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Soil Mechanics

Soil → The unconsolidated material composed by solid particles & formed by physical, mechanical & chemical disintegration of rocks is called soil.

→ Soils consists of organic & inorganic material.

→ Eg: Clay, Silt, Sand, gravel etc.

Soil mechanics deals with the properties & behavior of soil as a structural material.

Classification of Soil

[A] Based on particle size

Type of soil	Particle size (mm)
① Clay	< 0.002
② Silt	0.002 — 0.06
Fine silt	0.002 — 0.006
Medium silt	0.006 — 0.02
Coarse silt	0.02 — 0.06
③ Sand	0.06 — 4.75
Fine sand	0.06 — 0.2
Medium sand	0.2 — 2.0
Coarse sand	2.0 — 4.75
④ Gravel	4.75 — 60
⑤ Pebbles	4.75 — 80
⑥ Cobbles	80 — 200
⑦ Boulder	> 200

[B] Based on Cohesion

① Cohesive Soil
→ Formed Chemical Weathering.
→ E.g. Clay, plastic silt etc.

② Non-Cohesive soil
→ Formed physical weathering.
→ E.g. Non-plastic silt, sand, gravel etc

[C] Unified Soil Classification Syste

→ This system uses both particle size & plasticity characteristics of soil.

① Coarse grained soil
→ if more then 50% of soil retained on 0.075mm sieve.

② Fine grained Soil

→ if more then 50% of soil passing on 0.075 mm sieve.

③ organic soil

→ Soil containing organic matter component of soil, Consisting of plant, animal residues at Various stage.

Note: Highly organic soil (peat) are not used in engineering work.

→ In this system soil are classified into 15 groups.

D Indian standard Classifaction system

→ It is similar to USCS, except in the Classifaction of fine grained so

→ ISCS classifies soils into 18 groups.

E Classifaction of transported soil

→ soil transported by river — Alluvial

→ Soil deposit by sea — Marine

→ Soil deposit by lake — Lacustrine.

→ Soil deposit by Wind — Loess, dune sand, aeoline.

→ soil transported by gravity — Colluvial soil, talus.

→ Soil formed by decay of vegetable — peat

→ soil deposited by glacier/ice → glacier drift.

→ Soil formed by disintegration of rock — residual soil.

F Some Special Soil:

① Mooram → mixture of iron, stone, gravel & red clay.

② Loam → mixture of Sand, silt & clay.

③ Bentonite → Volcanic ash which contain very high % of Clay minerals montmorillonite.

→ High shrinkage & swelling properties.

→ Used during the drilling of bore hole.

④ Black Cotton soil → High shrinkage & swelling characteristics.
→ Low bearing capacity.

⑤ Laterite → Soil having perforated & cellular structure.

⑥ Hardpan → Soil strata which remain hard when wet.

⑦ Top soil → Disintegrated surface materials which supports plant & animal etc.

⑧ Varied Clay → Alternate deposition of silt & clay.

⑨ Loess → Fine grained yellow coloured soil having cohesive nature.

Note : → clay is highly plastic.
→ soil is plastic due to clay minerals.
→ Due to chemical weathering cohesive soil is formed.
→ Due to physical weathering cohesionless soil is formed.

Grading of soils

→ Distribution of particles of different sizes in soil mass.

① Well (uniform) graded soil → soil contains particle of different sizes in good proportion.

② Uniform soil → Soil contains particle of almost same sizes.

③ Gap (skip) graded soil → Soil which contain particles size such that intermediate particles are missing.

Specific Gravity of soil

Soil type	Specific gravity
① Organic soil	< 2
② Inorganic soil	2.68 – 2.80
③ Silt	2.60 – 2.70
④ Silty sand	2.60 – 2.70
⑤ Sand	2.65 – 2.68
⑥ Gravel	2.65 – 2.68

Coefficient of Curvature

$$\boxed{C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}}$$

if $C_c = 1 - 3$, well graded soil. (sand & grave

where;

D_{30} = % of particle fine then D_{30}.

D_{60} = % " " " " D_{60}.

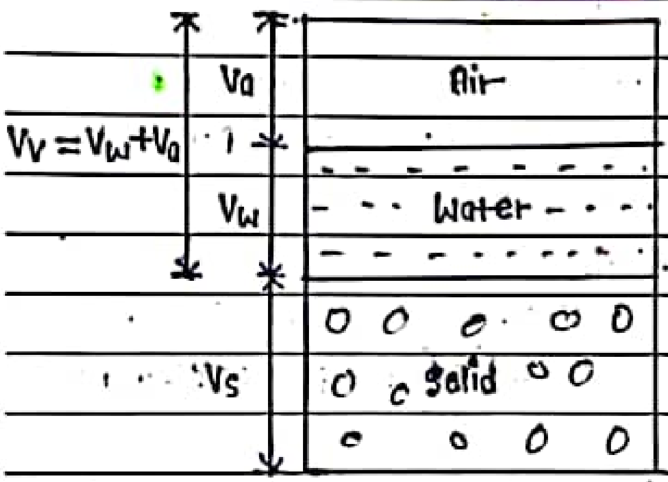
D_{10} = % " " " " D_{10}.

