Introduction to Geotechnical Site Investigation

What is Site Investigation

Module: Engineering Surveying

Dr Jonathan Black

Lecture 1

Introduction to SI

Lecture Content

- What is Site investigation & Why ?
- How to conduct a site investigation - stages
- Site investigation methods
  - Insitu testing
  - Lab testing
  - Design Parameters
- Resources

Introduction to SI

What is Site investigation ?

General definition….

"Site investigation is the process whereby all relevant information concerning the site of a proposed civil engineering development and its surrounding area are gathered"

Introduction to SI

Why do we need SI ?

- Assess suitability of ground conditions
- Assess risk for construction
- Determine the ground profile
  - Soil conditions – insitu & lab tests
  - Water table
- Generate design parameters
  - Determine ground bearing capacity
  - Settlement consideration
- Plan for construction – economic design
- Foresee difficulties & ground changes
- Investigate previous failures

Introduction to SI

Ground investigation - Aims

- **Determine soil profile**
  - **Soil properties & design parameters**
- **Collection of samples -** Lab investigation
  - Classification
  - strength properties
  - design parameters
  - specialist – contaminants
- **In-situ testing**

Introduction to SI

Ground investigation – factors to consider

- **Geological nature of the site**
  Topography, type of ground & ground water, previous failures
- **Type of building**
  Foundations design & technical requirements
- **Amount of existing information**
  Secondary information - Desk study
- **Variability of the soil**
  More variable – greater extent of investigation
- **Resources**
- Cost & Time, availability of plant

Introduction to SI

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Introduction to SI

How to conduct a SI ?

- **Desk Study**
- **Site Reconnaissance**

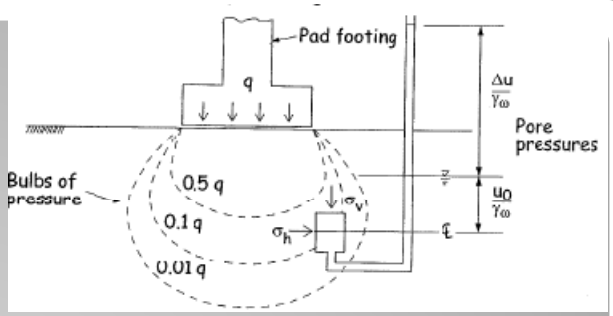
- **Detailed site exploration and Sampling**
  - Trial pits, Borings, collect samples

- **In-situ Testing**

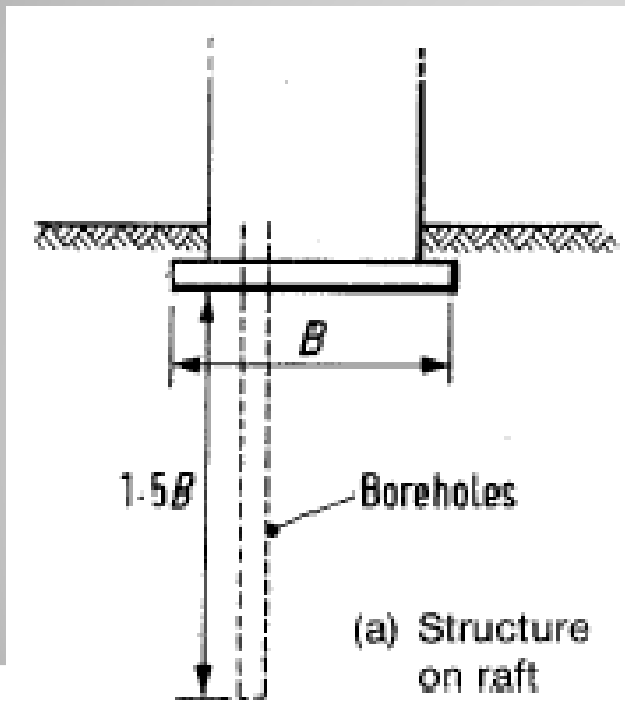
- **Laboratory testing of samples**
  - **Design parameters**
  - **Reporting results**
- **Final Report**

