Supplement of Saf. Nucl. Waste Disposal, 2, 65–65, 2023
https://doi.org/10.5194/sand-2-65-2023-supplement

SaND
Safety of Nuclear Waste Disposal
Open Access

Supplement of

On the influence of initial stress on final stress in data-calibrated numerical geomechanical models

Tobias Hergert et al.

Correspondence to: Tobias Hergert (tobias.hergert@kit.edu)

Karlsruhe Institute of Technology
TECHNISCHE UNIVERSITÄT DARMSTADT
GFZ Helmholtz Centre POTSDAM
SpannEnD 2.0
Funded by BGE BUNDESGESELLSCHAFT FÜR ENDLAGERUNG

About the influence of initial stress on final stress in data-calibrated numerical geomechanical models

Tobias Hergert [1], Steffen Ahlers [2], Luisa Röckel [1], Sophia Morawietz [3,4], Karsten Reiter [2], Moritz Ziegler [3], Birgit Müller [1], Oliver Heidbach [3,4], Frank Schilling[1], Andreas Henk [2]

[1]Institut für Angewandte Geowissenschaften, KIT, 76131 Karlsruhe, Germany
[2]Institut für Angewandte Geowissenschaften, TU Darmstadt, 64287 Darmstadt, Germany
[3]Helmholtz Zentrum Potsdam, Deutsches GeoForschungsZentrum GFZ, 14473 Potsdam, Germany
[4]Institute of Applied Geosciences, TU Berlin, 10587 Berlin, Germany

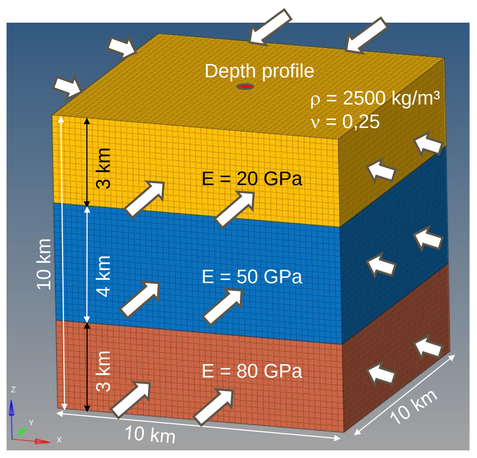
Email: tobias.hergert@kit.edu

1. Motivation

Planning and operation of subsurface facilities for waste storage require knowledge about the stress state at depth. Data-calibrated numerical models provide an adequate method to assess the stress conditions (e.g. safeND2023 contributions in session S07 by Ahlers *et al.* and Reiter *et al.*).

In general, such stress simulations require a definition of an initial stress state. Here we analyse how the choice of initial stress affects the final stress in data-calibrated models in areas of the model domain with no measured stress.

2. Generic model



A generic cubic-shaped numerical 3D model is considered consisting of three units with increasing Young's modulus E with depth (Fig. 1). Poisson's ratio ν and density ρ are assumed as constant. The base of the cube is free to move horizontally but constrained vertically. Horizontally directed displacement boundary conditions are applied at the vertical boundaries to account for tectonic stress. Gravity acts as a body force. The finite element software package Simulia Abaqus is used.

Fig. 1 Geometry, dimensions and rock properties (E, ν, ρ) of the generic numerical model.

3. Modelling approach

- An initial stress state is prescribed in order to
  - maintain the implemented (observed) geometry of interfaces, faults, etc. under the force of gravity
  - increase the ratio of horizontal to vertical stress towards a realistic reference stress state
- Initial stress (Fig. 2a) and subsequent acting of horizontal forces (representing tectonic stresses) (Fig. 2b) result in the final stress state

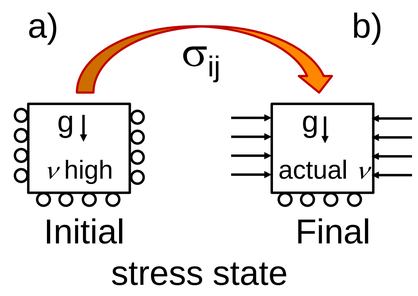
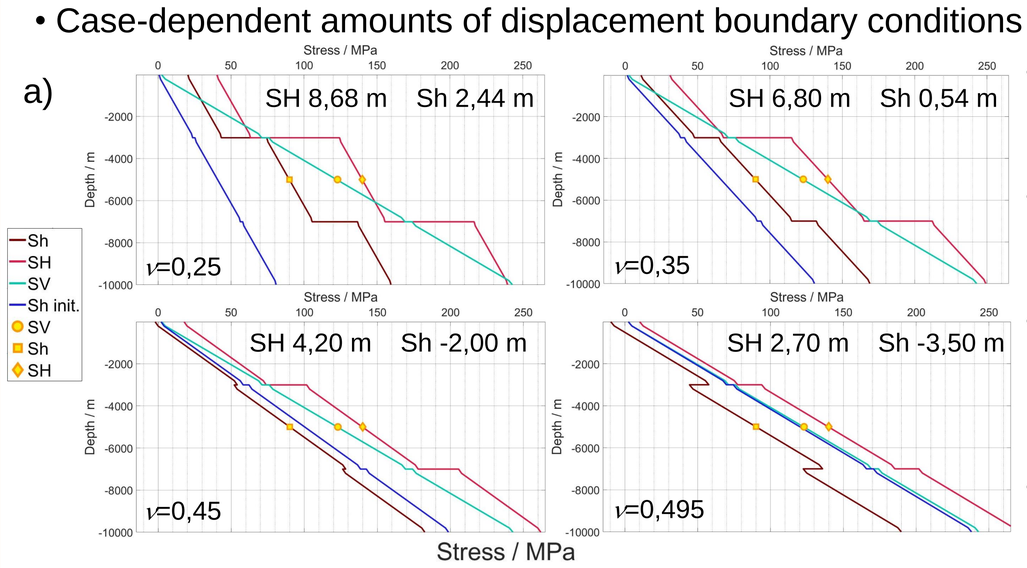


