CITY UNIVERSITY LONDON

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University of Sao Paulo – Polytechnic School
A Course of Lectures in Geotechnical Engineering

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2 Geological Origins of Engineering Soils

Topics

1 – Basic Soil Behaviour

2 – Geological Origins of Engineering Soils

3 – Simple Analyses with Pencil and Paper

4 – Parameters for Design

Fundamental components of an undergraduate course

Basic Principles

The ground is formed by natural processes in an environment governed by tectonics, climate and topography.

Engineering properties are determined by how the ground was formed.

Nothing is magic and there is no divine intervention.

The Key Question

How do the geological processes lead to the engineering properties?

2 – Geological origins of soils and rocks

2.1 Surface processes

2.2 Objective description of soil

2.3 Soil behaviour related to description

Basic Near Surface Processes

Weathering

Erosion

Transport

Deposition

It is all physics and chemistry

Basic Differences between Soils and Rocks

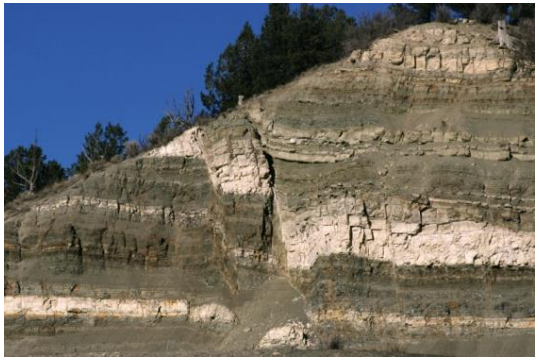
Soils

Unbonded grains

Failure generates slip planes

Material properties dominate.

Rocks

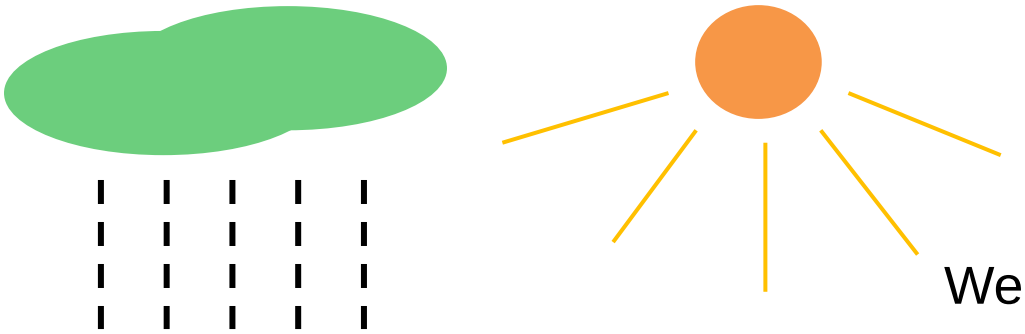


Bonded grains + cracks

Failure on pre-existing joints

Material properties not significant; joints dominate.

Weathering depends on environment.



Weathering - chemistry

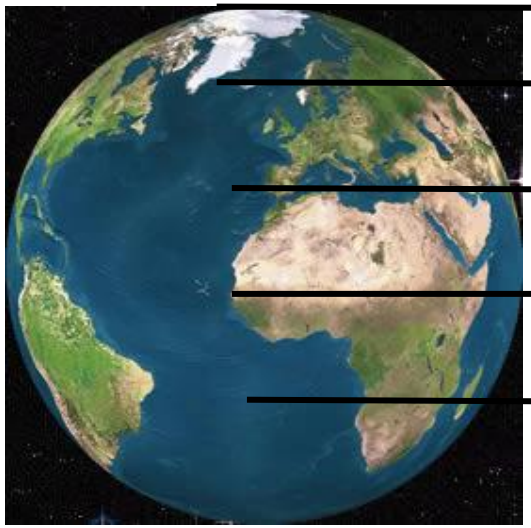
Residual or sedimented soil

Progressively weathered rock

Fresh rock

Depths vary

Environment = climate + topography



cold

temperate

hot dry

hot wet

Elevation

Latitude

Topography

Mountain
Plain
Coast
Ocean

Climate determines weathering product

	Weathering	Products
Hot wet	Chemical	Clay and quartz sand
Hot dry	Physical	Silt – sand - gravel
Glacial		
Temperate	Not much	

