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NCBR

HYBRID REBARS

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HR EXCELLENCE IN RESEARCH

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A numerical approach to (bond) behavior of GFRP bars with concrete

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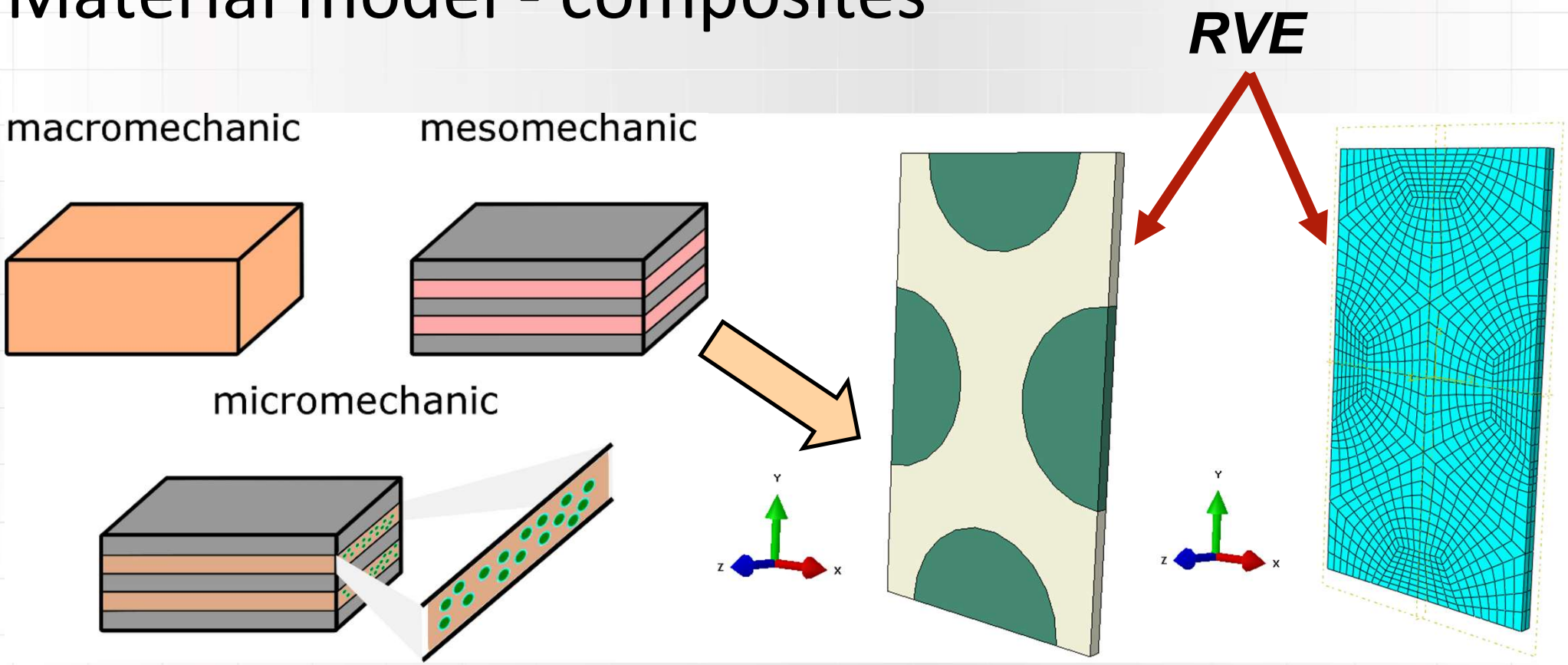
Material model - composites



level of details

geometry model

finite model

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Material model – composites - matrix

Biresin CR141	*100*
+	*:*
Biresin CH141	*90*
+	*:*
Biresin CA141	*2*

Quantity	Norm	Value	unit
Tensile strength	ISO 527	78	MPa
Young modulus (tensile)	ISO 527	3.2	GPa
Maximum elongation	ISO 527	3.3	%
Flexural strength	ISO 178	145	MPa
Young modulus (flexural)	ISO 178	3.1	MPa
Dens	ISO 1183	1.2	$g \cdot cm^{-3}$

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Material model – composites - fibres

pultrusion roving
4800 tex
John Manville

glass fiber	$E_1[MPa]$	$E_2[MPa]$	$E_3[MPa]$	$\nu_{12}\,[-]$	$\nu_{13}[-]$	$\nu_{23}[-]$	$G_1[MPa]$	$G_2[MPa]$	$G_3[MPa]$
values	73000	73000	73000	0.2	0.2	0.2	30416	30416	30416

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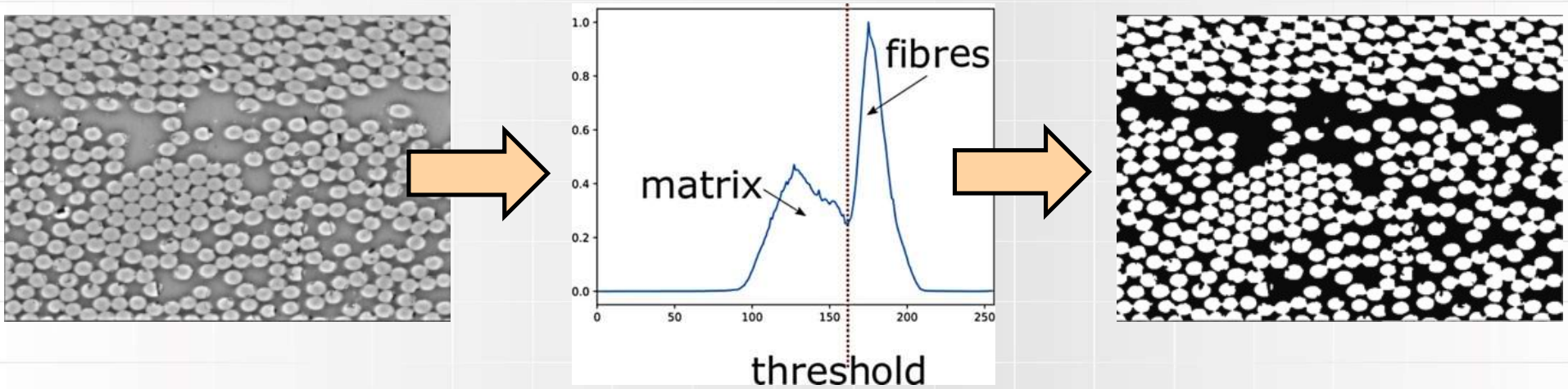
Material model – composites – fiber content



