WHY WE HAVE TO PERFORM SI?

1. ONE BOREHOLE EVERY THREE DAYS....COMPLETE SI REPORT IN THREE MONTHS !!!

2. ONE BOREHOLE PER DAY..... COMPLETE SI REPORT...ONE MONTH !!!

3. COMPLETE SI REPORT THREE DAYS........ NOT EVEN NECESSARY TO VISIT THE SITE !!!

4. AGREED...!
SOIL INVESTIGATION

Excavation & Boreholes
- Test Pits/Trenching
- Shallow Boring
- Deep Boring
- Hand Augering
- Mechanical Augering
- Percussion Drilling
- Wash Boring
- Rotary Drilling

Sounding Tests
- JKR/Mackintosh Tests
- Cone Penetration Test

Geophysical Survey

OBJECTIVES

1) To establish the general nature of the strata below at site
2) To obtain samples for laboratory testing
3) To allow in situ tests to be carried out
4) To install instruments such as piezometers
STAGES OF SOIL INVESTIGATION

Stage 1: Preliminary S.I.

- To obtain general subsoil profile for estimation of earthwork
- Preliminary or confirmation of layout and formation level
- Preliminary soil parameters and water level/table
- For conceptual designs and preliminary cost and time estimates

Stage 2: Detailed S.I.

usually carry out after optimum layout has been selected and confirmed.

- Plan for critical areas of concern
- Refine subsoil profile
- Obtain necessary soil parameters for detailed design of foundations
- At areas with difficult ground conditions (e.g. very soft soils, etc.)
- Major fill or cut areas that are more critical
- Locations with structures (e.g. retaining walls, areas with large loadings, etc.)

DEEP BORING

BOREHOLE & EXCAVATION

DEEP BORING

MECHANICAL AUGERING

PERCUSSION DRILLING

WASH BORING

ROTARY DRILLING
MECHANICAL AUGER

The auger is held vertically and is driven into the ground by rotating its handle by applying leverage. The auger is pressed down during the process of rotation. At every 30 cm of depth penetrated, the auger is taken out and the samples of the soils are collected separately for examination. This method can be conveniently used for soil penetration up to 15 m depth.

PERCUSSION BORING

This method consists of breaking up of the sub-strata by repeated blows from a bit or chisel. The material thus pulverized is converted into slurry by pouring water in the bore. At intervals the slurry is bailed out of the hole and dried for examination. This method can be adopted in soil and rocks having boulders.
WASH BORING

Wash boring consists of simultaneous drilling and jetting action. A hole is bored through a casing by using a drilling bit. Jetting action is accomplished by pumping water downward through the drilling bit to soften the soil. Samples taken using the wash boring method are disturbed samples.

ROTARY DRILLING

Rotary drilling is used to form a deep observation borehole or for obtaining representative samples of rock which could not be recovered using cable percussion. The drilling method involves a powered rotary cutting head on the end of a shaft, which is driven into the ground as it rotates. The system requires lubrication such as water to make the drilling pit easy to rotating into the ground and keep it cool.
OBJECTIVES
- To determine the sub-surface profile,
- To obtain SPT –N value
- To obtain the soil & rock samples – disturbed, undisturbed samples & rock coring

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Most rock formations can be drilled</td>
<td>• Requires capital expenditure in equipment.</td>
</tr>
<tr>
<td>• Water and mud supports unstable formations</td>
<td>• Water is required for pumping.</td>
</tr>
<tr>
<td>• Fast</td>
<td>• There can be problems with boulders.</td>
</tr>
<tr>
<td>• Operation is possible above and below the water-table</td>
<td>• Rig requires careful operation and maintenance.</td>
</tr>
<tr>
<td>• Possible to drill to depths of over 40 meters</td>
<td></td>
</tr>
</tbody>
</table>

Advantages: Most rock formations can be drilled, water and mud supports unstable formations, fast operation, possible to drill above and below water-table, possible to drill to depths of over 40 meters.

