

Seismic Load (X-direction – parallel to long dimension of tank)

Seismic load will be calculated in accordance with ACI 350.3-06. Refer to Appendix A for a step-by-step outline of the design method.

Basic Seismic Design Parameters

Depth of stored liquid, $H_L = 20'$

Wall height, $H_w = 20'$

Inside length of tank, $L = 24.5'$

ASCE 7-05:

- Figure 22-1; $S_s = 0.139$
- Figure 22-2; $S_1 = 0.052$
- Table 20.3-1 and geotechnical report; site classification = D
- Table 11.4-1; $F_a = 1.6$
- Table 11.4-2; $F_v = 2.4$

Eq. (9-35):

$$S_{DS} = (2/3)(S_s)(F_a) = (2/3)(0.139)(1.6) = 0.148$$

Eq. (9-36):

$$S_{D1} = (2/3)(S_1)(F_v) = (2/3)(0.052)(2.4) = 0.083$$

Table 4.1.1(a):

- Importance factor, $I = 1.25$

Table 4.1.1(b):

- Fixed-base tank, buried
- $R_i = 3.0$
- $R_c = 1.0$

Tank Dynamic Properties

Weight of one wall perpendicular to earthquake direction, $W_w' = 113k$

Weight of roof plus superimposed snow load of 40 psf, $W_r = 130k$

Weight of stored liquid, $W_L = 593k$

Effective mass coefficient, Eq. (9-44):

$$\varepsilon = \left[0.0151 \left(\frac{L}{H_L} \right)^2 - 0.1908 \left(\frac{L}{H_L} \right) + 1.021 \right] \leq 1.0$$

- $L = 24.5'$
- $H_L = 20'$
- $\varepsilon = 0.81$

Effective weight of impulsive component of stored liquid, W_i - use Eq. (9-1):

$$\frac{W_i}{W_L} = \frac{\tanh \left[0.866 \left(\frac{L}{H_L} \right) \right]}{0.866 \left(\frac{L}{H_L} \right)}$$

- $W_L = 593k$
- $L = 24.5'$
- $H_L = 20'$
- $W_i = 439k$

Effective weight of convective component of stored liquid, W_c - use Eq. (9-1):

$$\frac{W_c}{W_L} = 0.264 \left(\frac{L}{H_L} \right) \tanh \left[3.16 \left(\frac{H_L}{L} \right) \right]$$

- $W_L = 593k$
- $L = 24.5'$
- $H_L = 20'$
- $W_c = 190k$

General dimensional parameters:

- Height from base of wall to c.o.g. of wall, $h_w = 10'$
- Height from base of wall to c.o.g. of roof, $h_r = 20.5'$
- $L / H_L = 24.5 / 20 = 1.23$

Height above base of wall to c.o.g. of impulsive lateral force for case excluding base pressure, h_i , use eq. (9-3):

$$\frac{h_i}{H_L} = 0.5 - 0.09375 \left(\frac{L}{H_L} \right)$$

- $H_L = 20'$
- $L = 24.5'$
- $h_i = 7.70'$

Height above base of wall to c.o.g. of convective lateral force for case excluding base pressure, h_c , use eq. (9-5):

$$\frac{h_c}{H_L} = 1 - \frac{\cosh \left[3.16 \left(\frac{H_L}{L} \right) \right] - 1}{3.16 \left(\frac{H_L}{L} \right) \sinh \left[3.16 \left(\frac{H_L}{L} \right) \right]}$$

- $H_L = 20'$
- $L = 24.5'$
- $h_c = 13.34'$

Height above base of wall to c.o.g. of impulsive lateral force for case including base pressure, h_i' , use eq. (9-7):

$$\frac{h_i'}{H_L} = \frac{0.866 \left(\frac{L}{H_L} \right)}{2 \tanh \left[0.866 \left(\frac{L}{H_L} \right) \right]} - \frac{1}{8}$$

- $H_L = 20'$

- $L = 24.5'$
- $h_i' = 11.00'$

Height above base of wall to c.o.g. of convective lateral force for case including base pressure, h_c' , use eq. (9-8):

$$\frac{h_c'}{H_L} = 1 - \frac{\cosh\left[3.16\left(\frac{H_L}{L}\right)\right] - 2.01}{3.16\left(\frac{H_L}{L}\right) \sinh\left[3.16\left(\frac{H_L}{L}\right)\right]}$$

- $H_L = 20'$
- $L = 24.5'$
- $h_c' = 14.53'$

The calculation of the combined natural frequency of vibration (ω_i) of the containment structure and the impulsive component of the stored liquid is not required because the maximum value of C_i is used (S_{DS}). The assumption is that $T_i < T_s$ (see Section 9.4.1).

