Seismic Analysis of Elevated Circular Water Tank using various Bracing Systems

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Abstract— *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 aim 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 measure earthquake zones .In the analysis response spectrum method has been used for seismic analysis of structures for 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.*

Keywords—Circular water tank,SAP2000 v15,seismic analysis

I. INTRODUCTION

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, inflammable liquids and other chemicals. Thus Water tanks are very important for public utility and for industrial structure. Water tanks are very important components of lifeline. They are critical elements in municipal water supply, fire fighting systems and in many industrial facilities for storage of water of the paper. The contents of each section may be provided to understand easily about the paper.

Due to the lack of knowledge of supporting system some of the water tank were collapsed or heavily damages. So there is need to focus on seismic safety of lifeline structure using with respect to alternate supporting system which are Safe during earthquake and also take more design forces. Design of new tanks and safety evaluation of existing tanks should be carried out with a high level of accuracy because the failure of such structures, particularly during an earthquake, may be disastrous.

The main aim of study is to understand the behavior of different staging, under different loading conditions and strengthening the conventional type of staging by proper arrangement to give better performance during earthquake. to study the seismic performance of elevated circular water tank for various seismic zones II,III,IV of India for various heights of staging 12m,16m and 20 m for particular capacity of elevated water tanks. twenty seven models are made for analysis of elevated water tank. Seismic analysis is done by response spectrum method. To study the Indian standard codes guidelines for the analysis of such tanks

To study the suitability of different types of bracings considering tanks in different seismic zones and different heights of staging for a constant capacity of the circular water tank.To check the efficiency of a particular bracing in different seismic zones To study the seismic analysis of water tank by using response spectrum method using FEM Software SAP2000v15.

Water tank is modeled and analyzed for sloshing forces as per IIT KANPUR Guideline for different Indian Seismic zones. Validation of software result with IIT KANPUR Guideline.To study the effect of height of water tank staging at different earthquake zones. Comparison of base shear for various type of bracings Comparison of maximum displacement/nodal displacement of container

II. PROGRAM OF STUDY

Table No:1 Parameters for normal bracing

Required capacity (Cubic meter)	**500** m^3
For H/D ratio	**0.75**
H	0.75 D
Internal diameter of container $(\Pi/4)XD^2X0.75D$=capacity $(\Pi/4)X0.58D^3$=500	9.468313 m
Say D	**10 m**
Height(H)=0.75D H = 0.75X10	7.5m
Free board if not included above	0m
Height including free board H	7.5m
Capacity provided = $(\Pi/4)XD^2X0.75D$ =$(\Pi/4)X10^2X0.75X10$	589.05 m^3
Let thickness of wall of container= tw= 30 H+50 OR 150mm Whichever is more tw = 30 x 7.5+50	275mm
Say	**280mm**
C/C Diameter of tank =Diameter + thickness of wall = 10 + 0.28	10.28m
Outer Diameter of tank	10.56m
Floor slab= t	350mm
Floor beam	750 x300mm
Breadth (B)	300mm
Depth(D)	750mm
Bracing	
Breadth (B)	300mm
Depth (D)	500mm
Top roof slab = t	320mm

2.1 Design Horizontal Seismic Coefficient

Design horizontal seismic coefficient, *Ah* shall be obtained by the following expression,

Ah=Z/2xI/R x Sa/g

Where,

Z = Zone factor given in IS 1893 (Part 1): 2002,

I = Importance factor for social structure 1 as IITK guideline

R = Response reduction factor 1.8 for OMRF as per IITK guideline

Sa/g = Average response acceleration Coefficient,

Design horizontal seismic coefficient, *Ah* will be calculated separately for impulsive *(Ah)i*, and convective *(Ah)c* modes.

For hard soil sites

$Sa/g = 2.5$ for $T < 0.4$

$= 1.0/T$ for $T \geq 0.4$

For medium soil sites

$Sa/g = 2.5$ for $T < 0.55$

$= 1.36/T$ for $T \geq 0.55$

For soft soil sites

$Sa/g = 2.5$ for $T < 0.67$

$= 1.67/T$ for $T \geq 0.67$

Time period of impulsive mode,

Ti in seconds is given by,

$Ti=2\Pi\sqrt{mi+ms/k}$

Where,

ms = mass of container and one-third mass of staging

K = lateral stiffness of staging.

Lateral stiffness of the staging is the horizontal force required to be applied at thecenter of gravity of the tank to cause a corresponding unit horizontal displacement Time period of convective mode.

Tc = Cc √(D/g)

Where,

Cc = Coefficient of time period for convective mode

D = Inner diameter of tank.

Base shear in impulsive mode, just above the base of staging (i.e. at the top of footing of staging) is given by

Vi = (Ah)i (mi + ms)

Base shear in convective mode is given by

Vc= (Ah)c mc g

Where,

ms = Mass of container and one-third mass of staging

Total base shear *V*, can be obtained by combining the base shear in impulsive and convective mode through Square root of Sum of Squares (SRSS) rule and is given as follows,

V = Vi +Vc

2.2 Load Combinations:

Working combinations are considered for proper result interpretation.

Tank empty: self weight of structure + earthquake loads as per response spectra method.

Tank full: Self weight of structure + Earthquake loads as per response spectra method + Sloshing force. Method of analysis: Response spectra As per IS1893-1984 & IITK-GSDMA guidelines, by using Sap 2000-v15Hydro static pressure at base of wall

Impulsive Hydro static pressure at base of wall at y=0

Pi(Y) = Q (Y)x Ahi x 9810 x cos Φ

Convective Hydrostatic pressure at base of wall y=0

Qcw = 0.5625xcoshs(3.674xY/D)/cosh(3.674xh/D)

Convective Hydro static pressure at base of wall

Pcw(y=0) = 0.12 KN/SqM

Pi(Y)= Qcwx Ahc x 9810x D(1-(1/3)$\cos^2$ Φ)cosΦ

at y=h

Pcw(Y)= Qcwx Ahc x 9810x D(1-(1/3)$\cos^2$ Φ)cosΦ

III. RESULT AND INTERPRETATION

Table 2: Results of base shear for different bracing and for different staging height of staging for different seismic zones

TYPE OF BRACING	Base shear KN ZONE		
	II	III	IV
8 COL N 12M	94.296	165.265	276.67
8 COL R 12M	100.759	177.243	297.907
8 COL C 12M	91.743	160.579	268.44
8 COL N 16M	83.896	146.609	244.656
8 COL R 16M	92.941	248.189	286.636
8 COL C 16M	83.282	147.496	249.742
8 COL N 20M	79.58	141.634	241.069

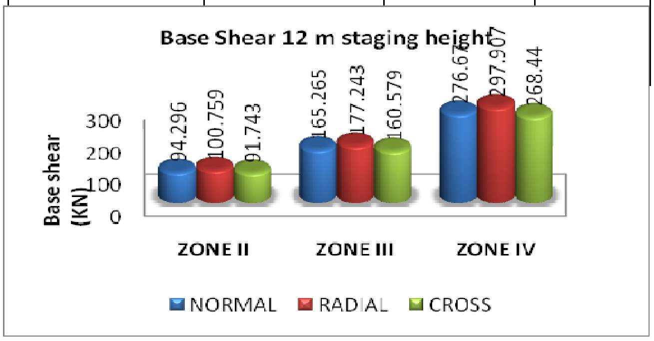

Fig.1Bar chart of base shear for 12m height of staging

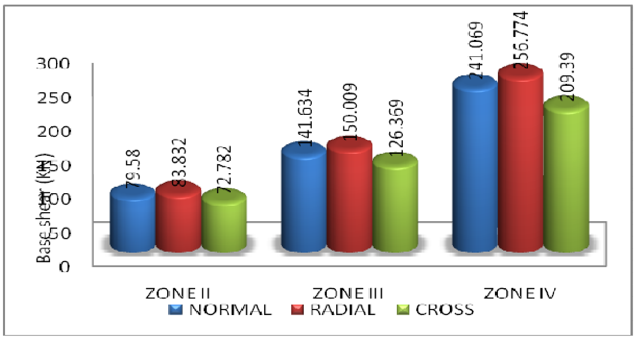

Fig. 2 Bar chart of base shear for 16m height of staging

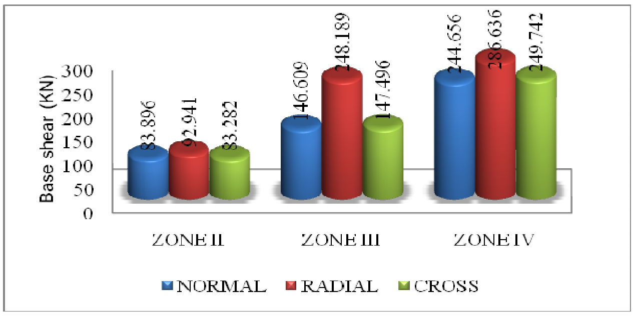

Fig.3 Bar chart of base shear for 20m height of staging

IV. CONCLUSION

1. Column moment in bracing increases by increasing height of staging of water tank.
2. Column moment is minimum for radial bracing.
3. Shear force in bracing increases by increasing height of staging.
4. Shear force in bracing is minimum for radial bracing.
5. Co son of base shear value by manual and sof method is in permissible limit that is 1.17% less value in software analysis as compare to manual.
6. Axial column force and base shear is not much affected by height of staging.
7. Bending moment in bracing increases by increasing height of staging.
8. Maximum displacement increases by increasing staging height for zone IV.
9. Cross bracing gives minimum value for base shear for all zone and staging height.
10. Maximum displacement value is minimum for radial bracing.
11. Maximum displacement is greater in cross bracing.
12. Overturning moment is minimum for cross bracing. by considering results of analysis radial bracing performs better in all manner as compared to cross bracing and normal bracing.

V. SCOPE FOR FUTURE WORK

1. It can be studied for different capacities of water tank. Different types of foundation can be used to give different end conditions and hence a different analysis.
2. Comparison of shaft type staging with frame type staging will be done.
3. Optimization for best type of staging & design cross section of column and braces can be done.
4. Variation of H/D ratio of container can be studied for different zones.
5. Variation for number of column with different staging heights at different zone can be studied.
6. Nonlinear analysis for Time history push over analysis can be done.
7. Different international codes with Indian codes can be compared.
8. Rectangular arrangement of column with circular column can be studied.

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