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# TRIDIMENSIONAL NUMERICAL FINITE ELEMENT METHOD TO SIMULATE DEEP TUNNELS WITH SHOTCRETE LINING

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Stabilizing underground openings such as tunnels excavated in rock mass remain a major concern of geotechnical engineers dealing with this kind of structures.

In tunnels, the rock mass strain and the ground pressure on lining depend on characteristics of the rock mass as well as of the geometry, the stiffness and the moment of the lining installation.

Pressure variation on lining and strain are caused by the advancement of excavation, and the time-dependent properties of the rock mass and lining.

This paper describes the numerical implementation of constitutive laws in the numerical code ANSYS. It is performed a numerical simulation with 3D finite elements of a deep tunnel. The rock mass presents the viscoplastic law of Perzyna. The shotcrete is modeled as a viscoelastic material with the constitutive laws of the Maxwell and the Kelvin chain model, proposed by Bazant. So the characteristics of the viscoelastic shotcrete changes with time until the stabilization. Both chain models had to be calibrated by comparing with de FIB Model Code (2010).

The finite elements simulation is performed by incorporating subroutines for the viscoelastic shotcrete model in the ANSYS code. The method to simulate the tunnel excavations is by activating and deactivating elements in sequential steps.

In the first part of the paper two validations are performed. The analytical solution and the deformation achieved on the stabilization in the ANSYS code are compared for the validation of an unlined tunnel. For a lined tunnel, validation is performed by comparing the results of the GEOMEC91 code with the ANSYS code. The results of the ANSYS code agree perfectly with the analytical model and the GEOMEC91 one.

Also a parametric study is undertaken with the ANSYS code varying some relevant parameters.

Finally, it is simulated a real experimental tunnel, which in situ measured data is available. The comparison of this data with the results from the ANSYS code shows a very good approximation.