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NCBR

HYBRID REBARS

unite! University Network for Innovation, Technology and Engineering

HR EXCELLENCE IN RESEARCH

Evaluated by IEP INSTITUTIONAL EVALUATION PROGRAMME www.iep-qaa.org

Analytical predictions of bond behavior of FRP bars with concrete

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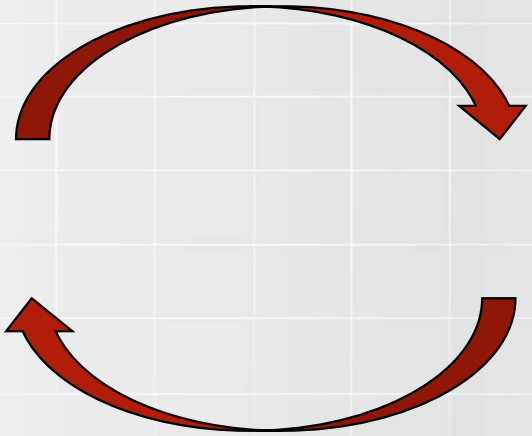
Bar to concrete behaviour

Shear stress along the composite bar – concrete interface



Composite bar free end **slip**

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Bond strength

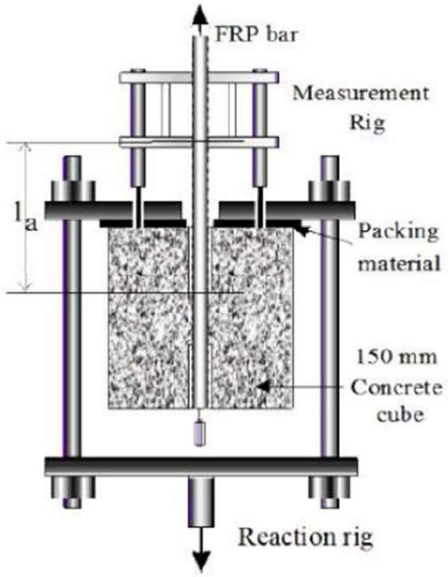
Bond strength

$$\tau = \frac{F}{C_b \cdot l}$$

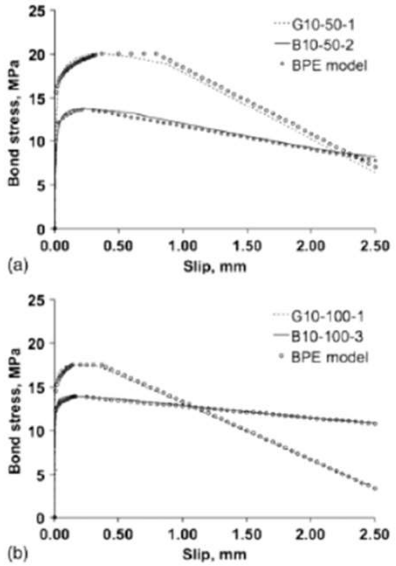
Elongation of bar

$$S_c = \frac{F \cdot L_a}{E_L \cdot A}$$

Example of pullout tests



Material of rebar influences bond strength



Sand coated rebars

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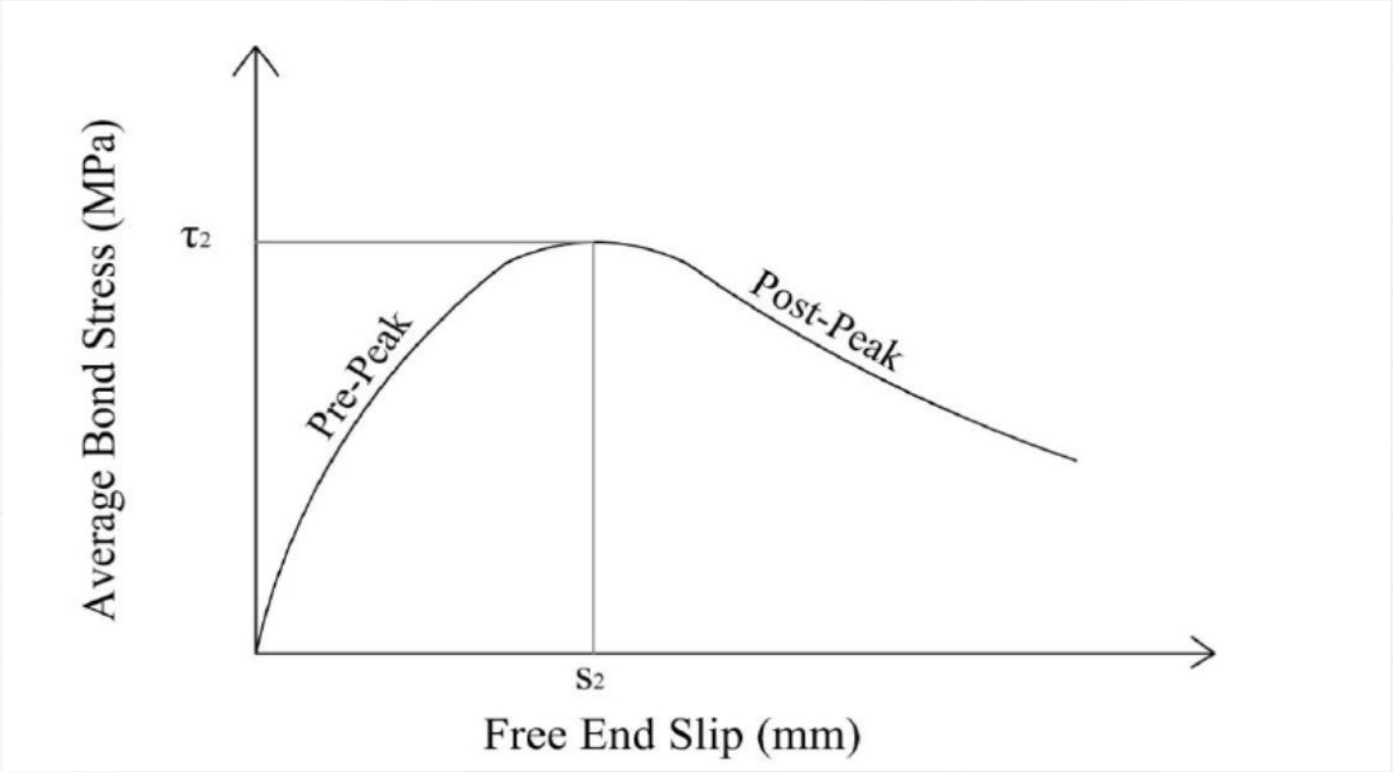
Bar to concrete behaviour - idea



