Parametric Study of Hydrodynamic Pressure for Ground Rested Rectangular RC Tank

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***Abstract* – Ground supported tanks are important components of lifeline and industrial facilities as it is used to store water and other liquids such as petroleum product, liquefied natural gas, chemical fluid and wastage of different forms in huge capacities. In this paper a parametric study on ground rested rectangular RC tank is carried out considering different length to depth ratio. The seismic analysis of tank has been performed considering water mass in two parts as impulsive mass and convective mass suggested by GSDMA guidelines. The response of tank has been compared in form of Time period in impulsive and convective mode, Design horizontal seismic coefficient, Base shear, Base moment and Hydrodynamic pressure due to impulsive and convective mode. From the results, it has been found that base shear, base moment and hydrodynamic pressure on wall are increases with increasing ratio of length to the depth of tank (b/a).**

***Keywords*-Ground Rested Tank, b/a ratio, Spring Mass Model, Hydrodynamic Pressure, Base Shear, Base Moment.**

I. INTRODUCTION

Liquid storage tanks have always been an important part of water distribution system and also used for storage of chemical, refined petroleum products etc. Water supply is a life line facility that must remain functional after disaster and also Indian geographical features are such that there is monsoon of four months only but for remaining eight months we have to make some kind of adjustments for getting water. Hence there is a need to store water so that it can be distributed to a large commodity of human society for satisfying their requirements. For storing water and its distribution, Water tanks rested on ground is an economical solution. Therefore, most municipalities in India have water supply system which depends on ground rested tanks for storage.

Most of the previous studies were focused on the tank containing liquid considering only one mass and it does not cover important aspect for analysis and design of water tanks related to the effect of hydrodynamic pressure of the water, which produce due to vibration of tank when earthquake strikes. But after the Bhuj earthquake, revision of current Indian code became inevitable. Hence, it was decided to develop guidelines under the project "Review of Building codes and preparation of Commentary and Handbooks" assigned by the Gujarat State Disaster Management Authority (GSDMA), Gandhinagar to the Indian Institute of Technology Kanpur in 2003 [1].

The stimulus of the present study is to understand the hydrodynamic pressure on ground rested rectangular liquid storage RC tank on the basis of GSDMA guidelines and to understand the effect of variation of length/depth ratio of tank on parameters like time period, base shear, base moment and hydrodynamic pressure for both the modes.

II. SPRING MASS MODEL

Two mass model for tank was proposed by Housner (1963) which is more appropriate and is being commonly used in most of the international codes including Draft code for IS 1893 (Part-II) [3]. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and base. Thus, total liquid mass gets divided into two parts, i.e., impulsive mass and convective mass. In spring mass model of tank-liquid system, these two liquid masses are to be suitably represented. Figure 1 represents the Spring Mass Model and description of hydrodynamic pressure distribution on tank wall.

