Cone Penetration Test (CPT)

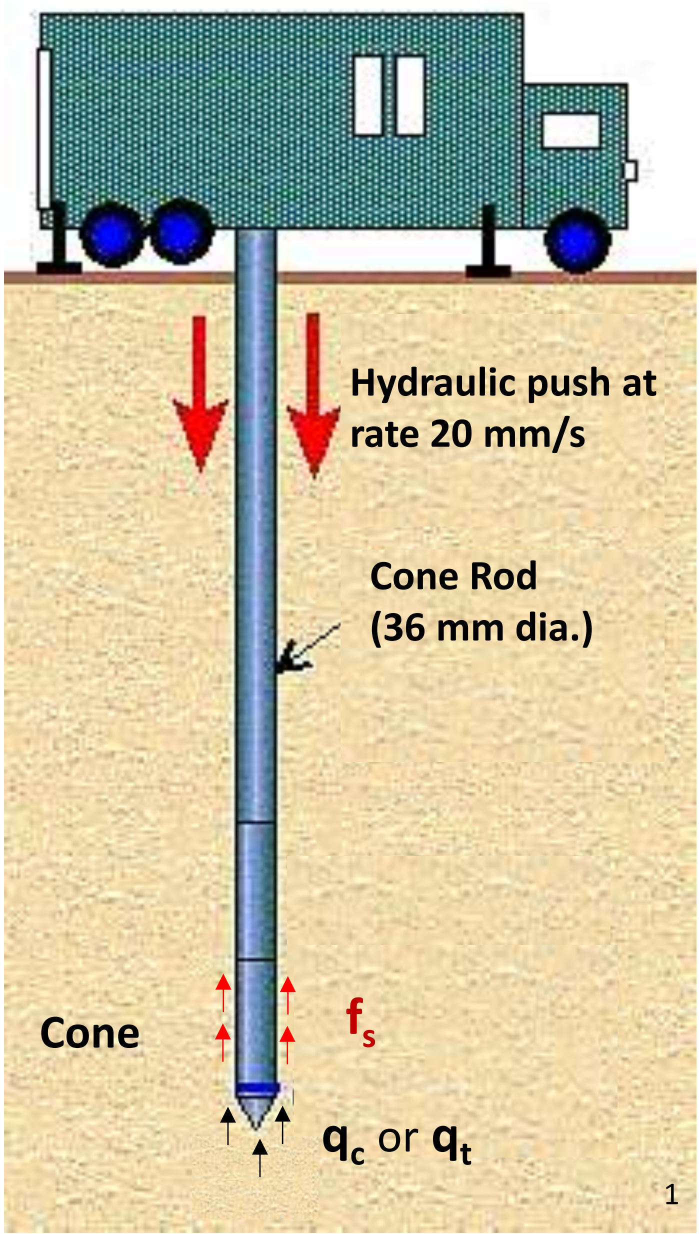
Definition

- called also "Dutch cone test“ or “Static Penetration test”.
- The test method consists of pushing an instrumented cone, with the tip facing down, into the ground at a slow controlled rate.
- Cone: 60 degree apex cone, Dia = 36 mm.

Measures

- Cone or Tip resistance (q_c) or (q_t)
- Sleeve friction (f_s)
- Water Pore pressure (u_b)
- Other variables e.g. Shear wave velocity (v_s)

