CASE STUDY - GEOHAZARD INVESTIGATION FOR OFFSHORE DRILLING SITES

Denny Tami, Ph.D
5th June 2020, 5pm (India) / 730pm (KL)

Webinar on

Organised by:
Dr. Parthasarathy
Chairman of the Indian Geotechnical Society (IGS) - Bengaluru Chapter
Webinar ID: 856 4942 2593 - Password: 888306

Webinar Overview

Geohazard Investigation or Survey is performed throughout a well life cycle from exploration, development, production, monitoring and decommissioning. The purposes of geohazard investigation are to identify, map and evaluate or quantify the impact of geohazards on planned activities and well operations. Hence, costly stability problems and dangerous accidents during offshore drilling activities due to various geohazards can be prevented.

The term geohazards refer to features of the geologic origin or human-made, on and/or beneath the seafloor, that poses a threat to engineered structures. The main devastating effects of geohazards are loss of lives, rig sinking, pipeline burst, environmental pollution, or structure collapse. The less harmful impacts have severe financial consequences as well as significant project delays.

PCSB 3D Conceptual Block Model for Jack-up Foundation Hazards
Source: OTC-28345-MS, Regional Suitability Mapping PRSM Project – An Update (Rohani et al, 2018)
Dr. Denny Tami

**Personal Info**
- Indonesian / Singapore PR
- BSc in Civil (ITB 1995, cum laude); MSc (ITB 1998, cum laude); Ph.D (NTU Singapore 2003)

**26-year experience in geotechnical field**
- 5 years at Bandung Institute of Technology, Indonesia
- 3 years at Nanyang Technological University, Singapore
- 4 years at CSC Piling Specialist, Singapore
- 6 years at Fugro, Singapore
- 7 recent years at Java Offshore, Singapore - KL - Jakarta

**Current role & responsibility**
- VP | GeoConsulting – Java Offshore

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**Acknowledgments**

**Organizer**
Dr. Parthasarathy
Chairman of the Indian Geotechnical Society (IGS) - Bengaluru Chapter

**Java Offshore**
Support and Permission from the Management
Assistance in reviewing of the slides

**Source of materials**
Clients’ data
Previous employers and colleagues
Internet

**Participants**
for the time and the attention
Who we are?

JAVA OFFSHORE - Brief Introduction

Established in 2012 from:
- Earlier incorporation of PT Offshore Works Indonesia in 2010
- Acquiring of Asian Geos Sdn Bhd in 2017

Java Offshore owns and operates:
- 7 dedicated geophysical and geotechnical vessels
- > 120 skilled permanent team members.
- > 80 contract staff operating.

- ISO 9001:2015;
- ISO 14001:2015;
- OHSAS 18001:2007 Certified

What we do?

GeoConsulting

Geophysical Survey
- Seafloor Mapping
- Seismic Profiling
- Navigation and Positioning
- Rig Move Positioning

Geotechnical Survey
- Soil Investigation
- Laboratory Testing
- Seabed CPT & SPT
- Jumbo Coring

GeoConsulting
- Geotechnical Consulting
- Geo-hazards Analysis
- Engineering Analysis - Offshore Foundation
- Structural Monitoring

GeoData

GeoSolutions

Operational Management

- Seafloor Mapping
- Seismic Analysis
- Laboratory Testing
- Geotechnical Consulting
- Geo-hazards Analysis
- Engineering Analysis - Offshore Foundation
- Structural Monitoring
- Geophysical Survey
- Seafloor Mapping
- Seismic Analysis
- Laboratory Testing
- Geotechnical Consulting
- Geo-hazards Analysis
- Engineering Analysis - Offshore Foundation
- Structural Monitoring
Outline & Objective

What to expect from this webinar:

- Survey Design *(planning for survey)*
- Geophysical Survey *(for non-specialist)*
- Geohazard Assessment Case Studies *(drilling related)*
- Geotechnical Investigation *(shallow water regime)*
- Geotechnical Engineering Case Studies *(drilling sites)*

- Understanding the need both Geophysical & Geotechnical surveys
- Sharing case studies, related to geohazard in offshore drilling sites
### Why perform Survey?

#### #1: Control of ground risk:
- Blowout, due to Shallow Gas
- Deep / Uneven / Slow spudcan penetration
- Shallow Water Flows

#### #2: Obtain ground parameters:
- Leg Penetration Analysis & Other Designs
- Punch through & Rapid uncontrolled leg run
- Location approval

### What Geohazard for Drilling Site is?

1. Shallow Gas
2. Spudcan-Pile Interaction
3. Ground Motion (Earthquake)
4. Thick Soft Clay Layer
5. Crust (Punch-Through)
6. Buried Channel(s)
7. Spudcan-Footprint/Crater Interaction
8. Spudcan-Pipeline Interaction
9. Scour
10. Coral

Source: Regional Suitability Mapping PRSM Project – An Update (Rohani et al, 2018)
Lifecycle Of Offshore Facilities
Survey needed in almost each phases

When to Conduct Survey?

