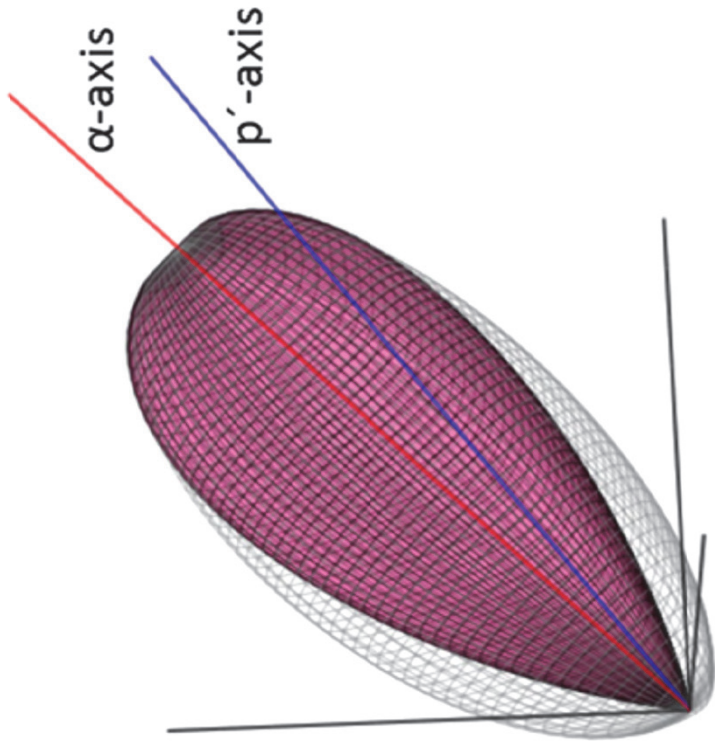
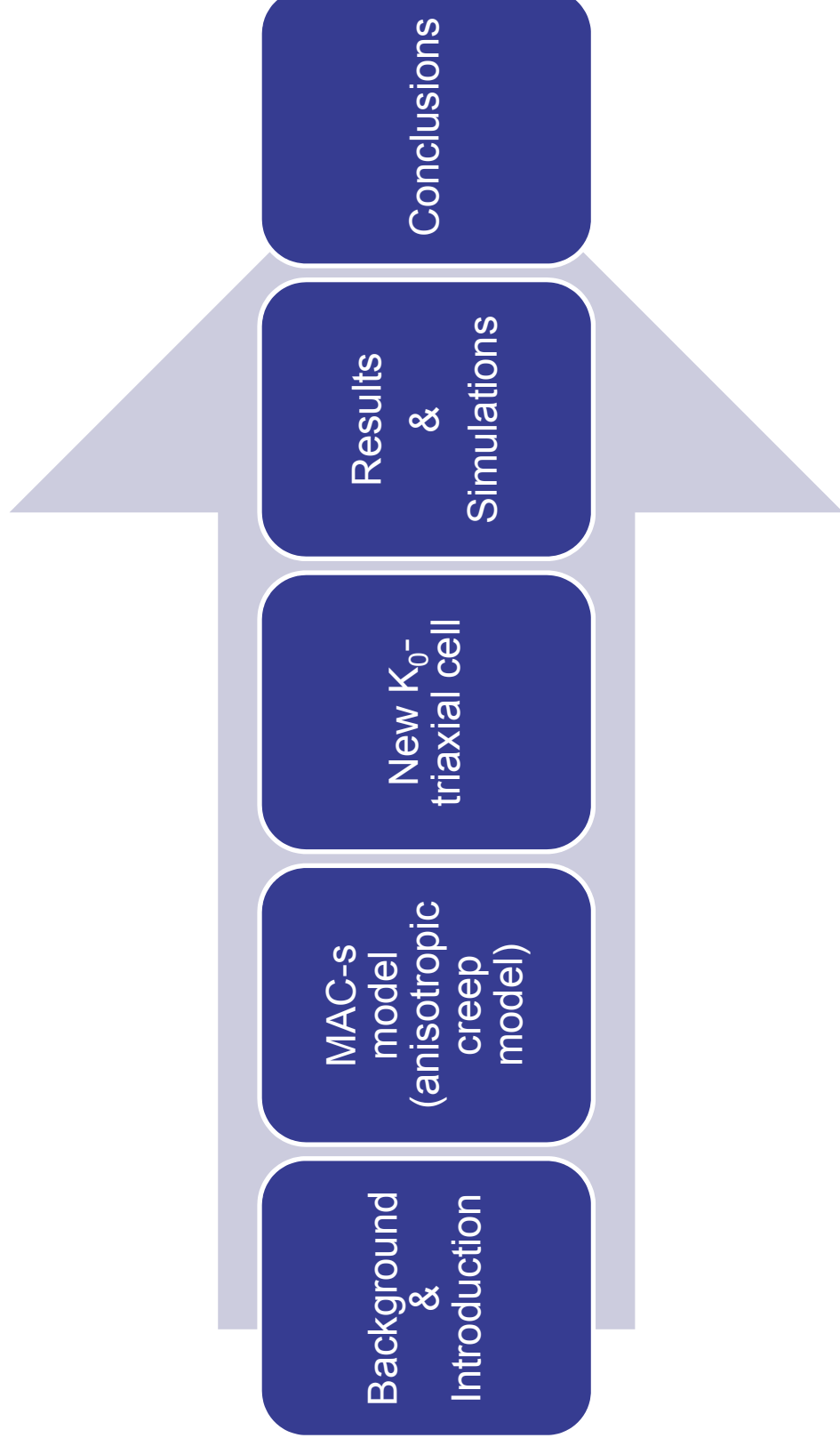


On Rate-Dependency of Gothenburg Clay

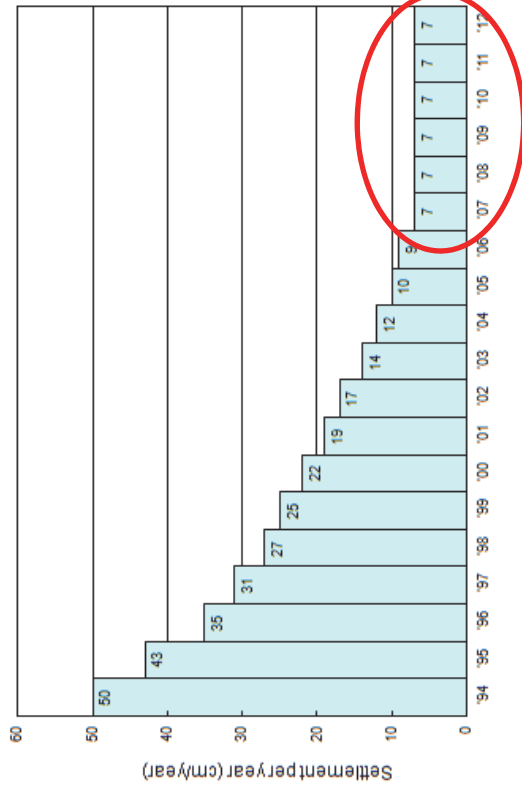
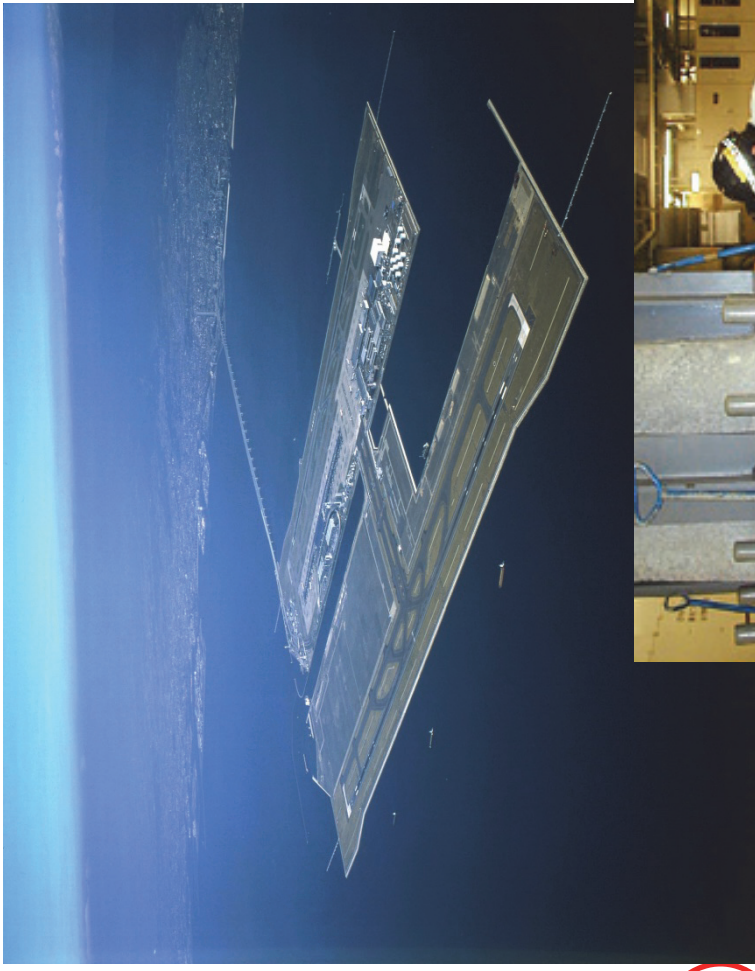


Mats Olsson
Chalmers/NCC Teknik

Outline



Background



On-going settlement 7 cm/yr

<http://www.nkiac.co.jp/en/tech/sink/index.html>



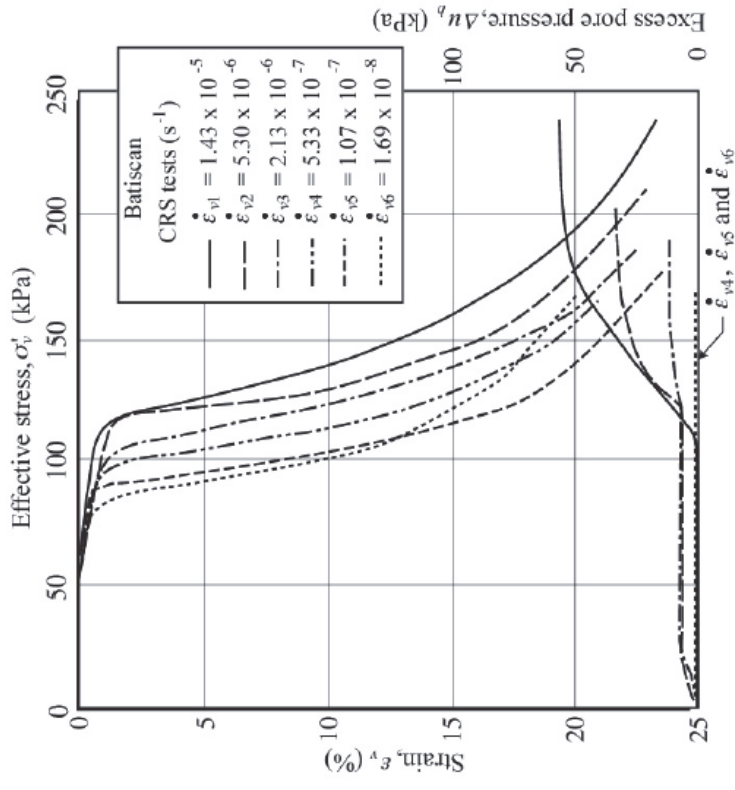
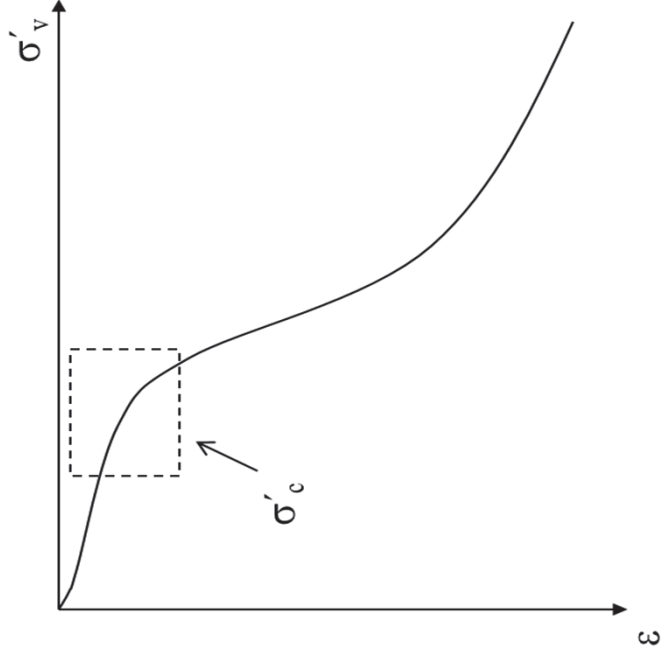
Introduction

