# 9 Stress Distribution Along a Grouted Rock Bolt

## 9.1 Problem Description

This problem examines the shear stress distribution along a thin annulus of grout around a grouted rock bolt subjected to an axial pull-out force. Figure 9-1 illustrates the situation and relevant parameters, while Figure 9-2 shows the problem as constructed in ***RS3***.

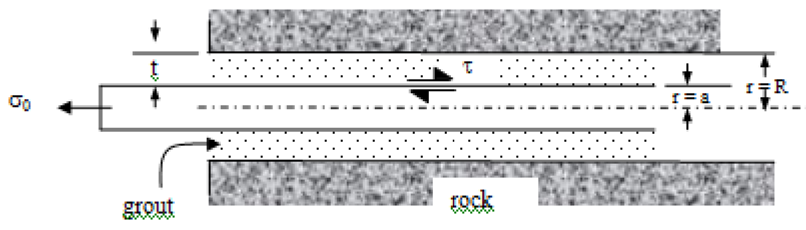


**Figure 9-1: Fully grouted rockbolt in elastic rock mass**

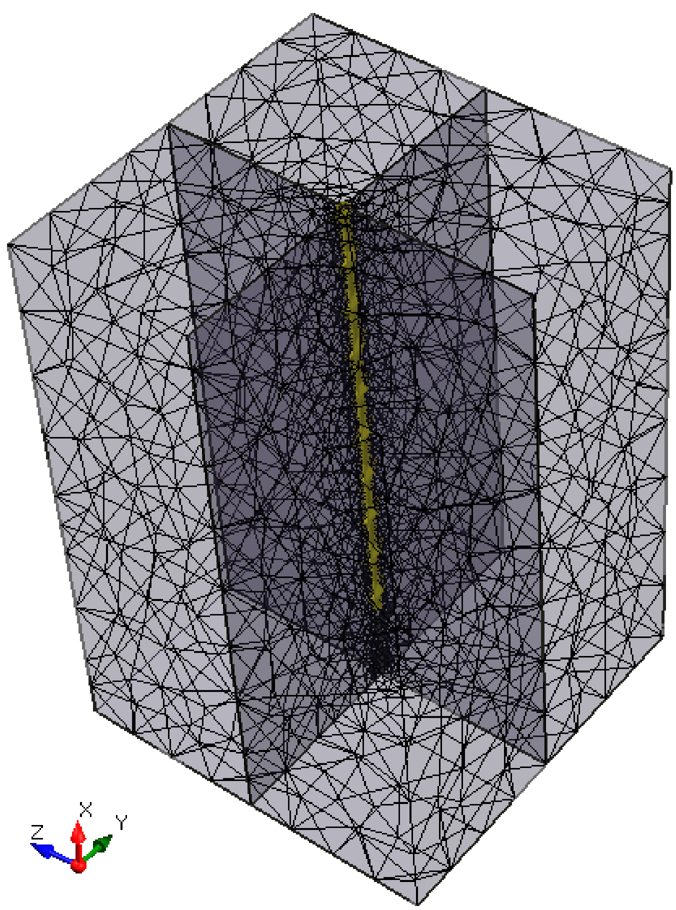


**Figure 9-2: Fully grouted rockbolt as modeled in *RS3***

Table 9-1 and Table 9-2 summarize the material and rockbolt properties used.

**Table 9-1: Model parameters**

| *Parameter* | *Value* |
|---|---|
| Young's modulus ($E$) | 75000 MPa |
| Poisson's ratio ($v$) | 0.25 |
| Hole radius ($R$) | 10.825 mm |

**Table 9-2: Bolt parameters**

| *Parameter* | *Value* |
|---|---|
| Tributary area | 232.5 $mm^2$ |
| Young's modulus ($E_a$) | 98600 MPa |
| Bond shear stiffness | 13882 MN/m |
| Grout shear modulus ($G_g$) | 493 MPa |
| Bolt radius ($a$) | 8.6 mm |
| Pull-out force | 0.1 MN |

