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How understanding true triaxial stress states can help in assessing the safety of mine openings?

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ABSTRACT

Knowledge of mining-induced stresses is a fundamental requirement for the safe design of underground mine openings including the selection of appropriate rock support systems. Most of the popular rock failure criteria postulate that the intermediate principal stress has no influence on the failure mechanism. However, specialized research (Kwasniewski et al. 2011) showed that this stress component influences both the shape of the failure envelope and the post-failure behaviour. In fact, for a given value of the minor principal stress, variation of the intermediate principal stress can significantly change the post-failure behaviour in terms of brittleness or ductility. A true-triaxial testing device allows investigating those effects in laboratory on small rock cubes (Tshibangu 1994). True-triaxial tests were performed on several rock materials, among which three limestones (Descamps & Tshibangu 2011). For compact limestones, the strength and the compactive strain increase with the intermediate principal stress. The effect is particularly visible at low minor principal stresses. For a porous limestone, the influence of the intermediate principal stress on the strength is not so obvious. However, the rock behaviour becomes more brittle. Figure 1 shows for the Vosges sandstone the shapes of limiting envelopes on the octahedral plane of 100 MPa. The hardening mechanism evolves from ductile in the classical triaxial state ($\sigma_2 = \sigma_3$) to more brittle for the triaxial extension ($\sigma_1 = \sigma_2$). This is identified by the distance between the elastic limit envelope and the failure one.

Optimizing the design of underground openings is still challenging in terms of stability as can be shown by some historical cases of collapse. For most mining countries, shallow deposits have been depleted, forcing mining operations to go deeper. South Africa is a typical example whereby gold mines are currently approaching four thousand meters of depth. Such extreme conditions have an influence on the rock material behaviour that needs an in-depth understanding. This issue is largely addressed in the country, especially in terms of rockburst.

In terms of modelling, one of the challenges is probably to feed the models with realistic constitutive laws that integrate the complex behaviour of rock masses. Based on experimental results in meridian and deviatoric sections, a new failure criterion was proposed to include the influence of the intermediate principal stress (Descamps et al. 2012). When assessing the state of stresses in the walls of mining openings, the tensor is truly triaxial. Implementing this evolution in a numerical model will help in understanding some “abnormal” cases of stability of underground openings.

References

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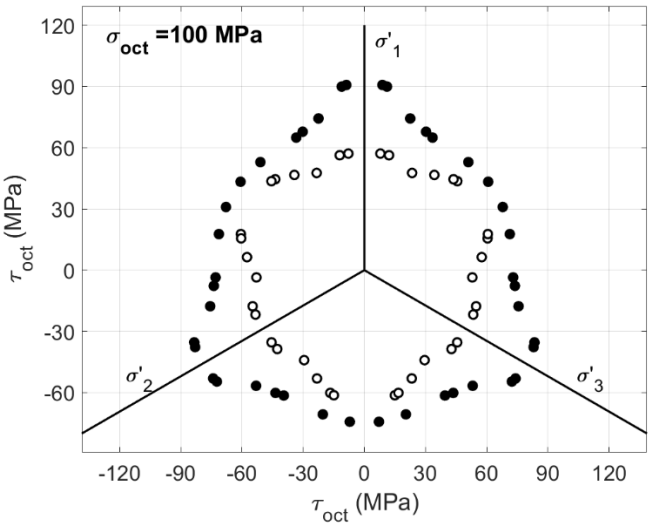

Figure1: Elastic and failure envelopes of the Vosges sandstone on the 100MPa octahedral plane.

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