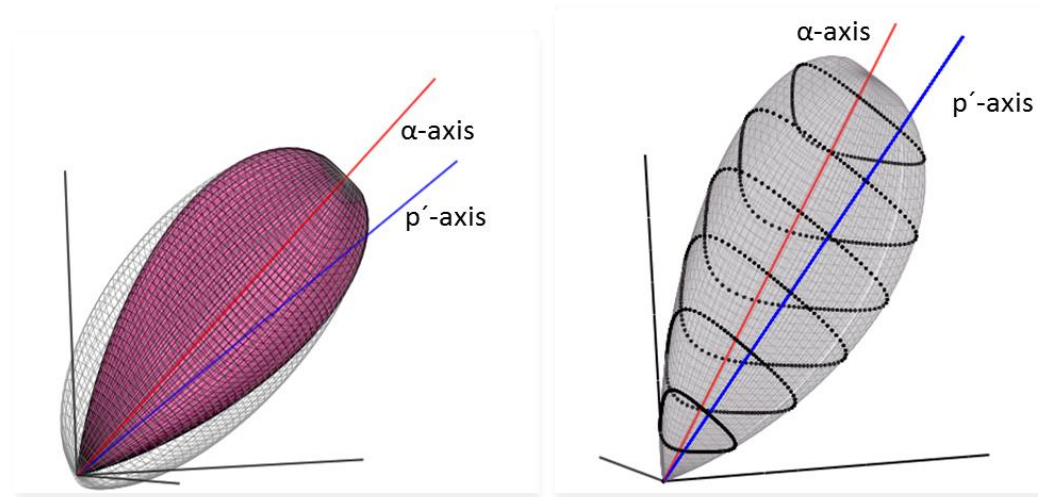


Implementation of a Modified Anisotropic Creep Model with Structure for Soft Soils with the use of **Physics Builder**

