DESIGN ANALYSIS & COMPARSION OF INTZE TYPE WATER TANK FOR DIFFERENT WIND SPEED AND SEISMIC ZONES AS PER INDIAN CODES

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Abstract

Any design of Water Tanks is subjected to Dead Load + Live Load and Wind Load or Seismic Load as per IS codes of Practices. Most of the times tanks are designed for Wind Forces and not even checked for Earthquake Load assuming that the tanks will be safe under seismic forces once designed for wind forces. In this study Wind Forces and Seismic Forces acting on an Intze Type Water tank for Indian conditions are studied. The effect of wind on the elevated structures is of prime importance as Wind flows relative to the surface of ground and generates loads on the structures standing on ground. Most of the designers consider the wind effect and neglect the seismic effect on the structure. The Indian Standard Code IS 875(Part-3) 2003 and IS 1893-2000 for Wind & Seismic effect is used in this study. The Elevated Structure is designed for various Wind forces i.e. 39 m/s, 44 m/s, 47 m/s & 50 m/s and the same is cross checked with different Seismic Zones i.e. Zone-II, Zone-III, Zone-IV, & Zone-V by 'Response Spectrum Method' and the maximum governing condition from both the forces is further used for design & analysis of staging. It is found from the analysis that the Total load, Total moments and Reinforcement in staging i.e. Columns, Braces & also for Raft foundation varies for Case-1, Case-2, Case-3 & Case-4.

Key Words: *Wind Load, Seismic Load, Intze Tank, and I.S.Codes etc…*

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1. INTRODUCTION

Water is life line for every kind of creature in this world. All around the world liquid storage tanks are used extensively by municipalities and industries for water supply, firefighting systems, inflammable liquids and other chemicals. Thus Water tanks plays a vital role for public utility as well as industrial structure having basic purpose to secure constant water supply from longer distance with sufficient static head to the desired location under the effect of gravitational force. With the rapid increase of human population, demand for drinking water has increased by many folds. Also due to shortage of electricity at many places in India and around the developing nations, it is not possible to supply water through pumps at peak hours. In such situations elevated water tanks become an important part of life. India is highly vulnerable to natural disasters like earthquake, draughts, floods, cyclones etc. Majority of Indian states and union territories are prone to one or multiple disasters. These natural calamities are causing many causalities and huge property loss every year. According to seismic code IS 1893(Part-1):2000, more than 60% of India is prone to earthquakes.

The main reason for life loss is collapse of structures It is said that natural calamities itself never kills people; it is badly constructed structure that kill. Hence it is important to analyze the structure properly for different natural calamities like earthquake, cyclones, floods and typhoons etc.

1.1 Wind Effect

Wind pressures acting at any height on a structure are computed by the methods recommended by the IS code. The basic wind speed (Vb) for any site shall be obtained from the basic wind map shown in IS 875 (Part-3) 2003 and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure:

[1]. Risk Coefficient (k_1 factor)
[2]. Terrain roughness, height and size of structure (k_2 factor); and
[3]. Local Topography (k_3 factor)

Design wind speed (Vz) at any height can be calculated as follows: $Vz = Vb\ k_1\ k_2\ k_3$
Where, Vz = Design wind speed at any height 'z' in m/s
Vb = Basic wind speed for any site
k_1 = Probability factor (Risk coefficient)
k_2 = Terrain, height and structure size factor and
k_3 = Topography factor
k_1, k_2 & k_3 are calculated by means of tables in IS 875 (Part-3) 2003.The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$Pz = 0.6\ Vz^2$$

Where, Pz = Design Wind pressure in N/m² at height z,
Vz = Design wind velocity in m/s height z.

1.2 Earthquake Effect

- For the purpose of this analysis, elevated tanks shall be regarded as systems with a single degree of freedom with their mass concentrated at their centers of gravity. By treating the tank as a single degree of freedom
- system, the free period T, in seconds, of such structures shall be calculated from the following formula: Free Period,

  $T = 2\pi\sqrt{\frac{\Delta}{g}}$ Where,
- Δ = the static horizontal deflection at the top of the tank under a static horizontal force equal to a weight 'W' acting at the center of gravity of tank.
  g = acceleration due to gravity.

- The design shall be worked out both when the tank is full and when the tank is empty, the weight W used in the design shall consist of the dead load of the tank and one-third the weight of the staging. When full, the weight of concrete is to be added to the weight under empty condition.
- The lateral force shall be taken equal to:
  Horizontal Load (P) = αh.W
- Where, weight W is calculated as below:
  αh = design horizontal seismic coefficient

  $\alpha h = \beta x\ I\ x\ F_o\ x\ \frac{Sa}{g}$ Where,

  F_o = seismic zone factor β = a coefficient depending upon the soil-foundation system
- I = a factor dependent upon the importance of the structure

  $\frac{Sa}{g}$ = the average acceleration coefficient which correspond to the fundamental time period of the tank.
- For tank empty: W = Wt. of container + 1/3 Wt. of staging For tank full: W = Wt. of container + wt. of water + 1/3 Wt. of staging
- The lateral seismic force P calculated is to be applied at center of gravity of the tank horizontally in the plane in which the structure is assumed to oscillate for the purpose of carrying out the lateral load analysis.

