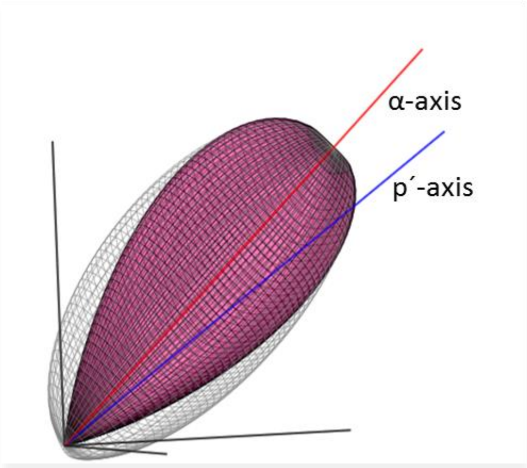
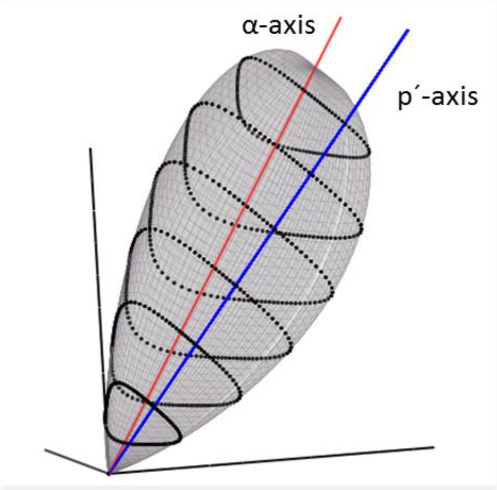
CHALMERS UNIVERSITY OF TECHNOLOGY

COMSOL CONFERENCE 2016 MUNICH

Implementation of a Modified Anisotropic Creep Model with Structure for Soft Soils with the use of Physics Builder





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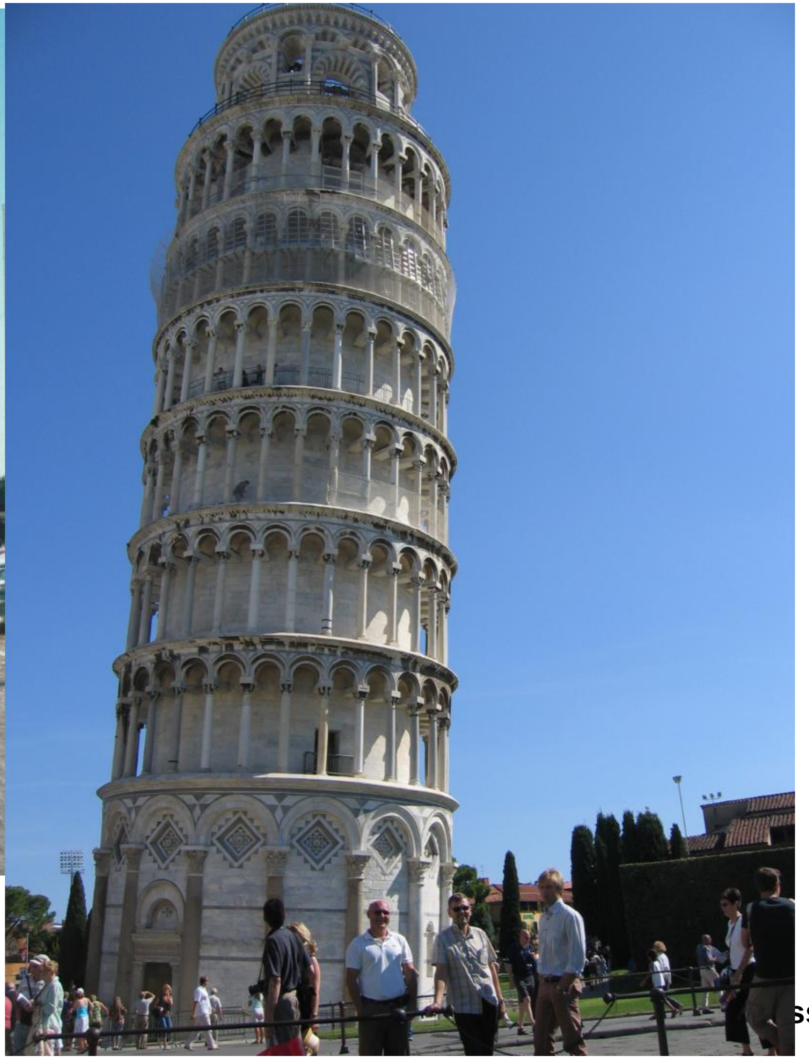
Outline

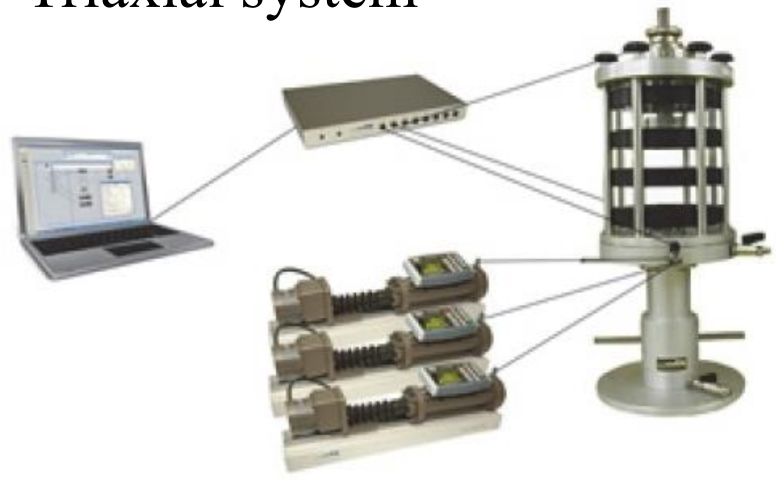
- Introduction
    - Creep/settlement in soft soils?
    - MAC-s model
- Physics builder
    - Implementation
    - GUI, input etc
- Validation of material model
    - Simulations
    - Example of real case

