10 Cylindrical Hole in an Infinite Hoek-Brown Medium

10.1 Problem Description

This problem addresses the case of a cylindrical tunnel in an infinite Hoek-Brown medium subjected to a uniform compressive in-situ stress field. Materials with failure surfaces defined according to the Hoek-Brown criterion have non-linear and stress-dependent shear strength. Plane strain condition is enforced by restricting the displacement of all the surfaces parallel to the face of the cylinder. Figure 10-1 shows the configuration and the finite element mesh of the model. Table 10-1 summarizes the model parameters.

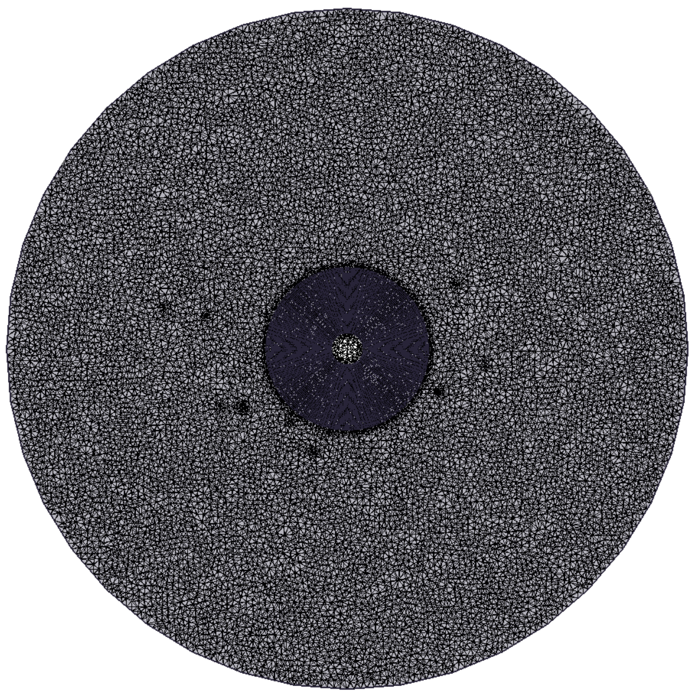

Figure 10-1: Circular tunnel in Hoek-Brown medium as constructed in *RS3*

Table 10-1: Model parameters

Model Specifications and Material Properties	*Value*
In-situ stress field (P_0)	30 MPa
Hole radius (a)	1 m
Young's modulus (E)	10000 MPa
Poisson's ratio (v)	0.25
Uniaxial compressive strength of intact rock (σ_c)	100 MPa
Dilation parameter	0°, 30°
m	2.515
s	0.003865
m_r	0.5
s_r	1e-5

The ***RS3*** model constructed uses a graded mesh with 4-noded tetrahedron elements and an in-situ hydrostatic stress field of 30 MPa.

10.2 Analytical Solution

According to [1] and [2], the radius of the yield zone r_e is given by:

$$r_e = ae^{\left[N\frac{2}{m_r\sigma_c}(m_r\sigma_c P_i + s_r\sigma_c^2)^{1/2}\right]}$$

Where

$$N = \frac{2}{m_r\sigma_c}(m_r\sigma_c P_0 + s_r\sigma_c^2 M)^{1/2}$$

$$M = \frac{1}{2}\left[\left(\frac{m}{4}\right)^2 + \frac{mP_0}{\sigma_c} + s\right]^{1/2} - \frac{m}{8}$$

The radial stress at $r = r_e$ is given by:

$$\sigma_{re} = P_0 - M\sigma_c$$

In the elastic region, the radial and tangential stresses are given by:

$$\sigma_r = P_0 - (P_0 - \sigma_{re})\left(\frac{r_e}{r}\right)^2$$

$$\sigma_\theta = P_0 + (P_0 - \sigma_{re})\left(\frac{r_e}{r}\right)^2$$

In the plastic (yielded) region, the radial and tangential stresses are given by:

$$\sigma_r = \frac{m_r\sigma_c}{4}\left[\ln\left(\frac{r}{a}\right)\right]^2 + \ln\left(\frac{r}{a}\right)(m_r\sigma_c P_i + s_r\sigma_c^2)^{1/2} + P_i$$

$$\sigma_\theta = \sigma_r + (m_r\sigma_c\sigma_r + s_r\sigma_c^2)^{1/2}$$

where P_i is the internal pressure (in this example, 0 MPa)

10.3 Results

Figure 10-2 and Figure 10-3 compare the stress distributions calculated by ***RS3*** with the ***Phase²*** results and analytical solution. ***RS3*** results are in very close agreement with the other two in both graphs. See Figure 10-4 and Figure 10-5 for contour plots of the radial and tangential stress distribution produced in ***RS3***.

