Reinforced Concrete

BEAM:

Working Stress Design Method:

* Singly Reinforced Beam ▸

Analysis Steps:

(1) Reinforcement Ratio, $\rho = \frac{A_s}{bd}$

(2) central axis co-efficient, $K = \sqrt{(\rho n)^2 + 2\rho n} - \rho n$ (For rectangular section)

where, $n = \frac{E_s}{E_c}$; $E_s = 29 \times 10^6$ psi $= 2 \times 10^5$ MPa

$E_c = 57000\sqrt{f_c'}$ psi $= 4700\sqrt{f_c'}$ MPa

(3) Lever arm coefficient, $j = 1 - \frac{K}{3}$

(4) $M_c = \frac{1}{2} f_c j K b d^2$ where, $f_c = 0.45 f_c'$

(5) $M_s = A_s f_s j d$ where, $f_s = 0.4 f_s$

(6) If $M_c > M_s$, The allowable Moment capacity of the beam is controlled by steel stress.

Hence, $M_n = M_s$

If $M_s > M_c$, The allowable Moment capacity of the beam is controlled by concrete stress. Hence, $M_n = M_c$

Design Steps:

(1) Assume, beam width, $b = 10'' - 12''$ and Total depth, $h = (\text{span Length})''$

(2) Total working load, W_T = self weight + DL + LL

(3) Working Moment, $M = \frac{WL^2}{8}$ (for simply supported beam)

(4) Depth check: $d_{req} = \sqrt{\frac{M}{Rb}}$ where, $R = \frac{1}{2} f_c j K$

$d_{eff} = h - \text{cover}$

If $d_{req} < d_{eff}$, singly reinforced beam is confirmed.

(5) $A_s = \frac{M}{f_s j d}$

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* Doubly Reinforced Beam:

Analysis Steps:

(1) A_s and A_s'

(2) $M_1 = \frac{1}{2} f_c j K b d^2$

(3) $A_{s1} = \frac{M_1}{f_s j d}$

(4) $A_{s2} = A_s - A_{s1}$

(5) $M_2 = A_{s2} f_s (d - d')$

$M_2 = A_s' f_s' (d - d')$ where, $f_s' = 2 f_s \times \frac{K - \frac{d'}{d}}{1 - K} \leq f_s$

(6) $M_n = M_1 + M_2$ (which one is lower)

Design Steps:

(1) Depth check: $d_{req} = \sqrt{\frac{M}{Rb}}$ where, $R = \frac{1}{2} f_c j K$

If $d_{req} > d_{eff}$. Doubly reinforced beam is confirmed.

(2) $M_1 = \frac{1}{2} f_c j K b d^2$

(3) $M_2 = M - M_1$

(4) $A_{s1} = \frac{M_1}{f_s j d}$

(5) $A_{s2} = \frac{M_2}{f_s (d - d')}$

(6) Tensile Reinforcement, $A_s = (A_{s1} + A_{s2})$

(7) Compression Reinforcement, $A_s' = \frac{M_2}{f_s' (d - d')}$ where, $f_s' = 2 f_s \times \frac{K - \frac{d'}{d}}{1 - K} \leq f_s$

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Ultimate Strength Design:

* Balanced steel Ratio, $\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$ where, $\varepsilon_y = \frac{f_y}{E_s}$; $\varepsilon_u = 0.003$

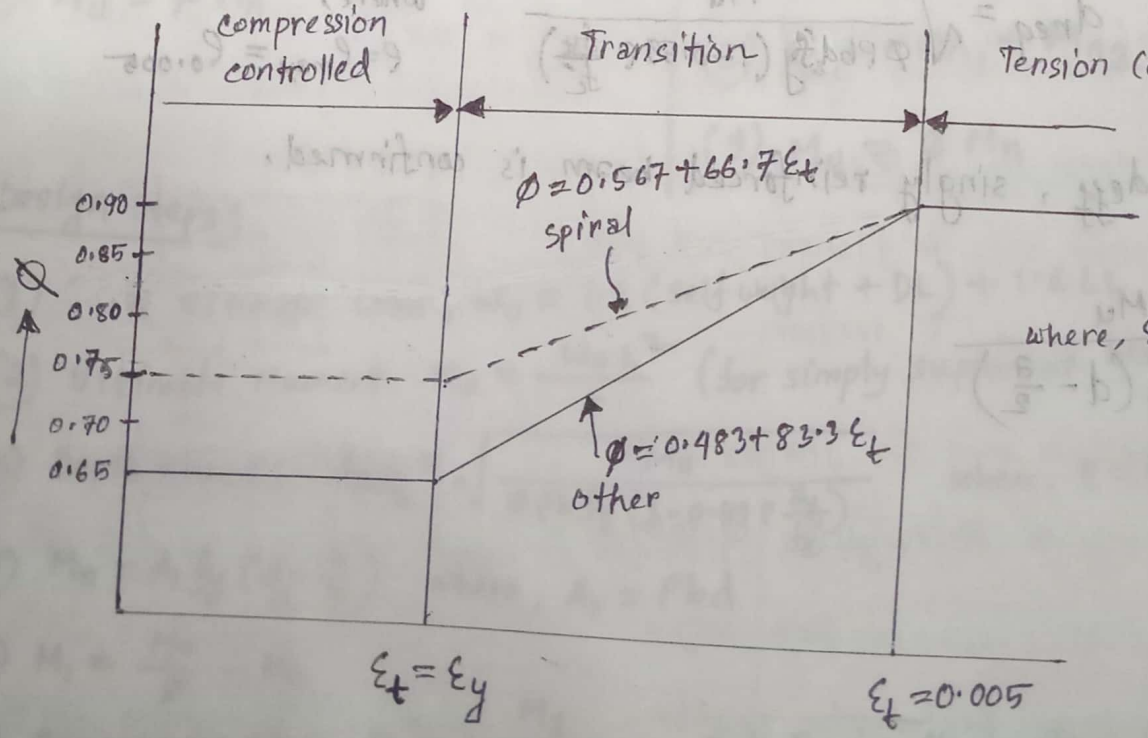
* Maximum Steel Ratio, $\rho_{max} = \rho_{0.005} = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.005}$ [For Design]

* Maximum Steel Ratio for Analysis, $\rho_{0.004} = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$

Here, $\beta_1 = 0.85 - 0.05 \times \frac{f_c' - 4000}{2000}$ and $0.65 \leq \beta_1 \leq 0.85$

For $f_c' \leq 4000$, $\beta_1 = 0.85$

* If $\rho < \rho_{max}$, singly reinforced beam is confirmed.
* If $\rho > \rho_{max}$, Doubly reinforced beam is confirmed.
* If $\rho < \rho_b$, steel yields before concrete crushing i.e. Under Reinforced Beam.
* If $\rho = \rho_b$, Steel yields and concrete crushes at the same time i.e. Balanced Reinforced Beam.
* If $\rho > \rho_b$, concrete crushes before steel yielding, i.e. over Reinforced Beam.



where, $\varepsilon_t = \varepsilon_u \times \frac{d_t - c}{c} \leq 0.005$

* Singly Reinforced Beam:

Analysis Steps:

(1) $\rho = \frac{A_s}{bd}$

(2) $\rho_{max} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.009}$ and, $\rho_b = 0.85\,\beta_1 \frac{f_c'}{f_y} * \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

(3) If $\rho < \rho_{max}$, Singly reinforced beam is confirmed.

(4) If $\rho < \rho_b$, under reinforced beam is confirmed.

(5) $M_n = A_s f_y \left(d - \frac{a}{2}\right)$

where, $a = \frac{A_s f_y}{0.85 f_c' b}$

(6) $M_u = \phi M_n$

(4) If $\rho > \rho_b$, over reinforced beam is confirmed.

(5) $M_n = A_s f_s \left(d - \frac{a}{2}\right)$

where, $f_s = E_s \varepsilon_t = E_s \varepsilon_u \left(\frac{d-c}{c}\right) \leq f_y$

Here, $c = \frac{a}{\beta_1}$

For value of 'a'

$C = T$

$\Rightarrow 0.85 f_c' a b = A_s f_s$

Design Steps:

(1) Total Ultimate Load, $W_u = 1.2(\text{Self weight} + DL) + 1.6\,LL$

(2) Ultimate Moment; $M_u = \frac{W_u L^2}{8}$ (for simply supported beam)

(3) Depth check: $d_{req} = \sqrt{\frac{M_u}{\phi \rho_b f_y \left(1 - 0.59 \rho \frac{f_y}{f_c'}\right)}}$

where, $\rho = \rho_{max} = \rho_{0.005}$

(4) If $d_{req} < d_{eff}$, singly reinforced beam is confirmed.

(5) $A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)}$

Doubly Reinforced Beam:

Analysis Steps:

(1) $\rho = \frac{A_s}{bd}$ and $\rho' = \frac{A_s'}{bd}$

(2) $\rho_{max} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$

(3) If $\rho > \rho_{max}$. Doubly reinforced Beam is confirmed.

(4) $\bar{\rho}_{cy} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{d'}{d} \times \frac{\varepsilon_u}{\varepsilon_u - \varepsilon_y} + \rho'$

(5) If $\bar{\rho}_{cy} < \rho$, compression steel will yield.

(6) $M_{n_1} = A_s' f_y (d - d')$

(7) $M_{n_2} = (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$

where, $a = \frac{(A_s - A_s') f_y}{0.85 f_c' b}$

(8) $M_1 = M_{n_1} + M_{n_2}$

(9) $M_u = \phi M_n$

(5) If $\bar{\rho}_{cy} > \rho$, compression bar will not yield.

(6) $M_{n_1} = A_s' f_s' (d - d')$

where, $f_s' = E_s \underbrace{\varepsilon_u \left(\frac{c - d'}{c}\right)}_{\varepsilon_s'} \leq f_y$

For the value of 'c'

$C = T$

$\Rightarrow 0.85\,\beta_1 f_c' b c + A_s' E_s \underbrace{\varepsilon_u \left(\frac{c - d'}{c}\right)}_{\varepsilon_s'} = A_s f_y$

(7) $M_{n_2} = 0.85 f_c' a b \left(d - \frac{a}{2}\right)$

(8) $M_n = M_{n_1} + M_{n_2}$

(9) $M_u = \phi M_n$

Design steps:

(1) Total Ultimate Load, $W_u = 1.2$ (self weight + DL) $+ 1.6$ LL

(2) Ultimate Moment, $M_u = \frac{W_u L^2}{8}$ (for simply supported beam)

(3) Depth check: $d_{req} = \sqrt{\frac{M_u}{\phi \rho b f_y \left(1 - 0.59 \rho \frac{f_y}{f_c'}\right)}}$ where, $\rho = \rho_{max} = \rho_{0.005}$

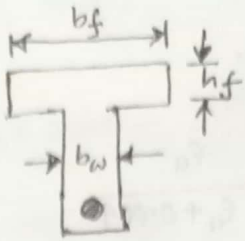
(4) $M_n = A_s f_y \left(d - \frac{a}{2}\right)$ where, $A_s = \rho b d$

(5) $M_1 = \frac{M_u}{\phi} - M_n$

(6) Compression Steel, $A_s' = \frac{M_1}{f_s' (d - d')}$ and Tension Steel, $A_{st} = A_s + \frac{A_s' f_s'}{f_y}$

T Beam:

Effective Flange Width:

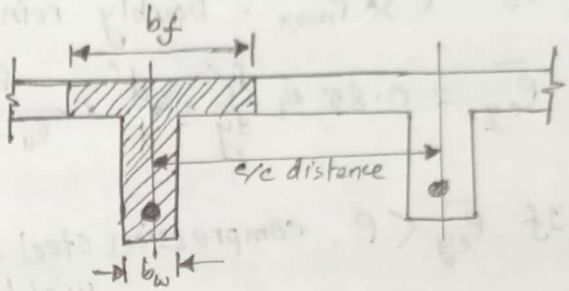


* For Isolated T Beam,

$$h_f \geq \frac{b_w}{2}$$

$$b_f \leq 4b_w$$

* For Interior T Beam,



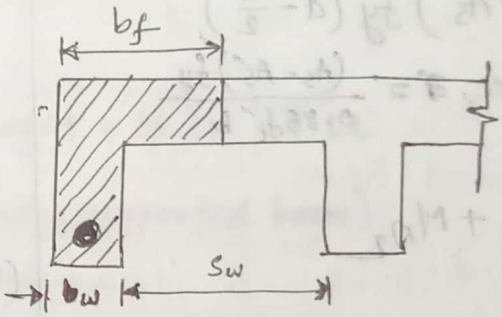
$$b_f = b_w + 16h_f$$

$$b_f = \frac{L}{4}$$

b_f = c/c distance of beams

The smallest of the above mentioned values must be used.

* For Exterior T Beam,



$$b_f \leq b_w + \frac{\text{clear span}}{12}$$

$$b_f \leq b_w + 6h_f$$

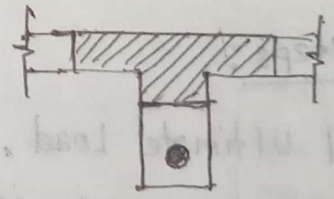
$$b_f = 0.5\, S_w$$

The smallest of above mentioned values must be used.

Compression Area in T Beam:

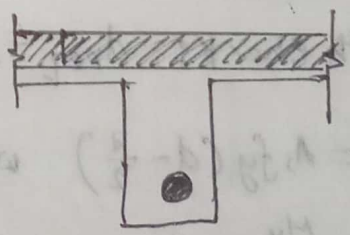
Case-1: compression area in flanges and web.

Behaves as a T section



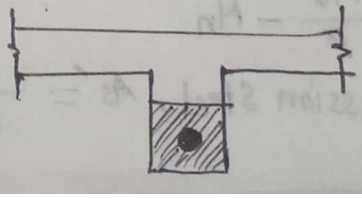
Case-2: compression area in flanges only.

Behaves as Rectangular section.



Case-3: compression area in web only.

Behaves as Rectangular section.



Analysis Steps:

(1) Determine Effective flange width, b_f

(2) $\rho = \frac{A_s}{b_f d}$

(3) $a = \frac{A_s f_y}{0.85 f_c' b_f}$

(4) If $a > h_f$, T beam Analysis is required.

(5) $M_{n_1} = A_{sf} f_y \left(d - \frac{h_f}{2}\right)$

where, $A_{sf} = \frac{0.85 f_c' (b_f - b) h_f}{f_y}$

(6) $M_{n_2} = (A_s - A_{sf}) f_y \left(d - \frac{a}{2}\right)$

where, $a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w}$

(7) $M_n = M_{n_1} + M_{n_2}$

(8) $M_u = \phi M_n$

(4) If $a < h_f$, Rectangular beam Analysis is required.

(5) $M_n = A_s f_y \left(d - \frac{a}{2}\right)$

where, $a = \frac{A_s f_y}{0.85 f_c' b_f}$

(6) $M_u = \phi M_n$

* self weight $= \left[\frac{c/c \times h_f}{144} + \frac{(h - h_f) \times b_w}{144}\right] \times 150$ plf

Design Steps:

(1) Determine effective flange width, b_f

(2) Total Ultimate Load, $W_u = 1.2 \times (\text{self weight} + DL) + 1.6\, LL$

(3) Ultimate Moment, $M_u = \frac{W_u L^2}{8}$ (for simply supported beam)

(4) $A_s = \frac{M_u}{\phi f_y \left(d - \frac{h_f}{2}\right)}$

(5) $\rho = \frac{A_s}{b_f d}$

(6) $a = \frac{A_s f_y}{0.85 f_c' b_f}$

(7) If $a > h_f$, T Beam design is required

(8) $\phi M_{n_1} = \phi A_{sf} f_y \left(d - \frac{h_f}{2}\right)$

(9) $\phi M_{n_2} = M_u - \phi M_{n_1}$

(10) $(A_s - A_{sf}) = \frac{\phi M_{n_2}}{\phi f_y \left(d - \frac{a}{2}\right)}$ where, $a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w}$

(11) $A_s = A_{sf} + (A_s - A_{sf})$

(7) If $a < h_f$, Rectangular Design is required.

(8) $A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)}$

Stirrup Design:

(1) Total Ultimate load, $W_u = 1.2DL + 1.6LL$

(2) Shear at support, $V_u = \frac{W_u L}{2}$

(3) Ultimate shear at a distance 'd' from the support, $V_{ud} = \frac{W_u L}{2} - \frac{W_u d}{12}$

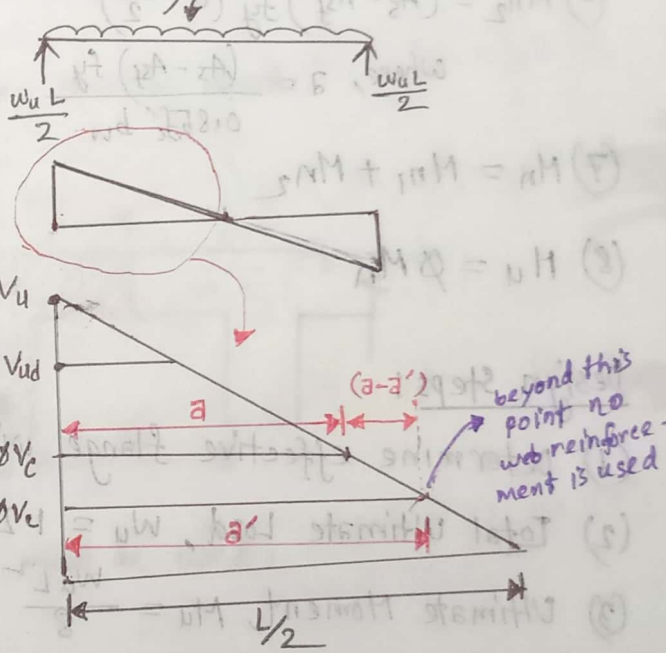
(4) Allowable shear, $\phi V_c = 2\phi \sqrt{f_c'}\, b_w d \quad [\phi = 0.75]$

(5) check: If, $\phi V_c \leq V_{ud}$, stirrup is required.

(6) The web steel must provide for V_{ud} within a distance 'a' from support. (the point after which no web reinforcement is required theoretically)

$$S = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c}$$ (Spacing of web with in 'a' distance)

But, According to code, Minimum web reinforcement must be carried a distance 'a'' from the support.



$$\text{Spacing, } S = \frac{\phi A_v f_y d}{V_{ud} - \frac{\phi V_c}{2}}$$

(7) $$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b_w} \leq \frac{A_v f_y}{50 b_w}$$

and, $$S_{max} = \frac{d}{2}$$

again, $S_{max} = 24$ inch

* First Stirrup is usually placed at a distance $\frac{S}{2}$ from the support.

Here, $$\frac{V_u}{L/2} = \frac{V_u - \phi V_c}{a}$$

again, $$\frac{V_u}{L/2} = \frac{V_u - \frac{1}{2}\phi V_c}{a'}$$

COLUMN:

Load Bearing Capacity of column:

In WSD, $P_{all} = \phi' A_g (0.25 f_c' + \rho_s f_s)$ where, $\phi' = 0.85$ (tied column)
$= 1.00$ (spiral column)

In USD, $P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$ where,
$\alpha = 0.80$ (tied column)
$= 0.85$ (spiral column)
$\phi = 0.65$ (tied column)
$= 0.70$ (spiral column)

Axial load that will stress the concrete to f_c:

$$P = f_c [A_g + (n-1) A_s]$$

ACI Recommendations:

(*) $\rho_s = 1\%$ to 8% ($2\% - 4\%$ are more commonly used)

(*) Minimum of 4 longitudinal bars (at least #5 bar) should be used for rectangular columns.

(*) Minimum of 6 longitudinal bars (at least #5 bar) should be used for circular columns.

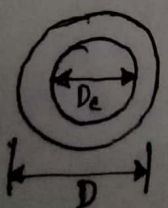
Design Specifications for Ties:

Spacing: $S = 16 d_b$ *d_b = longitudinal bar dia.
$= 48 d_t$ *d_t = Tie bar dia.
$=$ least dimension of column

Tie bar size:
* At least #3 bar for d_b = up to #10 bar
* At least #4 bar for d_b = #11 bar or larger.

Design specification for Spirals:

Spacing: $S_{max} = 3$ in
$S = \frac{1}{6} \times D_c$
$S_{min} = 1$ in



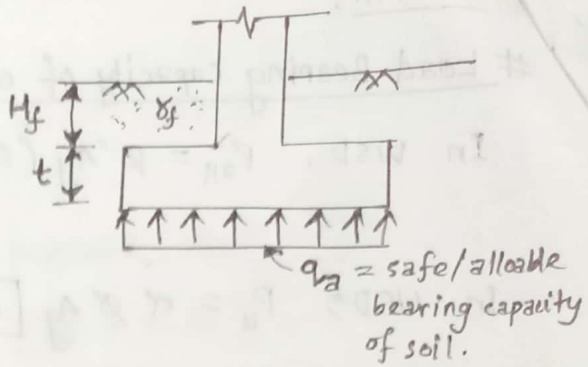
* Spiral bar size: not less than #3 bar (continuous)

* Spiral Reinforcement Ratio: $\rho_{sp} = \frac{4 A_{sp}}{S D_c}$

According to ACI code,

$$\rho_{sp} = 0.45 \left(\frac{A_g}{A_c} - 1\right) \frac{f_c'}{f_y}$$

FOOTING:



* Net pressure on footing,

$$q_{net} = q_a - \gamma_f H_f - t\gamma_c$$

* The required area of the footing,

$$A_{req} = \frac{\text{Total Load (DL+LL)}}{q_{net}}$$

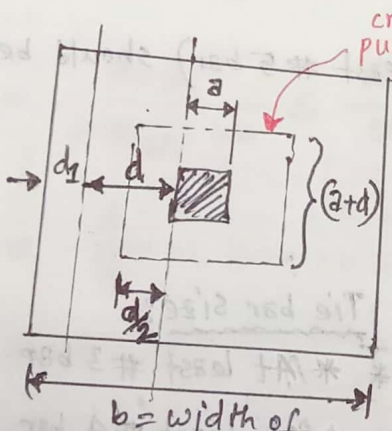
* Ultimate bearing pressure,

$$q_u = \frac{\text{Ultimate Load } (1.2DL + 1.6LL)}{\text{Area of footing}}$$

* **Punching Shear:**

Allowable punching shear, $\phi V_c = 4\phi\sqrt{f_c'}\, b_o d$ where, $b_o = 4\times(a+d)$ (a = column size)

Developed punching shear on footing, $V_{u_1} = q_u\left[b^2 - \left(\frac{a+d}{12}\right)^2\right]$



* For wall Footing,

$$V_{u_1} = q_u\left[\left(\frac{b-a}{2}\right) - d\right]$$

* **Beam Shear:**

Developed beam shear on footing, $V_{u_2} = q_u\, b\, d_1$

#Ultimate Moment: $M_u = \frac{1}{2} b q_u L^2$ where, $L = d + d_1$

* For wall footing, $M_u = \frac{1}{8} q_u (b-a)^2$

Beam

[PESCO-2015]

A rectangular beam has a width of 12" in an effective depth to the centroid of the reinforcing steel of 17.5 in. It is reinforced with four No. 9 bar in a row. If $f_y = 60$ Ksi, and $f_c' = 4$ Ksi. What is the ultimate moment capacity of the beam? Also check what would be the ϕ value?

Solution: Given, $b = 12"$, $d = 17.5"$, $A_s = (4 \times 1) = 4\ in^2$, $f_c' = 4$ Ksi and $f_y = 60$ Ksi

Now, $\rho = \frac{A_s}{bd} = \frac{4}{12 \times 17.5} = 0.019$

we know, $\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$ ($\varepsilon_y = \frac{f_y}{E_s}$) $= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29000}} = 0.0285$ (for $f_c' \le 4$ Ksi, $\beta_1 = 0.85$)

Since, $\rho < \rho_b$, It is under reinforced beam. (tension steel yield failure)

$\therefore M_n = A_s f_y \left(d - \frac{a}{2}\right)$ Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4.0 \times 60}{0.85 \times 4 \times 12"} = 5.88"$

$= 4 \times 60 \times \left(17.5 - \frac{5.88}{2}\right)$

$= 3494.4$ Kip-in.

Now, $M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\, \varepsilon_t$

$= 0.87 \times 3494.4$

$= 3040.13$ Kip-in.

$\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{17.5 - \frac{5.88}{0.85}}{\frac{5.88}{0.85}} = 0.0046$ ($c = \frac{a}{\beta_1}$)

$\therefore \phi = 0.483 + 83.3 \times 0.0046 = 0.866 \simeq 0.87$

(Ans.)

[BWDB-2016]

A rectangular beam of width 12" and effective depth 16" has a four No.s bars in a row on tension side. Check whether the beam is tension controlled or not. If $f_c' = 4$ ksi, and $f_y = 60$ ksi. Determine design capacity of the beam.

Solution: Given, $b = 12''$, $d = 16''$, $A_s = (4 \times 1) = 4\ in^2$, $f_c' = 4$ ksi and $f_y = 60$ ksi

$$\rho = \frac{A_s}{bd} = \frac{4}{12 \times 16} = 0.02083$$

$$\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29 \times 10^3}} = 0.0285$$

Since, $\rho < \rho_b$, it is under reinforced beam (tension steel yields at failure)

$\therefore M_n = A_s f_y \left(d - \frac{a}{2}\right)$ Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4 \times 60}{0.85 \times 4 \times 12} = 5.88''$

$= 4 \times 60 \times \left(16 - \frac{5.88}{2}\right)$

$= 3134.4$ Kip in

Now, $M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\, \varepsilon_t$

$\therefore M_u = (0.81 \times 3134.4)$ $\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{16 - \frac{5.88}{0.85}}{\frac{5.88}{0.85}} = 0.00394$

$= 2538.86$ Kip-in. which lies between 0.002 and 0.005.

Hence, The beam is in Transition region.

(Ans.) It is not tension controlled.

$\therefore \phi = 0.483 + 83.3 \times 0.00394 = 0.81$

[WASA-2017]

A rectangular beam of section 12"×20" carries a moment of 180 K-ft. Find out the reinforcement required to resist the moment and check either failure occurs by cracking of concrete or yielding of steel. Consider $f_c' = 3$ ksi, $f_y = 60$ ksi and $d' = 3$ in.

Solution: Given, $b = 12''$, $h = 20''$, $d' = 3$ in $\therefore d = (20-3) = 17''$

$f_c' = 3$ ksi, $f_y = 60$ ksi, $M = 180$ K-ft

We know,

$$M_u = \phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

Here, $a = \dfrac{A_s f_y}{0.85 f_c' b}$

$$\Rightarrow 180 \times 12 = 0.9 \times A_s \times 60 \times \left(17 - \frac{1.96 A_s}{2}\right) \qquad \Rightarrow a = \frac{A_s \times 60}{0.85 \times 3 \times 12} = 1.96 A_s$$

$$\Rightarrow A_s^2 52.92 A_s - 918 A_s + 2160 = 0$$

$$\therefore A_s = 2.81 \text{ in}^2$$

Now, $\rho = \dfrac{A_s}{bd} = \dfrac{2.81}{12 \times 17} = 0.014$

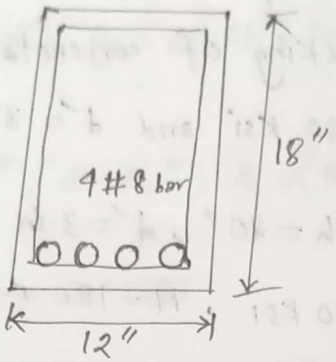
and, $\rho_b = 0.85 \beta_1 \times \dfrac{f_c'}{f_y} \times \dfrac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \dfrac{3}{60} \times \dfrac{0.003}{0.003 + \frac{60}{29 \times 10^3}} = 0.021$

Since, $\rho < \rho_b$ It is under reinforce beam (tension steel yields at failure)

(Ans.)

[BWDB-2018]

Determine the ultimate moment for the beam shown in below where, $f_c' = 4$ ksi, $f_y = 60$ ksi, clear cover = 1.5"



Solution: Given, $b = 12"$, $h = 18"$, $d = (18 - 1.5) = 16.5"$

$f_c' = 4$ ksi, $f_y = 60$ ksi, $A_s = (4 \times 0.79) = 3.16$ in^2

$$\therefore \rho = \frac{A_s}{bd} = \frac{(4 \times 0.79)}{12 \times 16.5} = 0.016$$

and, $$\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29 \times 10^3}} = 0.0285$$

Since, $\rho < \rho_b$ it is under reinforced beam. (tension steel yeilds at failure)

$$\therefore M_n = A_s f_y \left(d - \frac{a}{2}\right)$$ Here, $$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{3.16 \times 60}{0.85 \times 4 \times 12} = 4.65 \text{ in.}$$

$$= 3.16 \times 60 \times \left(16.5 - \frac{4.65}{2}\right)$$

$$= 2687.58 \text{ Kip-in.}$$

$M_u = \phi M_n$

$= 0.9 \times 2687.58$

$= 2418.82$ Kip-in.

Here, $\phi = 0.483 + 83.3 \times \varepsilon_t$

$$\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{16.5 - \frac{4.65}{0.85}}{\frac{4.65}{0.85}} = 0.006 > 0.005$$

$\therefore \varepsilon_t = 0.005$

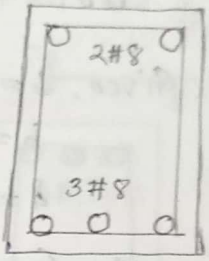
$\therefore \phi = 0.483 + 83.3 \times 0.005 = 0.90$

(Ans.)

[DMTCL-2019]

Calculate the ultimate moment capacity of the following beam:

Given, $h = 20''$, $b = 12''$, $d' = 2.5''$, $f_c' = 4$ ksi, $f_y = 60$ ksi. Assume singly Reinforced beam.



Solution: As, it is singly reinforced beam.

$$A_s = (3 \times 0.79) = 2.37 \text{ in}^2$$

$$\rho = \frac{A_s}{bd} = \frac{2.37}{12 \times (20 - 2.5)} = 0.0113$$

$$\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29 \times 10^3}} = 0.0285$$

Since, $\rho < \rho_b$ it is under reinforced beam (tension steeds at failure)

$$M_n = A_s f_y \left(d - \frac{a}{2}\right).$$

Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{2.37 \times 60}{0.85 \times 4 \times 12} = 3.4853$

$$= 2.37 \times 60 \times \left(17.5 - \frac{3.4853}{2}\right)$$

$$= 2240.7 \text{ Kip-in.}$$

$M_u = \phi M_n$ where, $\phi = 0.483 + 83.3\, \varepsilon_t$

$= (0.9 \times 2240.7)$

$= 2016.63$ Kip-in.

$$\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{17.5 - \frac{3.4853}{0.85}}{\frac{3.4853}{0.85}} = 0.0098 > 0.005$$

$\therefore \varepsilon_t = 0.005$

(Ans.)

$\therefore \phi = 0.483 + 83.3 \times 0.005 = 0.90$

[PGCB-2019]

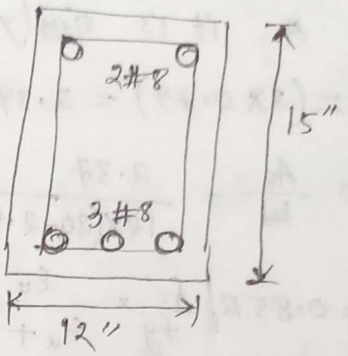
Determine the flexural moment capacity the cantilever beam having 15" depth and concrete clear cover 2.5 inch. Given $f_c' = 4$ ksi & $f_y = 60$ ksi (Assume singly Reinforced beam)

Solution: Given, $b = 12"$

$h = 15"$, $c.c = 2.5"$

$d = (15 - 2.5) = 12.5"$

$A_s = (2 \times 0.79) = 1.58\ in^2$



$$\rho = \frac{A_s}{bd} = \frac{1.58}{12 \times 12.5} = 0.0105$$

$$\rho_b = 0.85 \beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29 \times 10^3}} = 0.0285$$

Since, $\rho < \rho_b$ it is under reinforced beam. (tension steel yields at failure)

$$M_n = A_s f_y \left(d - \frac{a}{2}\right) \quad \text{Here, } a = \frac{A_s f_y}{0.85 f_c' b} = \frac{1.58 \times 60}{0.85 \times 4 \times 12} = 2.324$$

$$= 1.58 \times 60 \times \left(12.5 - \frac{2.324}{2}\right)$$

$$= 1074.8424\ \text{kip-in.}$$

Now,

$M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\,\varepsilon_t$ so, $\varepsilon_t = \varepsilon_u \times \frac{d-c}{c}$

$= (0.9 \times 1074.8424)$ $= 0.483 + 83.3 \times 0.005$ $= 0.003 \times \frac{17.5 - \frac{2.324}{0.85}}{\frac{2.324}{0.85}}$

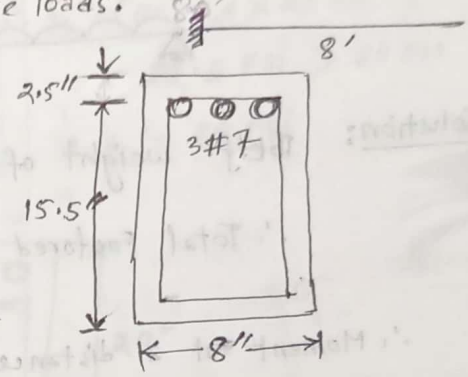
$= 967.36\ \text{kip-in.}$ $= 0.90$ $= 0.016 > 0.005$

$\therefore \varepsilon_t = 0.005$

(Ans.)

[BCIC-2017, BUET M.Sc.-2019, EGCB-20]

An 8 feet span cantilever beam has a rectangular section and reinforcement as shown in figure. The beam carries a dead load including its own weight of 1.5 K/ft and a live load of 0.9 K/ft. Using $f_c' = 4$ ksi and $f_y = 60$ ksi. Check if the beam is safe to carry the above loads.



Solution:

Given, D.L + S.W. = 1.5 K/ft

LL = 0.9 K/ft

$\therefore W_u = 1.2\,DL + 1.6\,LL$

$= (1.2 \times 1.5 + 1.6 \times 0.9) = 3.24$ K/ft

Moment due to factored load,

$$M_{req.} = \frac{WL^2}{2} = \frac{3.24 \times 8^2}{2} = 103.68 \text{ K-ft}$$

Nominal Moment capacity of the given section,

$$M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{3 \times 0.60 \times 60}{0.85 \times 4 \times 8} = 3.97$

$= 1.8 \times 60 \times \left(15.5 - \frac{3.97}{2}\right)$

$= 1459.62$ Kip-in

$\therefore$ ultimate moment capacity, $M_u = \phi M_n$

$= (0.9 \times 1459.62)$

$= 1313.66$ Kip-in.

$= 109.47$ Kip-ft

Here, $\phi = 0.483 + 83.3\,\varepsilon_t$

$\varepsilon_t = \varepsilon_u \times \frac{d-c}{c} = 0.003 \times \frac{15.5 - \frac{3.97}{0.85}}{\frac{3.97}{0.85}}$

$\therefore \varepsilon_t = 0.007 > 0.005$

$\therefore \varepsilon_t = 0.005$

$\therefore \phi = (0.483 + 83.3 \times 0.005)$

$= 0.90$

Since, $M_u = 109.47$ K-ft $> M_{req} = 103.68$ K-ft

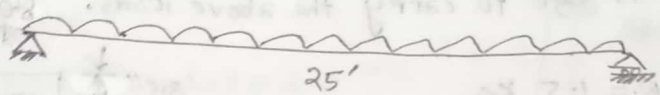
So,

The beam is safe to carry the mentioned loads.

(Ans.)

[Combined Bank-2020]

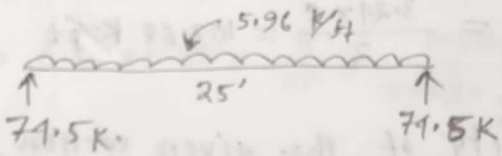
A rectangular beam of section 12" x 24" carries DL = 2 K/ft and LL = 2 K/ft. If the value of $f_c' = 4$ ksi, $f_y = 60$ ksi & $d' = 1.5$". Design the reinforcement at 10 ft from the support for the following beam:



Solution: Self weight of the beam $= \frac{12 \times 24}{144} \times 0.15 = 0.3$ K/ft

$\therefore$ Total Factored load, $W_u = 1.2 \times (0.3 + 2) + 1.6 \times 2.0 = 5.96$ K/ft

$\therefore$ Moment at a distance 10 ft from the left support.



$\therefore M = 71.5 \times 10 - 5.96 \times 10 \times \frac{10}{2}$

$= 417$ k-ft

We know, $M_u = \phi \rho b d^2 f_y \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$ where, $\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

$\Rightarrow 417 \times 12 = 0.9 \times 0.018 \times 12 \times d^2 \times 60 \left(1 - 0.59 \times \frac{0.018 \times 60}{4}\right)$ $= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.005}$

$= 0.0181$

$\Rightarrow d^2 = 517.02$

$\therefore d_{req} = 23.9$ in. $\simeq 23.5$"

$\therefore h_{req} = (23.5 + 1.5) = 25" > h = 24"$

Hence It is doubly reinforced beam. Let, c.c = 4" (double layer of tension reinforcement)

$M_n = A_s f_y \left(d - \frac{a}{2}\right)$ Here, $A_s = \rho b d = 0.018 \times 12 \times (24 - 4) = 4.32$ in^2

$= 4.32 \times 60 \times \left(20 - \frac{6.35}{2}\right)$ $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4.32 \times 60}{0.85 \times 4 \times 12} = 6.35$ in.

$= 4361$ Kip-in.

$M_1 = \left(\frac{417 \times 12}{0.9} - 4361\right) = 1599$ Kip-in

$$A_s' = \frac{M_1}{f_s'(d-d')} = \frac{1599}{60\times(20-1.5)}$$

$\therefore A_s' = 1.44\ in^2$

(compression reinforcement)

Provide 3 # 7 bar

Now, Tensile Reinforcement,

$$(A_s)_t = A_s + A_s' \times \frac{f_s'}{f_y}$$

$$= 4.32 + 1.44 \times \frac{60}{60}$$

$$= 5.76\ in^2$$

provide 6 # 9 bar.

Here, $f_s' = \varepsilon_s' E_s$

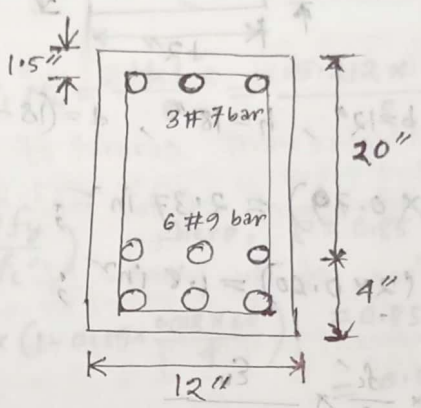
$$\varepsilon_s' = \varepsilon_u \times \frac{c-d'}{c} = 0.003 \times \frac{\frac{6.35}{0.85} - 1.5}{\frac{6.35}{0.85}}$$

$\therefore \varepsilon_s' = 0.0024$

$\therefore f_s' = (0.0024 \times 29 \times 10^3)$

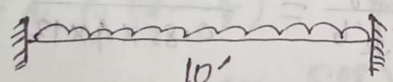
$= 69.6\ Ksi > 60\ Ksi$

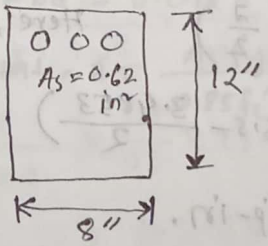
$\therefore f_s' = 60\ Ksi$



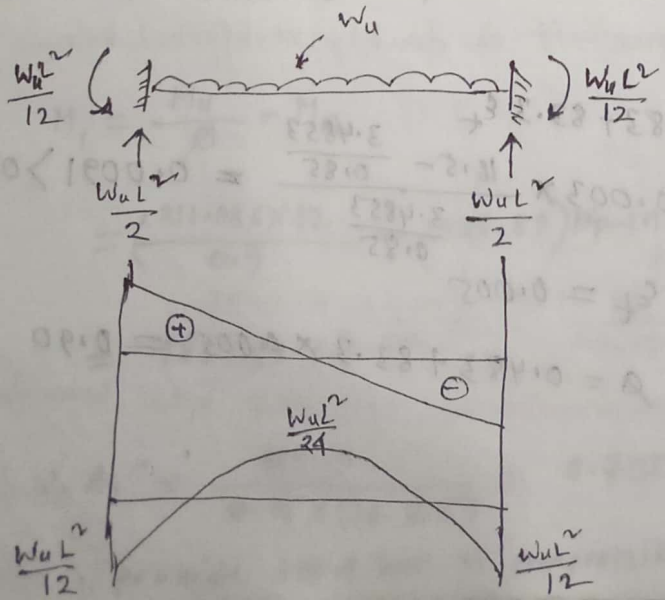
[BBAD-2018]

The span of a beam 10' long and ends are fixed. the maximum load controlled by the capacity in the negative moment region. Based on the flexural requirements, what is the maximum uniform live load the beam can carry? ($f_y = 40\ Ksi$, $f_c' = 3.5\ Ksi$, $M_n = 140.2\ Kip\text{-}in.$, $A_s = 0.62\ in^2$)





Solution:



Given, $M_n = 140.2\ Kip\text{-}in$

$\therefore M_u = (0.9 \times 140.2) = 126.18\ Kip\text{-}in$

$$\Rightarrow \frac{W_u L^2}{12} = 126.18$$

$$\Rightarrow \frac{W_u \times (10\times 12)^2}{12} = 126.18 \quad \therefore W_u = 0.10515\ Kip/in.$$

$= 1.262\ K/ft$

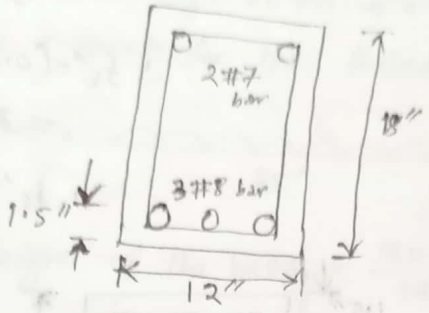
$W_u = 1.2\,DL + 1.6\,LL$

$$\Rightarrow 1.262 = 1.2 \times \frac{8\times 12}{144} \times 0.15 + 1.6\,LL \quad \therefore LL = 0.719\ K/ft$$

(Ans.)

[NPCBL – 2019, BIWTA – 2019]

Determine the ultimate moment capacity of the beam which clear cover is 1.5 inch. Consider $f_c' = 4$ ksi and $f_y = 60$ ksi.



Solution:

Given, $b = 12''$, $h = 18''$, $d = (18 - 1.5) = 16.5''$

$A_s = (3 \times 0.79) = 2.37 \text{ in}^2$; $\rho = \frac{A_s}{bd} = \frac{2.37}{12 \times 16.5} = 0.012$

$A_s' = (2 \times 0.60) = 1.8 \text{ in}^2$; $\rho' = \frac{A_s'}{bd} = \frac{1.8}{12 \times 16.5} = 0.0091$

We know,

$$\rho_{max} = 0.85 \beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.004} = 0.0206 > \rho$$

Hence It is singly reinforced beam.

$\therefore M_n = A_s f_y \left(d - \frac{a}{2}\right)$ Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{2.37 \times 60}{0.85 \times 4 \times 12} = 3.4853$ in

$= 2.37 \times 60 \times \left(16.5 - \frac{3.4853}{2}\right)$

$= 2098.5$ Kip-in.

$M_u = \phi M_n$

$= (0.9 \times 2098.5)$ Kip-in

$= 1888.65$ Kip-in

Here, $\phi = 0.483 + 83.3 \varepsilon_t$

$$\varepsilon_t = 0.003 \times \frac{16.5 - \frac{3.4853}{0.85}}{\frac{3.4853}{0.85}} = 0.0091 > 0.005$$

$\therefore \varepsilon_t = 0.005$

Hence, $\phi = 0.483 + 83.3 \times 0.005 = 0.90$

(Ans.)

[36th BCS]

A rectangular beam that must carry a service live load of 2.47 Kip/ft and a calculated dead load of 1.05 Kip/ft on an 18ft. simple span is limited in cross section for architectural reason to 10 inch width and 20 inch ~~total~~ depth. If $f_y = 60$ksi, $f_c' = 4$ ksi. Estimate the steel requirement.

Solution: Given, DL = 1.05 K/ft, LL = 2.47 K/ft

$\therefore W_u = (1.2 \times 1.05 + 1.6 \times 2.47) = 5.212$ K/ft

$\therefore M_u = \frac{W_u L^2}{8} = \frac{5.212 \times (18)^2}{8} = 211.086$ K-ft

We know,

$M_u = \phi \rho b d^2 f_y \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$

Here, $\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.005}$

$= 0.018$

$\Rightarrow 211.086 \times 12 = 0.9 \times 0.018 \times 10 \times d^2 \times 60 \times \left(1 - 0.59 \times \frac{0.018 \times 60}{4}\right)$

$\Rightarrow d^2 = 309.98$

$\therefore d_{req} = 17.6$ in. $>$ $d_{eff} = (20 - 4) = 16$ in.

Hence, it is doubly reinforced beam.

$M_n = A_s f_y \left(d - \frac{a}{2}\right)$

Here, $A_s = \rho b d = 0.018 \times 10 \times 16 = 2.88$ in^2

and, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{2.88 \times 60}{0.85 \times 4 \times 10} = 5.08$ in.

$\Rightarrow M_n = 2.88 \times 60 \times \left(16 - \frac{5.08}{2}\right)$

$\therefore M_n = 2328.89$ Kip-in

$M_1 = \frac{M_u}{\phi} - M_n$

$= \left(\frac{211.086 \times 12}{0.9} - 2328.89\right)$ Kip-in.

$= 485.59$ Kip-in

$\therefore A_s' = \frac{M_1}{f_s'(d - d')} = \frac{485.59}{f_s'(16 - 2.5)}$

Here, $f_s' = \varepsilon_s' E_s$

$\varepsilon_s' = \varepsilon_u \times \frac{c - d'}{c} = 0.003 \times \frac{\frac{5.08}{0.85} - 2.5}{\frac{5.08}{0.85}}$

$\therefore \varepsilon_s' = 0.00175$

$\therefore E_s = 0.00175 \times 29 \times 10^3 = 50.75$ ksi

$\therefore A_s' = \frac{485.59}{50.75 \times (16 - 2.5)} = 0.708$ in^2

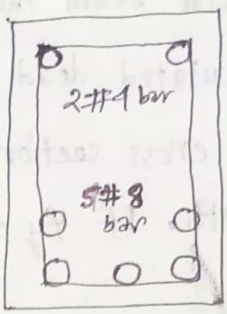
$\therefore$ provide 2#4 bar as compression reinforcement

Tension reinforcement,

$\therefore (A_s)_t = A_s + A_s' \times \frac{f_s'}{f_y}$

$= 2.88 + 0.708 \times \frac{50.75}{60} = 3.48 \text{ in}^2$

provide 5 # 8 bar



(Ans.)

[40th BCS]

A rectangular beam has a width 12" and effective depth to the centroid of the tension reinforcement consist of six no. 10 bars in two rows is 18 in. compression reinforcement of two no. 9 bars is placed 2.5 inch from the compression face of the beam. If $f_y = 50$ ksi and $f_c' = 5$ ksi. what is the design moment capacity of the beam.

Solution:

$A_s = (6 \times 1.27) = 7.62 \text{ in}^2$; $\rho = \frac{A_s}{bd} = \frac{7.62}{12 \times 18} = 0.0353$

$A_s' = (2 \times 1) = 2 \text{ in}^2$; $\rho' = \frac{A_s'}{bd} = \frac{2}{12 \times 18} = 0.0093$

We know,

$\rho_{max} = 0.85 \beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

$= 0.85 \times 0.85 \times \frac{5}{50} \times \frac{0.003}{0.003 + 0.005}$

$\therefore \rho_{max} = 0.0271 < \rho$, Hence it is doubly reinforced beam.

Then, $\rho_{cy} = 0.85 \beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} \times \frac{d'}{d} + \rho'$

$= 0.85 \times 0.80 \times \frac{5}{50} \times \frac{0.003}{0.003 + \frac{50}{29 \times 10^3}} \times \frac{2.5}{18} + 0.0093$

$= 0.0157 < \rho$, Hence compression bar will yield when beam fails.

$\therefore M_{n_1} = A_s' f_y (d - d')$

$= 2 \times 50 \times (18 - 2.5)$

$= 1550$ Kip-in.

$M_{n_2} = (A_s - A_s') \times f_y \times (d - \frac{a}{2})$ Here, $a = \frac{(A_s - A_s') \times f_y}{0.85 f_c' b}$

$= (7.62 - 2) \times 50 \times (18 - \frac{5.51}{2})$ $= \frac{(7.62 - 2) \times 50}{0.85 \times 5 \times 12}$

$= 4283.85$ Kip-in. $= 5.51$ in.

$\therefore M_n = M_{n_1} + M_{n_2} = (4283.85 + 1550) = 5833.85$ Kip-in

$M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\, \varepsilon_t$

$= (0.89 \times 5833.85)$ $\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{18 - \frac{5.51}{0.80}}{\frac{5.51}{0.80}}$

$= 5192.13$ Kip-in. $\therefore \varepsilon_t = 0.00484$

(Ans.) $\therefore \phi = 0.483 + 83.3 \times 0.00484 = 0.89$

Tension reinforcement

[WASA-2017, PGCL-2017, MPA-2019]

A rectangular beam has a width of 12 in. and an effective depth to the centroid of the reinforcing steel to 17.5 in. It is reinforced with 3-20 mm bars in one row. Find out the allowable working moment that can be resisted by the section if $f_s = 24000$ psi, $f_c = 1200$ psi.

Solution: Given, $b = 12''$, $d = 17.5''$ $\quad n = \frac{E_s}{E_c} = \frac{29\times10^6}{57000\sqrt{f_c'}} = \frac{29\times10^6}{57000\sqrt{\frac{1200}{0.45}}} = 9.85 \simeq 9$

$$A_s = 3 \times \frac{\pi}{4} \times \left(\frac{20}{25.4}\right)^2 = 1.46 \text{ in}^2$$

$$p = \frac{A_s}{bd} = \frac{1.46}{12\times17.5} = 0.007$$

$$K = \sqrt{2pn + (pn)^2} - pn = \sqrt{2\times0.007\times9 + (0.007\times9)^2} - (0.007\times9) = 0.2975$$

$$j = 1 - \frac{K}{3} = 1 - \frac{0.2975}{3} = 0.9$$

Now, $M_s = A_s f_s jd = 1.46\times24000\times0.9\times17.5 = 551880$ lb-in $= 46$ K-ft

$$M_c = \frac{1}{2} f_c jKbd^2 = \frac{1}{2}\times1200\times0.9\times0.2975\times12\times17.5^2 = 590388.75 \text{ lb-in}$$
$$= 49.2 \text{ K-ft}$$

Since, $M_c > M_s$, steel stress controls.

$\therefore$ Allowable working moment, $M_{all} = 46$ K-ft (Ans.)

[BHP-2017]

A simply supported of 10" × 18" section is a span length of 18' and distributed load is 1355 plf in additional of its weight. If $f_c' = 3000$ psi and $f_s = 20{,}000$ psi, then calculate the required steel area and draw the long and cross section of the beam.

Solution: self weight of the beam, $D.L = \frac{bh}{144}\times150 = \frac{10\times18}{144}\times150 = 187.5$ plf

Given, $LL = 1355$ plf

$\therefore$ Total load, $W = (D.L + L.L) = (187.5 + 1355) = 1542.5$ plf
$= 1.5425$ K/ft

$$M = \frac{wL^2}{8} = \frac{1.5425 \times 18^2}{8} = 62.47 \text{ k-ft}$$

We know,

$$M = \frac{1}{2} f_c j K b d^2$$

$$\Rightarrow 62.47 \times 12 = \frac{1}{2} \times (0.45 \times 3.0) \times 0.874 \times 0.378 \times 10 \times d^2$$

$$\Rightarrow d^2 = 336.16$$

$$\therefore d_{req} = 18.33 \text{ in.} > d_{given} = (18 - 2.5) = 15.5''$$

Hence, It is doubly reinforced beam

Here, $n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \simeq 9$

$$K = \frac{n}{n+r} \qquad r = \frac{f_s}{f_c} = \frac{20000}{0.45 \times 3000} = 14.81$$

$$\therefore K = \frac{9}{9 + 14.81} = 0.378$$

$$j = 1 - \frac{K}{3} = 1 - \frac{0.378}{3} = 0.874$$

Assume. steel will be provide two layers. and clear cover = 4"

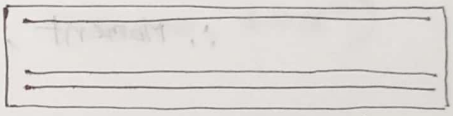
Hence, effective depth, $d = (18 - 4) = 14''$

Now,

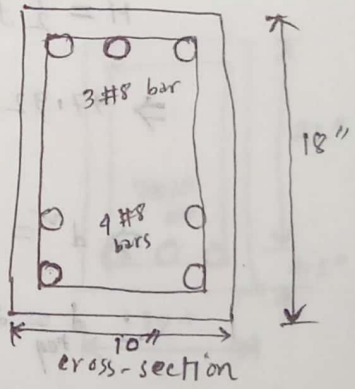
$$M_1 = \frac{1}{2} f_c j K b d^2$$

$$= \frac{1}{2} \times (0.45 \times 3.0) \times 0.874 \times 0.378 \times 10 \times 14^2$$

$$= 437.1 \text{ kip-in}$$



longitudinal section



cross-section

$$\therefore M_2 = M - M_1 = (62.47 \times 12 - 437.1) = 312.54 \text{ kip-in}$$

$$A_{s_1} = \frac{M_1}{f_s j d} = \frac{437.1}{20 \times 0.874 \times 14} = 1.786 \text{ in}^2$$

$$A_{s_2} = \frac{M_2}{f_s (d - d')} = \frac{312.54}{20 \times (14 - 2.5)} = 1.359 \text{ in}^2$$

$\therefore$ Tensile reinforcement, $A_s = A_{s_1} + A_{s_2} = (1.786 + 1.359) = 3.145 \text{ in}^2$

provide 4 # 8 bars

And,

Compression reinforcement, $A_s' = \frac{M_2}{f_s' (d - d')}$

$$= \frac{312.54}{12.825 \times (14 - 2.5)}$$

$$= 2.12 \text{ in}^2$$

Here, $f_s' = 2 f_s \times \frac{K - \frac{d'}{d}}{1 - K}$

$$= 2 \times 20 \times \frac{0.378 - \frac{2.5}{14}}{(1 - 0.378)}$$

$$= 12.825 \text{ Ksi} < f_s$$

provide 3 # 8 bar as compression reinforcement.

[BKB-2018]

A rectangular beam of 12" × 24" section must carry a uniformly distributed live load 680 plf and support the dead load of a wall weighing 380 plf in addition to its own self weight on a simple span of 24 ft. Find out the area of steel required, using intermediat grade steel at a working stress of 20000 psi and 3000 psi concrete at a working stress of 1350 psi, $n = 2.5^0$

Solution: self weight of the beam, S.W. $= \left(\frac{12 \times 24}{144} \times 150\right)$ plf $= 300$ plf

$\therefore$ Total dead load, D.L $= (300 + 380) = 680$ plf; Given, Live load $= 680$ plf

$\therefore$ Total load $=$ D.L + L.L $= (680 + 680) = 1360$ plf.

$\therefore$ Moment, $M = \frac{WL^2}{8} = \frac{1360 \times 24^2}{8} = 97920$ lb-ft $= 97.92$ K-ft

Now, $M = \frac{1}{2} f_c j K b d^2$

$\Rightarrow 97.92 \times 12 = \frac{1}{2} \times \frac{1350}{1000} \times 0.378 \times 0.874 \times 12 \times d^2$

$\Rightarrow d^2 = 439.1$

$\therefore d_{req} = 20.95$ in. $< d_{eff} = (24 - 2.5) = 22.5$ in.

Here, $n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \approx 9$

$r = \frac{f_s}{f_c} = \frac{20000}{1350} = 14.81$

$\therefore K = \frac{n}{n+r} = \frac{9}{9+14.81} = 0.378$

$j = 1 - \frac{K}{3} = 1 - \frac{0.378}{3} = 0.874$

Hence, It is singly reinforce beam.

Now, $A_s = \frac{M}{f_s j d} = \frac{97.92 \times 12}{20 \times 0.874 \times 22.5} = 2.96$ in^2

provide 3 # 9 bar.

(Ans.)



cross-section

[3rd BCS]

Design a simply supported rectangular beam for a bending moment of 1440 K-in. Concrete strength, $f_c' = 3500$ psi, steel strength, $f_y = 60000$ psi, modular ratio, $n = 9$. Design the beam using WSD.

Solution:

Given, $n = 9$

$$r = \frac{f_s}{f_c} = \frac{0.4 f_y}{0.45 f_c'} = \frac{0.4 \times 60}{0.45 \times 3.5} = 15.24$$

$$K = \frac{9}{9 + 15.24} = 0.371$$

$$j = 1 - \frac{K}{3} = \left(1 - \frac{0.371}{3}\right) = 0.876$$

We Know,

$$M = \frac{1}{2} f_c j K b d^2$$

$$\Rightarrow 1440 = \frac{1}{2} \times 0.45 \times 3.5 \times 0.876 \times 0.371 \times 12 \times d^2 \quad (\text{Assume, } b = 12'')$$

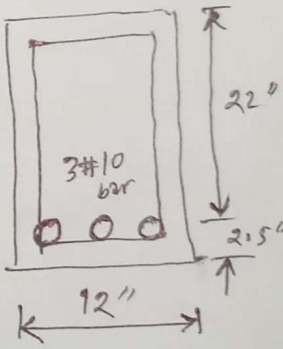
$$\Rightarrow d^2 = 468.87$$

$$\therefore d = 21.65'' \simeq 22''$$

Now,

$$A_s = \frac{M}{f_s j d} = \frac{1440}{20 \times 0.876 \times 22} = 3.74 \text{ in}^2$$

provide 3 #10 bars.

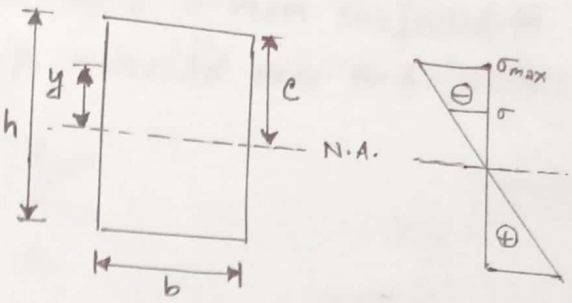


#

Stresses in Beam:

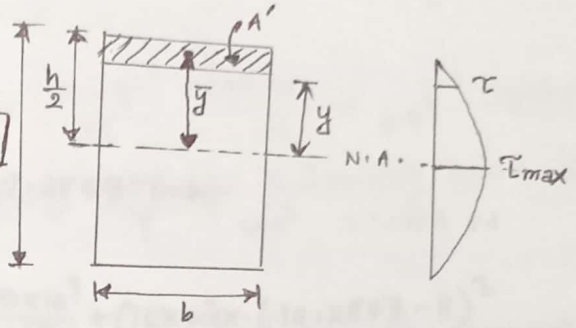
* Flexural Stress, $\sigma = \frac{My}{I}$

Maximum Flexural Stress, $\sigma_{max} = \frac{MC}{I}$



* Shearing Stress, $\tau = \frac{VQ}{Ib}$.

Maximum Shearing Stress, $\tau_{max} = \frac{VQ_{max}}{Ib}$ when, $\left[y = \frac{h}{4}\right]$



Here, $Q = A'\bar{y} = \left[\left(\frac{h}{2} - y\right) \times b\right] \times \left(y + \frac{\frac{h}{2} - y}{2}\right)$

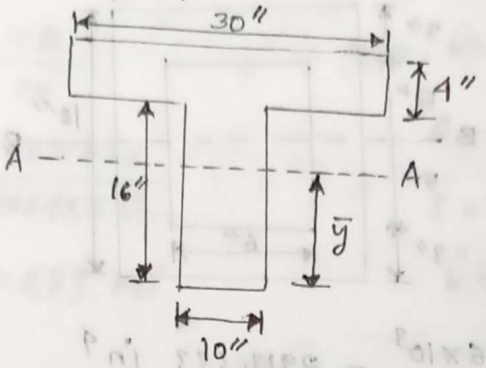
[Assumption of Formula: The shearing stress is uniform across the width of the cross sectio

Average shear stress, $\tau_{avg.} = \frac{V}{A}$

* Shear Flow, $q = \tau b = \frac{VQ}{I}$

Stresses in Beam:

Find the flexural stress at the bottom fiber of a T beam subjected to a bending moment of 100 Kip-ft about its centroidal axis A-A. [WRGICL-2014]



Solution:

$$\bar{y} = \frac{30\times4\times(16+\frac{4}{2}) + 16\times10\times\frac{16}{2}}{(30\times4)+(16\times10)} = 12.2857 \text{ inch.}$$

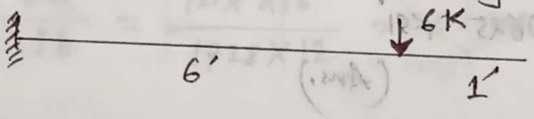
$$I_{A-A} = \frac{30\times4^3}{12} + (30\times4)\times(18-12.2857)^2 + \frac{10\times16^3}{12} + (16\times10)\times(12.2857-8)^2$$

$$= 10430.4762 \text{ in}^4$$

We know, $\sigma_{max} = \frac{MC}{I}$

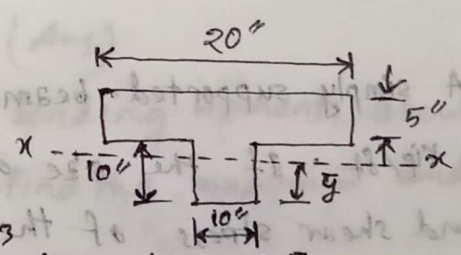
At bottom, $\sigma_{max} = \frac{100\times12.2857\times12}{10430.4762} = 1.41344 \text{ ksi}$ (Ans.)

Compute the maximum tensile stress of the following beam. Consider a section of T beam with web dimension of 10"×10" and flange dimension of 20"×5". [WASA-2014]



Solution:

$$\bar{y} = \frac{10\times10\times\frac{10}{2} + 20\times5\times(10+\frac{5}{2})}{(10\times10)+(20\times5)} = 8.75$$



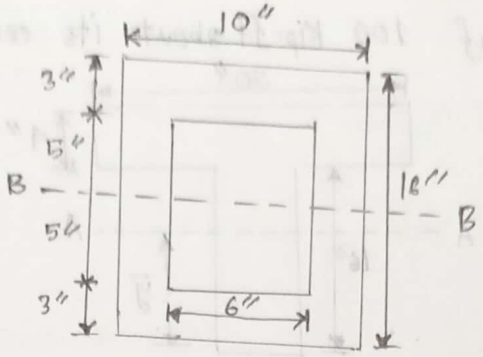
$$I_{x-x} = \frac{20\times15^3}{12} + (20\times15)\times(\frac{15}{2}-8.75)^2 - 2\times\left[\frac{5\times10^3}{12} + (5\times10)\times(\frac{10}{2}-8.75)^2\right]$$

$$= 3854.167 \text{ in}^4$$

$M_{max} = (6\times6) = 36 \text{ K-ft}$

We know, $\sigma_{max} = \frac{MC}{I} = \frac{(36\times12)\times8.75}{3854.167} = 0.98 \text{ ksi}$ (Ans.)

Find the maximum flexural compressive stress in a box section of 10"×16" subjected to bending moment of 100 K-ft about its axis B-B. [PGCL-2014]



Solution: $I_{B-B} = \frac{10\times16^3}{12} - \frac{6\times10^3}{12} = 2913.333 \text{ in}^4$

We know, $\sigma_{max} = \frac{MC}{I} = \frac{(100\times12)\times\frac{16}{2}}{2913.333} = 3.295 \text{ ksi}$ (Ans.)

Determine the bending stress and shear stress in a beam having 12"×12" section and subjected to maximum bending moment of 12 K-ft and shear force is 6 Kip. [BIFPCL-2015]

Solution:

$I = \frac{12\times12^3}{12} = 1728 \text{ in}^4$

$\therefore \sigma_{max} = \frac{MC}{I} = \frac{(12\times12)\times\frac{12}{2}}{1728} = 0.5 \text{ ksi}$

Then, $\tau_{max} = \frac{VQ}{Ib}$ Here, $Q = (12\times\frac{12}{2}\times\frac{12}{4}) = 216 \text{ in}^3$

$\therefore \tau_{max} = \frac{6\times216}{1728\times12} = 0.0625 \text{ ksi}$ (Ans.)

A simply supported beam of span 10 ft, is applied distributed load of 1 Kip/ft. If the size of the beam is 10"×10", Find the maximum bending and shear stress of the beam. [RRI-2015]

Solution: we know, $\sigma_{max} = \frac{MC}{I} = \frac{12.5\times12\times5}{833.33}$

$\therefore \sigma_{max} = 0.90 \text{ ksi}$

$\tau_{max} = \frac{VQ}{Ib} = \frac{5\times125}{833.33\times10} = 0.075 \text{ ksi}$ (Ans.)

Here, $M = \frac{1\times10^2}{8} = 12.5 \text{ K-ft}$

$C = \frac{10}{2} = 5"$

$I = \frac{10\times10^3}{12} = 833.33 \text{ in}^4$

$V = \frac{1\times10}{2} = 5 \text{ Kips}.$

$Q = 10\times\frac{10}{2}\times\frac{10}{4} = 125 \text{ in}^3$

Find the shear stress of section 12" × 22" subjected to a critical shear force of 48 Kips. [PGCB-2015, DNCC-2016, BPDB-2016]

Solution: we know, $\tau = \frac{VQ}{Ib}$ Here, $V = 48$ Kips

$= \frac{48 \times 726}{10648 \times 12}$

$= 0.273$ Ksi

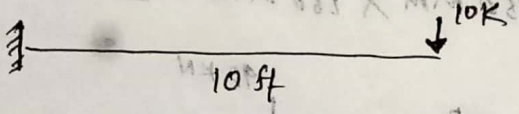
$Q = \left(12 \times \frac{22}{2} \times \frac{22}{4}\right) = 726$ in^3

$I = \frac{12 \times 23^3}{12} = 10648$ in^4

$b = 12$"

(Ans.)

Calculate the shear stress and bending stress of the following beam of section 12" × 12". [MPL-2017, JOCL-2018]



Solution:

$M_{max} = (10 \times 10) = 100$ K-ft

$V = 10.0$K , $I = \frac{12 \times 12^3}{12} = 1728$ in^3

$\sigma_{max} = \frac{MC}{I} = \frac{100 \times 12 \times \frac{12}{2}}{1728} = 4.167$ Ksi

$Q = 12 \times \frac{12}{2} \times \frac{12}{4} = 216$ in^3

$\therefore \tau_{max} = \frac{VQ}{Ib} = \frac{10 \times 216}{1728 \times 12} = 0.1042$ Ksi

(Ans.)

A 100 mm × 100 mm beam is subjected to bending moment about both principal axis of 1 KN-m and 2 KN-m. Find the maximum bending stress of the beam. [SGFL-2017]

Solution: Given, $M_x = 1$ KN-m , $M_y = 2$ KN-m

Here, $I_x = I_y = \frac{100 \times 100^3}{12} = 83.33 \times 10^5$ mm^4

$\sigma_x = \frac{M_x C}{I_x} = \frac{1 \times 10^6 \times \frac{100}{2}}{83.33 \times 10^5} = 6$ N/mm^2

$$\sigma_y = \frac{M_y c}{I_y} = \frac{2\times10^6 \times \frac{100}{2}}{83.33\times10^5} = 12 \text{ N/mm}^2$$

Hence, For Principal stresses,

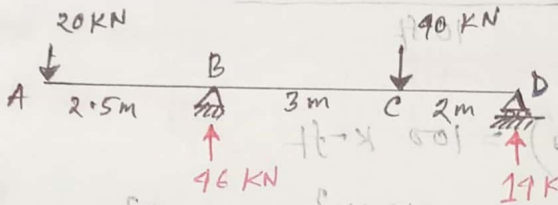
$$\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$= \frac{6+12}{2} + \sqrt{\left(\frac{6-12}{2}\right)^2}$$

$$= (9+3)$$

$$\therefore \sigma_{max} = 12 \text{ N/mm}^2$$

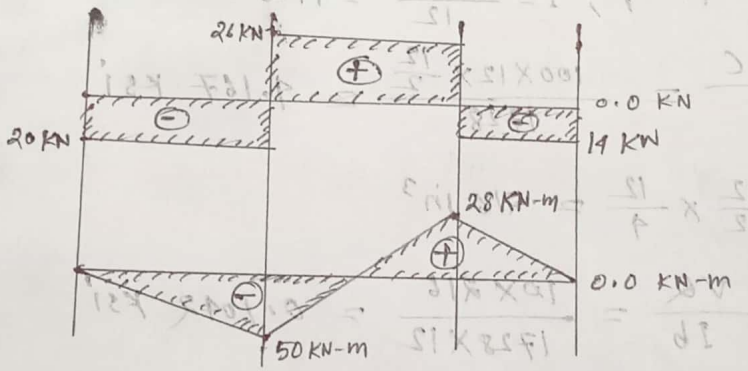
For the timber beam, loading is shown in figure, Draw SFD and BMD. Also determine the maximum normal stress due to bending if the beam size is 250 mm × 160 mm. [HBFC – 2018]



Solution:

SMD

BMD



$$\sigma_{max} = \frac{Mc}{I}$$

Here, $M_{max} = 50$ KN-m

$$= \frac{50\times10^6 \times 125}{20.83\times10^7}$$

$$= 30 \text{ N/mm}^2$$

$$c = \frac{250}{2} = 125 \text{ mm}$$

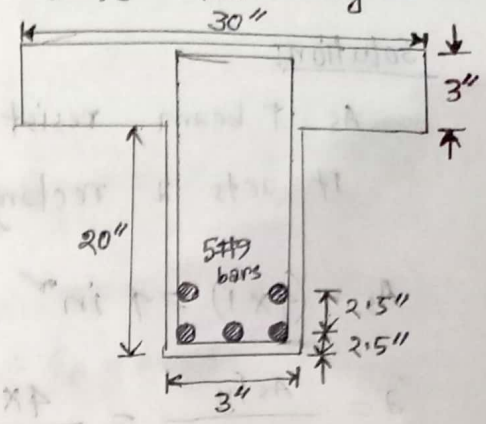
$$I = \frac{160\times250^3}{12} = 20.83\times10^7 \text{ mm}^4$$

(Ans.)

T- Beam

[RPGCL-2017; BPDB-18]

Determine the ultimate moment capacity of the beam. If $f_c' = 3$ Ksi and $f_y = 40$ Ksi



Solution: Given, $b_f = 30''$

$b_w = 3''$

$h_f = 3''$

$A_s = (5 \times 1) = 5\ in^2$

$d = 3 + 20 - 2.5 - \frac{2.5}{2}$

$= 19.25''$

$\therefore \rho = \frac{A_s'}{b\,d} = \frac{5}{30 \times 19.25} = 0.00866$

Now, $a = \frac{A_s f_y}{0.85 f_c' b_f} = \frac{5 \times 40}{0.85 \times 3 \times 30} = 2.614 < h_f$

So, Rectangular beam analysis is required.

$M_n = A_s f_y \left(d - \frac{a}{2}\right)$

$= 5 \times 40 \times \left(19.25 - \frac{2.614}{2}\right)$

$= 3588.6$ Kip-in

$\therefore$ Ultimate moment capacity, $M_u = \phi M_n$

$= (0.9 \times 3588.6)$ Kip-in

$= 3229.74$ Kip-in.

(Ans.)

where, $\phi = 0.483 + 83.3\,\varepsilon_t$

$= 0.483 + 83.3 \times 0.005$

$= 0.9$

but, $\varepsilon_t = 0.003 \times \frac{19.25 - \frac{2.614}{0.85}}{\frac{2.614}{0.85}}$

$= 0.016 > 0.005$

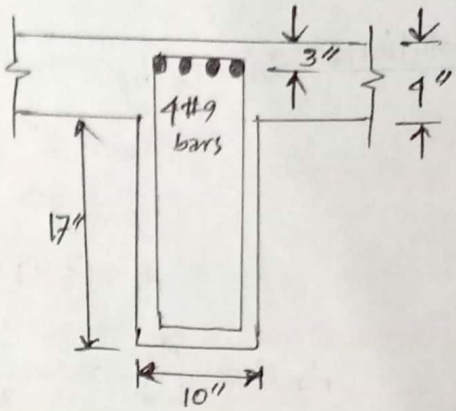
$\therefore \varepsilon_t = 0.005$

[PGCB-2018]

Calculate the negative nominal moment of the beam. Clear distance between the webs is 36" and span of the beam is 20 ft, $f_y = 60$ ksi, $f_c' = 5$ ksi, $B_1 = 0.8$

Solution:

As T beam resist negative moment, it acts a rectangular beam.



$$A_s = (4 \times 1) = 4 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4 \times 60}{0.85 \times 5 \times 10} = 5.647 \text{ in.}$$

Now,

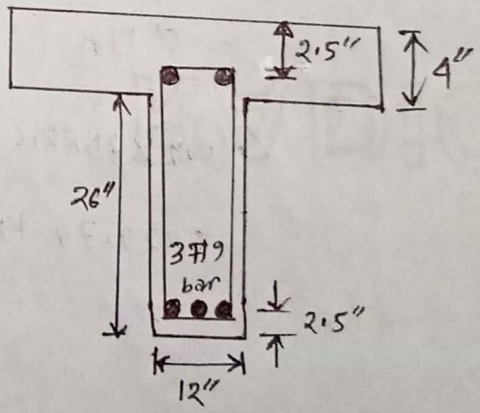
$$M_n = A_s f_y \left(d - \frac{a}{2}\right) = 4 \times 60 \times \left(18 - \frac{5.647}{2}\right) = 3642.36 \text{ K-in.}$$

(Ans.)

[GTCL-2018]

A reinforced concrete T-beam has a cross section in the positive region of span as shown below. The beam has a 30-ft span and is cast integrally with a floor slab that is 4 in thick. The clear distance between webs is 18 in. Determin the design positive moment capacity. Given, $f_c' = 3000$ psi and $f_y = 60000$ psi.

Solution:



Determination of effective flange width (b_f):

$$b_w + 16 h_f = 12 + 16 \times 4 = 76"$$

$$\frac{L}{4} = \frac{30 \times 12}{4} = 90"$$

c/c distance of beam $= (18 + 12) = 30"$

The smallest value is $= 30"$. Hence, $b_f = 30"$

$$A_s = (3 \times 1) = 3 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f_c' b_f} = \frac{3 \times 60}{0.85 \times 3 \times 30} = 2.353 \text{ in.} < h_f (= 4")$$

Hence, Rectangular beam analysis is required.

Now,

$M_n = A_s f_y \left(d - \frac{a}{2}\right)$

$= 3 \times 60 \times \left(27.5 - \frac{2.353}{2}\right)$

$= 4738.23$ kip-in.

$M_u = \phi M_n$

$= (0.9 \times 4738.23)$

$= 4264.41$ kip-in.

Here, $\phi = 0.483 + 83.3\varepsilon_t$

$\therefore \phi = 0.483 + 83.3 \times 0.005$

$= 0.9$

but, $\varepsilon_t = 0.003 \times \frac{27.5 - \frac{2.353}{0.85}}{\frac{2.353}{0.85}}$

$= 0.027 > 0.005$

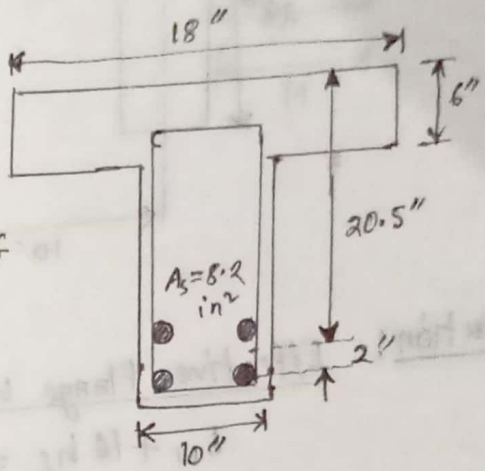
$\therefore \varepsilon_t = 0.005$

(Ans.)

[EED-2012]

Determine the ultimate moment capacity of the T beam in the figure:

(Given, $f_c' = 3000$ psi., $f_y = 40,000$ psi)



Solution: Given, $b_f = 18"$, $h_f = 6"$

$a = \frac{A_s f_y}{0.85 f_c' b_f} = \frac{8.2 \times 40}{0.85 \times 3 \times 18} = 7.15$ in. $> h_f$

Hence, T beam analysis is required.

Now,

$M_{n_1} = A_{sf} f_y \left(d - \frac{h_f}{2}\right)$ where, $A_{sf} = \frac{0.85 f_c' (b_f - b_w) \times h_f}{f_y}$

$= 3.06 \times 40 \times \left(20.5 - \frac{6}{2}\right)$ $= \frac{0.85 \times 3 \times (18-10) \times 6}{40} = 3.06$ in^2

$= 2142$ kip-in.

$M_{n_2} = (A_s - A_{sf}) \times f_y \times \left(d - \frac{a}{2}\right)$ where, $a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w} = \frac{(8.2 - 3.06) \times 40}{0.85 \times 3 \times 10}$

$= 8.06$ in.

$= (8.2 - 3.06) \times 40 \times \left(20.5 - \frac{8.06}{2}\right)$

$= 3386.23$ kip-in.

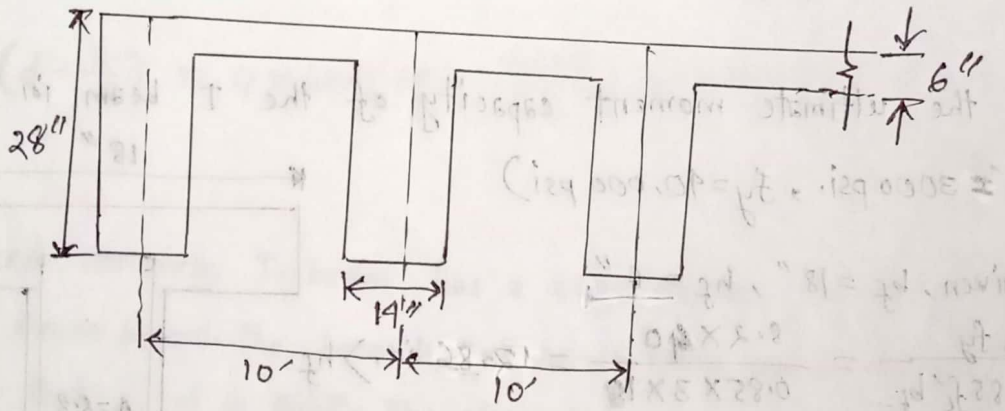
$M_n = M_{n1} + M_{n2} = (2142 + 3386.23)$ kip-in $= 5528.23$ kip-in.

$M_u = \phi M_n$ where, $\phi = 0.483 + 83.3\varepsilon_t$ but, $\varepsilon_t = 0.003 \times \frac{22.5 - \frac{8.06}{0.85}}{\frac{8.06}{0.85}} = 0.0041 < 0.005$

$= (0.826 \times 5528.23) = 4566.32$ kip-in $= 0.483 + 83.3 \times 0.0041 = 0.826$

[33rd BCS]

A concrete floor system consist of parallel T-beam spaced 10ft on centers and spanning 32 ft between supports. The 6 inch thick slab is poured monolithically with T-beam webs having width $b_w = 14''$ and total depth measured from the top of the slab of $h = 28''$. In addition to its own weight, each T-beam must carry a superimposed dead load of 50 psf and service live load of 225 psf. Material strength, $f_y = 60$ ksi, and $f_c' = 3$ ksi. Determine the required tensile area and needed rebars for typical member.



Solution: Effective Flange width:

$$b_w + 16 h_f = 14 + 16 \times 6 = 110''$$

$$\frac{L}{4} = \frac{32 \times 12}{4} = 96''$$

c/c beam spacing $= (10 \times 12) = 120''$

$\therefore$ The smallest value is 96". Hence, effective flange width, $b_f = 96''$

$$\text{self weight} = \left(\frac{120 \times 6}{144} + \frac{22 \times 14}{144} \right) \times 0.15 = 1.071 \text{ K/ft}$$

$\therefore$ total ultimate load, $w_u = 1.2 \times (1.071 + 0.05 \times 10) + 1.6 \times 0.225 \times 10 = 5.49 \text{ K/ft}$

$$M_u = \frac{w_u L^2}{8} = \frac{5.49 \times 32^2}{8} = 702.72 \text{ K-ft}$$

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})} = \frac{702.72 \times 12}{0.9 \times 60 \times (24 - \frac{6}{2})} = 7.44 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f_c' b_f} = \frac{7.44 \times 60}{0.85 \times 3 \times 96} = 1.82'' < h_f$$

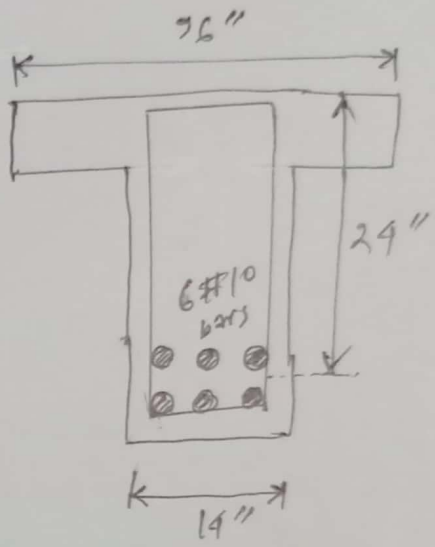
Hence, Rectangular beam design required.

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})} \quad \text{where, } a = 1.82''$$

$$= \frac{702.72 \times 12}{0.9 \times 60 \times (24 - \frac{1.82}{2})}$$

$$= 6.76 \text{ in}^2$$

∴ provide 6 # 10 bars in two layers.



Column

[DPDC-2014, FGCB-15, CPGBBL-18, CUET M.Sc-20]

Find the axial load of column 30"×12" which is reinforced with 12 Nos. 20mm diameter bar, consider $f_c' = 3.5$ Ksi and $f_y = 60$ Ksi.

Solution:

According to WSD, $P_{all} = \phi' A_g (0.25 f_c' + e_s f_s)$

$\Rightarrow P_{all} = 0.85 \times 360 \times (0.25 \times 3.5 + 0.01623 \times 0.4 \times 60)$

$\therefore P_{all} = 386.94$ Kip.

Here, $\phi' = 0.85$

$A_g = (30 \times 12) = 360$ in^2

$e_s = \frac{A_s}{A_g} = \frac{12 \times \frac{\pi}{4} \times (\frac{20}{25.4})^2}{360}$

$\therefore e_s = 0.01623$

According to USD, $P_u = \alpha \phi A_g [0.85 f_c' + e_s (f_y - 0.85 f_c')]$

$= 0.80 \times 0.65 \times 360 \times [0.85 \times 3.5 + 0.01623 \times (60 - 0.85 \times 3.5)]$

$= 730.18$ Kip

(Ans)

[WRGCL-2014]

Determine the maximum allowable axial commpressive force for a 15"×20" tied column having 2.5% steel reinforcement, $f_c' = 4$ Ksi and $f_y = 60$ Ksi

Solution:

According to WSD,

$P_{all} = \phi' A_g (0.25 f_c' + e_s f_s)$

$= 0.85 \times (15 \times 20) \times [0.25 \times 4 + \frac{2.5}{100} \times (0.4 \times 60)]$

$= 408$ Kip.

According to USD,

$P_u = \alpha \phi A_g [0.85 f_c' + e_s (f_y - 0.85 f_c')]$

$= 0.80 \times 0.65 \times (15 \times 20) \times [0.85 \times 4 + \frac{2.5}{100} \times (60 - 0.85 \times 4)]$

$= 751.14$ Kip.

(Ans)

[BGFCL-2017]

Design tie size and spacing of a 24"×16" rectangular column which is reinforced with 12-#9 bar.

Solution: Let, #3 bar is used as tie.

So, Spacing of Tie,

$s_{max} = 16 d_b = 16 \times (\frac{9}{8}) = 18"$

$s_{max} = 48 d_t = 48 \times (\frac{3}{8}) = 18"$

s_{max} = least dimension of column = 16"

Thus, provide # 3 bar @ 16" c/c as Tie

(Ans.)

[BPDB-2016]

Determine the allowable compressible load in the following column having cross-section 20"×20" with 10 – $\frac{3}{4}$" bar used. Given, $f_c' = 3$ ksi and $f_y = 60$ ksi.

Solution:

According to WSD,

$$P_{all} = \phi' A_g (0.25 f_c' + \rho_s f_s)$$

$$= 0.85 \times (20 \times 20) \times [0.25 \times 3 + \frac{10 \times 0.44}{20 \times 20} \times (0.4 \times 60)]$$

$$= 344.76 \text{ Kip.}$$

According to USD,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$= 0.80 \times 0.65 \times (20 \times 20) \times [0.85 \times 3 + (60 - 0.85 \times 3) \times \frac{10 \times 0.44}{20 \times 20}]$$

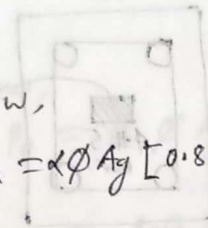
$$= 661.85 \text{ Kip.}$$

(Ans.)

TGTDCL-2018, BEPZA-19, NHA-2020]

A rectangular column of 15" × 15" section has reinforced with 8 No. 9 bars. If the value of $f_c' = 3$ Ksi and $f_y = 60$ Ksi. Find the ultimate design axial load of the column with zero eccentricity.

Solution:



We Know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$= 1.0 \times 0.65 \times (15 \times 15) \times \left[0.85 \times 3 + \frac{8 \times 1}{15 \times 15} \times (60 - 0.85 \times 3)\right]$$

$$= 671.70 \text{ Kip.}$$

(Ans:)

[PGCL-2014, DNCC-16, ERL-17, BGFCL-17]

Determine the nominal axial compression force for RCC column of 12" × 22" section having 2.5% mild steel reinforcement. Given, $f_c' = 4$ Ksi and $f_y = 60$ Ksi.

Solution:

We Know, $P_u = \phi P_n$

Thus, $P_n = \alpha A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$

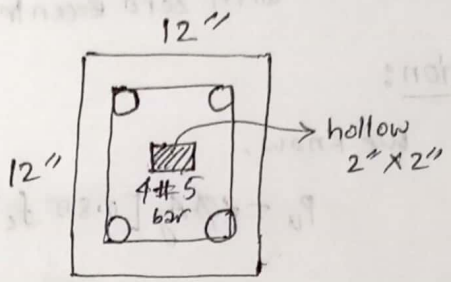
$$= 0.80 \times (12 \times 22) \times [0.85 \times 4 + (60 - 0.85 \times 4) \times 0.025]$$

$$= 1016.93 \text{ Kip.}$$

(Ans:)

[DPDC-2019, BUET M.Sc.-18]

A hollow rectangular column has shown in figure, the column is reinforced with four #5 bar. Determine the capacity of the column and also design the tie reinforcement.



Solution: Here,

$$A_g = (12\times12) - (2\times2) = 140 in^2$$

$$A_s = (4\times0.31) = 1.24\ in^2$$

$$\rho_s = \frac{A_s}{A_g} = 0.009 \simeq 0.01$$

Hence, $\rho_s = 0.01$

$$\therefore P_u = \alpha\phi A_g [0.85f_c' + \rho_s (f_y - 0.85f_c')]$$

$$= 0.80\times0.65\times140\times[0.85\times4 + 0.01\times(60 - 0.85\times4)]$$

$$= 288.72\ Kip.$$

Now, **Tie design:**

Let, provide #3 bar as tie.

Spacing of tie: $S_{max} = 16 d_b = (16\times\frac{5}{8}) = 10"$

$S_{max} = 48 d_t = (48\times\frac{3}{8}) = 18"$

S_{max} = least dimension of column = 12

So, provide #3 bar @ 10" c/c as tie.

(Ans.)

[GTCL – 2016]

The value of f_c' is 4000 psi, f_y = 60000 psi and steel area is 2% and the column section is 12". Find the design ultimate axial stress of the column with zero eccentricity.

Solution:

We know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$= 1.0 \times 0.65 \times (12 \times 12) \times [0.85 \times 4 + 0.02 \times (60 - 0.85 \times 4)]$$

$$= 424.2 \text{ Kip}.$$

$\therefore$ ultimate stress, $\sigma = \frac{P_u}{A_g} = \frac{424.2}{12 \times 12} = 2.95$ Ksi (Ans.)

[NPCBL – 2017, JB – 17]

Design a square tied column to support dead load of 500 Kips and live load of 400 Kips. Reinforcement ratio must be with in 1 to 2%. Assume, $f_c' = 4$ Ksi and $f_y = 60$ Ksi.

Solution: Total ultimate load, $P_u = 1.2DL + 1.6LL = (1.2 \times 500 + 1.6 \times 400)$

$= 1240$ Kips.

Let, $\rho = 2\% = 0.02$

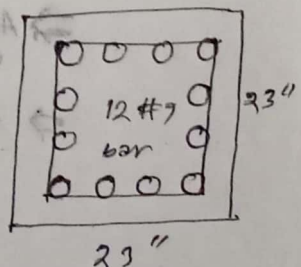
We know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$\Rightarrow 1240 = 0.80 \times 0.65 \times (b \times b) \times [0.85 \times 4 + 0.02 \times (60 - 0.85 \times 4)]$$

$$\Rightarrow b^2 = 526.2 \text{ in}^2$$

$\therefore b = h = 22.94$ in $\simeq 23$ in



Hence, size of the tie column = 23" × 23"

$$A_s = \rho_s A_g = 0.02 \times (23 \times 23) = 10.58 \text{ in}^2$$

provide 12 #9 bar

Tie design: Let use # 3 bar as tie.

$S_{max} = 16 d_b = 16 \times \frac{3}{8} = 18''$

$S_{max} = 48 d_t = 48 \times \frac{3}{8} = 18''$

S_{max} = least dimension = 23"

Hence, provide # 3 bar @ 18" c/c as tie.

(Ans.)

[36th BCS]

Design a circular spiral column to support an axial dead load 475 Kip. and a live load 250 K using $f_c' = 4$ ksi, $f_y = 60$ ksi. And a steel ratio of about 3%. Also design the necessary spirals.

Solution: Total Ultimate load, $P_u = 1.2\,DL + 1.6\,L.L$

$= (1.2 \times 475 + 1.6 \times 250)$

$= 970$ Kips.

We know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

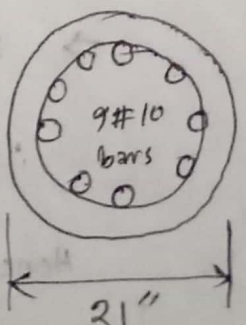
$$\Rightarrow 970 = 0.85 \times 0.70 \times A_g \times [0.85 \times 4 + 0.03 \times (60 - 0.85 \times 4)]$$

$$\Rightarrow 970 = 3.0333 A_g$$

$$\Rightarrow A_g = 319.8 \text{ in}^2$$

$$\Rightarrow \frac{\pi}{4} \times D^2 = 319.8$$

$$\therefore D = 20.18 \text{ in} \simeq 21 \text{ in}$$



$$\therefore A_s = \rho_s \times A_g = 0.03 \times \frac{\pi}{4} (21)^2 = 10.4 \text{ in}^2$$

provide 9 # 10 bar as main reinforcement

design of spiral:

Dia of core = $21-(1.5\times2) = 18$ in.

Now, $\rho_{sp} = 0.45\left(\frac{D^2}{D_c^2}-1\right)\frac{f_c'}{f_y} = 0.45\times\left(\frac{21^2}{18^2}-1\right)\times\frac{4}{60} = 0.01083$

Again, $\rho_{sp} = \frac{4A_{sp}}{s\times D_c}$ Let, provide #3 bar as spiral

$\Rightarrow 0.01083 = \frac{4\times0.11}{s\times18}$

$\therefore$ Spacing, $s = 2.25$ in.

But, $s_{max} = 3''$

$s = \frac{1}{6}\times D_c = \frac{1}{6}\times18 = 3''$

and $s_{min} = 1''$

Hence, provide #3 bar @ 2.25" c/c as spiral.

[BWDB-2019], [PGCB-2021]

A designer designed a 6" one way slab with 60 grade reinforcement. He used #4 bar as main reinforcement and provided spacing at 6 in c/c. A second designer designs the slab with 500 W reinforcement instead of 60 grade reinforcement. What would be the spacing of the slab by second designer, if he used 12 mm bar as main rebar instead of #4 bar?

Solution:

First designer: $\text{spacing} = \frac{\text{Area of bar providing}}{\text{Area of steel}} \times 12$

$\Rightarrow$ Area of main steel, $As_1 = \frac{0.20}{6} \times 12 = 0.40 \text{ in}^2/\text{ft}$

second designer: $500\,W = \frac{500 \times 145}{1000} = 72.5 \text{ Ksi}$

We know, $As_1 f_{y_1} = As_2 f_{y_2}$

$\Rightarrow As_2 = \frac{As_1 f_{y_1}}{f_{y_2}} = \frac{0.40 \times 60}{72.5} = 0.33 \text{ in}^2/\text{ft}$

Hence, spacing, $S = \frac{\frac{\pi}{4} \times \left(\frac{12}{25.4}\right)^2}{0.33} \times 12 = 6.37"$ c/c

(Ans.)

[BCIC-19, BADC-20]

A designer designed a 6" one way slab with 60 grade reinforcement. He used #4 bar as main reinforcement and provided spacing at 4.5 in c/c. A second engineer designs the slab with 500 W reinforcement instead of 60 Grade reinforcement and used 12 mm bar as main rebar instead of #4 bar. what would be the spacing of the slab by the second designer.

Solution:

First Engineer:

Area of main steel, $A_{s_1} = \frac{0.20}{4.5} \times 12 = 0.5333 \text{ in}^2/\text{ft}$

Second Engineer:

$500 W = 500 \times \frac{145}{1000} = 72.5 \text{ Ksi}$

$\therefore$ Area of steel required, $A_{s_2} = \frac{0.533 \times 60}{72.5} = 0.44 \text{ in}^2/\text{ft}$

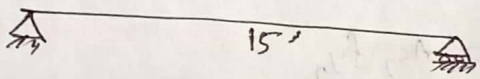
Hence, spacing, $s = \frac{\frac{\pi}{4} \times \left(\frac{12}{25.4}\right)^2}{0.44} \times 12 = 4.78'' \text{ c/c}$

(Ans.)

[LGD-2018, BMA-51]

Determine the slab thickness and spacing required for temperature and shrinkage reinforcement of one way slab, considering $f_y = 60$ Ksi

Solution:



As the slab is simply supported, the thickness of slab according to code, will be, $t = \frac{l}{20} = \frac{15 \times 12}{20} = 9 \text{ in.}$

Now, Given, $f_y = 60$ Ksi,

Temperature and shringkage reinforcement, $A_{s(min)} = 0.0018 bt$

$= 0.0018 \times 12 \times 9$

$= 0.1944 \text{ in}^2$

Let, providing # 3 bar.

$\therefore$ spacing, $s = \left(\frac{0.11}{0.1944} \times 12\right) = 6.8'' \text{ c/c} \simeq 6.75'' \text{ c/c}$

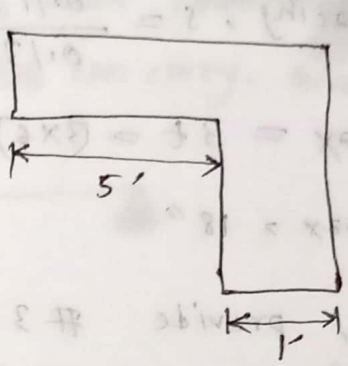
So, provide # 3 bar @ 6.75 " c/c as temperature and shrinkage reinforcement

(Ans.)

[BBAD-2018]

A one way slab is supported on RC beam as shown. The working Live load is 60 psf. Design the slab. (Given, $f_y = 60$ ksi, $f_c' = 4$ ksi)

Solution:



The slab is supported by one side only.
i.e. act as cantilever slab.

$\therefore$ Thickness of the slab, $t = \frac{l}{10}$

$= \frac{5 \times 12}{10} = 6''$

Now, self weight of slab, $S.W = \frac{t}{12} \times 150 = \frac{6}{12} \times 150 = 75$ psf

$\therefore$ Total ultimate load, $W_u = 1.2DL + 1.6LL = (1.2 \times 75 + 1.6 \times 60) = 186$ psf

$\therefore$ Moment, $M_u = \frac{W_u L^2}{2} = \frac{0.186 \times 5^2}{2} = 2.325$ K-ft

we know,

$$M_u = \phi \rho b d^2 f_y \left(1 - 0.59 \times \frac{\rho f_y}{f_c'}\right)$$

$$\Rightarrow 2.325 \times 12 = 0.9 \times 0.018 \times 12 \times 60 \times d^2 \left(1 - 0.59 \times \frac{0.018 \times 60}{4}\right)$$

$$\Rightarrow d^2 = 2.85$$

$\therefore d_{req} = 1.7'' < d_{eff} = (6-1) = 5''$ (ok)

where, $\rho = 0.85\beta_1 \frac{f_c'}{f_y}\left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$

$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.005}$

$= 0.018$

Now,

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})}$$

where, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s \times 60}{0.85 \times 4 \times 12}$

$\therefore a = 1.47 A_s$

$$\Rightarrow A_s = \frac{2.325 \times 12}{0.9 \times 60 \times (5 - \frac{1.47 A_s}{2})}$$

$\therefore A_s = 0.12$ in^2/ft

Given, $f_y = 60$ ksi.

$A_{s(min)} = 0.0018\,bt = 0.0018 \times 12 \times 6 = 0.13\ in^2 > A_s$

Hence, provide $0.13\ in^2/ft$ as main reinforcement. $\therefore A_s = 0.13\ in^2/ft$

Spacing, $s = \frac{0.11 \times 12}{0.13} = 10.15''$ c/c $\simeq 10''$ c/c

$S_{max} = 3t = (3 \times 6) = 18''$ or,

$S_{max} = 18''$

So, provide #3 bar @ 10" c/c as main reinforcement.

Temperature and shrinkage reinforcement:

Given, $f_y = 60$ ksi,

So, $A_{s(min)} = 0.0018\,bt = 0.0018 \times 12 \times 6 = 0.13\ in^2/ft$

Hence, provide #3 bar @ 10" c/c as shrinkage reinforcement.

Check for shear:

$$V_u = \left(1.15\,wL - \frac{wd}{12}\right) = \left(1.15 \times 0.186 \times 5 - \frac{0.186 \times 5}{12}\right) = 0.992\ kip$$

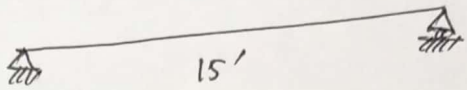
$$\phi V_c = 2\phi\sqrt{f_c'}\,b_w d = 2 \times 0.75 \times \sqrt{4000} \times 12 \times 5 = 5692\ lb = 5.692\ kip$$

$\phi V_c > V_u$

(OK)

[33rd BCS]

A 15′ long and 10′ wide uniformly loaded slab is simply supported along short sides; the long sides are unsupported. The slab thickness is 8″ with #5 bar spaced 6″ c/c as main flexural steel. Calculate the maximum uniformly load that the slab can carry. Given, $f_c' = 4$ ksi and $f_y = 60$ ksi.



Solution: Since, the slab is simply supported along two opposite side only. It is one way slab. Given, $t = 8''$ $\therefore d_{eff} = 8 - 0.75 - \frac{5}{8\times 2} = 6.9375''$

Area that provided, $A_s = \frac{0.31}{6} \times 12 = 0.62\ in^2$

We know, $M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$ where, $a = \frac{A_s f_y}{0.85 f_c' b}$

$= 0.9 \times 0.62 \times 60 \times \left(6.9375 - \frac{0.912}{2}\right)$ $= \frac{0.62 \times 60}{0.85 \times 4 \times 12}$

$= 217$ K-in $= 0.912$ in

We know, $M_u = \frac{w_u L^2}{8}$

$\Rightarrow w_u = \frac{8 M_u}{L^2} = \frac{8 \times 217}{(15\times 12)^2} = 0.0536$ K/in $= 0.643$ K/ft

self weight of the slab, S.W $= \frac{t}{12} \times 150 = \left(\frac{8}{12} \times 150\right) = 100$ psf $= 0.1$ ksf

We know,

$w_u = 1.2DL + 1.6 L.L$

$\Rightarrow 0.643 = 1.2 \times 0.1 + 1.6 \times L.L$

$\therefore L.L = 0.327$ ksf

(Ans:)

Footing

[BCIC-2017]

A footing size 10.5'×10.5'. Factored load on footing is 330 kip. and column size is 20"×20". Calculate the depth of footing considering shear check only. $f_c' = 4$ ksi.

Solution:

Ultimate bearing pressure of the footing, $q_u = \frac{W_u}{\text{Area of footing}}$

$= \frac{330}{10.5 \times 10.5}$

$= 2.99$ ksf $\simeq 3$ ksf

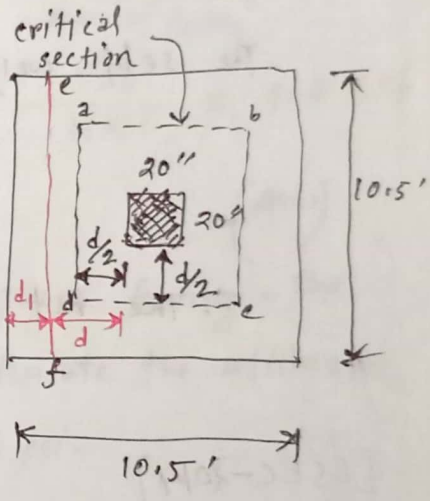
For punching failure,

critical perimeter, $b_o = 4 \times (20+d)$

The shear acting on this perimeter,

$$V_u = q_u \left[b^2 - \left(\frac{(20+d)}{12}\right)^2 \right]$$

$$= 3000 \times \left[10.5^2 - \left(\frac{20+d}{12}\right)^2 \right]$$



The design shear, $\phi V_c = 4 \phi \sqrt{f_c'}\, b_o\, d$

$= 4 \times 0.75 \times \sqrt{4000} \times 4 \times (20+d) \times d$

We know, $\phi V_c \geq V_u$

So,

$$3000 \times \left[10.5^2 - \left(\frac{20+d}{12}\right)^2 \right] = 4 \times 0.75 \sqrt{4000} \times 4 \times (20+d)\, d$$

$\Rightarrow$ $d = 12.512$ in. $\simeq 12.75$ in

check for beam shear: (on section ef) $\left[d_1 = \left(\frac{b - \frac{20}{12}}{2}\right) - \frac{d}{12} = 3.354167' \right.$

$V_u = q_u\, b\, d_1 = 3 \times 10.5 \times 3.354167 = 105.66$ kips.

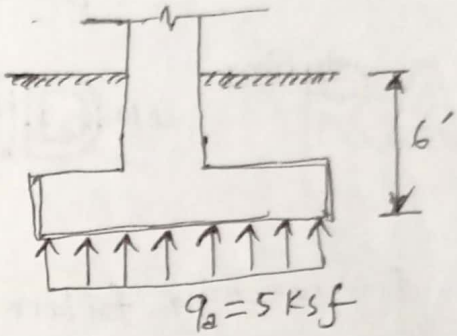
$\phi V_c = 2 \phi \sqrt{f_c'}\, b\, d = 2 \times 0.75 \times \sqrt{4000} \times (10.5 \times 12) \times (12.75 \times 12) = 182.887$ kip

$\phi V_c > V_u$ (OK)

[WRGCL-2014]

A RCC footing is to be constructed 6 feet below the grade If allowable soil pressure is 5 Ksf and self weight of soil is 100 pcf. What will be the effective soil pressure at the bottom of footing if depth of footing is 20"?

Solution: Given, depth of footing = 20"



∴ thickness of footing = (20+3)
= 23"

The pressure of soil on footing,

$= (6 - \frac{23}{12}) \times 100 = 408.33$ psf

The self weight of footing.

$= \frac{23}{12} \times 150 = 287.5$ psf

∴ The net pressure on footing, $q_{net} = 5 \times 1000 - (408.33 + 287.5)$

$= 4304.17$ psf

(Ans.)

[BSEC-2014]

If DL = 225 Kips & LL = 185 Kips on column, determine the footing size when bearing capacity of soil = 2 tsf

Solution: Total ultimate load, $W_u = 1.2DL + 1.6LL$

$= (1.2 \times 225 + 1.6 \times 185) = 566$ Ksf

Let, the thickness of footing = 12"

∴ the self weight of the footing $= \frac{12}{12} \times 150 = 150$ psf

Let, the footing is 5 ft below the grade.

∴ the pressure of soil on footing $= (5 \times 100) = 500$ psf

∴ Net pressure on soil, $q_{net} = q_a - (500 + 100)$

$= (2 \times 2 \times 1000 - 600) \text{ psf}$

$= 3400 \text{ psf} = 3.4 \text{ Kips.}$

The area of footing required, $A_{req.} = \frac{\text{Total load}}{q_{net}}$

$= \frac{225 + 185}{3.4}$

For square footing, $b^2 = 120.6 \text{ ft}^2$

$\therefore b = 10.98 \text{ ft} \simeq 11 \text{ ft}$

Hence, the ultimate bearing pressure, $q_u = \frac{\text{Total load}}{\text{Area of footing}}$

$= \frac{566}{11 \times 11} = 4.7 \text{ Ksf}$ (Ans.)

[BWDB — 2014]

A 12" square column is reinforced with a 10 ft square footing. The footing thickness is 20" and clear cover is 3.5". Calculate the ultimate punching shear capacity. if $f_c' = 3000 \text{ psi}$, $f_y = 60000 \text{ psi}$.

Solution: Given, $t = 20''$, clear cover $= 3.5''$

$\therefore d_{eff} = (20 - 3.5) = 16.5''$

critical perimeter, $b_o = 4 \times (12 + d) = 4 \times (12 + 16.5) = 114$

∴ Ultimate punching shear capacity,

$$\phi V_c = 4 \phi \sqrt{f_c'}\, b_o d = 4 \times 0.75 \times \sqrt{3000} \times 114 \times 16.5$$

$\therefore \phi V_c = 309079.8416 = 309.08 \text{ Kips.}$

(Ans.)

[BWDB-2019]

A 16" square column reinforced with 8 Nos. 20 mm bar up to footing and the column carries total 550 Kip. load. If the footing size is 9'x9' and effective depth is 29". Find the punching shear stress developed in the footing.

Solution: Given, total load, $W_u = 550$ Kip

footing size = 9'x9'

$\therefore$ ultimate bearing capacity, $q_u = \frac{\text{Total load}}{\text{footing Area}}$

$= \frac{550}{9 \times 9} = 6.79$ Ksf

For punching shear,

critical perimeter, $b_o = 4 \times (16 + 29) = 160" = 13.33'$

$\therefore$ Ultimate shear, $V_u = q_u \left[b^2 - \left(\frac{16+29}{12} \right)^2 \right]$

$= 6.79 \times \left[9^2 - 3.33^2 \right] = 474.55$ K

$\therefore$ punching stress, $\sigma = \frac{V_u}{b_o d} = \frac{474.55}{13.33 \times \frac{29}{12}} = 17.80$ Ksf

(Ans.)

Shear Reinforcement

[BBAD-2018]

A RCC beam is to be designed to carry a shear force V_u of 30 Kip. No web reinforcement is to be used and $f_c' = 4$ ksi. What is the minimum cross section if controlled by shear?

Solution: If No web reinforcement is used, $\frac{\phi V_c}{2} \geq V_u$

So, $V_u = \frac{1}{2} \phi V_c$

$\Rightarrow 30 \times 10^3 = \frac{1}{2} \times 0.75 \times 2\sqrt{f_c'}\, b_w d$

$\Rightarrow 30 \times 10^3 = \frac{1}{2} \times 0.75 \times 2 \times \sqrt{4000} \times b_w d$

$\Rightarrow b_w d = 632.46 \text{ in}^2$

Let, $b_w = 18$ in. Hence, $d = \frac{632.46}{18} = 35.14$ in. $\simeq 35.5$ in $\therefore h = (35.5 + 2.5) = 38''$

Hence, The cross section of the beam should be $18'' \times 38''$.

(Ans.)

[EGCB-2015]

Design stirrup of a beam which size is $21'' \times 15''$ and 10 #10 bar used in this beam. Given, $V_u = 40000$ lb, $f_y = 60$ ksi and $f_c' = 4$ ksi and clear cover = 3 inch.

Solution: Given, $V_u = 40000$ lb

we know, $\phi V_c = 2\phi\sqrt{f_c'}\, b_w d$

$= 2 \times 0.75 \times \sqrt{4000} \times 18.5 \times 15$

$\phi V_c = 26325.96 \text{ lb} < V_u$

Hence, stirrup is required.

Let, provide #3 bar U-stirrup.

Theoretical spacing, $s = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{0.75 \times (2 \times 0.11) \times 60000 \times 18.5}{40000 - 26325.96}$

$\therefore s = 13.4''$

Maximum spacing,

$$s_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b} = \frac{(2 \times 0.11) \times 60000}{0.75 \times \sqrt{4000} \times 15} = 18.55$$

again, $s_{max} = \frac{A_v f_y}{50 b_w} = \frac{(2 \times 0.11) \times 60000}{50 \times 15} = 17.6 < 18.55''$

$\therefore s_{max} = 17.6''$

Again, $s_{max} = \frac{d}{2} = \frac{18.5}{2} = 9.25''$

and, $s_{max} = 24$ inch.

So, provide #3 U stirrup @ 9.25" c/c

(Ans.)

[BCMCL-2020]

Determine ultimate shear capacity of the beam if $f_c' = 3$ ksi and $f_y = 60$ ksi.

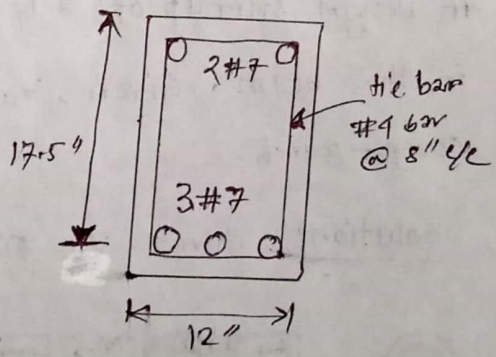
Solution:

We know,

$$\phi V_c = \phi \times 2\sqrt{f_c'}\, b_w d$$

$$\Rightarrow \phi V_c = 0.75 \times 2 \times \sqrt{3000} \times 12 \times 17.5$$

$$\therefore \phi V_c = 17253.26$$



Spacing, $s = \frac{\phi A_v f_y d}{V_u - \phi V_c}$

$$\Rightarrow 8 = \frac{0.75 \times (2 \times 0.20) \times 60000 \times 17.5}{V_u - 17253.26}$$

$\therefore V_u = 56628.26$ lb $= 56.63$ kip.

(Ans.)

EGCB-2015]

Design stirrup of a beam which size is 21" × 15" and 10 #10 bar used in this beam. Given, $V_u = 40000$ lb, $f_y = 60$ ksi, and $f_c' = 4$ ksi. clear cover = 3"

Solution:

We know, $\phi V_c = \phi 2\sqrt{f_c'}\, b_w d$

Here, $d = (21-3) = 18$"

$= 0.75 \times 2 \times \sqrt{4000} \times 15 \times 18$

$\therefore \phi V_c = 25614.95$ lb. $< V_u$

$\therefore$ stirrup is required.

Theoretical spacing, $S = \dfrac{\phi A_v f_y d}{V_u - \phi V_c}$

Let, provide #3 U-stirrup, $\therefore S = \dfrac{0.75 \times (2 \times 0.11) \times 60000 \times 18}{40000 - 25614.45}$

$= 12.39$ in.

Now, $S_{max} = \dfrac{A_v f_y}{\sqrt{f_c'}\, b_w} \le \dfrac{A_v f_y}{50 b_w}$

$\dfrac{A_v f_y}{0.75\sqrt{f_c'}\, b_w} = \dfrac{2 \times 0.11 \times 60000}{0.75 \times \sqrt{4000} \times 15} = 18.55$"

and, $\dfrac{A_v f_y}{50 b_w} = \dfrac{(2 \times 0.11) \times 60000}{50 \times 15} = 17.6$" $\therefore S_{max} = 17.6$"

Again, $S_{max} = \dfrac{d}{2} = \dfrac{18}{2} = 9$"

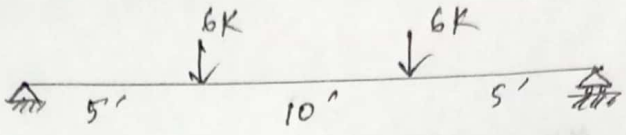
$S_{max} = 24$"

Hence, provide #3 U-stirrup @ 9" c/c

(Ans.)

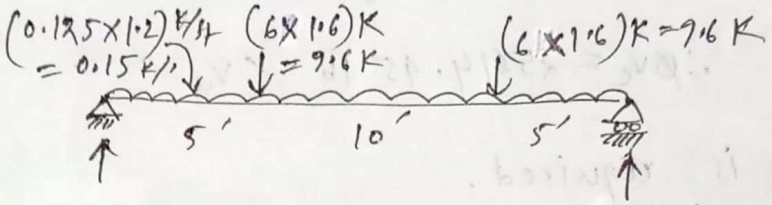
[BPDB – 2015]

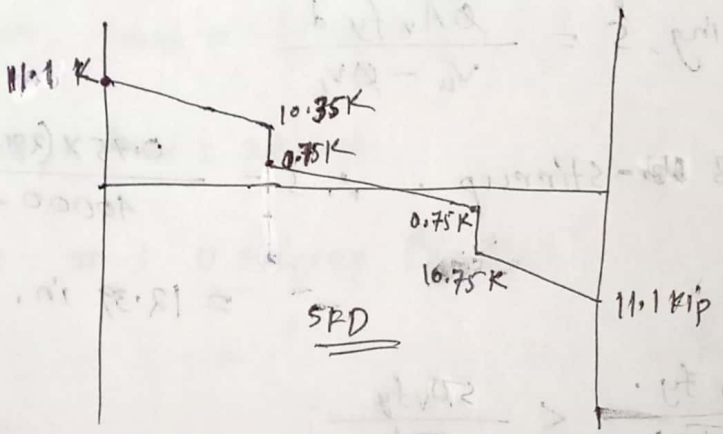
A rectangular beam of size 10" × 12". Design the shear reinforcement of the beam as shown in below. If $f_y = 60$ Ksi and $f_c' = 3000$ psi.



Solution: self weight of the beam $= \left(\frac{10}{12} \times \frac{12}{12} \times 0.15\right) = 0.125$ Kip/ft

For USD,





V_u at support $= 11.1$ Kip

V_u at a distance 'd', $V_{ud} = 11.1 - 0.15 \times \frac{10.5}{12} = 10.97$ Kip.

Now, $\phi V_c = 2\phi\sqrt{f_c'}\, b_w d = 2 \times 0.75 \times \sqrt{3000} \times 10 \times 10.5 = 8626.63$ lb

$\therefore \phi V_c < V_u$. Hence, stirrup is required.

Theoretical spacing, $S = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{0.75 \times 2 \times 0.11 \times 60 \times 10.5}{10.97 - 8.63} = 44.4''$

Then, $S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b} \le \frac{A_v f_y}{50 b_w}$

$\frac{A_v f_y}{0.75\sqrt{f_c'}\, b} = \frac{2 \times 0.11 \times 60000}{0.75 \times \sqrt{3000} \times 10} = 32.13''$

and, $\frac{A_v f_y}{50 b_w} = \frac{2 \times 0.11 \times 60000}{50 \times 10} = 26.4''$ $\therefore S_{max} = 26.4''$

Again, $S_{max} = \frac{d}{2} = \frac{10.5}{2} = 5.25''$

$S_{max} = 24$ in.

∴ Provide #3 bar @ 5.25" c/c

(Ans.)

[32th BCS]

A rectangular beam having $b = 12''$ and $h = 22''$, spans = 20 feet face to face of simple support. It has to carry service dead load of 1.63 K/ft and service live load of 3.10 K/ft, both uniformly distributed along the span. Design the shear reinforcement using #3 bar as vertical U stirrups. Material strengths are $f_c' = 4000$ psi and $f_y = 60000$ psi.

Solution:

Total ultimate load, $W_u = 1.2 \times DL + 1.6 \times LL$

$= (1.2 \times 1.63 + 1.6 \times 3.10) = 6.916$ Kip/ft

∴ V_u at support $= \frac{W_u L}{2} = \frac{6.916 \times 20}{2} = 69.16$ Kip.

∴ V_u at a distance d from support, $V_{ud} = 69.16 - 6.916 \times \frac{19.5}{12}$

$= 57.92$ Kip.

Now, $\phi V_c = 2\phi \sqrt{f_c'} b_w d = 2 \times 0.75 \times \sqrt{4000} \times 12 \times 19.5$

∴ $\phi V_c = 22199.1916 = 22.2$ Kip $< V_u$

Hence, stirrup is required.

Theoretical spacing, $S = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{0.75 \times 2 \times 0.11 \times 60.0 \times 19.5}{57.92 - 22.2}$

∴ $S = 5.40''$

$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'} b} = \frac{2 \times 0.11 \times 60000}{0.75 \times \sqrt{4000} \times 12} = 23.2'' \leq \frac{A_v f_y}{50 b_w}$

$\frac{A_v f_y}{50 b_w} = \frac{2 \times 0.11 \times 60000}{50 \times 12} = 22''$

$\therefore s_{max} = 22''$

And, $s_{max} = \frac{d}{2} = \frac{19.5}{2} = 9.75''$

$s_{max} = 24''$

So, provide #3 U stirrup @ $5.90''$ c/c $\simeq 5.25''$ c/c

(Ans.)

Prestressed Concrete

Analysis of Prestress

* Stress concept: $f = -\frac{F}{A} \pm \frac{Fey}{I} \mp \frac{My}{I}$

* Coupling concept: $f = -\frac{C}{A} \mp \frac{ce'y}{I}$ where, $c = F$

or, pressure line $e' = a - e$

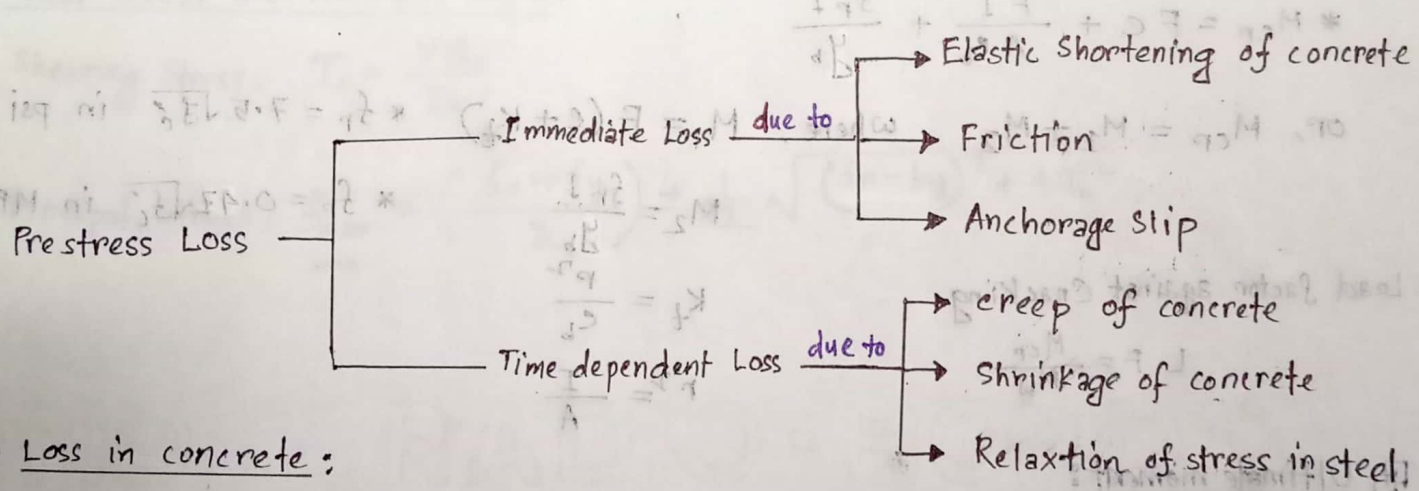
or, Thurst line $a = \frac{M}{F}$

* Load Balancing concept: $f = -\frac{F}{A} \mp \frac{M_{net}\, y}{I}$ where, $M_{net} = M_w - M_p$

$M_w = \frac{wL^2}{8}$ (for simply supported)

$M_p = Fe$

Losses of Prestress:



* Loss in concrete:

1. Elastic Shortening: Loss $= nf_c$ where, n = modular ratio $= \frac{E_s}{E_c}$

case-1: simultaneous tensioning → No loss due to elastic shortening

case-2: Successive tensioning → Cable 1 tensioned: No loss
Cable 2 tensioned: Loss in cable 1
Cable 3 tensioned: Loss in cable 1 and 2
. . . . . .
. . . . . .

2. Creep of concrete: (i) creep co-efficient method – Loss $= \phi n f_c$ where, ϕ = creep co-eff.

(ii) Ultimate creep strain method – Loss $= \varepsilon_{cc}\, f_c\, E_s$ $\phi = \frac{\text{creep strain}}{\text{Elastic strain}}$

↳ ultimate creep strain

3. Shrinkage of concrete: Loss = $\varepsilon_{es} E_s$

↳ Residual shrinkage strain

* Loss in steel:

1. Friction: Loss = $P_o(\mu\alpha + Kx)$ where, μ = co-eff. of friction bet^n cable and duct

α = cumulative angle between two points under consideration.

K = friction co-eff. for wave effect

x = distance from jacking end.

2. Anchorage slip: Loss = $\frac{\Delta}{L} \times E_s$

3. Relaxation of stress; Loss = % of intial prestress

Cracking Moment:

* $M_{cr} = Fe + \frac{FI}{A c_b} + \frac{f_r I}{c_b}$

or, $M_{cr} = M_1 + M_2$ where, $M_1 = F(e + K_t)$

$M_2 = \frac{f_r I}{c_b}$

$K_t = \frac{r^2}{c_b}$

$r^2 = \frac{I}{A}$

* $f_r = 7.5\sqrt{f_c'}$ in psi

* $f_r = 0.62\sqrt{f_c'}$ in MPa

* Load factor against Cracking,

L.F = $\frac{M_{cr}}{M_w}$

Ultimate moment:

1. $0.5 f_{pu} = \square \leq f_{se}$

2. $f_{ps} = f_{pu}\left(1 - 0.5\, \rho_p \frac{f_{pu}}{f_c'}\right)$ where, $\rho_p = \frac{A_{ps}}{b_f d}$

3. $a = \frac{A_{ps} f_{ps}}{0.85 f_c' b_f}$

If $a < h_f$, Rectangular Section is confirmed.

4. $\omega_p = \frac{\rho_p f_{ps}}{f_c'} = \square \leq 0.30$

5. $M_n = A_{ps} f_{ps}\left(d - \frac{a}{2}\right)$

6. $M_u = \phi M_n$

If $a > h_f$, I section is confirmed.

4. $A_{pf} = \frac{0.85 f_c'(b_f - b_w) h_f}{f_{ps}}$

$A_{pw} = A_{ps} - A_{pf}$

5. $\omega_{pw} = \frac{\rho_{pw} f_{ps}}{f_c'} \leq 0.30$

6. $M_w = A_{pw} f_{ps}\left(d - \frac{a'}{2}\right)$ where, $a' = \frac{A_{pw} f_{ps}}{0.85 f_c' b_w}$

$M_f = A_{ps} f_{ps}\left(d - \frac{h_f}{2}\right)$

7. $M_u = \phi M_n = \phi(M_w + M_f)$

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Deflection:

* **Due to Load:**
  1. Distributed Load — $\frac{5WL^4}{384EI}$
  2. concentrated load — $\frac{QL^3}{48EI}$

* **Due to tendon:**
  1. Straight Cable — $\frac{FeL^2}{8EI}$
  2. Parabolic Cable
     - concentric end → $\frac{5FeL^2}{48EI}$
     - eccentric end → $\frac{FL^2}{48EI}(5e_1 - e_2)$
  3. Sloping Tendon
     - concentric end → $\frac{FeL^2}{12EI}$
     - eccentric end → $\frac{FL^2}{12EI}(2e_1 - e_2)$

* **Long time deflection:**

$$a_f = \left[a_{iL} - a_{ip} \times \frac{P_t}{P_i}\right](1+\phi)$$

Shear Stress and Principal Stress:

Shearing Stress, $\tau_v = \frac{VQ}{Ib}$

Principal Stress, $f_{\substack{max \\ min}} = \left(\frac{f_x + f_y}{2}\right) \pm \frac{1}{2}\sqrt{(f_x - f_y)^2 + 4\tau_v^2}$

Properties of Fluid

* Density, $\rho = \frac{\text{mass}(m)}{\text{Volume}(V)}$; $\rho_w = 1000\ Kg/m^3 = 1\ g/cm^3$

* specific weight, $\gamma = \frac{\text{weight}(W)}{\text{volume}(V)}$; $\gamma_w = 9810\ N/m^3 = 9.81\ KN/m^3$

* specific volume, $v = \frac{\text{volume}(V)}{\text{mass}(m)} = \frac{1}{\rho}$

* Specific Gravity, $G_s = \frac{\gamma}{\gamma_w} = \frac{\rho}{\rho_w}$

* compressibility of fluid, $P = -K \frac{dv}{v}$ where, K = bulk modulus of Elasticity / volume

#viscosity:

Shear stress, $\tau = \mu \frac{du}{dy}$; μ = co.efficient of dynamic viscosity

$\frac{du}{dy}$ = rate of change of velocity w.r.t distance

= rate of shear stress

= rate of shear deformation

= velocity gradient

⇒ unit of viscosity:

S.I Unit —— $\frac{N \cdot s}{m^2}$

M.K.S unit —— $\frac{Kgf \cdot sec}{m^2}$

C.G.S unit —— $\frac{dyne\text{-}sec}{cm^2}$

$1\ poise = \frac{1}{10} \frac{N \cdot s}{m^2}$

* viscosity of water at 20°C = $\frac{1}{100}$ poise or 1 centi-poise = 0.001 N-s/m²

#Kinematic Viscosity:

$\nu = \frac{\text{viscosity}(\mu)}{\text{density}(\rho)}$

⇒ units of Kinematic viscosity:

S.I unit —— m^2/sec

C.G.S unit —— cm^2/sec or stokes

* 1 stokes = $10^{-4}\ m^2/sec$

* Kinematic viscosity of water = $10^{-6}\ m^2/sec$

[BWDB-2016]

* If the co-efficient of dynamic viscosity, $\mu = 1$ N-sec/m^2 and velocity distribution, $v = 0.9y - y^2$. Determine the shear stress at $y = 0.45$ m.

Solution: Given, $\mu = 1$ N-s/m^2

$v = 0.9y - y^2$

$y = 0.45$ m

We know, $\tau = \mu \cdot \frac{dv}{dy}$ Here, $\frac{dv}{dy} = \frac{d}{dy}(0.9y - y^2)$

$\tau_y = 1(0.9 - 2y) \Rightarrow \frac{dv}{dy} = 0.9 - 2y$

$\tau_{0.45m} = 1 \times (0.9 - 2 \times 0.45)$

$\therefore \tau_{0.45m} = 0$ N/m^2

(Ans.)

Pressure and It's Measurement

Pressure of a liquid:

Intensity of pressure, $p = \frac{F}{A}$; The pressure of a fluid on a surface will always act normal to the surface.

Pressure head of a liquid:

A liquid is subjected to pressure due to its own weight, this pressure increases as the depth of the liquid increases.

$\therefore$ Intensity of pressure, $p = \gamma h$ where, γ = specific weight of liquid

* Intensity of pressure of a liquid may be expressed in two ways.

(i) Force per unit area (N/m^2)

(ii) Equivalent static head (m of liquid)

Pascal's law:

The intensity of pressure at any point in a liquid at rest, is the same in all directions.

Relationship between Pressures:

Atmospheric Pressure: The atmospheric air exerts a normal pressure upon all surfaces with which it is in contact, and it is known as atmospheric pressure.

Gauge Pressure: It is the pressure, measured with the help of pressure measuring instrument, in which atmospheric pressure is taken as datumn (zero).

Absolute Pressure: Any pressure measured above the absolute zero of pressure, termed as absolute pressure.

Vacuum Pressure: It is defined as the pressure below the atmospheric pressure.

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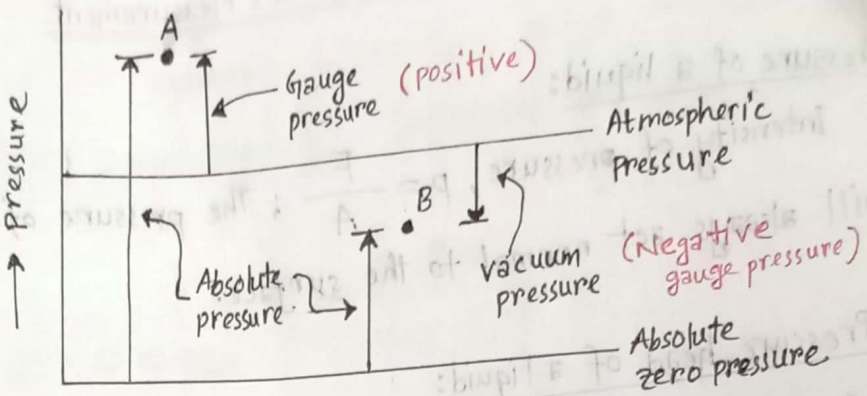


Fig. Relation between Pressures.

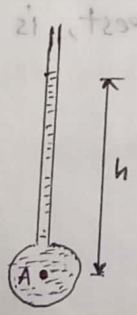
* Absolute Pressure = Atmospheric Pressure + Gauge Pressure

* Vacuum Pressure = Atmospheric Pressure − Absolute pressure

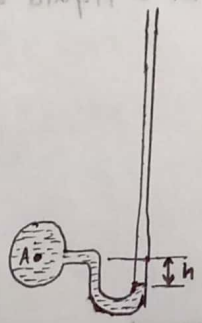
* Standard Atmospheric Pressure = 101.325 KPa, 10.3 m of water, 760 mm of marcary

Manometer:

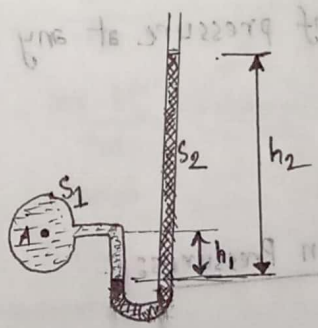
* Simple Manometer:



$P_A = \gamma h$

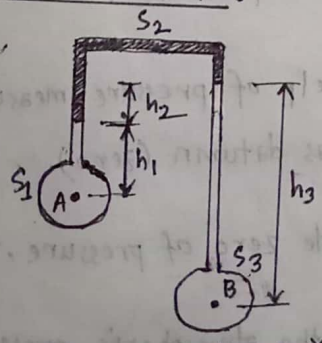


$P_A + \gamma h = 0$

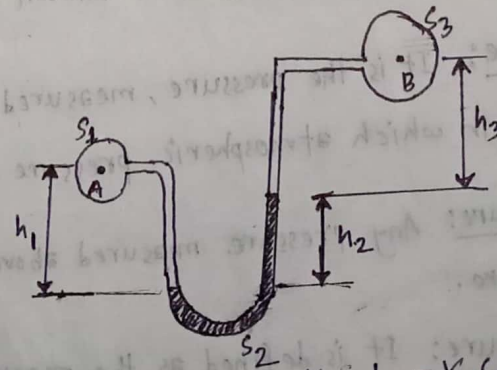


$P_A + \gamma_w S_1 h_1 - \gamma_w S_2 h_2 = 0$

* Differential Manometer:



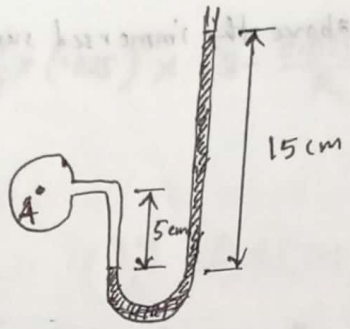
$P_A - \gamma_w S_1 h_1 - \gamma_w S_2 h_2 + \gamma_w S_3 h_3 = P_B$



$P_A + \gamma_w S_1 h_1 - \gamma_w {}_2 h_2 - \gamma_w S_3 h_3 = P_B$

[BWRB-2019]

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



Solution; The pressure of water in pipe, P_1:

$$P_A + \gamma_1 h_1 - \gamma_2 h_2 = 0$$

$$\Rightarrow P_A + (9.81 \times \frac{5}{100}) - (9.81 \times 13.6) \times \frac{15}{100} = 0$$

$$\therefore P_A = 19.5219 \text{ KN/m}^2$$

(Ans.)

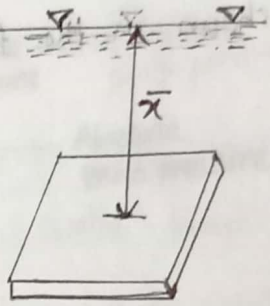
Hydrostatic Forces on Surfaces

Total Pressure and Center of pressure:

* Horizontally Immersed Surface:

F = Weight of the liquid above the immersed surface

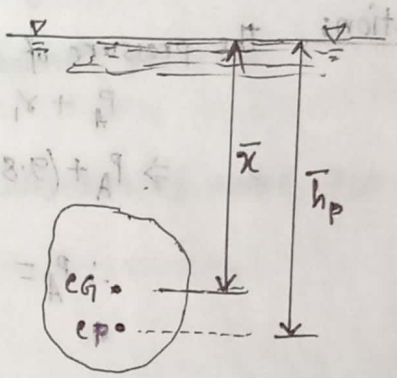
$= \gamma A \bar{x}$



* Vertically Immersed Surface:

$F = \gamma A \bar{x}$

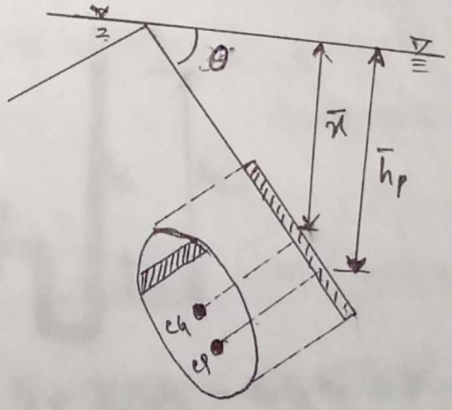
$\bar{h}_p = \frac{I_G}{A\bar{x}} + \bar{x}$



* Inclined Immersed Surface:

$F = \gamma A \bar{x}$

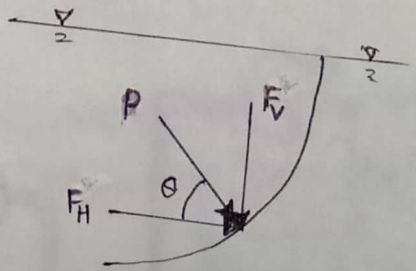
$\bar{h}_p = \frac{I_G \sin^2\theta}{A\bar{x}} + \bar{x}$

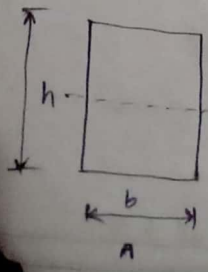


* curved Immersed surface:

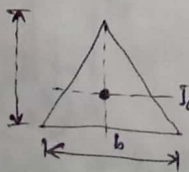
$F = \sqrt{F_H^2 + F_V^2}$

$\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right)$

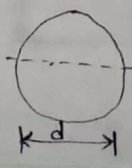




$I_G = \frac{bh^3}{12}$



$I_G = \frac{bh^3}{36}$



$I_G = \frac{\pi d^4}{64}$

[...L-2017]

Find the resultant force on one side of a 25 mm diameter vertical circular plate standing at the bottom of 3m pool water? Density of water = 1000 Kg/m³ and g = 9.8 m/s².

