Review on Non-Linear Time History Analysis of An Elevated Water Tank

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Abstract- *Elevated water tank is a water storage facility supported by a tower and constructed at an elevation. The height of the tower provides the pressure for the water supply system. The static potential reserved in the tank will be used to provide the pressure in the water pipes. They also present enough water pressure for firefighting when the pumping systems are not sufficient to provide large amount of water needed for fire extinguishing. These structures has large mass concentrated at the top of slender which have Supporting structure and hence these structure are especially vulnerable to horizontal forces due to earthquakes. The study focuses on the response of the elevated circular water tanks to dynamic forces in an earthquake. It aims to determine the effect on staging height under five different earthquake ground motion. The research is based on nonlinear time history analysis and simulation in SAP2000 v18. It also looks at response quantities such as base shear, time period, displacements, acceleration and acceleration of the water in the tanks. It is an effort to identify the behavior of RCC Elevated Water tank, by varying the volume of water.*

I. INTRODUCTION

Nonlinear time history analysis is known for simulating a structure behavior under severe earthquake more proper than other methods. Elevated water tanks are commonly used in public water distribution system. Being an important part of lifeline system, and due to post earthquake functional needs, seismic safety of water tanks is of considerable importance. Elevated water tanks also called as elevated service reservoirs (ESRs) typically comprises of a container and a supporting tower (also called as staging). Staging in the form of reinforced concrete shaft and in the form of reinforced concrete column-brace frame are commonly deployed. The column-brace frame type of staging is essentially a 3D reinforced concrete frame which supports the container and resists the lateral loads induced due to earthquake or wind. Aim of the present study is to bring out the differences in seismic behavior of column beam (Building) frame and column-brace (staging) frame in the post-elastic region and to quantify their ductility. In addition, nonlinear dynamic analysis is also performed to bring out the differences in the nonlinear dynamic behavior of two types of frames.

In public water distribution system, Elevated water tanks are generally used being an important part of a lifeline system. Due to post earthquake functional needs, seismic safety of water tanks is of most important. Elevated water tanks also called as elevated service reservoirs (ESRs) typically consists of a container and a supporting tower. In major cities and also in rural areas elevated water tanks forms an Integral part of water supply system. The elevated water tanks must remain functional even after the earthquakes as water tanks are most essential to provide water for drinking purpose. These structures has large mass concentrated at the top of slender which have Supporting structure and hence these structure are especially vulnerable to horizontal forces due to Earthquakes.

So far, there has been no experimental test program (such as shaking table) that has studied the nonlinear response of RC pedestals to the strong ground motions. The number of numerical studies is also very few and mainly limited to only one or two elevated water tanks with certain tank weight and pedestal dimensions. This is despite the fact that elevated water tanks have a wide range of tank sizes and pedestal heights which may result in considerably different seismic response behaviors.

II. STATE OF DEVELOPMENT

A literature review is a text of a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. in this research review various journal papers are being referred that are studied carefully before carrying out further thesis

G. W. Housner et. al.[1] Studied simplified formulae to calculate earthquake forces for a water tank considering it as a two-mass system is given. A dynamic analysis of tanks should take into account the motion of water relative to the tank as well as motion of the tank relative to the ground. If a closed tank is completely filled with water or completely empty, it is essentially a one-mass structure. Usually, the tanks have free water surfaces and therefore, there will be sloshing of water during an earthquake and this makes the tank essentially a two-mass structure. In this case, the dynamic behaviour of elevated water tank may be quite different. For some cases, the sloshing effect might be predominant whereas for some it might not be dominating. Therefore, A detailed understanding of dynamic behaviour of tanks is required. As the fluid containers are important in nuclear reactor installation, a detailed presentation of workable method for predicting the dynamic behaviour of the fluid is given by author. A hydrodynamic pressure develops when a fluid container is subjected to horizontal accelerations. Simplified formulas are given for container has in two fold symmetry, and the specific cases of a rectangular and a circular cylindrical container are treated in details. The more exact analysis shows that the pressure can be separated into impulsive and convective parts. The impulsive pressure is not impulses in the usual sense but is associated with inertia forces produced by accelerations of wall of the container and are directly proportional to these accelerations. The convective pressures are those produced by the oscillations of the fluid and are therefore the consequences of the impulsive pressure. In the analysis the impulsive and convective pressures are examined separately.

