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Structural Behavior of Water Tanks Under Dynamic Loading - A Review

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ABSTRACT

Liquid storage tanks are used to store a variety of accessories, including petrol, oil paint, and other materials like water. Any toxic material in damaged tanks causes environmental harm.The fluid inside the tank is divided into impulsive and convective liquid masses due to the fluid structure of the system, and both are convinced. The way the tank interacts with the girding soil structure will vary depending on the soil parcels' cohesiveness angle of disunion and angle of disunion, which are similar to elastic parcels. Depending on the support circumstances provided, raised tanks and ground-supported tanks respond in different ways. Height of the container, figure, soil viscosity, and type of foundation

Keyword: Fluid structure commerce, Soil structure commerce, Sloshing, Seismic response, Impulsive and Convective liquid mass

1. Introduction

Important factors in the construction of civil engineering structures include the stresses brought on by earthquakes and the sloshing of liquid inside tanks. Because failure of the holders and liquid slip would have implicitly negative economic and environmental effects, the seismic safety of liquid-filled holders is a major problem. As a result, a significant amount of exploratory effort has been focused on improving the determination of the seismic geste of liquid tanks and on improving

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Convective hydrodynamic pressure is exerted by this mass, which is designated as a convective liquid mass. Housner created

These two liquid millions must be accurately represented in the spring mass model of the tank-liquid system, and the model's parameters rely on the tank's shape. Early studies on tanks' seismic response only focused on the tank's dynamic response, treating the liquid and the tank as a single rigid entity. It was noted that rigid tank conception for tank modelling couldn't be adopted for tank analysis.

interaction between the liquid inside and the tank's wall Since the fluid structure of the system is complex, seismic analysis of liquid storage tanks is challenging. From the mastermind's perspective, storage tanks ought to. Studying the seismic response of water tanks is definitely required, according to a previous earthquake study.

Liquid storage tanks have a variety of different failure mechanisms, such as base sliding, shell buckling, sloshing damages, and support failure. According to several historical compliances of the seismic performances of liquid storage tanks, failures of storage tanks might express themselves in many different ways, depending on the

On the other hand, the dynamic reaction of liquid storage tanks is substantially impacted by the features of earthquakes.. The failure modes of a blockish tank differ greatly from those of other conceivable combinations of the aforementioned characteristics, which complicates the failure medium.

A structure's interaction with the earth that supports it affects how seismic surges are felt. Structure and soil commerce should be taken into account in seismic analysis.

The type of soil greatly influences how the soil develops and how commercial structures are built. Fine-grained or softer soils have advanced commerce with structure when the perpendicular stresses in various tank corridors also rise with a decrease in the girding soil's shear modulus. However, due to the tanks utilised in actual systems Earthquake forces for soft soil are roughly 18–19 less than those for medium soil, and for medium soil, they are roughly 26–27 less. For all earthquake zones, tank full conditions, and tank empty situations, the earthquake force for soft soil is approximately 40–41 less than that of hard soil.

2. LITERATURE REVIEW

The relationship between the stirring of the water in the tank and the stirring of the entire structure in relation to the ground was discussed by George W. Housner in 1963. He had three initial tank conditions in mind for the analysis. i.e., fully, empty, and partially filled. He claimed that the water tank's sloshing impact is disregarded in both the fully filled condition, or without any free board, and the empty situation. The water body in the tank will bear as a single mass structure in the two scenarios below. The impact of sloshing should be taken into consideration in the third scenario, where the water tank is not totally filled. The water body will then have a two-mass structure.. He eventually came to the conclusion that the greatest force that the half-filled tank may be subjected to may be considerably less than half the force that the full tank can be subjected to.

The IS legislation was amended for seismic design of elevated water tanks by Sudhir Jain and US Sameer in 1991. They arrived at straightforward equations that incorporate ray rigidity and allow estimations of carrying stiffness and, hence, time. For the purpose of calculating the seismic design forces, they provide the value of performance factor 3. If there are no clear instructions on how to determine the time period, the earthquake design criterion will be inadequate. There is now a method for calculating staging stiffness that takes ray inflexibility into account without using finite element analysis. This method is based on a well-established portal architecture that has been appropriately enhanced to add ray rigidity and three-dimensional staging..

Inflexibility-supported liquid storage tanks' dynamic reaction was developed by Anestis and Veletsosetal in 1992. Additionally, critical responses are predicted for harmonic and seismic excitations over a broad range of tank dimensions and soil stiffness, and the results are used to interpret the products of soil-structure trade. It has been demonstrated that soil-structure commerce may drastically lessen broad tanks' critical reactions while increasing those of altitudinous, stiff tanks with a high abecedarian natural frequency. It is further demonstrated that the advanced modes of vibration are negligible contributors to the overall response for tanks with height-to-compass rates of the order of 1.5 or lower.

Dynamic soil-tank commerce was examined by Medhat A. and Haroun et al. (1992) under vertical seismic excitations. It significantly modifies the hydrodynamic forces and moments acting on the tank structure. To evaluate the system response to ground seismic motions, computer programmes are used. The findings demonstrate that the tank's response is amplified by the tank's commerce with the foundation soil. This is due to both the tank's geometric components and the soil's shear-surge haste (which is advanced exaggeration for soft soils) (advanced exaggeration for altitudinous tanks). The findings also show that shell rigidity has a significant impact on tanks' dynamic posture; it adds to the exaggeration of pressures created in liquid and applied on tanks.; it contributes to the exaggeration of pressures developed in liquid and wielded on tank, thereby adding the base shear and capsizing moment, especially for stiff soils.

IS 1893–1984 has been modified and improved by SudhirK. Jain and Sajjad Sameer U (1993). They took into account every recommendation made by Sudhir Jain and Medhekar and added a few that weren't necessary: (1) The seismic analysis needs to take unintentional torsion into account. (2) The statute may be amended to include a formula for determining the height of water that sloshes. (3) Because the force in the tanks with flexible walls is greater than that in the tanks with rigid walls, the effects of hydrodynamic pressure for tanks with rigid walls and tanks with flexible walls should be compared separately. (4) A table should be used to present the stresses caused by hydrodynamic pressure in the tank's wall and base..

In 1998, Praveen K. Malhotra investigated the use of energy-dissipating anchors to fortify tanks against seismic activity. For two sword tanks that are supported on a dirt bed and connected to the girding ring foundation by sword hysteretic mutes, numerical data are reported. The tanks support as entirely anchored systems during low-position shaking; nevertheless, during heavy shaking, the base of the tanks raises, dispersing seismic energy through the inelastic action of the sword mutes. In liquid-storage tanks, energy-dissipating anchors can enhance the effective damping by more than 20.

In 2003, M.K. Shrimali and R.S. Jangid investigated the seismic response of elevated liquid storage tanks. Direct elastomeric comportments act as insulation for these tanks during actual earthquake ground shaking. The comportments are positioned at the bottom and top of the sword palace building in two different isolated tank forms. The tank's continuous liquid mass is modelled as lumped mass, sloshing mass, and rigid mass for impulsive mass. These lumped millions have a matching stiffness constant that has been determined based on the parcels of the tank wall and liquid mass. inversely grouped at the top and bottomSince the damping matrix for the isolated tank system is not classical in nature, the seismic response is obtained using Newmark's step-by-step method. In order to investigate the effects of key system characteristics on the effectiveness of seismic insulation, a parametric analysis is conducted on the responses of two different types of tanks, videlicet broad and slender tanks. The tank aspect rate, palace structure time period, damping, and insulation system time period are some of the colourful parameters taken into account. It has been demonstrated that the isolated tank's earthquake reactivity is greatly diminished. Additionally, it has been determined that a tank with a stiff palace structure has better insulation than one with a flexible palace structure.

Z. Chen and M.R. Kianoush investigated how different seismic zones affected concrete tank reaction. Study is done on how three different tanks react to three different time histories of ground movements that occur in three different seismic zones. They suggested a novel method for calculating the hydrodynamic pressures in blockish tanks that was based on successional analysis. In this system, the impact of wall rigidity on impulsive pressures is taken into account. Under the study of seismic ground movements, the geste of three different types of open top tanks is examined. The shallow, medium, and altitudinous tanks used in this study are divided into these categories. For dynamic time history analysis, three sets of historical data representing low, moderate, and high seismic zones are used. It has been determined that a lumped mass.The true geste of concrete liquid storage tanks cannot be accurately portrayed by an approach. The liquid storehouse tanks' dynamic response, as determined based on the existing design strategy's consideration of base shear, is overly cautious. This is mostly attributable to the error made in calculating the initial height for the liquid's impulsive mass. Additionally, it is determined that the hydrodynamic cargo greatly depends on the contribution of ground disturbance.

R. Jaiswal and S.K. Jain (2005) cite the restrictions in the IS 1893–1984 rule and offer some recommendations. Instead of using separate spring-mass models for tanks with rigid and flexible walls, a single spring-mass model is recommended for both types of tanks. Convective hydrodynamic pressure expressions are updated. The sloshing surge height is expressed simply. For raised water tanks with frame type carrying, new vittles are recommended for taking the influence of perpendicular excitation into account and describing the important direction of earthquake lading.

R. Livaoglu (2007) used a straightforward and quick seismic analysis approach to determine the dynamic geste of a fluid-blockish tank-soil/foundation system. For fluid, Housner's two mass approximations are utilised, and for the soil/foundation system, a cone model. This method can calculate base forces for soil/foundation system situations, including embedment and incompressible soil cases, relegation at the height of the impulsive mass, and sloshing relegation. Additionally, by altering the soil/foundation conditions, certain comparisons are done between base forces and sloshing responses for embedment and non-embedding circumstances. The findings demonstrate that decreasing soil stiffness generally causes a decrease in deportations and base shear forces. However, SSI, wall rigidity, and embedment had no impact on the sloshing deportations.

The seismic performance of tanks is estimated by Halil Sezen and Livaoglu et al. (2007), and the parameters affecting the dynamic geste are investigated. The tanks are subjected to simplified and finite element dynamic calculations, including the impact of thawing gas-structure commerce utilising a ground stir recorded at a nearby site. Finite element modelling and a simplified three-mass model are used to do the dynamic analysis. The analysis has proven that the two nearly full tanks were supported by columns whose axial and side strength was insufficient to withstand the earthquake's demand. Additionally, based on observed results, a prediction of an elastic response is made for the columns supporting the intact 25 entire identical tanks.

With a structural frame supporting the fluid-containing tank, Livaoglu and A. Dogangun (2007) explore the impact of foundation embedment on the seismic behaviour of the fluid-elevated tank-foundation-soil system. The analyses covered the sloshing products of the fluid inside the tanks and the soil-structure commerce of the elevated tanks situated on six different soils. The embedment in soft soil had a considerable impact on the models' foundations with and displacements, although this effect was less pronounced for any impact on the other response parameters, such as sloshing relegation..

In 2008, Algreane et al. and Gareane A. I. evaluated the soil and water geology of an elevated concrete water tank under seismic load. They have selected seven scenarios to compare using mechanical models for single degree of freedom (SDOF), two degree of freedom (2DOF), and finite element systems (FEM) models with and without soil structure commerce (SSI). Both the fluid structure economy (FSI) and the soil structure economy (SSI) have been separately evaluated utilising the direct technique and added mass approach. The outcome demonstrates that the impact of soil structure commerce on shear force, capsizing moment, and axial force at the base of an elevated tank is significant.

The impact of wall rigidity on the dynamic response of a blockish tank under vertical and perpendicular ground movements is examined by Ghanemmaghami and M.R. Kianoush (2010). Using the gauged seismic factors of the 1940 El- Centro earthquake data, two distinct finite- element models matching with shallow and altitudinous tank layouts are explored. It is assumed that the holders' bottom face is fastened to the solid ground. Fluid-structure commerce items on dynamic reaction of liquid storehouse equivalent to the height of supporting system and directly comparable to water tank capacity. Seismic forces advance in soft soil compared to medium soil and advance in hard soil compared to soft soil..

Moslemi and M. R. Kianoush (2012) look into how spherical open-top, ground-supported water tanks react dynamically. This study's main goal is to pinpoint the critical variables that influence how similar structures respond dynamically and to discuss the interactions between these variables. Sloshing of liquid free face, tank wall rigidity, perpendicular ground acceleration, tank aspect rate, and base fixity are studied parameters. Dynamic findings obtained using a strict FE system are contrasted with those obtained based on the vittles of the ACI law. Concrete tank models with various aspect rates are subjected to time history and free vibration evaluations. It has been determined that the present design method for predicting the hydrodynamic pressure, which is based on ACI law vittles, is overly cautious.. Finite element system can be directly employed in both free vibration and flash analysis of ground supported spherical tanks.

V. Waghmare and S. N. Madhekar (2013) investigated tank sloshing effects during gestation. Numerous factors, such as the height of the vessel, the level of the water in the tank (30, 50, 70, and full), and the height of the carrying, have been compared. It has been shown that sloshing of water in tanks depends on carrying height and aspect rate (h/D), in addition to the volume of water in the tank.

Researchers Uma Chaduvulaa and Deepam Patela et al. (2013) look at the effects of fluid-structure-soil interaction on elevated water tanks' susceptibility to earthquakes. At the CSIR-SERC in Chennai, an experimental disquisition for a 14 scale model of a circular sword elevated water tank was conducted on a shake table installation. An experimental analysis of combined perpendicular, vertical, and rocking motions on a water tank. A synthetic seismic excitation for 0.1 and 0.2 g accelerations, with the addition of a rocking stir angle, is taken into consideration for this investigation. Convective base shear and base moment values rise with increasing earthquake acceleration, but fall with increasing angular stir.

In 2015, Sanya Maria Gomez and Naveen V. M. evaluated the hydrodynamic impact on a raised RC tank. In order to determine the safety of sections, the stiffness requirements for shafts are independently calculated. ANSYS14.5 software was used to do a seismic study of the tank. It is planned that the demand for rigidity in staging would rise as a result of the influence of hydrodynamic goods.

The 2015 study by Dona Rose K. J., Sreekumar M., et al. examines the geste of overhead tanks under dynamic loading. ANSYS software is used to model tanks with various staging heights and coloured capacities. Two scenarios, a tank full position condition and a partial position condition, are analysed. For the study, both the hydrostatic and sloshing effects are taken into account. The peak relegation from the time history analysis is found to rise with staging heights, it is concluded. However, when tanks and wall rigidity are taken into account, the relegation initially lowers and then grows. The findings demonstrate that the wall rigidity and fluid damping packets have a significant impact on the seismic response of liquid tanks and should be taken into account when designing tanks.

In 2011, Suchita Hirde and Manoj Hedaoo did research on the seismic performance of elevated water tanks for India's diverse soil conditions and a range of various heights and capacities. They came to the conclusion that seismic forces directly correspond to seismic zones. As carrying height increased, the base shear values from the time history analysis increased. The base shears also change in size as their capacity grows. Under the identical staging conditions, it has also been found that base shear for half-capacity tanks is lower than for full-capacity tanks.

2015 saw the study of flash analysis of the elevated Intze water tank, fluid, and soil system by Neeraj Tiwari and M.S. Hora. Using ANSYS software, a 3D commerce analysis of the intze type water tank-fluid-concentrated soil system is conducted to estimate the top stresses in various corridors of the tank and supporting layered soil mass. Under various stuffing conditions of the Intze tank, the attendant diversions, Von-Mies stress, and natural frequency of the tank are determined together with an estimate of acceleration by flash analysis. Since the natural frequency of the commerce system is seen to decrease as the weight of water in the tank grows, different stuffing conditions will have different failure thresholds.

Research was done on the impact of vessel height on the base shear of an elevated water tank by RupachandraJ.Aware and Vageeshaetal. The analysis is done with the aid of STAAD-PRO software. It has been shown that as vessel height rises, base shear increases as well. Additionally, base shear grows steadily from zone II to zone V by altering the zone..

In 2015, J.Y. Richard Liew and Yonghui Wang evaluated the structural performance of a water tank while it was being loaded under static and dynamic pressure. To apply static and dynamic pressure to the samples, the loading was applied using a hydraulic selection or a dropped bullet on an inflated high pressure airbag. The test produced the samples' maximum resistance and failure modes, which were then compared to the numerical data. The tank with fully filled water position condition demonstrated up to 31 percent more flexural resistance under static loading than the empty water tank with the same material and figure, according to the static pressure test results..

3. CONCLUSIONS

According to the literature, a variety of parameters, such as fluid structure commerce, soil structure commerce, type of supports, wall rigidity, presence of mutes, carrying height, water filler circumstances, etc., affect the structural performance of water tanks. Water tank failure is brought on by a variety of factors. The fundamental issue is that water tanks lack the strength and capacity to withstand the worst conditions, making them unsafe under various loading levels. Therefore, it is a difficult problem for the designers to create a water tank that offers essential safety and strength. Knowing the tank's sensitivity to loads and its failure patterns is crucial for this.

REFERENCES

[1]. George W. Housner, “The Dynamic Behavior of Water Tank” *Bulletin of the Seismological Society of America,* (1963) Vol. 53(2), (381-387).

[2]. K Sudhir Jain and U.S Sameer, “Seismic Design of Frame Staging For Elevated Water Tank” *Ninth Symposium on Earthquake Engineering,* (1990), Vol1(12), (14-16).

[3]. S. Anestis and Veletsos et al, “Dynamic response of flexibility supported liquid- storage tanks”, *Journal of Structural Engineering-ASCE,* (1992), Vol. 118(1), (264-283).

[4]. Medhat and Haroun et al, “Parametric study of seismic soil- tank interaction I: horizontal excitation”, Journal of Structural Engineering-ASCE, (1992), Vol. 118(3), (783-797).

[5]. Sudhir K. Jain and M. S. Medhekar, “Proposed provisions for aseismic design of liquid storage tanks”, *Journals of structural engineering,* (1993), Vol.-20(3).

[6]. Praveen K. Malhotra, “Seismic strengthening of liquid storage tanks with energy dissipating anchors”, *Journal of Structural Engineering-ASCE,* (1998), Vol. 124(4), (405-414).

[7]. M.K. Shrimali and R.S. Jangid, “Earthquake Response ofIsolated Elevated Liquid Storage Tank” (2003).

[8]. J. Z. Chen and M. R. Kianoush, "Response of concrete liquid containing structures in different seismic zones",*13th world conference on earthquake engineering,* (2004), PN (1441)

[9]. Sudhir K. Jain and O. R. Jaiswal, *Journal of Structural Engineering,* (2005) Vol-32 (9).

[10]. R. Livaoglu, "Investigation of seismic behavior of fluid-rectangular tank-soil/foundation systems in frequency domain ", *Soil dynamics and earthquake engineering- ELSEVIER,* (2008), (132-146)

[11]. Halil Sezen and Livaoglu et al. "Dynamic analysis and seismic performance evaluation of above ground liquid- containing tanks", *Engineering structures- ELSEVIER,* (2008), (794-803).

[12]. R. Livaoglu and A. Dogangun, "Effect of foundation embedment on seismic behavior of elevated tanks considering fluid-structure –soil interaction", *Soil dynamics and earthquake engineering- ELSEVIER,* (2007), (855-863).

[13]. A.I Gareane and Algreane et al, "Behavior of elevated concrete water tank subjected to artificial ground motion", *Electronic journal of geotechnical engineering,* (2008), Vol.16, (387-406).

[14]. A.R Ghanemmaghami and M.R Kianoush, "Effect of wall flexibility on dynamic response of concrete rectangular liquid storage tanks under horizontal andvertical ground motions", *Journal of Structural Engineering-ASCE,* (2010), Vol. 136(4), (441-451).

[15]. Suchita Hirde and Manoj Hedaoo, "Seismic performance of elevated water tanks", *International Journal of Advanced Engineering Research and Studies,* (2011), Vol.1 (1), (78-87).

[16]. M. Moslemi and M.R. Kianoush, "Parametric study on dynamic behavior of cylindrical ground supported tanks", *Engineering structures-ELSEVIER,* (2012), (214-230).

[17]. M.V Waghmare and S.N Madhekar, " Behavior of elevated water tank under sloshing effect", *International Journal of Advanced Technology in CivilEngineering,*(2013), Vol.2 (1), (51-54)

[18]. Uma Chaduvulaa and Deepam Patela et al, "Fluid- structure- soil interaction effect on seismic behavior of elevated water tanks", *Procedia engineering-ELSEVIER,* (2013), (84-91).

[19]. V.M Naveen and Sanya Maria Gomez, "Study of hydrodynamic effect on RC elevated water tanks under seismic excitation", *International journal ofengineering and research,* (2015)

[20]. K.J Dona Rose and Sreekumar M et al, " A study of overhead water tanks subjected to dynamic loads", *International journal of engineering trends and technology,*(2015),(344-348).

[21]. Neeraj Tiwari and M. S. Hora, "Transient analysis of elevated intze water tank- fluid- soil system", *ARPN Journal of Engineering and Applied Sciences,* (2015), Vol.10 (2), (869-882).

[22]. Rupachandra J. Aware and Vageesha et al, "Effect of container height on base shear of elevated tank", *International Journal of Science and Research,* (2015),Vol.4 (12), (2123-2128).

[23]. Yonghui Wang and J.Y. Richard Lieu et al, "Structural performance of water tank under static and dynamic pressure loading", *International journal of impact engineering- ELSEVIER*, (2015), (110-123).