Simulation of the unsupported tunnel excavation using a 3D steady-state numerical method

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The simplified tunnelling design methods based on the convergence-confinement method and the self similarity principle from Corbetta were obtained from 2D axisymmetric models within an empirical approach. We propose a 3D numerical approach which aims to expand the application of the usual methods for various rock criteria, and with the perspective to use it for nonsymmetrical geometry and different excavation methods. The results are obtained on a 3D version of a cylindrical tunnel with usual criteria: the Von Mises, the Drucker-Prager and a smooth version of the Hoek-Brown criteria. The ground type is supposed to be a rock mass, and the effect of the gravity is neglected (which represents a deep excavation). In the steady-state algorithm, the referential of the observer is in movement with respect to the applied load, and we suppose the steady-state, so the advancement rate of the face has to be constant and the section far enough from the entrance. The plastic strains are transported from a Gauss point to the next, following the movement. The excavation is assimilated to the moving load, as shown in figure 1. The plastic strain is transported horizontally, so the plastic strain are computed independently along each flow line parallel to the excavation axis. The figure also shows that it is possible to increase the mesh density where the strain gradients are the largest.

With the Von Mises yield function, the plastic strains are only deviatoric since there is no dilatancy. The solutions are obtained quickly and used to compare the results with the ones from 2D axisymmetric geometry by Corbetta. The Hoek-Brown criterion is independent of the intermediate principal stress, so it has singular points in the deviatoric plane. Here we use the original Hoek-Brown criterion for intact rocks, and its shape function in the deviatoric plane is here replaced by a smooth and convex approximation. With the Drucker-Prager and Hoek-Brown criteria, the plastic strains are not only in the deviatoric plane, we use the projection in the stress space along the dilatancy angle.

This method gives result in 3D with different criteria and in reasonable execution time, it leads to the possibility to model nonsymmetrical geometries and different excavation methods.

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