S.C. Dutta, S.K. Jain, C.V.R. Murty et. al.[2] Studied elevated water tanks in past earthquakes (including 1952 Kern County and recent 1993 Killari earthquakes) has highlighted the importance of this problem. It is established that these structures may have amplified torsion-induced rotation if their torsional-to-lateral natural period ratio t is close to 1 and amplified displacement of structural elements due to the coupled lateral torsional vibration if t is within the critical range 0:7, t, 1:25: one reinforced concrete elevated water tank collapsed vertically downwards, burying the six supporting columns directly underneath the bottom slab of its container during the 1993 Killari, India. Elevated water tanks, with their broadly axi-symmetric geometry and mass distribution, should have no considerable eccentricity between centre of mass and centre of stiffness. Hence, they do not appear to be prone to torsion. However, asymmetric placement of ladders and water pipelines, sloshing of the water mass during shaking, and non-uniformity in construction may introduce small accidental eccentricity between centre of mass and centre of stiffness. This may cause progressively increasing localized damage in the yielded structural elements due to strength deteriorating characteristics of concrete under cyclic loading during an earthquake.Hence, to assess the torsional vulnerability of the elevated tanks, it needs to be investigated whether the ratio of torsional and lateral time periods, t , lie within the critical range of 0:7 , t , 1:25: In this paper, the stiffness characteristics of basic configuration of reinforced concrete moment-resisting frame staging's have been studied with a view to assess the vulnerability of such tanks due to occurrence of large torsional response under seismic excitation. The important conclusions arrived at in this paper is most of the usual tank stagings with basic configuration, the natural period ratio t may lie in the range 0:7, t, 1:25; this is the range, in which large torsional response occurs. The value of natural period ratio t may vary significantly between the tank-empty and tank-full conditions. Hence, in seismic design, efforts should be made to ensure that the ratio t does not lie in the critical range in either of the two conditions. Since, the magnitude and direction of accidental eccentricity causing torsional vibration is not known, it cannot be explicitly accounted for in the design. Hence, the possibility of changing t should be explored to reduce the effect of torsional coupling. The study shows that there is only a limited scope for changing t by modifying the number of columns *N*c, number of panels *N*p, and the relative column and beam stiffness parameter *K*r. Therefore, in general, it may be better to adopt a configuration other than the basic configuration; this issue has been addressed in the companion paper.

B. Devadanam , M K MV Ratnam et. al.[3]found that reinforced concrete elevated water tanks with frame staging, has shown better seismic resistance than reinforced concrete elevated water tanks with shaft staging. These can be attributed to the seismic energy absorption capacity of the frame staging. Hence this study is primarily focused on understanding the seismic behaviour and performance characteristics of elevated water tank with frame type staging. Moreover, circular tanks have minimum surface area when compared to other shapes for a given capacity of the tank. Hence the quantity of material required for circular water tank is less than that required for other shapes. Hence, a circular water tank has been adopted and seismic analysis of elevated RC circular water tanks has been performed as per IITK-GSDMA guidelines and behaviour of the water tank for various parameters viz., zone factor, soil condition, different staging heights have been analyzed. The modal characteristics (mode shapes and the modal participation mass ratio) of the structure were ascertained using SAP2000. The supporting structures i.e. the staging's were found vulnerable for seismic forces. Hence, an attempt has been made to study the effect of variations in staging height on the seismic behaviour of elevated water tank. The following observations were found in the analysis as the height of the staging has influence on base shear characteristics the base shear increases until a critical staging height and then it start decreasing. Care should be taken in avoiding the critical height. The variation of base shear with respect to seismic intensity factor is found to be linearly varying. Grade of concrete has influence on the stiffness of the staging which Effects the base shear of the structure. The base shear varies linearly with the change in soil from soft to hard.

