OPTUM GX

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

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1 Introduction

This document verifies the solid elements available in OPTUM GX 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 OPTUM GX, 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 OPTUM GX.

3 Circular footing on Tresca soil

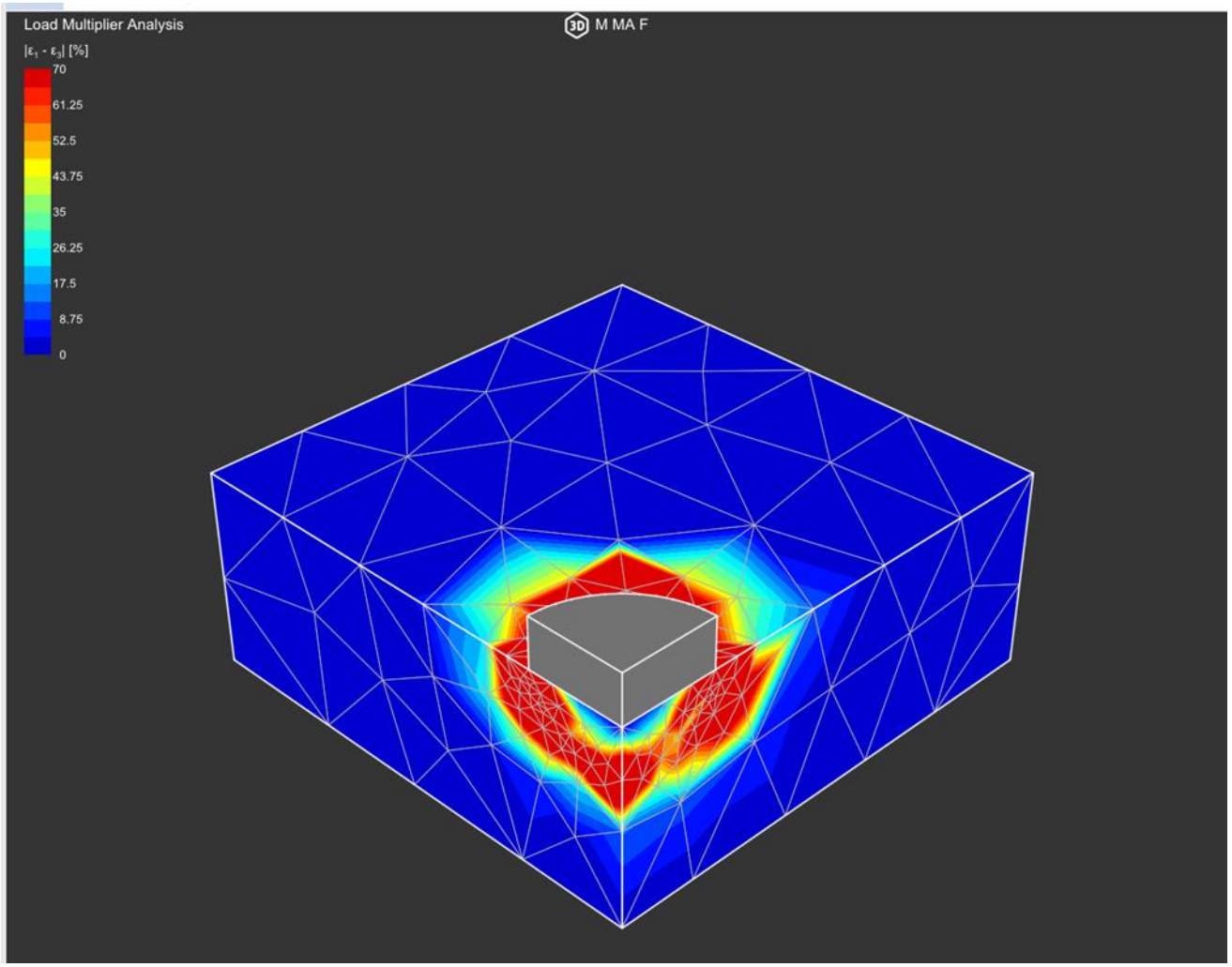

Figure 4: Shear strains (Mixed element)

Results:

Element	Limit load	Benchmark	Discrepancy (%)
Lower	582.7	604.8	-3.7%
Upper	626.9	604.8	+3.7%
Mixed	613.5	604.8	+1.4%

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:

Stiffness	
E_u (MPa)	30
Strength	
c_u (kPa)	100
Unit Weights	
γ_{dry} (kN/m^3)	18
γ_{sat} (kN/m^3)	20

Stage settings:

PROPERTIES	
Settings	
Element Type	Lower
Mesh	
Mesh	Medium
Mesh Adaptivity	Yes
Initial Conditions	
From	None
Safety	
Design Approach	Unity
Time	
Time Scope	Long Term
Advanced	
Multiplier	Load

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.