NUMERICAL REVIEW ON WATER ELEVATED TANKS

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Abstract- Water elevated tanks are one of the most important tools in supplying water for cities. Due to their damages in previous earthquakes, and the necessity for keeping them in safe and usable condition after earthquakes is obvious. Thus, by making various modeling, their behavior under seismic loading is investigated. Moreover, the pros and cons of dampers are also evaluated. In this thesis, the proposed concrete water tank is modeled under three different earthquakes of Tabas, Northridge and Chichi. Moreover, the damper is located in three various positions. The results are illustrated for different fullness of tanks.

Keywords- Water Elevated Tank, Friction Damper, Earthquake, SAP Software

I. INTRODUCTION

Civil engineering structures such as buildings, bridges and towers may be damaged or even collapsed because of shed loads. Seismic design of structures to resist damage has always been a concern for civil engineers. Despite much effort and progress in used codes structural are still vulnerable to earthquakes. The reason is that the structures are designed with the conventional methods are limited resistance capacity. Most of structures stiffness based on the stiffness and negligible damping of the structural resistance of materials has energy dissipation. According to the loads these structures are somehow disabled because they don't have the adaptability. For resisting earthquake loads strength and ductility of structures should be increase, but providing material for such purposes are expensive. Increasing the size of the school makes them more force and thus will require a larger size. Also there is no way to increase the structural damping. These factors led to the application of smart structures to in 1970. In this method some devices add to the structure to increase the seismic capacity. So this structure is not only dependent on the strength of its members, but also these devices increase the ability of energy dissipation structures. Also these designed structures have good safety. During construction or retrofit of structures, using of these devices reduce the consumption of materials, administrative costs and reducing the structural weight. Nowadays, these structures can be used in following:

- Structures under wind or earthquake excitations
- Structures such as hospitals and power plants required high safety
- Structures such as towers and bridges with high flexibility

One of the new technology structural engineering and seismic design is seismic isolators and their application in specific structures such as reservoirs. This system aligned in foot building on bridge decks and merge creating the necessary damping force to reduce the effects of destructive force.

In general, seismic control methods are divided into four groups depending on the type of performance:

- Seismic isolation
- Passive control methods
- Semi-active control method
- Active Control Method

In separation method structural dynamics will reduce with increasing frequency and the damper structure prediction followed.

In reservoirs structures, much mass is at a considerable distance from the foundation. Analysis of these structures under lateral forces can be significant, especially to maintain the security and efficiency of these structures. Since the period of these structures is generally high, the selection of appropriate analytical methods that can correct perception of system performance when coming into the lateral loads can be a critical. This thesis will attempt to do this particular study and present the results.

II. IMPORTANCE OF THE TOPIC AND ITS MOTIVES

Construct is a system that has endured load and pressure and transmits it. Structure is designed so that can provide this objective during the operation without irreparable damage. Structures are used as bridges, buildings, ships and etc. Loads applied to the structure may be static, gravity or dynamic such as earthquakes. Structural members include beams, columns, and braces that are themselves are a kind of shell structures. Structural behaviors and their components, such as dynamic deformations under loads or vibrations are called structural responses. Characterizing the dimensions of the sections and three-dimensional configurations, materials and components are called structure design. Structures must have a safety (strength and stability) and capacity utilization (stiffness) versus the loads. Various sciences such as mathematics, mechanics and materials are used in structural design. Conventional approach for

designing structures is that structural has sufficient rigidity and resistance against loads and has the ability to change shape. Such structures are the three causes of low capacity. First, the structures have low damping energy dissipation due to the materials used in them. In this case, there is no strategy to increase damping materials such as reinforced concrete and steel. Second, these structures have a fixed capacity for resistance and energy dissipation.

It cannot be flexible against stimuli such as wind and earthquakes. Third, these structures can withstand the loads in general by their hardness. These limitations led the researchers to look for other solutions. Advanced research with the use of new materials (or smart materials) led simple structures which can be developed inherent characteristics on the basis of the load change.

