Uniaxial Compressive Strength of Jointed Rock

Keywords

2D, Plane Strain, Interface, Arclength.

Problem Description

This example shows a rock column with a joint that is under uniform pressure. The joint is angled at a 30 degrees angle with respect to the vertical axis of the column. The model is 10 metres high and 5 metres wide. The boundary conditions are depicted in Figure 1.

Discretisation

The problem is modelled using triangle plane strain elements, TPN6. The finite element mesh can be found in Figure 1. The model is split into two blocks by interface elements, IPN6.

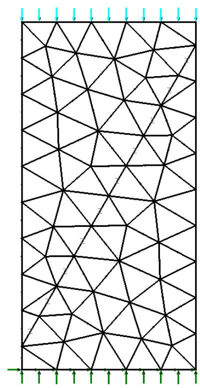


Figure 1: Modelling of jointed column

Material Properties

The material properties are defined using the Modified Mohr-Coulomb material model as shown in table 1.

Table 1: Modified Mohr-Coulomb material properties

Mass density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ_R	Cohesion, c_R	Dilation
2.7 t/m^3	180E3 kPa	0.2	35°	2.5 kPa	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
33°	1.5 kPa	0°

Loading Conditions

A 1kPa face load is applied to the upper surface (Figure 1) and is factored using the arclength procedure up to failure.

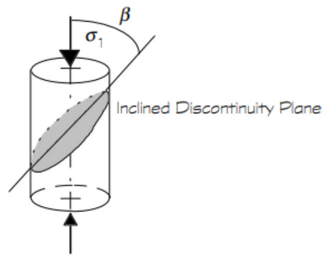
Theory

The uniaxial compressive strength of a rock mass, σ_1, which fails in accordance with the Mohr Coulomb failure criterion is defined by:

$$\sigma_1 = \frac{2c_R \, cos\varphi_R}{1 - sin\varphi_R} \qquad (1)$$

Hoek (1983) assumed that the shear strength of the discontinuity surfaces is defined by a friction angle, φ_j, and a cohesion, c_j. The axial strength, σ_1, of a triaxial specimen containing inclined discontinuities at an angle of β is then given by equation 2, which defines the joint strength where σ_3 is the minor principal stress

$$\sigma_1 = \sigma_3 + \frac{2(c_j + \sigma_3 \, tan\varphi_j)}{\left(1 - tan\varphi_j \, tan\beta\right) sin\, 2\beta} \qquad (2)$$



Modelling Hints

Arclength loading should be used when calculating failure loads.

Comparison

At small values of β, the column fails through slip along the joint. So the overall strength of the column increases with β to the point at which the shear failure occurs in the rock mass rather than by slip along the joint. For β equals 30° we calculate the axial pressure causing failure using equations 1 and 2 mentioned previously. For the specific problem geometry and material properties, the mass will fail by slip along the joint as shown in figure 3.

β	failure of the rock mass	Joint failure
35	9.6 kPa	5.542 kPa

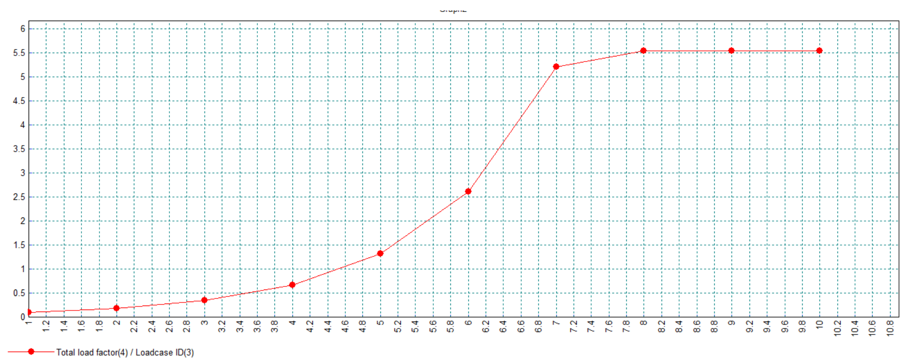


Figure 2: Total load factor

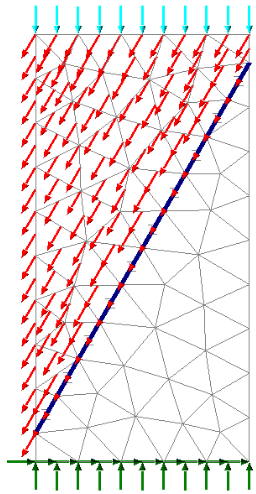


Figure 3: Displacement vectors

References

[1] J. C. Jaeger and N. G. Cook, Fundamentals of Rock Mechanics, 3rd Ed., London, Chapman and Hall, 1979

Input Data

compressive_strength_of_rock.lvb