Week 3 : (3HL) Coverage : Typical geotechnical problems and usual application of SI methods

Learning Outcomes :

At the end of this lecture/week, the students will be able to :

1. Discuss SI for different geotechnical problems
2. Propose procedures of doing the appropriate SI
OUTLINE of PRESENTATION

3.0 Planning Scope of Site Investigation
4.0 Procedures of SI
5.0 SI Common Methods
THE PURPOSE OF SITE INVESTIGATION

The purpose of all site investigation is the identification of the geotechnical and geoenvironmental characteristics of the ground at a site to provide the basis for the design of efficient, economic and safe projects.

Comprehensive accumulation of information on the ground and its characteristics will be used in an appropriate foundation design for the structures and pavement design and enables a practical, safe and economic construction process to be planned.
THE QUALITY INDICATORS OF A GOOD SITE INVESTIGATION

**Critical Success Factors:**

- Identification of Ground Hazards.
- Provision for better management of ground risk.
- Provision of better value for clients and users.
- Efficient processes which continuously improve.
- Provision of relevant, reliable information and effective supply chain management.

**Key Performance Indicators:**

- Preparation - Desk Study and reconnaissance survey.
- Design.
- Procurement.
- Management - project, risk and quality.
- Supervision.
- Reporting - factual, interpretative and ground model.
- Outcome - client satisfaction, project review and user feedback.
The planning of SI works should be carried out by *Qualified Geotechnical Engineers*. SI works should be executed by *Qualified SI contractor registered with CIDB*. SI works should be directed, monitored, supervised and Reported by *Qualified Geotechnical Engineers* registered with the BEM.
SELECTING AN SI CONTRACTOR

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

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

COMPLETE SI REPORT THREE DAYS........ NOT EVEN NECESSARY TO VISIT THE SITE !!!!
OBJECTIVES OF SITE INVESTIGATION

- To assess the general suitability of the site and neighbourhood for the proposed works, from a **geological and geotechnical** point of view.

- To provide **suitable geotechnical data** for all aspects of an economic, safe and reliable design of foundations, earthworks and temporary works, including assessment of the effects of any previous uses of the site.

- To assess the problems and constraints associated with the construction of the works arising from the soil or groundwater conditions and to plan the best method of construction.
OBJECTIVES OF SITE INVESTIGATION

- To assess the **quantity, quality and ease of extraction of construction materials** suitable for the works.

- To determine the changes in the stability, drainage and other geotechnical aspects of the site and the surrounding ground and buildings, which might be initiated by the construction works.

- To make comparison on the construction works by alternative methods or at alternative sites.
Desk Studies provide an opportunity to gather valuable information for negligible cost. They are carried out at the start of the Site Investigation, and involve reading existing information about the site. This existing information could include:

- Topographical Maps
- Geological Maps
- Aerial Photographs
- Satellite Images
- Existing SI records
- Geotechnical Journals, etc

Information obtained during the Desk Study will be taken into account when planning the SI.
# Types of Information Useful for Desk Studies

