

OPTUM GX

Verification of Mohr-Coulomb model in different soil tests



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1 Introduction

1.1 Failure criterion

The Mohr-Coulomb failure criterion is given by

$$F = |\sigma_1 - \sigma_3| + (\sigma_1 + \sigma_3)\sin \phi - 2c\cos \phi = 0 \quad (1.1)$$

where c is the cohesion and ϕ is the friction angle. The principal stresses (positive in tension) are ordered as:

$$\sigma_1 \leq \sigma_2 \leq \sigma_3 \quad (1.2)$$

1.2 Elastic law

The Mohr-Coulomb model uses Hooke's law which is given in terms of principal stresses and strains by

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu & -\nu \\ -\nu & 1 & -\nu \\ -\nu & -\nu & 1 \end{bmatrix} \begin{pmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{pmatrix} \quad (1.3)$$

where E is Young's modulus and ν is Poisson's ratio.

1.3 Biaxial test

In biaxial compression, failure occurs when

$$\sigma_{1,f} = \sigma_3 \frac{1 + \sin \phi}{1 - \sin \phi} - 2c \frac{\cos \phi}{1 - \sin \phi} \quad (1.4)$$

1.4 Triaxial tests

In triaxial compression, failure occurs when

$$\sigma_{1,f} = \sigma_3 \frac{1 + \sin \phi}{1 - \sin \phi} - 2c \frac{\cos \phi}{1 - \sin \phi} \quad (1.5)$$

while, in extension, failure occurs when

$$\sigma_{3,f} = \sigma_1 \frac{1 - \sin \phi}{1 + \sin \phi} + 2c \frac{\cos \phi}{1 + \sin \phi} \quad (1.6)$$

In triaxial compression with $\sigma_1 < \sigma_2 = \sigma_3$, the strains below failure are given by

$$\varepsilon_1 = \frac{1}{E} \sigma_1 - 2\nu\sigma_3, \quad \varepsilon_2 = \varepsilon_3 = \frac{1}{E} (1 - \nu)\sigma_3 - \nu\sigma_1 \quad (1.7)$$

2 Biaxial test

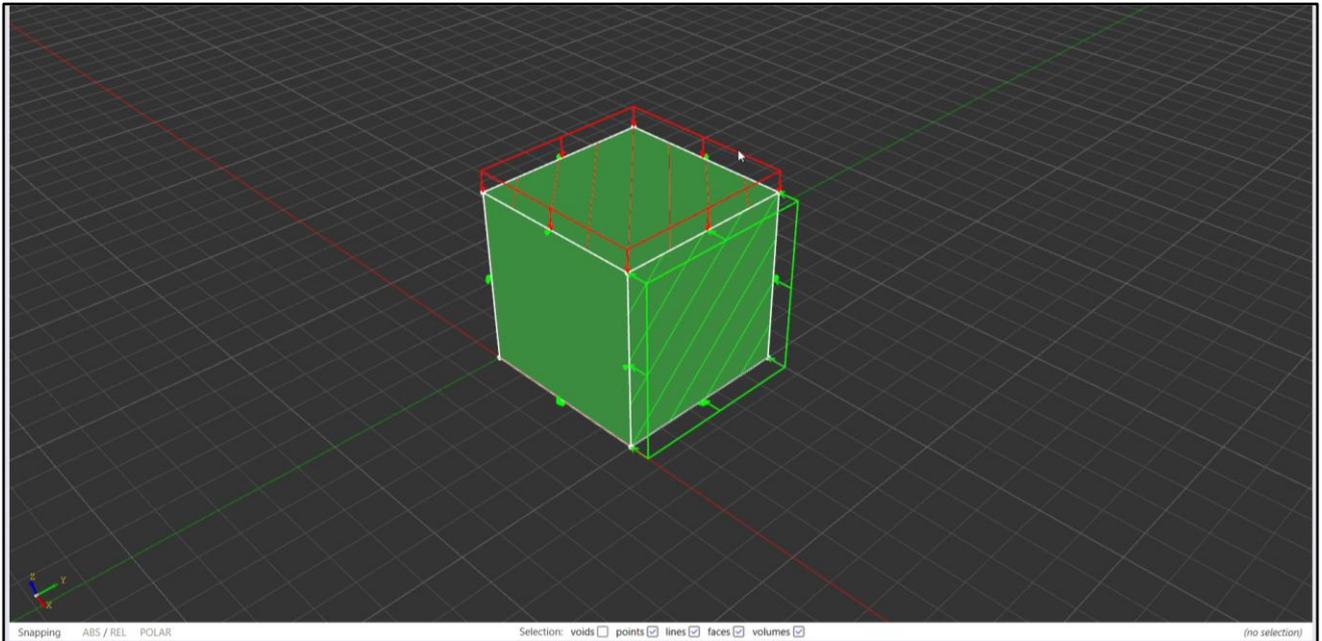


Figure 1: Biaxial test

| | |
|--------------------|---------|
| Benchmark | 262.088 |
| Results | 262.088 |
| Discrepancy | 0% |

General description:

Cubic 5x5m specimen. Selected sides normally supported to reproduce plane strain conditions. A fixed load of -100 kPa is applied along with a multiplier load of -1kPa. Limit analysis is then used to determine the collapse multiplier.

