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# Assessment of Seismic Vulnerability of Water Retaining Structure: A Review

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**Abstract:** As we all know that the seismic design of water retaining structure is very important because the water retaining structures are mainly used in storing the water and for environmental issues like wastewater treatment and other treatment process and also for the storage of liquid such as petrol or diesel. So it is important to study the seismic behavior of liquid retaining structure so that the earthquake resistant design can be easily done according to the earthquake forces and the type of region. In this review paper, basically the work that has been done earlier in the field of seismic design of liquid retaining structure is being reviewed and the loopholes of the study is being found and suitable strategies for further research is provided. For this study, various methods and technologies are reviewed that will give a brief description of the work that has been published.

**Keywords:** Water retaining structures, Seismic behavior, Vulnerability assessment, Over head tanks, Wastewater treatment plant.

## I. INTRODUCTION

The field of earthquake resistant design of structure is now a days in limelight the main reason behind this is that no region is now said to be non earthquake zone so the structure need to be designed according to the principle of seismic design of structure. as we are talking about the main structures like buildings nuclear reactors, these structure considered first in the priority for seismic design but as far as liquid retaining structures are concerned they are considered on lower priority then the primary structures. The liquid retaining structures contains sometime water and if this structures are used for environmental aspect then it is used for wastewater treatment plants, as these structures used in wastewater then they contains the untreated sewage and wastewater so if the earthquake will occur then it can damage the underground structure so if the structure will collapse then the water which is untreated in the liquid storage structure will discharge to the environment and that will cost more sufferings to the human as well as the flora and fauna. so it is very important aspect to analyse the liquid storage structures on the basis of seismic analysis so that the earthquake resistant forces is determined and the earthquake resistant design of the structure can be done according to that forces.



Figure 1: Wastewater Treatment Plant Seriously Damaged by Tohoku Tsunami in the Great East Japan Earthquake 2011.

One of the foremost powerful earthquakes recorded in history caused by the tsunami at the north eastern part of Japan is of magnitude of 9 on richter scale. It affects the 8 million households 270,000 buildings were destroyed. This damage also leads the destruction of water and waste water structures and distribution system.



Figure 2: Elevated water tank of PuertoVaras Hotel, May 22nd, 1960.

These are the some effect of earthquake on the liquid retaining structures that can be seen so there exist a need of study of seismic analysis and design of the liquid retaining structures.

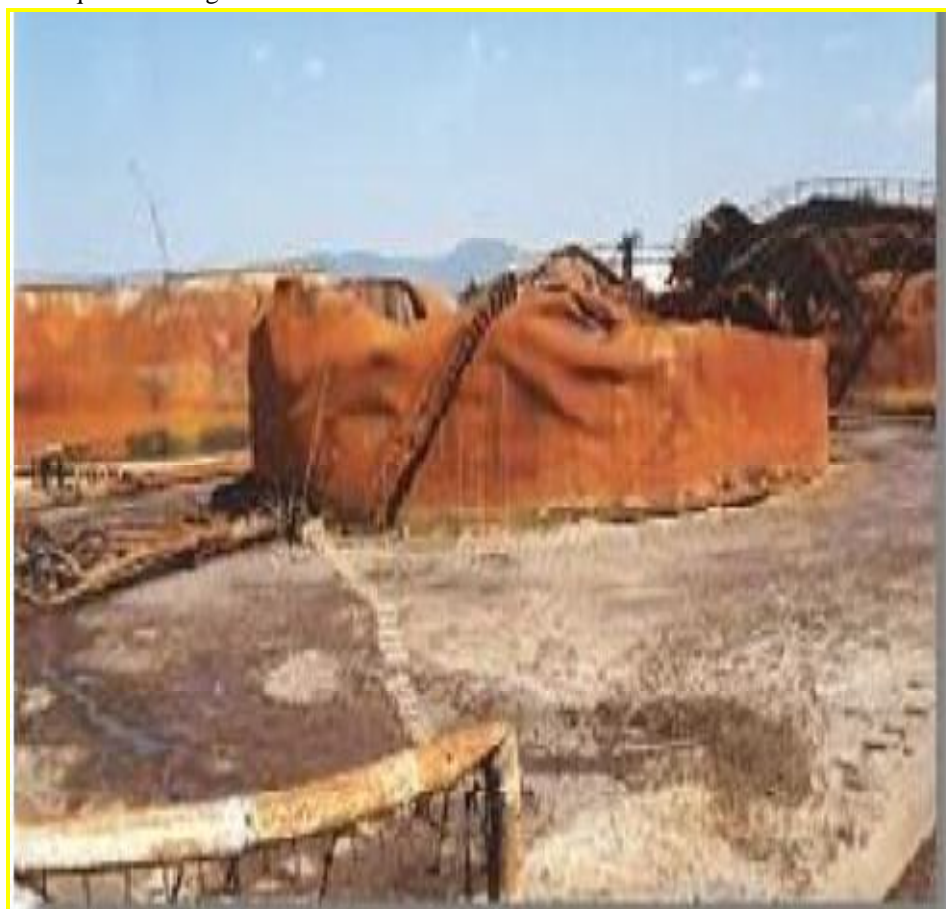


Figure 3:Damage caused by sloshing effect



In figure no 3 it can be seen that if the earthquake occurs then the liquid that is present in the tank will affect the wall and the liquid creates the sloshing effect on the tank wall which will create damage to the tank wall and these types of sloshing effect is caused by the seismic forces.



Figure 4: Buckling elephant foot type of tank wall.

As shown in figure 4 the seismic forces causes damage to the water tank in buckling of

## II. LITERATURE REVIEW

### A. *Seismic assessment of concrete tanks considering fluid structure interaction and nonlinear time history analysis*

This research work was carried out by H.Fried, M. Kwapisz, A. Lechner, R. Fleschin 2011 in this paper the water retaining structure is been analyzed by the time history analysis in this study the model of the liquid retaining structure is being taken into consideration and Why this work the seismic assessment of existing building is presented for Radioactive waste management. For this present study, the location Susan is the area with the highest earthquake hazard in Austria. The model is taken in consideration with liquid as well as the structure and both the models are combined together to determine the earthquake forces by time history method. In this method Modal analysis and finite element calculation is done and the artificial excitation three mode shapes is identified. In this present study finite element calculation is also done and it is found that there are various possibilities of strengthen the structures that can be investigated and the structural optimization of the structure can also be done. Hindi study is analyzed that the fluid structure interaction allows the simulation of water under dynamic loading is increased as compared to the simple structures.

### B. *Behavior of underground tank during earthquakes*

This research work was carried out by M. Hamada and S. Sato. In present study the researcher have done the study on underground tank which is constructed honor reclaimed soil Hindi study the researcher have observe the earthquake and then a method of earthquake response analysis is proposed for the particular type of tank this method is generated by using new mathematical model. In this model that tank is resumed to be a Cylindrical like structure and it is resting on the ground and the phone an elastic Foundation. in this study, the setup is brought and the real time of relation of the earthquake is being carried out and the various waves and the response of the structure is seen and recorded for the analysis and in this type of study the result is good because the observation is live and when the earthquake occurs then this study is being carried out.

### C. *Modeling and analysis of water tank stand modeling and analysis of water tank stand*

This research work was carried out by M.Chennababu, Dr. V. Krishnareddy in 2015. In this present study, it deals with the study of induce stress which is on the water tank stand the study is done by using advanced design software CATIA V5. The use of this software is done because the modelling can be done faster and the result that it will give is Accurate as compared to others. in this study, there are two modelling stages are involved 2 designer individual component of water tank stand and the second one is to assemble those components and make a whole structure. The component creation will be done import module and assemble of the

components is done in assembly module. Then the model is analyzed by using ANSYS software. In the study different load is being applied and according to that load different stresses is generated and they will be compared and the graph is been generated according to the result. Hindi study it is found that structural Steel is better than the iron and in the model analysis that The Steel is more than the iron and the use of Steel is highly preferable then the iron.

