AIR-1 Notes
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SOIL MECHANICS & FOUNDATION ENGINEERING

Handwritten notes by

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SOIL MECHANICS & FOUNDATION ENGINEERING

CONTENT

Soil Mechanics

→ Soil mechanics is the application of engineering mechanics in problems related to soil when used as a construction material & foundations on which we support our structures. It helps us to interpret the properties, behaviour & performance of various types of soil.

① Origin of soil
② Soil water relationship } Test①
③ Classification of soil } Test①
④ Clay mineral and Soil Structure
⑤ Compaction of soil → Test①
⑥ Permeability (** GATE)
⑦ Effective stress (** GATE)
⑧ Seepage (** GATE)
⑨ Compressibility and Consolidation → Test①
⑩ Shear strength of soil
⑪ Vertical stress (App^n)
⑫ Earth pressure theory (App^n)
⑬ Shallow foundation → Test① and Deep foundation → Test② (App^n)
⑭ Exploration, expansive soil, stability of slope. (App^n)

① Origin of Soil

→ Soil is an ~~unconsilat~~ unconsolidated material composed of soil particles produced by the disintegration of rock (gravel / Sand / silt/clay) or decomposition of vegetative (Organic Silt / clay) matter.

→ Formation of soil is due to disintegration and transportation of Igneous rock called parent rock or due to the decomposition of vegetative matter.

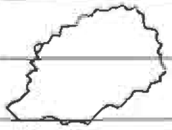
→ Disintegration of rock is due to weathering which are classified as:

(a) Physical weathering → Sand / gravel
(b) Chemical weathering → silt / clay

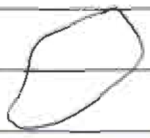
→ The physical weathering processes can be:

(a) Erosion of rock due to wind, water, glacier.
(b) Expansive force due to freezing water.
(C) Sudden change in temperature.
(d) Organic activity like growth of plant roots in existing cracks, rodents or worms etc.
(e) Unloading and resulting cracking.

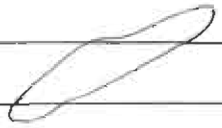
→ Soil formed by physical weathering has same mineralogical relationship and composition as that of parent rock.
→ Particles that are formed are bulky like sand and gravel.
→ The structural arrangement is called single grain structure
→ Single grain structure has no attraction or repulsion b/w the particles
→ Shape of particle formed are angular, rounded, elongated and flat



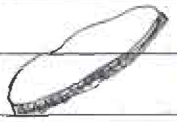
Angular
↳ Roughness more



Rounded
↳ Roughness ~~more~~ less



elongated
(low sphericity)



Flat

→ Quartz, Feldspar and Mica are primary soil minerals formed due to physical weathering.

(b) Chemical Weathering
→ The various chemical processes during chemical weathering are:
① Hydration - Reaction of minerals with H^+ and OH^- of water and these ions replace the existing cation.

② Oxidation - Acid produced during this process causes weathering

③ Carbonation - CO_2 in water dissolves minerals and they are carried away.

④ Desilication - Leaching of silica

NOTE: Leaching means when the water soluble parts are dissolved and washed out, the process is called Leaching.
In this process, mineral composition of the parent rock changes.

→ Chemical weathering process results in the formation of crystalline particles of colloidal size known as clay minerals like kaolinite, Illite and Montmorillonite.

NOTE: If -2 micron sized particles have cohesion b/w then it is called clay particle but if there is no cohesion then it is called clay-sized particle.

→ Most clay mineral particles have plate-like form. having high specific surface [high Surface area per unit volume or mass) with a result that the behavior is affected significantly due to presence of surface forces and hence water can significantly affect the behavior of clay.

⇒ Residual and Transported Soil

→ If the soil is still located at the place of it's origin, it is called residual soil and if it has been transported by wind, water or glacier it is called transported soil.

→ Residual soils have better engineering property and they have angular soil particles.

→ Laterite is an example of Residual soil, Black Cotton Soil

→ The transported soil have smaller grain particles and larger amount of pores.