Disadvantages: Requires capital expenditure in equipment, water is required for pumping, there can be problems with boulders, rig requires careful operation and maintenance.
### Information in Deep Boring Log

<table>
<thead>
<tr>
<th>No.</th>
<th>Element</th>
<th>No.</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project</td>
<td>19</td>
<td>Depth</td>
</tr>
<tr>
<td>2</td>
<td>Client</td>
<td>20</td>
<td>Number of Sample</td>
</tr>
<tr>
<td>3</td>
<td>Consultant</td>
<td>21</td>
<td>(SPT Test), Blows/cm</td>
</tr>
<tr>
<td>4</td>
<td>Reduced Level (Existing Ground Level)</td>
<td>22</td>
<td>Vane Shear Test (VS), Undisturbed/Remoulded</td>
</tr>
<tr>
<td>5</td>
<td>Borehole Number</td>
<td>23</td>
<td>Rock, %RQD/%TCR</td>
</tr>
<tr>
<td>6</td>
<td>Sheet Number</td>
<td>24</td>
<td>Remarks</td>
</tr>
<tr>
<td>7</td>
<td>Chainage</td>
<td>25</td>
<td>RQD(%) Calculation</td>
</tr>
<tr>
<td>8</td>
<td>Coordinate</td>
<td>26</td>
<td>Legend</td>
</tr>
<tr>
<td>9</td>
<td>Logged by</td>
<td>27</td>
<td>Undisturbed Sample (UD)</td>
</tr>
<tr>
<td>10</td>
<td>Drilled by</td>
<td>28</td>
<td>Disturbed Sample (D)</td>
</tr>
<tr>
<td>11</td>
<td>Starting Date</td>
<td>29</td>
<td>Mazier Sample (MS)</td>
</tr>
<tr>
<td>12</td>
<td>Finish Date</td>
<td>30</td>
<td>Core Sample (C)</td>
</tr>
<tr>
<td>13</td>
<td>Weather</td>
<td>31</td>
<td>Standard Penetration Test (N)</td>
</tr>
<tr>
<td>14</td>
<td>Type Of Drill</td>
<td>32</td>
<td>Pressuremeter Test (PMT)</td>
</tr>
<tr>
<td>15</td>
<td>Soil Description</td>
<td>33</td>
<td>Recovery Ratio (R/r)</td>
</tr>
<tr>
<td>16</td>
<td>Ground Water Level (G.W.L)</td>
<td>34</td>
<td>Signature (Certified by)</td>
</tr>
<tr>
<td>17</td>
<td>Graphic Log</td>
<td>35</td>
<td>SPT plot</td>
</tr>
<tr>
<td>18</td>
<td>Job No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Important Elements in Deep Boring

<table>
<thead>
<tr>
<th>No.</th>
<th>Element</th>
<th>No.</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduced Level (Existing Ground Level)</td>
<td>8</td>
<td>Recovery Ratio (R/r)</td>
</tr>
<tr>
<td>2</td>
<td>Borehole Number</td>
<td>9</td>
<td>Rock, %RQD/%TCR</td>
</tr>
<tr>
<td>3</td>
<td>Weather</td>
<td>10</td>
<td>Undisturbed Sample (UD)</td>
</tr>
<tr>
<td>4</td>
<td>Number of Sample</td>
<td>11</td>
<td>Disturbed Sample (D)</td>
</tr>
<tr>
<td>5</td>
<td>Soil Description</td>
<td>12</td>
<td>Mazier Sample (MS)</td>
</tr>
<tr>
<td>6</td>
<td>Ground Water Level (G.W.L)</td>
<td>13</td>
<td>Core Sample (C)</td>
</tr>
<tr>
<td>7</td>
<td>Depth</td>
<td>14</td>
<td>Standard Penetration Test (N)</td>
</tr>
</tbody>
</table>
### SPT N-Value

