Seismic Analysis of Rectangular and Circular RC Elevated Water Tank

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***Abstract*— : Elevated water tanks are large storage containers constructed for storing water supply at certain height to pressurize the system of water distribution. It comprises of a heavy water mass at the top of a slender staging which is utmost critical parameter consideration for the collapse of the tank during earthquakes. A detailed understanding of the performance of the structures under seismic forces is necessary to meet the safety objectives during construction and maintenance. Other modes of failures considered are sloshing damage at roof, buckling, inlet or outlet pipe breaks. From previous studies it was clear that inadequately designed elevated tanks were damaged heavily at the time of earthquakes. This may be due to the lack of knowledge regarding the behaviour of supporting system of the tank, and also due to improper selection of geometry of staging patterns. In the present work seismic analysis of rectangular and circular elevated water tanks are analysed using SAP 2000. From the study it is concluded that the primary mode shape of rectangular tank is translation and that of circular tank is torsion which needs to be eliminated. To eliminate the torsional mode shape in circular elevated water tank, orientations of columns are modified.**

Keywords*— *Circular tank, rectangular tank, two mass idealisation, SAP 2000

I. INTRODUCTION

Elevated water tanks are lifeline structures and are important for the continuous supply of water. Their performances are critical during and after strong earthquakes. So a thorough understanding about the seismic behaviour of these tank structures is necessary, to meet proper safety objectives while construction and maintenance. From past studies it was clear that inadequately designed e water tanks were damaged heavily at the time of earthquakes. This may be due to the lack of knowledge regarding the behaviour of supporting system of the tank, and also due to improper selection of geometry of staging patterns. As a result of the dynamic effect of water when tank containing water is subjected to seismic force, sloshing effect is generated. This exerts hydrodynamic force on the base and walls of the tank along with hydrostatic forces. So to include these hydrodynamic forces, the elevated tanks should be idealised as spring mass model according to IS 1893 (part 2) 2014.

II . SPRING MASS MODEL

Two mass idealization is more appropriate than one mass system since the tanks are not always full. When a tank with water mass is subjected to horizontal seismic motion walls of tank and liquid contained are subjected to horizontal acceleration [3]. The water mass in the inferior section of the tank behaves like a rigid mass connected to the walls of the tank and is called as impulsive mass which accelerates along the tank wall which exerts impulsive hydrodynamic pressure on the tank wall. Similarly water mass in the topmost region of the tank undergoes sloshing motion and this mass is known as convective mass and it induces convective hydrodynamic pressure on the base and walls of the tank. Thus entire liquid mass is divided into two masses, convective mass and impulsive mass [3]. The two mass idealization system is shown in Figure 1.

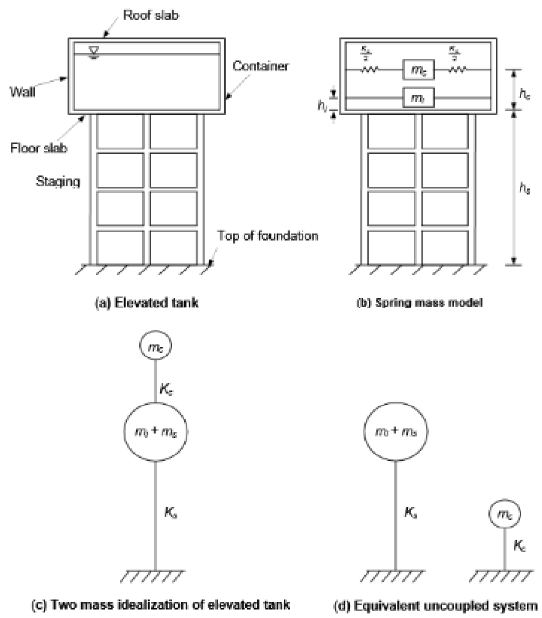

Figure 1 : Two Mass Idealization

III. DETAILS OF ELEVATED RC WATER TANK

For the analysis circular and rectangular elevated water tank of 100m³ with a staging height of 12m is used as in figure 2. The intermediate height taken is 2.5m. Seismic Zone III is considered.

