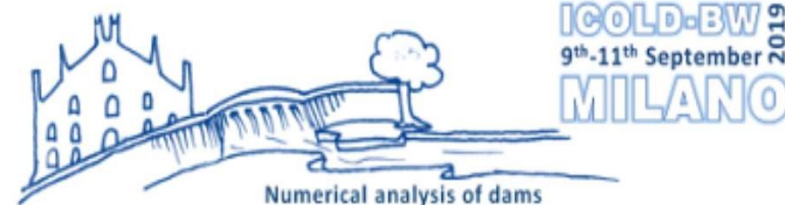




ICOLD
INTERNATIONAL
COMMISSION ON
LARGE DAMS



15th INTERNATIONAL BENCHMARK WORKSHOP ON NUMERICAL ANALYSIS OF DAMS

Theme C

*Analysis of pre-failure and failure of a levee on soft soil
with Modified Cam-clay model in DIANA*

M.V. Schwager¹, A.D. Tzenkov², G.M.A Schreppers³

¹ Swiss Federal Office of Energy

² Stucky Ltd

³ DIANA FEA BV



Schweizerische Eidgenossenschaft
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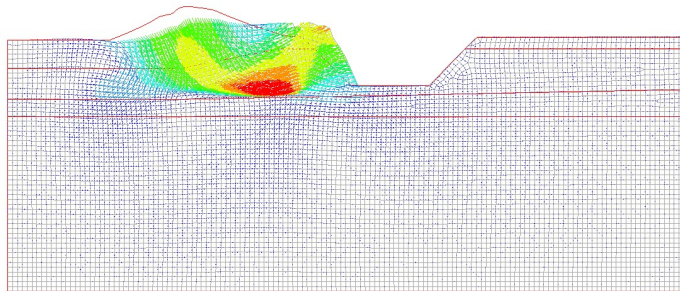
1. Preliminary strength reduction analyses



Undrained conditions

Total stress analysis, Tresca

Critical water level:
-2.2m NAP

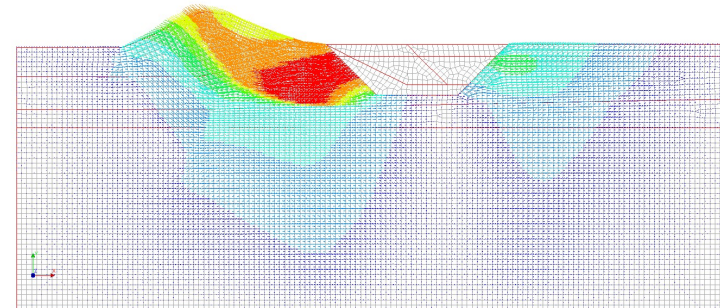


Failure mechanism (total deformation)

Drained conditions

Effective stress analysis, Mohr-Coulomb

Critical water level:
-2.6m NAP



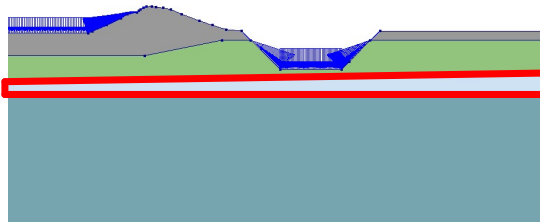
Failure mechanism (total deformation)

Strength and linear elastic stiffness parameters are derived from the results of the laboratory tests.

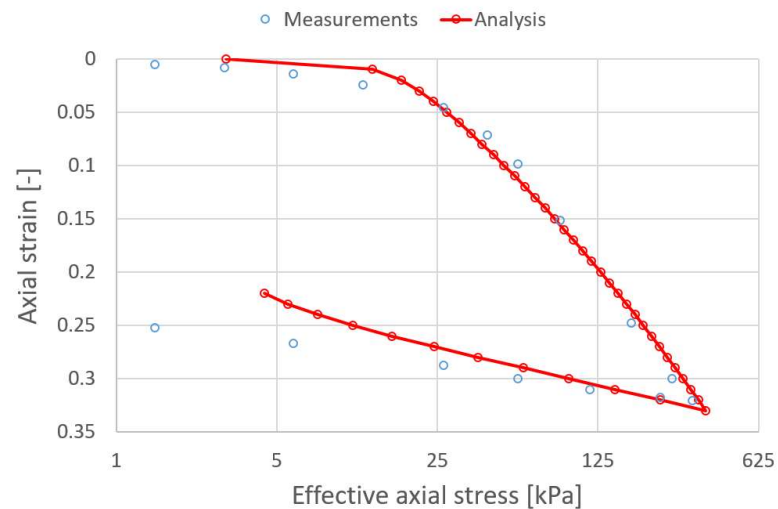
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2. Calibration of the Modified Cam Clay model

