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Parametric Study of Hydrodynamic Pressure for Ground Rested 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 circular RC tank is carried out considering different height to diameter ratio for different capacities. 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 maximum depth of water to the diameter of tank (h/D).*

Keywords-*Ground Rested Tank, h/D 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 circular liquid storage RC tank on the basis of GSDMA guidelines and to understand the effect of variation of height/diameter ratio of tank and tank capacities 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.

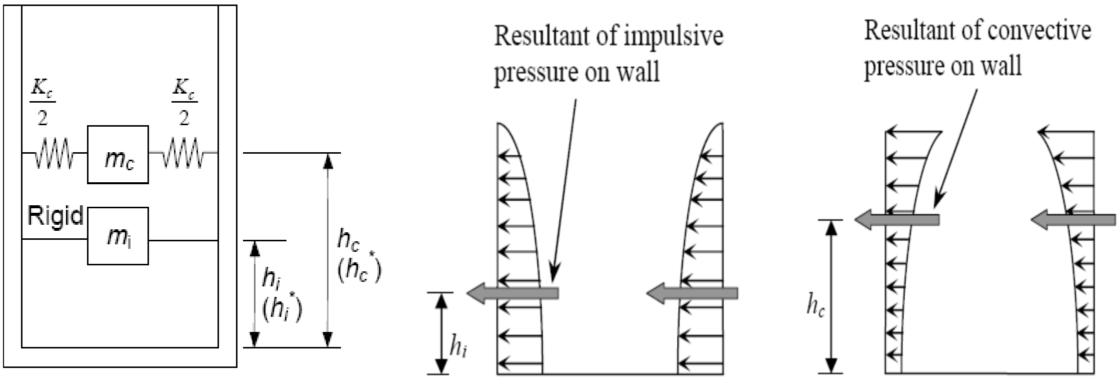


Fig-1 Spring Mass Model & description of hydrodynamic pressure distribution on wall

III. PROBLEM DESCRIPTION

In present work, a Ground rested circular RC water tank having various storage capacities of 600 m^3, 700 m^3, 800m^3, 900m^3, 1000m^3, 1200m^3 and 1500m^3 has been considered. For the parametric study purpose, seismic analysis of tank having different capacity is done by changing the height to diameter ratio from 0.3 to 0.9 with the increment of 0.1. For seismic analysis it has been considered that the water tank is located on medium soil and in seismic zone IV. 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.

Table-1 Problem Data

Type of Tank	Circular RC Ground Resting Tank
Capacity	600m^3, 700m^3, 800m^3, 900m^3, 1000m^3, 1200m^3, 1500m^3
h/D ratio	0.3, 0.4, 0.5, 0.6, 0.7, 0.8and 0.9
Seismic Zone	Fourth (IV)
Soil Condition	Medium
Importance Factor “I”	1.5
Response Reduction Factor “R”	2.0

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
4) Time period calculations
5) Design horizontal Seismic coefficient
6) Base shear and Base moment
7) Hydrodynamic pressure

V. RESULTS AND DISCUSSION

In this study, a reinforced ground rested circular water tank with various storage capacities of 600 m^3, 700 m^3, 800m^3, 900m^3, 1000m^3, 1200m^3 and 1500m^3 and with different height to diameter ratios 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 time period, base shear, base moment and Pressure are tabulated in Table 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 5.1, 5.2 For Impulsive & Convective respectively.

Table-2.1 Impulsive Time Period (Sec)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	0.03	0.03	0.03	0.03	0.03	0.04	0.04
0.4	0.03	0.03	0.03	0.04	0.04	0.04	0.05
0.5	0.03	0.04	0.04	0.04	0.04	0.05	0.05
0.6	0.03	0.04	0.04	0.04	0.04	0.05	0.06
0.7	0.04	0.04	0.04	0.05	0.05	0.05	0.06
0.8	0.04	0.04	0.05	0.05	0.05	0.06	0.06
0.9	0.04	0.05	0.05	0.05	0.05	0.06	0.07