Vint, L. M. (2012) "Investigation of bond properties of glass fiber reinforced polymer (GFRP) bars in concrete under direct tension". M. A. Sc. Thesis, Department of Civil Engineering, University of Toronto, Toronto, Canada.

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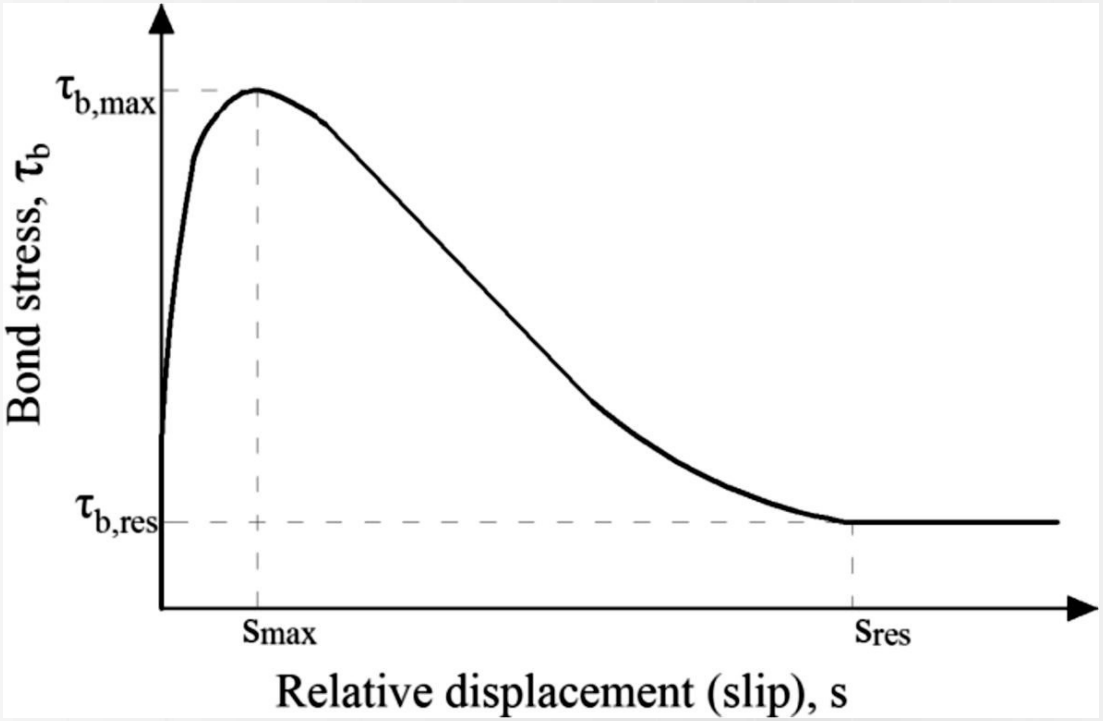
Bar to concrete behaviour - idea



Sandor Solyom, György L. Balázs, Analytical and statistical study of the bond of FRP bars with different surface characteristics, Composite Structures, Volume 270, 2021,113953, ISSN 0263-8223,
https://doi.org/10.1016/j.compstruct.2021.113953.

