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GeoStudio Example File
Shear Strength: Hoek-Brown

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Introduction

The Hoek-Brown criterion is an empirical relationship that is used to estimate the strength of rock in terms of major and minor principal stresses. In its Generalized form, the input strength parameters of the Hoek-Brown model are UCS Intact, mb, s, and a. In practice, it is common to calculate mb, s, and a from mi, GSI, and D. Details of the Hoek-Brown model are presented in the SLOPE/W Engineering book. The objective of this example is to demonstrate the use of the Hoek-Brown material model in SLOPE/W.

Background

The Hoek-Brown criterion produces a non-linear shear strength envelope that is a function of the effective normal stress. In SLOPE/W, a spline data point function is created to approximate the failure envelope and then used to determine the shear strength at the base of slice. The key of the implementation is that the SLOPE/W limit equilibrium formulation is based on the Mohr-Coulomb strength equation. As such, the cohesion and/or friction angle must be defined at the base of every slice. These values are determined by taking the tangential slope of the spline function for any base effective stress as shown in Figure 1. The effect is that c and ϕ are different for each slice along the slip surface.

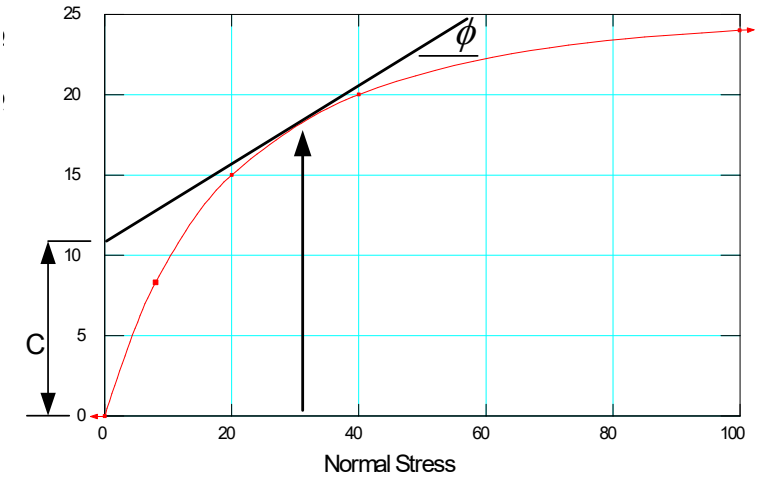

Figure 1. Equivalent c and phi for a curved failure envelope.

Numerical Simulation

For this example, there is a slope cut in a rather poor quality limestone. The strength properties are given as:

- The uniaxial compressive strength of the intact rock (UCS Intact): 20 MPa or 20,000 kPa
- Intact Rock Parameter (mi): 10
- Geological Strength Index (GSI): 20
- Disturbance Factor (D): 1 (highly disturbed)

Figure 2 shows the values of the input parameters of the Hoek-Brown criterion mb, s, and a computed from mi, GSI, and D by the program.

