

Seismic Analysis of Elevated Water Tank under Near Field and Farfield Earthquake

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ABSTRACT

As known from very upsetting experiences, liquid storage tanks were collapsed or heavily damaged during the earthquakes all over the world. The economic lifetime of concrete or steel tanks is usually in the range of 40 to 75 years. Damage or collapse of the tanks causes some unwanted events such as shortage of drinking and utilizing water, uncontrolled fires and spillage of dangerous fluids. Due to this reason numerous studies done for dynamic behavior of fluid containers; most of them are concerned with cylindrical tanks. The aim of the study is to analyse seismic effect of circular shape elevated water tank due to nearfield and Farfield earthquakes with empty and full water conditions. So, it is very important to select proper supporting system and shape of tank according to standard codal provisions. Here modelling of water tank simulated to nearfield and Farfield ground motion with SAP2000 Software. In this study, Seismic forces acting on an Elevated water tank e.g. circular tank are studied with constant staging height. Seismic responses including base shear, base moment and top displacement have been observed under different earthquake time history records. Responses of the elevated water tank subjected to Nearfield ground motion is very high as compared to Farfield ground motion for each model. So, it is desirable to design the tank under nearfield earthquake rather than Farfield earthquake with the necessary ductility requirements.

INTRODUCTION

Water is life line for every kind of creature in this world. All around the world liquid storage tanks are used extensively by municipalities and industries for water supply, firefighting systems, inflammable liquids and other chemicals. Thus, Water tanks play a vital role for public utility as well as industrial structure having basic purpose to secure constant water supply from longer distance with sufficient static head to the desired location under the effect of gravitational force. Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. All tanks are designed as crack free structures to eliminate any leakage. Water or raw petroleum retaining slab and walls can be of reinforced concrete with adequate cover to the reinforcement. Water and petroleum react with concrete and, therefore, no special treatment to the surface is required. Industrial wastes can also be collected and processed in concrete tanks with few exceptions. The petroleum product such as petrol, diesel oil, etc. are likely to leak through the concrete walls, therefore such tanks need special membranes to prevent leakage.

METHODOLOGY

The methodology includes the selection of type of water tank, fixing the dimensions of components for the selected water tank and performing linear and nonlinear dynamic analysis (Response Spectrum Method of Analysis) by IS: 1893-2016 and IS: 1893-2016 (Part 2) draft code. In this study, circular elevated water tank is considered for analysis. It is analysed for two different earthquake records (Northridge far field and Northridge nearfield) and for two tank-fill conditions, i.e. tank full and tank empty conditions. Lastly, the results of the analysis of tanks performed based on IS: 1893- 2016 and IS: 1893-2016 (Part 2) draft code have been compared by using the software SAP2000 software.

LITERATURE REVIEW

General

To provide a detailed review of the literature related to modelling of structures in its entirety would be difficult to address in

this chapter. A brief review of various studies on the application of time history analysis is presented in this section. This literature review focuses on recent contributions related to time history analysis past efforts most closely related to the needs of the present work.

Literature Review On Time History Analysis Undernear And Far Field Earthquake

Jain Sudhir K., Sameer U.S., (1995): -

Developed a model by using an approximate analysis of the hydrodynamic pressures exerted on the walls of rigid tanks subject to unidirectional horizontal seismic ground motion. He assumed the liquid, divided into two-mass system: a part of the liquid at the bottom of the container, known as the impulsive component behaves the same way as solid material while the liquid above it, known as, the convective component participates in sloshing with a different dynamic having long period of vibration. The liquid was assumed to be incompressible and undergo small displacement. Due to its implementation simplicity, the model has been adopted in many codes and standards with certain modifications.

Sudhir K. Jain & O.R. Jaiswal, September (2005): -

Proposed a single-DOF model for obtaining a satisfactory estimation of dynamic response of elevated water tanks. Measurements of time of concrete water towers indicate that the effective flexural rigidity changes considerably with the vertical load. For full tank, the nominal values suggested for I, E and L give time periods which were a very good approximation to the measured values.

Housner, G.W., (2014): -

studied the elastic and inelastic response of SDOF systems and MDOF frame structures subjected to near-fault ground motions. The global objective of the study is to acquire quantitative knowledge on near-fault ground motion effects. Moreover, they concluded that, equivalent pulses can represent the salient response features of nearfield ground motion.

METHODS OF ANALYSIS OF EARTHQUAKE FORCES

General

Seismic analysis is related to calculation of the response of a building or other structure under earthquakes. It is a part of the process of structural design which includes earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. During earthquake many of the buildings collapse due to lack of understanding of the inelastic behavior of structure. Elastic analysis gives only elastic capacity of the structure and indicates where the first yielding occurs. It cannot give any information about redistribution of forces and moments and failure mechanism.

For study of inelastic behavior of structure nonlinear analysis is necessary. The development of rational methodology that is applicable to the seismic design of new structures using available ground motion information and engineering knowledge, and yet is flexible enough to permit the incorporation of new technology as it becomes available has been supported for sometimes now. This is the focus of several major research and development efforts throughout the world. In majority of cases nonlinear analysis is used.

Method For Linear Static Analysis

This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces.

Linear Time-History Analysis

Time-history analysis is a step-by-step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or nonlinear.

Modal Analysis

Modal analysis is used to determine the vibration modes of a structure. These modes are useful to understand the behavior of the structure. They can also be used as the basis for modal superposition in response spectrum and modal time-history analysis cases.

TIME HISTORY ANALYSIS UNDER NEAR AND FAR FIELD

Nonlinear Dynamic Analysis

Since a severe earthquake ground excitation is expected to deform a structure into the inelastic range, design and assessment guidelines are increasingly requiring nonlinear dynamic analysis in the design process as well as for the seismic performance evaluation of existing structures and the nonlinear dynamic analysis requires some characterization of the correlations between ground motion intensity measures and structural response parameters. It gains more significance to understand which properties of a recorded ground motion are most strongly related to the response caused in the structure.

Ground Motion Database

The ground motion database compiled for numerical analyses in this study constitutes a representative number of far-fault and near-fault ground motions from a variety of tectonic environments. Two earthquake records were selected to cover a range of frequency content, duration, and amplitude. Near-fault records were chosen so as to consider the presence of both forward-directivity and fling-step effects. Hence the assembled database can be investigated in two sub database sets. The first set contains ordinary far field ground motion recorded within 80 km of the causative fault plane from earthquakes in the magnitude (Mw) range of 6.4 to 7.5 at soft soil or stiff soil sites. The second set includes near field ground motions characterized with forward directivity effect. These ground motions contain records either taken from soft soil or stiff soil sites. These records are from earthquakes having a magnitude (Mw) of range of 6.7 to 7.1 at a closest fault distance of 0.0 to 15.0 km. In this study the ground motion records have been extracted from PEER Strong Motion Database of Berkeley University.

Table 4.1 Important characteristics of near-field ground motion

S.NO	Earthquake	Mw	Station	Dist.(km)	PGA (g)
1.	Northridge	6.69	LA dam	11.79	0.84
2	Elcentro	6.53	Brawley Airport	43.15	0.32

Table 4.2 Important characteristics of far-field ground motion

S.NO	Earthquake	Mw	Station	Dist. (km)	PGA (g)
1.	Northridge	6.7	Huntington Bch-Waikiki	69.5	0.09
2	Landers Baker	7.3	Baker fire station	87.94	0.102

Modelling In Sap 2000

General Description Of Elevated Water Tank

In FEM, modelling of the problem is one of the aspects that govern the accuracy of the solution and efficiency of computational time. The columns and beams were modelled using frame elements. The tank wall was considered as shell element. Material property was assumed to be homogeneous within the material. The tank is an elevated one with moment resisting frame as supports, circular, thin-walled liquid container. The liquid height is defined by h. For the present study, water tank was modelled for full tank and empty tank condition. Constant staging conditions were provided for empty and full conditions of tank. While generating a model, the usual practice is to define the relationship among different degrees of freedom by using elements to connect the nodes. In this case special association among nodal degrees of freedom can be established using coupling. In the case of using two different elements that are bounded together at a node coupling of the nodes is required. This coupling causes the nodal results to be transferred from one element to the other, so that equilibrium of nodal values will be attained.

RESULTS AND DISCUSSIONS

General

In this research attempts are made to study the seismic behaviour of Elevated water tank for empty tank and full water level condition subjected to far field and near field ground motion. Time history analysis is performed for the models taking two sets of Northridge earthquake records.

CONCLUSIONS AND RECCOMENDATIONS

General

Elevated Water Tanks are important structures as it need to remain functional even during major seismic event. In the present study, the non-linear response of Elevated water tank using SAP2000 under the empty and loading condition has been carried out with the intention to study the relative importance of several factors in the non-linear analysis of Elevated water tank under near field and far field earthquake.

Conclusion

After performing the time history analysis on elevated water tank under empty and full tank condition subjected to near field and far field earthquake, the main observations and conclusions drawn are summarized below:

1. From Fig 6.5, It is clear that Base shear in full condition tank is higher than empty tank due to presence of water or hydro static pressure which creates the additional seismic weight.
2. Bending moment in full condition tank is higher than empty tank due to presence of water or hydro static pressure which creates additional moments at the base of the tank that is shown by Fig 6.6.
3. Maximum nodal displacement found at the top of water tank when tank is full condition due the presence of hydrostatic pressure on the cylindrical wall of the tank which has been observed from Fig 6.7.
4. The peak displacements from the time history analysis under Northridge earthquake records are below the maximum permissible displacement for empty and full water tank condition.
5. The peak displacements were compared with the permissible displacement as per IS 1893 :2002. As per this the permissible displacement 0.004 times the storey height.

SCOPE FOR FUTURE WORK

Further analytical study, should address the following research needs:

1. For the present study, the analyses were performed for the shaft type Elevated water tank under near and far field earthquake. This study can be extended to frame type elevated water tank by considering the different geometries such as rectangular and Intze type tank subjected to the chemical effect such as alkalinity, acidity and pH.
2. Further investigations can be carried out to reduce the responses of elevated water tank by using base isolation technique.
3. In this study time history analysis is done by taking ground acceleration record from the data given by PEER. Further investigation should be done by different ground acceleration data and for different zones.
4. Wind pressure should also be taken in consideration as the height of tank increases.
5. In cold regions, Effect of snow load can also be taken into account.

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