vol %	E_1[MPa]	E_2[MPa]	ν_{12} [−]	ν_{23} [−]	G_{12} [MPa]	G_{23} [MPa]
60%	44918	9946	0.251	0.406	3646	3538
70%	51939	13729	0.237	0.365	4970	5029
80%	58960	20672	0.223	0.321	7533	7827

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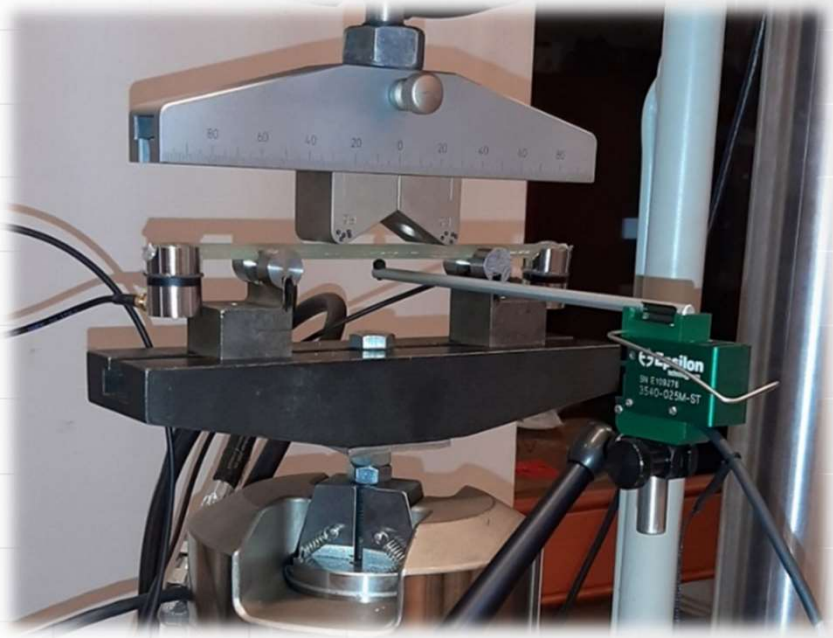
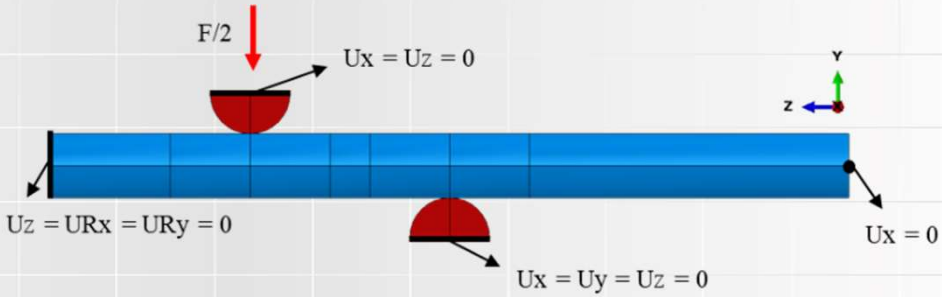
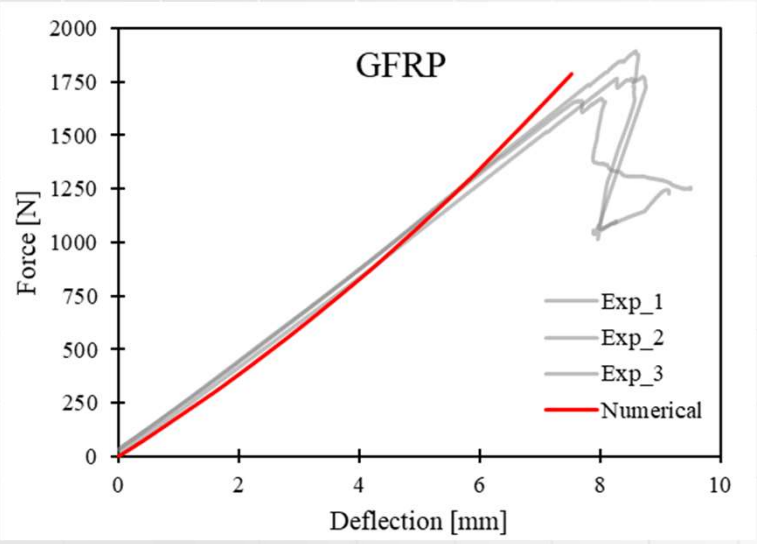
Material model – verification – 4PB