2. LITERATURE REVIEW

Various literatures has presented in the form of technical papers till date on the Wind and Seismic analysis of Elevated Water Tanks. Various issues and the points are covered in that analysis.i.e wind speed of various cities as per seismic zones, hydrodynamic pressure, and dynamic response of framed staging etc. Some of those are discussed below:

- **Khaza Mohiddin Shaikh and Prof. Vasugi K (2014) conclude that:** Analysis & Design of elevated water tanks against earthquake effect is of considerable importance. These structures must remain functional even after an earthquake. Most elevated water tank are never completely filled with water. Hence, a two- mass idealization of the tank is more appropriate as compared to one-mass idealization.
- **R.K.Prasad and Akshaya B. Kamdi (2012):** BIS has brought out the revised version of IS 3370 (part-1 & 2) after a long time from its 1965 version in year 2009. This revised code is mainly drafted for the liquid storage tank. This paper gives in brief, the theory behind the design of circular water tank using WSM and LSM. Design of water tank by LSM is most economical as the quantity of material required is less as compared to WSM. Water tank is the most important container to store water therefore, Crack width calculation of water tank is also necessary.
- **Hasan Jasim Mohammed (2011), conclude that:** An application of optimization method to the structural design of concrete rectangular and circular water tanks, considering the total cost of the tank as an objective function with the properties of the tank that are tank capacity, width and length of tank in rectangular, water depth in circular, unit weight of water and tank floor slab thickness, as design variables.
- **Pavan S. Ekbote and Dr. Jagdish G. Kori:** During earthquake elevated water tanks were heavily damages or collapsed. This was might be due to the lack of knowledge regarding the behavior of supporting system of the water tanks again dynamic action and also due to improper geometrical selection of staging patterns of tank. Due to the fluid structure interactions, the seismic behavior of elevated water tanks has the characteristics of complex phenomena. The main aim of this study is to understand the behavior of supporting system (or staging) which is more effective under different response spectrum method with SAP 2000 software. In this paper different supporting systems such as cross and radial bracing studied.

3. PRE PROCESSING DESIGN

3.1 Concept Of Domes

A dome may be defined as a shell generated by the revolution of a curve about a vertical axis. If the curve of revolution about the vertical axis is a segment of a circle, the shell formed is termed as spherical dome. Hence in spherical dome, a vertical section through the axis of revolution in any direction is essentially an arc of a circle. Similarly a conical dome is obtained by the revolution of a triangle about a vertical axis. Out of the two forms, spherical domes are commonly used.

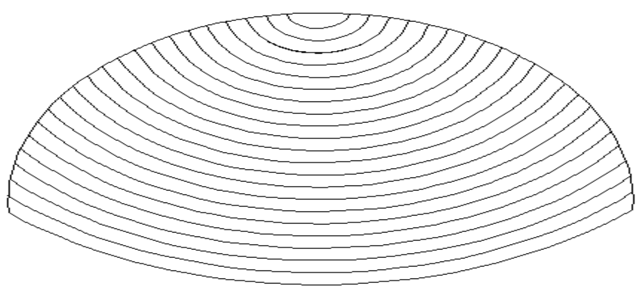

Fig -1: Spherical Dome

The domes are designed for the total vertical load only. The term total vertical load includes the weight of the dome slab and that of covering material, if any, over the slab; the weight of any other load suspended from the slab, and live load etc. No separate calculations are made for wind load and the effect of shrinkage and temperature changes because they are complex in nature and difficult to estimate. However, their effect is compensated by assuming extra live load to the extent of 1000 to 1500 N/sq. m of the surfaces of the dome. Alternatively the allowance for wind load etc. is made, by designing the dome with reduced value of permissible stresses.
Whatever may be the result of the design, the minimum thickness of dome slab should not be less than 80 mm and the minimum percentage of steel in both the directions (Meridonial and along the latitude) should not be less 2% of the area of concrete. In case of dome for water tanks, the minimum percentage of steel should not be less than 0.3%.

3.2. Intze Type Water Tank Design

3.2.1 General

It is found that for storing large volumes of water an elevated circular tank, provided with flat floor slab, works out to an uneconomical design. It is mainly on account of the fact that the floor slab becomes too thick for large diameters tanks. Intze tank is best suitable under such circumstances. An Intze tank essentially consist of a top dome (roof), the cylindrical wall and the floor slab, which is a combination of conical dome and bottom spherical dome. Being subjected to direct compression the thickness of the domical floor, works out to be much less and hence it proves to be economical alternative to flat slab floor. The proportion of the conical dome and the bottom dome are so arranged that the outward thrust from the bottom domed part of the floor balances the inward thrust due to the conical domed part of the floor.
The diameter of the bottom dome should preferably be about 65 to 70% of the diameter of the tank. From considerations of economy, the inclination of the conical dome should be between 50 to 55° with the horizontal. The proportions of different components of the tank under ideal conditions are given in fig. (2)

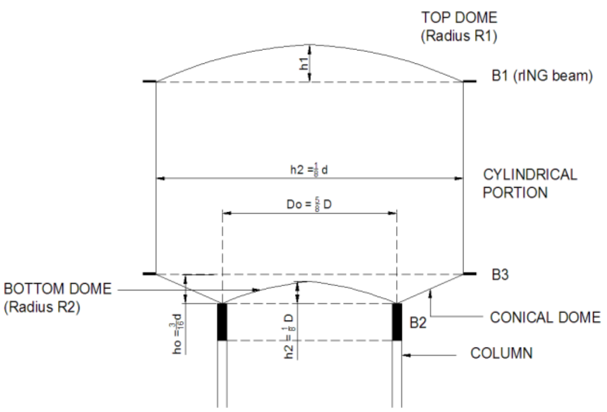

Fig -2: Components of Intze Tank

3.2.2 The Top Dome And Top Ring Beam:

The dome and ring beam are assumed to be freely connected to the cylindrical wall of the tank with the help of shear key. We shall design the top dome and its ring beam on membrane analysis, considering these to be independent of the tank wall which is assumed to be free at top.

