Case history: Soil investigation for offshore suction anchors

Over last 5 - 6 years anchoring of floating and fixed structures have to an increasing extent been done with suction anchors

- much quicker installation
- cost effective
- reliable design procedures
- require reliable soil parameters for optimal design of suction anchor dimensions

Basic principle

Seabed installation of suction anchor

Step by step Seabed installation normal duration 2-3 hrs

Suction anchors in deep waters

- Main foundation problems
  - penetration of skirts (must get to required depth)
  - bearing capacity for pull out forces (including cyclic loading in some cases)

- Soil parameters required
  - shear strength for penetration analyses
  - shear strength for bearing capacity

Depth for which soil information is required:
suction pile length + 1 diameter
Floating structure with suction anchors

Project information:
- Water depth: 340 m
- Four clusters, each with 4 anchors
- Overall anchor pattern diameter: 2,300 m
- Expected suction anchor dimensions:
  - Diameter: 5 m; length: 11 - 13 m
- Main geotechnical problems:
  - Penetration of skirts to required depth below seabed
  - Bearing capacity in terms of pull out resistance

Anchor pattern for North Sea Floating Production Unit

Soil investigation program:
- Nine boreholes to 15 m
- Intermittent CPTUs and sampling
- Laboratory tests including CAUC, CAUE and DSS

Soil design parameters based on correlations between CPTU and laboratory tests

Example borehole locations for one anchor cluster

Down-hole insitu testing

Operation with umbilical, hydraulic cylinder pushes tool below bottom of borehole. Data acquisition through cable and real-time display of test results. Depth limitation about 700 m.

Investigation for floating structure - example down-hole CPTU results
Selection of $N_{ef}$ factors for CPTU interpretation

Investigation for suction anchors - results from combined borehole with CPTU and sampling

Recommended design shear strengths for suction anchors

Deep-water sites around the world

Exxon Diana - Suction Pile anchors
- 12 anchors, each with 1500 ton holding capacity - Highest!
- 220 ton weight, 30.5 m penetration and 6.4 m diameter - Largest!
- 1500 m water depth - Deepest!
- First permanent suction pile mooring in the Gulf of Mexico

Exxon Diana - Suction Pile anchors
- Diana field
- Gulf of Mexico

NGI's main office, Sognsveien 72, Oslo
Exxon Diana - Geotechnical design

Exxon Diana Platform

Exxon Diana Mooring system

Downtown Houston

Diana Spar floating storage and production platform

Exxon Diana - Suction Pile installation

Gulf of Mexico, 18 October to 12 November 1999

Marine Contractor: Saipem, Vessel: S-7000

Suction pile installation contractor: NGI-FRAMO

Seabed at 1500 m depth

Ready for installation

Seabed piles

Suction Pile

Pump skid

Sealed at 1500 m depth
Exxon Diana - Suction Pile installation

Positioning and landing of Suction Pile

Slack lifting wire and close valves

Pump out entrapped water and penetrate by suction

Exxon Diana - Suction Pile installation

Weight penetration with free water evacuation

Petrobras P-18 Riser supports L/D = 8.5

Maximum suction penetration depth
Suction penetration response

Differential pressure inside anchor (kPa)

Penetration (m)

Predicted upper bound
Predicted lower bound

Soft homogeneous clay
typical for deep-water sites

Cone penetration resistance, Qc (MPa)

CPT A
CPT B
CPT C

Layered glacial clay
Haltenbanken Norway

Pre-installed conductors

Pre-installed conductors

Suction caisson
Conductor

Pre-installed conductors