International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 06 , June 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

SEISMIC ANALYSIS OF GROUND SUPPORTED WATER TANK WITH DIFFERENT ASPECT RATIOS

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ABSTRACT

Aspect ratio of tank wall is an important criterion to be decided by the structural Engineer. The behaviour of tank walls is greatly influence by the aspect ratio. For the ground supported water tank the tank walls are the critical element and will needs to be analyzed carefully. In the present paper the efforts are made to study the effect of aspect ratio of tank wall on seismic forces and behaviour of ground supported water tank. The seismic forces were calculated as per spring mass model suggested by IS 1S1893:2002.The parametric study is performed on the tank with different aspect ratios of tank tall. The adopted aspect ratios are 1.5, 2.0 2.5 and 3.0. The volume of tank is kept same for all aspect ratio and tank dimensions are worked out accordingly. Equivalent static analysis and response spectra dynamic analysis was carried out on the tank and parameters such as base shear, bending moment in tank wall, modal time period and roof displacement are compared and presented. Modelling and Analysis of tank is carried out using ETABS analysis package. There is considerable change in vertical moment and slight change in horizontal moment was observed. It is recommended to keep the aspect ratio between 2.5 to 3.0 for better control over the seismic forces.

Keywords: Aspect ratio, ETABS, Ground supported tank, Seismic analysis Spring mass model.

I. INTRODUCTION

Water tank is considered to be an important structure and needs to remain functional during earthquake event to satisfy the need of water after earthquake. The ground supported tank has been largely used to store water. The main elements of ground supported tank include base slab and tank walls. Since the tank is resting on the firm ground the base slab will not be a critical element and hence only nominal reinforcement and nominal steel will suffice, however the tank walls need to be analysed carefully.

When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion tank walls and liquid is 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 induced impulsive hydrodynamic pressure on tank wall and base. Liquid mass in upper region of tank undergo 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 in to two parts i.e. impulsive mass and convective mass

II. METHODOLOGY

In the present paper the ground supported water tank are analysed for different aspect ratios. Spring mass idealization as per IS 1893:2002 has been used to evaluate the seismic base shear.Four different mathematical models are prepared for the tank with different aspect ratio.

TABLE I. DETAILS OF ANALYSIS MODEL

Sr. No.	Item	Model M1	Model M2	Model M3	Model M4
1	Aspect ratio of wall L/h	1.5	2.0	2.5	3.0
2	Clear Length(m)	9.235	10.2	11.02	11.745
3	Height of water(m)	5.957	4.9	4.208	3.715
4	Volume of water(cum)	508.04	509.79	511.02	512.46

The equivalent static analysis and response spectra dynamic analysis was carried out on the above four model and parameters such as base shear, bending moment, modal time period and roof displacement are presented.

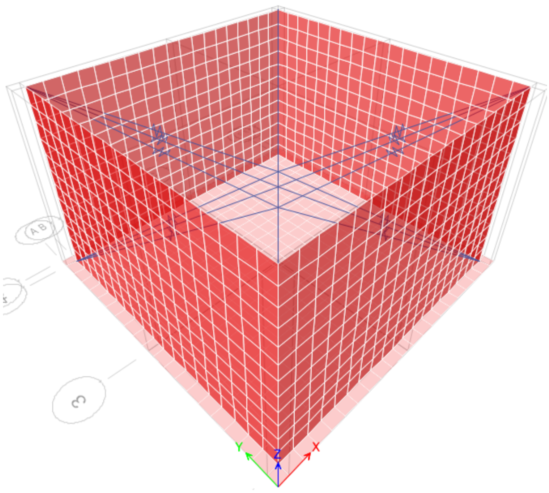

Fig.1 Mathematical Model of ground supported tank

III. MODELLING AND ANALYSIS

The tanks are modeled using finite element software ETABS as explained above. The weight of water tank are calculated for each model and detailed calculations of seismic load was performed as per IS 1893:2002 part II. To model the stiffness of soil below the base slab a point spring has been used. The support properties of spring were derived based on the safe bearing capacity and respective settlement. The point of application of seismic loads are regidly connected with the top and bottom of tank by using rigid link.Water load are applied as a uniformly varing hydrostatic load. The calculated seismic load is applied on each of the height namely impulsive height and convective height from the base. The square shape of tank was adopted and hence only unidirectional analysis is required to be performed. The load combinations are adopted as per limit state design for strength as per IS 456:2000. The stiffness of soil spring is calculated using safe bearing capacity and settlement. The lumped forces are for each of the tank model are shown in Table II

