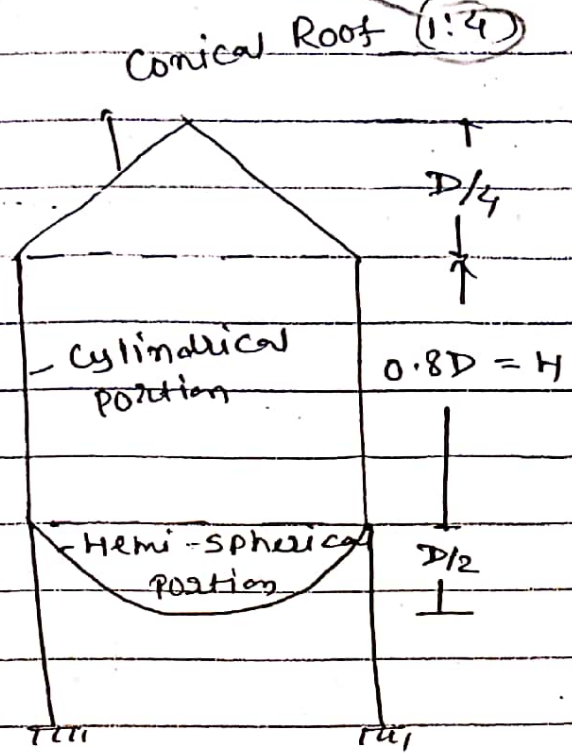
UNIT – III rd

$\frac{D/4}{D/2} = 1:2$

Water tanks

Circular Water tank



Design Steps.

Step 1st :- Determination of dia. of Cylindric portion

$$\text{Vol}^m = \underbrace{\frac{\pi}{4} D^2 \times H}_{\text{Vol}^m \text{ of Cylindrical portion}} + \underbrace{\frac{2}{3} \times \pi \times \left(\frac{D}{2}\right)^3}_{\text{Vol}^m \text{ of Hemi-sphere}}$$

Q. Design a Circular elevated Water tank of Capacity 250 KL. The Height of the tank of Water above G.L. is 8.7 m. The tank is supported over 8 c/ and tank is situated at Allahabad Railway station. take $f_y = 250\ N/mm^2$

Step Ist – Determine the dia of Cylindrical portion

Capacity = Vol^m of Cylindrical portion + Vol^m of Hemi-Spherical portion

$$250 = \frac{\pi}{4} D^2 \times H + \frac{2}{3} \times \pi \times \left(\frac{D}{2}\right)^3$$

$$250 = \frac{\pi}{4} D^2 \times (0.8 D) + \frac{2}{3} \times \pi \times \left(\frac{D}{2}\right)^3$$

{ 250 KL = 250 m^3 & H = 0.8 D

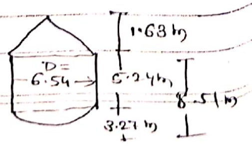
D = 6.54 m

Step IInd – Cal^n of Heights

Height of Conical portion $= \frac{D}{4} = \frac{6.54}{4} =$ ~~3.27 m~~ 1.63

Height of Cylindrical portion $= 0.8 \times D = 5.24$ m

Height of Hemi-spherical portion $= \frac{D}{2} =$ ~~1.63~~ 3.27 m



Step IIIrd – Thickness of Cylindrical portion

Let $\eta = 75\%$

$\sigma_{at} = 0.8 \times 0.6 \times f_y$ (→ 250) ---- 0.8 due to water retaining str.

$\rho_{water} = 9.81 \times 10^3\ N/m^3 = 9.81 \times 10^{-6}\ N/mm^3$

D = 6.54 m

H = 5.24 m

$\sigma = \frac{PD}{2t\eta}$ $P = \rho H$

$$t = \frac{\rho \times H \times D}{2 \eta \sigma_{at}}$$

$$= \frac{9.81 \times 10^{-6} \times 5.24 \times 10^3 \times 6.54 \times 10^3}{2 \times 0.75 \times 0.8 \times 0.6 \times 250}$$

t = 1.86 mm

add extra for corrosion purpose = 1.5 mm

So t = 1.86 + 1.5 = 3.36 < 6 mm

Hence provide 6 mm thick plate.

Step IV – Thickness of Hemi-spherical portion

Let H = 5.24 + 3.27 = 8.51 m

$\sigma = \frac{PD}{4t\eta}$

$$t = \frac{\rho H D}{4 \eta \sigma_{at}} = \frac{9.81 \times 10^{-6} \times 8.51 \times 10^3 \times 6.54 \times 10^3}{4 \times 0.75 \times 0.8 \times 0.6 \times 250}$$

t = 1.516 mm < 6 mm

Hence provide 6 mm thick plates

Step V — Thickness of Conical roof

Provide 5 mm thick plate for Conical roof section

so $t = 5$ mm

Assume dia of Rivet = 16 mm

dia of Hole = 16 + 1.5 = 17.5 mm

Step VI — Design Section Modulus —
(Stiffening Angle at top of cylindrical portion)
(to be provided around top of tank without roof)

$Z = 0.0578\, D^2 H$ — IS 805-1968 Pg 7

(See in Code when you put value of D & H in meter so you already get the Z value in cm^3)

$= 0.0578 \times 6.54^2 \times 5.24$

$= 12.95\ cm^3$

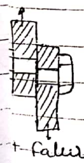
Take factor for steel = 1.15

$= 1.15 \times 12.95$

$Z_{req} = 14.89\ cm^3$

$Z_{xx} = Z_{yy} = 16.0\ cm^3 > 14.89\ cm^3$

Provide ISA 90mm x 90mm x 10mm equal angle Section from steel table pg No. 5



Rivet failure (shearing)

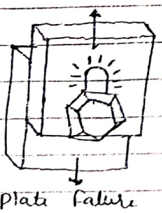


Plate failure Bearing

$= \frac{\pi}{4} d^2$

$A = d.t.$

Step VII — Cal^n of Rivetted value — $\left\{ \sigma = \frac{P}{A} \right.$

⇒ Shearing strength = Area x stress

$= A \times \tau_{vf}$

$= \frac{\pi}{4} d^2 \times 0.8 \times 100 \times 10^{-3}$ → multiply by 10^{-3} for applying in kilo

$= \frac{\pi}{4} (17.5)^2 \times 0.8 \times 100 \times 10^{-3}$

$= 24.05$ KN

⇒ Bearing strength = Area x stress

$= A \times \sigma_{pt}$

$= d.t \times \sigma_{pt}$

$= 17.5 \times 6 \times 0.8 \times 300 \times 10^{-3}$

$= 25.6$ KN

τ_{vf} & σ_{pt} → IS 800-1984 Pg-95

Take Min of Both. So.

$R_v = 24.05$ KN

Step VIII — Cal^n of Hoop Stress —

⇒ For Cylindrical portion $\sigma_1 = \gamma H \frac{D}{2}$

$\sigma_1 = 9.81 \times 10^{-6} \times 5.24 \times 10^3 \times \frac{6.54 \times 10^3}{2}$

$\sigma_1 = 168.08\ N/mm^2$

⇒ for Hemi-spherical portion :-

$\sigma_2 = \frac{PHd}{4t} = 9.81 \times 10^{-6} \times 8.51 \times 10^3 \times \frac{6.54 \times 10^3}{4t}$

(↑ take Height from top of cylindrical portion)

$\sigma_2 = 186.49 \ N/mm^2$

$\sigma_1 > \sigma_2$ so safe in stresses.