S. M. Maidankar, G.D. Dhawale et. al.[4] from the very upsetting experiences of few earthquakes, like Bhuj earthquake (2001) in India, R.C.C. elevated water tanks were heavily damaged or collapsed. The main finding of this study is to understand the behavior of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake for three different types of bracing systems, applied to the staging of elevated circular water tank for earthquake zones. Analysis is carried out using SAP2000 v15. Twenty seven models are used for calculating base shear and nodal displacements for staging with normal bracing, cross bracing, and radial bracing in staging. Variation in staging height is 12m, 16m, and 20 m at 4m each. After calculating base shear and nodal displacements of twenty seven models for empty and full tank combination of loads applying with different types of bracings which gives minimum base shear as well as considerable displacement for major earthquake zones. In the analysis response spectrum method has been used for seismic analysis of structures by using software. Sloshing forces and base shear was calculated from IITK guideline, the results obtain from software was compared with manual calculation. Hydrodynamic pressure for impulsive and convective mode was calculated.

R. Livaoglu, A. Dogangun et. al.[5]the aim of this paper is to investigate how the soil structure interaction affects sloshing response of the elevated tanks with frame staging system on different soil conditions. For this purpose, the elevated tanks with frame staging system which are built on six different soil profiles are analyzed for both embedded and surface foundation cases. Thus, considering these six different profiles described in well-known earthquake codes as supporting medium, a series of transient analysis have been performed to assess the effect of both fluid sloshing and soil-structure interaction. Fluid-elevated tank-soil/foundation systems are modeled with the Finite Element (FE) Technique. In these models fluid structure interaction is taken into account by implementing Lagrangian fluid FE approximation into the general purpose structural analysis computer code ANSYS. A 3-D FE model with viscous boundary is used in the analyses of elevated tanks-soil/foundation interaction. Four models are analyzed for embedment and no embedment cases. Finally results from analyses showed that the soil-structure interaction for the elevated tanks affected the sloshing response of the fluid inside the vessel. The other conclusion can be drawn from the study is that the sloshing response is affected from the embedment more in case of soft soil than the stiff soil. In other words, when the soil gets softer, the effect of the embedment on sloshing response becomes more visible.

P.V. Muthu , A. Prakashet. al.[6] this paper 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. To find out the design parameters for seismic analysis and also the importance in the sloshing effect consideration during the design. Here an elevated Intze type water tank is Analyzed and designed. The analysis is carried out for two cases namely, tank full condition considering only the hydrostatic effects and tank full condition considering the sloshing effect using STAAD pro. From the analysis it is concluded that, to consider the sloshing effect along with the effect of hydrodynamic pressure on container wall of the tank during the design is very important in earthquake prone regions. The results obtained from analyses are discussed considering the importance of the structure during seismic activity. There is almost 40% increase of time period for first and second mode on comparing hydrostatic case and sloshing case which indicates more consideration should be given to sloshing case rather than hydrostatic case. On examining the critical elements of staging, the maximum axial force in sloshing case increases 56% more than in hydrostatic case, 56% in shear force and 45% increase of bending moment in x-direction, while 40% in y-direction and 59% in z-direction. The check for critical members also reveals that the tank is stable for hydrostatic case of analysis but not when sloshing is included in the analysis for which the critical elements values are exceeding the limiting values. It is clear that all critical quantities are increasing while considering sloshing effect in our design procedure. In order to avoid the failure which was mentioned earlier it is mandatory to consider the sloshing effect in the design and necessary precautions should be taken in earthquake prone region rather than considering the sloshing as the criteria only for fixing the free board. Since this sloshing of water considerably differs the parametric values used in design and economy of construction.

