Cylindrical Tank : ออกแบบถังคอนกรีตกลม

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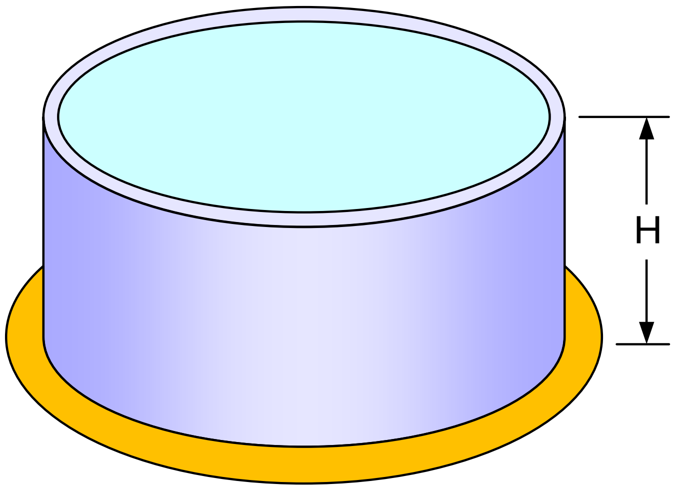
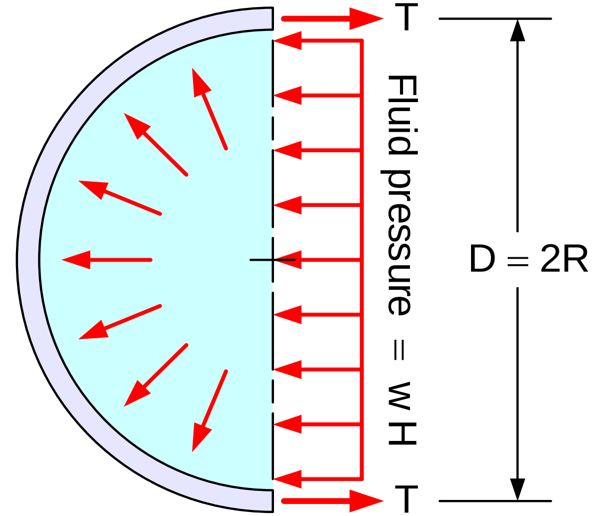
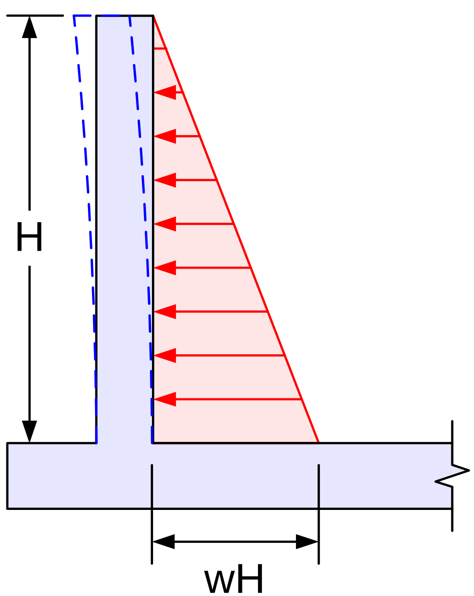
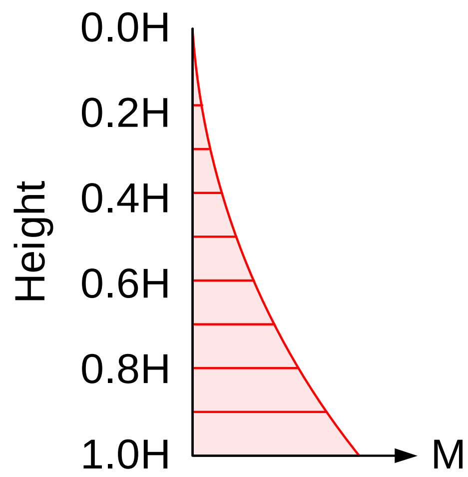








