ISSN 2277 – 5528
Impact Factor- 3.145

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

ELEVATED SERVICE RESERVOIR AND DESIGN

Sahane Abhijeet A[*1], Kandekar Sachin.B.[*2], Benke Vaibhav. G.[*3], Wakchaure A. V.[*4]
[*1]P.G. Student, M.E. Structure, A.V.C.O.E Sangamner, India
[*2]Assistant Professor, Civil Department, A.V.C.O.E Sangamner, India
[*3]P.G. Student, M.E. Structure, G.H.R.C.O.E ,Chas, Ahmednagar, India
[*4]P.G. Student, M.E. Structure A.V.C.O.E Sangamner, India

ABSTRACT

Overhead tank and storage reservoirs are used to store water, petroleum products, liquid petroleum and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential .the permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio.

This report gives in brief, the theory behind the design of liquid retaining structure (elevated circular water tank) using working stress method. Elements are design in limit state method.

Keywords: *Elevated Tanks, Water Tank, Design Format*

I. INTRODUCTION

For storage of large quantities of liquids like water, oil, petroleum, acid and sometime gases also, containers or tanks are required. These structures are made of masonry, steel, reinforced concrete and pre stressed concrete. Out of these, masonry and steel tanks are used for smaller capacities. The cost of steel tanks is high and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, besides the construction and design being simple, they are cheap, monolithic in nature and can be made leak proof.

Generally no cracks are allowed to take place in any part of the structure of Liquid Retaining R-C.C. tanks and they are made water tight by using richer mix (not less than M 30) of concrete. In addition sometimes water proofing materials also are used to make tanks water tight.

II. TYPES AND CLASSIFICATION OF WATER TANK

Tanks resting on ground: These are used for clear water reservoirs, aeration tanks, settling tanks etc. these are directly rest on the ground. The wall of these tanks are subjected to water pressure from inside and the base is subjected to weight of water from inside and soil reaction from underneath the base. It may be open at top or roofed. Water tank is made of lined carbon steel, it may receive water from surface water or from a water well allowing a large volume of water to be placed in inventory and used during peak demand cycles

Tanks resting on ground

Elevated Tanks: These tanks are supported on staging which may consist of masonry walls, R.C.C tower or R.C.C. column braced together- The walls are subjected to water pressure from inside. The base is subjected to weight of water, wt- of walls and wt. roof. The staging has to carry load of entire tank with water and is also subjected to wind loads.

Elevated Tanks

Underground tanks: These tanks are built below the ground level such as clarifiers filters in water treatment plants, and septic tanks .The walls of these tanks are subjected to water pressure from inside and

ISSN 2277 – 5528
Impact Factor- 3.145

earth pressure from outside. The base of the tanks is subjected to water pressure from inside and soil reaction from underneath. Always these are covered at top. These tanks should be designed for loading which gives the worst effect. The design principles of underground tanks are same as for tanks resting on the ground. The walls of the underground tanks are subjected to internal water pressure and outside earth pressure. The section of wall is designed for water pressure and earth pressure acting separately as well as acting simultaneously.

III. TYPE OF TANKS

From the design consideration storage tanks are further classified according to their shape and design principles as

(1) circular tanks.
(2) Rectangular tanks.
(3) Intze type tanks.
(4) Spherical tanks.
(5) conical bottom tanks.
(6) PSC Tanks

IV. COMPONENTS

(1) top dome.
(2) ring beam supporting the top dome.
(3) Cylindrical wall.
(4) Ring beam at the junction of the cylindrical wall and the conical shell.
(5) Conical shell.
(6) Bottom dome.
(7) The ring girder.
(8) Columns braces.
(9) Foundations.

V. MATERIALS USED FOR WATER TANK CONSTRUCTION

Following are the materials which are used in the construction of R.C.C. Water Tanks.

i) Concrete.
ii) Steel.
iii) Water Proofing materials.
iv) Minimum Reinforcement.

VI. PRIMARY LOADS CONSIDERED IN THE DESIGN

a) Dead Load
b) Live Load acting on Roof slab
c) Water Load inside the tank up to top of the Rectangular wall including free board.
d) Combination of all the above loads.

VII. DESIGN FORMAT OF ELEVATED SERVICE RESERVOIR

The tank is proposed of Circular type with Slabs to form the base and another Slab forming the roofing. Floor beams along the periphery of the Circular slab is proposed to transfer the loads to the Supporting Structure.

Design basis

(a) The Circular wall has been designed for Hoop Tension & Bending moment.
(b) The Floor beam has been designed for a bending between the supporting columns.
(c) The columns are designed for direct load and bending due to wind/seismic effect.