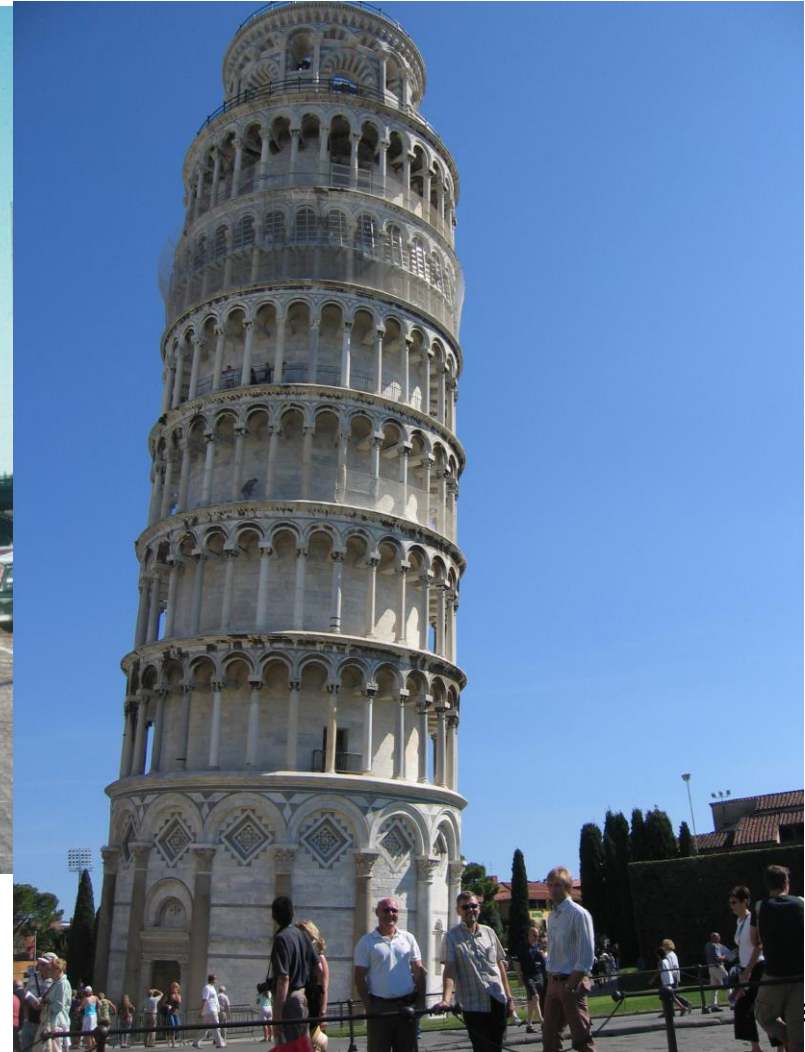


Mats Karlsson

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

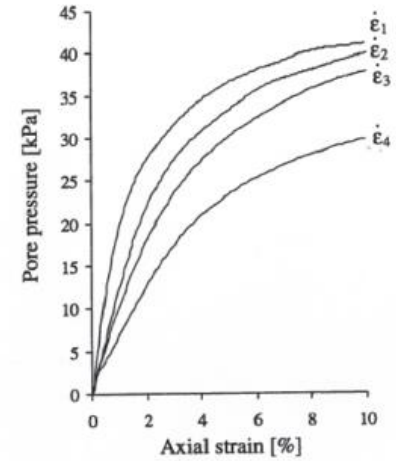
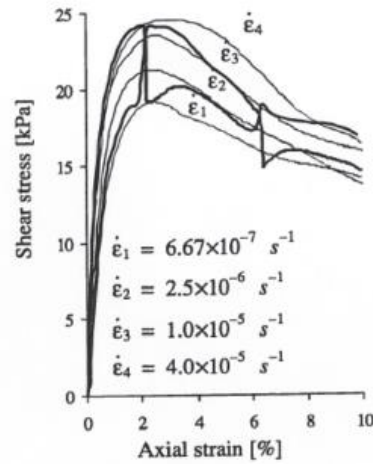
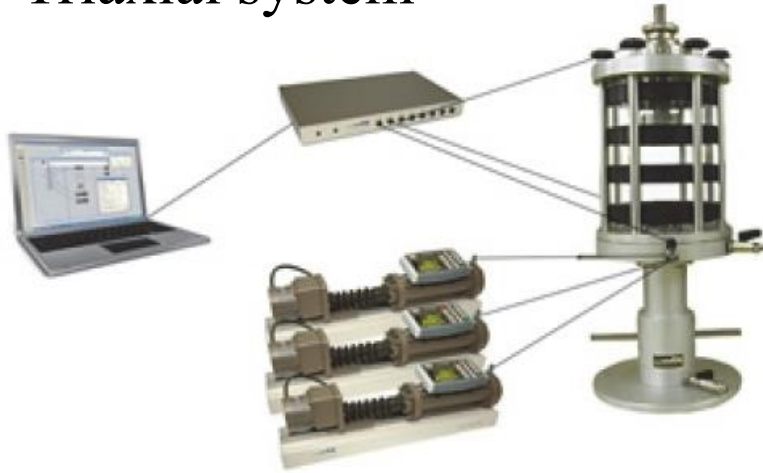
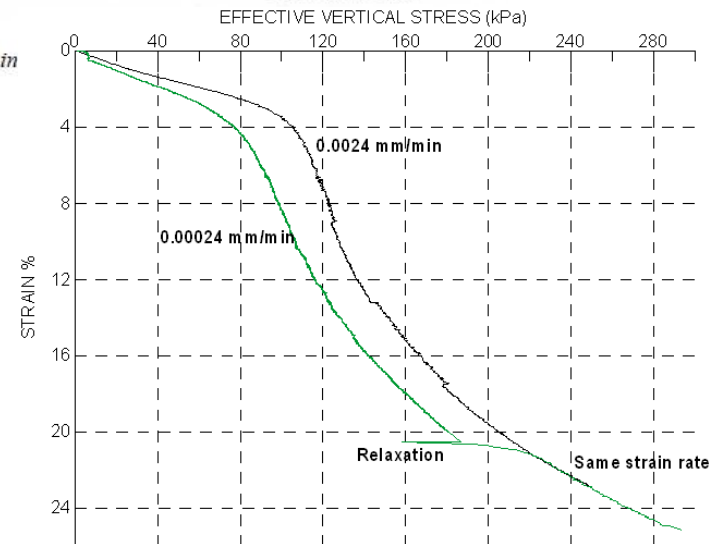
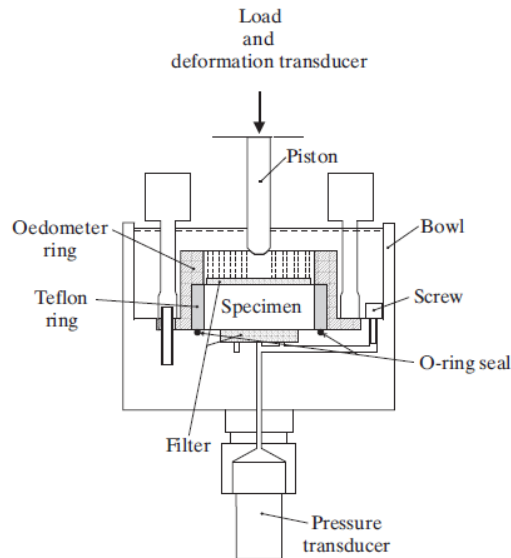


Figure 2.15. The effect of strain rate in
Länsivaara (1999)

Oedometer



Modified Anisotropic Creep model with structure (MAC-s)

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

MAC-s (reference surface NCS)
Based on Grimstad (2009), Karstunen et.al (2005)

