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Lateral Stability Improvement for Elevated Steel Water Storage Reservoir in Severe Wind and Earthquake Zone using Etabs

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ABSTRACT

Elevated water tanks are most commonly used in storing of water to supply at a certain height for pressurizing in the water distribution system for various purposes. A major irregularity is along the height of the structure due to heavy water mass on the top and phenomenon of hydrodynamic interaction between the fluid and the walls of the tanks, hence the effect on the whole structure, with the accelerating in horizontal causing the sloshing effect, which cannot be neglected because of the various research done on the elevated tank, which showed issues which a significant problems in terms of modeling, stability and design of the structure.

So, In the present study, the attempts are made to study the behavior of hydrodynamic effect (Impact of liquid sloshing) in water full and empty condition on elevated steel water storage reservoir in sever wind and earthquakes zone of India. The analysis is done with Equivalent static method, Response spectrum method and also P-Delta effect with different combination of lateral and horizontal braced supporting frame systems. For modeling and analysis were performed using Etabs Ultimate 17.0.1 –Finite element software. The results of the analysis, in terms of Displacement and Time period, are obtained. For a square tank capacity of 150 m^3.

Frame with wall supported on cantilever staging and X type diagonal lateral bracing with intermediate horizontal bracing is performed very well and it is most efficient in terms of material used for construction. Saving steel material in horizontal tie beams, Lateral bracing, and intermediate horizontal bracing. Time period decreased for the frame with intermediate horizontal bracing, hence increasing the overall stiffness of the frame and making the frame more stable in terms of displacement.

KEYWORDS: *Elevated water tanks, Frame Staging, Sloshing effect, Hydrodynamic pressure, Displacement, time period*

1. INTRODUCTION

Steel tanks are used for the storage of water and other liquids, acids, gasoline, alcohols, etc. Indian sub-continent is highly vulnerable to a natural disaster like earthquakes, drought, severe cyclones, flood, etc. According to IS 1893(part1):2016, more than 60% of India is prone to earthquake. And many elevated water tanks suffered damage to their Frame in Bhuj earthquakes of 2011.

In rural or urban areas elevated steel water storage reservoir forms an integral part of the water supply scheme for the public, so its functionality pre and post-earthquake and in cyclonic strong wind remain equally important.

Elevated steel water storage reservoir is most commonly used in storing of water to supply at a certain height for pressurizing in the water distribution system for various purposes. A major irregularity is along the height of the structure due to heavy water mass on the top and phenomenon of hydrodynamic interaction between the fluid and the walls of the tanks, hence the effect on the whole structure, with the accelerating in horizontal causing the sloshing effect, which cannot be neglected because of the various research done on the elevated tank, which showed issues which a significant problems in terms of modeling, stability and design of the structure.

Damages and failure to elevated steel water storage reservoir with both types of supporting system stated above are noted during an earthquake and strong cyclonic winds. Hence it becomes necessary to evaluate the optimum selection of the supporting system for the predefined requirements of elevated steel water storage reservoir. This project work is to study the hydrodynamic effect (Impact of liquid sloshing) on elevated steel water storage reservoir in severs wind and earthquakes zone of India, with different and combination of lateral and horizontal braced supporting systems. All the seismic analysis parameters are evaluated using the recommended procedure in latest code as well as in IIT-GSDMA (Guidelines for seismic design of liquid storage tanks), and is concentrated mainly to the Sloshing effect that is happening in the water storage tank during severe earthquake and strong cyclonic winds zone using Etabs Ultimate 17.0.1 –finite element software.

2. LITERATURE REVIEW

R V Raikar, Keerti M. Telsang, Kiran M. Malipatil, KLEMSSCET Belgavi : In this paper seismic analysis by Response spectrum method is carried out, with and without the bracing configuration.in considering different earthquakes zones (zone 2 to 5) and soil conditions. The analysis is carried out using STAAD-PRO V8i software.

The result for bare and braced frame tanks, which in terms of the time period, base shear and displacement for different seismic zones and soil condition are compared.
The results obtained are:

1. The 3&4th story of water tank showed better performance of the 2 storey in terms of displacement.
2. An increase overall stiffens is increased in the braced frame the unbraced one.

R. Livaoğlu1 and A. Doğangün: This paper specifically deals with the response of supporting Frame system of water tower he has considered cylindrical supporting and frame supporting system. The seismic analysis was performed considering fluid-structure interaction.

In the study displacement base lagrangian approach is selected model the fluid elevated tank interaction study. Three transitional degrees of freedom at each eight nodes is taken.

By the analysis carried out, Author calculated the peak response and corresponding time period where the maximum roof displacement, sloshing displacement, base moment &base shear.

The results obtained are:

1. Result found that at 9 &10 second maximum response are obtained for fame support & for cylindrical support at 5 &10 sec.
2. For frame support roof displacement are high.
3. Sloshing response is also affected so cannot be neglected o seismic analysis.
4. Cylindrical shaft system may be used in the region having seismic risk.

Anand H Shrigondekar and Rajesh D Padhye: The Basic plot behind this paper is to analysis of concert elevated water tank of 400m^3.For a different type of horizontal bracing arrangement at Frame. Analyzed by the linear dynamic method and seismic response method .tank full, partially, empty case.

Conclusions are:

1. Octagonal &radial bracing has higher base shear.
2. As the bracing level increase, storey displacement goes on decreases.
3. Less storey displacement has seen in octagonal and radial bracing.
4. As the level of bracing increase maximum Bending moment at bottom of Colum decreases.
5. Higher Base shear, Max BM &storey displacement seen in full as compared to half and empty tank.

Kulvendra Patel: In this paper involve the analysis of the entire water structure in different wind and earthquake zone by STAADPRO by Response spectrum method provide displacement, bending moment, Axil force, torsion.

The results obtained are:

1. The shape of the model becomes complicated due to higher modes. And modal frequency increase and requires more energy to excite these modes than the simples low-frequency modes.
2. More than 90% of the total seismic weight obtained for different modal in a different direction.

3. OBJECTIVES OF THE STUDY

The objectives of the study are:

1. And the main objective of this project work is to study the hydrodynamic effect (Impact of liquid sloshing) on elevated steel water storage reservoir in sever wind and earthquakes zone of India, with different and combination of lateral, intermediate horizontal braced supporting frame.
2. And study the empty and full reservoir in severs wind and earthquakes zone of India, with different and combination of lateral, intermediate horizontal braced supporting frame.
3. And to compare the results obtained from the analysis in terms of displacement and time period with different and combination of lateral, intermediate horizontal braced supporting frame.
4. And to compare the results obtained from the analysis in terms of displacement and time period of the frame with wall supported on cantilever staging and X type diagonal lateral bracing with intermediate horizontal bracing.
5. Suggesting the improved lateral stability braced supporting frame for elevated steel water storage reservoir in sever wind and earthquakes zones of India.

4. MODEL DESCRIPTION AND ANALYSIS

- A Steel water reservoir container of 1,50,000 liter (150m^3)
- Height 2m + 0.2 m as freeboard
- Square shape
- Total height up to staging 18m
- Number of storey 6
- Provide the two bay of 4.5c/c and Total 10 columns

4.1 Frames

In the present study total, seven Frames are modeled with full and empty tank using of Etabs Ultimate 17.0.1.

1. Frame without lateral bracing and with intermediate horizontal bracing.
2. Frame with X type diagonal lateral bracing without intermediate horizontal bracing.
3. Frame with X type diagonal lateral bracing and intermediate horizontal bracing.
4. Frame with chevron type lateral bracing without intermediate horizontal bracing.
5. Frame with chevron type lateral bracing and intermediate horizontal bracing.
6. Frame with chevron eccentrical type lateral bracing and intermediate horizontal bracing.
7. Frame with wall supported on cantilever staging and X type diagonal lateral bracing with intermediate horizontal bracing.

4.2 Earthquake parameters:

Table1

CONSTANT	VALUES
Zone	V
Importance	1.5
ordinary moment resisting frame (OMRF)	3.5
special moment resisting frame(SMFR)	4
Soil type	Medium

4.3 Wind parameters:

Table2

CONSTANT	VALUES
Zone	V
Wind speed	50 m/s
Risk Coefficient (k1Factor)	1.5
Terrain Category (K2)	1
Topography (k3Factor)	1
Importance Factor for Cyclonic Region (k4)	1.3

5. Result obtained from the analysis

Frame without lateral bracing and with intermediate horizontal bracing.

The displacement for full and empty condition is 2.3m and 1.2m The time period for full and empty condition is 0.01 and 1.6

FRAME1. Frame with X type diagonal lateral bracing without intermediate horizontal bracing.

FRAME2. Frame with X type diagonal lateral bracing and intermediate horizontal bracing.

FRAME3. Frame with chevron type lateral bracing without intermediate horizontal bracing.

FRAME4. Frame with chevron type lateral bracing and intermediate horizontal bracing.

FRAME5. Frame with chevron eccentrical type lateral bracing and intermediate horizontal bracing.

FRAME6. Frame with wall supported on cantilever staging and X type diagonal lateral bracing with intermediate horizontal bracing.

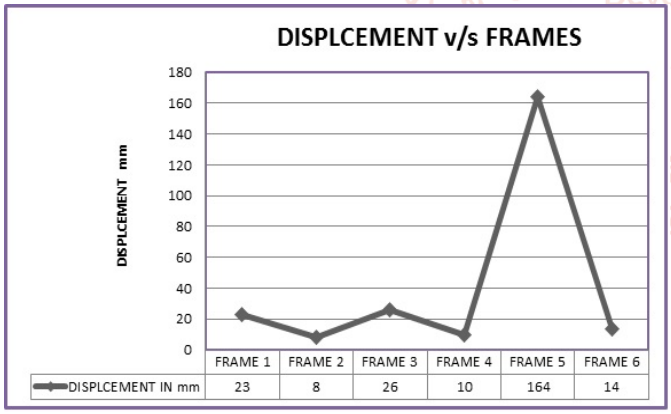

Fig.1 DISPLCEMENTv/sFRAMES FOR TANK EMPTY CONDITION

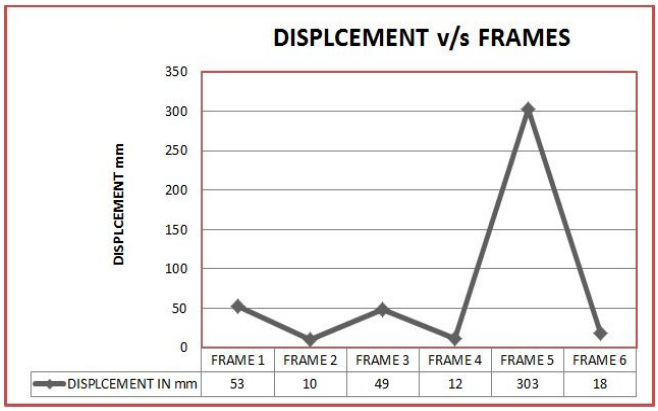

Fig.2 DISPLCEMENT v/s FRAMES FOR TANK FULL CONDITION

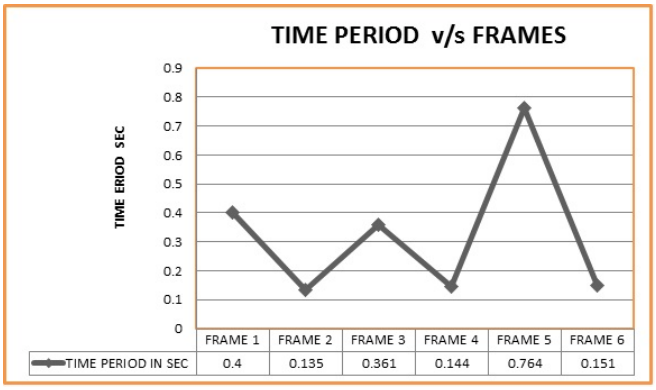

Fig.3 TIME PERIOD v/s FRAMES FOR TANK EMPTY CONDITION

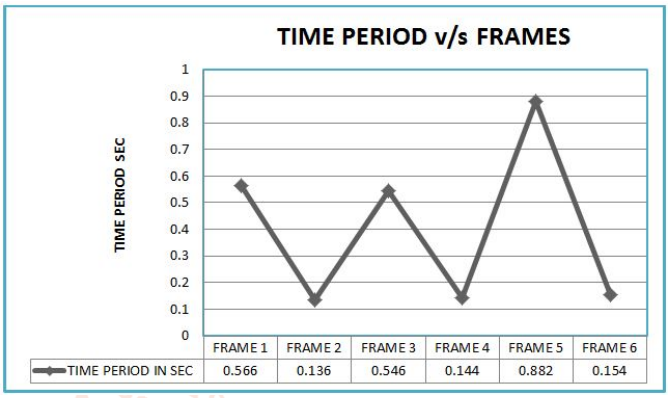

Fig.4 TIME PERIOD v/s FRAMES FOR TANK FULL CONDITION

6. Improved lateral stability

- Frame with wall supported on cantilever staging and X type diagonal lateral bracing with intermediate horizontal bracing is performed very well and it is the most efficient in terms of material used for construction. Saving steel material in horizontal tie beams, Lateral Bracing, and intermediate horizontal bracing.

- The cantilever portions on either side behaved like overhang and pushing the wall inside so controlling the lateral sway of the frame.

