Reinforced Concrete Tanks

1-Definition

The tanks are containers used to store water, chemical liquids, petroleum and similar liquids.

2-Types of Tanks

2-1-Based on Placement of Tank

1-Tanks resting on ground.

2-Underground tanks.

3-Elevated tanks.



Figure (1) Tank resting on ground, Underground tank and Elevated tank.

2-1-Based on Shape of Tank

1-Circular (For bigger capacities we go for circular tanks).
2-Rectangular (For smaller capacities we go for rectangular tanks).
3-Spherical.
4-Intze (constructed to reduce the project cost because lower dome in this construction resists horizontal thrust).
5- Conical Bottom.

Note:

Tanks resting on ground and Underground may have flat bottom slab, while Elevated ones may have flat or conical bottom.

Figure (2) Spherical tank, Intze tank and Conical bottom tank

2-3 Based on Construction Materials

1-Wood.

2-Reinforced Concrete (Non-prestressed).

3-Prestressed Concrete (For bigger tanks, prestressing is the superior choice resulting in a saving of up to 20%).

4-Steel (for crude oil, petroleum products and similar liquids).

5-Galvanized Steel (for water).

3-Components of Tanks

The main components of tanks are:-

1-Side walls.

2-Base slab (Considered as a foundation for resting on ground and underground tanks).

3-Roof slab (If any, sometimes the tank is opened).

4-Columns and Bracing (For elevated tanks).

5- Foundation (For elevated tanks).

4-Design Loads

The main design loads can be determined from:-

1-Internal liquid pressure, (for all types of tanks), (depends on the depth (H_{Liquid}) and unit weight of retained liquid (γ_{Liquid})).

2-External soil pressure, (for underground tanks), (depends on the depth (H_{Soil}) and unit weight of soil (γ_{Soil})).

3- Surcharge (Construction) load, (for underground tanks), (depends on the surcharge (Min. 5 kN/m^2)).

Surcharge refers to the vertical pressure or any load that acts over the ground surface. It is called as **surcharge** load. If a **surcharge** load is located closer to the excavation, pressure in the lateral direction will be created and it will act over the system.

4-Wind load, (for elevated tanks), (depends on the tank height (h) and intensity of the wind (w_s)).

5-Cases of Loading

5-1- Tanks resting on ground.

Case-1-Tank is empty→ Not critical case (neglected).

Case-2- Tank is full→ Governs (control).

5-2-Underground tanks.

Case-1-Tank is empty without backfill→ Not critical (neglected).

Case-2- Tank is full without backfill → To be checked, more critical case.

Csae-3- Tank is empty with backfill→ To be checked.

Csae-3- Tank is full with backfill→ To be checked, but not critical case.

6-Analysis Methods

There is several analysis methods are performed to analyze RC tanks such as:-

1-Bending Theory

2-Plate Load theory.

3-Finite Element analysis.

4-Approximate Method.

The commonly used method of analysis is “Approximate Method” which will be adopted in current course.

Characteristics of Material:

According of ACI 350:
$f'c \geq 30MPa$ for severe conditions
$f'c \geq 24MPa$ for normal conditions
$\gamma c=25$ kN/m^3
Concrete cover = 40mm
Cement Content:
Min.= 300-325 kg/m^3
Max.= 400 kg/m^3
W/C ratio =0.45
$Ec=4700\sqrt{f'c}$ MPa
fy= 275-420 MPa
Es= 200000 MPa
$\gamma brick=19$ kN/m^3
$\gamma soil=18$ kN/m^3
$\gamma w=10$ kN/m^3
Ko= 0.34 lateral coefficient of preasure
Factor of safety = total weight of empty structure (Ps)/ Uplift force due to ground water (Pf)
$F.S \geq 1.15$

7-Design of Rectangular Tanks

The walls of rectangular tanks are subjected to bending moments both in horizontal as well as vertical directions. The magnitudes of bending moment depend upon several factors such as length (L), breadth (B) and height (H) of the walls besides the end conditions at top and bottom ends of the walls (Free, Hinge or Fixed).
If the length of the wall (L) is greater in comparison to the height of the wall (H), bending moment will be mainly due to cantilever action, about the floor slab.

If, however, the height (H) is large in comparison to length (L), moments will be mainly in horizontal direction and the wall will bend as a thin vertical slab supported at the corners of the tank.
Length and breadth ratio (L/B) of the tank, also affects, the bending pattern of the tank walls.

If the ratio of the length of the tank (L) to its height (H) is equal or greater than (2), the long walls are designed as cantilever slab fixed at the base, while short walls are designed as horizontal slabs spanning between the long walls. Walls whose lengths (L) are equal to or less than their height (H) also come under this category.
Therefore, generally, the design of walls by approximate method is broadly classified into
two categories:-

1-Tanks having ratio $L/B < 2$
2-Tanks having ratio $L/B > 2$

7-1-Design of Rectangular Tanks having ratio L/B <2

In this case, tank is designed as a horizontal slab all around (between corners) and subjected to triangular load due to hydrostatic pressure from (0) at top to (H/4) or (1m) above the base (whichever is more).

