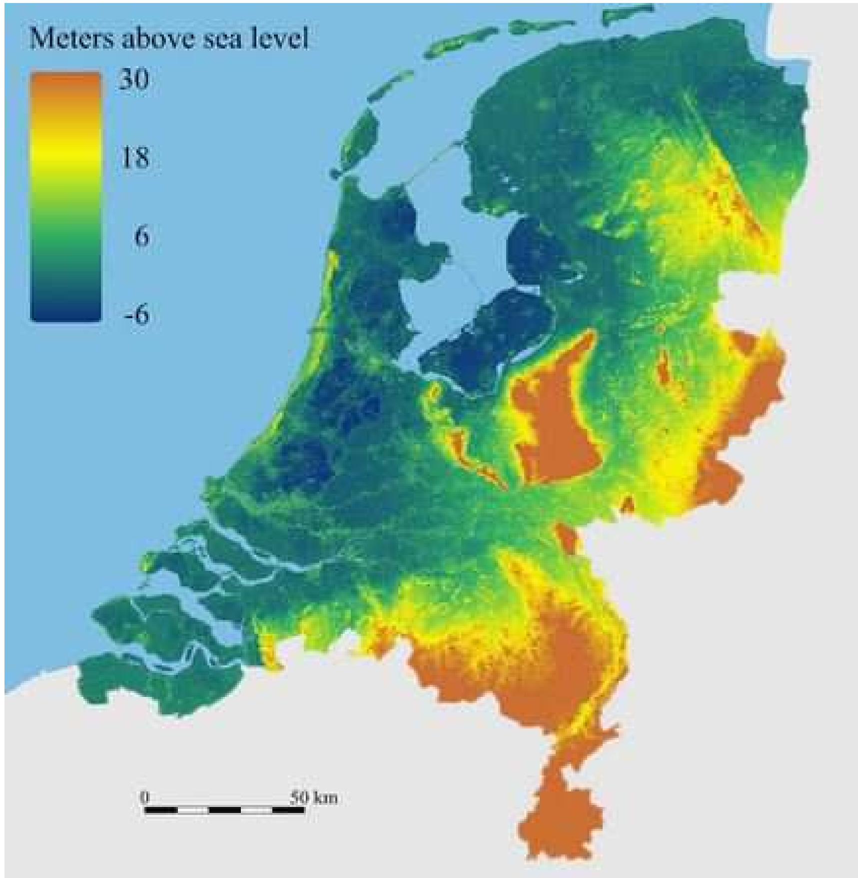
Investigating the bio-hydro-mechanical behaviour of peats

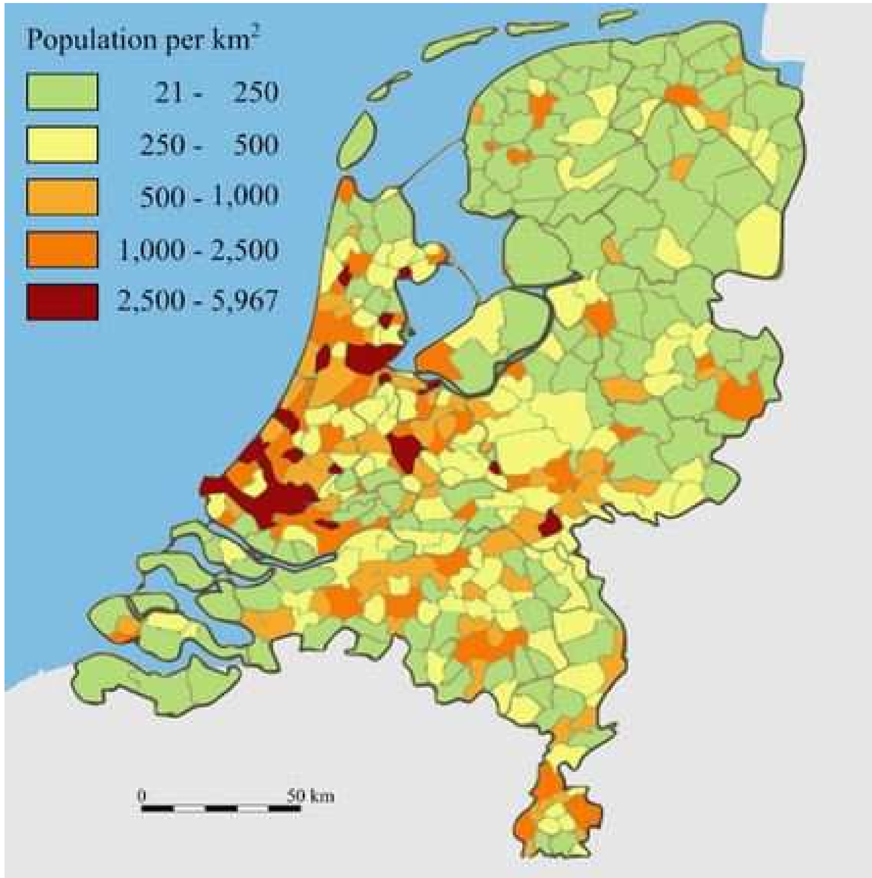
Cristina Jommi & Stefano Muraro

16-18 May 2016
Modern Trends in Geomechanics, Assisi

TU Delft

About 1/3 of the Netherlands is below the sea level





Soft deltaic deposits

Primary dykes: 3.600 km
+ Regional dykes: 14.000 km requiring full assessment every 6 years

North / South Holland / Rivierenland /Friesland

Dykes made of or founded on peat

Challenges

- Highly compressible matrix ---> 90% made of water & the rest can be 90% organic
- Very low stresses O(kPa), creeping ---> OCR, cohesion
- Heterogeneous & Anisotropic ---> ??

- Multilevel fibrous system
- Anaerobic degradation ---> slow / gas entrapment / mechanical response?
- Aerobic degradation ---> fast / affects fibres network / hydraulic properties / unsaturated Nor Md Zain, Hongfen Zhao