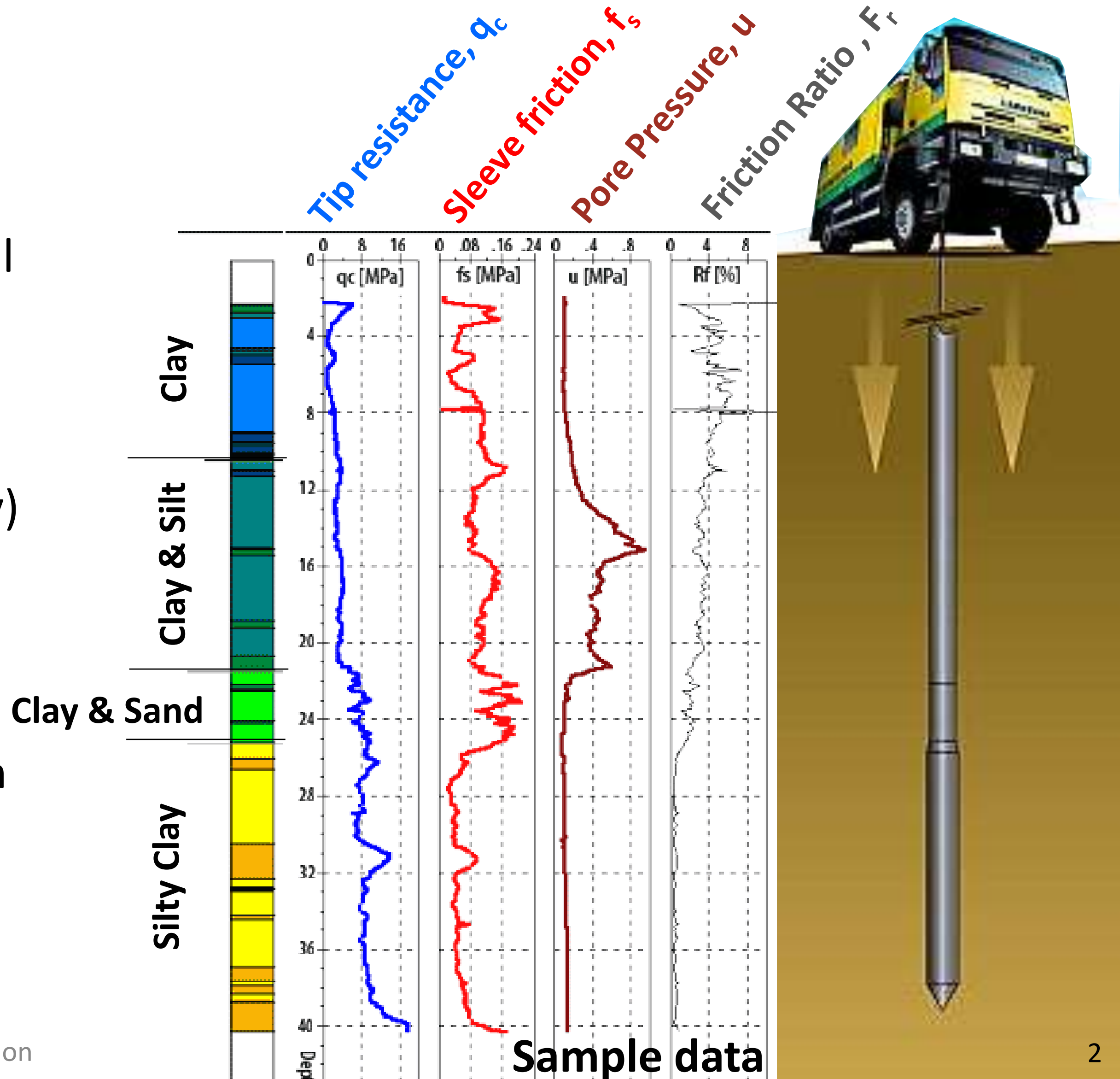
$$\text{Friction Ratio, } F_r = \frac{f_s}{q_c}$$



Cone Penetration Test (CPT)

Applications:

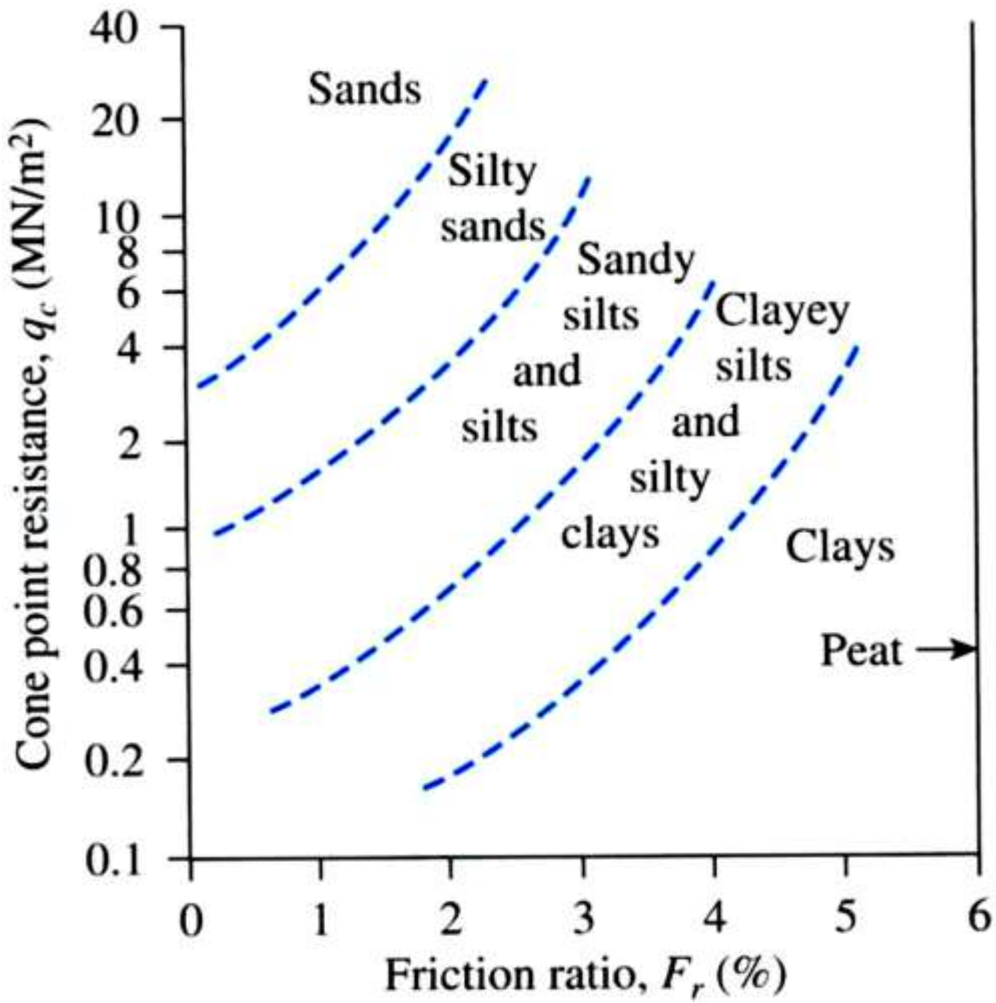
- Soil profile (stratigraphy): soil type identification
- Estimation of geotechnical parameters (strength, compressibility, permeability)
- Evaluation of groundwater conditions (pore pressure)
- Geo-environmental: distribution and composition of contaminants



Cone Penetration Test (CPT)

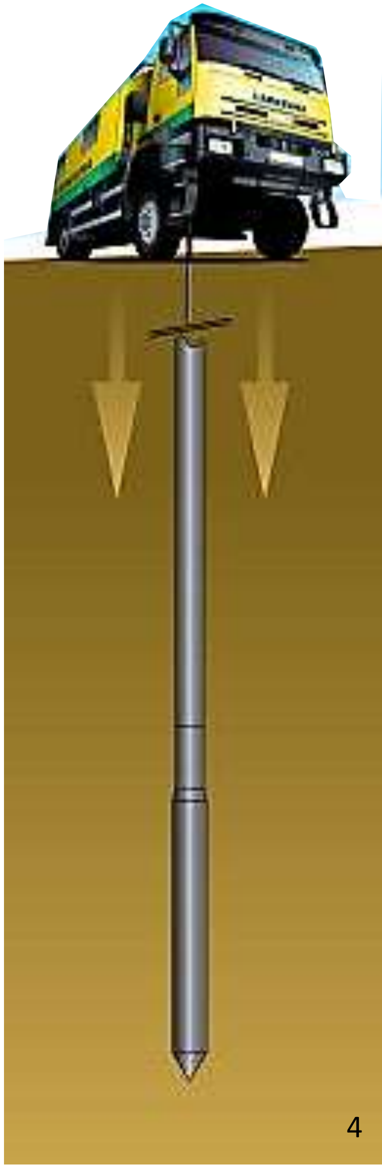
Soil Identification:

- Point resistance $\mathbf{q_c}$
  - High in granular soil
  - Low in cohesive soil
- Friction Ratio $\mathbf{F_r}$
  - Low in granular soil
  - High in cohesive soil
- However, the cone/tip (q_c) and sleeve (f_s) resistance increase with increasing overburden stress σ_0
- for accurate identification, normalization of q_c & f_s by overburden stress is required.