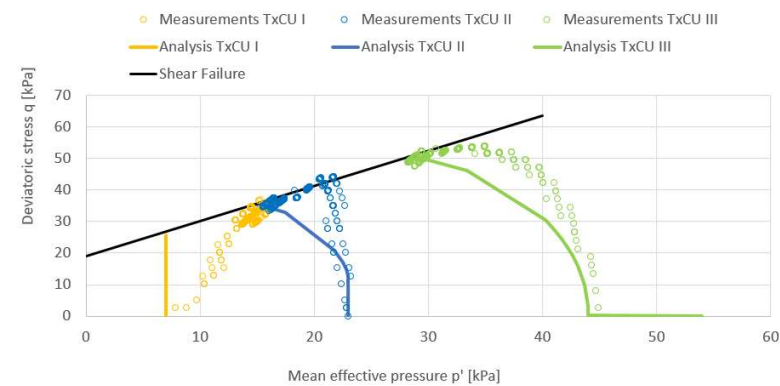
Organic Silt-clay material



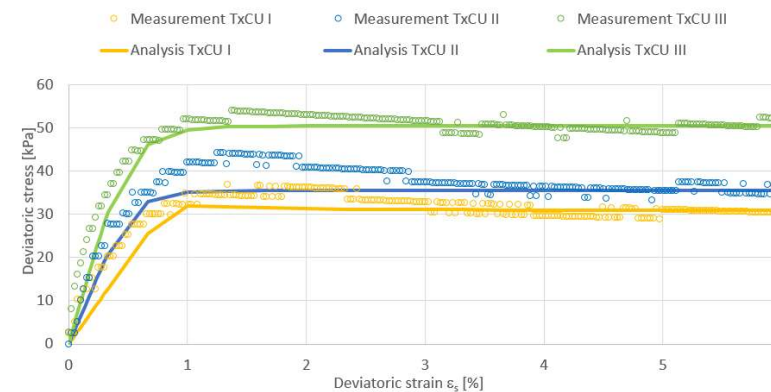
Oedometer test



Undrained triaxial shear tests



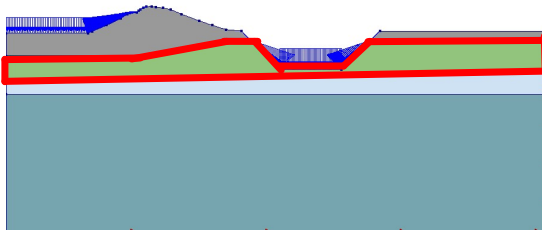
Effective stress path



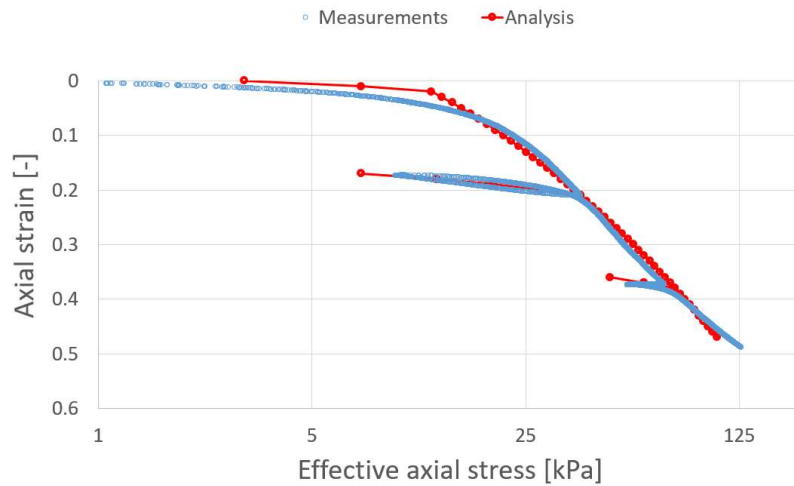
Deviatoric behaviour

2. Calibration of the Modified Cam Clay model

Peat material



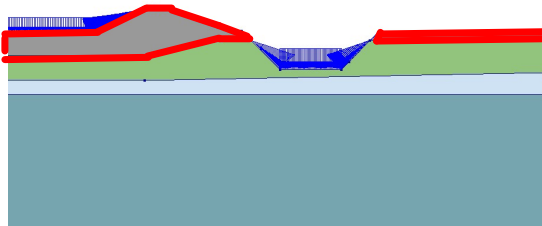
Oedometer test



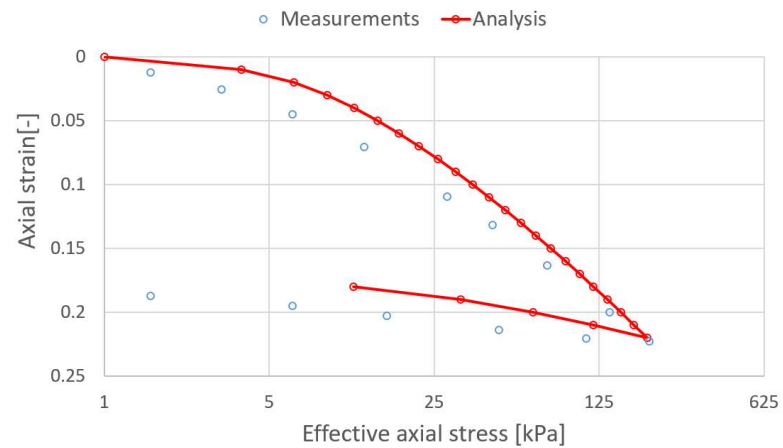
The shear strength parameters are derived from the direct simple shear tests.

2. Calibration of the Modified Cam Clay model

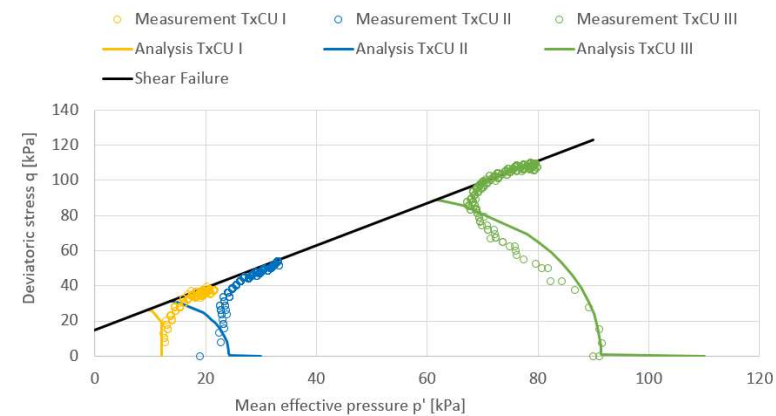
Dyke material



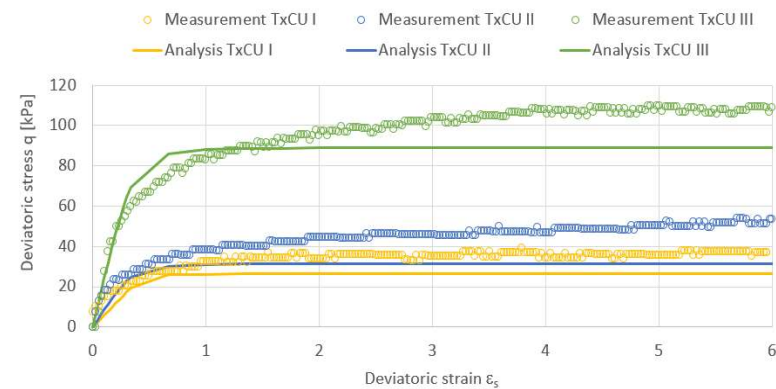
Oedometer test



Undrained triaxial shear tests



Effective stress path



Deviatoric behaviour

3. More comprehensive stress-strain analyses

Effective stress analyses, Modified Cam Clay model

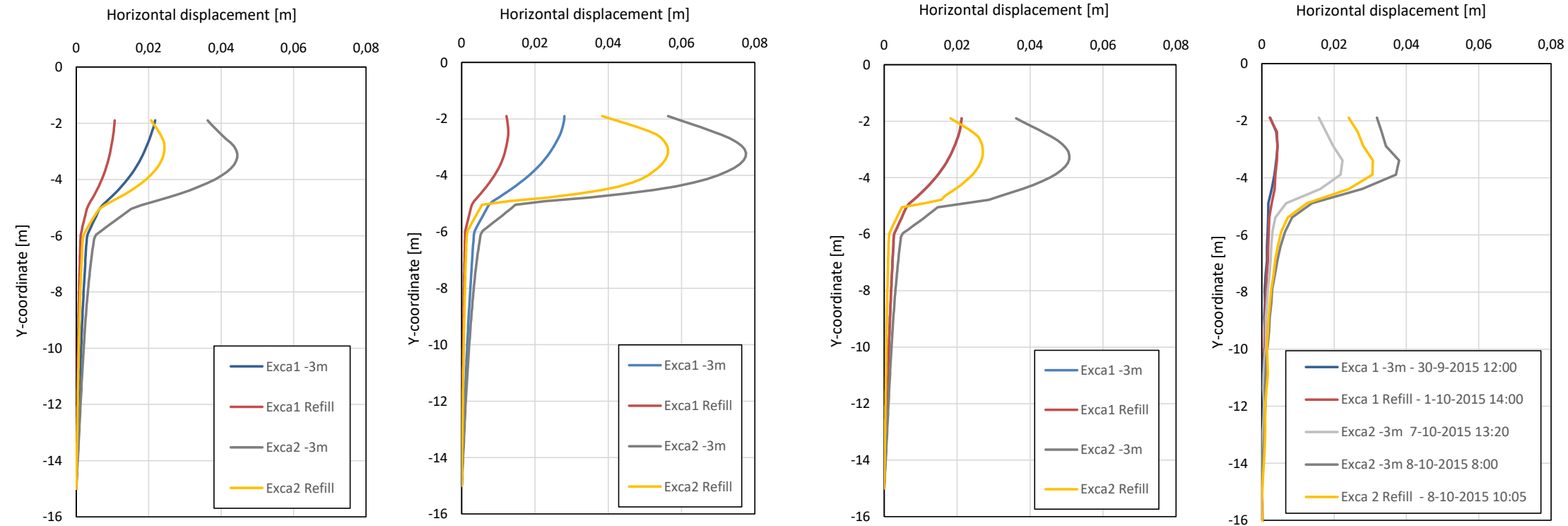


Undrained a.

Drained staggered a.

Coupled analysis