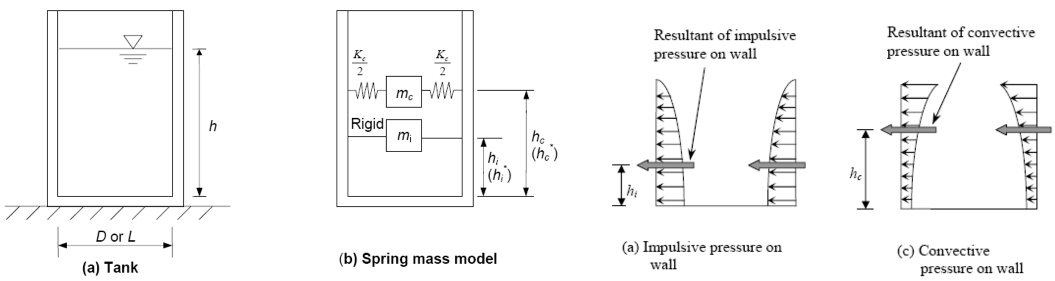


Figure 1 : Spring mass model for ground supported rectangular tank

III. PROBLEM DESCRIPTION

In present work, a Ground rested Rectangular RC water tank having various size of length from 15 to 2.5 and width from 15 to 2.5 has been considered. For the parametric study purpose, seismic analysis of tank having different size is done by changing the width to depth ratio from 3.00 to 0.50. For seismic analysis it has been considered that the water tank is located on hard soil and in seismic zone V. The data considered for seismic analysis of tanks are tabulated in Table-1. For all these tanks the hydrodynamic pressure, base shear, base moment, etc acting in impulsive and convective modes are calculated as per GSDMA Guideline. The results obtained are displayed in tabulated as well as graphical form as follows.

Type of tank	Rectangular RC ground resting tank
Size of tank	Width from 15 to 2.5 Length from 15 to 2.5
Wall thickness	0.4 m
Base thickness	0.5 m
Grade of concrete	M30
Support condition	Fixed base
Zone of earthquake	Zone V
Importance factor	1.5
Response reduction factor	2.0
Soil condition	Hard soil

IV. SEISMIC ANALYSIS

This chapter presents the seismic procedure carried out to determine the hydrodynamic pressures on tank wall. Liquid retaining structure was analyzed for self weight and seismic loads. Under static condition, liquid applies only hydrostatic pressure on container. But during base excitation liquid applies additional pressure on wall and base this is called hydrodynamic pressure. This is in additional to the hydrostatic pressure. Hydrodynamic forces exerted by liquid on tank wall shall be considered in the analysis in addition to hydrostatic forces. These hydrodynamic forces are evaluated with the help of spring mass model of tanks. The impulsive and convective masses and their points of application depends on aspect ratio of tanks and the all parameters of mechanical analogue are obtained from mathematical expressions given in the GSDMA Guideline.

Seismic analyses of all the water tank models for different capacities are performed as per guidelines given in GSDMA. The complete seismic analysis procedure of ground supported tanks consists following steps:

1) Weight calculations
2) Modelling of liquid
3) Time period calculations
4) Design horizontal Seismic coefficient
5) Base shear and Base moment
6) Hydrodynamic pressure

V. RESULTS AND DISCUSSION

In this study, a reinforced ground rested rectangular water tank with various size of width from 15 to 2.5m and length from 15 to 2.5m with different width to depth ratio has been considered. With considering two-mass water model, seismic responses including hydrodynamic pressure, base shear, base moment, etc are calculated as per GSDMA Guideline. The results obtained in form of base shear, base moment with fixed and hinged based are tabulated in Table 2.1, 2.2, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 For Impulsive & Convective respectively.

Table-2.1 Base shear (kN) For various b/a ratio

b/a ratio	Vi (kN)	Vc (kN)	V (kN)
3.00	2520	327	2541
2.50	2194	273	2211
2.00	1868	218	1881
1.75	1705	191	1716
1.50	1543	164	1551
1.25	1380	136	1386
1.00	1217	109	1222
0.75	1054	82	1057
0.50	891	55	893

