Design of Rectangular Concrete Tanks

RECTANGULAR TANK DESIGN

- The cylindrical shape is structurally best suited for tank construction, but rectangular tanks are frequently preferred for specific purposes
  - Easy formwork and construction process
  - Rectangular tanks are used where partitions or tanks with more than one cell are needed.

RECTANGULAR TANK DESIGN

- The behavior of rectangular tanks is different from the behavior of circular tanks
  - The behavior of circular tanks is axi-symmetric. That is the reason for the analysis to use only unit width of the tank
  - The ring tension in circular tanks was uniform around the circumference

RECTANGULAR TANK DESIGN

- The design of rectangular tanks is very similar in concept to the design of circular tanks
  - The loading combinations are the same. The modifications for the liquid pressure loading factor and the sanitary coefficient are the same.
  - The major differences are the calculated moments, shears, and tensions in the rectangular tank walls.

RECTANGULAR TANK DESIGN

- The requirements for durability are the same for rectangular and circular tanks.
- The requirements for reinforcement (minimum or otherwise) are very similar to those for circular tanks.
- The loading conditions that must be considered for the design are similar to those for circular tanks.

RECTANGULAR TANK DESIGN

- The restraint condition at the base is needed to determine deflection, shears and bending moments for loading conditions.
    - Base restraint conditions considered in include both hinged and fixed edges.
    - However, in reality, neither of these two extremes actually exist.
    - It is important that the designer understand the degree of restraint provided by the reinforcing bars that extends into the footing from the tank wall.
    - If the designer is unsure, both extremes should be investigated.

RECTANGULAR TANK DESIGN

- Buoyancy forces must be considered in the design process
  - The lifting force of the water pressure is resisted by the weight of the tank and the weight of soil on top of the slab

- Plate Analysis Results
  - This chapter gives the coefficients of deflections ***Cd***, Shear ***Cs*** and moments (***Mx, My, Mxy***) for plates with different end conditions. Results are provided from FEM analysis of two dimensional plates subjected to our-of-plane loads.
  - The Slabs was assumed to act as a thin plate.
  - For square tanks the moment coefficient can be taken directly from the tables in chapter 2.
  - For rectangular tank, adjustments must be made to account for redistribution for bending moments to adjacent walls.
  - The design coefficient for rectangular tanks are given in chapter3

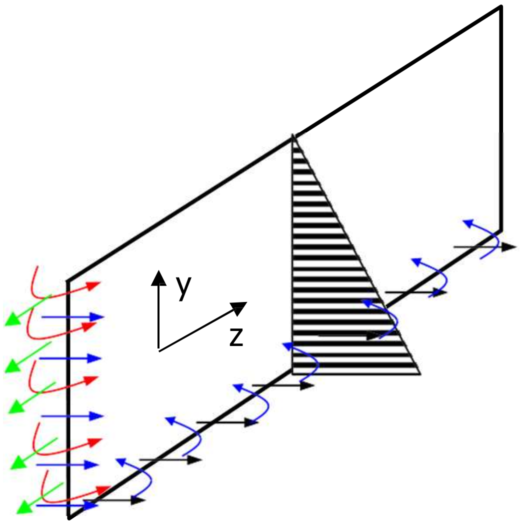
- Tank Analysis Results
  - This chapter gives the coefficients of deflections ***Cd*** and moments (***Mx, My, Mxy***). The design are based on FEM analysis of tanks.
  - The shear coefficient ***Cs*** given in chapter 2 may be used for design of rectangular tanks.
  - The effect of tension force, if significant should be recognized.

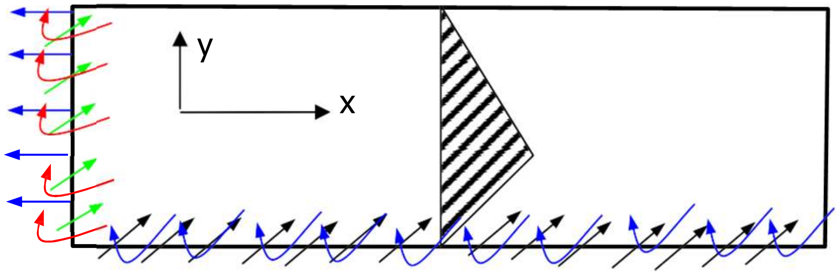
RECTANGULAR TANK BEHAVIOR

M_x = moment per unit width about the x-axis stretching the fibers in the y direction when the plate is in the x-y plane. This moment determines the steel in the y (vertical direction).

M_y = moment per unit width about the y-axis stretching the fibers in the x direction when the plate is in the x-y plane. This moment determines the steel in the x or z (horizontal direction).

M_z = moment per unit width about the z-axis stretching the fibers in the y direction when the plate is in the y-z plane. This moment determines the steel in the y (vertical direction).