Which factors need to consider?

Objectives of the Investigation?
→ Type of Survey & Method

Environment, Water Depth (Where the Location is)?
→ Survey System, Techniques, Safety

Stand Alone or Combined/Integrated Investigation?
→ Mode of Operations, Type of Vessel

Regulations, Standards, Permits, Code of Practices for Marine Activities?
→ Specifications, Safety, Legal & Financial Consequences
Industry Legislation, Regulations, Guidelines?

(including STANDARDS, PRACTICES, PERMITS)

**International / Local Maritime** Standards (IMO, IMCA, UKOOA, MIGAS, BP MIGAS, etc.)

**International (Offshore) Oil and Gas Industry** Standards and Code of Practices (API, DNV, SNAME, etc.)

**International Soil Mechanics/Geotechnical/Geophysical** Standards and Code of Practices (ASTM, BS, IAGC, etc.)

**Local Permits** that Vary from Country to Country (Operating, Immigration, Customs/Import and Re-Export, Security Clearance, Dispensation, Work Permits, etc.)

Survey Design (planning for survey)

Geophysical Survey (for non-specialist)

Geohazard Assessment (drilling related)

Geotechnical Investigation (shallow water regime)

Offshore Geotechnical Engineering (drilling sites)
Geophysical site survey for Drilling Site typically consists of:

1. Echo Sounding → water depth / bathymetry survey
2. Sonar Systems → seabed features
3. Magnetometer survey → magnetic anomalies
4. Sub Bottom Profilers → ground stratigraphy
5. 2D Hi-Res → shallow gas detection

JAVA OFFSHORE’s Dedicated Geophysics Survey Vessels
1. WATER DEPTH / BATHYMETRY EXAMPLES

2/3. SIDE SCAN SONAR IMAGES

- Identify Objects
  - Pipelines & cables
  - Wrecks
  - Debris
  - Seafloor topography
    - Rocks
    - Sand waves
    - Spudcan Footprints
    - Scars (trawling) and Ice Scouring
    - Pockmarks

- Seabed Sediments
  - High Backscatter
    - Gravel and coarse sands
  - Medium Backscatter
    - Fine to Medium Sands
  - Low Backscatter
    - Clays and silts
4. SUB-BOTTOM PROFILERS (SBP)

Sparker
Boomer
Pinger

SBP image removed

PENETRATION vs FREQUENCY

<table>
<thead>
<tr>
<th>Source</th>
<th>Function</th>
<th>Frequency</th>
<th>Vertical Resolution</th>
<th>Penetration through seabed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multibeam Echo Sounder</td>
<td>Bathymetry</td>
<td>200 kHz</td>
<td>n/a</td>
<td>0 m</td>
</tr>
<tr>
<td>Sub-bottom Profiler (Pinger)</td>
<td>Pipelines Foundation zone</td>
<td>1.4 – 4.5 kHz</td>
<td>&lt;0.3 m</td>
<td>10-100 m</td>
</tr>
<tr>
<td>High-resolution seismic (2D or 3D)</td>
<td>Shallow hazards</td>
<td>150 Hz</td>
<td>&lt;3 m</td>
<td>&lt;1500 m</td>
</tr>
<tr>
<td>Conventional 3D seismic</td>
<td>Reservoir exploration</td>
<td>50 Hz</td>
<td>&lt;10 m</td>
<td>&gt;3000 m</td>
</tr>
</tbody>
</table>
Case 1: Deep / Uneven Spudcan Penetration, due to buried channel(s)
Case 2: Coral
Case 3: Well at Active Seismicity Zone
Case 4: Shallow gas
Case 5: Crust Layer, potential punchthrough
Recall: Why need to do surveys:

#1: Control of ground risk

#2: Obtain ground parameters
Main Purposes: To Obtain Soil Geotechnical Parameters

Basic Soil Parameters Required for LPA (Leg Penetration Analysis)

<table>
<thead>
<tr>
<th>Sand</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain size</td>
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</tr>
<tr>
<td>Relative Density</td>
<td>Atterberg Limits</td>
</tr>
<tr>
<td>Max/Min Density</td>
<td>Water Content</td>
</tr>
<tr>
<td>Friction Angle</td>
<td>Unit Weight</td>
</tr>
<tr>
<td></td>
<td>Undrained shear strength</td>
</tr>
<tr>
<td></td>
<td>Remoulded shear strength</td>
</tr>
</tbody>
</table>

Methods of Offshore Geotechnical Investigation

- Seabed systems: penetration depth typically 6-12m but can be as deep as 40m in very soft deposit
- Downhole in drill pipe: penetration depth 250 m possible
Discussion & AOB

Downhole Mode - Drilling Equipment

RV Java Illithyia – Malaysian Flag

Top Drive

Rooster Box

Drill Bits

Derrick

Motion Compensator

Pipe Rack & Drill Pipe

Drawork & sampling winch

Seabed Frame

Miclyn Grace – Malaysian Flag

Which Vessel to use?

