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Non-Linear Time History Analysis of an Elevated Water Tank

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***Abstract:** It was discovered that reinforced concrete elevated water tanks with frame staging outperformed reinforced concrete elevated water tanks with shaft staging in terms of seismic resistance. These can be due to the frame staging's seismic energy absorption capability. As a result, the primary goal of this research is to better understand the seismic behavior and performance characteristics of elevated water tanks with frame staging. Furthermore, when compared to other shapes, circular tanks have the smallest surface area for a given tank size. As a result, the amount of material needed for a circular water tank is less than for other shapes. As a result, a circular water tank was chosen, and seismic analysis of elevated RC circular water tanks was carried out according to IITK-GSDMA guidelines, with the behavior of the water tank analysed for various parameters such as zone factor, soil condition, and different staging heights. SAP 2000 was used to determine the structure's modal characteristics (mode shapes and modal participation mass ratio).*
***Keywords:** SAP2000, Elevated water tank, Rectangular water tank, Circular water tank, Time history Analysis, Bhuj Earthquake*

I. INTRODUCTION

Elevated water tanks are generally used in public water distribution system. Being an important part of lifeline system, and due to post earthquake functional Demand, seismic safety of water tanks is of considerable importance. Elevated water tanks are 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 generally deployed. The column-brace frame type of system is essentially a 3D reinforced concrete frame which supports the container and resists the lateral loads induced due to earthquake or wind.

Aim of this 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 carried to bring out the differences in the nonlinear dynamic behavior of without 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 achieved. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the whole structure. A without 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.

II. 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 analysed for five different earthquake records i.e. time history analysis. The analysis is performed by using SAP 2000 software.

A. Time History Analysis

It is an analysis of the dynamic response of the structures at each interval 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 record. This makes this analysis method different from all of the other approximate analysis methods as the inertial forces are directly determined from these ground motions or in forces are determine as function of time, considering dynamic properties of building structures.

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B. Non-linear Time History Analysis

Time-History analysis is a step-by-step procedure where the loading and the response history are calculated at successive time increments, Δt– steps. During each step the response is evaluated from the starting conditions existing at the beginning of the step (displacements and velocities) and the loading history in the interval. Nonlinear time history analysis is the dynamic analysis in which the loading causes significant changes in stiffness. With this method the non-linear behavior may be easily considered by varying the structural properties (e.g. stiffness, k) from one step to the next. Therefore, these method is one of the most effective for the solution of non-linear response. Non-linear time history analysis utilizes the combination of ground motion records with a detailed structural model therefore is capable of producing results with relatively low uncertainty. In nonlinear dynamic analysis, the detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using scheme such as the square-root-sum-of-squares

III. PROBLEM STATEMENT

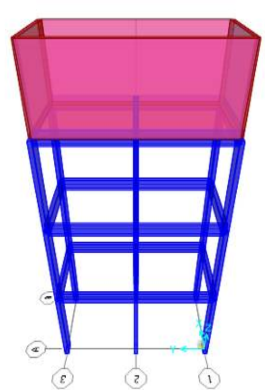
A. Design Data

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
For circular water tank:
Capacity=3.14*r^2*h

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

B. Modeling IN SAP2000

1) Rectangular Water Tank (Plain)



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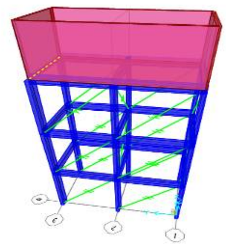
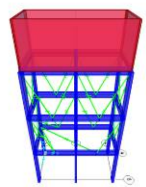
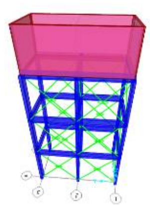
2) Rectangular Water Tank with Single Bracing

