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# Analysis of Rectangular Elevated Water Tank for Seismic Load from Zone II to Zone IV

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***Abstract:*** *Elevated water tanks are one of the most lifeline structures in earthquake prone regions. These structures have large mass concentrated at the top of slender supporting structures and are especially vulnerable to horizontal forces due to earthquake and wind. They are critical elements in municipal water supply, firefighting systems and in many industrial facilities for storage of water. Hence elevated water tanks must remain functional even after the earthquake.*

*The main aim of this study is to analyze the rectangular elevated water tank and comparing the forces created on elevated water tank in different seismic zones due to earthquake. Any Civil Engineering structures are conceived keeping in mind its intended use, the materials available, cost and aseptic considerations. The analysis of elevated water tank is performed on Impulsive mode and convective mode using the code IS: 1893 (Part – 2): 2014 and also we have considered the forces in both tank full and tank empty condition.*

*From this study, the forces acting on elevated water tank due to seismic forces are calculated for Zone II to Zone IV and also the base shear and base moment values are compared for Zone II to Zone IV. Then finally, values are represented in the form of tables and graphs.*

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## I. INTRODUCTION

Indian sub – continent is highly vulnerable to natural disasters like earthquake, draughts, floods, cyclones etc. Majority of states or union territories are prone to one or multiple disasters. These natural calamities are causing many casualties and innumerable property loss every year. Earthquakes occupy first place in vulnerability. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893 (Part -1): 2002, more than 60% of India is prone to earthquakes. After an earthquake, property loss can be recovered to some extent, however, the life loss cannot. The main reason for life loss is collapse of structures. It is said that earthquake itself never kill people, it is badly constructed structures that kill. Hence it is important to analyze the structure properly for earthquake effects.

Water supply is a life line facility that must remain functional following disaster. Most municipalities in India have water supply system, which depends on elevated water tanks for storage. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a sufficient height to pressurize a water distribution system.

These structures have large mass concentrated at top of slender supporting structure, hence these structure are especially vulnerable to horizontal forces due to earthquakes. Therefore, it is important to check the severity of these forces for particular region.

All over the World, the elevated water tanks were collapsed or heavily damaged during the earthquakes because of unsuitable design of supporting systems or wrong selection of supporting system and underestimated demand or overestimated strength.

Keeping these problems in consideration “Bureau of Indian Standards” has published codes especially for liquid retaining structures.

IS: 1893 (Part – 2): 2014 – “Criteria for earthquake resistant design of structures”(Part -2, Liquid retaining tanks) is based on the guidelines and suggestions by

IITK – GSDMA for seismic design of liquid storage tanks. This paper evaluates all the seismic analysis parameters using the recommended procedure in latest code as well as in IIT – GSDMA guidelines, and is concentrated mainly to the sloshing effect that is happening in the water during earthquake. Sloshing is defined as the periodic motion of the free liquid surface in partially filled container. It is caused by any disturbance to partially filled containers. If the liquid is allowed to slosh freely, it can produce additional hydrodynamic pressure in case of storage tanks. Hence, considerations of these forces are necessary, during analysis.

## II. OBJECTIVES

Following are the objectives of present study.

- To make a study about the seismic and analysis of rectangular elevated water tank.
- To make a study about the guidelines for the design of liquid retaining structure according to IS 1893 (Part I), IS 1893 (Part II).
- To determine and compare the base shear, overturning moment for different zone of earthquake considered.
- To study the hydrodynamic effect on elevated water tank.
- To compare the effects of Impulsive pressure and Convective pressure results.

## III. SCOPE

Scope of the study is to know the effect of seismic on rectangular elevated water tank considering Zone II, III, and IV with tank full and empty condition. Finite element modeling of tank was carried out using software Etab, seismic analysis was carried out. Base shear, overturning moment and hydrodynamic pressure on wall and base slab obtained from analysis were compared.

## IV. PROBLEM STATEMENT

The present work involves study of Seismic and Wind Analysis of Rectangular elevated water tank having capacity of 2500 cu.m considering various seismic zones.(i.e. II to IV). The tank is supported on RC staging of 20 columns with horizontal bracing at three levels. The aim of study is to find out the differences in various parameters of structure by using ETABS software.