S. Bozorgmehrnia, M.M. Ranjbar and R. Madandoustet. al.[7]In this research, a sample of reinforced concrete elevated water tank, with 900 cubic meters capacity, exposed to three pair of earthquake records have been studied and analyzed in time history using mechanical and finite-element modeling technique. The liquid mass of tank is modeled as lumped masses known as sloshing mass, or impulsive mass. The corresponding stiffness constants associated with these lumped masses have been worked out depending upon the properties of the tank wall and liquid mass. Tank responses including base shear, overturning moment, tank displacement, and sloshing displacement have been calculated. Results reveal that the system responses are highly influenced by the structural parameters and the earthquake characteristics such as frequency content. Based on this study the researcher concluded that in this study, an elevated 900 m3 water tank which was supported by moment resisting frame was considered. Using Housner two mass models, dynamic responses including base shear, overturning moment, roof and floor displacement, and sloshing displacement were assessed under three earthquake records. The dynamic responses of tank have been determined using time history analysis in three cases, i.e. empty, half-full and full. The critical response of elevated tanks does not always occur in full case of tanks and it may happen in lower percentage of fluid and even in empty case of the tank depending on the earthquake characteristics. Frequency content and properties of the earthquake in ranges of natural frequency are the most important factors in reduction or intensity of tank responses. Due to the difference between the impulsive and convective mass periods and also among the frequency contents and utilized earthquake records properties, the occurrence time of maximum roof and sloshing displacements are not the same and they depend on the aforementioned parameters.

K. J. Dona Rose, M. Sreekumar, A. S. Anumodet. al.[8]studied tanks of various capacities with different staging height is Modeled using ANSYS software. The analysis is carried out for two cases namely, tank full and half level condition considering the sloshing effect along with hydrostatic effect. The time history analysis of the water tank is carried out by using earthquake acceleration records of EL CENTRO. The tanks withstood the acceleration with the displacements within the permissible limits. The peak displacements and base shear obtained from the analysis were also compared. The methodology includes fixing the dimensions of components for the selected water tank and performing nonlinear dynamic analysis (time history analysis) by: 1893-2002 (part 2) draft code. This work proposes to study circular tanks of different capacity and staging height and column configuration. The analysis is carried out for tank with full capacity and half capacity and considering the sloshing effect along with hydrostatic effects. Finite Element Model (FEM) issued to model the elevated water tank using ANSYS software. The conclusions drawn based on the studies shows that the peak displacements from the time history analysis under EL CENTRO earthquake records are below the maximum permissible displacement for different water levels. The peak displacement from the time history analysis increases with staging heights. But the displacement first decreases and then increases with capacities. The displacement for half-filled tanks is lesser than the displacement for tanks with full capacity. The base shear values from time history analysis were increases as staging height increases. Also, the base shears decreases and then increases with capacity. Base shear for half capacity tanks are lesser than that for full capacity tanks under same staging condition.

Miss. S. A. Patil, Prof. A. H.Kumbhar et. al.[9]the author has analyzed to study the sloshing effect in elevated water storage tank. The aim of behavior of elevated water tank of liquid storage during the earthquake caused the overturning movements, seismically induced by slosh waves. Also it is found that the sloshing of height may either increase or decrease with increase in the height of water in the tank. Due to sloshing effect of water amplitude of vibration reduces suddenly due to damping of energy, liquid in the tank act as a liquid damper. The sloshing of water not depends on volume of water in tank, it depends on staging height. The sloshing of height may either increase or decrease with increase in the height of water in the tank. Due to sloshing effect of water amplitude of vibration reduces suddenly due to damping of energy, liquid in the tank act as a liquid damper. The sloshing of water not depends on volume of water in tank, it depends on staging height.

M. V. Waghmare, S. N. Madhekaret. al.[10] In the present study sloshing effect in elevated water tank is studied by using finite element method (FEM) based computer code. Various parameters have been considered such as height of container, depth of water in tank (30%, 50%, 70% and full) and height of staging etc. On the basis of the results obtained in the study, Although it is apparent that certain aspects of behavior of water tank are not yet clearly understood a number of conclusions may bedrawn. If the water tank is excited due to earthquake ground motion the displacement of water in the tank depends upon the volume of water contained in it. Sloshing of water in tank depends not only on the volume of water in tank but also on staging height and h/d ratio. When 200 m^3 tank was filled 30%and given earthquake excitation at staging height of 6.85 m maximum displacement of water was noted as 450 mm, which emphasis the need of study of sloshing phenomenon. It is observed that normally when tank was full maximum sloshing occurs at lower height but it it was not true when h/d ratio is small as in case of 120m^3 capacity tank.

