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Comparative Analysis of Seismic Behaviour of Multi-Storey Composite, Steel and Conventional RC Structure

Harish K N[1], Prof. Vahini M[2]
[1]P.G. Student, Department of Civil Engineering, Govt engineering college, Devagiri, Haveri, Karnataka, India
[2]Assistant Professor, Department of Civil Engineering, Govt engineering college, Devagiri, Haveri, Karnataka, India

***Abstract:** The present work seeks to investigate the seismic behaviour of a typical ordinary moment resisting framed structure with composite columns and conventional steel columns and examine the key design issues involved.*
The present study deals with seismic behaviour of a typical (G+12) storey framed concrete, steel and composite structure assessed through equivalent static method of analysis as per IS: 1893:2002 for moderate seismic zone III using ETABS software package. The analyses are performed on a suite of 3 types of ordinary moment resisting framed 3D space models with different column types – steel, concrete and composite.
The analysis is carried out and the results are compared in terms of critical earthquake response parameters such as base shear, storey drifts, roof displacements, and storey overturning moments. The main aim is to compare three different models which is subjected same load and other loading conditions.
Dynamic analysis and along with this response spectrum carried in order to compare the results and similar conditions and criteria.
At last pushover sample analysis in order to find the column failures has been carried out. Displacement for RCC and steel is more as compared with that of the composite structure. So while considering the displacement as the major criteria composite structure shows better performance.
***Keywords:** Composite columns, steel columns, seismic behaviour, multi-storey structure, column fracture.*

I. INTRODUCTION

The buildings in India are constructed with RCC and the adoption of steel structures is generally confined to industrial buildings and of late multi-storey buildings, which have acquired prominence by adopting composite structural elements. However, in recent times, the composite columns are gaining popularity for use in multi-storey buildings by virtue of their excellent static and earthquake resistant properties such as lower mass, high strength, rigidity and stiffness, significantly high toughness and ductility, large energy dissipation capacity.

Also, the composite systems are lighter in weight (about 20 to 40% lighter than concrete construction). Thus, the composite system is a more complete structural system than simple reinforced concrete or steel elements. When adopting a composite section, the amount of structural steel, reinforcing steel and concrete area, and the geometry as well as the position of the three materials represent relevant design parameters.

Indeed, a number of different combinations are possible thus leading to a flexible design. A steel concrete composite column is a compression member, comprising either a concrete encased hot rolled steel section or a concrete filled tubular section of hot rolled steel and is generally used as a loadbearing member in a composite framed structure. The load carrying capacity of composite columns is more than that of the bare reinforced column and the structural steel column included in the system.

II. OBJECTIVE OF THE PROJECT

A. To study the comparison of seismic behaviour of three types of multi-storey framed structures consisting of RCC, steel and composite columns.
B. To study displacement, drift and base shear of these structures subjected to dynamic analysis.
C. To compare the results for structures with RCC, steel and composite columns.
D. To study the pushover analysis in order to find out the failures of RCC, steel and composite columns.

III. METHODOLOGY

The structure resting on the ground starts vibrating when an earthquake occurs. Because it induces inertia forces in the structure. So in order to find out these forces and behaviour of the structure during the seismic activity, several researches have been conducted all over the world. This research involves the analysis techniques to determine the lateral forces purely from linear analysis. In India the Standardized method of analysis is followed by using a code – IS1893 (Part 1):2002 – "Criteria for Earthquake resistant design of structures". Analysis of the structures are mainly categorized as,

A. Linear Static Analysis
1) Equivalent static lateral force method

B. Linear Dynamic Analysis
1) Response spectrum analysis

C. Non-linear Static Analysis
1) Time history analysis

D. Non-linear Dynamic Analysis
1) Pushover analysis

Table 1: Load Combinations and Load Factors as Per Is 1893 (Part-1)

Load Combination	Load Factors
Gravity analysis	1.5 (DL+LL)
Equivalent Static Analysis	1.2 (DL+ LL ± EL_X) 1.2 (DL+ LL ± EL_Y)
	1.5(DL ± EL_X) 1.5(DL ± EL_Y)
	0.9 DL±1.5EL_X 0.9 DL ± 1.5EL_Y
Response Spectrum Analysis	1.2 (DL+ LL ± RS_X) 1.2 (DL+ LL ± RS_Y)
	1.5(DL ± RS_X) 1.5(DL ± RS_Y)
	0.9 DL±1.5RS_X 0.9 DL ± 1.5RS_Y

IV. ANALYSIS AND RESULTS

A. Data for Analysis

This study deals with the seismic behaviour of multi-storey structure. The work includes analysis of G+12 storey structure with RCC, steel and composite.

Plan Dimension : 83×74m
Total Height : 37.5m
Grade of concrete : M25
Grade of steel : Fe415
One-way slab : 200mm
Floor Finish load : 1kN/M^2
Live Load : 3kN/M^2
Density of concrete : 25kN/m^3

1) RCC Structure

Beam : 400×600 mm
Column : 600×600 mm.

2) Steel Structure

Beam : ISMB-500
Column : ISMB-550

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3) Composite Structure

Composite Beam : 400×600 mm (Concrete Encasement ISMB-500)
Composite Column : 600×600 mm (Concrete Encasement ISMB-550)

4) Seismic Loads

Seismic and its parameters in design will done by using the IS: 1893:2002. Which comes under the zone of the zone III EQ. Some description and its considerations will be shown below as per code book.

Zone : III
Zone factor : 0.16 (Refer Table 2)
Importance factor : 1.5 (Refer Table 6)
Soil Type : Medium

5) Code of RCC

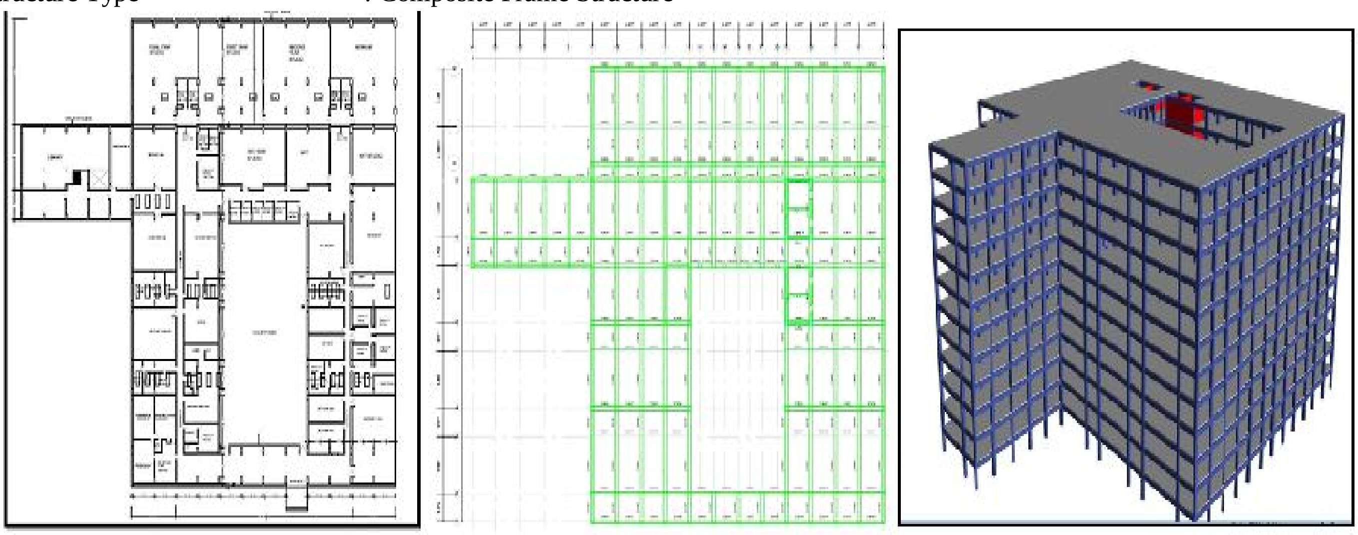
Response reduction Factor : 3.0(Refer Table 7)
Structure Type : RC Frame Structure

6) Code of Steel

Response reduction Factor : 4.0(Refer Table 7)
Structure Type : Steel Frame Structure

