International Journal of Innovative Research in Computer Science & Technology (IJIRCST)
ISSN: 2347-5552, Volume-11, Issue-1, January 2023
https://doi.org/10.55524/ijircst.2023.11.1.17
Article ID IRPV1089, Pages 87-91
www.ijircst.org

# Design and Compartive Study of Overhead Tank Subjected to Seismic Forces in Different Zones

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**ABSTRACT-** Overhead tank are generally classified as Ordinary Moment Resisting Frame (OMRF) and Special Moment Resisting Frame (SMRF) supported response reduction factor. Generally, the Overhead tank consists of structural members like slabs, beams, columns, and footings, where the subjected loads are transferred between the structural members and eventually transferred to the Sub-grade of the soil. The behavior of the Overhead tank is different for various sorts of loadings (Dead, Live, Wind, and Seismic) within the analysis and of overhead tank usefully Indian standards codes suggest various loads combinations supported probability of Occurrence. There are around 52 load combinations and IS codes suggest the lateral load (wind and seismic) acts independently but the load governing the planning of structural members is to be acknowledged. and therefore the present study to research the consequences of wind and seismic forces on Overhead tank structures of heights (15m) are considered in seismic zones II, III, IV, V where length and width of the structures are kept constant. An earthquake load is calculated as per IS and wind pressure calculated as per IS 875-1987. The analysis is done the use of STAAD.pro software.

**KEYWORDS-** Overhead Tank, Seismic Forces, Earthquakes, Wind Pressure

## I. INTRODUCTION

Types of Loads on Structures in the construction of an overhead tank, two major factors considered are safety and economy.

If the hundreds are adjudged and brought higher than the economy is affected. If the economy is taken into account and loads are taken lesser then the security is compromised.

Types of loads working on a structure are:

- Dead loads
- Imposed loads
- Earthquake loads
- Wind loads

### A. Dead Loads (DL)

The first vertical load that's considered is load. Dead load: These are the stationary or permanent loads that are transmitted to structure all over the life span. the load is primarily thanks to the self-weight of structural members, fixed permanent equipment has and weight of various materials. It majorly consists of the weight of roofs, beams, walls, and columns, etc. c. which are otherwise the permanent parts of the overhead tank. The Indian Standard Code Book for Dead Loads is IS 875 (Part -1) -1987. The calculation of dead a lot of each structure are calculated by the quantity of every section and multiplied with the unit weight.

### B. Imposed loads (IL)

The second vertical load that's considered in the design of a structure is imposed loads or live loads. Live loads are either movable or moving loads with none acceleration or impact. these masses are assumed to be produced via the meant use or occupancy of the construction which includes weights of movable partitions or fixtures and so forth. live loads keep it up changing from time to time. those masses are to be assumed via the designer. it's one among the main load within the design. The minimum values of live masses to be assumed are given in IS 875 (part 2)–1987. It depends upon the meant use of the building. a number of the important values are presented in the table below which are the minimum values and wherever necessary quite these values are to be assumed.

### C. Earthquakes Loads

Sudden movement on faults is liable for earthquakes. An earthquake is just the vibrations caused by the blocks of rock on either side of a fault rubbing against one another as they move in opposite directions. the larger the movement, the bigger the earthquake. Effect of Earthquake: Earthquakes occur when masses of rock in crust slip and slide against each other. this type of movement is commonest along a fault. when portions of crystal rock all of sudden slip and pass, they release widespread quantities of power, which then propagates there the crust as seismic waves. At the surface, these waves cause the bottom to shake and vibrate, sometimes violently.

Geologists classify seismic waves into large classes: body and surface: body waves are again divided into p and s waves. P waves means sound waves which means they compress and expand material as they pass. S wave's means water waves, which means they move material up and down.

After an earthquake strikes, P waves come first followed by S waves and then comes the slower Surface waves. Both waves move horizontally with ground but surface waves can move vertically. If earthquakes only moved the ground vertically, tanks might suffer little damage because all structures are designed to withstand vertical forces. But when horizontal waves exert causes Lateral accelerations, which are measured as G-Forces.

### *D. Earthquake Zones in India*

The various geology at specific places in the country means that the chance of damaging earthquakes taking location at specific places in different. Thus, a seismic zone map is required so that tanks and other structures located in different regions can be designed to withstand different level of ground shaking. Presently in India, we have the most effective 4 seismic zones II, III, IV, and V. nearby versions in soil kind and geology can't be represented at that scale. IS Code 1893 -2002 PART I assigns different zone factors based on past seismic intensities for different cities and towns.