Building on Soft soils



Soft soil behaviour

Triaxial system



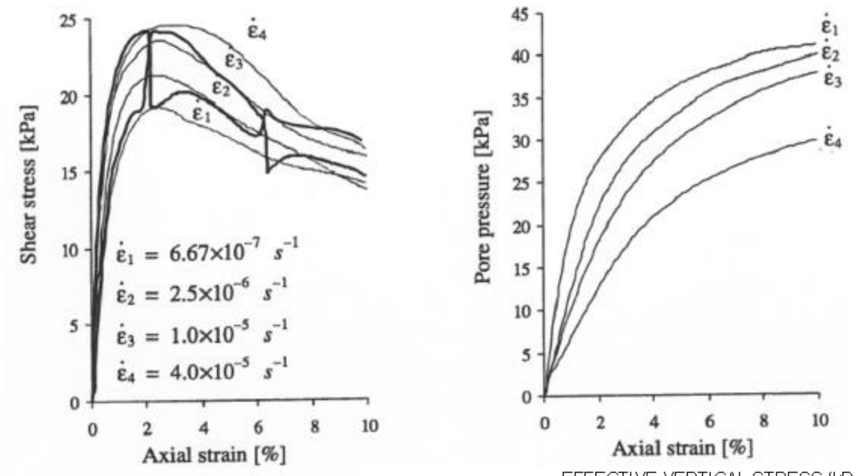
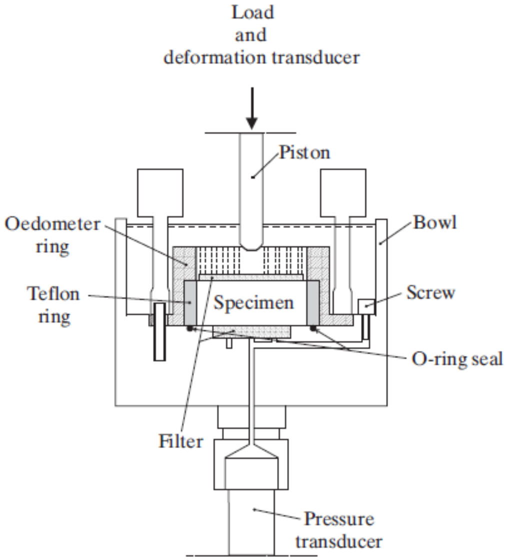
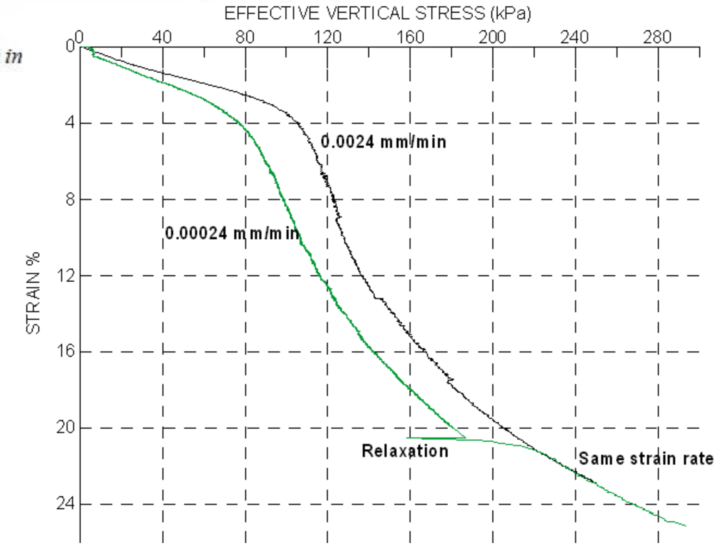


Figure 2.15. The effect of strain rate in Länsivaara (1999)

Oedometer





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Modified Anisotropic Creep model with structure (MAC-s)

$$p_{eq} = \frac{p'}{\left[1 - \dfrac{\frac{1}{2}\{\boldsymbol{\sigma}_d - p'\cdot\boldsymbol{\alpha}_d\}^T\{\boldsymbol{\sigma}_d - p'\cdot\boldsymbol{\alpha}_d\}}{p'^2\cdot\left(\mathrm{M}^2 - \frac{1}{2}\{\boldsymbol{\alpha}_\mathbf{d}\}^T\{\boldsymbol{\alpha}_\mathbf{d}\}\right)}\right]^{\frac{1}{m}}}$$

MAC-s (reference surface NCS)

Based on Grimstad (2009), Karstunen et.al (2005)

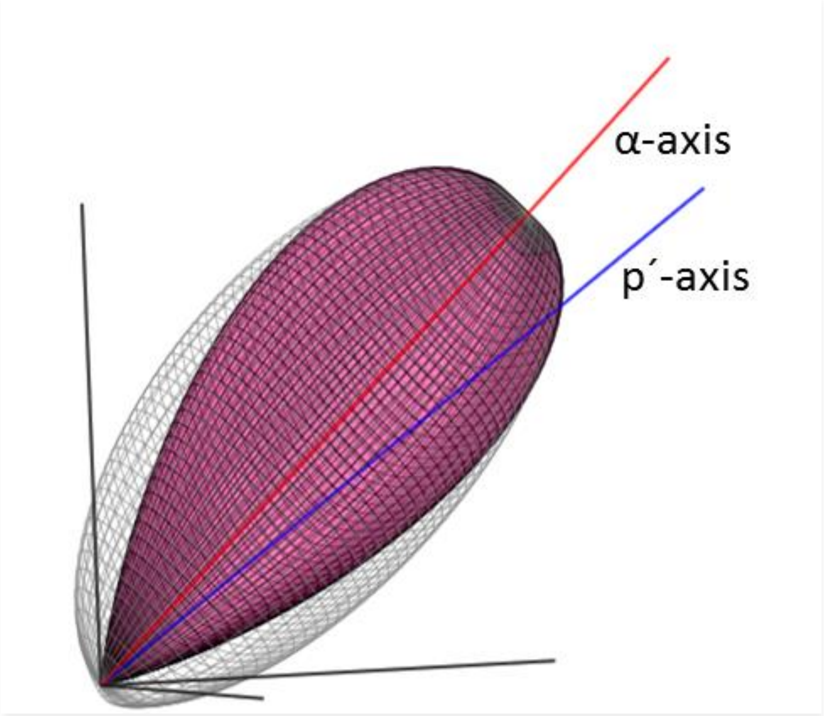
The plastic potential that is used for this model has the same shape as the CREEP-SCLAY1S model, i.e. the rotated ellipsoid

