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A Study on Seismic Wave Impacts and Structural Response in Mid-Rise RCC Buildings: A Case-Based ETABS Analysis

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Abstract: This study investigates the seismic response of a G+8 reinforced concrete residential building located in India's Zone III using ETABS software. The building is designed with earthquake-resistant features including shear walls, core walls, and moment-resisting frames, in accordance with IS 1893:2016 and IS 456:2000. Key structural parameters such as base shear, story displacement, and modal mass participation are analyzed. The results confirm that the structure satisfies seismic performance requirements with safe displacement limits and effective lateral load distribution. This case-based analysis highlights the significance of proper modeling and detailing in enhancing structural resilience against seismic impacts.
Keywords: Seismic analysis, Earthquake-resistant design, ETABS modeling, RCC building, Structural response.

I. INTRODUCTION

Earthquakes are among the most destructive natural hazards affecting built infrastructure, often leading to catastrophic losses of life and property. In earthquake-prone regions, particularly in developing countries like India, the safety of structures against seismic loads is a major concern for civil engineers. Seismic waves generated during an earthquake cause ground shaking that imposes lateral forces on buildings. These forces must be adequately resisted through strategic structural design to avoid failure or collapse.

Reinforced concrete (RCC) buildings, especially those in urban mid-rise categories (G+5 to G+10), are highly vulnerable due to their mass and stiffness properties. Earthquake-resistant design involves incorporating structural systems that enhance ductility, energy dissipation, and lateral stiffness. Components like shear walls, core walls, and moment-resisting frames are essential in countering seismic forces and ensuring performance during moderate to severe earthquakes.

This study focuses on the seismic behavior of a G+8 RCC residential building located in Zone III of the Indian seismic zoning map. The structure is modeled and analyzed using ETABS software as per IS 1893:2016 and IS 456:2000 provisions. The aim is to evaluate story displacement, base shear, bending moment, and modal participation ratios to assess the safety and stability of the building.

II. LITERATURE REVIEW

The advancement of earthquake-resistant design methods has been central to structural engineering over the past few decades. Researchers have studied various structural configurations and materials to improve seismic performance in buildings. Kumar and Agarwal (2012) emphasized the importance of integrating shear walls, base isolators, and dampers to reduce seismic vulnerability in mid- to high-rise buildings. They discussed the concept of tuned mass dampers and passive control systems as effective means of dissipating seismic energy. Venkataramana and Shreyasvi (2018) reviewed contemporary construction practices for seismic resilience, highlighting the use of moment-resisting frames (MRF), ductile detailing, and ground slope considerations. Their findings support that proper code-compliant design and execution significantly enhance seismic safety. Barmenkova (2019) focused on the foundation behavior of earthquake-resistant structures, concluding that freely supported foundation slabs over sandy cushions perform better than clamped foundations under seismic loads. Their work emphasizes reducing soil-structure interaction to manage horizontal seismic effects. Ahmad et al. (2020) explored the role of Fiber Reinforced Cement (FRC) composites in seismic retrofitting, stating that these materials offer higher ductility, lightweight properties, and corrosion resistance compared to traditional reinforcement methods. Further, the use of structural modeling tools such as ETABS, as demonstrated by various researchers, has proven essential for simulating seismic loads and optimizing design through automated code-based checks (CSI, 2021). These studies collectively support the adoption of modern materials, detailing techniques, and software-based structural simulation in enhancing earthquake resistance in reinforced concrete buildings.

III. RESEARCH METHODOLOGY

This study employs a simulation-based methodology using ETABS software to assess the seismic performance of a mid-rise RCC residential building. The structure is analyzed for its response under seismic loading as per the guidelines of IS 1893:2016 and IS 456:2000. The methodology includes building configuration setup, material definition, load application, and design verification.

A. Case Study Description

The selected case is a G+8 residential RCC building located in Seismic Zone III of India. The building is assumed to rest on medium soil and includes key lateral load-resisting elements such as shear walls, core walls, and moment-resisting frames.

