SOIL HYDRAULICS

Module-II

Generally water present in soil in any form is termed as soil water.

Types of soil water →
- (a) Ground water
- (b) Adsorbed water
- (c) Structure water
- (d) Capillary water

(a) Ground water:- (Gravity water/free water)

(i) It is the subsurface water which fills the voids of soil upto the ground water surface level.

(ii) This water is subjected gravitational force only, hence it is also called gravity water or free water.

(iii) This water obeys all law of hydraulics

(b) Adsorbed water:-

(i) This type of water is also called surface water

(ii) Generally this is of two types

Hygroscopic water:- It is the water which is being adsorbed by the soil solids from the atmosphere by physical forces of attraction & is adhered over the surface of solid.

- Water adsorption capacity of fine grained soil is more than coarse grained soil (because fine grained soils have more more surface area)

Water adsorption capacity —
- Clay (16-17 %)
- Silt (6-7 %)
- Sand (1%)
- Gravel (<1 %)

This hygroscopic water is densely packed sorrounding the soil solids and posses higher viscosity, higher boiling point & lower freezing point than normal water.

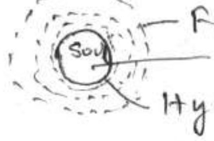
* Absorption:- is the passage of one substance into or through the bulk of another medium. Absorbed substance tends to saturate the hole/void of the medium to form a solution.

* Adsorption:- is the adhesion or sticking together

of molecules of a gas, liquid or dissolved solids to the surface of a solid or sometimes a liquid. Molecules are loosely held by the surfaces.

Film water :-

1. It is also adsorbed water which is formed due to condensation of aqueous vapours on the layer of hygroscopic water.
2. All the properties of film water are better than normal water and linient (not better than) hygroscopic water.



* Both Hygroscopic & Film water are immobile so it is both free water

(c) Structure water :-

1. It is the form of water which is chemically combined to crystal structure of soil mineral
2. Under normal engineering operation this water can't be separated or removed. Hence it is of no significance
3. Generally it can be removed only when temperature is increased beyond 110°C

(d) Capillary water :-

1. It is the water which is being lifted by surface tension forces above free water level.
2. This water is held in suspension in the voids of soil and fills it completely upto a certain distance above the ground water table.
3. This zone of water is termed as zone of capillary saturation.

By ovendrying method 3 types of water present in a soil mass are removed (i) Surface water (gravity water)
(ii) Capillary water
(iii) Adsorbed water

In any kind of drying method structural water will not be removed because it is a chemicalled bonded water so with the removal of this water content the chemical property of that particular soil is changed.

Estimation of capillary rise in soil deposit:
If D represents the average size of particle
d the size of voids we have

$$e = \frac{V_v}{V_s} = \frac{d^3}{D^3}$$

$$\therefore d = e^{1/3} D$$

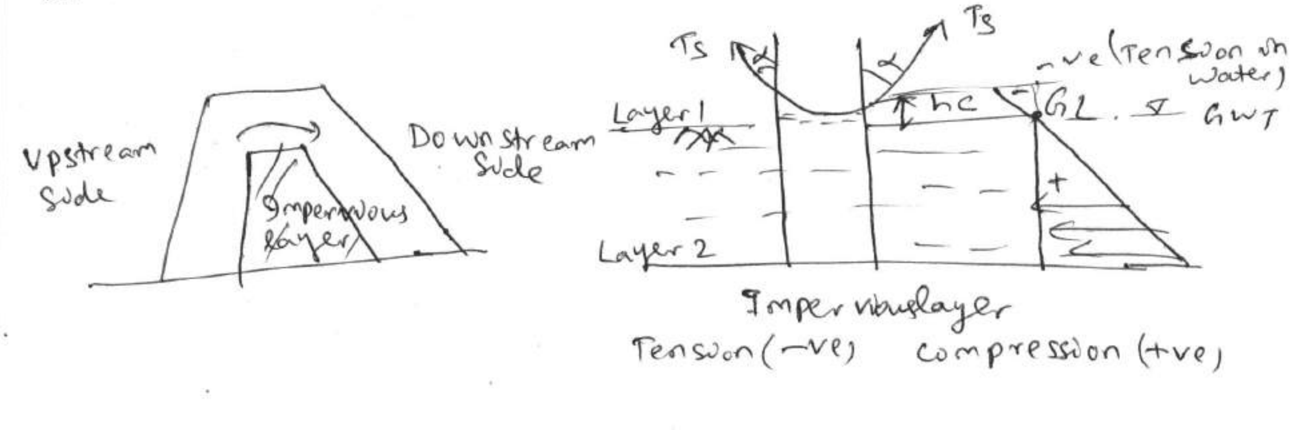
$$h_c = \frac{4 T_s \cos\alpha}{d \gamma_w}$$ – This can be used to estimate the capillary rise in natural soil formations as well as in other soil deposits.

