GeoStudio Example File
Underground Tunnel Excavation

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Introduction

This example simulates the excavation of a horseshoe shaped tunnel in highly weathered rock mass. The purpose is to demonstrate the features that are available in SIGMA/W for modelling rock deformation problems.

Numerical Simulation

Figure 1 shows the problem configuration. The model domain measures 35 m by 35 m approximately. The tunnel is horseshoe shaped with the greatest height of about 4.5 m and the greatest width of about 5 m. There are a total of 16 rock bolts installed in a radial pattern around the tunnel. Each bolt is about 5 m long.

The weak rock is modelled using the Generalized Hoek-Brown model. The elastic properties are defined with an effective elastic modulus of 1120 MPa and a Poisson's ratio of 0.3. The parameters of the failure criterion are defined as: UCS Intact = 50 MPa, m_b = 0.43, s = 6e-5, and a = 0.5.

The initial stress conditions prior to excavation are defined using Field Stresses. Two cases are simulated for illustrative purpose. In the first case, the angle of Sigma 1 is 35 degrees clockwise from +x direction; Sigma 1 and Sigma 3 are taken as 12 MPa and 8 MPa respectively. The second case is an isotropic stress field of 10 MPa. In both cases, the normal stress in the out-of-plane direction is taken as 10 MPa. Note that, material unit weights are ignored in In Situ analyses using Field Stresses.

The rock bolts are assumed to be fully bonded. The response of the bolts during excavation is simulated as Structural Beam in the numerical model. The bolts are 25 mm in diameter and spaced 1 m in the out-of-plane direction. The E-Modulus of the bolts is 2e5 MPa.

