TIME HISTORY ANALYSIS OF AN ELEVATED WATER TANK FOR BHUJ EARTHQUAKE DATA & VALIDATION ON SHAKE TABLE

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Abstract: 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. 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. These structures have large mass concentrated at the top of slender which have Supporting structure and hence these structures are especially vulnerable to horizontal forces due to earthquakes.

***keywords* – water pressure, staad-pro, water tank**

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 segment prop outline sort of arranging is basically a 3D fortified solid casing which underpins the compartment and opposes the sidelong loads instigated because of tremor 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.

Fig. 1.1: 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. The number of numerical studies is also very few and mainly limited to only one or two elevated water tanks with certain tank weight and pedestal dimensions. This shows the need to further evaluate some of the code requirements and equations. Poor performance in previous earthquakes, lack of experimental results, and importance of these structures as lifelines, very limited numerical studies, and evaluation of certain parts of the current code are the main drivers that necessitate a comprehensive study on the nonlinear performance of RC pedestals.

Elevated water tanks are employed in water distribution facilities in order to provide storage and necessary pressure in water net without rk systems. These structures have demonstrated poor seismic performance in the past earthquakes. In this study, a finite element method is employed for investigating the nonlinear seismic response of reinforced concrete (RC) pedestal in elevated water tanks. Pushover analysis is performed in order to construct the pushover curves, establish the over strength and ductility factor, and evaluate the effect of various parameters such as fundamental period and tank size on the seismic response factors of elevated water tanks.

1.2 PERFORMANCE OF ELEVATED WATER TANK

Land and seismological disclosures amid the 20thcentury have helped in starting the improvement of seismic construction regulations and tremor safe structures 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.

1.3 VARIOUS ANALYSIS METHODS

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

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 straight static strategy for investigation is restricted to little, standard structures.

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.

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.

Linear Time History Analysis: Linear Time History Analysis provides little more information than the response spectrum analysis for a much greater degree of effort and is rarely used.

The direct static technique for investigation is restricted to little, customary structures. Nonlinear time history analysis is the dynamic analysis in which the loading causes significant changes in stiffness.

1.4 MODAL PROVISION

One Mass Model

Elevated tanks shall be regarded as systems with a single degree of freedom with their mass concentrated at their centre of gravity. The analysis shall be without both when the tank is full and when empty. Structural mass m, includes mass of container and one-third mass of staging. Mass of container comprises of mass of roof slab, container wall, gallery, floor slab, and floor beams. When full, the weight of contents is to be added to the weight under empty condition. Staging acts like a lateral spring and one-third mass of staging is considered.

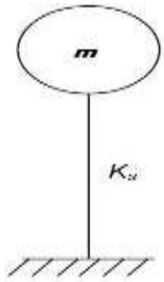


Fig.1.2: One mass idealization of tank

The free period T, in seconds, of such structures shall be calculated from the following formula,

$$T = 2\pi\sqrt{\frac{\Delta}{g}} \text{ -------------------------------------- } (1.1)$$

For modelling of the one mass model the lateral stiffness Ks is calculated by applying the lateral force to the staging of the existing tank. And deflection (Δ) is noted then by using following formula the stiffness is calculated.

$K = P / \Delta$ ………..(1.2)

This calculated stiffness is given by,

$K = 3EI / L3$………(1.3)

Equating eqn (1.2) and (1.3);

The equivalent diameter (De) for one mass model is calculated.

The lumped mass for one mass model is calculated from existing model and it consists of mass of water, mass of container and one third mass of staging.

Two Mass Model

A satisfactory spring mass analogue to characterize basic dynamics for two mass model of elevated tank was proposed by Housner (1963) after the Chilean earthquake of 1960, which

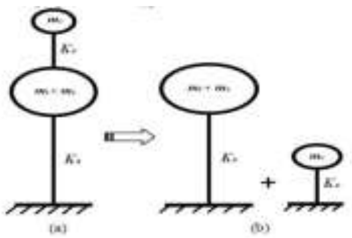


Fig.1.3: Two mass model for elevated tank

Where, mi, mc, Kc, etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility.

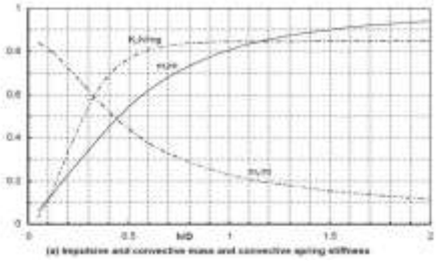


Fig.1.4: Impulsive and convective mass and convective spring stiffness

Time period of impulsive mode, Ti in seconds, is given by;

$$Ti = 2\Pi\sqrt{\frac{mi + ms}{Ks}} \quad \text{------------------------------------(1.4)}$$

Lateral stiffness of the staging is the horizontal force required to be applied at the centre of gravity of the tank to cause a corresponding unit horizontal displacement.