This
research
has the
following:

- **Aims**
 - Extend the understanding of Rate-Dependency of soft soils
 - Reduce uncertainties in predicting long-term settlements
- **Objectives**
 - To develop and test a new constitutive creep model and a new K_0 -triaxial cell
- **Limitations**
 - Model formulation restricted to monotonic loading conditions

Introduction Behaviour of soft soils

- Oedometer case



Leroueil et al. (2005)

Introduction

Evaluation of p_c from CRS test

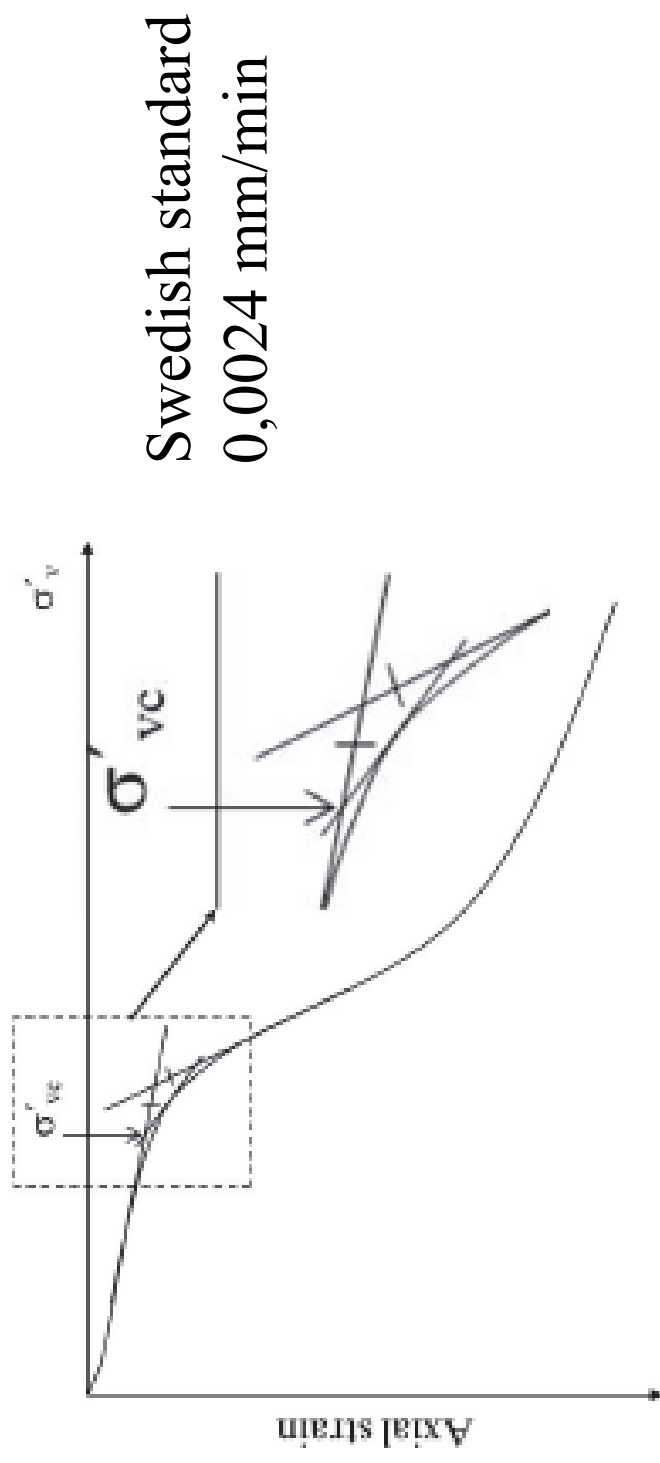
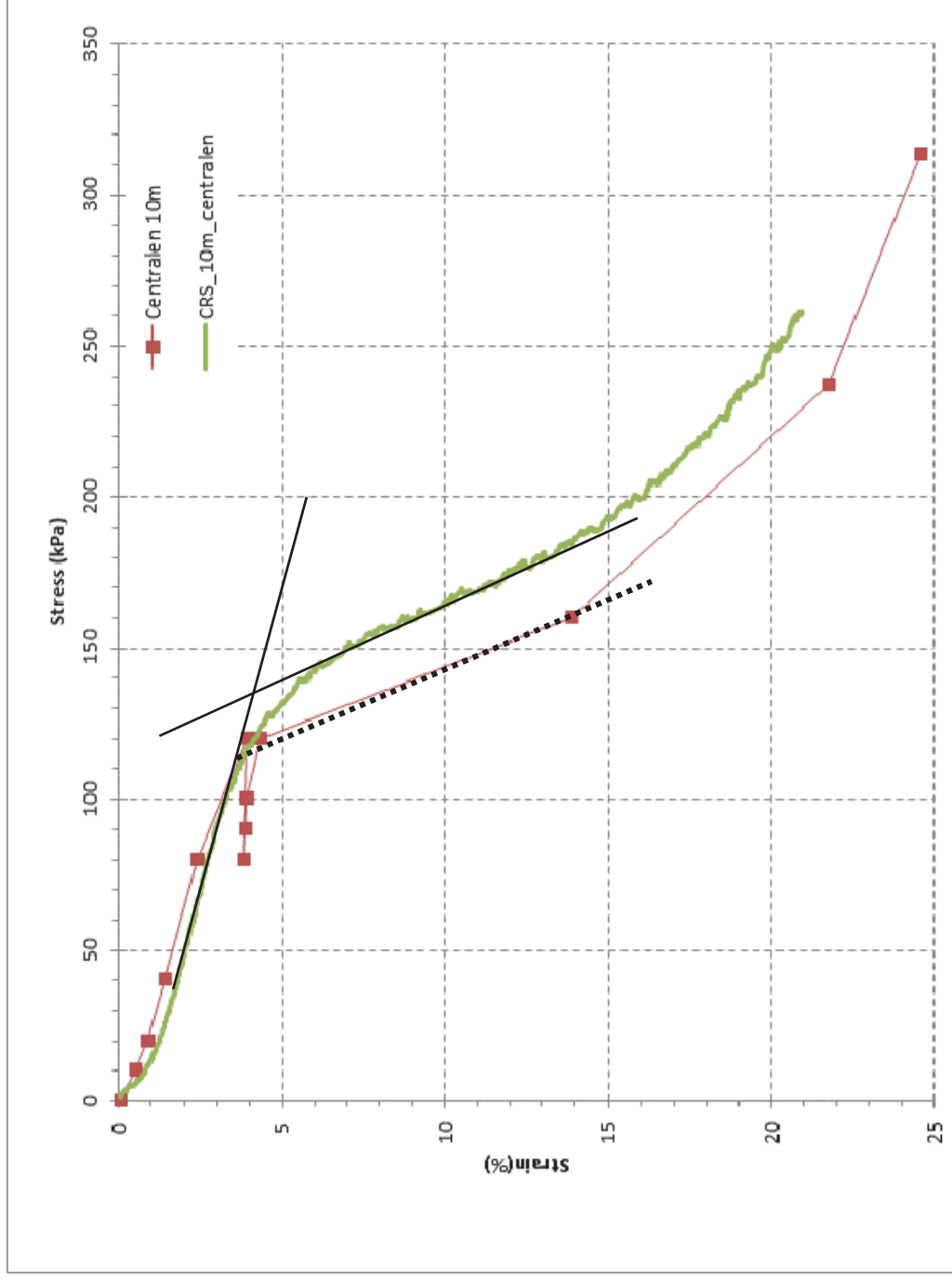


Figure 2.2. Evaluation of preconsolidation pressure from CRS oedometer test according to Salfors method, Olsson (2010).

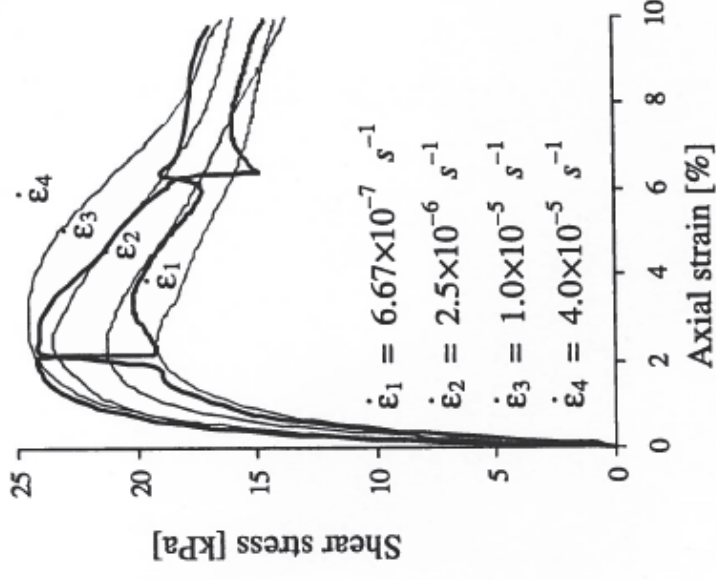
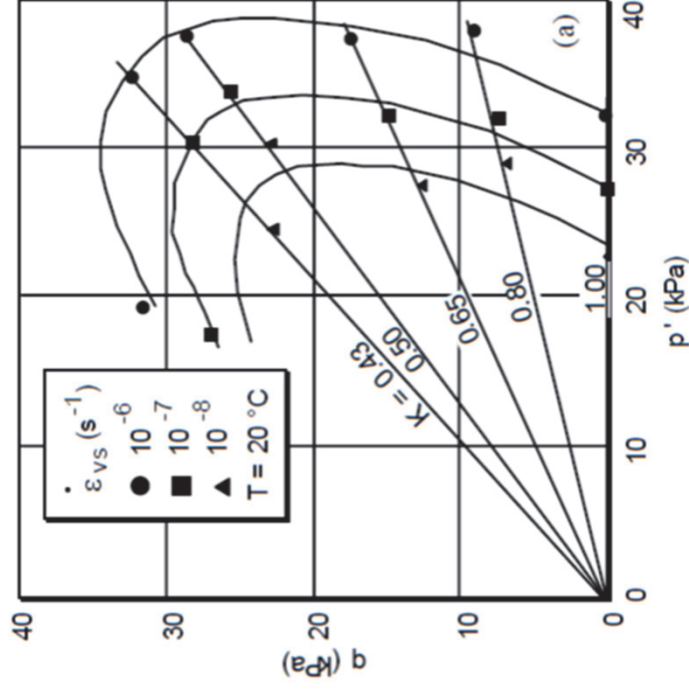
Introduction

Comparison - CRS and IL



Introduction Behaviour of soft soils

- Undrained triaxial tests



Leroueil et al. (2005)

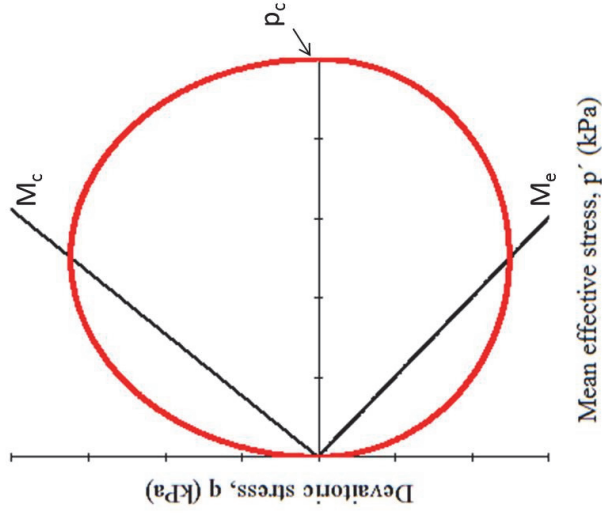
Lämsivaara (1999)