For rough estimate the equation suggested by Allen Hazen

$$h_c = \frac{C}{e D_{10}}$$ where h_c = capillary rise in cm
D_{10} = effective diameter of soil in cm
e = void ratio

C is an empirical constant which is taken between 0.1 to 0.5 (cm^2)

Capillary siphoning :- Capillary rise takes place above the free water surface. In case of composite earth dam is capillary rise can be lead to a serious problem which is called capillary siphoning.



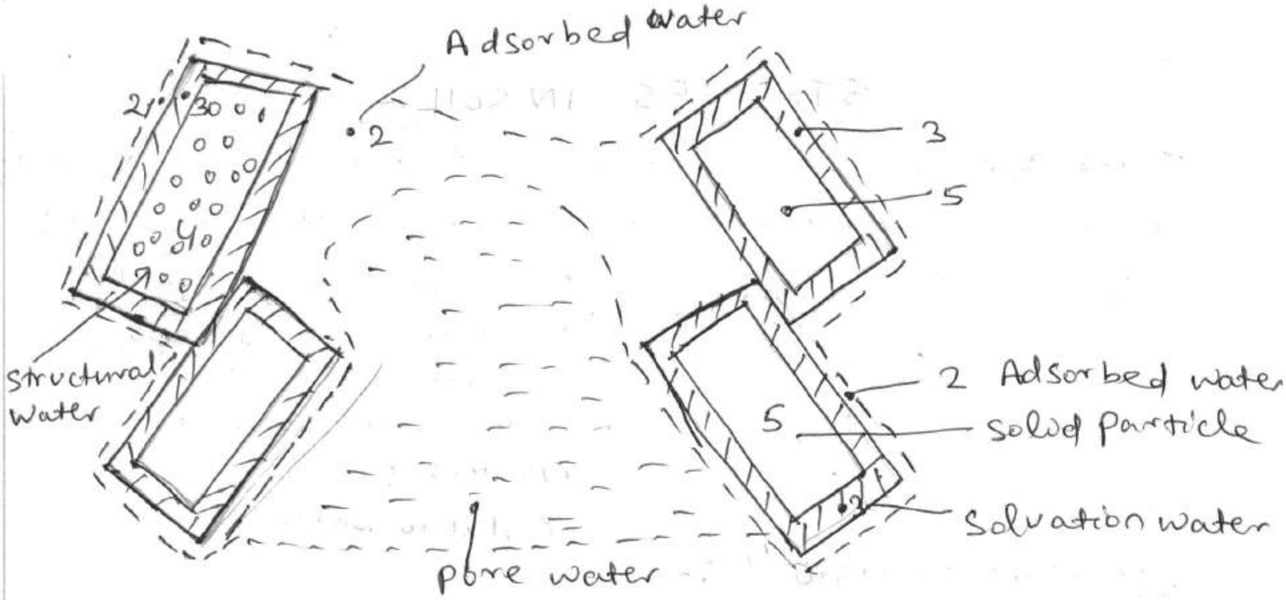


Figure Structural classification of water in soil.

