iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** V **Month of publication:** May 2017

DOI:

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Vibration Control of Unsymmetrical RC Building Using Tuned Mass Damper

Anjus Krishna P.[1], Aswathy P[2]
[1]PG Student, Department of Civil Engineering, APJ Abdul Kalam Technological University
[2] Assistant Professor of Department, Department of Civil Engineering, Thejus Engineering College, Kerala

Abstract*: Vibrations are one of many environmental factors that act on building and potentially reduce their lifetime. Current trends in construction demand taller and lighter structures, which are also flexible and having quite low damping value. Tuned mass dampers is a passive energy dissipating device which is comprised of a mass, springs and damper attached to the structure and are used for vibration control of structures when subjected to earthquake excitations. The aim of this project is to analysis the vibration of unsymmetrical structural frames subjected to seismic excitation and a general understanding of the structural behavior through SAP software. An additional RC top floor of 2% and 3% mass of building is installed and utilized as a large scale mass damper. L shaper unsymmetrical buildings was being analysed here under three different past earthquakes. Nonlinear time history analysis is carried out for buildings. The result obtained shows more reductions in base shear, net displacement, storey drift and increase in the time period of the building when 3% mass of building is provided as TMD.
Keywords*: TMD, Earthquake, Non Linear Dynamic Analysis, Time History Analysis.

I. INTRODUCTION

A tuned mass damper, also known as a harmonic absorber, is a passive energy dissipating system which consist of a mass, and spring that is attached to a structure in order to reduce the dynamic response of the structure. Their application can prevent discomfort, damage, or outright structural failure. The idea behind a tuned mass damper is that if a multiple-degree-of-freedom system has a smaller mass attached to it, and the parameters of the smaller mass are tuned precisely, then the oscillation of the system can be reduced by the smaller mass. If a soft storey made up of concrete and its columns, beams, and slab sizes which will be smaller than columns, beams, and slab sizes other stories of the building will be easier to implement as TMD. The height and member sizes of soft storey will be fixed based on the principle of TMD i.e. the natural frequency of TMD (soft storey) should have natural frequency same as that of main building.

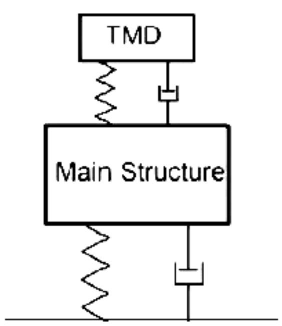


Fig.1 Schematic diagram of a tune mass damper

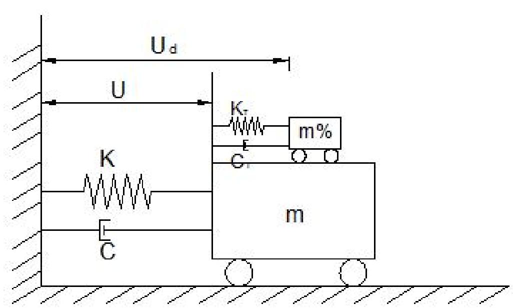


Fig.2 TMD parameters

Fig.1 shows a schematic diagram of tuned mass damper attached at the top of main mass. If a force is applied through the base, the main building starts moving and a corresponding displacement will occur to the structure. If a small mass is placed on the top of building attached to the main building, the small mass also moves with respect to main building. In such situation we can identify how motion of small mass will affect the response of main building. Fig.2 shows the parameters of TMD.

Where,

m = Mass of building
m% = Mass of tuned mass damper

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

K = Stiffness of building
KT = Stiffness of tuned mass damper
C = Damper of building
CT = Damper of tuned mass damper
U = Displacement of building
Ud = Displacement of tuned mass damper

II. ANALYSIS SOFTWARE SAP 2000

SAP 2000 is finite element software which performs the static or dynamic, linear or Non-linear analysis of structural systems. It offers many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects. The SAP building is idealized as an assemblage of area, line and point objects. Those objects are used to represent members like wall, floor, column, beam, and brace and link/spring. The basic frame geometry is defined with reference to a simple three dimensional grid system. With relatively simple modelling techniques, very complex framing situations may be considered. The program can automatically generate seismic load patterns to meet the requirements of various building codes. Types of output include reactions and member forces, mode shapes and participation factors, static and dynamic story displacements and story shears, inter-story drifts and joint displacements, tie history traces, and more. In this thesis use of the following elements is coming for modelling of building.

