Plane Strain Limit Load Analysis of Granular Material

Keywords

Elasto-Plastic, Drucker-Prager, Modified Mohr-Coulomb

Problem Description

A strip of granular material compressed by a rigid footing is analysed to determine its limit load. Details of the problem can be found in Figure 1.

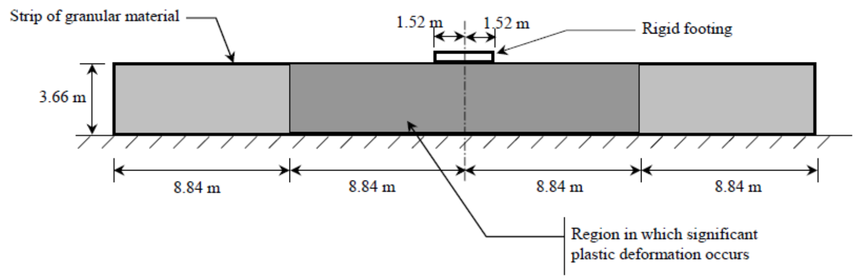

Figure 1: Dimensions of the granular material for which the limit load analysis is carried out. The dark shaded area is considered the region where significant plastic deformation takes place.

The strip of granular material is in fact considered to be infinitely long, so the vertical boundaries at the edge of the specimen have been positioned such that their presence has a minimal effect on the results.

The performance of two material models is examined – the Drucker-Prager material model and the modified Mohr-Coulomb material model.

Discretisation

Utilising symmetry about the centre plane, only one half of the problem in figure 1 is meshed. The strip itself is modelled using quadratic plane strain elements, QPN8. The finite element mesh can be found in figure 2.

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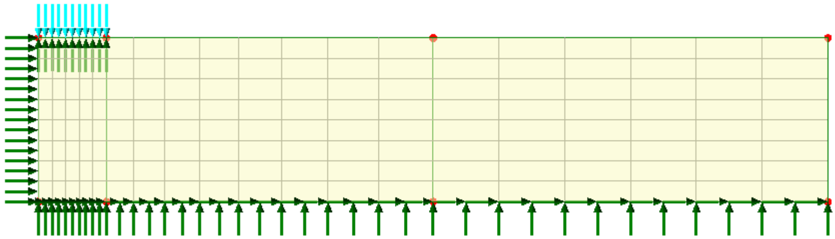

Figure 2: Finite element mesh showing supports and load

Material Properties

The material properties of the strip are defined using the Modified Mohr-Coulomb material model in one test and the Drucker-Prager material model in a second test. Table 1 gives the material properties for this test.

Table 1: Material properties

Modified Mohr Coulomb

Mass density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Cohesion, c
2 t/m^3	206.8E3 kPa	0.3	20°	68.94 kPa

Drucker-Prager

Mass density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Cohesion, c
2 t/m^3	206.8E3 kPa	0.3	15.9°	53.007 kPa

Loading Conditions

A compressive prescribed displacement is applied to the rigid footing in the vertical direction (Figure 2). A total prescribed displacement of 0.125m is applied.

Theory

The Brinch Hansen bearing capacity equation is one of the most widely used methods for calculating allowable bearing capacity of soil. It is an extension of the Terzaghi method that takes into account foundations on slopes and other conditions that the Terzaghi method does not. The collapse load is given by the following equation [1].

$$q_u = cN_c\lambda_{cs}\lambda_{ci}\lambda_{c\alpha}\lambda_{cd}\lambda_{ct} + qN_q\lambda_{qs}\lambda_{qi}\lambda_{q\alpha}\lambda_{qd}\lambda_{qt} + 0.5\gamma BN_\gamma\lambda_{\gamma s}\lambda_{\gamma i}\lambda_{\gamma\alpha}\lambda_{\gamma d}\lambda_{\gamma t} \quad (1)$$

Comparison

Figure 3 shows the displacement under the foundation versus the pressure applied to the foundation for both the Modified Mohr-Coulomb, and the Drucker-Prager material models. On the same graph are limit analysis solutions from Brinch Hansen and Prandtl. The graph shows that the material models have produced limit loads that lie between the two classic solutions.

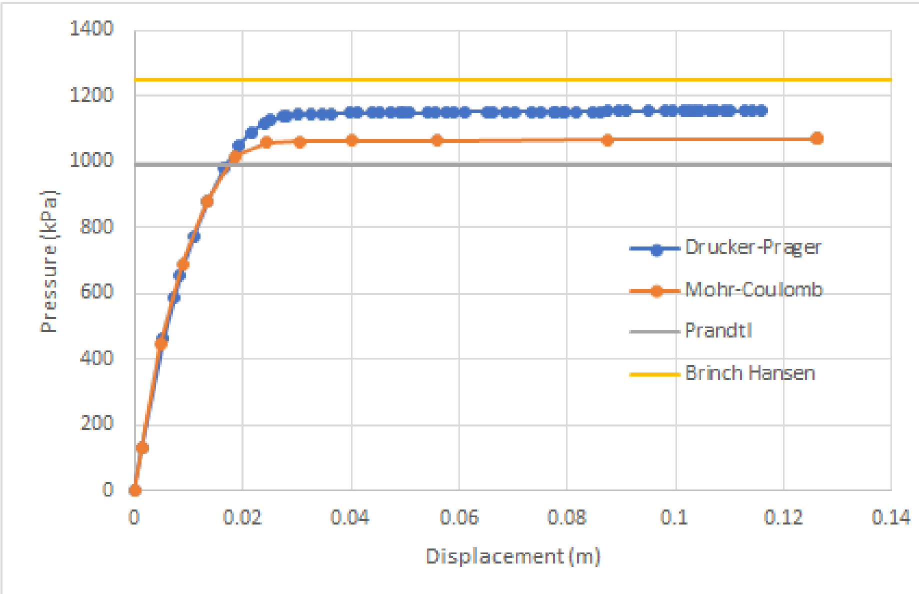

Figure 3: Variation of pressure underneath the footing against applied displacement

References

Input Data

Limit Load Analysis.lvb