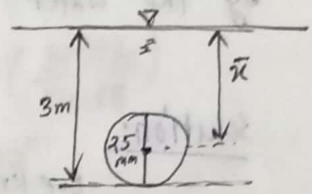
Solution:

We know,

$$F = \gamma A \bar{x}$$

$$= (1000 \times 9.8) \times \frac{\pi}{4} \times (.025)^2 \times (3 - \frac{0.025}{2})$$

$$= 14.37 \text{ N}$$



(Ans.)

[BI+P-2017]

25 mm diameter circular disk is on the base of a swimming pool of depth 2.5 m, width 3 m. Find the force on the circular disk. g = 9.8 m/s²

Solution:

We know,

$$F = \gamma A \bar{x}$$

$$= (9.8 \times 1000) \times \frac{\pi}{4} \times (.025)^2 \times (2.5 - \frac{0.025}{2})$$ [Assuming, circular disk is placed vertically]

$$= 11.97 \text{ N}$$

(Ans.)

If circular disk is placed horizontally,

$$F = (9.8 \times 1000) \times \frac{\pi}{4} \times (0.025)^2 \times 2.5$$

$$= 12.03 \text{ N}$$

(Ans.)

[BBAD – 2018]

A rectangular gate 2 m wide and 1.5 m high, is in a vertical plane. The gate is immersed vertically downwards, the top side being at a depth of 3 m below the free surface. Find the force exerted by the water on the gate and the position of center of pressure.

Solution:

we know,

Force, $F = \gamma A \bar{x}$

$= (9.81 \times 1000) \times (2 \times 1.5) \times \left(3 + \frac{1.5}{2}\right)$

$= 110362.5\ N$

position of center of pressure, $\bar{h}_p = \frac{I_G}{A\bar{x}} + \bar{x}$ Here, $I_G = \frac{1.5^3 \times 2}{12} = 0.5625$

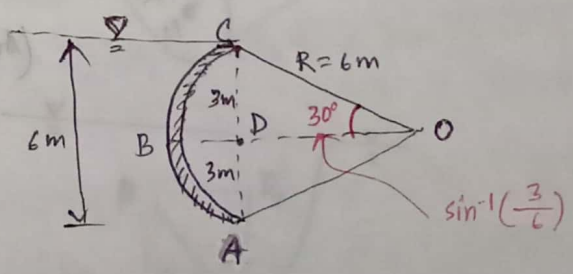
$= \frac{0.5625}{(2 \times 1.5) \times \left(3 + \frac{1.5}{2}\right)} + \left(3 + \frac{1.5}{2}\right)$

$= 3.8\ m$ (Ans.)

[BEPZA-2016]

Circular-arc tainter gate ABC pivots about point O. For the position shown, determine (a) the hydrostatic force on the gate (per meter of width in to the paper) and (b) the line of action of resultant force.

Solution:



Horizontal component of force acting on the gate, $F_x = \gamma A \bar{h}$ ($A = C \times 1$, per width of gate)

$= (9.81 \times 1000) \times (6 \times 1) \times \left(\frac{6}{2}\right)$

$= 176580\ N$

Area of ABCDA = ΔABCOA − ΔACO

Vertical component of force acting on the gate, $F_v = \gamma A \bar{h} = (9.81 \times 1000) \times \left[\frac{60}{360} \times \pi \times 6^2 - \frac{1}{2} \times 6 \times (\sqrt{6^2 - 3^2})\right] \times 1 = 31991.81\ N$ (per width of gate)

∴ Resultant force on the plate, $R = \sqrt{F_H^2 + F_V^2}$

$= \sqrt{(176.58)^2 + (31.992)^2}$

$= 179.45$ KN.

Inclination of resultant with horizontal, $\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right)$

$= \tan^{-1}\left(\frac{31.992}{176.58}\right)$

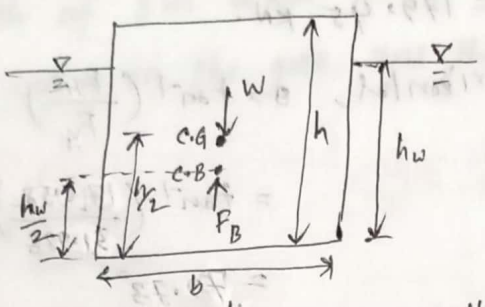
$= 10.27°$

(Ans)

Buoyancy and Floatation

* Total upward buoyance force, $F_B = W$
$= \gamma \times V$

where, W = Weight of block
γ = specific weight of fluid
V = total volume of the body



Archimedes' Principle: F_B = weight of fluid displaced by the body.
$= \gamma_w \times V_w$

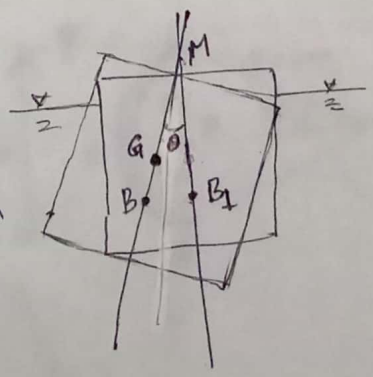
where,
V_w = volume of water displaced by block

* Volume of body in water = Volume of water displaced
* center of buoyancy = $\frac{h_w}{2}$
* If $W < F_B$, the body will float (submerge partially)
If $W = F_B$, the body will submerge fully.
If $W > F_B$, the body will sink.

* Meta centric Height:
When a body, floating in a liquid, is given a small angular displacement, it starts oscillating about some point. This point about which the body starts oscillating is called Metacenter.

* $BM = \frac{I}{V}$
* $GM = BM \pm BG$
  - $GM = +\square$ means stable
  - $GM = -\square$ means unstable
  - $GM = 0$ means Neutral equilibrium

(+) sign → if G is below B
(−) sign → if G is above B



* Resisting Moment: $R.M = \gamma V \cdot GM \cdot \theta$

,-2018]

A wood of 5 Kg weight flows in a water ; if the wood contain 60% of its volume at the time of floating, then what is the specific gravity of the wood.

Solution: For equilibrium, weight of block = weight of water displaced

$$\gamma V = \gamma_w V_w$$

$$\Rightarrow \frac{\gamma}{\gamma_w} = \frac{V_w}{V}$$

$$\Rightarrow G_s = \frac{h_w \times A}{h \times A} = \frac{h_w}{h} = \frac{0.6h}{h} = 0.6$$

(Ans.)

Fluid Kinematics

 # continuity Equation: $\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

$\Rightarrow A_1 V_1 = A_2 V_2$. (For incompressible flow $\rho_1 = \rho_2$)

Fluid Dynamics

 # Total Energy head of a fluid in motion, $H = z + \frac{P}{\gamma} + \frac{v^2}{2g}$

 # Bernoulli's Equation: In a steady flow of frictionless incompressible fluid, the total energy remains the same.

$$H = z + \frac{P}{\gamma} + \frac{v^2}{2g} = \text{constant}$$

(z: potential head, $\frac{P}{\gamma}$: pressure head, $\frac{v^2}{2g}$: velocity head)

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g}$$

* For real fluid,

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + h_L$$

CamScanner

[A-2019]

15 cm diameter pipe carries 70 L/sec of oil (G=0.75). At a section 15 cm above the datumin, the pressure is 2 cm vacuum of mercury. If $\alpha = 1.1$, then calculate the total head in A of the oil section.

Solution: We know,

Total head, $H = z + \frac{p}{\gamma} + \alpha\frac{v^2}{2g}$

$= 0.15 + \frac{2666.45}{7357.5} + \frac{1.1 \times 3.96^2}{2 \times 9.81}$

$= 1.39$ m

(Ans.)

Here, $z = 15$ cm $= 0.15$ m

$p = 2$ cm Hg $= 2 \times \frac{101325}{76}$ Pa

$= 2666.45$ Pa.

$\gamma = G\gamma_w = (0.75 \times 9810)$ N/m³

$= 7357.5$ N/m³

$v = \frac{Q}{A} = \frac{70 \times 10^{-3}}{\frac{\pi}{4} \times (.15)^2} = 3.96$ m/s

[BWDB-2016, DWASA-17]

The value of pressure, elevation and diameter of a pipe in a point P are 12 N/m², 5 m and 25 cm. Another point Q whose elevation and diameter are 3m and 17 cm. What will be the pressure at Q? Given discharge P to Q is 2 m³/sec. and head loss 1 m.

Solution:

We know,

$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$

$\Rightarrow 5 + \frac{12}{9.81 \times 1000} + \frac{(40.79)^2}{2 \times 9.81} = 3 + \frac{P_2}{9.81 \times 1000} + \frac{(88.11)^2}{2 \times 9.81} + 1$

$\Rightarrow P_2 = -310.091 \times (9.81 \times 1000)$

$\therefore P_2 = -304.2 \times 10^4$ N/m²

(Ans.)

Here,

$z_1 = 5$m

$z_2 = 3$m

$P_1 = 12$ N/m²

$P_2 = ?$

$v_1 = \frac{Q}{A_1} = \frac{2}{\frac{\pi}{4} \times (.25)^2}$

$= 40.79$ m/sec.

$v_2 = \frac{2}{\frac{\pi}{4} \times (.17)^2} = 88.11$ m/sec.

$h_L = 1$ m

[BWDB-2018]

A pipe discharge 40 m³/sec. Head loss is 10% of the difference of velocity head. Find out the pressure at point B.

	Point P	Point Q
Elevation	1011 m	1050 m
Pipe dia	50 cm	100 cm
Pressure	50 KPa	???

Solution:

Given, $Q = 40$ m³/sec.

$$V_1 = \frac{Q}{A_1} = \frac{40}{\frac{\pi}{4} \times (.50)^2} = 203.72 \text{ m/sec.}$$

$$V_2 = \frac{40}{\frac{\pi}{4} \times (1.00)^2} = 50.93 \text{ m/sec.}$$

$\therefore$ velocity head difference $= \left(\frac{203.72^2}{2g} - \frac{50.93^2}{2g}\right) = 1983.08$ m

$\therefore$ Head loss $= (0.10 \times 1983.08) = 198.3$ m

Now,

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$\Rightarrow 1011 + \frac{50 \times 10^3}{9.81 \times 10^3} + 1983.08 = 1050 + \frac{P_2}{9.81 \times 10^3} + 198.3$$

$$\Rightarrow P_2 = 17176101.8 \text{ Pa}$$

$$\therefore P_2 = 17176.102 \text{ KPa.}$$

(Ans.)

[DB - 2019]

Q In a horizontal pipe of 30 cm diameter, water flows with a velocity 2 m/s and the pressure is 52 KN/m². If the diameter of the pipe is 60 cm in the other end, what is the pressure?

Solution: For horizontal pipe, $z_1 = z_2$

Hence, From bernoulli's equation,

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} = \frac{P_2}{\gamma} + \frac{v_2^2}{2g}$$

$$\Rightarrow \frac{52\times10^3}{9.81\times1000} + \frac{2^2}{2\times9.81} = \frac{P_2}{9.81\times10^3} + \frac{0.5^2}{2\times9.81}$$

$$\Rightarrow P_2 = 1927 \times 10^3 \text{ N/m}^2$$ (Ans.)

we know,

$$A_1 v_1 = A_2 v_2$$

$$\Rightarrow v_2 = \frac{(30)^2 \times 2}{(60)^2} = 0.5 \text{ m/sec.}$$

Flow through Pipes (Head Loss)

* **Reynolds Number:** $Re = \frac{\rho V d}{\mu} = \frac{Vd}{\nu}$ where, ρ = density, μ = Dynamic viscosity, ν = Kinamatic viscosity, V = Average velocity, d = diameter of pipe

* If $Re < 2000$, Flow is laminar

and, $Re > 4000$, Flow is turbulant

if, $2000 < Re < 4000$, Flow is Transitional

* **Loss of Head:**

1. Major Loss (due to friction)
2. Minor Loss (- due to contraction, $h_c = 0.5 \frac{V^2}{2g}$
   - due to enlargement, $h_e = \frac{(V_1 - V_2)^2}{2g}$
   - due to obstraction such as gate or valves, $h_g = K_g \frac{V^2}{2g}$
   - due to bends or curves, $h_b = K_b \frac{V^2}{2g}$)

$C_c = \frac{A_c}{A_2}$ $\quad K_c = \left(\frac{1}{C_c} - 1\right)^2$

$K_g = \left[\frac{A}{A-a} \times \frac{1}{C_c}\right]^2$ (A: Area of pipe, a: Area of obs.)

Total loss, $H = h_f + h_c + h_e + h_g + h_b$

$h_i = 0.5 \frac{V_1^2}{2g}$ (entrance loss)

$h_e = \frac{V_2^2}{2g}$ (exit loss)

* **Hazen-Poiseuille Equation:**

Frictional loss, $h_f = \frac{32 \mu V L}{\gamma d^2}$ or, $\frac{32 \nu V L}{g d^2}$ [For laminar flow]

Again, viscosity of fluid, $\mu = \frac{h_f \gamma d^2}{32 V L} = \frac{\gamma (h_1 - h_2) d^2}{32 V L} = \frac{(P_1 - P_2) d^2}{32 V L}$

* **Darcy-Weisbach Equation:**

Frictional Loss; $h_f = f \frac{L V^2}{2gd}$ [For turbulant flow] (f → friction factor*)

$h_f = 4f' \frac{L V^2}{2gd}$ [Fanning Equation] where, $f' = \frac{f}{4}$ (f' → frictional co-efficient*)

* **Hydraulic loss:** From bernoulli's equation, $\underbrace{z_1 + \frac{V_1^2}{2g} + \frac{P_1}{\gamma}}_{H_1} = \underbrace{z_2 + \frac{V_2^2}{2g} + \frac{P_2}{\gamma}}_{H_2} + \Delta h_L$

$\Rightarrow \Delta h_L = H_1 - H_2$

if the pipe is horizontal ($z_1 = z_2$) and of equal diameter ($V_1 = V_2$), $\Delta h_L = \frac{P_1 - P_2}{\gamma}$

CamScanner

[...c-2019]

A fluid flows through a pipe having diameter 0.6 m and length 100 m. If the frictional co-efficient is 0.004 and the head loss is 25 m. Find out the discharge.

Solution: Neglecting minor losses,

Head loss; $dh_L \simeq h_f = \frac{4fLV^2}{2gd}$

Here, $f = 0.004$

$L = 100\,m$

$h_f = 25\,m$, $d = 0.6\,m$

$$\Rightarrow 25 = \frac{4 \times 0.004 \times 100 \times (3.537Q)^2}{2 \times 9.81 \times 0.6}$$

$$\Rightarrow (3.537Q)^2 = 183.9375$$

$$\therefore Q = 3.834\ m^3/sec.$$

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} \times (0.6)^2}$$

$$\therefore V = 3.537\,Q$$

(Ans.)

[BMA-51]

A fluid flows through a pipe having a diameter 0.5 m. length 100 m and discharge 0.4 m^3/s. If frictional co-efficient is 0.005. find the head loss due to friction.

solution: We know,

$$h_f = \frac{4fLV^2}{2gd}$$

Here, $f = 0.005$

$L = 100\,m$, $d = 0.5\,m$

$$V = \frac{Q}{A} = \frac{0.4}{\frac{\pi}{4} \times (.5)^2} = 2.04\ m/s$$

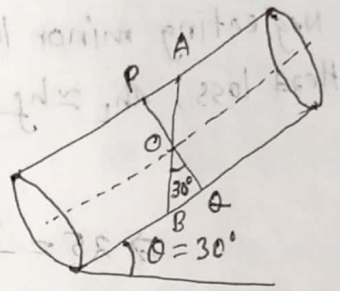
$$= \frac{4 \times 0.005 \times 100 \times (2.04)^2}{2 \times 9.81 \times 0.5}$$

$$= 0.85\ m$$

(Ans.)

[BCPCL-2016]

Diameter of a pipe is 4 ft. Angle of inclination, $\theta = 30^\circ$. The press in the center of pipe = 5 psi. Determine the pressure at the top & bottom level.



Solution: $OP = OQ = \frac{4'}{2} = 2'$

$$OA = OB = \frac{2}{\cos 30^\circ} = 2.31'$$

$$P_{top} = 5 - \gamma h = 5 - \left(\frac{62.4 \times 2.31}{144}\right) = 4 \text{ psi}$$

$$P_{bottom} = 5 + \gamma h = 5 + \left(\frac{62.4 \times 2.31}{144}\right) = 6 \text{ psi}$$

(Ans.)

[GTCL-2022]

A fluid, with a density of 900 kg/m³ and kinematic viscosity of 0.00001 m²/s, flows at 0.2 m³/sec. through a 500 m length of 200 mm diameter cast-iron pipe. Determine (a) the head loss, and (b) the pressure drop if the pipe drops down at 1 in 10 in the flow direction. if the friction factor is 0.0225.

Solution:

We know, $Re = \frac{Vd}{\upsilon}$ Here, $V = \frac{Q}{A} = \frac{0.2}{\frac{\pi}{4} \times (.2)^2} = 6.3662 \text{ m/s}$

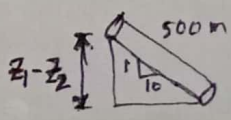
$$= \frac{6.3662 \times 0.2}{0.00001}$$

$$= 127324 > 4000$$ Hence, it is turbulent flow.

For turbulent flow, $h_f = \frac{fLV^2}{2gd} = \frac{0.0225 \times 500 \times 6.3662^2}{2 \times 9.81 \times 0.2} = 116.2 \text{ m}.$

For inclined pipe & $(V_1 = V_2)$,

$$\Delta h_L = z_1 - z_2 + \frac{(P_1 - P_2)}{\gamma}$$



$\therefore z_1 - z_2 = \frac{500}{\sqrt{101}} = 49.75$

$\Rightarrow 116.2 = 49.75 + \frac{\Delta P}{\gamma}$ $\therefore \Delta P = 651.875 \text{ KN/m}^2$ (Ans.)

[SM '17]

Diameter of a circular pipe is 50 cm. The value of $n = 0.016$, $s = 0.001$. Determine the discharge of the pipe flow.

Solution:

Given, $d = 50\ cm = 0.5\ m$, $s = 0.001$ and $n = 0.016$

$$\therefore A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (0.5)^2 = 0.20\ m^2$$

Now, $V = \frac{1}{n} R^{\frac{2}{3}} s^{\frac{1}{2}}$ Here, $R = \frac{A}{P} = \frac{0.20}{\pi \times 0.5} = 0.127$

open channel flow

$$= \frac{1}{0.016} \times (0.1273)^{\frac{2}{3}} \times (0.001)^{\frac{1}{2}}$$

$$= 0.5$$

Now, discharge, $Q = AV = (0.5 \times 0.2) = 0.10\ m^3/sec.$

(Ans.)

[DPDC - 2014]

Water is flowing in a pipe of a diameter 12 cm at a velocity of 2 m/sec. Find out the discharge.

Solution:

we know, $Q = AV$ Here, $A = \frac{\pi}{4} d^2$

$$= \frac{\pi}{4} \times (0.12)^2 = 0.01131$$

$$= 0.01131 \times 2$$

$$= 0.02262\ m^3/sec.$$

(Ans.)

[PGCL-2014, PGCB-15, BIFPCL-15]

Calculate the diameter of a circular pipe that has discharges 2.5 cusec water with a velocity of 6 fps.

Solution: Given, $Q = 2.5$ cusec $= 2.5\ ft^3/sec.$

$V = 6\ ft/sec.$

we know, $Q = AV$

$\Rightarrow 2.5 = \frac{\pi}{4} \times d^2 \times 6$

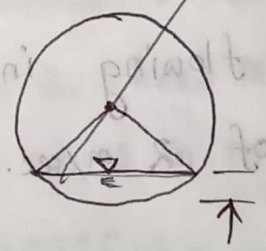
$\therefore d = 0.728' \simeq 8.74$ inch.

(Ans.)

[BWDB-2019]

An 18" diameter sewer pipe laid on a grade of 0.015 and manning's co-efficient 0.013. Find the velocity and discharge if the depth of 4.5".

Solution:



Properties of fluid:

Problem: If the co-efficient of dynamic viscosity, $\mu = 1$ N-sec/m^2 and velocity distribution, $v = 0.9y - y^2$. Determine the shear stress $y = 0.95$m. (BWDB—2016)

Solution: Given, $v = 0.9y - y^2$

$$\therefore \frac{dv}{dy} = 0.9 - 2y$$

Now, we know, $\tau = \mu \cdot \frac{dv}{dy} = 1 \times (0.9 - 2y) = (0.9 - 2 \times 0.95)$

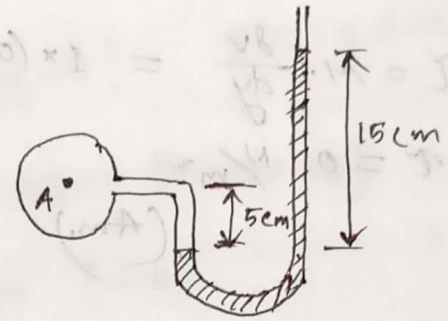
$$\therefore \tau = 0 \text{ N/m}^2$$

(Ans.)

Pressure and its measurement

(BWDB - 2019)

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



Solution:

$$P_A + \gamma_1 h_1 - \gamma_2 h_2 = 0$$

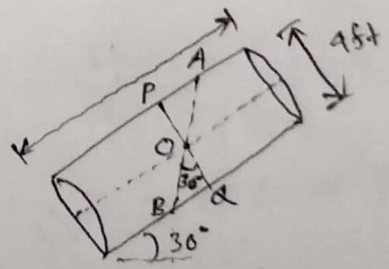
$$\Rightarrow P_A + 9.81 \times 0.05 - (9.81 \times 13.6) \times 0.15 = 0$$

$$\Rightarrow P_A = 19.523 \text{ KN/m}^2$$

(Ans)

(BCPCL-2016)

Problem: Diameter of a pipe is 4 ft, Angle of inclination, $\theta = 30°$. The pressure in the center of pipe = 5 psi. Determine the pressure at top and bottom level.



Solution:

$$OP = OQ = \frac{4}{2} = 2 \text{ ft}$$

$$OA = OB = \frac{2}{\cos 30°} = 2.31 \text{ ft}$$

$$P_{top} = 5 - \gamma h = \left(5 - \frac{62.4 \times 2.31}{144}\right) = 4.0 \text{ psi}$$

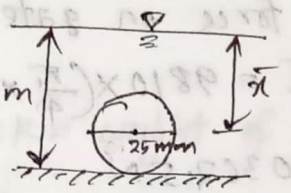
$$P_{bottom} = 5 + \gamma h = \left(5 + \frac{62.4 \times 2.31}{144}\right) = 6.0 \text{ psi}$$

(Ans.)

Hydrostatic Forces on Surfaces:

(SGIFCL-2017)

Problem: Find the resultant force on one side of a 25 mm diameter vertical circular plate standing at the bottom of 3 m pool water? Density of water = 1000 kg/m^3 and g = 9.8 m/s^2



Solution: The resultant force, $F = \gamma A \bar{x}$

$\Rightarrow F = 9810 \times \frac{\pi}{4} \times (.025)^2 \times \left(3 - \frac{0.025}{2}\right)$

$\therefore F = 14.37$ N

(Ans.)

(BHP-2017)

Problem: 25 mm diameter circular disk is on the base of a swimming pool of depth 2.5 m, width 3m. Find the force on the circular disk.

Solution:

If circular disk is placed vertically,

$F = \gamma A \bar{x} = 9810 \times \frac{\pi}{4} \times (0.025)^2 \times \left(2.5 - \frac{0.025}{2}\right)$

$\therefore F = 11.97$ N.

Now, if circular disk is placed horizontally,

$F = 9810 \times \frac{\pi}{4} \times (0.025)^2 \times 2.5 = 12.03$ N.

(Ans.)

(BBAD-2018)

Problem: A rectangular gate 2m wide and 1.5 m high is in a vertical plane. The gate is immersed vertically downwards, the top side being at a depth of 3m below the free surface. Find the force exerted by the water on the gate and position of the center of pressure.

Solution: The resultant force on gate,

$$F = \gamma A \bar{x} = 9810 \times (2 \times 1.5) \times \left(3 + \frac{1.5}{2}\right)$$

$$\therefore F = 110362.5\ N$$

position of center of pressure, $h_p = \frac{I_G}{A\bar{x}} + \bar{x}$ Here,

$$I_G = \frac{2 \times 1.5^3}{12}\ m^4 = 0.5625\ m^4$$

$$\Rightarrow h_p = \left(3 + \frac{1.5}{2}\right) + \frac{0.5625}{(2 \times 1.5) \times \left(3 + \frac{1.5}{2}\right)}$$

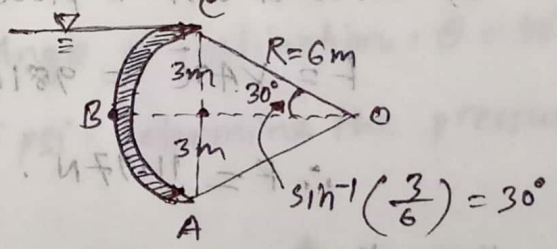
$$\therefore h_p = 3.8\ m.$$

(Ans.)

(BEP&A-2016) [BUET WRE'23]

Problem: Circular Arc tainter gate ABC pivots about point O. For the position shown, determine (a) the hydrostatic force on the gate (per meter of width into the paper) and (b) the line of action of resultant force.

Solution:



Horizontal component of force acting on gate,

$$F_x = \gamma A \bar{h}$$

$$\therefore F_x = 9810 \times (6 \times 1) \times \frac{6}{2} = 176580\ N = 176.580\ N$$

vertical component of force acting on gate,

$$F_V = \gamma A \bar{h} = 9810 \times \left[\frac{60}{360} \times \pi \times 6^2 - \frac{1}{2} \times 6 \times \sqrt{6^2 - 3^2}\right] \times 1 = 31991.8\ N = 31.992\ N$$

$$\therefore R = \sqrt{176.58^2 + 31.992^2} = 179.45\ KN \text{ and, } \theta = \tan^{-1}\left(\frac{31.992}{176.58}\right) = 10.27°$$

(Ans.)

Buoyancy and Floatation

Problem: A wood of 6 Kg weight flows in a water. If the wood contain 60% of its volume at the time of floating, then what is the specific gravity of the wood. (BWDB - 2018)

Solution:

For equilibrium,

weight of block = weight of water displaced

$$\gamma V = \gamma_w V_w$$

$$\Rightarrow \frac{\gamma}{\gamma_w} = \frac{V_w}{V}$$

$$\Rightarrow G_s = \frac{h_w \times A}{h \times A} = \frac{0.6\,h}{h} = 0.6$$

(Ans.)

Fluid Dynamics:

Problem: A 15 cm diameter pipe carries 70 l/sec. of oil ($G = 0.75$). At a section 15 cm above the datum, the pressure is 2 cm vacuum of mercury. If $\alpha = 1.1$, then calculate the total head in A of the oil section. (BIWTA-19)

Solution:

We know,

Total Head, $H = z + \frac{P}{\gamma} + \frac{\alpha v^2}{2g}$

$= 0.15 + \frac{2666.45}{7357.5} + 1.1 \times \frac{(3.96)^2}{2 \times 9.81}$

$= 1.39$ m

(Ans)

Here, $z = 15\text{cm} = 0.15$ m.

$P = 2$ cm Hg

$= 2 \times \frac{101325}{76}$ Pa

$= 2666.45$ Pa.

$\gamma = (0.75 \times 9810)$ N/m^3

$= 7357.5$ N/m^3

$v = \frac{70 \times 10^{-3}}{\frac{\pi}{4} \times (0.15)^2}$ m/s

$= 3.96$ m/s

$\alpha = 1.1$

(BWDB-2016)

Problem: The value of pressure, elevation and diameter of a pipe in a point 'P' are 12 N/m^2, 5 m and 25 cm. Another point Q whose elevation and diameter are 3 m and 17 cm. what will be the pressure at Q? Given, Discharge from P to Q is 2 m^3/sec and head loss 1 m.

Solution:

we know, From bernoulli's equation,

$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + h_L$

$5 + \frac{12}{9810} + \frac{40.74^2}{2 \times 9.81} = 3 + \frac{P_2}{9810} + \frac{88.11^2}{2 \times 9.81} + 1$

$\Rightarrow P_2 = -304.2 \times 10^4$ N/m^2 $= -3042$ KPa

(Ans)

Here, $v_1 = \frac{Q}{A_1} = \frac{2}{\frac{\pi}{4} \times (.25)^2}$

$= 40.74$ m/s

$v_2 = \frac{Q}{A_2} = \frac{2}{\frac{\pi}{4} \times (.17)^2}$

$= 88.11$ m/s

(BWDB-2018)

Problem: A pipe discharge 40 m³/sec. Head loss is 10% of the velocity head difference. Find out the pressure at point B

	Point P	Point B
Elevation (m)	1011	1050
Pipe dia. (cm)	50	100
Pressure (KPa)	50	?

Solution:

We know, From Bernoulli's equation,

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_L$$

$$\Rightarrow \frac{50}{9.81} + \frac{203.72^2}{2\times 9.81} + 1011 = \frac{P_B}{9.81} + \frac{50.93^2}{2\times 9.81} + 1050 + 198.3$$

$$\Rightarrow P_B = 17176.1 \text{ KPa}.$$

(Ans:)

Here,

$$V_A = \frac{Q}{A_A} = \frac{40}{\frac{\pi}{4}(.50)^2} = 203.72 \text{ m/s}$$

$$V_B = \frac{Q}{A_B} = \frac{40}{\frac{\pi}{4}\times(1)^2} = 50.93 \text{ m/s}$$

$$h_L = 0.1\times\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$$

$$= 0.1\times\left(\frac{203.72^2}{2\times 9.81} - \frac{50.93^2}{2\times 9.81}\right)$$

$$= 198.3 \text{ m}$$

(BWDB-2019)

Problem: In a horizontal pipe of 30 cm diameter, water flows with a velocity 2 m/s and the pressure is 52 KN/m². If the diameter of the pipe is 60 cm in other end, what is the pressure?

Solution: For horizontal pipe, $Z_1 = Z_2$. Assume head loss = 0

From Bernoulli's equation,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

Here,

$$A_2V_2 = A_1V_1$$

$$\Rightarrow V_2 = \frac{2\times(0.30)^2}{(0.60)^2} = 0.5 \text{ m/s}$$

$$\Rightarrow \frac{52}{9.81} + \frac{2^2}{2\times 9.81} = \frac{P_2}{9.81} + \frac{0.5^2}{2\times 9.81} \Rightarrow P_2 = 53.875 \text{ KN/m}^2$$

CamScanner

Problem: A pipe is laying at head of 525 m at one end 'P' and head of 580 m at other end 'Q'. The diameter of pipe at P and Q is 50 cm and 75 cm respectively. The discharge from P to Q is 0.02 m^3/s. If the pressure at P is 1000 KN/m^2, Determine the pressure at point Q. Assume head loss = 1 m. (DWASA - 2017)

Solution:

From Bernoulli's equation,

$$\frac{P_P}{\gamma} + \frac{v_P^2}{2g} + z_P = \frac{P_Q}{\gamma} + \frac{v_Q^2}{2g} + z_Q + h_L$$

Here,

$$v_P = \frac{Q}{A_P} = \frac{0.02}{\frac{\pi}{4} \times (.50)^2} = 0.102 \text{ m/s}$$

$$v_Q = \frac{Q}{A_Q} = \frac{0.02}{\frac{\pi}{4} \times (.75)^2} = 0.095 \text{ m/s}$$

$$\Rightarrow \frac{1000}{9.81} + \frac{(0.102)^2}{2 \times 9.81} + 525 = \frac{P_Q}{9.81} + \frac{(0.095)^2}{2 \times 9.81} + 580 + 1$$

$$\Rightarrow P_Q = 450.64 \text{ KN/m}^2$$

(Ans.)

Flow through pipes:

Problem: A fluid flows through a pipe having diameter 0.6 m and length 100 m. If the frictional co-efficient is 0.004 and the head loss is 25 m. Find out the discharge. (DSCC-2019)

Solution:

Neglecting minor losses,

$$h_f = \frac{4fLV^2}{2gd}$$

Here, $f = 0.004$, $L = 100\ m$, $h_f = 25\ m$, $d = 0.6\ m$

$$\Rightarrow 25 = \frac{4 \times 0.004 \times 100}{2 \times 9.81 \times 0.6} \times V^2$$

$$\Rightarrow V^2 = 183.9375$$

$$\therefore V = 13.56\ m/s$$

$$A = \frac{\pi}{4} \times (0.6)^2 = 0.282744\ m^2$$

Now,

discharge, $Q = AV = (13.56 \times 0.282744) = 3.834\ m^3/sec.$ (Ans.)

Problem: A fluid flows through a pipe having a diameter 0.5 m, length 100m. and discharge 0.4 m^3/s. If frictional co-efficient is 0.005, find the head loss due to friction. (BMA-51)

Solution:

We know,

$$h_f = \frac{4fLV^2}{2gd}$$

Here,

$$V = \frac{Q}{A}$$

$$\Rightarrow V = \frac{0.4}{\frac{\pi}{4} \times (0.5)^2}$$

$$\therefore V = 2.04\ m/s.$$

$$\Rightarrow h_f = \frac{4 \times 0.005 \times 100 \times (2.04)^2}{2 \times 9.81 \times 0.5}$$

$$\therefore h_f = 0.85\ m.$$

(Ans.)

Problem: A fluid, with a density of 900 kg/m³ and kinematic viscosity of 0.00001 m²/s, flow at 0.2 m³/sec. through a 500 m length of 200 mm diameter cast-iron pipe. Determine (a) the head loss (b) the pressure drop if the pipe drops down at 1 in 10 in the flow direction if the friction factor 0.0225. (GTCL-2022)

Solution:

We know, $V = \frac{Q}{A} = \frac{0.2}{\frac{\pi}{4} \times (0.2)^2} = 6.366 \text{ m/s}$

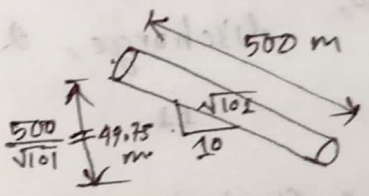
Now, $Re = \frac{Vd}{\nu} = \frac{6.366 \times 0.2}{0.00001} = 127324 > 4000$

Hence it is turbulent flow.

For turbulent flow, $h_f = \frac{fLV^2}{2gd} = \frac{0.0225 \times 500 \times 6.366^2}{2 \times 9.81 \times 0.2} = 116.2 \text{ m}$

For inclined pipe and $v_1 = v_2$

$$\frac{P_1}{\gamma} + z_1 = \frac{P_2}{\gamma} + z_2 + h_L$$



$$\Rightarrow \frac{P_1 - P_2}{\gamma} + (z_1 - z_2) = 116.2$$

$$\Rightarrow \frac{\Delta P}{\gamma} + 49.75 \text{ m} = 116.2$$

$$\Rightarrow \Delta P = (116.2 - 49.75) \times 9.81 = 651.87 \text{ KN/m}^2$$

(Ans.)

Problem: water is flowing in a pipe of diameter 12 cm at a velocity of 2 m/sec. Find out the discharge. (DPDC-2014)

Solution: We know,

$$Q = AV$$

$$\Rightarrow Q = \frac{\pi}{4} \times (.12)^2 \times 2$$

$$\therefore Q = 0.0226 \text{ m}^3/\text{sec.}$$

(Ans.)

Problem: Calculate the diameter of a circular pipe that has discharges 2.5 cusec. water with a velocity of 6 fps. (PGCL-2014, PGCB-15, BIFPCL-15)

Solution:

We know,

$$Q = AV$$

$$\Rightarrow A = \frac{Q}{V}$$

$$\Rightarrow \frac{\pi}{4} d^2 = \frac{Q}{V}$$

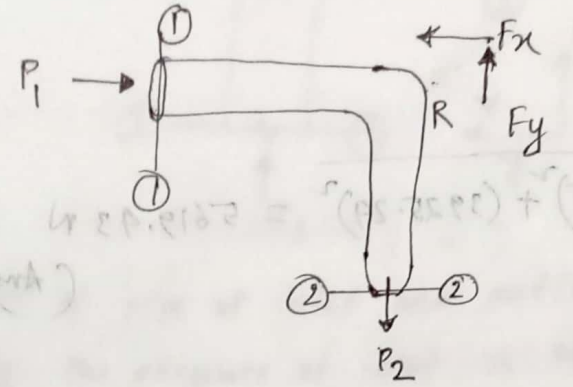
$$\therefore d = \sqrt{\frac{4Q}{\pi V}} = \sqrt{\frac{4 \times 2.5}{3.1416 \times 6}} = 0.728 \text{ ft} = 8.74 \text{ inch.}$$

(Ans.)

Problem:

(SGFCL-2017)

Problem: The diameter of a 90° bend pipe is 16 cm at inlet and 12 cm at outlet. Neglecting friction across bend, calculate the magnitude and direction of the force exerted on the bend by water flowing through is at 5 m/s and the inlet pressure is 75 KN/m².



Solution: we know, $Q = A_1V_1 = A_2V_2$

$$\Rightarrow V_2 = \frac{A_1V_1}{A_2} = \frac{(16)^2 \times 5}{(12)^2} = 8.889 \text{ m/s}$$

For $z_1 = z_2$, Bernoulli's equation is,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g}$$

$$\Rightarrow \frac{75}{9.81} + \frac{5^2}{2\times 9.81} = \frac{P_2}{9.81} + \frac{8.889^2}{2\times 9.81}$$

$$\Rightarrow P_2 = 48 \text{ KN/m}^2$$

$$Q = A_1V_1 = \frac{\pi}{4} \times (0.16)^2 \times 5^2 = 0.502656 \text{ m}^3/\text{s}$$

Now, In x-direction,

$$P_1A_1 - F_x = \rho Q(V_2 - V_1)$$

$$\Rightarrow 75\times 10^3 \times \frac{\pi}{4} \times (0.16)^2 - F_x = 1000 \times 0.502656 \times (0-5)$$

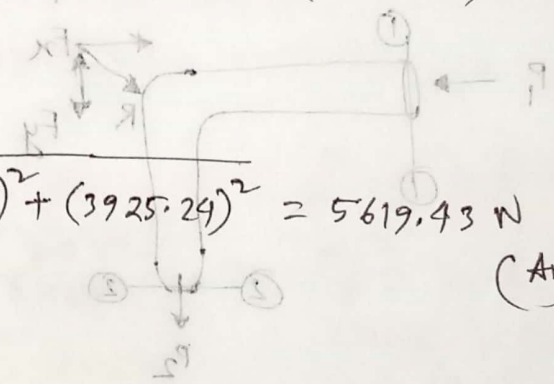
$$\Rightarrow F_x = 4021.25 \text{ N}$$

In Y direction,

$$P_2 A_2 - F_y = \rho Q (V_2 - V_1)$$

$$\Rightarrow 48 \times 10^3 \times \frac{\pi}{4} \times (0.12)^2 - F_y = 1000 \times 0.502656 \times (8.889 - 0)$$

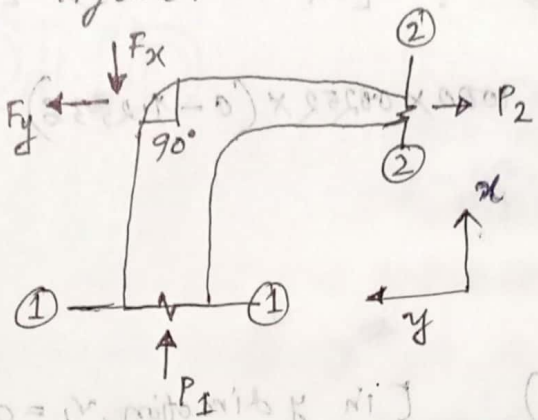
$$\Rightarrow F_y = 3925.29 \text{ N}$$



$$\therefore R = \sqrt{F_x^2 + F_y^2} = \sqrt{(9021.25)^2 + (3925.29)^2} = 5619.43 \text{ N}$$

(Ans)

Problem: Water flows through a 90° bend in a horizontal plane as depicted in the Figure:



The diameter of pipe at inlet and outlet is 16 cm and 12 cm respectively. The pressure at inlet is 140 KPa. Determine the magnitude of the force that would be required to hold the pipe section. Neglect the friction across bend.

Solution: Pressure at outlet will be zero as water discharges to atmosphere at outlet.

$$\frac{P_1}{\gamma_w} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma_w} + \frac{v_2^2}{2g} + z_2 .$$

For, $P_2 = 0$ and $z_1 = z_2$

$$\frac{P_1}{\gamma_w} + \frac{v_1^2}{2g} = \frac{v_2^2}{2g}$$

$$\Rightarrow \frac{140}{9.81} + \frac{v_1^2}{2\times 9.81} = \frac{(1.778 v_1)^2}{2\times 9.81}$$

$$\Rightarrow v_1 = 1.2536 \text{ m/s}$$

Here,

$$Q = A_1 v_1 = A_2 v_2$$

$$\Rightarrow v_2 = \frac{A_1 v_1}{A_2}$$

$$\Rightarrow v_2 = \frac{(16)^2}{(12)^2} \times v_1$$

$$\therefore v_2 = 1.778\, v_1$$

$$\therefore v_2 = (1.778 \times 1.2536) = 2.229 \text{ m/s}$$

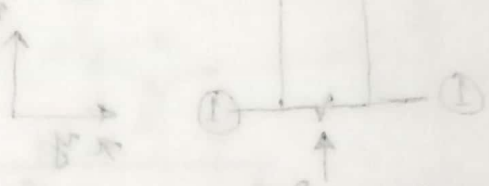
$$Q = A_1 v_1 = \frac{\pi}{4} \times (0.16)^2 \times 1.2536 = 0.0252 \text{ m}^3/\text{s}$$

In x direction,

$P_1 A_1 - F_x = \rho Q (V_2 - V_1)$ [In x direction, $V_2 = 0$]

$\Rightarrow 140 \times 10^3 \times \frac{\pi}{4} \times (.16)^2 - F_x = 1000 \times .0252 \times (0 - 1.2536)$

$\Rightarrow F_x = 2846.46\ N$



In Y direction

$P_2 A_2 - F_y = \rho Q (V_2 - V_1)$ [In y direction, $V_1 = 0$]

$P_2 = 0$

$\Rightarrow -F_y = 1000 \times 0.0252 \times (2.2289 - 0)$

$\Rightarrow F_y = 56.17\ N \ (\rightarrow)$

$\therefore$ Resultant force, $R = \sqrt{F_x^2 + F_y^2} = \sqrt{(2846.46)^2 + (56.17)^2} = 2847.\ N$

(Ans.)

Hydrology

Hydrologic Equation:

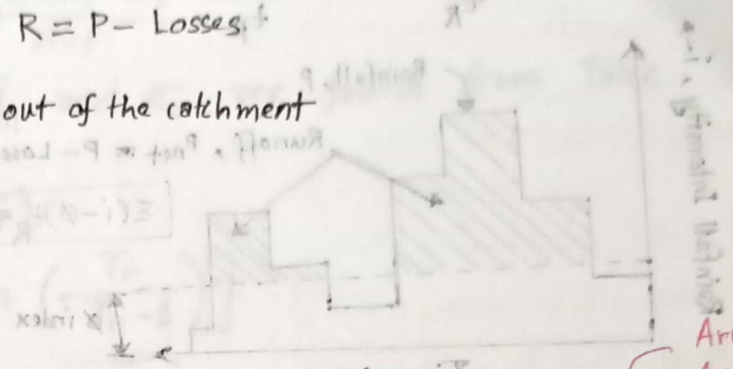
Inflow (I) − Outflow (O) = Change in storage (ΔS)

Water Budget Equation:

$P - R - G_1 - E - T = \Delta S$

where, P = Precipitation
R = Surface Runoff
} * R = P − Losses

G_1 = Net ground water flow out of the catchment
E = Evaporation
T = Transpiration
ΔS = Change in storage



Estimation of missing Rainfall Data:

If $\frac{N_i - N_x}{N_x} < 10\%$, Then Missing Rainfall Data, $P_x = \frac{1}{M}\left[P_1 + P_2 + \dots + P_m\right]$ — Arithmatic Average Method

and, If $\frac{N_i - N_x}{N_x} > 100\%$, Then, $P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \dots + \frac{P_m}{N_m}\right]$ — Normal Ratio Method

Adequacy of Raingauge station:

optimum Number of stations, $N = \left(\frac{C_v}{\varepsilon}\right)^2$

where,
C_v = co-efficient of variation $= \frac{\sigma_{m-1}}{\bar{P}} \times 100$ Here, $\sigma_{m-1} = \sqrt{\frac{\sum (P_i - \bar{P})^2}{m-1}}$
ε = Allowable degree of error
$\bar{P} = \frac{\sum P_i}{m}$

Probability of Rainfall/Flood:

Probability of occurance or exceedance, $P = \frac{1}{T}$ where, T = Recurrence Interval / Return Period

Probability of Non-occurance, $q = 1 - P$

Probability of an event occuring 'r' times in 'n' successive years,

$P_{r,n} = {}^nC_r \cdot P^r \cdot q^{n-r}$ where, ${}^nC_r = \frac{n!}{(n-r)!\,r!}$

Probability of an event occuring at least once in 'n' successive years, (=Risk)

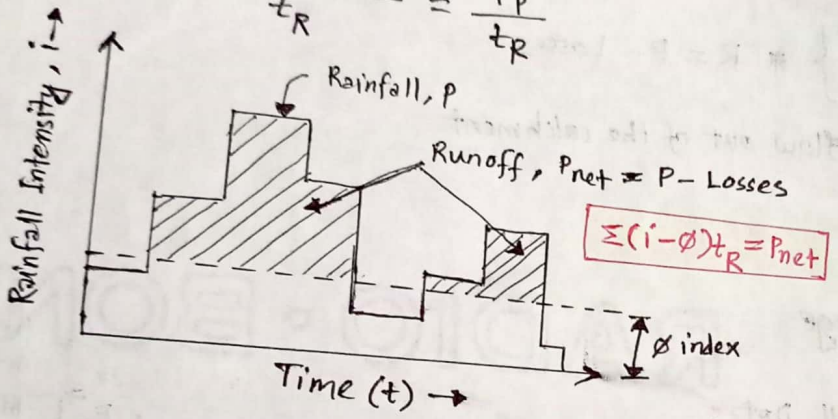
$P_1 = 1 - q^n$

Probability of an event not occuring at all in 'n' successive years, $P_{0,n} = q^n$

Infiltration Indices:

ϕ index $= \frac{\text{Basin Discharge}}{\text{Duration of Rainfall}} = \frac{P - Q}{t_e}$

W index $= \frac{P - Q - S}{t_R} = \frac{F_P}{t_R}$



Here,

P = Total Rainfall

Q = Surface Runoff

S = Effective surface Retention

t_R = Duration of storm during which $i > f_p$

F_P = Total Precipitation

t_e = Duration of storm during which $i \geq \phi$

i = Rainfall Intensity

Unit Hydrograph:

$P_{net} = P - \text{Losses}$

or, $P_{net} = \frac{\Sigma Q_d t}{A}$ where, Q_d = DRO

or, $P_{net} = \frac{DRO}{UGO}$ where, DRO = TRO − BFO

Here, P_{net} = Net Precipitation = Direct Runoff

P = Total Rainfall

Losses = Due to Infiltration

Q_d, DRO = Direct Runoff Ordinate

TRO = Total Runoff ordinate

UGO = Unit Hydrograph Ordinate

BFO = Base Flow Ordinate

t = Time interval between successive direct runoff ordinates

c = Runoff co-efficient = $\frac{P_{net}}{P}$

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Design Flood: (Gumble's Distribution Method)

(i) Mean/Average annual flood, $\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n}$

(ii) Standard deviation, $S_x = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}}$

(iii) For Known value of 'n', $\bar{y}_n$ and σ_n are found from Table.

(iv) For given return period (T_r),

$$y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$$

(v) Frequency Factor, $K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$

(vi) Design Flood, $X_T = \bar{X} + K_T \cdot S_x$

Run off Volume:

Total Runoff volume, $V = A P_{net} = CAP$

Total Rain water discharge, $Q = CIA$

where, C = Runoff co-efficient $= \frac{P_{net}}{P}$ [* $P_{net} = P - \text{Losses}$]

A = catchment Area

P_{net} = Net Rainfall / Run-off $= I \times t_R$

I = Intensity of Rainfall

t_R = Rainfall duration

P = Total Rainfall

Total Rainfall Volume = AP

Run off depth = $\frac{\text{Runoff volume}}{\text{catchment Area}}$

CamScanner

Catchment Characterestics:

* Stream density, $D_s = \frac{N_s}{A}$
* Drainage density, $D_d = \frac{L_s}{A}$
* Slope of the basin, $S = \frac{15\,(CI)\,N_c}{\Sigma L}$
* Form Factor, $F_f = \frac{W_b}{L_b} = \frac{A}{L_b^2}$
* compactness co-efficient, $C_c = \frac{P_b}{2\sqrt{\pi A}}$
* Elongation Ratio, $E_r = \frac{2R}{L_b}$

Here, N_s = Number of stream
L_s = Total length of all stream channels in the basin
A = Area of basin
CI = contour interval
N_c = Number of contour crossed by all the subdividing lines
W_b = Width of basin
L_b = Axial length of basin
P_b = Perimeter of the basin.
R = Radius of Equivalent circular area

Specific Yield: $S_y = \frac{W_y}{V}$

Specific Retention: $S_r = \frac{W_r}{V}$

where, W_y = volume of water drained
W_r = Volume of water retained

* $n = S_r + S_y$

storage co-efficient: $S = \gamma_w\, n\, b \left(\frac{1}{K_w} + \frac{1}{n E_s}\right)$

where,
b = Thickness of confined aquifer
K_w = Bulk modulus of elasticity of water.
E_s = Modulus of elasticity of soil grains.

Change in ground water storage:

$\Delta GWS = A_{aq} \times \Delta GWT \times (S \text{ or } S_y)$

where, A_{aq} = Area of aquifer
ΔGWT = Change in ground water table
S = storage co-efficient (confined aquifer)
S_y = Specific Yield (Unconfined aquifer)

Discharge from Well:

From unconfined aquifer, $Q = \frac{\pi K (H^2 - h^2)}{\ln\left(\frac{R}{r_w}\right)}$

From confined aquifer, $Q = \frac{2\pi K b (H-h)}{\ln\left(\frac{R}{r_w}\right)}$

where,

H = depth of water below G.W.T or piezometer level

h = depth of water in the well.

K = co-efficient of permeability

b = Thickness of aquifer.

* Interference among wells;

(i) Two wells ▸ $Q = \frac{2\pi T (H-h)}{\ln\left(\frac{R}{B r_w}\right)}$ where, B = distance between wells

T = Transmissibility of aquifer (= Kb)

(ii) Three wells in same line ▸

$$Q_1 = Q_3 = \frac{2\pi T (H-h) \times \ln\left(\frac{B}{r_w}\right)}{\ln\left(\frac{R}{B}\right) \times \ln\left(\frac{B}{r_w}\right) + \ln\left(\frac{B}{2r_w}\right) \times \ln\left(\frac{R}{r_w}\right)}$$

$$Q_2 = \frac{2\pi T (H-h) \times \ln\left(\frac{B}{2r_w}\right)}{2\ln\left(\frac{R}{B}\right) \times \ln\left(\frac{B}{r_w}\right) + \ln\left(\frac{B}{2r_w}\right) \times \ln\left(\frac{R}{r_w}\right)}$$

(iii) Three wells forming Triangle ▸

$$Q = \frac{2\pi T (H-h)}{\ln\left(\frac{R}{B^2 r_w}\right)}$$

* Spherical flow in a well:

$$Q = 2\pi K r_w (H-h)$$

Yield of cavity well:

$$Q = \frac{2\pi K y (H-h)}{1 - \frac{r_w}{R}}$$ where, y = depth of cavity

width of cavity, $r_e = \sqrt{(2r_w - y)y}$

Infiltration Indices:

Problem: If the surface runoff is 4.9 cm, determine the ϕ index. The rainfall rates for successive 1-hr intervals upto 5-hr are given below:

BWDB-19

Time (hr)	0	1	2	3	4	5
Rainfall Intensity (cm/hr)	0	0.6	3	2	4	2.4

Solution: Total precipitation, $P = (0.6 + 3 + 2 + 4 + 2.4) = 12$ cm

we know, $\phi = \frac{P-Q}{t_R} = \left(\frac{12-4.9}{5}\right) = 1.42$ cm/hr > 0.6 cm

Hence, Effective Rainfall, $P_e = (3 + 2 + 4 + 2.4) = 11.4$ cm

and Rainfall duration, $t_R = (5-1)\text{hr} = 4$ hr

$\therefore \phi = \left(\frac{11.4-4.9}{4}\right) = 1.625$ cm/hr (Ans.)

Problem: If Precipitation = 9 cm and Runoff = 5 cm. The rainfall data is provided below. Find out the value of ϕ index.

BWDB-18, BIWTA-19

Time (hr)	0	1	2	3	4	5	6
Rainfall (cm)	0	0.4	2.2	4	2.2	1.4	0.9

Solution: Total Rainfall, $P = (0.4 + 2.2 + 4 + 2.2 + 1.4 + 0.9) = 11.1$ cm

$\therefore \phi = \frac{P-Q}{t_R} = \left(\frac{11.1-5}{6}\right) = 1.017$ cm. > 0.4 cm, 0.9 cm.

Hence, Effective rainfall, $P_e = (2.2 + 4 + 2.2 + 1.4) = 9.8$ cm

and Rainfall duration $= (6-2)\text{hr} = 4$ hr

$\therefore \phi$ index $= \left(\frac{9.8-5}{4}\right) = 1.2$ cm/hr.

(Ans.)

Example: The rates of rainfall for successive 30 min. period of 3-hr storm are: 1.6, 3.6, 5.0, 2.8, 2.2, 1.0 cm/hr. The corresponding surface runoff is estimated to be 3.6 cm. Determine ϕ-index and W-index.

Solution:

Total Rainfall, $P = (1.6+3.6+5.0+2.8+2.2+1.0)\times\frac{30}{60}$

$= 8.1$ cm

$\therefore \phi = \frac{P-Q}{t_R} = \left(\frac{8.1-3.6}{3}\right) = 1.5$ cm/hr > 1.0 cm/hr

Hence, effective rainfall, $P_e = (1.6+3.6+5+2.8+2.2)\times\frac{30}{60}$

$= 7.6$ cm

Rainfall duration $= 2.5$ hr.

$\therefore \phi$ index $= \left(\frac{7.6-3.6}{2.5}\right) = 1.6$ cm/hr.

and, W index $= \frac{P-Q-S}{t_R} = \frac{8.1-3.6-0}{3} = 1.5$ cm/hr.

(Ans.)

//DWASA – 2017//

Example: Rainfall of magnitude 3.8 cm and 2.8 cm occuring on two consecutive 4-hr durations on a catchment of area 27 km^2 produced the following hydrograph of flow at the outlet of the catchment. Estimate the rainfall excess and ϕ index.

Time from start of Rainfall (hr.)	-6	0	6	12	18	24	30	36	42	48	54	60	66
Observed flow (m^3/s)	6	5	13	26	21	16	12	9	7	5	5	4.5	4.5

Solution: Here, Base flow $= 5$ m^3/sec.

Time (hr)	0	6	12	18	24	30	36	42	48
Flow without Base-flow (m^3/s)	0	8	21	16	11	7	4	2	0

(13-5) (26-5)

∴ Direct runoff volume $= (6\times60\times60)\times\left[\frac{1}{2}(0+8)+\frac{1}{2}(8+21)+\frac{1}{2}(21+16)\right.$
$\left.+\frac{1}{2}(16+11)+\frac{1}{2}(11+7)+\frac{1}{2}(7+4)+\frac{1}{2}(4+2)+\frac{1}{2}(0+2)\right]$

$= 1.4904\times10^6\ m^3$

∴ Runoff depth $= \frac{\text{Runoff volume}}{\text{Catchment Area}} = \frac{1.4904\times10^6}{27\times10^6} = 0.0552\ m$

Hence, Rainfall Excess $= 5.52\ cm$

Total Rainfall $= (3.8+2.8) = 6.6\ cm.$

Rainfall duration $= (4+4) = 8\ hr.$

∴ ϕ index $= \frac{P-Q}{t_R} = \left(\frac{6.6-5.52}{8}\right) = 0.135\ cm/hr.$ (Ans.)

f Unit Hydrograph:

Problem: The value of peak of a 6-hr flood hydrograph is 35 m^3/sec. and constant base flow is 10 m^3/sec. If the rainfall depth is 3.25 cm and infiltration rate is 0.125 cm/hr. Determine the peak of 6-hr unit hydrograph and runoff co-efficient. (BWDB-16, MPA-19, BIWTA-23)

Solution: Runoff depth = Rainfall depth − losses

$\therefore P_{net} = (3.25 - 0.125 \times 6) = 2.5$ cm.

DRO peak = Flood Peak − Base Flow $= (35 - 10) = 25$ m^3/sec.

$\therefore$ UG peak $= \frac{\text{DRO Peak}}{P_{net}} = \frac{25}{2.5} = 10$ m^3/sec.

(Ans.)

Example: The successive 3-hr ordinates of a 6hr UG for a particular basin are 0, 15, 36, 30, 17.5, 8.5, 3.0 cumec respectively, the flood peak observed due to 6-hr storm was 150 cumec. Assuming a constant base flow of 6 cumec and an average storm loss of 6 mm/hr, determine the depth of storm rainfall and the stream flow at successive 3 hr interval.

Solution: Here, UG peak = 36 cumec. Losses = 6 mm/hr = 0.6 cm/hr

Flood peak = 150 cumec

Base flow = 6 cumec.

$\therefore$ DRO peak = Flood peak − Base flow $= (150 - 6) = 144$ cumec.

Runoff depth, $P_{net} = \frac{\text{DRO peak}}{\text{UG peak}} = \frac{144}{36} = 4$ cm

$\therefore$ Rain fall depth, $P = P_{net} + \text{Losses} = (4 + 6 \times 0.6)$ cm

$P = 7.6$ cm.

Stream flow at 3-hr interval $= (0 \times 4 + 6) = 6, 66, 150, 126, 76, 40, 18.6$ cumec respectively.

TRO = DRO + BF = UG peak × P_{net} + BF

$(15 \times 4 + 6)$

[BUET WRE'15]

Example: the peak of flood hydrograph due to 3-hr duration isolated storm in a catchment is 270 m^3/sec. The total depth of rainfall is 5.9 cm. Assuming an average loss of 0.3 cm/hr. and a constant base flow of 20 m^3/sec. Estimate the peak of 3 hr. Hydrograph of the catchment.

If the area of the catchment is 567 km^2, determine the base width of the 3-hr unit hydrograph by assuming it to be triangular in shape.

Solution:

Flood peak = 270 m^3/sec.

Total losses = $(0.3 \times 3) = 0.9$ cm

Total Rainfall depth, P = 5.9 cm.

Hence, P_{net} = P - losses = $(5.9 - 0.9) = 5$ cm.

DRO peak = Flood peak − BF = $(270 - 20) = 250$ m^3/sec.

$\therefore$ UG peak = $\frac{\text{DRO peak}}{P_{net}} = \frac{250}{5} = 50$ m^3/sec.

(Ans.)

Let, Base width of 3-hr unit hydrograph = B

So, Area of UH = Area of catchment × 1 cm

$\Rightarrow \frac{1}{2} \times B \times 50 = 567 \times 10^6 \times 0.01$

$\Rightarrow B = 22.68 \times 10^4$ sec. = 63 hours.

(Ans.)

Run off co-efficient

Problem: An urban catchment has area of 8 ha, 17 ha, 50 ha, 10 ha for different purposes. If the corresponding run off co-efficient are 0.7, 0.1, 0.3 and 0.8 respectively, Find the equivalent run-off co-efficient. (BUET M.Sc.-17, BAPEX-22)

Solution: $$C_{eq} = \frac{\Sigma C_i A_i}{\Sigma A_i} = \frac{(8\times0.7 + 17\times0.1 + 50\times0.3 + 10\times0.8)}{(8+17+50+10)}$$

$\therefore C_{eq} = 0.3565$

(Ans.)

//BWDB-18//

Problem: A storm with 10 cm perticipation has direct runoff 60000 m^3 in 1 Km^2 catchment area. Calculate the run-off co-efficient.

Solution: Direct Runoff depth, $P_{net} = \frac{60000}{10} = 0.06\ m = 6\ cm.$

Given, Rainfall depth, $P = 10$ cm.

$\therefore$ Run-off co-efficient, $C = \frac{P_{net}}{P} = \frac{6}{10} = 0.6$

(Ans.)

//NHA-19//

Problem: calculate the discharge of rainwater from a paved surface of 100 m^2, when rainfall intensity is 1.5 cm/hr. Assume run-off co-eff. = 0.9.

Solution: We know, $Q = CIA = \left(0.9 \times \frac{1.5}{100} \times 100\right) = 1.35\ m^3/hr.$

(Ans.)

//BWDB-16//

Problem: The value of total direct runoff volume of a catchment is $6\times10^3\ m^3$. If Rainfall depth is 8 cm and Run-off co-efficient is 0.5, Determine the area of the catchment.

Solution: Run-off depth, P_{net} = Run-off co-efficient × Rainfall depth

$\therefore P_{net} = (0.5\times8) = 4$ cm.

$\therefore$ Area of the catchment = $\frac{\text{Run-off volume}}{\text{Run-off depth}} = \frac{6\times10^3}{0.04} = 15\times10^4\ m^2$

$= 15$ ha. (Ans.)

Gumbel's Distribution

* Flood frequency computations for a river at certain location by using Gumbel's distribution yielded is given below:

BWDB-20
SGFL-23

Return Period	Peak flood
50	40,809
100	46,300

Estimate the design flood magnitude for return period of 500 years. Also determine the design scouring depth using Lacey's regime equation if d_{50} of the bed material is 0.005 cm.

Solution: we know, $X_T = \bar{X} + K_T \cdot S_x$

Hence, $X_{50} = \bar{X} + K_{50} \cdot S_x$ ..... (I)

and $X_{100} = \bar{X} + K_{100} \cdot S_x$ ..... (II)

(II) − (I) $\Rightarrow X_{100} - X_{50} = S_x (K_{100} - K_{50})$

$$\Rightarrow S_x = \frac{46300 - 40809}{K_{100} - K_{50}}$$

$$\therefore S_x = \frac{5491}{K_{100} - K_{50}} \quad \text{..... (III)}$$

Again, $K_T = \frac{y_T - \bar{y}_n}{\sigma_n} = \frac{y_T}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n}$

and, $y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$

So, $y_{50} = -\ln\left[\ln\left(\frac{50}{49}\right)\right] = 3.902$

$y_{100} = -\ln\left[\ln\left(\frac{100}{99}\right)\right] = 4.6$

Hence, $K_{100} = \frac{4.6}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n}$ ..... (IV)

and $K_{50} = \frac{3.902}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n}$ ..... (V)

(IV) − (V) $\Rightarrow K_{100} - K_{50} = \left(\frac{4.6 - 3.902}{\sigma_n}\right) = \frac{0.698}{\sigma_n}$ ..... (VI)

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From (ii) & (vi), $S_x = \frac{5491\sigma_n}{0.698}$ $\therefore \frac{S_x}{\sigma_n} = 7866.76$ ..... (vii)

For 500 year return period,

$$y_{500} = -\ln\left[\ln\left(\frac{500}{499}\right)\right] = 6.214$$

Now,

$$(y_{500} - y_{100}) \times \frac{S_x}{\sigma_n} = X_{500} - X_{100}$$

$$\Rightarrow (6.214 - 4.6) \times 7866.76 = X_{500} - 46300$$

$$\therefore X_{500} = 58996.95 \text{ m}^3/\text{sec.}$$

(Ans.)

Now, silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{0.05} = 0.394$

∴ Lacey's Normal Regime scour depth,

$$R = 0.473\left(\frac{Q}{f}\right)^{\frac{1}{3}} = 0.473 \times \left(\frac{58996.95}{0.394}\right)^{\frac{1}{3}}$$

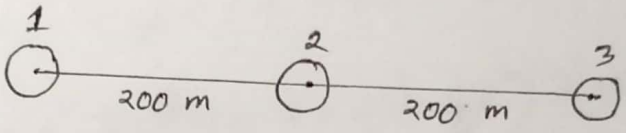
$$\therefore R = 25.12 \text{ m.}$$

(Ans.)

Discharge from wells:

[BWDB - 20]

Problem: Three pumping wells located along a straight, are spaced at 200 m apart. What would be the steady state pumping rate from each well so that near steady state drawdown in each well not exceed 2 m? The transmissibility of confined aquifer which all the wells fully penetrate is 2400 m^2/day and all the wells are 40 cm in diameter. The thickness of the aquifer is 40 m and the radius of the influence of each well is 800 m.



Solution;

$$Q_1 = Q_3 = \frac{2\pi T (H-h_w) \ln\left(\frac{B}{r_w}\right)}{\ln\left(\frac{R}{B}\right) \times \ln\left(\frac{B}{r_w}\right) + \ln\left(\frac{B}{2r_w}\right) \times \ln\left(\frac{R}{r_w}\right)}$$

$$= \frac{2 \times 3.1416 \times 2400 \times 2 \times \ln\left(\frac{200}{0.4}\right)}{\ln\left(\frac{800}{200}\right) \times \ln\left(\frac{200}{0.4}\right) + \ln\left(\frac{200}{2 \times 0.4}\right) \times \ln\left(\frac{800}{0.4}\right)}$$

$$= 3705.34 \text{ m}^3/\text{day}.$$

$$Q_2 = \frac{2\pi T (H-h_w) \times \ln\left(\frac{B}{2r_w}\right)}{2\ln\left(\frac{R}{B}\right) \times \ln\left(\frac{B}{r_w}\right) + \ln\left(\frac{B}{2r_w}\right) \times \ln\left(\frac{R}{r_w}\right)}$$

$$= \frac{2 \times 3.1416 \times 2400 \times 2 \times \ln\left(\frac{200}{0.4 \times 2}\right)}{2 \times \ln\left(\frac{800}{200}\right) \times \ln\left(\frac{200}{0.4}\right) + \ln\left(\frac{200}{2 \times 0.4}\right) \times \ln\left(\frac{800}{0.4}\right)}$$

$$= 2812.966 \text{ m}^3/\text{day}.$$

(Ans.)

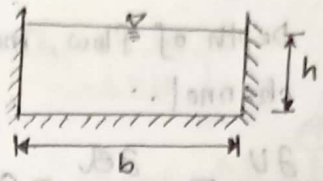
Open Channel Flow

Geometric Elements Some channel sections:

(1) Rectangular: $A = bh$

$P = b + 2h$

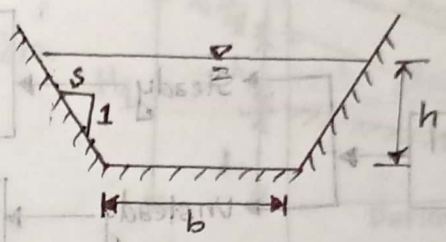
$B = b$



(2) Trapezoidal: $A = (b + sh)h$

$P = b + 2h\sqrt{1+s^2}$

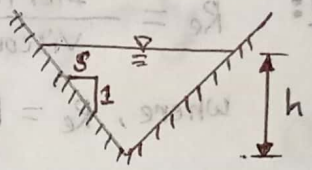
$B = b + 2sh$



(3) Triangle: $A = sh^2$

$P = 2h\sqrt{1+s^2}$

$B = 2sh$



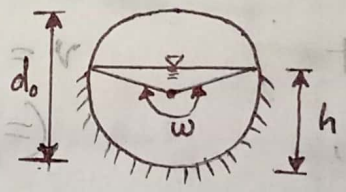
(4) Circular: $h = \frac{1}{2}\left[1 - \cos\left(\frac{\omega}{2}\right)\right] d_o$

$\omega = 2\cos^{-1}\left(1 - \frac{2h}{d_o}\right)$ rad.

$A = \frac{1}{8}(\omega - \sin\omega) d_o^2$

$P = \frac{1}{2}\omega d_o$

$B = \sin\left(\frac{\omega}{2}\right) d_o$



* Hydraulic Radius, $R = \frac{A}{P}$

* Hydraulic Depth, $D = \frac{A}{B}$

where, A = Flow Area
P = wetted perimeter
B = Top width

Wide Channel: when, $b >> h$ (generally $b \geq 10h$). The Alluvial Rivers are usually treated as a wide channel. For a wide channel, $R \approx h$ and, $A \simeq h$

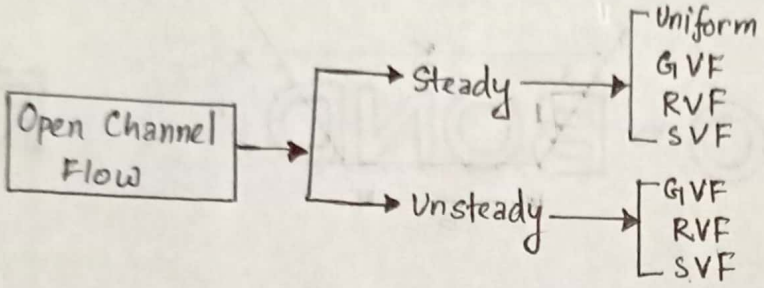
Types of Open Channel Flow:

* **Steady Flow:** Depth of flow, mean velocity and discharge do not change with time.

$$\frac{\partial h}{\partial t} = \frac{\partial U}{\partial t} = \frac{\partial Q}{\partial t} = 0 \quad \text{for fixed } x$$

* **Uniform Flow:** Depth of flow, mean velocity and discharge do not change the length of the channel.

$$\frac{\partial h}{\partial x} = \frac{\partial U}{\partial x} = \frac{\partial Q}{\partial x} = 0 \quad \text{for fixed } t$$



Effect of Viscosity:

$$Re = \frac{\text{Inertia Force}}{\text{Viscous Force}} = \frac{VR}{\nu}$$

When,

(1) $Re < 500$,
Flow is Laminar

(2) $Re > 12500$,
Flow is Turbulent

(3) $500 \leq Re \leq 12500$,
Flow is Transitional

where, Re = Reynold Number
V = Velocity of Flow
R = Hydraulic Radius $= \frac{A}{P}$
ν = Kinematic viscosity of water
$(= 10^{-6}\ m^2/sec$ at $20^\circ C)$

Effect of Gravity:

$$Fr = \sqrt{\frac{\text{Inertia Forces}}{\text{Gravity Forces}}} = \frac{V}{\sqrt{gD}}$$

When,

(1) $Fr = 1$, $V = \sqrt{gD}$,
Flow is critical

(2) $Fr < 1$, $V < \sqrt{gD}$
Flow is subcritical

(3) $Fr > 1$, $V > \sqrt{gD}$
Flow is supercritical

where, D = Hydraulic Depth $= \frac{A}{B}$
Fr = Fraude Number

CamScanner

Continuity Equation:

For steady Flow, $Q = A_1V_1 = A_2V_2 = \dots\dots$

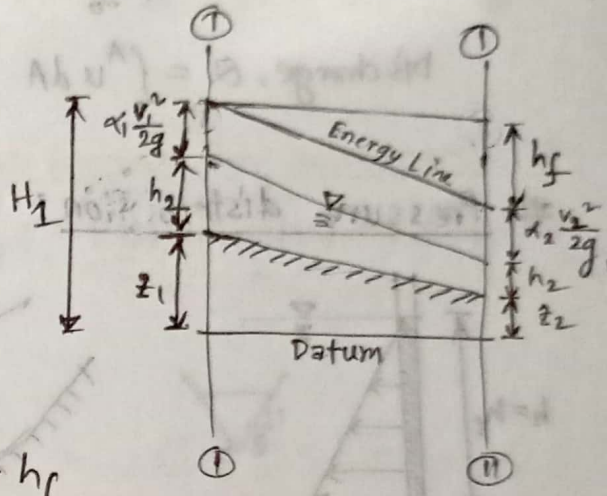
For steady spatially varied Flow, $Q_2 = Q_1 \pm qL$

For unsteady flow, $\frac{\partial Q}{\partial x} + T\frac{\partial y}{\partial t} = 0$

Energy Equation:

Total Energy or head at a channel section,

$$H = z + h + \alpha\frac{v^2}{2g}$$



According to Principle of Energy.

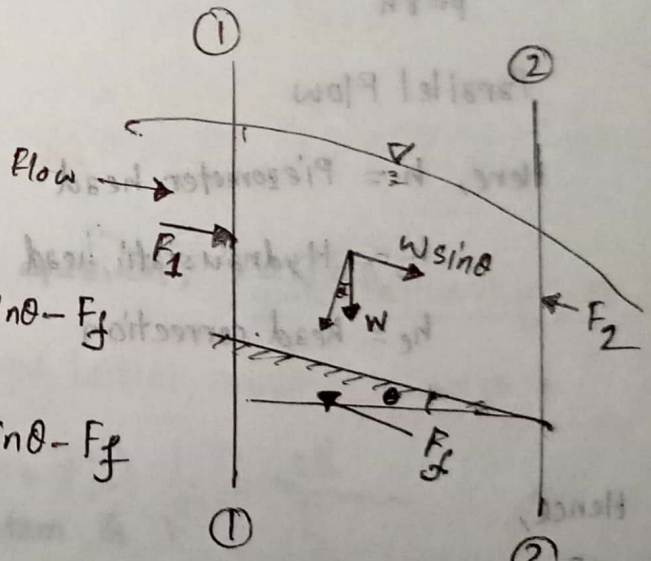
$$H_1 = H_2 + h_f$$

$$z_1 + h_1 + \alpha_1\frac{v_1^2}{2g} = z_2 + h_2 + \alpha_2\frac{v_2^2}{2g} + h_f$$

Momentum Equation:

$$\Sigma F_x = 0$$

$$M_2 - M_1 = F_1 - F_2 + W\sin\theta - F_f$$



$$\Rightarrow \rho Q B_2V_2 - \rho Q B_1V_1 = \gamma\bar{z}_1A_1 - \gamma\bar{z}_2A_2 + W\sin\theta - F_f$$

$$\Rightarrow \rho Q(B_2V_2 - B_1V_1) = \frac{1}{2}\gamma(h_1^2 - h_2^2) + W\sin\theta - F_f$$

Specific Energy:

The specific energy at a channel section, $E = h + \alpha\frac{v^2}{2g}$

Specific Force:

The specific force at a channel section, $F = \frac{Q^2}{Ag} + \bar{z}A$

Types of ...

Velocity distribution co-efficient:

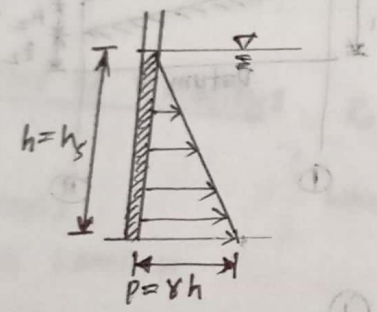
Energy co-efficient, $\alpha = \frac{\int_0^A v^3 dA}{V^3 A} = \frac{\sum v^3 \Delta A}{V^3 A}$

Momentum co-efficient, $\beta = \frac{\int_0^A v^2 dA}{V^2 A} = \frac{\sum v^2 \Delta A}{V^2 A}$

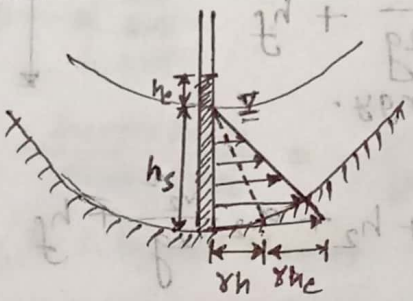
velocity, $V = \frac{1}{A}\int_0^A u\, dA$

Discharge, $Q = \int_0^A u\, dA$

Pressure distribution:

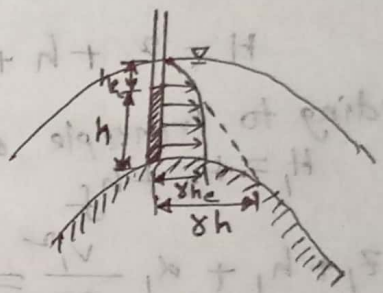


Parallel Flow



P > γh

Concave Flow



P < γh

Convex Flow

Here, h = Piezometer head

h_s = Hydraustatic head

h_e = head correction

* Total Pressure head, $h = h_s \pm h_e$

$= h_s \pm \frac{v^2}{gr} \times h_s$

$= h_s\left(1 \pm \frac{v^2}{gr}\right)$

* Total Pressure, $P = \gamma(h_s \pm h_e)$

$= \gamma h_s\left(1 \pm \frac{v^2}{gr}\right)$

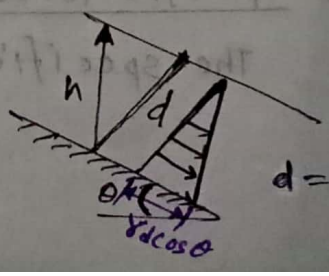
Hence,

For concave Flow, Total pressure, $P = \gamma h_s\left(1 + \frac{v^2}{gr}\right)$

and for convex Flow, Total pressure, $P = \gamma h_s\left(1 - \frac{v^2}{gr}\right)$

* Effect of slope on pressure distribution:

Pressure head, $\frac{P}{\gamma} = d\cos\theta = h\cos^2\theta$



$d = h\cos\theta$

Critical Flow:

The Froude Number is equal to unity. ($Fr = 1$)

$$\frac{V}{\sqrt{gD}} = 1 \Rightarrow \boxed{V = \sqrt{gD_c}}$$

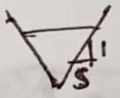
* section factor for critical flow, $Z_c = \frac{Q}{\sqrt{g\alpha}} = A\sqrt{D_c}$

computation of critical depth:

(1) Rectangular section: $y_c = \sqrt[3]{\frac{\alpha Q^2}{gB^2}}$

* For wide channel, $y_c = \sqrt[3]{\frac{\alpha q^2}{g}}$

(2) Triangular section: $y_c = \sqrt[5]{\frac{2Q^2}{gs^2}}$



specific Energy at critical depth:

(1) Rectangular channel: $E_c = \frac{3}{2} y_c$

(2) Triangular channel: $E_c = 1.25\, y_c$

(3) Trapezoidal channel: using critical flow equation, $V = \sqrt{gD_c}$

Uniform Flow:

(1) Chezy's Formula: $V = C\sqrt{RS}$ in fps system &

(2) Manning Formula: $V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$ in MKS system

$= \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$ in fps system

(3) Darcy Weisbach Formula: $h_f = f\frac{LV^2}{2gd}$ where, $d = 4R$

$\Rightarrow V = \sqrt{\frac{8g}{f}}\sqrt{RS}$ $\quad \frac{h_f}{L} = S$

(4) Relation between c, f and n: $c = \sqrt{\frac{8g}{f}} = \frac{1}{n} R^{\frac{1}{6}}$

* Strickler Formula for estimating 'n': $n = \frac{d_{50}^{\frac{1}{6}}}{21.1}$

* Normal depth: The depth of the uniform flow is called Normal depth.

* section factor for uniform flow, $Z_n = AR^{\frac{2}{3}} = \frac{nQ}{\sqrt{S}}$

Computation of Normal depth:

(1) For wide channel, $h_n = \left(\frac{nq}{\sqrt{S_0}}\right)^{\frac{3}{5}}$ using Manning's Formula.

$= \left(\frac{q}{c\sqrt{S_0}}\right)^{\frac{2}{3}}$ using chezy's Formula.

(2) For other channels, using Manning's Formula,

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

or, $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$

Hydraulic Jump:

* Relation between initial depth and sequent depth,

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right)$$

* Energy loss, $h_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$

* Relative loss $= \frac{h_L}{E_1}$

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

$V_1 = \sqrt{g D_1}$

* Length of jump, $L_j = 6 y_2$

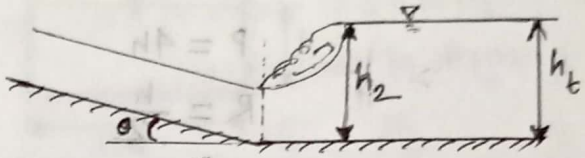
* Height of jump, $H_j = y_2 - y_1$

* Efficiency, $\eta = \frac{E_2}{E_1}$

* power dissipation, $H.P = \frac{\gamma Q h_L}{75}$

Hydraulic Jump in Sloping Channel:

1. If $h_t \leq h_2$, Jump forms on horizontal bed, and Type A jump occurs.



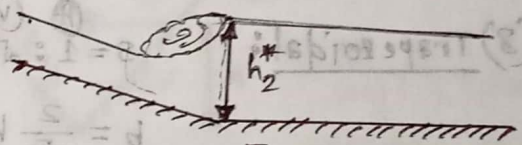
Type - A

2. If $h_2^* > h_t > h_2$, the toe of the jump on the slope and the end is on the horizontal bed and Type B jump occurs.



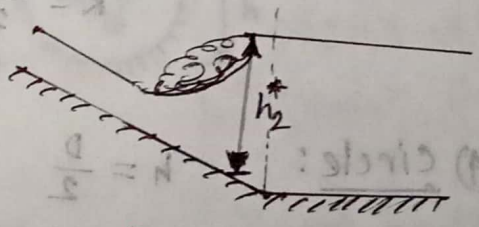
Type - B

3. If $h_2^* = h_t > h_2$, the end of the jump coincides with the intersection of sloping and horizontal beds, and Type C jump occurs.



Type - C

4. If $h_t > h_2^* > h_2$. Type D jump completely occurs on the sloping channel



Here,

$$h_2^* = \frac{h_1}{2}\left(\sqrt{1+8G_1^2} - 1\right)$$

where,

$G_1 = K_1 F_1$

$K_1 = 10^{0.027\theta}$

$d_2 = h_2^* \cos\theta$

Energy Loss, $\Delta E = L_j \tan\theta + (d_1 - d_2)\cos\theta + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$

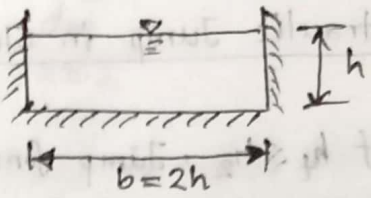
Best Hydraulic Section: (gives Maximum Discharge)

(1) Rectangular: $b = 2h$

$A = 2h^2$

$P = 4h$

$R = \frac{h}{2}$



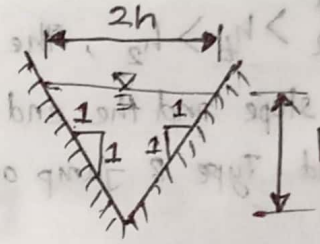
*(Half of a square)

(2) Triangular: $S = 1:1$

$A = h^2$

$R = \frac{\sqrt{2}}{4} h$

$P = 2\sqrt{2}h$



* (Half of a square)

(3) Trapezoidal: $S = 1 : \sqrt{3}$ (H : V)

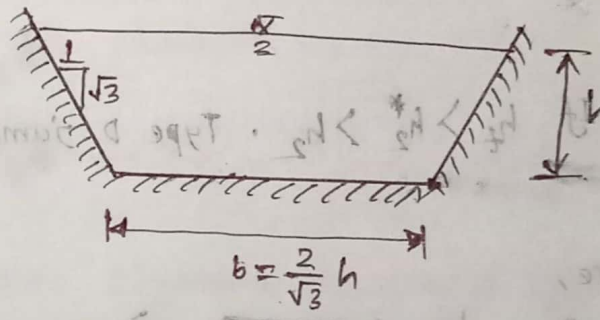
$b = \frac{2}{\sqrt{3}} h$

$A = \sqrt{3} h^2$

$P = 2\sqrt{3} h$

$R = \frac{h}{2}$

(Half of a Hexagon)

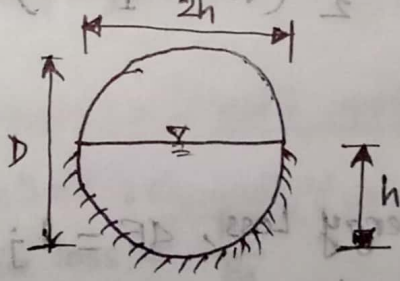


(4) circle: $h = \frac{D}{2}$

$A = \frac{\pi}{2} h^2$

$P = \pi h$

$R = \frac{h}{2}$



(Half of a circle)

* For designing a channel with best hydraulic section,

① $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \Rightarrow h_n = \square$

② $V = \frac{Q}{A}$

③ $F_r = \frac{V}{\sqrt{gD}}$

Irrigation

Time required to irrigate a strip of Land:

$$t = \frac{y}{f} \ln\left(\frac{Q}{Q - fA}\right)$$

where, y = Average depth of water over the strip

f = Rate of infiltration of the soil / Infiltration Capacity

Q = Discharge through supply ditch

A = Area of land to be irrigated.

$$A_{max} = \frac{Q}{f}$$

Salinity Concentration of soil solution:

$$C_s = \frac{C \times Q}{Q - (C_u - P_{eff})}$$

where, Q = Quantity of water applied

C = concentration of salt in irrigation water

C_u = consumptive use of water

P_{eff} = Effective rainfall

Low – C_1 : (100 ~ 250) micro mhos/cm
Medium – C_2 : (250 ~ 750) micro mhos/cm
High – C_3 : (750 ~ 2250) micro mhos/cm
Very High – C_4 : > 2250 micro mhos/cm

Sodium Absorption Ratio (SAR):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

where, concentration of all ions is in epm.

Equivalent per million (epm)

$$= \frac{\text{concentration of salt (ppm)}}{\text{its equivalent weight}}$$

$$\text{Equivalent weight} = \frac{\text{Atomic weight}}{\text{valence}}$$

Low – S_1 : (0 – 10)
Medium – S_2 : (10 – 18)
High – S_3 : (18 – 26)
Very High – S_3 : > 26

Duty – Delta Relationship:

$$\text{Delta } (\Delta) = 8.64 \times \frac{\text{Base Period } (B)}{\text{Duty } (D)}$$

Where, Δ in meter

B in days

D in ha/cumec

$$\text{Duty, } D = \frac{\text{Area } (A)}{\text{Discharge } (Q)}$$

* Higher duty indicates that, the canal is more efficient.

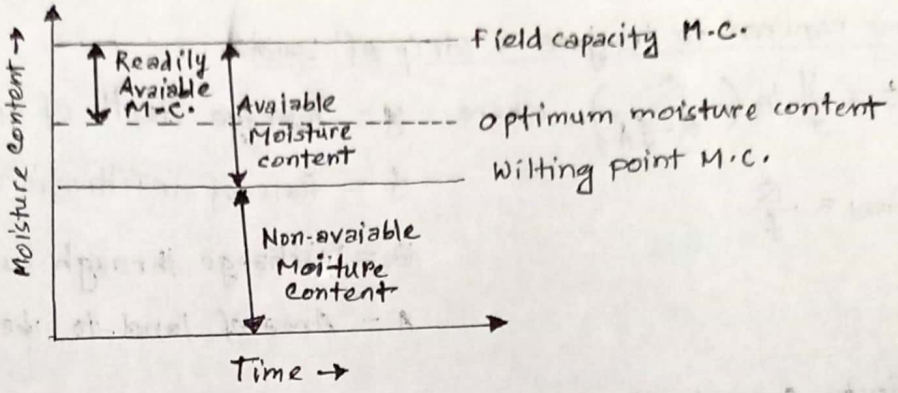
* Kharif Season : (1st April to 30th September)

* Rabi Season : (1st October to 1st March)

* Design Discharge = Higher Discharge among Two crops of ~~same~~ different season

Same ~~different~~ season হলে দুইটা Discharge মোট হবে Design Discharge মোট

Depth of water stored in root zone:



Depth of water stored at F.C $= \frac{\gamma_d}{\gamma} \times d \times F.C$

Depth of water stored at W.P $= \frac{\gamma_d}{\gamma} \times d \times W.P$

Depth of water available / Available Moisture Depth / Maximum storage capacity

$= \frac{\gamma_d}{\gamma} \times d \times [F.C - W.P.]$

Irrigation Efficiencies:

Water Conveyance Efficiency, $\eta_c = \frac{W_f}{W_r} \times 100\%$

Water Application Efficiency, $\eta_a = \frac{W_s}{W_f} \times 100\% = \frac{W_f - (R_f + D_f)}{W_f} \times 100\%$

Water Use Efficiency, $\eta_u = \frac{W_u}{W_f} \times 100\%$

Water storage Efficiency, $\eta_s = \frac{W_s}{W_n}$

Water distribution Efficiency, $\eta_d = \left[1 - \frac{y}{d}\right] \times 100\%$

Here, W_f = water delivered to farm
W_r = water supplied from river
W_s = water stored in root zone
W_u = water used benificially
R_f = surface Runoff
D_f = Deep percolation
W_n = water needed in the root zone prior to irrigation.

where,

y = Average Numerical deviation in the depth of water stored from average depth of water stored during irrigation.

d = Average depth of water stored

Irrigation Requirement:

Field Irrigation Requirement, $F.I.R = \frac{N.I.R}{\eta_a}$

Gross Irrigation Requirement, $G.I.R = \frac{F.I.R}{\eta_c}$

where,
N.I.R = Net Irrigation requirement
= Depth of water required in the root zone

* FIR = Quantity of water required to be supplied to field.
* GIR = Quantity of water needed at canal outlet.

Leaching Requirement:

$$L.R = \frac{D_d}{D_i} = \frac{E_{ci}}{E_{cd}} = \frac{E_{ci}}{2E_{ce}}$$

where, D_i = Depth of Irrigation water
D_d = Depth of Drainage water = $(D_i - C_u)$
E_{ci} = Electric conductivity of Irrigation water.
E_{cd} = Electric conductivity of drainage water.
E_{ce} = Electric Conductivity of saturation extract of soil.

Design of Irrigation channel:

Kennedy's Theory:

(i) $V_o = 0.55\, m\, y^{0.64}$

where, V_o = critical velocity
m = critical velocity ratio = (1.0 to 1.2) coarser sand
= (0.7 to 1.0) finer sand than standard
y = water depth

(ii) $A = \frac{Q}{V_o}$

(iii) Assuming side slope = $\frac{1}{2}H : 1V$

$A = (b + sy)y \Rightarrow b = \square$

(iv) $P = b + 2\sqrt{(1+s^2)}\,y$

(v) $R = \frac{A}{P}$

(vi) $V = \left[\frac{\frac{1}{n} + \left(23 + \frac{0.00155}{s}\right)}{1 + \left(23 + \frac{0.00155}{s}\right)\frac{n}{\sqrt{R}}}\right] \times \sqrt{RS}$

* If $V > V_o$, increase the depth (y)
* If $V < V_o$, decrease the depth (y)

Design of Regime channel:

(i) velocity, $V = \left[\frac{Qf^2}{140}\right]^{\frac{1}{6}}$ where, $f = 1.76\sqrt{d_{mm}}$

Q in cumec.

(ii) Hydraulic mean radius, $R = \frac{5}{2} \times \left(\frac{V^2}{f}\right)$

(iii) Area of channel, $A = \frac{Q}{V}$

(iv) wetted Perimeter, $P = 4.75\sqrt{Q}$

(v) Bed slope of channel, $S = \left[\frac{f^{\frac{5}{3}}}{3340 Q^{\frac{1}{6}}}\right]$

Scour Depth for Alluvial Rivers:

For wide rivers, $B \simeq P = 4.75\sqrt{Q}$ [bank full discharge / flood condition]

Lacey's Normal Regime Scour depth, $R_n = 0.473\left(\frac{Q}{f}\right)^{\frac{1}{3}}$

For any other value of active river width,

Lacey's Regime scour depth, $R = 1.35\left(\frac{q^2}{f}\right)^{\frac{1}{3}}$ where, $q = \frac{Q}{B}$

B = width of river

Tractive Force:

Dimensionless Tractive force, $\tau_0 = \frac{\tau_c}{\gamma_w d (G_s - 1)}$

Again, $\tau_0 = \gamma_w R S_0$ where, τ_c = Critical shear stress

$V_c = \sqrt{\frac{\tau_c}{\rho_w}}$

d = size of particle

G_s = specific gravity

R = Hydraulic mean Radius

S_0 = Bed Slope of channel

Sodium Absorption Ratio (SAR):

Problem: If the concentration of Na, Ca and Mg in a water sample are 345, 60, and 18 mg/L respectively. Find the SAR Value. (BUET WRE '15)

Solution: We know, $SAR = \dfrac{Na^+}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}}$

Here, $Na^+ = 345 \text{ mg/L} = \dfrac{345}{\left(\frac{23}{1}\right)} \text{ epm}$

$\therefore Na^+ = 15 \text{ epm}$

$Ca^{2+} = 60 \text{ mg/L} = \dfrac{60}{\left(\frac{40}{2}\right)} = 3 \text{ epm}$

and, $Mg^{2+} = 18 \text{ mg/L} = \dfrac{18}{\left(\frac{24.3}{2}\right)} = 1.48 \text{ epm}$

$\therefore SAR = \dfrac{15}{\sqrt{\dfrac{3 + 1.48}{2}}} = 10$ (Ans.)

Duty and Delta:

Problem: Find the delta for a crop when its duty is 864 hectares/cumec on the field, the base period of this crop is 120 days. (BUET MSc '15)

Solution: we know, $\Delta = \frac{8.64\,B}{D} = \frac{8.64 \times 120}{864} = 1.2$ m (Ans.)

[BWDB-16, 14]

Problem: A canal commands an irrigation area of 400 Ha. The duty of water on the field during the peak period is 220 Ha/cumec. Determine the design discharge of the canal at the off-take if the waterloss is canal is 30%.

Solution: we know, $Q = \frac{A}{D} = \frac{400}{220} = 1.82$ cumec.

since, water losses in the canal = 30%,

Design discharge, $Q_d = \frac{1.82}{(1-0.30)} = 2.6$ cumec. (Ans.)

[BWDB '20]

Problem: A water course has a culturable commanded area of 1200 hectares. The intensity of irrigation for crop A is 40% and for B is 35%, both the crops being Rabi crops. Crop A has Kor period of 20 day and crop B has Kor period of 15 days. Calculate the discharge of the water course if Kor depth for A is 10 cm and for B it is 16 cm.

Solution: For crop A: $A_A = (0.4 \times 1200) = 480$ ha.

$\delta_A = 10$ cm $= 0.1$ m and, $b_A = 20$ days.

$\therefore$ Duty, $D_A = 8.64 \frac{b_A}{\delta_A} = 8.64 \times \frac{20}{0.1} = 1728$ ha/cumec.

$\therefore$ Discharge required, $Q_A = \frac{A_A}{D_A} = \frac{480}{1728} = 0.278$ cumec.

For crop B: $A_B = (0.35 \times 1200) = 420$ ha.

$\delta_B = 16$ cm $= 0.16$ m and $b_B = 15$ days.

$\therefore D_B = 8.64 \times \frac{15}{0.16} = 810$ ha/cumec.

$Q_B = \frac{420}{810} = 0.519$ cumec.

$\therefore$ Design discharge, $Q_d = (0.278 + 0.519)$ cumec $= 0.79$ cumec.

[36th BCS]

Problem: Determine the discharge of the channel is to be designed for irrigating 5000 ha. Kharif crops and 5000 ha. for Rabi crops. The water requirement for Kharif crops and Rabi crops are 2.5 inch and 1.5 inch respectively. The base period for Kharif and Rabi are 3 weeks and 4 weeks respectively.

Solution: For Kharif crops: $A = 5000$ ha.

$\Delta = 2.5$ inch $= 0.0635$ m

$B = 3$ weeks $= 21$ days.

$\therefore$ Duty, $D_K = 8.64 \times \frac{21}{0.0635} = 2857.3$ ha/cumec.

$\therefore$ Required Discharge, $Q_K = \frac{5000}{2857.3} = 1.75$ cumec.

For Rabi crops: $A = 5000$ ha.

$\Delta = 1.5$ inch $= 0.0381$ m

$B = 4$ weeks $= 28$ days.

Duty, $D_R = 8.64 \times \frac{28}{0.0381} = 6349.6$ ha./cumec

$\therefore$ Required Discharge, $Q_R = \frac{5000}{6349.6} = 0.787$ cumec.

Since, $Q_K > Q_R$. Design discharge of the channel $= 1.75$ cumec. (Ans.)

Irrigation Efficiency:

[BWDB '18]

Problem: A stream of 130 Litres per second was diverted from a canal and 100 liters per second were delivered to the field. An area of 1.6 hectares was irrigated in 8 hours. The effective depth of root zone was 1.7 m. The runoff loss in the field was 420 cu. m. The depth of water penetration varied linearly from 1.7 m at the head end of the field to 1.1 m at the tail end. Available moisture holding capacity of the soil is 20 cm per meter depth of the soil. It is required to determine the water conveyance efficiency, water application efficiency, water storage efficiency and water distribution efficiency. Irrigation was started at a moisture extraction level of 50% of the available moisture.

Solution:

(i) water conveyance efficiency, $\eta_c = \frac{W_f}{W_r} \times 100\% = \frac{100}{130} \times 100\% = 76.9\%$

(ii) water application efficiency, $\eta_a = \frac{W_s}{W_f} \times 100\%$

Here, $W_f = 100$ L/sec. for 8 hours.

$= (100 \times 8 \times 3600)$ Litres.

$= 2880 \times 10^3$ Litre

$\therefore W_f = 2880\ m^3$

Since, runoff loss $= 420\ m^3$, $\therefore W_s = (2880 - 420) = 2460\ m^3$

$\therefore \eta_a = \frac{2460}{2880} \times 100\% = 85.4\%$

(iii) Available moisture holding capacity $= (20 \times 1.7) = 34$ cm.

Available moisture at the time of start of irrigation $= (0.5 \times 34) = 17$ cm.

$\therefore$ water needed to root zone $= (34 - 17) = 17$ cm

Volume of water need to root zone $= \left(7.6 \times 10^4 \times \frac{17}{100}\right) = 2720\ m^3$

$\therefore \eta_s = \frac{2460}{2720} \times 100\% = 90.4\%$

(iv) water distribution efficiency, $\eta_d = \left(1 - \frac{y}{d}\right) \times 100\%$

Here, Average depth $= \left(\frac{1.7+1.1}{2}\right) = 1.4\ m$.

$y = \frac{|1.7-1.4| + |1.1-1.4|}{2} = 0.3\ m$

$\therefore \eta_d = \left(1 - \frac{0.3}{1.4}\right) \times 100\% = 78.6\%$.

(Ans.)

[33rd BCS]

Problem: 15 cumecs of water is delivered to a 34 hectares field for 4 hours. Soil proving after the irrigation indicates that 0.3 meter of water has been stored in the root zone. Compute the water application efficiency.

Solution: We know,

$$\eta_a = \frac{\eta_s}{\eta_f} \times 100\%$$

Here, $\eta_s = (34 \times 10^4 \times 0.3) = 10.2 \times 10^4\ m^3$

$\eta_f = (15 \times 4 \times 3600) = 216 \times 10^3\ m^3$

$\therefore \eta_a = \left(\frac{10.2 \times 10^4}{216 \times 10^3} \times 100\%\right) = 47.22\%$.

(Ans.)

Field capacity:

[BWDB-16, WARPO-17]

Problem: The field capacity and moisture content at the time of irrigation are 27% and 19% respectively. The apparent specific gravity is 1.3 and root zone depth is 100 cm. Determine the time required to irrigate 2 ha. with a flow of 60 L/s if the water application losses are taken to be 20%.

Solution:

Depth of water stored in root zone $= \frac{\gamma_d}{\gamma_w} \times d \times (F.C - M.C)$

$= 1.3 \times \frac{100}{100} \times (0.27 - 0.19)$

$= 0.104$ m

Given, water application efficiency $= (100-20)\%$

$= 80\%$

$\therefore$ water required to supply to the field $= \frac{0.104}{0.8} = 0.13$ m

Volume of water required to supply $= (2 \times 10^4 \times 0.13) = 2600$ m^3

Time required to irrigate $= \frac{2600}{60 \times 10^{-3}} = 43333.33$ sec. $= 12.04$ hr.

(Ans.)

[BWDB-19, BADC-20]

Problem: Determine the field capacity of a soil for the following data: depth of root zone = 1.8 m, existing moisture = 8%, dry density of soil = 1450 Kg/m^3, quantity of water supplied = 650 m^3, Area to be irrigated = 1000 m^2, water lost due to deep percolation and evaporation = 10%.

Solution: volume of water loss $= (0.10 \times 650) = 65$ m^3

$\therefore$ volume of water used $= (650 - 65) = 585$ m^3

depth of water used $= \frac{585}{1000} = 0.585$ m

Now, Depth of water stored in root zone $= \frac{\gamma_d}{\gamma_w} \times d \times (F.C - M.C)$

$\Rightarrow 0.585 = \frac{1450}{1000} \times 1.8 (F.C. - 0.08)$

$\Rightarrow F.C = 0.304 = 30.4\%$ (Ans.)

[BWDB-18, TGTBCL-21, BUET WRE-15]

Problem: Determine the available moisture holding capacity of soil of an irrigation field having following data: Field capacity = 25%, permanent wilting point = 15%, specific weight = 14.7 KN/m³, Root zone depth = 90 cm.

Solution: Maximum storage capacity = Available moisture holding capacity

$= \frac{\gamma_d}{\gamma_w} \times d \ (F.C - P.W.P)$

$= \frac{14.7}{9.81} \times \frac{90}{100} \times (0.25 - 0.15)$

$= 0.135 \text{ m}$ (Ans.)

Lacey's Regime Scour Depth:

Problem: Calculate the scour depth of river having width = 500 m, unit discharge = 50 $m^3/sec/m$, d_{50} = 0.1 mm and design discharge = 80% of bank-full discharge. (BWDB-20)

Solution: Silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76 \times \sqrt{0.1} = 0.55$

Design discharge, $q = (0.8 \times 50) = 40\ m^3/sec./m$

Lacey's scour depth, $R_p = 1.35\left(\frac{q^2}{f}\right)^{\frac{1}{3}}$

$\therefore R_p = 1.35 \times \left(\frac{40^2}{0.55}\right)^{\frac{1}{3}} = 19.27$ m.

(Ans.)

//BWDB-2016//

Problem: The river ganga flows bank full of rate is 2500 m^3/sec. Find (i) Hydraulic geometry and (ii) Scour depth, If Bed material size is 0.15 mm

Solution:

Silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{0.15} = 0.68$

$$V = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}} = \left(\frac{2500 \times 0.68^2}{140}\right)^{\frac{1}{6}} = 1.422\ m/sec.$$

$$A = \frac{Q}{V} = \left(\frac{2500}{1.422}\right) = 1758.5\ m^2$$

$$R = \frac{5}{2} \times \frac{V^2}{f} = \frac{5}{2} \times \frac{1.422^2}{0.68} = 7.434\ m$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{2500} = 237.5\ m$$

Side Slope, $S = \frac{f^{\frac{5}{3}}}{3340\, Q^{\frac{1}{6}}} = \frac{0.68^{\frac{5}{3}}}{3340 \times 2500^{\frac{1}{6}}} = 9.27 \times 10^{-05}$

Regime scour depth, $R_p = 0.473\left(\frac{Q}{f}\right)^{\frac{1}{3}} = 0.473 \times \left(\frac{2500}{0.68}\right)^{\frac{1}{3}} = 7.3$ m

(Ans.)

Design of Irrigation channel using Lacey's Theory:

Problem: Design a stable alluvial channel using Lacey's Theory. The channel is to carry 10 m^3/s water through 1 mm sand. (BBAD - 2018)

Solution: silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{1} = 1.76$

$$V = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}} = \left(\frac{10 \times 1.76^2}{140}\right)^{\frac{1}{6}} = 0.78 \text{ m/sec.}$$

$$R = \frac{5}{2}\left(\frac{V^2}{f}\right) = 2.5 \times \left(\frac{0.78^2}{1.76}\right) = 0.86 \text{ m}$$

$$A = \frac{Q}{V} = \frac{10}{0.78} = 12.82 \text{ m}^2$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{10} = 15.02 \text{ m}$$

$$S = \left(\frac{f^{\frac{5}{3}}}{3340 Q^{\frac{1}{6}}}\right) = \left(\frac{1.76^{\frac{5}{3}}}{3340 \times 10^{\frac{1}{6}}}\right) = 5.23 \times 10^{-4} = 1 \text{ in } 1912. \quad \text{(Ans.)}$$

For a trapezoidal channel with $\frac{1}{2}$ H : 1V slopes

$$P = b + \sqrt{5}\,y = 15.02 \quad \ldots\ldots (i)$$

$$A = \left(b + \frac{y}{2}\right)y = 12.82 \quad \ldots\ldots (ii)$$

From (ii), $b = \frac{12.82}{y} - \frac{y}{2}$ putting the value of b in eqn (i)

$$\frac{12.82}{y} - \frac{y}{2} + \sqrt{5}\,y = 15.02$$

$$\Rightarrow y = 0.96 \text{ m} \quad \text{(Ans.)}$$

Hence, $b = P - \sqrt{5}y = (15.02 - \sqrt{5} \times 0.96) = 12.87$ m. (Ans.)

(30th BCS)

Problem: Design an irrigation channel of discharge 11270 cusec and the bed material size 0.019 cm using Lacey's theory. (SGFL-20, PGCB-20 DPDC-20)

Solution: Silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{0.19} = 0.66$

$$V = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}} = \left(\frac{11270 \times 0.3048^3 \times 0.66^2}{140}\right)^{\frac{1}{6}} = 1 \text{ m/sec.}$$

$$R = 2.5\left(\frac{V^2}{f}\right) = 2.5 \times \left(\frac{1^2}{0.66}\right) = 3.79 \text{ m}$$

$$A = \frac{Q}{V} = \frac{11270 \times 0.3048^3}{1} = 319.13 \text{ m}^2$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{319.13} = 84.85 \text{ m}$$

$$S = \left(\frac{f^{\frac{5}{3}}}{3340\, Q^{\frac{1}{6}}}\right) = \left(\frac{0.66^{\frac{5}{3}}}{3340 \times 319.13^{\frac{1}{6}}}\right) = 5.73 \times 10^{-5} = 1 \text{ in. } 17451$$

(Ans.)

For a trapizoidal channel, with $\frac{1}{2}$H : 1V side slope.

$$\therefore P = b + \sqrt{5}\, y = 84.85 \quad \ldots\ldots (i)$$

$$A = \left(b + \frac{y}{2}\right) y = 319.13 \quad \ldots\ldots (ii)$$

From (ii) $\Rightarrow b = \frac{319.13}{y} - \frac{y}{2}$ putting the value of b in eqn (i) we get,

$$\frac{319.13}{y} - \frac{y}{2} + \sqrt{5}\, y = 84.85$$

$$\Rightarrow y = 3.8736 \text{ m} \quad \text{(Ans.)}$$

$$\therefore b = \frac{319.13}{3.8736} - \frac{3.8736}{2} = 80.45 \text{ m}$$

(Ans.)

Tile Drainage System:

Problem: A drain of 15 cm diameter is laid at the end of a channel. The slope is 0.3% and manning's co-efficient is 0.014. Find the minimum drainage area in hactor where value of drainage co-efficient is 15 cm/day. (CPGCBL-18)

Solution:

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times (0.15)^2 = 1.767 \times 10^{-2}\ m^2$$

$$P = \pi D = (3.1416 \times 0.15) = 0.47\ m$$

$$\therefore R = \frac{A}{P} = \frac{1.767 \times 10^{-2}}{0.47} = 3.76 \times 10^{-2}\ m$$

We know, $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} = \frac{1}{0.014} \times 1.767 \times 10^{-2} \times (3.76 \times 10^{-2})^{\frac{2}{3}} \times (0.003)^{\frac{1}{2}}$

$$\therefore Q = 7.765 \times 10^{-3}\ m^3/sec. = 670.36\ m^3/day.$$

Minimum drainage area $= \frac{Q}{C} = \frac{670.36}{0.15} = 4469\ m^2 = 0.445$ ha.

(Ans.)

Problem: Determine the drain size at the outlet of 6 ha. of drainage system of DC is 1 cm and the tile grade is 0.3%. Assume the rugosity co-efficient for drain material as 0.011. (WARPO-17) (34th BCS)

Solution: volume of water passing the drain in 1 day $= \left(\frac{1}{100} \times 6 \times 10^4\right)\ m^3/day$

$= 600\ m^3/day$

$= 6.944 \times 10^{-3}\ m^3/sec.$

Now, $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$

$$\Rightarrow 6.944 \times 10^{-3} = \frac{1}{0.011} \times \frac{\pi}{4} D^2 \times \left(\frac{D}{4}\right)^{\frac{2}{3}} \times (0.003)^{\frac{1}{2}}$$

$$\Rightarrow 1.55 D^{\frac{8}{3}} = 6.944 \times 10^{-3}$$

$$\therefore D = 0.1315\ m = 13.15\ cm \text{ dia pipe.}$$

(Ans.)

Critical Tractive Force:

Problem: The value of dimensionless effective stress is $0.045\ N/m^2$. Find the (i) effective velocity (ii) value of incipient depth of a wide river channel with the bed sediment size of 0.2 mm with longitudinal river bed slope of 0.0001. specific gravity is 2.65. (BWDB-2016)

Solution: Dimensionless effective shear stress, $\tau_* = \dfrac{\tau_c}{(S_s - 1)\gamma_w d}$

$\therefore$ critical shear stress, $\tau_c = \tau_* (S_s - 1)\gamma_w d$

$= 0.045 (2.65 - 1) \times 9.81 \times 10^3 \times \dfrac{0.2}{1000}$

$= 0.1457\ N/m^2$

Again, critical shear friction velocity, $V_c = \sqrt{\dfrac{\tau_c}{\rho_w}} = \sqrt{\dfrac{0.1457}{1000}} = 0.01207\ m/s$ (Ans.)

Now, $\tau_{cr} = \gamma_w D S_0$

$\therefore$ Incipient depth, $D = \dfrac{\tau_{cr}}{\gamma_w S_0} = \dfrac{0.1457}{9810 \times 0.0001} = 0.1485\ m$

(Ans.)

Horse power required for pump:

$W.H.P = \frac{WH}{75}$ where, W = weight of water (Kg/sec.)

H = Total Head (m)

$W.H.P = \frac{QH}{3960}$ where, Q = volume of water to be pumped (gallon/minute) [gpm]

H = Total head (ft)

* 1 gallon = 3.785 Litre

$B.H.P = \frac{W.H.P}{\eta}$ where, η = Efficiency of pump and motor (combined)

B.H.P = Break Horse Power (Actual HP required to operate the pump)

* $H = h + h_f + h_v +$ other losses

where, h = Total static head (Difference in level between the lowest water level in the well and full supply level of the tank)

* $h_f = \frac{fLV^2}{2gd}$

where, f = friction factor

L = length of pipe

d = diameter of pipe

h_f = head loss due to friction

h_v = velocity head $= \frac{v^2}{2g}$

V = velocity of flow $= \frac{Q}{A}$

A = cross section area of pipe $= \frac{\pi}{4} d^2$

* $P = \frac{\gamma Q H_T}{\eta}$ (watt)

$\gamma = 9810\ (N/m^3)$, Q in (m^3/sec)

H_T in (m); 1 HP = 746 Nm/s

Probable Future Population:

Geometric progression method $\rightarrow P_f = P_p (1+r)^n$

where, P_f = Future Population

P_p = Present population

n = Design year

r = rate of annual growth of population.

* $r = \sqrt[n]{\frac{P_2}{P_1}} - 1$

pH Value:

By definition. $pH = -\log_{10}[H^+]$

$$pOH = -\log_{10}[OH^-]$$

$$pH + pOH = 14$$

$$[H^+] \times [OH^-] = 10^{-14}$$

$$[H^+] = 10^{-[pH]}$$

$$[OH^-] = 10^{-[pOH]}$$

* pH of mixture of solutions: $\boxed{\begin{matrix}pH_A \\ X\ mL\end{matrix}} + \boxed{\begin{matrix}pH_B \\ Y\ mL\end{matrix}} = \boxed{\begin{matrix}\text{New} \\ pH \\ (X+Y)\ mL\end{matrix}}$

concentration of $[H^+]$ in new solution,

$$[H^+]_{mix} = [H^+]_A + [H^+]_B$$

$$= 10^{-pH_A} \times \left(\frac{X}{1000}\right) + 10^{-pH_B} \times \left(\frac{Y}{1000}\right)$$

pH of New solution, $pH_{mix} = -\log [H^+]_{mix}$

Hardness:

T.H. = C.H + N.C.H

if Alkanity < T.H, Then, C.H = Alkanity

if Alkanity > T.H, Then, C.H = T.H

Harness as $CaCO_3$ (mg/L) = M^{++} (mg/L) $\times \frac{\text{Eq. wt. of } CaCO_3}{\text{Eq. wt. of } M^{++}}$

* Equivalent Weight = $\frac{\text{Molecular weight}}{\text{Valence}}$

Eq. wt. of $CaCO_3 = \frac{100}{2} = 50$

Eq. wt. of $Mg = \frac{24.4}{2} = 12.2$

Eq. wt. of $Ca = \frac{40}{2} = 20$

Eq. wt. of $Sr = \frac{87.6}{2} = 43.8$

CamScanner

Alkanity:

Total Alkanity = $HCO_3^- + CO_3^{2-} + OH^- - H^+$

Alkanity as $CaCO_3$ = M^- (mg/L) $\times \frac{\text{Eq. wt. of } CaCO_3}{\text{Eq. wt. of } M^-}$

$pH = (0 - 4.5)$ indicates No Alkanity
$pH = (4.5 - 8.2)$ indicates HCO_3^- Alkanity
$pH = (8.2 - 10)$ indicates CO_3^{2-} Alkanity

} * pH = (4.5 to 14) indicates Total Alkanity.

Amount of lime (CaO) needed to remove hardness:

To calculate quick lime or hydrated lime, use following equation:
(CaO) [$Ca(OH)_2$]

$$\text{Quick lime feed (mg/L)} = \frac{A + B + C + D}{\text{Lime purity (\%)}} \times \text{Lime Excess}$$

where, A = CO_2 in source water (mg/L as CO_2) $\times \frac{56}{44}$

B = OH^- Alkanity in softening (mg/L as $CaCO_3$) $\times \frac{56}{100}$

C = HCO_3^- Alkanity in softener effluent (mg/L as $CaCO_3$) $\times \frac{56}{100}$

D = Mg^{2+} removed in softening (mg/L as Mg) $\times \frac{56}{24.3}$

* For hydrated lime dosage, use same equation replacing 56 as 74.

Calculation of carbonate and bicarbonate Alkanity:

$$HCO_3^- \text{ Alkanity as } CaCO_3 \text{ (mg/L)} = \frac{50\times10^3\times\left[\frac{A}{50\times10^3}+[H^+]-\frac{K_w}{[H^+]}\right]}{1+\left(\frac{2K_2}{[H^+]}\right)}$$

$$CO_3^{2-} \text{ Alkanity as } CaCO_3 \text{ (mg/L)} = \left(\frac{2K_2}{[H^+]}\right)\times HCO_3^- \text{ Alkanity as } CaCO_3$$

$$[HCO_3^-] = HCO_3^- \text{ as } CaCO_3 \text{ (mg/L)} \times \frac{61}{50}$$

$$[CO_3^{2-}] = CO_3^{2-} \text{ as } CaCO_3 \text{ (mg/L)} \times \frac{30}{50}$$

Here, $K_w = 10^{-14}$

$K_2 = 4.68\times10^{-11}$

Bio-chemical Oxygen Demand (BOD):

* 5 Day BOD = Loss of oxygen (mg/L) × Dilution Ratio

$$\Rightarrow BOD_5 = (DO_i - DO_f)\times DF$$

where,

$$DF = \frac{\text{Bottle Volume}}{\text{Sample Volume}}$$

* BOD exerted at 't' Day,

$$BOD_t = L_o(1-10^{-Rt})$$

where, $R_{20} = 0.1$ per day.

L_o = Ultimate BOD/ BOD present in the sample of sewage

or, $BOD_t = L_o(1-e^{-Kt})$

t = time (day)

R = Rate constant (10-base)

K = Rate constant (e-base)

* BOD remaining at 't' Day

$$L_t = L_o\times10^{-Rt}$$

or, $L_t = L_o\times e^{-Kt}$

$$\boxed{K = 2.303R}$$

$$R_T = R_{20}(1.047)^{T-20}$$

* Mixing BOD (seeding):

$$BOD_m V_m = BOD_s V_s + BOD_d V_d$$

where, $V_m = V_s + V_d$

V_s = volume of sewage water

V_d = volume of dilute water

Velocity of settlement of particles in plain sedimentation tank:

For particle size ≤ 0.1 cm and $Re \leq 1$ ▶

$$V_s\ (mm/sec) = 418\ (S - S_w) \times d^2 \times \left(\frac{3T+70}{100}\right)$$

(d in mm)

Simplified equation: $V_s\ (m/sec.) = \frac{g}{18}(S-1)\frac{d^2}{\nu}$ (d in m; $\nu \rightarrow 10^{-6}\ m^2/sec.$)

where, S = Sp. Gr. of particle

S_w = Sp. Gr. of water ($=1$)

d = diameter of particle

ν = kinematic viscosity of water ($=1\ mm^2/sec.$ at $20^\circ c$)

T = Temperature ($^\circ c$)

For partical size > 1 cm and $Re > 2000$ ▶

$$V_s = \sqrt{\frac{4g}{3C_D}(S-1)d}$$ where, C_D = Newton's Drag co-efficient

Rectangular Sedimentation Tank:

Detention Period, $T = \frac{C}{Q} = \frac{L \times B \times H}{Q}$

Again, $T = \frac{\text{Distance of descend}}{\text{velocity of descend}} = \frac{H}{V} = \frac{S.W.D}{S.O.R}$

$$S.O.R = \frac{Q}{A} = \frac{Q}{B \times L}$$

where, L = length of the tank

B = width of the tank

H = Depth of the tank

S.W.D = side water Depth

S.O.R = Surface overflow rate

Q = Discharge / Rate of flow

A = Surface Area

* For circular sedimentation Tank,

$$C = D^2(0.011D^2 + 0.786H)$$

(cft) (ft) (ft)

* $1L = 0.0353\ ft^3$

Coagulation:

The most widely used coagulants are:

(i) Aluminium Sulphate ——— $Al_2(SO_4)_3 \cdot 18H_2O$

(ii) Ferric Sulphate ——— $Fe_2(SO_4)_3 \cdot 9H_2O$

(iii) Ferrus Sulphate ——— $FeSO_4 \cdot 7H_2O$

(iv) Ferric Chloride ——— $FeCl_3 \cdot 6H_2O$

* Molecular weight: Al = 27, Fe = 55.85, S = 32, Cl = 35.5, O = 16

Chemical Reactions:

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2$$

$$Fe_2(SO_4)_3 \cdot 9H_2O + 3Ca(HCO_3)_2 = 2Fe(OH)_3 + 3CaSO_4 + 9H_2O + 6CO_2$$

$$2FeCl_3 \cdot 6H_2O + 3Ca(HCO_3)_2 = 2Fe(OH)_3 + 3CaCl_3 + 6H_2O + 6CO_2$$

$$FeSO_4 \cdot 7H_2O + Ca(OH)_2 = Fe(OH)_2 + CaSO_4 + 7H_2O$$

Disinfection:

Contact Time period for killing pathogenic organisms,

In case of chlorine, $t = \sqrt{\frac{2}{K} \log_{10} \frac{N_o}{N_t}}$

In case of other disinfectant, $t = \frac{1}{K} \log_{10} \frac{N_o}{N_t}$

where,

N_o = No. of organism initially

N_t = No. of organism at time t

K = Reaction rate

Chlorination:

Determination of amount of bleaching powder:

(i) Total requirement of water (l/day) = water supply rate (lpcd) × Population

(ii) Quantity of chlorine required (mg/d) = chlorine dose (mg/l) × Amount of water (l/day)

(mg/d) $\xrightarrow{\times \frac{1}{10^6}}$ (kg/d) $\xrightarrow{\times 2.205}$ (lb/day)

(kg/d) $\xrightarrow{\times \frac{1}{10^3}}$ (ton/day)

(iii) Requirement of bleaching powder = $\frac{\text{Quantity of Chlorine}}{\text{\% chlorine in bleaching powder}} \times 100$

Filtration:

(i) Filter Area required = $\frac{\text{Flow rate / Filter capacity } (m^3/day)}{\text{Filtration rate } (m^3/day/m^2)}$ $\left[A = \frac{Q}{V}\right]$

(ii) Number of Filter units required = $0.04\sqrt{\text{Filter capacity } (m^3/day)}$

(iii) Area of Each Filter Unit = $\frac{\text{Filter Area required}}{\text{No. of Filter Units}}$

(iv) width of Filter Unit = $\sqrt{\frac{\text{Area of Each Filter Unit}}{1.5}}$ [Assuming $\frac{L}{B} = 1.5$]

(v) ∴ Length of Filter Unit = 1.5 × width of Filter unit.

(vi) wash water required = Filter Area × washing rate ($m^3/hr/m^2$) × washing period (hr)

(vii) Percentage of Filtered water required for washing = $\frac{\text{wash water}}{\text{Filter capacity}} \times 100\%$

* Assume,

Rate of Filtration = 5 $m^3/hr/day$

Rate of washing = 35 $m^3/hr/day$

Filtration period = 24 hrs including 5 min. for washing and 10 min. for resettlement.

Peak water demand:

$$Q = \frac{f\, q\, P_p (1+r)^n}{1 - \text{water losses (\%)}}$$

Strainer Design:

(i) Assume, Entrance velocity, $V_e = 0.01$ m/sec. (Should not exceed 0.03 m/sec.)

(ii) Entrance Area required, $A = \frac{Q}{V_e}$ where, Q = Design discharge (m^3/sec.)

(iii) The open Area of strainer per m of Tubewell

$A_s = (\%)$ open Area used $\times \pi d$ where, d = diameter of tubewell/Strainer

(iv) Length of strainer required = $\frac{\text{Entrance Area } (A)}{\text{Open Area } (A_s)}$

Quantity of Rain water Avaiable:

$Q = C\, I\, A$ where, C = Run-off co-efficient

I = Rainfall intensity

A = Area of catchment

Storage Volume Required $Q = q\, N$

$V = f\, Q$

f = Fraction of total avaiable rain-water required to stored for consumption

q = Amount of water required per capita per day (lpcd)

N = No. of person

Discharge of a Tubewell:

From unconfined aquifer, $Q = \frac{\pi K (H^2 - h^2)}{\ln(\frac{R}{r})}$

From confined aquifer, $Q = \frac{2\pi K m (H-h)}{\ln(\frac{R}{r})}$

where, K = co-efficient of permeability of the aquifer

H = water/piezometer level above the bottom of the aquifer

h = Static depth of water in well

R = Radius of circle of influence

r = radius of well

m = thickness of confined aquifer

T = Transmissibility of aquifer = K·m

(H-h) = Drawdown

Pit Design:

Effective Pit volume, $V_{eff} = CPN$

where,

c = Solid Accumulation Rate

P = persons

N = Design year

Total required pit volume,

$V_T = 1.33 \times CPN$

Septic Tank Design:

(i) Scum storage zone, $V_{sc} = 0.4 V_{sl}$

(ii) Sedimentation zone, $V_h = 10^{-3}(PQ) \times t_h$

where,

t_h = Minimum mean hydraulic retention time for sedimentation (days)

$t_h = 1.5 - 0.3 \log(PQ)$

P = persons

Q = waste water flow (l/day)

(iii) Sludge digestion zone, $V_d = 0.5 \times 10^{-3} \times P \times t_d$

where,

$t_d = 30 \times (1.035)^{35-T}$ (days)

T = temperature (°c) $\simeq 25°c$

(iv) Digestion sludge storage zone,

$V_{sl} = c\,P\,N$ where, $c = 0.06$ m^3/person year (for $N < 5$ years)

and $c = 0.04$ m^3/person year (for $N > 5$ years)

Total volume, $V = V_{sl} + 0.4V_{sl} + V_h + V_d$

* Total Effective Depth, $d = \frac{V_{sl}}{A} + \frac{V_{sc}}{A} + {}^{Total}_{a}$ clear space depth [Assume, $A = 3m^2$]

where, Total clear space depth = clear space depth + sludge clear depth

= sedimentation depth $\left(\frac{V_h}{A}\right)$

(which one is greater)

Here, sludge clear depth $= (0.82 - 0.26A) \geq 0.3$ m

clear space depth $= 0.075$ m

Sanitation

Problem: Design a low cost simple pit latrine for a family of six persons. The soil is fairly permeable and stable. The groundwater table is 5 m below ground level. Determine the size of the pit latrine required for a period of five years. The family uses water for anal cleansing. (WARPO-17)

Solution:

considering as a dry pit, As water being used for anal cleansing

Solids Accumulation Rate, $C = 0.06$ m³/person/year.

We know, $V = 1.33 \, C \, P \, N$

$= (1.33 \times 0.06 \times 6 \times 5) \, m^3$

$= 2.4 \, m^3$

∴ The required volume for the pit $= 2.4 \, m^3$

considering the dia. of the pit $= 1.25$ m

∴ Depth of the pit, $D = \dfrac{2.4}{\frac{\pi}{4} \times (1.25)^2} = 1.95 \, m \simeq 2.0 \, m.$ (Ans.)

(WZPDCL-23)

Problem: Design a soakage pit serving 20 family. Each family has 5 members. waster water flow is 90 l/capita/day; The soil is sandy loam with a long term infiltration rate of about 1500 l/m³-day. Effective depth of pit = 3 m.

Solution:

Waste water flow $= (90 \times 20 \times 5) = 9000$ l/day.

Given, infiltration rate = 1500 l/m³-day.

∴ The volume of filter media required $= \dfrac{9000}{1500} = 6 \, m^3$

∴ Area of soak pit $= \dfrac{6}{3} = 2 \, m^2$

∴ Diameter of soak pit required $= \sqrt{\dfrac{4 \times}{3.1416}} = 1.6$ m. (Ans.)

Problem: Design a septic tank to serve a household of ten persons who produce 90 lpcd of waste water. The tank is to be desludged every three years.

Solution:

(I) **Sedimentation zone:**

Minimum hydraulic retention time, $t_h = 1.5 - 0.3 \log(Pq)$

$= 1.5 - 0.3 \log(10 \times 90)$

$= 0.61$ days.

The volume required for sedimentation,

$V_h = 10^{-3}(Pq)\, t_h = (10 \times 90) \times 0.61 \times 10^{-3} = 0.55\ m^3$

(II) **Sludge digestion:**

Assume, design temperature $= 25^\circ C$

$t_d = 30 \times (1.035)^{35-T}$

$= 30 \times (1.035)^{35-25}$

$= 42.3$ days

∴ volume required for sludge digesion,

$V_d = 0.5 \times 10^{-3}(P) \times t_d$

$= 0.5 \times 10^{-3} \times 10 \times 42.3$

$= 0.21\ m^3$

(III) **Sludge storage:**

Assume, Sludge accumulation rate $= 0.06\ m^3$/person/year.

$V_{SL} = CPN$

$= 0.06 \times 10 \times 3$

$= 1.8\ m^3$

∴ Overall effective tank volume, $V = V_h + V_d + 1.4\, V_{SL}$

$= 0.55 + 0.21 + (1.4 \times 1.8)$

$= 3.28\ m^3$

Tank effective depth:

Assume cross sectional area $(1 \times 3)\ m^2 = 3\ m^2$

$\therefore$ the maximum depth of sludge, $d_{sl} = \frac{V_{sl}}{A} = \frac{1.8}{3.0} = 0.60\ m$

The maximum submerged scum depth, $d_{sc} = \frac{0.4\ V_{sl}}{A} = \frac{0.4 \times 1.8}{3.0} = 0.24\ m$

slum clear depth = 0.075 m (minimum)

Sludge clear depth $= (0.82 - 0.26A)$

$= (0.82 - 0.26 \times 3) = 0.04 < 0.03\ m$

$\therefore$ 0.03 m is adopted

$\therefore$ Total clear space depth $= (0.075 + 0.3) = 0.375$

Depth required for sedimentation $= \frac{V_n}{A} = \frac{0.55}{3} = 0.183 < 0.375$

0.375 m is adopted

$\therefore$ the total effective depth $= (0.60 + 0.24 + 0.375)\ m$

$= 1.215\ m \simeq 1.25\ m$

$\therefore$ Overall dimension $= (1.0 \times 3.0 \times 1.5)$

pH:

Problem: If the pH = 9.5, what is the $[OH^-]$ concentration ? (PGCB-19)

We know,

$$pH + pOH = 14$$

$$\Rightarrow pOH = (14 - 9.5) = 4.5$$

$$\Rightarrow [OH^-] = 10^{-4.5} \text{ moles/L}$$

$$\therefore [OH^-] = 3.16 \times 10^{-5} \text{ moles/L}$$

(Ans.)

[BTCL-18]

Problem: Find the hydrogen ion concentration and hydroxide ion concentration in tomato juice having pH of 4.10.

Solution: Given,

$$pH = 4.10$$

$$\Rightarrow [H^+] = 10^{-4.10} \text{ mole/L}$$

$$\therefore [H^+] = 7.94 \times 10^{-5} \text{ mole/L}$$

we know, $pH + pOH = 14$

$$\Rightarrow pOH = (14 - 4.1) = 9.9$$

$$\Rightarrow [OH^-] = 10^{-9.9} \text{ mole/L}$$

$$\therefore [OH^-] = 1.26 \times 10^{-10} \text{ mole/L}$$

(Ans.)

[NPCBL-19]

Problem: 100 gm H_2SO_4 mixed with 100 L water, determine the pH value of the mix.

Solution: 100 gm $H_2SO_4 = \frac{100}{98}$ mole $= 1.02041$ mole [Molecular weight of $H_2SO_4 = 98$]

$$\therefore \text{Morality, } M = \frac{1.02041 \text{ mole}}{100 \text{ L}} = 1.02041 \times 10^{-2} \text{ Mole/L}$$

$$H_2SO_4 = 2H^+ + SO_4^{2-}$$

$\therefore$ concentration of $[H^+] = (2 \times 1.02041 \times 10^{-2}) = 2.04082 \times 10^{-2}$ mole/L

$$\therefore pH = -\log(2.04082 \times 10^{-2}) = 1.69$$

(Ans.)

(GTCL-16)

Problem: The concentration of OH^- is 10^{-4} mole/L. Find the pH value.

Solution:

we know, $[H^+] \times [OH^-] = 10^{-14}$

$$\Rightarrow [H^+] = \frac{10^{-14}}{10^{-4}} = 10^{-10}$$

$$\therefore pH = -\log(10^{-10}) = 10$$

(Ans.)

[CAAB-2022]

Problem: In a water treatment plant, pH values of entering and leaving waters are respectively 7.5 and 8.5. Assuming linear variation of pH with time. Find out the average pH value of water.

Solution:

For entering water, $[H^+] = 10^{-7.5}$ mole/L

and leaving water, $[H^+] = 10^{-8.5}$ mole/L

$\therefore$ Average value of $[H^+] = \frac{10^{-7.5} + 10^{-8.5}}{2} = 1.74 \times 10^{-8}$ mole/L

$\therefore$ Average pH value of the water $= -\log(1.74 \times 10^{-8}) = 7.76$

(Ans.)

Alkanity

(GJCL-16)

Problem: The pH of a sample is 10 and a total alkanity of 332 mg/L. Calculate the carbonate and bicarbonate alkanity of the sample. Also calculate the carbonate and bicarbonate concentration.

Solution:

$$\text{carbonate alkanity as } CaCO_3 = \frac{50000 \times \left[\frac{A}{50000} + [H^+] - \frac{K_w}{[H^+]}\right]}{1 + \frac{2K_2}{[H^+]}} \text{ mg/L}$$

Here, Total alkanity, $A = 332$ mg/L

$[H^+] = 10^{-10}$

water ionization constant, $K_w = 10^{-14}$ at 25°C

second dissociation constant of carbonic acid, $K_2 = 4.68 \times 10^{-11}$ at 25°C

$$\therefore \text{Carbonate alkanity as } CaCO_3 = \frac{50000 \times \left[\frac{332}{50000} + 10^{-10} - \frac{10^{-14}}{10^{-10}}\right]}{1 + \frac{2 \times 4.68 \times 10^{-11}}{10^{-10}}}$$

$$= 168.90 \text{ mg/L}$$

$$\text{Bicarbonate alkanity as } CaCO_3 = \frac{2K_2}{[H^+]} \times [HCO_3^-]$$

$$= \frac{2 \times 4.68 \times 10^{-11}}{10^{-10}} \times 168.90$$

$$= 158.09 \text{ mg/L}$$

$$\text{Bicarbonate concentration, } [HCO_3^-] = \frac{158.9}{50 \times 10^3} \text{ moles/L} = 3.162 \times 10^{-3} \text{ moles/L}$$

$$\text{and carbonate concentration, } [CO_3^-] = \frac{168.90}{50 \times 10^3} \text{ moles/L} = 3.378 \times 10^{-3} \text{ moles/L}$$

CamScanner

Problem: A water sample contains 100 mg/L CO_3^{2-} and 75 mg/L HCO_3^- at a pH of 10. Calculate the alkanity exactly at 25°C.

Solution:

Given, pH = 10

$\Rightarrow -\log[H^+] = 10$

$\Rightarrow [H^+] = 10^{-10}$ moles/L $= 10^{-10}$ gm/L $= 10^{-7}$ mg/L

We know, $[H^+] \times [OH^-] = 10^{-14}$

$\Rightarrow [OH^-] = \frac{10^{-14}}{10^{-10}} = 10^{-4}$ moles/L $= 10^{-4} \times 17$ gm/L $= 17 \times 10^{-1}$ mg/L

$\therefore [OH^-] = 1.7$ mg/L

Now,

Total alkanity $= [HCO_3^-] + [CO_3^{2-}] + [OH^-] - [H^+]$

$= 75 \times \frac{50}{61} + 100 \times \frac{50}{30} + 1.7 \times \frac{50}{17} - 10^{-7} \times \frac{50}{1}$

$\therefore$ Total Alkanity $= 233.14$ mg/L as $CaCO_3$

(Ans.)