S. S. Besekar, M.R. Wakchaure et. al.[11] studied the sloshing effect & dynamic analysis in elevated water tank is studied by using finite element method (FEM) based computer software ANSYS. The main object of this paper is to compare the static and dynamic analysis of elevated water tank, to study the dynamic response of elevated water tank by both the methods, to study the hydrodynamic effect on elevated water tank &behaviour of water in different state with change of depth of water in tank (15%, 30%, 50%, 75% and full) and response spectrum analysis of elevated service reservoir. On the basis of the results obtained in the study, although it is apparent that certain aspects of behavior of water tank are not yet clearly understood a number of conclusions may drawn. Generally if the water tank is excited due to earthquake ground motion the displacement of water in the tank depends upon the volume of water contained in it. Sloshing frequency is an important parameter in the seismic analysis of tank-liquid system. For the regular tank geometries, such as circular and rectangular, the analytical expressions for sloshing frequency are quite well known. The critical response of elevated tanks does not always occur in full condition, it may also occur under half condition. The critical response depends on the earthquake characteristics and particularly frequency content of earthquake records. The critical response of the elevated tank due to fact that the hydrodynamic pressures of container in half condition as compared with the full condition are higher. In addition to the critical response, depends on the earthquake characteristics and particularly frequency content of earthquake records. Thus, structure response to each record in addition to the dynamic properties of the structure also depends on the above mentioned properties. Elevated water tank with compartment reduce the sloshing effect & stress, deflection, deformations of the tank.

S. K. Jangave, P. B. Murnalet. al.[12]worked on to understand the seismic behaviour of the elevated water tank with consideration and modeling of impulsive and convective water masses inside the container as one mass model and two mass model as per IS:1893-2002 under different time history records using finite element software SAP 2000.The present work aims at checking the adequacy of water tank for the seismic excitations. The result shows that structure response is exceedingly influenced by different capacities of water tank and their one mass and two mass models and earthquake characteristics. The responses include displacement at top level and base shear of existing model and its one mass and two mass model under the four different time history have been compared. For the study, water tanks with five different capacities are considered, each water tank is modeled as Existing, One mass and Two mass model. The models which are used in this report are of 500m3, 750m3 and 1000m3 capacities. The above models are analyzed for different time history data such as Kern city (1952), North Ridge (1994) and Imperial Valley (1979). The comparison is made between the structural responses of existing, one mass and two mass models of above different capacities. It is observed that the critical response depends on the earthquake characteristics and particularly frequency content of earthquake records also displacements for two mass models are less than one mass and existing model. Base shear also shows a minimum value for two mass model for all the three capacities. In some cases existing model shows maximum displacement than one mass than two mass model. There is sudden change in displacement values for north ridge earthquake data. All the above modeled water tanks shows maximum displacement for North ridge earthquake data and minimum displacement for Koyana earthquake data for all tank capacities.

D. Virkhareet. al. [13] It is carried out by considering various parameters like water storage capacity and staging height which are constant, different types of h/d ratio, various types of staging arrangement and variation in number of columns. The behavior of each tank with respect to other will be checked for base shear, roof displacement and plastic hinge formation sequence and its pattern within the staging.