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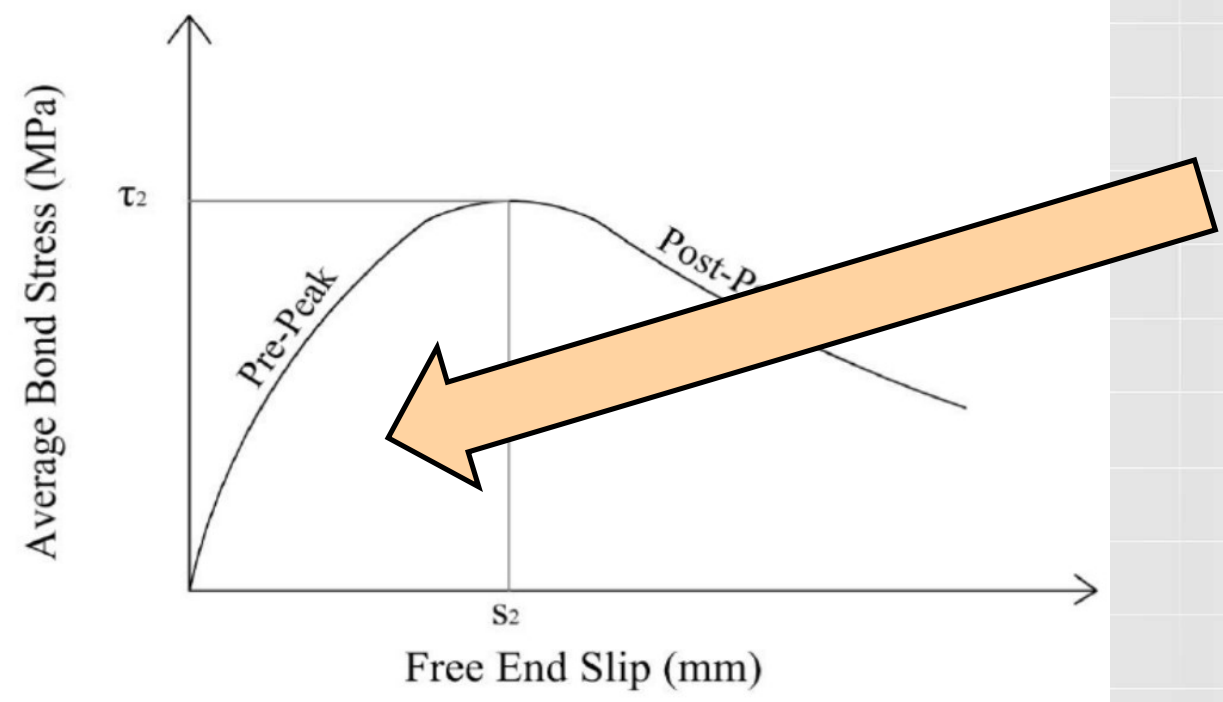
Bar to concrete behaviour – pre-peak



- transverse cracks
- lost of chemical adhesion

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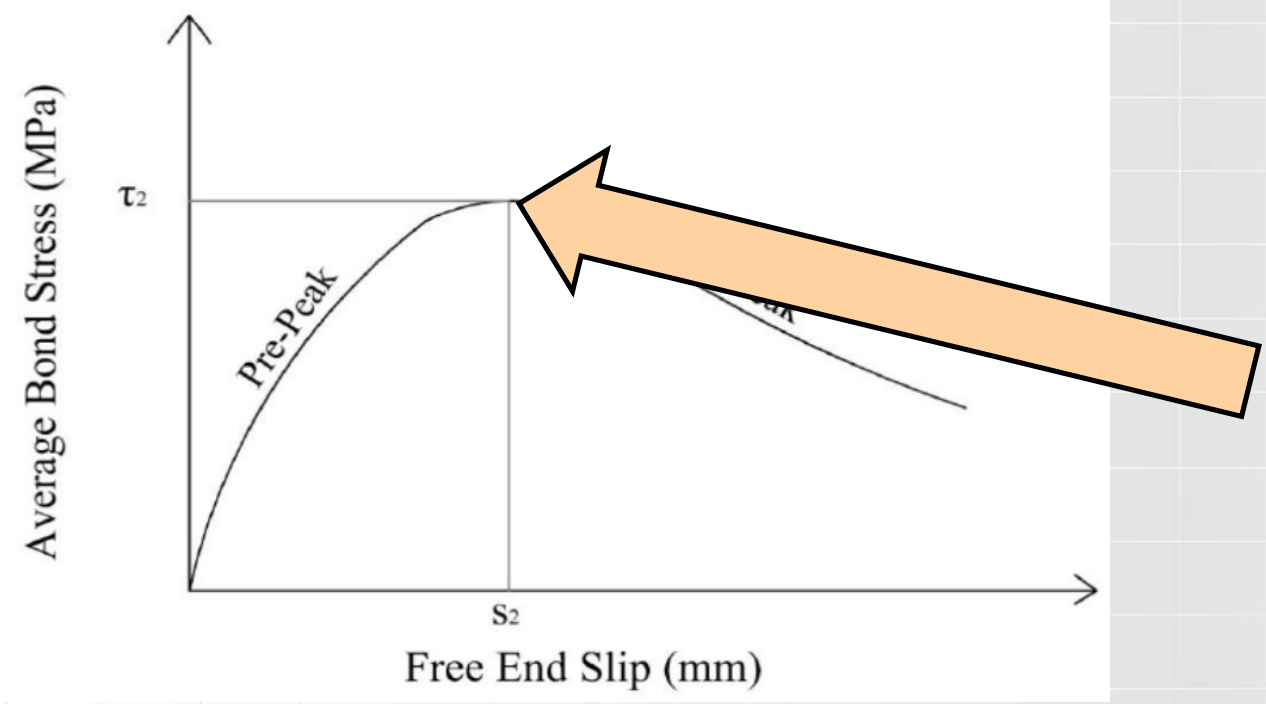
Bar to concrete behaviour – bond failure



