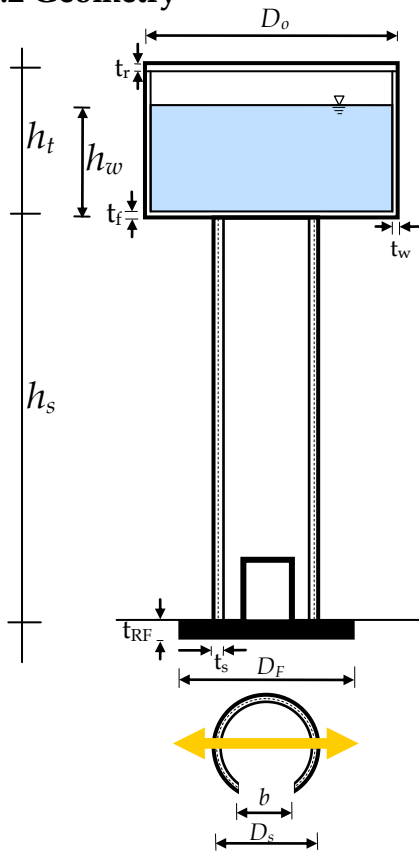


2. INPUTS

2.1 Basic Information

- | | | |
|-------------------------|----------------------|---|
| (1) Location | : Panchkula | Seismic Zone as per Indian Seismic Code: IV |
| (2) Type of Staging | : Shaft | Site-specific horizontal acceleration Z_{SS} : 1g |
| (3) Importance Factor I | : 1.5 | Detailing Type: Ordinary / Special R = 1.8/2.5 |
| (4) Capacity | : 454 m ³ | |
| (5) Shape of Water Tank | : Rectangular | |

2.2 Geometry



Inputs	Units
h_t	= 4.25m
D_o	= 12.5m
t_w	= 0.15 m
t_r	= 0.15 m
t_f	= 0.15 m
h_w	= 3.9 m
b	= 0.9 m
h	= 2.0 m
t_s	= 0.15 m
h_s	= 26 m
D_s	= 10 m
D_F	= 12 m
t_{RF}	= 1.00 m
<i>Vertical Reinforcement: Y16 @ 200 c/c</i>	
<i>Transverse Reinforcement: Y12 @ 175 c/c</i>	

Figure 2.1: Elevated Water Tanks- Shaft Staging

2.3 Materials and Structural System

- | | |
|---|---|
| (1) Grade of Concrete $f_{ck} = 15$ MPa | Modulus of Elasticity, $E_c = 5000\sqrt{f_{ck}} = 19,365$ 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 |