Calculate the frequency of vibration (ω_c) of the convective component of the stored liquid – use Eq. (9-13) and (9-12):

Eq. (9-13):

$$\lambda = \sqrt{3.16 g \tanh\left[3.16\left(\frac{H_L}{L}\right)\right]}$$

- $g = 32.17 \text{ ft/s}^2$
- $H_L = 20'$
- $L = 24.5'$
- $\lambda = 10.02$

Eq. (9-12)

$$\omega_c = \frac{\lambda}{\sqrt{L}}$$

- $\lambda = 10.02$
- $L = 24.5'$
- $\omega_c = 2.03$

Calculate the natural period of the first (convective) mode of sloshing, T_c – use Eq. (9-14):

$$T_c = \frac{2\pi}{\omega_c}$$

- $\omega_c = 2.03$
- $T_c = 3.10$

Calculate the seismic response coefficients C_i , C_c & C_t .

For C_i , assume $T_i < T_s$ (see above) – use Eq. (9-32):

$$C_i = S_{DS}$$

- $S_{DS} = 0.148$
- $C_i = 0.148$

For C_c , first find T_s – use Eq. (9-34):

$$T_s = \frac{S_{D1}}{S_{DS}}$$

- $S_{D1} = 0.083$
- $S_{DS} = 0.148$
- $T_s = 0.56$

$T_c [3.10] > 1.6/T_s [2.86]$ – use Eq. (9-38):

$$C_c = 6 \frac{0.4 S_{DS}}{T_c^2} = \frac{2.4 S_{DS}}{T_c^2}$$

- $S_{DS} = 0.148$
- $T_c = 3.10$
- $C_c = 0.037$

$$C_t = 0.4 S_{DS} = 0.4 * 0.148 = 0.06$$

Dynamic Lateral Forces

Lateral inertia force of one accelerating wall perpendicular to direction of earthquake force, P_w' – use Eq. (4-1a):

$$P_w' = C_i I \left[\frac{\varepsilon W_w'}{R_i} \right]$$

- $C_i = 0.148$
- $I = 1.25$
- $\varepsilon = 0.81$
- $W_w' = 113k$
- $R_i = 3.0$
- $P_w' = 5.6k$

Lateral inertia force of the accelerating roof, W_r – use Eq. (4-2):

$$P_r = C_i I \left[\frac{W_r}{R_i} \right]$$

- $C_i = 0.148$
- $I = 1.25$
- $W_r = 130k$
- $R_i = 3.0$
- $P_r = 8.0k$

Total lateral impulsive force associated with W_i , P_i – use Eq. (4-3):

$$P_i = C_i I \left[\frac{W_i}{R_i} \right]$$

- $C_i = 0.148$
- $I = 1.25$
- $W_i = 439k$
- $R_i = 3.0$
- $P_i = 27.1k$

Total lateral convective force associated with W_c , P_c – use Eq. (4-4):

$$P_c = C_c I \left[\frac{W_c}{R_c} \right]$$

- $C_c = 0.037$
- $I = 1.25$
- $W_c = 190k$
- $R_c = 1.0$
- $P_c = 8.8k$

Dynamic earth and groundwater pressure (P_{eg}) has been neglected in this analysis.

Total Base Shear

Base shear due to seismic forces applied at the bottom of the tank wall, V – use Eq. (4-5):

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2 + P_{eg}^2}$$

- $P_i = 27.1k$
- $P_w' = 5.6k$
- $P_r = 8.0k$
- $P_c = 8.8k$
- $P_{eg} = \text{not considered} = 0k$
- $V = 41.6k$

Moments at Base

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Vertical Acceleration

Spectral acceleration, Eq. (4-15):

$$\ddot{u}_v = C_t I \left[\frac{b}{R_i} \right] \geq 0.2 S_{DS}$$

- $C_t = 0.06$
- $I = 1.25$
- $b = \text{assume } 0.67$
- $R_i = 3.0$
- $\ddot{u} = 0.03$

Hydrodynamic pressure, p_{vy} , at level y above base – use Eq. (4-14):

$$p_{vy} = \bar{u}_v q_{hy}$$

- $p_{vy} = (0.03)(q_{hy})$

Force Distribution

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Stresses

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