STRUCTURAL DESIGN - II

Design of Water Tanks

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WATER TANKS

Introduction

A reinforced concrete tank is a very useful structure that is meant for the storage of water, swimming, and other purposes. Water tanks are used in uncracked theory where concrete is not allowed to crack on the tension side which means tensile stress is kept within permissible tensile stress in concrete.

WATER TANK

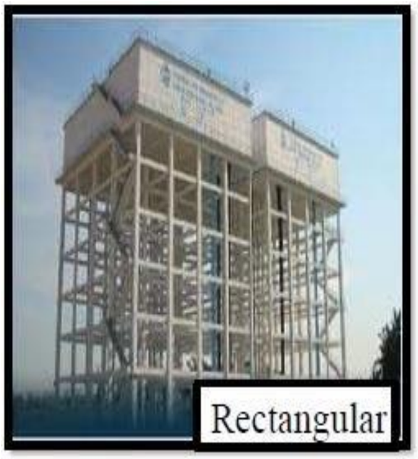
BASED ON PLACEMENT OF TANK

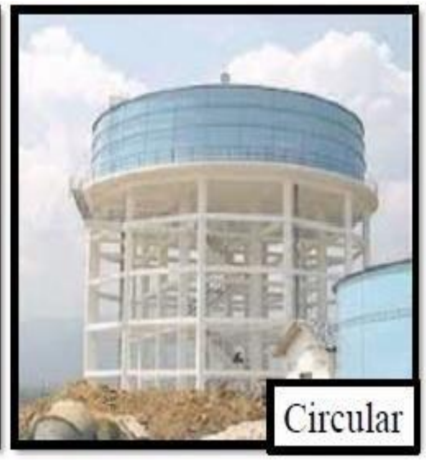
1. RESTING ON GROUND
2. UNDER GROUND
3. ELEVATED
4. INTZ
5. CONICAL BOTTOM
6. DOOMED BOTTOM

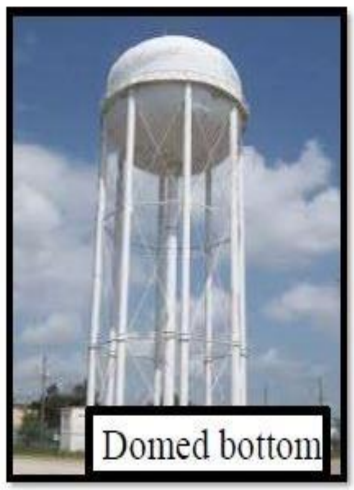
BASED ON SHAPE OF TANK

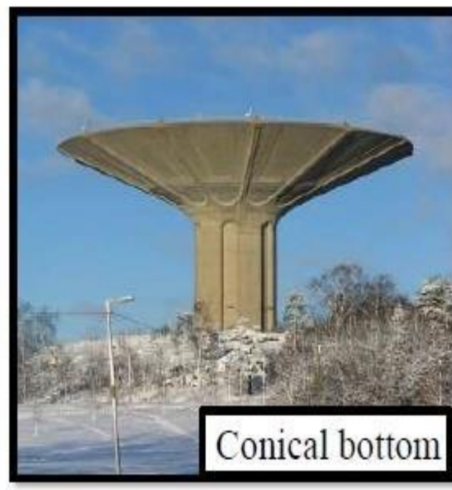
1. CIRCULAR
2. RECTANGULAR
3. SPHERICAL

Types of tanks based on shape



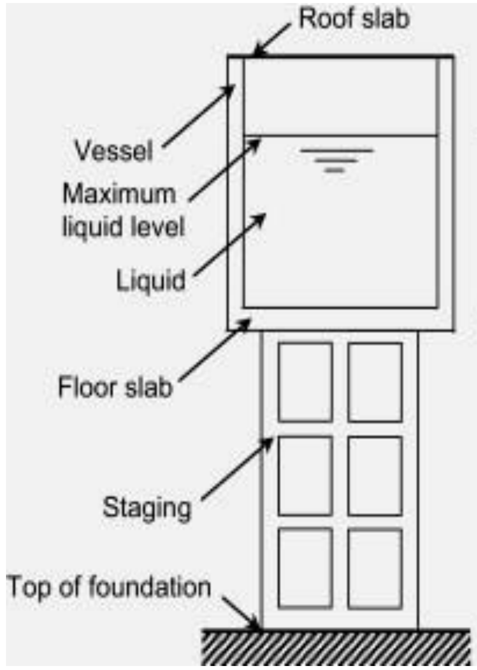






Rectangular Tank	Circular Tank	Intze Tank	Prestressed Tanks
For smaller capacities rectangular tanks are adopted	For bigger capacities circular tanks are recommended	Intze tank is constructed to reduce the project cost because lower dome in this construction resists horizontal thrust.	RCC tanks are cheaper only for smaller capacities up to 10-12 lakhs liters. For bigger tanks, prestressing is the superior choice resulting in a saving of up to 20%.