Rapid Assessment of Seismic Safety of Elevated Water Tanks with Shaft Staging

3. BASIC SAFETY CHECKS

3.1 Section Properties

Derived Quantities	Units
$D_i = D_o - 2t_w = 12.5 - 2 \times 0.15$	= 12.2 m
$W_{T_empty} = \left[\left(\frac{\pi}{4} \right) (D_o^2 - D_i^2) h_t + \left(\frac{\pi}{4} \right) D_o^2 (t_r + t_f) \right] \gamma_{concrete}$ $= \left[\left(\frac{\pi}{4} \right) (12.5^2 - 12.2^2) 4 + \left(\frac{\pi}{4} \right) 12.5^2 (0.15 + 0.15) \right] 25$	= 1501 kN
$W_{water} = \left[\left(\frac{\pi}{4} \right) D_i^2 h_w \right] \rho_{water} g = \left[\left(\frac{\pi}{4} \right) 12.2^2 \times 3.9 \right] 9.81$	= 4470 kN
$W_{T_full} = W_{T_empty} + W_{water} = 1501 + 4470$	= 5971 kN
$W_{staging} = \pi (D_s - t_s) t_s h_s \gamma_{concrete} = \pi (10 - 0.15) 0.15 \times 26 \times 25$	= 3016 kN
$I_s = \pi R_s^2 t_s = \pi \times 5^2 \times 0.15$	= 11.775 m ⁴
$A_s = \pi (D_s - t_s) t_s$	= 4.639 m ²
$r_e = \sqrt{\frac{I_s}{A_s}} = \sqrt{\frac{11.775}{4.639}}$	= 1.593 m
$W_{s_full} = W_{T_full} + \left(\frac{1}{3} \right) W_{staging} = 5971 + \left(\frac{1}{3} \right) 3016$	= 6976 kN
$W_{s_empty} = W_{T_empty} + \left(\frac{1}{3} \right) W_{staging} = 1501 + \left(\frac{1}{3} \right) 3016$	= 2506 kN
$W_{foundation} = \left(\frac{\pi}{4} \right) D_F^2 t_{RF} \rho_{concrete} g = \left(\frac{\pi}{4} \right) \times 12^2 \times 1 \times 25$	= 2826 kN
Equivalent shear wall length $l_e = 0.78 D_s = 0.78 \times 10 = 7.8$ m	
$\psi = \frac{b}{l_e} = \frac{0.9}{7.8} = 0.115$	
Eccentricity e due to unsymmetrical opening	
$e = 0.5 D_s \left(\frac{\psi}{2 - \psi} \right) = 0.305$	

3.2 Natural Period of Tank

<p>Tank Full $T_{full} = C_T \sqrt{\frac{W_{s_full} h_s}{E_s A_s g}} = 31.92 \sqrt{\frac{6976 \times 10^3 \times 26}{19365 \times 10^6 \times 4.639 \times 9.81}} ;$</p> <p>Tank Empty $T_{empty} = C_T \sqrt{\frac{W_{s_empty} h_s}{E_s A_s g}} = 31.92 \sqrt{\frac{2506 \times 10^3 \times 26}{19365 \times 10^6 \times 4.639 \times 9.81}}$</p> <p>where staging slenderness ratio $k = \left(\frac{h_s}{r_e}\right) = \frac{26}{1.593} = 16.32; C_T = 31.92$</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>k</th> <th>C_T</th> </tr> </thead> <tbody> <tr><td>5</td><td>14.4</td></tr> <tr><td>10</td><td>21.2</td></tr> <tr><td>15</td><td>29.6</td></tr> <tr><td>20</td><td>38.4</td></tr> <tr><td>25</td><td>47.2</td></tr> <tr><td>30</td><td>56.0</td></tr> <tr><td>35</td><td>65.0</td></tr> <tr><td>40</td><td>73.8</td></tr> <tr><td>45</td><td>82.8</td></tr> <tr><td>>50</td><td>1.8k</td></tr> </tbody> </table>	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	$T_{full} = 0.456 \text{ s}$	$T_{empty} = 0.274 \text{ s}$
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																							

3.4 Design Horizontal Seismic Force

Spectral Acceleration (S_a/g)			
Soil Type	Spectral Acceleration (S_a/g)		
Type I	$\frac{S_a}{g} = \begin{cases} 2.5 & 0 \leq T \leq 0.4 \\ 1.00/T & 0.4 \leq T \leq 4.0 \end{cases}$		
Type II	$\frac{S_a}{g} = \begin{cases} 2.5 & 0 \leq T \leq 0.55 \\ 1.36/T & 0.55 \leq T \leq 4.0 \end{cases}$	$(S_a/g)_{full} = 2.5$	$(S_a/g)_{empty} = 2.5$
Type III	$\frac{S_a}{g} = \begin{cases} 2.5 & 0 \leq T \leq 0.67 \\ 1.67/T & 0.67 \leq T \leq 4.0 \end{cases}$		
Horizontal seismic coefficient $A_h = \frac{Z_{SS} I}{R} \left(\frac{S_a}{g}\right)$		$= \frac{1.0 \times 1.5}{1.8} (2.5) = 2.08$	$= \frac{1.0 \times 1.5}{1.8} (2.5) = 2.08$
Base Shear Filled $V_B = A_h W_{s_full}$; Empty $V_B = A_h W_{s_empty}$		$= 2.08 \times 6976 = 14,510 \text{ kN}$	$= 2.08 \times 2506 = 5,212 \text{ kN}$
Governing Shear force V_u is greatest of Full and Empty condition		$= 14,510 \text{ kN}$	

