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Design Of Elevated Circular Water Tank Using Is-3370:2009

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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, Elevated circular water 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 paper gives in brief, the analysis and 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 flat bottom rigid base.

Elevated water tanks are one of the most important structures on earth regions. In urban cities and also in rural village 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 stage has to carry load from dome,ring beam,circular wall, hydrostatics pressure on 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 using various design codes.
- To know about the design philosophies of safe and economical overhead structure water tank design.
- Preparing a water tank design which is economical and safe, providing proper steel reinforcement and concrete and studying its safety according to various codes.

III. Material & Method Use In Design

- As we all know 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 tank full condition.
- M-20 grade of is not used because of higher grade lesser porosity of concrete.
- M30 grade of cement in concrete is used in desing not less than 30 KN/m3
- Coefficient of thermal expansion due to temperature=11×10-6/˚C
- Coefficient of shrinkage may be assume as = 450 × 10-6 for initial and 200 × 10-6 for drying condion
- Minimum cover required 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,dome,beam etc.). Code using IS: 3370-PART 2-2009
- Using IS: 456:2000

A. Design requirement of Concrete Structures

liquid retaining structures a dense impermeable concrete is required therefore to store water an all, proportion of fine aggregate and course aggregates to cement should be such as to give high quality of 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 concrete should be workable so, permeability of the thoroughly compacted concrete is dependent on water cement ratio. Permeable concrete must be use Increase in water cement ratio increases permeability, while concrete with low water cement ratio is difficult to compact. Other major causes of leakage in concrete are efects such as segregation and honey combing present in concrete. 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 3370:2009, has standards 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 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 member design the member are assumed to act independent of the other fixed at each joint
All the components are individually 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 = 33.94×10^3/1000×100
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 = 233.39×10^3/150
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= 233.39×10^3/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 = 9.84^2/15.91×0.345
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 = 0.0079×10×9.84^3
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 = 532.28×10^3/150
Ast = 3548.53mm^2
τ = Hoop tension/b.T+(M-1)Ast
τ = 532.28×10^3/1000×400+(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} =532.28×10^3/150
As_t= 3548.53mm^2 >$A_{st\ min}$
Provide hoop tension on both face of tank
Hence, As_t 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 ≥ 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 = $T(\frac{1+\left(\frac{D}{b}\right)}{1.7}) = 93.24\ (1 + \frac{(\frac{12500}{600})}{1.7})$

= 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 weight of 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 mm^2
A_c= (282743.34 – 2945.24) + (1.5×20×2945.24)
A_c = 368155.3 mm^2
I_e= ($\frac{\pi}{64} \times d^4$) + (2×1.5×20×3×490.87×150^2)
I_e=1.988×10^9 mm^4
Direct compressive stress = σ_{cc} = ($\frac{1082.25\times10^3}{368155.3}$)

= 2.94 N/mm^2

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

= 6.60 N/mm^2

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

Hence, $(\frac{\sigma''_{cc}}{\sigma_{cc}} + \frac{\sigma''_{cb}}{\sigma_{cb}}) < 1$

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 × sec30^0)

= (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= (0.897×300×450^2)/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 mm^2

$A_{st_2} = (\frac{97.04\times10^6}{230\times0.9\times350})$ = 1339.40 mm^2

A_{st}= (653.01+1339.40) = 1992.41 mm^2

Provide 6 bar of 22mmØ (A_{st}=2280.8mm^2)

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

Maximum shear force is brace

$= (\frac{151.11}{0.5\times7.95}) = (\frac{\text{moment in braace}}{\frac{1}{2}\text{length of brace}})$ = 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/mm^2

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

IV. Conclusion

The member size remained same designed by Working Stress Method per both IS 3370 (1967) and IS 3370 (2009).The Steel requirement increased when designed by Working Stress Method as per IS 3370 (2009) to over come this code has revised as the permissible stresses in steel were limited to 130 Mpa. The member size were unchanged when designed by Limit State Method as per IS 3370 (2009) for both limit state of collapse as well as deemed to satisfy. The size of members as well as the steel requirement of the structure were reduced when designed by using Limit State Method as per IS 3370 (2009), when compared with Working Stress Method as per IS 3370 (1967).Amount of steel quantity found more for a circular service reservoir design by WSM than that of LSM. More steel quantity found for a square service reservoir design by WSM than that of LSM.

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