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....!
SUBSURFACE INVESTIGATION

EXCAVATION & BOREHOLES
- JKR / MACHINTOSH PROBE
- CONE PENETRATION TEST
  - FIELD DATA COLLECTION
  - RESULTS INTERPRETATION

SOUNDING TESTS
- SEISMIC
- RESISTIVITY
  - FIELD DATA COLLECTION
  - RESULTS INTERPRETATION

GEOPHYSICAL SURVEY
- FIELD DATA COLLECTION
- RESULTS INTERPRETATION

TEST PITS/TRENCHING
- SHALLOW BORING
- HAND AUGERING

DEEP BORING
- MECHANICAL AUGERING
- PERCUSSION DRILLING
- ROTARY DRILLING

OBJECTIVES

1) To establish the general nature of the strata below at site
2) To obtain samples for laboratory testing
3) To verify the interpretation of geophysical surveys
4) To allow in situ tests to be carried out
5) To install instruments such as piezometers
STAGE OF SUBSURFACE 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.**
- 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
- ROTARY DRILLING
**Rotary Drilling**
- To determine the sub-surface profile,
- SPT – N value
- To obtain the soil samples – disturbed and undisturbed samples

<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>
<tr>
<td>• Possible to use compressed-air flush</td>
<td></td>
</tr>
</tbody>
</table>

**DEEP BORING MACHINE (ROTARY DRILLING)**

*The water is pumped through the rods to a drilling bit.*
### 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>
</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>9</td>
<td>Recovery Ratio (R/r)</td>
</tr>
<tr>
<td>2</td>
<td>Borehole Number</td>
<td>10</td>
<td>Rock, %RQD/%TCR</td>
</tr>
<tr>
<td>3</td>
<td>Weather</td>
<td>11</td>
<td>Undisturbed Sample (UD)</td>
</tr>
<tr>
<td>4</td>
<td>(SPT Test), Blows/cm</td>
<td>12</td>
<td>Disturbed Sample (D)</td>
</tr>
<tr>
<td>5</td>
<td>Soil Description</td>
<td>13</td>
<td>Mazier Sample (MS)</td>
</tr>
<tr>
<td>6</td>
<td>Ground Water Level (G.W.L)</td>
<td>14</td>
<td>Core Sample (C)</td>
</tr>
<tr>
<td>7</td>
<td>Depth</td>
<td>15</td>
<td>Standard Penetration Test (N)</td>
</tr>
<tr>
<td>8</td>
<td>Number of Sample</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EXAMPLE OF BOREHOLE LOG

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

SPT GRAPH OF BORELOG
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>Boulder</td>
<td>Mazier sample (MS)</td>
</tr>
<tr>
<td>Gravel</td>
<td>Undisturbed sample (UD)</td>
</tr>
<tr>
<td>Sand</td>
<td>Undisturbed piston sample (UP)</td>
</tr>
<tr>
<td>Silt</td>
<td>Disturbed sample (D)</td>
</tr>
<tr>
<td>Clay</td>
<td>Core sample (C)</td>
</tr>
<tr>
<td>Peat</td>
<td>Water sample</td>
</tr>
<tr>
<td>Shells</td>
<td>Standard penetration test (P)</td>
</tr>
<tr>
<td>Limestone</td>
<td>Wave shear test (VT)</td>
</tr>
<tr>
<td>Chert</td>
<td>In-situ field density test (FD)</td>
</tr>
<tr>
<td>Sandstone</td>
<td>Pedometer</td>
</tr>
<tr>
<td>Silicate</td>
<td>R = Recovery Ratio (mm/mm)</td>
</tr>
<tr>
<td>Quartzite</td>
<td>CL = Core Length (mm)</td>
</tr>
<tr>
<td>Coal</td>
<td>N = N value of SPT</td>
</tr>
<tr>
<td>Volcanics</td>
<td>SPT = Standard Penetration Test</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>NW = 3-inch inner dia. casing</td>
</tr>
<tr>
<td>Granite</td>
<td>HW = 4-inch inner dia. casing</td>
</tr>
<tr>
<td>Schist</td>
<td>NMLC = 2.56-inch hole dia. core barrel</td>
</tr>
<tr>
<td>Phyllite</td>
<td></td>
</tr>
</tbody>
</table>

Graphic Log

Uncorrected Borehole Log

Corrected Borehole Log
Standard Penetration Test (SPT)

- 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

Hammer – 63.5Kg

76cm

anvil

Split-Spoon Sampler
## STANDARD PENETRATION TEST

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Relatively quick and simple to perform</td>
<td>- The SPT does not typically provide continuous data (e.g. 5 ft. intervals), therefore important data such as weak seams may be missed</td>
</tr>
<tr>
<td>- Provides a representative soil sample</td>
<td>- Limited applicability to cohesive soils, gravels, cobbles boulders</td>
</tr>
<tr>
<td>- Provides useful index of relative strength and compressibility of the soil.</td>
<td>- Samples that are obtained from the SPT are disturbed</td>
</tr>
<tr>
<td>- Able to penetrate dense layers, gravel, and fill</td>
<td></td>
</tr>
</tbody>
</table>

## 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 higher value, (X) = Wrong Results.
STANDARD PENETRATION TEST CALCULATION

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</th>
<th>DESCRIPTION OF SOIL / ROCK</th>
<th>CONSISTENCY, COLOUR</th>
<th>RELATIVE DENSITY, GRAIN SIZE, TEXTURE ETC.</th>
<th>FIELD TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>(meter)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>Stiff, dark yellowish brown, fine sandy CLAY with traces of fine angular gravel (fill material)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>No. (Cts)</th>
<th>Field Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PENETRATION (mm)</th>
<th>75</th>
<th>75</th>
<th>75</th>
<th>75</th>
<th>75</th>
<th>75</th>
<th>N-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blow counts</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>N</td>
</tr>
</tbody>
</table>

SPT Resistance (N-value) is total number of blows to drive sampler the 2nd and 3rd 150 mm increments.
**SPT CORRELATION**

\[
N = \frac{50}{\text{Penetration Length}} \times 300 \text{ mm}
\]

**Example Calculation**

\[
SPT-N = \left(\frac{30 + 20}{75 + 30}\right) \times 300 = 143
\]

**SAMPLING**

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.

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.
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(1 meter length) and U3(500cm).
  - These casing will be pushed 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.

The tube will be pushed down to obtain the sample.

These sides will be sealed to prevent loss of moisture content.
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. That's 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 use a different casing.

The casing have its own bit to drill the rock.

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

EXAMPLE CALCULATION

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

\( l_{\text{sum of } 100} = \) 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

\[
RQD = \frac{(L1 + L2 + \ldots + Ln)}{L} \times 100\%
\]

ROCK QUALITY DESIGN (RQD) CLASSIFICATION TABLE

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>
Try this....

Calculate the RQD value of this sample??????

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
Answers

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

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

\[
RQD = 28 + 40 + 15 + 10 \times 100
\]
\[
\frac{150}{150} = 93 \times 100
\]
\[
\frac{150}{150} = 62\%, \text{ Rock mass quality = fair}\]

JKR PROBE/ MACKINTOSH PROBE

SUBSURFACE INVESTIGATION

SOUNDING TESTS

JKR / MACKINTOSH PROBE

CONE PENETRATION TEST

FIELD DATA COLLECTION

RESULTS INTERPRETATION
OBJECTIVE 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

![JKR Probe](image)

- Hammer – 5Kg
- 28cm
- Rod – 1.2m
- Cone
WHAT ARE THE DIFFERENT BETWEEN JKR PROBE AND MACKINTOSH PROBE??

Table compares the JKR and Mackintosh Probes

<table>
<thead>
<tr>
<th>TYPE OF PENETROMETER</th>
<th>CONE ANGLE</th>
<th>DIAMETER OF DIAMETER OF</th>
<th>WEIGHT OF</th>
<th>HEIGHT OF 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>

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.
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
SEISMIC REFRACTION SURVEY

SUBSURFACE INVESTIGATION

GEOPHYSICAL SURVEY

SEISMIC

FIELD DATA COLLECTION

RESULTS INTERPRETATION
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.

- Exploration of archaeological artifacts
- Exploration minerals (gold, copper, metal, oil, etc)
- Groundwater exploration
- Geological & Engineering research
- Adaptation usage of seismic
- Geotechnical engineering purposes
- Environmental

Three types of seismic wave that travel into 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 generated into ground

1. ACTIVE
   - Waves that generated by source (Sledge Hammer, explosive, etc)

2. PASSIVE
   - Waves that generated from surrounding environment

   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.

Layout of Geophones and Seismograph

Fig. 3: Layout of geophones and shot points along a seismic spread
Principle of Seismic Survey

Hammer & Plate

Seismometer or Geophone

Offset x

Sand & Gravel

Water-saturated Sand & Gravel

Operator or “Shooter”

Hammer & Plate

Seismometer or Geophone

Offset x

Sand & Gravel

Water-saturated Sand & Gravel
Shooter using the sledgehammer

Signal/wave will be produced
...refraction occurs and detected by geophones.
...lastly its recorded by seismograph

Example of raw data:

The first arrival time of P wave for 1st geophone
Example of interpreted data

Seismic Survey performed at site

Geophone  5 meter  Geophone
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></td>
</tr>
<tr>
<td>Quartzite</td>
<td>3000-5400</td>
<td></td>
</tr>
</tbody>
</table>
• 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*.

**ADVANTAGES**

**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.
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:
- \( V \) = Voltage (V)
- \( I \) = Current (A)
- \( R \) = Resistance (Ohm)

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

PROCEDURE
5/27/2016

Electric Current
Electrodes

C1
P1
P2
C2

10 cm embedded in soil

5 meter between each other.

Ground Level
Multicore cable
Electrode
Resistivity Meter
Selector

2D RESISTIVITY SURVEY LAYOUT

Fig. 5: Wenner - Schlumberger configuration
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
Apparatus For Resistivity Survey

Resistivity Meter
Selector
Electrode
5 meter
Apparatus For Resistivity Survey

Resistivity Meter
Selector

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 & GROUND SETTLEMENT MARKER
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).

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
- Tilt Plate Results for Plate No. 4
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.

**BUILDING SETTLEMENT MARKER**

**SAMPLE OF BUILDING SETTLEMENT MARKER RESULT**

![Graph showing settlement monitoring results over elapsed days for BSM 1 to BSM 6.]
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.
SAMPLE OF GROUND SETTLEMENT MARKER RESULT

GROUND SETTLEMENT MONITORING ON DOUBLE-STOREY TERRACE HOUSES AT JALAN UDANG GANTUNG 2, TAMAN CUEPACS, SEGAMBUT, K.L.

GROUND SETTLEMENT MARKER WITH XYZ POSITION
GROUND SETTLEMENT MONITORING ON DOUBLE-STOREY TERRACE HOUSES AT JALAN UDANG GANTUNG 2, TAMAN CUEPACS, SEGAMBUT, K.L.

EXAMPLE READING OF GROUND SETTLEMENT MARKER

THANK YOU