Uniformity Coefficient

$C_u = \frac{D_{60}}{D_{10}}$	if $C_u = 1$, Single graded soil
	$C_u < 2$, Uniform soil
	$C_u \doteq 2-4$, Poorly graded soil
	$C_u > 4$, Well graded soil (gravel)
	$C_u > 6$, Well graded soil (sand)

Three phase system of soil

→ Also known as block system.



fig; Three phase system

→ The diagram, which represents the three materials named soil, water & air is called three phase system.

→ The diagram, which represents the two materials either soil & water or soil & air (fully saturated or fully dried) is called two phase system.

→ Fully compacted & Consolidated soil is called one phase system.

→ $\boxed{\text{Total Volume } (V) = V_s + V_w + V_a}$ → Volume of soil.

Basic Terms

Volume Related terms

① Void ratio $(e) = \dfrac{\text{Volume of void } (V_v)}{\text{Volume of Solid } (V_s)}$

Case-I; $V_v = V_s \Rightarrow e = 1$

Case-II; $V_v > V_s \Rightarrow e > 1$

Case-III; $V_v < V_s \Rightarrow e < 1$

→ Void ratio may be equal, less or greater then one.

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② Porosity (n) = $\frac{\text{Volume of Void } (V_v)}{\text{Volume of soil } (V)}$

Case – I; $V_v \neq V$, $n \neq 1$
Case – II; $V_v \ngtr V$, $n \ngtr 1$
Case – III; $V_v < V$, $n < 1$

→ Porosity is always less then one.

③ Degree of Saturation (S) = $\frac{\text{Volume of Water } (V_w)}{\text{Volume of Voids } (V_v)} \times 100$

Case – I; Fully saturated soil, ($V_w = V_v$) ∴ $S = 100\%$
Case – II; Fully dry soil, ($V_w = 0$) ∴ $S = 0\%$
Case – III; partially saturated soil, $0 < S < 100\%$

→ It is expressed in percentage.

④ Air content (a_c) = $\frac{V_a}{V_v} \times 100\%$ = $\frac{V_v - V_w}{V_v}$ = $1 - \frac{V_w}{V_v}$ = $1 - S$

→ It is expressed in percentage.

⑤ percentage of air Void (η_a) = $\frac{\text{Volume of air } (V_a)}{\text{Total Volume of Soil } (V)} \times 100\%$

→ It is expressed in percentage.

Weight Related Terms

① Water content (w) = $\frac{\text{Weight of water } (W_w)}{\text{Weight of Solid } (W_s)} \times 100\%$ → Moisture Content

Note: Fine grained soil has more water content then coarse grained soil.

② specific gravity (G) = $\frac{\text{Weight of solid } (W_s)}{\text{Weight of water } (W_w)}$ or $\frac{\gamma_s}{\gamma_w}$

OR $G = \frac{\text{density of solid } (\rho_s)}{\text{density of water at } 4°C}$

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* **Bulk sp. gravity** $(G_m) = \dfrac{\gamma_s}{\gamma_w}$

→ Apperent sp. gravity.

* **Bulk/Moist/Wet density** $(\rho_{bulk}) = \dfrac{\text{Mass of soil (M)}}{\text{Total Volume(V)}}$

* **Density of solid** $(\rho_s) = \dfrac{M_s}{V_s}$

* **Dry density** $(\rho_{dry}) = \dfrac{M_s}{V}$

* **Density of water** $(\rho_w) = \dfrac{M_w}{V_w}$

* **Relative density** → It measures the degree of compaction of soil. → It is also called density index.

→ It is indicated by R_D or I_D.

$R_D = \dfrac{e_{max} - e_{natural}}{e_{max} - e_{min}}$

Where, e_{max} & e_{min} = Max^m & min^m Void ratio

$e_{natural}$ = Void ratio at natural state.

→ Applicable for cohesionless soil.

Case — I : When soil is in densest form, $R_D = 1$

Case — II : When soil is in [redacted] loosest form, $R_D = 0$

Case — III : When soil is in bet^n densest & loosest form, $0 < R_D < 1$.

Designation	Very loose	Loose	Medium	Dense	Very dense
I_D (%)	1 – 15	15–35	35–65	65–85	85 – 100

* **Saturated density** $(\rho_{sat}) = \dfrac{M_{sat}}{V}$

* **Submerged density** $(\rho_{sub}) = \dfrac{(M_s)_{sub}}{V}$ or, $\gamma_{sub} = \gamma_{sat} - \gamma_w$

→ It is also called buoyant density.

→ Submerged density is less then Saturated density.

* **Unit wt. of water** $(\gamma_w) = \dfrac{W_w}{V_w}$

* **Dry unit wt. of soil** $(\gamma_d) = \dfrac{W_s}{V}$

* **Unit wt. of solid** $(\gamma_s) = \dfrac{W_s}{V_s}$

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Important Relations

① $e = \frac{n}{1-n}$	⑤ $\gamma_d = \frac{G\gamma_w}{1+e}$
② $n = \frac{e}{1+e}$	⑥ $\gamma_{sub} = \frac{\gamma_w(G-1)}{1+e}$
③ $Se = wG$	⑦ $\eta_a = \frac{G(1-S)}{1+e}$
④ $\gamma = \frac{G\gamma_w(1+w)}{1+e}$	

Soil Water Relation

Types of Water in Soils

① **Gravitational Water** → The water flow due to force of gravity.

