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A Comparative Study on Seismic Behaviour of Plan Irregular Buildings

Ravi Tej M J[1], Chidananda G[2]
[1]*Student, M. Tech. in Structural Engineering, Department of Civil Engineering, Bapuji Institute of Engineering and Technology, Davanagere-577004, Karnataka, India*
[2]*Professor, Department of Civil Engineering, Bapuji Institute of Engineering and Technology, Davanagere-577004, Karnataka, India*

Abstract: Asymmetrical plan irregularities occur when the horizontal layout of a building is non uniform or unsymmetrical in one or more axes. These irregularities may arise from variations in building shape, size, or configuration, leading to non-uniform distribution of mass, stiffness, or load paths throughout the structure.

Considering equivalent static analysis (ESA) and response spectrum analysis (RSA) as per IS 1893-Part 1 (2016) considering seismic zones III, structure with square shaped plan performs better than the other shaped models (viz. T, L, H and Plus shapes) with least values of storey displacement and storey drift ratio, and also with higher value of storey stiffness. Thus, square plan shaped structure is seismically more resistant than T, L, H and Plus shaped structures.

I. INTRODUCTION

Earthquake is a naturally occurring phenomenon which is caused due movement between the tectonic plates along a fault line in the earth's crust. Earthquake causes violent and abrupt shaking of the ground surface. The quantitative measure of size of an earthquake is represented in magnitude and is measured using Richter scale. IS 1893-Part -1 (2016) provides the guidelines for analysis structures for earthquake force. India has been classified into various zones viz. II, III, IV and V. Asymmetrical plan irregularities occur when the horizontal layout of a building is non uniform or unsymmetrical in one or more axes. These irregularities may arise from variations in building shape, size, or configuration, leading to non-uniform distribution of mass, stiffness, or load paths throughout the structure.

II. BUILDING DESCRIPTION

Table 1 Shows the parameters of the developed RCC models

Table 1: Parameters of the developed RCC models

Sl. No.	Parameter	Remarks
1	Building type	Commercial
2	Structure type	G+12
3	Total No. of stories	13
4	Total height of building from ground floor to terrace	42.9 m
5	Size of column	300x750 mm
6	Size of beam	300x600 mm
7	Thickness of wall	300 mm
8	Thickness of slab	150 mm

Sl. No.	Parameter	Remarks
9	Base storey height	1.5 m
10	Typical storey height	3.3 m
11	Parapet wall height	0.9 m
12	Grade of concrete	M35
13	Concrete Density	25 kN/m^3
14	Grade of Rebar	Fe500
15	Live loads on floors excluding terrace	4 kN/m^2
16	Live loads on terrace	1.5 kN/m^2
17	Floor finish on terrace	2.4 kN/m^2
18	Floor finish of each floor except terrace	1.5 kN/m^2
19	Soil Type	Medium
20	Seismic zone	III
21	Importance factor	1
22	Response factor value	3
23	Dead load calculation	As per IS 875-Part 1 (1987)
24	Live load calculation	As per IS 875-Part 2 (1987)
25	Earthquake load calculation	As per IS 1893-Part 1 (2016)
26	Load combinations	As per IS 1893-Part 1 (2016)

Table 2 shows the identity for the developed RCC models

Table 2 : Identity for the developed RCC models

Sl. No.	Model ID	Plan shapes
1	M-I	Square
2	M-II	T
3	M-III	L
4	M-IV	H
5	M-V	Plus

Figures from 1to 10 shows the plan and elevation of the developed models.

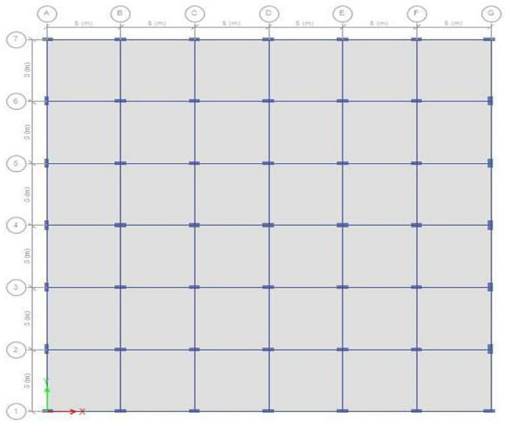

Fig. 1 : Plan of Square shaped model

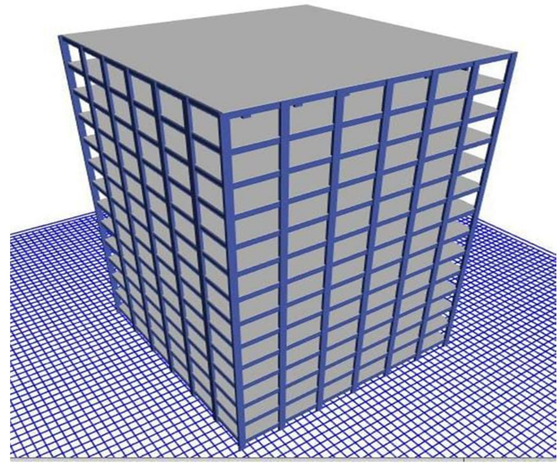

Fig. 2 : Elevation of Square shaped model

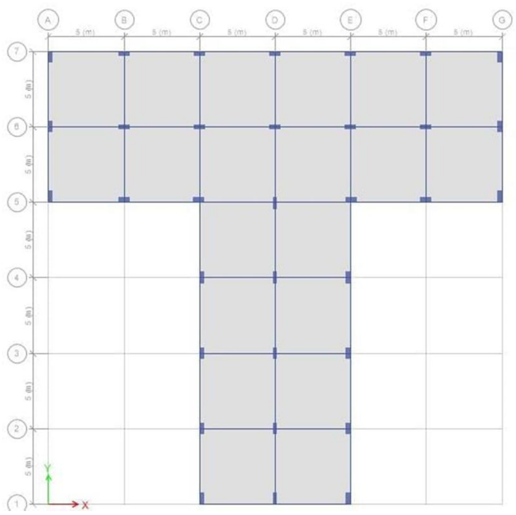

Fig. 3 : Plan of T shaped model

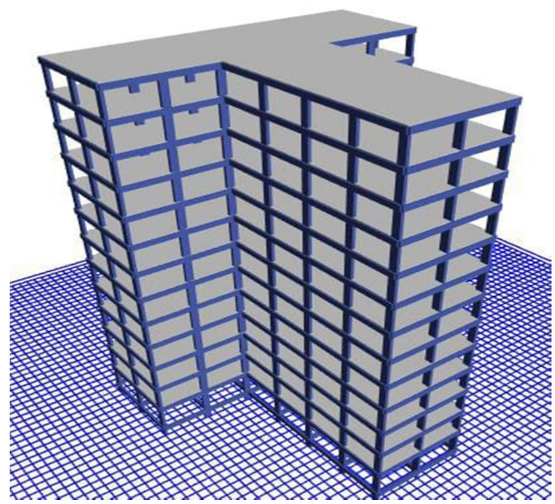

Fig. 4 : Elevation of T shaped model

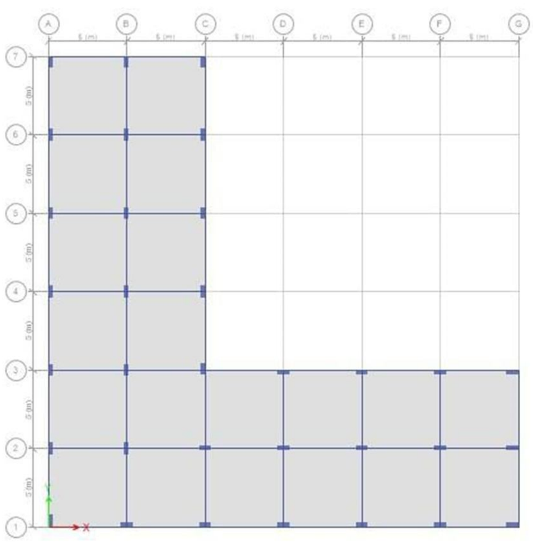

Fig. 5 : Plan of L shaped model

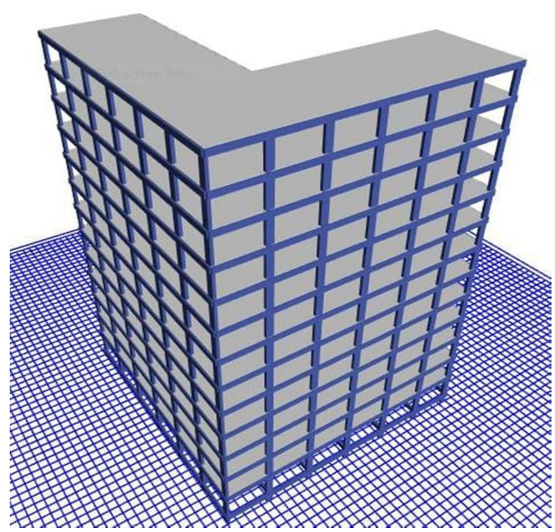

Fig. 6 : Elevation of L shaped model

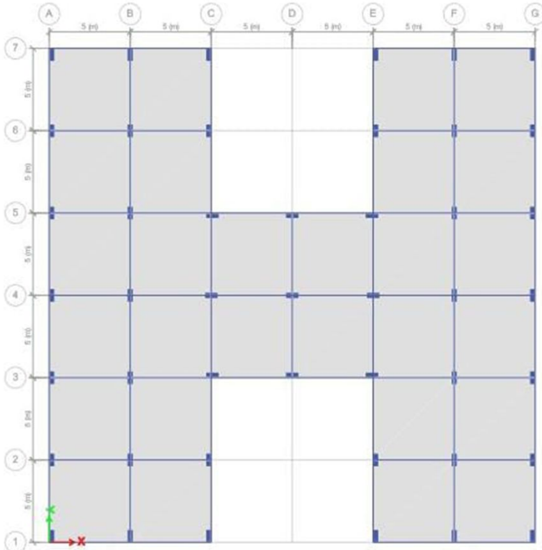

Fig. 7 : Plan of H shaped model

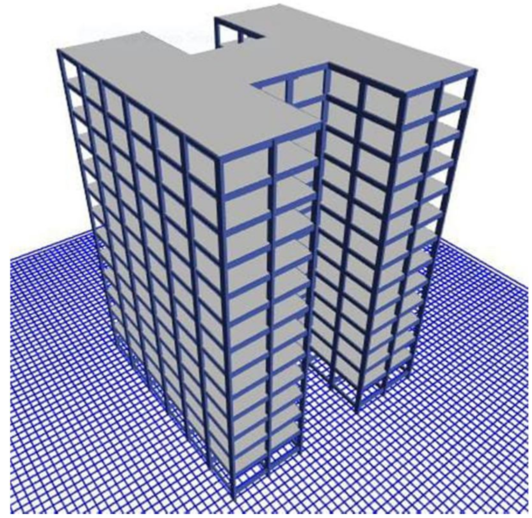

Fig. 8 : Elevation of H shaped model

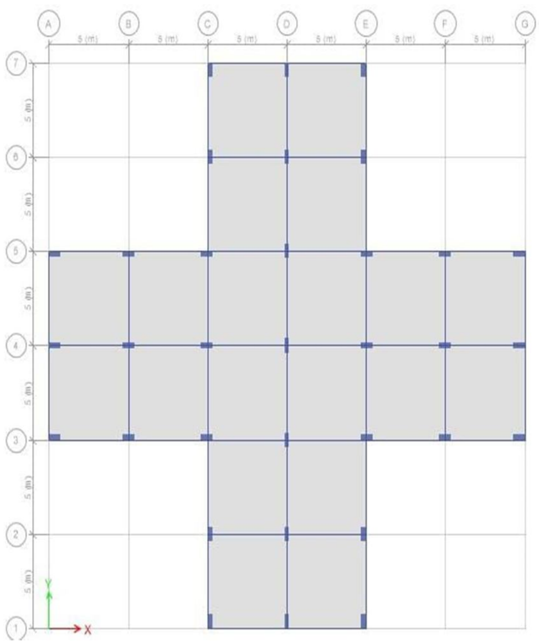

Fig. 9 : Plan of plus shaped model

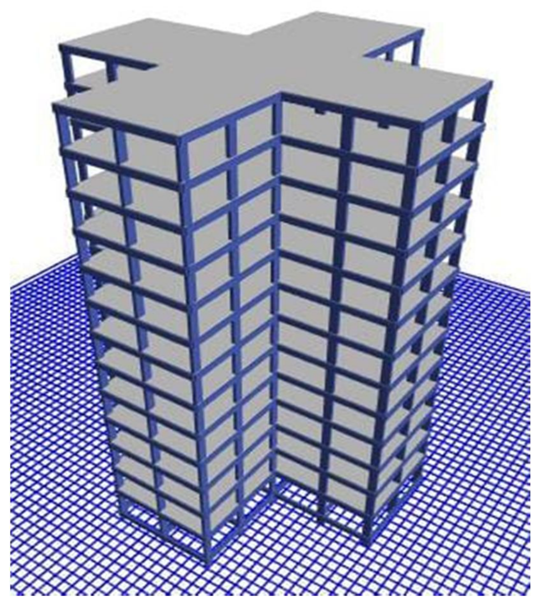

Fig. 10 : Elevation of plus shaped model

III. ANALYSIS OF RCC MODELS

Using ETABS software, the developed models are subjected to equivalent static analysis (ESA) and response spectrum analysis (RSA) as per IS 1893-Part 1 (2016) for different load combinations. Seismic parameters viz. storey displacement, drift ratio, stiffness, shear and overturning moments are obtained from the analysis of developed models in seismic zone III.