Ground Investigation

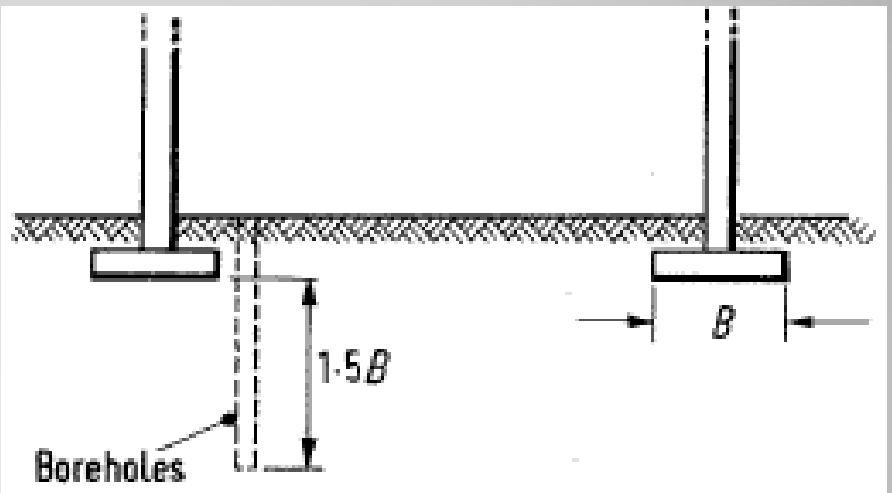
Depth of investigation



- Depths to which the proposed development affects the ground and groundwater



(a) Structure on raft

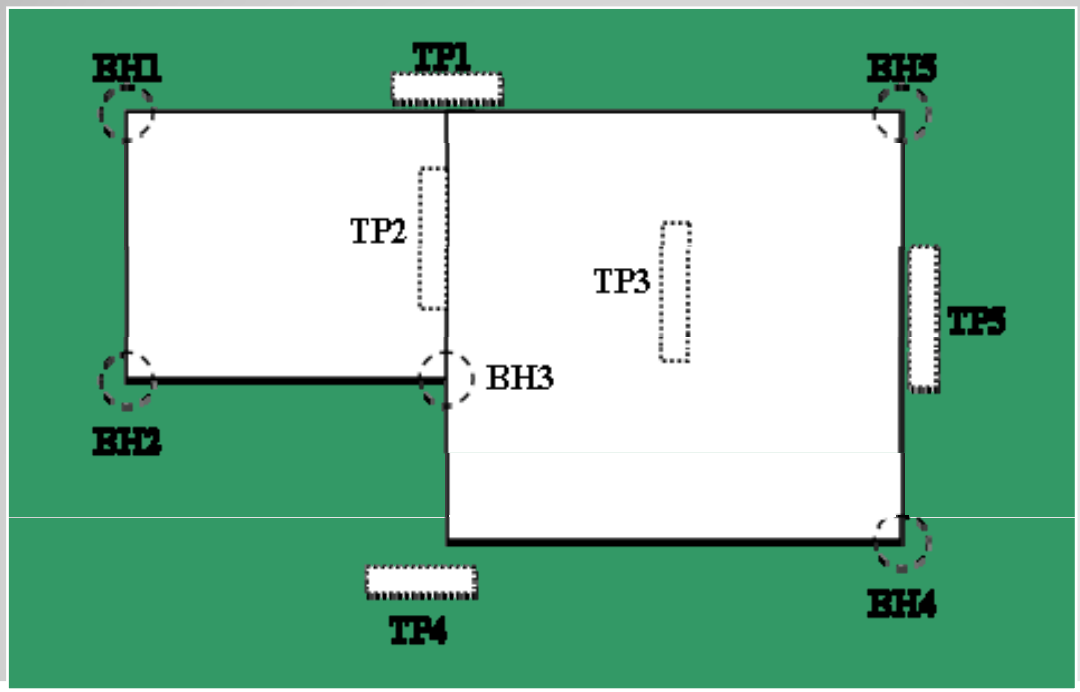


(b) Light structure, strip or pad footings (NB if spacing is less than 3 to 4*B*, consider as a raft)