Material Specifications:

a) Grade of Concrete = M___
b) Grade of steel - High yield deformed bars with yield stress = ___N/mm2

Strength parameters

Concrete For Container Portion = M___

Permissible stresses

Direct tension stress σ_{ct} =___ kg/cm²
Direct compressive stress σ_{cc} =___ kg/cm²
Bending tensile stress σ_{cbt} =___ kg/cm²
Bending comp stress σ_{cbc} =___ kg/cm²
Characteristic comp strength f_{ck} =___ kg/cm²
Shear =___ kg/cm²
Average Bond= ___x___
Local Bond = ___x___
Steel HYSD Fe =___ kg/cm²

Permissible stresses (Water Retaining members)

Tensile Stress in members under direct tension
Tensile stress in members in bending :
a) On Liquid retaining face of members =___ kg/cm²
b) On face away from liquid for members less than 225 mm =___ kg/cm²
c) On face away from liquid for members 225 mm or more =___ kg/cm²
Tensile stress in Shear Reinforcement :
a) For members less than 225 mm =___ kg/cm²
b) For members 225 mm or more =___ kg/cm²

Compressive stress in columns subjected to direct load =___ kg/cm²

Min Area of Reinforcement for Walls:

Min Area of Reinforcement for 100 mm thick Wall = 0.24 %
Min Area of Reinforcement for 450 mm thick or more = 0.16 %

For Concrete ; Design Constants :

σ_{st} =___ kg/cm²
σ_{cbc} =___ kg/cm²
m = 280 / (3 x σ_{cbc}) =____
r = σ_{st} / σ_{cbc} =____
K = m / (m+r) =____
j = 1 - (K / 3) =____
Q = 0.5 x σ_{cbc}xk x j =____

ISSN 2277 – 5528
Impact Factor- 3.145

For Un Cracked Section :
Permissible Bending Tension =___ kg/cm²
M.R = Q_{bd}^2 = (1/6) x b x d^2 x f
Q = (f / 6) = 3

Design Data :

Capacity =____KL
Staging = ____M
Seismic Zone = ___
R.C.C. to be M30 for container. Staging to be Designed with M20 Concrete and executed with M25 Concrete.

Hydraulic features :

Ground level =____m
Lowest water level (LWL) =____m
Max water level (MWL) =____m
Dead storage =____m
Free board =____m
Effective Water depth H =MWL-LWL =____m

Member sizes :

No of columns Supporting the ESR =____
No of Columns inside Container =____
No of Braces = ____Levels
Size of Container = ____Φ
Size of Column Supporting ESR = ____Φ
Size of Column inside Container = ____Φ
Braces = ___x___
Roof beam = ___x___
Floor beam = ___x___
Floor Ring beam = ___x___
The of side wall = ___x___

Loads:

Wind pressure =___ kg/m²
Live Load on Roof =___ kg/m2
Live Load on Walkway Slab =___kg/m2
Density of concrete =___kg/m³
Density of water =___kg/m³

Soil Parameters:

Safe bearing capacity of soil (SBC) (Assumed) = ___ t/m²
Depth of foundation = ___m
Depth of Ground Water table is at = ___m
Seismic Zone = III

Capacity Calculations:

Depth of Water between MWL & LWL (Live Storage) h = ___ m
Required Capacity of Tank $V_1 = \pi/4$ x d^2 x h= ___m^3
Inner Diameter of Tank Required = ___ m
Inner Diameter of Tank Provided D =___ m
Volume of Tank V_1 = ___ m^3
Consider freeboard of the Cylindrical Portion (FB)= ___ m
Volume of Free board Portion V_2 = ___ m^3
Height of Dead Storage Portion = ___ m
Volume of Dead Storage Portion V_3 = ___ m^3
Total Volume = ___ m^3
Total Height of the Cylindrical Portion (h) = ___ m
Volume of Internal Column = ___ m^3
Net Volume of Tank V_1 = ___ m_3

