International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 4, Issue 1, pp: (103-113), Month: April 2016 - September 2016, Available at: www.researchpublish.com

Retrofitting And Rehabilitation Of Existing Elevated Storage Water Tank

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Abstract: **Elevated water tanks are one of the most important lifeline structures in earthquake prone regions. In major cities and also in rural areas elevated water tanks forms an integral part of water supply scheme. These structures has large mass concentrated at the top of slender supporting structure hence these structures are especially vulnerable to horizontal forces due to earthquake. Analysis is done according to IS 1893 Part I & II, Wind analysis is done according to IS 875-1987 (Part III) & IS 875 draft (Part III). In this paper ESR of staging height 12m is considered with capacity varying from 20 m3 to 100 m3. Analysis has been done using SAP-2000.The Rehabilitation of the existing damaged Elevated storage reservoir with pile foundation is used in this work to evaluate the effectiveness of retrofitting techniques, called Concrete Jacketing. Economic aspects are studied for different innovative water tanks staging systems with reference to conventional frame type and shaft type staging of ESR. Reinforced concrete elevated water tanks are critical structures that are expected to remain functional after severe earthquake in order to serve water system network. During earthquake activity the liquid exerts impulsive and convective pressures (sloshing) on the walls and bottom of tank.**

Keywords**: Impulse mass, Convective mass, SAP-2000, Seismic analysis.**

I. INTRODUCTION

Water is source of every creation." In day to day life one cannot live without water. Therefore water needs to be stored for daily used. Depending upon the location of the tank the tanks can be name as overhead, on ground and underground. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a height sufficient to pressurize a water distribution system. Elevated concrete water tanks are mainly used for water supply and fire protection. One of the major problems that may lead to failure of these structures is earthquakes. Therefore the analysis of elevated tank must be carefully performed, so that safety can be assured when earthquake occurs and the tanks remain functional even after earthquake. The irregular shape of an elevated water tank, for which most of the mass of water confluent in the upper part of the tank makes it more sensitive for staging of tank to fail especially due to an earthquake

II. LITERATURE REVIEW

R. Ghateh at el (2015) presented a systematic approach is employed to establish the seismic response factors for a wide range of elevate water tank sizes and RC pedestal dimensions commonly built in industry. In total, forty-eight model configurations (prototypes) are selected and designed based on current codes and standards. The finite element (FE) method is then used for nonlinear static (pushover) analysis of the prototypes. The pushover curve of each prototype is developed and the seismic response factors are determined accordingly.

R. K. Ingle at el (2015) presented at providing governing load case for ESR i.e. whether wind or earthquake force is governing. Earthquake analysis is done according to IS 1893 Part I & II, Wind analysis is done according to IS 875-1987 (Part III) & IS 875 draft (Part III). In this paper ESR of staging height 12m is considered with capacity varying from 20 m3 to 100 m3. Analysis has been done using SAP-2000. Three types of soil conditions, namely soft, medium, hard and seismic zones, Zone-II, Zone-III, Zone-IV and Zone V are considered.

Keyur Y. Prajapati at el (2014) presented the main aim of this study is to compare cost for conceptualize innovative hybrid staging systems of ESR, considering seismic loading and analyzed with SAP2000. Economic aspects are studied for different innovative water tanks staging systems with reference to conventional frame type and shaft type staging of ESR.

Prof. Dr. KamilaKotrasová at el (2013) presented theoretical background for analytical calculating of elevated tanks during an earthquake and deals with comparing of simplified seismic design procedures for elevated tanks, and the applicability for subsoil classes. The analysis has been carried out considering four different subsoil classes A, B, C, D, given EC8. The design by simplified seismic procedures given EC8 and Housner model was compared.

Inel and Ozmen at el (2006): This paper discusses the effects of plastic hinge properties on nonlinear response of reinforced concrete buildings. The paper discusses the results of pushover analysis with default and user defined hinge properties. The paper gives details of reinforcement as well as other structural features of the building under consideration. It has been observed that plastic hinge length and spacing of transverse reinforcement does not affect the base shear capacity of the structure but they have considerable effects on displacement demands.

Applied Technology Council1 (1996): The document provides analytical procedures for evaluating the seismic performance of existing buildings. Simplified nonlinear analysis methods are provided. Use of nonlinear procedures in general has been discussed and capacity spectrum method is introduced. Although the methods mentioned in the document are not intended for new buildings, the analytical procedures are applicable to new structures as well. The analytical procedures incorporated in the methodology accounts for post elastic deformations of the structure by using simplified nonlinear static analysis methods.

P. Muthu Vijay at el (2014): presents analysis to study the effects of sloshing in overhead liquid storage tank. In such structure a large mass concentrated at the top of slender supporting structure makes the structure vulnerable to horizontal forces e.g. due to earthquakes. This study focuses mainly on the response of the elevated Intze type water tank to dynamic forces by both equivalents static method and finite element analysis using commercial software.