Fig. 2 Sketch showing how initial and final stress is established. a) Inital stress: a high Poisson's ratio is used while gravity acts under uniaxial strain conditions. The resulting state of stress is included in an undeformed model domain. b) Final stress state: displacement boundary conditions are applied at the vertical boundaries of the model domain to account for tectonic stress.

4a. Initial and final stress

- Four different initial stress states (given by ν = 0,25 / 0,35 / 0,45 / 0,495 in Fig. 2a; 3a)
- Predefined calibration data at 5 km depth
- Case-dependent amounts of displacement boundary conditions to fit the data (Figs. 2b; 3a)

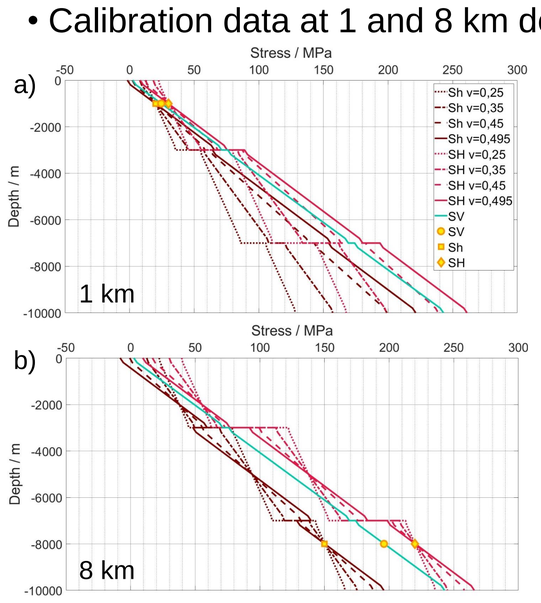


- Stress gradient in final stress correlates with initial stress
- Steps at interfaces decrease with increasing initial stress
- High horizontal stress at the surface at low initial stress, negative S_h magnitudes at high initial stress
- Partly change of tectonic regime at low initial stress
- Largest deviations between considered cases at interfaces
- Depth-dependent prediction quality
- There are distinct depths at which final stress is independent on initial stress. Differential stresses at these depths are proportional to Young's modulus in these units

Fig. 3 Stress paths for different initial stresses defined by variable Poisson's ratios (Fig. 2a) matching the calibration data at 5 km depth altogether. a) Individual cases, b) all stress paths

4b. Depth of data

- Calibration data at 1 and 8 km depth



- With shallow calibration data uncertainties in final stress related to the choice of initial stress increase with depth
- With deep calibration data variability in final stress is lower

Fig. 4 Stress paths for different initial stresses matching calibration data at 1 km (a) and 8 km (b) depth.

4c. Non-uniform BC's

- Depth-gradient in displacement boundary conditions
- Final stress state independent on choice of initial stress in the unit with calibration data

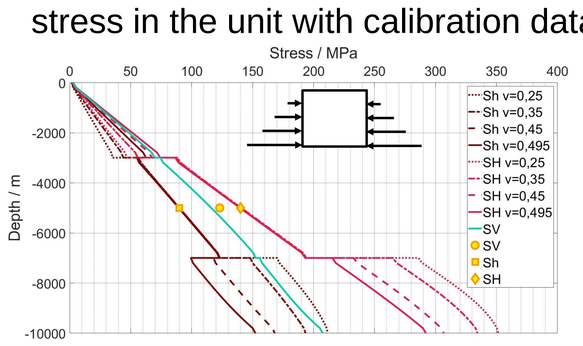


Fig. 5 Stress paths for different initial stresses matching calibration data at 5 km depth using non-uniform displacement boundary conditions

5. Conclusions

- The final stress state in data-calibrated models depends on the choice of initial stress for areas in which no data exist
- This uncertainty needs to be accounted for in addition to the uncertainties of the rock properties and of the stress data themselves