Design of roof slab :-

Let the Thickness of Slab be =___mm
Width of Panel =___ m
Effective Span of Slab = ___ m
Density of Concrete = ___kg/m3
Dead Wt. of Slab =___ x2500 = ___kg/m2
Floor Finish = ___kg/m2
Live Load = ___kg/m2
Total = ___kg/m2
Ly / Lx =
Negative moment Co efficient at continuous edge = ___
Positive moment Co efficient at Mid span = ___
Negative B.M =α_x x W_ux l_x^2 = ___ Kg-m
Positive B.M =α_y x W_ux l_x^2= ___ Kg-m
Effective thickness = ___ cm
Area of Steel Required at Support
-ve A_{st} = ____ cm^2
Area of Steel Required at Span
-ve A_{st} =___ cm^2
Min. area of steel required (A_{stmin}) =0.12% area =___ cm^2
Max. dia. Of bar (f max = D / 8) =___ mm
Min. area of steel required on each face (A_{stmin}) = ___ cm2
Max. allowble spacing (S_{max}) ar per IS 456 = ___ mm
Dia. Of bar (f) =___ mm
Area of Bar =___ mm^2
Required Spacing = ___ cm
Provided Spacing =___ cm
Provided Area = ___mm^2
Provide ___dia tor @ ____c/c both ways at bottom & alternate bars bent
Provide ___dia tor @____ c/c both ways at top
Check for Deflection :
L / d = ___
% of Compression Reinforcement Pc = ___
Multiplication Factor for Tension Reinforcement = ___
Multiplication Factor for Compression Reinforcement = ___
Modified L/ d Ratio = ___
Actual L/d Ratio = ___
Hence, SAFE OR NOT

Design of roof beam :-

Length of Span =___m
Let Width of Beam = ___cm

ISSN 2277 – 5528
Impact Factor- 3.145

Let Depth of Beam = ___cm
Clear Cover = ___ cm
Effective Depth = ___ cm
Load from Slab = ___ kg
U.D.L = ___ kg/m
S.F = ___kg
- ve B.M = ___ Kg-m
Net - ve B.M = ___ Kg-m
+ ve B.M = ___ Kg-m
Area of steel required for Support =___ cm^2
Min Area of Steel = 0.85 bd / f_y = ___ cm^2
Provided Area of Steel = ___cm^2
through + ___-___ TOR extra at bottom
% of Steel Provided = ___
Permissible shear stress in concrete (τ_c) = ___kg/cm2
Nominal shear stress (τ_v) = Vu/bd =___ kg/cm2
Net Shear force =___ kg
Stirrup Dia = ___mm
No of legs = ___
Area of Bar = ___ cm2
Spacing required is Min. of following
Max. 300 mm
0.75*d = ___mm
Minimum Shear Reinforcement = Asv / bSv ≥ (0.4/0.87fy)
$S_v \leq$ 0.87fyAsv / 0.4b
$S_v \leq$___ cm
0.75 d = ___ cm
= ___cm
Provided Spacing is Lesser of above two cases = ___ cm
Provide___ dia tor @___c/c throughout.

Design of floor slab:

Let the Thickness of Slab is =___mm
Width of Panel =___mm
Effective Span = ___
Density of Concrete = ___kg/m^3
Dead Wt of Slab =___kg/m^2
Water Load on Slab =___kg/m^2
Floor Finish =___kg/m^2
Total = ___kg/m^2
- ve B.M = ___Kg-m
+ ve B.M = ___Kg-m
σ_{bt} =___kg/cm^2
Permissible Bending Tension =___kg/cm^2
Provided Thickness is O.K or NOT
Effective thickness =___cm
-ve Ast = ___cm^2
+ve Ast = ___cm^2
Minimum Area of Steel = ___cm^2
Dia. Of bar (f) = ___mm
Area of Bar =___mm^2
Required Spacing = ___cm
Provided Spacing =___cm
Provided Area = ___mm^2
Provide ___dia tor @ ___cm c/c both ways at top
Dia. Of bar (f) =___mm
Area of Bar =___mm^2
Required Spacing = ___cm
Provided Spacing =___cm
Provided Area = ___mm^2
Provide ___dia tor @ ___ c/c both ways at bottom
Provide ___dia tor @ ___c/c both ways at bottom & alternate bars bent
Provide ___dia tor @ ___c/c both ways at top

Check for Deflection :

L / d = ___
% of Compression Reinforcement Pc = ___
Multiplication Factor for Tension Reinforcement = ___
Multiplication Factor for Compression Reinforcement =___
Modified L/ d Ratio =___
Actual L/d Ratio = ___
Hence, SAFE or NOT

Design of floor ring beam :-

Length of Span = ___m
Let Width of Beam = ___cm
Let Depth of Beam =___cm
Clear Cover =___cm
Effective Depth = ___cm
Max Bending Moment at Support = ___KN-m
Max Bending Moment at Span = ___KN-m
Max Shear Force = ___KN
Max Bending Moment at face of Support= ___KN-m
Un-cracked depth required = ___cm
However Provided Overall depth is ___cm
O.K. or NOT
Area of steel required for Support =___cm^2
Min Area of Steel = 0.85 bd / fy = ___cm^2
Provide___-___tor through at bottom (___cm^2)
% of Steel Provided = ___
Permissible shear stress in concrete (τ_c) = ___kg/cm^2
Nominal shear stress (τ_v) = V_u/bd =___kg/cm2
Net Shear force =___kg
Stirrup Dia =___mm
No of legs =___
Area of Bar = ___cm^2
Spacing Required = ___cm
Spacing required is Min. of following
(0.85x f_y x n x π /4 x {d2/(tv - tc)}B =___mm
Max. 300 mm
0.75*d = ___mm
Minimum shear reinforcement=A_{sv}/ b_{sv} ≥(0.4/0.87fy)