Water Depth | Seabed Mode | Downhole Mode
---|---|---
< 10m Nearshore / Riverbank | A-frame | LCT Jack-up Barge

10m – 120m Continental Shelf | DP/DP2 | 4-point mooring

> 120m Continental Slope to Deepwater | DP/DP4 |
ONBOARD LABORATORY

1. MV Test
2. Sample Extrusion
3. Cutting of sample
4. Torvane & PP tests
5. Visual description
6. Photograph
7. Moisture content test
8. UU Triaxial

SOIL CONDITIONS
Results of Geotechnical Survey

Boring Logs (client data) removed

Borehole Plan

Bow  Port  Starboard
JACK-UP RIG DETAILS
Parameter Required for Leg Penetration Analysis

Spudcan Details:
- Area: 150.6 m²
- Equivalent diameter: 13.80 m
- Tip below widest section: 1.86 m
- Volume: 225 m³

Intended Load:
- Lightship Weight: 44.6
- Maximum preload: 77.5 MN
Leg Penetration Analysis (LPA) - Failure Mechanisms

General shear failure
(both in layered- as in homogenous soil)

- Punch-through
- Squeezing
- Combination of the above

Notes:
- Formula for each failure mechanism is given in SNAME or ISO.
- Need to understand which mode of failure, given the actual (soil and spudcan) conditions, most likely to occur and apply the formula accordingly.

Why Worry About Punch-through?

Consequential costs of US$1 to US$10 million per failure (source: internet)
Case 1: Punch Through, due to inaccurate selection of Soil Parameters

- Simplification in necessary, but careful on the critical details
- Always be cautious when observe hard layers or lenses in soft clay deposit.

Case 2: Spudcan Footprint Interaction: penetration into existing footprints

- Most of Leg Penetration Analysis is a one-dimensional (1D) analysis
- But if a footprints, pipeline, foundation exist in the vicinity, it will require a three-dimensional (3D) analysis

Case 3: False-Alarm Punch Through, due to inaccurate analysis method

- In addition of accurate soil parameters (ie, Case 1 earlier), selection of appropriate mode of failures is also critical
- Need good engineering judgment and cannot be relayed totally on software to calculate
# Summary - Marine Geophysical and Geotechnical Services

## for Drilling Site / Rig Entry

### 1. Purposes

<table>
<thead>
<tr>
<th>Geophysics</th>
<th>Geotechnics</th>
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<tr>
<td>Collect subsurface data qualitatively</td>
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<tr>
<td>→ define any hazard → selection of well location</td>
<td>→ obtain soil parameters for geotechnical analysis → location approval</td>
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### 2. Scope

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<tr>
<th>Analogue and 2D High Resolution Survey from 1km x 1km to 5km x 5km with line spacing of 100m</th>
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<td>Borehole sampling &amp;/or CPTU at location of each jack-up rig leg</td>
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<td>Pilot hole, if deemed necessary to verify the absence of shallow gas</td>
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<th>Geohazard mapping</th>
<th>Leg Penetration Curves</th>
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<td>→ optimal wellhead location → rig approach</td>
<td>→ hazard for rig emplacement → final leg penetration</td>
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### 3. Results

- Collect subsurface data qualitatively → define any hazard → selection of well location
- Analogue and 2D High Resolution Survey from 1km x 1km to 5km x 5km with line spacing of 100m
- Borehole sampling &/or CPTU at location of each jack-up rig leg
- Pilot hole, if deemed necessary to verify the absence of shallow gas
- Geohazard mapping → optimal wellhead location → rig approach
- Leg Penetration Curves → hazard for rig emplacement → final leg penetration

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### The Last but not Least

#### Learning Point:

- Why we need both Geophysical & Geotechnical surveys.
- Simplifying data is necessary, but failure to understand the data details is fatal (jackup punch-through case)
- Wrong mind "Engineering is the ONLY important process":
  - Always put qualified & experienced people
  - Soil is not homogeneous material, need good judgment.
- Perception that Geophysical & Geotechnical surveys are not seen as important by engineers due to the work being lower value as opposed to EPC work.
Thank You for Listening