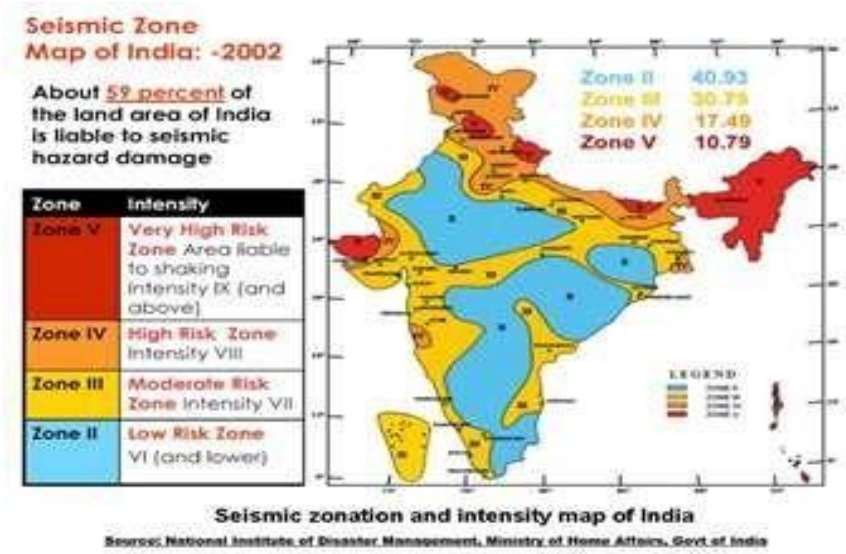


Figure 1: seismic zone

### *E. Wind Load*

Wind load is one of the important load influencing the design of a tank structure. For the analysis of a tank considering the effect of wind load, it is necessary to calculate the wind speed and pressure for different height of tank and for different geometry. various major standards and codes gives us the procedures and coefficients required for calculation of wind load for particular parameters, like for importance of tank, surrounding terrain, topography of tank size, pressure and force coefficients for different geometric shapes and sizes of tanks

### *F. Wind Load Phenomenon*

Over the past few years, the behavior and characteristics of the atmospheric wind in the lower layers of the atmosphere have become increasingly important in relation to design requirements over a broad range of engineering problems. Therefore is: 875 (part 3) – 1987 codebook suggests wind speed velocities for different heights of tanks.

### *G. Wind Pressure Calculations*

the simple wind speed for any site will be received by using including the following results to get design wind speed, vz at any height, z for the selected shape :(a)risk stage, (b)Terrain roughness and height of structure, (c) local topography, and (d) significance factor for the cyclonic location.

It can be mathematically expressed as follows:

$V_z = V_b\ k_1\ k_2\ k_3\ k_4$, wherein

$V_z$ = design wind velocity at any height z in m/s,

$k_1$ = possibility factor (threat coefficient) (see 5.3.1)

$k_2$ = terrain roughness and height factor (See 5.3.2),

$k_3$ = topography factor (see 5.3.3), and

$k_4$ = significance element for the cyclonic location

Observe: the wind speed can be taken as consistent up to a height of 15 m.

However, pressures for tanks less than 15m high may be reduced by 20% for stability and design of the framing.

Risk Coefficient (k1)

Fig.1gives primary wind speeds for terrain category 2 as relevant at 10 m height above mean floor stage based totally on 50 years mean return duration. The recommended life span to be assumed in the layout and the corresponding k1 factors for specific classes of structures for the reason of design are given in table 1. Within the design of all tanks and structures, a nearby simple wind velocity having an average return duration of 50 years will be used besides as detailed within the note of table 1.

### *H. Terrain and Height Factor (K2)*

Terrain in which a selected structure stands could be assessed as being one of the following terrain categories

- Category 1 – uncovered open terrain with a few or no obstructions and in which the average peak of any object surrounding the structure is much less than1.5 m.
- Category 2 – Open terrain with properly scattered obstructions having peak normally among 1.5 and 10 m.
- category 3 – Terrain with numerous carefully spaced obstructions having the dimensions of constructing-structures up to 10 m in peak without or with some

remoted tall structures.

- Category 4 – Terrain with numerous big excessive carefully spaced obstructions.

