SJE(PAPER-II) -2018 MAINS
OFFLINE TEST SERIES

Civil and Structural Engineering **Full Length Mock Test-1**

Solutions

01

(a) Ans: Tests for Bricks:

A brick is generally subjected to the following tests to find out its suitability for the construction of work.

1. **Absorption:** A brick is taken and it is weighed dry. It is then immersed in water for a period of 24 hours. It is weighted again and the difference in weight indicates the amount of water absorbed by the brick.
2. **Crushing Strength:** The crushing strength of a brick is found out by placing it in a compression testing machine. It is pressed till it breaks. As per IS: 1077-1970, the minimum crushing or compressive strength of bricks is 3.50 N/mm^2. The bricks with crushing strength of 7 to 14 N/mm^2 are graded as A and those having above 14 N/mm^2 are graded as AA.
3. **Hardness:** In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, the brick is treated to be sufficiently hard.

4. **Presence of soluble salts:** The soluble salts, if present in bricks, will cause efflorescence on the surface of bricks. For finding out the presence of soluble salts in a brick, it is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on its surface indicates absence of soluble salts.
   If the white deposits cover about 10 per cent surface, the efflorescence is said to be slight and it is considered as moderate, when the white deposits cover about 50 percent of surface.
5. **Shape and Size:** In this test, a brick is closely inspected. It should be of standard size and its shape should be truly rectangular with sharp edges. For this purpose, 20 bricks of standard size (190 mm × 90 mm × 90 mm) are selected at random and they are stacked lengthwise, along the width and along the height.

For good quality bricks, the results should be within the following permissible limits:

Length : 3680 mm to 3920 mm

Width : 1740 mm to 1860 mm

Height : 1740 mm to 1860 mm

6. **Soundness:** In this test, the two bricks are taken and they are struck with each other. The bricks should not break and a clear ringing sound should be produced.
7. **Structure:** A brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects such as holes, lumps, etc.

(b)

Sol:

Station point	Chainage	BS	IS	FS	Rise (+)	Fall (–)	RL	Remark
A	0	0.85					380.500	
	30		1.545			0.690	379.810	
	60		2.335			0.790	379.020	
	90		3.115			0.780	378.240	
	120	0.455		3.825		0.710	377.530	Change point
	150		1.380			0.925	376.605	
	180		2.055			0.675	375.930	
	210		2.855			0.800	375.130	
	240	0.585		3.455		0.600	374.530	Change point
	270		1.015			0.430	374.100	
	300		1.850			0.835	373.265	
	330		2.755			0.905	372.360	
B	360			3.845		1.090	371.270	
Total =		**1.898**		**11.125**	**0**	**9.230**		

Procedure: Observe that the given readings are gradually increasing initially, but they have suddenly decrease after the fifth and tenth readings. This indicates that the instrument was shifted after 5th and 10th readings. Then proceed as usual method.

Check:

$\Sigma BS - \Sigma FS = 1.895 - 11.125 = -9.230$

Σ Rise – Σ Fall = 0 – 9.230 = – 9.230

Last RL – 1st RL = 371.270 – 380.500 = –9.230

$$\text{Falling gradient of AB} = \frac{\text{difference of level}}{\text{horizontal distance}}$$

$$= \frac{9.230}{360} = \frac{1}{39} \text{ (i.e. 1 in 39)}$$

(c)

Sol: Consumptive use = 5 mm/day

Area to be irrigated = 60 ha

Q = 28 *l*ps

Application efficiency η_a = 40%

(i) Allowable depletion depth between irrigations:

Available moisture depth, = 140 × 0.3

= 42 mm

Readily available moisture depth

$(d_w) = 0.35 \times 42 = 14.7$ mm

∴ Allowable depletion depth between irrigations (d_w) = 14.7mm

(ii) Frequency of irrigation:

$$= \frac{\text{Readily available moisture depth } (d_w)}{\text{Consumptive use}}$$

$$= \frac{14.7 \text{ mm}}{5 \text{ mm/day}} = 2.94 \text{ day}$$

∴ Frequency of Irrigation = 2.94 days

(iii) Net application depth of water:

$$\eta_a = \frac{\text{water stored in root zone}}{\text{water applied in field}} \times 100$$

$$0.4 = \frac{\text{Area} \times d_w}{\text{Area} \times \text{depth of water applied}} \times 100$$

Depth of water applied

$= \frac{14.7}{0.4} = 36.75\,\text{mm}$

Since there is no rainfall, Runoff = 0.

Net application depth of water

= 36.75 – 0 = 36.75 mm

(iv) Volume of water required: (V)

V = Area to be irrigated × Net application depth of water

= 60 × 36.75 × 10 $^{-3}$

= 2.205 ha.m

Volume of water required = 22050 m^3

(v) Time required to Irrigate 4 ha plot:

V = Q × t

Volume of water required to irrigate 4 ha = Rate at which water delivered × time

$$\text{Time} = \frac{4\times10^4\times36.75\times10^{-3}\ (m^3)}{28\times10^{-3}\quad(m^3/s)}$$

= 52500 sec.

∴ Time required to irrigate 4 ha plot

= 14.583 hrs.

(d).

