# "SOIL" - INTRODUCTION

## Soil :-

To an, engineer, soil is the unaggregated or uncemented deposits of mineral and/ organic particles produced by the disintegration of rocks.

The void space betn the particles may contain air, water or both.

## Soil Engg. :-

Branch of civil engg. involving the study of soil, its behaviour & application as an engineering material.

It deals with all engg. problems related with soil

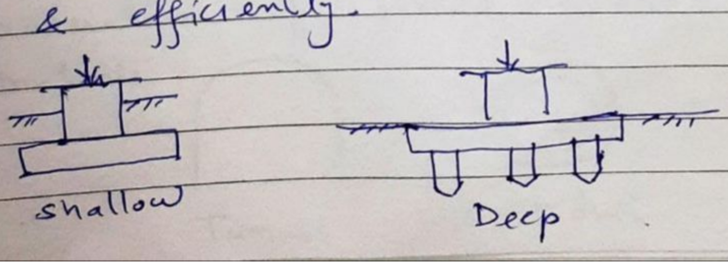
→ Site investigations.
→ Design & construction of fdn.
→ Earth retaining structures.
→ Earth structures etc

Geotechnical engg. is a broader term, which includes soil engg. rock mechanics & geology

## → Importance of Soil Engineering :-

### (1) Foundations :-

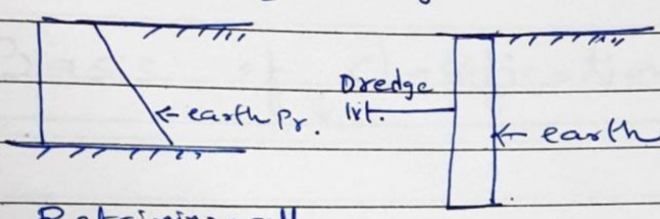
Any structure founded on or below the surface of earth. Fodn are required to transmit the load of structure of soil & safely & efficiently.



## 2. Retaining structures :-

When sufficient space is not available for a mass of soil to spread & form a safe slope, a stru. is req. to retain the soil

→ may be rigid retaining wall or sheet like bulkhead which is relatively flexible.

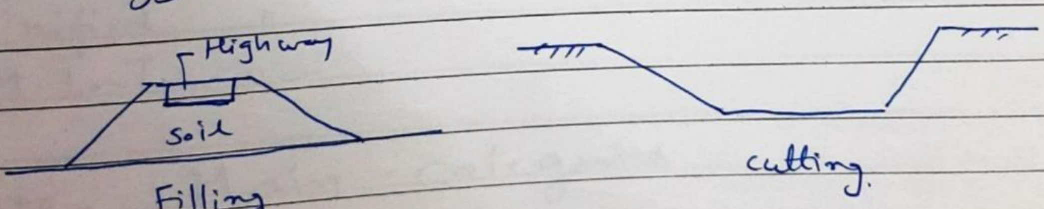



Retaining wall

sheet pile

## 3. Stability of Slopes :-

If soil surface is not horizontal, there is a component of wt. of soil which tends to move it downwards & causes instability of soil. It may natural or Manmade. Soil Engg. provides methods for checking & stability.

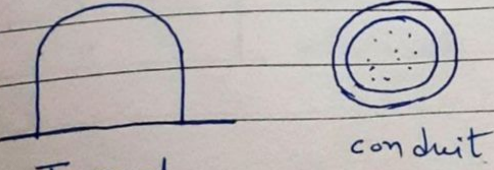



Filling

cutting.

## 4. Underground structure :-

.. like tunnels, shafts, conduits require evaluation of forces exerted by soil on these structures.

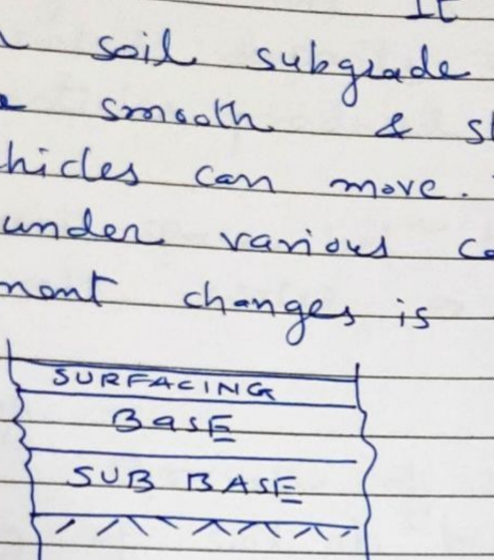


conduit

Tunnel

## 5. Pavment design :-

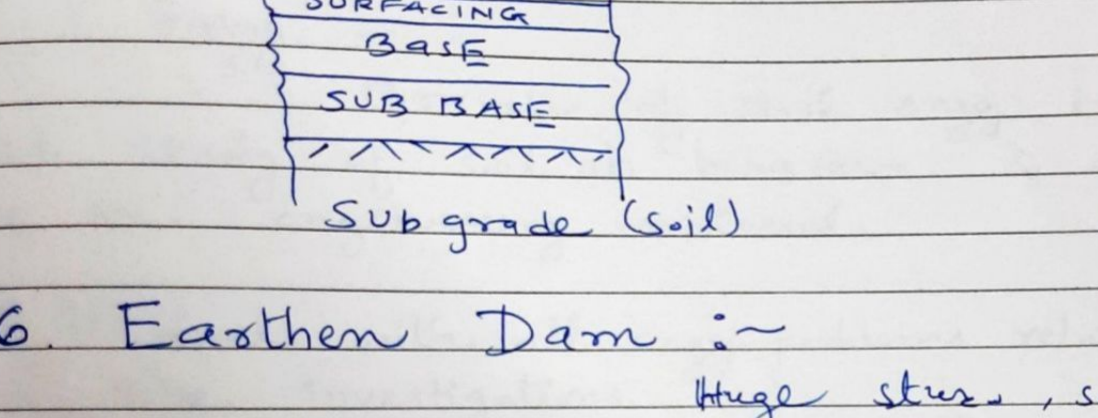
It is a hard crust placed on soil subgrade for the purpose of providing a smooth & strong surface on which vehicles can move. The behaviour of subgrade under various conditions of loading & environment changes is studied in Soil Engg.



Subgrade (Soil)

## 6. Earthen Dam :-

Huge strucs., soil is used as a construction material. They are built for creating water reservoirs. Design of earthen dam requires a knowledge of Soil Engg.