Introduction

Constitutive models

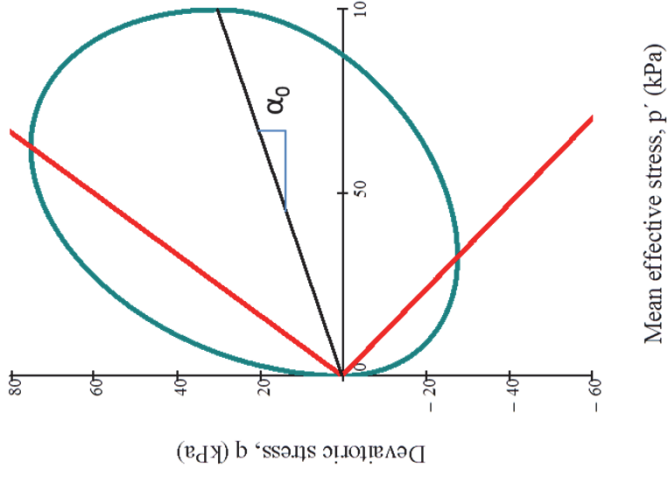
- Without creep effects
 - Modified Cam-Clay Model

(Roscoe & Burland, 1968)



S-CLAY1S

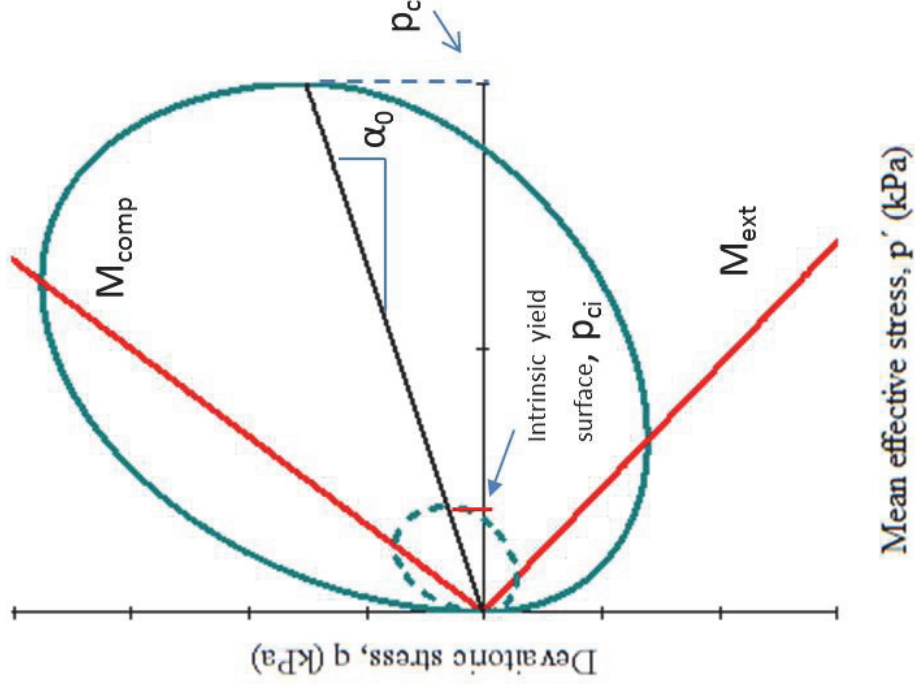
(Wheeler et al., 1999, Karstunen et al., 2005)



Introduction

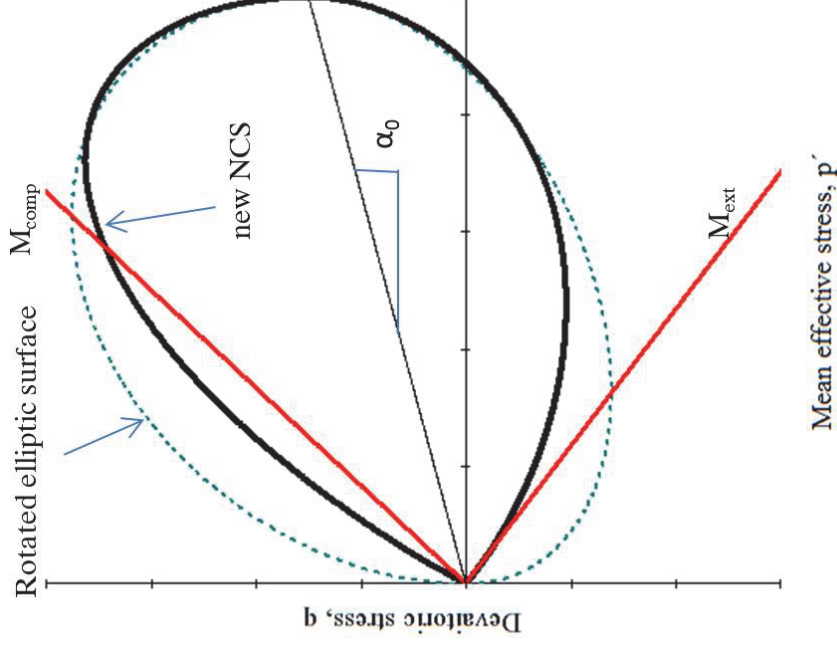
Constitutive models

- **With creep effects**
 - Isotropic Soft Soil Creep model
 - n-SAC model
 - CREEP-SCLAY1S

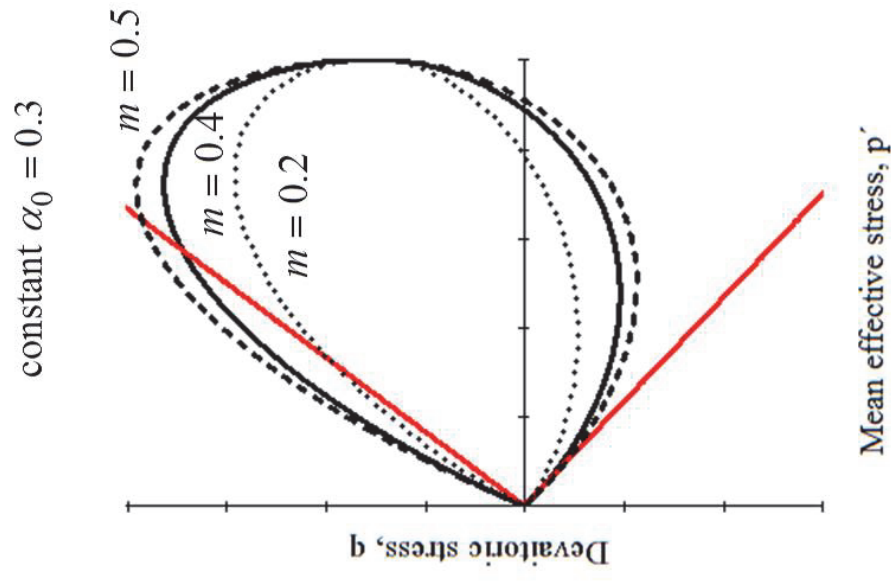


Modified Anisotropic Creep Model with structure (MAC-s model)

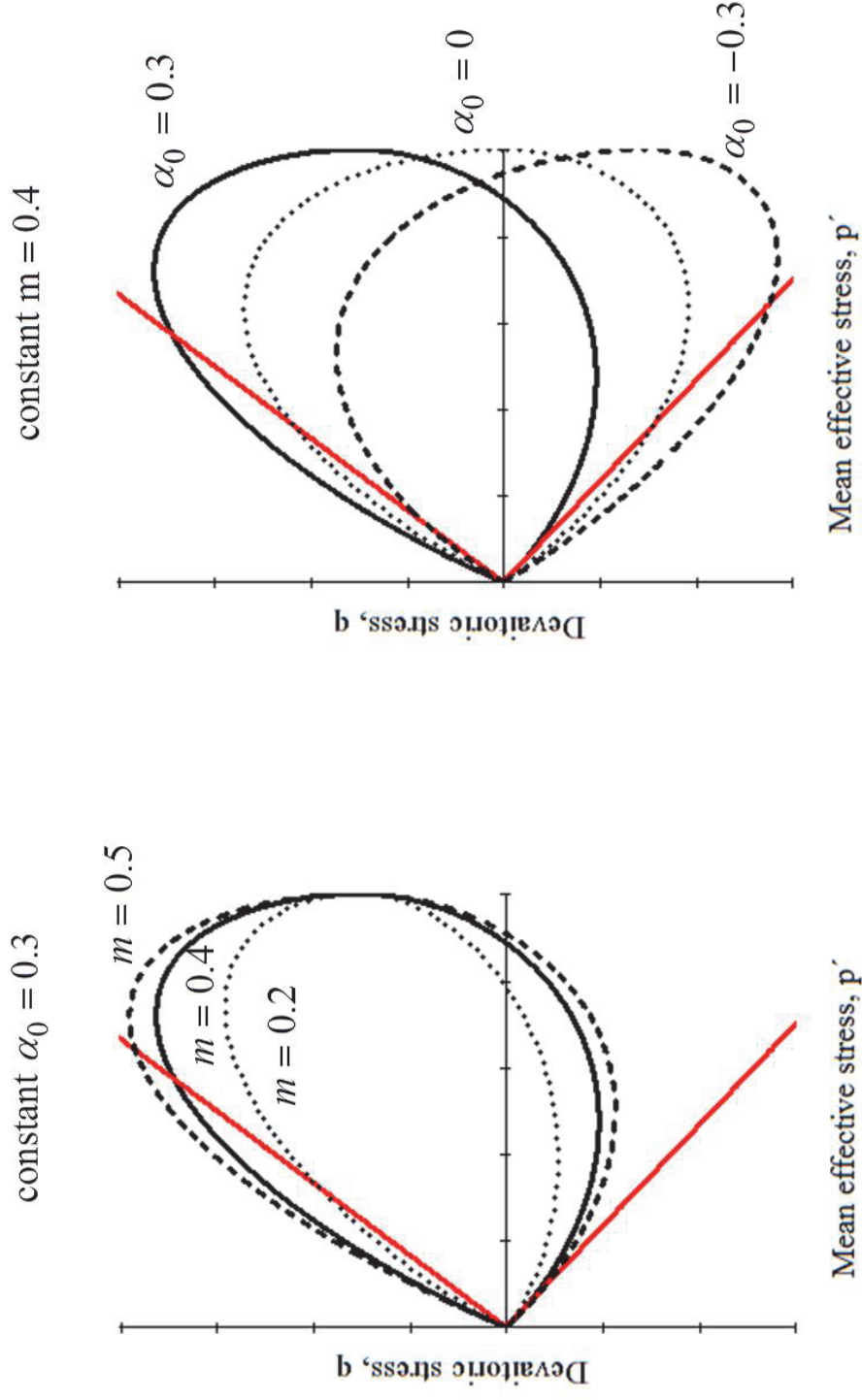
- MAC-s model aims to improve the prediction in OC state by formulating a new flexible normal compression surface (NCS)
- n-SAC => visco-plastic multiplier
- S-CLAY1S => hardening laws
- Implemented in FE code COMSOL Multiphysics (today also Plaxis)



