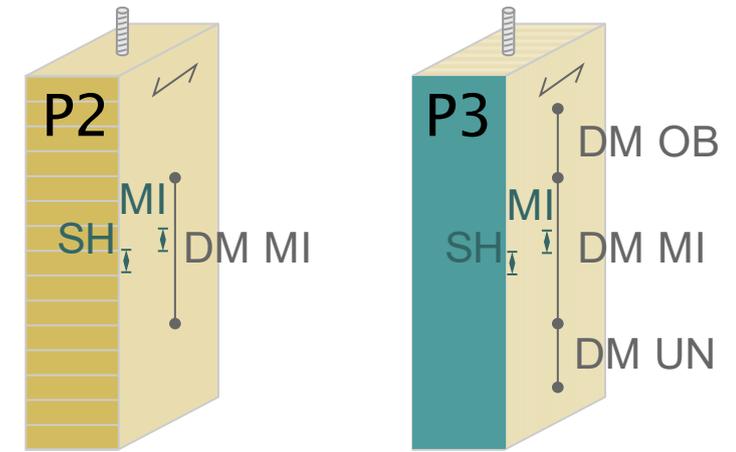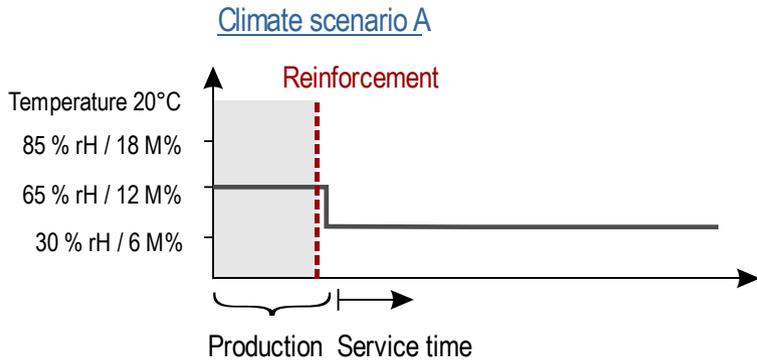
Results – Moisture content at the specimens

Climate scenario A

Temperature 20°C
85 % rH / 18 M%
65 % rH / 12 M%
30 % rH / 6 M%

Reinforcement

Production Service time

P2
MI
SH DM MI

P3
DM OB
MI
SH DM MI
DM UN

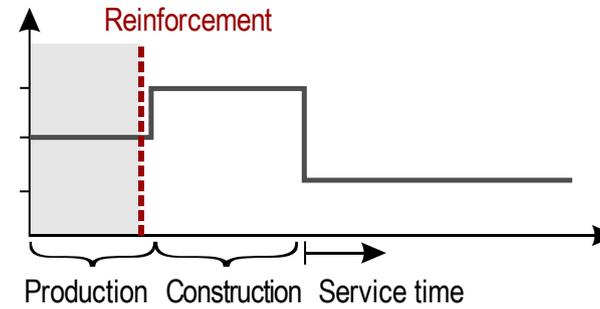### Climate scenario A - unsealed

Moisture content [M%]

- – – – P2_HF_MI_40
- – – – P2_HF_MI_15
- ―――― P2_HF_SH_40
- ―――― P2_HF_SH_15

Time [day]

Climate scenario A - sealed

Moisture content [M%]

- – – – P3_HF_MI_40
- – – – P3_HF_MI_15
- ―――― P3_HF_SH_40
- ―――― P3_HF_SH_15
- ―――― P11_HF_MI_15
- ―――― P11_HF_MI_40
- ―――― P13_HF_MI_15
- ―――― P13_HF_MI_40

Time [day]