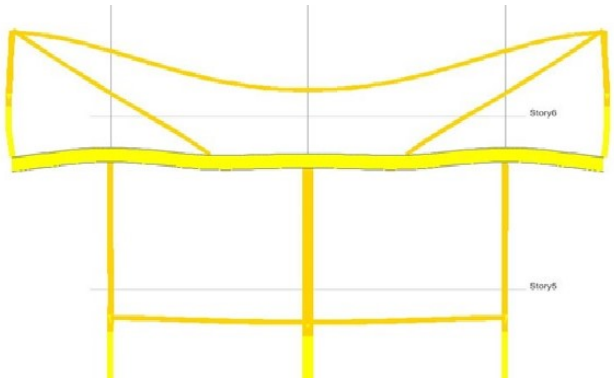

Fig.5 Overhang behavior on either side of staging

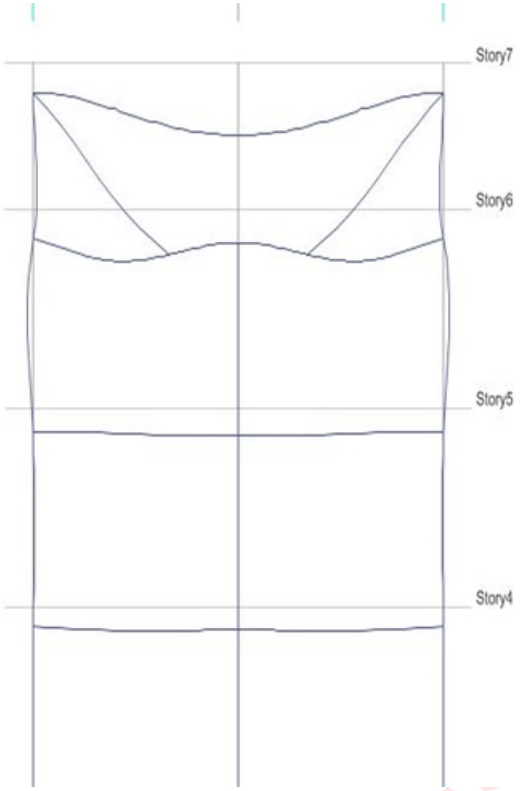

Fig.6 Normal simply supported staging

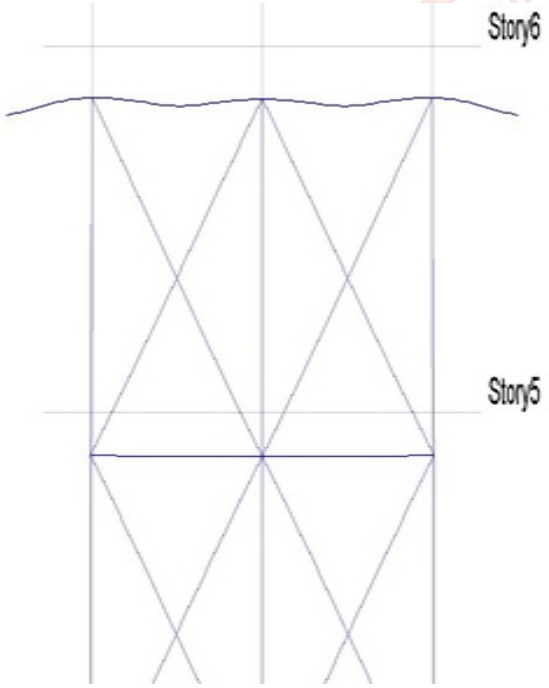

Fig.7 Cantilever staging

7. CONCLUSIONS

- The result shows that the bare frame is highly unacceptable for framing of elevated steel water storage reservoir in severe wind and earthquakes zones.
- Result for the empty tank condition is low value when compared to the tank full in terms of both displacement and time period.
- The displacement responses are changed by the combination of lateral and horizontal braced supporting frame system as expected. However, the change in the displacement values are considerably affected the frame system behavior.
- And also the introduction of intermediate horizontal bracing can effectively reduce the displacements of the frame.
- Frame with chevron eccentrical type lateral bracing with intermediate horizontal bracing did not perform well as compared to the other braced frames
- Time period decreased for the frame with intermediate horizontal bracing, hence increasing the overall stiffness of the frame and making the frame more stable in terms of displacement.
- Frame with wall supported on cantilever staging and X type diagonal lateral bracing is performed very well and it the most efficient in terms of material used for construction. Saving steel material in horizontal tie beams, Lateral Bracing, and intermediate horizontal bracing.

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