Ground Investigation

Extent of investigation

- No set rules
  - Common sense and experience



Introduction to SI

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Introduction to SI

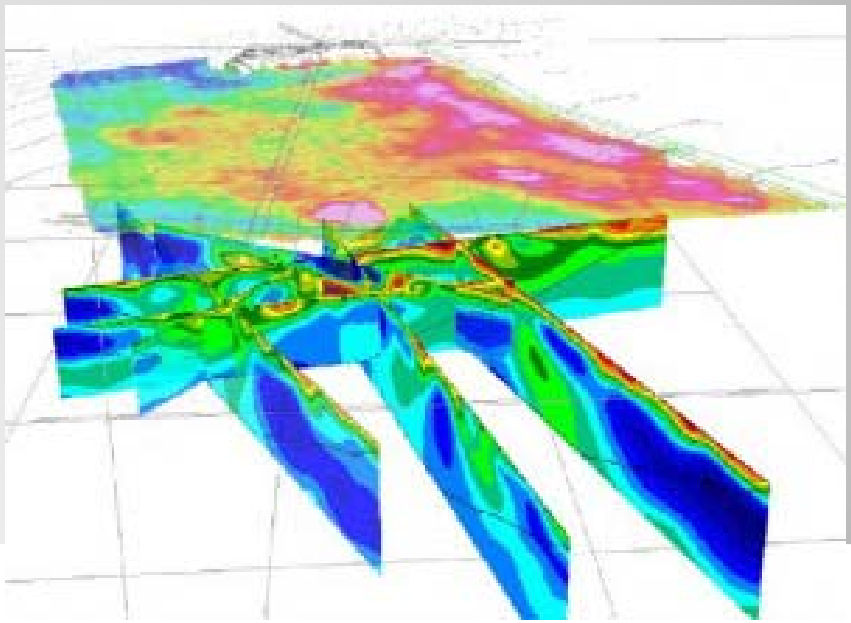
Ground investigation – Sample qualities

- *Class 1* – undisturbed – borings
  - Index tests, moisture content, density, strength, deformation
- *Class 2* – undisturbed – borings
  - Index tests, moisture content, grading, density
- *Class 3* – disturbed – bulk samples
  - Index tests & moisture content
- *Class 4*– disturbed – bulk samples
  - Index tests
- *Class 5* – disturbed – bulk samples - Strata identification

Introduction to SI

Ground investigation – Geophysical

- None intrusive
- Sender & receiver geophone
- Signal reflections & speed used to determine soil profile
- Difficult to interpret



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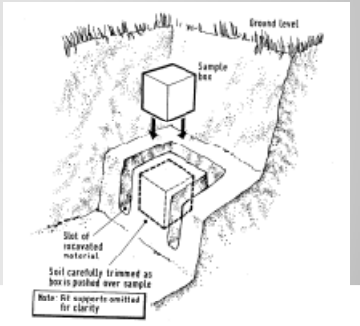
Ground investigation – Trial Pits

- Economical
- Trenches excavated by JCB or hand
- Typically 2 – 3 m deep but dependent on the water table
- Possible pumping required
- Usually in cohesive soils not sands…think of digging a hole at the beach!

Ground Investigation

Trial Pits

- Sample collection types
  - Disturbed Sample - Samples where the soils in-situ properties are not retained.
  - Block Sample - A sample that is not undisturbed but retains some in-situ properties.
  - Push in tube sample - Tube samples of the soil in a trial pit.

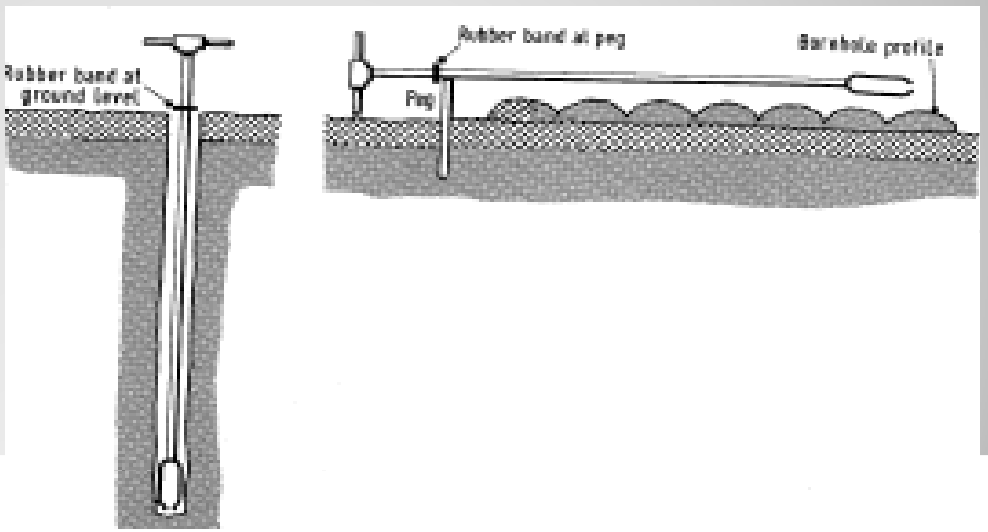


Ground Investigation

Boreholes

- A borehole is used to determine the nature of the ground (usually below 3m depth)
- The two principal types
  - light percussive and drilling machines

