Non-Linear Time History Analysis of An Elevated Water Tank

Miss. Nikita Gholap[1], Prof M.N.Shirsath[2]
[1] Dept of Civil Engineering
[2]Professor, Dept of Civil Engineering
G. H. Raisoni College of Engineering

Abstract- *This report Elevated water tank is a water storage facility supported by a tower and constructed at an elevation to provide useful storage and pressure for a water distribution system. The height of the tower provides the pressure for the water supply system. During the high peak hours of the water system, the static potential reserved in the tank will be used to provide the pressure in the water pipes and helps the pumping systems by maintaining the necessary water pressure without increasing pumping capacity. They also present enough water pressure for firefighting when the pumping systems are not sufficient to provide large amount of water needed for fire extinguishing. In public water distribution system, Elevated water tanks are generally used being an important part of a lifeline system. Due to post earthquake functional needs, seismic safety of water tanks is of most important. Elevated water tanks also called as elevated service reservoirs (ESRs) typically consists of a container and a supporting tower. Staging in the form of reinforced concrete shaft and in the form of reinforced concrete column-brace frame are commonly deployed. The column-brace frame type of staging is essentially a 3D reinforced concrete frame which supports the container and resists the lateral loads induced due to earthquake or wind. In major cities and also in rural areas elevated water tanks forms an Integral part of water supply system. The elevated water tanks must remain functional even after the earthquakes as water tanks are most essential to provide water for drinking purpose . Aim of the present study is to bring out the differences in seismic behavior of column beam (Building) frame and column-brace (staging) frame in the post-elastic region and to quantify their ductility. In addition, nonlinear dynamic analysis is also performed to bring out the differences in the nonlinear dynamic behavior of two types of frames. These analysis and design of elevated water tank of different type such as rectangular and circular water tank by using software SAP2000 by using various bracing system.*

Keywords- Elevated Water tank ,SAP 2000 , Bracing System

I. INTRODUCTION

Elevated water tanks are commonly used in public water distribution system. Being an important part of lifeline system, and due to post earthquake functional needs, seismic safety of water tanks is of considerable importance. Elevated water tanks also called as elevated service reservoirs (ESRs) typically comprises of a container and a supporting tower (also called as staging). Staging in the form of reinforced concrete shaft and in the form of reinforced concrete column-brace frame are commonly deployed. The column-brace frame type of staging is essentially a 3D reinforced concrete frame which supports the container and resists the lateral loads induced due to earthquake or wind. Aim of the present study is to bring out the differences in seismic behaviour of column beam (Building) frame and column-brace (staging) frame in the post-elastic region and to quantify their ductility. In addition, nonlinear dynamic analysis is also performed to bring out the differences in the nonlinear dynamic behavior of twithout types of frames. Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. A twithout or three dimensional model which includes bilinear or tri-linear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially.

1.1 Problem Statement

In the present study water tank is designed for Laxmi Township at Ranjangaon MIDC

- Design Data -
- Total Structure=200
- Minimum water capacity required=200 X 5 X 135=135000 lit.
- Considering 10% commercial use extra.
- Total Capacity=150000 lit. =150m3
- Staging Height=20m

- Assume height of tank=4m (Ref.IS 3370)
- Thickness of CROSS BRACING wall=180mm
- Thickness of base slab=200mm
- For rectangular water tank:
- CAPACITY=L*B*H
- 150=L*B*4
- Assume Aspect Ratio L/B = 2
- Therefore,
- L = 9m
- B = 4.5m
- For circular water tank:
- Capacity = 3.14/4*D2*4
- Diameter - 7m
- Beam size - 230x600
- Column size - 230x650
- Earthquake zone - III
- Time history – Bhuj
- Soil – Medium stiff
- Depth of Foundation - 1.5m

1.2 Project Objectives

Aim of the present study is to bring out the differences in seismic behaviour of column beam (Building) frame and column-brace (staging) frame in the post-elastic region and to quantify their ductility To meet these objectives, the tasks undertaken as a part of this project were as follows:

1. The analysis and design of elevated water tank of different type such as rectangular and circular water tank by using software
2. To compare response of braced and unbraced water tank to lateral loads and identify the suitable bracing systems for resisting the seismic loads efficiently.
3. To study the parameter such as displacement, base shear, velocity and acceleration are compared along with the parameter obtained from seismic analysis.
4. To study seismic analysis of elevated water tank by using various bracing system.