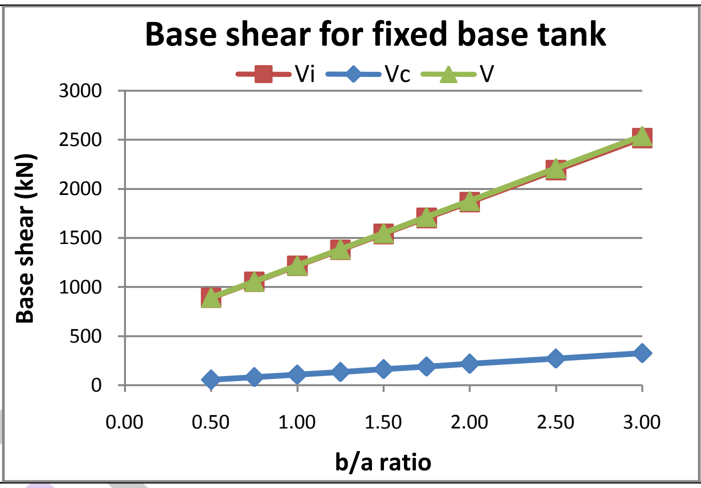


Table-2.2 Base moment (kN m) For various b/a ratio

b/a ratio	Mi (kN-m)	Mc (kN-m)	M (kN-m)
3.00	5578.52	886.36	5648.49
2.50	4898.41	738.63	4953.79
2.00	4218.41	590.9	4259.5
1.75	3878.26	517.04	3912.57
1.50	3538.21	443.18	3565.85
1.25	3198.16	369.32	3219.41
1.00	2858.1	295.45	2873.34
0.75	2518.05	221.59	2527.78
0.50	2178	147.73	2183.01

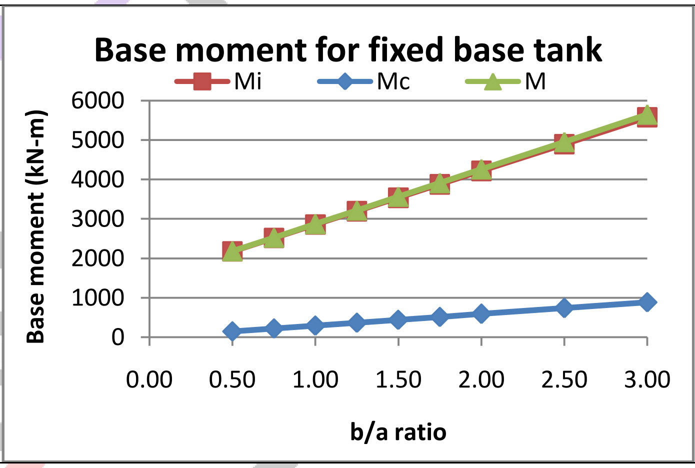


Table-3.1 Impulsive base shear (kN) for hinged base tank

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	Vi (kN)	Vi (kN)	Vi (kN)
3.00	2520		
2.50	2194	2087	
2.00	1868	1765	1642
1.75	1705	1603	1485
1.50	1543	1442	1328
1.25	1380	1281	1171
1.00	1217	1120	1014
0.75	1054	959	857
0.50	891	798	700

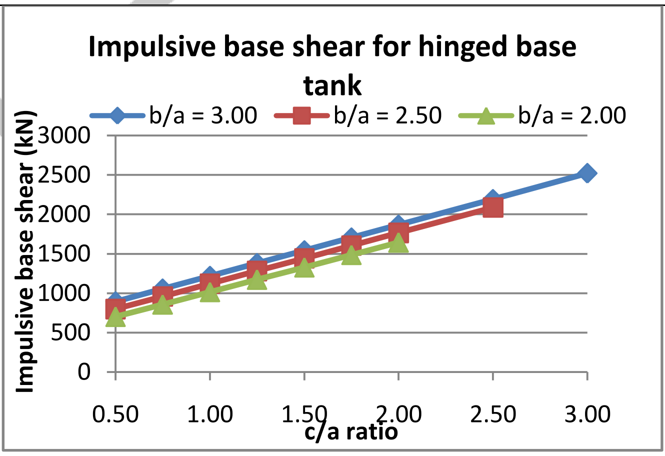
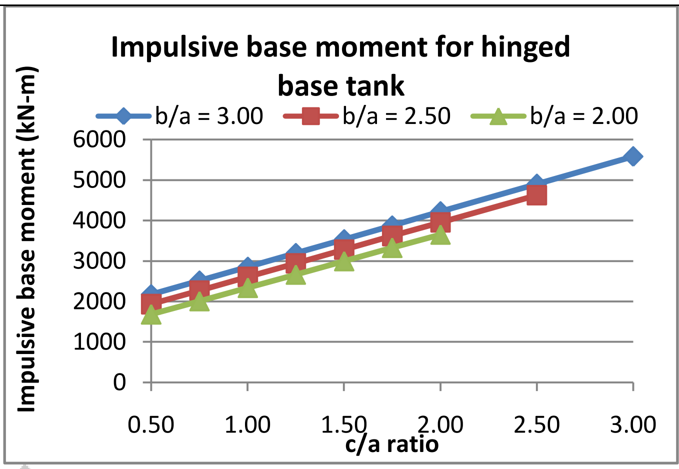


