Rigid Strip Footing on Soft Soil

Keywords

2D, Plane Strain, Soft Soil Model.

Problem Description

This example models a rigid footing resting on a 10m x 10m body of elasto-plastic soil using the Soft Soil Model (SSM). Two situations are considered: a case where the soil is normally consolidated and, for comparison, a situation where the soil is heavily overconsolidated.

Discretisation

The problem is modelled using 144 QPN8P elements discretised into the finite element mesh shown in Figure 1. The vertical boundaries are restrained from moving in the horizontal direction and in both vertical and horizontal directions at the bottom.

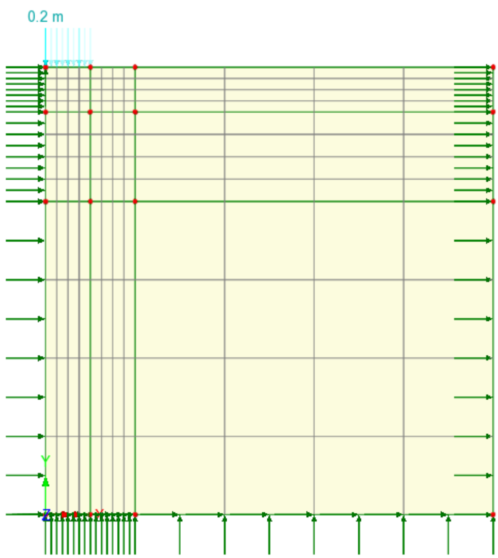

Figure 1: Finite element mesh showing supports.

Material Properties

The soil is modelled using the Soft Soil Model (SSM). Table 1 gives the material properties.

Table 1: Soft Soil Model material properties

Compression index, λ	**Swelling index, κ**	**Poisson's ratio, ν**	**Gradient of critical state line, M**	**Friction angle, ϕ**
0.05	0.0075	0.3	1.3	25°
Dilation angle, ψ	Cohesion c	Maximum tension stress	Minimum Pressure	*Pre-consolidation pressure p_c
0°	1kPa	1kPa	1kPa	100kPa
Initial void ratio, e	Density ρ	K_0 Over-consolidation ratio	Poisson's ratio for unloading	K_0 at rest for Normally consolidated clay
3	2.1E3kg/m^3	1 for Normally consolidated soil, 1000 for Overly consolidated soil)	0.4186046512	0.72

*Pre-consolidation pressure is calculated during the K0 initialisation procedure, so this value is overwritten.

Loading Conditions

The test is split into two phases. Firstly, a K_0 initialisation step is conducted. Here gravity loading is applied to the soil and initial stresses are calculated so that the soil is in equilibrium before any further analysis is undertaken. Secondly, a fixed displacement of 0.2m is applied directly to the nodes under the position of the footing (shown top left in Figure 1). This is a large displacement but allows both the normally consolidated and over-consolidated tests to fully fail.

Theory

The aim of this example is to show the difference between a normally consolidated soft soil where the cap surface plays a significant role and a situation where the soil fails only on the Mohr-Coulomb surface. An analytical approximation of the bearing capacity of the footing can be calculated by Terzaghi's equation

$$q_f = c \cdot N_c + \frac{1}{2} \cdot \gamma \cdot B \cdot N_\gamma$$

Where c is the cohesion, γ is the unit weight of the soil and B is the width of the footing. With other parameters relating to the friction angle:

$$N_c = \frac{N_q - 1}{\tan(\phi)}$$

$$N_\gamma = \left(N_q - 1\right)\tan(\phi)$$

$$N_q = e^{\pi \tan(\phi)} \tan^2(45° + \frac{\phi}{2})$$

Modelling Hints

The mesh shown in Figure 1 can be achieved by splitting the domain into surfaces and applying a line mesh with no element type to specify the number of elements desired in each area rather than using a uniform mesh for the whole soil.

Due to the nonlinear nature of the soil model, it is necessary to add nonlinear and transient control to both steps in the analysis.

Comparison

The analytical equations in the theory section above give an expected bearing capacity of 133.5kN. It can be seen in Figure 2 that both solutions tend towards this, although notably at different rates. As may be expected, the normally consolidated soil displaces much more at lower loads before finally reaching roughly the same final capacity.

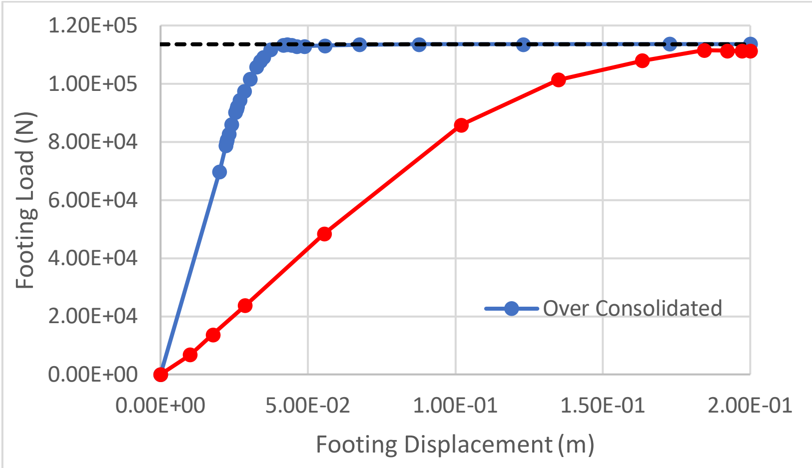

Figure 2: Displacement of footing versus applied load

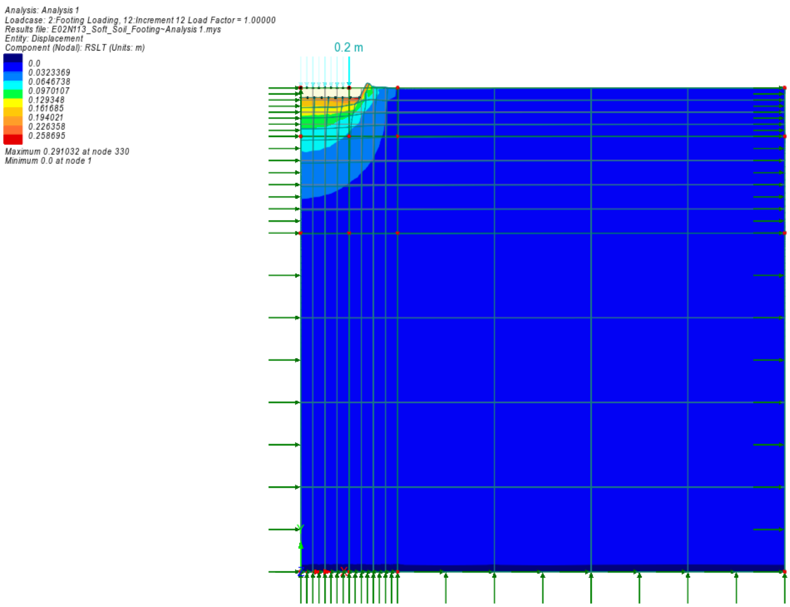

Figure 3: Displacement beneath footing

Input Data

soft_soil_footing.lvb