- Building Use: Residential
- Seismic Zone: Zone III
- Number of Stories: Ground + 8
- Story Height: 3.6 m
- Total Building Height: 34.8 m
- Structural System: Shear wall + Core wall + MRF
- Design Codes Used: IS 1893:2016, IS 456:2000, IS 13920:2016

B. Software Modeling in ETABS

1) Material Properties

Materials used in the analysis and design are presented in Table 1.

Table 1: Material Properties Used in Modeling

Material Type	Grade	Properties
Concrete	M30	fck = 30 MPa
Steel (Rebar)	Fe415 / Fe500	fy = 415 / 500 MPa
Concrete Density	—	25 kN/m³

2) Structural Element Dimensions

Dimensions of structural components are presented in Table 2. The Figure 1 shows the ETABS rendered 3D view of the RCC building model.

Table 2: Dimensions of Structural Components

Structural Element	Size (mm)
Columns	300 × 1200
Beams	230 × 500 to 350 × 800
Slabs	125 to 200 (thickness)
Shear Wall	1200 × 300

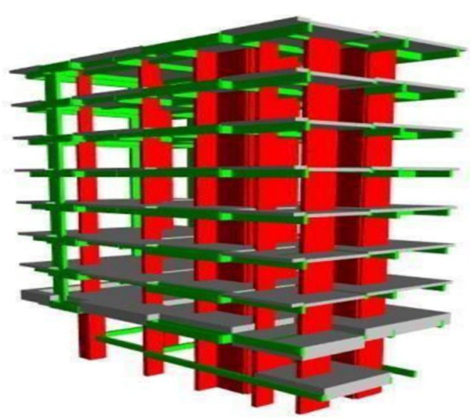

Figure 1: ETABS Rendered 3D View of the RCC Building Model

C. Load Definitions and Combinations

The building was subjected to the following loads as per IS 875 and IS 1893:

- Dead Load (DL): Self-weight + walls + floor finishes
- Live Load (LL): 2.0 kN/m² (Residential)
- Earthquake Load (EQx, EQy): Equivalent static method

The load combinations as per IS 1893:2016 are presented as Table 3. Figure

Table 3: Load Combinations as per IS 1893:2016

Load Case ID	Load Combination
LC1	1.5 (DL + LL)
LC2	1.2 (DL + LL ± EQx)
LC3	1.2 (DL + LL ± EQy)
LC4	1.5 (DL ± EQx)
LC5	1.5 (DL ± EQy)

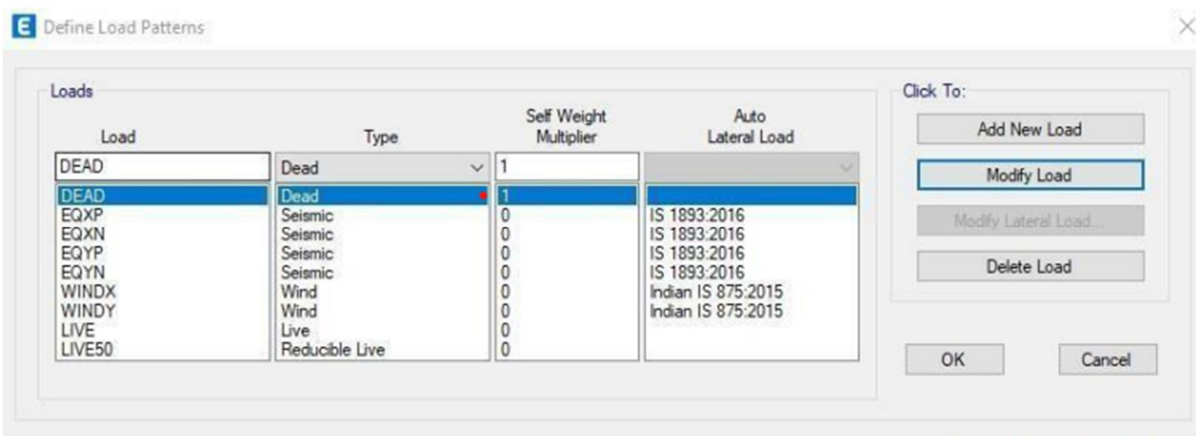

Figure 2: Load Pattern Assigned in ETABS

D. Seismic Load Parameters

The seismic base shear is calculated using the seismic coefficient method from IS 1893:2016:

$$A_h = \frac{ZI}{2R} \cdot \frac{S_a}{g} \tag{1}$$

The seismic design parameters for Zone III are presented as Table 4.