STAGING **-** It is required for tanks above ground level. It consists of column, braces and foundation. It is designed for gravity load due to water and self weight, wind load and earthquake load.



Stresses in concrete

Grade of Concrete	Permissible Stress in N/mm^2		Shear stress in N/mm^2
	Direct tension	**Tension due to bending**	
M_{15}	**1.1**	**1.5**	**1.5**
M_{20}	**1.2**	**1.7**	**1.7**
M_{25}	**1.3**	**1.8**	**1.9**
M_{30}	**1.5**	**2.0**	**2.2**
M_{35}	**1.6**	**2.2**	**2.5**
M_{40}	**1.7**	**2.4**	**2.7**

Permissible Stress

Sl. No.	TYPES OF STRESS	PERMISSIBLE STRESS in N/mm^2	
		Fe250	Fe415
1	Tensile stress in member under direct tension	115	150

2	Tensile stress in member in bending a)on liquid retaining face of member b)on face away from liquid for member less than	115	150
	225mm thick c)on face away from liquid for member greater than 225mm thick	115 125	150 190

Minimum area of steel =0.3% gross area

Cover = 25mm

ELEMENTS IN WATER TANK DESIGN:

1. Roof slab
2. Wall
3. Base slab

NOTE: walls and base slab comes under JOINTS which are of two types – RIGID and FLEXIBLE

THICKNESS OF WALL - Should not be less than

- 150 mm
- 30mm per metre depth +50mm
- Thickness required limiting the tensile stress in concrete to 1.3N/mm^2 (M_{20})

Circular tanks - Circular tanks on ground may be designed either with flexible connection of wall with base or with the rigid connection of wall with base in flexible connection the walls are not monolithic with base whereas in rigid connection walls are monolithic with base.

Circular tank with flexible joint between wall and base

The wall of such a tank will be designed as vertical cylinder subjected to water pressure. The intensity of water pressure at any depth h, ***p = wh*** units per unit area. The corresponding hoop tension per meter height,

T= (Wh*D)/2

Where ,

W= specific wt of water h=depth

D=diameter of tank

Problem (1) Design a circular tank resting on firm ground to the following particulars diameter of tank 3.5m, depth of water 3m, the wall and the base slab are not monolithic with each other. Specific weight of water is 9810 N/m^{3}. Use M_{25} grade concrete and Fe 415 steel bars

Step1: Given data

Diameter of tank=3.5m

Depth of water=3m

Specific wt of water =9810N/m^3

M_{25}

Step2: Thickness of wall

Should not be less than 150mm

30mm per meter depth + 50mm = (30*3)+50 =140mm

Provide a thickness of 150mm

Step3: Reinforcements

Consider the bottom 1m height of wall

Pressure intensity corresponding to centre of bottom 1m height of wall

P = Wh

=9810*2.5

=24525 N/m^2

Hoop tension /m, T =PD/2

= (2425*3.5)/2

= 42919 N

Steel required for 1m height (A_{st}) = T/(safe stress in steel) For Fe415 steel under direct tension, safe stress in steel = 150N/mm^2

A_{st} = 42919/150

= 237mm^2

Min steel required (A_{st} min) = 0.3% gross area (gross area=b*T

= (0.3/100) * 1000* 150

=450mm^2

Provide 10mm dia bars;

Spacing of 10mm dia bars = (1000*3.14*(10^2/4))/450

=174mm

Provide 10mm bars @ 170 mm c/c spacing

Vertical distribution steel = 0.3 % gross

=450mm^2

Step4: Base slab

Provide 150mm thick slab with top and bottom mesh with 10mm dia bars @250 mm c/c

Circular tanks with a wall retained at base (rigid) condition: in this case the wall will resist water pressure partly hoop action and partly by cantilever action at a certain height from the bottom there will be cantilever action and at a higher level hoop action

Methods to analyse

1. Dr. Reissners method
2. Carpenter's simplification of Dr. Reissners method
3. IS code

IS CODE

H^2/(D*t)

Hoop tension per metre height = coefficient * WHD/2 N

BM per metre run = coefficient * WH^3 N.m

Shear force at base of wall = coefficient * WH^2 N

Problem (2) Design a circular tank 12 m diameter of 4m height. The tank rest on firm ground and the walls of the tanks are retained (rigid) use M_{20} grade concrete and Fe 415 steel?