Climate determines weathering product

Chemical

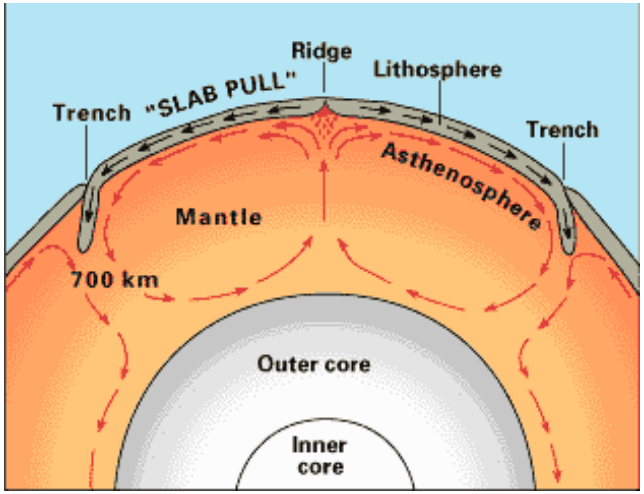
Clay

Quartz sand

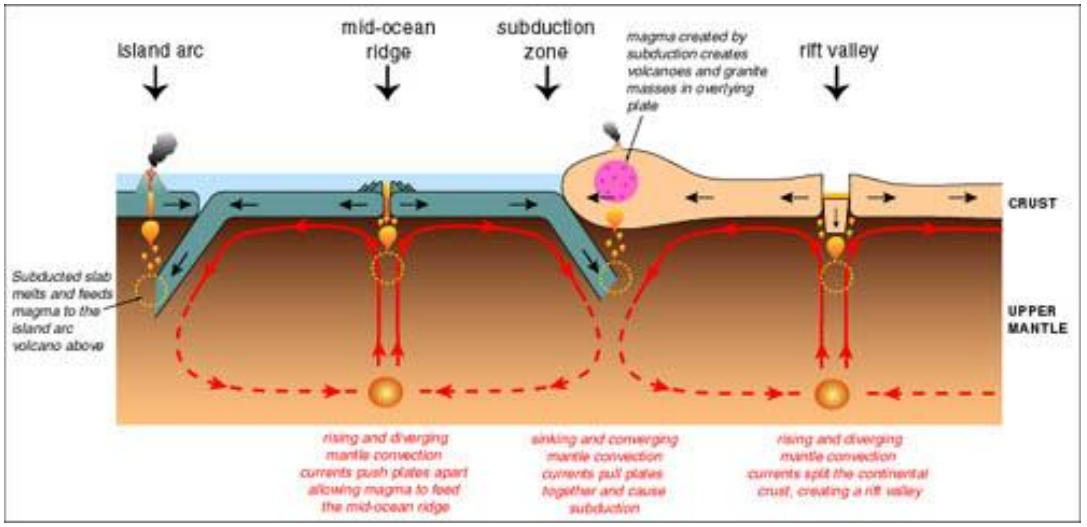
Physical

Broken rock

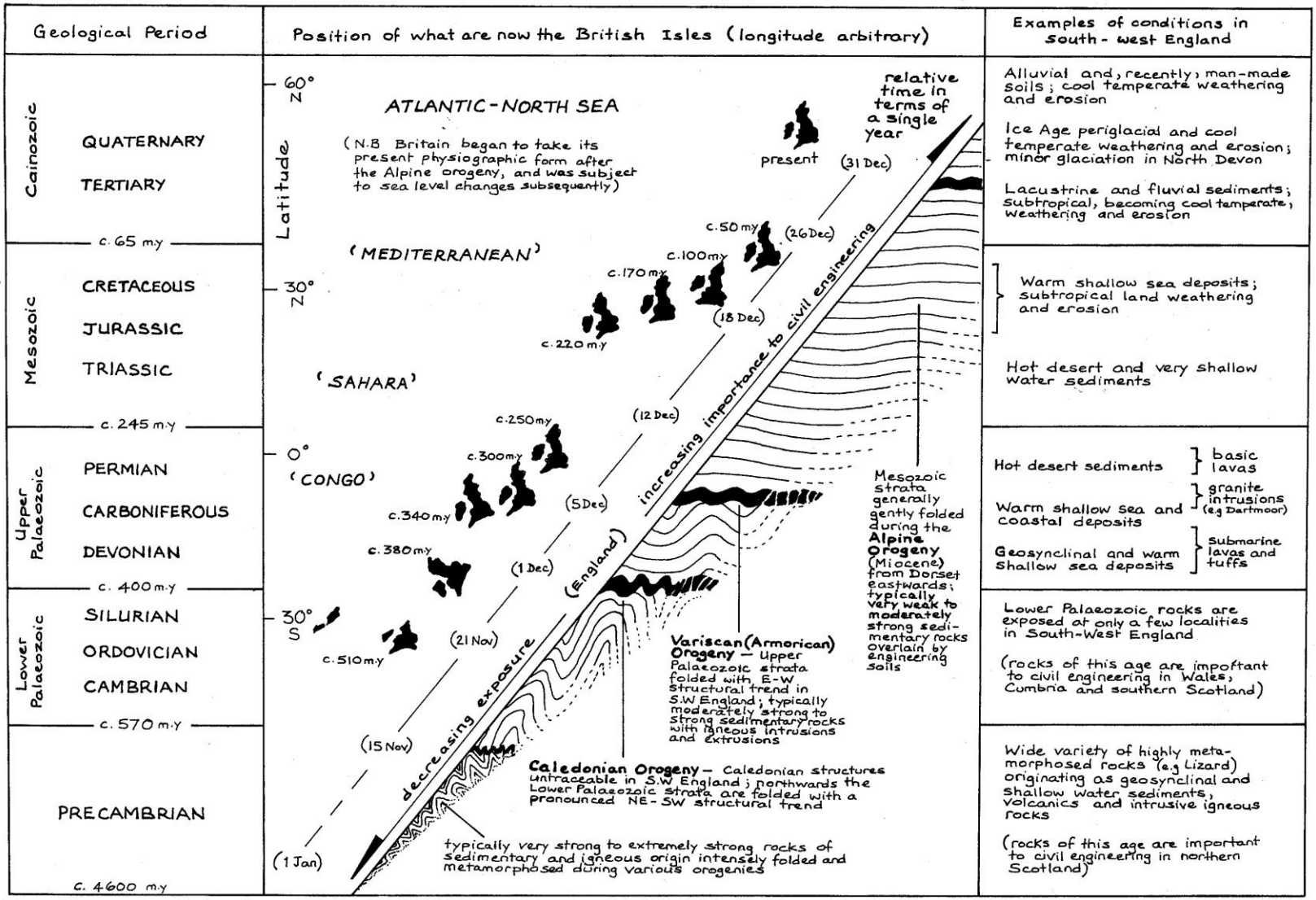
Tectonics – Continental Drift



1cm per year = 10km in 1 million years



Everywhere has been somewhere else


Geological Period
Position of what are now the British Isles (longitude arbitrary)
Examples of conditions in South-west England
Cainozoic
QUATERNARY
TERTIARY
c. 65 m.y
Mesozoic
CRETACEOUS
JURASSIC
TRIASSIC
c. 245 m.y
Upper Palaeozoic
PERMIAN
CARBONIFEROUS
DEVONIAN
c. 400 m.y
Lower Palaeozoic
SILURIAN
ORDOVICIAN
CAMBRIAN
c. 570 m.y
PRECAMBRIAN
c. 4600 m.y
Latitude
60° N
30° N
0°
30° S
ATLANTIC - NORTH SEA
(N.B Britain began to take its present physiographic form after the Alpine orogeny, and was subject to sea level changes subsequently)
('MEDITERRANEAN')
('SAHARA')
('CONGO')
relative time in terms of a single year
present
(31 Dec)
(26 Dec)
(18 Dec)
(12 Dec)
(5 Dec)
(1 Dec)
(21 Nov)
(15 Nov)
(1 Jan)
c.50 m.y
c.100 m.y
c.170 m.y
c.220 m.y
c.250 m.y
c.300 m.y
c.340 m.y
c.380 m.y
c.510 m.y
increasing importance to civil engineering
decreasing exposure
(England)
Mesozoic strata generally gently folded during the Alpine Orogeny (Miocene) from Dorset eastwards; typically very weak to moderately strong sedimentary rocks overlain by engineering soils
