Time History Analysis of Water Tank

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Abstract — Earthquake is the result of sudden release of energy in the earth's crust that generates seismic waves. Ground shaking and rupture are the major effects generated by earthquakes. It has social as well as economic consequences such as causing death and injury of living things especially human beings and damages the built and natural environment. In order to take precaution for the loss of life and damage of structures due to the ground motion, it is important to understand the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant rule in studying the behavior of structures under seismic loads. The strength of ground motion is measured based on the PGA, frequency content and how long the shaking continues. Ground motion has different frequency contents such as low, intermediate, and high. Present work deals with study of frequency content of ground motion on water tank. Linear time history analysis is performed in structural analysis and design (STAAD Pro) software. The proposed method is to study the response of water tank with fixed and pinned support frequency content ground motions.

Keywords: Water Tank, Ground Motion, Time History Analysis

I. INTRODUCTION

Water is an imperative commodity as food and air for existence of life. The elevated water storage tank is constructed for holding water supply at a certain height to pressurize the water distribution system. Liquid storage tanks are widely used by municipalities and industries for storing water, inflammable liquids and other chemicals. Typical geometries of elevated tank include cylindrical, square, rectangular and toroidal. These elevated tanks have various types of support structures like RC shaft, RC braced frame, steel frame and masonry pedestal. The frame type is the usual type of staging in practice. Columns and braces are the main components of the frame type of staging. The water storage tanks which are most inevitable part of water supply system are expected to remain functional even after an earthquake. Earthquakes are the most destructive natural calamity, inter alia, in terms of loss of life and destruction of property. Due to large mass of tank and water concentrated at an elevation from base, water tanks are sensitive to earthquake loading and it experiences a high damage due to shaking of ground during earthquake. Large amount of energy released during this phenomenon reaches to water tank from origin of occurrence in the form of seismic waves, this seismic wave has different features like Peak ground acceleration, frequency contents, effective duration of the ground motion, which affects the performance of water tank. During earthquakes, the elevated water tanks are critical and strategic structures, hence the damages of these structures may endanger drinking water supply, it may also lead to failure in preventing large fires and cause substantial economic loss. Seismic behavior of elevated tanks should be investigated in detail since these tanks are frequently used in seismic regions also and it is imperative to consider earthquake loading as a non-stationary process. Due to lack of awareness of supporting system some of the elevated tanks were heavily damages or collapsed.

A. Performance of Elevated Water Tank

Land and seismological disclosures amid the 20thcentury have helped in starting the improvement of seismic construction regulations and tremor safe structures and structures. The improvement in seismic design requirements has led to more robust, safe and reliable buildings. Due to the earthquake many buildings collapsed killing thousands of people.

Many elevated water tanks damage to their staging (support structure) in the Bhuj earthquake of January 26th 2001 and at least three of them collapsed. These water tanks are located in the area of a radius of approximately 125km from the epicenter. Tanks located in regions of the highest intensity of shaking collapsed while a few developed cracking near brace-column joint regions. Critical facilities like water tanks therefore require careful design. Frame type staging are generally regarded superior to shaft type staging for lateral resistance because of their large redundancy and greater capacity to absorb seismic energy through inelastic actions. Framed staging's have many flexural members in the form of braces and columns to resist lateral loads and damage to a few will not result in the sudden collapse of the structure as inelastic deformations and damage is distributed to a large number of frame members. The sections near the beam ends can be designed and detailed to sustain inelastic deformation and dissipate seismic energy. However, if the frame members and the brace column joints are not designed and detailed for inelastic deformations, a collapse of the staging may occur under seismic overloads. Sloshing, the motion of the free liquid surface inside its container is one of the major concerns in design liquid storage tanks, moving tankers fuel tank space vehicles and also in ships.in major cities and also in rural areas elevated water tank forms in integral part of water supply scheme and these tanks must remain functional to meet the demand in any extreme situation like earthquake, fire, etc. During the earthquakes, a number of large elevated water tanks were severely damaged whereas others survived without damage. An analysis of the dynamic behavior of such tanks must take into account the motion of the water relative to the tank as well as the motion of the relative to the ground.

II. ANALYSIS METHODS

The analysis of isolation system can be done by following ways:

- Linear Static Analysis: Linear analysis methods give a good indication of the elastic capacity of the structures and indicate where first yielding will occur. The straight static strategy for investigation is restricted to little, standard structures.