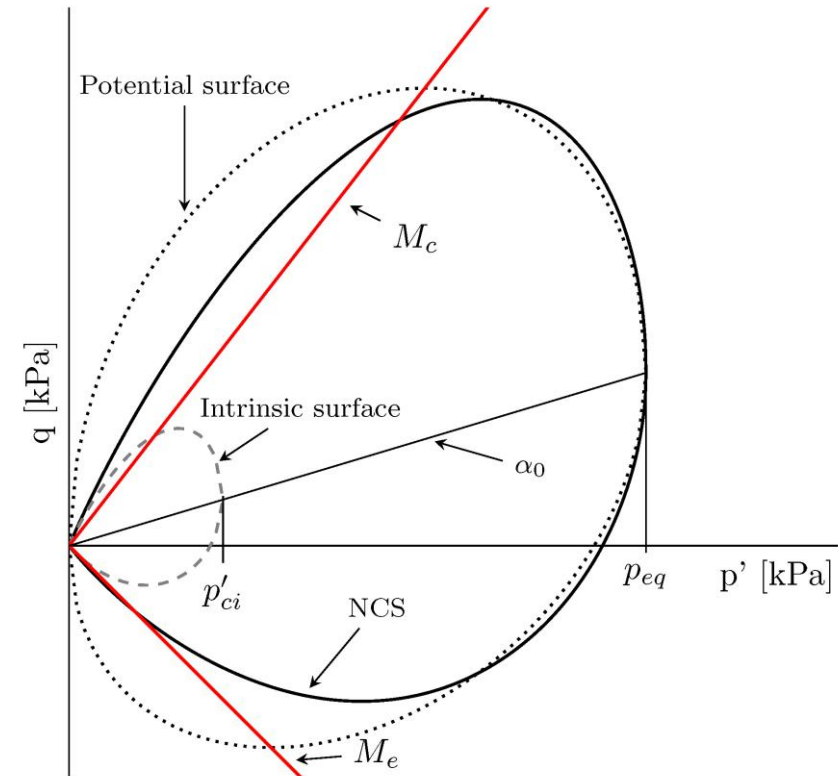
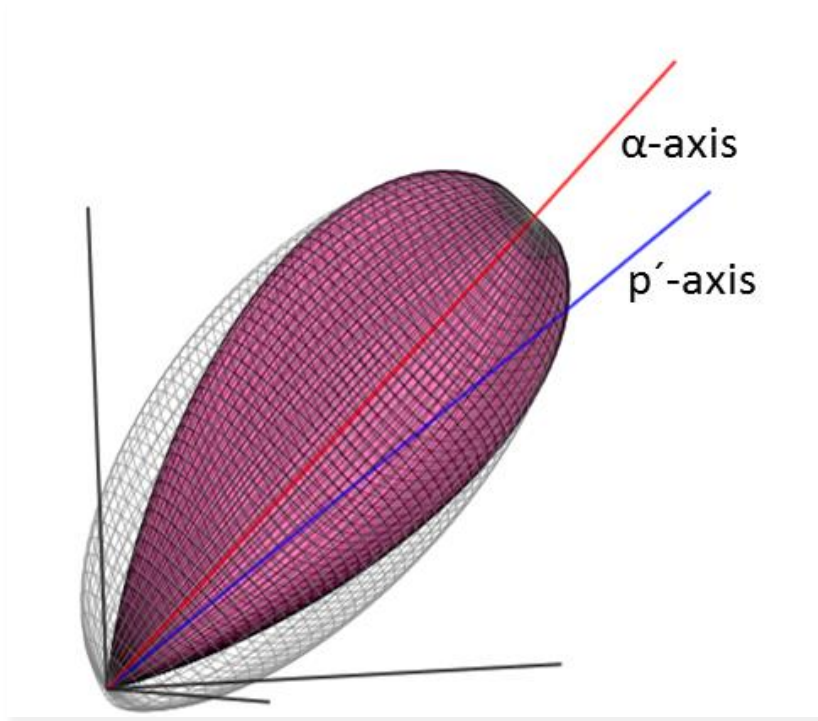
The plastic potential that is used for this model has the same shape as the CREEP-SCLAY1S model, i.e. the rotated ellipsoid