TABLE IIi. SEISMIC FORCE FOR WATER TANK

M	S1	hi (m)	S2	hw (m)	S3	hc (m)
M1	821.5	2.26	440.3	3.0	108.7	3.6
M2	649.9	1.86	401.6	2.5	142.9	2.9
M3	515.0	1.59	374.2	2.2	171.5	2.3
M4	441.4	1.41	353.6	1.9	177.2	1.9

S1- Siesmic force due to impulsive mass

S2- Seismic force due to container wall

S3- Seismic force due to convective mass

TABLE IIIII. DATA USED FOR ANALYSIS

Water capacity	500m^3
Zone	IV
Soil type	Medium
Importance factor	1.5
Response reduction factor	1.8
Safe bearing capacity of soil	150KN/m^2
Settlement	15mm
Thickness of base slab	300mm
Thickness of tank wall	300mm
Grade of concrete	M30
Free board	200mm

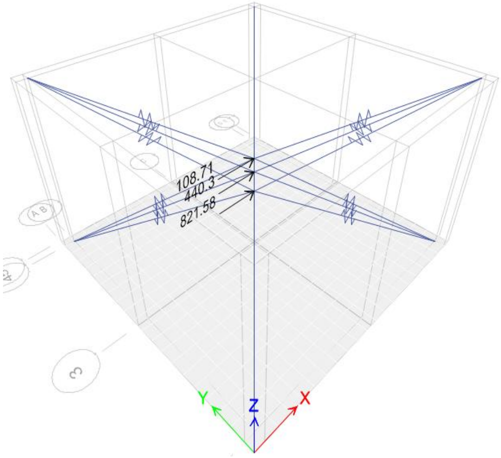

Fig2. Seismic forces Model M1

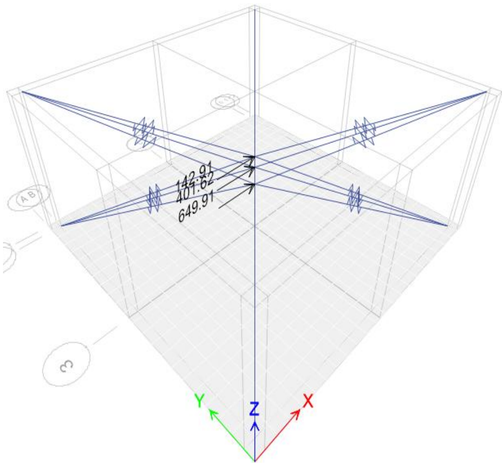

Fig3. Seismic forces Model M2

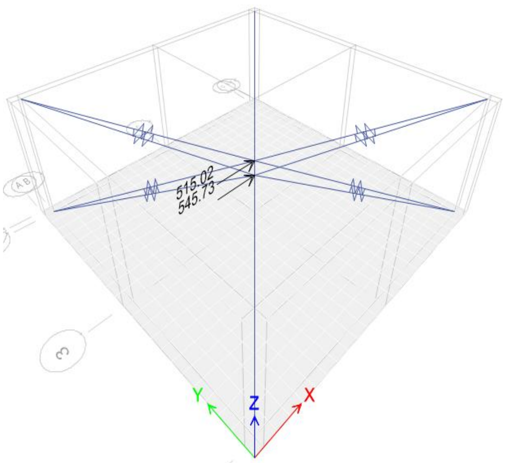

Fig4. Seismic forces Model M3

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ISSN 2319 - 8354

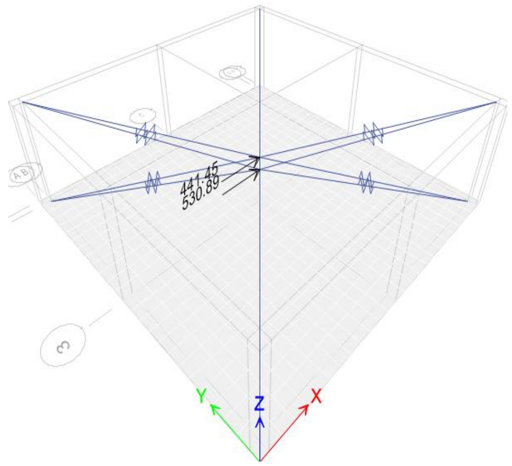

Fig5. Seismic forces Model M3

IV. RESULTS AND DISCUSSION

A. Static analysis

The variation of base shear in all the models is shown in Fig. 6. It is observed that the base shear decreases as the aspect ratio for the wall increases. There is around 29% reduction in base shear was observed when the aspect ratio changes from 1.5 to 3.0.