Ans: Given

Volume of wet cement concrete = 15 m^3

In concrete mix 1:2:4,

Volume of dry cement concrete = (Volume of wet cement concrete × 1.54) m^3

Volume of wet cement concrete = 15 × 1.54 =23.1 m^3

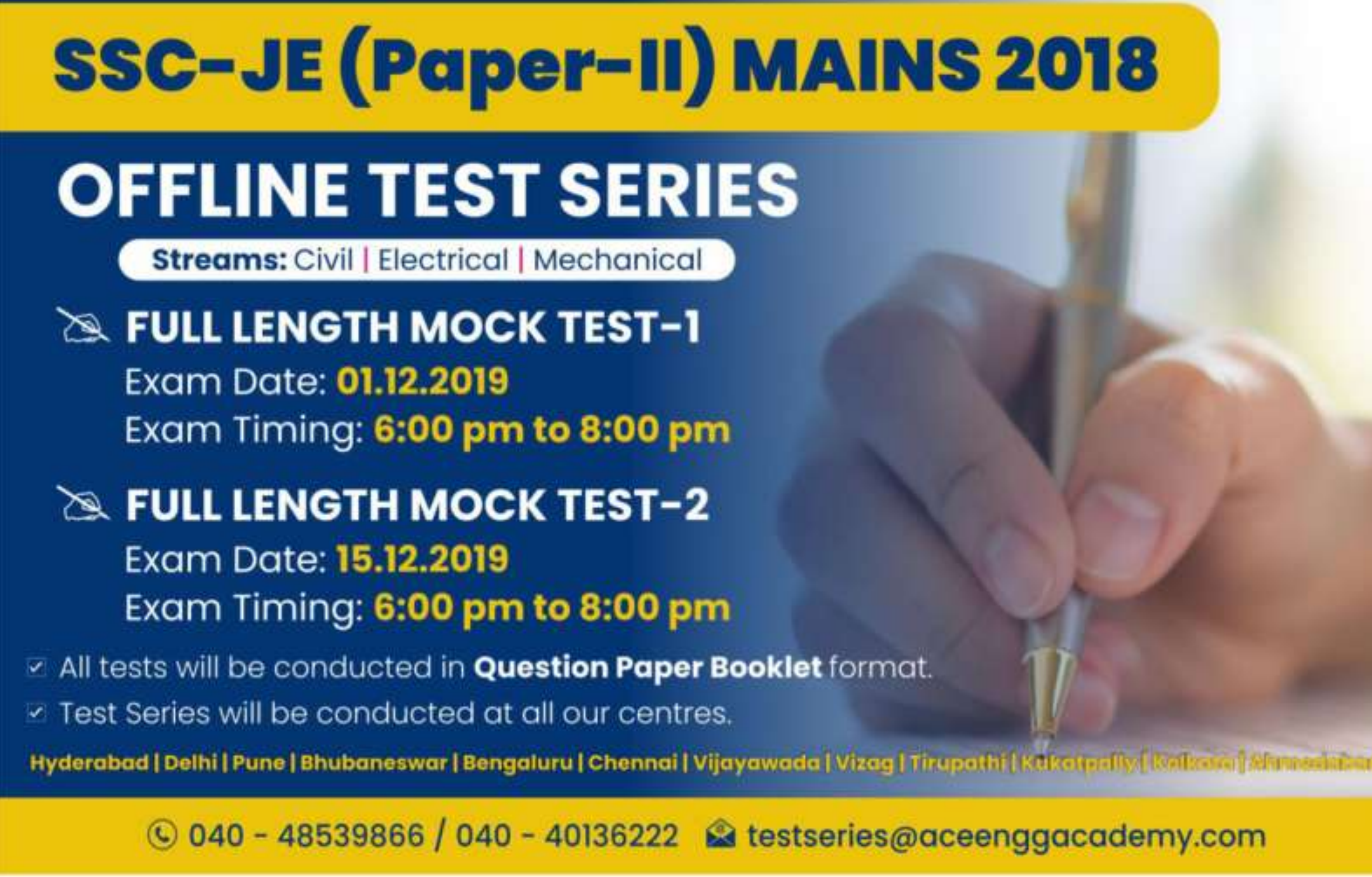
Total cement volume = 23.1 /7 = 3.3 m^3

Volume of 50 kg cement bag = 0.035 m^3

Total cement in bags = 3.3 / 0.035 = 94.28 bags ≈ 95 bags

Total fine aggregate volume = 23.1 × / 7 = 6.6 m^3

Total coarse aggregate volume = 23.1 × / 7 = 13.2 m^3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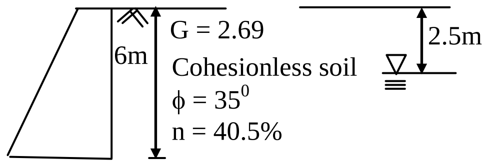
02.(a)

Sol:



$$e = \frac{n}{1-n} = \frac{0.405}{1-0.405} = 0.68$$

$$\gamma_d = \frac{\gamma_w G}{1+e} = \frac{10\times 2.69}{1+0.68} = 16.01 kN/m^3$$

$$\gamma_{sat} = \frac{\gamma_w [G+e]}{1+e} = \frac{10\times[2.69+0.68]}{1+0.68}$$

$$= 20.05 kN/m^3$$

Since the soil is cohesionless, C = 0

$p_a = K_a\,\sigma_v - 2C\sqrt{K_a}$

C = 0

$p_a = K_a\sigma_v$

At top:

$p_a = 0$ [$\because \sigma_v = 0$]

At 2.5m depth

$p_a = K_a\ \sigma_v$

$$K_a = \frac{1-\sin 35°}{1+\sin 35°} = 0.27$$

$\sigma_v = 16.01\times 2.5 = 40.025\ kN/m^2$

$p_a = 0.27\times 40.025 = 10.81\ kN/m^2$

At bottom of the wall:

$p_a = K_a\sigma_v' + \gamma_w.\ h$

$\gamma' = \gamma_{sat} - \gamma_w$

$\gamma' = 20.05 - 10 = 10.05 kN/m^3$

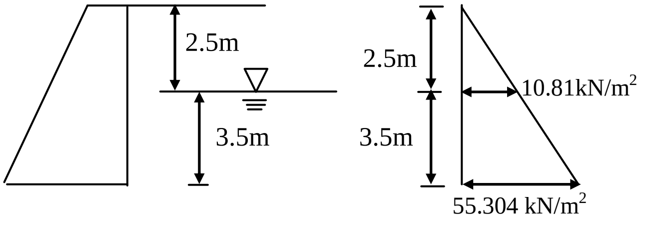
$\sigma_v' = (16.01 \times 2.5) + (10.05 \times 3.5)$

$= 75.2\ kN/m^2$

$p_a = 0.27\times 75.2 + 10\times 3.5$

$= 55.304\ kN/m^2$

Pressure diagram



Total active earth thrust

$$=\left(\frac{1}{2}\times 10.81\times 2.5\right)+\left(\frac{55.304+10.81}{2}\right)\times 3.5$$

= 129.212 kN/m

Taking Moment of areas about bottom of wall:

$$129.212\times \overline{H} = \left(\frac{1}{2}\times 10.81\times 2.5\right)\times\left(3.5+\frac{2.5}{3}\right)+\left[\frac{55.304+10.81}{2}\right]\times 3.5\times\left[\frac{2\times 10.81+55.304}{55.304+10.81}\right]\times\frac{3.5}{3}$$

$$\overline{H} = \frac{13.5125\times 4.33+115.69\times 1.357}{129.212}$$

= 1.668m from bottom of the wall

∴ Total resultant thrust acts at 1.668 m from bottom

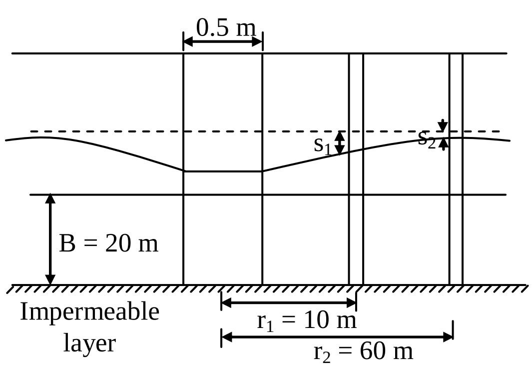
(b).

