Ground Investigation (GI) for Tunnel Projects
- Horizontal Directional Coring

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1. GI Planning for Tunnel Projects

Guidelines for GI Planning
4. GEO TGN24 (2005), “Site Investigation for Tunnel Works”

GI Strategies should be phased (TGN24, 2005)
1. Different stages of the project have different requirements.
2. Alignment and design requirements can change during project planning or design.

**Investigation Stage**
- General picture of ground condition
- To define preferred alignment
- Preliminary stage
- Limited GI

**Preliminary Stage**
- Focus on preferred alignment
- Coverage for further alignment modification
- Engineering parameters
- Hydrogeological model
- Geological model
- Geohazards identification

**Detailed Stage**
- Tunnel alignment fixed
- BH ends ~ 2.5 times tunnel diameter
- Detailed Engineering Design
- Detailed geological & hydrogeological model
- Effective Construction Programme
- Cost estimation for construction works

**Construction Stage**
- Exposed face
- To support design review
- Probe holes to assess geotechnical risks
- Continuous Monitoring
1. GI Planning for Tunnel Projects

A comprehensive GI plan is essential to identify
1. Potentially problematic ground
2. Groundwater conditions
3. For Tunnel Projects, it is valuable to obtain continuous geological and engineering information along tunnel alignment.

Advantages of using HDC
1. Continuous core sample.
2. Extent of problematic rock condition.
3. Genuine groundwater inflow measurement.
4. Reduce construction risks.
5. Facilitate the project programme in terms of time and cost.

2. Technically Advanced Drilling Method – HDC

Background of the HDC Technology
1. The system for directional coring was developed in Norway over 20 years ago.
2. A wireline version was subsequently launched in 2001.
3. The key specialist service provider, a Norwegian registered company, has more than 20 years of worldwide experience in directional coring.
2. Technically Advanced Drilling Method – HDC

The HDC system comprises **3 main components**

3. Windows software package for the planning and plotting of the borehole trajectory.

<table>
<thead>
<tr>
<th>Steerable Drilling Barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole surveying tool</td>
</tr>
</tbody>
</table>

2. Technically Advanced Drilling Method – HDC

The **3 main components of a steerable barrel**

1. Locking Piston – to provide a locked position for the barrel.
2. Packer Assembly – to maintain the toolface position during the drilling process.
3. Adjustable Eccentric Housing – to adjust the bending angle.
2. Technically Advanced Drilling Method – HDC

**Working Principles**

1. Define the trajectory and tolerance
2. Straight section - Conventional Wireline Drilling
3. Curve section - Steerable Drilling System
4. Navigation by toolface & dogleg angle
5. Borehole surveying (i.e. to get the azimuth and inclination)

**Steering System:**

1. Non-rotating outer barrel: Slides in a set toolface while drilling
2. Rotating inner core barrel: Drive the bit
3. Non-rotating innertube: Collect the core

**Steerable Barrel**

1. Provide deviated rock core when drilling in a controlled direction at a control rate.
2. Maximum core-run: 3 m.
3. Core diameter: 31.5 mm in deviated section.
4. Hole diameter: B-size (60 mm) or N-size (76 mm) in straight section.
5. Maximum bending angle: 20 deg/30 m.
6. Optimum bending angle: 9 deg/30 m (R=180 m)
2. Technically Advanced Drilling Method – HDC

Borehole Surveying Tool – PeeWee EMS
1. A miniature electronic multishot that is used for surveying of borehole profile.
2. Length of 0.975 m.
3. Diameter of 30 mm.
4. To provide orientation of a borehole

<table>
<thead>
<tr>
<th>Type of Barrel</th>
<th>Hole Diameter</th>
<th>Core Diameter</th>
<th>Length of Core Run</th>
<th>Typical Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV (in curve section)</td>
<td>76 mm</td>
<td>31.5 mm</td>
<td>3 m</td>
<td>9 m/day</td>
</tr>
<tr>
<td>NQ (in straight section)</td>
<td>76 mm</td>
<td>47 mm</td>
<td>3 or 6 m</td>
<td>25 m/day</td>
</tr>
</tbody>
</table>
3. Project References – HATS 2A

HATS 2A – the Pioneer Project in Hong Kong for:
- **First sub-sea level** application with HDC.
- **Deepest core** (reaching target zone at -160mPD) with HDC.
- **Longest** continuous samples below Victoria Harbour (i.e. over 1000m from HD01 & 04).
- In-situ **Groundwater Inflow Measurement** in sub-horizontal hole under sub-sea condition.

### Site Setup of HDC

**HDC02 at Central (610 m)**

<table>
<thead>
<tr>
<th>Working Area (length x width)</th>
<th>Length/Depth of Corehole</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 m x 20 m</td>
<td>~ 1000 m</td>
</tr>
<tr>
<td>15 m x 10 m</td>
<td>~ 500 m</td>
</tr>
</tbody>
</table>
Field Tests – Water Inflow Tests using Pump Down Packer System (PDPS)

1. Sectional inflows in HDC, along the proposed tunnel alignment.
2. Water quantity seeping naturally from the formation as a result of pressure difference (i.e. predicting inflow during excavation)
3. A more realistic hydrogeological model than using the conventional water absorption test.
4. To determine an effective grouting approach.
3. Project References – Po Shan Road

**Drainage Tunnel Design & Construction**

1. 2 nos. of HDC
2. Nov. 05 to Jan. 06
3. Tolerance envelope of 2 m radius

![Probe Holes and Existing HDC](image)

- **PS-HDD/01** 252 m
- **PS-HDD/02** 310 m

**Probe holes drilled at clock positions 10, 12 and 2.**
3. Project References – Route 8 – Eagle’s Nest Tunnel

Road Tunnel at Construction Stage
1. HDD/NP/1 (1152 m), March 04 to Sept. 04
2. HDD/SP/1 (550 m), Dec. 04 to Jan. 04
3. Tolerance envelope of 8 m radius

4. Summary

An Appropriate Design of GI Programme
1. Reliable information along tunnel.
2. Minimize uncertainties in ground models.

Interpretations of GI Data for Design and Risk Management
1. Defining a safe and economical construction design.
2. Reducing the Geological Risks.
3. Reducing the Contractual Risks.

In order to achieve an Effective GI Programme, a clear understanding of the project objectives is required. Make good use of the available Guidelines before Planning.
THANK YOU.