CONCRETE WATER TANK DESIGN PARAMETERS

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- # Introduction:

A concrete water tank is a large, container used to store water for a variety of purposes, such as irrigation, household use, fire suppression, and agricultural use. Concrete tanks are made by pouring concrete into a mold, which can be made in a variety of sizes and shapes to suit the needs of the user. Concrete water tanks are durable and long-lasting, making them a popular choice for storing water. They are also resistant to pests and other animals, and can be made to be resistant to freezing temperatures. Concrete water tanks can be used in both residential and commercial settings.

There are several benefits to using concrete water tanks:

1. Durability: Concrete is a strong and durable material that can withstand a wide range of temperatures and weather conditions. Concrete tanks can last for many years, making them a good long-term investment.

2. Customizable: Concrete tanks can be made in a variety of sizes and shapes to suit the needs of the user. This allows them to be customized to fit the available space and meet the specific needs of the user.

3. Low maintenance: Concrete tanks require minimal maintenance, making them a low-maintenance option for storing water.

4. Environmentally friendly: Concrete tanks can be made using recycled materials, making them an environmentally friendly option for storing water.

- **Water Tanks Types According to Construction:**

1. **Precast concrete tanks**: These tanks are made by casting concrete in a factory setting and are then transported to the site where they will be used.

2. **In-situ concrete tanks**: These tanks are constructed on site by pouring concrete into a mold.

- **Water Tanks Types According to Location:**

1. **An underground** concrete water tank is a large, container used to store water underground for a variety of purposes, such as irrigation, household use, fire suppression, and agricultural use. Underground concrete tanks are made by pouring concrete into a mold, which can be made in a variety of sizes and shapes to suit the needs of the user. They are then buried underground, with only a small access hatch or manhole cover visible at the surface.

2. **An above ground** concrete water tank is a large, container used to store water above ground for a variety of purposes, such as irrigation, household use, fire suppression, and agricultural use. Above ground concrete tanks are made by pouring concrete into a mold, which can be made in a variety of sizes and shapes to suit the needs of the user. They are then placed above ground, either on a foundation or on a platform, and are typically surrounded by a fence or other protective barrier to prevent damage

3. **Elevated concrete tanks**: These tanks are supported by a structure, such as a tower, and are used to provide water at a higher elevation.

• Concrete Water Tanks Design Process:

The design process for a concrete water tank involves several steps, including determining the tank's size and capacity, selecting a suitable site, and determining the appropriate construction materials and methods. Here is a general overview of the design process for a concrete water tank:

1. **Determine the size and capacity of the tank**: The first step in designing a concrete water tank is to determine how much water you need to store and how much space is available for the tank. You will need to consider factors such as the water usage patterns of the people that will be using the tank, the size of the property, and any local zoning requirements or building codes that may apply.

2. **Select a suitable site**: The next step is to choose a location for the tank that is safe, accessible, and able to support the weight of the tank. The site should be located at a sufficient distance from any buildings or structures to minimize the risk of damage in the event of a leak or spill.

3. **Determine the construction materials and methods**: Once you have determined the size and capacity of the tank and selected a suitable site, you will need to decide on the materials and construction methods to use. Concrete is a popular choice for water tanks due to its durability and longevity, but other materials such as steel or plastic may also be used. The construction method will depend on the size and shape of the tank, as well as the available resources and budget.

4. **Create a design plan**: With all of this information in hand, you can begin to create a detailed design plan for the tank. This plan should include drawings, specifications, and any necessary calculations to ensure that the tank is properly designed and constructed.

5. **Obtain necessary permits and approvals**: Before you can begin construction, you will need to obtain any necessary permits and approvals from local authorities. This may involve submitting your design plan and demonstrating that the tank meets all relevant building codes and regulations.

6. **Construct the tank**: With the design plan and necessary permits in place, you can proceed with the construction of the tank. This may involve excavating the site, pouring the concrete, and completing any necessary finishing work.

7. **Test and commission the tank**: Once the tank is constructed, it will need to be tested to ensure that it is watertight and able to hold the required volume of water. You may need to commission a professional engineer or other qualified individual to perform these tests.

• Structural Elements of Concrete Water Tanks:

A concrete water tank is typically made up of several structural elements that work together to support the weight of the water and any additional loads, such as the weight of the tank itself, the weight of the soil above the tank, and any external loads such as wind or snow.