Table-3.2 Impulsive base moment (kN-m) for hinged base

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	Mi (kN-m)	Mi (kN-m)	Mi (kN-m)
3.00	5578.52		
2.50	4898.41	4627.85	
2.00	4218.41	3954.46	3655.24
1.75	3878.26	3617.76	3326.32
1.50	3538.21	3281.07	2997.4
1.25	3198.16	2944.37	2668.48
1.00	2858.1	2607.68	2339.56
0.75	2518.05	2270.98	2010.64
0.50	2178	1934.28	1681.72



`*Table-3.3 Convective base shear (kN) for hinged base*

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	Vc (kN)	Vc (kN)	Vc (kN)
3.00	327		
2.50	273	236	
2.00	218	189	86
1.75	191	165	76
1.50	164	141	65
1.25	136	118	54
1.00	109	94	43
0.75	82	71	32
0.50	55	47	22

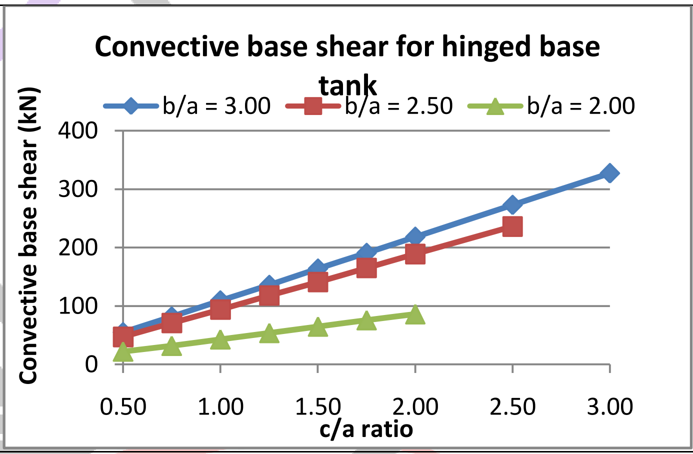


Table-3.4 Convective base moment (kN-m) for hinged base

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	Mc (kN-m)	Mc (kN-m)	Mc (kN-m)
3.00	886.36		
2.50	738.63	657.05	
2.00	590.9	525.64	251.78
1.75	517.04	459.93	220.3
1.50	443.18	394.23	188.83
1.25	369.32	328.52	157.36
1.00	295.45	262.82	125.89
0.75	221.59	197.11	94.42
0.50	147.73	131.41	62.94

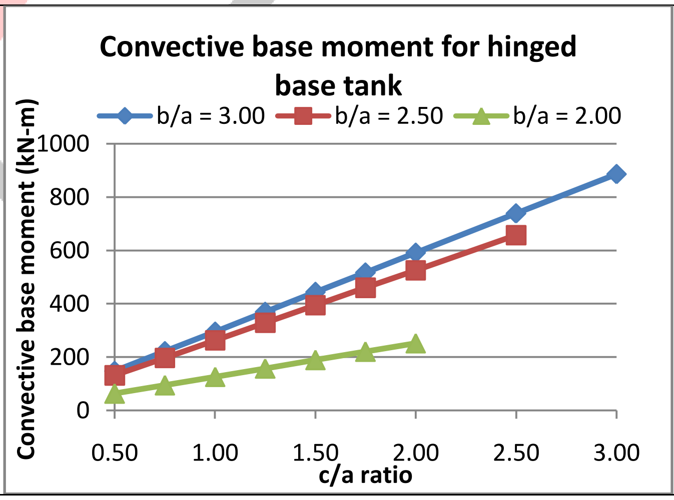


Table-3.5 Total base shear (kN) for hinged base

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	V (kN)	V (kN)	V (kN)
3.00	2541		
2.50	2211	2100	
2.00	1881	1775	1644
1.75	1716	1612	1487
1.50	1551	1449	1330
1.25	1386	1287	1172
1.00	1222	1124	1015
0.75	1057	962	858
0.50	893	799	701