<table>
<thead>
<tr>
<th>Aspect of Investigation</th>
<th>Type of Information</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Topography</td>
<td>Topographic Maps</td>
<td>JUPEM</td>
</tr>
<tr>
<td></td>
<td>Stereo Aerial photographs</td>
<td>MACRES (<em>Ikonos, QB</em>)</td>
</tr>
<tr>
<td></td>
<td>Satelite Image Maps</td>
<td>Google EARTH?</td>
</tr>
<tr>
<td>Geology</td>
<td>Geological Maps</td>
<td>JMG (Mineral and Geoscience Department)</td>
</tr>
<tr>
<td></td>
<td>Geological Publications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aerial photographs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil Survey Maps</td>
<td></td>
</tr>
<tr>
<td>Geotechnical parameters / geotechnical problems</td>
<td>Geotechnical / geological journals</td>
<td>Warta Geologi (GSM)</td>
</tr>
<tr>
<td></td>
<td>Previous geotechnical or SI reports.</td>
<td>Local Authorities</td>
</tr>
<tr>
<td>Groundwater conditions</td>
<td>Hydrological Maps</td>
<td>JPS (Department Irrigation and Drainage)</td>
</tr>
<tr>
<td>Meteorological conditions</td>
<td>Meteorological records</td>
<td>Meteorological Dept. JPS</td>
</tr>
<tr>
<td></td>
<td>Percipitation</td>
<td></td>
</tr>
<tr>
<td>Existing construction and services</td>
<td>Construction “as-built” drawings. Drawings from Utilities companies</td>
<td>Local Authorities, Contractors or Eng. Consultants, Utility Companies.</td>
</tr>
<tr>
<td></td>
<td>Topographical Maps, Aerial Photographs</td>
<td></td>
</tr>
<tr>
<td>Previous land use</td>
<td>Previous topographical and geological maps. Old Aerial photographs, etc</td>
<td>JUPEM, MACRES</td>
</tr>
</tbody>
</table>
The Site Reconnaissance Survey or the Walk-Over Survey is an important and necessary supplement to Desk Study and should cover the whole site area and the immediate vicinity.

- To compare & confirm desk study & obtain additional information
- Physically examine ground conditions, geotechnical hazards, exposed cut/geology, outcrop, weathering depth, previous slip, adjacent structures, etc.
- Give due consideration to environment & ecological impact.
- Execute brief geological mapping
- Questioning local individuals: flood & tide levels, etc.
### Example Checklist form for Site Reconnaissance

**SITE HYDROLOGY**
- Dry - Baren
- Desert
- Surface Water Conditions
  - None
  - Swampy
  - Pond
  - Lake
  - Ocean
  - Stream
  - River
- Subsurface Water
  - None
  - Not Obvious
  - Major Aquifer
  - Water Wells
  - Pumping from deep wells
  - Other Details

**SITE DRAINAGE**
- Runoff Features
  - Erosion
  - Flooding
  - Watersheds
  - Piping
  - Syncline
  - Other
- Natural
  - Excellent
  - Good
  - Fair
  - Poor
- Artificial Drains
  - Stormwater System
  - Retention Pond
  - Vertical well drains
  - Pumping Stations
  - Other

**SOIL AND ROCK CONDITIONS**
- Surface Soils
  - Topsoil
  - Presence of Fills
  - Evidence of Debris
  - Pollutants Contaminants
  - Agrarian types/farming
  - Evidence of slope instability
  - Landslides/slopes
- Creep

**Cracking**
- Scour
- Heave
- Subsidence
- Cut/Quarry Operations
- Fill/Borrow
- Other

**Subsurface Soils**
- USGS soil types:
  - SM, SC, SP, SW
  - CL, CH, ML, MH
  - PL, OL, OH
- Other:

**SURFACE ROCKS**
- Loose cobbles
- Boulders
- Rock outcappings
- Type of rocks
  - Igneous
  - Sedimentary
  - Metamorphic
  - Detrital
- Rock Features
  - Jointing Patterns
  - Faults
  - Discontinuities
  - Weathering
  - Places of weakness
  - Evidence of talus
  - Karst/subsoils
  - Caves
  - Other

**INVESTIGATIVE OPERATIONS**
- Existing test pits
- Existing boreholes
- Cased holes
- Blasting operations
- Dynamite
- ANFO
- Rammers
- Percussive Drills
- Erratics/boulders
- Coreholes
- Diamond drilling
- Wireline drilling
- Exploratory Adits
- Vertical shafts

**Tunnels**
- Poles/Holes

**PRIOR INFORMATION**
- Tax map records
- Federal Documents
- State records
- County tax maps
- City records files
- Personal files
- Interviews with neighbors and nearby businesses:

**TOPOGRAPHIC DATA**
- USGS Quadrangle Maps
- State Survey
- County Surveys
- Site Survey
- Transit/Level
- Aerial Photos
- GPS data