splitting cracks reach the entire concrete surface

OR

deformation of bar

OR

shearing in concrete

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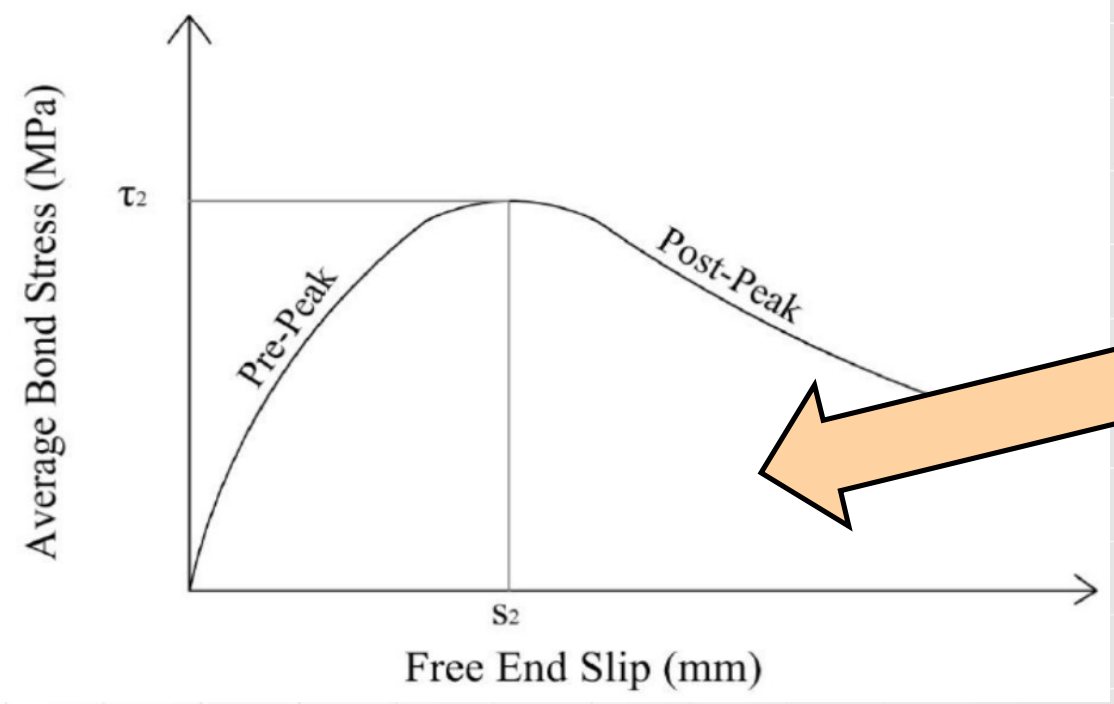
Bar to concrete behaviour – bond failure



residual bond stress

due to

surface friction

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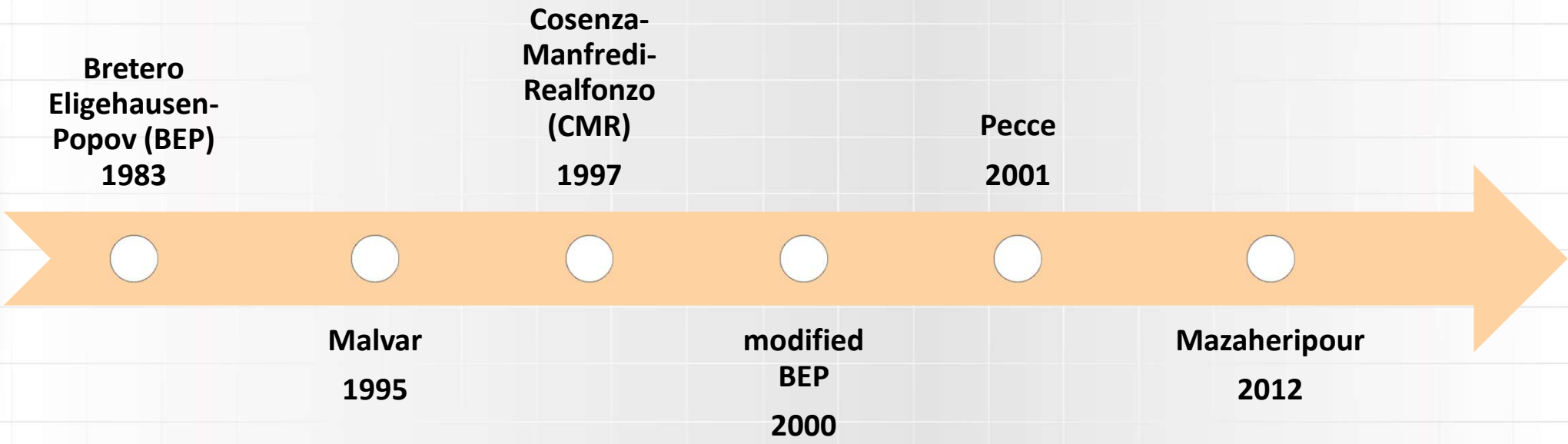
Analytical models - timeline



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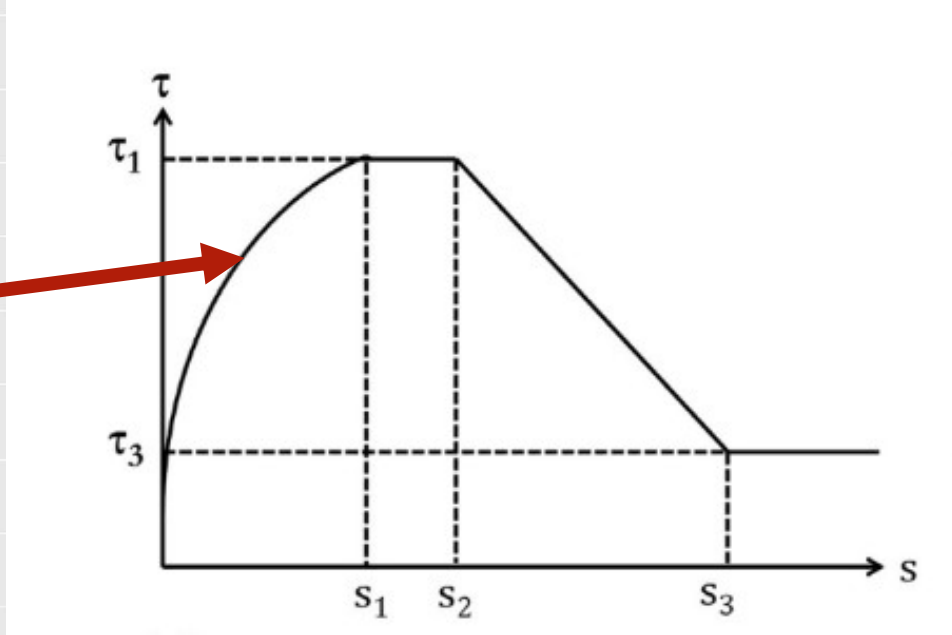
Analytical models – BPE model

