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Ans - 1 (a) - Critical depth

a) For rectangular channel

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \frac{2}{3} \times E_c$$

$$y_c = \frac{2}{3} \times 1.5 = 1m$$

$$\boxed{y_c = 1m}$$

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b) Triangular channel

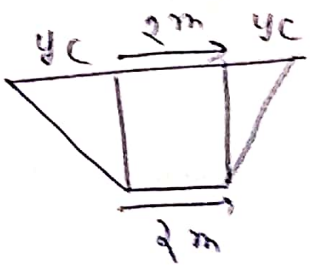
$$y_c = 0.8 \times E_c$$

$$\boxed{y_c = 1.2m}$$

c) Trapezoidal channel

$$E_c = y_c + \frac{V^2}{2g}$$

$$1.5 = y_c + \frac{Q^2}{A^2 \times 2g}$$



we know $F_r^2 = \frac{Q^2 T}{g A^3} = 1$

$$1.5 = y_c + \frac{1 \times A \times g}{T \times 2 \times g}$$

$$1.5 = y_c + \frac{0.5(2+2+2y_c) \times y_c}{(2+2y_c) \times 2}$$

$y_c = 1.095 m$

Q- 1 - (b) - For rectangular →

$$Q = \frac{2}{3} C_d L \sqrt{2g}\, H^{3/2}$$

1) $Q = \frac{2}{3} \times 0.6 \times 50 \times \sqrt{2 \times 9.81} \times (0.5)^{3/2}$

$Q = 31.32\ m^3/sec$

For Broad crested weir

1) $Q = 1.7\, C_D\, L\, H^{3/2}$

$Q = 1.7 \times 0.6 \times 50 \times (0.5)^{3/2}$

$Q = 18.03\ m^3/sec$

ii) velocity of approach ⇒ $V_a = \frac{18.03}{50} = 0.361\ m/sec$

$h_a = \frac{V_a^2}{2g} \Rightarrow 0.00663\ m$

$Q = 1.7\, C_d\, L\, ((H + h_a)^{3/2} - h_a^{3/2})$

$Q = 18.363\ m^3/sec$

Ans- 1-(C) → Module requirements

1) It should have sufficiency capacity to carry discharge of distributory and water course discharge

2) control in flow depth

3) control in the diversion or passing of water

4) should have a higher stability

5) should have a sufficient durability.

Types of modules-

1) Non modular outlet -

→ discharge in depends on both the head of distributory and water course.

→ ex → submerged outlet, weir type outlet

2) semi-modular / Flexible outlet

→ discharge depends upon ~~to~~ head of distributory channel ex → sub. pipe outlet, Kennedy's outlet

3) Rigid oullet -

→ discharge docs not depends upon the head difference b/w distributory and watr course

→ ex → Khanna's oulet

2) Gibbs' outlet

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Ans 1(d) - Different types of pipes

1) virtified clay pipe -

→ These pipes are ~~corr~~ acid resistance

→ mainly used when pipe carry huge amount of industrial waste in which there is high amount of acid present.

2) concrete pipes -

→ less corrosion ressitance

→ difficulty in placing of concrete pipes

→ diameter is less

→ concrete pipes are affected by the acid flowing in seawage

3) cast iron Pipes →

→ light in weight

→ corrosion ressistance

→ used for large diameter pipes

4) **steel pipes-**

→ strength is good

→ lesser corrosion resistance

→ ease in placing of such pipes

→ large diameter of such pipes can be used

5) **Prestressed concrete pipes-**

→ Large strength

→ difficulty in construction

→ difficultly in laying down of such pipe

Ans - 8(e) -

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$$Al_2(SO_4)_3 \cdot 14.3H_2O + 3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 \downarrow + 3CaSO_4 + 14.3H_2O + 6CO_2$$

i) alkalinity present

$$= \frac{3 \times 100}{599.4} \times 50 \frac{mg}{l}$$

$$= 25.025\ mg/l \text{ as } CaCO_3$$

ii) sludge produced -

dry solids $\Rightarrow \frac{2 \times 156}{599.4} \times 50 \frac{mg}{l} \times 10^{-6} \times 5 \times 10^{7} \times 0.65$

