Slope Failure with a Thin Weak Layer

Keywords

2D, Strain Plane, Phi-C reduction, Safety factor.

Problem Description

This example shows how to analyse the stability of a clayey slope which has a thin weak layer. The example comes from a paper by Griffiths and Lane (1999). The weak layer follows the slope parallel before turning horizontal in the toe zone. The stability of the slope is impacted by the presence of this thin weak layer. The slope is 10 metres high and slopes at a 26.57 degree angle to the horizontal.

Discretisation

The slope is modelled using quadratic plane strain elements, QPN8. The finite element mesh can be found in Figure 1.

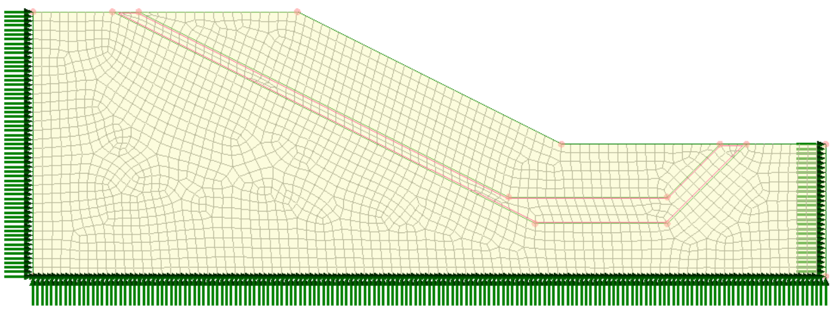

Figure 1: Finite element mesh showing supports

Material Properties

Material properties for the Modified Mohr-Coulomb model are given in table 1.

Table 1: Mohr-Coulomb material properties

	Mass density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Cohesion, c	Dilation
Soil	2 t/m^3	100E3 kPa	0.3	0°	50 kPa	0°
Weak layer	2 t/m^3	100E3 kPa	0.3	0°	30 kPa	0°

Loading Conditions

The soil weight due to gravity is the only load applied on the slope.

Theory

The limit equilibrium method is used primarily for slope stability analysis. This method identifies potential failure mechanisms and calculates safety factors for a specific geotechnical situation. The equilibrium of shear stress and shear strength determines stability. The slope is considered stable if the forces resisting movement are greater than the forces driving movement. The resistance is divided by the driving forces to calculate the factor of safety (FS). A safety factor greater than 1.00 indicates that the slope is stable. The phi-c reduction method, which gradually reduces the material shear strength until collapse occurs, is another technique commonly used with numerical analysis. As a result, a slope's factor of safety is *the ratio of actual soil shear strength to the minimum shear strength required to prevent failure*, or *the factor by which soil shear strength must be reduced to bring a slope to the verge of failure* (Duncan, 1996). LUSAS uses this technique to assess slope stability.

Modelling Hints

The Phi-c reduction attribute can be assigned to relevant features in the model for a specified analysis allowing the safety of a slope to be evaluated. By its very nature a Phi-c reduction analysis will always lead to failure, so it is best used in an analysis 'branch' where it can be used to study safety factors independent of the main solution.

Comparison

According to Griffiths and Lane's paper (1999), we can see the value of factor of safety is around 1.37 (Figure 2). This is confirmed with LUSAS where we obtained the value of 1.39. Figure 3 illustrates the effective shear strain plot at failure.

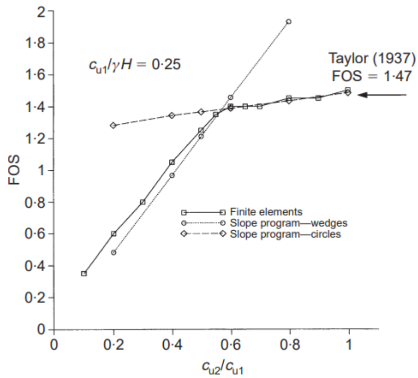

Figure 2: Computed factor of safety for different values of c1/c2

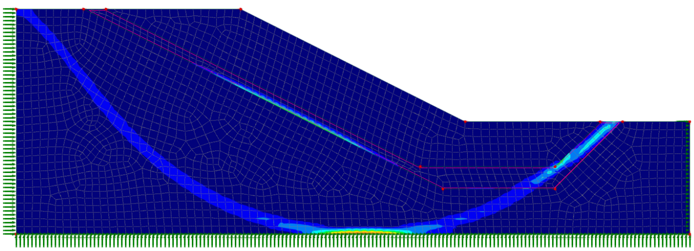

Figure 3: Maximum shear strain obtained from LUSAS giving FS = 1.39

References

[1] Griffiths, D.V. and Lane, P.A., Slope Stability Analysis by Finite Elements. Geotechnique, 49, 387-403, 1999.

Input Data

Slope_failure_with_thin_layer.lvb