Capillary water :- It is held due to the surface tension generated between the soil particles & water.

→ The maximum height achieved by capillary rise is denoted by $h_c = \frac{4 T_s \cos\alpha}{d \gamma_w}$ T_s = surface tension developed between soil particle & water molecules

γ_w = unit wt. of water α = contact angle

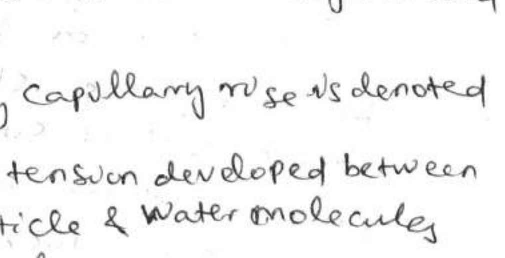
d = diameter of tube

Note: For pure water & glass surface the contact angle will be zero. (Smaller the value of d capillary rise height should be more)

→ The value of surface tension will be 75×10^{-6} kN/m at 20°C

→ If the temp. is increased, the surface tension decrease & the capillary rise is also decrease

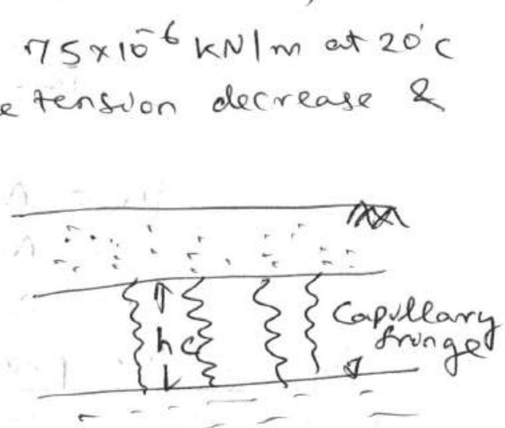
Capillary rise in soil mass :



→ For fine grain soil the capillary rise ~~fringe~~ is more

The voids in natural soil formations act as capillary tubes & water rises in the continuous voids to a certain ht. above water table. The ht. to which water rises the capillary rise depends on the size of voids.

The zone of soil strata saturated with capillary water is called ~~capillary~~ capillary fringe.



Pressure distribution due to capillary action.

STRESSES IN SOIL:-

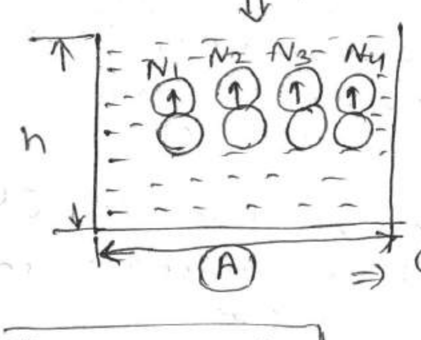
Total stress at a point in soil mass is due to self wt. of soil and over burdon pressure above that point.

So total stress (T_s) — Effective stress (σ')
(Intergranular pressure)
(Due to solid)
— pore water pressure (u)
(Neutral pressure)
(due to water)

Effective Stress (σ') :-

1. These are stresses which are being transferred by grain to grain contact leading to decrease in void ratio, increase in denseness and stability of soil.
2. Since these stresses are being transfered by grain to grain contact so they are also referred as intergranular pressure which tends to force the particle to come in contact with each other.