Here are some of the main structural elements that make up a concrete water tank:

1. **Foundation**: The foundation of a concrete water tank is the portion of the structure that supports the weight of the tank and transfers the load to the ground. The foundation is typically constructed from reinforced concrete and may include footings, grade beams, or other structural elements to provide additional support.

2. **Walls**: The walls of a concrete water tank are the main load-bearing elements that support the weight of the water and any additional loads. The walls are typically made from reinforced concrete and may be constructed using a variety of methods, such as cast-in-place or precast.

3. **Roof**: The roof of a concrete water tank is the structure that covers the top of the tank and helps to protect the water inside. The roof may be made from reinforced concrete, steel, or other materials, and may be flat, sloped, or dome-shaped.

4. **Anchors**: Anchors are used to hold the tank in place and resist lateral forces such as wind or earthquakes. The anchors are typically embedded in the foundation and may be made from steel or other high-strength materials.

5. **Joints**: Joints are the areas where different structural elements come together in a concrete water tank. These may include expansion joints to allow for movement due to temperature changes, construction joints to separate different stages of construction, and sealant joints to prevent water leakage.

• Codes Use for Designing Concrete Water Tanks:

There are several codes and standards that are commonly used for designing concrete water tanks. These codes provide guidelines for the design and construction of tanks to ensure that they are safe, reliable, and able to meet the needs of the users.

1. **American Concrete Institute (ACI-318 & ACI-350) Code**: The ACI code is a widely-used standard for the design and construction of concrete structures, including water tanks. It provides guidelines for the materials, design, and construction of concrete tanks, as well as requirements for testing and inspection.

2. **International Building Code (IBC)**: The IBC is a model building code that is used in many jurisdictions in the United States and internationally. It includes provisions for the design and construction of water tanks, including requirements for materials, structural design, and seismic design.

3. **American Water Works Association (AWWA) Standards**: The AWWA is a professional organization that develops standards and guidelines for the design and operation of water systems. They have several standards related to

concrete water tanks, including standards for materials, design, construction, and inspection.

4. **National Fire Protection Association (NFPA) Standards**: The NFPA is a professional organization that develops standards and codes for the protection of life and property from fire and other hazards. They have several standards related to water storage tanks, including requirements for fire protection, materials, and construction.

- **Force Use for Designing Concrete Water Tanks:**

1. **Lateral Water Pressure (F)**: refers to the pressure exerted on the sides of a concrete water tank by the water contained within the tank. This pressure can be significant, especially in tall tanks or tanks with high water levels. It is important to design the tank to be able to withstand the lateral water pressure to ensure the structural integrity of the tank.

   There are several factors that can affect the lateral water pressure on a concrete water tank, including:

- Height of the water level: The higher the water level in the tank, the greater the lateral water pressure will be. This is due to the increased weight of the water and the increased height from which it is acting on the tank.

- Shape of the tank: The shape of the tank can also affect the lateral water pressure. For example, a cylindrical tank will experience less lateral water pressure than a square or rectangular tank of the same volume, due to the distribution of the water's weight.
  The lateral water pressure on a concrete water tank can be calculated using the following equation:

  $P = \gamma H$ Where:

  P = lateral water pressure (N/m2 or pascals)

  γ = specific weight of water (N/m3)

  H = height of the water level above the point being considered (m)

  This equation assumes that the tank is symmetrical and the water level is uniform, and that the specific weight of the water is constant.

Example Soil and Water Pressure			
Water Unit Weight ɣw	=	10.00	KN/m3
Soil Unit Weight ɣs	=	18.00	KN/m3
Surcharge Load qa	=	12.00	KN/m2
Hight of Water Hw	=	3.00	m
Hight of Soil Side Hs	=	4.00	m
Angle of Side Friction θ	=	30.00	degree
Sin θ	=	0.50	
Rankins Coeffcient for active Soil Pressure Ka	=	0.33	
Rankins Coeffcient for Soil Pressure for Surcharge Load Ko	=	0.50	
Water Pressure at Bottom ɣw*Hw	=	30.0	KN/m2
Soil Pressure at Bottom Ps1 Ka*Hs*ɣs	=	24.0	KN/m2
Surcharge Pressure at Bottom Ps2 Ko*qa	=	6.0	KN/m2
Total Pressure at Bottom Case 2 Ps1+Ps2	=	30.0	KN/m2

2. **Lateral Soil Pressure (H)**: refers to the pressure exerted on the sides of a concrete water tank by the soil surrounding the tank. This pressure can be significant, especially if the soil is dense or the tank is buried deep underground. It is important to design the tank to be able to withstand the soil pressure to ensure the structural integrity of the tank.