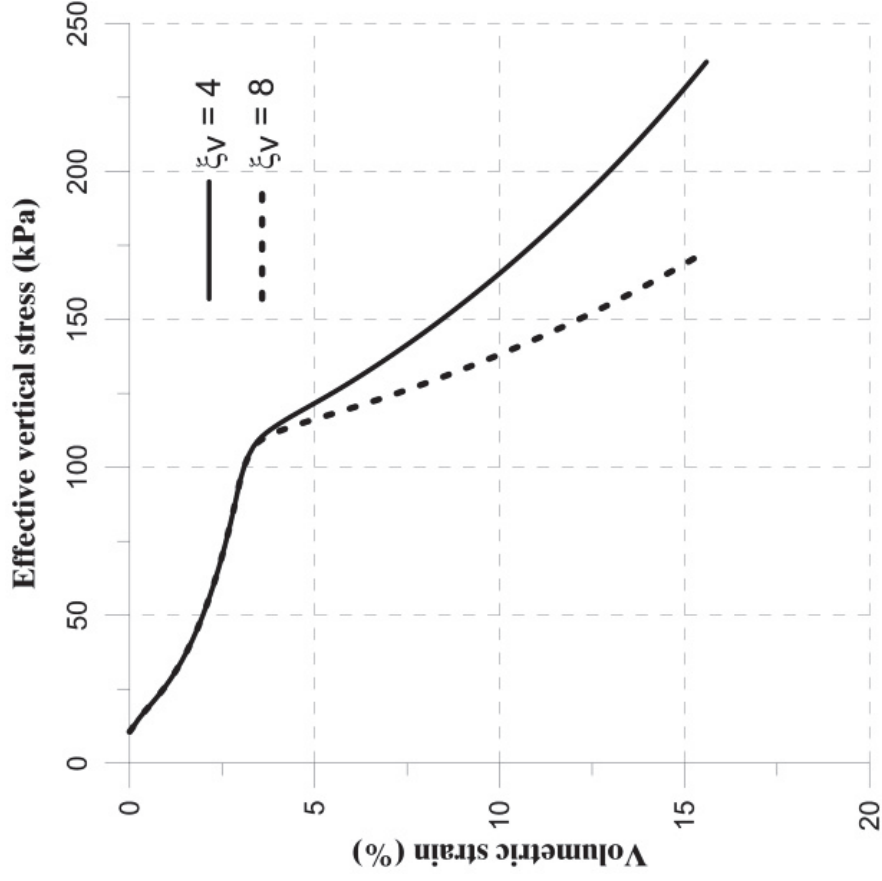
Influence of parameters



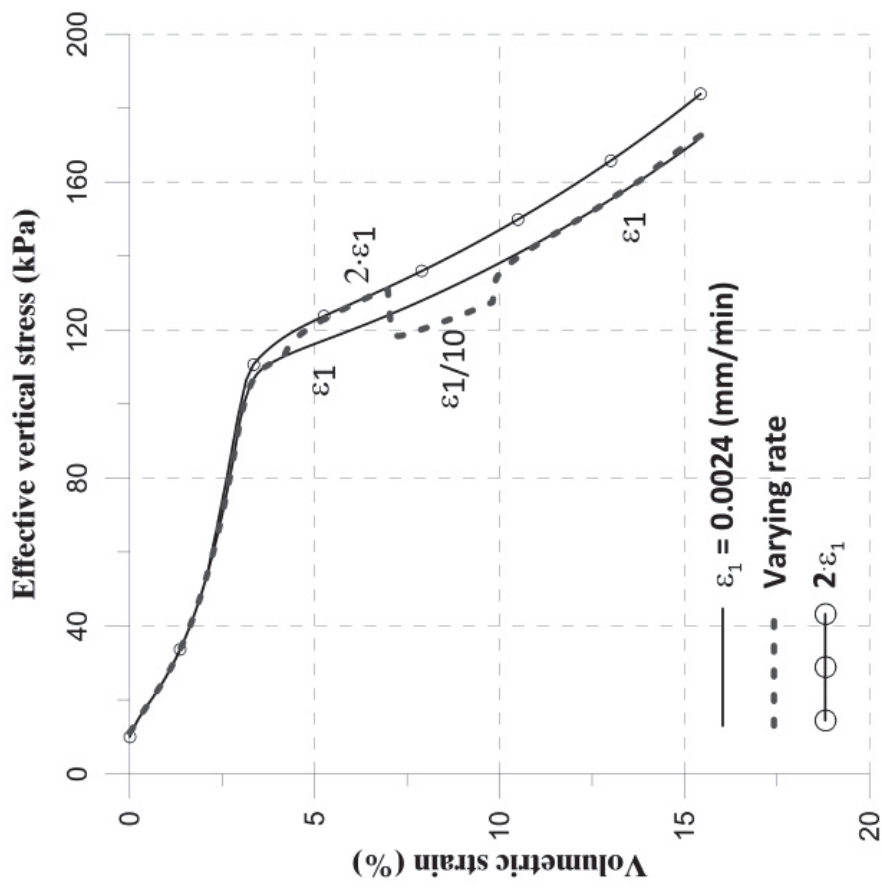
Influence of parameters



Model performance

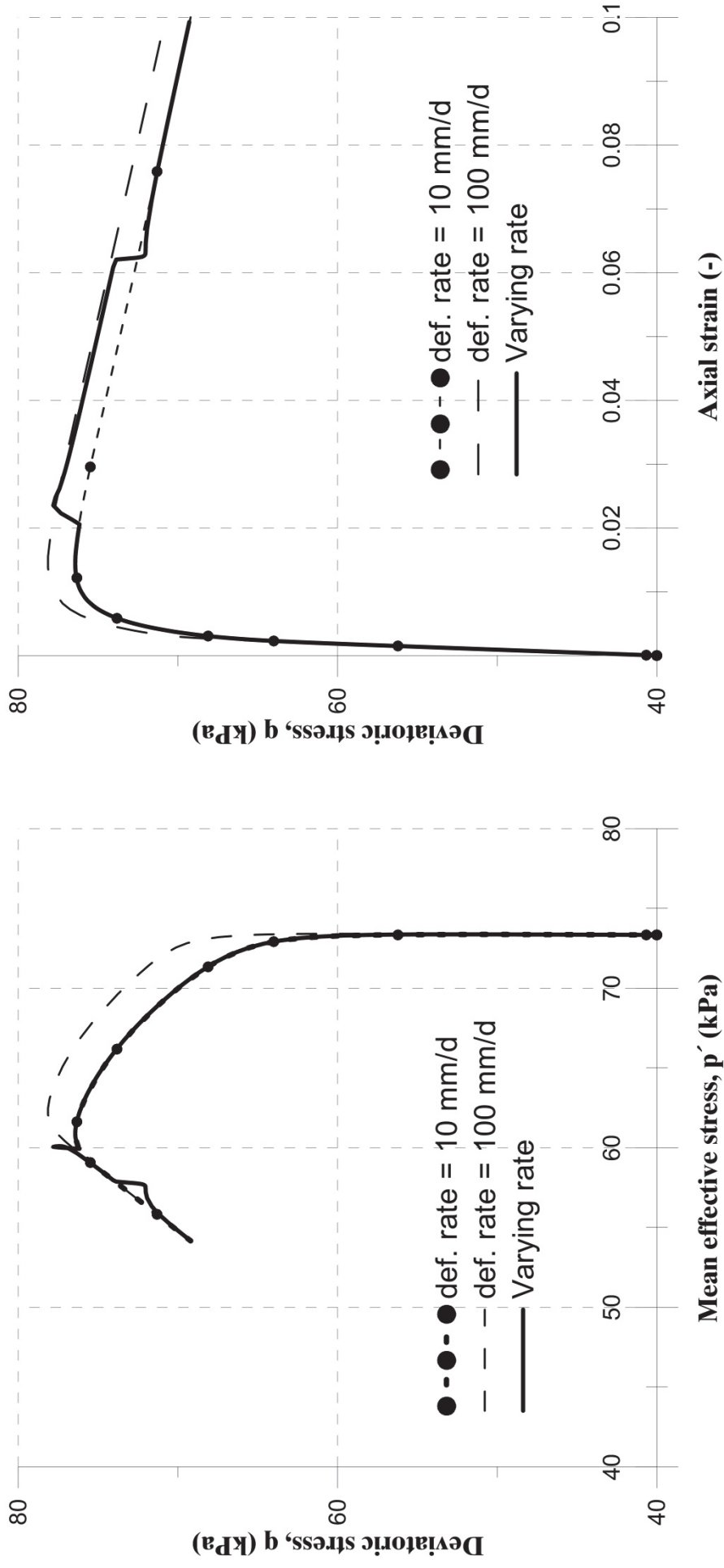


(a)

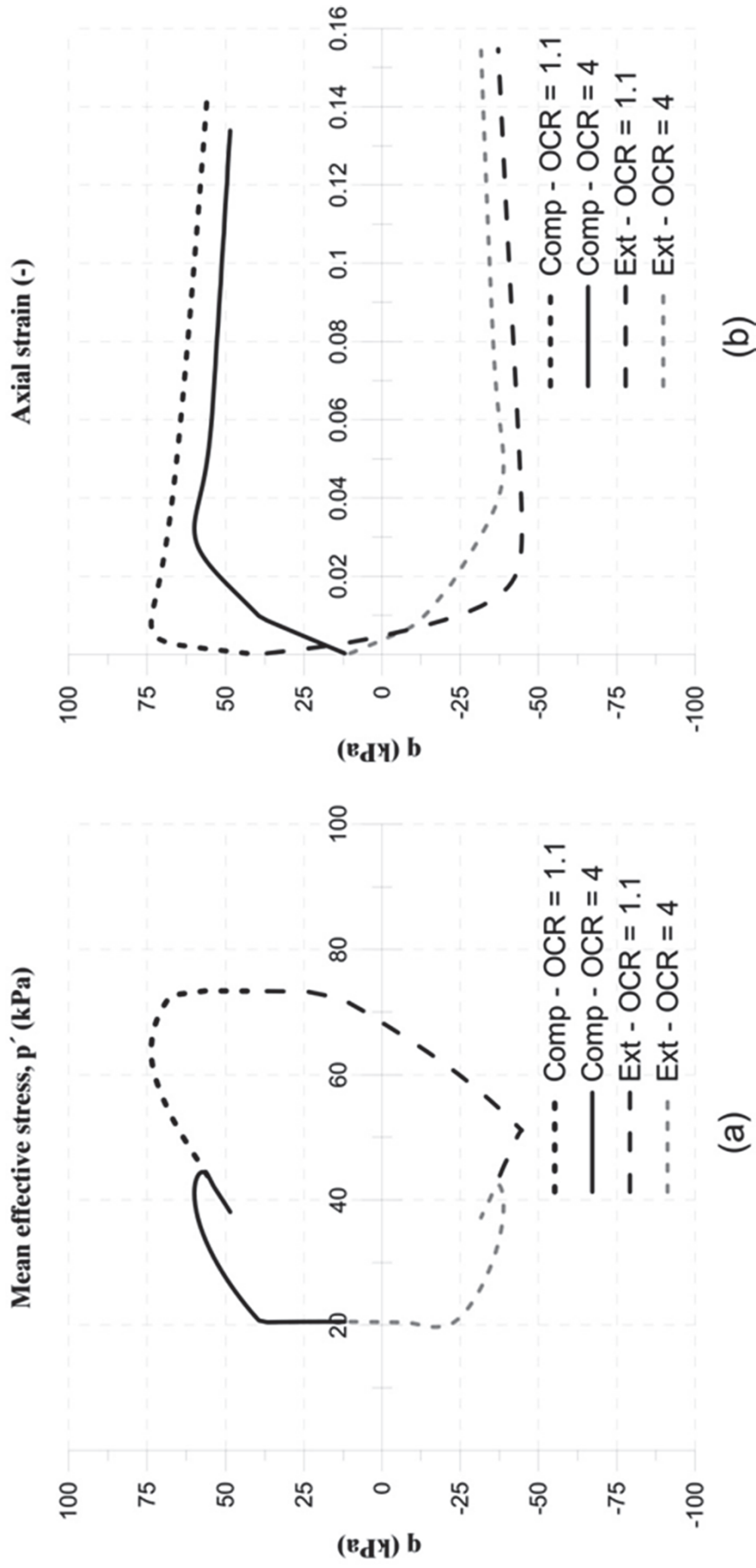


(b)