Measured



Calculated and measured displacements in inclinometer ItC at the toe of the dam.

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3. More comprehensive stress-strain analyses

Effective stress analyses, Modified Cam Clay model

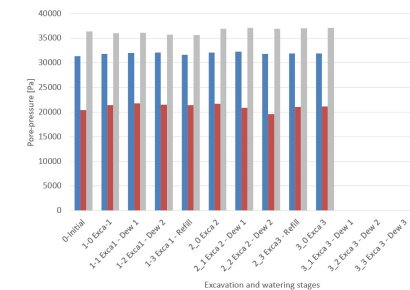
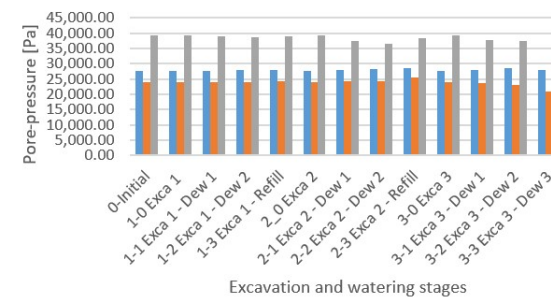
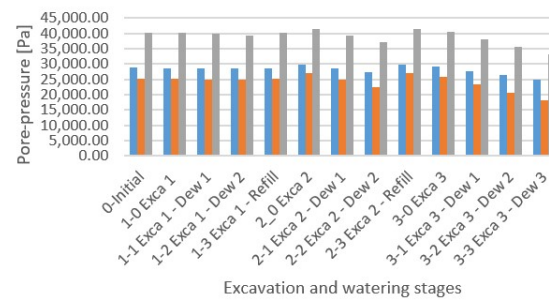
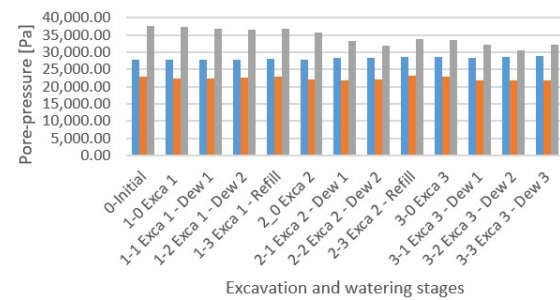


Undrained a.

