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Time History Analysis of Structure having Water Tank at the Top of Building Acting as a Tuned Liquid Damper

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Abstract-An earthquake is a natural phenomenon occurring worldwide. Depending upon the intensity, it may cause damage to life and property. Continuous research is carried out to find the different methods that can provide a solution to minimize this damage. The idea of seismic response control of the structures by using over head water tank as a passive TMD's is considered for the study. The main objective of this study is to find out response reduction of the structure subjected to different earthquake data. Analysis is carries out for six storied building with and without water tank for different water tank positions and different water levels such as empty water tank, half filled water tank and full filled water tank. Three types of earthquake data are considered for the study namely, El-Centro, Kobe and loma prieta. For performing Time history analysis SAP 2000 software is used in this study. Results show that tuning the parameters of water tank, it can be used as passive TMD to reduce the seismic response.

Keywords- Centre top, Center middle, Centre bottom, Tuned liquid damper, Time history analysis, Base shear, Roof displacement.

I. INTRODUCTION

Recent major earthquakes around the world have attracted the attention of understanding the way in which civil engineering structures respond during such dynamic events. Also due to urbanization, industrialization and development happening around the world demand for high-rise buildings has increased day by day. These buildings are more flexible and have low damping value. This result in to the increasing sensitivity of these buildings to dynamic excitations. So today's structural researchers main challenge is to develop innovative design to protect civil structures including material content and human occupants from hazards like wind and earthquake. The various vibration control methods such as passive, active, semi-active and hybrid systems are in the developing stage which can be used to reduce the structures response to earthquake or wind loads.

A passive control system operates without external power supply. It utilises the motion of the structure to develop the control forces. Passive control systems are very liable since they are unaffected by power outages which are common during earthquakes. Advantage of such devices is that their low maintenance requirements. Examples of passive systems are base isolation, elastic dampers, liquid column dampers, liquid mass dampers, metallic yield dampers and friction dampers. An active control system utilises external power for operation. Active system has the ability to adapt to different loading conditions and also able to control different vibration modes of the structures. Examples of active systems are active tuned mass dampers (ATMD), active tendon systems and actuators/ controllers. By combining active and passive control systems, hybrid systems may form. Due to which it enhances the robustness of the passive system and reduces the energy requirements of the active system. The Hybrid Mass Damper (HMD) and the hybrid seismic isolation system these are two approaches by which hybrid system can be implemented. Semi-active control systems, is also a type of control system which is based on semi-active devices. Semi active control system can be made by combining passive and active control systems. A semi active control device has properties that can be adjusted in real time but cannot inject energy into the controlled system. Such types of devices are referred to as controllable passive dampers because they act as an active control devices without requiring large power sources. Semi-active control systems have attracted a notable attention in recent years. Many of these systems can able to operate on external battery power alone, which is advantageous during seismic events when the main power source to the structure may fail. Also, because semi-active devices are not able to inject the energy into the structural system, they are unable to destabilize the system.

Tuned Liquid Damper (TLD) is a passive control device. TLD has been installed in structures to suppress horizontal vibrations in

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the structures. TLD is a liquid filled tank which is rigidly connected to the structure. TLD works on the sloshing wave developing and breaking at the free surface of the liquid. This able to dissipate the amount of energy released during the dynamic event and helps to increases the equivalent damping of the structure. At the time of resonance frequency of tank motion is close to the frequency of the tank liquid. At resonance, amount of sloshing and wave breaking occurs is large at the free surface of the liquid which helps in dissipating a significant amount of energy.

A. Objectives of the Study

1) To study the feasibility of implementing water tank as passive tuned mass damper for 6 storied structure by subjecting to real earthquake ground motions and by varying the position of the water tank at centre top, centre middle and centre bottom of the building with a water depth in water tank varying from empty , half filled and fully filled tank.
2) To Study the seismic behaviour of the structures having water tank as tuned mass damper using nonlinear time history analysis to reduce roof displacements and base shears.

II. METHODOLOGY

Time history analysis was carried out for structures without water tank and with water tank subjected to 3 types of earthquake data's (El Centro, Kobe, Loma prieta) with different position of water tank. This analysis is performed by using SAP2000 software.

A. Material properties

Parameter	Details
Number of storied	G+5)
Concrete grade	M25
Steel grade	Fe 415
Density of concrete	25 Kn/m3
Depth of foundation	1.5 m
Height of each storey	3m
Plan dimensions	28.58 x 21.60 meter
Beam size	0.23 m x 0.5 m
Column size	0.3 m x 0.6 m
Thickness of floor slab	125 mm
Thickness of lift wall	300 mm
Live load of floors	2kn/sq.m.
Finish load on floors	1.5 kn/sq.m.
Wall load	7.5 kn/m
Height of column on which water tank rest	2 m
Water tank volume	48000 litres

B. Optimization

For effectiveness of the TMD proper tuning of the characteristics of TMD to that of the structure is essential. In the present work the level of water in the tank is optimized and the objective function is to reduce the peak structural response subjected to seismic excitation by varying the position of the water tank on the roof of the structure. For optimization the water level is varied from empty tank, half filled tank and fully filled tank.

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C. Time History Records Summery

Table I Time History Data

Record	Station/ Year	Magnitude	PGA(g)
Imperial Valley	El centro 1940	6.9	0.32
Kobe (KI)	Kobe 1995	6.9	0.82
Loma Prieta (LI)	Gilory 1989	7.0	0.55

D. Modeling

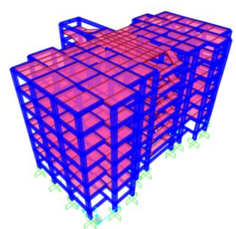

Fig.1 Model of building without water tank

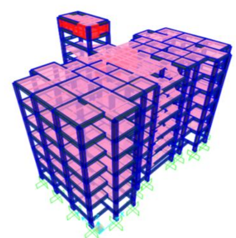

Fig.2 Model of building with water tank at centre top position

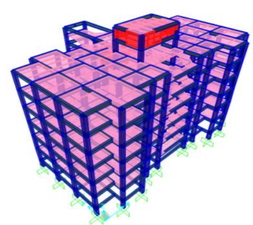

Fig.3 Model of building with water tank at center middle position

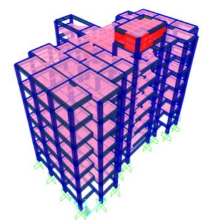

Fig.4 Model of building with water tank at centre bottom position

III. RESULTS

TableII

maximum base shear for various earthquake data with different condition of water tank

Sr. No.	Model name	Base Shear KN		
		El Centro	Kobe	Loma Prieta
1	No Water tank	1484.90	1118.16	1110.40
2	Centre Top Empty tank	1533.89	1306.17	1106.00
3	Centre Middle Empty tank	1474.02	1146.93	1115.55
4	Centre Bottom Empty tank	1458.14	1161.25	1107.33
5	Centre Top Half tank	1589.59	1339.74	1088.57
6	Centre Middle Half tank	1463.73	1175.61	1116.17
7	Centre Bottom Half tank	1440.02	1195.18	1101.06
8	Centre Top Full tank	1586.86	1304.92	1083.79
9	Centre Middle Full tank	1446.05	1212.12	1116.15
10	Centre Bottom Full tank	1419.29	1225.37	1096.22

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Table III

Max. Displacement for various earthquake data with different condition of water tank

Sr. No.	Model Name	Max Displacement mm		
		El Centro	Kobe	Loma Prieta
1	No Water tank	10.43	6.29	6.29
2	Centre Top Empty tank	12.45	7.49	6.72
3	Centre Middle Empty tank	10.34	6.26	6.15
4	Centre Bottom Empty tank	10.34	6.15	6.22
5	Centre Top Half tank	13.09	8.21	6.58
6	Centre Middle Half tank	10.26	6.22	6.02
7	Centre Bottom Half tank	10.25	6.29	6.16
8	Centre Top Full tank	12.91	9.78	5.98
9	Centre Middle Full tank	10.11	6.31	5.86
10	Centre Bottom Full tank	10.14	6.50	6.09

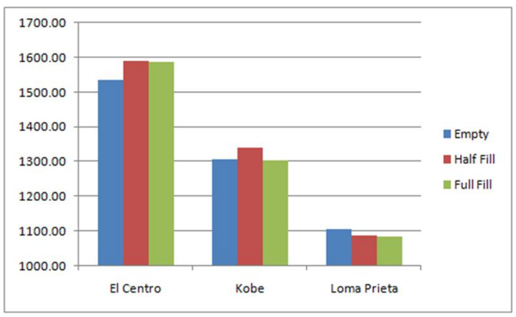

Fig.5 Base shear for center top position for different fill condition

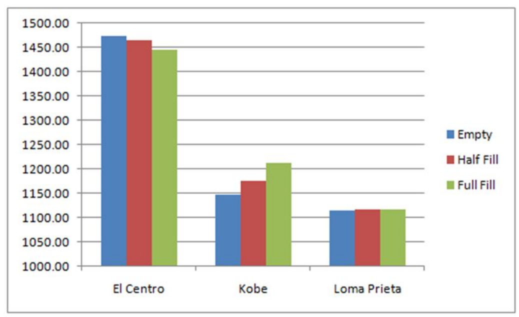

Fig.6 Base shear for center middle position for different fill condition

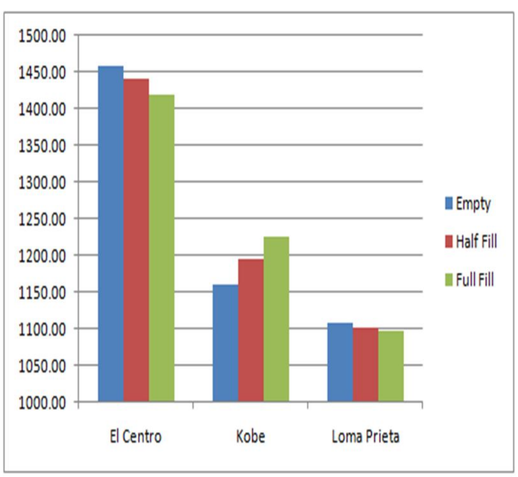

Fig.7 Base shear for center bottom position for different fill condition

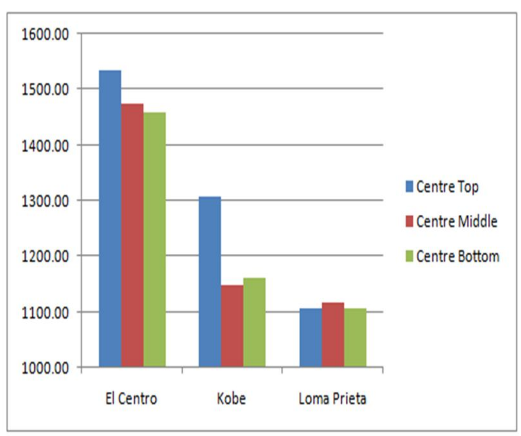

Fig.8
Base shear for empty water tank for different position of water tank

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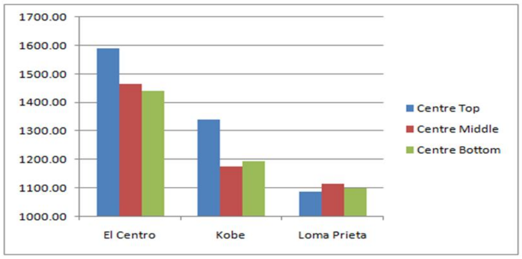

Fig.9 Base shear for half fill water condition for different position of water tank

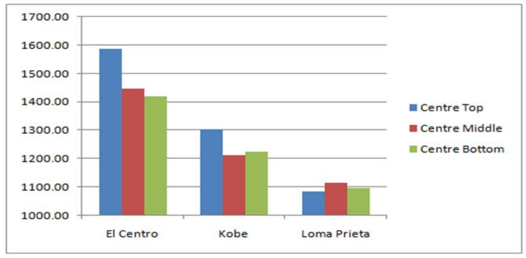

Fig.10 Base shear for full filled water condition for different position of water tank

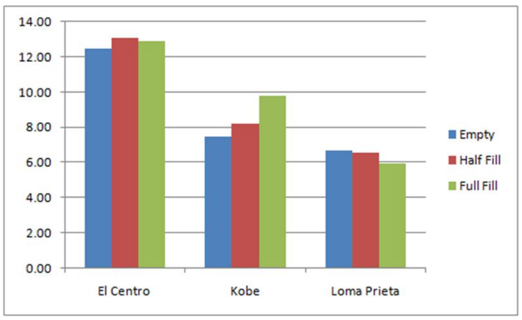

Fig.10 Maximum displacement for center top position of water tank for different filling condition water tank

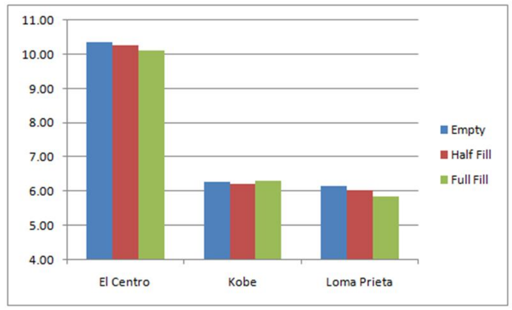

Fig.11 Maximum displacement for center middle position of water tank for different filling condition water tank

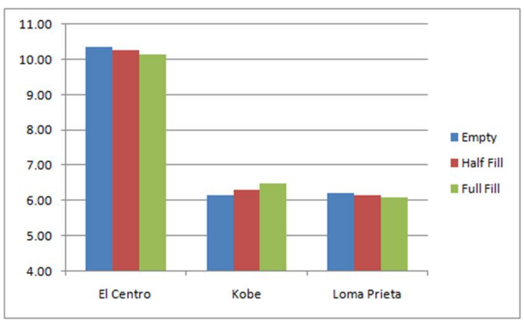

Fig.11 Maximum displacement for center bottom position of water tank for different filling condition water tank

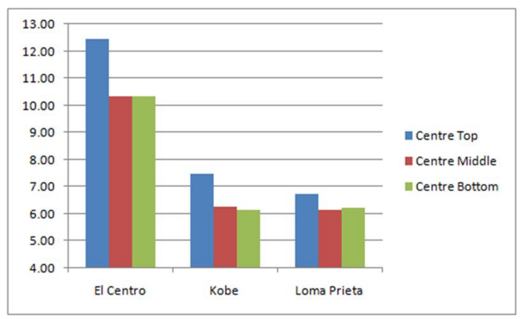

Fig.12 Maximum displacement for empty water tank for different position of water tank

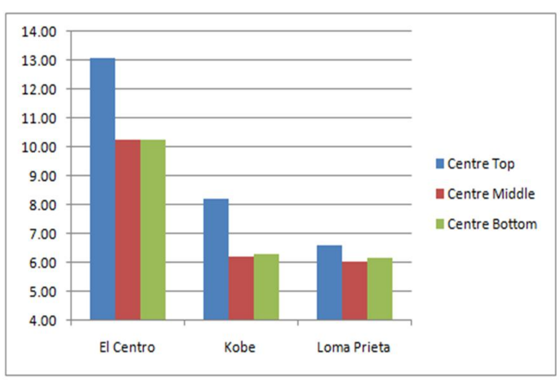

Fig.12 Maximum displacement for half filled water tank for different position of water tank

IV. DISCUSSION

A. Base Shear

1) *EL Centro Earthquake Data:* From Table II the maximum reduction is found when water tank is placed at centre bottom position and with full of water level. The reductions in base shear by 4.41% and 2.61% when the location of water tank is at centre bottom and centre middle respectively.
2) *Kobe Earthquake Data:* From Table II the maximum reduction is found when water tank is placed at centre bottom position and with full of water level. The reduction in base shear is by 4.41% and 2.61% when the location of water tank is at centre bottom and centre middle position respectively.
3) *Loma Prieta Earthquake Data:* From Table II the maximum reduction is found when water tank is placed at centre bottom position and with full of water level. The reduction in base shear by 1.27% when the water tank is placed at centre bottom position.

B. Roof Displacements

1) *EL Centro Earthquake Data:* From Table III the maximum reduction is found when water tank is placed at centre middle position and with full of water level. The reduction in roof displacement is by 3.06 % and 2.78% when the location of water tank is centre middle and centre bottom respectively.
2) *Kobe Earthquake Data:* From Table III the maximum reduction is found when water tank is placed at centre bottom position and with empty water level. The reduction in roof displacement is by 2.22 % when the location of water tank is centre bottom.
3) *Loma Prieta Earthquake Data:* From Table III the maximum reduction is found when water tank is placed at centre middle position and with full of water level. The reduction in roof displacement is by 6.83 % and 3.17% when the location of water tank is centre middle and centre bottom.

V. CONCLUSIONS

The feasibility of implementing water tanks as passive TMD and the optimum level of water was investigated analytically and the following conclusions can be drawn from the study.

A. It is seen that water tank can be act as passive TMD to control the vibrations of the structure subjected to earthquake loading.

B. The tuning can be done by combining the effect of water, tank and staging as the model with water tank shows good response reduction for most of the earthquake data taken for study.

C. Centre top position of water tank shows adverse effect for reduction of structures response to earthquake load, so water tank should not be provided at centre top position.

D. Centre middle and centre bottom position of water tank considerably reduces the responses of structure to earthquake loading.

E. Structure shows minimum response to earthquake loading when the water level in the tank is half filled and fully filled. Hence water level in the tank is maintained between half and full filled; it can reduce the peak responses of the structure to seismic forces.

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REFERENCES

[1] Bauer H.F., “oscillations of immiscible liquids in a rectangular container. A new damper for excited structures.” Journal of sound and vibration, 93(1), (1984), pp.117-133.

[2] Modi V.J., and Welt F., ‘damping of wind induced oscillations through liquid sloshing.”Journal of Wind engineering and industrial Aerodynamics, 30, (1988), pp.85-94.

[3] Fujji K.,Tamura Y., Sato T., Wakahara T., “Wind-induced vibration of tower and practical applications of tuned sloshing Damper.” Journal of wind Engineering and industrial Aerodynamics, 33, (1990), pp.263-272.

[4] Kareem Ahsan, “Reduction of Wind Induced Motion Utilizing a Tuned Sloshing Damper.” Journal of Wind Engineering and Industrial Aerodynamics, 36, (1990), pp.725-737.

[5] Sun L.M., Fujino Y., Pacheco B.M., and Chaiseri P., “Modeling of Tuned Liquid Damper (TLD).” Journal of Wind Engineering and Industrial Aerodynamics, 41-44, (1992), pp. 1883-1894.

[6] Wakahara T., Ohyama T., and Fujji K., “Suppression of Wind-induced Vibration of a Tall Building using Tuned Liquid Damper.” Journal of Wind Engineering and Industrial Aerodynamics, 41-44, (1992), pp. 1895-1906.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

[7] Yozo Fujino, Limin Sun, Benito M.Pacheco and Piyawat Chaiseri, "Tuned Liquid Damper for suppressing horizontal motion of structures" Journal of Engineering Mechanics 1992,118(10), PP 2017-2030.

[8] Tamura Y., Fujji K., Ohtsuki T., Wakahara T., and Kohsaka R., "Effectiveness of tuned liquid dampers under wind excitation, "Engineering Structures, Vol. 17, No.9,(1995), pp.609-621.

[9] Banerji P., Murudi M, Shah A.H. & Popplewell N., "Tuned liquid dampers for controlling earthquake response of structures", Earthquake Engg. Struct. Dyn, 29, (2000), pp.587-602.

[10] T.T.Soong, B.F.Spencer and JR., "Active, Semi-Active and Hybrid control structures" 12th World Conference on Earthquake Engineering 2000.

[11] Banerji Pradipta," Tuned Liquid Dampers For Control Of Earthquake Response" 13th World Conference on Earthquake Engineering,Vancouver,B.C. Canada Augest 1-6,2004 Paper no.1666.

[12] Tait M.J., Isyumov N. and Damatty A.A.El., "Effectiveness of a 2D TLD and Its Numerical Modeling", Journal of Structural Engineering, Vol. 133, No. 2,(2007), pp.251-263.

[13] Samanta and P.Banerji, "Structural control using Modified Tuned Liquid Dampers", 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing,China.

[14] Tait M.J., Isyumov N. and Damatty A.A.El., "Perfomance of Tuned Liquid Dampers", Journal of Engineering Mechanics 2008, 134(5): pp.417-427.

[15] G. Hemalatha and K.P. Jaya, "water tank as a passive TMD for seismically excited structures", ASIAN JOURNAL OF CIVIL ENGINEERING (BUILDING AND HOUSING) VOL. 9, NO. 4 (2008) pp.349-366

[16] Nishant Kishore Rai,G.R.Reddy,S.Ramanujam, V.Venkatraj and P.Agrawal, "Seismic response control system for structures", Defense Science Journal,Vol.59,No.3,May 2009,pp.239-251.

[17] Meziane Idir and Xiaohua Ding, "Fundamental frequency of water sloshing waves in a sloped bottom tank as tuned liquid damper", structures congress 2009 ASCE.

[18] Pradipta Banerji, Avik Samanta, "Earthquake vibration control of structures using hybrid mass liquid damper", Engineering Structures 33(2011) 1291-1301.

[19] S.Crowley, R.Porter, "Optimal Screen arrangement for a tuned liquid damper ",school of mathematics, University of Bristol,Bristol,BS8 1TW,UK, November 11,2011.

[20] Soumi Bhattacharya , Aparna(Dey)Ghosh," Seismic Vibration Control Of Elevated Water Tank By Multiple Tuned Liquid Dampers" , ISET Goldan Jubilee Symposium, Indian Society Of Earthquake Technology Department of Earthquake Engineering Building, IIT Roorkee, Rooekee October 20-21,2012 Paper no.E009.

[21] Emili Bhattacharjee, Lipika Halder and Richi Prasad Sharma, "An experimental study on tuned liquid damper for mitigation of structural response", Bhattacharjee et al.International Journal of Advance structural engineering 2013, 5:3.

[22] Jitaditya M. , Harsha Nimmala,Shameel Abdulla, Reza Tafreshi, "Tuned Liquid Damper", proceedings of the 3rd International Conference on Mechanical Engineering and Mechanics Prague,Czech Republic, Augest14-15,2014 Paper no.68.

[23] Bhosale Dattatray, G.R.Patil, Sachin Maskar, "Use of Overhead Water Tank to Reduce Peak Response of the Structure", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-4 Issue-2, July2014.

[24] Namrata Yannawar, G.R.Patil, "Response Behavior of a Three Storied Framed Structure With Tuned Liquid Damper" International Journal Of Innovative Research in Science,Engineering and Technology vol.3, Issue7, July2014: pp 14931-14936.

[25] D.Rupesh Kumar, Fahimeh Hoseinzadeh, " A study on effect of water tanks modeled as Tuned Mass Dampers on Dynamic properties of structures", International Journal of Research in Engineering and Technology volume:04 special issue:13,ICISE-2015, Dec.-2015. Pp 484-499.

[26] Jans Velicko,Liga Gaile, " Overview of tuned liquid dampers and possible ways of oscillation damping properties improvement", Environment Technology, Resources,Rezekne,Lativa Proceeding of the 10th International Scientific and Practical Conference, Volume I, pp 233-238.

[27] J.Sandya Rani, P.Srinivas Reddy, M.Koti Reddy, "Time history analysis of building structure with water tank as Passive Tuned Mass Damper", International Journal of Research in Engineering and Technology, Volume: 04 Special Issue: 01 NCRTCE-2014 Feb-2015.

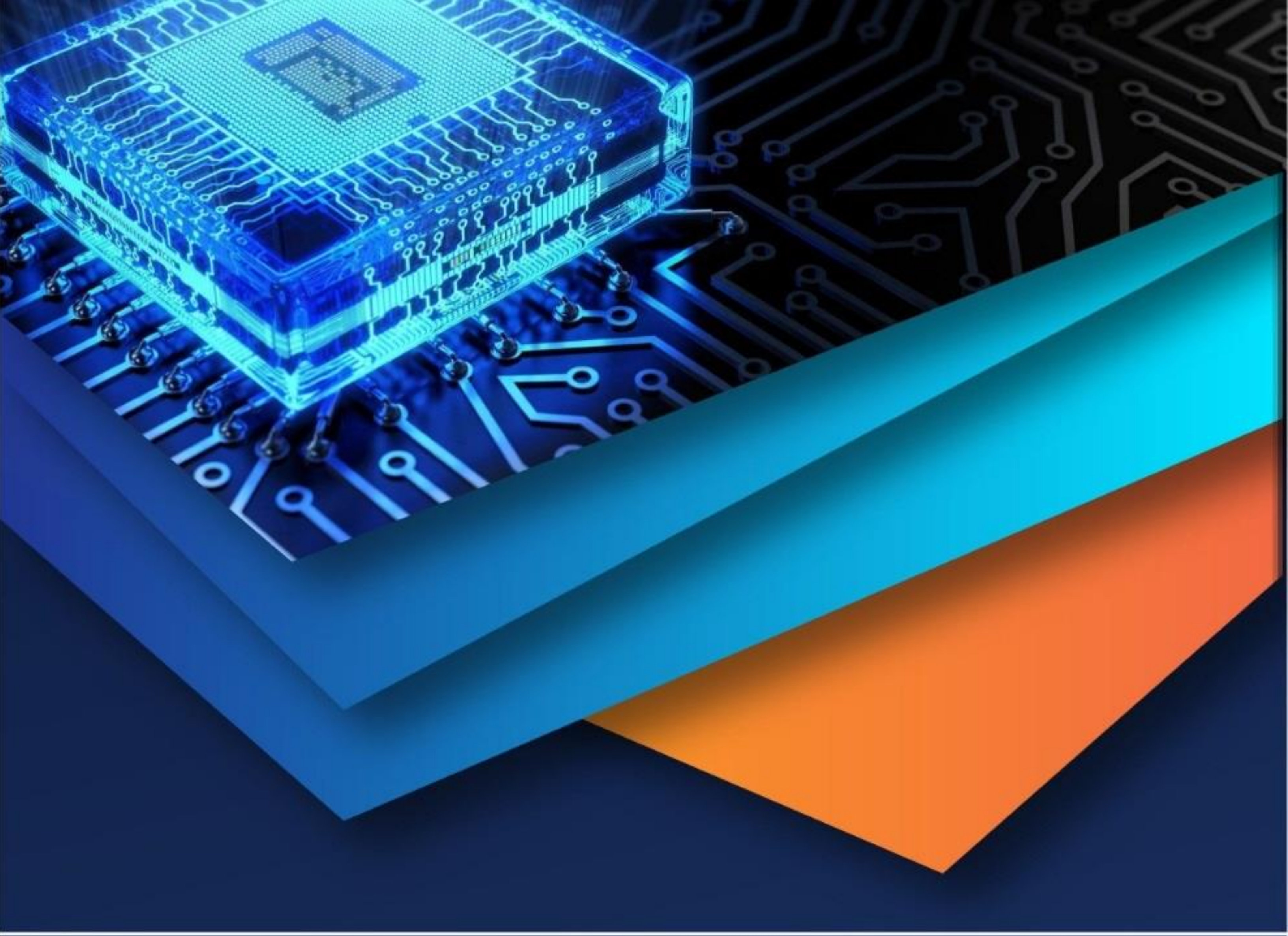
[28] Roshani V. Kartha, Ritzy R., "Tuned Liquid Damper to Control Earthquake Response in a Multi-Storied Building Frame", Roshni. V. Kartha Int. Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 5, Issue 8, (Part - 4) August 2015, pp.49-56.

[29] Roshani V. Kartha, Ritzy R., "Parametric Studies on Tuned Liquid Damper by Horizontal Shake Table Experiments", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 5 Ver. V (Sep. - Oct. 2015), PP 41-47.

[30] Rutuja S. Meshram, S.N.Khante, " Effectiveness of Water Tank as Passive TMD for RCC Building" International Journal of Engineering Research Volume No.5 Issue: special 3, pp:731-736.

[31] Muhammad Jamil Ahmad , Qaiser uz Zaman Khan and Syed Muhammad Ali, " Use of Water Tank as Tuned Liquid Damper(TLD) for Reinforced Concrete (RC) Structures", Arab Journal of Science and Engineering(2016)41:4953-4965.

[32] Supradip Saha,Rama Debbarma, " An experimental study on response control of structures using multiple tuned liquid dampers under dynamic loading" International Journal of Advance structural engineering DOI 10.1007/s40091-016-0146-5.



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