Step IX :- Cal^n of pitch :-

$\text{pitch} = \frac{R_v}{\text{stress}} = \frac{24.05 \times 10^3}{168.08} = 143.08 \ mm$

(take max stress ie σ_1 or σ_2)

$143.08 \not> 12t$ {12×6 = 72 mm So safe

So provide 72 mm pitch

- providing 16 mm φ rivett for connecting Roof and cylindrical portion and Hemi-spherical portion with pitch = 72 mm

Step X :- Design of Circular ~~portion~~ Girder :- around bottom of cylindrical portion

A) Self wt of Water $= \gamma_{water} \times Vol^m$

$(W_1) = 9.81 \times 10^3 \ N/m^3 \times 250 \ m^3$ (or 10 approx)

$= 9.81 \times 10^3 \ N \times 250$

$= 2452.50 \times 10^3 \ N$

B) Self wt of tank $(W_2) = \left[\pi D H t + \frac{1}{2} \pi D^2 \times t\right] \times \gamma_{steel}$

$W_2 = [\pi \times 6.54 \times 5.24 \times 0.006 + 0.5 \times \pi \times 6.54^2 \times 0.006] \times 7850 \ N/m^3$

$W_2 = 8234.65 \ N$

C) Wt of Conical Roof (W_3)

= av. perimeter × ht × thickness × γ

$= \left\{\sqrt{(1.63)^2 + \left(\frac{6.54}{2}\right)^2} \times 0.005 \times \left[\frac{\pi D + 0}{2}\right]\right\} \times \gamma_{steel}$

(H; out of Bracket; 7850 N/m³)

$= 1478.24 \ N$

D) W_4 factored load $W_4 = 1.15 \times (W_2 + W_3)$

$= 11650.21 \ N$

E) Wt. of Girder $W_5 = \pi D \times \gamma_{girder}$

$= \pi \times 6.54 \times 1500$

$= 30819.02 \ N$

Total $W = W_1 + W_4 + W_5$

$= 2452.5 \times 10^3 + 11650.21 + 30819.02$

$\boxed{W = 2.49 \times 10^6 \ N}$

1) Max. B.M.

Given in question condition C^m = 8 no.

Use IS 4995 Part II Pg No. 15

& IS 9178 Part II 1979 Pg No. 37

Max. B.M $= -0.00827 \ W R$ {W = load; R = Radius D/2}

$(B.M)_{max} = 67469.33 \ N\text{-}m$

Max. S.F. = $\frac{W}{16}$ = $\frac{2.49 \times 10^6}{16}$

= 155931.25 N

Torsion ~~Const~~ = 0.0006 WR

= $0.0006 \times 2.49 \times 10^6 \times \left(\frac{6.54}{2}\right)$

T = 4894.99 N-m

Required section modulus :-

$Z_{req} = \frac{(B.M)_{max}}{0.66 f_y}$ $\left\{ \frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R},\ \sigma = \frac{M}{I/y},\ \frac{I}{y} = Z,\ Z = \frac{M}{\sigma} \right.$

0.8 × 0.66 fy

$= \frac{67469.33 \times 10^3}{0.66 \times 250}$

= 408905.03 mm³ {10 mm − 1 cm

= 408905.03×10^{-3} cm³

Z_{req} = 408.9 cm³

Take factored Z_{req} = 1.15 × 408.9

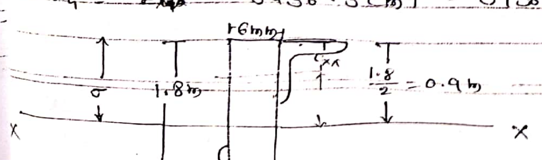
= 470.28 cm³

Provide equal angle section ISA 200×200×25mm − 2 nos. $Z_{xx} = Z_{yy}$ = (243.3 cm³ for one) × 2

Properties C_{xx} = 5.88 cm = 58.8 mm

A_{req} = 93.83 cm² = 9383 mm²

$I_G = I_{xx}$ = 3436.3 cm⁴ = 3436.3×10^4 mm⁴



$\left\{ \frac{5.24}{3} = 1.8\text{m} \right.$

$I_{xx} = I_{xx\ plate} + I_{xx\ angle\ section}$

$= \frac{bd^3}{12} + 2\left[I_G + A\left(\frac{1.8}{2} - C_{xx}\right)^2\right]$ (h^2)