<table>
<thead>
<tr>
<th>Cohesive soil</th>
<th>Non cohesive soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2 Very soft</td>
<td>0-4 Very loose</td>
</tr>
<tr>
<td>2-4 Soft</td>
<td>4-10 Loose</td>
</tr>
<tr>
<td>4-8 Firm</td>
<td>10-30 Medium dense</td>
</tr>
<tr>
<td>8-15 Stiff</td>
<td>30-50 Dense</td>
</tr>
<tr>
<td>15-30 Very stiff</td>
<td>&gt; Very dense</td>
</tr>
<tr>
<td>&gt; 30 Hard</td>
<td></td>
</tr>
</tbody>
</table>

### SPT GRAPH OF BORELOG

![Graph of Borehole Log](image-url)
## Graphic Log Description

<table>
<thead>
<tr>
<th>Legend</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill Material</td>
<td>Bulk sample (BS)</td>
</tr>
<tr>
<td>Bedding</td>
<td>Core sample (CI)</td>
</tr>
<tr>
<td>Gravel</td>
<td>Undisturbed sample (UD)</td>
</tr>
<tr>
<td>Salt</td>
<td>Disturbed sample (DI)</td>
</tr>
<tr>
<td>Sand</td>
<td>Disturbed pristine sample (DP)</td>
</tr>
<tr>
<td>Clay</td>
<td>Core sample (CO)</td>
</tr>
<tr>
<td>Shale</td>
<td>Water sample (WP)</td>
</tr>
<tr>
<td>Limestone</td>
<td>Standard penetration test (SPT)</td>
</tr>
<tr>
<td>Chert</td>
<td>N-value of SPT</td>
</tr>
<tr>
<td>Sandstone</td>
<td>Inductive field density test (IFD)</td>
</tr>
<tr>
<td>Siltstone</td>
<td>Recovery Ratio (rem)</td>
</tr>
<tr>
<td>Chalk</td>
<td>Core Length (m)</td>
</tr>
<tr>
<td>Volcanic</td>
<td>Nitrogen (N)</td>
</tr>
<tr>
<td>Fracture</td>
<td>SPT = Standard Penetration Test</td>
</tr>
<tr>
<td>Granite</td>
<td>HF4 = 4-inch laser data logging</td>
</tr>
</tbody>
</table>
| Schist | MUC = 2.95 wt.

## Graphic Log

### Uncorrected Borehole Log

<table>
<thead>
<tr>
<th>Kumpulan Ekram Sdn. Bhd.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Depth</td>
</tr>
<tr>
<td>Well Name</td>
<td>Measurement</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Corrected Borehole Log

<table>
<thead>
<tr>
<th>Kumpulan Ekram Sdn. Bhd.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Depth</td>
</tr>
<tr>
<td>Well Name</td>
<td>Measurement</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To determine the SPT N value
To provide information on the geotechnical engineering properties of soil.
To provide an indication of the relative density of granular deposits, such as sands and gravels
The test procedure is described in the British Standard
• Maximum depth of penetration is 450mm
• The blows will be counted on every 75mm until it reach 450mm or 50 blows
• The blows represent hardness of soil.

VIDEO OF SPT WORK
Advantages
- Relatively quick and simple to perform
- Provides a representative soil sample
- Provides useful index of relative strength and compressibility of the soil.
- Able to penetrate dense layers, gravel, and fill

Disadvantages
- The SPT does not typically provide continuous data (e.g., 5 ft. intervals), therefore important data such as weak seams may be missed
- Limited applicability to gravels, cobbles boulders
- Samples that are obtained from the SPT are disturbed

FACTOR AFFECTING ‘N’ VALUE

<table>
<thead>
<tr>
<th>ERRORS</th>
<th>CONSEQUENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequate cleaning of borehole</td>
<td>(X) N, sludge trapped in sampler</td>
</tr>
<tr>
<td>Casing driven bottom of the borehole</td>
<td>(↑) N in sand &amp; (↓) N in clay</td>
</tr>
<tr>
<td>Damage tip of sampling spoons</td>
<td>(↑) N</td>
</tr>
<tr>
<td>Loose joints on connecting rods</td>
<td>(↑) N</td>
</tr>
<tr>
<td>Not using guide rod</td>
<td>(↑) N, eccentric blows</td>
</tr>
<tr>
<td>Water level in borehole below ground water level</td>
<td>(↓) N especially sand at bottom of borehole, piping effect</td>
</tr>
</tbody>
</table>