Sol: Given:

$Q = 0.10\ m^3/sec$

$s_1 = 4$ m, $r_1 = 10$ m

$s_2 = 3$ m, $r_2 = 60$ m



$$Q=\frac{2\pi KB(s_1-s_2)}{\ell n\left(\frac{r_2}{r_1}\right)}$$

$$0.10=\frac{2\pi\times K\times 20(4-3)}{\ell n\left(\frac{60}{10}\right)}$$

$K = 1.4258\times 10^{-3}$ m/sec

Let S_w is drawdown in well

r_w is the radius of well = $\frac{0.50}{2}$ = 0.25 m

$$\therefore Q = \frac{2\pi KB(s_w - s_1)}{\ell n\left(\frac{r_1}{r_w}\right)}$$

$$0.10 = \frac{2\pi \times 20 \times 1.425 \times 10^{-3}(s_w - 4)}{\ell n\left(\frac{10}{0.25}\right)}$$

s_w = 6.06 m

Validity of Darcy's Law:

1. Darcy's law is valid for saturated soil in which laminar flow takes place.
2. For laminar flow conditions in soil, Reynolds no, should be less than 1.
3. Darcy's law is valid for flow in clays, silt and fine sands. In coarse sands, gravel and boulders, the flow may be turbulent and Darcy's law may not be applicable.

(c)

Sol: Given:

b = 300 mm

LL = 12 kN/m

l_{eff} = 8 m

M15, Fe415

Design a reinforced concrete beam with balanced section by working stress method.

Step1: Assume the depth of beam = 1000 mm

Effective cover = 50 mm

Step 2: Load calculations:

Dead load,

$W_D = \gamma_c \times b \times D$

$= 25 \times 0.3 \times 1$

= 7.5 kN/m

Live load, w_L = 12 kN/m

Total load = 7.5 + 12 = 19.5 kN/m

Step3: Moment calculation:

$$\text{Design moment, } M = \frac{w\ell^2}{8} = \frac{19.5 \times 8^2}{8} = 156 \text{ kN-m}$$

Step4: Check for depth:

$M_{lim} = Q\,bd^2$

Calculation of constants

From IS: 456

$\sigma_{cbc} = 5\,MPa$

$\sigma_{st} = 230\ MPa$

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3\times 5} = 18.67$$

$$K = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} = \frac{18.67\times 5}{18.67\times 5 + 230} = 0.289$$

$$j = 1 - \frac{K}{3} = 0.904$$

$$Q = \frac{1}{2}\sigma_{cbc}\, jK$$

$$= \frac{1}{2}\times 5\times 0.289\times 0.904 = 0.653$$

$M = Q\,bd^2$

$156\times 10^6 = 0.653 \times 300 \times d^2$

$d = 892.37 \simeq 900$ mm

$D = 900 + 50$

$= 950$ mm < Assumed one

Hence safe

Step5: Reinforcement in tension:

$M = \sigma_{st}\, A_{st}\, jd$

$156 \times 10^6 = 230 \times A_{st} \times 0.904 \times 900$

$A_{st} = 833.654$ mm

Use 16 mm ϕ bar

$$\text{Number of bars, } n = \frac{833.654}{\frac{\pi}{4}[16]^2}$$

$n = 4.14 \simeq 5$

Step6: Calculation of minimum reinforcement: **(From IS: 456)**

$$\frac{(A_{st})_{min}}{bd} = \frac{0.85}{f_y}$$

$$(A_{st})_{min} = \frac{0.85 \times bd}{f_y}$$

$$= \frac{0.85 \times 300 \times 900}{415} = 553 \text{ mm}^2$$

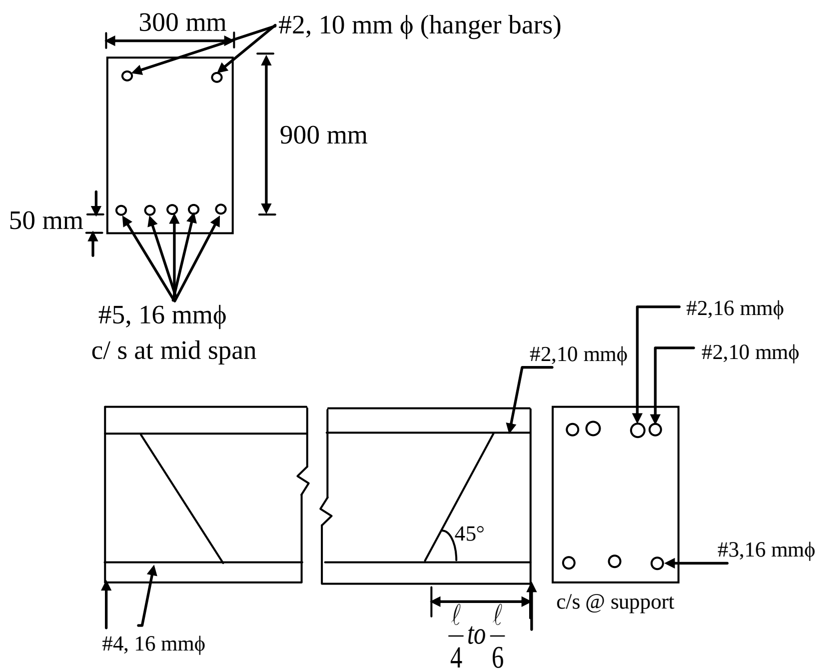
Step7:Calculation of maximum reinforcement: (From IS: 456)

$(A_{st})_{max} = 4\%$ bD

$$= \frac{4}{100} \times 300 \times 950 = 11400 \text{ mm}^2$$

Provide # 2 of 10 mm ϕ Hanger bar in compression zone.

Design Detail:



(d)

Ans:

(i) Useful life:

It represents the number of years the asset will be generating satisfactory revenue. It is also called as depreciable life/useful value.

(ii) Scrap value:

It is the value amount earned by the dismantling property which is of absolutely of no use except for selling as scrap. This term is used when the property or asset cannot be used other than it being broken down into smallest unit and sold as scrap.

The amount fetched by selling the units is known as scrap value.

(iii) Salvage Value:

It is the amount fetched by the property if the property is disposed without dismantling .The property or asset is of value to other agency but for the parent organization the asset will not be generating satisfactory revenue.

Once the property utility period is over the property sold as it is without breaking, then the amount earned by such is called salvage value.

03. (a)

Sol: (i) Latitude of CE = L′ = –εL

O = 200.75 + 100.25 – 199.0 – 100.0 + L′

L′ = –2

Departure of CE = D′ = –εD

0 = 199.25 + 99.75 – 100.5 – 200.5 + D′

D′ = 2

Magnitude of closing error, $e = \sqrt{D^{12} + L^{12}}$

$$e = \sqrt{(+2)^2 + (-2)^2}$$

e = 2.83 m

$$\theta = \tan^{-}\left(\frac{+2}{-2}\right) = 45° \ = S45°E = 135°$$

(ii) Correction to latitude of station B, using transit rule

L_s = 200.75 + 100.25 + 199 + 100.00

= 600 m

D_s = 199.00 + 100 + 100.5 + 200.5

= 600 m

$$C_L \text{ of } B = \left(-\sum L\right) \times \frac{L}{L_s}$$

$$= (-2) \times \left(\frac{100.25}{600}\right) = (-)0.334 \text{ m}$$

Corrected latitude of station 'B' = 100.25 – 0.3341

= 99.915 m

C_D of $'B' = (-\sum D) \times \frac{D}{D_s} = 2 \times \frac{199.25}{600}$

$= 0.6641$ m

Corrected departure of station 'B' = 199.25 + 0.6641

= 199.914 m

(iii) To calculate the independent co-ordinates add the latitude and departure of given station 'A' to The 'B' station for the respective values of latitude and departure.