Variscan (Armorican) Orogeny — Upper Palaeozoic strata folded with E-W structural trend in S.W England; typically moderately strong to strong sedimentary rocks with igneous intrusions and extrusions
Caledonian Orogeny — Caledonian structures untraceable in S.W England; northwards the Lower Palaeozoic strata are folded with a pronounced NE-SW structural trend
typically very strong to extremely strong rocks of sedimentary and igneous origin intensely folded and metamorphosed during various orogenies
Alluvial and, recently, man-made soils; cool temperate weathering and erosion
Ice Age periglacial and cool temperate weathering and erosion; minor glaciation in North Devon
Lacustrine and fluvial sediments; subtropical, becoming cool temperate, weathering and erosion
Warm shallow sea deposits; subtropical land weathering and erosion
Hot desert and very shallow water sediments
Hot desert sediments
basic lavas
Warm shallow sea and coastal deposits
granite intrusions (e.g Dartmoor)
Geosynclinal and warm shallow sea deposits
submarine lavas and tuffs
Lower Palaeozoic rocks are exposed at only a few localities in South-West England
(rocks of this age are important to civil engineering in Wales, Cumbria and southern Scotland)
Wide variety of highly metamorphosed rocks (e.g Lizard) originating as geosynclinal and shallow water sediments, volcanics and intrusive igneous rocks
(rocks of this age are important to civil engineering in northern Scotland)

