Non-Linear Time History Analysis of An Elevated Water Tank

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Abstract- *In terms of seismic resilience, it was determined that reinforced concrete raised water tanks with frame staging outperformed reinforced concrete elevated water tanks with shaft staging. This might be owing to the frame staging's capacity to absorb seismic energy. As a consequence, the major purpose of this study is to learn more about the seismic behaviour and performance of raised water tanks with frame staging. Furthermore, circular tanks have the least surface area for a given tank size when compared to other forms. As a consequence, the material required for a circular water tank is less than that required for other forms. As a consequence, a circular water tank was selected, and seismic study of raised RC circular water tanks was performed according to IITK-GSDMA criteria, with the water tank's behaviour examined for various factors such as zone factor, soil condition, and different staging heights. The modal properties of the structure were determined using SAP 2000. (mode shapes and modal participation mass ratio).*

I. INTRODUCTION

1.1 General

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 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 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.

Fig. 1 : Bending Shear Failure in beam

So far, there has been no experimental test program (such as shaking table) that has studied the nonlinear response of RC pedestals to the strong ground motions.

1.2 Performance of elevated water tank

Geological and seismological discoveries during the 20th century have helped in initiating the development of seismic building codes and earthquake resistant buildings and structures. The improvement in seismic design requirements has led to more robust, safe and reliable buildings. Due to the earthquake many buildings collapsed killing thousands of people. Therefore, to protect the earthquake effects/earthquake damages to the buildings and to protect the life of people, it's important to use seismic control techniques.

1.3 Various analysis systems

The analysis of isolation system can be done by following ways:

1.3.1. Linear Static Analysis: Linear analysis methods give a good indication of the elastic capacity of the structures and indicate where first yielding will occur. The linear static method of analysis is limited to small, regular buildings.

1.3.2 Linear Response Spectrum Analysis: Linear response spectrum analysis is the most common types of analysis used. This is sufficient for almost all isolation system based on LRB and / or HDR bearings.

1.3.3 Non-Linear Static Analysis: In a nonlinear static analysis procedure, the building model incorporates directly the nonlinear force-deformation characteristics of individual's components and elements due to inelastic material response. The nonlinear force-deformation characteristics of the building are represented by a Pushover curve, i.e. a curve of base shear vs. top displacement, obtained by subjecting the building model to monotonically increasing lateral forces or increasing displacements, distributed over the height of the building in correspondence to the first mode of vibration until the building collapses.

1.4 Aim and Objective

The main objectives of the present research work may be summarized as follows:

The analysis and design of elevated water tank of different type such as rectangular and circular water tank by using software

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

II. LITERATURE REVIEW

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

Studied simplified formulae to calculate earthquake forces for a water tank considering it as a twithout-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. Usually, the tanks have free water surfaces and therefore, there will be sloshing of water during an earthquake and this makes the tank essentially a twithout-mass structure. In this case, the dynamic behaviour of elevated water tank may be quite different. For some cases, the sloshing effect might be predominant whereas for some it might not be dominating. Therefore, A detailed understanding of dynamic behaviour of tanks is required. As the fluid containers are important in nuclear reactor installation, a detailed presentation of without rk able method for predicting the dynamic behaviour of the fluid is given by author.

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

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. Elevated water tanks, with their broadly axi-symmetric geometry and mass distribution, should have no considerable eccentricity between centre of mass and centre of stiffness. Hence, they do not appear to be prone to torsion.

B.Devadanam , M K MV Ratnam"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, 2015.

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 behaviour and performance characteristics of elevated water tank with frame type staging. Moreover, circular tanks have minimum surface area when compared to other shapes for a given capacity of the tank. Hence the quantity of material required for circular water tank is less than that required for other shapes. Hence, a circular water tank has been adopted and seismic analysis of elevated RC circular water tanks has been performed as per IITK-GSDMA guidelines and behaviour of the water tank for various parameters viz., zone factor, soil condition, different staging heights have been analyzed. The modal characteristics (mode shapes and the modal participation mass ratio) of the structure were ascertained using SAP2000.

