Transport-structural modelling of corrosion induced cracking of concrete

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http://framcos.org/FraMCoS-9/Full-Papers/266.pdf

Background

Experiments

Andrade et al. (1993), Alonso et al. (1998), Mullard and Stewart (2011), Wong et al. (2010), Michel et al. (2014), Šavija et al. (2015)

Models

Bažant (1979), Liu and Weyers (1998), Pantazopoulou and Papoulia (2001), Molina et al. (17), Lundgren (2005), Toongoenthong and Maekawa (2005), Tran et al. (2011), Ožbolt et al. (2012), Šavija et al. (2014)

Motivation

Missing link between pressure causing cracking and transport of corrosion products

Aim

Develop coupled transport-structural network approach to corrosion induced cracking

Outline

Modelling Approaches

- Steel/concrete interface (SCI)
- Axisymmetric model (AM)
- Network model (NM)

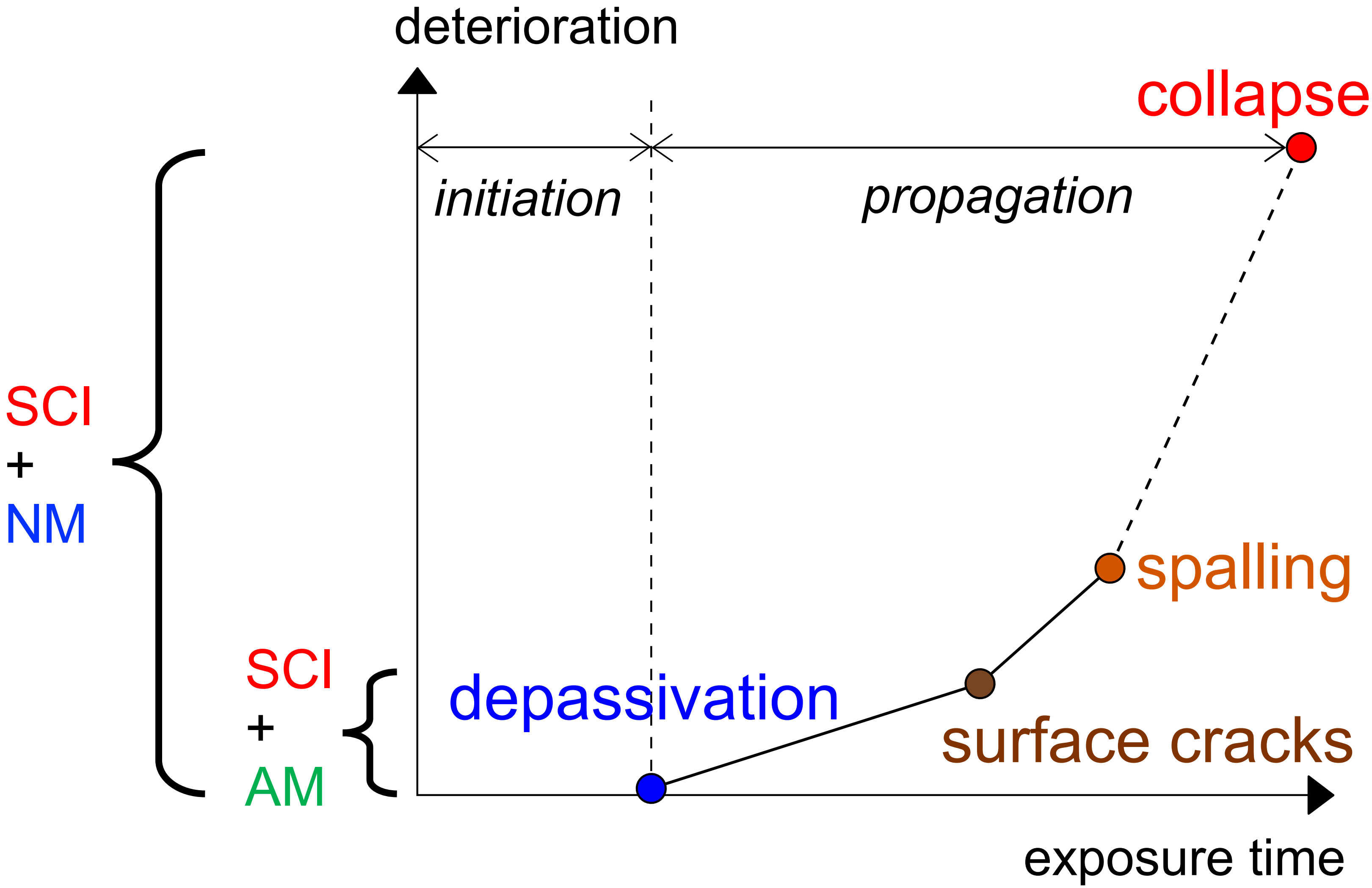
Verification

Calibration

Prediction

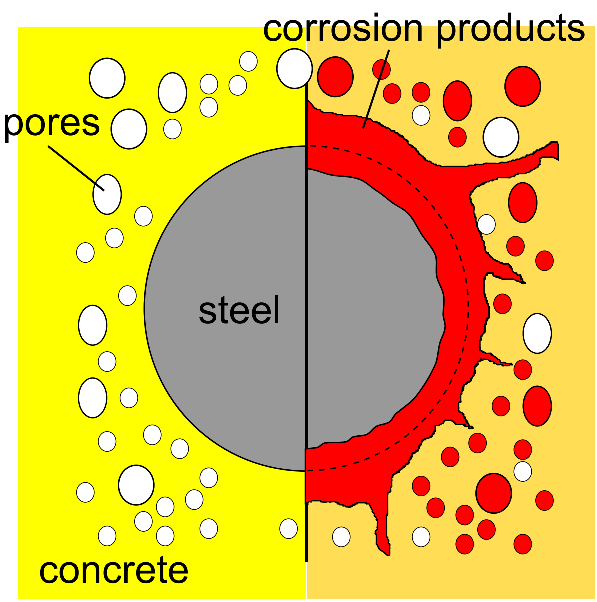
Modelling approaches

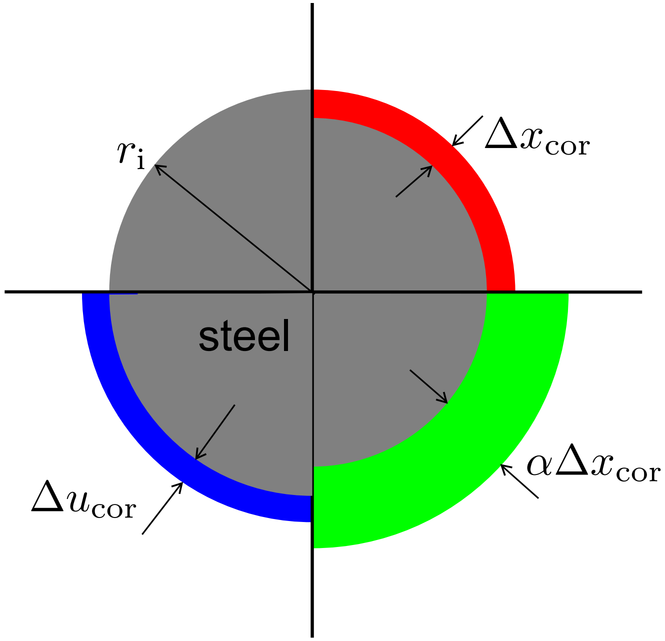
Modelling approaches



Tuutti (82)

Steel/concrete interface





$$\alpha\Delta x_\mathrm{cor} = \Delta x_\mathrm{cor} + \Delta u_\mathrm{cor} + q\Delta t$$

with $\Delta x_\mathrm{cor} = 0.0315 i_\mathrm{cor}\Delta t$

$$\Delta x_\mathrm{cor} = \frac{\Delta u_\mathrm{cor}}{\alpha - 1 - q/(0.0315 i_\mathrm{cor})}$$

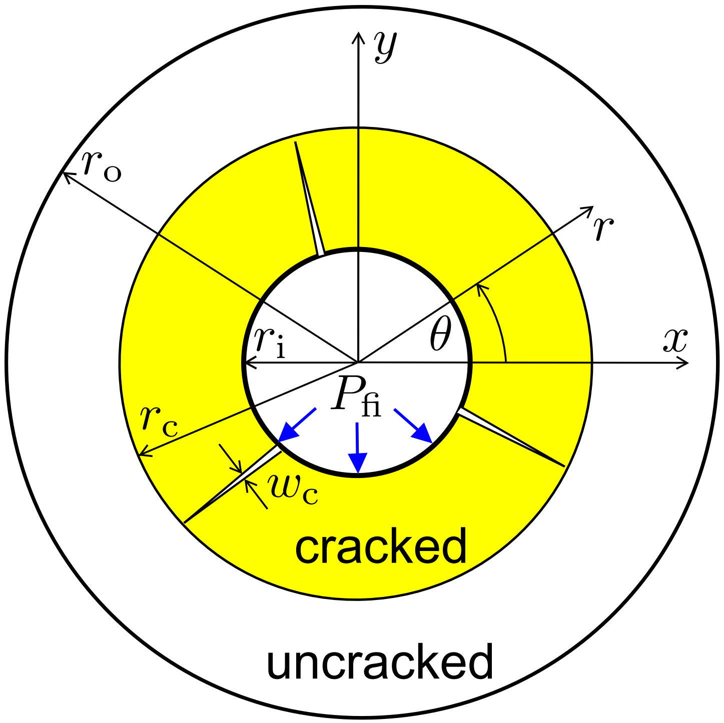
Axisymmetric model

Mechanical

$$\sigma_{\mathrm{r}} + \frac{d\sigma_{\mathrm{r}}}{dr} r - \sigma_\theta = 0$$

For zero Poisson's ratio:

$$\frac{d^2u}{dr^2} + \frac{1}{r}\frac{du}{dr} - (1-\omega)\frac{u}{r^2} = 0$$



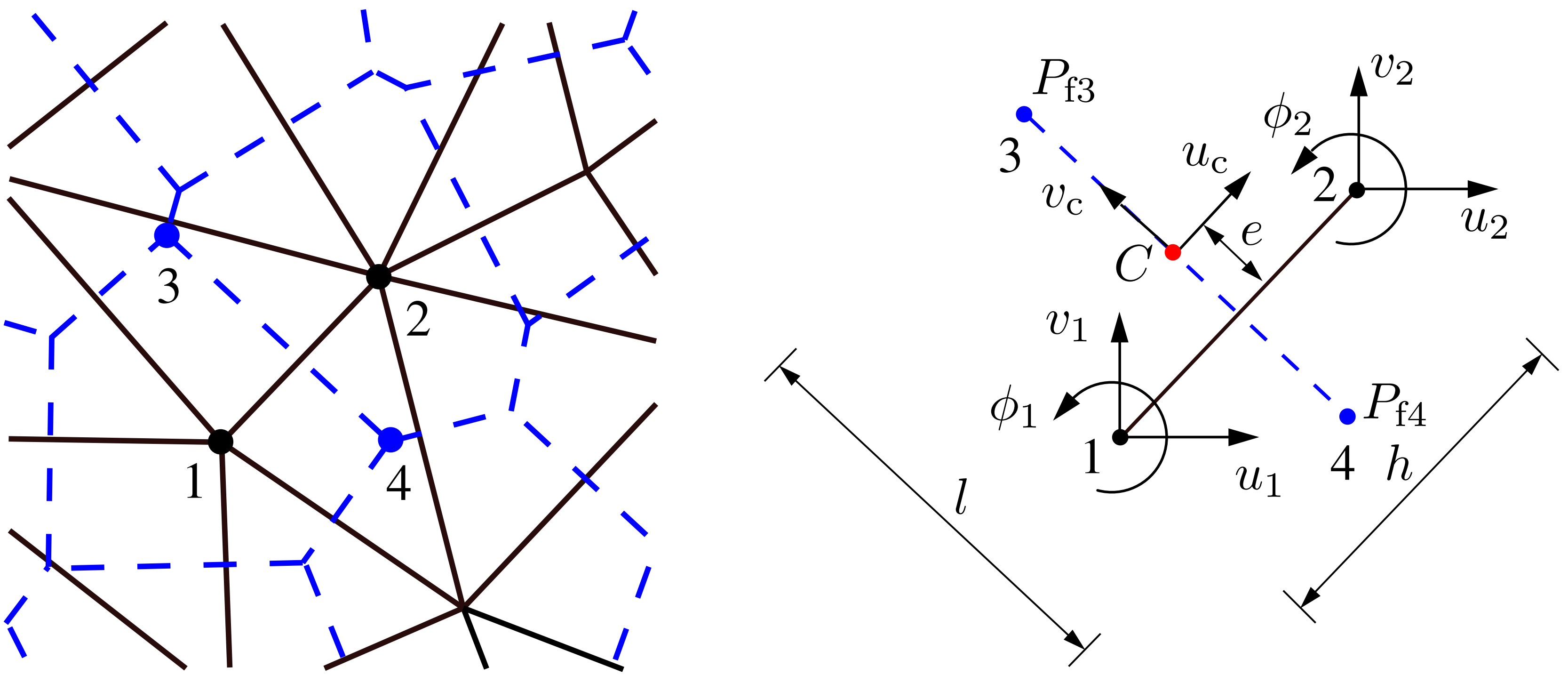
Transport

$$dP_{\mathrm{f}} = \frac{\mu}{\kappa}\frac{Q}{2\pi r t} dr = \frac{\mu}{\kappa} q\, dr$$

with $\kappa = \kappa_0 + \kappa_{\mathrm{c}}(r)$

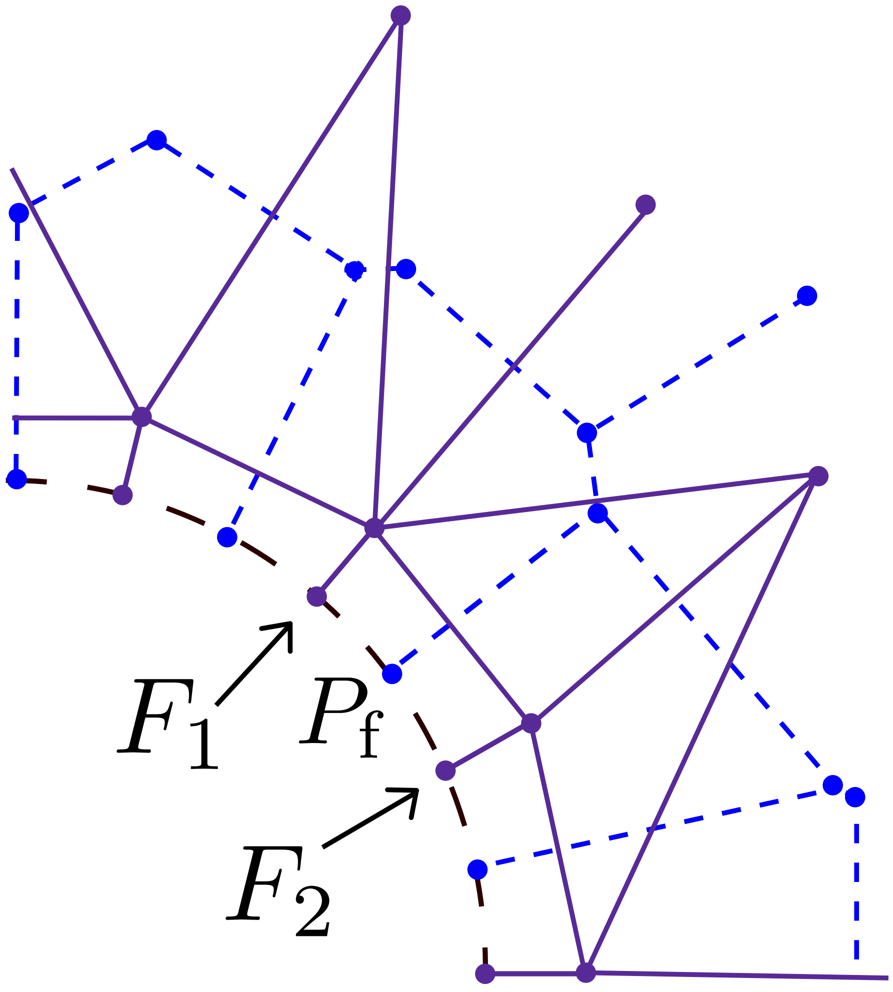
Pantazopoulou and Papoulia (2001)

Network model



Grassl et al. (2015), Grassl et al. (2009), Bolander and Saito (1998)

Coupling



Grassl et al. (2015)

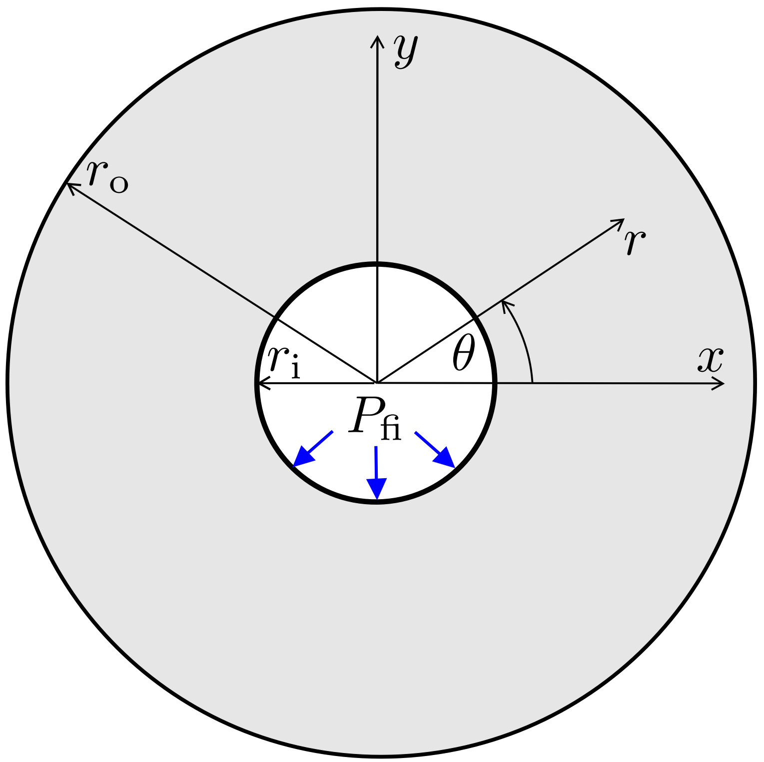
Verification

Geometry and Setup

Geometry

$r_{\mathrm{i}} = 8\ \mathrm{mm}$

$r_{\mathrm{o}} = 58\ \mathrm{mm}$



Mechanical

$E = 30\ \mathrm{GPa},\ \nu = 0$

$f_{\mathrm{t}} = 3\ \mathrm{MPa}$

$G_{\mathrm{F}} = 0.15\ \mathrm{N/mm}$

$n_c = 4$ (AM only)

Transport

κ_0

$\mu = 0.019\ \mathrm{MPas}$

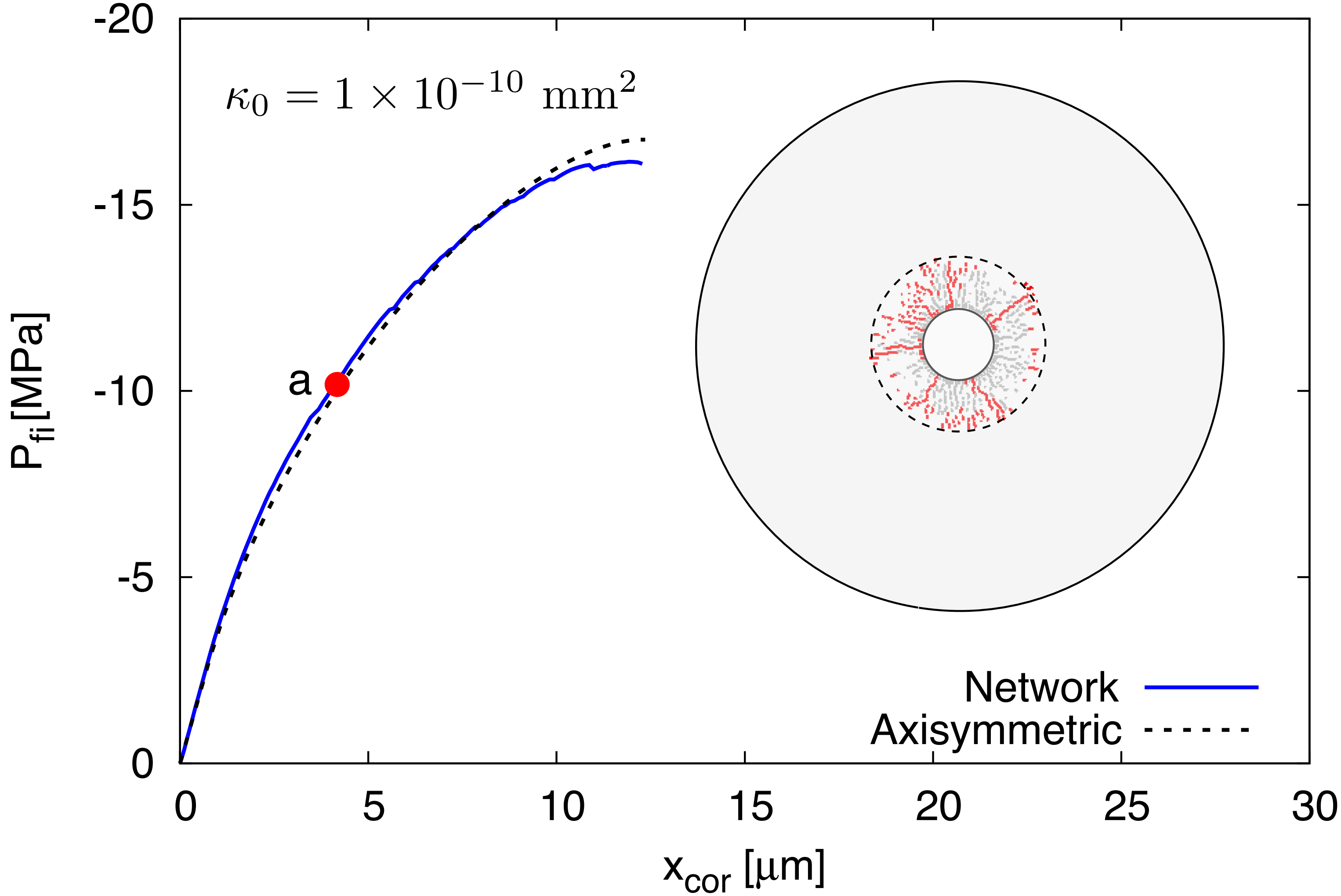
$\xi = 0.001$

Corrosion

$\alpha = 2$

$i_{\mathrm{cor}} = 100\ \mu\mathrm{A/cm}^2$

Verification: Permeability



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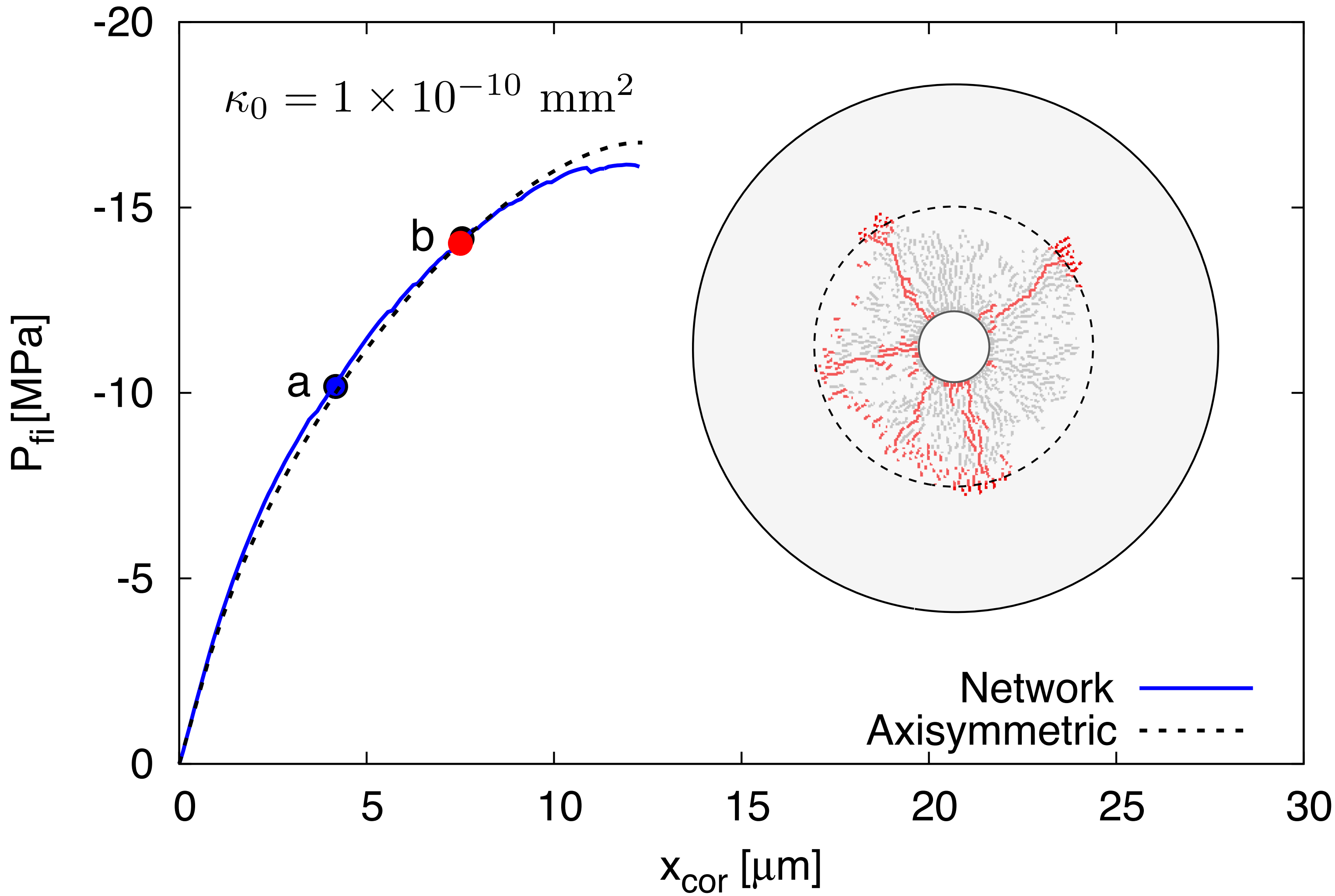

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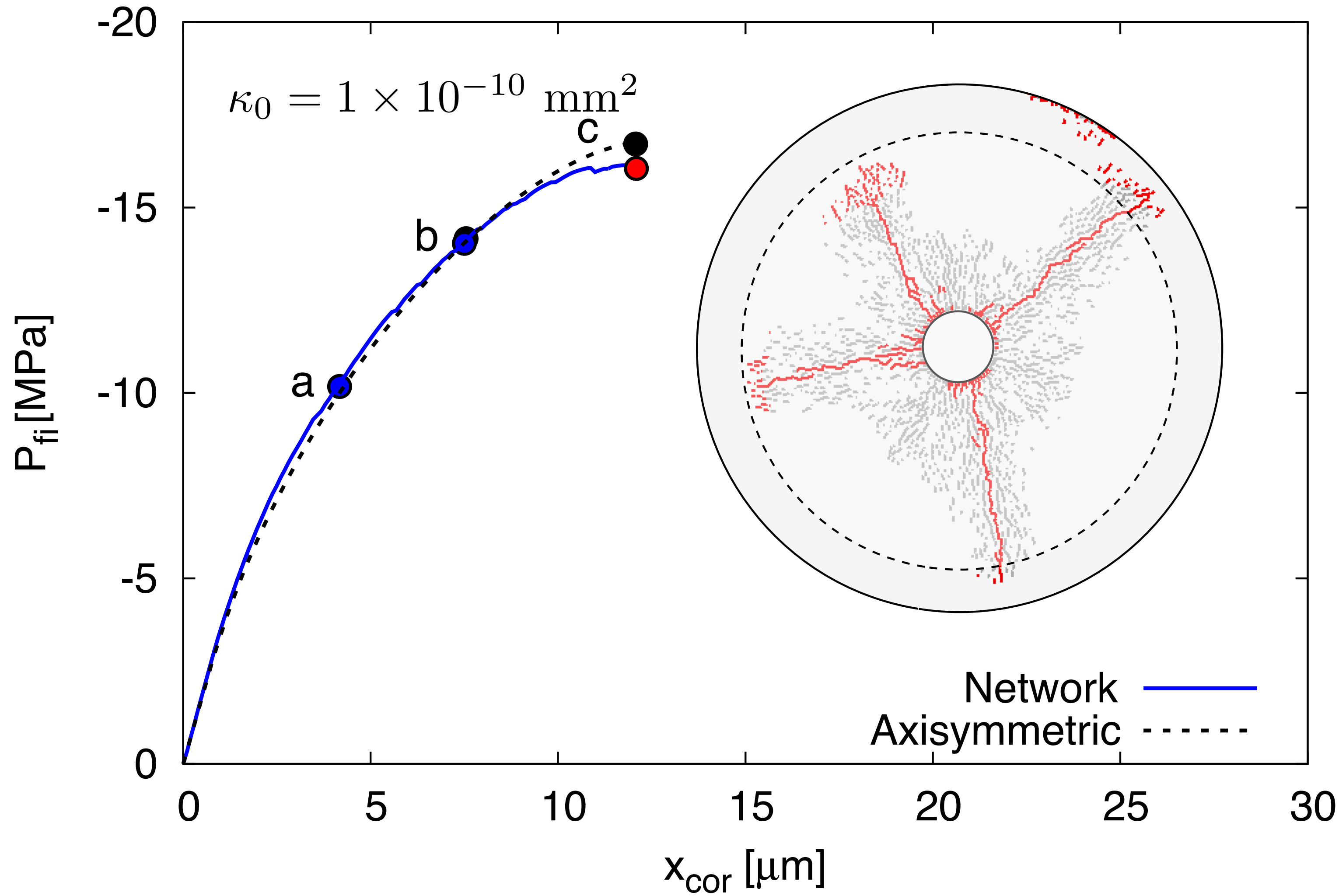

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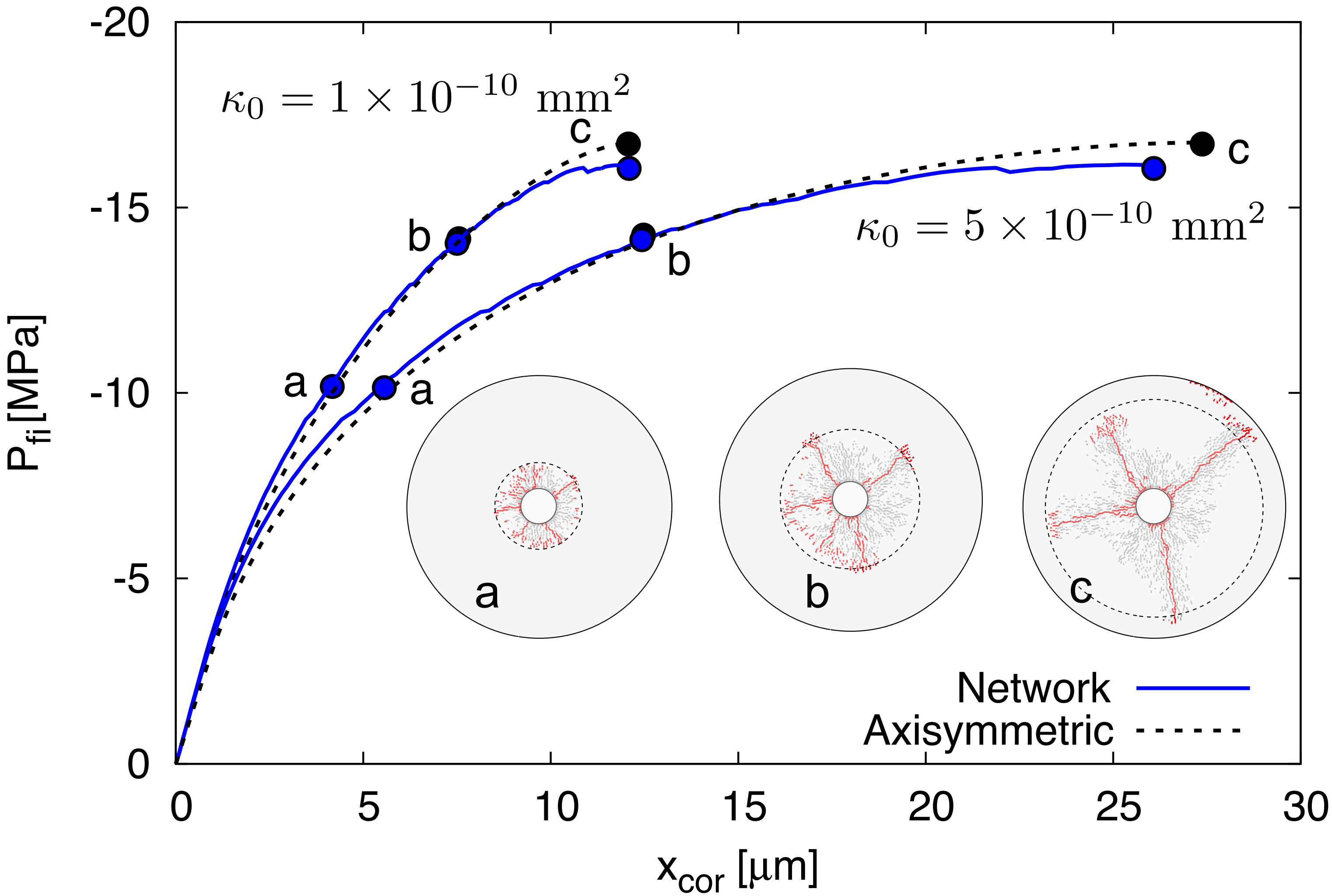
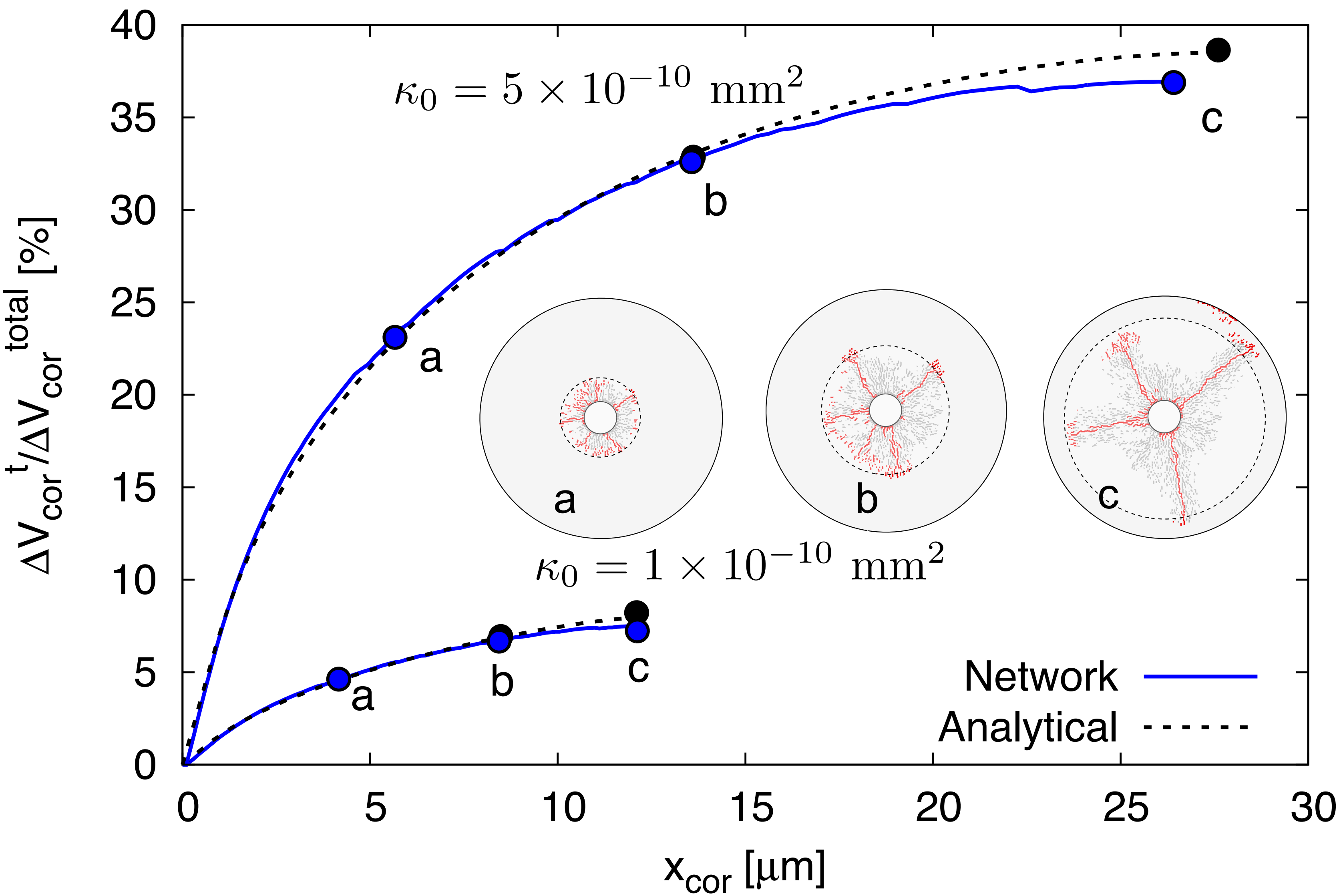
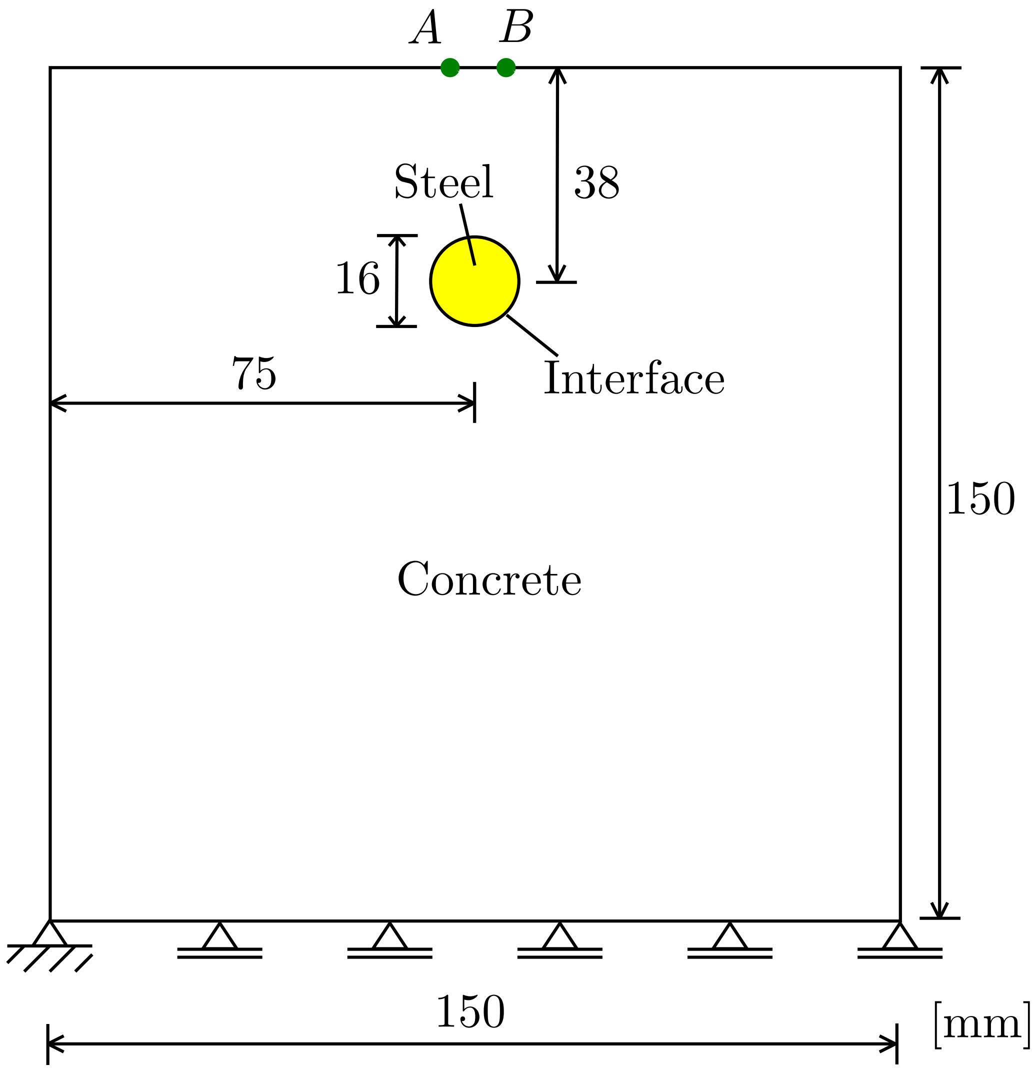


Verification: Permeability



Calibration

Calibration: Geometry and setup



Mechanical

$E = 29.6$ GPa, $\nu = 0$

$f_\mathrm{t} = 3.2$ MPa

$G_\mathrm{F} = 143$ N/m

Transport

$\xi = 0.001$

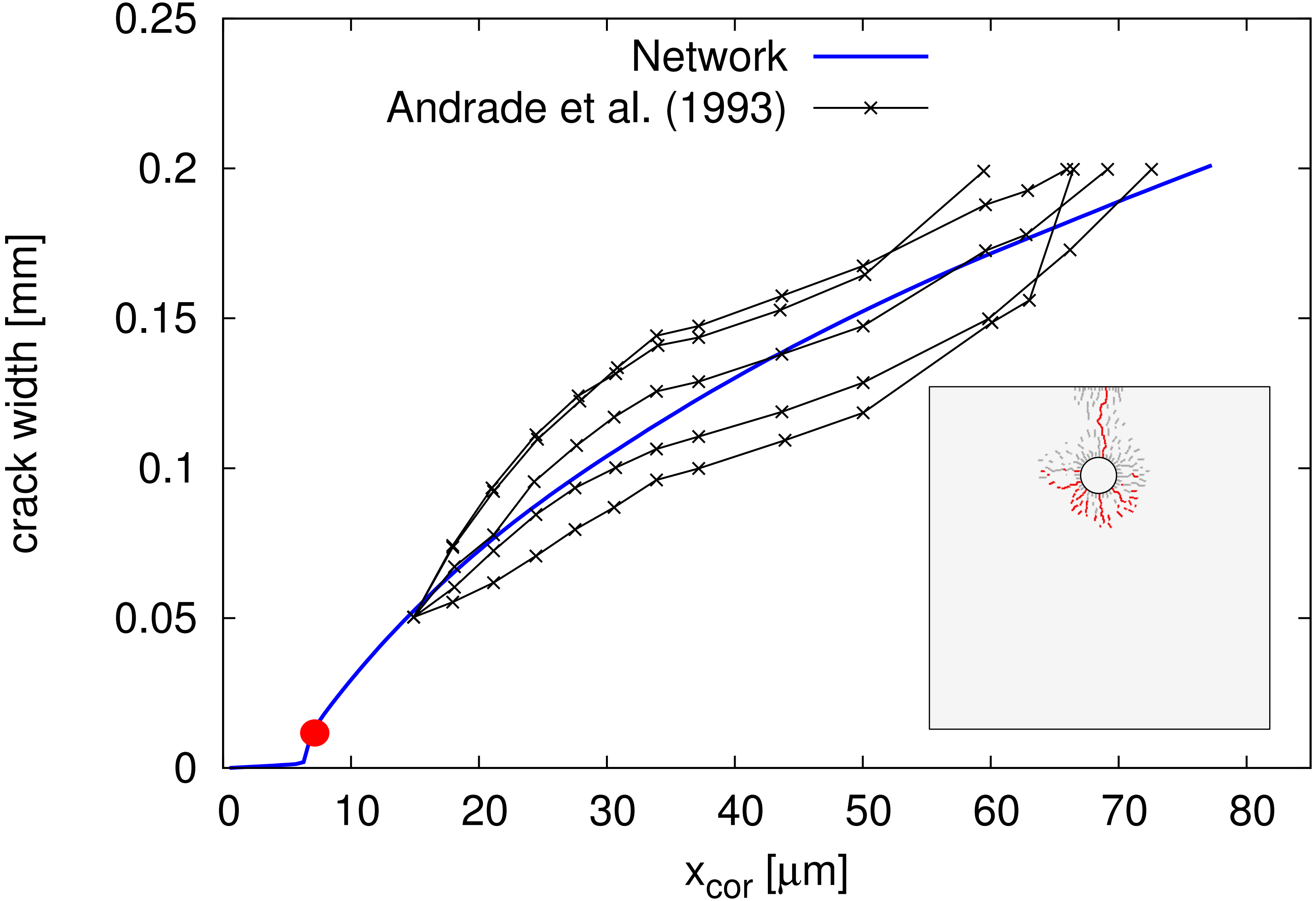
$\mu = 0.019$ MPas

Corrosion

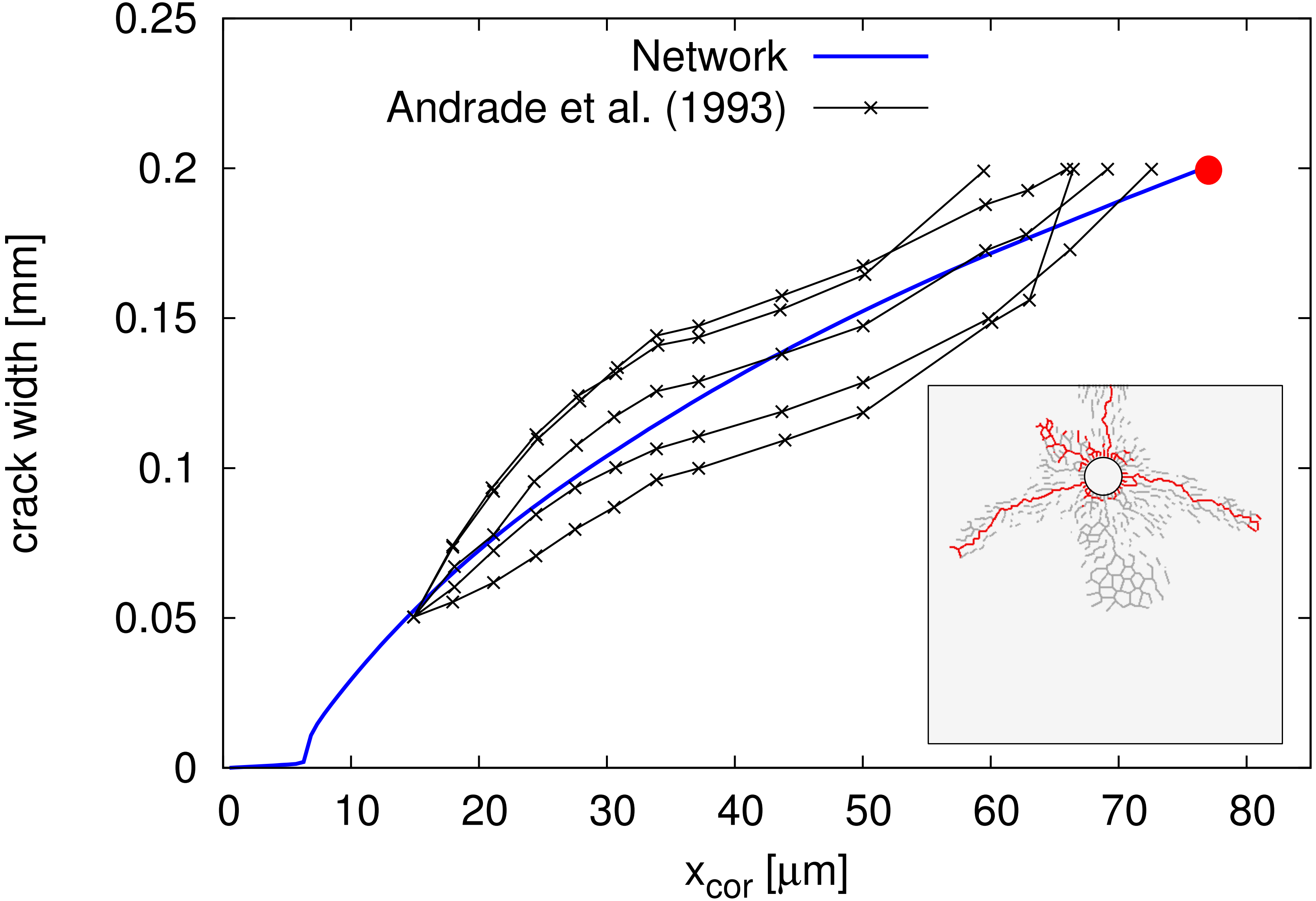
$\alpha = 2$

Andrade (1993)

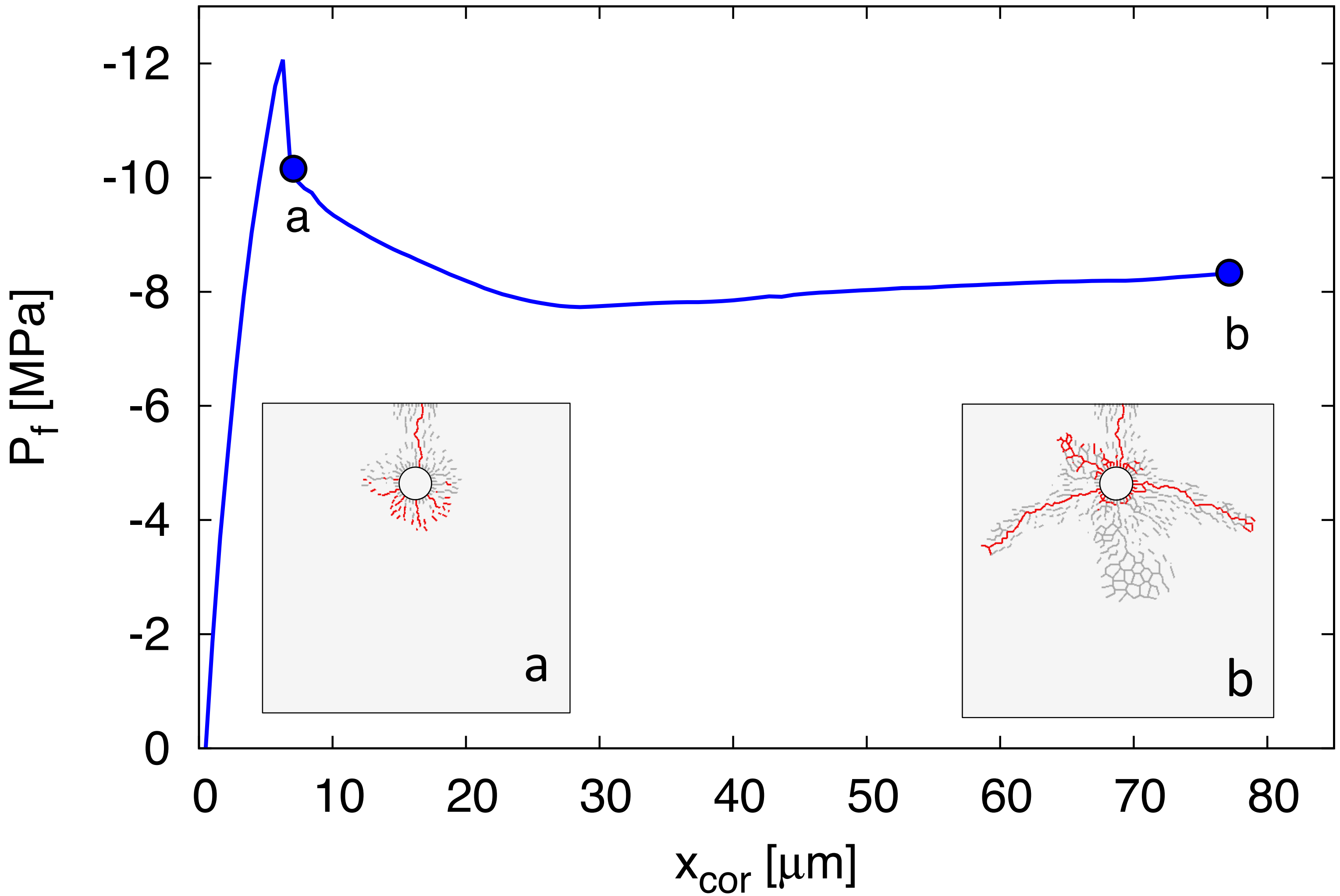
Calibration



Calibration



Calibration



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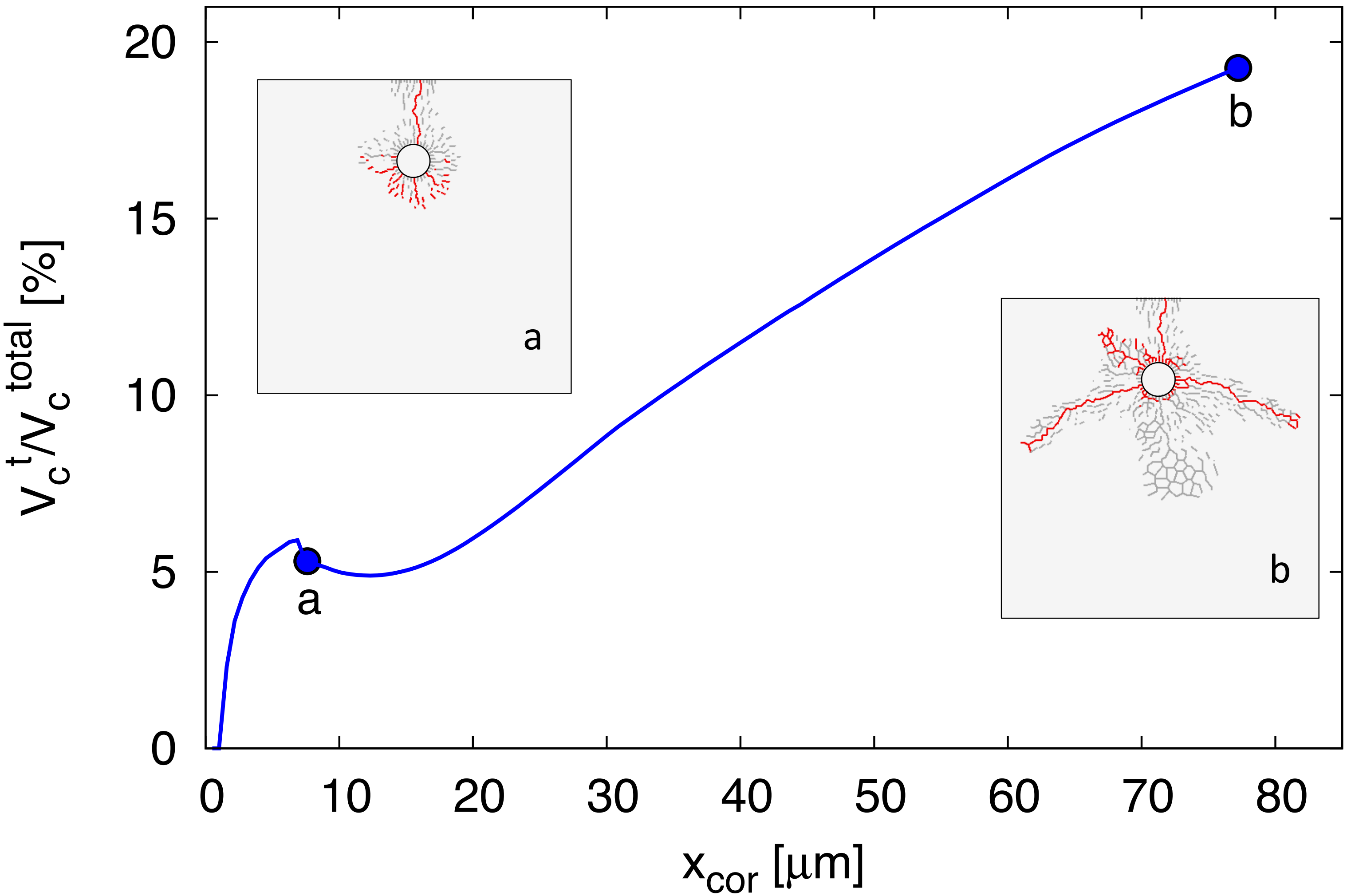
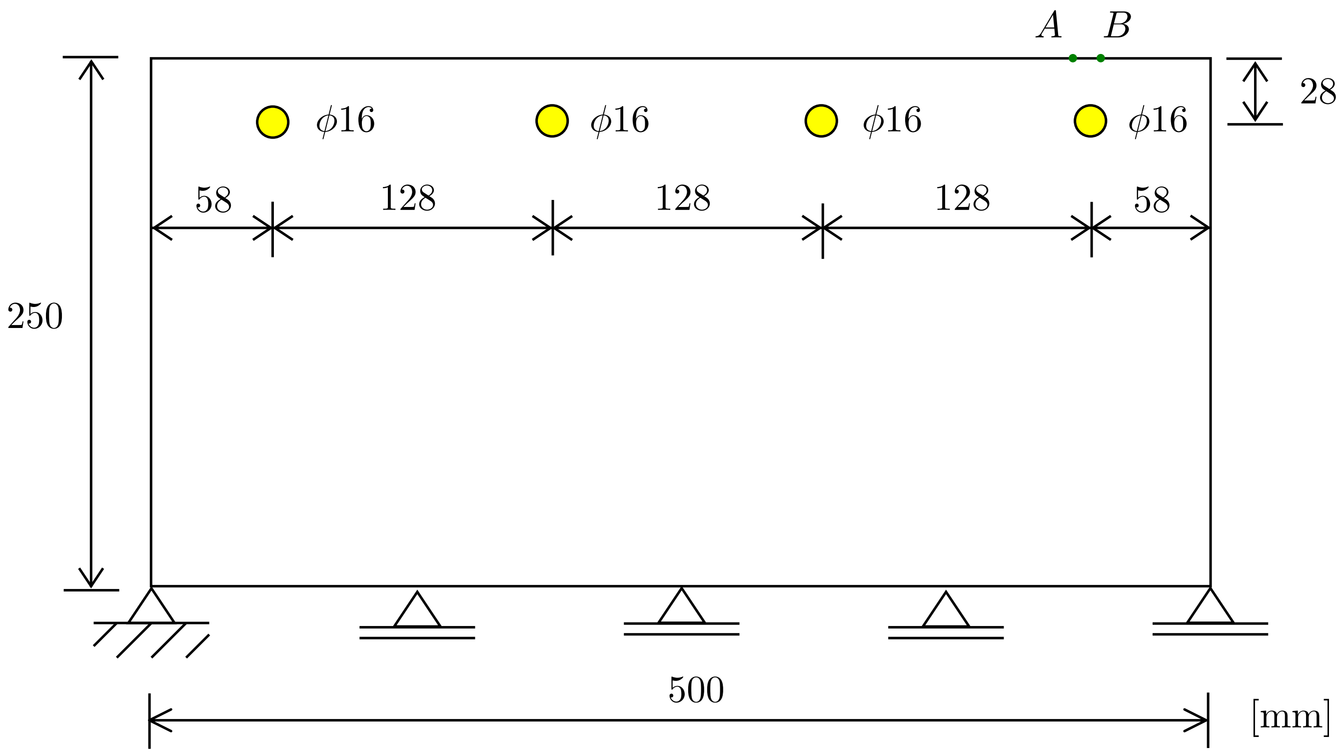


Validation

Validation: Geometry and setup



Mechanical

$$E = 28.5 \text{ GPa}, \ \nu = 0$$

$$f_{\mathrm{t}}^{\mathrm{m}} = 2.4 \text{ MPa}$$

$$G_{\mathrm{F}} = 128.76 \text{ N/m}$$

Transport

$$\xi = 0.001$$

$$\mu = 0.019 \text{ MPas}$$

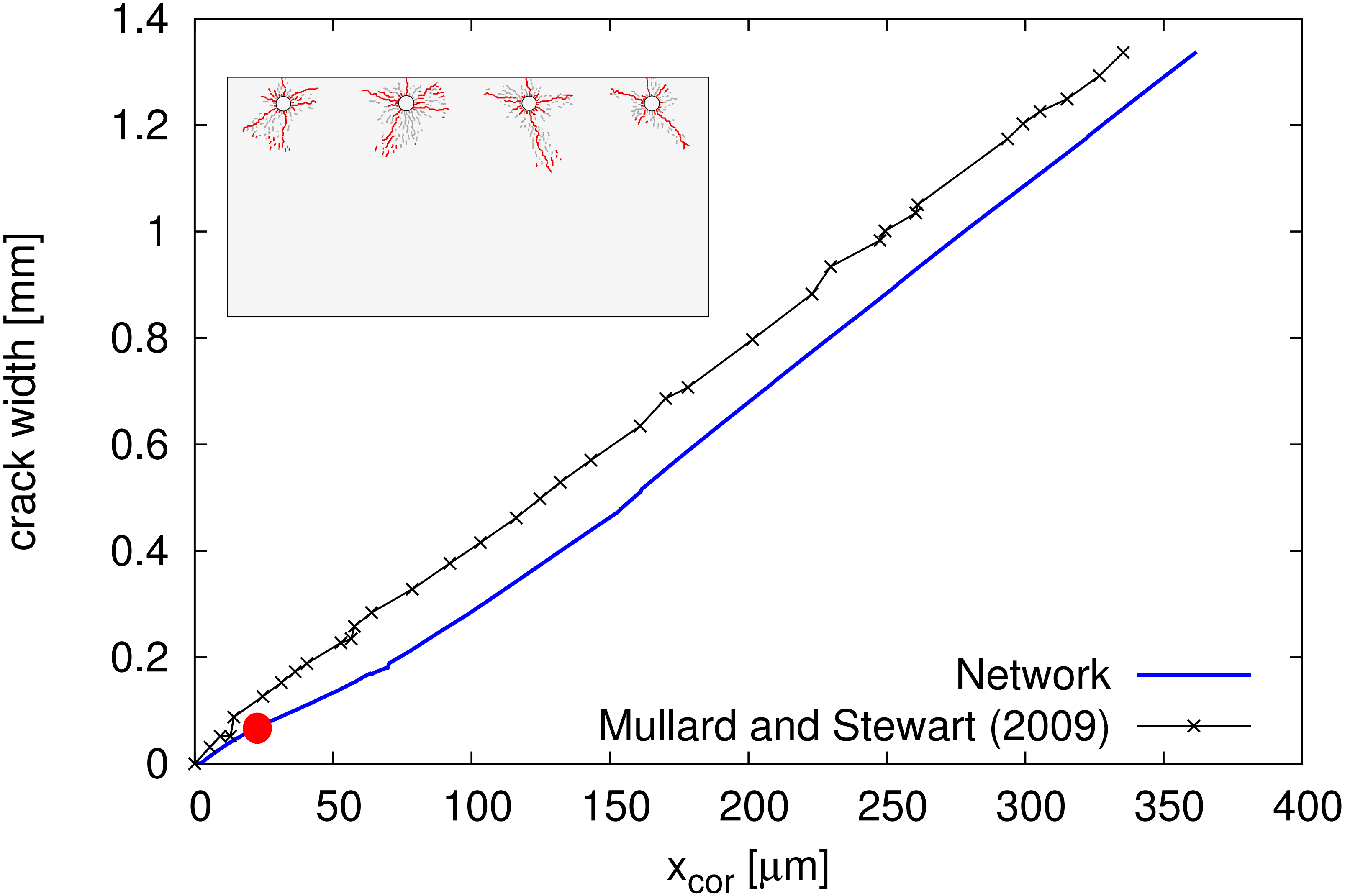
$$\kappa_0 = 1 \times 10^{-10} \text{ mm}^2$$

Corrosion

$$\alpha = 2$$

Mullard and Stewart (2009)

Validation: Results



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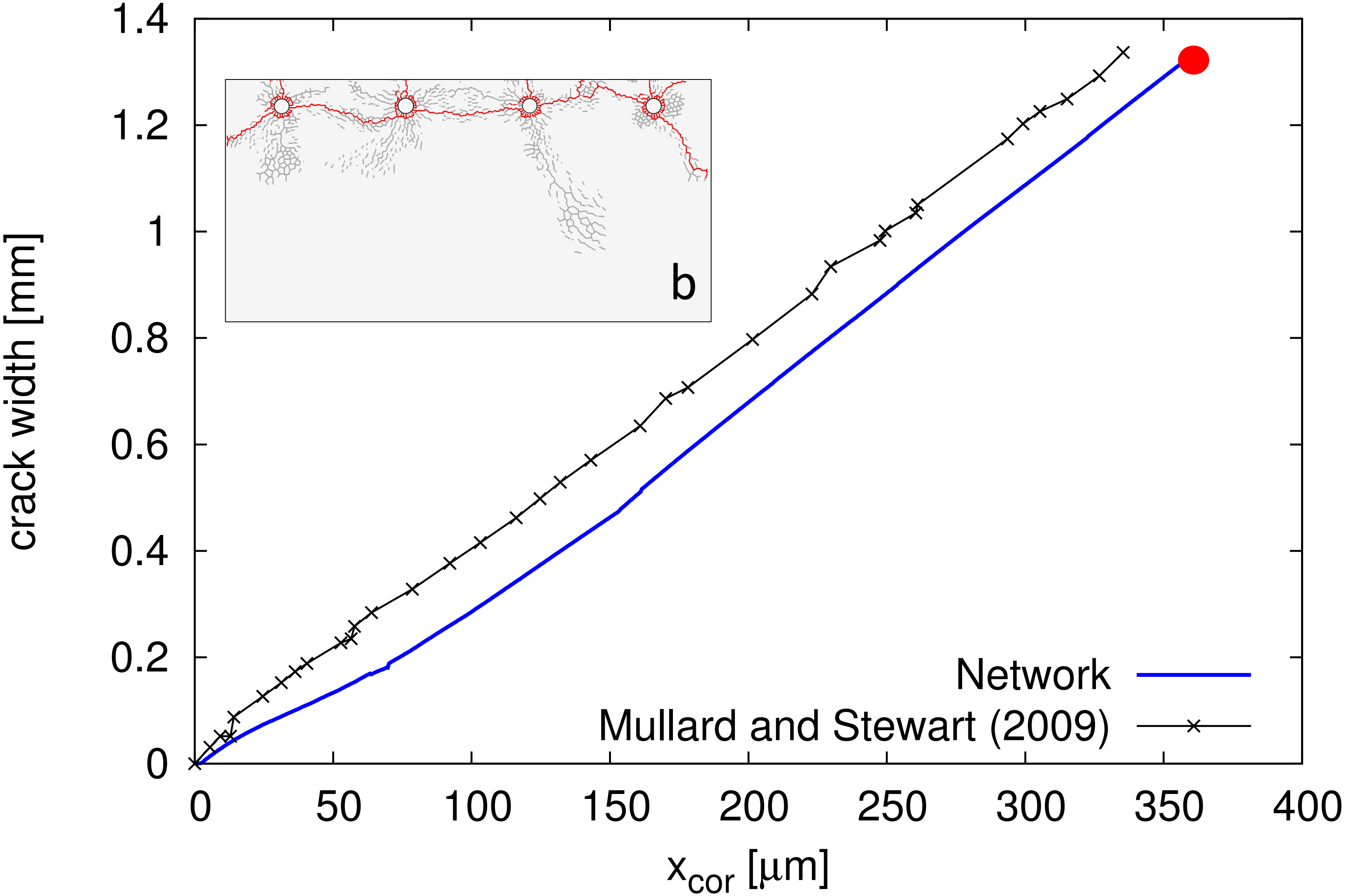

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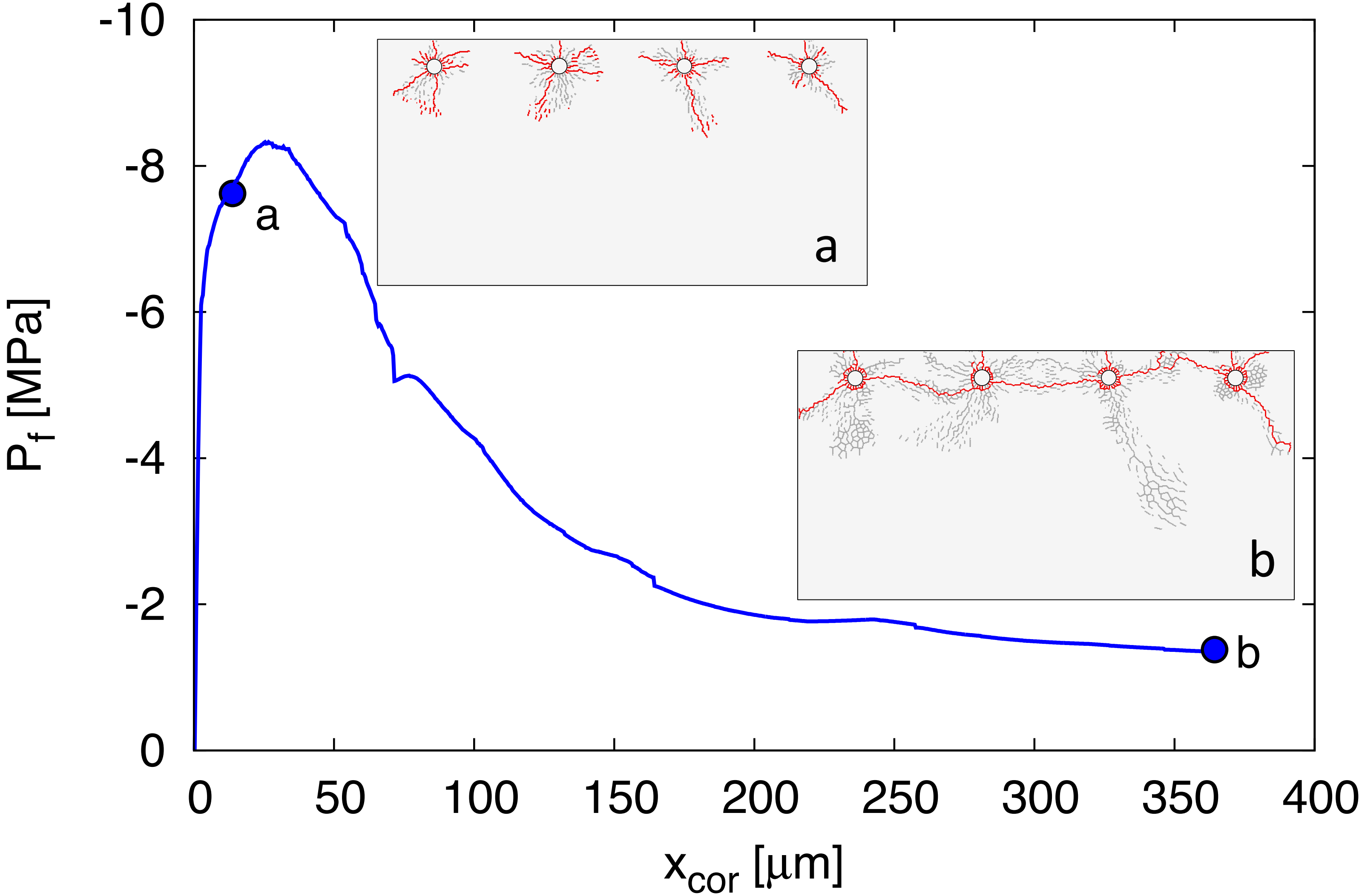
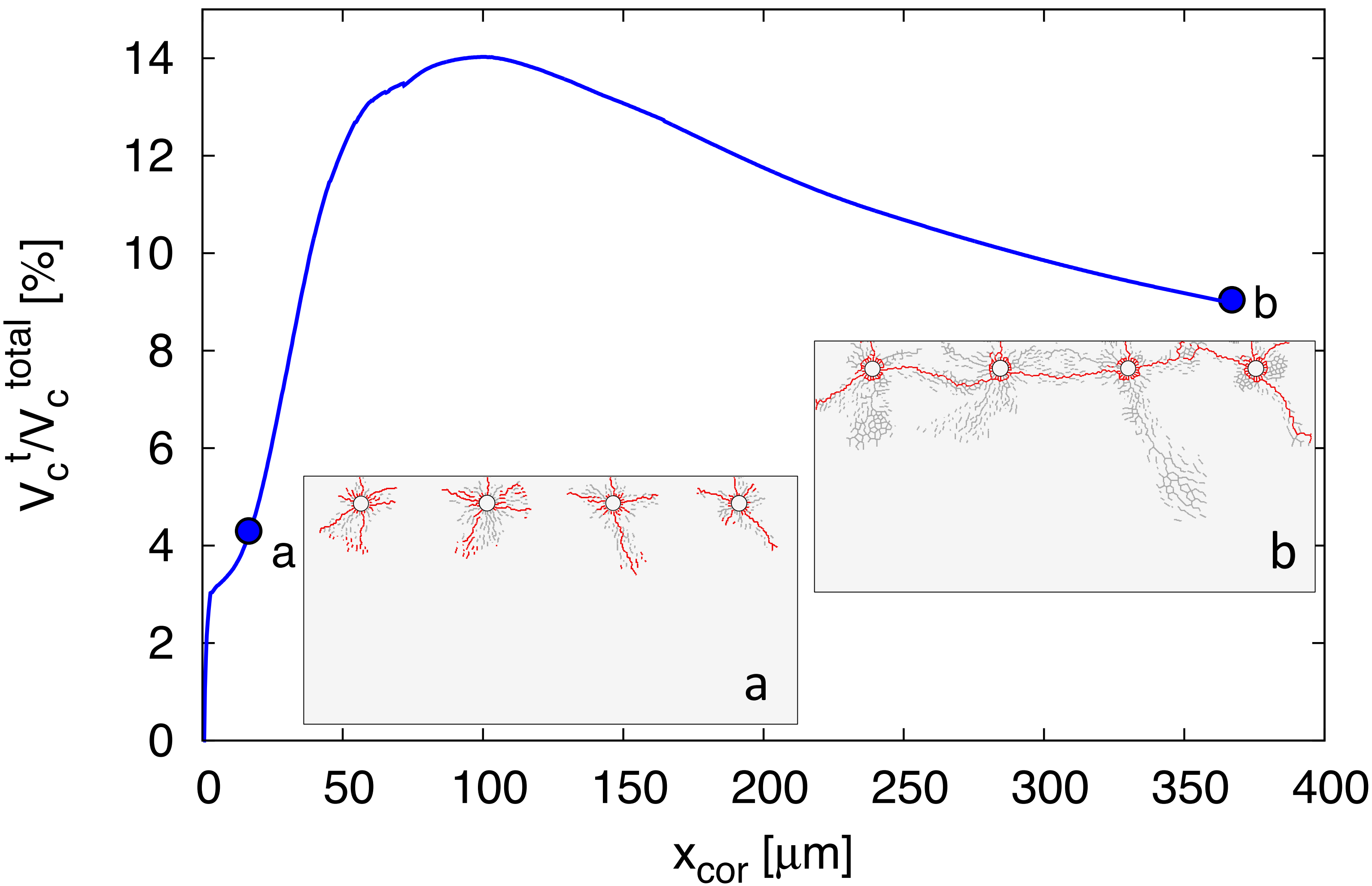


Validation: Results



Conclusions

Transport-mechanical modelling approach for corrosion induced cracking:

- Strong link between mechanical pressure and transport of rust products
- Cracks influence the transport once they reach the surface