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Effect of Different Staging Configurations on Seismic Performance of Circular Elevated Water Tank

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ABSTRACT
As known from very upsetting experiences adequately designed Elevated water tanks were heavily damaged or collapsed during earthquakes. Most of the damages observed during the seismic events arise due to causes like the lack of knowledge regarding the behavior of supporting system, improper selection and design of supporting system of elevated water tanks. This paper presents the study of seismic performance of the elevated water tanks for various seismic zones of India with variation in staging heights and different types of staging configurations. Total 27 combinations were analyzed using Response Spectrum Method (RSM) in finite element based software SAP2000 by considering two mass idealization systems. Tank responses including base shear, overturning moment and roof displacement have been observed with the aim of recommendation of best staging arrangement for different earthquake zones in India.
Keywords-Elevated water tanks, Frame staging, Response Spectrum, Seismic Zones, Two mass model.

I. INTRODUCTION

Water supply is a life line facility that must remain functional in post earthquake period to ensure potable water supply to earthquake-affected regions and to cater the need for fighting. Most municipalities in India have water supply system which depends on elevated water tanks for storage. Elevated water tanks consist of huge water mass at the top of a slender staging which is most critical consideration for the failure of the tank during earthquakes. Due to the lack of knowledge of supporting system some of the water tank were collapsed or heavily damaged. So there is need to focus on seismic safety of lifeline structure with respect to alternate supporting system which are safe during earthquake. The earthquake zoning map of India divides India into 4 seismic zones (Zone II, III, IV and V) where Zone V expects the highest level of seismicity whereas Zone II is associated with the lowest level of seismicity.

The frame type is the most commonly used staging in practice. The main components of frame type of staging are columns and braces. In frame staging, columns are arranged on the periphery and it is connected internally by bracing at various levels. The staging acts like a bridge between container and foundation for the transfer of loads acting on the tank.The aim of the present work is to suggest best suitable staging configuration by studying the seismic performance of Elevated water tankconsidering variations in staging arrangements, staging heights and earthquake zones. Diameter of columns is optimized for determination of minimum quantity of concrete and steel for each zone.

II. MODEL PROVISIONS

Two mass model proposed by Housner [1] and is being now commonly used in most of the international codes including draft code for IS 1893 (Part-II). Most elevated tanks are never completely filled with liquid hence two mass idealization of the tank is more appropriate as compared to one mass idealization. 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. This mass is termed as impulsive liquid mass which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and the base. Thus total liquid mass gets divided into two parts, i.e., impulsive mass and convective mass. The response of the two-degree of freedom system can be obtained by elementary structural dynamics. The two-mass idealization can be treated as two uncoupled single degree of freedom system. The stiffness (K_s) is lateral stiffness of staging. The mass (m_s) is the structural mass comprising of mass of tank container and one-third mass of staging as staging will acts like a lateral spring. Mass of container considers mass of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided. The two- mass model is shown in Fig 1.

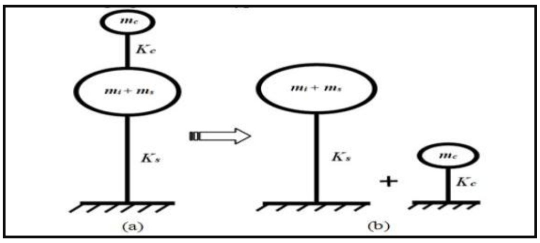

Fig. 1: Two mass model for elevated tank

III. Problem Statement

A reinforced elevated circular water tank with fixed base frame type tank with 500 m^3capacity is considered for present study. It is supported on RC staging consisting of 8 columns. Tank is located on medium soil. Grade of staging concrete is $M_{25}$and Fe 415, Density of concrete is 25 KN/m^3.Total 27 combinations studied for tank full condition by varying Staging height, Earthquake zones and Staging configurations as shown in Fig. 2.

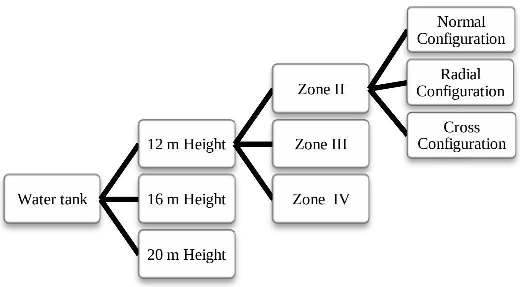

Fig. 2: Models for Analysis

Sr. No	Component	Size
1.	Roof slab	320 mm
2.	Wall	280 mm
3.	Floor slab	350 mm
4.	Floor Beams	750 ×300 mm
5.	Braces	300× 500 mm
6.	Column Diameter	400 mm
7.	Inner Diameter of tank	10 m
8.	Outer Diameter of tank	10.56 m
9.	Height of tank	7.5 m

Table 1: Sizes of various components of water tank

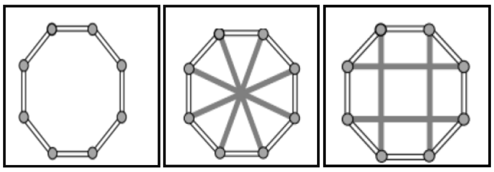

Fig. 3: Different types of staging configurations.