3.2.3 The Cylindrically Wall:

Let the diameter of tank be D and the height of cylindrical portion be H. The walls are assumed to be free at top and bottom. Due to this, tank walls will be subjected to hoop tension only without any B.M. Maximum hoop tension will occur at base, its magnitude being equal to W.h.d/2 per unit height. The tank walls are adequately reinforced with horizontal rings provided at both faces. In addition to this, vertical reinforcement is provided on both the faces in the form of distribution reinforcement.

3.2.4 Design Of Ring Beam At The Junction Of The Cylindrical Wall And Conical Dome:

Find hoop tension in the beam by the formula

$H = H_1 \times \frac{D}{2} + H_2 \times \frac{D}{2}$

Where H_1 is the horizontal component of the thrust T, due to w_1. w_2 being the load transmitted through the tank wall at the top of the conical dome. The value of H_1 is given by
$H_1 = w_1 \tan(\beta)$
And H_2 is the horizontal force due to water pressure at the top of the conical dome and its value is given by
$H_2 = w \times h \times d$
Where d is the assumed depth of the beam and h is the depth of water upto the centre of beam.
Having calculated H, the beam can be designed in a similar manner as the top ring beam. It is desirable to keep the depth of the beam less, so as to get more width, which may serve as walkway or inspection gallery around the tank.

3.2.5 Design OF CONICAL DOME:

The steps to be followed in the design are:

- Find the weight of water on the conical dome by taking average diameter and the corresponding depth of water. To this value add the self-weight of the conical dome slab and the load (w_1) transmitted through the tank wall at the top of the conical dome.
- Divide the total load obtained above by the perimeter of the conical dome at base, to get load per meter run at the conical dome base.
- Find Meridonial thrust in the slab due to (w_2) by the formula $T = \frac{w_2}{\cos\beta}$
- Find hoop tension due to water pressure and self-weight of the conical dome slab, we know that the water pressure will act, normal to the inclined slab surface. Let the intensity of water pressure at a depth h meter above conical dome base be 'p' and let, Dh be the diameter of the conical dome at this depth. Hoop

tension is then given by a general formula,

$$H = \left(\frac{p}{\cos\beta} + q.\tan\beta\right)\frac{Dh}{2}$$

Where 'q' is the weight of the conical slab per square meter of the surface area.

- With the help of the above formulae, find the value of hoop stress at bottom, mid height and top of the inclined conical dome slab and provide necessary hoop reinforcement.

3.2.6 Design Of Bottom Spherical Dome:

The bottom dome is designed in the similar manner as the top dome, except that the load of the water above the dome is added to the self-weight of the dome slab to get design load for the dome.

3.2.7 Design of bottom ring beam:

The steps to be followed in the design are:

- Find the net horizontal force (P) on the ring beam given by the formula,
  $P = T_1 \text{ x } \cos\alpha \sim \cos\gamma$
- If $T_1 \cos\alpha > \cos\gamma$, the result will be net inward force per meter i.e. the force will be compressive in nature.

  Find hoop stress given by,
- $= \frac{PD}{2} \text{ x } \frac{1}{bd}$ (compressive)

Being compressive in nature and normally very small in magnitude, its effect can be neglected. (In a well-proportioned tank the net horizontal force should be much less.)

- Find vertical load per meter run, given by
  $= T_1 \cos\beta \text{ x } T_2 \sin\gamma$

Alternatively: Vertical load per meter can also be found by dividing the total vertical loads by the perimeter of the bottom ring beam.

3.2.8 Design Of Staging:

Design of columns: Let W be the total vertical load (including live loads) due to tank and its contents above the staging. If n be the number of columns in the staging: Total load on each column = $\frac{W}{\eta}$. Add to this the vertical force Pω due to wind to which the column will be subjected to.

When the wind blows, the windward columns on leeward side experience downward forces. The neutral axis can be considered a line passing through the centre of the group of column circle and at right angles to the direction of wind. Let, Mw = Moment due to wind about the bottom of columns and let 'r' be the distance from any column to the neutral axis.

Σr^2 = Sum of the square of the distances of all the columns from N.A. The vertical force in any column at a distance r from N.A. is given by the formula

$$Pw = \frac{Mw \text{ x } r}{\Sigma r^2}$$

Alternatively: The maximum force in the remotest or the extreme column can also be calculated from the following formula

$$Pw = \frac{2Mw}{n \text{ x } R}$$

Where, R = radius of the column circle. It is obvious that the farthest column or the extreme column on the leeward side will govern the design of columns. The column should be designed for

- Maximum bending moment given by the equation B.M. = $\frac{1}{2}$ x Max. Horizontal shear x Distance between the bracing; and
- Total vertical Load = P + Pw

3.2.9 Design Of Foundations:

In order to obtain rigidity at the column base, combined footing is generally provided for Intze tank. Depending upon the allowable soil pressure the combined footing may either be in the form of solid circular raft or an annular circular raft.

