Site Investigation Field & Laboratory Tests

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Introduction

Site investigation is the gathering of information about the proposed location of a project, e.g. highway or buildings.

It is aimed at providing sufficient reliable subsurface information for most economical, satisfactorily safe foundation for the proposed structure.

Site investigation should reveal sufficient subsurface information for the design and construction of a stable foundation.

Site Investigation program should be aimed at representative results and the quality of design

Geotechnical Problems and Required Information

Based on geotechnical information:

- define required parameters,
- minimum number and depth of borings,
- frequency of sampling,
- types of field test,
- laboratory test,
- correlations

Geotechnical Problems and Important Information

- Topography
- Soil Profile
- Ground water condition
- Soil properties e.g density, soil classification, shear strength, modulus, consolidation properties, coefficient of permeability, water storage, OMC&MDD, CBR, etc.
- Interpretation of the data and selection of soil parameters needed for analysis and design of the foundation should be done carefully based on scientific knowledge, experience, and engineering judgment

Stages of Site Investigation

- Data collection and desk study
- Site visit/reconnaissance,
- Preliminary ground investigation,
- Detailed ground investigation, and
- Monitoring.

Data Collection & Desk Study

Data Gathering:

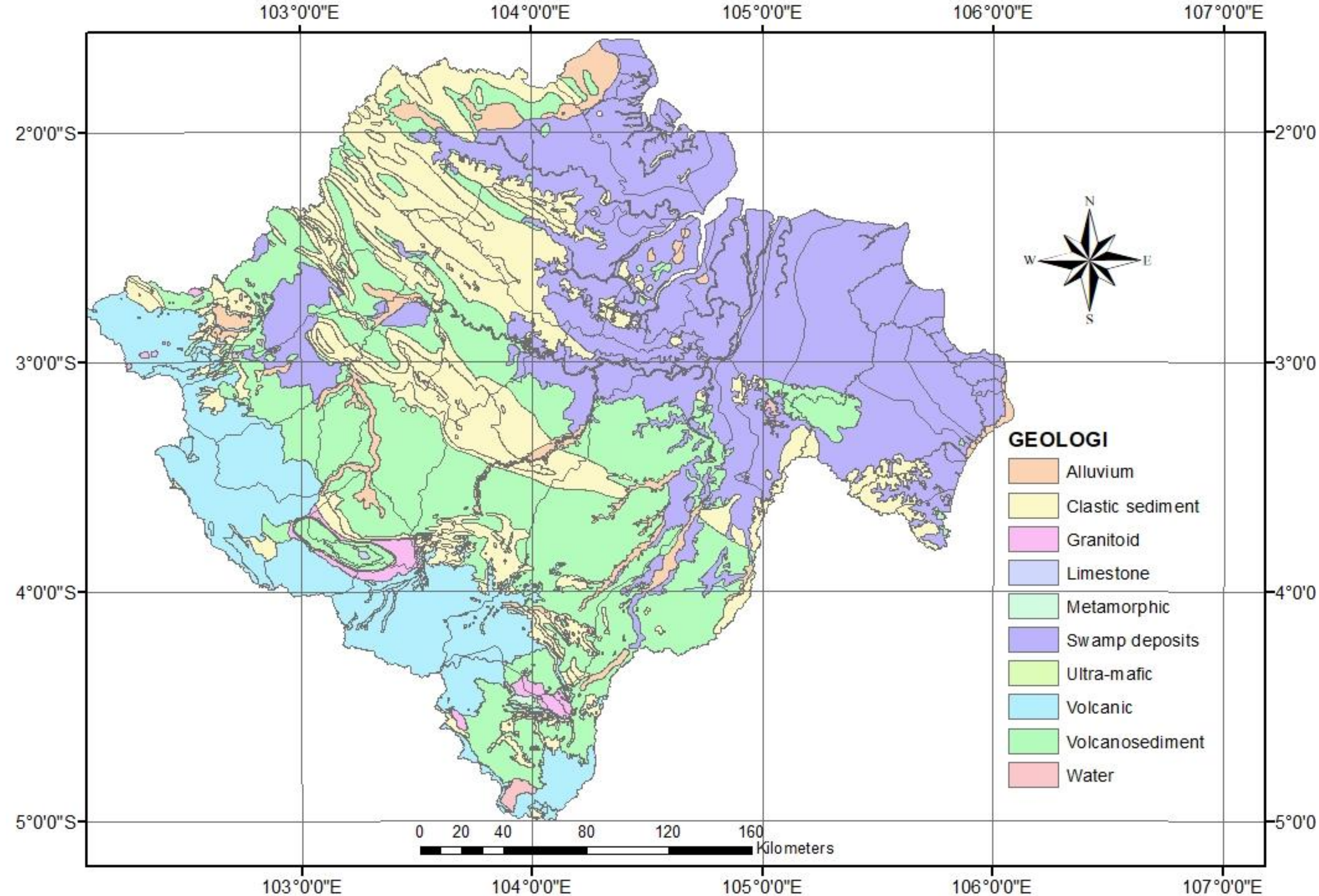
- Topographical map,
- Geological map,
- Site history,
- Soil-survey map,
- Utilities

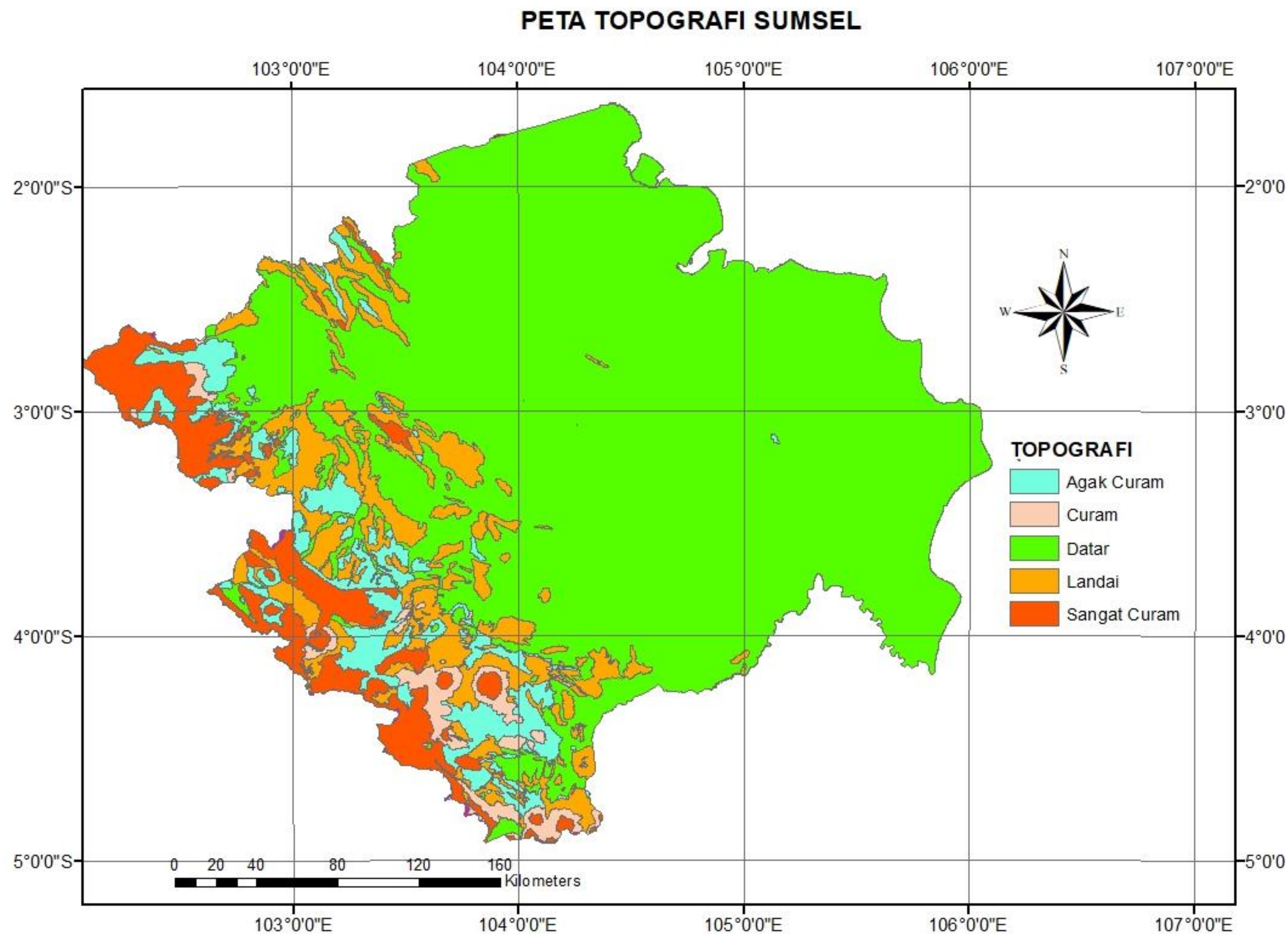
Sources Internet, Library

- Geological Map
- Satellite Image
- Topographical Map

It is essential when conducting a desk study that as much information as possible is obtained. Work at this stage of the investigation saves much time on the later stages and vastly improves the planning and quality of the investigation.

PETA GEOLOGI SUMSEL




PETA TOPOGRAFI SUMSEL
103°0'0"E
104°0'0"E
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5°0'0"S
N
S
W
E
TOPOGRAFI
Agak Curam
Curam
Datar
Landai
Sangat Curam
0 20 40 80 120 160
Kilometers

Reconnaissance / Site Visit

Early examination of the site to gain important information:

- Site lay-out
- Surface condition
- Climate and hazard water level (current, etc)

It is wise to take advantage of all sources of readily available information and advice and to plan the detailed subsurface investigation carefully. The best general indication of subsurface conditions is the performance of existing structures in the area. If the performance is generally good, it follows that soil conditions are good or at least that existing foundation designs are adequate. Photographs taken during the site visit can be invaluable for the analysis and design process.


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the desk study and reconnaissance is aimed at the *feasibility study* of the project being planned. If the desk study shows that the site is feasible for the structure, then *preliminary investigation* should follows.

Preliminary investigation

- *Preliminary investigation* is aimed at predicting the geological structures, soil profiles and the position of ground water table by geophysical method or by making a few boreholes.
- On large projects such as highway works and in other application covering large development areas, geophysical testing can be performed for preliminary investigation.

At the end of preliminary investigation, the owner should be able to come up with the *preliminary design* of the structure including the architecture, the material, and the cost estimation.

Once the design is prepared, then the owner should engaged an SI contractor to perform *Detailed Investigation*

Detailed Investigation

Consists of Boring, Sampling, testing

Boring refers to drilling or advancing a hole in the ground

Sampling refers to removing soil from the hole

Testing refers to determining the properties from the soil

Detail investigation is aimed at *detail design of the construction*.

Monitoring

Usually the investigation program is terminated when the detail design has been submitted.

This should not be the case because

Review of the Design can be made during construction based on information gained from *Monitoring program*

From now on, we will focus on detailed investigation (soil exploration), more commonly referred as:

GROUND INVESTIGATION

Planning

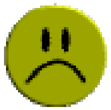
Planning means determining the *number of boreholes (spacing and depth)*, *drilling techniques*, *types and number of field test*, *number of samples to be taken in each boreholes*, *and laboratory tests to be performed.*

HOWEVER

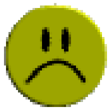
There are no clear cut criteria to give directly to the number and lay-out of borings for a specific project and location.

How many bore holes?

Not enough bore holes; soil profile and properties not well defined..



Too many bore holes and blows the budget.



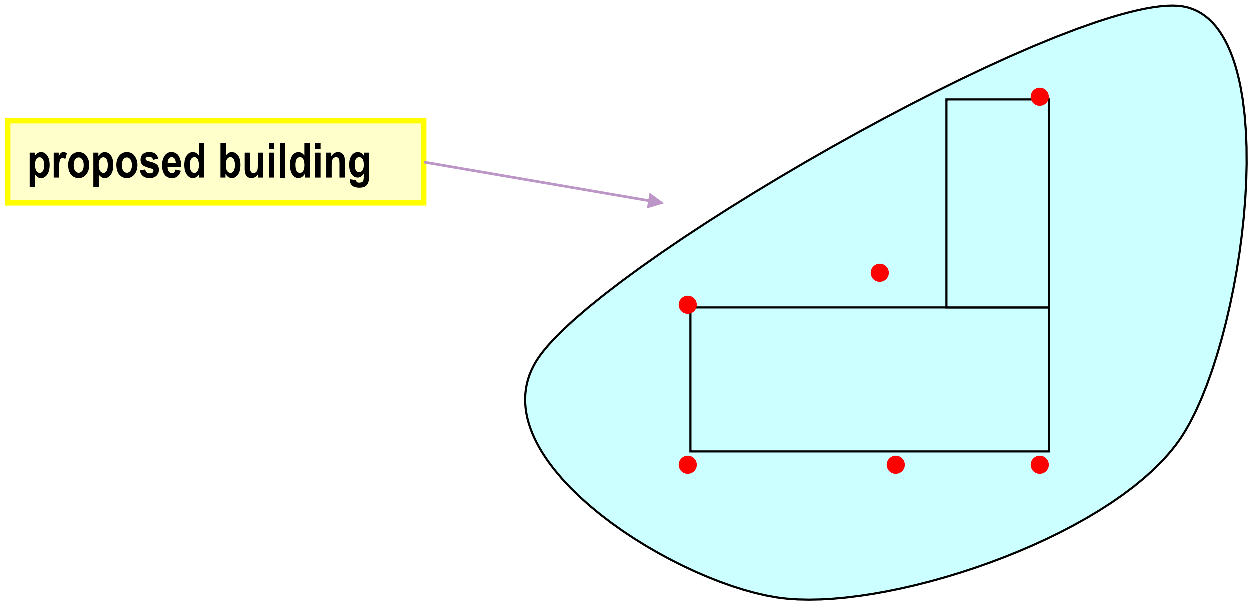
About right?

consider **type and size of the project, budget for site investigation, AND soil variability**

Lay out of boreholes

Locate the bore holes where the loads are expected.

Spacing may be increased if soil found to be uniform & reduced if found to be non-uniform



Depth of boreholes

Investigation must be carried out to the depth at which ground conditions cease to affect the work.

Boring should extend to a depth where stress changes become insignificant (less than 10% of the effective overburden pressure, or at least 10 m below the lowest building elevation)

In the case of very heavy structures, including tall buildings, borings should extend to bedrock.

In all cases, it is advisable to have at least one boring that extend to supporting strata or bedrock.