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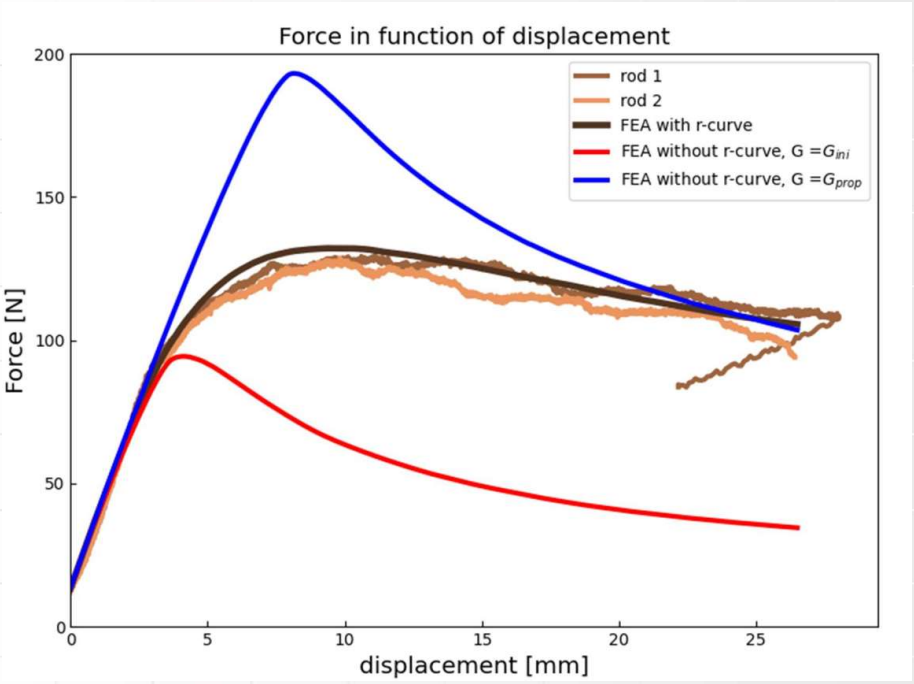
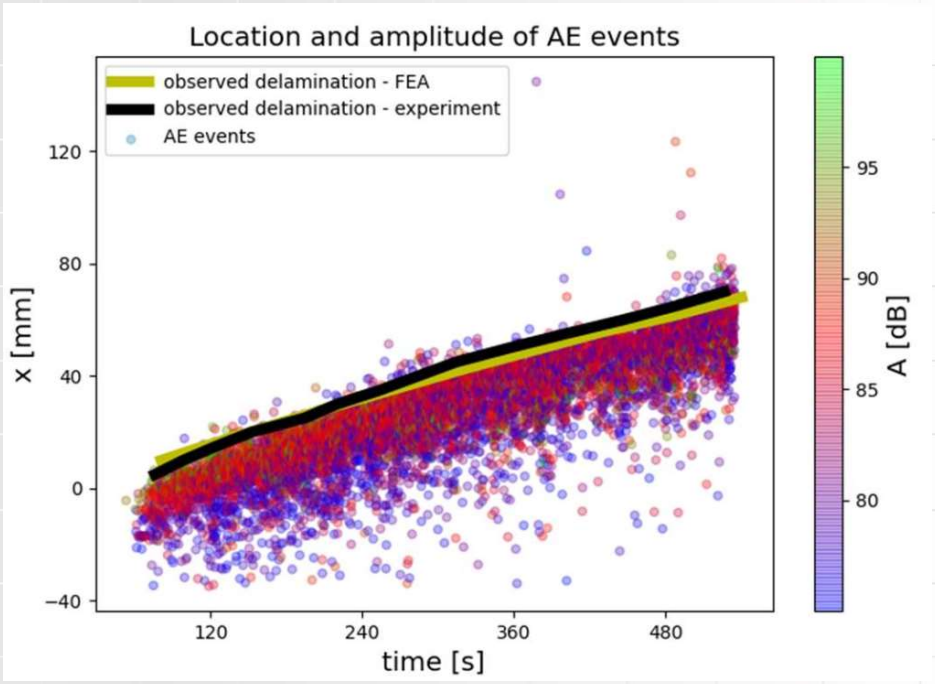
Material model – verification – DCB





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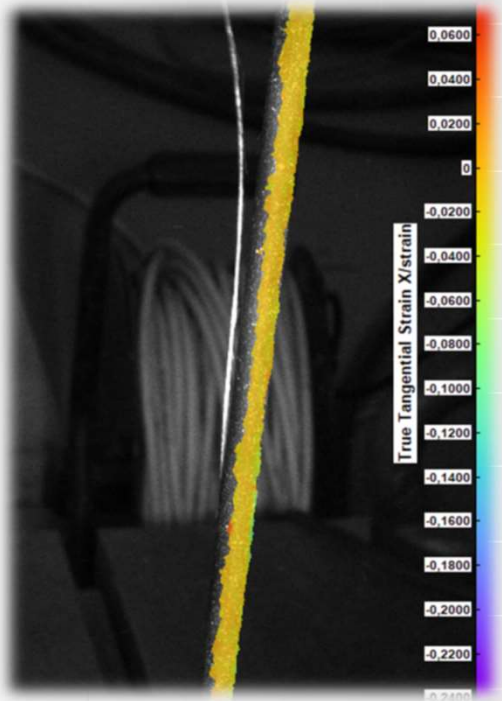
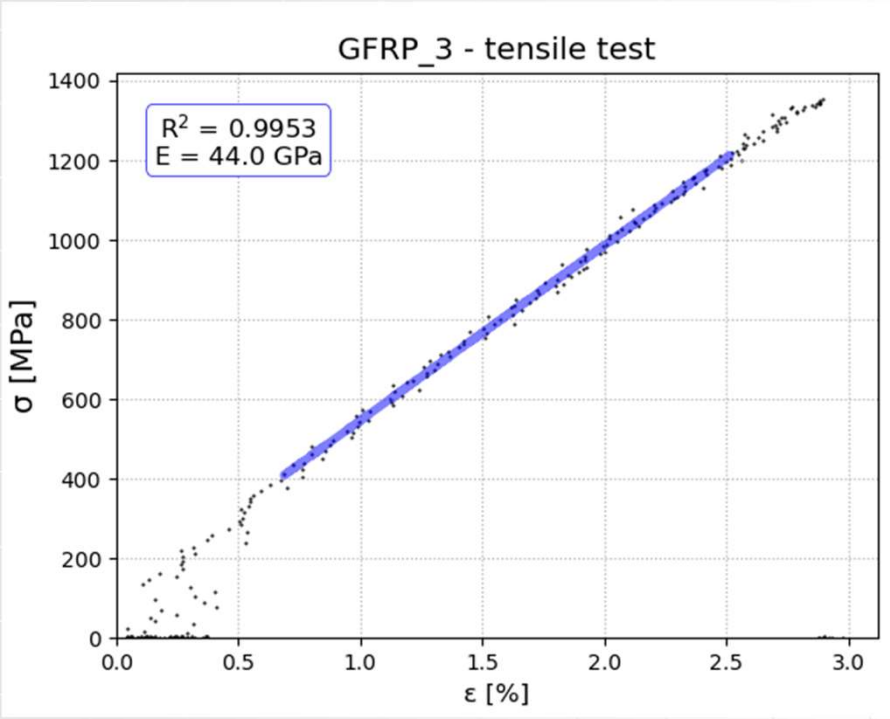
Material model – verification – DCB