Drained staggered a.

Coupled analysis

Measured



Calculated and measured pore-pressures at different stages in three piezometers
(blue bars: PmC5, red bars: PtC2, grey bars: PtC3)

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3. More comprehensive stress-strain analyses

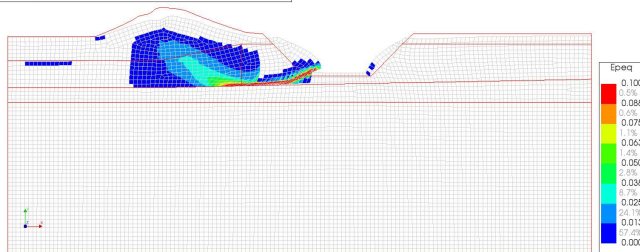
Effective stress analyses, Modified Cam Clay model



Undrained a.

Critical water level:
-3.0m NAP

Staged Construction - Stress analysis with User defined Water-level
Excavation 3 - Dewatering 3 - 14/10/2018, Time 24 day
Plastic Strains Epeq
min: 0.000 max: 0.485

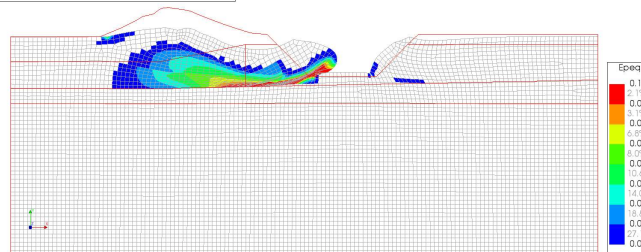


Failure mechanism (plastic shear strains)

Drained staggered a.

Critical water level:
<-3.0m NAP

Staged Construction Staggered analysis all drained
Excavation 3 - Dewatering 3 - 14/10/2018, Time 24 day
Plastic Strains Epeq
min: 0.000 max: 0.292

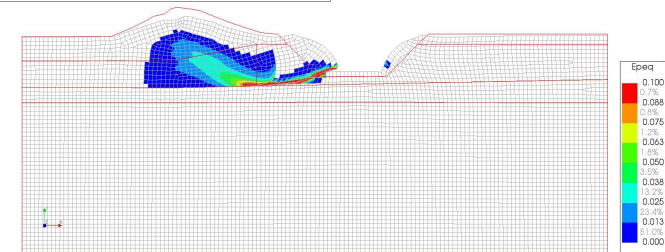


Failure mechanism (plastic shear strains)