RECTANGULAR TANK BEHAVIOR

- ***M_{xy} or M_{yz}*** = torsion or twisting moments for plate or wall in the x-y and y-z planes, respectively.

- All these moments can be computed using the equations
  - $M_x=(M_x \text{ Coeff.}) \times q\, a^2/1000$
  - $M_y=(M_y \text{ Coeff.}) \times q\, a^2/1000$
  - $M_z=(M_z \text{ Coeff.}) \times q\, a^2/1000$
  - $M_{xy}=(M_{xy} \text{ Coeff.}) \times q\, a^2/1000$
  - $M_{yz}=(M_{yz} \text{ Coeff.}) \times q\, a^2/1000$
- These coefficients are presented in Tables of Chapter 2 and 3 for Square and rectangular tanks
- The shear in one wall becomes axial tension in the adjacent wall. Follow force equilibrium.

RECTANGULAR TANK BEHAVIOR

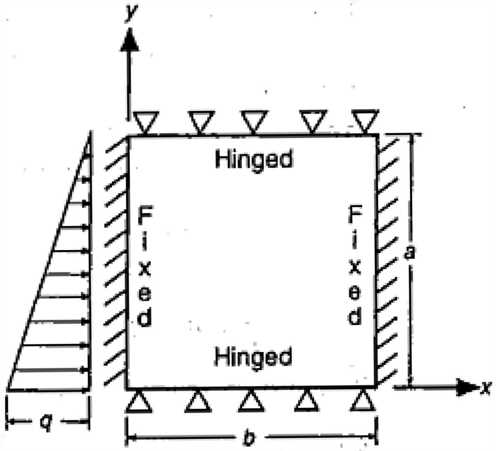
- The twisting moment effects such as M_{xy} may be used to add to the effects of orthogonal moments M_x and M_y for the purpose of determining the steel reinforcement
- The Principal of Minimum Resistance may be used for determining the equivalent orthogonal moments for design
  - Where positive moments produce tension:
    - $M_{tx} = M_x + |M_{xy}|$
    - $M_{ty} = M_y + |M_{xy}|$
    - However, if the calculated $M_{tx} < 0$,
      - then $M_{tx}=0$ and $M_{ty}=M_y + |M_{xy}^2/M_x| > 0$
    - If the calculated $M_{ty} < 0$
      - Then $M_{ty} = 0$ and $M_{tx} = M_x + |M_{xy}^2/M_y| > 0$
  - Similar equations for where negative moments produce tension

RECTANGULAR TANK BEHAVIOR

- Where negative moments produce tension:
  - $M_{tx} = M_x - |M_{xy}|$
  - $M_{ty} = M_y - |M_{xy}|$
  - However, if the calculated $M_{tx} > 0$,
    - then $M_{tx}=0$ and $M_{ty}=M_y - |M_{xy}/M_{2x}| < 0$
  - If the calculated $M_{ty} > 0$
    - Then $M_{ty} = 0$ and $M_{tx} = M_x - |M_{xy}/M_{2y}| < 0$

2 Plate Analysis Results

CASE 1



Shears & Deflections on page 2-5

Moments

b/a	page
4.0	2-6
3.0	2-6
2.5	2-7
2.0	2-7
1.75	2-8
1.50	2-8
1.25	2-9
1.0	2-9
0.75	2-10
0.5	2-10

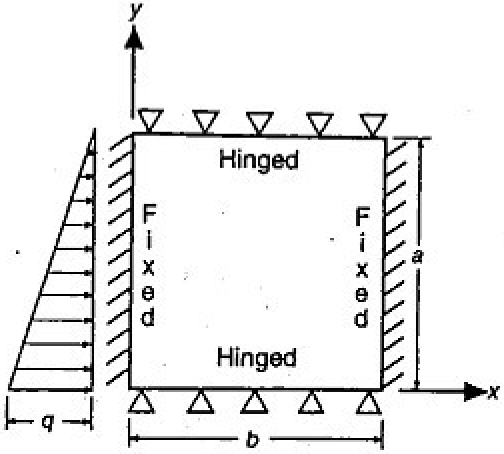
E : modules of elasticity
t : wall thickness
u: poisson ratio = 0.2

CASE 1

$$\text{Shear} = C_s \times q \times a$$

$$\text{Deflection} = \frac{C_d q a^4}{1000\,D}$$

$$D = \frac{Et^3}{12(1-\mu^2)}$$



Shear Coefficients, C_s

LOCATION \ b/a	4.0	3.0	2.5	2.0	1.75	1.5	1.25	1.0	0.75	0.5
Bottom edge — midpoint	0.33	0.33	0.32	0.30	0.28	0.26	0.23	0.20	0.16	0.11
Side edge — maximum	0.41	0.41	0.41	0.40	0.39	0.38	0.35	0.32	0.26	0.20
Side edge — midpoint	0.37	0.37	0.37	0.36	0.35	0.33	0.30	0.26	0.20	0.13
Top edge — midpoint	0.17	0.16	0.15	0.13	0.12	0.10	0.07	0.05	0.03	0.01