Classification Chart (Robertson et al., 1983)

Cone Penetration Test (CPT)



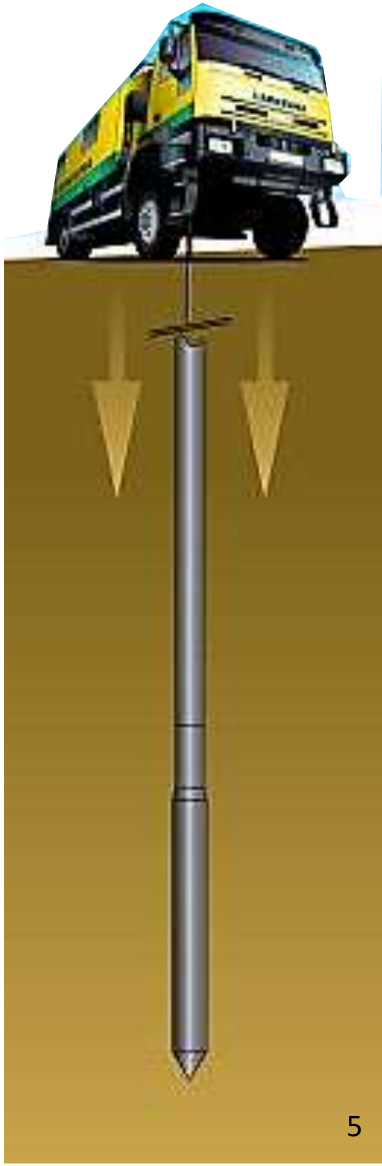
Advantages:

- Borehole is not necessary
- Almost continuous data (reading every 10mm)
- Elimination of operator error (automated)
- Reliable, repeatable test results

Disadvantages:

- Inability to penetrate through gravels and cobbles
- Newer technology = less populated database than SPT
- Lack of sampling

Cone Penetration Test (CPT)



Correlation with shear strength

- *In **Sand***: the drained friction angle (Ricceri et all's. 2002)

$$\phi' = \tan^{-1}\left[0.1 + 0.38\log\left(\frac{q_c}{\sigma'_o}\right)\right]$$

- *In **Clay***: undrained shear strength c_u

$$c_u = \frac{q_c - \sigma_o}{N_K}$$

$$OCR = 0.37\left(\frac{q_c - \sigma_o}{\sigma'_o}\right)^{1.01}$$

where:

q_c = the cone (tip) (point) resistance

σ'_0 & σ_0 = effective and total overburden pressure, respectively

N_K = Bearing factor depends on type of cone (varies from 11-20)

OCR = Over Consolidation Ratio

Cone Penetration Test (CPT)

Class example: Correlation with shear strength

In a deposit of normally consolidated dry sand, a cone penetration test was conducted. Following are the results:

Depth (m)	Point resistance of cone, q_c (MN/m^2)
1.5	2.06
3.0	4.23
4.5	6.01
6.0	8.18
7.5	9.97
9.0	12.42

Assuming the dry unit weight of sand to be 16 kN/m^3, estimate the average peak friction angle, ϕ', of the sand. **Use equation proposed by Ricceri et all's. 2002.**

Cone Penetration Test (CPT)

Solution:

Depth, m	q_c (MPa)	σ_0' (kPa)	q_c/σ_0'	ϕ' (Rad)	ϕ' (deg)
1.5	**2.06**	1.5 x 16 =24	2060 / 24 = 85.8	0.69	0.69x180/π=40º
3	**4.23**	48	88.1		
4.5	**6.01**				
6	**8.18**				
7.5	**9.97**				
9.0	**12.42**				

