Dynamic Response of Ground Supported Rectangular Water Tank

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***Abstract*— Large-capacity ground-supported tanks (LCS) are used to store a variety of liquids, such as water for drinking and fire-fighting, petroleum, chemicals, liquid natural gas and nuclear fuel assemblies. The satisfactory seismic response of such structures is crucial since collapse usually results in heavy consequences (fire, spilling of liquid, etc.). The main objectives of my project are to find the effect of change in dimensions on the dynamic response of rectangular water tank, to find out the effect of water level in the tank on the dynamic response of rectangular water tank, to analyze the effect of variation in loading parameter on the dynamic response of rectangular water tank and the time history of a past earthquake is studied and the loading pattern is applied to the water tank and the corresponding dynamic response is now studied using ANSYS.**

***Keywords*— Liquid Containing Structures (LCS); dynamic response; time-history**

I. INTRODUCTION

Liquid containing structure is one of the critical lifeline structures. There are many types of such storage tanks depending on the construction material, structure, content, volume and storage condition. Liquid storage tanks can be constructed by steel or concrete. It should be noted that due to excessive damages reported on steel tanks, the concrete storage tanks have become profoundly popular.

In recent earthquakes, on-the-ground concrete rectangular tanks have been seen to be vulnerable structural elements and they have suffered considerable destruction, because their seismic behaviour has not been appropriately predicted.

The dynamic behaviour of water tanks is governed by the interaction between the fluid and the structure. Under strong ground motion, concrete tank walls may deform significantly and produce loads which are different from those of a geometrically identical rigid tank. The dynamic response of the water tank mostly depends on the type of excitation, peak acceleration, effective duration of the earthquake and its frequency content. Other factors such as water level and tank plan dimensions also play important roles in the dynamic response of the rectangular tanks.

The seismic response of the rectangular water tanks has been the subject of many studies in the past several years. However, only few studies used the finite element method to predict this behaviour. In this study, finite element method will be used to predict the response of the seismically excited rectangular tanks. The finite element program, ANSYS (ANSYS R 14.5), is used for the dynamic modal and time history analysis.

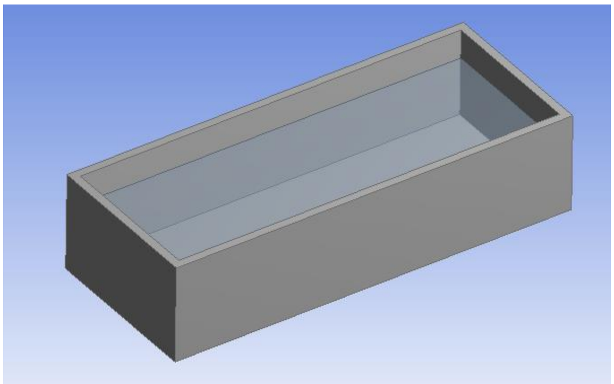

Fig. 1: Rectangular water tank in ANSYS

II. OBJECTIVES OF PRESENT STUDY

1) Time history analysis of water tank subjected to seismic load
2) Effect of change in dimension of water tank on the dynamic response
3) Effect of water height with particular tank size on dynamic response

A. *Example water tank*

The rectangular concrete water tank shown in Figure 1 is the subject of the study. The cross section parallel to the long side wall is adopted for X direction, along with the cross section parallel to the short side as Y direction. Twenty seven tank configurations are modelled in ANSYS (version 14.5) program. Different tank configurations and their symbols are presented in Table 1. As follows, in this thesis, Hw and tw represent the height and thickness of the tank wall, respectively. Lx and Ly represent inside dimension of the tank wall for longer and shorter side wall, respectively. HL is the water depth and 1m free board is provided.

TABLE 1: DETAILS OF TANK CONFIGURATIONS

`Group	Quarterly filled (H_L = 4 m)	Partially filled (H_L = 6 m)	Fully filled (H_L = 8 m)
	Lx Ly	Lx Ly	Lx Ly
1	QX50Y20 50 20 QX50Y30 50 30 QX50Y40 50 40	PX50Y20 50 20 PX50Y30 50 30 PX50Y40 50 40	FX50Y20 50 20 FX50Y30 50 30 FX50Y40 50 40
2	QX70Y20 70 20 QX70Y30 70 30 QX70Y40 70 40	PX70Y20 70 20 PX70Y30 70 30 PX70Y40 70 40	FX70Y20 70 20 FX70Y30 70 30 FX70Y40 70 40
3	QX90Y20 90 20 QX90Y30 90 30 QX90Y40 90 40	PX90Y20 90 20 PX90Y30 90 30 PX90Y40 90 40	FX90Y20 90 20 FX90Y30 90 30 FX90Y40 90 40

Modelling and analysis was performed in ANSYS 14.5 workbench. According to the engineering data we provide as input, ANSYS itself assumes the element type. To model water, Water Liquid was chosen from the default library and concrete properties were manually provided to model the tank.

The contact between water and the tank was given No Separation for modal analysis and Frictionless for time-history analysis. Meshing was done as auto-mesh by the workbench itself. Fine-meshing was adopted. Natural frequency of the tank was obtained from modal analysis. Later on, the time-history of Kobe (1995) earthquake was defined in transient analysis to obtain the dynamic response of the tank subjected to a real earthquake.

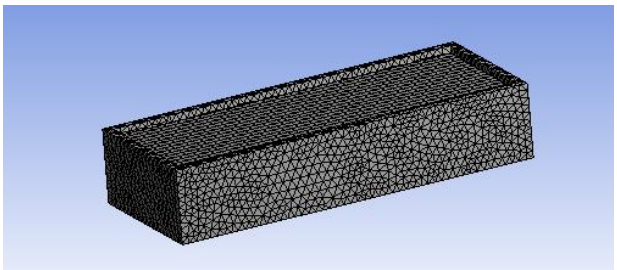

Fig. 2: Meshing of the tank and water

III. RESULTS AND DISCUSSIONS

The present study is to compare the dynamic response of water tank when water in it is of different levels, to compare the dynamic response with change in length to width ratio and to find out the response to a past earthquake.

TABLE 2: NATURAL FREQUENCY OF FX50Y20

MODE	NATURAL FREQUENCY (Hz)
1	11.283
2	16.763
3	23.708

TABLE 3: NATURAL FREQUENCY OF PX50Y20

MODE	NATURAL FREQUENCY (Hz)
1	12.238
2	17.324
3	21.954

TABLE 4: NATURAL FREQUENCY OF QX50Y20

MODE	NATURAL FREQUENCY (Hz)
1	11.292
2	13.185
3	15.515

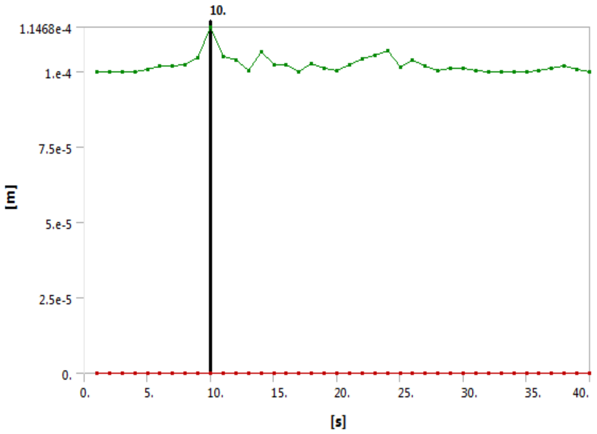

Fig. 3: Time-history response of FX50Y20

Comparison of the deformation of different configurations is given below:

A. Change in response with change in water level

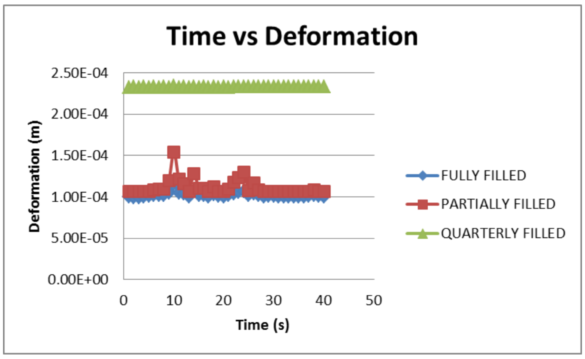

Fig. 4: 50×20

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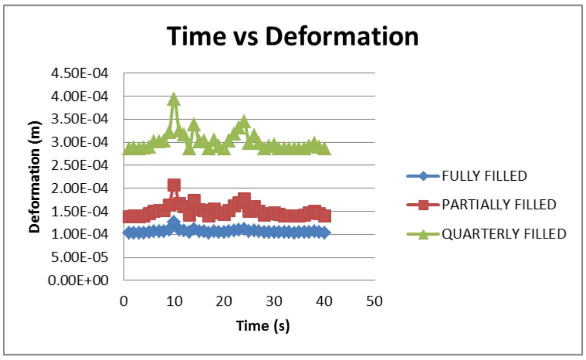

Fig. 5: 50×30

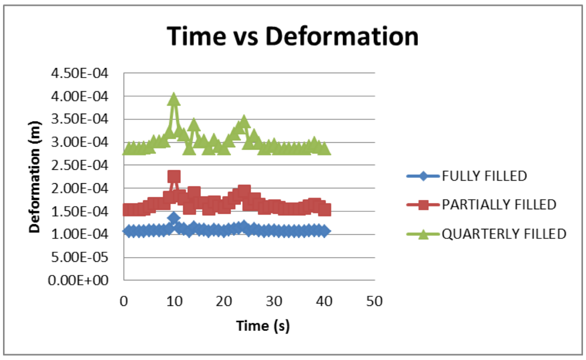

Fig. 6: 50×40

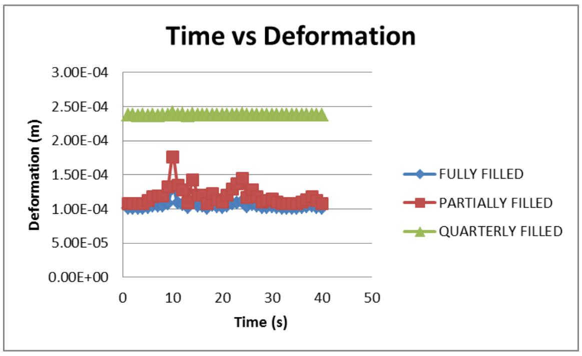

Fig. 7: 70×20

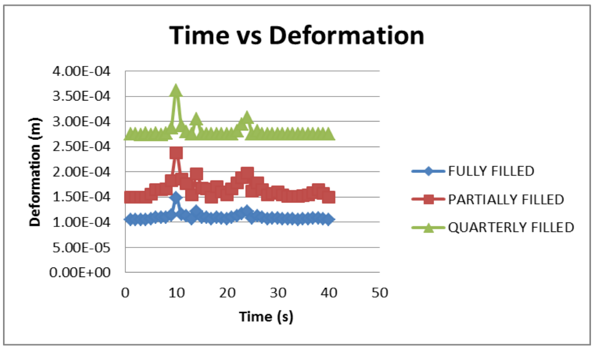

Fig. 8: 70×30

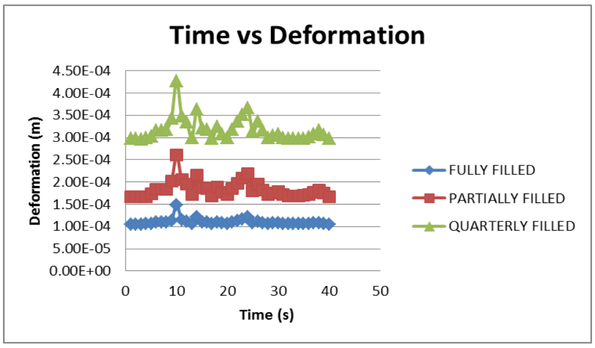

Fig. 9: 70×40

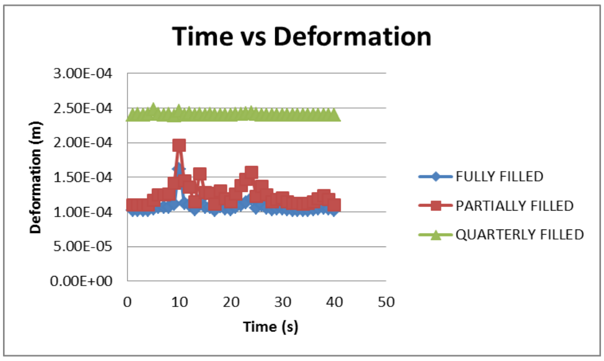

Fig. 10: 90×20

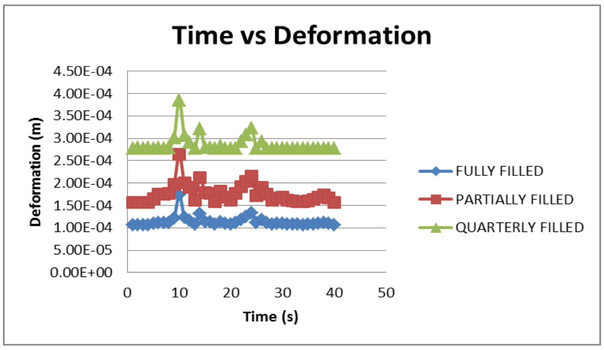

Fig. 11: 90×30

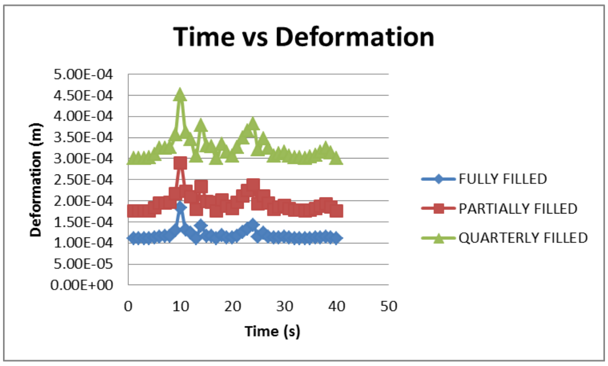

Fig. 12: 90×40

B. Change in response with change in l/w ratio

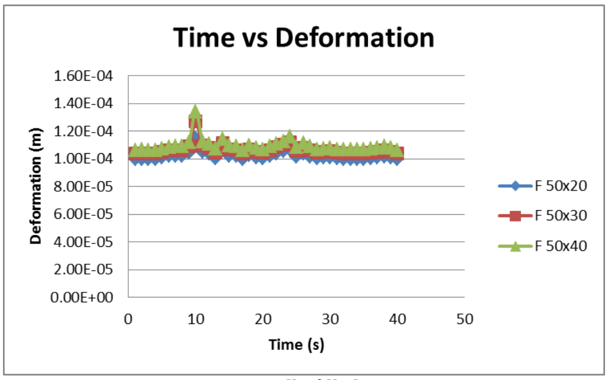

Fig. 13: Fully filled- 50×y

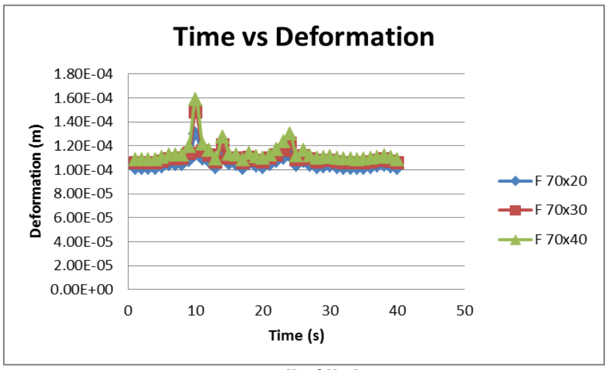

Fig. 14: Fully filled- 70×y

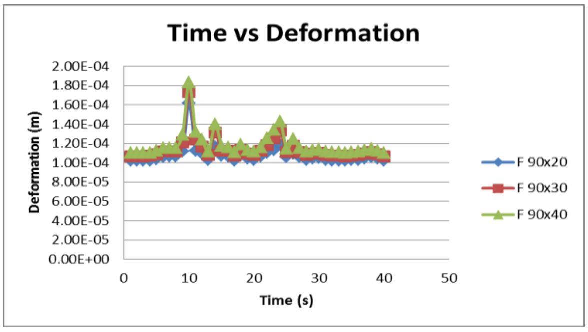

Fig. 15: Fully filled- 90×y

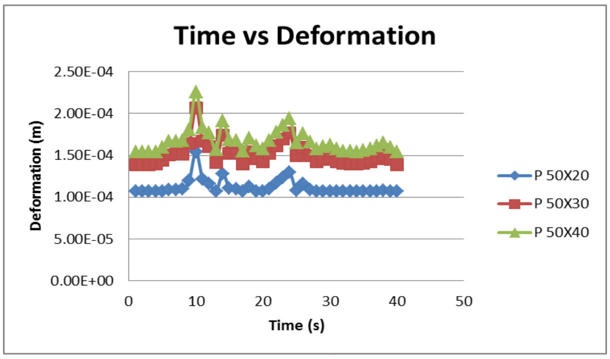

Fig. 16: Partially filled- 50×y

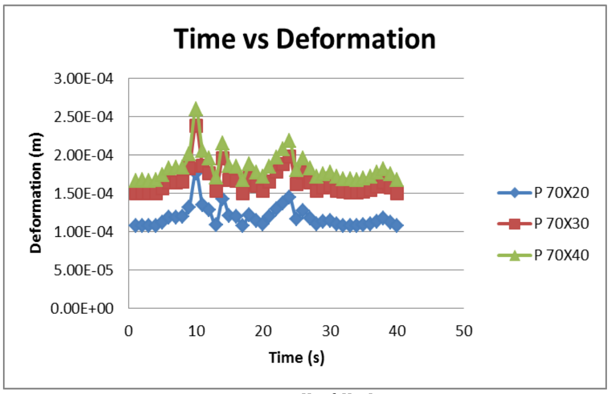

Fig. 17: Partially filled- 70×y

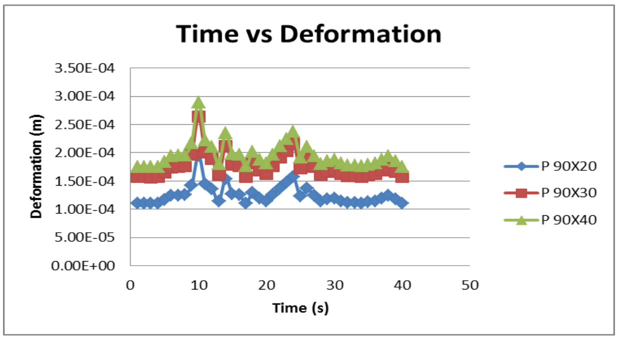

Fig. 18: Partially filled- 90×y

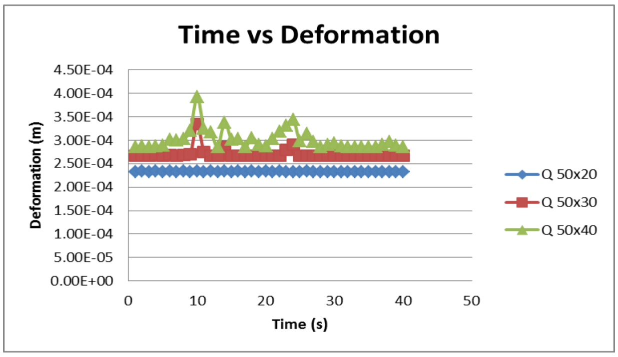

Fig. 19: Quarterly filled- 50×y

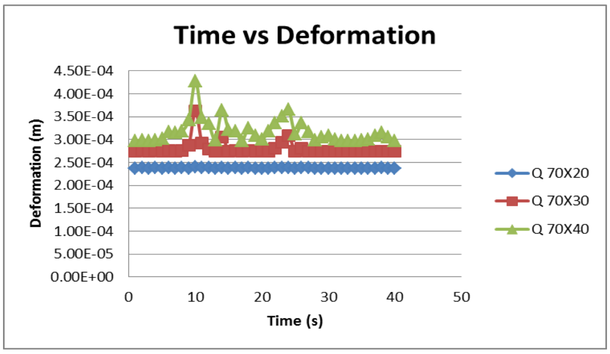

Fig. 20: Quarterly filled- 70×y

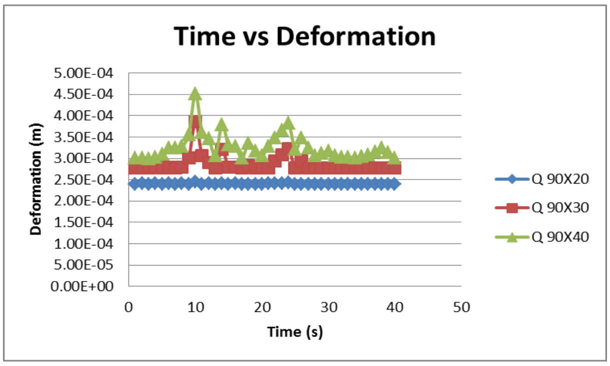

Fig. 21: Quarterly filled- 90×y

IV. CONCLUSIONS

In this study an effort was taken to compare dynamic response of ground supported comcrete rectangular water tank with different water levels and different configurations(length-to-width ratio). Following are the conclusions obtained from the graphs by comparing the deformations occurred:

1. The deformation values are increased from fully filled to quarterly filled condition of the tank.
2. As length-to-width ratio of the tank decreases the resulting deformation increases.
3. The time-history analysis shows that the water tank exhibits a satisfactory behaviour with the time-history pattern of Kobe(1995) earthquake.

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