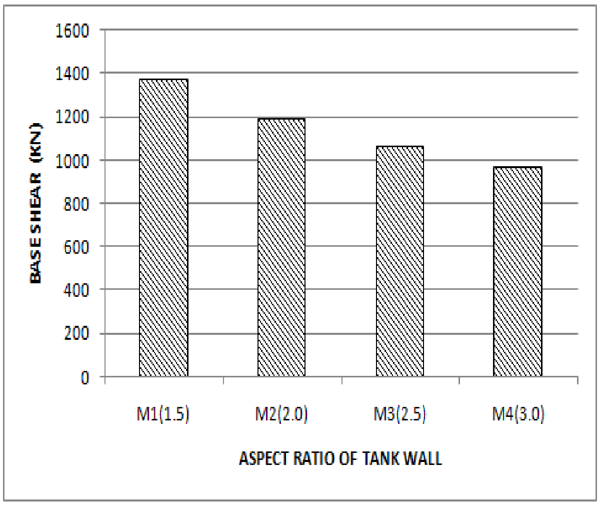

Fig6. Base shear Variation (Static analysis)

The variation of time period for convective and impulsive mode is shown in Fig. 7.It is observed that the time period for impulsive mode is maximum for model M1, however the time period for convective mode is found to be maximum for model M4.

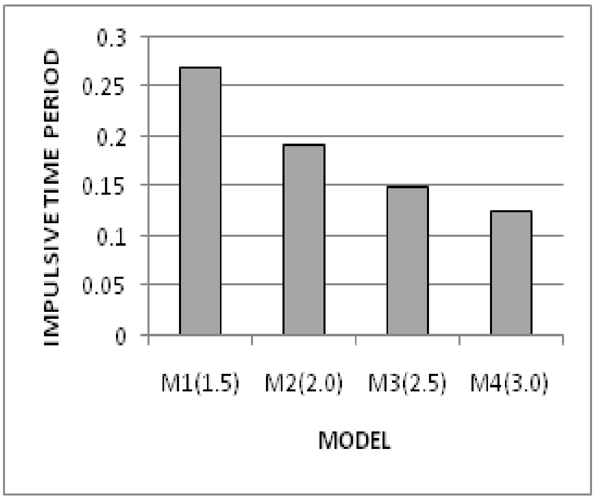

Fig. 7 Time period variation for Impulsive Mode

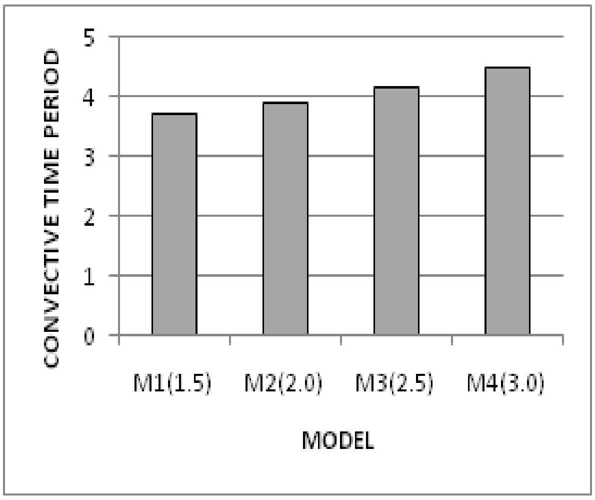

Fig. 8 Time period variation for Convective Mode

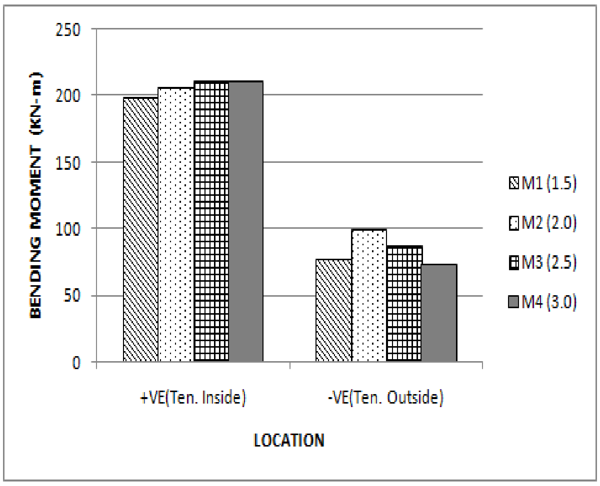

Fig. 9 Bending Moment Variation for Horizontal Bending

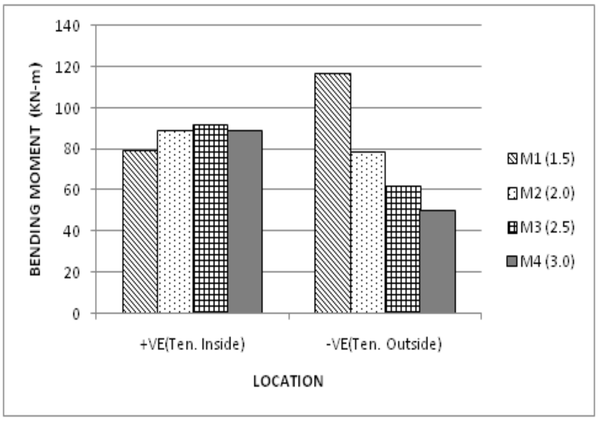

Fig. 10 Bending Moment Variation for Vertical Bending

The variation of bending moment for wall is shown in Fig.8 and Fig.9. The observation of moment in wall shows that good control over the vertical moment can be obtained by maintaining greater value of aspect ratio, however horizontal moment increases slightly.

B. Response Spectra Analysis

The Response spectra analysis is carried out on the above model. The modal response and base shear values are presented for all the models.

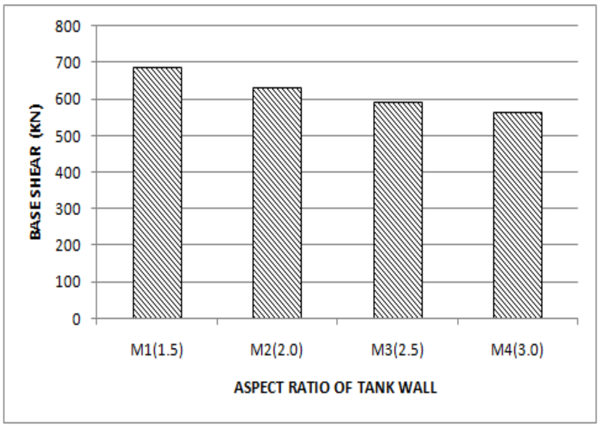

Fig. 11 Base shear Variation (Response Spectra analysis)

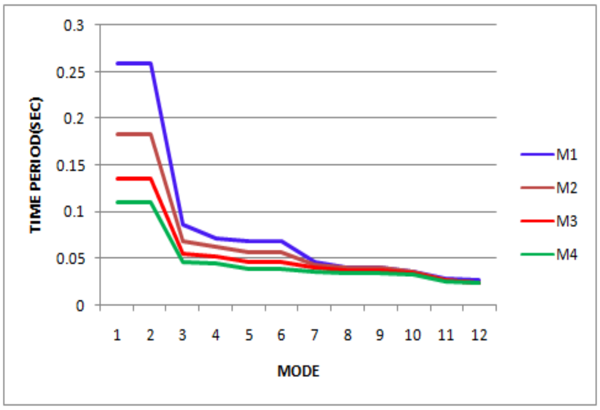

Fig. 12 Modal time period variation

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www.ijarse.com
IJARSE
ISSN 2319 - 8354