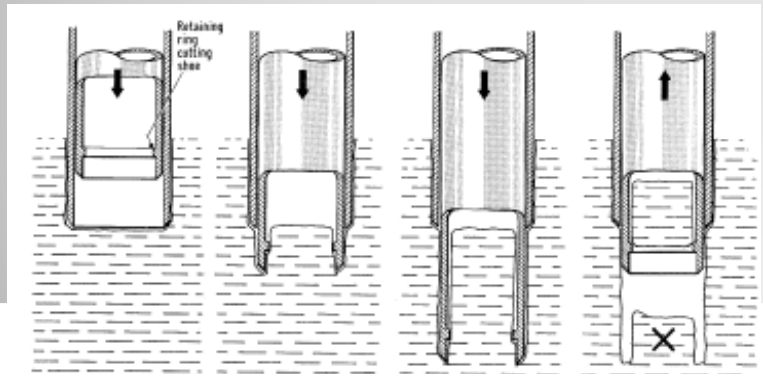
- Hand Auger



Ground Investigation

Boreholes – Light percussion

- **Light Percussive** is the process of making boreholes by striking the soil then removing it
- *Clay Cutter* - Used in cohesive materials
- *Shell* - Used for boring in silts and sands



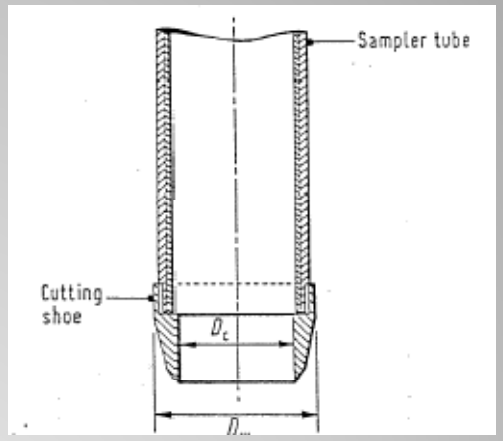
Ground Investigation

Boreholes – sample disturbance

- Affects quality of sample

$$Ar = \frac{(D_w)^2 - (D_c)^2}{(D_w)^2} \times 10$$

- Dw = tube outer casing diameter
- Dc = tube internal diameter



- Below 20% - Undisturbed
- Above 20% - Disturbed

Ground Investigation

Boreholes – sample disturbance

- Open Tube Sampler
  - Typically used in firm to stiff clays Samples
  - 100mm diameter (referred - U4)
  - 450mm long
  - Triaxial tests
  - Disadvantage – sample disturbance
  - Disturbance - typically 20 – 30%

Ground Investigation

Boreholes – sample disturbance

- Thin walled Sampler
  - Typically used is soft soils (more sensitive)
  - Diameter 75mm – 100mm
  - Lower sample disturbance (10%)
  - Static sampling can be applied
  - Sample cutting edge easily damaged by boulders No cutting shoe
  - Class 1 & 2 samples for
    - triaxial tests
    - Consolidation tests

Ground Investigation

Rotator Borings

- Flight auger
  - helix blade attached to a central shaft
  - disturbed samples can be obtained at surface level
  - Index properties/moisture content tests
- recent advance
  - Undisturbed samples
  - Hollow central shaft
  - helix rotates, cuts
  - soil samples - hollow centre

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Ground Investigation

In-situ tests

- In certain soils, such as sensitive silts and clays it is difficult to obtain good quality undisturbed samples
- In-situ tests

Test	Required to measure
Standard Penetration Test (SPT)	Relative Density (Shear strength)
Shear Vane (hand vane)	Shear Strength
Cone penetration Test (CPT)	Compressibility & Shear Strength
California bearing capacity (CBR)	Compressibility (Bearing capacity)
Plate bearing capacity	Compressibility (Bearing Capacity)
Piezometer	In situ stresses
Pumping test	Permeability

