Study The Fluid Structure Interaction Due to Dynamic Response of Elevated Concrete Water Tank

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Abstract: Fluid structure interaction (FSI) is complicated phenomena in which researches trying to suggest new techniques to account its effects in elevated concrete water tanks. Rectangular and circular shapes of elevated tanks have been chosen to conduct this study. In this paper the adding of impulsive mass to elevated tank has been modified instead to Westergaard approach, by examined six rectangular and six circular models of elevated tanks that suggested by authors through three dimensional finite elements method (FEM), using LUSAS FEA 14.1, based on vibration dynamic analysis to obtain the time of impulsive mass at every case. The results shows a small deviations obtained in both shapes (rectangular and circular) between Westergaard approach and approaches suggested.

Keywords: Elevated tanks, Fluid structure interaction, added mass approach.

INTRODUCTION

Remain functional of the elevated concrete water tanks after earthquakes accrued, is important issue for which the water supply to be used for livening and fire fighting that associated with earthquakes. Therefore analyzing of such structures should be performed with height level of accuracy and accounting any phenomena that may be able to associate with the response to earthquakes. Previous studies shows that FSI play an important effects on the shear forces at base and overturning moment of the elevated tanks.

There are four main approaches to investigate FSI through Finite elements method, three of them needs special software that includes fluid elements in their elements library such as ANSYS, ABAQUS and etc these approaches named as Lagrangian (Wilson and Khalvati, 1983: Livaoglua and Dogangu, 2007), Eulerian (Zienkiewicz and Bettes, 1978) and Lagrangian Eulerian (Donea, J., 1982 ). Whilst the fourth approach named as added mass method (Westergaard, 1931: Kuo, 1982: Doğangün and Livaoglu, 2006) that can be investigated with any conventional software without flow elements in their elements library such as SAP2000, LUSAS FEA, and. etc.

According to Housner (1963), under dynamic loads, water in the container of elevated tank gets divided to two parts, lower part exerts as impulsive mass, that connected with tank wall rigidly, named as impulsive mass and upper part that connected with the tank wall by springs, named as convective or sloshing mass, as shown in the Fig 1. In the finite elements model and according to added mass approach, the impulsive mass should be distributed according to Westergaad approach.

The difficulties task in building finite element model is adding the impulsive mass to the tank walls according to Westergaard approach. This paper is trying to suggest a new modification in order to simplify analyzing elevated tanks under dynamic load trough finite element model.

Fig. 1: Typical elevated tank with liquid divided into impulsive and sloshing mass.

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Modeling Techniques:
The analysis of structures under dynamic loads governing by the general equation of dynamic equilibrium which can be written as below

\[ M \ddot{a} + C \dot{a} + K = F(t) \]  

(1)

Where \( M \), \( C \) and \( K \) are mass, damping and stiffness matrices, \( \ddot{a} \), \( \dot{a} \) and \( a \) are the acceleration, velocity and displacement respectively, and \( F(t) \) is forcing function. In the natural frequency analysis Equation (1) became (2) as below under the three assumptions as below:

1-Zero damping \( [C] = 0 \)
2-No loading \( F(t) = 0 \)
3-Sinusoidal displacements

\[ [K][\phi] = [\lambda][M^*][\phi] \]  

(2)

where \( [\phi] \) is eigenvector matrix (mode shapes), \( [\lambda] \) is eigenvalue matrix (frequencies) and \( M^* \) is new mass after adding hydrodynamic mass to the mass walls of elevated tank

Suggested Model:
As shown in Fig 2, the distribution of masses that suggested by authors in which placed at level of center of gravity of the empty container of elevated tank in both cases circular and rectangular in the finite element models. The impulsive mass gets divided to six cases (4, 8, 16, 24, 48 and model No six the impulsive mass distributed equally along the walls of elevated tanks) as presented in Table 1.

![Fig. 2: Alternative masses distribution in case of circular and rectangular tanks.](image)

Case Studies:
Two elevated concrete water tanks rectangular and circular are chosen to conduct this study. The circular tank has a capacity of 250 m$^3$ with the top of water level at about 21.8 m above ground. The tank is spherical in shape, 8.6 m in diameter and 7.85 m in height at its centre. The support consists of 6 vertical circular columns and the columns are connected by the circumferential beams at regular intervals, of 4, 8, 12 and 16 m. The rectangular tank has a capacity 1255 m$^3$ and supported on reinforced concrete staging of 16 columns with horizontal bracings at intervals, of 6, 12, 18, and 24 m. The density of concrete used is 25kN/m$^3$ in both cases of elevated tank.
Table 1: Alternative parameters of the circular and rectangular elevated tank.

<table>
<thead>
<tr>
<th>Models</th>
<th>Impulsive mass (Ton)</th>
<th>Circular</th>
<th>Rectangular</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35.15</td>
<td>168.89</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17.58</td>
<td>84.45</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.79</td>
<td>42.22</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5.86</td>
<td>21.11</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2.93</td>
<td>10.56</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.18</td>
<td>9.38</td>
<td></td>
</tr>
</tbody>
</table>

Finite Elements Models:
The simulation of elevated tanks is conducted through finite element method using LUSAS FEA software. Frame element named as BMS3 is used to model beams and columns. Thin quadrilateral shell element named as QSI4 is used to model walls and domes. Joint element named as JNT4 is used to model the distribution impulsive liquid masses this elements are attached to the tanks walls as shown in Fig 3 (LUSAS FEA 14.1, User Manual., 2007).

RESULTS AND DISCUSSIONS
The results showed in Fig 4 and Fig 5 indicated that there is minor difference between values of times of impulsive mode in case of rectangular and circular tanks. For case-1, in which the impulsive mass is divided to 4 masses the deviation between values in this case and Westergaard approach around 0.4% the other cases also indicated to a very minor deviations in other cases. The same manner in case of circular tank where the deviation between case-1 and Westergaard indicated to around 3% in which the deviation is still having minor affects. Whilst the other cases are more accurate as more the number of impulsive mass divided increase

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**Fig. 4:** Values of impulsive mode for the rectangular tank.
**Fig. 5:** Values of impulsive mode for the circular tank.

**Conclusion:**
From the analysis results it can be concluded that the suggested method of adding impulsive mass to the walls of tank in case of circular and rectangular shapes do not affected significantly the dynamic analysis of elevated tanks in which creates increasing in base shear force and overturning moment less than the deviations obtained. Therefore the proposed method is more applicable in case of easily to implement finite element models for dynamic analysis of elevated tank than Westergaard approach.

**REFERENCES**


