Finite Element Modelling of Penetration tests into Martian analogue Materials

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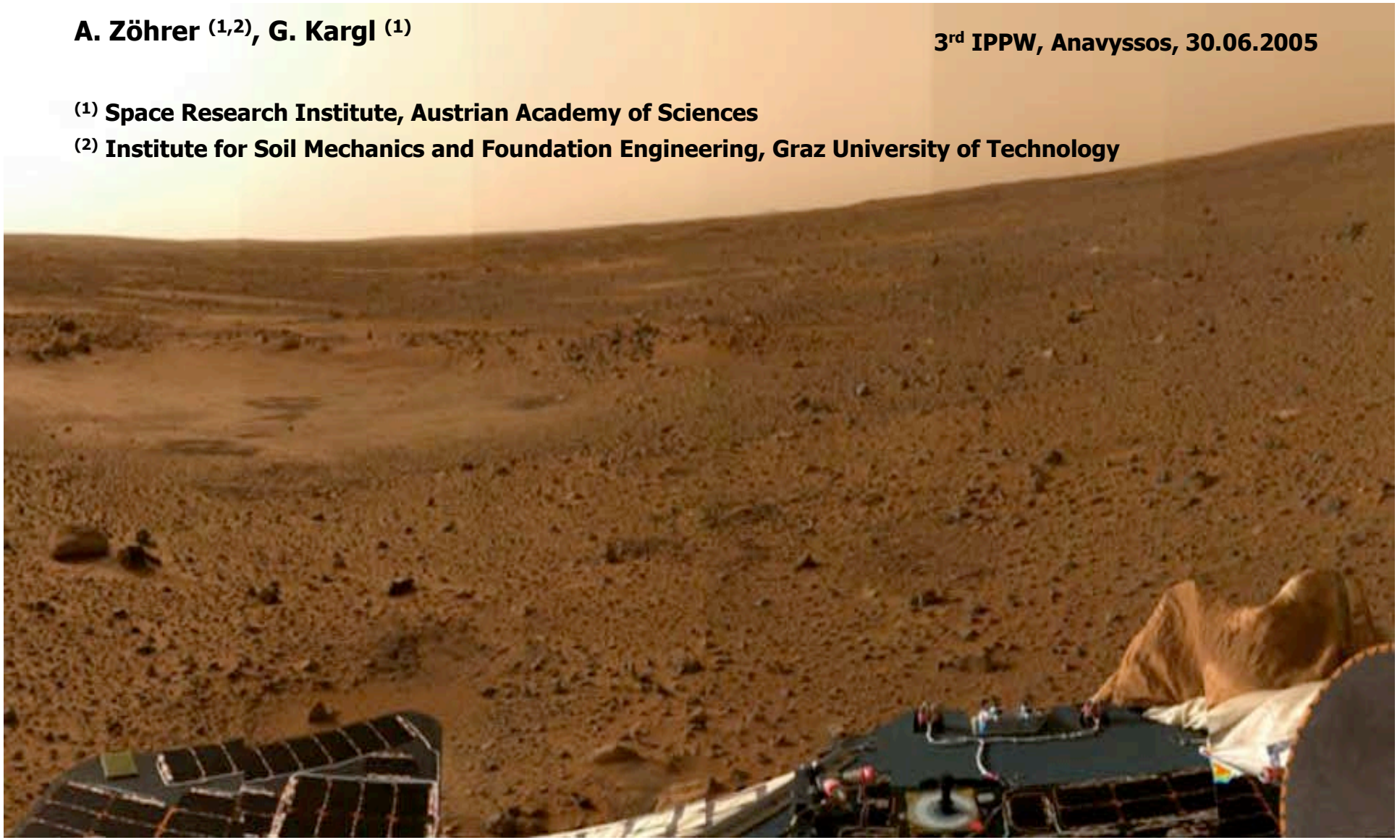


Introduction

Project description:

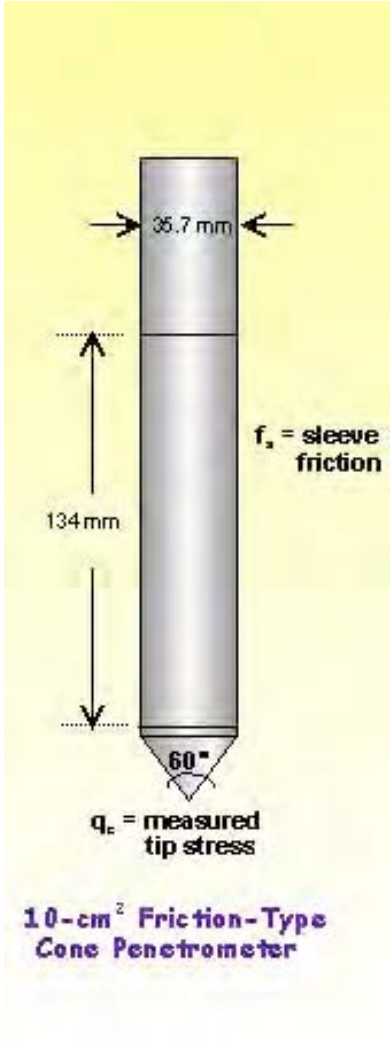
- Determination of Mechanical Parameters of the Martian Surface with Penetration Tests

Main parts of the project:

- Selection of materials for the laboratory tests
- Geotechnical and geological investigation of the selected materials
- Laboratory penetration tests using the characterized materials
- Numerical Modelling of the penetration process with the Finite Element Method

CPT in geotechnical practice

- Cone Penetration Test (CPT):
  - a conical tip (cone) on the end of a series of rods is pushed into the ground at a constant rate
  - measured values:
    - force acting on the cone: Q_c
    - sleeve friction: f_s
    - (pore pressure: u …CPTU only)
  - properties:
    - depth of penetration: up to 50 m
    - rate of penetration: 20 mm/s
    - verticality: initial deviation < 2°
    - interval of readings: 10 to 50 mm or continuously
    - depth measurement: depth wheel, cable drive
  - evaluation:
    - diagrams and equations depending on the soil classification and the cone type



