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GeoStudio Example File
Footing Bearing Capacity

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Introduction

SLOPE/W can be used to analyze the bearing capacity of a shallow footing. The model must be defined in a particular manner in order to obtain results that are commensurate with analytical solutions. The classical bearing capacity analyses are completed in this example for the undrained and frictional cases.

Background

Undrained Condition

The bearing capacity of a soil characterized by an undrained strength is given by:

$$q = N_c B S_u \quad \text{Equation 1}$$

where S_u is the undrained shear strength, B is the footing width, and N_c is a bearing capacity factor. The exact solution to the problem can be obtained using more complex analysis than the limit equilibrium method. A bearing capacity factor of 5.14 is obtained via the rigorous solution. In contrast, analysis by the limit equilibrium method alone results in N_c of 5.52 due to constraints on the location of the trial slip surface. More specifically, the trial slip surface is perfectly circular with its centre of rotation located above the edge of the footing at a height equal to $B \times \tan 23.2°$.

Drained Condition

The long-term bearing capacity is calculated using an effective stress analysis. The shear strength of the soil can be assumed purely frictional. The slip surface can be shown to assume a log spiral shape with entry and exit angles controlled by the active and passive earth pressure angles, respectively. Such constraints can be imposed on the trial slip surface in SLOPE/W.

There are many bearing capacity equations for various ground conditions, loading conditions, and embedment depth. A simplified equation for a footing at the ground surface is:

$$q = 0.5\gamma B N_\gamma \quad \text{Equation 2}$$

where γ is the soil unit weight, B is the footing width, and N_γ is a bearing capacity factor.

Numerical Simulation

Undrained Condition

The analysis definition comprises a footing of width B equal to 1 m and soil with an assumed undrained strength of 100 kPa. The bearing capacity for this scenario is:

$$q = N_c B S_u = 5.52(1.0)(100) = 552\ kPa \quad \text{Equation 3}$$

A surcharge load was used to simulate the footing pressure. The surcharge load was drawn at 0.1 m above the ground surface and the unit weight of the material was specified as 5520 kPa/m . The slip surface was defined using entry-exit, where the entry was defined by a single point at the edge of the footing, the exit by a range, and a centre of rotation drawn at $B\tan 23.2° = 0.4286$ m.

Drained Condition

The drained condition was simulated assuming a footing width of 2 m and a frictional soil with ϕ equal to 30 degrees and a total unit weight of 20 kPa/m. According to Bowles (1977), the bearing capacity can be calculated as:

$$q = 0.5\gamma B N_{\gamma} = 0.5(20)2.0(15.1) = 302\ kPa \quad \text{Equation 4}$$

A surcharge load was used to simulate the footing pressure. The surcharge load was drawn at 0.1 m above the ground surface and the unit weight of the material was specified as 3020 kPa/m. According to earth pressure theory, the base angle of the slip surface at the exit can be calculated as $\alpha = 45 - \phi/2 = 30°$. The exit angle was specified in the slip surface definition, but the entrance angle was simulated and verified.

Results and Discussion

Undrained Condition

Figure 1 shows the simulated result for the undrained analysis. Naturally, the computed factor of safety matches exactly the analytical bearing capacity equation that was formulated based only on limit equilibrium and an assumed perfectly circular slip surface.

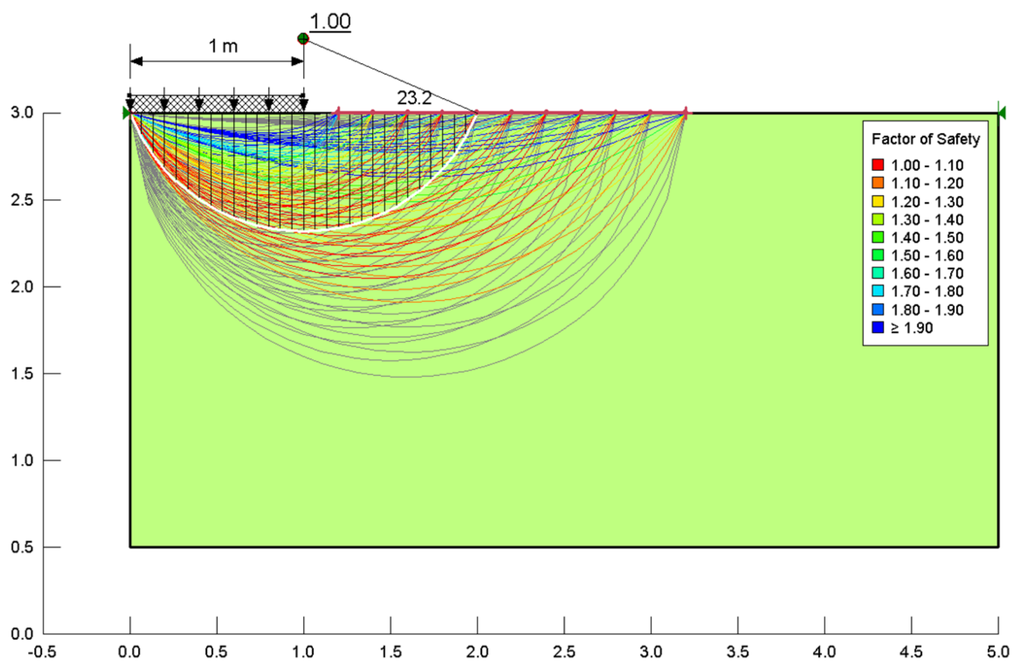

Figure 1. Simulated result for the undrained scenario.

