PLAXIS 3D Benchmark for Suction Anchor Bearing Capacity

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Plaxis bv
Objectives

• Demonstrate the capabilities of PLAXIS 3D to model suction anchor in soft clay easily and quickly

• Accurately predict bearing capacity of suction anchors including
  – H-V interaction
  – Load attachment point variation

• Match NGI benchmark results from Andersen et al (2005)*

Plaxis 3D FEA Modelling Overview

• Plaxis models defined according case C1 i.e.
  – Depth / Diameter = 5
  – Normally consolidated clay

• Two calculations series undertaken
  – Variation of load inclination $\theta$ at optimal load attachment point $\theta = 0^\circ, 10^\circ, 20^\circ, 30^\circ, 45^\circ, 90^\circ$
  – Variation of load attachment depth with a fixed $30^\circ$ load inclination

• Calculations done with PLAXIS 3D Research version
Model Presentation

- Failure mechanism to fit in soil model
- Half-geometry modeled
- Suction anchor modeled as stiff plate elements
- Very stiff plug
- Interface elements
  - Around the pile
  - Underneath the pile
Soil Material Properties

- Undrained behavior modeled in a total stress approach
  - Undrained stiffness $E_u = 5000 \text{ kPa}$ (not relevant as bearing capacity to be evaluated) and $v_u=0.495$
  - Undrained shear strength $s_{uc} = 1.25 \times z$ (based on DSS shear with no reduction) and $\varphi_u = 0^\circ$
  - Reduced shear strength along skirts $s_u = 0.65 \times s_{uc}$
- Soil unit weight
  - Saturated unit weight $\gamma_{sat}=16 \text{ kN/m}^3$
  - Initial effective vertical stress is therefore $\sigma'_{v,ini} = 6 \times z$
Meshing

- **Auto mesh generation**
  - 10 noded tet elements
  - Coarse mesh setting
  - Local refinement inside and around pile

- **Mesh characteristics**
  - 30000 elements
  - 44000 nodes
Plaxis Calculations

- Loading applied along the center line as a prescribed displacement
- Two calculations series undertaken
  - Variation of load inclination $\theta$ at optimal load attachment point $\theta = 0^\circ, 10^\circ, 20^\circ, 30^\circ, 45^\circ, 90^\circ$
  - Variation of load attachment depth with a fixed $30^\circ$ load inclination
- Use of multicore direct solver on a 8 core machine (two simultaneous runs over 4 cpus each)
Main Results for Horizontal Loading

Deformed shape at failure

Load displacement curve
Failure Mechanism for Horizontal Loading

Plastic points at failure

Plastic shear strain at failure
Main Results for Vertical Loading

Deformed shape at failure

Load displacement curve
Failure Mechanism for Vertical Loading

Plastic points at failure

Plastic shear strain at failure
H-V Interaction Diagram

- Results of load inclination variation calculation series

PLAXIS results (failure load interpreted as reaction force at 2m horizontal displacement)

Benchmark results
Variation of Load Attachment Point

- Deformed mesh at failure

- Below optimum with load attachment depth 20 m (z/D=0.55)
- Close to optimum with load attachment depth 17.5 m (z/D=0.70)
- Above optimum with load attachment depth 12.5 m (z/D=0.85)
Variation of Load Attachment Point

- Load vs displacement curves
Variation of Load Attachment Point

• Results of load att. point variation calculation series

**PLAXIS** results

**Benchmark** results
Computational Performance

- Calculation run on 2 x Intel® Xeon® Processor E5620 (Quadcore, 12M Cache, 2.40 GHz) so 8 threads in total
- Total wall clock time for load inclination variation study = 11h30m

<table>
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<th>Load inclination $\theta$</th>
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<th>Wall clock time</th>
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Conclusions

- PLAXIS 3D can straightforwardly deal with modeling of suction anchor without any geometric limitation
- PLAXIS 3D can predict reliable bearing capacities for all relevant loading scenarios
- Effortless definition of geometry, interfaces for soil structure interaction and initial stresses
- Good calculation performance with 6 loadcases fully run in less than half a day for a 130000 dof system