② **Free Water** → The Water that fill the void of soil mass.

③ **Capillary / Pore Water** → Water available for the growth of plant.
→ The water absorbed by plant roots.

④ **Hygroscopic Water** → The Water adhere on the surface of soil particles by making the thin layer.
→ can be removed by heating.

Method for Determination of Water Content

① **Oven Drying Method**

→ Most accurate laboratory Method.

→ Sample of soil is kept in oven at temperature 105°C to 110°C.

→ Sample of soil is kept in oven from a period of 24 hours.

② **Sand Bath Method**

→ Approximate field method.

→ Rapid but less accurate method.

③ Alcohol Method

→ Approximate field method.

→ Drying process completed by methylated spirit (alcohol).

④ Calcium Carbide Method

→ Quickest method (Fast method)

⑤ Pcynometer Method

→ This method is also [redacted] quick method.

→ It is used to determine water content for those soil whose specific gravity is known.

→ It is laboratory method.

→ Used for cohesionless soil only.

Particle size (grain size) Determination

① Sieve Analysis

→ Suitable for coarse grained soil.

→ e.g. sand, gravel etc.

② Sedimentation Analysis

→ Suitable for fine grained soil

→ eg; clay, silt etc.

→ stoke's law is used → Hydrometer Analysis is done

Consistency of Soil

→ It is the measure of firmness of soil.

→ measure the firmness of soil whether the soil is soft, hard or stiff.

→ Consistency of soil can be measured by atterberg limit.

→ Atterberg limit consists of ⓐ liquid limit

→ for cohesive soil ⓑ plastic limit

ⓒ Shrinkage limit

Note Book

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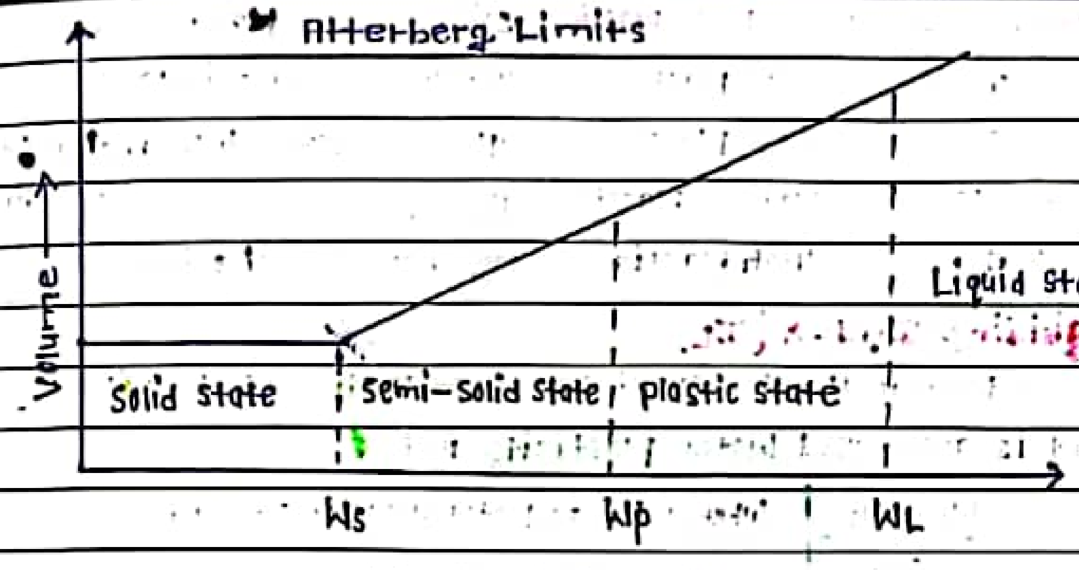
Atterberg Limits



① Liquid Limit (W_L)

→ Boundary of Water between liquid state & plastic state.

→ The water content at which soil is still in liquid state & posses very small shear strength.

→ It is determined by Casagrande apparatus. → 25 blow.

② Plastic Limit (W_p)

→ Boundary of water between plastic state & semi-solid state.

→ The water content at which soil just start to crumble (break) when rolled in to approximately 3mm in diameter.

③ Shrinkage Limit (W_s)

→ Boundary of water between semi-solid state & solid state.

→ The water content at which decrease in the water content & doesnot decrease in the volume of soil.

Soil Index

① plasticity Index (I_p)

→ $\boxed{I_p = W_L - W_p}$

Note: → if $W_p > W_L$, $\boxed{I_p = 0}$ plasticity index never be negative.

→ Cohesiveness of soil increase with increase of plasticity index.

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S.N	Plasticity Index	State of plastic	Soil	Nature
1.	0	Non-plastic	Sand, gravel	Cohesionless
2.	0–7	Low plastic	Silt	More cohesiven then sand
3.	7–17	Medium plastic	Silty clay	" " " silt
4.	>17	High plastic	Clay, shale	Cohesive

② Liquidity Index (I_L)

→ Used to indicate the consistency of undisturbed soil.

→ It is also called water plasticity index.