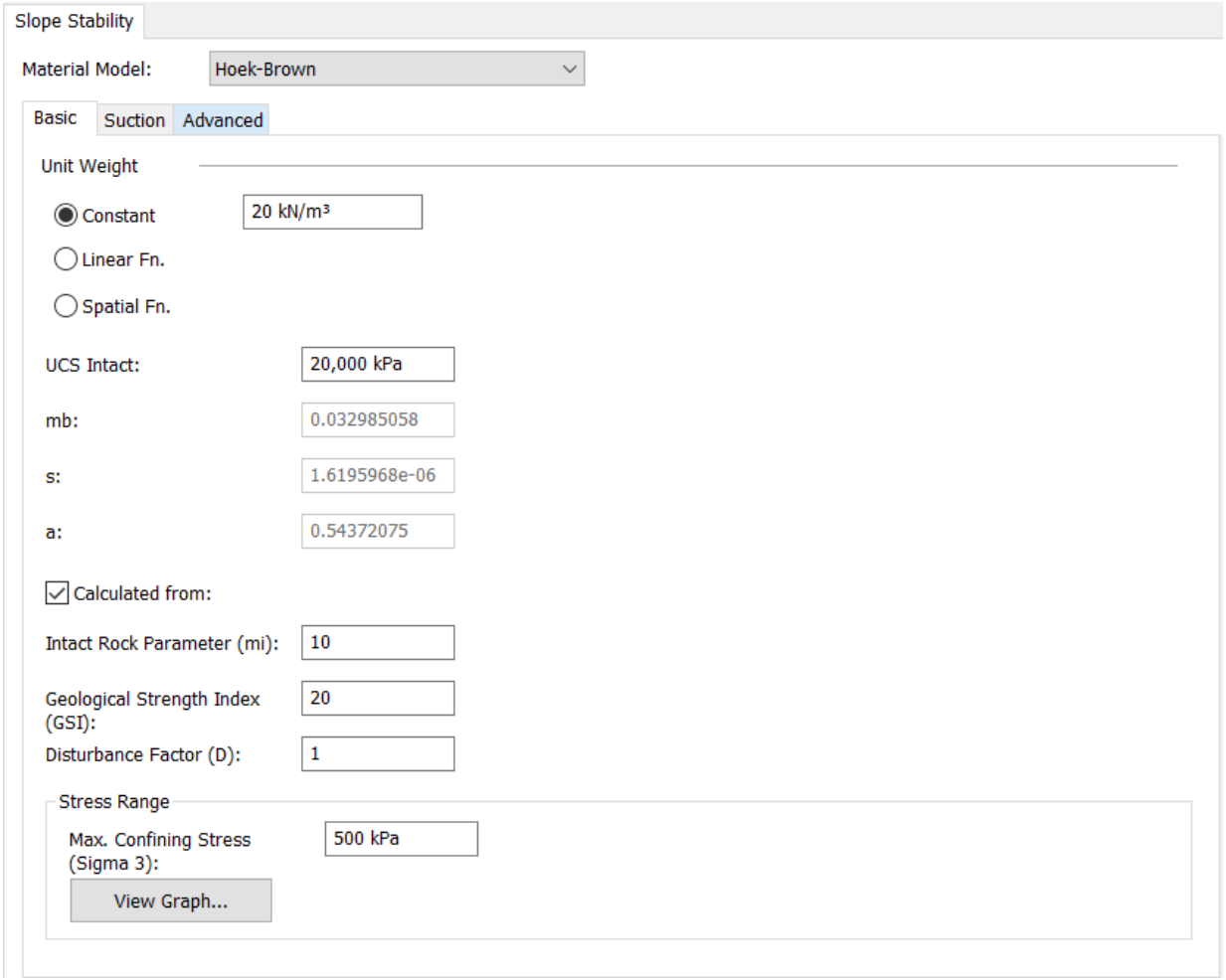

Figure 2. Input parameters of the Hoek-Brown material model.

Users can toggle off the Calculated from option and specify the values of mb, s, and a directly. This is required in some circumstances. One example is to model the rock strength using the original Hoek-Brown relationship (a = 0.5). For illustrative purpose, another material is created in this way in the example.

View Graph displays the shear strength envelope generated by the program (Figure 3). A reasonable maximum confining stress (Sigma 3) should be specified such that the data points of the spline adequately represent the range of the normal stresses in the domain.

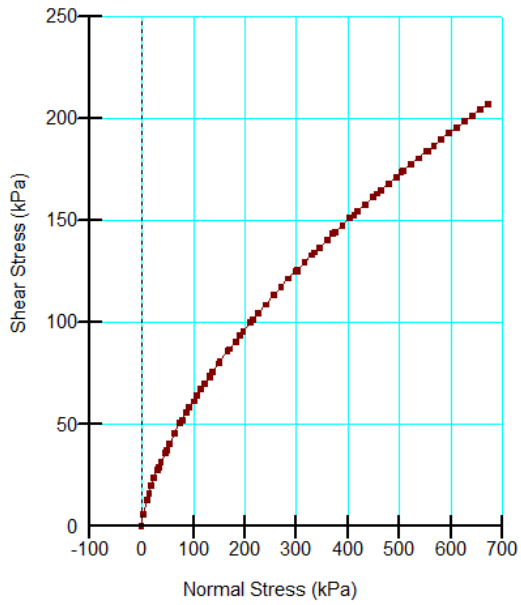

Figure 3. Curved failure strength envelope.