   There are several factors that can affect the soil pressure on a concrete water tank, including:

- **Depth of the tank**: The deeper the tank is buried, the greater the soil pressure will be. This is due to the increased weight of the soil above the tank and the increased height from which it is acting on the tank.
- **Density of the soil**: The density of the soil can also affect the soil pressure on the tank. Soils that are denser, such as clay or silt, will exert more pressure on the tank than soils that are less dense, such as sand or gravel.
- **Moisture content of the soil**: The moisture content of the soil can also affect the soil pressure on the tank. Wet soils are generally denser and heavier than dry soils, so they will exert more pressure on the tank.
- **External loads**: External loads such as the weight of buildings or vehicles, or the effects of wind or earthquakes, can also affect the soil pressure on the tank.

The Rankine formula is a commonly used equation for calculating the soil pressure on a retaining wall or other structure. It can also be used to calculate the soil pressure on a concrete water tank, as long as the tank is acting as a retaining wall and the soil is retained on one side of the tank.

The Rankine formula for calculating soil pressure is as follows:

$P = \gamma H(1 + \sin\alpha)$ **Where:**

P = soil pressure (N/m2 or pascals)

γ = specific weight of soil (N/m3)

H = depth of the tank (m)

α = angle of internal friction of the soil (degrees)

Example Soil and Water Pressure			
Water Unit Weight ɣw	=	10.00	KN/m3
Soil Unit Weight ɣs	=	18.00	KN/m3
Surcharge Load qa	=	12.00	KN/m2
Hight of Water Hw	=	3.00	m
Hight of Soil Side Hs	=	4.00	m
Angle of Side Friction θ	=	30.00	degree
Sin θ	=	0.50	
Rankins Coeffcient for active Soil Pressure Ka	=	0.33	
Rankins Coeffcient for Soil Pressure for Surcharge Load Ko	=	0.50	
Water Pressure at Bottom ɣw*Hw	=	30.0	KN/m2
Soil Pressure at Bottom Ps1 Ka*Hs*ɣs	=	24.0	KN/m2
Surcharge Pressure at Bottom Ps2 Ko*qa	=	6.0	KN/m2
Total Pressure at Bottom Case 2 Ps1+Ps2	=	30.0	KN/m2

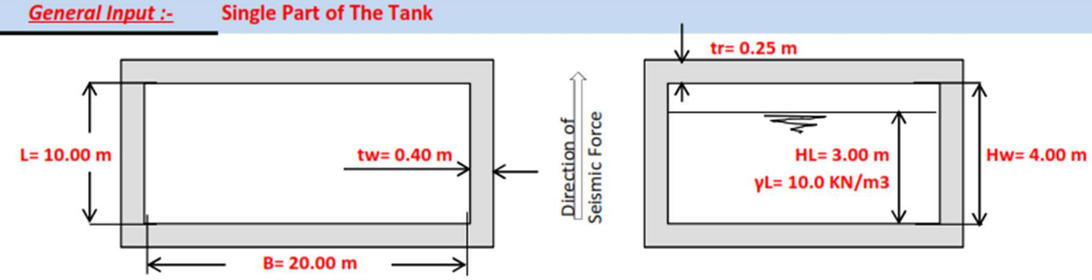
3. Lateral Dynamic Water Pressure (W Seismic)

The dynamic seismic loads on the tank should be calculated using modal analysis, which determines the natural frequencies and modes of vibration of the tank under earthquake excitation. The dynamic loads should then be calculated using time-history analysis, which involves simulating the ground shaking during the earthquake and the response of the tank to the shaking. According to ACI 350.3-06

Seismic Loads for Liquid-Containing Rectangular RC Tank, According ACI 350.3-06 , Appendix B Method
Based on 1997 Uniform Building Code Rev1.0

Project :-	Report Water Tank	Designed by:-	Msce.Zuhair M.Wali
Building :-	UnderGround Water Tank	Checked by:-	Msce.Zuhair M.Wali
Element:-	Water Tank Pressure	Date:-	08-Jan-23
Location:-	Sulaymaniah		

General Input :- **Single Part of The Tank**



Rectangular Tank Plan   Rectangular Tank Elevation

γc= 25.0 KN/m3
fc= 30.0 N/mm2   Ec= 25743.0 N/mm2   ACI318-08, Clause 8.5.1
g= 9.81 m/sec2

