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EVALUATION OF SEISMIC FORCES ON ELEVATED WATER TANK

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***Abstract* - Earthquake is one of the major natural calamities which have a potential to impart a disasters effect not only on human life but also on infrastructures. Water tanks are considered as an important structure as far as human need and fire protection are concerned. Hence, these structures should not collapse even after an earthquake. The provisions of IS 1893-2002 (Draft) are studied in lined with IITK-GSDMA guidelines. Stiffness of staging is calculated using ETABS analysis package. Seismic forces on various water tanks are calculated for different shapes (Circular and Rectangular) and different parameters such as time period, base shear, base moment, stiffness are presented. The main aim is to evaluate effect of shapes and aspect ratio of water tank on seismic forces. The parametric study suggests that the circular tank performs better than rectangular tank. However for rectangular tank the aspect ratio affects the stiffness of staging in a particular direction.**

Key Words: *Seismic forces, Aspect ratio, tank shape, ETABS.*

1. INTRODUCTION

Water is one of the prime elements responsible for life on earth and it is human's basic need for daily life. Effective water distribution depends on design of water tank in certain area. There are many different way for the storage of liquid such as underground tank, ground supported tank, elevated tank. Elevated tank are mainly use for the distribution of liquid under pressure for storing water, chemical, inflammable liquid etc. Thus elevated tanks are needs to design in such a way that they remain functional even after an earthquake too.

Elevated water tank are frequently use in seismic regions too. It consists of large mass of water at top of staging which is most critical consideration for the failure of tank during earthquake. Hence, seismic behavior of tanks needs to be investigated in detail.

Present study is primarily focused on understanding seismic behavior and performance characteristic of elevated water tank keeping volume of water constant and changing shape and dimension of container.

2. METHODOLOGY

In the present paper different shapes of water tank are used keeping same seismic weight of staging with the help of ETABS analysis. Spring mass model as per IS 1893:2002 has been used to evaluate the seismic base shear, time period, stiffness and overturning moment.

2.1 Model Description

100 m^3 capacity tanks are selected for the study. Six models are prepared having different shape and size considering M30 grade of concrete. Two models are circular and square in shape and four rectangular models having aspect ratio 1.2, 1.5, 1.8 and 2.1 respectively. As shown below.

Case 1 – Circular and Square tanks.

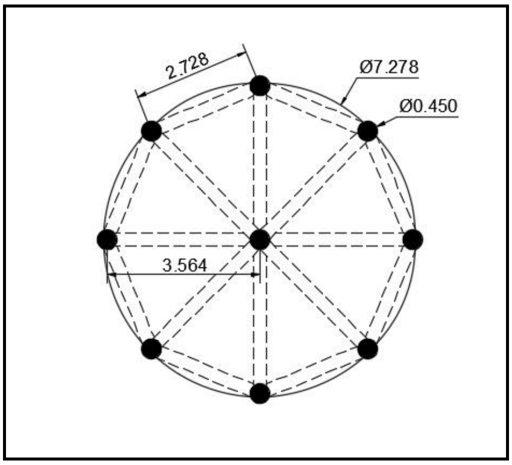

Fig -1: Model 1 (Plan)

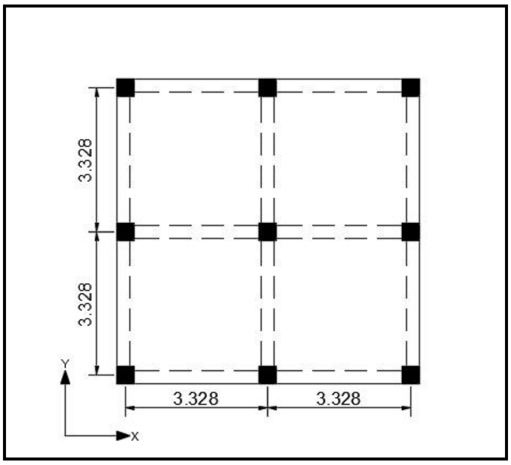

Fig -2: Model 2 (Plan)

Fig -3: FEM MODEL M1

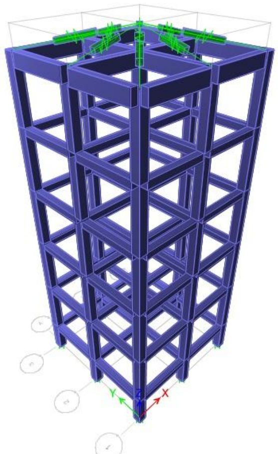

Fig -4: FEM MODEL M2

Case 2 – Rectangular tanks with different aspect ratio.

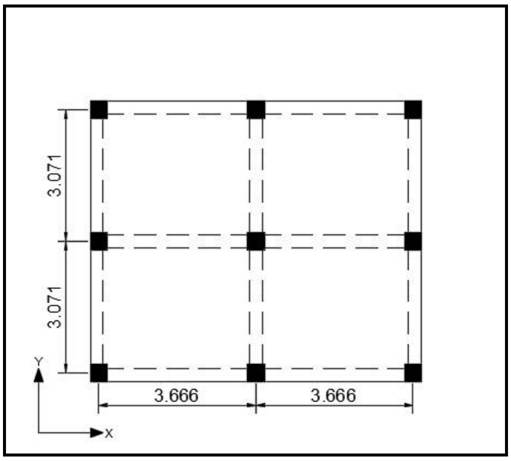

Fig -5: Model 3 (Plan) (Aspect ratio 1.2)

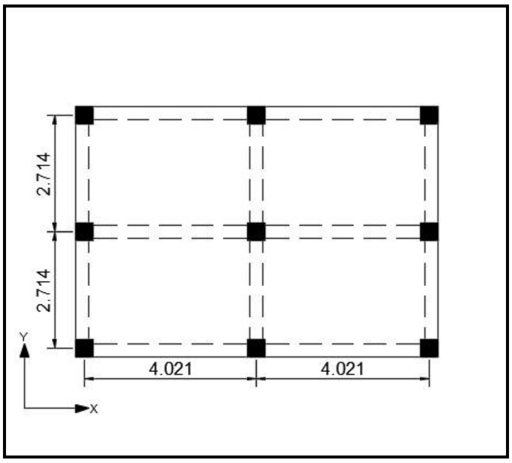

Fig -6: Model 4 (Plan) (Aspect ratio 1.5)

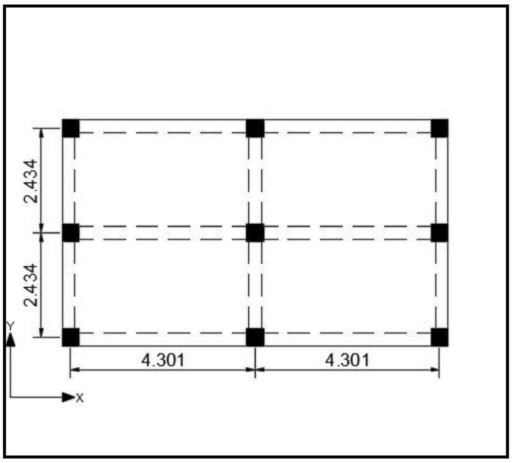

Fig -7: Model 5 (Plan) (Aspect ratio 1.8)

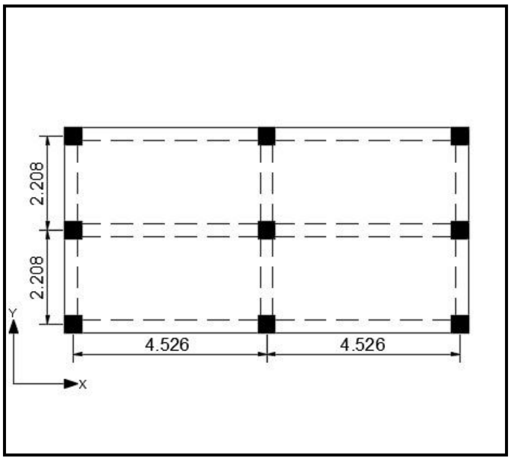

Fig -8: Model 6 (Plan) (Aspect ratio 2.1)

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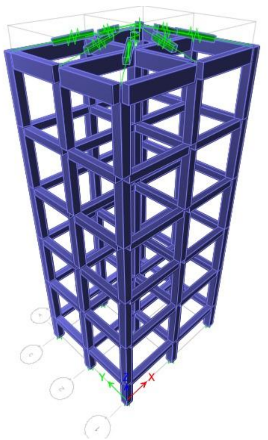

Fig -9: FEM MODEL M3 (Aspect ratio 1.2)

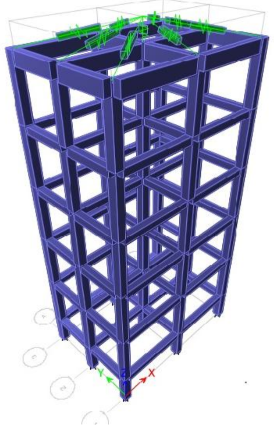

Fig -10: FEM MODEL M4 (Aspect ratio 1.5)

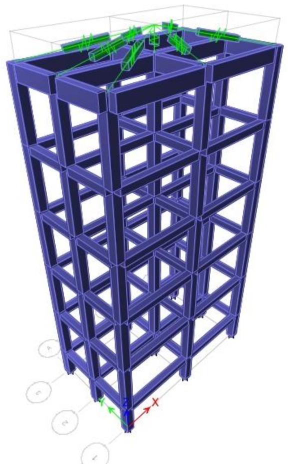

Fig -11: FEM MODEL M5 (Aspect ratio 1.8)

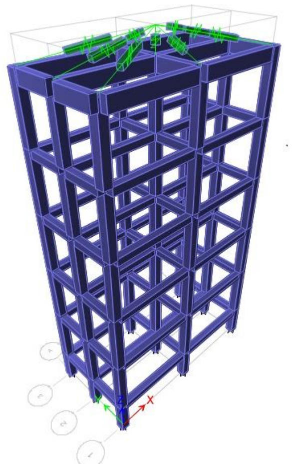

Fig -12: FEM MODEL M6 (Aspect ratio 2.1)

2.2 Analysis and Calculation

Equivalent static analysis and response spectra analysis was carried out on above model. For calculating the seismic weight of tank, weight of empty container plus 1/3 weight of staging is considered. Tank is model in finite element software ETABS. The walls are modeled as shell element with six degree of freedom at each node. Beams and columns are modeled as frame element. The lateral forces considering impulsive and convective masses due to earthquake is lumped at center mass of tank along both the principal directions. A rigid link is assumed from top of staging up to the CG of tank and lateral earthquake forces are lump on rigid link in both principle direction. For the present study CG of tank is taken as CG of empty container. Finally parameter such as base shear, displacement, overturning moment, time period for the above six models are presented. The weight of different components of tank is shown in table.

The parameters of spring mass model are (IS 1893:2002) shown in table 1 below.

Table -1: Parameters of spring mass model (Case 1)

Sr. No.	Parameters	X- Direction		Y- Direction	
		M1	M2	M1	M2
1	mi/m	0.40	0.43	0.40	0.43
2	mc/m	0.57	0.58	0.57	0.58
3	hi/h	0.38	0.38	0.38	0.38
4	hi*/h	1.13	1.05	1.13	1.05
5	hc/h	0.55	0.58	0.55	0.58
6	hc*/h	1.05	1.10	1.05	1.10
7	Cc	3.60	3.90	3.60	3.90
8	kc*h/mg	0.64	0.59	0.64	0.59

Table -2: Parameters of spring mass model (Case 2)

Sr. No.	Parameters	X- Direction			
		M3	M4	M5	M6
1	mi/m	0.39	0.35	0.35	0.34
2	mc/m	0.62	0.65	0.65	0.65
3	hi/h	0.38	0.38	0.38	0.38
4	hi*/h	1.23	1.35	1.35	1.35
5	hc/h	0.56	0.55	0.55	0.55
6	hc*/h	1.38	1.50	1.50	1.50
7	Cc	4	4	4.1	4.15
8	kc*h/mg	0.52	0.49	0.46	0.45

Table -3: Parameters of spring mass model (Case 2)

Sr. No.	Parameters	Y- Direction			
		M3	M4	M5	M6
1	mi/m	0.44	0.51	0.57	0.63
2	mc/m	0.57	0.51	0.46	0.41
3	hi/h	0.38	0.38	0.38	0.38
4	hi*/h	1.00	0.88	0.75	0.68
5	hc/h	0.55	0.58	0.63	0.64
6	hc*/h	1.22	0.91	0.85	0.75
7	Cc	3.80	3.75	3.65	3.60
8	kc*h/mg	0.60	0.68	0.73	0.75

Table -4: Weight of different components (Case 1)

Sr. No.	Component	Case 1	
		M 1	M 2
1	Roof Slab (KN)	124.80	149.32
2	Wall (KN)	234.48	571.45
3	Floor Slab (KN)	260.00	311.08
4	Floor Beam (KN)	212.19	179.68
5	Columns (KN)	526.04	529.20
6	Tie beam (KN)	530.48	527.20
7	water (KN)	981.00	981.00
8	Staging (KN)	1056.52	1056.40
9	Empty container (KN)	831.47	1211.53
10	Empty container + 1/3* (staging) (KN)	1183.64	1563.67
11	CG of Empty container (m)	0.74	0.90
12	Total Seismic weight (KN)	2164.64	2544.67

Table -5: Weight of different components (Case 2)

Sr. No.	Component	Case 2			
		M 3	M 4	M 5	M 6
1	Roof Slab (KN)	151.73	147.55	142.25	136.54
2	Wall (KN)	569.49	586.40	610.01	637.75
3	Floor Slab (KN)	316.10	307.40	296.36	284.46
4	Floor Beam (KN)	181.89	181.81	181.84	181.81
5	Columns (KN)	529.20	529.20	529.20	529.20
6	Tie beam (KN)	530.50	530.29	530.35	530.27
7	water (KN)	981.00	981.00	981.00	981.00
8	Staging (KN)	1059.70	1059.49	1059.55	1059.47
9	Empty container KN	1219.21	1223.17	1230.46	1240.56
10	Empty container + 1/3*(stagimg) (KN)	1572.45	1576.33	1583.64	1593.72
11	CG of Empty container (m)	0.88	0.92	0.97	1.03
12	Total Seismic weight (KN)	2553.45	2557.33	2564.64	2574.72

3. RESULTS AND DISCUSSION

Seismic data used for analysis

Table -6: Data used for analysis

Zone factor (Z)	0.24
Importance factor (I)	1.5
Response reduction factor (R)	2.5
Soil type	Medium

3.1 Case 1 – Circular and Square tanks.

3.1.1 TIME PERIOD

For model M1 and M2 the time period in both principle directions is same. Time period is found to be minimum for model M1 and maximum for model M2.

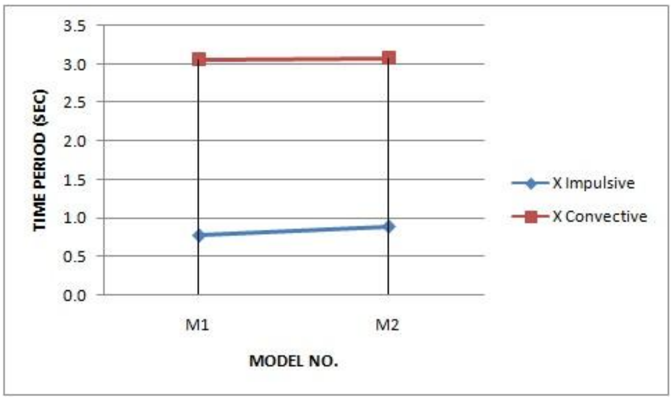

Chart -1: Time period.

3.1.2 BASE SHEAR

For model M1 and M2 the base shear in both principle directions is same. Base shear is found to be minimum for model M1 and maximum for model M2.

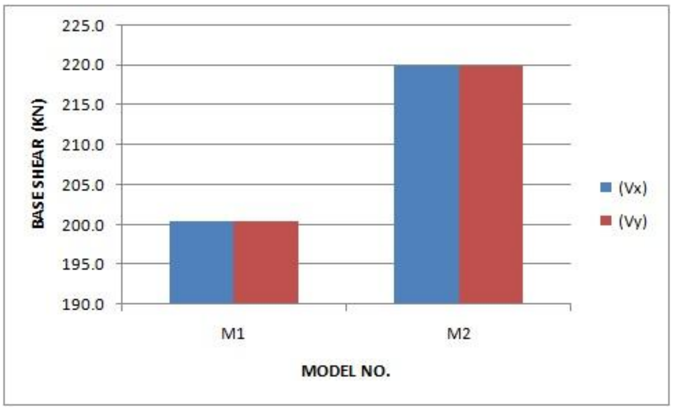

Chart -2: Base shear.

3.1.3 BASE MOMENT

For model M1 and M2 the base moment in both principle directions is same. Base moment is found to be minimum for model M1 and maximum for model M2.

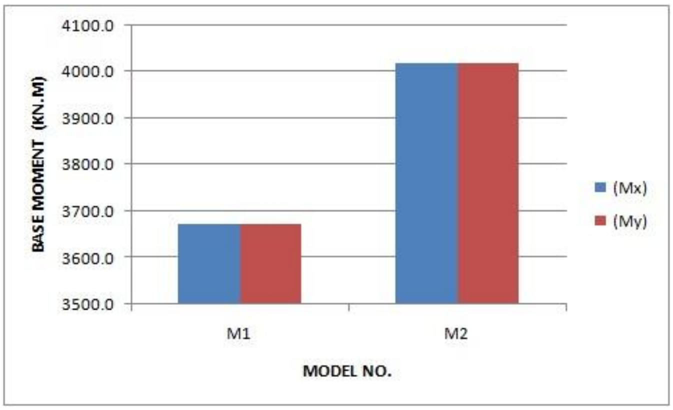

Chart -3: Base Moment.

3.1.4 STIFFNESS

Stiffness is found to be maximum for model M1 and minimum for model M2.

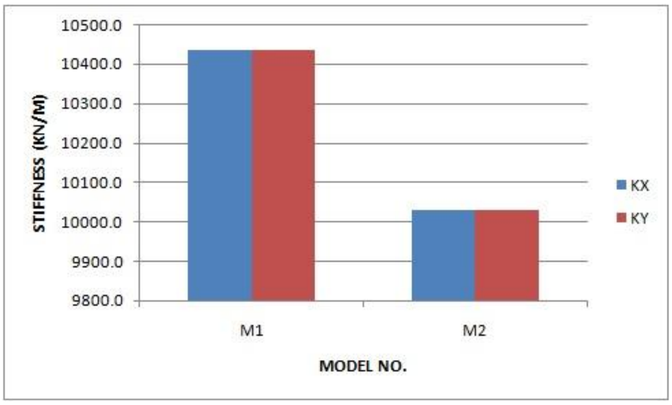

Chart -4: Stiffness

3.2 Case 2 – Rectangular tanks with different aspect ratio

3.2.1 TIME PERIOD

Time period for model M3 to M6 along X direction goes on increasing and goes on decreasing along Y direction as aspect ratio changes from 1.2 to 2.1.

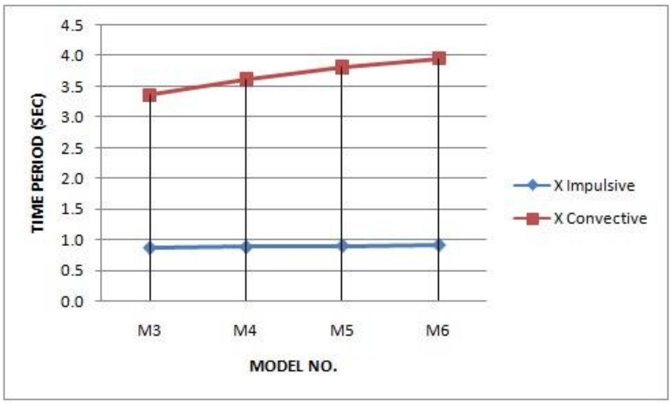

Chart -5: Time period (X- direction)

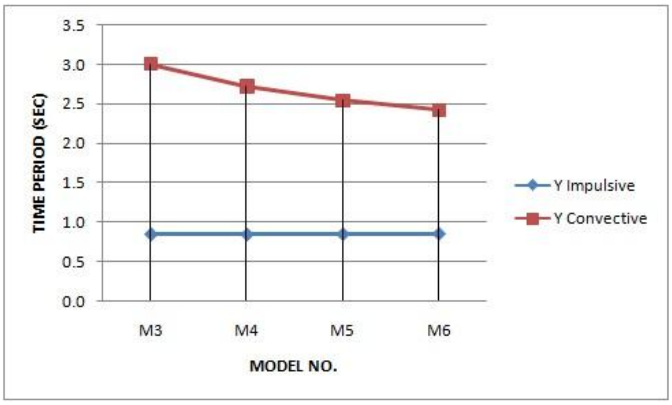

Chart -6: Time period (Y- direction)

3.2.2 BASE SHEAR

Base shear for model M3 to M6 in X direction goes on decreasing and in Y direction goes on increasing as aspect ratio changes from 1.2 to 2.1.

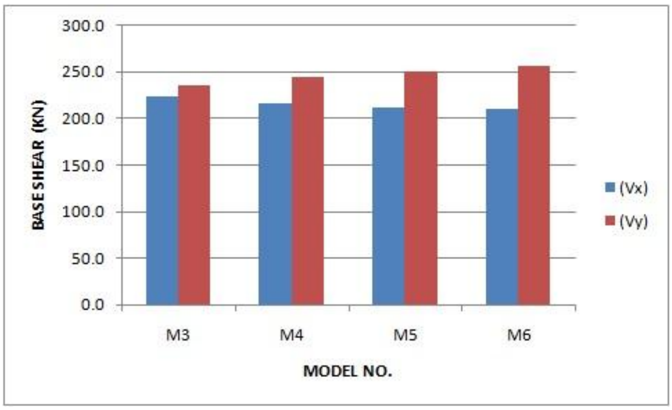

Chart -7: Base shear.

3.2.3 BASE MOMENT

Base moment for model M3 to M6 goes on decreasing along X direction and goes on increasing along Y direction as aspect ratio changes from 1.2 to 2.1.

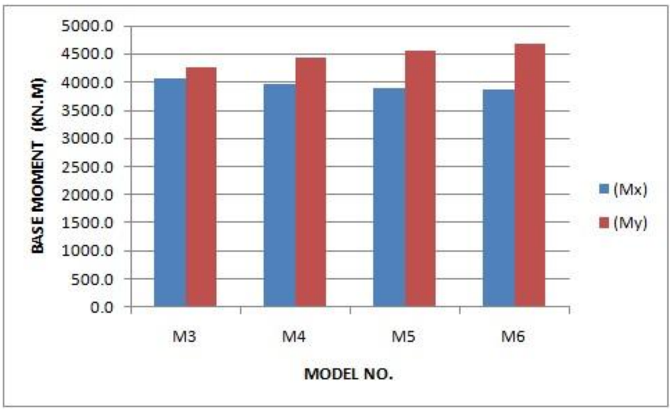

Chart -8: Base Moment.

3.2.4 STIFFNESS

Stiffness for model M3 to M6 along X direction goes on decreasing and goes on increasing along Y direction as aspect ratio changes from 1.2 to 2.1.

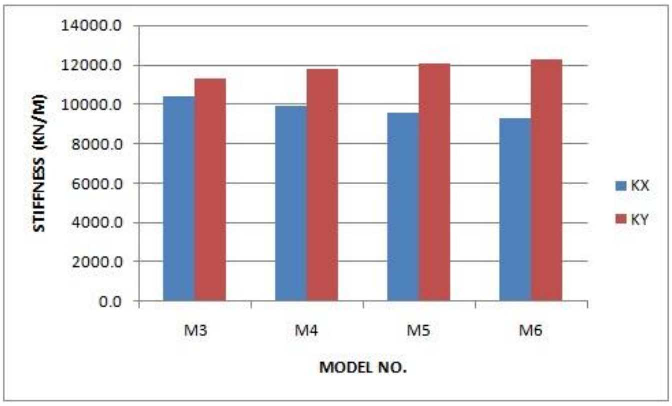

Chart -9: Stiffness

4. CONCLUSION

The performance of circular shape elevated water tank is found to be better than square shape elevated water tank.
The time period, base shear and base moment are found to be less in circular tank compare to rectangular tank.
Time period in case of convective mode in X direction and Y direction is found to be varying between 3.33 sec to 3.9 sec and 2.4 sec to 3 sec respectively with increase in aspect ratio from 1.2 to 2.1.
Base shear for model M3 to M6 in X direction decrease in the range of 1.33% to 3.3% and increase in Y direction in the range of 2.3% to 3.88% with successive increase in aspect ratio from 1.2 to 2.1.
Base moment for model M3 to M6 in X direction decrease in the range of 0.96% to 2.87% and increase in Y direction in the range of 2.47% to 3.88% with successive increase in aspect ratio from 1.2 to 2.1.
Increasing the depth of tank by 11.67% will decrease the staging stiffness by 4.3% in that particular direction. This may be because of the increase in length of flexural member which makes staging slender in that direction.

REFERENCES

[1] Ayazhussain M. Jabar, H. S. Patel, "SEISMIC BEHAVIOUR OF RC ELEVATED WATER TANK UNDER DIFFERENT STAGING PATTERN AND EARTHQUAKE CHARACTERISTICS", International Journal of Advanced Engineering Research and Studies, April-June, 2012, Issue III, Vol. I.

[2] Bojja.Devadanam , M K MV Ratnam , Dr.U RangaRaju, "Effect of Staging Height on the Seismic Performance of RC Elevated Water Tank", International Journal of Innovative Research in Science, Engineering and Technology, January 2015, Issue 1, Vol. 4, PP. 18568-18575.

[3] GAREANE A. I. ALGREANE, S. A. OSMAN, OTHMAN A. KARIM, AND ANUAR KASA "Dynamic Behaviour of Elevated Concrete Water Tank with Alternate Impulsive Mass Configurations" Proceedings of the 2nd WSEAS International Conference on ENGINEERING MECHANICS, STRUCTURES and ENGINEERING GEOLOGY, ISSN: 1790-2769, PP. 245-250.

[4] Mr. Nathu D.Thombare , Mr. Pravin B. Shinde , Prof. Vinod A. Choudhari , Miss. Madhuri P. Shinde, Miss. Karishma P.Yadav , Mr. Rajkumar M. Madake , "SEISMIC ANALYASIS AND DESIGN OF PROPOSED ELEVATED INTZ TYPE WATER TANK AT SBPCOE INDAPUR", NOVATEUR PUBLICATIONS INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT], MARCH-2015, ISSUE 3, VOLUME 2, PP.1-7.

[5] Pavan .S. Ekbote, Dr. Jagadish .G. Kori, "Seismic Behavior of RC Elevated Water Tank under Different Types of Staging Pattern", Journal of Engineering, Computers & Applied Sciences (JEC&AS), August 2013, ISSN No: 2319-5606, Volume 2, PP. 24-29.

[6] R. Livaog lua, A. Dog angu n, "Simplified seismic analysis procedures for elevated tanks considering fluid–structure–soil interaction", Journal of Fluids and Structures, 28 February 2006, PP. 421–439.

[7] S. Bozorgmehrnia, M.M. Ranjbar and R. Madandoust, "Seismic Behavior Assessment of Concrete Elevated Water Tanks", Journal of Rehabilitation in Civil Engineering, 1-2 (2013), PP. 69-79.

[8] IITK-GSDMA Guidelines for Seismic Design of Liquid Storage Tanks Provisions with commentary and explanatory examples.

[9] Draft IS: 1893 (Part-1) -2002 Criteria for Earthquake Resistant Design of Structures, General Provisions of Buildings, Bureau of Indian standards, New Delhi, India. (Fourth Revision)

[10] Draft IS: 1893-2002 (Part-II, Liquid Retaining Tanks) Criteria for Earthquake Resistant Design of Structures, Bureau of Indian standards, New Delhi, India.

[11] IS: 3370 (Part II) – 2009 code of practice for concrete structures for the storage of liquids part 2 reinforced concrete structures (First Revision)

[12] IS: 456-2000 Plain and Reinforced Concrete –Code Of Practice (Fourth Revision)

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