Model proposed for **steel rebars** by Eligehausen, Popov and Bertero in 1982.

$$\tau = \tau_1 \left(\frac{s}{s_1}\right)^{\alpha} For\ 0 \le s \le s_1$$

$\alpha = 0.2$ in presented research



Arnaud Rolland et. Al. Analytical and numerical modeling of the bond behavior between FRP reinforcing bars and concrete, CaBM, 2020 (231)

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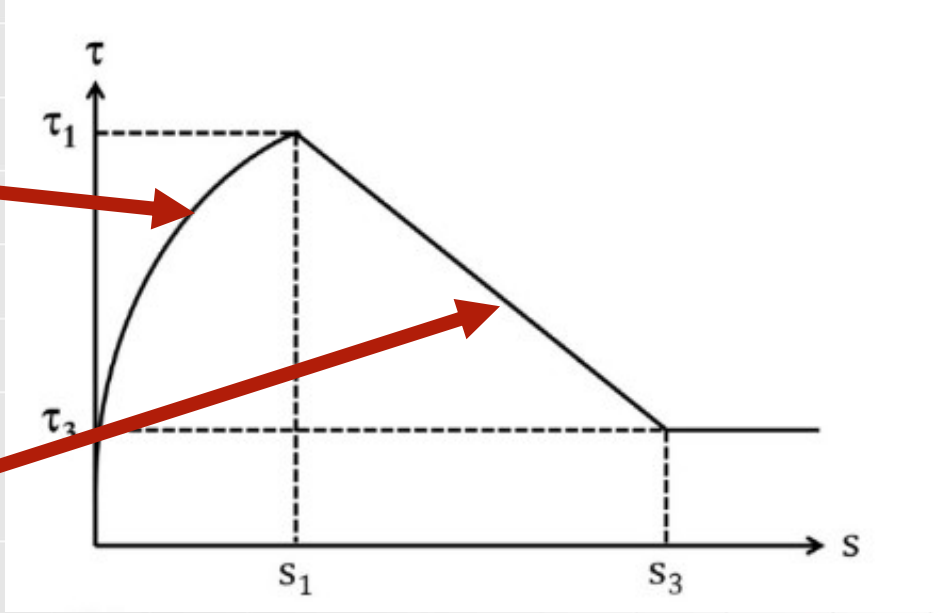
Analytical models – BPE model - modified

$$\tau = \tau_1 \left(1 - p\left(\frac{s}{s_1} - 1\right)\right) \quad s > s_{max'}$$

$$slope\colon\ p\left(\frac{\tau_1}{s_1}\right)$$



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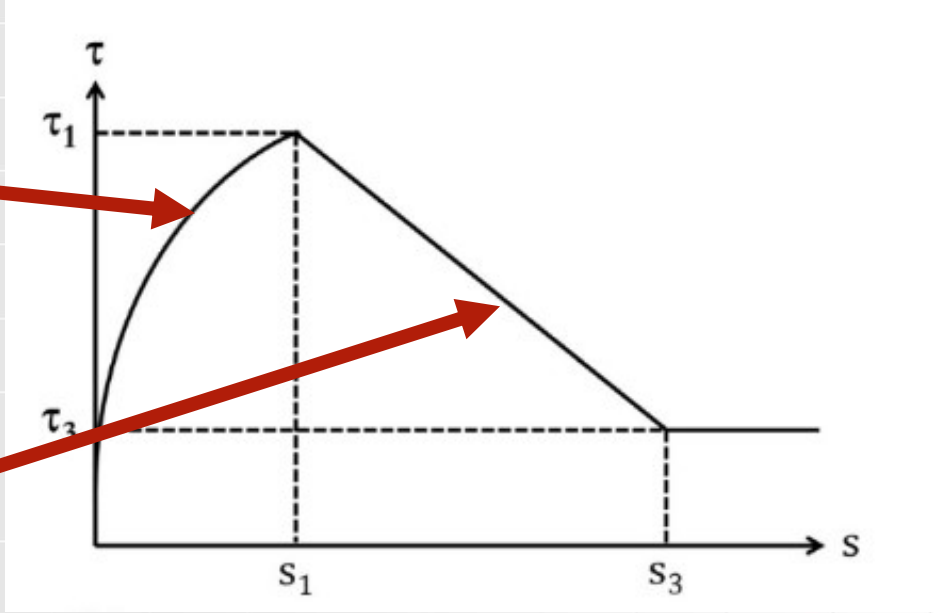
Analytical models – Malvar model

One of the first models developed for the bond-slip behavior of FRP bars and concrete

$$\tau = \tau_m \frac{F\left(\frac{s}{s_m}\right) + (G-1)\left(\frac{s}{s_m}\right)^2}{1 + (F-2)\left(\frac{s}{s_m}\right) + G\left(\frac{s}{s_m}\right)^2}$$