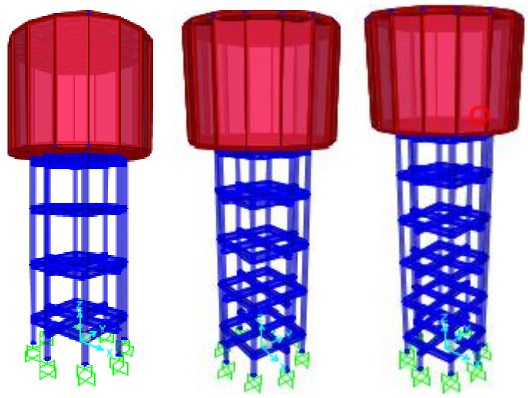

Fig. 4: 3D FE models of various staging levels for Zone III and cross staging configurations

IV. Results

Seismic responses such as stiffness, base shear, overturning moment and roof displacement are tabulated as follows.

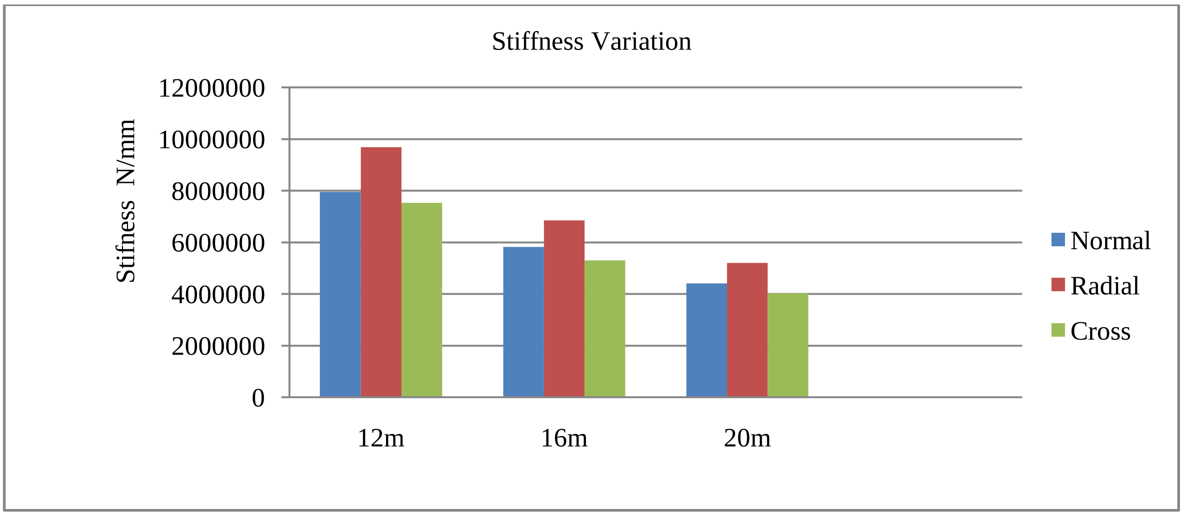

Fig.5: Stiffness variations

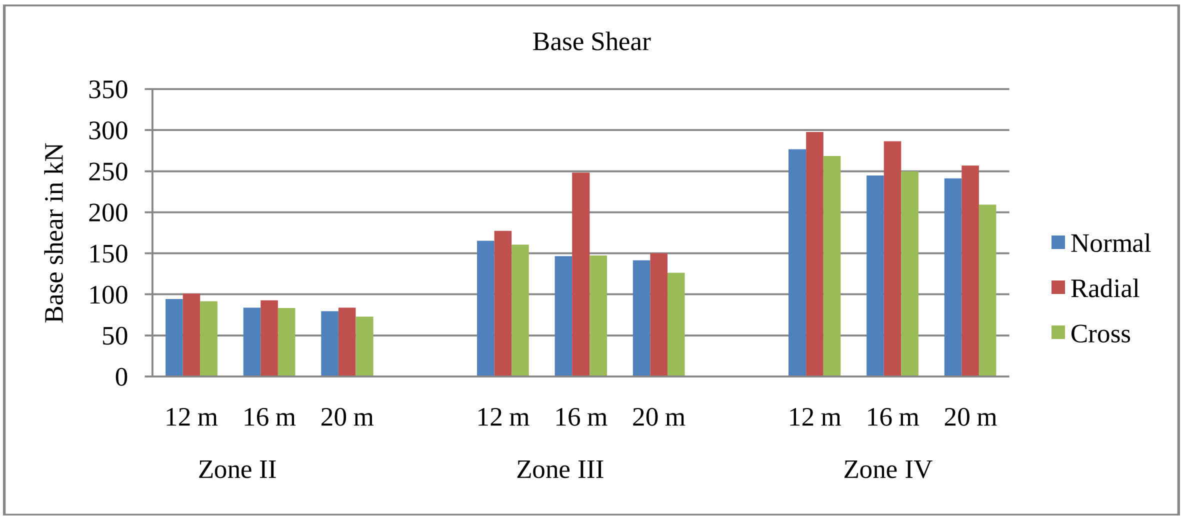

Fig.6: Base shear variations

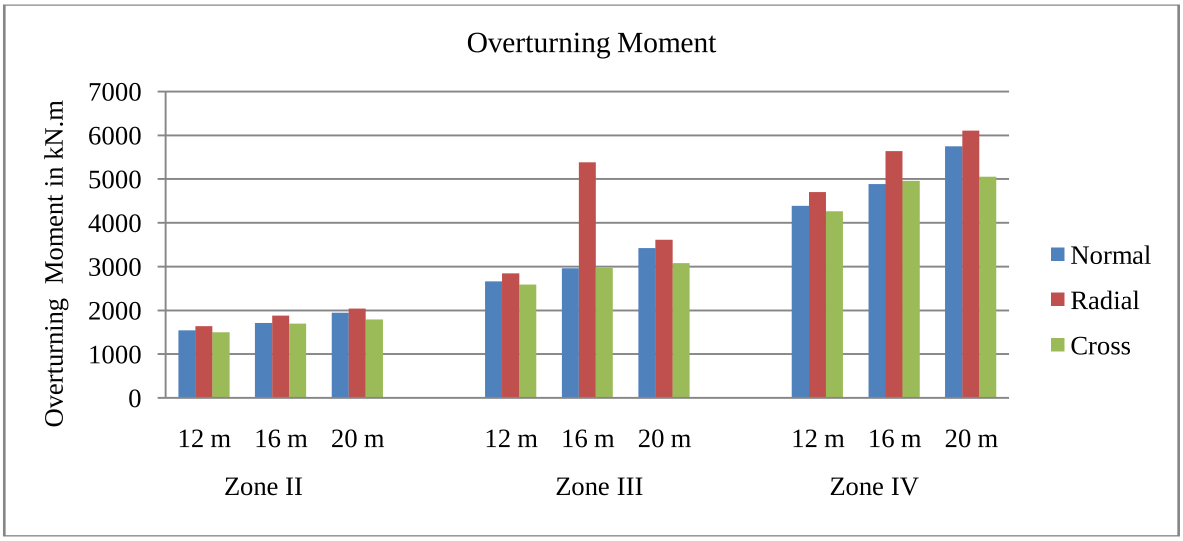

Fig. 7: Overturning moment variations

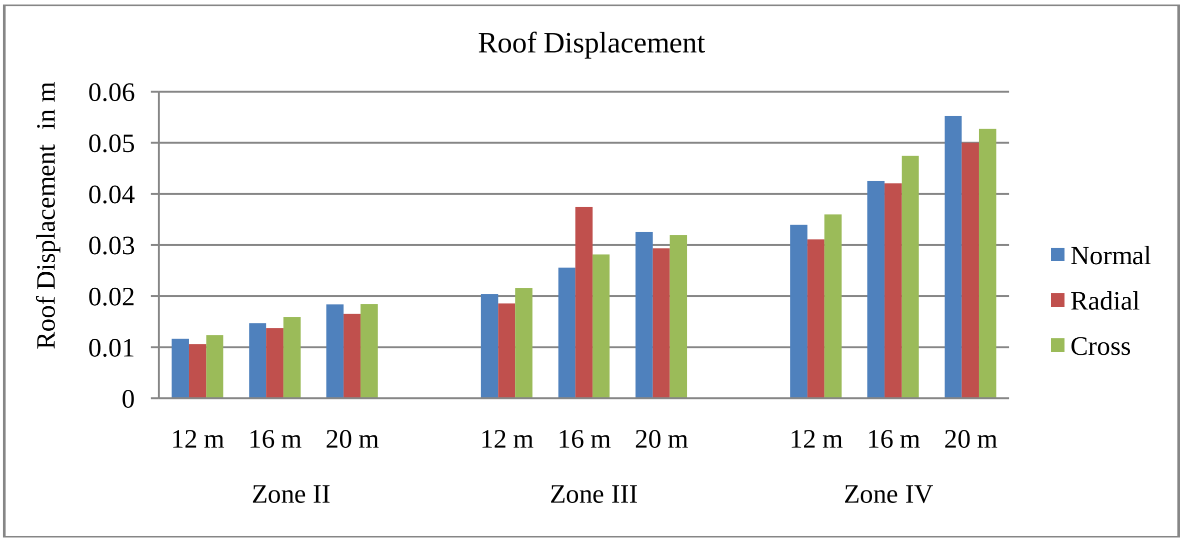

Fig.8: Roof Displacement variations

V. CONCLUSIONS

1. Radial configurationhas more stiffness than cross and normal and deflection vice versa.
2. With increase in staging height from 12m to 16m and change in seismic zones from zone II to zone IV, base shear and overturning moment are increasing for all configurations with tank full condition.
3. Top roof displacement is increased with the increase in the staging levels and severity of seismicity.
4. In radial configuration though base shear is more, roof displacement is less than cross and normalconfigurations for all zones. Hence performance of radial configuration is better.

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