Material properties:

| Material | |
|-------------------------------------|---|
| Name | MC Basic |
| Material Model | Mohr-Coulomb |
| Color | Change... |
| Reducible Strength | Yes |
| Drainage | |
| Drainage | Drained/Undrained |
| Cavitation Cut-Off | No |
| Stiffness | |
| E (MPa) | 0.1 |
| ν | 0.25 |
| Strength | |
| c (kPa) | 5 |
| ϕ (°) | 25 |
| Flow Rule | |
| Flow Rule | Associated |
| Unit Weights | |
| γ_{dry} (kN/m ³) | 0 |
| γ_{sat} (kN/m ³) | 0 |

Stage settings

| PROPERTIES | |
|---------------------------|-------------|
| Settings | |
| Element Type | Mixed ▼ |
| Mesh | |
| Mesh | Minimal ▼ |
| Mesh Adaptivity | No ▼ |
| Initial Conditions | |
| From | None ▼ |
| Safety | |
| Design Approach | Unity ▼ |
| Time | |
| Time Scope | Long Term ▼ |
| Advanced | |
| Multiplier | Load ▼ |

3 Triaxial compression test

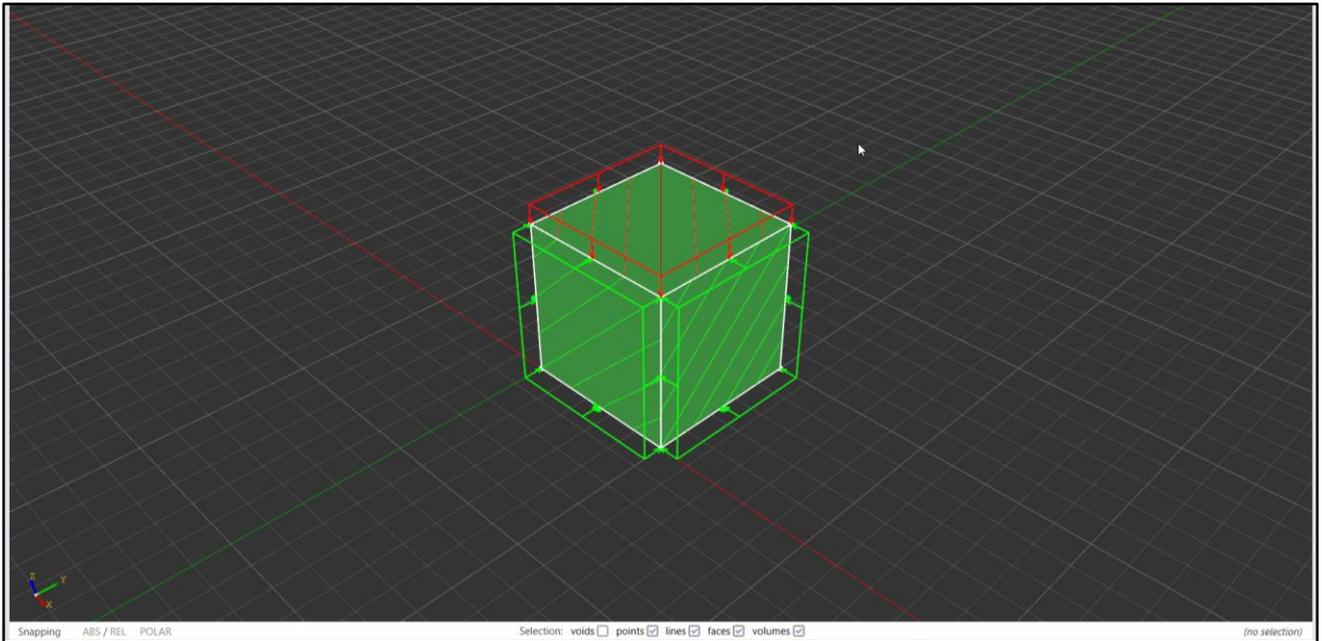


Figure 2: Triaxial compression test

| | |
|--------------------|---------|
| Benchmark | 262.088 |
| Result | 262.088 |
| Discrepancy | 0% |

General description:

Cubic 5x5m specimen. Selected sides normally supported to reproduce triaxial conditions. Fixed load of -100 kPa are applied along with a multiplier load of -1kPa. Limit analysis is then used to determine the collapse multiplier.