**GROUND COVER**
- Asphalt
- Grass
- Flowers
- Bushes
- Trees
- Forest
- Soil
- Gravel
- Concrete
- Rock Outcappings
- Evidence of fill/debris
- Prior Construction
- Existing Buildings
- Existing Buildings
- Roadways
- Other

**EXISTING TERRAIN**
- Level Ground
- Slope Conditions
- Gentle Dip
- Steep
- Hummocky
- Rolling Hills
- Mountainous

**NOTES & REMARKS**

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**DATE**
- Prepared by:
- Organization:

**ACCESSIBILITY**
- Easy
- By Vehicle only
- Difficult by car - Walk only
- Requires 4-wheeled drive
- Dozer and Grader Required
- Inaccessible
- Details:

**VISIT TO SITE**
- Date/Time of Day
- Visitors
- Weather Conditions
  - Sunny
  - Cloudy
  - Rain
  - Snow
  - Icy
  - Freezing

**GROUND COVER**
- Asphalt
- Grass
- Flowers
- Bushes
- Trees
- Forest
- Soil
- Gravel
- Concrete
- Rock Outcappings
- Evidence of fill/debris
- Prior Construction
- Existing Buildings
- Existing Buildings
- Roadways
- Other

**EXISTING TERRAIN**
- Level Ground
- Slope Conditions
- Gentle Dip
- Steep
- Hummocky
- Rolling Hills
- Mountainous
MAIN SUBSURFACE EXPLORATION

Developing a Site Investigation Program

For many projects and for many site conditions, the most difficult and crucial part of the planning phase involves the decisions regarding sampling/investigation method, boring locations, number of samples, number and types of laboratory tests, and the number of confirmatory samples.

At this stage, the types of potential sampling/investigation methods should have been identified and assessed.
HOW MANY BOREHOLES?

Example: A proposed site for multi-storey complex

Not enough boreholes, soil profile and properties not well defined 😞
Example: A proposed site for multi-storey complex

Too many boreholes and will blow the budget 😞
Example: A proposed site for a multi-storey complex

Here, we strike a good balance. Trial pits are quite cheap, and they certainly have a place in site investigation.
5.0 Common SI Methods

5.1 JKR/Mackintosh Probes
5.2 Hand Augering (HA)
5.3 Deep Boring (DB)
5.4 Deep Sound (DS) -100/200 kN Capacity
5.5 Test Pits, Bulk & Block Samples
5.6 Motorised Hand Boring (MHB)
5.7 Geophysical Survey
5.1 JKR/Mackintosh Probe

- Can be used to determine the thickness of unsuitable material to be removed and also for preliminary design of embankments.
- Limited to about 15 m.
- Record no. of blows/ft. then correlate to established chart to determine bearing capacity of soil.
5.2 Hand Augering (HA)

- Used in soft to stiff cohesive soils or sandy soils above water tables
- Maximum depth about 5 m
HAND AUGERING (HA)

COMMON TYPES OF HAND AUGER

- Posthole auger
- Small helical auger
- Dutch auger
- Gravel auger

TECHNIQUE FOR RECORDING A REPRESENTATIVE SOIL PROFILE USING A HAND AUGER

- Used in soft to stiff cohesive soils or sandy soils above water table.
- Maximum depth up to 5 m.
- Can be used to obtained open tube samples of 50 – 100 mm diameter.
5.2 Hand Augering (HA)
Percussion Drilling
5.3 Deep Boring (DB)

- Advanced by power rotary drilling
- Open hole rotary drilling or casing advancement drilling method
- Flushing medium. Clear water, mud water, etc
- Bentonite/mud water for coarse sand/fine gravel
5.3 Deep Boring (DB)

CONVENTIONAL APPROACH TO SI
METHODS OF ADVANCING BOREHOLES

WASH / ROTARY BORING

WATER JETTING
Hole advanced by jetting of high pressure water downwards into the soil below and surging and rotating action of casing. Hole advanced mainly by destructive forces of water under high pressure.