II. LITERATURE REVIEW

The dynamic behavior of water tanks G. W. Housner[1] Studied simplified formulae to calculate earthquake forces for a water tank considering it as a without-mass system is given. A dynamic analysis of tanks should take into account the motion of water relative to the tank as well as motion of the tank relative to the ground. If a closed tank is completely filled with water or completely empty, it is essentially a one-mass structure. In this case, the dynamic behavior of elevated water tank may be quite different. In the analysis the impulsive and convective pressures are examined separately.

Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging, S.C. Dutta, S.K. Jain [2] Studied elevated water tanks in past earthquakes (including 1952 Kern County and recent 1993 Killari earthquakes) has highlighted the importance of this problem. It is established that these structures may have amplified torsion-induced rotation if their torsional-to-lateral natural period ratio t is close to 1 and amplified displacement of structural elements due to the coupled lateral torsional vibration if t is within the critical range 0:7,t, 1:25: one reinforced concrete elevated water tank collapsed vertically downwards, burying the six supporting columns directly underneath the bottom slab of its container during the 1993 Killari, India This may cause progressively increasing localized damage in the yielded structural elements due to strength deteriorating characteristics of concrete under cyclic loading during an earthquake.

Effect of staging height on the seismic performance of RC elevated water tank B.Devadanam[3] Found that reinforced concrete elevated water tanks with frame staging, has shown better seismic resistance than reinforced concrete elevated water tanks with shaft staging. These can be attributed to the seismic energy absorption capacity of the frame staging. Hence this study is primarily focused on understanding the seismic behavior and performance characteristics of elevated water tank with frame type staging. The modal characteristics (mode shapes and the modal participation mass ratio) of the structure were ascertained using SAP2000. paragraph

III. METHODOLOGY

The main objective of this study is to examine the behavior of overhead circular water tank supported on frame staging considering different modelling systems. All the above cases are analyzed for five different earthquake records i.e. time history analysis. Th

1. Nonlinear Time History Analysis

Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments, Δt– steps. During each step the response is evaluated from the initial conditions existing at the beginning of the step (displacements and velocities) and the loading history in the interval.

2. Bracing

The most common reason for providing bracing on a steel-concrete composite structure is for the control of buckling in the main beams during unhealthy conditions.

3. Types of bracing

Single Diagonals Bracing Trussing, or triangulation, is formed by inserting diagonal structural members into rectangular areas of a structural frame, helping to stabilize the frame. If a single brace is used, it must be sufficiently resistant to tension and compression.

4. Cross-bracing

Cross-bracing (or X-bracing) uses t without diagonal members crossing each other. These only need to be resistant to tension, one brace acting to resist sideways forces at a time depending on the direction of loading. As a result, steel cables can also be used for cross-bracing.

5. V(Knee) Bracing

This involves without diagonal members extending from the top without corners of a horizontal member and meeting at a center point at the lower horizontal member, in the shape of a V. Inverted V-bracing (also known as chevron bracing) involves the without members meeting at a center point on the upper horizontal member's analysis is carried out using SAP 2000 software.

IV. RESULTS AND DISCUSSION

Table -1: Circular Water Tank

Circular Water Tank			
Sr No	**Name**	**Type**	**Max Value**
1	Circular Water Tank With Knee Bracing	Displacement(Ux)	6.66
		Velocity	$2.24x10^{-2}$
		Acceleration	1.02
		Base Shear	$6.15x10^{3}$
2	Circular Water Tank With Single Bracing	Displacement(Ux)	6.28
		Velocity	$2.22x10^{-2}$
		Acceleration	$9.82x10^{-1}$
		Base Shear	$8.83x10^{3}$
3	Circular Water Tank With Double Bracing	Displacement(Ux)	6.64
		Velocity	$2.24\ x10^{-2}$
		Acceleration	1.01
		Base Shear	$6.15x10^{3}$
4	Circular Water Tank Without Bracing	Displacement(Ux)	7.49
		Velocity	$2.70x10^{-2}$
		Acceleration	1.09
		Base Shear	$5.26x10^{3}$