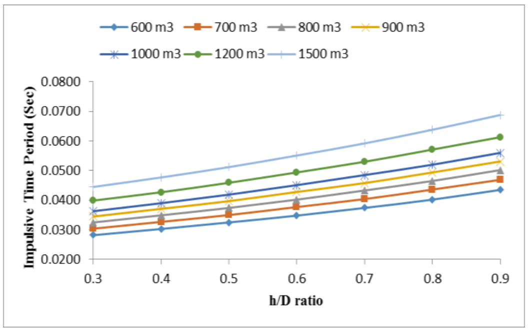


Table-2.2 Convective Time Period (Sec)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	4.32	4.43	4.53	4.62	4.62	4.85	5.03
0.4	3.89	3.99	4.08	4.16	4.16	4.36	4.52
0.5	3.64	3.74	3.82	3.9	3.9	4.09	4.21
0.6	3.49	3.58	3.66	3.73	3.73	3.92	4.07
0.7	3.38	3.46	3.54	3.61	3.61	3.79	3.94
0.8	3.29	3.38	3.45	3.53	3.53	3.7	3.84
0.9	3.23	3.31	3.38	3.45	3.45	3.62	3.76

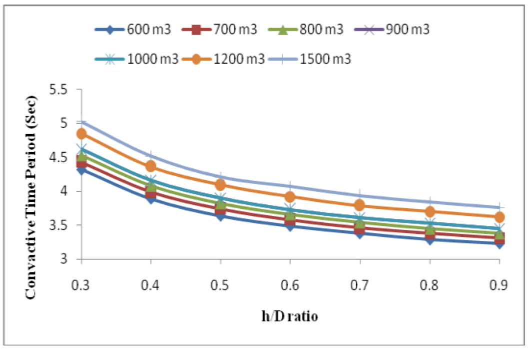


Table-3.1 Impulsive Base Shear results (kN)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	745	847	951	1053	1151	1358	1647
0.4	910	1040	1171	1300	1425	1671	2039
0.5	1051	1203	1355	1503	1662	1956	2387
0.6	1167	1349	1513	1691	1862	2195	2688
0.7	1265	1455	1646	1828	2026	2382	2922
0.8	1346	1559	1750	1955	2150	2550	3125
0.9	1426	1639	1849	2048	2262	2670	3298

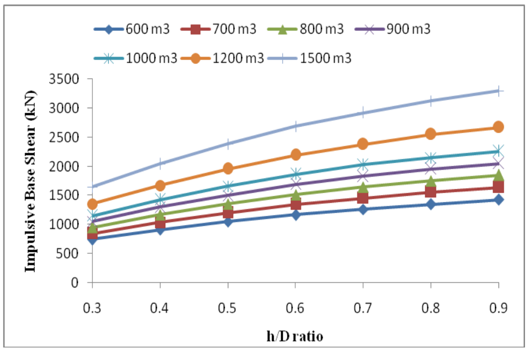


Table-3.2 Convective Base Shear results (kN)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	177	201	224	247	269	315	378
0.4	166	188	211	232	253	294	353
0.5	149	169	189	208	229	266	319
0.6	133	152	169	187	205	238	286
0.7	119	135	151	167	183	213	256
0.8	107	123	137	151	165	193	231
0.9	98	112	125	137	150	175	211

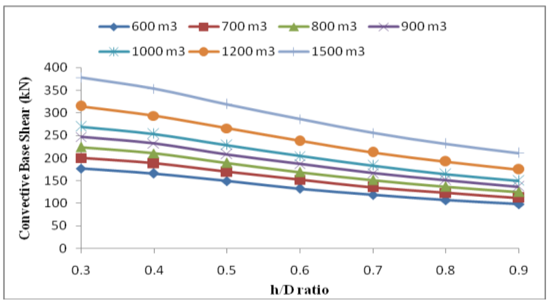


Table-4.1 Impulsive Base Moment results (kN-mt)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	1364	1618	1888	2162	2431	3028	3913
0.4	1967	2350	2750	3161	3572	4412	5752
0.5	2595	3105	3635	4174	4770	5926	7721
0.6	3215	3896	4543	5266	5988	7452	9761
0.7	3833	4622	5445	6259	7181	8909	11694
0.8	4500	5475	6384	7402	8405	10555	13842
0.9	5270	6348	7462	8560	9775	12207	16181

