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Design of R. C. C Overhead Water Tank

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ABSTRACT

The water tank is used to store water to tide over the daily requirements. Water tanks can be of different capacity depending upon the demand requirement of a municipal corporation. water which covers about 71% of the earth surface. This paper gives an overall designing procedure of an Overhead Circular tank using LIMIT STATE METHOD from IS-3370:2009. the crack width was also checked by a limit state of serviceability IS-3370: 2009. It was observed that in case of limit state design cost required is less. Obviously, the circular water tank is more economical compared to the square tank. This paper gives, the theory behind the design of a liquid retaining structure, Elevated circular water tank with a domed roof, circular wall, top ring beam, flat base slab, and bottom beam are design with limit state method.

Keywords: Economical Design, IS-3370:2009, Limit State Method, IS-456:2000, Circular Overhead Tank

I. INTRODUCTION

In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential Storage reservoirs and overhead tank are used to store water. This project gives in brief, the theory behind the design of liquid retaining structure,circular water tank with rigid base using limit state method.This report includes analyze and design circular water tank with rigid base.

Elevated water tanks are one of the most important lifeline structures in earthquake prone regions. In major cities and also in rural areas elevated water tanks forms an integral part of water supply scheme. This study presents the evaluation of seismic forces acting on elevated water tank e.g. circular water tank with frame staging affected by different parameters viz., seismic intensity, different wind speeds. Indian Standards for the design of liquid retaining structures have been recently revised in the year 2009. The earlier version allowed the design of water retaining structures by Working Stress Method only, But the revision of the code allows the Working stress method as well as Limit State method for designing RCC water tanks. Elevated tanks are supported on staging which may consist of masonary wallls, R.C.C. tower or R.C.C. columns braced together. The w alls are subjected to water pressure. the base h as to carry the load of water and tank load. The staging h as to carry load of water and tank. The staging is also designed for wind forces.

II. AIMS & OBJECTIVES

- To study the various forces acting on a water tank. Understanding the most important factors that plays role in designing of a water tank.
- To study the guidelines of design of water tank according to IS code and checking the design.
- To know about the design philosophies of water tank design.
- Preparing a water tank design which is economical and safe, providing proper steel reinforcement in concrete and studying its safety according to various codes.

III. MATERIAL & METHOD USE IN DESIGN

- We know that water is essential for every living thing and ground source of water are not easily available so water is stored in various type tank so for designing of tank required better serviceability.
- Dynamic analysis of liquid containing tank is a complex problem involving fluid-structure interaction.
- Concrete mix weaker than M-20 is not used because of higher grade lesser porosity of concrete.
- Minimum quantity of cement in concrete shall be not less than 30 KN/m3
- Coefficient of expansion due to temperature=11×10-6/˚C
- Coefficient of shrinkage may be taken = 450 × 10-6 for initial and 200 × 10-6 for drying
- Minimum cover to all reinforcement should be 20 mm or the diameter of main bar whichever is greater.
- An overhead liquid retaining structure is design using LIMIT STATE METHOD
- Avoiding the cracking in the tank and to prevent the leakage and the component of tank can be design using LIMIT STATE METHOD (example:- column, bracing, circular wall etc.). Code using IS: 3370-PART 2-2009
- IS: 456:2000

A. Design requirement of Concrete Structures

In water retaining structures a d ense impermeable concrete is required therefore, proportion of fine and course aggregates to cement shoul d be such as to give high quality concrete. Concrete mix weaker than M20 is not used. The minimum quantity of cement in the concrete mix shall be not less than 300 kg/m^3.The design of the concrete mix shall be such that the resultant concrete is sufficiently impervious. Efficient compaction preferably by vibration is essential. The permeability of the thoroughly compacted concrete is dependent on water cement ratio. Increase in water cement ratio increases permeability, while concrete with low water cement ratio is difficult to compact. Other causes of leak age in concrete are defects such as segregation and honey combing. All joints should be made water tight as these are potential sources of leakage.The design and construction of container for storage of liquid have been covered by IS 3370 (Parts 1 to 4), and this standard lays down the principles of design of staging for elevated liquid tanks All requirements of IS 456, IS 3370 (Part 1), IS 3370 (Part 2) and IS 1893 Part 2 in so far as they apply, shall be deemed to form part of this standard except where otherwise laid down in this standard. Design report containing basis of design, method of structural analysis, detailed computation of loads, structural analysis, design calculations with sizes of members and reinforcement.

B. Design With Member Analysis

In the membrane analysis the member are assumed to act independent of the others.

Hence individually all components of the structure are designed.