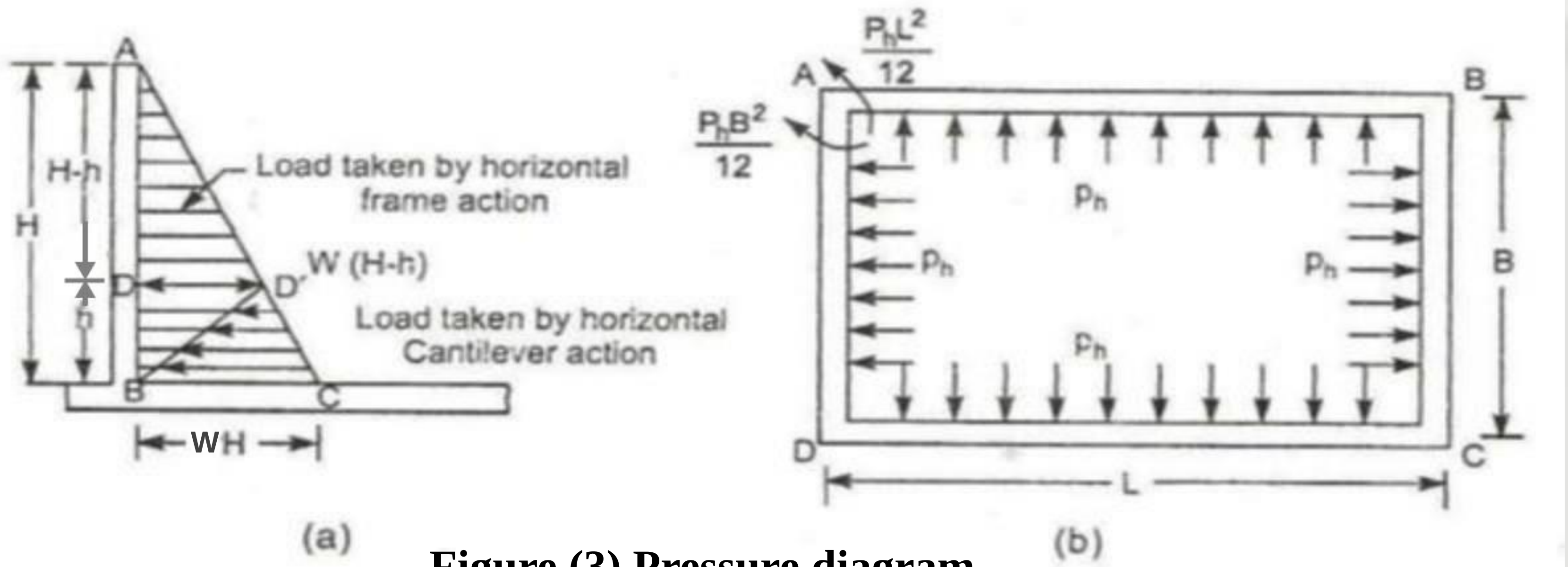

Figure (3) Pressure diagram

1-From bottom junction to height of (h=H/4 or h=1m) (whichever is more), the wall is treated as a vertical cantilever fixed at base.

2-Maximum Pressure [p_h=w(H-h)] at point (D), where (w=water unit weight).

3-Maximum Cantilever Moment {M=[1/2*(wH)*h] (h/3)}at distance (h/3) from the base.

4-The pressure (p_h) is resisted by the closed frame action of tank.

5-The Fixed End Moments at point (A) are ($p_h B^2/12$) and ($p_h L^2/12$). Using moment distribution method, they can be balanced.

7-1-1-Pull on Long Walls

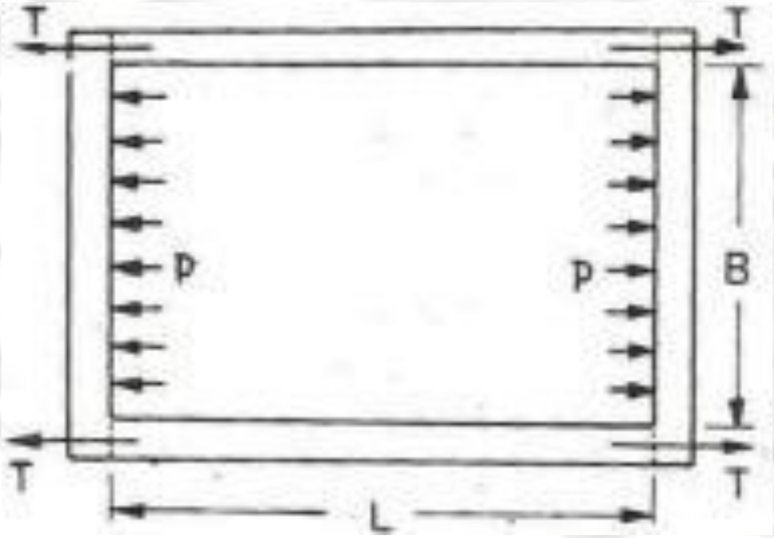

Figure (4) Pressure causing pull on long walls

Since the short walls span backed with Long walls, above D, the water pressure on short walls gets transferred to Long walls as Tension.