Coupled analysis

Critical water level:
-3.2m NAP

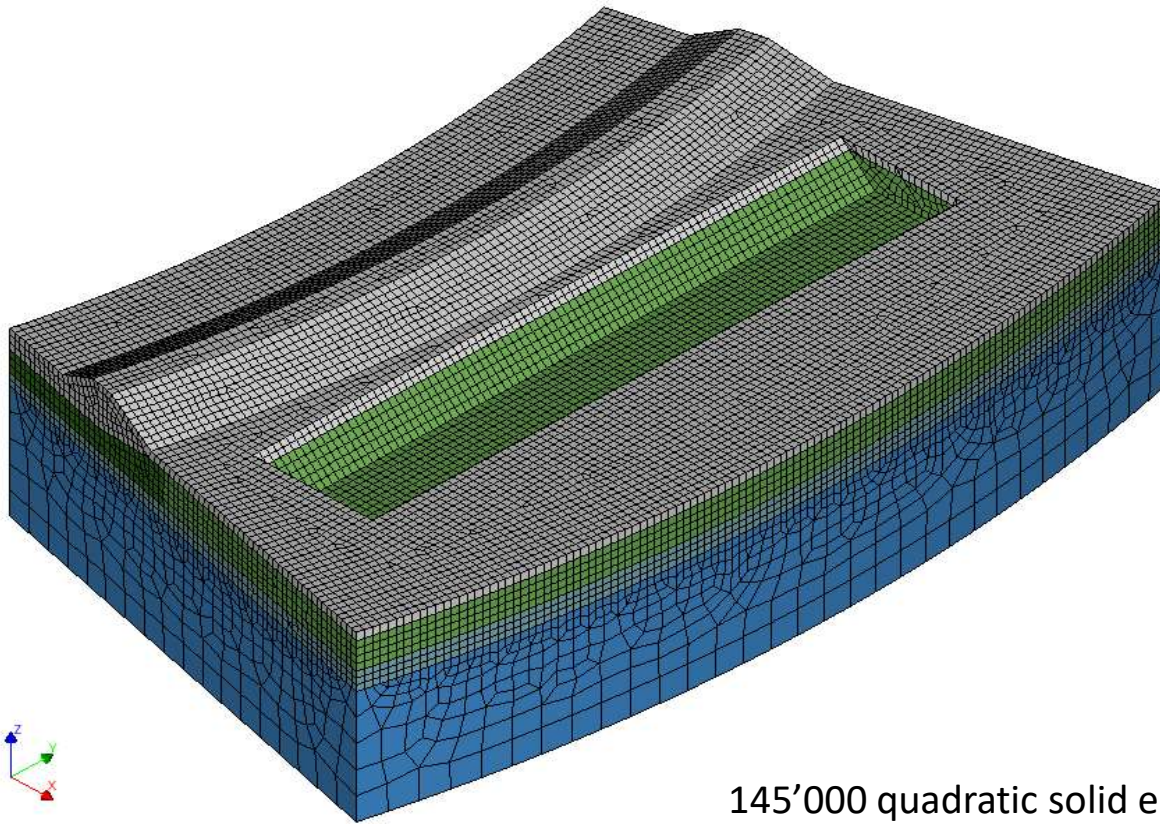
Phased Nonlinear analysis with Mixture formulation
Phase 4, Time-step 30, Time 15 day 18 hour, Left and Right and weight
Plastic Strains Epeq
min: 0.000 max: 0.527



Failure mechanism (plastic shear strains)

4. Influence of 3d effects

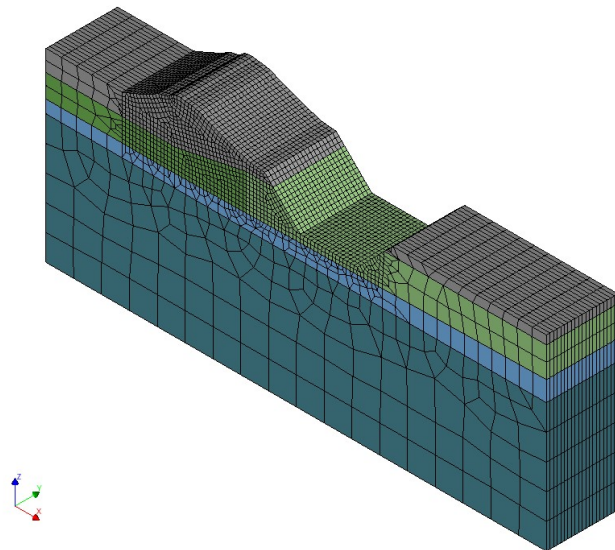
Effective stress analyses, Modified Cam Clay model



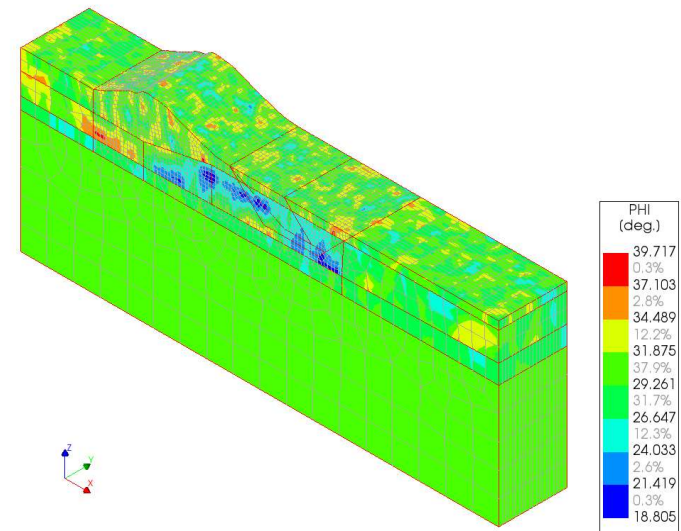
145'000 quadratic solid elements

5. Influence of spatial variability of shear strength

Effective stress analyses, Modified Cam Clay model



Model C7 - Random field 14
Model data
Plastic parameters PHI
min: 18.805deg, max: 39.717deg.