The design of membrane analysis is carried as follows,

Consider, M30 concrete

HYSD Fe 415 bars

Intensity of wind pressure = 1200N/m^2

Thickness of dome = 100mm

Bearing capacity = 180 KN/m^2

Let the diameter of cylindrical portion D = 15.91 m

R = 7.95, h = height of cylindrical

Rise h_1 = 1.98 m

Required volume = 1900 m^3

h = 9.54 m

Allowing for free board; h = 0.3 m For top dome, the radius R_1;

By property of circle R_1 = 15.82m

DESIGN OF TOP DOME

R_1 = 15.82 m

Let thickness t_1 = 100 mm = 0.1m

Semi central angle(ɵ)= 30.18^0 Taking Live load = 1.5 KN/m^2

Taking Dead load= 0.1× 25

Pressure on top of dome p = 0.1 × 25000 + 1500

P = $4000N/m^2$ Meridional thrust at edge

T_1 =W×R/ 1+cosɵ

T_1 = 33.94KN

Meridional stress =M.T/b. t = $33.94\times10^3/1000\times100$

σ =0.34 < $5N/mm^2$ (safe), since stresses are within safe limit, provide nominal reinforcement @ 0.3%

Ast= $300mm^2$

Provide 8mmØ steel bars at spacing 160mm

Both circumferentially & meridionally

Design of Ring Beam

Calculation for hoop tension in ring beam

Hoop tension = [meridional thrust] cosɵ× D/2

τ = 33.94×cos[30.18] ×15.19/2

τ = 233.39 KN

Calculation for area of main reinforcement

Ast = $233.39\times10^3/150$

Ast = 1555.93 mm^2

Provide 4nos of steel bar [two at top and two at bottom]

Ø = 25mm

Provide 4bars

Ast =1963.49mm^2

Calculation for size of ring beam

Hoop Tension /b^2 + (m-1) ×Ast. provided

1.2= $233.39\times10^3/b^2$ + (13.33-1) ×1963.49

b=300m provide ring beam of size 300×300mm & 8 mm Ø stirrups at 200mm c/c

Design of circular wall

T = 30H+50

T = 400mm

Calculation for maximum hoop tension

H^2/D.T = $9.84^2/15.91\times0.345$

Hoop tension =17.64

maximum hoop tension coefficient from table

0.68 at 0.7H

maximum hoop tension = coefficient × w.h × D/2

Hoop tension= 0.68×10×7.84×15.91/2

Hoop tension =532.285 KN

Calculation for maximum B.M

H^2/D.T = 17.64

Maximum B.M coefficient from table (10) IS3370

Coefficient = - 0.0079

Maximum B.M = Coefficient × W × H^3

B.M = $0.0079\times10\times9.84^3$

B.M = 75.26 KN.m

B.M = 75.26×10^6 N.mm

Check for hoop tension

Ast for hoop tension = Hoop tension/

τ = $532.28\times10^3/150$

Ast = 3548.53mm^2

τ = Hoop tension/b.T+(M-1)Ast

τ = $532.28\times10^3/1000\times400$+(13.33-1) ×3348.53

τ = 1.36 N/mm^2 >1.2 N/mm^2 (hence unsafe)

τ =1.19 > 1.2 N/mm^2 (hence safe)

Check for thickness of wall from B.M criteria

Neutral axis constant (k) = 1/1+

k=1/1+150/13033×7

lever constant (j) =1-k/3

j =1-0.38/3

j =0.87

j = 7×0.38×0.81/2

j = 1.16

B.M = Q.b.t^2

75.26×10^6 = 1.16×1000×t^2

t = 254.71 < t

t = 254.71 < 360mm (hence ok)

This provide T = 400

T = 360mm

Design of Reinforcement (Ast)

To Find Minimum R/F for T=400mm

Using IS 456:2000

Y= 0.17%, Interpolation

Ast_{min} = 0.17%.b.T

Ast_{min} = 680mm^2

To Find A_{st} For Hoop Tension (i.e. ring reinforcement)

A_{st} = Hoop Tension /σ_{st} =$532.28\times10^3/150$

A_{st}= 3548.53mm^2 >$A_{st\ min}$

Provide hoop tension on both face of tank

Hence, A_{st} for each face =1774.25mm^2

Let us provide 12mm ring bars

Spacing =60mm

Thus provide 12mm ring @50mm c/c on each face

To Find A_{st} For B.M (i.e. vertical steel bar for cantilever

At Inner Face A_{st} = B.M / σ_{st}. j × t

A_{st}=75.26×10^6/150×0.8×360 =1601.95mm^2

Povide this steel at inner face only using 12mm of vertical steel bars 70mm c/c

Thus provie 12mmØ vertical steel bar @30mm c/c

At outer face, distribution reinforcement

A_{st}=$A_{st\ min}$=680/2=340mm^2 Spacing =100mm

Tank Floor Slab

Tank floor slab in circular and fixed at the periphery to the circular ring beam

Load on the circular slab =W

W= (weight of water)+(self weight of slab assume as 400mm thickness)