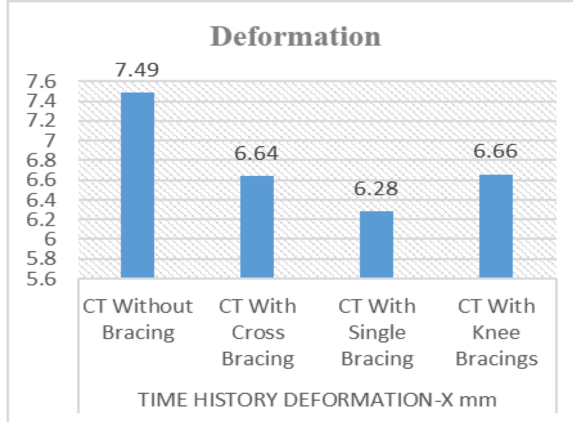

Chart -1 Deformation Vs Various Bracing Systems

Table -2: Time History Deformation

TIME HISTORY DEFORMATION-X mm			
CT Without Bracing	CT With Cross Bracing	CT With Single Bracing	CT With Knee Bracings
7.49	6.64	6.28	6.66

In this Fig. max deformation is 7.49 Circular tank without bracing. Difference between Circular tank without bracing and with single bracing is 15%.

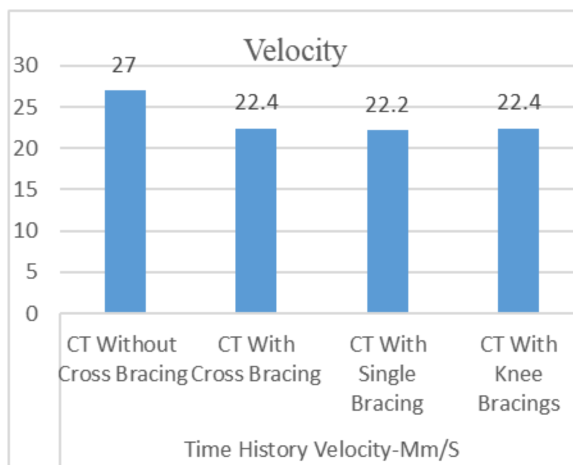

Chart -2 Velocity Vs Various Bracing Systems

Table -3 Time History Velocity

Time History Velocity-Mm/S			
CT Without Cross Bracing	CT With Cross Bracing	CT With Single Bracing	CT With Knee Bracings
$2.70x10^{1}$	$2.24x10^{1}$	$2.22x10^{1}$	$2.24x10^{1}$

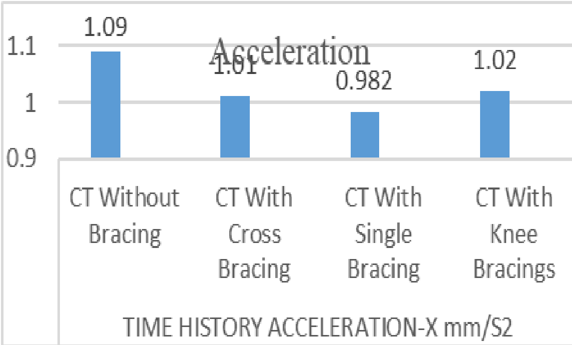

Chart -3 Velocity Vs Various Bracing Systems

Table -4: Time History Acceleration

TIME HISTORY ACCELERATION-X mm/S2			
CT Without Bracing	CT With Cross Bracing	CT With Single Bracing	CT With Knee Bracings
1.09	1.01	0.982	1.02

In this Fig. max acceleration is 1.09 mm/s^2 Circular tank without bracing. Difference between circular tank without bracing and Circular with single bracing is 10%.