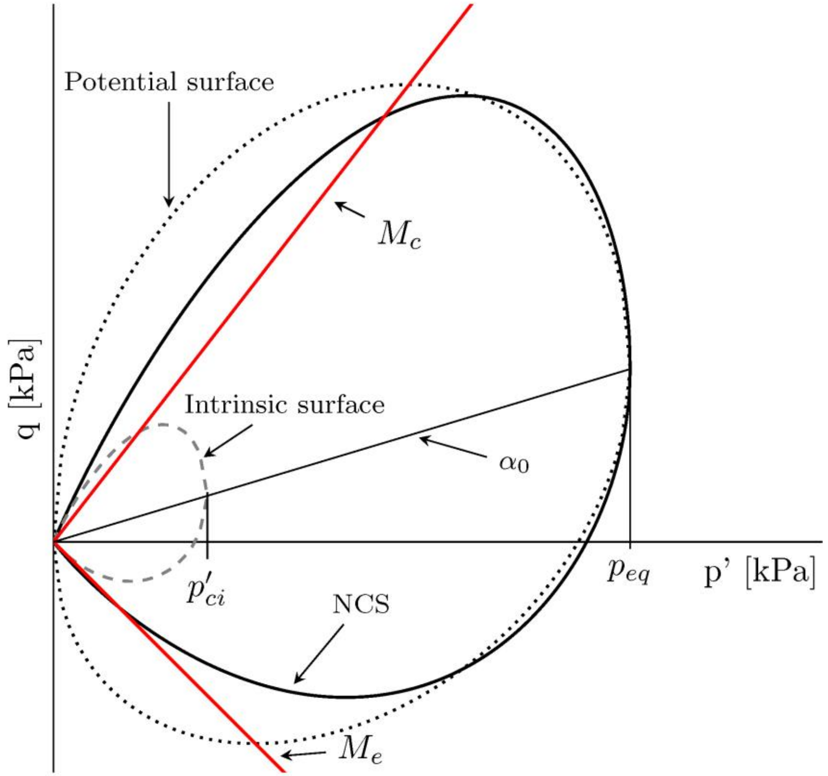
$$p_Q^{eq} = p' + \frac{3}{2}\cdot\frac{\{\boldsymbol{\sigma}_d - p'\cdot\boldsymbol{\alpha}_d\}^T\{\boldsymbol{\sigma}_d - p'\cdot\boldsymbol{\alpha}_d\}}{p'\left(M^2 - \frac{3}{2}\{\boldsymbol{\alpha}_d\}^T\{\boldsymbol{\alpha}_d\}\right)}$$

”Creep potential surface”

MAC-s model

- Graphical representation of the model





MAC-s model

- **Visco-plastic (rate) multiplier**

$$\dot{\lambda} = \frac{1}{r_{si} \cdot \tau} \cdot \left(\frac{p^{eq}}{(1+\chi) \cdot p'_{ci}} \right)^{r_{si} \cdot (\lambda_i^* - \kappa^*)} \cdot \frac{M_c^2 - \alpha_0^2}{M_c^2 - \eta_0^2}$$

Rotation of surfaces

$$d\boldsymbol{\alpha}_d = \left(\omega_v \left[\frac{3\boldsymbol{\eta}}{4} - \boldsymbol{\alpha}_d \right] \cdot \langle d\varepsilon_v^c \rangle + \omega_d^* \left[\frac{\boldsymbol{\eta}}{3} - \boldsymbol{\alpha}_d \right] \cdot d\varepsilon_d^c \right)$$

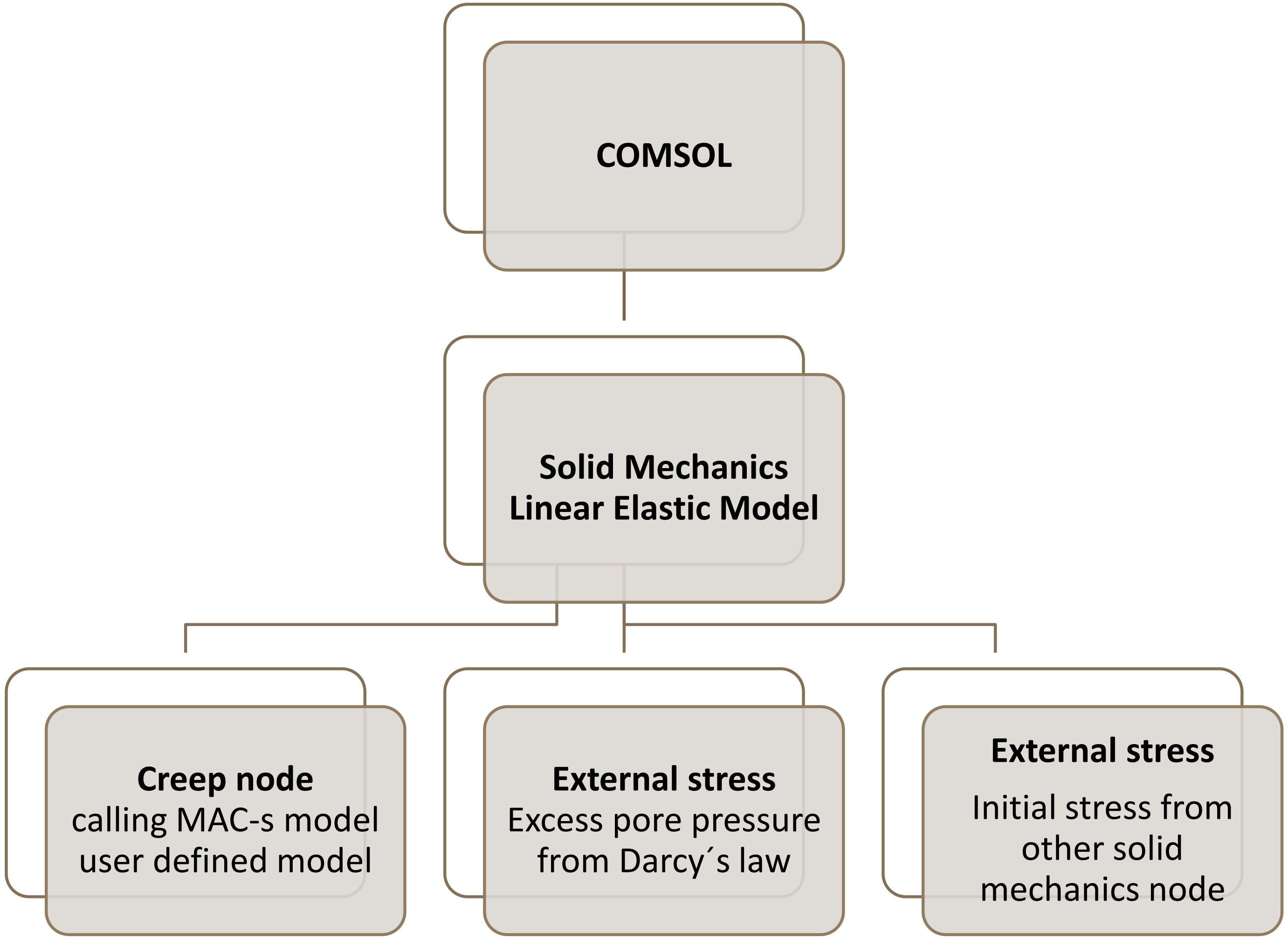
Change in size

$$p_{ci} = p_{ci0} \exp\left(\frac{\varepsilon_v^c}{\lambda_i^* - \kappa^*} \right)$$

Effect of structure

$$d\chi = -\chi \left(\xi_v \left| d\varepsilon_v^c \right| + \xi_d \left| d\varepsilon_d^c \right| \right)$$

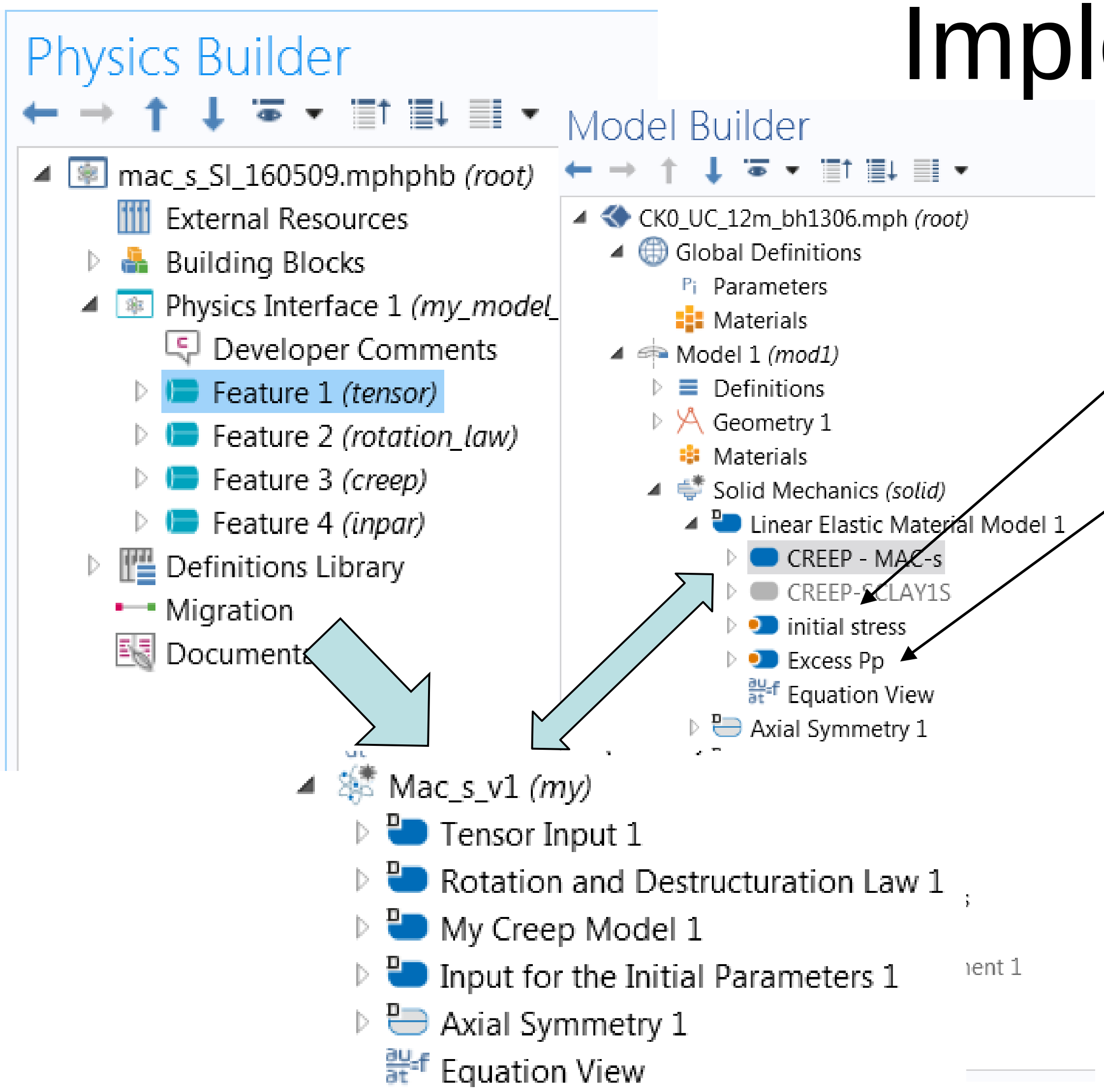
Implementation



Why?

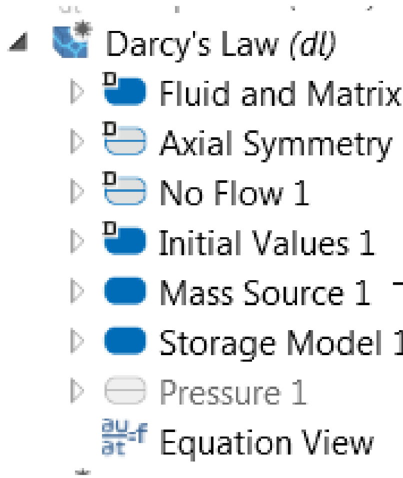
- Make it easy to share
- Valid for all relevant dimensions
- General for any case
- Easy to adopt and change the equations

Implementation



Initial stress calculated from another solid mechanics node (external stress input)

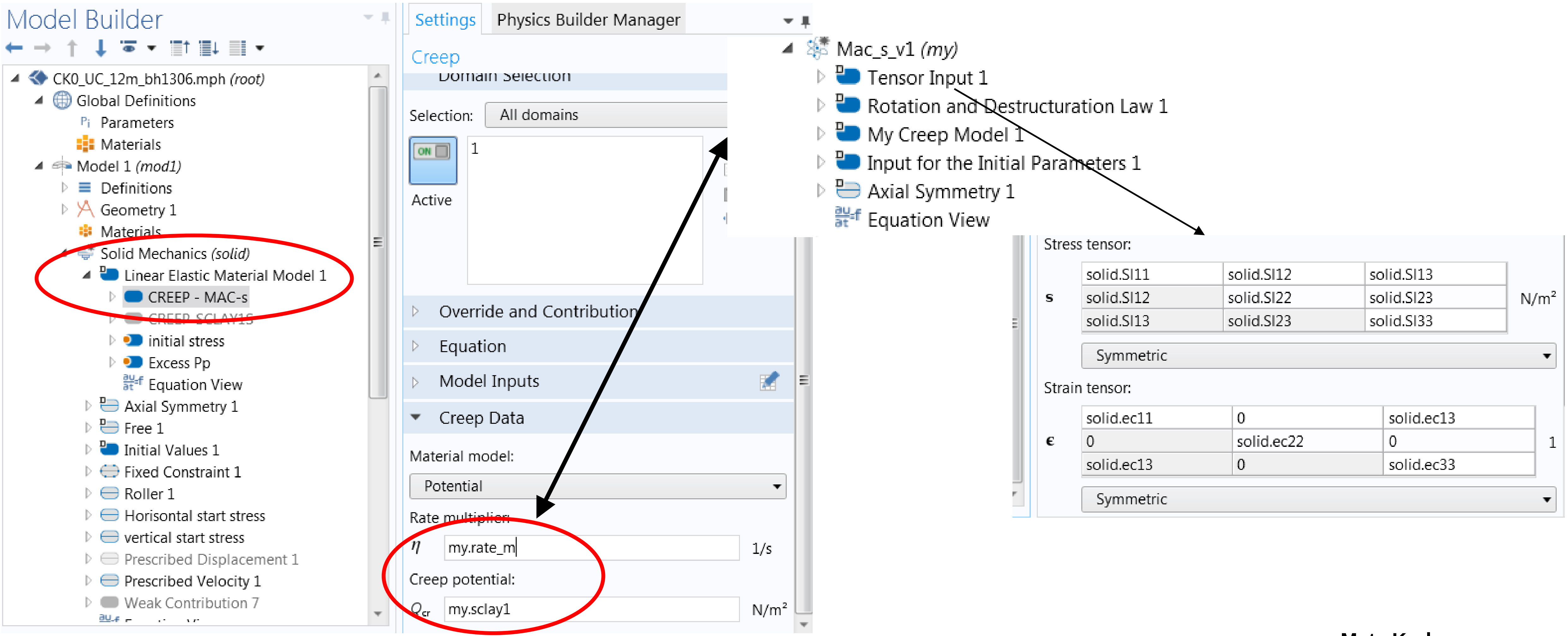
Excess pore pressure calculated in Darcy Law node (external stress pore pressure input)



-dl.rho*(d(solid.evol,TIME))

Permeability etc

Implementation



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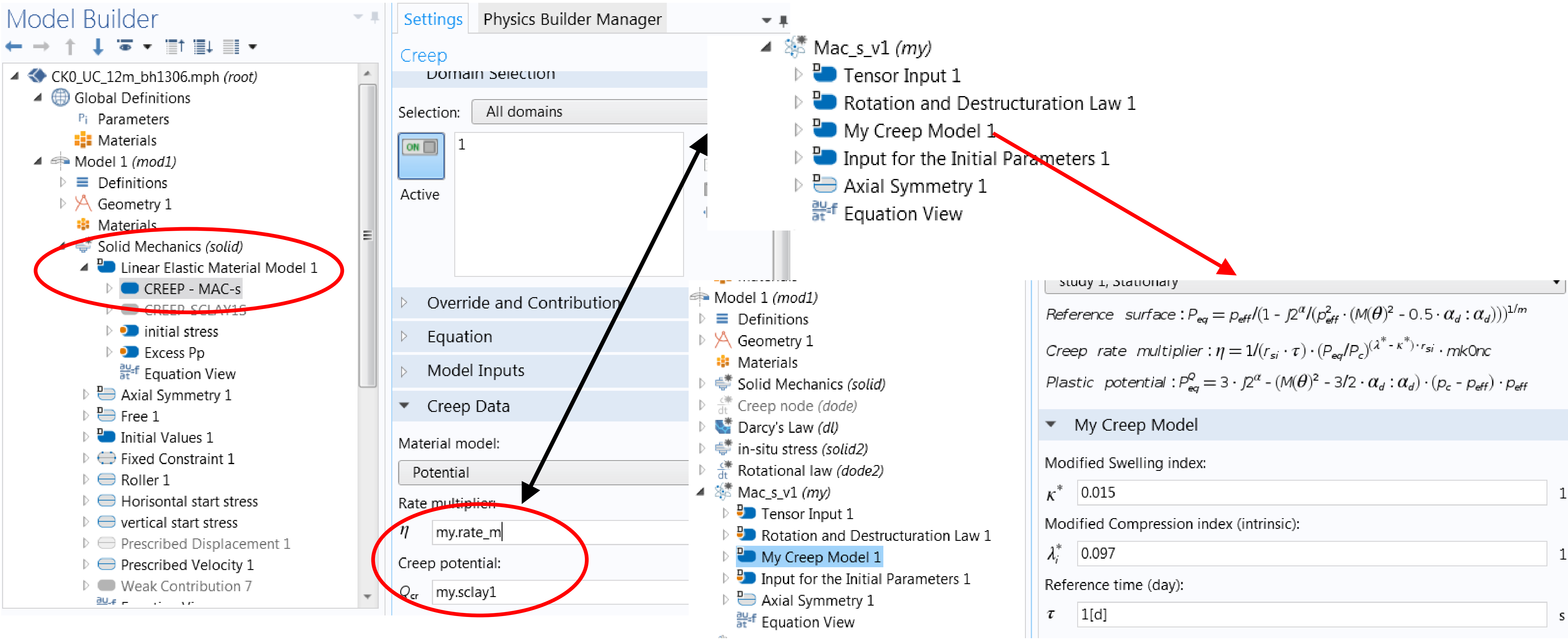
Implementation



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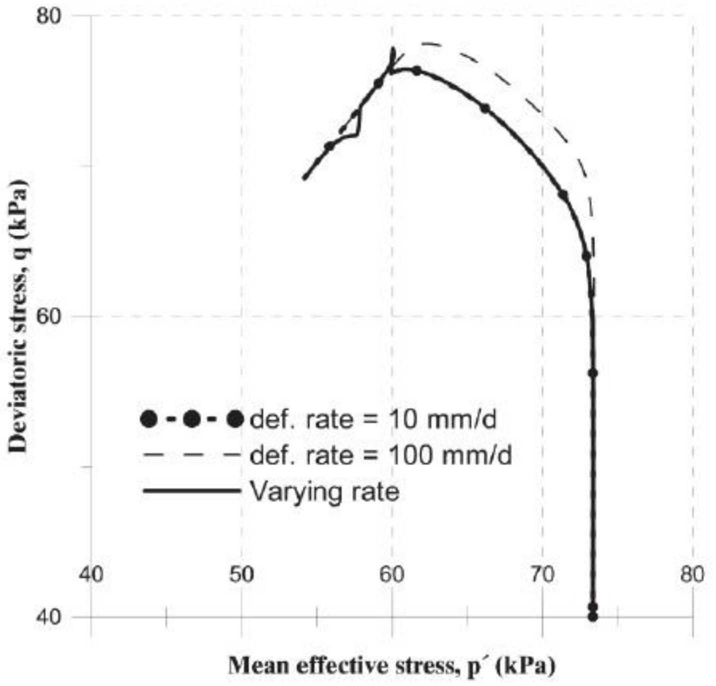
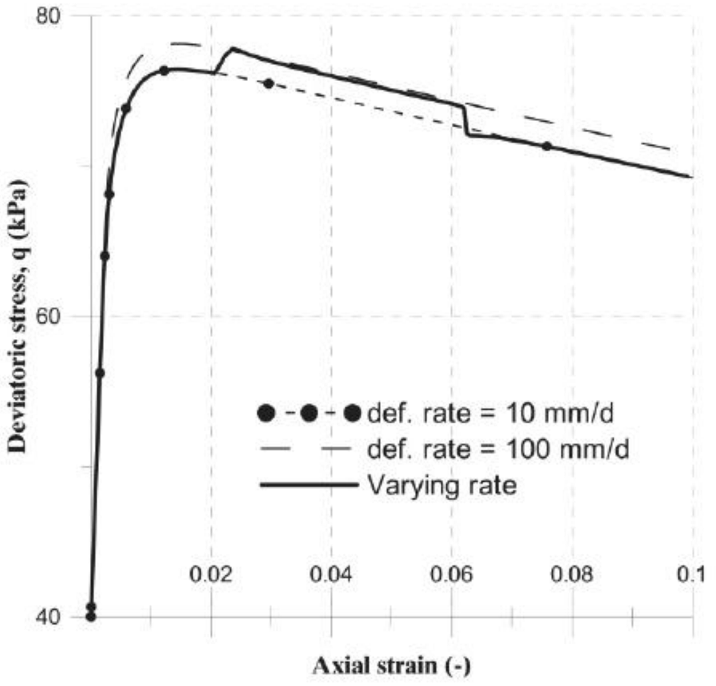
Simulations

Undrained triaxial test - compression





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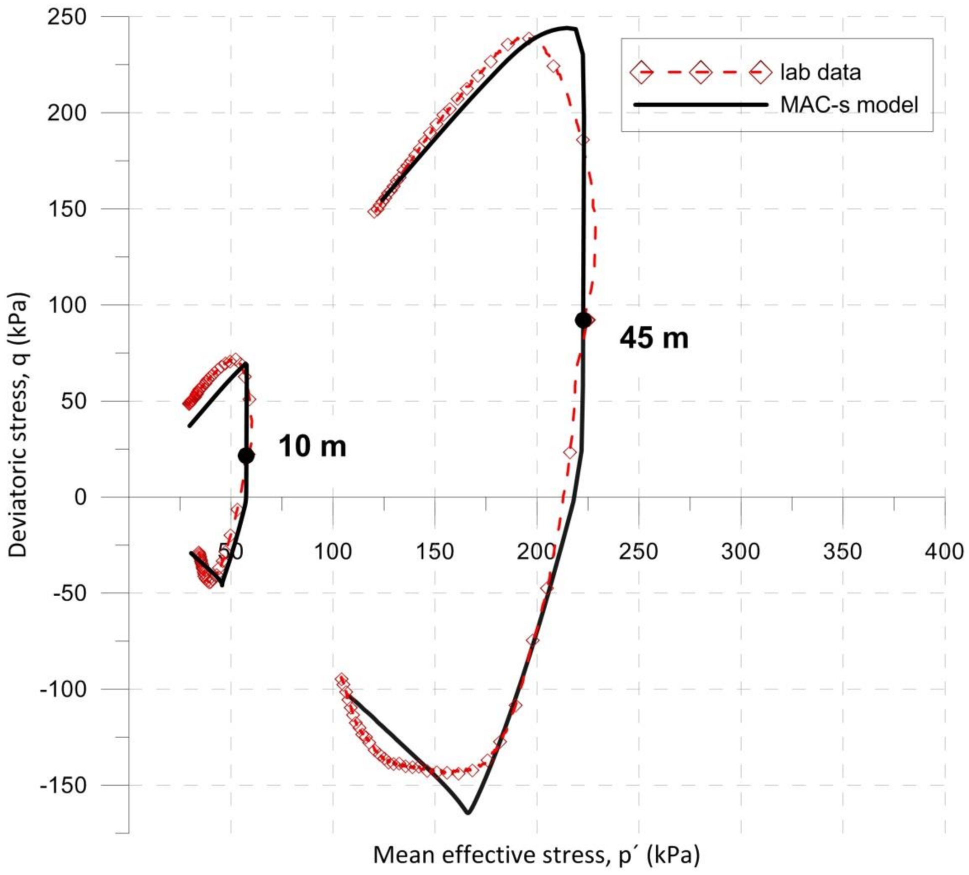
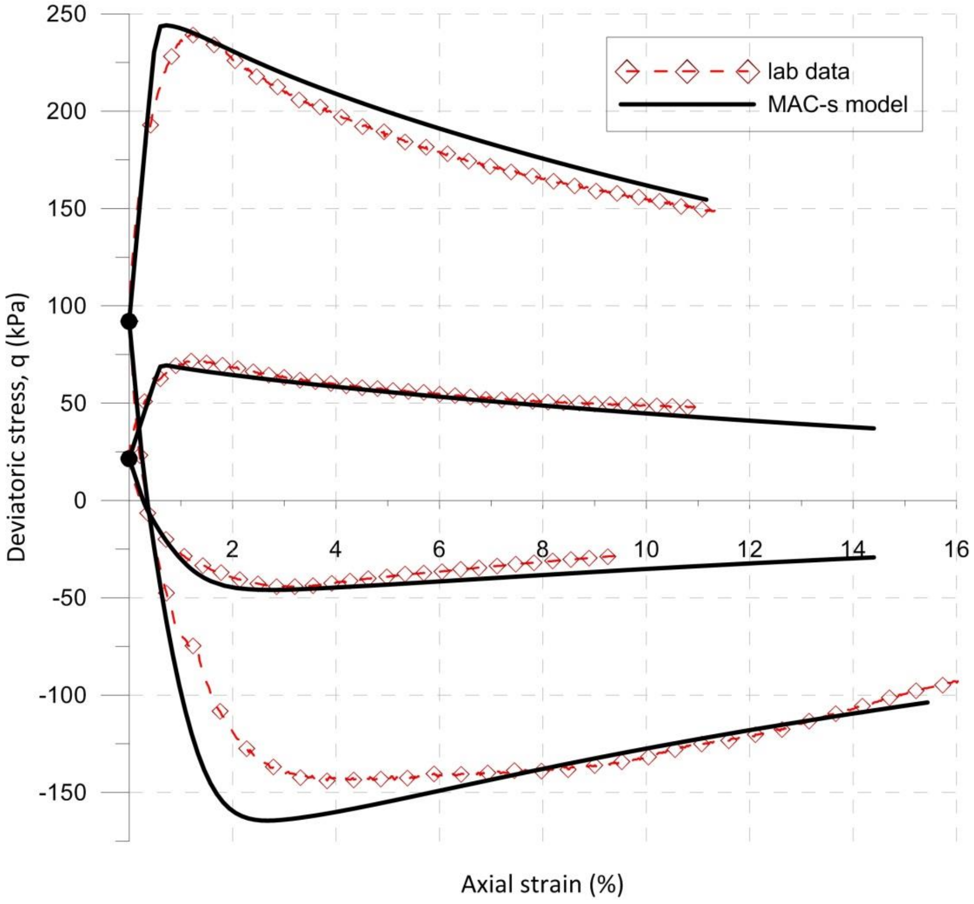
Simulations – triaxial tests