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

”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

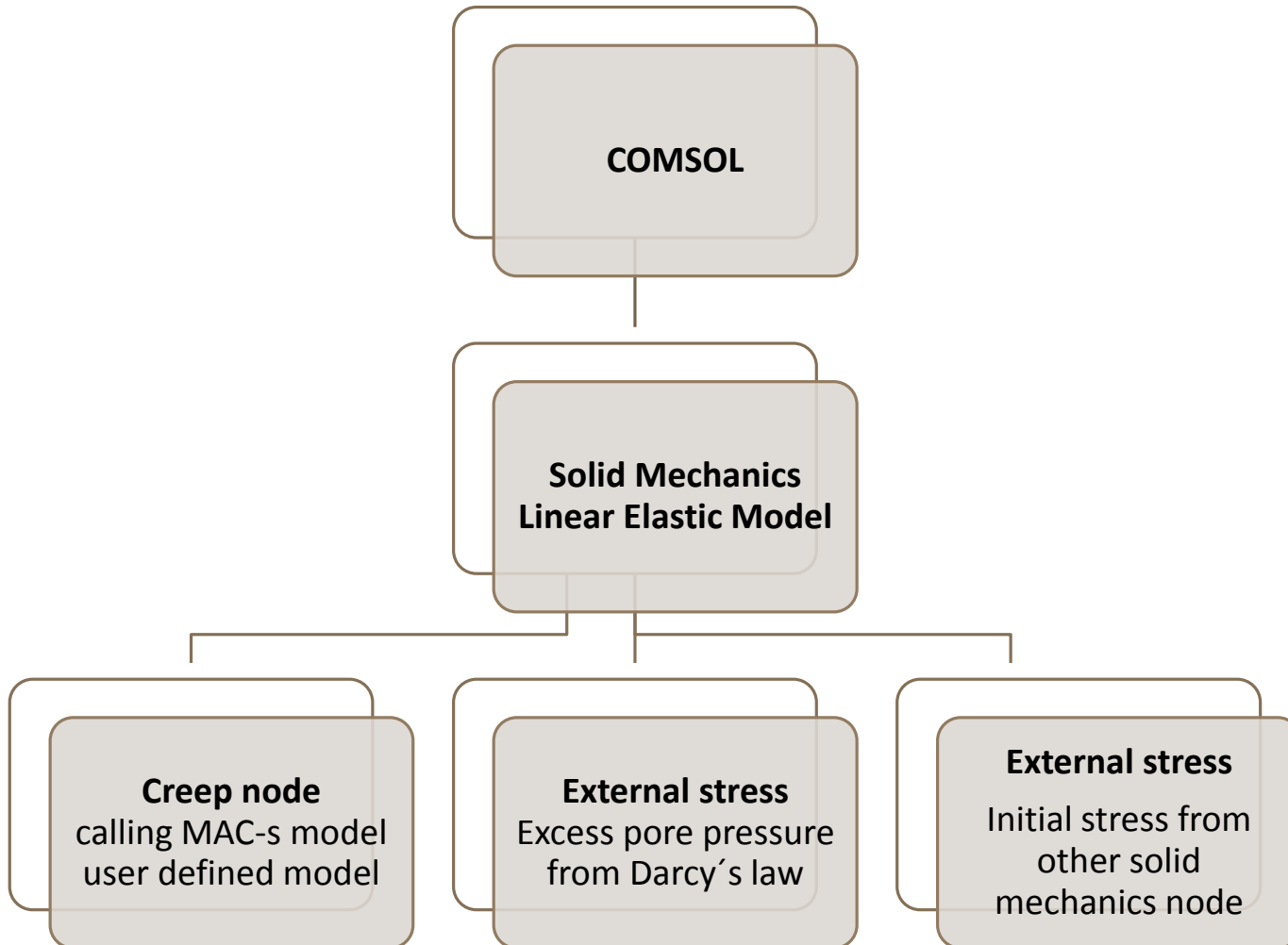
$$d\mathbf{a}_d = \left(\omega_v \left[\frac{3\boldsymbol{\eta}}{4} - \mathbf{a}_d \right] \cdot \langle d\varepsilon_v^c \rangle + \omega_d^* \left[\frac{\boldsymbol{\eta}}{3} - \mathbf{a}_d \right] \cdot d\varepsilon_d^c \right)$$