ISSN 2277 – 5528
Impact Factor- 3.145

$S_v \leq 0.87\ f_y$ x A_{sv} / 0.4b
$S_v \leq 30.39$ cm
0.75 d = ___cm
= ___cm
Provide ___dia tor @___c/c through out

Design of one meter wide gallery slab :

Length of Walkway =___m
Depth of Slab Required = L /7 = ___mm
Provided thickness of at Support = ___mm
Thickness at free end =___mm

Loading :
(1) Self Wt of Slab =___kg/m²
(2) Live Load = ___kg/m²
(3) Finishes =___kg/m²
Total Load W = ___kg/m²
Max B.M = $WL^2/2$ =___Kg-m
Clear Cover = ___cm
Effective Depth = ___cm
Ast Required =___cm²
Min Area of Steel = ___%
Ast = ___cm²
Note : The Floor Slab Top Reinforcement Should Extend up to end of Walk way Slab.

Design of Column inside Container :

Size of Column = ___Φ
Clear Cover = ___mm
Start IL = ___m
Floor Level = ___m
Total Height of Column = ___m
Clear Ht of Column = ___m
Effective Length of Column = ___m
L/d = ___
It will Designed as Long Column
Reduction factor =___
Axial load (Unfactored) = ___kgs
Max B.M (Unfactored) = ___Kg-m
Max B.M (Unfactored) = ___Kg-m
Design Load = ___kg
Load carrying capacity =___cm2
Provided C/S Area = ___cm2
Min % of Steel Required = ___%
Min Area of Steel Required = ___cm2
Provide dia of bar = ___mm
Area of Bar = ___cm2
Required no of Bars = ___no's
Provided no of Bars = ___no's
Provide ___ no's ___ tor =___cm2
Provide ___tor @ ___c/c links

Check in Working Stress Method :

Axial load (Unfactored) =___ kgs
Max B.M (Unfactored) =___ kg-m
Max B.M (Unfactored) = ___ kg-m
A = A_{sc} +(1.5m-1) A_t ___cm2
I = $(\Pi d^4 / 64) + (1.5m-1)$ x A_t x $(d/2 - x)^2$
d/2 =___cm
X = ___cm
I = ___cm4
Z = I/(d/2) = ___cm3
σ_{cc} Cal = P/ A = ___kg/cm2
σ_{cbc} Cal = My/ Z = ___kg/cm2
σ_{cbc} Cal = Mz / Z = ___kg/cm2
(σcc Cal / σcc) + (σcbcy Cal / σcbc) + (σcbcz Cal /σcbc) = ___<1
Hence SAFE or NOT
Load Carrying Capacity =___kgs
Weight of Container :
Roof Slab = ___kgs
Roof Beam = ___kgs
Wall =___kgs
Floor Slab = ___kgs
Floor Beam = ___kgs
Floor Ring Beam = ___kgs
Gallery = ___kgs
Roof Slab Exclusing Live Load Portion = ___kgs
Gallery Excluding Live load portion =___kgs
Weight of Internal Column =___kgs
Water =___kgs
Water in free board portion =___kgs
Total Wt of container in full condition Excluding Freeboard Portion =___kgs
Total Wt of container Including Freeboard Portion = ___kgs
Wt of empty container = ___kgs
Wt of Container in full condition excluding Free board & Live load = ___kgs
Height of C.G of empty container from top of floor slab will be
C.G of Empty Container = ___m
Height of C.G of container full from top of floor slab will be
C.G of container full =___m

Design of Staging :

No of Columns =___
Column Size =___Φ
Brace Levels =___
Size of Braces = ___
Floor Ring Beam = ___
Depth of foundation below G.L =___m
Height of Wall Portion h3 = ___m
Height of IV Column Panel = ___m
Depth of III Brace =___m
Height of III Column Panel = ___m
Depth of II Brace = ___m
Height of II Column Panel = ___m
Depth of I Brace = ___m

ISSN 2277 – 5528
Impact Factor- 3.145

Height of I Column Panel = ___m
Height of Column from top of footing to bottom of Floor beam = ___m