Investigated Materials

- analogue materials:
  1. Salten Skov (Denmark)
  2. JSC Mars-1 (Hawaii)
- additional materials:
  3. Schwarzl UK 4
  4. Fohnsdorfer Haldit
- geotechnical tests:
  - grain size distribution
  - grain density
  - triaxial tests / direct shear test
- geological tests:
  - chemical analysis
  - microscopic investigation
  - X-ray spectroscopy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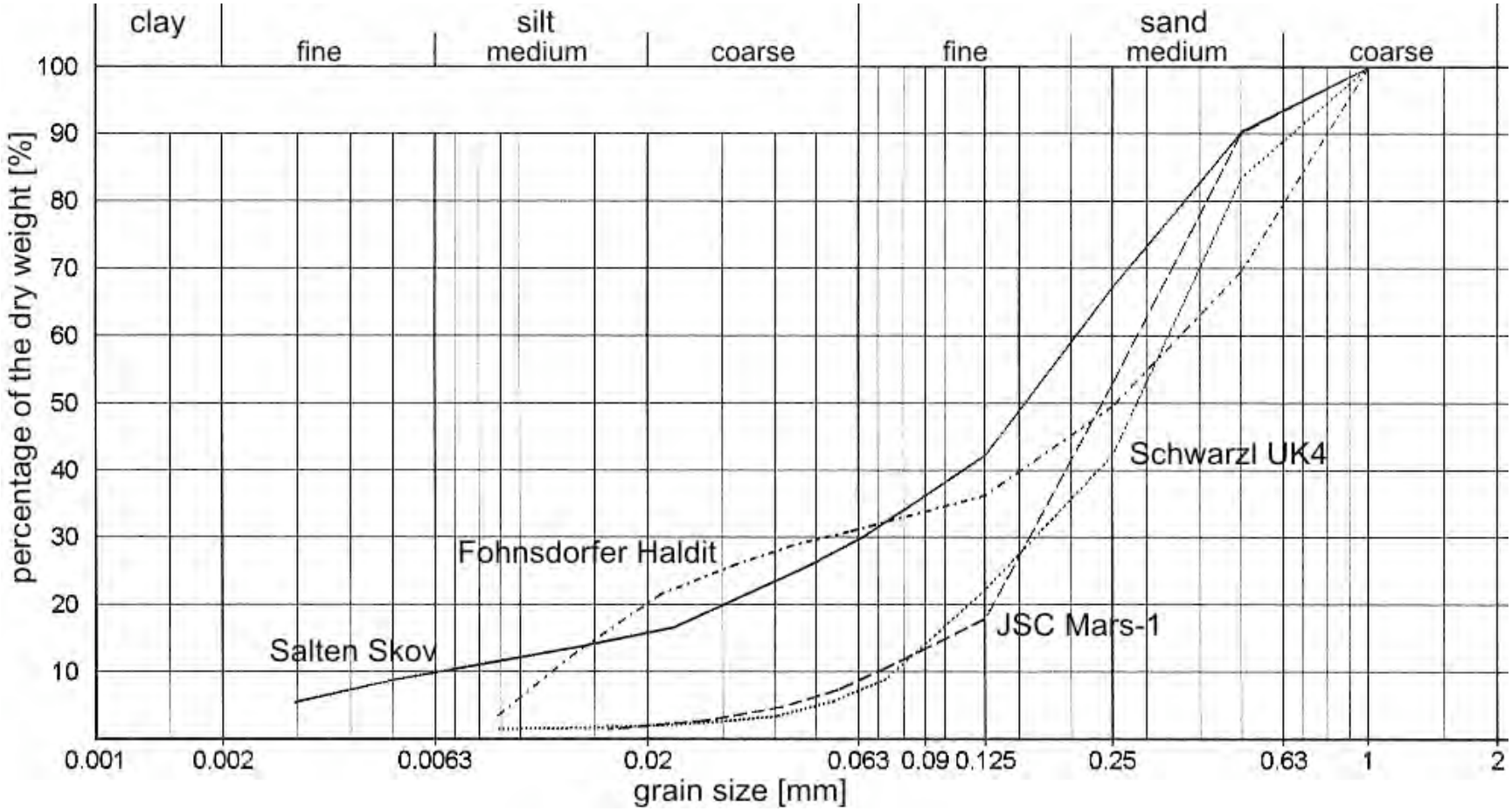
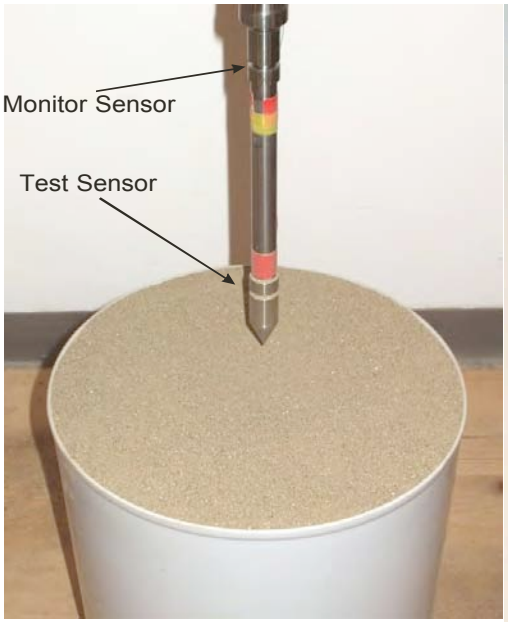
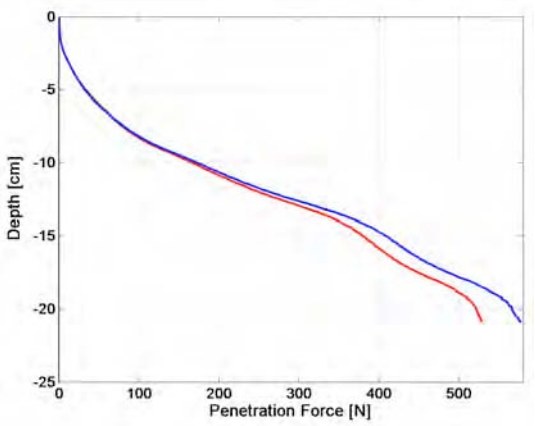
Grain Size Distribution Curves