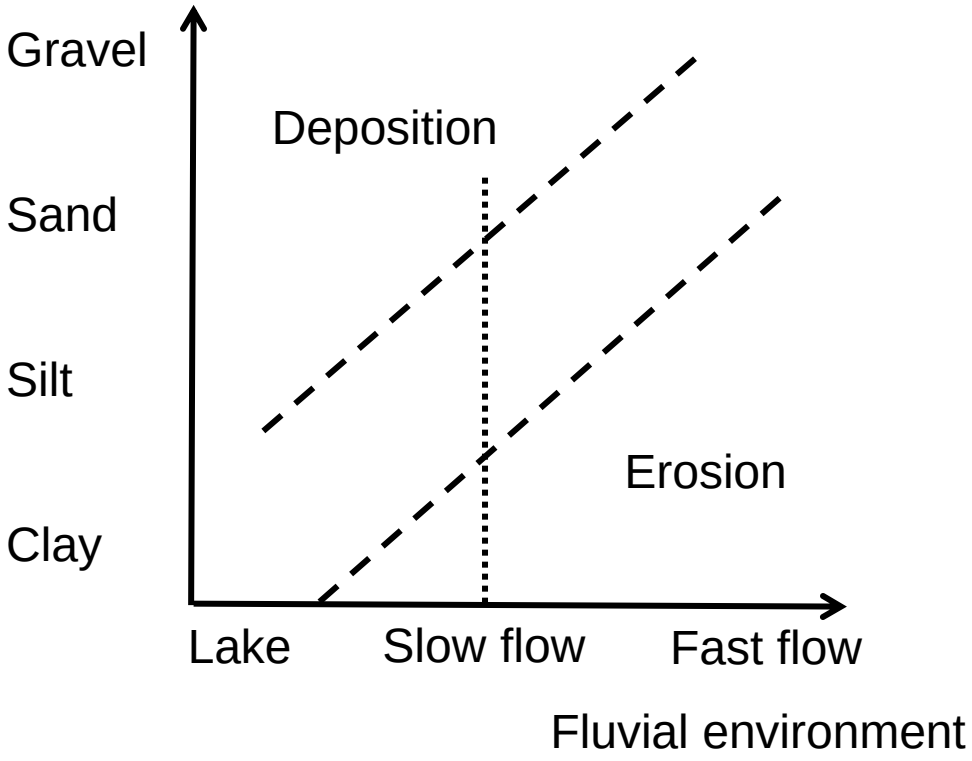
Basic Principles and Consequences

Residual soils and sedimented soils (unconsolidated sediment) depend more on the environment and climate and less on the parent rock.

Most geotechnical engineering is in “unconsolidated sediments” (residual soils and sedimented soils).

Very little age-based (capital letter) geology is relevant to geotechnical engineering.

Transport and sorting.