Return water Outside of casing

Cheap adapted machine. Very fast and cost less.

Test volume disturbed and altered. Samples and tests not representative or bad.

NO skill is required.

NOT in compliance with specification requiring sampling and testing or code of practice.
WASH BORING

Hole advanced by rotating and surging action of cutting bit attached to drill rod inside casing. Water discharged sideways and downwards into soils below.

Return water inside of casing, making related observations possible.

Casing

Hole advanced rotating and surging of bit attached to drill string.

Cutting bit

Most flushing water discharged downwards, some water enters soils below. With care, only some tests samples are possible.

Return water Inside of casing

Machine various including manual. More suited for drilling water wells and boring for disturbed samples.

Test volume disturbed and altered.

Samples and tests not representative or reliable.

Require some skill

Doubtful compliance with specification requiring sampling and testing or code of practice.
Hole advanced by cutting bit attached to the bottom of drill rod and hydraulic thrust. Soil cuttings transported upward by drilling water. Use compatible casings, rods, drag and cutting bits. Cutting bits varying with soil types. Almost all water discharged sideways.

Return water inside of casing

Machine suited for quality sampling and testing. High degree of observations possible – e.g. return water, water losses, penetration rates, etc.

Rig very costly

Test volume intact, samples acceptable, reliable.

Skill essential

In compliance with specification requiring sampling and testing and code of practice.
ROTARY DRILLING MACHINE

- Bolt and clevis
- Double sheave
- 4-leg derrick
- Wireline
- Manila rope
- Wire drum hoist
- Cathead hoist
- Controls
- Transmission
- Power unit
- Retractable slide base
- Drag skid base
- Drill platform
- Drill spindle
- Drill chuck
- Chucking rod
- Pressure hose
- Swivel drill head
- Feed pressure gauge
- Hydraulic feed cylinders
- Safety foot clamp
- Variable displacement water pump
- Fill
- Soil derived from In-situ Rock Weathering
- Rock
- Diamond casing shoe
- Drill rod coupling
- Drill rod
- Core-barrel
- Diamond bit
- Tee coupling
- Drive pipe
- Drive shoe
- Settling pit
- Flush type casing
Figure 3-4: Schematic of Drilling Rig for Rotary Wash Methods. (After Hvorslev, 1948).
# TABLE 3-2

## DIMENSIONS OF COMMON DRILL RODS

<table>
<thead>
<tr>
<th>Size</th>
<th>Outside Diameter of Rod mm (in)</th>
<th>Inside Diameter of Rod mm (in)</th>
<th>Inside Diameter of Coupling mm (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW</td>
<td>27.8 (1.095)</td>
<td>18.3 (0.720)</td>
<td>10.3 (0.405)</td>
</tr>
<tr>
<td>EW</td>
<td>34.9 (1.375)</td>
<td>22.2 (0.875)</td>
<td>12.7 (0.500)</td>
</tr>
<tr>
<td>AW</td>
<td>44.4 (1.750)</td>
<td>31.0 (1.250)</td>
<td>15.9 (0.625)</td>
</tr>
<tr>
<td>BW</td>
<td>54.0 (2.125)</td>
<td>44.5 (1.750)</td>
<td>19.0 (0.750)</td>
</tr>
<tr>
<td>NW</td>
<td>66.7 (2.625)</td>
<td>57.2 (2.250)</td>
<td>34.9 (1.375)</td>
</tr>
</tbody>
</table>

Note 1: “W” and “X” type rods are the most common types of drill rod and require a separate coupling to connect rods in series. Other types of rods have been developed for wireline sampling (“WL”) and other specific applications.