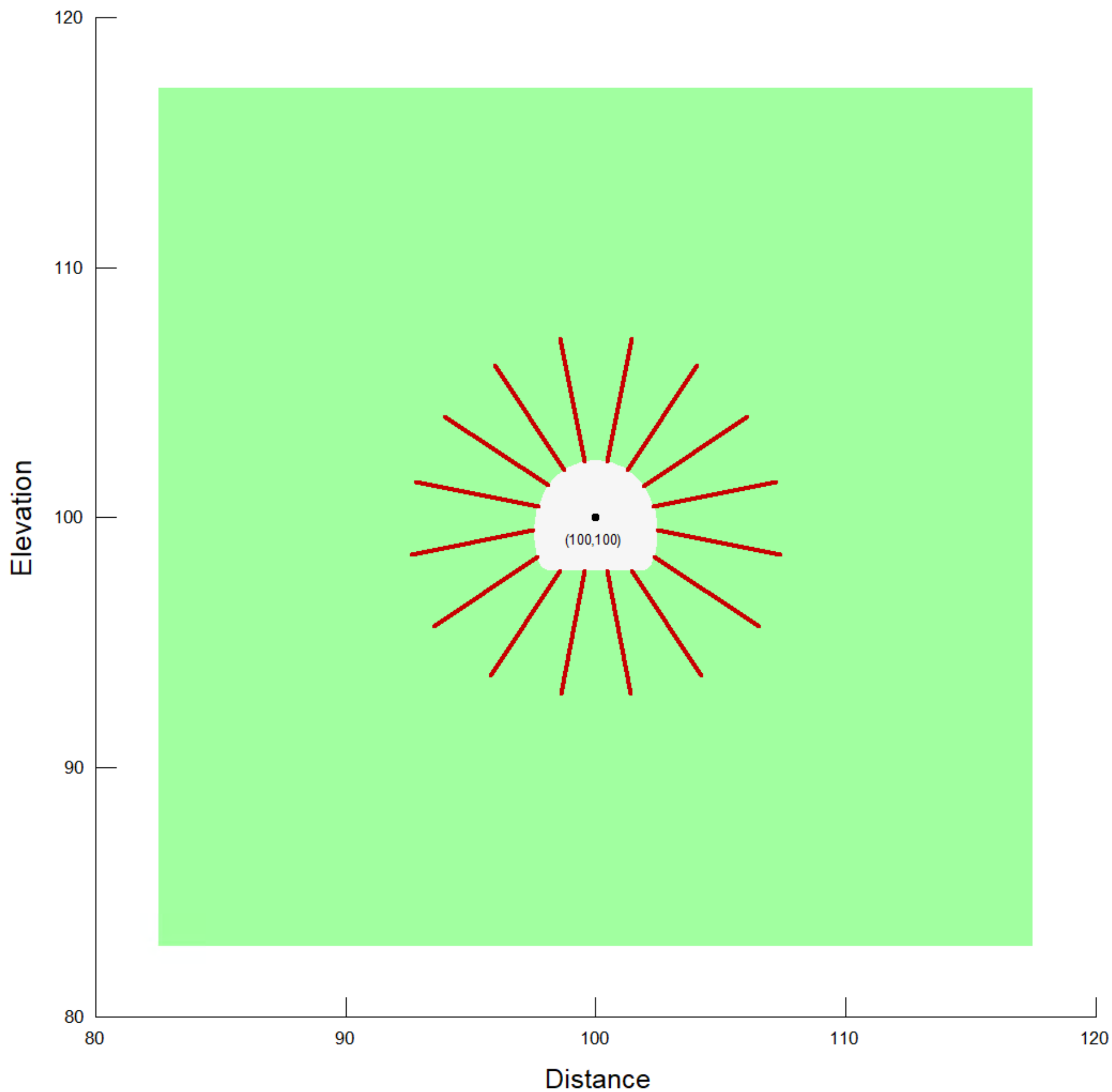

Figure 1. Example problem configuration.

Figure 2 presents the Analysis Tree for the tunneling simulation. The two branches correspond to the two initial stress conditions. The two child analyses following the In Situ analysis simulate tunnel excavation with and without rock bolts installed respectively.

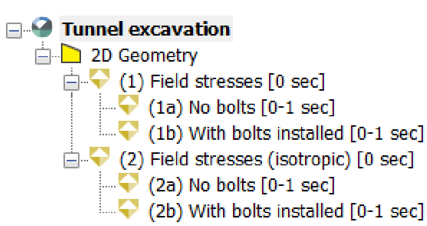

Figure 2. Analysis tree for the tunnel excavation simulation.

Results and Discussion

Without rock bolts installed

Figure 3 presents the plastic zone and the displacement vectors. The development of the plastic zone is influenced by the shape of the tunnel cross-section and the field stresses. The shape of the plastic zone is consistent with the defined field stresses. In isotropic initial stress condition, the shading area is influenced solely by the shape of excavation and hence is symmetric relative to the vertical centre line of the horseshoe shaped tunnel. Without bolts installed, the computed maximum displacement is about 85 mm and is about 76 mm in the isotropic initial stress condition.

