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Seismic Analysis of Circular Overhead Water Tank Using Staad Pro. Software with Different Zones: A Review

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Abstract: *Due to enormous need by the public, water has to be stored and supplied according to their needs. Water demand is not constant throughout the day. It fluctuates hour to hour. In order to supply constant amount of water, we need to store water. So to meet the public water demand, water tanks need to be constructed. They are grave elements in municipal water supply, firefighting systems and in many industrial amenities for storage of water. Intze type tank is commonly used overhead water tank in India. These tanks are designed as per IS: 3370 i.e. Code of practice for concrete structures for storage of liquids. BIS implemented the revised version of IS 3370 (part 1& 2) after a long time from its 1965 version in year 2009. Presently large number of overhead water tanks is used to distribute the water for public utility. Most of the water tanks were designed as per old IS Code: 3370-1965 without considering earthquake forces. The objective of this dissertation is to shed light on the Intze water tank designed considering the earthquake forces according to Indian standard code: 3370-2009 and draft code 1893-Part 2, (2005) considering zone-II and III. Intze tank supported on frame staging. Also this report includes analysis by STAAD Pro for seismic forces .Finally the results are validated with the results of calculation from the present study. Before taking up the design, the designer should first decide the most suitable type of staging of tanks and correct estimation of loads including statically equilibrium of structure particularly in regards to overturning of overhanging members shall be made. The design should be based on the worst possible combination of loads, moments and shears arising from vertical loads and horizontal loads acting in any direction. In this research by performing the analysis of Intze tank, what is deflection shape due to hydrostatic pressure then stresses, etc. which are analyzed.*

Keywords- STAAD Pro v8i, Intze water tank, IS: 3370-2009, displacement, Axial Force, Bending Moment.

Introduction

Liquid storage tanks are essential structures in water, oil and gas industrials and the behaviour of them during earthquake is more important than the economic value of the tanks and their contents. It is important that utility facilities remain operational following an earthquake to meet the emergency requirements such as firefighting water or meet the public demands as a source of water supply. For these reasons, serviceability becomes the prime design consideration in most of these structures. Those systems is the interplay among fluid and Structure. Prediction of analytical response of coupled area systems is very complicated and about no available. So most of investigations are concerned approximately numerical methods such as finite detail technique. In this paper Numerical evaluation of elevated concrete water tanks with important shaft is done through the use of finite detail software program which fluid- shape interplay is taken into consideration. Accelerated tanks need to continue to be useful inside the submitearthquake period to make sure water supply is available in earthquake-affected areas. by no means the much less, numerous improved tanks had been broken or collapsed in the course of beyond earthquakes because of the fluid–shape–soil/basis interactions, the seismic conduct of improved tanks has the characteristics of complex phenomena. Therefore, the seismic behaviour of Elevated tanks must be known and understood, and they need to be designed to be earthquake-resistant. A few popular packages had been finished, which cowl massive amounts of facts; these packages consist of STAAD seasoned and so on. However, a trendy-reason structural analysis software generally exists in each engineering workplace. So, the assessment of the applicability of these structural evaluation programs within the layout of improved tanks is important from an engineering factor of view and it'll be beneficial to present the application and consequences to designers. There is a second crucial reason that should be taken into consideration. This is, simplified models are used for a trustworthy estimate of the seismic threat of present accelerated tanks. Handiest if the anticipated threat is excessive, it's far convenient to measure all of the information (e.g. geometry of the tank, cloth residences) which might be required by the overall finite detail codes and to spend money and time to put together a dependable fashionable version.

A. Need for study of Water Tanks

A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential .The permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio .The increase in water cement ratio results in increase in the permeability .The decrease in water cement ratio will therefore be desirable to decrease the permeability, but very much reduced water cement ratio may cause compaction difficulties and prove to be harmful also. Design of liquid retaining structure has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. Cracks can be prevented by avoiding the use of thick timber shuttering which prevent the easy escape of heat of hydration from the concrete mass the risk of cracking can also be minimized by reducing the restraints on free expansion or contraction of the structure.

1. Water tanks are visually simple but structurally difficult
2. Difficult to take the load cases and load combinations
3. Distribution of stress in the structure
4. Distribution of mass
5. Hydro dynamic effects
6. Very critical problem is the slab and beam joints

B. Classification of water tanks

In general water tanks can be classified under 3-heads

1. Tanks resting on ground
2. Elevated tanks supported on staging and
3. Underground tanks.

C. Tanks resting on ground

These are used for clear water reservoirs, settling tanks, aeration tanks etc. these tanks directly rest on the ground. The walls of these tanks are subjected to water pressure from inside and the base is subjected to weight of water from inside and soil reaction from underneath the base. The tank may be open at top or roofed

D. Elevated tanks supported on staging

These tanks are supported on staging which may consist of masonry walls, R.C. tower or R.C. column braced together- The walls are subjected to water pressure from inside. The base is subjected to weight of water, weight of walls and weight of roof. The staging has to carry load of entire tank with water and is also subjected to wind loads.

E. Underground tanks

These tanks are built below the ground level such as clarifier's filters in water treatment plants, and septic tanks .The walls of these tanks are subjected to water pressure from inside and earth pressure from outside. The base of the tanks is subjected to water pressure from inside and soil reaction from underneath. Always these are covered at top. These tanks should be designed for loading which gives the worst effect. The design principles of underground tanks are same as for tanks resting on the ground. But the walls of the underground tanks are subjected to internal water pressure and outside earth pressure. The section of wall is designed for water pressure and earth pressure acting separately as well as acting simultaneously Classification of water tanks based on shape

1. Circular tanks
2. Rectangular tanks
3. Spherical tanks
4. Intze tanks and
5. Circular tanks with conical bottoms.

F. Lay out of overhead tanks

Generally the shape and size of elevated concrete tanks for economical design depends upon the functional requirements such as

1. Maximum depth of water
2. Height of staging
3. Allowable bearing capacity of foundation strata and type of foundation suitable
4. Capacity of tank and
5. Other site conditions.

G. Classification and lay out of elevated tanks

Based on the capacities of the tank the possible classification for types of elevated tanks may be as followed as given below for general guidance.

1. For tank up to 50m3 capacity may be square or circular in shape and supported on staging on three or four columns.
2. Tank capacity above 50 m3 and up to 200m3 may be square or circular in plan and supported on minimum four columns.
3. For capacity above 200m3 and up to 800 m3the tank may be square, rectangular, circular or Intze type tank. The number of columns to be adopted shall be decided based on the column spacing which

normally lies between 3.6m and 4.5m. For circular, Intze or conical tanks a shaft supporting structures may be provided

H. Intze Water Tank

The Intze principle is a name given to two engineering principles both named after the hydraulic engineer Otto Intze. In the one case the Intze principle relates to a type of water tower, in the other a type dam. Circular tanks with flat bottom as well as with domical bottom:In the flat bottom the thickness and reinforcement is found to be heavy. In the domed bottom though the thickness and reinforcement in the dome is normal, the reinforcement in the ring beam is excessive. Therefore in the cases of large diameter tanks and economical alternative would be to reduce its diameter at its bottom by conical dome. Such a tank is known as Intze tank and is very commonly used. The main advantage of Intze tank is that the inward radial thrust of the conical bottom balances the outward radial thrust of the spherical bottom. Water tanks designed on the Intze principle

I. LOAD COMBINATIONS

Design of liquid retaining structures involves decisions to be made by the engineer based on rules of thumb, judgment, code of practice and previous experience.

J. IMPOSED LOADS

Weight of water may be taken as live load for members directly continuing the same. The weight of water shall be considered as dead load in the design of staging.

K. Wind load

Wind shall be applied according to EBCS. While analysing the stresses the combination shall be as follows. Wind load with empty tank and Wind load with tank full. The worst combination of the stress on account of the above shall be considered while working out the permissible stresses. The following are the loads and loading conditions which over R.C. water tank

Table 1: Loading conditions.

No	Loads	Influence of loadon chimney/staging
1.	Dead Load	Static
2.	Live Load	Static+ Dynamic
3.	Wind Load	Static+ Dynamic
4.	Thermal stress	Static
5.	Seismic Load	Static+ Dynamic

L. Objective

1. The main objective of this study to identify the dynamic behaviour of elevated water tank under wind load.
2. To make a study about the analysis and design of water tanks.
3. To make a study about the guidelines for the design of liquid retaining Structure according to IS code.

4. To know about the design philosophy for the safe and economical design of water tank.
5. To develop programs for the design of water tank of flexible base and rigid base and the underground tank to avoid the tedious calculations.
6. In the end, the programs are validated with the results of manual calculation given in concrete Structure and then analysed by STAAD pro.

In this study Wind Forces and Seismic Forces acting on an Intze Type Water tank for Indian conditions are studied. According to seismic code IS 1893(Part-1) more than 60% of India is prone to earthquakes. The analysis was conducted as per the specifications of IS 3370, IS 456, IS 800, IS 875, IS 1893. The Intze type water tank was designed for 10Lakh Litres capacity of water for the Agiripalli Town at Krishna District in Andhra Pradesh. Different loads such as Dead Load, Live Load, and Wind load will be applied on STAAD.Pro model as well manual design at appropriate location as per codes used for Loading. All the results obtain from STAAD.Pro will be compared with the results of manual design Author has given following conclusions from his analysis

1. Seismic forces are directly proportional to the Seismic Zones,
2. Seismic forces are inversely proportional to the height of supporting system,
3. Seismic forces are directly proportional to the capacity of water tank, and
4. Seismic forces are higher in soft soil than medium soil, higher in medium soil than hard soil. Earthquake forces for soft soil is about 40-41% greater than that of hard soil for all earthquake zones and tank full and tank empty condition.

M. Modeling in Staad.Pro V8i

STAAD Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD Pro is the professional's choice for steel, concrete, timber, aluminium and cold-formed steel design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles and much more. The STAAD Pro Graphical User Interface: It is used to generate the model, which can then be analyzed using the STAAD engine. After analysis and design is completed, the GUI can also be used to view the results graphically.

N. General Properties

1. Click 'property' at left of screen> Define required dimensions for respective elements. Assign the property for various elements using any of the options present according to your convenient. Click 'Support' > Create >Select 'fixed' >click Add> assign at bottom part of beam.
2. Click 'Load and Definition' to apply wind load first we have to define it in first section. Enter your values. Keep exposure as –1. Click 'Load case details' to add DL, LL & WL. Add self-weight as DL Add Water load as LL Add Wind Load Select material as concrete and assign for entire tank

O. Water storage structure play vital role in civil engineering

1. Using water to prepare the soil in complex constructions. For example, the backside of a retaining wall, foundations, or below a road, to assist compact soil to its densest state.
2. Water as a compound for curing.
3. Using water as a raw resource in the production of several civil materials. Suppose during the quenching phase of the TMT process for the reinforcements, etc. Or in standardised testing (because different tests are carried out under differing water needs.

Water must also be taken into account as a weathering action (opposing) factor. Consider the task of estimating the damage to a steel building in a region that receives a lot of rain so that we may assess the structure's durability and implement protective measures. Alternatively, the ground water table rising and endangering the stability of the soil base and others.

2. Literature Review

Quadri et al. (2017) a total of 36 models were examined, including empty, partially filled, and fully filled water tanks. They take into account factors like the water storage capacity. The H/D ratio fluctuation in the number segment was taken into consideration while determining the water tank's height as constant. The staging patterns that were taken into consideration were radial staging, cross staging, standard staging, and hexagonal staging. They conducted software analysis using the finite element approach. The job was done with STAAD PRO V8i software. The analysis was carried out by comparing the reactions of each water tower to the responses of the other towers for characteristics such base shear, lateral displacement, axial pressures, and bending moments. Graphs were used to explain the tower's behaviour. Because the tower was fastened at the bottom and free at the top, its rigidity increased.

Hallale et al. (2018) twelve possibilities in all, and they were examined using a technique called dynamic analysis. First, several staging configurations are employed, and parametric studies on these models are done to assess the lateral stiffness, time duration, and displacement, among other things. The three states of the water tank are empty, half-full, and full. It takes into account the shear wall characteristics on these tank's six sides. Tank heights of 5, 10, and 20 metres were used. As a result, as the height of the tower rises, so does the amount of time. However, for all conditions, the moment induced by a shear wall at higher than that of 5m and 10m is greater in the radial and cross strut.

Tokhi et al. (2019) twelve possibilities in all, and they were examined using a technique called dynamic analysis. First, using the STAAD PRO V8i programme, multiple studies with an empty tank, a half-filled tank, and a completely filled tank in seismic zones III and V were conducted. The total tank capacity is 45000 litres, and the stage has a 27-meter height.Medium-quality soil is employed, and steel of the Fe415 grade is used with M30 grade concrete. In all seismic zone 3 conditions, rectangular and circular water tanks have lower base shear than intze water tanks, whereas in seismic zone 5, rectangular water tanks have higher base shear than intze and circular water tanks. In Intze Tank, time is more compressed.

Chetanagari et al. (2019) twelve possibilities in all, and they were examined using a technique called dynamic analysis. First, using STAAD PRO V8i and the response spectrum approach, the seismic analysis of a water tank with various staging configurations was evaluated in seismic zones 2, 3, and 4. First, an empty tank is inspected, then one that has been completely filled. By drawing curves of (SDOF) and earthquake frequency, which is obtained by equation, the method includes calculating the dynamic response spectrum. The displacement in the tank, the bending moment in the tank, the shear force in the tank, and the base shear in the tank are all separately included in the result analysis of the empty and full tank. Due to the horizontal brace, base shear, shear force increases for greater seismic zones, and displacement cause is reduced.

Ashfak and Vanpariya (2019) Structures for water storage are used to store water so that communities, businesses, universities, towns, cities, etc. can meet their daily water needs. In order for the water to reach the customers via gravity and pressure, specifically raised water tanks are utilised to distribute water to a specific region. These elevated constructions behave like an inverted pendulum with a narrow supporting framework and a huge mass concentrated at the top. As a result, these constructions are susceptible to earthquake-related horizontal stresses. RCC Elevated water tanks were severely damaged or collapsed due to the highly distressing experiences of a few earthquakes, such as the 2001 Bhuj earthquake in India

A. Gap of the Study

Following are the points to be notes while doing literature survey work:-

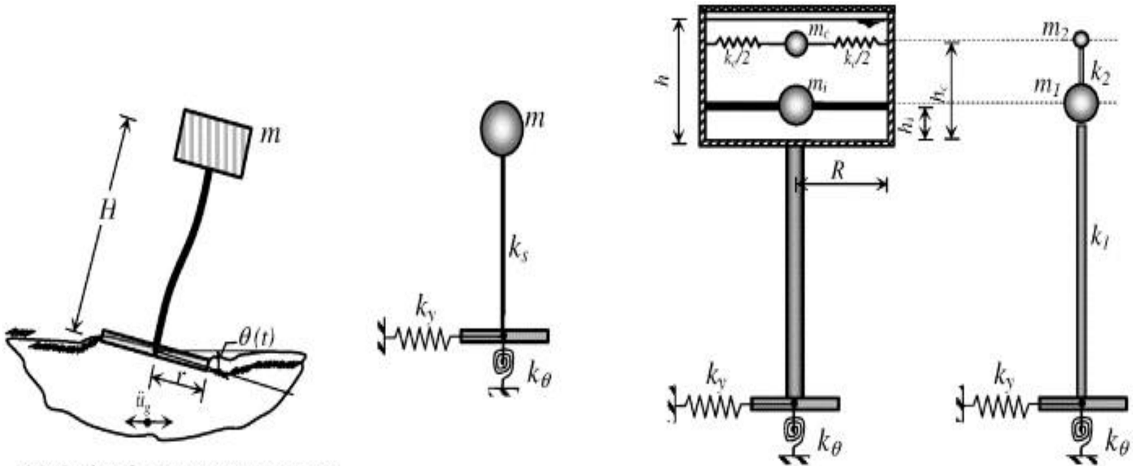
1. Study of mix design in water tank.
2. Study of different height of water tank.
3. Study of different ground angles of water tank.
4. Study of different earthquake zones of water tank.
5. Study of different capacity of water tank.
6. Study of different Bottle size of water tank.
7. Study of different country of water tank.
8. Study of different IS CODES of water tank.
9. Study of footing size as per different wind zone and speed.
10. Study of footing size as per different speed.
11. Study of column frame spacing and supports.
12. Study of thickness of raft foundation.
13. Study of wind pressure.

3. Dynamic Analysis of Intze Water Tank

Seismic analysis of elevated water tank involved two types of analysis

1. Equivalent Static analysis of elevated water tanks.
2. Dynamic analysis of elevated water tanks

Seismic analysis of elevated water tank involved two types of analysis, 1. Equivalent Static analysis of elevated water tanks. 2. Dynamic analysis of elevated water tanks Equivalent static analysis of elevated water tanks is the conventional analysis based on the conversion of seismic load in equivalent static load. IS: 1893- 2002 has provided the method of analysis of elevated water tank for seismic loading. Historically, seismic loads were taken as equivalent static accelerations which were modified by various factors, depending on the location’s seismicity, its soil properties, the natural frequency of the structure, and its intended use. Elevated water tank can be analyzed for both the condition i.e. tank full condition and tank empty condition. For both the condition, the tank can be idealized by one- mass structure. For equivalent static analysis, water-structure interaction shows, both water and structure achieve a pick at the same time due to the assumption that water is stuck to the container and acts as a structure itself and both water and structure has same stiffness. The response of elevated water tanks obtained from static analysis shows the high scale value. That’s why for large capacities of tanks, static response are not precise. If we analysed the elevated water tank by static method and design by the same, we get over stabilized or say over reinforced section but it will be uneconomical. That’s why static systems of designing of elevated water tanks is not useful in seismic zones. And hence, IS code provision for static analysis is restricted for small capacities of tanks only.



(a) A simple structure supports on deformable soil

(b) Simple idealized model for soil-structure interaction

(c) Springs-masses model for considering the effects of the fluid-structure-soil interaction model for the soil-structure interaction

Fig. 1: Mechanical model for the fluid–structure.

A. Single lumped-mass model

The equivalent spring-mass models have been proposed by some researchers to consider the dynamic behavior of the fluid inside a container as shown in Fig. 2. The fluid is replaced by an impulsive mass mi that is rigidly attached to the tank container wall and by the convective masses mcn that are connected to the walls through the springs of stiffness (kcn). According to the literature, although only the first convective mass may be considered (Housner, 1963), additional higher-mode convective masses may also be included (Chen and Barber, 1976; Bauer, 1964) for the ground-supported tanks. A single convective mass is generally used for the practical design of the elevated tanks (Haroun and Housner, 1981; Livaogˇ lu and Dogˇangu¨ n, 2005) and higher modes of sloshing have negligible influence on the forces exerted on the container even if the fundamental frequency of the structure is in the vicinity of one of the natural frequencies of sloshing (Haroun and Ellaithy, 1985).

4. Methodology

A. Structural Layouts

Each of the propped cantilevers was made rigid fixed to its base slab and was expected to be drawn inward at the top by the wall/top slab connecting reinforcements, in response to the outward hydrostatic loading on the wall. That was providing in view based on the fact that continuity reinforcement must be provided at corners and at memberjunctions to prevent cracking. The base slabs was typically a double overhanging single-spanned continuous slab, with wall point load and its applied fixed end moment at each overhang end. And the top slabs was laid out to be either two-way spanning or simply supported as stated by Anchor (1992 and 1981). The tank dimensions was deduce by application related to the formula for solid shapes volume calculations, Therefore (π x R2 x H) for cylinder was applied for the circular water tank; where, H and R, Breadth, Height and Radius respectively.

B. Wall Loading

The average water force and load, P in kN / meter width of the rectangular tank walls under flexural tension was derived as a point concentrated load by calculating the areas of the pressure diagrams of the water tank content on the walls, to be (ρH) x H/2, where ρ is the water density. By the centroid consideration of loading of the pressure diagram, one-third distance from the base, up each wall, was chosen as the point of application of the concentrated load. The circular water tank wall would be clearly in a state of simple hoop tension and its amount in kN per meter height of wall would be (ρH) x D/2. And it would still act at one-third distance from the base up each wall. The wall total working loads for both options were assumed purely hydrostatic. And the inclusion of wind load in the working load was purely made to be dependent on tank elevation above the ground level, but would always be applicable in the design of its support. The wind loads application point, if considered, would be at one-half the tank‟s height and acting against the lateral water force. Hence, the resultant lateral force, from the combination of the water force and wind force; if applicable, would be one-half way between the two forces, that is, five-twelfth of the tank‟s height.

C. Base Slab Loading

For every of the elevated water tank options, the base slab characteristic serviceability uniformly distribute load in kN/m per meter was the sum of its dead load, thyself-weight concrete and its finish, and its live load, that is, the weight of water to be contained. And the serviceability point load in kN / meter, acting on each of the base slabs, at the extremes of the overhangs was derived by adding up the wall dead load that is the base projection weight and a calculated fraction of the top slab load. But some notice difference may be experience in the calculations of the fractions of the loads from the circular water tank top slabs

D. Top Slab Loading

The top slab uniformly distributed load, in kN/m per meter run is calculate by adding up its combination of dead load, that is self-weight concrete, waterproof finish and its live load, to derive the characteristic serviceability load. Factors of safety of 1.4 and 1.6 was apply to the combination of dead and live loads respectively before their sum is make to achieve the require ultimate design load of top slab. The methodology includes the selection of type of water tank, fixing the dimensions of components for the selected water tank and performing linear dynamic analysis (Response Spectrum Method of Analysis) by IS: 1893-1984 and IS: 1893-2002 (Part 2) draft code. In this study, various capacity circular and rectangular overhead water tank is considered for analysis. It is analyzed for four different zones (zone-II to V), and for two tank-fill conditions, i.e. tank full and tank empty conditions. Lastly, the results of the analysis of tanks performed on the basis of IS: 1893- 1984 and IS: 1893-2002 (Part 2) draft code have been compared by using the software STAAD PRO software.

D. Fire Fighting Demand

The per capita fire demand is very less on an average basis but the rate at which the water is required is very large. The rate of fire demand is sometimes treated as a function of population and is worked out from following empirical formulae.

Table 2: Fire Fighting Demand.

S. No.	Authority	Formula (P in thousand)	Q for 1 lakh Population)
1	American Insurance Association	Q(L/min)=4637P (1-0.01OP)	41760
2	Kuchling's Formula	Q(L/min)=3182 P	31800
3	Freeman's Formula	Q(L/min)=1136.5 (P/5+10)	35050
4	Ministry of Urban Development Manual Formula	Q(kilo liters/d)=100P for P>50000	31623

5. Conclusion

Analysis and Design of Intze water tank against earthquake using Staad-pro V8i is considerable importance .This is done to remain structure functional even after earthquake. After detailed study of all paper following point are to be considered at the of time of seismic analysis of Intze water tank

1. Base shear of full water tank and empty water tank are increased with seismic zone II-&V because of zone factor, response reduction factor etc. while considering seismic analysis.
2. Base shear in full condition tank is slightly higher than empty tank due to absence of water or hydro static pressure.
3. Displacement of full water tank and empty water tank are increased with seismic zone II-V because of zone factor, response reduction factor etc. while considering seismic analysis.
4. Maximum nodal displacement and minimum nodal displacement found at the wall of water tank when tank is full condition.
5. Shear force and bending moment of full water tank and empty water tank are increased with seismic zone II-V because of zone factor, response reduction factor etc. while considering seismic analysis.
6. Shear force and bending moment in full condition tank is slightly higher than empty tank due to absence of water or hydro static pressure
7. The effect of earthquake is not same in all zone it varies from zone to zone (Zone II, III, IV, V).

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