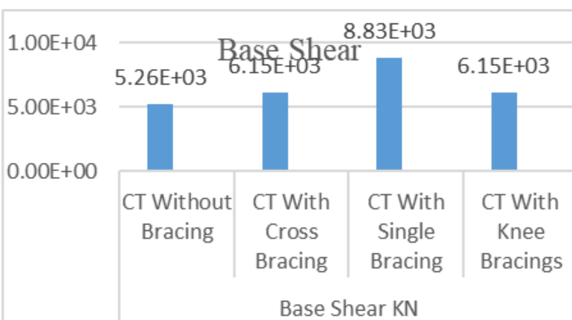

Chart -4 Base Shear Vs Various Bracing Systems

Table -5: Base Shear

Base Shear KN			
CT Without Bracing	CT With Cross Bracing	CT With Single Bracing	CT With Knee Bracings
5.26E+03	6.15E+03	8.83E+03	6.15E+03

In This Fig. Max. Base Shear is 8.83x10^3 KN obtain in single bracing system and Min. in without cross bracing. Using bracing for water tank increase the Base Shear.

The difference between the CT cross bracing and without bracing is 18%. The difference between the CT cross bracing and without bracing is 18%.

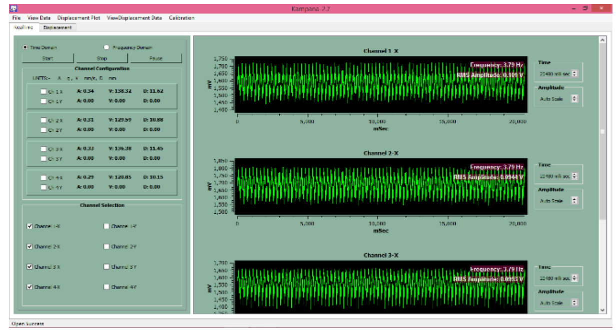

Chart -5: Elevated Water Tank without bracing

In practical steel water tank model without bracing fails at Richer scale 8.1. Which is shown low strength towards seismic force compare to braced structure

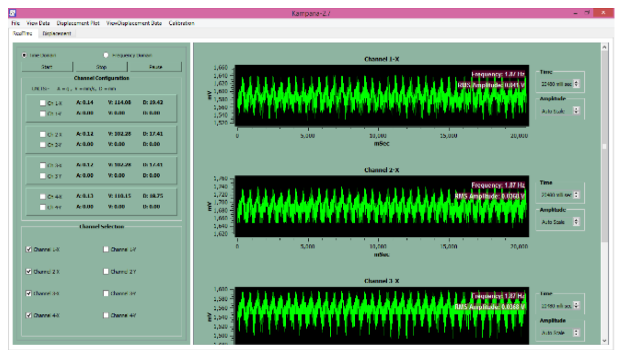

Chart -6 Elevated Water Tank with bracing

In practical steel water tank model with bracing fails at Richer scale 10.8, Hence Bracing system improvises seismic capacity of structure.

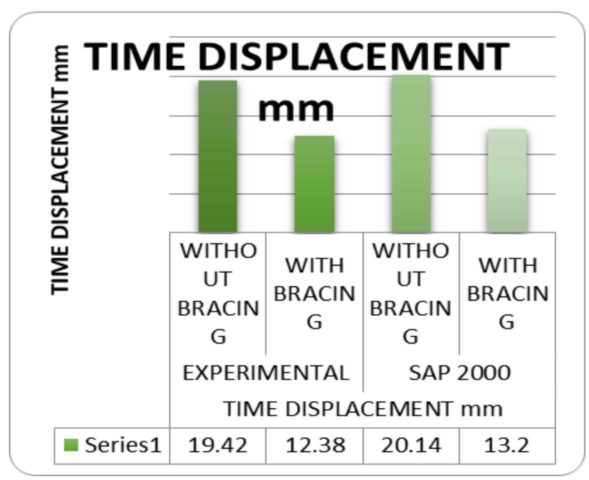

Chart -7: Time Displacement

From this Fig. experimental model without bacing displacement is 19.42 and with bracing 12.38. Similarly SAP model without bracing 20.14 and with bracing 13.2 hence it conclude that bracing system contribute in reduction of displacement.