Table 4: Seismic Design Parameters for Zone III

Parameter	Value
Seismic Zone Factor (Z)	0.16
Importance Factor (I)	1.5
Response Reduction Factor (R)	4.0
Soil Type	Medium (Type II)
Design Horizontal Acceleration Coefficient (Ah)	0.0517

The base shear is then distributed among different stories based on the formula:

$$Q_i = \frac{W_i h_i^2}{\sum W_j h_j^2} \cdot V_b \tag{2}$$

E. Design Verification and Detailing

After performing analysis, design checks were run for beams, columns, and shear walls. The design was validated through reinforcement detailing and member capacity checks. The sample reinforcement utilization is presented in Table 5.

Table 5: Sample Reinforcement Utilization (Selected Members)

Member Type	Location	% Steel Used	Status
Column C1	Ground Floor	1.22%	Safe
Beam B2	1st Floor Span	1.30%	Safe

IV. RESULTS AND DISCUSSION

The seismic behavior of the G+8 RCC building was analyzed using ETABS based on the input parameters and design codes described in the methodology. This section presents the findings from the simulation, including displacement, base shear, bending moments, modal participation, and design checks.

A. Story Displacement and Drift

The maximum story displacement was recorded at the top level under seismic loading in both X and Y directions. As shown in Table 6, the top story (9th) experienced a lateral displacement of 139.2 mm in the X-direction and 128.6 mm in the Y-direction. The corresponding inter-story drift values are 0.00398 and 0.00376, respectively—both well below the IS 1893:2016 limit of 0.004 times the story height. These displacement patterns are graphically illustrated in Figure 4, which demonstrates a smooth and predictable increase in displacement with height, indicating appropriate lateral stiffness distribution.

Table 6: Story Displacement and Drift (X and Y Directions)

Story Level	Displacement X (mm)	Displacement Y (mm)	Drift X	Drift Y
Roof (9th)	139.2	128.6	0.00398	0.00376
8^{th}	112.0	101.4	0.00381	0.00362
4^{th}	55.4	49.8	0.00345	0.00321
Ground	0.0	0.0	—	—

B. Base Shear Comparison

A comparison of base shear obtained from manual calculations and ETABS results is presented in Table 7. The software-calculated base shear was 1520.4 kN in the X-direction and 1486.7 kN in the Y-direction, which closely aligns with the manually computed values of 1496.3 kN and 1462.1 kN, respectively. This validates the accuracy of the ETABS model.

Table 7: Base Shear Comparison (Manual vs ETABS)

Direction	ETABS (kN)	Manual Calculation (kN)
X	1520.4	1496.3
Y	1486.7	1462.1

C. Bending Moment and Shear Force

Significant bending moments and shear forces were observed in beams and walls at the lower levels due to higher load concentrations. The bending moment distribution in a ground floor beam is illustrated in Figure 3, while Figure 4 shows the shear force distribution in a typical shear wall and corner column. These figures confirm the expected structural behavior where lower stories experience greater seismic demand, requiring enhanced detailing and confinement.