Results – Moisture content at the specimens

Results – Calculated average moisture content over the depth

Specimen #P2

Climate scenario A - $u_{average}$

$u_{average}$

Climate scenario A - $\Delta u_{average}$

$\Delta u_{average}$
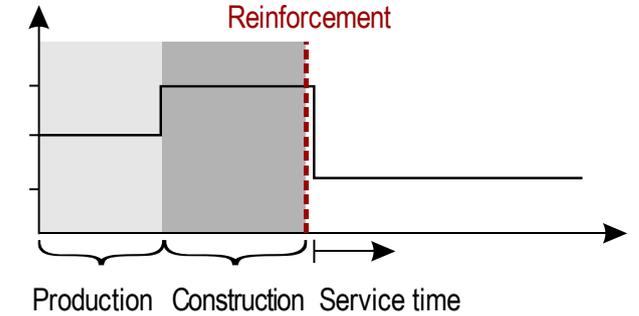
Results – Deformation and strains of the reinforcements
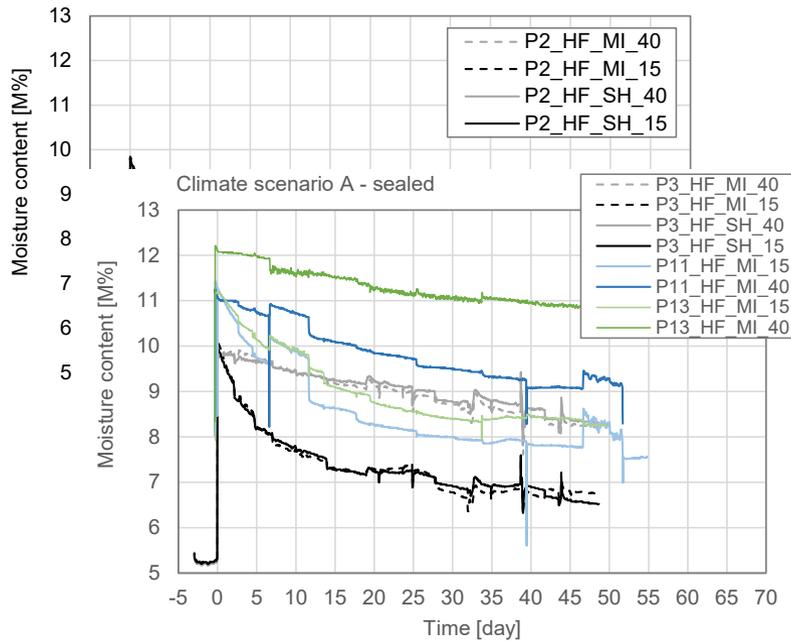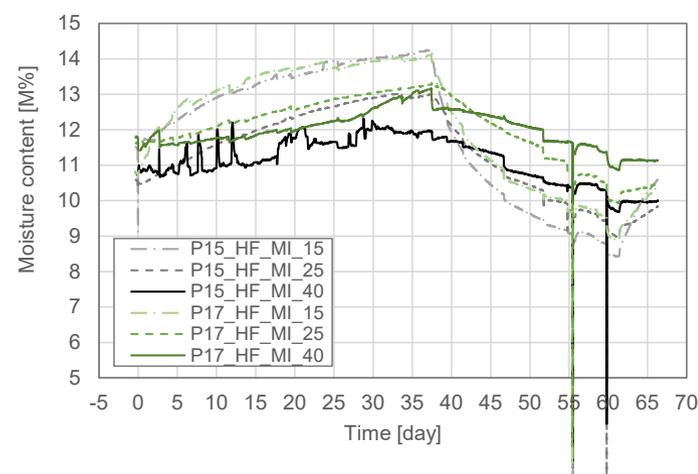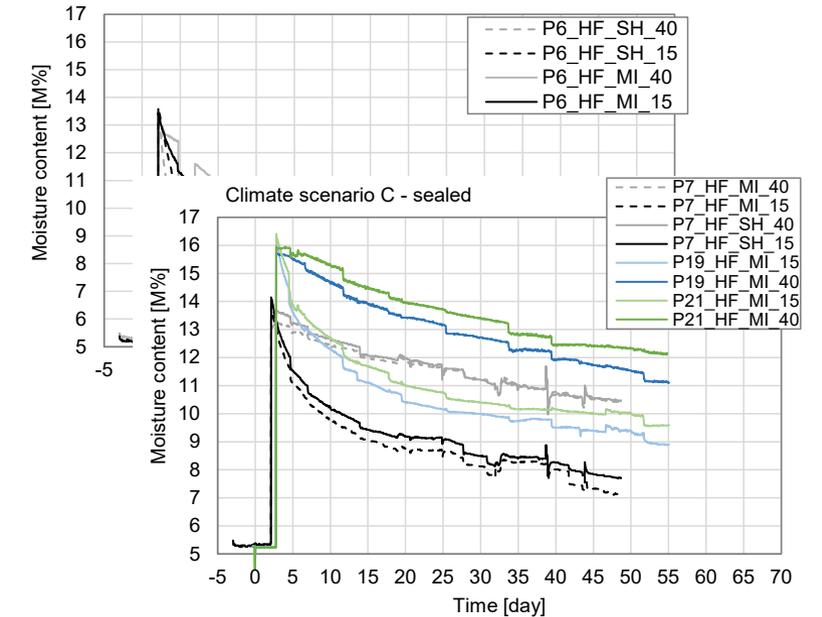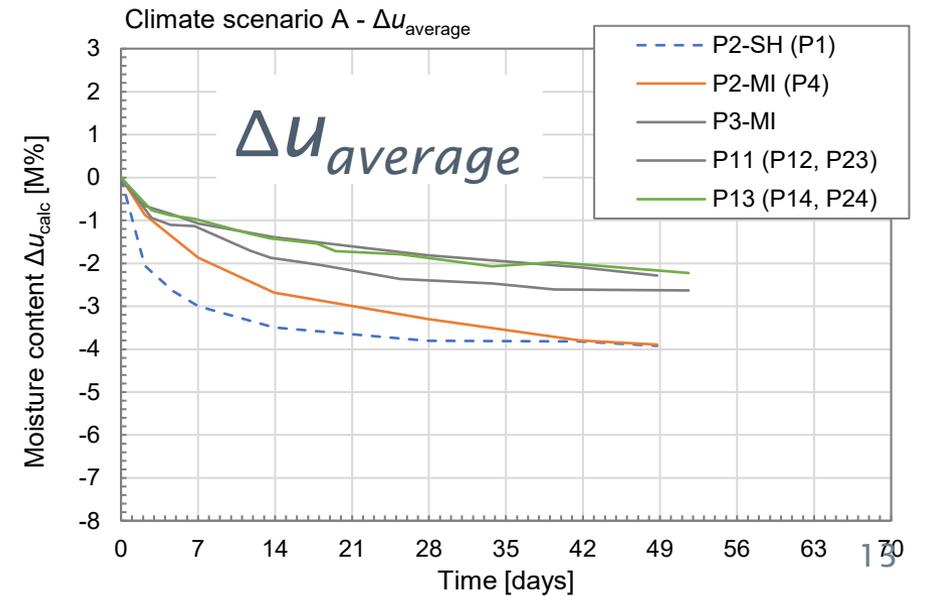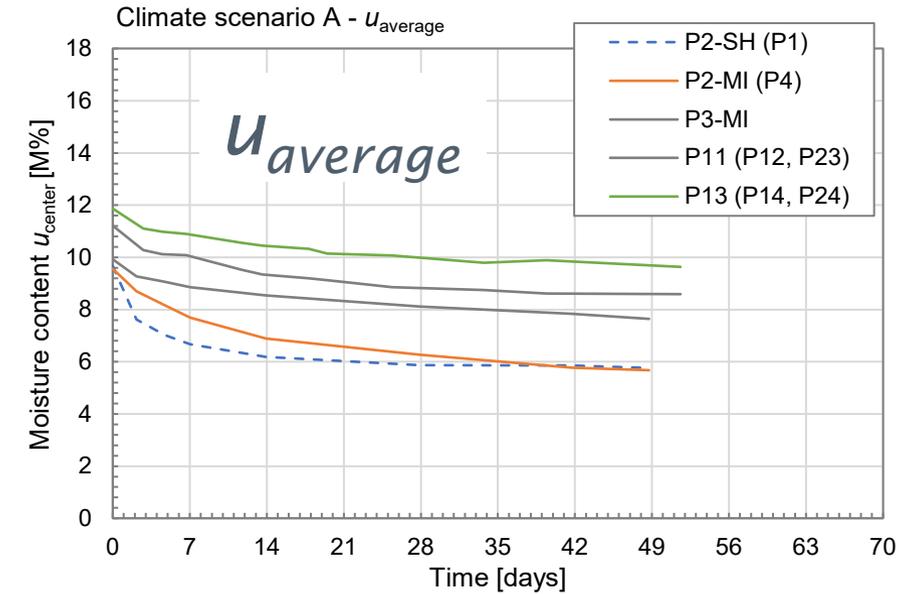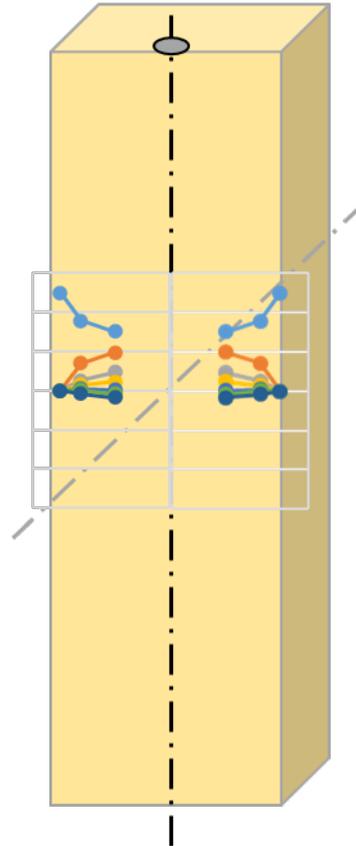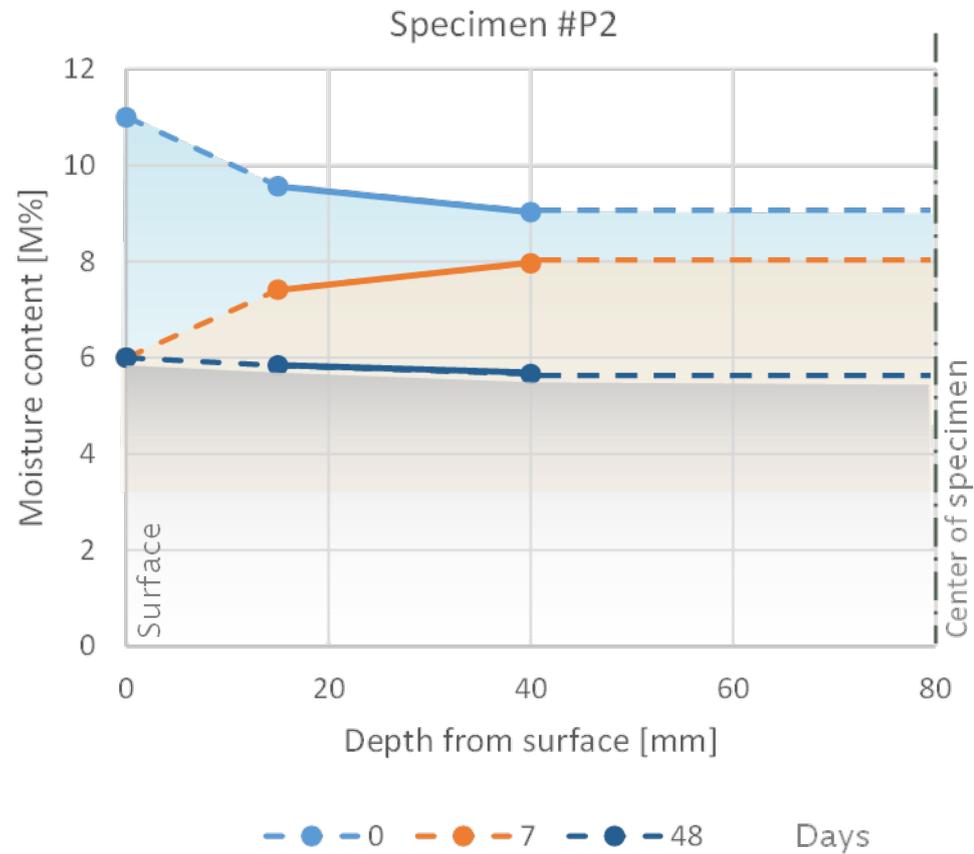