Ground Investigation

In-situ tests - SPT

- Standard Penetration Test
  - dynamic test
  - determine the soil relative density and shear strength characteristics

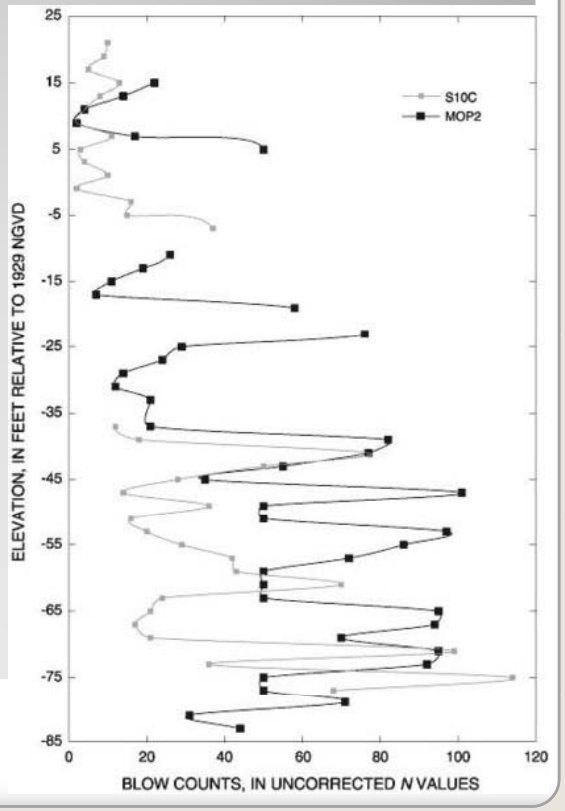
- 50mm sampler is driven
- drop hammer of 65kg falling through a distance of 0.76m
- driven a total of 450mm
- blows recorded for the last 300mm penetration

Ground Investigation

In-situ tests - SPT

- test is strongly influenced by the presence of ground water, as it leads to a reduction in effective stress

