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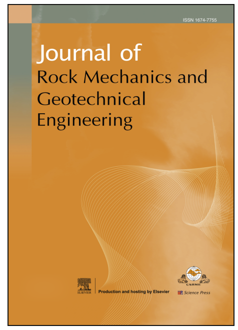

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Investigation of creep behaviours of gypsum specimens with flaws under different uniaxial loads

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Abstract: The aim of this study is to identify the influence of the dip angle of a pre-existing macrocrack on the lifetime and ultimate deformation of rock-like material. Prediction of lifetime has been studied for three groups of specimens under axial static compressive load levels. The specimens were investigated from 65% to 85% of UCS (uniaxial compressive strength) at an interval of 10% of UCS for the groups of specimens with a single modelled open flaw with a dip angle to the loading direction of 30° (first group), at an interval of 5% of UCS increment for the groups of specimens with single (second group), and double sequential open flaws with a dip angle to the loading direction of 60° (third group). This study shows that crack propagation in specimens with a single flaw follows the same sequences. At first, wing cracks appear, and then shear crack develops from the existing wing cracks. Shear cracking is responsible for specimen failure in all three groups. A slip is expected in specimens from the third group which connects two individual modelled open flaws. The moment of the slip is noticed as a characteristic rise in the axial deformation at a constant load level. It is also observed that axial deformation versus time follows the same pattern, irrespective of local geometry. Specimens from the first group exhibit higher axial deformation under different load levels in comparison with the specimens from the second and third groups.

Keywords: crack propagation; rock-like material; lifetime prediction; static compressive load; macrocrack; wing crack

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1. Introduction

Cracks in rocks can be the result of an excavation process and the redistribution of in situ stress field around the excavation. The excavation disturbed zone (EDZ) is of great interest for underground structures, which should maintain stable and be sealed for a long period of time. Displacements in the surrounding rocks could possibly trigger surface settlements and – in the case of radioactive waste management – contamination of the surrounding rock mass or biosphere. The aim of this study is to identify the influence of the dip angle of a pre-existing macrocrack on lifetime. By preparing specimens with defined crack geometry, we consider cases of underground structures where cracks with representative orientation are expected due to the primary stress state and the relative alignment of the underground opening.

Literature review shows that rock subjected to compressive stress displays characteristic fracture phenomena associated with different deformation characteristics. Bobet and Einstein (1998) conducted uniaxial and biaxial compression experiments to investigate crack patterns and temporal evolution of crack development in specimens of artificial rock-like material. Wong and Einstein (2009) followed a comparable experimental approach to observe crack coalescence in specimens prepared from gypsum as well as marble at macroscopic and microscopic scales, respectively. In these studies, different crack mechanisms, crack coalescence categories with different crack types and trajectories were identified. The influence of flaw geometries and material properties on the underlying mechanisms was documented. The effect of single and multiple flaws on the cracking behaviour under different geometries has been studied by Zhou et al. (2014). More recently, the cracking process was analysed using numerical calculation schemes and a deeper insight into the failure modes was gained (e.g. Cao et al., 2016; Liu et al., 2016).

Somehow independent of the first investigations, approaches towards lifetime prediction for rocks under static compressive and tensile loads were presented by Konietzky et al. (2009). In their work, a new simulation approach was introduced. The approach is mainly based on numerical calculation results gained from prismatic specimens containing regularly spaced flaw-like damage. Damjanac and Fairhurst (2010) proposed an exponential correlation between load level and time-to-failure. Further, the explicit consideration of time-dependent damage due to critical crack growth and damage evolution due to the subcritical crack growth until final failure was presented by Chen and Konietzky (2014) and Chen et al. (2015).

As stated by Bieniawski and Bernede (1979), laboratory experiments present an effective way to investigate the influence of applied stresses on rock-like materials. One of the most fundamental conclusions drawn from the early experimental study by Wong and Einstein (2006) is that tensile wing cracks are the first cracks in fracture propagation from existing flaws where most cases are independent of aperture and material.

Stability analysis for underground openings typically involves a comparison between the stresses field surrounding the excavation and the UCS (uniaxial compressive strength) of host rock. Once stress redistribution results in a critical imbalance of energy, the crack propagation is induced. Regardless of the rock type, in the case of rock-like material, the microscopic processes and further macroscopic

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