Hardness

Problem: The analysis of water from the bore shows the following results in mg/L as the ion: $Ca^{2+} = 60$, $Mg^{2+} = 48$, $Na^{+} = 103.5$, $K^{+} = 19.5$, $HCO_3^{-} = 244$, $SO_4^{2-} = 220.8$, $Cl^{-} = 78.1$. Find out the total hardness, carbonate hardness and non carbonate hardness in mg/L as $CaCO_3$. [NARPO-17, DMTCL-17]

Solution:

Total hardness as $CaCO_3 = 60 \times \frac{50}{20} + 48 \times \frac{50}{12.2} = 346.72$ mg/L

HCO_3^{-} Alkanity as $CaCO_3 = 244 \times \frac{50}{61} = 200$ mg/L

since, Alkanity < Total Hardness, carbonate Hardness = Alkanity

$\therefore$ C.H = 200 mg/L

$\therefore$ Non-carbonate Hardness $= (346.72 - 200) = 146.72$ mg/L

[PGCB-19] (Ans.)

Problem: A water has an alkanity of 200 mg/L as $CaCO_3$. The Ca^{2+} concentration is 160 mg/L as the ion and the Mg^{2+} concentration is 40 mg/L as the ion. The pH is 40 mg/L. Find the Total carbonate and non carbonate hardness.

Solution:

Total Hardness as $CaCO_3 = \left(160 \times \frac{50}{20} + 40 \times \frac{50}{12.2}\right) = 563.93$ mg/L

Since, Alkanity < Total Hardness, C.H = Alkanity = 200 mg/L

$\therefore$ N.C.H = T.H − C.H $= (563.93 - 200) = 363.93$ mg/L

(Ans.)

Problem: 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 the total hardness, Mg^{2+} and HCO_3^- as mg/L. (BWDB-19)

Solution: $\text{Meq/L} = \frac{\text{mg/L}}{\text{eq. wt.}}$

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

Total Hardness $= C.H + N.C.H = (3+1) = 4$ meq/L

we know,

Total Hardness $= Ca^{2+} + Mg^{2+} + Sr^{2+}$

$\Rightarrow 4 \text{ meq/L} = 2 \text{ meq/L} + Mg^{2+} + 0$

$\Rightarrow Mg^{2+} = (4-2) \text{ meq/L} = 2 \text{ meq/L}$

$\therefore Mg^{2+}$ as mg/L $= (2 \times 12.2)$ mg/L $= 24.4$ mg/L

since, C.H = Alkanity, $\therefore HCO_3^- = 3 \text{ eq/L} = (3 \times 61) = 183$ mg/L (Ans,)

[SGFL-17]

Problem: Laboratory analysis of water sample. All concentrations are "as substance". $Ca^{2+} = 74$ mg/L, $Mg^{2+} = 18.3$ mg/L, $Na^+ = 27.6$ mg/L, $K^+ = 39.1$ mg/L, pH = 7.8, $HCO_3^- = 274.5$ mg/L, $SO_4^{2-} = 72$ mg/L, $Cl^- = 49.7$ mg/L. Determine

(i) Hardness of the water sample in mg/L of $CaCO_3$.

(ii) Amount of Lime needed to remove hardness by $CaCO_3$.

Solution:

(i) Total Hardness as $CaCO_3 = \left(74 \times \frac{50}{20} + 18.3 \times \frac{50}{12.2}\right) = 260$ mg/L

(ii) Quick lime feed = $\frac{A+B+C+D}{\text{Lime purity}} \times$ excess lime dosage.

where

A (CO_2) = mg/l as $CO_2 \times \frac{56}{44}$ = 0 mg/l

B (HCO_3^-) = mg/l as $CaCO_3 \times \frac{56}{100}$ = $(274.5 \times \frac{50}{61}) \times \frac{56}{100}$ = 126 mg/l

C (OH^-) = mg/l as $CaCO_3 \times \frac{56}{100}$ = 0 mg/l

D (Mg^{2+}) = mg/l as Mg ion $\times \frac{56}{24.3}$ = $\left(18.3 \times \frac{56}{24.3}\right)$ = 42.17 mg/l

let, excess lime dosage = 1.15

Assuming, Lime purity = 100%

∴ Quick lime feed = $\frac{0+126+0+42.17}{\frac{100}{100}} \times 1.15$ = 193.9 mg/l

(Ans.)

Sedimentation Tank:

[CPGCBL-18]

Problem: One million gallon (MGD) per day of water flows through a sedimentation tank. If the size of the tank is 20′ × 50′ × 10′, find the detention time of the tank.

Solution:

We know, Detention time, $T = \frac{C}{Q} = \frac{L \times B \times H}{Q}$

$= \frac{20 \times 50 \times 10 \times 1000}{10^6 \times 3.785 \times 3.28^3}$ day

$= 0.0745$ day $= 1.788$ hrs

(Ans.)

[NPCBL-17, GTCL-18]

Problem: In 300 m^3 sedimentation tank water is flowing in at rate 1000 m^3/day. What is the detention time in hours?

Solution:

Detention time, $T = \frac{C}{Q} = \frac{300}{1000} = 0.3$ day $= 7.2$ hrs.

(Ans.)

[DPDC-14]

Problem: If the flow of water supply is 1023 m^3/day and volume of this tank is 93 m^3. Determine the detention period of the tank.

Solution:

Detention time, $T = \frac{C}{Q} = \frac{93}{1023} = 0.091$ day $= 2.184$ hrs.

(Ans.)

[BPDB-23, CPGCBL-21, EGCB-20]

Problem: A horizontal flow of grit chamber is used to pretreat waste water with flow rate of 26.5 ft^3/sec. The chamber is 5.9 ft in deep and width is 15 times the length. What is the width of the chamber if average approach velocity is 1.15 ft/sec.

Solution: we know, $Q = AV$

$\Rightarrow 26.5 = (B \times H) \times 1.15$

$\Rightarrow B = \frac{26.5}{1.15 \times 5.9} = 3.906$ ft. (Ans.)

LSG FCL-21

Problem: A water treatment plant has a flow rate of 0.6 m^3/sec. The settling basin at the plant has an effecting setting volume that is 20 m long, 6 m wide and 3 m deep. Will particles that have a settling velocity of 0.00 m/sec. be completely removed? If not, what percentage of particles will be removed?

Solution: We know, $Q = AV \Rightarrow V = \frac{Q}{A}$

$\therefore$ Required settling velocity for 100% removal, $V = \left(\frac{0.6}{20 \times 6}\right)$ m/s

$= 0.005$ m/s

Since, $W > 0.004$ m/sec, particles will not be removed completely.

$$\% \text{ partical removal} = \left(\frac{0.004}{0.005} \times 100\right) = 80\%$$

(Ans:)

Chlorination:

[GTCL-16, DESCO-15, DPDC-19]

Problem: The population of 2005 is 10000 and 2015 is 19500. What is the water demand of 2025? water demand is 90 l/ped. chlorine content of 0.5 mg/L is to be added in water. How much bleaching powder is needed if bleaching powder contains 25% of chlorine.

Solution:

Growth rate of population, $r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \sqrt[10]{\frac{19500}{10000}} - 1 = 0.069$

Future population in 2025, $P_f = P_p (1+r)^n$

$= 19500 (1+0.069)^{10} = 38003$

$\therefore$ Total water demand in 2025 $= (38003 \times 90)$ l/day.

$= 3420270$ l/day

$\therefore$ chlorine required $= (0.5 \times 3420270)$ mg/day $= 1710135$ mg/day

$= 1.71$ kg/day

$\therefore$ Amount of bleaching powder required $= \left(\frac{100}{25} \times 1.71\right)$ kg/day

$= 6.84$ kg/day. (Ans.)

[DPDC-14, RPGCL-17, BWDB-18, DTCA-18, BCIC-19]

Problem: 100 MLD water is to be supplied from a water treatment plant which containing 0.4 ppm Cl_2, if bleaching powder contains 25% available chlorine by weight. Find out the amount of bleaching powder in kg/day.

Solution:

waste water to be treated $= 100$ MLD $= 100 \times 10^6$ l/day.

Amount of chlorine required $= (100 \times 10^6 \times 0.4)$ mg/day.

$= 40 \times 10^6$ mg/day $= 40$ kg/day.

$\therefore$ Amount of bleaching powder required $= \left(\frac{100}{25} \times 40\right) = 160$ kg/day. (Ans.)

[ERL-17, DESCO-19]

Problem: 500 m^3/d water is to be supplied from a water treatment plant with chlorine concentration of 0.5 mg/L, if bleaching powder that is used for chlorine has contains 30% avaiable cl_2 (by weight). find out the amount of bleaching powder in kg/day.

Solution:

Amount of water to be treated = 500 m^3/day = 500×10^3 L/day.

Amount of chlorine required = $(0.5 \times 500 \times 10^3)$ mg/day = 25×10^4 mg/day.
= 0.25 kg/day.

∴ Amount of bleaching powder required = $\left(\frac{100}{30} \times 0.25\right)$ = 0.833 kg/day.

(Ans.)

[HED-20]

Problem: If Bleaching powder contains 30% chlorine, Find out the amount of bleaching powder to treat 4 million liter water per day with chlorine dosage of 0.5 mg/L

Solution:

Amount of water to be treated = 4×10^6 L/day.

∴ Amount of chlorine required = $(0.5 \times 4 \times 10^6)$ mg/day
= 2×10^6 mg/day = 2 kg/day.

Amount of bleaching powder required = $\left(\frac{100}{30} \times 2\right)$ = 6.67 kg/day.

(Ans.)

[WRGCL-14]

Problem: It is required to disinfect 500000 gpd of water with 0.3 mg/L chlorine dosage. If bleaching powder is used (which contains 25% of avaiable chlorine), how many Kg of bleaching powder are needed to treat the daily flow of water?

Solution: Amount of water to be treated = 500000 gpd = (500000×3.785) L/day
= 1892500 L/day.

Amount of chlorine required = (0.3 × 18925) mg/day

= 56775 mg/day = 0.56775 kg/day.

∴ Amount of bleaching powder required = $\left(\frac{100}{25} \times 0.56775\right)$ kg/day

= 2.271 kg/day.

(Ans.)

[EGCB-20]

Problem: A water treatment plant produces 1 ML waste water per day. Bleaching powder (40% Cl_2) is used to disinfect the water. You must maintain 0.5 mg/L Cl_2 residual in the finished water with a Cl_2 demand of 3.5 mg/L. Calculate the amount of bleaching powder required per day.

Solution:

Amount of water to be treated = 1 MLD = 10^6 L/day.

Given, chlorine dosage = (0.5 + 3.5) = 4 mg/L

Amount of chlorine required = (10^6 × 4.0) mg/day.

= 4×10^6 mg/day

= 4 kg/day.

∴ Amount of bleaching powder required = $\left(\frac{100}{40} \times 4\right)$ kg/day.

= 10.0 kg/day.

(Ans.)

BOD:

[BIFPCL-15, BCIC-16, JOCL-18]

Problem: Determine the ultimate BOD for a sewage having 5 day BOD at 20°C is 150 mg/L. Assume, reaction rate constant is 0.22/day.

Solution:

We know,

$$BOD_5 = L_o(1-e^{-5K})$$

$$\Rightarrow L_o = \frac{150}{1-e^{-5\times0.22}} = 224.849 \text{ mg/L}$$

(Ans)

[RPGCL-17, BWDB-18]

Problem: If the BOD_5 is 102.5 mg/L and $K = 0.23$/day at 20°C temperature. Determine the ultimate BOD.

Solution:

We know,

$$BOD_5 = L_o(1-e^{-5K})$$

$$\Rightarrow L_o = \frac{102.5}{1-e^{-5\times0.23}} = 150 \text{ mg/L}$$

(Ans.)

[MPL-2017, BPDB-18, SGFCL-18]

Problem: The amount of BOD_5 in a sewage found 200 mg/L at temperature 20°C. If Reaction rate constant = 0.22/day, then determine the BOD_{10} at the same temperature.

Solution: We know,

$$BOD_5 = L_o(1-e^{-5K})$$

$$\Rightarrow L_o = \frac{200}{1-e^{-5\times0.22}} = 299.79 \text{ mg/L}$$

Now, $BOD_{10} = L_o(1-e^{-10K}) = 299.79(1-e^{-10\times0.22}) = 266.57 \text{ mg/L}$

(Ans.)

[DSCC-16]

Problem: If the BOD_5 at 20°C of a sewage sample is 320 mg/L. Calculate its 10 days BOD at 30°C if $K = 0.23$/day.

Solution:

We know,

$$BOD_5 = L_o(1 - e^{-5K}).$$

$$\Rightarrow L_o = \frac{320}{1 - e^{-5\times 0.23}} = 468.27 \text{ mg/L}$$

At 30°C, $K_{30} = K_{20}(1.047)^{30-20} = (0.23 \times 1.047^{10}) = 0.364$ /day.

$$\therefore BOD_{10} = L_o(1 - e^{-10\times K}) = 468.27 \times (1 - e^{-10\times 0.364}) = 455.98 \text{ mg/L}$$

(Ans.)

[PGCB-17, RWASA-23]

Problem: If a 2% solution of sewage is incubated for 5 days at 20°C and dissolved oxygen depletion was 5 ppm. determine BOD_5 at 20°C.

Solution:

$$\text{Dilution Ratio} = \frac{100}{2} = 50$$

We know, $BOD_5 = (DO_i - DO_f) \times DR = (5 \times 50) = 250$ mg/L.

(Ans.)

~~[DWASA-14, BCIC-14]~~ [WARPO-15]

Problem: Waste water of 40 mL is mixed with diluted water 360 mL in a bottle. $DO_i = 8.5$ mg/L, $DO_f = 3.5$ mg/L. Find the BOD_5.

Solution:

$$\text{Dilution Factor} = \left(\frac{360+40}{40}\right) = 10$$

Now, $BOD_5 = (DO_i - DO_f) \times DF = (8.5 - 3.5) \times 10 = 50$ mg/L.

(Ans.)

[DESCO-15]

Problem: The value of initial DO = 3.6, after 5 days Final DO = 2.6. If Dilution factor is 0.6. Determine the 5 day BOD. Also determine BOD remaining and ultimate BOD. Given $K = 0.22\ day^{-1}$

Solution:

We know, $BOD_5 = (DO_i - DO_f) \times \frac{1}{DF} = (3.6 - 2.6) \times \frac{1}{0.6} = 1.67\ mg/L$

Again,

$BOD_5 = L_o (1 - e^{-5K})$

$\Rightarrow L_o = \frac{1.67}{1 - e^{-5 \times 0.22}} = 2.50\ mg/L$

BOD remaining $= L_o e^{-5K} = 2.50 \times e^{-5 \times 0.22} = 0.833\ mg/L$ (Ans)

[GTCL-16] [BGFCL-17]

Problem: The dilution factor = 0.5, value of $DO_i = 7.4$, after 5 days value of $DO_f = 4.4$. If BOD reaction rate constant = 0.2/day. Find out (i) BOD_5 (ii) BOD ultimate (iii) BOD remaining after 3 days.

Solution:

$BOD_5 = (DO_i - DO_f) \times \frac{1}{DF} = (7.4 - 4.4) \times \frac{1}{0.5} = 6\ mg/L$

BOD ultimate, $L_o = \frac{BOD_5}{1 - e^{-5K}} = \frac{6}{1 - e^{-5 \times 0.2}} = 9.49\ mg/L$

BOD remaining after 3 days $= L_o e^{-3K} = 6 \times e^{-3 \times 0.2} = 3.29\ mg/L$

[DPDC-16]

Problem: If 30 mL waste sample is mixed with 270 ml water, initial DO of the sample is 8 mg/L and final DO is 2 mg/L. Find 5-day BOD. (Ans)

Solution:

$BOD_5 = (DO_i - DO_f) \times DR$

Here, $DR = \frac{270 + 30}{30} = 10$

$= (8 - 2) \times 10$

$= 60\ mg/L$ (Ans)

[LGB AD-18]

Problem: Ten 5 mL samples of waste water are placed in 300 ml BOD bottles and diluted to full volume. Half of the bottles are tasted immediately and average initial concentration of dissolved oxygen = 7.9 mg/L, the remaining bottles are incubated for 5 days after which the average dissolved oxygen is determined to be 1.5 mg/L ($K_1 = 0.13$ per day). Find out (i) standard BOD (ii) ultimate carbonaceous BOD.

Solution:

$$\text{Dilution Ration} = \frac{300}{5 \times 10} = 6$$

$$\therefore BOD_5 = (DO_i - DO_f) \times DR = (7.9 - 4.5) \times 6 = 20.4 \text{ mg/L}$$

Again,

$$BOD_5 = L_o\left(1 - 10^{-5R}\right) \quad [R = K_1 = \text{Reaction rate constant (10 base)}]$$

$$\Rightarrow L_o = \frac{BOD_5}{1 - 10^{-5R}} = \frac{20.4}{1 - 10^{-5 \times 0.13}} = 26.28 \text{ mg/L}$$

(Ans.)

[NHA-19]

Problem: The dissolved oxygen is an unseeded sample of diluted waste having an initial DO of 8 mg/L and final DO after 5 days is 4 mg/L. If the sample is diluted in 1:50. Find the BOD_5 of the sample. If this BOD_5 water discharge in an open sources at a rate of 10 ft^3/s what will be BOD load per year (ton/year).

Solution:

$$BOD_5 = (DO_i - DO_f) \times DR = (8 - 4) \times 50 = 200 \text{ mg/L}$$

$$\text{BOD load per year} = \frac{200 \times 10^{-6} \text{ kg}}{10^{-3} \text{ m}^3} \times \frac{10 \times 3600 \times 24 \times 365}{(3.28)^3} \text{ m}^3/\text{year}$$

$$= 1787372.5 \text{ kg/year}$$

$$= 1787.4 \text{ Ton/year}$$

(Ans.)

[PDB-15, ERL-17]

Problem: A municipal waste water treatment plant discharge 1.2 m^3/sec of effluent having BOD of 60 mg/L that has a flow of 9.3 m^3/sec. and BOD of 6 mg/L. Assume complete mixing and Estimate the mixing BOD of the river just downstream of the flow.

Solution:

Mixing BOD at downstream of the river,

$$BOD_{mix} = \frac{BOD_w \times Q_w + BOD_r \times Q_r}{Q_w + Q_r} = \frac{1.2 \times 60 + 9.3 \times 6}{(1.2 + 9.3)}$$

$\therefore BOD_{mix} = 12.17$ mg/L

(Ans.)

[BWDB-20]

Problem: The waramurngundi tannery with a waste water flow of 0.011 m^3/sec. and BOD_5 of 590 mg/L discharges into Djanggawul creek. The creek has a 10-year, 7-day low flow of 1.7 m^3/s. At upstream of the waramurngundi tannery, the BOD_5 of the creek is 0.6 mg/L. The BOD rate constant (K) are 0.115 per day for the tannery and 3.7 per day for the creek. Calculate the initial ultimate BOD after mixing.

Solution: For tannery, $BOD_{ut} = \frac{BOD_5}{1 - e^{-5K}} = \frac{590}{1 - e^{-5 \times 0.115}} = 1349.2$ mg/L

For creek, $BOD_{uc} = \frac{BOD_5}{1 - e^{-5K}} = \frac{0.6}{1 - e^{-5 \times 3.7}} = 0.60$ mg/L

Now, $BOD_{u(mix)} = \frac{BOD_{ut} \times Q_t + BOD_{uc} \times Q_c}{Q_t + Q_c} = \frac{\times 0.011 + 0.6 \times 1.7}{0.011 + 1.7}$

$\therefore BOD_{u(mix)} = 9.27$ mg/L

(Ans.)

[BB AD-1987

[DWASA-14, BCIC-14]

Problem: A soil sample having 25 mL sewage water to dilute in 300 mL Bottle $D_i = 8.7$, $D_f = 3.7$ and dilute water seed sample $B_i = 3.7$ and $B_f = 2.6$. Determine the BOD_5.

Solution: When the dilution water is seeded,

$$BOD_5 = \frac{(D_i - D_f) - (B_i - B_f) f}{DF}$$

$$= \frac{(8.7 - 3.7) - (3.7 - 2.6)\left(1 - \frac{1}{12}\right)}{\left(\frac{1}{12}\right)}$$

$\therefore BOD_5 = 47.9$ mg/L

Here, $D_i = 8.7$ mg/L
$D_f = 3.7$ mg/L
$B_i = 3.7$ mg/L
$B_f = 2.6$ mg/L
$DF = \frac{25}{300} = \frac{1}{12}$
$f = (1 - DF)$

(Ans.)

[DMTCL-17]

Problem: A canal exerts waste water in a river at 8000 m^3/day. BOD of the waste water is given in 18 mg/L. What is the total amount of BOD exerted in river?

Solution:

Total amount of BOD exterted $= (8000 \times 10^3 \times 18) = 144 \times 10^6$ mg/day
$= 144$ kg/day. (Ans.)

[DPDC-20, BIWTA-22]

Problem: Waste water flowing from a city at a rate of 1.5 MGD is treated by primary sedimentation and secondary trickling filters with total surface area 700000 ft^2. The influent BOD_5 concentration is 300 mg/L and suspended solids concentration is 220 mg/L. The primary treatment process removes 33% of the BOD_5. Calculate the required loading rate Kg/ft^2/day.

Solution:

The amount of BOD_5 remained $= (1-0.33) \times 1.5 \times 10^6 \times 3.785 \times 300$

$= 1311.5 \times 10^6$ mg/day

$= 1311.5$ kg/day

The amount of suspended solid $= (1.5 \times 10^6 \times 3.785 \times 220)$ mg/day

$= 1249.05 \times 10^6$ mg/day

$= 1249.05$ kg/day

∴ Total solid $= (1311.5 + 1249.05)$ kg/day $= 2560.55$ kg/day

∴ Required loading rate $= \frac{2560.55}{700000} = 3.66 \times 10^{-3}$ kg/ft²/day. (Ans.)

[JB-2017]

Problem: Let there is a community with a population of 35000. The solid waste generation rate is 6.5 lb/capita-day. There is a necessity to design a landfill for the community. Estimate the required landfill area. Consider that, the compacted specific weight of solid wastes in landfill 800 lb/yd³ and average depth of compacted solid waste is 20 ft.

Solution:

Daily solid waste generation $= (35000 \times 6.5) = 227500$ lb/day

Volume of solid waste $= \frac{227500}{800} = 284.375$ yd³/day.

∴ Required Area of landfill $= \frac{284.375 \times 1.2}{20}$ [Assuming, 20% landfill volume for daily cover]

$= 17.06$ yd²/day

$= 6227.8$ yd²/year (Ans.)

[GTCL-16]

Problem: A canal exents waste water in a River at 55000 m^3/day. BOD of the waste water in given in 110 mg/L. What is the total amount of BOD exerted in the river? If a treatment plant is treating the waste to remove 70% BOD, what is the amount of BOD exerted?

Solution:

The total BOD exerted = $(55000 \times 10^3 \times 110)$ mg/day

$= 6050 \times 10^6$ mg/day

$= 6050$ kg/day.

After treating the waste water,

the amount of BOD exerted = $(1 - 0.70) \times 6050$ kg/day.

$= 1815$ kg/day. (Ans.)

[30th BCS]

Problem: Calculate BOD removal efficiency for the single stage high rate trickling filter. BOD loading is 750 g/m^3/d and re circulation ratio is 0.60.

Solution:

Recirculation factor, $F = \frac{1+R}{\left(1+\frac{R}{10}\right)^2} = \frac{1+0.6}{\left(1+\frac{0.6}{10}\right)^2} = 1.51$

Now, Efficiency for single stage, $E_1 = \frac{100}{1+0.4432\sqrt{\left(\frac{W_1}{VF}\right)}}$

Here, BOD Loading rate, $W_1 = 750$ g/m^3/d $= 0.75$ Kg/m^3/day.

$\therefore E_1 = \frac{100}{1+0.4432\sqrt{\frac{0.75}{1.51}}} = 76.2\%$ (Ans.)

[**Note:** Effluent BOD = BOD concentration $\times \left(\frac{100-E_1}{100}\right)$

For second stage trickling filter efficiency, $E_2 = \frac{100}{1+\frac{0.4432}{1-E_1}\sqrt{\frac{W_2}{VF}}}$

Effect of temperature, $E_T = E_{20}(1.035)^{T-20}$]

[PSCB-19]

Problem: The BOD of waste water sample is estimated to be 180 mg/L. What volume of undiluted sample should be added to a 300 mL bottle? Also, what are the sample size and dilution factor using this volume? Assume that 1 mg/L BOD can be considered in the BOD bottle.

Solution: Sample size needed $= \left(\frac{1}{180} \times 100\right) = 2.22\%$.

Volume of undiluted sample $= (300 \times 0.0222) = 6.66$ mL

So, a convenient sample volume would be 7.0 mL

Now, sample size needed $\left(\frac{7}{300} \times 100\right) = 2.33\%$.

$\therefore$ Dilution Ratio $= \frac{300}{7} = 42.86$ (Ans.)

[DMTCL-19]

Problem: Just below the point where a continuous discharge of pollution mixes with river, the BOD is 10.9 mg/L and DO is 7.6 mg/L. The river and waste mixture has a temperature of 20°C, a deoxygenation constant of 0.20/day, an average flow speed 0.3 m/sec. and an average depth of 3 m. The saturation value of DO at 20°C is 9.1 mg/L and reaeration constant is 0.41/day.

(i) Find the time and distance downstream at which the oxygen deficit is at a maximum.

(ii) Find the minimum value of DO.

Solution: Intial deficit, $D_o = (9.1 - 7.6)$ mg/L $= 1.5$ mg/L

$L_o = 10.9$ mg/L

Time at maximum oxygen deficit,

$$t_c = \frac{1}{K_r - K_d} \ln\left[\frac{K_r}{K_d}\left(1 - \frac{D_o}{L_o} \times \frac{K_r - K_d}{K_d}\right)\right]$$

$$= \frac{1}{0.41 - 0.20} \times \ln\left[\frac{0.41}{20} \times \left(1 - \frac{1.5}{10.9} \times \frac{0.41 - 0.20}{0.20}\right)\right]$$

$= 2.67$ days.

Distance downstream at maximum oxygen deficit,

$x_c = Vt_c = (0.3 \times 2.67 \times 24 \times 3600) = 69300\ m = 69.3\ km.$

The maximum oxygen deficit, $D_c = \frac{K_d}{K_r - K_d} \times L_o \left(e^{-K_d t} - e^{-K_r t}\right) + D_o e^{-K_r t}$

$= \frac{0.20}{0.41 - 0.20} \times 10.9 \times \left(e^{-0.20 \times 2.67} - e^{-0.4 \times 2.67}\right) + 1.5 \times e^{-0.41 \times 2.67}$

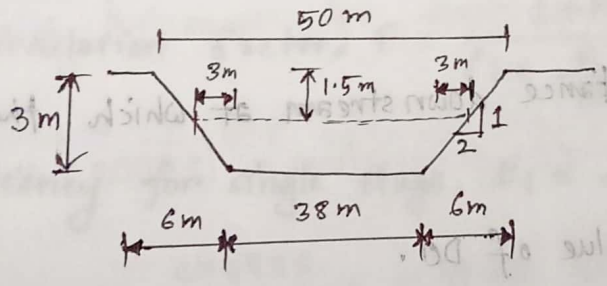
$= 3.1\ mg/L$

Minimum value of DO $= (9.1 - 3.1) = 6.0\ mg/L$ (Ans:)

[40th BCS]

Problem: An aerated Lagoon (50m x 50m at water surface) is 3m deep with banks sloped at 2H : 1V receives a waste water flow of 2.5 MLD with 600 mg/L BOD. Calculate the detention time, volumetric organic loading rate and F/M ratio. (Assuming that equivalent volatile SS concentration in the lagoon is 4000 mg/L)

Solution:



Volume of Lagoon $= \frac{1.5}{3} \times \left[(50 \times 50) + (38 \times 38) + 4 \times (44 \times 44)\right]\ m^3$

$= 5844\ m^3$

The amount of waste water flow $= 2.5\ MLD = 2.5 \times 10^6\ L/day = 2.5 \times 10^3\ m^3/day$

Detention time, $t = \frac{V}{Q} = \frac{5844}{2.5 \times 10^3} = 2.3376\ day.$

Volumetric organic loading rate = Flow × BOD conc.

$= (2.5 \times 10^6 \times 600)$ mg/day

$= 15 \times 10^8$ mg/day $= 1500$ Kg/day.

Mixed Liquid volatile suspended solids, MLVSS $= \left(5844 \times \frac{4000}{10^6} \times 10^3\right)$ Kg

$= 2337.6$ Kg.

$$F/M \text{ Ratio} = \frac{\text{BOD loading Rate}}{\text{MLVSS}} = \frac{1500}{2337.6} = 0.64 \text{ Kg BOD/day/Kg MLVSS}$$

(Ans.)

SO_2 Emission:

(DESCO-15)

Problem: A coal power uses 10 ton coal which contains 4% of sulfurs. Determine the amount of SO_2 emission.

Solution:

$$S + O_2 = SO_2$$
$$32g \quad 32g = 64g$$

Amount of sulfur used $= (0.04 \times 10) = 0.4$ ton $= (0.4 \times 1000)$ kg $= 400$ kg

∴ For 32g Sulfur, the amount of SO_2 emission = 64g

Hence, for 400×10^3 g Sulfur, the amount of SO_2 emission $= \frac{64}{32} \times 400 \times 10^3$

$= 800 \times 10^3$ g

$= 800$ kg (Ans.)

(PGCB-19) (BEWTA-22)

Problem: The boropukuria coal is burned at a rate 1.0 kg per second. Analysis of the BUET lab shows the coal revels a sulfur content of 3%. What is the annual rate of emission of SO_2? Assume that 5% of the sulfur in the coal ends up in the ash.

Solution:

Amount of sulfur $= (1 \times 0.03) = 0.03$ kg per second.

Since, 5% of sulfur ends up with ash,

∴ Avaiable sulfur content $= (0.95 \times 0.03)$ kg per second

$= 0.0285$ kg per second

$= (0.0285 \times 3600 \times 24 \times 365)$ kg per year

$= 898776$ kg per year

$S + O_2 = SO_2$

32g 32g 64g.

∴ 32kg 32kg 64 kg.

For 32kg of sulfur, amount of SO_2 emission = 64 kg.

∴ For 898776 kg of Sulfur, amount of SO_2 emission $= \left(\frac{64}{32} \times 898776\right)$ kg/year

$= 1797552$ kg/year

$= 1797.552$ ton/year. (Ans.)

Others:

Problem: 1000 L of water is contaminated with 25 mg/L toxic substances. Concentration of toxic substances is to be reduced to 0.5 mg/L be discharging. Determine the mass of toxic substances to be reduced? (SUFCL-17)

Solution:

Mass of toxic substances to be reduced = $(25 - 0.5) \times 1000$ mg

$= 24500$ mg $= 24.5$ g

(Ans.)

Engineering Materials

Fineness Modulus:

$$FM = \frac{\Sigma(\text{Cumulative percentage retained on standard sieves})}{100}$$

Where, standard sieves are:

- No. 100 sieve (0.15 mm)
- No. 50 sieve (0.30 mm)
- No. 30 sieve (0.60 mm)
- No. 16 sieve (1.18 mm)
- No. 8 sieve (2.36 mm)
- No. 4 sieve (4.75 mm)
- $\frac{3}{8}$ in. sieve (9.5 mm)
- $\frac{3}{4}$ in. sieve (19 mm)
- 1.5 in. sieve (37.5 mm)
- 3 in. sieve (75 mm)

* If two or more different variety of sand are mixed together, the combined fineness modulus of mixed sample can be determined –

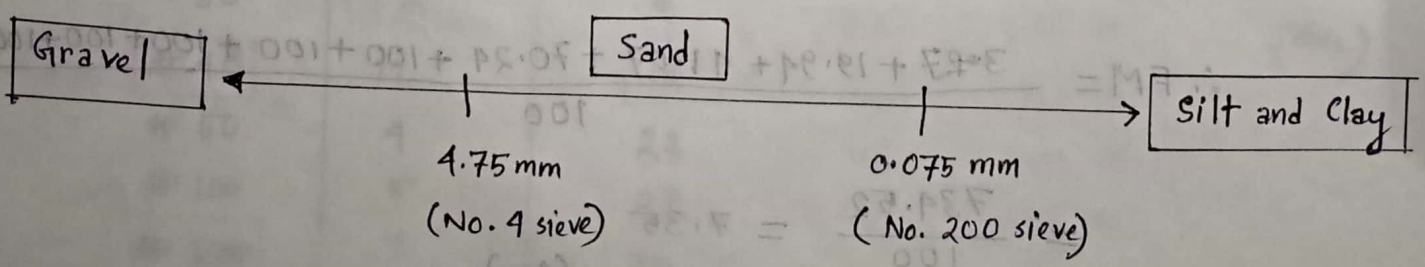
$$F_{com} = \frac{m_1F_1 + m_2F_2 + \cdots\cdots + m_nF_n}{m_1 + m_2 + \cdots\cdots + m_n}$$

* If R is the ratio of one variety of sand to be mixed with the other variety. Then,

$$R = \frac{F_1 - F_{com}}{F_{com} - F_2}$$

Here, $R = \frac{m_2}{m_1}$ if $F_1 > F_2$

* Grain Size:



[BUET M.Sc – 2011]

* Find the fineness modulus for the following sieves:

Sieve No.	3"	1.5"	$\frac{3}{4}$"	$\frac{3}{8}$"	#4
Sand retained (gm)	11	56	71	98	100

Solution:

Sieve No.	Sand retained (gm)	% retained	cumulative % retain
3"	11	$\frac{11}{336} \times 100 = 3.27$	3.27
1.5"	56	16.67	19.94
$\frac{3}{4}$"	71	21.13	41.07
$\frac{3}{8}$"	98	29.17	70.24
#4	100	29.76	100
#8	—	0	100
#16	—	0	100
#30	—	0	100
#50	—	0	100
#100	—	0	100

$\Sigma = 336$

$$\therefore FM = \frac{3.27 + 19.94 + 41.07 + 70.24 + 100 + 100 + 100 + 100 + 100 + 100}{100}$$

$$= \frac{734.52}{100} = 7.35$$

(Ans.)

[BUET M.Sc.-2014, ERL-13, BPDB-16, BGFCL-16, SGCL-17]

* Find the fineness modulus for 25% retain on each sieve of #30, #50, #100 and #200.

Solution:

Sieve No.	% retain	cumulative % retain
#30	25	25
#50	25	50
#100	25	75
#200	25	100 ✗

$$\therefore FM = \frac{25+50+75}{100} = 1.5$$

(Ans.)

[DPDC-2014, WASA-14, BCIC-17]

* Find the value of Fineness Modulus from the following sieves:

Sieve Size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	3	2	12	4	5	3	1

Solution:

Sieve No.	% retain	cumulative % retain
#4	0	0
#8	1	1
#16	3	4
#30	2	6
#40	12	18 ✗
#50	4	22
#100	5	27
#200	3	30 ✗
Pan	1	31 ✗

$$\therefore FM = \frac{1+4+6+22+27}{100} = 0.60$$

(Ans.)

[BBPZA-2016, DESCO-19, BPDB-18, SGIFL-20, PGICB-20, DPDC-20]

* Determine the fineness modulus and percent of silt and clay of the sample.

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	4	12	13	30	34	4	2

Solution:

Sieve No.	% retain	cumulative % retain
#4	0	0
#8	1	1
#16	4	5
#30	12	17
#40	13	30 ×
#50	30	60
#100	34	94
#200	4	98 ×
Pan	2	100 ×

$$\therefore FM = \frac{1+5+17+60+94}{100} = 1.77$$

% silt and clay = % passing through #200 sieve

$= (100-98)\%$

$= 2\%$

[WASA-2017, CPGCBL-18]

* Sieve analysis was performed for a sand and it has been found 20% sample retained on each sieve of #30, #40, #50, #100 and #200. Find the FM of the sand.

Solution:

Sieve No.	% retain	cumulative % retain
#30	20	20
#40	20	40 ×
#50	20	60
#100	20	80
#200	20	100 ×

$$\therefore FM = \frac{20+60+80}{100}$$

$= 1.6$

(Ans.)

[BWDB-2020]

* Sieve analysis was performed on a soil in the lab, determine the fineness modulus of that soil.

Sieve Size	$\frac{3}{8}$"	#4	#8	#16	#30	#50	#100	#150	#200	pan
Soil retained (gm)	0	20	10	30	40	30	40	20	10	0

Solution:

Sieve Size	soil retained	% retained	cumulative % retain
$\frac{3}{8}$"	0	0	0
#4	20	$\frac{20}{200} \times 100 = 10\%$	10
#8	10	5	15
#16	30	15	30
#30	40	20	50
#50	30	15	65
#100	40	20	85
#150	20	10	95 ×
#200	10	5	100 ×
Pan	0	0	0 ×

$\Sigma = 200$

$$\therefore FM = \frac{10 + 15 + 30 + 50 + 65 + 85}{100} = 2.55$$

(Ans.)

[RED-.

[WARPO-2017, BOCL-18]

* Find the fineness modulus of fine aggregate. And also determine the percentage of coarse aggregate and percent of silt and clay content.

Sieve Size (mm)	18.75	9.375	4.75	2.36	1.18	0.60	0.30	0.15	0.075	pan
Amount retained (gm)	175	125	100	50	20	10	10	4	4	2

Solution:

Sieve size (mm)	Amount retained (gm)	% retain	cumulative % retain
18.75	—	—	—
9.375	125	—	—
4.75	100	50	50
2.36	50	25	75
1.18	20	10	85
0.60	10	5	90
0.30	10	5	95
0.15	4	2	97
0.075	4	2	99 ×
Pan	2	1	100 ×

Fine Aggregate

$\Sigma = 200 + (125+175) = 500$

$\therefore FM = \frac{50+75+85+90+95+97}{100}$

$= 4.92$

% silt and clay $= \left(\frac{2}{500}\right) \times 100\%$

$= 0.4\%$

% coarse aggregate

$= \left(\frac{100+125+175}{500}\right) \times 100$

$= 80.0\%$

(Ans.)

[BGFCL-2017, ERL-17, WASA-17]

* 25% of a sand sample is retained on each of 0.60 mm, 0.425 mm, 0.30 mm and 0.15 mm sieve. Find the FM of sand sample.

Solution:

Sieve Size (mm)	% retain	cumulative % retain
0.60	25	25
0.425	25	50 ×
0.30	25	75
0.15	25	100

$\therefore FM = \frac{25+75+100}{100}$

$= 2.0$

(Ans.)

[BPDB - 2015, MPL - 17, GTCL - 18]

* Find the fineness modulus and percentage of silt and clay.

Sieve size	#4	#8	#16	#30	#50	#100	#200	Pan
% retained	0	1	4	12	43	2	2	4

Solution:

Sieve size	% retain	cumulate % retain
#4	0	0
#8	1	1
#16	4	5
#30	12	17
#50	43	60
#100	2	62
#200	2	64 ×
#Pan	4	68 ×

$\therefore FM = \frac{1+5+17+60+62}{100}$

$= 1.45$

% silt and clay = (68 − 64)%

= 4 %

(Ans.)

[BUET M.Sc - 2017, TGTDCL - 18]

* Find the fineness modulus of the following aggregate sample.

Sieve size (mm)	4.75	2.36	1.18	0.60	0.30	0.15	0.075
Weight retained (gm)	10	12	18	20	102	205	30

Solution:

Sieve size (mm)	Weight retained (gm)	% retain	cumulative % retain
4.75	10	$\frac{10}{397} \times 100 = 2.51$	2.51
2.36	12	3.02	5.53
1.18	18	4.53	10.06
0.60	20	5.04	15.1
0.30	102	25.69	40.79
0.15	205	51.64	92.43
0.075	30	7.56	100 ×
	$\Sigma = 397$		

$\therefore FM = \frac{2.51 + 5.53 + 10.06 + 15.1 + 40.79 + 92.43}{100}$

$= 1.664$

(Ans.)

[HED-2017]

* If two samples of sand (i) 400 gm of FM = 2.5 and (ii) 600 gm of FM = 1.8 were mixed together, what will be the combined FM of the mix.

Solution:

$$\text{Combined FM} = \frac{m_1 F_1 + m_2 F_2}{m_1 + m_2} = \frac{400 \times 2.5 + 600 \times 1.8}{400 + 600}$$

$$\therefore F_{com} = \frac{2080}{1000} = 2.08 \quad \text{(Ans.)}$$

Required Bricks:

* No. of bricks required for 100 cft brick works = 1200 Nos.
* No. of bricks required for 100 sq.ft BFS works = 300 Nos.
* No. of bricks required for 100 cft brick Khoa = 850 Nos.

Required Mortar:

* Amount of mortar required for 100 cft brickwork = 45 cft
* 1 bag cement = 1.25 cft * 1 cft steel = 490lb or 223 Kg

[BIFPCL-2015, BCIC-16]

* Determine the number of bricks required for 500 m^3 masonry wall.

Solution: $100\ cft = 100 \times (0.3048)^3 = 2.83\ m^3$

We know, For 100 cft or 2.83 m^3 brickworks, required bricks = 1200 Nos.

$\therefore$ For 500 m^3 brickworks, required bricks $= \frac{1200}{2.83} \times 500$

$\simeq 212015$ Nos.

(Ans.)

Required cement, sand and aggregate:

[BUET M.Sc – 2014, BGFCL – 2017, FRL – 17, MPL – 17]

* Determine the number of bags of cement required to cast 40ft long span beam section is 12" × 15" and mix ratio is 1:2:4.

Solution:

Volume of beam $= \left(\frac{12}{12} \times \frac{15}{12} \times 40\right) = 50$ cft

$\therefore$ Dry volume of cc $= (1.5 \times 50) = 75$ cft

Given, Mix ratio, C:FA:CA = 1:2:4

$\therefore$ Amount of cement required, $c = \frac{1}{(1+2+4)} \times 75 = 10.71$ cft

We know, 1 bag cement = 1.25 cft

$\therefore$ No. of cement bags required $= \frac{10.71}{1.25} = 8.57 \simeq 9$ bags (Ans.)

[EGCB – 2015]

* Determined the required amount of cement, sand and brick in 10 ft span of 10" × 12" size of beam in ratio 1:1.5:3.

Solution:

Volume of beam $= \left(\frac{10}{12} \times \frac{12}{12} \times 10\right) = 8.33$ cft

$\therefore$ Dry volume of cc $= (1.5 \times 8.33) = 12.5$ cft

Given, Mix ratio, C:FA:CA = 1:1.5:3

$\therefore$ Amount of cement required, $c = \frac{1}{1+1.5+3} \times 12.5 = 2.27$ cft

Amount of sand required, $FA = \frac{1.5}{5.5} \times 12.5 = 3.41$ cft

Amount of coarse aggregate required, $CA = \frac{3}{5.5} \times 12.5 = 6.82$ cft

$\therefore$ No. of bricks required for 6.82 cft Khoa $= \frac{850}{100} \times 6.82 = 57.97 \simeq 58$ (Ans.)

[BPDB-2018, BEPCL-16]

* Determine the volume of cement, sand and stone chips for 10 cft cement concrete mix of ratio 1:1.5:3.

Solution:

Dry volume of cc $= (1.5 \times 10) = 15$ cft

Given that,

C : FA : CA = 1 : 1.5 : 3

$\therefore$ Required cement, $c = \frac{1}{1+1.5+3} \times 15 = 2.73$ cft

Required sand, $FA = \frac{1.5}{5.5} \times 15 = 4.09$ cft

Required stone chips, $CA = \frac{3}{5.5} \times 15 = 8.18$ cft

(Ans:)

[EED-2019]

* Find the quantity of stone chips and cement for casting a RCC slab of size 12 ft x 8 ft and thickness 5 inch. The ratio of casting is 1:1.5:3.

Solution:

volume of slab $= \left(12 \times 8 \times \frac{5}{12}\right) = 40$ cft

$\therefore$ Dry volume of slab $= (1.5 \times 40) = 60$ cft

$\therefore$ Required cement $= \frac{1}{1+1.5+3} \times 60 = 10.91$ cft

Required stone chips $= \frac{3}{5.5} \times 60 = 32.73$ cft

(Ans:)

[BWDB-2018]

* Eight cube of 6" x 6" is made of concrete with ratio of 1:3:6. How many of cement bags required?

Solution:

Total volume of 8 cubes $= 8 \times \left(\frac{6}{12}\right)^3 = 1$ cft

$\therefore$ Dry volume $= (1.5 \times 1) = 1.5$ cft

$\therefore$ Amount of cement required $= \frac{1}{1+3+6} \times 1.5 = 0.15$ cft

we know, 1 bag $= 1.25$ cft. $\therefore$ No. of bag $= \frac{0.15}{1.25} = 0.12$ bags

(Ans:)

* A concrete block is of size (5 ft × 2.5 ft × 5 inch) and its density = 2130 Kg/m³. What Kg of cement is required for the concrete block of mix ratio 1:2:4.

Solution: volume of concrete block $= \left(5 \times 2.5 \times \frac{5}{12}\right) = 5.21$ cft

$\therefore$ Dry volume of cc $= (1.5 \times 5.21) = 7.815$ cft

Weight of concrete block =

$\therefore$ Amount of cement required $= \left(\frac{1}{1+2+4} \times 7.815\right)$ cft

$= 1.12$ cft

We Know, 1.25 cft = 1 bag cement

$\therefore$ No. of Bags $= \frac{1.12}{1.25} = 0.896$ Bags

Again, 1 bag = 50 Kg

Hence, Total amount of cement required $= (0.896 \times 50)$ Kg

$= 44.8$ Kg

$\simeq 45$ Kg.

(Ans.)

[EEED-2020]

* A concrete block is of size. 5 ft × 2.5 ft × 5 inch and its density = 2130 kg/m³ How much cement (kg) is required for the concrete block with mix ratio of 1:2:4.

Solution: Volume of concrete block = $\left(5 \times 2.5 \times \frac{5}{12}\right) = 5.21$ cft

$\therefore$ Weight of concrete block = $\left(5.21 \times \frac{2130}{3.28 \times 3.28 \times 3.28}\right)$ Kg

$= 314.5$ kg

$\therefore$ Dry weight of concrete block = (1.5×314.5) Kg

$= 471.75$ Kg

Amount of cement = $\left(\frac{1}{1+2+4} \times 471.75\right) = 67.4$ Kg

(Ans.)

[EEED-2015]

* Evaluate the amount of cement, sand and stone aggregate needed to cast on RCC beam of 20 ft long and size = 12" × 24". consider, mixing ratio is 1:1.5:3

Solution: Volume of beam = $\left(20 \times \frac{12}{12} \times \frac{24}{12}\right) = 40$ cft

$\therefore$ Dry volume of cc = $(1.5 \times 40) = 60$ cft

Amount of cement required = $\left(\frac{1}{1+1.5+3} \times 60\right) = 10.91$ cft

Amount of sand required = $\left(\frac{1.5}{5.5} \times 60\right) = 16.36$ cft

Amount of aggregate required = $\left(\frac{3}{5.5} \times 60\right) = 32.73$ cft

(Ans)

[PGCB-2018]

* Nine column having $\frac{\pi}{2}$ ft diameter and π m hieght need to cast in a mix ratio of 1:2:4. Find the amount of ingredients.

Solution:

Total volume of columns $= 9 \times \pi \times \left(\frac{\pi}{2 \times 2}\right)^2 \times (\pi \times 3.28) = 179.72$ cft

Dry volume of c.c $= (1.5 \times 179.72)$ cft $= 269.58$ cft

$\therefore$ Amount of cement required $= \left(\frac{1}{1+2+4} \times 269.58\right) = 38.51$ cft

sand required $= \left(\frac{2}{7} \times 269.58\right) = 77.02$ cft

Aggregate required $= \left(\frac{4}{7} \times 269.58\right) = 154.05$ cft

(Ans.)

[SGFL-2021]

* Calculate the materials needed for 100 cft fresh concrete with a mix ratio = 1 : 2.5 : 4.5

Solution:

Dry volume of concrete $= (1.5 \times 100)$ cft $= 150$ cft

$\therefore$ Required cement $= \left(\frac{1}{1+2.5+4.5} \times 150\right) = 18.75$ cft

required sand $= \left(\frac{2.5}{8} \times 150\right) = 46.875$ cft

required aggregate $= \left(\frac{4.5}{8} \times 150\right) = 84.375$ cft

(Ans.)

[BUET M.Sc.- 2014]

* A partition wall is 5" thickness, 25 ft length and 10 ft height. Using standard brick size, determine the amount of bricks, cement and sand if mortar ratio is 1:3

Solution: volume of brick wall $= \left(25 \times 10 \times \frac{5}{12}\right) = 104.17$ cft

We know,

For 100 cft brickworks required bricks = 1200 Nos.

∴ For 104.17 cft brickworks required bricks $= \frac{1200 \times 104.17}{100}$

$= 1250$ Nos.

Again,

For 100 cft brickworks required mortar = 45 cft

∴ For 104.17 cft brickworks, required mortar $= \frac{45}{100} \times 104.17$ cft

$= 46.88$ cft

Given, C:S = 1:3

∴ Amount of cement $= \left(\frac{1}{4} \times 46.88\right) = 11.72$ cft

Amount of sand $= \left(\frac{3}{4} \times 46.88\right) = 35.18$ cft

(Ans.)

[HBRI-2019]

* Calculate the amount of cement, fine aggregate and reinforcement (consider 0.75%) of the footing size = 10'×10' and thickness = 18"

Solution: volume of footing $= \left(10 \times 10 \times \frac{18}{12}\right) = 150$ cft

∴ Dry volume of cc $= (1.5 \times 150) = 225$ cft. Assume, C:FA:CA = 1:2:4

Req. cement $= \left(\frac{1}{7} \times 225\right) = 32.14$ cft, Req. sand $= \left(\frac{2}{7} \times 225\right) = 64.29$ cft

Req. aggregate $= \left(\frac{4}{7} \times 225\right) = 128.57$ cft, Req. steel $= \left(150 \times \frac{0.75}{100}\right) = 1.125$ cft

(Ans.)

Specific Gravity:

Bulk Specific Gravity (SSD) $= \frac{B}{B-C}$

Bulk Specific Gravity (Dry) $= \frac{A}{B-C}$

Apparent Specific Gravity $= \frac{A}{A-C}$

% Absorption $= \frac{B-A}{A} \times 100\%$

where,

A = Oven dry weight

B = SSD weight

C = SSD sample weight in water

[ERL-2017, MPL-17, JOCL-18]

* For a coarse aggregate sample, air dry weight is 1790 gm, weight when it is immersed in water 1180 gm and SSD weight is 1850 gm. Calculate the bulk specific gravity, apparent specific gravity and also % absorption.

Solution: Given, A = 1790 gm

B = 1850 gm

C = 1180 gm

$\therefore$ Bulk specific gravity (SSD) $= \frac{B}{B-C} = \frac{1850}{1850-1180} = 2.76$

Bulk specific gravity (dry) $= \frac{A}{B-C} = \frac{1790}{1850-1180} = 2.67$

Apparent specific gravity $= \frac{A}{A-C} = \frac{1790}{1790-1180} = 2.93$

% Absorption $= \frac{B-A}{A} \times 100 = \frac{1850-1790}{1790} \times 100 = 3.35\%$

(Ans.)

CamScanner

[PGCL-2014] [BPDB-16, NPCBL-17]

* The dry mass of a sample of aggregate 1982 g. The mass in saturated surface dry condition is 2006.7 g. The volume of water exerted by the sample is 734.4 cm^3. Find the bulk specific gravity, apparent specific gravity and percentage of absorption of the sample.

Solution: Given, $A = 1982\ g$

$B = 2006.7\ g$

and, $A - C = 734.4\ g$ [$\because 1\ g = 1\ cm^3$]

Absorbed water, $B - A = (2006.7 - 1982) = 24.7\ gm$

$\therefore$ % Absorption $= \frac{24.7}{1982} \times 100 = 1.246\%$

Now, $B - C = (A - C) + (B - A) = (734.4 + 24.7) = 759.1\ g$

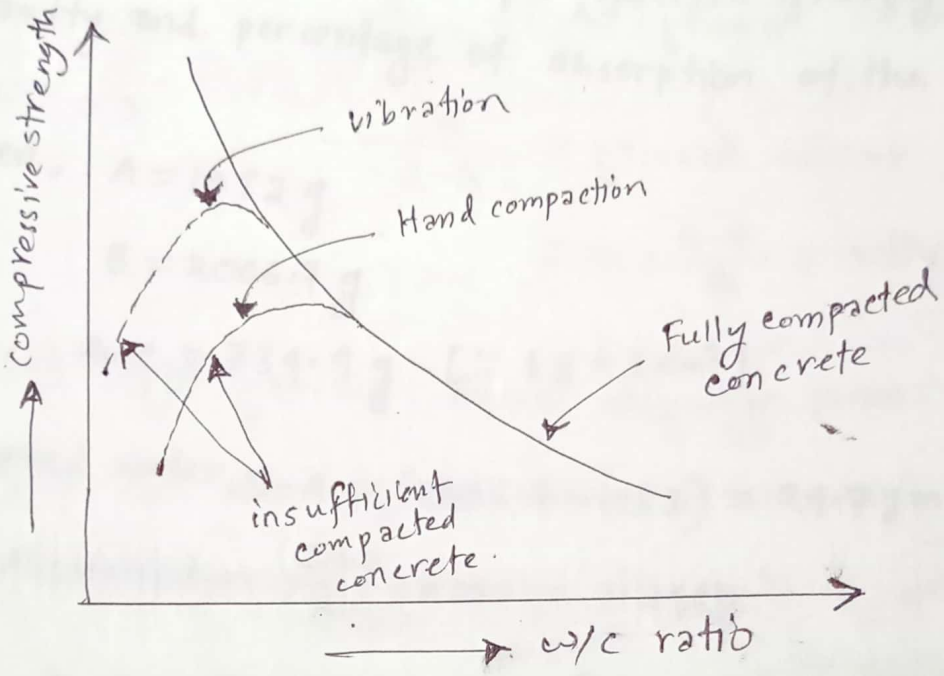
$\therefore$ Bulk specific Gravity (SSD) $= \frac{B}{B - C} = \frac{2006.7}{759.1} = 2.644$

Bulk specific Gravity (dry) $= \frac{A}{B - C} = \frac{1982}{759.1} = 2.611$

Apparent specific Gravity $= \frac{A}{A - C} = \frac{1982}{734.4} = 2.699$

(Ans.)

Relation between compressive strength and w/c ratio for different types of compaction.



Chain Correction:

1. True length of the line, $(TL) = \frac{L'}{L} \times$ Measured Length (ML)
2. True Area of the land, $(TA) = \left(\frac{L'}{L}\right)^2 \times$ Measured Area (MA)

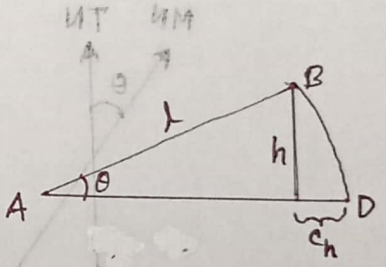
where, L = Standard length or True length of chain

L' = True length of chain (L) ± error

* use (+ve) sign, when the chain is too long.
* use (-ve) sign, when the chain is too short.

Tape Correction:

1. Temperature correction, $C_t = \alpha (T_m - T_o) L$
2. Pull Correction, $C_p = \frac{(P_m - P_o) L}{AE}$
3. Slope correction, $C_h = \frac{h^2}{2l}$ (always negative)
4. Sag Correction, $C_s = \frac{L W^2}{24 n^2 P_m^2}$



where, T_m, P_m ➤ during measurement

T_o, P_o ➤ at which the tape was standardize

T = Temperature
P = Pull

L = Length of tape

W = Total weight of tape

n = No. of span

Representative Fraction (RF):

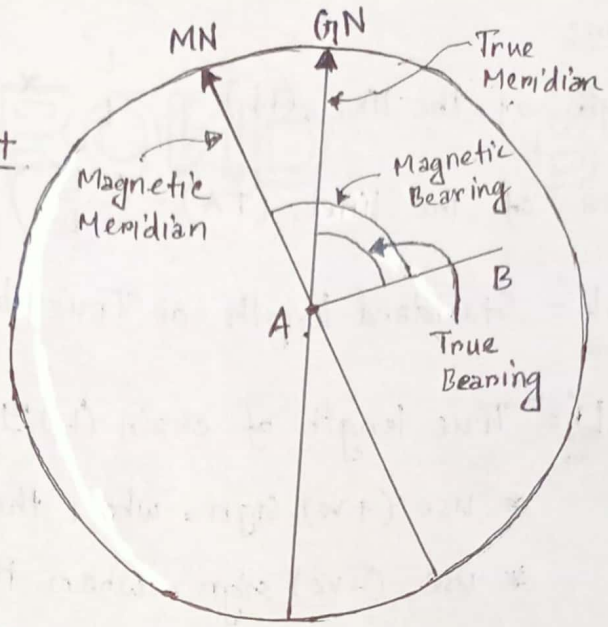
$$RF = \frac{\text{distance on drawing of object}}{\text{corresponding actual distance of object}}$$

* True distance $= \frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times$ Measured distance

Magnetic Bearing:

1. Reduced Bearing:

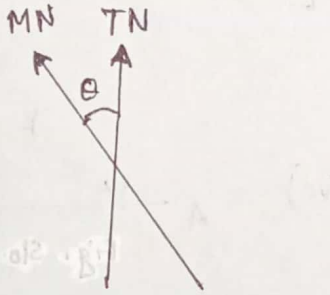
WCB	RB(QB)	Quardrant
0-90°	WCB	NE
90-180°	180-WCB	SE
180-270°	WCB-180	SW
270-360°	360-WCB	NW



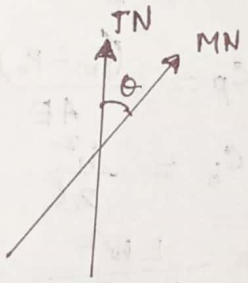
2. Magnetic Declination:

True Bearing = Magnetic Bearing − Declination (west)

= Magnetic Bearing + Declination (East)



Declination (west)

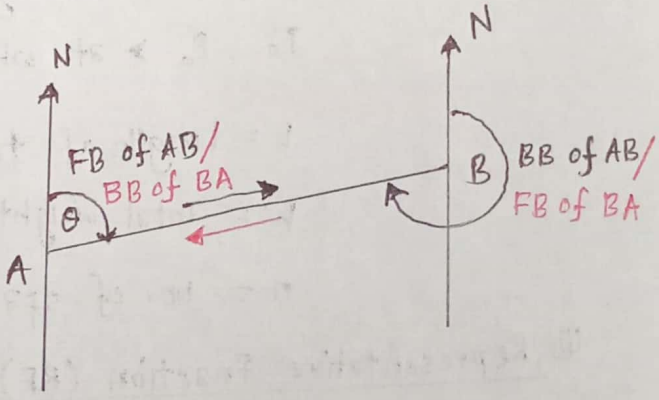


Declination (East)

3. Fore Bearing and Back Bearing:

Back Bearing = Fore Bearing ± 180°

* Use (+ve) sign, when FB < 180°
* Use (−ve) sign, when BB > 180°



Chain Correction:

1. Correction applied to Incorrect Length:

$$\text{True length of the line (TL)} = \left(\frac{L'}{L}\right) \times \text{Measured Length (ML)}$$

Where, L = Standard length or True length of chain (L)

L' = True length of chain (L) ± error (e)

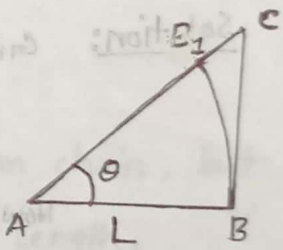
* use (+ve) sign, when the chain is too long
* use (-ve) sign, when the chain is too short

2. Correction of Incorrect Area:

$$\text{True Area} = \left(\frac{L'}{L}\right)^2 \times \text{Measured Area}$$

3. Hypotenusal Allowance:

Hypotenusal Allowance per tape, $B_1C = L(\sec\theta - 1)$



[WRGCL-2014, BPDB-16, WARPO-17, JOC-18, DESCO-19]

* A correct distance of 1000 m was measured with a 25 m chain which was actually found to be 24.90 m. Calculate the chain distance.

Solution: Given data, TL = 1000 m, L = 25 m, L' = 24.90 m

We know, $TL = \left(\frac{L'}{L}\right) \times ML \Rightarrow 1000 = \left(\frac{24.9}{25}\right) \times ML \quad \therefore ML = 1004.016\text{m}$

∴ The chain distance / measured distance = 1004.016 m. (Ans.)

[BBAD-2018, AB-17]

* The length of the line measured with 20m chain found to be 250 m. It was subsequently found that the chain was 10 cm too long. What is the length of the line?

Solution: Given data, $ML = 250\,m$, $L = 20\,m$, $e = +10\,cm$ (too long)

$$\therefore L' = L + e = \left(20 + \frac{10}{100}\right) = 20.10\,m$$

We know, True length of the line, $TL = \frac{L'}{L} \times ML$

$$\therefore TL = \left(\frac{20.10}{20} \times 250\right) m = 251.25\,m$$

(Ans.)

[BREB-2018]

* The length and breadth of a plot of land were measured by an engineer's chain exactly 20m in length at begining. But it was found to be 20.03 m at the end. Calculated Area is 50.4 m^2. Find the correct Area.

Solution: Given, $L = 20\,m$

$L' = 20.03\,m$ $\quad \therefore$ error $= (20.03 - 20) = 0.03\,m$

Now, considering mean elongation, $e = \frac{0.03}{2} = 0.015\,m$

$\therefore$ Mean length of chain, $L' = (20 + 0.015) = 20.015\,m$

We know,

$$\text{True Area} = \left(\frac{L'}{L}\right)^2 \times \text{Measured Area}$$

$$= \left(\frac{20.015}{20}\right)^2 \times 50.4$$

$$= 50.476\,m^2$$

(Ans.)

[MPL-2017, JOCL-18]

* A road is actually 25320 ft long. This distance is measured by a defective chain and it was found 25270 ft. How much increase or decrease needed of the length for the chain of 100 ft.

Solution: Given data, $TL = 25320$ ft

$ML = 25270$ ft

$L = 100$ ft

We know, $TL = \left(\frac{L'}{L}\right) \times ML$

$\Rightarrow 25320 = \frac{L'}{100} \times 25270$

$\Rightarrow L' = 100.198$ ft

$\therefore$ error, $e = (100.198 - 100) = 0.198$ ft. Hence, the chain is too long.

So, The chain is needed to decrease 0.198 ft.

(Ans.)

[TGTDCL-2021]

* The distance between two points measured 1000 m with a 25 m chain, but it was found that the chain is 25.15 m. Calculate the actual length.

Solution: Given data, $ML = 1000$ m

$L = 25$ m

$L' = 25.15$ m

We know, $TL = \frac{L'}{L} \times ML$

$\Rightarrow TL = \left(\frac{25.15}{25}\right) \times 1000$

$\therefore TL = 1006$ m

$\therefore$ Actual distance $= 1006$ m. (Ans.)

[BBAD-2018, AB-17]

[BUET MSc - 2014]

* Chainage of a survey line is actual 36990 ft, but it found in practical field is 36995 ft. Find the percentage of error. *

Solution:

$$\text{percentage of error} = \frac{36995 - 36990}{36990} \times 100 = 0.0135\%$$

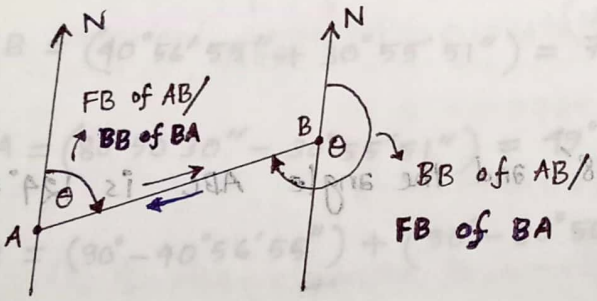
(Ans.)

Magnetic Bearing:

1. Reduced Bearing:

WCB	RB (QB)	Quardrant
0° – 90°	WCB	NE
90° – 180°	180 – WCB	SE
180° – 270°	WCB – 180	SW
270° – 360°	360 – WCB	NW

2. Fore Bearing and Back Bearing:



* Back Bearing (BB) = Fore Bearing (FB) ± 180°

Where,

+ve sign ⇝ FB < 180°

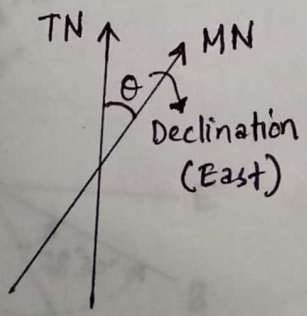
-ve sign ⇝ FB > 180°

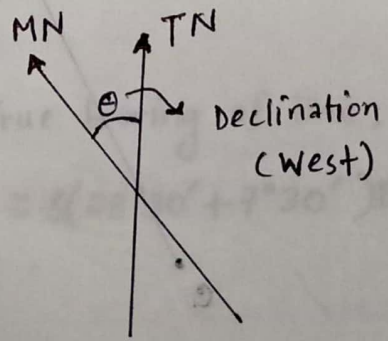
3. Magnetic Declination:

True Bearing = Magnetic Bearing – Declination (west)

= Magnetic Bearing + Declination (East)

} For WCB

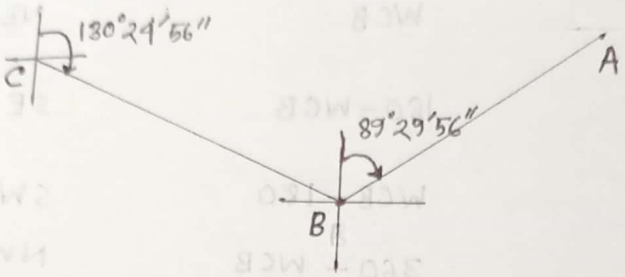




[PGCB-2017]

* Find the angle ABC if fore bearing of line CB and BA are 130°24'56" and 89°29'56" respectively.

Solution:



$\angle ABC$ = 360 − BB of CB + FB of BA

= 360 − (180 + 130°24'56") + 89°29'56"

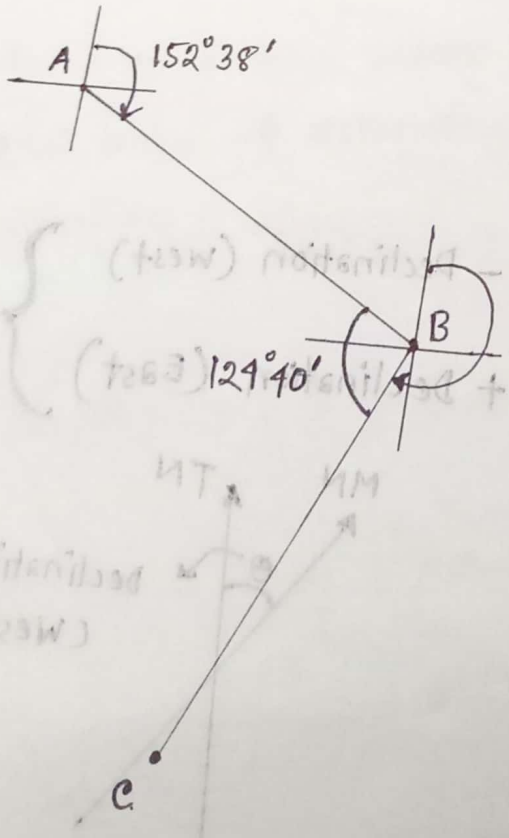
= 139°5'0"

(Ans.)

[DPDC-2014]

* The bearing of Line AB is 152°38' and the angle ABC is 124°40'. Find the bearing of BC.

Solution:



Here,

$\angle ABC$ = BB of AB − FB of BC

$\Rightarrow 124°40' = (180° + 152°38') - FB \text{ of } BC$

$\Rightarrow FB \text{ of } BC = (332°38' - 124°40')$

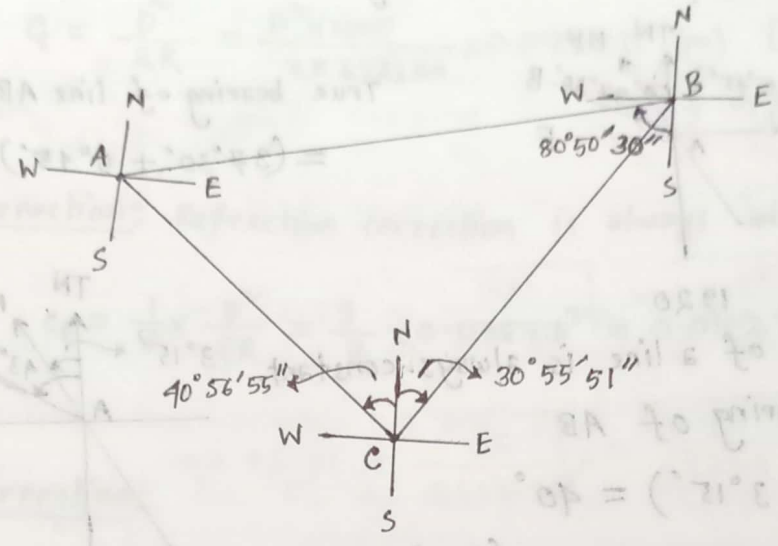
$\therefore FB \text{ of } BC = 207°58'$

(Ans.)

[PGCL-2014, DTCA-18, BADC-20, BPDB-21]

* Calculate the internal angles of a triangle, if the bearing of line BA = S 80°50′30″ W, CA = N 40°56′55″ W and CB = N 30°55′51″ E

Solution:



$\angle ACB = (40°56'55'' + 30°55'51'') = 71°52'46''$

$\angle CBA = (80°50'30'' - 30°55'51'') = 49°54'39''$

$\angle CAB = (90° - 40°56'55'') + (90° - 80°50'30'') = 58°12'35''$

Check:

$\angle ACB + \angle CBA + \angle CAB$

$= 180°$

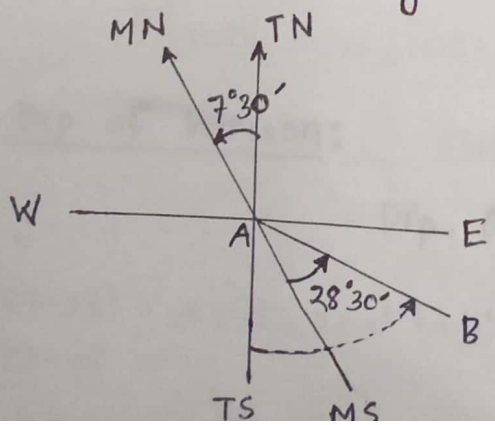
(Ans.)

[BUET M.Sc.-2017]

* The magnetic bearing of a line AB is S 28°30′E. Calculate the true bearing if the declination 7°30′ west.

Solution:

True bearing = Magnetic Bearing ± Declination



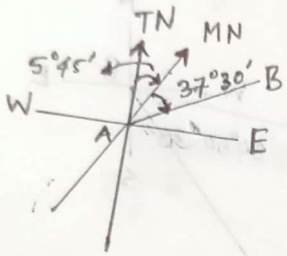
Here, True bearing of line, AB

$= S(28°30' + 7°30')E = S\,36°0'E$

[BUET M.Sc. - 2018]

* In 1920, the magnetic bearing was N 37°30′ E and the declination was 5°45′ E. What will be the True bearing in 2015 if the declination in 2015 is 3°15′ E?

Solution:



1920

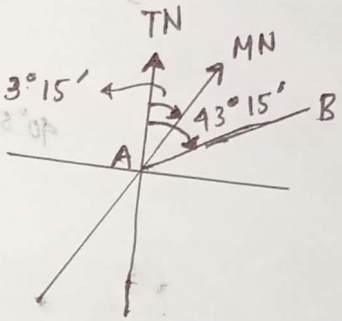
The True bearing of a line is always constant.

∴ Magnetic bearing of AB

$= (43°15′ - 3°15′) = 40°$ (Ans.)

True bearing of line AB

$= (37°30′ + 5°45′) = 43°15′$



2015

Correction to be applied in Levelling:

1. **Curvature correction:** curvature correction is always subtractive (i.e. negative)

$$C_c = \frac{D^2}{2R} = \frac{D^2 \times 1000}{2 \times 6371\,\text{Km}} = 0.0785\,D^2\ (\text{m}) \quad [\text{Negative}]$$

D in Km

2. **Refraction correction:** Refraction correction is always additive. (i.e. positive)

$$C_r = \frac{1}{7} \times \frac{D^2}{2R} = \frac{1}{7} \times 0.0785\,D^2 = 0.0112\,D^2\ (\text{m}) \quad [\text{positive}]$$

D is Km.

3. **combined correction:**

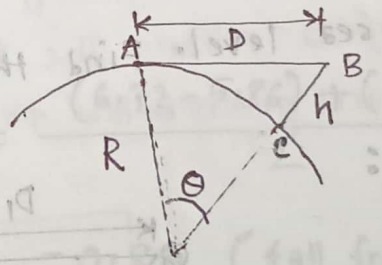
combined correction = curvature correction + Refraction correction

$$= -0.0785\,D^2 + 0.0112\,D^2$$

$$= -0.0673\,D^2\ (\text{m})$$

It is also expressed as, $-\frac{6}{7} \times \frac{D^2}{2R}$

4. **visible horison distance:**



considering curvature and refraction corrections,

$$h = 0.0673\,D^2$$

$$\therefore D = \sqrt{\frac{h}{0.0673}}$$

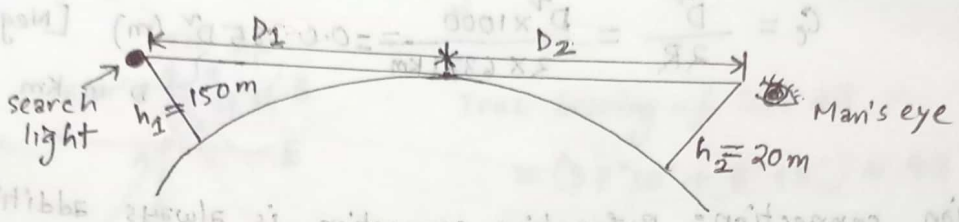
5. **Dip of horison:**

$$\text{Dip}, \theta = \frac{D}{R}$$

[BCPCL-2016]

* Height of search light from sea level is 150 m and observes eye at 20 m from sea level. Determine the distance between the observer and search light.

Solution:



$$D_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{150}{0.0673}} = 47.21 \text{ Km}$$

$$D_2 = \sqrt{\frac{h_2}{0.0673}} = \sqrt{\frac{20}{0.0673}} = 17.24 \text{ Km}$$

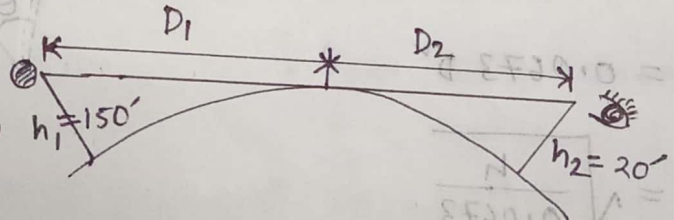
∴ The distance between the observer and search light, $D_1 + D_2 = (47.21 + 17.24)$ Km
$= 64.45$ Km (Ans.)

[SGFCL-2017]

* A man on the deck of a ship observes the light of a light house which is 150 ft above sea level. If the man's eye level is 20 ft above sea level. Find the actual distance between them.

Solution:

Given,
$h_1 = 150$ ft $= 45.73$m
$h_2 = 20$ ft $= 6.1$ m



$$\therefore D_1 = \sqrt{\frac{45.73}{0.0673}} = 26.07 \text{ Km}$$

and, $$D_2 = \sqrt{\frac{6.1}{0.0673}} = 9.52 \text{ Km}$$

∴ The distance between the observer and light house, $D_1 + D_2 = (26.07 + 9.52)$ Km
$= 35.59$ Km (Ans.)

Reciprocal surveying:

In reciprocal levelling,

True difference between the level $= \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$

where, a_1, b_1 = staff reading in first setting.

a_2, b_2 = staff reading in second setting.

[RPGCL-2017, BCIC-17]

* In a reciprocal levelling, two points A and B are taken on opposite banks of a river. Two stations C and D & their measurement points are given. Find out the RL of A if the RL of B is 108.82m.

Station	staff Reading on	
	A	B
A	6.72	5.86
B	4.96	4.18

Solution:

True difference between A and B $= \frac{(6.72 - 5.86) + (4.96 - 4.18)}{2}$

$= 0.82$ (fall from B to A)

Given, RL of B = 108.82m

$\therefore$ RL of A $= (108.82 - 0.82) = 108$ m

(Ans.)

[PGCL-2017, M.Sc, BUET-19]

* In a reciprocal levelling, Find the true elevation of Q if the reduced level of P is 100 m.

Station	Staff Readings	
	P	Q
P	3.69	2.48
Q	4.59	3.34

Solution:

True difference between P and Q $= \frac{(3.69-2.48)+(4.59-3.34)}{2}$

$= 1.23$ (fall from Q to P)

Given, RL of P = 100 m.

$\therefore$ RL of Q $= (100 + 1.23) = 101.23$ m (Ans.)

[GTCL-2018]

* In reciprocal levelling, two points A and B are taken on opposite banks of a river. The two station C and D & their measurement points are given below table. Find the RL of B, if RL of A = 108.82

Stations	Staff Readings	
	A	B
C	5.79	5.12
D	4.96	4.18

CamScanner

Solution:

True difference between A and B $= \frac{(5.79-5.12)+(4.96-4.18)}{2}$

$= 0.725$ m (fall from B to A)

Given, RL of A = 108.82 m

$\therefore$ RL of B $= (108.82 + 0.725) = 109.54$ m

(Ans.)

Calculation of Reduced Level:

[JB-2017]

* The following consecutive staff reading was taken using dumpy level: 0.705, 1.655, 0.890, 3.015 and 1.655. The first reading was taken on a benchmark whose RL is 150.605 m. calculate the reduced levels of the stations by rise and fall method.

Solution:

Station	BS	IS	FS	Rise (+)	Fall (−)	RL
1	0.705					150.605
2		1.655			0.95	149.655
3		0.890		0.765		150.42
4	1.655	3.015	3.015		2.125	148.295
5			1.655	1.36		149.655
	ΣBS = 0.705		ΣFS = 1.655	ΣRise = 2.125	ΣFall = 3.075	

Check:

$\Sigma BS - \Sigma FS = (0.705 - 1.655) = -0.95$

$\Sigma Rise - \Sigma Fall = (2.125 - 3.075) = -0.95$

$Last\ RL - First\ RL = (149.655 - 150.605) = -0.95$

Computation of Area & Volume

1. Mid-Ordinate Rule:

$$\text{Area of plot} = (h_1 + h_2 + h_3 + \ldots\ldots + h_n) \times d$$

(d → common distance between two ordinates)

where, $h_1 = \frac{O_1 + O_2}{2}$

$h_2 = \frac{O_2 + O_3}{2}$

. . . . .

2. Average-Ordinate Rule:

$$\text{Area of plot} = \frac{O_1 + O_2 + O_3 + \ldots\ldots + O_n}{n+1} \times l$$

(l → length of base line)

3. Trapezoidal Rule:

$$\text{Area of plot} = \frac{d}{2}\left\{ O_1 + O_n + 2 \times (O_2 + O_3 + \ldots\ldots + O_{n-1}) \right\}$$

4. Simson's Rule:

$$\text{Area of plot} = \frac{d}{3}\left\{ O_1 + O_n + 4(O_2 + O_4 + O_6 \ldots) + 2(O_3 + O_5 + \ldots) \right\}$$

* limitation: This rule is applicable only when the no. of division is even i.e no. of ordinates is odd.

computation of volume:

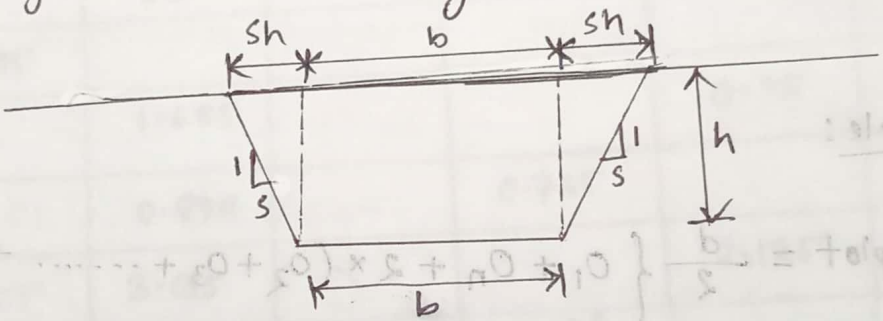
1. Trapezoidal Rule: (Average end area)

Volume (cutting/Filling), $V = \frac{b}{2}\{A_1 + An + 2(A_2 + A_3 + \cdots + An-1)\}$

2. Prismoidal Rule:

Volume (cutting/Filling), $V = \frac{D}{3}\{A_1 + An + 4(A_2 + A_4 + \cdots) + 2(A_3 + A_5 + \cdots)\}$

* when ground is level along transverse direction



cross sectional area, $A = \left(\frac{b+b+2sh}{2}\right) \times h = (b+sh)\,h$

[DTCA-2018, BBAD-2018, BWDPB-19]

* Calculate the volume of earthwork necessary for a portion of an irrigation canal from the following data by trapezoidal rule.

Chainage (ft)	0	100	200	300	400	500
Area (ft^2)	850	875	860	855	860	865

Solution:

According to Trapezoidal Rule,

$$V = \frac{d}{2} \times \{A_1 + A_n + 2(A_2 + A_3 + \cdots + A_{n-1})\}$$

$$= \frac{100}{2} \times \{850 + 865 + 2(875 + 860 + 855 + 860)\}$$

$$= 430750 \text{ cft}$$

(Ans.)

[BCSC-2019]

* Calculate the volume of road embankment by trapezoidal rule.

Solution:

Interval (ft)	100	200	300	400	500
Area (ft^2)	10	25	30	50	60

According to Trapezoidal Rule,

$$V = \frac{100}{2} \times \{10 + 60 + 2 \times (25 + 30 + 50)\}$$

$$= 14000 \text{ cft}$$

(Ans.)

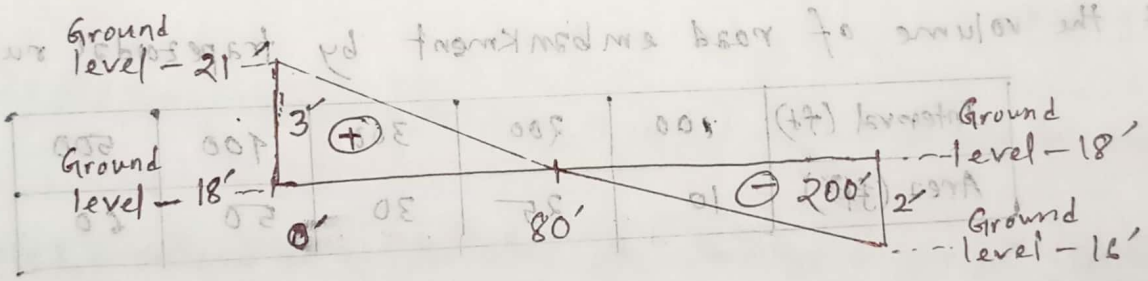
[SGFL-2017, BGFCL-17]

* An embankment of width 25 ft and side slopes 2.5 H : 1 V is required to be made on a ground which is level in a direction traverse to the center line. calculate the volume of earth work. The ground level along the center line of the embankment is given below:

chainage (ft)	0	80	200
GL (ft)	21	18	16

Solution:

Chainage	GL	FL	Cutting (+)	Filling (-)
0	21	18	3	–
80	18	18	–	–
200	16	18	–	2



Area of cutting $= (b + sh) \times h = (25 + 2.5 \times 3) \times 3 = 97.5\ ft^2$

Area of filling $= (b + sh) \times h = (25 + 2.5 \times 2) \times 2 = 60\ ft^2$

$\therefore$ volume of cutting $= \left(\frac{0 + 97.5}{2}\right) \times 80 = 3900\ ft^3$

and, volume of filling $= \left(\frac{0 + 60.0}{2}\right) \times (200 - 80) = 3600\ ft^3$

(Ans.)

[EED-2019]

* Figure 1 & 2 represents two highway cross section (pre work) 100ft apart. Compute the volume of earth work to be required for the design of the section.

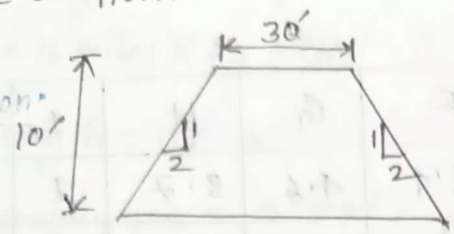


Fig. 1

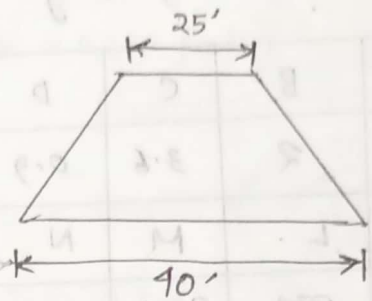
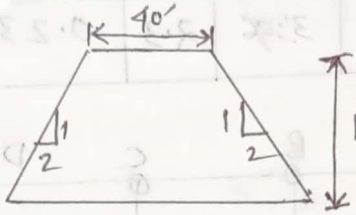


Fig. 2



Design section

Fig. 3

Solution:

$A = (b + Sh) \times h$

Area of section-1, $A_1 = (30 + 2 \times 10) \times 10 = 500\ ft^2$

Area of section-2, $A_2 = \frac{1}{2}(40 + 25') \times 12 = 390\ ft^2$

∴ Prework volume, $V_1 = \frac{1}{2} \times (A_1 + A_2)$

$= \frac{100}{2} \times (500 + 390)$

$= 44500\ ft^3$

Post work volume $= \{(40 + 2 \times 14) \times 14\} \times 100$

$= 95200\ ft^3$

∴ Volume of earth work required $= (95200 - 44500)\ ft^3$

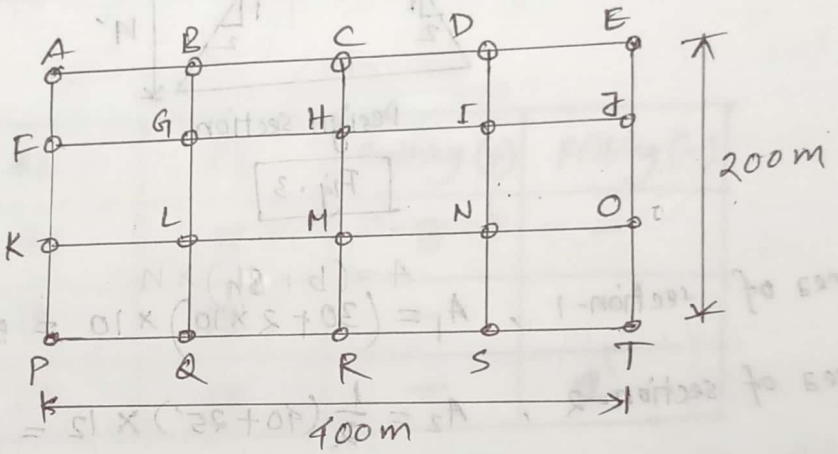
$= 50700\ ft^3$

(Ans.)

[PMO-2015]

* The area of land is 400m x 200m and Reduced Level at different point in the land is below table which is shown in figure. Determine the earth filling work.

point	A	B	C	D	E	F	G	H	I	J
RL	0.8	2	3.6	0.9	10	2.1	4.6	8.7	1	0.2
point	K	L	M	N	O	P	Q	R	S	T
RL	12	5.4	5	7.9	2.3	0.23	0	3.6	11	7



Solution:

Area of each rectangular $= \left(\frac{400}{4} \times \frac{200}{3}\right) = 6666.67\ m^2$

volume, $V = \frac{A}{4}\left(1\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 4\Sigma h_4\right)$

Here,

$1\Sigma h_1 = 1\left(\underset{A}{0.8} + \underset{E}{10} + \underset{P}{0.23} + \underset{T}{7}\right) = 18.03\ m$

$2\Sigma h_2 = 2\left(\underset{F}{2.1} + \underset{K}{12} + \underset{J}{0.2} + \underset{O}{2.3} + \underset{B}{2} + \underset{C}{3.6} + \underset{D}{0.9} + \underset{Q}{0} + \underset{R}{3.6} + \underset{S}{11}\right)$

$= 76\ m$

$3\Sigma h_3 = 3 \times (0) = 0\ m$

$4\Sigma h_4 = 4\left(\underset{G}{4.6} + \underset{H}{8.7} + \underset{I}{1} + \underset{L}{5.4} + \underset{M}{5} + \underset{N}{7.9}\right) = 130.4\ m$

Volume, $V = \frac{6666.67}{4} \times (18.03 + 76 + 0 + 130.4) = 374050.187\ m^3$

(Ans)

[PGCB-2015]

Photometric Surveying

* For aerial photography, determine the number of flight lines from the following data,

Area = 16 miles X 20 miles (1 mile = 5280 feet)

Focal length = 12"

Photography size = 9" x 9"

photograph scale = 1: 10000

overlap = 60%

Sidelap = 25%

Flight lines in the direction of 20 miles and the outer lines coincide with boundaries.

Solution:

Given, $S = \frac{H}{f} = 10000$, $l = 9"$, $P_l = 60\%$, $P_s = 25\%$, $L_1 = 20m$, $L_2 = 16m$

We know, Number of flight line, $N_2 = \frac{L_2}{\quad} + 1$

$$= \frac{L_2}{(1-P_s) \times S \times \omega} + 1$$

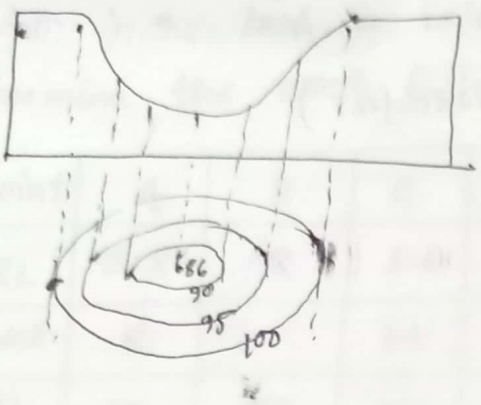
$$= \frac{16 \times 5280}{(1-0.25) \times 10000 \times \frac{9}{12}} + 1$$

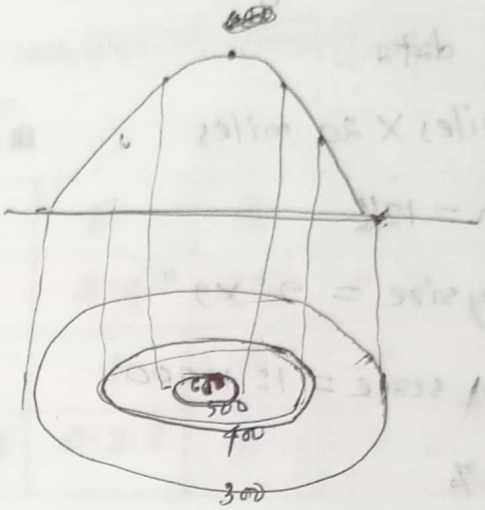
$$= 16.02$$

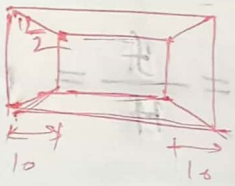
$$\simeq 17 \text{ Nos. flight}$$

(Ans.)

Draw contour for pond and hill.





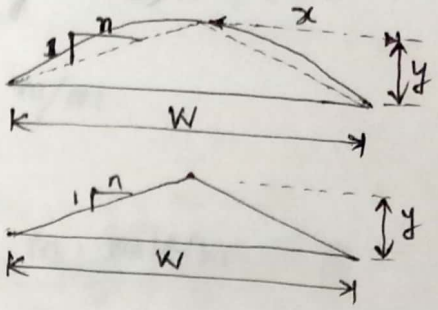


Highway Engineering

Highway Geometric Design:

* **Camber:** (i) For parabolic shape, $y = \frac{2x^2}{nW}$

(ii) For straight, $y = \frac{W}{2n}$



* Stopping Sight distance (SSD):

Stopping distance = lag distance + braking distance

$\therefore SD(m) = Vt + \frac{V^2}{2g(f \pm n)}$ where, V is in m/sec.

[t = 2.5 sec.]

$SD(ft) = 1.47\,Vt + \frac{V^2}{30(f \pm n)}$ where, V is in mph (mile/hr)

If not given, $f = \frac{11.2}{32.2} = 0.35$

*Note:

For two way traffic with two lane, SSD = SD

For two way traffic with single lane, SSD = 2SD

For head light sight distance, SSD = SD

For intermediate sight distance, SSD = 2SD

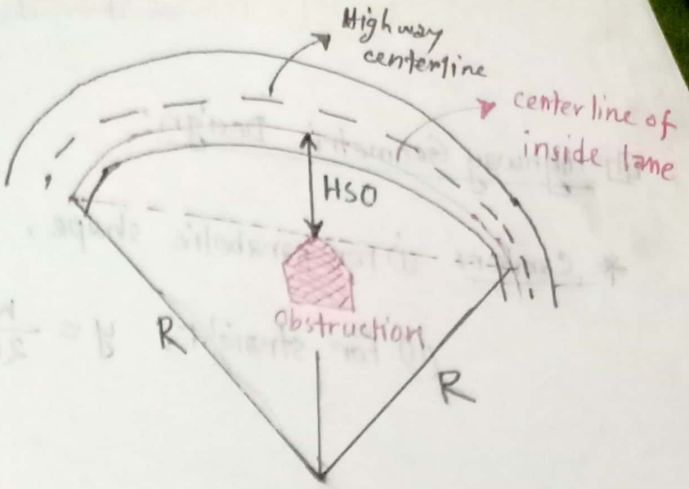
1 Kmph = $\frac{1}{3.6}$ m/sec.

1 mph = 0.447 m/sec.

1 mile = 5280 ft = 1609.34 m

Horizontal sight line Offset (HSO):

$$HSO = R\left(1 - \cos\left(\frac{28.65}{R} \times SSD\right)\right)$$



* Overtaking Sight Distance (OSD):

$OSD\ (m) = d_1 + d_2 + d_3$ where, $d_1 = V_b t$ [V_b, V is in m/sec]

$= (V_b t + V_b T + 2s + VT)$ $d_2 = V_b T + 2s$ Here, $s = (0.2 V_b + 6)$

$d_3 = VT$ $T = \sqrt{\frac{4s}{a}}$ (m/sec^2)

$t = 2.0$ sec.

* Minimum overtaking zone = 3 OSD
* Desirable overtaking zone = 5 OSD

$OSD\ (ft) = d_1 + d_2 + d_3 + d_4$ where, $d_1 = 1.47\, t_1 \left(V_b - m + \frac{a t_1}{2}\right)$

$= 1.47 \left(V_b t_1 + \frac{1}{2} a t_1^2\right)$

Here, $m = V - V_b$

V = speed of overtaking/passing vechicle

V_b = speed of over taken/passed vechicle $= (V - 4.5)$

t_1 = time for initial maneuver

t_2 = time overtaking vechicle is travelling in another lane

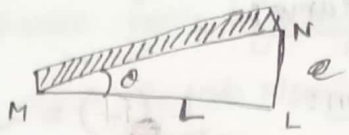
$d_2 = 1.47\, V t_2$

d_3 = safe distance bet^n overtaking vehicle and opposite vechicle = (100 ~ 300ft)

$d_4 = \frac{2}{3} \times d_2$

* Superelevation:

$$e = \tan\theta = \frac{NL}{ML}$$



$$e+f = \frac{V^2}{gR}$$ where, R is in m and V is in m/sec.

$$e+f = \frac{V^2}{15R}$$ where, R is in ft and V is in mile/hr

* Extra widening of Pavement:

$$W_e = W_m + W_{ps}$$

$$= \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

where, W_m = mechanical widening

W_{ps} = psychological widening

n = number of traffic lanes

l = length of wheel base (6.0 ~ 6.1

V = Design speed (Kmph)

R = Radius of curve, (m)

* Length of summit Curve: (crest verticle curve)

For SSD:

① When $L > S$, $L(m) = \frac{NS^2}{4.4}$ $\quad L(ft) = \frac{NS^2}{2158}$ (%)

Where, $N = n_1 - n_2$

S = SSD

② When $L < S$, $L(m) = 2S - \frac{4.4}{N}$

$L(ft) = 2S - \frac{2158}{N}$ (%)

For OSD:

① When, $L > S$, $L(m) = \frac{NS^2}{9.6}$

② When, $L < S$, $L(m) = 2S - \frac{9.6}{N}$



Summit

* Length of valley curve:

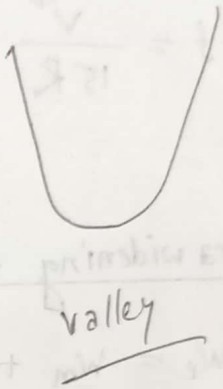
Comfort condition:

$$L(m) = 2\left[\frac{NV^3}{C}\right]^{\frac{1}{2}} = 0.38(NV^3)^{\frac{1}{2}}$$

Where, C = rate of change of centrifugal acceleration = 0.6 m/sec³

$$L(ft) = \frac{NS^2}{46.5}$$

Head light sight distance condition:



① When, $L > S$, $L(m) = \frac{NS^2}{(1.5 + 0.035S)}$

$$L(ft) = \frac{NS^2}{400 + 3.5S}$$

② When, $L < S$, $L(m) = 2S - \frac{1.5 + 0.035S}{N}$

$$L(ft) = 2S - \frac{400 + 3.5S}{N}$$

[LGED-2018, BPDB-15, BWDB-13, WRMCL-19]

* Calculate the stopping sight distance for a highway for which the design speed is 50 mph. Assume, $f = 0.42$ and also assume reasonable values for other data items involved in calculations.

Solution: We know,

$$SSD, (ft) = 1.47\,Vt + \frac{V^2}{30(f \pm n)}$$

Here, $V = 50$ mph, $f = 0.42$, $t = 2.5$ sec., $n = 0$

$$= 1.47 \times 50 \times 2.5 + \frac{(50)^2}{30 \times (0.42)}$$

$$= 382.16 \text{ ft}$$

(Ans)

Alternate Solution: Given, $V = 50$ mph $= \left(50 \times \frac{1609.34}{3600}\right)_{\text{m/sec.}} = 22.352$ m/sec.

We know,

$$SSD, (m) = Vt + \frac{V^2}{2g(f \pm n)}$$

$$= 22.352 \times 2.5 + \frac{(22.352)^2}{2 \times 9.81 \times 0.42}$$

$$= 116.51 \text{ m.}$$

(Ans.)

* Calculate the safe SSD for design speed of 45 Kmph for two way traffic on a two lane road. Assume, co-efficient of friction, $f = 0.38$ and reaction time, $t = 2.5$ sec.

Solution: Given, $V = 45$ Kmph $= \left(45 \times \frac{1000}{3600}\right)_{\text{m/sec.}} = 12.5$ m/sec.

We know,

$$SSD = Vt + \frac{V^2}{2gf} = 12.5 \times 2.5 + \frac{12.5^2}{2 \times 9.8 \times 0.38} = 52.23 \text{ m}$$

(Ans.)

[DESCO-2015]

* A car travelling at 50 mph on a highway observes a crash ahead of it. If the driver stopped the car 5 m in front of the crash, find the distance, it has travelled. perception time = 2.5 sec.

Solution: Given, $V = 50$ mph Assume, $f = 0.35$

$t = 2.5$ sec.

we know, $SSD. (ft) = 1.47\,Vt + \frac{V^2}{30f}$

$= 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times 0.35}$

$= 421.85$ ft (Ans.)

[35th BCS]

* Calculate the safe stopping sight distance for design speed of 50 Kmph for (a) two way traffic on a two lane road (b) two way traffic on a single lane road.

Solution: Given, $V = 50$ Kmph $= \frac{50}{3.6}$ m/sec. $= 13.89$ m/sec.

Assume, $f = 0.37$

$\therefore SD. (m) = Vt + \frac{V^2}{2gf} = 13.89 \times 2.5 + \frac{(13.89)^2}{2 \times 9.8 \times 0.37}$

$\therefore SD = 61.33$ m

(a) For two way traffic on two lane road, $SSD = SD = 61.33$ m

(b) For two way traffic on single lane road, $SSD = 2SD$

$= (2 \times 61.33)$ m

$= 122.66$ m (Ans.)

[90th BCS]

* Calculate the safe stopping sight distance of a vehicle travelling at a speed of 80 kmph on a upward gradient of 2%. Assume, perception and brake reaction time, $t = 2.5$ sec. and co-efficient of friction = 0.36

Solution:

Given, $v = 80$ kmph $= \frac{80}{3.6}$ m/sec. $= 22.22$ m/sec.

$t = 2.5$ sec, $f = 0.36$, $n = \frac{2}{100} = 0.02$ (+ve)

Now,

$$SSD, (m) = vt + \frac{v^2}{2g(f+n)}$$

$$= 22.22 \times 2.5 + \frac{(22.22)^2}{2 \times 9.8 \times (0.36 + 0.02)}$$

$$= 121.85 \text{ m}$$

(Ans.)

[LGD-2018]

* Calculate the safe SSD for design speed of 45 kmph for two way traffic on a lane road. Assume co-efficient of friction, $f = 0.38$ and reaction time, $t = 2.5$ sec.

Solution:

Given, $v = 45$ kmph $= \frac{45}{3.6}$ m/s $= 12.5$ m/sec.

$f = 0.38$, $t = 2.5$ sec.

We know, $SSD = vt + \frac{v^2}{2gf} = 12.5 \times 2.5 + \frac{(12.5)^2}{2 \times 9.8 \times 0.38}$

$\therefore SSD = 52.23$ m

(Ans.)

[HED-2020]

* Calculate the SSD for design speed of 30 mph with a gradient 5.1%

Solution:

Given, $V = 30$ mph

$$n = \frac{5.1}{100} = 0.051$$

Assume, $t = 2.5$ sec.

$f = 0.35$

We know, $SSD = 1.47Vt + \frac{V^2}{30(f \pm n)}$

$$= 1.47 \times 30 \times 2.5 + \frac{30^2}{30 \times (0.35 \pm 0.051)}$$

$\therefore$ SSD = 185.06 ft (for upgradient, $n = +0.051$)

and, SSD = 210.58 ft (for down gradient, $n = -0.051$)

(Ans.)

[NHA-2020] [BPDB-23]

* A motorist travelling at 55 mile/hr downgrade 5% on a highway observes a crash ahead of him, involving on overturned truck that is completely blocking the road. If the motorist was able to stop his vehicle 30 ft from the over turned truck, what was his distance from the truck when he first observes the crash? Assume perception time = 2.5 sec.

Solution:

Given, $V = 55$ mile/hr

$$n = -\frac{5}{100} = -0.05$$

$t = 2.5$ sec.

We know, $SSD = 1.47Vt + \frac{V^2}{30(f-n)} = 1.47 \times 55 \times 2.5 + \frac{55^2}{30 \times (0.35 - 0.05)}$

$\therefore$ SSD = 538.24 ft

$\therefore$ Distance from the truck = (538.24 + 30) = 368.24 ft

(Ans)

[EGCB-2020]

* A car is travelling at 50 mph during perception and reaction time is 2.5 sec. and declaration rate is 11.2 ft/sec^2. Determine the stopping sight distance.

Solution: Given, $v = 50$ mph

$t = 2.5$ sec.

$a = 11.2$ ft/sec^2

We know, $SSD = 1.47\,vt + \frac{v^2}{30\left(\frac{a}{g}\right)} = 1.47 \times 50 \times 2.5 + \frac{(50)^2}{30 \times \frac{11.2}{32.2}}$

$\therefore SSD = 423.33$ ft

(Ans.)

[BWDB-2016]

* A directional sign needed highway turn off 85th percentile speed is 50 mph, vechicle turn at design speed is 25 mph, car travel at 50 mph during perception and reaction time is 2.5 sec. to read and understand the sign and decleration or (breaking) at 0.3 g. What is the maximum distance the direction sign should be placed in advance of the turn off?

Solution: Given, $u = 50$ mph

$v = 25$ mph

$t = 2.5$ sec.

$a = 0.3g$

We know, $SSD = 1.47\,ut + \frac{u^2 - v^2}{30\left(\frac{a}{g}\right)}$

$= 1.47 \times 50 \times 2.5 + \frac{50^2 - 25^2}{30 \times \left(\frac{0.3g}{g}\right)}$

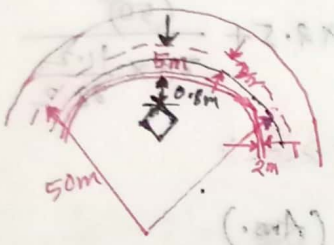
$= 392.083$ ft

(Ans.)

[ꝺB-2017]

* The corner of a building is situated next to inner side of a two lane horizontal curve with a radius of 50 m on a rural highway. Each lane is 3m with 2m shoulder. The corner is 0.8m away from the shoulder. Is it safe to drive at a speed of 90 kmph on this curve? If not how would you remedy the problem? Assume, perception-reaction time = 2.5 sec and deceleration rate = 3.3 m/sec.²

Solution: Given, $V = 90 \text{ kmph} = \frac{90}{3.6} \text{ m/sec.} = 25 \text{ m/sec.}$



$t = 2.5 \text{ sec.}$

$a = 3.3 \text{ m/sec}^2$

$$SSD = Vt + \frac{V^2}{2gf} = 25 \times 2.5 + \frac{(25)^2}{2g \times (\frac{a}{g})}$$

$\therefore SSD = 157.2 \text{ m}$

$$\therefore \text{Required } HSO = R \times \left(1 - \cos \frac{28.65}{R} \times SSD\right)$$

Here, $R = (50 - \frac{3}{2}) \text{ m} = 48.5 \text{ m}$

$$= 48.5 \times \left(1 - \cos \frac{28.65}{48.5} \times 157.2\right)$$

$$= 50.92 \text{ m}$$

but, Available $HSO = 0.8 + 2 + \frac{3}{2} = 4.3 \text{ m} < 50.92 \text{ m}$

Hence, It is not safe to drive at 90 kmph speed

Remedy:

$$\text{Available } HSO = R \times \left(1 - \cos \frac{28.65}{R} \times SSD\right)$$

$$\Rightarrow 4.3 = 48.5 \left(1 - \cos \frac{28.65}{48.5} \times SSD\right)$$

$$\Rightarrow SSD = 41.15 \text{ m}$$

$$\therefore \text{Available stopping sight distance} = Vt + \frac{V^2}{2g(\frac{a}{g})}$$

$$\Rightarrow 41.15 = V \times 2.5 + \frac{V^2}{2 \times 3.3}$$

$\Rightarrow$ safe speed, $V = 10.18 \text{ m/sec.} = 36.65 \text{ kmph}$

$\simeq 36 \text{ kmph (Ans.)}$

TCA-2018]

Determine the minimum passing sight distance required for a two lane, two-way highway where average speed of passing vechicle is 51 mph, average speed of the passed vehicle is 41 mph, time of the preliminary delay for passing vehicle is 4 sec, average acceleration rate for passing vehicle is 1.43 mph/sec, time passing vehicle occupies the opposite lane is 10 sec. and safe clearence distance of 180 feet.

Solution:

We know,

$$OSD = d_1 + d_2 + d_3 + d_4$$

where,

$$d_1 = 1.47 t_1 \left(v - m + \frac{2t_1}{2}\right)$$

Here, $t_1 = 4$ sec.
$a = 1.43$ mph/sec.
$v = 51$ mph
$m = (v - v_b) = (51 - 41) = 10$ mph

$$= 1.47 \times 4 \times \left(51 - 10 + \frac{1.43 \times 4}{2}\right)$$

$$= 257.9 \text{ ft}$$

$$d_2 = 1.47 v t_2$$

Here, $v = 51$ mph
$t_2 = 10$ sec.

$$= (1.47 \times 51 \times 10) \text{ ft}$$

$$= 749.7 \text{ ft}$$

$$d_3 = 180 \text{ ft}$$

and, $d_4 = 0.67 d_2 = (0.67 \times 749.7) = 502.3$ ft

∴ Minimum passing sight distance $= (257.9 + 749.7 + 180 + 502.3)$ ft

$$= 1689.9 \text{ ft}$$

$$\simeq 1690 \text{ ft}$$

(Ans.)

[PGCL-2014]

* Determine the safe radius of circular curve for the following condition where the symbol contains usual meaning:

$V = 60$ mph, $e = 0.4$ ft per 10 ft, $f = 0.15$ and $g = 32.2$ ft^2/sec.

Solution:

We know,

$$e + f = \frac{V^2}{15R}$$

Here,

$V = 60$ mph

$e = 0.4$ ft per 10 ft

$f = 0.15$

$$\Rightarrow \frac{0.4}{10} + 0.15 = \frac{(60)^2}{15 \times R}$$

$$\Rightarrow R = 1263.16 \text{ ft}$$

[NPCBL-2017, RPGCL-17]

* Given that, Radius of curve = 300 ft, frictional factor = 0.02. Limited speed 30 Kmph. what is the angle of curve or banking of road?

Solution:

We know,

$$e + f = \frac{V^2}{gR}$$

Here,

$V = 30 \text{ Kmph} = \frac{30}{3.6} = 8.33$ m/s

$f = 0.02$

$R = 300 \text{ ft} = \frac{300}{3.28} \text{ m} = 91.46$ m

$$\Rightarrow e = \frac{(8.33)^2}{9.8 \times 91.46} - 0.02$$

$$\Rightarrow e = 0.0574$$

$$\Rightarrow \tan\theta = 0.0574$$

$$\therefore \theta = \tan^{-1}(0.0574) = 3.286^\circ$$

(Ans)

[PGCB – 2017]

* If $e = 0.10$ and $f = 0.15$, design speed = 100 Kmph, determine the radius of curvature.

Solution:

We know, $e + f = \frac{V^2}{gR}$

Here, $V = 100 \text{ Kmph} = \frac{100}{3.6}$ m/sec.

$\therefore V = 27.78$ m/sec.

$e = 0.10$

$f = 0.15$

$\Rightarrow 0.10 + 0.15 = \frac{(27.78)^2}{9.8 \times R}$

$\therefore R = 315$ m

(Ans.)

[BBAD – 2018]

* Radius of a horizontal circular curve is 100 m. The design speed is 50 Kmph and design co-efficient of lateral fraction is 0.15. Calculate super elevation required if full lateral friction is assumed to develop.

Solution:

We know,

$e + f = \frac{V^2}{gR}$

Here, $V = 50 \text{ Kmph} = \frac{50}{3.6}$ m/sec. $= 13.89$ m/sec.

$f = 0.15$

$R = 100$ m

$\Rightarrow e + 0.15 = \frac{(13.89)^2}{9.81 \times 100}$

$\Rightarrow e = 0.197 - 0.15$

$\therefore e = 0.047$

(Ans.)

[SGFCL – 2017]

* Determine the minimum radius of a horizontal curve required for a highway if the design speed is 60 mi/h. The superelevation rate is 0.04 and co-efficient of friction is 0.12.

Solution: We know, $e + f = \frac{V^2}{15R} \Rightarrow 0.04 + 0.12 = \frac{60^2}{15 \times R}$

$\therefore R = 1500$ feet

(Ans.)

[DSCC-2019]

* An existing horizontal curve on a highway has a radius of 465 ft, which restricts the posted speed limit on this section of the road to only 61.5% of the design speed of the highway. If the curve is to be improved so that its posted speed will be the design speed of the highway, determine the minimum radius of the new curve. Assume that, the rate of super elevation is 0.08 for the both the existing curve and the new curve to be designed.

Solution: Given, $R = 465$ ft

$e = 0.08$

Assume, $f = 0.16$

We know,

$$e + f = \frac{V^2}{15R}$$

$$\Rightarrow 0.08 + 0.16 = \frac{V^2}{15 \times 465}$$

$\therefore V = 40.91$ mile/hr.

Hence, design speed $= \frac{40.91}{0.615} = 66.52$ mile/hr

For design speed, assume $f = 0.11$

Now, $0.08 + 0.11 = \frac{(66.52)^2}{15 \times R}$

$\Rightarrow R = 1552.6$ ft

(Ans.)

[SFGL-2021]

* A crest vertical curve is to be designed to join a +3% grade with a -2% grade at a section of two lane highway. Determine the minimum length of the curve if the design speed of the highway is 60 mi/h, $S < L$ and a perception-reaction time of 2.5 sec. The deceleration rate for braking is 11.2 ft/sec^2.

Solution:

We know,

if $L > S$, $L = \frac{NS^2}{2158}$ Here, $N = n_1 - n_2 = 3 - (-2)$

$= 5$

$S = SSD$

Now,

$$SSD = 1.47vt + \frac{v^2}{30(f-n)}$$

$$= 1.47 \times 60 \times 2.5 + \frac{60^2}{30\left(\frac{11.2}{32.2} - \frac{3}{100}\right)}$$

$$= 598.06 \text{ ft}$$

Hence,

$$L = \frac{5 \times (598.06)^2}{2158} = 828.72 \text{ ft} > S \quad \text{(OK)}$$

Minimum Length of the curve, $L = 828.72$ ft (Ans)

[BUET M.Sc -2013]

* An existing verticle curve on a highway joins a +4.4% grade with a -4.4% grade. If the length of the curve is 275 ft. what is the maximum safe speed on this curve? What speed should be posted if 5 mph increments are used? Assume, $a = 11.2$ ft/sec^2, perception-reaction time = 2.5 sec. and $S < L$

Solution: if $L > S$, we know, $L = \frac{NS^2}{2158} \Rightarrow \frac{\{4.4 - (-4.4)\} \times S^2}{2158} = 275$

$\therefore S = 259.69$ ft

Now, $SSD = 1.47\,vt + \frac{v^2}{30\left(\frac{2}{g} - n\right)}$

$\Rightarrow 259.69 = 1.47 \times v \times 2.5 + \frac{v^2}{30\left(\frac{11.2}{32.2} - \frac{1.4}{100}\right)}$

$\Rightarrow 0.1097\,v^2 + 3.675\,v - 259.69 = 0$

$\therefore v = 34.7$ mile/hr

If a speed limit of 5 mi/hr to be posted, to satisfy this condition $(34.7 - 5) = 29.7$ mi/hr should be used.

(Ans.)

[DTCA-2018, DMTCL-19, BUET M.Sc-18]

* A toll bridge carries 5000 vehicle/day. The current toll is 150 taka. When the toll is increased by 25 taka, traffic volume decreases by 500 vehicle/day. Determine the amount of toll that should be charged such that revenue is maximimized.

Solution: Assume, Toll increase = 'x' TK $\therefore$ The toll = $(150 + x)$ TK

Considering linear relationship between traffic volume and cost,

$$V = 5000 - \frac{500}{25} \times x = (5000 - 20x)$$

Now, Revenue, R = Traffic volume × Toll $= (5000 - 20x)(150 + x)$

$= 750000 - 3000x + 5000x - 20x^2$

$= 750000 + 2000x - 20x^2$

For maximum value of x,

$\frac{dR}{dx} = 0$

$\Rightarrow 2000 - 40x = 0$

$\Rightarrow x = 50$ $\therefore$ The new toll should be $(150 + 50) = 200$ TK

$\therefore$ Additional Revenue $= (5000 - 20 \times 50) \times 200 - (5000 \times 150) = 50,000$ TK

(Ans.)

Traffic Engineering

Traffic Volume Study:

* **ADT (Average Daily Traffic):** Average flow of traffic only for few days like 7 days, 15 days

* **AADT (Annual Average Daily Traffic):** Average flow of traffic for one year.

* **DHV (Design Hourly Volume):** 30th height hourly volume that will exceed only 29 hrs out of 8760 hrs in a year. (Traffic congestion is expected for 29 hrs in a year)

* **TPF (Traffic Projection Factor):**

$$A = P(1+r)^{n+x}$$

where, P = Number of vehicle/day at last census
r = Annual rate of increase in traffic
n = Design period in years
x = construction period in years
A = Projected No. of vehicle within design period.

Traffic Speed Studys:

* **Flow:** $q = \frac{n}{T} \times 3600$ (vehicle/hr) Here, n = No. of vehicles passing a point in T sec.
q = Equivalent hourly flow.

* **Density:** $K = \frac{n}{L} \times 5280$ (vehicle/mile)

* **SMS (space mean speed):** $SMS = \frac{n}{\Sigma(\frac{1}{V})}$ or $\frac{nL}{\Sigma(t)}$

* **TMS (Time mean speed):** $TMS = \frac{\Sigma(V)}{n}$

* **Flow density relationship:**

Flow = density × SMS

$$q = K \times V_s = K \times V_f \left(1 - \frac{K}{K_j}\right)$$

Where,
V_f = free flow
K_j = jam density

* **Modal Speed:** speed that is most likely to occur. (peak value of frequency distribution curve)

* **Mean speed:** Arithmatic average speed. $V_{mean} = \frac{\Sigma f_i V_i}{n}$

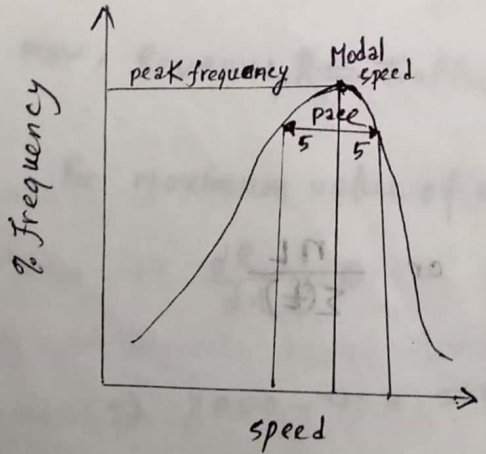
* **Median Speed:** 50th percentile speed in cumulative frequency distribution curve

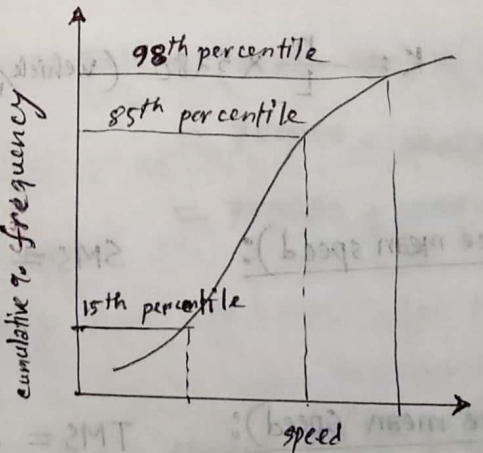
* **Upper Speed limit:** 85th percentile speed in cumulative frequency distribution curve.

* **Lower Speed limit:** 15th percentile speed in cumulative frequency distribution curve.

* **Design Speed for Geometric design:** 98th percentile speed in cumulative frequency distribution curve.

* **Pace:** 10 Km/hr increment in speed within which the highest percentage of drivers are observed.





Data Analysis:

* **Standard error of the mean:**

$$S_e = \frac{\sigma_s}{\sqrt{n}} \quad \text{where,} \quad \sigma_s = \sqrt{\frac{\Sigma(V_i - V_{mean})^2}{N-1}}$$

(σ_s → standard deviation)

* **sample size:**

$$n_p = \frac{Z^2 \sigma_s^2}{S_e^2}$$

where, Z is calculated from standard Normal distribution Table for particular confidence level.

* **confidence interval:**

$$\mu = V_{mean} \pm Z\sigma_s$$

For 95% confidence, $Z = 1.96$

For 99.7% confidence, $Z = 3.0$

For 90% confidence, $Z = 1.645$

For 99% confidence, $Z = 2.576$

For 85% confidence, $Z = 1.04$

For 50% confidence, $Z = 0$

* **Expansion Factor:**

* Hourly Expansion Factor (HEF) = $\frac{\text{Total Volume for 24-hr period}}{\text{Volume for particular hour}}$

* Daily Expansion Factor (DEF) = $\frac{\text{Average Total Volume for week}}{\text{Average volume for particular day}}$

* Monthly Expansion Factor (MEF) = $\frac{\text{Annual Average Daily Traffic}}{\text{Average Daily Traffic for particular month}}$

* Traffic Capacity:

$$c = \frac{1000\,V}{S}$$ where, V = speed in Kmph

S = Average center to center spacing of vehicle / Space Head way.

$$S = Sg + L$$

$$= (Vt + L)$$ [speed in m/sec.]

L = Length of vehicle $\cong$ (5m) Avg.

* Traffic Signal:

* Minimum Yellow Interval, $T_{min} = \delta + \frac{W+L}{1.47V} + \frac{V}{2g\left(\frac{a}{g} \pm n\right)}$

Here,

δ = perception - reaction time (= 1 sec.)

W = width of intersection

L = Length of vehicle ($\simeq$ 20ft)

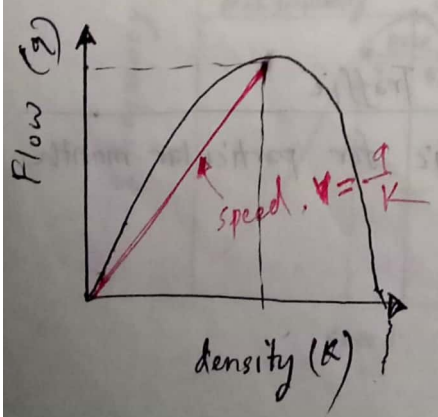
a = constant rate of banking deceleration (3ft/sec^2)

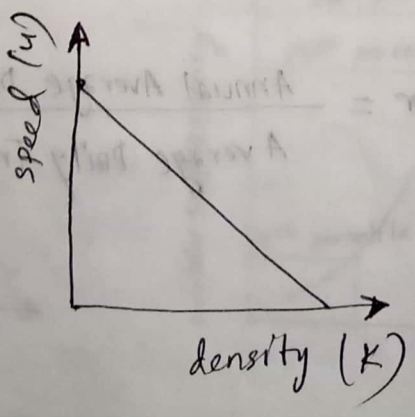
n = Gradient

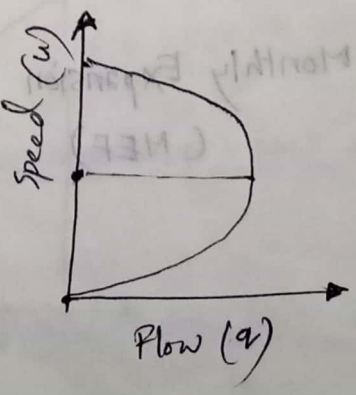
V in mph (mile/hr)

* All Red Interal, $R = \frac{W+L}{V}$

* Fundamental Diagram of Traffic Flow:







[DESCO – 2015]

* In speed density relationship, $V_s = 65\left(1 - \frac{K}{116}\right)$, determine the following condition: (i) Flow density and flow speed. (ii) free flow, jam density and capacity.

Solution:

We know,

$$V_s = V_f\left(1 - \frac{K}{K_j}\right) \quad \ldots\ldots (i)$$

considering speed in Kmph.

comparing $V_s = 65\left(1 - \frac{K}{116}\right)$ with eqn (i), we obtain, free flow, $V_f = 65$ Kmph and jam density, $K_j = 116$ vehicle/Km

Now,

$$q = V_s K = 65\left(1 - \frac{K}{116}\right) \times K \quad \ldots\ldots (ii)$$

$$\therefore q = 65K - \frac{65}{116} \times K^2 \quad \ldots\ldots (iii)$$

For maximum flow (q_{max}), $\frac{dq}{dK} = 0 \Rightarrow \frac{d}{dK}\left(65K - \frac{65}{116}K^2\right) = 0$

$$\Rightarrow 65 - 2 \times \frac{65}{116} \times K = 0$$

$$\Rightarrow K = 58 \text{ vehicle/Km}$$

$\therefore$ Flow density, $K = 58$ vehicle/Km

Putting the value, $K = 58$ vehicle/hr in eqn (i) and eqn (ii),

$$\text{Flow speed, } V_s = 65 \times \left(1 - \frac{58}{116}\right) = 32.5 \text{ Kmph.}$$

And,

$$q = \left(65 \times 58 - \frac{65}{116} \times 58^2\right) = 1885 \text{ vechicle/hour.}$$

(Ans.)

[BWDB-2016]

* As part of a class project, a group of students collected a total of 120 spot speed samples at a location and determined from this data that the standard variation of the speeds was ±6 mile/hr. If the project required that the confidence level will be 95% and the limit of acceptable error was ±1.5 mi/hr. Determine whether these students satisfied the project requirement.

Solution;

Given, $\sigma = \pm 6$ mile/hr.

$$d = \pm 1.5$$

For confidence level 95%, $Z = 1.96$

We know, Minimum sample size require, $N = \left(\frac{Z\sigma}{d}\right)^2$

$$= \left(\frac{1.96 \times 6}{1.5}\right)^2$$

$$= 61.45 \simeq 62 < 120$$

(OK)

Hence, they satisfied the project requirements.

[DPDC-2019, BWDB-18, DESCO-15]

* An engineer wishing to obtain the speed characteristics on a bypass around her city at a confidence level of 95%, and an acceptable limit of ± 1.0 mile/hr collected a total of 130 spot speed samples and determined that the variance is 25 (mile/h)^2. Has the engineer met with all of the requirements of the study?

Solution: Given, $\sigma^2 = 25\ (\text{mile/h})^2$, $d = 1.0$ mile, $Z = 1.96$ (for 95% confidence)

We know, $N = \left(\frac{Z\sigma}{d}\right)^2 = \frac{Z^2}{d^2} \times \sigma^2 = \frac{1.96^2}{1.0^2} \times 25 = 96.04 < 130$

Hence, The engineer met the requirements of the study.

[EGCB-2020]

* Estimate the mean speed at a point where the density is 175 vehicle/mile and the flow is 10000 vehicle/hr.

Solution: We know,

$$q = K V_s$$

$$\Rightarrow V_s = \frac{q}{K} = \frac{10000}{175} = 57.14 \text{ mile/hr.}$$

Ans.

[PGCB-2017]

* Collected time required by four vehicles for travelling 1 Km were 1.6, 1.2, 1.5 and 1.7 minute respectively. Find the space and time mean speed.

Solution: we know, space mean speed, $V_s = \frac{nd}{\Sigma t_i}$

$$= \frac{4 \times 1000}{(1.6+1.2+1.5+1.7) \times 60}$$

$$\therefore V_s = 11.11 \text{ m/sec.}$$

Now, $V_T = \frac{\Sigma V_i}{n}$ Here, $V_1 = \frac{d}{t_1} = \frac{1000}{1.6 \times 60} = 10.4167$ m/s

$= \frac{(10.4167 + 13.89 + 11.11 + 9.804)}{4}$ similarly, $V_2 = 13.89$ m/s

$= 11.305$ m/sec. $V_3 = 11.11$ m/s

$V_4 = 9.804$ m/s

(Ans.)

[TGTDCL-2018]

* Find space and time mean speed for the values of 55, 60, 45, 95 and 60 mile/hr.

Solution: We know,

SMS, $V_s = \frac{n}{\Sigma(\frac{1}{v_i})} = \frac{5}{(\frac{1}{55}+\frac{1}{60}+\frac{1}{45}+\frac{1}{95}+\frac{1}{60})} = 59.34$ mile/hr.

TMS, $V_T = \frac{\Sigma v_i}{n} = \frac{55+60+45+95+60}{5} = 63$ mile/hr.

[NPCBL-2019, BCIC-19]

* Find the time mean speed and space mean speed from the following data:

Time (sec)	22	21	20	18	20	20
Distance (m)	300	300	300	300	300	300

solution: We know, SMS, $V_s = \frac{nd}{\Sigma t_i} = \frac{6 \times 300}{(22+21+20+18+20+20)} = 14.876$ m/s

Again, TMS, $V_T = \frac{\Sigma v_i}{n}$

Here, $V_1 = \frac{d}{t_1} = \frac{300}{22} = 13.64$ m/s

$= \frac{(13.64+14.286+15+16.67+15+15)}{6}$

$= 14.93$ m/s

(Ans.)

Similarly, $V_2 = 14.286$ m/s

$V_3 = 15$ m/s

$V_4 = 16.67$ m/s

$V_5 = 15$ m/s

$V_6 = 15$ m/s

[PGCB – 2019]

* In a place, number of vehicle passes per hour is shown in the table. If hourly factor is 42 then find daily ADT.

Vehicle Type	PCU factor	Flow (vehicle/hr)
Bus	3	41
car, deep	1	263
Micro, Taxi	0.5	55
NMV	0.5	48
Motor cycle	0.1	43

Solution:

Total volume $= (3\times41 + 1\times263 + 0.5\times55 + 0.5\times48 + 0.1\times43)$ PCU/hr

$= 441.8$ PCU/hr

Given, HEF = 42

We know, $HEF = \frac{\text{Total volume for 24-hr period}}{\text{Volume for particular hour.}}$

$\therefore$ Total volume for 24-hr period $= (42\times441.8)$ PCU/day.

$= 18555.8$ PCU/day ✓

[BWDB – 2013]

* Find the design hourly volume, if ADT = 20000 vehicle/day and K = 0.1

Solution: We Know, $MEF = \frac{AADT}{ADT}$ Assume, MEF = 1

$\therefore$ ADT = AADT = 20000 vehicle/day

Now, DHV = K × AADT $= (0.1\times20000) = 2000$ vehicle/day (Ans)

[BWDB-2013]

* Flow modulus of a city is given for 25% area is 2.84, for 50% Area is 3.12, for 15% area is 1.342, for 10% area is 1.82. Find the combined flow modulus of the city.

Solution: Flow modulus of the city = $(0.25 \times 2.84 + 0.50 \times 3.12 + 0.15 \times 1.342 + 0.10 \times 1.82)$

$= 2.6533$ (Ans.)

[BIFPCL-2015]

* A four lane two way road, the ADT is 4000 vehicle/day and commercial vechicle is 45%. Determine the number of commercial vechicle of one-way road.

Solution: No. of commercial vehicle of one way $= 0.45 \times \frac{4000}{2}$

$= 900$ vehicle/day (Ans)

[DPDC-2019], [BWDB-16]

* It is observed that 40 traffic crashes occured on a 17.5 miles long section of highway in one year. The ADT on the section is 5000 vehicles.

(a) Find the rate of total crashes per 100 million vehicle miles.

(b) Find the rate of total crashes per 100 million vechicle miles, if 5% of the crashes involved fatalities.

Solution: vechicle-mile of travel $= (5000 \times 17.5 \times 365 \times 1) = 31.9375 \times 10^6$ vehicle-mile

For 31.9375×10^6 vehicle mile car crashes $= 40$

$\therefore 100 \times 10^6$ vechile mile car crashes $= \frac{40 \times 100 \times 10^6}{31.9375 \times 10^6} = 125.24$ crashes

Rate of crashes = 126 crashes/100 million vechicle mile

If 5% of crashess involved fatalities, rate of crashes $= (126 \times 0.05) = 6.3 \simeq 7$ crashes/100 million vechile-mile (Ans)

NESCO–2021]

* An intersection located in an urban area has a maximum speed on the approach roads of 45 mile/hr. The width of the intersection is 48 ft for all approaches. The average length of a vechide is assumed to be 20 ft. What should be the minimum length of the red clearance interval for the intersection?

Solution; All-Red interval $= \frac{W+L}{1.47V} = \frac{48+20}{1.47\times 45} = 1.03$ sec. (Ans.)

[PGCL–2017]

* Determine the total intergreen time for a 2 face traffic signal having cycle time, $C = 66$ sec., Green time for N-S direction, $G_{NS} = 29$ sec and for E-W direction, $G_{EW} = 27$ sec.

Solution;

We Know,

Cycle time = Total inter green + $G_{NW} + G_{EW}$

$\Rightarrow 66$ = Total inter green + 29 + 27

$\therefore$ Total intergreen = 15 sec. (Ans.)

[BWDB–2018, BUET M.Sc–18, NHA–20] [BIWTA–23]

* Let the cycle time for an intersection is 60 sec, green time for a phase is 27 sec, corresponding yellow time is 4 sec. If the saturation headway is 2.9 sec/vechile, start up lost time is 2 sec/phase, clearence lost time is 1 sec/phase, Find the capacity of movement per lane.

Solution; Given cycle time, $C_i = 60$ sec. saturaturation headway = 2.9 sec/veh.

Green time, $G_i = 27$ sec.

yellow time; $Y_i = 4$ sec.

Total lost time, $t_L = (2+1) = 3$ sec.

saturation flow, $s_i = \frac{3600}{h} = \frac{3600}{2.4} = 1500$ veh/hr.

effective green, $g_e = G_i + Y_i - t_L$

$= 27 + 4 - 3$

$= 28$ sec.

$\therefore$ capacity per lane, $c = \frac{g_e}{c_i} \times s_i = \left(\frac{28}{60} \times 1500\right) = 700$ veh/hr.

(Ans.)

[DNCC-2020]

* Determine the minimum yellow interval at an intersection whose width is 40 ft if maximum allowable speed on the approach roads is 30 mile/hr. Assume average length of the vehicle is 20 ft.

Solution:

We know, minimum yellow interval $= 2 + \frac{W+L}{1.47V} + \frac{1.47V}{2a}$

$= 1 + \frac{40+20}{1.47 \times 30} + \frac{1.47 \times 30}{2 \times 11.2}$

$= 4.33$ sec.

(Ans.)

[DCTA-2018], [BOGCMC]-22]

* If utilities for auto, bus and walk are 0.47, -1.525 and -2.5 respectively. Determine their mode share probabilities using a basic logit model.

Solution: Given, $U_a = 0.47$, $U_b = -1.525$ and $U_w = -2.5$

Now, Mode share probabilities, $P_a = \frac{e^{0.47}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.842$

$P_B = \frac{e^{-1.525}}{e^{0.47} + e^{-1.525} + e^{-2.5}}$ and, $P_w = \frac{e^{-2.5}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.0432$

$= 0.115$

(Ans.)

[PGCL-20M, SGCL-17, BIWTA-19]

* A new office is expected to add 800 pedestrain per hour at it's 15ft side walk during the peak 10 Minutes. The side walk already has a flow 1400 pedestrains during the peak period. Around 3ft of the width of sidewalk is used for light posts and other obstruction. Determine the new flow rate and maintain the unit measurement.

Solution:

effective sidewalk $= (15-3) = 12$ ft

$$\text{Average flow rate} = \frac{v}{t} = \frac{800+1400}{\left(\frac{10}{60}\right)} = 13200 \text{ pedestrian/hr}$$

$$\text{Flow rate per ft of sidewalk} = \frac{13200}{12} = 1100 \text{ pedestrians/hr/ft}$$

(Ans.)

[NPCBL-2017]

* Distance of two compasses of a university is 5 km. Operation speed of bus is 30 Kmph. Total time required for return whole distance is 10 min. What is the number of bus needed for 10 minute headway?

Solution:

Assume, Layover time, $T_A = T_B = 2$ minutes at either end of the route.