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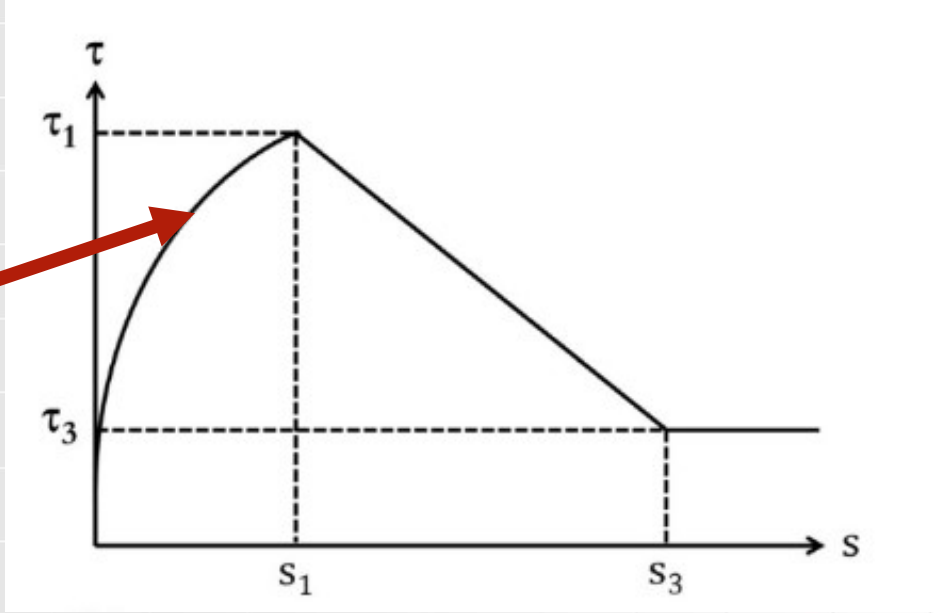
Analytical models – CMR model

The CMR model was developed by Consenza, Manfred and Realfonzo is a modification of the ascending branch of the bond-slip curve proposed in the BPE model.

$$\tau = \tau_m(1 - exp^{\left(\frac{s}{s_r}\right)})^{\beta}$$



$s_r = -1.1, \beta = 2$ in presented research based on experiments

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Cosenza, E., G. Manfredi, and R. Realfonzo. 1997. "Behavior and Modeling of Bond of FRP Rebars to Concrete." Journal of Composites for Construction 1 (2): 40–51. https://doi.org/10.1061/(asce)1090-0268(1997)1:2(40).

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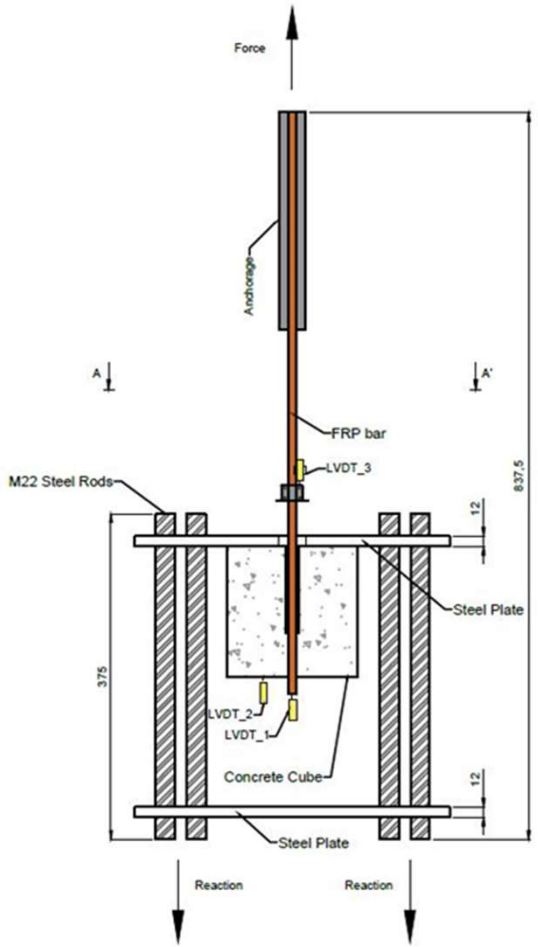
Experimental validation



Bond strength

$$\tau_{max} = \frac{Force}{\pi \, \emptyset_f \, L_{emb.}}$$

Pullout test

Pullout tests are the most simple and economical test to evaluate bond performance of a rebar embedded in concrete.

More details in:

ACI 440.3R standard

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Experimental setup

Tensile load is applied in FRP rebar at a rate of **0.1 mm/minute**.