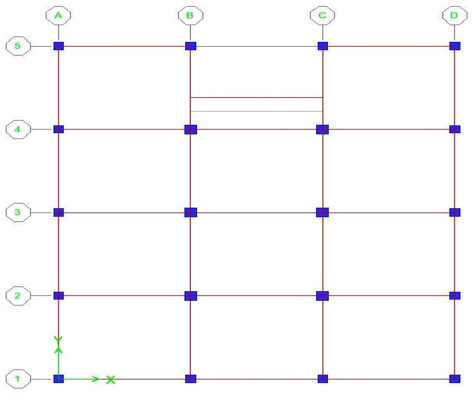


**Figure 1: Plan of Rectangular Elevated Water Tank**

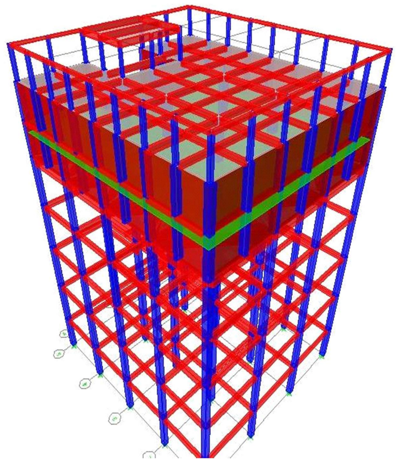

**Figure 2: Elevation of Rectangular Elevated Water Tank**

**Table 1: Preliminary Data**

| **Particulars** | **Model A,B,C** |
|---|---|
| Capacity Of Tank (cu.m) | 2500 |
| Max.Length in 'X' Direction (m) | 21 |

| | |
|---|---|
| Max.Length in ‘Y’ Direction (m) | 22.5 |
| No.of Staging | 3 |
| Height of Staging (m) | 4.85 |
| Total height of Staging (m) | 19.4 |
| Height of Tank (m) | 6.45 |
| Tank Bottom Slab Thickness (mm) | 200 |
| Tank Top Slab Thickness (mm) | 115 |

**Table 2 : Seismic Parameters**

| Sr. No | Parameter | Model A | Model B | Model C | IS Code |
|---|---|---|---|---|---|
| 1 | Seismic Zone | II | III | IV | **IS 1893 Part-I, 2002** |
| 2 | Zone Factor (Z) | 0.1 | 0.16 | 0.24 | **IS 1893 Part-I, 2002,** Clause 6.4.2 |
| 3 | Importance Factor (I) | 1.5 | 1.5 | 1.5 | **IS 1893 Part-2, 2014,** Clause 4.5 |
| 4 | Response Reduction factors (R) | 3.5 | 3.5 | 3.5 | **IS 1893 Part-2, 2014,** Clause 4.5 |
| 5 | Type of Soil | Hard | Hard | Hard | As Per geotechnical report |

# V. METHODOLOGY

FOR SEISMIC ANALYSIS AS PER IS 1893 (PART-2):2014

Most elevated tanks are never completely filled with liquid. Hence two-mass idealization of the tank is more appropriate as compared to one-mass idealization, which was used in IS: 1893: 1984. Two-mass model proposed by Housner (1963) and is being now commonly used in most of the international codes including IS: 1893 (Part-2):2014. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass and induces impulsive hydrodynamic pressure on tank wall and similarly on base. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and base. Thus total liquid mass gets divided into two parts, i.e. impulsive mass and convective mass.

For elevated tanks, impulsive and convective parameters with rectangular container are available in IS: 1893 (Part-2): 2014. The two-degree of freedom system shown in Figure - 1c, can be treated as two uncoupled single degree of freedom system as shown in Figure – 1d. Later represents, the impulsive mass plus structural mass (mi + ms) behaving as an inverted pendulum with lateral stiffness equal to that of the staging (Ks) and the other represent convective mass (mc) with spring of stiffness (Kc).

Structural mass (ms) includes mass of container and one-third mass of staging. Mass of container comprises of roof slab, container wall, gallery (if any), floor slab and floor beams. The response of the two-degree of freedom system can be obtained by elementary structural dynamics. However, for most elevated tanks, it is observed that the two time periods are well separated. Hence, the two mass idealizations can be treated as two uncoupled single degree of freedom systems.