experimental set up



DIC results



linear regression

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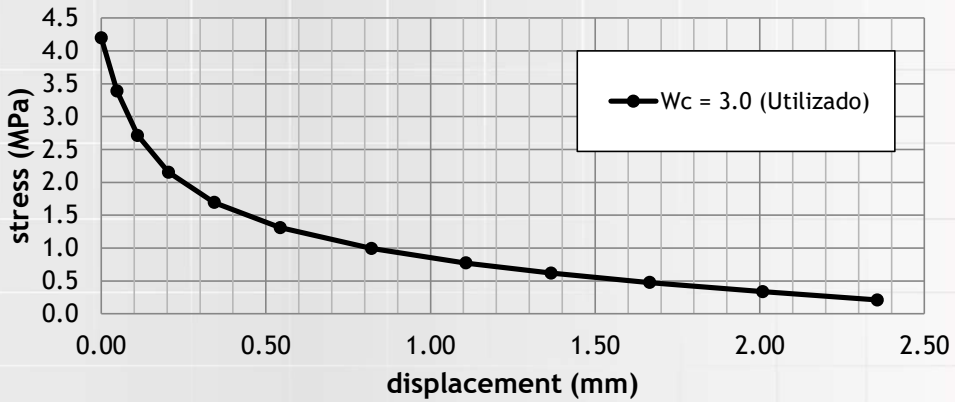
Material model – concrete

quantity	value	unit
Young Modulus	38.9	GPa
Poisson coefficient	0.4	-
Dilation angle ψ	35	°
eccentrity ϵ	0.1	-
σ_{b0}/σ_{c0}	1.16	-
K_c	2/3	-
viscosity μ	1e-6	-



concrete damaged plasticity

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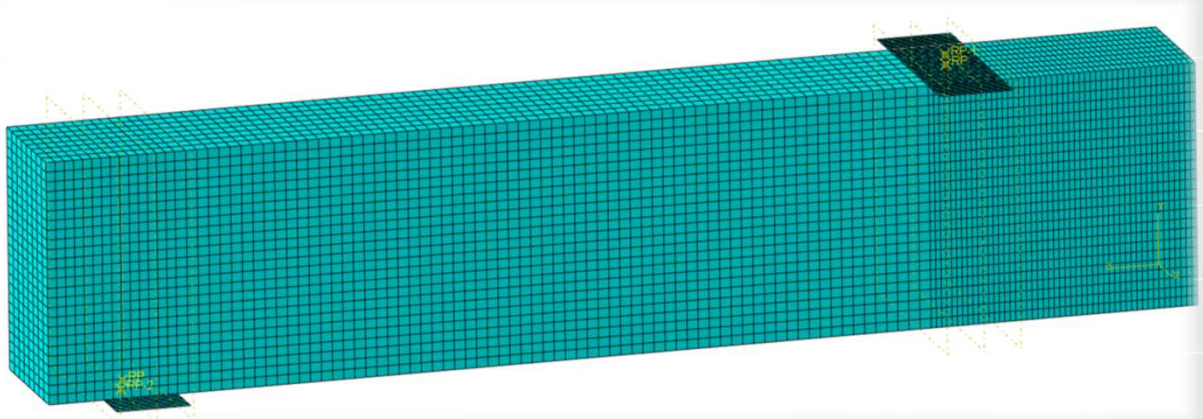
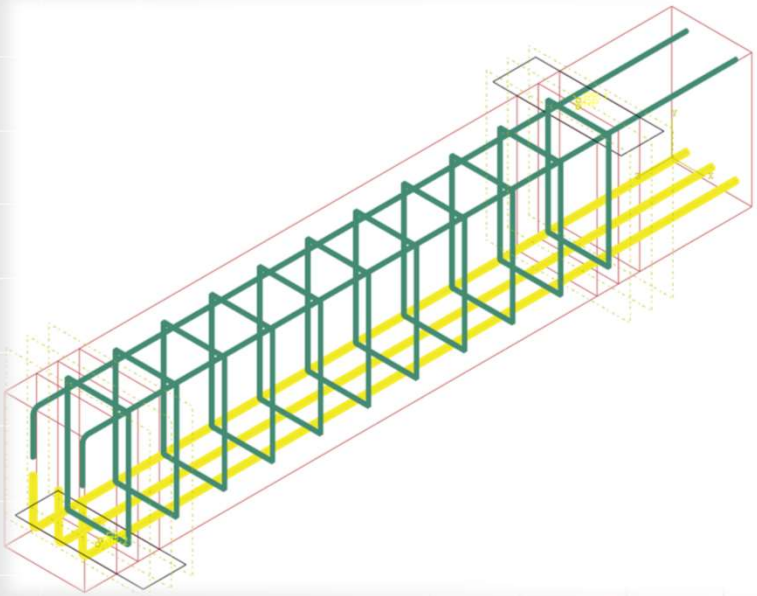
Numerical model – 4PB



