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Seismic Analysis Of Elevated Water Tank With Different Staging Configuration

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Abstract
Earthquake being one of the most destructive natural calamities which can directly affect in lives as well as in lifeline facilities. Elevated water tanks are considered as structure of high importance and are considered to remain functional during earthquakes as well. Elevated water tanks are highly vulnerable to the lateral forces due to earthquake. This paper presents the performance of the Elevated water tank for the different Staging Configuration. For the analysis 450m3 RC Intze type water tank is taken. The behavior of water tank is investigated considering different types of bracing like Normal staging, Hexagonal staging, Cross Staging, Radial staging with central column, X bracing , Chevron Bracing, Global Bracing, K-bracing ,V-bracing using SAP2000 software for full fill tank condition in 5 storey and 6 storey. Pushover analysis is mainly used to strength and storey drift of the structure. In particular case, static pushover analysis is used to estimate strength capacity of elevated water tank under the action of lateral force. From pushover analysis sequence of the member yielding and the progress of the overall capacity curve is also obtained.

Keywords
Elevated water tank, Staging, Pushover, SAP2000

1. Introduction

Nepal is seismically vulnerable country as it lies in subduction zone of India-Australia and Eurasian plate. Including Gorkha Earthquake of magnitude 7.9, large number of earthquakes has occurred in the last century. So, from here it is clear that we have the danger of large earthquake. Elevated water tanks are one of the most important lifeline structures. But the poor performance of these structure were reported in previous earthquakes like Jabalpur 1997 (Rai, 2003), Chile (Steinbrugge, 1960) and Gujarat 2001 (Rai, 2003). Other structures which may have uniform dead and live load during their life time, whereas elevated water tanks experience different gravity loads while working in the water system. As these structure consists of large concentrated mass at the top of slender supporting structure hence they are more vulnerable to horizontal force due to earthquake. On average when the structure is empty, the overall weight of the structure may fall to 75% of the full tank state. Complication in the seismic design of elevated water tanks occurs due to change in gravity loads.

2. Objective of the study

1. Assess the relative performance of various Staging Configuration in 5 storey and 6 storey Elevated water tank using hexagonal bracing, cross bracing, radial bracing, X bracing, Chevron , Global, Inverted V horizontal and vertical and K bracing for full water tank condition.
2. To conduct the pushover analysis and comparing performance of various staging configuration.

3. Analysis and Result

Column and Beams in the support system are modeled as frame element having two nodes with six DOFs (3 translation and 3 rotations) at each node, Slab and wall are as thin shell element having four nodes with six DOFs (3 translation and 3 rotations) at each node .

Water is modeled as an equivalent mechanical model proposed by ACI code and GSDMA. The ACI/GSDMA mechanical model has divided the total water mass into two equivalent lumped mass. One is impulsive mass and another is convective mass. Impulsive mass is that which behaves as rigidly connected to the tanks under horizontal earthquake ground motion. Here the mass accelerates along with the wall and which induces impulsive hydrodynamic pressure. Convective mass is that which undergoes sloshing motion under horizontal earthquake motion. This mass is freely move and exerts convective hydrodynamic pressure. This mass is connected to the tank by equivalent spring having stiffness equal to sloshing stiffness of water. The Convective mass, impulsive mass, height of applications, spring stiffness required for equivalent mechanical model are calculated. The study is carried out on reinforced cement concrete elevated intze tank supported on frame type staging, which is commonly used in practice. The study was limited to 6 different types of staging with external bracing and 3 different types of staging with internal bracing patterns with 5 and 6 story staging.

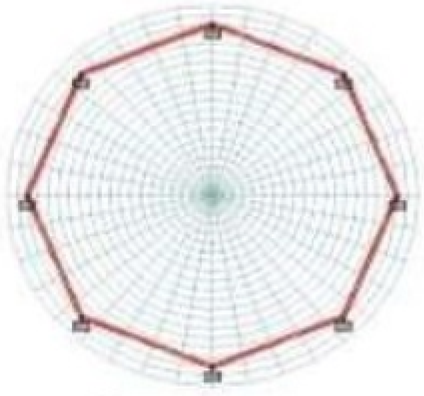

Figure 1: Normal staging

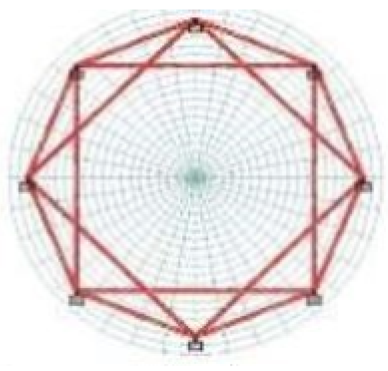

Figure 2: Hexagonal staging

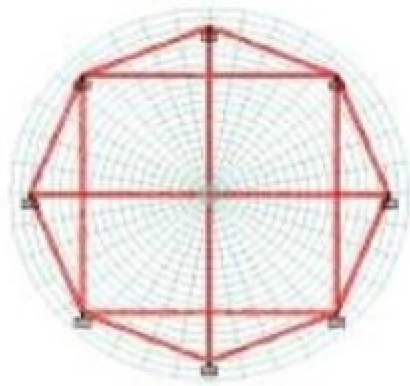

Figure 3: Cross staging

Figure 4: Radial staging with central column

Table 1: Ca and Cv Parameters

Code	Level of EQ	Ca	Cv
ATC-40	Max EQ	0.45	1.2
	Design EQ	0.36	0.96
	Serv. EQ	0.34	0.64
IS-1893	Max EQ	0.36	0.6
	Design EQ	0.18	0.3

Pushover Analysis is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for the structure subjected to selected earthquake. In particular case, static pushover analysis is used to estimate strength capacity of elevated water tank under the action of lateral force. For pushover analysis, auto hinged properties of concrete as per FEMA 356 is used. Concrete – beam flexure with M3 DOF for beam and concrete –column flexures with P-M2-M3 DOF for column are assigned.Displacement-controlled pushover analysis is performed in which specified drift of controlled point is assigned as known and lateral loads required are monitored. Using a pushover analysis, a

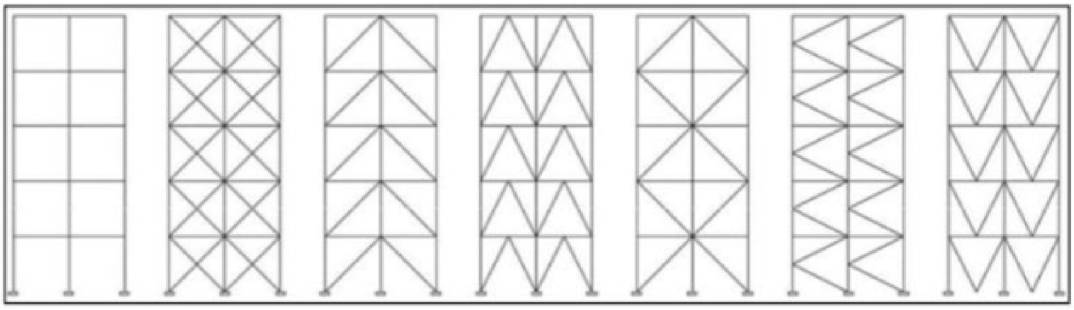

Figure 5: Figure showing various type of internal as well as external bracing system.

characteristic nonlinear force-displacement relationship is determined. The relation between base shear and control node displacement is plotted which is known as Pushover Curve or Capacity Curve. From pushover curve following response characteristic are obtained:

1. Force and displacement capacities of the structure
2. Sequence of the member yielding and the progress of the overall capacity curve
3. Performance level of structure for different earthquake demand

Evaluation of performance and failure mechanism was carried out with nonlinear static pushover analysis. Parameters set for nonlinear pushover analysis are given in Table 1. The maximum responses are determined for different parameters of Elevated water tank. The Reponses are of Top story displacement and Time Period.

4. Result from analysis

The results obtained are presented in table 2, table 3 and table 4.

