Parametric Study to Analyze Hydrodynamic Response for Intze Water Tank

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Abstract

Indian sub-continent is vulnerable to natural disasters like earthquakes, cyclones, floods etc. Collapse of structures causes people to life loss that cannot be recovered. Elevated water tanks are considered lifeline structure during any calamities hence it must remain serviceable even after disaster so that domestic as well as incidental needs are fulfilled. Seismic response or behavior of such structures are necessary to be studied in order to meet safety objectives. According to IS 1893 (Part2): 2014 elevated water tank is considered as two mass model. In the present study, efforts are made to understand the behavior of RC intze tank supported on frame type staging, when it is subjected to dynamic pressure. Various parametric studies have been carried out to study the hydrodynamic response by varying the tank capacities they are $500m^3$, $750m^3$,$1000m^3$, height to diameter ratio of cylindrical wall from 0.4 to 0.8, different seismic zones and soil types. Seismic analysis and design is carried out in excel sheet. Here configuration of staging was taken same for all the cases. It is observed that system responses such as time period, hydrodynamic pressure, base shear, overturning moment, sloshing wave height are highly influenced by geometrical parameters.
Keyword- Intze Water Tank, RCC Frame Staging, Sloshing Wave Height, Hydrodynamic Pressure, Impulsive and Convective Mode, Parametric Study

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I. INTRODUCTION

Water is basic need of every living being hence its storage and distribution becomes a prime matter of concern. This depends on design of large storage tanks. In general water tanks are mainly classified as elevated water tank and ground supported water tank. Elevated water tanks are mainly used for water supply schemes and they could be supported on RCC shaft, RCC or steel frame or masonry pedestal. The main advantage of intze tank is that its conical and bottom spherical domes provides an economy and proportions of their proportions are so arranged that the outward thrust from bottom dome balances the inward thrust due to the conical dome.

Sloshing the term refers to the movement of liquid inside another object which is typically undergoing motion. Liquid sloshing and free surface motion not only affects the dynamics of flow inside the container, but also the container itself and sometime it results in heavy loss of life and property.

Phenomenon of liquid sloshing in storage tanks presents a great interest for several industrial branches like naval, aerospace, automobile, civil and nuclear engineering. Thus there is a need to estimate sloshing frequency of liquid in tank, hydrodynamic pressure on wall and proper analysis of fluid tank interaction under seismic excitations for evaluating the performance of storage tanks. There are many codes which recommends (IIT-GSDMA, 2007) procedures that use mechanical models of fluid- tank system that simplifies the analysis.

II. SEISMIC ANALYSIS AS PER IS 1893 (PART2) :2014

Based on work of Housner (1963) this code follows two mass model for elevated water tank. System of tank is considered as two degree of freedom, in which the impulsive mass along with structural mass of container and staging corresponds to first degree of freedom and convective mass corresponds to the second degree of freedom. Both of them imparts hydrodynamic force. With this adoption the accuracy of estimated natural time period which was questionable earlier it is now accurate and hence design force for the tank is determined with high accuracy.

Practically tank is always not completely full of water. When tank is partially full, the free surface is subjected to ground motion it undergoes two types of dynamic fluid pressures. During an earthquake the part of water in lower region vibrates with the container is called impulsive mass and it behaves like a mass that is connected rigidly to tank wall. It induces impulsive hydrodynamic pressure on tank wall and base. Liquid mass in upper region moves relative to the container is called convective mass. It exerts convective hydrodynamic pressure on tank wall and base.

