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Parametric Study of Intze-Type Water Tank Supported on Different Staging Systems based on IS:3370-1965 & IS:3370-2009

KEYWORDS: Intze-Tank, Staging System, Codal Revision.

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ABSTRACT Water tanks are very imperative for public convenience and for industrial structure. Water tanks are very significant components of lifeline. They are grave elements in municipal water supply, fire fighting systems and in many industrial amenities for storage of water. From the very upsetting experiences of few earthquakes in India, R.C.C elevated water tanks were profoundly damaged or collapsed. This might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank due to the dynamic effect, improper geometrical selection of staging, and also due to lack of earthquake resistant design. The main aim of this study is to understand the significant of considering earthquake loads in design & the behavior of different staging under different loading conditions and strengthening the conventional type of staging to give enhanced performance during earthquake.

INTRODUCTION

The water is source of every conception. In day to day life, one cannot live without water. The overhead liquid storing tank is the most effectual storing competence used for domestic or even industrial rationale. Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank. The tanks can be made in different shapes like rectangular, circular and intze types. The tanks can be made of RCC or even of Structural steel. Steel tanks are widely used in railway yards. Overhead tanks and storage

Reservoirs are used to store water, liquid petroleum and similar liquids. Reservoir is a general tenure used to liquid storage structure and it can be below or above the ground level. Reservoirs below the ground level are normally built to store large quantities of water. The overhead tanks are supported by the column which acts as stage. This elevated water tanks are built for direct distribution of water by gravity flow and are usually of smaller capacity.

Intze Tank- An intze tank is characterized by its diameter. Figure shows the components and their recommended dimensions for an Intze tank.
An intze tank has the following components which are subjected to different forces as under:
Top dome– is subjected to meridional thrust.
Top ring beam- hoop tension (provide width > depth for space availability for inspection purpose)
Cylindrical wall- hoop tension (due to water pressure)
Middle ring beam - hoop tension (horizontal component of meridional thrust)
Conical dome- meridional thrust (due to weight of components above, weight of water and self weight) and hoop tension (due to water pressure and self weight)
Bottom dome– meridional thrust (due to weight of water and self weight
Bottom ring beam– (Net inward hoop tension = Inward thrust from conical dome– outward thrust from bottom dome)

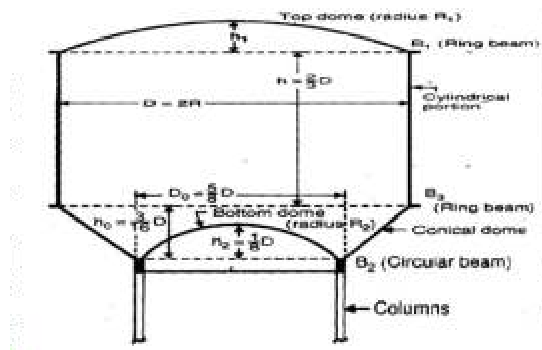

Figure 1: Components of Column Supported Intze Tank

After a long time IS 3370 is revised in year 2009 from its 1965 version. In present work intze tank is analyzed and designed for these cases. Case: 1 is design of Intze tank as per IS: 3370 (1965) without considering earthquake forces & case: 2 is design of intze tank as per IS 3370: (2009) with considering earthquake forces as per Draft IS: 1893-2005.

Figure 2: Collapsed 265 kL water tank in Chobari village, about 20 km from the epicenter of bhuj earthquake. The tank was approximately half full during the earthquake.

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Figure 3: Intze Tank-Supporting on Columns

Figure 4: Intze Tank-Supporting on Shafts

The hydrodynamic pressure & sloshing effect is not being considered while designing elevated tanks.
There are primarily two types of supporting systems (staging systems) named shaft supported system & column supported system. Here we are checking the appropriateness of both the staging systems according to earthquake forces. The value of permissible concrete stresses in calculation relating to resistance to cracking (for direct tension) is 1.5 N/mm2. The value of permissible limit of stresses of Steel (in direct tension, bending and shear) in IS 3370 :(1965) is 150 N/mm2 and in IS 3370: (2009) is 130 N/mm2.

LITERATURE SURVEY
Pavan S. Ekbote and Dr. Jagadish G. Kori (2013), Elevated water tanks were profoundly smashed or collapsed during earthquake. This was might be owing to the lack of familiarity regarding the performance of supporting system of the water tanks against 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 intricate 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 were studied.

R.V.R.K.Prasad and Akshaya B. Kamdi (2012), Storage elevated water tanks are used to store water. 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. In this revision important is that limit state method is incorporated in the water tank design. This paper gives in brief, the theory behind the design of circular water tank using WSM and LSM. Design of water tanks 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.

Asari Falguni & Prof. M.G.Vanza (2012) has thrown light on the results of an analytical investigation of the seismic response of elevated water tanks using fiction damper. In This paper, the behavior of RCC elevated water tank is studied with using friction damper (FD). For FD system, the main step is to determine the slip load.

Ayazhussain M. Jabar and H. S. Patel (2012), has investigated to be aware of the deeds of supporting system which is more effective under different earthquake time history is carried out with SAP 2000software. As known from very upsetting experiences, elevated water tanks were heavily damaged or collapsed during earthquake. This was might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank again dynamic effect and also due to improper geometrical selection of staging patterns.
Hasan Jasim Mohammed (2011), studied 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.

IITK-GSDMA (2007), for seismic design of water tanks, IS 1893:1984 has very limited provisions. These provisions are only for elevated water tanks and tanks resting on ground are not considered. Even for elevated water tanks, effect of sloshing effect of vibration are not included in IS 1893:1984. Moreover, compared with the present international practice for seismic design of water tanks, there are many limitations in the provisions of IS 1893:1984. Thus, one finds that at present in India there is no proper Standard for seismic design of water tanks. In view of non-availability of a Proper Standard on seismic design of water tanks, present Guidelines is prepared to help designers for seismic design of water tanks. This Guidelines is written in a format very similar to that of IS code and in future, BIS may as well consider adopting it as IS 1893 (Part 2).