Table 1: Factors to obtain design wind speed variation with height in deferent terrains for deferent classes of buildings structures

| Height | Terrain Category 1 Class | | | Terrain Category 2 Class | | | Terrain Category 3 Class | | | Terrain Category 4 Class | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| m | A | B | C | A | B | C | A | B | C | A | B | C |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| 10 | 1·05 | 1·03 | 0·99 | 1·00 | 0·98 | 0·93 | 0·91 | 0·88 | 0·82 | 0·80 | 0·76 | 0·67 |
| 15 | 1·09 | 1·07 | 1·03 | 1·05 | 1·02 | 0·97 | 0·97 | 0·94 | 0·87 | 0·80 | 0·76 | 0·67 |
| 20 | 1·12 | 1·10 | 1·06 | 1·07 | 1·05 | 1·00 | 1·01 | 0·98 | 0·91 | 0·80 | 0·76 | 0·67 |
| 30 | 1·15 | 1·13 | 1·09 | 1·12 | 1·10 | 1·04 | 1·06 | 1·03 | 0·96 | 0·97 | 0·93 | 0·83 |
| 50 | 1·20 | 1·18 | 1·14 | 1·17 | 1·15 | 1·10 | 1·12 | 1·09 | 1·02 | 1·10 | 1·05 | 0·95 |
| 100 | 1·26 | 1·24 | 1·20 | 1·24 | 1·22 | 1·17 | 1·20 | 1·17 | 1·10 | 1·20 | 1·15 | 1·05 |
| 150 | 1·30 | 1·28 | 1·24 | 1·28 | 1·25 | 1·21 | 1·24 | 1·21 | 1·15 | 1·24 | 1·20 | 1·10 |
| 200 | 1·32 | 1·30 | 1·26 | 1·30 | 1·28 | 1·24 | 1·27 | 1·24 | 1·18 | 1·27 | 1·22 | 1·15 |
| 250 | 1·34 | 1·32 | 1·28 | 1·32 | 1·31 | 1·26 | 1·29 | 1·26 | 1·20 | 1·28 | 1·24 | 1·16 |
| 300 | 1·35 | 1·34 | 1·30 | 1·34 | 1·32 | 1·28 | 1·31 | 1·28 | 1·22 | 1·30 | 1·26 | 1·17 |
| 350 | 1·37 | 1·35 | 1·31 | 1·36 | 1·34 | 1·29 | 1·32 | 1·30 | 1·24 | 1·31 | 1·27 | 1·19 |
| 400 | 1·38 | 1·36 | 1·32 | 1·37 | 1·35 | 1·30 | 1·34 | 1·31 | 1·25 | 1·32 | 1·28 | 1·20 |
| 450 | 1·39 | 1·37 | 1·33 | 1·38 | 1·36 | 1·31 | 1·35 | 1·32 | 1·26 | 1·33 | 1·29 | 1·21 |
| 500 | 1·40 | 1·38 | 1·34 | 1·39 | 1·37 | 1·32 | 1·36 | 1·33 | 1·28 | 1·34 | 1·30 | 1·22 |

Note 1 — See 5.3.2.2 for definitions of Class A, Class B and Class C structures.

Note 2 — Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between 2 heights for simplicity.

### I. Height Factor

The effect of topography can be large at a site while the upwind slope (6) is more than approximately 3", and under that, the value of k3 may be taken to be the same to 1-O. The value of ks is limited within the range of 1 to 1.36 for slopes more than 3O

Table 2: Risk coefficients for different classes of structures in different wind speed zones

| Class of Structure | Mean Probable design life of structure in years | $k_1$ factor for Basic Wind Speed (m/s) of | | | | | |
|---|---|---|---|---|---|---|---|
| | | 33 | 39 | 44 | 47 | 50 | 55 |
| All general buildings and structures | 50 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Temporary sheds, structures such as those used during construction operations (for example, formwork and false work), structures during construction stages, and boundary walls | 5 | 0.82 | 0.76 | 0.73 | 0.71 | 0.70 | 0.67 |
| Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings, etc. | 25 | 0.94 | 0.92 | 0.91 | 0.90 | 0.90 | 0.89 |
| Important buildings and structures such as hospitals, communication buildings, towers and power plant structures | 100 | 1.05 | 1.06 | 1.07 | 1.07 | 1.08 | 1.08 |

### J. Design Wind pressure

The design wind pressure at any peak above suggest ground stage will be received by using the following relationship between wind pressure and wind speed

PZ =0.6 Vz 2 in which

PZ = design wind pressure in N/ms at peak

Vz - design wind speed in m/s at peak.

