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DOI
10.6084/m9.figshare.14773023.v1

Publication date
2021

Document Version
Final published version

Citation (APA)
Escanellas, A., Cámara, E., Liaudat, J., & Carol, I. (2021). *Experimental and numerical study of the time dependent behavior of fracture propagation in salt rock*. Abstract from The Biot-Bažant Conference on Engineering Mechanics and Physics of Porous Materials and Structures, Evanston , United States. https://doi.org/10.6084/m9.figshare.14773023.v1

Experimental and numerical study of the time dependent behavior of fracture propagation in salt rock

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Abstract:
In underground salt and potash mines, such as the ones in the region of Bages in central Catalonia, long-term deformations and stability of the mine tunnels are strongly influenced by the viscous (creep) behavior of saline rock. Tunnel excavation causes deviatoric stresses which in turn trigger creep strain in the salt rock. It has been often considered that the main consequences of creep are time-dependent convergences with potential consequences for the serviceability of the mine. However, creep deformations may be accompanied by stress redistribution, and potentially also by cracking and fracture, especially if rock exhibits pre-existing discontinuities and/or layers separated by weaker contacts. In this way, tunnel cross-sections that are perfectly stable after excavation, with time may not only deform, but also approach failure collapse.

Traditionally, salt rock has been mainly characterized with regard to the creep behavior, while strength issues have been addressed independently in ways similar to other rock materials, via strength criteria such as Mohr-Coulomb, etc. However, there seem to be very few studies considering the fracture mechanics of salt rock.

In this paper, the on-going experimental and numerical research along this line at ETSECCPB-UPC is described. This includes standard creep tests as well as mode I fracture Wedge Splitting Tests (WST). WSTs have been performed at different loading rates with the purpose of assessing the time dependency of parameters such as the tensile strength and the specific apparent fracture energy. Preliminary test results show that as the loading rate is increased, the tensile strength seems higher but the apparent fracture decreases.

Numerical calculations include finite element simulations of the WST, as it has been done before for other rock types by some of the authors[1]. Continuum elements with visco-elastic behavior were used to represent the salt rock material, while the fracture path was represented via pre-inserted zero-thickness interface elements. As a first attempt, the constitutive model used for the interface elements was a (time-independent) elasto-plasticity framework with fracture energy-based evolution laws[2]. The preliminary numerical simulations qualitatively reproduce the experimental results, however, it seems that in order to quantitatively fit the experimental results, a new time-dependent constitutive model for the interface elements would be required in which fracture properties and evolution should interact with creep and time-dependent behavior.

[1] Liaudat, J. et al. (2015). Numerical modelling of the Wedge Splitting Test in rock specimens, using fracture-based zero-thickness interface elements. In *COMPLAS XIII*: proceedings of the XIII International Conference on Computational Plasticity: fundamentals and applications (pp. 974-981). CIMNE.

[2] Carol, I., Prat, P.C., and López, C.M., 1997. A normal/shear cracking model. Application to discrete crack analysis. *ASCE J. Engrg. Mech.*, 123(8):765–773