4. POST PROCESSING DESIGN

The details of 675 Cu.m Intze type overhead water tank considered for different wind and seismic analysis are mentioned below:

4.1 Structural Details

- Storage capacity = 675 Cu.m
- Water Depth = 4 m
- Free board = 0.30 m
- Height of staging = 20.0 m
- S.B.C = 8 T/m²
- Grade of concrete = M-30
- Grade of steel = 415 N/mm²
- Outer Diameter = 15.75 m
- Internal Diameter = 15.45 m

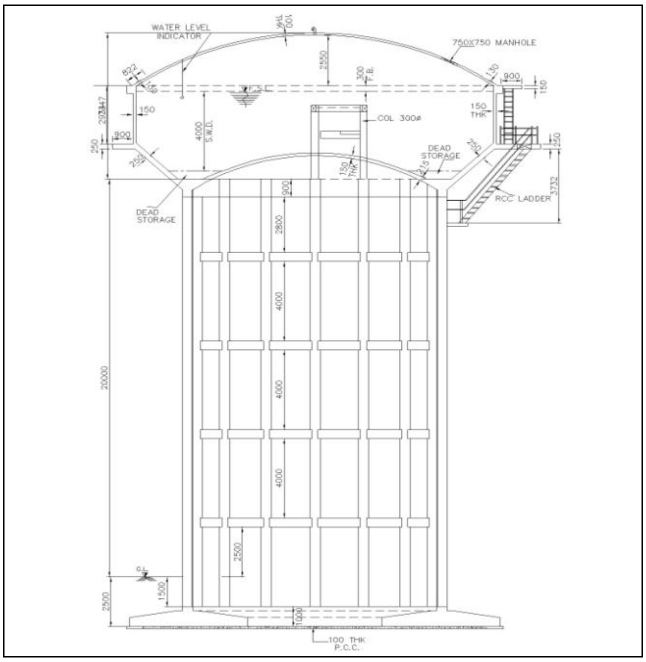

Fig -3: Intze Type Water Tank

4.2 Design of Intze tank as per IS:3370

- **Top Dome**
- Thickness = 100 mm
- Force = 4.5 KN/m^2
- Hoop Stress = 0.293 N/mm^2
- Meridonial stress = 0.325 N/mm^2
- Reinforcement = 350 mm^2

- **Top Ring Beam**
- Size = 400 x 400 (mm)
- Meridonial Thrust = 32.5 KN/m^2
- Hoop tension = 202.80 KN
- Tensile stress = 1.30 N/mm^2
- Reinforcement = 1770 mm^2

- **Cylindrical Wall**
- Height = 400 x 400 (mm)
- Thickness = 150 (mm)
- Hoop tension = 230.10 KN/m
- Reinforcement = 2818 mm^2

- **Middle Ring Beam**
- Size = 250 x 900 (mm)
- Hoop tension = 375 KN
- Reinforcement = 2885 mm^2
- Tensile Stress = 1.49 N/mm^2

- **Conical Dome**
- Thickness = 250 (mm)
- Meridonial thrust = 258 KN/m
- Hoop tension = 416.50 KN/m
- Tensile stress = 1.498 N/mm^2
- Reinforcement = 3204 mm^2

- **Bottom Spherical Dome**
- Thickness = 150 (mm)
- Meridonial thrust = 157.34 KN/m
- Meridonial stress = 1.280 N/mm^2
- Hoop stress = 1.156 N/mm^2
- Reinforcement = 525 mm^2

- **Bottom Ring Beam**
- Size = 450 x 900 (mm)
- Load = 346.0 KN/m
- Hoop Compression = 156.20 KN
- Hoop stress = 0.385 N/mm^2
- Reinforcement = 2181.41 mm^2

Further the Columns, Braces and Foundation for staging is designed using STAAD PRO V8i software for different wind speed as per IS 875 (Part-3)-2003 and seismic analysis for different earthquake zones by "Response spectrum method" as per IS 1893-2003. Following are the different cases for which staging is designed and compared:

- Case-1 Wind Speed = 39 m/s Zone-II
- Case-2 Wind Speed = 47 m/s Zone-III
- Case-3 Wind Speed = 50 m/s Zone-IV
- Case-4 Wind Speed = 55 m/s Zone-V