P → Total pressure (Self wt. of soil & over burden pressure)



Contact pressure (N/m^2) $= \dfrac{N_1 + N_2 + N_3 + \dots}{\text{Area of contact of soil solids}}$

ΣN → Upward

$\Rightarrow C_p = \dfrac{\Sigma N}{A_c}$ → Not possible to find out real area

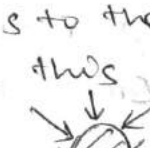
$$\boxed{A = A_w + A_c}$$

A_c → Area of contact
A_w → Area of water

$\because A_c \simeq 0$ So $A = A_w$

Pore Water pressure (u) :-

1. It is the pressure which is being transmitted by pore fluid (water) & it is equal to weight of the water column above the concerned section or point in the soil mass.
2. Since this water pressure acts all around the soil solids, so it doesnot tends to the soil solid to come in contact with eachother. For this reason it is called as neutral pressure.
3. It doesnot affect the mechanical property of soil mass



Neutral pressure
Ex: Shearforce / Shear resistance

Effective stress, $\sigma' = \frac{\Sigma N}{A}$ → A Doesnot exist
So we always 1st calculate σ & u, then σ' is calculate

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

Pore water pressure = $\frac{\text{Weight of water}}{\text{Area of water}} = \frac{A_w h \gamma_w}{A_w}$

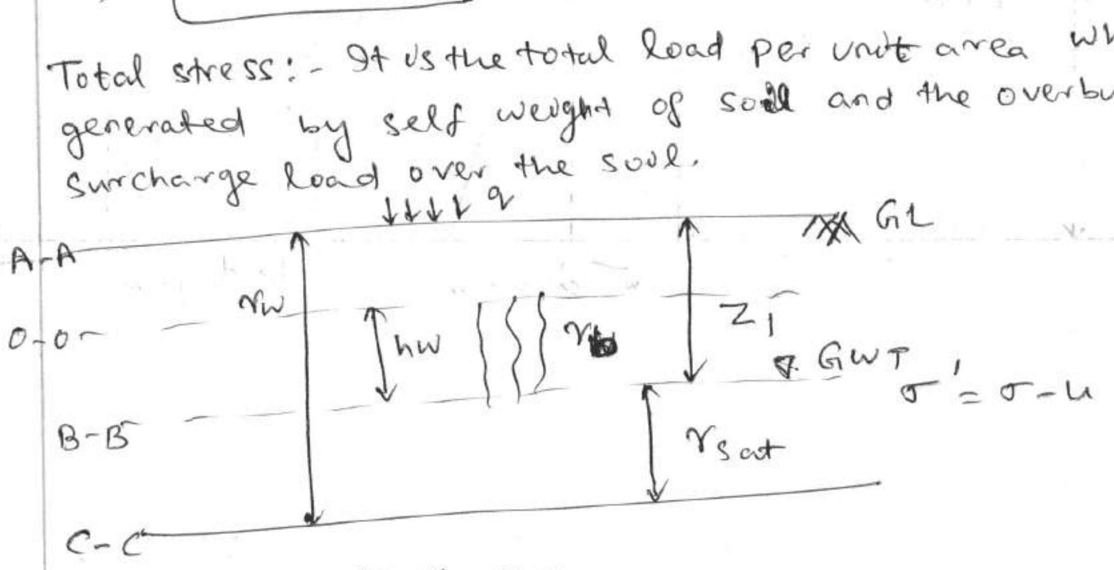
$P\downarrow = N\uparrow + (u \times A_w)\uparrow$

$\Rightarrow \frac{P}{A} = \frac{N}{A} + \frac{u A_w}{A}$

$\Rightarrow \boxed{\sigma = \sigma' + u}$

P = Total downward force
N = Intergranular force
$u \times A_w$ = Pore water force

Total stress :- It is the total load per unit area which is generated by self weight of soil and the overburden or surcharge load over the soil.



At A-A σ = q + self wt. = 0
$u = 0$
$\sigma' = q$

At O - O $\sigma = q + \gamma_b (Z_1 - h_w)$
$u = 0$ (as there is no pore water pressure Just above O-O section)
$u = -h_w \gamma_w$ (It is the pore water pressure generated due to capillary rise of water from ground water table. As this pressure is generated due to capillary rise hence it is negative)

