

# **Hydro-mechanical analysis of the fracturing induced by the excavation of nuclear waste repository galleries using shear banding**

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## **Abstract:**

The long-term management of high-level nuclear wastes is envisaged by deep geological repository. Due to the safety function of the host formation, the behaviour of the Excavation Damaged Zone (EDZ) that develops around underground galleries during their drilling is of paramount importance. The EDZ is dominated by fracturing process which engenders irreversible modifications of the hydro-mechanical properties of the porous rock. In this zone, a significant hydraulic permeability increase of several orders of magnitude is observed. It may alter the safety function of the host formation by creating preferential flow paths for the migration of radionuclides towards the biosphere. Consequently, the understanding and the prediction of the EDZ hydro-mechanical behaviour are crucial issues for the long-term management of nuclear wastes. Among the different low-permeability media that are envisaged for the deep repository, the Callovo-Oxfordian claystone is studied.

The fracturing behaviour, the water transfers, and the coupled processes that occur around the underground galleries are most particularly addressed, especially in the EDZ. The fractures induced by the excavation process are reproduced with strain localisation in shear bands. An appropriate model allowing to properly reproduce the strain localisation in geomaterials with finite element methods is used. It is an enhanced model for microstructure media called the coupled local second gradient model and which involves a regularisation method. Its application is extended to unsaturated anisotropic rocks with compressible solid grains. The numerical modelling of the fractured zone with shear banding provides information about its shape, extent, fracturing structure, and behaviour that are in good agreement with in situ measurements. In particular, the shape of the EDZ in the Callovo-Oxfordian claystone is governed by its anisotropy and the gallery convergence strongly depends on the appearance of the shear bands.

The fluid transfers and the coupled processes are investigated in the EDZ. The impact of the rock fracturing on its hydraulic properties is addressed by taking into account strain localisation effects at macroscale. The evolution of the intrinsic water permeability is expressed by a strain-dependent relation which engenders a more pronounced increase of the permeability inside the shear bands. In agreement with experimental measurements, an important increase is reproduced in the excavation damaged zone. After gallery excavation, the hydraulic transfers in the rock surrounding the galleries are investigated by considering the interaction between the rock and the gallery air. These transfers are studied at large-scale during the reproduction of gallery air ventilation. Depending on the air hygrometry, the gallery ventilation implies drainage and desaturation of the surrounding rock which affect the shear banding development. The hydraulic transfers in the rock which depend on the water exchanges at gallery wall are also studied.

The proposed approach aims to highlight the important hydro-mechanical aspects to take into account for the reproduction of the EDZ behaviour in unsaturated biphasic media with shear banding. The focus is resolutely on the large-scale numerical modelling of the EDZ as well as on the reproduction of the mechanical and hydraulic experimental measurements performed around galleries.

**Keywords:** Excavation damaged zone - Fracturing - Numerical modelling - Strain localisation - Shear banding - Unsaturated anisotropic rock