Gareane A. I. Algreane at el (2011): presented the soil and water behaviour of elevated concrete water tank under seismic load. An artificial seismic excitation has been generated according to Gasparini and Vanmarcke approach, at the bedrock, and then consideration of the seismic excitation based on one dimension nonlinear local site has been carried out.

Dr. SuchitaHirde at el (2011): This paper presents the study of seismic performance of the elevated water tanks for various seismic zones of Indiafor various heights and capacity of elevated water tanks for different soil conditions. The effect of height of water tank,earthquake zones and soil conditions on earthquake forces have been presented in this paper with the help of analysis of 240models for various parameters.

III. METHODOLOGY

Two mass models for elevated tank were proposed by Houser [Houser, 1963] which is more appropriate and is being commonly used in most of the international codes. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts.

A. Impulsive liquid mass-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.

B. Convective liquid mass- 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 of elevated water tank shown in Figure 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 as shown in Figure .Structural mass, includes mass of container and one-third mass of staging. Mass of container comprises of mass of roof slab, container wall gallery, floor slab, and floor beams. Staging acts like a lateral spring and one-third mass of staging is considered based on classical result on effect of spring mass on natural frequency of single degree of freedom system. Most elevated tanks are never completely filled with liquid. Hence a two-massidealization of the tank shown in Figure is more appropriate as compared to a one mass idealization, which was used in IS 1893: 1984.

The response of the two-degree of freedom system can be obtained by elementary structural dynamics. However, for most elevated tanks it is observed that the two periods are well separated. Hence, the system may be considered as two uncoupled single degree of freedom systems as shown in Figure This method will be satisfactory for design purpose, if the ratio of the period of the two uncoupled system sex cedes 2.5. If impulsive and convective time periods are not well separated, then coupled 2-DOF system will have to be solved using elementary structural dynamics. There are two cases for seismic analysis namely tank empty condition and tank full condition. For tank empty condition, tank will be considered as single degree of freedom system and empty tank will not have convective mode of vibration whereas tank full condition is considered as two degree of freedom system.

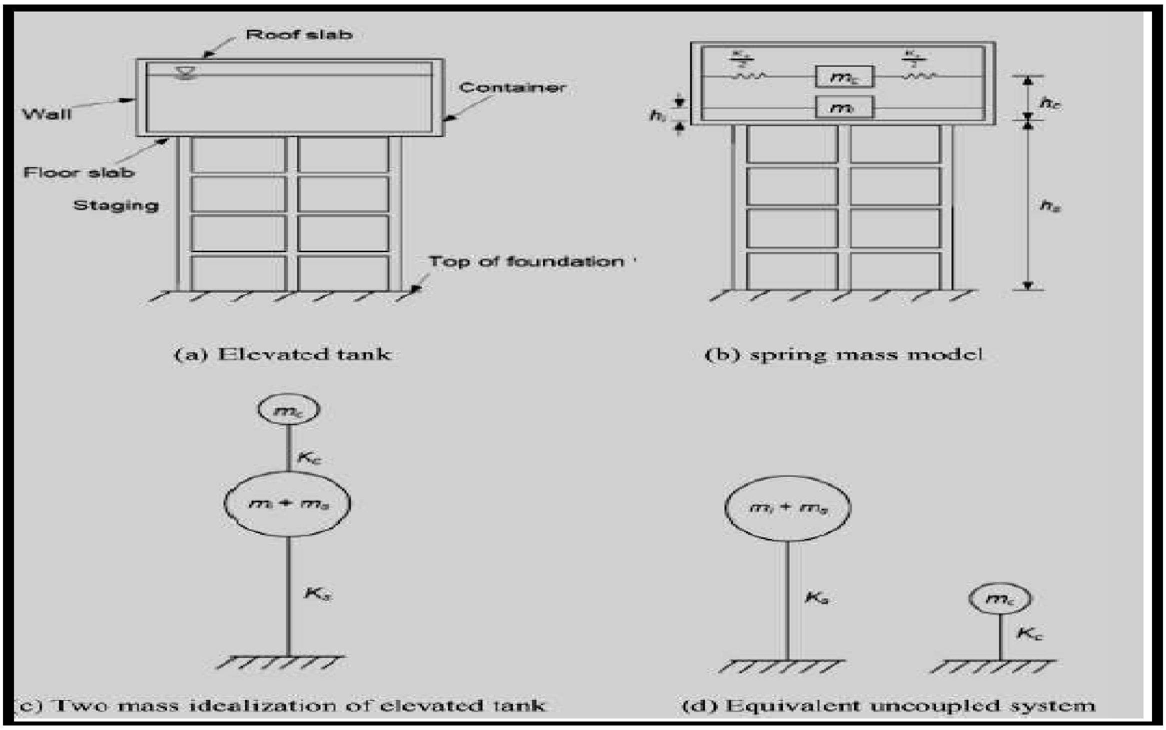

Fig.1: Two mass idealization of elevated tank

C. Effect of earthquake zone on earthquake forces:

The results obtained from analysis are analyzed and shown in graphical form. To study the effect of earth quake zones on earthquake forces, graphs are plotted taking staging height as abscissa and the earth quake forces as ordinate for 50,000 liter and 1, 00,000 liter capacity elevated water tank. Earthquake forces for different staging height for soft, medium and hard soil conditions for tank empty and tank full condition are shown in Figure 8 to Figure 13. From these graphs, it is observed that, earthquake forces decreases with increase in staging height and increases with increase in zone factor for soft, medium and hard soil conditions for tank empty and tank full condition. Earthquake forces for zone IIis about 37-38% less than zone III, about 58-59% less than zone IV and about 72-73% less than zone Earthquake forces for zone III is about 33-34% less than zone IV and about 55-56% less than zone V. Earthquake forces for zone IV is about 33-34% less than zone V. Earthquake forces increases from zone Ito zone V for soft, medium and hard soil conditions for tank empty and tank full condition. Since zone factor value increases from zone I to zone V, earthquake forces increases in that order. Earth quake forces for tank full condition are about 21-28%greater than that of tank empty condition. Hence tankfull condition is more severe as compared to tank empty condition.

D. Effect of staging height on earthquake forces

Earthquake forces decreases with increase in staging height because as staging height increases this structure becomes more flexible. Therefore time period increases due to which structural response factor decreases from lower to higher staging height. This affects the earthquake forces.

E. Effect of type of soil on earthquake forces:

Graphs are plotted taking staging height as abscissa and the forces as ordinate for reinforced cement concrete elevated tanks of 50,000 liter and 1, 00,000capacity to study the effect of soil type on earth quake forces. The effect of soil condition on earth quake forces is shown in figure 14 to figure 21. From these graphs it is observed that, earthquake force decreases with increase in staging height. Earth quake forces for soft soil is about 18-19% greater than that of medium soil, Earthquake forces for medium soil is about 26-27% greater than that of hard soil, Earthquake forces for soft soil is about 40-41%greater than that of hard soil for all earthquake zones and tank full and tank empty condition. There sponses for soft soil are more because of structural response factor (Sa/g). Since this value is more for soft soil as compared to medium and hard soil; soft soil condition is more severe than medium soil condition and hard soil condition and medium soil condition is more severe than hard soil condition. Table gives time period for elevated water tanks of 50, 000 liter and 1, 00,000 liter capacity having different staging heights for tank empty and tank full condition.

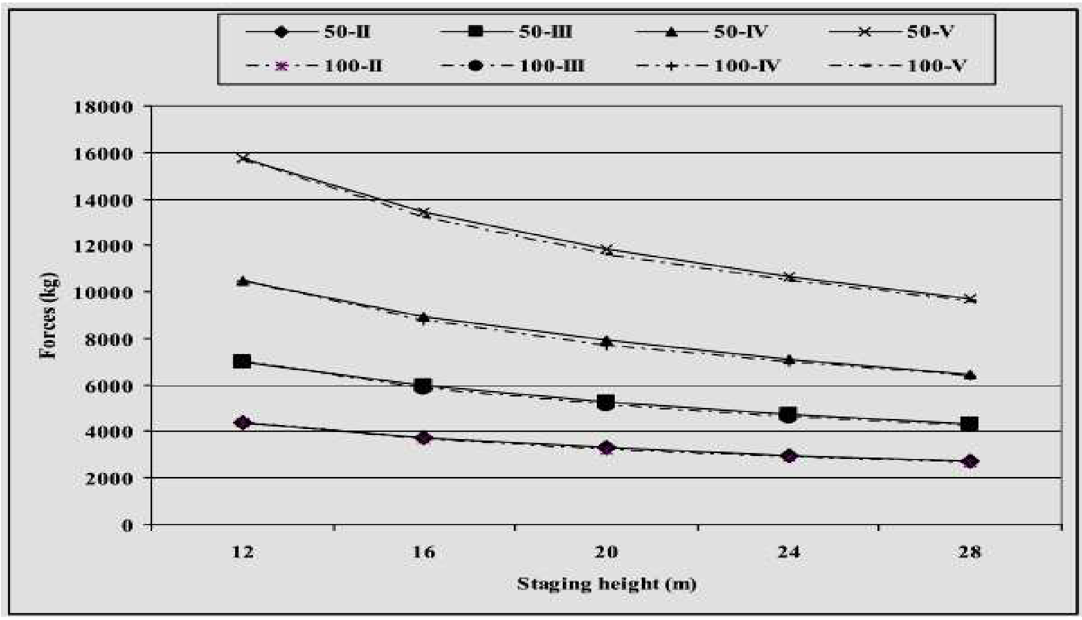

Fig.2: Earthquake forces for tank empty condition for soft soil

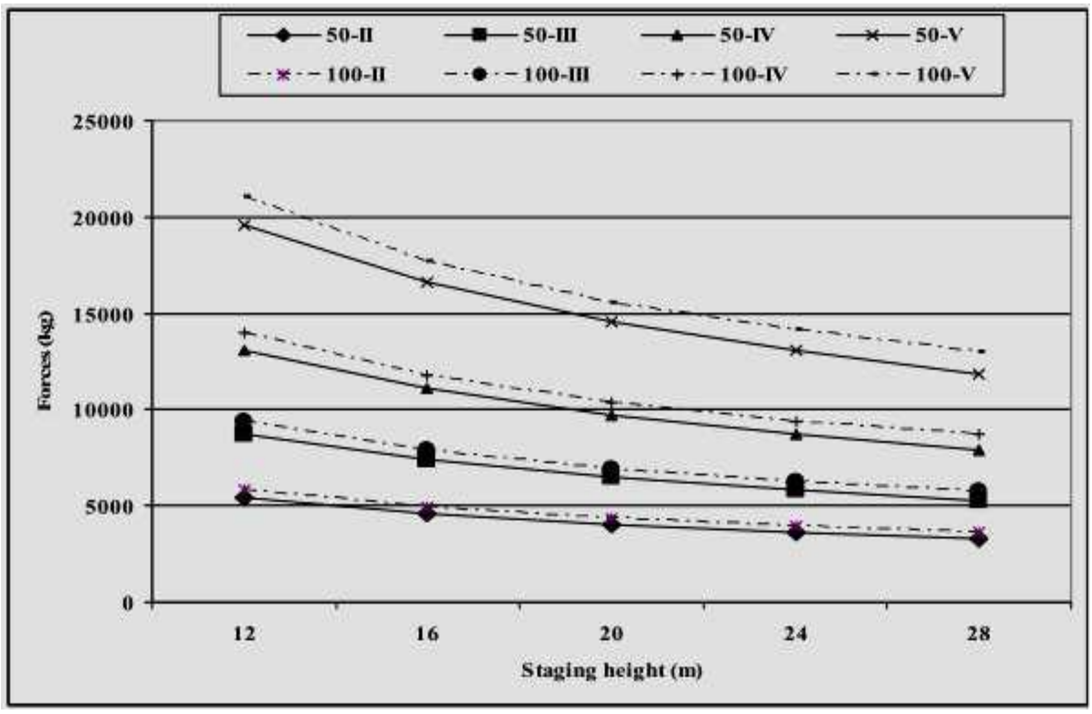

Fig.3: Earthquake forces for tank full condition for soft soil

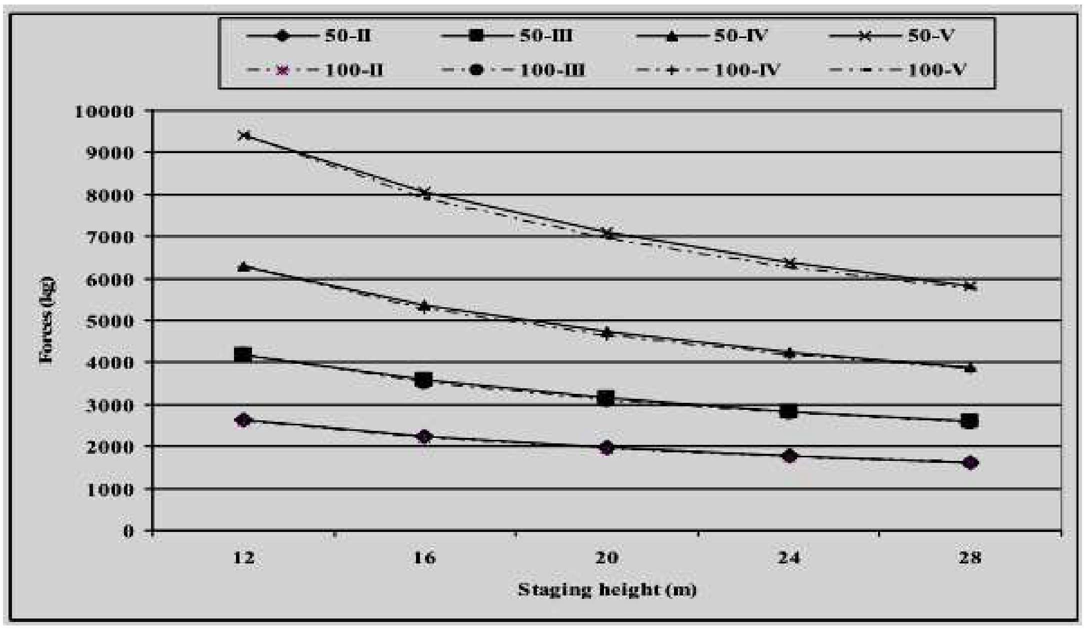

Fig.4: Earthquake forces for tank empty condition for hard soil

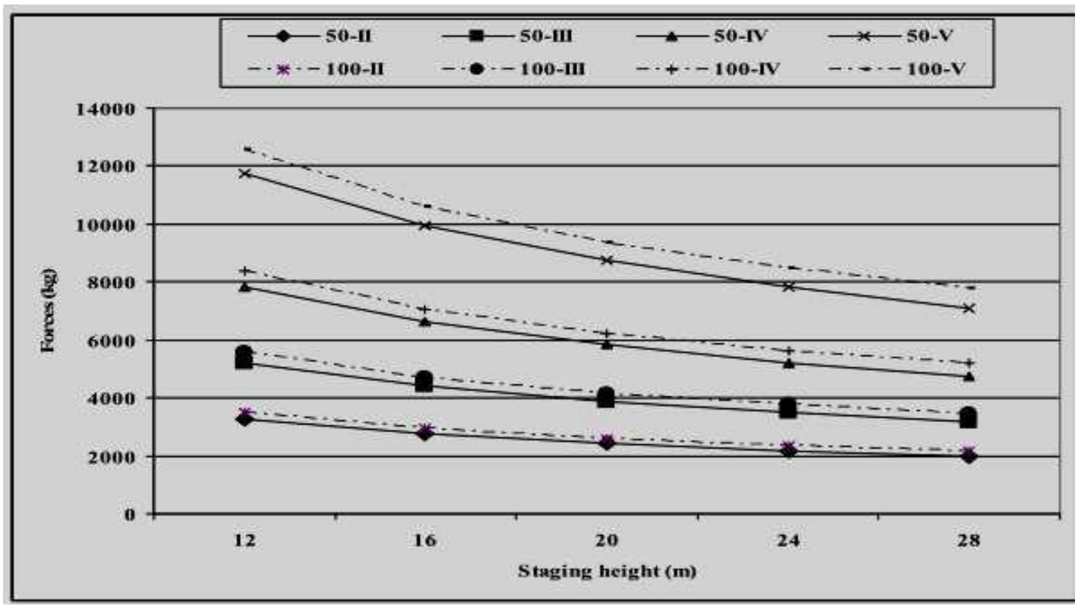

Fig.5: Earthquake forces for tank full condition for hard soil

TABLE.I: TIME PERIOD FOR ELEVATED WATER TANKS OF 50,000 LITER AND 1, 00,000 LITER CAPACITY HAVING DIFFERENTSTAGING HEIGHTS FOR TANK EMPTY AND TANK FULL CONDITION.

Staging height	Time Period for tank empty condition (sec)		Impulsive Time Period for tank full condition (sec)		Convective Time Period for tank full condition (sec)	
	50 liter	100 liter	50 liter	100 liter	50 liter	100 liter
12m	0.708	1.163	0.875	1.52	2.274	2.55
16m	0.874	1.437	1.071	1.866	2.274	2.55
20m	1.043	1.691	1.267	2.182	2.274	2.55
24m	1.217	1.936	1.467	2.48	2.274	2.55
28m	1.4	2.175	1.674	2.77	2.274	2.55

F. Finite Element Modeling:

FEM of the Intze tank is rendered for the following dimensions, The Intze Tank is to be designed for the capacity of 10,00,000 liters with staging height of 20 m above ground on a hard strata in Seismic zone IV by using concrete of grade M20 and Steel of grade Fe415.

- Top dome plate thickness: 150mm
- Tank wall plate thickness: 300mm
- Bottom conical dome plate thickness: 500mm
- Top ring beam dimension: 350*500mm
- Bottom ring beam dimension: 1000*730mm
- Circular ring beam dimension: 600*1200mm
- Top ring dimension: 350*500mm
- 8 columns of diameter : 750mm
- And Of height (including 1m inside GL) : 2160mm
- Bracings : 300*600mm
- Raft circular foundation: 450mm (Depth) 13.65m (dia.)

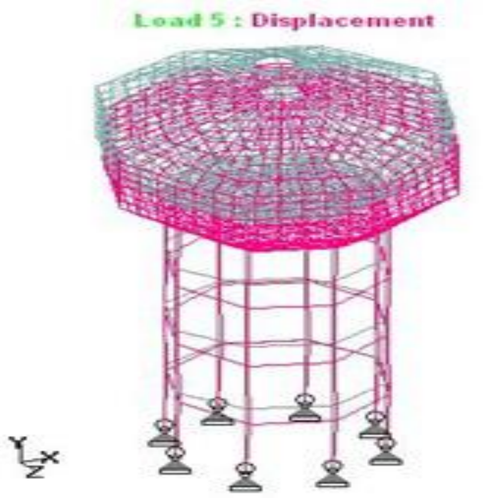

Fig.6: Tank with Its Full Capacity by Considering Only Hydrostatic Forces.

Fig.7: Tank with Its Full Capacity Considering Hydrostatic Forces Along with Sloshing Forces in the Tank

TABLE.II: SUPPORT REACTIONS OF INTZE TANK BY CONSIDERING HYDROSTATIC FORCES

Support Reactions (KN)			
Node	Horizontal		Vertical
	FX	FZ	FY
1	3.086	49.609	9.715
9	11.321	38.885	28.623
17	-0.891	27.991	27.899
25	-5.889	36.042	9.903
33	3.075	46.885	-16.824
41	9.546	37.07	-25.002
49	4.068	27.914	-23.164
57	-7.549	37.757	-6.21

TABLE.III: SUPPORT REACTIONS OF INTZE TANK BY CONSIDERING SLOSHING ALONG WITH HYDROSTATIC FORCES

Support Reactions			
Node no.	Horizontal		Vertical
	Fx kN	Fz kN	Fy kN
1	0	69.29	0
9	13.063	52.486	-7.288
17	0	37.681	-10.315
25	-13.062	52.486	-7.288
33	0	69.291	0
41	13.063	52.486	7.288
49	0	37.681	10.315
57	-13.063	52.486	7.288

TABLE.IV: MODE SHAPES FOR HYDROSTATIC CASE

Mode Shapes					
Mode	Frequency Hz	Period Seconds	Participation X %	Participation Y %	Participation Z %
1	0.103	9.725	80.691	0	1.355
2	0.103	9.678	1.349	1.138	82.125
3	0.593	1.685	0.017	98.836	1.057
4	0.846	1.182	0.137	0	0
5	2.343	0.427	16.482	0	0.068
6	2.728	0.367	0.059	0.024	14.045

TABLE.V: MODE SHAPES FOR SLOSHING CASE

Mode Shapes					
Mode	Frequency Hz	Period Seconds	Participation X %	Participation Y %	Participation Z %
1	0.075	13.407	87.414	0	0
2	0.075	13.393	0	0	88.208
3	0.457	2.187	0	100	0
4	0.571	1.751	0	0	0
5	2.023	0.494	11.294	0	0
6	2.169	0.461	0	0	10.217

IV. RESULT AND DISSCUSSION

The Earthquake ranks as one of the most destructive events recorded so far in India in terms of death, damage to infrastructure and devastation in last fifty years. The major cities affected by the earthquake are Bhuj, Anjar, Gandhi ham, Khandala port, Morbi, Ahemdabad, Rajkot, Sundarnagar etc. where majority of damages occurred. Every earthquake leaves a trail of miseries by loss of life and destruction, but it also provides a lesson to human society particularly engineers, architects for improving designs and construction practices. In this work analysis of different Elevated water tank models is carried out for earthquake zone IV. Comparison of different performance characteristics is made to check the performance of Elevated water tank having different configuration. Bracing is done with single compression having different conditions to improve the seismic performance of the water tank. Non- linier analysis is carried out on elevated water tank models using the software SAP 2000.

RESULT:

Pushover Analysis:

1) Analysis of elevated water tank in full condition before and after retrofitting The formation of hinges in the given structure after the deformation is as show in fig.

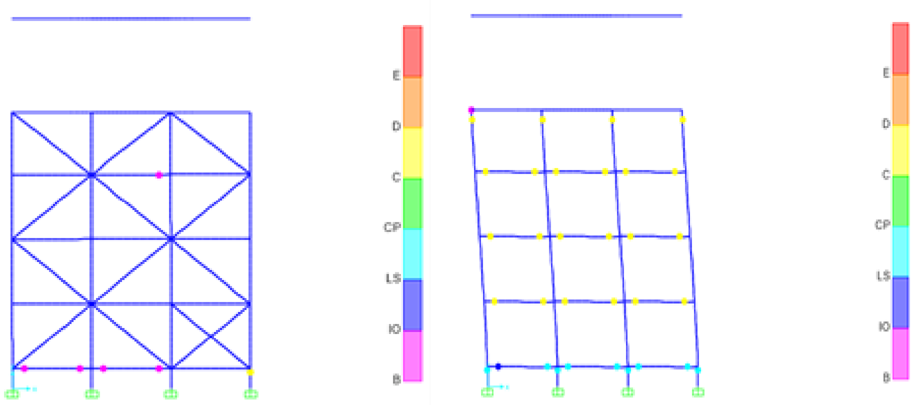

Fig.8: The formation of hinges in the given structure after the deformation

2) Analysis of elevated water tank in full condition for base shear The values of base shear at different condition when tank is full condition as shown fig.

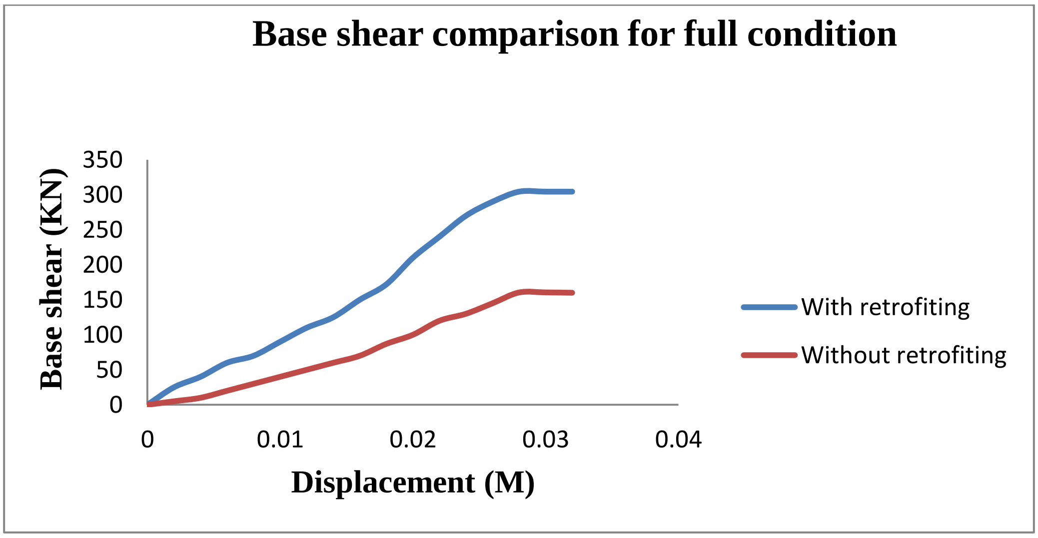

Fig.9: Pushover analysis under full Condition

3) Analysis of elevated water tank in empty condition for base shear The values of base shear at different condition when tank is empty condition as shown in fig.

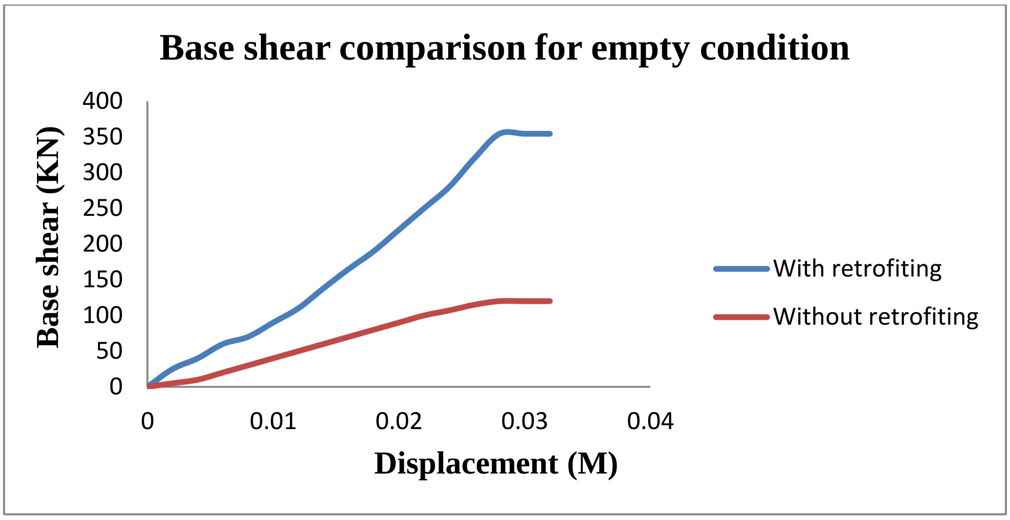

Fig.10: Pushover analysis under empty Condition

4) Comparison between the values of story drift in different full condition The values of story drift ratio at different condition when tank is full condition as shown in fig

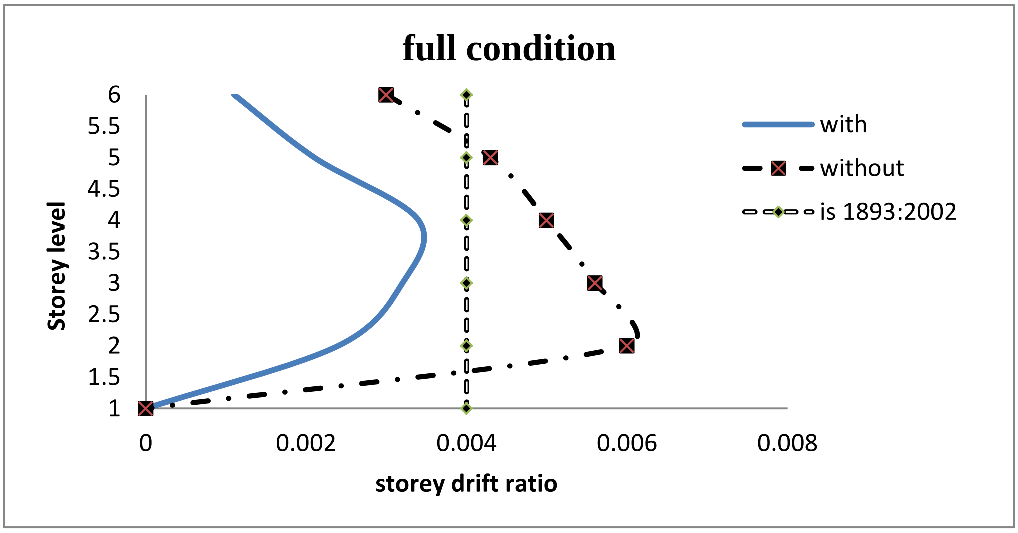

Fig.11: Comparison between the values of story drift in full condition

5) Comparison between the values of story drift in empty condition The values of story drift ratio at different condition when tank is empty condition as shown in fig

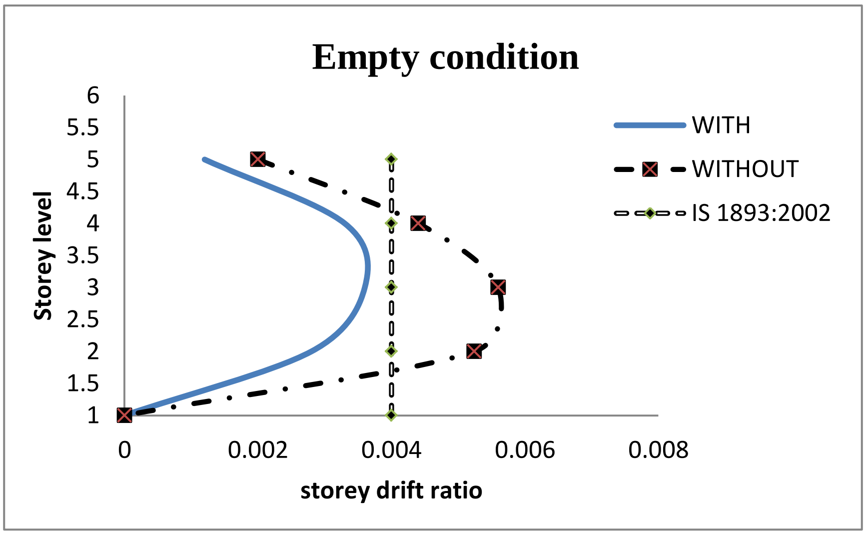

Fig.12: Comparison between the values of story drift in empty condition

Discussion:

From the above analysis following point observed that:

1. The capacity of shear force is increased by provision of single in full condition .In single bracing system capacity of base shear force is 304.4 KN.

2. The capacity of shear force is also increased by provision of single bracing in empty condition

3. The value of story drift is reduced by provision of single bracing system. In full condition this value is reduced 59 %.

4. The value of story drift is reduced by provision of single bracing system in empty condition it's reduced by 38%.

V. CONCLUSION

From the above result it is found that, Due to provision of IS 1893-2002 the basic parameter required for calculation of seismic force is different i.e. R, I, Z etc. IS 1893-2002 provides the value of response factor (R) and importance factor (I) is different for different types of structure. Seismic zone is divided into four categories which is five category in IS 1893-1984. Due to changes in basic value of seismic force the seismic force of given structure is different as compare to seismic force calculated by IS 1893-1984. In the analysis of seismic force by IS 1893-2002 the effect of impulsive and convective pressure is considered which is not consider in old code. Most of the water tank got failed due to negligence of concept of sloshing effect of the water tank. Given structure is not capable to carry the seismic force calculated by considering IS 1893-2002. For given demand of existing story drift ratio of water tank has not fulfilled the criteria of permissible drift as IS 1893-2002, so it observes that there is need of increases stiffness of that staging frame to get drift ratio within permissible. The required capacity of given structure is 245.77 KN But at this condition capacity of given structure is 160 KN. To maintain given structure to resist above seismic force retrofitting of given structure is necessary. Retrofitting of given structure is carried out by provision of single bracing on compression side. From the analysis by providing single bracing the 60 % of story drift ratio is reduced as compare to previous. By provision of single compression bracing capacity of given structure is increase by 304.4 KN which is satisfactory for given structure.

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