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1 Soils

- 1.1 Composition, Weathering, Terminology, Engineering Properties
- 1.2 Classification, Particle Size Analysis, Grading
- 1.3 Physical Properties, Compaction
- 1.4 Earth Pressure, Stability of Slopes, Retaining Walls
- 1.5 Bearing Capacities

1.1 Composition, Weathering, Terminology, Properties

- All soils originate from Rocks
- Rock Types:
 - Igneous rocks – Formed by cooling from hot molten material (magma); e.g. Granite, Basalt
 - Sedimentary rocks – Formed in layers by settling of sediments in water; e.g. Limestone, Sandstone
 - Metamorphic rocks – Formed by changing of existing rock due to extreme heat or pressure; e.g. (heat) Marble, Quartz (Pressure) Slate
- All conversion of rocks to soils take place near the surface of the earth (hence the term weathering of rocks) due to wind, rain, frost (and ice), temperature and gravity
- Composition:
 - Rock fragments (> 2mm)
 - Mineral grains (2 mm > down to > 1µm)
 - Organic matter
 - Water
 - Air
- Two major groups:
 - Coarse soils (> 0.06mm) – Sands and Gravels
 - Fine soils (0.06mm > and finer) – Silts and Clays
- Terminology:
 - Rock – in engineering means having to blast for excavation
 - Soil – in engineering means loose or diggable material
 - Organic soils – in engineering means soils containing organic matter in varying degrees of decomposition
 - Peat – in engineering means comprising entirely of organic matter

- Transported soils – means soils that have been transported from its original place during the weathering process
- Residual soils – means soils that have been weathered but remained in the original place
- Cohesive soils – means soils that contain finer particles of clay or silt that binds all particles together to impart plasticity
- Cohesionless soils – means coarse-grained soils such as sands and gravels that has no plasticity
- Engineering Properties:
 - Grade
 - Porosity
 - Shear Strength
 - Compressibility
 - Bearing Strength
 - Cohesion

1.2 Classification, Particle Size Analysis, Grading

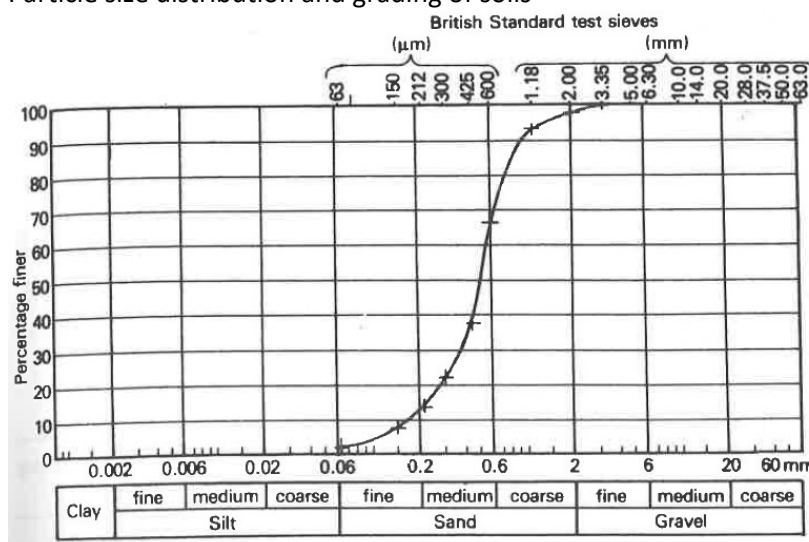
- Needs for a classification system?
- Basic Classification: Coarse, Fine and Organic

Particle Size (mm)	200	60	20	6	2	0.6	0.2	0.06
Classification	Boulders	Cobbles	Gravels			Sands		
			Coarse	Medium	Fine	Coarse	Medium	Fine

Particle Size (mm)	0.06	0.02	0.006	0.002
Classification	Silts			Clays
	Coarse	Medium	Fine	

Source: Whitlow, R. (2001)

- Particle Size Analysis: Sieve Analysis - Sample, Sub-sample, Oven drying, Nest of standard sieves, agitation of the whole nest and then individual sieves, Particle size distribution
- For fine grained soils wet sieving
- Even finer particles through a sedimentation process using Stokes' law
- Particle size distribution and grading of soils



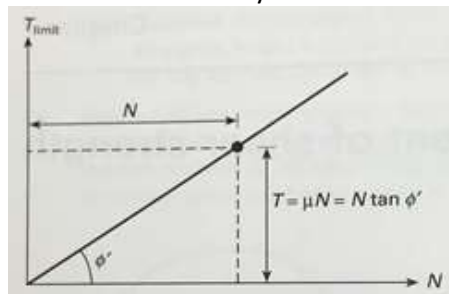
Source: Whitlow, R. (2001)

1.3 Physical Properties, Compaction

- Physical properties of a soil that define its state
- For engineering purposes; Solid (soil), Liquid (water), Gas (air) are all intermixed
- Soil models are therefore considered;

Unit Solid Volume Model	Unit Solid Mass Model	Unit Total Volume Model
For one unit volume of solids, how much volume of water and air is there in the soil sample?	For one unit mass of solids, how much mass of water and air is there in the soil sample?	For one unit volume of soil, how much volume of solids, water and air is there?
$V_s = 1$	$M_s = 1$	$V_s + V_w + V_a = 1$
$V_w ?$	$M_w ?$	
$V_a ?$	$M_a ?$	