Lay out, depth & types

Construction type	Number bore	Depth
Houses < 2 story	1/500 m^2	3 m
Industrial Buildings < 2 story	1/500 m^2	6 m
Heavy Industry	1/250 m^2	30 m
buildings;	1/250 m^2	1.5 x B
other facilities	1/500 m^2	
Buildings < 6 story	1/250 m^2 (min 5)	30 m
Multi-story Buildings > 6 story	1/250 m^2 (min 5)	1.5 x B

Types of Boring

B < 30 m, up to 3-story hand bore

B < 120 m, up to 2 story hand bore

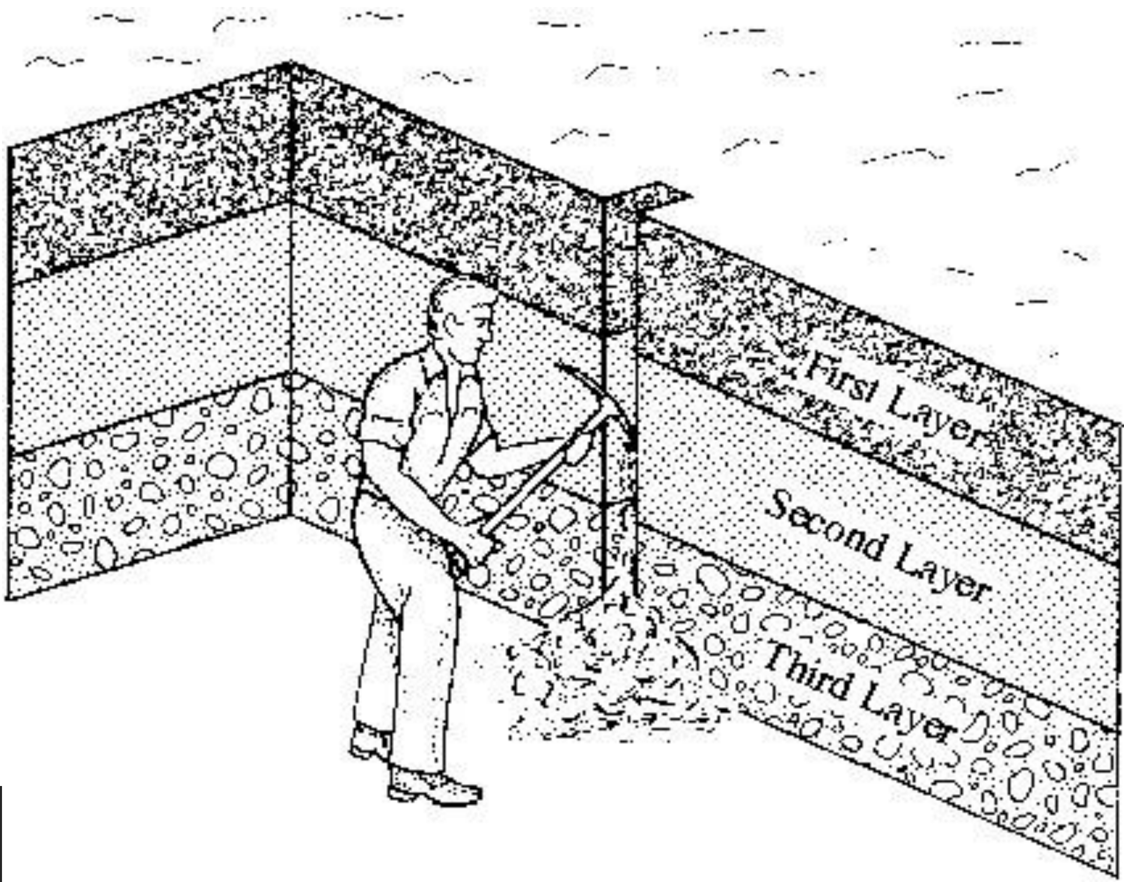
Otherwise: Machine Bore

Boring techniques

- Trial pits
- Soil Boring
  - Hand auger may be used to a depth of 6 m
  - Power augers may be used to bore much deeper & quicker
  - Power auger set with a drill rig can be used to obtain samples from deeper strata (10 to 30 m) or even to 100 m depth.
  - Methods for advancing a hole into the ground are the wash boring, percussion drilling and rotary drilling.
- Core Boring

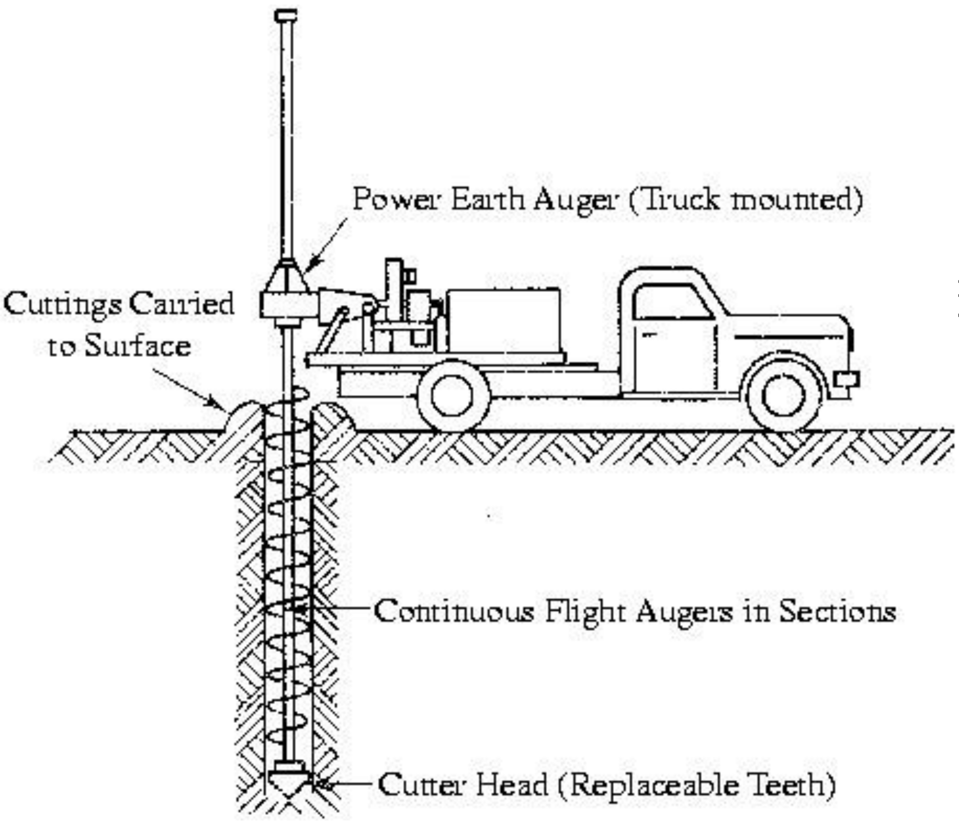
Trial Pits

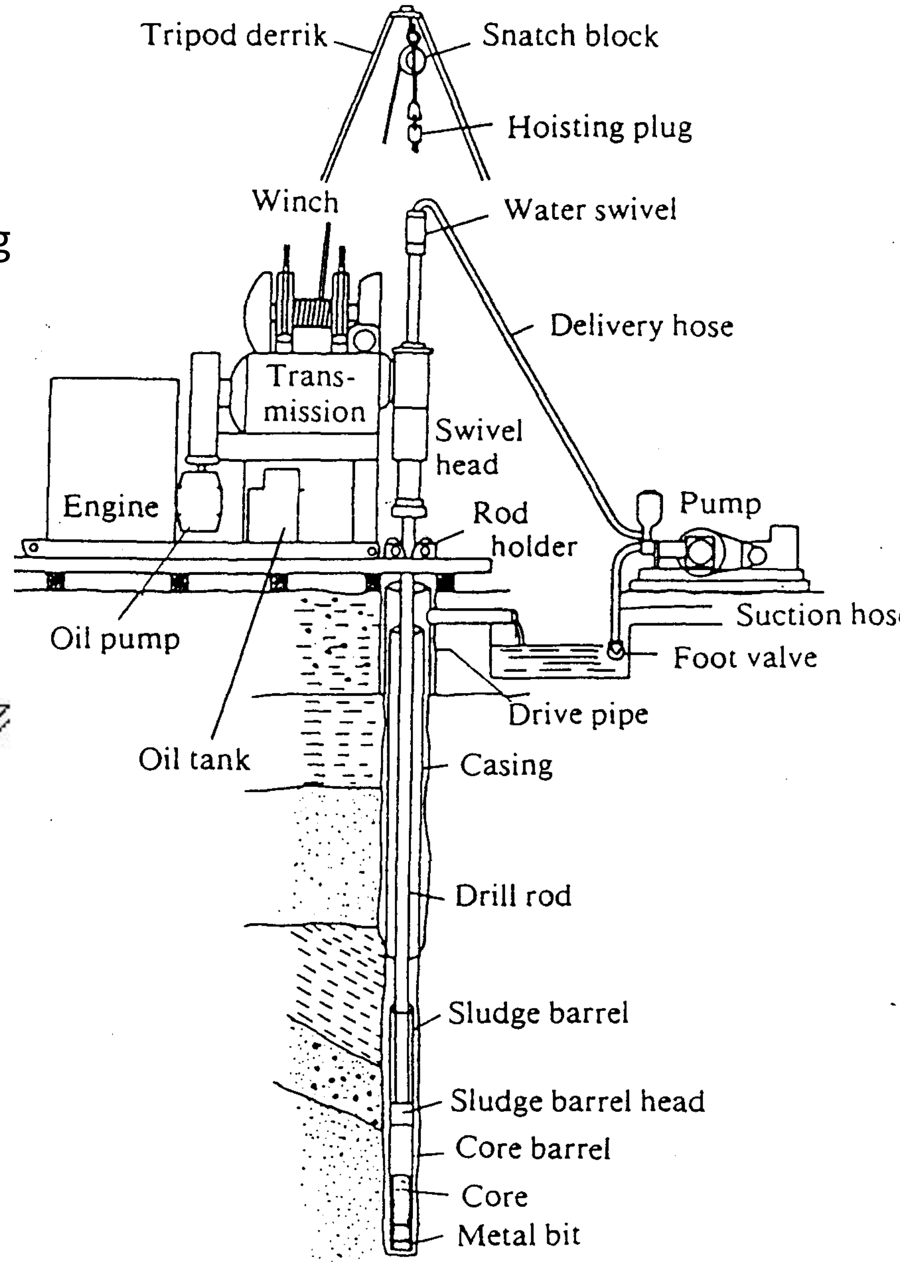
Shallow excavations going down to a depth no greater 6 m. The pits are excavated either manually (less than 2 m) or by wheeled backhoe (2 to 4 m) and hydraulic excavator (4 to 6 m). Used for block sampling and reliable assessment of soil condition



Soil Borings

Percussion boring





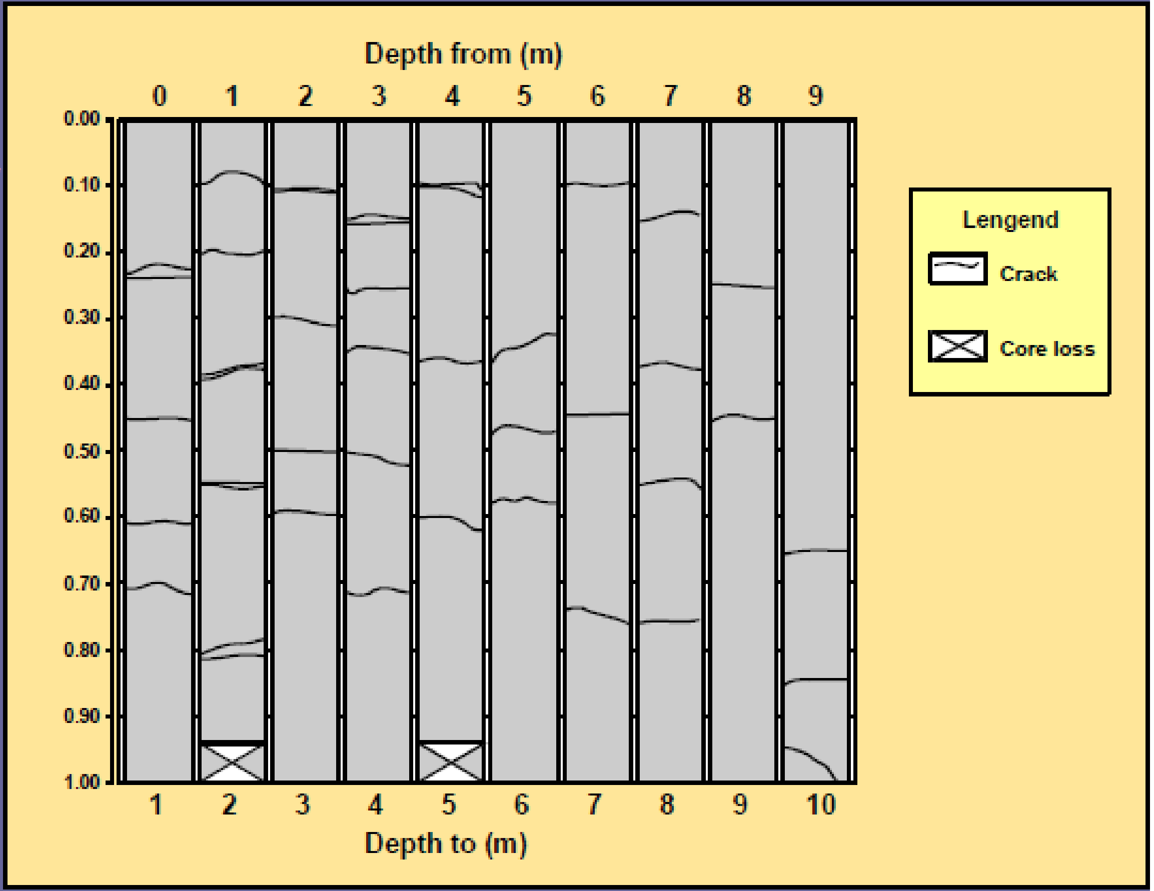
Rotary boring

Core Borings

- Core borings are used to drill into & through rock formations
- Core borings are performed using a core barrel with a hard cutting bit containing tungsten carbide or commercial diamond chips
- Core remains in the core barrel and may be removed for examination by bringing the barrel to the surface
- Rock specimen may be removed & sent to laboratory for testing & analysis

Cored samples

- Core Logging
- Check Uniformity
- Check Cracks
- Check for Weak Spots



Sampling

Sampling refers to the taking of soil sample from bored hole.

Disturbed or Undisturbed

Disturbed samples are usually used for soil grain-size analysis, determination of *LL* & *PL* and specific gravity of soil, compaction test and CBR (California bearing ratio)

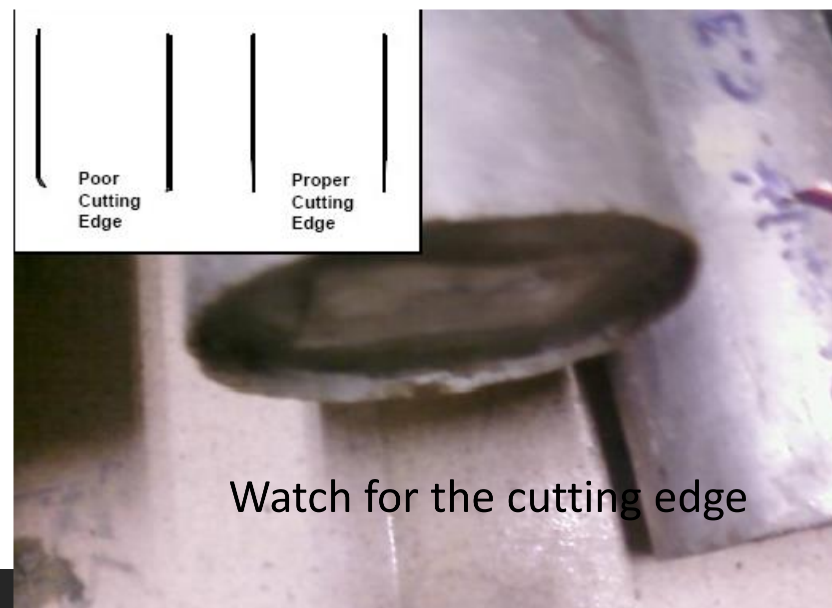
For determination of water content, strength, compressibility & permeability, it is necessary that the sample should be the same as in-situ condition, undisturbed samples should be used

Sampling/ undisturbed

collect undisturbed clay samples by thin walled sampler
(e.g. shelby tube, OD sampler, Piston sampler)