finite model



reinforcement

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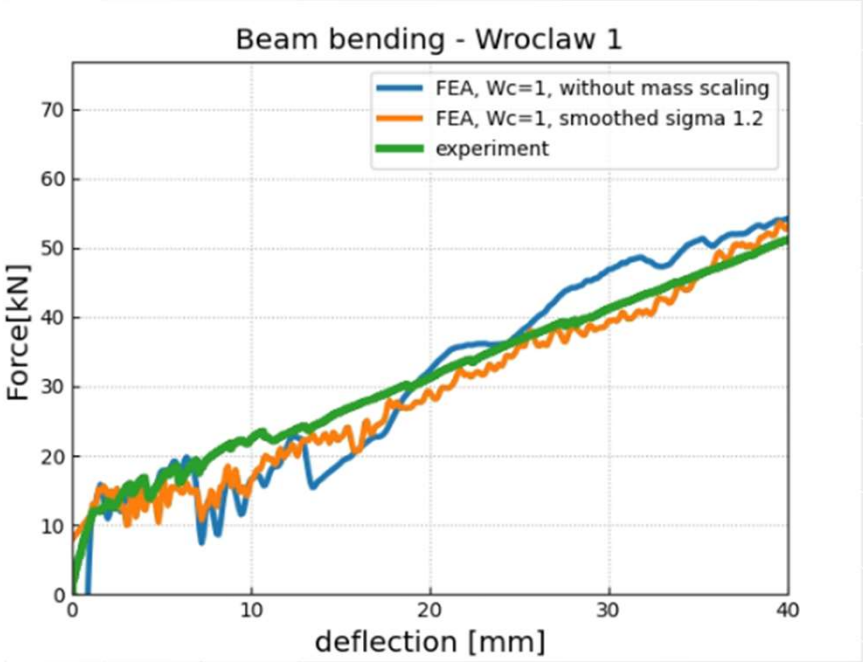
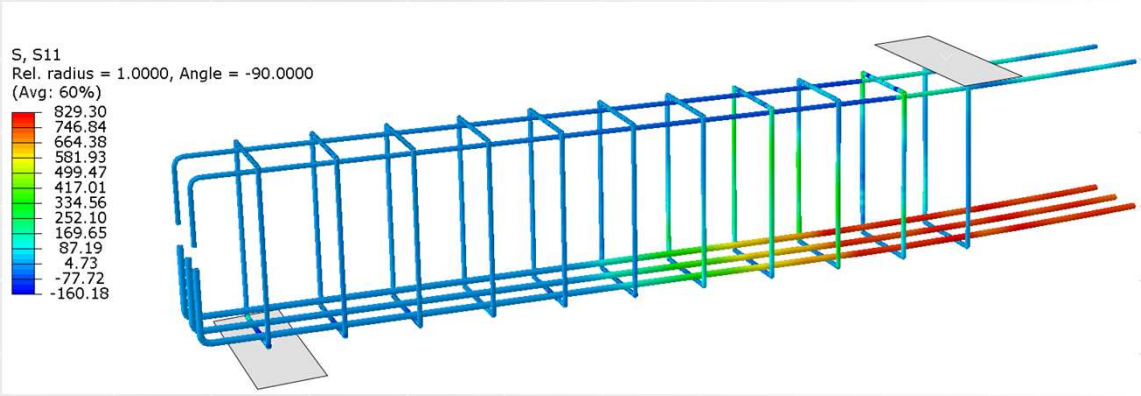
Numerical model – results



FEA & experiment comparison



stresses in reinforcement

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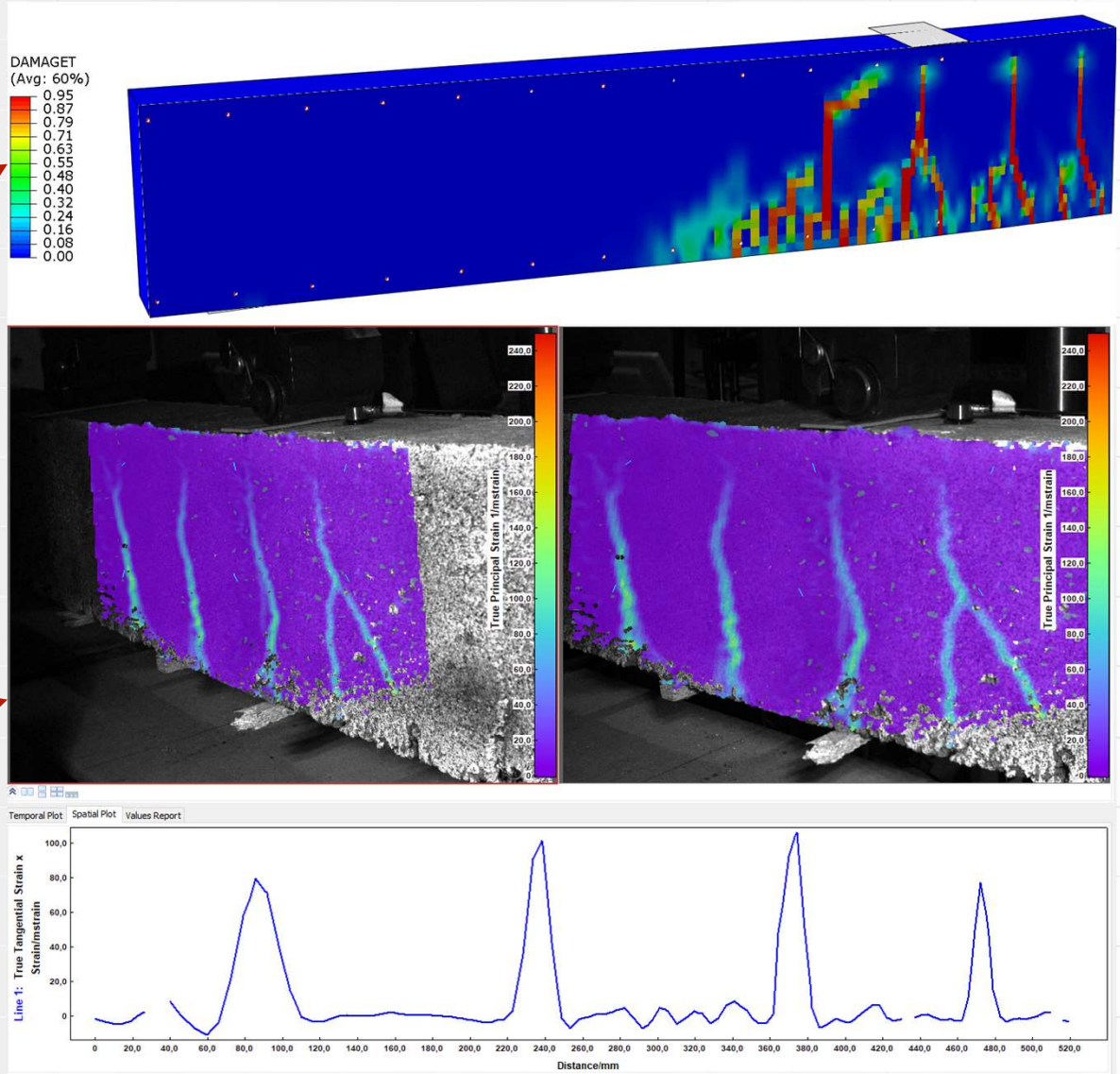
FEA & DIC