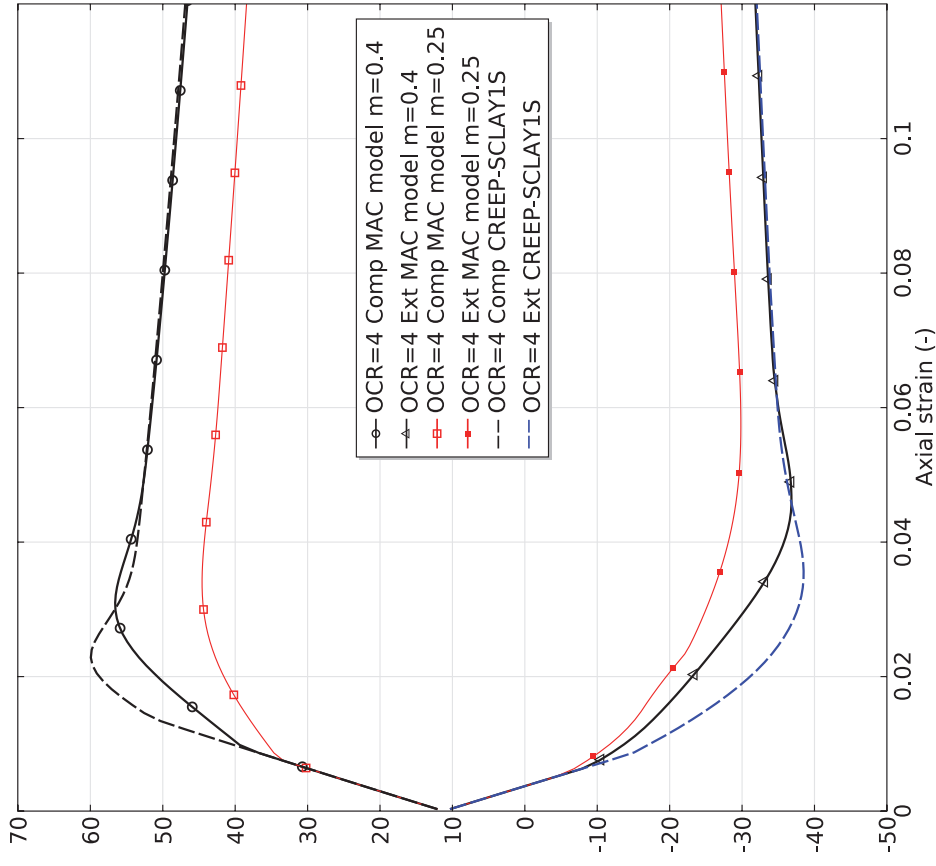
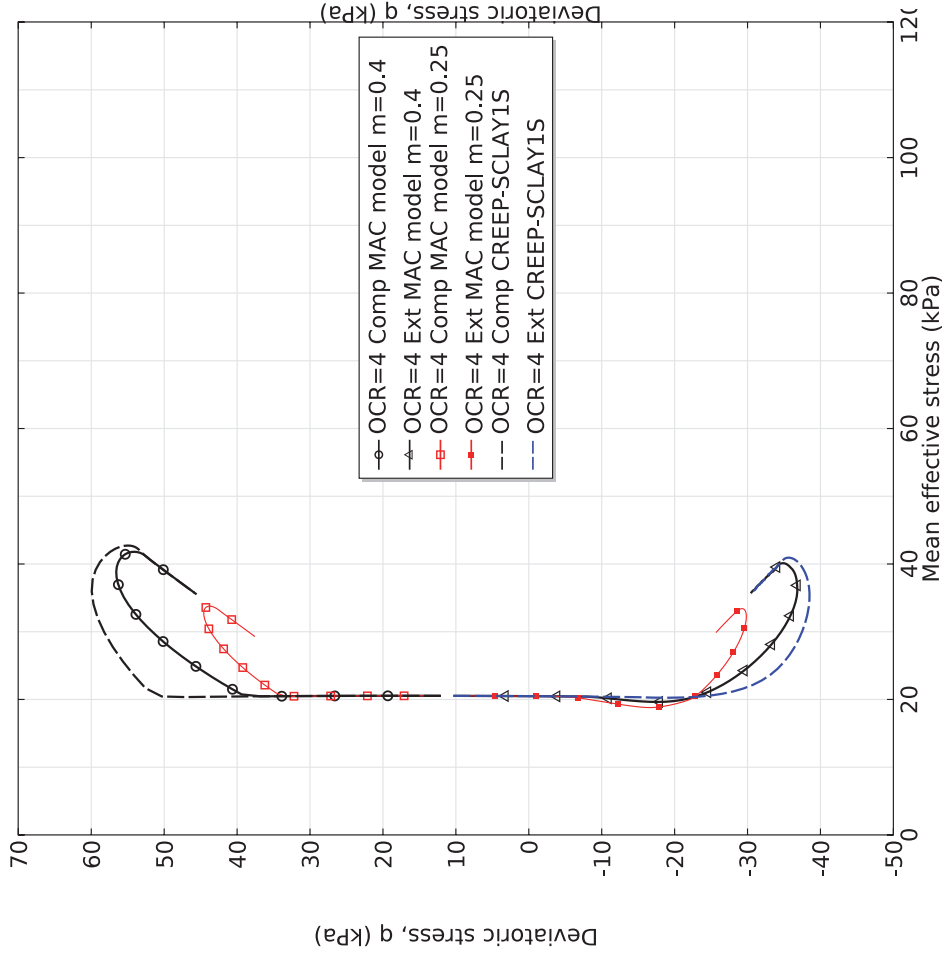
Model performance



Model performance



Model performance

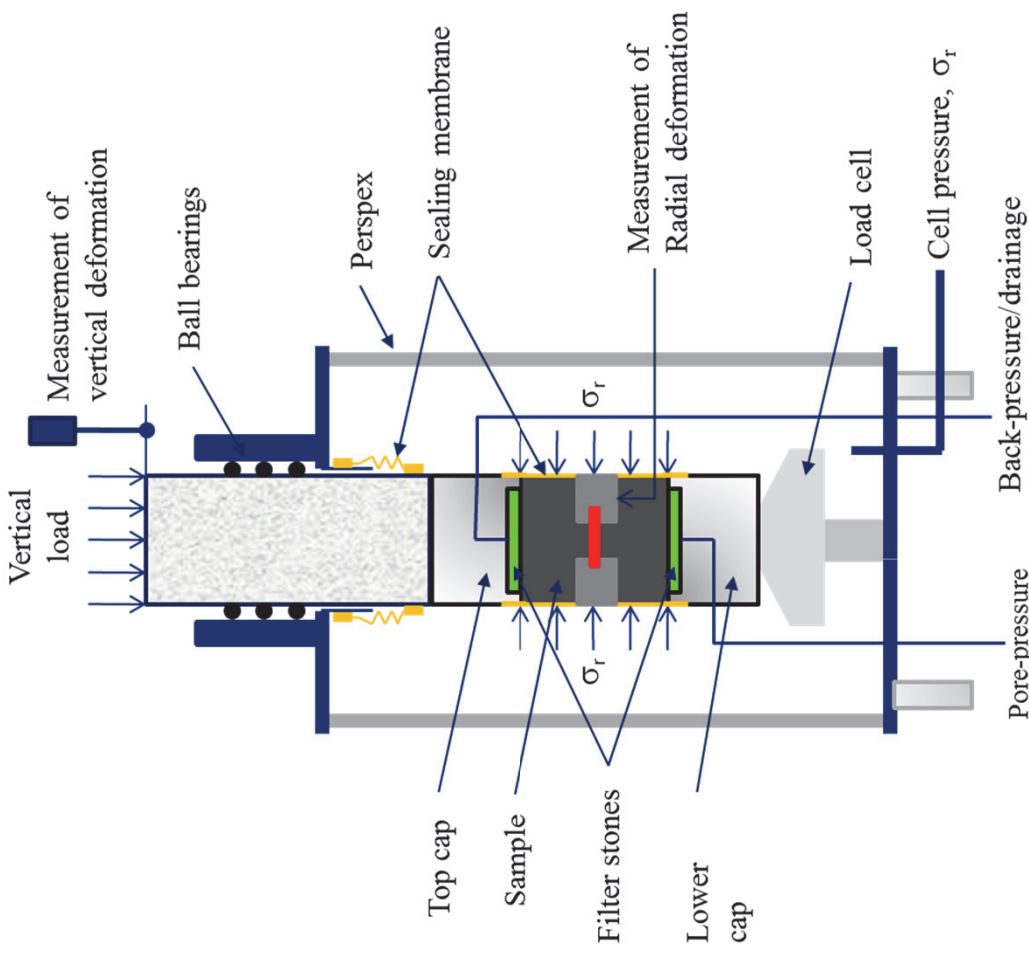


New K_0 -triaxial cell

- Input parameters for advanced constitutive models such as MAC-s
 - Strength parameters - Triaxial tests
 - Deformation parameters – Oedometer tests (IL/CRS)
 - Creep parameters – IL Oedometer
 - K_0^{nc} – new K_0 -triaxial cell

New K_0 -triaxial cell

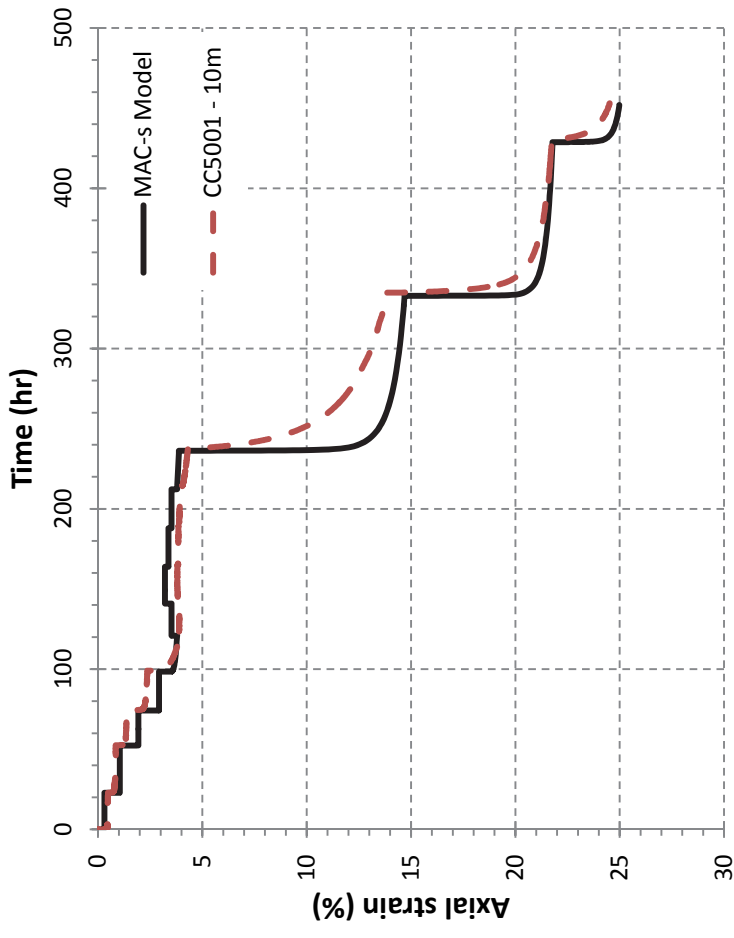
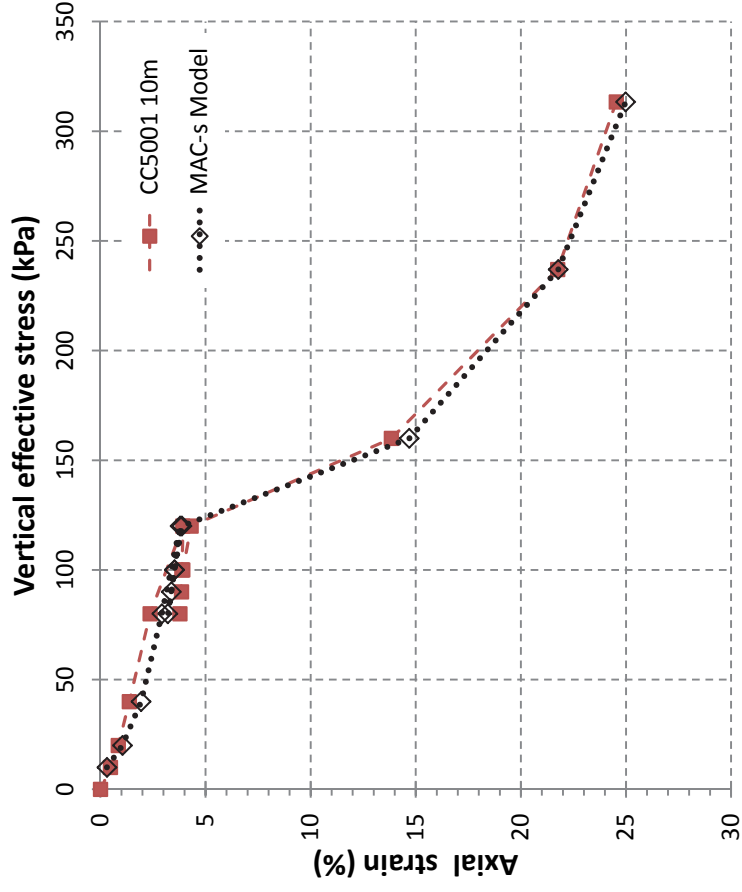
- Measure K_0 value as a function of stress and strain
- Incremental loading
- Deformation gauge control zero radial deformation