ϕ'_{av} =

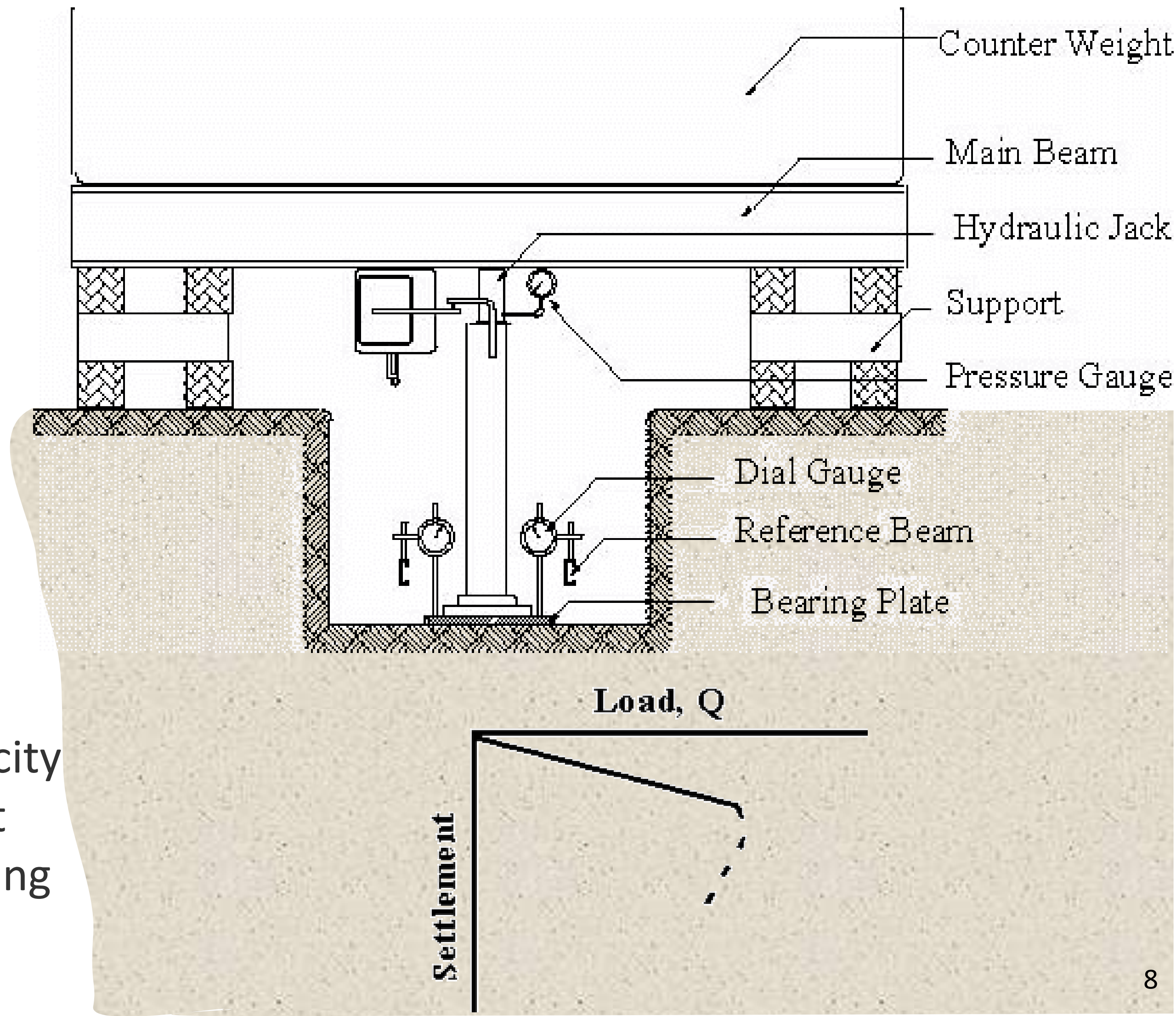
$$\phi' = \tan^{-1}\left[0.1 + 0.38 \log\left(\frac{q_c}{\sigma'_o}\right)\right]$$