Change in size

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

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

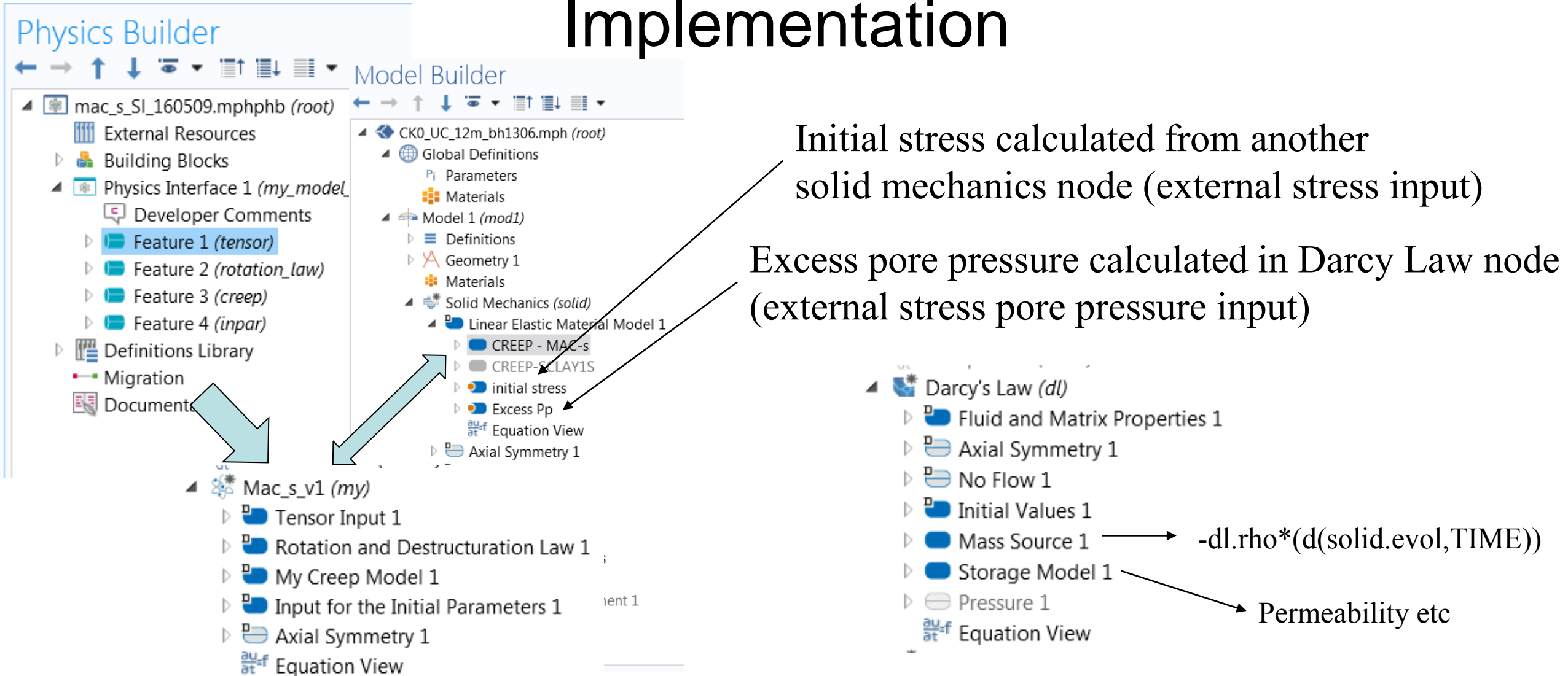
Implementation



Why?

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

Implementation



Implementation

The screenshot displays the COMSOL Multiphysics interface for implementing a creep model. The left pane shows the model tree with 'Solid Mechanics (solid)' and 'Linear Elastic Material Model 1' circled in red. The middle pane shows the 'Creep' settings with 'Creep Data' circled in red. The right pane shows the 'Equation View' with a table for the stress tensor and a table for the strain tensor.

Model Tree (Left Pane):

- CK0_UC_12m_bh1306.mph (root)
 - Global Definitions
 - Parameters
 - Materials
 - Model 1 (mod1)
 - Definitions
 - Geometry 1
 - Materials
 - Solid Mechanics (solid)
 - Linear Elastic Material Model 1
 - CREEP - MAC-s
 - CREEP - SCLAY15
 - initial stress
 - Excess Pp
 - Equation View
 - Axial Symmetry 1
 - Free 1
 - Initial Values 1
 - Fixed Constraint 1
 - Roller 1
 - Horizontal start stress
 - vertical start stress
 - Prescribed Displacement 1
 - Prescribed Velocity 1
 - Weak Contribution 7

Creep Settings (Middle Pane):

- Domain Selection: All domains
- Active: ON
- Material model: Potential
- Rate multiplication: η my.rate_m | 1/s
- Creep potential: Q_{cr} my.sclay1 | N/m²

Equation View (Right Pane):

Mac_s_v1 (my)

- Tensor Input 1
- Rotation and Destructuration Law 1
- My Creep Model 1
- Input for the Initial Parameters 1
- Axial Symmetry 1
- Equation View

Stress tensor:

solid.SI11	solid.SI12	solid.SI13	N/m ²
solid.SI12	solid.SI22	solid.SI23	
solid.SI13	solid.SI23	solid.SI33	

Symmetric

Strain tensor:

solid.ec11	0	solid.ec13	1
0	solid.ec22	0	
solid.ec13	0	solid.ec33	

Symmetric

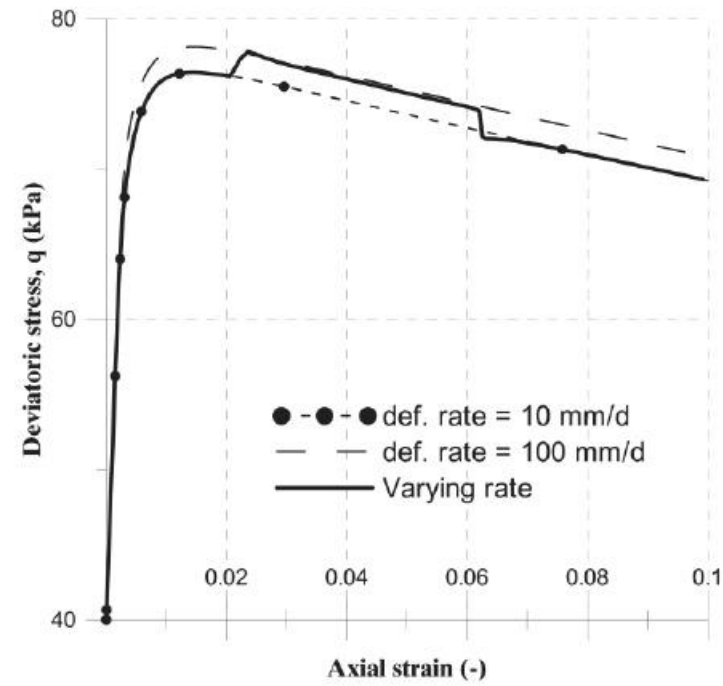
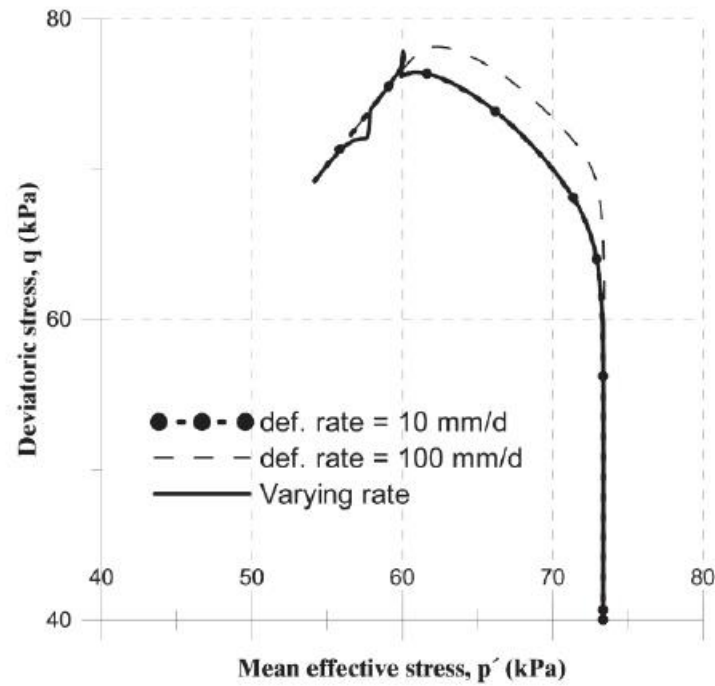
Implementation

The screenshot displays the COMSOL Multiphysics Model Builder interface. The left-hand tree view shows the model structure, with 'Solid Mechanics (solid)' and 'Linear Elastic Material Model 1' highlighted in red. Under 'Linear Elastic Material Model 1', the 'CREEP - MAC-s' component is also highlighted in red. The central 'Physics Builder Manager' shows the 'Creep' settings for 'Mac_s_v1 (my)'. The 'Creep Data' section is expanded, showing 'Material model: Potential', 'Rate multiplication: η my.rate_m', and 'Creep potential: Q_{cr} my.sclay1', all of which are circled in red. The right-hand panel shows the 'My Creep Model' settings, including 'Modified Swelling index: κ^* 0.015', 'Modified Compression index (intrinsic): λ^* 0.097', and 'Reference time (day): τ 1[d]'. A red arrow points from the 'My Creep Model' section to the 'Creep Data' section in the central panel.