- Corrections to N-value
  - Overburden pressure
  - Energy Blow loss



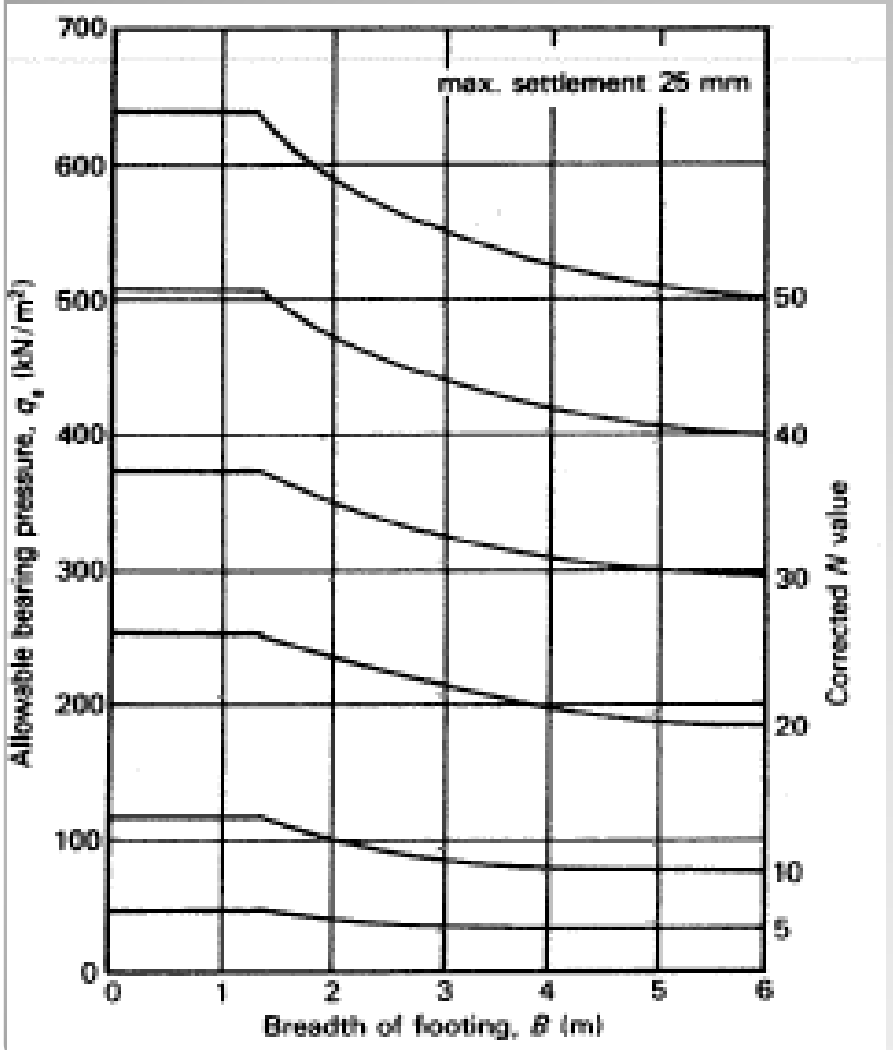


Table 11.6 Classification using SPT N-values

(a) Cohesionless soils

SPT N-value	*Relative density*	
	Description	*I_d(%)*
<4	Very loose	0–15
4–10	Loose	15–35
10–30	Medium dense	35–65
30–50	Dense	65–85
>50	Very dense	85–100

(b) Cohesive soils

SPT N-value	*Consistency*	*Approximate undrained shear strength (kPa)*
<2	Very soft	<20
2–4	Soft	20–40
4–8	Firm	40–75
8–15	Stiff	75–150
>15	Very stiff or hard	>150

Ground Investigation

In-situ tests - SPT

- SPT generates Relative density or shear strength
- Meyerhof (1965) proposed relationships to determine the allowable bearing pressure:
- For B < 1.25 m $$q_a = \frac{S_L N}{1.9}$$
- For B > 1.25 m $$q_a = \frac{S_L N}{1.9}\left[\frac{B+0.33}{B}\right]^2$$
  - Where SL = permitted settlement limit (mm)
  - N = Average N value between z = D and z = D +B
  - B = Breadth of footing

Ground Investigation

In-situ tests - CPT

- Cone Penetration Test
  - Static test
  - determine the soil relative density and compressibility
  - Cone angle of 60º and an end diameter of 35.7 mm
  - end area of 1000mm^2
  - Pushed 80mm into the soil at a constant rate of 20 mm/s
  - compressibility coefficient similar to c_v

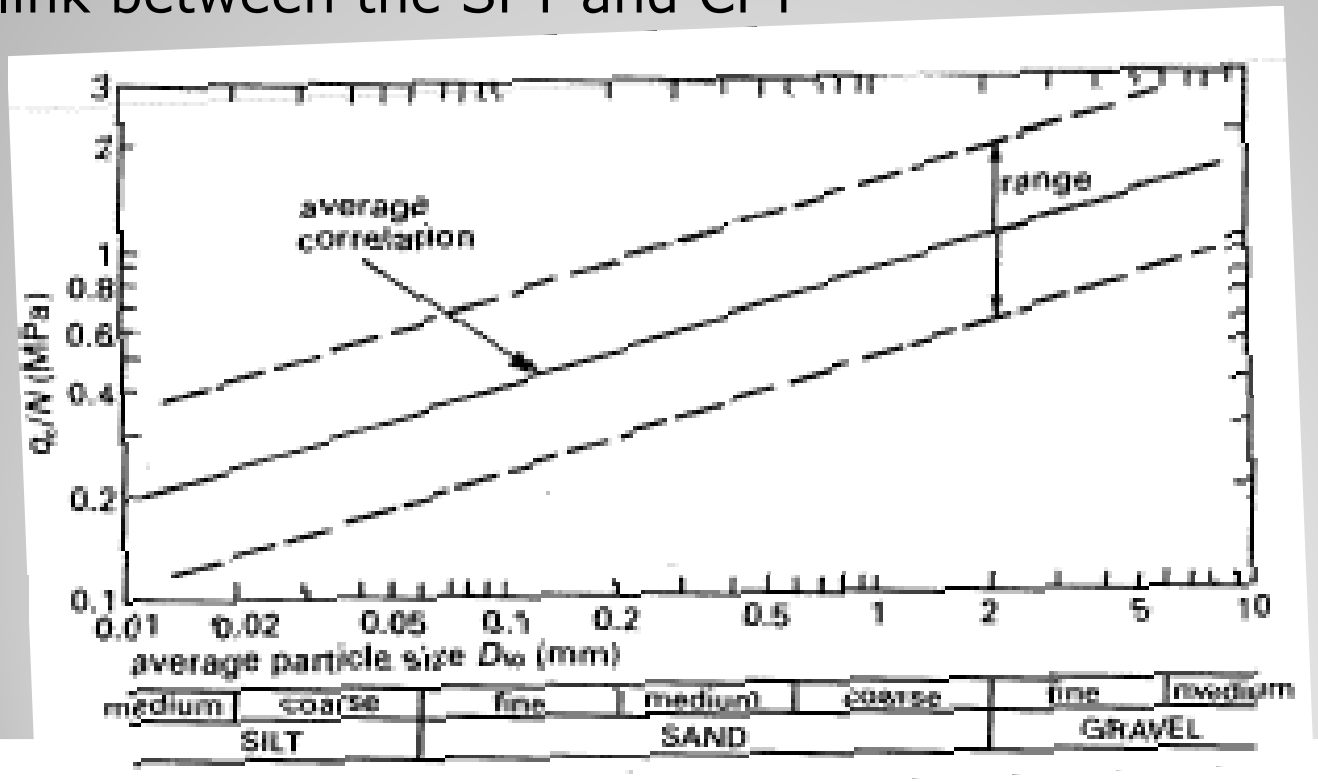
$$C = \frac{1.5q_c}{\sigma'_0}$$

  - Qc = cone resistance (Mpa)
  - σ'_o = effective overburden (MPa)

Ground Investigation

In-situ tests - CPT

- Burland and Burbidge (1985)
- link between the SPT and CPT

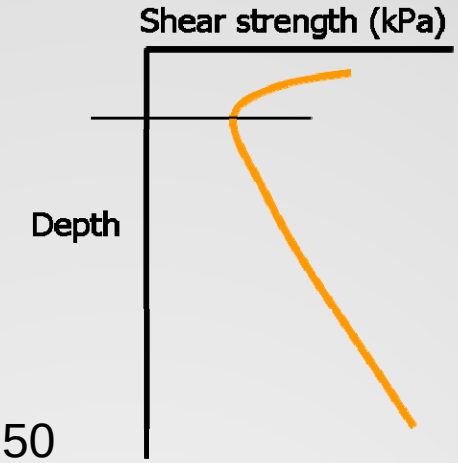


Ground Investigation

In-situ tests – Shear Vane

- Shear vane tests (hand vane tests)
  - determine the in situ undrained shear strength (c_u)
  - four bladed vane
  - driven into the soil the vane is rotated

TERM	Cu (kPa)
Very Soft	Less then 20
Soft	20 – 40
Soft to Firm	40 – 50
Firm	50 – 75
Firm to Stiff	75 – 100
Stiff	100 – 150
Very stiff	Greater than 150



- Normally consolidated deposits
- Inverted profile
- Due to
  - Environmental factors
  - Temperature change
  - Water table fluctuation

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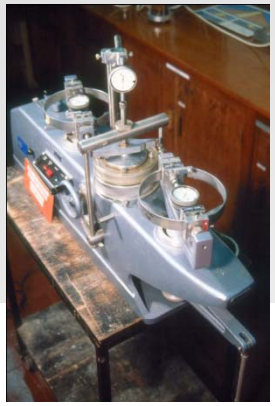
Ground Investigation

Lab tests

- laboratory tests include:
  - Atterberg limits and water content
  - Particle-size analysis – type of soil structure
  - Consolidation - Cc/Cs/cv/Mv/T90/U/OCR
  - Soil compaction
  - Direct shear and Triaxial shear – ϕ/ ϕ' / Cu / c'
    - Critical state parameters
  - California bearing ratio - CBR



Ground Investigation

Lab tests – shear strength

- Test depends on material
  - Sand – direct shear box
  - Clay – Triaxial
- **soil composition**: mineralogy, grain size and grain distribution, shape of particles, pore fluid.
- **state**: void ratio, effective normal stress and stress history.
- **structure:** arrangement of particles - layers, joints, fissures.
- **loading conditions:** drained and undrained; type of loading, i.e., magnitude, rate (static, dynamic).

Introduction to Surveying

Lecture Resources

Simons, Menzies and Mathews (2002)
A short course in Geotechnical Site Investigation

BS5930:1981 Code of Practice for SI

Weltman and Head (1983) Site investigation manual

Chris Clayton – Site investigation (MOLE)