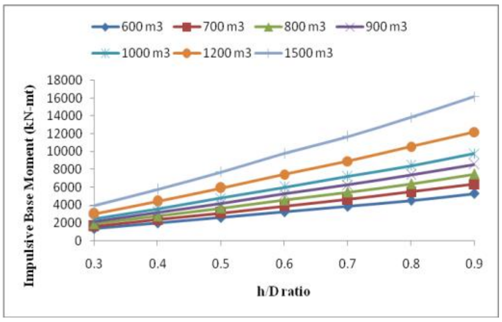


Table-4.2 Convective Base Moment results (kN-mt)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	397	473	553	634	714	889	1146
0.4	474	566	663	760	858	1056	1367
0.5	522	623	727	833	948	1171	1511
0.6	550	664	772	891	989	1245	1612
0.7	571	684	803	919	1048	1290	1672
0.8	586	709	803	948	1071	1331	1722
0.9	605	724	845	964	1094	1351	1765

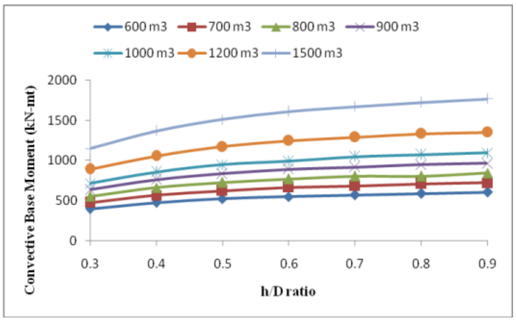


Table-5.1 Impulsive Pressure results (kN-sq.mt)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	7.81	8.21	8.59	8.93	9.23	9.83	10.57
0.4	9.27	9.76	10.2	10.61	10.98	11.65	12.55
0.5	10.37	10.91	11.4	11.85	12.3	13.06	14.05
0.6	11.13	11.74	12.26	12.77	13.23	14.05	15.13
0.7	11.64	12.26	12.83	13.34	13.85	14.69	15.82
0.8	11.96	12.63	13.18	13.72	14.21	15.12	16.27
0.9	12.18	12.82	13.4	13.91	14.43	15.32	16.54

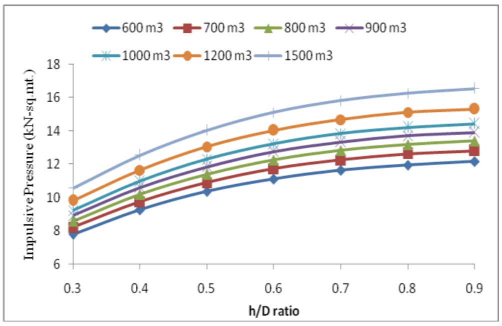
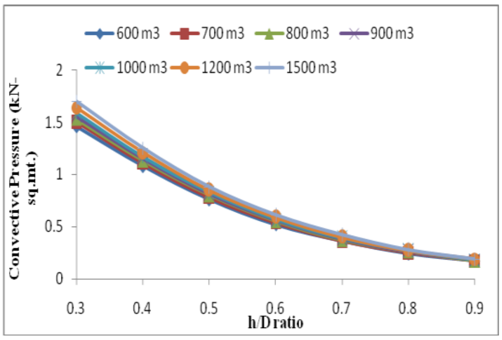


Table-5.2 Convective Pressure results (kN-sq.mt)

h/D ratio	600 m^3	700 m^3	800 m^3	900 m^3	1000 m^3	1200 m^3	1500 m^3
0.3	1.46	1.5	1.53	1.56	1.59	1.64	1.7
0.4	1.08	1.11	1.13	1.15	1.17	1.21	1.25
0.5	0.76	0.78	0.8	0.81	0.83	0.85	0.88
0.6	0.52	0.54	0.55	0.56	0.57	0.59	0.61
0.7	0.36	0.36	0.37	0.38	0.39	0.4	0.42
0.8	0.24	0.25	0.26	0.26	0.27	0.27	0.28
0.9	0.17	0.17	0.17	0.18	0.18	0.19	0.19



VII. CONCLUSION

The conclusions obtained based on the results from seismic analysis of ground rested circular tank are discussed below.

- Time period in Impulsive mode increase with increasing ratio of (h/D) .Time period in Convective mode decrease with increasing ratio of (h/D).

- The base shear for impulsive mass increases with increase in h/d ratio for all capacities. While for convective mass decreases with increase in h/d ratio for all capacities. This was due to the difference in time period for both the modes.
- In base moment for impulsive mass increases with increase in h/d ratio for all capacities. While for convective mass decreases with increase in h/d ratio for all capacities.
- As h/d ratio increases, impulsive hydrodynamic pressure increases compared to convective mode.

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