Installation of suction caissons for Offshore Wind Turbines

Danish Geotechnical Society Seminar 1\textsuperscript{st} April 2014

Presented by Tor Inge Tjelta
Installation of suction caissons for OWT’s
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Experience in offshore wind?
Installation of suction caissons for OWT’s

Experience in offshore wind?

Not much
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Three Met Masts: Horns Rev 2 and Dogger Bank East & West

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**Worldwide experience**
Suction caisson foundations world wide

More than 30 years experience in variable soil conditions
Why suction techniques & foundations

- First time used in 1980
- «Re-invented» in 1985 and early 1990’s
- Extensively used since 1995. WHY?
  - Cost and reliability
  - Precise positioning
  - Predictable capacity
  - Robust solution
  - Relatively insensitive to soil conditions
  - «Cheap driving force» with incredible capacity
    - Gullfaks C: > 500 000 tons (300 kPa x 17000 m²)
    - Aasgard B/C: suction in the order of 1500 kPa (15 bar)

Little experience prior to 1995
- Floating production
- Subsea structures
GFC and Åsgard Suction Caissons

500 000 tons driving force, or 1500 KPa suction:
Noise free!
Suction applications since 1980

Year

Permanent Suction anchors installed

- Gullfaks C Penetration test
- Snorre TLP
- Troll GBS platform
- Draupner jacket
Suction history

- Gorm 1980
- Gullfaks C 1985/89
- Draupner and Sleipner Jackets w/ Bucket foundations 1994 & 95
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1. Gullfaks C test 1989
Gullfaks C Penetration test 1985

Instrumented concrete skirt segment

Water injection
Gullfaks C Penetration test 1985

Twin cylinders penetrated 22m deep
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2. Dudgeon 2013
Dudgeon field penetration tests

• An offshore test program at Dudgeon 2013
• 11 test locations
• Multiple tests at several locations; 20 tests in total

Water jets at skirt tip at 12m³/hr supply
Dudgeon field penetration tests objectives

• Prove installation feasibility of bucket foundations at Dudgeon

• Test program included:
  – Investigation of skirt friction in Bolders Bank clay, several locations
  – Investigation of mitigation techniques:
    • “Cyclic penetration”
    • Water injection at skirt tip
    • Cyclic penetration in combination with water injection
  – Investigation of penetration resistance in layered soils with sand layers of limited thickness
  – Investigation of penetration through dense sand layers below clay

• Investigation of pump performance and in particular limits with respect to cavitation in the pump.
Test program - details

The following seabed categories were tested:

1) Channel infill (soft clay)
2) Regular Bolders Bank clay
3) Clay with «sand-spikes»
4) Clay with sand layers
5) Clay crust
6) Sand
7) «Most challenging»
Test structure

- Dimensions:
  - Height: 5.0m
  - Diameter: 3.4m
  - Weight: 12.8 T

- Features:
  - 20° vent valve
  - Pressure sensors & Inclinometers
  - Pump loop
  - Inside Echosounder
  - Outside Echosounder

- Water supply indication
Best and high estimate tip and total resistance at some locations
Test result
Location «CPT-100»

- Category: Clay with sand-layer
- Always considered a challenge
- Proved to be relatively easy
Conclusions Dudgeon field tests

- Skirt penetration achievable all over Dudgeon to significant depths
  - The small diameter test-anchor was penetrated to more than 4m at every location
  - For an 8m dia bucket this scales to approx. 8-10m penetration
- The results proves significant penetration is achievable even without water injection
- Valuable information on installation equipment obtained (pump, valves, cavitation limits etc.)
- ....
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3. CT/OWA Trial Installation Project
OWA Trial Installation Project Business Case

(Extract from presentation to OWA partners 17th March 2014)
Introduction

• Reducing foundation CAPEX is integral to ensuring the offshore wind industry’s cost reduction ambitions are achieved.
• Suction bucket technology is a potentially important technology in realising this.
• One such suction bucket concept, is the Universal Foundation, which leads the OWA foundation workstream in terms of its cost reduction potential.
• Suction bucket technology however has a far wider ranging potential for the industry and it is imperative that the application of the general installation principles are understood in order to enable further technological and concept development within the industry.
• The suction installation process for bucket foundations needs de-risking before it can be considered technically and commercially viable as a foundation solution for the offshore wind market.
• This is the aim of the OWA trial installation project.
The Need Case

- Cost comparison using OWA foundation cost benchmarking tool
- Based on 8MW WTG in 25 metre water depth shows 34% cost reduction potential

£/MW: XL MP v UF
Project History

- Summer 2011 project initially proposed by Carbon Trust in OWA.
- Summer 2012 interested partners EON, DONG, Statkraft, Statoil.
- Statoil as Lead Participant
- Scaled down 5MW design planned to be trialled
- 4 x test locations on Dogger Bank
- Cost indication: £4.0m project (£2.0m from OWA and £2.0m from UF)
- Planned for execution in 2013 however delayed due to failure at Dogger Bank met mast west
Scope of Work – Test Sites

• Planning operations at Dudgeon, Hornsea and Dogger Bank wind farm zones.

• Acquire as many tests as possible in a 28 day offshore period.

• Site selection currently ongoing – aim to test performance in challenging layered soils (clay over sand) and other conditions representative for Round 3 wind farm sites (sites selected to be presented to OWA project)
Location 1074: Clay over «layered» sand

Depth [m] | Soil Description
--- | ---
0.0 - 1.2 m: Dense to very dense dark grey slightly silty fine becoming medium SAND, with a few organic matter and shell fragments
1.2 - 4.5 m: Firm becoming very stiff dark grey slightly sandy CLAY
- from 1.2 m to 2.6 m - with shell fragments and pockets and thin laminates of sand
- from 1.2 m to 1.6 m - clay with rounded to subrounded fine gravel
4.5 - 11.4 m: Medium dense to very dense olive brown fine to medium SAND, with a few shell fragments and rounded to subrounded fine to medium gravel
11.4 - 18.4 m: Very stiff dark grey to very dark grey slightly sandy CLAY, with a few rounded to subrounded fine gravel of mixed lithologies including chalk
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## Think Installation Installation Installation Installation

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### Mitigations

### Trial Installation Project
Installation is always important!

- Installation of suction caissons can be «a piece of cake», however can also go seriously wrong.
- Structural failure or penetration refusal are two of the issues.
Some DOs and DON’Ts in suction caisson installation

• **Know your site**
  «you pay for a soil investigation whether you do one or not - and in the latter case you are likely to pay more»

• **Design** (geotechnical, structural and marine operations)

• **Experience** important
  no need to repeat all past mistakes

• Don’t make too many assumptions

• **Don’t save money on pumps!**
  (they are not expensive anyway)

• Before taking equipment and/or new solutions offshore; TESTING
Conclusions

- Suction caissons are used world wide
  - Technology is simple
  - Installation equipment is simple
  - **Require soil information**
- Challenges
  - High aspect ratios (L/D>>1)
  - High pullout loads (passive suction)
  - Drained tension loads
  - **Layered soils** (installation)
  - **Boulders** (not really?)
  - **Gravel beds**
- “No limitation”? (few if any real failures in oil & gas)
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Thank you for your attention!