Effective stress at O-O
$$\boxed{\sigma' = q + \gamma_b (Z_1 - h_w)}$$

Just below O - O
$$\boxed{\sigma' = q + \gamma_b (Z_1 - h_w) + h_w \gamma_w}$$

At B - B $\quad \sigma = q + \gamma_b z_1$

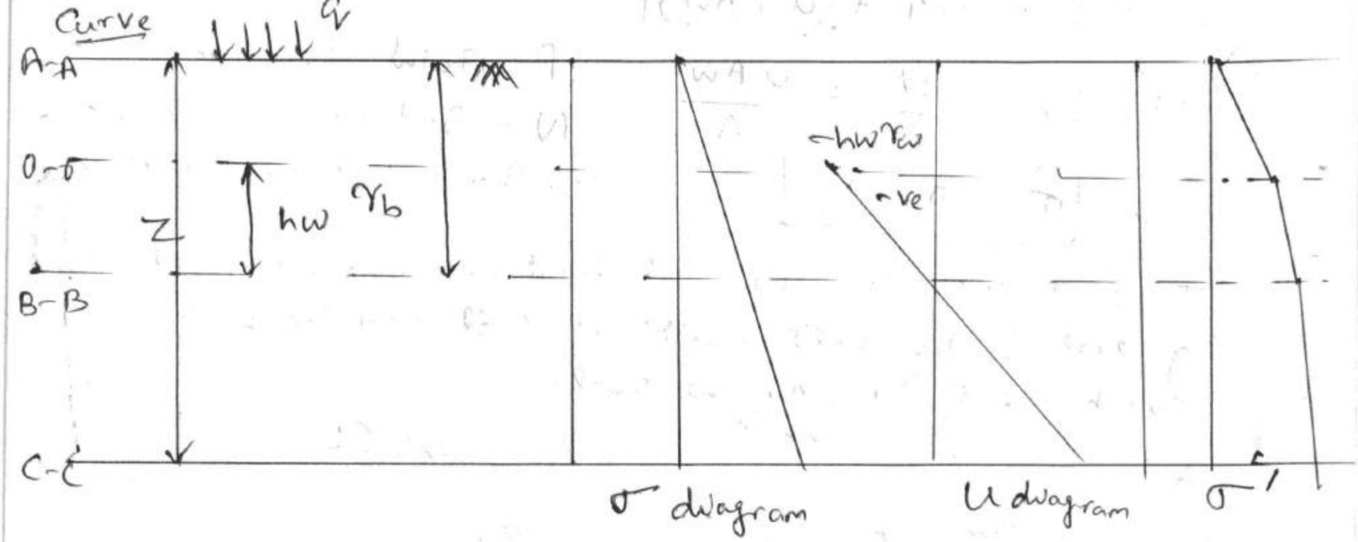
$u = 0$

$\sigma' = q + \gamma_b z_1$

At C - C $\quad \sigma = q + \gamma_b z_1 + \gamma_{sat}(z - z_1)$

$u = \gamma_w (z - z_1)$

$\sigma' = q + \gamma_b z_1 + \gamma_{sat}(z - z_1) - \gamma_w (z - z_1)$



Case (i) Submerged soil mass with water table above the Surface

At AA Total pressure $\sigma = \gamma_{sat} z_1 + \gamma_w z_2$