- Linear Response Spectrum Analysis: Linear response spectrum analysis is the most common types of analysis used. This is sufficient for almost all isolation system based on LRB and / or HDR bearings.
- Non-Linear Static Analysis: In a nonlinear static analysis procedure, the building model incorporates directly the nonlinear force-deformation characteristics of individual's components and elements due to inelastic material response.
- Linear Time History Analysis: Linear Time History Analysis provides little more information than the response spectrum analysis for a much greater degree of effort and is rarely used.
- The direct static technique for investigation is restricted to little, customary structures. Nonlinear time history analysis is the dynamic analysis in which the loading causes significant changes in stiffness.

III. Methodology

A. *Time History Analysis*

Time history analysis is a technique used in structural engineering and other fields to study the dynamic behavior of structures subjected to time-varying loads or forces. It is a computational method that involves analyzing the response of a structure over time based on the input of a known time history of forces or displacements.

In time history analysis, the structure's response is determined by solving the equations of motion considering the dynamic forces acting on the structure at each time step. The analysis takes into account the mass, stiffness, and damping properties of the structure, as well as the time-varying external loads. It provides valuable insights into how a structure behaves under transient or dynamic loading conditions, which cannot be accurately predicted using simpler static analysis methods.

Time history analysis is particularly important for structures subjected to severe dynamic events, such as earthquakes, windstorms, or explosions. By simulating the actual time-varying loads experienced by the structure, engineers can assess its dynamic behavior, identify potential weaknesses or failure modes, and optimize its design for enhanced performance and safety.

It offers several advantages over simplified methods, making it a crucial tool in the analysis and design of structures subjected to dynamic forces. Here are some key benefits:

- Realistic Representation: By considering the time-varying nature of loads, time history analysis provides a more accurate representation of the actual behavior of structures. This enables engineers to better understand the dynamic response and identify potential vulnerabilities.
- Evaluation of Safety: Dynamic events such as earthquakes can pose significant risks to the safety of structures. Time history allows engineers to assess the performance of a structure under extreme loading conditions, helping them ensure its safety and durability.
- Design Optimization: Through time history, engineers can iteratively refine the design of a structure to enhance its performance. By evaluating different scenarios and considering the dynamic response, they can make informed decisions to achieve an optimal design solution.
- Compliance with Codes and Standards: Many building codes and standards require the consideration of dynamic loads in the design process. Time history analysis enables engineers to meet these requirements and ensure that structures adhere to the necessary regulations.

IV. Structural Modeling

A. *Proposed Work*

In the present study, two elevated water tanks with 1000m3 capacities are considered. Tank diameter is 10m. Tank boundary conditions are fixed and pinned respectively. In full tank condition, the water level is 3.41m and free board is taken as 0.59. The tank container is of circular type. Young's modulus and the weight of concrete per unit volume are taken as 27386MPa and 25kN/m3. The container is filled with water of density 1000 kg/m3.

Model Input Data

Capacity	1000 m3	1000 m3
Diameter	10m	10m
Column dimension	0.5m x0.5m	
Tank height	5m	
Plate thickness of tank	0.125m	
Floor beam	0.2m x 0.4m	
Ring beam	0.4mx0.4m	
Brace beam	0.4m x 0.4m	
Floor slab thickness	0.3m	
Staging height considered	10m,12m,15m	
Boundary condition at the base	Fixed	Pinned

B. *Structural Modeling*

Concrete is the most widely used material for construction. It is strong in compression, but weak in tension, hence steel, which is strong in tension as well as compression, is used to increase the tensile capacity of concrete forming a composite construction named reinforced cement concrete. RC buildings are made from structural members, which are constructed from reinforced concrete, which is formed from concrete and steel. Tension forces are resisted by steel and compression forces are resisted by concrete. The word structural concrete illustrates all types of concrete used in structural applications.

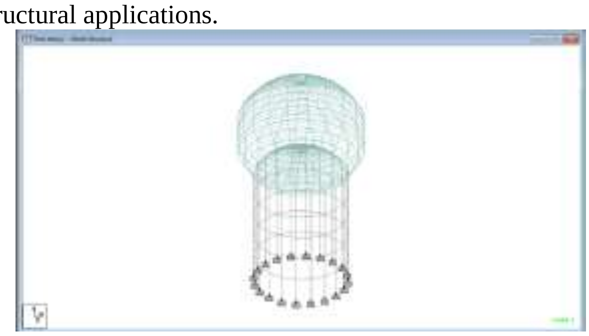

Fig. 1: Two dimensional design of elevated water tank with Fixed support

Fig. 2: Two dimensional design of elevated water tank with pinned support

V. Ground Motion and Time History Analysis

A. Ground Motion

An earthquake is a hysteria of ground quaking caused by a sudden discharge of energy in the earth's lithosphere. This energy may come mainly from stresses formed during tectonic processes, which involves interaction between the crust and the inner side of the earth's crust. Strain energy stored inside the earth will be released and maximum of it changes to heat, sound and remaining as seismic waves. The science of the earthquake is called seismology. The source and nature of earthquakes is the science of seismology.

Sources of earthquake are tectonic, volcanic, rock fall or collapse of cavity which are natural source and mining induced earthquake, reservoir induced earthquake, and controlled source (explosive) which are man-made source. In fact, 90 percent of the earthquakes are due to plate tectonics. There are six continental sized plates which are African, American, Antarctic, Australia-Indian, Euro-Asian, and pacific plate.

The motion of sufficient strength that effects people and environment is called strong ground motion. It is described by three transitions and three rotations. The effect of the three rotations is very small which may be neglected. The maximum absolute value of the ground acceleration is peak ground acceleration (PGA). PGA, frequency content and duration are the most important characteristics of earthquake. The rock site experiences higher acceleration, soil site undergoes higher velocity, and higher displacement.

B. Ground Motion Records

Water tanks are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC structure under seismic loads.

For fixed support condition peak ground acceleration value found as 0.049g peak ground velocity found as 1.29 mm/sec and peak ground acceleration found as 0.039mm as per the result found after execution of time history analysis on water tank.

For pinned support condition peak ground acceleration value found as 0.771 g peak ground velocity found as 0.953 mm/sec and peak ground acceleration found as 0.891 mm as per the result found after execution of time history analysis on water tank.

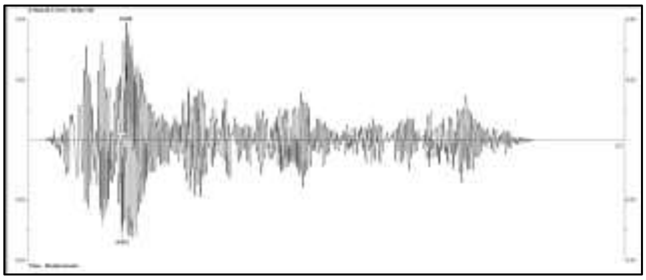

Fig. 4: Peak ground displacement for water tank with fixed support.

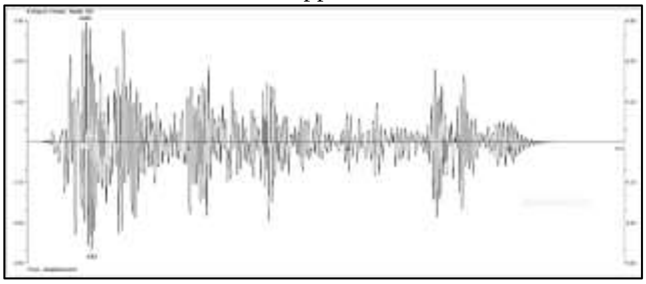

Fig. 5: Peak ground displacement for water tank with pinned support

VI. Conclusion

The PGA value is directly related to the severity of ground motion and can be used as an indicator of the potential damage caused by an earthquake. the PGA values experienced by the water tank with fixed supports is lower compared to structures with pinned supports. Means the fixed support condition helps to distribute the seismic forces more evenly throughout the structure, reducing localized damage and potential failure modes.

Water tank with fixed support has higher PGV values compared to pinned support. The fixed support condition allows less deformation and tends to transfer more seismic energy to the structure, leading to higher ground velocities. Whereas the water tank with pinned support has lower PGV values compared to fixed support conditions. The pinned support condition allows more deformation and tends to dissipate some of the seismic energy through rotational movement, leading to lower ground velocities.

The PGD is smaller in case of water tank with fixed boundary condition so that the fixed supports resist the displacement or deformation of the structure, thereby minimizing the impact on the ground. Whereas the PGD in case of water tank with pinned support is larger compared to fixed supports. This results the pinned supports do not fully resist the displacement or deformation of the structure, which can transfer more movement or rotation to the ground.

It can be summarized that A structure with a fixed support, such as a fixed base or fixed connections, can provide enhanced earthquake resistance due to its ability to resist lateral forces and maintain stability during seismic events. Fixed supports offer greater stiffness compared to pinned support. This increased stiffness helps to limit excessive displacements and deformations during an earthquake. Stiffer structures have a higher natural frequency, which means they are less likely to resonate with the shaking frequency of an earthquake, reducing the potential for significant damage.

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