ʳᵈ Sept,
EDNESDAY

7. EFFECTIVE STRESS

→ Total Stress (σ)

It is the stress due to total load.

* Neutral Stress or Pore water Pressure (u)

It is the pressure in the water

* Effective Stress (σ')

It is the total stress minus neutral stress.

It's also called intergranular pressure. It is the stress which controls the behaviour of soil, shear strength of soil and volume change of soil.

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

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

$$\sigma = \frac{W}{A}$$

where W → total load (external load + self wt. of soil)

A → total c/s area of soil

$$u = \gamma_w h$$

where h → pressure head = depth of water in piezometer

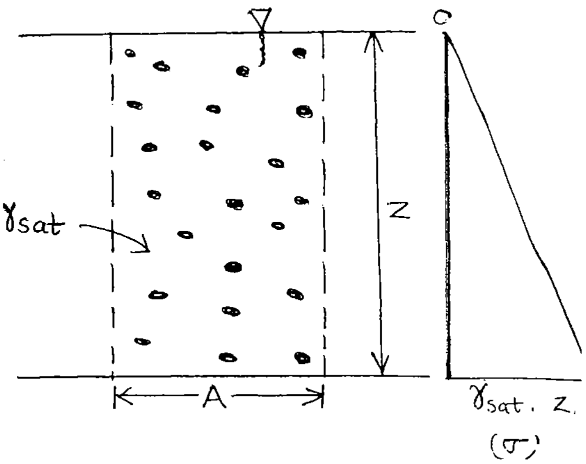
∴ σ & u can be measured, but σ' can't be measure

However it can be computed using σ & u values.

$$\sigma = \frac{W}{A}$$

$$= \frac{A \cdot z \cdot \gamma_{sat}}{A}$$

$$\therefore \boxed{\sigma = z \cdot \gamma_{sat}}$$



$$u = \gamma_w h$$

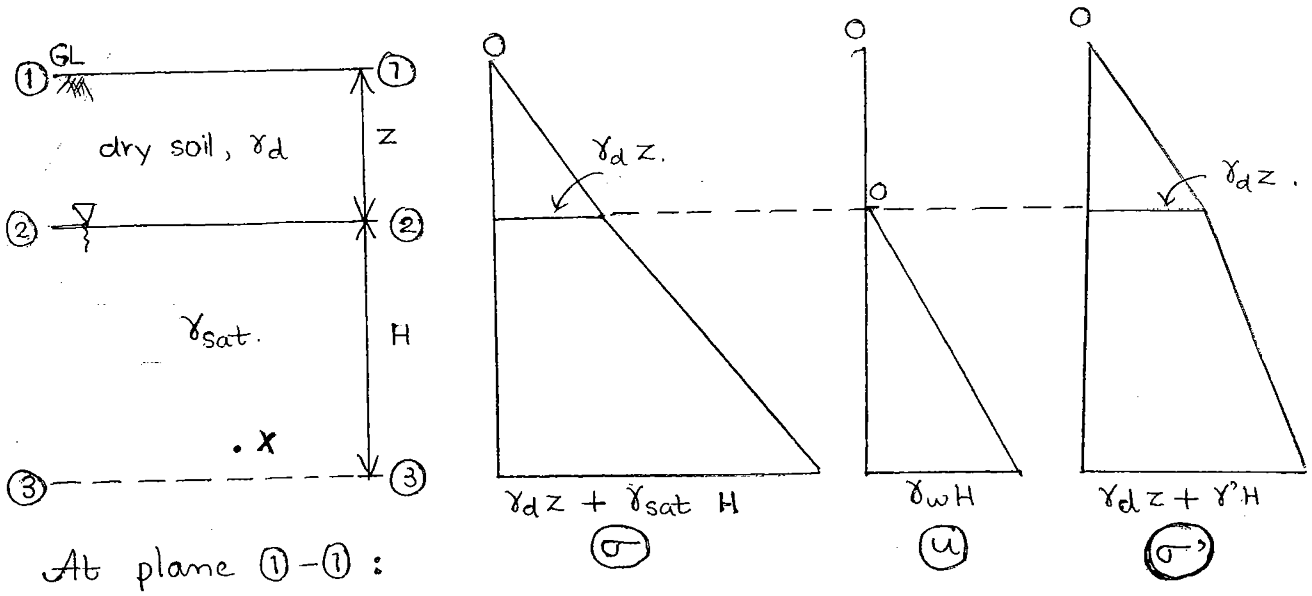
$$\therefore \boxed{u = \gamma_w \cdot z}$$

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

$$= \gamma_{sat} z - \gamma_w z.$$

$$= (\gamma_{sat} - \gamma_w) z.$$

$$\therefore \boxed{\sigma' = \gamma' z}$$



At plane ①-① :

$\sigma = 0$; $u = 0$; $\sigma' = 0$

At plane ②-② :

$\sigma = \gamma_d \cdot z$; $u = 0$; $\sigma' = \gamma_d z$.