$$u = \gamma_w (z_1 + z_2)$$

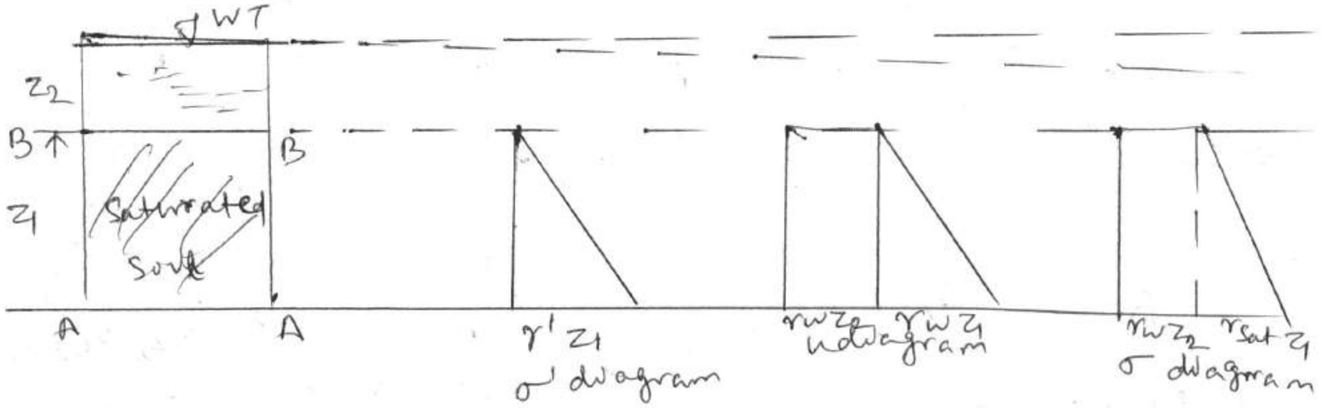
$$\sigma' = \sigma - u = \gamma_{sat} z_1 + \gamma_w z_2 - \gamma_w z_1 - \gamma_w z_2$$

$$\sigma' = (\gamma_{sat} - \gamma_w) z_1 = \gamma' z_1$$

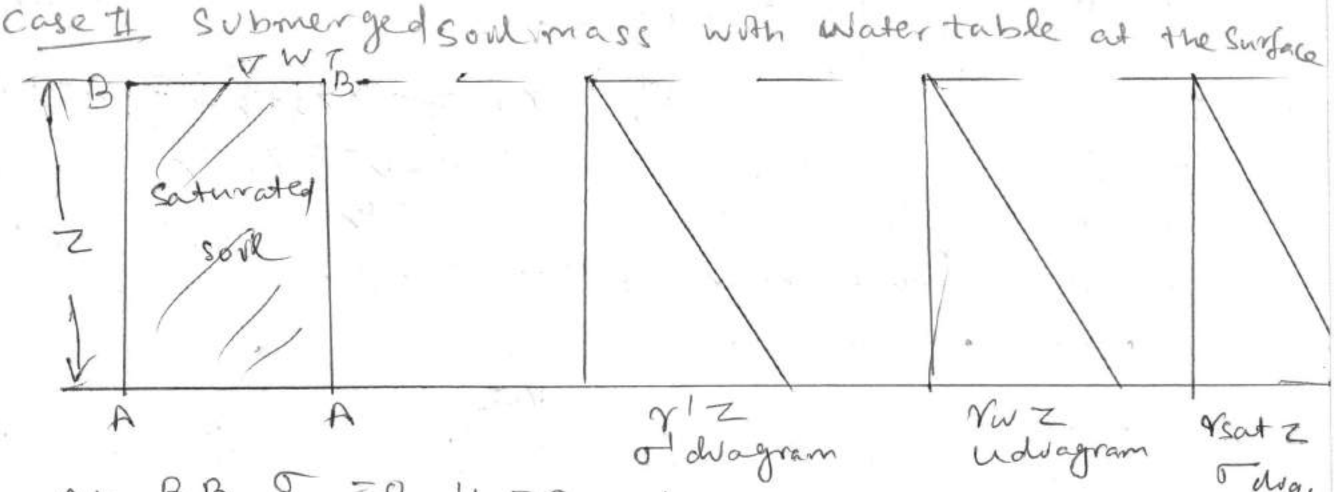
At BB $\sigma = \gamma_w z_2$

$u = \gamma_w z_2$

$\sigma' = \sigma - u = 0$



Case II Submerged soil mass with water table at the Surface



At BB $\sigma = 0$ $u = 0$ $\sigma' = 0$

At AA $\sigma = \gamma_{sat} z$ $u = \gamma_w z$ $\sigma' = \sigma - u = \gamma' z$