#### D. Simple procedure for seismic analysis of liquid-storage tanks

This research work was carried out by Praveen K. Malhotra, Thomas Wenk, and Martin Wieland. In this paper, there is a theoretical background is considered for simplified seismic design of cylindrical ground supported liquid retaining structures. In this study, there will be 2 actions that is being considered one is impressive and second one is convective and this effect can be considered on both Steel as well as concrete liquid retaining structure on the rigid Foundation. In this present study base year overturning moment and other parameters are calculated by using the response spectra of the site and in this paper some calculations are used which will provider wider concept of the seismic design procedure for ground supported tanks. In this paper the work that is done is also published in the guidelines provided by Indian Institute of Technology Kanpur for liquid retaining structures. In the guidelines provided by Indian Institute of Technology Kanpur the convective and impulsive both the modes are considered for designing the liquid retaining structures.

- 1) *Evaluation of seismic forces on elevated water tank:* This research work was carried out by NankarAniket R.1, NavaleShrikant S.2, PalveGaurav A. in 2015. In this present study, the liquid retaining structure is analyzed and the response of liquid retaining structures is being obtained and for this present study the earthquake resistant design of liquid retaining structure code IS 1893-2002 is being used and also the guidelines provided by Indian Institute of Technology Kanpur is also taken into consideration for the analysis of the structures. In the present study, the spring mass model is considered for the analysis and the analysis is done by using ETABS Analysis package. In this present paper, the earthquake forces on different shapes like rectangular and circular is calculated for different parameters such as base year this moment time period are calculated. In this present paper it is considerable that deals with effect of shape and acid ratio of the water tank on seismic forces. In this paper, it is that the circular tanks perform better than the rectangular tank but for rectangular tank the aspect ratio effect in a particular direction. For the present study ETABS Analysis is taken into the consideration.
- 2) *Seismic analysis of completely buried rectangular concrete reservoir:* This research work was carried out by Anup Y Naik, Rakshan K M, Ashok P G in 2015. In this paper, the behavior of liquids that are present in liquid retaining structures is being studied because it is very important aspect to study because is the earthquake will occur then the liquid that is present in the container will move and it will be according to the earthquake intensity so it is important to analyses the behavior of the liquid in the seismic load so that the walls can be designed according to that load and it will not harm the outer walls of the container. In this study, a rectangular tank is analyzed for principal direction for seismic forces and the variation of the forces on the different level of that is present in the structure. For the present study, there is a model that is being used named as HOUSNERS Mechanical model.
- 3) *Finite element analysis of underground water tank with different safe bearing values of soil:* This research work was carried out by PunithC, Usha, JayalakshmiRaju, M. Adil Dar in 2015. In this present study, the underground liquid Storage tank is being considered because for the environmental engineering part of view the underground water tanks are used for that various sewage treatment plants and for other Industrial waste treatment. These tanks are constructed mainly by the rain force concrete Steel. Present study the underground water tank is analyzed by using finite element method and the main important part of this paper is seismic calibration stage which can be done by software called SAP2000 FEM Package.
- 4) *Seismic analysis of liquid storage tanks:* This research is done by SYED SAIF UDDIN in year 2013 by using the codes IS 1893:2002 and considering the spring mass model of the liquid retaining structure. In the present study the researcher shows that the previous codes that was available earlier to the IS 1893:2002 was IS 1893:1984 and it has very limited provision for seismic design of elevated tanks so the new IS code is introduced in year 2002 for the better analysis of the water retaining structures on the basic of seismic consideration. In this study an intz type tank is analyzed on the basis draft of IS 1893:2002 and also by the software SAP 2000 by which the forces caused by earthquake on the tank is being calculated. By this study the researcher found that the hydrodynamic pressure in elevated and ground supported tanks is 15% to 25% respectively. In this study it is also found that there is a need of increasing the permissible stress when the seismic consideration is taken in the design by working stress method.
- 5) *Seismic Behavior of RC Elevated Water Tank under different types of staging pattern:* This research is carried out by Pavan .S. Ekbote and Dr. Jagadish .G. Kori in this present study it is studied that when the earthquake occurs then it will affect the tank

