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A Non- Linear Dynamic Behaviour of Circular Elevated Water Tank for different levels of water under El-Centro Earthquake Excitation

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Abstract*— The Braced Elevated Water tanks which currently practicing in India are catastrophic if they were subjected to severe horizontal thrust like Earthquake. Water tanks are very important for storing and distribute water to the farther end of the user in the distribution system. Especially elevated water tanks have specific significance in storing and supplying water for maintaining suitable pressure for the reach of public houses and also for the industrial uses. Demand of water is day by day increasing because of increase in the population. The need of revision of water tanks with more precautions in design after proper analysis with extreme loads has to be made for the survival of human community.

In this paper, an Octagonal braced elevated water tank with 400 m^3 has been designed and analysed with Time History Data of El-Centro Earthquake with peak ground acceleration of 3.417 m/s^2 and lasts for 53.76 sec for finding the response of the structure such as base shear, tank displacement, Max Bending Moment at the base of column under tank for Empty, Full and Half Full condition have been calculated and then results have been compared. For this study, Staad pro v8i software is used for design and analysis of water tank and compared results for all conditions of the tank.

***Keywords*— El-Centro Earthquake, Tank Half full condition, Joint Base Shear, Support Reaction, Staad Pro**

I. INTRODUCTION

Elevated water tanks are censorious and prudent structures; damage of these structures are very vulnerable when they are subjected to natural calamity viz., earthquake. Elevated Water tanks are constructed for storing large amount of water from the treatment plant, for the community. The population in India, increasing decade by decade. The need of increase in storage of water, to attain present & future water needs of the human community has to be made. Because of the earthquake when water tanks are affected, disturbance in supplying safe drinking water, unable to putout large fire catches and also several industries which rely on public water reservoirs may cause major economic loss. To prevent catastrophic failure of water, more precautions in design after proper analysis with extreme loads has to be made for the survival of human community. Whatever may be the cause of distress but water tanks should fulfill the purpose for which it has been designed and constructed with minimum maintenance throughout its intended life. Durgesh C Rai [1] investigated that the current design of the circular shaft type staging was very poor and the tanks designed using those parameters were extremely vulnerable under lateral loads. He also studied the tanks which were damaged in 2001 Bhuj earthquake and that was taken as a benchmark in his study. Haroun and Ellaithy developed a model including an analysis of a variety of elevated rigid tanks undergoing translation and rotation. The model considers fluid sloshing modes and it assesses the effect of tank wall flexibility on the earthquake response of the elevated tanks [2]. Haroun and Temraz analyzed models of two-dimensional X-braced elevated tanks supported on the isolated footings to investigate the effects of dynamic interaction between the tower and the supporting soil-foundation system but they also neglected the sloshing effects [3]. Marashi and Shakib carried out an ambient vibration test for the evaluation of the dynamic characteristics of elevated tanks [4]. Livaoglu and Dogangun proposed a simple analytical procedure for seismic analysis of fluid-elevated tank-foundation-soil systems, and they used this approximation in selected tanks [5]. Livaoglu conducted a comparative study of seismic behavior of the elevated tanks considering both fluid-structure and soil-structure interaction effects on elevated tanks. Resheidat and Sunna investigated the behavior of a rectangular elevated tank considering the soil-foundation structure interaction during earthquakes. They neglected the sloshing effects on the seismic behavior of the elevated tanks and the radiation damping effect of soil [6].

II. DESCRIPTION OF THE ELEVATED TANK

The salient features of Frame type staging elevated water tank are:

TABLE I
FEATURES OF FRAME TYPE STAGING ELEVATED WATER TANK

Capacity of tank - 400cum	Height of staging - 16m
Grade of Concrete - M25	Grade of Steel - Fe415
Depth of Water - 4.25m	Free Board - 0.25m
Diameter of Tank - 10m	Radius of Tank - 5m
Diameter of top ring beam - 10m	Diameter of bottom ring beam - 10m
Rise of top dome - 1.5m	Rise of bottom dome - 1m
Radius of top dome - 9.083m	Radius of bottom dome - 6.625m
Thickness of top dome - 0.1m	Thickness of bottom dome - 0.25m
Thickness of conical dome - 0.35m (tapering section)	Thickness of cylindrical wall - 0.25 to 0.185m
	Height of conical dome - 1.5m (B/w tank wall and conical dome)
Size of ring beam - 0.80 x 0.45	
Size of top ring beam - 0.32 x 0.2m	Size of bottom ring beam - 0.8 x 0.5m
Number of columns - 8 Nos.	Diameter of column - 0.5m
Size of bracings - 0.30 x 0.50m	Length of each bracing - 2.75m
Number of stages - 4 stages	

III. MODELLING

The modelling of the structure is done by using Staad Pro version V8i.The following considerations are made for proper design the structure.

i. User defined material data like span, load and grade of concrete and steel are to be given as input
ii. Effective span is calculated by adding the effective depth to the span
iii. Load conditions has been taken as per IS- 875 Part-1 & Part-5 recommendations, for the calculation of Dead load and Hydrostatic Load.
iv. Maximum stresses and deflections have been calculated
v. With the maximum bending moment the area of steel is has been calculated

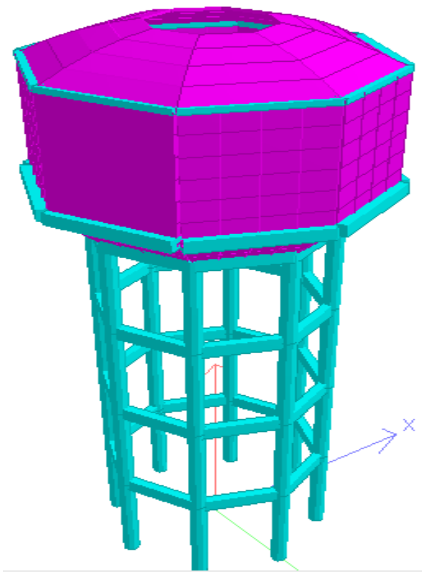

Fig. 1 3D Rendered view of Elevated water tank

IV. PROBLEM ANALYSIS

The 400m^3 capacity Water Tank was initially designed using design software i.e., STAAD Pro., for all combinations of loads according to latest IS-456 and IS-875 code provisions. Later the structure was analysed by the Staad Pro. The Braced water tank was subjected to its static loads such as self-weight, Full Water, Half full water and Empty condition, in addition to this El-Centro earthquake spectra with Peak Ground X-Acceleration, PGA =3.417 m/s^2 occurred for 53.76 sec has been considered. Time effects are continuous since the start of loading till the end of analysis.

V. RESULTS & DISCUSSIONS

The following results are the maximum values after giving Time History Data of EL-CENTRO earthquake. The time of occurrence is 53.76 sec with a time step of 0.02 seconds. During this time period various deformations have been observed and the maximum values are noticed.

TABLE II
MAXIMUM VALUES OF THE DIFFERENT LEVEL OF WATER IN TANK

Tank	Joint displacement		Support reaction		Column	Beam	
	X-translation(mm)	Z-translation(mm)	Force-Y(KN)	Support reaction Moment-Z(KN-m)	Axial force(KN)	Shear-Y(KN)	Moment-Z(KN-m)
Empty	46.527	96.662	108.520	76.972	104.201	50.62	271.987
Half full	142.501	209.196	296.198	198.051	129.422	117.009	491.218
Full	98.286	364.477	228.821	124.002	209.147	91.062	378.144

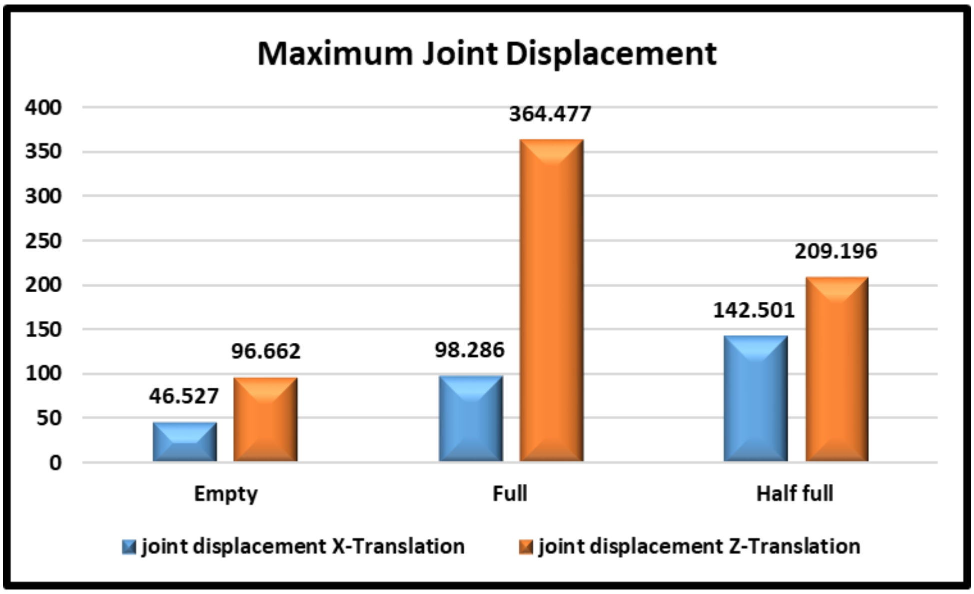

Fig. 2 Maximum Displacement for different levels of water

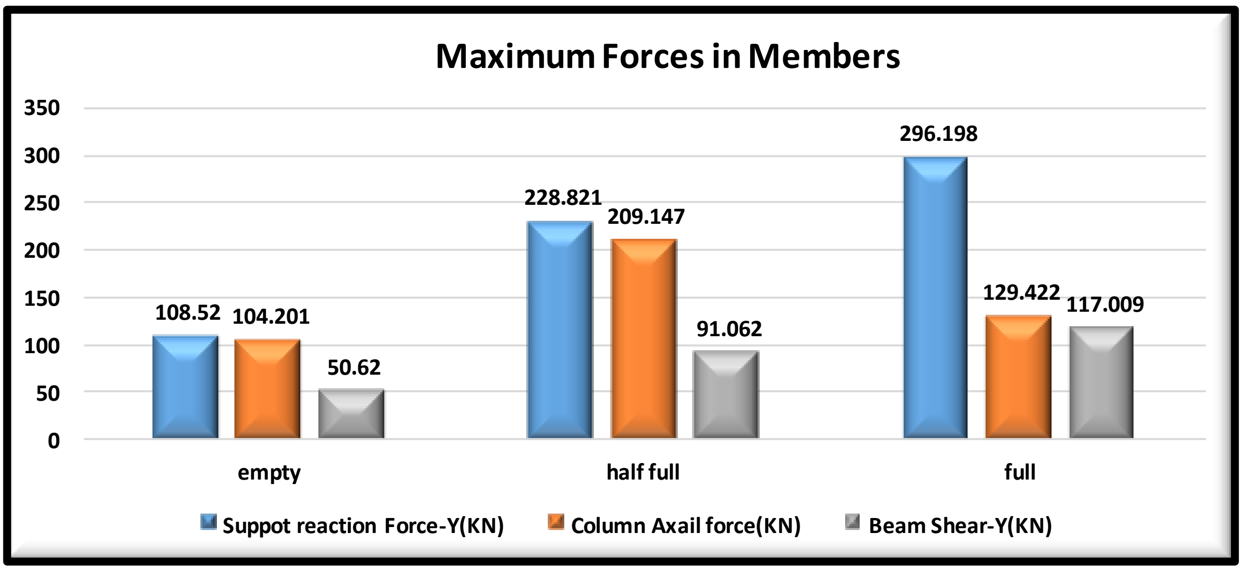

Fig. 3 Maximum forces for different levels of water in the tank

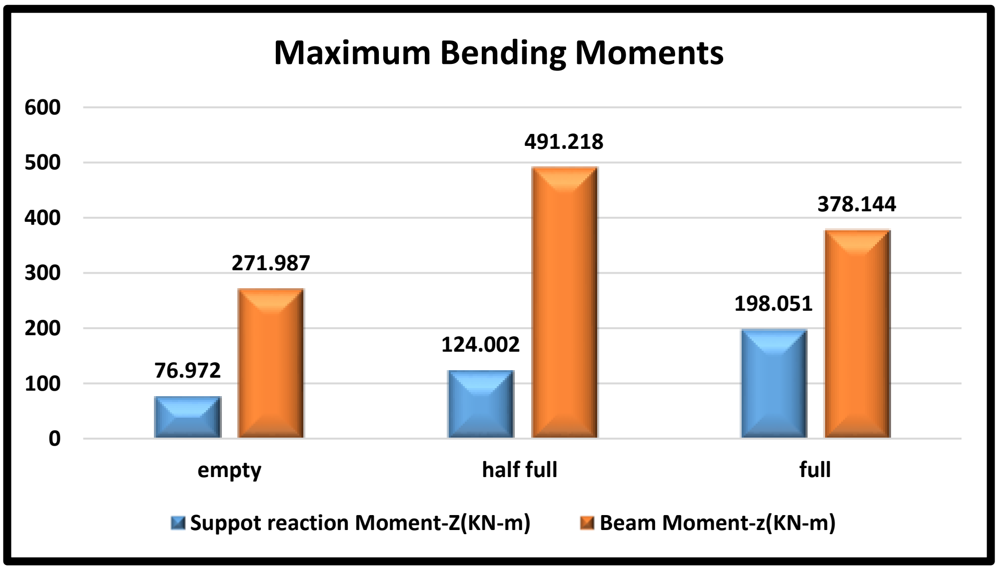

Fig.4 Maximum Bending Moments for different levels of water in the tank