FEA

DIC



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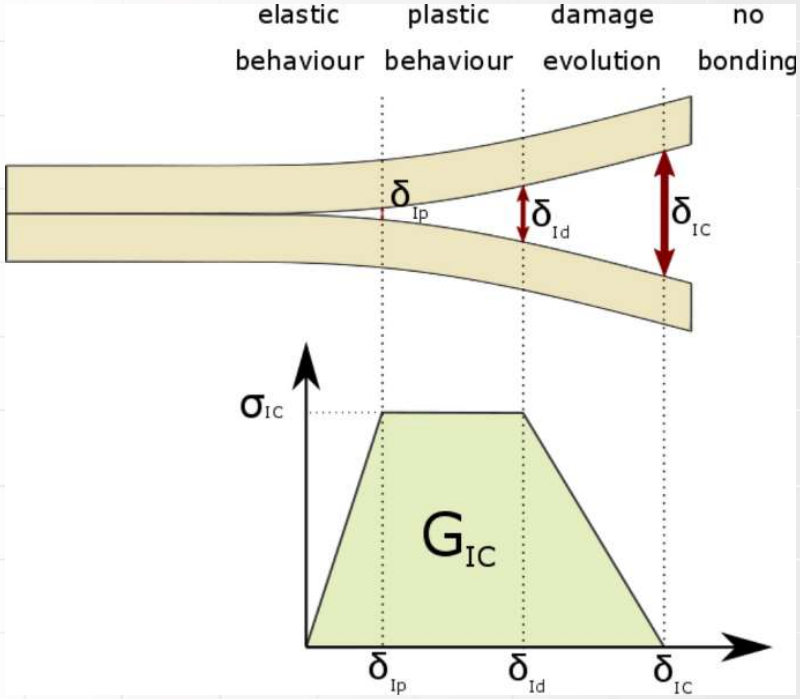
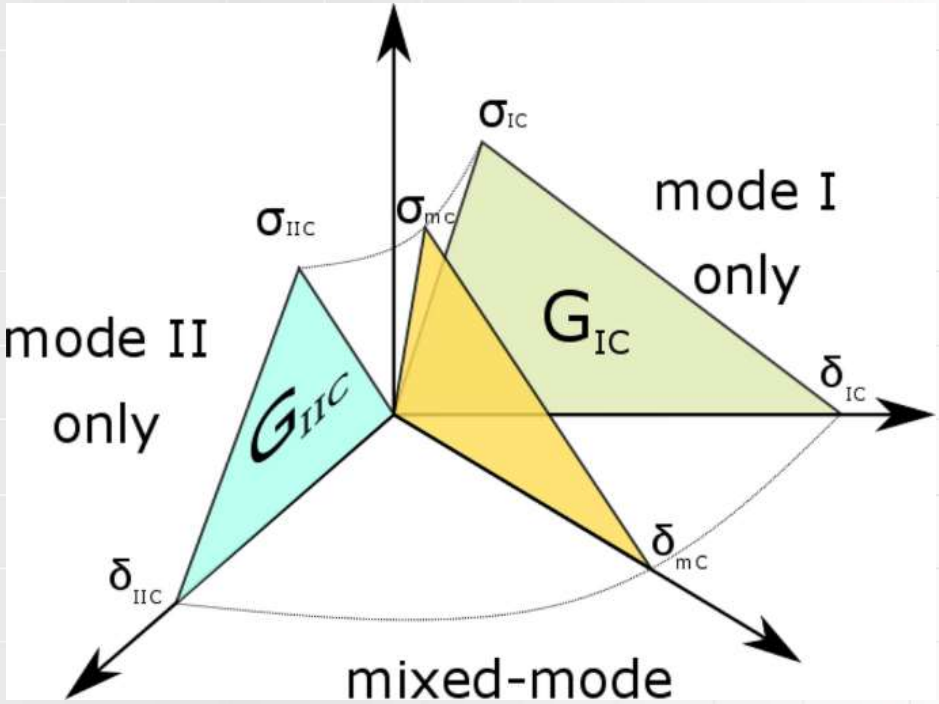
Bond behaviour - cohesive surfaces