Three linear variable displacement transducers were used to record the **slip of the rebar relative to the concrete cube**.

concrete cube

stand

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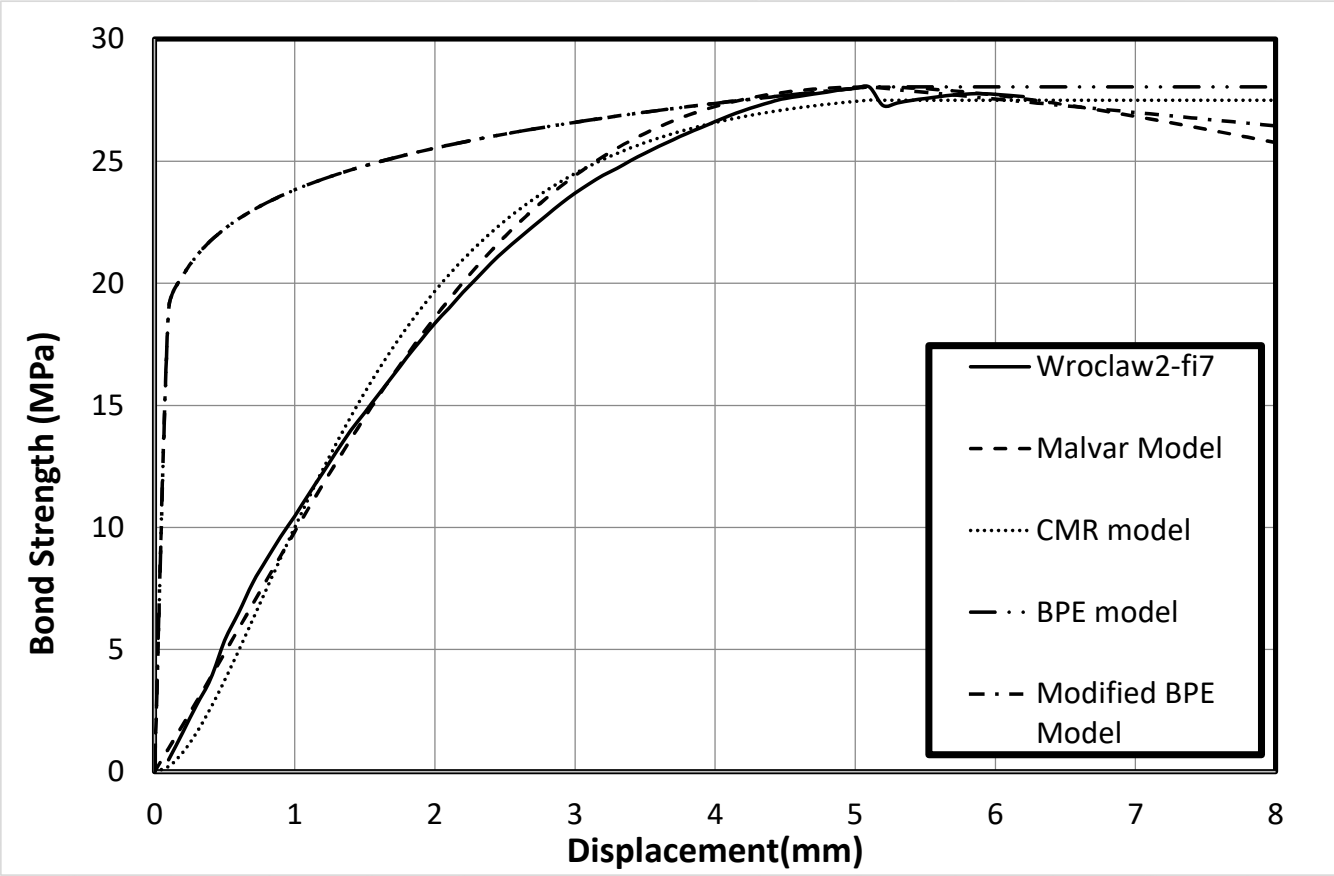
Analytical models – comparison to experimental values – rods ϕ7



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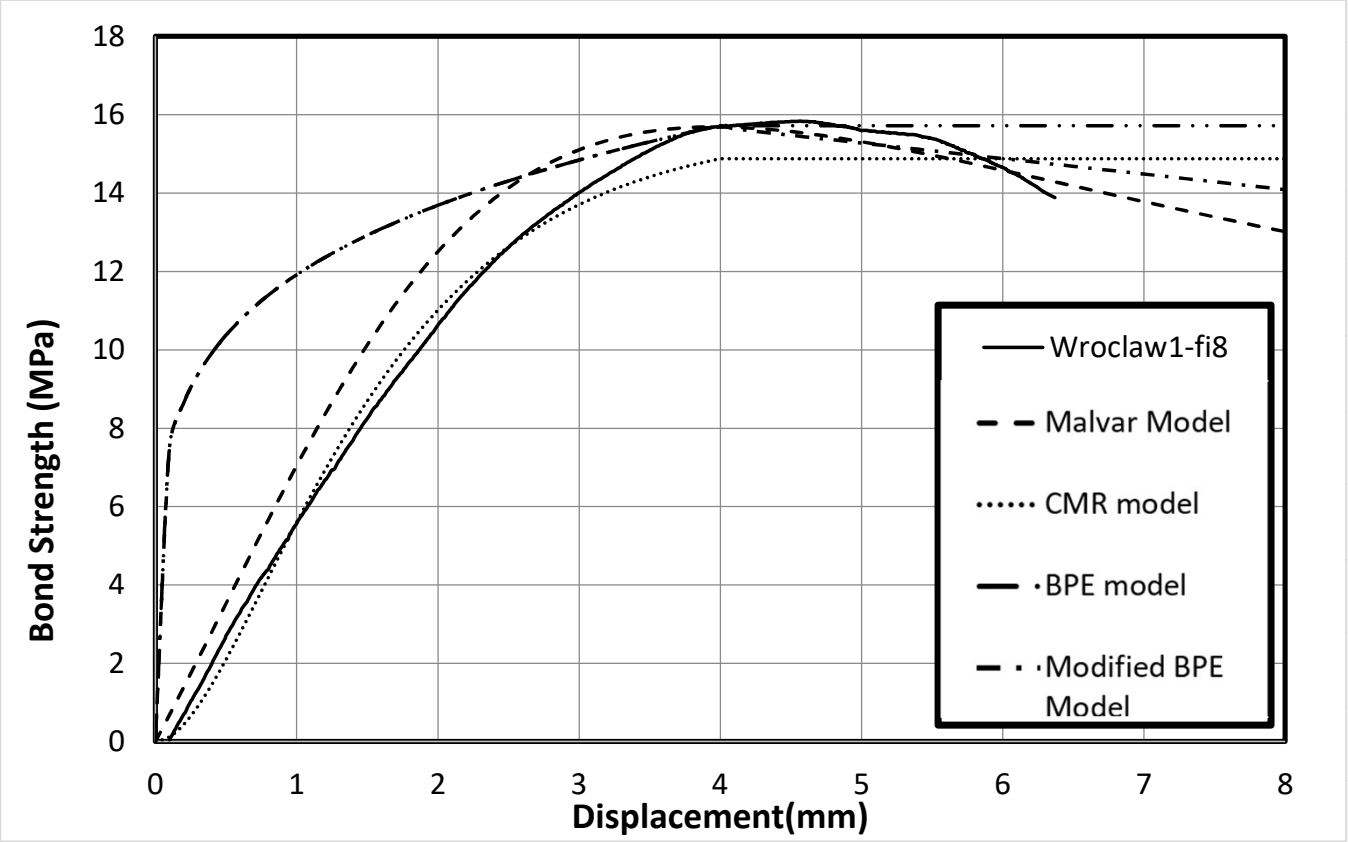
Analytical models – comparison to experimental values – rods ϕ8