W= (10×9.84) + (0.4×25)

W= 98.4+10

W=108.4 KN/m^2

Max. radial and circumferential moment

Positive moment at centre of span is M_{rp}

M_{rp} = (3/16 W.r^2) =1284.59 KN.M

-tive moment at support

Mm = (W.r^2/16) = (108.4×7.95^2/8)=856.39KN.M

Circumferential moment is given by the relation

M_c= (W.r^2/16)=108.4×7.95^2/16=428.19KN.M

Effective depth of slab is given by d

Depth = $\frac{\sqrt{M}}{Qb} = \frac{\sqrt{1284590000}}{1.009\times1000}$ =1128.33mm

Adopt depth =1150mm

Reinforcement in circular slab

Ast (centre of span) =[1284.59×10^6/190×0.89×1150]

Ast =6605.76mm^2

Ast (support) =[856.39×10^6/150×0.89×1150]

Ast =5578.18mm^2

Ast (circumferential moment) = 428.19×10^6/150×0.88×270

Ast =12014.31mm^2

Provide 25mmØ bars at 70mm c/c, length 4m from support at top radically & circumferentially.

Bottom beam

Total load on bottom beam

Weight of water = 1000KN

Load from dome = 2πR.r.w

= 399.86KN

Weight of top ring beam = 0.30×0.40×25×π×16.31

= 512.63KN

Weight of cylindrical wall =π×16.31×0.4×9.54×25

= 4888.24K

Weight of floor slab = π7.35×0.4×25

= 249.76KN

Weight of bottom beam = 0.4×0.6×π×16.31×25

= 768.60KN

Total vertical load = 7819.15KN

= W/π. D =7819.15/π×16.31

= 152.60KN/M

Moment and shear force in beam

+ve B.M of support = 0.00148W.B

= 920kN.M

Live B.M of centre of support = 0.0075W.R

= 466.21kN.M

Torsion moment = 0.0015WR

= 93.24kN.M

Shear force at support = v

v = total load/2×no.of column

v = 7358/2×21

v = 186.17KN

Shear force at section of maximum tension is given by

V = [175.19-143.60×7.95×π×12.79/180]

= 83.37KN

Design of support section

Bending moment (M) = 920KN.M

Shear force (V) = 83.31 KN.M

Effective depth = $\sqrt{\frac{M}{\emptyset}}$1159.75mm

Adopt (d) = 1200mm

Overall depth = 1250mm

Ast = $\frac{920\times10^6}{150\times0.88\times1200}$= 5808mm^2

Provide 8mm bar of 32mm Ø

Ast = 6434mm^2

Spacing at 120mm

$\tau = (\frac{v}{b.d}) = \frac{186.17\times10^3}{600\times1200} = 0.25\ \frac{N}{mm^2}$

$(\frac{100Ast}{b.d}) = (\frac{1000\times6434}{600\times1200}) = 0.89$

From table no.23 IS 456:2000

$\tau_v = \tau_e$

provide minimum shear reinforcement

$\frac{Asv}{bsv} \geq \frac{0.4}{0.87fy}$

provide minimum shear reinforcement

$\frac{Asv}{600} \geq 1.10\times10^{-3}$

$0.3 \geq 1.10$

Design of centre at span section

Bending moment (M) = 466.21KN.m

Ast = $(\frac{466.21\times10^8}{190\times0.89\times1200})$ = 2297.50mm^2

Minimum quantity of steel is obtained

Ast = $(\frac{0.85b.d}{fy}) = (\frac{0.85\times600\times1200}{415})$

Ast = 1474.70mm^2

Provide 3 bar of 32 mm Ø (Ast = 2412.74mm^2)

Design of section subjected to maximum tension and shear

Torsion moment (T) = 93.24 KN.M

Shear force (V) = 83.37 KN.M

Bending moment (M) = 0

Overall depth (D) = 1250mm

Width of section (b) = 600mm

Ms = T$(\frac{1+(\frac{D}{b})}{1.7})$ = 93.24 $(1 + \frac{(\frac{12500}{600})}{1.7})$

= 96.32KN.m

Me = (M + Ms) = (0+96.32) = 96.32KN.M

Ast = $(\frac{96.32\times10^6}{190\times0.890\times1200})$ = 474.67mm^2

But minimum reinforcement is 1474.70mm^2

Provide 3 bar of 32mm Ø

Ve=V+1.6 (T/b)

Ve=332.01KN

τ=0.46

As per Ast =0.20= 0.20<0.46

Hence shear reinforcement are required use 12mm two legged stirrups with side cover of 25mm &50mm at top and bottom