Station	L	D
A	100	100
B	99.915	199.914

The independent co-ordinates of B = (99.915, 199.914)

(b)

Sol: Square B = 2m, D = 1.2 m $c' = 0$, $\phi' = 30^o$

$\gamma = 19.2$ kN/m^3, $\gamma' = 10.1$ kN/m^3, $N_q = 22$, $N_\gamma = 20$

(i) Water table is well below the base of the foundation:

$q_u = 1.3\, C\, N_c + \gamma\, D\, N_q + 0.4\, \gamma\, B\, N_\gamma$

In this case, $q_u = \gamma\, D\, N_{q'} + 0.4\, \gamma\, B\, N_\gamma$

$q_u = 19.2 \times 1.2 \times 22 + 0.4 \times 19.2 \times 2 \times 20 = 814$ kN/m^2

(ii) Water table rises to the level of the base of the foundation:

$q_u = \gamma\, D\, N_q + 0.4\, \gamma'\, B\, N_\gamma$

$= 19.2 \times 1.2 \times 22 + 0.4 \times 10.1 \times 2 \times 20 = 668.48$ kN/m^2

(iii) Water table rises to the ground level:

$q_u = \gamma'\, D\, N_q + 0.4\, \gamma'\, B\, N_\gamma$

$= 10.1 \times 1.2 \times 22 + 0.4 \times 10.1 \times 2 \times 20 = 428.24$ kN/m^2

(c)

Sol: Given B.G track

V = 110 kmph

(i) To find radius of curvature:

We know that, By Martin's formula for BG track in transition zone

$V = 4.58\sqrt{R}$

$110 = 4.58\sqrt{R}$

$R = 576.84$ m

$= 577$ m

(ii) To find degree of curvature:

$$D = \frac{1720}{R}$$

$$D = \frac{1720}{577}$$

$D = 2.98°$

(iii) To find super elevation (equilibrium cant):

Given $V_{max} = 110$ kmph

Take, $V_{avg} = \frac{3}{4}V_{max} = 82.5\,\text{kmph}$

$$e = \frac{GV^2}{127R}$$

Where, G = 1.676 m for B.G track

$$e = \frac{1.676 \times 82.5^2}{127 \times 577}$$

$e = 0.155$ m

$e = 15.5$ cm

Maximum allowed = $\frac{1}{10}$ of gauge

= 16.76 cm

Hence ok

(iv) To find length of transition:

Higher of the following

(i) $L = 7.2\,e = 7.2 \times 15.5 = 111.6$ m

(ii) $L = 0.073\,DV_{max} = 0.073 \times 10 \times 110 = 80.3$ m

[for speeds > 100 kmph D = 100 mm (B.G)]

(iii) $L = 0.073\,eV_{max}$

$= 0.073 \times 15.50 \times 110$

$= 124.47$ m

$\therefore$ L = 124.47 m, say 125 m

(d)

Sol: Given:

Power developed, P = 3500 kW

Head, H = 120 m

Overall efficiency, η_o = 85%

Coefficient of velocity, C_V = 0.98

To find:

Diameter of the nozzle

Overall efficiency, $\eta_o = \dfrac{P}{\rho g Q H}$

$$0.85 = \frac{3500 \times 10^3}{1000 \times 9.81 \times Q \times 120}$$

Q = 3.498 m^3/s

Velocity of jet, $V = C_V \times \sqrt{2gH}$

$$= 0.98 \times \sqrt{2 \times 9.81 \times 120}$$

V = 47.551 m/s

Discharge = Area of jet × Velocity

$$3.497 = \frac{\pi}{4} \times d^2 \times 47.551$$

d = 0.306 m

d = 30.6 cm $\Rightarrow$ d $\simeq$ 31 cm

04(a).

Sol: Given two pipes are connected in parallel

Length of pipe 1 = L_1 = 2500 m

Length of pipe 2= L_2 = 2500 m

Dia. of pipe 1 = D_1 = 80 cm = 0.8 m

Dia of pipe 2 = D_2 = 60 cm = 0.6 m

Friction factor = 0.024

Total flow, Q = 250 lit/sec = 0.25 m^3/sec

Let the discharge in pipe (1) and pipe (2) are Q_1 and Q_2 respectively

$Q = Q_1+Q_2$ --------------- (1)

Also, head loss in pipe (1) and pipe (2) are h_{f_1} & h_{f_2} respectively

As the two pipes are connected in parallel

$$h_{f_1} = h_{f_2}$$

$$\frac{8fLQ_1^2}{\pi^2.g.d_1^5} = \frac{8f.LQ_2^2}{\pi^2.g.d_2^5}$$

$$\frac{Q_1^2}{Q_2^2} = \frac{(0.8)^5}{(0.6)^5}$$

$\therefore$ $Q_1 = 2.05\ Q_2$

Substitute this value in equation (1),

$Q_1+Q_2 = Q$

$2.05\ Q_2+Q_2 = 250$

$$Q_2 = \frac{250}{3.05}$$

$Q_2 = 81.97$ lit/sec

$\therefore$ $Q_1 = 250 - 81.97$

$Q_1 = 168.03$ lit/sec

(b)

Sol: Given:

Two way traffic,

Speed of overtaking vehicles (A),

$V = 65$ kmph

Speed of overtaken vehicle (B),

$V_b = 40$ kmph

Acceleration of overtaking vehicle = a

$= 0.92\ m/s^2$

To Find:

(i) Safe overtaking sight distance

(ii) Minimum overtaking zone

(i) Safe Overtaking sight Distance : (OSD)

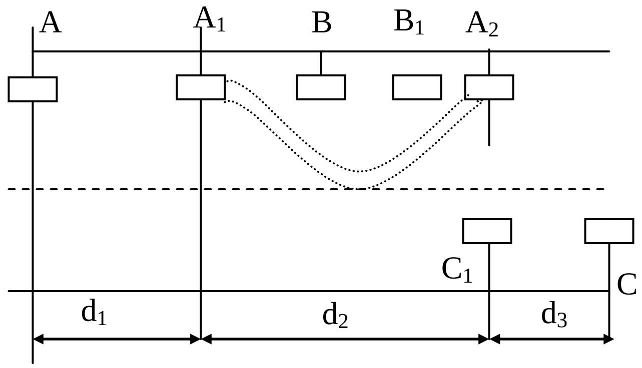
$OSD = d_1 + d_2 + d_3$

$AA_1 = d_1 = 0.278\ V_b t$

$A_1A_2 = d_2 = 0.278\ V_b T + 2S$

$CC_1 = d_3 = 0.278\ VT$

$T = \sqrt{\frac{4S}{a}}$; $S = 0.2\ V_b + 6$



$T = \sqrt{\dfrac{4 \times 14}{0.92}}$; $S = 0.2 \times 40 + 6 = 14$ m

$T = 7.80$ sec

$OSD = d_1 + d_2 + d_3$

$OSD = (0.278 \times 40 \times 2.0) + (0.278 \times 40 \times 7.80) + (2 \times 14) + (0.278 \times 65 \times 7.80)$