A. Frame Element

The Frame element is a very powerful element that can be used to model beams, columns, braces, and trusses in planar and three-dimensional structures. Nonlinear material behaviour is available through the use of Frame Hinges. The Frame element uses a general, three-dimensional, beam-column formulation which includes the effects of biaxial bending, torsion, axial deformation, and biaxial shear deformations.

B. Shell Element

The Shell element is a type of area object that is used to model membrane, plate, and shell behaviour in planar and three-dimensional structures. The shell material may be homogeneous or layered through the thickness. Material nonlinearity can be considered when using the layered shell. The Shell element is a three- or four-node formulation that combines membrane and plate-bending behaviour. The four-joint element does not have to be planar.

III. MODEL DETAILS

G+7 RC L shaped buildings take for the investigation in this paper. Modeling is done using SAP 2000 software. Non-linear time history analysis carried out by considering El-Cento, Landers and Loma Prieta earthquakes. Comparison between without and with TMD having 2% and 3% mass of building is to be carried out.

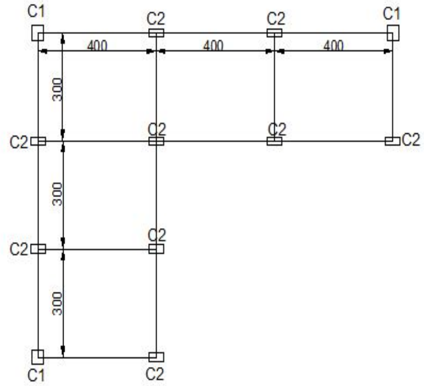


Fig. 3 Beam Column Layout of shaped building

The details such as grade of concrete, grade of steel, beam sizes, columns sizes and all other parameters taken for RC building is

Volume 5 Issue V, May 2017
ISSN: 2321-9653

tabulated here.

TABLE 1
Geometry property of building

Floor to floor height	3m
Plinth height above GL	1m
Slab thickness	100mm
Column I	400 x 400 mm
Column II	230 x 500 mm
Beam	230 x 500 mm
Grid Spacing X – Direction	3 m
Grid Spacing Y - Direction	4 m
Grade of concrete	M20
Grade of steel	Fe 415

Live load taken for all building models is 4 kN/m^2, floor finish is taken as 1 kN/m^{2}and live load on all roof is taken as 1.5 kN/m^2. For wall having thickness 23cm, wall load is taken as 12.67 kN/m.

Modelling and analysis steps:

A. Setting the Problem Dimension
B. Grid Spacing and Location of Joints
C. Define Material Property
D. Define Frame Elements
E. Define Slab Elements
F. Draw Frame and Slab Elements
G. Defining the Load Patterns
H. Define the Time history Function
I. Defining the Load Cases
J. Displaying the Result
K. Analysis of the Structure

Rescale Using Checked Records

	Result ID	Spectral Ordinate	Record Seq. #	MSE	Scale Factor	Tp(s)	D5-75(s)	D5-95(s)	Arias Intensity (m/s)	Event	Year	Station	Mag
view	1	SRSS	6	-	1.0	-	17.7	24.2	1.6	Imperial Valley-02	1940	El Centro Array #9	6.95
view	2	SRSS	766	-	1.0	1.729	2.7	11.0	1.2	Loma Prieta	1989	Gilroy Array #2	6.93
view	3	SRSS	864	-	1.0	-	21.7	27.1	2.3	Landers	1992	Joshua Tree	7.28

Fig. 4 Selected earthquakes data from the PEER website

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The 3-D view of unsymmetrical building modelled in SAP 2000 is shown in fig.5.

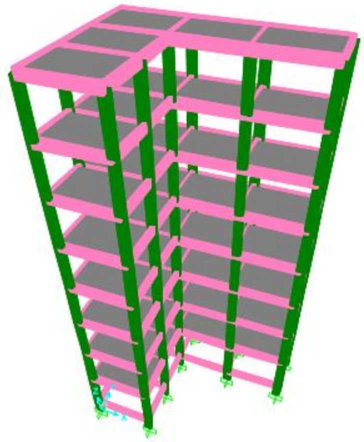


Fig. 5 3-D Model of irregular building without TMD

TABLE 2
Modal period in Sec

Output Case	L shaped building
MODE 1	2.00691
MODE 2	1.45757
MODE 3	1.28134
MODE 4	0.63645
Mode 5	0.46924

Table 2 shows the time period of different modes of L shaped RC building. From the results we can see the first mode is greater compared to all other modes. So the fundamental time period is taken as first mode time period. Total mass of building which can be calculated or can collect from the software itself is 10265.184kN

IV. DESIGN OF TUNED MASS DAMPER

The fundamental principal of TMD is that, the fundamental frequency of tuned mass damper will be equal to the fundamental frequency of building. From modal analysis, we will get the fundamental time period (T) of building. Total mass of building is already defined or can collect from the software itself.

Therefore the circular frequency of building, ω can be calculated from the equation:

$$\omega = \frac{2\pi}{T}$$

Stiffness of building (k) can be determined from the formulae:

$$\omega = \sqrt{\frac{k}{m}}$$

where,

m= mass of building

Mass Ratio of building (γ) is taken as 2% and 3%. As we know

$$\text{Mass ratio, } \gamma = \frac{md\%}{M}$$

We can find the mass of tuned mass damper from the above equation.

Damping in Building for RC building (β) should be taken as 5%.

Amplitude of First Mode (φ) can be collected from analysis.

Therefore, Tuning Ratio(f_opt) can be obtained from the formulae:

$$f_{opt} = \frac{1}{1+\mu\varphi}\left(1-\beta\sqrt{\frac{\mu\varphi}{1+\mu\varphi}}\right)$$

Tuning Ratio is the ratio of circular frequency of tuned mass damper to the circular frequency of building.

$$f_{opt} = \frac{\omega d}{\omega}$$

Thus we can found circular frequency of damper.

So the stiffness of damper can be obtained from the formulae

$$K_{opt} = m\omega d^2$$

As we know the number of columns it will help to find the stiffness of one column, and this will leads to find moment of inertia of the section from the equation:

$$k_{opt} = \frac{12EI}{h^3} n$$

Thus we can fix the size of column by:

$$I = \frac{bd^3}{12}$$

We can fix the dimensions of slab and beam from the remaining mass of damper.

TABLE 3

Geometric parameters of TMD

Building Model	L shaped building	
TMD Parameters	2% TMD	3% TMD
Total Mass of TMD (kN)	205.303	308
Height of Column (m)	3	3
Column depth (mm)	63.44	70.19
Column width (mm)	79.3	87.73
Thickness of Slab (mm)	100	175
Depth of Beam (mm)	200	200
Width of Beam (mm)	181.34	142.5

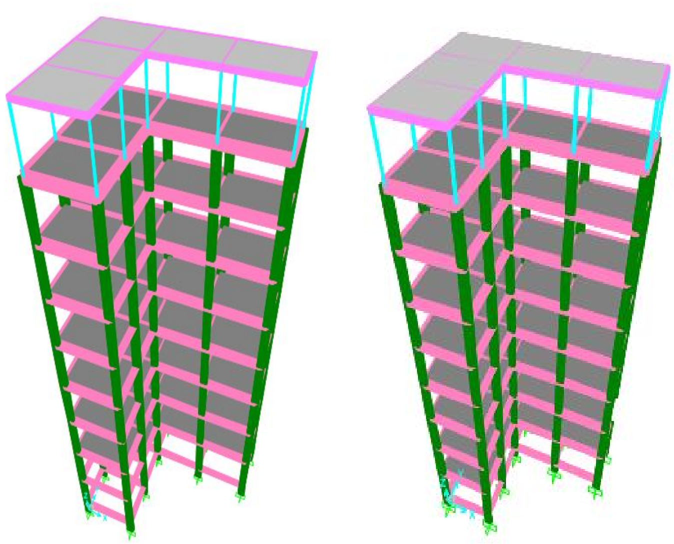


Fig. 6 3-D Model of irregular building with 2%mass TMD, and 3%mass TMD respectively

Volume 5 Issue V, May 2017
ISSN: 2321-9653

V. RESULTS AND DISCUSSION

A. Modal period

Table 4 shows the fundamental time period of building under three different conditions.