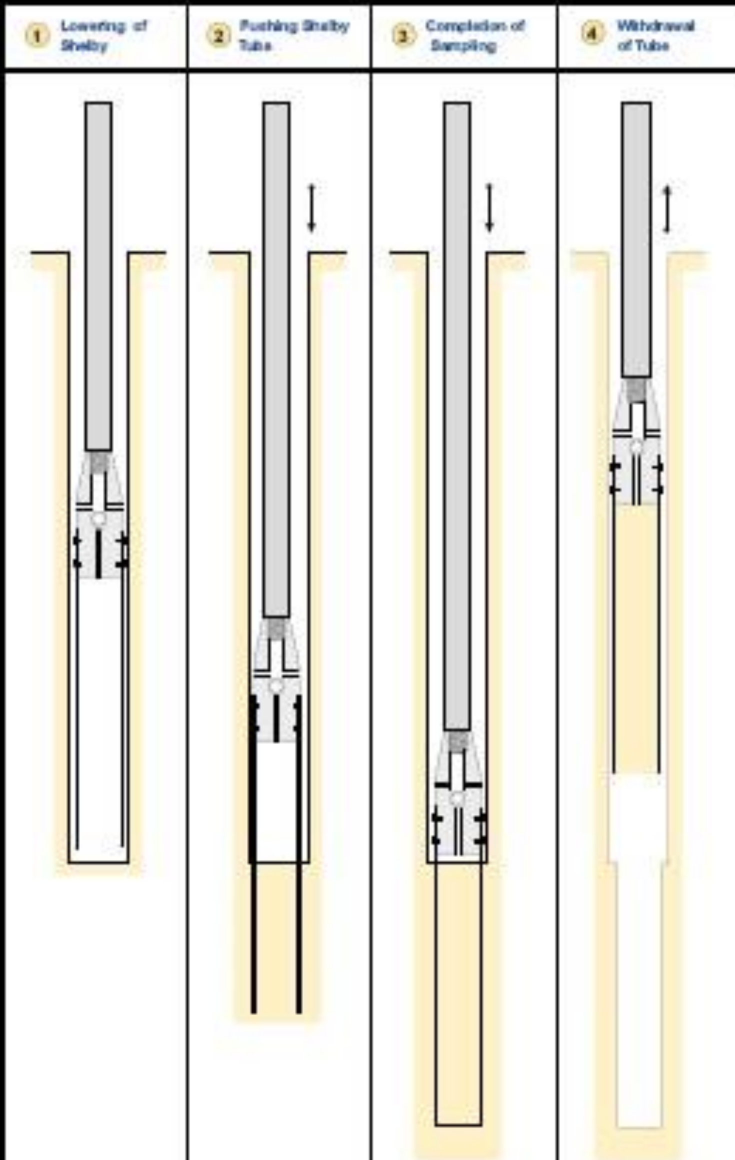
Shelby tube

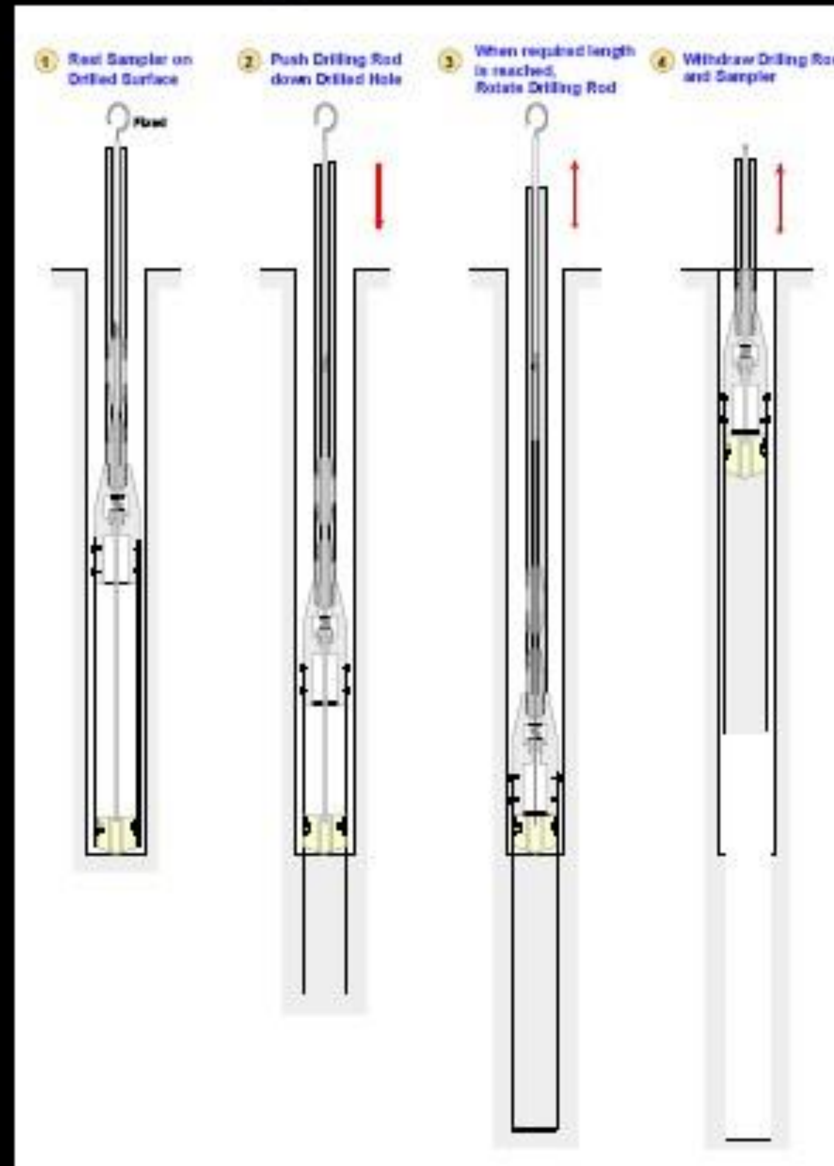
Piston sampler:
-Fixed end
-Free end



Undisturbed Sampling (UD)

Push-in versus Stationary Piston



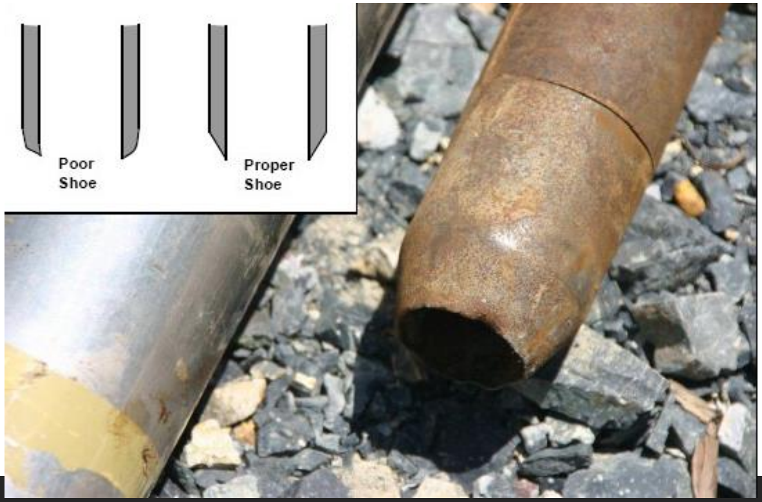


Sampling/ disturbed

Disturbed samples can be obtained from auger boring, core boring, split spoon sampler in standard penetration test, pit and trench, and some types of samplers such as thick walled sampler, displacement sampler, and Beggemann sampler.

Split spoon sampler from SPT test

I.D. = 35 mm O.D.= 50 mm



Undisturbed samples - Quality evaluation

Good quality samples are required in order to get a good estimate of soil characteristics thus we should evaluate **the Sample Quality**

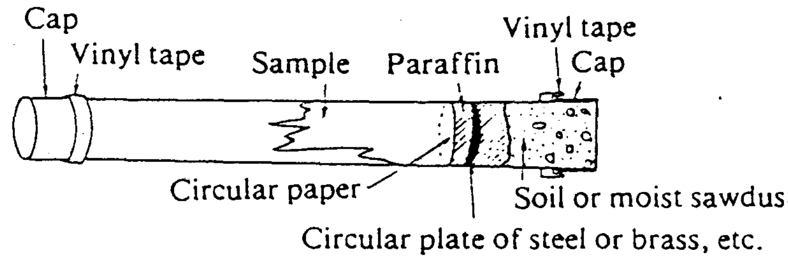
Quality evaluation:

- **At site:** visual inspection, recovery ratio, pocket penetration test, X-ray
- **Test results:** stress strain curve (strain at failure), consolidation curve (pre-consolidation pressure)

Sources of disturbance include:

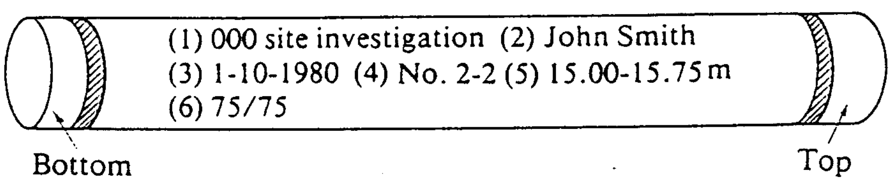
Drilling; Tube Sampling; Transportation & Delivery; Storage; Extrusion From Tube; Cavitation & Water content redistribution; Trimming & Mounting in Triaxial Cell; HUMAN ERROR

Quality evaluation



- Immediately after the tube containing the sample is brought to the ground surface, the ends of the tube should be sealed with paraffin wax

- After sealing the tube, the following data should be attached to the sampling tube:
  (1) project name,
  (2) name of drilling operator,
  (3) date of the sampling,
  (4) borehole number and sample number, and
  (5) depth of the sample
  (6) length of tube



Visual inspection of “undisturbed” samples shoud be made to ensure that there is:

- ✓ no visible distortion or strata in the sample,
- ✓ no opening or softening of the material,
- ✓ specific recovery ratio (SRR) should not be less than 95%,

$$\text{SRR} = \frac{\text{length of undisturbed sample recovered from the tube}}{\text{length of the tube}}$$

- ✓ area ratio should be less than 15%.

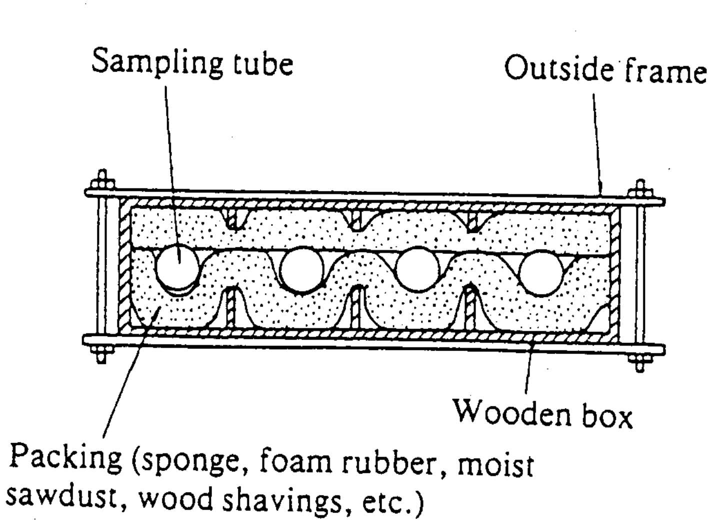
$$A_r(\%) = \frac{D_o^2 - D_i^2}{D_i^2} \times 100\%$$

where D_i = inside diameter,
D_o = outside diameter

Transporting & Storage

The sealed tube should then be sent for testing in the laboratory. Care should be taken during shipment and storage because these may result in serious sample disturbance.

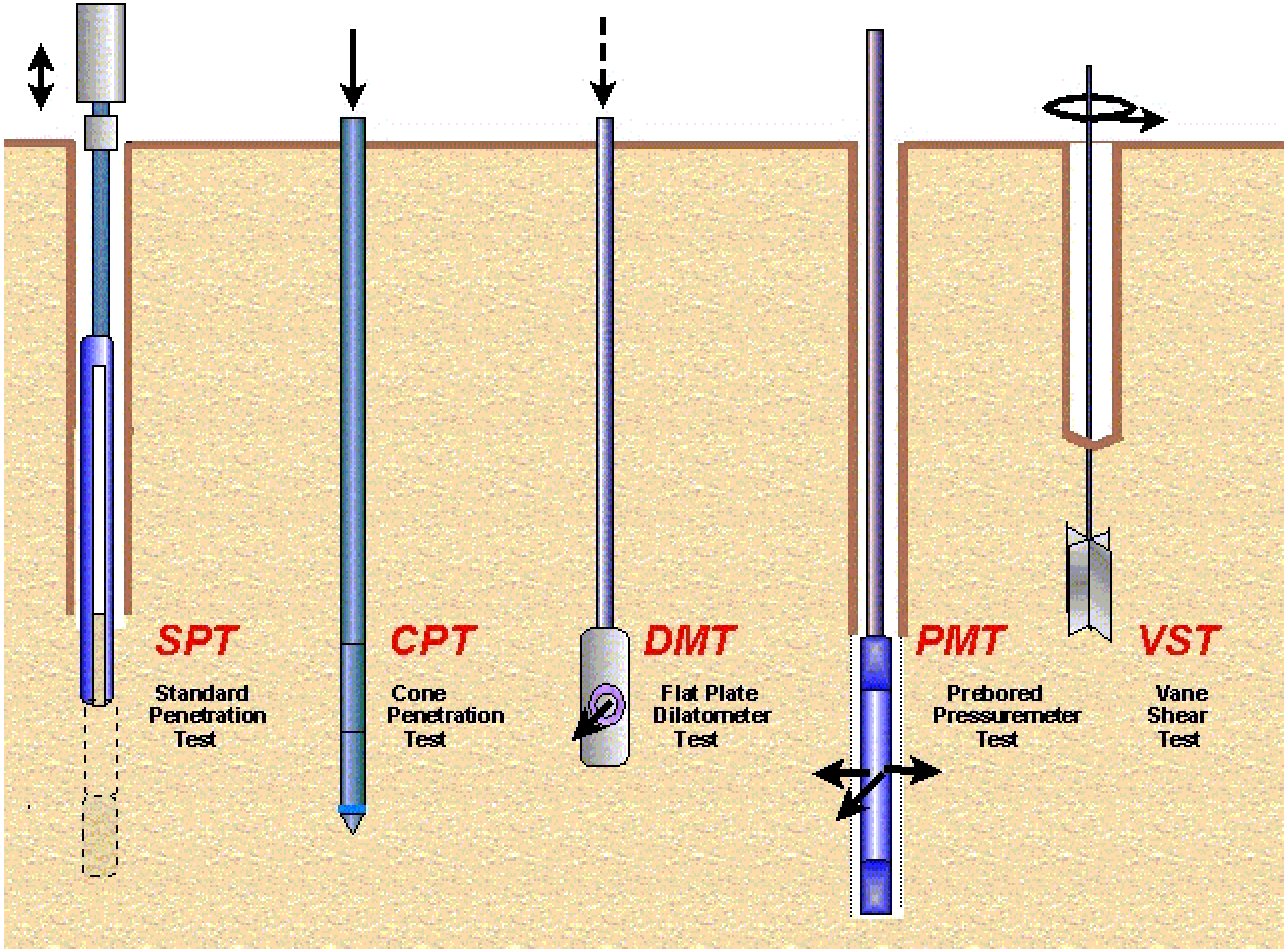
The safest way is to transport the samples carefully by hand. If this is not possible, the samples should be put in a box with cushioning material or padding to protect the samples from vibration and considerable handling. The boxes should be marked for careful handling.