1-Total Tension= w (H-h)*B
2-Pull on each Long wall (T_L)
3-T_L= (1/2) w (H-h) B

7-1-2-Pull on Short Walls

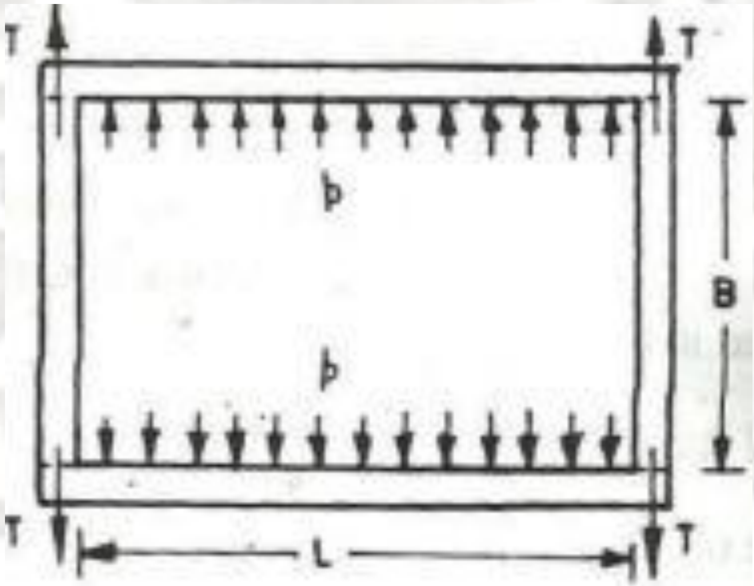

Figure (5) Pressure causing pull on short walls

In the similar fashion, long walls support the short walls and water pressure gets transferred to short walls as Tension (pull).

1-Total Tension= w (H-h)*L
2-Pull on each short wall (T_B)
3-T_B = (1/2) w (H-h).L

7-2-Design of Rectangular Tanks having ratio L/B >2

In this case, the Long walls are treated as vertical cantilever fixed at base and short walls are treated as Horizontal slabs (bending horizontally) between Long walls.

7-2-1-Bending Moment

1-Maximum B.M in long walls= $(1/2)wH*H*(H/3) = wH^3/6$

2-For short walls, Maximum BM may be taken as:

a) BM at ends of span= $[w(H-h)B^2]/12$

b) BM at center of span= $[w(H-h)B^2]/16$

7-2-2- Pull on Long and Short Walls

1-Pull on Long wall (T_L)= $0.5w(H-h).B$

2-Pull on Short Wall (T_B)= $w(H-h)*1$

Due to monolithic construction, it is assumed that water pressure on about (1m) of long wall adjacent to corner causes Tension in short wall.

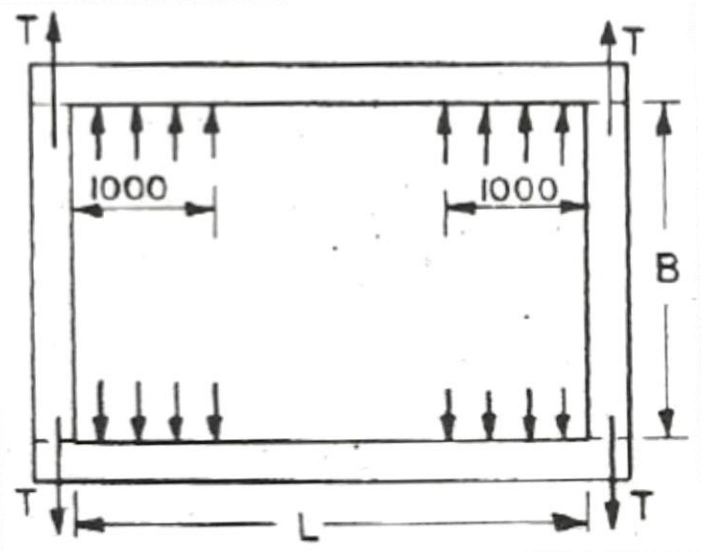

Figure (6) Pressure causing pull on short walls