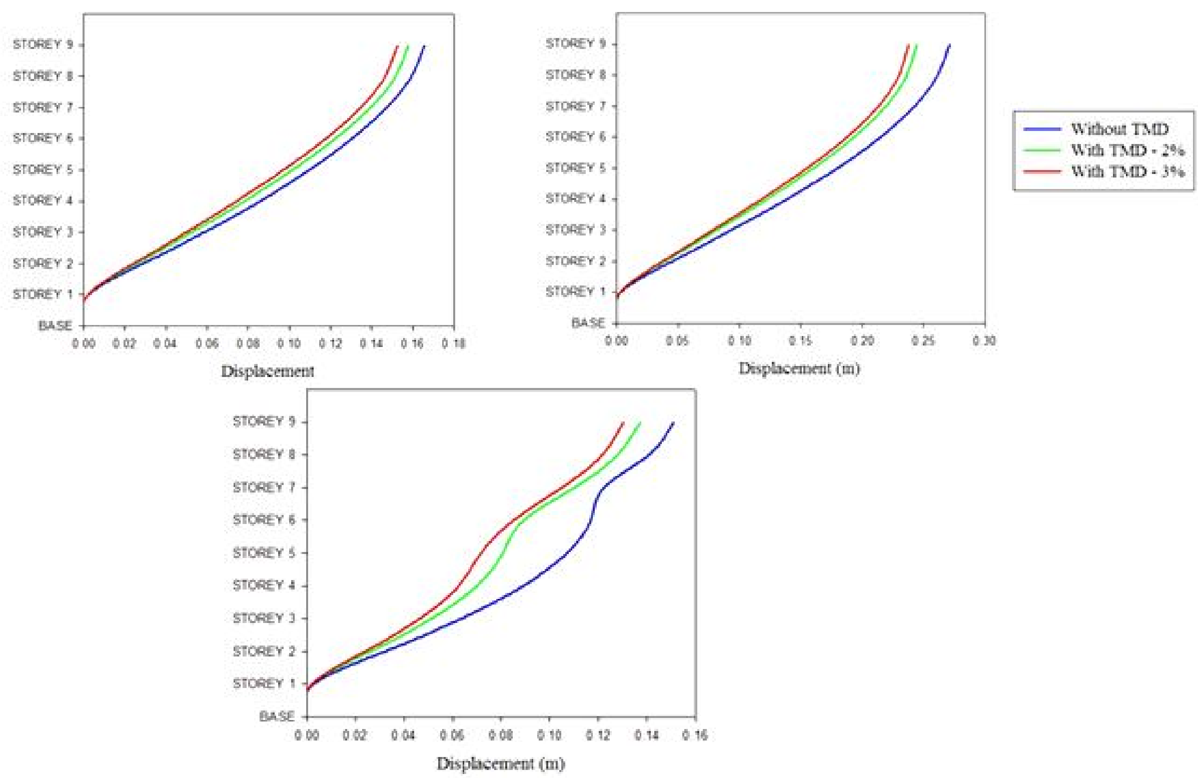
TABLE 4
Modal period of building models

L shaped building	Modal period
Without TMD	2.00691
2% TMD	2.14224
3% TMD	2.31453

Mode period of building with 3% TMD is comparatively more.

B. Net storey displacement

Fig 7 shows the variation in the deformation of building without and with TMD under three different earthquakes. From the analysis it can see that buildings having TMD which is 3%mass of building is much better than 2%. Large variation is occurred in unsymmetrical L shaped building



.

Fig. 7 Storey Vs Displacement of each storey of building under Elcentro, Landers, Loma Prieta earthquakes

TABLE 5
Reduction in displacement of building models in %

Earthquakes	Average Displacement Reduction in %	
	2% TMD	3% TMD
Imperial valley	5.38	7.14
Landers	6.69	8.63
Loma Prieta	4.67	7.48