Importance factor I	= 1.00	ACI 350.3-06, Table 4.1.1(a)
R_c	= 1.00	ACI 350.3-06, Table 4.1.1(b)
R_i	= 2.00	ACI 350.3-06, Table 4.1.1(b)
SEISMIC ZONE	3	
Z factor	0.3	UBC 97, TABLE 16-I
Soil Profile	Very Dense	
Soil Profile Type	SC	UBC 97, TABLE 16-J
N_a For Zone 4 only	1	UBC 97, TABLE 16-S
N_v For Zone 4 only	1	UBC 97, TABLE 16-T
C_a	0.330	UBC 97, TABLE 16-Q
C_v	0.450	UBC 97, TABLE 16-R
$T_s = 0.40C_v/C_a$	0.545	sec, UBC 97, FIGURE 16-3

1-Calculation the Equivalent Weight for impulsive W_i & convective W_c component:

W_L = 8000.0 KN , L / H_L = 3.33 , W_w = 2464.0 KN , W_r = 1326.0 KN

$$W_i = W_L * \frac{\tanh\left[0.866\left(\frac{L}{H_L}\right)\right]}{0.866\left(\frac{L}{H_L}\right)}$$ = 0.34 WL = 2754.2 KN ACI 350.3-06, Eq 9-1

$$W_c = W_L * 0.264\left(\frac{L}{H_L}\right)\tanh\left[3.16\left(\frac{H_L}{L}\right)\right]$$ = 0.65 WL = 5201.7 KN ACI 350.3-06, Eq 9-2

2-Calculation the Height of center of gravity for impulsive h_i & convective h_c components:

$$\text{For } \frac{L}{H_L} < 1.333, \quad h_i = H_L * \left[0.5 - 0.09375\left(\frac{L}{H_L}\right)\right]$$
$$\frac{L}{H_L} \geq 1.333, \quad h_i = H_L * 0.375$$
= 1.125 m ACI 350.3-06, Eq 9-3 & Eq 9-4

$$h_c = H_L * \left[1 - \frac{\cosh\left[3.16\left(\frac{H_L}{L}\right)\right] - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left[3.16\left(\frac{H_L}{L}\right)\right]}\right]$$ = 1.603 m ACI 350.3-06, Eq 9-5

3-Calculation the fundamental period of oscillation of the tank for impulsive T_i & convective T_c components:

$W = W_w + W_r + W_i$ = 6544.2 KN , $h_w = H_w/2$ = 2.00 m , $h_r = H_w + t_r/2$ = 4.13 m

$h = \frac{(W_w h_w + W_i h_i)}{(W_w + W_i)}$ = 1.54 m , $k = \frac{E_c}{4 \times 10^3}\left(\frac{t_w}{h}\right)^3$ = 113178.7 KN/m ACI 350.3-06, R9.2.4

$T_i = 2\pi\sqrt{\frac{W}{gK}}$ = 0.48 sec ACI 350.3-06, Eq 9-11

$\lambda = \sqrt{3.16 g \tanh\left[3.16\left(\frac{H_L}{L}\right)\right]}$ = 4.79 $T_c = \frac{2\pi}{\omega_c} = \left(\frac{2\pi}{\lambda}\right)\sqrt{L}$ = 4.15 sec ACI 350.3-06, Eq 9-13,14

$T_c = \frac{2\Pi}{\omega_c} = 2\Pi\sqrt{\frac{W_c}{gk_c}}, \therefore K_c =$ = 1214.5 KN/m

Seismic Loads for Liquid-Containing Rectangular RC Tank, According ACI 350.3-06 , Appendix B Method
Based on 1997 Uniform Building Code Rev1.0

Project :-	Report Water Tank	Designed by:-	Msce.Zuhair M.Wali
Building :-	UnderGround Water Tank	Checked by:-	Msce.Zuhair M.Wali
Element:-	Water Tank Pressure	Date:-	08-Jan-23
Location:-	Sulaymaniah		

For $T_i \leq T_s$ $C_i = 2.5C_a$
For $T_i > T_s$ $C_i = C_v/T_i$
In addition, for Seismic Zone 4
$C_i \geq 1.6ZN_v$
= 0.825 ACI 350.3-06, Appendix B, Eq B-1,2,3

For $T_c \leq 1.6/T_s$ $C_c = \frac{1.5C_v}{T_c} \leq 3.75C_a$
For $T_c > 1.6/T_s$ $C_c = 6\frac{C_a}{T_c^2}$
= 0.115 ACI 350.3-06, Appendix B, Eq B-4,5

