Behaviour of RC Overhead Water Tank Under Different Staging Patterns

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***Abstract*—Water tanks and especially the elevated water tanks are structures of high importance which are considered as main lifeline elements that should be capable of keeping the expected performance i.e. operation during and after earthquakes. Thus researchers, in recent years, have focused on studying seismic behaviors of these tanks, particularly ground tanks, while only few of these researches have concerned with the elevated tanks and even less with the reinforced concrete elevated tanks. In this research, a sample of a reinforced concrete elevated water tank with 400 m3 have been studied and analyzed by linear dynamic method and seismic response such as base shear, tank displacement under tank empty condition for different type of staging configuration have been calculated and then results have been compared.**

***Keywords*—— Seismic Response, Elevated water tank, staging, and SAP 2000**

I. INTRODUCTION

Most water supply systems in developing countries, such as India, depend on overhead storage tanks. The strength of these tanks against lateral forces such as those caused by earthquakes, needs special attention.

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. Elevated water tanks are critical and strategic structures; damage of these structures during earthquakes may endanger drinking water supply, cause to fail in preventing large fires and may cause substantial economic loss. 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

A research activity has been primarily focused on understanding the seismic behavior of ground and elevated water tanks. It has been observed since last suffered decade that the supporting structures for elevated water tanks have damage after strong earthquakes leading to collapse of certain elevated water tanks-Bhuj and Latur post-earthquake studies. It can be observed that reinforced concrete elevated water tanks with frame staging, has shown better seismic resistance than reinforced concrete elevated water tanks with shaft staging.

Because of large mass, especially when the tank is full, earthquake forces are more or less govern the lateral force design criteria in the zone of high seismic activity. In the extreme case, total collapse of tank shall be avoided. However, some damage repairable may be acceptable during severe shaking not affecting the functionality of tank. 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.

II. ASSUMPTION IN THE ANALYSIS

For complete analysis of structure, necessary matrices generated on the basis of following assumptions:

1. The structure is idealized into an assembly of beams, plates, and solid type elements joined together at their nodes. The assemblage is loaded and reacted by concentrated load acting at the nodes. These nodes may be both forces and moments which may act in specified direction

2. A beam may tie as a longitudinal structural member having a constant doubly symmetric or near doubly symmetric cross section along its length. Beam member always carry an axial force. They may also be subjected to shear and bending in two arbitrary perpendicular planes and also subjected to torsion.

3. Internal and external loads acting on each node are in equilibrium. If torsion or bending properties are defined for any member, six degree of freedom is considered at each node in the generation of relevant matrices.

4. Two types of co-ordinate systems are used in the generation of required matrices and are referred to as local and global systems

III. LUMPED MASS MODEL

For the purpose of this analysis, elevated tanks shall be regarded as systems with a single degree of freedom with their mass concentrated at their Centre of gravity. The damping in the system may be assumed as 5 percent of the critical for concrete The Time period T, in seconds, of such structure shall be calculated from the following formula:

$$T = 2\pi\frac{\sqrt{K}}{\sqrt{m}}$$

Where

m = mass of the tank container + 1/3 rd. weight of staging.

Ks = lateral stiffness of the staging.

The lateral force shall be taken equal to:

Ah * W

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Where
Ah = Design horizontal seismic coefficient
W= Seismic Weight.
The design shall be worked when tank is empty the weight W used in the design shall consist of the dead load of the tank and one-third the weight of the staging.
Design horizontal seismic coefficient shall be calculated W by response spectra method
Ah = Z/2.I/R (Sa/g)
The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression:
VB = Ah. W
Where,
Ah = Design horizontal acceleration spectrum value as per 6.4.2, of IS 1893 and
W = Seismic weight of the tank.

IV. TWO MASS MODEL

Two mass model for elevated tank was proposed by Housner (1963) which is more appropriate and is being commonly used in most of the international codes including Draft code for IS 1893 (Part-II). 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.

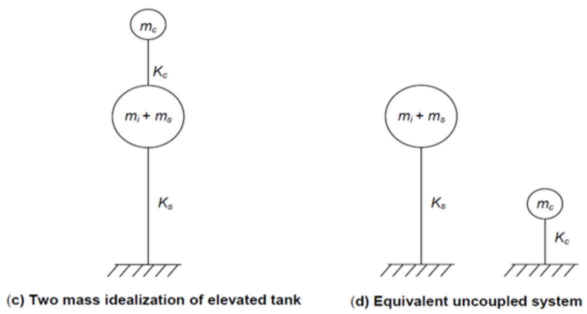

Fig 1: Two mass Idealization of Elevated Water Tank

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 base. For representing these two masses and in order to include the effect of their hydrodynamic pressure in analysis, spring mass model is adopted for ground-supported tanks and two-mass model for elevated tanks