$$= 1301.30\ Kg/day \times 0.65 = 845.85\ Kg/day$$

volue of slude produce $= \frac{1301.30 \times 0.65}{1040}$

$$= 0.8133\ m^3/day$$

Ans- 3(a) - shaft power = 7357.5 KW

overall efficiency $\eta_o = \frac{S.P}{W.P}$

$W.P = \frac{7357.5}{0.6}$

$\gamma Q H = \frac{7357.5}{0.6}$

$9.81 \times Q \times 5.5 = \frac{7357.5}{0.6}$

$Q = 227.27 \, m^3/sec$

speed ratio = 2.09

speed of wheel = $2.09\sqrt{2 \times 9.81 \times 5.5}$

$U = 21.71 \, m/sec$

velocity of flow $V_f = 0.68\sqrt{2 \times 9.81 \times 5.5}$

$V_f = 7.064 \, m/sec$

discharge $Q = \frac{\pi}{4}(D_R^2 - D_b^2) \times 7.064$

$227.273 = \frac{\pi}{4} \times \left(D_R^2 - \frac{1}{9} \times D_R^2\right) \times 7.064$

$D_R = 6.78 \, m$

dia of runner $D_R = \underline{6.78\ m}$

dia of boss $= \frac{1}{3} \times 6.78 = \underline{2.26\ m}$

we know $u = \frac{\pi D_R N}{60}$

$21.71 = \frac{\pi \times 6.78 \times N}{60}$

$$\boxed{N = 61.15\ rpm}$$

specific speed $N_s = \frac{N\sqrt{Q}}{H^{3/4}}$

$N_s = \frac{61.15\sqrt{227.27}}{(5.5)^{3/4}}$

$$\boxed{N_s = 256.70\ rpm}$$

<u>In term of power</u> $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

$N_s = \frac{61.15\sqrt{73575}}{(5.5)^{5/4}}$

$$\boxed{N_s = 622.74\ rpm}$$

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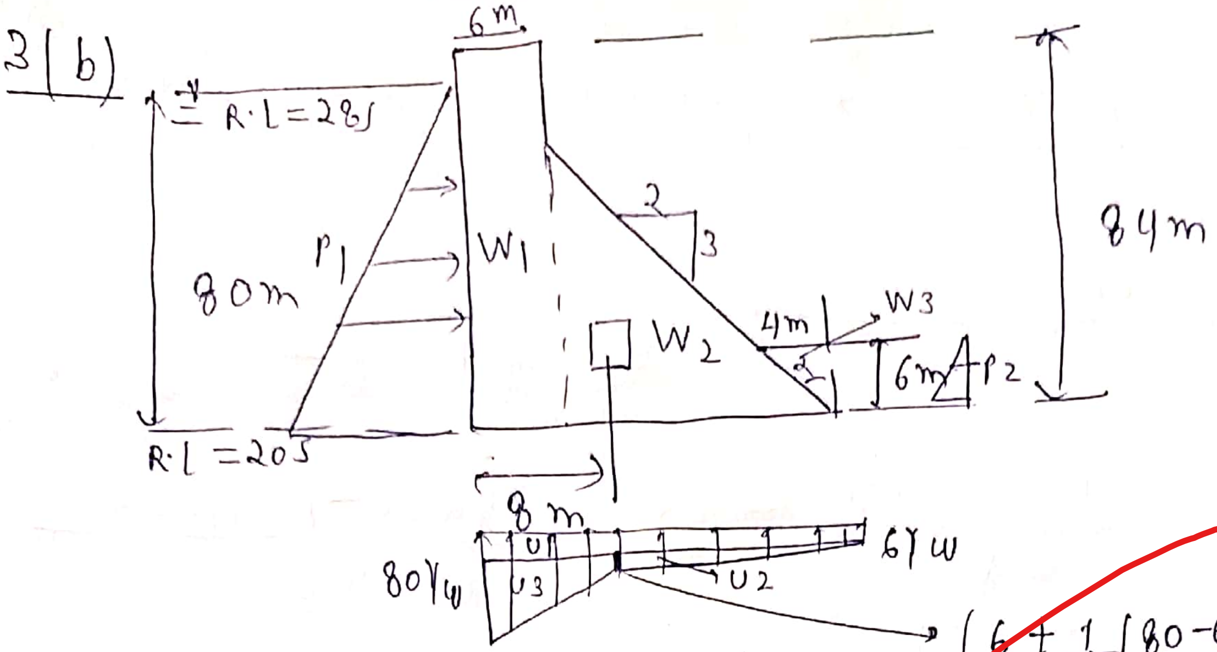
3 (b)