From scientific knowledge towards simple, but more reliable assessment rules

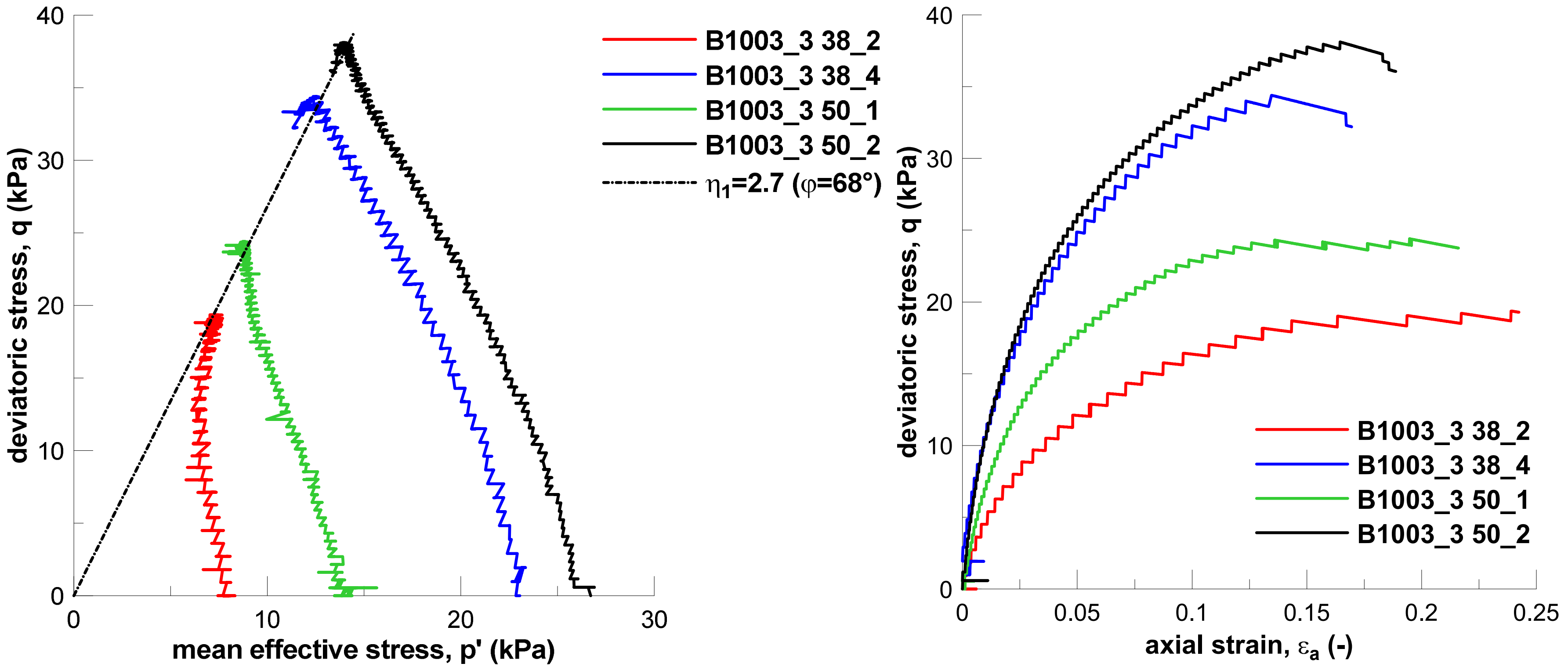
"Operative" shear strength based on M-C criterion at threshold strains

No attempt is made to properly describe the pre-failure behaviour

Need for exploiting existing information

(Wilnis dyke failure, 26-08-2003)

Typically, results from standard TXCU on saturated samples



A simple elastic-plastic approach

- Non associated Modified Cam-clay

$$f = q^2 - M_f^{\,2} p' \left(p'_c - p' \right) \qquad \text{Yield locus}$$

$$g = q^2 - M_g^{\,2} p' \left(p'_g - p' \right) \qquad \text{Plastic potential}$$

- Hardening law depending on both volumetric and distortional plastic strain

$$\frac{\delta p'_c}{p'_c} = \frac{v}{\lambda - \kappa} \left(\dot{\varepsilon}_p^p + D \dot{\varepsilon}_q^p \right)$$

particles packing → $\dot{\varepsilon}_p^p$

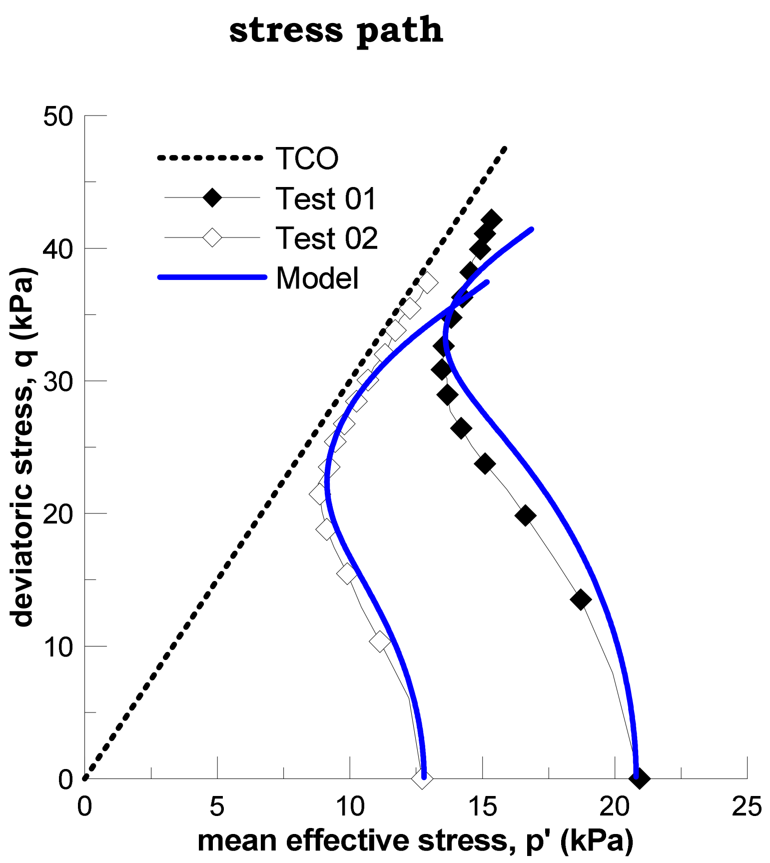
Particles realignment → $\dot{\varepsilon}_q^p$

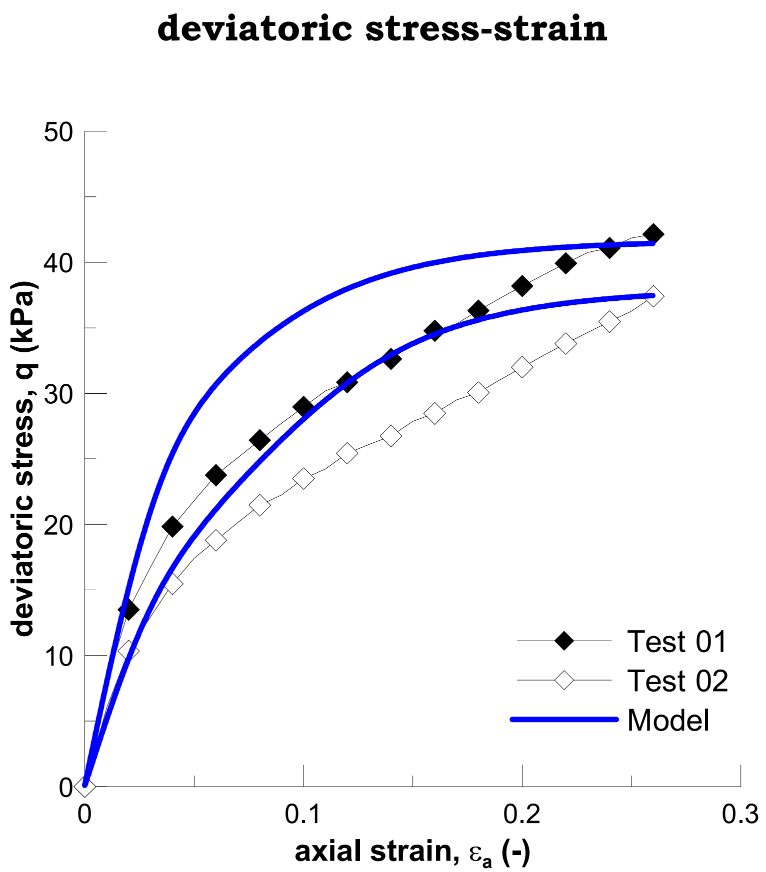
- Saturation law for D to reduce dilatancy at failure