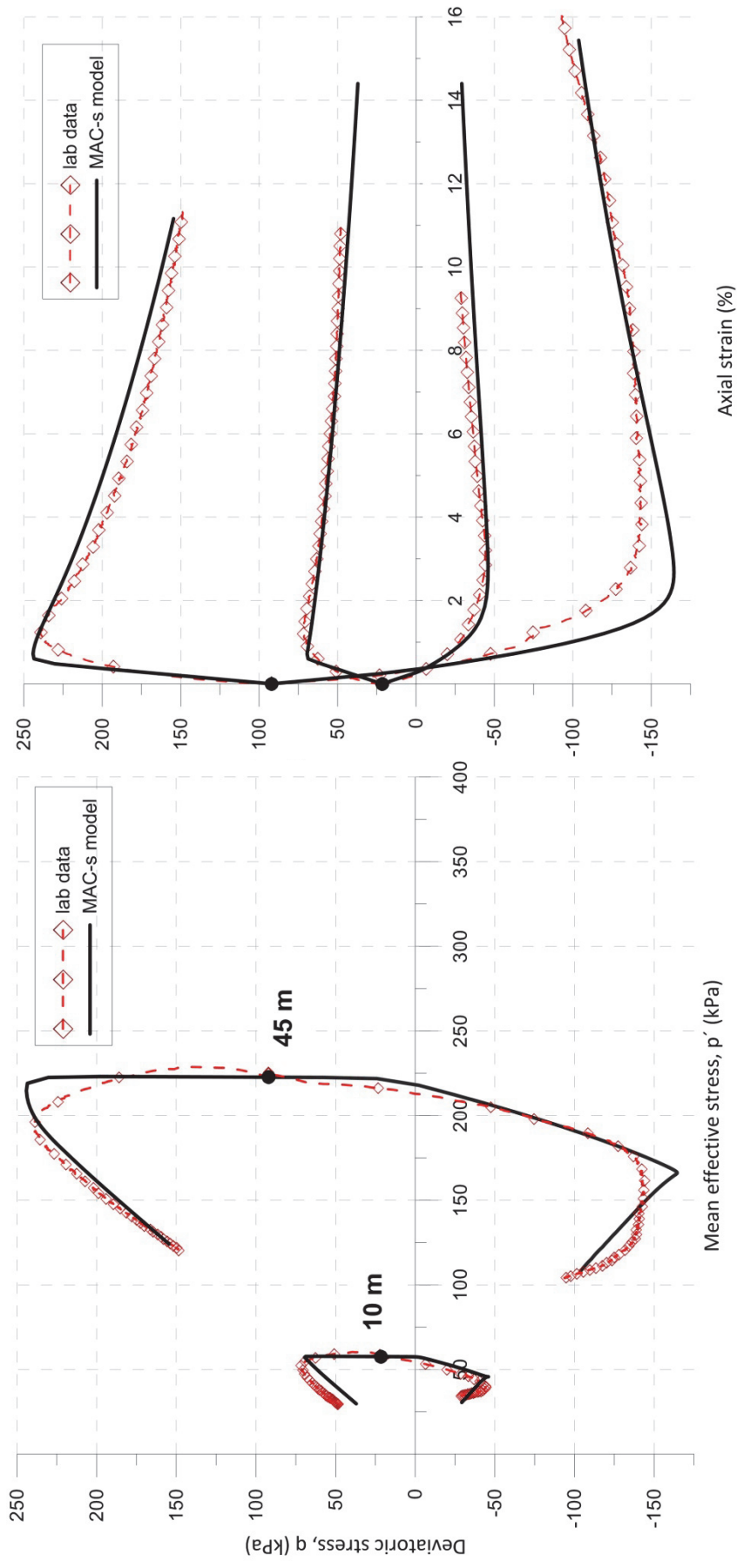
Results & Simulations

- Performance of the MAC-s model compared to experimental data
 - Stepwise IL oedometer
 - Undrained triaxial test
 - Undrained triaxial test OCR=4
 - Drained p' - q stress path tests
- Experimental results from K_0 -triaxial cell
 - Stress-strain
 - K_0 -time
 - p' - q stress path
 - K_0 -normalized stress

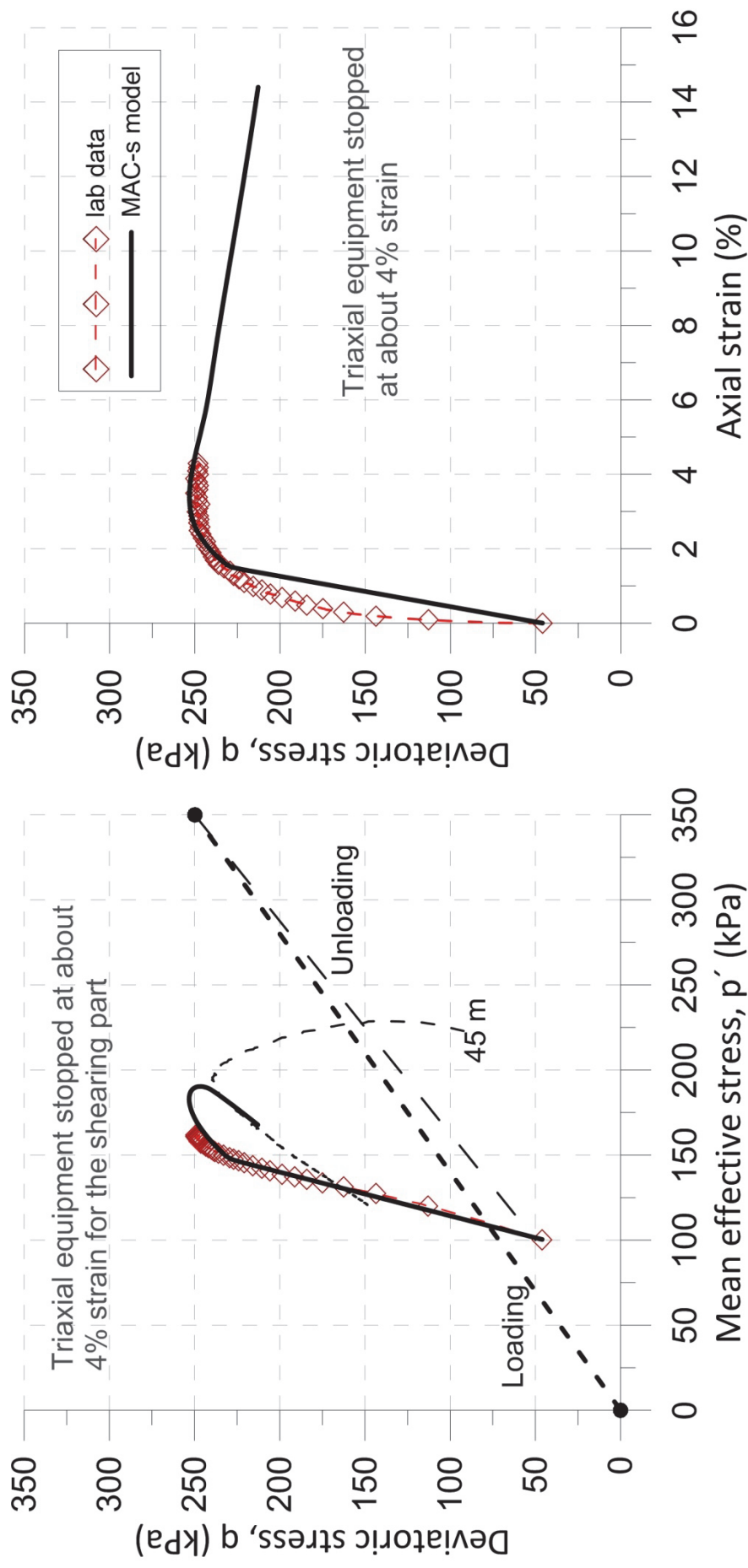
Results & simulations



Results & simulations

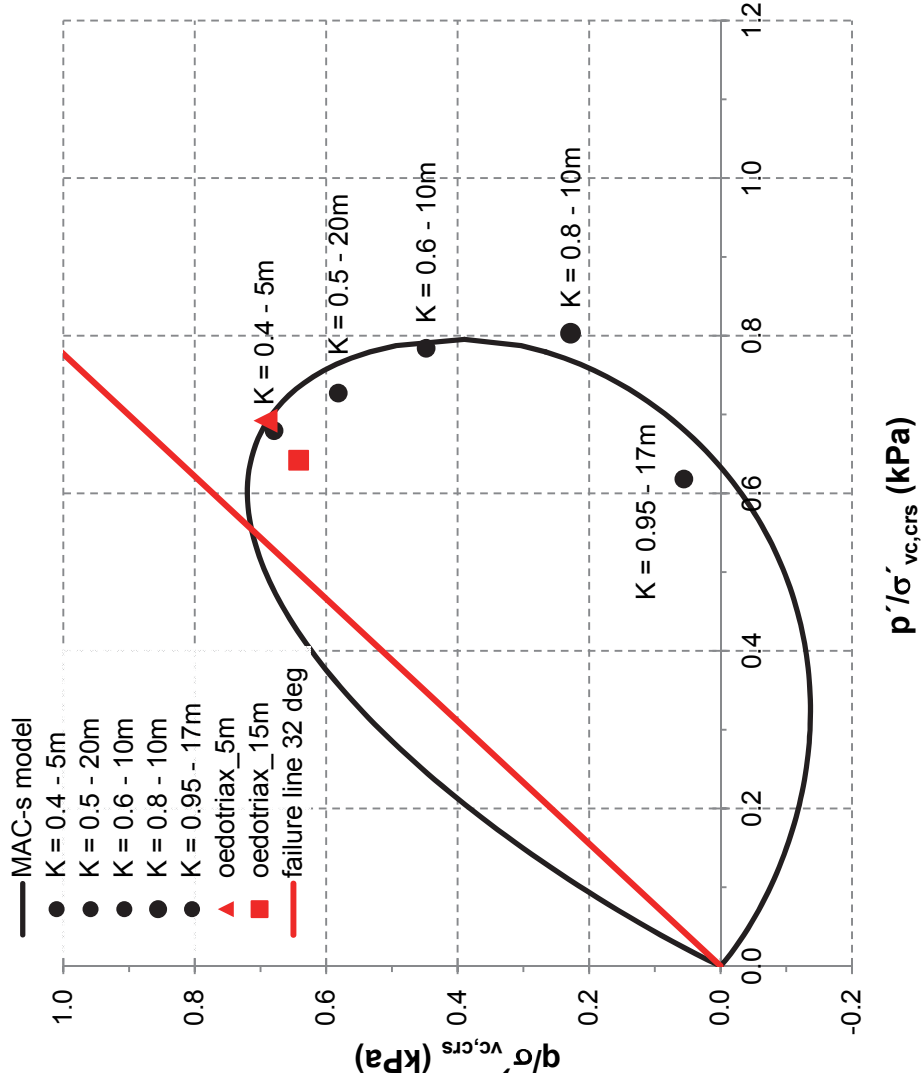


Results & simulations



Results

Drained p' - q stress path tests (constant K_0)