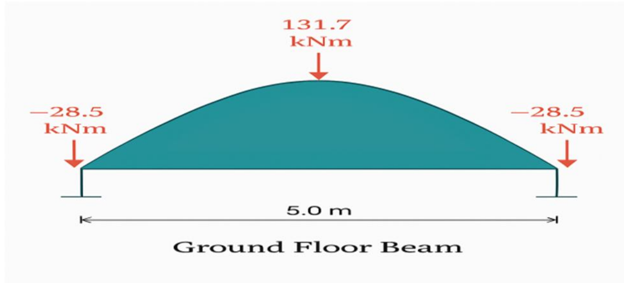

Figure 3: Bending Moment Diagram for Ground Floor Beam

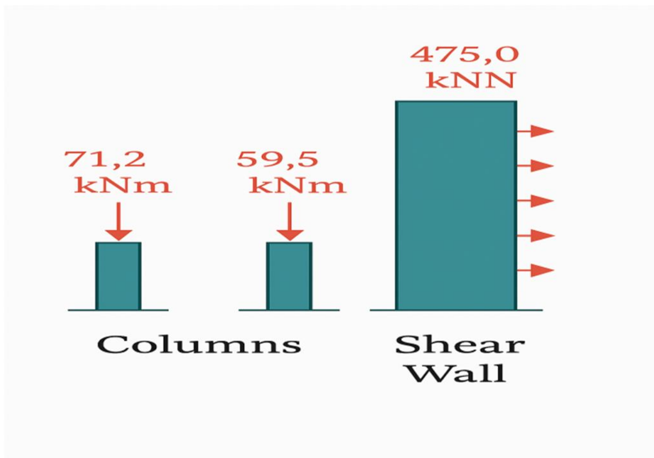

Figure 4: Shear Force Distribution in Shear Wall and Columns

D. Modal Analysis Results

The modal analysis showed that the first three modes contributed more than 90% to the total mass participation in both directions, as shown in Table 8. The time periods for Mode 1 and Mode 2 were 1.164 s and 1.118 s, respectively. The corresponding deformation patterns of the first and second modes, depicted in Figure 5, show translational movement primarily in the X and Y directions, respectively.

Table 8: Modal Mass Participation Ratios

Mode	Time Period (sec)	X-Direction (%)	Y-Direction (%)
1	1.164	68.25	0.42
2	1.118	0.56	67.82
3	0.943	15.47	17.63

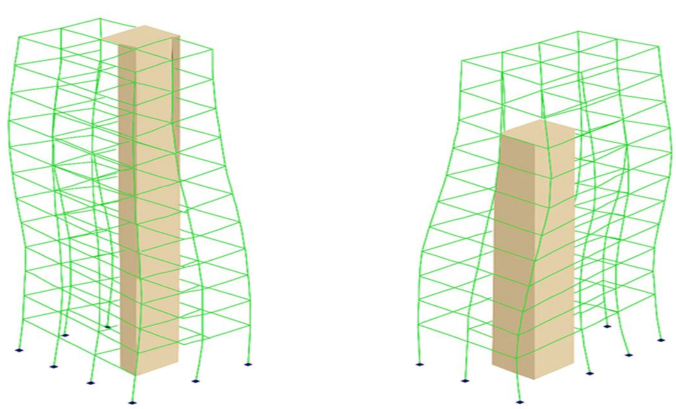

Figure 5: Mode Shapes (Mode 1 and Mode 2)

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E. Design Verification

Post-analysis design verification in ETABS confirmed that all key structural members passed strength and serviceability checks. The steel reinforcement utilization across critical columns and beams remained within IS 456:2000 limits, as detailed in Table 9. The visual layout of reinforcement from ETABS is presented in Figure 6, which illustrates proper detailing in accordance with ductility provisions under IS 13920:2016.

Table 9: Design Check Summary for Key Members

Member	Location	Steel Utilized (%)	Status
Column C1	Ground Floor	1.22%	Safe
Beam B2	1st Floor Span	1.30%	Safe
Shear Wall	Mid-Height	1.45%	Safe