Spacing of Circular Hoops :
Spacing should be lesser of the following :
1.) 1/4 of Minimum Member Dimension = ___ mm
2.) 100 = 100 mm
Spacing of Hoops S = ___mm
Clear Cover = ___mm
Dia of Circular Hoops = 10 mm
Core Diameter measured to the outside of hoop D_k =___mm
Area of Concrete Core A_k =___mm2
Gross area of Column C/S Ag =___mm2
Area of bar forming circular hoop is $A_{sh} = 0.09SD_kf_{ck}/f_y ((A_g/A_k)-1)$
A_{sh} =___mm^2
Provided C/S of bar forming circular hoop = ___mm^2
Provided Circular Hoop bar of dia___ mm is O.K
Thus Circular Hoops of Dia ___mm at a spacing of ___mm c/c will be adequate
Provided C/S of bar forming Tie = ___mm2
h/6 = ___mm
Thus Ties of Dia ___mm at a spacing of ___mm c/c will be adequate for a height of
(h/6) i.e. ___mm

Design of raft foundation:
Load coming on to the Foundation = ___kgs
Let Self weight of foundation (15%) = ___kgs
Total load coming from Foundation = ___kgs
Depth of foundation below G.L = ___m
Safe Bearing Capacity of Soil =___Kg/m^2
Area of Raft Required = ___m^2
Side of Raft Required = ___m
Side of Raft to be provided = ___m
Area of Raft Provided = ___m^2
Upward Pressure = ___kg/m^2
Net upward Pressure = ___kg/m^2

Check for Uplift :
Depth of foundation below ground level =___m
Uplift Pressure on Foundation of Structure should be considered as per available
water table at site in rainy season. However, minimum uplift up to 50% of depth of foundation below ground level for safety purpose may be considered.
Depth of Water table Below G.L =___m
So, Depth of Water table is far below Foundation Level For Uplift, 50% of dept of foundation below ground level should be considered
Unit Wt of Water = 1000 kg/m^3
Uplift Pressure = 1.5x1000 = 1500 kg/m^2
Upward Load = 8.8^2 x 1500 = 116160 kgs
Self Wt of Raft = ___kgs
Self Wt of Raft Beam = ___kgs
Weight of P.C.C = ___kgs
Total Dead Wt of Structure Including staging = ___kgs
Total Upward Load = 116160 kgs
Total Downward Load = ___kgs
Factor of Safety = Total Downward load/Total
If upward load =___>1.25
Safe against Uplift.

VIII. CONCLUSIONS

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. Without power also we can consume water by gravitational force.

Elevated Service Reservoir of any capacity with staging has been designed considering M30 concrete for the Container and M20 for staging. However, M25 concrete is used for staging.

Detailed format of structural drawings have been prepared.

IX. ACKNOWLEDGEMENT

It gives me immense pleasure in submitting my seminar report. I would like to express my sincere humble, deep sense of gratitude to my seminar guide Prof. Kandekar S.B. for his counsel and constructive guidance, active interest and constant encouragement. It would not have been possible for me to complete this work without his critical analysis and valuable guidance.

I am also thankful to faculty and staff members of our department for their kind co-operation and help during this seminar.

Last but not the least, I am thankful to my parents, friends, my classmates and colleagues who helped to sustain my determination to accomplish this work in spite of many hurdles.

REFERENCES

I) Dr. S. A. Halkude, A. A. Perampalli ,Volume 3, Issue 5, November 2013 International Journal of Engineering and Innovative Technology (IJEIT) V. S. Bachal, Dr. S. N. Tande, ISSN : 0975-5462 Vol.

II) 6 No.6 Jun 2014, page 276-286, International Journal of Engineering Science and Technology (IJEST)

III) Krishna Rao M.V, Rathish Kumar. P, Divya Dhatri. K Volume: 04 page 74-83 Special Issue: 01 | NCRTCE-2014 | Feb-2015 eISSN: 2319-1163 | pISSN: 2321-7308

IV) IITK-GSDMA guidelines for seismic design of liquid storage tanks provisions with commentary and explanatory examples

V) C. Neuwirth, A. Peck , S.P. Simonovi Modeling structural change in spatial system dynamics ScienceDirect Environmental Modelling & Software 65 (2015) 30e40

VI) Attila Ambrus, Reka Mizsei, Vera Adam-Vizi Biochemistry and Biophysics Reports 2 (2015) 50–56

VII) Nathanael Beeker Paul Malisani Nicolas Petit IFAC-Papers Online 48-11 (2015) 078-085 Dynamical modelling for electric hot water tank. Science direct.