→ Depending on the transporting agency soils are classified as.

① Alluvial soil → Transported by running water like rivers
② Lacustrine soil → Deposited in still water like lake
③ Marine soil → Deposited in sea water
④ Aeolian soil → Deposited by air, wind.
⑤ Glacial deposits - Transported by ice, glaciers.

→ Names of various types of soils

① Bentonite

It has high %age of clay mineral montmorillonite and it is highly plastic and results from the decomposition of volcanic ash Highly water absorbent and great swelling and shrinkage tendency

② Black Cotton soil

It is a residual soil consisting of high %age of Montmorillonite. It has low Bearing capacity and high swelling /shrinkage. It is formed by chemical weathering of Basalt Rock. It is dark in color and is good for growing cotton.

NOTE: Stabilisation of Black cotton soil is done using lime stabilisation and reduces plasticity hence ~~increases~~ makes the soil friable

③ Loess

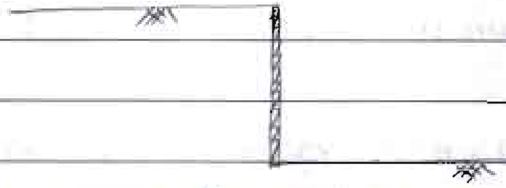
It is a fine grained (silty sized), homogeneous, friable (easily crushable)

NOTE:
< 2 μm → clay
2 μm - 75 μm → silt } fine grained
75 μm - 4.75 mm → sand
4.75 mm - 80mm → gravel } coarse-grained
80mm - 300mm ↳ Cobble
~~[illegible] Cobble~~
>300 mm - Boulder

Aeolian

air borne deposits having uniform grain size and high void ratio.

→ It can stand deep vertical cut because of slight cementation b/w particles due to $CaCO_3$ and Montmorillonite.



→ It has continuous root holes and hence permeability in vertical direction is much greater than that in the horizontal direction.

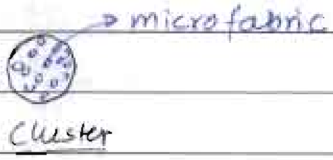
→ It is found in arid and semi-arid region and it is highly porous.

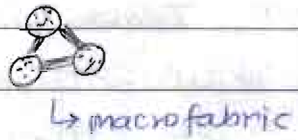
→ It is subjected to collapse when saturated.

→ It has loose meta-stable fabric [arrangement of particles], low density and high compressibility.

→ It has low Bearing capacity.

→ It's macro-fabric is bulky granular.





④ Till

→ It is an unstratified soil made by melting of glaciers.

→ The deposit consists of particles of different sizes ranging from boulder to clay.

→ It can be easily densified by compaction and it is a well graded soil.

→ It has high shear strength. Also known as boulder clay.

⑤ Marl

→ It is a stiff marine calcareous clay of greenish color.

⑥ Varved Clay

→ These are sedimentary deposits consisting of alternate thin layers of clayey silt and silty clayey

NOTE: Clayey Silt
Adjective Noun
Noun represents main component.

→ These clays are results of deposition in glacial lakes due to periods of alternating

→ Shear resistance of varved clay is much smaller along horizontal plane and hydraulic conductivity is much greater in horizontal plane as compared to vertical plane.

⑦ Indurated Clay

→ Induration means clay has become more firm and it does not soften under prolonged wetting.

NOTE: Induration is a term used to describe degree of Lithification
→ Lithification is the conversion of unconsolidated sediments into sedimentary rocks by porosity destruction through compaction and cementation.

⑧ Diatomaceous Earth

→ Diatoms are minute unicellular marine organisms.

→ Diatomaceous earth is a fine light grey soft sedimentary deposit of silicious remains of skeletons of diatoms.

⑨ Lateritic soil

→ Lateritic soils are formed by decomposition of rocks, removal of silica and accumulation of Iron and aluminium Oxides.

→ It is a residual deposit formed from basalt.

→ Presence of Iron oxide imparts reddish color and high specific gravity.
→ Generally it hardens with passage of time.