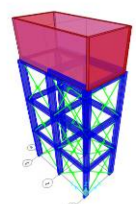


3) Rectangular Water Tank with Knee Bracing

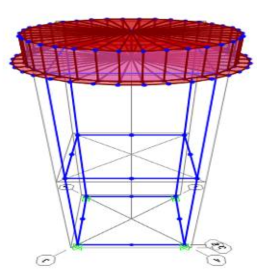


4) Rectangular Water Tank with Cross Bracing

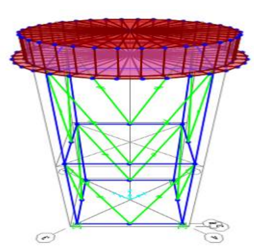




5) Circular Water Tank without Bracing (Plain)



6) Circular Water Tank with Knee Bracing



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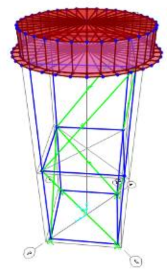
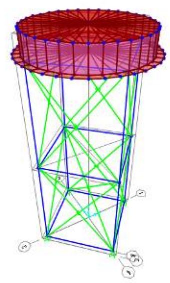
7) *Circular Water Tank with Single Bracing*



8) *Circular Water Tank with Cross Bracing*



IV. RESULTS AND DISCUSSION

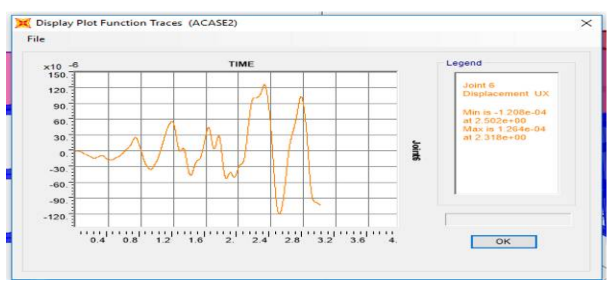
A. General

The result of analytical parameter such as story drift, base shear, and time history analysis of Composite frame are carried out. These results are shown in tabular form. The interpretations of this result are compared graphically. Also soil structure interaction comparison of composite element with element are done by tabular form

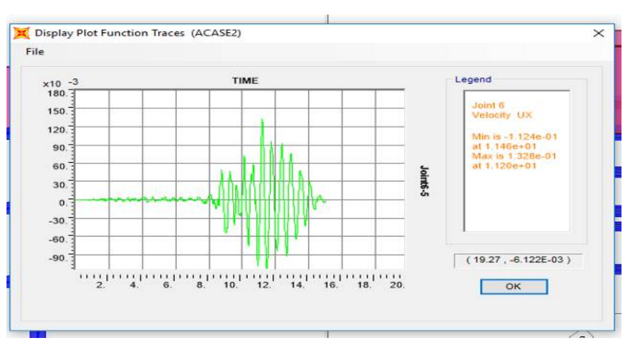
Following graphs are obtained from SAP-2000:

1) *For Rectangular Water Tank*

a) *Displacement (Ux)*



b) *Velocity*



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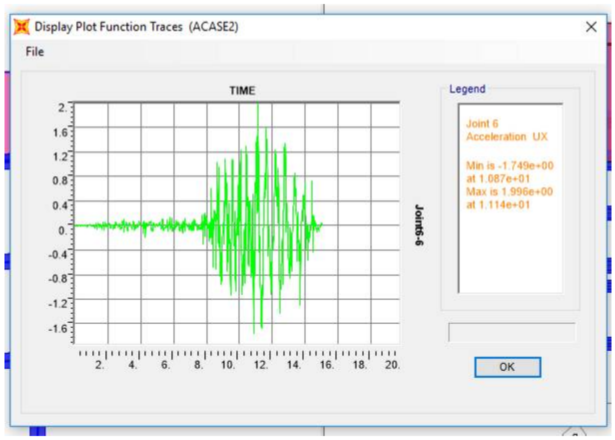
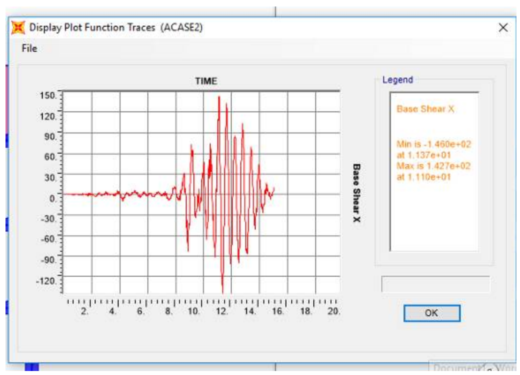
c) Acceleration



