Static and Dynamic Analysis of Water Tank by FEM: A Review

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ABSTRACT

The water tanks are very important life line structures which needs to be survived after any type of disaster. To increase the performance of the circular water tanks, baffle walls can be effectively provided. RC Elevated Water tanks are one of the important and indispensable Structure at time of Earthquake and especially after the earthquake. During the Past Study of many Failure of ESR. For this reason, relating to Earthquake behavior of storage tanks has attracted attention of many researchers. The main aim of Study is to behavior of water tank at under different type of soil-layered condition by Using FEM ANSYS Software to Obtained Result of different Stress pattern and Deformation and Von-Mises Stress and the results will be compared. In this study various literature work on water tank studied and compared.

Keyword: RC Elevated water tank, Static analysis, interaction of soil and structure, Finite element Method, ANSYS Software.

1. Introduction

A water tank is a container for storing liquid. The need for a water tank is as old as civilization, to provide storage of water for use in many applications, drinking water, irrigation, agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. A water tank is a structure used to store water to tide over the daily requirement. Cost, shape, size and building materials used for constructing water tanks are influenced by the capacity of water tank. Shape of the water tank is an important design parameter because nature and intensity of stresses are based on the shape of the water tank. In general, for a given capacity, circular shape is preferred because stresses are uniform and lower compared to other shapes. 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. elevated Storage reservoirs and RC overhead Water tank are Generally used to Supply water, liquid petroleum, petroleum products and similar liquids and also used Fire Preservation. In The motion of the Storage reservoirs is the without Consider of the Liquid nature of the product is due to lateral or Circumduction Motion. lateral and Circumduction vibrations due seismic motion. These lateral forces induce there are two different types of vibration in the water of the tank. Upper portion of tank container is in including sloshing effect that's convective and bottom lower portion is call impulsive. Generally, All tanks are designed as crack free structures to Discharge any leakage because of one of the major problems that may have to failure of these structures is due to earthquakes. Therefore, the analysis of RC elevated Water tank must be carefully performed, so that safety can be Confident when earthquake occurs and the Reservoirs remain Utility even after earthquake. RC Elevated water tank is different irregular part but higher Eucharist is at the top of EVT like as container is so more sensitive area to any seismic load, especially due to an earthquake. Structural seismic behavior deals with methods to determine the stresses pattern and deformation of a structure subjected to dynamic loads. A stress analyst generally ignores the influence of the settlements of layered supporting soil on the structural behavior of the super structure of the tank. In general, however, the structure will be interaction with the surrounding Layered soil. In this paper Earlier studies have to indicated that interaction behaviors and effects are actually significant, particularly for the tank resting on highly compressible settlement soils.
2. Water Tank
A water tank is a container for storing liquid. The need for a water tank is as old as civilization, to provide storage of water for use in many applications, drinking water, irrigation, agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include the general design of the tank, and choice of construction materials, linings. Reinforced Concrete Water tank design is based on IS 3370: 2009 (Parts I – IV). The design depends on the location of tanks, i.e. overhead, on ground or underground water tanks. The tanks can be made of RCC or even of other hand the underground tanks rest below the ground level.

Classification of water tank:
In this section, the types of water tanks are discussed in detail. There are different types of water tank depending upon the shape, position with respect to ground level etc.

![Classification of water tank](image)

**Figure 1.1: Classification of water tank**
From the position point of view and placement of tank, water tanks are classified into three categories. Those are,

- a) Underground tanks
- b) Tanks resting on ground
- c) Overhead water tanks

In most cases the underground and on ground tank are circular or rectangular in shape but the shape of the overhead tanks are influenced by the aesthetical view of the surroundings and as well as the design

**A). Underground water tank**
An Underground storage tank (UST) is a storage tank that is placed below the ground level. Underground storage tanks fall into three different types:

- Steel/aluminium tank, made by manufacturers in most states and conforming to standards set by the Steel Tank Institute.
- Composite overwrapped a metal tank (aluminium/steel) with filament windings like glass fibre/aramid or carbon fiber or a plastic compound around the metal cylinder for corrosion protection and to form an interstitial space.
- Tanks made from composite material, fibreglass/aramid or carbon fibre with a metal liner (aluminium or steel).