Earth Dam

## → Fundamental Use of Soil.

| As a construction material | As a foundation |
| --- | --- |
| • Highway embankment | Building |
| • Railway " | Bridge |
| • Earth dam | Highway, |
| • Filling in low lying areas. | Canals, Dam, Tunnels. |

# Soil Formation in Geological Cycle :

By weathering of rocks due to mech. disintegration or chemical decompositions. When a rock surface gets exposed to atmosphere for an appreciable time, it disintigrates or decomposes into small particles & thus soils are formed.

- Erosion
- Transporation
- Deposition
- Upheaval

Weathering :

- Temp. changes
- Wedging "
- Spreading of roots of plants
- Abrasion

- Hydration
- carbonation
- Oxidation
- solution

Cohesionless soil are formed by physical weathering
cohesive soil " chemical ".

- chemical Weathering :-

Hydration
water with rock mat.

Carbonation
CO2 with water

Oxidation
O2 with rock mat.

Solution
Rock minerals form a sol with water

# (2)
# Soil- Classification

it is the arrangement of soil groups such that soils in a particular group have similar behaviour.

carried out by several agencies for diff$^n$ purposes.

For engg. point. To find suitability of soil for const. of dams, highways / or foundations.

## Basis of classification of soils.

- Particle size
  - useful for cohesionless soil
  - Methods of class$^n$.
    1. I. S. class$^n$
    2. International "
    3. Unified "
    4. M. I. T. "
- Consistency
  - useful for cohesive soil
  - Methods of class$^n$.
    1. I. S. plasticity chart.

→ Three Main categories

| Coarse | Fine | Highly Organic |
|---|---|---|
| >50% of total Mat. wt. is larger than 75 Micron (0.075 mm) IS s. | " " " smaller than 75 " " | contain large % of fibrous organic matter i.e peat, shells cinders etc |

→ I. S. classification

| | |
|---|---|
| > 300 mm | Boulder |
| 80 mm to 300 mm | cobble |
| 20 to 80 mm | Coarse gravel |
| 4.75 to 20 | Fine gravel |
| 2. to 4.75 | Coarse sand |
| 0.425 to 2 mm | Medium " |
| 0.075 to 0.425 | Fine " |
| ~~0.075 to~~ . | |
| 0.002 to 0.075 | Silt |
| < 0.002 | clay. |

→ Diff$^n$ Bet$^n$ Coarse grained & Fine grained

| | Coarse grained | Fine grained |
|---|---|---|
| 1. | > 50% of the total mat. by wt. is larger than 75 micron IS sieve | > 50% of the total mat. by wt. is smaller than 75 micron IS sieve. |
| 2 | sand, gravel cobbles | clay. silt fine sand. |
| 3 | cohesionless | Cohesive |
| 4. | Doesn't have plasticity property | possess plasticity property |
| 5 | Very small amount of adsorbed water | large amount of adsorb water |

# Grain size distribution by Sieve Analysis.

Depending upon max. size of material present qty. in soil, wt. of soil sample ~~max~~ for analysis may be as follows:-

| Max. size | wt. to be taken (Kg) |
|---|---|
| 63 | 50 |
| 20 | 6.5 |
| 10 | 1.5 |
| 4.75 | 0.375 |

→ Sieve the sample retained on 4.75 mm ....

→ Determine wt. of mat. retained on each sieve

→ Same way sieve the dried mat. passing th. 4.75 mm & retained on 75 Mic.

- Duration : 10 min.
- Find wt. of mat. retained on each sieve.
- Calculate % of soil retained on each sieve on the basis of total wt.
- Det. the % passing th. each sieve.
- Draw curve for passing Vs size of particles. known as particle size Dist. curve or Grading curve

## Particle size distribution Curve :-

it is plotted with % passing as ordinate and the particle size as abscissa (on log scale) also called grading curve. represents the dist. of particles of diff^n sizes in the soil mass.

(1) Uniformity co-efficient (Cu)

It is a measure of particle-size ranges and is given by the ratio of a $D_{60}$ to $D_{10}$ sizes.

$D_{60}$ = Particle size such that 60% of the soil is finer than this size.

$D_{10}$ = " " " " 10% " " "
(also known as effective size)

- The larger numerical value of Cu, the more is the range of particles.

- Soil with a value of Cu, less than 2 are uniform soils.

- Sands with Cu >6, are well-graded
- Gravels with Cu > 4, are well graded

## Co-efficient of Curvature (Cc) :-

The factor representing the shape of particle size curve is ----

$$\boxed{Cc = \frac{D(30)^2}{D60 \times D10}}$$

where
$D_{30}$ = Particle size corresponding to 30% finer.

- For well graded soil, the Cc is betn 1 & 3.

## USE OF PARTICLE SIZE DIST. CURVES.

1. Co. of permeability can be determined from this.
2. It is required for design of drainage filters.
3. classification of coarse grained Soils.
4. To know the susceptibility of a soil to frost act.
5. Provide an index to the shear strength of soil
6. Useful for soil stabilisation & for the design of pavements.

→ Particle size dist. curves for diffn Types of soil

1. Particle size of diffn size in good prop. Well graded
2. If it has an excess of certain particles - Poorly "
3. Some intermediates size missing - Gap "
4. A curve higher up & to left. relatively fine grained
5. Curve to right indicates coarse grained --

Consistency Limits :-

It is a physical state in which it exists. Used to denote degree of firmness of soil. like soft, firm stiff or hard.

In 1911, Swedish agriculture engineer Atterberg mentioned a fine grained soil can exist in four states,

(1) Liquid (2) plastic (3) Semi-solid or Solid.

The water contents at which the soil changes from one state to other ---

→ Liquid limit :- ($W_L$)

containing high water,
no shear strength
can flow like liquid

As the w.c is reduced, the soil becomes stiffer & starts developing resistance to shear deformation

Water content at which soil starts getting shear strength or cease to be liquid or it change from one stage to plastic change

→ Plastic limit :— ($W_p$)

as the mini. w.c. at which a soil will just begin to crumble when rolled into as

3 Shrinkage limit :—

w.c. at which soil changes from semi-solid to solid ....

- It is the max. w.c. which soil doesnot remain saturated, ....

→ Plasticity Index ($I_p$)

The numerical diffⁿ betⁿ L.L & P.L. is ..

$$\therefore \quad I_p = W_L - W_P$$

→ Imp. property for an Fine-grained soils.

→ Shrinkage Index :-

The numerical diffⁿ betⁿ plastic & shrinakage limit.

$$I_s = W_p - W_s$$

→ Liquidity Index :-

$$I_L = \frac{W - W_p}{I_p} \times 100$$ Where $W$ = w.c. in natural condition

When soil is at liquid limit $I_L = 100\%$, behave as liquid.