Quality Assurance

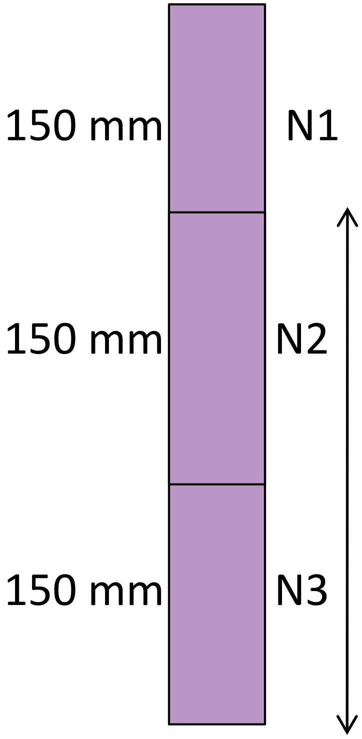
- Samples should be tested as soon as possible after arrival at the laboratory.
- On arrival, it is important to check the conditions of the samples and compare it with the states recorded in the field.
- The samples should be stored in a room where the temperature and humidity are kept constant and similar to the in-situ conditions.
- The sample storage area should be of sufficient size to cater for the number of samples being handled without overcrowding.
- The types of test should be determine in advance based on the type of the problem and soil condition

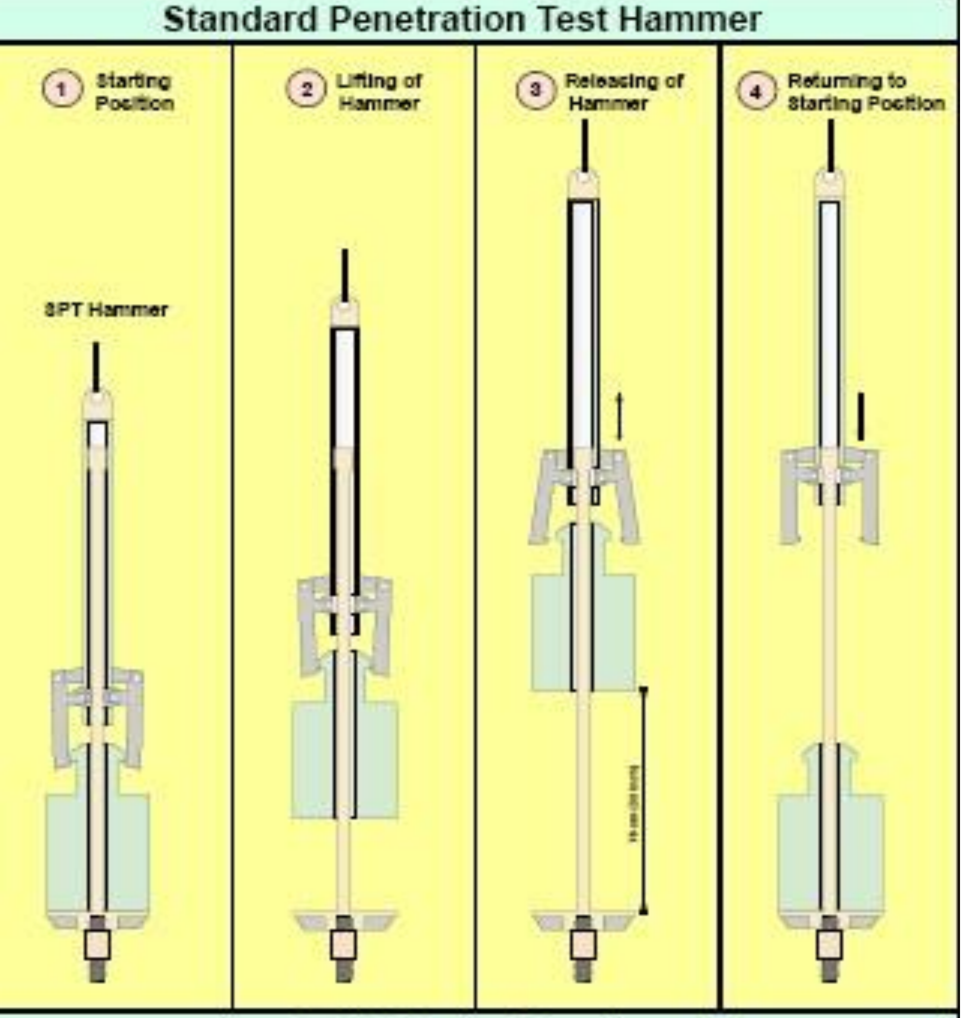
In-situ/Field Testing

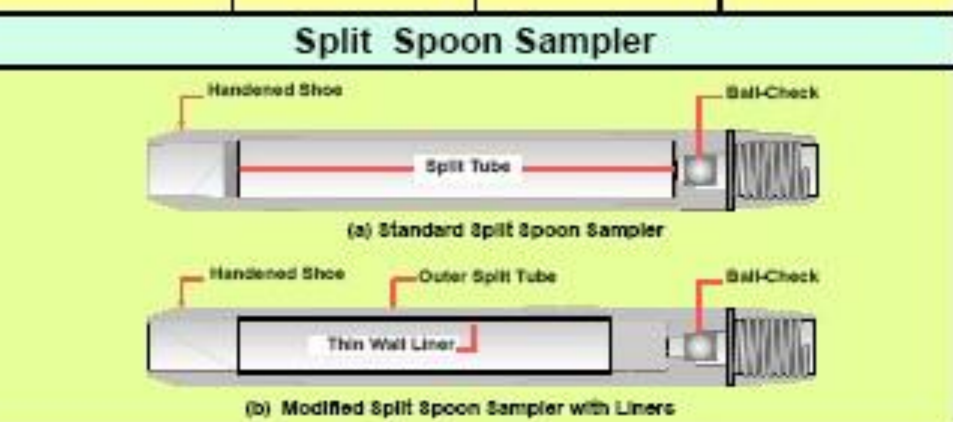


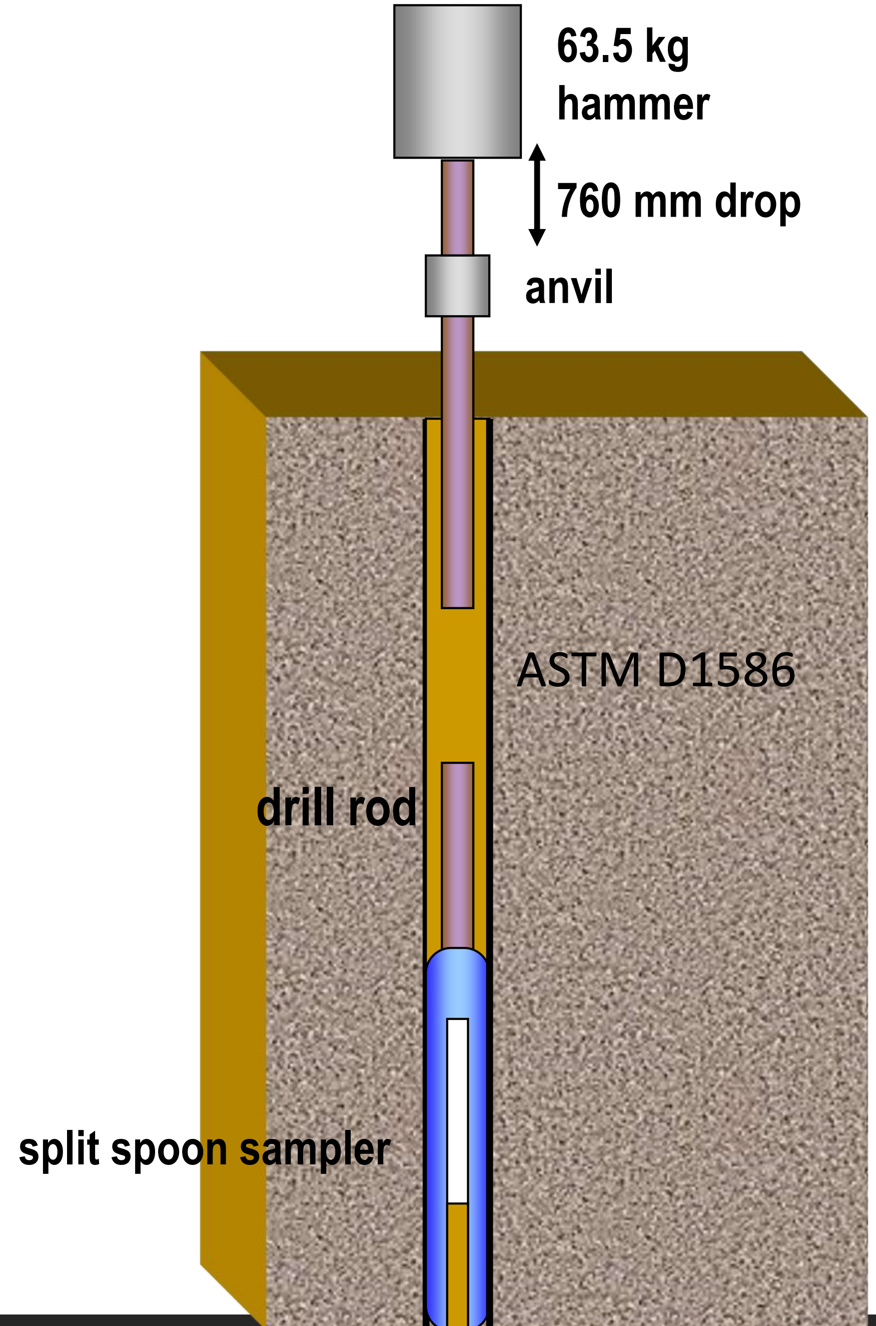
Standard Penetration test (SPT)

- The Standard Penetration Test utilizes a split spoon sample
- As the sampler is driven into the soil, the number of blows required to penetrate each of the three 150 mm increments is recorded separately
- The N-value is the number of blows required to penetrate the last 300 mm
- After the blow counts have been obtained, the sampler can be removed & opened to obtain a disturbed sample for subsequent testing




Standard Penetration Test Hammer
1 Starting Position
2 Lifting of Hammer
3 Releasing of Hammer
4 Returning to Starting Position
SPT Hammer


Split Spoon Sampler
Hardened Shoe
Ball-Check
Split Tube
(a) Standard Split Spoon Sampler
Hardened Shoe
Outer Split Tube
Ball-Check
Thin Wall Liner
(b) Modified Split Spoon Sampler with Liners


63.5 kg hammer
760 mm drop
anvil
ASTM D1586
drill rod
split spoon sampler

The N-values can be affected by the following:

- Drill rod lengths
- Presence of liners in sampler
- Borehole diameter

$$N_{60} = \frac{E_m \, C_B \, C_S \, C_R}{0.60} N$$

SPT results are also influenced by overburden pressure (σ_0‘) at locations where blow counts are made

$$N_{60}' = N_{60} \times (100/\sigma_0)^{1/2}$$

The SPT test should be halted when soil shows some refusal i.e. when more than 50 blows are required to penetrate any 150 mm increment or 100 blows are obtained for 300 mm penetration or if 10 successive blow produce no advance in the penetration.

Example 1

A standard penetration test was performed in a 150 mm diameter boring at a depth of 8 m below the ground surface. The actual blow count N was 19. The soil is normally consolidated sand with a unit weight of 20.40 kN/m^3, and the ground water table is at depth 15 m. (a) Calculate the N_{60} value if for the field condition $E_m = 0.73$, $C_S = 1$, $C_B = 1.05$, $C_R = 0.95$ (b) compute the corrected N value if ground water is found at depth of 2 m below the ground surface.

Solution

a.Corrected N value with respect to field condition:

$$N_{60} = \frac{E_m \, C_B \, C_S \, C_R}{0.60} N = \frac{0.73 \times 1.05 \times 1 \times 0.95}{0.6} 19 = 23$$

c. Corrected N value with respect to overburden pressure if groundwater at -2 m

$$\sigma' = 2 \text{ m} \times 20.40 + 6 \text{ m} \times (20.40 - 9.80) = 104.40 \text{ kPa}$$

$$N_{60}' = N_{60} \, C_N = N_{60} \left(\frac{100}{\sigma_o'} \right)^{0.5} = 23 \times \sqrt{\frac{100}{104.40}} = 22$$

SPT N (blows/300 mm)	Relative density (%)	Internal friction angle	State of packing
4	20	30	Very loose
4 – 10	20 – 40	30 – 35	Loose
10 – 30	40 – 60	35 – 40	Compact
30 – 50	60 – 80	40 – 45	Dense
> 50	> 80	45	Very Dense

Several soil parameters have been established through empirical correlations with *N*-values,

SPT N (blows/300 mm)	c_u (kPa)	Consistency
2	10	Very soft
2 – 4	10 – 25	Soft
4 – 8	25 – 50	Medium
8 – 15	50 – 100	Stiff
15 – 30	100 – 200	Very Stiff
> 30	> 200	Hard

Tabel 2. Korelasi Antara Kepadatan Relative (Dr) Dan Sudut Geser Dalam (Ø) Dengan Nilai SPT N'70 Untuk Tanah Pasir (BOWLES, 1988)

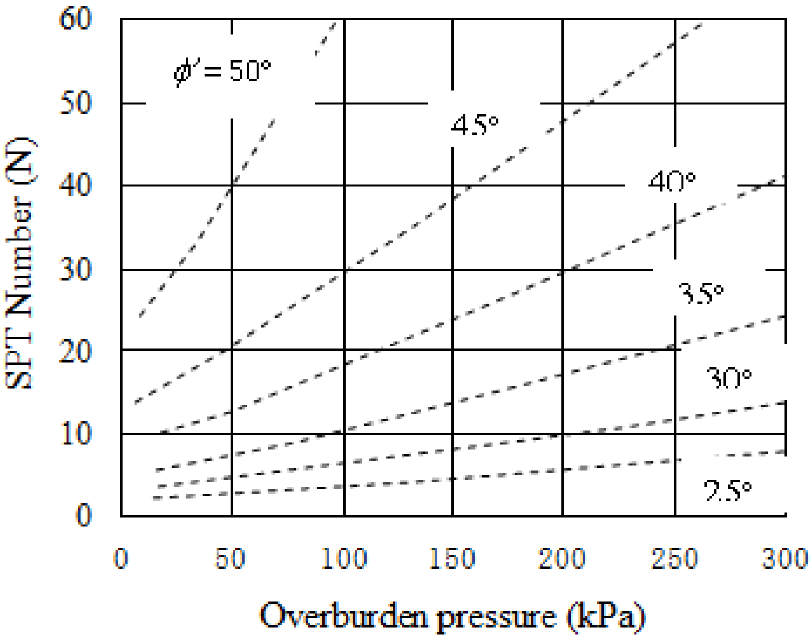
Deskripsi	SangatLepas (Very Loose)	Lepas (Loose)	AgakPadat (Medium)	Padat (Dense)	SangatPadat (Very Dense)
Kepadatan relative, Dr (%)	0 – 15	15 – 35	35 – 65	65 – 85	>85
SPT N'70 : Halus : Medium : Kasar	1 – 2 2 – 3 3 – 6	3 – 6 4 – 7 5 – 9	7 – 15 8 – 20 10 – 25	16 – 30 21 – 40 26 – 45	 >40 >45
Ø : Halus : Medium : Kasar	26 – 28 27 – 28 28 – 30	28 – 30 30 – 32 30 – 34	30 – 34 32 – 36 33 – 40	33 – 38 36 – 42 40 – 50	>50
γ_{wd} (kN/m^3)	11 – 16	14 – 18	17 – 20	17 – 22	20 – 23

Tabel 3. Hubungan Antara Nilai SPT, CPT Dan Sudut Geser Dalam Pasir (Schmertmann,1978)

Tipe Pasir	Kepadatan relative, Dr (%)	SPT, N60 (Terzaghi dan Peck 1967)	CPT, qc (kN/m^2) (Meyerhof 1974)	Sudut geser Dalam	
				Meyerhof 1974	Peck, Hanson, dan Tornburn 1974
Sangat lepas	<20	<4	–	<30	<29
Lepas	20 – 40	4 – 10	0 – 5000	30 – 35	29 – 30
Medium	40 – 60	10 – 30	5000 – 15000	35 – 48	30 – 36
Padat	60 – 80	30 – 50	15000 – 25000	38 – 41	36 – 41
Sangat Padat	>80	50	25000 – 40000	41 – 44	>41

Tabel 4. Konsistensi Tanah Lempung Berdasarkan Nilai SPT (Bowles, 1988)

Kondisi	Konsistensi	Nilai N SPT	Bila Tanah Dipencet mengunakan Telunjuk dan Ibu Jari
Normally	SangatLunak	0 – 2	Merembes keluar
Consolidated	Lunak	3 – 5	Mudah berubah bentuk
Berusia muda	Menengah	6 – 9	
Overconsolidated	Kaku	10 – 16	Sukar untuk berubah bentuk
Berusia tua	Sangat kaku	17 – 30	Sangat sukar berubah bentuk
cemented	Keras	>30	Hampir tidak bisa berubah bentuk



Cone Penetration Test

(ASTM D 3441 and D 5778)

The most advanced and developed in-situ testing currently available is the cone penetration test.

Device:

cone, friction sleeve, piezometer

some rods

measuring devices.

