2. INPUTS

2.1 Basic Information

(1) Location : Srinagar (J&K) — Seismic Zone as per Indian Seismic Code: V
(2) Type of Staging : Frame — Site-specific horizontal acceleration Z_{SS} : 0.36g
(3) Importance Factor I : 1.5 — Detailing Type: Ordinary / Special R = 1.8 / 2.5
(4) Capacity : 50 m³
(5) Shape of Water Tank : Circular — Stirrups with : 90˚/ 135˚ hooks

2.2 Geometry

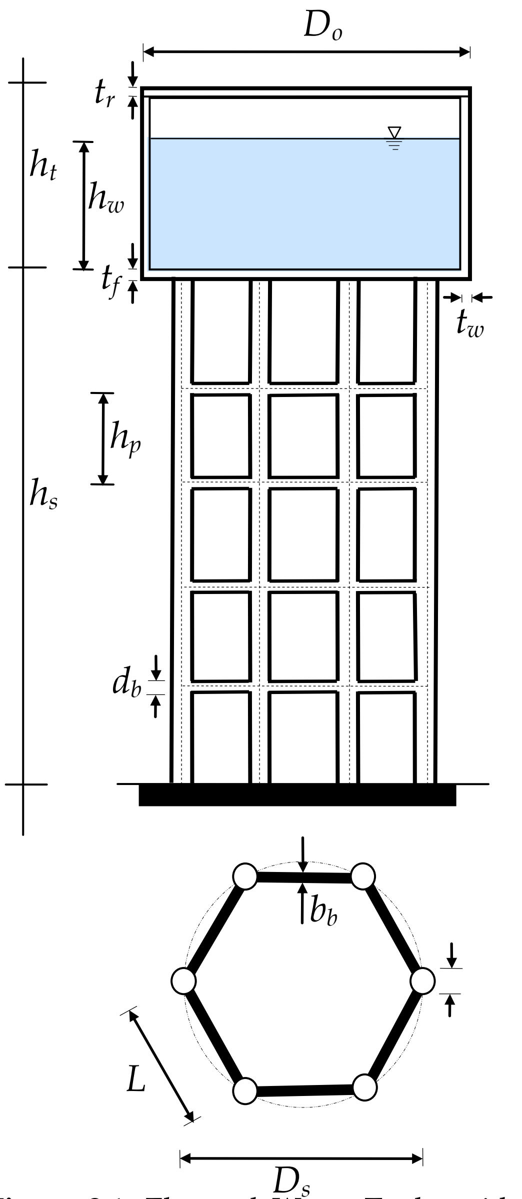

Figure 2.1: Elevated Water Tanks with Frame Staging

Inputs	*Units*
N_p	= 4
h_s	= 12 m
h_t	= 3.3 m
D_o	= 5.05 m
t_w	= 0.20 m
t_f	= 0.20 m
t_r	= 0.12 m
h_w	= 3.00 m
D_s	= 4.85 m
N_c	= 4
b_b	= 0.30 m
d_b	= 0.45 m
d_c	= 0.45 m
D_F	=6 m
t_{RF}	=0.75 m

Beam size: 0.30×0.45 m×m *Longitudinal rebar* ϕ: 16Y- 3 No.s (Top) 16Y- 4 No.s (Bottom) $d_{b,eff}$= 0.450-0.020-0.008-0.008= 0.414 m *Transverse rebar* ϕ: 8Y @ 150mm	*Cover:* 20 mm
Column size: 0.45 m ϕ *Longitudinal rebar* ϕ: 20Y- 16 No.s $d_{c,eff}$= 0.450-0.020-0.008-0.010= 0.402 m *Transverse rebar* ϕ: 8Y @ 150mm	*Cover:* 20 mm

2.3 Materials and Structural System

(1) Grade of Concrete f_{ck} = 20 MPa Modulus of Elasticity, $E_c = 5000\sqrt{f_{ck}}$ = 22360 MPa

(2) Type of Soil **(Tick ONE)**

(i) *Rocky and Hard Soil*	**N>30**	:	Type I
(ii) *Medium Soil*	**30>N>10**	:	Type II
(iii) *Soft Soil*	**10<N**	:	Type III

3. BASIC SAFETY CHECKS

3.1 Section Properties

Derived Quantities	*Units*
$h_p = h_s / N_p = 12/4$	= 3.00 m
$D_i = D_o - 2\, t_w = 5.05 - 2\times 0.2$	= 4.65 m
$W_{T\_empty} = \left(\pi/4\right)\left[\left(D_0^2 - D_i^2\right)h_t + D_0^2\left(t_r + t_f\right)\right]\gamma_{concrete}$ $= \left(\pi/4\right)\left[\left(5.05^2 - 4.65^2\right)3.3 + 5.05^2\left(0.12 + 0.20\right)\right]25$	= 411 kN
$W_{water} = \left[\left(\pi/4\right)D_i^2 h_w\right]\rho_{water} g = \left[\left(\pi/4\right)4.65^2 \times 3\right]9.81$	= 500 kN
$W_{T\_full} = W_{T\_empty} + W_{water} = 411 + 500$	= 911 kN
$L = D_s \sin\left(\pi/N_c\right) = 4.85 \times \sin\left(\pi/4\right)$	= 3.43 m
$W_{staging} = N_c\left(\pi\left(d_c/2\right)^2 h_s + N_p b_b d_b L\right)\gamma_{concrete}$ $= 4\left(\pi\left(0.45/2\right)^2 12 + 4\times 0.3\times 0.45\times 3.43\right)25$	= 376 kN
$I_b = \dfrac{b_b d_b^3}{12} = \dfrac{0.3\times 0.45^3}{12}$	= 0.00228 m^4
$I_c = \dfrac{\pi d_c^4}{64} = \dfrac{\pi \times 0.45^4}{64}$	= 0.00201 m^4
$K_r = \left(\dfrac{I_c}{I_b}\right) = \dfrac{0.00201}{0.00228}$	= 0.88
$W_{s\_full} = W_{full} + \left(1/3\right)W_{staging} = 911 + \left(1/3\right)376$	= 1036 kN
$W_{s\_empty} = W_{empty} + \left(1/3\right)W_{staging} = 411 + \left(1/3\right)376$	= 536 kN
$W_{foundation} = \left(\pi/4\right)D_F^2 t_{RF}\,\rho_{concrete} g = \left(\pi/4\right)\times 6^2 \times 0.75\times 25$	= 530 kN

3.2 Lateral Stiffness of the Staging

Soft Soil	*Intermediate and Hard Soil*	*Calculation*
Top panel $k_{panel} = \dfrac{12 E_c I_c N_c}{h^3}\left[\dfrac{1}{1 + K_r\left(\frac{L}{h}\right)}\right]$	Top and bottom panels $k_{panel} = \dfrac{12 E_c I_c N_c}{h^3}\left[\dfrac{1}{1 + K_r\left(\frac{L}{h}\right)}\right]$	$= \dfrac{12\times 22360\times 10^3 \times 2.01\times 10^{-3}\times 4}{3^3}\left[\dfrac{1}{1 + 0.88\left(\frac{3.43}{3}\right)}\right]$ = 39,828 kN/m
All other panels $k_{panel} = \dfrac{12 E_c I_c N_c}{h^3}\left[\dfrac{1}{1 + 2K_r\left(\frac{L}{h}\right)}\right]$	Intermediate panels $k_{panel} = \dfrac{12 E_c I_c N_c}{h^3}\left[\dfrac{1}{1 + 2K_r\left(\frac{L}{h}\right)}\right]$	$= \dfrac{12\times 22360\times 10^3 \times 2.01\times 10^{-3}\times 4}{3^3}\left[\dfrac{1}{1 + 2\times 0.88\left(\frac{3.43}{3}\right)}\right]$ = 37936 kN/m
Lateral Stiffness of staging $K_{staging} = 1\bigg/\sum_{j=1}^{N_{panels}}\left(\dfrac{1}{K_{panel}}\right)$		$= 1\bigg/\left(\dfrac{1}{39828} + \dfrac{1}{26525} + \dfrac{1}{26525} + \dfrac{1}{26525}\right)$ = 7235 kN/m

3.3 Natural Period of the Tank

Tank Full $T_{full} = 2\pi \sqrt{\frac{W_{s\_full}}{gK_{staging}}}$; Tank Empty $T_{empty} = 2\pi \sqrt{\frac{W_{s\_empty}}{gK_{staging}}}$	$T_{full} = 2\pi \sqrt{\frac{911}{9.81 \times 7235}}$ = 0.71 s	$T_{full} = 2\pi \sqrt{\frac{411}{9.81 \times 7235}}$ = 0.47 s

3.4 Design Horizontal Seismic Force

	Tank Full	**Tank Empty**
Spectral Acceleration (S_a/g) *Soil Type* / *Spectral Acceleration (S_a/g)* Type I: $\frac{S_a}{g} = \begin{cases} 2.5 & 0 \le T \le 0.4 \\ 1.00/T & 0.4 \le T \le 4.0 \end{cases}$ Type II: $\frac{S_a}{g} = \begin{cases} 2.5 & 0 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.0 \end{cases}$ Type III: $\frac{S_a}{g} = \begin{cases} 2.5 & 0 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.0 \end{cases}$	$(S_a/g)_{full}$= 1.67/T =1.67/0.71 = 2.35	$(S_a/g)_{empty}$ =2.5
Horizontal seismic coefficient $A_h = \frac{Z_{SS} I}{R} \left(\frac{S_a}{g} \right)$	$= \frac{0.36 \times 1.5}{1.8} (2.35)$ = 0.71	$= \frac{0.36 \times 1.5}{1.8} (2.5)$ = 0.75
Base Shear Filled $V_B = A_h W_{s\_full}$; Empty $V_B = A_h W_{s\_empty}$	= 0.71× 911 = 647 kN	= 0.75 × 411 = 308 kN
Governing Shear force V_u is greatest of Full and Empty condition = 647 kN		

3.5 Shear Beams

Over strength shear in beams at level j, $V_{bj} = \frac{1.4 V_b h_p}{N_c R_s} \operatorname{cosec}\left(\frac{\pi}{N_c} \right)$	$= \frac{1.4 \times 647 \times 3}{4 \times (4.85/2)} \operatorname{cosec}\left(\frac{\pi}{4} \right)$ = 396 kN

3.6 Shear Columns

Top panel, $V_c = \frac{2.8 V_b}{N_c} \left[\cos^2\left(\frac{\pi}{N_c} \right) + \frac{K_r}{3} \right]$	$= \frac{2.8 \times 647}{4} \left[\cos^2\left(\frac{\pi}{4} \right) + \frac{0.88}{3} \right]$ = 359 kN
Other panels, $V_c = \frac{1.4 V_p h_p}{N_c R_s} \cos\left(\frac{\pi}{N_c} \right) \cot\left(\frac{\pi}{N_c} \right)$	$= \frac{1.4 \times 647 \times 3}{4 \times (4.85/2)} \cos\left(\frac{\pi}{4} \right) \cot\left(\frac{\pi}{4} \right)$ = 198 kN

3.7 Shear Capacity of Beam

Percentage of Longitudinal Reinforcement $\rho = \frac{100 A_{t\_st}}{A_c}$	$= \frac{100 \times 200.96 \times 7 \times 10^{-6}}{0.3 \times 0.414}$ = 0.11
For a percentage of Longitudinal Reinforcement ρ *in shaft wall,* from Table 19 of IS:456-2000, Design Shear Stress of Concrete τ_c	= 0.28 MPa
Area of concrete $A_{bc} = b_b d_{b,eff}$	= 0.3×0.414 = 0.124 m²

Shear Carried by Concrete $V_{uc} = \tau_b A_{bc}$	= 0.28 ×0.124×10⁶ N = 35 kN
Shear Carried by Steel $V_{us} = 0.87 f_y A_{t\_st} \frac{d_b}{s_v}$	$= 0.87 \times 415 \times 101 \times \frac{450}{150}$ = 109 kN
If hooks are 90° Total Shear Capacity of Beam $V_{u,beam} = V_{uc} + V_{us}$	= 35 + 0 =35 kN **< Shear Demand for Beams**
If hooks are 135° Total Shear Capacity of Beam $V_{u,beam} = V_{uc}$	= 35+109 = 144 kN **< Shear Demand for Beams**

3.7 Shear Capacity of Columns

Percentage of Longitudinal Reinforcement $\rho = \frac{100 A_{t\_st}}{A_c}$	$= \frac{100 \times 314 \times 16 \times 10^{-6}}{0.45 \times 0.402}$ = 2.7
For a percentage of Longitudinal Reinforcement **ρ** *in shaft wall,* from Table 19 of IS:456-2000, Design Shear Stress of Concrete τ_c	= 0.82 MPa
Area of concrete $A_{cc} = \frac{\pi}{4} d_{c,eff}{}^2$	$= \frac{\pi}{4} \times 0.402^2$ = 0.127 m²
Shear Carried by Concrete $V_{uc} = \tau_c A_{cc}$	= 0.82 ×0.127×10⁶ N = 104 kN
Shear Carried by Steel $V_{us} = 0.87 f_y A_{t\_st} \frac{d_c}{s_v}$	$= 0.87 \times 415 \times 101 \times \frac{450}{150}$ = 110 kN
If hooks are 90° Total Shear Capacity of Column $V_{u,column} = V_{uc} + V_{us}$	= 104+0 = 104 kN **< Shear Demand for Columns**
If hooks are 135° Total Shear Capacity of Column $V_{u,column} = V_{uc}$	= 104+110 = 214 kN **< Shear Demand for Columns**

3.8 Check for Overturning Moment

Over Turning Moment $M_{OT} = V_B\left(h_s + \frac{h_t}{2}\right)$	= 911(12+3.3/2) = 12,435 kNm	= 411(12+3.3/2) = 5,610 kNm
Restoring Moment $M_R = \left(W_{tank} + W_{staging} + W_{foundation}\right)\left(1 - \frac{2}{3}A_h\right)\frac{D_F}{2}$ where D_F, is diameter of the foundation	$= (911+376+530)\left(1-\frac{2}{3}\times 0.71\right)\frac{6}{2} =$ = 2,858 kNm	$= (411+376+530)\left(1-\frac{2}{3}\times 0.75\right)\frac{6}{2} =$ =1,886 kNm
Factor of Safety = M_R/M_{OT}	= 2858 /12435 = *0.23*	= 1886 /5610 = *0.34*
Check	**<< 1.5**	**<< 1.5**