⑩ Marine Deposit

→ It has low shearing strength, high compressibility and contains organic matter. It is soft and highly plastic.

⑪ Colluvial soil

→ Gravity deposited soil. Also named as Talus. It has irregular and coarse particle.

⑫ Peat

→ It is an organic soil having fibrous particles formed from vegetative matter under conditions of excessive moisture.
→ It is highly compressible and not suitable for foundations.

⑬ Muck

→ Mixture of fine soil particles in highly decomposed organic matter and black in color and extremely soft in consistency.

⑭ Loam

→ Mixture of sand, silt and clay.

⑮ Hard Pan

→ It does not disintegrate when submerged in water and offers great resistance to penetration.

⑯ Tuff

→ It is a fine grained soil composed of particles ejected from volcanoes and deposited by wind and water.

⑰ Dispersive clay (Easily Erodable)

→ It occurs in soil of low and medium plasticity that contains montmorillonite.

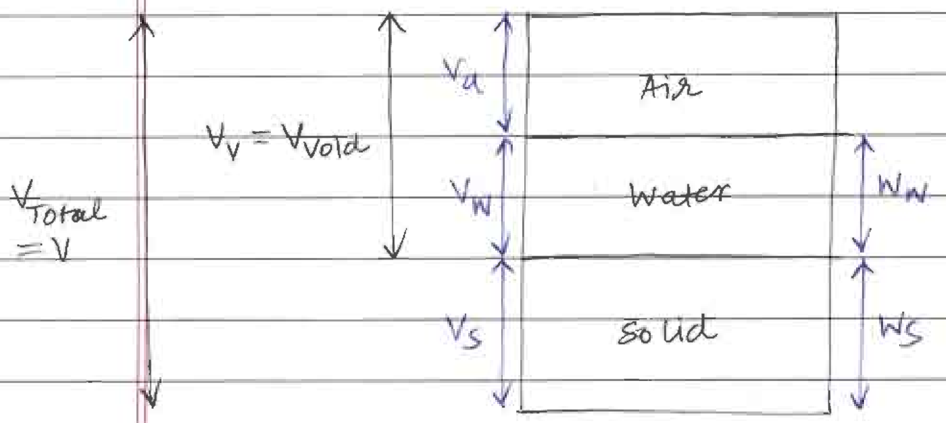
→ It is treated with lime to make it non dispersive.

⑱ Collapsing soil

→ Soil susceptible to large decrease in volume when saturated.

② Soil-Water Relationship

⇒ Phase Diagram of soil



→ Soil is generally a 3-phase system but completely saturated soil and completely dry soil are called 2-phase system.

⇒ Basic Definitions

① Water content $w = \frac{W_w}{W_s}$

NOTE: In Environmental Engg,

$$w = \frac{W_w}{W_w + W_s} = \frac{W_w}{W}$$

→ It has no upper limit and for dry soil it is zero.

→ Fine-grained soil have more moisture content than coarse grained soil.

② **Void Ratio** $e = \frac{V_v}{V_s}$

→ It has no upper limit

→ Void ratio of fine grained soil are generally higher than that of coarse grained soil although the size of void is large in case of coarse grained soil

NOTE: $e_{\cancel{clay}\ sand} \rightarrow 0.5 \text{ to } 0.7$
$e_{clay} \rightarrow 0.8 \text{ to } 0.9$ } generally

③ **Porosity** $n = \frac{V_v}{V}$

→ It's upper limit is 1.

→ If porosity is high density will be less.

④ **Degree of Saturation** $S = \frac{V_w}{V_v}$

→ For dry sole, $S = 0$ and for saturated soil, $S = 1$

⑤ **%age air void** $n_a = \frac{V_a}{V}$

⑥ **Air content** $a_c = \frac{V_a}{V_v} = 1 - S$

⑦ **Bulk Unit Weight** $\gamma_t = \frac{W_{Total}}{V_{Total}}$

⑧ **Unit weight of solid** $\gamma_s = \frac{W_{solid}}{V_{solid}}$

⑨ Unit wt. of water, $\gamma_w = \frac{W_w}{V_w} = 9.81\ kN/m^3$

⑩ Dry unit weight, $\gamma_d = \frac{W_s}{V_{Total}}$

→ γ_d is used as a measure of denseness of soil i.e. higher value of γ_d indicated that more solids are packed in the unit volume of soil and hence soil is more compacted.