II. METHODOLOGY

2.1. 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 2.1

Table 2.1: Properties of Ground Motion

Earthquake Area	Magnitude	Record/ Component	PGA
EI-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

2.2 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.

2.3 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 stabilise the frame. If a single brace is used, it must be sufficiently resistant to tension and compression.

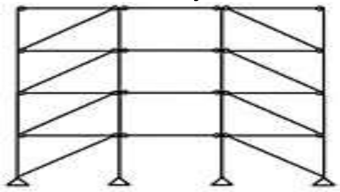


Fig 2.1 Single Diagonal Bracing

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.

Fig 2.2 Cross Bracing

However, this provides the least available space within the façade for openings and results in the greatest bending in floor beams.

V (Knee) Bracing

This involves without diagonal members extending from the top without corners of a horizontal member and meeting at a centre 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 centre point on the upper horizontal member.

III. 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*5*135=135000 lit.

Considering 10% commercial use extra.

Total Capacity=150000lit. =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

Length (L): 9m

Width (B): 4.5m

Height (H): 4m

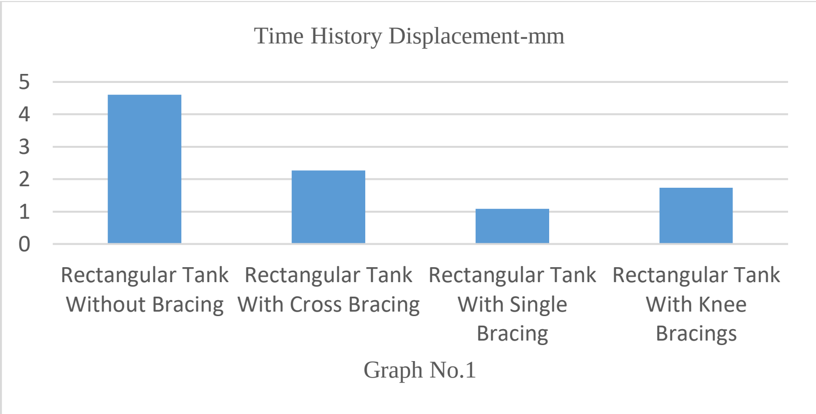
IV. RESULT and DISCUSSION

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

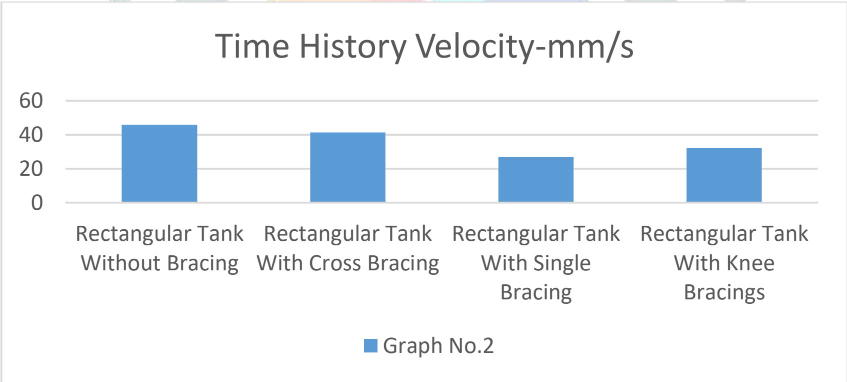
Model no.1	Rectangular water tank without bracing
Model no.2	Rectangular water tank with single bracing
Model no.3	Rectangular water tank double bracing
Model no.4	Rectangular water tank knee bracing