→ $I_L = \frac{W_n - W_p}{I_p}$ Where; W_n = Natural water content.

if I_L = -ve, soil is semi-solid or solid state.

if $I_L = 0$, soil is very stiff.

if $I_L = 1$, soil is very soft behaves like plastic.

if $I_L > 1$, soil is in liquid state.

③ Consitency Index (I_c)

→ $I_c = \frac{W_L - W_n}{I_p}$ Where; W_n = Natural water content.

if I_c = -ve, soil is liquid.

if $I_c = 0$, soil is in liquid limit

if $I_c = 1$, soil is in plastic limit

if $I_c > 1$, soil is in semi-solid state. i.e. it is stiff.

④ Shrinkage Index (I_s)

→ $I_s = W_p - W_s$

⑤ Flow Index

→ Slope of flow curve.

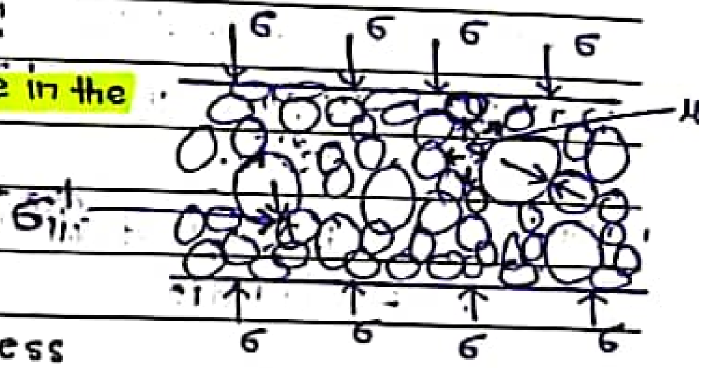
→ The graph betn water content & logs of blows is known as flow curve.

⑥ Toughness Index (I_T)

→ $I_T = \frac{I_p}{F}$

Terzaghi principle of Effective Stress

He states that "All measurable effect of changes such as compressive, shear strength, deformation, distortion are due to change of effective stress."



→ The measurable change in the soil is due to function of effective stress.

$\boxed{\text{Total Stress } (\sigma) = \sigma' + u}$

Where, σ' = Effective stress
u = pore water pressure

$\therefore \boxed{\sigma' = \sigma - u}$

→ The principle of effective stress is most important principle in soil mechanics.

Assumptions.

1. The soil is homogenous & isotropic
2. The soil is fully saturated.
3. The solid particles are incompressible.
4. Compression & flow are one-dimensional.
5. Strain in the soil are relatively small.
6. Darcy's law is valid for all hydraulic gradients.

Factor Affecting Effective Stress

→ Effect of water table fluctuation on effective stress.
→ Effective stress under hydrostatic condition.
→ Effective stress due to surcharge load.
→ " " in soil saturated by capillary action.
→ " " — seepage condition.
→ Quick sand condition.

Quick sand condition / Boiling sand

→ All the cohesionless soil looses the shear strength due to "zero effective stress" is the condition of quick sand.

→ At quick sand condition

Critical exit (hydraulic) gradient $\boxed{i_c = \frac{G-1}{1+e}}$

Where, G = sp. gravity of soil

e = void ratio

Darcy's Law

It states that "Velocity of flow through the soil mass is directly proportional to the hydraulic gradient."

$V \propto i$ — Where; V = velocity of flow

$\therefore V = ki$ — i = hydraulic gradient

$\therefore Q = VA = kiA$ — k = coefficient of permeability

→ Darcy's law is valid for — Q = Discharge

① Laminar flow — A = c/s area of soil mass ⊥ to flow.

② Saturated soil

permeability of soils

→ The flow of water through the void of soil mass is called permeability of soil.

→ A material which contains continuous void is said to be permeable.

Factors Affecting the permeability

① Type of soil

⟶ Coarse grained soil has more permeability then fine grained so

⟶ $\boxed{k = CD_{10}^2}$ $(\because k \propto D_{10}^2)$

Where, C = Constant

D_{10} = Effective grain size

② void ratio

→ $K = \frac{e^3}{1+e}$ → Void ratio increase, the permeability of soil also increase.

→ greater the void ratio, the higher value of coefficient of peremeability.

③ Entrapped air

→ $K \propto \frac{1}{\text{Entrapped air}}$

④ Degree of saturation

→ Fully saturated soil has more permeability then partially saturated

⑤ presence of impurities

→ presence of impurities, decrease the permeability of soil.

⑥ compaction.

→ proper compaction decrease the permeability of soil.

Types of soil	Coeff. of permeability (cm/sec)
Gravel	>1
Coarse Sand	$10^{-1} - 1$
Medium sand	$10^{-2} - 10^{-1}$
Fine Sand	$10^{-3} - 10^{-2}$
Silty sand	$10^{-7} - 10^{-3}$
Silt	$10^{-9} - 10^{-7}$
clay	$< 10^{-9}$

Coefficient of permeability

→ It is defined an average velocity of flow that will occur through the total cross-sectional area of soil under unit hydraulic gradient.

→ It is expressed in terms of cm/sec, m/day or ft/day.

Determination of Coefficient of permeability

[A] Laboratory Method

① Constant head Method

→ Suitable for coarse grained soil.

→ eg; Sand gravel etc.

