OptumG3

Verification of solid elements for bearing capacity analysis of a circular foundation on a Tresca soil

Op⁺um^CE

OPTUM COMPUTATIONAL ENGINEERING

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1   Introduction

This document verifies the solid elements available in OptumG3 with respect to the bearing capacity of a circular foundation on a Tresca soil.

Three elements are available: Lower, Upper, and Mixed.

The Lower element computes limit loads that are generally below the exact solution. The element aims to satisfy the differential equations of equilibrium everywhere (as opposed to standard finite elements which impose equilibrium on average). In OptumG3, a slight relaxation is used for free surfaces. This increases the accuracy substantially but may result in limit loads that are slightly above the exact solution. This normally only occurs for very coarse meshes.

The Upper element computes limit loads that are generally above the exact solution. As with standard finite elements, the element satisfies the strain-displacement relations everywhere. In addition, the flow rule is satisfied everywhere. To avoid the well-known locking problem a slight relaxation of the strict upper bound requirements is used. This may in principle result in limit loads that are slightly below the exact solution although it is a very rare occurrence.

The Mixed element combines the different requirements of the Upper and Lower bound elements to deliver an element with a superior performance. The limit loads may, depending on the problem, converge from above or below, though almost always with a relatively limited error, even for coarse meshes. The Mixed element is the default and recommended element in OptumG3.
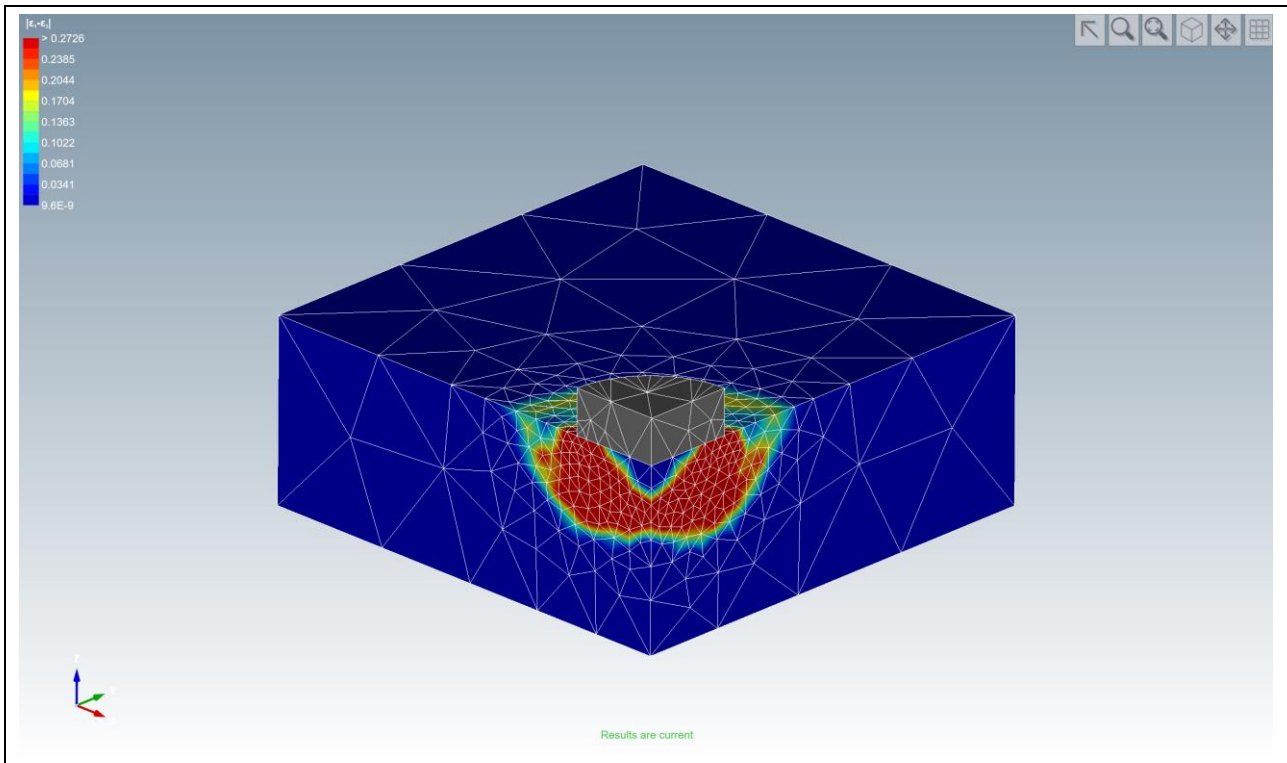
Circular foundation on Tresca
soil

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2   Circular footing on Tresca soil

Figure 4: Shear strains (Mixed element)

Results:

Element	Limit load	Benchmark	Discrepancy (%)
Lower	584.485	604.822	-3.4%
Upper	630.808	604.822	+4.3%
Mixed	611.687	604.822	+1.1%

The benchmark is computed using the method of characteristics program of Martin (2004) which is known to produce very accurate solutions.

General description:
Solid domain: 5x5x2m. Foundation: Rigid weightless solid modelled as an N-Prism with N = 48 (N = 12 for the quarter model). Sides are supported normally, bottom is fully fixed. A distributed multiplier load of -1kPa is applied to the top of the foundation. The soil is modelled as a Tresca material with s_u = 100 kPa. Limit Analysis is used to determine the limit loads (collapse multipliers).

Material properties:

Strength

Strength	
Option	Standard
s_u (kPa)	100

Unit Weight

Unit Weight	
γ (kN/m³)	18

Stage settings:

Settings	
Element Type	Mixed
No of Elements	2000

Mesh	
Mesh Adaptivity	Yes
Adaptive Iterations	3
Start Elements	1000

Note: Element Type = Lower and Element Type = Upper are used for the first two analyses.

Reference:
Martin C.M. 2004. ABC – Analysis of Bearing Capacity. Available online from http://www2.eng.ox.ac.uk/civil/people/cmm/software.