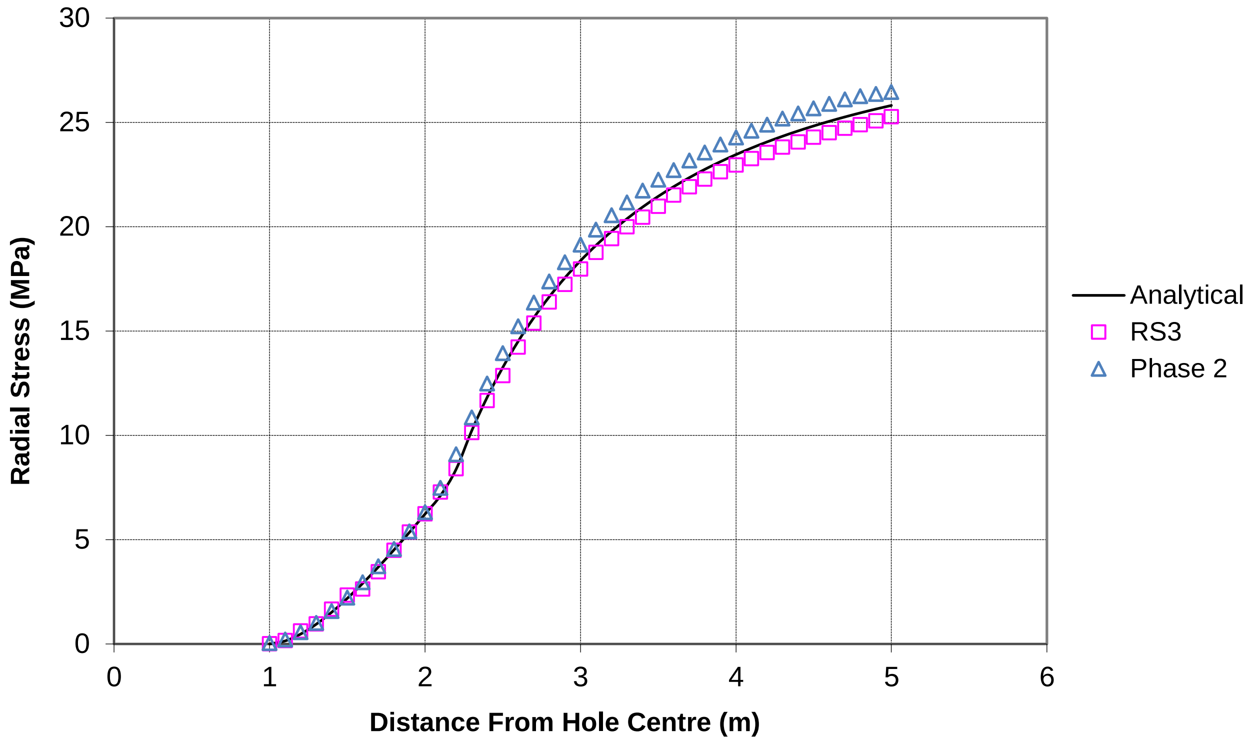

Figure 10-2: Comparison of radial stresses for all solutions

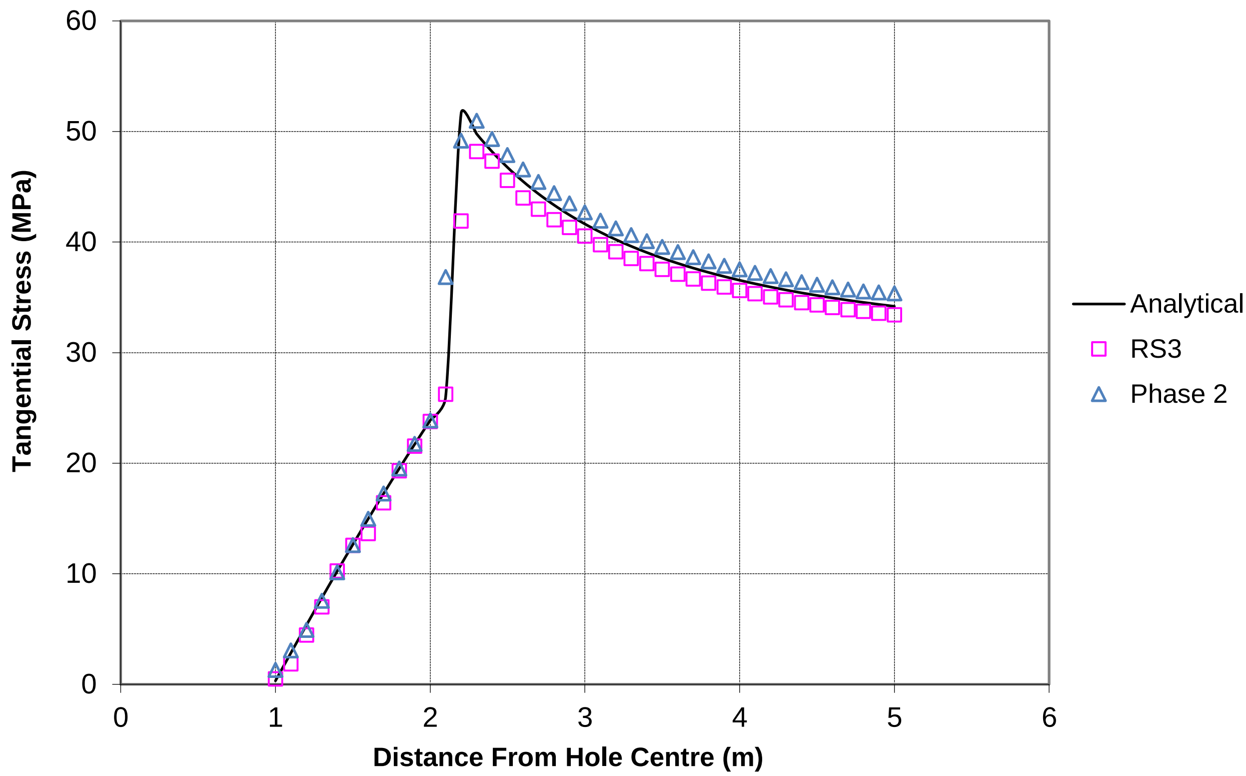

Figure 10-3: Comparison of tangential stresses for all solutions

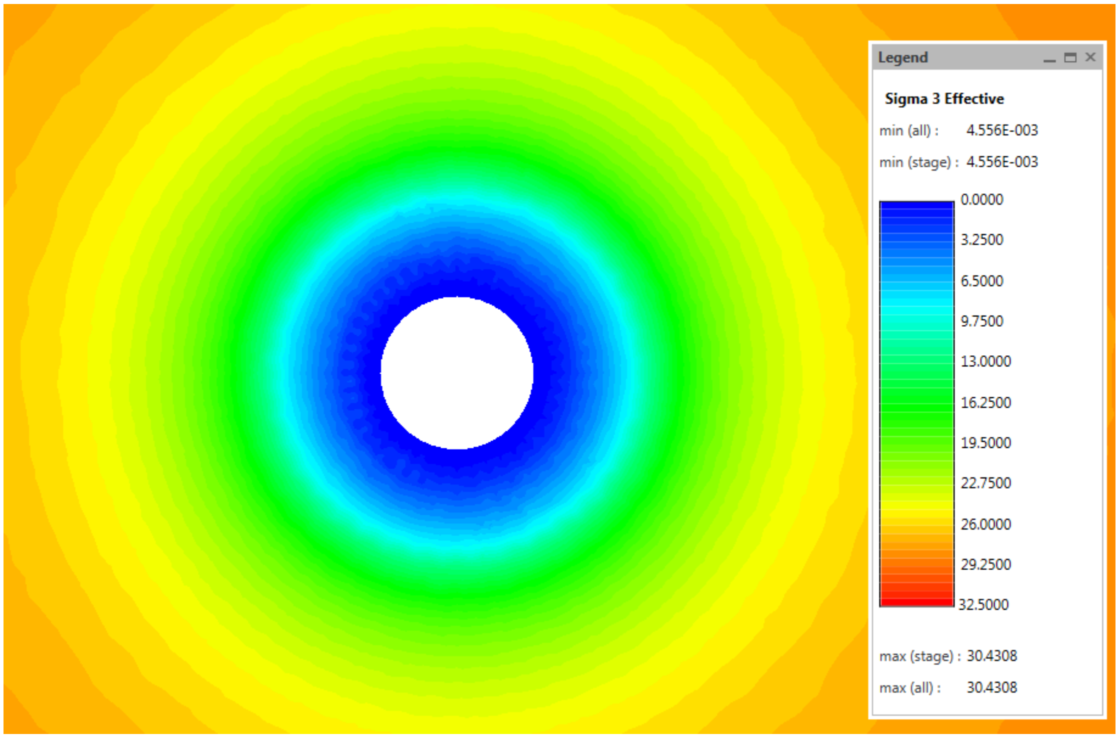

