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Seismic Analysis of Existing Underground Water Tank Using ETABS

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***Abstract* - The design principles specify high serviceability criteria with strong water tightness and fracture prevention criteria to reduce leakage and deterioration of reinforcing steel. Considering these strict restraints, additional emphasis is placed on accurately estimating the governing design forces in order to meet both economic and workability requirements. There have been few studies on seismic analysis of underground water tanks with dynamic forces. The goal of this research is to understand the response of an underground water tank that has been subjected to seismic loads by comparing the output data. Existing underground water tanks have been used in the study, and finite element modelling of the same tank was performed in ETABS17 for soil conditions according to IS 1893 Part-2-2014.**

Keywords –**Dynamic Pressure, Design Seismic Forces, Seismic Response, Underground Water Tank**

I. INTRODUCTION

Underground water tanks (UGT) are used to store liquids (water, oil, gas, etc.). Walls of underground water tank are to water pressure from inside and soil pressure from outside. The bottom of the tank is subject to internal water pressure and soil reactions from underneath. These tanks should be designed for a worst loading scenario. Underground tanks have the same design and operational principles as tanks that are resting on the ground. Concrete liquid-containing structures are recognized as important utilities during earthquakes. Seismic ground motion causes varied loading conditions in water storage tanks. In addition to the inertial force caused by the weight of the tank walls, hydrodynamic stresses are applied to the tank walls. Due to the general interaction term between the flexible structure and the liquid, the hydrodynamic stress in a flexible tank can be substantially higher than in a rigid container during seismic excitation. [1-3]. The hydrodynamic pressure of an earthquake is often separated into impulsive and convective components. The impulsive component is caused by the tank wall interaction with the liquid and is highly dependent on the wall flexibility, whereas the convective component is produced by the slosh wave. [4]. The dynamic strain on a tank structure caused by fluid displacement inside a tank with a restricted free surface is referred to as sloshing.IS 1893 -Part 2-2014 suggested performing seismic analysis of underground water tank as technique supplied for on ground water tank using dynamic soil coefficient for earth pressure; however, the procedure to compute dynamic soil coefficient is not given in the IS code.

The present study aims at understanding the behaviour of an underground water tank subjected to earthquake loads and compare the output results to understand its behaviour. The specific objective of this study is to calculate seismic load acting on underground water tank as per Indian Standard Codes and investigate effect of seismic loading for underground water tank.

II. MODELLING IN ETABS

Existing water tank situated at Sanwer, Indore (M.P.) is taken for the study. Length and width of underground water tank is 9 m and 4 m respectively Height of tank is 3 m including free board. The thickness of outer and partition wall of tank is 250 mm and 300 mm respectively. The thickness of the bottom slab is 300 mm.

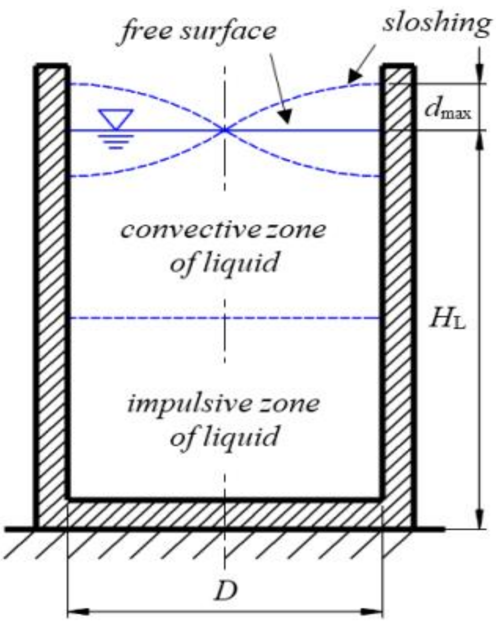

Fig.1. Impulsive and Convective Zone in UGT

Fig.2. Existing Underground Water Tank (UGT)

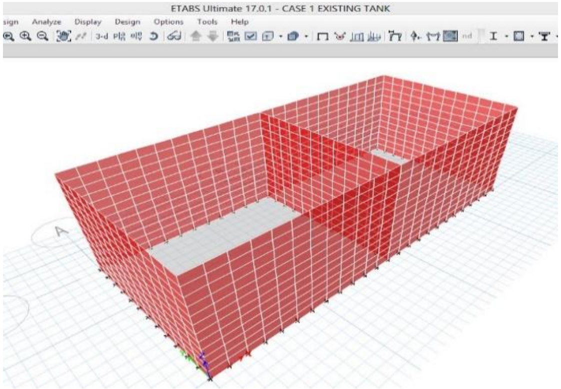

Fig.3. UGT modelling in ETABS

III. LOADING CONDITIONS

Internal water pressure and external soil pressure are two of the most essential loads for which UGT is designed and tested. In ETABS, both water and soil pressure are given as non-uniform shell pressures on the walls of UGT.

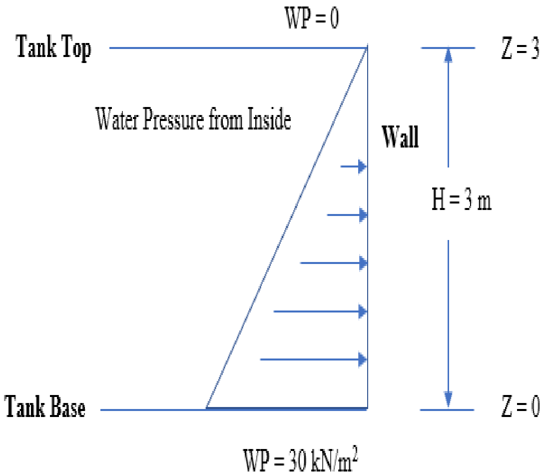

Fig.4. Water Pressure distribution on Tank Walls

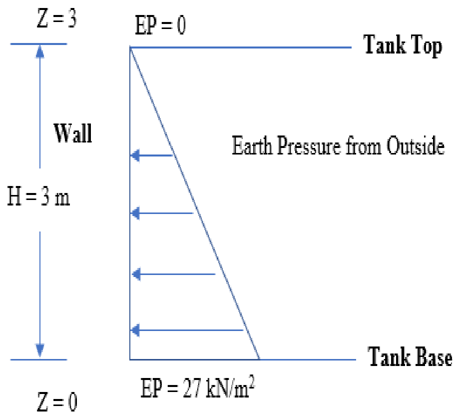

Fig.5. Earth Pressure distribution on Tank Walls

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IV. SEISMIC LOADING

In addition to hydrostatic forces, earthquake-induced hydrodynamic forces on tank walls should be considered. Hydrodynamic forces on UGTs can be estimated using the same approach as that on ground tanks, according to IS 1893-Part 2-2014 [5]. Dynamic pressure on soil must be estimated in UGT. Seismic zone-3 has been used for earthquake analysis in this study due to the location of UGT. In both the X and Y directions, seismic forces in terms of base shear, moment at base of wall, and hydrodynamic pressure on wall in both impulsive and convective modes were calculated using an Excel sheet.

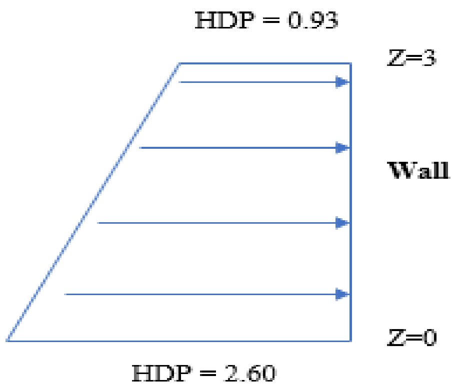

Fig.6. Hydro-dynamic Pressure (HDP) distribution on UGT Walls in X – direction

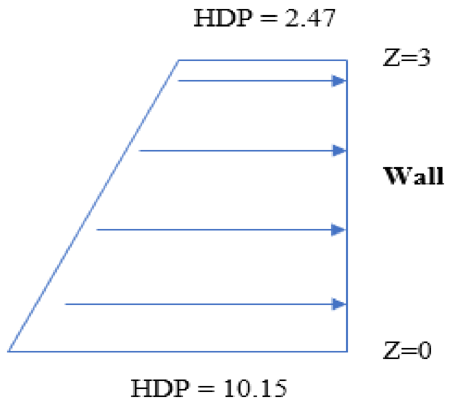

Fig.7. Hydro-dynamic Pressure (HDP) distribution on UGT Walls in Y – direction

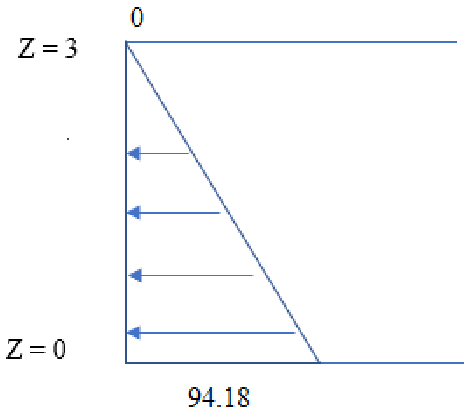

Fig.8. Dynamic Earth Pressure distribution on UGT Walls

V. RESULT AND DISCUSSIONS

A. *Local Axis for Elements*

In ETABS global axes X, Y and Z are used to model and define modelling properties but for defining loads on shells and understanding the results of shell elements local axes 1,2 and 3 has been used. For result tabulation vertical moment, horizontal moment and shear forces are studied for UGT wall. In Case of base slab Moment along shorter and longer span has been studied.

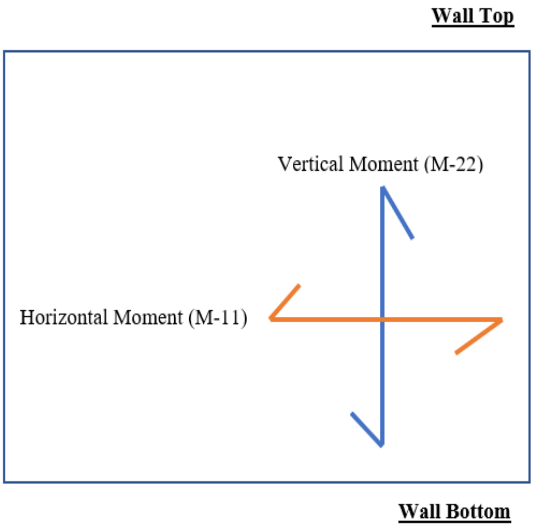

Fig.9. Direction of Moments for UGT Walls

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B. Design forces for wall along X and Y direction

The bending moments developed in the tank wall along X and Y direction under the gravity and seismic loading are shown in figure 10 and 11. Moments at the base of the wall when seismic forces are taken into account are greater than the equivalent moments when seismic forces are not taken into account.. On shorter wall i.e., along Y direction, design forces increase by 150%. As wall along Y are affected by seismic forces in X direction which have less intensity as compared to Y direction seismic forces. Due to which design forces do not increase like X direction.

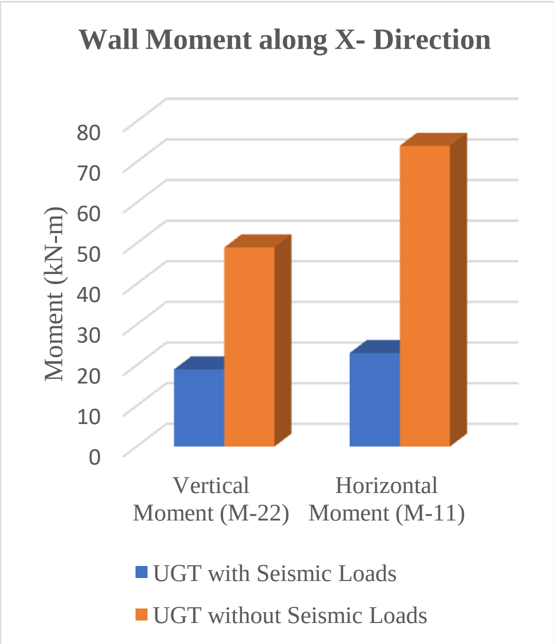

Fig.10. Vertical and Horizontal Moments for Walls in X- direction

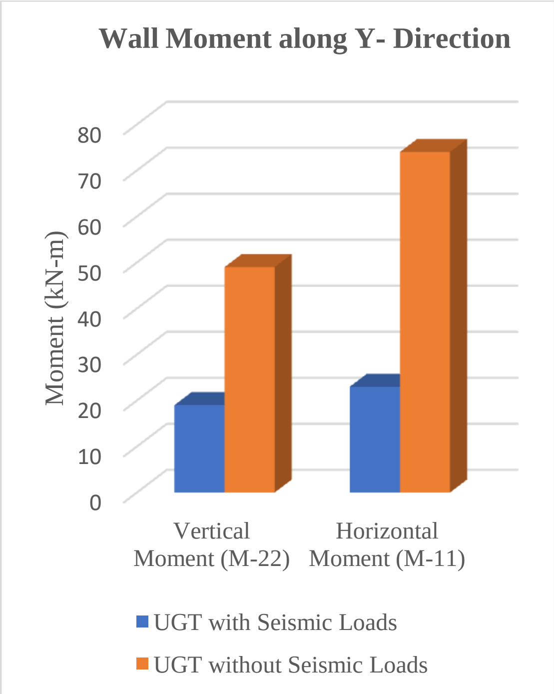

Fig.11. Vertical and Horizontal Moments for Walls in Y- direction

Wall thickness of tank wall governs the shear forces criteria. For existing tank, 250 mm wall thickness can only resist up to 65 kN intensity shear force. On considering seismic forces shear forces increased by 170% as shown in figure 12, which might be leads to failure of wall thickness.

C. Design Moments at Base Slab

When seismic loads are considered in relation to soil conditions, the bending moments in the base slab caused by seismic forces are greater than those caused by non-seismic forces. Although in case of horizontal M11 moment the change on moment is not significant.

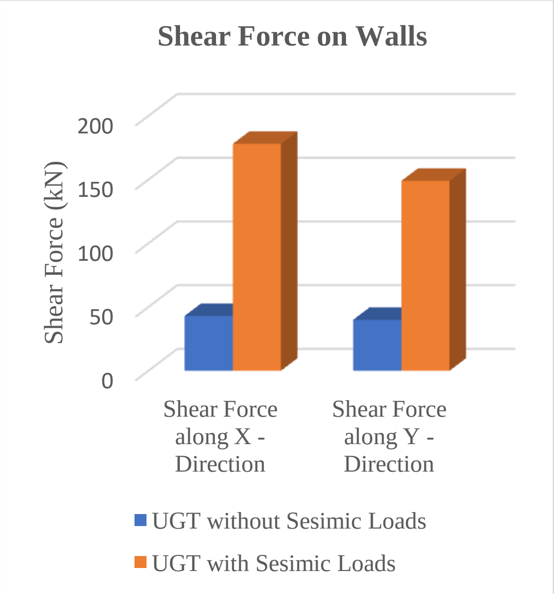

Fig.12. Shear Force on Walls

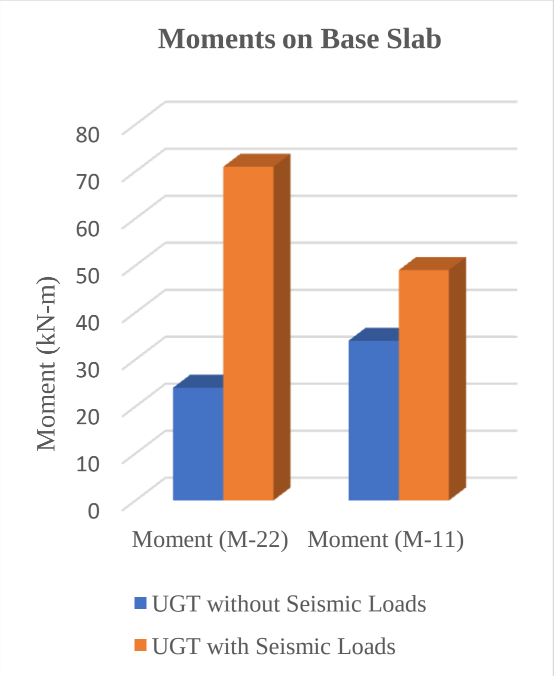

Fig.13. Moments on Base Slab

VI. CONCLUSION

Traditionally as mentioned in IS1893 Part-2-2014, seismic design of underground water tank should be conducted as per the procedure given for on ground tank, but due to lack of information regarding dynamic soil coefficient, seismic analysis of UGT neglected by designer. ETABS was used to perform a three-dimensional finite element analysis. IS1893-Part 2-2014 is used to calculate the Seismic design forces using excel sheet for both X and Y direction.

The following conclusions can be taken from the present research.

1. According to the findings, seismic forces should be accounted for underground water tanks in all earthquake zones.
2. When seismic forces are considered, the moments at the base of the walls along both X and Y direction exceeds the moments in the existing tank walls. Even though soil conditions have little bearing on design force.
3. Shear forces govern the thickness of wall, and when seismic forces hac been considered, shear forces increase, and which results into a redesign the thickness of walls.

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