→ $\boxed{k = \frac{VL}{HAt}}$ Where; V = Volume of Water

L = Length of soil sample

H = Head of Water

A = C/s area of soil sample

t = time taken for Collection of Water

② Variable or Falling head method

→ Suitable for fine grained soil.

→ eg; Clay Silt etc.

→ Usually unsaturated sample are tested.

→ $\boxed{k = \frac{aL}{A(t_2-t_1)} \log_e \frac{h_1}{h_2}}$ Where;

a = Cross-section of tube above soil sample

A = Cross-section of soil sample

t_1 = Intial time (0) | L = Length of soil sample

t_2 = Final time | h_1 = Initial head

h_2 = Final head

[B] Field Method

① pumping test ② Bore hole test ③ Recuperation test

Compaction of Soil

→ The process of removal of air from the Void of Soil.

→ The expulsion of air from the Void of air.

→ It is measured by proctor test.

Purpose of compaction

- → To increase the shear strength of soil.
- → To increase the dry density of soil.
- → To decrease the permeability of soil.
- → To increase the permeability of soil.
- → To minimize the shrinkage & swelling property.

Compaction	Consolidation
→ Artificial process.	→ Natural process.
→ Quick process.	→ Gradual process.
→ Dynamic load applied.	→ Static load applied.
→ Conducted in unsaturated soil.	→ Conducted in saturated soil.
→ Volume of soil is decrease	→ Volume of soil is decrease
by reducing the air voids	by expulsion of water from void

Factor Affecting the Compaction

① **Types of soil** → Coarse grained soil will be more compacted then fine grained soil for same amount of compaction.

② **Method of compaction** → Dynamic method of compaction gives more compaction then static method of compaction.

③ **Amount of compaction** → Amount of compaction increases the rate of compaction also increase.

④ **Water content** → The dry density of the soil increase with an increase, the water content upto omc, beyond omc if water content increase, the density will be decreases.

⑤ **Admixture** → By using the different admixture lime, cement bitumen etc can be increased rate of compaction.

Optimum Moisture Content (OMC) :
Optimum Water Content (OWC)

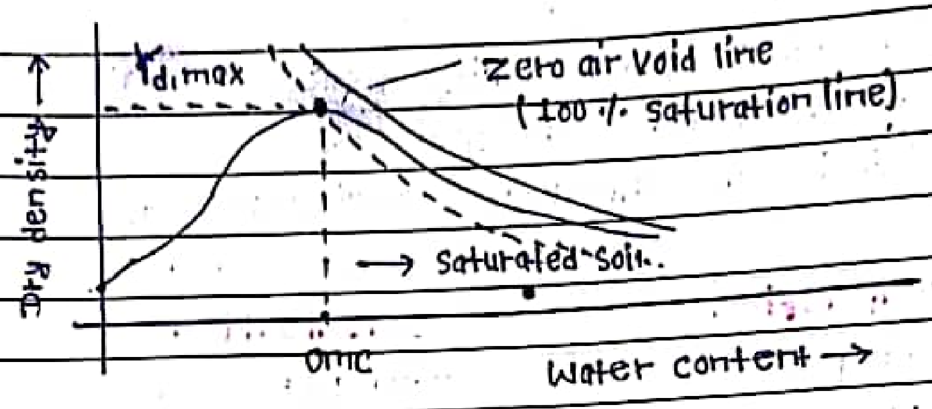


fig: Compaction curve

→ The water content at which maximum dry density occurs, the particular water content is known as OMC.

→ dry density of soil $(\gamma_d) = \dfrac{\text{Bulk unit wt } (\gamma)}{1+w}$

→ Compaction curve is plotted betn water content & dry density.

Soil	OMC for Compaction (Range %)
Clayey Sands, Sand-Clay mix	11 – 10
Sand-silt-Clay mix with plastic,	15 – 11
Silt + clay fraction	[illegible]
Inorganic silt, clayey silt	24 – 12
Inorganic clay	24 – 12
organic silt	33 – 21
Inorganic clay, highly plastic	36 – 19
organic clay	45 – 21

Zero air void line → A line which show the water content – dry density relation for compacted soil, containing a constant % of air voids is known as zero air void line.

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$\gamma_d = \frac{(1-\eta_a) G \gamma_w}{1+wG}$ When air void is zero,

$\therefore \gamma_d = \frac{G \gamma_w}{1+wG}$

Methods of compaction.

[A] Laboratory Method

S.N	Description	Standard proctor Test	Modified proctor Test
1.	Weight of ~~hammer~~	2.5 kg	5 kg
2.	Drop height	30 cm	45 cm
3.	Sample filling in layer	3	5
4.	Compaction of layer	25 blow	25 blow
5.	Face diameter of rammer	50 mm	50 mm

[B] Based on: Instrument used

① Smooth Wheel Roller → Suitable for cohesionless soil.

② Pneumatic tyred Roller :→ Suitable for cohesive & cohesionless soil.

③ Sheep foot Roller → Suitable for cohesive soil. (up to 30c

④ Vibrating Roller → Suitable for cohesionless soil for small thickness

⑤ Vibrating plate compactor → Suitable for cohesionless soil for large thickness. (> 30 cm) → Monkey Jumper → large area.