C. Storey drift

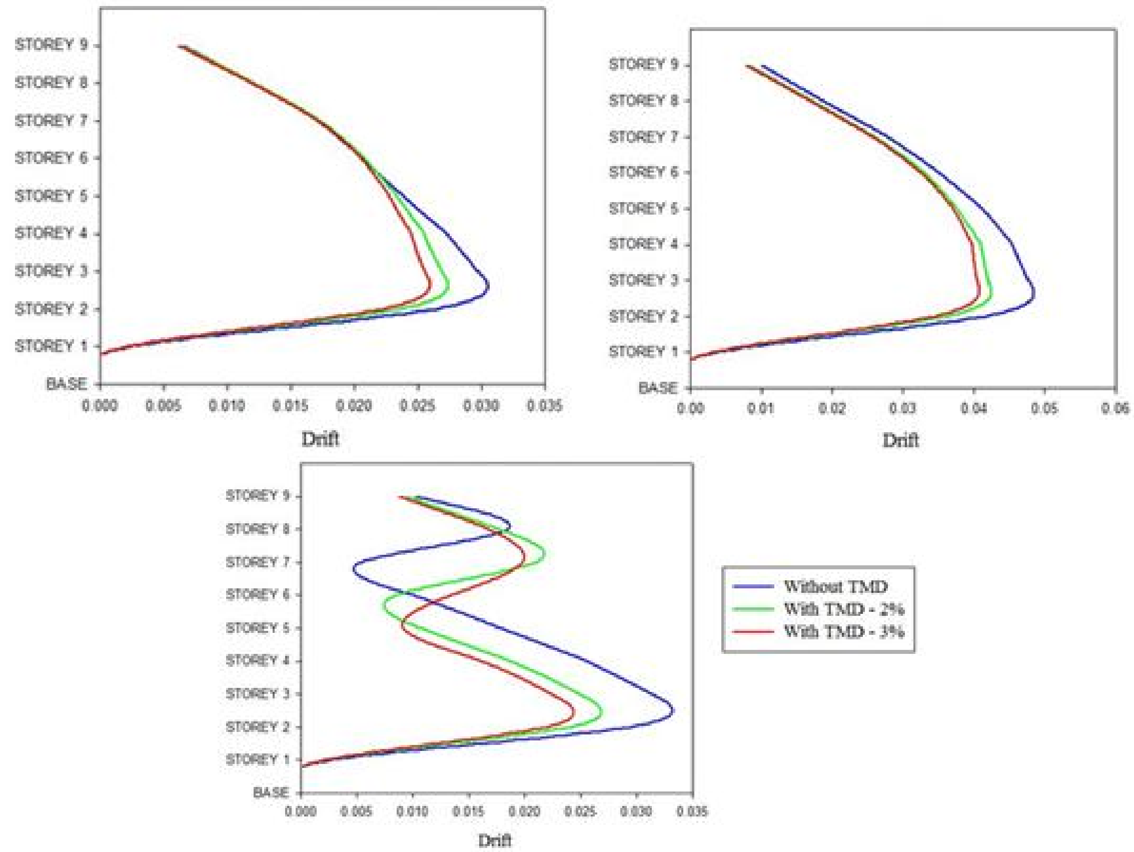


Fig 8 shows the variation in the drift of each storey of same building under three different earthquakes.

TABLE 6
Reduction in drift of building models in %

Earthquakes	Average Drift Reduction in %	
	2% TMD	3% TMD
Imperial valley	1.2	2.07
Landers	1.72	3.2
Loma Prieta	1.6	1.7

Although the buildings with TMD behave much better than building without TMD, the results show less variation in results between 2% TMD. But 3% TMD building is much better compared to building without TMD. From the analysis it can be see that mid stories is having much drift in building without TMD and this can be reduced by this TMD up to 20% and can make the building more stable.

D. Base shear

The bar chart shown below presence the base shear of same building without and with TMD under different earthquakes. From all bar charts we can analysis that by providing Tuned Mass Damper at top of building, we can reduce the base shear of building up to 20 to 25%. And also there is having large variation in base shear between with and without TMD. Among that 2% and 3% TMD, TMD of 3% mass is much better compared to TMD with 2% mass of building.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