$\left(6 + \frac{1}{3}(80-6)\right)\gamma_w = \frac{92}{3}\gamma_w$

Force (KN)	Calculation	L.A (m) (about toe)
W_1 ↓	$6 \times 84 \times 23.5 = 11844$ KN	53 m
W_2 ↓	$0.5 \times 50 \times 75 \times 23.5 = 44062.5$ KN	100/3
P_1 (→)	$\frac{1}{2} \times 9.81 \times (80)^2 = 31392$ KN	80/3
P_2	$\frac{1}{2} \times 9.81 \times (6)^2 = 176.58$ KN	6/3 = 2
U_1 ↑	$6 \times 9.81 \times 56 = 3296.16$ KN	28
U_2 ↑	$24.67 \times 9.81 \times 0.5 \times 48 = 5808.30$ KN	32
U_3 ↑	$0.5(74 + 24.67) \times 9.81 \times 8 = 3871.68$ KN	[illegible]
W_3 ↓	$0.5 \times 4 \times 6 \times 9.81 = 117.72$ KN	4/3

$\Sigma V = 42930.36\ KN + 117.72 = 43048.08\ KN$

→ max^m vertical stress - $= \frac{\Sigma V}{B}\left(1 + \frac{6e}{B}\right)$

$\bar{x} = \frac{\Sigma M_R - \Sigma M_O}{\Sigma V} = \frac{2096992.12 - 1319160.75}{43048.08}$

$\boxed{\bar{x} = 18.07 m}$

$e = \frac{B}{2} - \bar{x} = 9.93 m$

max^m vertical stress at toe

$\sigma = \frac{43048.08}{56}\left(1 + \frac{6 \times 9.93}{56}\right)$

$\boxed{\sigma = 1586.57\ KN/m^2} < 2500\ KN/m^2$

max^m vertical stress at heel

$\sigma = \frac{43048.08}{56}\left(1 - \frac{6e}{B}\right)$

$\boxed{\sigma = -49.24\ KN/m^2}$ → tension

ii) major principle stress

$$= \sigma_v \sec^2\alpha - p' \tan^2\alpha$$

$\tan\alpha = 2/3$

$\sec\alpha = 1.2018$

major principle stress $= 1586.57 \times (1.2018)^2 - 9.81 \times 6 \times (2/3)^2$

$$\sigma_{max} = 2265.36 \ KN/m^2$$

iii) Intensity of shear stress

$\tau = (\sigma_v - \sigma') \tan\alpha$

$\tau = (1586.57 - 9.81 \times 6) \times 2/3$

$$\tau = 1018.47 \ KN/m^2$$

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Ans - 3 - (c) -

Population = 1,00,000

Total discharge = 180×10^5 = 18 MLD

$$\frac{q_{design}}{q_{max}} = \frac{1}{3} = 0.3333$$

Proportionate velocity for proportion discharge of 1/3

$$\frac{v}{V} = 0.8909 + \frac{0.9022-0.8909}{0.3370-0.3217}(0.3333-0.3217)$$

$$\boxed{\frac{v}{V} = 0.899}$$

Proportionate depth

$$\frac{d}{D} = 0.39 + \frac{0.40-0.39}{0.3370-0.3217}(0.3333-0.3217)$$

$$\boxed{\frac{d}{D} = 0.3976}$$

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3 – (c) (ii) Total dry sludge = $0.068 \times 40{,}000$