$\phi'_{av} = \Sigma\phi' / 6$

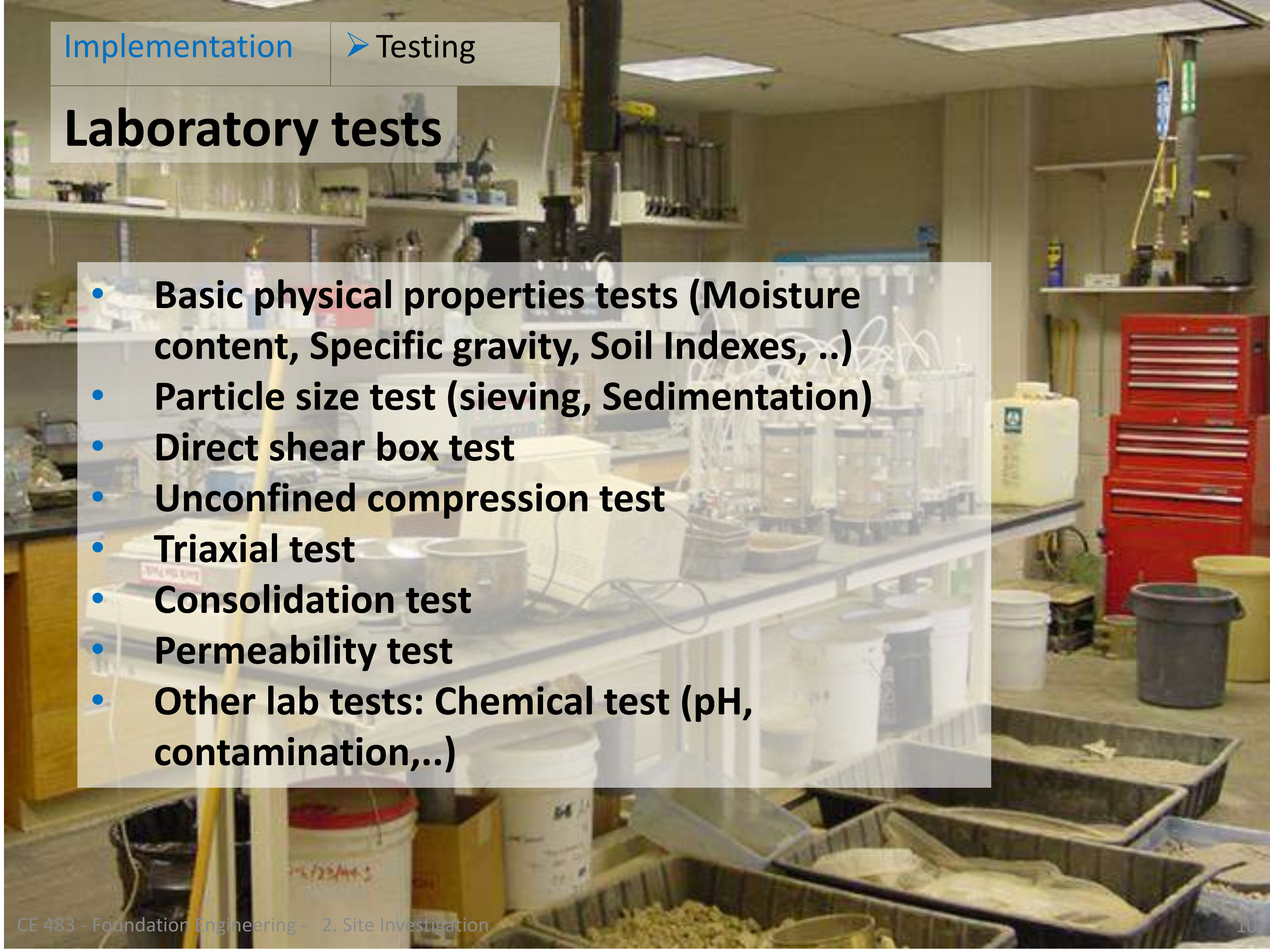
Note. tan $^{-1}$ is inverse tangent, the angle returned is in Radian.

Plate Load Test (PLT)

- Plate load test is a field test to determine the ultimate bearing capacity of soil.
- The test essentially consists in loading a rigid steel plate at the foundation level and determining the settlement corresponding to each load increments.
- The ultimate bearing capacity is then taken as the load at which the plate starts sinking at a rapid rate.