Case III Partly submerged soil mass

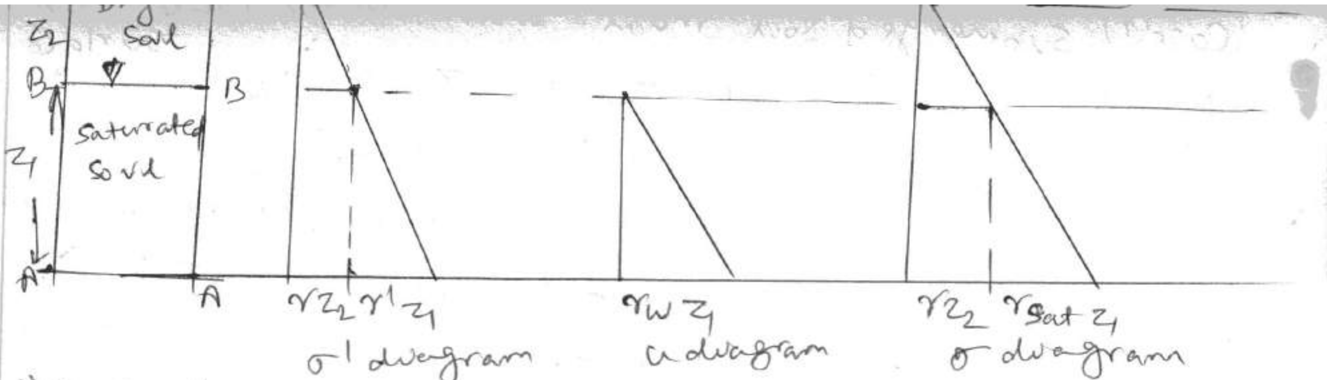
At AA $\sigma = \gamma_{sat} z_1 + \gamma z_2$

$u = \gamma_w z_1$

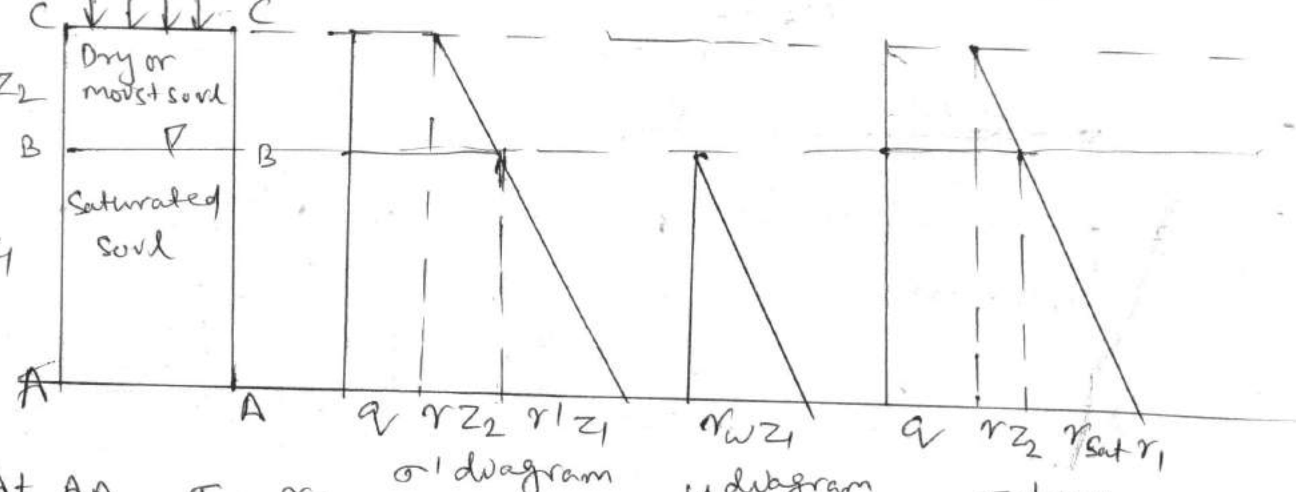
$$\sigma' = \sigma - u = (\gamma_{sat} - \gamma_w) z_1 + \gamma z_2 = \gamma' z_1 + \gamma z_2$$