Results and Discussion

Figure 4 and Figure 5 present the critical slip surface and factor of safety along with a Slip Surface Color Map showing all valid slip surfaces. Figure 6 presents the friction angle (Degrees) and cohesion (kPa) along the critical slip surface. Both parameters change as the base effective stress changes because the tangential slope and y-intercept of the spline function changes with effective stress.

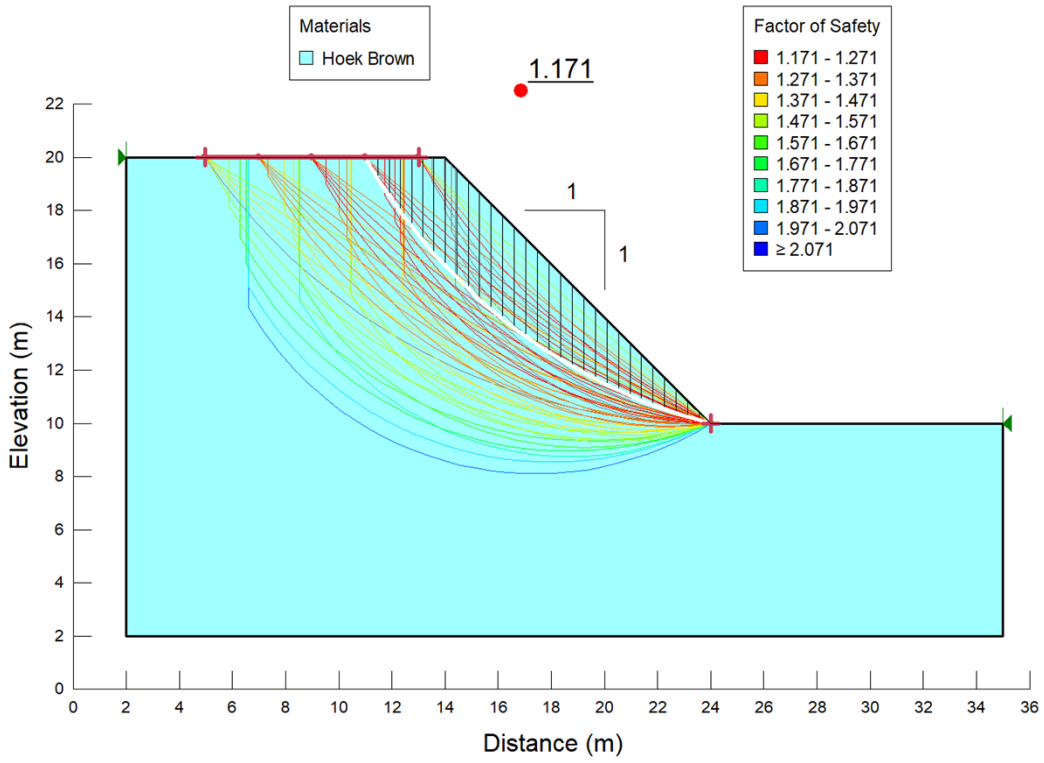

Figure 4. Stability analysis results (UCS intact = 20 MPa, mi = 10, GSI = 20, D = 1).

