Seismic Performance Of R.C Water Tank Tower By Using Finite Element Analysis

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Abstract- *Elevated water tanks as one of the main lifeline elements are the structures of high importance. Since they are extremely vulnerable under lateral forces, their serviceability performance during and after strong earthquakes is a matter of concern. As such, in recent years, the seismic behavior of water tanks has been the focus of a significant amount of studies. This project evaluates the seismic response of elevated conical shaped Reinforced Concrete water storage tank, which was designed under the Indian Standard codes for R.C water tank. A combined fluid-structure finite element model was developed using SAP 2000 software. The Lacco-North earthquake time history record was used to develop response spectrum as input for design level ground motion. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and joint forces in structural systems. The method involves the calculation of only the maximum values of the displacements joint forces and joint acceleration in each mode using smooth design spectra that is the earthquake motion of Lacco-North. Seismic demand of the elevated water tank around Chennai region for a wide range of structural characteristics was assessed. The results clearly reflect the benefit of different retrofit techniques are required to mitigate the anticipated seismic risk.*

I. GENERAL

Water storage tanks are important components to the continued operation community water distribution systems in the event of earthquakes. Current knowledge about the performance and seismic response of liquid storage tanks is extensive, but many of the analytical and theoretical results used in current design code approaches are based on a number of simplifying conditions, including small deformation and linear elastic material assumptions.

Earthquake was proven to cause worst phenomenon that can happen in human life with a lot of damages. Earthquake happened when two tectonic plates moved or slipped from its placed and produced energy that transferred to the earth's surface. The energy is transformed into a seismic wave or vibration of the ground motion. The ground acceleration from the wave are recorded and keep as time history analysis data.

In this project the water tank is located the around Chennai region. Based on the map of seismic zone of India, Chennai is located outside the earthquake active zone. However, there is still a small percentage effect on earthquake vibration that could reach Chennai because recently the Tsunami occurred in 2004 proves that Chennai is vulnerable to earthquakes.

Therefore according to the above situation, India shall not be considered as one of the country which is totally safe from earthquake. Structures designed in Indian region must include the seismic effect which will increase the safety factor of the structure. This project is done to illustrate the analysis of an R.C water tank tower designed in Chennai. It is known that the structure built in Chennai do have some considerable seismic effect. The conventional structure design does not include the seismic loading. Therefore, this study is conducted to observe the effect and the performance of a water tower structure which it is subjected to the earthquake loading.

A. Objective of Study

The objectives of this study are:

(a) To study the dynamic characteristic of the structure.
(b) To determine the behavior of water tank tower structure when earthquake occurs.
(c) To compare performance of structure under seismic loading with the design capacity of the water tank tower.
(d) To compare the performance of structure using SAP2000 software with the theoretical calculation.

B. Scope of Study

The scope of study is limited to only one type of water tank tower structure. The tower is analyzed using SAP2000 to see the behavior of the structure so that it can be designed with less structural damages caused by earthquake vibration. The results from SAP2000 will be compared with the theoretical calculation method to solve the problem. The water tower`s located at Chennai is taken as a model for this study and the earthquake data for analysis purpose is taken from Elcentro and Lacco-North 00 KL's data simulation for seismic hazard assessment for India Region.

II. METHODOLOGY

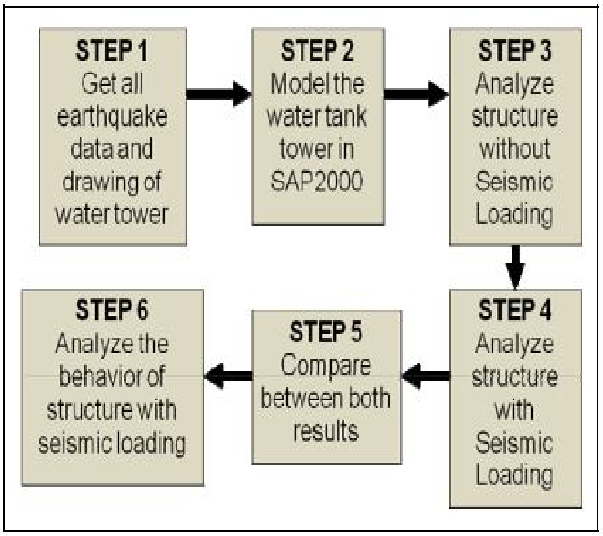


Fig.1Flow Layout of seismic analysis of water tank tower structure

III. SIMULATION MODELS FOR INELASTICANALYSIS

The basic three activities which are to be carried for analyzing the structure are a) Model generation b) The calculations to obtain the analytical results c) Results verification. These are all facilitated by tool contained in the program's graphical environment. The water tank tower is modeled using the data given in the table 3.1 and 3.2. The supports were assigned in the footing level as fixed supports. Water tank tower is one of the simple structures because it can be idealized as a concentrated or lumped mass, m supported by the massless structure with the stiffness, k in the lateral direction. So that in earth quake analysis the water tank as modeled to SDOF system.

NO	PROPERTIES	UNIT	VALUE
1	Volume of structure	m^3	744.189
2	Volume of water	m^3	454
3	Weight total Volume	Kg	2240957
4	Mass per Volume	kg/m^3	228438
5	Moment of Inertia	m^4	456.08
6	Stiffness, k	kN/m	17.103×10^6

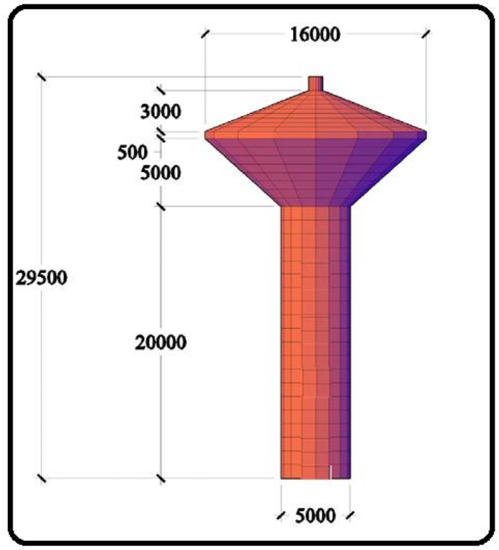


Fig.2 The SAP model of the water tank

As mentioned earlier, this software analysis is divided into two cases according to the analysis method on the water tower structure. The result analysis from software divided into two cases according to the loading excitation on the water tower structure. Case 1 is the free vibration analysis which is consist only gravitational load from self-weight (dead load) and additional of water pressure (load from water). Analysis in case 2 result includes the external excitation which is load from earthquake. Both cases are analyzed using linear analysis and structure is undamped which means no damped component to stiffen the structure from earthquake.

For this study purposes, data of Lacco-north 00 is used for time history analysis and response spectrum analysis which is taken from IS 1893-2002.Using software analysis, result for deflection, rotation, moment and shear produce in 3-dimensional results which are in direction of x-axis and z-axis. Table 2 shows the loading involved in each analysis cases.

Table 2 Analysis cases according to the loading excitation

CASE	ANALYSIS	LOADING	DESCRIPTION
1	Free Vibration	Selfweight of structure including the water pressure load.	Dead Load + Water Pressure
2	Harmonic Vibration	Selfweigth, water pressure include the earthquake loading.	Dead Load + Water Pressure + EQ Load (Time History and Response Spectrum)

A. Free Vibration Analysis

This case, structures were analyzed without any external dynamic excitation (earthquake loading) or free vibrationanalysis. This analysis allowed seeing the behavior of the structure in frequencies without any external loading.The structure only cater loading.The structure only cater loading from selfweight and water pressure due to gravity.Gravity load evaluated as acceleration which is 9.81m/s2 and 1.0 factored from dead load of the structure. The result from gravitational cause the p-delta effect and deformed of structure as shown below.

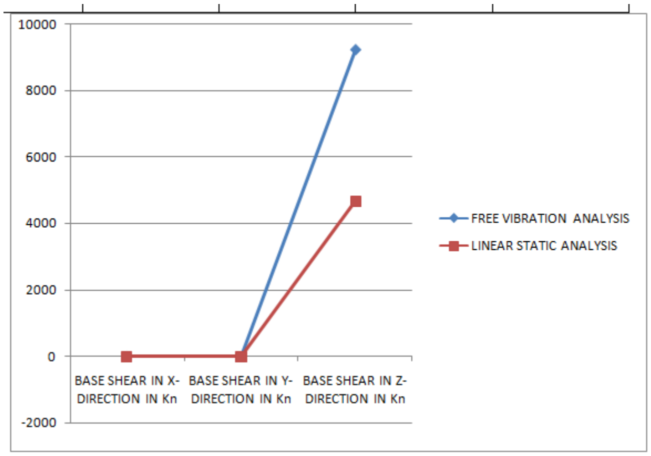


Fig.3 Base Reaction Comparison between Linear static to Free Vibration Analysis

B. Time Histroy and Response Pectrum Analysis

For this study analysis, external excitations were added to water tower structure model which is time history and response spectrum of Lacco North 00 data. The time history intensities for Lacco North 00 data is 0.19g where `g` value is 9.81 m/s2 as gravity acceleration and response spectrum analysis give maximum response of water tank tower. Figure 4.7 below show the graph of Lacco North 00 ground acceleration versus time and Figure 4.8 shows the response spectrum graph of IS 1893-2002.

To compare and see the different in the result, four load cases were divided; Load Case 1: Dead Load, Load Case 2: Combine dead load and water pressure, Load Case 3: Combine dead load, water pressure and Time History Analysis, and Load Case 4: Combine dead load, water pressure and Response Spectrum Analysis. Displace contour for Response spectrum & Time history as below

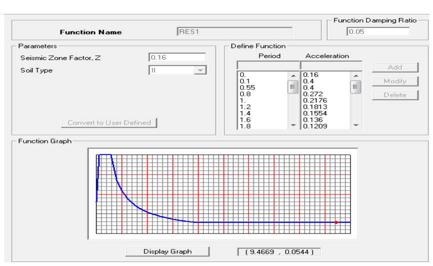


Fig. 4 Response spectrum Graph (IS 1893-2002)

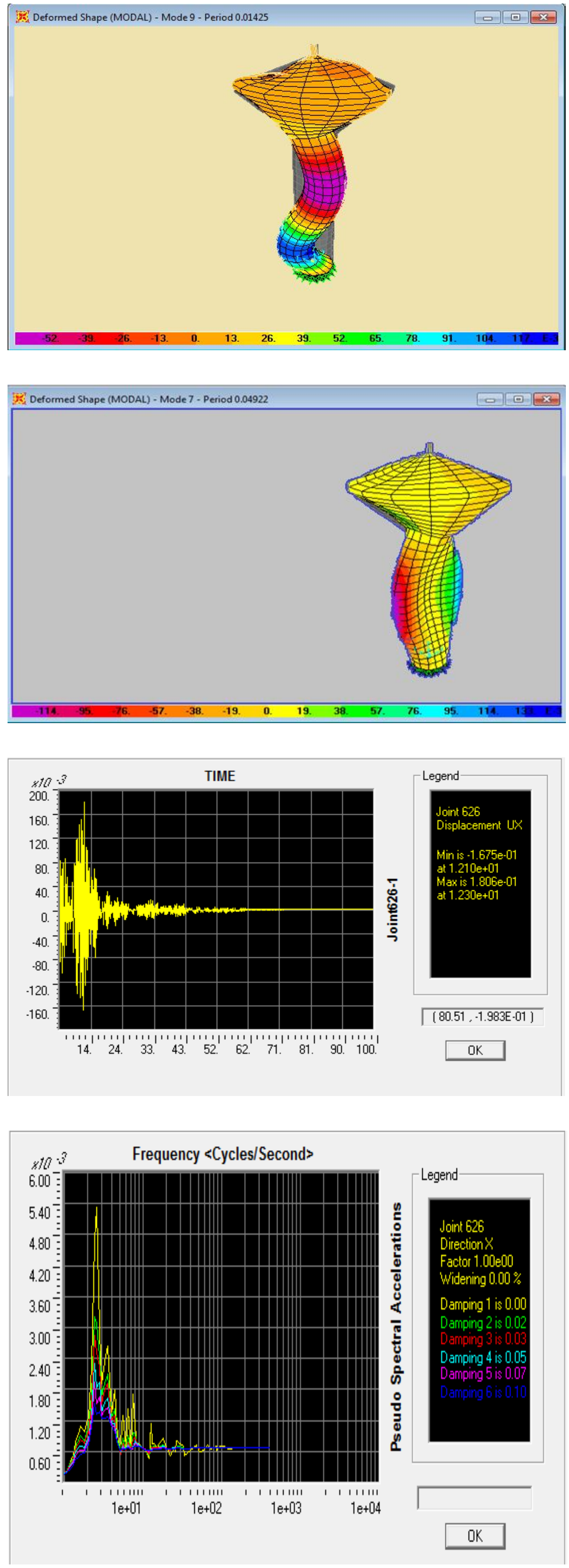


Fig. 5 Analysis Reports and Time History from SAP2000

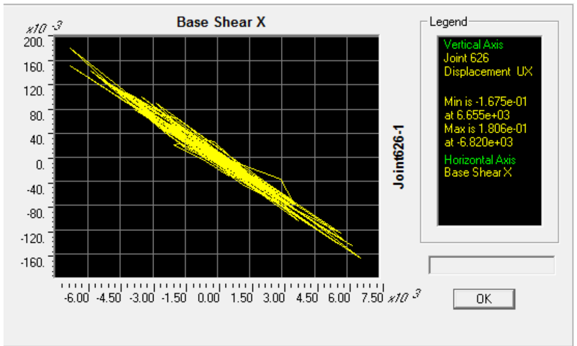
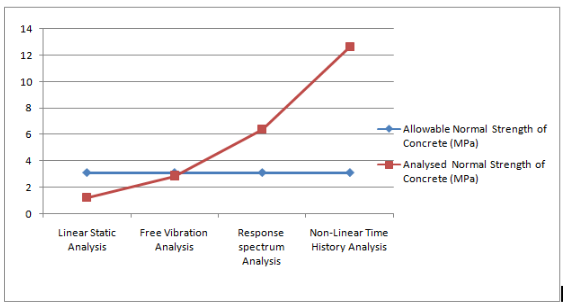


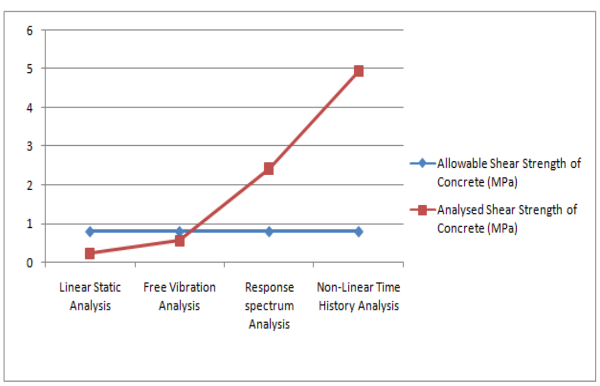
Fig.6 Base Shear Vs Displacement Response Plot for 626th Joint

V. RESULT AND DISCUSSION

A. Maximum Normal Strength From Time History Analysis And Response Spectrum Analysis



B. Maximum Shear Strength From Time History Analysis And Response Spectrum Analysis



V. CONCLUTION

From the result we can conclude that normal stress increase when additional loading occurs on structure. Compared to the capacity of material, the structure should be used higher strength of concrete. Although increasing, earthquake of intensity 0.19g did not give any big different in-terms of stresses.

The results for deformations show that the deflection is different between theoretical calculation and software analysis. This is because the assumption of parameter to get the result is different where using software more detailed compare to calculation which is simpler. From the results of different data show that the stresses are increasing when the value of maximum ground acceleration are increasing. Although the increase is uniformly in straight line, we can conclude that the strength of concrete will achieve its maximum capacity and the structure will be failed. In this study,structure considered failed in normal stress when the time history data reach at 0.70g. However in shear stress still adequate compare to the capacity of concrete strength.

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