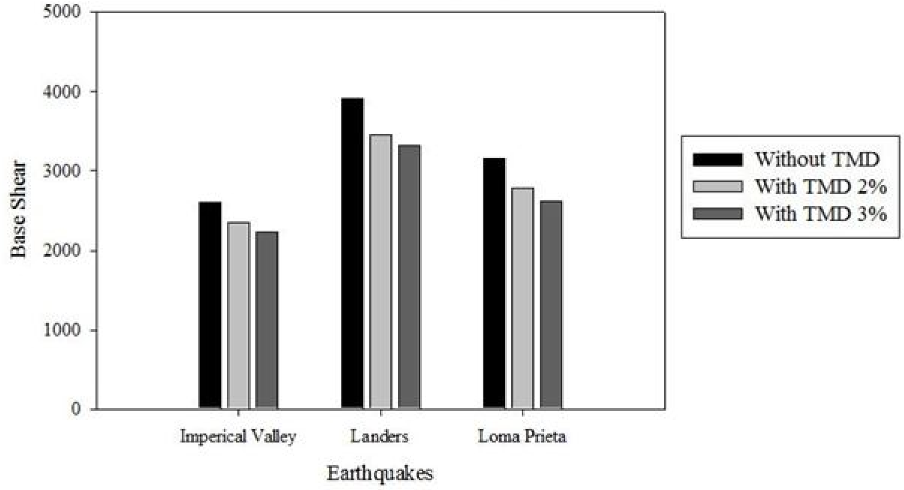


Fig. 9 Base shear of L building under earthquakes

VI. CONCLUSIONS

A. From the time history analysis performed in building it can be concluded that, the provision of TMD as top irregular unsymmetrical building is the easiest and economical method for vibration controle in order to reduce structural response due to lateral excitations.

B. The response of building under earthquakes depends on the amount of percentage TMD provided.

C. Response reduction is found more in TMD with 3% modal mass than 2% modal mass, though both the results gives greater variation compared to building without TMD.

D. Displacement and base shear reduction is found to be 10 to 20%.

REFERENCES

[1] Thakur V.M., Pachpor P.D. "Seismic Analysis of Multistoried Building with TMD" International Journal of Engineering Research and Applications ISSN: 2248-9622, Vol. 2, Issue 1, Jan-Feb. 2012, pp. 319-326

[2] A. Kaveh, S. Mohammadi, O. Khadem hosseini, A. Keyhani and V.R. Kalatjari "Optimum Parameters Of Tuned Mass Dampers For Seismic Applications Using Charged System Search", IJST, Transactions of Civil Engineering, Vol. 39 , No. C1, pp 21-40, 2015

[3] Alireza Heysami "Types of Dampers and their Seismic Performance During an Earthquake", Current World Environment Vol. 10(Special Issue 1), 1002-1015, 2015

[4] Chapter 4, Tuned Mass Damper Systems , onCh04v2.fm Page 222 Thursday, July 11, 2002

[5] Genda Chen, Jingning Wu Optimal Placement Of Multiple Tune Mass Dampers For Seismic Structures, J. Struct. Eng. 127:1054-1062, 2001.

[6] Haruna Ibrahim, Daha S. Aliyu, Hafizu Hamza "Vibration control of a frames structure using tuned mass damper", 2nd international conference on science, technology and management, University of Delhi(UD),Conference Centre,New Delhi (India)27 September 2015.

[7] IS 1893-1 (2002): Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings [CED 39: Earthquake Engineering]

[8] Johnson, Lawrence D. Reaveley ,Chris Pantelides Jerod G "A rooftop tuned mass damper frame", Earthquake Engng Struct. Dyn. 32:965–984, 2003(DOI: 10.1002/eqe.257).

[9] Kenny C. S. Kwok "Damping increase in building with tuned mass damper", J. Eng. Mech. 1984.110:1645-1649, 1984.