M. Masoudi (2009)et. al.[14] study evaluation of response modification factor (R) of elevated concrete tanks. The failure mechanism of elevated concrete tanks with shaft and frame staging along with seismic behavior of these construction types. In order to modify the current code-based seismic design methodology, computer models have been established to determine the response modification factors, r, of the shaft and frame staging elevated tanks. The effects of multi-component earthquakes, fluid–structure interaction and the p–d effects on the inelastic response of elevated tanks have been studied by conducting linear and nonlinear response history analyses. According to results of analyses and observed inelastic behaviour during past earthquakes, the r factors for shaft and frame staging elevated concrete tanks have been evaluated regarding the seismicity of the site. Moreover, the shortcomings associated to the current simplified seismic analysis and current design procedures have been addressed and a more rational modeling has been suggested especially for the shaft staging systems to enhance distribution of the ductility.The results of the analysis show that in some of the earthquakes, the beams of all stories enter the inelastic range. Therefore, the design of these staging types requires proper reinforcement details in the beams of all stories. Usually, capacity design philosophy leads too very strong columns. They behave relatively rigid compared to the beams. therefore, formation of only one plastic hinge at the end of one beam or column base, theoretically causes formation of plastic hinges at both ends of all beams and developing a full mechanism in the frame staging. This means that in terms of redundancy, frame staging supporting a large mass at top behaves completely different than moment resisting frames typically used as lateral load bearing systems in buildings because in the building structures the total mass of the system is distributed in all story levels. Despite frame staging's having almost uniform ductility demand distribution in members, height-wise distribution of mass in building frames causes a lateral displacement pattern in which the system ductility demand is not necessarily distributed uniformly in all beams.

F. Omidinasab et. al.(2008) [15] studied seismic vulnerability of elevated water tanks using performance based-design. in this research, a sample of a reinforced concrete elevated water tank, with 900 cube meters under seven earthquake records have been studied and analyzed in dynamic time history and the tank's responses including base shear, overturning moment, tank displacement, and sloshing displacement under these seven record have been calculated, and then the results have been compared and contrasted.

A. M. Jabar, H. S. Patel et. al.[16]the main aim of this study is to understand the behaviour of supporting system which is more effective under different earthquake time history records with SAP 2000software. Here two different supporting systems such as radial bracing and cross bracing are compared with basic supporting system for various fluid level conditions. For later conditions water mass has been considered in two parts as impulsive and convective suggested by GSDMA guidelines. In addition to that impulsive mass of water has been added to the container wall using Westergaard's added mass approach. Tank responses including base shear, overturning moment and roof displacement have been observed, and then the results have been compared and contrasted. The result shows that the structure responses are exceedingly influenced by the presence of water and the earthquake characteristics. The critical response occurs in case of full tank and sometime in empty tank. This result may be due to the fact that the hydrodynamic pressures of container in half-full case as compared with the full filling case are higher. In addition, it can be also assigned to the effect of the frequency content of earthquake records. Frequency content and properties of the earthquake in ranges of natural frequency elevated tank are the most important factors in reduction or intensity of tank responses. Thus, structure responses to each record in addition to the dynamic properties of the structure also depend on the above mentioned properties. Earthquake records with high frequency content cause excitation of responses such as base shear force, overturning moment and roof displacement are compared and following conclusions are obtained. In empty condition, higher base shear for cross bracing pattern in Loma Prieta time history. For Kobe earthquake, lower base shear and overturning moment in cross bracing and radial bracing pattern respectively in empty condition. In case of half- full condition, lowest base shear and overturning moment for Radial Bracing in Loma Prieta and Kobe earthquake intensity respectively. For basic staging overturning moment is highest in half-full condition for Loma Prieta having high PGA value. In case of full condition, highest base shear is obtained for radial bracing in Imperial Valley having low PGA value. Roof displacement is considerably decreases with increase in PGA value of earthquake time history and also noted higher value in Imperial Valley. Higher roof displacement values are obtained in full fill up condition for all patterns.

III. CONCLUSION

This paper focuses only on the literature review of previously published studies. The findings of this paper arethe sloshing response is affected from the embedment more in case of soft soil than the stiff soil. In other words, when the soil gets softer, the effect of the embedment on sloshing response becomes more visible. The sloshing as the criteria only for fixing the free board. Since this sloshing of water considerably differs the parametric values used in design and economy of construction. The variation of base shear with respect to seismic intensity factor is found to be linearly varying. Grade of concrete has influence on the stiffness of the staging which Effects the base shear of the structure. The base shear varies linearly with the change in soil from soft to hard. The convective pressures are those produced by the oscillations of the fluid and are therefore the consequences of the impulsive pressure. In the analysis the impulsive and convective pressures are examined separately.

REFERENCES

[1] G. W. Housner (1963), "The dynamic behaviour of water tanks", Bulletin of the Seismological Society of America, Vol.53, No.2, pp 381-387.