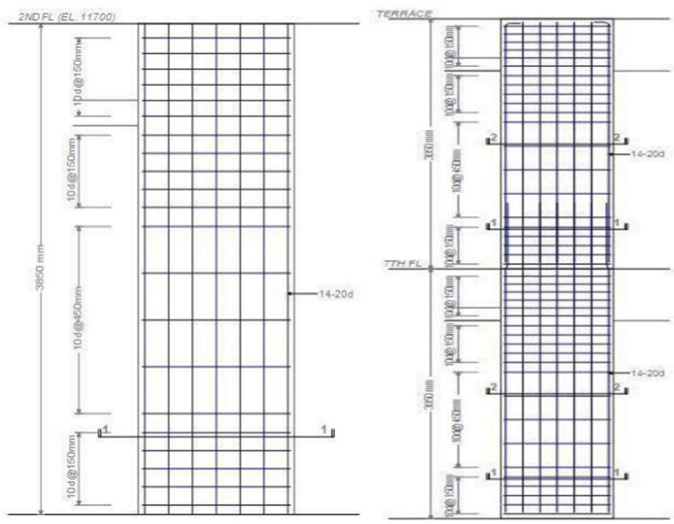

Figure 6: Beam and Column Reinforcement Layout (ETABS Snapshot)

F. Discussion

The analysis of the G+8 RCC residential building under seismic loading has provided critical insights into the structural behavior and effectiveness of earthquake-resistant design strategies.

The story displacement results (Table 6, Figure 4) indicate that lateral movements progressively increase with building height, which is expected in shear wall-frame systems. The maximum inter-story drift values remained within the prescribed IS 1893:2016 limit of 0.004 times the story height, indicating that the structural stiffness is sufficient to resist seismic lateral displacements.

The comparison of base shear from manual calculations and ETABS output (Table 7) demonstrates excellent consistency, validating the accuracy of the model and its compliance with IS code provisions. Minor differences between manual and software values (less than 2%) are attributed to rounding and refinement in software algorithms.

The bending moment and shear force distributions (Figures 5 and 6) confirm the concentration of forces at the base and lower stories of the structure, consistent with expected structural mechanics under seismic excitation. The shear wall and core systems effectively absorb these forces, highlighting the critical role of these components in structural resilience.

Modal analysis revealed that more than 90% of the mass participation is captured within the first three modes (Table 8), ensuring that the structure's dynamic characteristics are well-represented in the analysis. The mode shapes (Figure 7) show typical translational behaviors, reinforcing the importance of symmetric mass and stiffness distribution in avoiding torsional effects.

The design verification outcomes (Table 9, Figure 8) confirmed that all key structural components meet strength and ductility requirements. The reinforcement ratios for beams and columns remained within safe limits as per IS 456:2000 and IS 13920:2016, with sufficient anchorage and confinement detailing to enhance post-yield behavior.

Overall, the integration of shear walls, core walls, and a moment-resisting frame system provided balanced lateral stiffness, ductility, and redundancy—critical for seismic resilience. The ETABS-based case analysis reinforces the importance of advanced modeling tools in visualizing internal forces, optimizing structural layout, and validating safety through code-based design checks.

V. CONCLUSION

This study analyzed the seismic performance of a G+8 reinforced concrete residential building located in Seismic Zone III of India using ETABS software. The structural system incorporated shear walls, core walls, and a moment-resisting frame, and was designed according to IS 1893:2016 and IS 456:2000 standards.

Key findings from the analysis include:

1) The maximum story displacement and inter-story drift remained within permissible IS code limits, ensuring structural safety under seismic loading (Table 6, Figure 4).
2) Base shear values calculated through ETABS closely matched manual calculations, validating the accuracy and reliability of the modeling process (Table 7).
3) Bending moments and shear forces were effectively distributed through structural components, particularly in the lower stories where force concentration is highest (Figures 5 and 6).
4) The first three mode shapes captured over 90% of the mass participation, confirming dynamic adequacy and ensuring realistic response predictions (Table 8, Figure 7).
5) Design checks confirmed that all critical members met strength and ductility requirements, with reinforcement detailing complying with IS code specifications (Table 9, Figure 8).

In conclusion, the combination of ductile detailing, lateral load-resisting elements, and code-based ETABS modeling ensures safe and efficient performance of mid-rise RCC structures in moderate seismic zones. This study emphasizes the importance of integrated structural design and advanced analytical tools in improving resilience and minimizing seismic risk in residential buildings.