O. R. Jaiswal et al, (2006), In this research paper, provisions of ten seismic codes on water tanks are reviewed and compared. This review has revealed that there are significant differences among these codes on designing of seismic forces for various types of water tanks. Reasons for these differences are critically examined and the need for a unified approach for seismic design of liquid storage tanks is highlighted.

Durgesh C. Rai and Bhumika Singh (2004), studied Reinforced concrete pedestal (circular, hollow shaft type supports) are popular choice for elevated tanks for the ease of Construction and the more solid form it provides compared to framed construction. In the recent past Indian earthquakes, Gujarat (2001) and Jabalpur (1997), thin shells (150 to 200 mm) of concrete pedestals have performed unsatisfactorily when great many developed circumferential tension flexural cracks in the pedestal near the base and a few collapsed.

Durgesh C Rai (2003), describes about the performance of elevated tanks in bhuj earthquake of January 26th 2001. The current designs of supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake and the Bhuj earthquake provided another illustration when a great many water tank staging's suffered damage and a few collapsed.

CONCLUSIONS
Comparison of Top Dome design: In top dome all stress is within permissible limits as per both designs because of not considering the seismic effect on IS: 3370-2009. Only increase 43% reinforcement provided in top dome due to

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change of criteria of minimum reinforcement as per IS: 3370-2009.

Comparison of Top Ring Beam design (B1): Hoop tension is not changed but criteria of permissible limit of steel is changed 150 N/mm2 to 130 N/mm2 as per IS: 3370-2009. Hence area of reinforcement +21% is increased.

Comparison of Cylindrical Wall design: Due to the effect of earthquake forces, hoop tension is increased by the amount of 57% and thickness of cylindrical wall comes increased. Reinforcement in cylindrical wall is increased by the significant amount of 82% because of decrease permissible limit of stress in steel and increased hoop tension.

Comparison of Middle Ring Beam design (B2): Due to consideration of seismic forces hoop tension is increased by the amount of 45% and Reinforcement in Middle Ring Beam is increased 50% due to increase of hoop tension and decrease permissible limit of stress in steel as per IS: 3370-2009.

Comparison of Conical Dome design: Meridional thrust and Hoop tension both forces are increased because of considering the seismic effect. For 400mm thickness of conical dome maximum tensile stress is 1.56 N/mm2 which is greater than permissible limit of tensile stress in concrete 1.5 N/mm2. Hence need to increase the thickness of the conical dome 450mm. And Reinforcement of conical dome is increased 48% because of decrease the permissible limit of stress in steel and increase the hoop tension.

Comparison of Bottom Dome design: Meridional thrust increased by 51% because of considerations of seismic effects. And For 250mm thickness of bottom dome meridional stress is increased 1.81 N/mm2 which is greater than permissible limit of stress in concrete 1.5 N/mm2 because of increased intensity of load per unit area. To reduce the meridional stress increase the thickness of bottom dome 250mm to 320 mm. And Reinforcement provided in bottom dome is increased by the amount of 114% because of decrease the permissible limit of stress in steel 130 N/mm2.

Comparison of Bottom Ring Beam design: Hoop compression and hoop stresses are increased due to increase the difference of the inward thrust from conical dome and outward thrust from bottom dome. And increased value of hoop stresses does not exceed the permissible limit hence safe in both designed. And Total vertical load in the Bottom Ring Beam is increased by the amount of 50% due to the increasing summation value of the vertical component of thrust of conical dome and bottom dome in redesigned of water tank as per IS: 3370-2009 (considering earthquake forces).

Comparison of Column design: Axial load in the bottom of column is increased by the amount of 45% due to the increase of vertical component of thrust transfer through conical dome and bottom dome. Very large amount of overturning B.M. is increased due to the consideration of seismic effect as per Draft Code IS: 1893-2005 (part-II) in the redesigning of water tank as per new IS Code: 3370-2009 (part I & II). To exist the safety condition of column, increase the diameter of column 700 mm to 1000 mm. And also increase larger amount of longitudinal reinforcement provided in column.

Comparison of Column Bracing design: Bending moment in column bracing is increased by 75% because of base shear increased due to seismic effect consideration and depth of column bracing increased because of increased bending moment. Bending Moment at bottom of column goes on decreasing as level of bracing increases for different bracing types. The performance of Hexagonal and Radical type bracing is better. Story displacement goes on decreasing as level of bracing increases and Hexagonal & Radical type bracing gives less story displacement as compared to other bracing types.

Overturning moment: For basic staging overturning moment is highest as compare to the other staging pattern. Over-turning moment increases as bracing level increases for different types of bracings. Over-turning moment is more Hexagonal & Radical bracings of Full tank condition than Half Full and Empty condition.

Base Shear: Base shear increases as bracing level increases for different types of bracings. Base shear is more for Hexagonal & Radical bracings of Full tank condition than Half Full and Empty condition.

Staging: Looking to the above literature study only frame type staging with a single row of columns placed along the periphery of a circle, are not adequate to support container of elevated water tanks. Apart from that, it is required to identify suitable modified water tank staging system by determining what improvements or added features are necessary for staging part of water tank for better performance during earthquake. The current designs of RC shaft type circular staging (supporting structure) for elevated water tanks are extremely vulnerable to lateral loads caused by earthquakes. It is evident from the damages sustained to staging as far as 125km away from the epicentral tract of the Bhuj earthquake.

The slender staging that results from the low design forces is a very unfavorable feature for seismic areas for elevated water tanks

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