A SENSITIVITY STUDY OF THE LONG-TERM BEHAVIOUR OF AN EXCAVATION IN CLAYSTONE WITH A YIELDABLE SUPPORT SYSTEM

Miguel A. Manica[1], Philipp Herold[2], Eric Simo[2]

[1]*Institute of Engineering, National Autonomous University of Mexico, Mexico City, Mexico*
[2]*BGE TECHNOLOGY GmbH, Peine, Germany*

8TH INTERNATIONAL CONFERENCE
13-16 June 2022 - Nancy (France)
ON CLAYS IN NATURAL AND ENGINEERED BARRIERS FOR RADIOACTIVE WASTE CONFINEMENT

Introduction

Within the R&D project "Support Structures of Underground Openings in a HLW/SF Repository in Claystone – AGEnT", BGE TECHNOLOGY GmbH and its partners developed lining systems for future high-level waste and spent fuel repositories in claystone. The current concept involves a concrete based support structure made of wedge blocks, combined with a compressible grout material in the extrados to moderate the interactions between the lining and the host rock. However, the compression capacity of the grout may be exhausted during service life by the long-term deformation of the host rock, resulting in a nonuniform increase of load transferred to the lining and a corresponding increase of internal forces. Therefore, the correct characterisation of the long-term behaviour of the host rock appears essential for the performance assessment of repositories. The present work involves a sensitivity study of the parameters characterising the creep deformation component of a constitutive model (Mánica et al. 2021) used to represent the claystone formation in the long-term simulation of a representative drift.

Host Rock Formation Model

- The constitutive model used to characterise the behaviour of host rock formation is that put forward by Mánica et al. (2021).
- It incorporates a number of features that are considered relevant for the satisfactory description of indurated clays:
  - a nonlinear yield criterion
  - strength and stiffness anisotropy
  - strain-softening
  - a non-associated flow rule
  - rate-dependency
  - creep deformations,
  - permeability increase with damage
  - nonlocal regularisation

Creep Deformation Mechanism

$$\mathrm{d}\boldsymbol{\epsilon}^{\mathrm{c}} = \dot{\boldsymbol{\epsilon}}^{\mathrm{c}}\mathrm{d}t$$

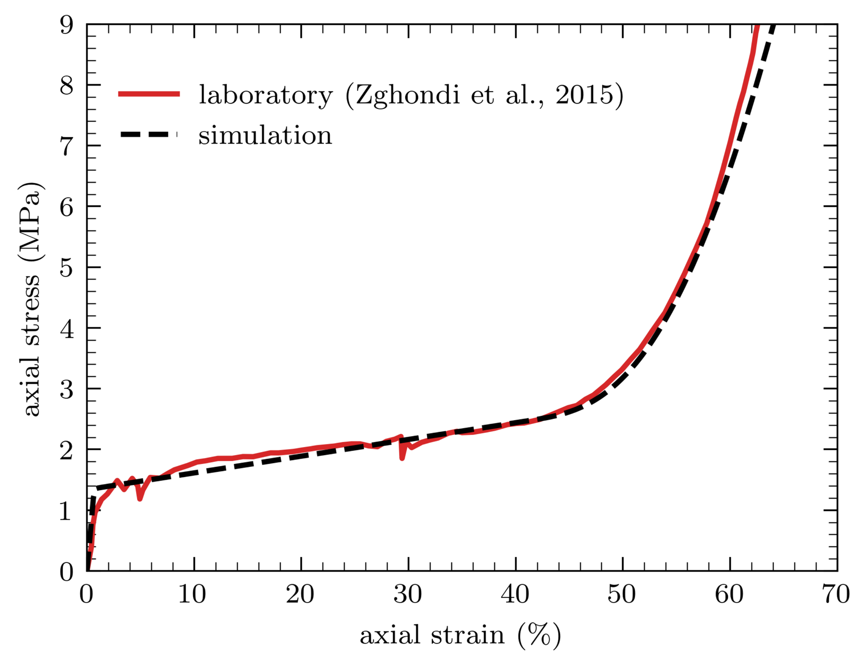
$$\dot{\boldsymbol{\epsilon}}^{\mathrm{c}} = \begin{cases} \mathbf{0} & \text{if } \epsilon^{\mathrm{p}}_{\mathrm{eq}} \le \epsilon_{\mathrm{thr}} \\ \gamma \mathrm{e}^{(-m\epsilon^{\mathrm{c}}_{\mathrm{eq}})}\left(\mathbf{s} + \mu p' \mathbf{I}\right) & \text{if } \epsilon^{\mathrm{p}}_{\mathrm{eq}} > \epsilon_{\mathrm{thr}} \end{cases}$$