$= \frac{6 \times 1800^3}{12} + 2\left[3436.3 \times 10^4 + 9383\,(900 - 58.8)^2\right]$

$I_{xx} = 1.62 \times 10^{10}$ mm⁴ & $y = \frac{1800}{2} = 900$ mm

provide section Modulus (Z) = $\frac{I_{xx}}{y}$ $\left\{ Z = \frac{I}{y} \right.$

$= \frac{1.62 \times 10^{10}}{900}$

Z = $18.07 \times 10^6 > 408.90 \times 10^3$ mm³ so safe.

The section of circular girder consist of 1.8m of plate of the cylindrical shell of the circular tank and 2 ISA 200mm×200mm×25mm

Step XI :- Calⁿ of moment of inertia of section :- Check for stresses :-

1) Torsion Const. (I) = $\sum \frac{1}{3} a t^3$

$I = \frac{1}{3} \times 1800 \times 6^3 + 2\left[\frac{1}{3} \times 200 \times 25^3 + \frac{1}{3}(200 - 25) \times 25^3\right]$

I = 4035850 mm⁴

2) Shear stress due to torsion :- = $\frac{T}{I} \times t_{max}$

$= \frac{4894.99 \times 10^3 \times (25+6)}{4035850} = 36.38\ \frac{N}{mm^2}$

3) Shear Stress due to Shear force

$= \frac{Max.\ S.F}{Area}$

$= \frac{Shear\ Force}{2\times\left(\begin{matrix}Angle\\Section\end{matrix}\right) + \left(\begin{matrix}Area\ of\\plate\end{matrix}\right)}$

$= \frac{155931.25}{2\times 9383 + 6\times 1800}$

$= 5.27\ N/mm^2$

4) Total Shear Stress :-

$= \begin{bmatrix}Shear\ Stress\\due\ to\ torsion\end{bmatrix} + \begin{bmatrix}Shear\ Stress\ due\ to\\Shear\ force\end{bmatrix}$

$\tau_{av} = 36.38 + 5.27 = 41.65\ N/mm^2$

$41.65\ \frac{N}{mm^2} < 0.4\ f_y = 100\ N/mm^2$

so Safe

5) Hoop Stress σ_{at}

$\sigma_{at} = \left[\frac{\rho H D}{2\eta t}\right]$

$= \frac{9.81\times10^{-6}\times5.24\times10^{3}\times6.54\times10^{3}}{2\times0.75\times6}$

$\sigma_{at} = \sigma_x = 37.35\ N/mm^2$

6) Bending stress $(\sigma_{bt}) = (\sigma_y)$

$= \frac{(B.M)_{max}}{I_{provide}} = \frac{67469.33\times10^{5}}{18.07\times10^{6}}$

$= 3.73\ N/mm^2$

$\sigma_{at} + \sigma_y$ = ~~3.73 N/mm2~~ = 37.35 + 3.73

= ~~3.73~~ 41.08 $< 0.66\ f_y = 165\ N/mm^2$

so Safe.

7) principal stress :-

$\sigma_p = \left[\frac{\sigma_x + \sigma_y}{2}\right] + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{av}^2}$