" " " $I_L = 0$, behave as Semi-Solid.

→ Consistency Index ($I_c$)

$$I_c = \frac{W_L - W}{I_p}$$

→ When soil at plastic limit, $I_c = 100\%$, indi:- relatively firm.
$I_c = 0$, " soft, less s.s. (shear strength)

$$\boxed{I_L + I_c = 0.}$$

→ I.S. plasticity chart :-

symbol used in I.S. plasticity chat are.

| | |
|---|---|
| C - clay | H - High plasticity |
| M - Silt. | I = Med " |
| O - Organic soil | L = Low " |

CH - clay with high plasticity
MI - Silt " Med. "
OL - Organic soil with Low plasticity.

From I.S. plasticity chart, fine grained soil is subdivided into 3 categories.

| | | sy. |
|---|---|---|
| (a) Silts & clays of low Compressibility, | $W_L < 35$, | L |
| (b) " & " Med. " | $W_L = 35$ to $50$, | I |
| (c) " " High " | $W_L > 50$. | H |

(3)

# COMPACTION

Defination :-

It is a process by which soil particles are artificially rearranged and packed together into a closer state of contact by mechanical means in order to decrease the void ratio (or porosity) of the soil & thus increase its dry density.

The process may be accomplished by rolling, tamping or vibration. Air during compaction is expelled from the void space in the soil mass and, therefore the mass density is increased. Compaction of soil mass is done to improve the engineering properties.

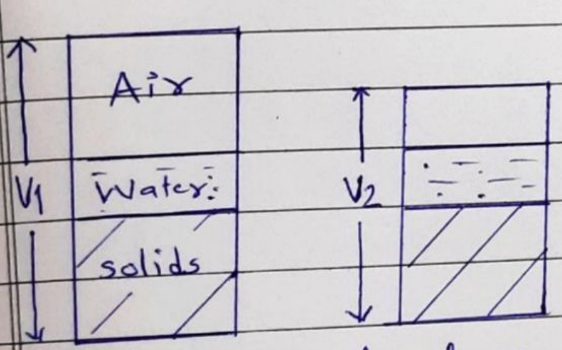
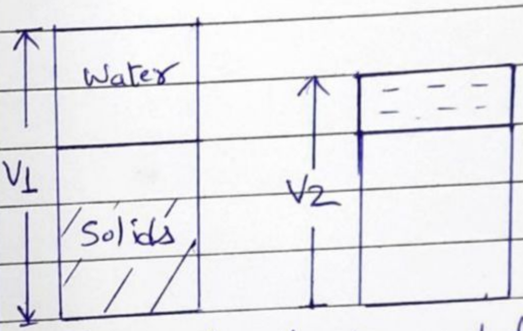
Effect of Compaction on soil properties :-

1. Increase in shear strength & bearing capacity.
2. Decrease in permability & Compressibility.
3. Danger of settlement ↓
4. Due to ↑ in ~~stability~~ density of structures like dams, embankments for road, canals railway etc ↑

→ Consolidation :-

When soil is fully saturated, compression of soil occurs mainly due to explusion of water from the voids static pressure. This process is ...

→ Due to escape of water, solid particles shift from one position to another by rolling & sliding & thus attain a closer state of packing.

| | Compaction | Consolidation |
|---|---|---|
| 1 | soil particles are artificially rearranged & packed to gater in a closer state of contact | When the soil is fully saturated, compression of soil occurs mainly due to explusion of water from the voids under static pressu |
| 2. | ↓ in vol. due to removal of air from voids. | ↓ in vol. of soil is due to removal of water from voids. |
| 3 |  |  |
| 4 | Dynamic load, ie rolling, tamping, vibration. | The load is static. |
| 5 | rapid process. | very slow. |
| 6 | Artificial process | Natural process. |

→ Compaction Curve :-

In 1993, R.R. Proctor showed definite relationship betn soil water & dry density. Soil sample was compacted in a cylinder of volume 1000 cc at diffn w/c & dry densities were obtained.

$\gamma_d = \dfrac{\gamma_b}{1+\omega}$ where $\gamma_d$ = dry density

$\gamma_b$ = bulk " $= W/V$

$W$ = wt of wet soil

$V$ = vol. of soil (1000 cc)

$\omega$ = water content of soil.

Compaction curve is plotted betn w.c. as abscissa and dry density as ordinate. Dry density ↑ in ↑ w.c. till max. density is attained. With further ↑ in w.c., dry density ↓

At low w.c. the soil is rather stiff & has lot of void spaces & ∴ $\gamma_d$ is low. As w.c ↑, soil particles get lubricated & slip over each other. & move into densely packed positions & dry density is ↑.

However, at a w.c. more than optimum, the additional water reduces the dry density.

→ M.D.D. and O.M.C.

With increase in w.c., initially the $\gamma_d$ ↑, & becomes maxi. With further ↑ in w.c. $\gamma_d$ ↓.

The water content at which dry density is max. is called O.M.C.

→ The $\gamma_d$ corresponding to O.M.C. is called ...

Range of O.M.C. for sand - 6 to 10%
→ " " silty " - 8 to 12%
silt - 12 to 16%
clay - 14 to 20%

→ Zero air void line OR Saturation line :-

For a given w.c. theoretical max. density is obtained, when there are no air voids. (i.e. Sr is 100%.) The line showing the $\gamma_d$ as a function of w.c. for soil containing no air voids is called Zero air voids line or the Saturation line.

$$\gamma_d = \frac{G.\gamma_w}{1+e}$$

$$\therefore \gamma_d = \frac{G.\gamma_w}{1+\frac{wG}{S_r}} \quad \text{but } S_r = 1$$

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

Note: 100% air voids not removed. so it is theoritical density is only hypothetical.

If $Sr = 90\%$, the eq$^n$

$$\gamma_d = \frac{G.\gamma_w}{1 + \frac{wG}{0.9}}$$

In terms of % air voids ($n_a$)

$$\gamma_d = \frac{(1 - n_a).G.\gamma_w}{1 + w.G}$$

## → Standard Proctor Test :~ (I.S. 2720 Part 7 1965)

To establish relationship bet$^n$ w.c. & $\gamma_d$ by light compaction test.