### K. Wind pressure calcultion

Type of structure: overhead tank; Terrain category = 1

Length = 6m, Width = 4m, Height=15m; Class-B (Between 15m-50m)

Type of zone = zones II, III, IV, V

Basic WIND SPEED ($V_b$) = 60m/sec

$K_1$= Risk coefficient for important tanks/towers = 1

$K_2$ = terrain, structure height and size factor

$K_3$ = topography factor = 1 (upwind slope < 3º)

Design WIND SPEED = $V_Z = V_B K_1 K_2 K_3$

Design WIND PRESSURE = $P_z = 0.6 V_Z^2$

## II. METHODOLOGY

The study involves the following steps:

Structural Design: The overhead tank is designed based on relevant design codes and standards considering the water load, live load, and dead load. The design incorporates appropriate reinforcement detailing and concrete strength.

Seismic Analysis: The tank is subjected to seismic forces based on the spectral acceleration values corresponding to different seismic zones. Finite Element Analysis (FEA) is employed to simulate the response of the tank under seismic loading.

Comparative Study: The tank's response is analyzed for multiple seismic zones, ranging from low seismicity to high seismicity regions. The performance of the tank is evaluated in terms of displacement, stress distribution, and potential failure modes.

## III. RESULTS AND DISCUSSION

The results of the study are presented as follows:
Displacement Analysis: The displacement of the tank increases with the increase in seismic zone. This indicates that tanks located in higher seismic zones experience more significant displacements during an earthquake.
Stress Distribution: The stress distribution in the tank's walls and base varies with seismic zone. Tanks in higher seismic zones experience higher stresses, particularly at the base. This emphasizes the importance of proper foundation design to withstand seismic forces.
Failure Modes: The analysis reveals potential failure modes for different seismic zones. In lower seismic zones, the tank remains within elastic limits, while in higher seismic zones, plastic deformation and cracking may occur. Proper detailing of reinforcement can mitigate these effects.

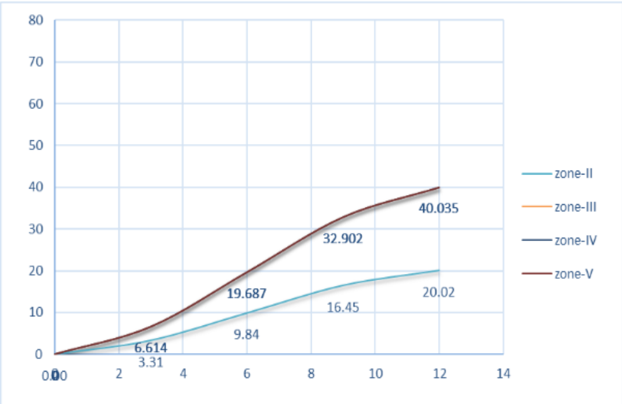


Figure 1: Comparison of Maximum Displacement Graphs of Tanks for Various Seismic Zones

