Probabilistic performance assessment of a deep tunnel for a radioactive waste repository in French COx claystone

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Probabilistic performance assessment of a deep tunnel for a radioactive waste repository in French COx claystone

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Abstract

A preliminary probabilistic study of the stability of a circular drift excavated for a radioactive waste repository in the French Callovo-Oxfordian claystone is presented and discussed. An analytical mechanical model assuming isotropic elastic behaviour and linear plastic softening was used. Particular emphasis here is placed on the uncertainty of mechanical property values. The test results from several laboratories showed considerably variable property values and they have been interpreted statistically in this investigation. The obtained statistical results were used in a Monte Carlo framework. The performance of the drift was evaluated in terms of the probability of threshold exceedance in the extent of the plastic zone.

Introduction

One of the main objectives of research programs for feasibility studies for deep geological repository of radioactive waste is the performance and safety assessment of disposal tunnels. In the case of variable material property values of the host rock, probabilistic calculations can be carried out to determine the probability of unsatisfactory performance. For example, Arnold et al. [1] implemented a simplified probabilistic framework based on an analytical Drucker-Prager softening model and investigated the probability of exceedance of a certain plastic limit around the proposed disposal drifts in the Dutch Boom Clay. This paper seeks to gain more confidence in the proposed analytical model when applied in a preliminary tunnel stability assessment, by first comparing the predicted radial displacement with the measurements that are available in the French disposal drifts at the Meuse/Haute-Marne (MHM) URL. To this end, the variability in the mechanical and deformation properties in the COx claystone was first characterised by reinterpreting the test results from various laboratories. Then, the results are used as input in the reliability-based framework to assess the performance of a disposal drift in terms of the probability of having a plastic zone.

Probabilistic interpretation of the test results

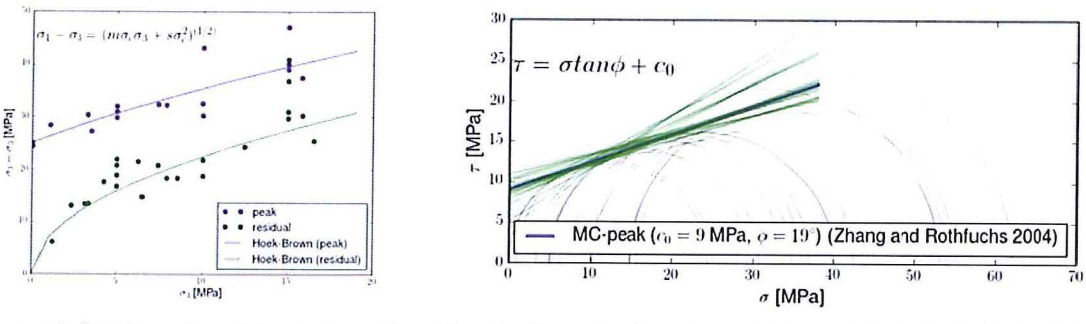

Figure 1: Peak and residual strength of the Callovo-Oxfordian argillite at MHM-URL (After [2]) (left) and Mohr circles (grey) and failure envelops (green) reinterpreted from left figure (right)

The data from different laboratories showed considerable variabilities. This has been interpreted probabilistically in this section to obtain point statistics used in the Monte Carlo simulation in the next section. Figure 1 (left) shows the peak and residual strength of the COx clay at MHM URL from ANDRA and GRS [2]. Based on the values σ_1 and σ_3 in the left figure, the Mohr circles are first plotted pair by pair. Then a straight line that is tangential to the two circles is defined (i.e. the failure envelope defining c_0 and ϕ). In this way, multiple envelop lines can be defined, resulting in a range of values for c_0 and ϕ. The same procedure was repeated for the data points at residual state. The distributions of ϕ, c_0 and c_r are shown in Figure 2 in terms of mean (μ), standard deviation (σ) and the coefficient of variation (cov). A normal distribution is seen to fit to of the tangential modulus is assumed to be approximately half that of elastic modulus and the COV is assumed to be the same, as little data is available about the tangential modulus.

Monte Carlo simulation

The GCS drift has been analysed in this section. It has a circular section with a radius of 2.6 m. As it was excavated with a road header, an over excavation (overcut) of 15 mm is used in the simulation. The support (fibre shotcrete) was 21 cm thick [4]. The drift was parallel to σ_H, and the initial in situ stress state was quasi-isotropic (σ_H = *16.12 MPa*, σ_h = σ_v = *12.4 MPa*) [5]. A pore water pressure of $u_{w,0}$ = 4.5 MPa was used at a depth of -490 m. The statistics in Table 1 were used in the MC simulation, assuming truncated normal distributions. The results are shown in Figure 4 and the radial displacements (Figure 4 left) are compared to the measurements [6].

Results/Discussion

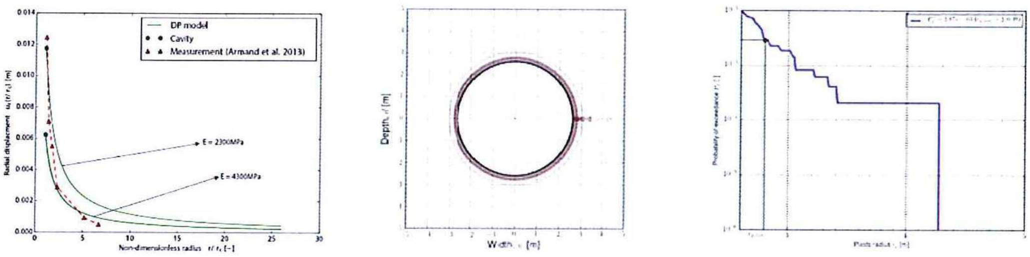

Figure 4: Deterministic radial displacement (left), plastic radius around the tunnel opening (middle, plastic softening zone in grey and plastic residual zone in red) and probability of exceedance (P_f) of a plastic zone limit ($r_{p,lim}$) (right)

Conclusion

The preliminary assessment compares favourably well with radial displacement measurements. The proposed probabilistic framework provides a way to assess the probability of unsatisfactory performance in terms of the exceedance of a certain plastic limit. However, the idealised isotropic DP model is not able to predict the anisotropic convergence measurements.

Acknowledgments

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