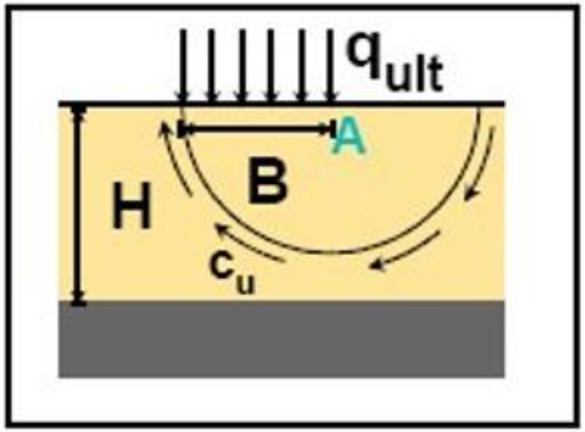
Two types of cone

mechanical

electrical

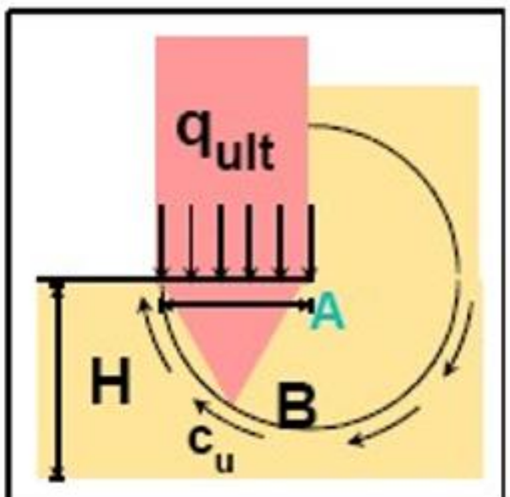
Correlation between resistance & soil types can give valuable information regarding soil type as a function of depth

Cone Penetration Test (Mechanical)

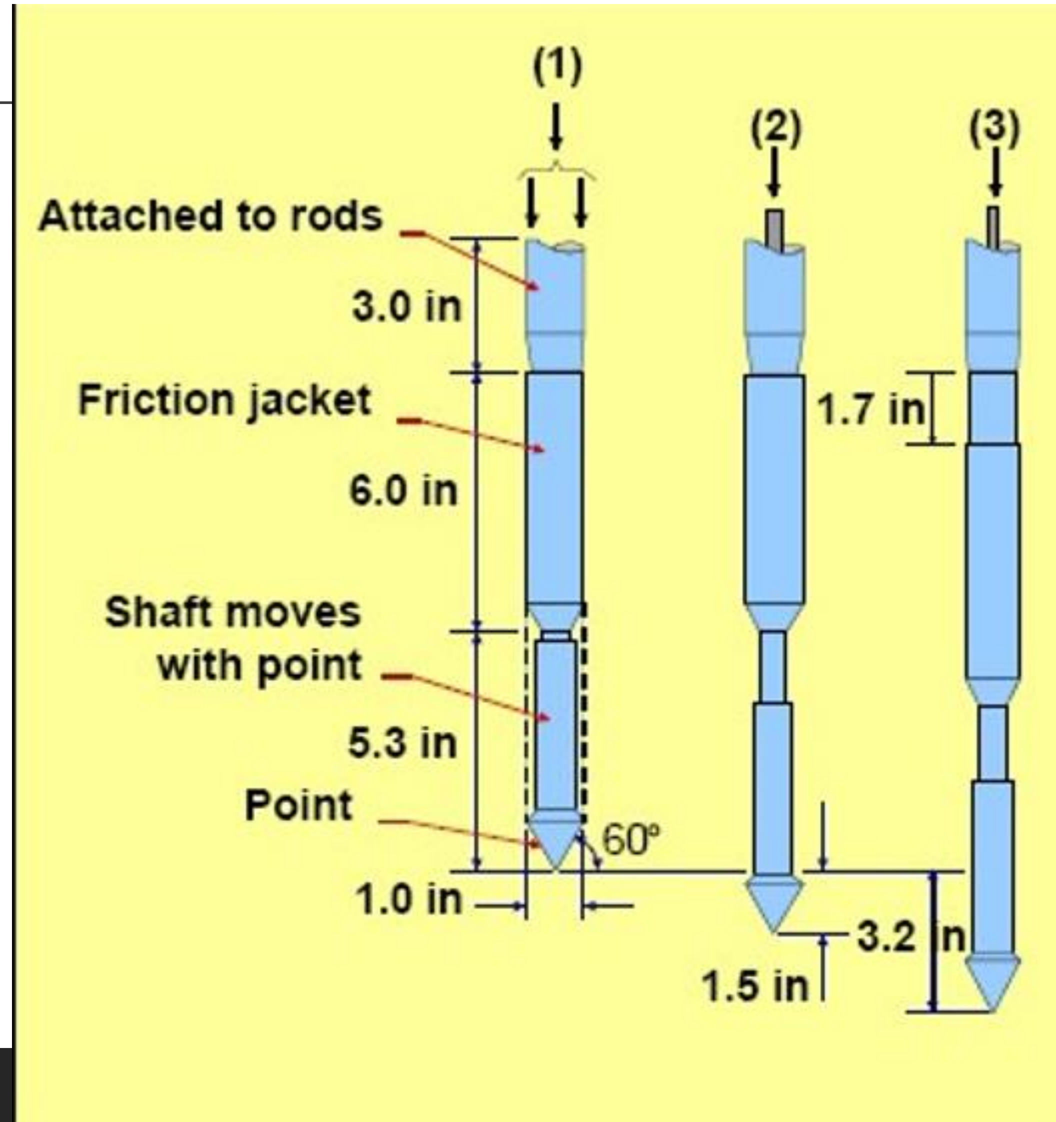


Taking moment at Point A:

Driving Moment, $M_{driving}$ = q_{ult} x B x B/2
Resisting Moment, $M_{resisting}$ = c_u x B π x B
Equating, Resisting Moment = Driving Moment,
Giving, $q_{ult} = 2\pi c_u \approx 6 c_u$



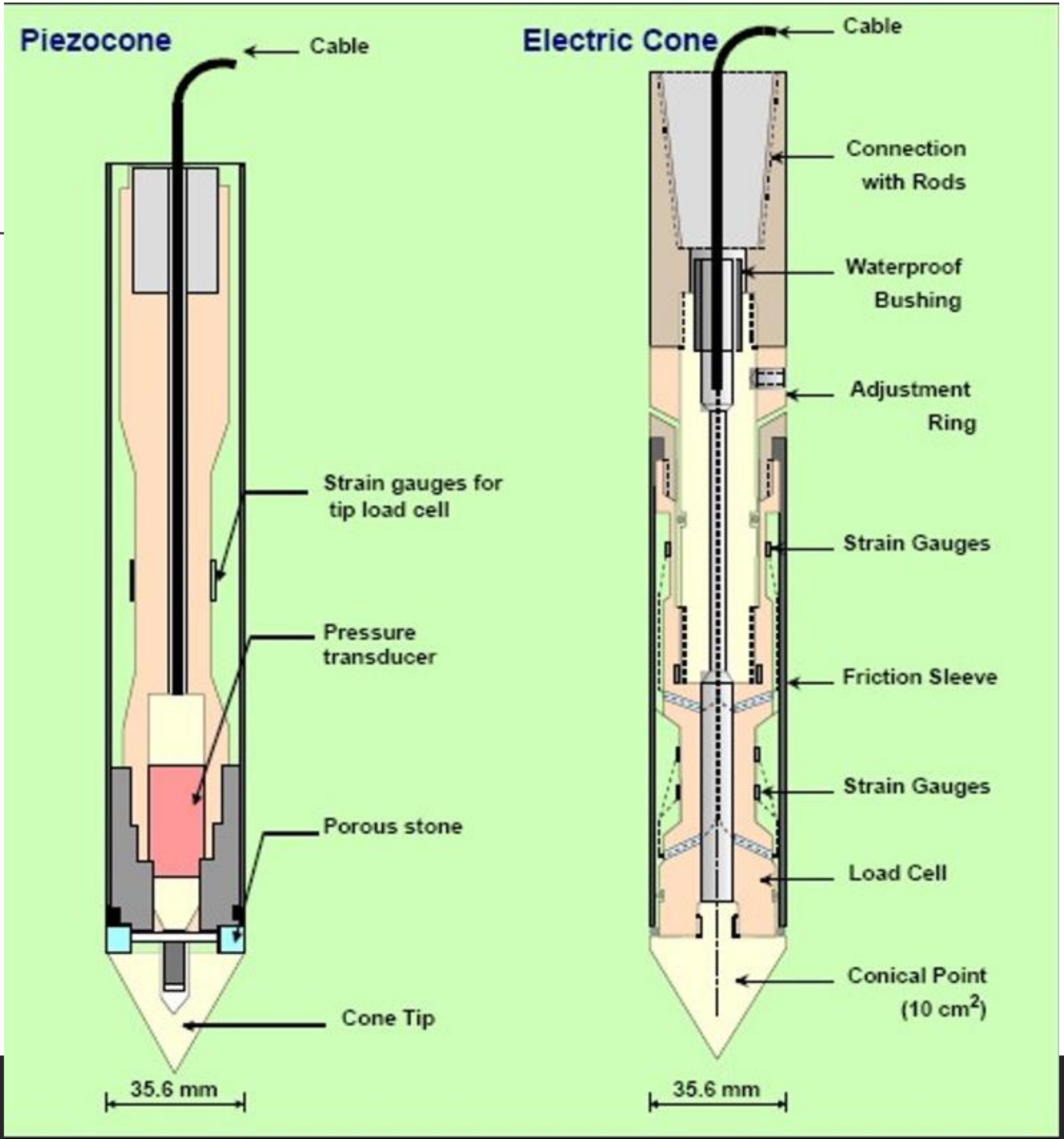
Giving, $q_{ult} = 3\pi c_u \approx 9 c_u$



Cone Penetration Test (Electrical)

- Direct measurement at tip
- More accurate
- Can measure pore water pressure

- Other type
- Can measure seismicity



Cone Penetration Test

Cone resistance:

$$q_c = \frac{\text{total force acting on penetrometer}}{\text{projected area}}$$

Friction resistance:

$$f_s = \frac{\text{total friction force acting on friction sleeve}}{\text{surface area}}$$

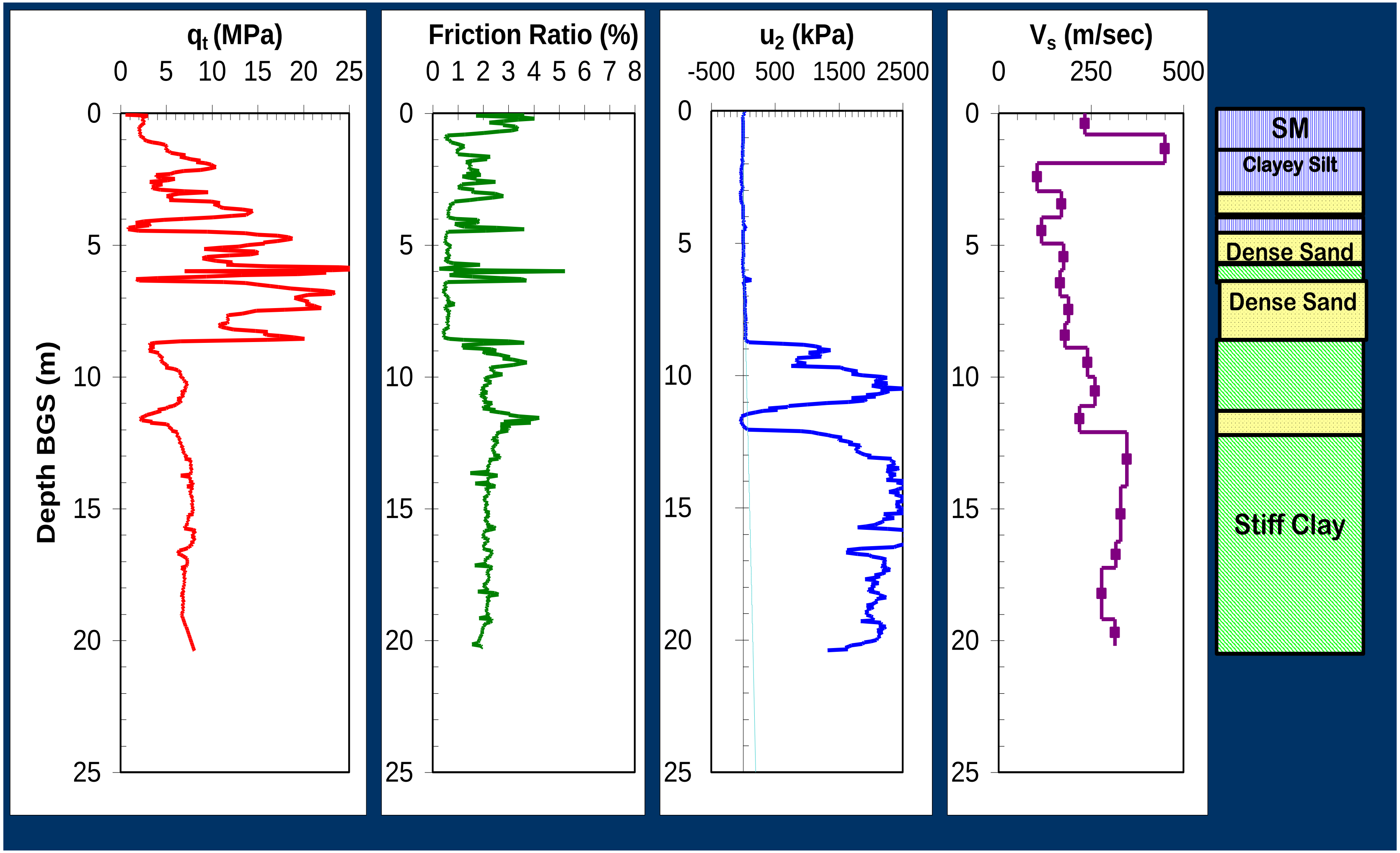
Friction ratio:

$$F_r = \frac{f_s}{q_c}$$

CPT vs. Soil Boring

- CPT is a model test – It is like a driven pile
- Can obtain Good Profiling
- Cannot obtain soil samples
- Shear strength rely on Correlations
- Limited depth – Capacity – Structure
- Capacity prediction for Driven pile OK but for Bore pile maybe inadequate

Cone Penetration Test



Hubungan antara konsistensi dengan tekanan konus (sumber : Begemann,1965)

Konsistensi	Tekanan konus qc (kg/cm^2)	Undrained Cohesion (T/m^0)
Sangat Lunak *(Very soft)*	< 2.5	<1.25
Lunak *(Soft)*	2.5 – 5.0	1.25 – 2.50
Teguh *(Firm)*	5.0 – 10	2.50 – 5.00
Kaku *(Stiff)*	10 – 20	5.00 – 10.00
Sangat kaku *(Very stiff)*	20 – 40	10 – 20
Keras *(Hard)*	> 40	> 20

KORELASI HASIL SONDIR DENGAN SHEAR STRENGTH DAN N SPT

Hubungan antara kepadatan, relative density, nilai N, qc dan Ø

(sumber : Begemann,1965)

Kepadatan	Relative Density (Dr)	Nilai N	Tekanan konus qc (kg/cm^2)	Suduut geser dalam ($Ø^0$)
Sangat Lepas *(Very loose)*	< 0.2	< 4	< 20	< 30
Lepas *(Loose)*	0.2 – 0.4	4 – 10	20 – 40	30 – 35
Agak Padat *(Medium dense)*	0.4 – 0.6	10 – 30	40 – 120	35 – 40
Padat *(Dense)*	0.6 – 0.8	30 – 50	120 – 200	40 – 45
Sangat Padat *(Very dense)*	0.8 – 1.0	> 50	> 200	> 45

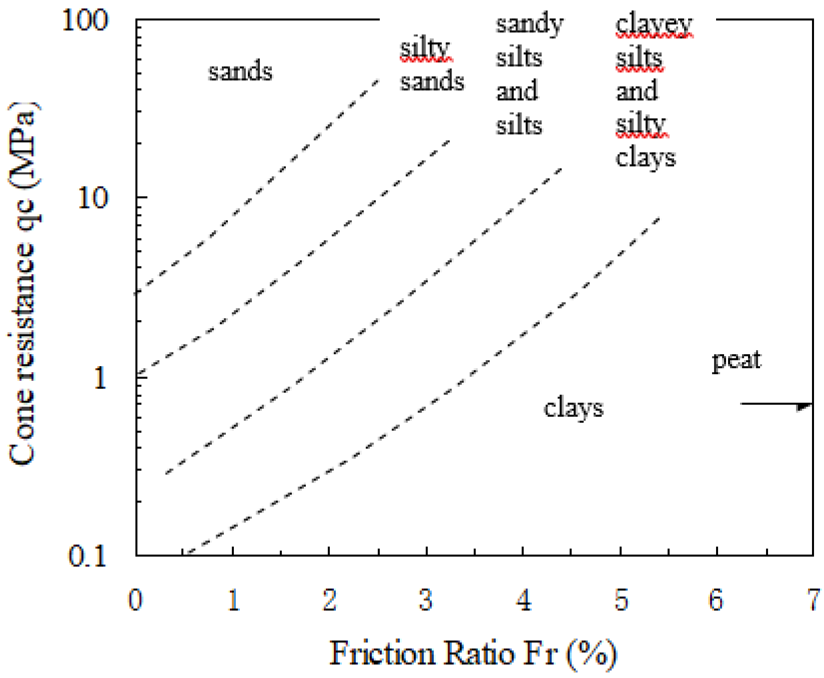


Figure 2.12 Soil classification based on CPT test results

Robertson and Campanella (1983)

The cone penetration resistance can be related to the undrained shear strength (c_u) of cohesive soil by the following equation:

$$c_u = \frac{q_c - \sigma'_o}{N_k}$$

In which σ'_o is the overburden pressure and N_k is the cone factor which ranges from 15 to 20 depending on the type cone used.