Solution:

Step1: given data

Diameter of tank =12m

Height of tank = 4m

Walls are retained at base

Step2: Thickness of wall

Should not be less than 150mm

30mm per metre depth +50mm = (30*4)+50 =170mm provide

Step3: reinforcement

Hoop tension (refer under 0.6 H)

$H^2/(D*t)$ $=4^2/(2*0.17)$

= 7.81

Coefficient under 0.6H

6 0.514 7.8 ? 8

0.575

Interpolate:

(0.514-(0.514-0.575)*(7.8-6)) / (8-6)

Coefficient for 7.8 = 0.57

Max hoop tension = coefficient*(W*H*D)/2

= (0.57*9810*4*12)/2

= $134.2*10^3$ N

A_{st} = T/ safe stress in steel

$=134.2* 10^3/150$

= $394.6mm^2$

Ast min =0.3% gross area

= (0.3/100)*1000*170

= $510mm^2$

Provide 10mm dia bars

Spacing of 10mm dia bars = $(1000 * 3.14 * (10^2/4)) / 894.6$

=87.99mm

Provide 10mm dia bars @100 mm c/c Cantilever action

(BM) at 1H:

$H^2/(D*t)$		1H	
6	-0.0187 7.8	?	
8		-0.0146	

Interpolate:

(- 0.0187-(-0.0187-(-0.0146))*(7.8-6) / (8-6) = -0.015 Maximum cantilever moment = Coefficient $*WH^3$

= $-0.015 * 98109 * 4^3$

=9417.6 N.m

A_{st} = BM/ (safe stress * 0.85d) (d=eff. Cover of 30mm provide)

= $9417.6 * 10^3 / (150*0.85*140)$

= $527.6 mm^2$

A_{st} min = 0.3/100 * 1000* 170

=$510 mm^2$

Provide 10mm dia bars

Spacing = $(1000*3.14*(10^2/4))/527.6$

=148mm c/c

Vertical steel distribution = 0.3% gross are

= $510 mm^2$

Step 4: Base slab

Provide 150mm thick slab with top and bottom mesh with 10mm dia bars @ 250mm c/c.

RECTANGULAR WATER TANK RESTING ON GROUND

Rectangular tanks are useful for smaller capacities and for large capacity circular water tank are preferred .let centre line dimension of the tank be (L*l) where,

L= long plan dimension

L=short plan dimension

i. If (L/l <2) the wall is designed as continuous horizontal slab subjected to a water pressure 'Wh 'per unit area.
ii. If (L/l >=2) the long walls are considered as vertical continuous cantilevering for the whole pipe from base. The short walls are considered as spanning between long wall at end taken as fixed.

PROBLEM 1 A reinforced concrete tank is 6m*3m with a max depth of 2.5m of water. The tank rest on ground 150m *150mm. splays are provided at the junction of walls and base slab.

Design a tank using M_{20} grade concrete and Fe 250 steel.

Solution:

Step1: given data

L=6m

L=3m

Depth of water =2.5m

150mm*150mm splays are provided

M_{20} fe415, L/l =6/3=2

Since the ratio is equal to 2, the long walls will be designed as vertical cantilever and short wall as spanning between the long walls

Step2: design of long wall

They are designed as vertical continuous since splays are provided effective height

Effective ht =2.5-0.15=2.35m

Max BM per metre width of long wall ***= (W*H^3)/6***

Where,

W= specific wt

$WH^3/6$ $= (9810*2.35^3)/6$

= 21219 N.m

This BM produces tension near water face

Moment of resistance (M.R)= Qbd^2

In code book

M_{20}**:** Fe 250; Q=1.33 &

M_{20}**:** FE415; Q=1.16

Equate BM to M.R

$21219*10^3$ = $1.33 *1000d^2$

D = 126mm (130mm)

Provide an effective cover of 30mm

Overall thickness of wall = 130+30 =160mm

A_{st} =BM/ (safe stress *0.85*d)

= $(21218* 10^3)/ (115*0.35*130)$

=$1670mm^2$

A_{st} min = 0.3% GA

= (0.3/100)*1000*160

=$480mm^2$

Provide 12mm dia bars

Spacing of 12mm dia bars = $(1000*3.14*(12^2/4))/1670$

=68mm

Provide 12mm dia bars @ 100 mm c/c

Pull in long wall for bottom 1m ht = (WHD)/2

= (9810*(2.35-1)*3)/2

=19865N

A_{st} = T/(safe stress)

= 19865/115

=$172mm^2$ (safe stress =$115N/mm^2$)

A_{st} min =$480 mm^2$

Spacing of 12mm dia bar = $(1000*3.14*(12^2/4))/480$

=235mm

Provide 12mm dia bars @ 100mm c/c.