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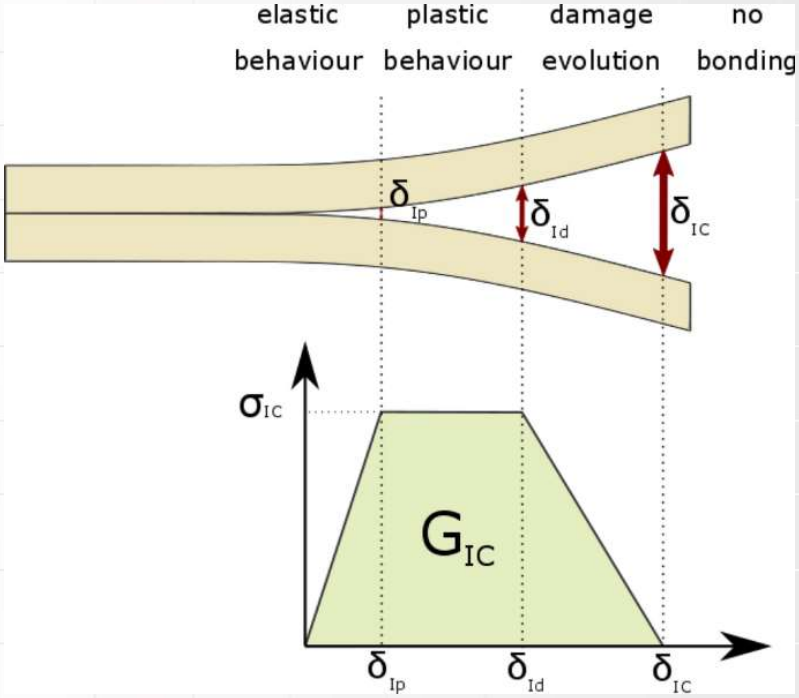
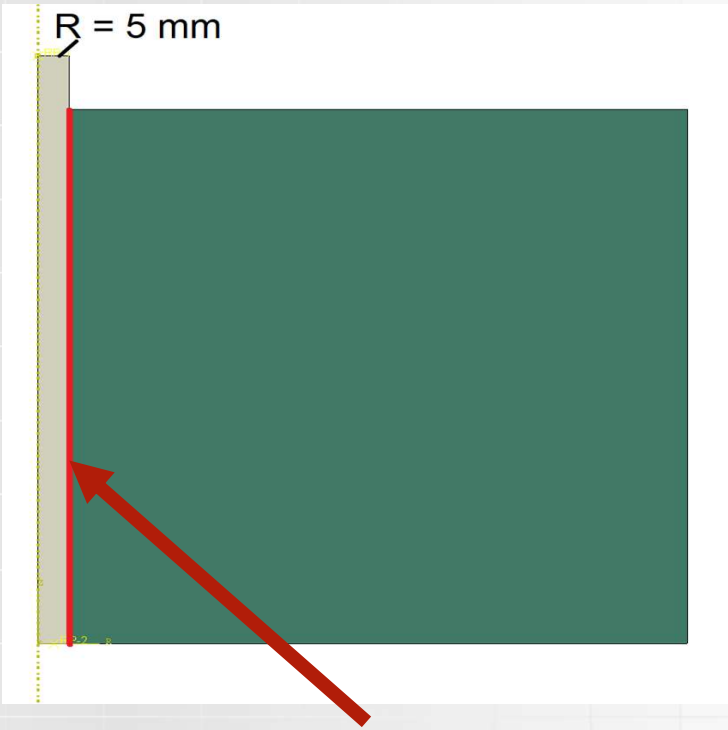
What to do with model?





composite rod – concrete interface cohesive surface

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Conclusions

- Models proposed originally for bond between metals and concrete like BPE or modified BPE are not sufficient for composites material
- Better results can be achieved by using other models created for composites like Malvar or CMR
- Obtained models can be used to implement them into numerical models