⑥ Rammer → Suitable for cohesive & cohesionless soil for small thickness & small area.

⑦ Vibrofloatation → Suitable for cohesionless soil for large thickness & small area

Consolidation

It is a process involving decrease in the water content of a saturated soil without replacement of the water by air.

→ It is measure by oedometer or consolidometer.

→ Unit of Consolidation is cm^2/sec. or $Inches^2/min$.

→ The opposite to Consolidation due to increase in Water Content or increase in Volume of Solid is Known as Swelling.

Types of Consolidation.

① Initial Consolidation

→ The reduction in the Volume of soil after application of load.

→ It is also known as immediate Consolidation.

→ for Saturated Soil it occurs due to Compression of Solid particles.

② Primary Consolidation

→ The reduction in the Volume of soil after completion of initial Consolidation due to expulsion of Water from Voids.

③ Secondary Consolidation

→ The reduction in the Volume of soil after completion of primary consolidation.

→ The quantity of Secondary Consolidation is Very Small.

Stage of Consolidated Soil

① Under Consolidated Soil

→ Soil is not fully Consolidated under existing over burden pressure.

→ Over Consolidated Ratio (OCR) < 1.

② Normally Consolidated Soil

→ Soil is fully Consolidated under existing over burden pressure.

→ OCR = 1.

③ Over Consolidated Soil

→ Soil is over Consolidated at present under the existing over burden pressure then in past.

→ OCR > 1.

Shear strength of soils

→ The shear strength of soil is maximum resistance to shear stresses just before the failure.

→ Also called shear resistance.

Columb's Law of shear strength

Assumption

→ Soil is homogeneous & isotropic.

→ Coefficient of permeability is constant.

→ Angle of repose is constant.

→ Angle of internal friction is constant. (ϕ)

→ Normal stress is independent of cohesion.

→ At zero normal stress, the shear stress of soil equal to cohesion

→ Strength envelope is a st. line starting from origin (cohesionless soil) & from co-ordinates (cohesive soil).

Principle

The shear strength of soil

$\tau = \sigma \tan\phi + c$ (cohesive soil) —— (i)

$\tau = \sigma \tan\phi$ (cohesionless soil) —— (ii)

Where;

τ = Shear strength of soil

σ = Normal stress

ϕ = Angle of internal friction

c = cohesion

From eqⁿ (i)

eqⁿ (i) compare with $y = Mx + C$

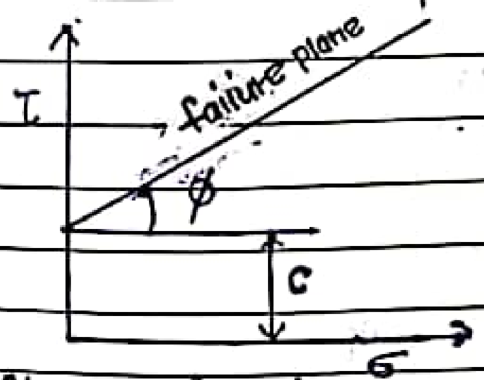


fig: cohesive soil

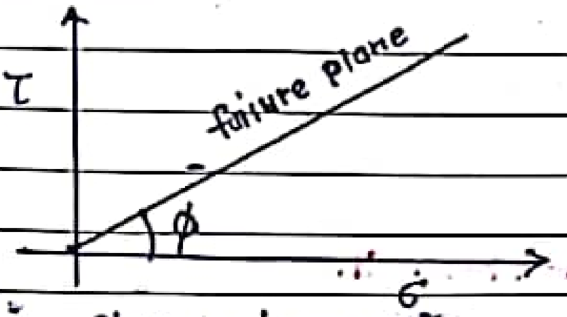
$$\tau = \sigma \tan\phi + c$$

$$\tau - c = \sigma \tan\phi$$

$$\tan\phi = \frac{\tau - c}{\sigma}$$

$$\therefore \boxed{\phi = \tan^{-1}\left(\frac{\tau - c}{\sigma}\right)}$$

From eqn (II) : eqn (II) Compare with $y = mx$, . . .



$\tau = \sigma \tan\phi$

$\tan\phi = \frac{\tau}{\sigma}$

$\therefore \boxed{\phi = \tan^{-1}\left(\frac{\tau}{\sigma}\right)}$

fig: Cohesionless soil

Note : The slope of failure plane $= \tan\phi$

Important Terms

① Adhesion → It is the attraction betn two or more molecules of different liquid / material.

→ Example; surface of glass tube, water etc.

② Cohesion → The property of soil holding its grain together.

③ Angle of internal friction → The measure of the resistance of soil to sliding along a plane.

④ Angle of repose → if mass of earth or other material is left exposed to weather for some time, it side will sleep & gradually attain a stable slope without tending to slide.