Total cycle time, C = Travel time + Layover time

$$C = \frac{2\times 5}{30}\times 60 + (2+2) = 24 \text{ minutes.}$$

$$\text{No. of vehicle} = \frac{\text{cycle time}}{\text{Headway}} = \frac{24}{10} = 2.4 \simeq 3 \text{ units}$$

(Ans.)

[ERL-2017, MPL-2017, DOCL-18]

* A two way two lane road ADT is 1000, If the commercial vehicle is 45% and load 27 Kip. Calculate the ESAL for commercial in one direction.

Solution:

Commercial vehicle in one direction = $0.45 \times \frac{1000}{2} = 700$ vehicle/day

∴ Equivalent axel load factor, $EALF = \left(\frac{L}{L_s}\right)^4 = \left(\frac{27}{18}\right)^4 = 5.0625$

∴ ESAL = (ADT × EALF) = $(900 \times 5.0625) = 4556.25$ (Ans.)

[WARPO-2017]

* Determine ESAL for load repetitions is 1.5 million and axel load is 120 KN.

Solution:

$L.E.F = \left(\frac{L}{L_s}\right)^4 = \left(\frac{120}{80}\right)^4 = 5.0625$

∴ $ESAL = (5.0625 \times 1.5 \times 10^6) = 7.594 \times 10^6 \simeq 7.6$ Millions. (Ans.)

[WASA-2017]

* Axle load of 27 Kip and 36 Kip are repeated 30 and 15 times respectively on pavement of 24 hours. what will be the Equivalent single axel load (ESAL) in a year.

Solution: L.E.F for 27 Kip $= \left(\frac{27}{18}\right)^4 = 5.0625$

L.E.F for 36 Kip $= \left(\frac{36}{18}\right)^4 = 16$

∴ ESAL for 27 Kip $= (5.0625 \times 30) = 151.875$

ESAL for 36 Kip $= (16 \times 15) = 240$

∴ Total ESAL in a year $= (151.875 + 240) \times 365 = 143034.375$ (Ans.)

[BPDB-2016, CPGCBL-2018]

* Two closely imparted 20.5 KN load on each road. The applied pressure is 0.7 Mpa. If the two wheel is replaced by a single wheel of same property, then find out the imparted effective diameter on soil (by considering circular imparted effect) by the single wheel.

Solution:

we know, $P = \frac{F}{A}$

$\Rightarrow A = \frac{F}{P}$

$\Rightarrow \frac{\pi}{4} d^2 = \frac{2 \times 20.5}{0.7 \times 10^3}$ ✓

$\Rightarrow d = 0.273 \text{ m}$

(Ans.)

[RPGCL-2017, GTCL-2018]

* The radius of a tyre imprint is approximated to a circle of 150 mm. What is the maximum loading duration on a particular point of pavement by a truck moving at a speed of 60 kmph?

Solution: Duration is the time required to cross the diameter of the tyre imprint. Therefore,

$$t = \frac{d}{V} = \frac{2 \times 150 \times 10^{-3}}{\frac{60}{3.6}} = 0.018 \text{ sec.}$$

(Ans.)

[BWDB – 2014, BPDB – 16, CPGCBL – 18]

* CBR value found of 10 Kms length as 3.8, 2.8, 3.2, 4.3, 2.8, 4.7, 4.3, 3.9, 4.1 and 4.5%. Find the average CBR, standard deviation, CBR at 50% and 85% reliability.

Solution:

Average CBR value, $\bar{x} = \frac{\Sigma x_i}{n} = \frac{3.8+2.8+3.2+4.3+2.8+4.7+4.3+3.9+4.1+4.5}{10}$

$\therefore \bar{x} = \frac{38.4}{10} = 3.84$

Standard deviation, $S_d = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}}$

$= \sqrt{\frac{(0.04)^2+(1.04)^2+(0.64)^2+(0.16)^2+(1.04)^2+(0.86)^2+(0.46)^2+(0.06)^2+(0.26)^2+(0.}{9}}$

$= 0.687$

$\therefore$ CBR at 50% reliability, $X_{50} = \bar{x} - Z_{50} S_d$

$= 3.84 - 0 \times 0.687$

$= 3.84$

and, CBR at 85% reliability, $X_{85} = \bar{x} - Z_{85} S_d$

$= 3.84 - 1.04 \times 0.687$

$= 3.13$ (Ans.)

[PGCB – 2018]

* Same problem;

CBR at 90% reliability, $X_{90} = 3.84 - 1.64 \times 0.687$

$= 2.71$ (Ans.)

[PGCB-2015, DNCC-16, BPDB-18]

* Calculate the angularity number for the aggregate sample from the following data: Relative density of the aggregate 2.8, mass of water required to fill the cylinder 2500 gm. mass of cylinder filled with compacted aggregate 5150 gm and mass of cylinder 1100 gm.

Solution:

We know,

$$\text{Angularity number} = 67 - \frac{W}{W \times G_s} \times 100$$

Here,

$W = (5150 - 1100)$ gm

$G_s = 2.8$

$w = 2500$ gm

$$= 67 - \frac{(5150-1100)}{2500 \times 2.8} \times 100$$

$$= 9.14$$

$$\simeq 9$$

(Ans.)

[BADC-2020]

* Determine the specific gravity of a bituminous material from pycnometer test.

Mass of pycnometer = 30.48 gm

Mass of pycnometer filled with water = 57.66 gm

Mass of pycnometer filled $\frac{3}{4}$ part with bitumen = 57.68 gm.

Solution:

We know,

$$\text{specific Gravity of Bitumen} = \frac{C - A}{(B-A) - (D-C)}$$

Here,

$A = 30.48$ gm

$B = 57.66$ gm

$C = 57.68$ gm

$D = 57.68 + \frac{1}{4} \times (57.66 - 30.48)$

$= 64.475$ gm

$$= \frac{(57.68 - 30.48)}{(57.66 - 30.48) - (64.475 - 57.68)}$$

$$= 1.33$$

(Ans.)

[SGCL-2017]

- Standard rail length of BG track is 12.80 m. If 45 Kg rail is used in a particular BG track in Rajshahi, what is the total weight of each individual rail girder? What maximum axel load can be safely imposed on the track?

Solution:

Total weight of each individual rail girder = No. of rail x weight of rail per unit length x length of rail

$= (1 \times 45 \times 12.8)$ Kg

$= 576$ Kg (Ans.)

Maximum axel load = 560 x sectional weight of rail in Kg/m.

$= (560 \times 45)$ Kg $= 25200$ Kg. (Ans.)

[35th BCS]

* A curve of 5° is situated on a section of broad gauge. the maximum permissible speed in the section is 50 Km/hr. Find out the amount of equilibrium cant.

Solution: Given, $D = 5°$, $v = 50$ Kmph $= \frac{50}{3.6} = 13.89$ m/sec.

Radius of the curve, $R = \frac{1750}{D} = \frac{1750}{5} = 350$ m.

We know, $e = \frac{Gv^2}{gR} = \frac{1750 \times (13.89)^2}{9.8 \times 350} = 98.43$ mm (Ans.)

[40th BCS]

* A 7 degree curve branches off from a 4 degree main curve in an opposite direction in the layout of a B.G. yard. If the speed of the branch line is restricted to 30 Km/hr. Determine the speed restriction on the main line. Assume permissible cant deficiency 75 mm

Solution: Given, $D = 4°$, $v = 30$ Kmph $= \frac{30}{3.6} = 8.33$ m/sec.

Now, $R = \frac{1750}{D} = \frac{1750}{7} = 250$ m

We know, $e = \frac{GV^2}{gR} = \frac{1676 \times (9.33)^2}{9.8 \times 250} = 47.471$ mm

$\therefore$ Negative superelevation $= (47.47 - 75) = -27.53$ mm

Hence, Maximum superelevation that can be provided on main line

$e_{max} = (75 + 27.53) = 102.53$ mm

Then,

Radius of the main curve $= \frac{1750}{D} = \frac{1750}{4} = 437.5$ m.

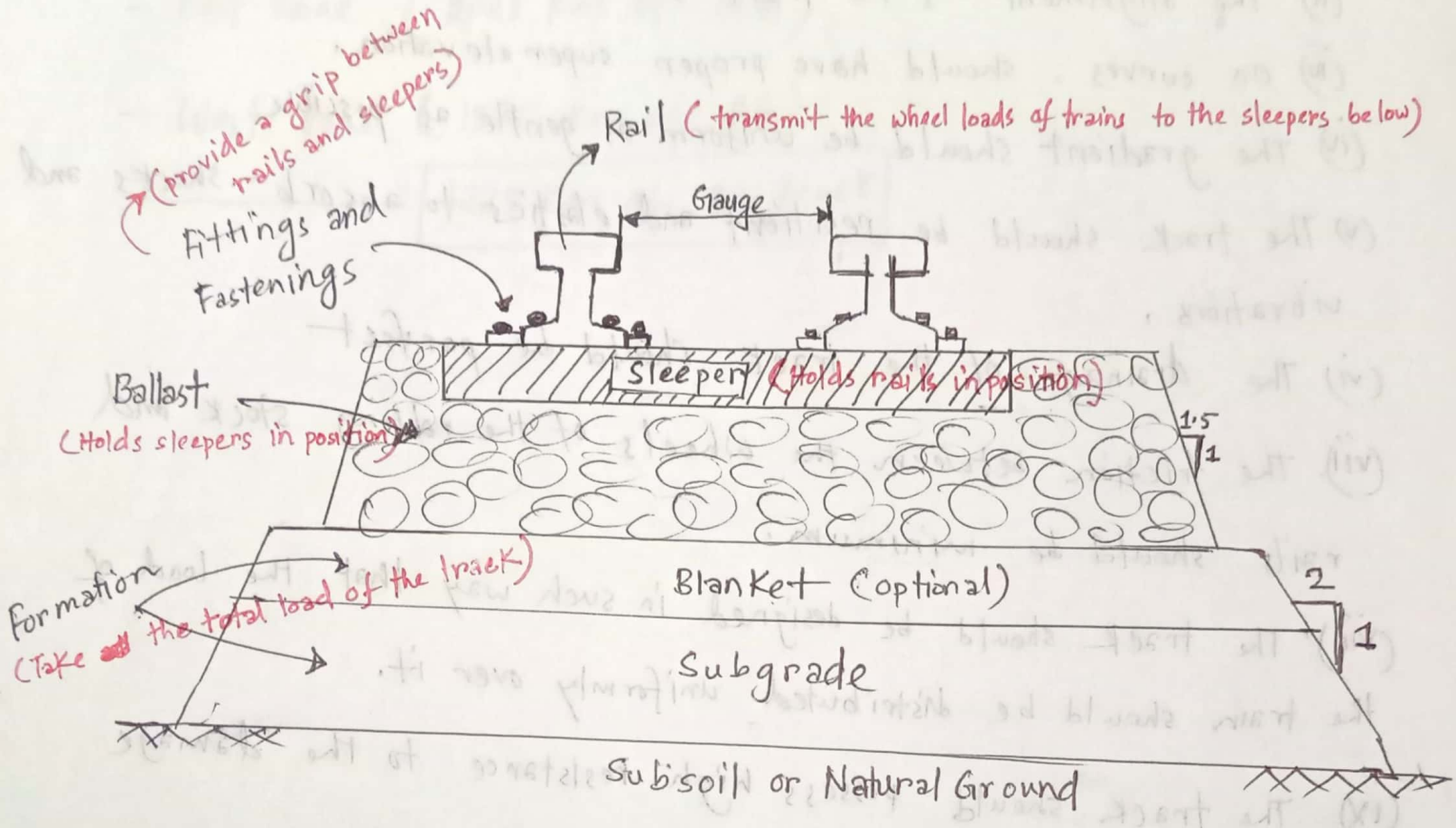
$\therefore$ speed for main line, $V = \sqrt{\frac{gRe}{G}} = \sqrt{\frac{9.8 \times 437.5 \times 102.53}{1676}}$

$\therefore V = 16.20$ m/sec. $= 58.32$ kmph.

(Ans.)

Railway Track

components of a railway track: (Functions of them)



Types of Gauge:

1. Standard gauge (1435 mm)
2. Narrow gauge (762 mm)
3. Meter gauge (1000 mm)
4. Broad gauge (1676 mm)

Railway Track

Basic requirements of an Ideal ~~alignment~~:

(i) The gauge of the track should be correct and uniform.

(ii) The alignment of the track should be correct.

(iii) on curves, should have proper super elevation.

(iv) The gradient should be uniform as gentle as possible.

(v) The track should be resilient and elastics to absorb shocks and vibrations.

(vi) The drainage of the track should be perfect

(vii) The friction between the wheels of the rolling stock and rails should be minimum.

(viii) The track should be designed in such way that the load of the train should be distributed uniformly over it.

(ix) The track should possess high resistance to the damage at the time of derailment.

(x) the rails should have perfect cross level.

Factor affecting the choice of rail gauge:

① Traffic considerations: wider gauge → Larger wagons → More traffic

② speed of movements: Higher speed → Larger wheels → Wider gauge

③ Geographical considerations: Mountainous terrain → Sharper curves → narrow curves

(iv) cost of construction: wider gauge → increase in cost

(v) Development of poor areas: poor areas → Narrow gauge

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Gauge in Bangadesh:

Total length of route = 3600 Km

- East zone (2025 Km of MG)
- West zone (1575 Km of BG)

1225 Km of DG track

Geotechnical

Particle Size Classification:

Soil Type	Coarse Grained Soil		Fine Grained Soil	
	Gravel	Sand	Silt	Clay
USCS	76.2 mm to 4.75 mm	4.75 mm to 0.075 mm	< 0.075 mm	
AASHTO	76.2 mm to 2 mm	2 mm to 0.075 mm	0.075 mm to 0.002 mm	< 0.002 mm

Sieve Analysis ⟷ Hydrometer Analysis

Co-efficient of uniformity: $C_u = \frac{D_{60}}{D_{10}}$

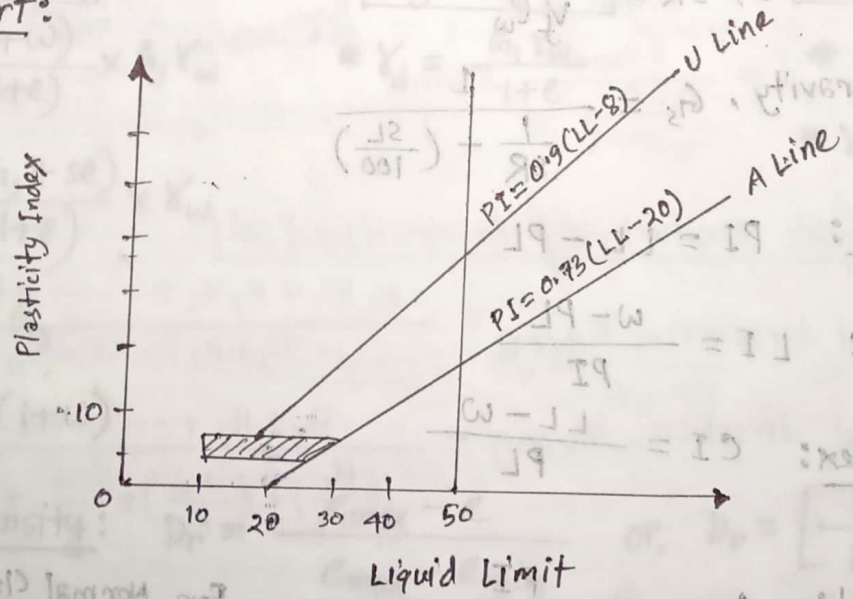
Co-efficient of curvature/gradation: $C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}$

Sorting Co-efficient: $S_o = \sqrt{\frac{D_{75}}{D_{25}}}$

For well graded Gravel, $C_u \geq 4$ and $1 \leq C_c \leq 3$

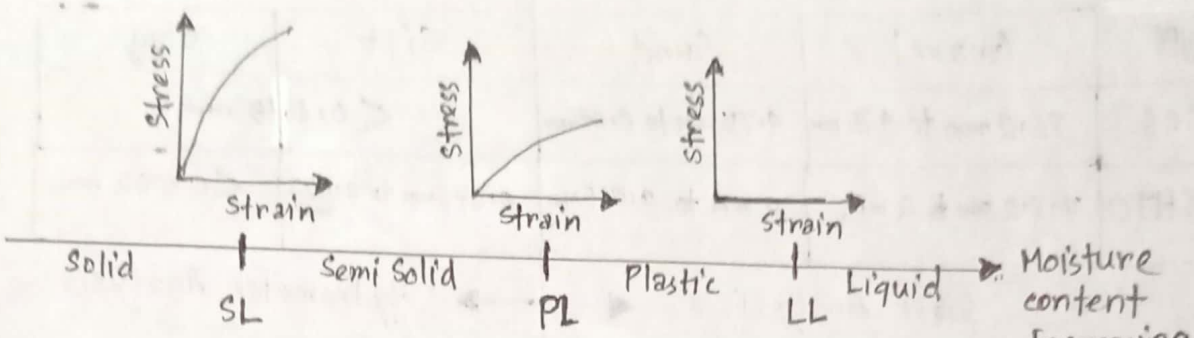
For well graded Sand, $C_u \geq 6$ and $1 \leq C_c \leq 3$

Plasticity Chart:



* LL < 50 indicates Low plasticity (L), LL > 50 indicates High plasticity (H)
* PI Below A Line indicates silt (M), PI above A Line indicates clay (C)
* PI below U Line indicates Organic (O), PI above U Line indicates Inorganic.

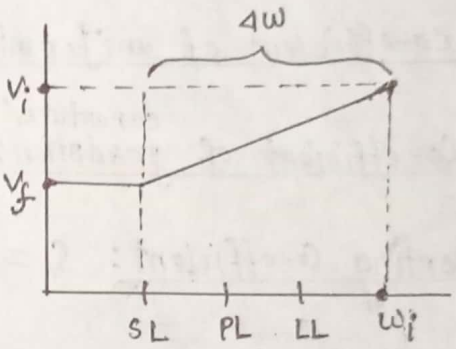
Atterberg Limits:



Shrinkage Limit: $SL = \omega_i - \Delta\omega$

where, $\omega_i = \frac{M_1 - M_2}{M_2} \times 100\%$

$\Delta\omega = \frac{(V_i - V_f)\rho_w}{M_2} \times 100\%$



* Shrinkage Ratio, $SR = \frac{M_2}{V_f \rho_w}$

* Specific Gravity, $G_s = \frac{1}{\frac{1}{SR} - \left(\frac{SL}{100}\right)}$

Plasticity Index: $PI = LL - PL$

Liquidity Index: $LI = \frac{\omega - PL}{PI}$

Consistancy Index: $CI = \frac{LL - \omega}{PL}$

Activity of Clay: $A = \frac{PI}{\%\ \text{Clay Fraction}}$

For Normal Clays, $0.75 < A < 1.25$

Inactive clays, $A < 0.75$

Active clays, $A > 1.25$

Sensibility of Clay: $S_t = \frac{C_u\ (\text{undisturbed})}{C_u\ (\text{remolded})}$

S_t	Type
1	Insensitive
1-8	sensitive
8-64	Quick

Weight - Volume Relationship:

Void ratio, $e = \frac{V_v}{V_s}$

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

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

Degree of saturation, $S = \frac{V_w}{V}$

Water content, $\omega = \frac{W_w}{W_s}$

Specific Gravity, $G_s = \frac{\gamma_s}{\gamma_w}$

Unit weight, $\gamma = \frac{W}{V}$ $[W = W_s + W_w]$

Dry unit weight, $\gamma_d = \frac{W_s}{V}$

Submerged unit weight, $\gamma' = \gamma_{sat} - \gamma_w$

* Unit weight of water,
  $\gamma_w = 9.81\ KN/m^3$
  $= 62.4\ lb/ft^3$
  $= 1\ g/cc$

Moist Condition

* $\gamma = \frac{(1+\omega)}{(1+e)} \times G_s \gamma_w$
* $\gamma = \frac{(G_s + se)}{(1+e)} \times \gamma_w$
* $se = \omega G_s$
* $\gamma = \gamma_d (1+\omega)$

Dry Condition

* $\gamma_d = \frac{G_s \gamma_w}{1+e}$

Saturated Condition

* $e = \omega_{sat} G_s$
* $\gamma_{sat} = \gamma_d + n\gamma_w$

Relative Density:

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \quad \text{or,} \quad D_r = \left[\frac{\gamma_d - \gamma_{d(min)}}{\gamma_{d(max)} - \gamma_{d(min)}}\right] \times \left[\frac{\gamma_{d(max)}}{\gamma_d}\right]$$

Dr (%)	Type
0-15	Very Loose
15-50	Loose
50-70	Medium
70-85	Dense
85-100	Very Dense

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Suitability Number: $S_N = 1.7\sqrt{\frac{3}{(D_{50})^2} + \frac{1}{(D_{20})^2} + \frac{1}{(D_{10})^2}}$

S_N	Type
0-10	Excellent
10-20	Good
20-30	Fair
30-50	Poor
>50	Unsuitable

Dynamic compaction: Significant depth of penetration,

$D\,(m) = \frac{1}{2}\sqrt{W_H h}$ where, W_H in metric ton, h in meter

1 metric ton = 2.205 Kip

Determination of Hydraulic conductivity:

* Constant Head Test ▶ $K = \frac{QL}{Aht}$

* Falling Head Test ▶ $K = \frac{aL}{At}\ln\left(\frac{h_1}{h_2}\right)$

Absolute permeability of soil: $\bar{K} = \frac{\eta}{\gamma_\omega} \times K$ where,

η = viscosity of water

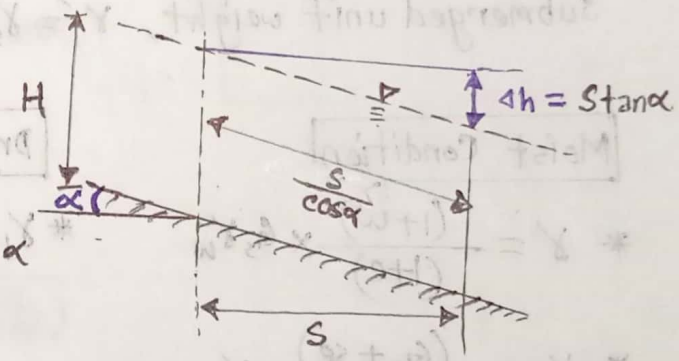
K = Hydraulic conductivity of soil

Rate of seepage through soil:

$q = KiA$ where,

$i = \frac{\text{head loss } (\Delta h)}{\text{length } (L)}$

$i = \frac{S\tan\alpha}{\frac{S}{\cos\alpha}} = \sin\alpha$



Equivalent Hydraulic Conductivity in stratified soil:

Flow in horizontal direction, $K_{H(eq)} = \frac{K_1H_1 + K_2H_2 + \cdots + K_nH_n}{H_1 + H_2 + \cdots + H_n}$

Flow in vertical direction, $K_{v(eq)} = \frac{H_1 + H_2 + \cdots + H_n}{\left(\frac{H_1}{K_1}\right) + \left(\frac{H_2}{K_2}\right) + \cdots + \left(\frac{H_n}{K_n}\right)}$

Rate of flow through flow net:

For Isotropic Soil ($K_H = K_V$), $q = K\left(\frac{N_f}{N_d}\right)H$

For Anisotropic Soil ($K_H \neq K_V$), $q = \sqrt{K_H \times K_V}\left(\frac{N_f}{N_d}\right)H$

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Compressibility of soil

 # Over consolidation Ratio: $OCR = \frac{\sigma_c'}{\sigma'}$ where, σ_c' = Pre consolidation pressure
σ' = Present effective vertical pressure

 # e-logσ' relationship:

For Normally consolidated clays, C_c = Compression Index = Slope of e-logσ' plot.

*** Compression Index:** $C_c = \frac{\Delta e}{\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)}$; $C_c = 0.009\,(LL-10)$

For over-consolidated clays, C_s = Swell Index = Slope of the rebound curve

*** Swell Index:** $C_s = \frac{\Delta e}{\log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)}$; $C_s \simeq \frac{1}{5}$ to $\frac{1}{10}\,C_c$

 # Secondary Compression Index: $C_\alpha = \frac{\Delta e}{\log\left(\frac{t_2}{t_1}\right)}$

 # Degree of consolidation: $U_z = 1 - \frac{u_z}{u_0}$ where, u_z = excess pore water pressure at time 't'.
u_0 = Initial pore water pressure

*** co-efficient of compressibility:** $a_v = \frac{\Delta e}{\Delta\sigma}$

*** co-efficient of volume compressibility:** $m_v = \frac{a_v}{1+e_o}$

*** co-efficient of consolidation:** $c_v = \frac{k}{\gamma_w m_v}$

*** Time factor:** $T_v = \frac{c_v t}{H_{dr}^2}$ where, H_{dr} = length of maximum drainage path.

* $H_{dr} = \frac{H_c}{2}$ (for both side drainage)

 # Average Degree of Consolidation:

$$U = \frac{S_{c(t)}}{S_c}$$

For $U = 0$ to 60%, $T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$ ⇝ $T_v \propto U^2$ So, $t \propto U^2$

For $U > 60\%$, $T_v = 1.781 - 0.933 \log(100 - U\%)$

Compaction of soil

Proctor Test:

* Standard Proctor Test:

Volume of mold = 944 cm^3 or $\frac{1}{30}$ ft^3

Height of drop = 304.8 mm or 12 inch

Weight of hammer = 2.5 Kg or 5.5 lb

No. of blows = 25 blows to each layer

No. of layer = 3

* Modified Proctor Test:

Volume of mold = 944 cm^3 or $\frac{1}{30}$ ft^3

Height of drop = 457 mm or 18 inch

Weight of hammer = 4.54 Kg or 10 lb

No. of blows = 25 to each layer

No. of layers = 5

Compaction Energy:

$$E = \frac{\left(\text{No. of blows per layer}\right) \times \left(\text{No. of layers}\right) \times \left(\text{weight of Hammer}\right) \times \left(\text{Height of drop of Hammer}\right)}{\text{Volume of Mold}}$$

For Standard Proctor Test, $E = \frac{25 \times 3 \times 2.5 \times 9.81 \times 0.3048}{944 \times 10^{-6}} = 594 \times 10^3$ N-m/m^3

$= 594$ KN-m/m^3

For Modified Proctor Test, $E = \frac{25 \times 5 \times 4.54 \times 9.81 \times 0.457}{944 \times 10^{-6}} = 2695 \times 10^3$ N-m/m^3

$= 2695$ KN-m/m^3

Relative compaction:

$$R(\%) = \frac{\gamma_{d\,(field)}}{\gamma_{d\,(max\text{-}lab)}} \times 100$$

$$R = \frac{R_o}{1 - D_r(1 - R_o)} \quad \text{where, } R_o = \frac{\gamma_{d(min.)}}{\gamma_{d\,(max.)}}$$

D_r = Relative density

* Determination of $\gamma_{d\,(field)}$ by sand cone method:

$$\gamma_{d\,(field)} = \frac{W_3}{V}$$

where, W_3 = dry weight of soil $= \frac{W_2}{1 + w}$

W_2 = weight of moist soil excavated from hole

w = moisture content

V = volume of excavated hole $= \frac{W_5 - W_c}{\gamma_{d\,(ottawa\ sand)}}$

W_5 = weight of sand to fill the hole and cone $= W_1 - W_4$

W_c = weight of sand to fill the cone only

W_1 = combined weight of the jar, cone and sand

W_4 = combined weight of the jar, cone and sand after inverted and filled the hole.

Dynamic Compaction:

1 tonne = 0.907 metric ton

Significant depth of densification,

$D \simeq \frac{1}{2}\sqrt{W_H h}$ W_H in metric ton, D, h in meter

In English Unit, 1 tonne = 2000 lb = 2 Kip

$D = 0.61\sqrt{W_H h}$ W_H in Kip, D, h in feet

Settlement of Shallow Foundations

Elastic Settlement:

* For Clay: ($\mu_s = 0.5$) $S_e = A_1 A_2 \frac{q_0 B}{E_s}$

where, $A_1 = f\left(\frac{H}{B}, \frac{L}{B}\right) \simeq (0.6 - 1.4)$

$A_2 = f\left(\frac{D_f}{B}\right) \simeq (0.92 - 0.95)$

L = length of foundation

B = width of foundation

D_f = Depth of foundation

q_0 = Net load per unit area of the foundation

H = depth of bottom of the foundation to a rigid layer

* For sand: $S_e = q_0 (\alpha B') \frac{1 - \mu_s^2}{E_s} I_s I_f$

where, E_s = Modulus of Elasticity (Average, $z = 0$ to $z = 5B$)

μ_s = poisson's ratio of soil

$B' = \frac{B}{2}$ for center

I_s = Shape factor $(0.6 \sim 0.99)$

I_f = depth factor $(0.60 \sim 0.99)$

$\alpha = 4$

Consolidation settlement:

Primary Consolidation:

* For normally consolidated clay, $S_{c(p)} = \frac{C_c H}{1 + e_0} \log\left(\frac{\sigma_0' + \Delta\sigma}{\sigma_0'}\right)$

* For over consolidated clay, (if $\sigma_0' + \Delta\sigma' \leq \sigma_c'$) Then,

$$S_{c(p)} = \frac{C_s H}{1 + e_0} \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right)$$

(If $\sigma_0' + \Delta\sigma' > \sigma_c'$) Then,

$$S_{c(p)} = \frac{C_s H}{1 + e_0} \log\left(\frac{\sigma_c'}{\sigma_0'}\right) + \frac{C_c H}{1 + e_0} \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_c'}\right)$$

Here, C_c = Compression Index $= \frac{\Delta e}{\log\left(\frac{\sigma_2}{\sigma_1}\right)} = 0.009(LL - 10)$

C_s = Swell Index $= \left(\frac{1}{5} \sim \frac{1}{10}\right) C_c$

$\Delta\sigma = \frac{\Delta\sigma_t' + 4\Delta\sigma_m' + \Delta\sigma_b'}{6}$

Secondary settlement: $S_s = C_\alpha' H \log\left(\frac{t_2}{t_1}\right)$ where, $C_\alpha' = \frac{C_\alpha}{1+e_p}$

$e_p = e_o - \Delta e$

Here, C_α = secondary compression index = $\frac{\Delta e}{\log\left(\frac{t_2}{t_1}\right)}$

Calculation of increase of vertical stress under a Foundation:

$$\Delta\sigma_z = q I_4$$

where, $$I_4 = \frac{2}{\pi}\left[\frac{m_1 n_1}{\sqrt{1+m_1^2+n_1^2}} \times \frac{1+m_1^2+2n_1^2}{(1+n_1^2)(m_1^2+n_1^2)} + \sin^{-1}\frac{m_1}{\sqrt{m_1^2+n_1^2}\sqrt{1+n_1^2}}\right]$$

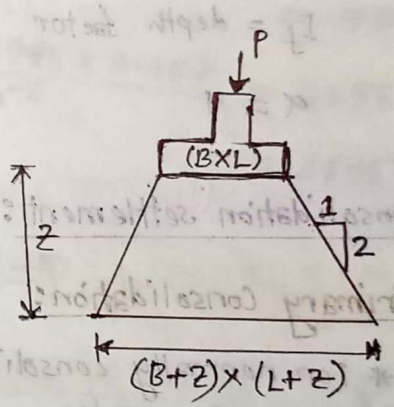
$$m_1 = \frac{L}{B}$$

$$n_1 = \frac{z}{b}$$

$$b = \frac{B}{2}$$

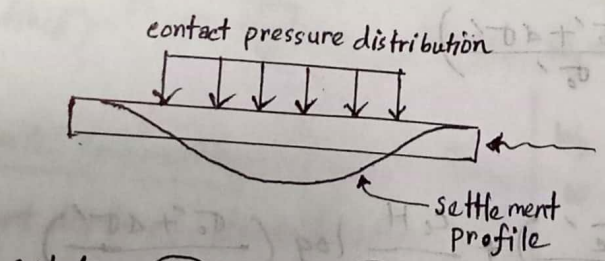
* Approximate method (2V : 1H method)

$$\Delta\sigma_z = \frac{P}{(B+z)(L+z)}$$

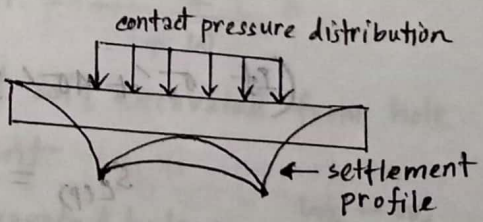


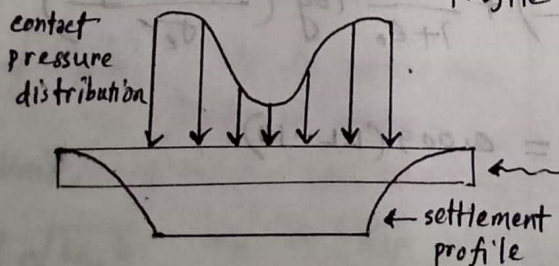
Elastic Settlement Profile:

In Clay:

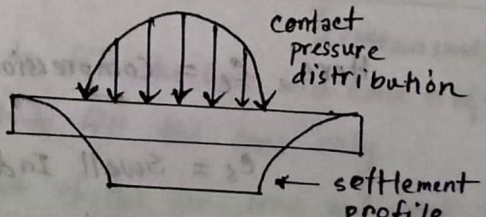


Flexible Foundation





Rigid Foundation



In Sand:

Subsoil Exploration

Degree of disturbance of sample:

It can be expressed by Area Ratio.

$$A_r(\%) = \frac{D_o^2 - D_i^2}{D_i^2} \times 100$$

where, D_o = outside diameter of sampler.
D_i = Inside diameter of sampler.

* If $A_r \leq 10\%$, the sample can be considered 'Undisturbed'.

Correlation for standard penetration number:

Cohesive soil:

$q_u = 0.58 P_a N_{60}^{0.72}$ and, $CI = \frac{LL - w}{LL - PI}$

* Approximate correlation among CI, N_{60} and q_u:

Standard penetration Number, N	consistancy	consistancy Index, CI	unconfined compressive strength, q_u
< 2	very soft	< 0.5	< 25
2 to 8	soft to Medium	0.5 to 0.75	25 to 80
8 to 15	stiff	0.75 to 1.0	80 to 150
15 to 30	very stiff	1.0 to 1.5	150 to 400
> 30	Hard	> 1.5	> 400

Granular soil:

corrected standard penetration Number, $(N_1)_{60} = C_N N_{60}$

where, $C_N = \sqrt{\frac{1}{\left(\frac{\sigma_o'}{P_a}\right)}}$ (Liao and Whitman's Relationship)

Skempton's Relationship:

$C_N = \frac{2}{1 + \left(\frac{\sigma_o'}{P_a}\right)}$ [for Normally consolidated fine sand]

$C_N = \frac{3}{2 + \left(\frac{\sigma_o'}{P_a}\right)}$ [for Normally consolidated coarse sand]

$C_N = \frac{1.7}{0.7 + \left(\frac{\sigma_o'}{P_a}\right)}$ [for over consolidated sand]

* correction for submergence / dilatency: For very fine & silty sand situated below the water table $(N_1)_{60} = 15 + \frac{1}{2}(N_{60} - 15)$ when $N_{60} > 15$

* Approximate relation between $(N_1)_{60}$ and Dr:

$(N_1)_{60}$	Relative Density, Dr
0–5	0–5
5–10	5–30
10–30	30–60
30–50	60–95

Meyerhof developed,

$$N_{60} = \left[17 + 21\left(\frac{\sigma_o'}{P_a}\right)\right] D_r^2$$

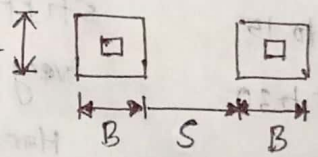
* Approximate relationship between ϕ' and $(N_1)_{60}$:

$$\phi' = 27.1 + 0.3(N_1)_{60} - 0.00054\,(N_1)_{60}^2 \quad \text{(Wolff)}$$

$$\phi' = \sqrt{20\,(N_1)_{60}} + 20 \quad \text{(Hatanaka and Uchida)}$$

Depth of Boring:

① For Isolated, spread footing or Raft: $D = 1.5B$



$S \geq 4B$

② For Adjacent footings: $D = 1.5L$ for $S < 2B$

③ For Pile foundations: $D = 1.5 \times$ width of the pile group or [10 to 30 m or more]

Spacing of Boring:

Type of Project	Spacing
Multistory Building	10–30 m
one story industrial plants	20–60 m
Highways	250–500 m
Residential subdivisions	250–500 m
Dams and dikes	40–80 m

No. of stories	Boring Depth
1	3.5 m
2	6 m
3	10 m
4	16 m
5	24 m

Bearing capacity for shallow foundation

Terzaghi's Equation: $q_u = cN_c\left(1+0.3\times\frac{B}{L}\right) + qN_q + \frac{1}{2}\gamma BN_\gamma\left(1-0.2\times\frac{B}{L}\right)$ (For rectangular)

$q_u = c'N_c + qN_q + \frac{1}{2}\gamma BN_\gamma$ (for strip/continuous footing)

$q_u = 1.3c'N_c + qN_q + 0.4\gamma BN_\gamma$ (for square footing)

$q_u = 1.3c'N_c + qN_q + 0.3\gamma BN_\gamma$ (for circular footing)

where, $N_q = K_q \tan\phi' = \dfrac{e^{2\left(\frac{3\pi}{4}-\frac{\phi'}{2}\right)\tan\phi'}}{2\cos^2\left(45+\frac{\phi'}{2}\right)}$

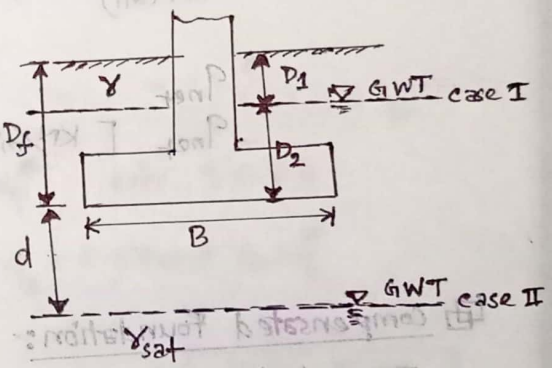
$N_c = (K_c+1)\tan\phi' = \cot\phi'(N_q-1)$

$N_\gamma = \frac{1}{2}(K_\gamma \tan\phi' - 1)\tan\phi' = \frac{1}{2}\times\left(\frac{K_{P\gamma}}{\cos^2\phi'}-1\right)\tan\phi'$ ($K_{P\gamma}$: passive earth pressure co-efficient)

$q = \gamma D_f$

For undrained condition ($\phi = 0$): $N_\gamma = 0$, $N_q = 1$, $N_c = 5.7$

* Effect of water table:



case-I: $(0 \le D_1 \le D_f)$

$q = D_1\gamma + D_2(\gamma_{sat} - \gamma_w)$

γ is replaced by $\gamma' = \gamma_{sat} - \gamma_w$

case-II: $(0 \le d \le B)$

$q = \gamma D_f$

γ is replaced by $\bar{\gamma} = \gamma' + \frac{d}{B}(\gamma - \gamma')$

case-III: $(d > B)$; water have no effect on bearing capacity equation.

γ is replaced by $\gamma_{av} = \frac{1}{B}[\gamma D + \gamma'(B-D)]$ for $D \le B$

$\gamma_{av} = \gamma$ for $D > B$

Meyerhof's Equation:

The general bearing capacity equation:

$$q_u = c'N_c F_{cs} F_{cd} F_{ci} + qN_q F_{qs} F_{qd} F_{qi} + \frac{1}{2}\gamma BN_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i}$$

Factor of safety:

* Allowable load bearing capacity, $q_{all} = \frac{q_u}{FS}$
* Net ultimate bearing capacity, $q_{net(u)} = q_u - q$ where, $q = \gamma D_f$
* Allowable net ultimate bearing capacity, $q_{all(net)} = \frac{q_{net(u)}}{FS} = \frac{q_u - \gamma D_f}{FS}$

Bearing capacity of Mat foundation:

* For clay: $q_u = 5.14\, c_u \left(1 + 0.195 \frac{B}{L}\right)\left(1 + 0.4 \frac{D_f}{B}\right) + q$
* For sand:

$$q_{net(all)}\ [Kip/ft^2] = 0.25\, N_{60}\left[1 + 0.33\left(\frac{D_f}{B}\right)\right][Se\ (inch)]$$

$$\leq 0.33 N_{60}\,[Se\ (inch)]$$

$$q_{net}\ [KN/m^2] = \frac{N_{60}}{0.08}\left[1 + 0.33\left(\frac{D_f}{B}\right)\right]\left[\frac{Se\ (mm)}{\quad}\right]$$

$$\leq 16.33\, N_{60}\left[\frac{Se\ (mm)}{25}\right]$$

Compensated Foundation:

The net pressure increase in the soil under a mat foundation can be reduced by increasing the depth D_f of the mat. This approach is generally referred to as compensated foundation design.

The net average applied pressure on soil, $q = \frac{Q}{A} - \gamma D_f$

* For fully compensated foundation, $q = 0$. Hence, $D_f = \frac{Q}{A\gamma}$
* Factor of safety against bearing capacity failure for partially compensated foundation,

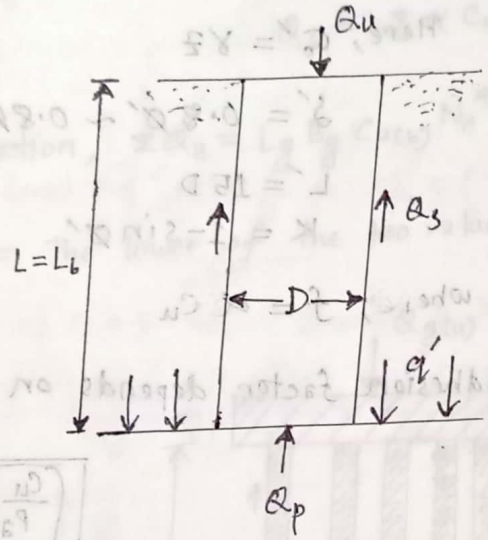
$$FS = \frac{q_{net(u)}}{\frac{Q}{A} - \gamma D_f}$$

Pile Foundation

Ultimate load carrying capacity of a Pile:

$Q_u = Q_p + Q_s$ where, Q_p = point bearing capacity

Q_s = Frictional resistance (skin friction)



L = Length of embedment

L_b = Length of embedment in bearing-stratum

D = Diameter of pile

Point bearing capacity, Q_p:

 # Sand: ($c'=0$) $Q_p = A_p q_p$ where, $q_p = q' N_q^*$ Here, $q' = \gamma L$

$\therefore Q_p = A_p q' N_q^* \leq A_p q_l$ where, $q_l = 0.5 \tan\phi' P_a N_q^*$

Here, $A_p = \frac{\pi}{4} D^2$

$P_a = 100\ KN/m^2$ or $1000\ lb/ft^2$

N_q^* depends on soil friction angle, ϕ

ϕ	N_q^*
25°	26
30°	56.3
35°	143

 # Clay: ($\phi'=0$) $Q_p = A_p q_p$ where, $q_p = c_{u(b)} N_c^* = 9 c_{u(b)}$

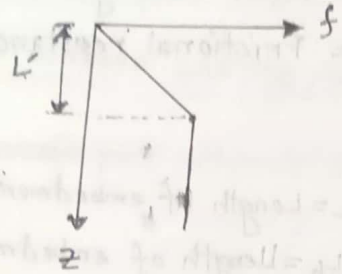
$= 9 c_{u(b)} A_p$

 # Based on SPT Value: $Q_p = 0.4 \frac{L}{D} P_a N_{60} \leq 4 P_a N_{60}$

where, N_{60} = Average value of SPT number near pile point (about 10D above and 4D below the pile point)

Skin friction, Q_s:

 # Sand: ($c' = 0$) $\quad Q_s = \Sigma P \Delta L f$ where, $f = K \sigma_0' \tan\delta'$ for $z = 0$ to L'



$f = f_{z=L'}$ for $z = L'$ to L

Here, $\sigma_0' = \gamma z$

$\delta' = 0.5\phi' \sim 0.8\phi'$

$L' = 15\,D$

$K = 1 - \sin\phi'$

 # Clay: ($\phi' = 0$) $\quad Q_s = \Sigma P \Delta L f$ where, $f = \alpha c_u$

Adhesion factor depends on $\frac{c_u}{p_a}$

 # Based on SPT value:

$Q_s = P L f_{av}$ where, $f_{av} = 0.02\, p_a (\bar{N}_{60})$ for high displacement driven pile.

Here, $\bar{N}_{60}$ = Average SPT number

$f_{av} = 0.01\, p_a (\bar{N}_{60})$ for low-displacement driven pile

$\frac{c_u}{p_a}$	—	α
≤ 0.1	—	1.0
0.2	—	0.92
0.3	—	0.82
0.4	—	0.71
0.6	—	0.62
0.8	—	0.54
1.0	—	0.48

Ultimate capacity of group piles in clay:

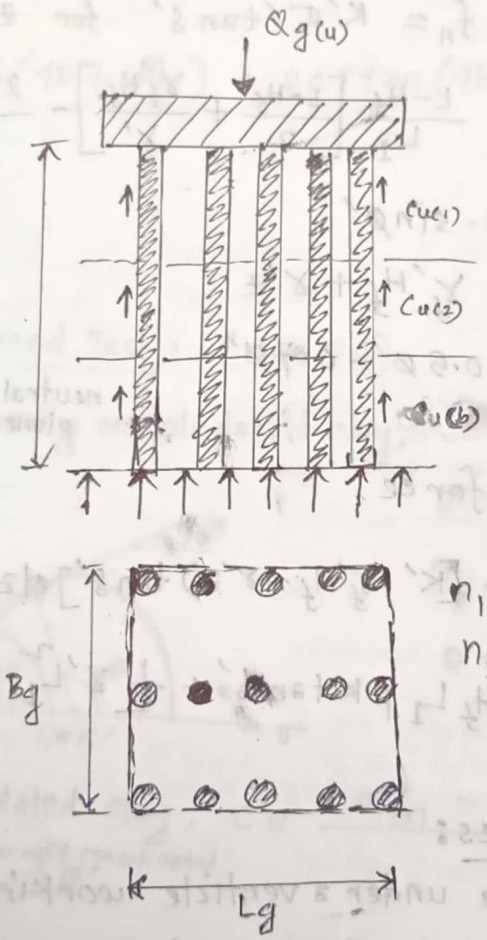
Individual action, $\Sigma Q_u = n_1 \times n_2 \, (Q_p + Q_s)$

where, $Q_p = 9 C_{u(b)} A_p$

$Q_s = \Sigma \alpha C_u p \Delta L$

Group action, $\Sigma Q_u = L_g B_g C_{u(b)} N_c^* + \Sigma 2 (L_g + B_g) C_u \Delta L$

$Q_{g(u)}$ = The lower of the two values of ΣQ_u



Group Efficiency of pile, $\eta = \dfrac{Q_{g(u)}}{\Sigma Q_u \text{ (Individual action)}}$

Negative skin friction:

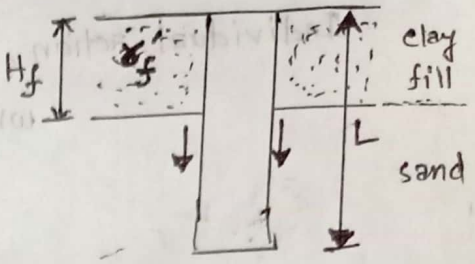
Clay fill over granular soil:

$f_n = K' \sigma_0' \tan\delta'$

where, $K' = 1 - \sin\phi'$

$\sigma_0' = \gamma_f' z$

$\delta' = 0.5\phi' \sim 0.7\phi'$



Total downward drag force,

$$Q_n = \int_0^{H_f} p(K' \gamma_f' z \tan\delta')\, dz = \frac{1}{2} \gamma_f' H_f^2 p K \tan\delta'$$

Granular soil fill over clay:

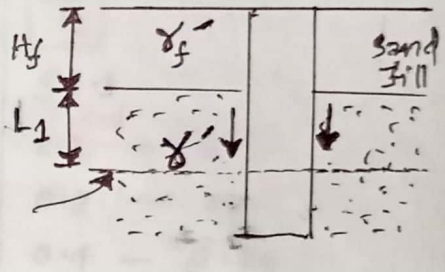
$f_n = K' \sigma_0' \tan\delta'$ for $z = 0$ to $z = L_1$

where, $L_1 = \frac{L - H_f}{L_1}\left[\frac{L - H_f}{2} + \frac{\gamma_f' H_f}{\gamma'}\right] - \frac{2\gamma_f' H_f}{\gamma'}$

$K' = 1 - \sin\phi'$

$\sigma_0' = \gamma_f' H_f + \gamma' z$

$\delta' = 0.5\phi' - 0.7\phi'$



Total downward drag force,

$$Q_n = \int_0^{L_1} p\,[K'(\gamma_f' H_f + \gamma' z)\tan\delta']\, dz$$

$$= \gamma_f' H_f L_1 p K \tan\delta' + \frac{1}{2}\gamma' L_1^2 p K' \tan\delta'$$

Elastic settlement of piles:

Total settlement of a pile under a verticle working load Q_w,

$$S_e = S_{e(1)} + S_{e(2)} + S_{e(3)}$$ where,

Here,

$$S_{e(1)} = \frac{(Q_{wp} + \xi Q_{ws}) L}{A_p E_p}$$ where, $\xi = (0.5 \sim 0.67)$

$$S_{e(2)} = \frac{Q_{wp} D}{A_p E_s} \times (1 - \mu_s^2) I_{wp}$$ $I_{wp} = 0.85$

$$S_{e(3)} = \frac{Q_{ws} D}{pL E_s} \times (1 - \mu_s^2) I_{ws}$$ $I_{ws} = 2 + 0.35\sqrt{\frac{L}{D}}$

$S_{e(1)}$ = Elastic settlement of pile

$S_{e(2)}$ = settlement of pile caused by the load at pile tip

$S_{e(3)}$ = settlement of pile caused by the load transmitted along pile shaft.

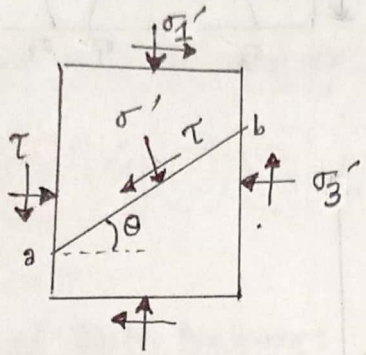
E_p = Modulus of Elasticity of pile material

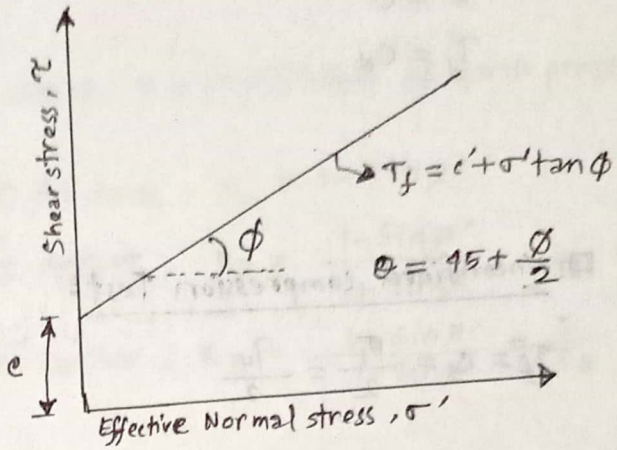
E_s = Modulus of Elasity of soil at or below the pile point

Shear Strength of soil

Mohr-coulomb failure criteria:

* $\tau_f = c' + \sigma' \tan\phi$





* $\sigma_1' = \sigma_3' \tan^2\left(45 + \frac{\phi}{2}\right) + 2c' \tan\left(45 + \frac{\phi'}{2}\right)$

* $\sigma_1 = \sigma_3' + \Delta\sigma_d$

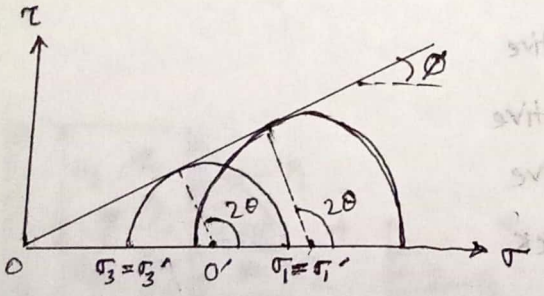
Consolidated - Drained Test: ($\Delta u_d = 0$)

* For sand and normally consolidated clay, $c = 0$

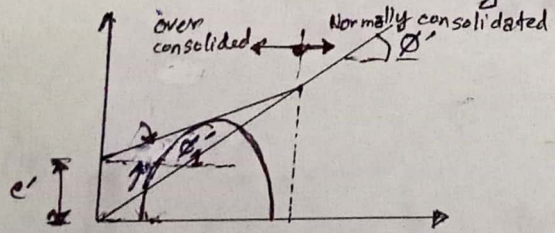
$$\phi' = \sin^{-1}\left(\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3}\right)$$

$$\tau_f = \sigma' \tan\phi'$$

$$\theta = 45 + \frac{\phi'}{2}$$



* For over consolidated clay, $c' = \dfrac{\sigma_{1(1)}' - \sigma_{3(1)}' \tan^2\left(45 + \frac{\phi_1'}{2}\right)}{2\tan\left(45 + \frac{\phi_1'}{2}\right)}$



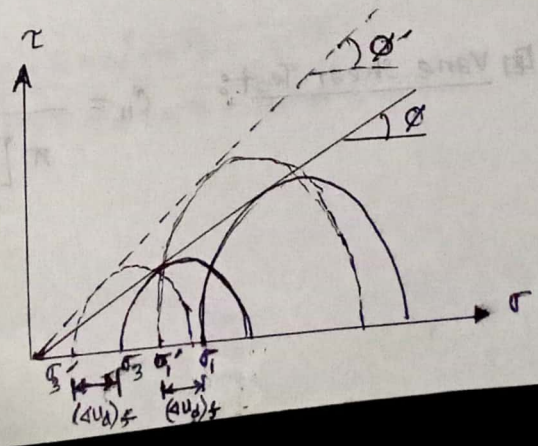
$$\phi_1' = 2\left\{\tan^{-1}\left[\frac{\sigma_{1(1)}' - \sigma_{1(2)}'}{\sigma_{3(1)}' - \sigma_{3(2)}'}\right]^{0.5} - 45\right\}$$

Consolidated Undrained Test:

* For sand and normally consolidated clay,

$$\phi = \sin^{-1}\left(\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3}\right)$$

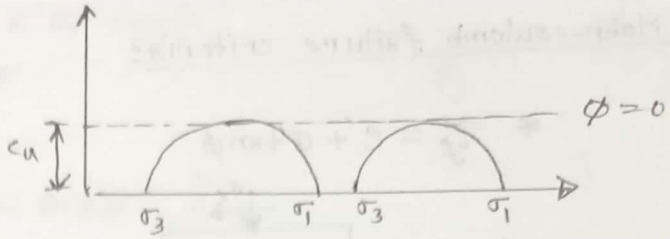
$$\phi' = \sin^{-1}\left[\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3 - 2(\Delta u_d)_f}\right]$$



Unconsolidated - Undrained Test:

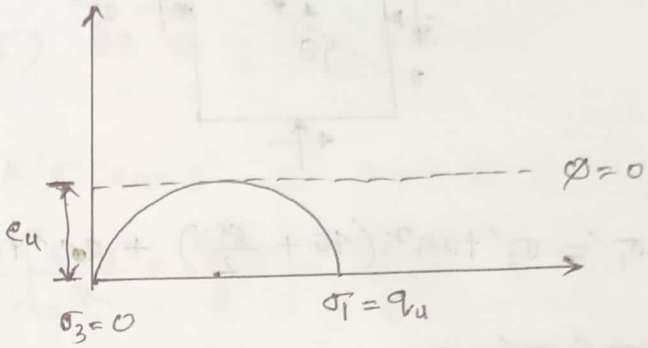
$$\phi = 0$$

$$\tau_f = c_u$$



Unconfined compression Test:

$$\tau_f = c_u = \frac{\sigma_1}{2} = \frac{q_u}{2}$$



Sensitivity of clay:

$$S_t = \frac{c_u \text{ (undisturbed)}}{c_u \text{ (remolded)}} = \frac{\tau_f \text{ (undisturbed)}}{\tau_f \text{ (remolded)}}$$

S_t	classification
1	Insensitive
1-2	slightly sensitive
2-4	Medium sensitive
4-8	very sensitive
8-16	Slightly quick
16-32	Medium quick
32-64	very quick
>64	Extra quick

Vane Shear Test:

$$c_u = \frac{T}{\pi \left[\frac{d^2 h}{2} + \beta \frac{d^3}{4}\right]}$$

where, T = The torque applied

d = diameter of shear vane

h = height of shear vane

$\beta = \frac{1}{2}$ for triangular mobilization

$= \frac{2}{3}$ for uniform

$= \frac{3}{5}$ for parabolic

Earth Pressure

Vertical Earth Pressure: $\sigma_v' = \gamma z$

Lateral Earth Pressure: $\sigma_H' = K \sigma_v'$ where, K = co-efficient of earth pressure

* **Co-efficient of earth pressure:**

(i) At rest, $K_o = 1 - \sin\phi'$

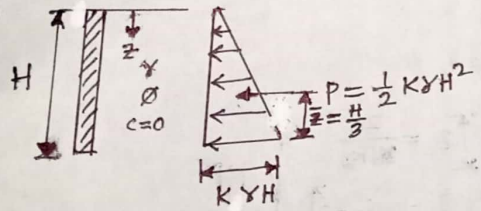
(ii) Active, $K_a = \frac{1-\sin\phi'}{1+\sin\phi'}$

(iii) Passive, $K_p = \frac{1+\sin\phi'}{1-\sin\phi'} = \frac{1}{K_a}$

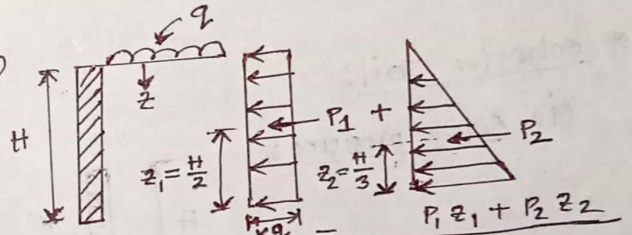
Distribution of Earth Pressure:

* **Cohesionless soil:** (c=0)

(i)



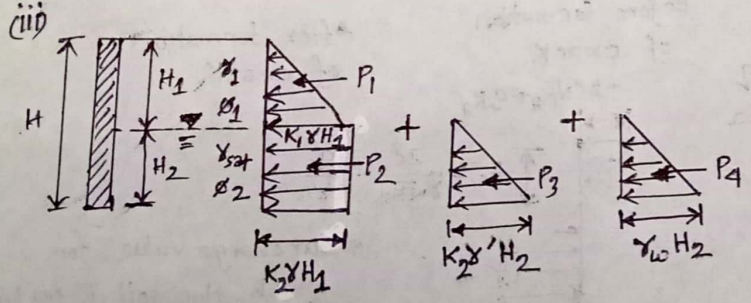
(ii)



$P_1 = Kq H$

$P_2 = \frac{1}{2} K\gamma H^2$

(iii)



$P_1 = \frac{1}{2} K_1 \gamma H_1^2$

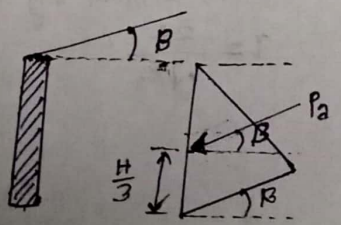
$P_2 = K_2 \gamma H_1 H_2$

$P_3 = \frac{1}{2} K_2 \gamma' H_2^2$

$P_4 = \frac{1}{2} \gamma_w H_2^2$

$\bar{z} = \frac{P_1 z_1 + P_2 z_2 + \cdots}{P_1 + P_2 + \cdots}$

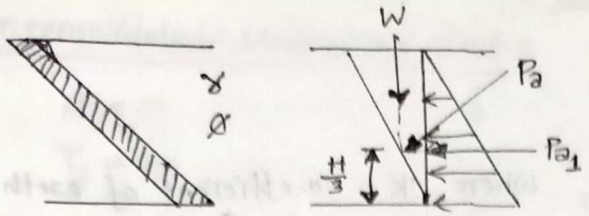
(iv)



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

$K_a = \cos\beta \times \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$

(v)

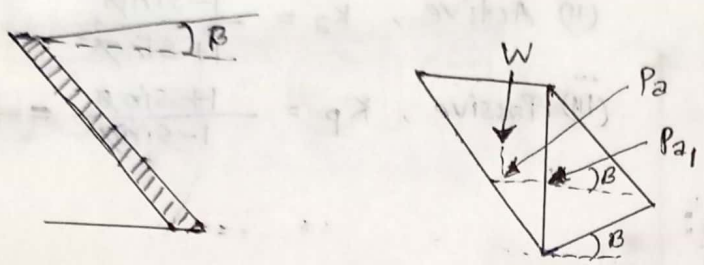


$P_{a_1} = \frac{1}{2} K_a \gamma H^2$

W = weight of soil

$P_a = \sqrt{P_{a_1}^2 + W^2}$

(vi)



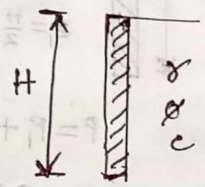
$P_{a_1} = \frac{1}{2} K_a \gamma H$

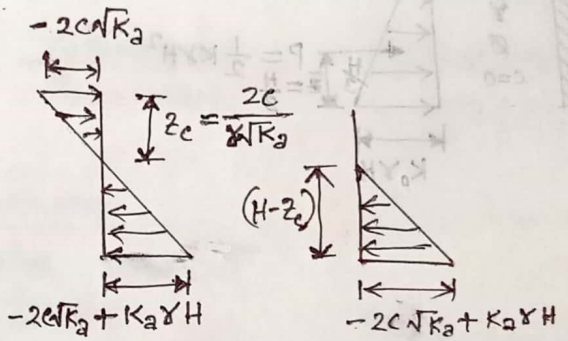
W = weight of soil

$P_a = \sqrt{P_{a_{1H}}^2 + (W + P_{a_{1V}})^2}$

* cohesive soil:

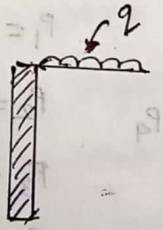
(i) Active pressure:

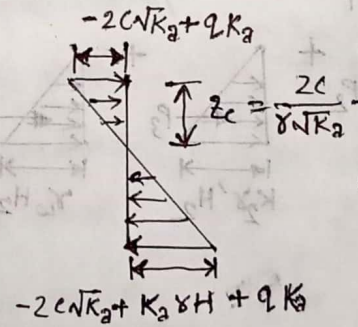




Before formation of crack

After formation of crack

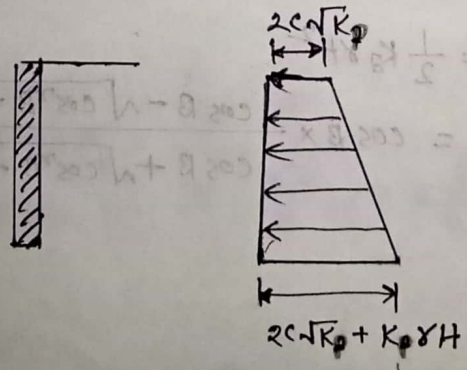




* surcharge value for which the soil is critically stable without any support

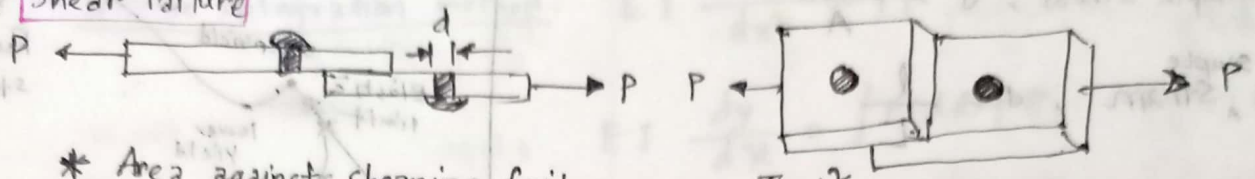
$q = \frac{2c}{\sqrt{K_a}}$

(ii) Passive pressure:



Shearing Stress, Bearing Stress and Tearing stress

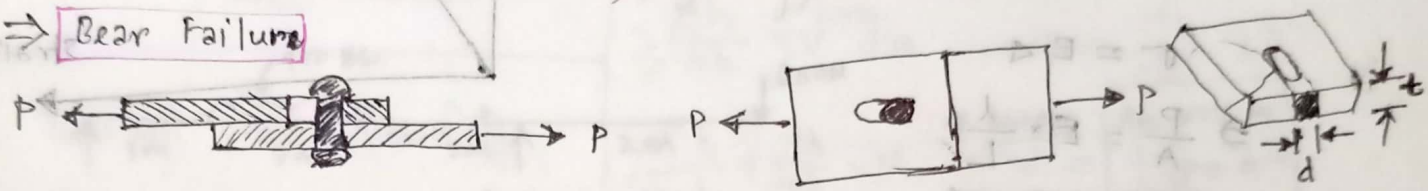
⇒ **Shear Failure**



* Area against shearing failure, $A_s = \frac{\pi}{4} d^2$

(bolt failure)

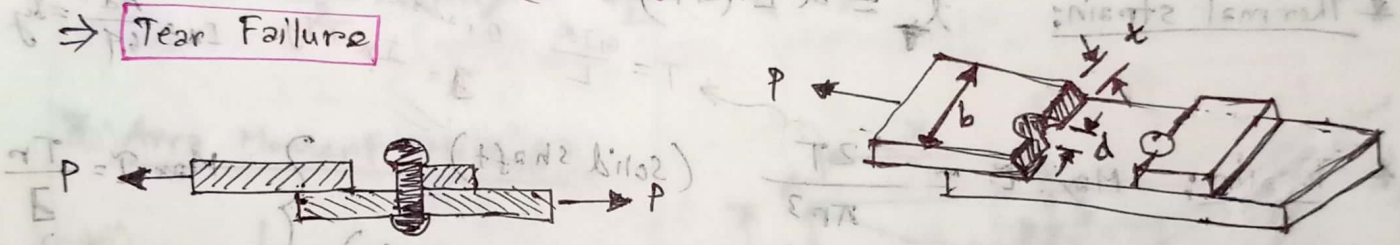
⇒ **Bear Failure**



* Area against bearing failure, $A_b = (t \times d)$

(Plate deformed)

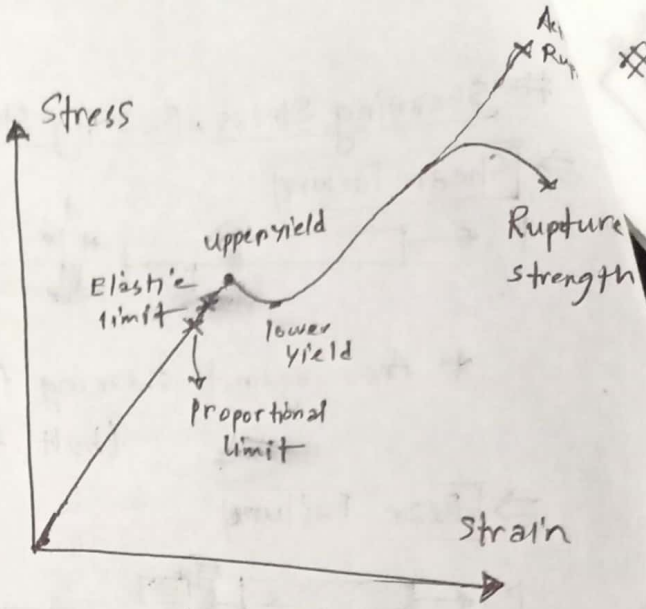
⇒ **Tear Failure**



* Area against tearing failure, $A_t = (b-d)t$

(plate failure)

Stress and Strain:



* Simple stress, $\sigma = \frac{F}{A}$

* Simple strain, $\delta = \frac{l}{L}$

Stress $\propto$ Strain

$$\sigma = E\delta$$

$$\Rightarrow \frac{P}{A} = E \times \frac{\lambda}{L}$$

$$\Rightarrow \boxed{\lambda = \frac{PL}{AE}}$$

* Thermal strain: $\lambda_t = \alpha L (\Delta T)$

* Torsion: $\text{Max. } \tau = \frac{2T}{\pi r^3}$ (solid shaft)

$\text{Max. } \tau = \frac{2TR}{\pi(R^4 - r^4)}$ (Hollow shaft)

$T = \frac{GJ\theta}{L}$ θ radian

$J = I_x + I_y$ $I_x = \frac{\pi d^4}{64} = I_y$

$\text{Max } \tau = \frac{Tr}{J}$ → polar moment of inertia.

Torque $= \frac{P}{2\pi f}$

Stresses in Beam:

Flexural stress, $f = \frac{My}{I}$

Average shear stress, $\tau = \frac{V}{A}$

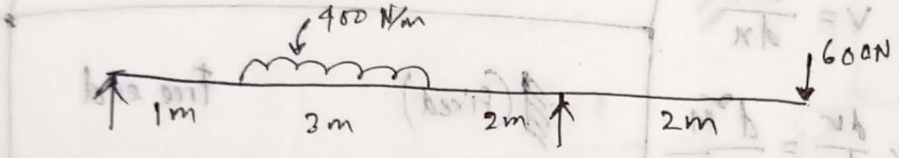
Max. shear stress, $\tau = \frac{VQ}{Ib}$ Shear flow $= \tau b$

Beam deflection:

* **Double Integration method:** $EI\frac{d^2y}{dx^2} = M$

$$EI\frac{dy}{dx} = \int M\,dx + C_1$$

$$EIy = \iint M\,dx\cdot dx + C_1x + C_2$$



$R_1 = 500\ N$ $\quad R_2 = 1300\ N$

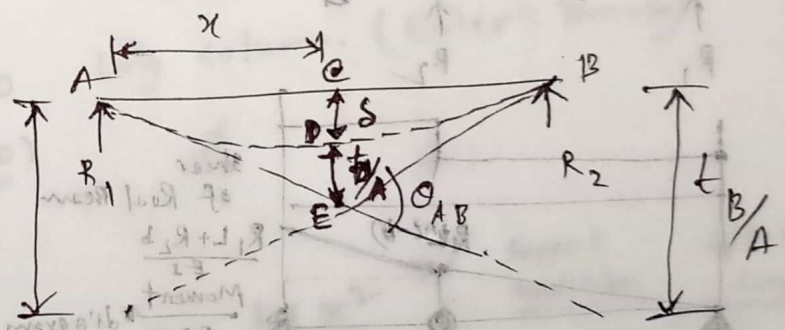
* **Hints:** At $x=6$ m, $y=0$; At $x=0$ m, $y=0$

$$M = 500x - \frac{400}{2}\times\langle x-1\rangle^2 - \frac{400}{2}\times\langle x-1\rangle^2 + 1300\langle x-6\rangle$$

* **Area Moment Method:**

$$\text{Area} = \frac{1}{n+1}\cdot bh \qquad t_{A/B}$$

$$\bar{x} = \frac{1}{n+2}\cdot b$$



$$\theta_{AB} = \frac{1}{EI}(\text{area})_{AB}$$

$$t_{B/A} = \frac{1}{EI}(\text{area})_{BA}\times\bar{x}_B$$

$$CE = \frac{t_{B/A}}{L}\times x$$

$$DE = t_{D/A} = \frac{1}{EI}(\text{area})_{BA}\times\bar{x}_D$$

$$\delta = CE - DE$$

Conjugate beam method :

EIy = deflection

$EI\frac{dy}{dx}$ = slope

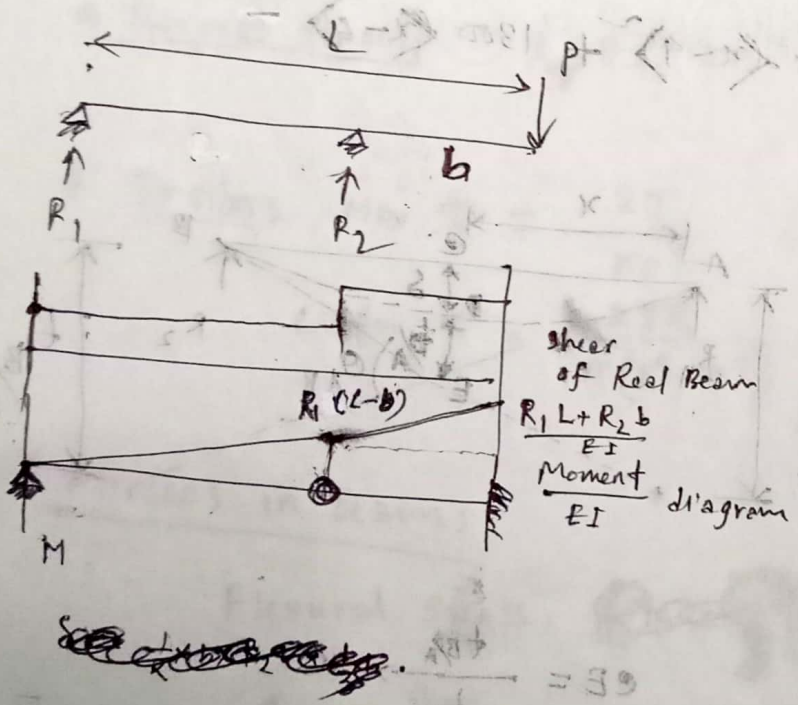
$EI\frac{d^2y}{dx^2}$ = Moment

$EI\frac{d^3y}{dx^3}$ = shear or, $V = \frac{dM}{dx}$

$EI\frac{d^4y}{dx^4}$ = Load or, $\frac{dV}{dx} = \frac{d^2M}{dx^2}$

Real Beam	Conjugate Beam
$\frac{M}{EI}$	load
slope	shear
Deflection	Moment

(Fixed)	Free end
Free end	(Fixed)
External (Hinge)	(Hinge)
(internal Hinge)	(Link)
(Link)	(internal Hinge)



Column:

Short column (Crushing)

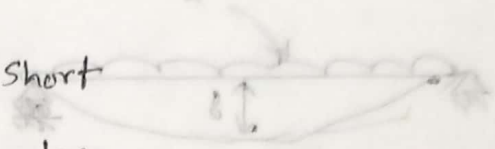
Long column (Bulking)

intermediat column (crushing & Bulking)



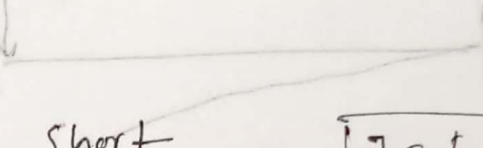
$$\frac{\text{Effective length}}{\text{least lateral dimention}} < 12 \text{ Short}$$

$$\geq 12 \text{ long}$$

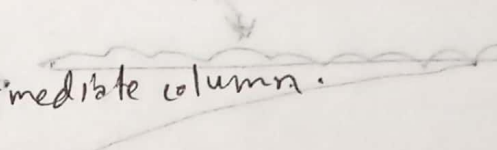


$$\text{Slenderness Ratio} = \frac{\text{Effective length}}{\text{least radius of gyration}} < 45 \text{ Short}$$

$J = I_{xx} + I_{yy}$



$$32 < \frac{L_{eff}}{r} < 100$$ intermediate column.



$\frac{L_{eff}}{r} > 100$ (120) long column.. (Euler's Formula)

Euler's Formula:

Critical load for a column, $P = \frac{EI\pi^2}{L_e^2}$

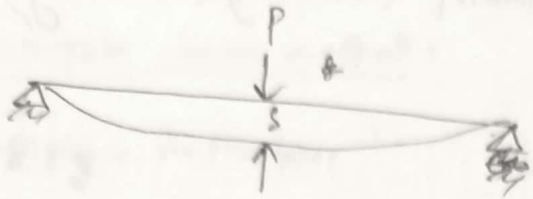
putting $I = r^2 A$, $P = \frac{E\pi^2}{Le^2} \times r^2 A$

$$\Rightarrow \frac{P}{A} = \frac{E\pi^2}{\left(\frac{Le}{r}\right)^2}$$

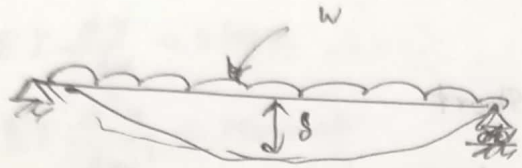
Applicable for $\left[\frac{Le}{r} \geq 100\right]$

Support condition	Effective Length
both Fixed	$\frac{L}{2}$
one Fixed, one hinged	$0.7L$
both hinged	L
one Fixed, other free	$2L$

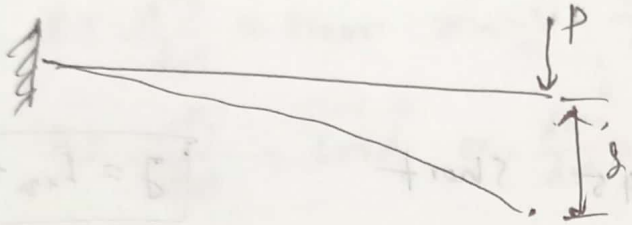
Deflection :



$$\delta = \frac{PL^3}{48EI}$$



$$\delta = \frac{5wL^4}{384EI}$$



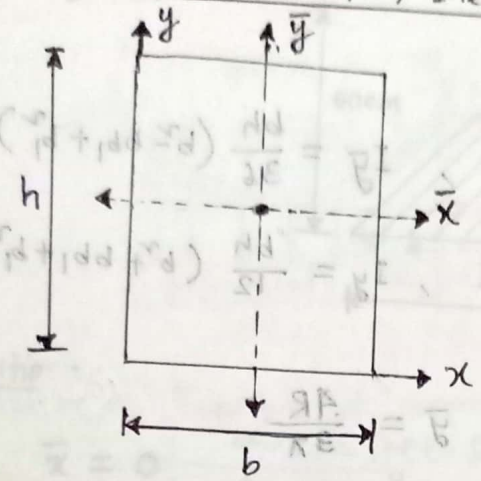
$$\delta = \frac{PL^3}{3EI}$$



$$\delta = \frac{wL^4}{8EI}$$

Centroid & Moment of Inertia

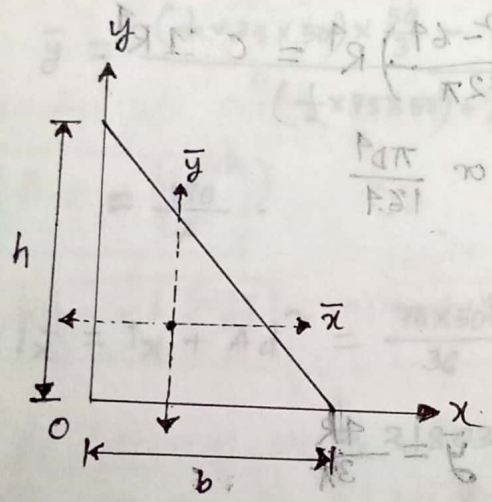
Centroid & Moment of Inertia of some known geometric shape:



$$\bar{x} = \frac{b}{2}, \quad \bar{y} = \frac{h}{2}$$

$$I_{\bar{x}} = \frac{bh^3}{12}, \quad I_{\bar{y}} = \frac{hb^3}{12}$$

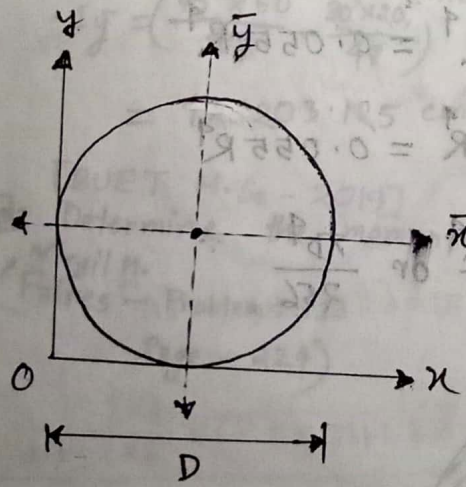
$$I_x = \frac{bh^3}{3}, \quad I_y = \frac{b^3h}{3}$$



$$\bar{x} = \frac{b}{3}, \quad \bar{y} = \frac{h}{3}$$

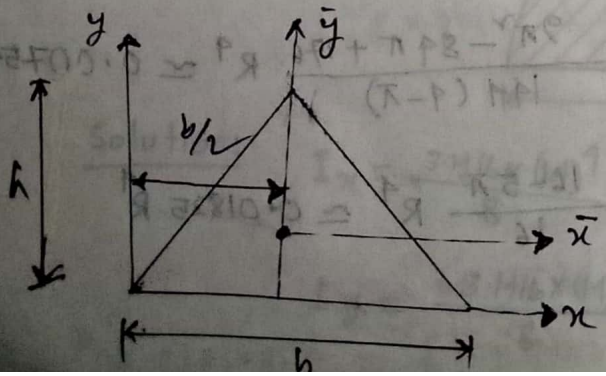
$$I_{\bar{x}} = \frac{bh^3}{36}, \quad I_{\bar{y}} = \frac{hb^3}{36}$$

$$I_x = \frac{bh^3}{12}, \quad I_y = \frac{b^3h}{12}$$



$$\bar{x} = \frac{D}{2}, \quad \bar{y} = \frac{D}{2}$$

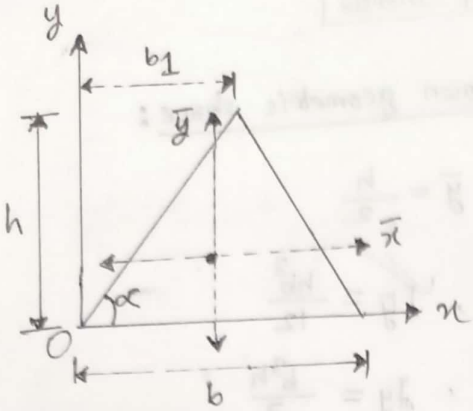
$$I_{\bar{x}} = \frac{\pi D^4}{64}, \quad I_{\bar{y}} = \frac{\pi D^4}{64} \text{ or } \frac{\pi R^4}{4}$$



$$\bar{x} = \frac{b}{2}, \quad \bar{y} = \frac{h}{3}$$

$$I_{\bar{x}} = \frac{bh^3}{36}, \quad I_{\bar{y}} = \frac{b^3h}{48}$$

$$I_x = \frac{bh^3}{12}, \quad I_y = \frac{7b^3h}{48}$$

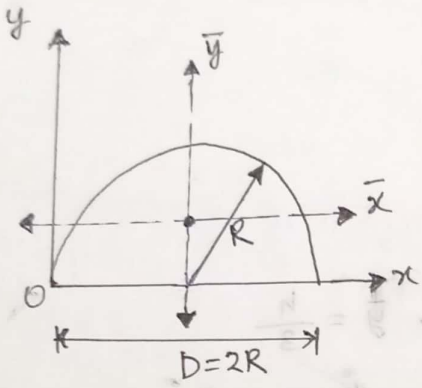


$$\bar{x} = \frac{b+b_1}{3} \quad \text{where, } b_1 = \frac{h}{\tan\alpha}$$

$$\bar{y} = \frac{h}{3}$$

$$I_{\bar{x}} = \frac{bh^3}{36}, \quad I_{\bar{y}} = \frac{bh}{36}(b^2 - bb_1 + b_1^2)$$

$$I_x = \frac{bh^3}{12}, \quad I_y = \frac{bh}{12}(b^2 + bb_1 + b_1^2)$$

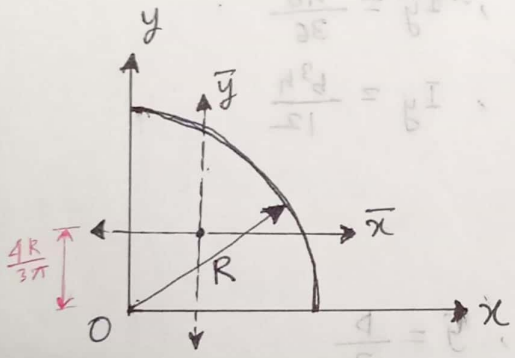


$$\bar{x} = \frac{D}{2}, \quad \bar{y} = \frac{4R}{3\pi}$$

$$I_{\bar{x}} = \left(\frac{9\pi^2 - 64}{72\pi}\right) R^4 = 0.11R^4$$

$$I_{\bar{y}} = \frac{\pi R^4}{8} \text{ or } \frac{\pi D^4}{128}$$

$$I_x = \frac{\pi R^4}{8}$$

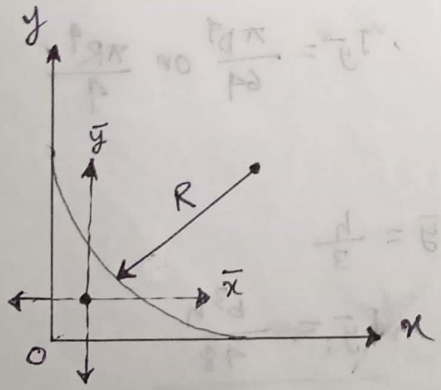


$$\bar{x} = \frac{4R}{3\pi}, \quad \bar{y} = \frac{4R}{3\pi}$$

$$I_{\bar{x}} = \left(\frac{9\pi^2 - 64}{144\pi}\right) \times R^4 = 0.055R^4$$

$$I_{\bar{y}} = \left(\frac{9\pi^2 - 64}{144\pi}\right) \times R^4 = 0.055R^4$$

$$I_x = I_y = \frac{\pi R^4}{16} \text{ or } \frac{\pi D^4}{256}$$



$$\bar{x} = \left(\frac{10-3\pi}{12-3\pi}\right) \times R$$

$$\bar{y} = \left(\frac{10-3\pi}{12-3\pi}\right) \times R$$

$$I_{\bar{x}} = I_{\bar{y}} = \frac{9\pi^2 - 84\pi + 176}{144(4-\pi)} R^4 \simeq 0.00754R^4$$

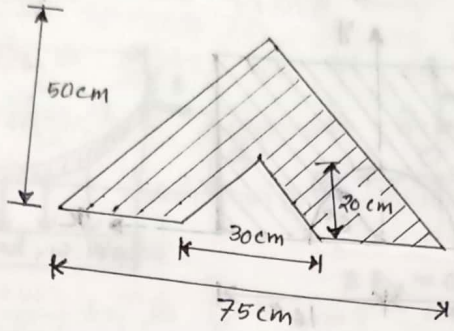
$$I_x = I_y = \frac{16-5\pi}{16} R^4 \simeq 0.01825R^4$$

Radius of gyration, $r = \sqrt{\frac{I}{A}}$

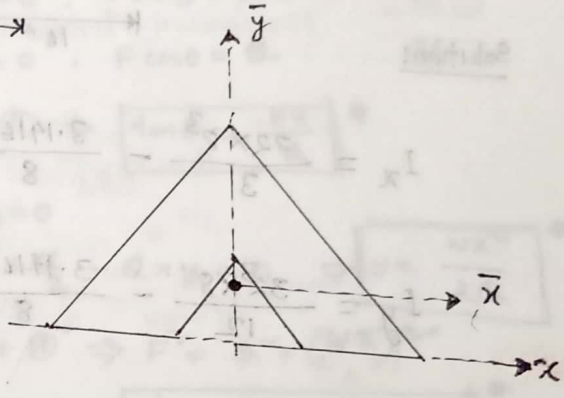
Polar moment of inertia, $J = I_x + I_y$

[BUET M.Sc.-2018]

Determine the moment of inertia of the following figure about its centroidal axis.



Solution:



$$\bar{x} = 0$$

$$\bar{y} = \frac{\left(\frac{1}{2}\times 75\times 50\right)\times \frac{50}{3} - \left(\frac{1}{2}\times 30\times 20\right)\times \frac{20}{3}}{\left(\frac{1}{2}\times 75\times 50\right) - \left(\frac{1}{2}\times 30\times 20\right)}$$

(A_1, y_1, A_2, y_2)

$$= \frac{130}{7}.$$

$$I_{\bar{x}} = I_x + Ad^2 = \frac{75\times 50^3}{36} + \left(\frac{75\times 50}{2}\right)\times\left(\frac{50}{3} - \frac{130}{7}\right)^2 - \left[\frac{30\times 20^3}{36} + \left(\frac{30\times 20}{2}\right)\times\left(\frac{20}{3} - \frac{130}{7}\right)^2\right]$$

$$= 218035.7143 \text{ cm}^4$$

$$I_{\bar{y}} = \left(\frac{75^3\times 50}{48} - \frac{30^3\times 20}{48}\right)$$

About its base (x axis) $I_x = \frac{75\times 50^3}{12} - \frac{30\times 12^3}{12} = 761250 \text{ cm}^4$

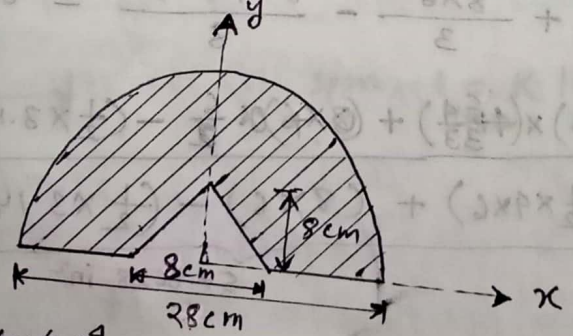
$$= 428203.125 \text{ cm}^4$$

(Ans.)

[BUET M.Sc - 2019]

Determine the moment of inertia about x and y axis.

Virgil M.
(Faires – Problem : 813
Page – 224)



Solution:

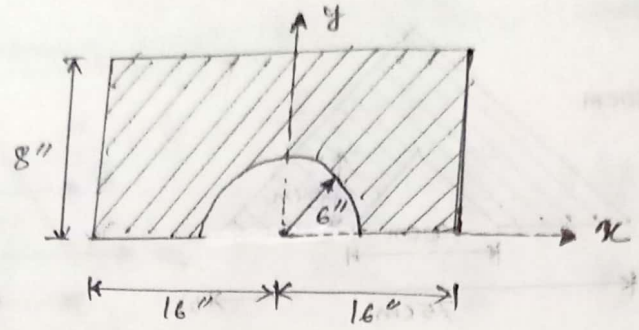
$$I_x = \frac{3.1416\times (14)^4}{8} - \frac{8\times 8^3}{12} = 14744.62987 \text{ cm}^4$$

$$I_y = \frac{3.1416\times (14)^4}{8} - \frac{8^3\times 8}{48} = 15000.62987 \text{ cm}^4$$

(Ans.)

[PGICL'21]

For the shaded area of following figure, compute I_x and I_y.



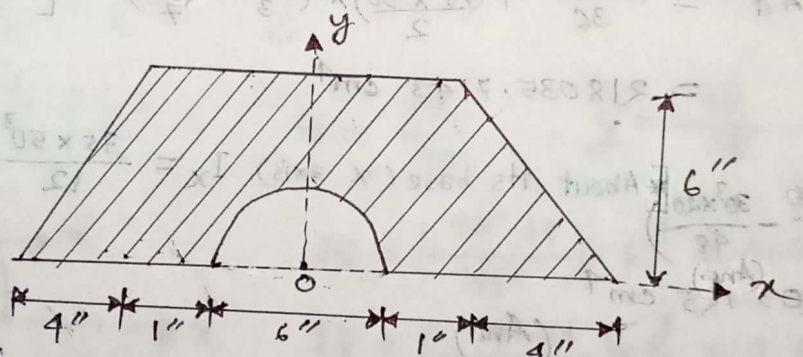
Solution:

$$I_x = \frac{32 \times 8^3}{3} - \frac{3.1416 \times (6)^4}{8} = 4952.394133 \text{ in}^4$$

$$I_y = \frac{32^3 \times 8}{12} - \frac{3.1416 \times 6^3}{8} = 11336.39413 \text{ in}^4$$

(Ans.)

For the shaded area of following figure, determine I_x, I_y, $I_{\bar{x}}$



Solution:

$$I_x = \frac{4 \times 6^3}{12} \times 2 + \frac{8 \times 6^3}{3} - \frac{3.1416 \times 3^4}{8} = 688.1913 \text{ in}^4$$

$$\bar{y} = \frac{2 \times (\frac{1}{2} \times 4 \times 6) \times (\frac{6}{3}) + (8 \times 6) \times \frac{6}{2} - (\frac{1}{2} \times 3.1416 \times 3^2) \times \frac{4 \times 3}{3 \times 3.1416}}{2 \times (\frac{1}{2} \times 4 \times 6) + (8 \times 6) - (\frac{1}{2} \times 3.1416 \times 3^2)}$$

$\Rightarrow \bar{y} = 3.007$

57.8628 in^2

$\bar{x} = 0$

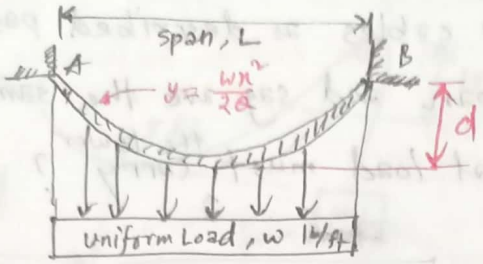
$$I_{\bar{x}} = I_x - Ad^2 = 688.1913 - 57.86 \times (3.007)^2 = 165 \text{ in}^4$$

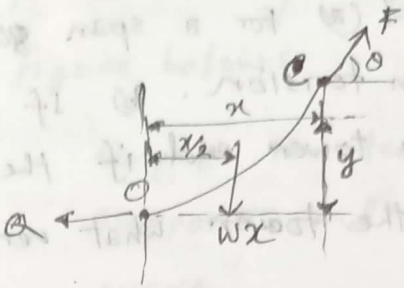
$$I_y = \frac{8^3 \times 6}{12} - \frac{3.1416 \times 3^4}{8} + 2 \times 6 \times \frac{4^3}{36} + 4 \times 6 \times (4 + \frac{4}{3})^2 = 928.1913 \text{ in}^4$$

(Ans.)

Flexible Chord

Parabolic Chord:





$$s = \int \left[1 + \left(\frac{wx}{Q}\right)^2\right]^{0.5} dx$$

$\Sigma F_x = 0$, $F \sin\theta = wx$ ..... (I)

$\Sigma F_y = 0$, $F \cos\theta = Q$ ..... (II)

(I) ÷ (II) $\Rightarrow$ $\boxed{\tan\theta = \frac{wx}{Q}}$ *

$\Sigma M_c = 0$

$wx \times \frac{x}{2} - Q \times y = 0 \Rightarrow \boxed{y = \frac{wx^2}{2Q}}$ *

(I)^2 + (II)^2 $\Rightarrow F^2 = Q^2 + (wx)^2$

$\therefore F = \sqrt{Q^2 + (wx)^2}$ *

Maximum Tension at support,

$$F = \sqrt{Q^2 + \left(\frac{WL}{2}\right)^2}$$

Tension at point o (lower point)

$$\boxed{Q = \frac{WL^2}{8d}}$$

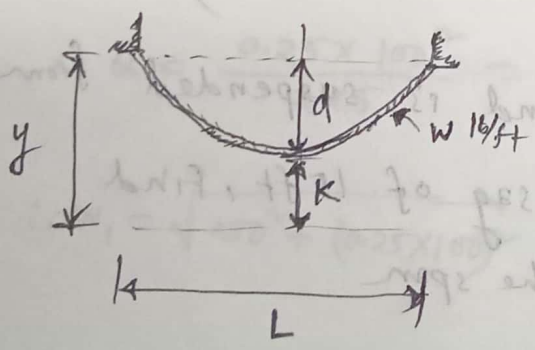
$$\boxed{\tan\theta = \frac{WL}{2Q}}$$

Length of the curve

$$\boxed{S = L + \frac{8d^2}{3L} - \frac{32d^4}{5L^3}}$$

The catenary:

when a flexible chord with a uniform self weight w per unit length is suspended between two points and acted on by the force of gravity only, the curve of the chord is called catenary.



$$K = \frac{s^2 - d^2}{2d}, \quad y = K + d$$

$F_{max} = wy$.

span, $L = K \ln\left(\frac{s+y}{K}\right)$

A cable weighing 6 lb per ft is suspended from two supports on the same level (a) For a span 800 ft and a sag of 60 ft, determine the maximum tension. (b) If six cables as described pass across a supporting tower and if the span and sag are the same on each side of the tower what vertical load must the tower carry?

Solution: (a) Maximum Tension, $F_{max} = \sqrt{Q^2 + \left(\frac{WL}{2}\right)^2}$

Where, $Q = \frac{WL^2}{8d} = \frac{6 \times 800^2}{8 \times 60} = 8000$ lb

Now, $F_{max} = \sqrt{8000^2 + \left(\frac{6 \times 800}{2}\right)^2} = 8352.25$ lb.

(b) vertcle load of one cable $= WL$

$= (6 \times 800) = 4800$ lb

∴ vertical load of six cables $= (6 \times 4800) = 28800$ lb

∴ The tower must carry $= 28800$ lb.

(Ans.)

A 60 ft (=2s) cable weighs 360 lb and is suspended from two points at the same elevation. For sag of 15 ft, Find

(a) the tension at the support (b) the span

Solution: $K = \frac{s^2 - d^2}{2d} = \frac{\left(\frac{60}{2}\right)^2 - 15^2}{2 \times 15} = 22.5$ ft

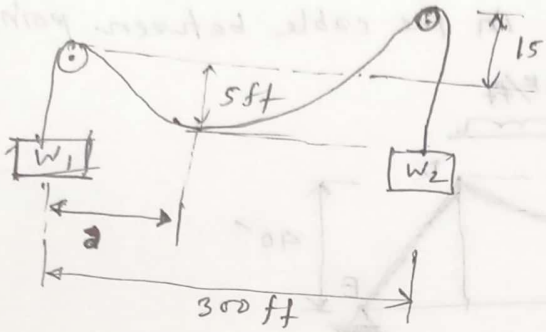
$y = K + d = (22.5 + 15) = 37.5$ ft

(a) $F_{max} = w \times y = \left(\frac{360}{60}\right) \times 37.5 = 225$ lb

(b) $L = K \ln\left(\frac{s+y}{K}\right) = 22.5 \times \ln\left(\frac{30 + 37.5}{22.5}\right) = 24.7$ ft.

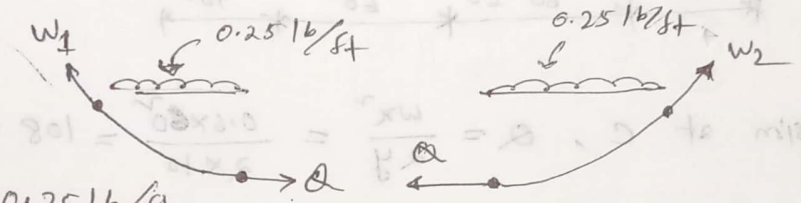
(Ans.)

A wire weighing 4 oz. per ft is strung between two supports 300 ft apart as shown in figure below:



compute the tension at both support and length of the curve.

Solution:



$w = 4$ oz

$= \frac{4}{16}$ lb $= 0.25$ lb/ft

$$Q = \frac{wa^2}{2 \times 5} \qquad Q = \frac{w(300-a)^2}{2 \times (15+5)}$$

Hence,

$$\frac{wa^2}{2 \times 5} = \frac{w(300-a)^2}{2 \times 20}$$

$\Rightarrow a = 100$ ft

$$\therefore Q = \frac{0.25 \times 100^2}{2 \times 5} = 250 \text{ lb}$$

$$\therefore W_1 = \sqrt{250^2 + (0.25 \times 100)^2} = 251.25 \text{ lb}$$

$$W_2 = \sqrt{250^2 + [0.25 \times (300-100)]^2}$$

$$= 254.95 \text{ lb.}$$

(Ans.)

Length of the wire, $S = \int_0^{100} \left[1 + \left(\frac{0.25 \times 100}{250}\right)^2\right]^{0.5} + \int_0^{200} \left[1 + \left(\frac{0.25 \times 200}{250}\right)^2\right]^{0.5}$

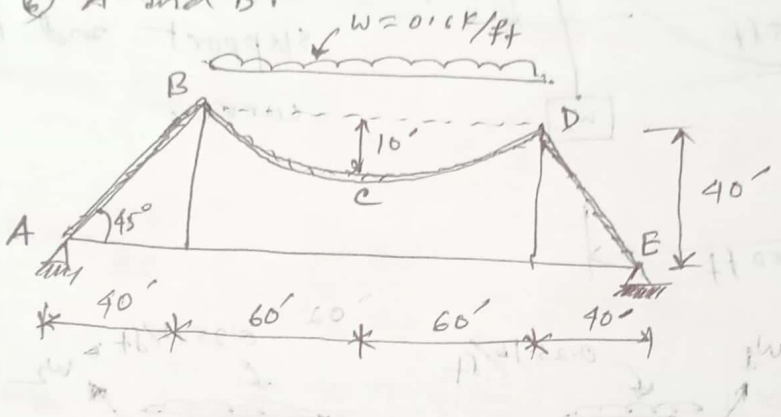
$$\int_0^{100} \left[1 + \left(\frac{wx}{Q}\right)^2\right]^{0.5}$$

$= 304.96$ ft

(Ans.)

(BCS-43rd)

#BWDB'20: A cable supported roof carries a uniform load as shown in Figure below. If the cable sag at midspan is set to 10 ft, what maximum tension in the cable between points (a) B and D. (b) A and B.



Solution:

(a) Tension at C, $Q = \frac{wx^2}{2y} = \frac{0.6 \times 60^2}{2 \times 10} = 108$ Kip

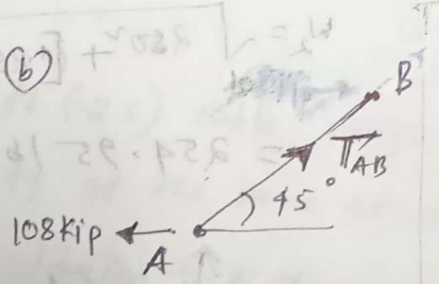
Maximum tension at support B & D,

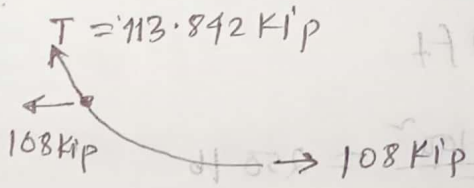
$$T_{max} = \sqrt{Q^2 + (wx)^2} = \sqrt{108^2 + (0.6 \times 60)^2}$$

$$\therefore T_{max} = 113.842 \text{ Kip.}$$

(Ans.)

(b)





$\Sigma F_x = 0$, $T_{AB} \cos 45^\circ = 108$

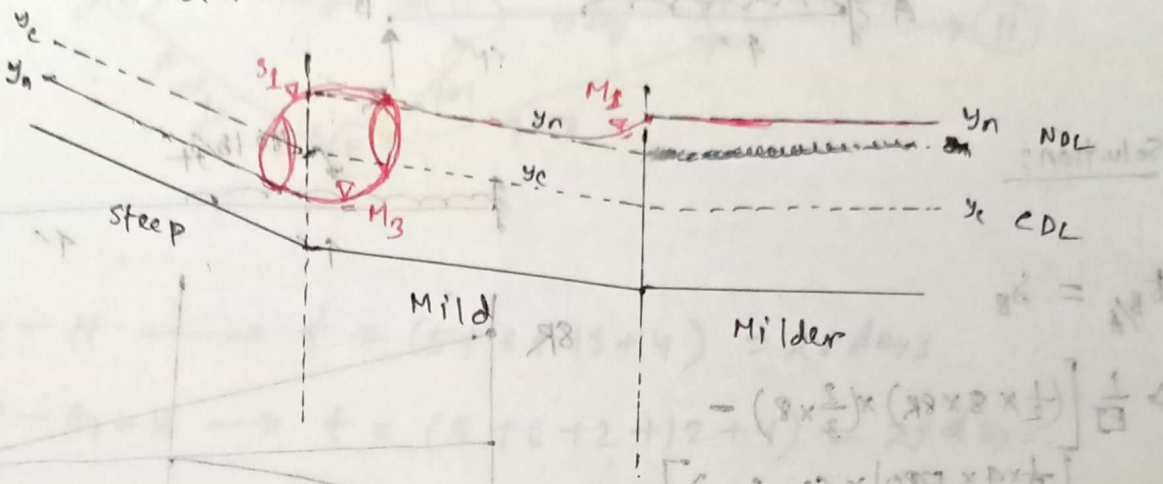
$\therefore T_{AB} = 152.74$ Kip

(Ans.)

MGMCL-2022 BUET

1. Draw water surface profile following the channel slope :
Steep – mild – milder

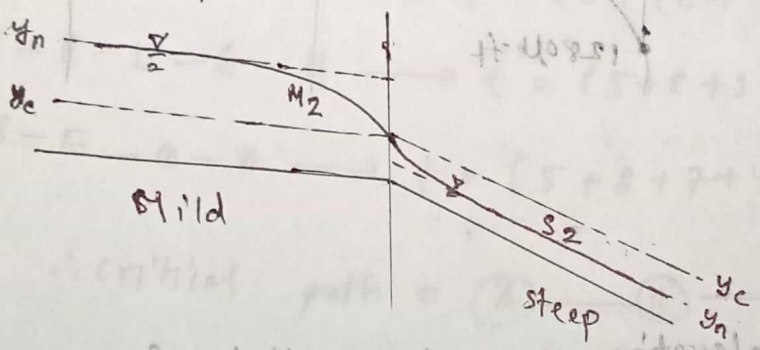
Solution:



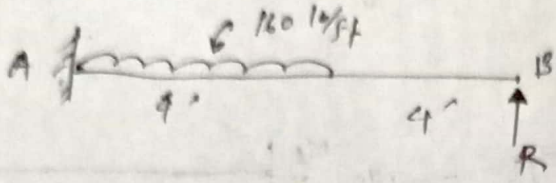
* Steep to Mild → jump

* (NDL to NDL) → water level

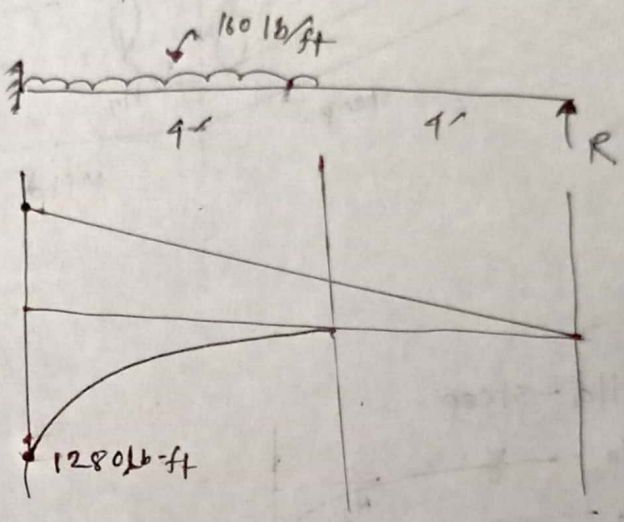
* mild – steep



② Find the value of 'R' from the beam of 15"×17" which deflection at B is zero and value of EI constant.



Solution:



$$\delta_{B/A} = \delta_B$$

$$\Rightarrow \frac{1}{EI}\left[\left(\frac{1}{2}\times 8\times 8R\right)\times\left(\frac{2}{3}\times 8\right) - \left(\frac{1}{3}\times 4\times 1280\right)\times\left(4+\frac{3}{4}\times 4\right)\right] = 0$$

$$\Rightarrow \frac{512R}{3} - \frac{35840}{3} = 0$$

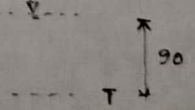
$$\Rightarrow R = 70 \text{ lb}$$

(Ans.)

③ Turbine located at an elevation 90 m below that of the surface of water. The friction head in the pipe line = 10 m. Turbine efficiency = 85%. flow of water = 2 m³/sec. what is the power delivered in kw.

Solution:

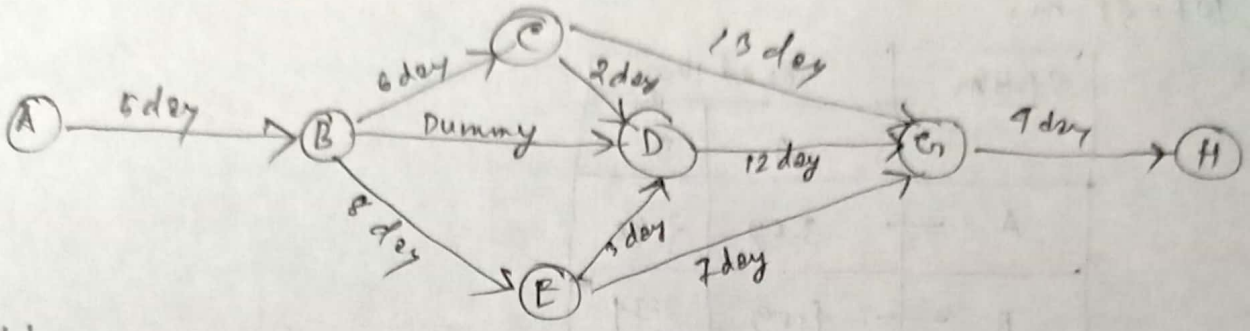
Total head = (90 + 10) = 100 m



$$P = \frac{\gamma Q H_T}{\eta} = \frac{9810\times 2\times 100}{0.85} = 2308235.3 \text{ Watt} = 2308.24 \text{ KW}$$

(Ans.)

④ Find the critical path of given Network:



Solution;

A – B – C – G – H ⟶ $t = (5+6+13+4) = 28$ days

A – B – C – D – G – H ⟶ $t = (5+6+2+12+4) = 29$ days.

A – B – D – G – H ⟶ $t = (5+12+4) = 21$ days

A – B – E – D – G – H ⟶ $t = (5+8+3+12+4) = 32$ days.

A – B – E – G – H ⟶ $t = (5+8+7+4) = 24$ days.

∴ critical path = A — B — E — D — G — H

(Ans)

⑤ Determine the fineness modulus and % silt and clay of following sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	pan
% retain	0	1	4	12	13	30	31	4	2

Solution;

sieve size	#4	#8	#16	#30	#40	#50	#100	#200	pan
% cumulative	0	1	5	17	30	60	94	98	100

∴ FM of the sample = $\frac{4+5+17+60+94}{100} = 1.77$

% silt and clay = $(100 - 98) = 2\%$

(Ans)

(6) In a reciprocal leveling. Find the RL of A, if RL of B is 101.23 m.

Solve:

Station	Reading	
	A	B
A	3.69	2.148
B	4.59	3.34

Solution: Difference in level between two point

$$= \frac{(3.69 - 2.148) + (4.59 - 3.34)}{2}$$

$$= 1.23 \text{ m}$$

RL of A = (101.23 − 1.23) = 100 m (Ans.)

(7) What problem will be arised after Metro Rail launched in Dhaka city? Write Major 2 Problem.

Solution; (1)

(2)

(8) Fill in the blanks:

(a) Weight of hammer in SPT test = 63.5 Kg or 140 lb

(b) Value of Faecal Coliform according to ECR = 0 per 100 mL

(c) calculate discharge, if rainfall intensity = 1.5 cm/hr, Runoff co-efficient = 0.9 and Area of basin = 100 m². $Q = \frac{1.5}{100} \times 0.9 \times 100 = 1.35 \text{ m}^3/\text{hr}$

(9) Define BOD and COD. Why BOD is smaller than COD?

ELBL – 2022 BUET

① A RCC column 16" square, $f_c' = 3$ ksi, reinforced with 8 # 7 bar, $f_y = 60$ ksi, supported a total design load of 550 kips on 9ft square footing with a depth of 24 inch. caculate the punching shearing stress that ~~depend~~ developed on footing.

Solution:

Ultimate bearing capacity, $q_u = \frac{\text{Total load}}{\text{Footing Area}}$.

$= \frac{550}{9 \times 9} = 6.79$ ksf

For punching Failure,

critical perimeter, $b_o = 4 \times (16 + 24) = 160" = 13.33$ ft

$\therefore$ Ultimate shear, $V_u = 6.79 \left[9^2 - \left(\frac{16+24}{12}\right)^2\right] = 474.55$ K

$\therefore$ punching stress, $\sigma = \frac{V_u}{b_o d} = \frac{474.55}{13.33 \times \frac{24}{12}}$

$= 17.80$ ksf

Ans.

② Write Full form of the following:

ETP, COD, UNICEF, SPT, ECR.

Solution:

ETP = Effluent ~~Environment~~ Treatment Plant

COD = Chemical Oxygen Demand.

UNICEF = United Nations Children's Fund. Emergency

SPT = Standard Proctor Test or,
Standard Penetration Test

ECR = Environmental Coventi'on Rules.

③ Fill in the gaps:

(i) The soil transported by wind is called Aeoline soil.

(ii) Porosity = 0.6, void ratio = 1.5 $\quad e = \frac{n}{1-n}$

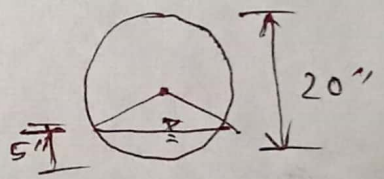
(iii) PL = 20%, PI = 30%, LL = 50%

(iv) Sand retained 100% on 100 no. sieve, FM = 1

(v) $D_0 = 0.1$, $D_{60} = 0.3$, C_u = 3

④ A circular cross section sewer pipe diameter of 20". Calculate the velocity and discharge if depth of flow = 5", n = 0.013 and s = 0.0015

Solution:



$$\omega = 2\cos^{-1}\left(1 - \frac{2h}{d_0}\right)$$

$$= 2\cos^{-1}\left(1 - \frac{10}{20}\right)$$

$$= 2.0944 \text{ rad.}$$

$$\therefore A = \frac{1}{8}(\omega - \sin\omega) d_0^2 = \frac{1}{8} \times (2.0944 - \sin 2.0944) \times 20^2 = 61.42 \text{ in}^2$$

$$P = \frac{1}{2} \omega d_0 = (0.5 \times 2.0944) \times 20 = 20.944 \text{ in.}$$

$$R = \frac{A}{P} = 2.93 \text{ in.}$$

$$\therefore V = \frac{1.49}{n} \cdot R^{\frac{2}{3}} S^{\frac{1}{2}} = \frac{1.49}{0.013} \times \left(\frac{2.93}{12}\right)^{\frac{2}{3}} \times (0.0015)^{\frac{1}{2}} = 1.735 \text{ ft/sec.}$$

$$\therefore Q = AV = \left(\frac{61.42}{144} \times 1.735\right) = 0.74 \text{ ft}^3/\text{sec.}$$

(Ans)

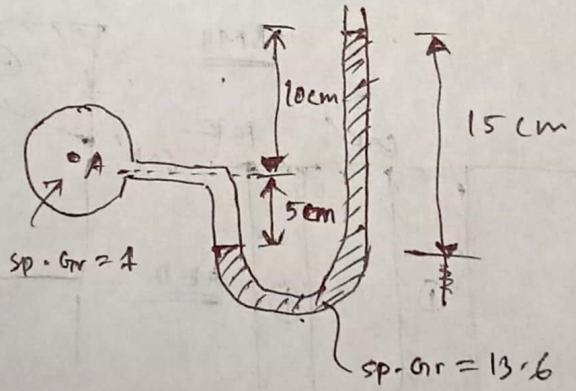
(5) Why using a manometer is important?

Solution: Manometer is a device that is used to –

(i) measure pressure of fluid.

(ii) HVAC system maintenance.

(6) A U tube manometer containing Hg (Sp. Gr. = 13·6) has its right limb open to the atmosphere. the left limb is full of the water & it is connected to a pipe containing water under pressure. Find the pressure of water in the pipe above the atmosphere for the manometer reading below the figure:



Solution:

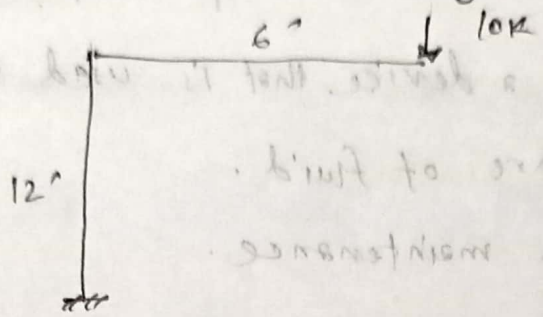
$h + 1 \times 5 = 15 \times 13.6 = 0$

$\Rightarrow h = 199$ cm.

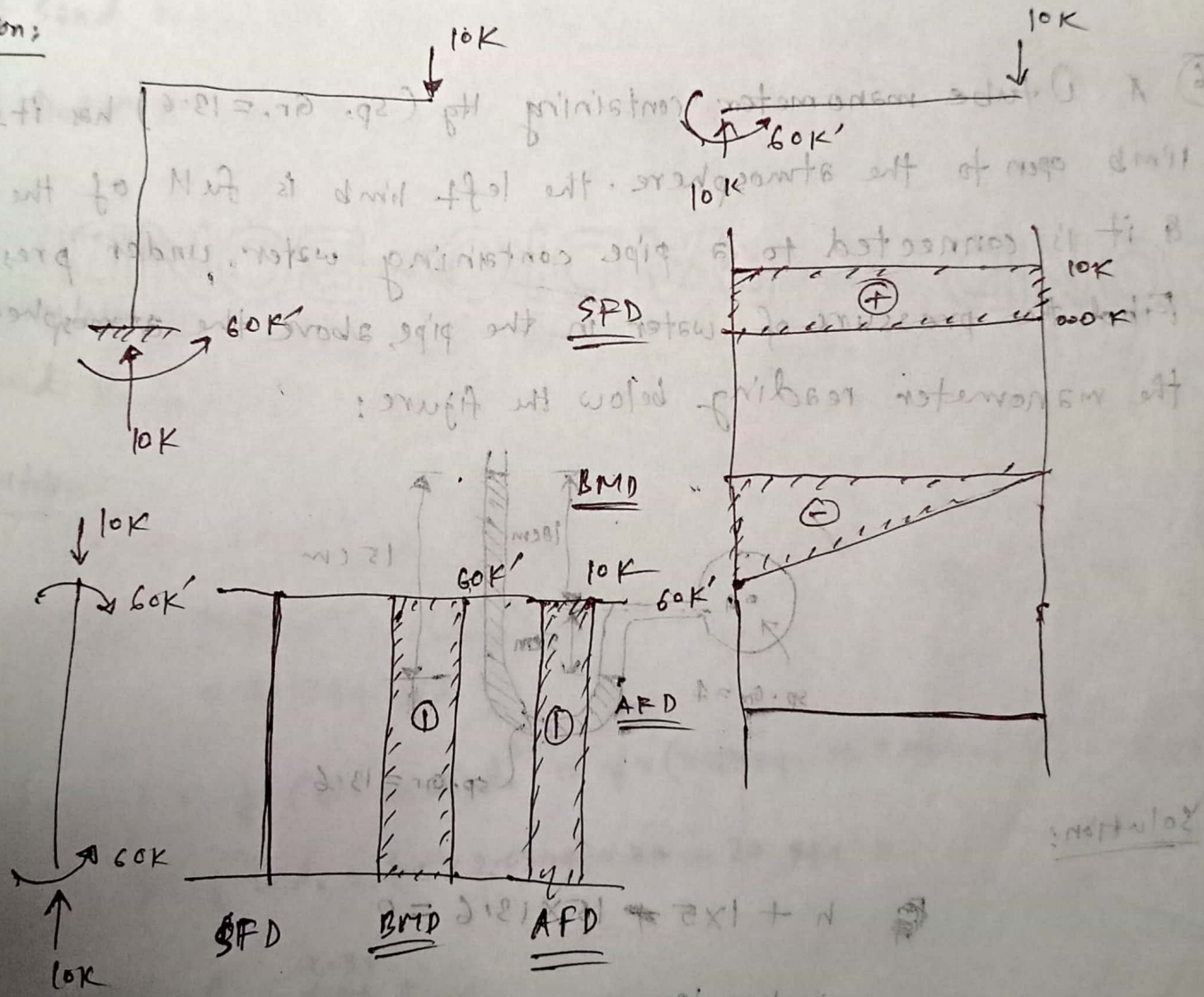
$\therefore P_A = \gamma h = \left(9.81 \times \frac{199}{100}\right) = 19.54$ KN/m²

(Ans)

(7) Draw AFD, SFD and BMD of the following structure:



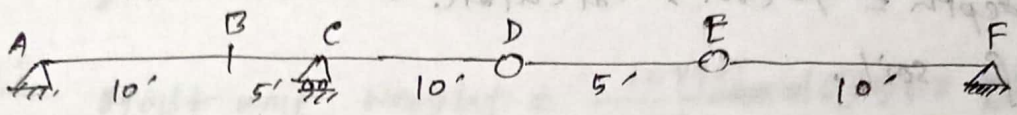
Solution:



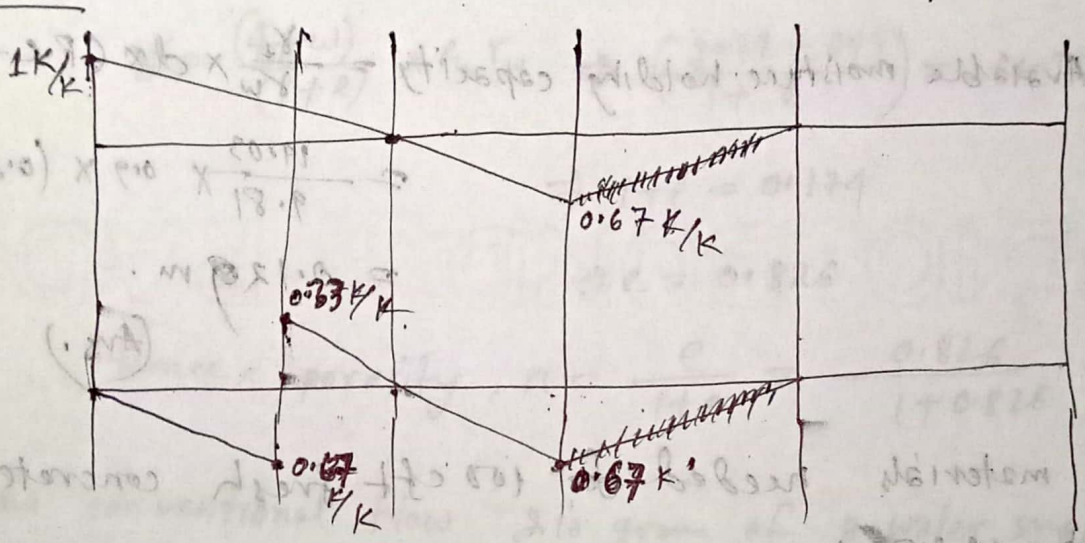
TGTDCL-2021

BUET

① Draw IL for reaction at A and shear at B.



Solution:



② What is BRT? Write four characteristics of BRT.

Solution: BRT means Bus Rapid Transit. It is a high quality bus based transited system that delivers fast, comfortable and cost effective urban mobility through provision of segregated right of way infrastructure.

characteristics of BRT:

(i) High capacity vehicles.

(ii) Dedicated lanes and alignment.

(iii) High speed mobility.

(iv) Off-board fare collection

③ An irrigation field has has following data: Field capacity = 25%. Permanent wilting point = 15%, specific weight = 14.03 KN/m³, Root zone depth = 90 cm. Calculate available moisture holding capacity of soil.

Solution:

$$\text{Available moisture holding capacity} = \frac{\gamma_d}{\gamma_w} \times d \times (F.C - P.W.P)$$

$$= \frac{14.03}{9.81} \times 0.9 \times (0.25 - 0.15)$$

$$= 0.129 \text{ m}.$$

(Ans.)

④ Find the materials needed for 100 cft fresh concrete with a mix ratio = 1 : 2.5 : 4.5.

Solution:

Dry volume = (1.5 × 100) = 150 cft

∴ Total ratio = (1 + 2.5 + 4.5) = 8

∴ cement required = $\left(\frac{1}{8} \times 150\right)$ = 18.75 cft = 15 bags.

sand required = $\left(\frac{2.5}{8} \times 150\right)$ = 46.875 cft

Stone chips required = $\left(\frac{4.5}{8} \times 150\right)$ = 84.375 cft.

(Ans.)

(5) The moist weight of 0.006 m^3 of soil is 10 kg. If the moisture content is 13% and specific gravity of soil = 2.71. Find the porosity of the soil sample.

Solution:

$$\text{Moist unit weight} = \frac{10 \times 9.8}{0.006} = 16350 \text{ N/m}^3$$

$$= 16.35 \text{ kN/m}^3$$

$$\gamma = \frac{(G_s + w)}{(1+e)} \times G_s \gamma_w \Rightarrow \left(\frac{2.71 + 0.13}{1+e}\right) = 16.35$$

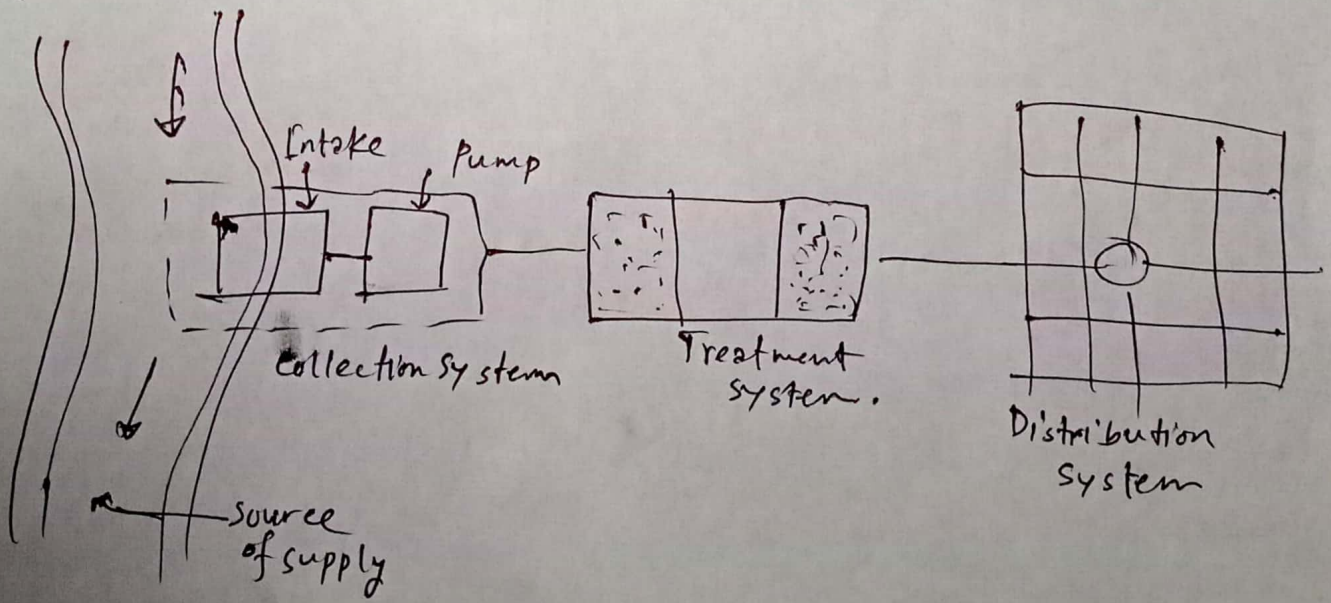
$$\Rightarrow 1 + e = 0.174$$

$$\Rightarrow e = 0.826$$

Hence, porosity, $n = \frac{e}{1+e} = \frac{0.826}{1+0.826} = 0.4524$ (Ans)

(6) Draw conventional flow diagram of a water supply system.

Solution:

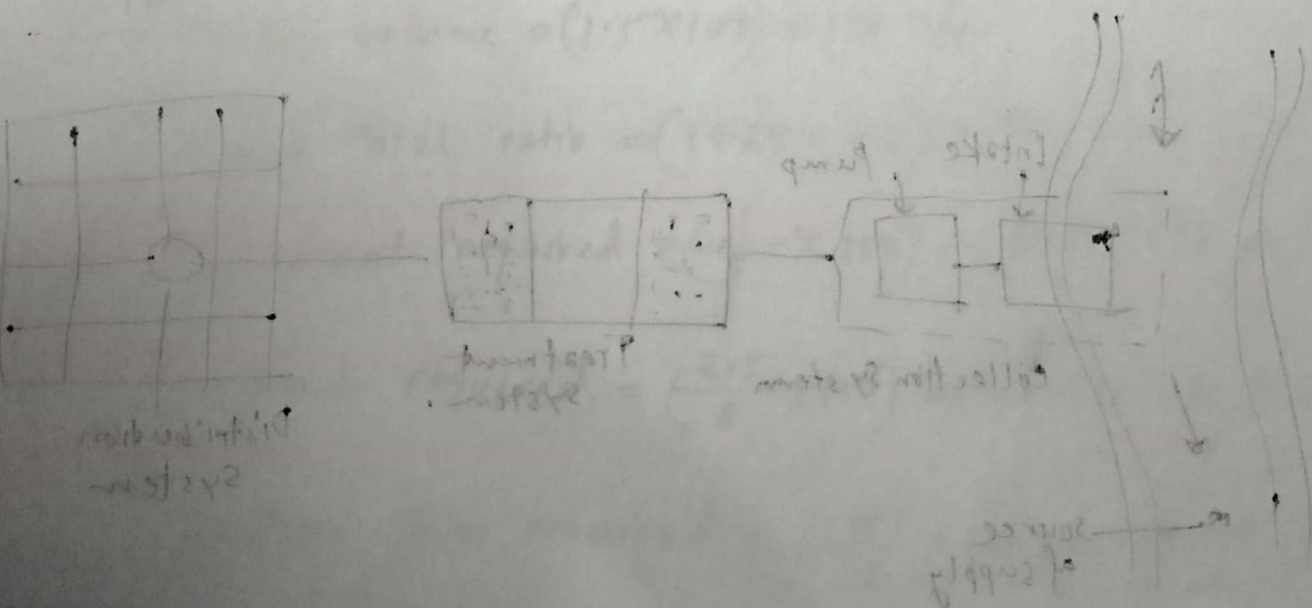


(07) The distance between two points measured 1000 m with a 25 m chain, but it was found the chain is 25.15 m. Calculate the actual length.

Solution:

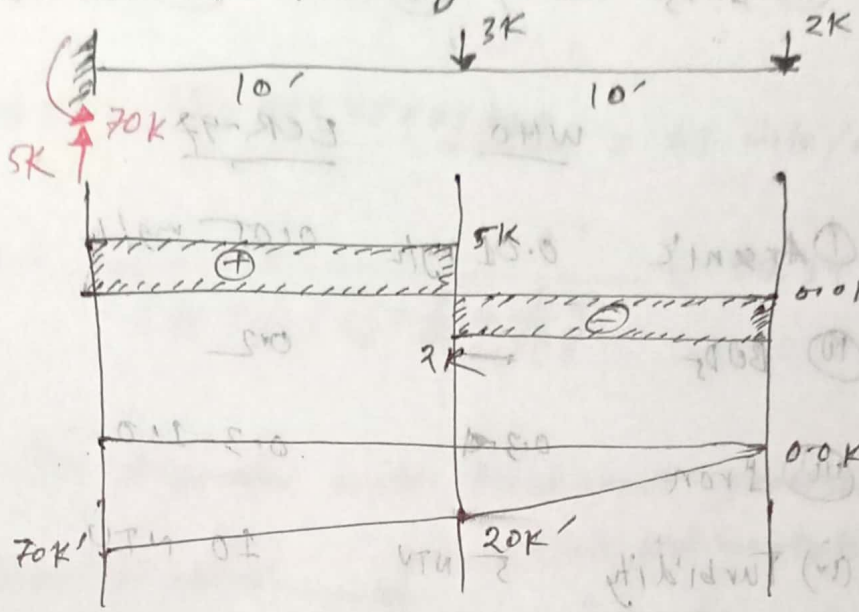
$$TL = \frac{L'}{L} \times ML = \frac{25.15}{25} \times 1000 = 1006 \text{ m.}$$

(Ans)



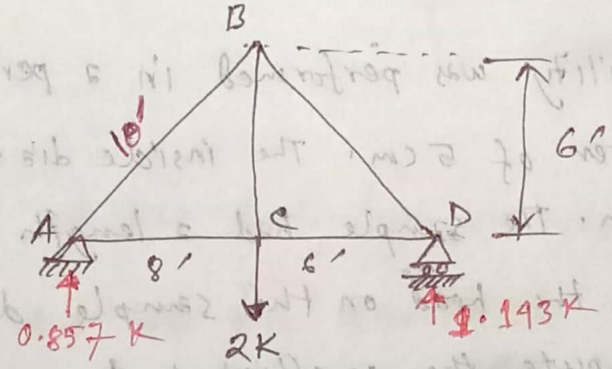
TGTDCL – 2018 [BUET]

① Draw SFD and BMD for following beam:



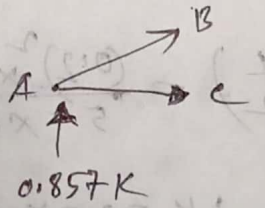
Solution:

② Find the axial force for member AB and AC.



Solution:

Joint A:



$AB = -\left(\frac{0.857}{6} \times 10\right) = 1.428$ (C)

$AC = \left(\frac{1.428}{10} \times 8\right) = 1.143$ (T)

(Ans.)

③ A rectangular column of 15" × 15" has reinforcement of 8 no. 9 bar. If the value of $f_c' = 3000$ psi and $f_y = 60000$ psi. Find the ultimate design axial load of the column with zero eccentricity.

Solution:

$P_u = \alpha \phi A_g [0.85 f_c' + P_s (f_y - 0.85 f_c')]$

$= 1 \times 0.65 \times (15 \times 15) \times [0.85 \times 3 + 0.0356 \times (60 - 0.85 \times 3)]$

$= 671.71$ kip.

$P_s = \frac{8}{15 \times 15} = 0.0356$

(Ans.)

④ write down the standard value of following parameters.

(i) Arsenic (ii) BOD_5 (20°C) (iii) Iron (iv) Turbidity (v) TDS

Solution:

	WHO	ECR-97
(i) Arsenic	0.01 mg/L	0.05 mg/L
(ii) BOD_5	—	0.2
(iii) Iron	0.3	0.3–1.0
(iv) Turbidity	5 NTU	10 NTU
(v) TDS	1000 mg/L	1000 mg/L

⑤ A falling head permeability was performed in a permeameter with an inside diameter of 5 cm. The inside diameter of standard pipe was 2mm. The sample had a length of 8cm. During period of 6 min. the head on the sample decreased from 100 to 50 cm. Compute the co-efficient of permeability.

Solution;

We know, $K = \frac{aL}{At} \log\left(\frac{h_1}{h_2}\right) = \frac{(0.2)^2 \times 8}{5^2 \times (6 \times 60)} \times \log\left(\frac{100}{50}\right)$

$\therefore K = 215 \times 10^{-5}$ cm/sec. (Ans.)

⑥ The sign shape for (i) mandatory sign (ii) cautionary sign and (iii) Informatory sign.

Solution:

(i) circular

(ii) Triangular

(iii) Rectangular

(7) Find space and time mean speed for the spot speed of 55, 60, 45, 95 and 60 mile/hr.