7) Code of Composite

Response reduction Factor : 5.0(Refer Table 7)
Structure Type : Composite Frame Structure



a) Typical Floor Plan b) Typical Key Plan c) 3D View of G+12 Storey Structure

Figure 1: Typical Plans View of G+12 Storeys for Composite, Steel and Conventional RC Structure

B. Maximum Displacement

Table 2: Maximum Displacement Values @ X and Y Direction

Type Of Structure	Displacement Along X-Direction (mm)	Displacement Along Y-Direction(mm)
RCC	43.576	46.224
Steel	33.559	37.083
Composite	19.033	19.725

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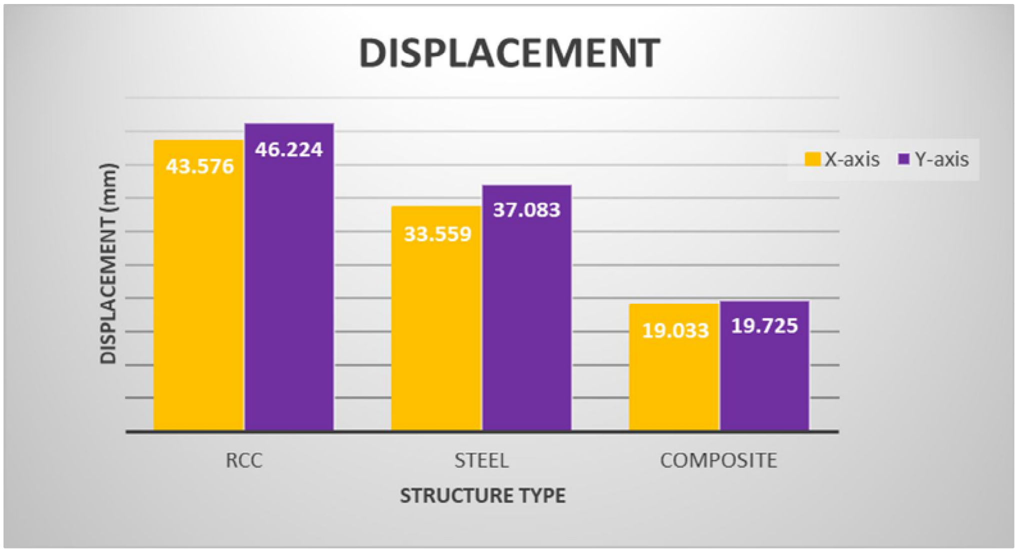

Figure 2: Maximum Displacement

C. *Maximum Drift*

Table 3: Maximum Drift Values @ X and Y Direction

Type Of Structure	Drift Along X- Direction	Drift Along Y-Direction
RCC	0.00105	0.000768
Steel	0.000944	0.000937
Composite	0.000391	0.000319

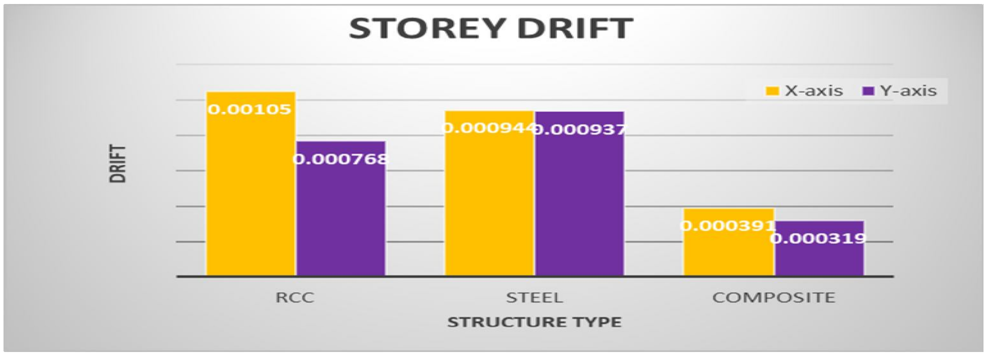

Figure 3: Maximum Drift

D. *Story Shear*

Table 4: Maximum Shear Values @ X and Y Direction

Type Of Structure	Shear Along X-Direction (kN)	Shear Along Y-Direction (kN)
RCC	25109.4209	24801.8956
Steel	8391.2641	8692.3050
Composite	21210.5774	19341.5803

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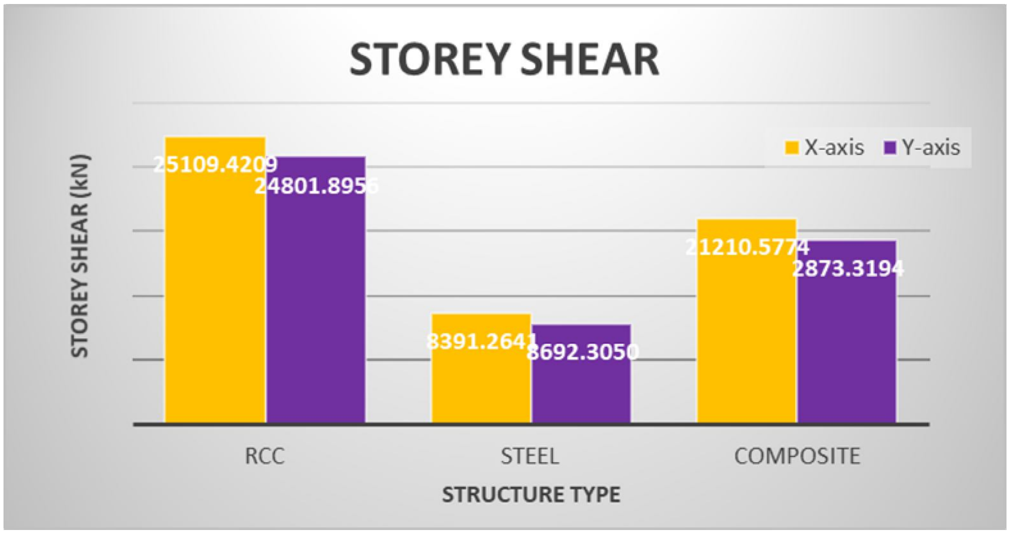

Figure 4: Maximum Shear

E. Comparative Percentage (%) Variation for Displacement

Table 5: Maximum Displacement Comparison

Compare to RCC	Increase (%)	Decrease (%)	Compare to Steel	Increase (%)	Decrease (%)	Compare to Composite	Increase (%)	Decrease (%)
Steel	-	19.775	RCC	19.775	-	RCC	56.332	-
Composite	-	56.332	Composite	-	43.289	Steel	43.289	-

1) Displacement reduces by 56.332% and 43.289% for composite structure when compared to RCC and steel structure respectively.
2) Displacement reduces by 19.775% for steel structure when compared to RCC structure and increases by 43.289% when compared to composite structure.
3) RCC structure experiences a displacement increase of 19.775% and 56.332% when compared to steel and composite structures respectively.

F. Comparative Percentage (%) Variation for Drift

Table 6: Maximum Drift Comparison

Compare to RCC	Increase (%)	Decrease (%)	Compare to Steel	Increase (%)	Decrease (%)	Compare to Composite	Increase (%)	Decrease (%)
Steel	-	18.036	RCC	18.036	-	RCC	62.761	-
Composite	-	62.761	Composite	-	58.580	Steel	58.580	-

1) Drift reduces by 62.761% and 58.580% for composite structure when compared to RCC and steel structure respectively.
2) Drift reduces by 18.036% for steel structure when compared to RCC structure and increases by 58.580% when compared to composite structure.
3) Storey drift of composite structures are comparatively less than RCC structures and steel structures.
4) Storey drift of RCC structure increases by 18.03% and 62.76% when compared to steel and composite structures respectively.

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G. Comparative Percentage (%) Variation for Shear

Table 7: Storey Shear Comparison

Compare to RCC	Increase (%)	Decrease (%)	Compare to Steel	Increase (%)	Decrease (%)	Compare to Composite	Increase (%)	Decrease (%)
Steel	-	61.430	RCC	61.430	-	RCC	28.550	-
Composite	-	28.550	Composite	46.044	-	Steel	-	46.044

1) Story shear reduces by 28.5% and increases by 46.04% for composite structure when compared to RCC and steel structures respectively.
2) Story shear reduces by 61.4% and 46.04% for steel structure when compared to RCC structure and composite structure.
3) Story shear of composite structures are comparatively less than RCC structures and more of steel structures.
4) An increase of Storey shear by 61.43% and 28.55% is observed for RCC structures when compared with steel and composite structures respectively.