Supporting Tower

Loads on Column

total load from ring beam=7819.15KN

total load on each column=7819.15/21 =372.34KN

self weight of column= 0.28×25×30=210KN

taking dia. of column=600mm^2

area =0.28m

self weightof braces=4×0.30×0.450×25×7.95=107.33KN

total axial load on each column = tank empty=619.67-1000/21

=229.21KN

tank full condition= on each column=372.34+14+107.33

=619.67KN

Size of bracing = (0.30×0.45)

Wind force

Intensity of wind pressure = 1.5 $\frac{KN}{m^2}$

Reduction coefficient for circular shape = 0.7

Wind force on top of dome and cylindrical wall (including bottom ring beam)

= 0.7×1.5×11.74×16.71

= 205.98KN

Wind force in column = 21×0.6×30×1.8

= 680.4 KN

Wind force on braces = (4×16×0.45×1.5) = 43.2 KN

Total horizontal wind force = (205.98+378+43.2) = 627.18 KN

Assuming contra flexure point at mid height of column and fixity at the base

The moment at the base of column is obtained

M = (0.5×625.18×4.4) =1379.78 KN.M

M_1= moment at the base of column due to wind load

M_1= (205.98×31.74) + (378×21) + (43.2×21)

M_1=15383 KN. M

V = Reaction developed at base of exterior column

$$M_1 = \sum M + \frac{v}{r_1}\sum r^2$$

r_1 = 7.95cos30^0= 6.88 m

r_2 = 4.4× (6.88) = 208.27

15383 = 1379.78 + $(\frac{v}{6.88})$× 208.27

V = 462.58 KN

Total load on column at base is obtained as

P = (619.67 + 462.58) = 1082.25 KN

Moment in each column at base is

M = 1379.78/21 = 65.70 KN.M

Eccentricity = e = (M/P) =$(\frac{65.70\times10^6}{1082.25\times10^3})$

e= 60.70 mm

Since, eccentricity is small direct stresses are predominant using 6 bars of 25mmØ equally spaced on all face

A_{sc} = (6×490.87) = 2945.24 mm²

A_c = (282743.34 – 2945.24) + (1.5×20×2945.24)

A_c = 368155.3 mm²

$I_e = (\frac{\pi}{64} \times d^4) + (2\times1.5\times20\times3\times490.87\times150^2)$

$I_e = 1.988\times10^9$ mm⁴

Direct compressive stress = $6_{cc} = (\frac{1082.25\times10^3}{368155.3})$

= 2.94 N/mm²

Bending stress = $6"_{cb} = (\frac{65.70\times10^6\times200}{1.988\times10^9})$

= 6.60 N/mm²

Permissible stress in concrete is increased by 33.33 percent while considering wind effects

Hence, $(\frac{6"_{cc}}{6_{cc}} + \frac{6"_{cb}}{6_{cb}}) < 1$

Condition is not safe

Increase diameter by 100 mm

Adopt 700mm diameter of column and 10mmØ ties at 200mm.

DESIGN OF BRACING

Moment in base = (2× moment in column × sec30⁰)

= (2×65.70×1.15)

= 151.11 KN. m

Section of brace = d (0.30×0.45)

b = 350 mm

d = 400 mm

Moment of resistance of section is given by

$M_1 = (0.897\times300\times450^2)/10^6$

M_1=54.07 KN. M

Balance moment = M_2 = (M -M_1)

= (151.11 – 54.07) =97.04 KN. M

$A_{st_1} = (\frac{54.07\times10^6}{230\times0.90\times400}) = 653.01$ mm²

$A_{st_2} = (\frac{97.04\times10^6}{230\times0.9\times350}) = 1339.40$ mm²

A_{st} = (653.01+1339.40) = 1992.41 mm²

Provide 6 bar of 22mmØ (A_{st}=2280.8mm²)

Length of brace = (2×7.95×sin30) = 7.95m

Maximum shear force is brace

$= (\frac{151.11}{0.5\times7.95}) = (\frac{moment\ in\ braace}{\frac{1}{2}length\ of\ brace}) = 38$ KN

$= (\frac{100A_{st}}{b.d}) = (\frac{100\times2280.8}{350\times400}) = 1.6$

From table 23 of IS: 456, t_c= 0.43 N/mm²

Since, $t_c < t_v$ Provide nominal shear reinforcement using 8mm diameter 2 legged stirrups.

IV. CONCLUSION

Storage of water in the form of tanks for drinking and washing purposes, swimming pools for exercise and enjoyment, and sewage sedimentation tanks are gaining increasing importance in the present day life. For small capacities we go for rectangular water tanks while for bigger capacities we provide circular water tanks.Design of water tank is a very tedious method. Particularly design of under ground water tank involves lots of mathematical formulae and calculation. It is also time consuming. Hence program gives a solution to the above problems.There is a little difference between the design values of program to that of manual calculation. The program gives the least value for the design. Hence designer should not provide less than the values we get from the program. In case of theoretical calculation designer initially add some extra values to the obtained values to be in safer side.

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