wall and the collapse will be very damage full due to the lack of knowledge of proper behavior of supporting system and geometrical selection of Staging patterns. In this study the main aim is to study the behavior of the supporting system using SAP 2000 software. In this present paper different supporting system are analysed such as radial bracing and cross basing. In this study it is found that if the base shear increases then the level of bracing is increased. It is also found that the base shear is more for hexagonal and radial type bracing for full tank condition than the half full and empty condition. It is also found that overturning moment is high for full tank condition then the half. it is also found that the performance of hexagonal and radical type bracing is better than the our bracings

- 6) *Behavior of an elevated RC tank subjected to various Earthquake responses:* In this present study J. Yogeshwarana, C.Pavithrab carried out the analysis of elevated concrete tank with frame Staging is considered in this paper it is also seeded that in the previous studies the response of liquid with that of the tank structure is neglected but in this paper the spring mass model approach is used for calculating the seismic forces in this study 900 cubic meter capacity tank is considered and is analyzed in time history analysis using STAAD pro. In this study it is found that the hydrodynamic pressure generated by the liquid is having more significant impact on the wall and the base of the slab of the structure. The value of base year varies according to the feeling condition of the water inside the tank. in this study it is also found that the wall of the tank must be designed according to the earthquake resistant conservation so that the failure will not take place. In this study it is also found that is stress developed on the tank all are dependent on the intensity of the earthquake and it is also considerable that the filling of the tank.
- 7) *IITK-GSDMA guidelines for seismic design of liquid storage tanks:* In the present guidelines which is given by the Indian Institute of Technology Kanpur and Gujarat State Disaster Management Authority, in this study the commentary on the code IS 1893:2002 Is done by Indian Institute of Technology Kanpur for liquid retaining structures. In the present study the convective and impulsive masses has been taken for the study. In the present study the base year and overturning moment is being calculated in X direction as well as in Y direction and other seismic Coefficient are also calculated on the basis of IS1893:2002. In the present study it is found that by using the working stress method design the seismic forces are not higher enough even for seismic zone 5 so the design of the liquid retaining structure on the ground and below the ground is not must considered for seismic design earlier. In the present study all the earthquake forces and the base shear and our turning moment is being calculated and it is found that the earthquake resistance analysis and design is very important for the liquid retaining structure so that the structure will remain safe.

### III. CONCLUSION

In this present paper, the earthquake resistant design of liquid retaining structures is being reviewed and it is found that the work that is done in this field are basically the general work that is being done and some work is done on the Indian Standard code and other codes and for the analysis of the structure some software's are used. in the present review, it is found that there are so many areas of research that is still need to be considered for the better results as in the study that is available in this field consist of two modes 1 is convective and other one is impulsive but the study can also be done by considering both the mode as one so that the liquid and the structure can be analyzed by taking consideration so that the result will be much accurate. in some of the cases it is found that the use of software is done for the analysis of various parameters but the software's are Not accurate because they are using some assumptions and these assumptions are somehow affecting the results so there exist a need of study by which the assumptions that are used in software should be minimized for the better result. In some of the papers it is found that the observation of earthquake has been considered live by a model and the analysis is being carried out by the seismic waves recording. this will provide a better result because the earthquake that will offering this the real output and the damage caused by the earthquake can be easily determined but there are few limitation of this method because it is very hard to create a real earthquake problem as in the earthquake there are some factors that is need to be considered like liquefaction of the ground and boiling of sand. So, in this review paper it is considered that the literature that is available is not enough in the field of earthquake resistance analysis and design of liquid retaining structure. In addition with other studies and guidelines provided by institutions is not much sufficient effective to give the proper result of the seismic behavior of the water retaining structures. The software used in the studies described above is mainly SAP 2000 and STAAD pro which have also some assumptions and they are basically designed by considering the best and ideal condition that will give the error in the amount of forces. So there is a need of such type of study which will do not have the limitations and error as mentioned above.

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