The spatial variation of the friction angle is derived from the CPT profiles.

The horizontal correlation length is assumed to be 2.5 times the vertical correlation length.

Stochastic properties of the random field:

Layer	Average [°]	Standard deviation [°]	Vertical correlation length [m]
Dyke	30	3.7	0.10
Peat	28	3.8	0.60
Organic Silt-clay	30	1.6	0.25
Foundation	31	0.8	0.25

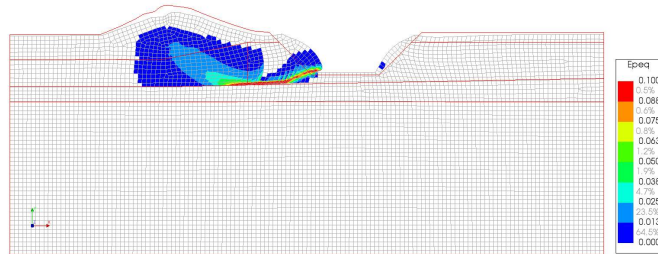
5. Influence of spatial variability of shear strength

Effective stress analyses, Modified Cam Clay model



2D-model

Staged Construction Staggered analysis All undrained
Excavation 3 - Dewatering 2 - 14/10/2017, Time 24 day
Plastic Strains Epeq
min: 0.000 max: 0.288

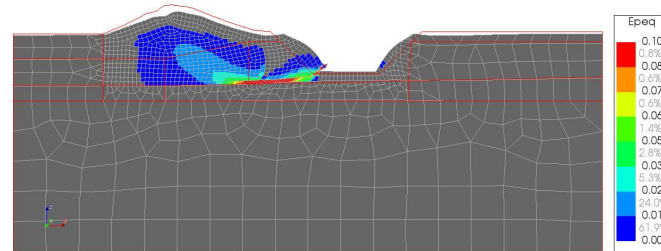


Failure mechanism (plastic shear strains)

3D-model

(without spatial variability)

Staged Construction Staggered analysis - All undrained
Excavation 3 - Dewatering 2 - 14/10/2017, Time 24 day
Plastic Strains Epeq
min: 0.000 max: 0.419

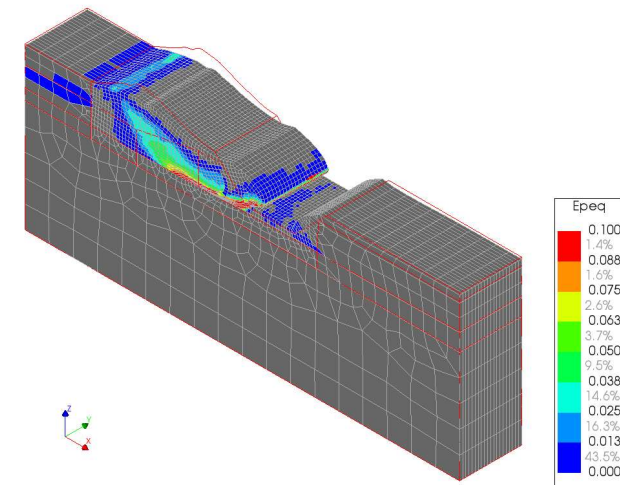


Failure mechanism (plastic shear strains)

3D-model

(with spatial variability)

Staged Construction Staggered Analysis Undrained - Random field 14
Excavation 3 - Dewatering 3 - 14/10/2018, Time 24 day
Plastic Strains Epeq
min: 0.000 max: 0.783



The results of the 2D model and the 3D model are almost identical.

The influence of the random spatial variation of the friction angle is found to be minor.

Conclusions



- The hydraulic conditions in the full-scale experiment are expected to be close to undrained conditions.
- The levee is supposed to fail when the water table in the polder reaches -3.2 NAP (according to the results of the fully coupled transient mixture analysis).
- The Modified Cam Clay model is found to be appropriate for the natural deposits. It can serve as an approximation for the Dyke material.
- The influence of the random spatial variability of the shear strength is found to be minor. However, the systematic spatial distributions of the permeabilities (governing the pore pressures) and the stress history (resulting in over-consolidation of soils) are considered to be essential.



Thank you very much!