Note: Where N = SPT’N’ values, (↓) = Giving misleading lower value, (↑) = Giving misleading higher value, (X) = Wrong Results
1) The number of hammer blows is counted.
2) The number required to drive the sampler three successive 150mm increments is recorded.
3) The first increment (0-150mm) is not included in the N value as it is assumed that the top of the test area has been disturbed by the drilling process.
4) The SPT N is the number of blows required to achieve penetration from 150-450mm.

**WHAT IS THE SPT “N” VALUE??**

<table>
<thead>
<tr>
<th>DEPTH (m)</th>
<th>DESCRIPTION OF SOIL / ROCK</th>
<th>CONSISTENCY, COLOUR, RELATIVE DENSITY, GRAIN SIZE, TEXTURE ETC.</th>
<th>SAMPLE No.</th>
<th>Field Test</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00-3.45m</td>
<td>Stiff, dark yellowish brown, fine sandy CLAY with traces of fine angular gravel (finely mixed)</td>
<td></td>
<td>P0432</td>
<td>1, 2, 3, 2, 3</td>
<td>N = 31% Rv = 3.1%</td>
</tr>
</tbody>
</table>
Example Calculation:

\[
SPT-N = \frac{(30 + 20)}{(75 + 30)} \times 300 = 143
\]
How to Obtain?

SAMPLE

Disturbed
- Split Spoon

Undisturbed
- Thin Wall
- Mazier

Coring

DISTURBED SAMPLE

- Disturbed sample is taken when the SPT is carried out.
- The sample is used for testing, such as Particle Size Distribution, Atterberg Limit, Density Test.
- SPT is known as Standard Penetration Test. The value of SPT show the hardness of the soil. SPT reading start form 0 – 50 blows (very soft – hard).
- These value is obtained from the blows produced by a hammer pounding a rod to penetrate the soil layer.
- The maximum depth of penetration is 450mm.
- The termination of SPT is when it reached maximum depth 450mm or 50 blows.
• The SPT is taken using split spoon.
• The length of split spoon in 450mm.
• Inner diameter (35mm), outer diameter (50mm)
• The sample inside split spoon known as disturbed sample.

**DISTURBED SAMPLE VIDEO**
UNDISTURBED SAMPLE

• Undisturbed sample is taken based on engineer/site officer instruction. Usually it is taken when the hardness of soil is changing from one level to another level.

• Type of test for undisturbed sample is
  – One-Dimensional Test
  – Consolidated Undrained Test
  – Unconsolidated Undrained Test.

UNDISTURBED SAMPLE

• There are 2 types of sampling method for Undisturbed sample:
  – Thin-Wall Tube
  – Mazier

  – Thin-Wall Tube
    • Undisturbed sample is taken using stainless steel casing. There are 2 types of casing, U2(1meter length) and U3(500cm).
    • These casing will be push inside the drilling hole using hydraulic or pounded with hammer to obtain a sample.
    • After that, the sample will be sealed to prevent changes of soil properties.
THIN-WALL TUBE

The tube will be pushed down to obtain the sample.

These sides will be sealed to prevent loss of moisture content.

500mm

UNDISTURBED SAMPLE

- Mazier
  This technology takes large diameter (101 mm) core samples in 1,2m length pieces.

  i) Using triple wall core barrel permits removal of the sample as it is taken from the ground, guaranteed the 'in situ condition of the core. Thats why these samples in addition good for large diameter geotechnical laboratory tests beyond geological purposes.

  ii) The third, inner tube made of plastic and continuously cover the sample.

  iii) The Wire Line system allows that only the core barrel (second and third tubes) have pulled out to the surface after 1,2 m core drilling, while the outer tube (the first) works as a casing.
Coring is done when SPT encounter the rock layer.

