Simple Slope Stability

Keywords

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

Problem Description

This example corresponds to a homogeneous slope with a 1 in 2 gradient. We compare the output of Limit Equilibrium method with techniques available in LUSAS to calculate the factor of safety.

Discretisation

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

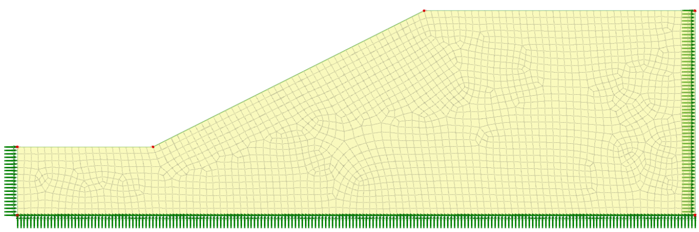

Figure 1: Finite element mesh showing supports

Material Properties

A plastic material using the Modified-Mohr-Coulomb model is defined 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
2 t/m^3	50.0E3 kPa	0.4	19.6°	3 kPa

Loading Conditions

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

Theory

LUSAS employs the phi-c reduction method, which gradually reduces the material's shear strength until collapse occurs, to calculate a factor of safety. When the slope is initially stable, phi-c reduction is used; otherwise, LUSAS displays a nonconvergence message, indicating that the slope is unstable and the factor of safety is obviously less than one. Since the slope in question demonstrates instability, phi-c reduction cannot be used directly. In this case, we can gradually apply the load affecting the slope up to the point of failure to give an estimate of the factor of safety. Alternatively, we can artificially increase the strength of the soil so that the slope does not fail and apply phi-c reduction to this modified problem.

The safety factor is defined

$$SF = \frac{availble\ shear\ strength}{shear\ strength\ at\ failure}$$

And for the Mohr-Coulomb criteria this is represented

$$SF = \frac{c + \tan\phi}{c_r + \tan\phi_r}$$

Introducing a scaling factor α for the original strength

$$SF_\alpha = \frac{\alpha(c + \tan\phi)}{c_r + \tan\phi_r}$$

$$SF_\alpha = \frac{\alpha c + \tan\phi_\alpha}{c_r + \tan\phi_r}$$

Where

$$\tan\phi_\alpha = \tan(\arctan(\alpha\tan\phi))$$

The safety factor of the original problem is then given by

$$SF = \frac{SF_\alpha}{\alpha}$$

Using a scale factor of α=1.5 the scaled cohesion and friction angle are given in table 2.

Table 2: Scaled strength parameters

Angle of friction, ϕ	Cohesion, c
28.11°	4.5 kPa

Comparison

LUSAS gives 0.79 as the factor of safety estimated by the amount of gravity load applied at failure and also a value of 0.96 when the scaled strength parameters are used., whereas the value obtained by Bishop's method is 0.94. The following figures 2,3 and 4 show the failure surface and effective shear strain for the different solutions.

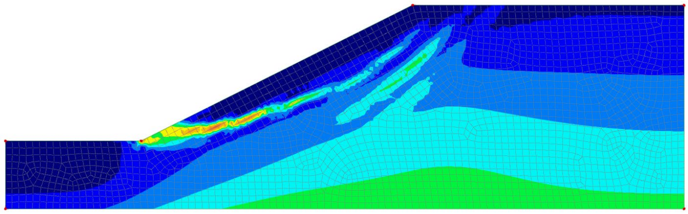

Figure 2: Effective shear strain with original strength parameters (FS = 0.79)

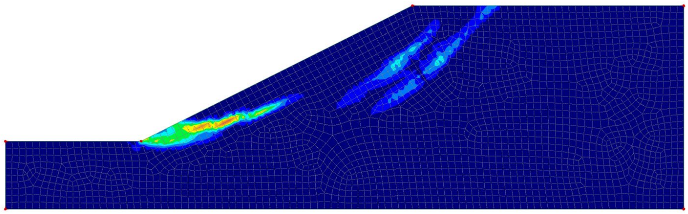

Figure 3: Effective shear strain with scaled strength parameters (FS = 0.96)

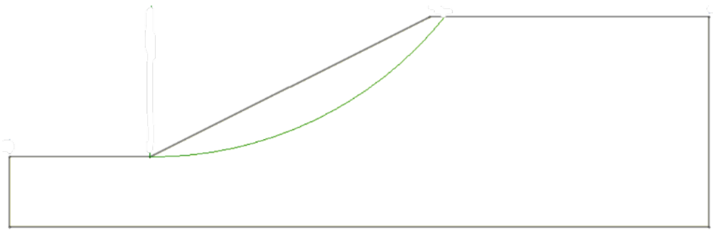

Figure 4: Failure surface using Bishop Method (FS = 0.94)

Input Data

FOS_simple_slope.mdl