d) Base Shear



Analysis Parameter for Rectangular Water Tank			
Sr. No.	Name	Type	Max Value
1	Without Bracing	Displacement (Ux)	4.6mm
		Velocity	45.9mm/s
		Acceleration	6.5mm/s^2
		base shear	1.43x10^{2}kn
2	Single Bracing	Displacement (Ux)	2.26mm
		Velocity	41.31 mm/s
		Acceleration	5.85 mm/s^2
		base shear	6.45x10^{2}kn
3	Knee Bracing	Displacement (Ux)	1.09mm
		Velocity	26.85 mm/s
		Acceleration	3.8025 mm/s^2
		base shear	3.36x10^{2}kn
4	Cross Bracing	Displacement (Ux)	1.74mm
		Velocity	32.2218mm/s
		Acceleration	4.563 mm/s^2
		base shear	3.74x10^{2}kn

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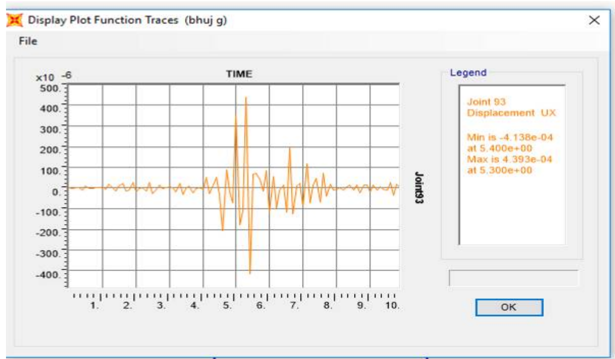
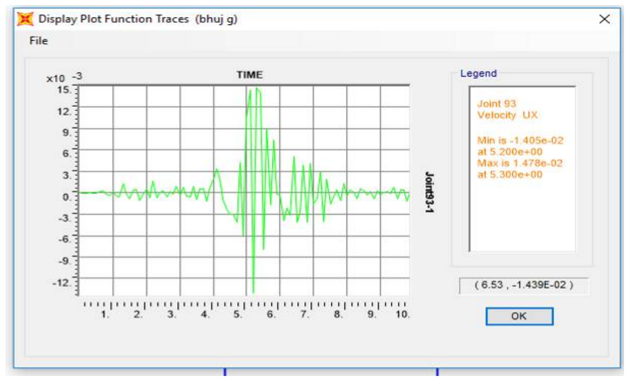
2) For Circular Water Tank

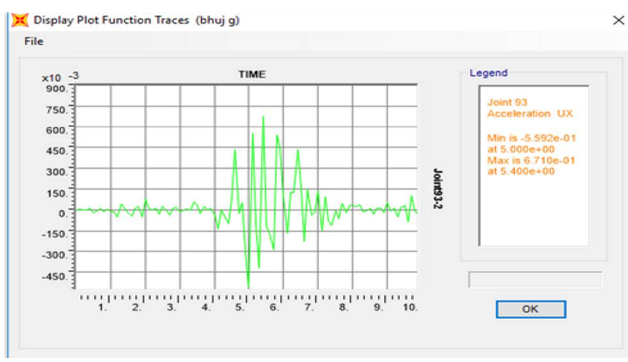
a) Displacement



b) Velocity



c) Acceleration



d) Base Shear

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

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 150m^3 capacity and for time history analysis bhuj earthquake is considered. Various models of bracing systems are proposed and following conclusions are made.

A. 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
B. 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
C. 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
D. 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%
E. 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.
F. In accordance to velocity and acceleration parameter circular water tank gives better results than rectangular water tank.
G. The bhuj intensity is considered in zone IV which has time period of 132 sec and for this nonlinear dynamic analysis the circular water tank with bracings is observed to be most effective as its stiffness is observed more than rectangular water tank

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