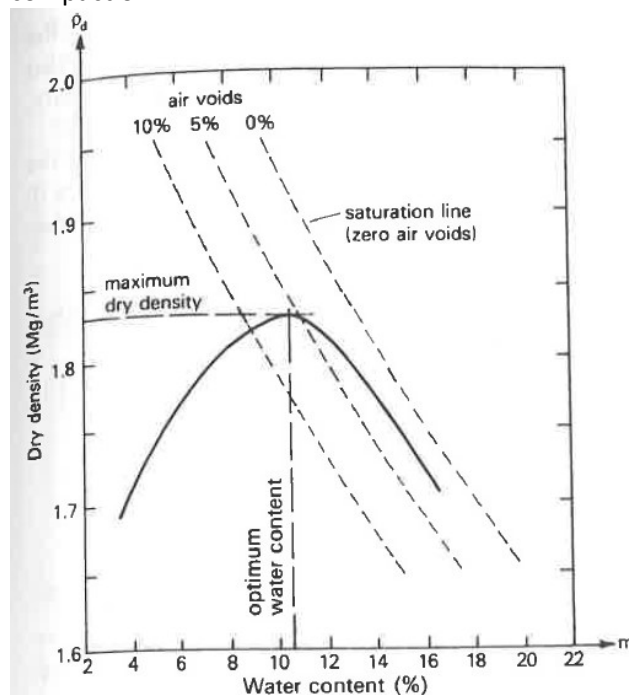
- Unit solid volume model is commonly used
- Void Ratio (e):
 - Volume not occupied by solids is known as voids volume (this volume is occupied by water and air)
 - Void Ratio; $e = \frac{\text{volume of voids}}{\text{volume of solids}} = \frac{V_a + V_w}{V_s}$
- Porosity (n):
 - Porosity; $n = \frac{\text{volume of voids}}{\text{total volume}} = \frac{V_a + V_w}{V_a + V_w + V_s} = \frac{eV_s}{eV_s + V_s} = \frac{e}{1+e}$
- Degree of Saturation (S_r):
 - Degree of saturation; $S_r = \frac{\text{volume of water}}{\text{volume of voids}} = \frac{V_w}{V_a + V_w}$
 - For dry soils; $S_r = 0$
 - For saturated soils; $S_r = 1$
- Grain specific gravity (G_s):
 - Ratio of the mass of a given volume of a material to the mass of the same volume of water
 - Grain specific gravity; $G_s = \rho_w M_s$ (is also the Particle or grain density)
- Water content (w):
 - Water content; $w = \frac{\text{Mass of water}}{\text{Mass of solids}} = \frac{M_w}{M_s}$
- Angle of Friction (ϕ):
 - Same as between any other two surfaces;



Source: Whitlow, R. (2001)

- However, when a normal pressure is applied on a soil (loading a soil), changes will occur in the pore water pressure as well as the volume of the soil. Water may also seep out. This also depends on the “stress history” of the soil.
- Compaction:
 - To increase the soil density by reducing the void ratio (and the permeability)

- To increase the shear strength and bearing capacity
- To reduce future volume changes and settlement
- Each soil type will have a maximum state of compaction achievable (different for laboratory and field conditions)
- There is an optimum moisture content at which this is achieved.
- Addition of water forms a film of water around the particles allowing them to move freely by reducing friction.
- At some point however, the water pressure between particles start to build up and start to push the particles apart.
- The water content at which this starts to happen is the optimum water content for compaction.



Source: Whitlow, R. (2001)

1.4 Earth Pressure, Stability of Slopes, Retaining Walls

- Civil engineering projects will require the ground profile to be changed, to have vertical or near vertical faces of soils
- At times, depending on the soil type, these faces may be able to support themselves, but at other times they may need support in the form of structures
- Different types of earth pressures are generated depending on the movement of the structure supporting them;
 - Passive pressures are generated when the structure supporting the soil move towards the soil
 - Active pressures are developed when the structure moves away from the soil
 - At-rest pressures are the pressures developed when the structure is rigid and does not move
 - Gravity Retaining Structures - depend on their own weight for stability
 - Masonry walls
 - Gabion walls
 - Crib walls
 - Reinforced concrete structures support by a cantilevering action

- Counterfort walls have a tension stiffener (counterfort) connecting the back of the wall and the base, reducing the bending and shear forces
- Buttressed walls are when a similar arrangement is provided at the front of the wall (in compression)
- Embedded Retaining Structures – consist of vertically driven sheets of piles that may be anchored, tied, propped or simply cantilevered
 - Driven sheet piles (timber, pre-cast concrete, steel) – flexible, usually for temporary works
 - Braced or propped walls
 - Contiguous bored-piled walls
 - Secant bored-piled walls
 - Diaphragm walls
- Reinforced and Anchored Earth
 - Reinforced earth walls (reinforcement, geotextile mesh) – used in sea walls etc.
 - Soil nailing – driven reinforcing bars with a facing of shotcrete
 - Ground anchors

1.5 Bearing Capacities

- Ultimate bearing capacity (q_f) is the intensity of bearing pressure that the soil can bear before failing (collapsing in shear)
- The net bearing pressure (q_n) is the net change in total stress experienced by the soil. i.e. the difference between the applied stress and the stress removed due to the excavation.
- Factor of safety against shear failure is usually = $\frac{\text{net ultimate bearing capacity}}{\text{net bearing pressure}}$
- 3 is preferred, but a minimum of 2.5 is normally required for building works
- Presumed bearing values for common soils;

Types of Soils	Bearing Capacity (kPa)
Hard Rocks	10,000
Slates	3,000
Chalk	600
Gravel	>600
Compact Sand	>300
Loose Sand	<100
Soft Clays and Silts	<75

Source: Whitlow, R. (2001)

References Used:

Whitlow, R. (2001), "Basic Soil Mechanics", Pearson Education Ltd, ISBN:0582-38109-6