Carpenter's Method

For cylinder tank of height H and diameter D

Maximum moment : $M = F\,w\,H^3$

Maximum tension ring : $T = \frac{1}{2} wHD(1 - K)$

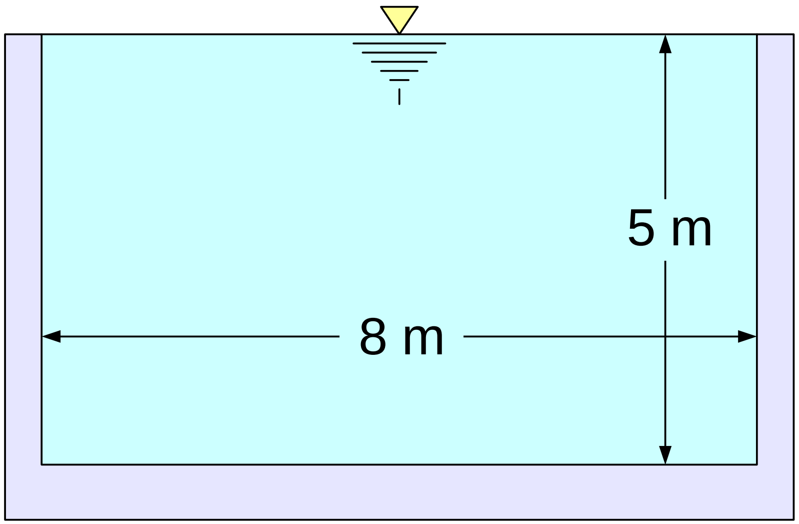
Maximum tension ring position at KH from base

Minimum wall thickness : $t = (30H + 50)$ mm

H/D	F				K			
	H/t				H/t			
	10	20	30	40	10	20	30	40
0.1	0.075	0.047	0.036	0.028	-	-	-	-
0.2	0.046	0.028	0.022	0.015	-	0.50	0.45	0.40
0.3	0.032	0.019	0.014	0.010	0.55	0.43	0.38	0.33
0.4	0.024	0.014	0.010	0.007	0.50	0.39	0.35	0.30
0.5	0.020	0.012	0.009	0.006	0.45	0.37	0.32	0.27
1.0	0.012	0.006	0.005	0.003	0.37	0.28	0.24	0.21
2.0	0.006	0.003	0.002	0.002	0.30	0.22	0.19	0.16
4.0	0.004	0.002	0.002	0.001	0.27	0.20	0.17	0.14

ตัวอย่างการออกแบบ : Cylindrical Water Tank

The open cylindrical reinforced concrete tank is 5 m deep and 20 m in diameter. Concrete compressive strength is f'_c = 280 kg/cm^2 and reinforcement f_y = 4,000 kg/cm^2. water unit weight w = 1,000 kg/m^3, shrinkage coefficient ε_{sh} = 0.0003



(1) Wall thickness

Simple formula:

$$t = (30H + 50)$$
$$= 30 \times 5 + 50$$
$$= 200 < 300 \text{ mm}$$

USE t = 30 cm

ACI 350 :
$H \geq 3.0$ m

Tension ring : $$T = \frac{1}{2} wHD(1-K)$$

$$H/D = 5/8 = 0.625$$

$$H/t = 5/0.2 = 25$$

	20	**25**	30
0.5	0.37	**0.345**	0.32
0.625		**0.324**	
1.0	0.28	**0.26**	0.24

0.324 → **K**

$$T = \frac{1}{2} wHD(1-K) = \frac{1}{2} \times 1.0 \times 5 \times 8 (1-0.324) = 13.52 \text{ tons}$$

ACI 350 :

$$n = \frac{E_s}{E_c} = \frac{2.04 \times 10^6}{15{,}100\sqrt{280}} \cong 8$$

$$t = \frac{\varepsilon_{sh} E_s + f_s - n f_{ct}}{100 f_s f_{ct}} T = \frac{0.0003 \times 2.04 \times 10^6 + 1{,}700 - 8 \times 33.47}{100 \times 1{,}700 \times 33.47} T$$

$$t = 0.000359\, T \quad \text{where T is in kg}$$

$$t = 0.359\, T \quad \text{where T is in tons} = 0.359 \times 13.52 = 4.85 < 30 \text{ cm}$$ **OK**