$$D = D_0 \exp\left(-D_1 \varepsilon_q^p\right)$$

TUDelft

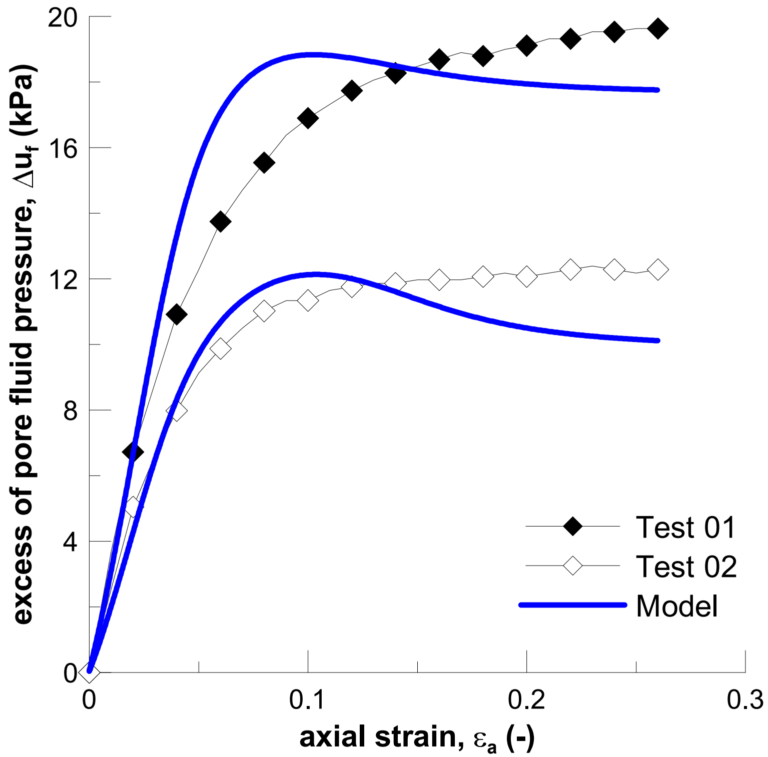
Comparison with data from TXCU



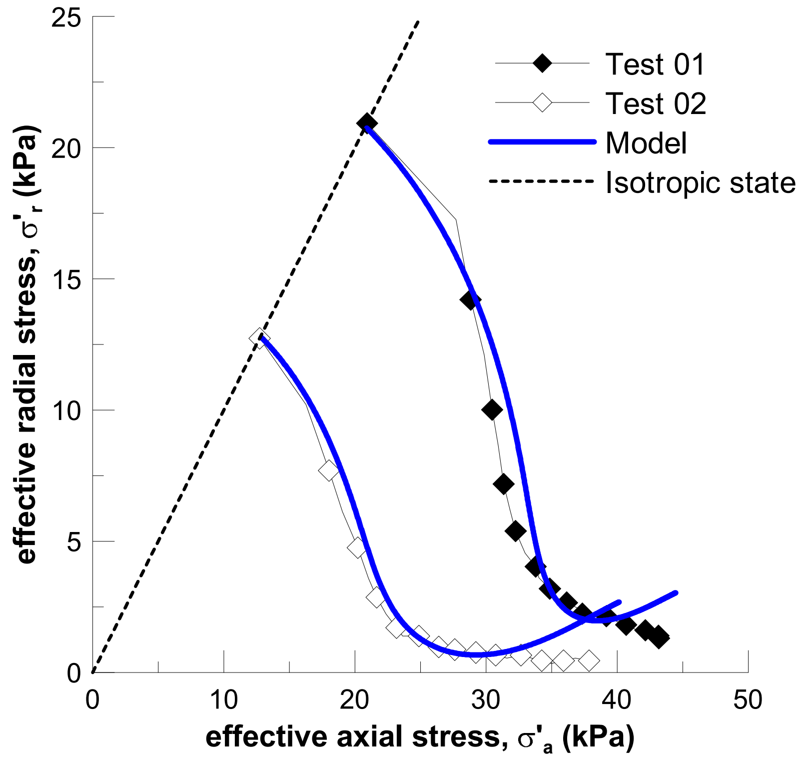


TxCU on natural peat samples

excess of pore fluid pressure



axial-radial stress



Multiscale fibrous network

Elastic-plastic matrix + diffused fibres: volumetric averaging

$$\boldsymbol{\sigma}' = \mu_m \sigma'_m + \mu_f \sigma'_f$$

soil matrix volumetric fraction

fibres volumetric fraction

$$\dot{\boldsymbol{\sigma}}' = \mu_m [M_m] \dot{\boldsymbol{\varepsilon}}_m + \mu_f [M_f] \dot{\boldsymbol{\varepsilon}}_f$$