At BB $\sigma = \gamma z_2$ $u = 0$ $\sigma' = \sigma - u = \gamma z_2$

At CC $\sigma = 0$, $u = 0$ $\sigma' = 0$



(iv) Partly submerged soil mass with surcharge



At AA $\sigma = \gamma_{sat} Z_1 + \gamma Z_2 + q$

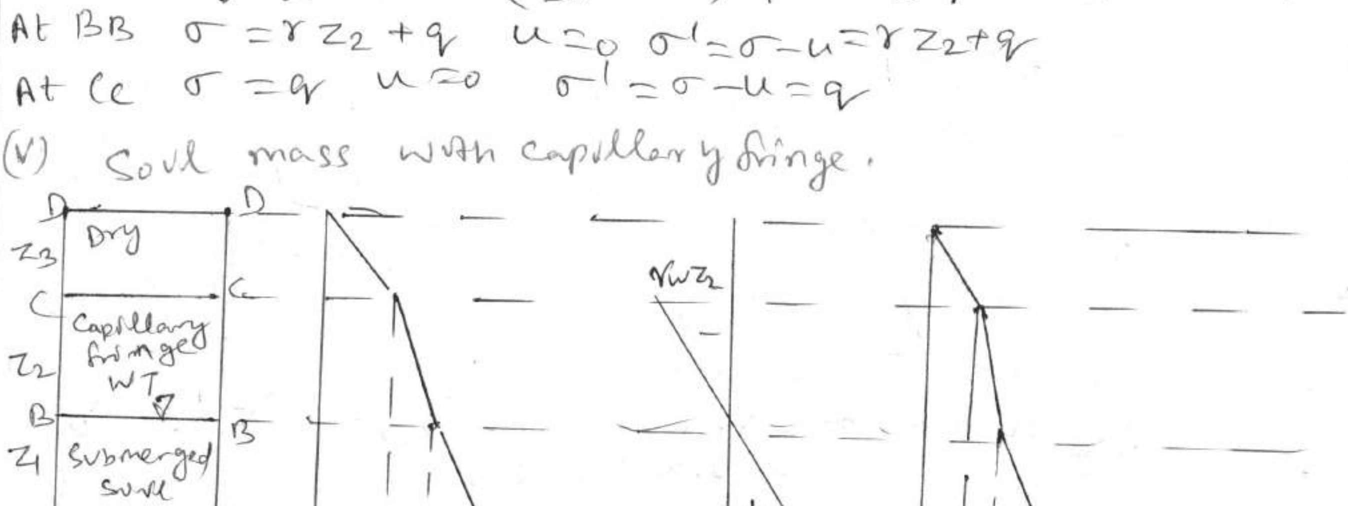
$u = \gamma_w Z_1$

$\sigma' = \sigma - u = (\gamma_{sat} - \gamma_w) Z_1 + \gamma Z_2 + q = \gamma' Z_1 + \gamma Z_2 + q$

At BB $\sigma = \gamma Z_2 + q$ $u = 0$ $\sigma' = \sigma - u = \gamma Z_2 + q$

At CC $\sigma = q$ $u = 0$ $\sigma' = \sigma - u = q$

(V) Soil mass with capillary fringe.



At AA $\sigma = \gamma_{sat} Z_1 + \gamma_{sat} Z_2 + \gamma Z_3$, $u = \gamma_w Z_1$

$\sigma' = \gamma' Z_1 + \gamma_{sat} Z_2 + \gamma Z_3$

At BB $\sigma = \gamma_{sat} Z_2 + \gamma Z_3$ $u = 0$ $\sigma' = \sigma - u = \gamma_{sat} Z_2 + \gamma Z_3$

At CC $\sigma = \gamma Z_3$ $u = -\gamma_w Z_2$ $\sigma' = \gamma Z_3 + \gamma_w Z_2$

80 At DD $\sigma = 0$ $u = 0$ $\sigma' = 0$