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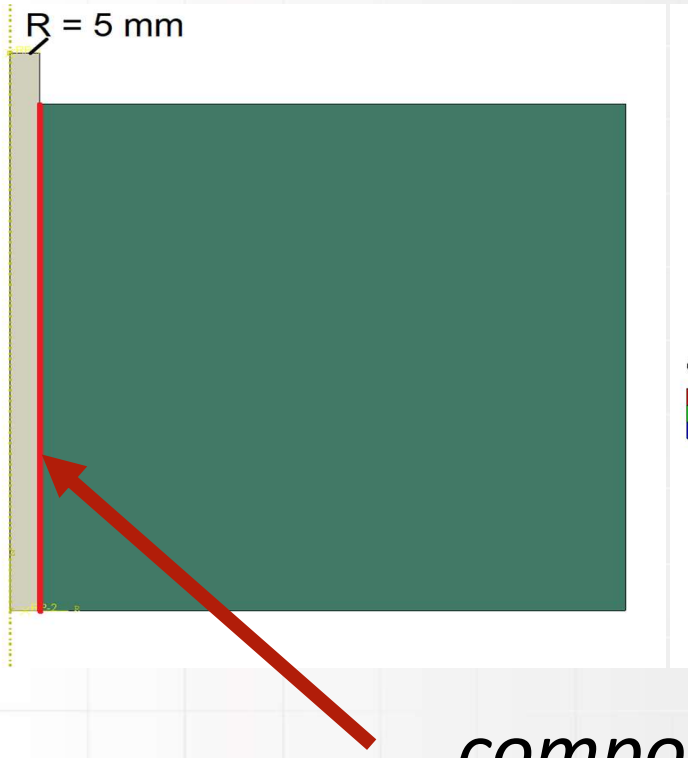
Modeling of bond behaviour – 2D (axis-symmetry)



composite rod – concrete interface

cohesive surface

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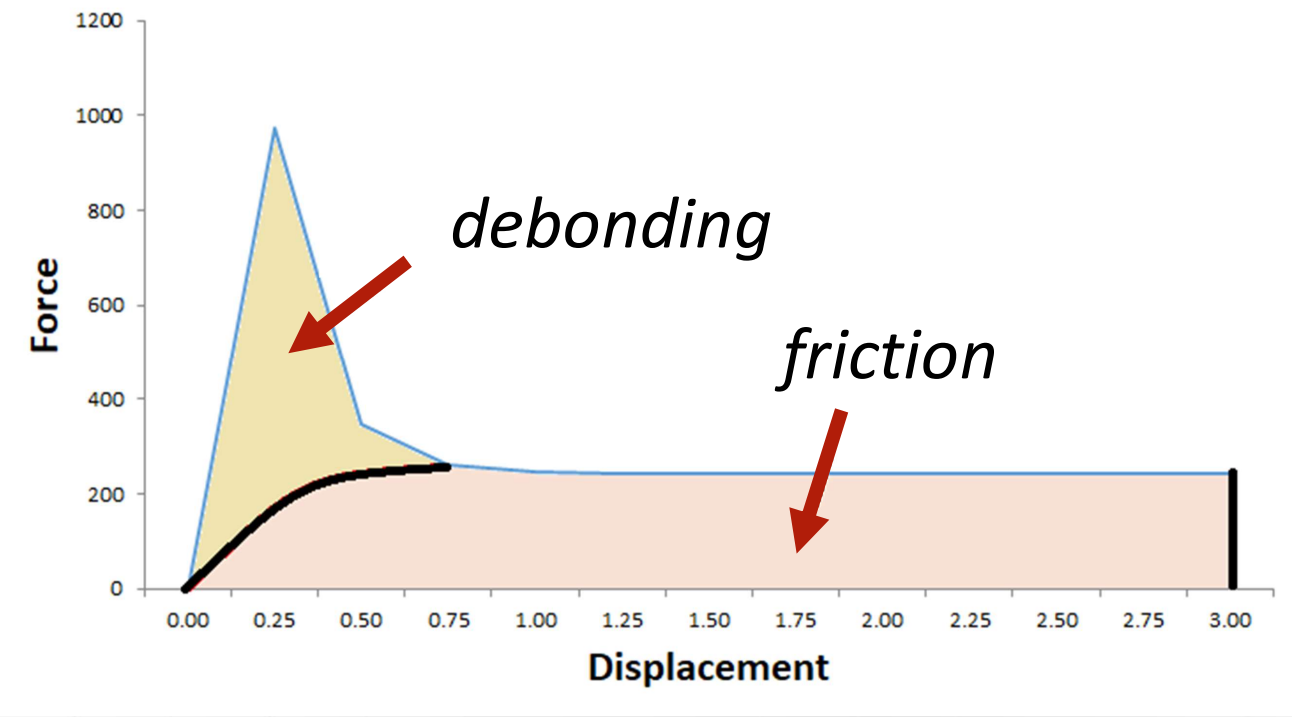
Modeling of bond behaviour - cohesive surfaces