Laboratory tests

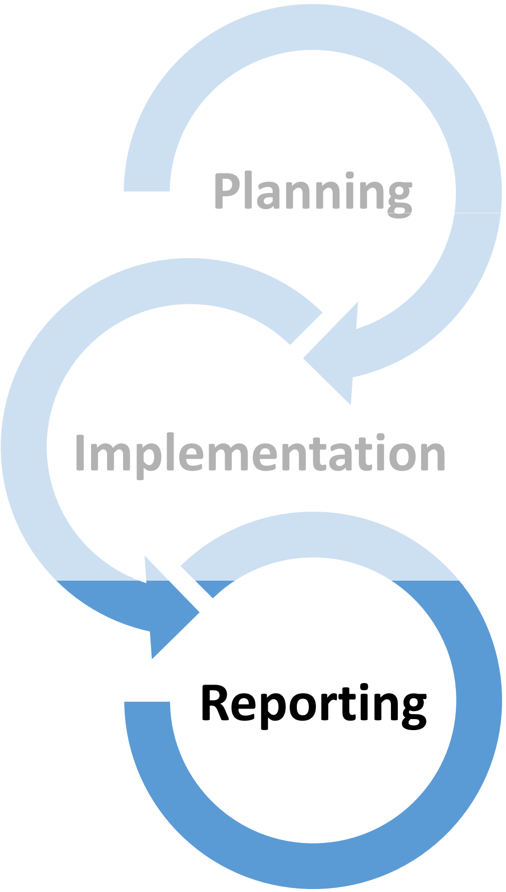


Laboratory tests

- Basic physical properties tests (Moisture content, Specific gravity, Soil Indexes, ..)
- Particle size test (sieving, Sedimentation)
- Direct shear box test
- Unconfined compression test
- Triaxial test
- Consolidation test
- Permeability test
- Other lab tests: Chemical test (pH, contamination,..)

Reporting

- ➢Preparation of Borehole
- ➢Site Investigation Report



Sequence of Site Investigation

Preparation of Boring Logs

Initial information: Name and address of the drilling company, Driller's name, Job description and reference number, boring information (number, type, and location of, and date of boring).

Boring Log

Name of the Project: Two-story apartment building

Location: Johnson & Olive St. Date of Boring: March 2, 2005

Boring No.: 3 Type of Boring: Hollow-stem auger Ground Elevation: 60.8 m

Soil description	Depth (m)	Soil sample type and number	N_{60}	w_n (%)	Comments
Light brown clay (fill)					
Silty sand (SM)	1				
	2	SS-1	9	8.2	
°G.W.T. 3.5 m; Light gray clayey silt (ML)	3	SS-2	12	17.6	LL = 38 PI = 11
	4				
	5	ST-1		20.4	LL = 36 q_u = 112 kN/m²
	6	SS-3	11	20.6	
Sand with some gravel (SP)	7				
End of boring @ 8 m	8	SS-4	27	9	

N_{60} = standard penetration number
w_n = natural moisture content
LL = liquid limit; PI = plasticity index
q_u = unconfined compression strength
SS = split-spoon sample; ST = Shelby tube sample

°Groundwater table observed after one week of drilling

Example of a typical boring log

Preparation of Boring Logs

Subsurface stratification: which can be obtained by visual observation of the soil brought out by auger, split-spoon sampler, and thin-walled Shelby tube sampler.

Groundwater: Elevation of water table and date observed, use of casing and mud losses, and so on

Boring Log

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	2	SS-1	9	8.2	
	3	SS-2	12	17.6	LL = 38 PI = 11
G.W.T. 3.5 m Light gray clayey silt (ML)	4				
	5	ST-1		20.4	LL = 36 q_u = 112 kN/m^2
	6	SS-3	11	20.6	
Sand with some gravel (SP)	7				
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Groundwater table observed after one week of drilling

Preparation of Boring Logs

In-situ tests: Standard penetration resistance and the depth of SPT

Samples: Number, type, and depth of soil sample collected; in case of rock coring, type of core barrel used and, for each run, the actual length of coring, length of core recovery, and RQD.

Boring Log

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°Groundwater table observed after one week of drilling

Preparation of Boring Logs

Class example

The following borehole is part of a site investigation (SI) carried out over a proposed location.