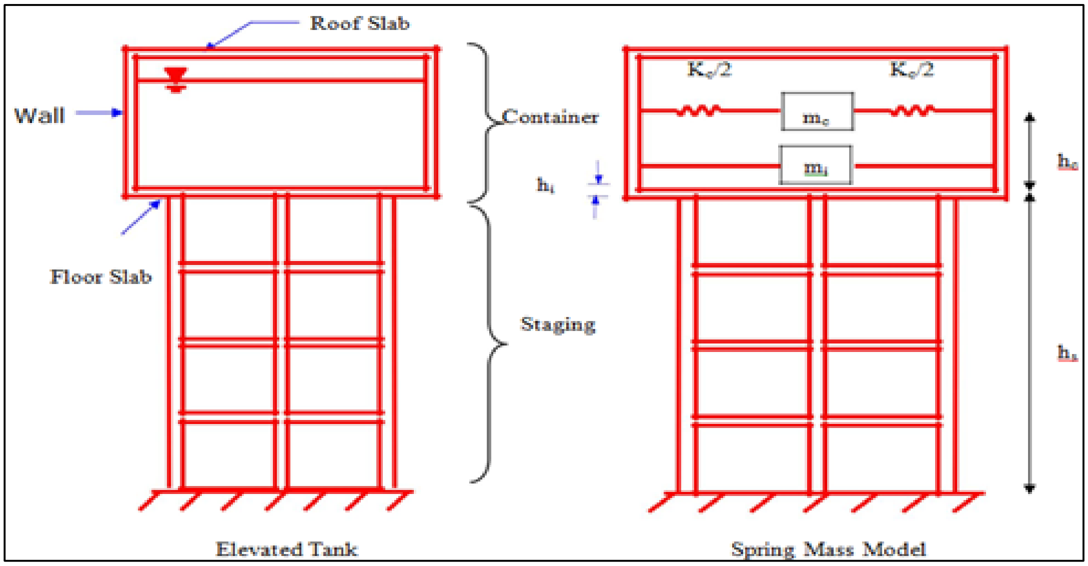


Fig. 1: Spring Mass Model

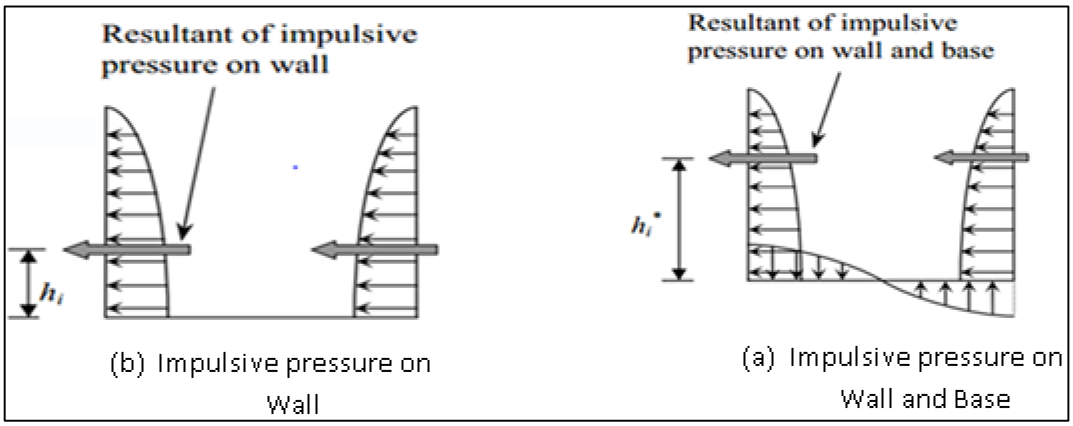


Fig. 2: Impulsive and Convective Hydrodynamic Pressure

III. PARAMETRIC STUDY FOR HYDRODYNAMIC RESPONSE

Parametric study is carried out for various parameters like:
Tank capacities = 500, 750, 1000 m^3.
(h/D) ratio = 0.4, 0.5, 0.6, 0.7, 0.8.
Seismic zones = 3, 4 and 5.
Soil conditions = soft, medium and hard.
Intze tank supported on frame type staging having 6 no. Of RC columns (0.65m dia.) and bracings of 0.3mx0.6m is taken for study.
The grade of concrete selected for study was M30