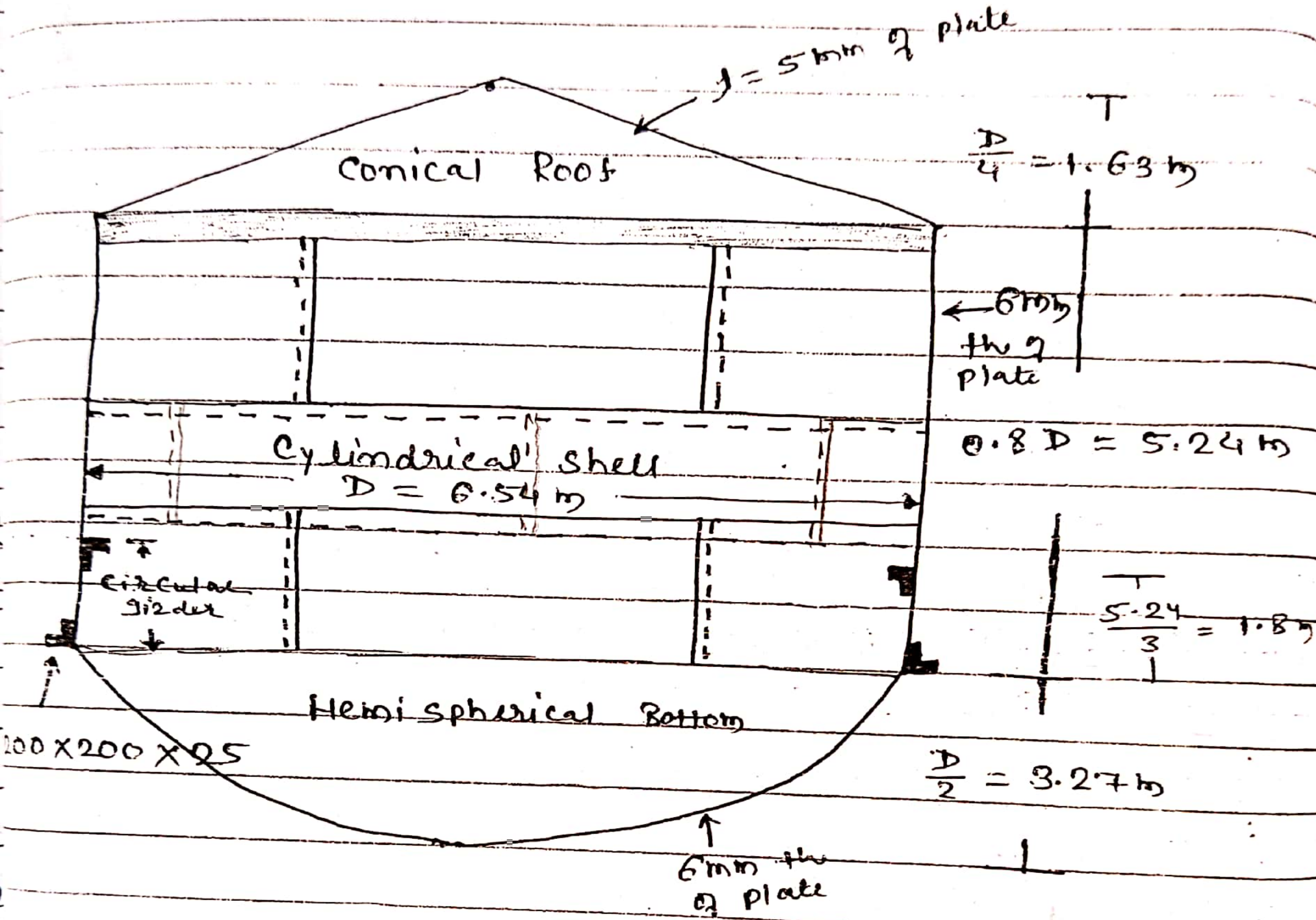
$= \left[\frac{37.35 + 3.73}{2}\right] + \sqrt{\left(\frac{37.35 - 3.73}{2}\right)^2 + (41.65)^2}$

$\sigma_p = 65.45\ N/mm^2 < 0.8\times0.6\times f_y$ (250) N/mm^2

$< = 120\ N/mm^2$

(allowable stress in tension in the plate)

Hence Safe.


t = 5mm of plate
Conical Roof
D/4 = 1.63 m
6mm th of plate
0.8 D = 5.24 m
Cylindrical shell
D = 6.54 m
Circular girder
5.24/3 = 1.8 m
Hemi spherical Bottom
200 X 200 X 25
D/2 = 3.27 m
6mm th of plate