⑪ Saturated unit weight, $\gamma_{sat} = \frac{\text{Weight of sat. soil}}{\cancel{\text{Weight}}\ \text{Volume of sat. soil.}}$

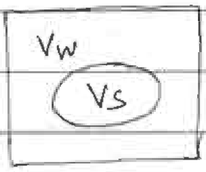
→ Saturated unit wt. will be a function of water content and as water content increases, γ_{sat} decreases.

⑫ Submerged unit weight, $\gamma_{sub} = \gamma_{sat} - \gamma_w$

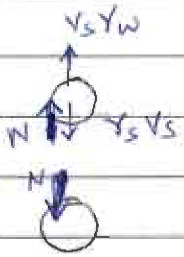
→ When the soil is submerged below ground water table, Buoyant force acts on the particle and hence,

$$\frac{\text{Buoyant weight}}{\text{Volume of soil}} = \gamma_{sub}.$$

→ $\gamma_{sub} \times V$ = Weight (Buoyant) of soil



$$\begin{aligned}\gamma_{sub} \cdot V &= (\gamma_{sat} - \gamma_w)V \\ &= \gamma_{sat} V - \gamma_w V \\ &= (\gamma_{sat} V_w + \gamma_{sat} V_s) - \gamma_w V_s - \gamma_w V_w \\ &= \cancel{\gamma_w V_w} + \gamma_s V_s - \gamma_w V_s - \cancel{\gamma_w V_w} \\ &= V_s(\gamma_s - \gamma_w)\end{aligned}$$



So, $N + V_s \gamma_w = \gamma_s V_s$

$$\Rightarrow \boxed{N = (\gamma_s - \gamma_w)V_s}$$

NOTE:

A saturated soil may not be submerged soil. like a soil saturated with capillary water is not submerged soil. Only soil below the water table is called submerged soil.

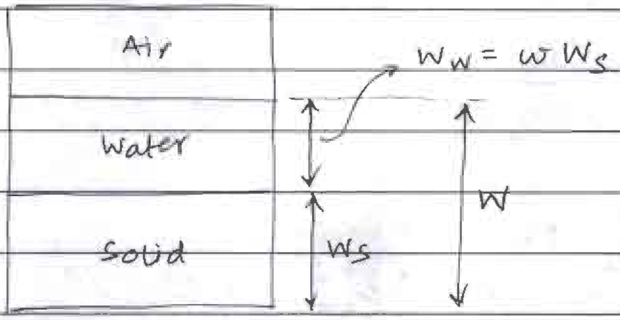
⑬ Specific gravity of solids $G_s = \frac{\gamma_s}{\gamma_w}$

→ Generally for inorganic soils, $G_s \in (2.6, 2.7)$
and for organic soils, $G_s \in (1.5, 2)$

→ Specific gravity of solids is also called absolute specific gravity or grain specific gravity

⑭ Mass specific gravity of soil, $G_m = \frac{\gamma_t}{\gamma_w}$ → bulk unit weight

⇒ Some important Relationship



① $W = W_s + W_w = W_s + w W_s$

⇒ $\boxed{W_s = \frac{W}{1+w}}$

② $V_v = e V_s$

So, $V = V_v + V_s = (1+e) V_s$ ⇒ $\boxed{V_s = \frac{V}{1+e}}$

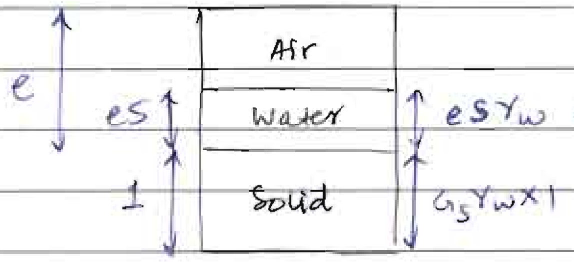
③ $n = \frac{V_v}{V} = \frac{e V_s}{(1+e) V_s} = \boxed{\frac{e}{1+e} = n}$