A. Time Period

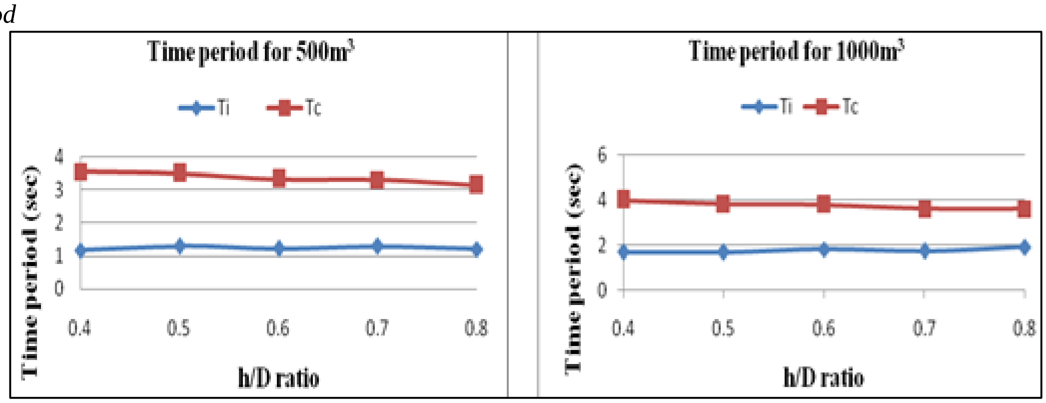
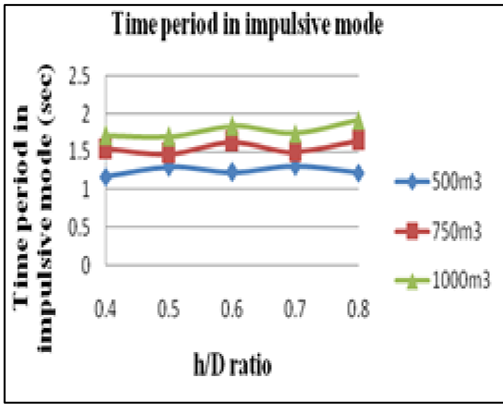


Fig. 3: h/D ratio v/s Time period



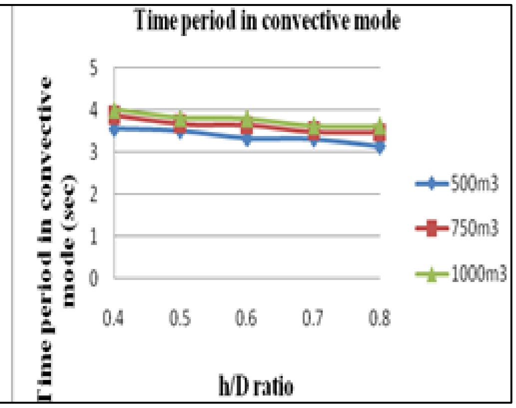
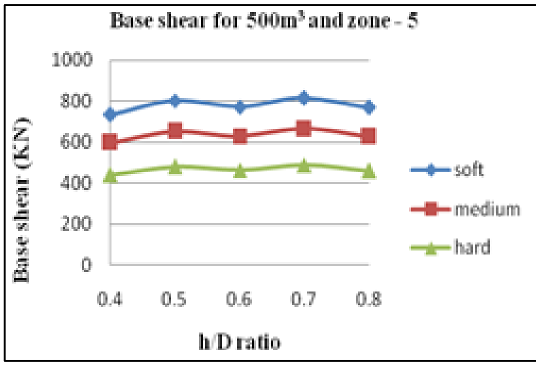


Fig. 4: h/D ratio v/s Time period in impulsive mode   Fig. 5: h/D ratio v/s Time period in convective mode

B. Base Shear



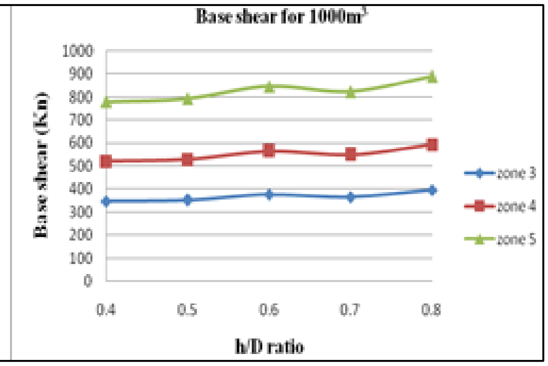
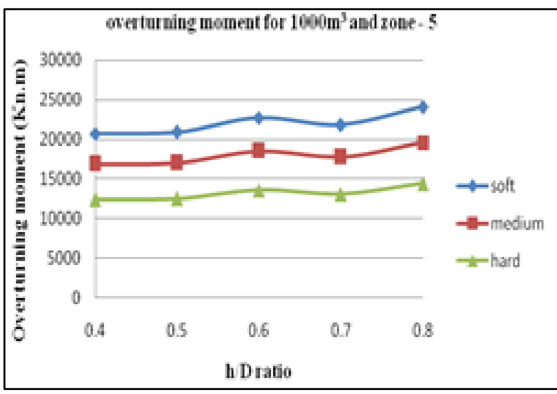


Fig. 6: h/D ratio v/s base shear for different soil type   Fig. 7: h/D ratio v/s base shear for different zones