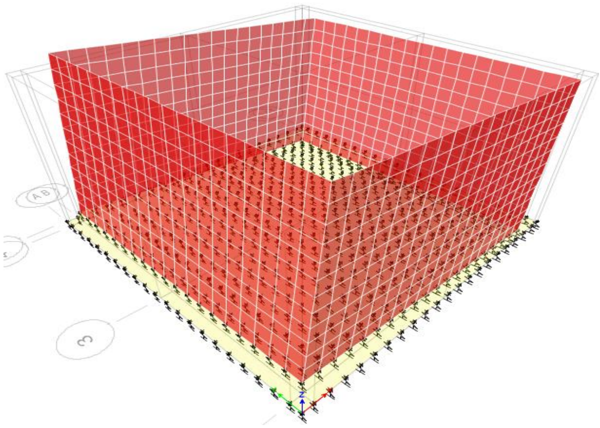

Fig. 13 Modal deformation shape for Mode 1(M1)

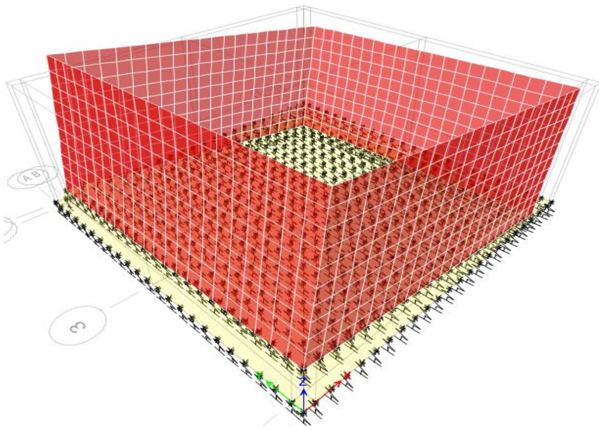

Fig. 14 Modal deformation shape for Mode 1(M2)

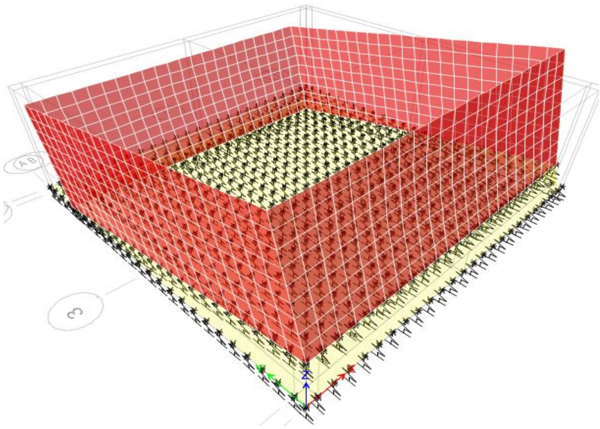

Fig. 15 Modal deformation shape for Mode 1(M2)

The modal time period is found to be maximum for model M1 and it is minimum for model M4 where aspect ratio is maximum. It is observed that the time period decreases as aspect ratio of wall increases. Hence it is recommended to have aspect ratio of 3.0 for better control over time period.

V. CONCLUSIONS

It is observed from the results obtained that the selection of proper aspect ratio is necessary. As aspect ratio increases the base shear decreases, this may be because of the reduced height of tank walls. Maximum vertical bending moment decreases as aspect ratio increases, however subsequent increase in horizontal moment for wall may occur. There is considerable change in vertical moment and slight change in horizontal moment for wall with change in aspect ratio was observed. There is around 57.3% reduction in vertical moment was found when aspect ratio increases from 1.5 to 3.0. Hence it is advisable to increase the aspect ratio of wall for better control over the vertical bending. It should be noted that the difference in base shear goes on reducing as aspect ratio increases. There is around 12 to 13% decrease in base shear was observed for every 0.5 change in aspect ratio of wall. It is recommended from the current analysis to keep the aspect ratio between 2.5 to 3.0.

VI. ACKNOWLEDGEMENT

I wish my gratitude towards my guide Professor Dr. R.S. Talikoti for his constant interest, encouragement and valuable guidance during completion of project work. He constantly shored me up, enabling me to develop an understanding of the project. I would like to thank Prof. Dr. R.S. Talikoti, Head of Civil Department, for his kind co-operation and constant inspiration during this course. Finally, I am thankful to all staff members of Civil Engineering Department and principal V.J.Gond of Sapkal College of Engineering for their kind help.

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