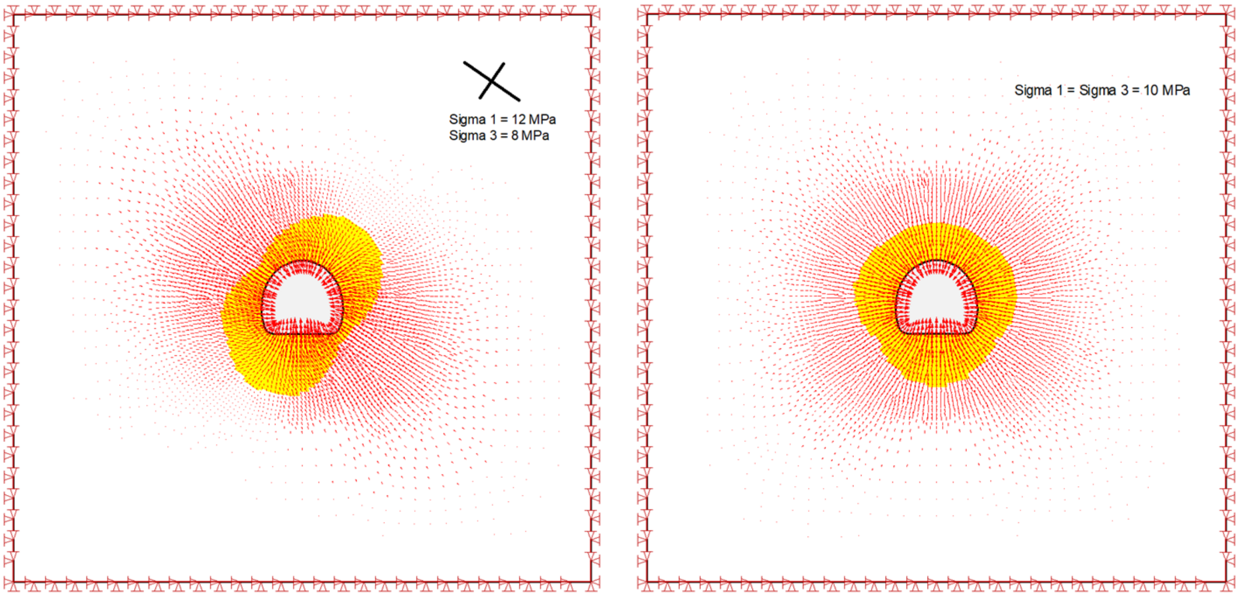

Figure 3. Plastic zones without bolts installed under different insitu stress conditions.

With rock bolts installed

The installation of the rock bolts reduces the area of plastic zone. As can be seen in Figure 4, plastic state develops in much shallower depths around the tunnel compared to the excavation without rock bolt stabilization. Nonetheless, the influence of field stresses is still reflected in the shape of the shading area. With the bolts installed, the computed maximum displacement is reduced to about 38 mm for the anisotropic field stress case and 36 mm for the isotropic field stress case.

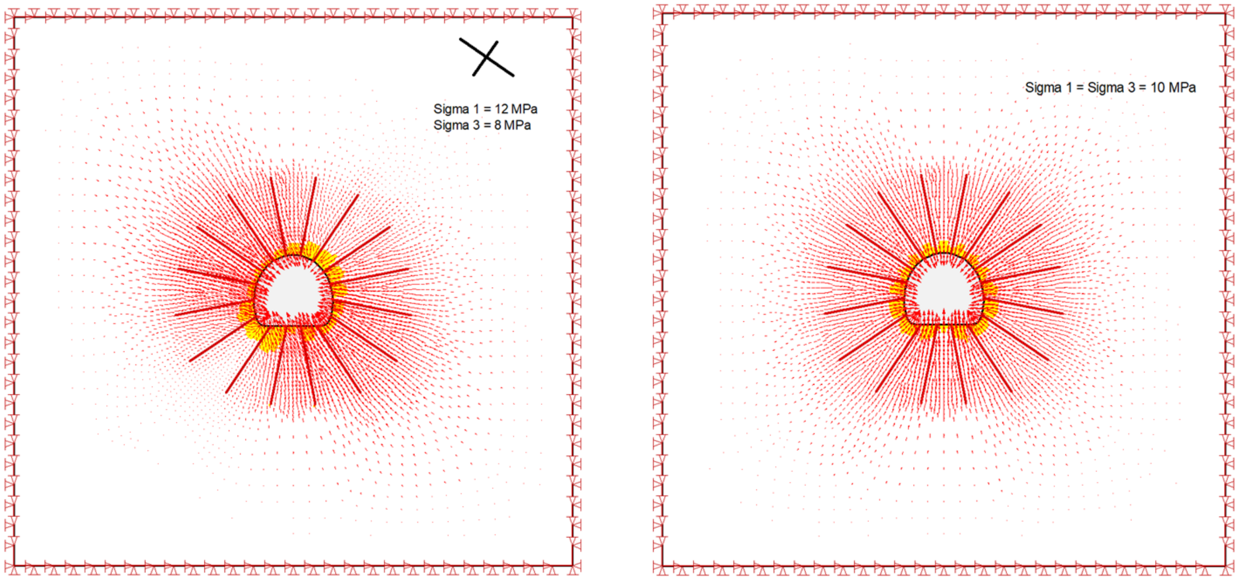

Figure 4. Plastic zones with bolts installed under different insitu stress conditions.