River flow speed varies with position (inside and outside bends) and with season

Wind has the same effect but the size-velocity relationship is different

Glaciers move all sizes

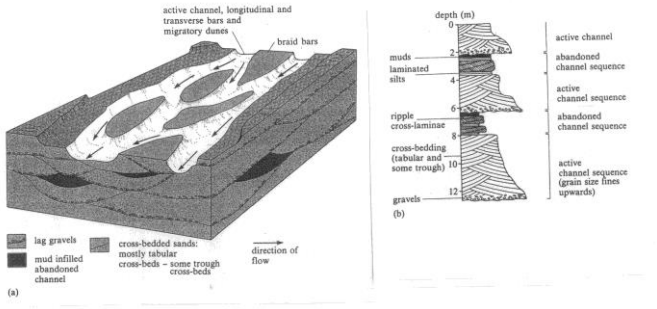
Deposition Environments.

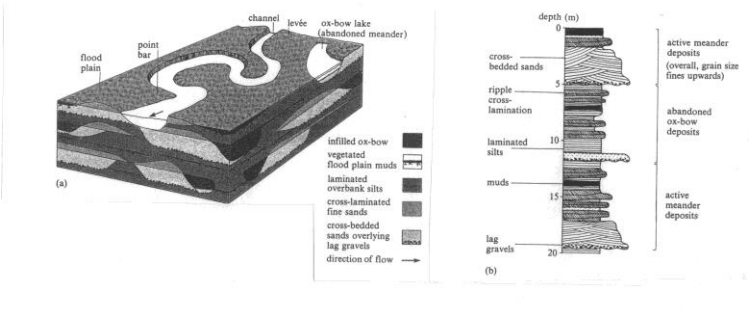
Deserts

Glacial

Coast

Deposition Environments – Rivers





Keywords

Tectonics

Everywhere has been somewhere else.

Environment

Climate and topography control the processes.

Processes

Processes determine what is formed.

The Question to Ask.

Where should I go in the World today to see this soil or rock being created; and what has happened to it since?

2 – Geological origins of soils and rocks

2.1 Surface processes

2.2 Objective description of soil

2.3 Soil behaviour related to description

What to do in practice

Describe soil in the field

Describe a soil sample in the office

Interpret standard descriptions in borehole logs

Revise when lab tests results come in

Relate what you are looking at to the geological processes that formed it. Where did the material come from? How was it transported? What was the environment of deposition? What happened since?

Basic Description

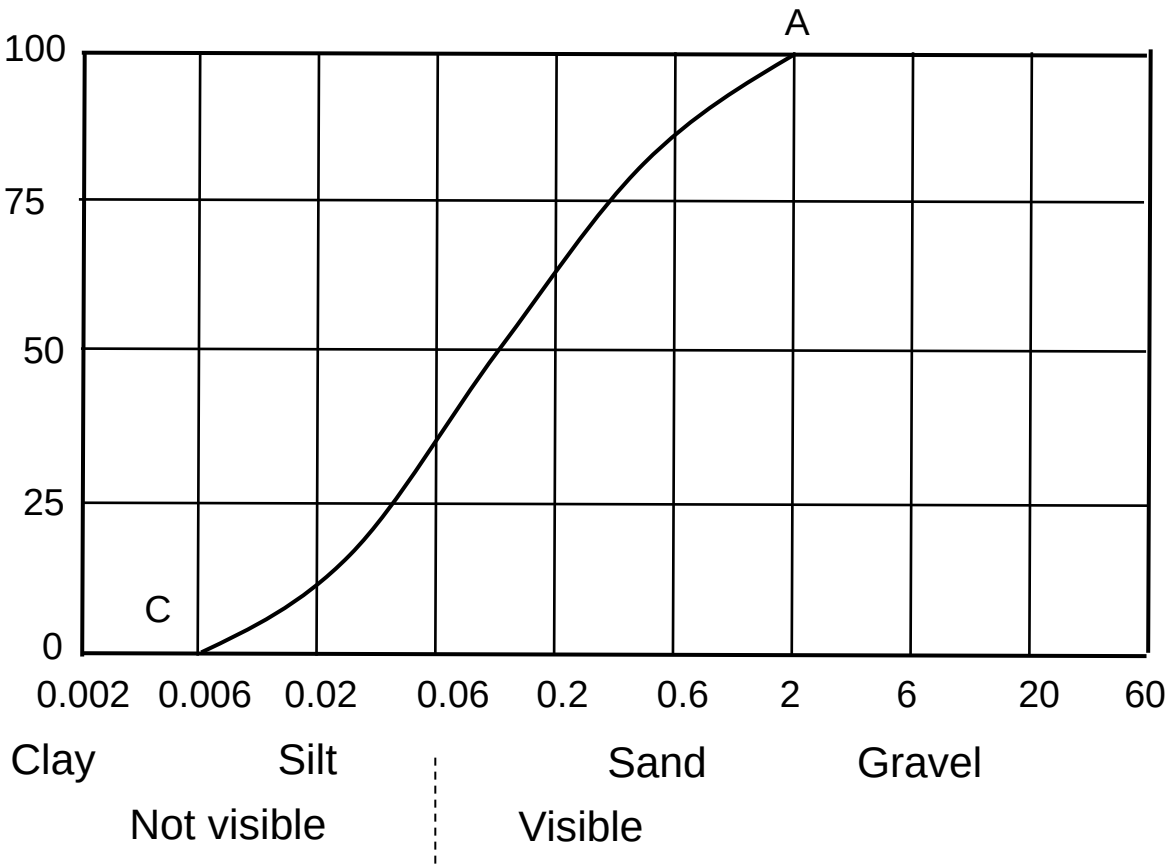
	Soils	Rocks
What it is	The grains	Geological name(s)
State	Dense - loose	Weathering grade
Structure	Bonding and fabric	Joints