[2] B. Devadanam and M K Ratnam (2015), "Effect of staging height on the seismic performance of RC elevated water tank",International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 1, January 2015.

[3] S.C. Dutta, S.K. Jain, and C.V.R. Murty (2000), "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging", Soil Dynamics and Earthquake Engineering , Vol.19 (2000) pp183–197.

[4] R. Livaoğlu andA. Doğangünk (2008), "Sloshing

response of the cylindrical elevated tanks with frame staging system on different soil conditions", Technical University, Department of Civil Engineering. 61080,Gumushane, Turkey. Institute of Thermo mechanics, Prague, 2008.

[5] S. M. Maidankar, G.D. Dhawale, and S.G. Makarande (2015), "Seismic analysis of elevated circular water tank using various bracing systems", International Journal of Advanced Engineering Research and Science Vol-2, Issue-1, Jan.- 2015

[6] P. M.Vijay and A. Prakash (2014), "Analysis of sloshing impact on overhead liquid storage structures", IMPACT: International Journal of Research in Engineering & Technology Vol. 2, Issue 8, Aug 2014, pp127-142

[7] M.M. Ranjbar and R. Madan (2013), "Seismic Behavior Assessment of Concrete Elevated Water Tanks", Journal of Rehabilitation in Civil Engineering pp 69-79.

[8] K. J. Dona Rose, M. Sreekumar and A. S. Anumod (2015), "A Study of Overhead Water Tanks Subjected to Dynamic Loads", International Journal of Engineering Trends and Technology (IJETT) – Volume 28 Number 7 - October 2015.

[9] S. A. Patil, A. H. Kumbhar, and T. F. Mujawar (2016), "Elevated Water Tank Under Sloshing Effect", International Journal for Scientific Research & Development Vol. 4, Issue 05, 2016

[10] M. V. Waghmare and S. N. Madhekar (2013), "Behaviour of Elevated Water Tank Under Sloshing Effect", International Journal of Advanced Technology in Civil Engineering, Vol.-2, Issue-1, 2013.

[11] M. R.Wakchaure and S. S. Besekar (2014), "Behaviour of Elevated Water Tank Under Sloshing Effect", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 2, February – 2014.

[12] S. K. Jangave and P. B. Murnal (2014), "Structural Assessment of Circular Overhead Water Tank Based on Frame Staging Subjected to Seismic Loading", International Journal of Emerging Technology and Advanced Engineering, Vol. 4, Issue 6, June 2014.

[13] D. Virkhare and L. Vairagade (2015), "Pushover Analysis of Water Tank Staging", Civil Engineering Department, G.H.R.A.E.T N Structural Consultant, Techpro Consultancy, Nagpur, Maharashtra, India IRJET/July 2015.

[14] M. Masoudi, (2012), "Evaluation of Response Modification Factor (R) of Elevated Concrete Tanks", Engineering Structures, Vol.39 (2012) pp199-209.

[15] F. Omidinasab and H. Shakib (2008), "Seismic Vulnerability of Elevated Water Tanks Using Performance Based-Design" The 14th World Conference on Earthquake Engineering, October 12- 17, 2008, Beijing, China.

[16] A. M. Jabar and H. S. Patel (2012), "Seismic behaviour of RC elevated water tank under different staging pattern and earthquake characteristics", International Journal of Advanced Engineering Research and Studies, Vol.1 April-June, 2012, pp293-296.

[17] S.C. Dutta, S.K. Jainb and C.V.R. Murty (2000), "Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging",Soil Dynamics and Earthquake Engineering , Vol.19 (2000) pp183–197.

[18] P. K.Malhotra, T.Wenk and M.Weiland , "Simple Procedure of Seismic Analysis of liquid-Storage Tanks", Structural Engineering, Vol. 3, pp197–201.

[19] D.C. Rai (2001), "Performance Of Elevated Tanks In Mw 7.7 Bhuj Earthquake of January 26, 2001",International Conference on Seismic Hazard With Particular Reference to Bhuj Earthquake of January 26, 2001, Oct. 3–5, New Delhi.