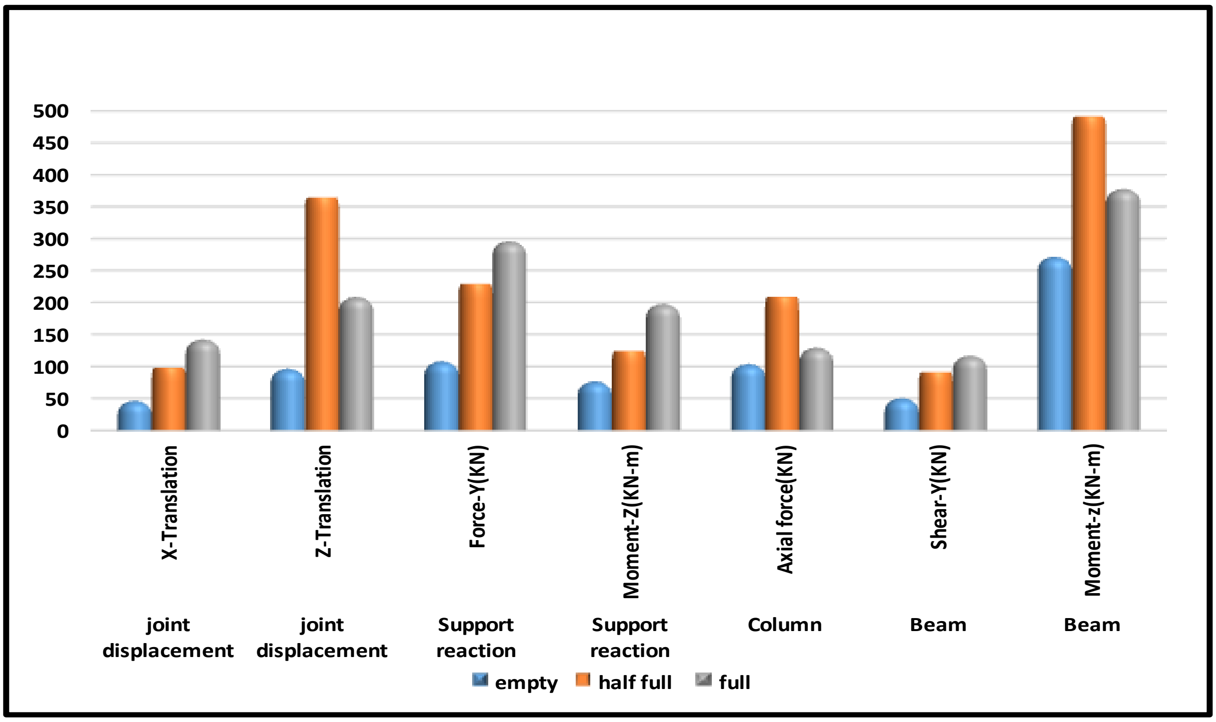

Fig.5 Maximum values of various parameters for different levels of water in the tank

The percentage of increment of following results as compared with failure of circular elevated water tank at half full condition.