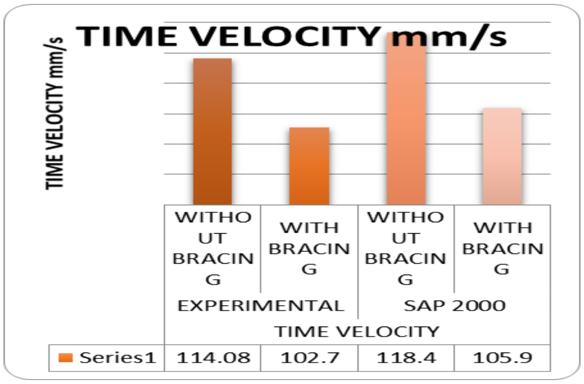

Chart -8 velocity in practical model without bracing is 114.08 and with bracing 102.7; In SAP model without bracing 118.4 and with bracing is 105.9.

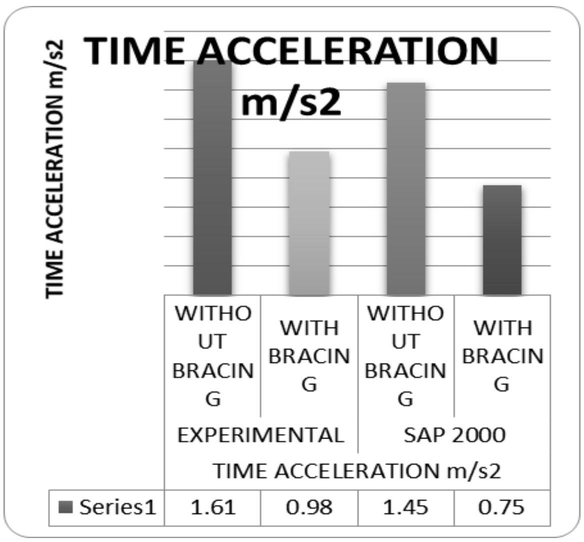

Chart -9 : Time Acceleration

From this Fig. accelration in practiacl model with bracing and without bracing is diffeence is 40% reduction in aceeleation. In SAP-2000 same modelling for with bracing and without bracing is 50%

V. CONCLUSIONS

In the given study the elevated water tank with various bracing systems are studied for staging height 20m.Firstly water tank model is designed for 150m3 capacity and for time history analysis bhuj earthquake is considered. Various models of bracing systems are proposed and following conclusions are made.

1) For the time-displacement results in SAP 2000,difference between rectangular water tank without bracing and rectangular water tank with single bracing is 42%,because the diagonal bracings increase resistance to lateral bracings
2) For the time-velocity results in SAP 2000Difference between rectangular water tank without bracing and rectangular water tank with single bracing is 30% because the diagonal bracings increase resistance to lateral bracings
3) For the time-acceleration results in SAP 2000Difference between circular water tank without bracing and rectangular water tank with single bracing is 5% because the diagonal bracings increase resistance to lateral bracings
4) For circular water tank without bracing max deformation is 7.49 mm. Difference between circular water tank without bracing and circular water tank with single bracing is up to 15-20%
5) By performing the analysis of circular and rectangular water tanks with different bracing systems we came to the conclusion that rectangular water tank is more sustainable as compared to circular water tank in accordance to displacement. And the displacement of circular and rectangular water tank is 6.28mm and 2.26mm respectively.
6) In accordance to velocity and acceleration parameter circular water tank gives better results than rectangular water tank.
7) The bhuj intensity is considered in zone IV which has time period of 132 sec and for this non linear dynamic analysis the circular water tank with bracings is observed to be most effective as its stiffness is observed more than rectangular water tank.

REFERENCES

[1] G. W. Housner (1963), "The dynamic behaviour of water tanks", Bulletin of the Seismological Society of America, Vol.53, No.2, pp 381-387.