$P_w = \frac{C_i I}{R_i}W_w$ = 1016.4 KN $P_r = \frac{C_i I}{R_i}W_r$ = 547.0 KN ACI 350.3-06, Appendix B, Eq B-6,7

$P_i = \frac{C_i I}{R_i}W_i$ = 1136.1 KN $P_c = \frac{C_c I}{R_c}W_c$ = 597.6 KN ACI 350.3-06, Appendix B, Eq B-8,9

5-Calculation the total Base Shaer V:

$V = \sqrt{(P_w + P_r + P_i)^2 + P_c^2}$ = 2764.8 KN ACI 350.3-06, Appendix B & Eq 4-5

6-Dynamic force distribution above base per Wall perpendicular to ground motion:

$y_{Top} = H_L, y_{Bottom} = 0$

$$P_{iy} = \frac{\frac{P_i}{2}\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{H_L^2} / B$$

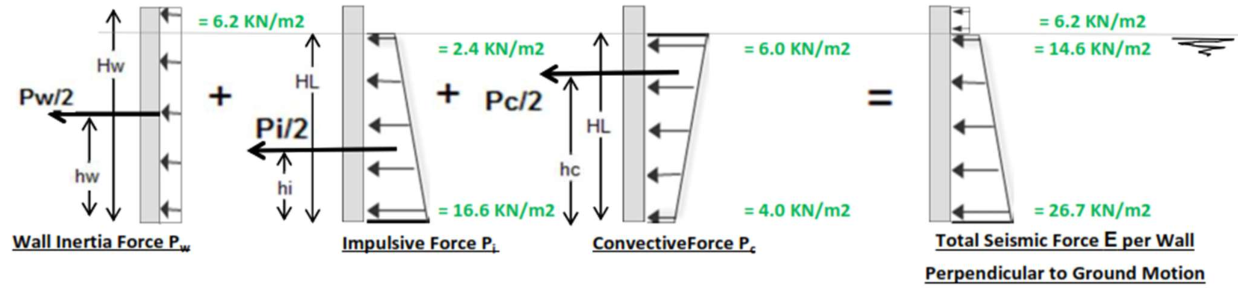
$P_{i\,Top}$ = 2.4 KN/m2
$P_{i\,Bottom}$ = 16.6 KN/m2

$$P_{cy} = \frac{\frac{P_c}{2}\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{H_L^2} / B$$

$P_{c\,Top}$ = 6.0 KN/m2
$P_{c\,Bottom}$ = 4.0 KN/m2

ACI 350.3-06, R5.3.1

$P_w = \frac{P_w}{2(B + t_w)H_w}$ = 6.2 KN/m2



Dynamic force distribution above base per Wall perpendicular to ground motion

7- Load Cominations:

Note that, the Calculated Seismic Force E above is based on Strength-level Forces (ultimate loads).

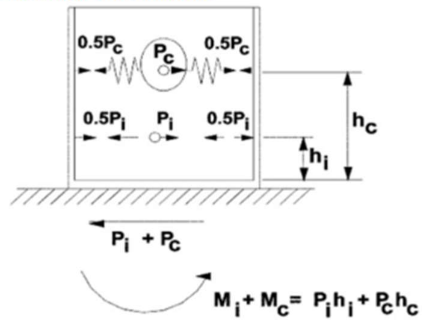
For allowable stresses Design (ASD) Method (service loads), the design seismic forces shall be reduced by a factor of 1.4

$S = 1.0\,D + 1.0\,L + E/1.4$ ACI 350.3-06, Appendix B, Clause B.5

For Ultimate Strength Design method (factored loads), follow ACI 350-06, Clause 9.2.1 load combinations.

$U = 1.2D + 1.0\,L + 1.0\,E$

$U = 0.9D + 1.0\,E$



4. Lateral Dynamic Soil Pressure (H Seismic)

Dynamic earth pressure is the lateral pressure exerted by soil on a retaining wall or other structure due to the ground shaking during an earthquake. The dynamic earth pressure profile is a graphical representation of the lateral soil pressure acting on the wall as a function of the wall's height.