## 9.2 Analytical Solution

According to Farmer (1975) [1], the shear stress distribution along a fully grouted rock bolt is given by

$$\frac{\tau}{\sigma_0} = 0.1\exp\frac{-0.2x}{a}$$

where $\tau_x$ is the shear force in the grout, $\sigma_0$ is the applied pull-out stress, $x$ is the distance from the head of the bolt and $a$ is the bolt radius. This equation is developed using the following assumptions:

1. The grout shear modulus $G_g = 0.005E_a$
2. The hole radius $R = 1.25a$, where $a$ is the bolt radius

In order for the above assumptions to hold true, the grout shear modulus was set to 493 MPa. The grout shear stiffness was then calculated using the following equation [2]:

$$K_g = \frac{2\pi G_g}{\ln(1 + t/a)}$$

The bolt tributary area was set to 232.5 $mm^2$, equivalent to a bolt having a radius $a$ = 8.6 mm. By assumption 2 above, the radius of the hole $R$ = 10.825 mm.

## 9.3 Results

The shear stress acting on the bolt can be calculated for two scenarios:

1. The shear stress acts at the boundary between the bolt and the grout. In this case, the shear stress is given by:

$$\tau = \frac{F_s}{2\pi a}$$

where $F_s$ is the shear force.

2. The shear stress acts at the boundary between the grout and the rock. In this case, the shear stress is given by:

$$\tau = \frac{F_s}{2\pi R}$$

Both of these cases are plotted in Figure 9-3, which shows the shear stress distribution along the bolt length. As can be seen, the two bracket the analytical solution.

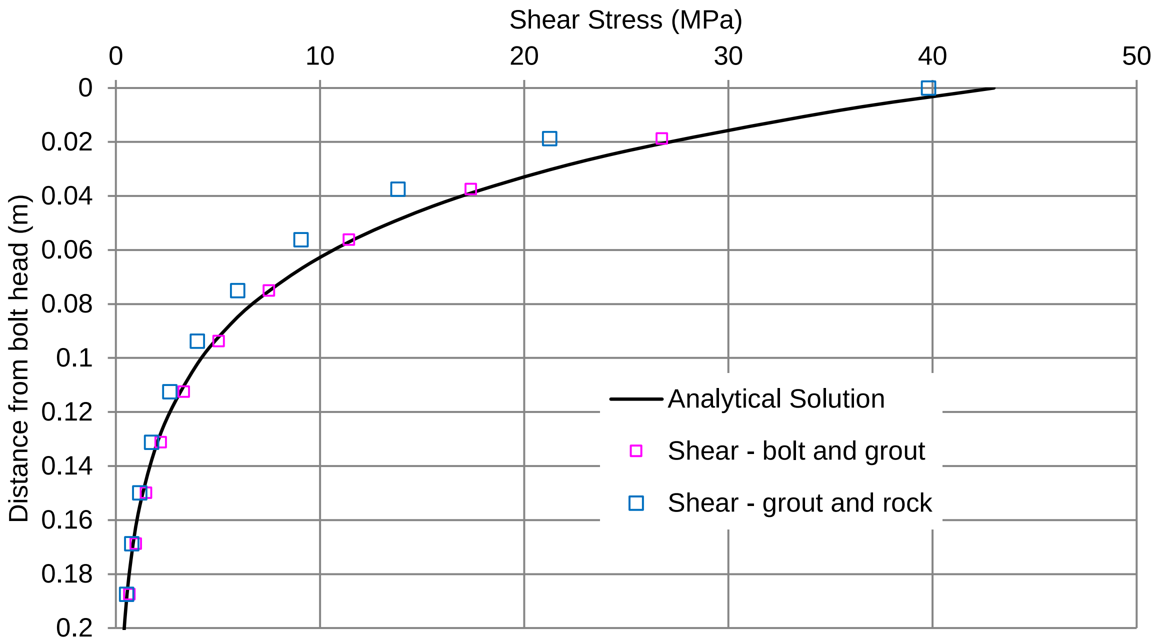


**Figure 9-3: Shear stress distributions along bolt**

## 9.4 References

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

2. Itasca Consulting Group Inc., 2004. *FLAC v 5.0 User's Guide – Structural Elements*, Minneapolis, Minnesota, USA.

## 9.5 Data Files

The input data file **V009.rs3model** can be found in the ***RS3*** installation folder.