3.5 Shear Demand and Capacity of Shaft Staging

Shear Force due to Torsional Moment $V_T = V_B e / D_s$	$= \frac{14510 \times 0.305}{10} = 443 \text{ kN}$	
Design Horizontal Shear Force on the staging cross-section	$V_d = 0.5V_b + V_T$ $= 0.5 \times 14510 + 443$ $= 7,688 \text{ kN}$	$V_d = 0.5V_b - V_T$ $= 0.5 \times 14510 - 443$ $= 6,812 \text{ kN}$

3.6 Shear Capacity of Shaft Staging

Area of cross section through the opening of the shaft staging A_c	$A_c = 0.8l_e t_s$ $= 0.8 \times 7.8 \times 0.15$ $= 0.936 \text{ m}^2$	$A_c = 0.8(l_e - b)t_s$ $= 0.8(7.8 - 0.9)0.15$ $= 0.828 \text{ m}^2$
Percentage of Longitudinal Reinforcement $\rho = \frac{100A_{t_st}}{A_s}$	$= \frac{100 \times 0.031}{4.64}$ $= 0.67$	$= \frac{100 \times 0.029}{4.51}$ $= 0.64$
For a percentage of Longitudinal Reinforcement ρ in shaft wall, from Table 19 of IS:456-2000, Design Shear Stress of Concrete τ_c	$= 0.52 \text{ MPa}$	$= 0.52 \text{ MPa}$
Shear Carried by Concrete $V_{uc} = \tau_c A_c$	$= 0.52 \times 0.94 \times 10^6 \text{ N}$ $= 489 \text{ kN}$	$= 0.52 \times 0.83 \times 10^6 \text{ N}$ $= 432 \text{ kN}$
Shear Carried by Steel V_{us}	$= 0.87 f_y A_{t_st} \frac{0.8l_e}{s_v}$ $= 0.87 \times 415 \times 113 \times \frac{0.8 \times 7800}{175} =$ 1455 kN	$= 0.87 f_y A_{t_st} \frac{0.8l_e - b}{s_v}$ $= 0.87 \times 415 \times 113 \times \frac{(0.8 \times 7800 - 900)}{175} =$ 1287 kN
Total Shear Capacity of Shaft Staging $V_{u,shaft} = V_{uc} + V_{us}$	$= 489 + 1455$ $= 1944 \text{ kN}$ < Shear Demand V_d	$= 432 + 1287$ $= 1719 \text{ kN}$ < Shear Demand V_d

3.6 Check for Overturning Moment

Over Turning Moment $M_{OT} = V_B \left(h_s + \frac{h_t}{2} \right)$	$= 14510(26 + 4.25/2)$ $= 4,08,093 \text{ kNm}$	$= 5212(26 + 4.25/2)$ $= 1,46,587 \text{ kNm}$
Restoring Moment $M_R = (W_{tank} + W_{staging} + W_{foundation}) \left(1 - \frac{2}{3} A_h \right) \frac{D_F}{2}$ where D_F , is diameter of the foundation	$= (5971 + 3016 + 2826) \left(1 - \frac{2}{3} \times 2.08 \right) \frac{10}{2}$ $= -23,247 \text{ kNm}$	$= (1501 + 3016 + 2826) \left(1 - \frac{2}{3} \times 2.08 \right) \frac{10}{2}$ $= -14,451 \text{ kNm}$
Factor of Safety = M_R / M_{OT}	$= ?$	$= ?$
Check	<< 1.5	<< 1.5