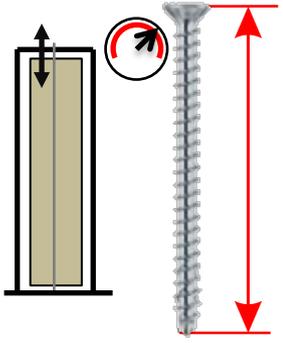Climate scenario A
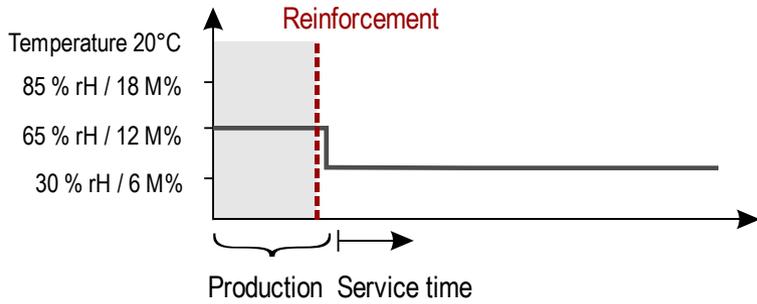
Climate scenario B
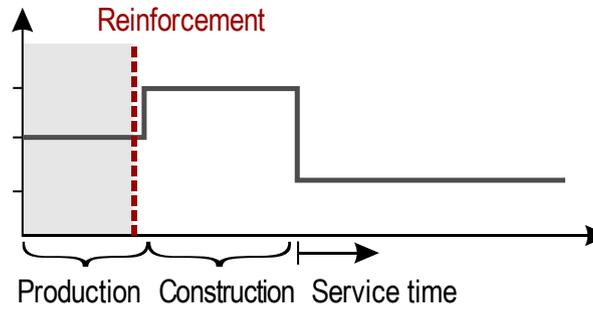
Climate scenario C
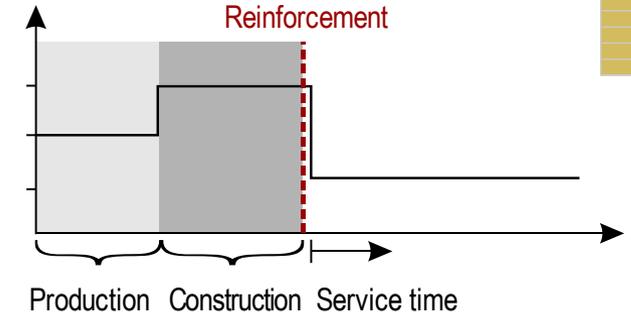
Climate scenario A - unsealed
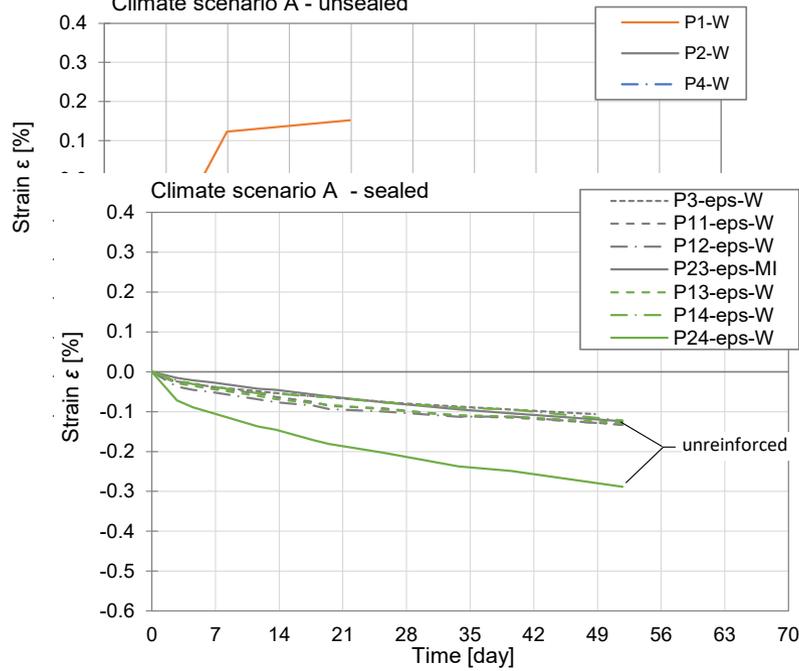
Climate scenario A - sealed
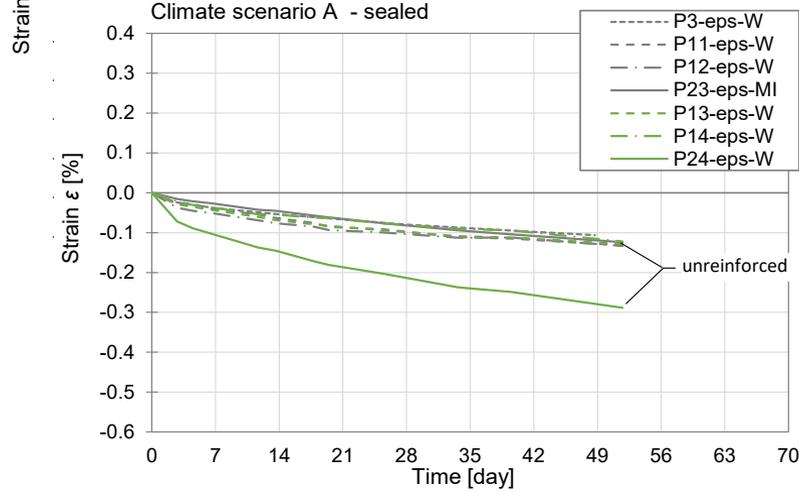
Climate szenario B - sealed
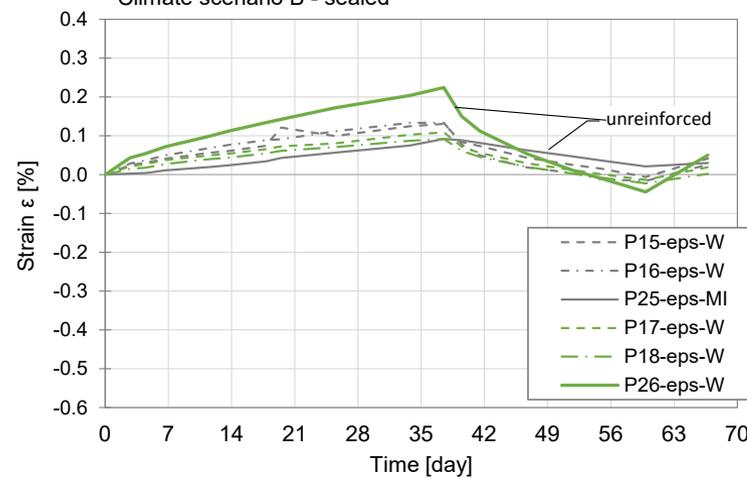
Climate scenario C - unsealed
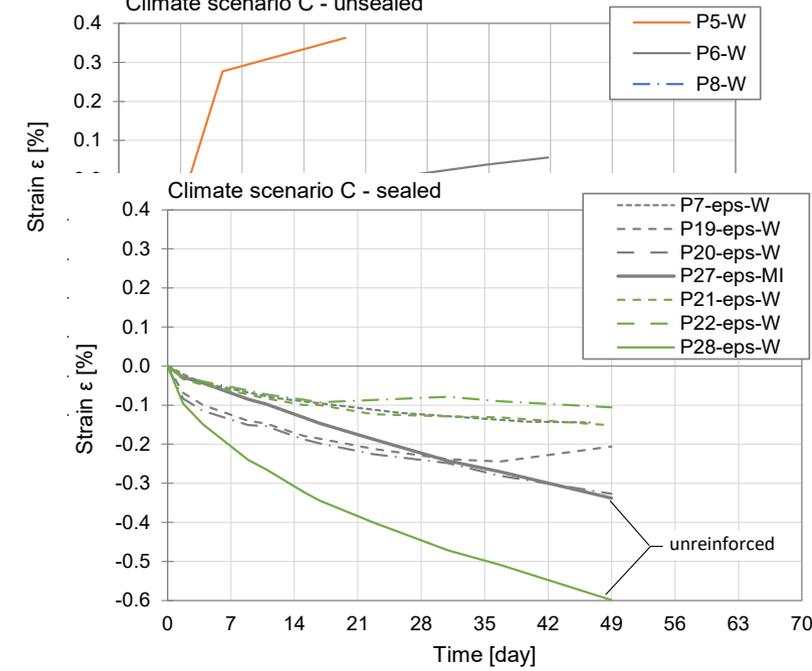
Climate scenario C - sealed
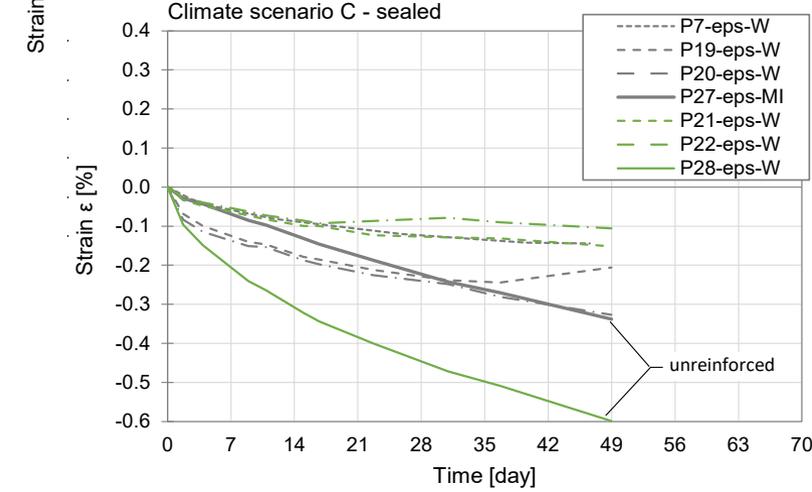
Results – Deformation and strains on wood surface

Results – Characterization of the cracking behaviour

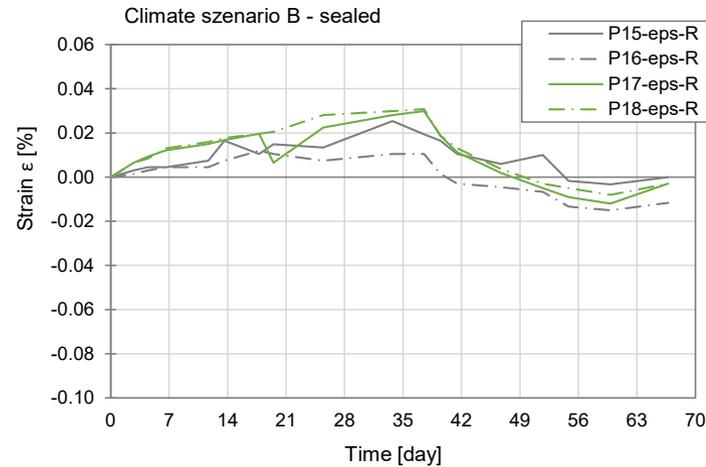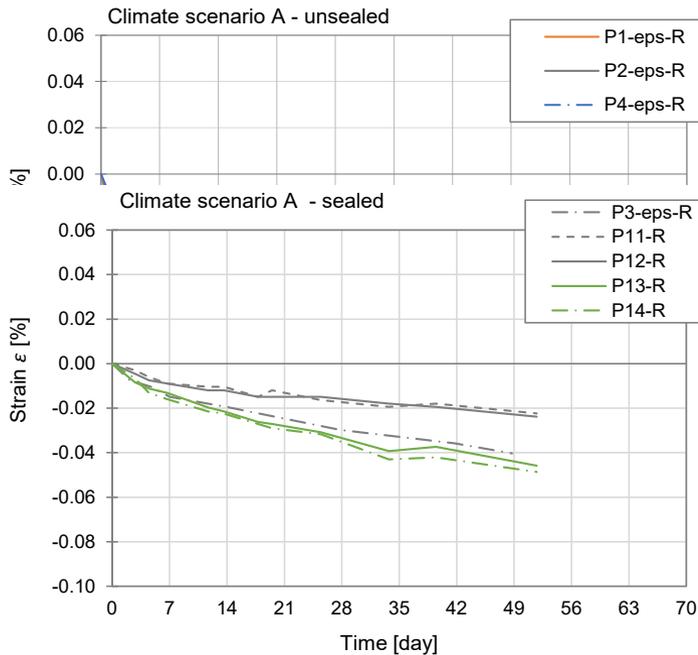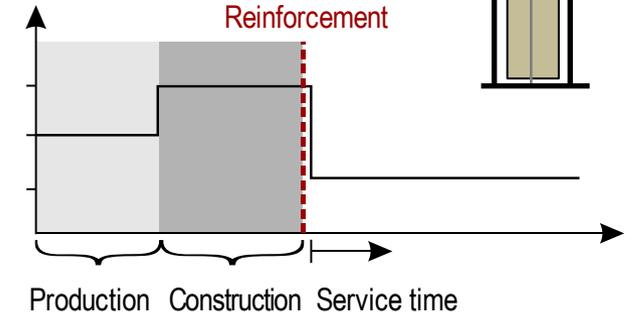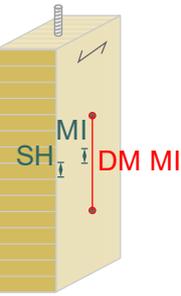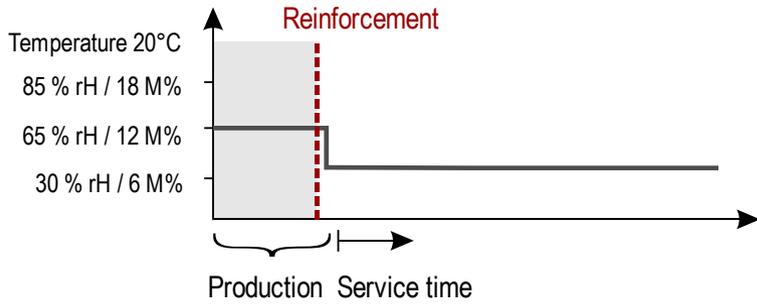Climate scenario A