Solution:

$$TMS = \frac{55+60+45+95+60}{5} = 63 \text{ mile/hr}.$$

$$SMS = \frac{5}{\left(\frac{1}{55}+\frac{1}{60}+\frac{1}{45}+\frac{1}{95}+\frac{1}{60}\right)} = 59.34 \text{ mile/hr}.$$

(8) Write down the steps for water treatment process.

Solution:

(i) Clarification
- plain sedimentation
- coagulation
- Flocculation
- Filtration

(ii) Dis infection

(9) Find FM of the following sample.

Sieve size	#4	#8	#16	#30	#50	#100	Pan
% retain	0	0	6	40	100	323	31

Solution;

Sieve size	#4	#8	#16	#30	#50	#100	Pan
cum. % retain	0	0	6	46	146	469	500
% cum. retain	0	0	1.2	9.2	29.2	93.8	100

$$\therefore \text{FM of the sample} = \frac{1.2+9.2+29.2+93.8}{100} = 1.334$$

(Ans)

(10) A strip footing carrying a load of 340 KN/m which is located at EGL. water table is located at EGL. $\gamma_{sat} = 21$ KN/m^3, width of the footing = 2m and depth of the water = 1m, FS = 3, ultimate pressure = 530 KN/m^2, Use $q_n = q_u - \gamma D_f$. Prove that size of footing is safe.

Solution:

Net ultimate bearing, $q_n = q_u - \gamma D_f$

$= 530 - (21 - 9.81) \times 1$

$= 518.81$ KN/m^2

Allowable bearing capacity,

$q_{all} = \frac{q_n}{FS} = \frac{518.81}{3} = 172.94$ KN/m^2

Applied pressure $= \frac{340}{2} = 170$ KN/m < 172.94 KN/m^2

Hence, Footing size is safe (Proved).

RPGCL-2017 BUET

(1) 20 MLD of water is to be supplied from a water treatment plant with chlorine concentration of 0.5 ppm. If bleaching powder that is used for chlorination has 25% avaible chlorine (by weight). Estimate the amount (in kg) of bleaching powder required on chlorination per day.

Solution:

Amount of chlorine required $= (20\times10^6 \times 0.5)\times10^{-6}$ kg/day

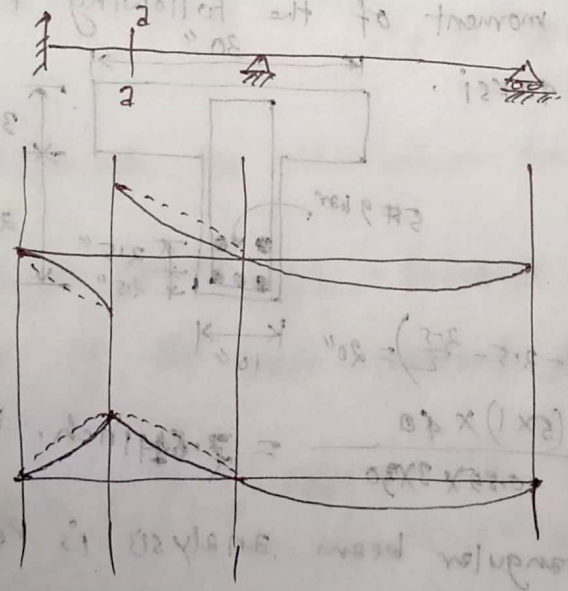
$= 10$ kg/day.

$\therefore$ Amount of bleaching powder required $= \left(\frac{100}{25}\times10\right) = 40$ kg/day

(Ans.)

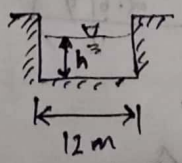
(2) Draw Influence line (Qualitative) at section a-a for shear and moment.

Solution:



(3) A open channel of 12 m wide has a velocity of 6 m/s. Find the depth of flow if bed slope = 0.0028 and $n = 0.013$.

Solution:



we know,

$$v = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Here, $A = bh = 12h$

$P = 12 + 2h$

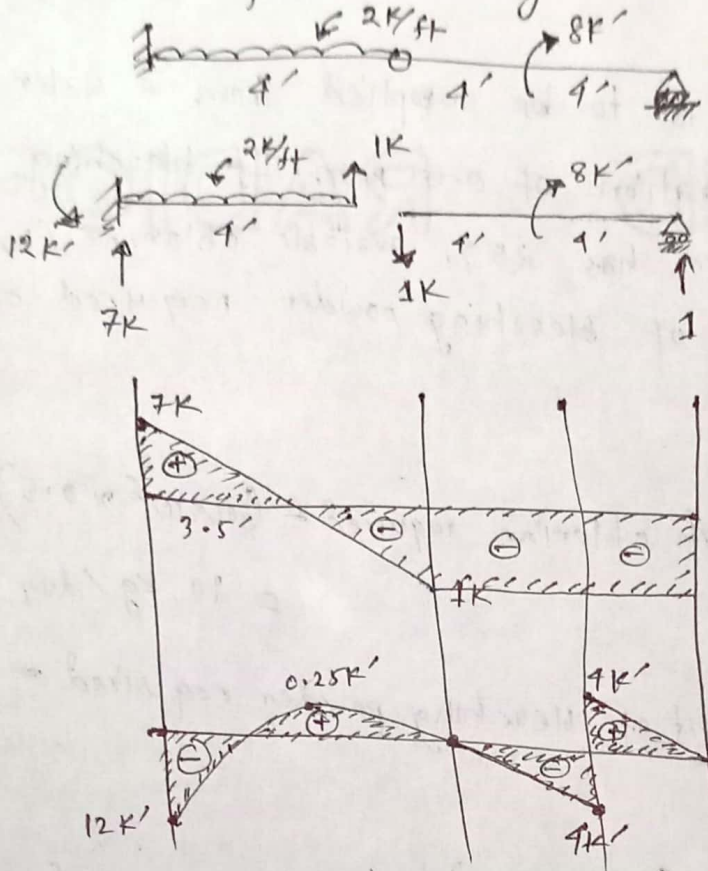
$\therefore R = \frac{12h}{12+2h} = \frac{6h}{6+h}$

$$\Rightarrow 6 = \frac{1}{0.013}\times\left(\frac{6h}{6+h}\right)^{\frac{2}{3}} \times (0.0028)^{\frac{1}{2}}$$

$\Rightarrow h = 2.55$ m (Ans.)

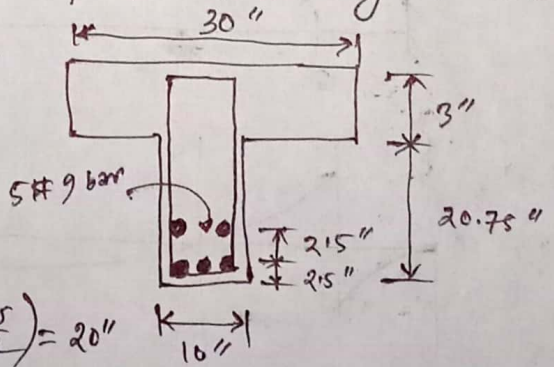
(4) Draw SFD and BMD of the following structure.

Solution:



(5) Determine the ultimate moment of the following T Beam.

Given, $f_c' = 3$ ksi, $f_y = 40$ ksi.



Solution: $d_{eff} = \left(20.75 + 3 - 2.5 - \frac{2.5}{2}\right) = 20"$

$$a = \frac{A_s f_y}{0.85 f_c' b_f} = \frac{(5\times 1)\times 40}{0.85\times 3\times 30} = 2.614 \text{ inch.}$$ ~~h_f~~

Hence ~~R beam~~ Rectangular beam analysis is required.

$$\therefore M_U = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$= 0.9\times 5\times 40\times\left(20 - \frac{2.614}{2}\right)$$

$$= 3369.74 \text{ K-in.}$$

(Ans.)

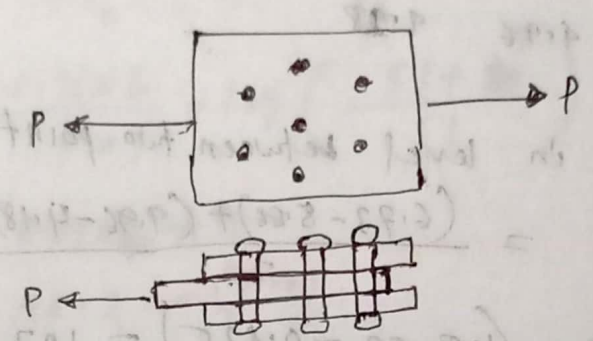
$$\phi = 0.483 + 83.3\varepsilon_t$$

$$= 0.483 + 83.3\times 0.003\times \frac{20 - \frac{2.614}{0.85}}{\frac{2.614}{0.85}}$$

$$= 1.85 > 0.9$$

$$\therefore \phi = 0.9$$

(6) what will be the maximum value of tensile load at 'P' for the bolted connection. All plates are 0.75" and bolt diameter 0.50 inch. Shearing stress in the rivets is limited to 20 Ksi and the bearing stress in the plates is limited to 30 Ksi.



Solution:

$$\tau_s = \frac{P}{n \times \frac{\pi}{4} d^2} \Rightarrow P = (2 \times 7) \times \frac{\pi}{4} \times (0.5)^2 \times 20$$

$$\therefore P = 54.978 \text{ Kip.}$$

Again

$$\sigma_b = \frac{P}{n(t \times d)} \Rightarrow P = 30 \times 7 \times (0.75 \times 0.5)$$

$$\therefore P = 78.75 \text{ Kip.}$$

∴ Allowable Maximum tensile load = 54.978 Kip. (Ans.)

(7) BOD_5 at 20°C is 102.5 mg/L. Estimate the ultimate BOD of the waste water if BOD rate constant for 20°C is 0.23 per day.

Solution:

$$BOD_5 = L_o (1 - e^{-KX5})$$

$$\Rightarrow L_o = \frac{102.5}{1 - e^{-0.23 \times 5}} = 149.99 \text{ mg/L}$$

(Ans)

(8) If R.L of B is 108.82 ft. Calculate the RL of A.

Station	Reading	point
	A	B
A	6.73	5.86
B	4.96	4.18

Solution:

Difference in level between two point

$$= \frac{(6.73-5.86)+(4.96-4.18)}{2} = 0.825$$

$\therefore$ RL of A $= (108.82 - 0.825) = 107.995$ m.

(Ans)

(9) The radius of a tyre imprint is approximated to a circle of 150 mm. What is the maximum loading duration on a particular point of pavement by truck moving at a speed of 80 Kmph?

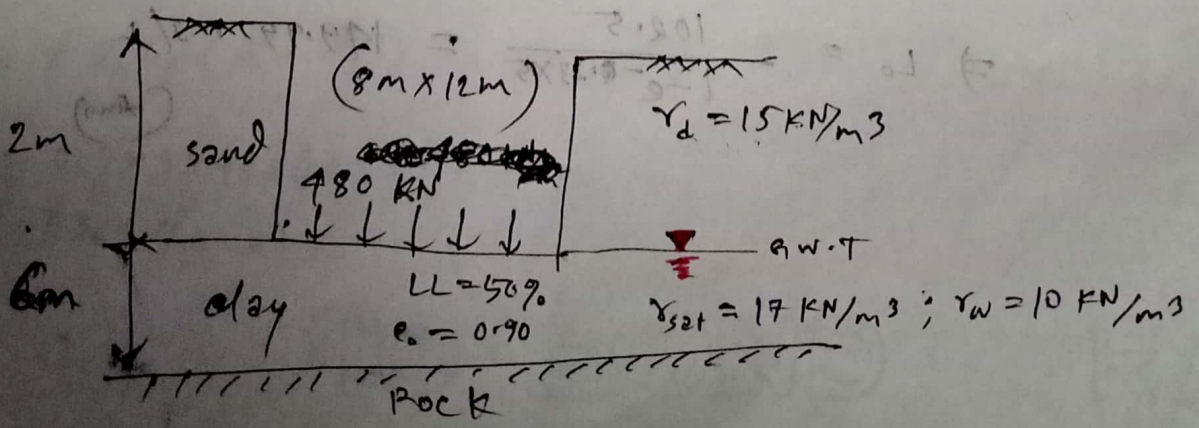
Solution:

We know,

$$t = \frac{s}{v} = \frac{2\times 150}{\frac{80}{3.6}} = 13.5 \text{ sec.}$$

(Ans)

(10) Determine the primary settlement at center of the raft foundation. Assume Normally consolidated deposits.



Solution: $\sigma_0' = 15 \times 2 + (17-10) \times \frac{6}{2} = 51 \text{ KN/m}^2$; $\Delta\sigma' = \frac{180}{12 \times 8} = 5$

$C_c = 0.007 \times (LL - 10) = 0.007 (50 - 10) = 0.36$

we know, $S_c = \frac{C_c H_c}{1 + e_0} \times \log \left(\frac{\sigma_0' + \Delta\sigma}{\sigma_0'} \right)$

$= \frac{0.36 \times 6}{1 + 0.9} \times \log \left(\frac{51 + 5}{51} \right)$

$= 0.0962 \text{ m}$

$= 46.2 \text{ mm}$ (Ans)

(11) The difference between maximum void to minimum void on a sand sample is 0.30. If the relative density of the sample is 60.67 at $e = 0.40$. calculate the void ratio and dry density of the sample at loosest condition.

Solution:

we know,

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$

$$\Rightarrow 66.67 = \frac{e_{max} - 0.40}{0.30} \times 100$$

$\therefore e_{min} = (0.60 - 0.30) = 0.30$

$\Rightarrow e_{max} = 0.60$

$$\gamma_d = \frac{G_s \gamma_w}{1 + e} = \frac{2.65 \times 9.81}{1 + 0.60} = 16.25 \text{ KN/m}^3$$

$$\gamma_{sat} = \frac{(G_s + e)}{1 + e} \gamma_w = \frac{(2.65 + 0.6)}{1 + 0.6} \times 9.81 = 19.92 \text{ KN/m}^3$$

(Ans)

(12) Given dry ~~density~~ unit weight of soil = 1.65 gm/cc and specific gravity = 2.67. Determine the saturated unit weight and void ratio. Calculate the hydraulic head that would produce a quick condition in a sand stratum if thickness is 1.47 m.

Solution;

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

$$\Rightarrow 1+e = \left(\frac{2.67 \times 1}{1.65}\right)$$

$$\Rightarrow e = 0.618 \quad \text{(Ans.)}$$

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

$$= \left(\frac{2.67 + 0.618}{1+0.618}\right) \times 1$$

$$= 2.03 \text{ gm/cc.} \quad \text{(Ans)}$$

For quick condition,

$$i_c = \frac{G_s - 1}{1+e} = \frac{2.67-1}{1+0.618} = 1.032$$

Hydraulic head, $h = (i_c \times L) = (1.032 \times 1.47) = 1.517 \text{ m}$ (Ans)

RPGCL-2022

① A column has a cross section of 16" x 20" and is reinforced by 6 No. 9 bar. Determine the axial load that will stress the concrete to 1200 psi. Assume, $n = 8$, $f_c' = 3$ ksi, $f_y = 60$ ksi

Solution:

The axial load $= f_c [A_g + (n-1) A_s]$

$= 1200 \times [16 \times 20 + (8-1) \times (6 \times 1)]$

$= 434,400$ lb

$= 434.4$ Kip.

② Calculate BOD_{10} of a sample. Given, $BOD_5 = 237$ mg/L, $K_{20} = 0.23$ per day

Solution:

$BOD_5 = L_o (1 - e^{-Kx5})$

$\Rightarrow L_o = \frac{237}{1 - e^{-0.23 \times 5}} = 346.81$ mg/L

$\therefore BOD_{10} = L_o (1 - e^{-0.23 \times 10}) = (346.81 \times 0.89974) = 312.04$ mg/L

(Ans.)

③ Write the characterestics of pavement.

Solution:

(i) Structurally sound
(ii) sufficient thick to distribute load
(iii) Dust proof
(iv) Hard wearing surface
(v) Impervious.
(vi) Longer life span.
(vii) Good riding quality.
(viii) Less friction.
(ix) Skid resistance.
(x) Durable. etc.

④ A man is spraying water into a car at a speed of 4 m/sec. The diameter of the water jet is 2.5 cm. If the jet hits the car surface perpendicularly, calculate the force on the car surface due to the water jet. Neglect all losses.

Solution:

Force exerted on car surface, $F = \rho A V^2$

$= 1000 \times \frac{\pi}{4} \times (0.025)^2 \times 4^2$

$= 7.854\ N$

(Ans.)

⑤ 4-m wide rectangular channel with a sluice gate has an upstream water depth of 2.5 m, and down stream depth of 0.4 m. calculate the discharge through the channel. Neglect all losses.

Solution:

$Q = A_1 V_1 = A_2 V_2$

$\Rightarrow V_1 = \frac{A_2 V_2}{A_1} = \frac{4 \times 0.4 \times V_2}{4 \times 2.5} = 0.16\, V_2$

Now, From Bernoulli's Eqn. $(Z_1 = Z_2)$

$$Z_1 + h_1 + \frac{V_1^2}{2g} = Z_2 + h_2 + \frac{V_2^2}{2g}$$

$$\Rightarrow 2.5 + \frac{(0.16 V_2)^2}{2g} = 0.4 + \frac{V_2^2}{2g}$$

$$\Rightarrow 0.9744\, V_2^2 = (2.5 - 4) \times 2 \times 9.81$$

$\Rightarrow V_2 = 6.503$ m/s $\quad \therefore V_1 = (0.16 \times 6.503) = 1.04$ m/s

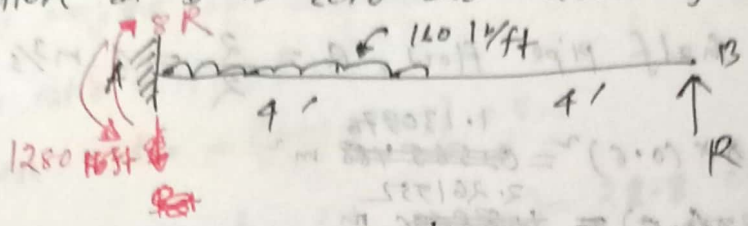
$\therefore Q = (4 \times 0.4 \times 6.503) = 10.4048\ m^3/s$

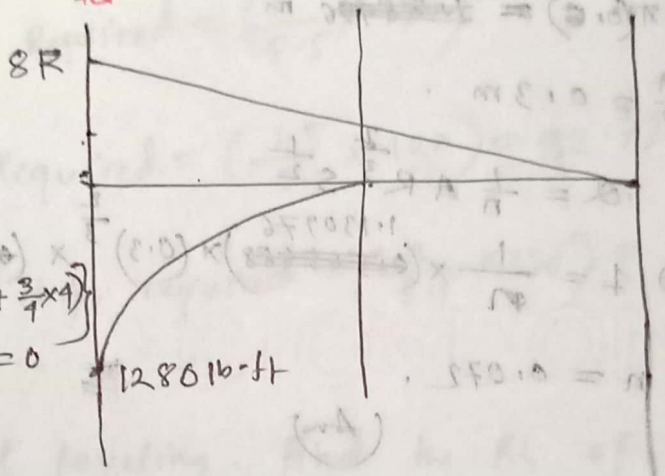
(Ans.)

KUET-2021

① Find the value of reaction (R) from the following beam which deflection at B is zero and value of EI constant.

Solution:





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

centroid = $\frac{1}{n+2}$

$t_{B/A} = \delta_B$

$\Rightarrow \frac{1}{EI}\left\{\left(\frac{1}{2}\times 8\times 8R\right)\times\left(\frac{2}{3}\times 8\right) - \left(\frac{1}{3}\times 4\times 1280\right)\times\left(4+\frac{3}{4}\times 4\right)\right\} = 0$

$\Rightarrow \frac{512R}{3} - \frac{35840}{3} = 0$

$\Rightarrow R = 70$ lb

(Ans.)

② A 3m wide channel carries a total discharge of 12 m^3/sec. Calculate the critical depth.

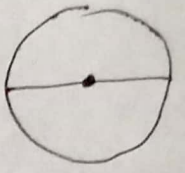
Solution: $q = \frac{Q}{b} = \frac{12}{3} = 4\ m^2/sec.$

For wide channel; $h_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{4^2}{9.81}} = 1.17$ m.

(Ans.)

③ A pipe flow of radius 0.6 m and discharge of 2 m^3/sec. Bed slope = 1 in 50. Find the value of manning's 'n' if pipe flow is half.

Solution: For half pipe flow, $Q = \frac{2}{2} = 1\ m^3/s$



$A = \frac{1}{2} \times \pi \times (0.6)^2 = 1.130976\ m^2$

$P = \frac{1}{2} \times 2\pi(0.6) = 2.261952\ m$

$\therefore R = \frac{A}{P} = 0.3\ m$.

we know, $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$

$\Rightarrow 1 = \frac{1}{n} \times (1.130976) \times (0.3)^{\frac{2}{3}} \times \left(\frac{1}{50}\right)^{\frac{1}{2}}$

$\Rightarrow n = 0.072$.

(Ans)

④ Determine the fineness modulus and percent of silt and clay of the sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	pan
% retain	0	1	4	12	13	30	34	4	2

Solution:

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	#pan
cum. % retain	0	1	5	17	30	60	94	98	100

FM of the sample $= \frac{0+1+5+17+60+94}{100} = 1.77$

% silt and clay $= (100 - 98) = 2\%$.

(Ans)

⑤ Determine the volume of cement, sand, and brick chips for 80 cft concrete for the mix ratio of 1:1.5:3.

Solution:

Dry weight of concrete mix = $(1.5 \times 80) = 120\ ft^3$

Mix ratio = 1:1.5:3

∴ Total ratio = $(1+1.5+3) = 5.5$

∴ Cement Required = $\left(\frac{1}{5.5} \times 120\right) = 21.8$ cft = 17.45 Bags
≃ 18 Bags.

Sand Required = $\left(\frac{1.5}{5.5} \times 120\right) = 32.73$ cft

Bricks chips required = $\left(\frac{3}{5.5} \times 120\right) = 65.45$ cft

(Ans)

⑥ In a reciprocal leveling. Find the RL of Q if RL of P is 100 m.

Station	Reading station point	
	P	Q
P —	3.69	2.48
Q —	4.59	3.34

Solution:

Difference in RL between two point

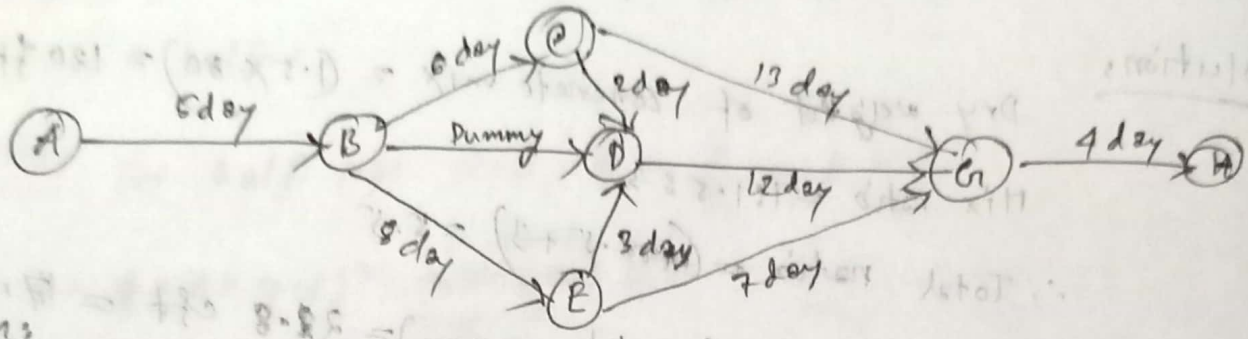
$$= \frac{(3.69-2.48)+(4.59-3.34)}{2} = 1.23\ m$$

(Fall from Q to P)

∴ RL of Q = $(100 + 1.23) = 101.23$ m

(Ans.)

(7) Find the critical path for given network.



Solution;

A — B — C — G — H ⟶ t = (5 + 6 + 13 + 4) = 28 days.

A — B — C — D — G — H ⟶ t = (5 + 6 + 2 + 12 + 4) = 29 days.

A — B — D — G — H ⟶ t = (5 + 12 + 4) = 21 days.

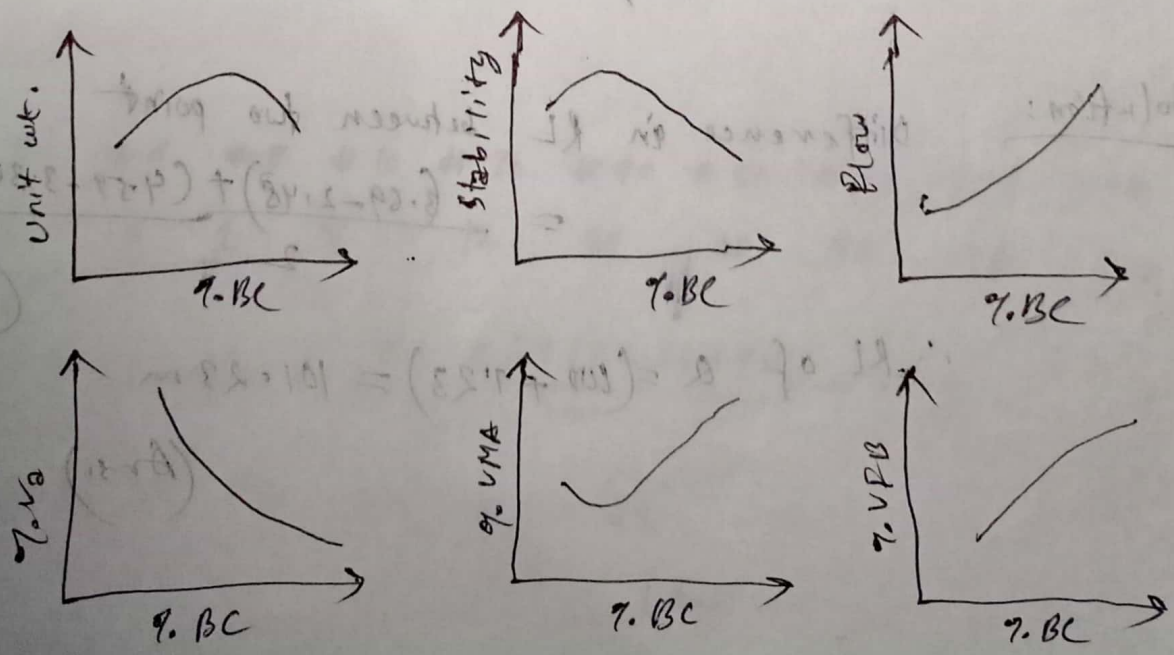
A — B — E — D — G — H ⟶ t = (5 + 8 + 3 + 12 + 4) = 32 days.

A — B — E — G — H ⟶ t = (5 + 8 + 7 + 4) = 24 days.

Hence, critical path = A — B — E — D — G — H

(8) Draw qualitative test property curves for hot mix design by Marshall Method. (Ans)

Solution;



GTDCL – 2021 [BUET]

① Determine the size of a circular drain, draining 8 hectars of a drainage basin if the drainage co-efficient is 1·4 cm. and grade is 3%. Assume rugosity co-efficient for the tile material is 0·013.

Solution:

Volume of water passing the drain in 1 day $= \left(\frac{1.4}{100} \times 8 \times 10^4\right) m^3/day$

$= 1120\ m^3/day.$

in 1 sec. $= \frac{1120}{24 \times 3600}\ m^3/s$

$= 0.012963\ m^3/s$

For circular drain,

$A = \frac{\pi}{4} D^2$, $P = \pi D$, $\therefore R = \frac{A}{P} = \frac{D}{4}$

$Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$

$\Rightarrow 0.012963 = \frac{1}{0.013} \times \left(\frac{D}{4}\right)^{\frac{2}{3}} \times \left(\frac{\pi D^2}{4}\right) \times (0.03)^{\frac{1}{2}}$

$\Rightarrow D^{\frac{8}{3}} = 3.1211 \times 10^{-3}$

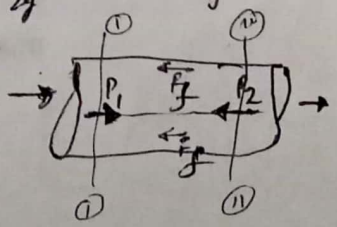
$\therefore D = 0.115\ m = 11.5\ cm.$ (Ans.)

② Prove that, for constant discharge and constant rate, value of frictional resistance of a pipe, the head loss is inversly proportional to the 5th power of the pipe diameter.

Solution: From bernoulli's eqn, $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f$

For, $z_1 = z_2$ and $V_1 = V_2$ (for $d_1 = d_2$)

$\frac{P_1}{\gamma} - \frac{P_2}{\gamma} = h_f \Rightarrow P_1 - P_2 = \gamma h_f$ ..... ①



Frictional resistance $F_f = f' \times p \times L \times V^2$ (where, $V = V_1 = V_2$)

p = perimeter

Pressure force at ①-①, $F_1 = P_1 \times A$

at ①'-①', $F_2 = P_2 \times A$

Now,

$\Sigma F_x = 0$

$(P_1 - P_2)A - F_f = 0$

$\Rightarrow P_1 - P_2 = \frac{F_f}{A}$

$\Rightarrow \gamma h_f = \frac{f' P L V^2}{A}$

$\Rightarrow \gamma h_f = f' \times \frac{4}{d} \times L V^2$

$\Rightarrow h_f = \frac{f'}{\gamma} \times \frac{4}{d} \times L V^2$ Now, $Q = AV \Rightarrow V = \frac{Q}{A} = \frac{4Q}{\pi d^2}$

$\Rightarrow h_f = \frac{f'}{\gamma} \times \frac{4}{d} \times L \times \frac{16 Q^2}{\pi^2 d^4}$

$\Rightarrow h_f = \frac{4f}{\gamma} \times \frac{L}{\pi^2} \times \frac{16 Q^2}{d^5}$

(Proved)

(3) (a) LL and PL are respectively 50 and 20, PI = 30

(b) The weight of SPT hammer = 63.5 kg or 140 lb.

(c) The value of total coliform according to ECR'97 = 0 n per 100ml

(d) The value of N_c for foundation is 9.

(4) A saturated soil has water content 30% and sp. gr. of 2.7. what is the void ratio of the soil?

Solution:

$Se = \omega G_s$

$\Rightarrow 1 \times e = (0.3 \times 2.7)$

$\Rightarrow e = 0.81.$

(Ans)

(5) Determine the fineness modulus and percentage of clay and silt of the sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	pan.
g. retain	0	1	4	12	13	20	34	2	4

Solution:

Sieve size -	#4	#8	#16	#30	#40	#50	#100	#200	pan.
Cum. % retain -	0	1	5	17	40	60	94	96	100

$$\therefore FM \text{ of the sample} = \frac{1+5+17+60+94+96}{100} = 1.77$$

% Silt and clay $= (100 - 96) = 4\%$

(6) Calculate the mean speed at point where the value of flow is 10000 vehicle/hr, density is 175 vehicle/mile. (Ans)

Solution:

$$q = KV_s$$

$$\Rightarrow V_s = \frac{q}{K} = \frac{10000}{175} = 57.14 \text{ mile/hour.}$$

(7) Waste water flowing from a city at a rate of 1.5 MGD is treated by primary ~~concentration is 300 mg/l and suspended solids concentration~~ sedimentation and secondary trickling filters with total surface area is $700000\ ft^2$. The influent BOD_5 process removes 33% of the BOD_5. Calculate the required loading rate is $kg/ft^2/d$.

Solution: The remaining $BOD_5 = (1-0.33) \times 1.5 \times 10^6 \times 3.78 \times 300$

(7) Waste water flowing from a city at a rate of 1.5 MGD is treated by primary sedimentation and secondary ~~sedimentation~~. trickling filter with total surface area of 700000 ft^2. The influent of BOD_5 concentration is 300 mg/L and suspended solids concentration is 220 mg/L. The primary treatment process removes 33% of the BOD_5. Calculate the required loading rate in $kg/ft^2/day$.

Solution:

BOD_5 remaining after primary treatment process

$= (1-0.33) \times 1.5 \times 10^6 \times 3.785 \times 300 \times 10^{-6}$ kg/day

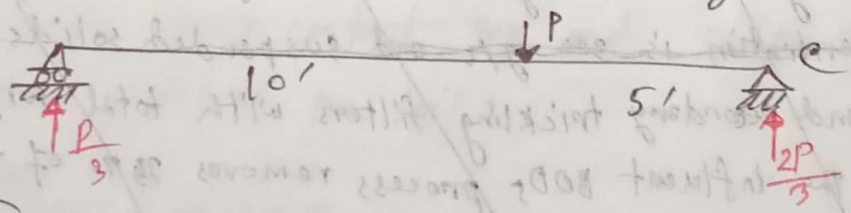
$= 1141.19$ kg/day.

Total suspended solid $= 1.5 \times 10^6 \times 220 \times 10^{-6} \times 3.785 = 1249.05$ kg/day

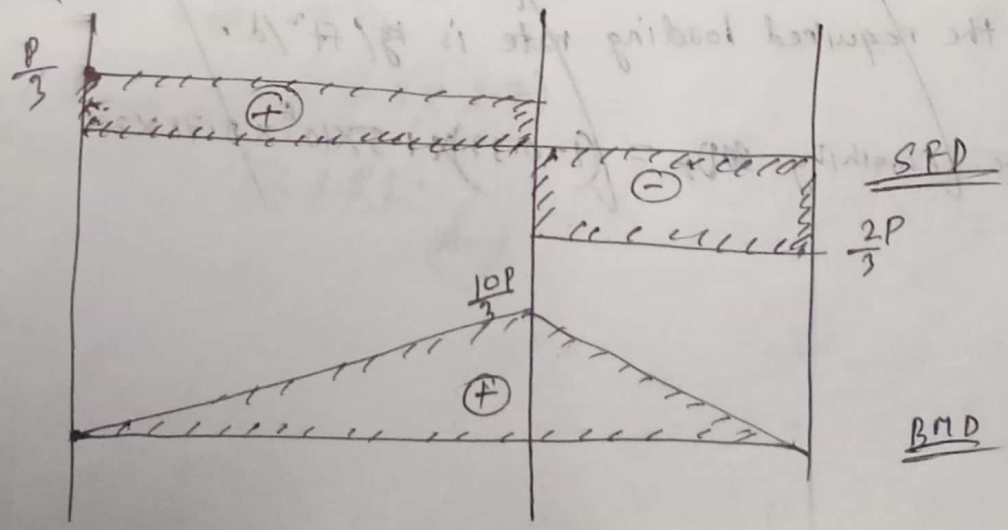
Total solid $= (1141.18 + 1249.05)$ kg/day $= 2390.23$ kg/day

$\therefore$ loading rate $= \frac{2390.23}{700000} = 3.41 \times 10^{-3}$ kg/ft^2/day.

(8) Draw SFD and BMD of the following structure. (Ans)



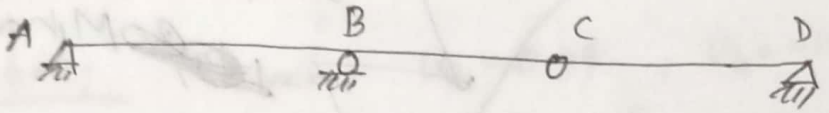
Solution:



BOGMCL - 2022

1. (Structure)

Draw IL diagram of reaction at A of the following beam:





IL for R_A

2. (Materials) Ratio = 1 : 2.5 : 4

concrete volume = 100 cft

Determine the number of other ingredients

Solution:

Dry volume = (1.5×100) cft = 150 cft

Total ratio = $(1 + 2.5 + 4) = 7.5$

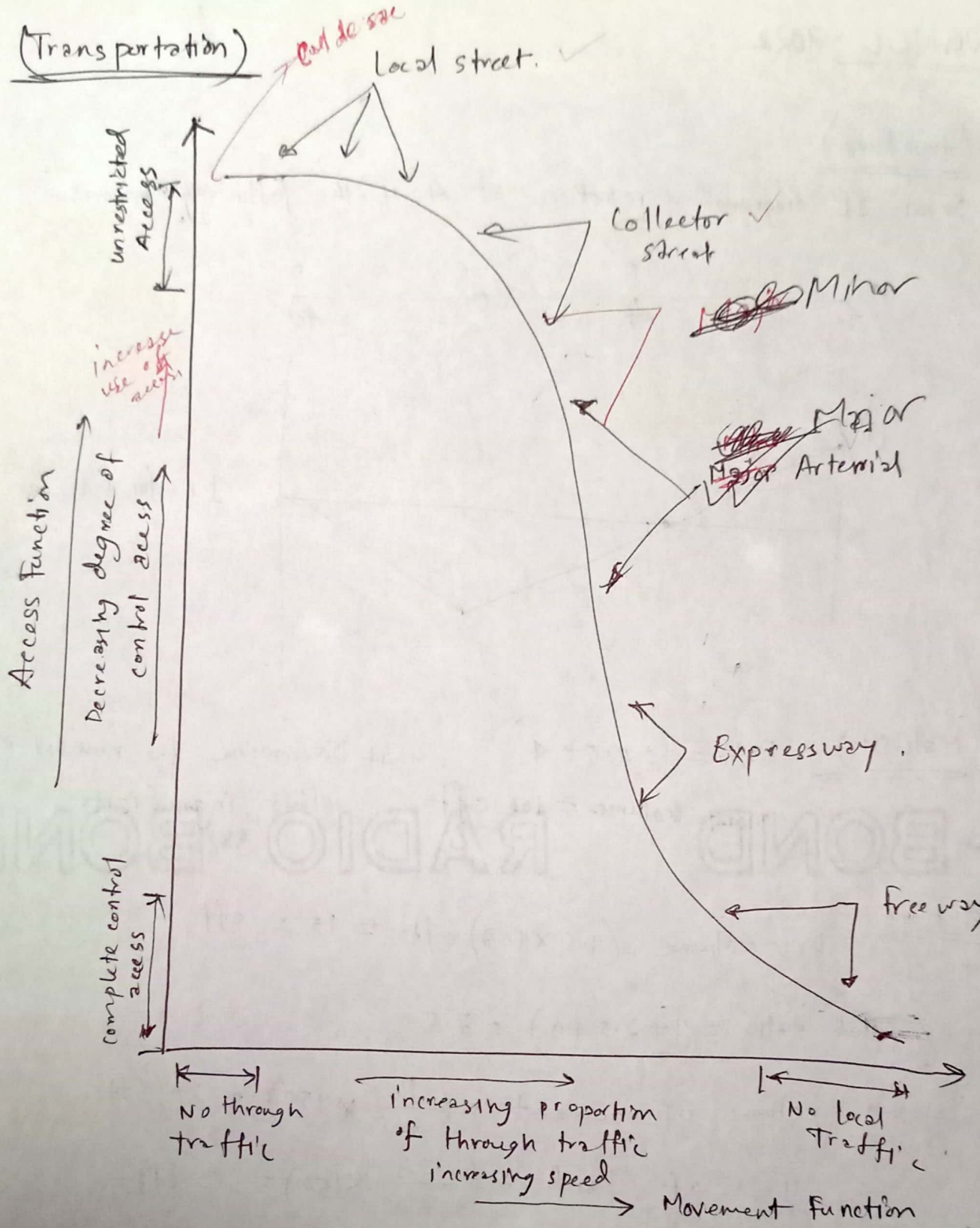
∴ volume of cement = $\left(\frac{1}{7.5} \times 150\right) = 20$ cft

" of sand = $\left(\frac{2.5}{7.5} \times 150\right) = 50$ cft

" of ~~stone~~ brick chips = $\left(\frac{4}{7.5} \times 150\right) = 80$ cft

(Ans.)

3. (Transportation)



4. (Transportations)

If utilities for Auto = 0.47, bus = −1.525 and walk = −2.5 Determine their mode share probabilities using a basic legit model.

Solution: Given, $U_a = 0.47$, $U_b = -1.525$, $U_w = -2.5$

∴ Mode share probabilities, $P_a = \frac{e^{0.47}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.842$

$P_B = \frac{e^{-1.525}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.115$

$P_L = \frac{e^{-2.5}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.0432$

(Ans.)

5. (Geotech): A sample of dry sand was tested in the direct shear apparatus under a normal load of 36 kg. The sample failed under a shearing load of 58 lb. The sample was 2" × 2". What is the angle of friction.

Solution:

We know,

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

$\therefore \phi = \tan^{-1}\left(\frac{14.5}{19.89}\right)$

$= 36.15°$

(Ans.)

Here, $\sigma = \frac{36 \times 2.20}{2 \times 2}$

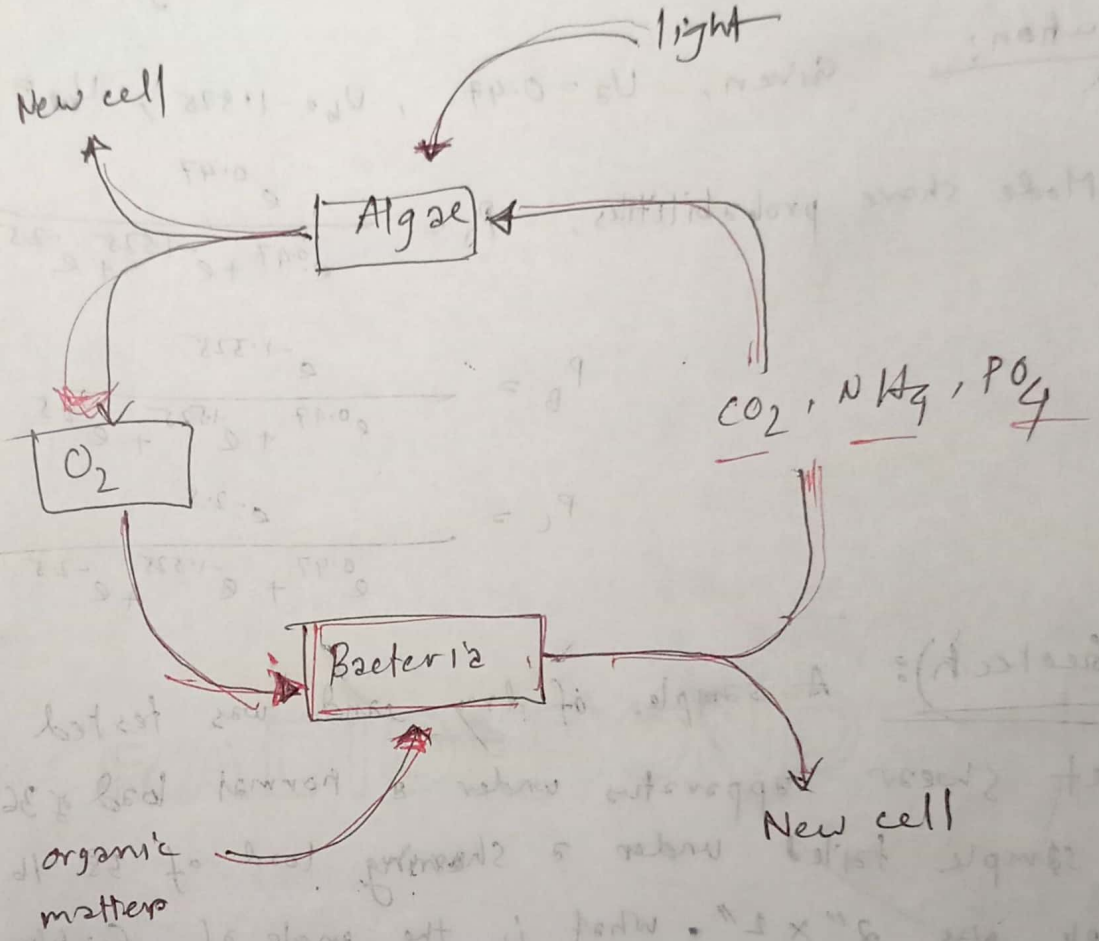
$= 19.89$ psi

$c = 0$ (for sand)

$\tau_f = \frac{58}{2 \times 2} = 14.5$

6. (Environment)

Draw Algae-bacteria symbiosis in a floculative Pond.



7. (Open channel Flow)

Calculate the uniform flow depth and critical depth for a wide rectangular channel with a bed slope of 0.00017 and per unit width discharge of $2\ m^2/sec$. Manning co-efficient = 0.018.

For wide channel, $R \simeq h$

Solution:

We know,

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \Rightarrow \frac{1}{0.018} \times h^{\frac{2}{3}} \times (0.00017)^{\frac{1}{2}} = \frac{q}{h}$$

$$\Rightarrow h^{\frac{5}{3}} = \frac{2 \times 0.018}{(0.00017)^{0.5}} = 2.76 \quad \therefore h = 1.89\ m$$

Ans.

$V = \sqrt{gD} = \sqrt{}$

critical $\left(\frac{2}{1.84}\right)^2 = gD$

$\Rightarrow D = 0.120\ m$

8. A nine group pile consisting of 24" diameter were cast in clayey soil, whose unconfined compressive strength is 1000 lb/ft², Each pile is 50 ft. Using reduction factor $\alpha = 0.5$, the factor of safety = 3. Determine the allowable skin friction of a single pile.

Solution:

we know,

Skin friction, $Q_s = \alpha C A_{surface}$

$= 0.5 \times 500 \times \pi DL$

$= (0.5 \times 1500 \times 3.1416 \times \frac{24}{12} \times 50)$

$= 78539.16$

$= 78.54$ Kip

Let, $\alpha = 0.5$

$c = \frac{q_u}{2}$

$= \frac{1000}{2}$ lb/ft²

$= 500$ lb/ft²

$\therefore$ Allowable skin friction, $(Q_s)_{all} = \frac{78.54}{3} = 26.18$ Kip.

9. Fill in the Gaps:

(i) value of bearing capacity factor N_c for deep foundation 9.

(ii) Unconfined compressive strength of soft clay soil in its undisturbed and remoulded state are 100 KN/m² and 50 KN/m². Sensitivity of the clay $\left(\frac{100}{50}\right) = 2$.

(iii) The effective angle of internal friction ϕ of a soil = 30°. co-efficient of active earth pressure of the soil is $\frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$.

BGDCL-2021 BUET

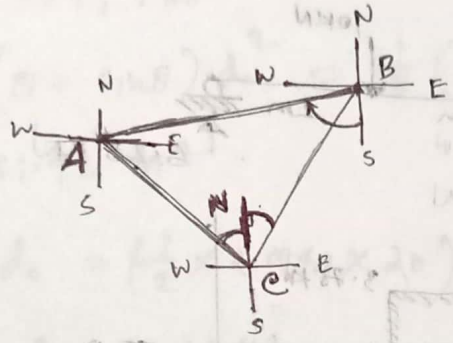
① Calculate the internal angle of a triangle. If the bearing of

BA = S 48° 56' 52" W

CA = N 56° 48' 20" W

CB = N 32° 36' 40" E

Solution:



$\angle ACB = (56°48'20" + 32°36'40")$

$= 89°25'$

$\angle ABC = 48°56'52" - 32°36'40"$

$= 16°20'12"$

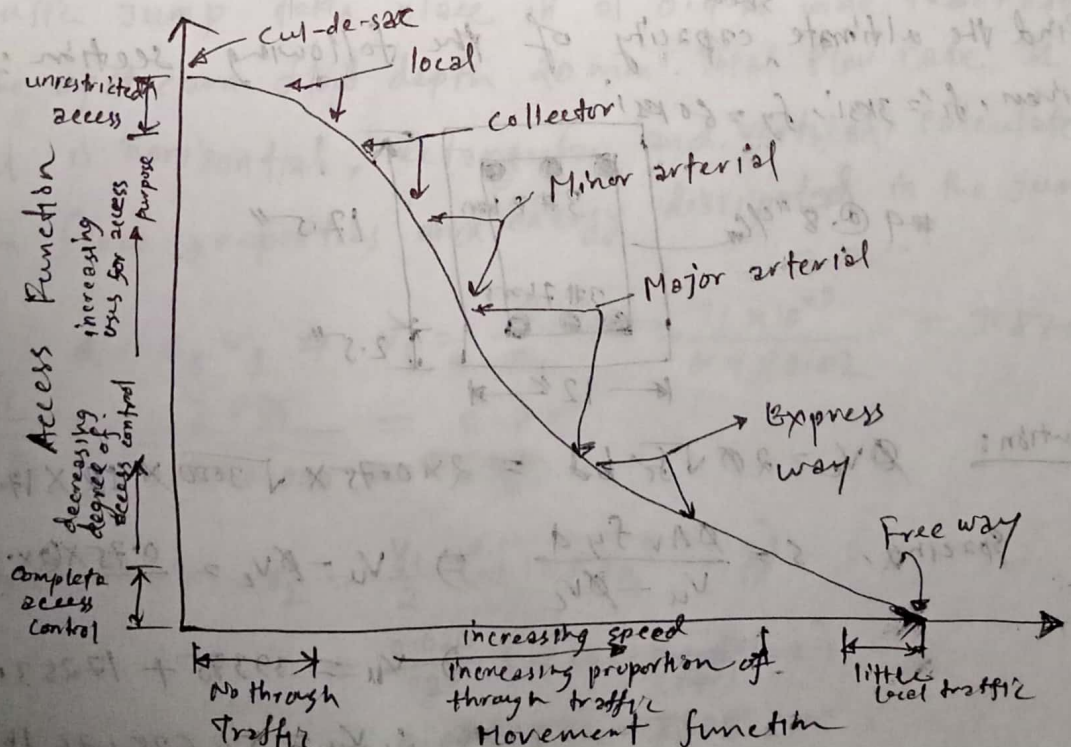
$\angle BAC = (90 - 48°56'52") + (90 - 56°48'20")$

$= 74°14'48"$

(Ans.)

② Draw diagram of Access and movement function.

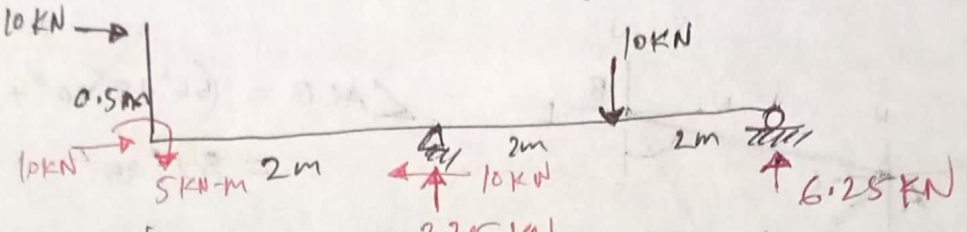
Solution:



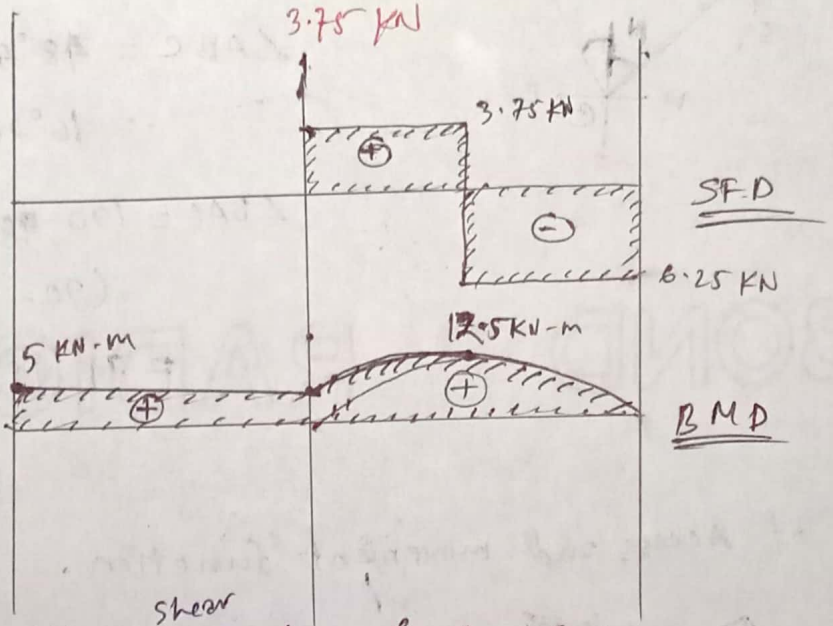
③ For SPT test, 1st, 2nd and 3rd 15 cm penetration are 8, 10, 12 respectively. Calculate the value of Field penetration number, N.

Solution: Field Penetration number, $N = (10+12) = 22$ (Ans:)

④ Draw SFD & BMD of following Beam:

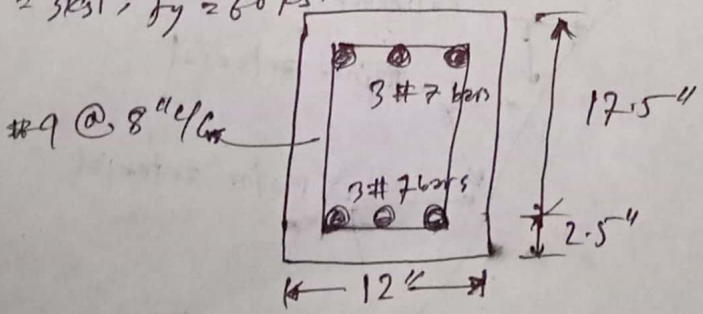


Solution:



⑤ Find the ultimate shear capacity of the following section:

Given, $f_c' = 3$ ksi, $f_y = 60$ ksi



Solution: $\phi V_c = 2\phi\sqrt{f_c'}\,bd = 2\times 0.75\times\sqrt{3000}\times 12\times 17.5 = 17253.26$ lb

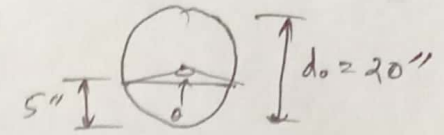
Spacing, $s = \dfrac{\phi A_v f_y d}{V_u - \phi V_c} \Rightarrow V_u - \phi V_c = \dfrac{0.75\times(2\times.20)\times 60000\times 17.5}{8}$

$\Rightarrow V_u = 39375 + 17253.26$ lb

$\therefore V_u = 56628.26$ lb $= 56.63$ K (Ans)

(6) A circular pipe having a diameter of 20", n = 0.011 and s = 0.015. The depth of water 5". Find the velocity and discharge.

Solution:



$$\theta = 2\cos^{-1}\left(1 - \frac{2h}{d_0}\right)$$

$$= 2\cos^{-1}\left(1 - \frac{2\times 5}{20}\right)$$

$$\theta = 2.0944 \text{ rad.}$$

$$A = \frac{1}{8}(\theta - \sin\theta) d_0^2 = \frac{1}{8}(2.0944 - \sin 2.0944) \times 20^2$$

$$\therefore A = 61.42 \text{ in}^2.$$

$$P = \frac{1}{2}\theta d_0 = \left(\frac{1}{2} \times 2.0944 \times 20\right) = 20.944 \text{ inch.}$$

$$\therefore R = \frac{A}{P} = \frac{61.42}{20.944} = 2.93 \text{ inch} = 0.244 \text{ ft}$$

$$\therefore V = \frac{1}{n} R^{\frac{2}{3}} s^{\frac{1}{2}} = \frac{1.49}{0.011} \times (0.244)^{\frac{2}{3}} \times (0.015)^{\frac{1}{2}} = 6.48 \text{ ft/sec.}$$

$$Q = AV = \left(\frac{61.42}{144} \times 6.48\right) = 2.763 \text{ ft}^3/\text{sec.}$$

(Ans)

(7) A hydraulic jump takes place in a 0.4 m wide laboratory channel. The upstream flow depth 20 mm. Total flow rate 31 l/sec. The channel is horizontal, rectangular and vertical. Calculate downstream flow properties and energy dissipated in the jump.

Solution:

$$Q = A_1 V_1 \Rightarrow V_1 = \frac{Q}{A_1} = \frac{31 \times 10^{-3}}{0.4 \times 0.02} = 3.875 \text{ m/s}$$

$$Fr_1 = \frac{V_1}{\sqrt{gD_1}} = \frac{3.875}{\sqrt{9.81 \times 0.020}} = 8.75$$

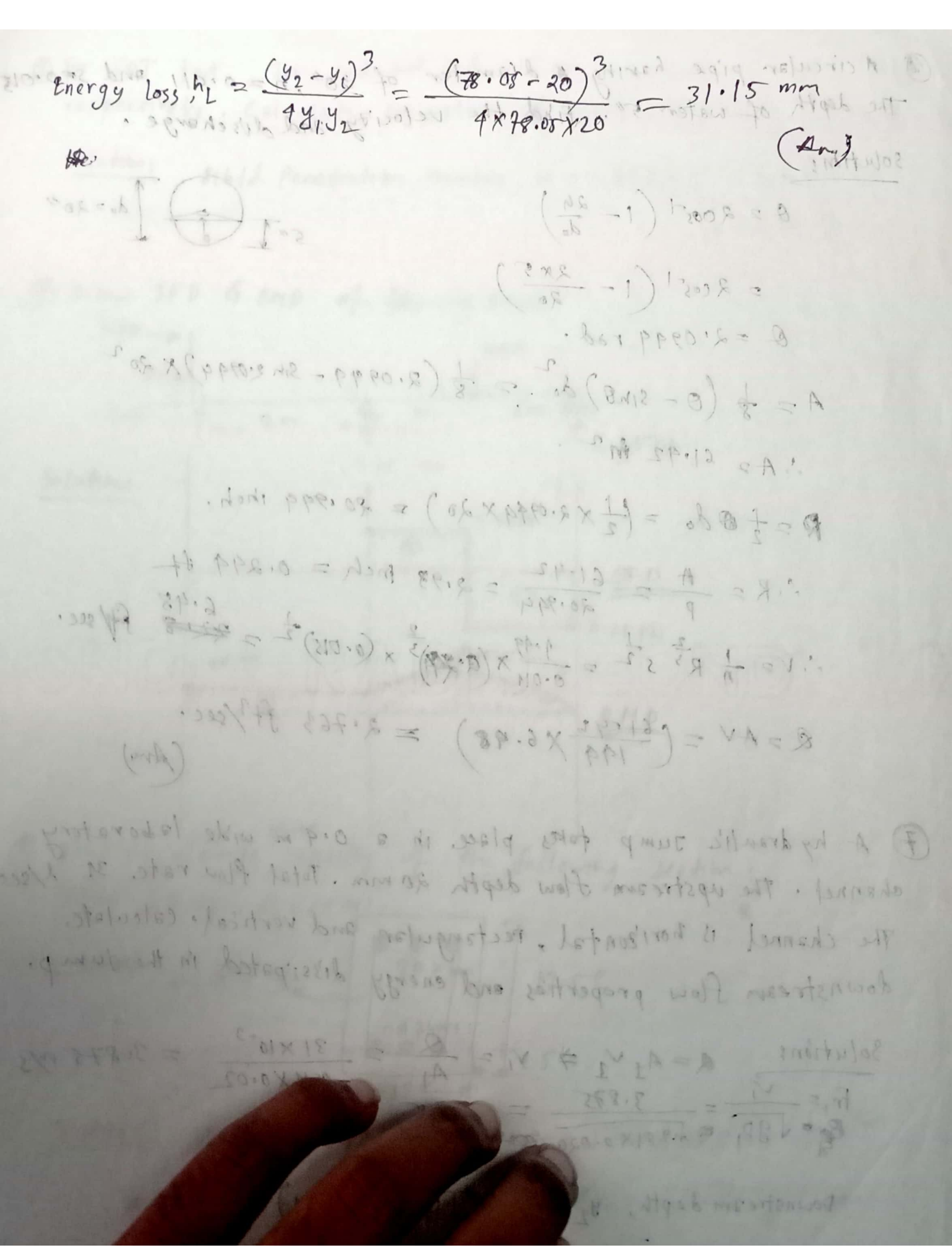
Downstream depth, $y_2 = \frac{y_1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right)$

$$= \frac{0.020}{2}\left(\sqrt{1 + 8 \times (8.75)^2} - 1\right)$$

$$= 0.07805 \text{ m} = 78.05 \text{ mm.}$$

Energy loss, $h_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2} = \frac{(78.05 - 20)^3}{4 \times 78.05 \times 20} = 31.15$ mm

(Ans)



PGCL-2021

BUET

① Environmental Engineering: The population of a city was 1,00,000 in 2000 and 1,95,000 in 2015. The water demand in 2025 is 90 lpcd. The disinfection of water is to be carried out with bleaching powder containing 25 percent of active chlorine. If the chlorine dose required for disinfection is 0.5 mg/l, calculate the quantity of bleaching powder per year.

Solution:

population growth rate in between 2000 and 2015, $r = \sqrt[n]{\frac{P_2}{P_1}} - 1$

$= \sqrt[15]{\frac{1,95,000}{1,00,000}} - 1$

$= 0.04553$

∴ Total population in 2025, $P_f = P_p(1+r)^n$

$= 1,95,000 \times (1 + 0.04553)^{10}$

$= 304362.4 \simeq 304363$ Nos.

∴ Total requirement of water $= (90 \times 304363) = 27392670$ l/day

Required chlorine dose for disinfection $= (27392670 \times 0.5)$ mg/day

$= (13696335)$ mg/day

$= 13.7$ Kg/day

∴ Quantity of bleaching required. $= \left(\frac{100}{25} \times 13.7\right) = 54.8$ Kg/day

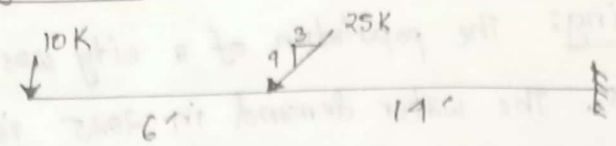
$= (54.8 \times 365)$ Kg/year

$= 20002$ Kg/year

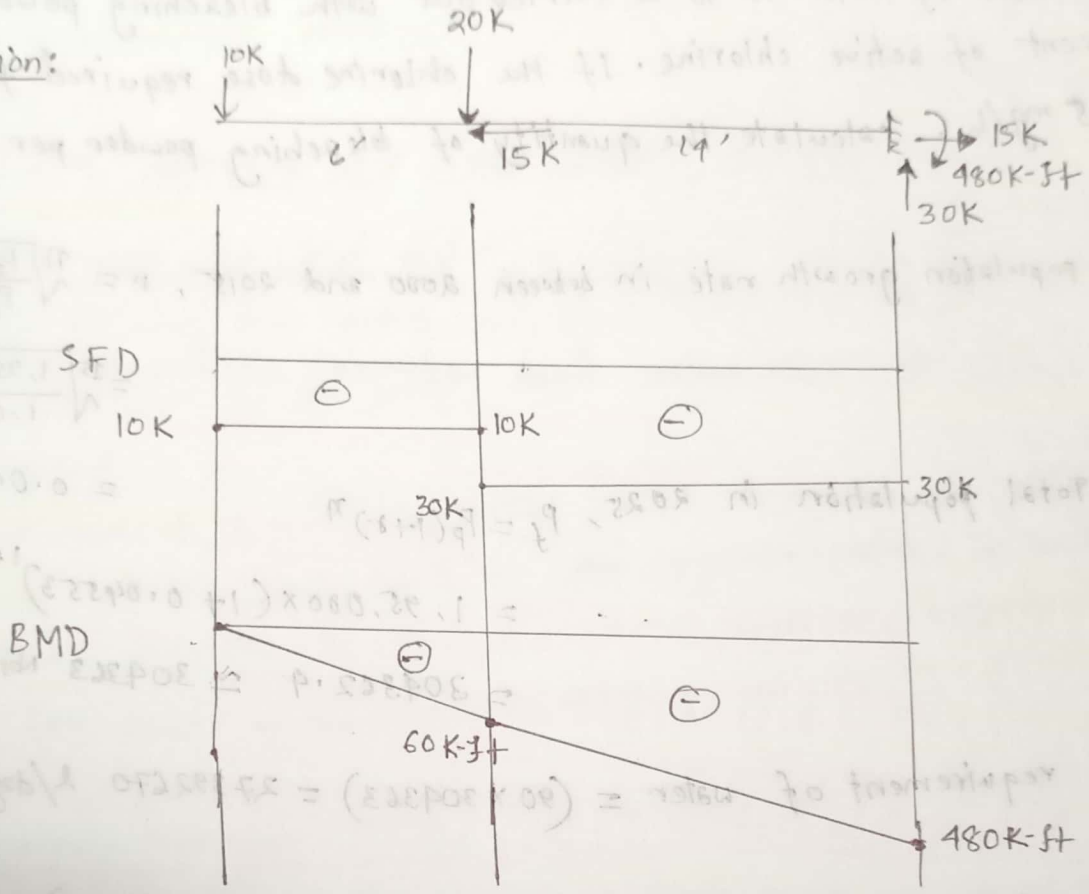
$= 20$ ton/year

(Ans.)

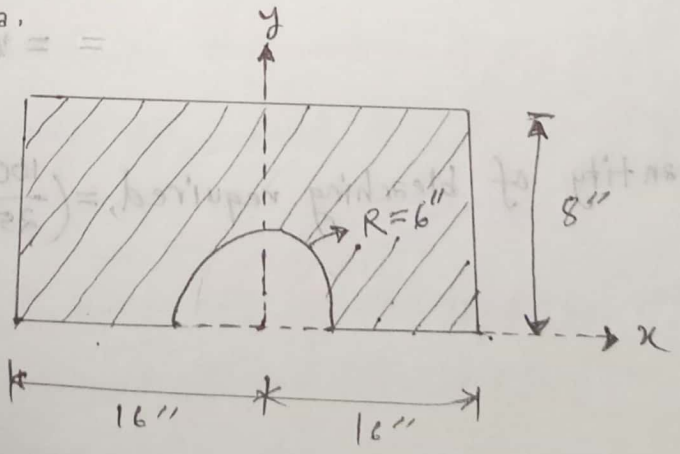
② **Structural Engineering:** Draw SFD and BMD of the following structure:



Solution:



③ **Analytic Mechanics:** Determine the centroid and moment of inertia along X-Y axis of the shaded Area.



Solution:

$$\bar{x} = \frac{A_1 x_1 - A_2 x_2}{A_1 - A_2} = \frac{(32\times 8)\times 0 - (\frac{\pi}{2}\times 6^2)\times 0}{(32\times 8) - (\frac{\pi}{2}\times 6^2)} = 0 \text{ inch}$$

$$\bar{y} = \frac{A_1 y_1 - A_2 y_2}{A_1 - A_2} = \frac{(32\times 8)\times 4 - (\frac{\pi}{2}\times 6^2)\times(\frac{4\times 6}{3\pi})}{(32\times 8) - (\frac{\pi}{2}\times 6^2)} = \frac{880}{199.4512}$$

$$= 4.4121 \text{ inch}$$

$$I_x = I_{x_1} - I_{x_2} = \frac{bh^3}{3} - \frac{\pi r^4}{8} = \frac{32\times 8^3}{3} - \frac{\pi\times 6^4}{8} = 4952.4 \text{ in}^4$$

$$I_y = I_{y_1} - I_{y_2} = \frac{bh^3}{12} - \frac{\pi r^4}{8} = \frac{32^3\times 8}{12} - \frac{\pi\times 6^4}{8} = 21336.4 \text{ in}^4$$

(Ans.)

(4) Hydrology: The rate of rainfall for successive 1 hr period of 5 hr storm are:

Time (hr)	1	2	3	4	5
Rainfall (cm)	0.4	2	3	2	1.6

The corresponding surface runoff is estimated to be 5 cm. Find the ϕ index and w-index.

Solution: Total precipitation, $P = (0.4+2+3+2+1.6) = 9$ cm

$$\phi\text{-index} = \frac{P-R}{t} = \frac{9-5}{5} = 0.8 \text{ cm/hr} > 0.4 \text{ cm}$$

Hence, effective rainfall, $P_e = (9-0.4) = 8.6$ cm/hr

and effective time period, $t_e = (5-1) = 4$ hr

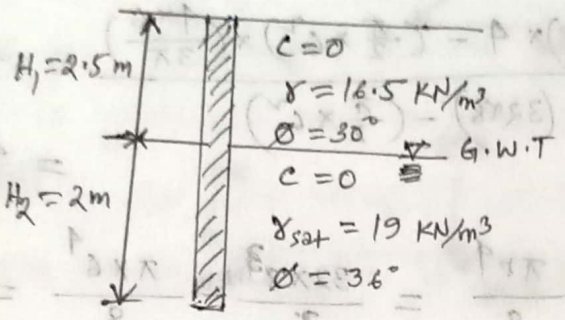
$$\therefore \phi\text{-index} = \frac{P_e - R}{t_e} = \frac{8.6-5}{4} = 0.9 \text{ cm/hr}$$

Now,

$$w\text{-index} = \frac{P-R-I}{t} = \frac{9-5-0}{5} = 0.8 \text{ cm/hr}$$

(Ans.)

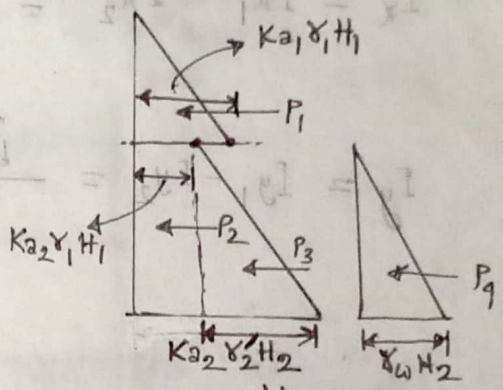
⑤ Geotechnical Engineering: calculate the active earth pressure and center of location of the pressure.



Solution:

$$K_{a_1} = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = \frac{1}{3}$$

$$K_{a_2} = \frac{1-\sin 36°}{1+\sin 36°} = 0.2596$$



pressure diagram

$$P_1 = \frac{1}{2} \times K_{a_1}\gamma_1 H_1 \times H_1 = \frac{1}{2} \times \frac{1}{3} \times 16.5 \times 2.5^2 = 17.1875 \text{ KN/m}$$

$$P_2 = K_{a_2}\gamma_1 H_1 \times H_2 = 0.2596 \times 16.5 \times 2.5 \times 2 = 21.417 \text{ KN/m}$$

$$P_3 = \frac{1}{2} \times K_{a_2}\gamma_2' H_2 \times H_2 = \frac{1}{2} \times 0.2596 \times (19-9.81) \times 2^2 = 4.77145 \text{ KN/m}$$

$$P_4 = \frac{1}{2}\gamma_w H_2^2 = \frac{1}{2} \times 0.2596 \times 9.81 \times 2^2 = 5.09335 \text{ KN/m}$$

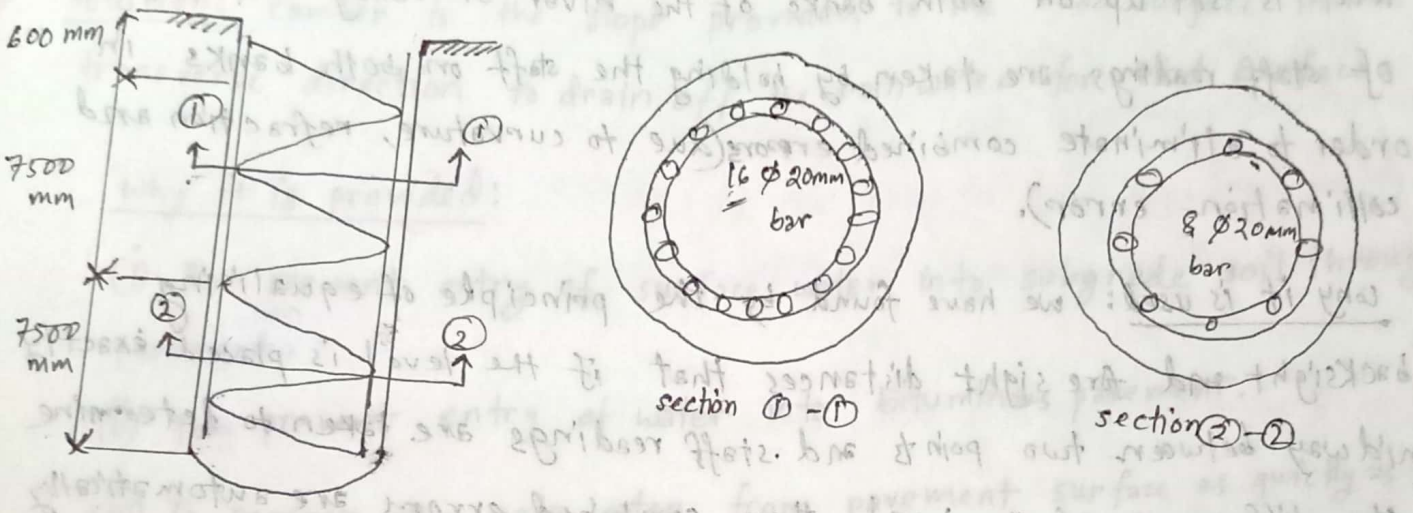
∴ Total active earth pressure, $P_a = (P_1 + P_2 + P_3 + P_4) = 48.4693$ KN/m

∴ Center of location of pressure, $\bar{z} = \dfrac{(17.1875 \times (2 + \frac{2.5}{3}) + 21.417 \times \frac{2}{2} + 4.77145 \times \frac{2}{3} + 5.09335 \times \frac{2}{3})}{48.4693}$

$$= \frac{76.69145}{48.4693} = 1.5823 \text{ m from bottom}$$

(Ans.)

Geotechnical Engineering: Estimate the quantity (kg) of main reinforcement for the following pile:



Solution:

Total length of one bar = $(600 + 7500 + 7500) = 15600\ mm = 15.6\ m$

Area of one bar = $\frac{\pi}{4} \times \left(\frac{20}{1000}\right)^2 = 3.1416 \times 10^{-4}\ m^2$

∴ Volume of one bar = $(3.1416 \times 10^{-4} \times 15.6) = 4.9 \times 10^{-3}\ m^3$

For section ①-①:

weight of 16 bar = $(16 \times 4.9 \times 10^{-3} \times 7850) = 615.44\ kg$

For section ②-②:

weight 8 bar = $(8 \times 4.9 \times 10^{-3} \times 7850) = 307.72\ kg$

∴ Total quantity of bar = $(615.44 + 307.72) = 923.16\ kg$

(Ans:)

$1\ m^3 = 7850\ kg$

steel

⑦ Surveying:

What is Reciprocal surveying? Why it is used?

Solution: Reciprocal Surveying: It is a surveying technique in which the level is set up on both banks of the river or valley and two sets of staff readings are taken by holding the staff on both banks in order to eliminate combined errors (due to curvature, refraction and collimation error).

Why it is used: we have found by the principle of equalising backsight and foresight distances that if the level is placed exactly midway between two points and staff readings are taken to determine the difference of the level, then combined errors are automatically eliminated.

But in case of a river or valley, it is impossible to set up the level midway between two points on opposite banks. In such cases, the method of levelling is adopted, which involves reciprocal observations from both banks of the river or valley.

⑧ Engineering Materials:

What is Bleeding of concrete? Write causes and prevention of it:

Solution: Bleeding of concrete is known as water gain. It is a particular form of segregation, in which the water comes up to the surface and accumulates at the top being of lowest specific gravity among all the ingredients of concrete.

causes: (i) when concrete is mixed with high amount of water.

(ii) Due to bad proportied and insufficiently mixed concrete.

prevention: (i) Adding air entraining admixtures.

(ii) Adding more cement in the mix.

(iii) Maintain proper proportion of concrete mix.

Transportion Engineering:

* what is camber ? why it is provided?

Solution: camber is the slope provided to the road surface in the transverse direction to drain off the rain water for road surface.

Why it is provided:

(i) To prevent entry of surface water into subgrade soil through pavement.

(ii) To prevent entry of water into bituminous pavement.

(iii) To remove the rain water from pavement surface as quickly as possible.

① **Fluid Mechanics:** A fluid with a density of 900 Kg/m³ and kinematic co-efficient of viscosity 0.00001 m²/sec, flows at 0.2 m³/sec. through a 500 m length of 200 mm diameter cast iron pipe. Determine (a) the head loss (b) the pressure drop if the pipe slope down at 1 in 10, the flow direction. [friction factor = 0.0225]

Solution:

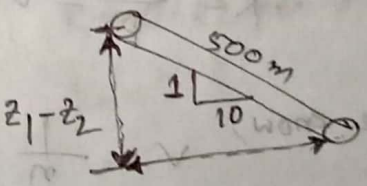
(a) we know, $Re = \frac{Vd}{\nu}$ where, $V = \frac{Q}{A} = \frac{0.2}{\frac{\pi}{4} \times (0.2)^2} = 6.3662$ m/s

$= \frac{6.3662 \times 0.2}{0.00001}$

$= 127324 > 4000$, Hence, it is turbulent flow.

For turbulent flow, $h_f = \frac{fLV^2}{2gd} = \frac{0.0225 \times 500 \times 6.3662^2}{2 \times 9.81 \times 0.2} = 116.2$ m (Ans)

(b) for inclined pipe & $(V_1 = V_2)$,



$$h_f = z_1 - z_2 + \frac{(P_1 - P_2)}{\gamma}$$

$$\Rightarrow 116.2 = \frac{500 \times 1}{\sqrt{10^2 + 1^2}} + \frac{\Delta P}{9.81}$$

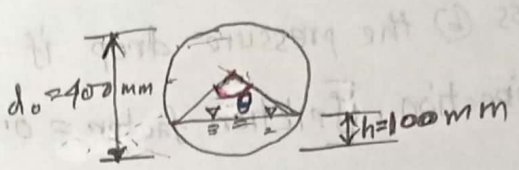
$$\Rightarrow \Delta P = 651.875 \text{ KN/m}$$

(Ans.)

Open channel Flow

~~Fluid Mechanics~~: A circular cross-section sewer pipe with a diameter = 400 mm and manning's co-efficient, n = 0.013 is laid on a grade of 0.015. What will be the velocity and discharge with the depth of flow in 100 mm.

Solution:



We know,

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

$$= 2\cos^{-1}\left(1 - \frac{2\times 0.100}{0.400}\right)$$

$$= 2.0944 \text{ rad.}$$

Now, $$A = \frac{1}{8}(\theta - \sin\theta) d_o^2 = \frac{1}{8}\times[2.0944 - \sin(2.0944)] \times (0.4)^2$$

$$\therefore A = 0.02457 \text{ m}^2$$

$$P = \frac{1}{2}\theta d_o = \left(\frac{1}{2}\times 2.0944 \times 0.400\right) = 0.4189 \text{ m}$$

$$\therefore R = \frac{A}{P} = 0.058659 \text{ m}$$

We know, $$V = \frac{1}{n} R^{\frac{2}{3}} \times S^{\frac{1}{2}} = \frac{1}{0.013} \times (0.058659)^{\frac{2}{3}} \times (0.015)^{\frac{1}{2}} = 1.4222 \text{ m/s}$$

$$\therefore Q = AV = (0.02457 \times 1.4222) = 0.035 \text{ m}^3/\text{sec.}$$

(Ans:)

③ Environmental Engineering:

(a) Define BOD and COD.

Solution: BOD: The amount of oxygen required for microbs to carry out the biological decomposition of dissolved solids or organic matter in sewage under aerobic conditions at standard temperature is known as the B.O.D.

COD: The amount of oxygen required to oxidize the organic matter by strong oxidizing agent under acidic conditions.

(b) The BOD_5 of a water sample at 20°c is 120 mg/L. If BOD rate constant at 20°c is 0.22 per day (10 base). Determine the ultimate BOD of the water sample.

Solution: We know,

$$BOD_5 = L_o(1-10^{-Rt})$$

$$\Rightarrow 120 = L_o(1-10^{-0.22\times5})$$

$$\therefore L_o = 130.35 \text{ mg/L}$$

Here, $BOD_5 = 120$ mg/L

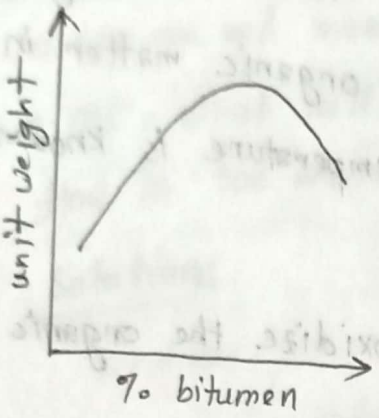
$R = 0.22$ per day

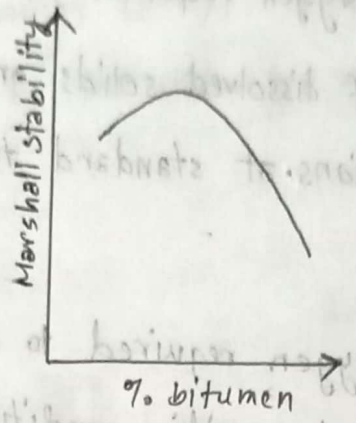
$L_o = ?$

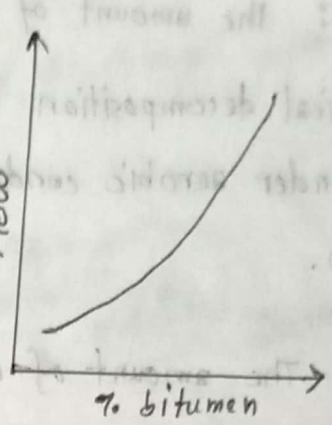
(Ans)

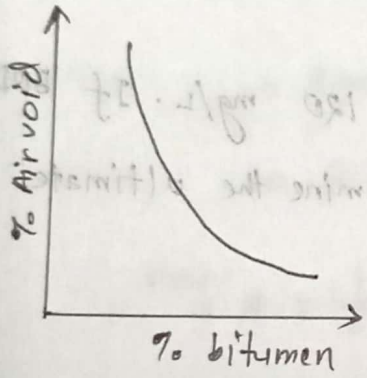
④ Transportation Engineering:

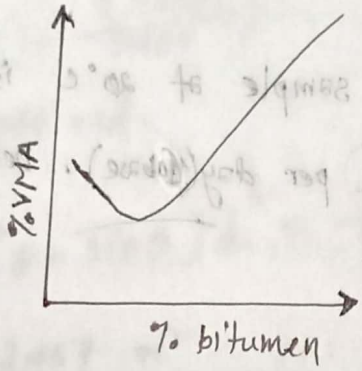
(a) Draw characteristic curves of Marshall Method.

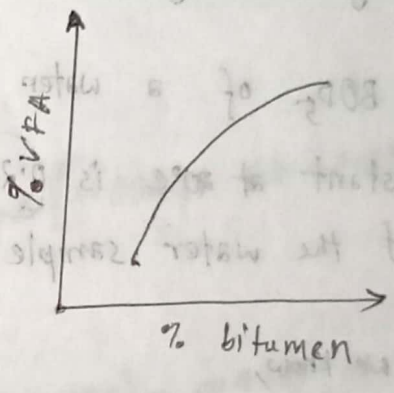












(b) Fill in the gaps:

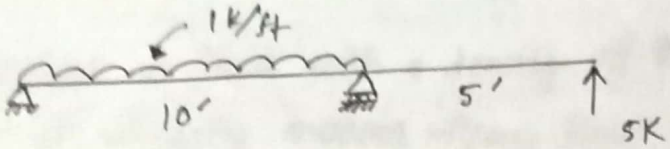
(i) Liquid limit and plasticity Index of a soil are 50 and 20 respectively. plastic limit of the soil is $(50-20)=30$. [$\because PI = LL - PL$]

(ii) weight of hammer in SPT is 63.5 Kg or 140 lb

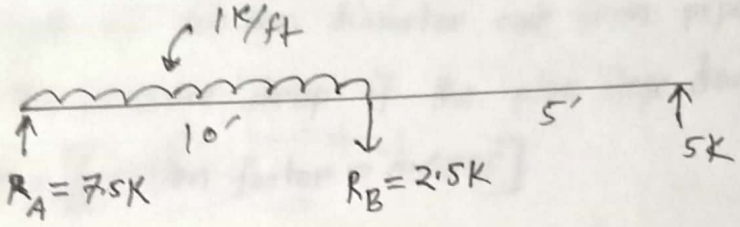
(iii) Allowable Arsenic value $(0.05 \text{ ppm} \times 1000) = 50$ ppb : (WHO = 0.01 mg/L)

(iv) Sylhet Sand FM is 2.5 .

⑤ **Structural Engineering:** Draw SFD and BFD for the following beam.



Solution:

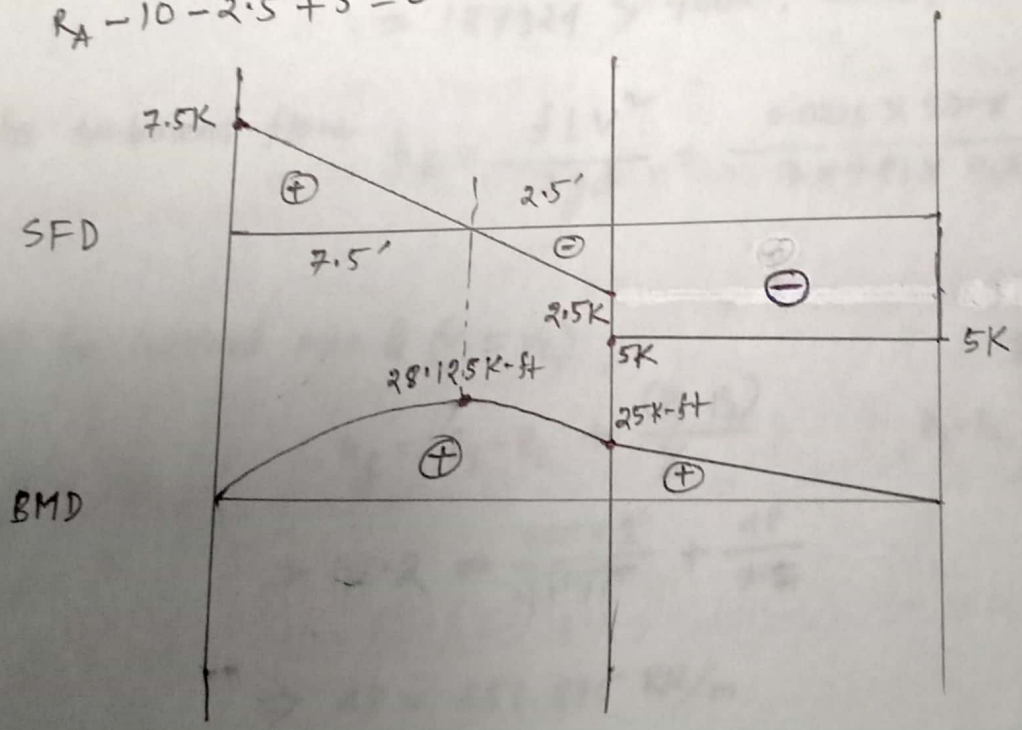


$\Sigma M_A = 0$

$$(10\times1)\times\frac{10}{2} + R_B \times 10 - 5\times(10+5) = 0 \Rightarrow R_B = 2.5K$$

$\Sigma F_y = 0$

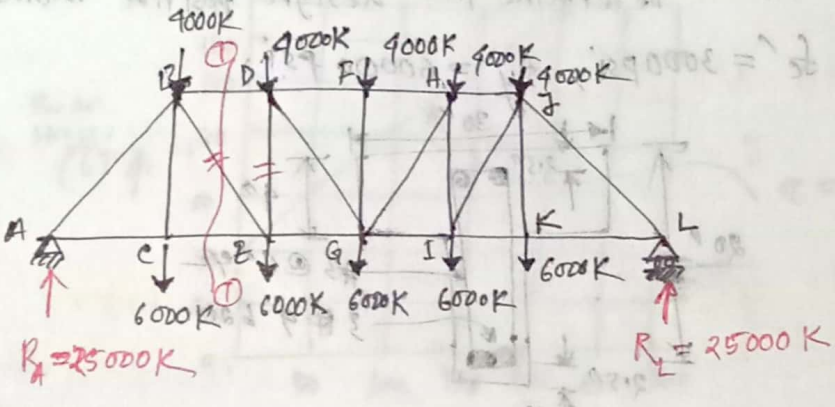
$$R_A - 10 - 2.5 + 5 = 0 \Rightarrow R_A = 7.5K$$



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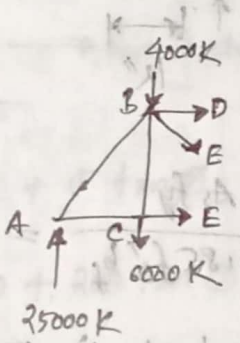
BUET

① Determine the member forces in DE and BE.



Solution:

Taking section ①-①



section ①-①

$\Sigma M_B = 0$

$25000 \times 20 - CE \times 20 = 0$

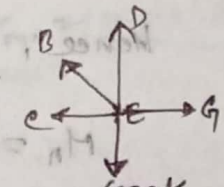
$\Rightarrow CE = 25000\,K\ (T)$

$\Sigma F_y = 0$

$25000 - 4000 - 6000 - \frac{BE \times 20}{28.2843} = 0$

$\Rightarrow BE = 21213.225\,K\ (T)$

joint E :

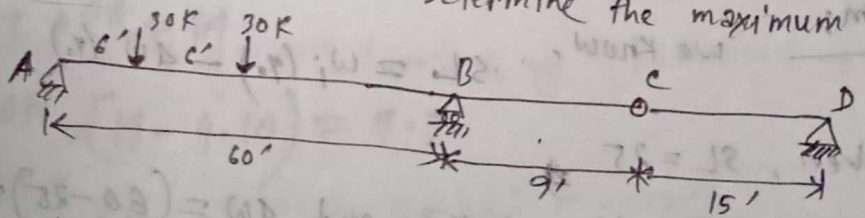


$DE + \frac{BE \times 20}{28.2843} = 6000$

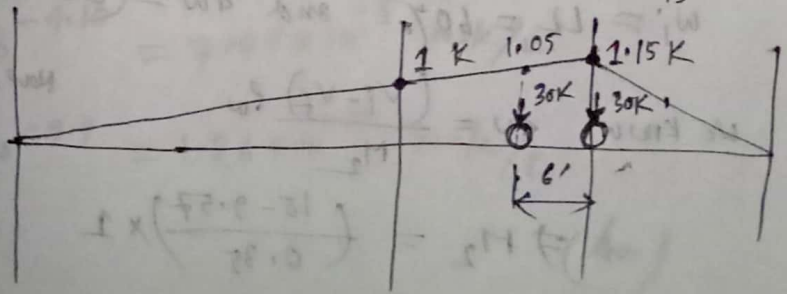
$\Rightarrow DE = 6000 - \frac{21213.225 \times 20}{28.2843}$

$\therefore DE = -9000\,K = 9000K\ (C)$

② A group of moving load consists of a pairs of 30K load acting (Ans) 6 feet constant apart on a beam shown below. Determine the maximum reaction at support B.



solution:



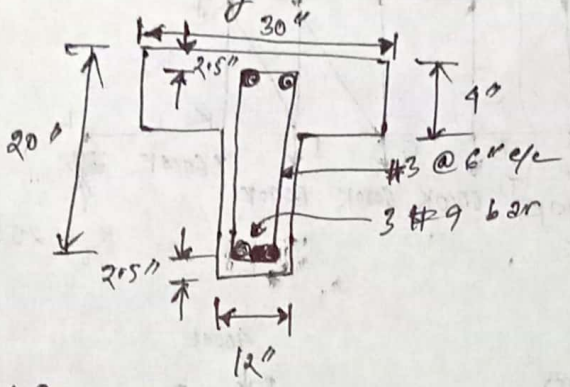
IL for R_B

Maximum Reaction at B = $(30 \times 1.05 + 30 \times 1.15)$

= 66 K

(Ans.)

(3) A reinforce concrete T beam has a cross section in the positive region of span as shown below. Determine the design positive moment capacity of the beam if $f_c' = 3000$ psi, $f_y = 60000$ psi. (5)



Solution:

$A_s = (3 \times 1) = 3\ in^2$

Now, $A_s = \dfrac{0.85 f_c' a b}{f_y} \Rightarrow a = \dfrac{A_s f_y}{0.85 f_c' b_f} = \dfrac{3 \times 60}{0.85 \times 3 \times 30} = 2.353\ in < h_f$

Hence, Rectangular beam analysis is required.

$M_n = A_s f_y \left(d - \frac{a}{2}\right) = 3 \times 60 \times \left(20 - \frac{2.353}{2}\right) = 3388.23$ K-inch.

(Ans.)

(4) A clay sample has atterberg limits, LL = 60, PL = 40, SL = 25. The sample shrink from 15 cm^3 to 9.57 cm^3. when the moisture content is decreased from LL to SL. what is the dry specific gravity of the clay sample.

Solution:

we know, $SL = w_i(\%) - \Delta w(\%)$

Given, SL = 25 %

$w_i = LL = 60\%$ and $\Delta w = (60 - 25) = 35\%$

we know, $\Delta w = \dfrac{(v_i - v_f)\rho_w}{M_2}$

$\Rightarrow M_2 = \left(\dfrac{15 - 9.57}{0.35}\right) \times 1$

$\Rightarrow M_2 = 15.5143$ g

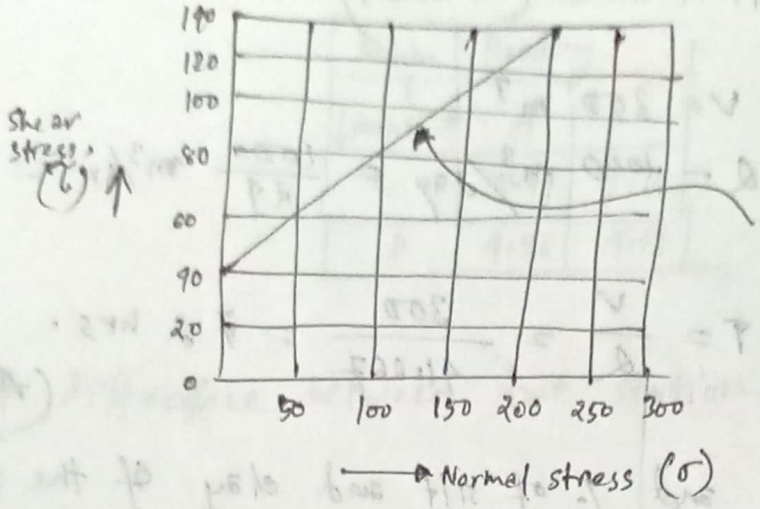
Now, $SR = \dfrac{M_2}{v_f \rho_w} = \dfrac{15.5143}{9.57 \times 1}$

$\therefore SR = 1.62$

$\therefore G_s = \dfrac{1}{\frac{1}{SR} - \left(\frac{SL}{100}\right)}$

$\therefore G_s = \dfrac{1}{1.62 - 0.25} = 2.72$ (Ans.)

(5) From the following graph determine the cohesion c and angle of internal friction ϕ.



Solution:

We know, $\tau = c + \sigma \tan\phi$ Here, $c = 40$

$\tau = 140$ N/mm²

$\sigma = 200$ N/mm²

$\Rightarrow 140 = 40 + 200 \tan\phi$

$\Rightarrow \tan\phi = \left(\frac{140-40}{200}\right)$

$\Rightarrow \phi = \tan^{-1}\left(\frac{1}{2}\right)$

$\therefore \phi = 26.565^\circ$ (Ans.)

(6) Find the hydrogen ion concentration and hydroxide ion concentration in tomato juice having pH of 4.10.

Solution;

$pH + pOH = 14$

$\Rightarrow pOH = (14 - 4.10) = 9.9$

$\therefore [H^+] = 10^{-4.10} = 7.94 \times 10^{-5}$ mole/L

$[OH^-] = 10^{-9.9} = 1.26 \times 10^{-10}$ mole/L

(Ans)

(7) In 300 m^3 sedimentation tank water is flowing at a rate 1000, what is the detention time (in hours)?

Solution: Given, $V = 300\ m^3$.

$Q = 1000\ m^3/day = \frac{1000}{24}\ m^3/hr = 41.667\ m^3/hr$.

We know, $T = \frac{V}{Q} = \frac{300}{41.667} = 7.2$ hrs. (Ans)

(8) Determine the F.M and % of silt and clay of the sample.

Sieve Size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	4	12	13	30	34	4	2

Solution:

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	# pan
cum. % retain	0	1	5	17	30	60	94	98	100

$\therefore FM = \frac{0+1+5+17+60+94}{100} = \frac{177}{100} = 1.77$.

% silt and clay $= (100 - 98) = 2\%$.

(9) The radius of a tyre imprint is approximately to a circle of 150 mm. What is the maximum loading duration on a particular point of pavement by a truck moving at a speed of 60 kmph?

Solution:

Maximum loading duration, $t = \frac{0.150 \times 2}{\frac{60 \times 1000}{3600}} = 0.018$ sec.

(Ans)

(10) Below the two station A and B their measurement are given. Find out the RL of A if RL of B is 108.82 ft.

Station / Point	Reading A	Reading B
c	5.79	5.12
b	4.96	4.18

Solution:

RL difference between two station $= \frac{(5.79 - 5.12) + (4.96 - 4.18)}{2}$

$= 0.725$ ft (fall from B to A)

$\therefore$ RL of A $= (108.82 - 0.725) = 108.095$ ft

(Ans)

GTCL-2016

BUET

1. (a) Value of angle of friction is 36°, the active earth pressure co-efficient = 0.26 $\left(K_a = \frac{1-\sin\phi}{1+\sin\phi}\right)$

(b) If the D_{10} and D_{60} value are 0.02 and 0.9 mm respectively, co-efficient of uniformity = 45 $\left(C_u = \frac{D_{60}}{D_{10}}\right)$

(c) A sieve analysis results in 100% retained in No. 50 sieve, the FM of the sample is 2. [#50 100 100; #100 100 100]

(d) If plastic limit 20%, plasticity index = 30%, Liquid limit of the sample is 50%. $(PI = LL - PL)$

2. The thickness of a clay layer is 2.5 m. The value of void ratio is 0.7 and compression index is 0.28. The existing pressure at the mid of the layer is 40 KN/m² and 30 KN/m² pressure is applied to the mid height of the layer. Find the consolidation settlement.

Solution: we know;

$$S_c = \frac{C_c H}{1+e} \times \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right)$$

$$\Rightarrow S_c = \left(\frac{0.28 \times 2.5}{1+0.7}\right) \times \log\left(\frac{40+30}{40}\right)$$

$\therefore S_c = 0.1 \text{ m} = 102 \text{ mm}$

(Ans.)

(3) There are nine piles in a group, each having 18 in dia, 65 ft long (L) alfa = 0.5, cast in situ pile in clay layer. What is the skin friction of a single pile? Given unconfined compressive strength of soil is 1000 lb/ft².

Solution:

$$Q_s = \alpha C_u p L$$

$$C_u = \frac{q_u}{2} = \frac{1000}{2} = 500 \text{ lb/ft}^2$$

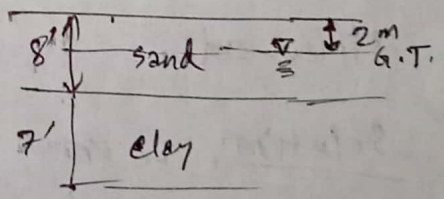
$$= 0.5 \times 500 \times 3.1416 \times \frac{18}{12} \times 65$$

$$= 76576.5 \text{ lb}$$

$$= 76.577 \text{ Klb.} \quad \text{(Ans.)}$$

(4) A sand layer has 8 ft depth, W.T. is at 2m depth from top the sand layer is overlaying a clay layer of large depth. the moist (above water table) and saturated unit weight are 13.5 kN/m² and 18 kN/m² respectively. Find the total and effective pressure at 15 ft depth.

Solution:



Total pressure = effective pressure + water pressure

Effective pressure at 15 ft depth, $\sigma_0' = 2 \times 13.5 + 13 \times (18 - 9.81) = 133.47 \text{ kN/m}^2$

And, Total pressure = $133.47 + (13 \times 9.81) = 261 \text{ kN/m}^2$

(Ans.)

(5) Dry and moist weight of a soil sample are 39.54 lb and 39.93 lb respectively; the volume of soil sample is 0.33 ft³. Find the bulk and dry unit weight of sample. Also find MC.

Solution:

$$\gamma_{moist} = \left(\frac{39.93}{0.33}\right) = 121 \text{ lb/ft}^3$$

$$\gamma_{dry} = \left(\frac{39.54}{0.33}\right) = 104.67 \text{ lb/ft}^3$$

We know, $\gamma_{moist} = \gamma_d (1+w)$

$$\Rightarrow 1+w = \frac{121}{104.67}$$

$$\therefore w = (1.156 - 1) = 0.156 = 15.6\%$$

(Ans)

(6) The pH of a soil sample is 10 and a total alkanity of 332 mg/L. Calculate the carbonate Alkanity and bicarbonate alkanity of the soil sample. Also calculate the carbonate and bicarbonate concentration.

Solution:

$$\text{Carbonate Alkanity as } CaCO_3 = \frac{50000 \times \left[\frac{332}{50000} + 10^{-10} - \frac{10^{-14}}{10^{-10}}\right]}{1 + \frac{2 \times 4.68 \times 10^{-11}}{10^{-10}}}$$

$$= 168.90 \text{ mg/L}$$

$$\text{Bicarbonate Alkanity as } CaCO_3 = \frac{2 \times 4.68 \times 10^{-11}}{10^{-10}} \times 168.90$$

$$= 158.09 \text{ mg/L}$$

$$[CO_3^{=}] = \frac{168.90}{50 \times 10^3} \text{ mole/L} = 3.162 \times 10^{-3} \text{ moles/L}$$

$$[HCO_3^-] = \frac{158.9}{50 \times 10^3} \text{ mole/L} = 3.378 \times 10^{-3} \text{ moles/L}$$

(Ans)

(7) The dilution factor = 0.5, value of DO initial, after 5 days, and BOD reaction rate constant ~~are given~~ $K = 0.23$/day. Find (i) BOD_5 (ii) Ultimate BOD (iii) BOD remaining after 5 days.

Solution: $BOD_5 = \frac{(DO_i - DO_f)}{DF} = \frac{(10-5)}{0.5} = 10$ mg/L

$BOD_5 = L_o(1 - e^{-K \times 5})$

$\Rightarrow L_o = \frac{10}{(1 - e^{-0.23 \times 5})} = 14.63$ mg/L

BOD remaining after 5 days $= L_o e^{-K \times 5} = (14.63 \times e^{-0.23 \times 5})$ mg/L

$= 4.63$ mg/L

(Ans.)

(8) The population of 2005 and 2015 are 10000 and 19500 respectively. What is the water demand of 2025? Given water demand = 90 lpcd. How much bleaching powder is needed if 20% chlorine is found in bleaching powder? Chlorine content of 0.5 mg/L is to be added in the water.

Solution: Growth rate, $r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \left(\sqrt[10]{\frac{19500}{10000}} - 1\right) = 0.069$

Future population, $P_f = P_p(1+r)^n = 19500(1 + 0.069)^{10}$

$= 38003$

∴ Total water demand in 2025 $= (38003 \times 90)$ L/day

$= 3420270$ L/day.

Chlorine required $= (0.5 \times 3420270)$ mg/day $= 1710135$ mg/day

$= 1.71$ kg/day.

∴ bleaching powder required $= \left(\frac{100}{20} \times 1.71\right) = 8.55$ kg/day

(Ans.)

(9) A canal exits waste water in a river at 5000 m^3/day. BOD of the waste water is 110 mg/L. What is the total amount of BOD exerted in the river? If a treatment plant is treating the waste to remove 70% BOD. what is the amount of BOD exerted?

Solution:

Total BOD exerted = $(5000 \times 10^3 \times 110)$ mg/day

= 6050 Kg/day.

After treating,

The amount of BOD exerted = $(1 - 0.70) \times 6050$ kg/day

= 1815 kg/day.

(Ans.)

(10) (a) The cause of hardness of water — bi-valent posite cation of Mg, Ca, Sr.

(b) The OH^- concentration is 2.1×10^{-9}, pH = 5.32.

(c) The unit of turbidity — NTU

(11) True / False:

(a) The layer of road foundation just above the existing ground level is wearing course. (True)

(b) Stopping sight distance only depends on vehicle speed. (False) * $SSD = vt + \frac{v^2}{2g(n \pm f)}$

(c) The speed of a vehical instantaneous at the moment of passing a point is design speed. (False). Spot speed

(d) AIV, TPF, soundness, Brittleness etc. tests are of bitumen contents. (False)

Aggregate

(v) In underdeveloped areas, meter gauge are used. (True)

(vi) In Bangladesh, the ballast used is mainly broken stone. (True)

(vii) The track from which the train diverts is called Main track. (True)

(viii) The longitudinal deformation of rail is technically known as creeping. (True)

(ix) The light is used to see in fog is ~~Broken~~ Yellow light. (False)

(12) Draw the cross section with detailing of rigid and flexible pavement.

Solution:

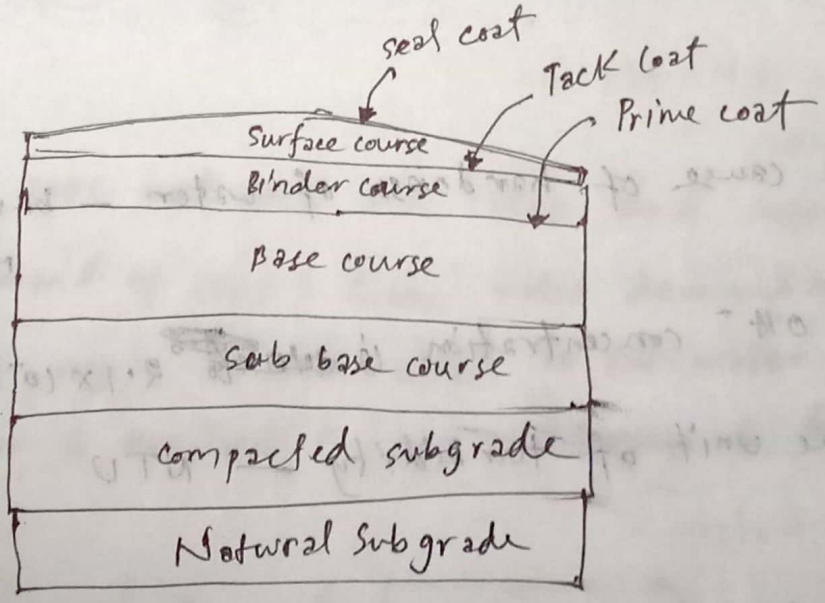


Fig. Flexible pavement

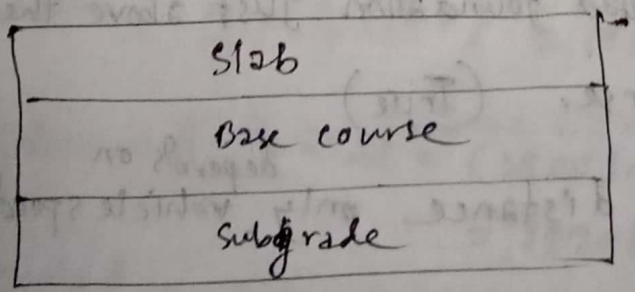
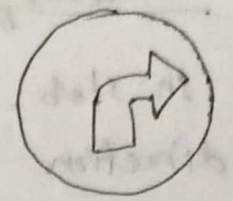


Fig. Rigid Pavement

(13) The sign shape for (i) Mandatory (ii) cautionary (iii) Instructive sign.

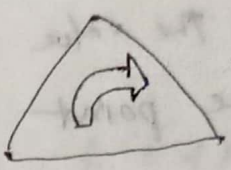
Solution:

(i) Mandatory Sign: Circular shape



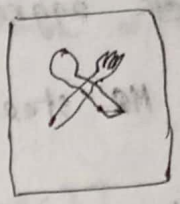
Direction

(ii) Cautionary Sign: Triangular shape



Right hand curve.

(iii) Instructive Sign: Rectangular shape



Restaurant

(14) Differentiate among Prime coat, Tack coat and seal coat.

Solution:

Prime coat: It is the first single coat of liquid bituminous materials to an absorpsent surface before placing bituminous wearing course.

Tack coat: It is an application of bituminous binder after the prime coat on surfaces previously treated before giving a new bituminous wearing course.

seal coat: It is very thin surface treatment or ~~single~~ a single coat of surface dressing over certain pervious bituminous pavement.

(15) Write the factors affecting pavement design.

Solution:

(i) Design wheel load.
(ii) subgrade soil
(iii) climate factors
(iv) Pavement component materials.
(v) Environmental factors.
(vi) other Special factors..

(16) (a) In RCC structure, the reinforcement is provided by embedding deformed steel bars.

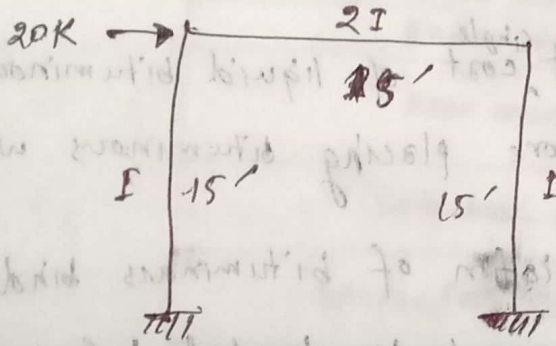
(b) In slab, the short direction bar is placed below the long direction bar.

(c) The value of bending moment of a beam is ~~zero~~ Maximum at the point where the shear stress changes its sign.

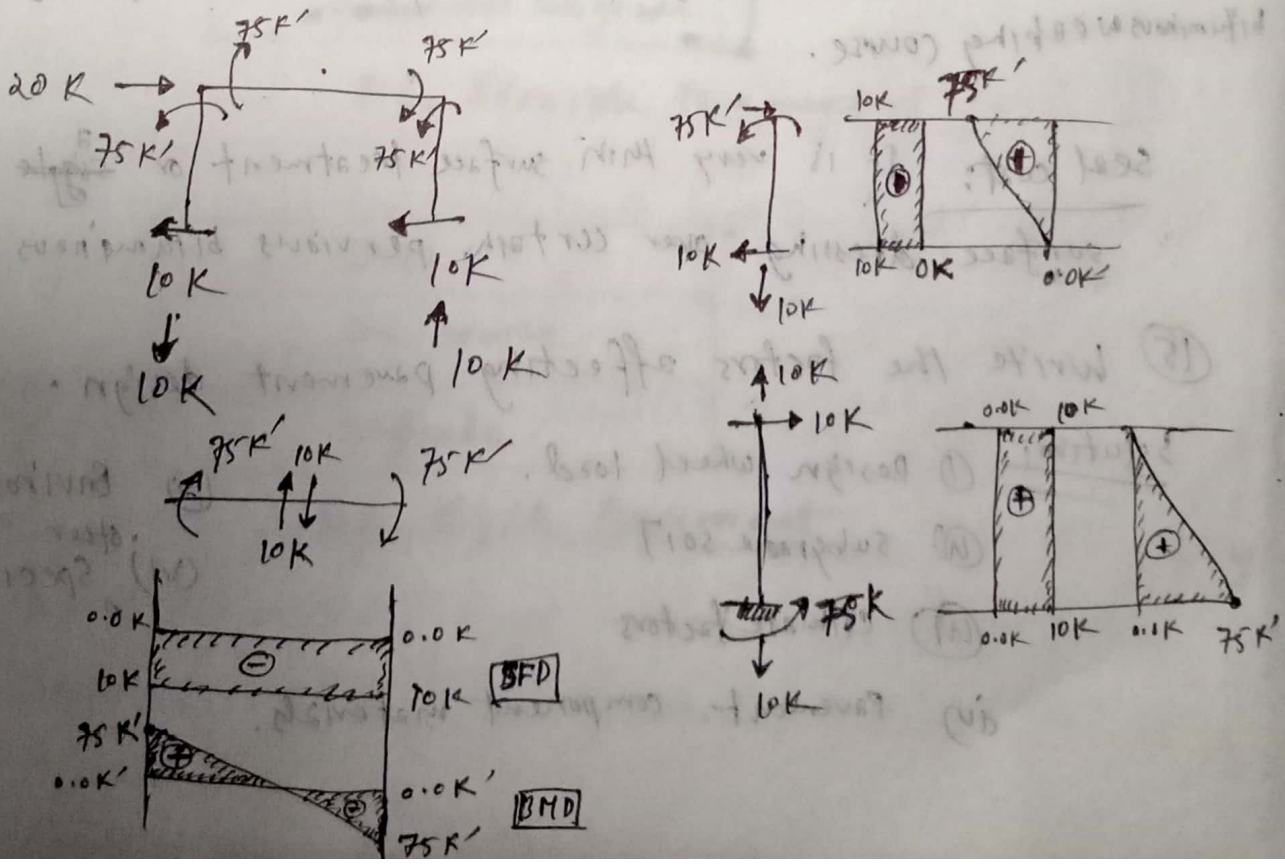
(d) Brick aggregate are normally weaker than stone aggregate.

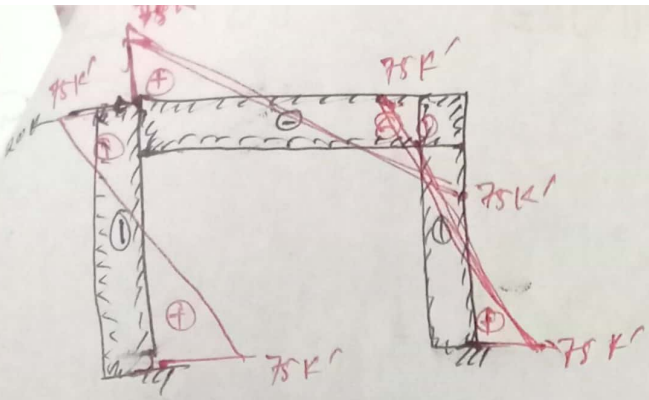
(e) The HS. steel bars are provided a grade on yield strength.

(17) Find the SFD and BMD diagram using portal method.



Solution:





(18) The column size = 12" × 12", steel ratio = 2%, $f_c' = 4$ K, $f_y = 60$ K. Find the ultimate axial stress of the column with zero eccentricity.

Solution: we know,

$$P_u = \alpha \phi A_g \left[0.85 f_c' + \rho_s (f_y - 0.85 f_c')\right]$$

$$= 1.0 \times 0.65 \times (12 \times 12) \left[0.85 \times 4 + 0.02 (60 - 0.85 \times 4)\right]$$

$$= 429.2 \text{ K/p}.$$

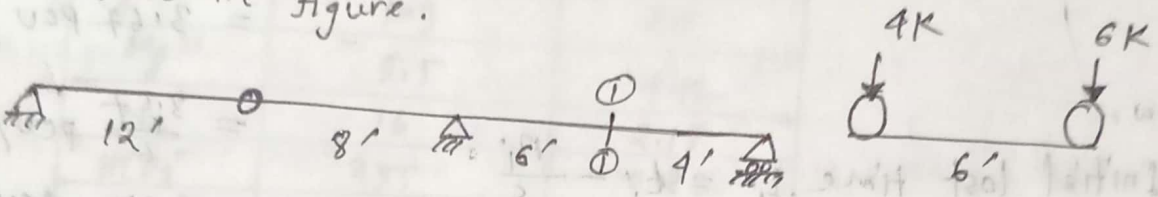
Ultimate stress, $\sigma_u = \frac{424.2}{12 \times 12} = 2.95$ KSI (Ans)

(19) The thickness of a brick wall is 250 mm, 2 m in height. Find the horizontal distributed wind load for which base shear is just negative. Given, the unit weight of the masonry is 18.5 KN/m³.

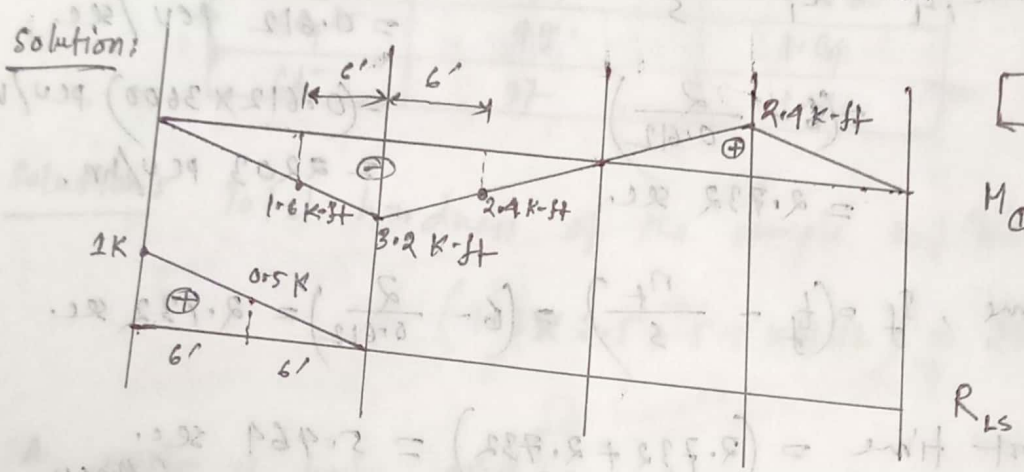
#SGFL-2023

BUET

1. (a) Draw Influence Line for moment at section ①-① and for reaction at left support. Also calculate the maximum negative moment and maximum reaction for the moving load as shown in figure.



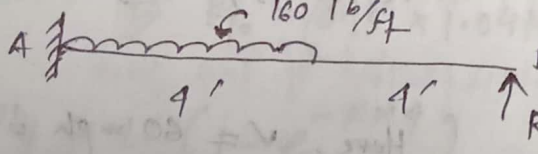
Solution:



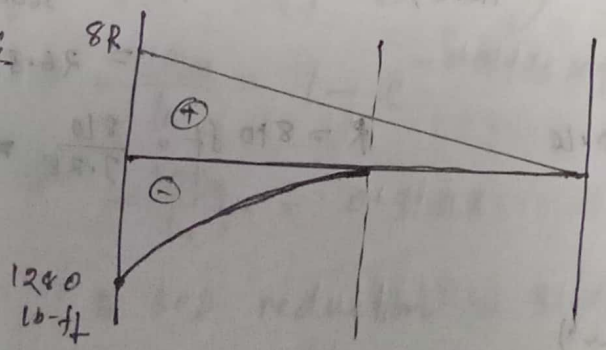
Max. Negative Moment at section ①-① = $(4 \times 3.2 + 2.4 \times 6)$ K-ft
= 27.2 K-ft

Max. Reaction at left support = $(4 \times 1 + 0.5 \times 6)$ K = 7K

(b) Find the value of R from the beam of 15" × 17" which deflection at B is zero and value of EI is constant.



Solution:



$t_{B/A} = \delta_B = 0$

$\frac{1}{EI} \times \left[\left(\frac{1}{2} \times 8 \times 8R\right) \times \left(\frac{2}{3} \times 8\right) - \left(\frac{1}{3} \times 4 \times 1280\right) \times \left(4 + \frac{3}{4} \times 4\right) \right] = 0$

$\Rightarrow \frac{512R}{3} - \frac{35840}{3} = 0 \Rightarrow R = 70 \text{ lb}.$

2. (a) Find the saturation flow and total lost (Initial and End) time if 48 sec is green plus amber time, and flow at 6s interval is 2, 4, 4, 3, 4, 3, 4, 2.

Solution:

saturation flow per 6 sec interval $= \frac{4+4+3+4+3+4}{6}$ pcu

$= 3.67$ pcu / sec

$= \frac{3.67}{6}$ pcu/sec.

$= 0.612$ pcu/sec.

$= (0.612 \times 3600)$ pcu/hr

$= 2203$ pcu/hr.

Now,

Initial lost time, $I_i = t_i - \frac{n_i}{s}$

$= \left(6 - \frac{2}{0.612}\right)$

$= 2.732$ sec.

Final lost time, $I_f = \left(t_f - \frac{n_f}{s}\right) = \left(6 - \frac{2}{0.612}\right) = 2.732$ sec.

$\therefore$ Total lost time $= (2.732 + 2.732) = 5.464$ sec. (Ans)

(b) In an expressway which is travelling along a horizontal curve of radius $R = 810$ ft at legal speed limit of 60 mph. Determine the the angle, at which the pavement should be banked to avoid outward sliding. Given, friction factor, $f_s = 0.16$. Use following formula: $e = \frac{v^2}{gR} - f_s$ where the symbols contains usual meaning.

Solution: $e = \frac{v^2}{gR} - f_s$

Here, $v = 60$ mph $= \frac{60 \times 5280}{3600 \times 3.28}$ m/s

$= 26.83$ m/s

$R = 810$ ft $= \frac{810}{3.28}$ m $= 246.95$ m

$\Rightarrow e = \frac{(26.83)^2}{9.81 \times 246.95} - 0.16$

$\Rightarrow \tan\theta = 0.137$

$\therefore \theta = 7.809^\circ$ (Ans)

3. ~~(a) Find the BOD reduction percentage of a sample at 4 days having 10°C, BOD rate~~

(a) The following analysis of a ground water express as $CaCO_3$. Find the total hardness of the water sample.

Ion	mg/L as ion	EW $CaCO_3$ ion
Ca^{2+}	103	2.5
Mg^{2+}	5.5	4.12
Na^{+}	16	2.18
HCO_3^{-}	255	0.82
SO_4^{2-}	99	1.04
Cl^{-}	37	1.41

Solution: Total hardness of the sample as $CaCO_3$

$$= (103 * 2.5 + 5.5 \times 4.12) = 280.16 \text{ mg/L}$$

(Ans)

(b) A waste is being discharge into a river that has a temperature of 10°C. What fraction of the maximum oxygen consumption in four days if BOD reduction rate determined in the laboratory under standard conditions is 0.15 (e base).

Solution: we know, $K_T = K_{20}\, 1.047^{T-20}$

$$\Rightarrow K_{10} = \left(0.15 \times 1.047^{10-20}\right) = 0.09476$$

Now, $BOD_4 = L_o\left(1 - e^{-K \times 4}\right)$

$$\Rightarrow \frac{BOD_4}{L_o} = 1 - e^{-0.09476 \times 4}$$

$$\Rightarrow \frac{BOD_4}{L_o} = 0.3155$$

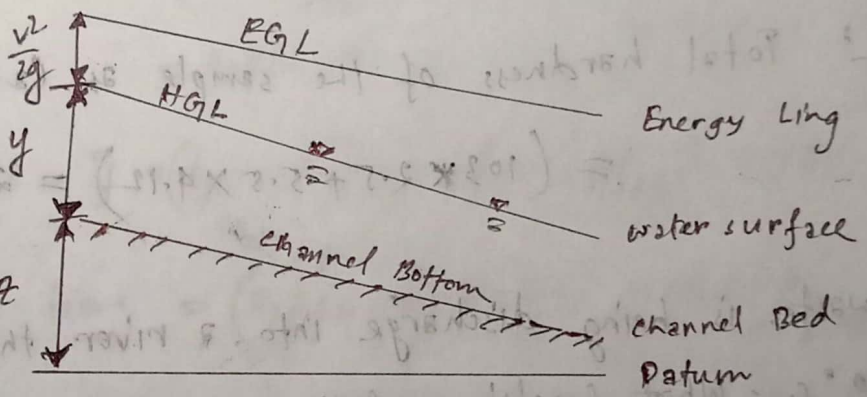
$\therefore$ % BOD reduction = 31.55%.

(Ans)

4. (a) Define HGL and EGL. Also draw HGL and EGL of flow in a river.

Solution: HGL: It is the line joining the points representing static head / piezometer head + elevation head at various cross section of river or pipe.

EGL: It is the line joining the points representing static head / piezometer head + elevation head + velocity head at various section of river / pipe.



(b) A bridge is to constructed at a river side having design life of 120 years using gumble's distribution method. the estimated flood discharge peaks at the proposed bridge site of the river for two return periods of 30 years and 70 years are 32500 cumec. and 56200 cumec respectively. Estimate the magnitude of flood peak in this river for a return period of 120 year.

Solution: we know, $X_T = \bar{X} + K_T \cdot S_x$ where, $K_T = \frac{y_T - \bar{y}_n}{\sigma_n}$

$y_T = -\ln\left[\ln\left(\frac{T_r}{T_r - 1}\right)\right]$

Here, $y_{30} = -\ln\left[\ln\left(\frac{30}{29}\right)\right] = 3.3843$

$y_{70} = -\ln\left[\ln\left(\frac{70}{69}\right)\right] = 4.2413$

$y_{120} = -\ln\left[\ln\left(\frac{120}{119}\right)\right] = 4.7833$

Now, $X_{30} = \bar{x} + K_{30} \cdot S_x$ ..... (I)

$X_{70} = \bar{x} + K_{70} \cdot S_x$ ..... (II)

$X_{120} = \bar{x} + K_{120} \cdot S_x$ ..... (III)

From (II) − (I) $\Rightarrow X_{70} - X_{30} = (K_{70} - K_{30}) \cdot S_x$ ..... (IV)

From (III) − (II) $\Rightarrow X_{120} - X_{70} = (K_{120} - K_{70}) \cdot S_x$ ..... (V)

Then,

$$K_{30} = \frac{3.3843 - \bar{y}_n}{\sigma_n} = \frac{3.3843}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n} \quad \text{..... (VI)}$$

$$K_{70} = \frac{4.2413}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n} \quad \text{..... (VII)}$$

$$K_{120} = \frac{4.7833}{\sigma_n} - \frac{\bar{y}_n}{\sigma_n} \quad \text{..... (VIII)}$$

From, (VII) − (VI) $\Rightarrow K_{70} - K_{30} = \frac{4.2413 - 3.3843}{\sigma_n} = \frac{0.857}{\sigma_n}$

(VIII) − (VII) $\Rightarrow K_{120} - K_{70} = \frac{4.7833 - 4.2413}{\sigma_n} = \frac{0.542}{\sigma_n}$

Now, From (IV) $\Rightarrow (56200 - 32500) = \frac{0.857}{\sigma_n} \times S_x$

$$\Rightarrow \frac{S_x}{\sigma_n} = 27654.6091$$

From (V) $\Rightarrow X_{120} - 56200 = \frac{0.542}{\sigma_n} \times S_x$

$\Rightarrow X_{120} = 56200 + (0.542 \times 27654.6091)$

$\therefore X_{120} = 71188.8$ cumec. (Ans.)

5. (a) A 12'×8' rectangular footing will be constructed on a saturated silty clay layer at a depth of 5 ft from the EGL. The average unconfined compression strength of the soil for that layer is 2000 psf. Determine the ultimate bearing capacity of footing under undrained condition of the soil. Use Terzaghi's bearing capacity equation and consider the shape factor only.

Solution:

We know, for rectangular footing,

$$q_u = cN_c\left(1+0.3\times\frac{B}{L}\right)+qN_q+\frac{1}{2}\gamma BN_\gamma\left(1-0.2\times\frac{B}{L}\right)$$

For undrained condition ($\phi=0$),

$$N_\gamma = 0,\ N_q = 1 \text{ and } N_c = 5.7$$

$$\therefore q_u = 5.7c\left(1+0.3\times\frac{B}{L}\right)+\gamma D_f$$

$$= 5.7\times 1000\times\left(1+0.3\times\frac{8}{12}\right)+(64\times 5)$$

$$\therefore q_u = 7160 \text{ psf}$$

(Ans.)

Here,

$$c_u = \frac{q_u}{2}$$

$$\Rightarrow c_u = \frac{2000}{2} \text{ psf}$$

$$\therefore c_u = 1000 \text{ psf}$$

Assume,

$$\gamma = \gamma_{sat} - \gamma_w$$

$$= 64 \text{ pcf}$$

(b) In a field a hole cut off volume = 0.2 ft³ and wet mass of the hole = 25 lb, dry mass of the hole = 20 lb. Find the bulk unit wt, dry unit wt. and moisture content of the soil.

Solution:

$$\gamma_m = \frac{W}{V} = \frac{25}{0.2} = 125 \text{ lb/ft}^3$$

$$\gamma_d = \frac{W_s}{V} = \frac{20}{0.2} = 100 \text{ lb/ft}^3$$

We know,

$$\gamma_m = \gamma_d (1+w)$$

$$\Rightarrow 1+w = \frac{125}{100}$$

$$\Rightarrow w = (1.25 - 1) = 0.25$$

$\therefore$ moisture content = 25% (Ans.)

6. (a) For a sieve analysis of a soil sample results are found. Find Fineness modulus of the sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
weight retained (gm)	0	0	2	10	20	40	18	8	2
% retain	0	0	2	10	20	40	18	8	2
cum % retain	0	0	2	12	32	72	90	98	100

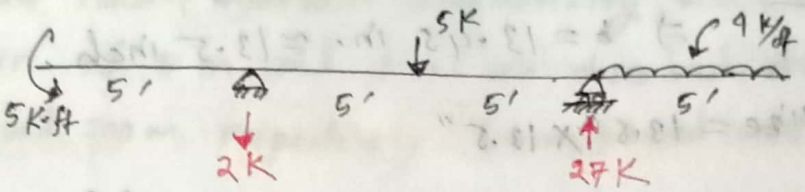
$\therefore$ FM of the sample = $\frac{2+12+72+90}{100} = 1.76$

(Ans.)

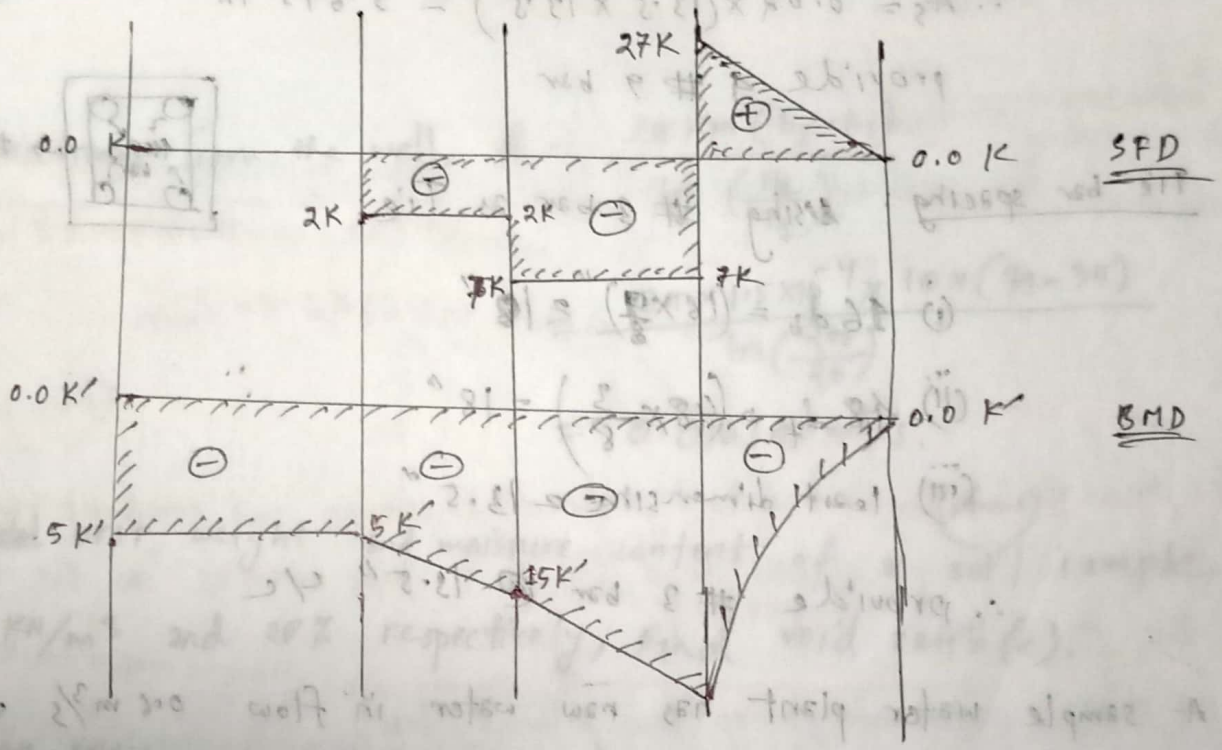
SGFCL-2021

BUET

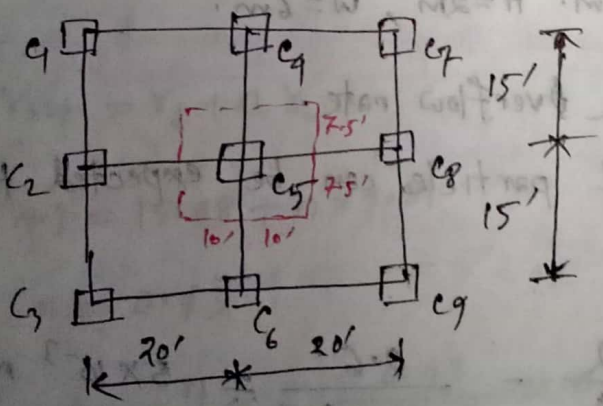
1. Draw SFD and BMD of the following structure:



Solution:



2. A load of 250 psf per floor. Design the column (C_5) at the ground floor of a 5 storied building, If $f_c' = 3000$ psi, $f_y = 60000$ psi.



Solution: Total load on column $= 250 \times (10+10) \times (7.5+7.5) \times 5 = 375000$ lb

$= 375$ Kip.

We Know,

$P_u = \phi\alpha\left[0.85 f_c' + \rho_s(f_y - 0.85 f_c')\right] A_g$

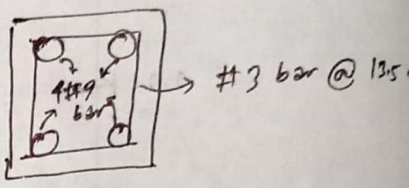
$\Rightarrow 375 = 0.70 \times 0.80 \times \left[0.85 \times 3 + 0.02 \times (60 - 0.85 \times 3)\right] A_g$

$\Rightarrow A_g = 181 \text{ in}^2$ $\Rightarrow b = 13.45 \text{ in.} \simeq 13.5 \text{ inch.}$

$\therefore$ column size $= 13.5'' \times 13.5''$

$\therefore A_s = 0.02 \times (13.5 \times 13.5) = 3.645 \text{ in}^2$

provide 4 # 9 bar



Tie bar spacing: Using #3 bar as Tie.

(i) $16 d_b = \left(16 \times \frac{9}{8}\right)'' = 18''$

(ii) $48 d_t = \left(48 \times \frac{3}{8}\right) = 18''$

(iii) least dimension $= 13.5''$

$\therefore$ provide #3 bar @ 13.5" c/c

3. A sample water plant has raw water in flow 0.6 m^3/s and has been found through experimentation that all particle settle at a rate of $V_s = 0.004$ m/s. A proposed rectangular settling tank has an effective settement zone L = 20m. H = 2m, W = 6m.

(i) Determine surface overflow rate.

(ii) what fraction of particle can be expected to be removed from tank?

Solution: (i) $SOR = \frac{Q}{A} = \frac{0.6}{20 \times 6} = 5 \times 10^{-3}$ m/s

(ii) % of removal $= \frac{V_s}{V_o} \times 100 = \frac{0.004}{5 \times 10^{-3}} = 80\%$.

(Ans)

4. An artesian aquifer 10 m thick with piezometeric surface 40 m above the bottom confining layer is being pumped by a fully penetrating wall. Aquifer is of medium sand (Hydraulic conductivity, $K = 1.5 \times 10^{-4}$ m/s) steady state drawdown of 5 m and 1 m are observed at nonpumping well located 20 m and 200 m respectively from pumed well. Determine the discharge.