Note 2: Adapted after Boart Longyear Company and Christensen Dia-Min Tools, Inc. For updates, see: [http://www.boartlongyear.com/](http://www.boartlongyear.com/)
# Table 3-3

## Dimensions of Common Flush-Joint Casings

<table>
<thead>
<tr>
<th>Size</th>
<th>Outside Diameter of Casing mm (in)</th>
<th>Inside Diameter of Casing mm (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW</td>
<td>36.5 (1.437)</td>
<td>30.1 (1.185)</td>
</tr>
<tr>
<td>EW</td>
<td>46.0 (1.811)</td>
<td>38.1 (1.500)</td>
</tr>
<tr>
<td>AW</td>
<td>57.1 (2.250)</td>
<td>48.4 (1.906)</td>
</tr>
<tr>
<td>BW</td>
<td>73.0 (2.875)</td>
<td>60.3 (2.375)</td>
</tr>
<tr>
<td>NW</td>
<td>88.9 (3.500)</td>
<td>76.2 (3.000)</td>
</tr>
</tbody>
</table>

Note 1: Coupling system is incorporated into casing and are flush, internally and externally.

Note 2: Adapted after Boart Longyear Company and Christensen Dia-Min Tools, Inc. For updates, see: [http://www.boartlongyear.com/](http://www.boartlongyear.com/)
SPT Samples as obtained using proper boring methods

SPT samples as obtained from Wash bores
The subsurface conditions observed in the soil samples and drilling cuts or perceived through the performance of the drilling should be described by the driller. In addition to the description of individual samples, the boring log should also describe various strata.
COMMON FIELD TESTS

- SPT: Standard Penetration Test
- CPT: Cone Penetration Test
- DMT: Flat Plate Dilatometer Test
- PMT: Prebored Pressuremeter Test
- VST: Vane Shear Test
The SPT involves the driving of a hollow thick-walled tube into the ground and measuring the number of blows to advance the split-barrel sampler a vertical distance of 300 mm (1 foot). A drop weight system is used for the pounding where a 63.5-kg (140-lb) hammer repeatedly falls from 0.76 m (30 inches) to achieve three successive increments of 150-mm (6-inches) each. The first increment is recorded as a “seating”, while the number of blows to advance the second and third increments are summed to give the N-value ("blow count") or SPT-resistance (reported in blows/0.3 m or blows per foot). If the sampler cannot be driven 450 mm, the number of blows per each 150-mm increment and per each partial increment is recorded on the boring log. For partial increments, the depth of penetration is recorded in addition to the number of blows. The test can be performed in a wide variety of soil types, as well as weak rocks, yet is not particularly useful in the characterization of gravel deposits nor soft clays. The fact that the test provides both a sample and a number is useful, yet problematic, as one cannot do two things well at the same time.

**ADVANTAGES**
- Obtain both a sample & a number
- Simple & Rugged
- Suitable in many soil types
- Can perform in weak rocks
- Available throughout the U.S.

**DISADVANTAGES**
- Obtain both a sample & a number*
- Disturbed sample (index tests only)
- Crude number for analysis
- Not applicable in soft clays & silts
- High variability and uncertainty
STANDARD PENETRATION TEST (SPT)

Drive head

Split tube

Drive shoe

Split-spoon sampler

50 mm

76 mm

457 mm

76 mm

Drop hammer

Extension rod

Split spoon sampler

borehole

SPT test in borehole

Split-spoon sampler
SEQUENCE OF DRIVING SPLIT BARREL SAMPLER DURING THE STANDARD PENETRATION TEST (SPT)

63.5-kg Drop Hammer Repeatedly Falling 0.76 m

Anvil

Borehole

Drill Rod ("N" or "A" Type)

Split-Barrel (Drive) Sampler [Thick Hollow Tube]:
- O.D. = 50 mm
- I.D. = 35 mm
- L = 760 mm

First Increment

Second Increment

Third Increment

N = No. of Blows per 0.3 meters

Seating

0.15 m

0.15 m

0.15 m

0.15 m

Hollow Sampler Driven in 3 Successive Increments

Standard Penetration Test (SPT) Per ASTM D 1586

Need to Correct to a Reference Energy Efficiency of 60% (ASTM D 4633)