Example 2

The cone penetration test results shown in Figure 2.11 indicate that the cone penetration resistance of the soil at depth of 5 – 9 m is about 10 kgf/cm^2.. The average friction ratio of the soil is about 4%. (a) Use Figure 2.12 to estimate the type of soil on that layer, (b) Estimate the undrained shear strength of the soil if the unit weight of the soil is 18 kN/m^3, the ground water table is at 4 m depth, and the cone factor is 20.

Solution

$$q_c = 10 \text{ kgf/cm}^2 = 1 \text{ MPa} = 1000 \text{ kPa}$$

(a) From Figure 2.12, for q_c 1 MPa and $F_r = 4\%$, the soil is clay or clayey silt or silty clay

(b) Overburden pressure in the middle of clay layer (7 m):

$$\sigma'_o = 4\times18+3\times(18-9.8) = 96.6 \text{ kPa}$$

$$c_u = \frac{q_c - \sigma'_o}{N_k} = \frac{1000 - 96.6}{20} = 45 \text{ kPa}$$

Vane Test

Vane shear test is used to determine the in-place shear strength for soft clays, especially those who lose part of their strength when disturbed

A vane tester consists of 2 thin metal blades attached to a vertical shaft

The test is carried out by pushing the tester into the soil & applying a torque to the vertical shaft

- No soil sample is obtained from the test
- Results can be corrected with PI (Bjerrum)

$$c_u = \frac{T}{\pi\left[(d^2h/2) + (d^3/6)\right]}$$

$$S = \frac{T_{peak}}{T_{res}}$$

Example of Test results:

MAA GEOTECHNICS CO., LTD.

FIELD VANE SHEAR TEST

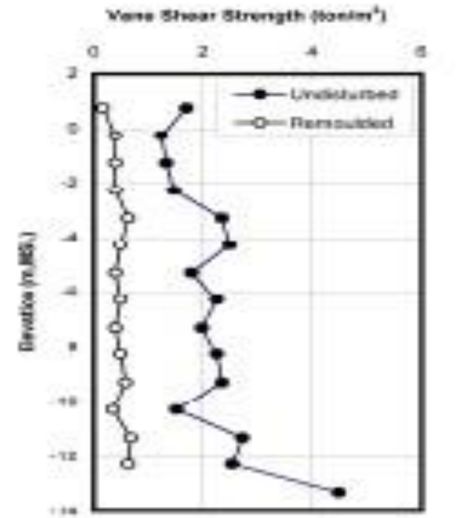
Project : TMT Ban Pho Test Course   Test No : FV-2 (BH-4)   Elevation (m, MSL): +1.215
Location : CHA CHOENG SAO   Date : 19 Jul 07

GEONOR VANE BORER (Serial No. 1679)

Vane width (d) 6.5 cm
Vane heigth (h) 13 cm

Torque Scale (kg-cm)
m = 4.6707
c = -8.4628

Elevation FL (m)	UNDISTURBED Max. Torque (div.)	UNDISTURBED c_u (ton/m^2)	REMOULDED Max. Torque (div.)	REMOULDED $c_{u(rem)}$ (ton/m^2)	Sensitivity $S_t = \frac{c_u}{c_{u(rem)}}$
0.7	38	1.7	5	0.2	10.1
-0.3	28	1.2	10	0.4	3.1
-1.3	30	1.3	10	0.4	3.3
-2.3	33	1.5	10	0.4	3.7
-3.3	52	2.3	15	0.6	3.7
-4.3	55	2.5	12	0.5	5.1
-5.3	40	1.0	10	0.4	4.5
-6.3	50	2.3	12	0.5	4.6
-7.3	44	2.0	10	0.4	4.0
-8.3	50	2.3	12	0.5	4.6
-9.3	52	2.3	14	0.6	4.0
-10.3	34	1.5	9	0.4	4.3
-11.3	60	2.7	16	0.7	4.0
-12.3	56	2.5	15	0.6	4.0
-13.3	> 98	> 4.5	-	-	-



Remarks: 1. Vane Shear Strength

$$c_u = \frac{\tau}{\pi(hd^2/2 + d^3/6)} \text{ ton/m}^2$$

τ = Max. torque, kg-cm
h = Height of vane, cm
d = Width of vane, cm

2. Sensitivity

$$S_t = \frac{c_u}{c_{u(rem)}}$$

Example 3

A vane tester with diameter & height of 92 mm & 184 mm respectively requires a torque of 23.50 N·m to shear a clayey soil $PI = 48\%$, Determine the soil's cohesion.

Solution

$$c = \frac{T}{\pi\left[\left(d^2 h/2\right) + \left(d^3/6\right)\right]}$$

$$c = \frac{23.50\ \text{kN}\cdot\text{m}}{\pi\left[\frac{(0.092)^2\cdot(0.184)}{2} + \frac{(0.092)^3}{6}\right]}$$

$$c = 82\ \text{kN/m}^2$$

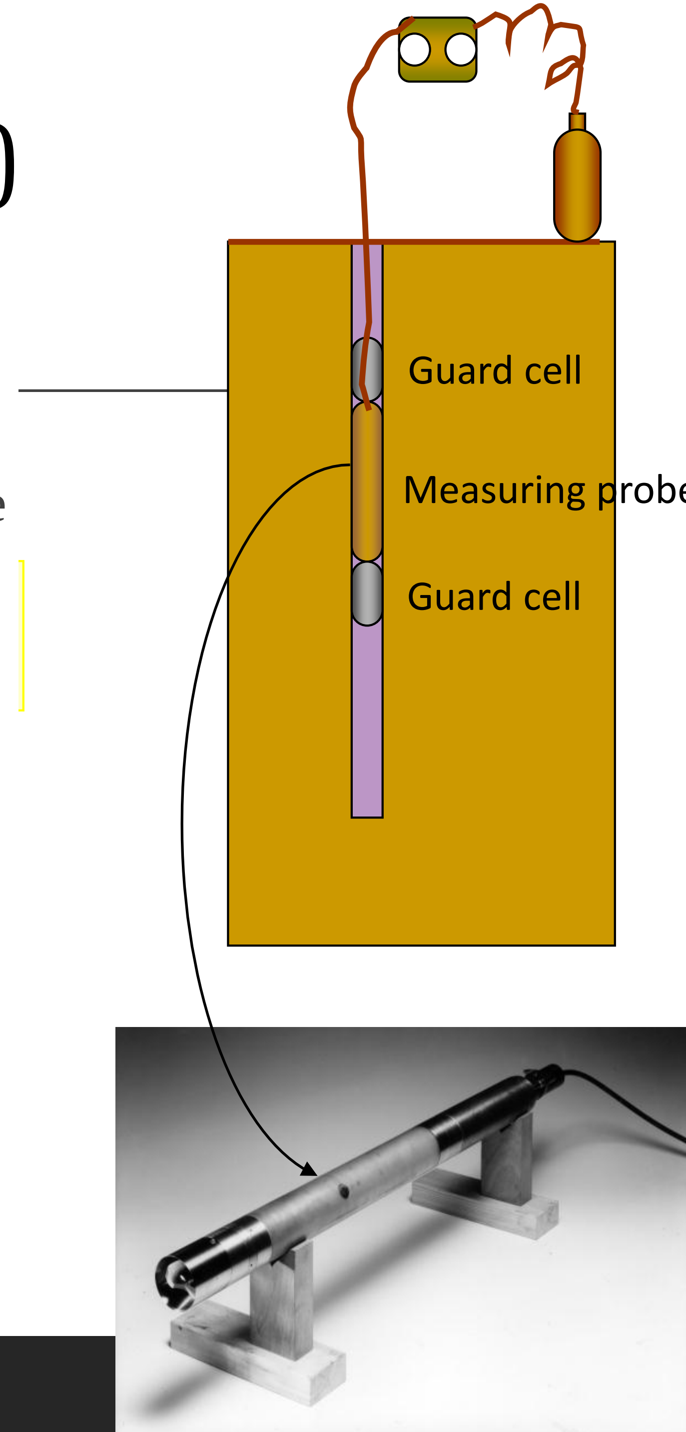
Pressure Meter Test (PMT)

Device: a probe, measuring unit, cable.

The test is performed in a borehole by pushing the probe into the

ground and loading it horizontally until it reaches the limit pressure or capacity of the device.

Measured parameters include pressuremeter modulus (E_m), undrained shear strength (c_u), and insitu horizontal stress in the ground (σ'_{ho}).



Dilatometer test (DMT)

The test is similar to the pressure meter test, but the measurement is made through a blade with a stainless-steel membrane mounted on one side of the blade. The test is carried out by pushing or hammering a dilatometer blade into the soil at rate between 10 - 30 mm/seconds, while measuring penetration resistance and then using gas pressure to expand the membrane approximately 1.1 mm into the soil

Groundwater Table

- Location of GWT is of great importance, e.g. a soil's bearing capacity is reduced when the GWT is at or near a footing
- Location of GWT is not fixed

  It tends to rise or fall during periods of wet or dry seasons
- Fluctuations may results in reduction of foundation stability & in extreme cases, structures may float out of the ground

- GWT can be located by measuring down to the water level in existing wells in an area

Groundwater Table

If adjacent soil is pervious, water level in a boring hole will stabilize in a short time

If soil is relatively impervious, it may take a longer time

General practice is to leave it for at least 24 hours to allow water to rise in the hole & stabilize

The hole should be filled after tests for safety reasons

Laboratory Testing

To get a good quality of testing results, the samples retrieved from the ground should be tested as soon as possible after arrival at the laboratory.

The types of laboratory test and the number of sample to be tested should be decided in advance based on the problems and the soil conditions.

All tests should be carried out following standard procedure such as American Standard Testing Methods (ASTM) or SNI or other standard methods designated by the authority.

Soil paramters required include : Basic properties, Soil Classification; Shear strength parameters (for stability); Settlement (Stress-strain); Consolidation (Modulus parameters)

Limitations in soil boring and Testing

CLAY

$N < 15$; Take Undisturbed sample then do Laboratory tests

$N > 15$; can rely on Field Test (Field Test dominate)

SAND

High Fines and $N < 15$; Take Undisturbed sample then do Laboratory tests

High Fines $N > 15$; can rely on Field Test (Field Test dominate)

Low Fines ; can rely on Field Test (Field Test dominate)

Laboratory Testing

No.	Geotechnical Structure	Soil Profiling	Soil Classification	Modulus	Strength	Consolidation	Permeability	Compaction	Chemical Tests
1	Embankment	X	X		X	X		X	
2	Dyke/Earth-Dam	X	X	X	X	X	X	X	
3	Slope	X	X		X		X	X	
4	Footing	X	X	X	X	X		X	X
5	Pile	X	X		X				X
6	PVD	X	X		X	X	X	X	
7	Soil Cement	X	X	X	X	X		X	X
8	Underground Structure	X	X	X	X		X		X
9	Excavation	X	X	X	X		X		

Laboratory Testing

No.	Geotechnical Structure	Laboratory															Field					
		Physical Properties							Others				Strength				Boring		CPT		Others	
		Water Content	Unit Weight	Gradation - Sieve	Gradation - Hydrometer	Specific Gravity	Atterberg Limits	Profiling	Consolidation	Permeability	Compaction (on Fill)	Chemical Tests	Unconfined Compression	Triaxial Shear	Direct Shear	CBR (on Fill)	SPT	Tube Sampling	Mechnical CPT	Electrical CPT	Field Vane (Soft to Medium Clay only)	Groundwater Level
1	Embankment	A	A	A	-	B	A	A	A	-	A	-	A	B	-	A	A	A	C	C	A	A
2	Dyke/Dam	A	A	A	A	B	A	A	A	A	A	-	A	-	A	A	A	A	C	C	A	A
3	Slope	A	A	A	A	B	A	A	B	B	B	-	A	A	B	B	A	A	-	-	-	A
3	Footing	A	A	A	-	B	A	A	B	-	B	B	A	B	-	B	A	B	-	-	-	A
4	Pile	A	A	A	-	B	A	A	B	-	-	B	A	-	-	-	A	A	C	C	A	A
5	PVD	A	A	A	A	B	A	A	A	-	A	-	A	B	-	A	A	A	C	C	A	A
6	Soil Cement	A	A	A	A	B	A	A	B	-	A	A	A	-	-	A	A	A	C	C	A	A
7	Underground	A	A	A	A	B	A	A	A	A	-	A	A	-	-	-	A	A	C	C	A	A

Note: A - Essential B - Partial C - Option

- Laboratory testing program often generates a large amount of data
- Select only representative results by evaluating the quality of undisturbed samples.
- Summary of laboratory test results is very useful

only representative results should be reported and used for design.

Table 4d Summary of Laboratory Test Results for Borehole No. BH-04

Sample No.	Depth (m)		Water Content (%)	Total Unit Weight (ton/m^3)	Liquid Limit, LL (%)	Plasticity Index, PI (%)	Specific Gravity, Gs	Grain Size Analysis (%)					Undrained Shear Strength, c_u (ton/m^2)		Modulus @50% Stress, E50	SPT N value	USCS	Soil Description
	From	To						Gravel	Sand: Coarse	Sand: Medium	Sand: Fine	Silt+Clay	PP Test	UC Test				
SS01	0.75	1.20	44.7					3	7	7	3	80				2	-	Silty CLAY with sand
UD02	1.50	2.00	92.7	1.44	95.7	55.9		0	0	0	3	97	<1.25	1.1	107	-	CH	Silty CLAY
UD03	3.00	3.50	70.7	1.54	72.1	39.4	2.58	0	0	0	1	99	<1.25	0.7	33	-	CH	Silty CLAY
UD04	4.50	5.00	101.9	1.43	120.6	75.3	2.51	0	0	0	0	100	<1.25	2.6	227	-	CH	Silty CLAY
UD05	6.00	6.50	77.3	1.49				0	0	0	6	94	<1.25	1.8	125	-	-	Silty CLAY
UD06	7.50	8.00	67.7	1.58	64.4	32.7		0	0	0	5	95	<1.25	1.9	164	-	CH	Silty CLAY
UD07	9.00	9.50	70.2	1.56	88.0	51.1	2.56	0	0	1	2	97	<1.25	2.3	371	-	CH	Silty CLAY
UD08	10.50	11.00	75.6	1.48	90.3	55.2	2.57	0	0	1	4	95	<1.25	1.9	257	-	CH	Silty CLAY
UD09	12.00	12.50	56.3	1.57				0	0	0	0	100	1.25	2.6	257	-	-	Silty CLAY
UD10	13.50	14.00	63.0	1.57	71.9	40.6	2.56	0	0	0	1	98	1.25	3.1	182	-	CH	Silty CLAY
UD11	15.00	15.50	25.1	1.99				0	0	1	8	91	7.50	10.7	906	-	-	Silty CLAY
SS12	16.50	16.95	29.4	1.93				0	0	0	2	98				12	-	Silty CLAY
SS13	18.00	18.45	27.2	1.94				0	0	0	2	98				16	-	Silty CLAY
SS14	19.50	19.95	27.9	1.95	64.4	36.8		0	0	0	1	99				18	CH	Silty CLAY
SS15	21.00	21.45	26.0	1.92			2.58	0	0	0	0	100				19	-	Silty CLAY
SS16	22.50	22.95	14.3	2.17	28.6	14.0		0	0	2	48	50				16	CL	Sandy CLAY
SS17	24.00	24.45	17.9		NP	NP		0	0	0	61	39				19	SM	Silty SAND
SS18	25.50	25.95	18.1		NP	NP		0	0	0	77	23				43	SM	Silty SAND

Notes : UD denotes Shelby Tube Sample, SS denotes Split Spoon Sample and NP denotes Nonplastic

PP : Strength from Pocket Penetrometer (less reliable)

UC : Strength from Unconfined Compression Test

* denotes Insufficient Soil for Testing.