Table 2: Performance points for different types of bracing system

Type of Bracing	Base Shear (kN)	Monitored Disp (m)
No Bracing	2626.244	0.103
Cross Bracing	2725.696	0.073
Radial Bracing	3719.122	0.106
Hexagonal Bracing	2634.958	0.092

Table 3: Top storey displacements and time period for differnt bracings for 6 storey

Types of Bracing	Top Story Disp. (mm)	Time Period (sec)
No Bracing	33.95	1.565
Cross Bracing	30.324	1.402
Hexagonal	27.665	1.365
Radial Bracing	26.21	1.132
X -Bracing	7.21	0.546
Chevron Bracing	10.55	0.795
Global Bracing	11.056	0.818
V & Horizontal	12.52	0.952
V & Vertical	13.28	0.965
K-Bracing	9.41	0.646

Table 4: Top storey displacements and time period for differnt bracings for 5 storey

Types of Bracing	Top Story Disp. (mm)	Time Period (sec)
No Bracing	26.0135	1.265
Cross Bracing	24.77	1.102
Hexagonal	28.86	1.12
Radial Bracing	23.306	1.086
X -Bracing	10.21	0.646
Chevron Bracing	13.323	0.765
Global Bracing	14.112	0.768
V & Horizontal	14.326	0.796
V & Vertical	15.256	0.825
K-Bracing	12.074	0.772

5. Conclusion

- Linear analysis of the existing structure is carried out statically as well dynamically so as to know the seismic performance of structure. The static and response spectrum analysis is carried as per IS 1983:2002 Part I. The maximum total base shears of 974 KN for static coefficient method and of 889KN for response

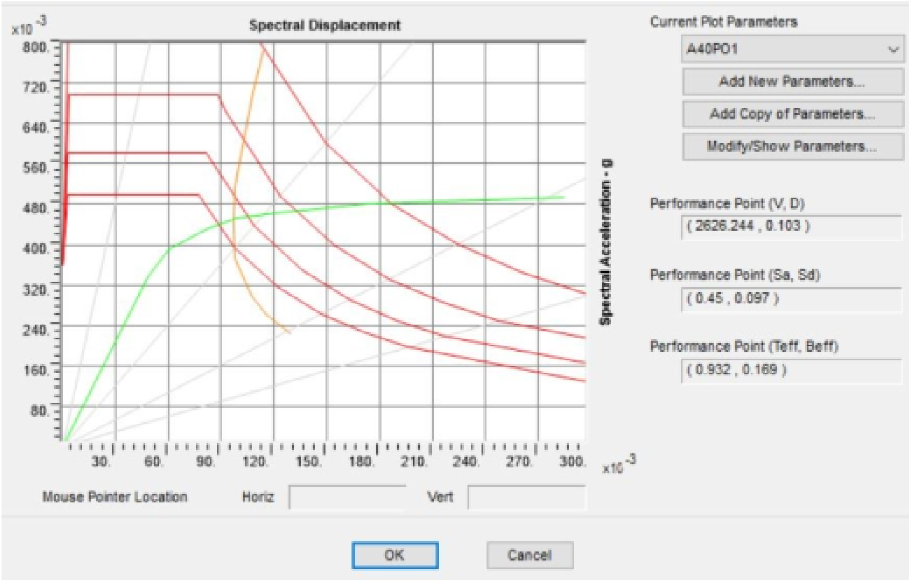

Figure 6: Pushover curve without Bracing

spectrum method are found. There is no significant change in total base shear for hydrodynamic analysis (954 KN maximum for dynamic analysis). The maximum top displacement of 33.5mm for static coefficient method and 31.6 mm for response spectrum method are found. Since hydrodynamic have both damping and amplification characteristics. But, no clear damping / amplification in response are observed from static and response spectrum analysis.

- Radial type of the bracing shows greater resistance. Also the performance level of bracing system increases for three different plane based internal patterns.
- Time period decreases with bracing system compared to that of without braces as the earthquake forces are counteracted by the ductility of the structure.
- Among the various types of bracing used X type bracing shows Significant decrease in time period and displacement of the structure.

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