BWDB – 2019

(1) Prove that $\gamma_{sat} = \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$

<u>Sol^n</u> : $\gamma_{sat} = \frac{W}{V} = \frac{W_s + W_w}{V}$

$$\Rightarrow \gamma_{sat} = \frac{G_s \gamma_w + w G_s \gamma_w}{1+e}$$

$$= \frac{(1+w)\, \cancel{e}\, G_s \gamma_w}{1+e}$$

$$= \frac{(1+w)\left(\frac{e}{w}\right)\gamma_w}{(1+e)}$$

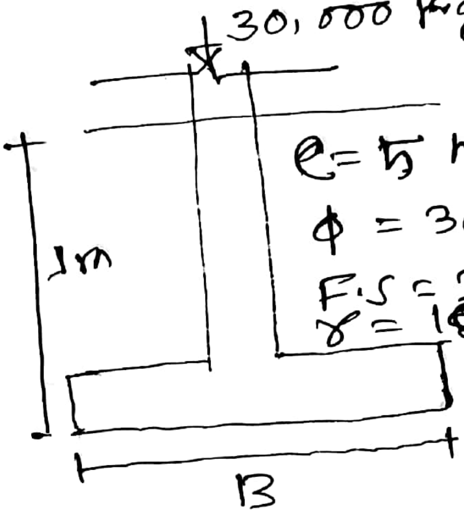
$Se = wG$

$\Rightarrow G_s = \frac{e}{w}$

$$= \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$$

(Proved)

③ A square footing is shown in the fig. The footing will carry a gross mass of 30,000 kg using a factor of safety 3. Determine the size of the footing - that is the size of B.



$c = 5$ kN
$\phi = 30°$
F.S = 3
$\gamma = 18.15$ kN/m³

<u>Soln:</u> $Q_{all} = \dfrac{30000 \times 9.81}{1000}$

$= 294.3$ kN

For square footing with factor of safety,

$$Q_{all} = \frac{Q_u}{F.S}$$

$$\Rightarrow \frac{Q_{all}}{B^2} = \frac{1}{3}\left(1.3\,cN_c + qN_q + 0.4\,\gamma B N_\gamma\right)$$

$$\Rightarrow \frac{294.3}{B^2} = \frac{1}{3}\left(1.3 \times 5 \times 30.14 + 18.15 \times 1 \times 18.40 + 0.4 \times 18.15 \times B \times 15.6\right)$$

For $\phi = 30°$
$N_c = 30.14$
$N_q = 18.40$
$N_\gamma = 15.668$

$\Rightarrow$ ~~B = 0.156 m.~~

$\Rightarrow B = 1.15$ m (around)

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(4) Find the volume by trapezoidal rule.

Interval (m)	0	100	200	300	400	500
Area (m^2)	560	650	700	620	650	760

Soln: By trapezoidal rule;

$$V = \frac{d}{2}\left[\left(\frac{A_0 + A_5}{\cancel{2}}\right) + 2\left(A_1 + A_2 + A_3 + A_4\right)\right]$$

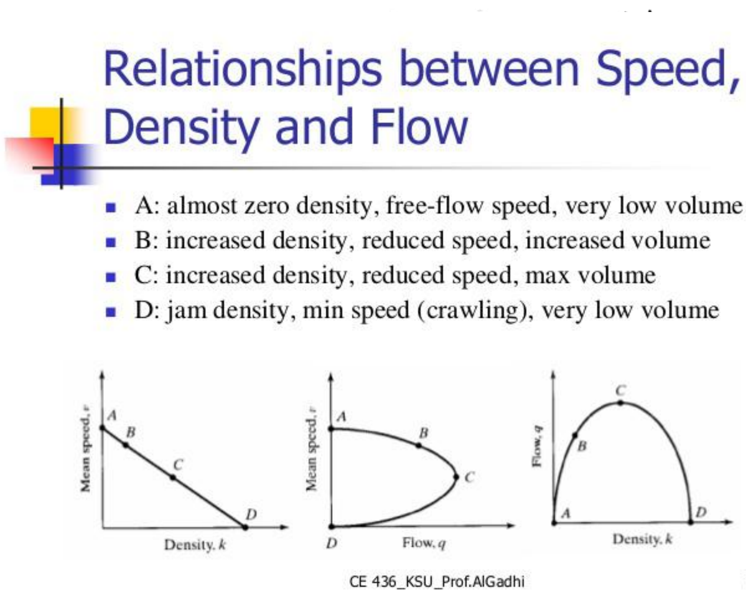
$$= \frac{100}{2}\left[\left(560 + 760\right) + 2\left(650 + 700 + 620 + 650\right)\right]$$