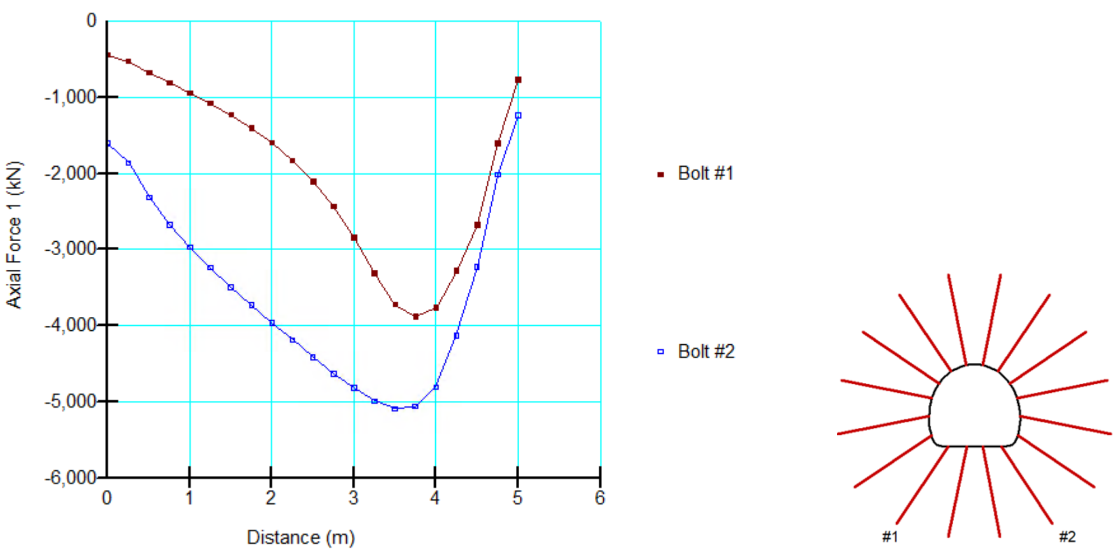

Figure 5. Rock bolt forces consistent with the defined field stresses.

The axial forces mobilized in two rock bolts together with the locations of the selected bolts are presented in Figure 5 and Figure 6. Greater tensile forces are recorded in Bolt #2, which roughly aligns with Sigma 1 of the defined field stresses. Bolt #1 is about in the direction of Sigma 3. In isotropic field stresses, as expected, the forces mobilized in the two bolts are almost identical.

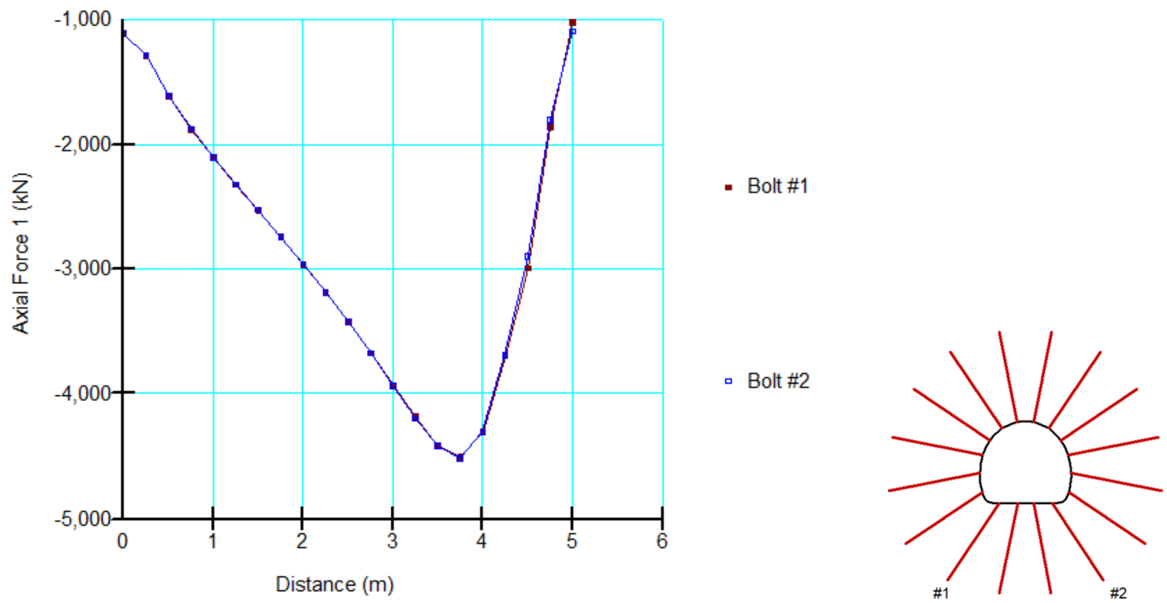

Figure 6. Rock bolt forces in isotropic field stresses.

Summary and Conclusions

This example demonstrates that SIGMA/W can be used to simulate the underground excavation in rock. The insitu stress condition is established using Field Stresses. The Generalized Hoek-Brown constitutive model is used to simulate the response of rock. The rock bolts and tunnel liner if considered can be modelled as structural beams.