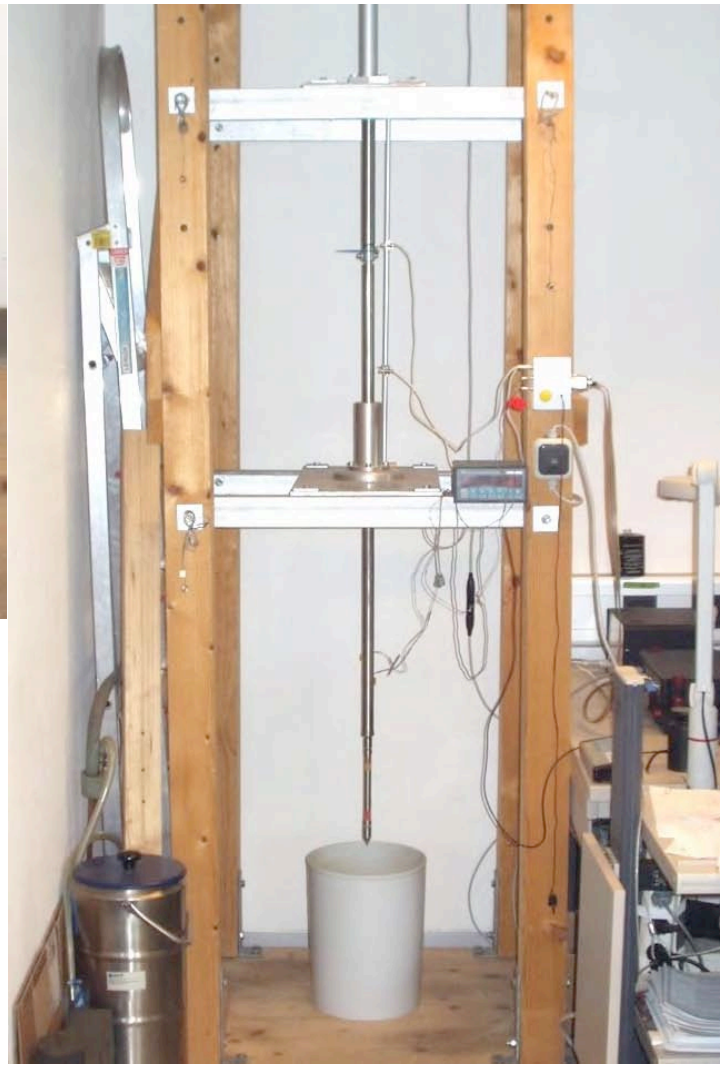


Laboratory Penetration Tests

- differences to CPT:
  - small scale
  - depth < 1 m
  - limited to low forces
- tip:
  - Ø = 18 mm
  - 5 diff. shapes
- evaluation of a penetration test:
  - force vs. depth - diagram

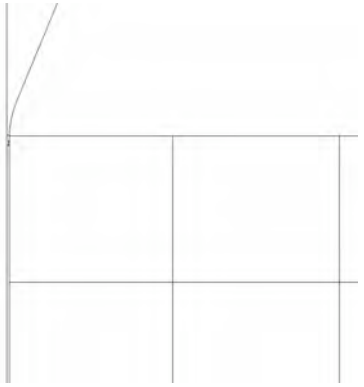




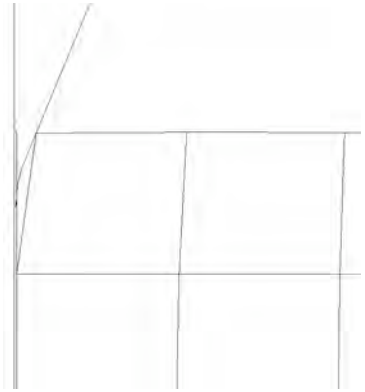


Numerical Modelling

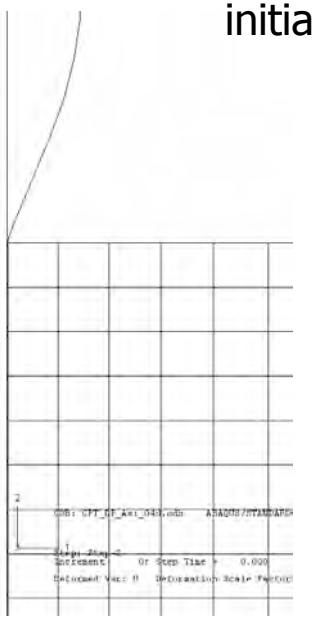
- Finite Element Method
- software: ABAQUS 6.5
- requirements:
  - axisymmetric modelling
  - separate modelling of penetrometer and sample
  - large displacements
  - interface soil-penetrometer
  - „left" boundary
  - adaptive mesh (AM)