Solution:

Discharge from the well, $Q = \frac{2\pi K m (h_2 - h_1)}{\ln\left(\frac{r_2}{r_1}\right)}$

$= \frac{2\pi \times 1.5 \times 10^{-4} \times 10 \times (39 - 35)}{\ln\left(\frac{200}{20}\right)}$

$= 0.01634 \ m^3/s.$ (Ans.)

5. If saturated unit weight and moisture content of a soil sample are 19.3 KN/m³ and 28% respectively, Find void ratio (e).

Solution: We know,

$\gamma_{sat} = \gamma_d (1 + \omega_{sat})$

$\Rightarrow \gamma_d = \frac{\gamma_{sat}}{1 + \omega_{sat}} = \frac{19.3}{(1 + 0.28)} = 15.08 \ KN/m^3$

Now,

$\gamma_{sat} = \gamma_d + n \gamma_w$

$\Rightarrow 19.3 = 15.08 + n \times 9.81$

$\Rightarrow n = 0.43$

Now, $e = \frac{n}{1 - n} = \frac{0.43}{1 - 0.43} = 0.755$

(Ans)

6. A field sample of an unconfined aquifer is packed in a test cylinder. Length and diameter of cylinder are 50 cm and 6 cm respectively. Field sample tested for a period of 3 min. under a constant head difference of 18.3 cm. As a result of 45.2 cm^3 of water is collected at the outlets, Find the hydraulic conductivity of the sample.

Solution: We know,

For constant head test, $K = \frac{QL}{hAt} = \frac{45.2 \times 50}{18.3 \times 3.1416 \times (\frac{6}{2})^2 \times 3}$

$\Rightarrow K = 1.6346$ cm/min.

(Ans.)

7. Prove that, for a constant rate of discharge and constant value of friction factor 'f', the frictional head loss in a pipe varies as the fifth power of the diameter.

solution:

pressure drop due to head loss,

$\Delta p = \rho g \Delta h$

$\Rightarrow \Delta h = \frac{\Delta p}{\rho g}$

Now,

~~From Head loss per unit length of pipe, $h_L = \frac{\Delta h}{L} = \frac{1}{L} \times \frac{\Delta p}{\rho g}$~~

From darcy-weisbach equation, $h_f = f \cdot L \cdot \frac{v^2}{2gD}$

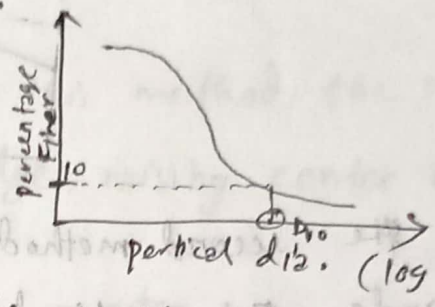
Again, $Q = AV = \frac{\pi}{4} D^2 \times V \Rightarrow V = \frac{4Q}{\pi D^2}$

So, $h_f = f \cdot L \cdot \frac{1}{2gD} \times \frac{16Q^2}{\pi^2 D^4} = f \cdot L \cdot \frac{8Q^2}{\pi^2 g D^5}$

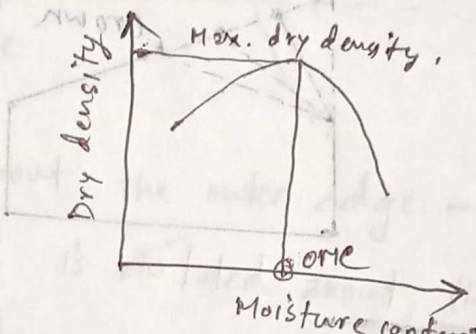
(proved)

8. Define. (i) Effective Grain Size. (ii) optimum moisture content.

Solution: (i) Effective Grain Size means the diameter of the sample that corresponds to the 10 percentile finer by dry weight on the grain size distribution curve.



(ii) optimum moisture content is the moisture content corresponding to the maximum dry density of soil sample.



9. Explain diagrammatically the method of attaining superelevation considering a crowned pavement revolved about the profile of ~~the profile of~~ the inside edge.

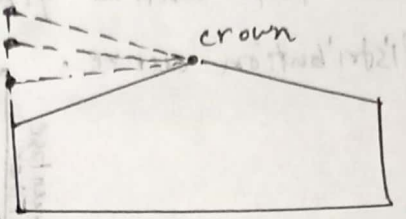
Solution: Superelevation is provided in the following two methods:

(i) Elimination of the crown of the cambered section.

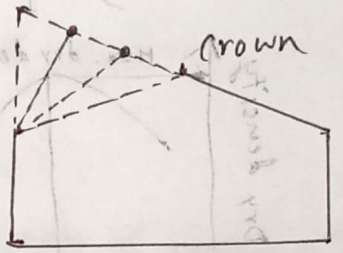
(ii) Rotation of pavement to attain full superelevation.

(i) Elimination of the crown of the cambered section — In this method, the outer half of the camber is gradually decreased. this may be done by two methods.

(a) In first method, the outer half of the camber is rotated about the crown at the desired rate such that the surface falls on the same plane as the inner half.



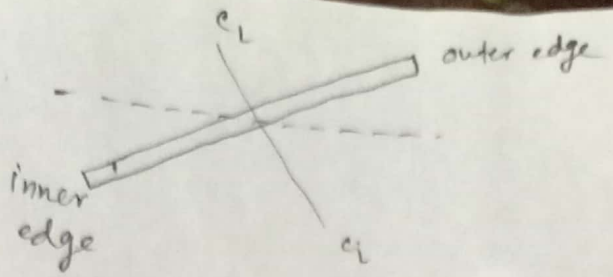
(b) In the second method, the crown is progessively shifted outwards. This methods is not usually adopted.



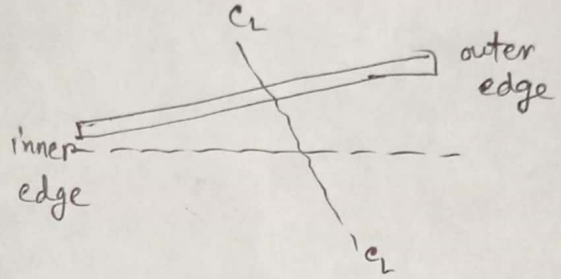
(ii) Rotation of Pavement to attain full superelevation —

In this stage, superelevation is gradually provided over the full width of the carriageway, so that the required superelevation is avaiable at the beginning of the circular curve. The different method employed for attaining the superelevation is as follows:

(a) Revolving Pavement about the center line: In this method the surface of the road is ~~avaiable at the beginning of the circular curve. The different method employed for attaining the superelevation is as follows:~~ rotated about the center line of the carriage way, gradually lowering the inner edge, and rising the upper edge. This method is widely used.



(b) Revolving about the inner edge – In this method, the surface of the road is rotated about the inner edge, raising center and outer edge.



(c) revolving pavement about the outer edge – In this method, the surface of the road is rotated about the outer edge depressing the center and inner edge.

10. A crest vertical curve as to be designed to join a +3% grade with a −2% grade at a section of a two lane highway. Determine the stopping sight distance, if the design speed of Highway 60 mi/hr. and a perception and reaction time is 2.5 sec. the deceleration rate for braking is 11.2 ft/sec^2

Solution:

we know,

$$SSD = 1.47\,Vt + \frac{V^2}{30\left(\frac{a}{g} - n\right)}$$

$$= 1.47 \times 60 \times 2.5 + \frac{60^2}{30 \times \left(\frac{11.2}{32.2} - 0.03\right)}$$

$$= 220.50 + 377.56$$

$$= 598.1 \text{ ft}$$

(Ans.)

SGFCL-2020

BUET

1. Design an irrigation channel to carry a discharge of 11270 cusec. The bed material size is 0.014 cm. Use Lacey's theory for design. Assume reasonable value for missing data.

Solution: Silt factor, $f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{0.14} = 0.66$

$$V = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}} = \left(\frac{11270 \times 0.3048^3 \times 0.66^2}{140}\right)^{\frac{1}{6}} = 1 \text{ m/s}$$

$$A = \frac{Q}{V} = \frac{11270 \times 0.3048^3}{1} = 319.13 \text{ m}^2$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{319.13} = 84.85 \text{ m}$$

$$R = 2.5\left(\frac{V^2}{f}\right) = 2.5 \times \left(\frac{1^2}{0.66}\right) = 3.79 \text{ m}$$

$$S = \left(\frac{f^{\frac{5}{3}}}{3340 Q^{\frac{1}{6}}}\right) = \left(\frac{0.66^{\frac{5}{3}}}{3340 \times 319.13^{\frac{1}{6}}}\right) = 5.73 \times 10^{-5} = 1 \text{ in. } 17451 \quad \text{(Ans.)}$$

For a trapezoidal channel with $\frac{1}{2}$H : 1V side slope,

$$P = b + \sqrt{5}\,y = 84.85 \quad \ldots\ldots (i)$$

$$A = \left(b + \frac{y}{2}\right) y = 319.13 \quad \ldots\ldots (ii)$$

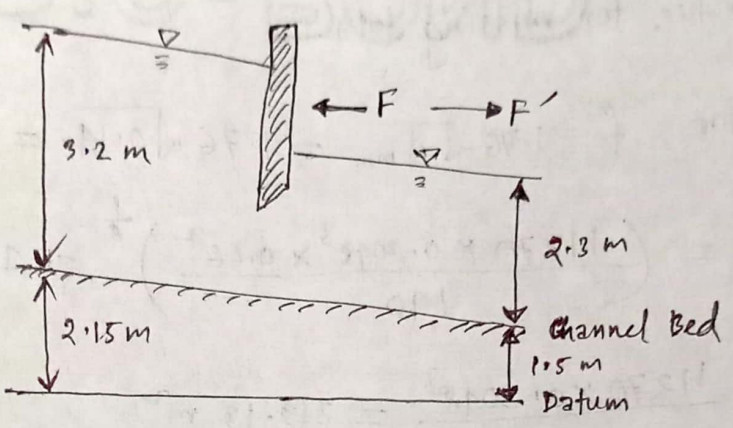
From (ii) $\Rightarrow b = \frac{319.13}{y} - \frac{y}{2}$ putting the value of b in eqn (i) we get,

$$\frac{319.13}{y} - \frac{y}{2} + \sqrt{5}\,y = 84.85$$

$$\Rightarrow y = 3.8736 \text{ m}$$

$$\therefore b = \frac{319.13}{3.8736} - \frac{3.8736}{2} = 80.45 \text{ m} \quad \text{(Ans.)}$$

2. Given, width of channel 5m, head loss due to friction between A & B is 0.32 m. Assume energy and momentum co-efficient as unity. Calculate the force acting on the wall.



Solution: we know, $Q = V_1 A_1 = V_2 A_2$ (From continuity eqⁿ)

$$\Rightarrow V_1 = \frac{V_2 A_2}{A_1} = \frac{V_2 \times b y_2}{b y_1} = \frac{2.3}{3.2} V_2 \quad \text{---(1)}$$

Now, from Bernoulli's eqⁿ,

$$z_1 + y_1 + \frac{V_1^2}{2g} = z_2 + y_2 + \frac{V_2^2}{2g} + h_L$$

$$\Rightarrow 2.15 + 3.2 + \left(\frac{2.3}{3.2}\right)^2 \times \frac{V_2^2}{2\times 9.81} = 1.5 + 2.3 + \frac{V_2^2}{2\times 9.81} + 0.32$$

$$\Rightarrow V_2^2 = 49.923$$

$$\therefore V_2 = 7.066 \text{ m/s}$$

$$\text{So, } V_1 = \left(\frac{2.3}{3.2} \times 7.066\right) = 5.0784 \text{ m/s}$$

$$\therefore Q = (5.0784 \times 5 \times 3.2) = 81.2545 \text{ m}^3/\text{s}$$

From momentum eqⁿ,

$$\rho Q(V_2 - V_1) = \frac{1}{2}\gamma y_1^2 - \frac{1}{2}\gamma y_2^2 - F$$

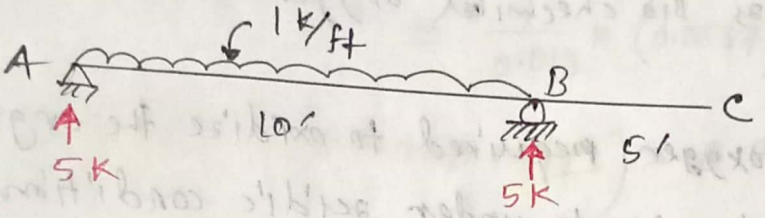
$$\Rightarrow 1000 \times 81.2545 \times (7.066 - 5.0784) = \frac{1}{2} \times 9810 \times (3.2^2 - 2.3^2) - F$$

$\therefore F = -137221.7$ N $\therefore$ The force exerted on fluid by gate $= -137221.7$ N

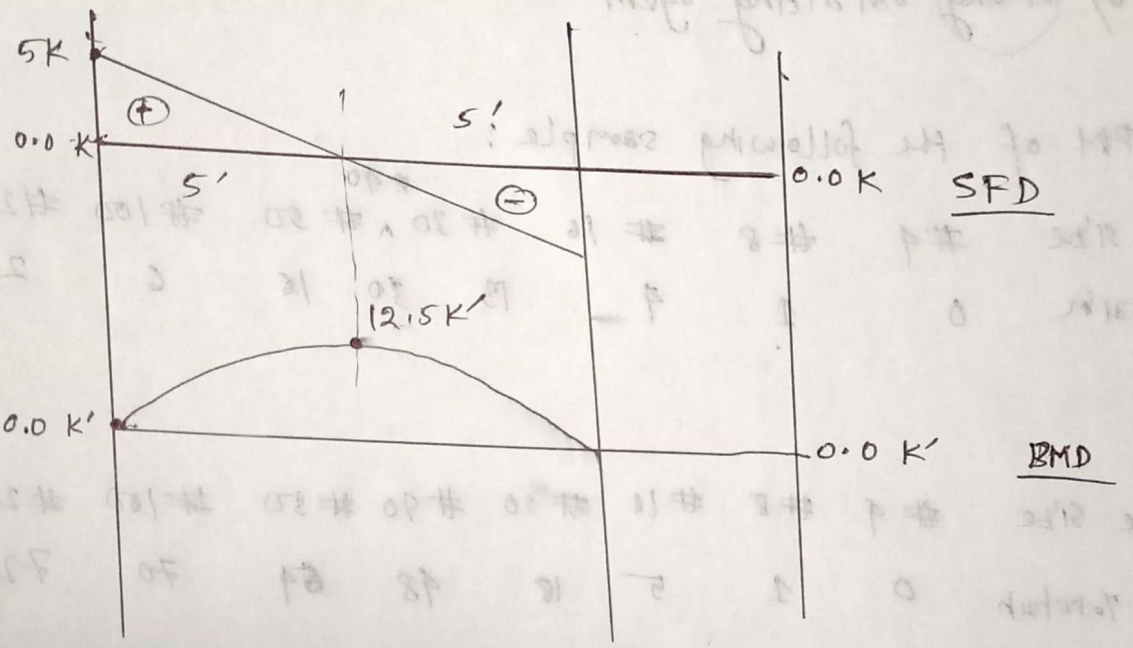
The force on the weir plate is in the opposite direction to the the force exerted on fluid by gate. $F' = 137221.7$ N

(Ans.)

3. Draw SFD and BMD of the following figure:

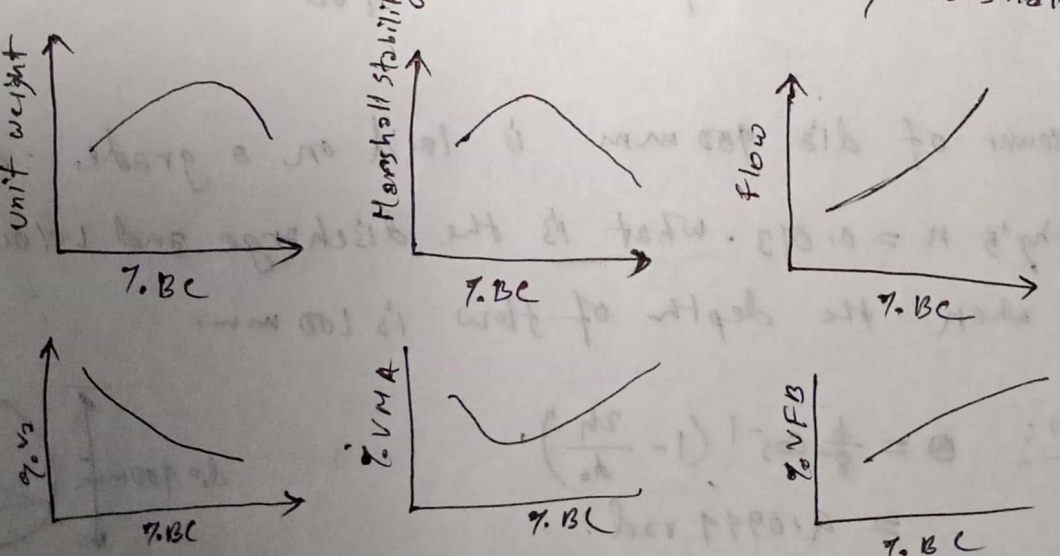


Solution:



1. Draw qualatitive test property curve of HMB by Marshall Method.

Solution:



5. Define BOD and COD

Solution:

BOD: The amount of oxygen required by micro-organism to carry out the biological decomposition of dissolved solids or organic matters in sewage under aerobic conditions at standard temperature is known as Bio chemical oxygen demand (BOD)

COD: The amount of oxygen required to oxidize the organic and inorganic matter by strong oxidizing agent under acidic conditions.

6. Find FM of the following sample:

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	4	13	30	16	6	2	1

Solution:

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
cum. % retain	0	1	5	18	48	64	70	72	76

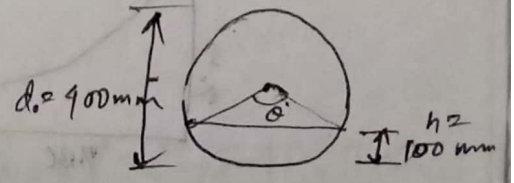
$$\therefore \text{FM of the sample} = \frac{1+5+18+64+70}{100} = 1.58$$

(Ans.)

7. A sewer of dia 900 mm is laid on a grade of 0.015 with manning's $n = 0.013$. What is the discharge and velocity of the sewer when the depth of flow is 100 mm.

Solution: $\theta = 2\cos^{-1}\left(1 - \frac{2h}{d_0}\right)$.

$= 2.0944$ rad.



$A = \frac{1}{8}(\theta - \sin\theta) d_o^2 = \frac{1}{8}(2.0944 - \sin 2.0944) \times (0.4)^2 = 0.0246\ m^2$

$P = \frac{1}{2} \omega d_o = \frac{1}{2} \times 2.0944 \times 0.4 = 0.419\ m$

$R = \frac{A}{P} = \frac{0.0246}{0.419} = 0.0587\ m$

Velocity, $V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} = \frac{1}{0.013} \times (0.0587)^{\frac{2}{3}} \times (0.015)^{\frac{1}{2}} = 1.423\ m/s$

Discharge, $Q = AV = (0.0246 \times 1.423) = 0.035\ m^3/s$.

(Ans.)

SGPL-2017 [BUET]

① Abbreviation: BNBC, AASHTO, ASCE, ACI

BNBC = Bangladesh National Building Code

AASHTO = American Association of State Highway and Transportation officials.

ASCE = American society of Civil Engineers.

ACI = American concrete Institute.

② Write advantages and disadvantages of Traffic signals.

Solution:

Advantages:

(i) provide orderly movement of traffic

(ii) increase traffic handling capacity of the intersection.

(iii) reduce frequency of certain types of accidents especially right angle and pedestrians.

(iv) provide for nearly continuous movement of traffic at desired speed along a given route of co-ordination.

Disadvantages:

(i) At off peak periods signal controllers with fixed time and plan cause unnecessary delay and increase drivers' irritation - in consequence promote disrespect of the signal indication.

(ii) Increase in certain types of accidents (especially rear-end collisions at dilemma zone.)

(3) Define PERT and CPM. Write advantages of project management. (5)

PERT: Program Evaluation and Review Technique (PERT) is a project management planning tool used to calculate the amount of time it will take to realistically finish a project.

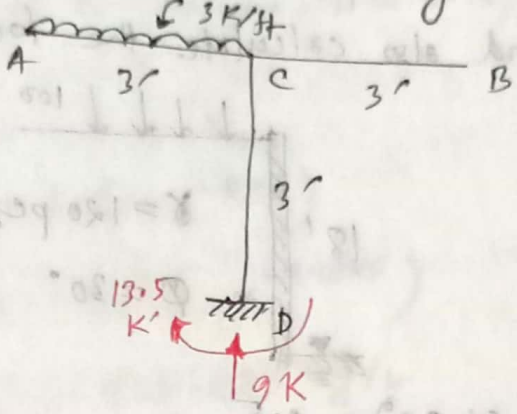
CPT: Critical Path method (CPT) is a step-by-step project management technique for process planning that defines critical and non-critical tasks with the goal of preventing project schedule problems.

Advantages:
(i) Reduce the chance of a project failing.
(ii) Ensure a minimum level of quality and that results meet requirements and expectations.
(iii) Make things simpler and easier for staff with a single point of contact running the overall project.
(iv) Keep costs, time frames and resources to budget.

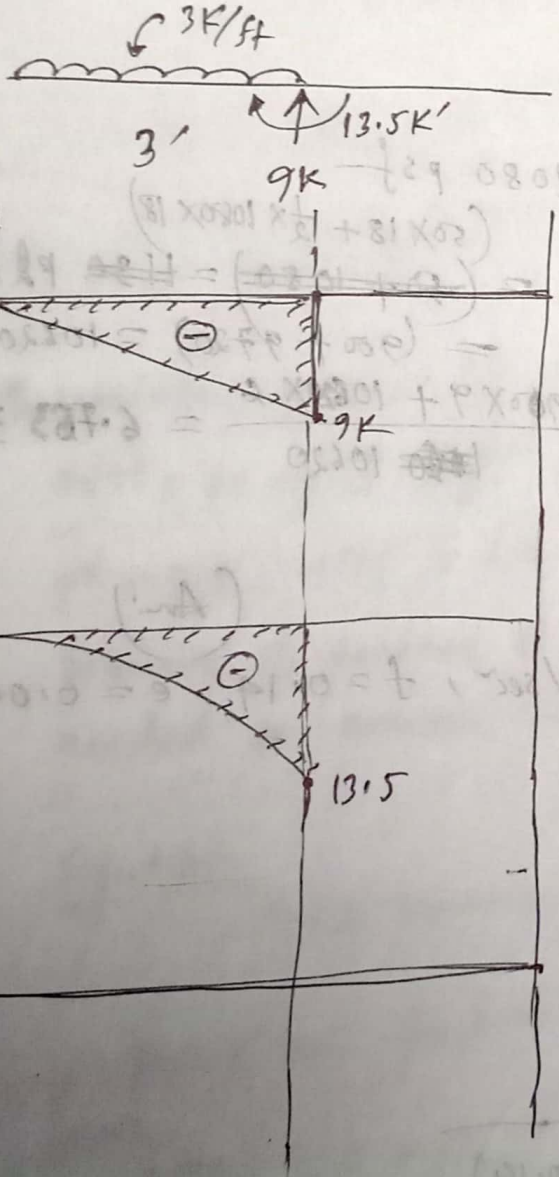
(4) Define combined footing. What is the proposition of combined footing system.

Solution: when two or three columns are located very near to each other, A single substructure or spread footing is ~~proved~~ provided for them. This footing is called combined footing.

⑤ Draw SFD and BMD and Axial Forces Diagram for all members.



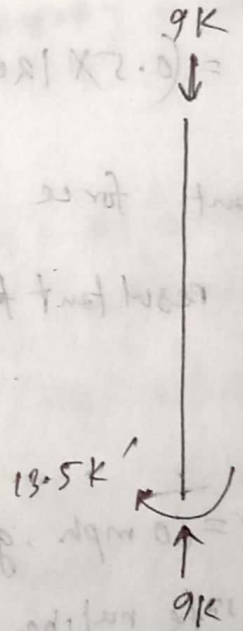
Solution:

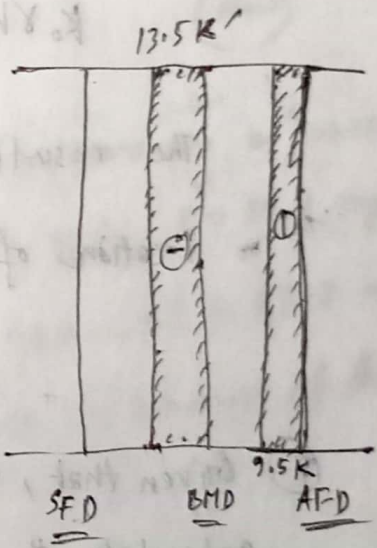


SFD

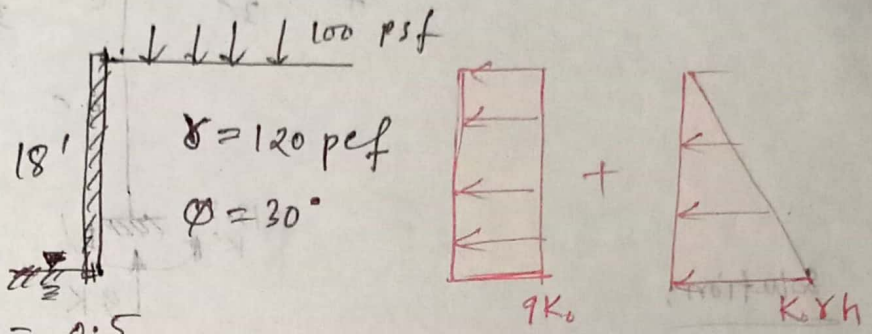
BMD

AFD





(6) Determine the magnitude of resultant force per unit length of wall in rest condition and also calculate the location of the resultant force. (20)



Solution:

$K_0 = (1 - \sin 30^\circ) = 0.5$

$qK_0 = (100 \times 0.5) = 50$ psf

$K_0 \gamma h = (0.5 \times 120 \times 18) = 1080$ psf

The resultant force on the wall $= (50 \times 18 + \frac{1}{2} \times 1080 \times 18)$

$= (900 + 9720) = 10620$ plf

location of resultant force $= \frac{900 \times 9 + 10620 \times 6}{10620} = 6.763$ ft from bottom.

(Ans.)

(7) Given that, $v = 60$ mph, $g = 32.2$ ft/sec^2, $f = 0.14$, $e = 0.04$ ft/ft calculate the safe ruling radius.

Solution:

We, know,

$$R = \frac{v^2}{15(e+f)}$$

$$\Rightarrow R = \frac{60^2}{15(0.04+0.14)}$$

$$\therefore R = 1333.33 \text{ ft}$$

(Ans)

⑧ The amount of BOD_5 in a sewage found 200 mg/L at temp. 20°C. What is the BOD_7 at 20°C. Assume, K = 0.18/day.

Solution:

We know,

$$BOD_5 = L_o(1-e^{-K\times 5})$$

$$\Rightarrow 200 = L_o(1-e^{-0.18\times 5})$$

$$\Rightarrow L_o = 337.024 \text{ mg/L}$$

Now, $BOD_7 = L_o(1-e^{-K\times 7})$

$\therefore BOD_7 = 337.024\times(1-e^{-0.18\times 7}) = 241.426$ mg/L (Ans)

⑨ Laboratory analysis of water sample: All concentrations are as "substance"

$Ca^{++} = 74$ mg/L, $Mg^{2+} = 18.3$ mg/L, $Na^{+} = 27.6$ mg/L, $K^{+} = 39.1$ mg/L

pH = 7.8, $HCO_3^- = 274.5$ mg/L, $SO_4^{2-} = 72$ mg/L, $Cl^- = 49.7$ mg/L

Determine (i) Hardness of water in mg/L of $CaCO_3$ (ii) Amount of lime needed to remove hardness by $CaCO_3$.

Solution:

Total hardness as $CaCO_3 = \left(74\times\frac{50}{20} + 18.3\times\frac{50}{12.2}\right) = 260$ mg/L

Quick lime feed $= \frac{A+B+C-D}{\text{lime purity}} \times$ excess lime dosage.

where,

$A(CO_2) = 0$ mg/L

$B(HCO_3^-) = \left(274\times\frac{50}{61}\right)\times\frac{56}{100} = 126$ mg/L

$C(OH^-) = 0$ mg/L

$D(Mg^{2+}) = 18.3\times\frac{56}{24.3} = 42.17$ mg/L

$\therefore$ Lime required $= \frac{0+126+0+42.17}{\frac{100}{100}}\times 1.15 = 193.4$ mg/L

(10) Standard rail length of BG track is 12.80m. If 45 kg rail is used in particular BG track in Rajshahi, what is the total weight of each rail Girder. What is the maximum axle load can be safely imposed on that track.

Solution: Total weight of the rail = No. of rail × unit weight of rail per unit length × length of rail

$= (1 \times 45 \times 12.8) = 576$ kg.

Maximum axle load = 560 × sectional weight of rail in kg/m.

$= (560 \times 45) = 25200$ kg $= 25.2$ ton. (Ans.)

(11) A man on the deck of a ship observes the light of the light house which is 150' above the sea level. If the man eye level is 20' above the sea level. Find the actual distance between them.

Solution:

$$D_1 = \sqrt{\frac{h_1}{0.0673}} = \sqrt{\frac{(150 \div 3.28)}{0.0673}} = 26.06 \text{ Km}.$$

$$D_2 = \sqrt{\frac{h_2}{0.0673}} = \sqrt{\frac{(20 \div 3.28)}{0.0673}} = 9.52 \text{ Km}.$$

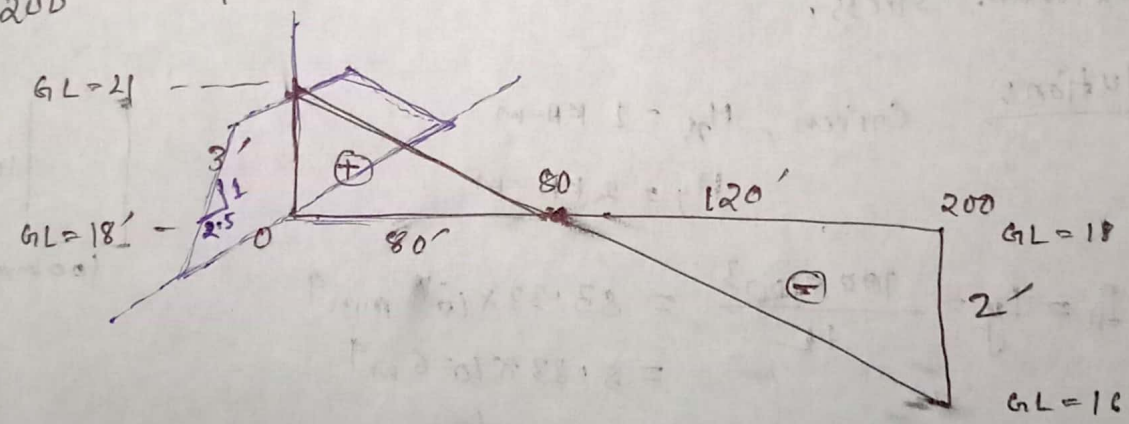
∴ Distance between them $= (26.06 + 9.52) = 35.58$ Km (Ans.)

2) An embankment of width 25 ft and side slope 2.5H : 1V is required to be made on a ground which is level in a direction transverse to the center line. Calculate the volume of the work. The ground level along the center line of the embankment is given below:

Chainage (ft)	0	80	200
GL (ft)	21	18	16

Solution:

Chainage	GL	FL	cutting (+)	Filling (−)
0	21	18	3	—
80	18	18	—	—
200	16	18	—	2



Area of cutting = $(b+sh)\times h = (25+2.5\times3)\times3 = 97.5\ ft^2$

Area of filling = $(25+2.5\times2)\times2 = 60\ ft^2$

∴ volume of cutting = $\left(\frac{0+97.5}{2}\right)\times80 = 3900\ ft^3$

volume of filling = $\left(\frac{0+60}{2}\right)\times120 = 3600\ ft^3$

(Ans)

(13) Find the resultant force on one side of a 25 mm diameter vertical circular plate standing at the bottom of 3m pool water. Density of water = 1000 kg/m³ and g = 9.8 m/s².

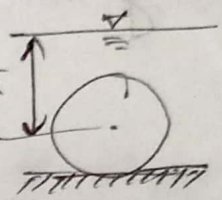
Solution:

The resultant force, $F = \gamma A \bar{x}$

$= 9810 \times \frac{\pi}{4}(0.025)^2 \times \left(3 - \frac{0.025}{2}\right)$

$= 19.37$ N.

(Ans)

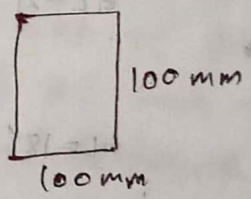


(14) A 100 mm by 100 mm beam is subjected to bending moment of 1 KN-m and 2 KN-m applied about both principal axis. Find maximum stress.

Solution:

Given, $M_x = 1$ KN-m

$M_y = 2$ KN-m



$I_x = I_y = \frac{100 \times 100^3}{12} = 83.33 \times 10^5$ mm⁴

$= 8.33 \times 10^{-6}$ m⁴

We know, $f_x = \frac{M_x y}{I_x} = \frac{1 \times 0.05}{8.33 \times 10^{-6}} = 6002.4$ KN/m²

$f_y = \frac{M_y y}{I_y} = \frac{2 \times 0.05}{8.33 \times 10^{-6}} = 12004.80$ KN/m²

Here, shear stress, $\tau = 0$

∴ Maximum principal stress, $f = \left(\frac{f_x + f_y}{2}\right) + \frac{1}{2}\sqrt{(f_x - f_y)^2 + 4\tau_{xy}^2}$

$= \left(\frac{6002.4 + 12004.80}{2}\right) + \frac{1}{2}\sqrt{(6002.4 - 12004.8)^2}$

$= 66004.8$ KN/m²

WZPDCL - 2019

KUET

1. Find the finess modulus of a sand sample for 100% retain on #30 sieve.

Solution:

Sieve No.	% retain	Cumulative % retain
# 30	100	100
# 50	–	100
# 100	–	100

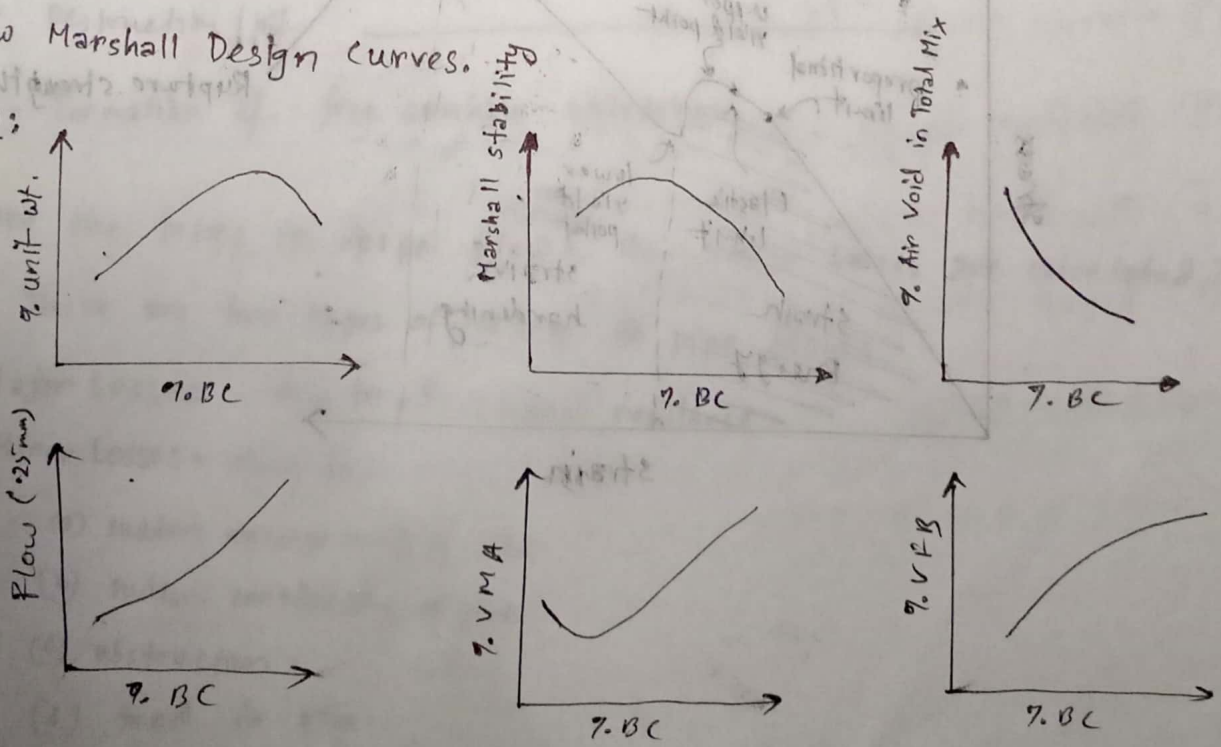
$\therefore$ FM of the sample $= \frac{100+100+100}{100} = 3$ (Ans.)

2. Why slump test is performed?

Solution: The concrete slump test measures the consistency of freshly concrete mix before it sets. It is performed to check the workability of freshly made concrete, therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. So, The main reason to perform the test is to ensure batches of the same concrete are of constant quality and strength.

3. Draw Marshall Design curves.

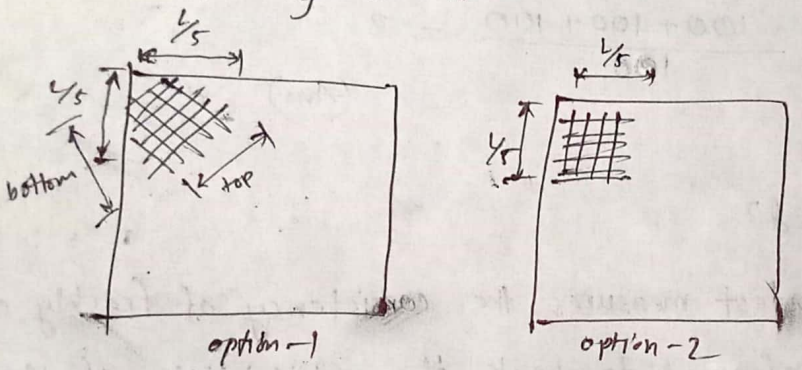
Solution:



4. why corner reinforcement is used in two way slab. show ACI specification.

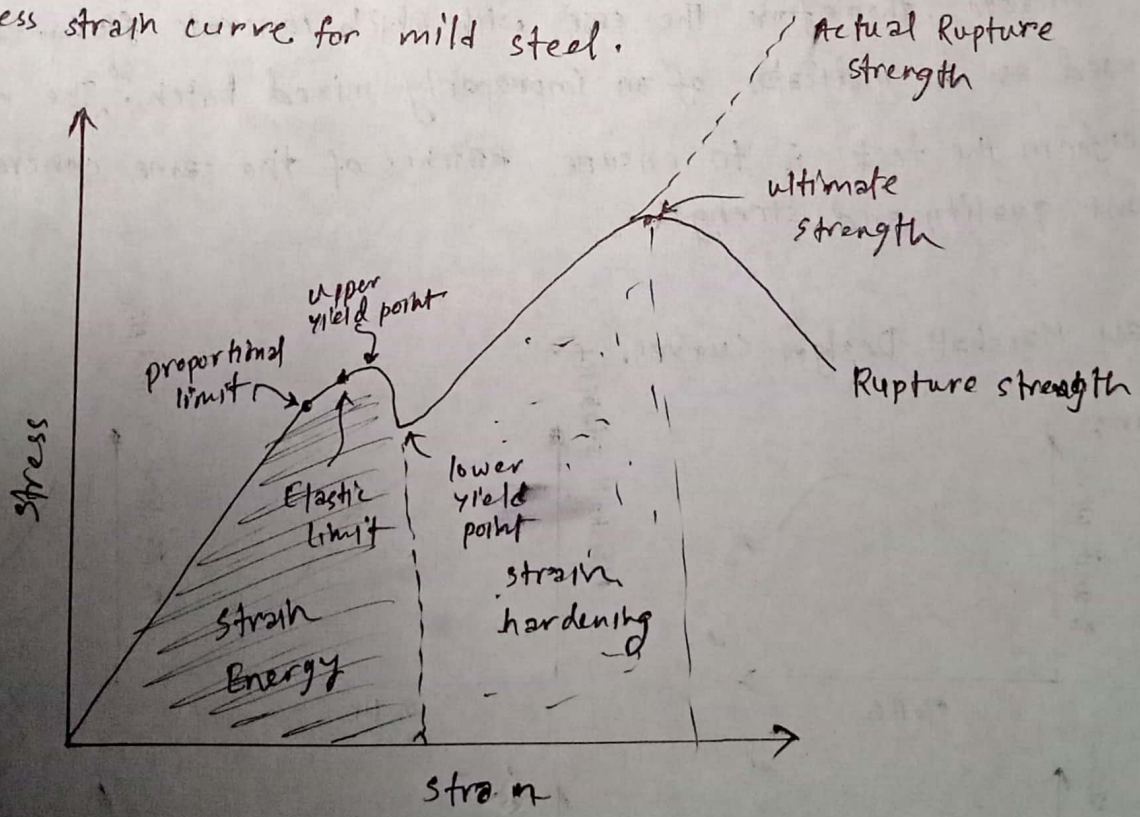
Solution: A special reinforcement shall be provided at exterior corners in both bottom and top of the two way slab, for a distance in each direction from the corner equal to one-fifth the larger span of the corner panal. It is provided due to -

(i) resist diagonal crack.
(ii) resist twisting moment at exterior corner.



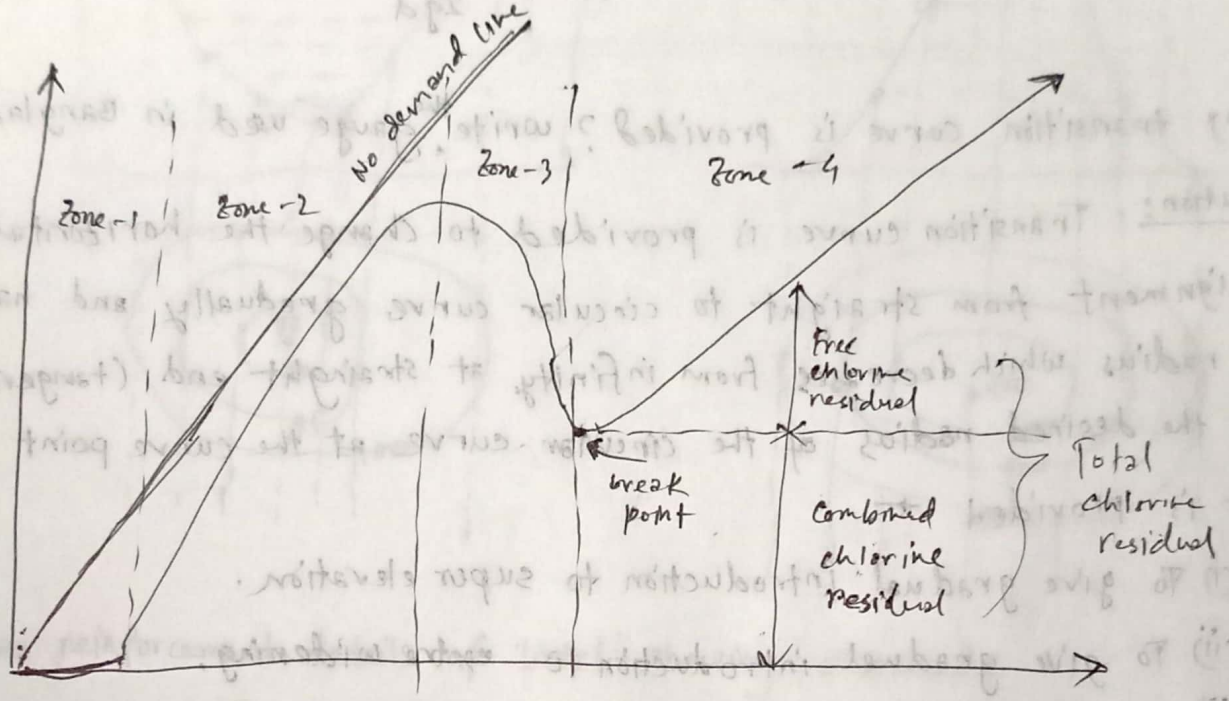
5. Draw stress strain curve for mild steel.

Solution:



6. Draw chlorination curve. Define break point chlorination.

Solution: The addition of chlorine at break point is called break point chlorination. It is also known as free residual chlorine. Its purpose is to oxidize all the organic matter.



Zone-1: consumption of chlorine by reducing compound.

Zone-2: Formation of chloramine and chloro-organic compound.

Zone-3: Destruction of

Zone-4:- Formation of free available chlorine.

7. What are the losses in pipe flow? How Major Losses are calculated?

Solution: There are two types of losses in pipe flow:

(i) Major Losses due to - Frictional resistance

(ii) Minor Losses due to -

(a) sudden enlargement of pipe

(b) sudden contraction of pipe

(c) obstruction.

(d) bend in pipe.

(e) entrance and exit etc.

Calculation of major loss:

(i) Hazen-poiseuille equation: $h_f = \frac{32 \upsilon V L}{g d^2}$ (For laminar flow)

(ii) Darcy-weisbach equation: $h_f = \frac{4 f L V^2}{2 g d}$ (For turbulent flow)

8. Why transition curve is provided? write the gauge used in Bangladesh.

Solution: Transition curve is provided to change the horizontal alignment from straight to circular curve gradually and has a radius which decreases from infinity at straight end (tangent point) to the desired radius of the circular curve at the curve point.

It is provided -

(i) To give gradual introduction to super elevation.

(ii) To give gradual introduction to extra widening.

(iii) To enhance the aesthetic appearence of the road.

Gauge used in Bangladesh:

(i) Narrow Gauge (762 mm)

(ii) Meter Gauge (1000 mm) ✓

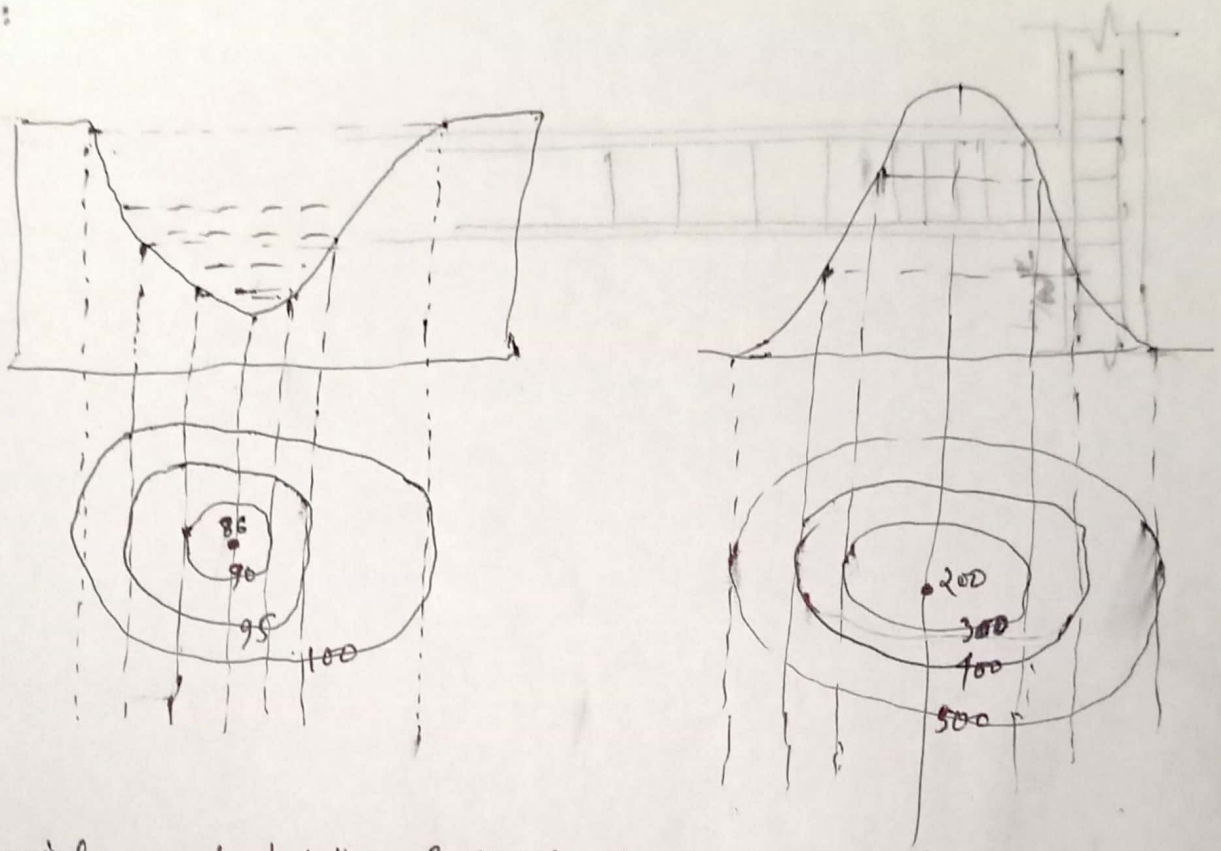
(iii) Standard Gauge (1435 mm)

(iv) Broad Gauge (1676 mm) → Dual Gauge.

~~(v) Dual Gauge~~

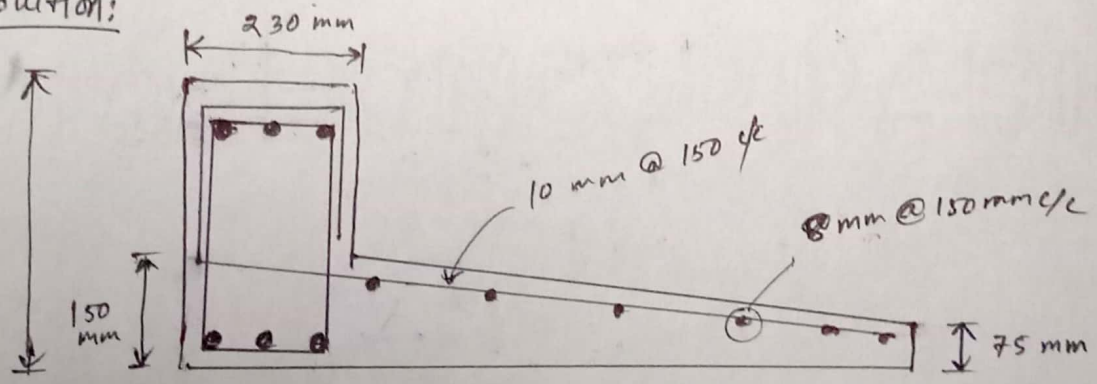
9. Draw countour of pond and hill.

Solution:



10. Draw reinforcement details of lintel showing sunshade.

Solution:

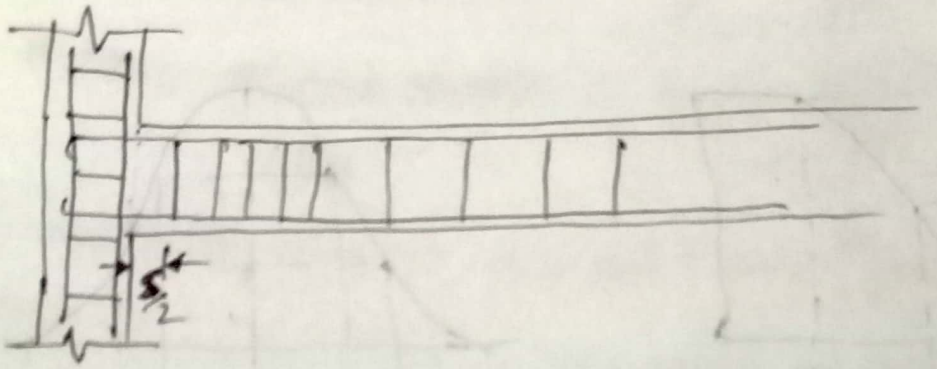


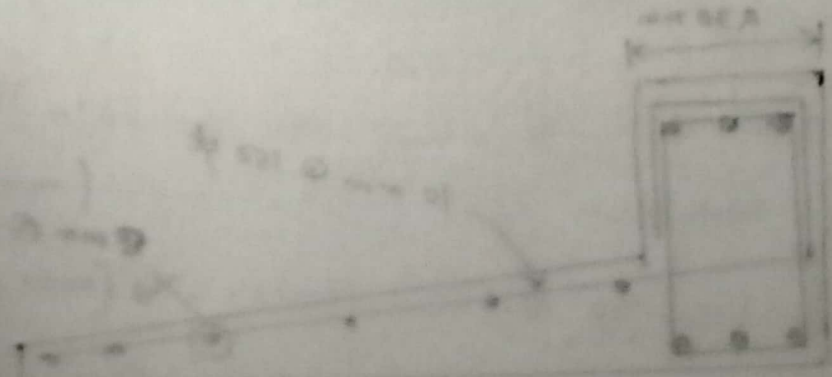
11. SFD & BMD

12. IL

13. Sedimentation Tank related Problem. [Find detention time, Discharge a
volume of tank is given]

14. Reinforcement detail at support of a beam.





BPDB-2023 BUET

1.

(a) Fill in the gaps:

(i) void ratio of soft clay is 1.5, porosity is 0.6.

(ii) The angle of internal friction of a soil is 30°, co-efficient of active earth pressure $\frac{1}{3}$.

(iii) The N_c value for deep foundation is 9.

(iv) The unconfined compressive strengths of soft clay in undisturbed sample and remoulded state are 50 KN/m² and 25 KN/m² respectively. Sensitivity of the clay 2.

(b) A dry sand was tested in direct shear apparatus under normal load of 36 kg, sample was failed under shear load of 58 lb. The sample size was 2 inch in height and 2 inch in width. Calculate the angle of internal friction.

Solution: We know,

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

Here, $c = 0$

$$\sigma = \frac{36 \times 2.205}{2 \times 2} = 19.845 \text{ psi}$$

$$\tau = \frac{5}{2 \times 2} = 14.5 \text{ psi}$$

$$\Rightarrow 14 = 0 + 19.845 \tan\phi$$

$$\therefore \phi = \tan^{-1}\left(\frac{14.5}{19.845}\right) = 36.15^\circ$$

(Ans.)

(c) A moist soil having volume of $0.2\ ft^3$ and weighs 25 lb. The oven dry weight is 20 lb. Calculate the bulk unit weight, dry unit weight and water content of soil. (5)

Solution:

Bulk unit weight, $\gamma = \frac{W}{V} = \frac{25}{0.2} = 50\ lb/ft^3$

Dry unit weight, $\gamma_d = \frac{W_s}{V} = \frac{20}{0.2} = 40\ lb/ft^3$

We know, $\gamma = \gamma_d(1+w)$

$\Rightarrow 1+w = \frac{\gamma}{\gamma_d} = \frac{50}{40}$

$\therefore w = (1.25 - 1) = 0.25 = 25\%$

(Ans)

2. Calculate the Fineness Modulus of the sample. Also determine co-efficient, uniformity and percent of fine (silt and clay) of the sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	5	12	23	30	12	8	6	4

Solution:

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	Pan
cumulative % retain	0	5	17	40	70	82	90	96	100
% Finer	100	95	83	60	30	18	10	4	0

$\therefore$ FM of the sample $= \frac{5+17+40+82+90}{100} = 2.34$

% silt and clay $= (100 - 96) = 4\%$

co-efficient of uniformity, $C_u = \frac{D_{60}}{D_{10}} = \frac{0.60}{0.15} = 4$ (Ans)

5. (a) The depth of equivalent constant stress of a singly reinforced rectangular beam, $a = 3.5''$ and effective depth is $16.5''$. The ratio of depth of rectangular stress block, β_1 is assumed to be 0.85. comment whether the beam is tension controlled or compression controlled. The value of $\frac{c}{d_t}$ is 0.60 (compression zone) and 0.375 (tension zone)

Solution:

We know, $c = \frac{a}{\beta_1} = \frac{3.5}{0.85} = 4.1176''$

$\therefore \frac{c}{d_t} = \frac{4.1176}{16.5} = 0.25'' < 0.375$

Hence, the beam is tension controlled beam.

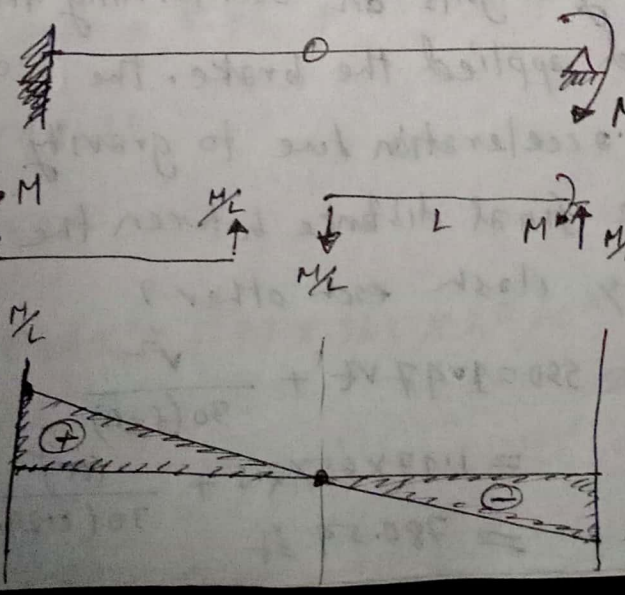
Alternative:

$\varepsilon_t = \varepsilon_u \times \frac{d_t - c}{c}$

$= 0.003 \times \left(\frac{16.5 - 4.1176}{4.1176}\right) = 0.009 > 0.005$

Hence, the beam is tension controlled.

(b) Draw BMD of the following beam having span of 2L. A concentric Moment is applied at end point.



Solution:

4. (a) The 5-day BOD of a water sample is 125 mg/L in 20°C. The reaction constant at 20°C is 0.22/day. Calculate the ultimate BOD.

Solution:

We know,

$$BOD_5 = L_o(1 - e^{-5 \times k})$$

$$\Rightarrow L_o = \frac{125}{(1 - e^{-5 \times 0.22})} = 187.37 \text{ mg/L}$$

(Ans)

(b) A horizontal flow of grit chamber is used to pretreat waste water with flow rate 26.5 ft^3/sec. The chamber is 5.9 ft in deep and width is 15 times the length. What is the width of the chamber if average approach velocity is 1.15 ft/sec.

Solution:

We know,

$$Q = AV$$

$$\Rightarrow 26.5 = (B \times H) \times 1.15$$

$$\Rightarrow B = \frac{26.5}{1.15 \times 5.9} = 3.906 \text{ ft}$$

(Ans)

5. A driver moving at a speed of 65 mph on 3% downgrade section of a highway sights an overturning truck 800 ft away on the highway and applied the brake. The co-efficient of friction is 0.29, acceleration due to gravity is 32.2 ft/sec^2. What would be the final distance between the two stopped vehicle? Will they clash each other?

Solution: We know, $SSD = 1.47Vt + \frac{V^2}{30(f \pm n)}$

$$= 1.47 \times 65 \times 2.5 + \frac{(65)^2}{30(0.29 - 0.03)}$$

$$= 780.59 \text{ ft}$$

Distance between the two stopped vehicle = (800 − 780.54) ft

= 19.46 ft

Hence, they will not clash each other. (Ans.)

(b) Calculate ESAL for design years of 20 from following data. Use 4th power formula.

Load (Kip)	Number per day	Load (Kip)	Number per day
20	10	16	24
24	15	14	29
28	18	12	30
22	19	26	35
18	25	30	16

Solution:

$$\text{per day ESAL} = 10\times\left(\frac{20}{18}\right)^4 + 15\times\left(\frac{24}{18}\right)^4 + 18\times\left(\frac{28}{18}\right)^4 + 19\times\left(\frac{22}{18}\right)^4 + 25\times\left(\frac{18}{18}\right)^4$$
$$+ 24\times\left(\frac{16}{18}\right)^4 + 29\times\left(\frac{14}{18}\right)^4 + 30\times\left(\frac{12}{18}\right)^4 + 35\times\left(\frac{26}{18}\right)^4 + 16\times\left(\frac{30}{18}\right)^4$$

$$= (15.24 + 47.41 + 105.39 + 42.99 + 25 + 14.98 + 10.61 + 5.92 + 152.36 + 123.46)$$

$$= 543.36$$

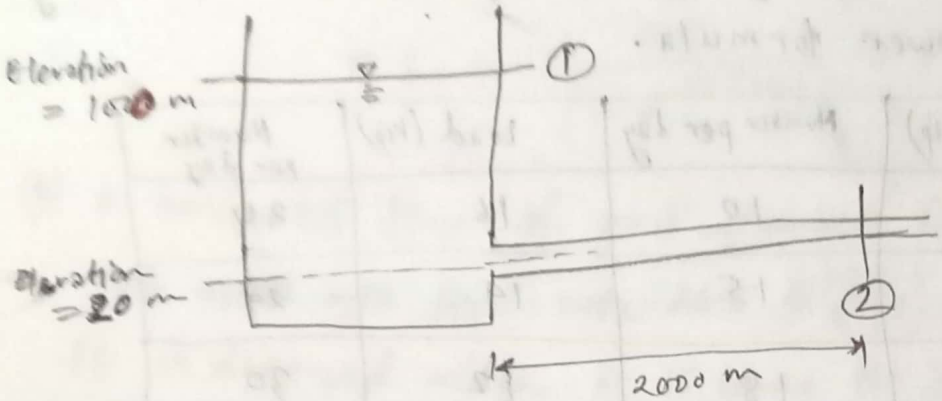
$$\simeq 544$$

$$\therefore \text{Design ESAL} = (544\times 365\times 20) = 3.97\times 10^6 \text{ ESAL}$$

$$\simeq 3.97 \text{ MSA}$$

(Ans.)

6. (a) The water flows from a thermal power plant through a pipe having diameter of 20 cm. Flow velocity is 1 m/s. and friction factor of the pipe is 0.015. Find the pressure at point 2.



$P_1 = 101.325$ KPa.

Solution:

We know,

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + h_f$$

$$\Rightarrow 1000 + \frac{101.325}{9.81} + 0 = 20 + \frac{P_2}{9.81} + \frac{1^2}{2\times 9.81} + 7.695$$

$$\Rightarrow P_2 = 870163 \text{ KN/m}^2$$

Here, $h_f = \frac{fLv^2}{2gd}$

$= \frac{0.015 \times 2000 \times 1^2}{2\times 9.81 \times 0.20}$

$= 7.695$ m

(Ans)

(b) water flows in a rectangular channel having width of 3m, longitudinal slope is 0.001 and manning's coefficient is 0.20. If the flow depth is 1m, calculate the flowrate if it is uniform flow.

Solution: $Q = AV = \frac{1}{n} A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$

$= \frac{1}{0.20} \times 3 \times (0.6)^{\frac{2}{3}} \times (0.001)^{\frac{1}{2}}$

$Q = 0.34 \text{ m}^3/\text{sec}.$

(Ans)

Here, $A = (3\times 1) = 3 \text{ m}^2$

$P = 3 + (2\times 1) = 5$ m

$\therefore R = \left(\frac{3}{5}\right) = 0.6$ m

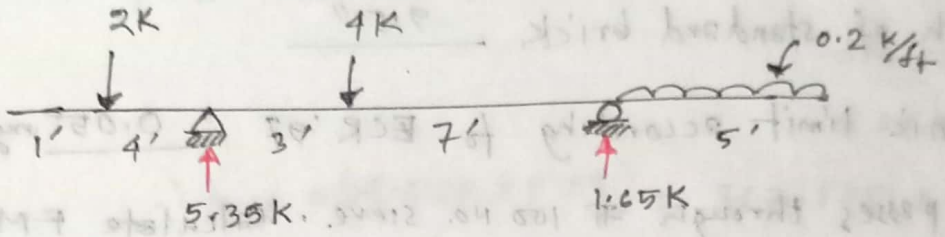
$S = 0.001$

$n = 0.20$

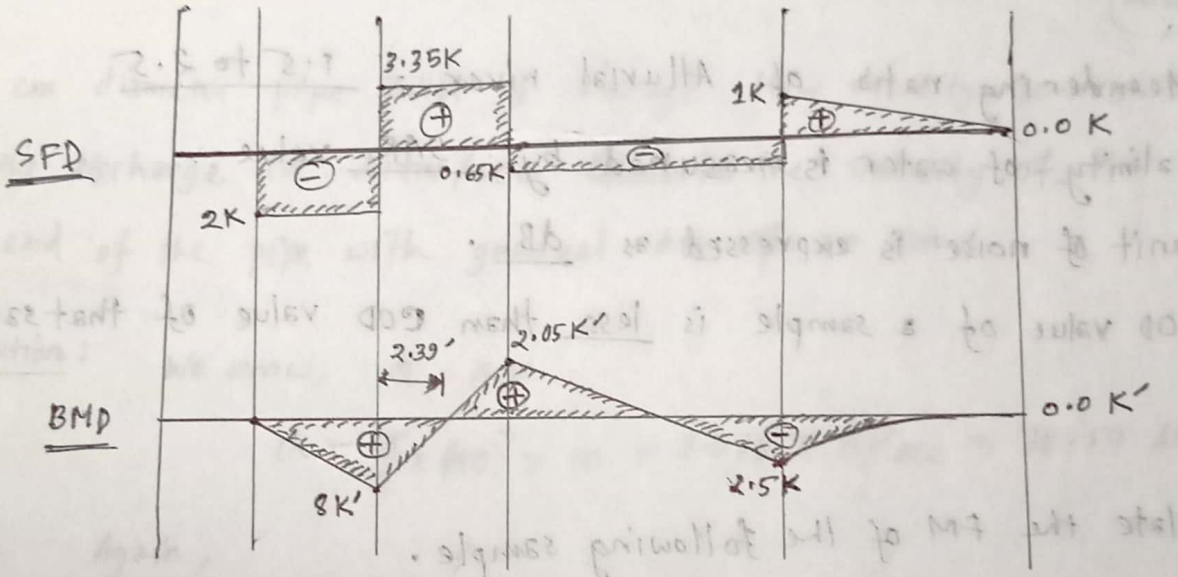
BPDB-2021

BUET

1. Draw SFD & BMD of the following beam:



Solution:



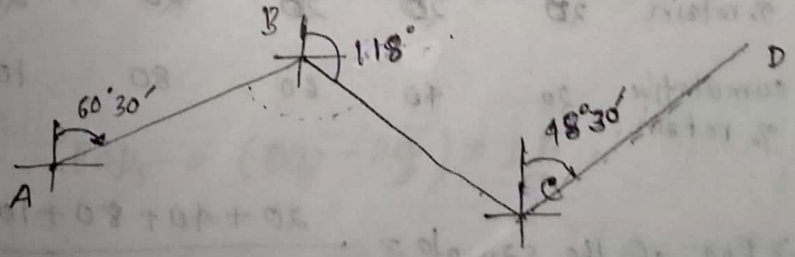
2. Calculate the internal angle of the traverse. The FB of three line

AB ⟶ 60°30′

BC ⟶ 118°

CD ⟶ 48°30′

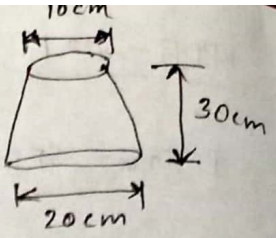
Solution:



internal $\angle B = 180° + 60°30' - 118° = 122°30'$

(Ans.)

3. (a) Slump test height of Mold is 30 cm



(b) Initial setting time of ordinary cement 30-45 min.

(c) Length of standard brick 9.5"

(d) Arsenic limit according to ECR '97 0.05 mg/L

(e) 100% passes through # 100 No. sieve. Calculate FM = 0

4. (a) Meandering ratio of Alluvial river = 1.5 to 2.5

(b) Salinity of water is measured by SAR value.

(c) unit of noise is expressed as dB.

(d) BOD value of a sample is less than COD value of that sample.

(e)

5. calculate the FM of the following sample.

Sieve No.	#16	#30	#40	#50	#100
retain (gm)	20	20	20	20	20

Solution:

sieve No.	#16	#30	#40	#50	#100
% retain	20	20	20	20	20
cumulative % retain	20	40	60	80	100

$$\therefore \text{FM of the sample} = \frac{20+40+80+100}{100} = 2.4$$

(Ans.)

6. A rectangular tank of length 5m, width 3m and height 2.5m. Calculate pressure force at the bottom of the tank.?

Solution: vertical pressure at the bottom of the tank = γh

$= (9.81 \times 2.5)\ KN/m^2$

$= 24.525\ KN/m^2$

$\therefore$ force $= (24.525 \times 5 \times 3) = 367.875\ KN.$

(Ans.)

7. 10 cm diameter pipe with a average flow velocity 10 m/s. Calculate the discharge in litre/sec. Calculate the velocity of the another end of the pipe with gradual dia of 20 cm.

Solution: We know, $Q = AV$

$$Q = \frac{\pi}{4} \times (0.10)^2 \times 10 = 0.07854\ m^3/sec = 78.54\ litre/sec.$$

Again,

$$\frac{\pi}{4} \times (0.20)^2 \times V_2 = 0.07854$$

$$\Rightarrow V_2 = 2.5\ m/sec.$$

(Ans.)

8. Initial and Final Do of a sample is 7 mg/L and 3 mg/L. Given, K (ebase) = 0.20 day^{-1}. Calculate the BOD_5 value. Also calculate Ultimate BOD.

Solution: We know,

$$BOD_5 = (DO_i - DO_f) \times DF$$

$$\Rightarrow BOD_5 = (7-3) \times 50 \quad [\text{Assuming, } DF = 50]$$

$$\Rightarrow BOD_5 = 200\ mg/L$$

(Ans)

Again, $BOD_5 = L_o(1 - e^{-0.2 \times 5})$

$$\Rightarrow L_o = \frac{200}{0.632} = 316.40\ mg/L$$

(Ans)

BUET

BPDB-2020

1. What is fineness modulus? Calculate the FM of the following sample:

# Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	pan
% retained	0	1	4	12	13	30	39	1	2

Solution: Fineness Modulus: It is an empirical formula obtained by taking the sum of cumulate percentages of sand retained on a specified series of sieves and dividing the sum by 100.

Specified sieves are: No. 4, 8, 16, 30, 50, 100

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	pan
cumulative % retain	0	1	5	17	30	60	94	98	100

$\therefore$ FM of the sample $= \dfrac{1+5+17+60+94}{100} = 1.77$ (Ans.)

2. Determine the volume of cement, sand and stone chips of 10 cft cement concrete with ratio 1 : 1.5 : 3.

Solution: Dry volume of concrete $= (1.5 \times 10) = 15$ cft

Total ratio $= (1+1.5+3) = 5.5$

$\therefore$ Amount of cement required $= \left(\dfrac{1}{5.5} \times 15\right) = 2.73$ cft

Amount of sand required $= \left(\dfrac{1.5}{5.5} \times 15\right) = 4.09$ cft

Amount of stone chips required $= \left(\dfrac{3}{5.5} \times 15\right) = 8.18$ cft

(Ans.)

3. A rectangular channel width is 20 ft, Manning's coefficient = 0.021, longitudinal slop = 0.0015 and discharge 300 cfs. Find the normal depth and velocity.

Solution: We know,

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

Here, $R = \frac{A}{P}$

$A = bh = 20h$

$P = b + 2h = 20 + 2h$

$$\Rightarrow V = \frac{1.49}{0.021} \times \left(\frac{20h}{20+2h}\right)^{\frac{2}{3}} \times (0.0015)^{\frac{1}{2}}$$

$$\Rightarrow V = 2.748 \left(\frac{20h}{20+2h}\right)^{\frac{2}{3}}$$

Then, $Q = AV$

$$\Rightarrow 300 = 20h \times 2.748 \left(\frac{20h}{20+2h}\right)^{\frac{2}{3}}$$

$$\Rightarrow h = 3.08 \text{ ft}$$

$$\therefore V = 2.748 \times \left(\frac{20 \times 3.08}{20 + 2 \times 3.08}\right)^{\frac{2}{3}} = 4.864 \text{ ft/sec.}$$

(Ans.)

4. Calculate the angularity number for the aggregate sample from the following data: relative density of aggregate = 2.8, mass of water required to fill the cylinder 2500 g, mass of cylinder filled with compacted aggregate 5150g and mass of ~~aggregate~~ cylinder = 1100g

Solution:

We know,

$$\text{Angularity Number, } N = 67 - \frac{W_2}{W_w \times G_s} \times 100$$

$$= 67 - \frac{(5150 - 1100)}{2500 \times 2.8} \times 100$$

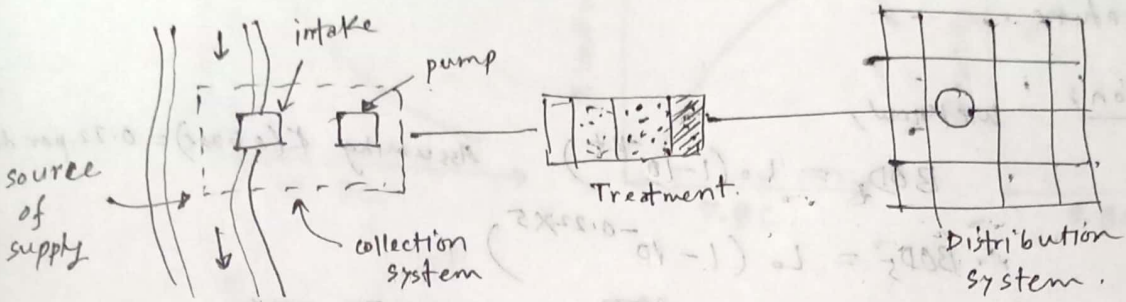
$$= 9.14$$

$$\simeq 9$$

(Ans)

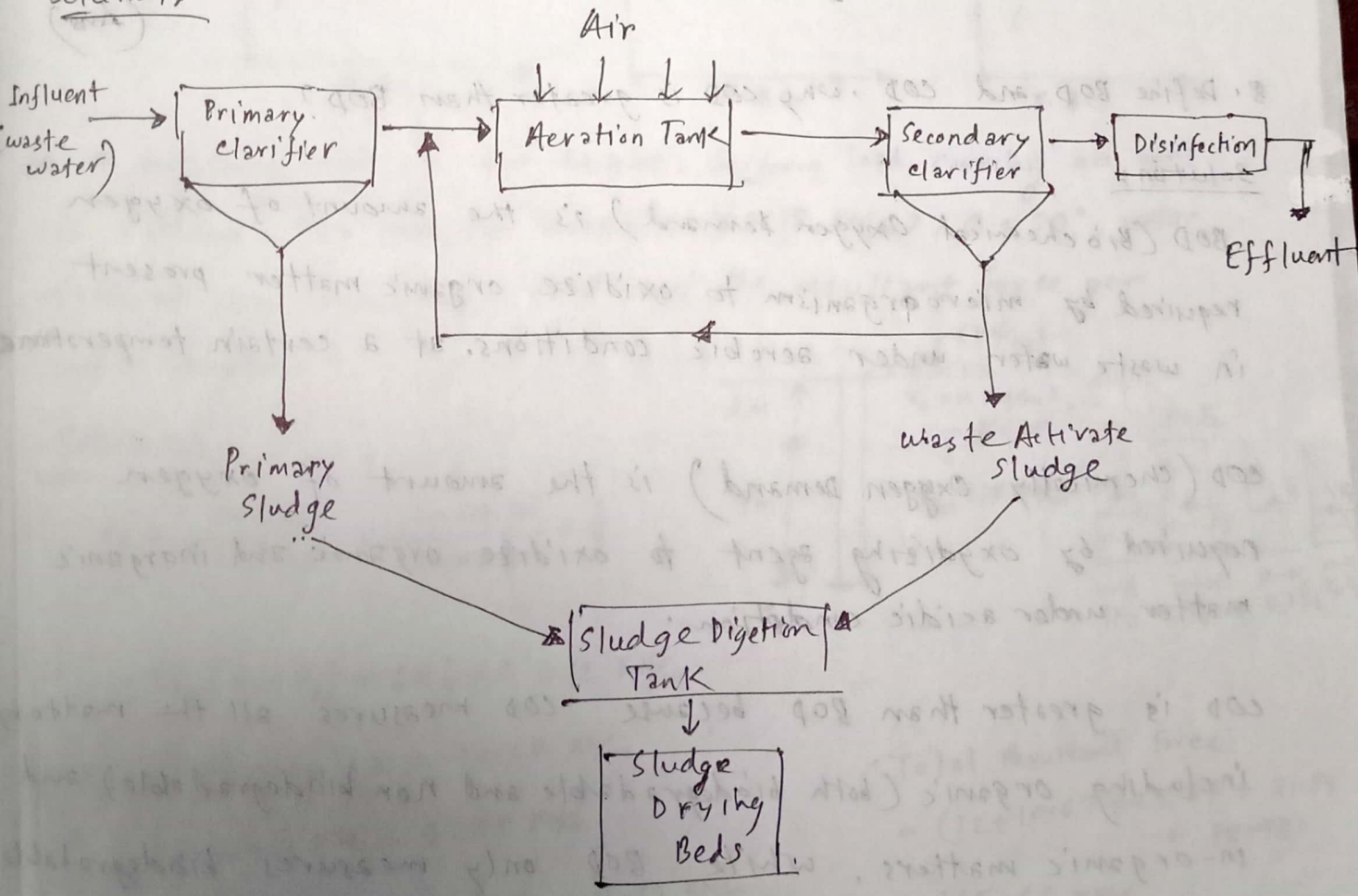
5. Flow diagram of essential elements of water supply system.

Solution:



6. Flow diagram of conventional activated sludge process.

Solution:



7. The amount of BOD_5 in a sewage found 200 mg/L at temperature 20°C. If K = 0.22 per day, then determine the BOD_{10} at the same temperature.

Solution;

We know,

$$BOD_t = L_o(1 - e^{-kt})$$ Assuming K(e base) = 0.22 per day

$$\therefore BOD_5 = L_o(1 - e^{-0.22 \times 5})$$

$$\Rightarrow L_o = \frac{200}{0.667} = 299.79 \text{ mg/L}$$

Again, $BOD_{10} = 299.79 \times (1 - e^{-0.22 \times 10}) = 266.57$ mg/L

(Ans.)

8. Define BOD and COD. Why COD is greater than BOD?

Solution;

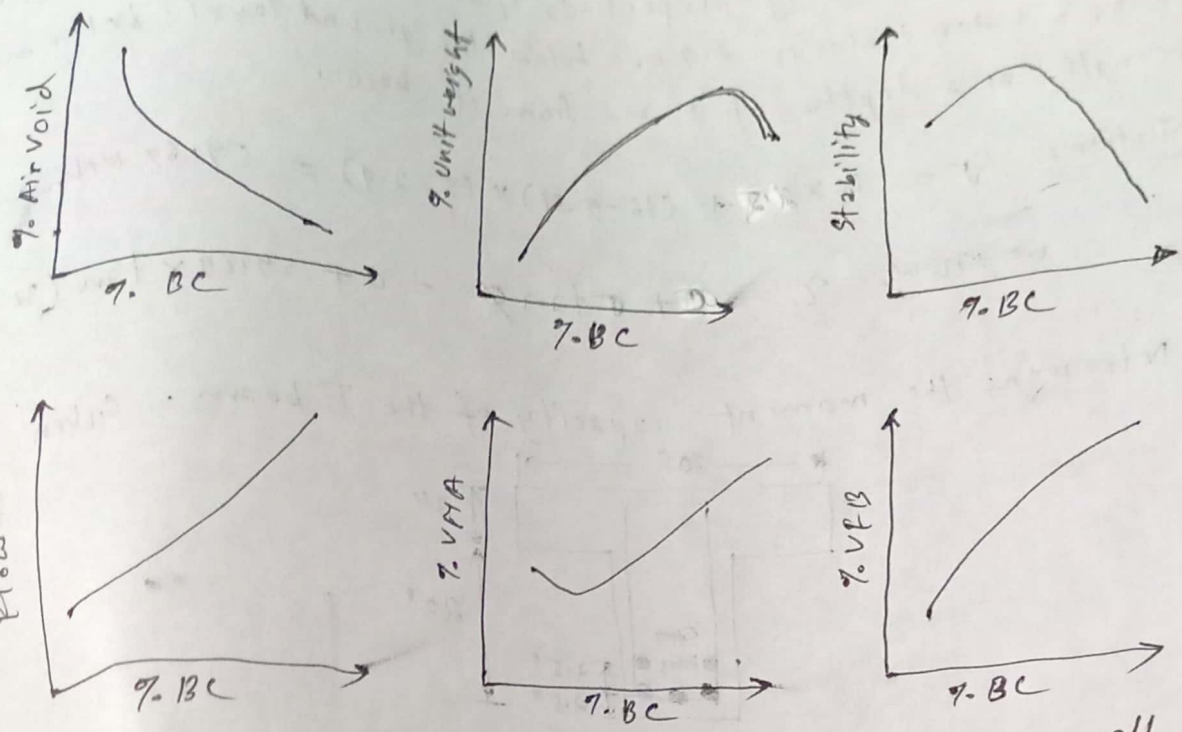
BOD (Biochemical Oxygen Demand) is the amount of oxygen required by microorganism to oxidize organic matter present in waste water under aerobic conditions at a certain temperature.

COD (chemically Oxygen Demand) is the amount of oxygen required by oxydizing agent to oxidize organic and inorganic matter under acidic condition.

COD is greater than BOD because COD measures all the matters including organic (both biodegradable and non biodegradable) and in-organic matters, while BOD only measures biodegradable organic matters.

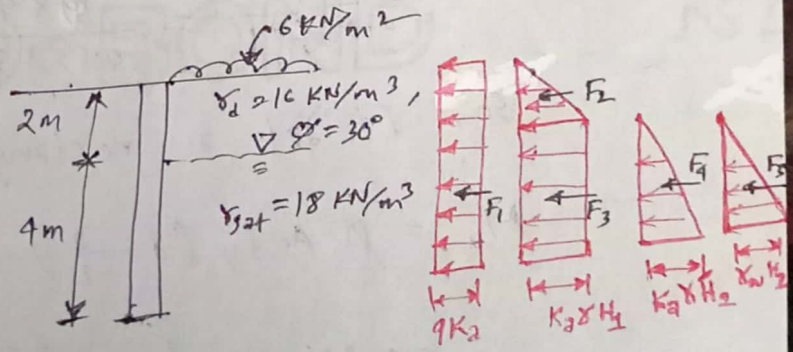
9. Draw Marshall Mix Design Curves.

Solution:



10. A retaining wall is 6 m height, Uniform load carrying on wall is 6 KN/m², Non cohesive backfill, $\gamma = 18\ KN/m^3$, $\phi = 30°$, water table at 2 m from top. Find out the resultant force per unit length.

Solution:



$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = \frac{1}{3}$$

$$F_1 = qK_a(H_1+H_2) = 6 \times \frac{1}{3} \times 2 = 12\ KN/m$$

$$F_2 = \frac{1}{2} \times \left(\frac{1}{3} \times 12 \times 2\right) \times 2 = 10.67\ KN/m$$

$$F_3 = \left(\frac{1}{3} \times 16 \times 2\right) \times 4 = 42.67\ KN/m$$

$$F_4 = \frac{1}{2} \times \left[\frac{1}{3} \times (18-9.81) \times 4\right] \times 4 = 21.84\ KN/m$$

$$F_5 = \frac{1}{2} \times (9.81 \times 4) \times 4 = 78.48\ KN/m$$

∴ Total Resultant Force

$= (12 + 10.67 + 42.67 + 21.84 + 78.48)$

$= 165.66\ KN/m$

11. A sand layer having properties, $\gamma_t = 16\ KN/m^3$, $\gamma_{sat} = 18\ KN/m^3$, $G_s = 2.6$, $\phi = 36°$. Water table is 2.9 m below the ground level. Determine shear strength at a depth of 5 m from its base.

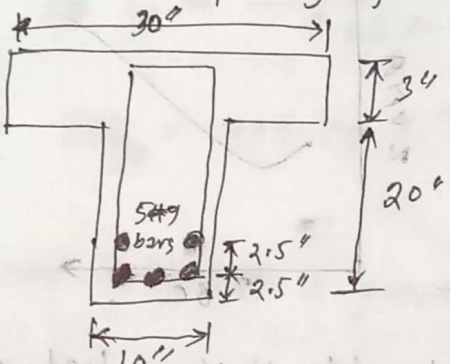
Solution: $\sigma = 16 \times 2.4 + (18 - 9.81) \times (5 - 2.4) = 59.69\ KN/m^2$

we know, $\tau = c + \sigma \tan\phi = 0 + 59.69 \times \tan(36) = 43.37\ KN/m^2$

(Ans)

12. Determine the moment capacity of the T beam. Given, $f_c' = 3\ ksi$

$f_y = 40\ ksi$



Solution:

effective depth, $d_{eff} = (23 - 3.5) = 19.5"$; $A_s = 5 \times 1 = 5\ in^2$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{5 \times 40}{0.85 \times 3 \times 30} = 2.61"$$ $h_f\ (= 3\ in)$

So, it acts as rectangular beam.

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$= 0.9 \times 5 \times 40 \left(19.5 - \frac{2.61}{2}\right)$$

$M_u = 3275\ K\text{-}ip\text{-}in.$

$\phi = 0.483 + 83.3\,\varepsilon_t$

$= 0.483 + 83.3 \times 0.003 \times \dfrac{19.5 - \frac{2.61}{2}}{\frac{2.61}{2}}$

$\phi = 1.05 > 0.9$

$\therefore \phi = 0.9$

(Ans.)

BPDB - 2016 BUET

1. Difference between maximum and minimum void ratio is 0.3 and field void ratio = 0.4. If Relative density = 66.66%. Find the saturated density (Given, $G_s = 2.7$)

Solution: we know,

$$D_r(\%) = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$

$$\Rightarrow 66.66 = \frac{e_{max} - 0.4}{0.3} \times 100$$

$$\Rightarrow e_{max} = 0.60 \quad \text{[loosest condition]}$$

we know,

$$\gamma_{sat} = \frac{(G_s + e)}{1+e} \times \gamma_w = \frac{(2.7 + 0.6)}{1 + 0.6} \times 9.81 = 20.23 \ KN/m^3$$

2. Evaluate the ratio of Energy imparted by MPT and SPT test.

Solution: We know,

Energy imparted by proctor test

$$E = \frac{\text{No. of layer} \times \text{No. of Blow} \times \text{height of drop} \times \text{weight of hammer}}{\text{volume of mold}}$$

For SPT test

$$E_S = \frac{3 \times 25 \times 1 \times 5.5}{\left(\frac{1}{30}\right)}$$

$$\therefore E_S = 12375 \ lb\,ft/ft^3$$

For MPT test,

$$E_M = \frac{5 \times 25 \times 1.5 \times 10}{\left(\frac{1}{30}\right)}$$

$$\therefore Em = 56250 \ lb\,ft/ft^3$$

$$\text{Ratio} = \frac{E_m}{E_S} = \frac{56250}{12375} = 4.545$$

(Ans.)

3. Rainfall Intensity = 2.4 m/yr. Run off co-efficient = 0.7. Find catchment Area. Daily water demand is 15 lped of 7 people.

Solution:

We know, $Q = CIA$

$\Rightarrow 38.325 = 0.7 \times 2.4 \times A$

$\Rightarrow A = 22.8125\ m^2$

(Ans.)

Here, $Q = (15 \times 7)$ l/day

$= 105 \times 10^{-3}\ m^3/day$

$= 38.325\ m^3/year$

$C = 0.7$

$I = 2.4\ m/year$

4. If 25% retaining each sieve of # 30, # 50, # 100 and # 200. Find the FM of the sample.

Solution:

sieve no	# 30	# 50	# 100	# 200
% retain	25	25	25	25
cumulative % retain	25	50	75	100

$\therefore$ FM of the sample $= \dfrac{25+50+75}{100} = 1.5$

(Ans.)

5. Find the ultimate load capacity of a rectangular column (20"×20") and reinforcement $8 - (\frac{3}{4})''$, $f_c' = 4$ ksi, $f_y = 60$ ksi

No. 6 bar

Solution:

In WSD, $P_{all} = \phi \alpha A_g [0.85 f_c' + \rho (f_y - 0.85 f_c')]$

$= 0.65 \times 0.80 \times 20 \times 20 \times \left[0.85 \times 4 + \dfrac{8 \times 0.44}{20 \times 20} \times (60 - 0.85 \times 4)\right]$

$= 810.8$ Kip.

(Ans.)

6. Calculate total pressure and effective pressure on a swimming pool of 5 m deep.

Solution: Total pressure $= \gamma h = (9.81 \times 5) = 49.05$ KN/m²

Effective pressure $= 0$ KN/m²

(Ans)

7. Two close wheel imparted 20.5 KN load each on road. Applied pressure = 0.7 MPa. If two wheel replaced by a single wheel of similar property. Find imparted effective diameter on soil by single wheel.

Solution: Equivalent single wheel load $= (2 \times 20.5) = 41$ KN

We know, $P = \frac{F}{A}$

$\Rightarrow A = \frac{F}{P}$

$\Rightarrow \frac{\pi}{4}(d)^2 = \frac{41 \times 10^3}{0.7}$

$\Rightarrow d = 273.08$ mm

(Ans)

8. A wide channel $n = 0.026$, $S = 0.0028$. Find normal depth and velocity, if discharge $= 30$ m³/sec.

Solution: We know, $Q = AV = A \times \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$

For wide channel $b = 1$

Here, $A = h$

$R = \frac{A}{P}$

$\therefore R = \frac{h}{1+2h}$

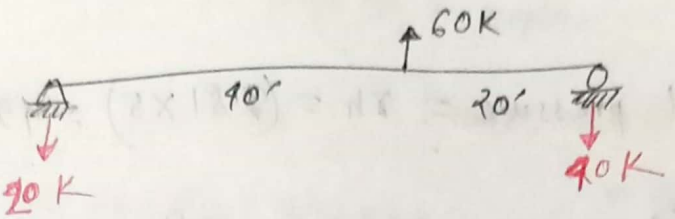
$\Rightarrow 30 = h \times \frac{1}{0.026} \times \left(\frac{h}{1+2h}\right)^{\frac{2}{3}} \times (0.0028)^{\frac{1}{2}}$

$\Rightarrow h = 23.73$ m.

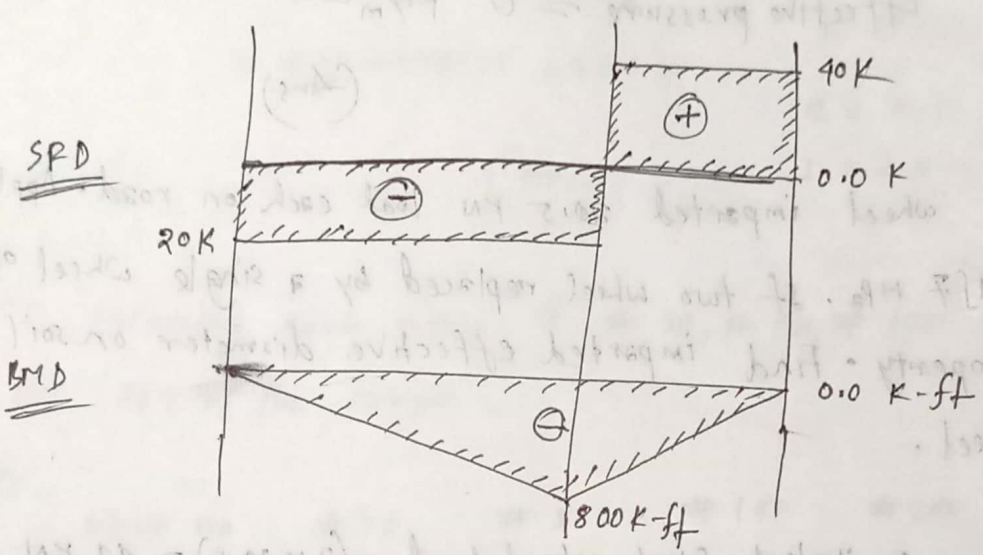
$\therefore Q = AV \Rightarrow 30 = 23.73 \times V \Rightarrow V = 1.2693$ m/sec.

(Ans)

9. Draw SFD and BMD of the following beam.



Solution:



10. CBR value found 10 kms length as 3.8, 2.8, 3.2, 4.3, 2.8, 4.7, 4.3, 3.9, 4.9, 4.5%. Find the design CBR value at 50% and 90% reliability.

Solution: Average CBR value, $\bar{x} = \left(\frac{3.8+2.8+\cdots\cdots+4.9+4.5}{10}\right) = 3.92$

Standard deviation, $S_1 = \sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}}$

$$= \sqrt{\frac{(3.8-3.92)^2+(2.8-3.92)^2+\cdots\cdots+(4.5-3.92)^2}{(10-1)}}$$

$$= 0.763$$

For 50% reliability, Design CBR $= (3.92 - 0.763 \times 0) = 3.92$
$(z = 0)$

For 90% reliability, Design CBR $= (3.92 - 0.763 \times 1.64) = 2.67$.
$(z = 1.84)$

(Ans.)

11. calculate the maximum shear stress of rectangular beam (6"x 12") when vertical shear force = 48 K.

Solution:

We know,

$$\tau_{max} = \frac{VQ}{Ib}$$

$$= \frac{48 \times 108}{864 \times 6} \text{ Ksi}$$

$$\therefore \tau_{max} = 1 \text{ Ksi}$$

(Ans.)

Here, $V = 48$ K

$Q = \left(6 \times \frac{12}{2} \times \frac{6}{2}\right) = 108 \text{ in}^3$

$I = 6 \times \frac{12^3}{12} = 864 \text{ in}^4$

$b = 6"$

12. One million gallon liter of water (1 mgd) pass through a sedimentation tank if size of Tank 20'x50'x10'. Find detention time.

Solution:

we know,

$$Q = \frac{V}{T}$$

$$\Rightarrow T = \frac{20 \times 50 \times 10}{133563.4}$$

$$\Rightarrow T = 0.0749 \text{ day}$$

$$\therefore T = 1.797 \text{ hour.}$$

(Ans.)

Here,

$Q = 1$ mgd

$= 10^6$ Gallon

$= 10^6 \times 3.785 \times 10^{-3} \times (3.28)^3$

$= 133563.4 \text{ ft}^3/\text{day}$

BPDB-2015

BUET

1. Fill in the gap

(a) The horizontal distance between two contours is called Horizontal Equivalent.

(b) The line of collimation must be coincide the axis of telescope.

(c) Primary functions of sleeper is to hold the rails to correct gauge and alignment.

(d) Contour line is drawn through point of same elevation.

(e) Percentage of wear aggregate is determined by Los Angeles Abrasion value.

(f) Permissible limit of iron in drinking water is 0.3 – 1 mg/L.

(g) Slump test of concrete is carry out to determine its consistency.

(h) A #40 slot size tubewell will have an opening of $\frac{40}{1000} \times 25.4$ mm.

(i) when Alum is added to water as coagulant, it decreases the pH value.

(j) Surface runoff is the quantity of water that sealed the stream channels.

2. True/False.

(a) The upper part of the ground is called sub grade. False

(b) The ultimate stress is less than breaking stress. False

(c) The maximum bending moment of simply supported beam with external load lies at point of loading. True

(d) contra-flexure point occur only shear diagram. True.

3. calculate the stopping sight distance for highway design speed is 50 Kmph. Assume, $f = 0.42$ and also required data taken assume for standardization.

Solution: we know,

$$SSD = Vt + \frac{v^2}{2gf}$$

Here, $V = 50.0$ mph
$= 73.5$ ft/s
$t = 2.5$ sec.

$$= 73.5 \times 2.5 + \frac{(73.5)^2}{2 \times 32.2 \times 0.42}$$

$$= 383.48 \text{ ft}$$

(Ans.)

4. Define Fixture unit in plumbing system.

Solution: Fixture unit (FU), is not a flow rate unit but a design factor. A FU is used in plumbing design for both water supply and waste water. A FU is equal to 1 ft^3 of water drained in an $1\frac{1}{4}$" dia. pipe over 1 minute.

5. Why removal of turbidity is essential to effective disinfection?

Solution:

6. concrete pile of 24" dia. embedded in clay. unconfined compressive strength of the soil is 4 Ksf and the embedded length of the pile is 30 ft. Calculate ultimate load carrying capacity of the pile if adhesive friction between clay and pile is 0.95, unit weight of clay 100 lb/ft^3 and water table exist at ground.

Solution:

$Q_u = Q_p + Q_s$

$= cN_c A_p + \alpha C_u PL$

$= 2 \times 9 \times \frac{\pi}{4} \times (\frac{24}{12})^2 + 0.95 \times 2 \times \pi \times \frac{24}{12} \times 30$

$= 226.2$ Kip

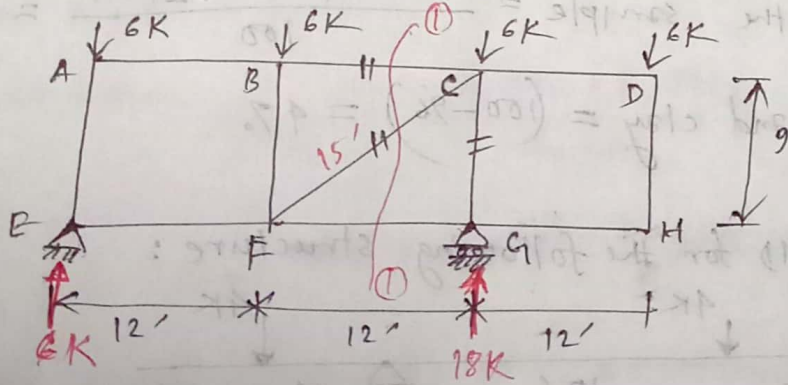
(Ans)

Here, $c = \frac{q_u}{2} = \frac{4}{2} = 2$ Ksf

$N_c = 9$

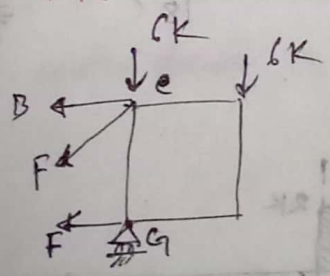
$\alpha = 0.$

7. Find the bar forces of the member BC, CF and CG.



Solution:

From Section ①-①,



$\Sigma F_y = 0$

$\frac{CF}{15} \times 9 + 6 + 6 - 18 = 0$

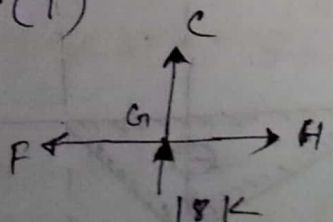
$\Rightarrow CF = 10$ Kip (T)

$\Sigma M_F = 0$

$6 \times 12 + 6 \times 24 - 18 \times 12 - BC \times 9 = 0$

$\therefore BC = 0$

Joint G:



$\Sigma F_y = 0$

$GC + 18 = 0 \Rightarrow GC = -18$ Kip

$\therefore GC = 18$ Kip (C)

3. calculate th... -1

8. Percentage of void is 50%. If specific gravity of soil solid is 2.7. then calculate the submerged unit weight.

Solution: We know,

$\gamma' = \gamma_{sat} - \gamma_w$

$\Rightarrow \gamma' = (20.928 - 9.81)$

$\therefore \gamma' = 11.118$ KN/m³

Here, $\gamma_d = \frac{G_s \gamma_w}{1+e}$

$= \frac{2.7 \times 9.81}{1+0.5}$

$= 17.658$ KN/m³

(Ans:) $\gamma_{sat} = \gamma_d + n\gamma_w = 17.658 + (\frac{0.5}{1+0.5} \times 9.81)$

$= 20.928$ KN/m³

9. Find the FM of the following sample. Also find % silt and clay.

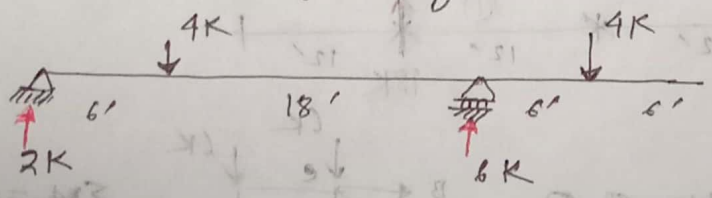
Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	4	12	32	43	2	2	4
cumulative % retain	0	1	5	17	49	92	94	96	100

Solution:

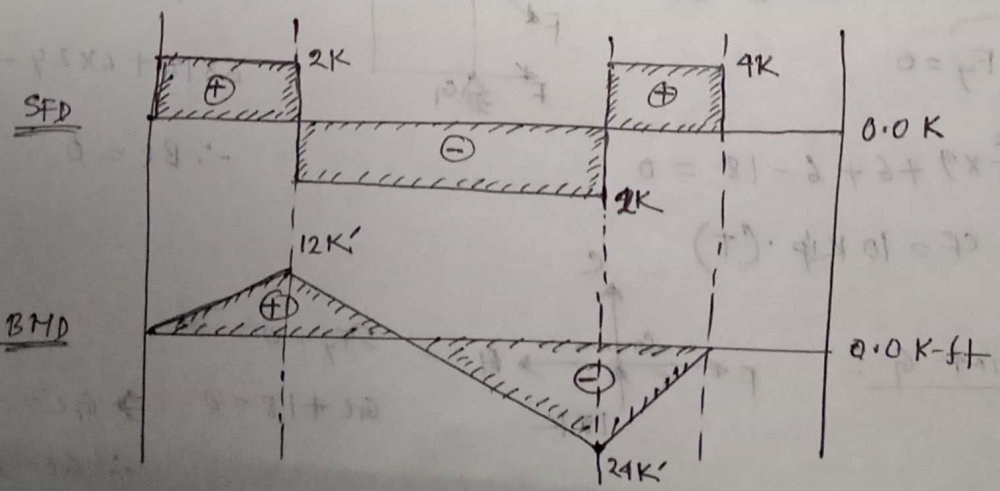
$\therefore$ FM of the sample $= \frac{1+5+17+2+99}{100} = 2.09$

% silt and clay $= (100-96) = 4\%$

10. Draw SFD and BMD for the following structure:



Solution:



11. In an unconfined compression test sample of clay 8 cm long and 4 cm dia fails under a load 12 kg at 7% strain. Find undrained strength of clay taking in account that the effect of cross section of the sample.

Solution: Area of the test sample, $A = \frac{\pi}{4}(4)^2 = 4\pi \text{ cm}^2$

Corrected Area, $A_c = \frac{A}{1-\varepsilon} = \frac{4\pi}{1-0.07} = 13.51 \text{ cm}^2$

unconfined compression strength,

$$q_u = \frac{F}{A} = \frac{12 \times 9.81}{13.51 \times 10^{-4}} = 87135.5 \text{ N/m}^2 = 87.14 \text{ KN/m}^2$$

$\therefore$ undrained shear strength, $c = \frac{q_u}{2} = \frac{87.14}{2} = 43.57 \text{ KN/m}^2$ (Ans.)

12. A municipal waste water treatment plant discharge 1.2 m^3/sec. of effluent having 60 mg/L that has a flow of 9.3 m^3/sec. and BOD 6mg/L. Assume complete mixing. Estimate the mixing BOD of the river just downstream of the rain fall.

Solution: we know,

$$BOD_{mix} = \frac{Q_1 BOD_1 + Q_2 BOD_2}{Q_1 + Q_2} = \frac{1.2 \times 60 + 9.3 \times 6}{1.2 + 9.3}$$

$\therefore$ BOD mix $= 12.17$ mg/L

(Ans.)

13. A wooden flume ($n = 0.012$) with a rectangular section in 2' wide flume discharge of 3 ft^3/sec. water down 1% slope. What is the depth of flow?

Solution:

We know,

$$Q = AV = 2h \times \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

Here,

$$R = \frac{A}{P} = \frac{2h}{2+2h}$$

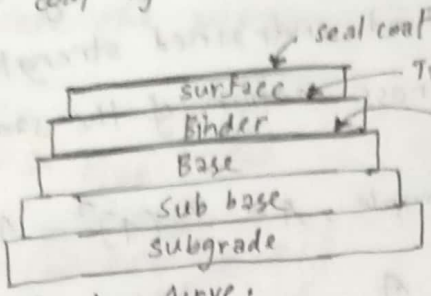
$$\Rightarrow 3 = 2 \times h \times \frac{1.49}{0.012} \times \left(\frac{2h}{2+2h}\right)^{\frac{2}{3}} \times (0.01)^{\frac{1}{2}}$$

$$\Rightarrow h = 0.314 \text{ ft}$$

(Ans.)

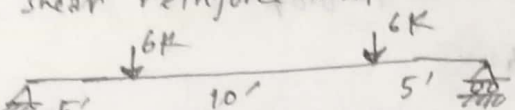
16. Draw the layer and coat of the flexible pavement.

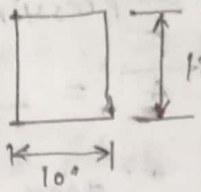
Solution:



17. Draw Marshall Mix Design curve.

18. Design the shear reinforcement below the beam $f_y = 60$ ksi and $f_c' = 3$ ksi

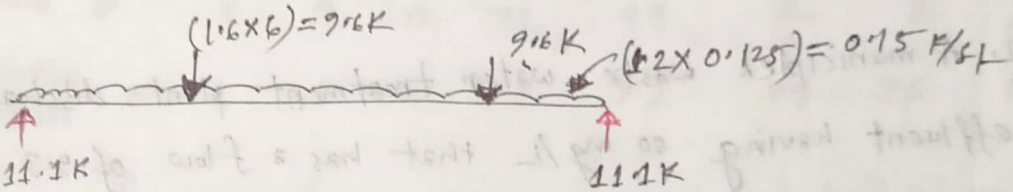




$d = (12 - 1.5) = 10.5"$

Solution: self weight of the beam $= \left(\frac{10}{12} \times \frac{12}{12} \times \frac{150}{1000}\right) = 0.125$ K/FL

for USD Design,



V_u at support $= 11.1$ K

V_u at a distance 'd' from the support, $V_u = 11.1 - 0.15 \times \frac{10.5}{12}$

$= 10.97$ Kip.

Now, $\phi V_c = 2\phi\sqrt{f_c'}\, bd$

$= 2 \times 0.75 \times \sqrt{3000} \times 10 \times 10.5$

$\therefore \phi V_c = 8626.63\,lb = 8.63$ Kip. $< V_u$

Hence, stirrup is required.

Theoretical spacing, $S = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{0.75 \times (2 \times 0.11) \times 60 \times 10.5}{10.97 - 8.63} = 44.4"$

But, $S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b} = \frac{(2 \times 0.11) \times 60}{0.75 \times \sqrt{3000} \times 10} = 32.13"$

again, $S_{max} = \frac{A_v f_y}{50 b_w} = \frac{(2 \times 0.11) \times 60}{50 \times 10} = 26.4"$

$S_{max} = \frac{d}{2} = \frac{10.5}{2} = 5.25"$

$S_{max} = 24"$

Hence, provide #3 bar @ 5.25" c/c (Ans)

BUET

BPDB-2019

1. The combined fineness modulus of fine aggregate ($F_f = 2.85$) and coarse ($F_c = 6.77$) was found to be 5.3. If 8.49 cft of combined and well packed aggregate is required, determine the volume of fine and coarse aggregate to be mixed initially. Take shrinkage factor = 0.75

Solution: we know,

$$R = \frac{F_1 - F_c}{F_c - F_2} = \frac{6.77 - 5.3}{5.3 - 2.85} = \frac{1.47}{2.45} = \frac{3}{5}$$

$$\frac{F_2}{F_1} = \frac{3}{5}$$

Given, compacted volume = 8.49 cft

$\therefore$ loose volume $= \frac{8.49}{0.75} = 11.32$ cft

$\therefore$ volume of fine aggregate $= \left(\frac{3}{5+3}\right) \times 11.32$ cft

$= 4.245$ cft

and, volume of coarse aggregate $= \left(\frac{5}{5+3}\right) \times 11.32$ cft

$= 7.075$ cft (Ans.)

2. Find the number of cement bags of 100 cft casting concrete with mixing ratio 1:2:4.

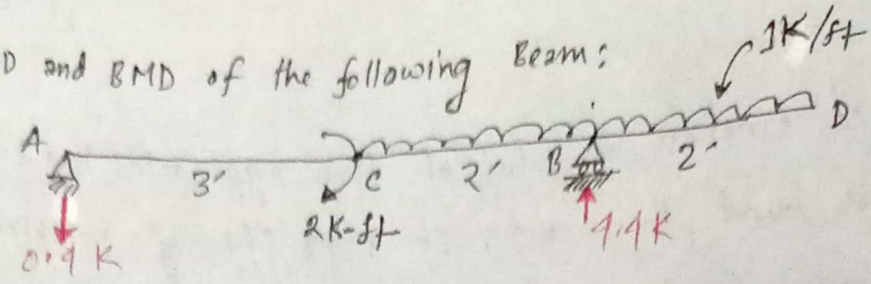
Solution: Dry volume $= (1.5 \times 100) = 150$ cft

Total ratio $= (1+2+4) = 7$

Amount of bags $= \left(\frac{1}{7} \times 150\right) = 21.43$ cft $= 17.193$ bags.

(Ans.)

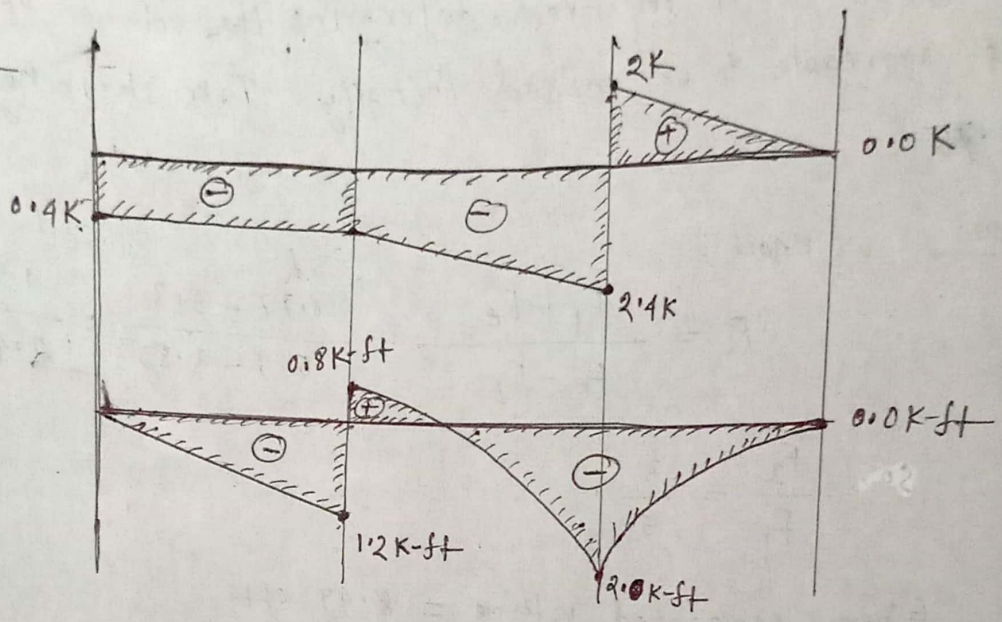
3. Draw SFD and BMD of the following Beam;



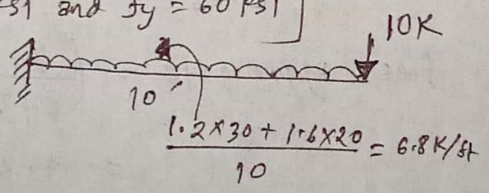
Solution;

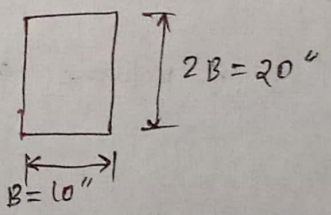
SFD

BMD



4. Given, DL = 30 K , LL = 20 Kip. Design web reinforcement of the foll beam. [$f_c' = 3$ Ksi and $f_y = 60$ Ksi]





Solution: Total ultimate load, $w_u = 1.2 \times 30 + 1.6 \times (20 + 10) = 84$ Kip.

$\therefore V_u$ at support = 84 Kip

V_u at a distance 'd' from the support $= 84 - 6.8 \times \frac{(20 - 2.5)}{12}$

$= 74.083$ Kip.

$\phi V_c = 2\phi \sqrt{f_c'}\, b\, d$

$= 2 \times 0.75 \times \sqrt{3000} \times 10 \times 17.5$

$= 14377.72$ Kip

$\phi V_c = 14.38$ Kip. $< V_u$. Hence, stirrup must be provided.

Theoretical spacing, $S = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{0.75 \times (2 \times 0.11) \times 60 \times 17.5}{79.083 - 14.38} = 2.9''$

But,

$S_{max} = \frac{A_v f_y}{0.75\sqrt{f'_c} b} = \frac{2 \times 0.11 \times 60000}{0.75 \times \sqrt{3000}} = 32.13''$

$S_{max} > \frac{A_v f_y}{50 b_w} = \frac{2 \times 0.11 \times 60000}{50 \times 10} = 26.4''$

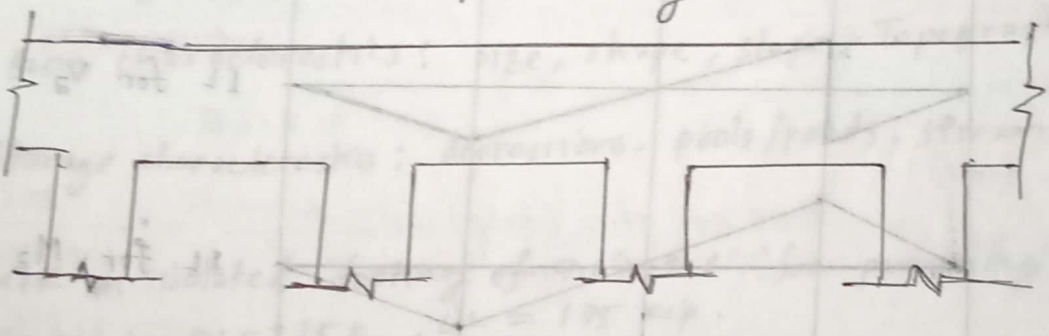
Again,

$S_{max} = \frac{d}{2} = \frac{17.5}{2} = 8.75''$

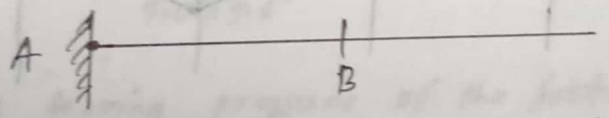
and, $S_{max} = 24''$

Hence, provide #3 ~~bars~~ U stirrup @2.9" c/c (Ans)

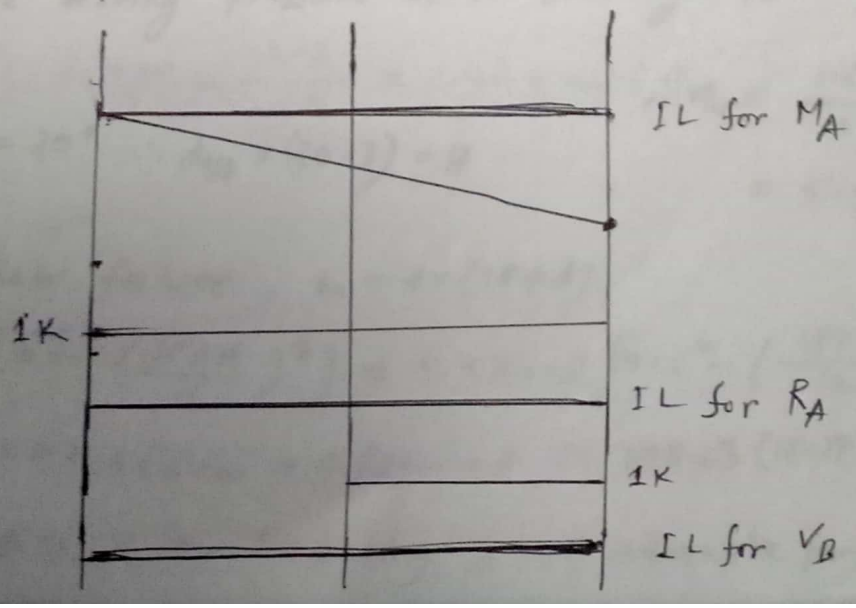
5. Show the reinforcement of following beam:



6. Draw IL for shear and moment at support of a cantilever beam. Also draw IL for shear at section B.

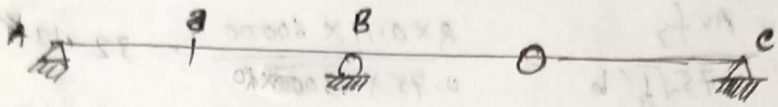


Solution:

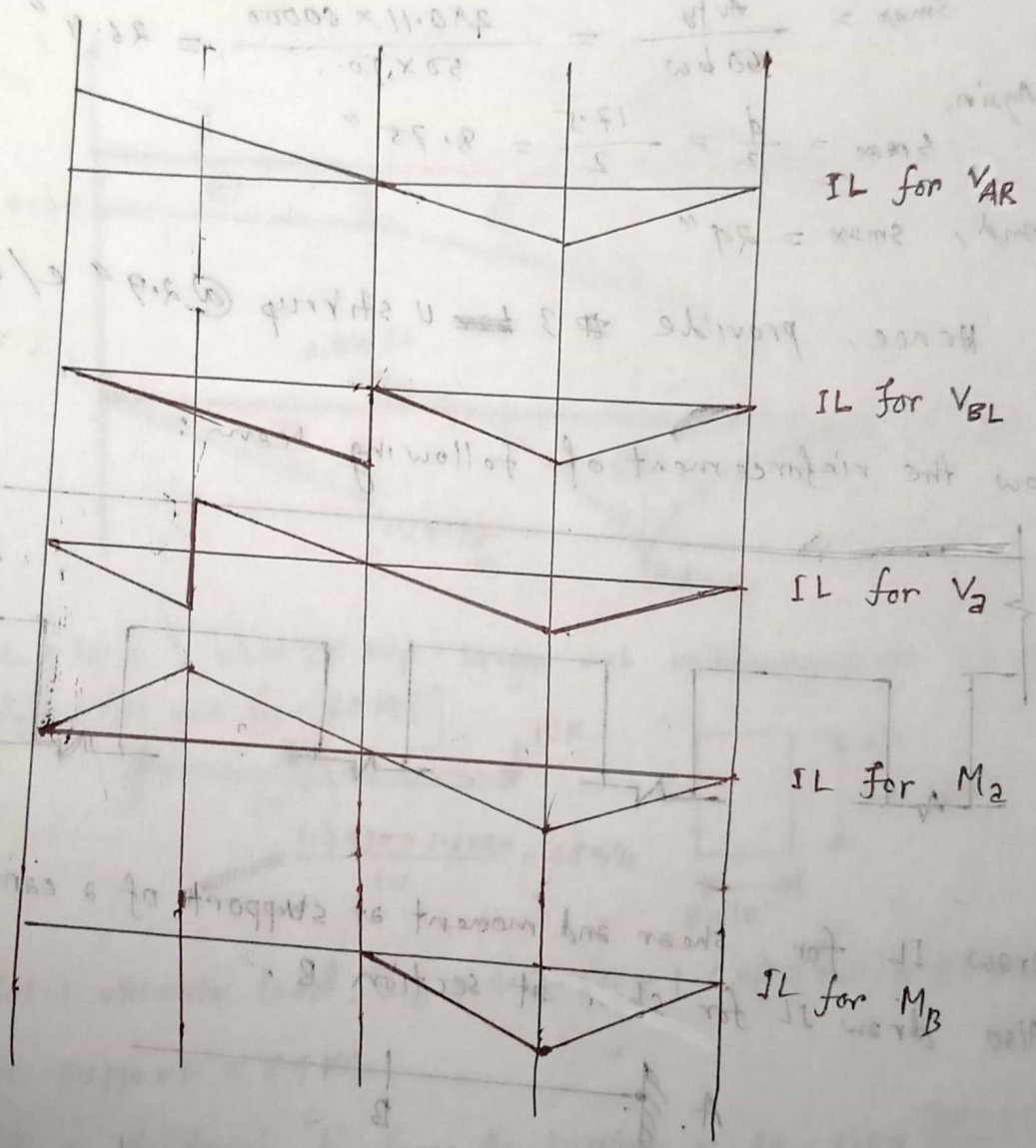


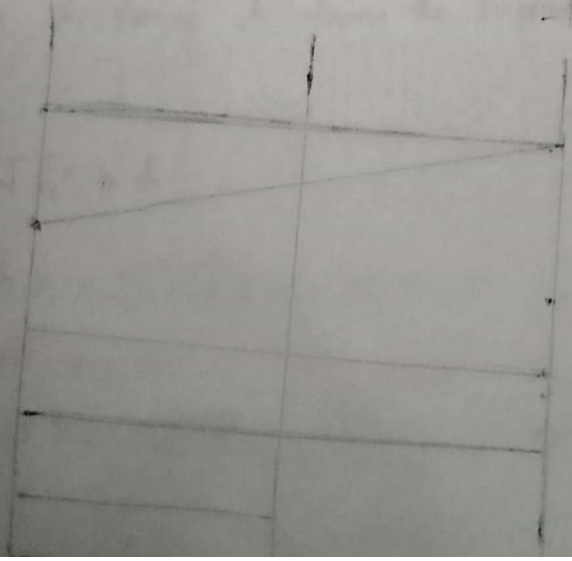
qualitative

7. Draw IL for shear at A (just Right), B (just left) and section '2'. Draw IL for Moment at section '2' and B.



Solution:





8. what is runoff and write the factors affecting Runoff.

Solution: Runoff: The portion of precipitation which appears in the surface streams of either perennial or intermittant nature is called Runoff.

Runoff = Rainfall − Losses

Factors affecting Run off:

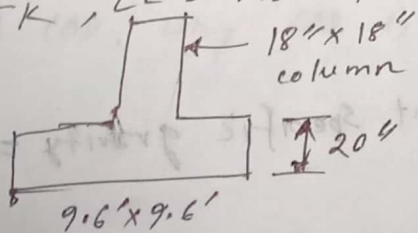
(I) Storm Characterestics: Nature of storm, intensity, duration, frequency etc.

(II) Meteorological Characterestics: Temperature, Humidity, wind, pressure. etc.

(III) Basin characterestics: size, shape, slope, Topography, vegetation etc.

(IV) Storage characterestics: depressions, pools/ponds, stream, channels etc.

9. check an isolated footing of 9.6'x 9.6' for punching shear. Given $f_c' = 4$ ksi, DL = 225K, LL = 175 Kip.



Solution: ultimate bearing pressure of the footing, $q_u = \frac{W_u}{\text{Area of footing}}$

$\therefore q_u = \frac{1.2\times 225 + 1.6\times 175}{9.6\times 9.6}$

$= 5.97$ ksf

Given, $\phi = 20°$ $\therefore d_{eff} = (20-3) = 17$

For punching shear failure, $b_o = 4\times(18+d)$

$\therefore V_u = q_u\left[5^2 - \left(\frac{18+d}{12}\right)^2\right] = 5.97\times 10^3\left[9.6^2 - \left(\frac{18+17}{12}\right)^2\right] = 499.4$ Kip

Again $\phi V_c = 2\times 0.75\times\sqrt{3000}\times 4(18+d)\times d = 328.63(18+17) = 195.5\times 10^3$ lb

$V_u > \phi V_c$. So The footing is not adequate for punching.

~~Hence $5.97\times10^{3}\left[9.6^{2}-\left(\frac{18+d}{12}\right)^{2}\right]=328.63(18+d)d$~~

~~$2d$~~

10. The mass of a sample of aggregate is 1206.0gm. The mass in a saturated surface dry condition is 1226.8gm. The volume of water occupying the same volume of aggregate excluding pores is 440.6 cm^3. Find the bulk specific gravity, apparent specific gravity and % absorption.

Solution: we know,

Bulk specific gravity (SSD) $= \frac{B}{B-C}$

Given,

$A = 1206.0\ gm$

$B = 1226.8\ gm$

$C = (1206 - 440.6)$

$= 765.4\ gm$

$= \frac{1226.8}{1226.8-765.4}$

$= 2.66$

Bulk sp. gr. (dry) $= \frac{A}{B-C} = \frac{1206}{1226.8-765.4}$

$= 2.614$

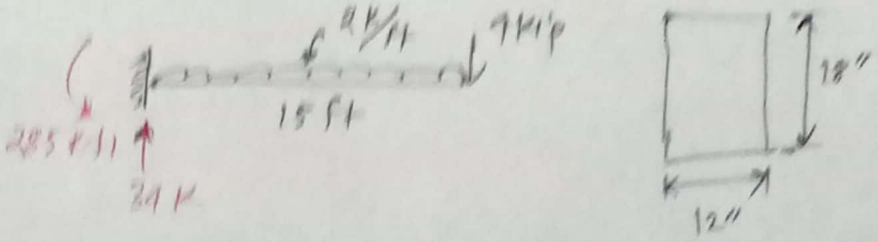
Apparent Specific gravity $= \frac{A}{A-C} = \frac{1206}{1206-765.4}$

$= 2.74$

% absorption $= \frac{B-A}{A} \times 100\% = \left(\frac{1226.8-1206}{1206}\right) \times 100$

$= 1.725\ \%$

11. Find the shear stress and bending stress of the following beam:



Solution;

We know, Maximum shear stress, $\tau = \frac{VQ}{Ib}$

Here,

$Q = 12 \times \frac{18}{2} \times \frac{7}{2}$

$= 186 \text{ in}^3$

$I = \frac{12 \times 18^3}{12} \text{ in}^4$

$= 5832 \text{ in}^4$

$b = 12"$

$= \frac{34 \times 186}{5832 \times 12}$

$= 0.236 \text{ ksi}$

Bending stress, $f = \frac{My}{I} = \frac{285 \times 9 \times 12}{5832}$

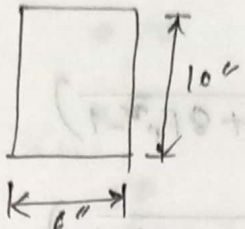
$= 5.28 \text{ ksi}$

Average shear stress, $\tau_{avg} = \frac{V}{A} = \frac{34}{12 \times 18} = 0.16 \text{ ksi}$

12. Define BOD and COD. Why COD is greater than BOD.

BPDB - 2013 [BUET]

1. Determine the flexural stress of a beam section and have moment 50 K-ft.



Solution: we know,

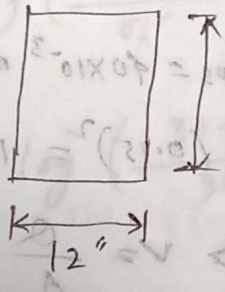
$$f = \frac{MY}{I} = \frac{50 \times 12 \times 5}{500}$$

$$I = \frac{6 \times 10^3}{12} = 500 \text{ in}^4$$

$$\therefore f = 6 \text{ KSI}$$

(Ans.)

2. Determine the compressive load capacity of a column having 10- $\frac{3}{4}$" dia bar, $f_c' = 4$ KSI and $f_y = 60$ KSI



Solution: we know,

$$P_u = \alpha \phi A_g \left[0.85 f_c' + \rho_s (f_y - 0.85 f_c') \right]$$

$$= 0.80 \times 0.65 \times (12 \times 16) \left[0.85 \times 4 + \frac{10 \times 0.44}{12 \times 16} (60 - 0.85 \times 4) \right]$$

$$= 2911.47 \text{ Kip.}$$

(Ans.)

3. The subsequent depth ratio 16.48 of a jump, what will be the Fraud number and type of jump?

Solution: We know,

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8F_r^2}-1\right)$$

$$\Rightarrow 16.48 = \frac{1}{2}\left(\sqrt{1+8F_r^2}-1\right)$$

$$\Rightarrow F_r = 12 \quad \text{which is greater than 9.}$$

So, Type of Jump = strong

4. The discharge of pipe is 40 lps and pipe dia. 150 mm the head loss loss due to friction is $13\frac{v^2}{2g}$. If efficiency 73%, what will be the input power.

Solution: Given, $Q = 40 \text{ lps} = 40\times10^{-3}\ m^3/sec.$

$$A = \frac{\pi}{4}\times(0.15)^2 = 1.767\times10^{-2}\ m^2$$

$$Q = AV \Rightarrow V = \frac{Q}{A} = \frac{40\times10^{-3}}{1.767\times10^{-2}} = 2.264\ m/sec.$$

Head loss due to friction, $h_L = 13\times\frac{(2.264)^2}{2\times9.81} = 3.4\ m.$

$$\therefore \text{Input Power} = \frac{\gamma Q h_L}{746\,\eta} = \frac{9.81\times10^3\times40\times10^{-3}\times3.4}{746\times0.75} = 2.385\ HP.$$

5. Determine the stopping sight distance for a highway with design speed 30 mph. $f = 0.42$. Assume missing data.

Solution:

$$SSD = 1.47Vt + \frac{v^2}{30f} = 1.47\times30\times2.5 + \frac{30^2}{30\times0.42}$$

$$\therefore SSD = 181.7\ ft.$$

(Ans.)

7. For a sand sample 25% retain on each of 30, 50, 100 and 200 No. sieve. Determine the FM of the sample.

Solution:

Sieve No.	#30	#50	#100	#200
% retain	25	25	25	25
cumulative % retain	25	50	75	100

$\therefore$ FM of the sample $= \frac{25+50+75}{100} = 1.5$ (Ans.)

8. Determine the settlement of a clay sample of 2.5 m in the middle height of the clay. Increasing pressure = 30 kN/m^2 and Initial pressure = 30 kN/m^2. Given, $C_c = 1.5$, $e_0 = 0.8$

Solution: we know,

$$S_c = \frac{C_c H_c}{1+e_0} \times \log\left(\frac{\sigma_0' + \Delta\sigma_0'}{\sigma_0'}\right)$$

$$= \frac{1.5 \times 2.5}{1+0.8} \times \log\left(\frac{30+30}{30}\right)$$

$$= 0.627 \text{ m}$$

(Ans.)

9. A nine group pile each of 60ft long. The unconfined compressive strength = 1000 kip/ft^2. dia of pile = 18". The factor of safety = 3 Determine the allowable bearing capacity of the each pile.

Use, $\alpha = 0.56$.

Here, $C = \frac{1000}{2} = 500$ k/ft^2

Solution: we know, $Q_u = C N_c A_p + \alpha C_u p L$

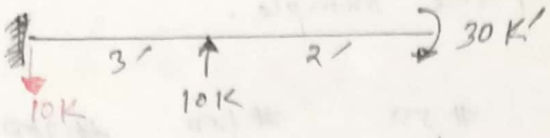
$$= 500 \times 9 \times \frac{\pi}{4} \times \left(\frac{18}{12}\right)^2 + 0.56 \times 500 \times \pi \times \frac{18}{12} \times 60$$

$$= 87120.5 \text{ kip}.$$

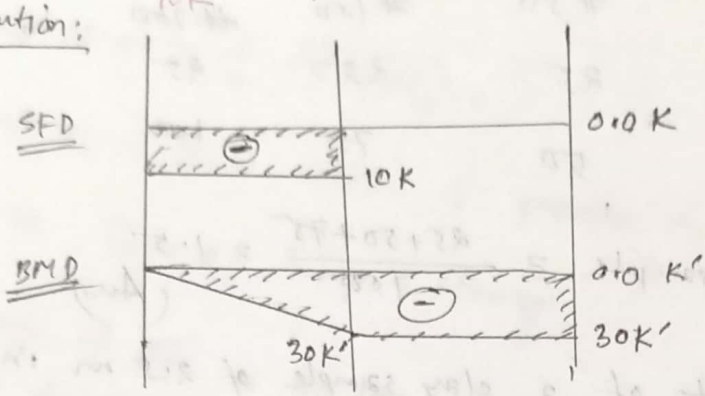
$\therefore Q_{all} = \frac{Q_u}{FS} = \frac{87120.5}{3} = 29040.165$ kip. (Ans.)

subsequent depth ratio ...
Fraud number

10. Draw SFD and BMD of the following beam:



Solution:



11. Determine the apparent sp. gr. bulk sp. gr. and % absorption of a sample.
oven dry weight of sample = 3420 gm
SSD weight of sample = 3485.
volume of the specimen = 1200 cm^3

Solution; Given,
A = 3420
B = 3485
C = (3420 − 1200) = 2220 gm

Bulk sp. gr. (dry) = $\frac{A}{B-C}$
= $\frac{3420}{3485-2220}$
= 2.70

Bulk sp. gr. (SSD) = $\frac{B}{B-C}$
= $\frac{3485}{3485-2220}$
= 2.755

Apparent sp. gr. = $\frac{A}{A-C}$ = $\frac{3420}{3420-2220}$
= 2.85

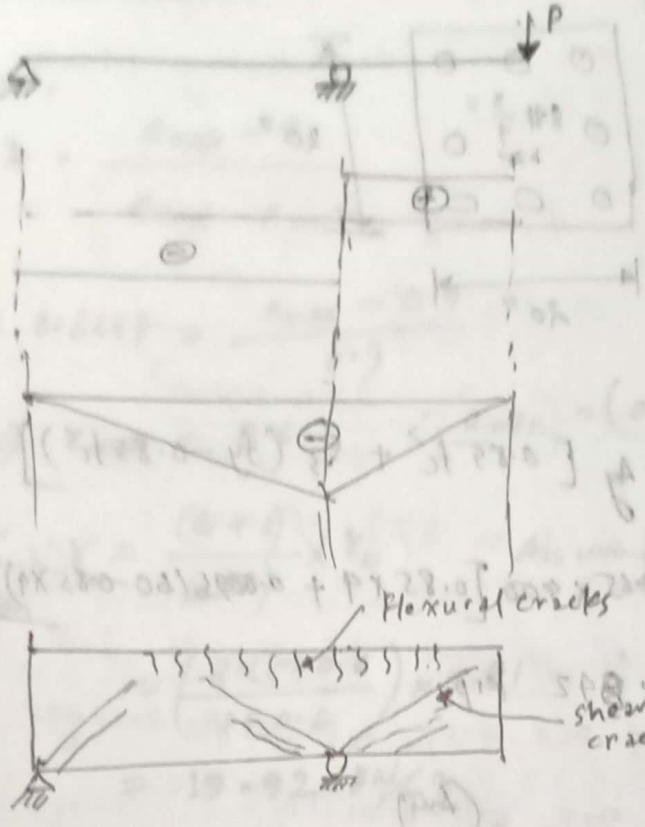
% Absorption = $\left(\frac{3485-3420}{3420}\right) \times 100\%$ = 1.90 %

(Ans.)

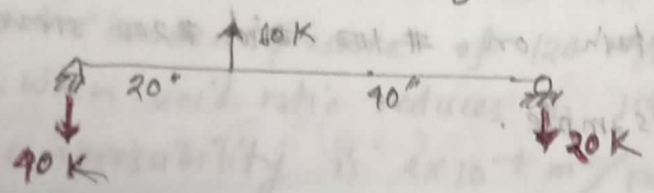
12. What is the impact of climate change.
13. Why COD is greater than BOD
14. Explain Hardy Principal for sanitary plumbing fix.
15. Write the significant of the following term — (a) NO_3
(b) E-coli.