Drained Condition

Figure 2 shows the simulated result for the drained analysis. Again, the computed factor of safety matches the analytical bearing capacity equation that was formulated based only on limit equilibrium and a perfectly log-spiral slip surface. View | Slice Information can be used to examine the slice base inclination at the entry point. The simulated angle is at 63.3 degrees, which is close to the active earth pressure angle of $\alpha = 45 + \phi/2 = 45°$.

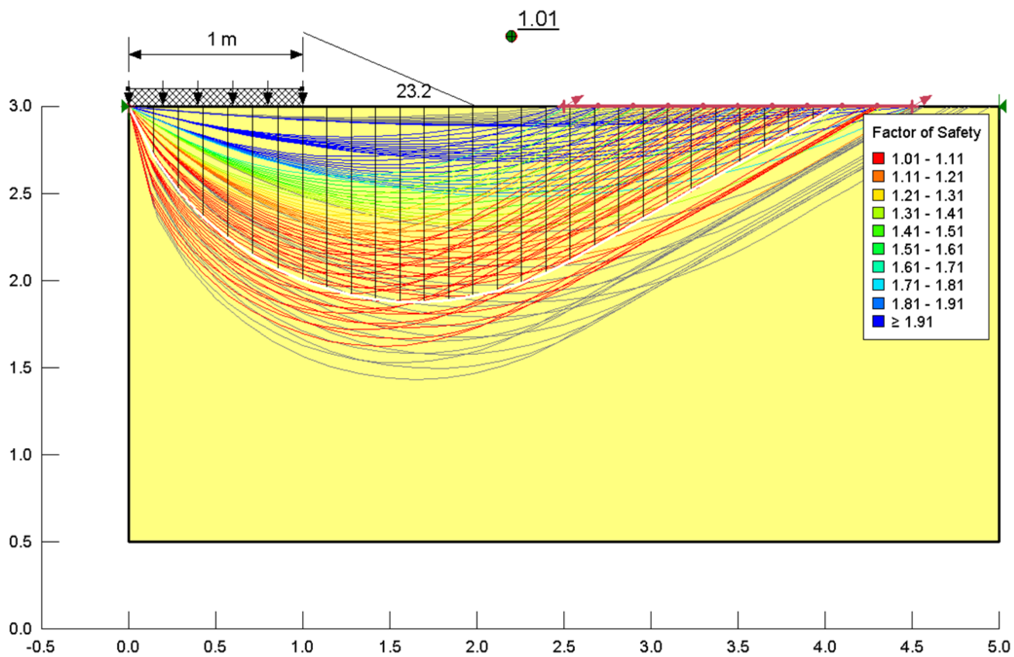

Figure 2. Simulated result for the drained scenario.

It is necessary to use only half of the footing when simulating bearing capacity problems. The reason for this can be comprehended by looking at the results of a SIGMA/W stress-deformation analysis. Figure 3 shows the displacement vectors resulting from the loading of a footing. The displacements are symmetrical about the axis of symmetry as expected.

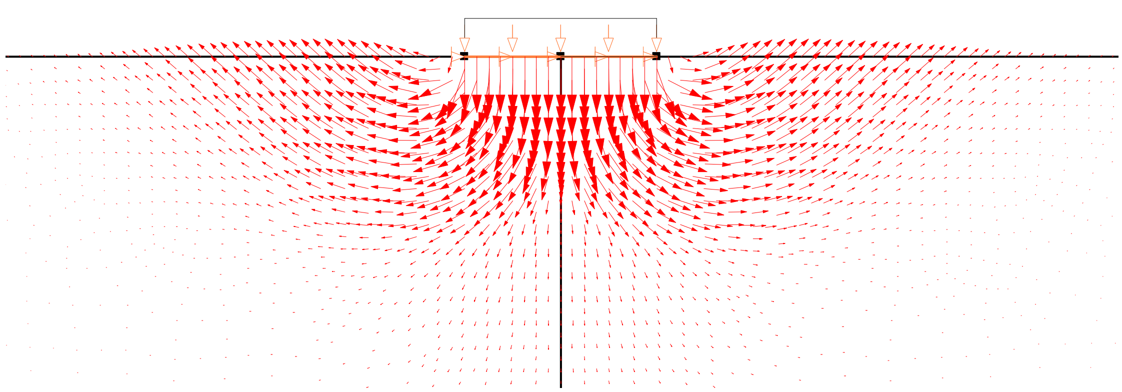

Figure 3. Displacement vectors from a SIGMA/W load-deformation analysis.

Given the displacement pattern, it is readily evident that a slip surface starting at the edge of the full footing width could not be analyzed. The slip surface would pass through part of the displacement field in which the direction of movement was opposite of the slip surface direction. All of the displacement vectors must point in the direction of the assumed movement. The entire width must be used in closed-form solutions when computing the ultimate bearing capacity; however, only half the footing can be modeled in a limit equilibrium analysis.

Summary

This illustrative example shows that a SLOPE/W limit equilibrium analysis can be used to analyze bearing capacity problems. Care must be taken to properly define the entry-exit zone and center of rotation for comparison to closed-form analytical solutions. Moreover, only half of the footing width is modeled.

References

Bowles, J.E. (1977). *Foundation Analysis and Design*, McGraw-Hill, 2nd Edition, p. 116 & p. 118.