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Time History analysis of elevated water tank with different type of bracing system using SAP2000

Meet J. Bhojani[1], Prof. V. V. Agrawal[2], Prof. V. B. Patel[3]

[1]Final year student, M.E. STRUCTURE, BVM Engineering College., Vallabhvidyanagar.
[2]Asst. Professor, Structural Engineering Department, BVM Engineering College., Vallabhvidyanagar.
[3]Asst. Professor, Structural Engineering Department, BVM Engineering College., Vallabhvidyanagar.

Abstract - From the very offensive past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during the earthquakes all over the world. General observations are pointing out that the reasons towards the failure of supporting system which reveals that the supporting system of elevated tanks has more critical importance than the other structural types of tanks. Most of the damages observed during seismic events arise due to the causes like improper and unsuitable design of supporting system, mistakes during selection of supporting system, improper arrangement of supporting elements and underestimated demand or overestimated strength etc. Consequently, the aim of this study is to know the effectiveness of supporting systems of elevated tank with different alteration like different type of bracing system for intze tank. In this study time history analysis of tank doing with considering the dual mass system in sap2000 and compare the result of base shear, base moment and displacement and finally study discloses the importance of suitable supporting configuration to remain withstands against heavy damage or failure of the elevated water tanks during seismic events.

KEYWORDS: Elevated water tank; Intze tank; bracing system; Time history; SAP000.

I. INTRODUCTION

Water is the elixir of life; hence water storage structure is obvious very important. The elevated water tank is the most common requirement for all types of user such as residential, commercial, industrial etc. Supply of drinking water is an essential after destructive earthquake. Without required water supply, the uncontrolled fire due to earthquake may cause more damage than the earthquake themselves. Hence the water supply system should be design as seismic performance of water tank draws special significance in the design. Generally, to store the water different type of tank are used like ground supported tank, underground tank, elevated tank. Elevated water tank is constructed at sufficient height to cover large area for supply of water.

Elevated water tanks consist of huge water mass at top of a slender staging column which are most critical consideration for the failure of tank during earthquakes. In the past earthquakes including Bhuj earthquake of 26 Jan 2001, damages had been observed widely in support structures. It is due to the lack of Knowledge of supporting system, so there is need to focus on seismic safety of lifeline structure using modification with respect to supporting system which are safe during earthquake and also take more design forces.

Figure 1. Collapsed 265 KL water tank in Chobari village about 20km from the epicenter. The tank was approximately half full during the earthquake. (Source: - paper presented by Durgesh C. Rai)

The present study is an effort to identify the seismic behavior of elevated water tank under Time History Method with consideration and modelling of impulsive and convective water masses inside the container for different types of bracing using structural software SAP2000.

II. MODEL PROVISIONS

A satisfactory spring mass analogue to characterize basic dynamics for two mass model of elevated tank was proposed by Housner (1963) after the chileane earthquake of 1960, which is more appropriate and is being commonly used in most of the international codes including GSDMA guideline. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall, termed as impulsive liquid mass. Liquid mass in the upper region of tank undergoes sloshing motion, termed as convective liquid mass. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis, two-mass model is adopted for elevated tanks.

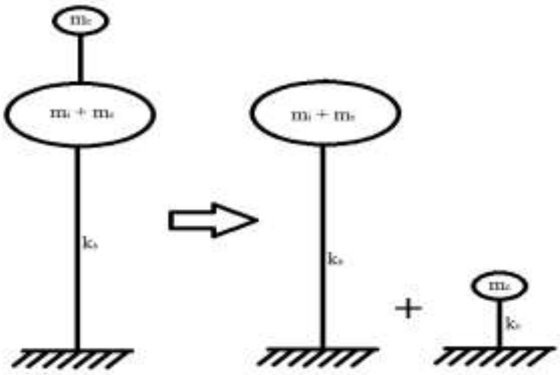

Figure 2. Dual mass system of elevated tank (GSDMA guideline)

In spring mass model convective mass (m_c) is attached to the tank wall by the spring having stiffness (K_c), whereas impulsive mass (m_i) is rigidly attached to tank wall. For elevated tanks two-mass model is considered, which consists of two degrees of freedom system. Spring mass model can also be applied on elevated tanks, but two-mass model idealization is closer to reality. The two- mass model is shown in Fig. (2). where, m_i, m_c, K_c, h_i, h_c, h_s etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility. The two-mass model was first proposed by G. M. Housner (1963) and is being commonly used in most of the international codes. The response of the two-degree of freedom system can be obtained by elementary structural dynamics.

However, for most of elevated tanks it is observed that both the time periods are well separated. Hence, the two-mass idealization can be treated as two uncoupled single degree of freedom system as shown in Fig. 2. The stiffness (K_s) is lateral stiffness of staging. The mass (m_s) is the structural mass and shall comprise of mass of tank container and one third mass of staging as staging will acts like a lateral spring. Mass of container comprises of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided. Staging part of elevated water tanks follows the provisions given by Criteria for design of RCC staging for overhead water tanks (First revision of IS 11682): Draft Code. This draft standard lays down criteria for analysis, design and construction of reinforced cement concrete staging of framed type with columns.

2.1. TYPES OF BRACING SYSTEM USED

Models are used for calculating base shear, base moment and nodal displacements for staging without bracing, with alternate cross bracing in staging, alternate diagonal bracing in staging, alternate K - bracing in staging, alternate V - bracing in staging.

III. STUDY PARAMETERS

A reinforced elevated water tank with different supporting systems including innovative staging of water tank considered for the present study. The study is carried out on an Intze shape water container of reinforced cement concrete. The storage capacity of water tank is 500 m^3. A finite element model (FEM) is used to model the elevated tank system using SAP 2000.The staging heights considered for study are 16 m with 4 m height of each panel. Grade of concrete and steel used are M20 and Fe415 respectively. The bracing used in this study are normal bracing, alternate diagonal bracing, X-bracing, inverted V-bracing and K-bracing. In this study time history analysis of empty tank and full tank was presented. The time history taken was Loma Prieta and Kobe earthquake The other relevant data used in the modeling is tabulated in table 1.

Table 1: Dimension of Elevated Water Tank Components

Description	Data
Capacity of the tank (m^3)	500
Unit weight of concrete (kN/m^3)	25
Thickness of top Dome (m)	0.100
Rise of Top Dome (m)	2.00
Size of Top Ring Beam (m)	0.300 x 0.300
Diameter of tank (m)	9.00
Height of Cylindrical wall (m)	7.00
Thickness of Cylindrical wall (m)	0.250
Size of bottom Ring Beam (m)	0.900 x 0.400
Rise of Conical dome (m)	1.5
Thickness of Conical shell (m)	0.500
Rise of Bottom dome (m)	1.2
Thickness of Bottom dome shell (m)	0.250
Size of Circular Ring Beam (m)	0.950 x 0.500
Number of Columns (circular)	8
Diameter of columns(m)	0.650
Size of bracings(m)	0.400 x 0.400
Staging Height(m)	16
Panel Height (m)	4

IV. RESULTS

- Result for base shear, base moment, and displacement of all model are given below.

FLUID LEVEL	BASE SHEAR(KN)

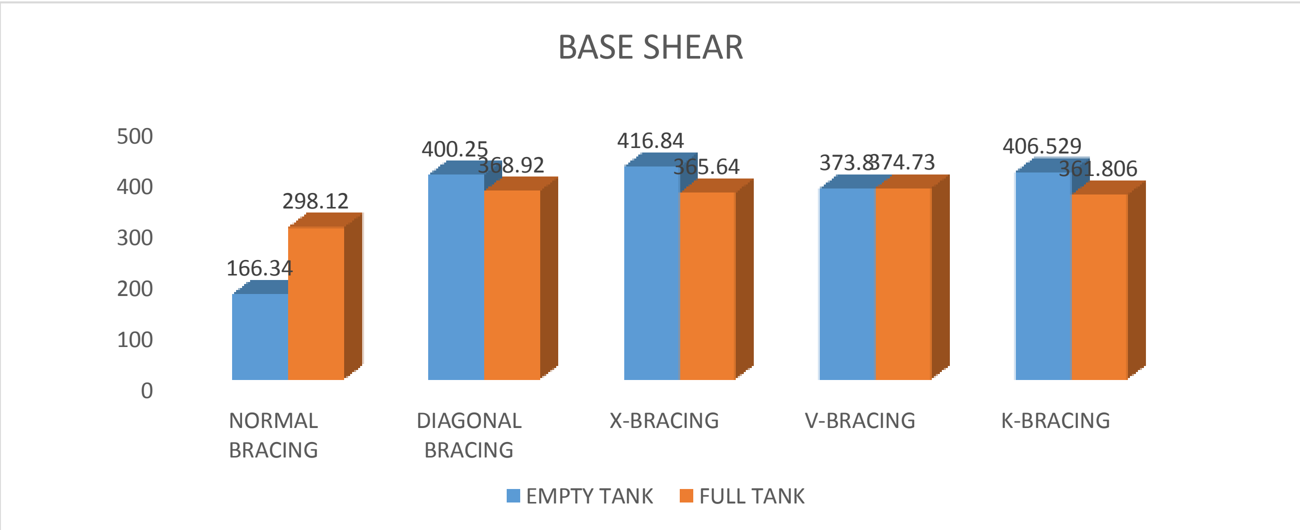

Table 2: Base shear of 16m. height Intze tank for Loma Prieta earthquake

FLUID LEVEL CONDITION	BRACING TYPE				
	NORMAL BRACING	DIAGONAL BRACING	X-BRACING	V-BRACING	K-BRACING
BASE SHEAR (KN) / BASE MOMENT (KN.m)					
EMPTY TANK	166.34	400.25	416.84	373.8	406.529
FULL TANK	298.12	368.92	365.64	374.73	361.806

	BRACING TYPE				
	NORMAL BRACING	DIAGONAL BRACING	X-BRACING	V-BRACING	K-BRACING
EMPTY TANK	6983.23	16160.89	16169.05	16457.08	16112.4035
FULL TANK	4585.17	12892.41	17198.21	13982.79	17108.1253

	NORMAL BRACING	DIAGONAL BRACING	X-BRACING	V-BRACING	K-BRACING
EMPTY TANK	362.3	829.6	857.94	868.58	852.405
FULL TANK	257.73	730.25	972.85	794.06	977.371

Figure 3. Base shear of 16m. height Intze tank for Loma Prieta earthquake.

Table 3: Base shear of 16m. height Intze tank for Kobe earthquake

Figure 4. Base shear of 16m. height Intze tank for Kobe earthquake

Table 4: Base moment of 16m. height Intze tank for Loma Prieta earthquake
Figure 5. Base moment of 16m. height Intze tank for Loma Prieta earthquake
Table 5: Base Moment of 16m. height Intze tank for Kobe earthquake