Reinforcement

Climate scenario C

Reinforcement

Results – Characterization of the effect of reinforcements

Full composite action
Independent of depth l

l

$\varepsilon = \dfrac{\Delta l}{l}$

$\varepsilon = S\dfrac{\Delta l}{l}$

$S = 1.575$

simplified/
measured

theoretically

Compliance composite action
Dependency on depth l

F

A_2, E_2

A_1, E_1 A_1, E_1

$K_{ser}/2$

K_{ser}

K_{ser}

K_{ser}

$K_{ser}/2$

$\varepsilon_{composite}$

$S = f(l)$

Slip moduls K_{ser} = 25 $D\,l$
ETA SFS WB-T rod

Compliance
composite
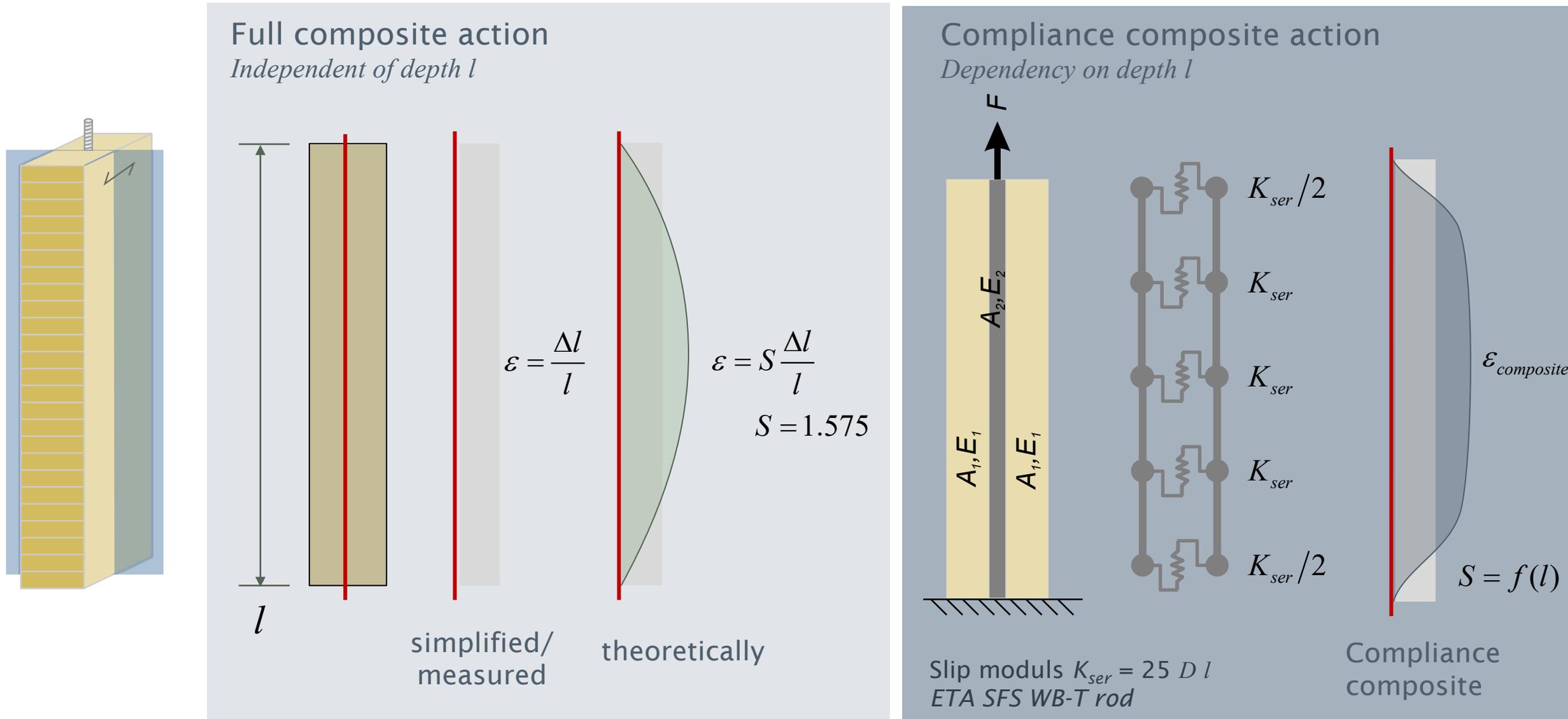
Results – Characterization of the effect of reinforcements
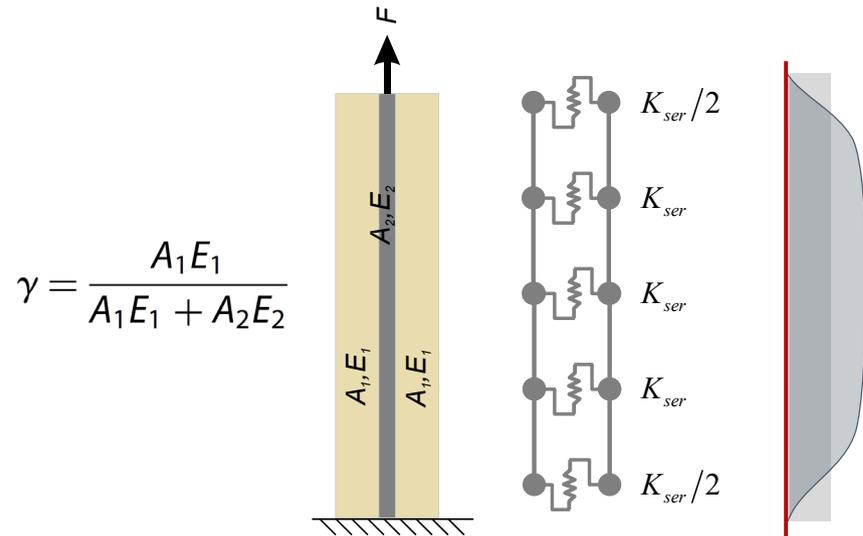
$$\gamma = \frac{A_1 E_1}{A_1 E_1 + A_2 E_2}$$