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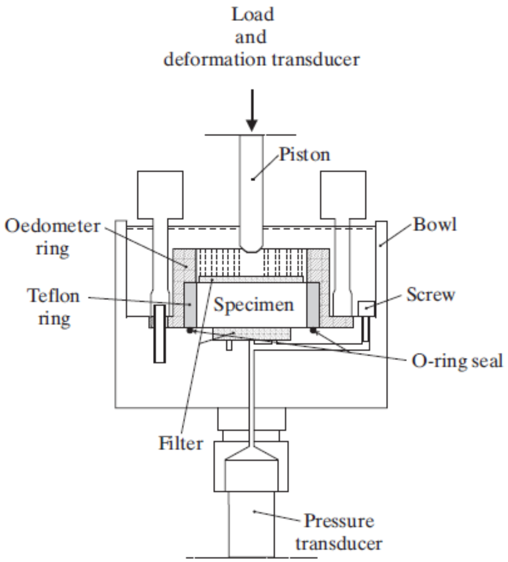
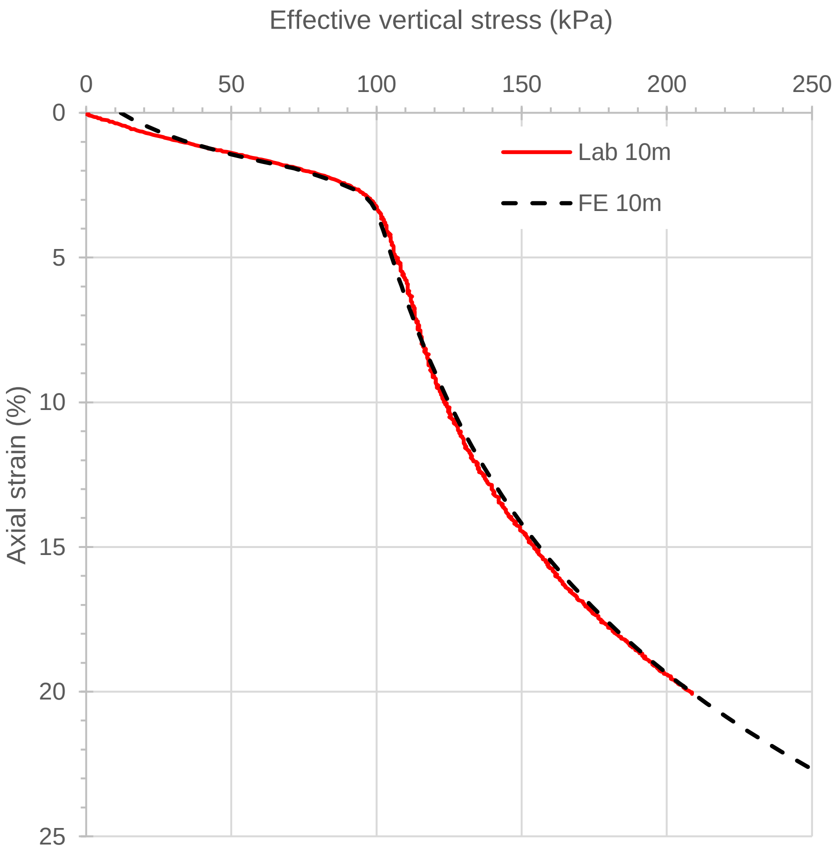
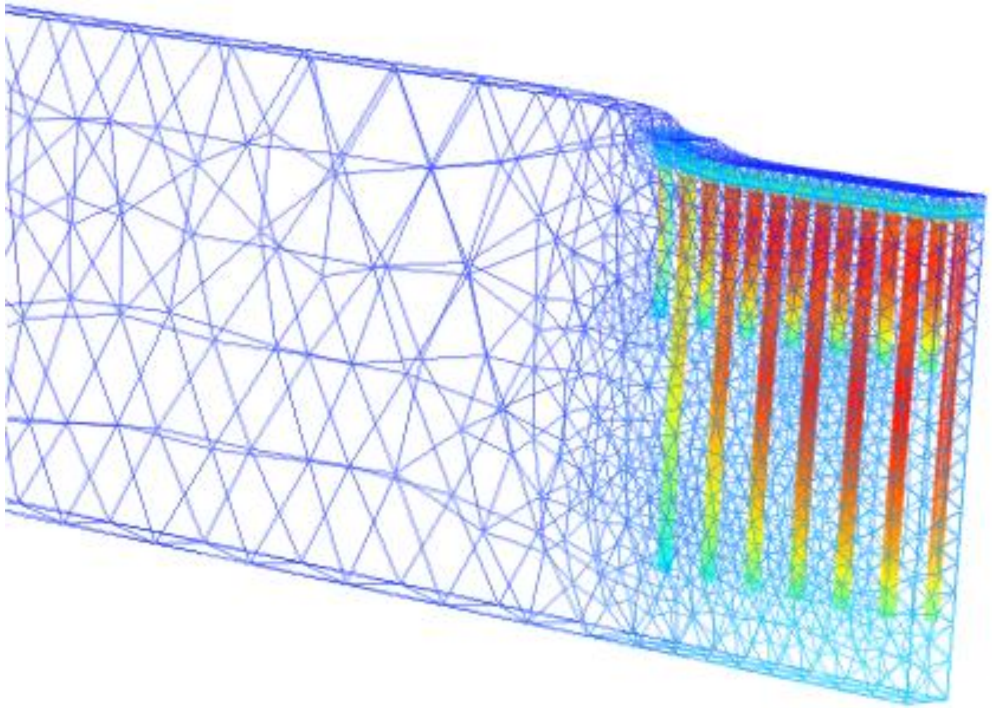
Simulations – Oedometer test





Real case – Road embankment Lime-Cement Column reinforcement



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Thank you
for
your attention