1. Draw qualitative shear and flexural cracks in a simply supported beam shown in below:

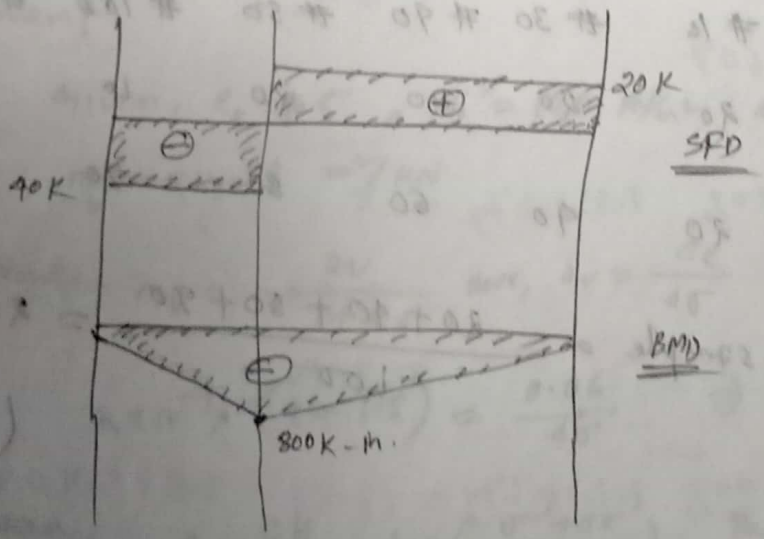
Solution:



2. Draw SFD and BMD of the following beam:



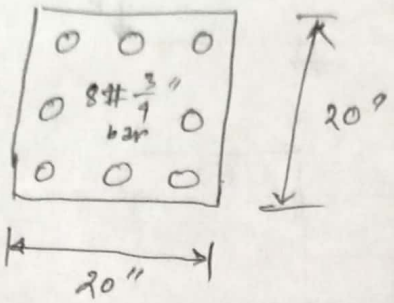
Solution:



SFD

BMD

3. Determine the ultimate axial compression strength of the following column. Given, $f_c' = 4$ ksi, $f_y = 60$ ksi.



Solution:

We know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$= 0.8 \times 0.65 \times 400 [0.85 \times 4 + 0.0088 (60 - 0.85 \times 4)]$$

$$= 810.8 \text{ kip.}$$

(Ans)

$A_g = (20 \times 20)$
$= 400 \text{ in}^2$

$\rho_s = \frac{A_b}{A}$

$= \frac{8 \times 0.44}{20 \times 20}$

$= 0.0088$

4. For a sand sample, 20% retain on each of #16, #30, #40, and #50. Rest 20% retain on #100 and #200 sieve equally. Find the FM of the sample.

Solution:

Sieve No.	#16	#30	#40	#50	#100	#200
% retain	20	20	20	20	10	10
cumulative % retain	20	40	60	80	90	100

$\therefore$ FM of the sample $= \frac{20 + 40 + 80 + 90}{100} = 2.3$

(Ans.)

5. Difference between maximum and minimum void ratio is 0.3. If relative density 66.67% at void ratio 0.4, what will be the saturated density at its loosest state?

Solution: we know,

$$I_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

$$\Rightarrow 0.6667 = \frac{e_{max} - 0.4}{0.3}$$

$$\Rightarrow e_{max} = 0.6 \quad \therefore e_{min} = (0.6 - 0.3) = 0.3$$

Then we know, $\gamma_{sat} = \frac{(G+e)}{(1+e)} \times \gamma_w$ Assume, $G_s = 2.65$

At loosest condition $e = e_{max} = 0.6$

$$= \left(\frac{2.65 + 0.6}{1 + 0.6}\right) \times 9.81$$

$$= 19.92 \text{ KN/m}^3$$

(Ans.)

6. A clay stratum of 5 m thick has the initial void ratio of 1.5 and effective overburden pressure of 120 KN/m². What is the increased pressure, when void ratio reduces to 1.44. Value of co-efficient of volume compressibility is 2×10^{-4} m²/KN. Also calculate the final settlement.

Solution: Given, $e_0 = 1.5$, $\sigma_0' = 120$ KN/m², $\Delta e = (1.5 - 1.44) = 0.06$

$m_v = 2 \times 10^{-4}$ m²/KN

Now, $m_v = \frac{a_v}{1 + e_0}$ Here, $a_v = \frac{\Delta e}{\Delta \sigma} = \frac{0.06}{\Delta \sigma}$

$$2 \times 10^{-4} \times (1 + 1.5) = \frac{0.06}{\Delta \sigma} \Rightarrow \Delta \sigma = 120 \text{ KN/m}^2$$

Then, $S = \frac{C_c H}{1 + e_0} \times \log\left(\frac{\sigma' + \Delta\sigma'}{\sigma'}\right)$ Here, $C_c = \frac{0.06}{\log\left(\frac{120+120}{120}\right)} = 0.2$

$$= \frac{0.2 \times 5}{1 + 1.5} \times \log\left(\frac{120 + 120}{120}\right) = 0.12$$

(Ans.)

* $S = \frac{\Delta e H}{1 + e_0}$

$= \frac{0.06 \times 5}{1 + 1.5} = 0.12$m (Ans.)

7. Two close wheel imparted 20.5 kN load each on road. The applied pressure is 0.7 MPa. If the wheel is replaced by a single wheel of same properties. Then find out the imparted effective diameter on soil (considering circular imparted) by the single wheel.

Solution: we know, $P = \frac{F}{A}$

$$\Rightarrow A = \frac{F}{P}$$

$$\Rightarrow \frac{\pi}{4} \times D^2 = \frac{2 \times 20.5 \times 10^3}{0.7}$$

$$\Rightarrow D = 273.08 \text{ mm}.$$

(Ans)

8. CBR value found of 10 km length as 3.8, 2.8, 3.2, 4.3, 2.8, 4.7, 4.3, 3.9, 4.1 and 4.5%. Find the average CBR and Design CBR at 50% and 90% reliability.

Solution: Average CBR, $\bar{x} = \frac{3.8 + 2.8 + \ldots\ldots + 4.1 + 4.5}{10} = 3.84$

$$S_d = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{(3.8-3.84)^2 + (2.8-3.84)^2 + \ldots\ldots + (4.5-3.84)^2}{10-1}}$$

$\therefore S_d = 0.607$

$\therefore$ Design CBR at 50% reliability $= \bar{x} - z s_d$

$= 3.84 - (0 \times 0.607)$

$= 3.84$

Design CBR at 90% reliability $= (3.84 - 1.645 \times 0.607)$

$= 2.84$

(Ans)

one million gallon of water passes through a sedimentation tank through a sedimentation tank. If the size of the Tank is $20' \times 50' \times 10'$. Find the detention time of the tank.

Solution:

we know,

$$T = \frac{V}{Q} = \frac{L \times B \times H}{Q}$$

Here,

$Q = 1\,Mgd = 1 \times 10^6 \times 3.785\ l/day$

$= (3.785 \times 10^6 \times 10^{-3}) \times (3.28)^3\ ft/day$

$= 13.36 \times 10^4\ ft/day$

$\therefore T = \frac{20 \times 50 \times 10}{13.36 \times 10^4} = 0.075\ day$

$\therefore T = 1.8\ hrs.$

(Ans)

10. Calculate the total pressure and effective pressure of a swimming pool having 5 m of water level from ground.

Solution:

Total pressure $= \gamma_w h = (9.81 \times 5) = 49.05\ KN/m^2$

effective pressure $= 0\ KN/m^2$

(Ans)

11. Rain fall Intensity $= 2.9\ m/yr$. Run off coefficient $= 0.7$. Find the minimum catchment for daily water demand is 15 lped of 7 people.

Solution: Total demand $= (15 \times 7) = 105\ l/day = 105 \times 10^{-3}\ m^3/day$

$= 4.375 \times 10^{-3}\ m^3/hr$

we know,

$Q = CIA$

Here, $I = 2.9\ m/yr = \frac{2.9}{365 \times 24} = 2.74 \times 10^{-4}\ m/hr$

$\Rightarrow A = \frac{Q}{CI} = \frac{4.375 \times 10^{-3}}{0.7 \times 2.74 \times 10^{-4}} = 22.81\ m^2$

(Ans)

12. Calculate the minimum capacity of the storage tank required for a family of 10 person to be supplied with 10 lpcd of rain water. The rainfall intensity is 2.5 m/year and the rainfall distribution is such that at least 35% of the rain water must be stored for uninterrepted water supply throughout the year. Also calculate minimum catchment area required when the co-efficient of runoff = 0.7

Solution:

Given, $Q = (10 \times 10) = 100$ l/day $= 100 \times 10^{-3}$ m^3/day

$I = 2.5$ m/year $= \frac{2.5}{365}$ m/day $= 6.85 \times 10^{-3}$ m^3/day

$C = 0.7$

effective volume stored in tank, $V = fQ$

$= (0.35 \times 100 \times 10^{-3})$

$= 0.035$ m^3/day

$= 12.775$ m^3/year.

Minimum area required for rainwater, $A = \frac{Q}{CI}$

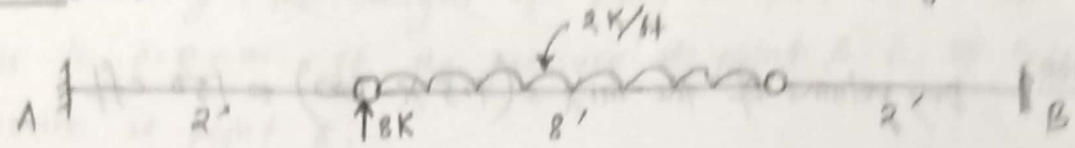
$= \frac{100 \times 10^{-3}}{0.7 \times 6.85 \times 10^{-3}}$

$= 20.86$ m^2

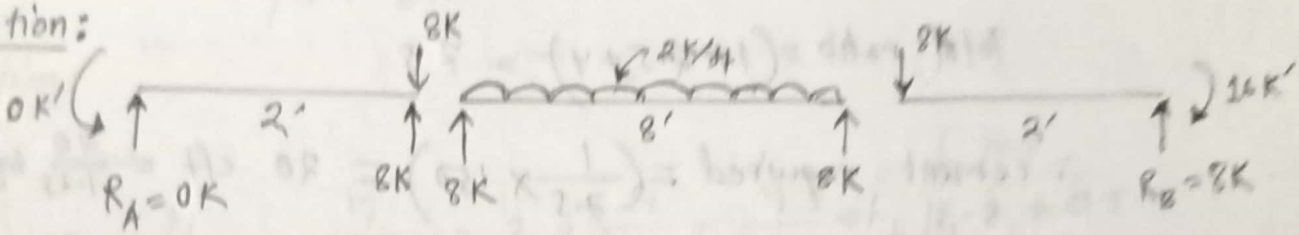
(Ans.)

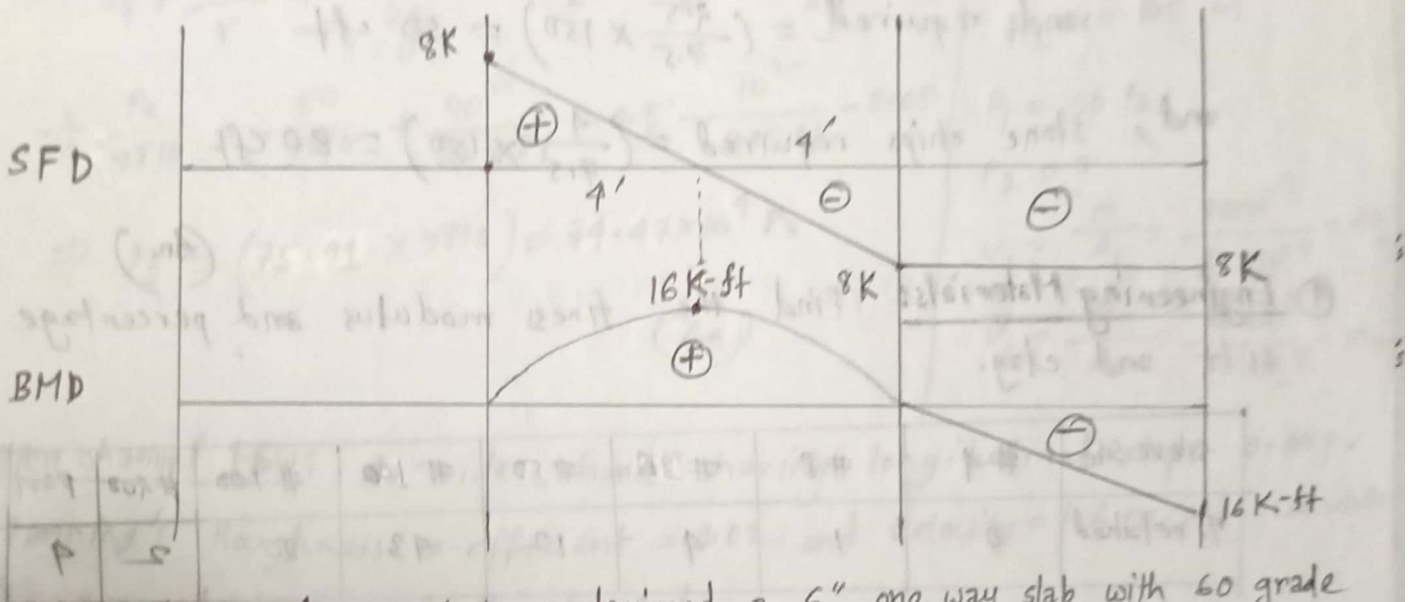
PGCB-2021 & CPGCBL-2022 [Exam Taker: BUET]

① **Structure:** Draw SFD and BMD of the following structure:



Solution:





② **Reinforced Concrete:** A designer designed a 6" one way slab with 60 grade reinforcement. He used # 4 bar as main reinforcement and provided spacing at 5 in c/c. A second designer designs the slab with 500 W reinforcement instead of 60 Grade reinforcement and used 12 mm bar as main rebar instead of # 4 bar. What would be the spacing of slab by the second designer.

Solution:

For First designer: Reinforcement used in the slab, $A_{st(1)} = \frac{0.20}{5} \times 12 = 0.48 \text{ in}^2$

For Second designer: Rebar Grade, $f_{y_2} = 500\,W = (500 \times 145) = 72500$ psi

$f_{y_1} = 60$ Grade $= 60,000$ psi

Now, Required steel, $A_{st(2)} = \frac{0.48 \times 60000}{72500} = 0.3972 \text{ in}^2$

$\therefore$ spacing, $S = \frac{\frac{\pi}{4} \times (\frac{12}{25.4})^2}{0.3972} \times 12 = 5.3$ in c/c $\simeq 5.25$" c/c (Ans.)

③ **Engineering Materials:** A freshly concrete mix of 100 cft is mixed in a proportion of 1:2·5:4, find the volume of ingredients used in the mix.

Solution: Dry volume of the mix $= (1.5 \times 100) = 150$ cft

Total ratio $= (1 + 2.5 + 4) = 7.5$

$\therefore$ cement required $= \left(\frac{1}{7.5} \times 150\right) = 20$ cft $= \frac{20}{1.25}$ bags $= 16$ bags

sand required $= \left(\frac{2.5}{7.5} \times 150\right) = 50$ cft

and, stone chips required $= \left(\frac{4}{7.5} \times 150\right) = 80$ cft

(Ans:)

④ **Engineering Materials:** Find the finess modulus and percentage of silt and clay.

sieve size	#4	#8	#16	#30	#50	#100	#200	pan
% retained	0	1	4	12	43	2	2	4

Solution:

cumulative % retain	0	1	5	17	60	62	64	68

$\therefore$ FM of the sample $= \frac{0+1+5+17+60+62}{100} = 1.45$

% silt and clay = % passing #200 sieve $= (68 - 64) = 4\%$

(Ans:)

⑤ **Fluid Mechanics:** Water flows through a pipe from A to B at 80 l/sec, cross sectional area of the pipe at A and B is 20 cm^2 and 80 cm^2 respectively. The height of point B from A is 0.5 m and head loss is 0.05 m. If the pressure at point A is 50 Pa, find out the pressure at point B.

Solution:

we know,

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$$\Rightarrow \frac{P_2}{9810} = \frac{50}{9810} + \frac{40^2}{2\times 9.81} - 0.5 - \frac{10^2}{2\times 9.81} - 0.05$$

$$\Rightarrow P_2 = (75.91 \times 9810) = 74.47\times 10^4 \text{ Pa}$$

(Ans)

Here,

$z_2 - z_1 = 0.5$ m

$h_L = 0.05$ m

$P_1 = 50$ Pa

$P_2 = ?$

$V_1 = \frac{Q}{A_1} = \frac{80\times 10^{-3}}{20\times 10^{-4}} = 40$ m/s

$V_2 = \frac{Q}{A_2} = \frac{80\times 10^{-3}}{80\times 10^{-4}} = 10$ m/s

⑥ **Open channel Flow:** A wide channel having longitudinal slope 0.001. Manning's Roughness co-efficient = 0.02 and velocity = 1.6 m/sec. Calculate the normal depth of the channel.

Solution: for wide channel, $R = h$

we know, $V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$

$$\Rightarrow h^{\frac{2}{3}} = \frac{nV}{\sqrt{S}} = \frac{0.02\times 1.6}{\sqrt{0.001}} = 1.012$$

$\therefore h = 1.018$ m.

(Ans)

⑦ **Environment Engineering:** The dilution factor is 50 for 5 days BOD test having initial dissolve oxygen 7.4 mg/l and final dissolved oxygen 4.3 mg/l. The rate of constant (e base) is 0.2 per day. Determine the ultimate BOD.

Solution:

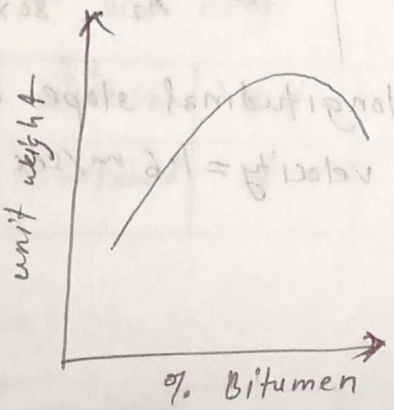
We know, $BOD_5 = (DO_i - DO_f) \times DF = (7.4 - 4.3) \times 50 = 155 \text{ mg/l}$

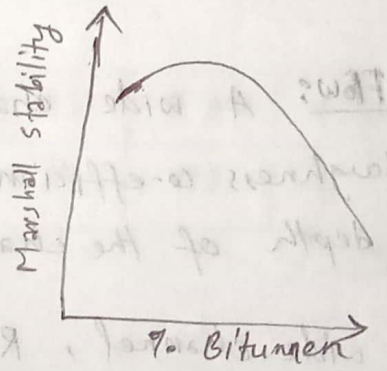
Now, $BOD_5 = L_o (1 - e^{-K \times 5})$

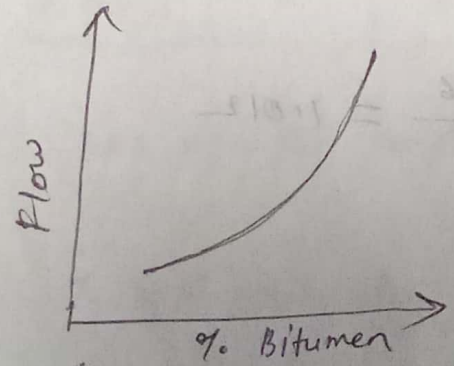
$\Rightarrow L_o = \frac{155}{(1 - e^{-0.2 \times 5})} = 245.21 \text{ mg/l}$

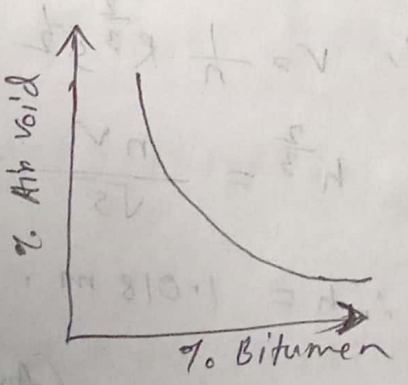
(Ans.)

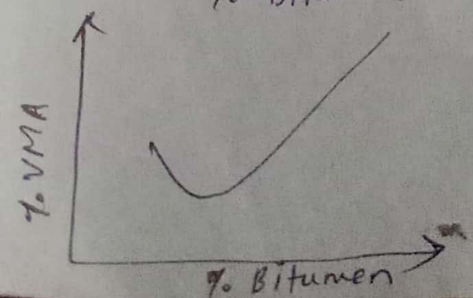
⑧ **Transportation Engineering:** Draw Marshall Design Curve.

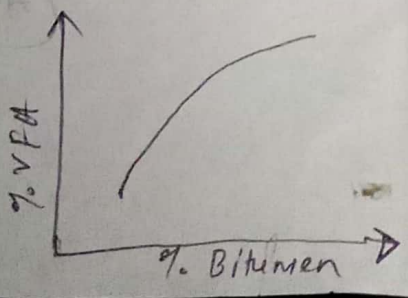












PGCB-2020 BUET

1. A wide channel with $S_o = 0.0025$ carries a discharge of $3\ m^2/sec$. compute the normal depth and velocity using manning's formula if $n = 0.020$.

Solution; We know, $V = \frac{1}{n} h^{\frac{2}{3}} S_o^{\frac{1}{2}}$

$\Rightarrow V = \frac{1}{0.020} \times h^{\frac{2}{3}} \times (0.0025)^{\frac{1}{2}}$

$\Rightarrow V = 2.5\, h^{\frac{2}{3}}$

Then, $Q = AV = h \times 2.5\, h^{\frac{2}{3}}$ For wide channel, $A \simeq h$ $(b=1)$

$\Rightarrow h^{\frac{5}{3}} = \frac{Q}{2.5} = \frac{3}{2.5}$

$\therefore$ Normal depth, $h = \left(\frac{3}{2.5}\right)^{\frac{3}{5}} = 1.1156\ m$.

$\therefore V = 2.5 \times (1.1156)^{\frac{2}{3}} = 2.69\ m/sec$. (Ans)

2. Design an irrigation channel using Lacey's theory in alluvial soil from following data:
Discharge = 15 cumec. Lacey's silt factor = 1.0, Side slope = $\frac{1}{2}:1$

Solution; $V = \left[\frac{Qf^2}{140}\right]^{\frac{1}{6}}$

$\therefore V = \left[\frac{15 \times 1^2}{140}\right]^{\frac{1}{6}} = 0.689\ m/s$

$A = \frac{Q}{V} = \frac{15}{0.689} = 21.765\ m^2$

$R = 2.5\left(\frac{V^2}{f}\right) = 2.5\left(\frac{0.689^2}{1}\right) = 1.187\ m$

$P = 4.75 \times \sqrt{Q} = 4.75\sqrt{15} = 18.40\ m.$

$S = \left[\frac{f^{\frac{5}{3}}}{3340 Q^{\frac{1}{6}}}\right] = \left[\frac{1^{\frac{5}{3}}}{3340 \times (15)^{\frac{1}{6}}}\right] = \frac{1}{5245.2}$

Now, $A = (b+sh)h$

$\Rightarrow (b+0.5h)h = 21.765$ ..... ①

Again,

$P = b + 2(\sqrt{1+s^2}) \times h$

$\Rightarrow b + 2\sqrt{1+(0.5)^2} \times h = 18.40$

$\Rightarrow b = 18.40 - 2.236h$

putting the value of b in eqn ① we get,

$(18.40 - 2.236h + 0.5h)h = 21.765$

$\Rightarrow h = 1.3565$ m

$\therefore b = (18.40 - 2.236 \times 1.3565) = 15.37$ m.

(Ans:)

Calculate the amount of bleaching powder needed to disinfectant 1000000 Liter water in a storage tank to a dose of 5 ppm. Bleaching poweder contains 25% Chlorine.

Solution:

Amount of chlorine $= (1000000 \times 0.5)$ mg

$= 500000$ mg $= 0.5$ Kg

$\therefore$ Bleaching powder required $= \left(\frac{100}{25} \times 0.5\right) = 2$ Kg.

(Ans:)

4. Find the FM & % of silt and clay.

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	5	12	12	31	30	2	4

Solution:

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
cumulative % retain	0	1	6	18	30	61	94	96	100

$\therefore$ FM of the sample $= \frac{1+6+18+61+94}{100} = 1.83$

% silt & clay = % passing the #200 sieve.

$= (100 - 96) = 4\%$

5. Reciprocal leveling was done to determine the difference in elevation between station A & B. The following observations are made:

Station at	staff reading. A	B
A	$a_1 = 3.20$	$b_1 = 2.50$
B	$a_2 = 2.30$	$b_2 = 1.90$

If RL of A = 210 m, Find the RL of B.

Solution: True difference between A and B $= \frac{(a_1 - b_1) + (a_2 - b_2)}{2}$

$= \frac{(3.20 - 2.50) + (2.30 - 1.90)}{2}$

$= 0.55$ m

$\therefore$ RL of B $= (210 + 0.55) = 210.55$ m.

(Ans)

6. Define BOD and COD. which value is greater and why?

Solution:

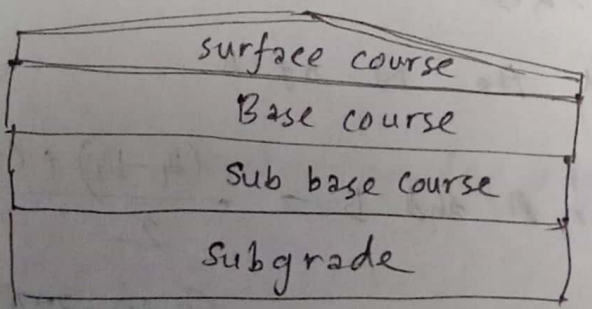
BOD: BOD (Biological Oxygen Demand) is defined as the amount of oxygen required by micro organism for the decomposition of biodegradable organic matter under aerobic condition.

COD: COD (chemical Oxygen Demand) is defined as the amount of oxygen required by oxidizing agent for oxidation of both ~~biodegra~~ organic matter and inorganic matter under acidic condition.

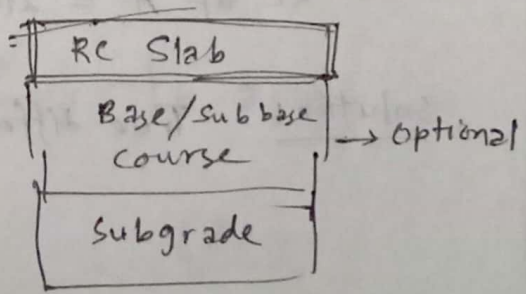
COD is greater than BOD because COD measures all types of organic matter (biodegradable and non biodegradable) and in organic matter while, BOD only measures biodegradable ~~wate~~ organic matter.

7. Draw a cross section of Flexible and Rigid Pavement.

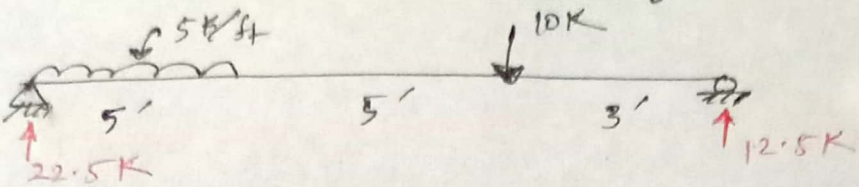
Solution:



Flexible Pavement



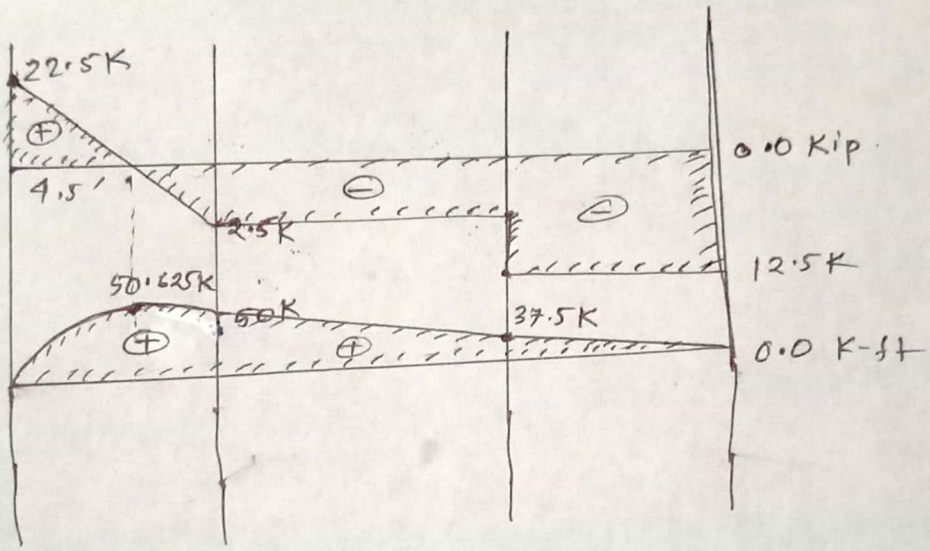
8. Draw SFD and BMD of the following beam:



Solution:

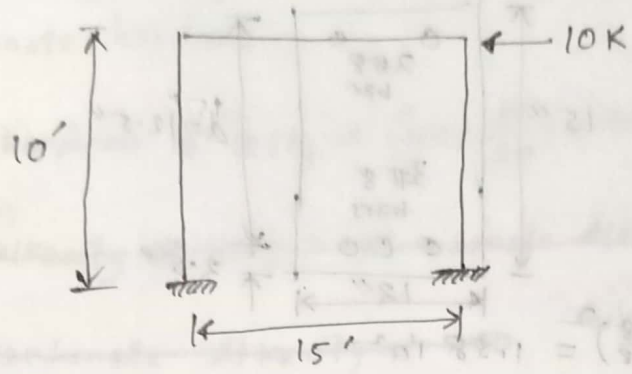
SFD

BMD

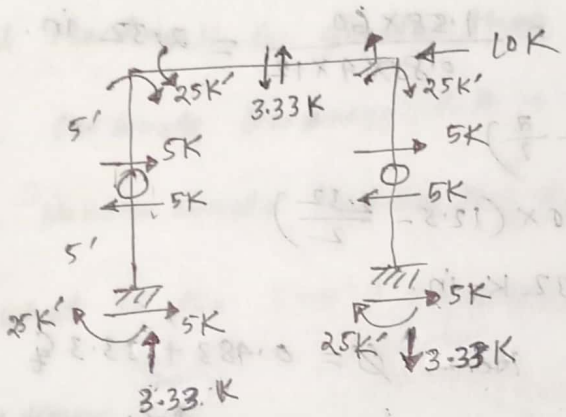


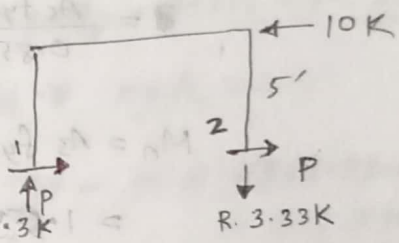
PGCB - 2019 [BUET]

1. Draw BMD, SFD and AFD by portal method.



Solution:





$\Sigma F_x = 0$

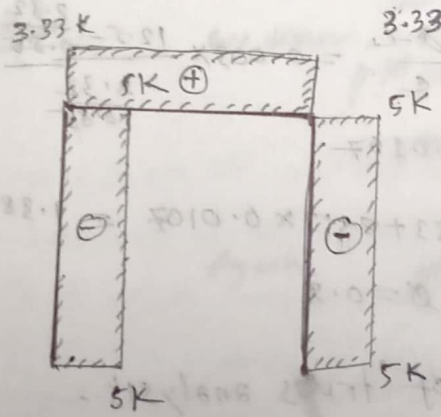
$2P - 10 = 0$

$\Rightarrow P = 5K$

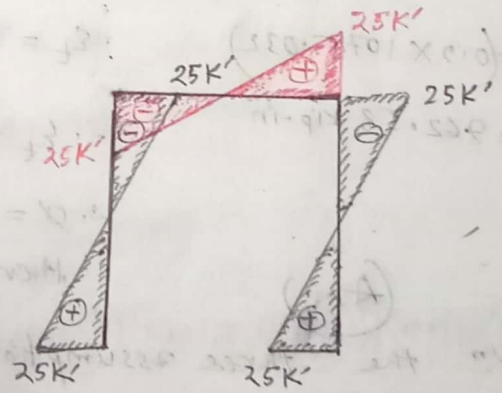
$\Sigma M_1 = 0$

$10 \times 5 - R_2 \times 5 = 0$

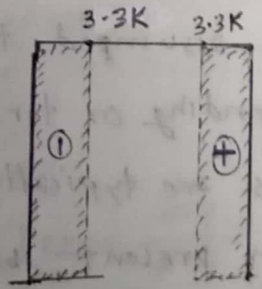
$\Rightarrow R_2 = 3.33K$



SFD

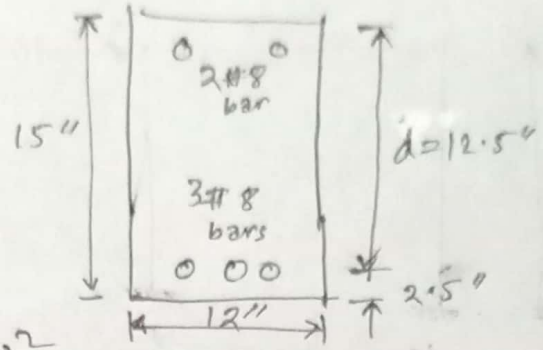


BMD



AFD

2. Determine flexural moment capacity of the cantilever beam having concrete clear cover = 2.5 inch. Given f_y = 60 ksi, f_c' = 4 ksi. Assume singly reinforced.



Solution: $A_s = 2 \times \frac{\pi}{4}\left(\frac{8}{8}\right)^2 = 1.58 \text{ in}^2$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{1.58 \times 60}{0.85 \times 4 \times 12} = 2.32 \text{ in.}$$

$$\therefore M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

$$= 1.58 \times 60 \times \left(12.5 - \frac{2.32}{2}\right)$$

$$M_n = 1075.032 \text{ K-in.}$$

$M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\,\varepsilon_t$

$= (0.9 \times 1075.032)$ $\varepsilon_t = \varepsilon_u \times \frac{d-c}{c} = 0.003 \times \frac{12.5 - \frac{2.32}{0.85}}{\frac{2.32}{0.85}}$

$M_u = 962.53$ Kip-in $\therefore \varepsilon_t = 0.0107$

$\therefore \phi = 0.483 + 83.3 \times 0.0107 = 1.38 > 0.9$

Hence, $\phi = 0.9$

(Ans:)

3. Write down the three assumption of truss analysis.

Solution: (i) Trusses are usually analyzed under assumption of linear elastic behavior.

(ii) Truss members are assumed to only experience axial deformation and no bending or torsional deformations.

(iii) The joints in a truss are typically assumed to be pinned.

(iv) There is no friction present between the members and supports.

(v) The weight of members are to be neglected.

4. Alkanity of a water sample is 200 mg/L as $CaCO_3$. The Ca^{2+} concentration is 160 mg/L as the ion and Mg^{2+} concentration is 40 mg/L as the ion. The pH is 8.1. Find the total, carbonate and non bicarbonate hardness.

Solution: Total hardness as $CaCO_3 = \left(160 \times \frac{50}{20} + 40 \times \frac{50}{12.2}\right) = 563.93$ mg/L

~~Total alkanity as HCO_3 = bicarbonate Alkanity × 1.22~~

Given, Alkanity = 200 mg/L

~~∴ bicarbonate Alkanity = 200~~

We know, If Total Hardness is greater than Alkanity, Then, C.H = Alkanity

Hence, Carbonate Hardness, C.H = 200.0 mg/L

∴ Noncarbonate Hardness, N.C.H = TH − C.H = (563.93 − 200)
= 313.93 mg/L (Ans')

5. If pH = 9.5, what is the $[OH^-]$ concentration.

Solution: We know,

$$pH + pOH = 14$$

$$\therefore pOH = (14 - 9.5) = 4.5$$

Again, $pOH = -\log[OH]$

$$\Rightarrow [OH^-] = 10^{-4.5} = 3.16 \times 10^{-5} \text{ mole/L}$$

6. Grain size distribution of a soil are given below. Find C_u, C_c. Comment is it well graded?

% finer	partial size
60	0.4
	0.2
30	0.05
10	

Solution: $C_u = \frac{D_{60}}{D_{10}} = \frac{0.4}{0.05} = 8$

$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(0.2)^2}{0.4 \times 0.10} = 2$

since, $C_u > 6$ and $1 \le C_c \le 3$, Hence the soil is well-graded.

7. Determine the ultimate capacity of a strip footing of 1 m is laid at a depth of 1.5 m. water table is at 8 m below the ground level. Given, $\gamma = 16\ KN/m^3$, cohesion $= 30\ KN/m^2$, $\theta = 35^\circ$, $N_c = 17$, $N_q = 12$, $N_\gamma = 5$.

Solution: $q_u = CN_c + qN_q + 0.5\gamma BN_\gamma$

$= 30 \times 17 + 8 \times 12 + 0.5 \times 16 \times 1 \times 5$

$= 646\ KN/m^2$

Here, $C = 30\ KN/m^2$

$q = (16 \times 0.5) = 8\ KN/m^2$

8. Find the active pressure of the sandy soil at a depth 4.5 m. where $\phi = 37^\circ$, $\gamma = 16.5\ KN/m^3$

Solution: $K_2 = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 37}{1+\sin 37} = 0.248$.

Now, $P_2 = K_2 \gamma H$

$= (0.2486 \times 16.5 \times 4.5)$

$= 18.414\ KN/m^2$

9. The BOD of a waste water is estimated to be 180 mg/L. what volume of undiluted sample should be added to a 300 mL bottle? Also, what are the sample size and dilution factor using this volume? Assume 4 mg/L BOD can be consumed in the BOD Bottle.

Solution:

sample size needed $= \frac{4}{180} \times 100 = 2.22\%$.

$\therefore$ volume of undiluted sample $= (0.0222 \times 300)\ mL$

$= 6.67\ mL \simeq 7\ mL$

$\therefore$ Actual sample size $= \left(\frac{7}{300} \times 100\right) = 2.33\%$

$\therefore$ Dilution factor $= \frac{300\ mL}{7.00\ mL} = 42.9$ (Ans.)

10. In a place, number of vehicle passes per hour is shown in table below:

vehicle	pcu factor	Flow (veh/hr)
Bus	3	41
car	1	263
3 Wheeler	0.5	55
NMT	0.5	48
Mottorcycle	0.1	43

If HEF = 42, then find the daily ADT.

Solution:

we know,

$$HEF = \frac{\text{Total No. of vehicle in a day (24-hour)}}{\text{No. of vehicle for a particular hour}}$$

$\therefore$ Daily volume = HEF × No. of vehicle in a hour.

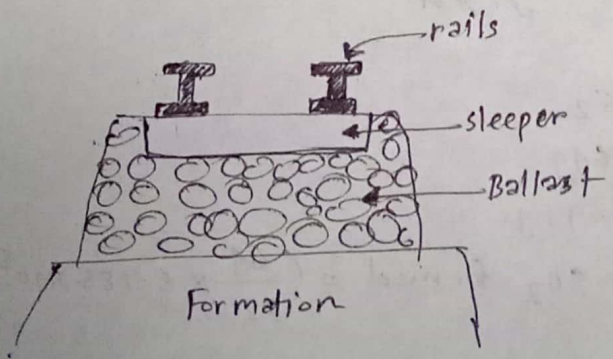
$= 42 \times (3\times41 + 263\times1 + 0.5\times55 + 0.5\times48 + 0.1\times43)$

$= 18555.6$ pcu/day

≈ 18556 pcu/day.

(Ans)

11. Draw permanent way of Railway.



12. A 36 kip axle load is repeated 1000 times a day. What will be the number of standard axles for this axle load in a year?

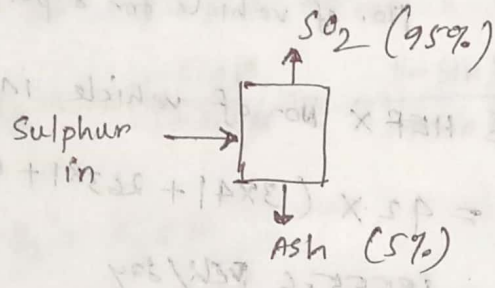
Solution: Load Equivalency factor $= \left(\frac{L}{L_S}\right)^4 = \left(\frac{36}{18}\right)^4 = 16$

$ESAL_{(year)} = 365 \times 1000 \times 16 = 5840000$ times.

(Ans.)

13. The boropukuria coal is burned at a rate 1 Kg/sec. Analysis of BUET lab shows the coal revels a sulphur content of 3 what is the annual rate of emission of SO_2. Assume that 5% of the sulphur in the coal ends up in the ash.

Solution:



The amount sulphur in $= (1 \text{ Kg/sec.} \times 0.03) = 0.03$ Kg/sec.

The amount of sulphur available for conversion of SO_2

$= (0.95 \times 0.03 \times 60 \times 60 \times 24 \times 365)$ Kg/year

$= 8.988 \times 10^5$ Kg/year

$S + O_2 = SO_2$

32g 64g

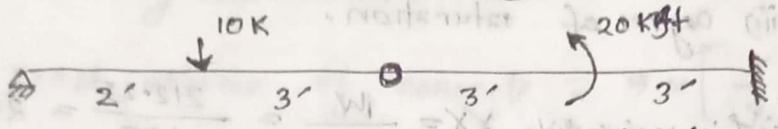
32 Kg 64 Kg

∴ Amount of SO_2 formed $= \left(\frac{64}{32} \times 8.988 \times 10^5\right) = 1.78 \times 10^6$ Kg/year

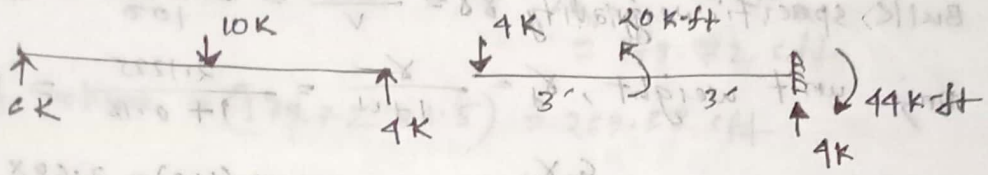
(Ans.)

PGCB-2018 BUET

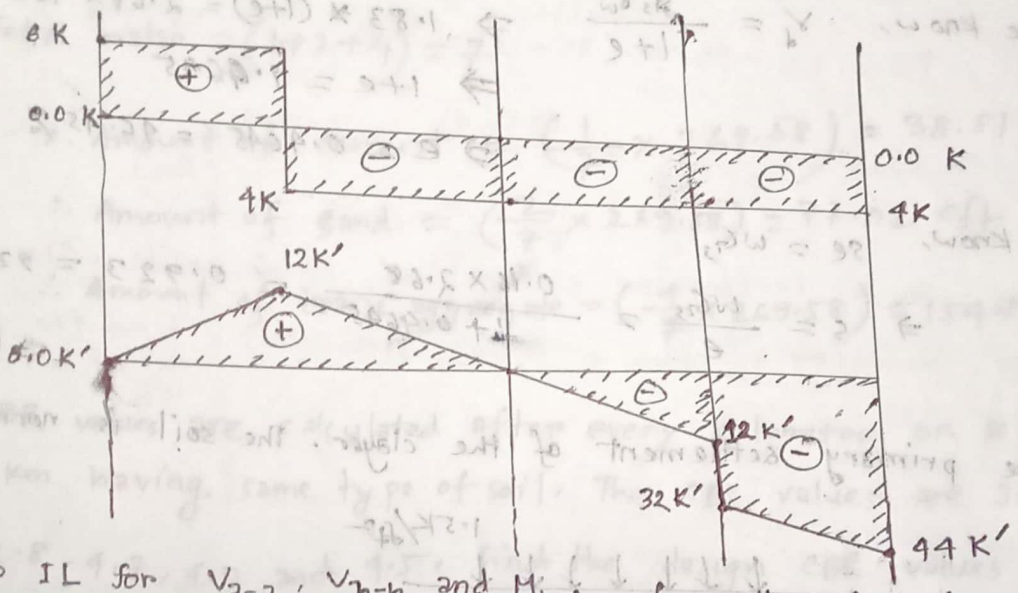
1. Draw SFD and BMD of the following beam:



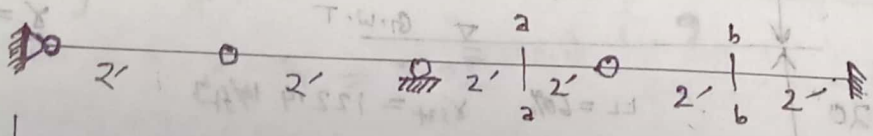
Solution:

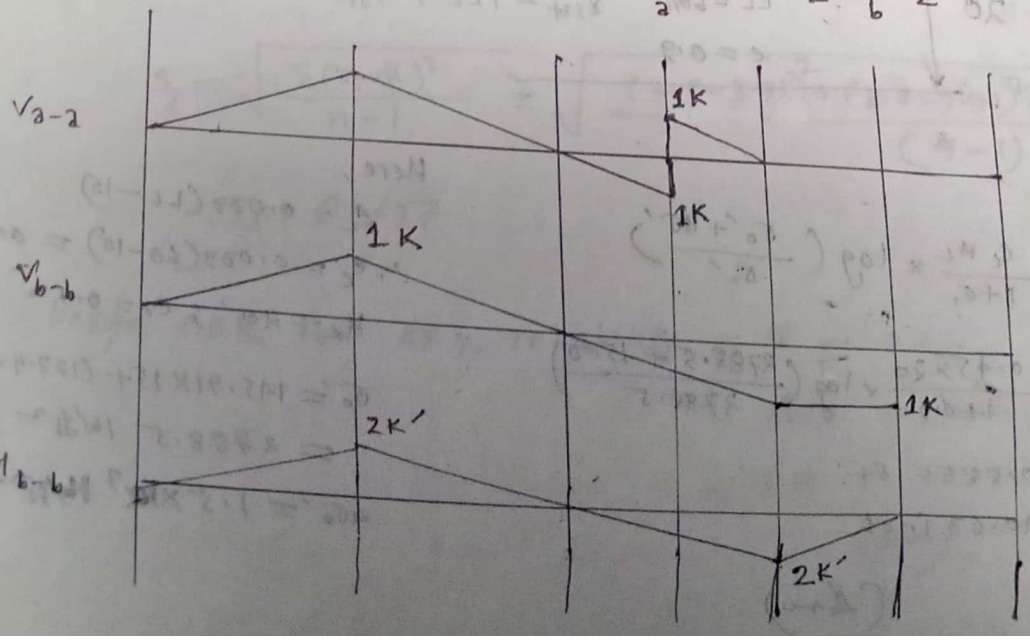


SFD



2. Draw IL for V_{a-a}, V_{b-b} and M_{b-b} for the following structure.





3. A moist soil sample of 100 cm^3 has mass of 212.25 gm. water content is 16%. specific gravity of soil is 2.68. Calculate (i) void ratio (ii) Dry unit weight (iii) Degree of saturation.

Solution:

Bulk unit weight, $\gamma = \frac{M}{V} = \frac{212.25}{100} = 2.1225\ gm/cm^3$

Dry unit weight, $\gamma_d = \frac{\gamma}{1+w} = \frac{2.1225}{1+0.16} = 1.83\ gm/cm^3$

We know, $\gamma_d = \frac{G_s \gamma_w}{1+e}$ $\Rightarrow 1.83 \times (1+e) = 2.68 \times 1.0$

$\Rightarrow 1+e = 1.4645$

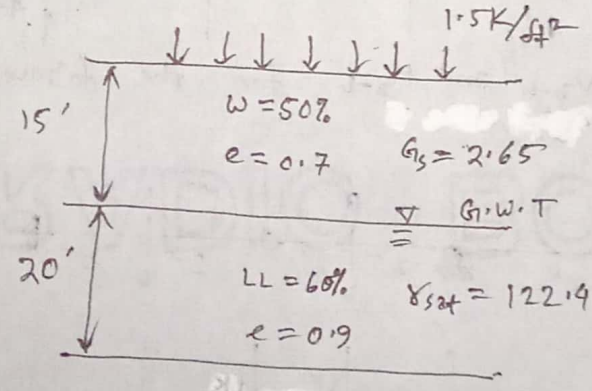
$\Rightarrow e = 0.4645 = 46.45\%$

We know, $se = wG_s$

$\Rightarrow s = \frac{wG_s}{e} = \frac{0.16 \times 2.68}{0.4645} = 0.923 = 92.3\%$

(Ans.)

4. Determine the primary settlement of the clayer. The soil is normally consolidated.



$\gamma = \frac{G_s \gamma_w (1+w)}{1+e} = \frac{2.65 \times 62.4}{1+0.7} \times (1+0.5)$

$\gamma = 145.91\ lb/ft^3$

Solution:

We know,

$S_c = \frac{C_c H_c}{1+e_0} \times \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right)$

$= \frac{0.45 \times 20}{1+0.9} \times \log\left(\frac{2788.5 + 1500}{2788.5}\right)$

$= 0.8855\ ft$

$= 10.63\ inch.$

(Ans.)

Here,

$C_c = 0.009(LL - 10)$

$\therefore C_c = 0.009(60-10) = 0.45$

$H_c = 20'$; $e_0 = 0.9$

$\sigma_0' = 145.91 \times 15 + (122.4 - 62.4) \times \frac{20}{2}$

$= 2788.5\ lb/ft^2$

$\Delta\sigma' = 1.5 \times 10^3\ lb/ft^2$

5. 9 column of 'π' meter height, diameter of $\frac{\pi}{2}$ ft is casted in concrete mix ratio 1:2:4 by bolume. Find the amount of ingredients in dry ~~volumes~~ conditions.

Solution: Total volume of concrete $= 9 \times \left[\frac{\pi}{4} \times \left(\frac{\pi}{2}\right)^2 \times (\pi \times 3.28)\right]$

$= 179.72$ cft

$\therefore$ Dry volume $= (179.72 \times 1.5) = 269.58$ cft

Total ratio $= (1+2+4) = 7$

$\therefore$ Amount of cement $= \left(\frac{1}{7} \times 269.58\right) = 38.51$ cft

$\therefore$ Amount of sand $= \left(\frac{2}{7} \times 269.58\right) = 77.02$ cft

$\therefore$ Amount of coarse aggregate $= \left(\frac{4}{7} \times 269.58\right) = 154.05$ cft

6. The CBR values are calculated after every kilometer on selected sketch of 10 km having same type of soil. The CBR values are 3.8, 2.8, 4.5, 3.9, 4.2, 2.8, 4.7, 4.0 and 4.5. Find the design CBR values for 85% reliability.

Solution: Average CBR, $\bar{x} = \frac{3.8+2.8+4.5+\ldots\ldots\ldots+4.7+4.0+4.5}{9}$

$\therefore \bar{x} = 3.91$

$$S_d = \sqrt{\frac{\Sigma(x_i-\bar{x})^2}{n-1}} = \sqrt{\frac{(3.8-3.91)^2+(2.8-3.91)^2+\ldots\ldots\ldots+(4.5-3.91)^2}{(9-1)}}$$

$\therefore S_d = 0.697$

Design CBR for 85% reliability $= \bar{x} - z \times S_d$

$= 3.91 - 0.697 \times 1.04$

$= 3.18$ (Ans.)

7. Given, $D_{10} = 0.0162$ m, $D_{30} = 0.1018$ mm, $D_{60} = 0.577$ mm and $LL = 35\%$, $PL = 13\%$, $w = 4\%$.

Find the values of C_u, C_c and PI, CI

Solution:

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.577}{0.0162} = 35.62$$

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(0.1018)^2}{0.577 \times 0.0162} = 1.11$$

$$PI = LL - PL = (35 - 13) = 22\%$$

$$CI = \frac{LL - w}{PI} = \frac{(35-4)}{22} = 1.409$$

(Ans:)

8. Water flow in a rectangular channel of 10 m wide. The channel slope = 0.0028, velocity of flow = 5 m/s, $n = 0.013$. Find the depth of the flow.

Solution: We know,

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

Here, $n = 0.013$

$$R = \frac{A}{P}$$

where, $A = bh = 10h$

$P = (b + 2h) = 10 + 2h$

$\therefore R = \frac{10h}{10+2h}$

$S = 0.0028$

$V = 5$ m/s

$$\Rightarrow 5 = \frac{1}{0.013} \times \left(\frac{10h}{10+2h}\right)^{\frac{2}{3}} \times (0.0028)^{\frac{1}{2}}$$

$$\Rightarrow h = 1.87 \text{ m}.$$

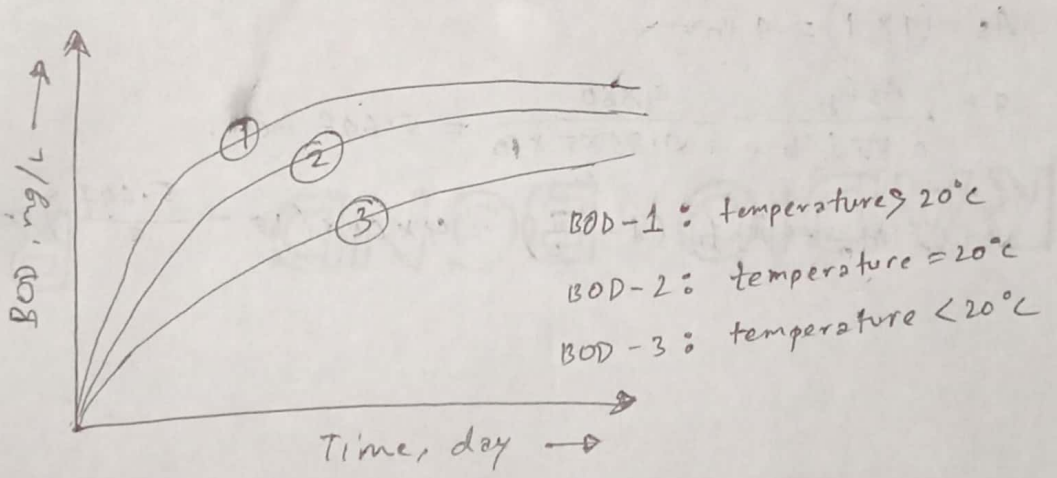
(Ans:)

9. write down the five green house gas.

Solution: CO_2, CH_4, O_3, CFC, N_2O

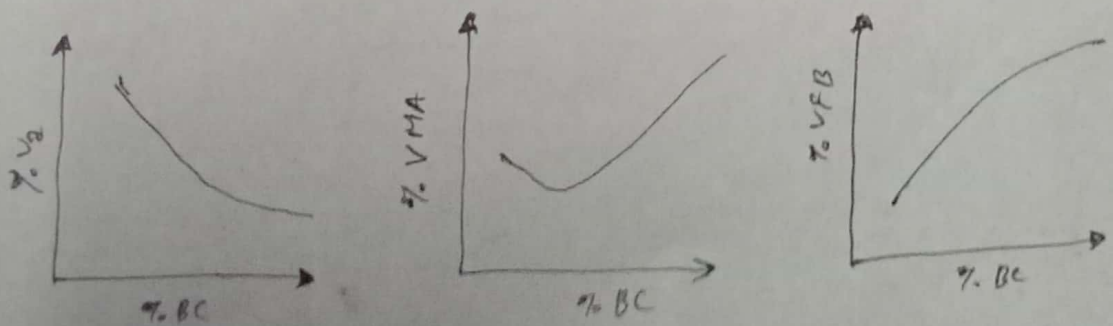
10. Why COD > BOD. Draw BOD curves for different temperature.

Solution: COD > BOD because more organic compounds can be oxidized than biologically oxidized. COD measures all type of organic matter including both biodegradable and non biodegradable organic matter, while BOD only measures biodegradable organic matter.



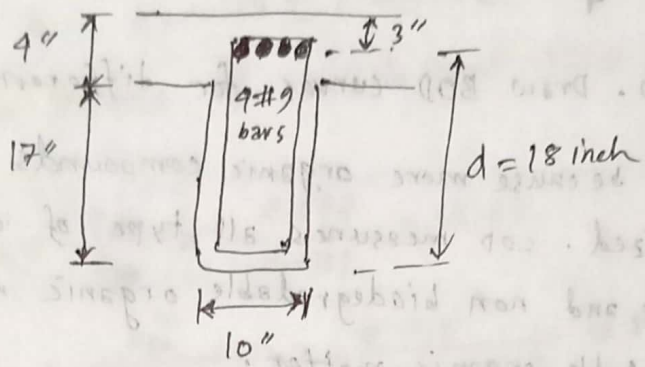
11. Draw Marshall Mix design curves.





12. Calculate the Negative nominal moment of the beam. Given,

$f_y = 60$ KSi, $f_c' = 5$ KSi, $\beta_1 = 0.8$



Solution; As T beam resist negative moment, It acts a rectangular beam.

$A_s = (4 \times 1) = 4$ in^2

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4 \times 60}{0.85 \times 5 \times 10} = 5.647 \text{ inch.}$$

Now, $M_n = A_s f_y \left(d - \frac{a}{2}\right) = 4 \times 60 \times \left(18 - \frac{5.647}{2}\right) = 3692.36$ Kip-in.

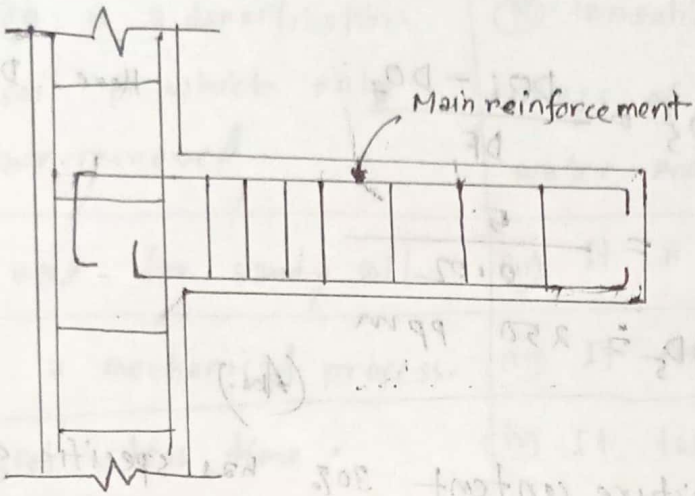
(Ans.)

PGCB – 2017

MIST

1. Show typical cantilever beam reinforcement detailing.

Solution:

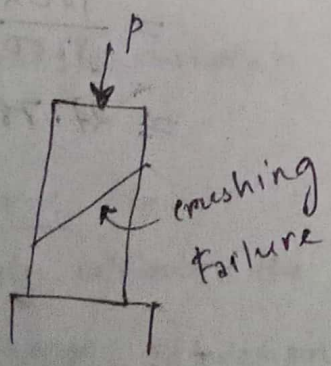


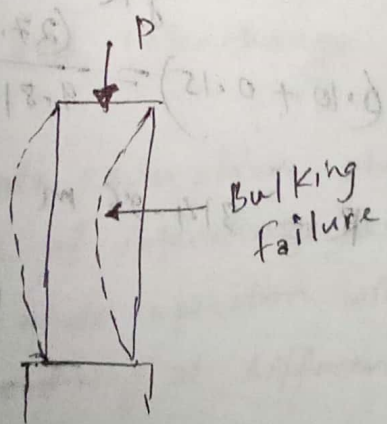
2. Difference between intial setting time and final setting time.

Solution:

Initial Setting Time	Final setting Time
(i) The time between the water is added to cement till it starts losing its plasticity is called as intial setting time.	(i) The time between water added to cement till it completely loses its plasticity and attains sufficient hardness to resist certain pressure
(ii) Initial setting time should not be less than 30 min.	(ii) Final setting time should not be more than 10 hrs.

3. Short column and long column failure pattern.





4. If a 2% solution of sewage is incubated for 5 days at 20°C and dissolved oxygen depletion was 5 ppm, determine BOD_5.

Solution: We know, $BOD_5 = \frac{DO_i - DO_f}{DF}$ Here, DF = 0.02%

$$= \frac{5}{0.02}$$

$$\therefore BOD_5 = 250 \text{ ppm}$$

(Ans.)

5. A saturated soil of moisture content 30% has specific gravity 2.65. Determine the dry unit weight.

Solution: Let, the soil is fully saturated, S = 1

We know, $Se = wG_s$

$$\Rightarrow e = (0.3 \times 2.65) = 0.795$$

Now, $\gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{2.65 \times 9.81}{1+0.795} = 14.48 \text{ KN/m}^3$

(Ans)

6. If $e = 0.10$ and $f = 0.15$, design speed = 100 Kmph, determine radius of curvature.

Solution:

We know,

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow (0.10 + 0.15) = \frac{(27.78)^2}{9.81 \times R}$$

$$\Rightarrow R = 314.96 \text{ m}$$

(Ans.)

$v = 100$ Kmph

$$= \frac{100 \times 10^3}{3600} \text{ m/sec.}$$

$= 27.78$ m/sec

7. Differentiate between compaction and consolidation.

Solution:

Compaction	Consolidation
(i) Compaction is a densification process of soil in which only air voids are removed.	(i) Consolidation is a densification process of soil in which both water and air voids are removed.
(ii) It is used for sandy soil.	(ii) It is used for clayey soil.
(iii) It is a mechanical process.	(iii) It is a natural process.
(iv) It takes less time.	(iv) It takes more time.

8. What are the forces acting on gravity dam?

Solution:
(i) water pressure
(ii) Earthquake forces
(iii) Silt pressure
(iv) Ice pressure
(v) uplift pressure
(vi) the stabilizing force due to its own weight.

9. What are the methods of grading of asphalt?

Solution:
(i) Performance grading.
(ii) Penetration grading.
(iii) Viscosity grading.
(iv) Viscosity of aged residue grading.

10. Differentiate between flyover and interchange.

Solution:

Flyover: Flyover is a grade seperation whereby traffic moves seperately without the provision of interchange between them.

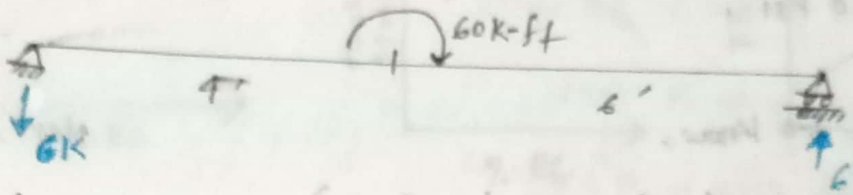
Interchange: Interchange is a grade seperation with inter connecting facilities of two or more roadway at different level.

11. Why aeration is necessary in waste treatment process?

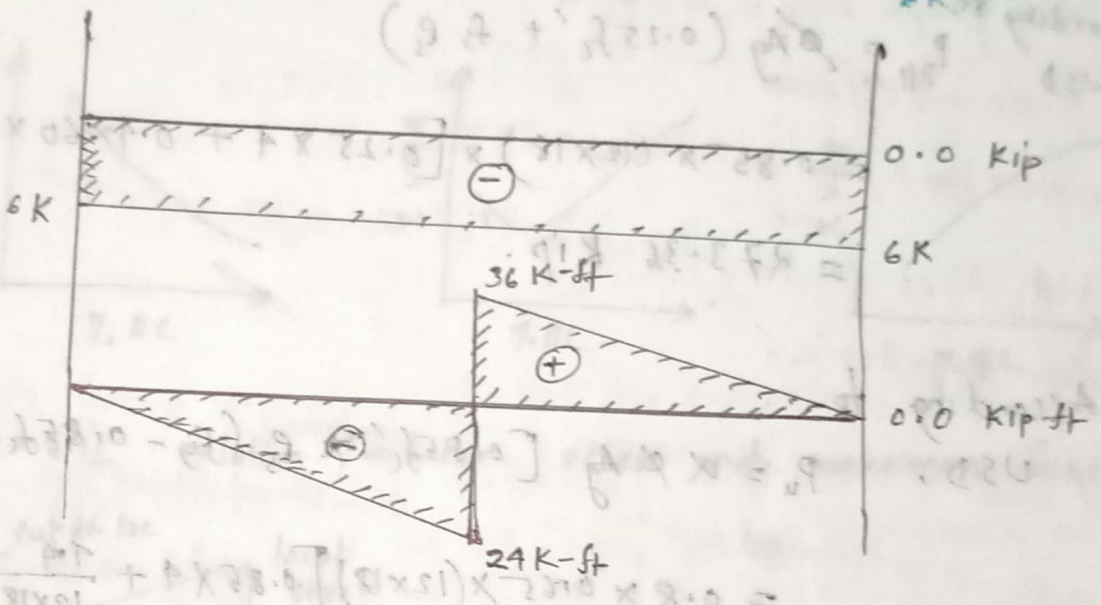
12. How SPT N counts in field?

13. If a partially saturated soil becomes fully saturated soil due to change in water table, then how it affects void ratio of soil?

1. Draw SFD and BMD of the following beam;



Solution:



2. Determine the maximum shear stress of a beam section 16"×12" subjected to vertical force 48 Kip.

Solution: we Know,

Maximum shear stress, $\tau_{max} = \frac{VQ}{Ib}$

$= \frac{48 \times 384}{4096 \times 12}$ Ksi

$= 0.375$ Ksi

(Ans.)

Here,

$V = 48$ K

$Q = (12 \times \frac{16}{2} \times \frac{8}{2})$

$= 384$ in^2

$b = 12$ in

$I = \frac{12 \times 16^3}{12}$ in^4

$= 4096$ in^4

3. Calculate the allowable axial compression force of a column section 12" × 18" consisting of 10 – $\frac{3}{4}$" bars. Given, $f_c' = 4$ ksi & $f_y = 60$ ksi.

Solution: We know,

According to WSD $P_{all} = \phi A_g (0.25 f_c' + f_s \rho_s)$

where, $A_s = \frac{\pi}{4} \times \left(\frac{3}{4}\right)^2 \times 10$

$= 4.4 \text{ in}^2$

$= 0.85 \times (12 \times 18) \times \left[0.25 \times 4 + 0.4 \times 60 \times \frac{4.4}{12 \times 18}\right]$

$= 273.36$ Kip.

According to USD, $P_u = \alpha \phi A_g \left[0.85 f_c' + \rho_s (f_y - 0.85 f_c')\right]$

$= 0.8 \times 0.65 \times (12 \times 18) \left[0.85 \times 4 + \frac{4.4}{12 \times 18} \times (60 - 0.85 \times 4)\right]$

$= 511.4$ Kip.

(Ans.)

4. Calculate the angularity number for the aggregate sample from the following data:

Relative density = 2.8

Mass of water required to fill cylinder = 2500 gm

Mass of cylinder filled with aggregate = 5150 gm

Mass of cylinder = 1100 gm.

Solution:

We know,

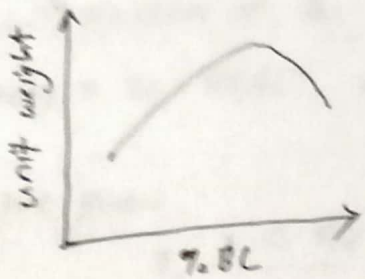
$$\text{Angularity Number} = 67 - \frac{W.}{W_{ax} G_s} \times 100$$

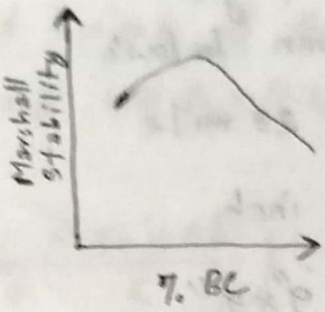
$$= 67 - \frac{(5150 - 1100)}{2500 \times 2.8} \times 100$$

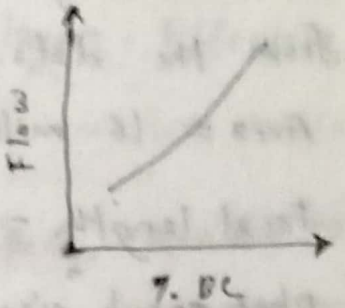
$= 9.14 \simeq 9$ (Ans.)

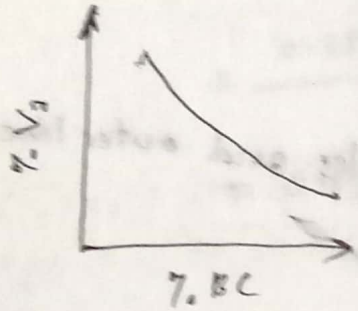
6. Draw Marshall Mix Design Curves.

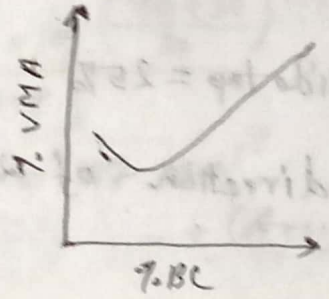
Solution:

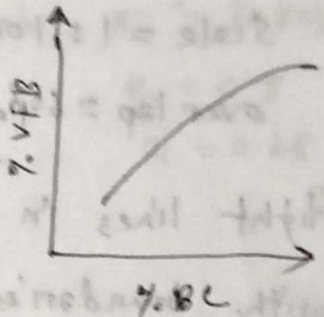




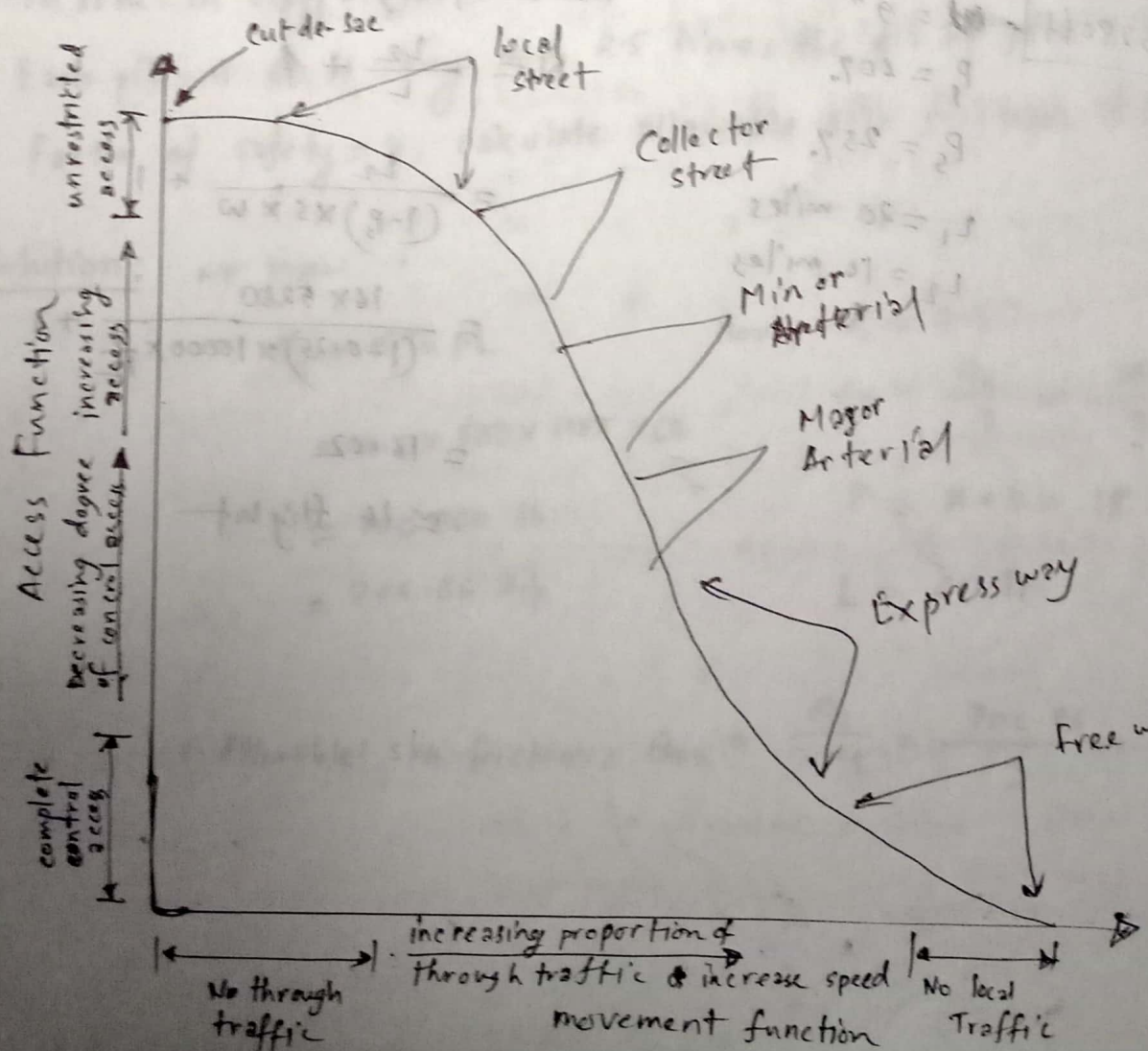








7. Draw schematic relation between access and movemen function



8. For aerial photography, determine the number of flight lines from the data given below:

Area = 16 mile x 20 mile

Focal length = 12 inch

Photograph size = 9" x 9"

Scale = 1 : 10000

over lap = 60%, side lap = 25%

Flight lines in the direction of 20 miles and outer lines coincide with boundaries.

Solution: Given, S = 10000

1 mile = 5280 ft

$w = 9''$

$P_f = 60\%$

$P_s = 25\%$

$L_1 = 20$ miles

$L_2 = 16$ miles

We know,

Number of flight line,

$$N = \frac{L_2}{L} + 1$$

$$= \frac{L_2}{(1-P_s) \times S \times w} + 1$$

$$= \frac{16 \times 5280}{(1-0.25) \times 10000 \times \frac{9}{12}} + 1$$

$$= 16.02$$

$\simeq$ 16 flight

9. Calculate the settlement of 2.5 m deep clay layer due to an increase of 30 KN/m^2 pressure at the mid height of the layer. Effective vertical stress = 30 KN/m^2, $e_o = 0.8$ and $C_c = 0.28$.

Solution: We know,

$$S_c = \frac{C_c H_c}{1+e_o} \times \log\left(\frac{\sigma_o' + \Delta\sigma'}{\sigma_o'}\right)$$

$$= \frac{0.28 \times 2.5 \times \log\left(\frac{30+30}{30}\right)}{(1+0.8)}$$

$$= 0.117 m = 117 mm \quad \text{(Ans:)}$$

Here, $H_c = 2.5$ m

$\Delta\sigma' = 30$ KN/m^2

$\sigma_o' = 30$ KN/m^2

$e_o = 0.8$

$C_c = 0.28$

10. A 9-pile group consisting of 18" dia concrete piles were cast in situ in clay layer whose unconfined compressive strength is 1020 lb/ft^2. Each pile is 60 ft long and 2.5 times the dia of pile. $\alpha = 0.5$, Factor of safety = 3, calculate allowable skin friction of a single pile.

Solution: We know,

$$Q_s = \alpha C_u P L$$

$$= 0.5 \times 500 \times 18\pi \times 60$$

$$= 706800 \text{ lb}$$

$$= 706.86 \text{ kip}$$

Here, $\alpha = 0.5$

$$C_u = \frac{q_u}{2} = \frac{1020}{2} = 500 \text{ lb/ft}^2$$

$P = \pi \times D = 18\pi$ inch $= 1.5\pi$ ft

$L = 60$ ft

Allowable skin friction, $Q_{all} = \frac{Q_s}{FS} = \frac{706.86}{3} = 235.62$ kip (Ans)

11. In natural state, a moist soil has a volume of $0.4\ ft^3$ and weighs 50 lb. oven dry weight 40 lb. Calculate the bulk unit weight, dry unit weight and moisture content.

Solution:

Bulk unit weight, $\gamma_{bulk} = \frac{50}{0.4} = 125\ lb/ft^3$

dry unit weight, $\gamma_{dry} = \frac{40}{0.4} = 100\ lb/ft^3$

we know, $\gamma_d = \frac{\gamma_{bulk}}{1+w}$

$\Rightarrow w = \left(\frac{\gamma_{bulk}}{\gamma_{dry}} - 1\right) = \left(\frac{125}{100} - 1\right) = 0.25$

$\therefore w = 25\%$ (Ans)

12. sieve analysis were performed for a coarse sand and it has been found that 100% sample retained on #30 sieve.

Solution:

sieve No.	4	8	16	30	50	100
% retained	0	0	0	100	0	0
cumulative % retained	0	0	0	100	100	100

$\therefore$ FM of the sample $= \frac{100+100+100}{100} = 3$ (Ans.)

13. Calculate the diameter of a circular pipe that discharges 2.5 cfs water with a velocity of 6 fps.

Solution: we know, $Q = AV$

$\Rightarrow \frac{\pi}{4} D^2 = \frac{Q}{V}$

$\Rightarrow D^2 = \frac{4Q}{\pi V} = \frac{4 \times 2.5}{6\pi}$ $\therefore D = 0.728\ ft = 8.74\ inch$ (Ans)

14. What are the factors affecting the per capita consumption of water.

Solution:

(i) size of the city
(ii) characteristic of people
(iii) climate condition
(iv) pressure of water
(v) Quality of water
(vi) sewerage facilities
(vii) water rates & metering
(viii) Nature of supply
(ix) Efficiency of management
(x) No. of Inhabitants.

15. Define following Terms:

(a) sewerage. (b) sewer (c) night soil (d) stock

16. True or False.

F (a) In a beam the concentration load applied on the point of the bending moment is zero (maximum) in that point.

T (b) The area under stress-strain diagram to determine toughness.

F (c) Effective length of the both end fixed beam is L. (0.5L)

T (d) In two way slab, the main reinforcement is below the short direction.

F (e) In one way slab, the main rebar along the long (short) direction

T (f) If the elongation of the body is 0.01 and the length is 0.8. then strain will be 0.0125. $\varepsilon = \frac{\Delta}{L} = \frac{0.01}{0.8} = 0.0125$

17. True or False

F (a) ACV test is done for ~~weaker~~ not aggregate.

F (b) The aggregate sample for AIV test has to be oven dried for 24 hrs. 4 hrs.

T (c) Cycle time is obtained by adding the loss time with effective green.

T (d) Level of service E indicates approaching unstable flow condition. T

F (e) Most around particle has ~~most~~ less amount of intergranular void.

F (f) ~~A~~ theodolite instrument can be used as a level. also measures horizontal and vertical angle.

18. (a) The workability of concrete in slump is expressed as mm.

(b) The increase in volume of dry sand when water is added is called Bulking of sand.

(c) The process of adding water to lime to convert it in to hydrated lime is termed as slaking

(d) the compressive strength of meo-grade concrete is approximately 3000 psi.

(e) According to ASTM, minimum initial setting time for ordinary portland cement is 45 min.

$\frac{40}{} = \frac{}{CA}$

PGCB-2014 [BUET]

1. Design a pumping unit to deliver 23760 gph of water from a well to an overhead tank against a static head of 60 ft. The total loss of head due to friction, velocity etc. is estimated to be 40 ft.

Solution:

Theoretical horse power required to operate a pump,

$$P = \frac{QH}{3960}$$

where, $Q = 23760 \text{ gph} = \frac{23760}{60} \text{ gpm}$

$= 396 \text{ gpm}$

$$= \frac{396 \times 100}{3960}$$

$H = (60+40) \text{ ft} = 100 \text{ ft}$

$\boxed{P = 10 \text{ WHP}}$

1 US gallon = 3.785 L

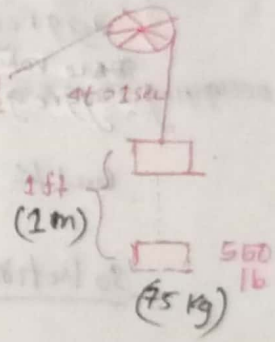
1 UK gallon = 4.54 L

1 US ton = 907.2 Kg = (907.2 × 2.2046) = 2000 lb

1 UK tonne = 1000 Kg = (1000 × 2.2046) = 2204 lb

* 1 HP = 746 Watts

* 1 metric HP = 735.5 Watts (Horse)



2. Calculate the diameter of pipe that discharge 1143 cfs water in a irrigation field with a velocity of 4 fps.

Solution:

We know, $Q = AV$

$$\Rightarrow A = \frac{Q}{V}$$

$$\Rightarrow \frac{\pi}{4} \times d^2 = \frac{1143}{4}$$

$$\Rightarrow d^2 = \frac{1143}{\pi}$$

$$\therefore d = 19.07 \text{ ft}$$

(Ans.)

3. Determine the safe radius of circular curve from the following data: $V = 60$ mph, $e = 0.04$ ft/ft, $f = 0.12$, $g = 32.2$ ft/sec^2.

Solution:

We know, $e + f = \frac{V^2}{15R}$

$\Rightarrow (0.12 + 0.04) = \frac{60^2}{15 \times R}$

$\Rightarrow R = \frac{60^2}{15 \times 0.16}$

$\therefore R = 1500$ ft

(Ans.)

4. The dry mass of sample of aggregate = 1988 gm. The mass of aggregate in SSD condition = 2006.7 gm. The volume of water occupying the same volume as aggregate excluding pores, 734.4 cm^3. Find the apparent specific gravity, bulk specific gravity and percentage absorption.

Solution: Given, $A = 1988$ gm

$B = 2006.7$ gm

$A - C = 734.4$ (Sp. gr. of water = 1 gm/cm^3)

Here, $B - A = (2006.7 - 1988) = 18.7$ gm

Apparent specific gravity $= \frac{A}{A - C} = \frac{1988}{734.4} = 2.70$

Bulk sp. gr. (Dry) $= \frac{A}{B - C} = \frac{A}{(A - C) + (B - A)} = \frac{1988}{734.4 + 18.7}$

$= 2.64$

Bulk sp. gr. (SSD) $= \frac{B}{B - C} = \frac{2006.7}{753.1} = 2.66$

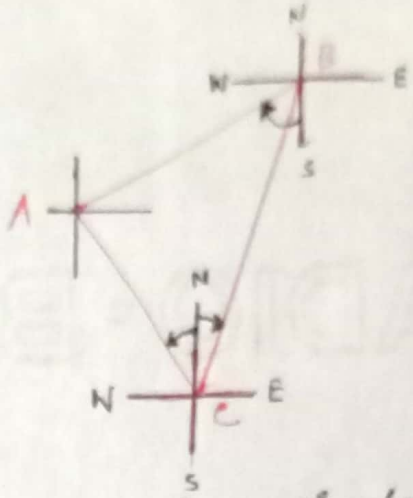
Absorption $= \frac{B - A}{A} \times 100\% = \frac{18.7}{1988} = 0.94\%$ (Ans.)

Find Internal angle of a closed traverse ABC as follows:

BA : S 80°50'30" W

CA : N 40°56'55" N

CB : N 30°55'50" E



Solution:

$$\angle ABC = (90° - 80°50'30") + (90° - 40°56'55") = 58°12'35"$$

$$\angle ACB = (40°56'55" + 30°55'50") = 71°52'45"$$

$$\angle ABC = (80°50'30" - 30°55'50") = 49°54'40"$$

Check: $\angle ABC + \angle ACB + \angle ABC = (58°12'35" + 71°52'45" + 49°54'40")$

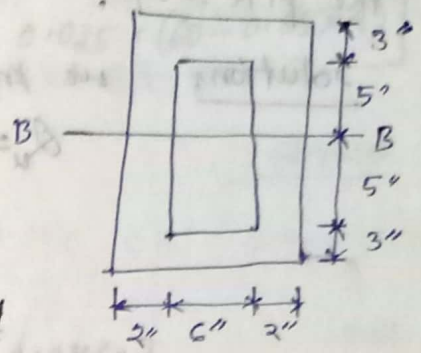
$= 180°$

(Ans)

PGCB - 2013

Exam Taker: BUET

1. Determine the flexural stress of the following beam if Bending Moment at section B-B is 100 K-ft.



Solution:

We know,

$$f = \frac{My}{I}$$

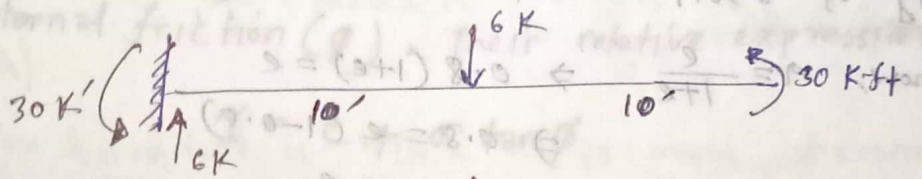
Here, $M = 100$ K-ft

$$I = \frac{10 \times 16^3}{12} - \frac{6 \times 10^3}{12} = 2913.33 \text{ in}^4$$

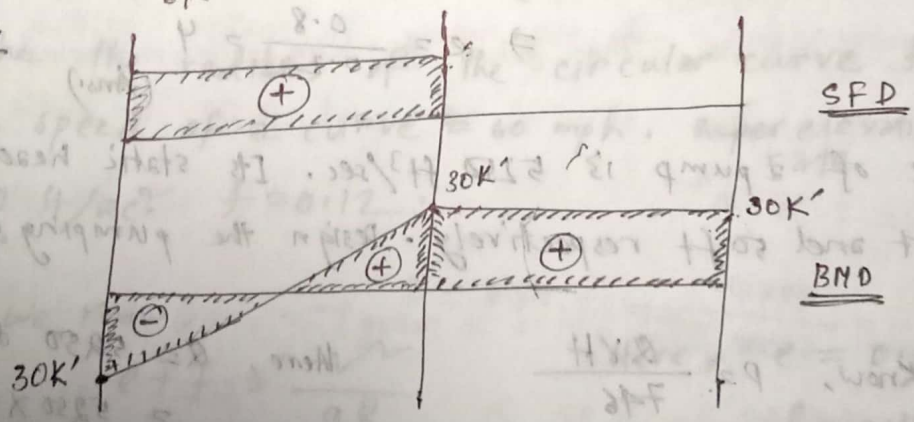
$$\therefore f = \frac{100 \times 12000 \times 8}{2913.33} = 3295.2 \text{ psi}.$$

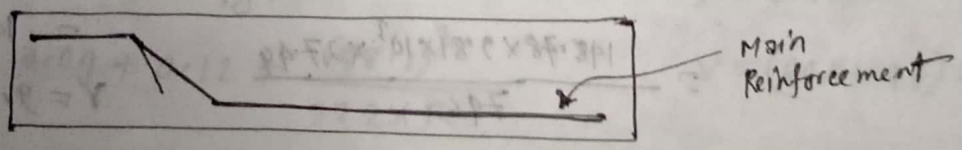
(Ans)

2. Draw the bending moment diagram and location of the main tensile reinforcement of the cantilever beam.



Solution:





3. Determine the capacity of a pile driven into the clay, the embedded length of the pile is 30ft and unconfined compressive strength of the pile = 25 psi and adhesion capacity = 0.8. The diameter of the pile = 24".

Solution: we know,

$$Q_u = Q_p + Q_s$$

$$= C_u N_c^* A_p + \alpha C_u P L$$

$$= 12.5 \times 9 \times 452.3904 + 0.8 \times 12.5 \times 27143.424$$

$$= 322328.16 \text{ lb}$$

$$\boxed{Q_u = 322.33 \text{ K}}$$

(Ans.)

Here,

$C_u = \frac{q_u}{2} = \frac{25}{2} = 12.5 \text{ psi}$

$A_p = \frac{\pi}{4} \times (24)^2 = 452.3904 \text{ in}^2$

$N_c^* = 9$

$\alpha = 0.8$

$PL = \pi DL = 3.1416 \times 24 \times 30 \times 12$

$= 27143.424 \text{ in}$

4. If the porosity of a soil is 80%. Determine its void ratio.

Solution: we know, $n = \frac{e}{1+e}$

$$\Rightarrow 0.8(1+e) = e$$

$$\Rightarrow 0.8 = e(1-0.8)$$

$$\Rightarrow e = \frac{0.8}{0.2} = 4$$

(Ans.)

5. The discharge of a pump is 5250 ft^3/sec. Its static head and head loss are 40 ft and 50 ft respectively. Design the pumping station.

Solution:

we know, $P = \frac{Q \gamma H}{746}$

$$= \frac{148.78 \times 9.81 \times 10^3 \times 27.44}{746}$$

$$= 53685.72 \text{ HP}$$

(Ans.)

Here, $Q = 5250 \text{ ft}^3/\text{sec}$.

$= 5250 \times (0.3048)^3$

$= 148.78 \text{ m}^3/\text{sec}$

$\gamma = 9.81 \times 10^3 \text{ N/m}^3$

$H = (h_s + h_f) = (40+50)$

$= 90 \text{ ft} = 27.44 \text{ m}$

CamScanner

6. Determine the compressive load of column, 12"×22" If $\rho_s = 2.52$, $f_c' = 4$ Ksi & $f_y = 60$ Ksi

Solution: We know,

In USD, $P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$

$= 0.80 \times 0.65 \times (12 \times 22) \times [0.85 \times 4 + 0.025 \times (60 - 0.85 \times 4)]$

$= 661$ Kip.

(Ans)

In WSD, $P_{all} = \phi' A_g [0.25 f_c' + \rho_s f_s]$

$= 0.85 \times 12 \times 22 \times [0.25 \times 4 + 0.025 \times 0.4 \times 60]$

$= 359.04$ Kip.

7. What are the strength parameter of soil. Write their relative expression.

Solution: The strength parameters of soil are cohesion (c) and angle of internal friction (ϕ). Their relative expression is:

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

8. Determine the radius of the circular curve from the following data: The speed of a curve = 60 mph. super elevation rate = 0.04 ft/ft. $g = 32.2$ ft/sec^2. $f = 0.12$.

Solution: We Know,

$$e + f = \frac{v^2}{gR}$$

Here, $e = 0.04$

$f = 0.12$

$v = (60 \times 1.47) = 88.2$ ft/sec.

$\Rightarrow 0.04 + 0.12 = \frac{(88.2)^2}{32.2 \times R}$

$\Rightarrow R = 1509.94$ ft

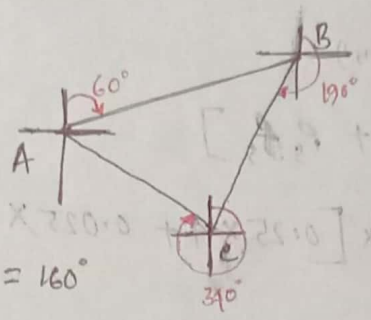
(Ans)

9. What is Liquid Index?

Solution: $LI = \frac{w - PL}{LL - PL}$

10. Determine the internal Angle of a closed traverse ABC.
FB of AB = 60°, BC = 190° and CA = 340.

Solution:



Here,

BB of CA = (340 − 180) = 160°

∴ ∠BAC = (160° − 60°) = 100°

Again,

BB of AB = (60 + 180) = 240°

∴ ∠ABC = (240 − 190) = 50°

And, BB of BC = (190 − 180) = 10°

∴ ∠BCA = 360 − (340 − 10) = 30°

(Ans.)

11. A reinforced concrete beam of 10" × 25" is reinforced with 3 #8 bar. If f_y = 60 ksi, f_c' = 4 ksi, Then find the allowable moment capacity of the beam.

Solution:

$A_s = (3 \times 0.79) = 2.37\ in^2$

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{4000}} = 8.04 \simeq 8$

$r = \frac{f_s}{f_c} = \frac{0.4 \times 60}{0.45 \times 4} = 13.33$

$\therefore K = \frac{n}{n + r} = \frac{8}{8 + 13.33} = 0.375$

$j = \left(1 - \frac{K}{3}\right) = \left(1 - \frac{0.375}{3}\right) = 0.875$

$M_c = \frac{1}{2} f_c\, j K b d^2 = \frac{1}{2} \times (0.45 \times 4) \times 0.875 \times 0.375 \times 10 \times (25 - 2.5)^2 = 1495$ K-in

$M_s = A_s f_s j d = 2.37 \times (0.4 \times 60) \times 0.875 \times (25 - 2.5) = 1119.825$ K-in

So,
Allowable Moment capacity = 1119.825 K-in.

(Ans)

12. Determine the quantity of rainwater. If Area of the basin = 25 m^2, intensity of rainfall = 10 m/yr and run-off co-efficient = 0.8

Solution:

$\therefore$ Quantity of rainwater, $Q = CIA$

$\therefore Q = (0.8 \times 10 \times 25) = 200\ m^3$ (Ans.)

13. If pH of a sample water is 4. What is the OH^- concentration of that sample.

Solution:

Given, $pH = 4$

$\therefore [H^+] = 10^{-4}$

we know, $[H^+] \times [OH^-] = 10^{-14}$ mole/L

$\therefore [OH^-] = \frac{10^{-14}}{10^{-4}} = 10^{-10}$ mole/L (Ans.)

14. One million gallons of water per day (1 mgd) passes through a sedimentation tank which is 50 ft long, 20 ft wide and 10 ft deep. Find the velocity of the flow.

Solution:

We Know, 1 gallon = 3.785 Liter

we know, $V = \frac{Q}{A} = \frac{(10^6 \times 3.785) \times 10^{-3} \times (3.28)^3}{24 \times 3600 \times 20 \times 10}$ ft/sec.

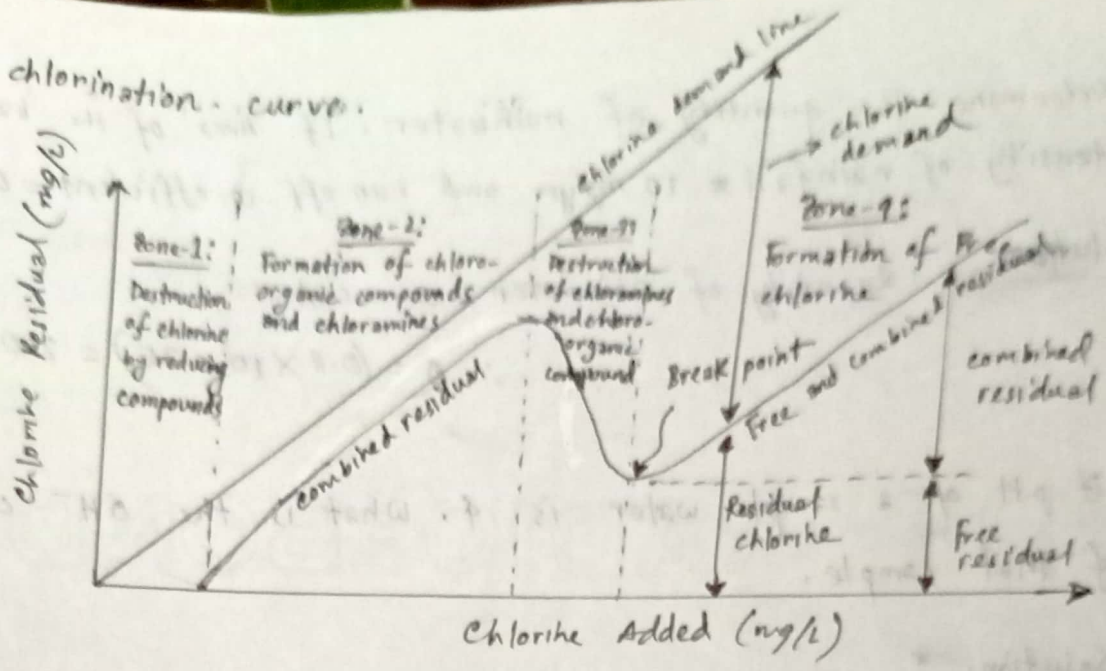
$\therefore V = 0.00773$ ft/sec. (Ans.)

Additional:

Detention time, $T = \frac{\text{Volume}}{\text{Discharge}}$

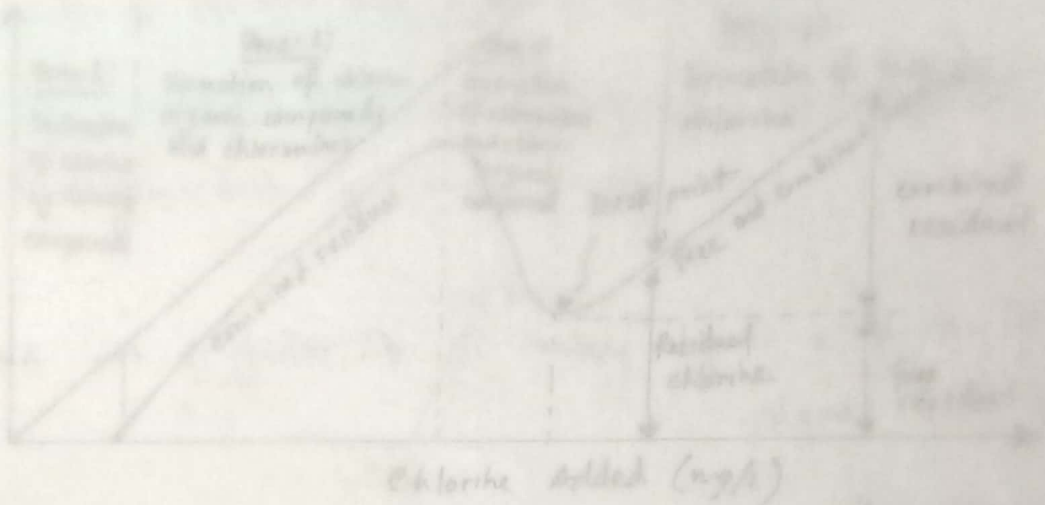
$= \frac{50 \times 20 \times 10 \times 24}{(10^6 \times 3.785) \times 10^{-3} \times (3.28)^3} = 1.8$ hrs. (Ans)

15. Draw chlorination curve.



16. write the functions of septic tank.

19. What is the impact of climate change in Bangladesh.



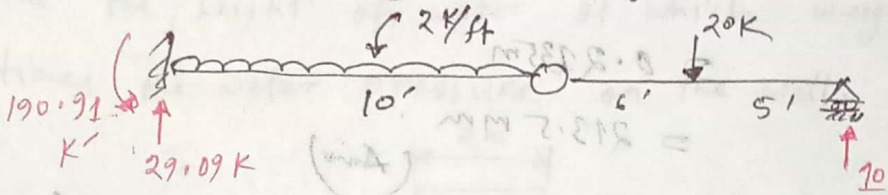
20. What is Industrial waste? Write the name of 10 industrial wastes.

DESCO-2022 MIST

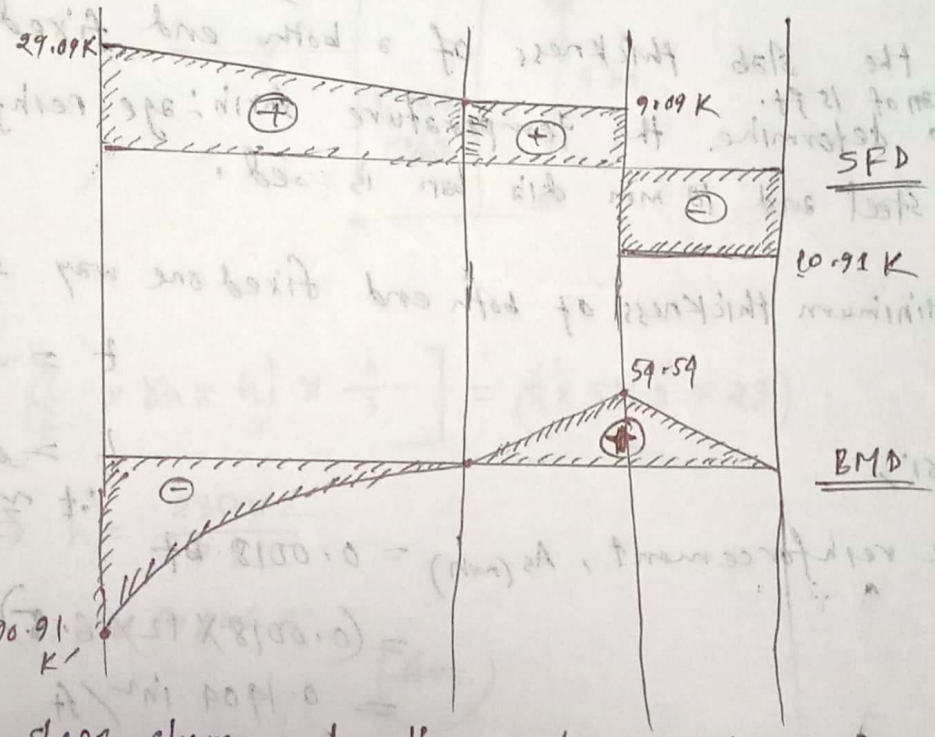
1. write four methods to increase the bearing capacity of soil.

Solution: (i) compaction
(ii) vibroflotation
(iii) Precompression
(iv) Sand drains etc.

2. Draw SFD and BMD of the following beam:

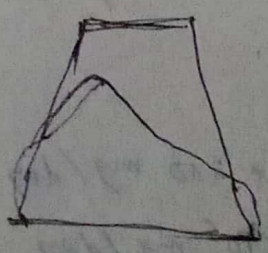


Solution:

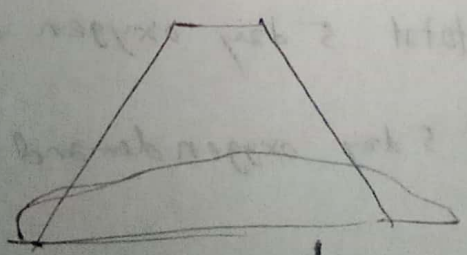


3. What does shear slump and collapse slump indicate?

Solution: Shear slump indicates the lack of cohesion in concrete mix. and collapse slump indicates that the concrete mix is very wet.



Shear slump



collapse slump

4. Given, compression Index, $C_c = 0.27$, void ratio, $e = 0.7$, depth of clay layer = 5m, Increase overburden pressure = 30 KN/m². Effective stress = 35 KN/m². Determine the settlement of the clay layer.

Solution: we know, $S_e = \frac{H C_c}{1+e} \times \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right)$

$$= \frac{5 \times 0.27}{1+0.7} \times \log\left(\frac{35+30}{35}\right)$$

$$= 0.2135 m$$

$$= 213.5 mm.$$

(Ans)

5. Determine the slab thickness of a both end fixed one way slab with a clear span of 15 ft. and also determine the temperature shrinkage reinforcement. If 60 grade steel and 10 mm dia bar is used.

Solution: Minimum thickness of both end fixed one way slab $= \frac{l}{28}$

$$t = \frac{15 \times 12}{28} \text{ inch}$$

$$t = 6.43 \text{ inch}$$

$\therefore t \simeq 6.5$ inch

For, $f_y = 60$ KSI,

Temperature reinforcement, $A_{s(min)} = 0.0018\ bt$

$$= (0.0018 \times 12 \times 6.5)\ in^2/ft$$

$$= 0.1404\ in^2/ft$$

providing # 10 mm bar @ $\frac{12}{0.1404} \times \frac{\pi}{4} \times \left(\frac{10}{25.4}\right)^2 = 10.9''$ c/c

(Ans)

6. Average sewage flow is 7500 L/day. Average 5 day BOD = 200 mg/L Determine the total 5 day oxygen demand.

Solution: Total 5 day oxygen demand = 7500×200 mg/day

$$= 1.5 \times 10^6 \text{ mg/day}$$

$$= 1.5 \text{ kg/day}.$$

7. Given, Runoff volume = 7×10^{-3} m^3, Rainfall depth = 10 cm, Runoff co-efficient = 0.3. Determine the catchment area.

Solution:

We know,

$$V = CAP$$

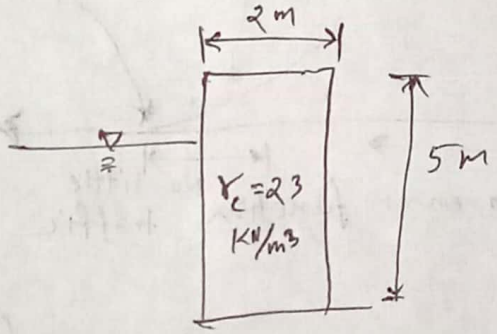
Here, $P = \frac{10}{100}$ m

$= 0.1$ m

$$\Rightarrow A = \frac{V}{CP} = \frac{7 \times 10^{-3}}{0.3 \times 0.1}$$

$$\therefore A = 0.233 \text{ m}^2$$ (Ans.)

8. Determine the height of water at which weight of wall will three times the water pressure on the wall.



Solution:

$$3 \times \left[\left(\frac{1}{2} \times \gamma h \times h \right) \times \frac{h}{3} \right] = (2 \times 5 \times 1 \times 23)$$

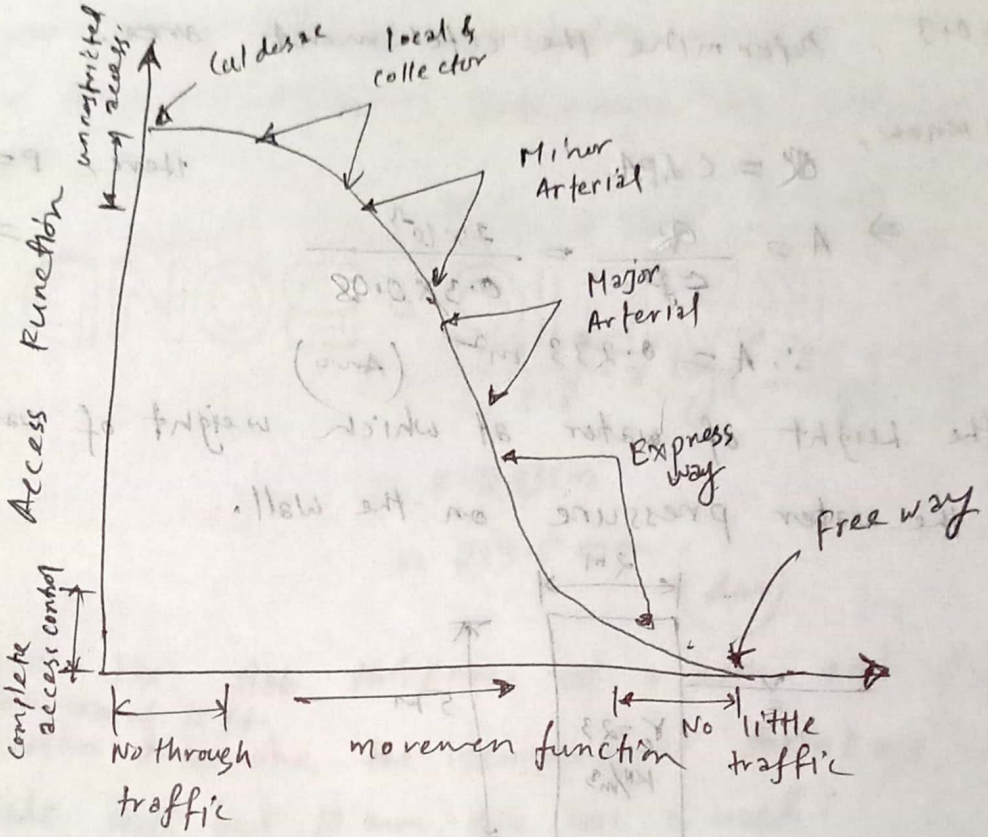
$$\Rightarrow h^3 = \frac{230 \times 2}{9.81}$$

$$\therefore h = 3.606 \text{ m}.$$

(Ans.)

9. Draw the access movement function diagram.

Solution:



10. Write the factors that affect the design of flexible pavement.

solution:

(i) Design wheel load factors
(ii) subgrade soil
(iii) climate factors
(iv) Environmental factors
(v) ~~the~~ Pavement component materials etc.

DESCO - 2019

BUET

1. Determine the fineness modulus and percentage of silt and clay of the sample.

Sieve size	#4	#8	#16	#30	#40	#50	#100	#200	pan
% retain	0	1	4	12	13	30	34	4	2

Solution:

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	pan
% cumulative retained	0	1	5	17	30	60	94	98	100

$$\therefore \text{FM of the sample} = \frac{1+5+17+60+94}{100} = 1.77$$

% silt and clay $= (100 - 98) = 2\%$ (Ans.)

2. 500 m^3/d water is to be supplied from a water treatment plant with chlorine concentration of 0.5 mg/L. If bleaching powder that is used for chlorine contains 30% available chlorine. Find the amount of bleaching powder in kg/day.

Solution: Amount of chlorine required $= (500 \times 10^3 \times 0.5)$ mg/day

$= 25 \times 10^4$ mg/day

$= 0.25$ kg/day

$\therefore$ Amount of bleaching powder required $= \left(\frac{100}{30} \times 0.25\right)$

$= 0.833$ kg/day.

3. Determine the volume of cement, sand and stone chips of 100 cft concrete mix with 1:3:6

Solution: Total ratio $= (1+3+6) = 10$

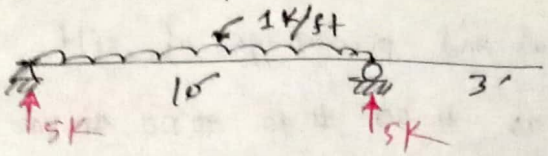
Dry volume of concrete $= (1.5 \times 100) = 150$ cft.

Amount of cement required $= \left(\frac{1}{10} \times 150\right) = 15$ cft

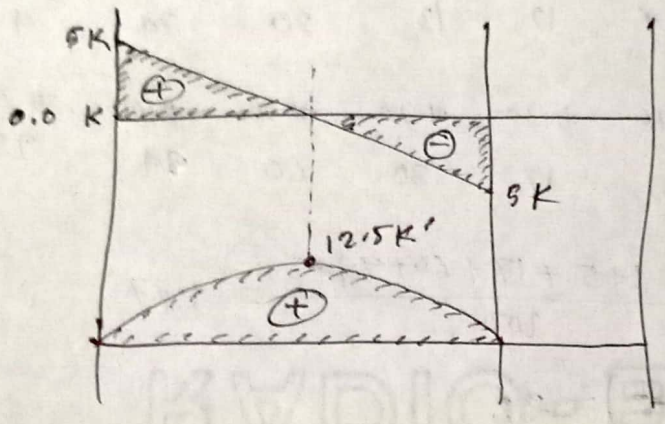
Amount of sand required $= \left(\frac{3}{10} \times 150\right) = 45$ cft

Amount of stone chips required $= \left(\frac{6}{10} \times 150\right) = 90$ cft. (Ans.)

4. Draw SFD and BMD of the beam:



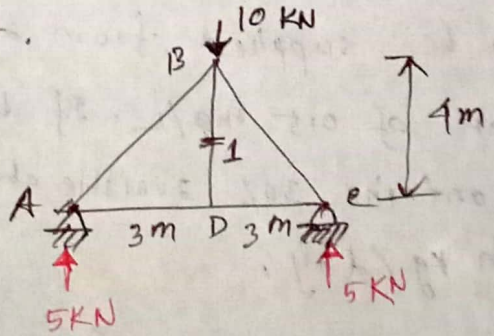
Solution:



SFD

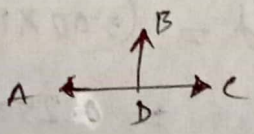
BMD

5. Find out the stress of member 1 and the members of the left hinge from the support.



Solution:

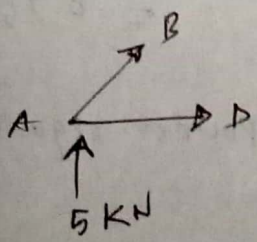
joint D:



$\Sigma F_y = 0$

$DB = 0$

joint A:



$AB = \frac{-5}{4} \times \sqrt{4^2+3^2} = 6.25\ KN\ (c)$

$AD = \frac{6.25}{\sqrt{4^2+3^2}} \times 3 = 3.75\ KN\ (\ )$

6. Total volume of a soil sample is 150 cm^3, saturated weight is 250 gm and dry weight of the sample is 210 gm, if the specific gravity of the soil is 2.6, Find out the saturation of the soil sample.

Solution:

we know, $w = \frac{W_w}{W_s} = \frac{W - W_s}{W_s} = \frac{250-210}{210} = 0.1905 = 19.05\%$

Then, $\gamma_d = \frac{G_s \gamma_w}{1+e}$ Here, $\gamma_d = \frac{W_s}{V} = \frac{210}{150} = 1.4$

$\Rightarrow 1+e = \frac{2.6 \times 1.0}{1.4}$

$\Rightarrow e = 0.857 = 85.79\%$

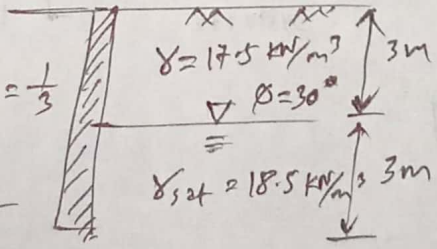
Now, $se = wG_s$ $\Rightarrow S = \frac{wG_s}{e} = \frac{0.1905 \times 2.6}{0.857} = 0.578 = 57.8\%$

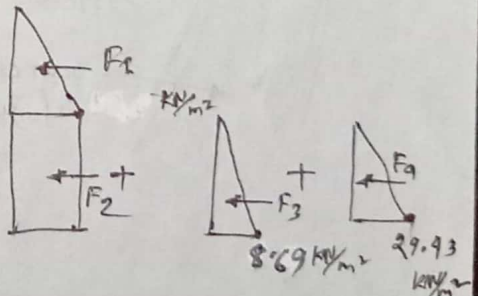
(Ans:)

7. A retaining wall is 6m height, water table 3 m from top. Unit weight of soil above and below the water table is respectively, $\gamma = 17.5\ KN/m^3$ and $\gamma = 18.5\ KN/m^3$, $\phi = 36°$. Draw active pressure diagram and find out the resultant force per unit length.

Solution:

$\phi = 30°$, $\therefore K_a = \frac{1-\sin 30°}{1+\sin 30°} = \frac{1}{3}$





$K_a \gamma_1 H_1 = (17.5 \times 3) \times \frac{1}{3} = 17.5\ KN/m^2$

$K_a \gamma' H_2 = (18.5 - 9.81) \times 3 \times \frac{1}{3} = 8.69\ KN/m^2$

$\gamma_w H_2 = (9.81 \times 3) = 29.43\ KN/m^2$

$\therefore F_1 = (\frac{1}{2} \times 17.5 \times 3) = 26.25\ KN/m$

$F_2 = (17.5 \times 3) = 52.5\ KN/m$

$F_3 = (\frac{1}{2} \times 8.69 \times 3) = 13.035\ KN/m$

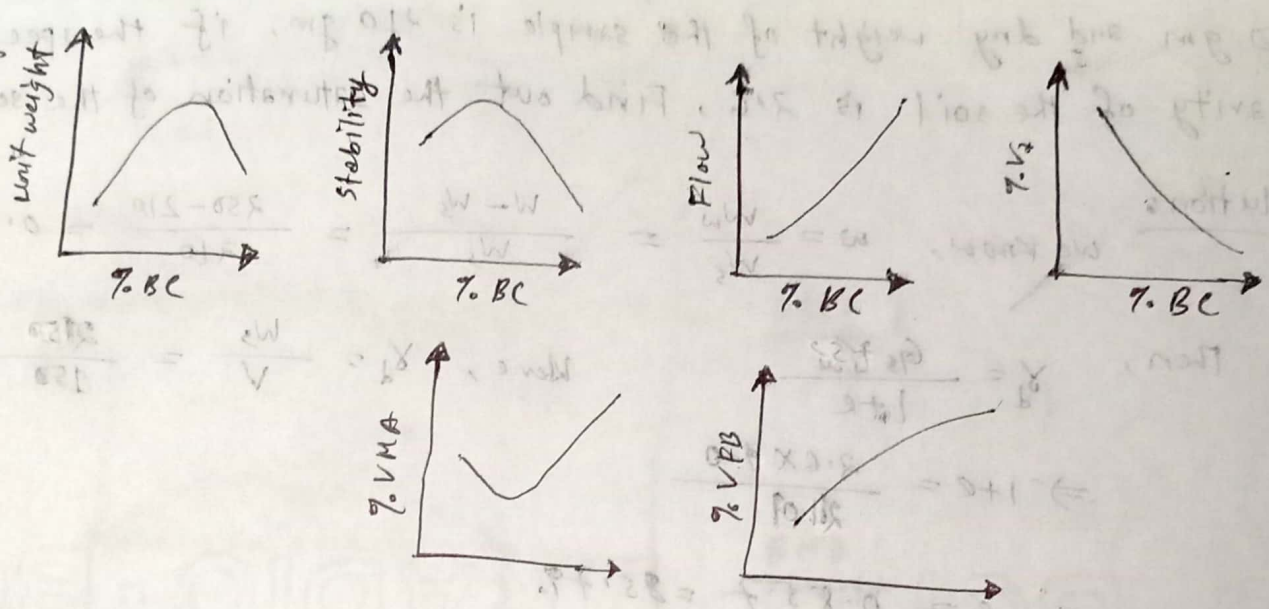
$F_4 = (\frac{1}{2} \times 29.93 \times 3) = 44.195\ KN/m$

$R = (F_1 + F_2 + F_3 + F_4) = 135.93\ KN/m.$

(Ans)

8. Draw Marshall Mix Design Curve.

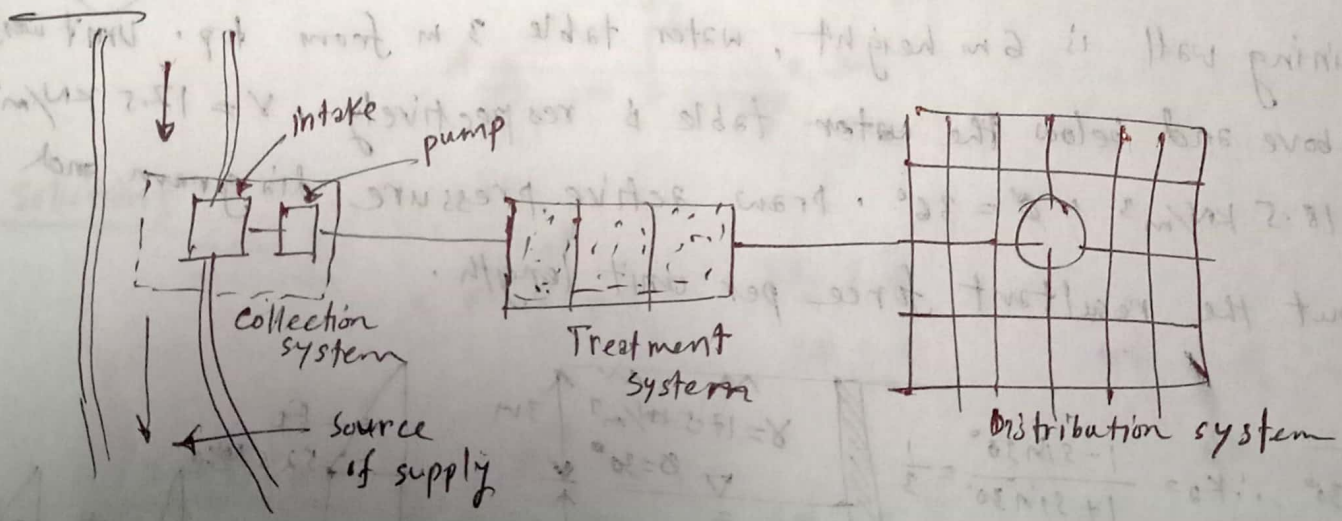
Solution:



9. Define BOD and COD. Why COD is greater than BOD?

10. Draw Flow Diagram of Essential element of water supply system.

Solution:



DESCO-2015 [BUET]

1. A coal power plant uses 10 ton coal which contains 4% sulphur. Determine the amount of sulphur dioxide emission?

Solution:

Total coal = 10 ton = (10×1000) kg = 10×10^3 kg

Amount of sulphar = $(0.04 \times 10 \times 10^3) = 400$ kg.

We know,

$$S + O_2 \longrightarrow SO_2$$

32g — 64g

32 kg — 64 kg

From 32kg sulphar, sulphur dioxide emission = 64kg

" 400kg " , " " " = $\left(\frac{64}{32} \times 400\right)$ kg = 800 kg

(Ans.)

2. Intial dissolved oxygen and final dissolved oxygen is 3.6 and 2.6 respectively. Given, DF = 0.6, Find the BOD_5, BOD remaining and ultimate BOD. Assume, $K = 0.22\ day^{-1}$.

Solution: we know, $BOD_5 = (DO_i - DO_f) \times DR$ $\quad DR = \frac{1}{0.6} = 1.67$

$= (3.6 - 2.6) \times 1.67$

$= 1.67$ mg/L

Now, $BOD_5 = L_o(1 - e^{-0.22 \times 5})$

$\Rightarrow L_o = \frac{1.67}{1 - e^{-0.22 \times 5}} = 2.50$ mg/L

BOD remaining $= L_o e^{-kt} = 2.50 \times e^{-0.22 \times 5} = 0.833$ mg/L

(Ans.)

3. Population of two individual years 1990 and 2000 is given 200000 and 300000 respectively. Determine the population year of 2010. Also one day demanded water disifect in a volume of this water is 25 ML and amount of chlorine used in 0.396 mg/L. Determine the amount of bleaching powder? 25% Cl_2 is required

Solution:

$$r = \sqrt[10]{\frac{300000}{200000}} - 1 = 0.0414$$

Now, $P_f = 300000 \times [1 + 0.0414]^{10} \approx 450087.59 \approx 450088$

Now, Total $Cl_2 = (25 \times 10^6 \times 0.396)$ mg/day $= 9.9 \times 10^6$ mg/day
$= 9.9$ Kg/day.

25 Kg Cl_2 is found from 100 Kg bleaching powder.

9.9 Kg ——— $= \left(\frac{100}{25} \times 9.9\right) = 39.6$ Kg/day Bleaching powder

4. water flow through a pipe which diameter is 10 inch and flow velocity is 50 m/sec. Find the discharge in Litre.

Solution: $Q = AV$

$\Rightarrow Q = \frac{\pi}{4} \times (0.254)^2 \times 50$

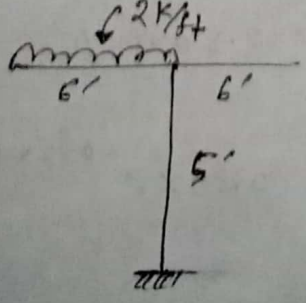
$\therefore Q = 2.5335$ m³/sec. $= 2533.5$ Liter/sec.

(Ans.)

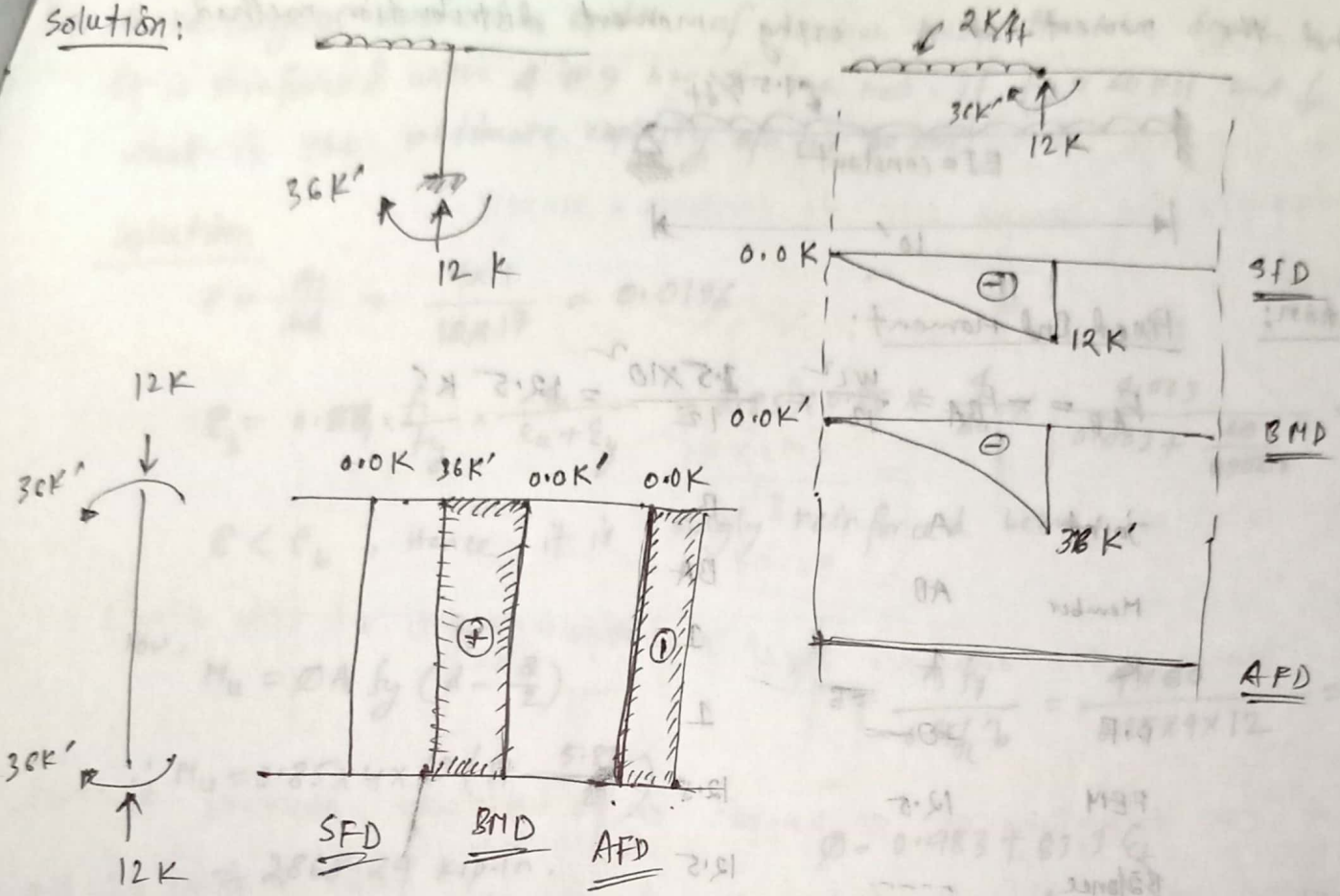
d = 10 inch $= \left(\frac{10 \times 25.4}{1000}\right)$ m.

$\therefore d = 0.254$ m

5. Draw AFD, SFD and BMD of the following Frame.



Solution:



6. Using Terzaghi's equation, Find the bearing capacity of a footing. Necessary Data was given below: Footing size = 2m × 2m, Foundation depth = 1m, $C = 18\ KN/m^2$, $\phi = 35°$, $N_c = 57.7$, $N_q = 41.4$ and $N_\gamma = 42.4$.

Solution: we know,

For square footing,

$$Q_u = 1.3\,CN_c + qN_q + 0.4\,\gamma N_\gamma B$$

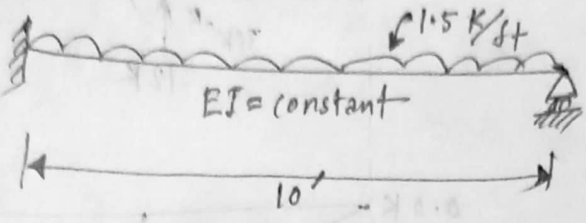
$$= 1.3 \times 18 \times 57.7 + (18 \times 1) \times 41.4 + 0.4 \times 18 \times 42.4 \times 2$$

$q = \gamma D_f$

$$\therefore Q_u = 2219.94\ KN/m^2$$

(Ans.)

7. Find the moment of A using moment distribution method.

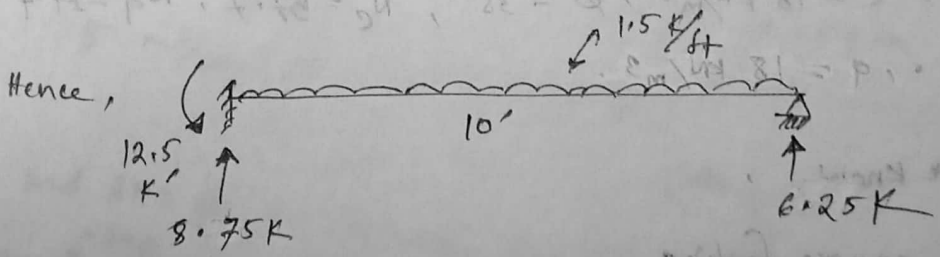


Solution:

Fixed End Moment:

$$F_{AB} = -F_{BA} = \frac{WL^2}{12} = \frac{1.5 \times 10^2}{12} = 12.5 \text{ K'}$$

Joint	A	B
Member	AB	BA
K	1	1
D.F	~~0.5~~	1
FEM	12.5	12.5
Balance	----	12.5
CO	12.5	---
Balance	----	---
Total	12.5	0



8. Determine the ultimate bearing capacity of strip footing 1.2 m and having depth of the foundation is 1.5 m. Take $C = 30 \text{ KN/m}^2$ $\gamma = 20 \text{ KN/m}^3$, $\phi = 0°$, $N_c = 5.14$ and $N_q = 1$ and ~~$N_\gamma = 2.9$~~.

Solution: we know, for strip footing,

$$q_u = 1.3CN_c + qN_q + ~~0.5\gamma B N_\gamma~~ \quad (\phi = 0)$$

$$= 1.3 \times 30 \times 5.14 + (20 \times 1.5) \times 1 + ~~0.5 \times 20 \times 1.2 \times 2.9~~$$

$$= ~~259.26~~ \text{ KN/m}^2 \sim 260.46 \text{ KN/m}^2$$

9. A rectangular beam has width of 12 inch and effective depth = 17 in. If it is reinforced with 4 #9 bar in one row, If $f_y = 60$ ksi and $f_c' = 4$ ksi, what is the ultimate capacity of the beam?

Solution:

$$\rho = \frac{A_s}{bd} = \frac{4 \times 1}{12 \times 17} = 0.0196$$

$$\rho_b = 0.85\beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + \frac{60}{29000}} = 0.59$$

$\rho < \rho_b$, Hence it is singly reinforced beam.

Now, $M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4 \times 60}{0.85 \times 4 \times 12} = 5.88$$

$$\therefore M_u = 0.85 \times 4 \times 60 \left(17 - \frac{5.88}{2}\right)$$

$= 2868.29$ kip-in.

(Ans.)

$\phi = 0.483 + 83.3\,\varepsilon_t$

$$\varepsilon_t = \varepsilon_u \times \frac{d - c}{c} = 0.003 \times \frac{17 - \frac{5.88}{0.85}}{\frac{5.88}{0.85}}$$

$\therefore \varepsilon_t = 0.0044$

$\therefore \phi = (0.483 + 83.3 \times 0.0044)$

$= 0.85$

10. Determine the passive pressure on a sheet pile 10 m height if the soil retaining has following properties: $\phi = 35^\circ$ and $\gamma = 19$ KN/m^3.

Solution: $K_p = \frac{1 + \sin\phi}{1 - \sin\phi} = 3.69$ (where $\phi = 35^\circ$)

$P_p = K_p \gamma H = (3.63 \times 19 \times 10) = 689.7$ KN/m^2

$\therefore F_p = \left(\frac{1}{2} \times 689.7 \times 10\right) = 3498.5$ KN/m.

(Ans.)

12. An engineer checking the speed characteristics at confidence level 95%. Accepta limit 1.0 km/h collected 130 spot speed data, variance = 25 $(km/hr)^2$. Determine the sample size to conduct a survey.

Solution:

We know, $N = \left(\frac{2\sigma}{d}\right)^2$ Give

$$= \frac{1.96^2 \times 25}{1^2}$$

$$= 96.04$$

Hence, The engineer meet the requirements of the study.

13. A car travelling at 50 mph on a highway observes a crash ahead of it. If the driver stooped the car 5 m in front of the crash, find the distance, it has travelled. Preception time = 2.5 sec.

Solution:

We know,

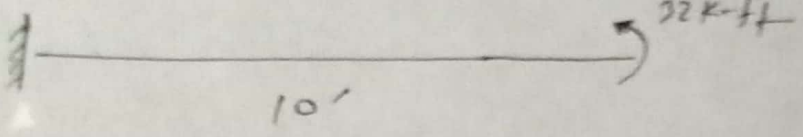
$$SSD = 1.47Vt + \frac{v^2}{30 \cdot f}$$

$$= 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times 0.35} \quad [\text{Assuming } f = 0.35]$$

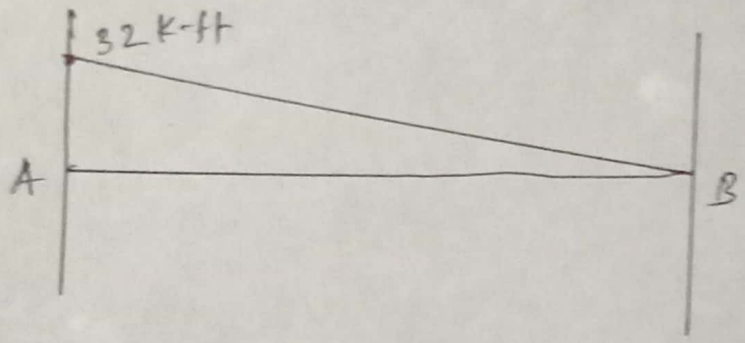
$$= 421.85 \text{ ft}$$

(Ans.)

1. Using Moment area method, find the deflection in span fixed beam. A moment value of M was given at free end shown in figure, where, $E = 2 \times 10^6$ kg/cm² and $I = 10^5$ cm⁴



Solution:



$$t_{B/A} = \frac{1}{EI} \times \left(\frac{1}{2} \times 10 \times 32 \times \frac{2}{3} \times 10\right)$$

$$= \frac{1066.67}{4.099 \times 10 \times 0.116}$$

$$= 2.25 \times 10^{-} \text{ ft}$$

$$= 2.7 \times 10^{-} \text{ in}$$

$E = 2 \times 10^6$ kg/cm²

$= 2 \times 10^{10}$ kg/m²

$= \frac{2 \times 10^{10}}{(3.28)^2}$ kg/ft²

$= \frac{2 \times 10^{10}}{(3.28)^2} \times$ [illegible] K/ft²

$= 4.099 \times 10^6$ K/ft²

$I = 10^5$ cm⁴

$= 10^{-3}$ m⁴

$= 0.116$ ft⁴

DPHC – 2020 BUET

1. Fill in the gaps:

(a) Initial setting time of OPC should not be less than 30 min.

(b) Total faecal coliform in drinking water as BD standard 0/100 ml.

(c) Hammer weight in SPT test 140 lb.

(d) No. of standard size brick required for 100 cft brick work is 1200 Nos.

(e) FAR value of a building 4000 ft^2 area of each floor, Total 10 storey on a land area of 10000 ft^2 is 4.0.

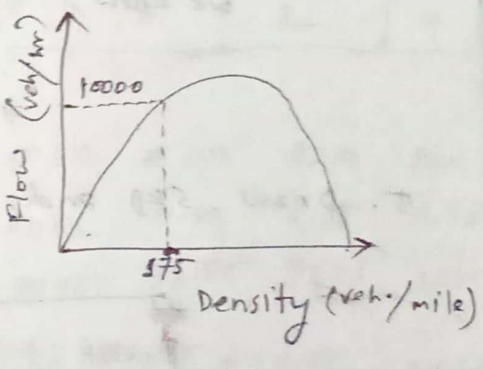
2. Determine the mean speed from the following graph where density 175 vehicle/mile and flow volume, 10000 Veh./hr.