$$\Delta\varepsilon = \Delta\sigma/E + \alpha\Delta u. \tag{3}$$

$$\Delta\varepsilon_0 = (F_e + \alpha_1\Delta u_1 A_1 E_1)/(A_1 E_1 + A_2 E_2). \tag{4}$$

$$\Delta\sigma_1 = ((F_e + \alpha_1\Delta u_1 A_1 E_1)/(A_1 E_1 + A_2 E_2) - \alpha_1\Delta u_1)E_1 \atop \Delta\sigma_2 = (F_e + \alpha_1\Delta u_1 A_1 E_1)/(A_1 E_1 + A_2 E_2)E_2 \tag{5}$$

$$\Delta\sigma_1 = \alpha_1\Delta u_1(\gamma - 1)E_1 \, and \, \Delta\sigma_2 = \alpha_1\Delta u_1\gamma E_2. \tag{6}$$
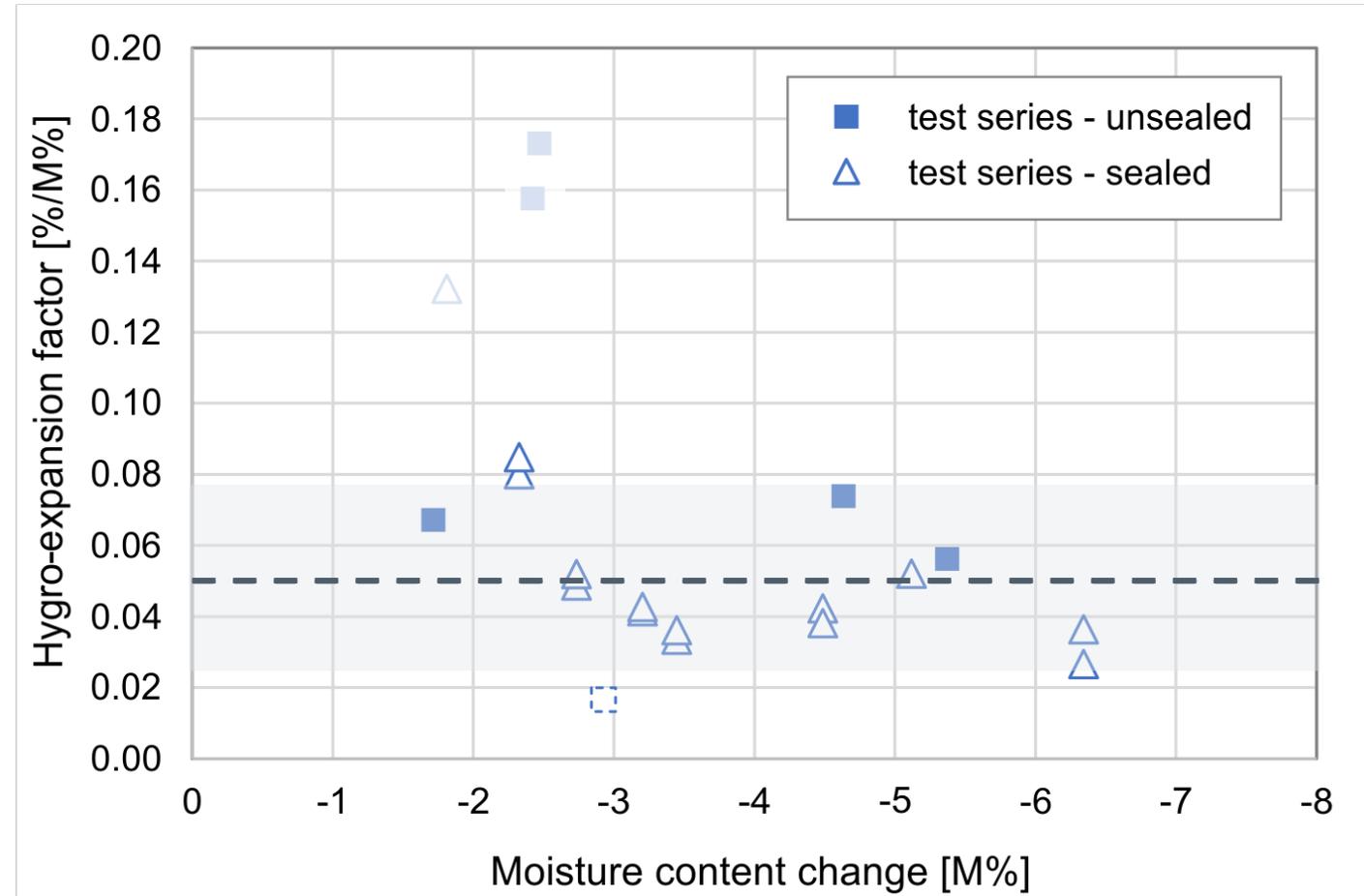
Conclusion and recommendations