$$\epsilon^{\mathrm{c}}_{\mathrm{eq}} = \left(\boldsymbol{\epsilon}^{\mathrm{c}} : \boldsymbol{\epsilon}^{\mathrm{c}}\right)^{1/2}$$

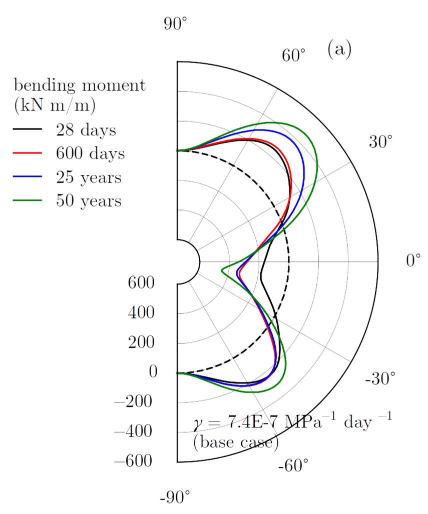
- γ controls the initial strain rate
- m controls the reduction of the strain rate as creep deformations accumulate over time
- μ controls the amount of volumetric creep strains
- ϵ_{thr} is a threshold plastic strain from which the creep mechanism is activated

Compressible Grout Material Model

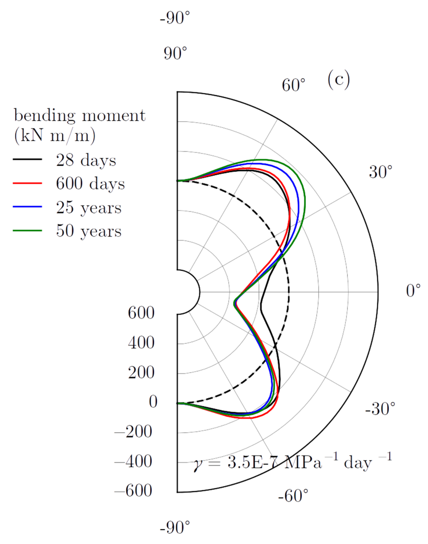
- Simple elastoplastic strain-hardening model
- Once the yield pressure is reached, the material can deform substantially with a small increase in stresses.
- However, for large deformations, the compression capacity can be exhausted and the stiffness can increase again.