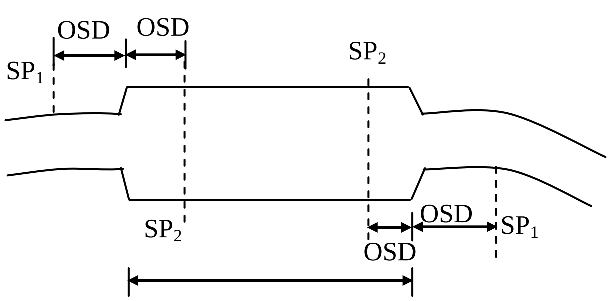
$OSD = 277.9 \simeq 278$ m

(ii) Minimum OSD:

Overtaking zone $= 3(d_1 + d_2 + d_3)$

$= 3\ (278)$

$= 834$ m



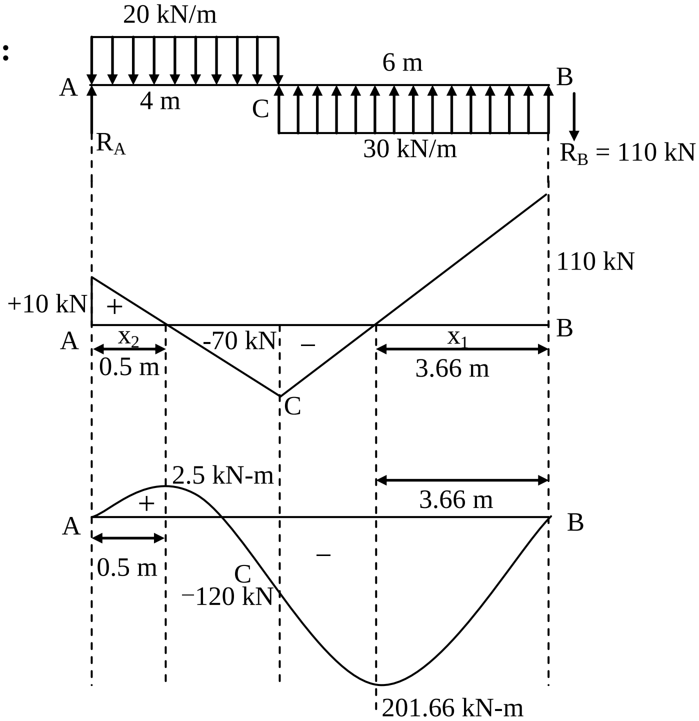
Minimum overtaking Zone = 834 m

$SP_1 \rightarrow$ Sign post "overtaking zone ahead"

$SP_2 \rightarrow$ Sign post "end of overtaking zone"

(c)

Sol:



$R_A + R_B = (20 \times 4) - (30 \times 6)$

$= 80 - 180 = -100$ kN

$\Sigma M_A = 0$

$(R_B \times 10) + (30 \times 6 \times 7) - (20 \times 4 \times 2) = 0$

$R_B + 126 - 16 = 0$

$R_B = -110$ kN

$R_A = +10$ kN

At $x = 0 \Rightarrow SF_A = 10$ kN

At $x = 4 \Rightarrow SF_C = -70$ kN

BM will be maximum where shear force changes sign.

Let 'x_1' be a distance from end 'B' where S.F. changes it's sign

From similar Δ^{les}

$$\frac{110}{x} = \frac{70}{6-x} \Rightarrow x_1 = 3.66$$

Taking moment at x = 3.66

$$-110 \times 3.66 + 30 \times 3.66 \times \frac{3.66}{2} = -201.66 \text{ kN-m}$$

For the part AC

Let 'x_2' be the distance from the end 'A' where SF changes it's sign

$$\frac{10}{x} = \frac{70}{4-x} \Rightarrow x_2 = 0.5 \text{ m}$$

Moment @ 0.5 m from end 'A'

$= 10 \times 0.5 - 20 \times 0.5 \times 0.25$

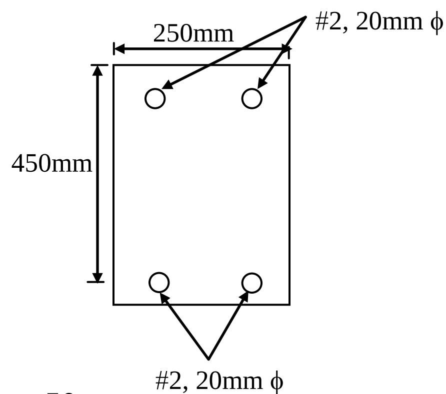
$= 5 - 2.5 \Rightarrow 2.5$ kN-m

Maximum Sagging moment is 2.5 kN-m

Maximum Hogging moment is 201.66 kN-m

5(a).

Sol:



Given:

f_{ck} = 20 MPa

f_y = 415 MPa

Assume effective cover = 50 mm

Effective depth = 500 – 50

= 450 mm

Service load = 40 kN/m

Factored load = 1.5 ×40 = 60 kN/m

Factored shear force,

$$V_u = \frac{w\ell}{2} = \frac{60 \times 5}{2} = 150 \text{ kN}$$

Nominal shear stress , $\tau_v = \frac{V_u}{bd}$

$$= \frac{150 \times 10^3}{250 \times 450} = 1.33 \text{ N/mm}^2$$

To calculate τ_c

$$P_t = \frac{100 A_{st}}{bd} = \frac{100 \times 2 \times \frac{\pi}{4}(20)^2}{250 \times 450} = 0.56\%$$

By linear interpolation from given table

$$\tau_c = 0.48 + \frac{(0.56 - 0.48)}{(0.75 - 0.5)}(0.56 - 0.5)$$

$= 0.499 \simeq 0.5$

$\tau_v > \tau_c$

$\therefore$ Design of shear reinforcement

Design shear force, (V_{us})

$V_{us} = V_u - \tau_c bd$

$= 150 \times 10^3 - 0.5 \times 250 \times 450$

$= 93750$ kN

Assume 2 legged 8 mm ϕ mild steel vertical stirrups

$A_{sv} = 2 \times \frac{\pi}{4}(8)^2 = 100.53\ mm^2$

For vertical stirrups

(From IS:456 - 2000)

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$$

$$S_v = \frac{0.87 \times 250 \times 100.53 \times 450}{93750} = 104.9mm$$

$\simeq 100$ mm c/c

Minimum shear reinforcement

$$\frac{A_{sv}}{b.S_v} = \frac{0.4}{0.87 f_y}$$

$$\frac{100.53}{250 \times S_v} = \frac{0.4}{0.87 \times 250}$$

$S_v = 218.65$

$\simeq 210$ mm c/c

Check :