▸ Experimental test series successfully carried out

▸ Realistic values observed for moisture content, displacement and strains

▸ Effective hygro-expansion coefficients calculated $\alpha_{\text{eff,reinf}} = 0.05\ \%\!/_{M\%}$

▸ $\alpha_{\text{eff,reinf}}$ includes effects of mechanosorptive relaxation and time dependent creep under the presence of reinforcement

▸ Theoretical hygroexpansion coefficient of wood perp. to grain lie around $\alpha_{\text{r,t}} = 0.25\ \%\!/_{M\%}$

▸ Therefore, larger moisture content impacts are possible without cracking

▸ Next steps: calculating the forces within the reinforcement during climate exposure

▸ Research report will be available by end of the year
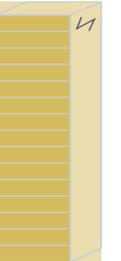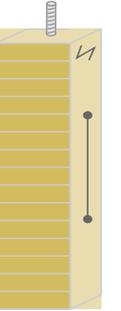
Project – Funding, Partners, Experts

- ▶ Funding by Federal Office of Environmental FOEN Switzerland

- ▶ Duration of 24 months

- ▶ Research report will be available soon

https://www.bfh.ch/de/forschung/forschungsprojekte/2019-719-067-285/
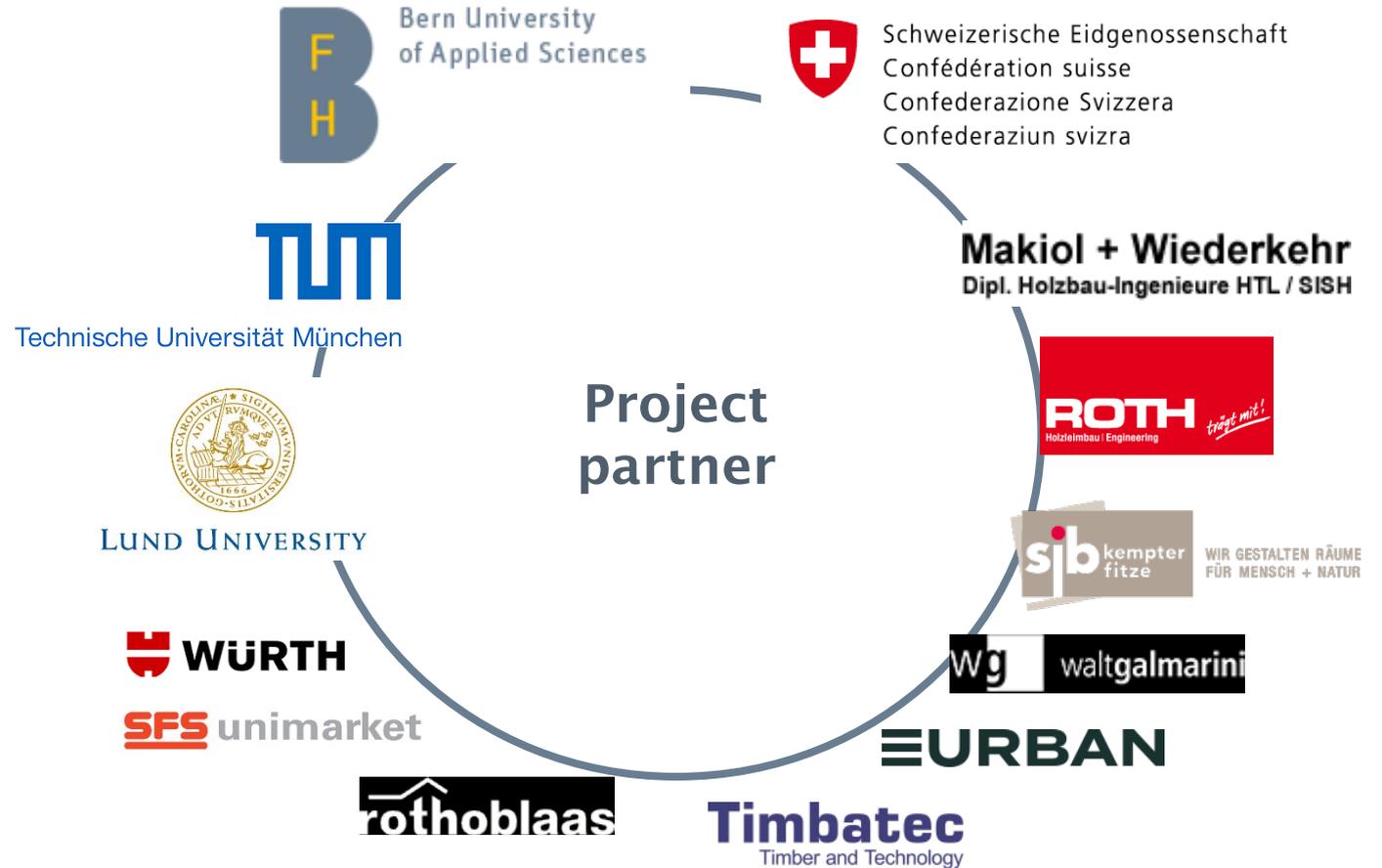
Thank you for your attention!

Dr. Bettina Franke, Prof. Dr. Steffen Franke

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steffen.franke@bfh.ch

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