Underground water storage tanks are used for underground storage of potable drinking water, wastewater & rainwater collection. So whether you call it a water tank or water cistern, as long as you are storing water underground these are the storage tanks for you. Plastic underground water tanks (cistern) are a great alternative to concrete cisterns.
B). Tanks resting on ground
In this section, we are studying only the tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks etc. are supported on ground directly. The walls of these tanks are subjected to pressure and the base is subjected to weight of water. These tanks are rectangular or circular in their shape.

C). Overhead water tanks
Overhead water tanks of various shapes can be used as service reservoirs, as a balancing tank in water supply schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they are not affected by climatic changes, are leak proof, provide greater rigidity and are adoptable for all shapes.

From shape of tank, water tanks may be classified as types. These are,
  a) Circular tanks  
  b) Conical or funnel shaped tanks  
  c) Rectangular tanks  
  d) Intze type  
  e) Spherical type

a) Circular tanks
Circular tanks are usually good for very larger storage capacities the side walls are designed for circumferential hoop tension and bending moment, since the walls are fixed to the floor slab at the junction. The bottom slab is usually flat because it’s quite economical.

b) Conical or funnel shaped tanks
This tank is best in architectural feature and aesthetic this tank has another important advantage that its suitable for high staging the tank’s hollow shaft can be easily built. It can be economical and rapidly constructed using slip from processing of casting. They can also be built using pre-cast concrete elements.

c) Rectangular tanks
The walls of Rectangular tank are subjected to bending moments both in horizontal as well as in vertical direction. The analysis of moment in the wall is difficult since water pressure results in a triangular load on them. The magnitude of the moment will depend upon the several factors such as length, breadth and height of tank, and conditions of the support of the wall at the top and bottom edge. If the length of the wall is more in compression to its height the moment will be mainly in vertical direction i.e. the panel will bend as a cantilever. If, however, height is larger in comparison to length, the moments will be in horizontal direction, and the panel will bend as a thin slab supported on the edges. The wall of the tank will thus be subjected to both bending moment as well as direct tension.
d) Intze type tank
INTZ type water tank is one such water tank which has circular shape with a spherical top and conical slab with spherical dome at the bottom. In this type of water tank, the inward forces coming from the conical slab counteract the outward forces coming from the bottom dome which result less stress on the concrete bottom slab of the water tank. Due to lesser stresses, the thickness of the concrete bottom slab reduces and reducing the amount of concrete required which has direct influence on the cost of the water tank.

Figure (d): Intze type Water tank  Figure (e): Spherical type water tank

e) Spherical type
This type of storage tank is preferred for storage of high-pressure fluids. A sphere is a very strong structure. The even distribution of stresses on the sphere's surfaces, both internally and externally, generally means that there are no weak points. Spheres however, are much costlier to manufacture than cylindrical or rectangular tanks. An advantage of spherical storage tanks is that they have a smaller surface area per unit volume than any other shape of tank. This means, that the quantity of heat transferred from warmer surroundings to the liquid in the sphere, will be less than that for cylindrical or rectangular storage vessels.

3. Proposed Methodology

- Modeling of Water tank
  Modeling of the designs of water tank structure using ANSYS Workbench has been explained in detail. The intention of finite element investigation is to reconstruct the mathematical behavior of an actual engineering structure. The Water tank model comprises all the nodes, elements, material properties, real constants, boundary conditions and additional features that are used to characterize the physical system. First model be generated then specific boundary conditions will be applied on the specific nodes then final analysis will be conducted.

- Layout of ANSYS Workbench
Model Generation

First we double click the “Static Structural” a small window will open where we can rename it as shown in figure 1. If we want to change the material we will double click on “Engineering Data”. For drawing the beam we double click on “Geometry”. After double clicking on “Geometry” a separate window names as “Design Modeler” shown in figure will come out, where first we select the dimensions on which we want to work shown in figure.
• **Modelling of Tank and Soil Using**

Modelling the contact surface of soil and tank is one of the important parts of soil-tank interaction modelling. Generally, contact surface between tank and soil is modeled in two ways: complete cohesion or friction contact surface in which there is soil and tank slip and segregation between them. In ANSYS program, mechanical contacts between two objects are possible in two ways: surface to surface contact and surface to node contact which are more accurate than the first state. In this research, two contacts between interfaces have been considered: friction contact and vertical contact. In friction contact, penalty formulation with friction coefficient of 0.7 has been used. In vertical contact, penalty formulation has been used. It is possible to select Rayleigh damping in ANSYS program in specifications of materials. Critical damping coefficients have been assumed 5% for this research which are in line with studies. Radiation damping play very important role in modelling of soil and dynamic issues especially issues of soil-structure interaction. In this research, infinite elements and dampers have been used for modelling the soil-tank interaction. Using infinite elements, one can be release from effect of undesirable phenomenon of packing in modelling. Cubic three-dimensional elements with 8 nodes which have three degrees of freedom in each node have been used for modelling soil and tank system.

4. **Literature Study**

Significant researches were carried out on seismic behavior of liquid storage tanks and a few published works on natural frequency or seismic response characteristics of reinforced concrete (RC) water tanks are reviewed in this section.

**Naveen Kumar S M et al. 2019 (1)** The present study emphasis is placed on the analysis and design of elevated water tank structures by manual method and by using SAP2000 software for gravity and lateral loading. A typical intze water tank is considered for the study. The structure is modeled using SAP2000 software using a combination of plate and line elements. The gravity loading consists of vertical and horizontal water pressure along with the self weight of the structure. The lateral loading is in the form of seismic loading as per the provisions of IS 1893. The structure is analyzed for combinations involving gravity and lateral loading. Push over analysis is also performed. The structure is then designed for the internal forces using SAP2000 and manual methods. The results of the present study reveal that SAP2000 is convenient and efficient tool for the analysis and design of water tank structures. The push over curve reveals the ductility of the structure. The results of design from SAP2000 and manual methods are in good agreement with each other.

**Prashant A Bansode et al. 2018 (2)** Reinforced concrete elevated water tanks are very important structures. They are considered as main lifeline elements during and after earthquakes. An elevated water tank behaves like an inverted pendulum, which consist of huge water mass at the top of a slender staging. This is most critical consideration for the failure of the tank during earthquakes. Basically, supporting system, so called staging is formed by a group of columns and horizontal braces provided at intermediate levels to reduce the effective length of the column. Staging is responsible for lateral resistance of complete structure. The objective of this study is, to understand the behavior of different staging system, under different tank conditions. Response Spectrum Analysis is carried out on three different types of bracing systems of elevated water tank in all zones by using STAAD Pro V8i 2007. Comparison of base shear and nodal displacements of elevated water tank for empty and full condition is done. The spring mass model as per IS 1893:2002 Part 2 has been used for the analysis.

**Vyankatesh et al. 2017 (3)** study of elevated water tanks subjected to dynamic loading supported on RC framed structure and concrete shaft structure with different capacities and placed in different seismic zones. History of earthquake reveals that it has caused numerous losses to the life of people in its active time, and also post-earthquake time have let people suffer due to damages caused to the public utility services. Either in urban or rural areas elevated water tanks forms integral part of water supply scheme, so its functionality pre and post-earthquake remains equally important. These events showed that importance of supporting system is uncompromising for elevated tank as compared to any other type of tank. Damages caused are the results of unsuitable design of supporting system; wrong selection of supporting system, etc. These structures
have heavy mass concentrated at the top of slender supporting system hence these structures are especially vulnerable to horizontal forces due to earthquakes.

**Vajir et. al. (4)** Studied an Analytical and numerical analysis of composite material storage tank under seismic loading. Dynamic characteristics of industrial equipment, as for example pressurized vertical tank is taken for study. An evaluation of existing technical solutions and design guidelines apropos composite material pressure vessel under seismic loading has been carried out. In particular, attention has been focused on the seismic design and analysis of tanks for storage of hazardous and corrosive materials. They are very common worldwide and can help to develop methods of seismic analysis able to take account of composite material orthotropic behavior. Advanced FEM analyze have been carried out and a comparison between procedures of ASME RTP-1 & FEM has been discussed. A satisfactory capacity of simplified models to fit the overall response of tanks has been shown.

**N Beemkumar et. al. (5)** A detailed survey has been done on the use of solar energy to meet the thermal requirement of different purposes. From detailed study designing of the apparatus according to the standard conditions and specifications are done to increase the efficiency and to reduce the heat loss. Thermal analysis is done on the model and the results were analyzed and compared. The results obtained from experimental work are compared with ANSYS output. The competence of the TES is calculated and further improvements are made to enhance its performance. During charging process, the temperature distribution from heat transfer fluid (HTF) to PCM is maximum in copper encapsulations followed by aluminum encapsulations and brass encapsulations. The comparison shows only when the electrical power as an input source. The efficient way of captivating solar energy could be a better replacement for electrical input.

**Prasad et. al. 2017 (6)** Performed seismic analysis and design of strengthening techniques of steel storage tank. Here in this study the finite element approach with the aid of ANSYS software is taken. ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. Here seismic analyses of strengthening techniques along with the design of tank were discussed. From the analysis with strengthening techniques among GFRP and TPP, GFRP is good since it reduces the deformation and its market cost is less compared with TPP. Also, GFRP can be adopted since it is easily available in market which reduces the seismic parameters. Provision of Foundation gives a better performance. It can be adopted where stability is prominent than costs.

**Chaudhari et. al. (7)** Numerical study on circular water tank with and without baffle wall is carried out for hydrodynamic forces and past earthquake data. From all the above results and graphical representations, it can be seen that baffled tank increases the performance of circular water tank. From comparison of height of baffle wall, it is concluded that one half height baffle wall has less deformation by about 32% and stresses are less by 60 to 80% than baffle wall of one third or two third height of tank. From comparison of effect of opening in baffle wall, it is concluded that provision of opening is not recommended as it results in swirl effect and increases stresses.

**Dhruv Saxena et. al. 2017 (8)** studied to know the importance of continuity analysis for practical consideration. In this study analysis of Intze type container of water tank is carried out by both methods by using conventional method and finite element method. In conventional method. The finite element modelling and analysis are done by using of STAAD Pro Software. Two different capacity tanks were analyzed by all three methods and with different ratios of height of the conical shell to height of the cylindrical shell. In this study only Intze type tank is considered, because in the present scenario of fast and large scale infrastructure development, most of water tanks are constructed of large to medium capacity having heavy load on bottom dome and its diameter is large, the ring beam needs large amount of reinforcement. It becomes more economical to reduce its diameter by introducing a conical dome to reduce the ring tension. The bottom ring beam in Intze tank required much lighter reinforcement as the thrust from the conical dome opposes the force from the bottom dome, hence Intze tank is economical.

**Thorat et. al. 2016 (9)** nonlinear analysis of reinforced concrete open square elevated storage reservoir (ESR). In this study component wise static analysis with tank full condition is carried out. Means the components of
the RCC open square ESR like tank wall, tank slab, supporting beam, supporting frame and footing are modeled and static analysis by considering all the design loads is carried out in order to find maximum stresses produced in the tank components. Concrete is modeled using SOLID65 element and reinforcement is modeled using LINK180 element. Also discrete type of modeling technique is used in order to model rebar in the concrete. For modeling and analysis ANSYS Mechanical APDL software is used.

Maheswari et. al. 2016 (10) This study presents the evaluation of seismic forces acting on elevated water tank e.g. circular water tank with frame staging affected by different parameters viz., seismic intensity, different wind speeds. Seismic forces acting on the tank are also calculated changing the seismic zone of IS:1893-2002 for seismic design has been referred. The staging of circular tank has been modeled by using the software STAAD PRO. From the present study, it was observed that, for elevated tanks, the two degree of freedom idealization of tank should be used for analysis instead of using single degree of freedom of idealization of tank as the effect of convective hydrodynamic pressure has been included in the analysis of the tanks. Finite element modeling and analysis of elevated RC circular tank has been carried out using STAAD PRO software.

Naveen et. al. 2015 (11) evaluated the applicability of the general purpose with analysis program ANSYS14.5 in the modeling and seismic analysis of elevated water tanks. It is found that ductility demand on staging increases due to hydrodynamic effects. From this analysis it can be conclude that the section provided by Water Authority Department is not sufficient to accommodate the hydrodynamic forces and sloshing effects of water during base excitation during fully filled conditions. And it was found that hydrodynamic forces have greater effects on water tanks during earthquakes, which were not taken into consideration by the Water Authority Department while designing.

Dhumal et. al. 2016 (12) Studied FEA model of rectangular elevated water tank with baffle wall is model using ANYSIS 16.0 sloshing effect is a major problem encountered in the analysis of design of reinforced concrete rectangular elevated water tank. In this paper study of baffle wall is done with varying parameters such as thickness, spacing of baffle wall. In second stage opening effects are studied in baffle walls. Present study is based on Finite Element Simulation of elevated RCC water tank in ANSYS workbench In first stage pressure and loads are calculated in accordance with IS 1893:2002 part-2. Later comparison is made between water tank with baffle wall and without baffle wall. Deformation and shear stress along long wall is considerably reduced by using baffle walls.

George et. al. 2016 (13) analyze the response behavior of an RCC elevated rectangular water tank. The static structural, modal and transient analyses were carried out using the ANSYS 15 WORKBENCH. The effect of water height on the tank response was studied by using 100%, 75%, 50% and 25% water fill conditions. Hence seismic behavior of these structures during the earthquakes has to be investigated in detail in order to meet the safety objectives while containing construction and maintenance costs. In the present study, an elevated RCC rectangular water tank was modeled and analyzed using the ANSYS software. The static structural, modal and transient analyses were conducted. It was observed that the responses of the tanks elevated with an increase in the water heights.

Jingyuan et. al. 2015 (14) Investigated the finite element software ABAQUS to trace the dynamic response history of large reinforced concrete storage tank during different seismic excitations. The dynamic characteristics and failure modes of the tank’s structure were investigated by considering the rebar’s effect. Calculation results show that the large concrete storage tank remains in safe working conditions under a seismic acceleration of 55 cm/s^2. The joint of the concrete wall and dome begins to crack when seismic acceleration reaches 250 cm/s^2. As the earthquake continues, cracks spread until the top of the wall completely fails and stops working. The maximum displacement of the concrete tank and seismic acceleration are in proportion. Peak displacement and stress of the tank always appear behind the maximum acceleration.

Anumod et. al. 2014 (15) Studied the effect of various components of earthquake on sloshing response of liquid storage tanks. First, commonly used theory for unidirectional analysis of liquid behavior in cylindrical tanks was reviewed. Second, the Finite Element Modeling (FEM) strategy which was used to simulate dynamic response of the liquid tank system was described. The FEM was validated using a set of manual calculation which is used in available design guidelines. A parametric study for some vertical, cylindrical
ground supported tanks with different aspect ratios excited by various time series of earthquake accelerations was performed. Each tank was subjected to unidirectional and bidirectional excitations of earthquake accelerations. The variations of maximum sloshing wave height during the above analysis were described. The tanks under this study were analyzed in a known earthquake in India and the effects on sloshing wave height were studied.

Eltaly et. al. 2014 (16) current research is based on the verification of previous analytical approaches that were used to obtain modal parameters of water tanks as a basic step to study the behavior of these structures under seismic loads. Due to the complex nature of theoretical approaches especially when considering the dynamic nature of structure, ANSYS finite element software was used. Housner method was adopted to represent the dynamic behavior of water elevated tank subjected to horizontal base excitation. Two cases of tanks were studied, and their validated 3D models showed quite good agreement with the experimental modal results. The analytical approach efficiently simulated the dynamic behavior of all tanks in the current study.

Sarokolayi et. al. 2014 (17) The present study investigated, the effect of the rotational ground motion correlated components on the linear dynamic response of a water storage tanks. The finite element method with Lagrangian approach to model the fluid structure interaction is used. The rotational components of the ground motion are deduced from the translational components by solving the wave propagation equations in 3D. The parametric study included the analyses of a water tank subjected to four earthquake records and considered empty, 40 and 80 % full tanks.

5. Expected outcome
- All the different paper and referred material gives clear idea about analysis and design of RCC Overhead water tank.
- It is clearly seen what amount of work is carried out for Elevated water tank from literature review.
- In soil structure and Fluid Structure interaction there are many types of work as possible in different type of water tank base on finite element method to evaluation and performance base work like as to define base shear Over turning moment impulsive and convective lumped mass etc.
- In the Past Work not use different Parameter to define mode shape and natural frequency and different type of stress pattern. And Very low focus on different Staging used.

References
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