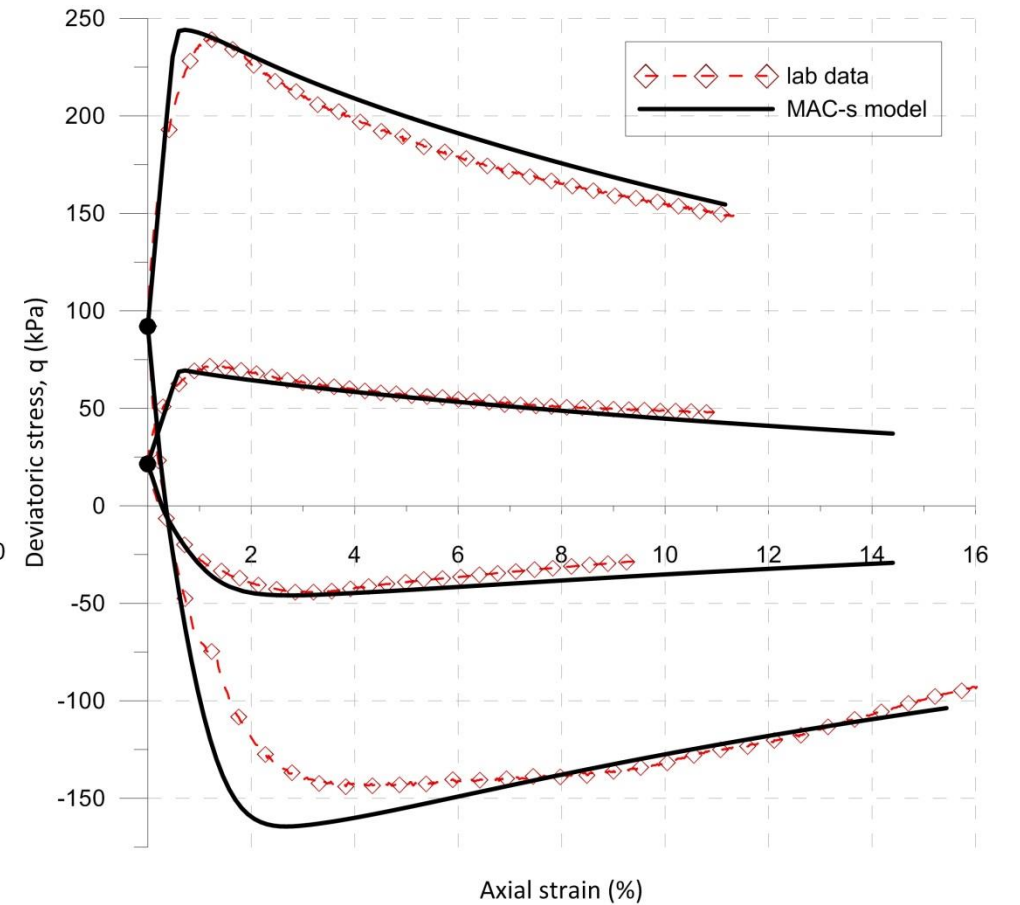
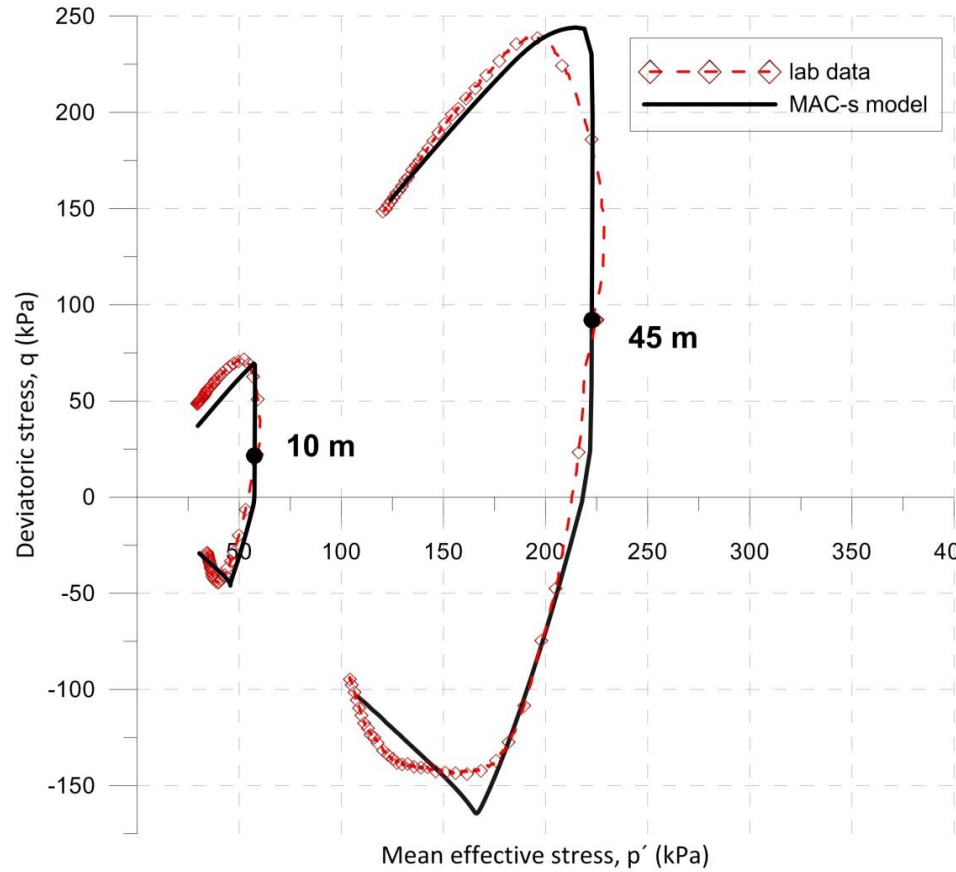
Simulations