(2) Tension Ring $$T_u = \frac{1}{2} w_u H D (1 - K)$$

$$w_u = \text{Sanitary coefficient} \times (1.7 \times \text{Lateral force})$$

$$= 1.65 \times (1.7 \times 1.0) = 2.81 \text{ ton/m}$$

$$T_u = \frac{1}{2} \times 2.81 \times 5 \times 8 (1 - 0.324) = 37.99 \text{ tons}$$

$$A_s = T_u / (0.9 \times f_y) = 37.99 / (0.9 \times 4.0) = 10.55 \text{ cm}^2\text{/m}$$

USE DB12 @ 0.20 m in 2 layers (A_s = 11.3 cm^2/m)

Check tensile stress in concrete:

$$f_{ct} = \frac{T + \varepsilon_{sh} E_s A_s}{A_c + n A_s}$$

$$= \frac{37.99 \times 10^3 / (1.65 \times 1.7) + 0.0003 \times 2.04 \times 10^6 \times 11.3}{30 \times 100 + 8 \times 11.3}$$

$$= 6.62 \text{ kg/cm}^2 < [2\sqrt{f'_c} = 2\sqrt{280} = 33.47 \text{ kg/cm}^2] \quad \textbf{OK}$$

(3) Bending Moment $M = F w H^3$

$$w_u = \text{Sanitary coefficient} \times (1.7 \times \text{Lateral force})$$

$$= 1.3 \times (1.7 \times 1.0) = 2.21 \text{ ton/m}$$

$$H/D = 5/8 = 0.625$$

$$H/t = 5/0.2 = 25$$

	20	**25**	30
0.5	0.012	**0.0105**	0.009
0.625		**0.0093**	→ **F**
1.0	0.006	**0.0055**	0.005

$$M_u = 0.0093 \times 2.21 \times 5^3 = 2.57 \text{ t-m/m}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{2{,}570 \times 100}{0.9 \times 100 \times 25^2} = 4.57 \text{ kg/cm}^2$$

$$\rho = \frac{0.85 f'_c}{f_y}\left(1 - \sqrt{1 - \frac{2R_n}{0.85 f'_c}}\right)$$

$$= \frac{0.85 \times 280}{4{,}000}\left(1 - \sqrt{1 - \frac{2 \times 4.57}{0.85 \times 280}}\right) = 0.00115 < [\,\rho_{max} = 0.0229\,] \quad \textbf{OK}$$

$$A_s = \rho\, b\, d = 0.00115 \times 100 \times 25 = 2.875 \text{ cm}^2\text{/m}$$

$$A_{s,min} = 0.0018\, b\, t = 0.0018 \times 100 \times 30 = 5.4 \text{ cm}^2\text{/m}$$ control

USE DB12 @ 0.20 m ($A_s = 5.65$ cm²/m) ($A_s = A_b\,(100/s)$)

Check max spacing $= \dfrac{z^3}{2 \times d_c^2 \times f_s^3} = \dfrac{20{,}600^3}{2 \times 5^2 \times 1{,}700^3}$

$$= 35.6 \text{ cm} > 20 \text{ cm} \quad \textbf{OK}$$

(4) Shear Force

$$V = 0.5\, w\, H^2$$

$$w_u = \text{Sanitary coefficient} \times (1.7 \times \text{Lateral force})$$

$$= 1.0 \times (1.7 \times 1.0) = 1.70 \text{ ton/m}$$

$$V_u = 0.5 \times 1.70 \times 5^2 = 21.25 \text{ tons}$$

$$V_c = 0.53\sqrt{f'_c}\, b\, d = 0.53\sqrt{280} \times 100 \times 25 / 10^3 = 22.17 \text{ tons}$$

$$V_s = 1.3\,(V_u - \phi V_c) / \phi = 1.3\,(21.25 - 0.85 \times 22.17) / 0.85$$

$$= 3.679 \text{ ton}$$

Increase t = 35 cm → d = 30 cm → $V_s = 0$

(5) Detail Reinforcement