Project :-	Report Water Tank		Designed by:-	Msce.Zuhair M.Wali		
Element:-	Water Tank Pressure		Date:-	08-Jan-23		
Location:-	Sulaymaniah					

Site Class	C		
Wall Hight H	4		
Ss	0.7		
S1	0.2		
SDs	0.57		
SD1	0.2		
Kh =PGH =(SDS / 2.5)	0.228	Table 11.8-1 ASCE find FPGA	
Y Soil	18		
FPGA	1.2		
Pressure at TOP	1.5*Kh*Y *H*FPGA		30
Pressure at Bottom	0.5*Kh*Y *H*FPGA		10

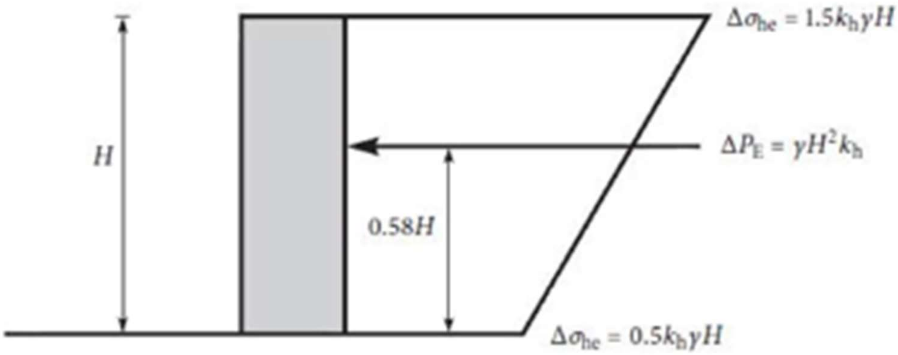


Figure 5. Dynamic earth pressure profile on rigid walls, after Matthewson et al. [26].

TABLE 11.8-1 Site Coefficient F_{PGA}

	Mapped Maximum Considered Geometric Mean (MCE_G) Peak Ground Acceleration, PGA					
Site Class	PGA ≤ 0.1	PGA = 0.2	PGA = 0.3	PGA = 0.4	PGA = 0.5	PGA ≥ 0.6
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.9	0.9	0.9	0.9	0.9	0.9
C	1.3	1.2	1.2	1.2	1.2	1.2
D	1.6	1.4	1.3	1.2	1.1	1.1
E	2.4	1.9	1.6	1.4	1.2	1.1
F	See Section 11.4.8					

Note: Use straight-line interpolation for intermediate values of PGA.

STANDARD ASCE/SEI 7-16

- **Design Load Combination for Design:**

This is will include the following pattern loads:

- Dead :D
- Live: LL
- F: Lateral Water Pressure as Live load
- H: Soil lateral Pressure as Dead
- W Seismic: Lateral Dynamic Water Pressure as Live load
- H Seismic: Lateral Dynamic Soil Pressure as Dead
- Qx= 1.0 Ex + 0.3 Ey
- Qy= 1.0 Ey + 0.3 Ex

(1): 0.9D+1.7F

(2): 0.9D+1.7H

(3): 1.4D+1.4F

(4): 1.2D+1.2F+1.6LL

(5): 1.2D+1.6H+1.6LL

(6):1.2D+1.2F+1.6LL+0.9H

(7): 1.2D+1.2F+1.0LL

(8):1.316D+1.2F+W Seismic+QX+1.0LL

(18): 0.784D+0.9F+W Seismic +QX+0.9H+0.9H Seismic

(19): 0.784D+0.9F+W Seismic +QY+0.9H+0.9H Seismic

(9): 1.316D+1.2F+W Seismic+QY+1.0LL

(10): 1.316D+1.2F+W Seismic+QX+1.0LL+0.9H+0.9 H Seismic

(11): 1.316D+1.6H+1.6 H Seismic+QX+1.0LL

(12): 1.316D+1.2F+W Seismic+QY+1.0LL+0.9H+0.9 H Seismic-1

(13): 1.316D+1.6H+1.6 H Seismic+QY+1.0LL

(14): 0.784D+QX+1.6H+1.6H Seismic

(15): 0.784D+QY+1.6H+1.6H Seismic

(16): 0.784D+0.9F+W Seismic +QX

(17): 0.784D+0.9F+W Seismic +QY

DESIGN OF REINFORCED CONCRETE TANKS

(ACI 318 / ACI 350)

Recommended Reading:

A. Codes

1. ASCE7-05 - Minimum Design Loads for Buildings and other Structures

2. ACI 318-06 – Building Code requirements for Reinforced Concrete

3. ACI 350R – 06 – Environmental Engineering Concrete Structures.

B. Technical Literature

1. Munshi, Javeed A. Rectangular Concrete Tanks (Rev. 5th Ed.), Portland Cement Association, 1998.

2. Portland Cement Association, 1992. Underground Concrete Tanks

3. Portland Cement Association, 1993. Circular Concrete Tanks without prestressing

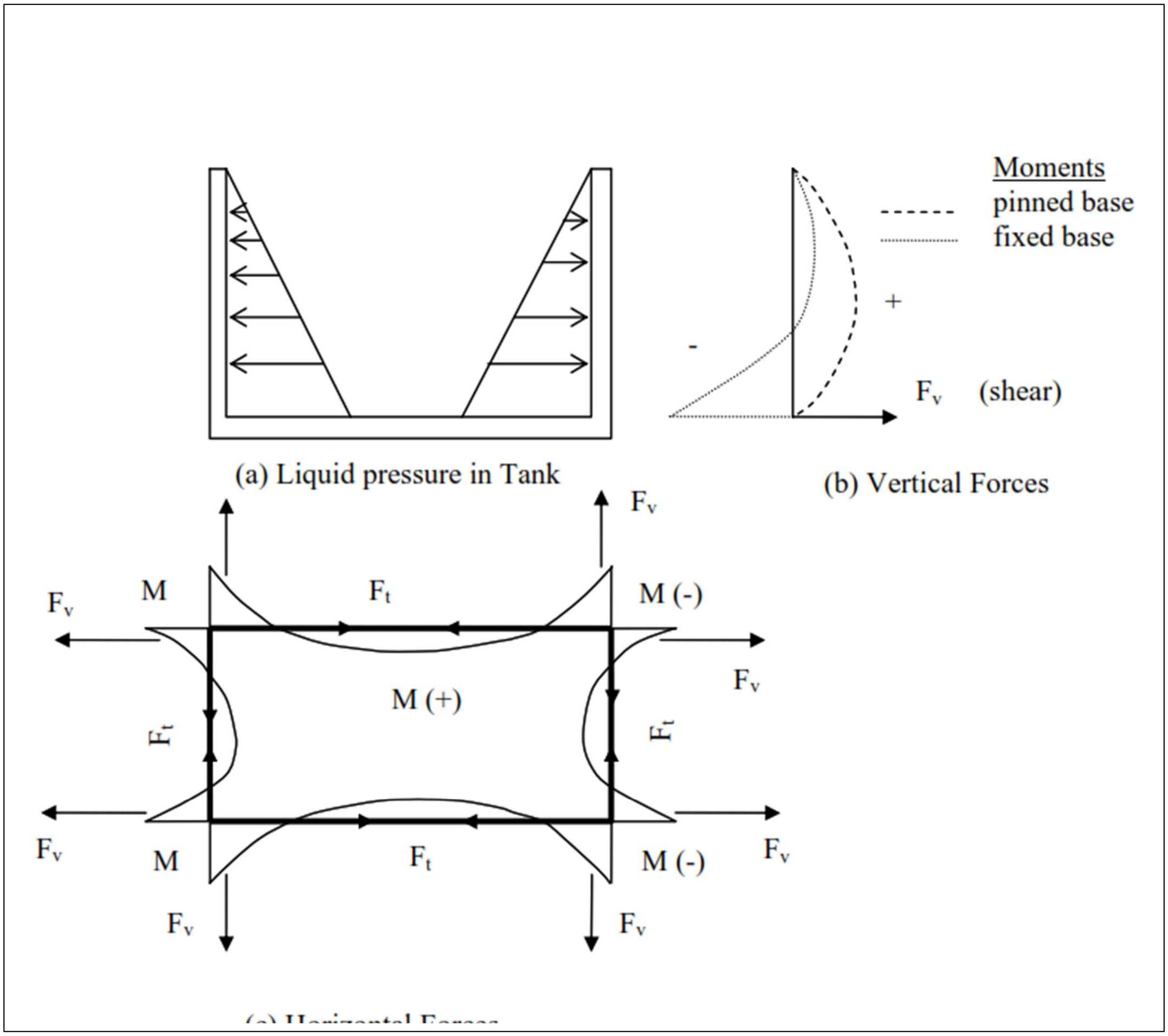
RECTANGULAR TANKS

Design Considerations

- Flexure – bending in walls and base
- Shear - wall-to-base, wall-to-wall junctions
- Tension - horizontal tension in walls, base
- Deflection – vertical/ horizontal deflections of wall
- Cracking - thermal, flexural, tension cracks
- Flotation - when base is located below water table level
- Base Fixity - (i) Fixed (ii) Pinned
- Both may need to be investigated