→ The angle betn horizontal & it slope is called angle of repose

→ The numerical value of angle of repose varies 0 – 90°

Clay (wet excavated)	15°	
Clay (lump)	25–40°	
Gravel (loose dry)	30–45°	
Gravel (natural)	25–30°	
Flour (wheat), Chalk, Sand (wet)	45°	
Sand (dry)	34°	
Sand (wet filled)	15–30°	
Sand (wet)	45°	
Snow	38°	
Ashes	40°	

Earth pressure,

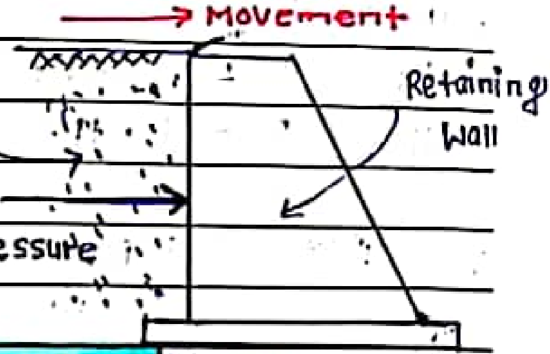
Lateral Earth pressure

→ The pressure exerted by soil on any retaining structure (i.e. retaining wall, Gabbion etc) is known as lateral earth presure

① Active pressure

→ if the retaining wall moves away from the backfill.

→ Backfill moved towards the retaining wall.



→ Active earth pressure $(P_a) = K_a \gamma H$

Where; γ = Unit wt. of soil

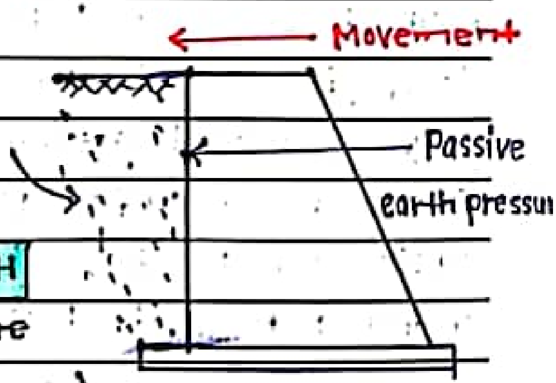
H = depth of soil

K_a = Coefficient of active earth pressure.

$$\therefore \boxed{K_a = \frac{1-\sin\phi}{1+\sin\phi}} = \tan^2(45 - \phi/2)$$

② passive Earth pressure

→ if the retaining wall moves towards the backfill.



→ passive earth pressure $\boxed{(P_p) = K_p \gamma H}$

→ K_p = coeff. of passive earth pressure

$$\boxed{K_p = \frac{1+\sin\phi}{1-\sin\phi}} = \tan^2(45 + \phi/2)$$

③ Pressure at rest

→ No movement of wall.

→ pressure at rest $\boxed{(P_0) = K_0 \gamma H}$

$\therefore \boxed{K_p > K_0 > K_a}$, $\boxed{K_a \times K_p = 1}$

Where;

K_0 = coefficient of pressure at rest

$\boxed{K_0 = 1 - \sin\phi} = \frac{\mu}{1-\mu}$

→ μ = poission ratio

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Coefficient of earth pressure

$K = \dfrac{\text{Horizontal stress } (P)}{\text{Vertical stress } (\gamma H)}$

Note : Total Lateral Earth pressure

$P_a = K_a \gamma H$	$P_p = K_p \gamma H$	$P_0 = K_0 \gamma H$

$\therefore$ $H = 0$, $P_a = 0$

at $H/2$, $P_a = K_a \gamma * H/2 = \frac{1}{2} K_a \gamma H$

at H, $P_a = K_a \gamma H$

$\therefore$ Total lateral earth pressure = Area of pressure diagram

$$\boxed{T = \frac{1}{2} K_a \gamma H^2}$$

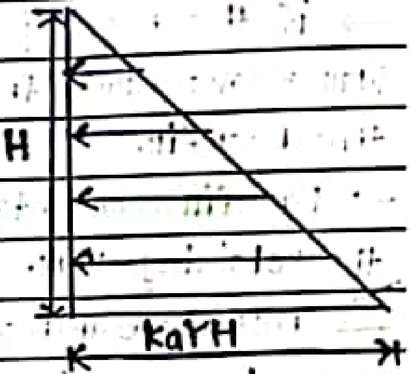


fig: pressure diagram

① Total lateral earth pressure, $T \propto H^2$

② Lateral earth pressure $\propto H$

Rankine's Earth pressure Theory

Assumptions

① The backfill soil must be dry, cohesionless, homogeneous, isotropic & semi-infinite.

② The back of the retaining wall is smooth & vertical.

③ The ground surface is plain, which may be horizontal, vertical or inclined.

④ There is no friction betn back of wall & backfill soil.

Principle

Ⓐ Cohesive soil

① Active earth pressure

$$\boxed{P_a = K_a \gamma H - 2c\sqrt{K_a}}$$

② Passive earth pressure

$$\boxed{P_p = K_p \gamma H + 2c\sqrt{K_p}}$$

(B) Cohesionless soil

① Active earth pressure	② passive earth pressure
$\boxed{P_a = K_a \gamma H}$	$\boxed{P_p = K_p \gamma H}$

$\therefore (C = 0)$

Note: ① Height of point of zero pressure, $\boxed{H = \frac{2C}{\gamma}}$

② Unsupported height of cut $\boxed{(H_c) = \frac{4C}{\gamma}}$ → critical height

Foundation Engineering

Foundation : Foundation is the lowermost part of structure that transfers load from superstructure to sub-soil which is in direct contact to sub-soil.