TABLE III
COMPARISON OF CIRCULAR ELEVATED WATER TANK WITH VARIOUS LEVELS OF WATER

Tank	Joint displacement	Support reaction	Column		Beam		
	X- translation(%)	Z- translation(%)	Force-Y(%)	Support reaction Moment-Z(%)	Axial force(%)	Shear-Y(%)	Moment-Z(%)
Empty	32.60	46.20	36.63	38.86	80.5	43.26	55.36
Half full	100	100	100	100	100	100	100
Full	68.97	174.9	77.25	62.61	161.6	77.80	76.98

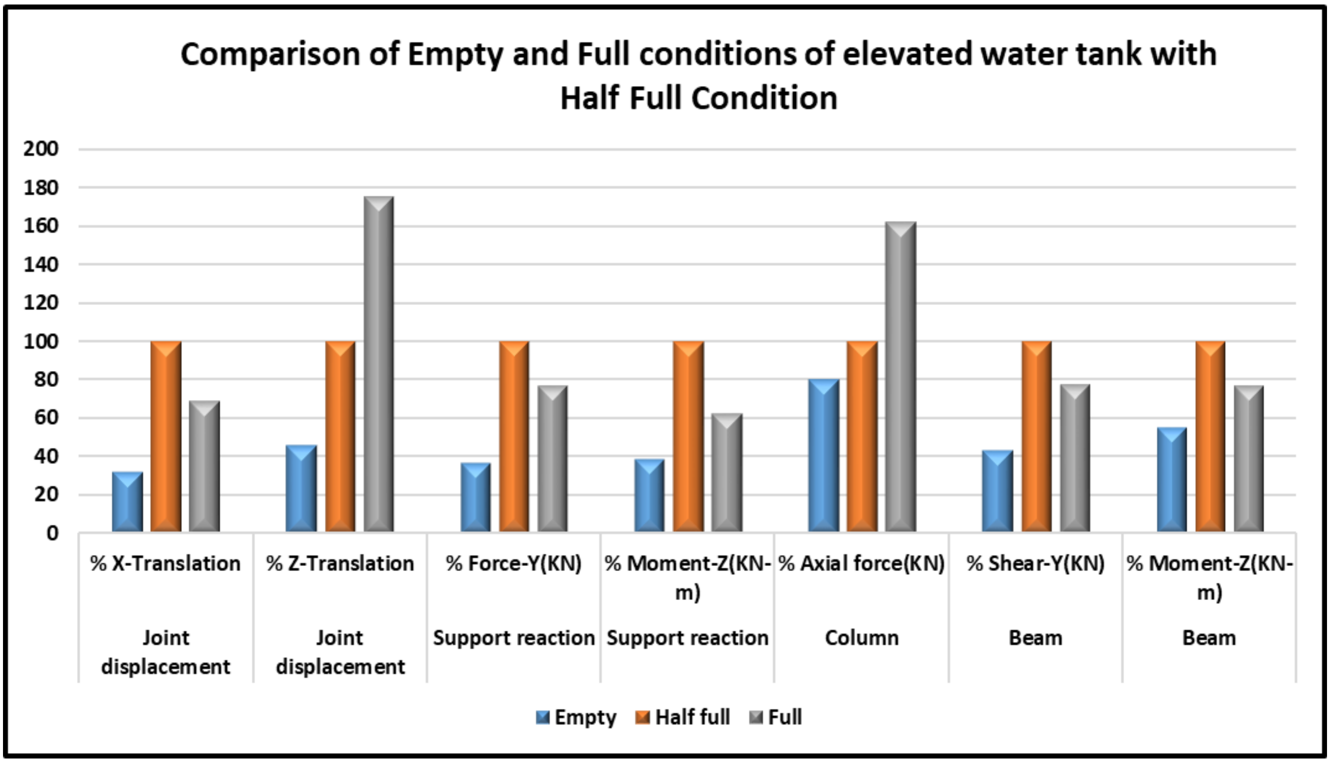

Fig.6 Comparison of Empty and Full conditions of elevated water tank with Half Full Condition

VI. CONCLUSIONS

1. From the results, it was observed that X- Displacement in comparison with Z- Displacement is less, though the application of Seismic load in X- direction, i.e., tension cracks may observe on Z-faces of the tank
2. In Full tank condition, axial failure of the beam is more predominant compared with other two cases (i.e., Tank Empty and half full conditions)
3. %Shear in Y-direction for Half full condition is more in comparison with Empty & Full tank conditions i.e., joint failure may occur at the juncture of column & beam.
4. Failure in Z-translation and axial failure is more when water is full compared to other two levels
5. Elevated water tank with empty condition is the ideal condition.

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