Figure 6. Base Moment of 16m. height Intze tank for Kobe earthquake

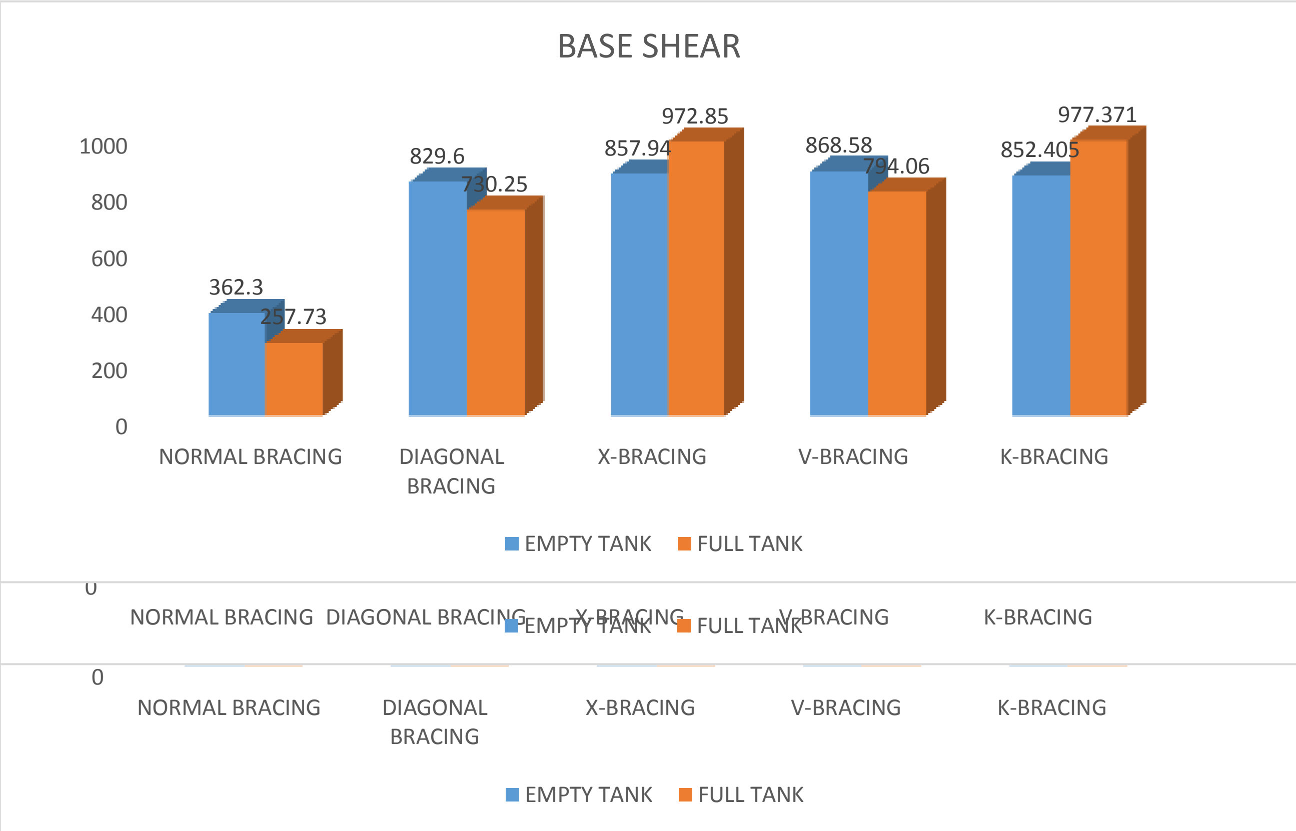

Table 61: Displacement of 16m. height Intze tank for Loma Prieta earthquake

Figure 7. Displacement of 16m. height Intze tank for Loma Prieta earthquake

FLUID LEVEL CONDITION	DISPLACEMENT(mm)				
	BRACING TYPE				
	NORMAL BRACING	DIAGONAL BRACING	X-BRACING	V-BRACING	K-BRACING
EMPTY TANK	27.277	27.751	24.384	27.578	24.429
FULL TANK	22.241	26.258	28.126	27.076	28.063

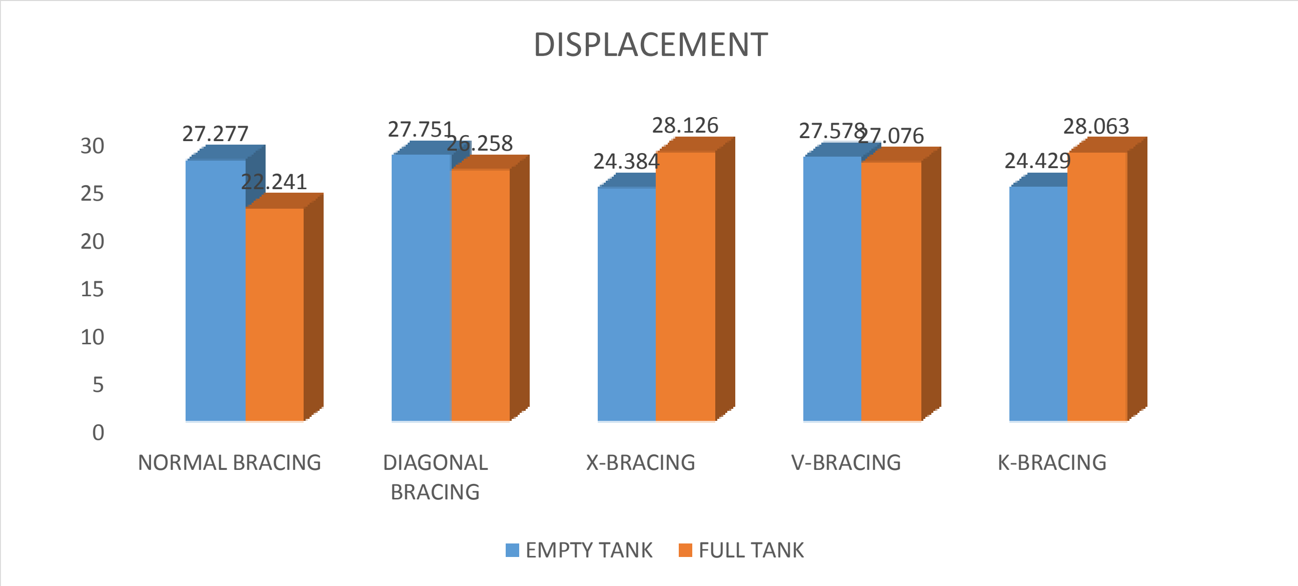

Table 7: Displacement of 16m. height Intze tank for Kobe earthquake

Figure 8. Displacement of 16m. height Intze tank for Kobe earthquake

V. CONCLUSION

- In above result we seen that for Loma Prieta time history, the maximum base shear and base moment occur in empty tank with X – bracing and 16m height.
- for Kobe time history, the maximum base shear and base moment occur in full tank with K – bracing and 16m height.
- The lowest displacement for Loma Prieta time history occur in full tank with X – bracing and 16m height.
- The lowest displacement for Kobe time history occur in empty tank with diagonal bracing and 16m height.
- From the above result it was concluded that X – bracing is best suitable for elevated water tank.

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