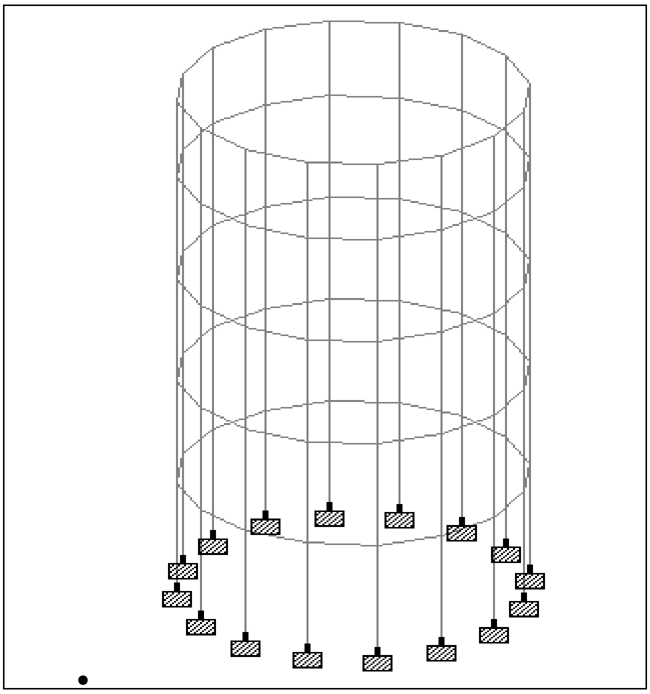

Fig -4: 2-D Staad Model Intze tank

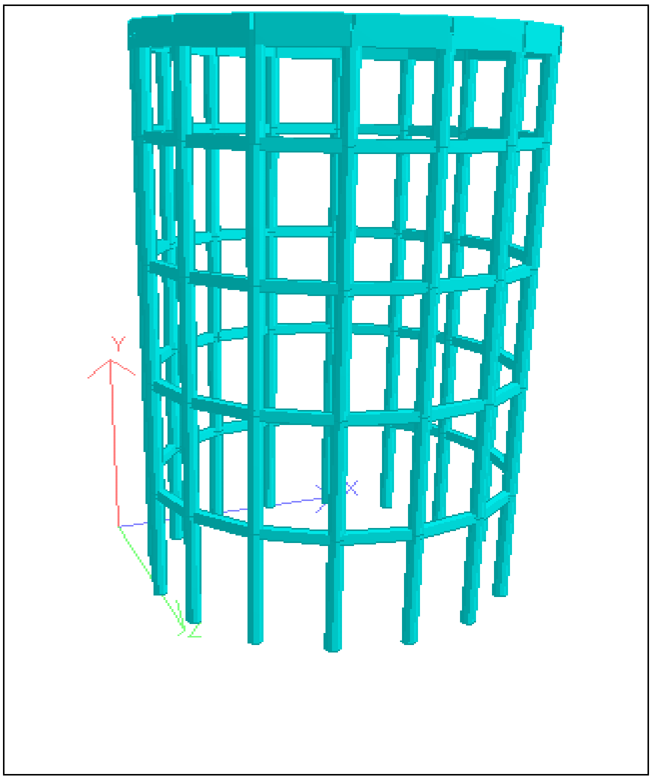

Fig -5: 3-D Staad Model Intze tank

5. ANALYSIS AND COMPARSION OF RESULTS FOR DIFFERENT CASES OF INTZE TANK

For each case different model has been prepared and the loading as per theoretical calculation has been entered and analyzed in Staad Pro software to get total loads and moments on different structural elements of staging. Following are the results for different cases:

Table -1: Wind and Seismic analysis results (Case-1)

CASE-1		
Wind Speed - 39 m/s		Seismic Zone-II
WIND ANALYSIS		
Total Wind Load	210.00	KN
Total Wind Moment	3308.05	KN (Theoretical)
Total Wind Moment	3152.4	KN (Staad Pro)
Applying 160 KN load at top 16 nodes of the frames		
Deflection	2.26	mm
EARTHQUAKE ANALYSIS		
Tank Full Condition	121.13	KN
Tank Empty Condition	68.71	KN

Table -2: Bracing analysis results (Case-1)

BRACING DETAILS	**SIZE: 250 MM X 400 MM**	
Typical Calculation For Lowest Braces:		
Moment at Face	37.51	KN.m (Staad Pro)
Torsional Moment	2.73	KN.m (Staad Pro)
Typical Calculation For Second lowest Braces:		
Moment at Face	36.49	KN.m (Staad Pro)
Torsional Moment	2.15	KN.m (Staad Pro)
Typical Calculation For Third lowest Braces:		
Moment at Face	28.88	KN.m (Staad Pro)
Torsional Moment	1.78	KN.m (Staad Pro)
Typical Calculation For Top Outer Braces:		
Moment at Face	18.674	KN.m (Staad Pro)
Torsional Moment	0.99	KN.m (Staad Pro)

Table -3: Column analysis results (Case-1)

COLUMN DETAILS		**SIZE: 400 MM DIA CIRCULAR**
Lowest Column Height Ground i.e. 1st Storey		
Total Load	919.04	KN (Theoretical Value)
Total Moment	49.34	KN.m (Staad Pro Result)
Permissible stress		1.27 < 1.33
Middle Column Height i.e.3rd Storey		
Total Load	814.94	KN (Theoretical Value)
Total Moment	30.31	KN.m (Staad Pro Result)
Permissible stress		1.21 < 1.33
Top Column Height Ground i.e. 4th Storey		
Total Load	814.94	KN (Theoretical Value)
Total Moment	30.46	KN.m (Staad Pro Result)
Permissible stress		1.23 < 1.33

Table -4: Raft foundation analysis results (Case-1)

RAFT FOUNDATION	**SIZE: 16 M X 5 M**	
Total Load	12792.50	KN
Total Moment	3895.91	KN.m
Depth	700	mm
Ring Beam	450 X 1000	mm

Table -5: Wind and Seismic analysis results (Case-2)

CASE-2		
Wind Speed - 44 m/s		Seismic Zone-III
WIND ANALYSIS		
Total Wind Load	292.34	KN
Total Wind Moment	4521.94	KN (Theoretical)
Total Wind Moment	4334.55	KN (Staad Pro)
Applying 160 KN load at top 16 nodes of the frames		
Deflection	2.05	mm
EARTHQUAKE ANALYSIS		
Tank Full Condition	223.86	KN
Tank Empty Condition	133.29	KN

Table -6: Bracing analysis results (Case-2)

BRACING DETAILS		**SIZE: 250 MM X 450 MM**
Typical Calculation For Lowest Braces:		
Moment at Face	50.00	KN.m (Staad Pro)
Torsional Moment	2.87	KN.m (Staad Pro)
Typical Calculation For Second lowest Braces:		
Moment at Face	48.66	KN.m (Staad Pro)
Torsional Moment	2.26	KN.m (Staad Pro)
Typical Calculation For Third lowest Braces:		
Moment at Face	38.12	KN.m (Staad Pro)
Torsional Moment	1.85	KN.m (Staad Pro)
Typical Calculation For Top Outer Braces:		
Moment at Face	24.36	KN.m (Staad Pro)
Torsional Moment	0.99	KN.m (Staad Pro)

Table -7: Column analysis results (Case-2)

COLUMN DETAILS		**SIZE: 450 MM DIA CIRCULAR**
Lowest Column Height Ground i.e. 1st Storey		
Total Load	967.78	KN (Theoretical Value)
Total Moment	67.65	KN.m (Staad Pro Result)
Permissible stress		1.31 < 1.33
Middle Column Height i.e.3rd Storey		
Total Load	912.34	KN (Theoretical Value)
Total Moment	41.48	KN.m (Staad Pro Result)
Permissible stress		1.08 < 1.33
Top Column Height Ground i.e. 4th Storey		
Total Load	912.31	KN (Theoretical Value)
Total Moment	40.99	KN.m (Staad Pro Result)
Permissible stress		1.07 < 1.33