V. FLUID STRUCTURE INTERACTION

During lateral base excitation seismic ground causes hydrodynamic pressure on the tank depends on the geometry of tank, height of liquid, properties of liquid and fluid-tank interaction. Proper estimation of hydrodynamic pressure requires a rigorous fluid-structure interaction analysis. In the mechanical analogue of tank-liquid system, the liquid is divided in two parts as, impulsive liquid and convective liquid. The impulsive liquid moves along with the tank wall, as it is rigidly connected and the convective and sloshing liquid moves relative to tank wall as it under goes sloshing motion. This mechanical model is quantified in terms of impulsive mass, convective mass, and flexibility of convective liquid. Housner (1963) developed the expressions for these parameters of mechanical analogue for circular and rectangular tanks. Fluid- structure interaction problems can be investigated by using different approaches such as added mass Westergaard approach, Lagrangian approach (Wilson and Khalvati), Eulerian approach (Zienkiewicz and Bettes), or the Eulerian-Lagrangian approach (Donea). The simplest method is added mass approach and can be investigated by using some of conventional Finite Element Method software such as SAP2000, STAAD Pro and LUSAS.

VI. PROBLEM DESCRIPTION

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 is acting like a bridge between container and foundation for the transfer of loads acting on the tank. In elevated water tanks, the head requirement for distribution of water is satisfied by
Adjusting the height of the staging portion. A reinforced elevated intze water tank having different staging arrangements and staging levels has been considered for the present study. A reinforced concrete Intze type elevated water tank with fixed base connection and 2, 3 & 4 level bracing is considered for present study. The storage capacity of water tank is 400 m3. Grade of concrete and steel are M20 and Fe415 respectively. Tank is located on hard soil and in seismic zone IV. Bearing Capacity of soil is 250 KN/m2. FEM structural software SAP2000 is used to model water tank.

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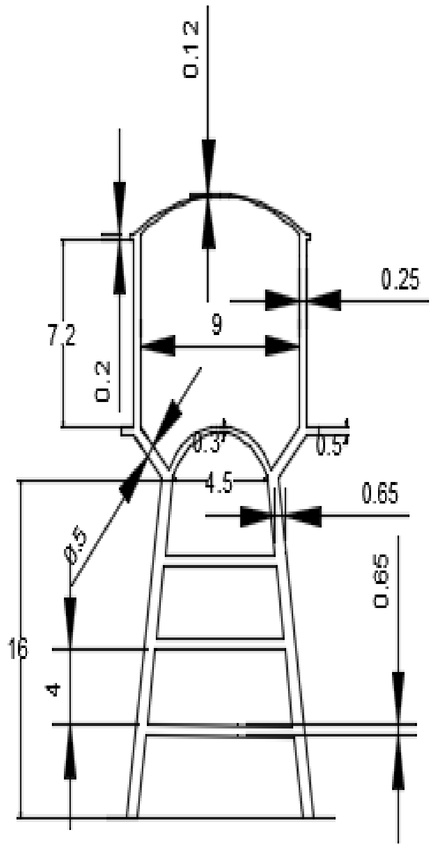

Fig 2: Schematic Diagram of Intze type water tank

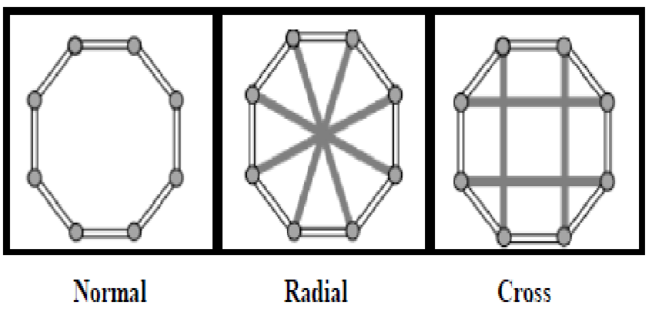

Fig 3: Different type of staging Configuration.

Particulars	Size/ Value
Capacity of the tank (m3)	400
Unit weight of concrete (kN/m3)	25
Thickness of Top Dome (m)	0.12
Size of Top Ring Beam (m)	0.25 x 0.2
Rise of Top Dome (m)	1.5
Diameter of Tank (m)	9
Height of Cylindrical Wall (m)	7.2
Thickness of Cylindrical Wall (m)	0.25
Size of Bottom Ring Beam (m)	0.9 x 0.5
Rise of Conical Dome (m)	1.5
Thickness of Conical Dome (m)	0.5
Rise of Bottom Dome (m)	1.5
Thickness of Bottom Dome (m)	0.3
Number of Columns (Circular)	8
Number of Bracings Level	3 & 4
Size of Circular Ring Beam (m)	0.5 x 0.65
Distance between intermediate Bracing (m)	4, 3.2
Height of staging (m)	16
Diameter of Columns (m)	0.65
Size of Bracing (m)	0.35 x 0.65

RESULTS

TABLE I. TABLE 1: BASE SHEAR FOR 2 LEVEL BRACING

Type of Bracing	Base Shear (kN)
Octagonal Bracing only	458
Octagonal and Cross	489
Octagonal and radial	493

TABLE II. TABLE 2: STOREY DISPLACEMENT FOR 2 LEVEL BRACING

Type of Bracing	Storey displacement (mm)
Octagonal Bracing only	8.59
Octagonal and Cross	8.58
Octagonal and radial	8.52

TABLE III. TABLE 3: BASE SHEAR FOR 3 LEVEL BRACING

Type of Bracing	Base Shear (kN)
Octagonal Bracing only	476
Octagonal and Cross	525
Octagonal and radial	529

TABLE IV. TABLE 4: STOREY DISPLACEMENT FOR 3 LEVEL BRACING

Type of Bracing	Storey displacement (mm)
Octagonal Bracing only	8.18
Octagonal and Cross	8.17
Octagonal and radial	8.12

TABLE V. TABLE 5: BASE SHEAR FOR 4 LEVEL BRACING

Type of Bracing	Base Shear (kN)
Octagonal Bracing only	514
Octagonal and Cross	579
Octagonal and radial	584

TABLE VI. TABLE 6: STOREY DISPLACEMENT FOR 4 LEVEL BRACING

Type of Bracing	Storey displacement (mm)
Octagonal Bracing only	7.87
Octagonal and Cross	7.85
Octagonal and radial	7.79

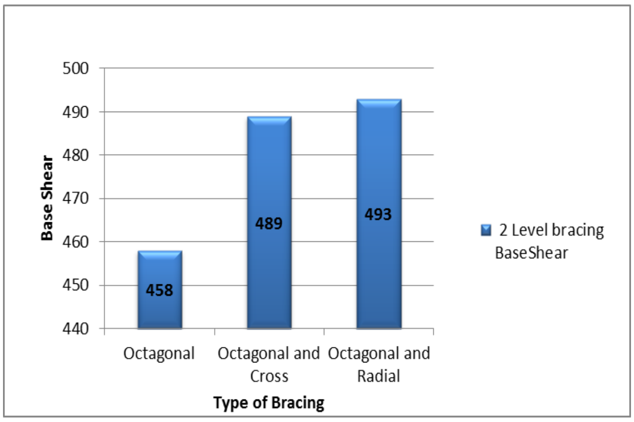

Fig 4: Graph of Base Shear VS Type of bracing for 2 level bracing

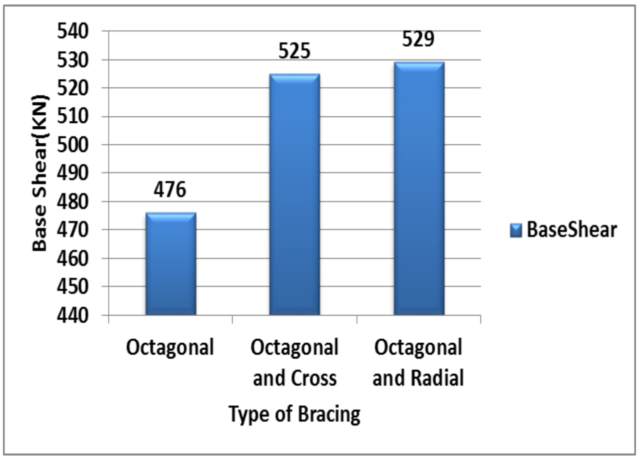

Fig 5: Graph of Base Shear VS Type of bracing for 3 level bracing

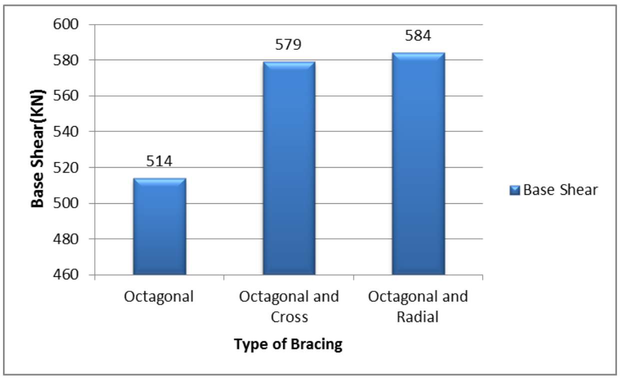

Fig 6: Graph of Base Shear VS Type of bracing for 4 level bracing

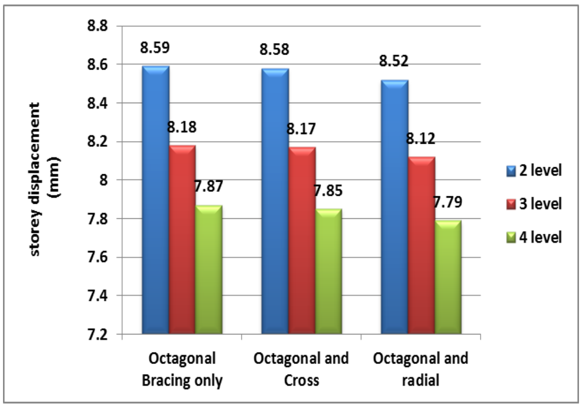

Fig 7: Graph of Storey displacement VS Type of bracing at 2, 3 and 4 level

CONCLUSION

- Base Shear and storey displacement are compared with respect to level of bracing.
- Base shear increases as bracing level increases for different types of bracings
- Base shear is more for Octagonal & Radial bracings of empty tank condition
- Story displacement goes on decreasing as level of bracing increases.

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