Solution:

$$\text{Speed} = \frac{\text{Volume}}{\text{density}}$$

$$= \frac{10000}{175}$$

$$= 57.14 \text{ mile/hr.}$$



3. A waste water of 1.5 MGD discharge on a primary sedimentation tank & trickling filter. Area of trickling filter = 70,000 ft^2. The influent BOD_5 is 300 mg/L and suspended solid concentration 240 mg/L. If the efficiency of the primary tank is 33%. Compute the organic loading on trickling filter.

Solution: BOD_5 after removal of primary tank = $300 - (0.33 \times 300)$
$= 201$ mg/L

Given, Suspended solid = 240 mg/L

∴ Total = $(201 + 240) = 441$ mg/L

Daily flow = 1.5 MGD = $1.5 \times 10^6 \times 3.785$ Litre = 56.775×10^5 Litre

∴ Total organic load = $\left(56.775 \times 10^5 \times \frac{441}{10^6}\right)$ = 2504 Kg

Load on trickling filter = $\frac{2504}{70000}$ = 3.57×10^{-3} Kg / ft^2-day.

(Ans.)

4. Mass of a soil 23.8 gm and total volume is 12.2 cm^3, Oven dry weight of the soil 19 gm and volume 11.8 cm^3. Calculate void ratio.

Solution:

$$\rho = \frac{M}{V} = \frac{23.8}{12.2} = 1.95 \text{ gm/cm}^3$$

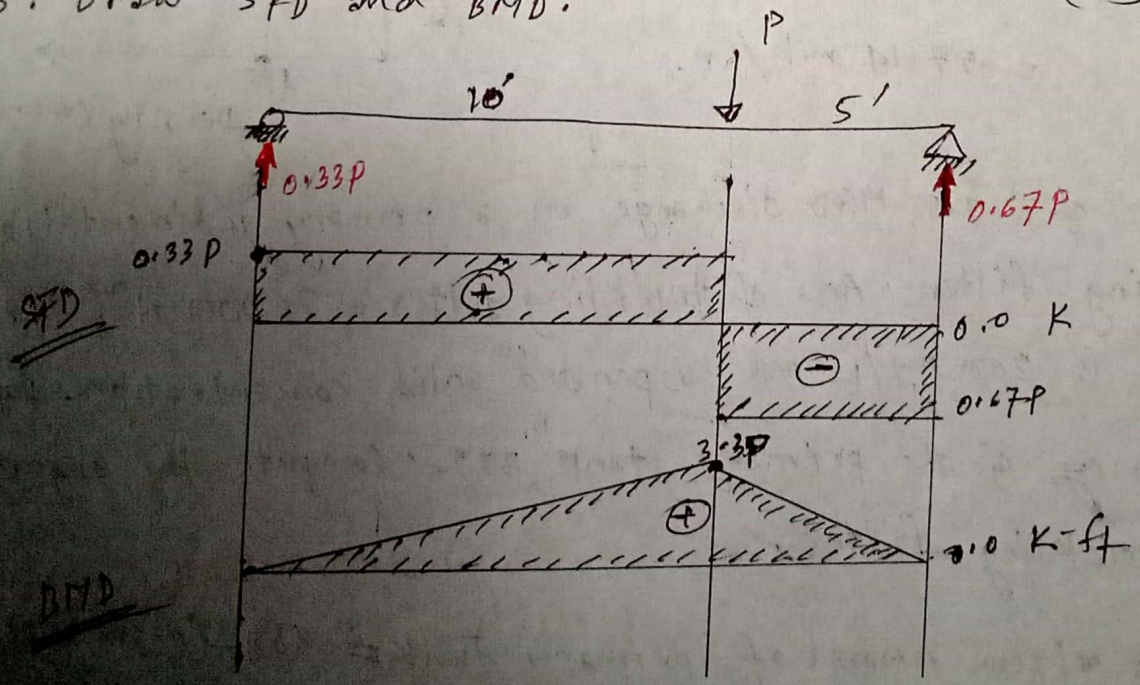
$$\rho_d = \frac{11.8}{12.2} = 1.61 \text{ gm/cm}^3$$

We know, $\rho_d = \frac{e}{1+e}$

$$\Rightarrow 1+e = \frac{1.95}{1.61} \Rightarrow e = 0.21$$

(Ans.)

5. Draw SFD and BMD.



6. Calculate the volume of ingredients required for 100 cft fresh concrete (1 : 1.5 : 3)

Solution:

Dry volume $= (1.5 \times 100) = 150$ cft

sum of ratio $= (1 + 1.5 + 3) = 5.5$

$\therefore$ Amount of cement $= \left(\frac{1}{5.5} \times 150\right) = 27.27$ cft

Amount of fine aggregate $= \left(\frac{1.5}{5.5} \times 150\right) = 40.91$ cft

Amount of coarse aggregate $= \left(\frac{3}{5.5} \times 150\right) = 81.81$ cft (Ans.)

7. Find the FM and % silt and clay.

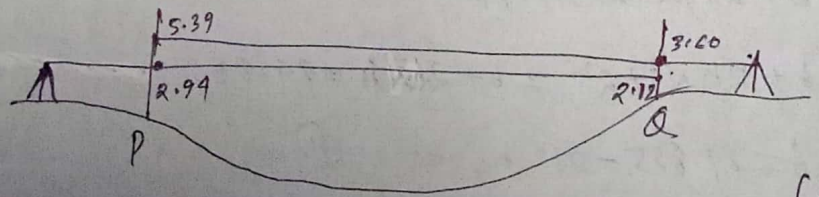
Sieve	#4	#8	#16	#30	#40	#50	#100	#200	Pan
retain	0	1	4	13	30	20	10	2	4

Solution:

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1.19	4.76	15.48	35.71	23.81	11.90	2.38	4.76
cumulate % retain	0	1.19	5.95	21.43	57.14	80.95	92.85	95.23	100

$\therefore$ FM of the sample $= \frac{1.19 + 5.95 + 21.43 + 80.95 + 92.85}{100} = 2.024$. (Ans.)

(8) Calculate the RL of point Q if the RL of point P is 100 ft.



Solution: True difference between P and Q $= \frac{(2.94 - 2.12) + (5.39 - 3.60)}{2}$

$= 1.305$

$\therefore$ RL of Q $= (100 + 1.305) = 101.305$ ft (Ans.)

9. A wide channel having $n = 0.025$, slope $= 0.0025$, discharge $= 3\ m^3/sec$. Calculate the normal depth & velocity.

Solution: For wide channel, $R \simeq h$, $b = 1$

Now, $Q = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$

$\Rightarrow 3 = \frac{1}{0.025} \times h \times h^{\frac{2}{3}} \times (0.0025)^{\frac{1}{2}}$

$\Rightarrow h = 1.275\ m$

$\therefore V = \frac{Q}{A} = \frac{3}{1.275} = 2.35\ m/sec.$ (Ans.)

10. You have to design an irrigation channel of discharge 11270 cusec. The average size of the bed material is 0.014 cm. Using Lacey's theory, determine the cross-section dimension and longitudinal slope of the channel.

Solution: Given, $Q = 11270$ cusec. $= 11270 \times (0.3048)^3 = 319.13$ cumec.

$$f = 1.76\sqrt{d_{mm}} = 1.76\sqrt{(0.014 \times 10)} = 0.658$$

Now, $V = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}} = \left(\frac{319.13 \times 0.658^2}{140}\right)^{\frac{1}{6}} = 0.998\ m/sec.$

$$A = \frac{Q}{V} = \frac{319.13}{0.998} = 319.77\ m^2$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{319.13} = 84.855\ m$$

Assume, side slope $= 1V : 2H$

Then, $A = (b + 2h)h = 319.77$ ..... (i)

$$P = b + 2h\sqrt{1+2^2} = b + 2\sqrt{5}\,h = 84.855$$

$\Rightarrow b = 84.855 - 2\sqrt{5}\,h$ ..... (ii)

From (i), $(84.855 - 2\sqrt{5}h + 2h)h = 319.77$

$\Rightarrow h = 4.31\ m$ Hence, $b = (84.855 - 2\sqrt{5} \times 4.31) = 65.58\ m$

Longitudinal slope $= \frac{f^{\frac{5}{3}}}{3340 \times Q^{\frac{1}{6}}} = \frac{(0.658)^{\frac{5}{3}}}{3340 \times (319.13)^{\frac{1}{6}}} = 5.7 \times 10^{-5}$ (Ans.)

DPDC-2019 [BUET]

1. Write the pre-mechanism by which heavy metals ions are removed during coagulation process?

Solution: Coagulation is a process of addition of salt that produces positive ions in water and application of rapid agitation for good mixing leading to destabilization of colloids and promotion of frequent contact among particles.

The heavy metal ions in water are positively charged, and the coagulants are negatively charged. When the coagulants are added to water, they neutralize the charge on the heavy metals, causing them to form a solid than can be easily removed from the water.

2. Determine Euler Buckling Stress of a 12 ft long column having cross-sectional properties: $r_x = 4.25$ in., $r_y = 2.1$ in. Assume pinned-pinned end for strong axis bukling and fixed-pinned end for weak axis bukling. Given, $E = 29 \times 10^6$ psi

Solution: We know, $\sigma = \frac{P}{A} = \frac{E\pi^2}{\left(\frac{Le}{r}\right)^2}$

For strong axis bucking, $Le = L = 12$ ft, $r = \sqrt{4.25^2 + 2.1^2} = 4.758$ in

$$\sigma_s = \frac{29\times10^6 \times 3.1416^2}{\left(\frac{12\times12}{4.758}\right)^2} = 312.81\times10^3 \text{ psi}$$

For weak axis buckling, $Le = 0.7L = (0.7\times12) = 8.4$ ft,

$$r = \sqrt{2.1^2 + 4.25^2} = 4.758$$

$$\therefore \sigma_w = \frac{29\times10^6 \times 3.1416^2}{\left(\frac{8.4\times12}{4.758}\right)^2} = 637.7\times10^3 \text{ psi}$$

(Ans)

3. It is observed that 40 traffic crashes occured on a 17.5 miles long section of highway in one year. ADT given on that section is 5000 vehicles. Determine

(a) The rate of total crashes per 100 million vehicle-miles.

(b) the rate of fatal crashes per 100 million vehicle-miles, if 5% of the crashes involved fatalities.

Solution: vehicle-mile of travel in a year $= (365 \times 5000 \times 17.5)$

$= 31.9375 \times 10^6$ vehicle-miles

For 31.9375×10^6 vehicle-miles car crashes $= 40$

$\therefore$ For 100×10^6 vehicle-miles car crashes $= \frac{40 \times 100 \times 10^6}{31.9375 \times 10^6}$ Nos.

$= 125.24$ crashes

$\simeq 126$ crashes

$\therefore$ Rate of crashes = 126 crashes/100 million vehicle-miles.

if 5% crashes involved fatalities, rate of crashes $= (0.05 \times 126)$

$= 6.3 \simeq 7$ crashes

$\therefore$ Rate of fatal crashes = 7 crashes/100 million vehicle-miles (Ans.)

4. The initial void ratio of an underlaying saturated clay layer 5 m thick is 1.4 due to the weight of super imposed embankment fill. The void ratio of clay layer decrease 1.4 to 1.1. Determine the consequent settlement of that clayer.

Solution: we know, $S_c = \frac{H_c C_c}{1+e_0} \times \log\left(\frac{\sigma_0'}{\sigma_0' + \Delta\sigma'}\right)$

Now, $\Delta e = C_c \log\left(\frac{\sigma_0'}{\sigma_0' + \Delta\sigma'}\right) = (1.4 - 1.1) = 0.3$

$\therefore S_c = \frac{5 \times 0.3}{1 + 1.4} = 0.625$ m (Ans.)

5. Determine axial load of column. Given, column section = 12" × 12" 4 # 5 bar. A hole at the middle of the column of 2" × 2". $f_c' = 4$ ksi, $f_y = 60$ ksi.

Solution: We know,

$$P_u = \alpha \phi A_g [0.85 f_c' + \rho_s (f_y - 0.85 f_c')]$$

$$= 0.8 \times 0.65 \times 140 [0.85 \times 4 + 0.009 (60 - 0.85 \times 4)]$$

$$= 284.60 \text{ kip}.$$

(Ans.)

Here,

$A_g = (12 \times 12) - (2 \times 2)$

$= 140 \text{ in}^2$

$\rho_s = \frac{A_s}{A_g}$

$= \frac{4 \times 0.31}{140}$

$= 0.009$

6. Write the major gases of green house.

Solution: 1. CO_2 - produced by burning fossil fuels, deforestation etc.

2. CH_4 - produced by natural process such as decomposition of organic matter.

3. N_2O - produced by agricultural and industrial activities.

4. Fluorinated gases - HCFs, PFCs, SF6 etc.

7. Given, saturated sample has moisture content 12%, $G_s = 2.7$. Determine the unit weight of that sample.

Solution: We know, $se = wG_s$

$\Rightarrow 1 \times e = 0.12 \times 2.7$ (For 100% saturation, $S = 1$)

$\Rightarrow e = 0.324$

Now, $\gamma = \frac{(1+w)}{(1+e)} G_s \gamma_w = \left(\frac{1+0.12}{1+0.324}\right) \times 2.7 \times 9.81$

$\therefore \gamma = 24 \text{ kN/m}^3$

(Ans.)

8. What are the main problem for extraction of groundwater and collection of surface water in Bangladesh?

Solutions:

1. Over use of ground water: In Bangladesh, ground water is the primary source of drinking water for majority of the population. Due to non-stop extraction of groundwater leads to deplelation of aquifers and a decline in water table.

2. contamination of surface water: The surface water in bangladesh is contaminated by industrial wastes. This poses a significant health risk to the pollution.

3. scarsity of water: In dry season, there is scarcity of both surface and ground water.

Addressing these challenges requires combination of strategies, including improved water management and regulation, better infrastructure and technology for water extraction and treatment and public education on water conversion and hygiene.

9. Draw SFD and BMD.

DPDC - 2016 BUET

1. A wide channel with discharge 20 $m^3/sec.$, $S_o = 0.0028$, $n = 0.026$, Find Normal depth and velocity.

Solution: For wide channel, $R \simeq h$, $\beta \simeq 1$

We know,

$$Q = AV$$

$$\Rightarrow Q = h \times \frac{1}{n} \times h^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

$$\Rightarrow 3 = h \times \frac{1}{0.026} \times h^{\frac{2}{3}} \times (0.0028)^{\frac{1}{2}}$$

$\therefore h = 1.262$ m.

$\therefore V = \frac{Q}{h} = \frac{3}{1.262} = 2.377$ m/sec. (Ans)

2. A distance is measured 1000 m with a 25 m tape which was actually 24.9 m. Calculate the true length of distance.

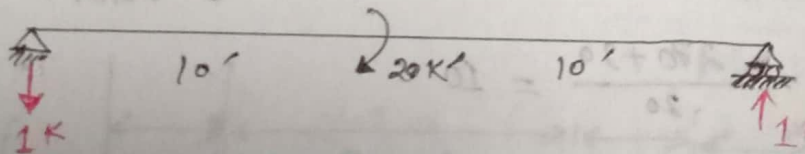
Solution:

$$TL = \frac{L'}{L} \times ML$$

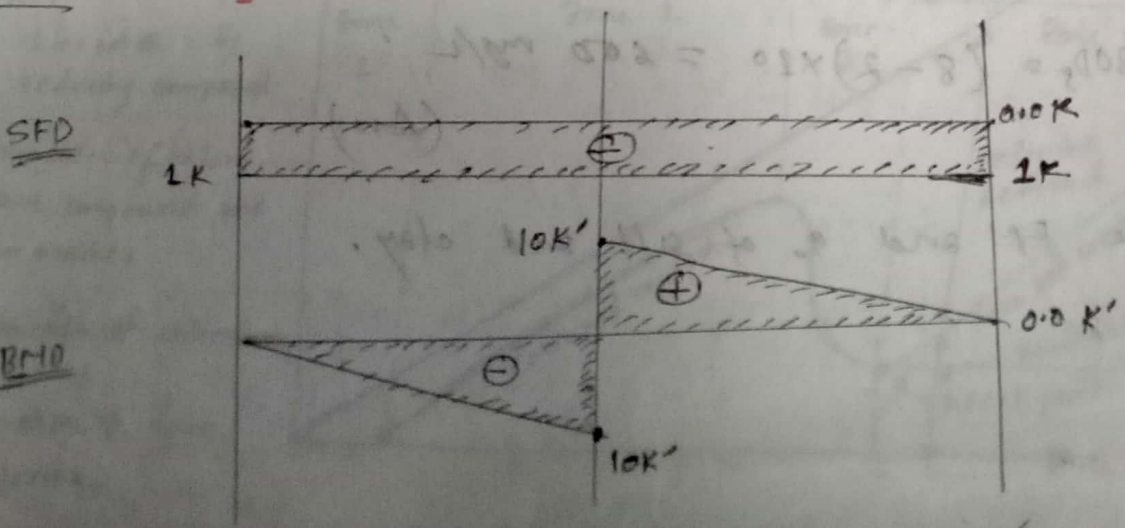
$$\Rightarrow TL = \frac{24.9}{25} \times 1000$$

$$\Rightarrow TL = 996 \text{ m}.$$ (Ans.)

3. Draw SFD and BMD of the following beam:

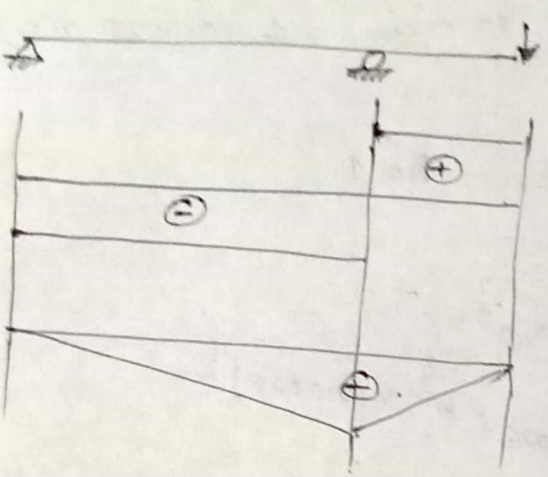


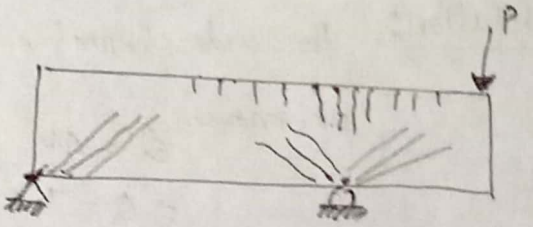
Solution:



4. Draw shear and flexure cracks of following beam

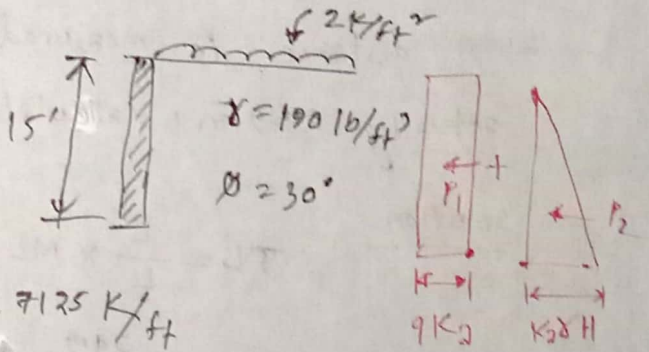
Solution:





5. A retainning wall retains soil with angle of friction 30°, unit weight of soil 190 lb/ft³ with a surcharge load 2K/ft². Determine the active earth pressure of soil.

Solution: $K_a = \frac{1-\sin 30^\circ}{1+\sin 30^\circ} = \frac{1}{3}$



$P_1 = qK_a H = (2 \times \frac{1}{3} \times 15) = 10$ K/ft

$P_2 = \frac{1}{2} \times K_a \gamma H \times H = \frac{1}{2} \times \frac{1}{3} \times 190 \times 15 \times 15 = 7125$ K/ft

∴ Total Force per feet of wall = $(10 + 7125) = 7135$ K/ft

6. Find BOD_5 if intial DO of a soil sample = 8 mg/L and final DO = 2 mg/L (Ans.)
if 30 ml waste sample is mixed with 270 ml water.

Solution: $DF = \frac{270+30}{30} = 10$

∴ $BOD_5 = (8-2) \times 10 = 600$ mg/L.

(Ans.)

7. Find the FM and % of silt and clay.

1. 1 Mgd water passes through a sedimentation tank of 50'×20'×10', what will be the detention time?

Solution: we know, $Q = \frac{V}{T}$

Here, $Q = 1$ Mgd $= 10^6 \times 3.785 \times 10^{-3} \times (3.28)^3$ ft³/day $= 133863.4$ ft³/day

$\Rightarrow T = \frac{50 \times 20 \times 10}{133563.4}$

$\Rightarrow T = 0.0795$ day

$\therefore T = 1.797$ hrs. (Ans)

2. what is pH? The pH of a solution is 10. Calculate the OH^- ion.

solution: pH: pH is a quantitative measures of Acidity and Basicity of aqueous or any liquid solution.

Given, $pH = 10$

we know, $pH + pOH = 14 \Rightarrow pOH = (14 - 10) = 4$

Now, $pOH = -\log [OH^-]$

$\Rightarrow [OH^-] = 10^{-4}$ mole/l. (Ans)

3. Draw typical chlorination curve and show the break point in the curve.

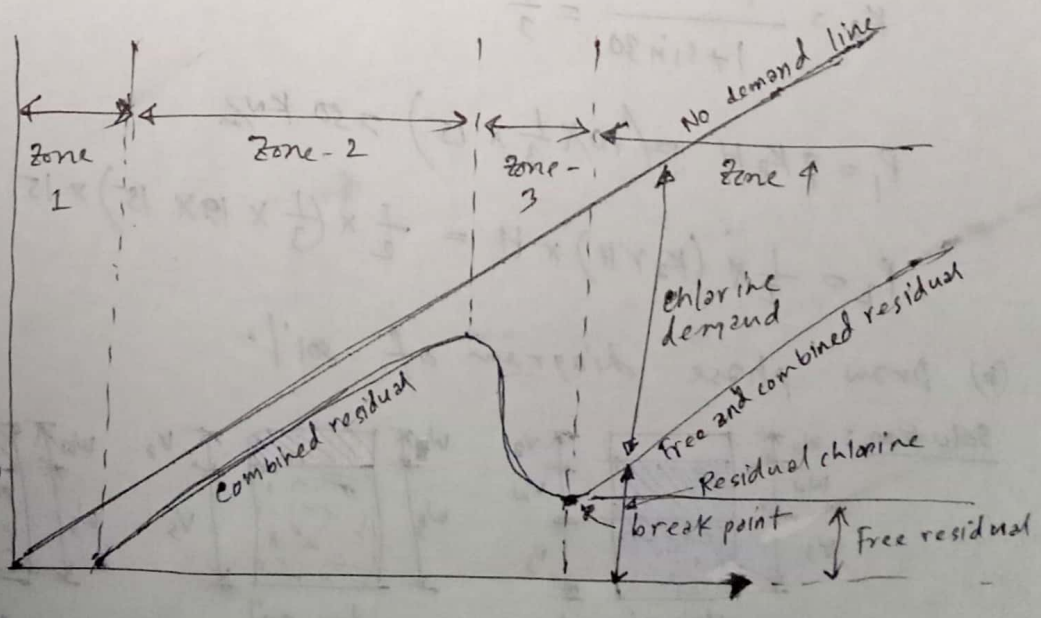
Solution:

Zone 1: Destruction of chlorine by reducing compound

Zone 2: Formation of chloro-organic compound and chloramines

Zone-3: Destruction of chloramines

Zone 4: Formation of free chlorine.



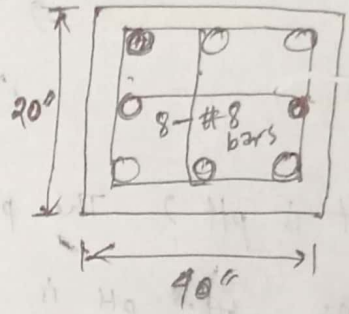
4. calculate FM of the sample.

5. Given, Rain Area = 20 m^2, Runoff co-efficient = 0.8. Rain fall intensity = 10 m/year. Find the quantity of rain water.

Solution:

$$Q = CIA = (0.8 \times 10 \times 20) = 160 \ m^3/year.$$

6. Design Tie of the following column section.



Solution: Assume, #3 bar will be used as Tie.

Spacing:

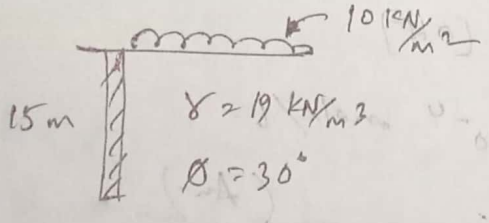
$$S_{max} = 16 d_b = 16 \times \frac{8}{8} = 16"$$

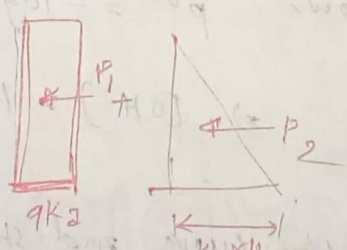
$$S_{max} = 48 d_t = 48 \times \frac{3}{8} = 18"$$

$$S = 20"$$

So, Use #3 bar @ 16" c/c.

7 (a) Determine the active earth pressure on retaining wall.





Solution:

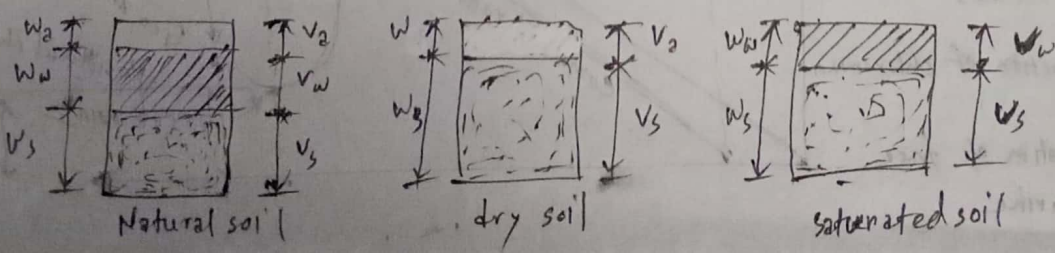
$$K_a = \frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$$

$$P_1 = q K_a H = \left(10 \times \frac{1}{3} \times 15\right) = 50 \ KN/m$$

$$P_2 = \frac{1}{2} \times (K_a \gamma H) \times H = \frac{1}{2} \times \left(\frac{1}{3} \times 19 \times 15\right) \times 15 = 712.5 \ KN/m$$

(b) Draw phase diagram of soil.

Solution:



8. Area measured with Gunters chain is 32000 m^2. But after measurement, it was found to be Engineering chain. What is the correct area.

Solution:

$$\text{True Area} = \left(\frac{L'}{L}\right)^2 \times \text{Measured Area}.$$

$$\therefore \text{True Area} = \left(\frac{66}{100}\right) \times 32000 = 21120 \ m^2 \quad \text{(Ans.)}$$

9. What is standard axles. A axial load 20 Kip after one year is found to be repeated 10 times. What is the standard axle load?

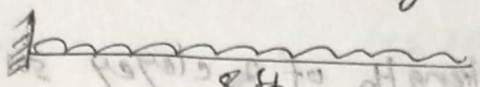
Solution:

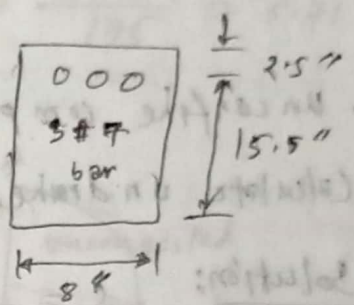
$$\text{L.E.F for 20 K} = \left(\frac{20}{18}\right)^4 = 1.524$$

$$\therefore \text{ESAL} = (365 \times 10 \times 1.524) = 5562.6 \quad \text{(Ans.)}$$

1. Check whether the beam is safe in flexure to carry a dead load including its self weight of 1.5 K/ft, live load = 0.9 K/ft. Use USD method. Given, $f_c' = 4$ KSI, $f_y = 60$ KSI.

Solution:





$W_u = 1.2DL + 1.6\,LL$

$\therefore W_u = (1.2 \times 1.5 + 1.6 \times 0.9) = 3.24$ K/ft

$\therefore M_{req.} = \frac{W_u L^2}{2} = \frac{3.24}{2} \times (8)^2 = 103.68$ K-ft

Now, $M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$ Here, $a = \frac{A_s f_y}{0.85 f_c' b} = \frac{3 \times 0.6 \times 60}{0.85 \times 4 \times 8}$

$\therefore a = 3.97$"

$= 0.9 \times (0.6 \times 3) \times 60 \times \left(15.5 - \frac{3.97}{2}\right)$

$= 1313.66$ kip-in.

$M_u = 109.47$ kip-ft $>$ $M_{req.}$

$\phi = 0.483 + 83.3\,\varepsilon_t$

$= 0.483 + 83.3 \times 0.003 \times \frac{15.5 - \frac{3.97}{0.85}}{\frac{3.97}{0.85}}$

$= 1.06 > 0.9$

Hence, $\phi = 0.9$

Hence, the beam is safe to carry the load.

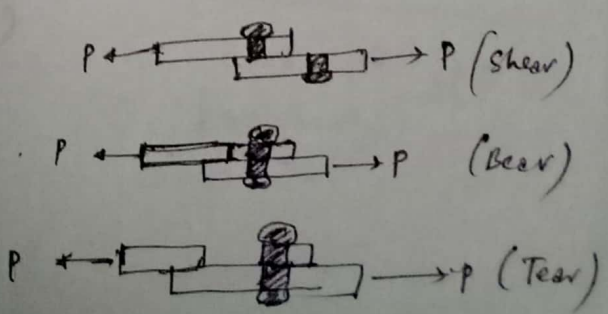
(Ans.)

2. States different types of failure in Rivet joints.

Solution: (i) shearing failure in rivets

(ii) Bearing failure in plate

(iii) Tearing failure in plate



3. In SPT test, the value of N for 1st, 2nd and 3rd 15cm penetration were 10, 15 and 20. calculate the field SPT value.

Solution:

$\therefore$ SPT value $= (15+20) = 35$.

4. Unconfine compressive strength of a clayey soil is 100 K/ft^2. Calculate undrained shear strength.

Solution:

$$S = \frac{q_u}{2} = \frac{100}{2} = 50 \ K/ft^2$$

5. A horizontal flow of a grit chamber has flow rate 26.5 ft^3/sec. and 5.9 ft deep, width is 15 times the length of the chamber. Determine the width of grit chamber. Assume, the approach velocity of flow = 1.15 ft/sec.

Solution: we know,

$$Q = AV$$

$$\Rightarrow A = \frac{Q}{V}$$

$$\Rightarrow B \times H = \frac{26.5}{1.15}$$

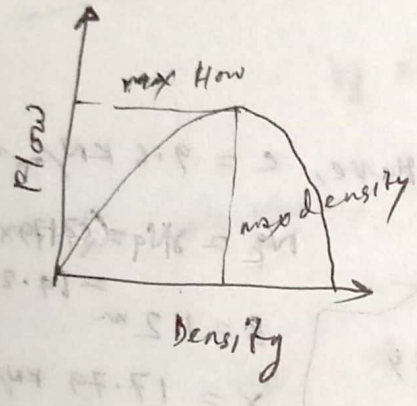
$$\Rightarrow 15L \times 5.9 = 23.04$$

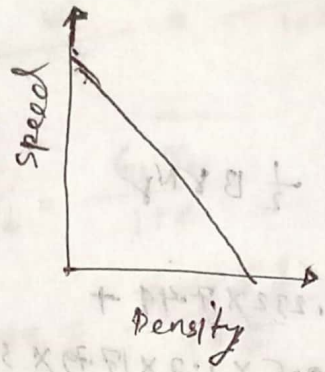
$$\Rightarrow L = 0.26 \ ft \quad \therefore \text{Width} = (15 \times 0.26) = 3.906 \ ft$$

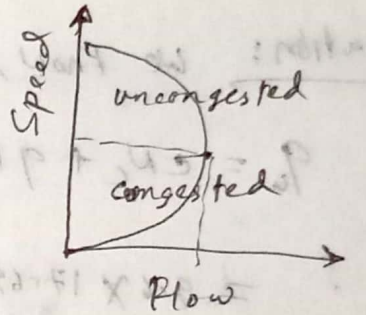
(Ans.)

6. Draw flow density velocity relationship curve. Estimate the mean velocity at a point where, flow is 1000 veh/hour and the density is 175 vehicle/mile.

Solution: we know; $q = kv \Rightarrow v = \frac{q}{k} = \frac{1000}{175} = 5.71$ mile/hr







7. What is stopping sight distance. Calculate SSD of a vehicle of velocity, $v = 50$ mile/hr, reaction time, $t = 2.5$ sec. and deceleration rate, $a = 20$ ft/sec.

Solution: The minimum sight distance available on highway at any spot to stop a vehicle travelling at design speed safely without any collision is called SSD.

We know, $SSD = 1.47 vt + \frac{v^2}{30(f \pm n)}$

$= 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times \left(\frac{20}{32.2}\right)}$

$= 317.92$ ft

(Ans)

8. Determine the ultimate bearing capacity of continuous footing width 1.2 m is located at a depth of 0.8 m below the ground surface. The properties of foundation soil are given: $\gamma = 17.79\ KN/m^3$, $c = 9.6\ KN/m^2$, $\phi = 20°$. Note: GWT is far below than footing base.

Solution: We know,

$$q_u = cN_c + qN_q + \frac{1}{2}B\gamma N_\gamma$$

$$= 9.6 \times 17.69 + 14.232 \times 7.44 + 0.5 \times 1.2 \times 17.79 \times 3.64$$

$$= 314.56\ KN/m^2$$ (Ans.)

Here, $c = 9.6\ KN/m^2$

$q = \gamma h = (17.79 \times 0.8) = 14.232\ KN/m^2$

$B = 1.2\ m$

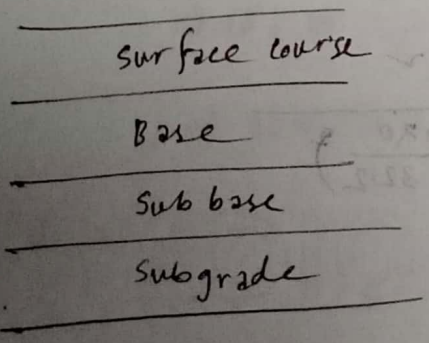
$\gamma = 17.79\ KN/m^3$

$$N_q = \frac{e^{2(\frac{3\pi}{4} - \frac{\phi'}{2})\tan\phi'}}{2\cos^2(45 + \frac{\phi}{2})} = 7.44$$

$$N_c = (N_q - 1)\cot\phi = 17.69$$

$$N_\gamma = \frac{1}{2}\left(\frac{K_p}{\cos^2\phi} - 1\right)\tan\phi = 3.64$$

9. # Draw typical cross section of flexible pavement.



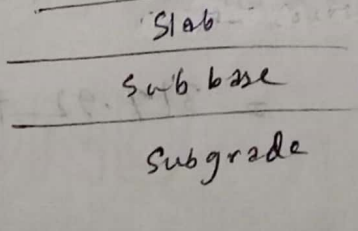


Fig. Flexible Pavement

10.

A undisturbed sample of soil has a volume of 100 cm³ and mass of 190 gm on oven drying for 24 hr, the mass reduced to 160 gm. If G=2.68. Determine the void ratio, porosity and degree of saturation.

Solution:

$$\gamma = \frac{W}{V} = \frac{190}{100} = 1.9 \text{ gm/cc}$$

$$\gamma_d = \frac{W_s}{V} = \frac{160}{100} = 1.6 \text{ gm/cc}$$

We know,

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

$$\Rightarrow 1+e = \frac{2.68 \times 1}{1.6}$$

$$\Rightarrow e = 0.675 = 67.5\%$$

$$\therefore n = \frac{e}{1+e} = \frac{0.675}{1.675} = 0.403 = 40.3\%$$

$Se = wG_s$ where, $\gamma = \gamma_d(1+w)$

$$\Rightarrow 1+w = \frac{1.9}{1.6}$$

$$\Rightarrow w = (1.1875 - 1) = 0.1875$$

$$\Rightarrow S = \frac{0.1875 \times 2.68}{0.675}$$

$$\therefore S = 0.7444 = 74.44\%$$

(Ans)

#11. water treatment plant produces 1 MLD of water, bleaching powder (90% chlorine) used to disinfect the water. Residual chlorine is 0.5 mg/L. Chlorine demand was 3.5 mg/L. Estimate the amount of bleaching powder kg/day.

Solution: chlorine dose = (3.5 + 0.5) = 4 mg/L

∴ Amount of chlorine required = $(1 \times 10^6 \times 4)$ mg/L

= 4 kg/L

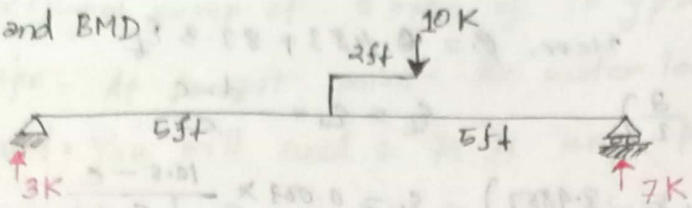
∴ Bleaching powder required = $\left(\frac{100}{90} \times 4\right)$ = 10 kg/day

(Ans.)

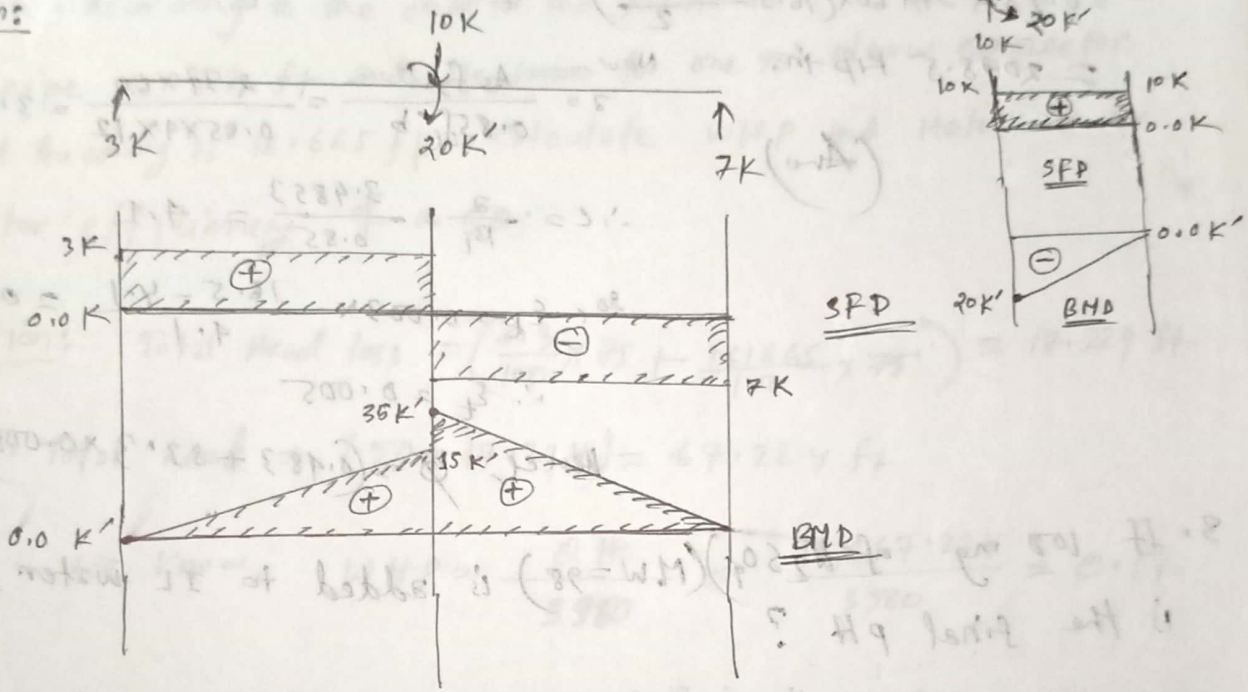
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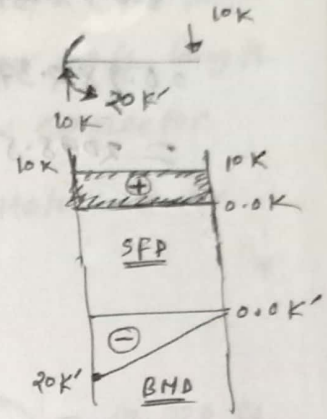
BUET

1. Draw SFD and BMD:

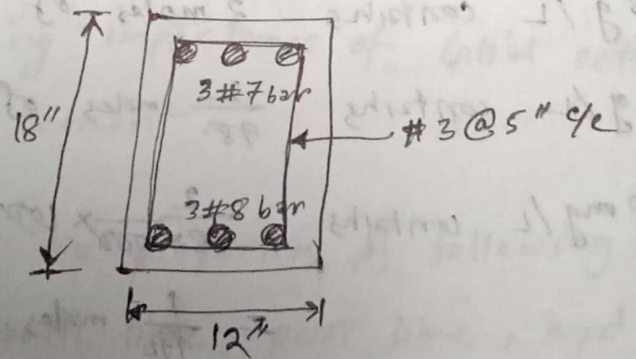


Solution:





2. Determine the ultimate capacity of a beam if clear cover = 1.5 in, $f_c' = 4$ ksi and $f_y = 60$ ksi.



Solution:

$A_s = (3 \times 0.79) = 2.37 \text{ in}^2$

$\rho = \frac{A_s}{bd} = \frac{2.37}{12 \times (18 - 1.5)} = 0.012$

$\rho_{max} = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} = 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.005} = 0.020$

Since $\rho_{max} > \rho$, It is a singly reinforced beam.

Then,

$M_u = \phi M_n$ Here, $\phi = 0.483 + 83.3\,\varepsilon_t$

$= 0.9 \times A_s f_y \left(d - \frac{a}{2}\right)$ $\varepsilon_t = \varepsilon_u \times \frac{d-c}{c}$

$= 0.9 \times 2.37 \times 60 \times \left(16.5 - \frac{3.4853}{2}\right)$ $\varepsilon_t = 0.003 \times \frac{16.5 - c}{c}$

$=$ 5 Kip-in. Now,

$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{2.37 \times 60}{0.85 \times 4 \times 12} = 3.4853$ in.

(Ans)

$\therefore c = \frac{a}{\beta_1} = \frac{3.4853}{0.85} = 4.1$

So, $\varepsilon_t = 0.003 \times \frac{16.5 - 4.1}{4.1} = 0.0091 > 0.005$

$\therefore \varepsilon_t = 0.005$

Hence, $\phi = (0.483 + 83.3 \times 0.005) = 0.90$

8. If 100 mg of H_2SO_4 (MW = 98) is added to 1L water, what is the final pH ?

Solution:

$H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$

98 g/L contains 2 moles of $[H^+]$

$\therefore$ 1 g/L contains $\frac{2}{98}$ moles of $[H^+]$

100 mg/L contains $\frac{2}{98 \times 1000} \times 100$ moles of $[H^+]$

$= \frac{1}{490}$ moles.

$\therefore pH = -\log\left(\frac{1}{490}\right) = 2.69$

(Ans)

4. Planned to irrigate a garden by pumping from a dug well using centrifugal pump at a rate of 10 gpm through 1 in plastic pipe. At lowest point the water level is 50 ft below the garden level. You will need a 75 ft long plastic pipe (Horizontal length). According to the chart the frictional head per 100 ft length of pipe is 6.3 ft and the same for one 90° elbow connector and threading is 16.665 ft. Calculate WHP and Motor HP for motor efficiency of 0.50.

Solution: Total Head loss $= \left(\frac{6.3}{100} \times 75 + \frac{16.665}{100} \times 75\right) = 17.224$ ft

$\therefore$ Total head $= (50 + 17.224) = 67.224$ ft

We know, $WHP = \frac{QH}{3960} = \frac{10 \times 67.224}{3960} = 0.17$.

$\therefore$ Motor horsepower $= \frac{0.17}{0.5} = 0.34$.

(Ans.)

5. Write Engineering importance of intial setting time and soundness test of cement.

6. Define and write one properties of following lime:
Quick lime, hydraulic lime, poor lime, hydrated lime.

7. Define characterestics of strain composition of plastic materials.

Mongla Port Authority – 2023

KUET

1. What is one way and two way slab? Why distribution steel is used in slab? Why corner reinforcement is provided? How do you check a doubly reinforced beam?

Solution:

One way slab: If a slab is supported on two opposite site only, it will bend or deflect in direction perpendicular to the supported edges. The structural action is one way and the loads carried by the slab in the deflected short direction. This type of slab is called a one-way slab. The ratio of long side to short side of one way slab is or greater than 2.

Two way slab: If a slab is supported on four sides and the ratio of long side to the short side is smaller or lesser than 2, the slab will will deflect in double curvature in both directions. The floor loads are carried in two direction to the four beams surrounding the slab. This types of slab is called two slabs.

Why distribution steel is used in slab:

Distribution bar in a reinforced concrete slab is provided perpendicular to main bar. It is provided to.

(i) prevent shrinkage stresses and temperature effects. (cracking)
(ii) distribute the load equally to main bar
(iii) keep main bar position.

Why corner reinforcement is provided:

(i) To resist diagonal cracks
(ii) To resist twisting moment at exterior corner

check for doubly reinforced beam:

If $\rho > \rho_{max}$, The beam should be analysised as doubly reinforced beam.

where, $\rho = \frac{A_s}{bd}$ and $\rho_{max} = 0.85\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$

If $d_{req} > d_{eff}$, The beam should be designed as doubly reinforced beam.

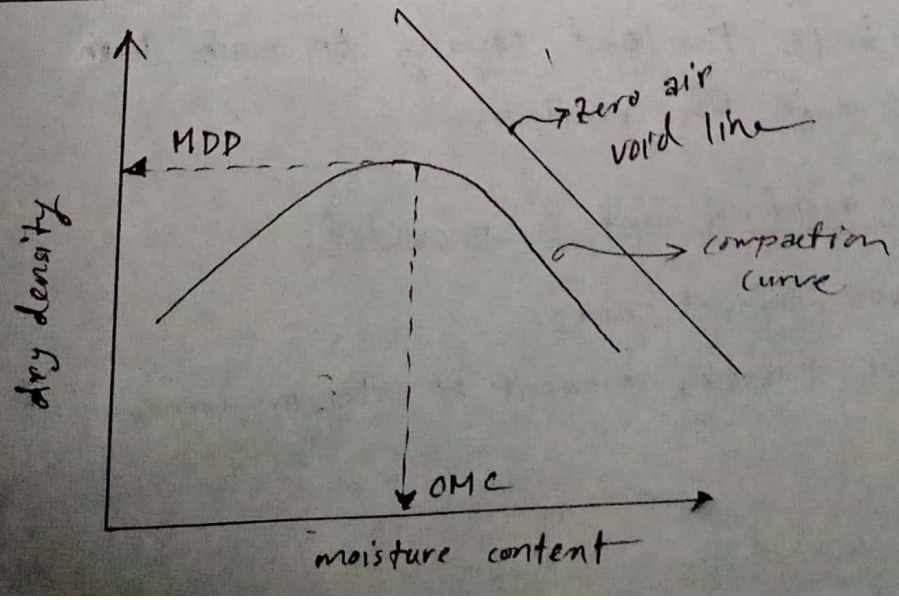
$$d_{req} = \sqrt{\frac{M_u}{\phi \rho f_y (1 - 0.59 \rho \frac{f_y}{f_c'})}}$$

here, $\rho = \rho_{max} = 0.85\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.005}$

2. Difference between compaction and consolidation. Sketch a typical graph compaction. what is degree compation or relative compaction?

Solution:

compaction	Consolidation
(i) compaction is densification process of soil, in which only air voids are removed from soil by mechanical means.	(i) consolidation is also a densification process of soil, in which both water and air voids are removed by static loading.
(ii) It is a fast process	(ii) It is a gradual process
(iii) It is done by short time loading	(iii) It is done by long time loading.
(iv) It is done for sandy soil	(iv) It is done for clayey soil



Relative compaction: Relative compaction indicates degree of compaction of soil. It is the ratio of compacted dry density to the maximum dry density found in laboratory. It is expressed as-

$$R(\%) = \frac{\gamma_d(\text{field})}{\gamma_d(\text{max-lab})} \times 100.$$

3. Draw typical diagram of rigid pavement and flexible pavement.

Solution:

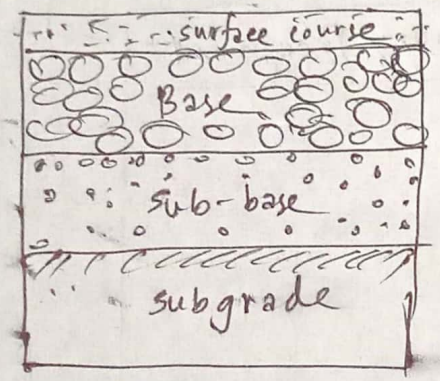


Fig. Flexible pavement

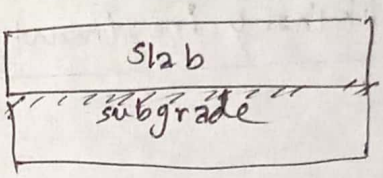


Fig. Rigid pavement

4. State the Manning's and chezy's formula for calculating discharge of a open channel flow. Derive relationsheep between Manning's and chezy's formula and roughness co-efficient.

Solution: **Manning's formula:** $Q = A \times \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$

Chezy's formula: $Q = A C \sqrt{RS}$

Relationship: From Manning's and chezy's formula,

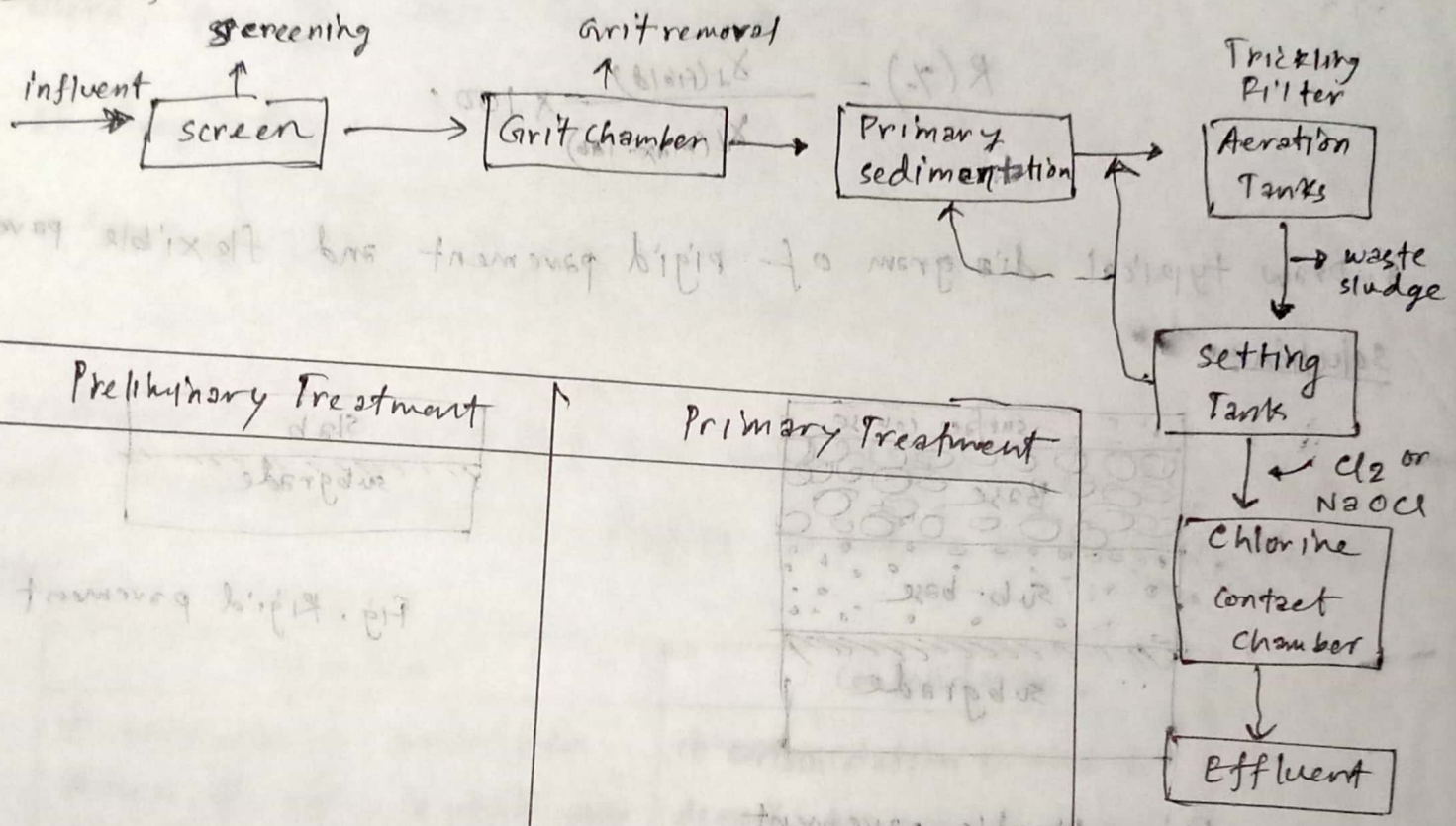
$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} = C\sqrt{RS}$$

$$\Rightarrow \frac{1}{n} \sqrt{RS} \times R^{\frac{2}{3}} = C \sqrt{RS} \times R^{\frac{1}{2}}$$

$$\Rightarrow C = \frac{R^{\frac{2}{3}-\frac{1}{2}}}{n} \qquad \therefore C = \frac{R^{\frac{1}{6}}}{n}$$

5. Write the steps of conventional waste water treatment. Differentiate between preliminary treatment and primary treatment process.

Solution:



BIWTA-2023 [BUET]

1.(a) Fill in the gaps:

(i) A pitot tube measure the total head of a point

(ii) The steady flow does not depend on time.

(iii) If a wide rectangular channel of 2m width has water depth of 0.5 m, Then the hydraulic depth is 0.5 m.

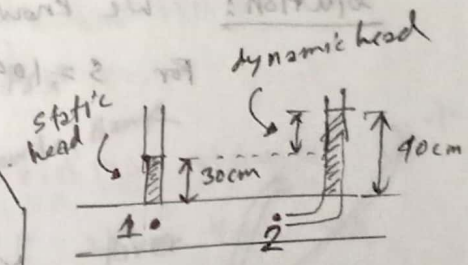
(iv)

(v)

(vi)

(b) Consider a piezometer and pitot tube that are tapped into horizontal water pipe. If the piezometer head and pitot tube head is 30 cm and 40 cm respectively. What is the velocity of water in the pipe?

Solution:



We know,

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g}$$

$$\Rightarrow 0.3 + \frac{v_1^2}{2g} = 0.4 + 0 \quad [z_1 = z_2]$$

$$\Rightarrow v_1^2 = 2g \times (0.4 - 0.3)$$

$$\Rightarrow v_1 = \sqrt{2 \times 9.81 \times 0.1} = 1.40 \text{ m/sec.}$$

(Ans)

dynamic head,

$$\frac{v^2}{2g} = \Delta h$$

$$\Rightarrow v = \sqrt{2g\Delta h}$$

$$\Rightarrow v = \sqrt{2g \times (0.4 - 0.3)}$$

$$\therefore v = 1.40 \text{ m/s}$$

(Alternate solution)

2.

(a) Fill in the gaps:

(i) Weight of hammer in SPT test (Standard Penetration Test) 140 lb.

(ii) Energy in standard proctor test is 594 KN-m/m³

(iii) N_c value for deep foundation 9.

(iv) If void ratio of a soil is 0.5, then porosity 0.33.

(v) If Angle of friction of a soil is 30°, passive earth co-efficient 3.

(vi) If plasticity Index of a soil is 30% and Liquid Limit is 50%. find PL 20%.

(b) The saturated water content of a soil sample is 30%. If specific gravity is 2.7. Find void ratio, porosity & saturated unit weight.

Solution: We know,

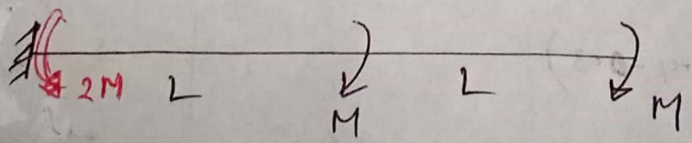
For $S = 100\%$, $e = wG_s = (0.3 \times 2.7) = 0.81 = 81\%$

$$n = \frac{e}{1+e} = \frac{0.81}{1+0.81} = 0.447 = 44.7\%$$

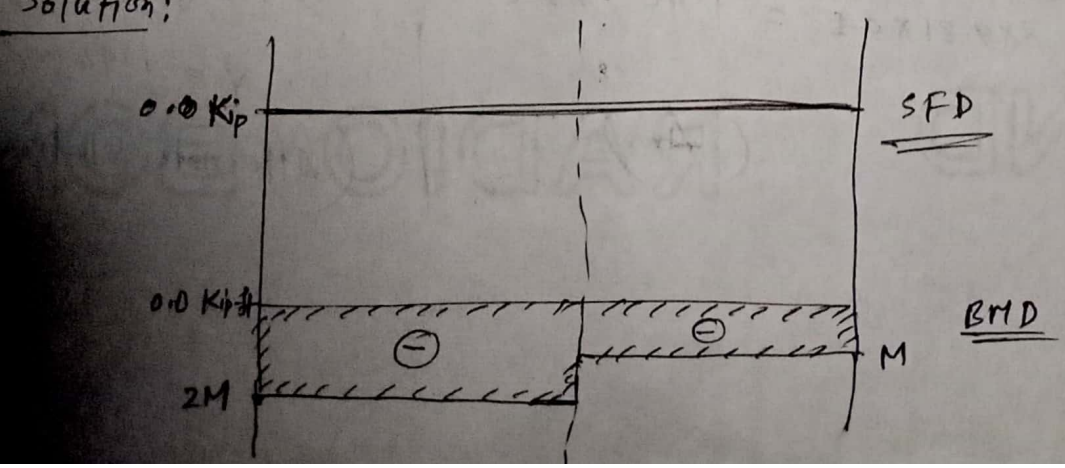
$$\gamma = \frac{(G_s + e)}{1+e} \times \gamma_w = \frac{(2.7 + 0.81)}{(1+0.81)} \times 9.81 = 19.024 \text{ KN/m}^3$$

(Ans.)

3. (a) Draw SFD and BMD of following beam:



Solution:



(b) Find the maximum and minimum reinforcement ratio of a beam. If $f_c' = 3$ ksi and $f_y = 60$ ksi

Solution:

We know,

Max. Reinforcement ratio, $\rho_{max} = \rho_{0.005} = 0.85\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.005}$

$= 0.85 \times 0.85 \times \frac{3}{60} \times \left(\frac{0.003}{0.003 + 0.005}\right)$

$= 0.01355$

Minimum Reinforcement Ratio,

$\rho_{min} = \frac{3\sqrt{f_c'}}{f_y} = \frac{3 \times \sqrt{3000}}{60000} = 0.00274$

again, $\frac{200}{f_y} = \frac{200}{60000} = 0.0033 > 0.00274$

Hence, $\rho_{min} = 0.00274$. (Ans)

4(a) Write the components of a diversion head works.

Solution:

(i) Weir or Barrage
(ii) Divide wall
(iii) Fish Ladder
(iv) Under sluices
(v) Silt Excluder
(vi) Weir proper etc.
(vii) Canal Head Regulator.

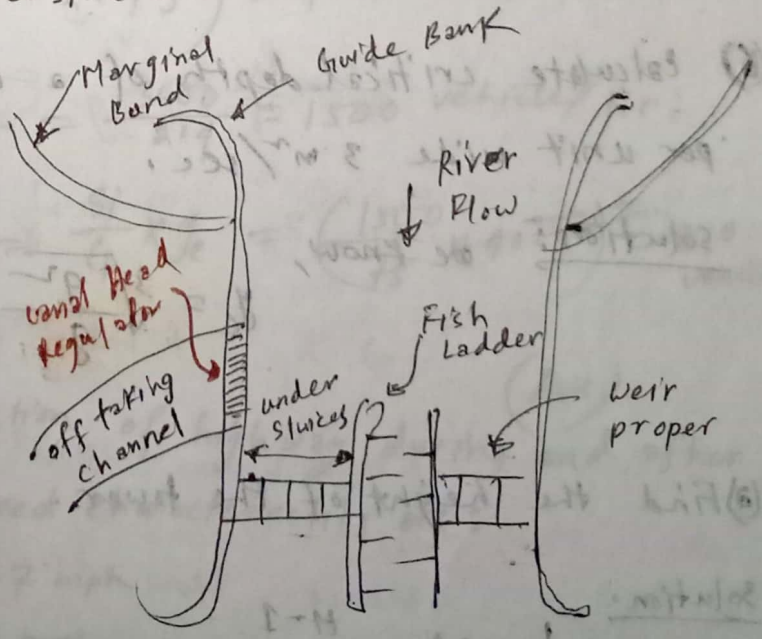


Fig. Layout of diversion head works

5. Find the FM of the sample, co-efficient of uniformity and percent of fine (silt and clay) present in the sample.

Sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
% retain	0	1	4	12	23	30	20	6	4

Solution:

sieve No.	#4	#8	#16	#30	#40	#50	#100	#200	Pan
Cumulative % retain	0	1	5	17	40	70	90	96	100
% finer	100	99	95	83	60	30	10	4	0

$\therefore$ FM of the sample $= \dfrac{1+5+17+70+90}{100} = 1.83$

$Cu = \dfrac{D_{60}}{D_{10}} = \dfrac{0.425}{0.15} = 2.833$

% silt and clay $= (100-96) = 4\%$ (Ans.)

4. (b) Calculate critical depth of a wide rectangular channel of having discharge per unit wide 3 m^2/sec.

Solution: we know,

$$y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{3^2}{9.81}} = 0.97 \text{ m}.$$

(Ans.)

6. (a) Find the height of the tower.

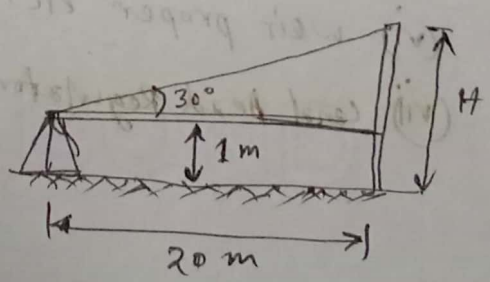
Solution:

$$\tan 30^\circ = \frac{H-1}{20}$$

$$\Rightarrow H = (1 + 20 \tan 30^\circ)$$

$\therefore H = 12.547$ m

(Ans.)



(b) An area of a land measured by a 20 m chain was found to be 1·2 ha. But after that the chain was found to be 20·03 m. Find the actual area of the land?

Solution: True Area $= \left(\frac{L'}{L}\right) \times$ Measured Area

$$\text{True Area} = \left(\frac{20.03}{20} \times 1.2\right) = 1.2018 \text{ ha.} \quad \text{(Ans.)}$$

7. (a) A signalized intersection approach has two lanes with no exclusive left or right turning lanes. The approach has a 40 sec. green out of a 75 sec. cycle. The yellow plus all red intervals for the phase 4 sec. If the start up lost time is 2.0 sec./phase, the clearence lost time is 1.5 sec/phase, and the saturation headway is 2.4 sec./vehicle under prevailing conditions, what is the capacity of the intersection approach?

Solution: Effective green = Inter green + yellow + all red − lost time

$$\therefore g_e = (40 + 4 - 2 - 1.5) = 40.5 \text{ sec}$$

saturation flow, $S_i = \frac{3600}{h} = \frac{3600}{2.4} = 1500$ vehicle/hr.

$$\therefore \text{capacity per lane, } C = \frac{S_i}{C} \times g_e = \left(\frac{1500}{75} \times 40.5\right) = 810 \text{ vehicle/hr}$$

(Ans.)

(b) Speed data were collected a section of highway during and after utility maintenance work. The speed characterestics are:

$\bar{u}_1 = 35.5$ mph
$s_1 = 7.5$ mph
$n_1 = 250$

$\bar{u}_2 = 38.7$ mph
$s_2 = 7.4$ mph
$n_2 = 280$.

Determine whether there was any significant difference between average speed at the 95% confidence level.

Solution:

$$S_d = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{7.5^2}{250} + \frac{7.4^2}{280}} = 0.65$$

$$|\bar{U} - \bar{U}_2| = |38.7 - 35.5| = 3.2 \text{ mph}.$$

Now, $Z = 1.96$ for 95% confidence level.

So, $Z S_d = (1.96 \times 0.65) = 1.3 \text{ mph} < |\bar{U}_1 - \bar{U}_2|$

Hence, It can be concluded that the difference in mean speeds is significant at 95% confidence level.

8. (a) A uniform diameter pipe having pressure at A and B are 100 KPa and 300 KPa. A point is 10 m above from B point. Find the direction of flow.

Solution: Let, Flow direction is A to B.

From Bernoulli's equation,

$$Z_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} = Z_B + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + h_f$$

$$\Rightarrow (Z_A - Z_B) + \frac{1}{\gamma} \times (P_A - P_B) = h_f \quad [\because V_A = V_B]$$

$$\Rightarrow h_f = 10.0 + \left(\frac{100 - 300}{9.81}\right)$$

$$\Rightarrow h_f = -10.387 \text{ m}$$

Hence, Flow direction is B to A.

(a) Determine the normal depth of a wide rectangular channel having discharge per unit width = 3 m^2/sec. Given, longitudinal slope is 1m in 1 Km and manning's co-efficient = 0.015.

Solution:

We know, For wide channel, $R \simeq h$, $A \simeq h$

Hence, $q = \frac{1}{n} \times h \times h^{\frac{2}{3}} \times s^{\frac{1}{2}}$ where, $S = \frac{1}{1000} = 0.001$

$$\Rightarrow h^{\frac{5}{2}} = \frac{nq}{s^{\frac{1}{2}}} = \frac{0.015 \times 3}{(0.001)^{\frac{1}{2}}}$$

$$\Rightarrow h^{\frac{5}{2}} = 1.423$$

$$\therefore h = 1.15 \text{ m}$$ (Ans.)

9. (a) 25 MLD water is to be supplied from a water treatment plant which containing 0.4 mg/L chlorine. If bleaching powder contains 30% available chlorine. Find the amount of bleaching powder in kg/day.

Solution: Amount of Cl_2 required $= (25 \times 10^6 \times 0.4)$ mg/day

$= 10 \times 10^6$ mg/day $= 10$ kg/day.

Amount of bleaching powder required $= \left(\frac{100}{30} \times 10\right) = 33.33$ kg/day.

(Ans.)

(b) The boropukuria coal is burned at a rate 10.00 kg per sec. The coal contains 3% sulfar. What is the annual emission rate of SO_2?

Solution: Amount of sulfar $= (10 \times 0.03) = 0.3$ kg/sec. $= (0.3 \times 3600 \times 24 \times 365)$ kg/year

$= 9460.8 \times 10^3$ kg/year

$S + O_2 = SO_2$

32g = 64g

32kg = 64g

$\therefore$ Annual emission rate of $SO_2 = \left(\frac{64}{32} \times 9460.8 \times 10^3\right) = 1892.16 \times 10^4$ kg/year.

(Ans.)

10.)

(a) The peak of 3 hr flood hydrograph is 35 m^3/sec. If the constant base flow is 20 m^3/sec and rainfall depth is 5 cm. Determine the peak of 5h unit hydrograph. Also determine Run-off co-efficient

Solution:

We know, $DRO = TRO - BFO$

$\therefore DRO = (35 - 20) = 15\ m^3/sec.$

Then, $P_{net} = \frac{DRO}{UGO}$

$\Rightarrow UGO = \frac{DRO}{P_{net}} = \frac{15}{5} = 3\ m^3/sec$

Run off co-efficient $= \frac{15}{35} = 0.43$ (Ans.)

#DNCC-2022

MIST

1. Basic wind speed of chittagang is 80 m/s and siesmic zone co-efficient 0.25 (zone-3). [* For Dhaka, wind speed = 65.7 m/s and Z = 0.20 (zone-2)]

2. Minimum depth of footing for cohesive soil 1.5 m and for cohesionless soil 2 m. [* for temporary structure, minimum depth of the footing = 0.4 m]

3. For special Moment frame (SMF) design, the minimum and maximum reinforcement ratio for columns 1% and 6% respectively.

4. Response Modification factors for SMF and IMF are 8(1) & 8(Rc) and 4.5 (5-Rc) respectively. [* for OMF, R = 3.5]
R = 3 (Rc)

5. Minimum overall factor of safety for drilled shafts is 2 when the design is based on the pile load test, and is 3 without any load test information.

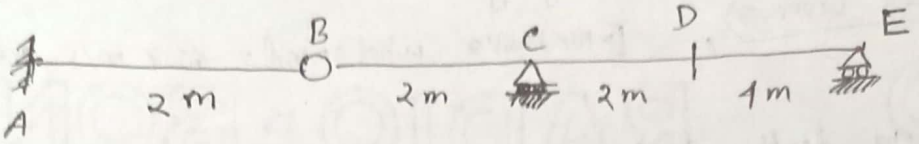
6. Write two criteria for dynamic analysis of structure.

Answer: (i) Evaluates the behavior of systems, including changes over time.
(ii) considered inertia force along with dynamic force.

Structure:

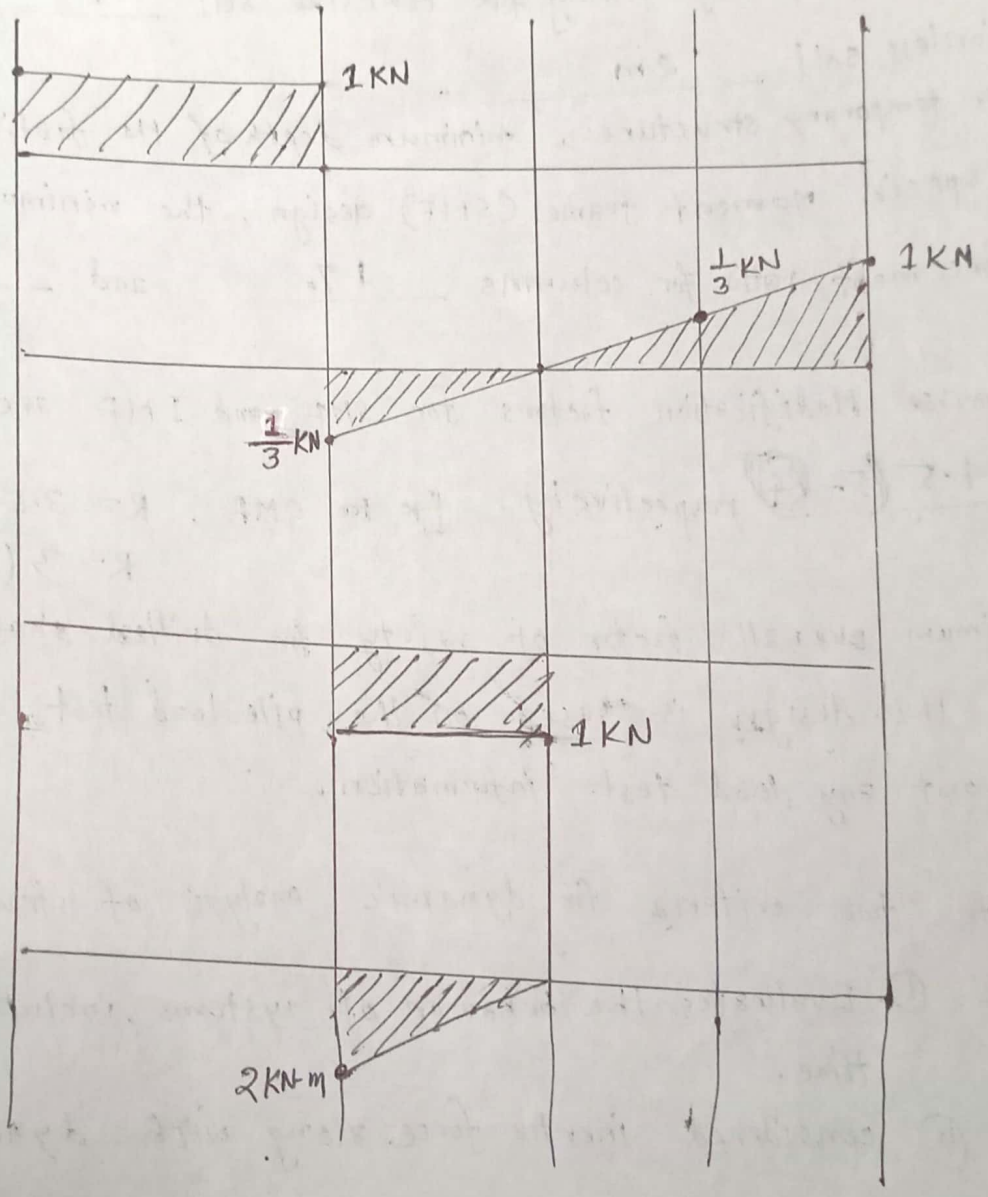
7. Draw Influence Line for reaction at A and E, share at just left of c and moment at c.

Solution:



IL for

R_A



R_E

V_{cL}

M_c

Environment:

8. Why COD is greater than BOD? Explain SDG's goal that deal with drinking water.

Answer: COD is greater than BOD because:

(i) More organic compounds can be chemically oxidised than biologically oxidised.

(ii) BOD measures the oxygen required for micro-organisms to decompose organic matter only, whereas COD measures the oxygen required to decompose both organic and inorganic constituents.

COD includes both biodegradable and non biodegradable substances while, BOD contains only biodegradable. This is why COD is greater than BOD.

SDG's goal dealing with drinking water: SDG has 17 goals. The goal that related to drinking water is No. 6 goal.

SDG's 6 No. Goal (Clean water and sanitation): Ensure availability and sustainable management of water and sanitation for all.

9. What is stabilizing Ponds? write down the names of different kinds of waste stabilizing ponds. Also enlist primary functions.

Answer: An artificial pond of shallow depth designed and built for waste water treatment to reduce organic compounds and remove pathogens from waste water, is known as oxidation ponds or stabilizing ponds or lagoon.

CamScanner

Classification of stabilizing ponds:

Stabilizing ponds may be of —

(i) Aerobic ponds : develop intense algal growth.

(ii) Anaerobic ponds : used as pretreatment of high strength wastes.

(iii) Floculative ponds : functions aerobically at the surface while anaerobic conditions prevail at bottom.

Primary functions of stabilizing Pond :

The main function of the stabilizing pond is the removal of carbon-containing organic matter.

The stabilizing ponds purify the sewage by dual action of aerobic bacteria and algae.

The sewage is stored under aerobic conditions which are favourable for growth of algae.

The aerobic bacteria obtain oxygen from the atmosphere and use it in the decomposition of carbohydrates of sewage.

Carbohydrates is also broken up by algae by the process of photosynthesis into carbon and oxygen.

The carbon is used in producing more carbohydrates and the realeased oxygen keeps the dissolved oxygen content of water at high level.

Transportation:

(10) Write down the names of 4 polymers used for bitumen modifications.

Answer:

(i) Ethylene vinyl Acetate (EVA)

(ii) Styrene Butadiene styrene (SBS)

(iii) Styrene Butadiene Rubber (SBR)

(iv) Ethylene glycidil Acrylate (EGA)

(11) Given, Road width = 7.5 m, The radius of curvature = 240 m, co-efficient of friction = 0.15, velocity = 80 Km/hr. Calculate the Superelevation.

Solution:

We know,

$$e + f = \frac{v^2}{gR}$$

Here, $R = 240$ m

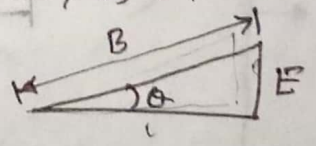
$v = 80$ Km/h $= \frac{80}{3.6}$ m/s $= 22.22$ m/s

$f = 0.15$

$B = 7.5$ m

$$\Rightarrow e + 0.15 = \frac{(22.22)^2}{9.81 \times 240}$$

$$\Rightarrow e = 0.0597$$



$$\Rightarrow \tan\theta = 0.0597$$

$e = \tan\theta \times \sin\theta = \frac{E}{B}$

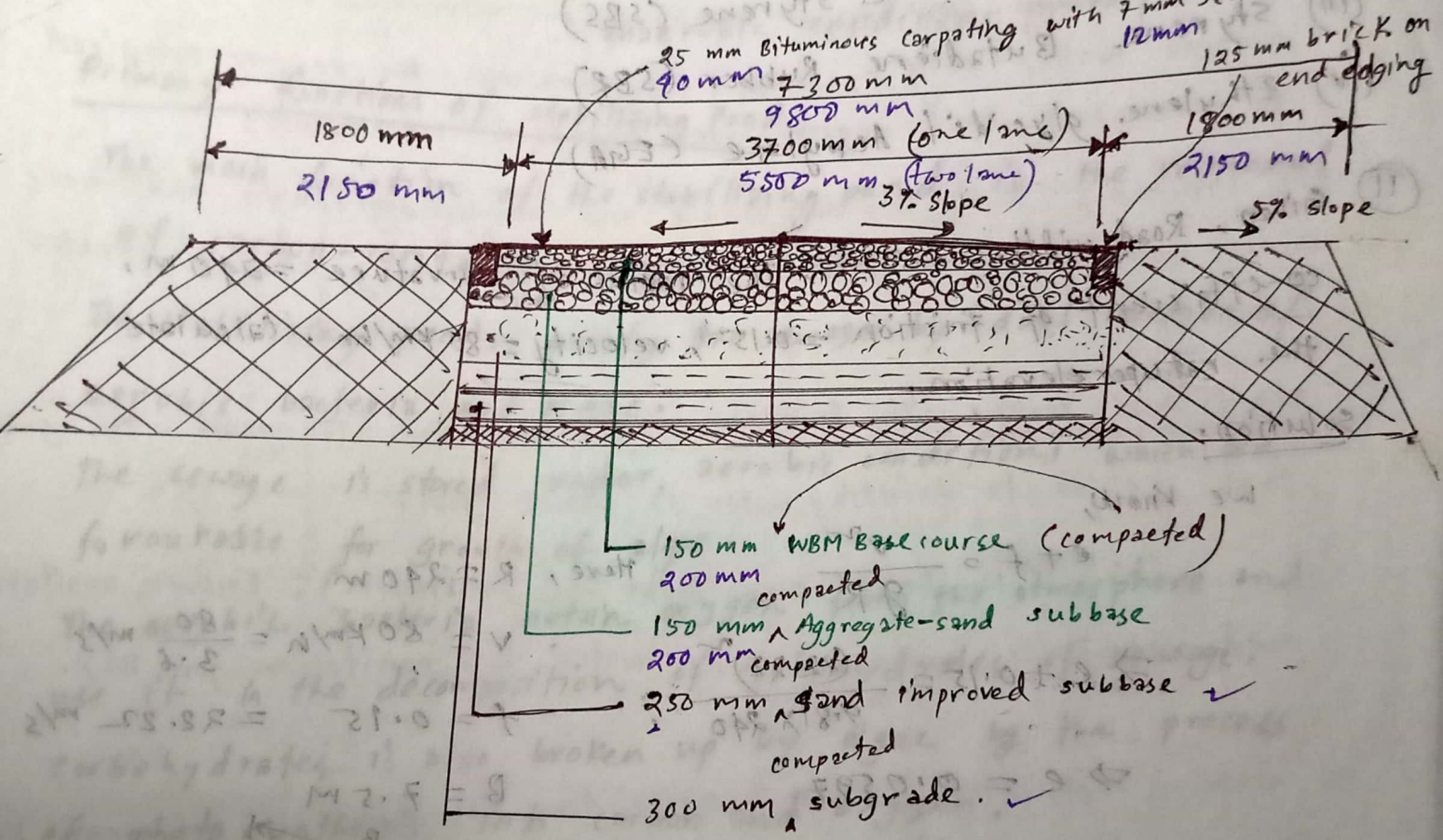
$$\Rightarrow \frac{E}{B} = 0.0597$$

$$\Rightarrow E = (0.0597 \times 7.5)\,m = 0.4481\,m$$

(Ans.)

(12) Draw a typical standard section view of a two lane road way with all layers and shoulder with dimensions. [Following LGED & RHD specification]

Answers:



Engineering Materials:

(13) Write the factors affecting the strength of concrete. Also write different types of admixtures in concrete.

Answer:

Factors affecting the strength of concrete:

(i) Grading of aggregate
(ii) Moisture content in aggregates
(iii) water cement ratio
(iv) Proportioning of ingredients
(v) Method of mixing.
(vi) placing and compaction.
(vii) curing

Different types of admixture:

Admixtures can be divided in to following groups:

(i) Air-entraining agents (ASTM C260)
(ii) Chemical admixtures (ASTM C494 and BS 5075)
    - water reducing admixtures
    - shrinkage reducing admixtures
    - setting control admixtures
        - Retarding
        - Accelerators
(iii) Mineral admixtures
    - silica fume
    - slag
    - Fly ash
    - Metakaoline
(iv) Miscelleneous admixtures
    - Latexes
    - corrosion inhibitors
    - expansive admixtures

open channel flow

~~Fluid Mechanics~~ :

(16) A sluice gate is used to control and measure the discharge per discharge in an open channel. calculate the discharge per unit width in the channel, when upstream and downstream water depth are 1 and 0.2 meters respectively.

Solution:

we know, From continuity equation,

$$v_1 A_1 = v_2 A_2$$

$$\Rightarrow v_1 \times y_1 \times b = v_2 \times y_2 \times b$$

$$\Rightarrow v_1 = 0.2\, v_2 \quad \ldots\ldots (1)$$

Now, From bernoulli's equation, $(z_1 = z_2)$

$$y_1 + \frac{v_1^2}{2g} = y_2 + \frac{v_2^2}{2g}$$

$$\Rightarrow \frac{v_2^2 - v_1^2}{2g} = y_1 - y_2$$

$$\Rightarrow v_2^2 - (0.2 v_2)^2 = (1 - 0.2) \times 2 \times 9.81$$

$$\Rightarrow 0.96\, v_2^2 = (7.848 \times 2)$$

$$\Rightarrow v_2 = 4.044 \text{ m/sec.}$$

$$\therefore q = y_2 v_2 = 0.2 \times 4.044 = 0.809 \text{ m}^2/\text{sec}$$ (Ans.)

Project Management:

(15) write the characterestics of critical path of a network.

Answer: The critical path is the longest path through the network and time along this path gives the project duration.

characterestics:

(i) The project to be planned should consist of clearly recognisable activities.

(ii) These activities must have definite commencement and completion dates.

(iii) The events must occur in a definite pattern and must have a technological sequence.

Geotechnical:

1c. A moist soil has a volume of $0.33\ ft^3$ and weighs $39.93\ lb$. The moisture content of the soil is 15% and specific gravity of soil, $G_s = 2.67$. Calculate — (a) dry unit weight (b) void ratio (c) porosity (d) degree of saturation.

Solution:

$$\gamma = \frac{W}{V} = \frac{39.93}{0.33} = 121\ lb/ft^3$$

(a) $$\gamma_d = \frac{\gamma}{1+w} = \frac{121}{(1+0.15)} = 105.22\ lb/ft^3$$

(b) we know, $\gamma_d = \frac{G_s \gamma_w}{1+e}$

$$\Rightarrow 105.22 = \frac{2.67 \times 62.4}{1+e} \Rightarrow e = 0.5835 = 58.35\%$$

(c) $$n = \frac{e}{1+e} = \frac{0.5835}{1+0.5835} = 0.3685 = 36.85\%$$

(d) we know, $Se = wG_s \Rightarrow S = \frac{wG_s}{e} = \frac{0.15 \times 2.67}{0.5835} = 0.6864 = 68.64\%$

(Ans.)

NESCO'2021 [BUET]

Transportation:

① An intersection located in an urban area has a maximum allowable speed on the approach roads of 45 mile/hr. The width of the intersection is 48 ft for all approaches. The average length of a vehicle is assumed to be 20 ft. What should be the minimum length of the red clearance interval for this intersection.

Solution: Give, $W = 48$ ft, $L = 20$ ft, $V = 45$ mile/hr.

We know,

$$\text{Red clearance interval} = \frac{W+L}{1.47V}$$

$$= \frac{48+20}{1.47\times 45} = 1.028 \text{ sec.}$$

(Ans.)

Reinforced Concrete:

② The cross section of a beam reinforced with 3 in² of steel. Assume the tension steel yields at maximum moment. What is the area of concrete required to balance the steel force when the steel yields? $f_c' = 4$ ksi and $f_y = 60$ ksi.

Solution:

Tension steel yields at maximum moment i.e. $(f_s = f_y)$

$C = T$

$$\frac{1}{2} f_c K b d = A_s f_s$$

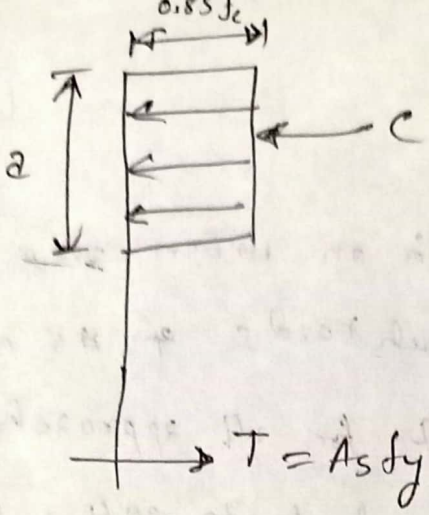
Here, $f_c = (0.45 \times 4) = 1.8$ ksi

$f_s = .4 f_y = (0.4 \times 60) = 24$ ksi

$$\rho_b = \frac{A_s}{bd}$$

$$\rho_b = (.85 \beta_1 \times \frac{f_c'}{f_y} \times \frac{.003}{.003 + \frac{f_y}{E_s}})$$

Solution:



$C = 0.85 f_c' a b$

$T = A_s f_y$

$C = T$

$\Rightarrow 0.85 f_c' a b = 3 \times 60$

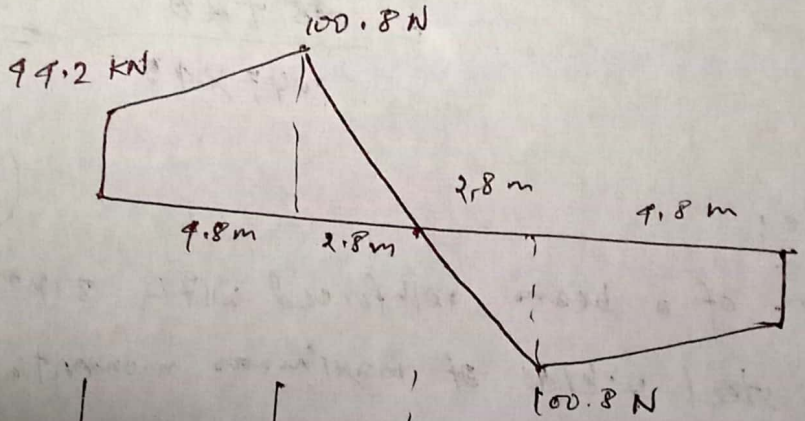
$\Rightarrow ab = \frac{3 \times 60}{0.85 \times 4}$

$\therefore$ required concrete area = 52.94 in^2

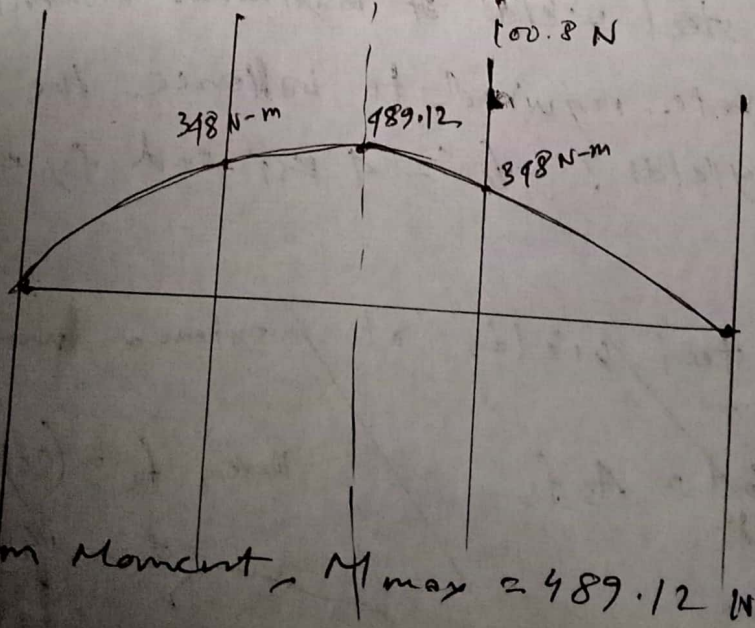
(Ans.)

Structure:

(3) SFD of simply supported beam is given. Find the maximum moment of the beam.



Solution:

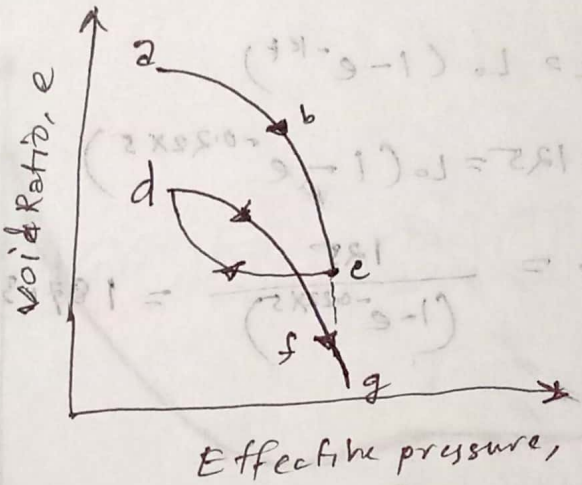


$\therefore$ Maximum Moment, $M_{max} = 489.12$ N-m

Geotechnical Engineering:

(4) Draw qualitative diagram of e log P curve for consolidation of a soil sample test.

Solution:



~~(5) If the effective stress on the failure plane is Normal of~~

(5) A cylindrical sample having a cohesion of 80 KPa, has sujected to a normal stress 225 KPa. If the soil strength of soil is 300 KPa, Find the angle of internal friction.

Solution:

We know,

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

$$\Rightarrow 300 = 80 + 225 \times \tan\phi$$

$$\Rightarrow \tan\phi = \frac{300-80}{225} = 0.978$$

$$\therefore \phi = \tan^{-1}(.978) = 44.36^\circ$$

(Ans)

0.851

Environment:

(6) Determine the ultimate BOD for a sewage having 5-day BOD at 20°C, BOD_5 = 125 mg/L. Assume, K = 0.22/Day.

Solution:

We know,

$$BOD_t = L_o(1-e^{-Kt})$$

$$\Rightarrow 125 = L_o(1-e^{-0.22\times 5})$$

$$\Rightarrow L_o = \frac{125}{(1-e^{-0.22\times 5})} = 187.37 \text{ mg/L}$$

(Ans)

Fluid Mechanics:

(7) water is flowing in a fire hose with velocity 1 m/s. pressure 200 KPa. At the nozzle, the pressure decreases to atmospheric pressure 101.3 KPa. and there is is no change in height. Calculate the velocity of water existing at the end of the nozzle.

Solution: Since $z_1 = z_2$

We know,

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} = \frac{P_2}{\gamma} + \frac{v_2^2}{2g}$$

$$\Rightarrow \frac{v_2^2}{2g} = \frac{200}{9.81} + \frac{1^2}{2\times 9.81} - \frac{101.3}{9.81}$$

$$\Rightarrow \frac{v_2^2}{2g} = 10.11$$

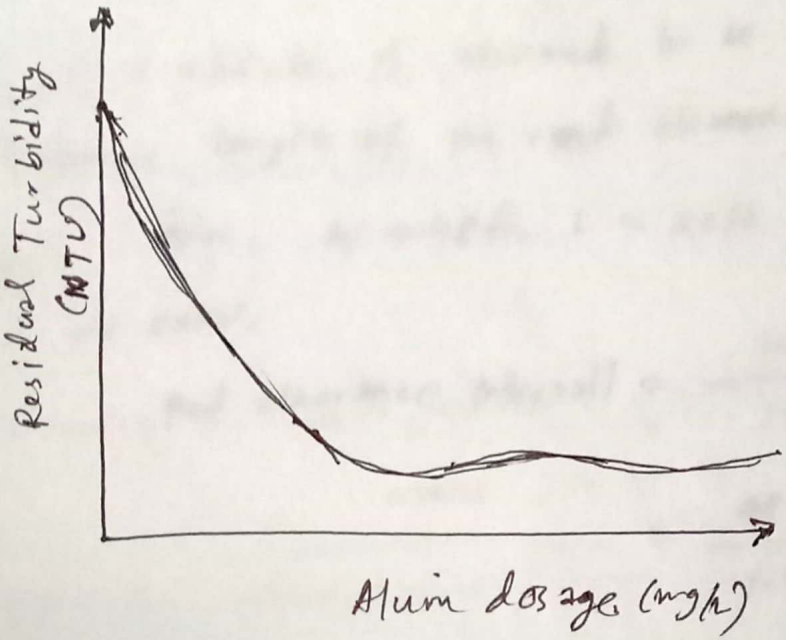
$$\Rightarrow v_2^2 = (10.11\times 2\times 9.81) = 198.4 \quad \therefore v_2 = 14.085 \text{ m/s}$$

(Ans)

Environment:

(8) Draw a typical qualitative diagram for alum-dosage versus residual turbidity in a coagulation-Flocculation jar test of surface water sample.

solution:



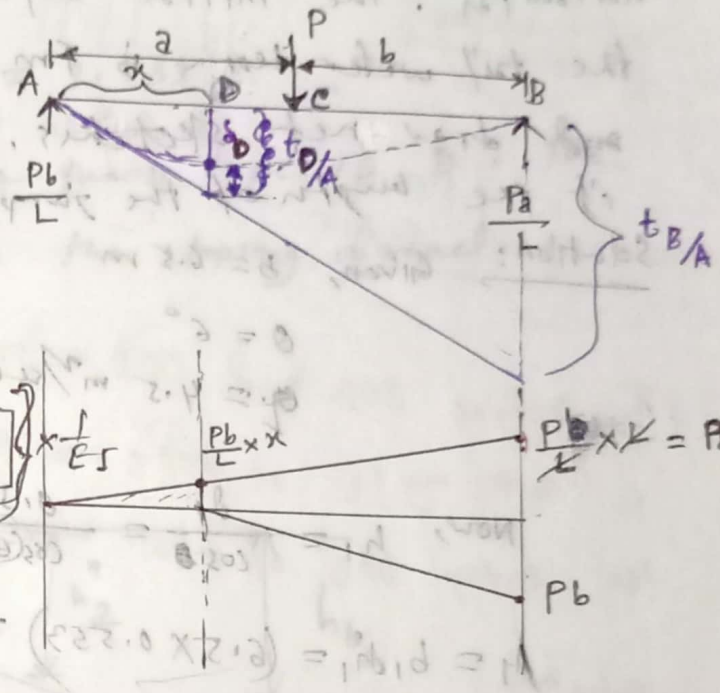
#DWASA '2021

BUET

Structure: Determine maximum deflection of the beam with moment area method. EI is constant. Length of the beam = L, P = point load on simply supported beam from left support at 'a' distance and 'b' from the right support.

Solution:

Let, Maximum ~~deflection~~ deflection occurs at D. x distance from left support.



$$t_{D/A} = \left(\frac{1}{2} \times x \times \frac{Pb}{L} \times x\right) \times \frac{x}{3} \times \frac{1}{EI}$$

$$= \frac{1}{6L} Pbx^3 \times \frac{1}{EI}$$

$$t_{B/A} = \left\{\left[\left(\frac{1}{2} \times L \times Pb\right) \times \frac{L}{3}\right] - \left[\left(\frac{1}{2} \times b \times Pb\right) \times \frac{b}{3}\right]\right\} \times \frac{1}{EI}$$

$$= \left[\frac{1}{6} PbL^2 - \frac{1}{6} Pb^3\right] \times \frac{1}{EI}$$

$$= \frac{1}{6} Pb(L^2 - b^2) \times \frac{1}{EI}$$

Now, From similar Triangle,

$$\frac{t_{D/A}}{L} = \frac{t_{D/A} + \delta_{max}}{x}$$

$$\Rightarrow \frac{\frac{1}{6} Pb(L^2 - b^2)}{L^2} = \frac{\delta_{max} + \frac{1}{6L} Pbx^3}{x}$$

$$\Rightarrow \delta_{max} \times L + \frac{1}{6L} Pbx^3 = \frac{1}{6} Pbx(L^2 - b^2)$$

$$\Rightarrow \delta_{max} = \frac{1}{L} \times \left[\frac{1}{6} Pbx(L^2 - b^2) - \frac{1}{6} Pbx^3\right]$$

$$\Rightarrow \delta_{max} = \frac{Pbx}{6L} \times \left[L^2 - b^2 - x^2\right] \times \frac{1}{EI}$$

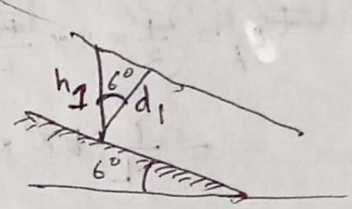
Open channel Flow: Hydraulics Sir (Example - 7.4)

② A rectangular channel water is flowing per meter length as 9.5 $m^3/s/m$. 6.5 m wide channel, at 6° angle with horizontal. The initial depth of flow is 0.55 m and the tail water depth is 4m. Determine the type of jump and draw net sketches. Also compute the energy loss in jump if the length of the jump is 4m.

Solution: Given, $b = 6.5$ m $\quad d_1 = 0.55$ m.

$\theta = 6°$

$q = 4.5$ m^2/sec $\quad h_t = 4$ m.



Now, $h_1 = \frac{d_1}{\cos\theta} = \frac{0.55}{\cos(6)} = 0.553$ m

$A_1 = b\,d_1 = (6.5 \times 0.55) = 3.575$ m

$Q = q \times b = (4.5 \times 6.5) = 29.25$ m^3/sec.

$\therefore V_1 = \frac{Q}{A_1} = \frac{29.25}{3.575} = 8.182$ m/s

$Fr_1 = \frac{V_1}{\sqrt{g d_1}} = \frac{8.182}{\sqrt{9.81 \times 0.55}} = 3.522$

$\frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right)$

$\Rightarrow h_2 = \frac{1}{2}\left(\sqrt{1 + 8 \times (3.522)^2} - 1\right) \times 0.553 = 2.149$

Since, $h_t > h_2$, the jump occurs on the sloping channel.

Now, we have to calculate h_2^*

$K_1 = 10^{0.027 \times \theta}$

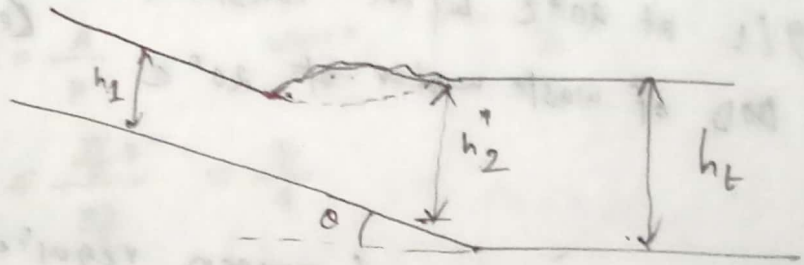
$= 10^{0.027 \times 6} = 1.1452$

$Q = K_1 P_1 = 1.1452 \times 3.522 = 5.119$

Now, $h_2^* = \frac{h_1}{2}\left(\sqrt{1+8G^2} - 1\right) = \frac{0.553}{2} \cdot \left(\sqrt{1+8 \times 3.114^2} - 1\right)$

$= 3.733\ m$

$\therefore h_t > h_2^* > h_2$, The jump type is D. The jump is entirely occurs on the sloping channel.



$d_2 = h_2^* \cos\theta = (3.733 \times \cos 6) = 3.713\ m$

$\therefore A_2 = b d_2 = (6.5 \times 3.713) = 24.1345\ m^2$

$V_2 = \frac{Q}{A_2} = \frac{29.25}{24.1345} = 1.212\ m/s$

Energy loss in jump, $\Delta E = L_j \tan\theta + (d_1 - d_2)\cos\theta + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$

$= 4 \times \tan 6 + (0.553 - 3.713)\cos 6 + \left(\frac{8.182^2}{2 \times 9.81} - \frac{1.212^2}{2 \times 9.81}\right)$

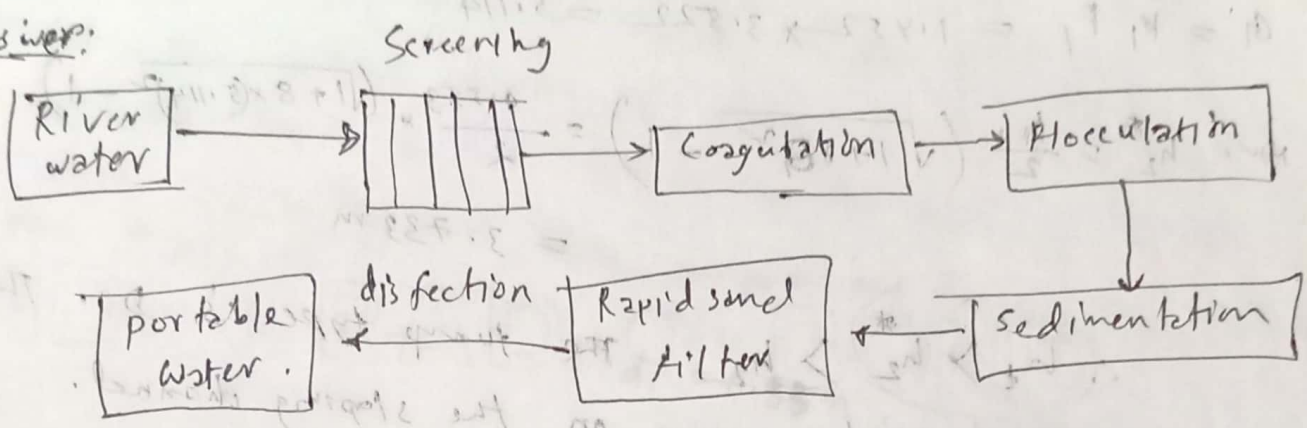
$= 0.615\ m$ of water.

(Ans)

Environment:

(3) Draw flow diagram of water treatment river water.

Answer:



(4) Define BOD and COD. The 5 day BOD of waste water is 200 mg/L at 20°C with constant 0.21/day. Determine the 10 day BOD of waste water at 20°C (e base)

Solution;

BOD is the amount of oxygen required for microbs to decompose organic matter in sewage under aerobic condition at standard temperature.

COD is the amount of oxygen required to oxidize both organic and inorganic substances by strong oxidizing agent under acidic condition.

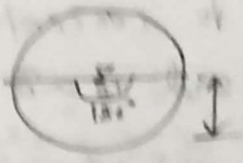
Given, $BOD_5 = 200$ mg/L $\quad K_{20} = 0.21$ per day.

$$BOD_5 = L_o(1-e^{-K\times 5}) \Rightarrow L_o = \frac{200}{(1-e^{-0.21\times 5})} = 307.66 \text{ mg/L}$$

Now, $BOD_{10} = 307.66(1-e^{-0.21\times 10}) = 269.985$ mg/L

(Ans.)

Q. Design a sewer pipe half full of water flow with 300 cfs. longitudinal slope of that pipe is 0.0025 and manning's coefficient = 0.015.

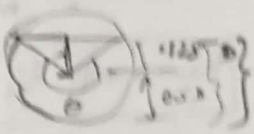


Solution: Given,

$Q = 300\ cfs$

$S = 0.0025$

$n = 0.015$



Now, $A = \frac{\pi}{4} D^2 \times \left(\frac{180^\circ}{360}\right) = \frac{\pi}{8} \times D^2$

$R = \frac{A}{P}$ where, $P = \frac{\pi D}{2}$

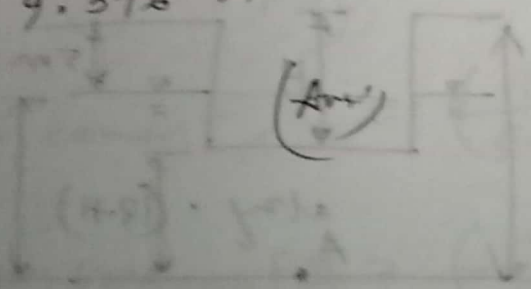
$\Rightarrow R = \frac{\frac{\pi}{8} D^2}{\frac{\pi D}{2}} = \frac{D}{4}$

Now, $Q = AV$

$\Rightarrow 300 = A \times \frac{1.49}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$

$\Rightarrow 300 = \frac{\pi}{8} D^2 \times \frac{1.49}{0.015} \times \left(\frac{D}{4}\right)^{\frac{2}{3}} \times (0.0025)^{\frac{1}{2}}$

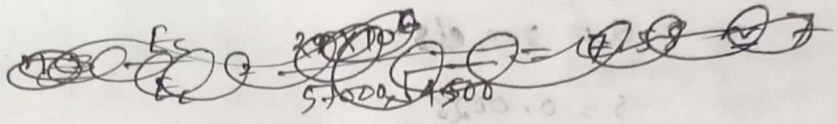
$\Rightarrow D = 9.346\ ft$



Reinforced Concrete:

(6) A RCC column of size $20" \times 25"$ and 12 no. 32mm longitudinal bar is used. Determine the axial load that will be subjected to concrete stress of 1500 psi. Given $f_c' = 7.5$ ksi, $f_y = 60$ ksi and $n = 8$.

Solution:



We know,

$$P = f_c [A_g + (n-1) A_s]$$

$$= 1500 \times \left[(20 \times 25) + (8-1) \times 12 \times \frac{\pi}{4} \left(\frac{32}{25.4}\right)^2\right]$$

$$= 907070.26 \text{ lb}$$

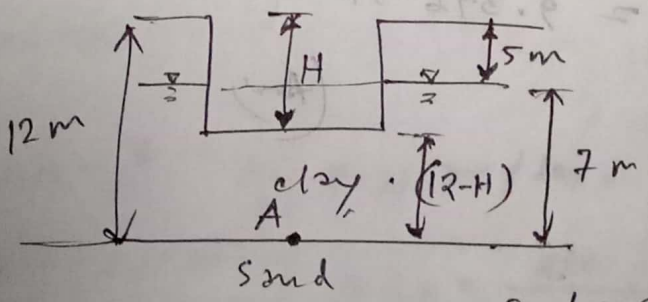
$$= 907.07 \text{ Kip.}$$

(Ans.)

Geotechnical Engineering: (Example - 9.9) BM Das

(7) A 12m saturated clay layer underlined a sand layer. water Table is 5m below the ground surface. Determine the permissible depth of cut of clay layer. The saturated clay unit weight is 18.9 KN/m³

Solution:



For heaving to occur in clay layer,

$\sigma_A = U_A$ → water pressure.

$\Rightarrow 18.9 \times (12 - H) = (7 \times 9.81) \Rightarrow H = 8.367$ m

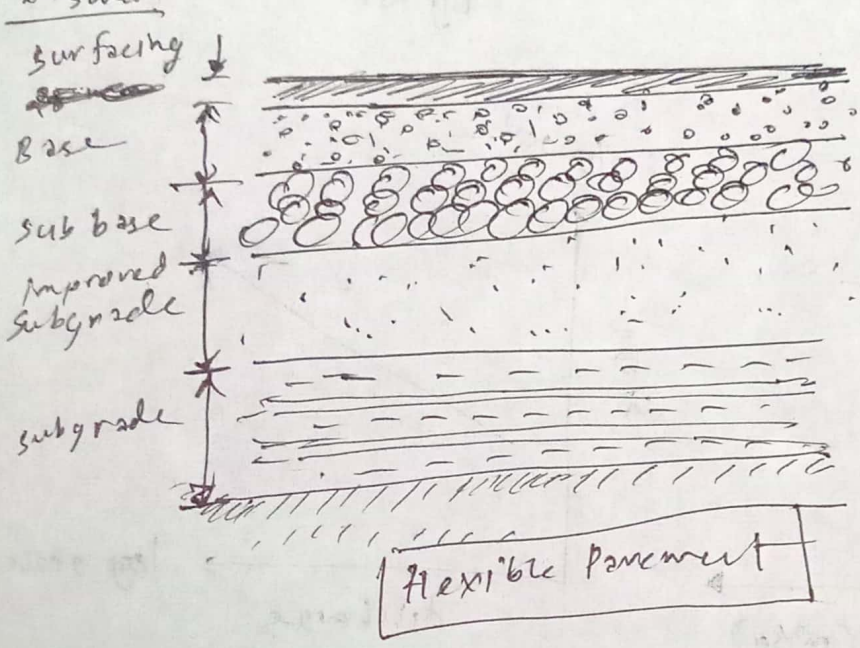
(Ans.)

* factor of safety against heaving, $F = \frac{\sigma_A}{U_A}$

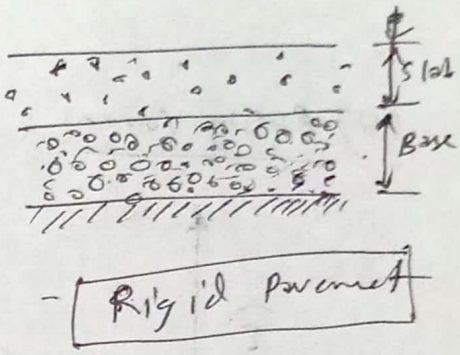
Transportation:

(8) Draw the cross section of flexible pavement and rigid pavement.

Answer:



Flexible Pavement



Rigid Pavement

Engineering Material:

(9) Determine the volume of cement, sand and stone chips of 10 cft casting with proportion of 1:1.5:3.

Solution:

Dry ~~weight~~ volume $= (1.5 \times 10) = 15$ cft

$\therefore$ Total ratio $= (1 + 1.5 + 3) = 5.5$

$\therefore$ Amount of cement, $C = \left(\frac{1}{5.5} \times 15\right) = 2.727$ cft

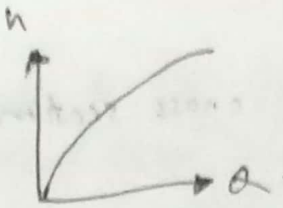
Amount of sand, $FA = \left(\frac{1.5}{5.5} \times 15\right) = 4.091$ cft

Amount of stone chips, $CA = \left(\frac{3}{5.5} \times 15\right) = 8.182$ cft

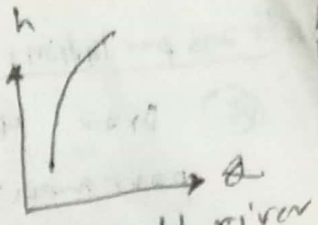
(Ans.)

Hydrology:

(a) Draw (a) Rating Curve
(b) IDF Curve

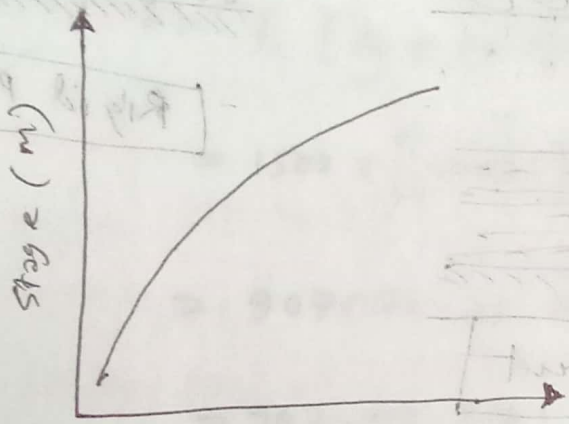


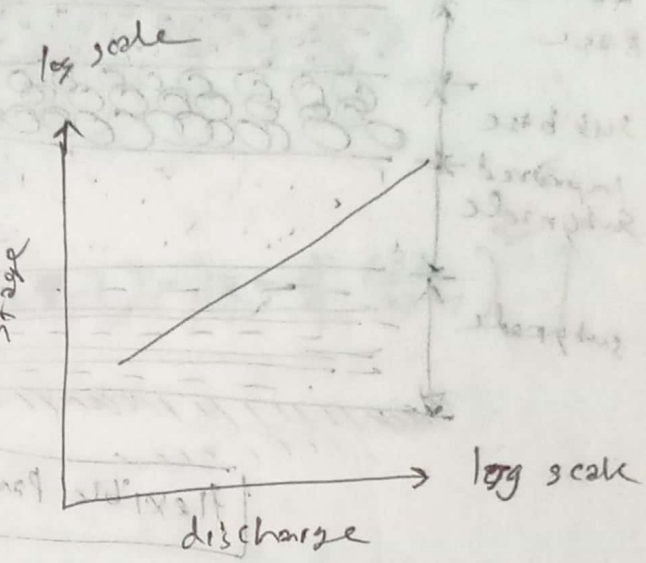
Big River



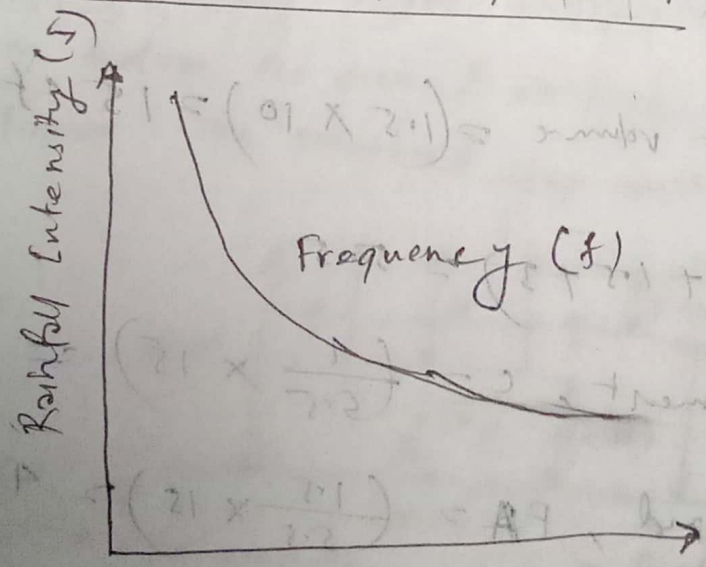
small river

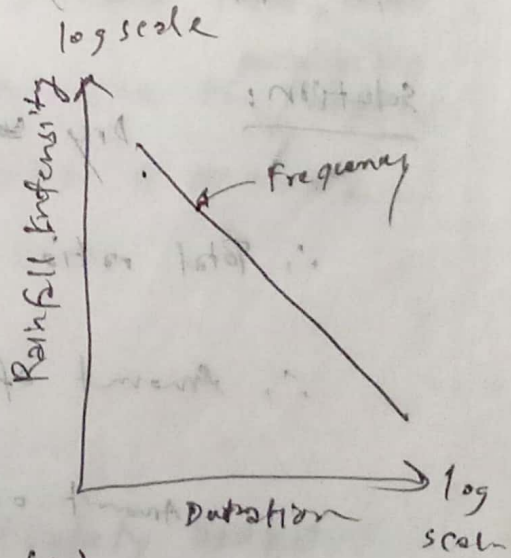
(a) Rating Curve:





(b) Intensity duration Frequency Curve:





DMTCL - 2022

1. Speed data were collected at a section of highway during and after utility maintenance work. The speed characteristics are given as $\bar{u}_1$, s_1 and $\bar{u}_2$, s_2 as shown below. Determine whether there was any significant difference between the average speed at the 95% confidence level.

$\bar{u}_1 = 35.5$ mile/h	$\bar{u}_2 = 38.7$ mi/h
$s_1 = 7.5$ mile/h	$s_2 = 7.4$ mi/h
$n_1 = 250$	$n_2 = 280$

Solution: The standard deviation of the difference in means

$$s_d = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{7.5^2}{250} + \frac{7.4^2}{280}} = 0.65$$

Now,

The difference in means $= |\bar{u}_1 - \bar{u}_2| = |35.5 - 38.7| = 3.2$ mile/h

and, $z s_d = (1.96 \times 0.65) = 1.3$ mile/h [For 95% confidence level, $z = 1.96$]

Since $|\bar{u}_1 - \bar{u}_2| > z s_d$, It can be concluded that the difference in mean speeds is significant at 95% confidence level. (Ans:)

2. The utility functions for auto and transit are as follows:

Auto : $U_A = -0.46 - 0.35\,T_1 - 0.08\,T_2 - 0.005\,C$

Transit: $U_T = -0.07 - 0.05\,T_1 - 0.15\,T_2 - 0.005\,C$

The travel characteristic between two zones are as follows:

Parameters	Auto	Transit
T_1 = Travel Time (min.)	20	30
T_2 = waiting Time (min.)	8	6
C = cost (Taka)	320	100

Determine the probability of selecting Auto and Mass Transit Mode.

Solution: percentage of travel in the zone by Auto and Transit as follows:

$$U_A = -0.46 - (0.35 \times 20) - (0.08 \times 8) - (0.005 \times 320) = -9.70$$

$$U_B = -0.07 - (0.35 \times 30) - (0.08 \times 6) - (0.005 \times 100) = -11.55$$

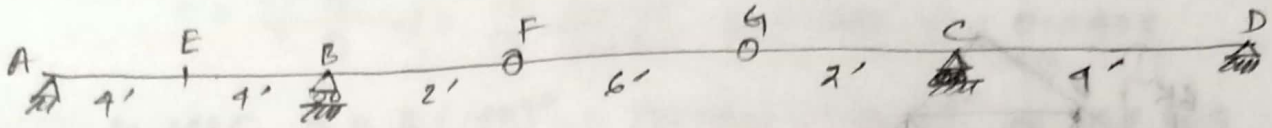
Now,

$$P_A = \frac{e^{U_A}}{e^{U_A} + e^{U_T}} = \frac{e^{-9.70}}{e^{-9.70} + e^{-11.55}} = 0.86 = 86\%$$

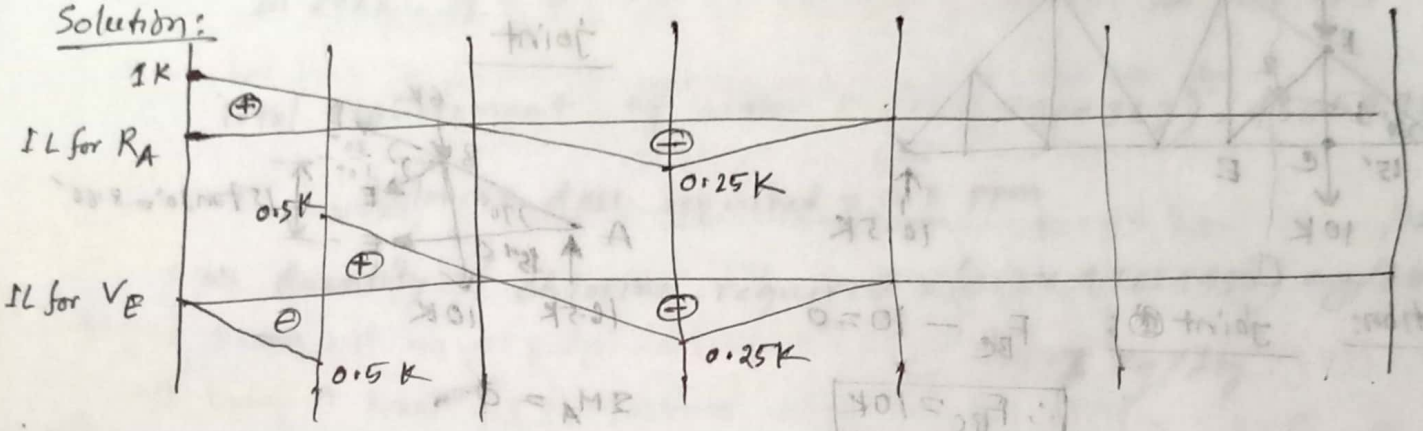
$$P_B = \frac{e^{U_T}}{e^{U_A} + e^{U_T}} = \frac{e^{-11.55}}{e^{-11.55} + e^{-9.70}} = 0.14 = 14\%$$

(Ans.)

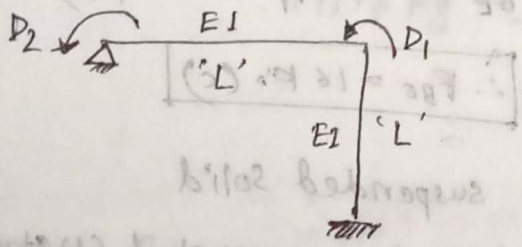
3. Draw IL for R_A and V_E



Solution:

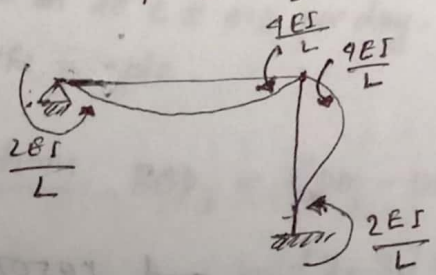


4. Determine the stiffness matrix for the following structure:



Solution:

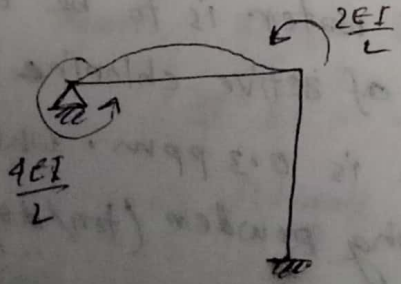
case-1: $D_1 = 1$, $D_2 = 0$



$$S_{11} = \frac{4EI}{L} + \frac{4EI}{L} = \frac{8EI}{L}$$

$$S_{21} = \frac{2EI}{L}$$

case-2: $D_2 = 1$, $D_1 = 0$

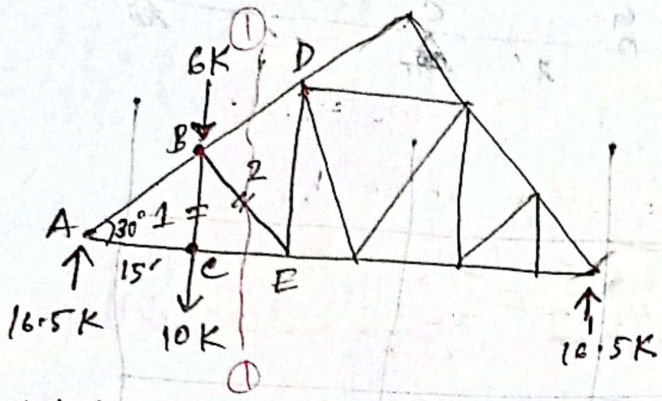


$$S_{12} = \frac{2EI}{L}$$

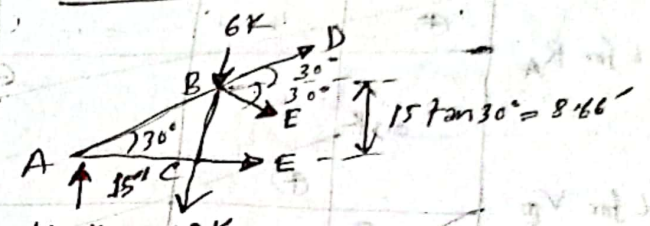
$$S_{22} = \frac{4EI}{L}$$

$$\therefore \text{Stiffness Matrix } = S = \frac{EI}{L}\begin{bmatrix} 8 & 2 \\ 2 & 4 \end{bmatrix} \quad \begin{matrix} D_1 & D_2 \end{matrix}$$

5. Determine the member force in 1 and 2



joint :



Solution: joint C: $F_{BE} - 10 = 0$

$\therefore F_{BC} = 10K$

$\Sigma M_A = 0$

$16 \times 15 + F_{BE} \times \sin 30° \times 15 + F_{BE} \cos 30° \times = 0$

$\Rightarrow F_{BE} = -16$ Kip $= 16$ kip (c)

$\therefore F_{BE} = 16$ Kip (c)

6. Five MCQs :

1. Full Form of MLSS — Mixed Liquor suspended Solid
2. Purest Iron — (a) cast Iron (b) Wrought Iron (c) Mild steel (d) stainless Steel
3.
4.
5.

7. The population of a town was 100000 in 2000 and 195000 in 2015. The town is to be supplied water at the rate of 150 liter per capita per day. The disinfection of water is to be carried out with bleaching powder containing 25% of active chlorine. If the chlorine dose required for disinfection is 0.3 ppm. what will be the required quantity of bleaching powder (ton/day) after 2025. (PGCL-2021)

Solution: We know,

$$r = \sqrt[n]{\frac{P_2}{P_1}} - 1 = \sqrt[15]{\frac{195000}{100000}} - 1 = (1.0455 - 1) = 0.0455$$

In 2025, $P_f = P_p(1+r)^n = 195000 \times (1.0455)^{10} \simeq 304363$

Total requirement of water = $(150 \times 304363) = 45654450$ l/day

Chlorine dose required = 0.3 ppm

∴ Quantity of chlorine required = (0.3×45654450) mg/day

= 13.7 kg/day.

25 kg active chlorine is found from 100 kg bleaching powder

∴ 13.7 kg ——— $\frac{100 \times 13.7}{25}$ kg/day.

= 54.8 kg/day.

= 0.055 ton/day. (Ans)

8. Data from waste water BOD test are: Initial DO = 7 mg/L and DO after 3 day = 4 mg/L. Given deoxygen rate at 20°C = 0.2 per day. Determine the 5 day BOD and ultimate BOD in the sample.

Solution: $BOD_3 = (DO_i - DO_3) \times DR$

$= (7-3) \times 50$ (Assume, DR = 50)

$BOD_3 = 200$ mg/L

Again, $BOD_3 = L_o(1 - e^{-3 \times 0.2})$

$\Rightarrow L_o = \frac{200}{(1 - e^{-0.6})} = 443.26$ mg/L

∴ Ultimate BOD, $L_o = 443.26$ mg/L

Now, $BOD_5 = 443.26 \times (1 - e^{-5 \times 0.2}) = 280.2$ mg/L (Ans)

9. write the use of piezometer.

Answer: (i) To measure the pressure of underground water.

(ii) To measure static pressure of fluid in a container.

(iii) helpful in calculation to find the performance of soil and rock.

10. The soil used in an embankment construction is founded to have maximum dry density = 19 KN/m³ from SPT test. The specification are: 95% compaction. After finishing compaction of a layer the moist weight of the sample = 18 KN/m³ and water content 12%. Does it meet the specification?

Solution: We know, $R = \frac{\gamma_d(\text{field})}{\gamma_{d(\max\text{-lab})}} \times 100\%$

$\Rightarrow 0.95 = \frac{\gamma_d(\text{field})}{19}$

Required $\Rightarrow \gamma_d(\text{field}) = (0.95 \times 19) = 18.05\ KN/m^3$

After compaction, $\gamma_d(\text{field}) = \frac{18}{1+0.12} = 16.07\ KN/m^3$

Now

11. Given, compression index = 0.5, initial void ratio = 1.2. Normal pressure increase from 140 KPa to 240 KPa. Find the find the final void ratio.

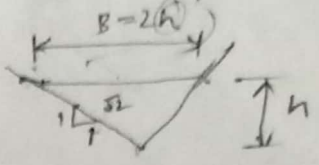
Solution: we know, $C_c = \frac{\Delta e}{\log\left(\frac{\sigma_2}{\sigma_1}\right)} = \frac{e_1 - e_2}{\log\left(\frac{\sigma_2}{\sigma_1}\right)}$.

$\Rightarrow 0.5 = \frac{1.2 - e_2}{\log\left(\frac{240}{140}\right)}$

$\Rightarrow e_2 = 1.083$ (Ans.)

11. Find the top width of a best ~~hydraulic~~ hydraulic triangular section if discharge, $Q = 1 m^3/sec$.

Solution:



We know,

$$\frac{Q^2}{g} = \frac{A_c^3}{B}$$

$$\Rightarrow \frac{1}{g} = \frac{(h^2)^3}{2h}$$

$$\Rightarrow h^5 = \frac{2}{g}$$

$$\therefore h = \left(\frac{2}{g}\right)^{\frac{1}{5}}$$

$$B = 2h = 2 \times \left(\frac{2}{g}\right)^{\frac{1}{5}}$$

$V = \sqrt{gD}$

$Q = AV$

$\Rightarrow 1 = h^2 \times \sqrt{g \times \frac{h}{2}}$

$\Rightarrow h^2 \times \sqrt{g} \times \left(\frac{h}{2}\right)^{\frac{1}{2}} = 1$

$\Rightarrow h^2 \times \sqrt{h} = \sqrt{\frac{2}{g}}$

$\Rightarrow h^{\frac{5}{2}} = \left(\frac{2}{g}\right)^{\frac{1}{2}}$

$\Rightarrow h = \left(\frac{2}{g}\right)^{\frac{1}{5}}$

Here,

$A = \frac{1}{2} \times 2h \times h = h^2$

$P = 2\sqrt{2}h$

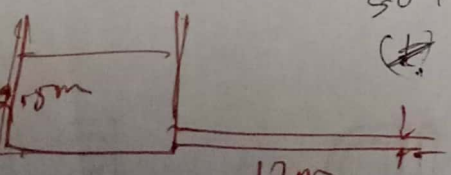
$R = \frac{A}{P} = \frac{h^2 \cdot h}{2\sqrt{2}h} = \frac{h}{2\sqrt{2}}$

$D = \frac{A}{B} = \frac{h^2}{2h} = \frac{h}{2}$

$B = 2h = 2 \times \left(\frac{2}{g}\right)^{\frac{1}{5}}$

12. Given, sedimentation tank dimension = 4m × 3m × 2.5m, A pipe of gradient 1 in 30 is connected to the bottom of the tank. Find the size of the pipe. [diameter & velocity missing]

Solution:



$2.5 = \frac{V_1^2}{2g} + \dots$

$\Rightarrow V_1 = \dots$

$Q = AV$

$Q = AV$

$A = 2.5$

$B = 400$

$Q = AV$

$= \frac{\pi}{4} D^2 \times \sqrt{2gh}$

$C = L \times B \times H$

$Q = \frac{C}{t}$

R. A tank of having 4 × 3 × 2.5m dimension having 2.5m water depth, a pipe of 12m length & 400 mm diameter is below the tank. Find the flow rate of the pipe.

113. Rain Area = 10 m x 10 m, Rainfall Intensity = 100 mm/hr. A drain having slope of 1cm/km. What time needed to carry the rain water. [Run off co-efficient missing]

A
I
C

$Q = CIA$

DMTCL – 2019

1. Geotech:

Estimate the pull out capacity of a cast in situ bored concrete pile of dia. 500 mm and length 15 m. Pile installed in a homogeneous sand deposit. If density = 18 KN/m^3. and internal friction 30°. water table is at ground surface.

Solution:

$Q_s = \Sigma P \Delta L f$

Here, $P = \pi D = (3.1416 \times 0.5) = 1.5708$ m

$L' = 15D = (15 \times 0.5) = 7.5$ m

$f_{7.5} = K \sigma_o' \tan\delta'$

where, $\phi = 30°$

$K = 1 - \sin\phi'$

$= 1 - (\sin 30°)$

$K = \frac{1}{2}$

$\delta' = 0.8\phi = (0.8 \times 30)$

$\therefore \delta' = 24°$

$\sigma_o' = \gamma' z$

$= (18 - 9.81) \times 7.5$

$= 61.425$

$= 0.5 \times 61.425 \times \tan(24°)$

$= 13.6741$ KN/m^2

$Q_s = 1.5708 \times 7.5 \times \left(\frac{0 + 13.6741}{2}\right)$

$+ 1.5708 \times (15 - 7.5) \times 13.6741$

$= 241.64$ KN

(Ans.)

2. The soil used in an embankment construction is found to have a max. dry density of 19 KN/m³ from standard proctor construction test. The specifications are: minimum 95% compaction. After finishing a layer by roller a block of soil is extracted from the compaction layer using a pipe section of 100 mm length and 75 mm internal dia. Wet and dry weight of extracted soil is 865 gm and 810 gm respectively. Does the layer meet specifications.

Solution:

We know, $R = \frac{\gamma_d (field)}{\gamma_d (max-lab)}$

$\Rightarrow 0.95 = \frac{\gamma_d (field)}{\gamma_d (max-lab)}$

$\gamma_d (field) = (0.95 \times 19) = 18.05 \ KN/m^3$

$W = \frac{W_w}{W_s} = \frac{865 - 810}{810} = 6.79\%$

$\therefore$ volume of soil block $= \pi r^2 h = 3.1416 \times \left(\frac{75}{2}\right)^2 \times 100$

$= 4.42 \times 10^5 \ mm^3$

$= 4.42 \times 10^{-4} \ m^3$

$\therefore$ Dry unit weight, $\gamma_d = \frac{W_s}{V} \times g = \frac{0.81}{4.42 \times 10^{-4}} \times 9.81$

$= 17977 \ N/m^3 = 17.98 \ KN/m^3$

(It does not fulfil the specification)

3. (Environment)

A waste water is discharged thro an out fall to a fresh water stream of mean velocity = 1 m/s. The DO and BOD of the stream after receiving the waste water 8.5 mg and 25 mg/l. Determine the time and distance downstream water depth is m minimum. (K_d = deoxygenic rate = 0.25/day); K_r = reaeration rate = 0.4/day. sulfure concentration of DO = 9.2)

Solution:

Initial oxygen deficit $D_o = (9.2 - 8.5) = 0.7$ mg/l

Initial BOD, $L_o = 25$

time, $t_c = \frac{1}{K_r - K_d} \times \ln\left[\frac{K_r}{K_d}\left(1 - \frac{D_o(K_r - K_d)}{L_o K_d}\right)\right]$

$= \frac{1}{0.4 - 0.25} \times \ln\left[\frac{0.4}{0.25} \times \left(1 - \frac{0.7}{25} \times \left(\frac{0.4 - .25}{.25}\right)\right)\right]$

$= 3.02$ days. (3.02 × 24 × 3600)

∴ distance, $x = vt = (1 \times 3 \times 24 \times 3600) = 260928$

$= 260.928$ km.

(Ans.)

(4.) A treatment plant treats 3780 m³ waste daily. If influent suspended solid 220 mg/L and treated water, suspended solid concentration 5 mg/L; calculate solid sludge produced by the plant in kg/day.

Solution: Total suspended solid removed $= (220 - 5) = 215$ mg/l

$= \frac{215 \times 1000}{1000 \times 1000}$ kg/l

$= 0.215$ kg/m³

∴ Total solid sludge $= (0.215 \times 3780) = 812.7$ kg/day. (Ans)

(5) What is skin friction? In what kind of soil it occures?

(6) Why are used high strength concrete in precast prestressed girder.

(7) SFD & BFD by portal Method.

(8) Access movement diagram.

(9) Speed volume density relation.

(10) Mode choice of bus, auto, walk,

(11) RCC math.