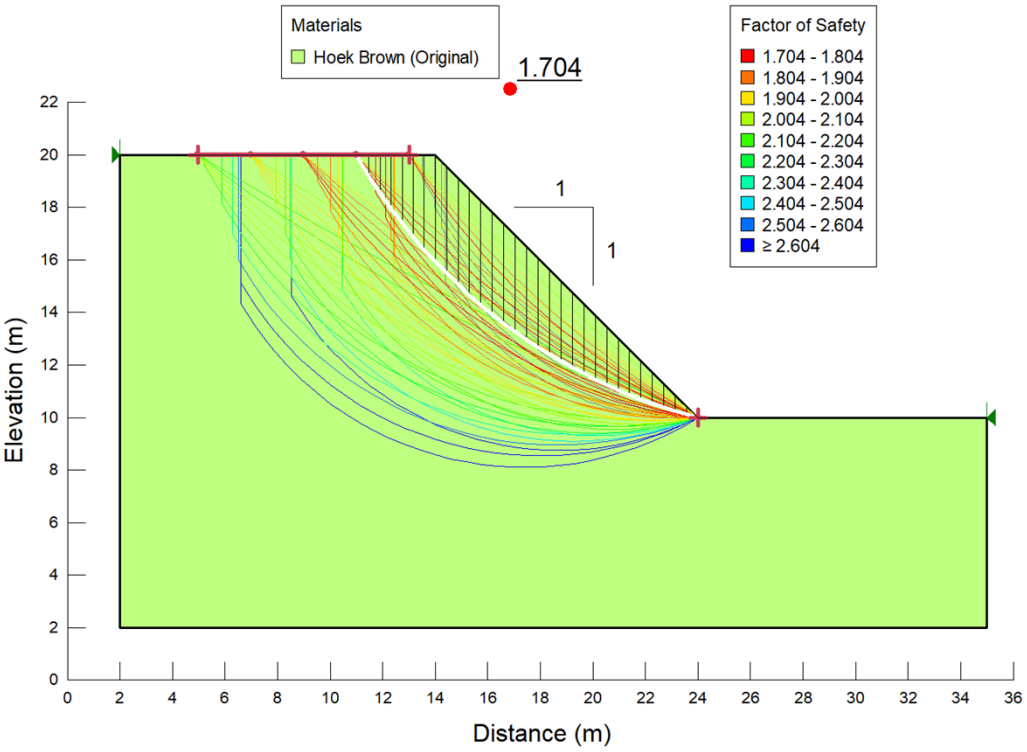

Figure 5. Stability analysis results (UCS intact = 20 MPa, mb = 0.045, s = 1e-6, a = 0.5).

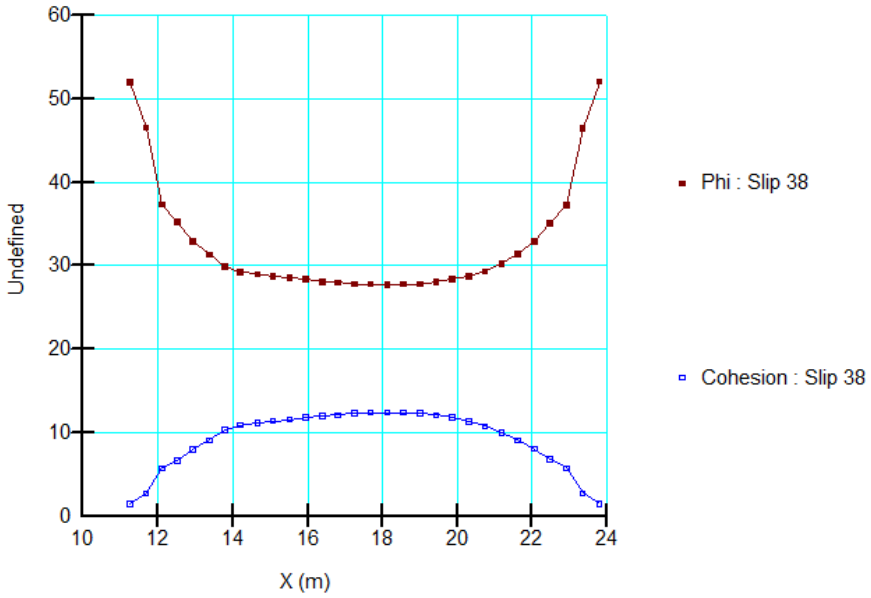

Figure 6. Variation of c and phi along the critical slip surface.

Summary and Conclusions

The Hoek-Brown material model is implemented in SLOPE/W using a spline data point function. SLOPE/W determines the corresponding tangential slope and y-intercept from the function for the given base normal effective stress. This gives the appearance that the frictional angle and cohesion are varying along the slip surface.