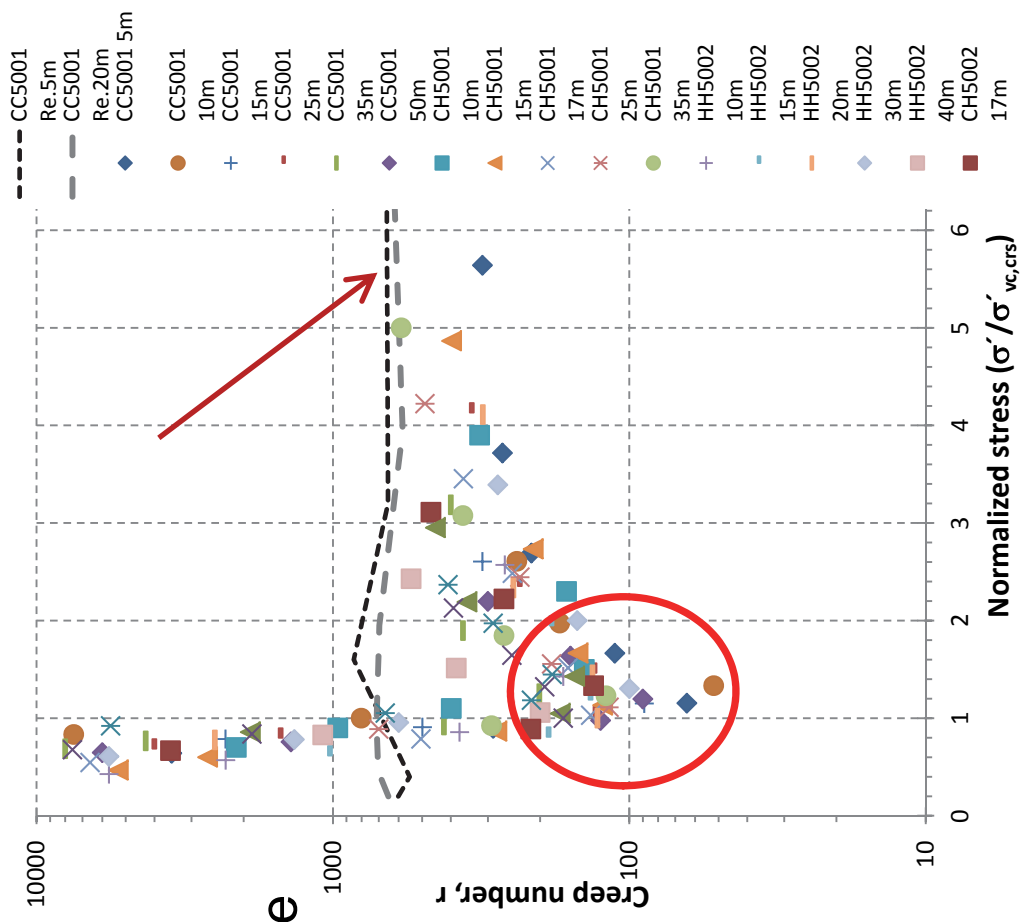


Results – K_0 triaxial cell

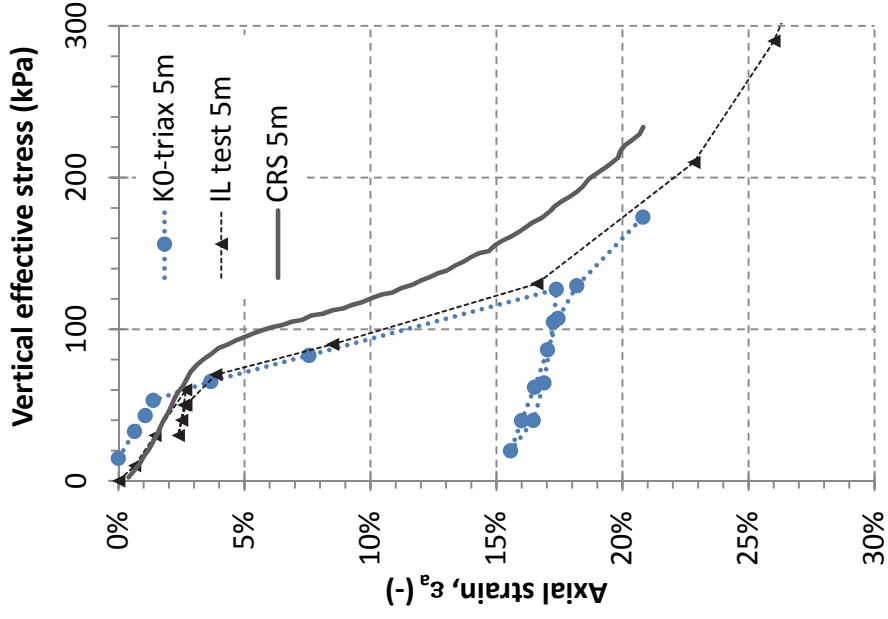
- 2 tests
- Depth 5 m and 15 m
- Conducted in room temperature

- Index properties

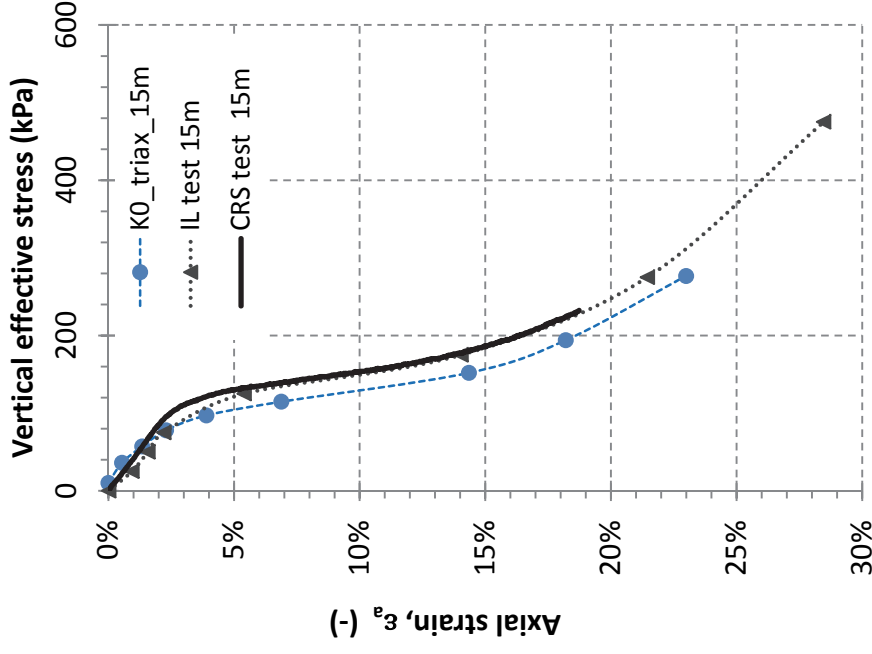
<i>depth : 5m</i>	<i>depth : 15m</i>
$\rho = 1.62 \text{ (t/m}^3\text{)}$	$\rho = 1.56 \text{ (t/m}^3\text{)}$
$w_N = 68\%$	$w_N = 78\%$
$w_L = 67\%$	$w_L = 70\%$