Rectangular Water Tank

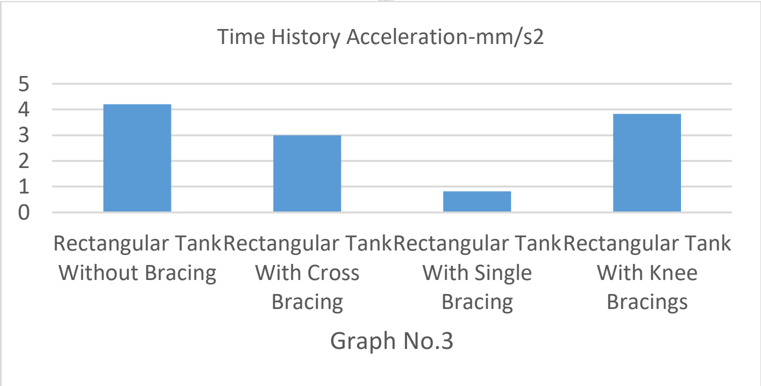
Fig 4.1: Rectangular Water Tank



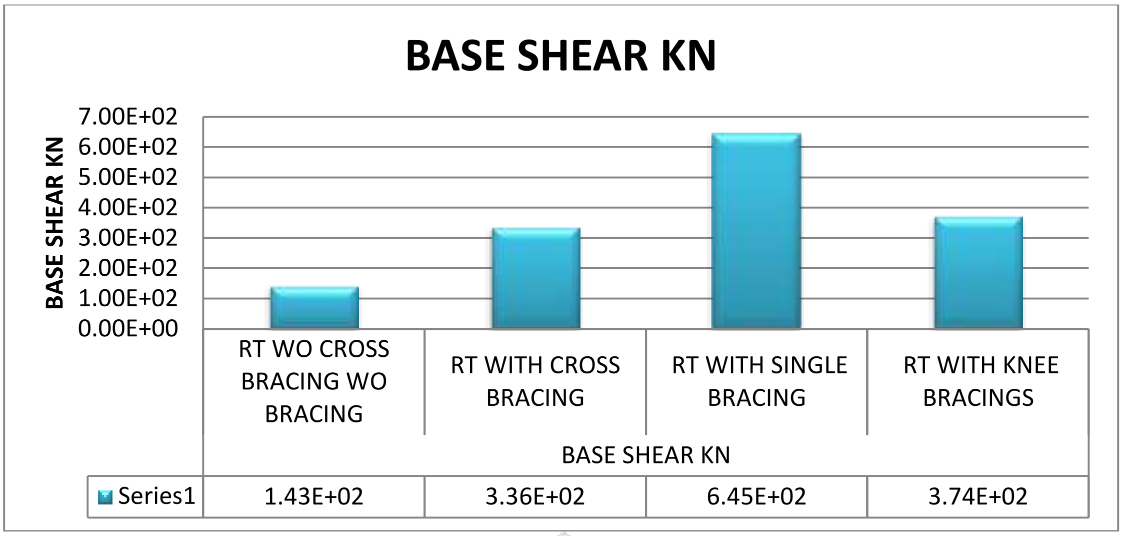
Graph 4.1:time history displacement



Graph 4.2:time history displacement



Graph 4.3:time history acceleration



Graph 4.4:base shear

EXPERIMENTAL RESULTS

The above problem statement is validated through shake table test for rectangular water tank with bracing and without bracing.