H. Pushover Analysis for Column Fracture for RCC Structure

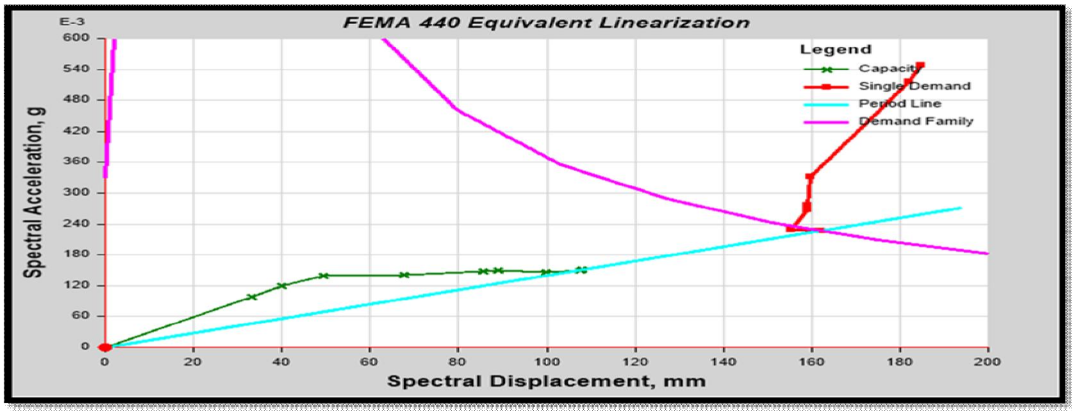

Figure 5: Pushover Plot

From above analysis, figure 5 shows the hinge patterns. Plastic hinge formation starts with the yielding of structural members of above pushover plot shows the most of the hinges formed the RCC structure are in between the proportionality limit and the yielding state. The capacity curve shows the in order to approve apply the proper seismic values are the demand the structure above will be representing those criteria's. the ground motion which will be of the earthquake will be going to be represented as a curve which is known as and demand curve. the capacity curve will be represented as the point of performance curve at the intersections level shown as in figure. during the consideration of the analysis in the earth structure the basic is considered to be as value 4655.5914 KN and the performance obtained at the displacement of 122.215mm.

I. Pushover Analysis for Column Fracture for Steel Structure

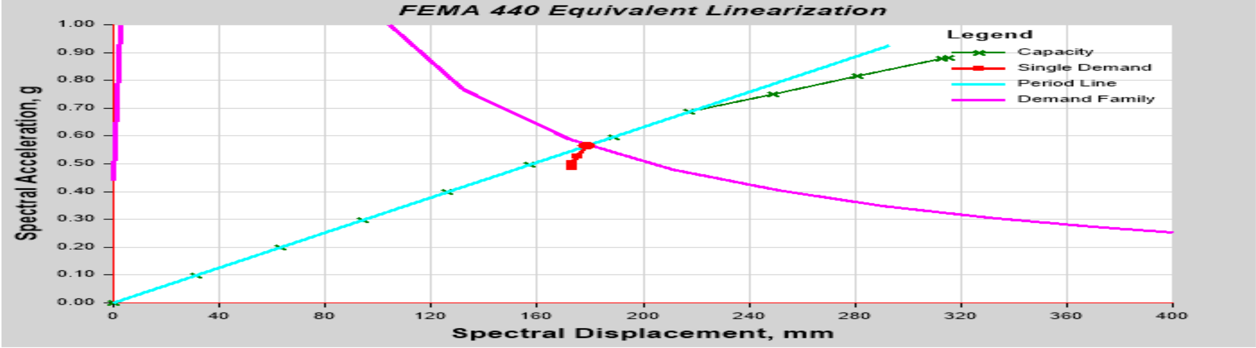

Figure 6: Pushover Plot

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From above analysis, figure 6 shows the hinge patterns. Plastic hinge formation starts with the yielding of structural members of ground stories which will be going to be then travels under the consideration to upper stories which will comes under the yielding of elements like the columns. Under theses analysis the base shear which will be of the structure value will be 2286.4967 KN and the performance obtained at the displacement of 204.927mm.

J. Pushover Analysis for Column Fracture for Composite Structure

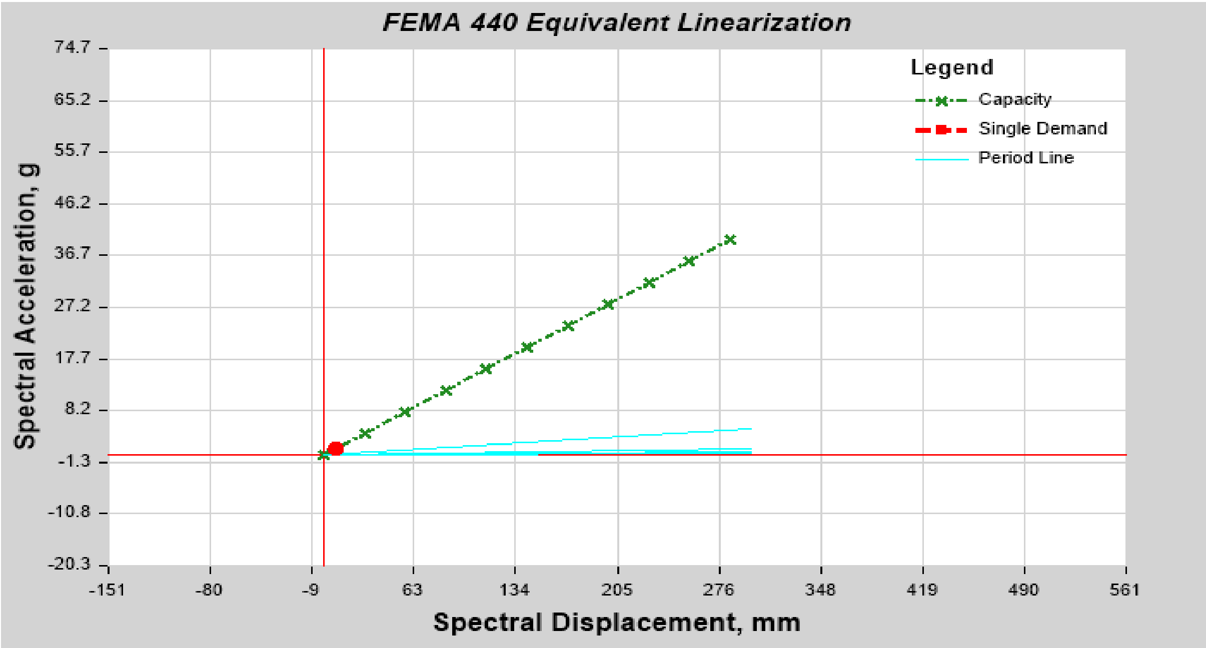

Figure 7: Pushover Plot

From above analysis, figure 7 shows the hinge patterns. Plastic hinge formation which will be going to be then travels under the consideration to upper stories which will comes under the yielding of elements like the columns. Under theses analysis the base shear which will be of the structure value will be 9950.5976 KN and the performance obtained at the displacement of 99.520mm.

V. CONCLUSION

In this work an attempt has been made to check the performance of structure for the different structures such as Composite, Steel and RCC. The dynamic analysis is carried out and along with the response spectrum is carried in order to compare the results and criteria.

Totally G+12 storey are considered for the analysis. The conclusions based on the analysis presented here,

A. Under displacement the composite structure shows remarkable reduction in displacement when compared with all other structures.
B. Displacement reduces by 56.332% and 43.289% for composite structure when compared to RCC and steel structure, but it is within the permissible limits by H/500, where H is storey height for both X and Y direction along longitudinal and transverse direction.
C. Storey drift of composite structures are less than RCC structures and steel structures.
D. Drift reduces by 62.761% and 58.580% for composite structure when compared to RCC and steel structure respectively it is also within permissible limits by 0.004H, where H is storey height along for the transverse and longitudinal direction.
E. Story shear of composite structures are comparatively less than RCC structures and steel structures.
F. Story shear reduces by 28.5% and increases by 46.04% for composite structure when compared to RCC and steel structures respectively.
G. Composite structures are efficient when compared to RCC and steel structures.
H. Under pushover analysis shows the real behavior of columns of the structures. It could help the grasp of the structural capacity with great efficiency as well as accuracy.

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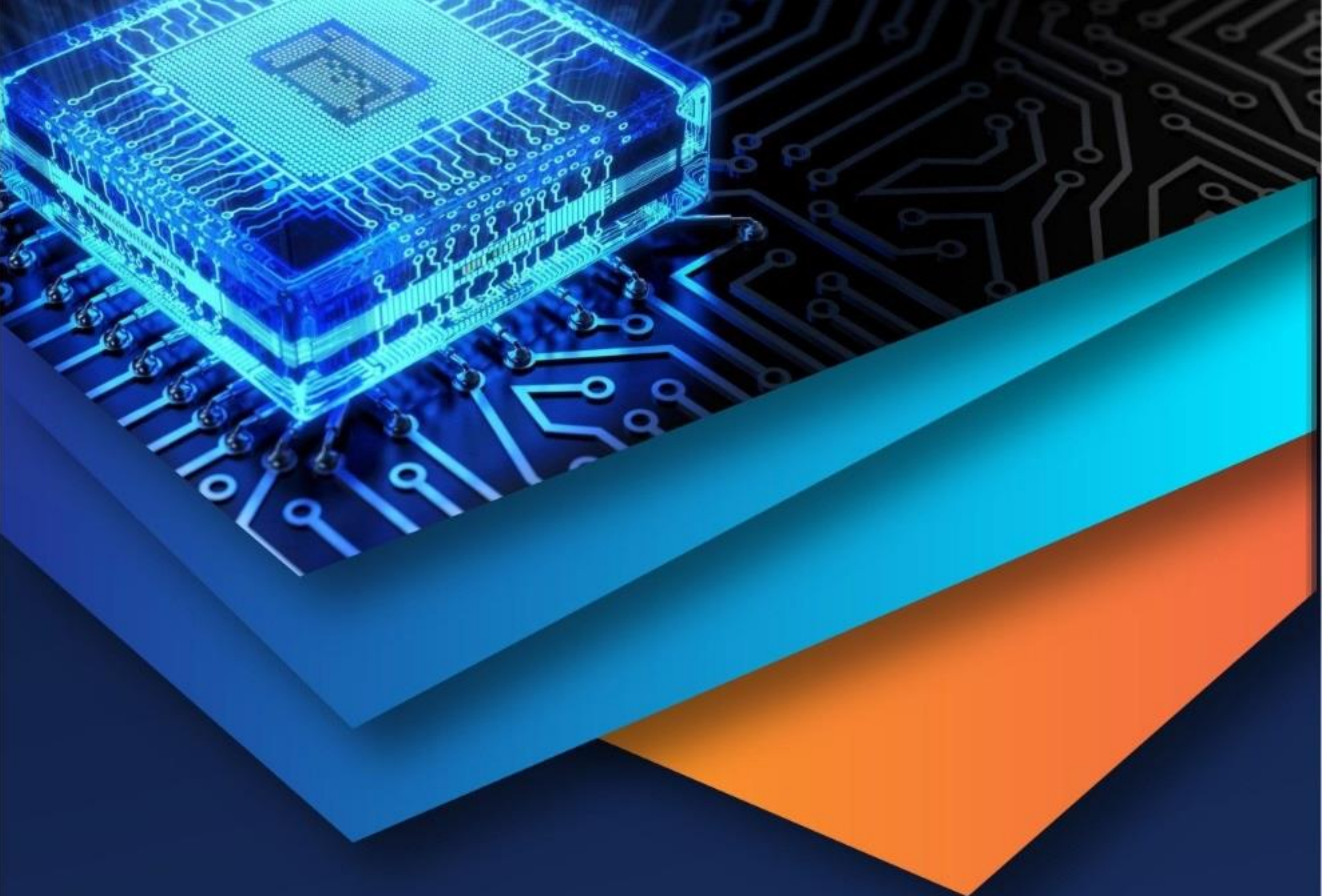

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