Smaller of the following

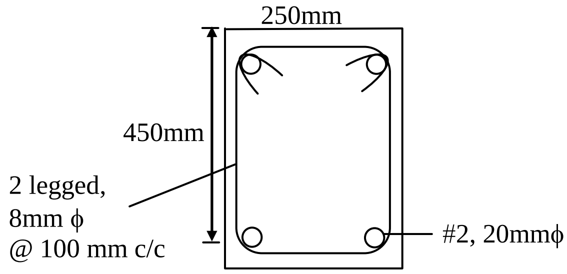
(i) $0.75d = 0.75 \times 450 = 337.5$ mm

(ii) Cal. $S_v = 100$ mm

(iii) Min $S_v = 210$ mm

(iv) 300 mm

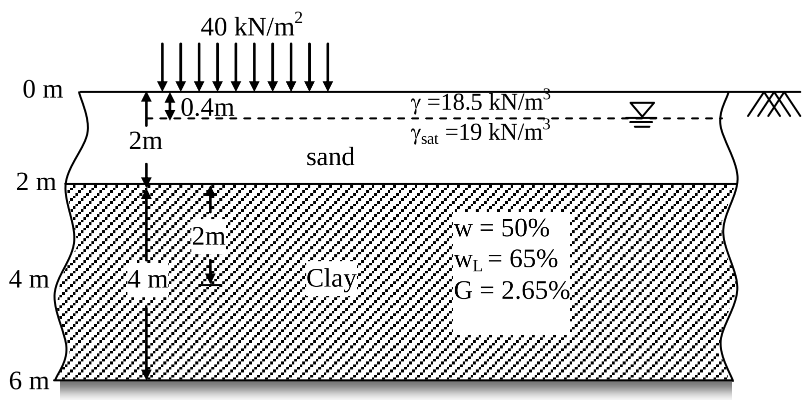
Design details:



(b)

Sol:

(a) The soil profile is as shown in figure.



For the clay stratum:

$w = 50\%$

$G = 2.65$

Since it is saturated, $e = w.\,G$

$= 0.50 \times 2.65$

$= 1.325$

This is the initial void ratio, e_0

$$\gamma_{sat} = \frac{(G+e)}{(1+e)}\gamma_w = \frac{(2.65+1.325)}{(1+1.325)} \times 10 \text{ kN/m}^3$$

$$= \frac{3.975 \times 10}{2.325} \text{kN/m}^3$$

$= 17.1 \text{ kN/m}^3$

$\gamma' = (\gamma_{sat} - \gamma_w) = 7.1 \text{ kN/m}^3$

Initial effective overburden pressure at the middle of the clay layer:

$$\bar{\sigma}_o = (0.4 \times 18.5) + (1.6 \times (19 - 10)) + (2 \times 7.1) \text{kN/m}^2$$

$= 36 \text{ kN/m}^2$

Let us assume that the applied surface pressure of 40 kN/m^2 gets transmitted to the middle of the clay layer undiminished.

$\therefore \quad \Delta\bar{\sigma} = 40 \text{ kN/m}^2$

The compression index, C_c may be taken as:

$C_c = 0.009\ (w_L - 10)$

$\therefore\ C_c = 0.009\ (65 - 10) = 0.495$

The consolidation settlement, S, is given by

$$S = \frac{H.C_c}{(1+e_0)}\log_{10}\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$

$$= \frac{400\times 0.495}{(1+1.325)}\log_{10}\frac{(36+40)}{36}\text{cm}$$

$= 27.64$ cm

(b) Thickness of the laboratory sample H = 25 mm

Since it is two-way drainage with porous discs on either side, the drainage path,

$$d = \frac{H}{2} = \frac{25}{2} = 12.5 \text{ mm}$$

Time for 90% primary compression, t_{90} = 81 minutes

Time factor T_v = 1.781 – 0.933 log (100 – U%)

T_{90} =1.781 – 0.933 log (100 – 90)

T_{90} = 0.848

$$\therefore T_{90} = \frac{C_v t_{90}}{d^2}$$

$$\therefore \quad 0.848 = \frac{C_v \times 81\times 60}{(12.5)^2}$$

$C_v = 2.726 \times 10^{-2}$ mm^2/cc

$\therefore$ Coefficient of consolidation $C_v = 2.726 \times 10^{-4}$ cm^2/sec

(c).

Sol: Given data:

Population of town = 75000

Rate of water supply = 150 lit/capital/day

Discharge = 150 × 75000 lit / day

= 11250000 lit / day

$$= \frac{11250000}{24\times 60} = 7812.5 \text{ lit / min}$$

Rate of filtration = 100 lit /min/ m^2

(i) To find the size & Number of filter beds.

Total area of filter

$$= \frac{\text{Discharge}}{\text{ROF(Rate of Filtration)}}$$

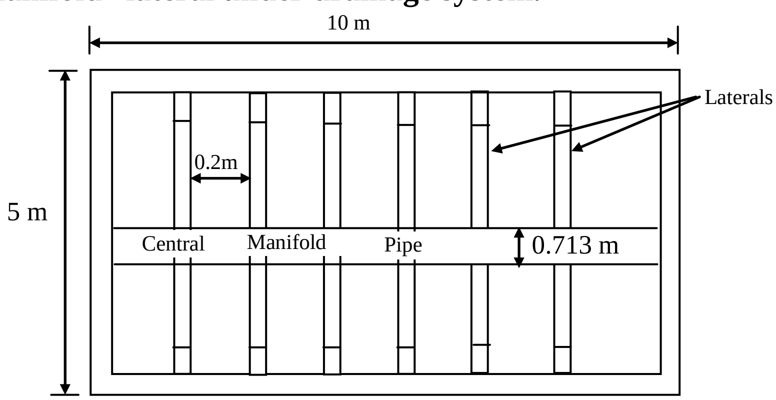
$$= \frac{7812.5}{100} = 78.125 \text{ m}^2.$$

Assume the size of each filter = 10 × 5

$$\text{Number of filter} = \frac{78.125}{50} = 1.56 \simeq 2$$

(ii) Design of under–drainage system.

Manifold– lateral under drainage system.



Let us assume that the area of the perforation is 0.2% of the total filter area.

∴ Total area of perforation = 0.2% Filter area

$$= \frac{0.2}{100} \times 50 = 0.1 \text{ m}^2$$

Assuming the area of each lateral

= 2 times the area of perforation

= 2× 0.1 = 0.2 m^2

Assuming the area of the manifold to be about twice the area of laterals.