Results – K_0 triaxial cell

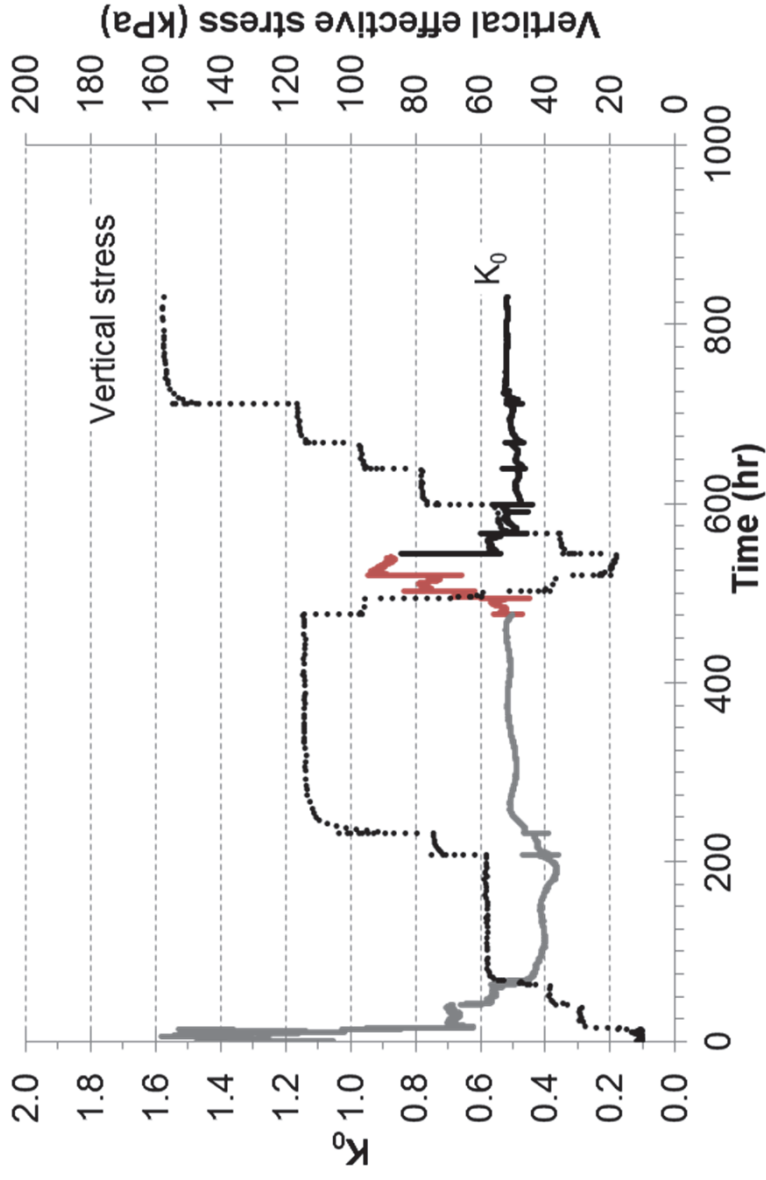


Depth: 5 m

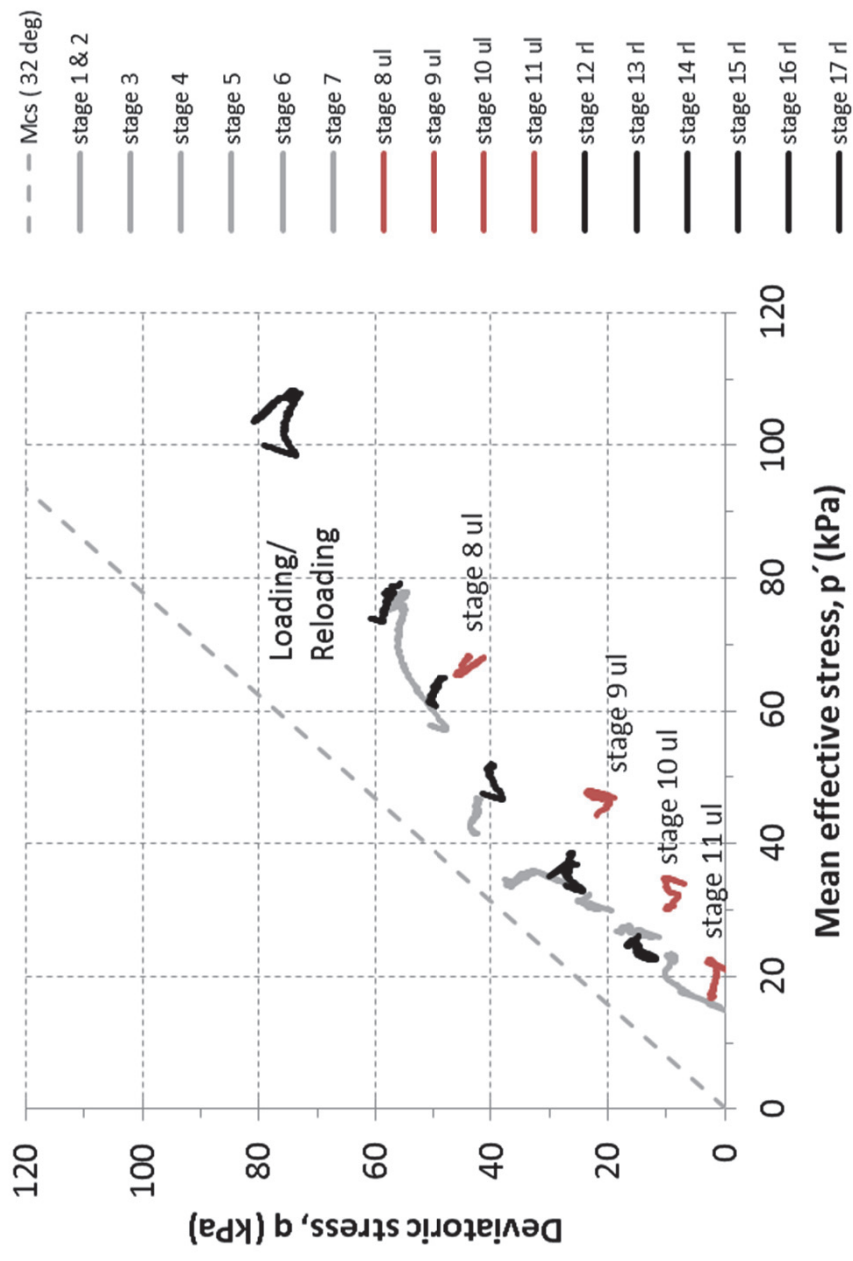


Depth: 15 m

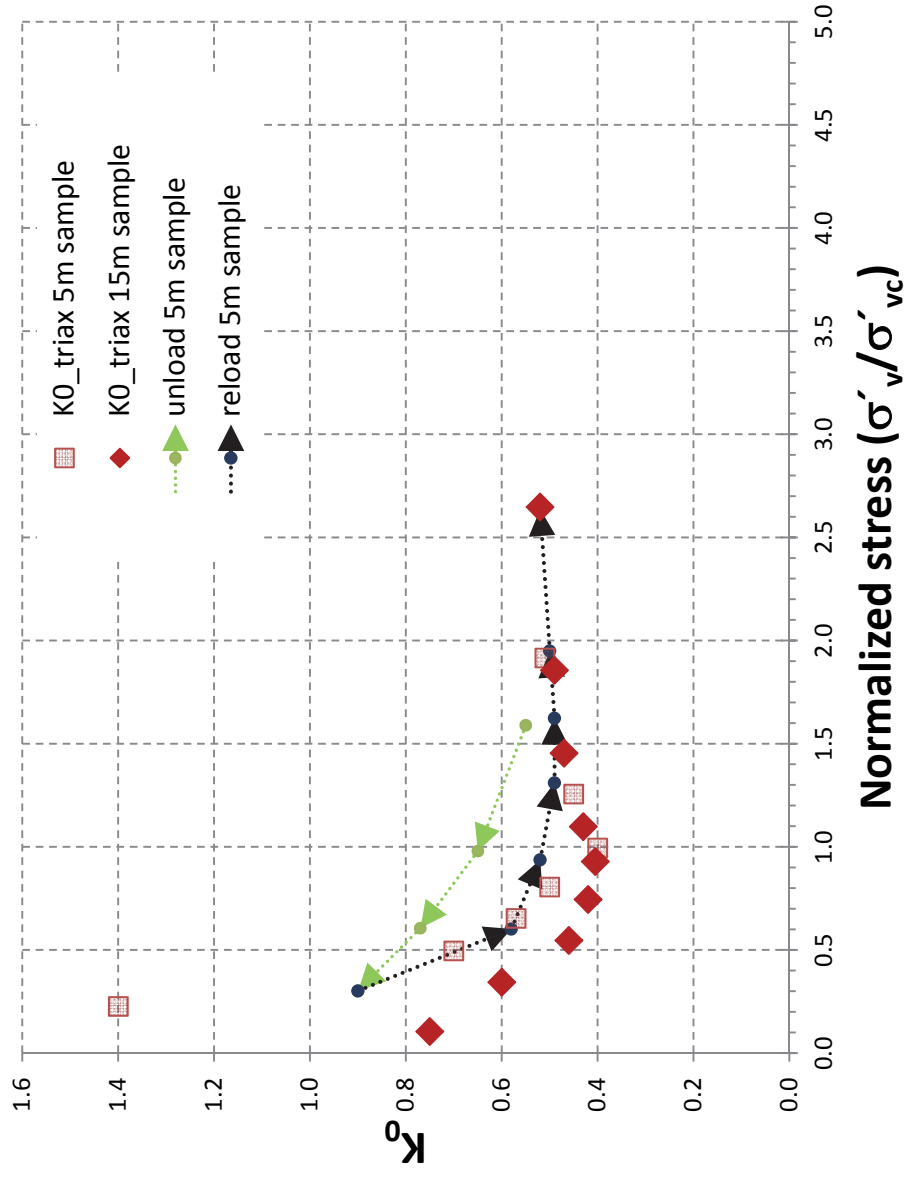
Results - K_0 triaxial cell



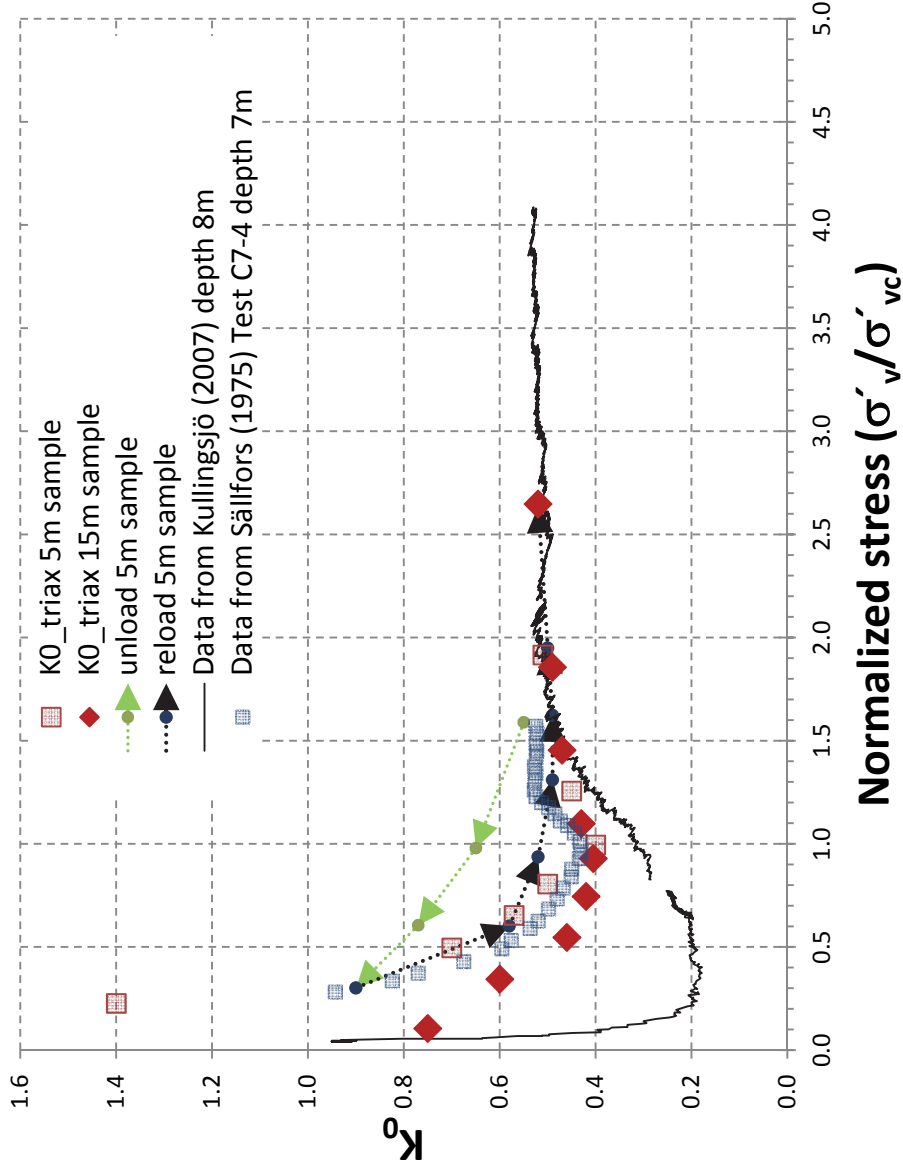
Results - K_0 triaxial cell



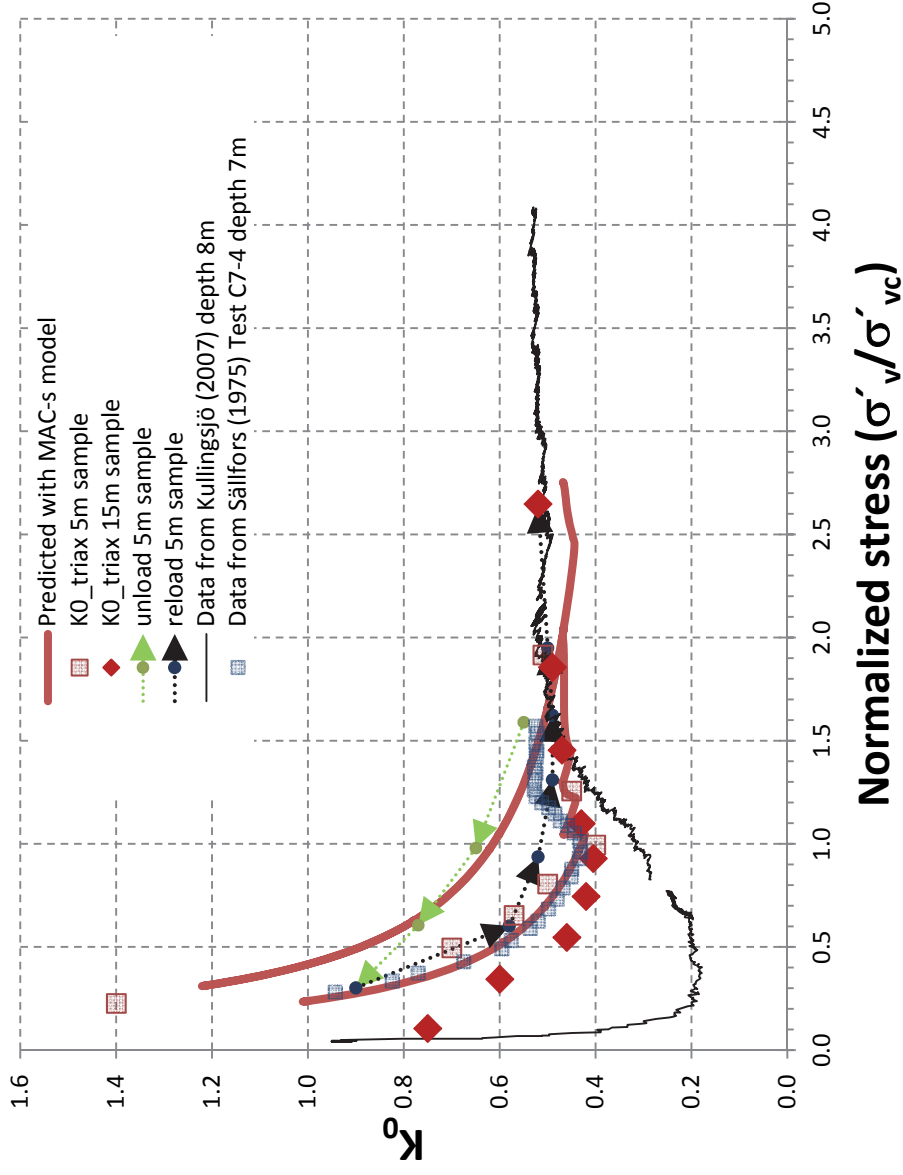
Results - K_0 triaxial cell



Results - Comparison K_0



Results - Comparison K_0



Conclusions

- **A modified creep model with a versatile normal compression surface**
- **A newly developed K_0 -triaxial cell**
- **The evaluated K_0^{nc} value is in a range of 0.50-0.55 (Gothenburg Clay)**

Recommendations

- **More experimental testing**
 - For validating the model formulation
 - For gathering more data on K_0^{nc} values for soft soils
 - With load reversals to capture the soils unload and reload behaviour
 - To establish the intrinsic properties of Gothenburg Clay
- **Improve the model to incorporate a small strain formulation**

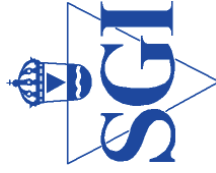
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