Assess the *subsoil conditions* and *ground-water conditions* based on the borehole data. In particular write about:

- Soil layers: types, description, depth…
- Soil properties: shear strength properties -based on SPT.
- Ground water depth

Boring Log

Name of the Project: Two-story apartment building

Location: Johnson & Olive St. Date of Boring: March 2, 2005

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°Groundwater table observed after one week of drilling

Figure 2.41 A typical boring log

Site Investigation Report

- **When**: After the completion of all of the field and laboratory work, a site investigation report is prepared.
- **Why:** for the use of the design office and for reference during future construction work.
- The report is also called soil exploration report or Geotechnical Factual report.

What should be included in the site investigation report?

Site Investigation Report

The report should contain descriptions of the followings:

- **Purpose** & **Scope** of the investigation
- **Site** & **Structure**: site location, existing structures, drainage conditions, vegetation,… and information about the structure.
- **Factual Details of field exploration:** boreholes, samples, and testing. For each type, quantities, method, tools should be presented.
- **Geological setting** of the site (variation of depth and thickness of layers as interpreted from the borings)
- **Subsoil** and **water-table** conditions, (soil parameters as interpreted from the testing results).
- **Design analysis & recommendations**: type of foundation, allowable bearing pressure, settlement estimation, and any special construction procedure; alternatives design solution.
- **Conclusions** and limitations of the investigations

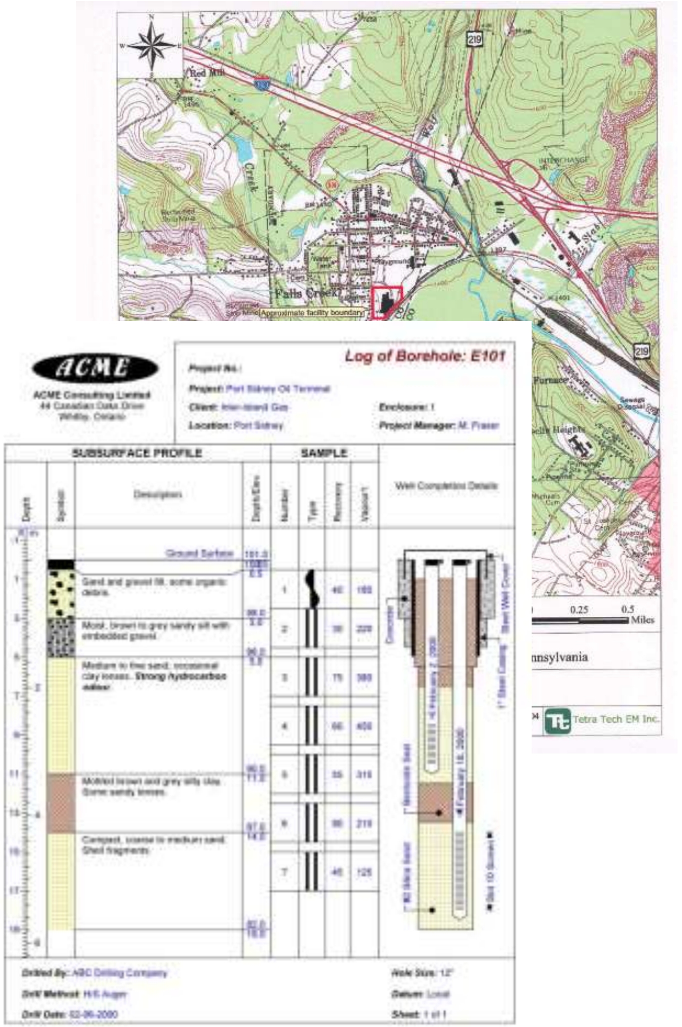
Usually given in another report (Geotechnical Design Report)

➤ Site Investigation Report

The following **graphical presentations** must be attached to the report:

1. General map showing site location
2. A plan view of the location of the borings with respect to the proposed structures and those nearby
3. Boring logs (including in-situ tests results and samples)
4. Laboratory test results

5. Other graphical presentations (geotechnical cross section based on the boring logs, photos of the field work and soil samples,…)



➢ Site Investigation Report

Geotechnical cross section based on the boring logs