initial



after 2.5 mm



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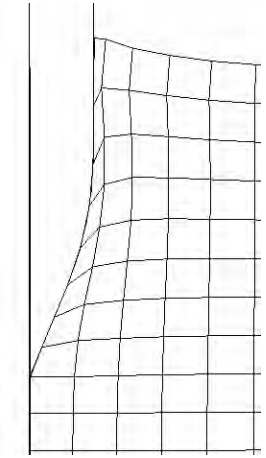
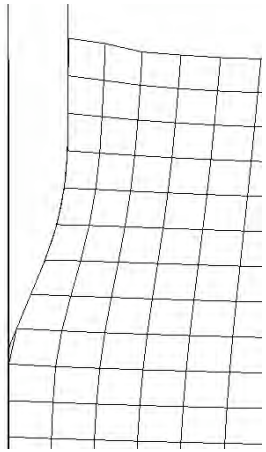


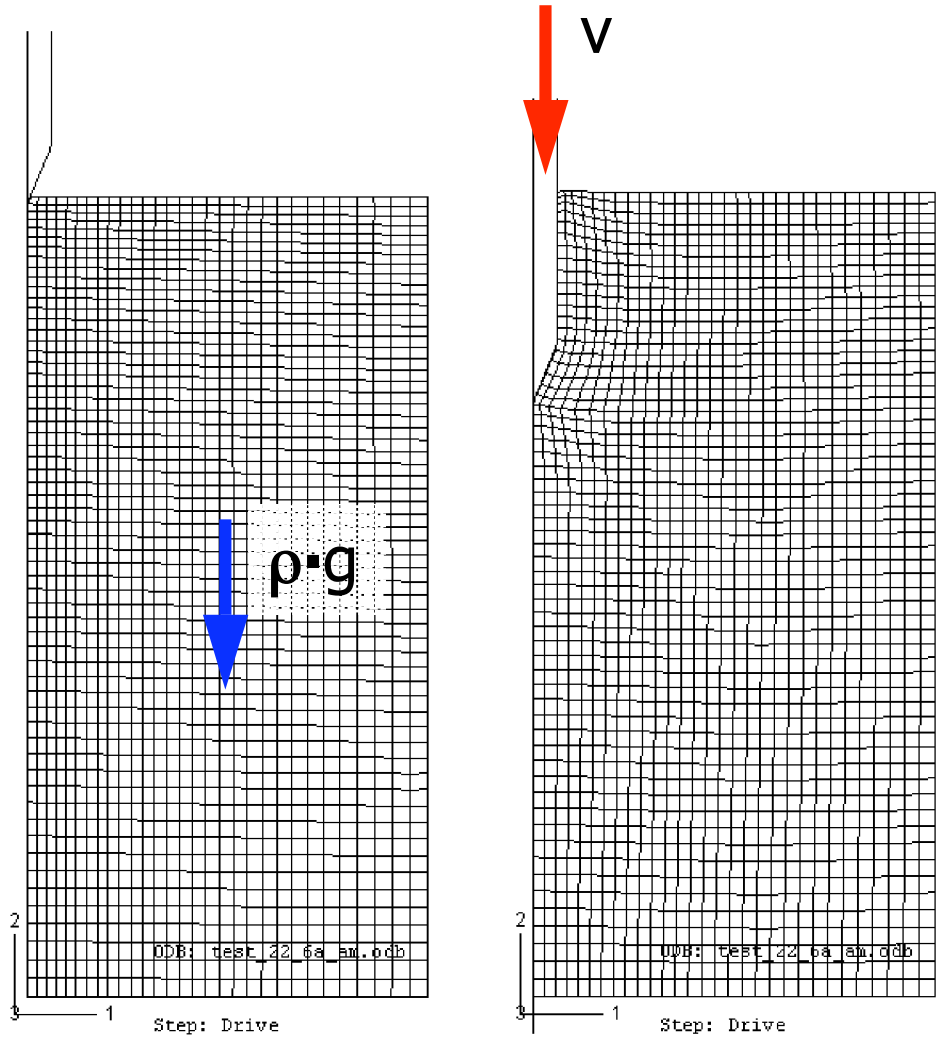
without AM



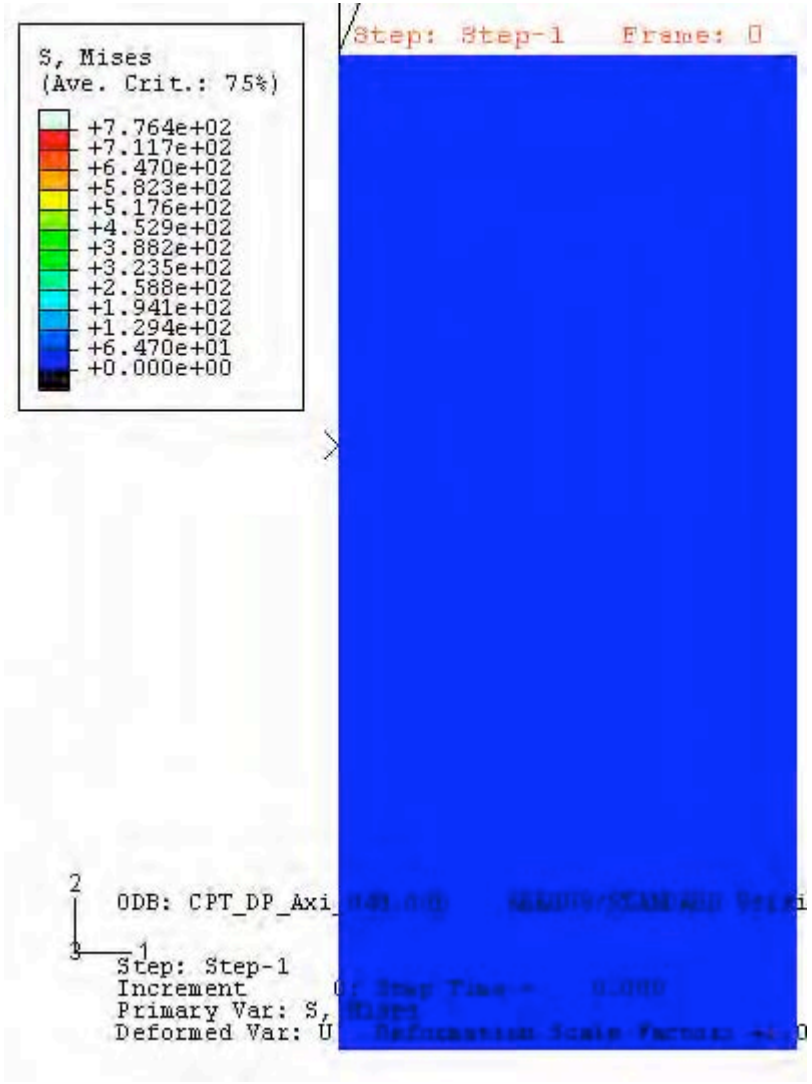
with AM

Numerical Modelling