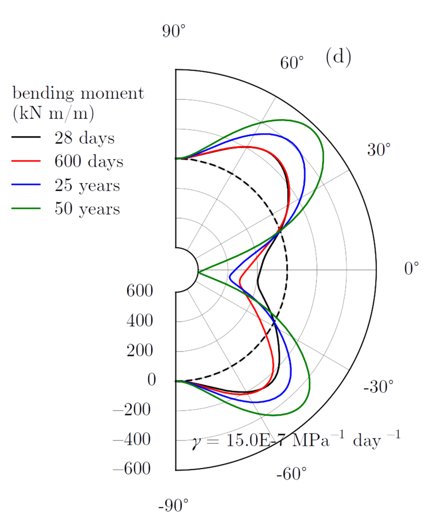


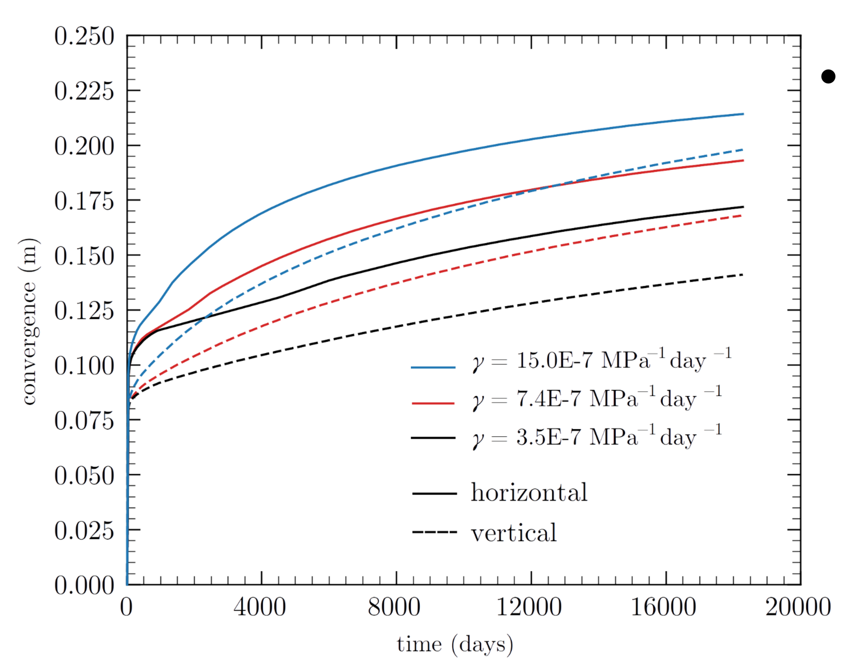
Results Obtained



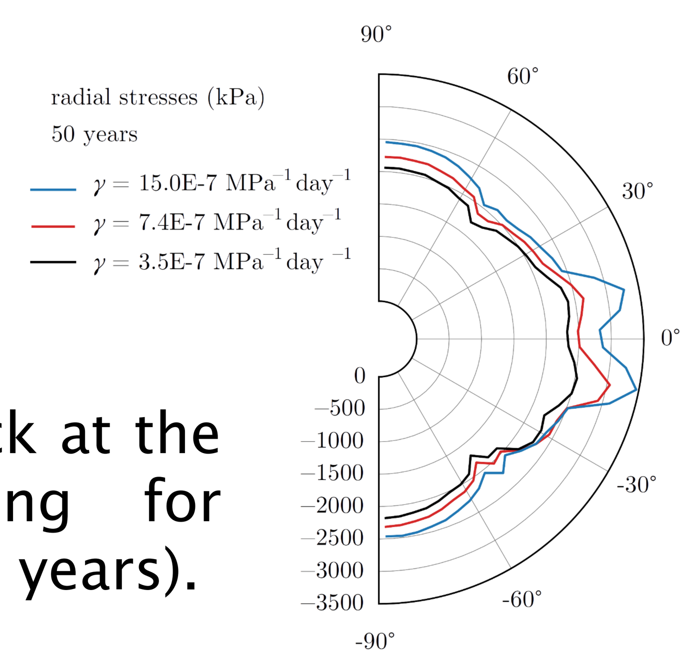
- Evolution of bending moments in the lining for different values of the creep parameter γ.







- Rock convergences in the rock for different values of γ.



- Radial stresses in the rock at the contact with the lining for different values of γ (50 years).

Conclusions

- The long-term behaviour of the excavation is mainly controlled by the creep deformation mechanism, which in turn controls the evolution of internal forces in the lining. The latter also depends strongly on the interactions of these deformations and the compressible grout material in the extrados.
- For some creep parameters, long-term deformations can exhaust the compression capacity of the grout, with a significant increase in internal forces.
- The time-dependent behaviour of the host rock cannot be disregarded in the design of repositories.

References

- Mánica M A, Gens A, Vaunat J, Armand G, Vu M-N (2021) Numerical simulation of underground excavations in an indurated clay using non-local regularisation. Part 1: Formulation and base case. *Geotechnique* 1-21.
- Herold, P.; Simo, E.; Räuschel; H.; Engelhardt, H.-J.; te Kook, J.; Pflüger, B.; Scior, C.; Studeny, A. (2020) Ausbau von Grubenbauen für ein HAW-Endlager in Tongestein, Abschlussbericht, BGE TEC 2020-26, BGE TECHNOLOGY GmbH, Peine

BGE TEC
BGE TECHNOLOGY GmbH
INSTITUTO DE INGENIERÍA UNAM
MANAGED BY
PTKA Project Management Agency Karlsruhe
Karlsruhe Institute of Technology
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag