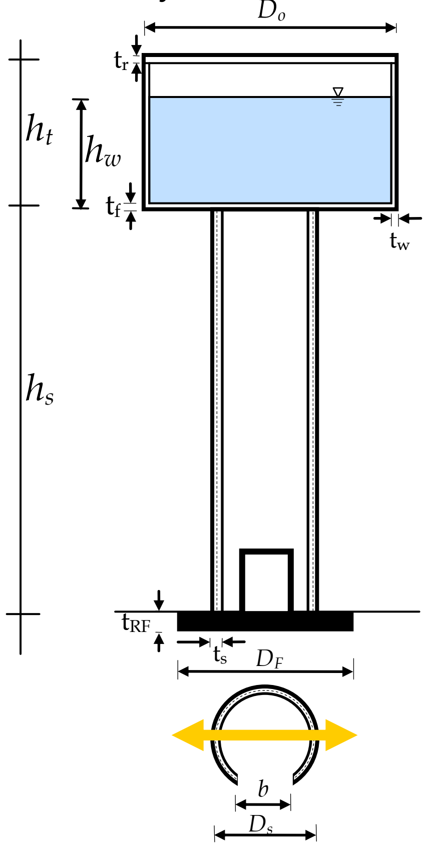
2. INPUTS

2.1 Basic Information

(1) Location : Srinagar
(2) Type of Staging : Shaft
(3) Importance Factor I : 1.5
(4) Capacity : 75 m^3
(5) Shape of Water Tank : Rectangular

Seismic Zone as per Indian Seismic Code: V
Site-specific horizontal acceleration Z_{SS} : 0.36g
Detailing Type: Ordinary / Special R = 1.8 / 2.5

2.2 Geometry



Inputs	*Units*
h_t	= 3.300 m
D_o	= 6.000 m
t_w	= 0.200 m
t_r	= 0.120 m
t_f	= 0.120 m
h_w	= 3.000 m
b	= 1.250 m
h	= 2.500 m
t_s	= 0.200 m
h_s	= 12.000 m
D_s	= 4.250 m
D_F	= 6.500 m
t_{RF}	= 0.750 m
Vertical Reinforcement: Y16 @ 200 c/c *Transverse Reinforcement:* Y12 @ 175 c/c	

Figure 2.1: Elevated Water Tanks- Shaft Staging

2.3 Materials and Structural System

(1) Grade of Concrete f_{ck} = 20 MPa   Modulus of Elasticity, $E_c = 5000\sqrt{f_{ck}}$ = 22,360 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*
$D_i = D_o - 2t_w = 6.0 - 2\times 0.2$	= 5.6 m
$W_{T\_empty} = \left[\left(\pi/4\right)\left(D_0^{\,2} - D_i^{\,2}\right)h_t + \left(\pi/4\right)D_0^{\,2}\left(t_r + t_f\right)\right]\gamma_{concrete}$ $= \left[\left(\pi/4\right)\left(6.0^2 - 5.6^2\right)3.3 + \left(\pi/4\right)6.0^2\left(0.12+0.12\right)\right]25$	= 184 kN
$W_{water} = \left[\left(\pi/4\right)D_i^{\,2}h_w\right]\rho_{water}g = \left[\left(\pi/4\right)5.6^2\times 3.3\right]9.81$	= 797 kN
$W_{T\_full} = W_{T\_empty} + W_{water} = 184 + 797$	= 981 kN
$W_{staging} = \pi\left(D_s - t_s\right)t_s h_s \gamma_{concrete} = \pi\left(6-0.2\right)0.2\times 12\times 25$	= 1093 kN
$I_s = \pi R_s^{\,3} t_s = \pi\left(\frac{D_s - t_s}{2}\right)^3 t_s = \pi\times\left(\frac{6-0.2}{2}\right)^3\times 0.2$	= 15.3 m^4
$A_s = \pi\left(D_s - t_s\right)t_s = \pi\times(6-0.2)\times 0.2$	= 3.64 m^2
$r_e = \sqrt{\frac{I_s}{A_s}} = \sqrt{\frac{15.3}{3.64}}$	= 2.04 m
$W_{s\_full} = W_{T\_full} + \left(1/3\right)W_{staging} = 981 + \left(1/3\right)1093$	= 1345 kN
$W_{s\_empty} = W_{T\_empty} + \left(1/3\right)W_{staging} = 184 + \left(1/3\right)1093$	= 548 kN
$W_{foundation} = \left(\pi/4\right)D_F^{\,2}t_{RF}\rho_{concrete}g = \left(\pi/4\right)6.5^2\times 0.75\times 25$	= 622kN
Equivalent shear wall length $l_e = 0.78D_s$ = 3.315 m $\psi = \frac{b}{l_e}$ = 1.25/3.315= 0.377	
Eccentricity e due to unsymmetrical opening $e = 0.5D_s\left(\frac{\psi}{2-\psi}\right)$ = *0.5× 4.25×(0.377)/(2-0.377) = 0.493* m	

3.2 Natural Period of Tank

Tank Full $T_{full} = C_T \sqrt{\frac{W_{s\_full} h_s}{E_s A_s g}} = 15.3 \sqrt{\frac{1345 \times 10^3 \times 12}{22360 \times 10^6 \times 3.64 \times 9.81}}$;

Tank Empty $T_{empty} = C_T \sqrt{\frac{W_{s\_empty} h_s}{E_s A_s g}} = 15.3 \sqrt{\frac{548 \times 10^3 \times 12}{22360 \times 10^6 \times 3.64 \times 9.81}}$

where *staging slenderness ratio* $k = \left(\frac{h_s}{r_e}\right) = \frac{12}{2.04}$ =5.88; C_T = 15.3

k	C_T
5	14.4
10	21.2
15	29.6
20	38.4
25	47.2
30	56.0
35	65.0
40	73.8
45	82.8
>50	1.8k

T_{full} = 0.07 s

T_{empty} =0.044 s

3.4 Design Horizontal Seismic Force

	Tank Full	Tank Empty
Spectral Acceleration (S_a/g)	$(S_a/g)_{full}$ = 2.5	$(S_a/g)_{empty}$ = 2.5
Horizontal seismic coefficient $A_h = \frac{Z_{SS} I}{R}\left(\frac{S_a}{g}\right)$	$= \frac{0.36 \times 1.5}{1.8}(2.5)$ = 0.75	$= \frac{0.36 \times 1.5}{1.8}(2.5)$ = 0.75
Base Shear Filled $V_B = A_h W_{s\_full}$; Empty $V_B = A_h W_{s\_empty}$	= 0.75×1345 = 1,009 kN	= 0.75×548 = 411 kN
Governing Shear force V_u is greatest of Full and Empty condition	= 1,009 kN	

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	$\frac{S_a}{g} = \begin{cases} 2.5 & 0 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.0 \end{cases}$

3.5 Shear Demand on Shaft Staging

Shear Force due to Torsional Moment $V_T = V_B e / D_s$	$= \frac{1009 \times 0.493}{4.25}$ = 117 kN	
Design Horizontal Shear Force on the staging cross-section	$V_d = 0.5V_b + V_T$ = 0.5×1009+ 117 =622 kN	$V_d = 0.5V_b - V_T$ = 0.5×1009-117 = 388 kN

3.6 Shear Capacity of Shaft Staging

Area of cross section through the opening of the shaft staging A_c	$A_c = 0.8 l_e t_s$ = 0.8×3.315×0.2 = 0.53 m[2]	$A_c = 0.8(l_e - b)t_s$ = 0.8(3.315-1.25)0.2 = 0.33 m[2]
Percentage of Longitudinal Reinforcement $\rho = \frac{100 A_{t\_st}}{A_s}$	$= \frac{100 \times 0.012}{3.64}$ = 0.33	$= \frac{100 \times 0.011}{3.39}$ = 0.32
For a percentage of Longitudinal Reinforcement ρ *in shaft wall,* from Table 19 of IS:456-2000, Design Shear Stress of Concrete τ_c	= 0.39 MPa	= 0.39 MPa
Shear Carried by Concrete $V_{uc} = \tau_c A_c$	= 0.39 × 0.53×10[6] N =207 kN	= 0.39 × 0.33×10[6] N =129 kN
Shear Carried by Steel V_{us}	$= 0.87 f_y A_{t\_st} \frac{0.8 l_e}{s_v}$ $= 0.87 \times 415 \times 113 \times \frac{0.8 \times 3135}{175}$ =585 kN	$= 0.87 f_y A_{t\_st} \frac{0.8 l_e - b}{s_v}$ $= 0.87 \times 415 \times 113 \times \frac{(0.8 \times 3135 - 1250)}{175}$ = 293 kN
Total Shear Capacity of Shaft Staging $V_{u,shaft} = V_{uc} + V_{us}$	= 207 + 585 = 792 kN **> Shear Demand V_d**	= 129 + 293 = 422 kN **> Shear Demand V_d**

3.7 Check for Overturning Moment

Over Turning Moment $M_{OT} = V_B \left(h_s + \frac{h_t}{2} \right)$	= 1009 ×(12+3.3/2) = 13,772 kNm	= 411× (12+3.3/2) = 5,610 kNm
Restoring Moment $M_R = (W_{\text{tank}} + W_{\text{staging}} + W_{\text{foundation}})\left(1 - \frac{2}{3} A_h\right) \frac{D_F}{2}$ where D_F, is diameter of the foundation	$= (981 + 1093 + 622)\left(1 - \frac{2}{3} \times 0.75\right)\frac{6.5}{2}$ = 4360 kNm	$= (184 + 1093 + 622)\left(1 - \frac{2}{3} \times 0.75\right)\frac{6.5}{2}$ = 3070 kNm
Factor of Safety = M_R/M_{OT}	= 4360/13772 = 0.32	= 3070/5610 = 0.55
Check	**<< 1.5**	**<< 1.5**