Table 1: Details of circular tank

Diameter	6.52m
Roof Slab	120mm
Floor Slab	200mm
Floor Beam	250mmX600mm
Wall	200mm
Gallery	110mm
Braces	300mmX450mm
Column	450mmX500mm

Table 2: Details of Rectangular tank

Length	8.2m
Breadth	4.1m
Roof Slab	180mm
Floor Slab	200mm
Floor Beam	250mmX600mm
Wall	200mm
Gallery	150mm
Braces	300mmX450mm
Column	450mmX500mm

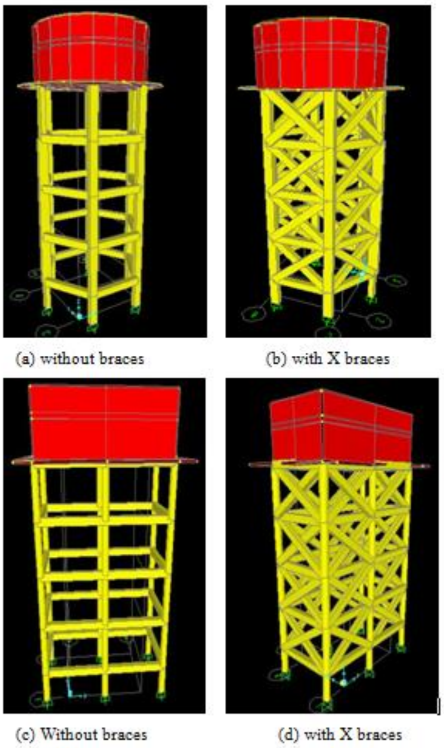

Figure 2: Tank Models

IV. FINITE ELEMENT MODELLING OF TANKS

The structural elements of the supporting frame system were modelled as beam elements and area elements such as tank wall, roof slab and floor slab were modelled using shell elements. To incorporate the dynamic behaviour of the fluid mass in the FEM tank models, two masses were considered. The primary mass is the impulsive mass component of the fluid which is calculated as per IS 1893 (part 2). It is firmly connected to the tank wall by constraining the movement in y and z direction. The second mass is the convective mass component of the fluid which is connected using a system of springs to the walls of the tank constrained in x and y direction; the stiffness of the spring is calibrated to create the first convective mode. The spring mass parameters calculated during initial design are given in Table 3 and 4. The impulsive mass has been modeled as concentrated mass placed at a height h_i from the bottom of the tank. This mass is connected using a system of "link" elements to the vertical walls. The convective mass, which is at a height h_c, is connected to the walls using a system of springs to imitate the equivalent stiffness as accurately as possible. The stiffness of each spring has been calibrated in turn to have stiffness in the direction equal to kc/2.

Table 3: Parameters of Spring Mass Model for circular tank

Mass of water	100163Kg
Mass of structure	91149.5Kg
Impulsive mass	82654.31Kg
Convective mass	46074.98Kg
Spring stiffness of convective mode, k_c	103.42kN/m
Height of convective mass, h_c	2.96m
Height of impulsive mass h_i	2.405m

Table 4: Parameters of Spring Mass Model for rectangular tank

Mass of water	100856 Kg
Mass of structure	127380.56Kg
Impulsive mass	89761.84Kg
Convective mass	43368Kg
Spring stiffness of convective mode, k_c	128.25kN/m
Height of convective mass, h_c	2.96m
Height of impulsive mass h_i	2.405m

V. RESULTS AND DISCUSSIONS

Table 5: Time period of circular tank

Model	**Time period (s)**
Circular water tank	5.23
Circular tank with X braces	4.81
Rectangular tank	7.31
Rectangular tank with X braces	6.56

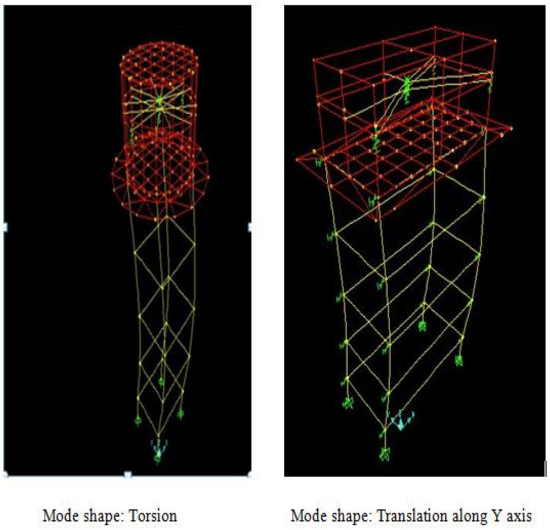

Figure 3: Mode shapes

Table 6: Convective and Impulsive Time Period

Model	Convective Time Period (s)	Impulsive Time period (s)
Circular water tank	2.13	1.01
Circular tank with X braces	2.05	0.982
Rectangular tank	2.36	1.035
Rectangular tank with X braces	2.25	0.996

Table 7: Base shear

Model	Base Shear (kN)
Circular water tank	1015.73
Circular tank with X braces	1422.35
Rectangular tank	1245.11
Rectangular tank with X braces	1586.09

Table 8: Base Moment

Model	Base Moment (kNm)
Circular water tank	3213.54
Circular tank with X braces	4765.87
Rectangular tank	4532.18
Rectangular tank with X braces	6731.41

INFERENCES

- The mode shape for braced and un braced circular water tank is torsion and that for rectangular water tank is translation as in figure 3.
- Time period decreases when bracings are added.
- Base shear and moment is more for rectangular water tank than circular water tank.
- Shear and moment increases with the introduction of bracings.

Since the primary mode shape of elevated circular water tank is torsion, it is critical during earthquakes and is needed to be eliminated. So the positions of alternate columns are rearranged to eliminate torsion as in figure 4.

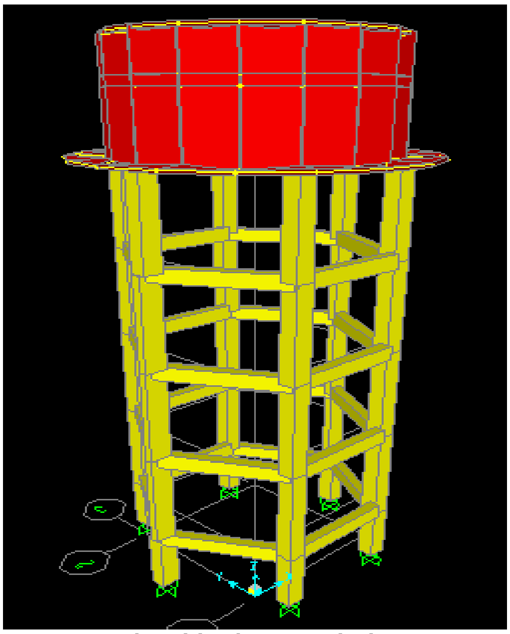

Figure 4: Tank model with rearranged column position

Table 8: Modal analysis Result

Model	Time period (s)
Circular water tank	5.56
Circular tank with X braces	5.04
Rectangular tank	7.49
Rectangular tank with X braces	6.83

INFERENCES

- The mode shape is translation along Y direction.
- So the position of columns can be rearranged to eliminate torsional seismic mode.
- This is because as the structure becomes irregular its torsion effect decreases.

VI. CONCLUSION

Circular and rectangular RC elevated water tanks were analysed using SAP 2000 and the following conclusions obtained were as follows

- The mode shape of circular water tank is torsion and that of rectangular is translation along Y axis.
- Time period decreases for water tank models with bracings.
- Shear and moment values increases for braced structures. This is due to the increase in mass due to bracings.
- The torsional mode shape of circular tank can be eliminated by rearranging the positions of column.
- Element size required for rectangular tank is more when compared to circular tank. So circular tank is more economical.

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