Table -8: Raft foundation analysis results (Case-2)

RAFT FOUNDATION	SIZE: 16 M X 5.8 M	
Total Load	13397.67	KN
Total Moment	5354.42	KN.m
Depth	700	mm
Ring Beam	450 X 1000	mm

Table -9: Wind and Seismic analysis results (Case-3)

CASE-3		
Wind Speed - 47 m/s		Seismic Zone-IV
WIND ANALYSIS		
Total Wind Load	326.59	KN
Total Wind Moment	5084.00	KN (Theoretical)
Total Wind Moment	4872.45	KN (Staad Pro)
Applying 160 KN load at top 16 nodes of the frames		
Deflection	2.30	mm
EARTHQUAKE ANALYSIS		
Tank Full Condition	253.2	KN
Tank Empty Condition	155.6	KN

Table -10: Bracing analysis results (Case-3)

BRACING DETAILS	SIZE: 250 MM X 450 MM	
Typical Calculation For Lowest Braces:		
Moment at Face	55.97	KN.m (Staad Pro)
Torsional Moment	3.21	KN.m (Staad Pro)
Typical Calculation For Second lowest Braces:		
Moment at Face	54.67	KN.m (Staad Pro)
Torsional Moment	2.54	KN.m (Staad Pro)
Typical Calculation For Third lowest Braces:		
Moment at Face	43.07	KN.m (Staad Pro)
Torsional Moment	2.09	KN.m (Staad Pro)
Typical Calculation For Top Outer Braces:		
Moment at Face	27.59	KN.m (Staad Pro)
Torsional Moment	1.12	KN.m (Staad Pro)

Table -11: Column analysis results (Case-3)

COLUMN DETAILS		SIZE: 450 MM DIA CIRCULAR
Lowest Column Height Ground i.e. 1st Storey		
Total Load	986	KN (Theoretical Value)
Total Moment	77.3	KN.m (Staad Pro Result)
Permissible stress		1.30 < 1.33
Middle Column Height i.e.3rd Storey		
Total Load	915	KN (Theoretical Value)
Total Moment	49.7	KN.m (Staad Pro Result)
Permissible stress		1.19 < 1.33
Top Column Height Ground i.e. 4th Storey		
Total Load	915	KN (Theoretical Value)
Total Moment	46.45	KN.m (Staad Pro Result)
Permissible stress		1.16 < 1.33

Table -12: Raft foundation analysis results (Case-3)

RAFT FOUNDATION	SIZE: 16 M X 5.8 M	
Total Load	13599.00	KN
Total Moment	6014.48	KN.m
Depth	700	mm
Ring Beam	450 X 1000	mm

Table -13: Wind and Seismic analysis results (Case-4)

CASE-4		
Wind Speed - 50 m/s		Seismic Zone-V
WIND ANALYSIS		
Total Wind Load	376.88	KN
Total Wind Moment	5865.36	KN (Theoretical)
Total Wind Moment	5623.76	KN (Staad Pro)
Applying 160 KN load at top 16 nodes of the frames		
Deflection	2.67	mm
EARTHQUAKE ANALYSIS		
Tank Full Condition	324.79	KN
Tank Empty Condition	239.86	KN

Table -14: Bracing analysis results (Case-4)

BRACING DETAILS	SIZE: 250 MM X 450 MM	
Typical Calculation For Lowest Braces:		
Moment at Face	64.6	KN.m (Staad Pro)
Torsional Moment	3.7	KN.m (Staad Pro)
Typical Calculation For Second lowest Braces:		
Moment at Face	63.1	KN.m (Staad Pro)
Torsional Moment	2.93	KN.m (Staad Pro)
Typical Calculation For Third lowest Braces:		
Moment at Face	49.71	KN.m (Staad Pro)
Torsional Moment	2.41	KN.m (Staad Pro)
Typical Calculation For Top Outer Braces:		
Moment at Face	31.86	KN.m (Staad Pro)
Torsional Moment	1.30	KN.m (Staad Pro)

Table -15: Column analysis results (Case-4)

COLUMN DETAILS		SIZE: 450 MM DIA CIRCULAR
Lowest Column Height Ground i.e. 1st Storey		
Total Load	1014.62	KN (Theoretical Value)
Total Moment	89.03	KN.m (Staad Pro Result)
Permissible stress		1.30 < 1.33
Middle Column Height i.e.3rd Storey		
Total Load	921.31	KN (Theoretical Value)
Total Moment	53.9	KN.m (Staad Pro Result)
Permissible stress		1.18 < 1.33
Top Column Height Ground i.e. 4th Storey		
Total Load	921.31	KN (Theoretical Value)
Total Moment	53.62	KN.m (Staad Pro Result)
Permissible stress		1.17 < 1.33

Table -16: Raft foundation analysis results (Case-4)

RAFT FOUNDATION	**SIZE: 17 M X 6 M**	
Total Load	13853.43	KN
Total Moment	6942.08	KN.m
Depth	900	mm
Ring Beam	450 X 1000	mm

Following are the Comparison charts for total loads and moments on staging as per analysis results for different cases mentioned above:

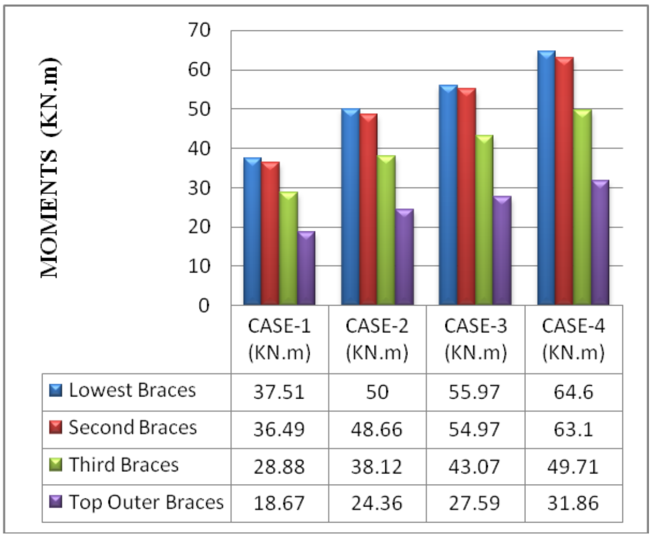

Chart -1: Moments at face of bracings

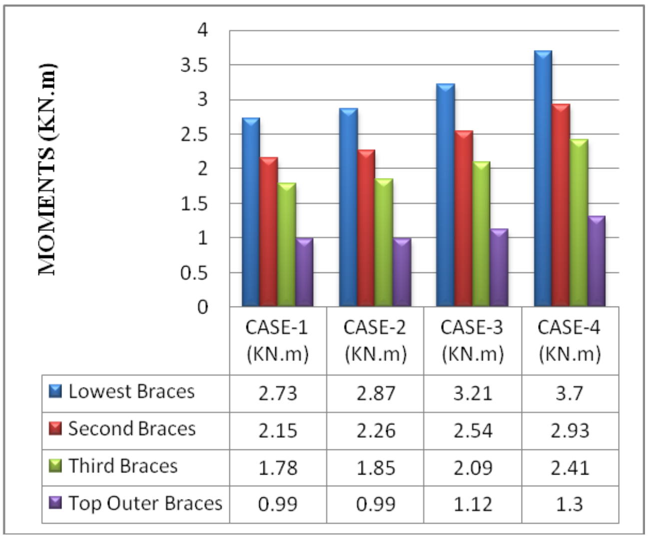

Chart -2: Torsional moments at bracings

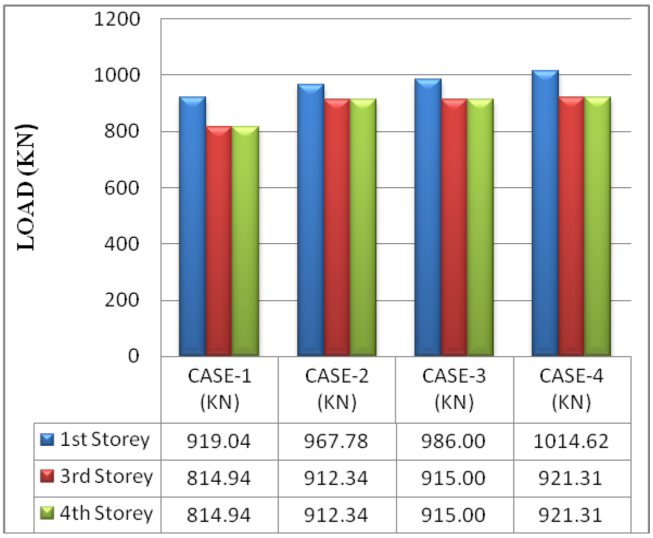

Chart -3: Total load on Column

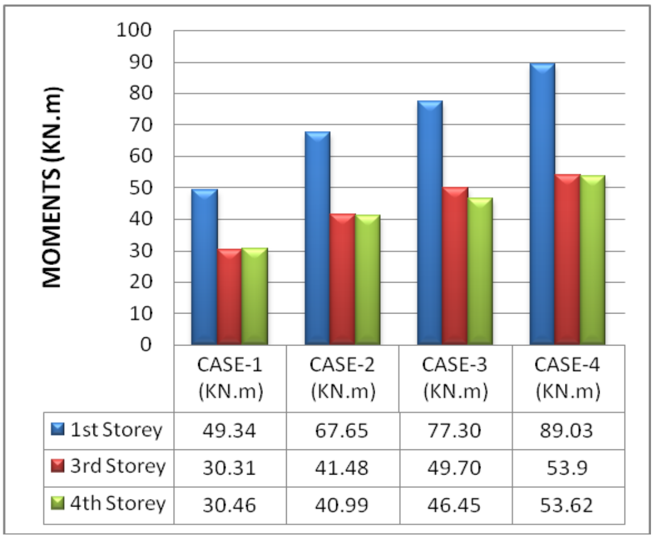

Chart -4: Total moments on Column

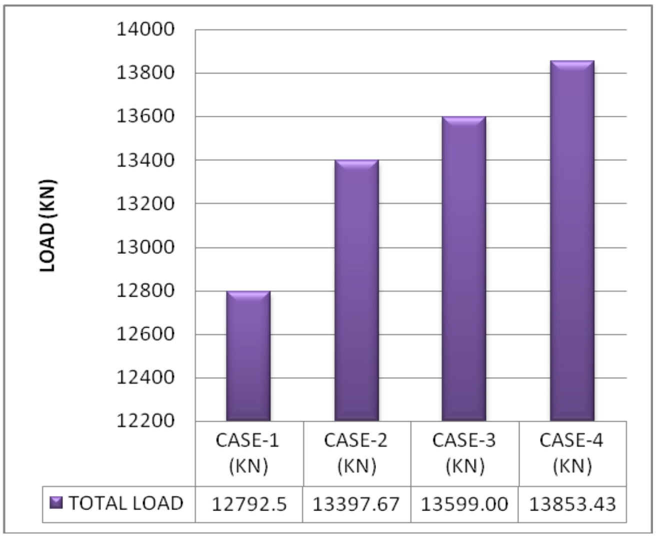

Chart -5: Total Load on Foundation

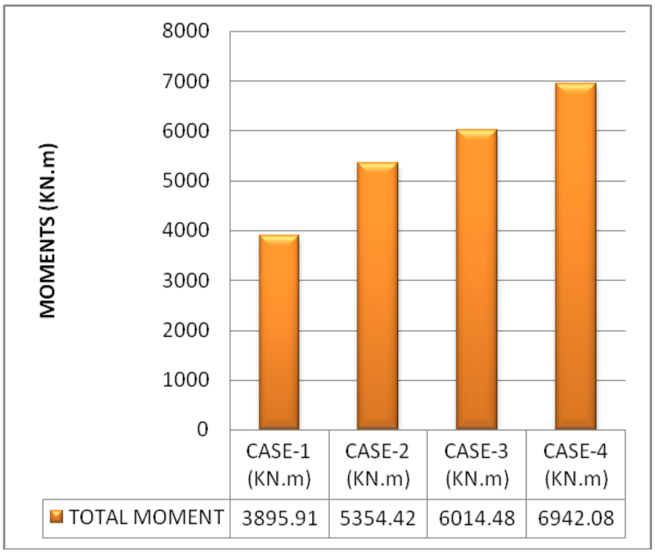

Chart -6: Total moments on Foundation

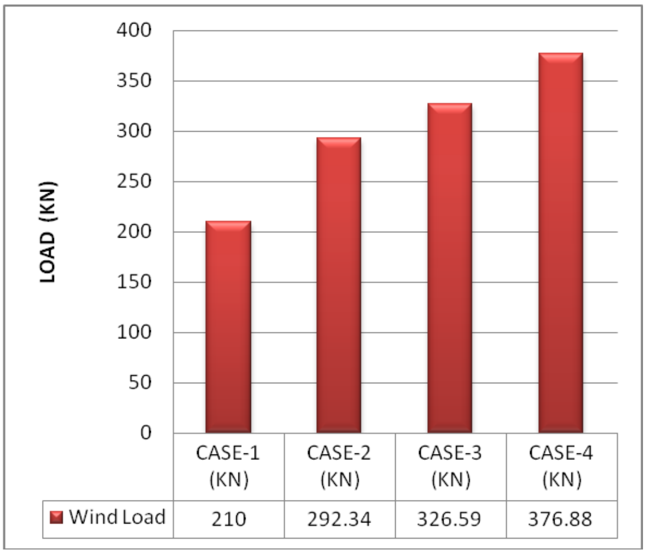

Chart -7: Total wind load on Intze tank

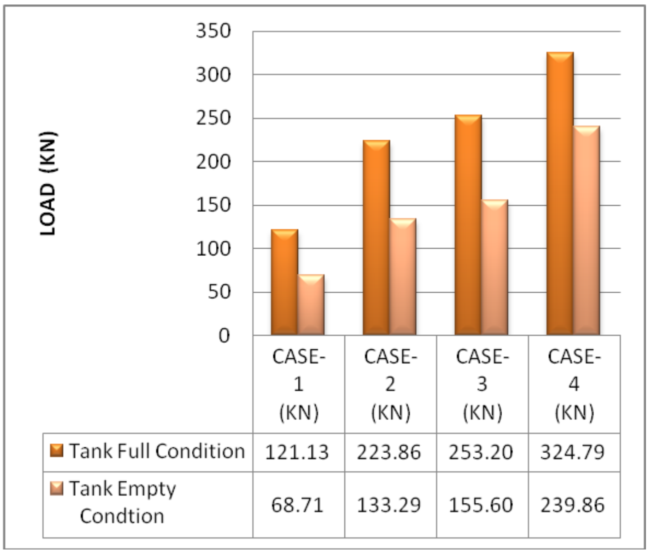

Chart -8: Total Seismic load for tank full and tank empty condition

6. CONCLUSIONS

Following are the conclusions based on the design and analysis carried out in this project:

- As the wind speed and seismic zone increases for the same bearing capacity volume of concrete and quality of steel both are increased.
- We have seen that, as the wind speed increases the wind force on staging goes on increasing for different cases.
- From chart-1, we analyzed that the wind load has been increased by almost 15-18% in each case.
- From chart-2, we come to know that the seismic load in case-4 has been increased almost 3 times as compared to case-1 in tank full condition. Similarly, the seismic load in case-4 has been increased 4 times in tank empty condition.
- From chart-3, we analyzed that for different cases the moments at face of braces, from lowest braces to top outer braces has been increased almost 2 times in each cases.
- Similarly, from chart-4, we see that the torsional moment has been increased almost 3 times as the wind speed increases.
- From chart-5, we analyzed that the Total load on columns in 1st storey goes on increasing in each case, but the Total load on 2nd & 3rd storey remains almost constant in each case.
- From chart-6, we analyzed that the total moments on column on 1st storey goes on increasing in each cases.
- As the wind speed goes on increasing the load on Raft Foundation goes on increasing in each case by almost 2-5 % from chart-7.,
- From chart-8, we analyzed that the total moments on Raft foundation has been increased by 15 % as the wind speed increases in each case.
- As the Load and moments on foundation goes on increasing in each case the size of Raft Foundation goes on increasing.
- In each case, as the wind speed goes on changing or increasing the wind moment calculated manually and analyzed from Staad Pro software differ by 4-5 %.

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