④ $e = \frac{V_v}{V_s}$ and $n = \frac{e}{1+e}$ ⇒ $n + ne = e$

⇒ $\boxed{e = \frac{n}{1-n}}$

⑤ $\boxed{eS = wG_s}$

⑥



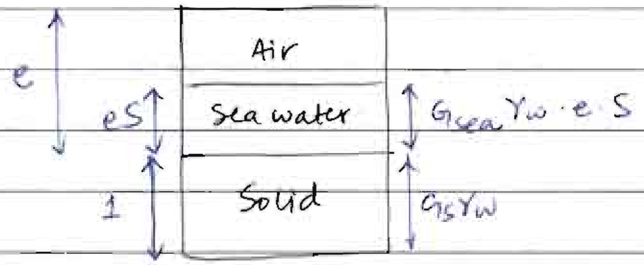
$eS\gamma_w = wG_s\gamma_w$

$$\boxed{\gamma_t = \frac{G_s\gamma_w(1+w)}{1+e}}$$

$$\gamma_t = \frac{G_s\gamma_w\left(1+\frac{eS}{G_s}\right)}{1+e}$$

$$\boxed{\gamma_t = \frac{\gamma_w(G_s+eS)}{1+e}}$$

⑦



So, $\boxed{\gamma_t = \frac{e\,\gamma_w(G_s + G_{sea}\cdot eS)}{1+e}}$

⑧ $\boxed{\gamma_{sat} = \frac{\gamma_w(G_s+e)}{1+e}}$

⑨ $$\gamma_{sub} = \gamma_{sat} - \gamma_w$$
$$= \frac{\gamma_w (G_s + e)}{1+e} - \gamma_w$$

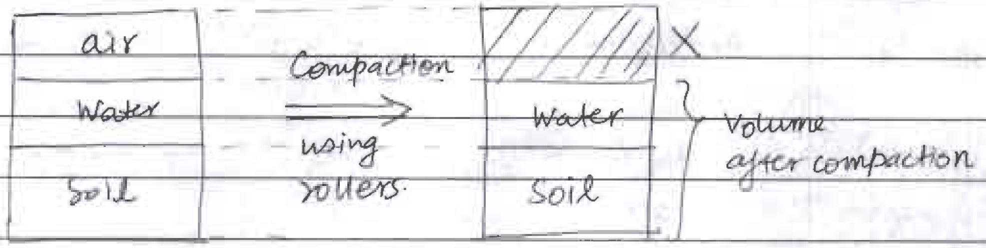
$$\boxed{\gamma_{sub} = \frac{(G_s - 1)\gamma_w}{(1+e)}}$$

⑩ $$\boxed{\gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{\gamma_t}{1+w}}$$

⑪ $$1 - n_a = 1 - \frac{V_a}{V} = \frac{V - V_a}{V} = \frac{V_w + V_s}{V} = \frac{W_w}{\gamma_w V} + \frac{W_s}{V G_s \gamma_w}$$
$$= \frac{W_s}{\gamma_w V}\left[w + \frac{1}{G_s}\right] = \frac{\gamma_d}{\gamma_w}\left(\frac{1 + w G_s}{G_s}\right)$$

$$\Rightarrow \quad \boxed{\gamma_d = \frac{G_s \gamma_w (1 - n_a)}{1 + w G_s}}$$

⑫



$$\boxed{\gamma_d = \frac{G_s \gamma_w}{1 + w G_s}}$$ → Zero air void Dry density.

Zero air void dry density is the theoretical maximum dry density at a particular water content. It can never be achieved practically.

Q. The total unit weight of a soil is 16 KN/m^3. The specific gravity of solid particle of soil is 2.67. Water content of the soil is 17%. Assuming $\gamma_w = 9.81$ KN/m^3. Calculate.