# Seismic Evaluation of Elevated Water Tanks

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*Abstract*— Elevated water tanks are one of the most important lifeline structures in earthquake prone regions. In major cities and also in rural areas elevated water tanks forms an integral part of water supply scheme. These structures has large mass concentrated at the top of slender supporting structure, hence these structures are especially vulnerable to horizontal forces due to earthquake. Elevated water tanks that are inadequately analyzed and designed have suffered extensive damage during past earthquakes. The objectives to be achieved through this concept are Study of seismic resistant design of elevated water tanks as per IS CODE: 1893 and IITK-GSDMA guidelines, seismic analysis of Elevated water tanks using SAP2000, Study the influence of various parameters (Viz., Seismic intensity, soil conditions, etc.) on the seismic behaviour of elevated water tank and Study the influence of staging height on the base shear and ductility characteristics of elevated water tank by performing nonlinear static analysis using SAP2000.

***Key words:*** Seismic Resistant Design, SAP2000, IITK-GSDMA, Pushover Analysis, Time History Analysis

## 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. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to pressurization the water distribution system. Many new ideas and innovation has been made for the storage of water and other liquid materials in different forms and fashions. There are many different ways for the storage of liquid such as underground, ground supported, elevated etc. Liquid storage tanks are used extensively by municipalities and industries for storing water Thus Water tanks are very important for public utility and for industrial structure. Elevated water tanks consist of huge water mass at the top of a staging which are most critical consideration for the failure of the tank during earthquakes. 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, Pushover Analysis option will allow engineers to perform pushover analysis as per FEMA -356 and ATC-40. Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or collapse condition.

## II. PURPOSE OF DOING PUSH OVER ANALYSIS

The pushover is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis. The following are the examples of such response characteristics:

1) The realistic force demands on potentially brittle elements, such as axial force demands on columns, force demands on brace connections, moment demands on beam to column connections, shear force demands in reinforced concrete beams, etc.
2) Estimates of the deformations demands for elements that have to form inelastically in order to dissipate the energy imparted to the structure.
3) Estimates of the inter storey drifts that account for strength or stiffness discontinuities and that may be used to control the damages and to evaluate P-Delta effects.
4) Identification of the strength discontinuous in plan elevation that will lead to changes in the dynamic characteristics in elastic range.

## III. SCOPE OF PRESENT STUDY

In the present study, modeling of the Elevated circular water tank (Base fixed) under loads has been analyzed using SAP2000 software and the frame is analyzed using SAP2000 software up to the failure and the load deformation curves and results are obtained. In this study default hinges are used in beams and columns and thus pushover graph is obtained from excel spread sheet.

## IV. METHOD OF ANALYSIS

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures. There are two methods of analysis, elastic and inelastic methods. In the present study inelastic analysis is adopted. Inelastic analysis procedures basically include inelastic time history analysis and inelastic static analysis which is also known as pushover analysis.

## V. PUSH OVER ANALYSIS USING SAP 2000

Consider a circular tank of 12 column concrete staging as shown in Figure 1(a).There are two models one model is with internal bracing and another model is without internal bracing. The intention is to demonstrate the step by step procedure of pushover analysis in SAP2000.

There are two types of staging plans are as follows:

– 12 column with internal bracing plan
– 12 column without internal bracing plan

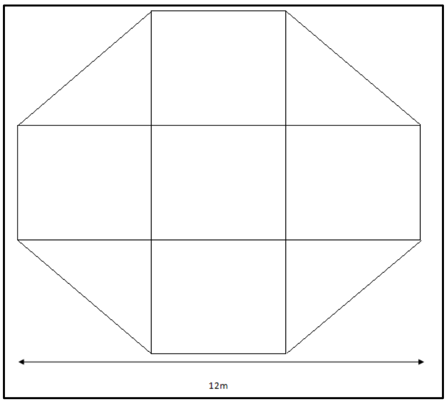


Fig. 1: Plan of 12 Columns with internal bracing

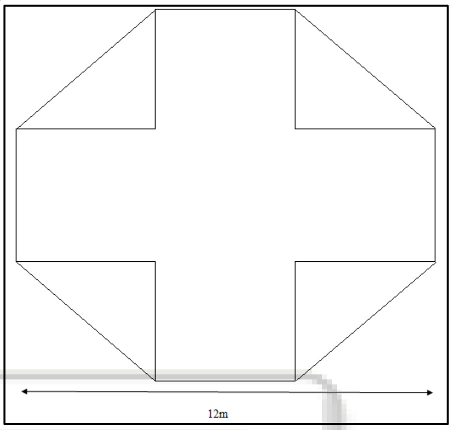


Fig. 2: Plan of 12 columns without internal bracing

| | |
|---|---|
| Capacity | 500 $m^3$ |
| Diameter of Container | 12 m |
| Grade of Concrete | $M_{30}$ |
| Grade of Steel | Fe500 |
| Roof Slab thickness | 0.12 m |
| Floor Slab thickness | 0.2 m |
| Diameter of column | 0.65 m |
| Base beam size | 0.3 m x 0.4 m |