Length of coring is 1.5m. The technique is different from disturbed and undisturbed sample. It uses a different casing.

The casing has its own bit to drill the rock.

From the obtained result, the quality of the rock can be determined, which is also known as RQD.
ROCK QUALITY DESIGN (RQD)

EXTRACTION OF CORE SAMPLE FROM CASING

EXAMPLE CALCULATION

\[
RQD = \left( \frac{L_{\text{sum of } 500}}{L_{\text{tot core run}}} \right) \times 100 \%
\]

- \(L_{\text{sum of } 100}\): Sum of length of core sticks longer than 100 mm measured along the center line of the core
- \(L_{\text{tot core run}}\): Total length of core run

\[
RQD = \frac{(L_1 + L_2 + \ldots + L_n)}{L} \times 100\%
\]
From the RQD index the rock mass can be classified as follows:

<table>
<thead>
<tr>
<th>RQD</th>
<th>Rock mass quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25%</td>
<td>very poor</td>
</tr>
<tr>
<td>25-50%</td>
<td>poor</td>
</tr>
<tr>
<td>50-75%</td>
<td>fair</td>
</tr>
<tr>
<td>75-90%</td>
<td>good</td>
</tr>
<tr>
<td>90-100%</td>
<td>excellent</td>
</tr>
</tbody>
</table>

**TOTAL CORE RECOVERY (TCR) CALCULATION**

\[
TCR = \left( \frac{l_{\text{sum of pieces}}}{l_{\text{tot core run}}} \right) \times 100\%
\]

- \(l_{\text{sum of pieces}}\) = Sum of length of core pieces
- \(l_{\text{tot core run}}\) = Total length of core run
Try this:

Calculate the RQD value of this sample?

\[
RQD = \left( \frac{l_{\text{sum of } 100}}{l_{\text{tot core run}}} \right) \times 100 \%
\]

- \( l_{\text{sum of } 100} \) = Sum of length of core sticks longer than 100 mm measured along the center line of the core
- \( l_{\text{tot core run}} \) = Total length of core run

\[
RQD = \frac{28+40+15+10}{150} \times 100
\]

\[
= \frac{93}{150} \times 100
\]

\[
= 62\%, \text{ Rock mass quality = fair}
\]
OBJECTIVES OF JKR/MACKINTOSH PROBE

- Obtaining rough characteristics of surface conditions
- Preliminary tool to locate weak spots
- Can be used to determine the thickness of unsuitable material to be removed and also for preliminary design of embankments.
- Record no. of blows/ft. then correlate to established chart to determine bearing capacity of soil.
- To check the consistency of the subsoil
WHAT ARE THE DIFFERENT BETWEEN JKR PROBE AND MACKINTOSH PROBE??
For practical application:
- Results of JKR Probe and Mackintosh Probe can be taken as equivalent.
- JKR Probe created as equivalent to Mackintosh Probe as Mackintosh Probe is patented in the early days.

Table compares the JKR and Mackintosh Probes

<table>
<thead>
<tr>
<th>TYPE OF PENETROMETER</th>
<th>CONE ANGLE</th>
<th>DIAMETER OF WEIGHT (Kg)</th>
<th>DIAMETER OF HAMMER (mm)</th>
<th>FALL (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JKR</td>
<td>60°</td>
<td>25</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>MACKINTOSH</td>
<td>30°</td>
<td>25</td>
<td>13</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Termination criteria
- Blows/300mm (maximum 400 blows/300mm)
- Recommended depth, 15 meters

Precautionary measures
- Free fall and consistent drop height
- Components and apparatus properly washed and oiled
Common Errors of JKR Probe / Mackintosh Probe

- Drop height less than 300mm resulting higher Blow counts
- Exerting force onto the hammer resulting in lower blow count
- Penetration depth not marked correctly
- Wrong counting
- Driving bent rod giving more blow counts

Limitations of JKR Probe/ Mackintosh Probe

- Unable to penetrate hard layers and problems may arise when these hard layers are underlain by softer layers
- Unable to penetrate deeply into medium strength material and gravelly ground
- Not suitable to used in stony ground - pointer and rods would damaged
- Probing at great depth in the soft soil - wall may collapse; side friction on the rod is measured together with the resistance - results misleading
Example of JKR Probe Form

Table and Graph Corelation Between JKR Probe & Bearing Capacity
CORELATION BETWEEN JKR PROBE AND SPT N VALUE

PROF. CHIN FUNG KEE
• N = 0.091(M) + 1.8
• N = SPT
• M = MP BLOWS

SEISMIC REFRACTION SURVEY

- SOIL INVESTIGATION
- GEOPHYSICAL SURVEY
- SEISMIC REFRACTION
- RESISTIVITY SURVEY
Seismic waves are waves of energy that—through the earth, for example as a result of an earthquake, explosion or some other process that impacted ground.

- Waves that travel into the ground were reflected and refracted back to surface and in use for living adaptation.
Three types of seismic waves that travel into the ground:

1. Direct Wave
2. Reflected Wave
3. Refracted Wave

In a seismic refraction study, refraction waves are to be used for interpretation. Seismic refraction provides clear differentiation of rock and soil boundary.

Waves that are generated into the ground:

1. ACTIVE
   - Waves generated by source (Sledge Hammer, explosive, etc)
2. PASSIVE
   - Waves generated from surrounding environment
Seismic study consist of:

- **Survey**
  - To determine and mark location of source and receiver

- **Source**
  - Generate to released/produced energy(wave)
  - Examples: Hammer, vibroseis, explosive (dynamite)

- **Geophones**
  - Detect seismic wave

- **Seismograph**
  - Record and measure motions of the ground, including seismic wave.

Seismic Refraction Survey Method usually used in Geotechnical purposes

- A seismic line consist of a series of 24 geophones with 12 on either side of geophones channel.

- The geophones are laid down about 5m length to each others under sub-surface.

- Shots will be performed about 7 times using sledgehammer which are divided into far shots for 2 times, end shots for 2 times, intermediate shots for to 2 times and 1 for middle shot.

- Each of geophones will received signal/seismic wave that produced by sledgehammer(shot) and its recorded in the seismograph.
Fig. 3: Layout of geophones and shot points along a seismic spread

Principle of Seismic Survey

Hammer & Plate  Seismometer or Geophone

Sand & Gravel

Water-saturated Sand & Gravel
Signal/wave will be produced

Source or "Shot"  Offset x  Seismometer or Geophone

Sound pulse

Sand & Gravel

Water-saturated Sand & Gravel

and...

Source or "Shot"  Offset x  Seismometer or Geophone

Sand & Gravel

Water-saturated Sand & Gravel
...refraction occurs and detected by geophones.

...lastly its recorded by seismograph.
Example of raw data:

The first arrival time for P wave for 1st geophone

Example of interpreted data
Example of interpreted data

Seismic survey performed at site
What kind of equipment used in a seismic survey?

Table. Seismic Compressional Wave Velocities (after Bonner and Schock, 1981) Velocity in m/s

<table>
<thead>
<tr>
<th>Material</th>
<th>Unsaturated</th>
<th>Water-saturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>200-1000</td>
<td>900-2000</td>
</tr>
<tr>
<td>Sandy-gravel</td>
<td>400-600</td>
<td>900-1600</td>
</tr>
<tr>
<td>Clay</td>
<td>700-1200</td>
<td>1100-2500</td>
</tr>
<tr>
<td>Alluvium</td>
<td>400-900</td>
<td>1000-2000</td>
</tr>
<tr>
<td>Soil</td>
<td>320-450</td>
<td>1000-1800</td>
</tr>
<tr>
<td>Weathered bedrock</td>
<td>300-900</td>
<td>1200-1800</td>
</tr>
<tr>
<td>Granite</td>
<td>4200-5500</td>
<td>5000-6500</td>
</tr>
<tr>
<td>Basalt</td>
<td>5500-6200</td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td>2500-5100</td>
<td>3000-5500</td>
</tr>
<tr>
<td>Limestone</td>
<td>3300-6200</td>
<td></td>
</tr>
<tr>
<td>Metamorphic rocks</td>
<td>3000-6500</td>
<td></td>
</tr>
<tr>
<td>Andesite</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Shale</td>
<td>3700-5000</td>
<td>5300</td>
</tr>
<tr>
<td>Quartzite</td>
<td>3000-5400</td>
<td></td>
</tr>
</tbody>
</table>
ADVANTAGES

• Can detect both lateral and depth variations in a physically relevant parameter.
• Can produce detail images of structural features present in the subsurface.
• Can be use to delineate stratigraphic and depositional features.

DISADVANTAGES

• Amount of data collected in a survey can rapidly become overwhelming.
• Data is expensive to acquire and the logistics of data acquisition are more intense than other geophysical methods.
• Data reduction and processing can be time consuming, require sophisticated computer hardware, and demand considerable expertise.
• Direct detection of common contaminants present at levels commonly seen in hazardous waste spills is not possible.
• A low density layer underneath a high density layer could interfere the velocity value detected in a seismograph.
RESISTIVITY SURVEY

SOIL INVESTIGATION

GEOPHYSICAL SURVEY

SEISMIC REFRACTION

RESISTIVITY SURVEY
INTRODUCTION

• The purpose of resistivity survey is to determine the resistance rate underneath the earth surface.
• The soil resistivity is related to numerous geological parameter such as amount of liquid and mineral content, porosity and degree of water saturation in the rock.
• This survey have been used for many decades in hydrogeological, soil investigation and mining as well.

RESISTIVITY CONCEPT

• The measurement of the resistance rate of subsurface is using the Wenner concept.
• Basically, this concept is using 4 electrodes at the same time to get resistivity value.
• The measurement of resistance are normally made by allowing the current flow through subsurface. The flowing current is then being measured. From the current and voltage value, resistivity can calculated.
RESISTIVITY CONCEPT

FORMULA:

\[ V = IR \]

Where:

- \( V \) = Voltan (V)
- \( I \) = Current (A)
- \( R \) = Resistance (Ohm)

PROCEDURE

1. The electrode embedded about 10cm in soil.
2. Each of electrode is located 5 meter each other and connected through cable to the selector. The selector is connected to resistivity meter.
3. The selector act as controller to these four electrode, known as C1, P1, P2, C2.
4. Current will flow from C1 to C2.
5. The function of electrode P1 & P2 is to determine the resistance produce by the soil.
Electric Current

Electrodes

Ground Level
10 cm embedded in soil
5 meter between each other.

Resistivity Meter
Selector

Fig. 5: Wenner - Schlumberger configuration

2D RESISTIVITY SURVEY LAYOUT
CONCEPT OF RESISTIVITY

- Resistance is inversely with current
- The lower resistance value, the higher amount of current flow through it.
- Water is a bad conductor, but, the underground water is the best electrical conductor.
- This is because the underground water contain dissolved minerals.
- These mineral make underground water the best conductor.
- The lower reading of resistance show that the area is saturated.
- Meanwhile, a higher reading of resistance means the layer is dry and hard.

EXAMPLE OF RESISTIVITY RESULT
EXAMPLE OF 3D RESISTIVITY MODELING

- Resistivity Survey Lines,
- 3D Resistivity Modeling
- Site Photos
Location of resistivity survey lines and boreholes

PHOTOS OF RESISTIVITY SURVEY WORKS
Topography, resistivity lines and groundwater occurrences in study area

3-D resistivity distribution at depth 1 meter from ground surface
3-D resistivity distribution at depth 3 meter from ground surface

3-D resistivity distribution at depth 4 meter from ground surface
3-D resistivity distribution at depth 6 meter from ground surface

3-D resistivity distribution at depth 10 meter from ground surface
Advantages of Resistivity

Non-destructive mapping technique
- The greatest advantage is it doesn't disturb the structure nor the function of the soil.

Temporal monitoring
- This approach is advance for monitoring the physical changes in soil water distribution.

Data acquisition facilities
- The improvement of computer controlled multi electrodes arrays has led to an important development of electrical imaging.

Large sensitivity of the measurement
- The sensitivity of the electrical resistivity measurement is spread over a wide range depending on the soil physical properties.
RESISTIVITY OF ROCKS, SOILS & MINERALS

INSTRUMENTATION
INCLINOMETER

• Inclinometers are used to monitor subsurface movements and deformations. Typical applications include:
  – Detecting zones of movement and establish whether movement is constant, accelerating, or responding to remedial measures.
  – Checking that deformations are within design limits, that struts and anchors are performing as expected, and that adjacent buildings are not affected by ground movements.
  – Verifying stability of dams, dam abutments, and upstream slopes during and after impoundment.
  – Monitoring settlement profiles of embankments, foundations, and other structures (horizontal inclinometer).

INCLINOMETER

• An inclinometer system has two components: (1) inclinometer casing and (2) an inclinometer measurement system.
  – Inclinometer casing provides access for subsurface measurements. Grooves inside the casing control the orientation of the inclinometer sensor and provide a uniform surface for measurements.
  – Inclinometer casing is usually installed in a borehole. It can also be embedded in fill, buried in a trench (horizontal inclinometers), cast into concrete, or attached to a structure.
  – Portable measurement systems include a probe, cable, and readout. Portable systems are economical because they can be carried from site to site. They are accurate because the entire length of the casing is measured twice in each survey.
  – The first survey establishes the initial profile of the casing. Subsequent surveys are compared to the initial. Changes in the profile indicate that movement has occurred.
Piezometer

- Used to measure ground water level and pressure in a system by measuring the height to which a column of the liquid rises against gravity,
- Also measures the pressure (more precisely, the piezometric head) of groundwater at a specific point.
- Installed in the borehole
TILTMETER

- To monitor changes in the inclination of a structure.
- Data can provide an accurate history of movement of a structure and early warning of potential structural damage.
- Typical applications include:
  - Monitoring rotation caused by mining, tunneling, soil compaction, or excavation.
  - Monitoring rotation of concrete dams and retaining walls.
- Tilt plates are available in ceramic or bronze. Both are dimensionally stable and weather resistant.
- The accelerometer is housed in a rugged frame with machined surfaces that facilitate accurate positioning on the tilt plate.
- The bottom surface is used with horizontally-mounted tilt plates and the side surfaces are used with vertically-mounted tilt plates.

SAMPLE OF TILTMETER RESULT

TILT PLATE RESULTS FOR PLATE NO. 2: TP2 (House No. 41)

TILT PLATE RESULTS FOR PLATE NO. 4: TP4 (House No. 42)
The purpose of this test is to determine the vertical displacement of existing building or structure due to settlement, slope failure or construction activities.

It consists of 16mm diameter steel female socket and stainless steel male threaded plug to fit into female socket.

A precision levelling / Total station are used for the monitoring of the Building Settlement Marker.
The purpose of installing the surface settlement marker is to monitor the settlement or any movement of the ground surface.

The surface settlement marker consist of 20mm outer diameter stainless steel rod with a length of 0.50m. The steel rod is installed 0.48m into the ground with 0.02m above the ground surface.

A precision levelling and positioning apparatus (Survey equipment) is used for the monitoring of the surface settlement marker.

For more accurate result total station is used for X,Y & Z position.
GROUND SETTLEMENT MONITORING ON DOUBLE-STOREY TERRACE HOUSES AT JALAN UDANG GANTUNG 2, TAMAN CUPEACS, SEGAMBUT, K.L.

GROUND SETTLEMENT MARKER WITH XYZ POSITION
Setting up the borehole equipment at the prescribed location

Start drilling up to 1m or 1.5m interval using boring drill bit

Change the drill bit with the split spoon → take SPT → disturbed sample

Repeat the whole process for the next intervals

Undisturbed sample and coring

WORK SEQUENCE OF ROTARY DRILLING WORK