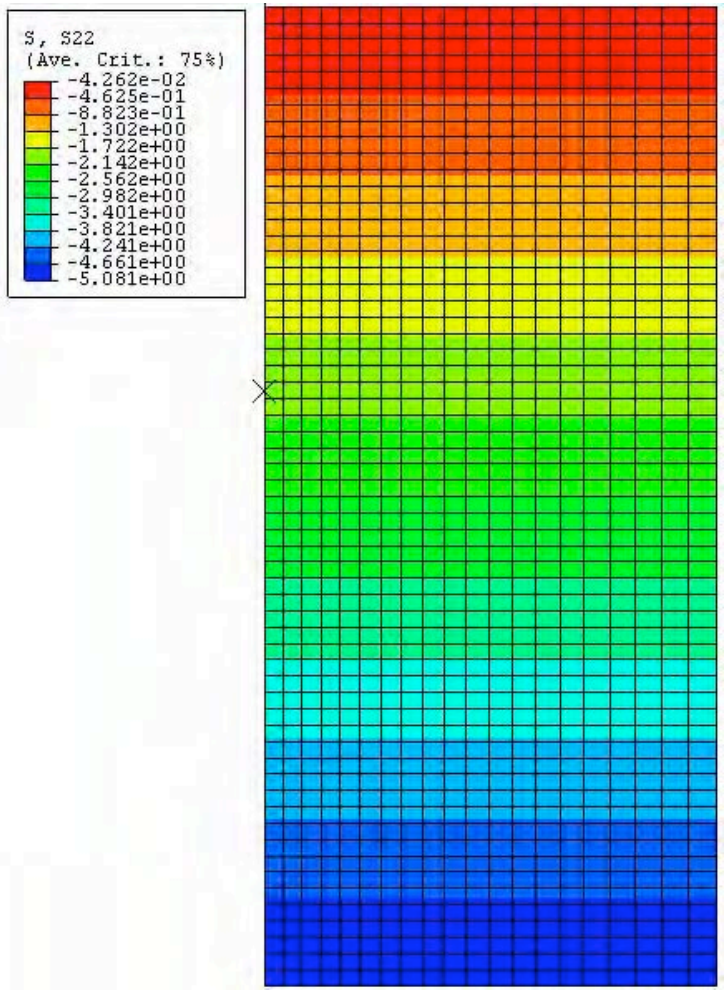
- geometry: equal to the test
- discretisation: 1200 4-noded elements
- constitutive model:
  - linear Drucker-Prager-model with hardening approach
- calculation steps:
  - 1. initial conditions
  - 2. penetration of the cone with constant velocity