Figure 10-4: Radial stress contour plot in *RS3*

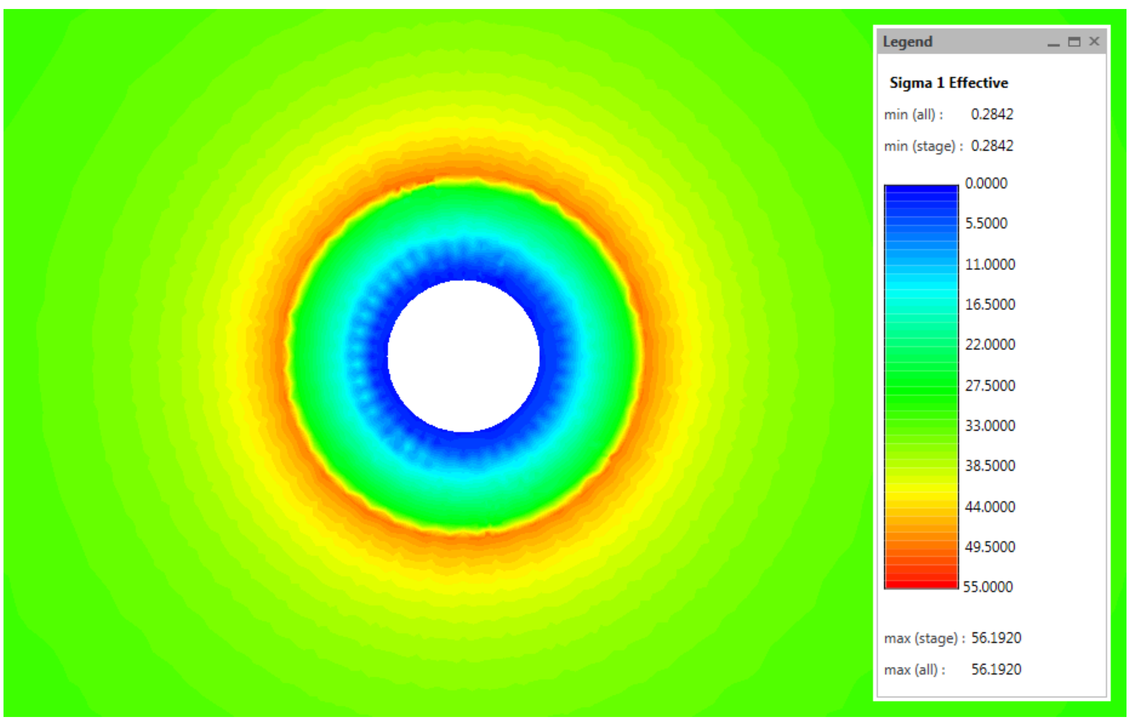

Figure 10-5: Tangential stress contour in *RS3*

10.4 References

1. Hoek, E. and Brown, E. T., (1982) *Underground Excavations in Rock*, London: IMM, PP. 249-253

2. Itasca Consulting Group, INC (1993), "Cylindrical hole in an Infinite Hoek-Brown Medium", *Fast Lagrangian analysis of Continua* (Version 3.2), Verification Manual.

10.5 Data Files

The input data file **V010.rs3model** can be found in the ***RS3*** installation folder.