$= 2720 \text{ Kg}$

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Total Incoming sludge volume

$$= \frac{100}{6} \times \frac{2720}{1020} = 44.44 \text{ m}^3$$

$$\frac{3.5}{100} \times V_{digestor} = 44.44$$

volume of digestor $V = 1269.84 \text{ m}^3$

Take $H = 3 \text{ m}$

$$\frac{\pi}{4} \times D^2 \times 3 = 1269.84$$

$D = 23.215 \text{ m}$

Provide $D = 24 \text{ m}$, $H = 3 \text{ m}$ } — digestor dimension

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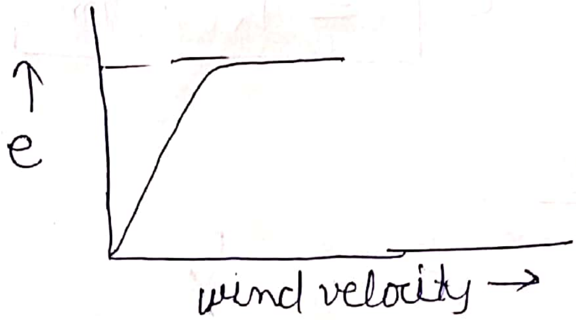
Ans – 4(a) – Factor affecting evaporation
(i)

1) Temp → As the temp increases evaporation also increases

2) wind velocity – as the wind velocity increases the evaporation also increases upto certain limit and than it becomes const



3) salinity – If water is saline, than evaporation from it will be lesser than the normal water

4) surface area –
If more surface area is exposed to atmosphere more evaporation will be there.

5) Humidity – If humidity is high in atm. than the evaporation will be lesser

6) Topography and Hydrography of the area

7) depth of water in stream

In summer season there is an higher evaporation from the shallow stream

In winter season there is higher evaporation from the deeper stream

8) Pressure – Increase in pressure increases the evaportion upto certain limit

4-(a) (ii)

Evaporation Pan method

In this method there is a pan, in which there is water is filled, and it is placed in free atmosphere and evaportion is determined.

→ with the help of this pan we can calculate the evaporation from lake

lake evaporation = Cp X Pan evaporation

Cp → Pan coefficient

$C_p \rightarrow 0.7 \rightarrow$ A, L type

$\rightarrow 0.8 \rightarrow$ ISI

b) Analytical method

1) water budget method -

Total inflow - Total outflow = Change in storage

$$\left(\frac{I_1 + I_2}{2}\right) \times \Delta t - \left(\frac{Q_1 + Q_2}{2}\right) \times \Delta t = S_2 - S_1$$

II) Energy Balance method

III) mass transfer approach

Ans- 4(b) - water supply = 130 X 50,000

= 6500 m^3/day

Total sewage = 0.8 X 6500 = 5200 m^3/day

max^m design sewage = $\frac{3 \times 5200}{86400}$ = 0.1806 m^3/sec

$Q = 0.1806\ m^3/sec$

velocity of flow in rising main = 1.2 m/sec

Area of pipe main = $\frac{0.1806}{1.2}$ = 0.1505 m^2

$\frac{\pi}{4} \times D^2 = 0.1505$

$D = 0.437\ m$ or ≃ 440 mm

Provide dia of rising main = 440 mm

ii) B.H.P required = $\frac{\gamma Q H_{total}}{\eta \times 0.746}$

$H_{Total} = (205-195) + 0.3 + h_f \rightarrow \left(\frac{f l v^2}{2 g D}\right)$

$= 10 + 0.3 + \frac{0.01 \times 100 \times (1.2)^2}{2 \times 9.81 \times 0.437} = 10.47\ m$

$$B.H.P \text{ required} = \frac{9.81 \times 0.1806 \times 10.47}{0.746 \times 0.6}$$

$$BHP \text{ required} = 41.434 \; H.P$$

Ans- 4-(C)- $B = 3.5 m$, $y = 2 m$

$Q = 15 m^3/sec \longrightarrow F_r < 1 \rightarrow$ subcritical

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specific energy at U/s $E_1 = y_1 + \frac{v_1^2}{2g}$

$$E_1 = 2 + \left(\frac{15}{3.5 \times 2}\right)^2 \times 2 \times 9.81 = 2.234 m$$

1) width contraction - $B_2 = 2.5 m$

$$y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\left(\frac{15}{2.5}\right)^2 \times 9.81\right)^{1/3} = 1.542 m$$

$$E_C = \frac{3}{2} \times y_c = 2.314 \; m$$

as $E_1 < E_C \rightarrow$ so can't possible

so we have to increse the depth at U/s sec^n

$$E_1' = E_C$$

$$y_1' + \left(\frac{1.5}{3.5 \times y_1}\right)^2 \frac{}{\times 2 \times 9.81} = 2.314$$

$$y_1' = 2.314 - \frac{0.93615}{y_1'^2}$$

$$\boxed{y_1' = 2.102\,m \;/\; 0.78\,m}$$

so u/s depth of water = 2.102 m

d/s depth " = 1.542 m

ii) when $B_2 = 2.2\,m$

$$E_c = \left(\frac{q^2}{g}\right)^{1/3} \times \frac{3}{2} = \left(\frac{\left(\frac{1.5}{2.2}\right)^2}{9.81}\right)^{1/3} \times 1.5$$

$$\boxed{E_c = 2.52\,m} > E \text{ at u/s}$$

so u/s depth has to increase

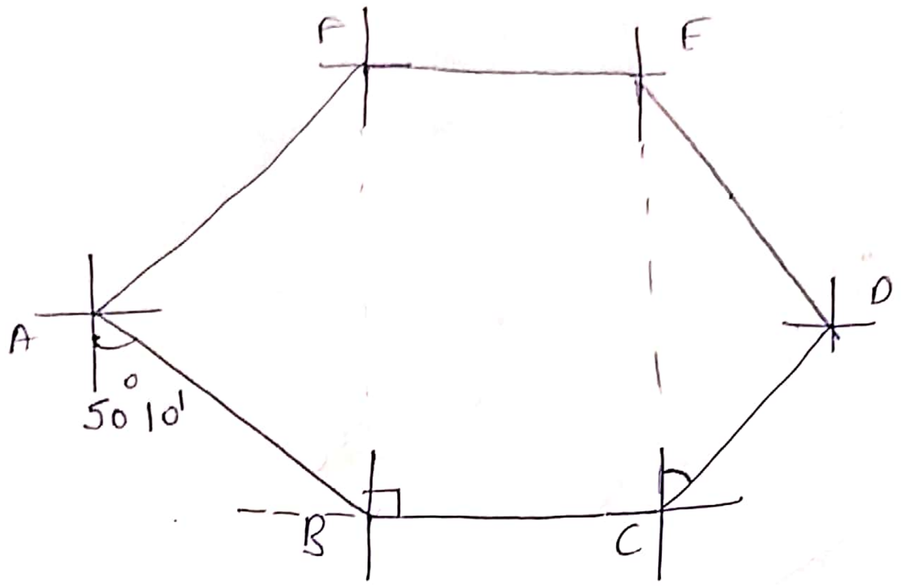
$$E_1' = E_c$$

$$y_1' + \frac{0.93615}{y_1'^2} = 2.52$$

$$\boxed{y_1' = 2.35\,m} \longrightarrow \text{u/s water depth}$$

$$y_c = 1.68\,m \longrightarrow \text{d/s water depth}$$

Ans- 5(a)



Bearing of side AB = $180° - 50°10' = 129°50'$

Bearing of side BC = $90°$

Bearing of side CD = $50°10'$

Bearing of DE = $360° - 50°10' = 309°50'$

Bearing of EF = $270°$

Bearing of FA = $230°10'$

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Ans- 5(b) -

fos against sliding

$$FOS = \frac{MR}{MO}$$

$$FOS = \frac{C_u \times R^2 \times \theta}{W \times e}$$

$$FOS = \frac{20 \times (9)^2 \times \left(71^\circ \times \frac{\pi}{180^\circ}\right)}{329 \times 4.8}$$

$$\boxed{FOS = 1.27}$$

ii) If shading portion removed

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Ay – 5 – (c) – Length, R = 220m, V = 65 KMPH = 18.06 m/s