S. M. Maidankar, G.D. Dhawale"Seismic analysis of elevated circular water tank using various bracing systems", International Journal of Advanced Engineering Research and Science Vol-2, 2015

From the very upsetting experiences of few earthquakes, like Bhuj earthquake (2001) in India, R.C.C. elevated water tanks were heavily damaged or collapsed. The main finding of this study is to understand the behavior of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake for three different types of bracing systems, applied to the staging of elevated circular water tank for earthquake zones. Analysis is carried out using SAP2000 v15. Twenty-seven models are used for calculating base shear and nodal displacements for staging with normal bracing, cross bracing, and radial bracing in staging. Variation in staging height is 12m, 16m, and 20 m at 4m each. After calculating base shear and nodal displacements of twenty-seven models for empty and full tank combination of loads applying with different types of bracings which gives minimum base shear as well as considerable displacement for major earthquake zones. In the analysis response spectrum method has been used for seismic analysis of structures by using software. Sloshing forces and base shear was calculated from IITK guideline, the results obtain from software was compared with manual calculation. Hydrodynamic pressure for impulsive and convective mode was calculated.

III. METHODOLOGY

3.1 General

The main objective of this study is to examine the behaviour of overhead circular water tank supported on frame staging considering different modelling systems. All the above cases are analysed for five different earthquake records i.e. time history analysis. The analysis is carried out using SAP 2000 software.

3.2 Time History Analysis

It is an analysis of the dynamic response of the structures at each increment of time, when its base is subjected to a specific ground motion time history. In this method, the structure is subjected to real ground motion records.

3.3 Non-linear 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.

Properties of ground motions under consideration are tabulated in Table 3.1.

Table 2: Properties of Ground Motion

Earthquake Area	Magnitude	Record/ Component	PGA
El-Centro (1940)	7.2	El-Centro 1940,	0.35 g
Bhuj (2001)	7.7	Bhuj (2001), India	0.38 g
Uttarkashi (2001)	6.6	Uttarkashi (2001), India	0.31 g
Koyna (1967)	6.5	Koyna(1967)	0.31g
Chamoli (1999)	6.8	Chamoli(1999)	0.31g

IV. PROBLEM STATEMENT

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

Fig 4.1Township at Ranjangaon MIDC.

4.1 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. =150m^3
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*D^2*4
Diameter - 7m
Beam size - 230x600
Column size - 230x650
Earthquake zone - III
Time history – Bhuj
Soil – Medium stiff
Depth of Foundation - 1.5m

4.2 SAP-2000 Models

From the problem statement mentioned in above chapter the following models are proposed for time history analysis for earthquake data of Bhuj data.

Model No.1	Rectangular water tank without bracing
Model No.2	Rectangular water tank with single bracing
Model No.3	Rectangular water tank double bracing
Model No.4	Rectangular water tank knee bracing
Model No.5	Circular water tank without bracing
Model No.6	Circular water tank with single bracing
Model No.7	Circular water tank double bracing
Model No.8	Circular water tank knee bracing

Rectangular Water Tank (Plain)

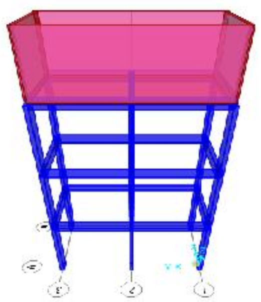


Fig 4.2: Rectangular water tank without Bracing

Rectangular Water Tank with Single Bracing

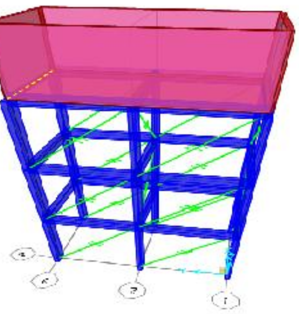


Fig 4.3: Rectangular water tank with Single Bracing

V. RESULTS AND DISCUSSION

5.1 Analysis Parameter for Rectangular Water Tank

Table 5.1: Rectangular Water Tank

Rectangular Water Tank			
Sr. No.	Name	Type	Max Value
1	Without Bracing	Displacement (Ux)	4.6
		Velocity	45.9
		Acceleration	6.5
		base shear	1.43x10^2
2	Single Bracing	Displacement (Ux)	2.26
		Velocity	41.31
		Acceleration	5.85
		base shear	6.45x10^2
3	Knee Bracing	Displacement (Ux)	1.09
		Velocity	26.8515
		Acceleration	3.8025
		base shear	3.36x10^2
4	Cross Bracing	Displacement (Ux)	1.74
		Velocity	32.2218
		Acceleration	4.563
		base shear	3.74x10^2