IV. RESULTS AND DISCUSSION

Figures 11 to 20 shows the variation of storey displacement, drift ratio, stiffness, shear, overturning moments over the number of stories in both X and Y directions obtained for all the RCC models by Equivalent static method

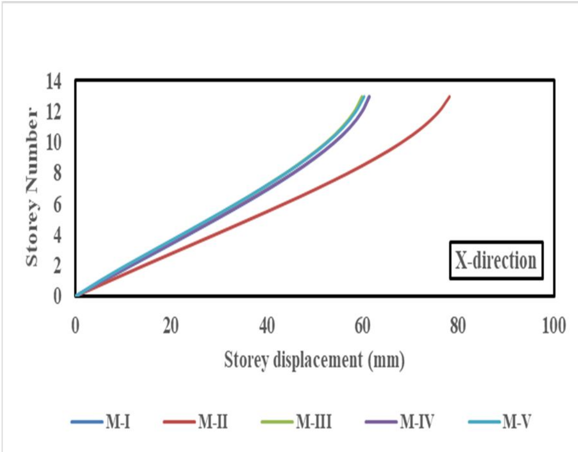

Fig. 11 : Storey displacement in X-direction from ESA

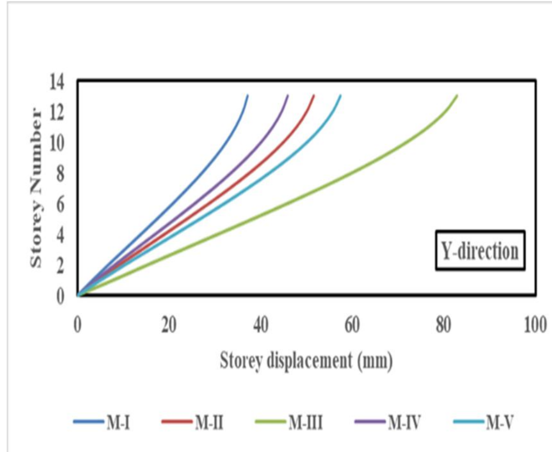

Fig. 12: Storey displacement in Y-direction from ESA

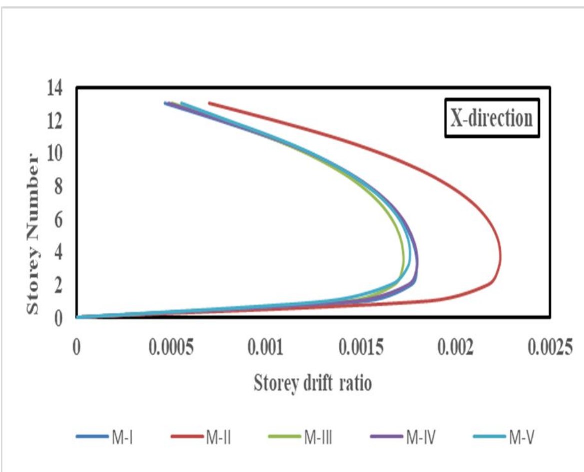

Fig. 13 : Storey drift in X-direction from ESA

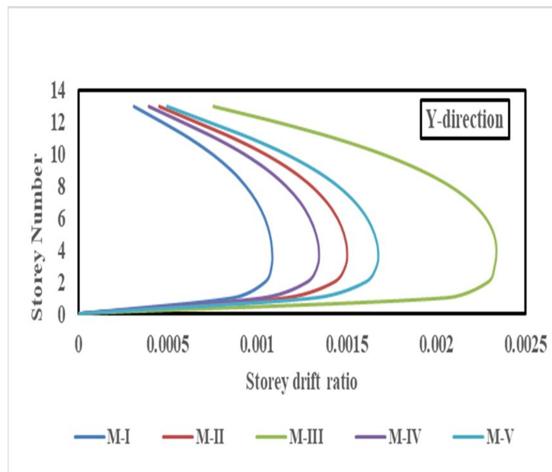

Fig. 14 : Storey drift in Y-direction from ESA

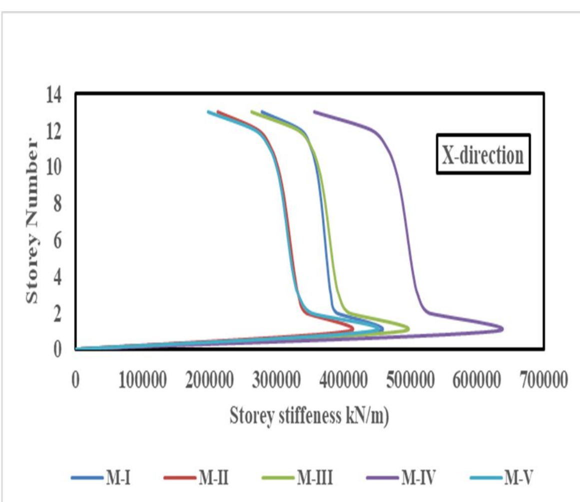

Fig. 15 : Storey Stiffness in X-direction from ESA

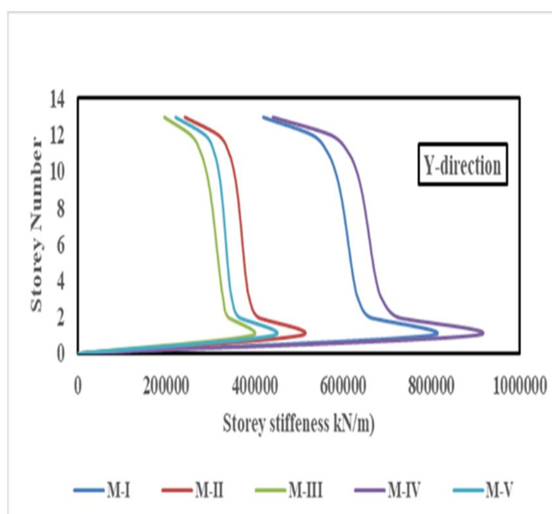

Fig. 16 : Storey stiffness in Y-direction from ESA

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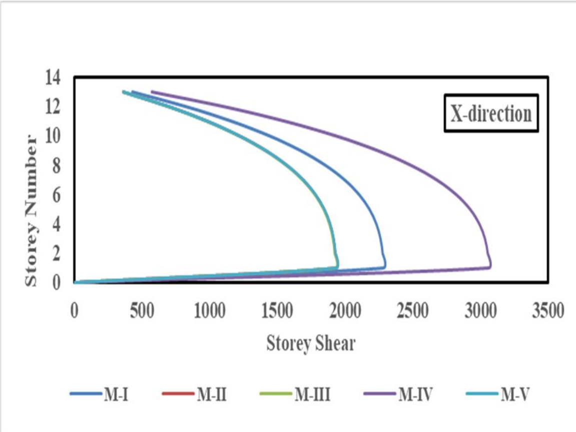


Fig. 17 : Storey Shear in X-direction from ESA

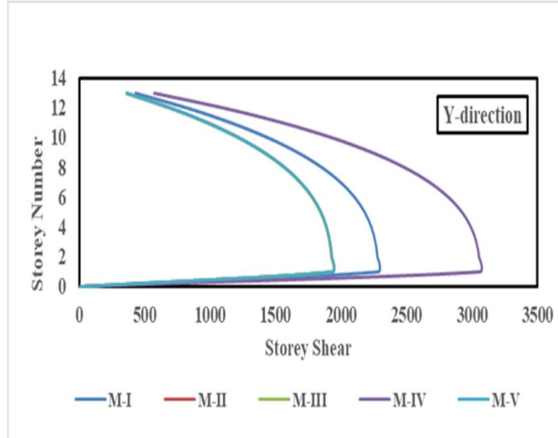


Fig. 18 : Storey Shear in Y-direction from ESA

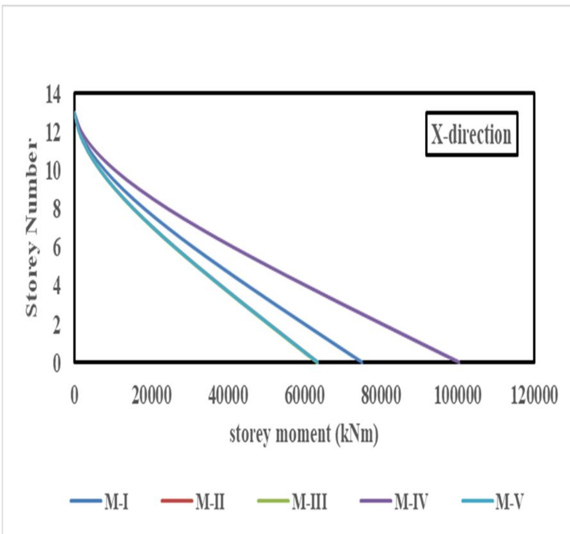


Fig. 19 : Overturning moment in X-direction from ESA

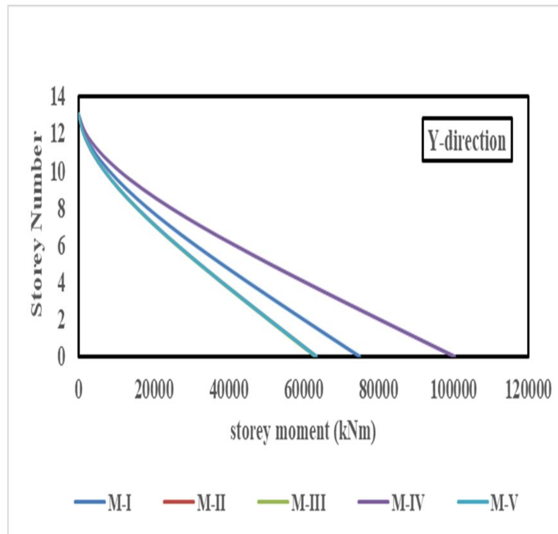


Fig. 20 : Overturning moment in Y-direction from ESA

From the Figs. 11 and 12, it is observed that, all the models exhibit similar kind of variation in storey displacement. However, storey displacement in X-direction is found to be more than that of Y-direction.

From the Figs. 13 and 14, it is observed that, all the models exhibit similar kind of variation in storey drift ratio. However, drift ratio in X-direction is found to be more than that of Y-direction.

From the Figs.15 and 16, it is observed that, all the models exhibit similar kind of variation in storey stiffness. However, storey stiffness in Y-direction is found to be more than that of X-direction.

From the Figs. 17 and 18 it is observed that, all the models exhibit similar kind of variation in storey shear in both X and Y directions.

From the Figs. 19 and 20, it is observed that, all the models exhibit similar kind of variation in overturning moments in both X and Y-directions.

Figures 21 to 30 shows the variation of storey displacement, drift ratio, stiffness, shear, overturning moments over the number of stories in both X and Y directions obtained for all the RCC models by Response spectrum method.