C. Base Moment



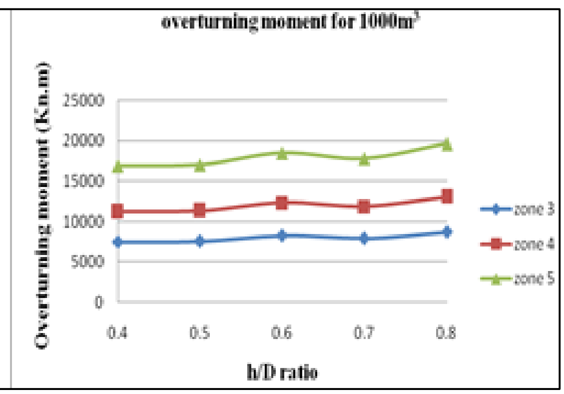
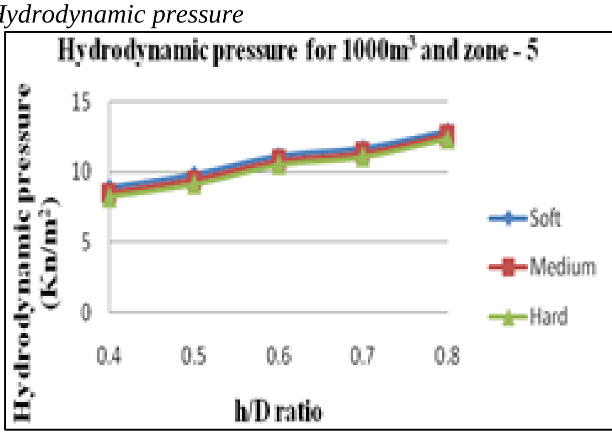


Fig. 8: h/D ratio v/s overturning moment for different soil type   Fig. 9 h/D ratio v/s overturning moment for different zones

D. Hydrodynamic pressure



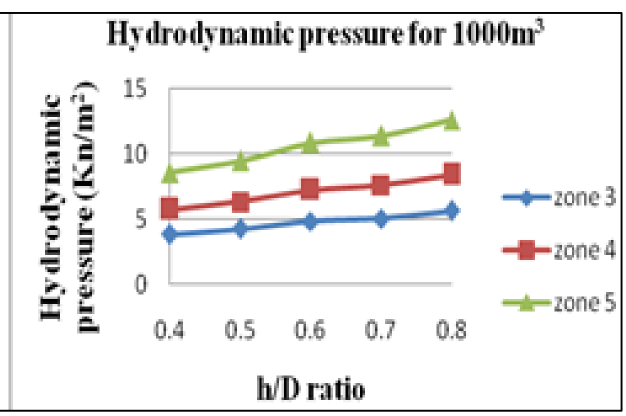


Fig. 10: h/D ratio v/s hydrodynamic pressure for different soil type   Fig. 11: h/D ratio v/s hydrodynamic pressure for different zones

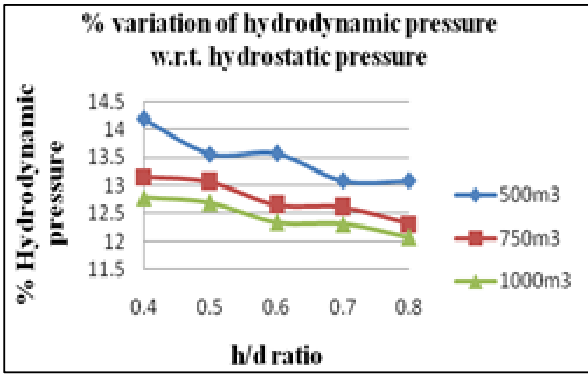


Fig. 12: -% variation of hydrodynamic pressure w.r.t. hydrostatic pressure for soft soil and zone – 5

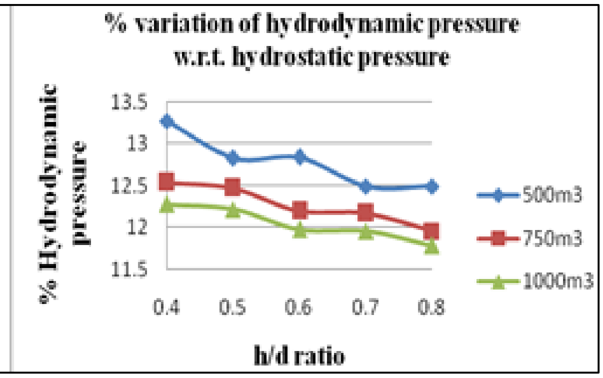


Fig. 13: -% variation of hydrodynamic pressure w.r.t. hydrostatic pressure for medium soil and zone - 5

E. Sloshing wave height

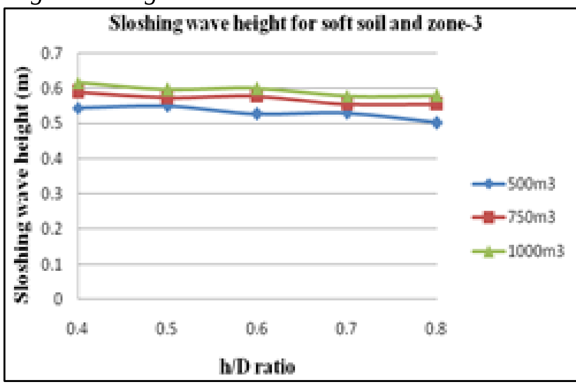


Fig. 14: Sloshing wave height for soft soil and zone-3

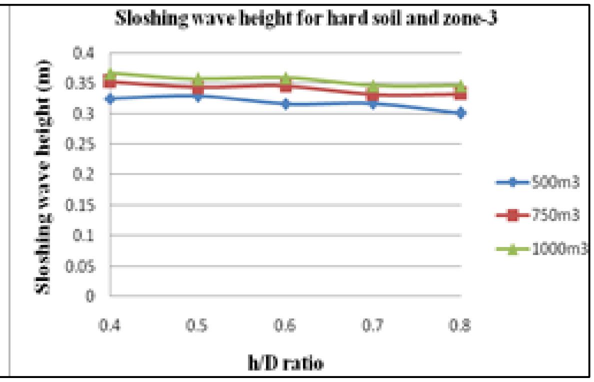


Fig. 15: Sloshing wave height for Hard soil and zone-3

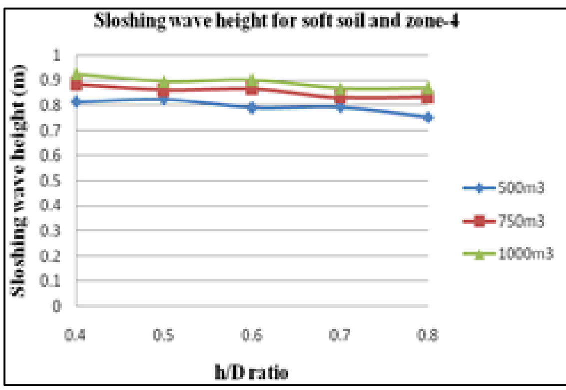


Fig. 16: Sloshing wave height for soft soil and zone- 4

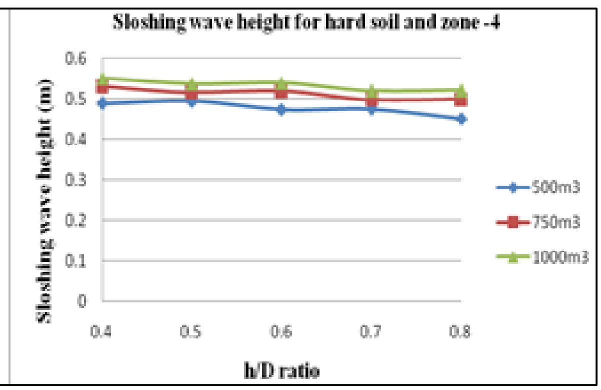


Fig. 17: Sloshing wave height for Hard soil and zone- 4

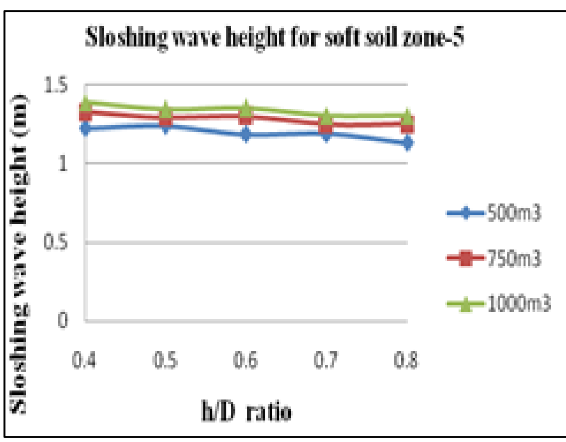


Fig. 18: Sloshing wave height for soft soil and zone- 5

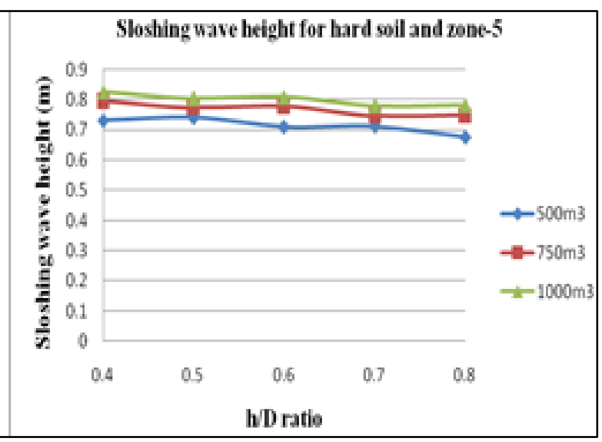


Fig. 19: Sloshing wave height for Hard soil and zone- 5

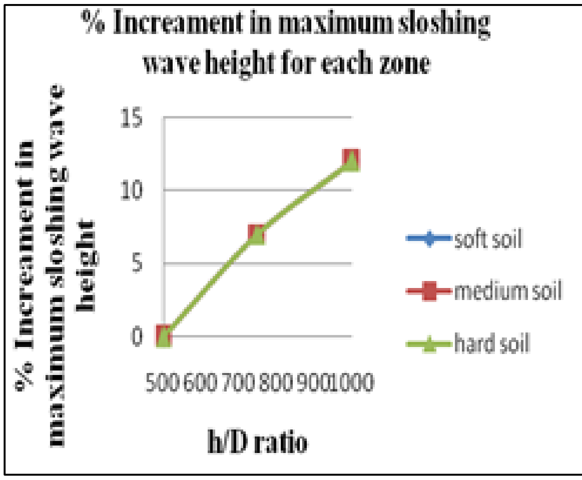


Fig. 20: - % Increase in maximum sloshing wave height for each zone

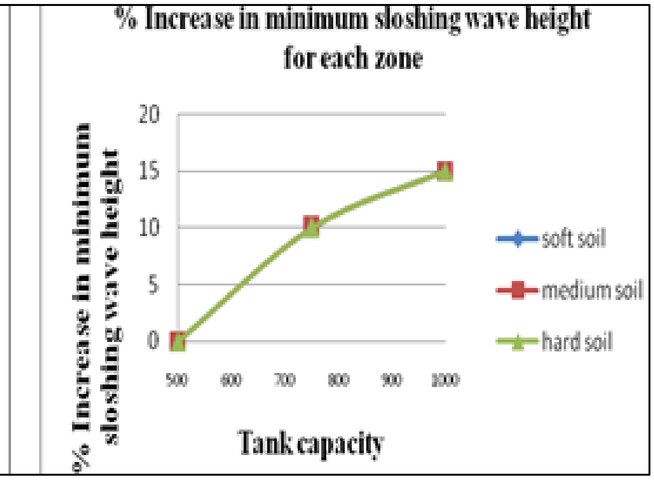


Fig. 21: - % Increase in minimum value of sloshing wave height for each zone

IV. CONCLUSION

- Convective time period is considerably higher than the impulsive time period. When tank capacity increases maximum impulsive time period is observed for (h/D) = 0.8 and maximum convective time period is for (h/D)= 0.4 . Time period is independent of soil type and seismic zones and it increase with increase in tank capacity.
- There is increase in values of base shear and overturning moment respectively with change in hard to soft soil.
- It is also observed that the values of base shear and overturning moment increases largely with change in zone - 3 to zone – 5.
- The hydrodynamic pressure value increases with increase in zone factors.
- Maximum hydrodynamic pressure is 14.19% of hydrostatic pressure which is less than 33% and not critical for intze tank. It is also observed that % hydrodynamic pressure w.r.t. hydrostatic pressure decreases, as h/D ratio increases.
- Sloshing wave height increases with increase in tank capacities and decreases for hard soil as compared to soft and medium soil. There is increase of maximum value by 7% and 12% for $750m^3$ and $1000m^3$ respectively for each zone. Similarly increase of minimum value by 10% and 15% for $750m^3$ and $1000m^3$ respectively for each zone.

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