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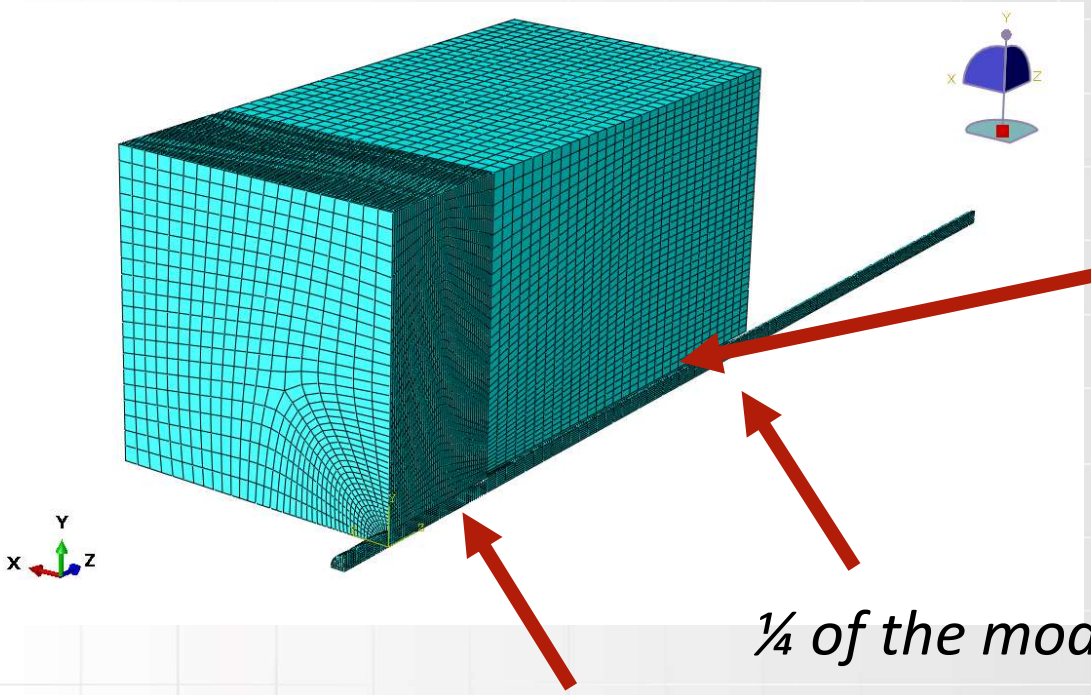
Modeling of bond behaviour – 3D



¼ of the model

C38DR elements

Contact was simulated using the **surface – to - surface** contact option.

The contact interaction property was defined as **Cohesive Behavior with Damage**.

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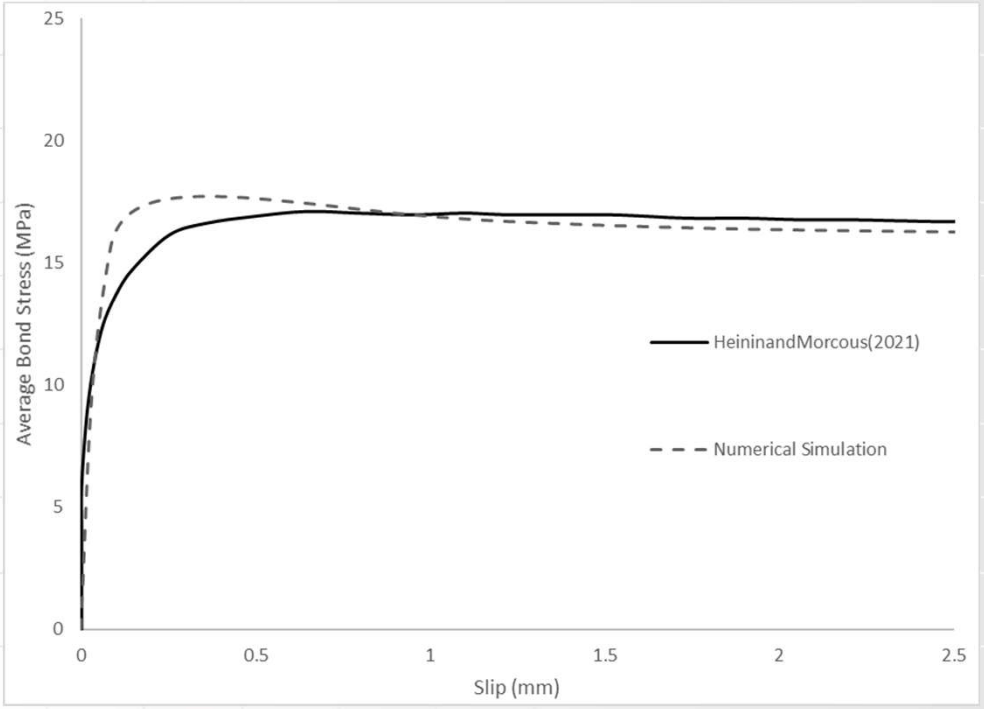
Modeling of bond behaviour – 3D



quantity	value	unit
K_{nn}	178629	$N \cdot mm^{-3}$
K_{ss}	1786	$N \cdot mm^{-3}$
K_{tt}	1786	$N \cdot mm^{-3}$
Damage initiation	100	MPa
Damage propagation	500	$N \cdot mm^{-1}$

$$k_{ss} = k_{tt} = \frac{\tau_m}{s_m}$$

$$k_{nn} = 100k_{ss} = 100k_{tt}$$

Eliya Henin, George Morcous, Bond behavior of helically wrapped sand coated deformed Glass Fiber-Reinforced Polymer (GFRP) bars in concrete, Construction and Building Materials, 2021, https://doi.org/10.1016/j.conbuildmat.2021.123120.

Biruk Tekl et. Al., Bond Properties of Sand-Coated GFRP Bars with Fly Ash–Based Geopolymer Concrete, Journal of Composites for Construction, 2016 10.1061/(ASCE)CC.1943-5614.0000685

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Conclusions

- Modeling of cocrete beams reinforced by composite rebars require well-prepared material models for composite material, concrete and their interface
- Bond behaviour can be successfully modelled with cohesive zone model approach utilizing cohesive surfaces or elements
- Analytical and/or experimental procedures should be utilized in order to obtain required data for bond behaviour