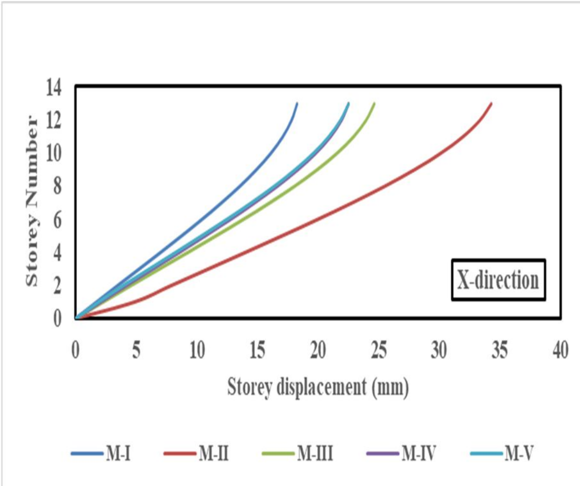


Fig. 21 : Storey displacement in X-direction from RSA

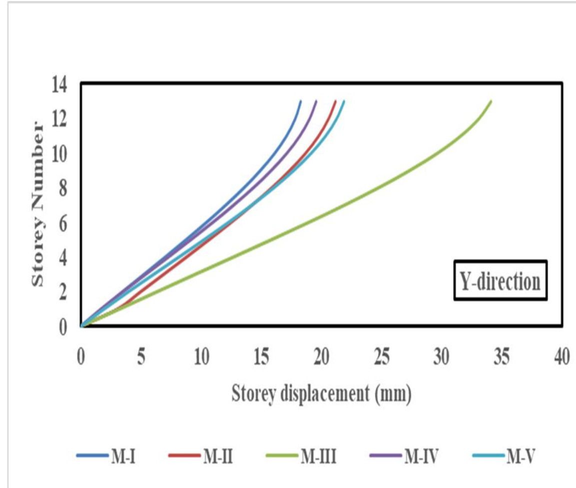


Fig. 22 : Storey displacement in Y-direction from RSA

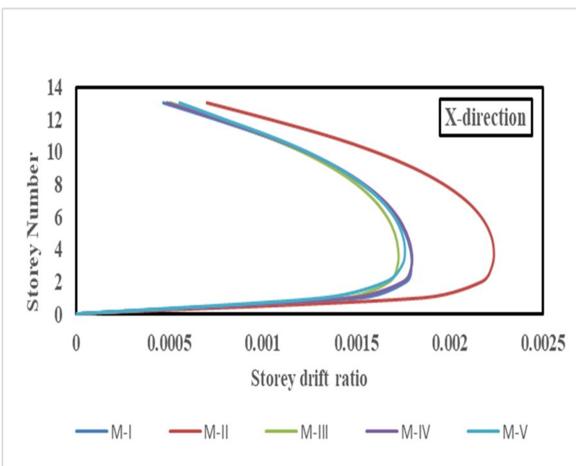


Fig. 23 : Storey drift ratio in X-direction from RSA

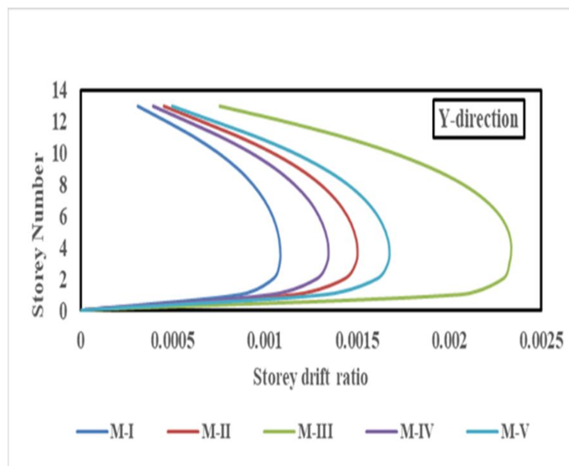
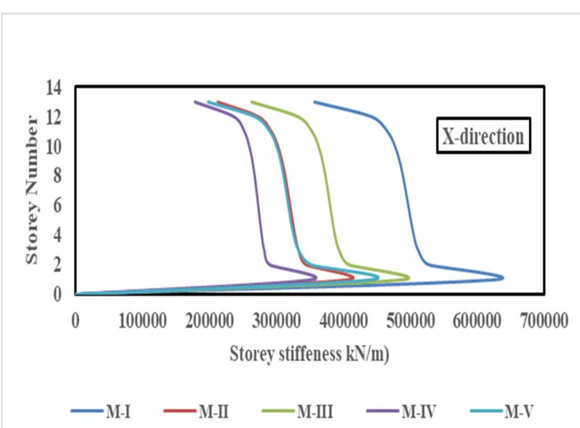
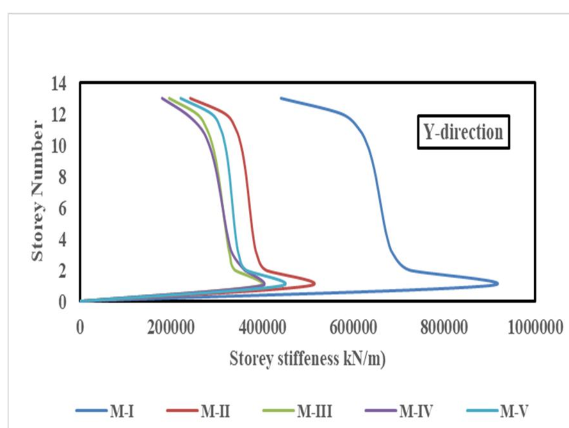


Fig. 24 : Storey drift ratio in X-direction from RSA





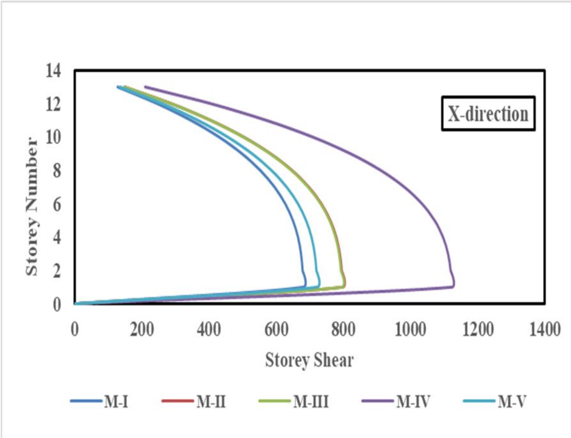


Fig. 27 : Storey shear in X-direction from RSA

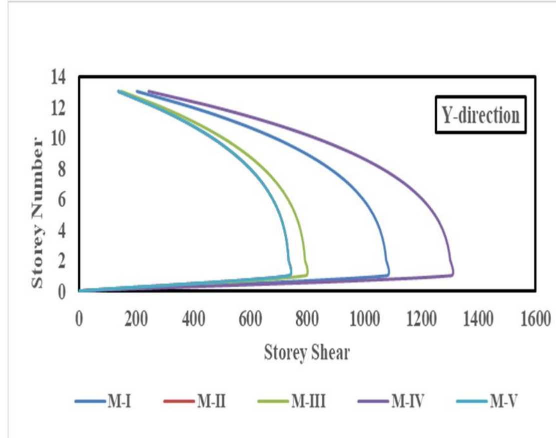


Fig. 28 : Storey shear in X-direction from RSA

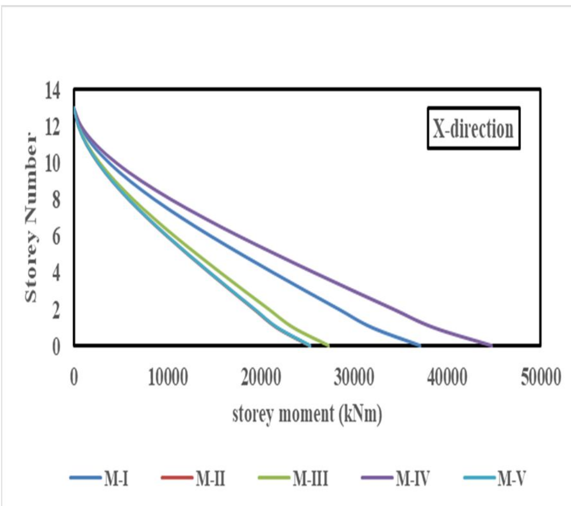


Fig. 29 : Overturning Moment in X-direction from RSA

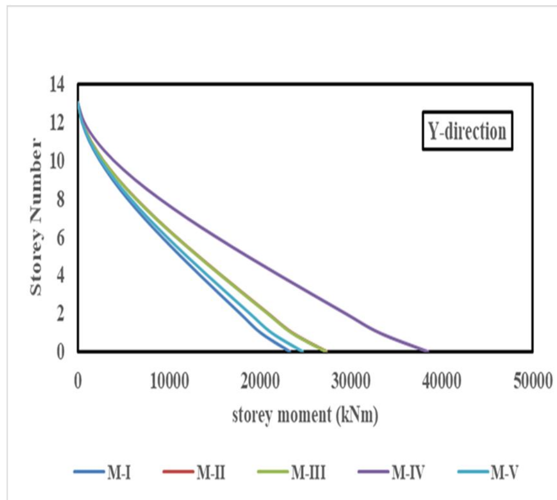


Fig. 30 : Overturning Moment in X-direction from RSA

From the Figs. 21 and 22, it is observed that, all the models exhibit similar kind of variation in storey displacement. However, storey displacements in X-direction is found to be more than that of Y-direction.
From the Figs 23 and 24, it is observed that, all the models exhibit similar kind of variation in storey drift ratio. However, storey drift ratio in X-direction is found to be more than that of Y-direction.
From the Figs. 25 and 26, it is observed that all the models exhibit similar kind of variation in storey stiffness. However, storey stiffness in Y-direction is found to be more than that of X-direction.
From the Figs. 27 and 28, it is observed that, all the models exhibit similar kind of variation in storey shear. However, storey shear in Y-direction is found to be more than that of X-direction.
From the Figs. 29 and 30, it is observed that, all the models exhibit similar kind of variation in storey overturning storey moment. However, storey overturning storey moment in X-direction is found to be more than that of Y-direction.

Figures 31 to 40 show the variation of maximum storey displacement, drift ratio, stiffness, shear and overturning moment for all the models by ESA and RSA.

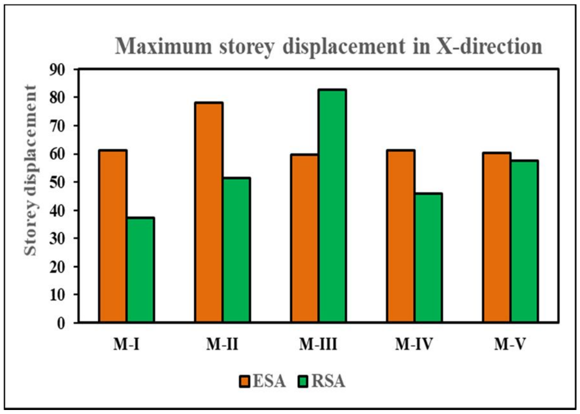


Fig. 31 : Comparison of maximum storey displacement in X- direction.

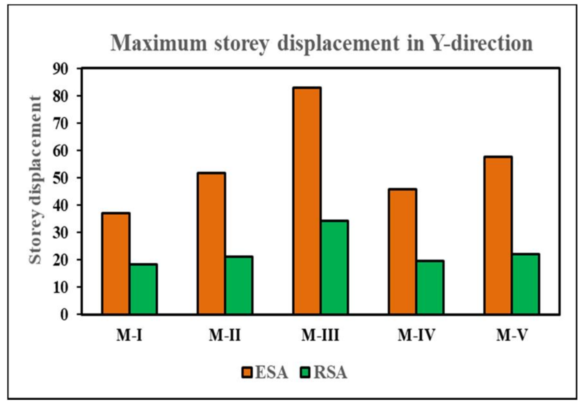


Fig. 32: Comparison of maximum storey displacement in Y- direction.

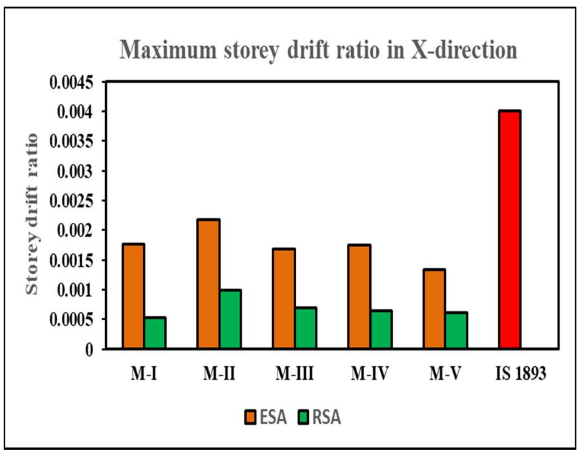


Fig. 33 : Comparison of maximum storey drift ratio in X- direction.

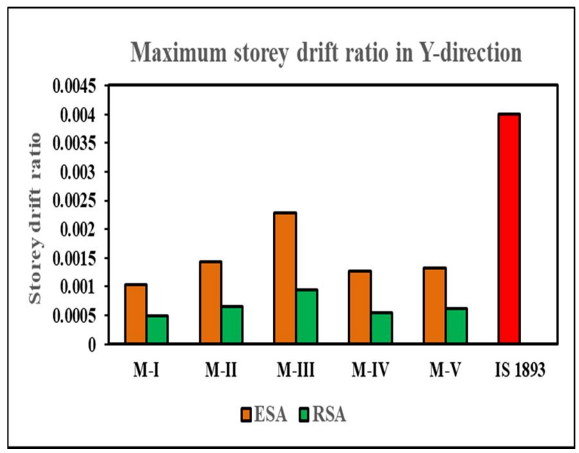


Fig. 34 : Comparison of maximum storey drift ratio in Y- direction.

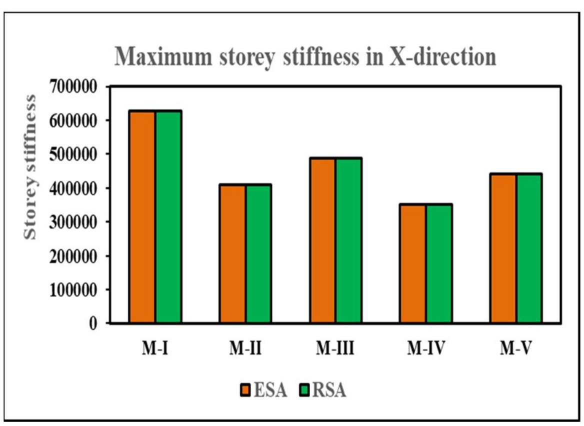


Fig. 35 : Comparison of maximum storey stiffness in X- direction.

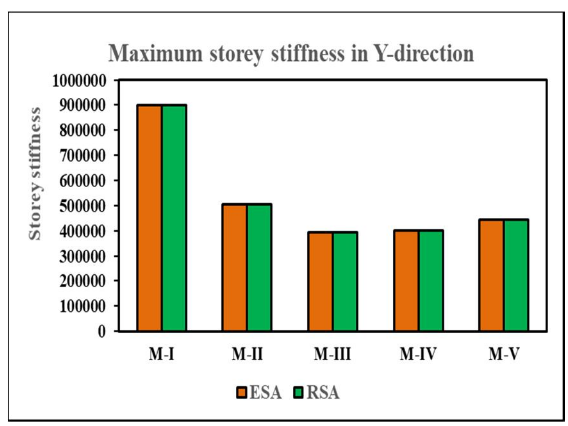


Fig. 36 : Comparison of maximum storey stiffness in Y- direction.

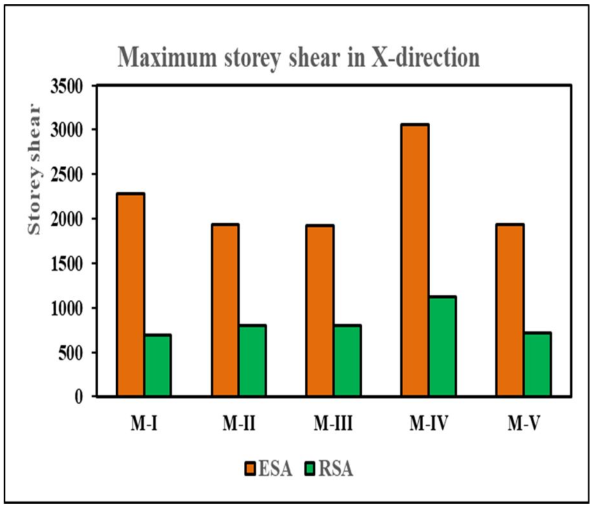


Fig. 37 : Comparison of maximum storey shear in X-direction.

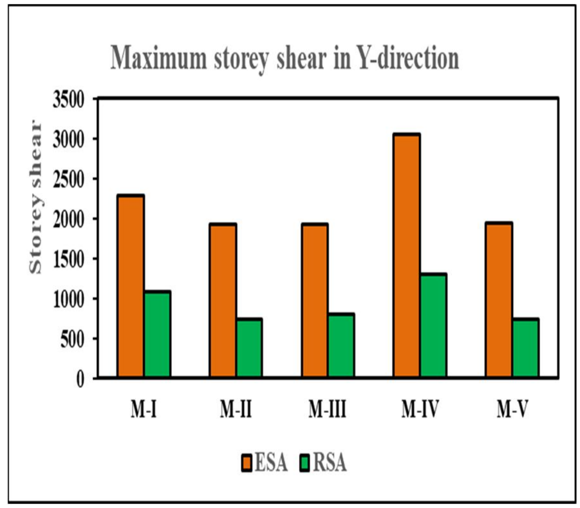


Fig. 38 : Comparison of maximum storey shear in X-direction.

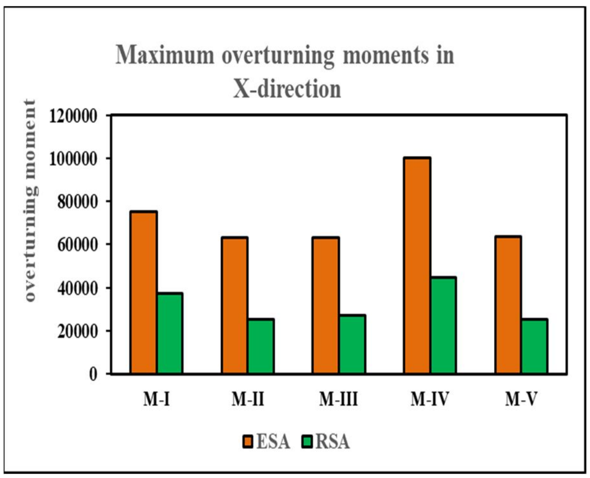


Fig. 39 : Comparison of overturning moment in X-direction.

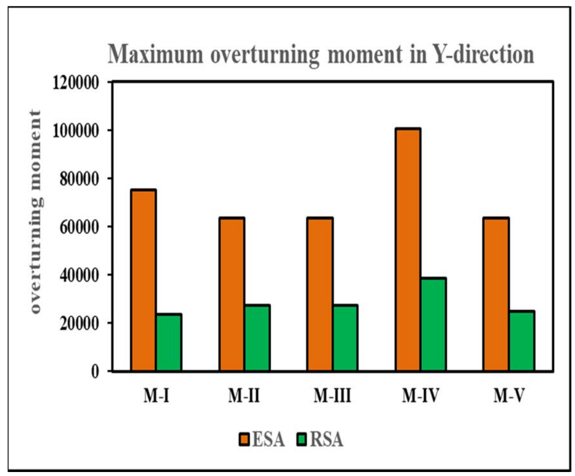


Fig. 40 : Comparison of overturning moment in Y-direction.

From Figs. 31 to 40, it is observed that, for all the models, equivalent static analysis predicts higher values of storey displacement, storey drift ratio, storey shear and overturning moment than that predicted by response spectrum analysis. In both methods of analysis, maximum storey drift ratio in all the models is within the allowable limits specified in Cl.7.11.1 of IS 1893-Part 1(2016). In both X and Y directions, least values of storey displacement and storey drift ratio, and also higher value of storey stiffness is observed in square shaped model as compared with T, L, H and Plus plan shaped models.

V. CONCLUSIONS

In the present study, seismic performance of RCC structures with various plan irregularities is investigated using ETABS software. Seismic parameters viz. storey displacement, drift ratio, stiffness, shear, overturning moment, time period and natural frequency for the developed RCC models are obtained in both X and Y directions by equivalent static analysis (ESA) and response spectrum analysis (RSA) as per IS 1893-Part 1 (2016) considering seismic zones III.

The important conclusions drawn from the present study are as follows.

1) In both methods of analyses, maximum storey displacement is observed in model M-II (T shape) in X-direction where as in Y-direction, the maximum displacement is observed in model M-III (L shape). However, least displacement is observed in model M-I (Square shape) in both X and Y directions.

2) In both methods of analyses, maximum storey drift ratio value in all models is within the allowable limits specified in Cl.7.11.1 of IS 1893-Part 1(2016). Maximum storey drift is observed in model M-II (T shape) in X -direction where as in Y-direction the max drift is observed in model M-III (L shape). However, least drift is observed in model M-I (Square shape) in both X and Y directions.
3) In both methods of analyses, maximum storey stiffness is observed in model M-I (square shape) in both X and Y direction. However, least stiffness is observed in model M-IV (H Shape) in X direction and in model M-III (L shape) in Y direction.
4) In both methods of analyses, maximum storey shear is observed in model M-IV (H shape) in both X and Y direction. However, least storey shear is observed in model M-I (square shape) in X-direction and in model M-II (T shape) in Y-direction.
5) In both methods of analyses, maximum overturning moment is observed in model M-IV (H shape) in both X and Y directions. However, least storey shear is observed in model M-II (T shape) in X-direction and in model M-I (square shape) in Y-direction.
6) As compared to RSA, for all the models, ESA predicts higher values of storey displacement, storey drift ratio, storey shear and overturning moment.

Concluding Remarks

For all the models, equivalent static analysis predicts higher values of storey displacement, storey drift ratio, storey shear and overturning moment than that predicted by response spectrum analysis. In both the methods of analysis, maximum storey drift ratio in all the models is within the allowable limits specified in Cl.7.11.1 of IS 1893-Part 1(2016). Considering both the methods of analysis, structure with square shaped plan performs better than the other shaped models with least values of storey displacement and storey drift ratio, and also with higher value of storey stiffness. Thus, square plan shaped structure is seismically more resistant than T, L, H and Plus shaped structures.

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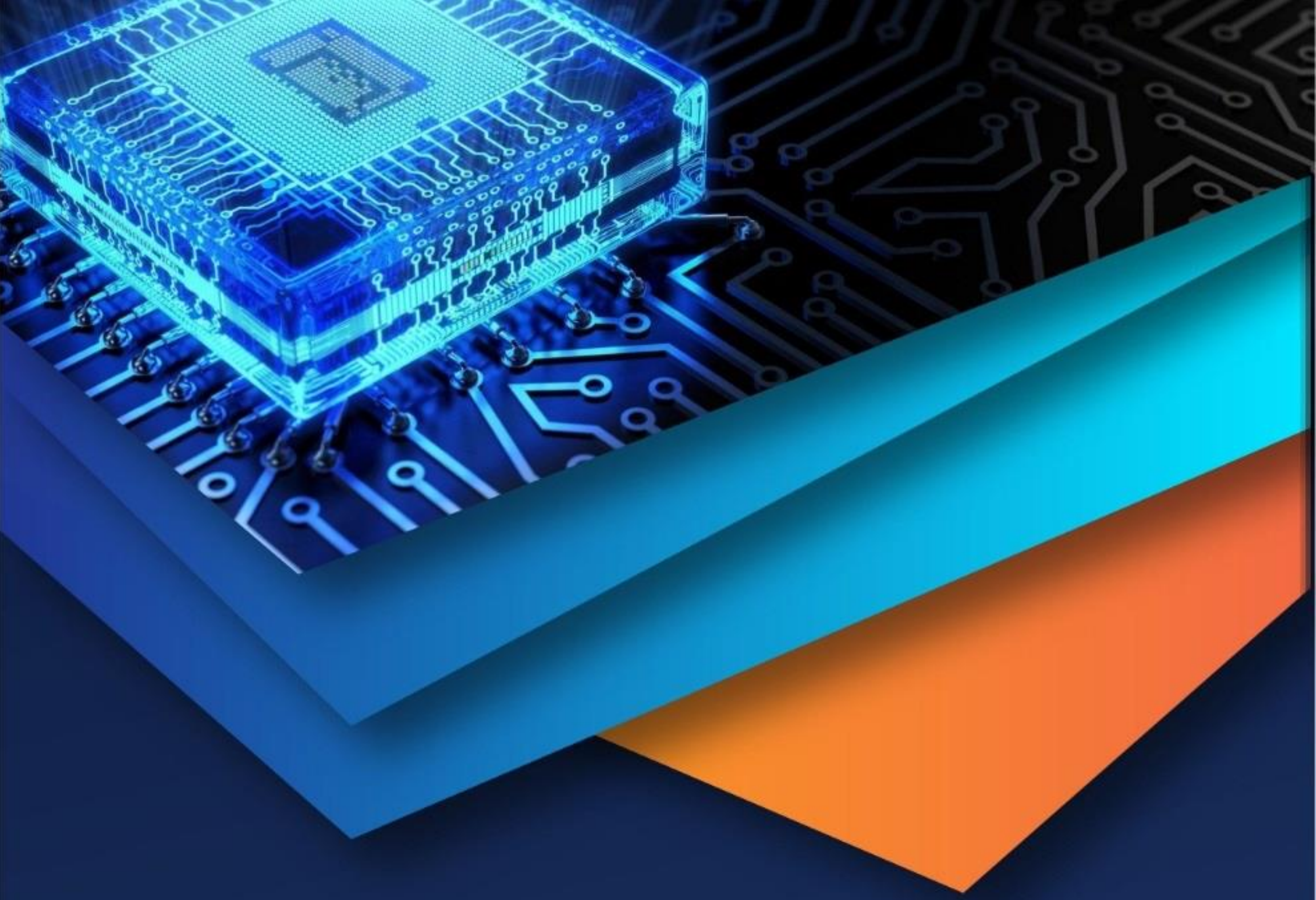

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IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

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