** denotes Disturbed

Geotechnical report

While the geotechnical report content and format will vary, all geotechnical reports should contain certain basic essential information, including:

- Summary of all subsurface exploration data, including subsurface soil profile, exploration logs, laboratory or in situ test results, and ground water information;
- Interpretation and analysis of the subsurface data;
- Specific engineering recommendations for design;
- Discussion of conditions for solution of anticipated problems; and
- Recommended geotechnical special provisions.

Site Investigation (SI) Report

SI report should include the following:

- Scope of investigation
- Description of the proposed structure
- General site conditions
- Detailed of the field exploration and results
- Laboratory testing and results
- Foundation recommendations
- **Attachments**
  - Graphic presentation of the site-location map,
  - Location of bore with respect to the proposed structures and those existing nearby,
  - Boring logs,
  - Data and graphical presentation of laboratory test results.
  - Brief calculations to support your recommendation

Borehole-log

should include

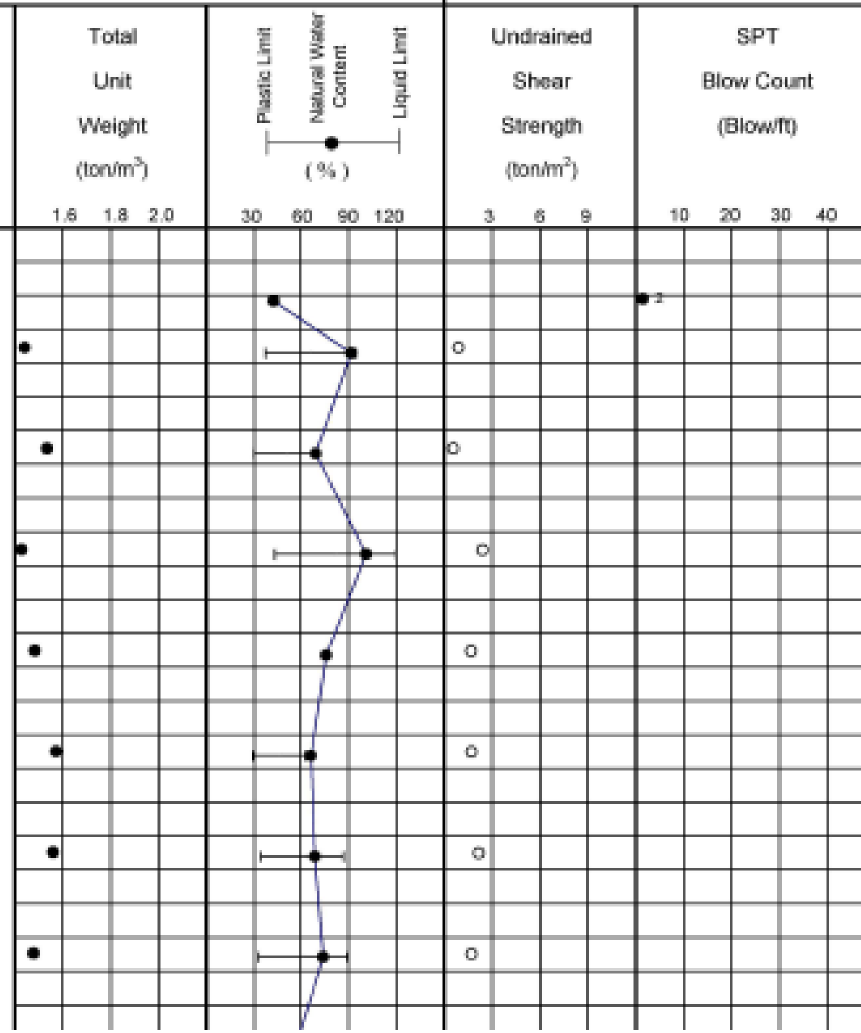
- soil stratifications,
- groundwater table
- SPT number OR other field test
- results of laboratory testing (include summary)

It is recommended that the draft of bore-hole logs *should be prepared during exploration in the field* because it also summarizes the detail of the exploration program and the actual condition at the site.

Example of borelog

MAA GEOTECHNICS CO., LTD.	BORING LOG	BORING NO. BH-04 SHEET 1 OF 1
PROJECT: TMT Ban Pho Test Course LOCATION: CHA CHOENG SAO CLIENT: Thai Obayashi Corporation Ltd.	Coordinates: N: 1,506,638.600 E: 718,941.686 Ground Elevation (MSL) : +1.215 m Max.Drilling Depth : 25.95 m	G.W.L. : -0.12 m Starting Date: 20-Jul-07 Finishing Date: 21-Jul-07

DEPTH (m.)	GRAPHIC LOG	SOIL DESCRIPTION	SAMPLING METHOD	SAMPLE NO.	RECOVERY (cm)
		Silty CLAY, Brownish Gray and Light Greenish Gray; Very Soft to Soft. (CH)			
1			SS	01	28
2			UD	02	50
3			UD	03	40
4					
5			UD	04	45
6			UD	05	40
7					
8			UD	06	40
9			UD	07	50
10					
11			UD	08	50
		12.00 m			



PROJECT:	Chiva Som International Health Resort	N : 2071	E : 1853	Ground El. :	778 m,MSL
LOCATION:	Khao-Kho, Phetchabun	Start Drilling Depth :	-11.75 m	Starting Date :	18 Jan 07
CLIENT:	Chiva-Som International Health Resorts Co.,Ltd.	Max. Drilling Depth :	-15.25 m	Finishing Date :	22 Jan 07

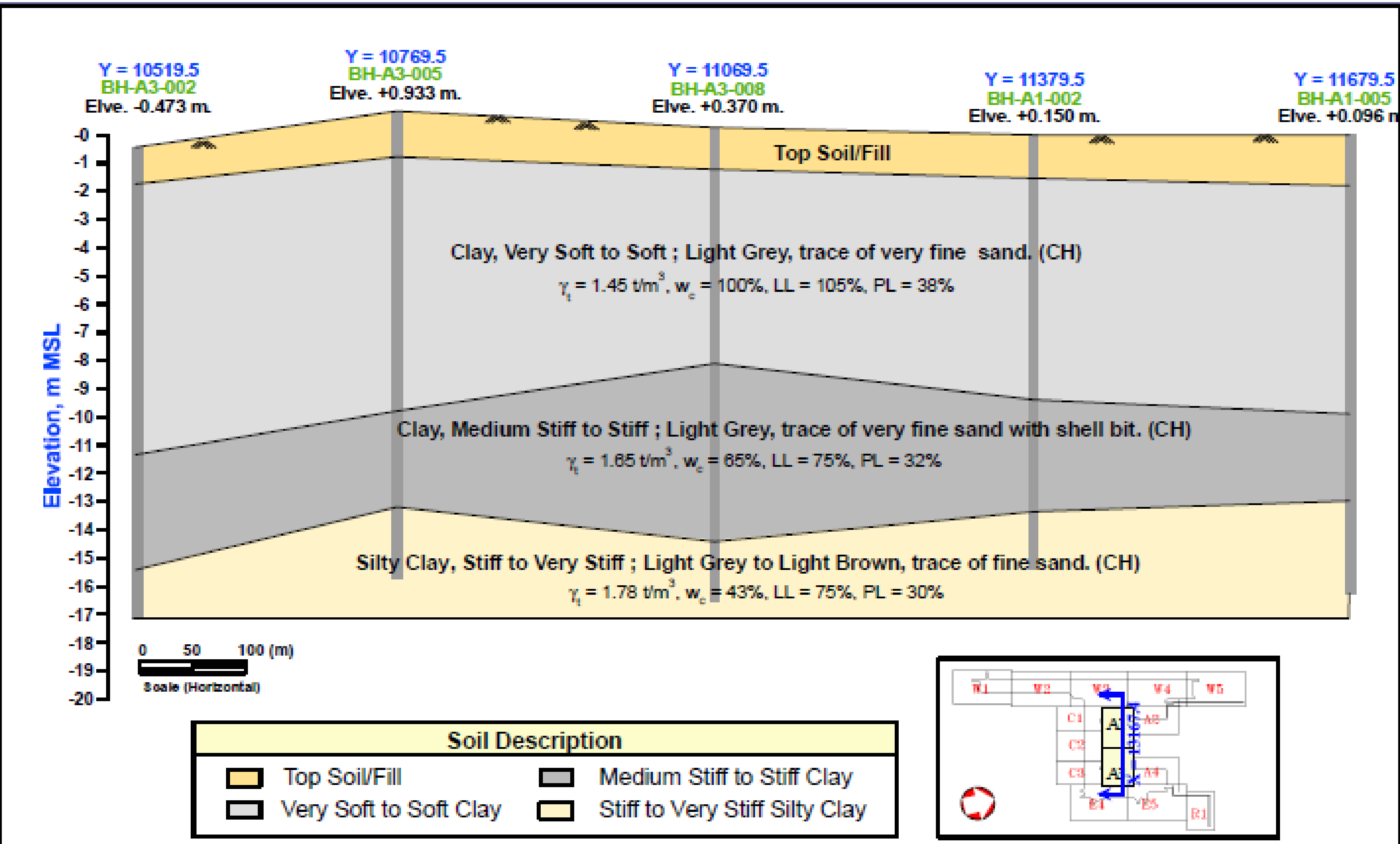
Depth (m)	Sample No.	Photograph	Symbol	Rock Description	Core Run (cm)	Recovery (cm)	R.Q.D (%)	Fracture Index (/m)	Unconfined Compressive Strength (ton/m^2) 2000 4000 6000 8000
11.75	CR01	LOSS		**Sandstone, Medium Gray, Clastic Texture; Moderately Weathered.** **12.25 m (765.75 m, MSL)**	50	24	0	>20	
12.25	CR02			**Pebbly Sandstone, Dark Gray, Clastic Texture; Slightly Weathered.** **12.50 m (765.50 m, MSL)** **Pebbly Sandstone, Brownish to Medium Gray, Clastic Texture; Moderately to Slightly Weathered.**	100	100	50	16	2848
12.75									

Soil or Geologic profile

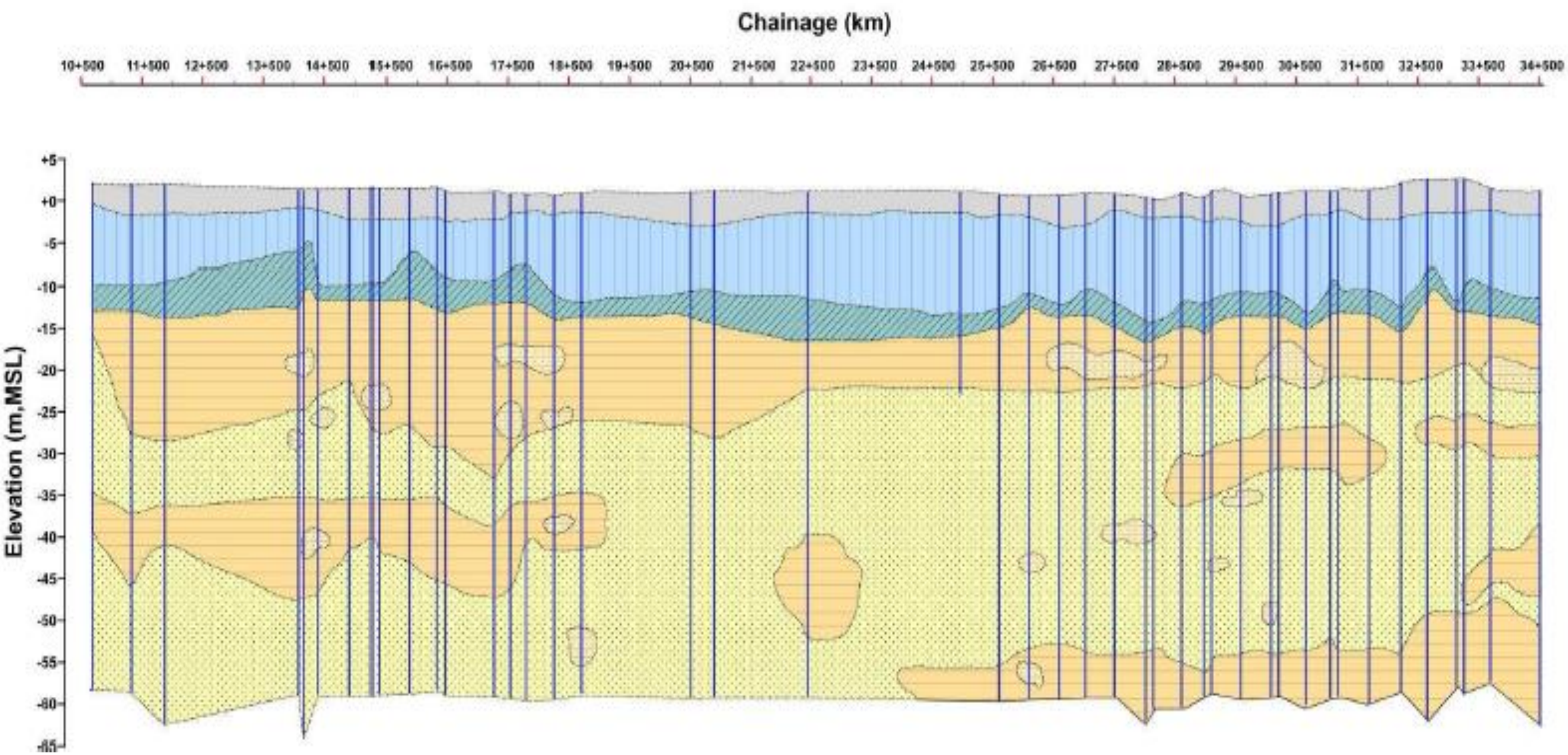
Data obtained from a series of test borings can best be presented by preparing a geologic profile:

- Arrangement of various layers of soil
- Groundwater table
- Existing/proposed structures
- Soil properties data (e.g., SPT values)

The profile is prepared with data obtained from boring, sampling and testing of each borehole.

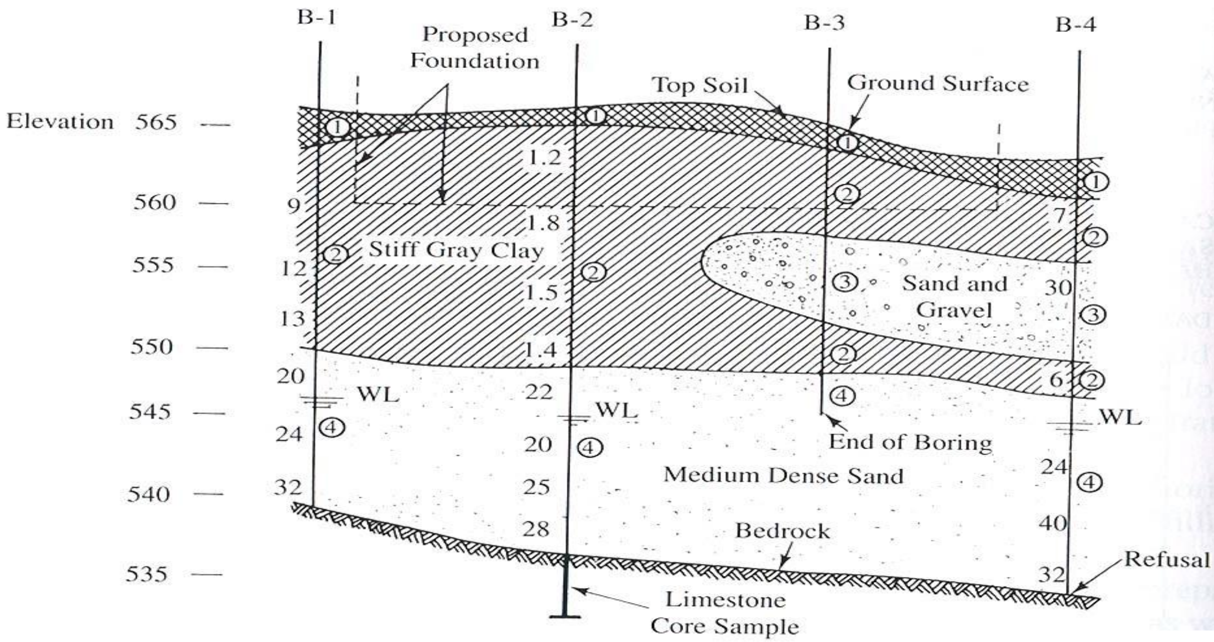

Y = 10519.5
BH-A3-002
Elve. -0.473 m.
Y = 10769.5
BH-A3-005
Elve. +0.933 m.
Y = 11069.5
BH-A3-008
Elve. +0.370 m.
Y = 11379.5
BH-A1-002
Elve. +0.150 m.
Y = 11679.5
BH-A1-005
Elve. +0.096 m
Top Soil/Fill
Clay, Very Soft to Soft ; Light Grey, trace of very fine sand. (CH)
γt = 1.45 t/m3, wc = 100%, LL = 105%, PL = 38%
Clay, Medium Stiff to Stiff ; Light Grey, trace of very fine sand with shell bit. (CH)
γt = 1.65 t/m3, wc = 65%, LL = 75%, PL = 32%
Silty Clay, Stiff to Very Stiff ; Light Grey to Light Brown, trace of fine sand. (CH)
γt = 1.78 t/m3, wc = 43%, LL = 75%, PL = 30%
Elevation, m MSL
-0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
0 50 100 (m)
Scale (Horizontal)
Soil Description
Top Soil/Fill
Very Soft to Soft Clay
Medium Stiff to Stiff Clay
Stiff to Very Stiff Silty Clay

Soil profile

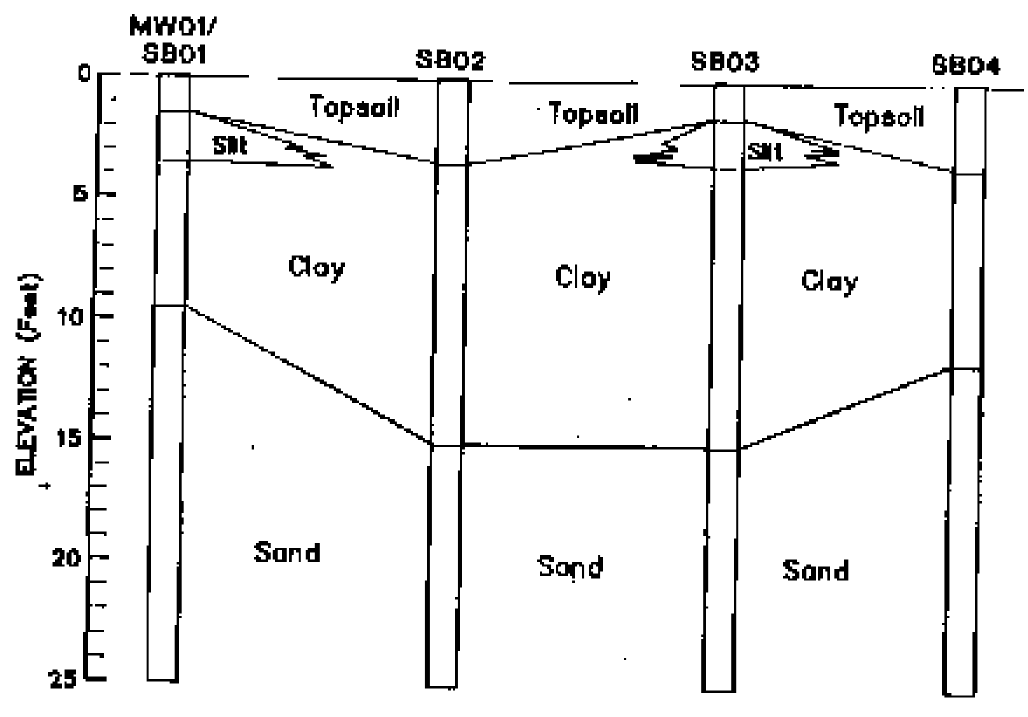


Many boreholes

Soil profile



Note: (1) (2) , . . . = Top Soil, Stiff Gray Clay, . . .
9, 12 , . . . = Standard Penetration Resistance (Nu
1.2, 1.8 , . . . = Unconfined Compressive Strength (k



Soil profile-legend

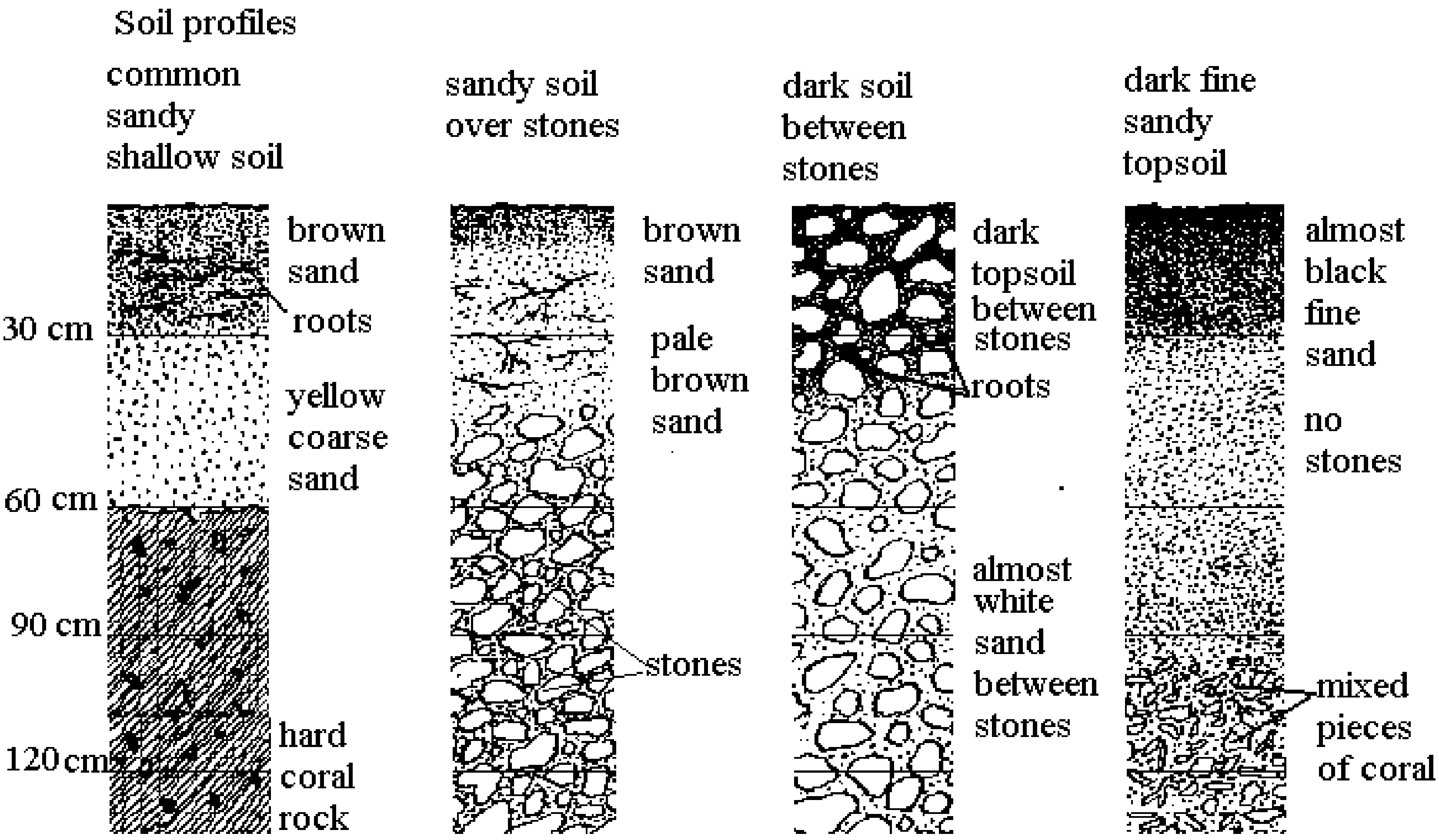


Table A-4 Colour Chart

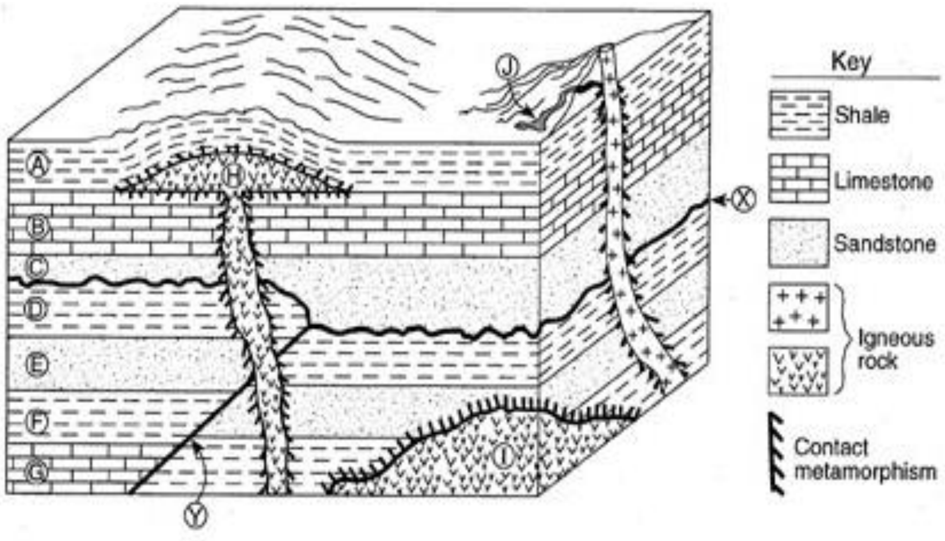
	1	Blackish red		26	Dusky yellow green
	2	Dusky red		27	Light greenish gray
	3	Dark reddish brown		28	Grayish yellow green
	4	Grayish red		29	Grayish green
	5	Moderate reddish brown		30	Dusky blue green
	6	Pale reddish brown		31	Grayish blue green
	7	Pale red		32	Very dusky red purple
	8	Grayish pink		33	Grayish red purple
	9	Grayish brown		34	Black
	10	Dark yellowish brown		35	Grayish black
	11	Pale brown		36	Olive black
	12	Pale yellowish brown		37	Grayish black
	13	Light brown		38	Greenish black
	14	Grayish brown		39	Dark gray
	15	Grayish orange pink		40	Olive gray
	16	Pale yellowish orange		41	Medium dark gray
	17	Olive gray		42	Brownish gray
	18	Moderate olive brown		43	Medium gray
	19	Light olive gray		44	Light brownish gray
	20	Yellowish gray		45	Light olive gray
	21	Grayish olive green		46	Medium light gray
	22	Dark greenish gray		47	Light gray
	23	Light greenish gray		48	Yellowish gray
	24	Light olive brown		49	Very light gray
	25	Dark greenish yellow		50	White

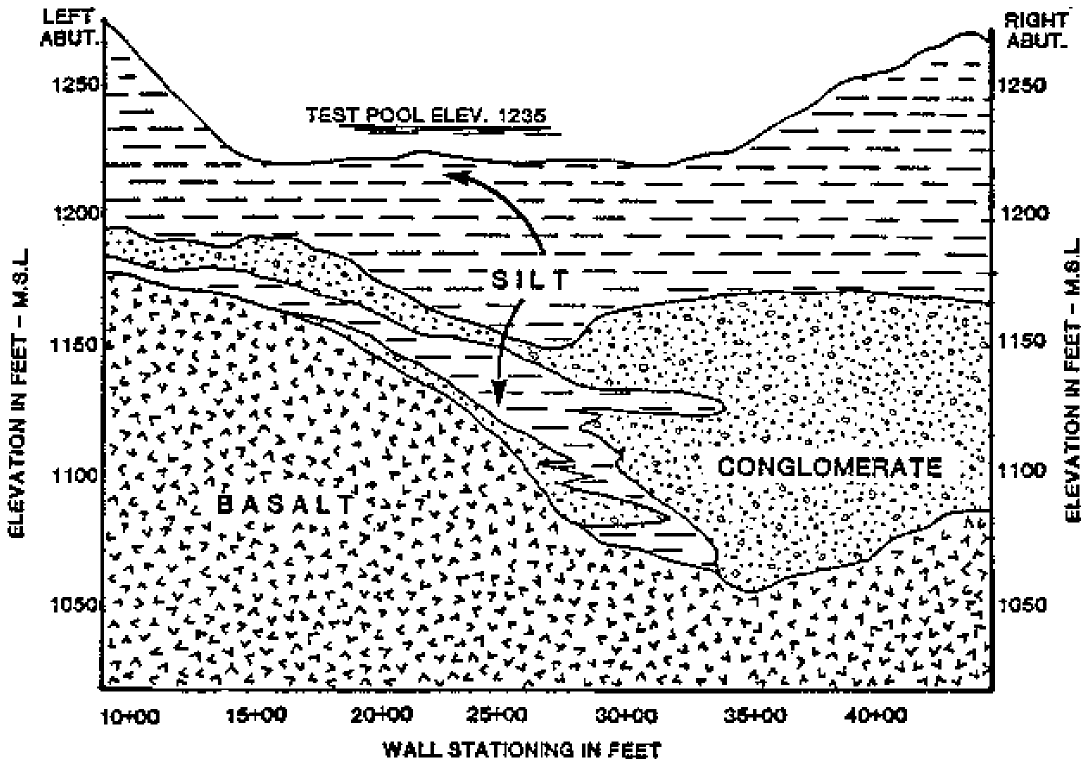
Table A-5 Symbols for Boring Log

LEGEND :

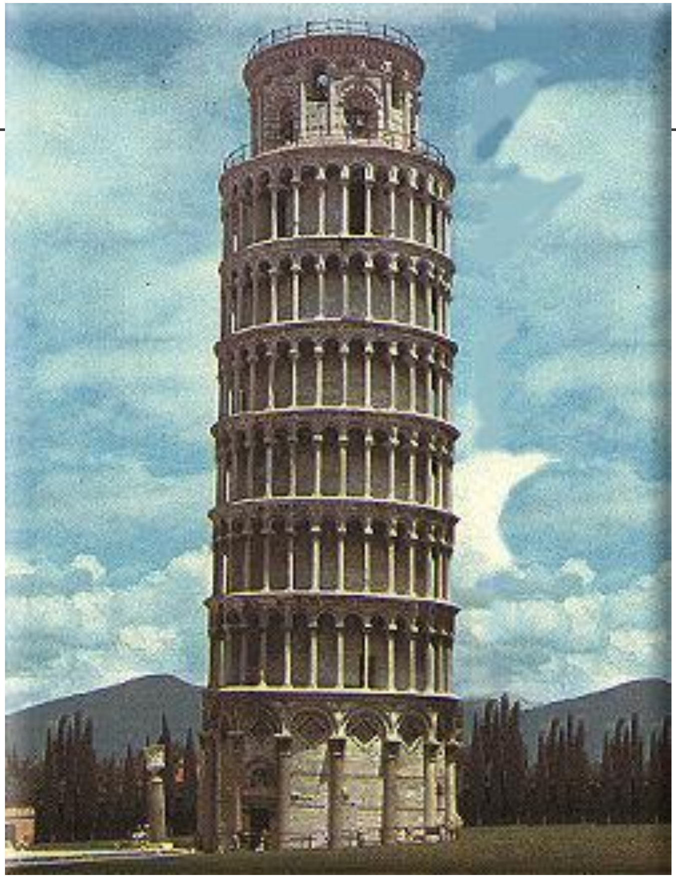
Clayey SAND	Silty SAND
Sandy/Silty CLAY	Sandy SILT

Soil or Geologic profile





If only they had proper site investigation…



…Tower of Pisa will not be leaning today!

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