**NOTE:** The displacements& direction x-factor valves same in zone-II, III, IV

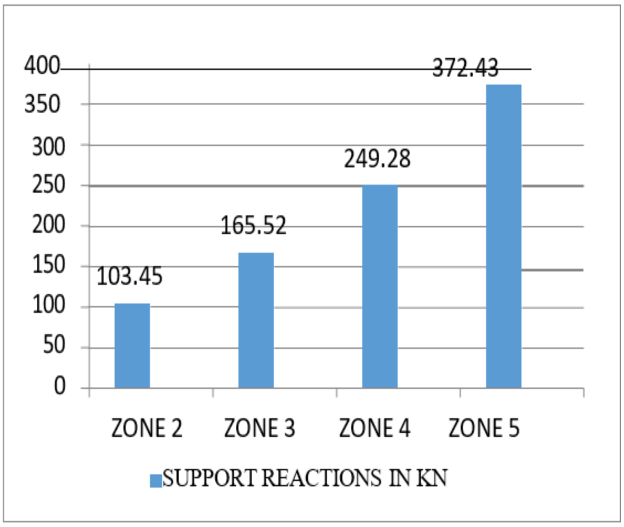


Figure 2: Comparison of Support Reactions of Tank for Various Seismic Zones

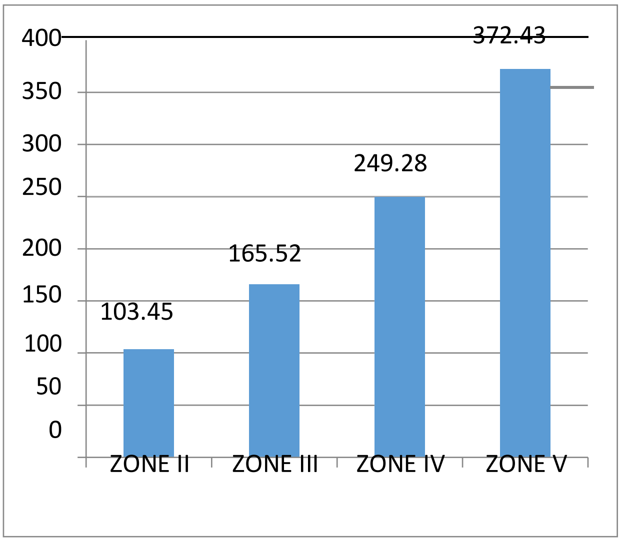


Figure 3: Maximum support reactions along direction Y

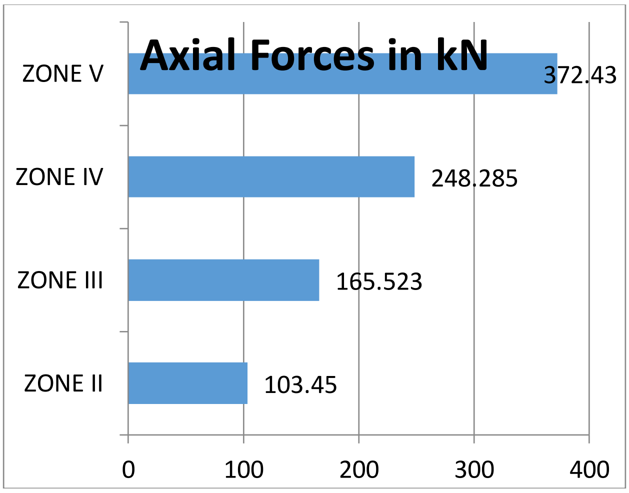


Figure 4: Comparison of Maximum Axial Forces of Tank for Various Seismic Zones

### L. *Seismic Drift Results*

As per IS: 1893(part 1):2002 Clause 7.11.1, The storey drift in any storey due to the minimum specified design lateral force, with partial load 0factor of 1.0 shall not exceed 0.004 times of the storey height (h).
Height of the storey (h) = 3m =3000mm. Maximum Storey Drift = 0.004x3000 =12mm.

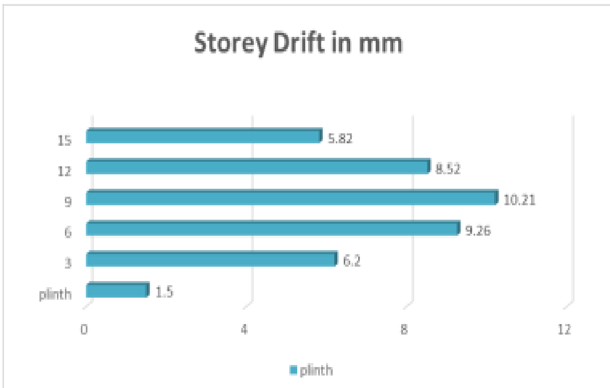


Figure 5: Maximum storey drift in Zone-V under earthquake loads for tank

Maximum displacement due to wind loads along length(x-direction)
Maximum Displacement For tank = (15000)/ (500) = 30mm. Displacement of Structures for Lateral Wind Load along Length=15m, Direction: X

## IV. CONCLUSION

As per IS: 456:2000, clause (20.5), Maximum lateral sway at the top should not exceed (H/500) for wind loads, where H is the Height of the tank. Maximum Displacement For tank = 30mm. As per IS: 1893(part 1):2002 Clause 7.11.1, The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times of the storey height(h=3000mm).Maximum Storey
Drift = 0.004x3000=12mm.

- Maximum Wind Displacement is in Limits for 15m (tank) (16.03mm)
- The Lateral Drift for tank is in limits for Zones II, III &IV. But it exceeds its limits for Zone V.
- The Maximum Drift for tank (15.83mm) Occurs in Seismic Zone –V.
- Base shear of full water tank and empty water tank are increased with seismic zone II-V because of zone factor, response reduction factor etc. while considering seismic analysis.
- Maximum nodal displacement and minimum nodal displacement found at the wall of water tank when tank is full condition
- For Axial Forces and Support Reactions, considering 15m (tank) (103.45 kN) Seismic Zone –II as reference the values for Zone –III, IV, V Increases by 1.6, 2.4, 3.6 times of reference structures respectively.
- Structure Height does not influence in axial forces and Support Reactions for different Structures in Various Zones.
- Governing Load case for structure 15m (tank) Zone –V is 1.5D. L+1.5E.L.

From all the conclusions, it is concluded that Seismic Force is more predominant than wind Force

## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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