Loading Conditions

Condition 1 - Internal Water Pressure only (before backfilling, i.e. leakage test)
Condition 2 - External Earth Pressure only (before filling tank)
Condition 3 - Tank full and Soil backfilled (resistance provided by soil is ignored)



(a) Liquid pressure in Tank

(b) Vertical Forces

STRENGTH DESIGN METHOD

Basic Requirement:
Design Strength ≥ Required Strength

Ø(Nominal Strength) ≥ U
φR n ≥ U

(ACI 318 Sect. 9.2) U = 1.4 (D + F)…………. (2.1)

(ACI 350 cl. 2.6.5) U = 1.7 (D + F)…………...(2.2)

D = dead load
F = liquid pressure

Sanitary Durability Factors - ACI 350 applies sanitary durability factors (based on crack width calculations) to obtain the Required Strength

Required Strength = Sanitary Coefficient x U

$$U_r = C_s \times U \qquad (2.3)$$

Sanitary Coefficients are:

Cs = 1.3 (bending)

Cs = 1.65 (direct tension / hoop tension)

Cs = 1.3 (shear beyond shear capacity of concrete – stirrup design)

Cs = 1.0 (concrete shear)

Strength Design Requirements

(a) Flexural Reinforcement

Design Strength ≥ 1.3U

$$\phi M_n \geq 1.3(1.4M_D + 1.7\,M_L + 1.7\,M_F) \qquad (2.4)$$

(b) Direct Tension Reinforcement

Design Strength ≥ 1.65U

$$\phi N_n \geq 1.65(1.4N_D + 1.7N_L + 1.7N_F) \qquad (2.6)$$

(c) Stirrup Shear Reinforcement

Design Strength ≥ 1.3 (Vc - ØVc)

$$\phi V_s \geq 1.3\,(V_u - \phi V_c) \qquad (2.7)$$

(d) Concrete Shear and Compression Reinforcement

Design Strength ≥ 1.0 U

$$\phi V_n \geq 1.0V_u \qquad (2.8)$$

(e) Minimum reinforcement (ACI 318-05 cl. 10.5)

$$A_{s,\,min} = \frac{\sqrt[3]{f_c'}}{f_y} b_w d \geq 200\frac{b_w d}{f_y} \qquad (2.9)$$

Concrete sections with t ≥ 24″ use

(f) Minimum cover = 2 in.

(g) Minimum thickness for walls over 10 ft. high = 12 ins.

Serviceability for Normal Sanitary Exposure (ACI 350, cl. 2.6.6)

Crack Control Maximum Design crack width

- Severe exposure = 0.010 in.
- Aesthetics = 0.008 in.

Crack width calculation is based on the following equation:

Where, $z = f_s \sqrt[3]{d_c A}$ (2.10)

Z is a quantity limiting distribution of flexural reinforcement (ACI 350 limits)
$z \leq 115$ kips/in (crack width = 0.010 in)
$z \leq 95$ kips/in (crack width = 0.008 in)
fs = calculated stress in reinforcement at service loads, ksi dc = concrete cover to centroid of closest rebar
A = effective area of concrete surrounding flexural reinforcement with same centroid divided by the number of bars, in2.
The maximum spacing it given by,

$$b_w = \frac{Z^3}{2d_c^2 f_s^3} \quad (2.11)$$

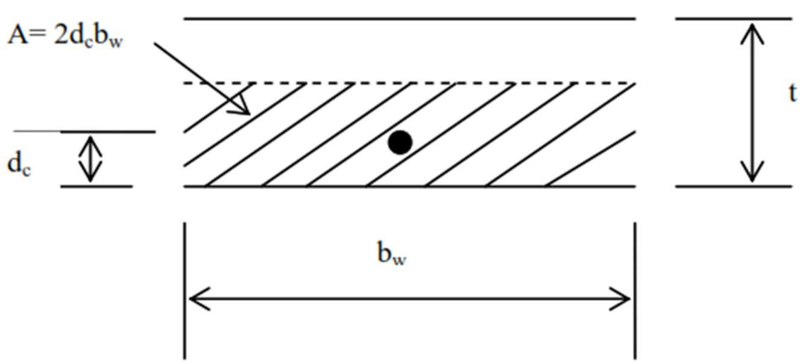


Fig. 1.0 - Calculation of A