Undrained triaxial test - compression

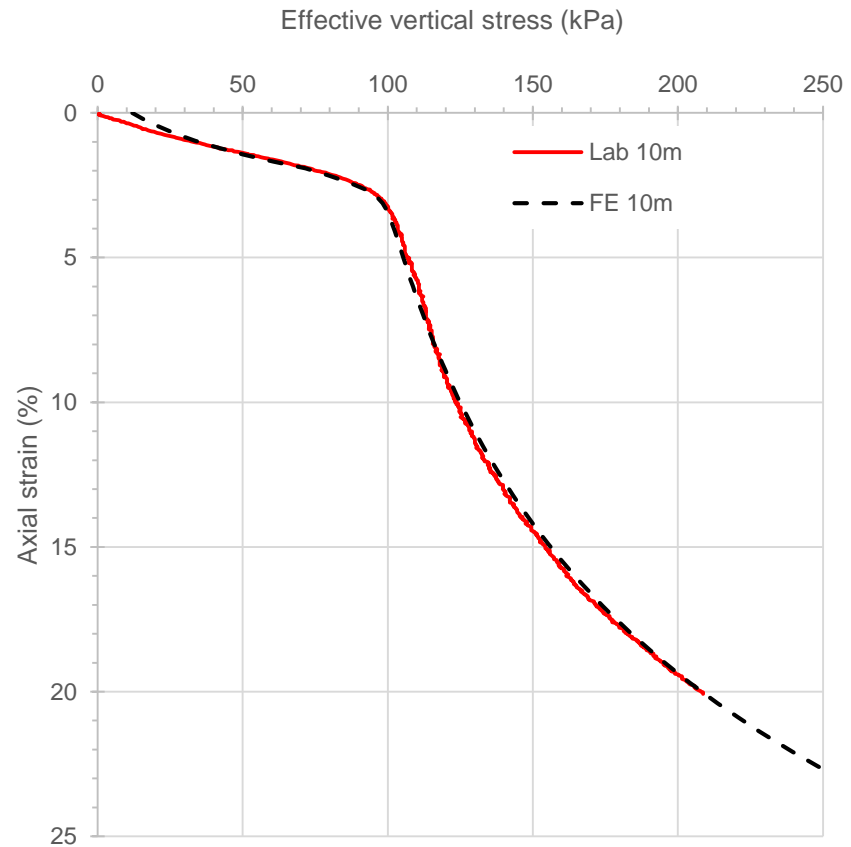
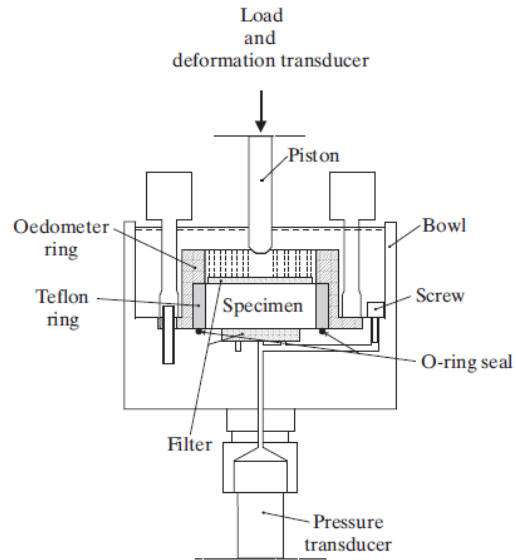




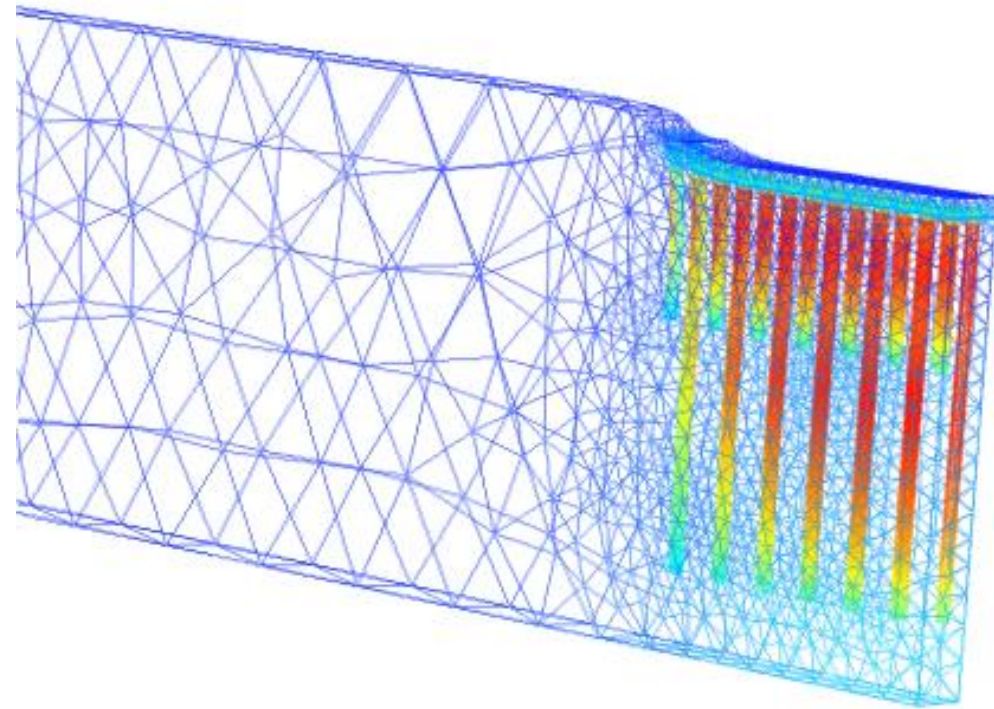
Simulations – triaxial tests



Simulations – Oedometer test



Real case – Road embankment Lime-Cement Column reinforcement



**Thank you
for
your attention**