Based on rate of change of acceleration

$$L = \frac{v^3}{CR} \Rightarrow$$

$$C = \frac{80}{75+V} = \frac{80}{75+65} = 0.5714$$

$$\boxed{L = 46.82\ m}$$

ii) Based on introduction of superelevation

$$L = \frac{NeW}{2}$$

design of superelevation $e = \frac{V^2}{225R} = \frac{(65)^2}{225 \times 220}$

$$e = 0.085 \not> 0.07$$

so take $e = 0.07$

$$e + \mu = \frac{v^2}{gR}$$

$$\mu = 0.081 < 0.15 \quad \text{ok}$$

so take $e = 0.07$ → Plain and rolling condit

$$L = \frac{150 \times 0.07 \times 7.5}{2} = \underline{39.375m}$$

iii) length based on empirical

$$L = \frac{2.7 V^2}{R} = \frac{2.7 \times (65)^2}{220} = \underline{51.85m}$$

so provide length of transition curve = 51.85m

$$\boxed{L \approx 52m}$$

shift of curve $S = \frac{L_s^2}{24R} = \frac{(52)^2}{24 \times 220} = \underline{0.51m}$

Ans 5(d) –

Based on martin's formulla

$$V_{max} = 4.58\sqrt{R}$$

$$V_{max} = 4.58\sqrt{R}$$

Radius $R = \frac{1720}{1} = \underline{1720m}$

$$V = 4.58\sqrt{1720} = \underline{189.95 Km/hr}$$

ii) $e = \frac{G V_{avg}^2}{127 R}$

$\frac{80}{1000} = \frac{1.67 \times V^2}{127 \times 1720}$

$V_{avg} = 102.29 \ Km/hr$

iii) $e_{act} = e_{equil} - C.D$

$e_{max} = 80 + 100$

$e_{max} = 180 \ mm$

$\frac{180}{1000} = \frac{1.67 \times V_{max}^2}{127 \times R}$

$V_{max} = 153.44 \ Km/hr$

→ permissible max^m speed = 153.44 Km/hr

Based on Length of curve

$V = \frac{198 L}{e} = \frac{198 \times 120}{80} = 297 \ Km/hr$

$= \frac{198 L}{C.D} = \frac{198 \times 120}{100} = 237.6 \ Km/hr$

$V_{max} = 153.44$ Km/hr → max^m permissible speed

Ans - 5(c) -

12

avg discharge for 2 min

$$= \frac{(541 + 503 + 509 + 474) \times 10^{-6}}{2 \times 60 \times 4}$$

$$= 4.22 \times 10^{-6}\ m^3/sec$$

avg difference in head

$$= \frac{(76 + 72 + 68 + 65)}{4} = 70.25\ mm$$

$$q = k\, i\, A$$

$$4.22 \times 10^{-6} \times 1 = k \times \frac{70.25}{150} \times \frac{\pi}{4} \times (0.1)^2$$

$$k = 1.147 \times 10^{-3}\ m/sec$$

Temp correction = 1.09

$$k = 1.25 \times 10^{-3}\ m/sec$$

Ans – 7(a) – (i)

For at depth of 1 m

1) safe pressure – $\frac{q_{nu}}{FOS} + \gamma D_f$

$$\frac{1.1 \times 10^3}{B \times 1} = \frac{cN_c + (N_q - 1)\gamma D_f + 0.5 B \gamma N_\gamma}{FOS} + \gamma D_f$$

$$\frac{1100}{B} = \frac{18 \times 22.3 + (11.9 - 1) \times 19 \times 1 + 0.5 \times B \times 19 \times 9.53}{3}$$

$$+ 19 \times 1$$

$$\frac{1100}{B} = \frac{1331}{6} + 30.178 B$$

$$\boxed{B = 3.39 m}$$

II) when $d_f = 2m$

$$\frac{1100}{B} = \frac{18 \times 22.3 + 10.9 \times 19 \times 2 + 0.5 \times B \times 19 \times 9.53}{3}$$

$$+ 19 \times 2$$

$$\frac{1100}{B} = 309.87 + 30.178 B$$

$$\boxed{B = 2.79 m}$$

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7-(a) (ii) embankment - $\gamma_d = 18\ KN/m^3$