Equipments :- compaction mould, 1000 ml. cap.
Rammer, mass 2.6 kg, 50 mm $\phi$, 310 mm freefall
Detachable base plate.
Collar, 60 mm high.
I.S. sieve 4.75 mm size.
oven, desicator, wt. balance.
Large mixing pan.
st. edge, spatula
Graduated jars,
Mixing tools, spoons trowels etc

Methods :- 1) about 20 kg of soil passing the 4.75 mm sieve,

2) Add water to it to bring w.c. as per type of soil. Leave it in air tight for 18 to 20 hrs.

3. Divide the soil in 6 to 8 parts.
4. clean & dry the mould & base plate. Grease. Take empty wt. of mould
5. Take @ 2.5 kg of the processed soil, & placed it in the mould in 3 equal layers. Each layer is compacted by std. rammer of 2.6 kg mass & 310 mm free fall giving 25 blows.
6. Remove the collar & trim off the excess soil projecting above the mould using a straight edge.
7. Determine wt. W1
8. Take the soil sample for the water content determination & determine water content.
9. Add @ 3% of water to a fresh portion of processed soil & repeat above steps.
10. Determine bulk density & dry density.

$$\gamma_b = W/V$$

$$\gamma_d = \frac{\gamma_b}{1+w}$$

OBSERVATIONS TABLE

| SR.No. | Obs. | Sample Numbers 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1. | Wt. of empty mould = $W_1$ | | | | |
| 2. | " + compacted soil = $W_2$ | | | | |
| 3. | Wt. of comp. soil = $W = W_2 - W_1$ | | | | |
| 4. | Bulk density $\gamma_b = W/V$ gm/cm³ | | | | |
| 5. | Water content = $w$ % | | | | |
| 6. | Dry density = $\gamma_d = \frac{\gamma_b}{1+w}$ gm/cm³ | | | | |

# Factors Affecting Compactions.

## 1) Water content :-

↓ w.c., the soil is stiff & offers more resistance to compaction.

↑ w.c. the soil particles get lubricated, becomes more workable & particles have closer packing.

→ Dry density ↑ with ↑ in w.c. till O.M.C. is reached. With further ↑ w.c. the air voids do not ↓ total voids (air + water) ↑ & dry density ↓.

## 2. Amount of Compaction :-

↑ compactive energy. ↑ $\gamma_d$ & ↓ OMC

However, the ↑ in M.D.D. does not have a linear relationship with ↑ of compactive effort.

## 3. Type of soil :-

Depends on by types of soil.

- Coarse grained soils can be compacted to higher dry density than fine grained soil.
- A well graded sand attains a much higher $\gamma_d$ than poorly graded soil.
- cohesive soil have high air voids, these soil attains a relatively lower max. $\gamma_d$ as compared with cohesionless soils.

4. Method of Compaction :
$\gamma_d$ depends on wheather the method of compaction utilizes kneading action, dynamic or stationary action.

5 Thickness of layer :~
In Lab. soil layer. 30 to 40 mm
field 200 to 300 mm.
lesser thickness of soil layer gives higher $\gamma_d$.

6 Saturation line :~
If all air voids are removed from the soil by compaction, the soil becomes fully saturated & higher max. dry density is achieved. ∴ saturation below 100% results in lower max. $\gamma_d$. Practically 100% sat. not possible.

7 Admixtures:-
By adding some admixtures, improved $\gamma_d$. The most commonly are lime, cement....

8 Stone Content :~
With addition of aggregate of 20 to 30 mm size upto 40% volume, the $\gamma_d$ ↑.

# Methods of Field Compaction

1. Rolling 2. Ramming 3. Vibrations-

1. Rolling. - Diff. types of rollers are used for compaction of soil. compaction depends on following factors.

- contact pressure.
- No. of passes. (5 to 15)
- Layers thickness. (< 15 cm)
- speed of roller.
- Diff. Types of rollers used are.

(i) Smooth wheel rollers :-

For compacting granular base courses of highways & runways.

- not effective for compaction of deep layers.

(ii) Pneumatic Type rollers :-

Useful for compacting cohesive as well as cohesionless soil.

(iii) Sheep Foot Rollers :-

Ideally suited for cohesive soils.

The rollers compact the soil by the combination of tamping & kneading action.

(iv) Vibratory Roller :-

For granular soils.

2) Ramming :~

Hand operated rammer consists of a block of iron, 3 to 5 kg in mass. attached to a wooden rod.

- much heavier @ 30 to 150 kg.
- to compact soils adjacent to existing structures or confined areas such as trenches, within plinth of buildings etc

3 Vibrations :~

Vibrator is mounted on a drum, It is called a vibratory rollers.

Mains use is to compact granular base for highway and runways where thickness of layer is small.

Ex:1 Following observations were recorded in Lab. Draw compaction curve & find OMC & MDD.

| Sr. No. | w.c. | $\gamma_b$ kN/m³ |
|---|---|---|
| 1 | 6 | 16 |
| 2 | 8 | 17.3 |
| 3 | 10 | 20.0 |
| 4 | 14 | 18.8 |

Solⁿ.

$$\gamma_d = \frac{\gamma_b}{1+\omega}$$

$$\gamma_{d_1} = \frac{16}{1+0.06} = 15.0 \text{ kN/m}^3$$

$\omega_1 = 6\%$

2. $W_2 = 8\%$ $\quad \gamma_{d2} = \frac{17.3}{1+0.08} = 16.02\ kN/m^3$

3 $w_3 = 10\%$ $\quad \gamma_{d3} = \frac{20.0}{1+0.10} = 18.18\ kN/m^3$

4 $w_4 = 14\%$ $\quad \gamma_{d4} = \frac{18.8}{1+0.14} = 16.49\ kN/m^3$

| Sr no. | w/c | $\gamma_d$ ($kN/m^3$) |
|---|---|---|
| 1 | 6 | 15.09 |
| 2 | 8 | 16.02 |
| 3 | 10 | 18.18 |
| 4 | 14 | 16.49 |

# SHEAR - STRENGTH

When soil is loaded, shearing stresses are induced. When it reaching a limiting value, shear deformation take place, leading to failure of soil mass.

↓

Sinking of footing or wedge behind retaining wall or slide in earth embankment.

→ S. S. is resistance to deformation by continous shear displacement of soil

→ Imp. engg. property.

→ Cohesion :—

Attraction bet$^n$ the molecules of same mat. (soil) is --

particles adhere to each other.

ex. Dry sand.

It depends on

1. Finness of clay particles
2. Type of clay mineral
3. Amount of clay
4. water content.

→ Internal Friction :—

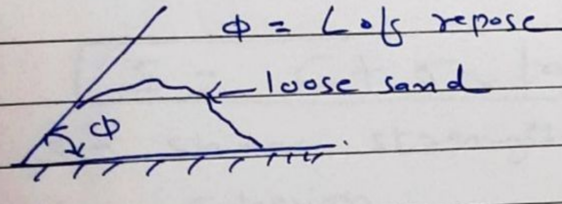
Internal resistance bet$^n$ the individual soil particles at their contact points is ---

3 → Angle of Internal Friction :-

It represents the frictional resistance bet$^n$ the soil particles, which is directly $\propto$ to the normal stress.

Angle of Internal Friction depends on
1) Shape of particles
2) Roughness of surface
3) Denseness of soil
4) Denseness of soil.
Uniform sand, $\phi$ lies betn 27° to 37°
Well graded " , 30° to 44°.

Angle of repose :-
The $\angle$ made by an inclined surface of a heap of granular materials like sand with horizontal is called ....




Shear strength :-
resistance to deformation by continous shear displacement of soil particles upon the action of a shear stress.
It consititutted basically ....
(1) The structural resistance. ($\because$ interlocking of particles)
(2) The frictional resistance ($\because$ Translocation betn indi. soil particles at their contact pts.)
(3) Cohesion, betn the surface of the soil particles

# coulomb's Law For Shear strength

As/ Mohr's the failure is caused by a critical combination of the normal & shear stresses.

$S = f(\sigma n)$

A plot betn $\tau$ & $\sigma n$ at failure, is a curved line.

The s.s. (S) of a soil at a point on a particular plane was expressed by coulomb as a linear function of normal stress on that plane as

$\boxed{S = C + \sigma n . \tan\phi}$ coulomb's eqn.

S - shear strength

c - cohesion

$\sigma n$ - normal stress

$\phi$ - Angle of internal friction

# Types of Soil Based on Total Strength

1) cohesionless soil ($\phi$- soil)

- don't have cohesion, $\therefore C=0$
- S.S. from intergranular friction
- also called frictional soils.
- $S = \sigma_n \cdot \tan\phi$

ex. Sand & Gravels.

2) Purely cohesive soil (C- soil)

- exhibits C, but $\phi = 0$
- Called C- soils.
- eq $S = C$.

ex. saturated clays.

3) Cohesive frictional soils (C- $\phi$ soil)

- C & $\phi$ Both values
- called C- $\phi$ soils
- eqn

$S = C + \sigma_n \tan\phi$

ex. clayey sand, silty sand sandy clay

# Mohr circle Method For Shear Strength of Soil

coulomb considered relation betn s & $\sigma_n$ is linear

Mohr " " " curved

The fig. shows three dim. soil element,

$\sigma_1$ = Major principal stress
$\sigma_3$ = Minor " "
$\sigma_2$ = Intermediate " "

In fig. two dim. soil element, failure makes $\angle \theta$ with major plane. The eqn. is

$$\sigma_n = \frac{(\sigma_1 + \sigma_3)}{2} + \frac{(\sigma_1 - \sigma_3)}{2} \cos 2\theta$$

$$\tau = \frac{(\sigma_1 - \sigma_3)}{2} \sin 2\theta$$

The magnitude of $\tau$ is max. when $\theta = 45°$ or $135°$

$\therefore \tau_{max} = (\sigma_1 - \sigma_3)/2.$

# Tests for shear strength.

1. Direct shear test (Box shear)
2. Triaxial Compression Test
3. Unconfined " "
4. Vane shear test

In shear tests, there are 2 stages.

1. Consolidation stage :– Here, normal stress (confining pressure) is applied to the specimen and it is allowed to consolidate.

2. Shear stage :– Shear stress is applied to specimen to shear it.

Shear tests based on drainage Conditions

1. Unconsolidate un-drained Test (UU Test)

no drainage is permitted during consolidation stage & shear stage also.

As no time is allowed for consolidation of or dissipation of excess pore water pressure, the test can be conducted quickly in a few minutes.

(Quick Test Q- Test)

## Consolidated Un-drained Test. (CU Test)

Consolidate in the 1st stage
Drainage is permitted until the consolidation is complete.

In 2nd stage specimen is sheared, no drainage is permitted.
(called R Test)

Q use for quick Test.
S " " slow Test
R falls betn Q & S.

## Consolidated drainged test (CD test)

To Consolidate in 1st stage to sample when it is completed, it is sheared at a very slow rate to ensure that fully drained condition exist & the excess pore water is zero.

(called S. Test. slow Test).

→ Direct Box shear Test. (In soft copy)

Merits :-

1. preparation is easy, simple & Convenient.
2. th. of sample is quick & pore press. dissipates, very rapidly so CD & CU takes relatively small period
3. Ideally conducted for cohesionless soils.
4. apparatus is cheap.

## Demerits :-

→ The stress dist. is not uniform
more at edges & less in centre.
Thus full strength of soil is not mobilised

→ Area under shear ↓ as test progresses.
But corrected area can't be determined &
i.e. Original area is taken for calⁿ of stress.

→ stress condition are known only at failure.

→ The orientation of failure plane is predetermined. This may not be weakest plane.

→ Measurement of pore water is not possible

→ control of drainage is very difficult.
only drained Tests can be conducted on highly permeable soils.

→ The side wall of shear box cause lateral restraint on specimen and don't allow it to deform laterally.

# Examples.

ex.1 Find s.s. of cohesionless if $\sigma_n$ is 2 N/mm² & $\phi$ - 30°

Soln:- For cohesionless $c = 0$, $\sigma_n = 2\ N/mm^2$

As per coulomb's eqn.

$$S = c + \sigma_n \cdot \tan\phi$$
$$= 0 + 2 \cdot \tan 30°$$
$$= 1.154\ N/mm^2$$

$$\boxed{S = 1.15\ N/mm^2}$$

ex.2 During direct shear test on c-$\phi$ soil, soil fails s. stress 16 kN/m² & $\sigma_n$ 20 kN/m² $\phi = 27°$, Find c. of soil

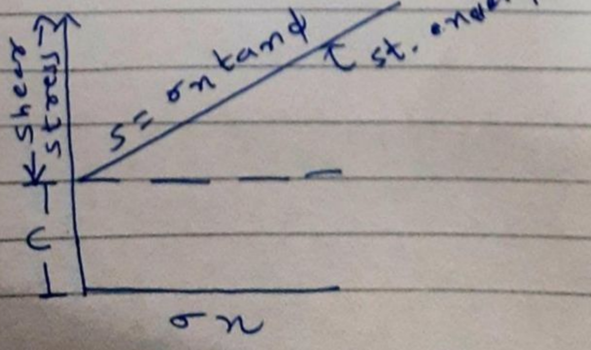
Soln:-
$$S = 16\ kN/m^2$$
$$\sigma_n = 20\ kN/m^2$$
$$\phi = 27°$$

$$S = c + \sigma_n \tan\phi$$
$$16 = c + 20 \cdot \tan 27°$$

$$\boxed{c = 5.82\ kN/m^2}$$

ex- State Coulomb's law for s. strength

$$S = c + \sigma_n \cdot \tan\phi$$



# Examples on
## Index properties of Soil

3/3/21

**ex: 1** Given data:-

(1) $V = 200\ cm^3$

(2) $W = 320\ gm$

(3) $Wd = 280\ gm$

(4) $Ww = 320 - 280 = 40\ gm$

Find:- (1) $W_c$ (2) $\gamma_b$ (3) $\gamma_d$

Solⁿ:- (1) $W_c = \frac{Ww}{Wd} \times 100\%$

$= \frac{40}{280} \times 100 = \boxed{14.28\ \%}$

(2) Bulk density - $\gamma_b = \frac{W}{V} = \frac{320}{200} = \boxed{1.60\ g/cm^3}$

(3) Dry density - $\gamma_d = \frac{Wd}{V} = \frac{280}{200} = \boxed{1.40\ g/cm^3}$

$\boxed{\text{OR} \quad \gamma_d = \frac{\gamma_b}{1+w}} = \frac{1.60}{1+0.1428} = \boxed{1.40\ g/cm^3}$

ex: 2 Given data :-

(i) $\omega = 34\% = 0.34$

(ii) $G = 2.7$

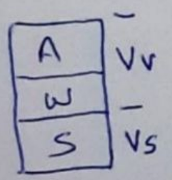
(iii) $\gamma_w = 1.0\ gm/cc$ OR $10\ kN/m^3$

Find (i) void ratio (e) (ii) Dry density ($\gamma d$) (iii) Bulk density $\gamma b$

Sol$^n$ :- (i) Void ratio (e) =

$$\boxed{WG = e.S_r}$$

યાદ રાખો :- When sample is fully saturated then value of $S_r = 1$




$e = \frac{Vv}{Vs}$

$$e = \frac{WG}{S_r} = \frac{0.34 \times 2.7}{1} = \boxed{0.918}$$

(ii) Dry density :- $(\gamma d) = \frac{Wd}{V}$

$$\boxed{\gamma d = \frac{G.\gamma_w}{1+e}} = \frac{2.7 \times 1}{1+0.918} = \boxed{1.407\ gm/cm^3}$$

(iii) Bulk density $(\gamma b) = \frac{W}{V}$

$$\gamma d = \frac{\gamma b}{1+w}$$

$$\therefore\ 1.407 = \frac{\gamma b}{1+0.34} = \boxed{1.88\ gm/cm^3}$$

3/3/21

3 Given data:-

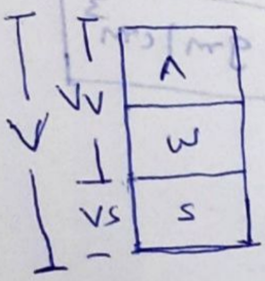
(i) $W = 38\% = 0.38$

(ii) $G = 2.7$

(iii) $S_r = 1$

Find (i) Void ratio (e) (ii) Porosity (n)

$$e = \frac{V_v}{V_s} \qquad n = \frac{V_v}{V}$$



$$\boxed{WG = e\,S_r}$$ 2 No.

$$e = \frac{WG}{S_r} = \frac{0.38 \times 2.7}{1} = \boxed{1.026}$$

(ii) $$\text{Porosity } (n) = \frac{e}{1+e} = \frac{1.026}{1+0.26} = \boxed{0.506}$$

---

ex: 6 Given data:-

$(e) = 0.9$, $G = 2.6$, $S_r = 0.8$, Density of water $= 1\, g/cc$

$\gamma_w = 1.0\, g/cc$

Find: w, $\gamma_b$, $\gamma_d$

Sol^n: $WG = e \cdot S_r$

$$\therefore e = \frac{w \cdot G}{S_r}$$

$$0.9 = \frac{w \times 2.6}{0.8} \quad \therefore \boxed{w = 27.7\%}$$

$w = 0.277$

(II) $$\gamma_d = \frac{G \cdot \gamma_w}{1+e} = \frac{2.6 \times 1}{1+0.9} = \boxed{1.368\ g/cc}$$

(III) $$\gamma_d = \frac{\gamma_b}{1+w} \quad \therefore 1.368 = \frac{\gamma_b}{(1+0.277)}$$

3) 5

ex: 9 given :- $W = 600$ gm
$V = 350$
$w = 20\%$
$G = 2.7$, $\gamma_w = 1$ gm/cm$^3$

Find. void ratio (e) & Dry density.

Sol$^n$:

$$\gamma_b = \frac{W}{V} = \frac{600}{350} = \boxed{1.714 \text{ gm/cm}^3}$$

$$\gamma_d = \frac{\gamma_b}{1+w} = \frac{1.714}{1+0.20} = \boxed{1.428 \text{ gm/cm}^3}$$

$$\gamma_d = \frac{G.\gamma_w}{1+e}$$

$$\therefore e = \frac{G.\gamma_w}{\gamma_d} - 1 = \frac{2.7\times 1}{1.428} - 1 = \boxed{0.89}$$

---

ex: 10 given :- $n = 30\%$
$G = 2.7$

Find. (i) = e, (ii) $\gamma_d$

Sol$^n$. ① void ratio $(e) = \frac{n}{1-n} = \frac{0.30}{1-0.30} = \boxed{0.428}$

(2) Dry density $(\gamma_d)$

$$\gamma_d = \frac{G.\gamma_w}{1+e} = \frac{2.7\times 1}{1+0.428} = \boxed{1.89 \text{ g/cm}^3}$$

3)

15 given: $G = 2.75$

$W = 2.05$ kg

$\omega = 18\%$

$V = 950$ cc.

Find (1) $n$, (2) $e$ (3) $Sr$ (4) $\gamma d$

Solⁿ:

$$\gamma b = \frac{W}{V} = \frac{2.05 \times 1000}{950} = 2.157 \text{ gm/cm}^3$$

(1) $$\gamma d = \frac{\gamma b}{1+\omega} = \frac{2.157}{1+0.18} = \boxed{1.828 \text{ gm/cc}}$$

(2) $$\gamma d = \frac{G \cdot \gamma w}{1+e} = \frac{2.75 \times 1}{1+e} = 1.828$$

$$\therefore e = \frac{2.75 \times 1}{1.828} - 1 = \boxed{0.957}$$

(3) $$n = \frac{e}{1+e} = \frac{0.957}{1+0.957} = \boxed{0.489}$$

(4) $$WG = e \cdot sr$$

$$\therefore Sr = \frac{W \cdot G}{e} = \frac{0.18 \times 2.75}{0.957} = 0.517 = \boxed{51\%}$$

ex: $e = 0.5$, $G = 2.7$, $\gamma w = 1.0$ gm/cc. - Find. $n, \gamma d, \gamma sat$

Solⁿ: i) $$n = \frac{e}{1+e} = \frac{0.5}{1+0.5} = \boxed{0.333}$$

2) $$\gamma d = \frac{G \cdot \gamma w}{1+e} = \frac{2.7 \times 1}{1+0.5} = \boxed{1.8 \text{ gm/cm}^3}$$

3) $$\gamma sat = \frac{(G+e)\gamma w}{1+e} = \frac{(2.7+0.5)1}{1+0.5} = \boxed{2.13 \text{ gm/cm}^3}$$

ex:2 given: $\omega = 45\% = 0.45$

$\omega_L = 52\%$

$\omega_P = 27\%$

Find. $I_P, I_L, I_C$

$I_P = \omega_L - \omega_P = 52 - 27 = 25\%$

$$I_L = \frac{\omega - \omega_P}{I_P} = \frac{45-27}{25} = 0.72.$$

$$I_C = \frac{\omega_L - \omega}{I_P} = \frac{52-45}{25} = 0.28$$

---

ex:3 effective grain size $[D_{10}] \rightarrow 0.15$ mm

30% finer size $[D_{30}] \rightarrow 0.40$ mm

60% finer size $[D_{60}] \rightarrow 0.82$ mm

Find $C_u$ & $C_c$

(i) $$C_u = \frac{D_{60}}{D_{10}} = \frac{0.82}{0.15} = 5.47$$

(ii) $$C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}} = \frac{(0.40)^2}{0.82 \times 0.15} = 1.30$$

(i) $W_P = 20\%$

(ii) $W_L = 60\%$

(iii) $\omega = 50\%$

Find $I_P$, $I_L$

(i) $I_P = W_L - W_P = 60 - 20 = 40\%$

(ii) $I_L = \dfrac{\omega - W_P}{I_P} = \dfrac{50 - 20}{40} = \dfrac{30}{40} = 0.75$

Ex:6 given: $\omega = 24\%$, $\omega_L = 49\%$, $W_P = 28\%$

$D_{60} = 0.06\ mm$, $D_{30} = 0.04\ mm$, $D_{10} = 0.008\ mm$

Find = $I_P$, $C_u$, $C_c$, $I_c$

sol^n: (i) $I_P = 49 - 28 = 21\%$ —— (1)

(ii) $C_u = \dfrac{D_{60}}{D_{10}} = \dfrac{0.06}{0.008} = 7.5$ —— (2)

(iii) $C_c = \dfrac{(D_{30})^2}{D_{60} \times D_{10}} = \dfrac{(0.04)^2}{0.06 \times 0.008} =$

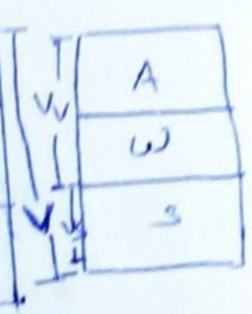
(iv) $I_c = \dfrac{W_L - \omega}{I_P} = \dfrac{49 - 24}{21} = 1.19$

19/1/21 (1)

# Derive Equations.

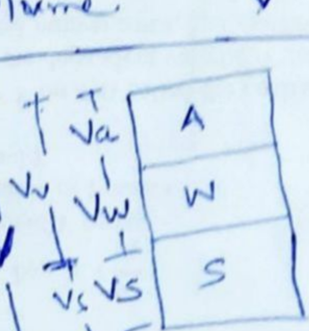
(1) $e = \frac{n}{1-n}$ OR $n = \frac{e}{1+e}$

**Porosity** $= \frac{\text{Vol. of Voids}}{\text{Total volume}} = \frac{V_v}{V}$




$n = \frac{V_v}{V}$

$n = \frac{V_v}{V_v + V_s}$




$\frac{1}{n} = \frac{V_v + V_s}{V_v}$

$\frac{1}{n} = \frac{V_v}{V_v} + \frac{V_s}{V_v}$

$\therefore e = \frac{V_v}{V_s}$

Void ratio =

$\frac{1}{n} = 1 + \frac{1}{e}$

$\therefore \frac{1}{n} = \frac{e+1}{e}$

$$\boxed{\therefore n = \frac{e}{e+1}}$$

$$\boxed{e = \frac{n}{1-n}}$$

Now $n(e+1) = e$

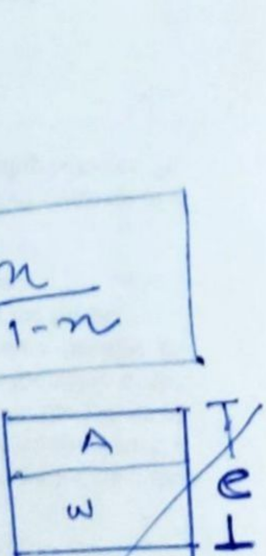
$\therefore ne + n = e$

$\therefore \cancel{n(e+1) = e}$

$n = e - ne$

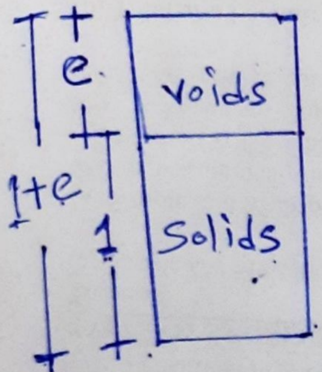
$\therefore n = e(1-n)$

$$\boxed{\therefore \frac{n}{1-n} = e}$$

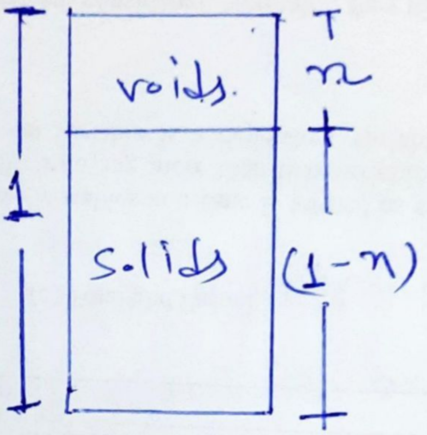


2

$$n = \frac{e}{1+e} = \frac{\text{vol. of voids}}{\text{Total vol.}} = \frac{V_v}{V}$$




$$e = \frac{n}{1-n} = \frac{\text{vol. of voids}}{\text{vol. of solid}}$$

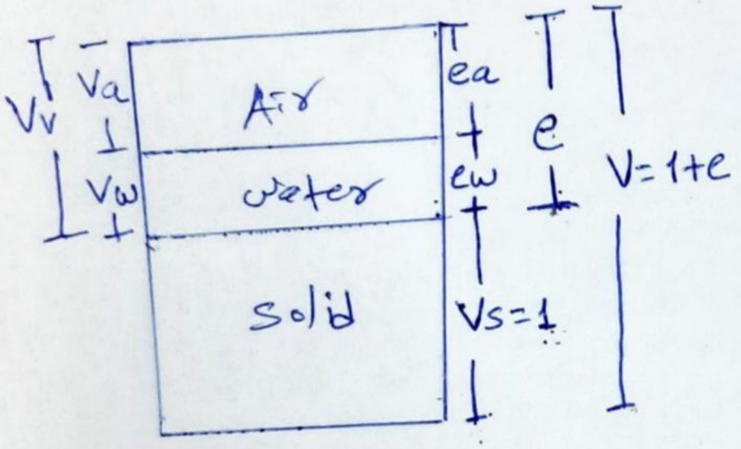


19/1/21

Derive eqn.

$e$, $G$, $w$ and $S_r$

$$\boxed{e = \frac{w \cdot G}{S_r}}$$




Soil element

where
$e_w$ = water void ratio
$e$ = Void ratio
$V_s = 1$ = vol. of solids.

We know that

① $S_r = \frac{V_w}{V_v}$

$\therefore S_r = \frac{e_w}{e}$

$\therefore e_w = e \cdot S_r$ ---- (I)

Now, $w = \frac{W_w}{W_s}$

$\therefore w = \frac{\gamma_w \cdot V_w}{\gamma_s \cdot V_s}$

$\therefore \gamma_s = \frac{W_s}{V_s}$

From Fig. $V_w = e_w$, $V_s = 1$

$\therefore w = \frac{\cancel{\gamma_w} \cdot e_w}{G \cdot \cancel{\gamma_w} \cdot 1}$

$G = \frac{\gamma_s}{\gamma_w}$

$\therefore w = \frac{e_w}{G}$

$\therefore e_w = w \cdot G$ ---- (II)

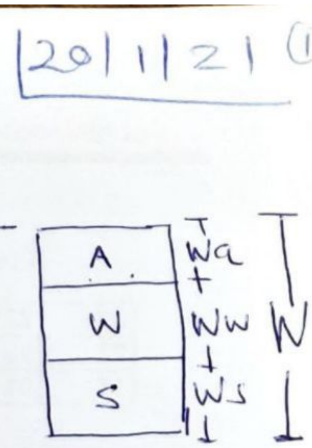
From (I) & (II)

$e S_r = w G$

$\therefore \boxed{e = \frac{wG}{S_r}}$ Find.

20/1/21 (1)

(3) Derive. $\gamma_b = \dfrac{(G + e \cdot S_r)\gamma_w}{1+e}$




We know that

$$\gamma_b = \frac{W}{V} = \frac{W_s + W_w}{V}$$

$\because \gamma_s = \dfrac{W_s}{V_s}$

$$\therefore \gamma_b = \frac{\gamma_s \cdot V_s + \gamma_w \cdot V_w}{V}$$

From Fig.

$$\therefore \gamma_b = \frac{\gamma_s \cdot 1 + \gamma_w \cdot e_w}{1+e}$$

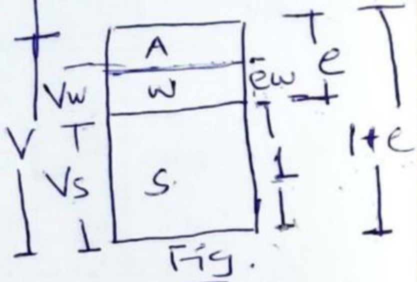



Fig.

$V_s = 1$

$V_w = e_w$

$V = 1+e$

$G = \dfrac{\gamma_s}{\gamma_w}$

$$\therefore \gamma_b = \frac{G \cdot \gamma_w + e_w \cdot \gamma_w}{1+e}$$

$$\therefore \gamma_b = \frac{\gamma_w (G + e_w)}{1+e}$$

$\because e_w = e \cdot S_r$

$$\therefore \boxed{\gamma_b = \frac{(G + e \cdot S_r)\gamma_w}{1+e}}$$

If fully saturated soil, $S_r = 1$, $\gamma_b = \gamma_{sat}$

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

If fully dry soil, $S_r = 0$, $\gamma_b = \gamma_d$

$$\gamma_b = \frac{(G+0)\gamma_w}{1+e}$$

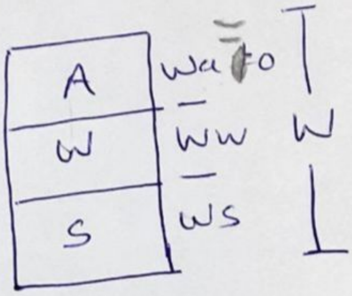
$$\therefore \boxed{\gamma_d = \frac{G \cdot \gamma_w}{1+e}}$$

20/1/21

Derive $\boxed{\gamma d = \dfrac{\gamma b}{1+w}}$

We know that

$$w = \cancel{\frac{Ws}{W}}\ \frac{Ww}{Wd} \quad \text{(By definition of w.c.)}$$




$$\therefore 1 + w = 1 + \frac{Ww}{Wd}$$

$$\therefore 1 + w = \frac{Wd + Ww}{Wd} \quad \text{L.C.}$$

$$\therefore 1 + w = \frac{W}{Wd} \qquad \Big|\ \because W = Wd + Ww$$

$$\therefore Wd = \frac{W}{1+w}$$

$$\therefore \frac{Wd}{V} = \frac{W}{V(1+w)} \qquad \Big|\ \because \frac{Wd}{V} = \gamma d$$

$$\therefore \gamma d = \boxed{\frac{\gamma b}{1+w}} \qquad \Big|\ \because \frac{W}{V} = \gamma b$$