Types of Foundation

① Shallow Foundation	② Deep Foundation
→ if $\frac{\text{depth}}{\text{Width}} \le 1$	→ if $\frac{\text{depth}}{\text{Width}} > 1$
(a) Isolated footing	(a) pier foundation
(b) combined footing	(b) Well foundation
(c) strip footing	(c) pile foundation
(d) Strap footing	
(e) Grillage footing	
(f) Mat foundation.	

Bearing capacity

→ The supporting power of the soil.

→ The resisting power of the soil.

Types of Bearing Capacity

① **Ultimate bearing Capacity (q_u):** It is the max^m soil pressure at the base of foundation at which soil fails in shear.

② **Net ultimate bearing capacity (q_{nu}):** It is the max^m soil pressure in excess of overburden pressure at the base of foundation at which soil fails in shear. $q_{nu} = q_u - \gamma D_f$

③ **Net safe bearing capacity (q_{ns}):** It is the safe soil pressure at the base of the foundation in excess of overburden pressure which soil will resist safely without any risk of shear failure.

$$q_{ns} = \frac{q_{nu}}{FOS}$$

④ **Gross safe bearing capacity (q_s):** It is the maximum gross pressure which the soil can carry safely without shear failure. $q_s = q_{ns} + \gamma D_f$

Factors Influencing Bearing Capacity

① **Type of foundation** → Deep foundation increase bearing capacity more then shallow foundation.

② **Size of foundation** → Higher the width of footing greater will be the bearing capacity because of larger area.

③ **Depth of foundation** → An increase in the depth of foundation will result in an increase in surcharge q at the base level of the foundation, leading to increase in bearing capacity.

④ **Shape of foundation**

Modes of Foundation Failure

① General shear failure

→ It occurs mostly in dense sand & stiff clay.

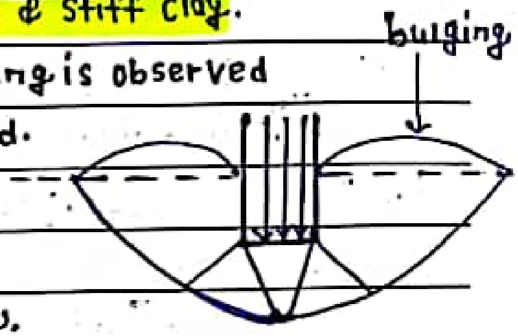
→ At the time of failure large bulging is observed

→ Very less settlement is observed.

→ found in shallow foundation.

→ Very well defined failure pattern.

→ sudden failure is observed by tilting.



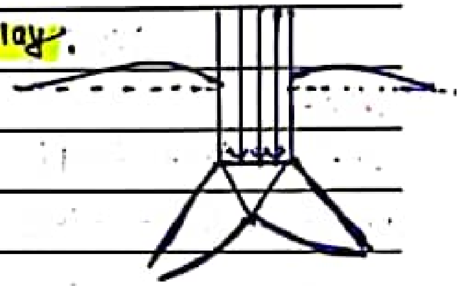
② Local shear failure

→ It occurs in medium dense sand & Clay.

→ No or very less bulging is observed.

→ Large settlement is observed.

→ failure surface does not reach to ground.



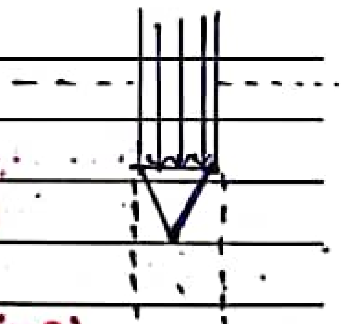
③ punching shear failure

→ It occurs in loose sand or soft clay.

→ No bulging of soil.

→ Very large settlement is observed.

→ Found in shallow & deep foundation.



Terzaghi's principle of General Bearing Capacity

Assumption

→ The soil is homogenous, isotropic & Coulomb's low of shear strength is valid.

→ The footing has rough base.

→ failure zone does not extend above the base of foundation.

→ Shear resistance of soil above the base of foundation is neglected.

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→ Footing is continuous & shallow.

→ Two dimensional eqn held good.

Principle

Ultimate bearing capacity for shallow strip footing for general shear failure is

$$\boxed{q_u = CN_c + \gamma D_f N_q + 0.5 B \gamma N_\gamma}$$

where; C = Cohesion

γ = Unit wt of soil

B = Width of foundation

D_f = Depth of foundation

N_c, N_q, N_γ = Bearing capacity factors

Note:

① for square footing, $\boxed{q_u = 1.3CN_c + \gamma D_f N_q + 0.4 B \gamma N_\gamma}$

② for circular footing, $\boxed{q_u = 1.3CN_c + \gamma D_f N_q + 0.3 B \gamma N_\gamma}$

for local shear failure

$$C = \tfrac{2}{3}C$$

$$\phi = \tfrac{2}{3}\tan\phi$$

Bearing capacity of different soil

Cohesionless soil

Gravel, sand & gravel	45 ton/m²
Coarse sand compacted & dry	45 ton/m²
medium sand	25 ton/m²
Loose gravel or sand gravel	25 ton/m²
Fine sand & silt	15 ton/m²
Fine sand, loose & dry	10 ton/m²