Boorrow pit - $\gamma_b = 17\ KN/m^3$ { $\gamma_d = \frac{\gamma_b}{1+w}$)

$$(\gamma_d)_{br} = \frac{17}{1+0.05} = 16.19\ KN/m^3$$

void ratio ~~from~~ of embankment soil

$e_1 \rightarrow$ we know $(\gamma_d)_1 = \frac{G\gamma_w}{1+e_1}$

$$18 = \frac{2.7 \times 9.81}{1+e_1}$$

$$\boxed{e_1 = 0.4715}$$

void ratio of borrow pit soil $\rightarrow e_2$

$$(\gamma_d)_2 = \frac{G\gamma_w}{1+e_2}$$

$$e_2 = \frac{2.7 \times 9.81}{16.19} - 1$$

$$\boxed{e_2 = 0.636}$$

volume of solids $V_s = \frac{V}{1+e}$

volumes of solids will be constant

$$\frac{V_1}{1+e_1} = \frac{V_2}{1+e_2}$$

$$\frac{1}{1+0.4715} = \frac{V_2}{1+0.636}$$

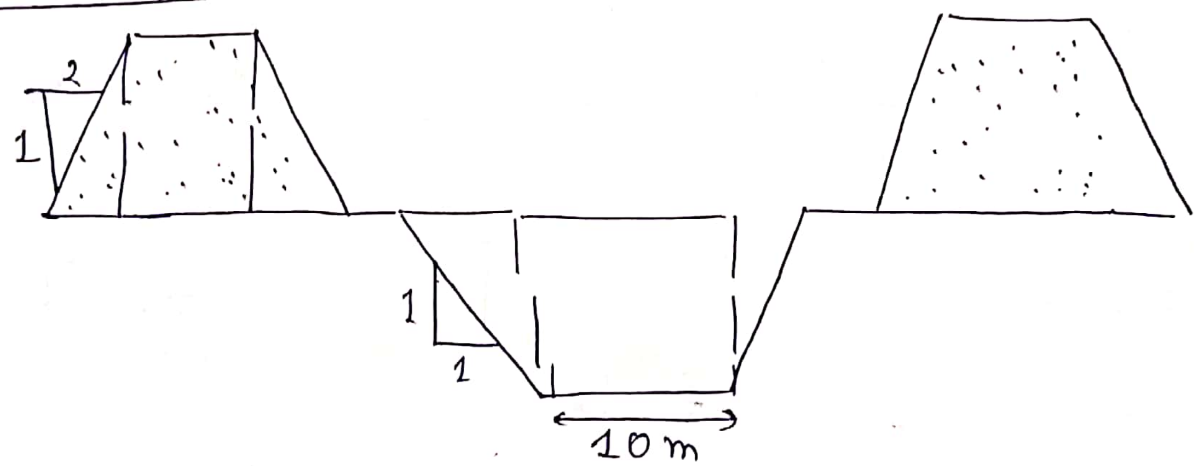
$$V_2 = 1.112\ m^3$$

as swell factor = 1.2

volume required from borrow pit

$= 1.2 \times 1.112 = 1.334\ m^3$

Ans- 7(b) -



Ay – II – (i) – (ii)

i) Radius $R = \frac{V^2}{125f}$

$R = \frac{(60)^2}{125 \times 0.15} = 192m$

ii) $R = \frac{0.388 W^2}{\frac{T}{2} - S}$

$S = 6 + \frac{7.5}{2} = 9.75m$

$T = 22.5m$

$R = \frac{0.388 \times (35)^2}{\frac{22.5}{2} - 9.75} = 316.86m$

Radius $R = max^m (192, 180m, 316.86m)$

so Provide $R = 317m$

10

Ans - 7 - (c) (ii)

For A type -

capacity = $\frac{5}{0.3 \times 60}$ ⇒ 16.66 air/hr

5

For aircraft B -

capacity = $\frac{3}{0.5 \times 45} \times 60$ = 8 aircraft/hr

For aircraft C type -

capacity = $\frac{2 \times 60}{0.2 \times 30}$ = 20 aircraft/hr

so aircraft capacity = ~~16.6~~

= 8 aircraft/hr