Grading – distribution of sizes

Fraction smaller than the size %

A = largest size

C = smallest size



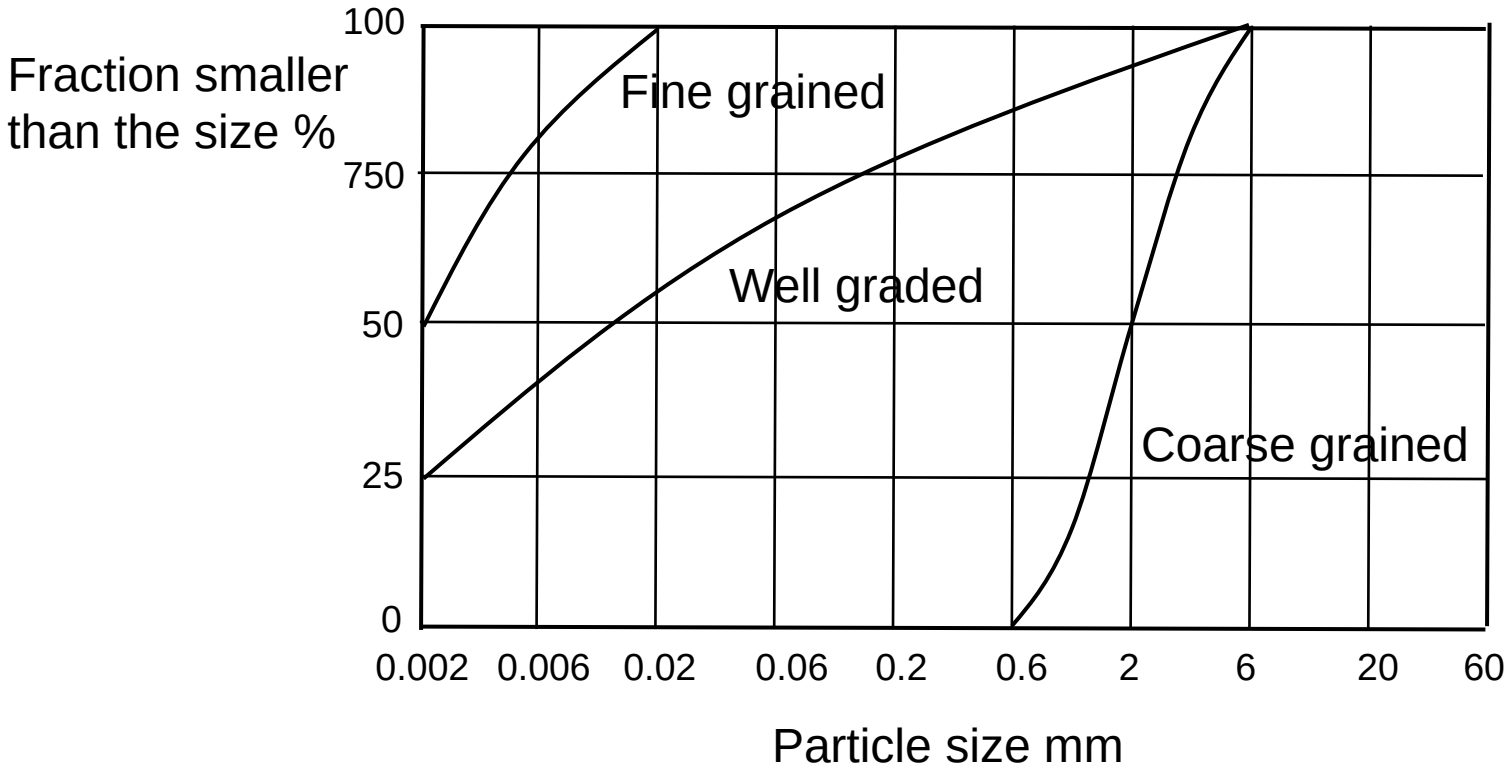
How to estimate grading – always draw a grading curve

