Shear Stress Along Rock Bolt

Keywords

2D Axisymmetric, Interface stiffness, Shear Stress.

Problem Description

In this example we explore the distribution of shear stress along a grouted rock bolt when it experiences an axial pull-out force.

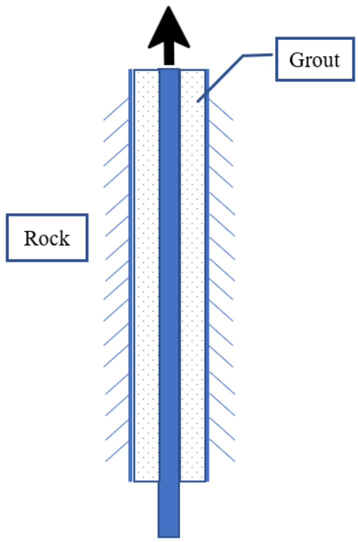

Figure 1: Grouted rock bolt

The problem is addressed through two axisymmetric analyses. In the first analysis, the grout is represented using axisymmetric elements, whereas in the second, it is treated as an interface. The rock bolt has a radius of 8.6mm and a length of 0.5m whilst the grout is 2.15mm thick.

Discretisation

In the first analysis, the problem is modelled using **Axisymmetric Solid** elements, QAX8. The finite element mesh can be found in figure 2. In the second analysis, the grout is replaced with **Axisymmetric** interface elements, IAX6 (figure 3).

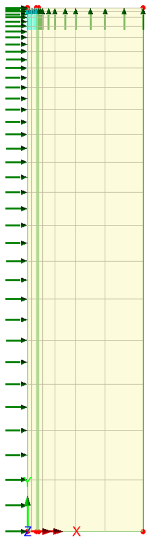

Figure 2: Meshing and boundary conditions

Figure 3: Meshing and boundary conditions (with interface)

Material Properties

The material properties are defined using an isotropic linear elastic model with properties given in table 1.

Table 1: Modified Mohr-Coulomb material properties

	Rock	Grout	Bolt
Young modulus, E	75.0E3 MPa	986.0 MPa	98.6E3 MPa
Poisson's ratio	0.0	0.0	0.0

The interface between the two blocks is modelled using an elasto-plastic interface material with yielding (slip) defined using the Mohr-Coulomb criterion with properties defined as follows:

Table 2: Interface properties

Angle of friction, φ_j	Cohesion, c_j	Dilation	Normal stiffness	Tangential stiffness
20°	1E6 MPa	20°	1E6 MPa/m	229300 MPa/m

Loading Conditions

A 430.38 MPa face load is applied to the upper surface (Figure 3).

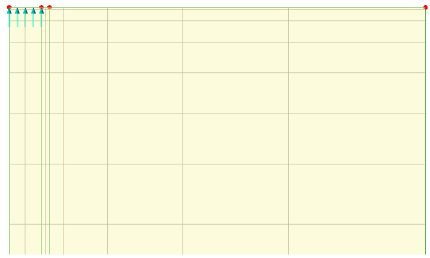

Figure 3: Applied load

Theory

The shear stress distribution along a fully grouted rock bolt is given by the following equation (Farmer, 1975) [1].

$$\frac{\tau}{\sigma_0} = 0.1e^{-0.2x/a} \qquad (1)$$

where τ is the shear force in the grout, σ_0 is the applied pull-out stress, x is the distance from the tip of the bolt and a is the bolt radius.

Modelling Hints

In the second analysis in which we simulate the grout with an interface, the interface shear stiffness K_s is calculated by equating the shear stress, τ_I, in the interface with that in the grout.

$$\tau_I = G\frac{du}{dx} = K_s du$$

The grout layer has a shear modulus *G*=493 MPa ($E_{grout}/2$) and the layer is 2.15mm thick

$$K_s = \frac{G}{dx} = \frac{493}{0.00215} = 229300\ MPa/m$$

Comparison

Figure 5 shows a very good match between the analytical and numerical solutions of the shear stress distribution along the bolt. The interface elements accurately follow the analytical solution, however, the isoparametric elements predict a higher peak stress which rapidly diminishes towards zero at the very end of the bolt.

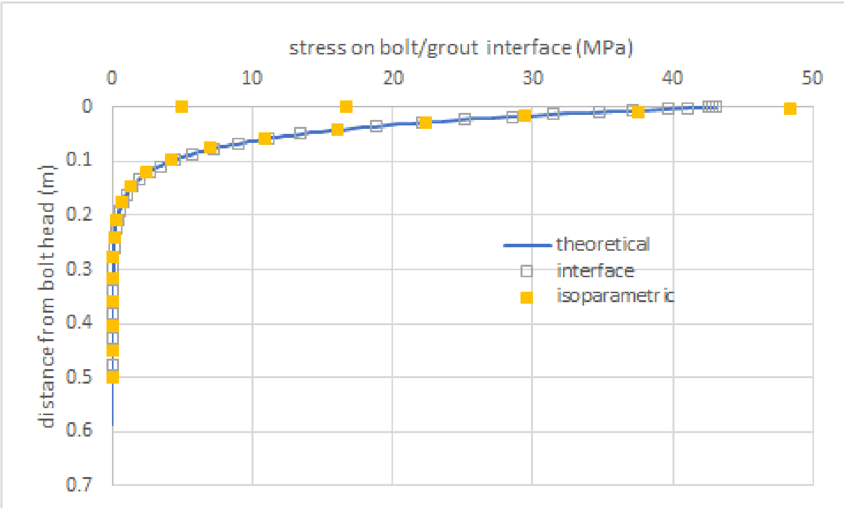

Figure 5: Shear stress along bolt

References

[1] Farmer, (1975), "Stress distribution along a resin grouted rock anchor", Int. J. Rock Mech. Min. Sci. Geomech. Abstr., **11**, 347-351.

Input Data

rock_bolt_isoparametric_grout.lvb

rock_bolt_interface_grout.lvb