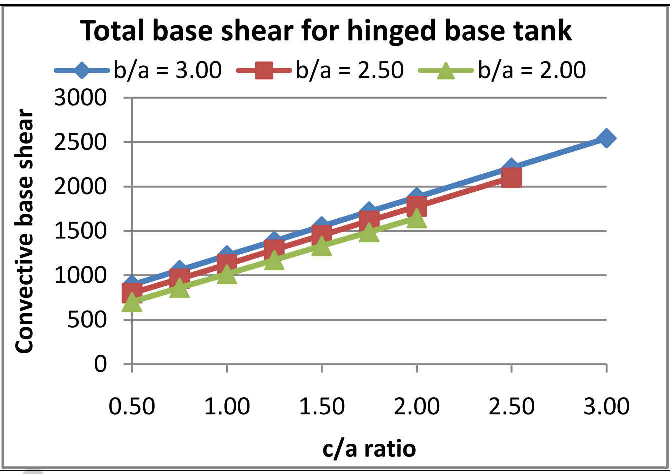
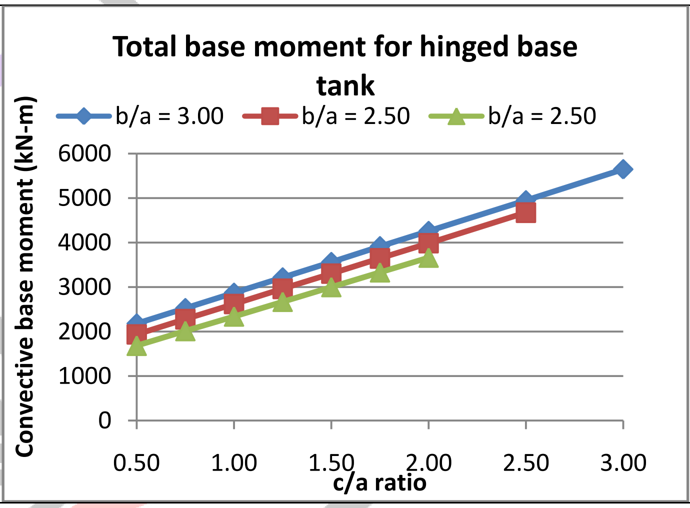


Table-3.6 Total base moment (kN-m) for hinged base

c/a ratio	b/a = 3.00	b/a = 2.50	b/a = 2.00
	M (kN-m)	M (kN-m)	M (kN-m)
3.00	5648.49		
2.50	4953.79	4674.26	
2.00	4259.5	3989.24	3663.9
1.75	3912.57	3646.88	3333.61
1.50	3565.85	3304.67	3003.34
1.25	3219.41	2962.64	2673.11
1.00	2873.34	2620.89	2342.94
0.75	2527.78	2279.52	2012.86
0.50	2183.01	1938.74	1682.9



VII. CONCLUSION

- Parametric study is carried out for various sizes and various base condition of tank. Result is obtained in form of impulsive and convective base shear and base moment.
- Comparison of each result is carried out with respect to various b/a ratio which gives clear idea about behavior of hydrodynamic pressure.
- The base shear for impulsive mass increase with increase in b/a ratio for all tanks. While convective mass also increase with increase in b/a ratio. This was due to the change in time period for the both modes.
- Both impulsive and convective base shear increase as capacity increases because of increased in height (h),length (L), width (B) and mass of liquid.
- The base moment for the impulsive mass increase with the increase in the b/a ratio while for convective mass increase with increase in b/a ratio. This due to the change in time period and the capacity increase with the increase in b/a ratio.

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