ROVDrill Mk2
THSiS Evening Meeting
Wednesday 25\textsuperscript{th} Feb
Geotechnical Survey Techniques
ROVDrill Mk1

Original ROVDrill Mk.1

- Originally built for deep water mining sampling application in 2008
- Client: Nautilus Minerals Inc.
- Established good and proven track record of reliability and core recovery:
  - 18m boreholes / NQ core
  - 96 holes drilled
  - 2000m water depth
  - Successful campaign in extreme topographic seabed conditions

Limitations:

- Designed for specific coring application to 20m depth
- No in situ testing e.g. CPT
- No push/piston sampling in soft soils
ROVDrill Mk2

ROVDrill Mk.2 Improvements

- CPT Capability
- Push & Piston Sampling
- Increased Borehole depth
- Push & Piston Sampling
- Subsea Mud System

Borehole Capabilities

- Continuous CPT to 112.7m
- Continuous Sampling (2.7m Sampler) to 56.4m
- Composite Borehole (3m CPT with 2 x 1.5m Sampler) to 58.2m
Subsea Mud System

Pure-Bore® Liquid

- Bespoke polymer drilling fluid developed, specific to constraints of subsea drilling units – PureBore Liquid
- Environmentally friendly CEFAS gold rated.
- Non-toxic drilling fluid
- Fast and efficient mixing in salt or fresh water
- Effective in all ground conditions
- High yield point and gel strength for maximum cuttings suspension and transport
- Provide optimal lubrication, cuttings transportation, and gelling characteristics, even in low concentrations (basic polymer);
- Create a filter cake to enhance stability of the borehole walls, particularly in non-cohesive soils (additional features of the advanced polymer).
Subsea Mud System

Notes:
1 - All 2” hosing to be fitted with stainless steel hose clamps
2 - All fittings and hose ends to be stainless steel
3 - 2” hosing to be cut to length during installation
4 - Parker push lock hose and fittings to be used for mud injection
5 - Parker push lock hose to be cut to length during installation
Rock Coring

Area: The Skerries, North west coast of Anglesey

Water depth: 15 to 30 meters

Borehole & CPT Depth: 20 meters - Rock coring

Soil conditions: Medium strong to strong Metasiltstone

Continuous working through high seabed currents up to 8 knots recorded and high sea swells up to 4 meters
Close Approach Work

Client: Apache
Area: Forties Alpha Field, North Sea
Water depth: 105 to 125 meters
Borehole & CPT Depth: 38.5 meters
Soil conditions: Sandy silt underlain by very soft to soft clay
Close proximity operation – within 30m of the side of the FAS Platform
Close Approach in Very Shallow Water

Client: Total
Area: Offshore Gabon
Water depth: 12.5 to 60 meters
Borehole & CPT Depth: 15 to 40 meters - push and piston samples recoveries
Soil conditions: Very dense sand overlaying firm to hard clay
Shallow water and close approach working
New ROVDrill Piston Sampler System

- Developed through Gardline
- Initial Testing at Onsøy by NGI
  - (Extract from report)
    One set of CRSC and CAUC triaxial tests have been carried out on each of the three samples from the second borehole. The results from these laboratory tests have been compared with previous CAUC tests on block samples and NGI's 54 and 72 mm piston samples from the same test site.

  On average the quality of the new piston samples are equally good, or slightly better than the NGI piston samples. Using NGI's criteria for evaluation of sample quality the two upper samples are in the best category: Very good to excellent. The quality of the deepest sample is in the Good to fair category.
Piston Sampler

Client: Statoil
Area: Offshore Norway
Water depth: 380 to 400 meters
Borehole & CPT Depth: 26 meters - push and piston sample recoveries
Soil conditions: Very soft to firm clay
HSE benefit highlighted by Statoil removal of human interface
Piston Sampler
Deep Water

Client: MODEC
Area: Offshore Ghana
Water depth: 1300 to 1800 meters
Borehole & CPT Depth: 40 meters - piston sample recoveries
Soil conditions: Homogenous very soft clay
High quality piston sample recovery
Development of piston sampler

**RECIPE**: Supported by extensive literature

- The sample diameter as large as possible: Increase representativeness, reduce disturbance
- Relatively small area ratio: ideally below 15%
- Cutting shoe angle needs to be as sharp as practically possible, ideally close to 5°
- The piston should be absolutely stationary relative to seafloor.
- The length of sample entering the sample tube should be the same as the penetration.
- Constant rate of penetration between 0.4 and 4 cm/s.
- The length of the sampler should be ideally no more than 1 m in order to ease transportation and extrusion operations.

**IMPLEMENTATION**: Challenge maximise storage space.... Compromises are required

- Sampler and sampling tube should be limited to 3m
- The sampler and sampling tube should be a self contained independent unit in order for the manipulator arm to handle the sample with ease
- Sample diameter should be limited in order to increase the storage capability and integrate with the system
- Sampling tube length should be maximized to increase storage capacity
# Development of piston sampler

<table>
<thead>
<tr>
<th>PISTON SAMPLER DIMENSIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Diameter</td>
<td>90 mm</td>
</tr>
<tr>
<td>Total Sampler Length</td>
<td>3000 mm</td>
</tr>
<tr>
<td>Sample Length</td>
<td>1300 mm</td>
</tr>
<tr>
<td>Sample Tube Inside diameter, $D_i$</td>
<td>72.1 mm</td>
</tr>
<tr>
<td>Sample Tube Outside diameter, $D_o$</td>
<td>76.1 mm</td>
</tr>
<tr>
<td>Cutting Angle</td>
<td>5°</td>
</tr>
<tr>
<td>Area Ratio $C_a = (D_o^2 - D_i^2) \times 100 / D_o^2$</td>
<td>11.4%</td>
</tr>
</tbody>
</table>
WHilst pushing

Water pump pressurises cylinder

Dynamic piston advances Shelby tube

Water is vented through the rod out into the borehole

Static piston seals and supports sample

SHELBY TUBE SHOWN IN GREEN

Resetting sampler

High pressure water is pumped through connector

Water in cylinder is pushed out through threaded pin

Dynamic piston moves upwards

Home position
Anisotropically consolidated compression tests results

The results confirm that the new sampler provides very well defined peak strengths comparable with block sampler results and with relatively high rates of strain softening.
Sample Quality Assessment

Change in axial strain when consolidating to in situ vertical stress is good indicator of sample disturbance.

It has been found convenient to express this as change in void ratio normalized to initial void ratio: $\Delta e/e_i$

<table>
<thead>
<tr>
<th>OCR</th>
<th>$\Delta e/e_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>2-4</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>4-6</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>

Effect of sample disturbance is to give too low $p_c$'

Change in void ratio normalized to initial void ratio: $\Delta e/e_i$
Sample Quality Assessment
Comparison with conventional sampler – Barents Sea

Sample quality assessment

CRS Test results

Criteria for sample quality (Lunne et al., 1998)

Distance between boreholes 107 and 112 is 2 m
With practice and experience....

Offshore Ghana

The majority of samples fall on the Very Good to Excellent Category

Sample handling can play a fundamental role for on preservation of sample quality