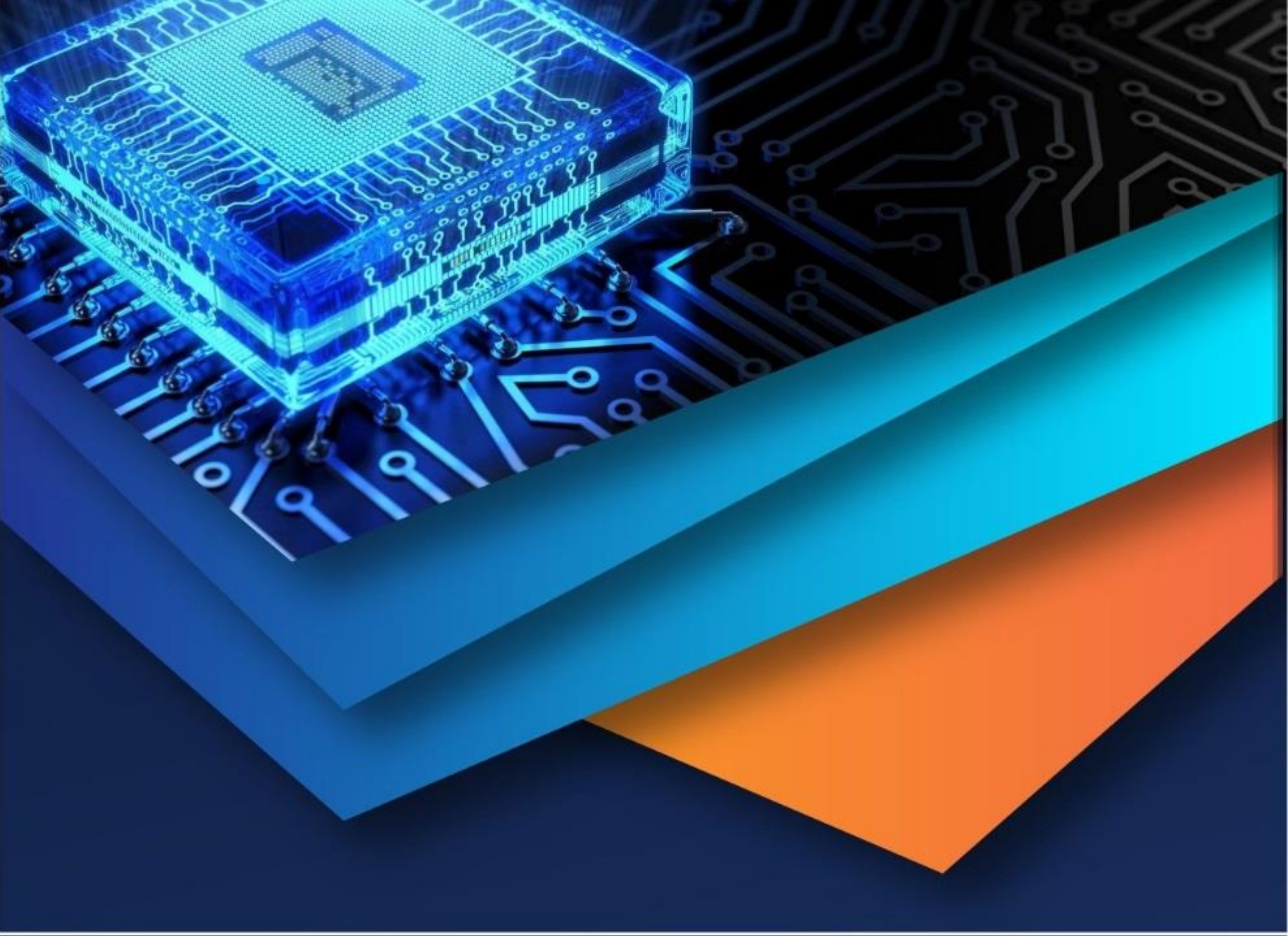
[10] Mr. Ashish A. Mohite, Prof. G.R. Patil. "Earthquake Analysis of Tall Building with Tuned Mass Damper", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN : 2278-1684, p-ISSN : 2320–334X PP 113-122, 2015

[11] O R Jaiswal "Simple tuned mass damper to control seismic response of elevated tanks", 13th World Conference on Earthquake Engineering Vancouver, B. C., Canada, August 1-6, 2004, Paper No. 2923.

[12] Prof. Amar shitole, Prof. D.T. Rahane "Study of Tuned Mass Dampers System as Vibration Controller in Multistoried buildings", International journal of advanced and innovative research ISSN:2278-7844; 281-284, 2012.

[13] Roberto Villaverde "A seismic Roof Isolation System: Feasibility Study with 13-Story Building", J. Struct. Eng.128:188-196, 2002.

[14] G.S. Balakrishna, Jini Jacob "Seismic analysis of building using two types of passive energy dissipation devices", International Conference On Innovations In Civil Engineering 8th and 9th of May 2014 ICIE-2014



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY