FE modelling of rebar laps in steel fibre reinforced concrete

Peter Grassl, Jane Middlemiss
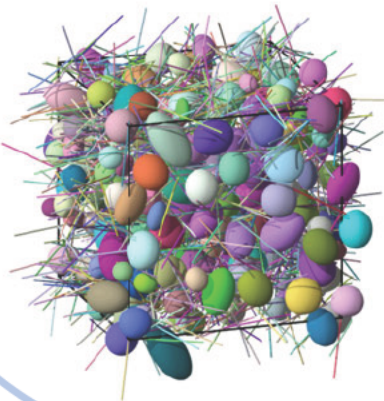
James Watt School of Engineering

University of Glasgow, UK

Virtual laboratory for concrete at University of Glasgow
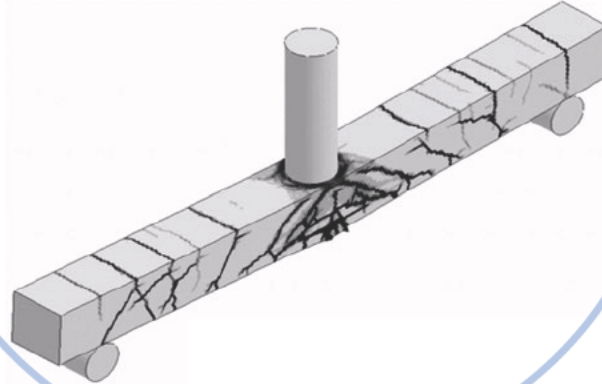
Meso/micro scale modeling

Improving understanding

Constitutive modelling

damage

$$\boldsymbol{\sigma} = (1 - \omega)\mathbf{D}_e : \boldsymbol{\varepsilon}$$

plasticity

$$\boldsymbol{\sigma} = \mathbf{D}_e : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_p)$$

damage-plasticity

$$\boldsymbol{\sigma} = (1 - \omega_t)\bar{\boldsymbol{\sigma}}_t + (1 - \omega_c)\bar{\boldsymbol{\sigma}}_c$$

$$\bar{\boldsymbol{\sigma}} = \mathbf{D}_e : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_p) = \bar{\boldsymbol{\sigma}}_t + \bar{\boldsymbol{\sigma}}_c$$

Structural modelling

http://petergrassl.com

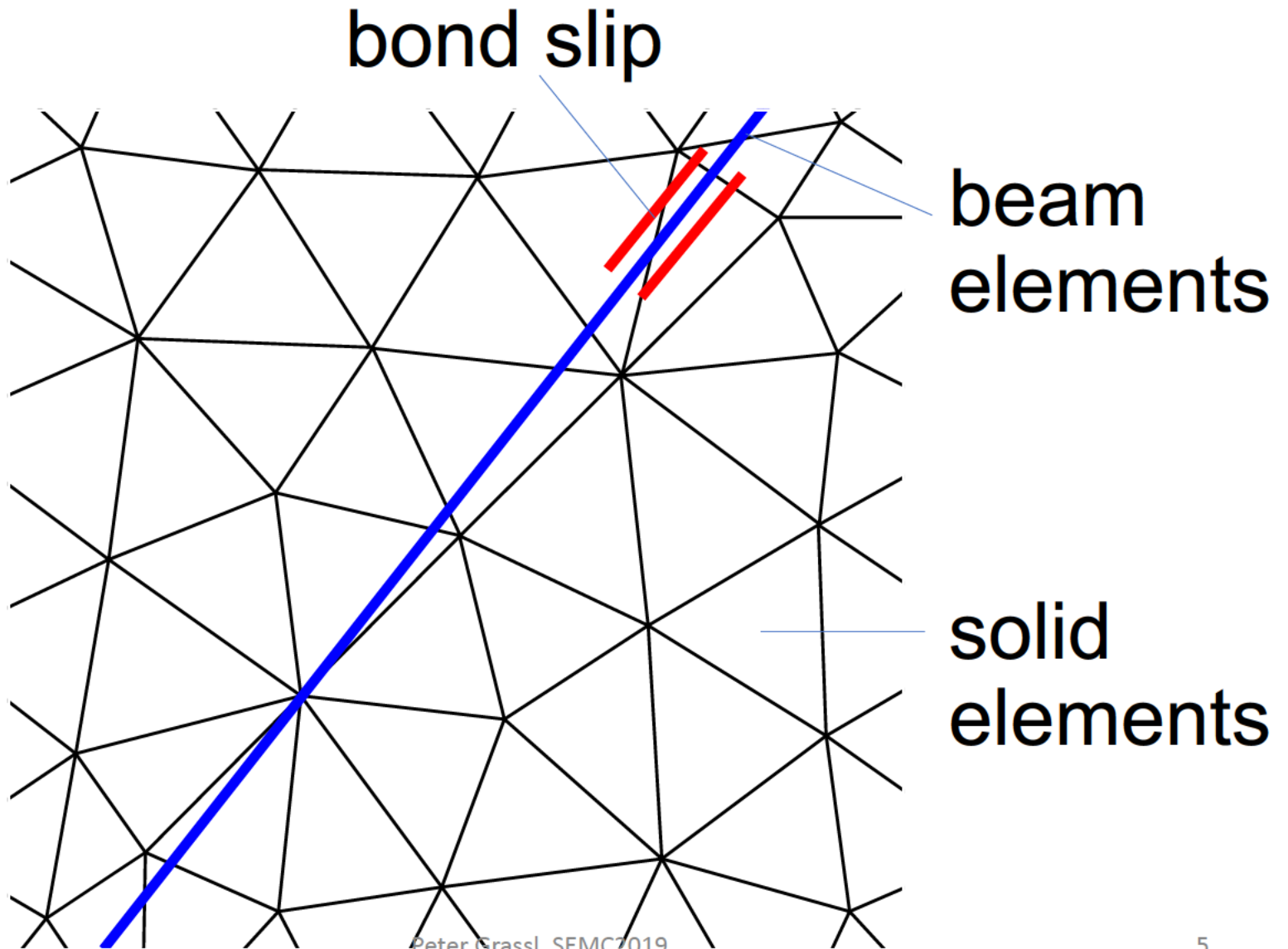# Background: Structural concrete
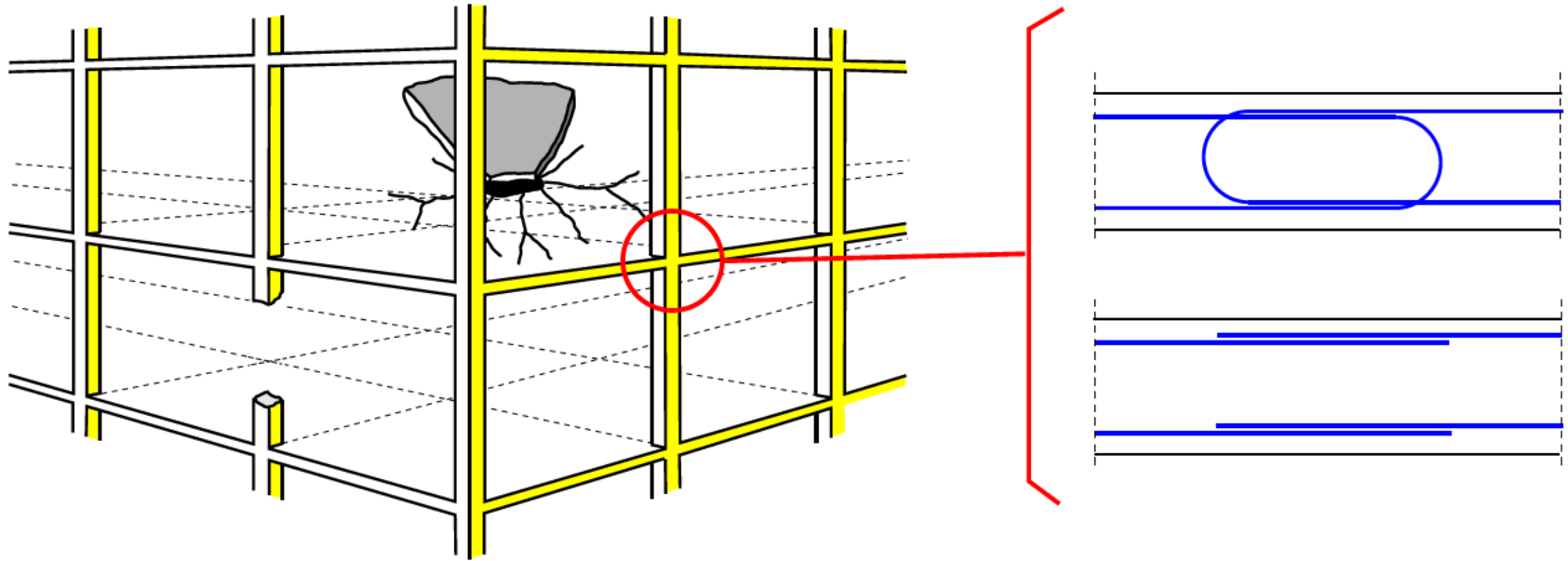
Aim

Investigate influence of concrete properties (addition of fibres) on straight rebar laps

Approach

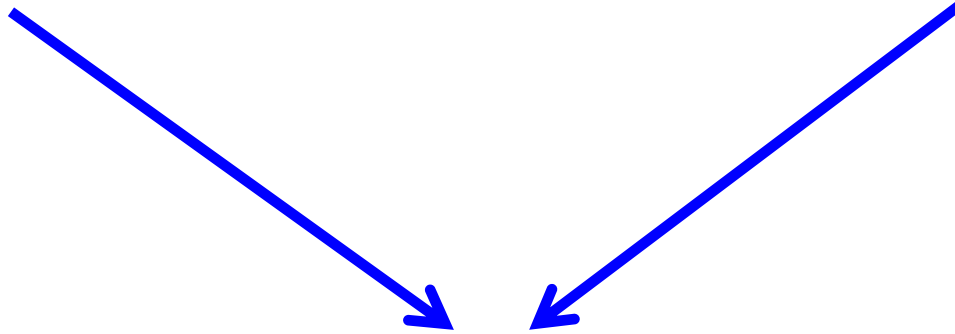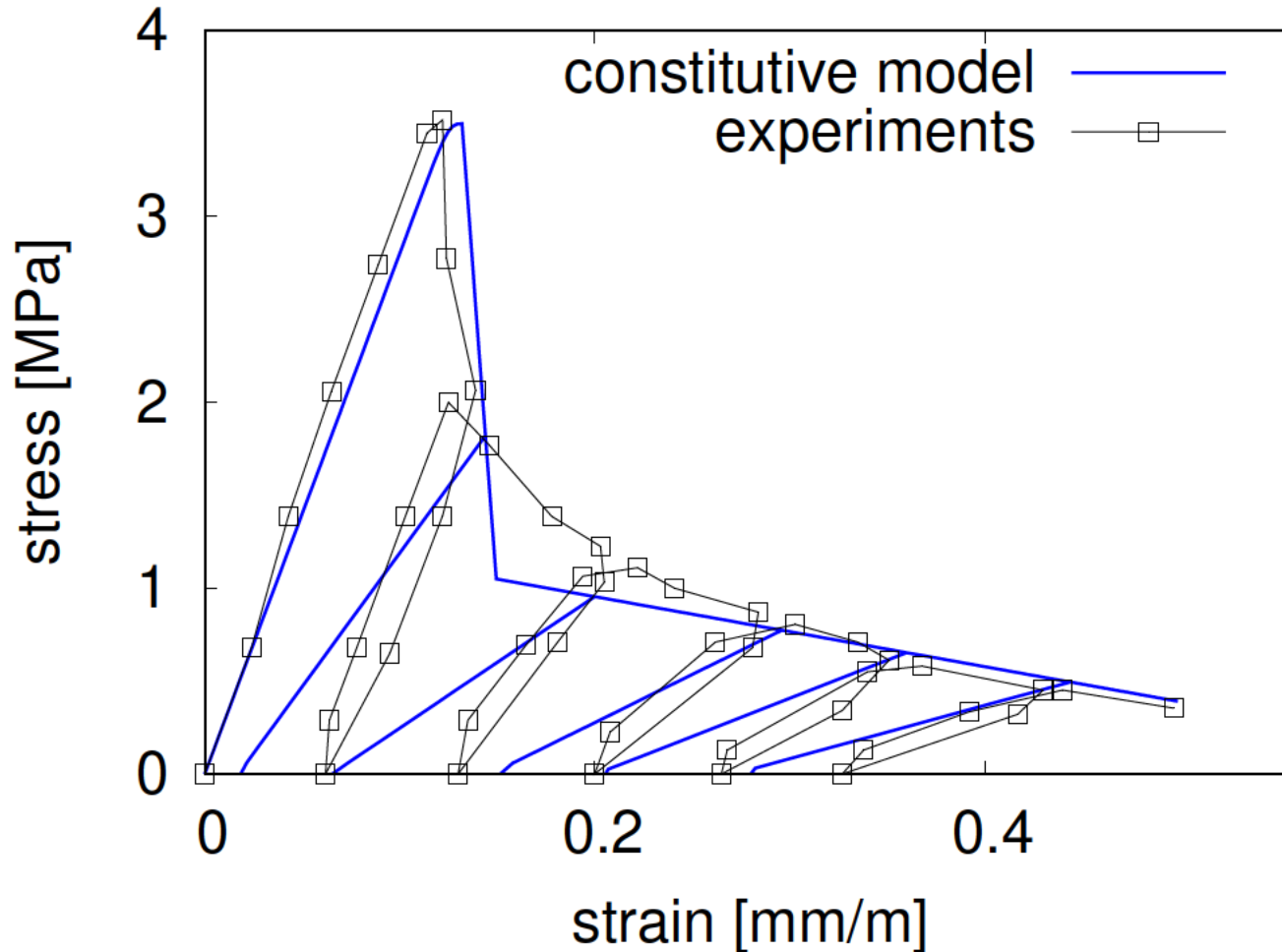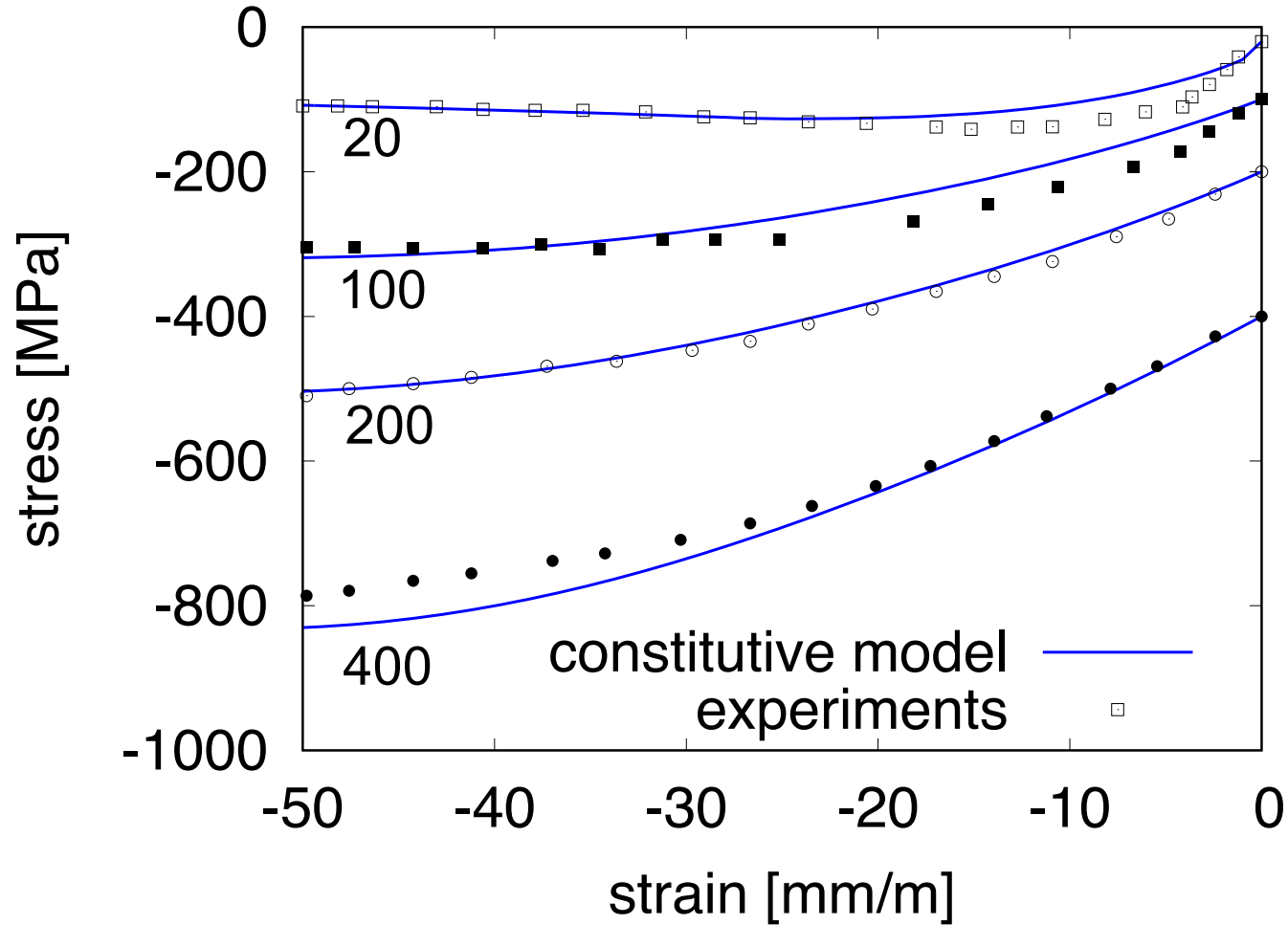## 3D nonlinear finite element analysis with damage plasticity model (CDPM2)

FE approach: Mesh

bond slip

beam elements

solid elements

Constitutive model for concrete

damage

$$\boldsymbol{\sigma} = (1 - \omega)\mathbf{D}_{\mathrm{e}} : \boldsymbol{\varepsilon}$$

plasticity

$$\boldsymbol{\sigma} = \mathbf{D}_{\mathrm{e}} : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_{\mathrm{p}})$$

damage-plasticity

$$\boldsymbol{\sigma} = (1 - \omega_{\mathrm{t}})\bar{\boldsymbol{\sigma}}_{\mathrm{t}} + (1 - \omega_{\mathrm{c}})\bar{\boldsymbol{\sigma}}_{\mathrm{c}}$$

$$\bar{\boldsymbol{\sigma}} = \mathbf{D}_{\mathrm{e}} : (\boldsymbol{\varepsilon} - \boldsymbol{\varepsilon}_{\mathrm{p}}) = \bar{\boldsymbol{\sigma}}_{\mathrm{t}} + \bar{\boldsymbol{\sigma}}_{\mathrm{c}}$$

Ref: CDPM2 Grassl et al. (2013)

Constitutive response for concrete

Ref: Grassl et al. (2013), Gopalaratnam and Shah (1985)

Constitutive response for concrete

Ref: Grassl et al. (2013), Caner and Bazant (2000)

Crack-band approach

$$h_e = \sqrt[3]{V_e}$$

Graph axes and labels: σ, f_t, f_{t1}, w_{f1}, w_f, $w_c = h_e \varepsilon_t$

Ref: Bazant and Oh (1989)   Peter Grassl, SEMC2019   9
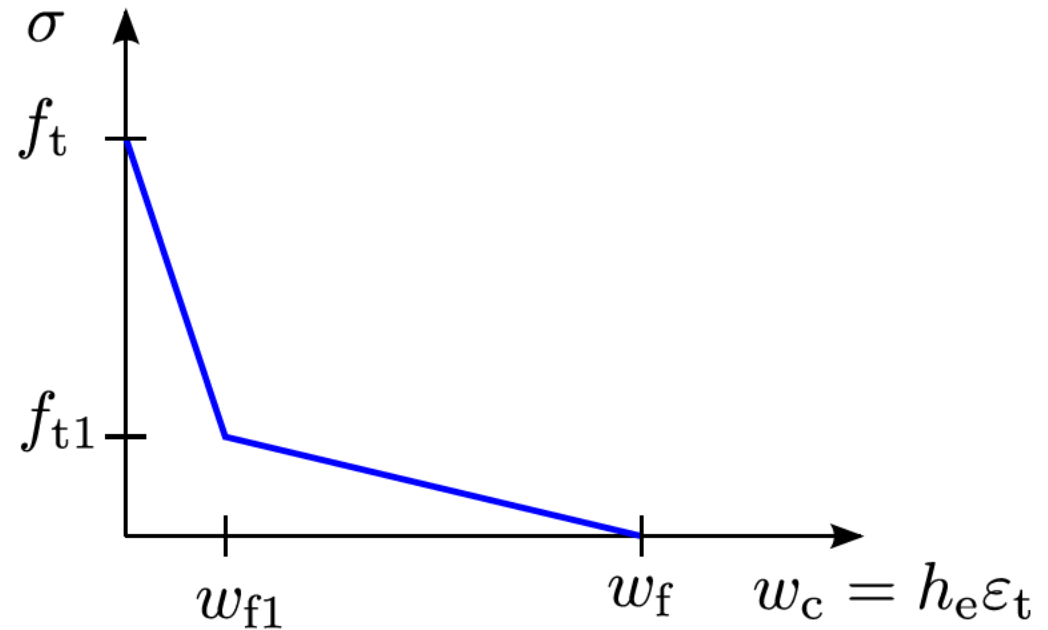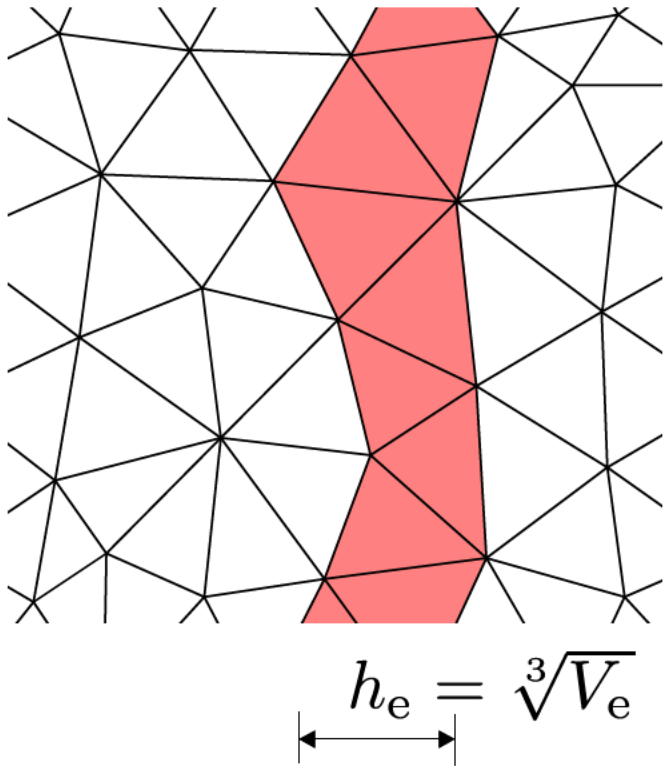
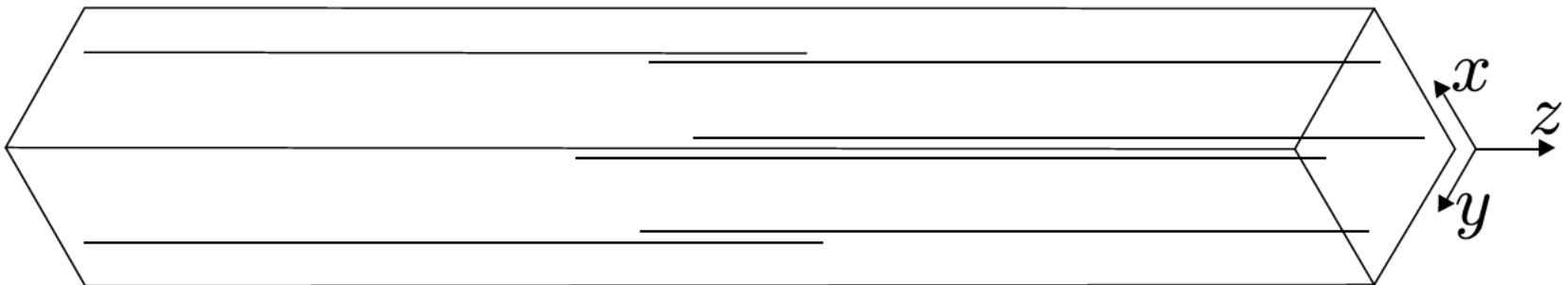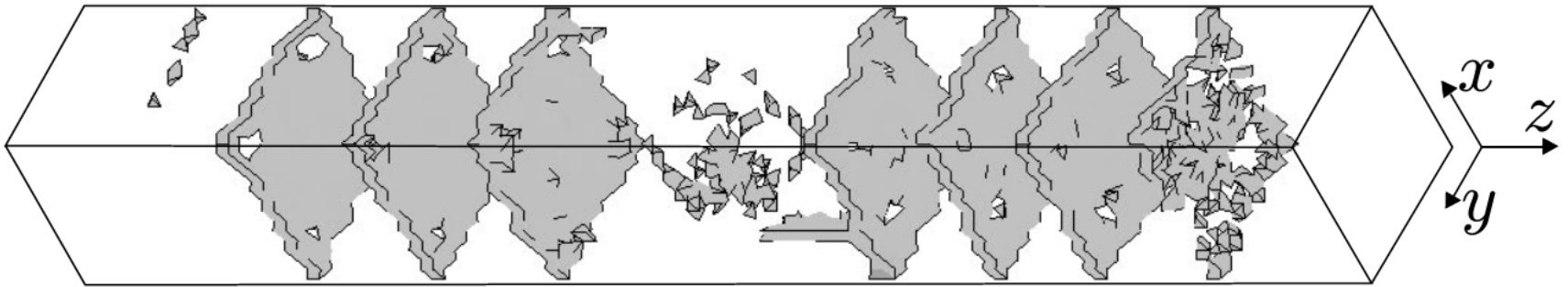# Constitutive models

Bond
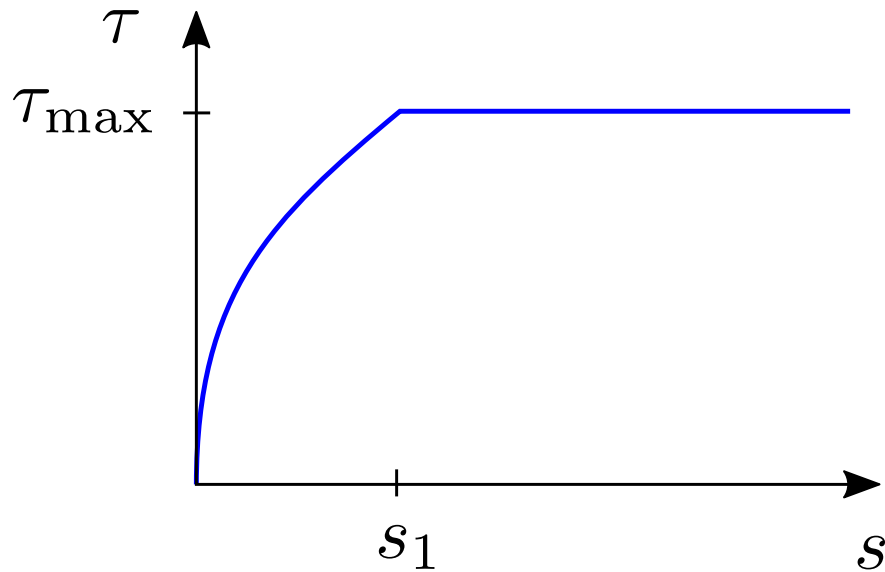
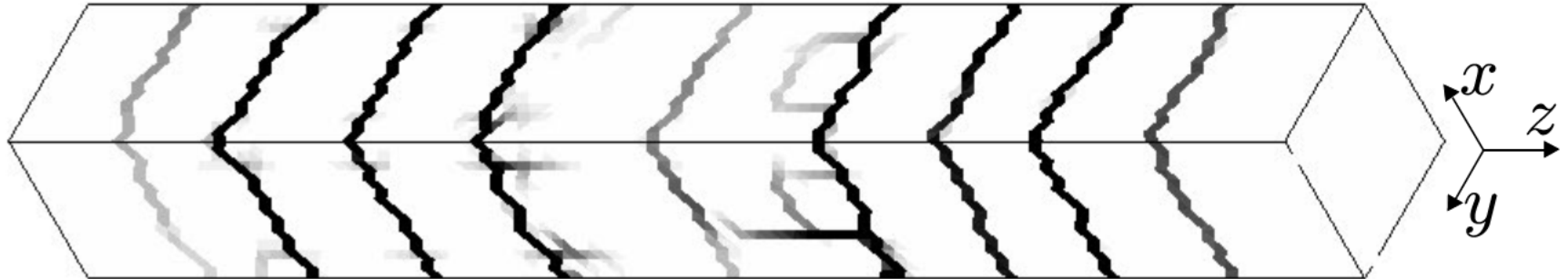## Steel
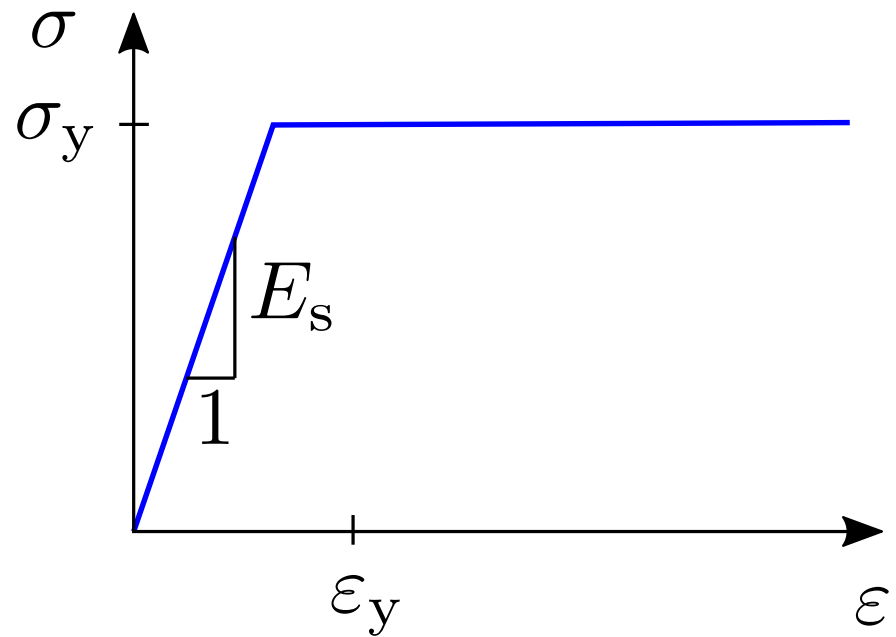
Geometry and setup
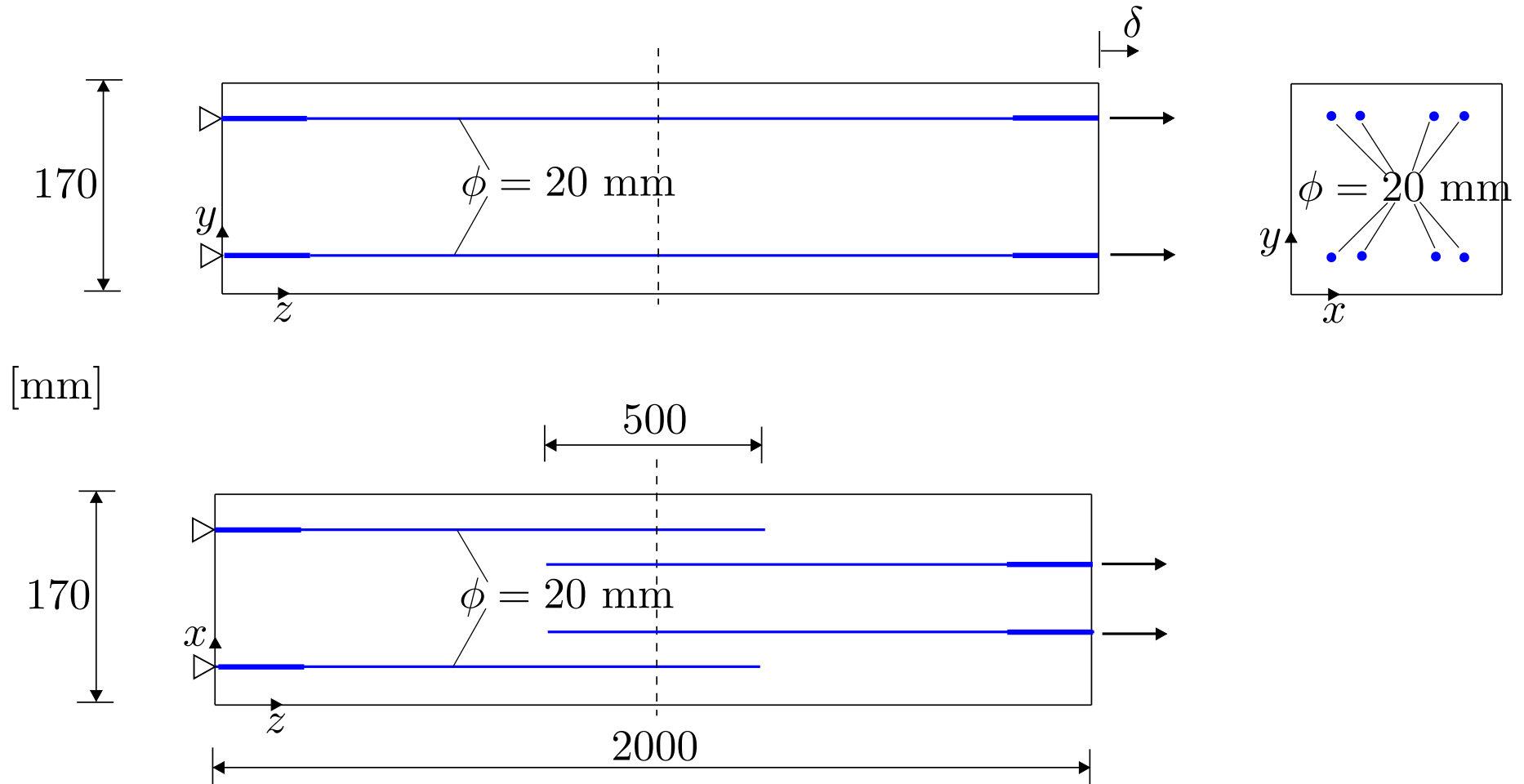
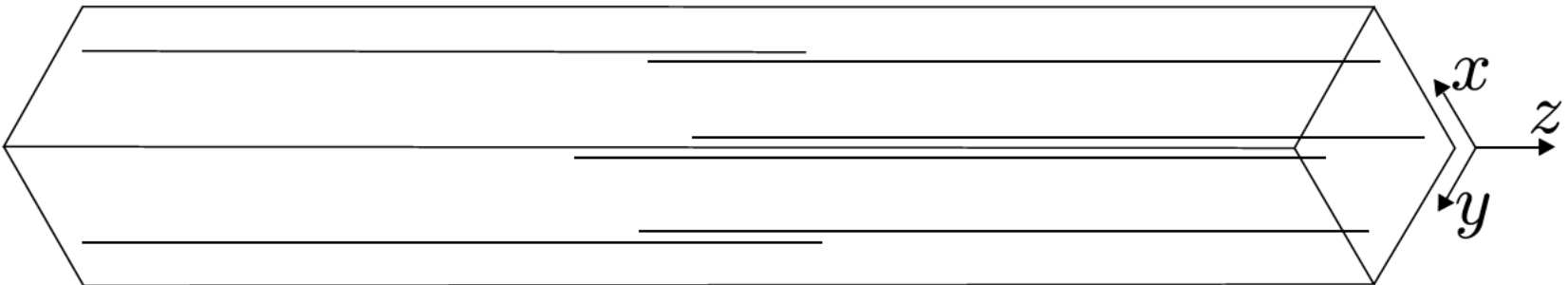# Plain and fibre reinforced concrete

Stress crack-opening input

Load-displacement

Legend: no fibres (solid line), fibres (dashed line)

Axes: $F/(4F_y)$ versus d/d_y
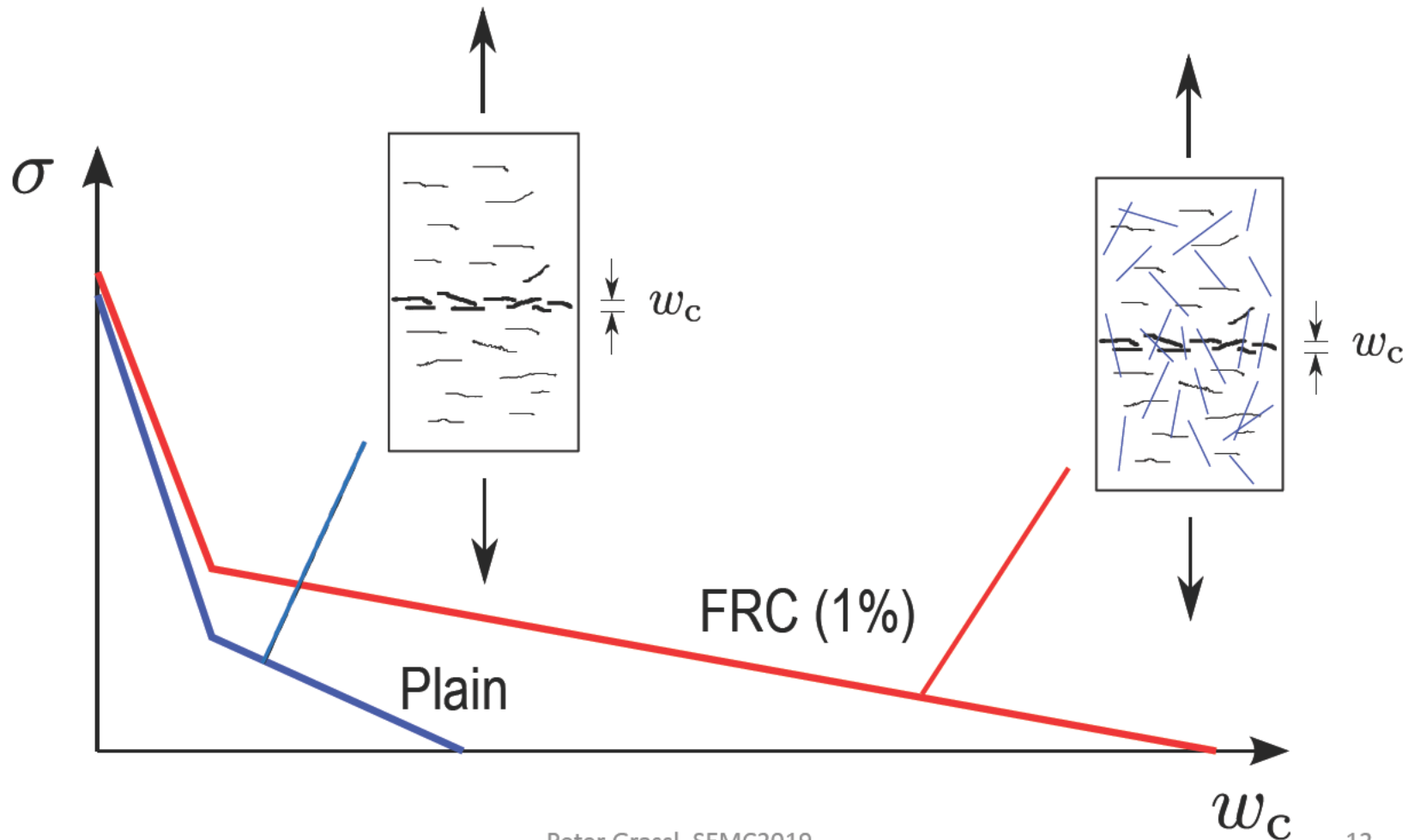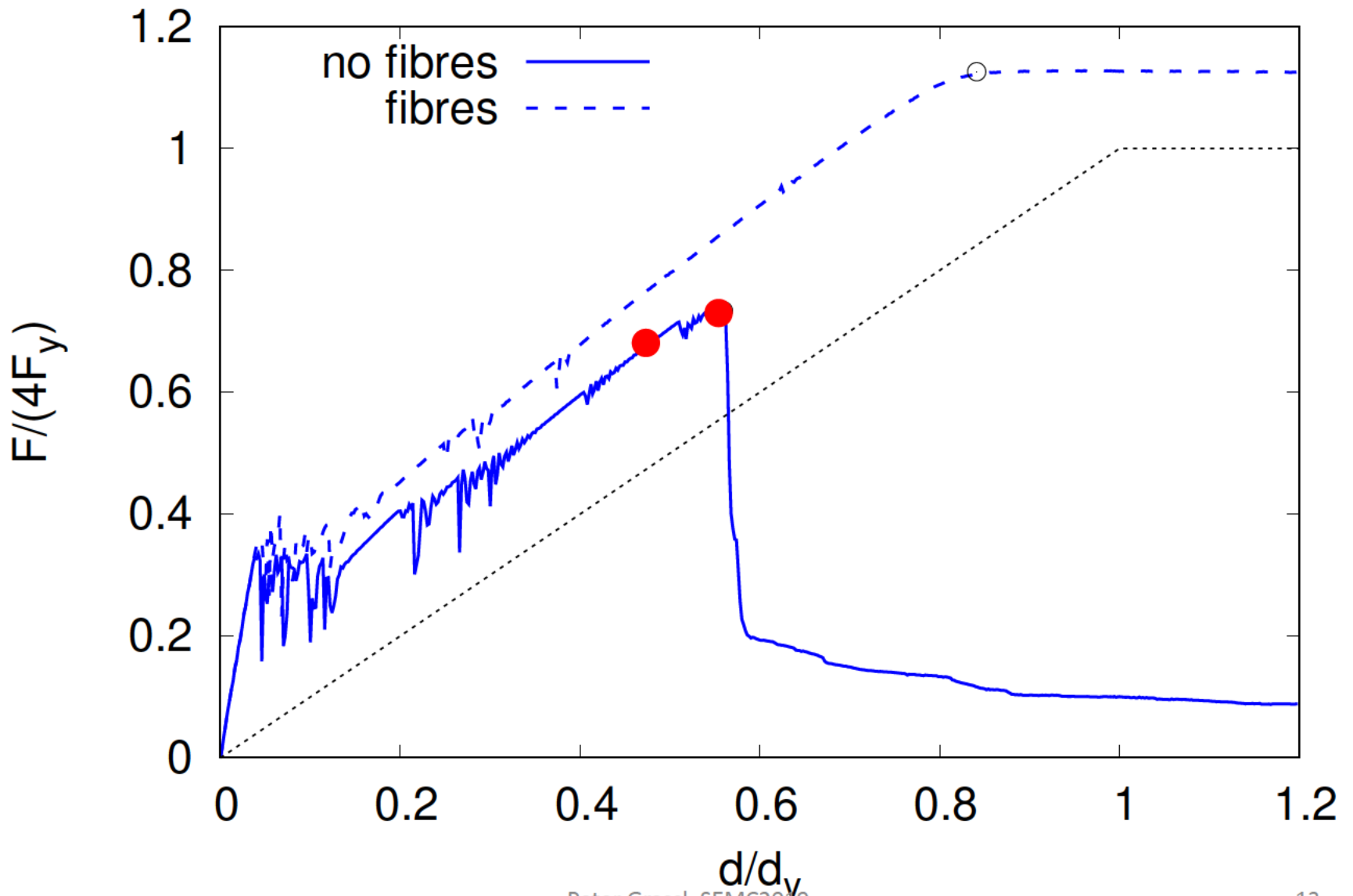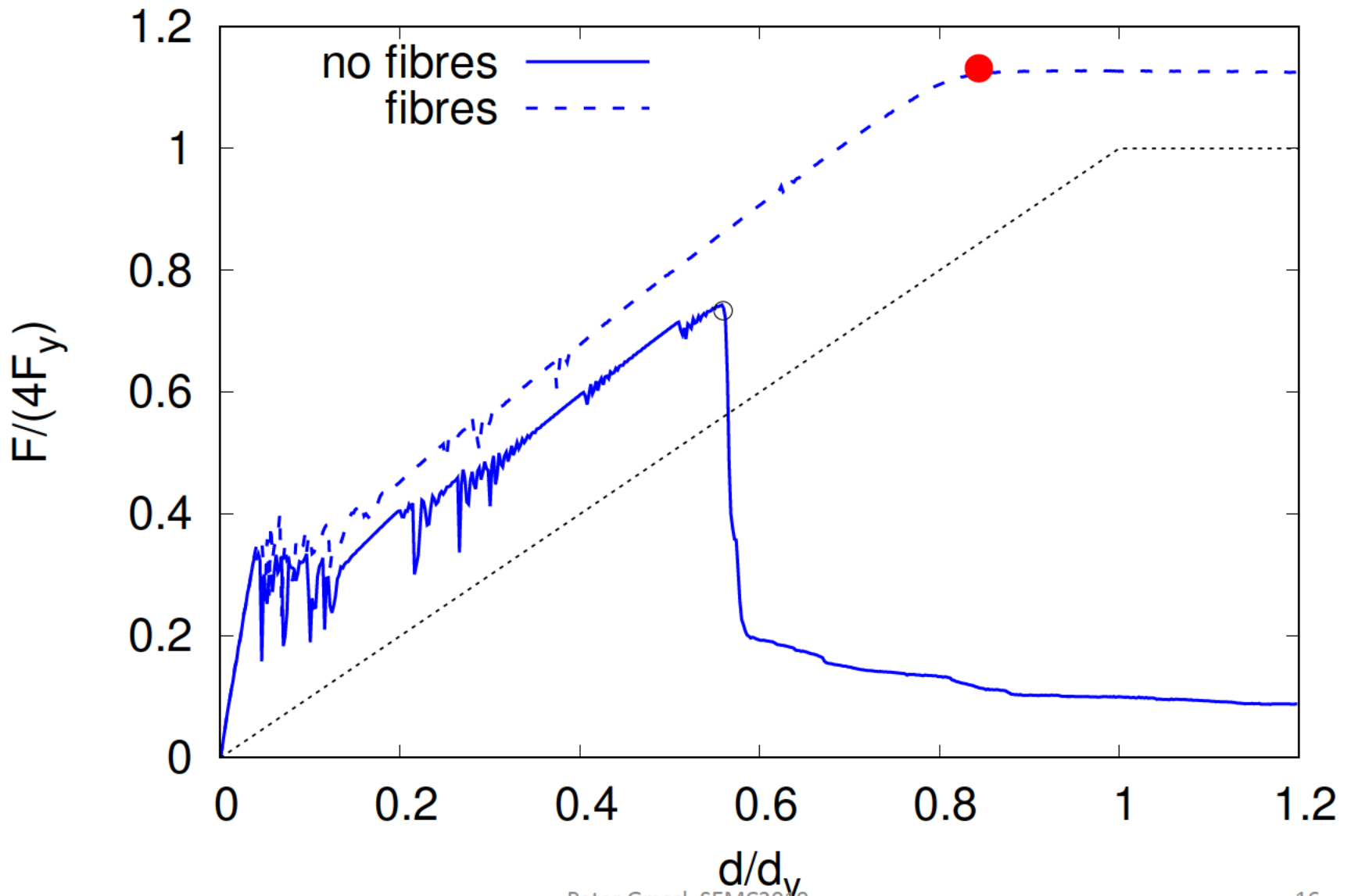
Cracks for no fibres: Pre-Peak

Cracks for no fibres: Peak

Load-displacement

Legend: no fibres (solid line), fibres (dashed line)

Y-axis: $F/(4F_y)$

X-axis: d/d_y
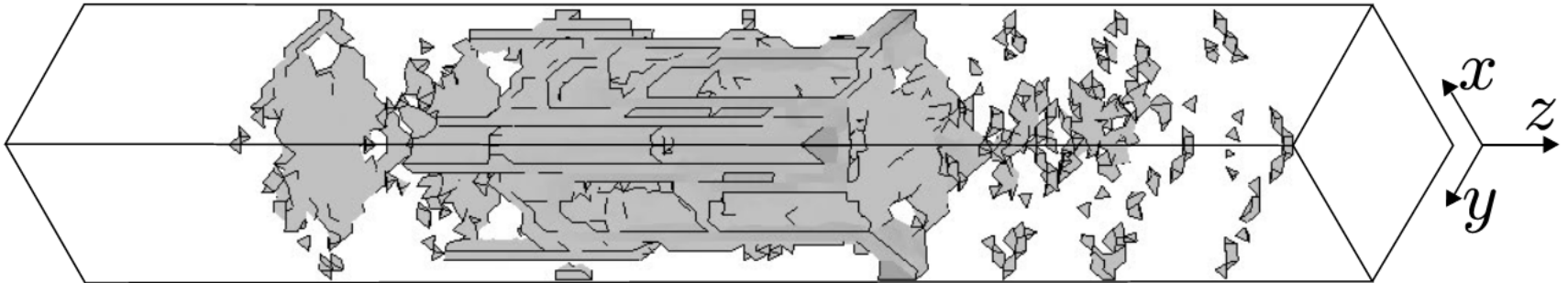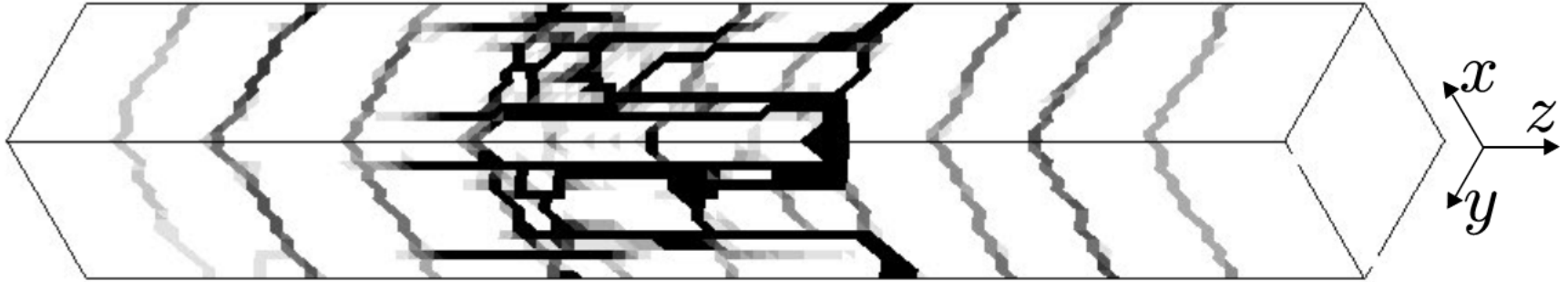
Cracks for fibres: Peak
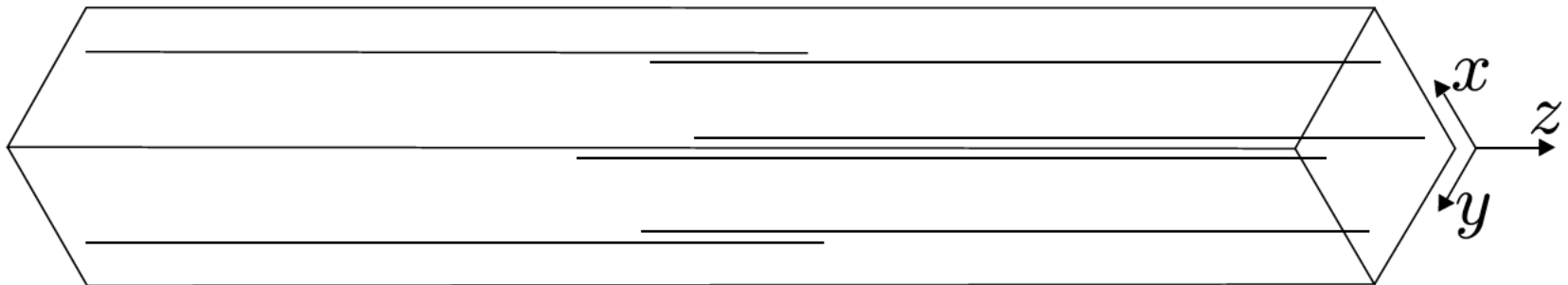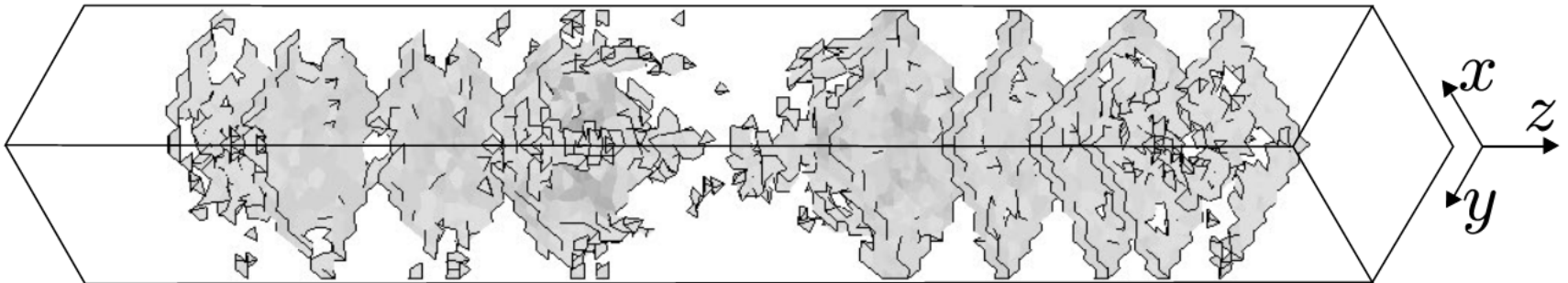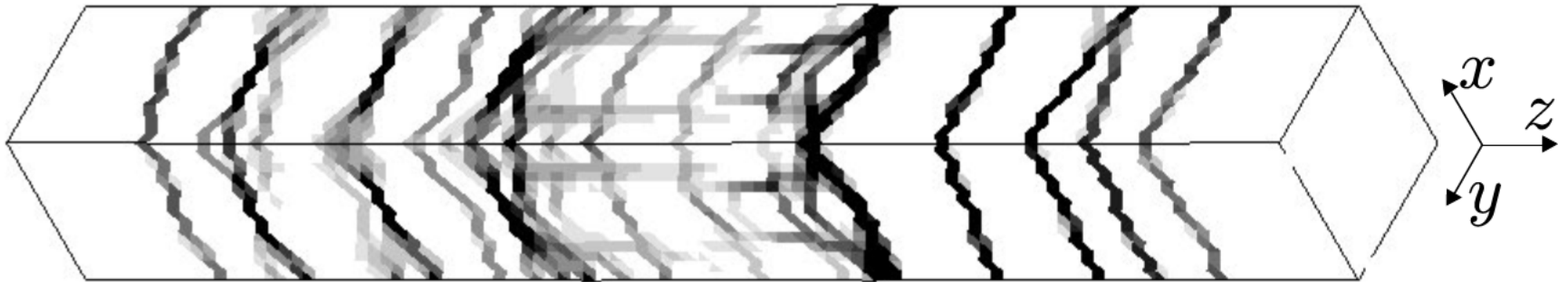
Discussion

FE-approach is capable of producing spalling failure in loop splices with plain concrete.

In the model, adding fibres prevents sudden failure mode.