Deflection Coefficients, C_d

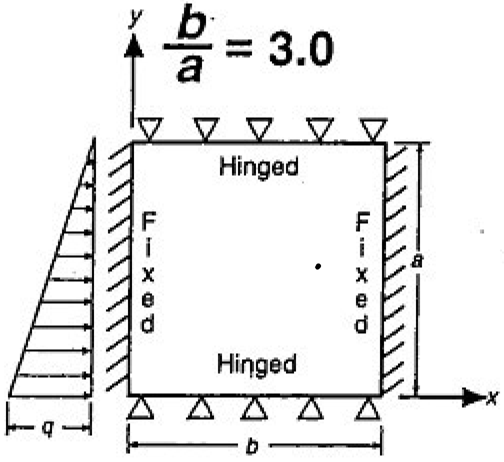
Along Midheight ($y = a/2$)

b/a \ x	END	0.1b	0.2b	0.3b	0.4b	0.5b
		0.9b	0.8b	0.7b	0.6b	
4.0	0	2.60	6.20	8.70	10.10	10.50
3.0	0	1.60	4.20	6.40	7.70	8.10
2.5	0	1.10	3.10	4.80	6.00	6.30
2.0	0	0.70	2.00	3.20	4.00	4.30
1.75	0	0.50	1.50	2.40	3.00	3.20
1.5	0	0.40	1.00	1.70	2.10	2.30
1.25	0	0.20	0.60	1.10	1.40	1.50
1.0	0	0.10	0.30	0.60	0.70	0.80
0.75	0	0.00	0.10	0.20	0.30	0.30
0.5	0	0.00	0.00	0.00	0.00	0.00

Along Midspan ($x = b/2$)

b/a \ y	BOT.	0.1a	0.2a	0.3a	0.4a	0.5a	0.6a	0.7a	0.8a	0.9a	TOP
4.0	0	2.10	4.00	5.30	6.10	6.30	5.90	5.00	3.60	1.90	0
3.0	0	2.00	3.70	4.90	5.70	5.80	5.40	4.60	3.30	1.70	0
2.5	0	1.80	3.30	4.50	5.10	5.20	4.90	4.10	2.90	1.50	0
2.0	0	1.50	2.70	3.60	4.10	4.20	3.90	3.30	2.30	1.20	0
1.75	0	1.20	2.30	3.00	3.40	3.50	3.20	2.70	1.90	1.00	0
1.5	0	1.00	1.80	2.40	2.60	2.70	2.40	2.00	1.40	0.70	0
1.25	0	0.70	1.20	1.60	1.80	1.80	1.60	1.30	0.90	0.50	0
1.0	0	0.40	0.70	0.90	1.00	1.00	0.80	0.70	0.50	0.20	0
0.75	0	0.20	0.30	0.40	0.40	0.40	0.30	0.20	0.20	0.10	0
0.5	0	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0

Moment coefficient for Slabs with various edge Conditions



Moment = Coef. × $qa^2/1000$

M_x	END	0.1b	0.2b	0.3b	0.4b	0.5b
		0.9b	0.8b	0.7b	0.6b	
TOP	0	0	0	0	0	0
0.9a	-3	3	9	12	14	15
0.8a	-6	6	17	24	28	29
0.7a	-9	9	25	35	39	41
0.6a	-11	11	31	43	49	51
0.5a	-12	14	36	49	55	57
0.4a	-13	16	38	51	57	59
0.3a	-12	17	37	48	53	55
0.2a	-10	15	32	40	44	45
0.1a	-6	11	20	24	26	27
BOT.	0	0	0	0	0	0

M_y	END	0.1b	0.2b	0.3b	0.4b	0.5b
		0.9b	0.8b	0.7b	0.6b	
TOP	0	0	0	0	0	0
0.9a	-16	0	4	5	4	4
0.8a	-32	0	8	9	8	8
0.7a	-45	0	11	13	12	11
0.6a	-56	0	14	15	14	14
0.5a	-62	1	16	17	16	15
0.4a	-64	2	16	17	16	16
0.3a	-59	3	15	16	15	14
0.2a	-48	4	12	12	12	11
0.1a	-28	3	7	7	7	7
BOT.	0	0	0	0	0	0

M_{xy}	END	0.1b	0.2b	0.3b	0.4b	0.5b
		0.9b	0.8b	0.7b	0.6b	
TOP	0	17	14	8	3	0
0.9a	0	17	14	8	3	0
0.8a	0	15	12	7	3	0
0.7a	0	12	9	5	2	0
0.6a	0	7	5	3	1	0
0.5a	0	2	1	0	0	0
0.4a	0	4	4	2	1	0
0.3a	0	10	8	5	2	0
0.2a	0	15	12	7	3	0
0.1a	0	20	14	8	3	0
BOT.	0	21	15	8	4	0