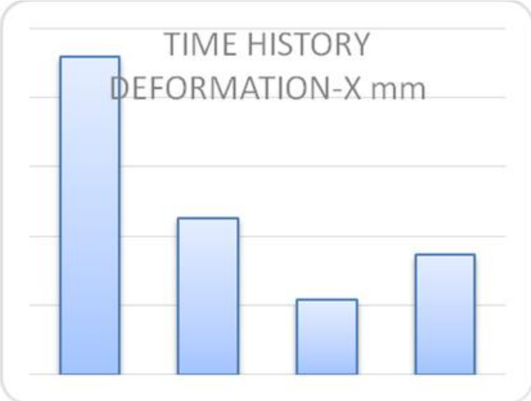


Table 5.2 Time History Deformation

Time History Deformation-X mm			
RT Without Bracing	Rt With Cross Bracing	RT With Single Bracing	Rt With Knee Bracings
4.6	2.268	1.09	1.74

In this graph maximum deformation is 4.6 mm rectangular tank without bracing difference between Rectangular Tank without Bracing and rectangular tank with Single Bracing is 30%.

Rectangular Water Tank			
Sr. No.	Name	Type	Max Value
1	Without Bracing	Displacement (Uy)	4.37
		Velocity	0
		Acceleration	6.175
		base shear	138.567
2	Single Bracing	Displacement (Uy)	2.147
		Velocity	39.2445
		Acceleration	5.5575
		base shear	625.005
3	Knee Bracing	Displacement (Uy)	1.0355
		Velocity	25.508925
		Acceleration	3.612375
		base shear	325.584
4	Cross Bracing	Displacement (Uy)	1.653
		Velocity	30.61071
		Acceleration	4.33485
		base shear	362.406

In this graph maximum deformation is 4.37 mm rectangular tank without bracing difference between Rectangular Tank without Bracing and rectangular tank with Single Bracing is 28%.

Time History Deformation Y mm			
RT Without Bracing	Rt With Cross Bracing	RT With Single Bracing	Rt With Knee Bracings
4.37	1.653	2.147	1.0355

5.2.1 Deformation vs Various Cases

5.2.2 Velocity vs Various Cases

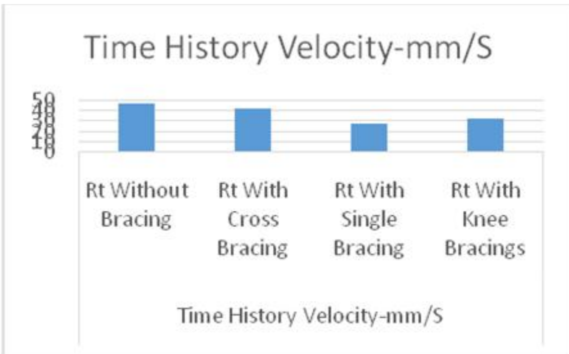
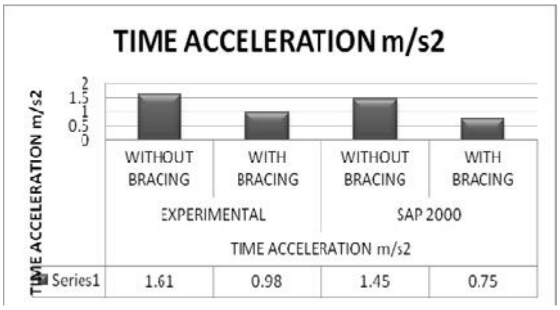


Table 5.2Time History Velocity



Graph 5.3: Time Acceleration

From this graph 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%

VII. CONCLUSION

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.

- 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
- 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
- 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

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