By inspection

By sedimentation

Interpret the borehole log description

Grading



Grading dominates drainage

Coarse grained soils – sand and gravel

Visual inspection

Shape and surface texture
- rough and angular
- smooth and rounded

Colour related to mineralogy
- colourless – quartz
- white – carbonate
- red, yellow, grey – same as parent rock

Fine grained soils – silt and clay

Estimate plasticity; add water so state changes from crumbly to flowing;
- add little water – low plasticity
- add much water – high plasticity

Be careful with silty clay and clayey silt
- small fraction of montmorillonite or
- large fraction of kaolinite

$$\text{Activity } A = \frac{PI}{\%\ \text{clay}}$$

< 0.5 = kaolinite

> 5 = montmorillonite

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Strength of coarse grained soils

Dry the soil and pour it into a heap; $i = \phi'_c$

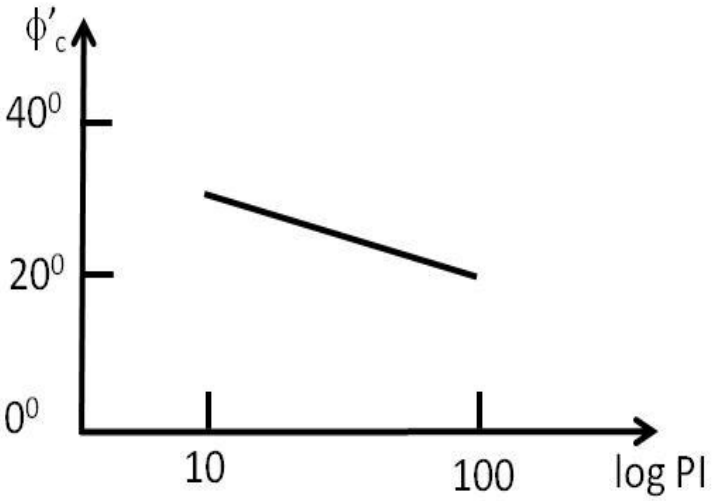
Constant volume (large strain) strength

Smooth rounded grains; $\phi'_c = 30^0$

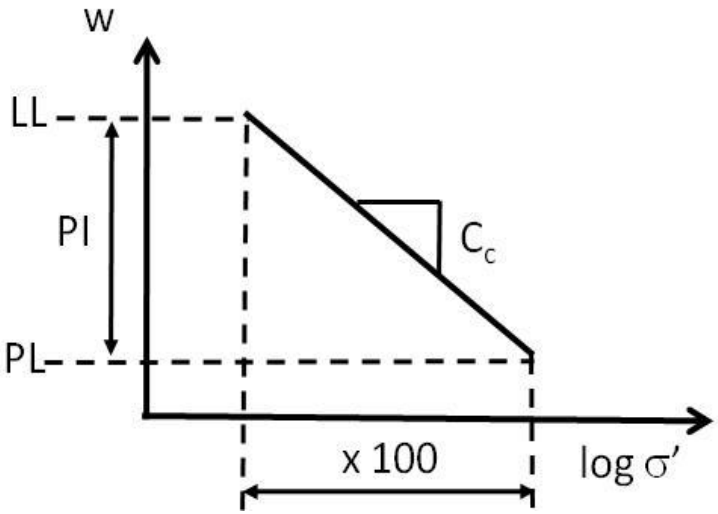
Rough angular grains; $\phi'_c = 33^0$

Carbonate sand; $\phi'_c = 40^0$

If you have Atterberg limits



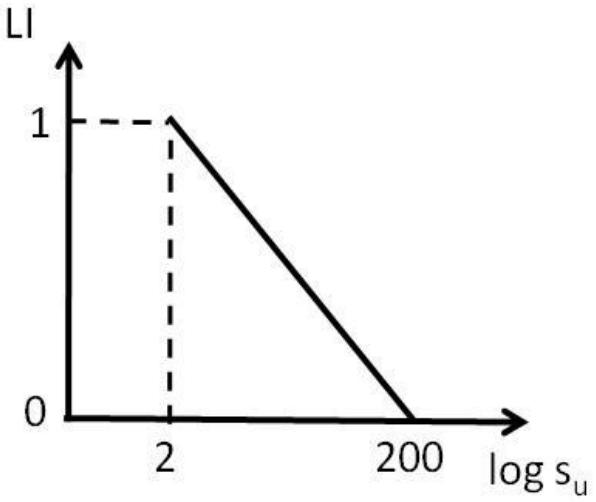
Constant volume ϕ'_{cv}



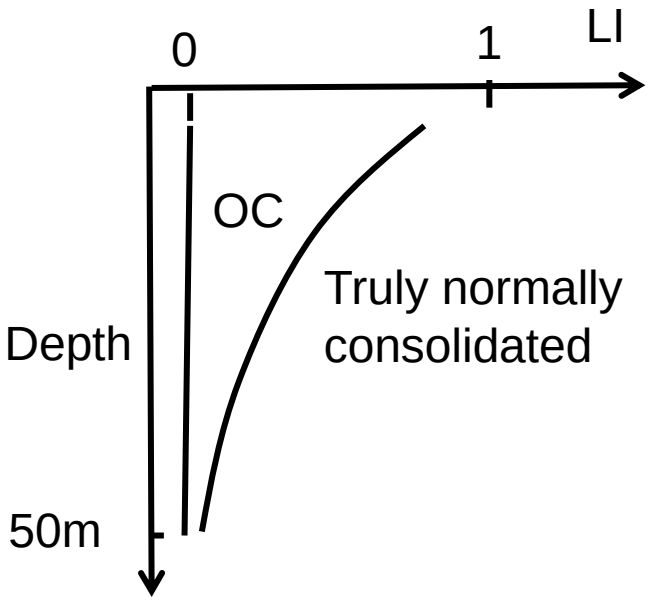
Compressibility C_c

If you have Atterberg limits and water content

Always calculate the liquidity index;
at liquid limit LI = 1 and at plastic limit LI = 0



Undrained strength



In the ground

Manipulation – undrained strength

Result	Undrained strength s_u kPa
Flows	~2
Extrudes between fingers	<10
Easily moulded	10 – 20
Moulded with strong pressure	20 – 40
Indented by thumb	40 – 75
Indented by thumbnail	75 – 150
Difficult to mark with thumbnail	>150

Grading and drainage

Coarse grained – visible grains

normal construction is drained

effective stress parameters

Fine grained – grains not visible

normal construction is undrained followed by consolidation

total stress strength and consolidation parameters

Well-graded – coarse and fine grains

Are there enough fine grains to fill the spaces between the coarse grains?

What about fabric (layers + bonding)?

Layers; examine outcrop or split sample

Influences permeability

Bonding; submerge in water and wait until pore pressures equalise.

Will bonding survive the strains Imposed by the works?

Geology - Engineering

1 Describe the soil grains, how they are packed (loose or dense) and fabric.

2 Are these descriptions compatible with the geological processes that formed the soil?

3 What can be deduced about engineering behaviour and parameters from these descriptions?

4 Do lab and field test results agree with these deductions? If not, why not?

Key Message

Engineering properties must result from how the soils were formed by natural geological processes.

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