$$= 328000 \ m^3$$

(~~Ans~~)

⑤ Show theoratical relationship between speed flow and density ?

Ans: C ... ighway of length
l in ... point in the
section ... l T, all the
vehicl ... same direction.



The ... icle travelling

The d ...

The avg. No of vehicles travelling over L is given by, $\dfrac{\sum_{i=1}^{N} t_i}{T}$

where t_i is the time ~~of interval~~ of travel of the ith vehicle over the length L; then

$$D = \frac{\sum_{i=1}^{N} t_i}{T} \Big/ L$$

$$\Rightarrow D = \frac{\dfrac{N/T}{L}}{\dfrac{1}{N}\sum_{i=1}^{N} t_i}$$

$\therefore$ Density $= \dfrac{\text{flow}}{\text{space mean speed}}$ (Pro)

(6) Find the ϕ-index if the direct run-off is 4.9 cm.

Time from the start in hr	1	2	3	4	5
Incremental rainfall in each hr in cm	1.5	2.5	4.1	3	1.9

Soln: Total precipitation, $P = 1.5 + 2.5 + 4.1 + 3 + 1.9$

$= 13$ cm

Direct run-off, $R = 4.9$ cm

$\therefore$ ϕ-index $= \dfrac{P-R}{te} = \dfrac{13-4.9}{5} = 1.62$ cm/hr

but for ϕ-index $= 1.62$ cm/hr; first hour rainfall would become ineffective.

$\therefore$ ϕ-index $= \dfrac{13-4.9-1.5}{5-1}$ cm/hr

$= 1.65$ cm/hr

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(7) Labor... 40 mg/l.

Total Ca... -/l.

Assume ... due to.

HCO_3^-. ... = 1 meq/l.

Determi... mg^{2+} and

HCO_3^-

Soln:

$\Rightarrow$ Ca

Laboratory test shows $Ca^{2+} = 40$ mg/L. Total carbonate hardness = 3 Meq/L. Assume carbonate hardness only due to HCO_3^-. Non carbonate hardness = 1 Meq/L. Determine total hardness and Mg^{2+} and HCO_3^- as mg/L?

Soln: Total hardness = Carbonate + Non-Carbonate

$= (3+1)$ Meq/L

$= 4$ Meq/L

Now, Total hardness $= (Ca^{2+} + Mg^{2+})$ as $CaCO_3$

$\Rightarrow 4 = \left(\frac{40}{40} \times 2\right) + Mg^{2+}$

$\Rightarrow Mg^{2+} = 4 - 2 = 2$ Meq/L $= \frac{2 \times 24}{2}$ mg/L $= 24$ mg/L

Now, carbonate hardness = HCO_3^- as $CaCO_3$

$\Rightarrow HCO_3^- = 3$ Meq/L

$\Rightarrow HCO_3^- = \frac{3 \times 61}{1} = 183$ mg/L (Ans)

N.B: $Meq = \frac{mg_{(substance)}}{MW_{(mg)}} \times Valence$ → Molecular weight

$mg = \frac{Meq \times MW}{Valence}$

Ca^{2+} as $CaCO_3 = \frac{40}{20} = 2$ meq/L

$$\left[\text{Formula: } meq = \frac{mg}{\text{atomic wt} \times \text{valence}}\right]$$

$\therefore mg^{2+} = 4 - 2 = 2$ meq/L

$= 2 \times 24 = 48$ mg/L

$CH = HCO_3^- = 3$ meq/l

$\Rightarrow HCO_3^- = 3 \times 51 = 153$ mg/L

(8) A RCC footing is 10'×10'. Determine the Punching stress when effective depth of the footing $d = 16.5''$. ~~and~~ Given and $a = 10''$, $f'_c = 3$ ksi.

Solⁿ: Shear force $= \left[10\times10 - (a+d)^2\right] \times$ soil pressure

$$SF = \left[10\times10 - \frac{(10+16.5)^2}{144}\right] \times w \text{ lb}$$

$$= \left[(100 - 4.876)\, w\right] \text{ lb}$$

Punching Area, $P = 4(a+d)\times d$

$$= 4(10+16.5)\times 16.5$$

$$= 1749 \text{ in}^2$$

Punching stress $= \frac{SF}{P} = \frac{(100-4.876)\, w \text{ lb}}{1749 \text{ in}^2}$

$$= 0.054\, w \text{ lb/in}^2 \text{ — (i)}$$

allowable Stress, $V_0 = 2\sqrt{f'_c} = 2\sqrt{3000}$

$$= 109.54 \text{ psi — (ii)}$$

from (i) & (ii) $\rightarrow$ $W = 2028.6$ psf

$\therefore$ Punching stress $= \frac{(100-4.876)\times 2028.6}{1749}$

$$= 109.54 \text{ psi (Ans)}$$

(9) An 18" dia sewer with $n = 0.013$ is laid on a grade of 0.015. What will be the velocity and discharge when the depth of flow is 4.5"?

<u>Sol</u>:

$$\theta = 2\cos^{-1}\left(1 - \frac{2d}{D}\right)$$

$$= 2\cos^{-1}\left(1 - \frac{2\times 4.5}{18}\right)$$

$$= 120^\circ = 2.094^{r}$$

$$A = \frac{1}{8}(\theta - \sin\theta) D^2 = \frac{1}{8}(2.094 - \sin 120^\circ) \times 18^2$$

$$\cancel{= 49.72 \text{ in}^2}$$

$$= 61.29 \text{ in}^2$$

$$P = \frac{1}{2}\theta D$$

$$R = \frac{1}{4}\left(1 - \frac{\sin\theta}{\theta}\right) D = \frac{1}{4}\left(1 - \frac{\sin 120^\circ}{2.094}\right) \times \frac{18}{12}$$

$$\Rightarrow \cancel{R = 0.2438} \Rightarrow R = 0.22 \text{ ft}$$

$$\therefore V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

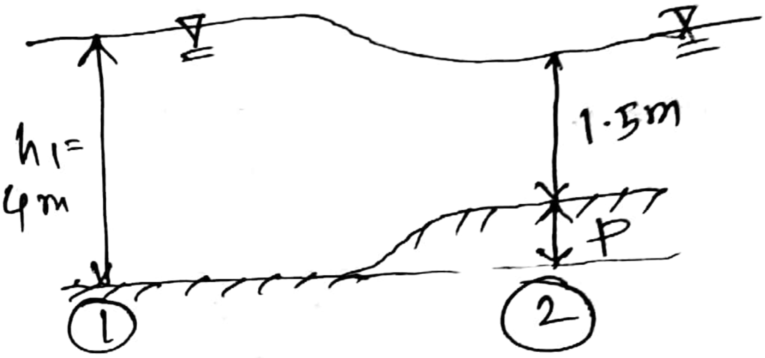
$$\Rightarrow V = \frac{1.49}{0.013} \cancel{.2658} (0.224)^{2/3} (0.015)^{1/2}$$

$$\Rightarrow V = 5.12 \text{ ft/sec}$$

Now, $Q = AV = \frac{61.29}{12\times 12} \times 5.12 = 2.18 \text{ ft}^3/\text{s}$

10) In a rectangular channel 3m wide depth of 4m water flows at a velocity of 2 ms^{-1}. In the downstream a smoth upward step in the channel bed to produce a depth of 1.5 m. Calculate the change in the water level.

Solⁿ :



~~Q = 3×4×1~~

$Q = A_1 V_1 = 3 \times 4 \times 2$

$\Rightarrow Q = 24 m^3/s$

$V_2 = \frac{Q}{A_2} = \frac{24}{3 \times 1.5} = \cancel{2.67}\ 5.33\ m/s$

applying energy eqⁿ betⁿ (I) & (II) section

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g}$$

$$\Rightarrow 4 + \frac{2^2}{2 \times 9.81} = (1.5 + P) + \frac{5.33^2}{2 \times 9.81}$$

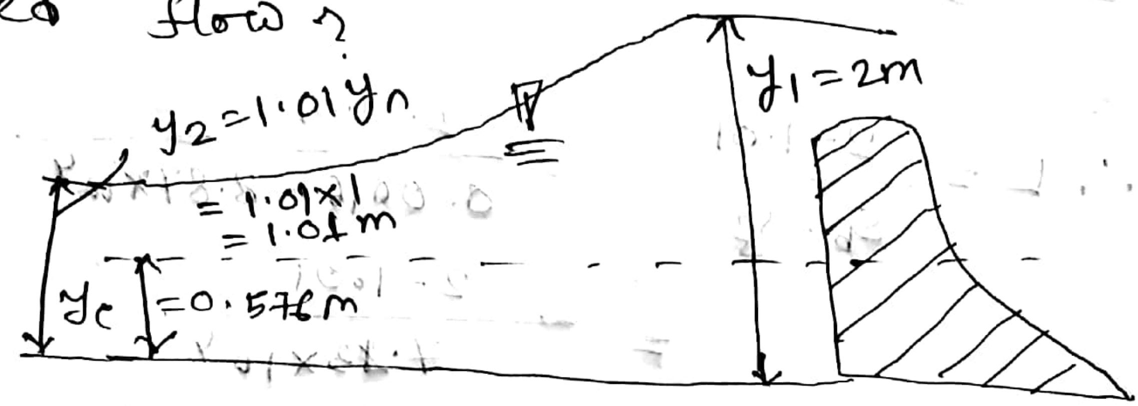
~~⇒ P = 2.5 m~~

$\Rightarrow P = 1.254\ m$

change in water level $= 4 - (1.5 + 1.254)$
$= 1.25\ m$

(11) A rectangular channel 8m wide bed slope of 0.0016 and n = 0.0025. Normal depth and critical depths are 1 m and 0.576 m. Compute the length of back water created by a dam which backs up a depth 2m immediately behind the dam in a gradually varied flow ?

Sol^n:



$y_2 = 2m$, $y_1 = 1.01\, y_n = 1.01 \times 1 = 1.01\, m$

from, $Q = AV = (8 \times 1) \times \frac{1}{0.0025} \times \left(\frac{8 \times 1}{8 + 2 \times 1}\right)^{2/3} \times (0.0016)^{.5}$

$= 110\ m^3/s$

$V_1 = \frac{Q}{A_1} = \frac{110}{8 \times 2}$

$= 6.875\ ms^{-1}$

$E_1 = y_1 + \frac{V_1^2}{2g}$

$= 2 + \frac{6.875^2}{2 \times 9.81}$

$= 4.41\ m$

$S_{f_1} = \frac{V_1^2 n^2}{R_1^{4/3}} = \frac{6.875^2 \times .0025^2}{\left(\frac{2 \times 8}{2 \times 2 + 8}\right)^{4/3}}$

$V_2 = \frac{Q}{A_2} = \frac{110}{8 \times 1.01} = 13.75\ ms^{-1}$

$E_2 = y_2 + \frac{V_2^2}{2g}$

$= 1.01 + \frac{13.75^2}{2 \times 9.81}$

$= 10.64\, m$

$S_{f_2} = \frac{V_2^2 n^2}{R_2^{4/3}}$

$= \frac{13.75^2 \times 0.0025^2}{\left(\frac{8 \times 1.01}{8 + 2 \times 1.01}\right)^{4/3}}$

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$\Rightarrow \delta_{f_1} = 2.01 \times 10^{-4}$ | $S_{f_2} = 1.57 \times 10^{-3}$

$$\bar{S}_f = \frac{S_{f_1} + S_{f_2}}{2} = \frac{2 \times 10^{-4} + 1.57 \times 10^{-3}}{2}$$

$$\Rightarrow \bar{S}_f = 8.87 \times 10^{-4}$$

$$\therefore L = \frac{2 - 1.01}{S_b - S_f} = \frac{2 - 1.01}{0.0016 - 8.87 \times 10^{-4}}$$

$$= \frac{2 - 1.01}{7.13 \times 10^{-4}}$$

$$= 1388 \text{ m}$$

Example 2.20. *Determine the field capacity of a soil for the following data :*

(*i*) *Depth of root zone = 1.8 m*

(*ii*) *Existing moisture = 8%*

(*iii*) *Dry density of soil = 1450 kg/m*^{3}

(*iv*) *Quantity of water applied to soil = 650 m*^{3}

(*v*) Water lost due to deep percolation and *evaporation* = 10%

(*vi*) *Area to be irrigated = 1000 m*^{3} (*AMIE 1999* (*Summer*) *Exam.*)

Solution. Volume of total water applied = 650 m^3.

Water wasted = 10% of 650 m^3 = 65 m^3.

Water used in raising m.c up to field capacity = 650 – 65 = 585 m^3.

Depth of water used in raising m.c up to to field capacity from the existing 8%

$$= \frac{585 \text{ m}^3}{\text{Area} = 1000 \text{ m}^2} = 0.585 \text{ m}$$

But water depth required in root zone of depth *td* increase m.c, is given by eqn.

$$= \frac{\gamma_d}{w}\left[\text{upper limit mc} - \text{lower limit mc, as fractions}\right]$$

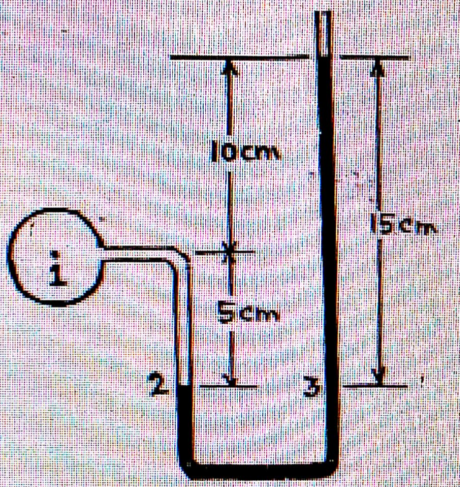
$$\therefore \quad 0.585 = \frac{1.45 \ t/\text{m}^3}{1 \ t/\text{m}^3} \times 1.8 \text{ m}\left[F.C - 0.08\right]$$

or $$(F.C - 0.08) = 0.224$$

or $$F.C = 0.224 - 0.08 = 0.144$$

Hence, Field capacity = **14.4%** **Ans.**

A U-tube manometer containing Hg (sp.gr.13.6) has its right limb opened to the atmosphere as shown in the figure. The left limb is full of water and is connected to a pipe containing water under pressure. Find the pressure of water in the pipe above atmosphere for the manometer readings as shown in the figure.



Solution Equating the pressure at 2-3, we have

$$h_1 \times 1 + 0.05 \times 1 = 0.15 \times 13.6$$

or,

$$h_1 = 0.15 \times 13.6 - 0.05 \times 1 = 1.99 \ m \ of \ water$$

$$\therefore p_1 = \gamma h_1 = 9.81 \times 1.99 = 19.52 \ kN/m^2$$

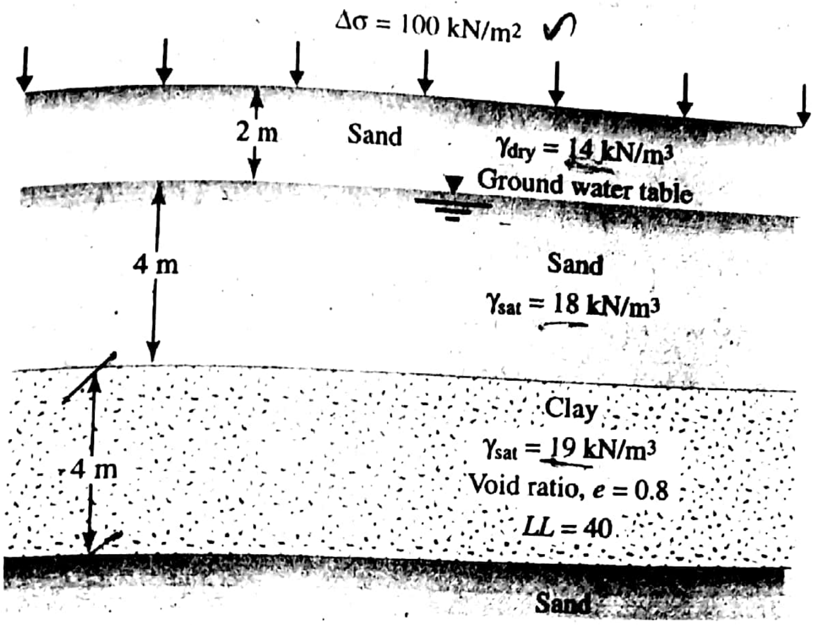


Figure 10.19

Solution

a. The average effective stress at the middle of the clay layer is

$$\sigma'_O = 2\gamma_{dry} + 4[\gamma_{sat(sand)} - \gamma_w] + \tfrac{4}{2}[\gamma_{sat(clay)} - \gamma_w]$$

or

$$\sigma'_O = (2)(14) + 4(18 - 9.81) + 2(19 - 9.81) = 79.14 \text{ kN/m}^2$$

From Eq. (10.24),

$$S_c = \frac{C_c H}{1 + e_O} \log\left(\frac{\sigma'_O + \Delta\sigma'}{\sigma'_O}\right)$$

From Eq. (10.28),

$$C_c = 0.009(LL - 10) = 0.009(40 - 10) = 0.27$$

So

$$S_c = \frac{(0.27)(4)}{1 + 0.8} \log\left(\frac{79.14 + 100}{79.14}\right) = 0.213 \text{ m} = \mathbf{213\ mm}$$

b. $\sigma'_O + \Delta\sigma' = 79.14 + 100 = 179.14 \text{ kN/m}^2$

$\sigma'_c = 190 \text{ kN/m}^2$

Because $\sigma'_O + \Delta\sigma' < \sigma'_c$, use Eq. (10.26) to get

$$S_c = \frac{C_s H}{1 + e_O} \log\left(\frac{\sigma'_O + \Delta\sigma'}{\sigma'_O}\right)$$

$$C_s = \frac{C_c}{6} = \frac{0.27}{6} = 0.045$$

$$S_c = \frac{(0.045)(4)}{1 + 0.8} \log\left(\frac{79.14 + 100}{79.14}\right) = 0.036 \text{ m} = \mathbf{36\ mm}$$

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