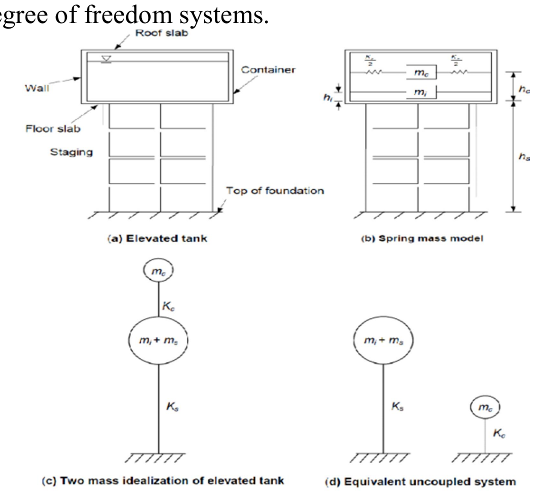


**Figure 3:** Two-Mass Idealization of Elevated Tank

## VI. RESULTS

Comparison of Seismic Parameters for Zone II to IV

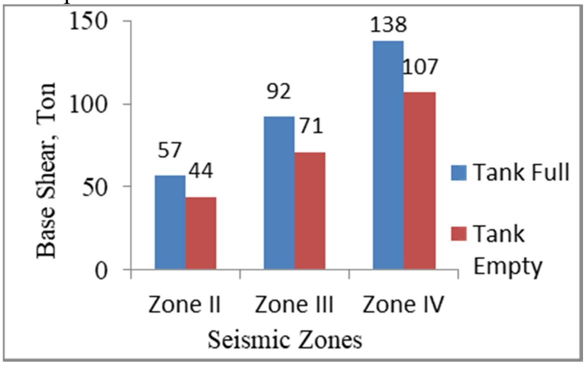


**Figure 4:** Base Shear Vs Seismic Zones (Tank Full and Empty)

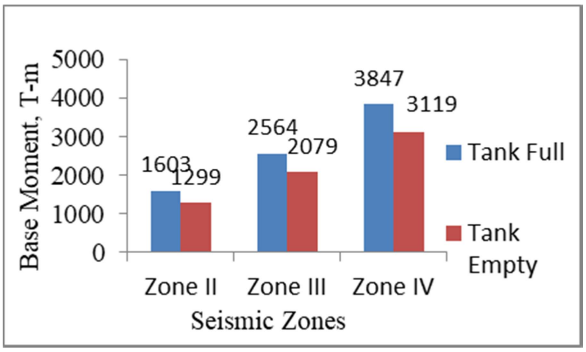


**Figure 5:** Base Moment Vs Seismic Zones (Tank Full and Empty)

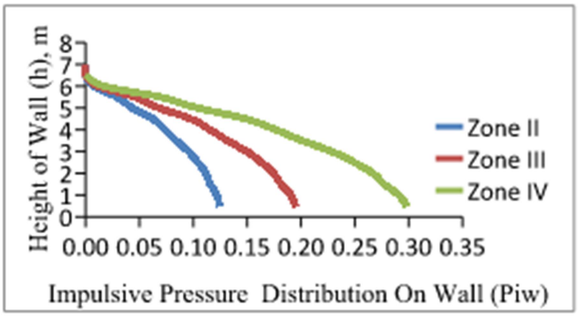


**Figure 6:** Impulsive Pressure Distributio On Wall (Piw) Vs Seismic Zones

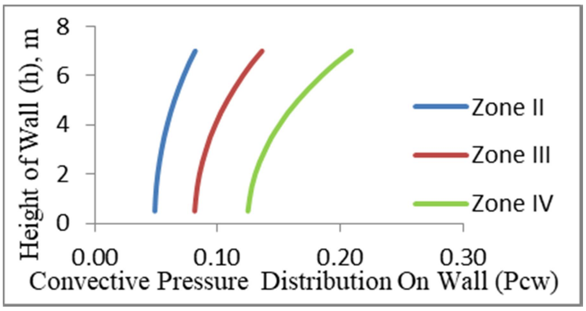


**Figure 7:** Convective Pressure Distribution On Wall (Pcw) Vs Seismic Zones

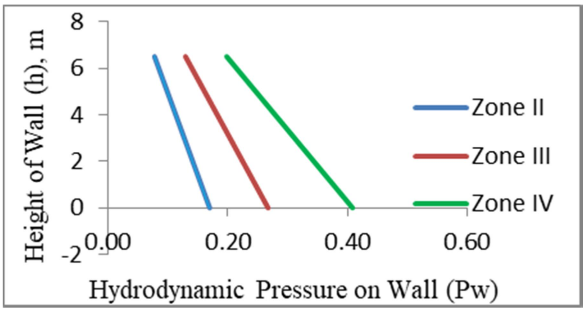


**Figure 8 :** Hydrodynamic Pressure On Wall (Pw) Vs Seismic Zones

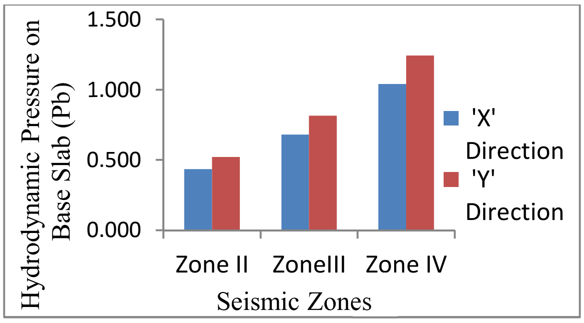


**Figure 9:** Hydrodynamic Pressure On Base Slab (Pb) Vs Seismic Zones

## VII. CONCLUSION

- As Shown in Fig.4, Base Shear increases in the range of 60 – 150% with increase of seismic zone successively from Zone II to Zone IV considering hard rock in tank full and empty conditions.
- As Shown in Fig.5, Base Moment increases in the range of 50 – 150% with increase of seismic zone successively from Zone II to Zone IV considering hard rock in tank full and empty conditions.
- As Shown in Fig.8 & 9, Hydrodynamic Pressure on Wall and Base slab increases in the range of 45 – 145% with increase of seismic zone successively from Zone II to Zone IV considering hard.

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