By means of this new system is added device to the structure, the structure acts somehow smart because it can evaluate their performance and adjust based on their loads. Intelligent structures can change the data storage, processing time and understand the commands necessary to protect and preserve structural integrity to issue.

Application of these concepts in civil engineering to resist wind and seismic loads is new and still a lot of research in this area is underway. The issue of retrofitting air reservoir water as a major structural water supplier of cities according to their vulnerability in past earthquakes, keeping them operational after an earthquake is critical. Therefore, it is necessary to do the necessary modeling while studying the behavior of structures during earthquakes, and advantages and disadvantages of using isolation bearings is studied.

III. HYPOTHESIS

Concrete reservoirs used in this study are cylindrical shape.
The reservoir is analyzed for different percentages of the filling.
Dynamic analysis is done in three-dimensional.
SAP nonlinear modeling software is used.

In this study the dimensions of the reservoir is relatively small, therefore, the hydrodynamic effects of the fluid in the reservoir is neglected and the behavior of the fluid-structure interaction is not considered.

IV. QUESTION OF STUDY

According to modeling and results in this case the following hypothesis are used: using of Friction damper leads to a reduction of the target changing. Also using of Friction damper leads to change in shear base and the SAP2000 software was used to modeling.

V. REVIEW OF THE LITERATURE ON ISOLATED RESERVOIRS SEISMIC ANALYSIS OF CONCRETE ELEVATED TANK

In this paper a vibration analysis is investigated with cylindrical base of concrete air reservoirs due to the interaction of structural dynamics, fluid bed soil that has been presented by Moghaddam in the Regional Conference on Earthquake Engineering and Seismology.

In General storage reservoirs are divided in terms of types of relying in air bearing (concrete and steel) and ground (buried and semi-buried). In this study, the seismic behavior has been investigated by concrete-based air reservoirs earthquake.

The first mechanistic model was proposed by Havezner for reservoirs with rigid wall that despite of Simple assumptions have yet approved by the regulations of designing reservoirs. The fluid model is divided into two parts pulsatile and oscillatory. Figure 1 for reservoir fluid mass, radius R and height H and M, part of pulsatile and oscillating rigid reservoir is connected with certain stiffness which in following determining mass and height of these two parts is proposed.

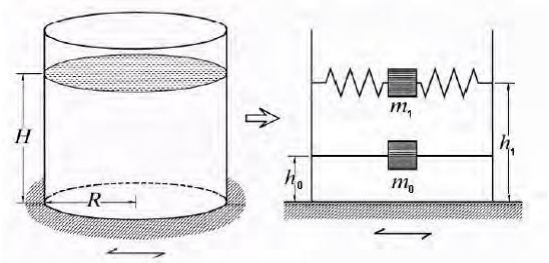


Figure 1-mechanical model of interaction in reservoir

VI. AIR RESERVOIRS DAMAGES IN EARTHQUAKE

the stimulatory effect of the earthquake, the air reservoirs and underground reservoirs have experienced significant losses, however, studies on air reservoirs to a lesser extent in the development of improved methods. The air reservoirs on the base transmission cylindrical bending frame are divided into two categories. Architectural requirements of each of them and each one have crucial advantage.

Air reservoirs with cylindrical basis are many common bases in concreted air reservoirs with large volumes. In mentioned structures the only lateral system is the concreted cylindrical basis and unlike the frame-based reservoirs defined high degree of power and the ability to relay routes have militants, have not certain cylindrical basis.

Figure, respectively is a view of aerial reservoirs with concrete cylindrical base - and a frame base.



Figure 2-cylindrical column elevated tank



Figure 3-frame column elevated tank

STRUCTURAL MODELING AND FLUID

Ebadollah Zadeh and colleagues in a paper has worked for seismic analysis of concrete-based Air cylindrical reservoirs l with regard to the interaction between structural dynamics, fluid and soil have.

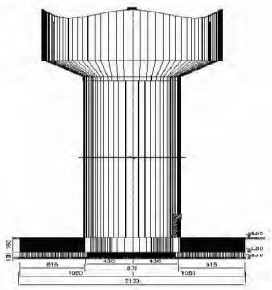


Figure 4- concrete elevated tank geometry with cylindrical columns

Table 1- material properties

Fluid		concrete	
2.1GPa	Bulk module	200GPa	Elasticity module
1000 kg/m^3	density	2400 kg/m^3	density
1.15E-4 kg.s/m^2	viscosity	0.25	Poison ratio

In this paper, the structural environment and fluid and both is used directly by the foundation of the model and the finite element method to analyze the interaction of the direct solution method. For this purpose software ANSYS given the diversity of its elements were used for modeling and analysis of numerical.

Table 2- concrete elevated tank geometry with cylindrical columns

reservoir		Column	
150 cm	height		
610 cm	Wall height	2075 cm	height
1620 cm	diameter	810 cm	diameter
30 cm	thickness	40 cm	thickness

Due to the symmetry of the system, only half of the geometry is modeled and symmetry boundary conditions appropriate to the boundaries of the reservoir model is used. Need to model the larger environment of the soil and the number of computing elements, there is greater need to spend a lot of time and cost. Thus the idea of using boundaries arose which trying to adapt to near the soil properties to the characteristics of the environment. These borders are applicable in the frequency domain and time domain which is used in the problem of nonlinear time domain boundaries, including the boundaries of the energy absorber.

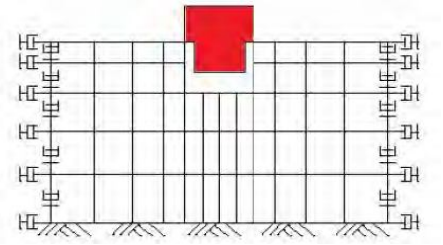


Figure 5- application of perpendicular dampers in earh boundary

FINITE ELEMENT OF SOIL STRUCTURE AND AIR TANK MODELING

Static and dynamic analysis are necessary in study the geometry model, it is also necessary material properties for each part determined by laboratory tests. Soil structure interaction model is used in this paper as a disk with a radius of 12 meters and a field soil with a depth of 2 meters. Finite element model is used in Figure 5.

For modeling the scope ANSYS software is used that have the ability to model fluid And soil. The basic model of the element Shell63, Fluid80 reservoir modeling elements and eight node elements used to model soil Solid45. The modeling of energy absorbing element boundaries comBIN14 used.

The results of this study show that the number of vibrational modes of the fluctuating dynamic behavior of ductile wall cabinets and base unlike the model of mechanical equivalent are more than one. Oscillatory modes near the structural and fluid modes due to the creation of hybrid modes.

The time history analysis, records that have a lower dominant frequency oscillatory modes of the system are relatively high periods, which stimulates and empowers long wave hydrodynamic pressure is high at the level of the free surface of fluid. Records that have a higher dominant frequency, increase aligned to pulse stimulation modes the hydrodynamic pressure on the tank bottom and lower aligned. Vibrational modes with periods of high air reservoirs due to a low base shear than the other structures in the analyzed showing the time history of the show. The analysis of soil-structure interaction model showed that increases the soft soil reservoirs are half empty vessels to be filled than the opposite is true for hard soil.

VII. ANALYTICAL METHODS OF EARTHQUAKE RESISTANT STRUCTURES

The method of analysis can be divided into four groups, namely:
. Near static analysis (equivalent lateral load)
. On-linear static analysis (capped overs)
. Linear dynamic analysis (spectral and time history)
. Non-linear dynamic analysis

Among the methods of a static method to construct low of conventional and common applications are used as the building and use it for building grade a high importance is not recommended. Any other methods mentioned with regard to efficiency and time and cost required to analyze the whole structure.

Since the force applied to the structure during an earthquake cannot be evaluated exactly using the equivalent lateral load analysis, more accurate assessment of dynamic forces and the behavior of the structure. The method of linear dynamic range of the spectrum maximum response modes designed to extract and cluster together to respond whole system maximum is achieved. SRSS and CQC sum type.

Linear dynamic analysis of structures affected by an acceleration time histories mapped and its response in the force structure or shift in the history of the form is obtained from different. Mostly to address structural study time histories method of direct integration in small time intervals are used and the gathering and putting together a response to the responses obtained at any time histories.

Building on the analysis of nonlinear dynamical behavior and other characteristics as non-linear structures and be ¬ analyzed. This method allows the real behavior of the structure.

VIII. SELECTED ACCELEROMETER

Acceleration time history dynamic analysis and seismic mapping, which is one of the most laws to investigate the seismic behavior of structures mapping suggested that the general this acceleration in this categories:

Accelerometer which is based on the spectrum plan and bylaw made numerical methods. Feature of such Accelerometer is that the spectrum of design standards and consistent design philosophy, and the other can be an indication of the characteristics can easily be used for seismic design.

Accelerometer recorded earthquake will consist generally known and destructive earthquakes occurred in different parts of the world. Because the characteristics of earthquake seismology may be different with other regions, and the differences may be observed in different parts of the design spectrum. In this study, three earthquakes Accelerometer is used Tabas, Northridge and Chichi. Tabas earthquake, the Richter 7.8 earthquake was occurred at about 7 pm on September 25, 1357, the city of Tabas and surrounding villages devastated. In this earthquake, about 15,000 people lost their lives.

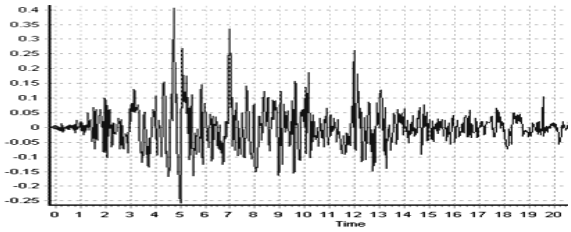


Figure 6- Tabas earthquake record

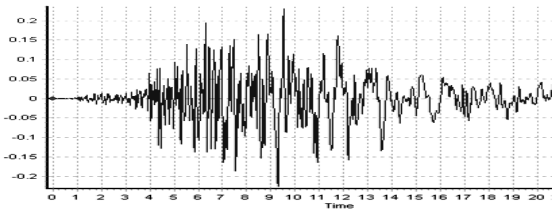


Figure 7- Northridge earthquake record

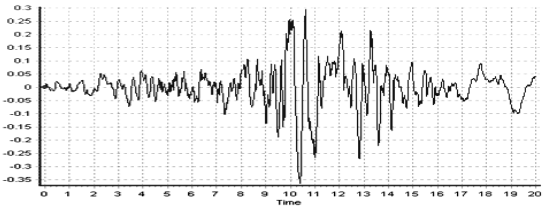


Figure 8- Chichi earthquake record

IX. MODELING OF FRICTION DAMPER ON SAP SOFTWARE

In following, we explain how friction damper model is presented in the SAP 2000 software. From DEFINE introduces the elements of the LINK as a damper. In link/support type we could choose types of damper. Using of plastics for modeling is recommended according to the research literature on the subject. It is because of Friction damper hysteresis curve is similar to an ideal elastoplastic material.

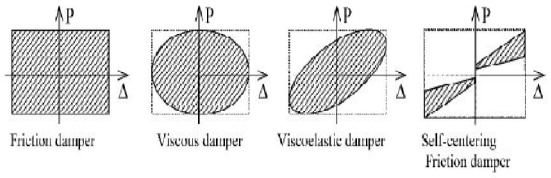


Figure 3- Hysteric diagram in various dampers

Table 3- 1- input parameters in SAP

Parameter	value
Mass	10
Effective stiffness	17858
Effective damping	15%
stiffness	17858000

Yield strength	22680KN
Yield exponent	0.8
Post yield strength ratio	0.1

The final model is presented as below:

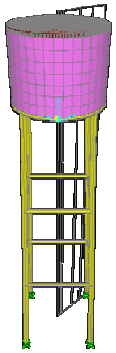


Figure 10- final model

Three various locations for the damper are presented in the below figure.

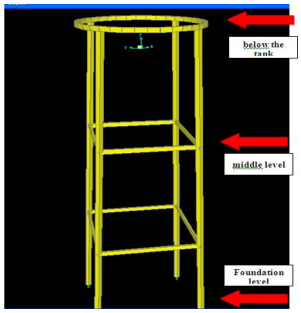


Figure 11- locations for the friction damper

The columns are assumed to be 2IPE14 and the beams are UNP 16. the restraints and connection are also rigid.

X. SUMMARY OF RESULTS

Water elevated tanks are an important equipments in supplying water for cities, and keeping them in safe condition is necessary during earthquake. so, by modeling this structures, the pros and cons of using damper in restraints are investigated. in this thesis, three earthquake records of Tabas, Northridge and chichi are selected. Moreover, the damper is located in three different location of structure. The various fullness of reservoir is also investigated.

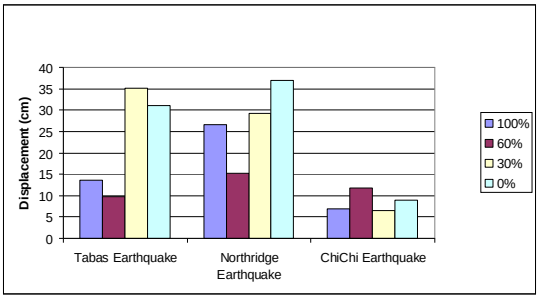


Figure 12- comparison of reservoir displacement in empty condition during earthquakes

In the above figure, the upper level displacement is illustrated in various fullness of reservoir, for Tabas, Northridge and Chichi earthquakes.

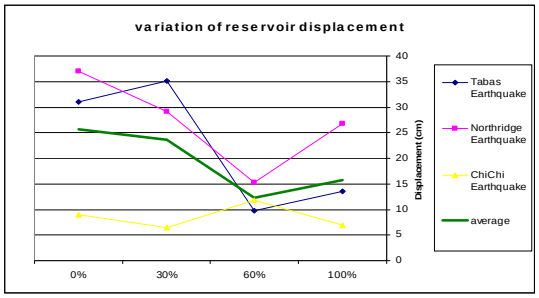


Figure 13- comparison of reservoir displacement in empty condition during earthquakes

In case of not using a damper, the variation of displacement in upper level is decreased as the fullness of reservoir increases. Yet, this is an approximate behaviour, and the least displacement occurs for 60% reservoir fullness. The displacement decreases from 25.7 cm in empty case to 15.7 cm for 100% full reservoir. So the complete fullness of the reservoir makes 40% reduction in displacements.

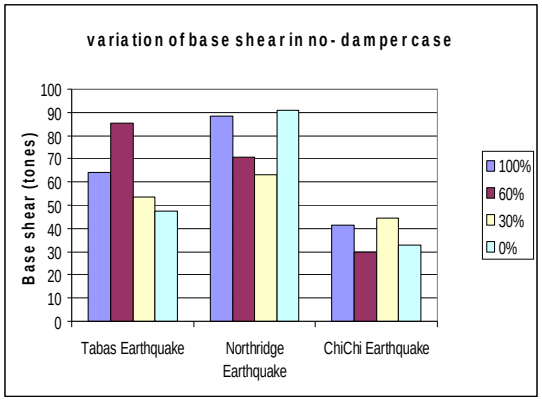


Figure 14- comparison of reservoir base shear in different fullness during earthquakes

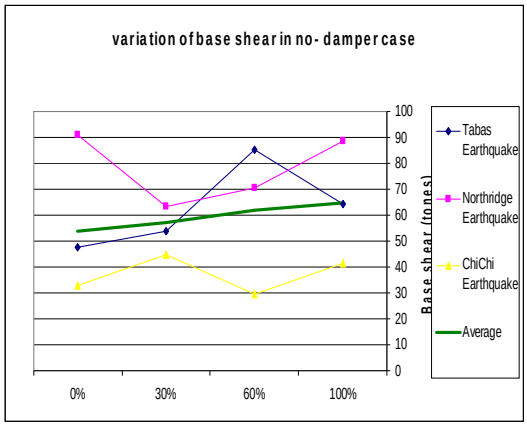


Figure 15- comparison of reservoir base shear in different fullness during earthquakes

Based on the graph, the relation between base shear and water volume in reservoir is direct and it is decreasing. in the average condition it is equal to 20%.

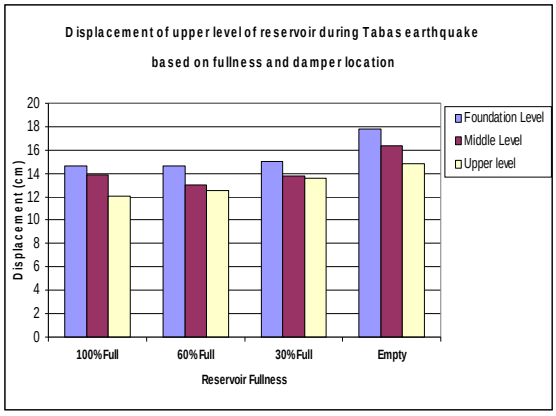


Figure 16- comparison of reservoir displacement based on damper location during Tabas earthquake

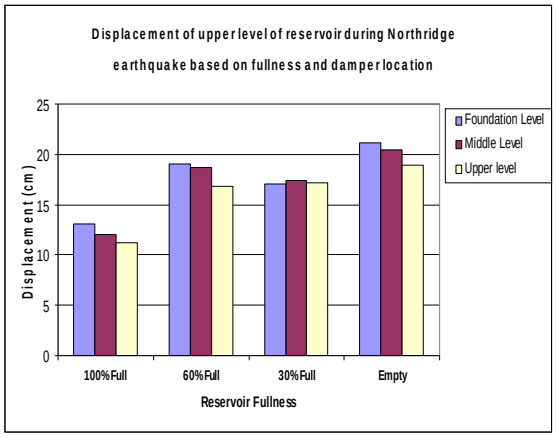


Figure 17- comparison of reservoir displacement based on damper location during Northridge earthquake

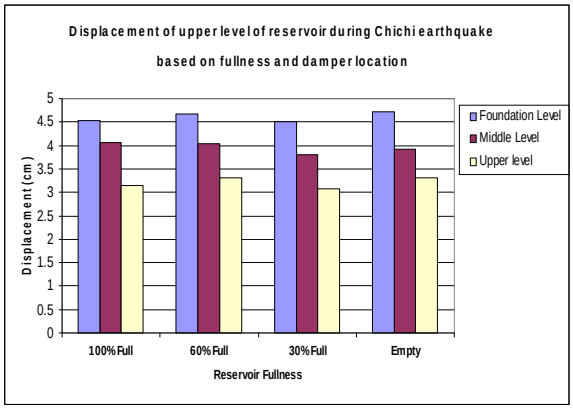


Figure 18- comparison of reservoir displacement based on damper location during Chichi earthquake

Based on the graphs, it is observed that in all earthquakes the upper level location of damper will cause the reduction of displacements and so a better performance. This reduction is between 8% to 19%.

In case of using a damper, the maximum displacements are for empty reservoir.

The results show that the best location for damper is the upper level, therefore the investigation of base shear is limited to this case only.

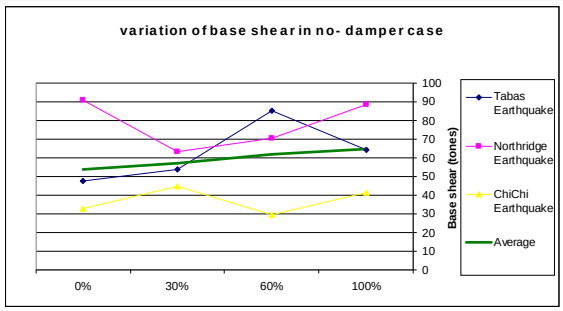


Figure 19- comparison of base shear in no-damper case

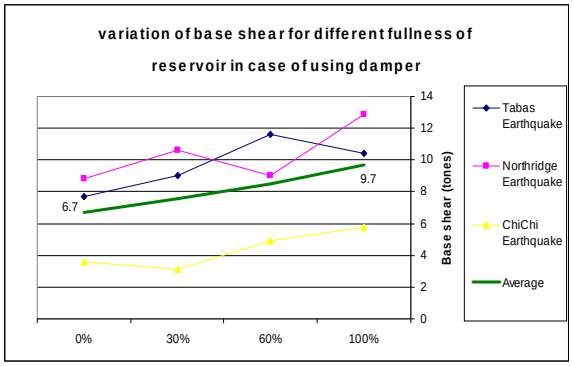


Figure 20- comparison of base shear in dampered case

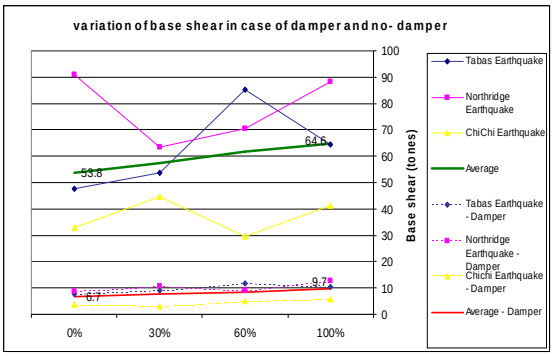


Figure 21- comparison of base shear in dampered and no-damper cases

Based on the graph, the variation of base shear is decreasing with reduction in reservoir fullness. Using a damper in upper level, the base shear decreases from 9.7 tons for full condition to 6.7 tons for empty case which equals to 31% reduction. In case of not using damper, the base shear decreases from 64.6 tones to 53.8 tones which equals to 17% reduction. Therefore, using a damper will reduce the base shear for 14%.

CONCLUSION

The obtained results are listed as below:

1. Based on the graph, the variation of base shear is decreasing with reduction in reservoir fullness. Using a damper in upper level, the base shear decreases from 9.7 tones for full condition to 6.7 tons for empty case which equals to 31% reduction. In case of not using damper, the base shear decreases from 64.6 tons to 53.8 tones which equals to 17% reduction. Therefore, using a damper will reduce the base shear for 14%.
2. Based on the graphs, it is observed that in all

earthquakes the upper level location of damper will cause the reduction of displacements and so a better performance. this reduction is between 8% to 19%. in case of using a damper, the maximum displacements are for empty reservoir.

3. Based on the graph, the relation between base shear and water volume in reservoir is direct and it is decreasing. in the average condition it is equal to 20%.

4. in case of not using a damper, the variation of displacement in upper level is decreased as the fullness of reservoir increases. yet, this is an approximate behaviour, and the least displacement occurs for 60% reservoir fullness. the displacement decreases from 25.7 cm in empty case to 15.7 cm for 100% full reservoir. so the complete fullness of the reservoir makes 40% reduction in displacements.

5. In empty reservoir, the variation of displacement is generally decreasing. it decreased from 14.5 cm for case of foundation damper, to amount of 12.3 cm in case of below tank damper. This equals to 15% reduction. So, the best performance is for empty reservoir condition, in case of locating the damper below the tank.

6. In 30% full reservoir, the variation of displacement is generally decreasing. It decreased from 12.1 cm for case of foundation damper, to amount of 11.2 cm in case of below tank damper. This equals to 7% reduction. So, the best performance is for 30% full reservoir condition, in case of locating the damper below the tank.

7. In 60% full reservoir, the variation of displacement is generally decreasing. It decreased from 12.7 cm for case of foundation damper, to amount of 10.8 cm in case of below tank damper. This equals to 15% reduction. So, the best performance is for 60% full reservoir condition, in case of locating the damper below the tank.

8. In 100% full reservoir, the variation of displacement is generally decreasing. It decreased from 10.7 cm for case of foundation damper, to amount of 8.7 cm in case of below tank damper. This equals to 18.7% reduction. So, the best performance is for 100% full reservoir condition, in case of locating the damper below the tank.

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