[2] B. Devadanam and M K Ratnam (2015), "Effect of staging height on the seismic performance of RC elevated water tank",International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 1, January 2015.

[3] S.C. Dutta, S.K. Jain, and C.V.R. Murty (2000), "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging", Soil Dynamics and Earthquake Engineering, Vol.19 (2000) pp183–197.

[4] R. Livaoğlu andA. Doğangünk (2008), "Sloshing response of the cylindrical elevated tanks with frame staging system on different soil conditions", Technical University, Department of Civil Engineering. 61080,Gumushane, Turkey. Institute of Thermo mechanics, Prague, 2008.

[5] S. M. Maidankar, G.D. Dhawale, and S.G. Makarande (2015), “Seismic analysis of elevated circular water tank using various bracing systems”, International Journal of Advanced Engineering Research and Science Vol-2, Issue-1, Jan.- 2015

[6] P. M.Vijay and A. Prakash (2014), “Analysis of sloshing impact on overhead liquid storage structures”, IMPACT: International Journal of Research in Engineering & Technology Vol. 2, Issue 8, Aug 2014, pp127-142

[7] M.M. Ranjbar and R. Madan (2013), “Seismic Behavior Assessment of Concrete Elevated Water Tanks”, Journal of Rehabilitation in Civil Engineering pp 69-79.

[8] K. J. Dona Rose, M. Sreekumar and A. S. Anumod (2015), “A Study of Overhead Water Tanks Subjected to Dynamic Loads”, International Journal of Engineering Trends and Technology (IJETT) – Volume 28 Number 7 - October 2015.

[9] S. A. Patil, A. H. Kumbhar, and T. F. Mujawar (2016), “Elevated Water Tank Under Sloshing Effect”, International Journal for Scientific Research & Development Vol. 4, Issue 05, 2016

[10] M. V. Waghmare and S. N. Madhekar (2013), “Behaviour of Elevated Water Tank Under Sloshing Effect”, International Journal of Advanced Technology in Civil Engineering, Vol.-2, Issue-1, 2013.

[11] M. R.Wakchaure and S. S. Besekar (2014), “Behaviour of Elevated Water Tank Under Sloshing Effect”, International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 2, February – 2014.

[12] S. K. Jangave and P. B. Murnal (2014), “Structural Assessment of Circular Overhead Water Tank Based on Frame Staging Subjected to Seismic Loading”, International Journal of Emerging Technology and Advanced Engineering, Vol. 4, Issue 6, June 2014.

[13] D. Virkhare and L. Vairagade (2015), “Pushover Analysis of Water Tank Staging”, Civil Engineering Department, G.H.R.A.E.T N Structural Consultant, Techpro Consultancy, Nagpur, Maharashtra, India IRJET/July 2015.

[14] M. Masoudi, (2012), “Evaluation of Response Modification Factor (R) of Elevated Concrete Tanks”, Engineering Structures, Vol.39 (2012) pp199-209.

[15] F. Omidinasab and H. Shakib(2008), “Seismic Vulnerability of Elevated Water Tanks Using Performance Based-Design” The 14th Withoutrld Conference on Earthquake Engineering, October 12- 17, 2008, Beijing, China.

[16] M. Jabar and H. S. Patel (2012), “Seismic behaviour of RC elevated water tank under different staging pattern and earthquake characteristics”, International Journal of Advanced Engineering Research and Studies, Vol.1 April-June, 2012, pp293-296.

[17] S.C. Dutta, S.K. Jainb and C.V.R. Murty (2000), “Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging”,Soil Dynamics and Earthquake Engineering , Vol.19 (2000) pp183–197.

[18] P. K.Malhotra, T.Wenk and M.Weiland , “Simple Procedure of Seismic Analysis of liquid-Storage Tanks”, Structural Engineering, Vol. 3, pp197–201.

[19] D.C. Rai (2001), “Performance Of Elevated Tanks In Mw 7.7 Bhuj Earthquake of January 26, 2001”,International Conference on Seismic Hazard With Particular Reference to Bhuj Earthquake of January 26, 2001, Oct. 3–5, New Delhi..