Table 1: Details of material property, size of components and other parameter details

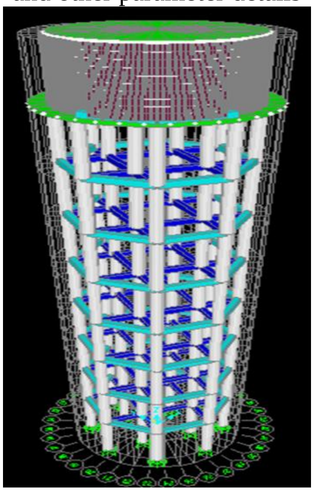

Fig. 3: Complete model of elevated water tank

1) Step 1: Geometry
2) Step 2: Section and Material properties
3) Step 3: Nonlinear hinge properties
4) Step 4: Load patterns and load cases
5) Step 5: Analysis.
6) Step 6: Results

## VI. Result and Discussions

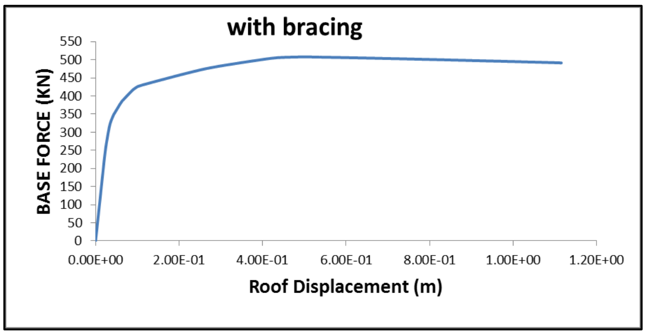


Fig. 4: Capacity Curve for the Example Frame (Base Shear versus Roof Displacement)

Figure 4 shows the capacity curve for the example Water tank considered. The base shear is linear up to 27.83 kN force corresponding to roof displacement 0.002 m.

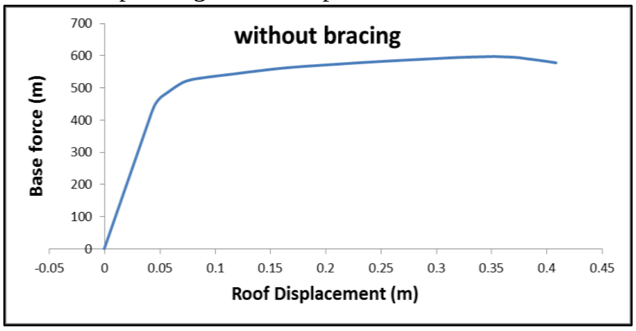


Fig. 5: Capacity Curve for the Example Frame (Base Shear versus Roof Displacement)

Figure 5 shows the capacity curve for the example Water tank considered. The base shear is linear up to 25.26 kN force corresponding to roof displacement 0.002.

## VII. Time History Analysis

Time history analysis of the frame is carried out to determine the response of the frame under a loading I. Time history analysis is the most natural and intuitive approach. The response history is divided into time increments and structure is subjected to a sequence of individual time-independent force pulses. II. Here time history records of "LOMA "are used for the time history analysis. They are shown as a function graph as below. LOMA record is divided into 2000 points of acceleration data equally spaced at 0.020 sec. (Units: cm/sec).

| Joint | Displacement | |
|---|---|---|
| | With Bracing | Without Bracing |
| 0 | 0 | 0 |
| 1 | 0.008214 | 0.019375 |
| 2 | 0.0231 | 0.041879 |
| 3 | 0.039798 | 0.061622 |
| 4 | 0.05208 | 0.077078 |
| 5 | 0.058792 | 0.088572 |
| 6 | 0.062946 | 0.102059 |
| 7 | 0.065337 | 0.119906 |
| 8 | 0.067022 | 0.132712 |

Tables 2: Result of displacement for LOMA Earthquake

The above table displays the displacement result for LOMA Earthquake comparing the different types of model. The above results are been calculated in meter. Considering the displacement of the joint with form the original point after analysis.

 

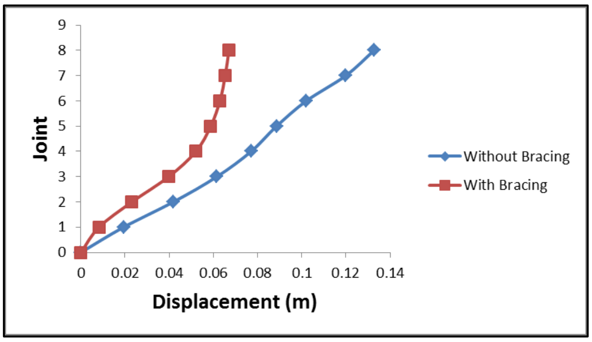


Fig. 6: LOMA Displacement graph

## VIII. CONCLUSION

Above result shows that the model with bracing result is better as compared to the result model without bracing. The above table displays the displacement result for LOMA Earthquake comparing the different types of model. The above results are been calculated in meter. Considering the displacement of the joint with form the original point after analysis. On x-axis in the graph indicates the displacement in meter respectively while y-axis indicates the join of the structure.

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