Note: Occasional Fourth Increment Used to provide additional soil material

SPT Resistance (N-value) or “Blow Counts” is total number of blows to drive sampler last 300 mm (or blows per foot).
<table>
<thead>
<tr>
<th>Measured N-value</th>
<th>Apparent Density</th>
<th>Behavior of 13 mm Diameter Probe Rod</th>
<th>Relative Density, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4</td>
<td>Very loose</td>
<td>Easily penetrated by hand</td>
<td>0 - 20</td>
</tr>
<tr>
<td>&gt;4 - 10</td>
<td>Loose</td>
<td>Firmly penetrated when pushed by hand</td>
<td>20 - 40</td>
</tr>
<tr>
<td>&gt;10 - 30</td>
<td>Firm</td>
<td>Easily penetrated when driven with 2 kg. hammer</td>
<td>40 - 70</td>
</tr>
<tr>
<td>&gt;30 - 50</td>
<td>Dense</td>
<td>A few centimeters penetration by 2 kg. hammer</td>
<td>70 - 85</td>
</tr>
<tr>
<td>&gt;50</td>
<td>Very Dense</td>
<td>Only a few millimeters penetration when driven with 2 kg. hammer</td>
<td>85 - 100</td>
</tr>
</tbody>
</table>
# EVALUATION OF THE CONSISTENCY OF FINE-GRAINED SOILS

<table>
<thead>
<tr>
<th>Uncorrected N-value</th>
<th>Consistency</th>
<th>Unconfined Compressive Strength, $q_u$, kPa</th>
<th>Results Of Manual Manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2</td>
<td>Very soft</td>
<td>&lt;25</td>
<td>Specimen (height = twice the diameter) sags under its own weight; extrudes between fingers when squeezed.</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Soft</td>
<td>25 - 50</td>
<td>Specimen can be pinched in two between the thumb and forefinger; remolded by light finger pressure.</td>
</tr>
<tr>
<td>4 - 8</td>
<td>Firm</td>
<td>50 - 100</td>
<td>Can be imprinted easily with fingers; remolded by strong finger pressure.</td>
</tr>
<tr>
<td>8 - 15</td>
<td>Stiff</td>
<td>100 - 200</td>
<td>Can be imprinted with considerable pressure from fingers or indented by thumbnail.</td>
</tr>
<tr>
<td>15 - 30</td>
<td>Very stiff</td>
<td>200 - 400</td>
<td>Can barely be imprinted by pressure from fingers or indented by thumbnail.</td>
</tr>
<tr>
<td>&gt;30</td>
<td>Hard</td>
<td>&gt;400</td>
<td>Cannot be imprinted by fingers or difficult to indent by thumbnail.</td>
</tr>
</tbody>
</table>
5.4 Deep Sound (DS)

- Static Dutch Cone Penetrometer
- Used to supplement Deep Boring (DB) results in filling areas which are fluvial or soft formation
- Not suitable for gravel abundant subsoil
Cone Penetration Equipment
CONE PENETRATION TEST

![Diagram of cone penetration test results]
5.5 Test Pit, Bulk & Block Samples

- Usually to access suitability of soil as filling material
- Up to 2 m or more (with excavator)
- Visual inspection in Test Pit
- Bulk samples for Laboratory Tests
- Undisturbed block for Strength Test
METHODS OF EXPLORATION

- Hand Augering (HA)
- JKR / Mackintosh Probes
- Deep Sounding (DS)
An engineer supervising and marking samples from trial pit

Trial pit showing soil Profiles
A Very Large Trial Pit

Enables visual inspection, locating strata boundaries, and access for **undisturbed block samples**.
5.5 Test Pit, Bulk & Block Samples
5.7 Geophysical Survey

- Used to supplement borehole results covering large areas
- Include seismic refraction method & electrical resistivity method
- Can be used to predict corrosivity of soil & geological features and cavities
5.7 Geophysical Survey

- Electrical Resistivity Method
- Seismic Refraction Method
Soil samples obtained for engineering testing and analysis, in general, are of two main categories:

**Disturbed Samples**
Disturbed samples are those obtained using equipment that destroy the macro structure of the soil but do not alter its mineralogical composition. Specimens from these samples can be used for determining the general lithology of soil deposits, for identification of soil components and for general classification purposes (grain size distribution, Atterberg limits) and compaction characteristics of soils.

**Undisturbed Samples**
Undisturbed samples are obtained in clay soil strata for use in laboratory testing to determine the engineering properties of those soils. Undisturbed samples of granular soils can be obtained, but often specialized procedures are required such as freezing or resin impregnation and block or core type sampling. Undisturbed samples are obtained with specialized equipment designed to minimize the disturbance to the in-situ structure and moisture content of the soils. Specimens obtained by undisturbed sampling methods are used to determine the strength, stratification, permeability, density and compressibility properties...
# COMMON SAMPLING METHODS

<table>
<thead>
<tr>
<th>Sampler</th>
<th>Disturbed / Undisturbed</th>
<th>Appropriate Soil Types</th>
<th>Method of Penetration</th>
<th>% Use in Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Split-Barrel (Split Spoon)</td>
<td>Disturbed</td>
<td>Sands, silts, clays</td>
<td>Hammer driven</td>
<td>85</td>
</tr>
<tr>
<td>Thin-Walled Shelby Tube</td>
<td>Undisturbed</td>
<td>Clays, silts, fine-grained soils, clayey sands</td>
<td>Mechanically Pushed</td>
<td>6</td>
</tr>
<tr>
<td>Continuous Push</td>
<td>Partially Undisturbed</td>
<td>Sands, silts, &amp; clays</td>
<td>Hydraulic push with plastic lining</td>
<td>4</td>
</tr>
<tr>
<td>Piston</td>
<td>Undisturbed</td>
<td>Silts and clays</td>
<td>Hydraulic Push</td>
<td>1</td>
</tr>
<tr>
<td>Pitcher</td>
<td>Undisturbed</td>
<td>Stiff to hard clay, silt, sand, partially weather rock, and frozen or resin impregnated granular soil</td>
<td>Rotation and hydraulic pressure</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Denison</td>
<td>Undisturbed</td>
<td>Stiff to hard clay, silt, sand and partially weather rock</td>
<td>Rotation and hydraulic pressure</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Modified California</td>
<td>Disturbed</td>
<td>Sands, silts, clays, and gravels</td>
<td>Hammer driven (large split spoon)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Continuous Auger</td>
<td>Disturbed</td>
<td>Cohesive soils</td>
<td>Drilling w/ Hollow Stem Augers</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Bulk</td>
<td>Disturbed</td>
<td>Gravels, Sands, Silts, Clays</td>
<td>Hand tools, bucket augering</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Block</td>
<td>Undisturbed</td>
<td>Cohesive soils and frozen or resin impregnated granular soil</td>
<td>Hand tools</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
DISTURBED SAMPLES OBTAINED FROM SPT
UNDISTURBED CLAY SAMPLES

Required for triaxial, consolidation tests in the lab.

Good quality samples necessary.

\[ A_R < 10\% \]

\[ A_R = \frac{O.D.^2 - I.D.^2}{I.D.^2} \times 100 \text{ (\%)} \]

The thicker the wall, the greater the disturbance.

Take good care in transport and handling.
(a) Internal discharge (WX design)  
(b) Annual discharge (WM design)  
(c) Face discharge (F design)
Figure 6. Stationary piston sampler.

Figure 7. Denison Sampler.
Figure 8. Pitcher sampler.
Figure 18
Typical thin-walled open-tube sampler (U75)
Core-catcher attachment for soil of low cohesion

Area ratio = \( \frac{D_w^2 - D_c^2}{D_c^2} \times 100\%
\)

Note: \( D_c < D_w \)
\( D_1 < D_w \)
2.3.2 Rotary diamond coring

Continuous rock cores are required in most cases using a coring bit and core barrel (see Figures 14 and 15).
**Core Recovery**, \( CR = \frac{\text{Total length of rock recovered}}{\text{Total core run length}} \)

\[
CR = \frac{(250 + 200 + 250 + 190 + 60 + 80 + 120) \text{ mm}}{1,200 \text{ mm}}
\]

\( CR = 96\% \)

**RQD**

\[
RQD = \frac{\sum \text{Length of sound pieces } > 100 \text{ mm}}{\text{Total core run length}} \times 100\%
\]

\[
RQD = \frac{(250 + 190 + 200) \text{ mm}}{1,200 \text{ mm}} \times 100\%
\]

\( RQD = 53\% \)

Figure 94. Calculation of core recovery and RQD.
Table 39. Rock quality description based on RQD.

<table>
<thead>
<tr>
<th>RQD Value</th>
<th>Description of Rock Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25 %</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>

rock classification systems were developed by the Council for Scientific and Industrial Research (CSIR) in South Africa (referred to as the “Q-rating system”) and the Norwegian Geotechnical
### A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RANGES OF VALUES</th>
<th>For this low range — uniaxial compressive test is preferred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength of intact rock material</td>
<td>Point load strength index</td>
<td>8 MPa</td>
</tr>
<tr>
<td>Uniaxial compressive strength</td>
<td>&gt;200 MPa</td>
<td>100 to 200 MPa</td>
</tr>
<tr>
<td>Relative Rating</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

| Drill core quality RQD | 90% to 100% | 75% to 90% | 50% to 75% | 25% to 50% | <25% |
| Relative Rating | 20 | 17 | 13 | 8 | 3 |

| Spacing of joints | >3 m | 1 to 3 m | 0.3 to 1 m | 0.1 to 0.3 m | <0.5 m |
| Relative Rating | 30 | 25 | 20 | 10 | 5 |

| Condition of joints | Very rough surfaces (Not continuous) | Slightly rough surfaces (Separation <1 mm) | Slightly rough surfaces (Separation 1-2 mm) | Slickensided surfaces or Gouge <5 mm thick or Joints open 1 to 5 mm | Soft gouge >5 mm thick or Continuous joints |
| Relative Rating | 25 | 20 | 12 | 6 | 0 |

### B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

<table>
<thead>
<tr>
<th>Strike and dip orientations of joints</th>
<th>Very favorable</th>
<th>Favorable</th>
<th>Fair</th>
<th>Unfavorable</th>
<th>Very Unfavorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnels</td>
<td>0</td>
<td>-2</td>
<td>-5</td>
<td>-10</td>
<td>-12</td>
</tr>
<tr>
<td>Foundations</td>
<td>0</td>
<td>-2</td>
<td>-7</td>
<td>-15</td>
<td>-25</td>
</tr>
<tr>
<td>Slopes</td>
<td>0</td>
<td>-5</td>
<td>-25</td>
<td>-50</td>
<td>-60</td>
</tr>
</tbody>
</table>

### C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

<table>
<thead>
<tr>
<th>RMR Rating</th>
<th>Class No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 to 81</td>
<td>I</td>
<td>Very good rock</td>
</tr>
<tr>
<td>80 to 61</td>
<td>II</td>
<td>Good rock</td>
</tr>
<tr>
<td>60 to 41</td>
<td>III</td>
<td>Fair rock</td>
</tr>
<tr>
<td>40 to 21</td>
<td>IV</td>
<td>Poor rock</td>
</tr>
<tr>
<td>&lt;20</td>
<td>V</td>
<td>Very poor rock</td>
</tr>
</tbody>
</table>
CONVENTIONAL APPROACH TO SI

THANK YOU.