ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

COMPARATIVE STUDIES ON PERFORMANCE OF OVERHEAD TANK STRUCTURES WITH DIFFERENT SUPPORT AND END CONDITIONS

Maritta Rodrigo[*1], Mr. Subramanian Thiru[2] & Dr. S.N. Ramaswamy[3]
[*1]PG student, Department of Civil Engineering, Kalasalingam University, Krishnankoil,Virudhunagar-626126
[2&3]Assistant Professor, Department of Civil Engineering, Kalasalingam University, Krishnankoil,Virudhunagar-626126

ABSTRACT
Earthquake has now become a major cause of destruction and fatalities, and this continues at a higher rate. The consequence of strong earthquake ground shaking has become more threatening to both human and assets. Water tank is one among the important component of lifeline and public utility. RC Elevated liquid storage tanks were heavily damaged, some even collapsed to ground during the events recorded in India. Plan of the building is one of the major aspects. Building should be symmetrical such as a square, rectangle, octagon etc. i.e., it must be symmetrical with respect to axis. In symmetrical plans torsion does not occur.Efficacy of prototype-scaled elevated water tank models in a bi-axial shake table with varied geometries and staging systems were planned and corresponding values were analysed and compared with experimental results. The project emphasizes on the fact that most efficient geometry of staging is octagon with column at the centre and they were analysed under various types of bracings and results were also obtained such that the most efficient prototype model that withstands vibration for longer period of time was the one with octagon staging and diagonal bracing at a h/d ratio of 0.45-0.47.

Keywords : Magnitude, Intensity, Hydrodynamic Pressure, Earthquake shake table.

I. INTRODUCTION

Earthquakes have been one of the most upsetting experiences of disasters. Although many measures have mean taken to safeguard people and properties, steps have been taken to protect structures such as overhead water tanks that gets collapsed initially. Water is one among the most important human basic needs for daily life. Water tanks are important components of lifeline. They are critical elements in municipal water supply, industrial facilities for storage of water and fire-fighting systems.

An overhead water tank is a large water storage container with itssignificance of holding water supply at certain height to pressurize the water distribution system. Most of the overhead water tanks undergo failure due to their staging. Hence there is a necessity to check the seismic safety of a lifeline structure and concentrate on some other alternate supporting features which are regarded to be safe during earthquake. Bhuj earthquake is one of the recent examples in which the overhead water tanks were damaged due to improper staging conditions. Majority of them were cylindrical shaft type staging, in which circumferential cracks were formed near the base, and a few were frame type staging.Many innovations have been made for storage of water in different forms. In general, liquid storage tank can be classified based on heads, geometry, and support (staging) etc. They are classified as under-ground, ground supported and elevated liquid storage container based on their heads. Based on geometry and design point of view, they can be classified as square, rectangular, circular, intze tanks etc. Shaft and frame type supports are classified based on staging conditions. Also, there are various types of bracings for staging with crosstype bracing, chevron type bracing, k-type bracing, diagonal bracing, v-type bracing, alternate cross type bracing, alternate chevron type bracing, alternate k-type bracing, alternate diagonal bracing, alternate v-typebracing, etc.

ISSN 2348 – 8034
Impact Factor- 5.070

II. EVOLUTION OF FORM

The various forms are shown in the figure below, based on the factors such as Aspect Ratio, Circularity, Convexity and Solidity.

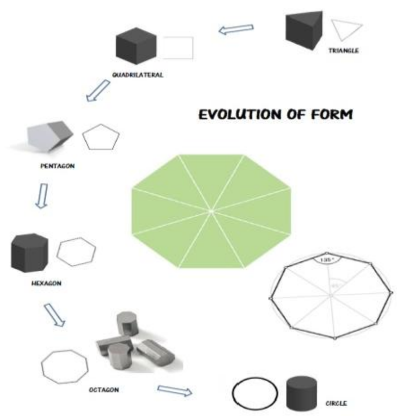


Figure 1: Evolution of form

Octagon is preferred due to the following factors

Table 1: Analysis of various shapes–dimensionless shape factors

GEOMETRY	ASPECT RATIO	CIRCULARITY	CONVEXITY	SOLIDITY
Circle	1.00	1.00	1.00	1.00
Octagon	1.00	0.97	1.00	1.00
Square	1.00	0.89	1.00	1.00

III. RESULTS OBTAINED IN CALCULATIONS

From the occurences of Gujarat Bhuj Earthquake on Jan 26, 2001; the design details were collected and evaluated as per 'IITK-GSDMA Guidelines for seismic Design of Liquid Storage tanks' from Gujarat State disaster Management Authority, October 2007 obtaining the seismic designing of an elevated water tank and a G+6 residential building for linear static analysis and calculations. The Total Base Shear (238.38kN) and the Base Moment (4504.75kN-m) in tank full condition were more than that of the Total Base Shear (176.53kN) and the Base Moment (3280.05kN-m) in tank empty condition, design will be governed under tank full condition.

IV. VARIATION OF m_i/m AND m_c/m VS. h/D RATIO

The impulsive mass participation factor (m_i/m) for the corresponding height to depth (h/D) ratio is calculated by the following expression,

$m_i/m = [\tanh (0.866xD/h)]/[0.866xD/h]$

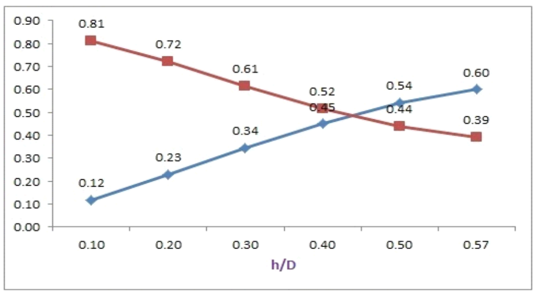
The convective mass participation factor (m_c/m) for the corresponding height to depth (h/D) ratio is calculated by the following expression,

$m_c/m = 0.23x[\tanh (3.68xh/D)]/[h/D]$

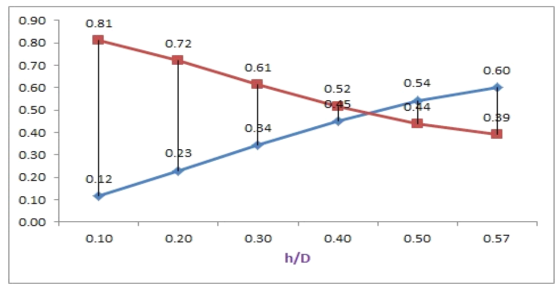
ISSN 2348 – 8034
Impact Factor- 5.070

Table 2: h/d ratio Tabulation

‘h’ Value	‘h/D’ Ratio	Corresponding Value	
		m_i/m	m_c/m
0.70	0.10	0.115	0.810
1.40	0.20	0.230	0.720
2.10	0.30	0.344	0.614
2.80	0.40	0.449	0.517
3.50	0.50	0.542	0.437
4.00	0.57	0.599	0.391



Variation of m_i / m & m_c / m Vs h/D Ratio



Unit value of mass participation factor at h/D ratio - 0.45

It has been found that the increased ratio of maximum depth of water to the diameter of tank i.e. h/D will lead to increased impulsive mass participation factor and decreased convective mass participation factor. The graph also defines that the sum of mass participation factor i.e. (m_i and m_c) exhibit unit value all along the horizontal axis. For h/D ratio of 0.45, the mass participation factors for impulsive and convective are nearly equal.

V. EARTHQUAKE SHAKE TABLE

The Earthquake shake table is a device for shaking structural models or building components with a wide variety of simulated ground motions, including reproduction of recorded earthquake time-histories. Various models are placed and tested and videos are taken, using these video records and data from transducers, the dynamic behaviour of the specimen model is interpreted. The rewards of shake table test over other testing methods (Pushover, Quasi-static, Pseudo-dynamic etc.) are, it is the best way to simulate earthquake ground motion effects. It commences real dynamic effects such as the inertia forces, damping forces and there is no necessity for any loading device to be attached, which may influence the structural performance.

5.1 Testing

A gravity load of 8 kilograms was placed on the structure and tested in a bi-axial shake table for dynamic loading with various Peak Ground Acceleration (PGA) - 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35 and 0.4 etc. for failure. The efficiency of the model, E = Maximum PGA sustained by the model / Total weight of the model. The various shapes of the developed prototype models with bracings such as, diagonal bracing, X bracing, Alternate X bracing, 3- level diagonal bracing, whose elevationsare depicted as follows:

ISSN 2348 – 8034
Impact Factor- 5.070

1.**OCTAGON:**

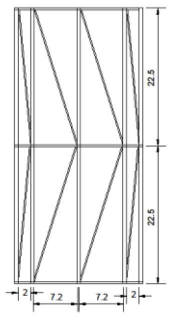


Figure 2: Diagonal Bracing:

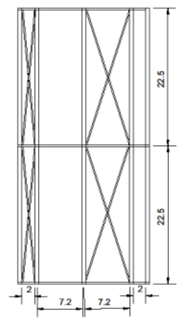


Figure 3: X – Bracing:

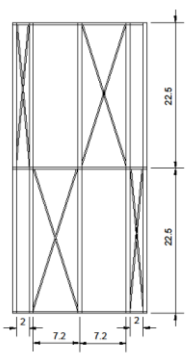


Figure 4: Alternate X – Bracing:

:

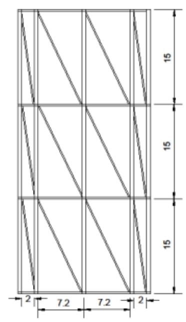


Figure 5: 3 Level Diagonal Bracing

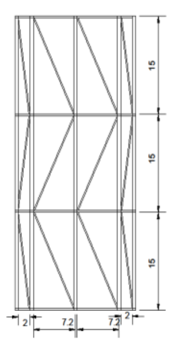


Figure 6: 3 Level Diagonal Bracing:

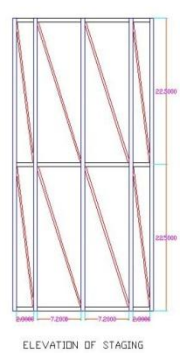
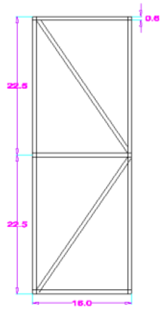


Figure 7: Diagonal Bracing:

ISSN 2348 – 8034
Impact Factor- 5.070

2. SQUARE:



:

Figure9: Diagonal Bracing:

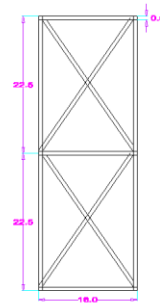


Figure10: X – Bracing

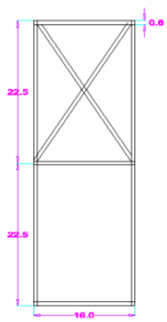


Figure 11: Alternate X – Bracing:

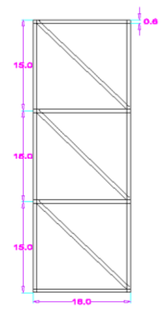


Figure12: 3 Level Diagonal Bracing:

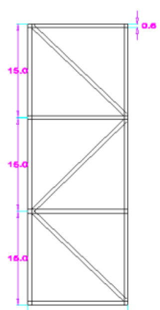


Figure13: 3 Level Diagonal Bracing:

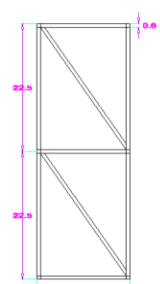


Figure14: Diagonal Bracing:

ISSN 2348 – 8034
Impact Factor- 5.070

3. RECTANGLE:

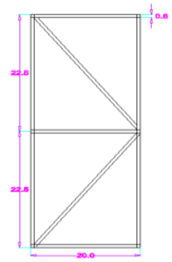


Figure 15: Diagonal Bracing:

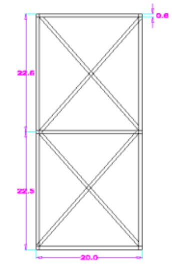


Figure16: X – Bracing:

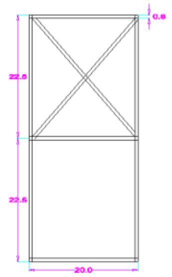


Figure17: Alternate X – Bracing:

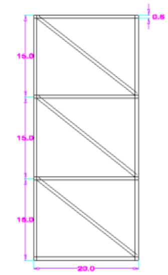


Figure18: 3 Level Diagonal Bracing:

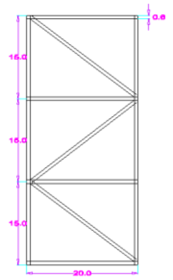


Figure19: 3 Level Diagonal Bracing:

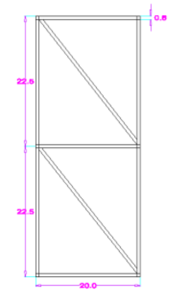


Figure20: Diagonal Bracing:

The plans of the above stagings are given below:

ISSN 2348 – 8034
Impact Factor- 5.070

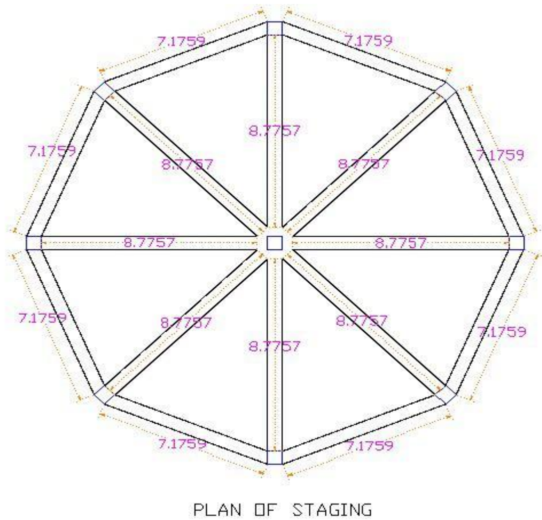
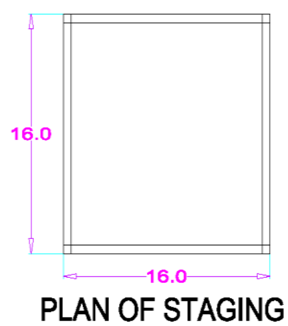


Figure 21: OCTAGON



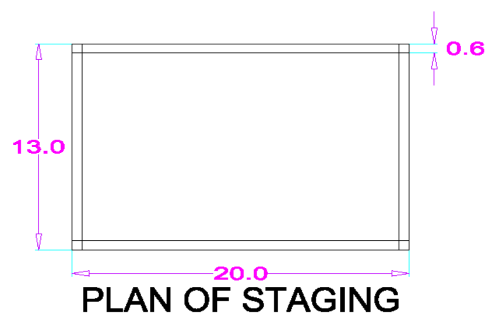


Figure 22: SQUARE ***Figure 23: RECTANGLE***

VI. RESULTS AND DISCUSSIONS

The prototype models were tested in a biaxial table, the suitable h/d ratio was found to be within 0.45-0.47, the time of collapse was analyzed and the best type of staging and bracing condition was found to be octagon as also by the evolution of form.

VII. CONCLUSION

The most preferred type of staging is Frame type staging and under various bracing conditions the best type of bracing is selected as Octagon with diagonal type of bracing. The h/d ratio is found to be between the range of 0.45-0.47 Hence, by selecting such geometry conditions during the construction of a Overhead water tank considering the seismic safety provides a safer structure and availability of water during emergent situations; as the main reason for failure of over head water tanks was due to the lack of knowledge in the design of tanks and improper selection of stagings.

ISSN 2348 – 8034
Impact Factor- 5.070

REFERENCES

1. *C. S. C Dutta, "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging", Soil Dynamics and Earthquake Engineering– Vol19. pp. 183 – 197, (2000)*
2. *Prof. Sudhir K. Jain, "Guidelines for seismic design of liquid storage tanks", Indian Institute of Technology, Kanpur & NICEE, (2007)*
3. *Andreas Stavridis, Benson Shing, Joel Conte , "Design, Scaling, Similitude and Modeling of Shake-table test structures", University of California, San Diego, (2010)*
4. *Jordan E. Barnes, "Seismic Modeling with an Earthquake Shake Table", Linfield College, (2012)*
5. *Chirag N. Patel, H. S. Patel, "Supporting systems for RC elevated water tanks", International Journal of Advanced Engineering Research and Studies ISSN: 2249 – 8974, (2012)*
6. *Dr. A. K. Hashmi, Dr. D. V. Pattewar, "Impact of sloshing motion of water on ground supported circular liquid storage tank" – International Journal of Engineering Research & Technology ISSN: 2278 – 0181, (2013)*
7. *Prof. A. Rajan 2 "Necessity of dynamic analysis of elevated water storage structure using different bracing in staging", International Journal of Research in Advent Technology – Vol2. eISSN: 2321 – 9637, (2014)*
8. *Dr. Mahendra S. Kadu2, "Seismic investigation of RC Elevated water tank for different types of staging patterns", International Journal of Engineering Trends and Technology – Vol14. eISSN: 2231 – 5381, (2014)*
9. *G. P. Deshmukh, Ankush K.Patekhede,"Analysis of elevated water storage structure using different staging systems" – International Journal of Research in Engineering and Technology ISSN: 2319 – 1163, (2015)*
10. *B. Sravani "Performance of elevated circular water tank in different seismic zones" – International Journal for Technological Research in Engineering ISSN: 2347 – 4718, (2016)*