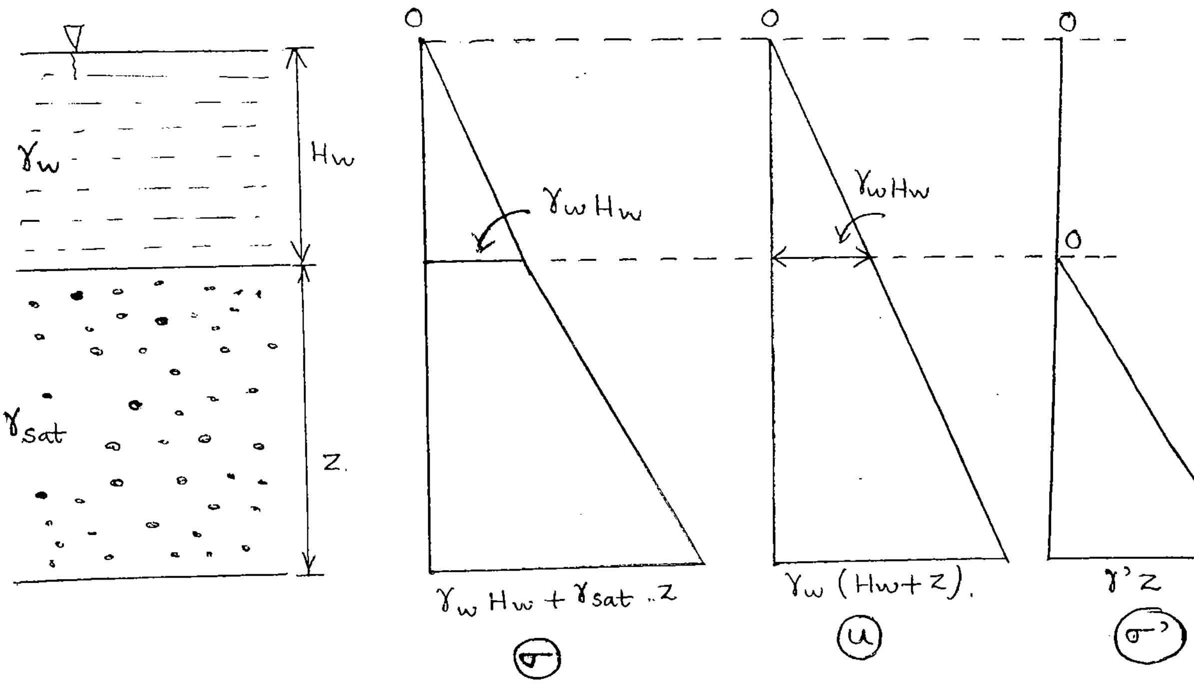
At plane ③-③ :

$\sigma = \gamma_d \cdot z + \gamma_{sat} \cdot H$

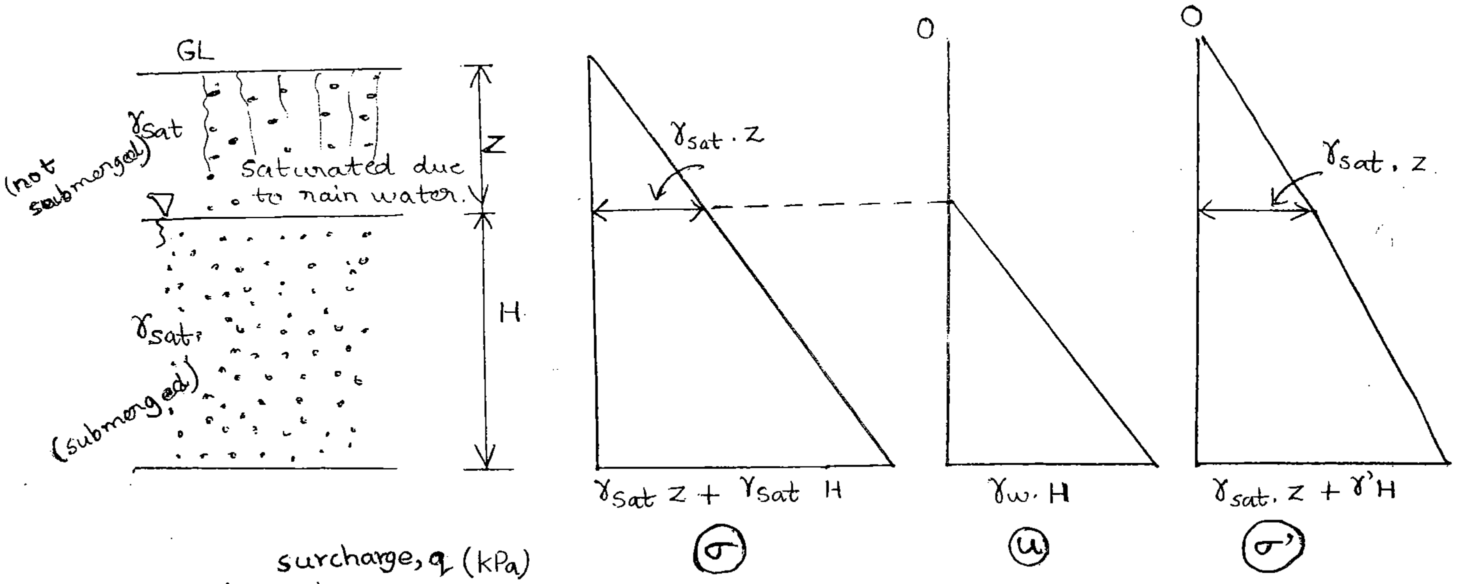
$u = \gamma_w \cdot H$

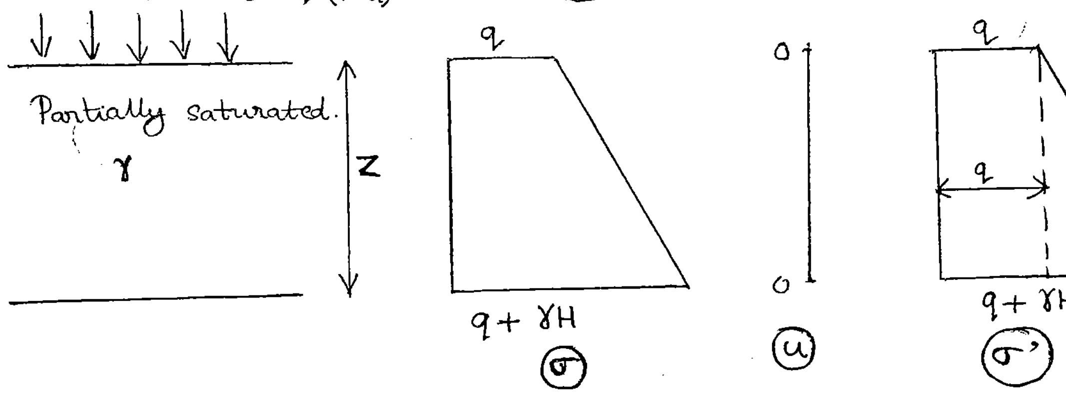
$\sigma' = \gamma_d z + \gamma' H$

- If WT raises, then σ & u increase, but σ' decreases.
- If WT falls, then σ & u decrease but σ' increases.

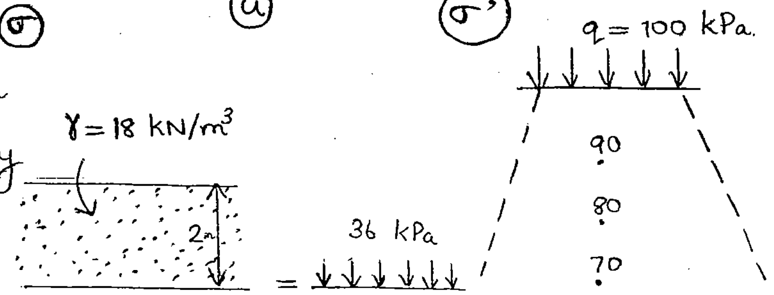


⊙ Effective stress below the bed level is totally independent of depth of water (H_w) above bed level.





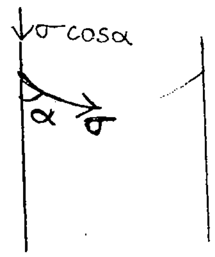
Above stress distribution diagrams are possible only if surcharge is infinite

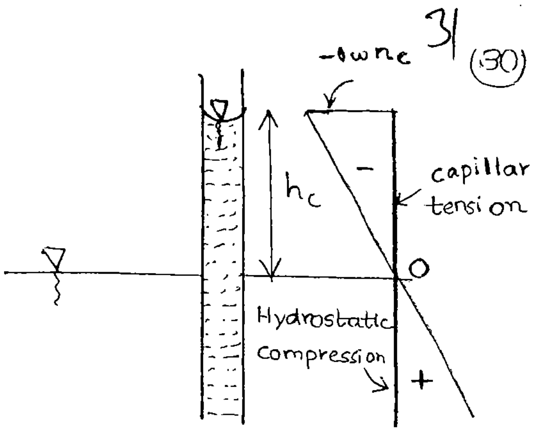


→ Capillarity

Due to capillarity, the capillary water is under tension whereas the wall of capillary tube is under compression.

'$\sigma \cos\alpha$' causing compression on the walls.





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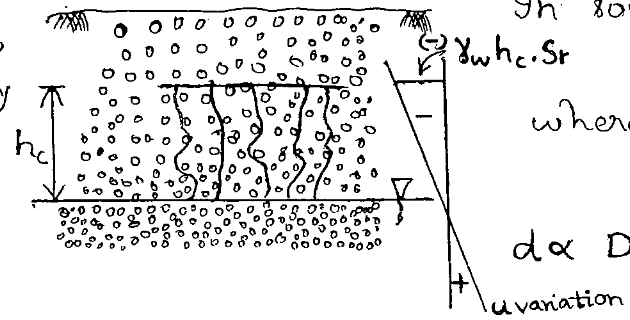


In soils, capillarity rise, $h_c \approx \frac{0.3}{d}$

where d — diameter of void (cm)

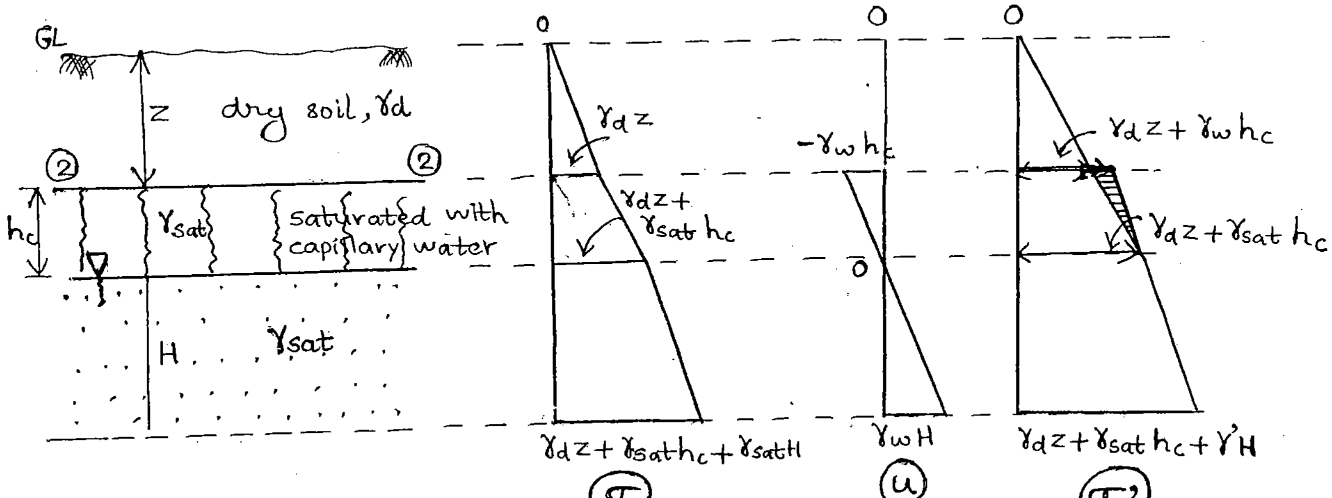
h_c — capillary height (cm)

$d \propto D_{10} \Rightarrow h_c \propto \frac{1}{D_{10}}$

- For gravel & coarse sand, h_c is negligible.
- h_c is highest for clay.

$$d \propto e D_{10} \Rightarrow h_c \propto \frac{1}{e D_{10}}$$

For clay, effect of size of particle on capillary height is more than that of void ratio.



At level ②-②:

a) Just above

$\sigma = \gamma_d z$

$u = 0$

$\sigma' = \gamma_d z - 0 = \gamma_d z$

b) Just below

$\sigma = \gamma_d z$

$u = -\gamma_w h_c$

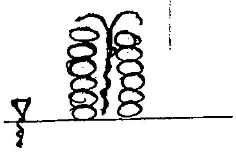
$\sigma' = \gamma_d z - (-\gamma_w h_c) = \gamma_d z + \gamma_w h_c$

$- \quad \sigma' = \sigma - u.$

$\sigma' = \sigma$ if $u = 0$ → dry & partially saturated soil

$\sigma' < \sigma$ if u is +ve. → below WT

$\sigma' > \sigma$ if u is −ve → in capillary zone



Soil molecules act like walls of the capillary tube and they are under compression. ∴ σ' incre in capillary zone.

Frost heave (night time) & Frost boil (day time) are disadvantages of capillary acti

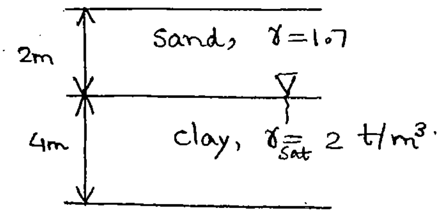
But capillary increases the shear strength of soil. ($S = c + \sigma' \tan\phi$)

2. $\sigma' = \gamma' z$

$100 = \gamma' z.$

Taking $\gamma' = 10$, $z = \underline{10\ m}$

3. At centre of clay,



$\sigma = 2\gamma + 2\gamma_{sat} = 7.4\ t/m^2$

$u = 2\gamma_w = 2\ t/m^2$

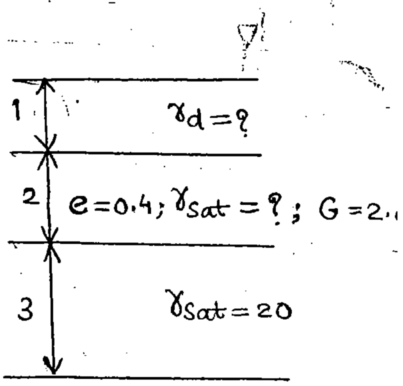
$\sigma' = \sigma - u = 7.4 - 2 = \underline{5.4\ t/m^2}$

(OR)

$\sigma' = 2\gamma + 2\gamma'$

$= 2 \times 1.7 + 2(2-1) = \underline{5.4\ t/m^2}$

4. $\sigma' = 3 \times 18 + 7 \times 10 = \underline{124\ t/m^2}$

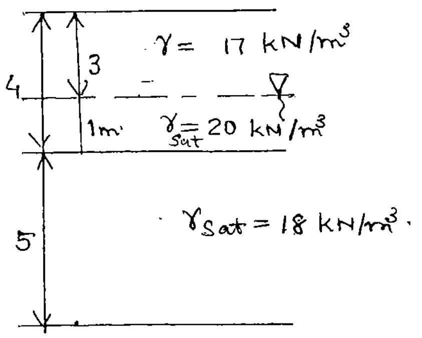


5. $\gamma_d = \dfrac{G\gamma_w}{1+e} = 18.93\ kN/m^3$

$\gamma_{sat} = \gamma_w \left(\dfrac{G+e}{1+e}\right) = 21.78\ kN/m^3.$

$\sigma' = 1 \times 18.93 + 2(21.78 - 10) + 3(20 - 10) = \underline{72.49\ kN/m^2}$

Q. 7 b) Calculate σ' at a depth of 2.4 m below GL for the above capillarity case.



6. $\sigma'_{(9m)} = 17 \times 3 + (20 - 9.81) \times 1 + (18 - 9.81)\,5 = \underline{102.14 \text{ kN/m}^2}$

7. a) After capillary rise,

At 9 m depth,

$\sigma = 2 \times 17 + 20 \times 2 + 5 \times 18 = 164$

$u = 6\gamma_w = 58.86$

$\sigma' = \sigma - u = 105.14$ kPa

$\Delta\sigma' = 105.14 - 102.14 = \underline{3 \text{ kPa}}$

b) At 2.4 m depth,

$\sigma = 2\gamma_d + 0.4\gamma_{sat}$

$= 2\gamma_d + 0.4 \times 20 = \underline{42 \text{ kPa}}$

$\sigma' = \sigma - (-u) = 42 + (3 - 2.4)\,9.81$

$= \underline{47.886 \text{ kPa}}$

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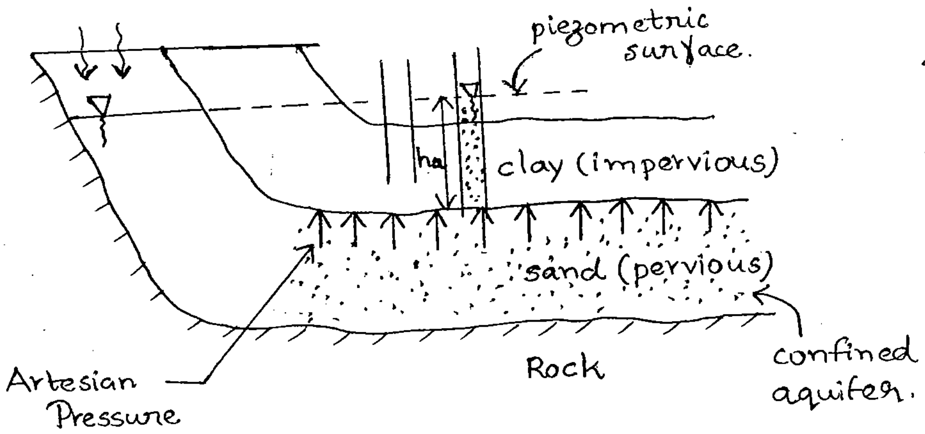
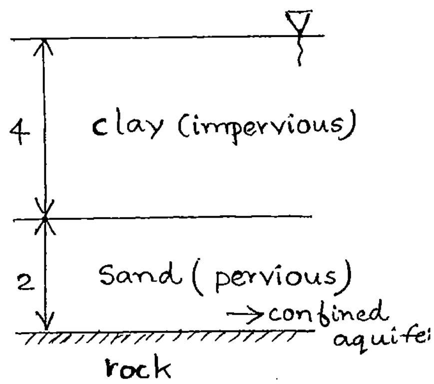
8.





ha → artesian pressure head.

Artesian pressure = $\gamma_w h_a$

Springs are developed only when piezometric surface is above GL.

8. a) Effective stress at a depth of 6m $= \gamma'_{clay} \times 4 + \gamma'_{sand} \times 2 - \gamma_w h_a$

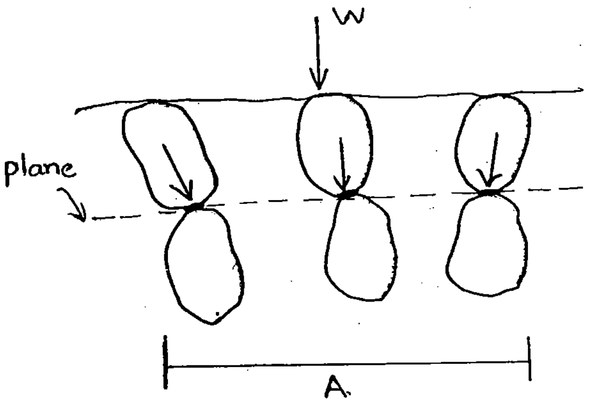
$$= (19.5-10)4 + (18.5-10)2 - 10\times 2$$

$$= \underline{\underline{35 \text{ kPa}}}$$

b). When $h_a = 1$,

$$\sigma' = 55 - 10\times 1 = 45 \text{ kPa}.$$

$$\Delta\sigma' = \underline{\underline{10 \text{ kPa}}}$$



$A_c \rightarrow$ area of contact.

$A_w \rightarrow$ area of water

$A \rightarrow$ total area of soil.

A_c is very small.

$$A = A_w + A_c \approx A_w.$$

$$W = u A_w + \Sigma N_v.$$

Dividing by A,

$$\frac{W}{A} = u\frac{A_w}{A} + \frac{\Sigma N_v}{A}$$

$$\Rightarrow \sigma = u + \frac{\Sigma N_v}{A}.$$

Comparing above equation with, $\sigma = u + \sigma'$

$$\therefore \sigma' = \frac{\Sigma N_v}{A}.$$

It is equal to the total vertical reaction force transmit at the points of contact of soil grains divided by the total area, including that occupied by water.

It is much smaller than actual contact stress. $\left(\frac{\Sigma N_v}{A_c}\right)$