Area of Manifold = 2 × 0.2 = 0.4 m^2

∴ Diameter of manifold (d)

$$\frac{\pi}{4}(d)^2 = 0.4$$

d = 0.7136 m

d = 71.36 cm

$$\text{Length of each lateral} = \frac{5 - 0.713}{2} = 2.14 \text{ m}$$

Assuming spacing between lateral

= 20 cm c/c

$$\text{Number of lateral on each side} = \frac{\text{length}}{\text{spacing of each lateral}} = \frac{10}{0.2} = 50$$

Total Number of lateral = 2 × 50 = 100

$$\text{Area of each lateral} = \frac{\text{Total area of lateral}}{\text{Number of lateral}} = \frac{0.2}{100} = 0.2 \times 10^{-2}$$

$$\text{Diameter of lateral} = \sqrt{\frac{4 \times 0.2 \times 10^{-2}}{\pi}} = 0.05 \text{ m} = 5 \text{ cm}$$

Assuming the diameter of perforation = 8 mm

$$\text{Area of each perforation} = \frac{\pi}{4}\left(8 \times 10^{-3}\right)^2 = 5.026 \times 10^{-5} \text{ m}^2$$

Number of perforation required

$$= \frac{\text{Total area of perforation}}{\text{Area of each perforation}}$$

$$= \frac{0.1}{5.026 \times 10^{-5}} = 1989.65$$

Perforation on each side

$$= \frac{\text{Total number of perforation}}{\text{Number of lateral}}$$

$$= \frac{1989.65}{100} = 19.96 \simeq 20$$

Spacing of perforation

$$= \frac{\text{length of each lateral}}{\text{Number of perforation per each lateral}}$$

$$= \frac{2.14}{20} = 107 \times 10^{-3} \text{ m} = 10.7 \text{ cm c/c}$$

Check:

$$\frac{\text{length of lateral}}{\text{Diameter of lateral}} = \frac{2.14}{0.05} = 42.8 \not> 60$$

Hence ok.

(iii) To find wash water discharge, Q_B

$Q_B = V_B \times$ area of each filter

$= 0.45 \times 50$

$= 22.5 \text{ m}^3/\text{min}$

06(a)

Sol: Full strength of plate

P_t = cross sectional area of plate × allowable tensile stress

= (150×20) ×150 = 450 ×10^3 N = 450 kN

Size of fillet weld S = 12 mm

Effective throat thickness t = k.S

$$= \frac{1}{\sqrt{2}} \times 12 = 8.49 \text{ mm}$$

Let q be the average shear stress in fillet weld average shear stress in fillet may be calculated by equating strength of fillet weld (P_s) to the full tensile strength of plate (P_t)

[Strength of fillet weld along edge of plate + strength of fillet weld along circular slot]

= Pull tensile strength of plate

$\{([2(150+70.72) + 50] \times 8.49 \times q) + (\pi \times 60 \times 8.49 \times q)\} = 450\times10^3$

$5772.34q = 450\times10^3$

$\Rightarrow q = 77.96 \text{ N/mm}^2$

Average shear stress in fillet weld

$q = 77.96 \text{ N/mm}^2$

(b)

Sol: For Steel f_y = 290MPa and f_u = 440 MPa

Diameter of bolt d = 25mm

Diameter of bolt hole d_o = 28 mm

Width of plate B = 320 mm

Thickness of plate t = 16 mm

[The aim of this question is to find the tensile strength of the plate, since the type of design method for solving this question is not specified, But yield stress of steel as well as ultimate tensile stress of steel are given without any partial safety factors, Hence it is assumed to solve above question by considering working stress method of design as per IS800:1984 and the same question is also solved by considering limit state design method of IS800:2007]

(i) (Working Stress method design procedure of IS 800:1984)

The tensile strength of plate based

$P_t = A_{net} \times \sigma_{at}$

Where

σ_{at} = Permissible axial tensile stress in the plate = 0.6 f_y = 0.6 × 290 = 174 Mpa

A_{net} = Net effective sectional area of plate

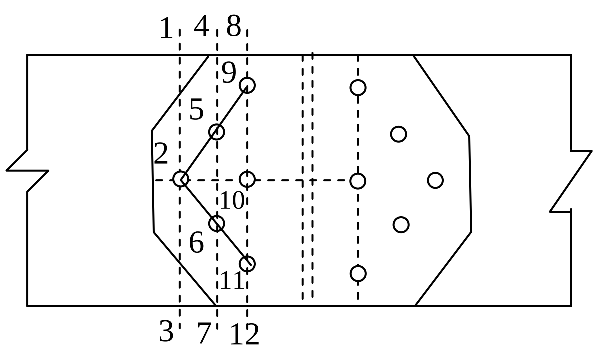
Where

A_n = Net effective sectional area of plate

$A_{net} = A_n = (B - n \times d_o) \times t$ for chain pattern of bolting

$$A_{net} = A_n = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$ for

Staggered pattern of bolting



Net sectional area of plate along section 1-2-3

$$A_{net} = (B - n \times d_o) \times t = (320 - 1 \times 28) \times 16 = 4672 \text{ mm}^2$$

Net sectional area of plate along section 4-5-2-3

$$A_{net} = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 2 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} = 4505.66 \text{ mm}^2$$ Net sectional area of plate along section

4-5-2-6-7

$$A_{net} = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 3 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60}$$

$= 4339.33 \text{ mm}^2$

Net sectional area of plate along section 8-9-5-2-3

$$A_{net} = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g} = (320 - 3 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 50}$$

$$= 4395.66 \text{ mm}^2$$

Net sectional area of plate along section

8-9-5-2-6-7

$$A_{net} = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g} = (320 - 4 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 50} = 4226.33 \text{ mm}^2$$

Net sectional area of plate along section

8-9-5-2-6-11-12

$$A_{net} = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 5 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60}$$

$$+ \frac{65^2 \times 16}{4 \times 50} + \frac{65^2 \times 16}{4 \times 50} = 4119.33 \text{ mm}^2$$

Hence net effective sectional area of plate

$$A_{net} = 4119.33 \text{ mm}^2$$

The tensile strength of plate based

$P_t = A_{net} \times \sigma_{at} = 4119.33 \times 174$

$= 716.76 \times 10^3$ N = 716.76 kN

(ii)

(Limit state design procedure of IS 800:2007)

Partial safety factor against f_y $\gamma_{mo} = 1.10$

Partial safety factor against f_u $\gamma_{m1} = 1.25$

The tensile strength of plate as per limit state design of IS 800:2007 is lesser of T_{dg}, T_{dn} and T_{db}

Where T_{db} is design tensile strength of plate based on block shear failure need not to be calculated and considered because the bolt hole has minimum end distance and pitch distance as per IS800:2007. Hence The tensile strength of plate as per limit state design of IS 800:2007 is lesser of T_{dg}, and T_{dn}

The tensile strength of plate based on gross section yielding T_{dg}

$$T_{dg} = A_g \times f_y / \gamma_{mo}$$
$$= (320 \times 16) \times 290 / 1.10$$
$$= 1349.81 \times 10^3 \text{ N} = 1349.81 \text{ kN}$$