Fig 4.2: Shake table test

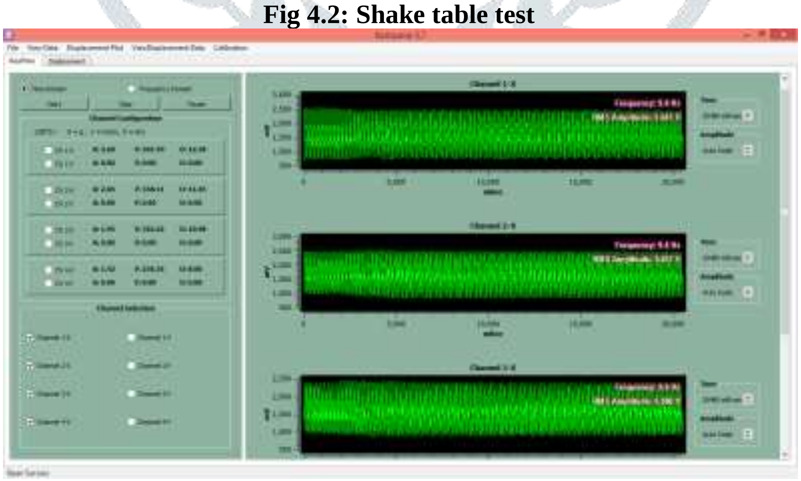
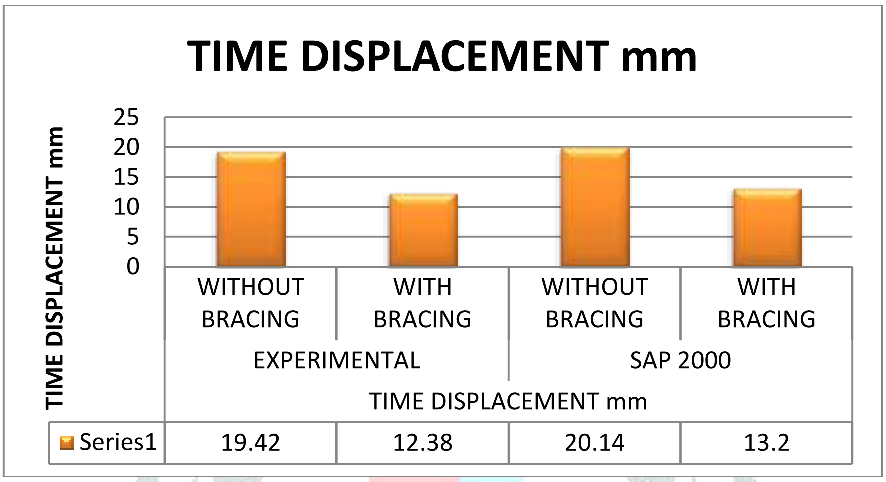
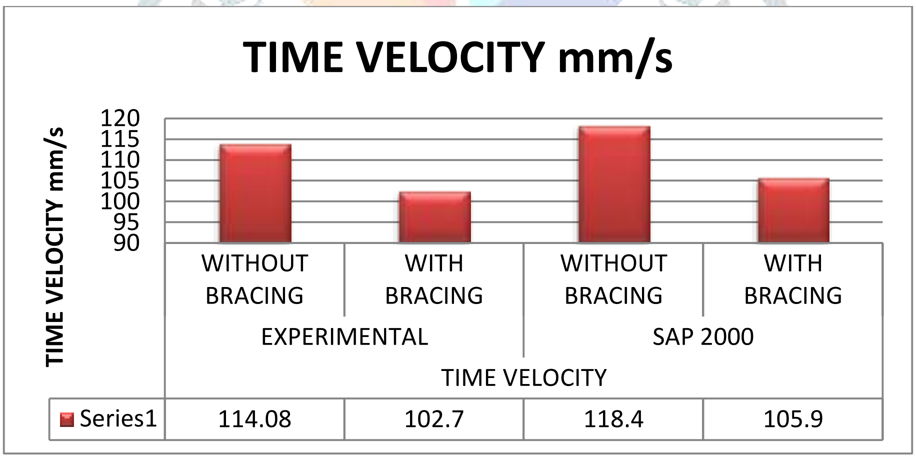


Fig 4.3: Time-Displacement with bracing

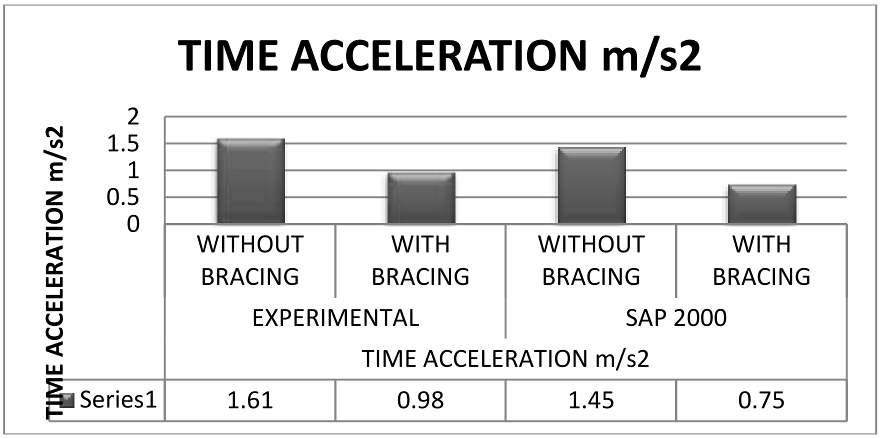
Fig 4.: Time displacement without bracing



Graph 4.5:time displacement



Graph 4.6:time velocity



Graph 4.7:time acceleration

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

1. For rectangular water tank without bracing max velocity is 45mm/s. Difference between rectangular water tank without bracing and rectangular water tank with single bracing is 5%
2. For rectangular water tank without bracing max deformation is 6.8 mm. Difference between rectangular water tank without bracing and rectangular water tank with single bracing is 30%
3. After SAP 2000 model analysis experimental set up is done in shake table test with and without bracing for frequency 8.1 Hz and maximum deformation is observed is 19.42 mm which is reduced by 10-15% in bracing system
4. Same results are validated in SAP 2000 and results with experimental matches up to 15-20%

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