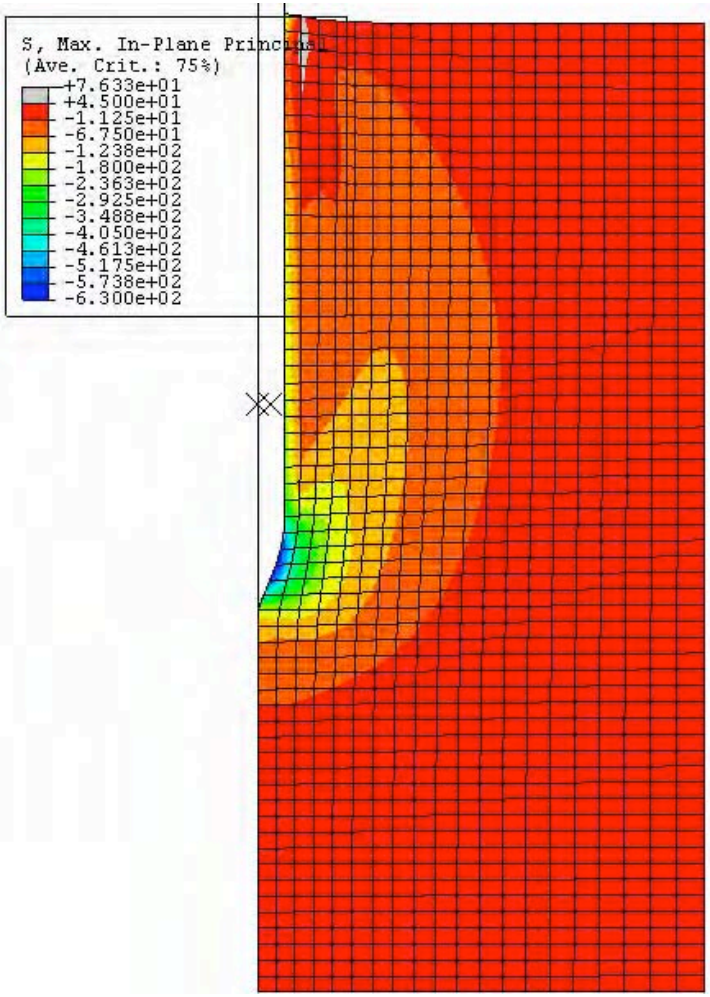
Numerical Simulation - Video



Results

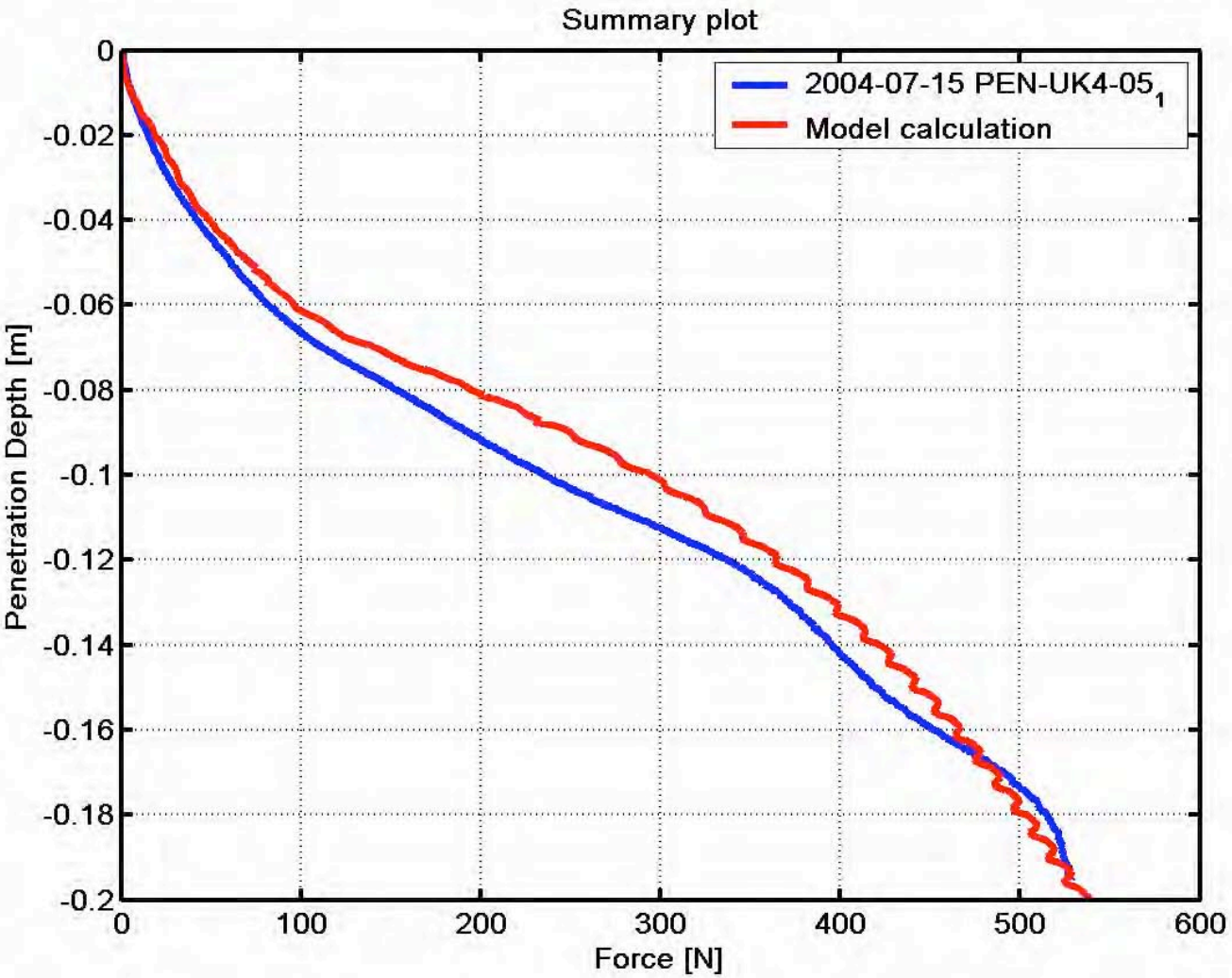


initial conditions: vertical stress



max. depth: principal stresses

Laboratory Test vs. Numerical Simulation



Conclusions

- The presented model enables an accurate modelling of the penetration process
- The main parameters can be calibrated using the results of the laboratory tests
- Different constitutive models can be implemented
- Parametric studies can be done more effective because fewer laboratory tests are necessary:
  - Geometry of the cone
  - Material parameters
  - Boundary conditions (gravity)

Thank You for your attention