The tensile strength of plate based on Net section rupture T_{dn}

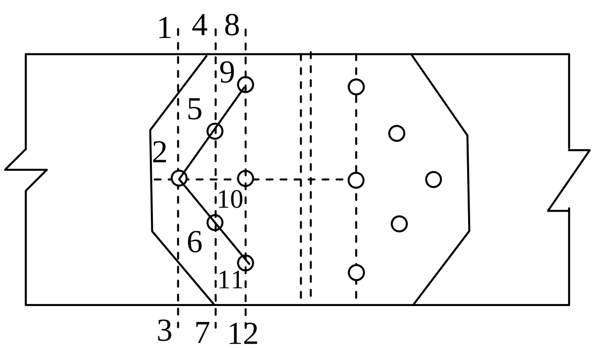
$$T_{dn} = \frac{0.9 \times A_n \times f_u}{\gamma_{m1}}$$

Where

A_n = Net effective sectional area of plate

$A_n = (B - n \times d_o) \times t$ for chain pattern of bolting

$A_n = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$ for staggered pattern of bolting



Net sectional area of plate along section 1-2-3

$A_n = (B - n \times d_o) \times t = (320 - 1 \times 28) \times 16 = 4672 \text{ mm}^2$ Net sectional area of plate along section *4-5-2-3*

$$A_n = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 2 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} = 4505.66 \text{ mm}^2$$

Net sectional area of plate along section

4-5-2-6-7

$$A_n = (B - n \times d_o) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g} = (320 - 3 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60}$$

$$= 4339.33 \text{ mm}^2$$

Net sectional area of plate along section

8-9-5-2-3

$$A_n = \left(B - n \times d_o\right) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g} = (320 - 3 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 50}$$

$= 4395.66 \text{ mm}^2$

Net sectional area of plate along section

8-9-5-2-6-7

$$A_n = \left(B - n \times d_o\right) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 4 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 50} = 4226.33 \text{ mm}^2$$

Net sectional area of plate along section

8-9-5-2-6-11-12

$$A_n = \left(B - n \times d_o\right) \times t + \sum_{i=1}^{n} \frac{p^2 t}{4g}$$

$$= (320 - 5 \times 28) \times 16 + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 60} + \frac{65^2 \times 16}{4 \times 50} + \frac{65^2 \times 16}{4 \times 50}$$

$= 4119.33 \text{ mm}^2$

Hence net effective sectional area of plate

$A_n = 4119.33 \text{ mm}^2$

The tensile strength of plate based on Net section rupture T_{dn}

$$T_{dn} = \frac{0.9 \times A_n \times f_u}{\gamma_{m1}}$$

$$= \frac{0.9 \times 4119.33 \times 440}{1.25}$$

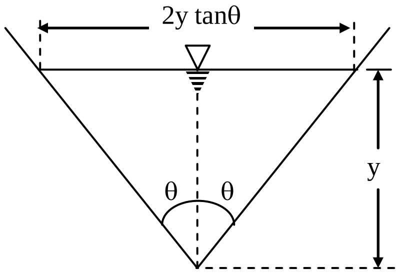
$$= 1305.0 \times 10^3 \text{ N} = 1305.0 \text{ kN}$$

The tensile strength of plate

T_d = Minimum of T_{dg} and T_{dn} = 1305.0 kN

(c)

Sol: Hydraulically efficient Triangular channel:



Let, θ = Semi vertex angle

Top width T = 2y tanθ

$A = y^2 \tan\theta \qquad \therefore\ y = \sqrt{\dfrac{A}{\tan\theta}}$

$P = 2y \sec\theta$

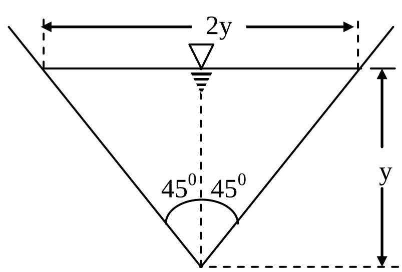
$= 2\sqrt{\dfrac{A}{\tan\theta}}\sec\theta = 2\sqrt{A}\,\dfrac{\sec\theta}{\sqrt{\tan\theta}}$

For 'P' to be minimum, $\dfrac{dP}{d\theta} = 0$

$$\frac{dP}{d\theta} = 2\sqrt{A}\left(\frac{\sqrt{\tan\theta}\sec\theta\tan\theta - \sec\theta\dfrac{\sec^2\theta}{2\sqrt{\tan\theta}}}{\tan\theta}\right) = 0$$

Solving, $\sin\theta = \dfrac{1}{\sqrt{2}}$

$\therefore \theta = 45^o$ or m= 1



∴ **The most efficient triangular cross-section channel is half of a square with its diagonal horizontal.**

Hydraulic Radius $R = \dfrac{A}{P} = \dfrac{y^2\tan\theta}{2y\sec\theta}$

$R = \dfrac{y}{2\sqrt{2}}$.

(d)

Ans: The Important concrete admixtures are the following:

1. **Water-reducing agents:** Water-reducing admixtures which will give greater which will give greater workability to the concrete. It disperses the cement particles and makes concrete more workable. They are classified into two groups.

(a) **Plasticizers:** These chemicals were the first to be introduced for the above purpose. They are organic or combination of organic and inorganic substances. One of the common chemicals used is Lignosulphonic acid in the form of either its calcium or sodium salt (LS). These chemicals are comparatively cheap in price. They reduce the water requirement 8 to 15 percent.

(b) **Superplasticizers:** These are chemicals which will decrease the water requirement for a given workability more than plasticizers, by more than 15%. They can reduce the water requirement even upto 30 percent. These chemicals are costly; and as all superplasticizers do not match all types of cement, trial mixes must be made before a given chemical is used at the site. There are used for the preparation of self-compacting concrete.

2. **Retarders:** The setting has to be delayed or retarded, so that at the site it is in a plastic state. In such situations, set-retarding agents are used. Retards are also used in many other situations like where we have a obtain exposed aggregate surface in concrete. The most commonly used chemical as retarder is calcium sulphate. Common sugar if added in dose of 0.2 percent, also retards setting of cement up to 72 hours.

3. **Set accelerators:** Set accelerators are the substances added to concrete to accelerate setting of concrete. Some of them are so active that a "stonehard concrete" can be obtained in about two minutes.

4. **Waterproofing admixture:** Waterproofing admixtures are the chemicals which we can add to cement mortars or to concrete mixes to make them waterproof.
   The following are few trade names.
   - **Aquaproof:** It is a white powder to be mixed at 1 kg per bag of cement. It increases impermeability of concrete.
   - **Cico:** Cico No 1 is one of the very popular water proofing additive to cement.
   - **Impermo:** This is also a waterproofing compound added to cement to make it impervious.

5. **Air-entraining agents:** These agents incorporate millions of stable isolated air bubbles in concrete. Such concrete has been found to resist action of frost much better than ordinary concrete. As it also increases workability, it was used in India on many projects before the advent of plasticizers to increase workability of concrete.
   The materials used as air-entraining agents are natural wood resins, animal and vegetable oils, sulphonated organic compounds, etc.