Material properties:

| Material | |
|-------------------------------------|---|
| Name | MC Basic |
| Material Model | Mohr-Coulomb |
| Color | Change... |
| Reducible Strength | Yes |
| Drainage | |
| Drainage | Drained/Undrained |
| Cavitation Cut-Off | No |
| Stiffness | |
| E (MPa) | 0.1 |
| ν | 0.25 |
| Strength | |
| c (kPa) | 5 |
| ϕ (°) | 25 |
| Flow Rule | |
| Flow Rule | Associated |
| Unit Weights | |
| γ_{dry} (kN/m ³) | 0 |
| γ_{sat} (kN/m ³) | 0 |

Stage settings:

| PROPERTIES | |
|---------------------------|-------------|
| Settings | |
| Element Type | Mixed ▼ |
| Mesh | |
| Mesh | Minimal ▼ |
| Mesh Adaptivity | No ▼ |
| Initial Conditions | |
| From | None ▼ |
| Safety | |
| Design Approach | Unity ▼ |
| Time | |
| Time Scope | Long Term ▼ |
| Advanced | |
| Multiplier | Load ▼ |

4 Displacements

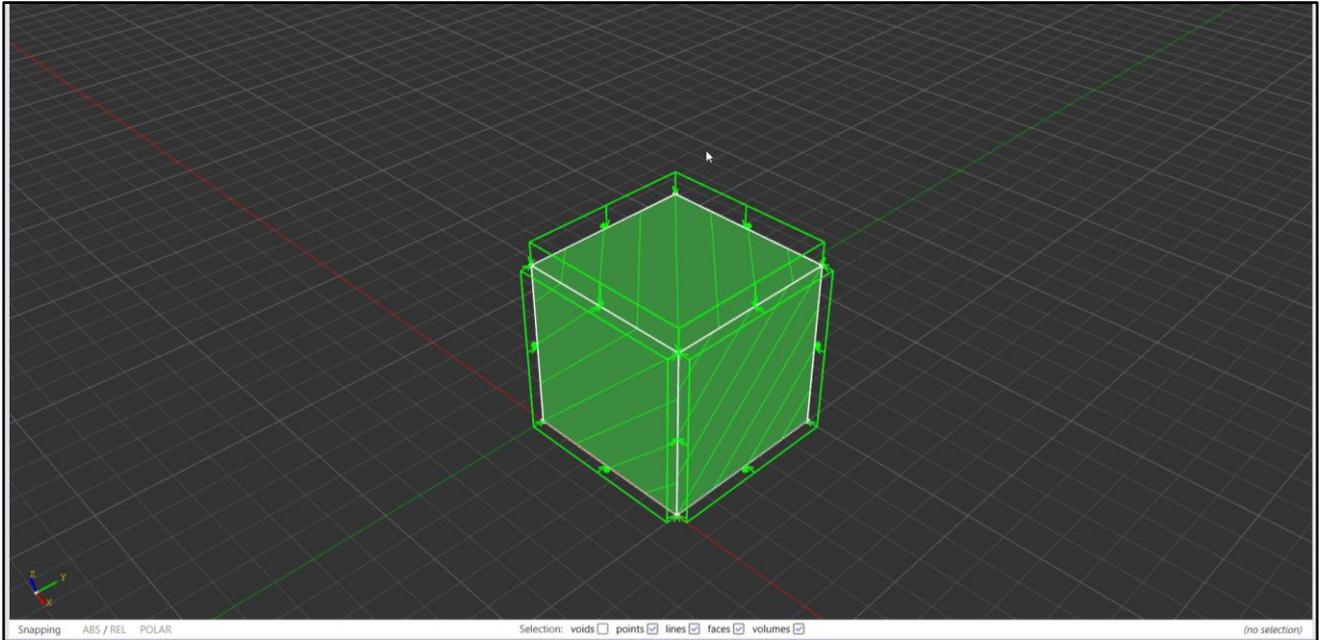


Figure 3: Triaxial compression test for elastic analysis

Results:

| | Result | Benchmark | Discrepancy (%) |
|-----------------|--------|-----------|-----------------|
| ε_1 | -1.5 | -1.5 | 0% |
| ε_2 | -0.25 | -0.25 | 0% |
| ε_3 | -0.25 | -0.25 | 0.0% |

General description:

Cubic 5x5m specimen. Selected sides normally supported to reproduce triaxial conditions. Fixed load of -100 kPa are applied horizontally along with a fixed load of -200 vertically. Elastic analysis is then used to determine the displacements.

Material Properties:

| Material | |
|-------------------------------------|---|
| Name | MC Basic |
| Material Model | Mohr-Coulomb |
| Color | <i>Change...</i> |
| Reducible Strength | Yes ▼ |
| Drainage | |
| Drainage | Drained/Undrained ▼ |
| Cavitation Cut-Off | No ▼ |
| Stiffness | |
| E (MPa) | 0.1 |
| ν | 0.25 |
| Strength | |
| c (kPa) | 5 |
| ϕ (°) | 25 |
| Flow Rule | |
| Flow Rule | Associated ▼ |
| Unit Weights | |
| γ_{dry} (kN/m ³) | 0 |
| γ_{sat} (kN/m ³) | 0 |

Stage Settings:

| PROPERTIES | |
|--------------------|-----------------|
| Settings | |
| Element Type | Mixed ▼ |
| Analysis type | Elastoplastic ▼ |
| Mesh | |
| Mesh | Minimal ▼ |
| Mesh Adaptivity | No ▼ |
| Initial Conditions | |
| From | None ▼ |
| Initial stresses | None ▼ |
| Safety | |
| Design Approach | Unity ▼ |
| Time | |
| Time Scope | Long Term ▼ |