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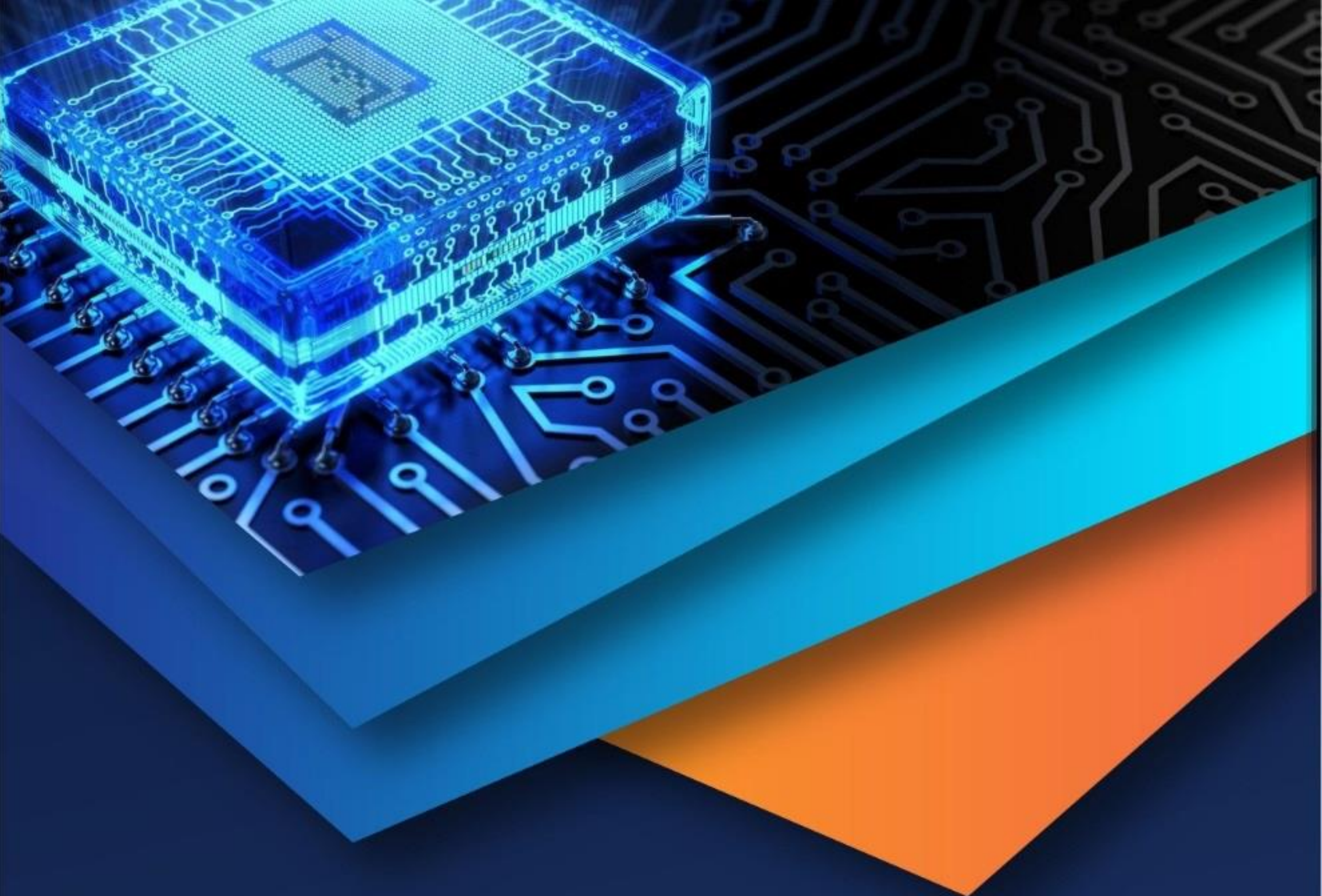

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