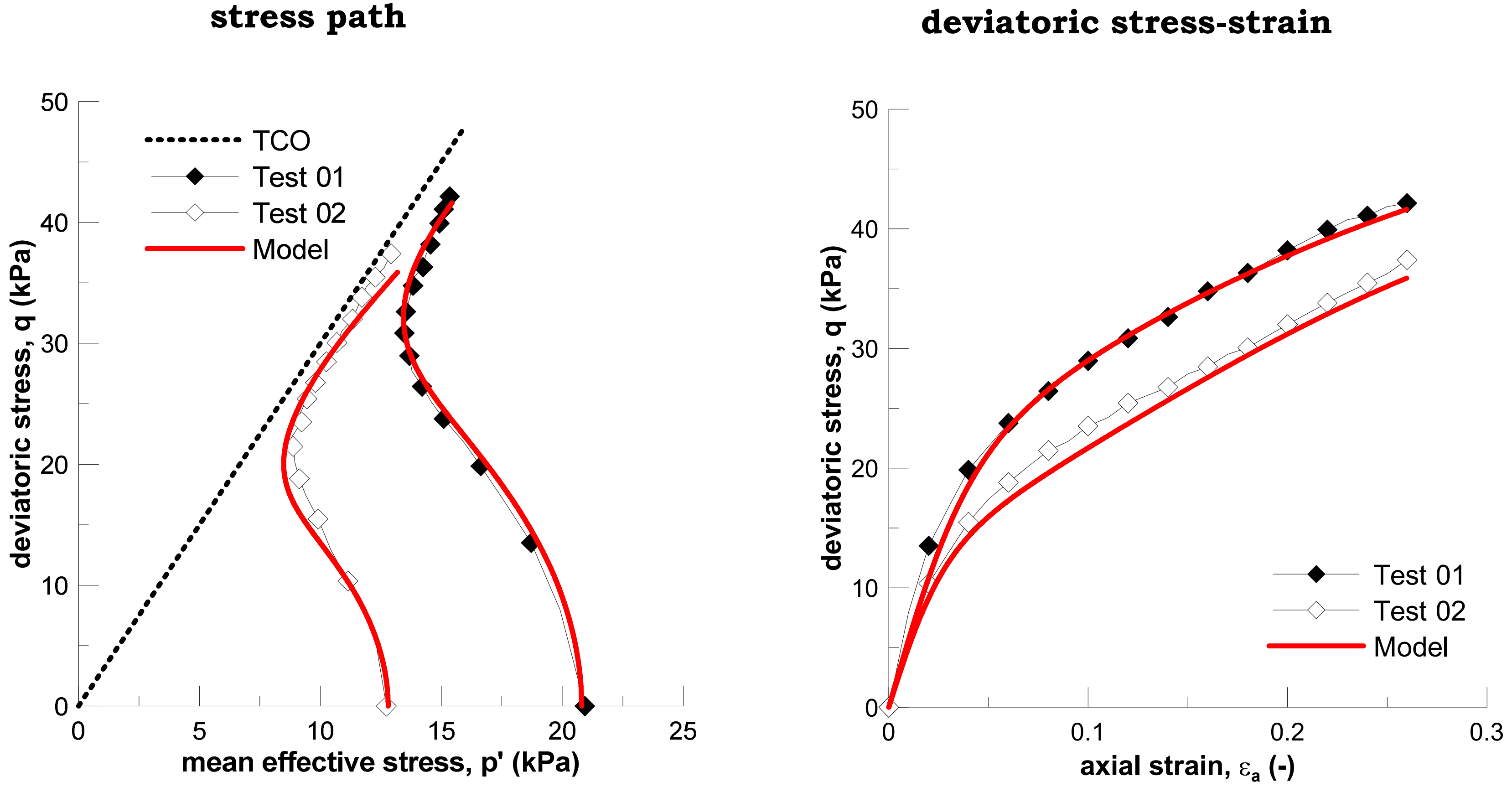
soil matrix tangent stiffness

fibres stiffness

μ_m and μ_f : measured volume fractions

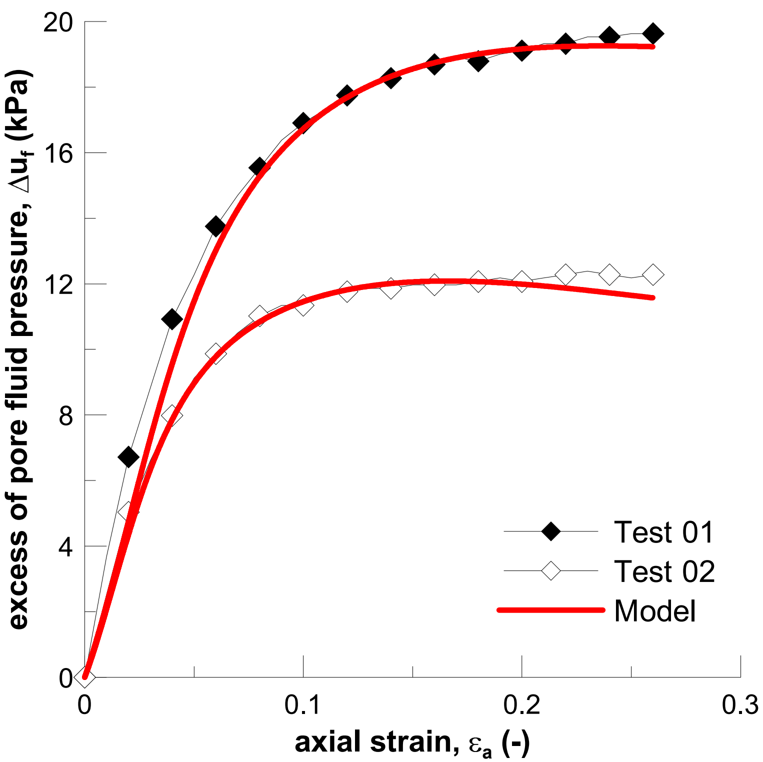
Comparison with experimental data

- TxCU on natural peat samples
- Matrix volumetric fraction $\mu_m = 0.25$ (Test 01), $\mu_m = 0.35$ (Test 02)

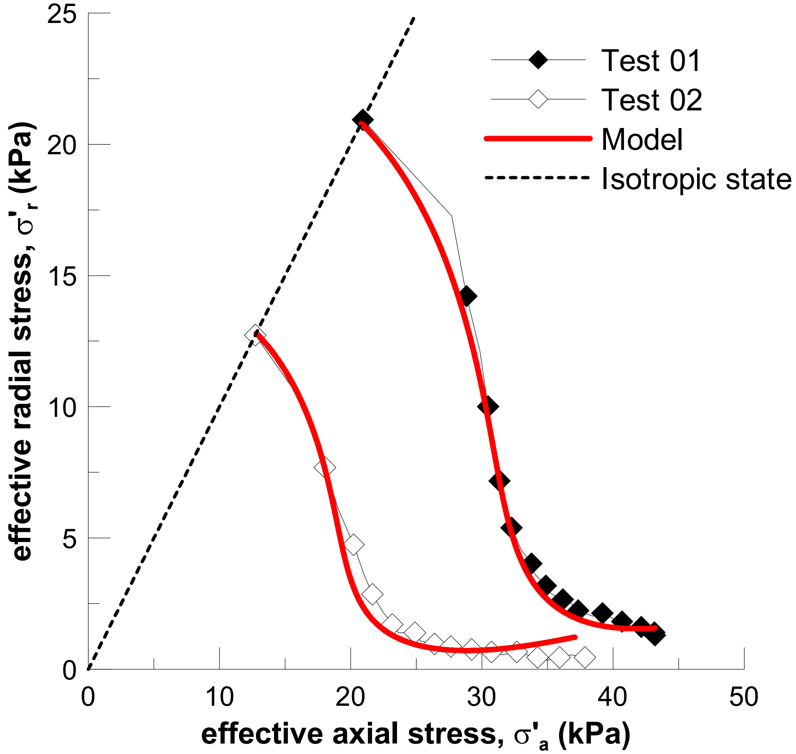


TU Delft

excess of pore fluid pressure

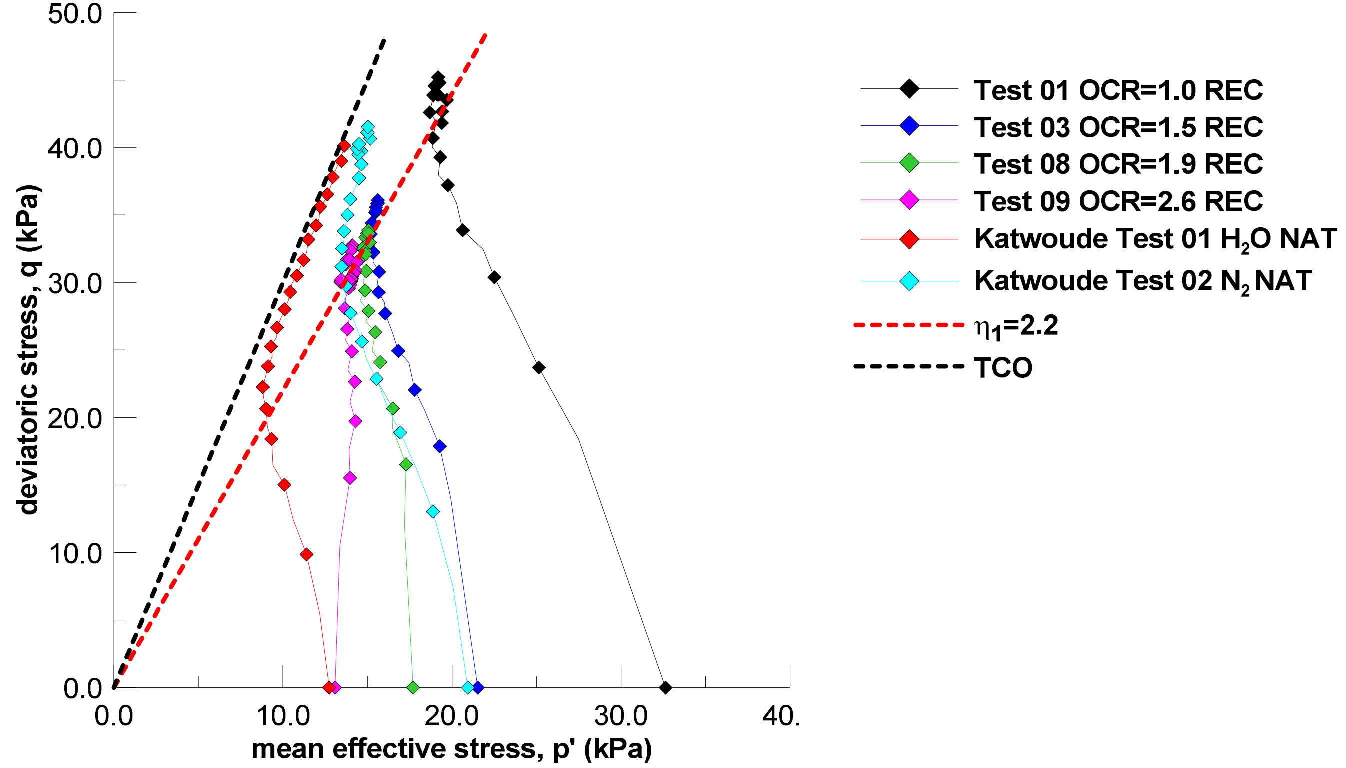


axial-radial stress



TU Delft

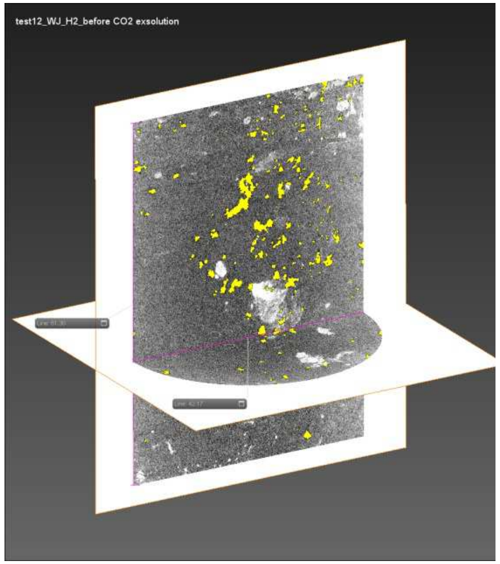
Multilevel fibrous system



A bio-hydro-mechanical system

Field test Markermeer Dykes
Zwanenburg, (2013)

Field test Leendert de Boerspolder

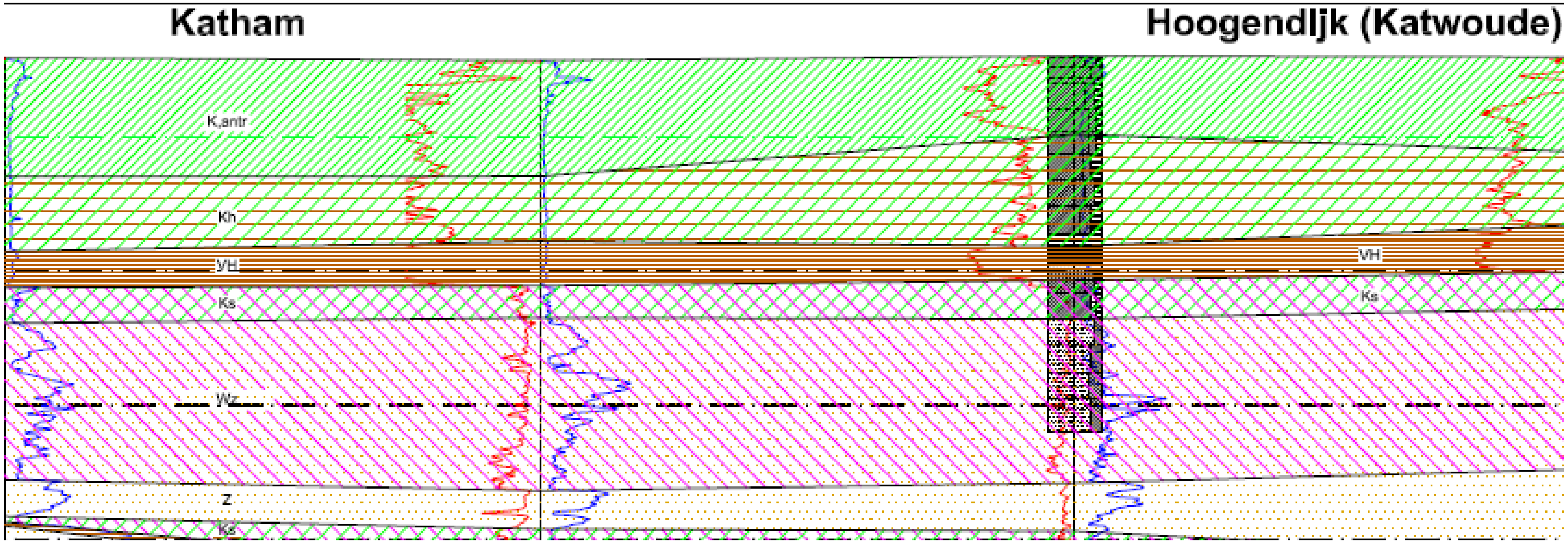


MicroCT scan

Trivellato (2014)

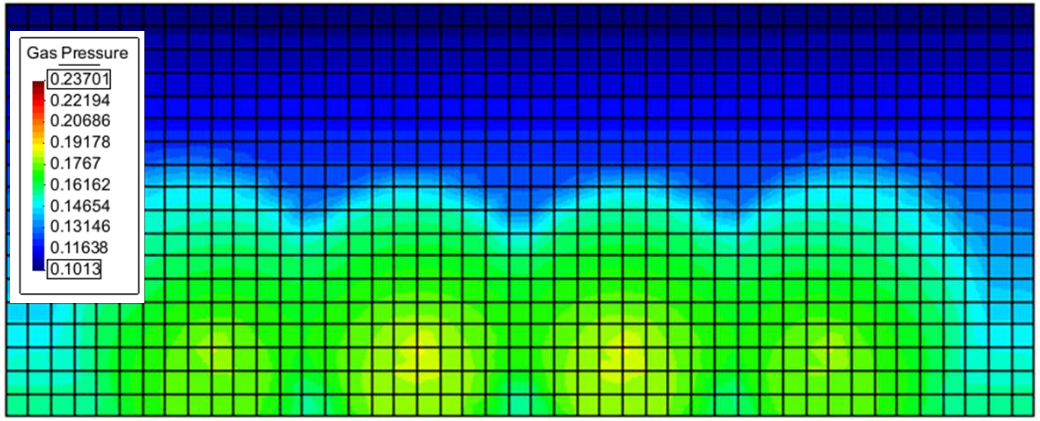
Gas formation in peats: does it affect the hydromechanical response?

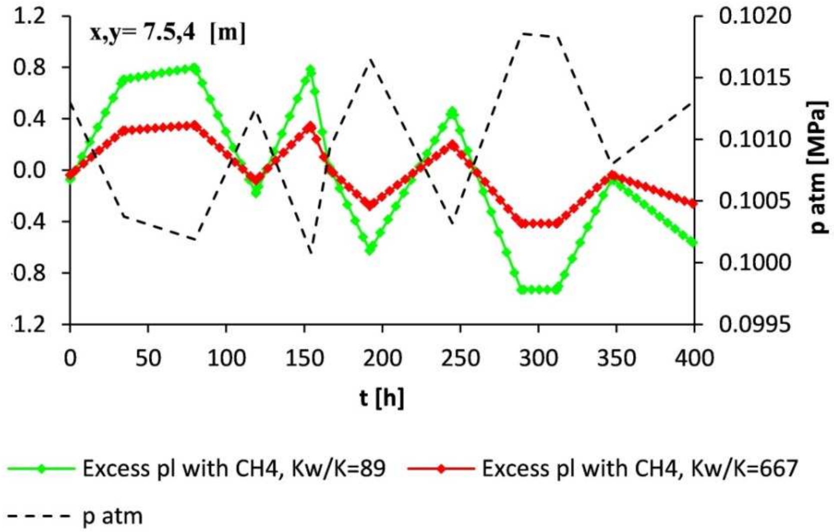
Numerical analysis on the influence of biogenic gas on the pore water pressure response in peats



Assessment of 30km of the Markermeer Dykes
Dijken op Veen, Deltares 2014

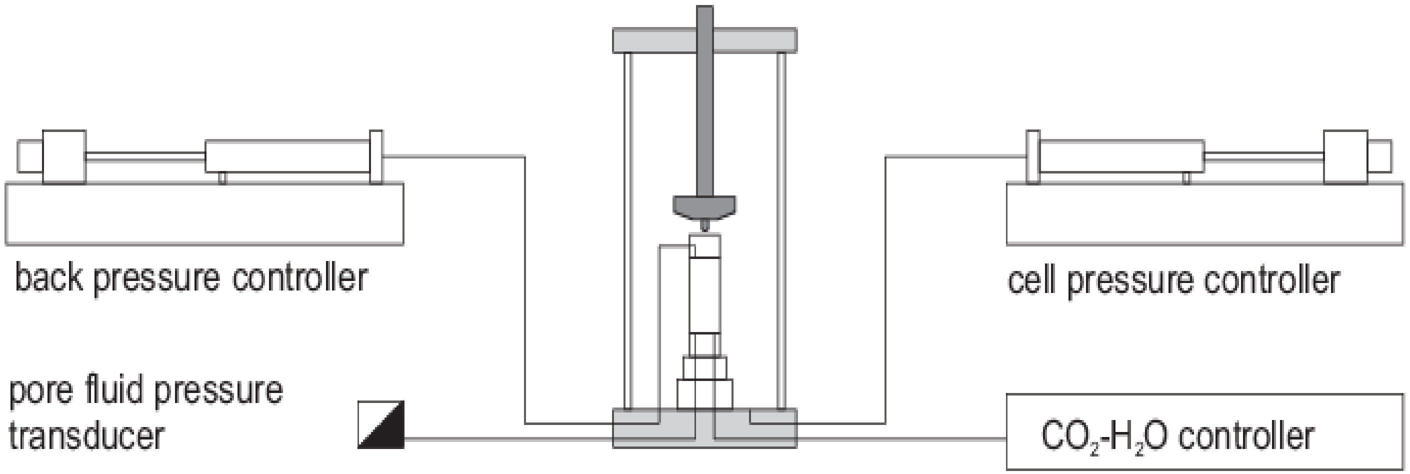
Preliminary FEM coupled analysis with Code_Bright





Gas generation in a layered soil profile

What is the influence of gas on the (undrained) shear behaviour?

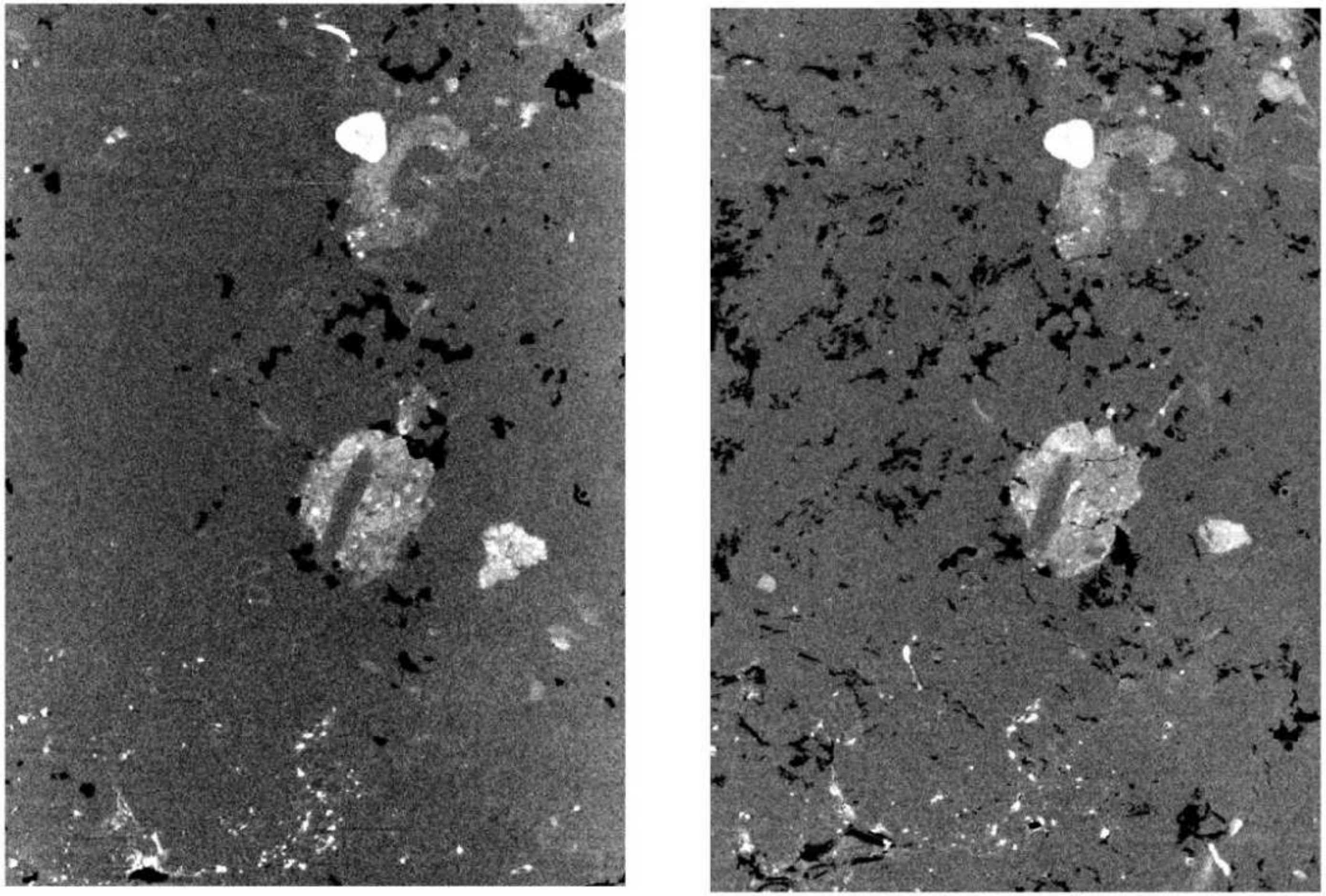


Flushing with CO_2 super-saturated water and undrained unloading

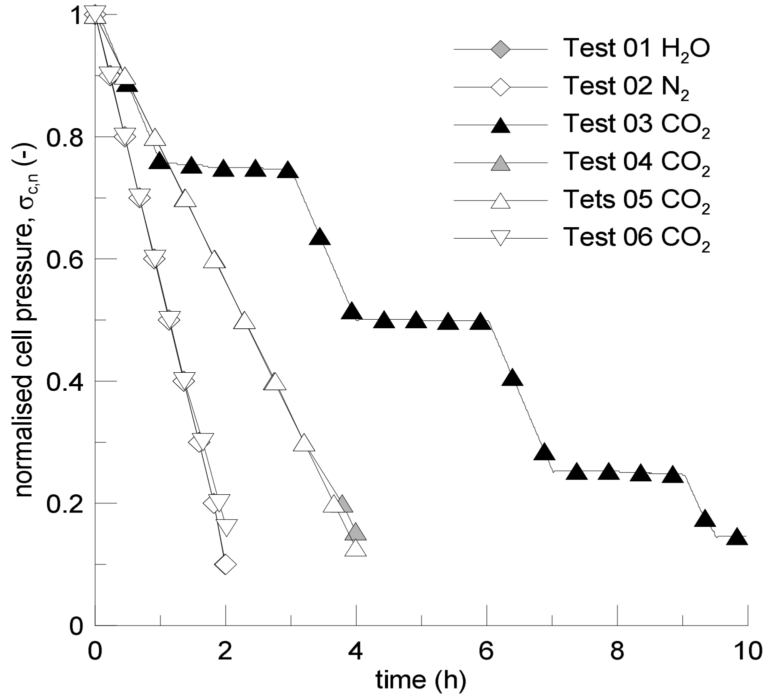
Controlled gas generation inside peat samples

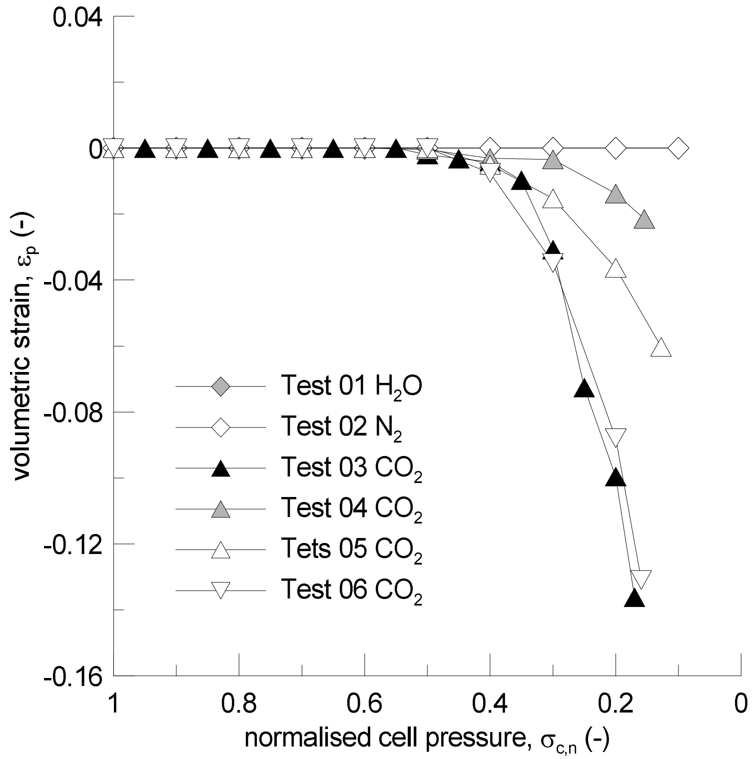
Lunne et al. (2001), Amaratunga & Grozic (2009), Sultan et al. (2012)

Tracking gas generation with MicroCT

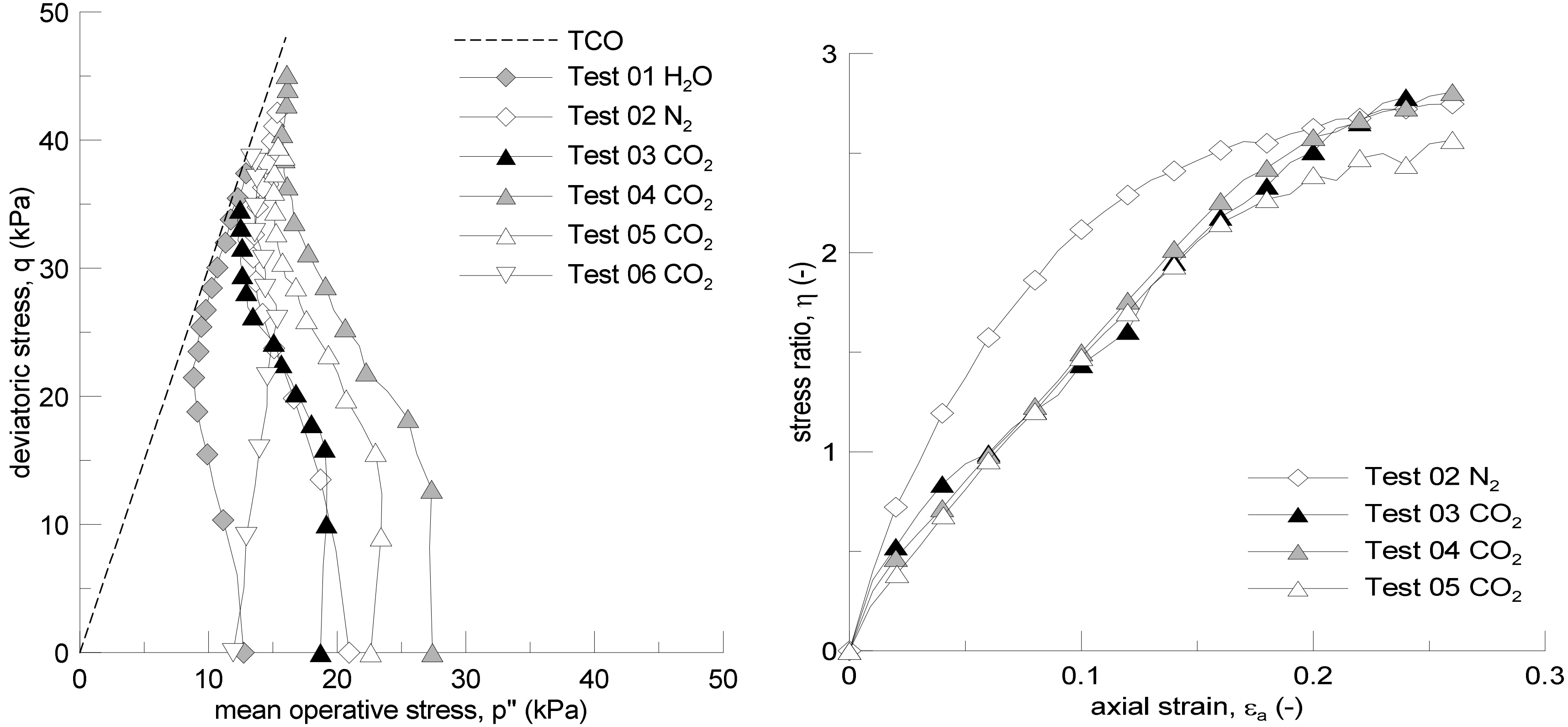


Results: gas exsolution

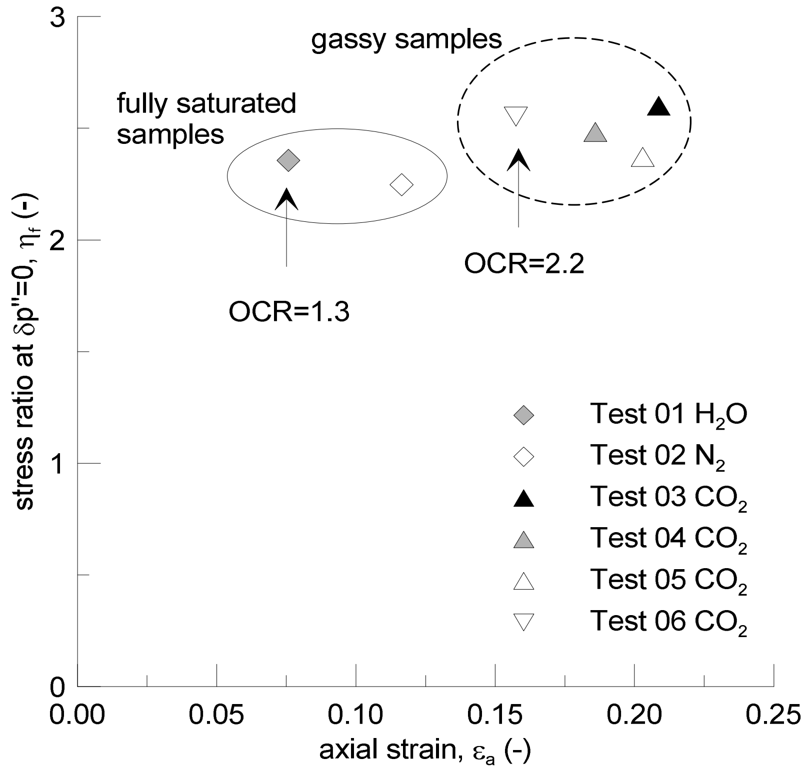




Undrained shear response



Shear strength



Preliminary conclusions & perspectives

- Operational shear strength criteria based on admissible axial strains are very much affected by the type and network of fibres and on the (random) amount of entrapped gas
- Modelling the behaviour of peats at an "operational" level can be pursued with simple models, provided the mutual effect of the different bio-hydro-mechanical coupling are accounted for properly
- Evaluation of "standard" frameworks for unsaturated soils to model the effect of gas on the pre-failure and failure behaviour – coupling the "geometrical" effect of fibres and gas
- Evaluation of other potential effective constitutive approaches (hypoplasticity with D.Mašin)
- Coupling with bio-chemical effects for aerobic degradation