iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** I **Month of publication:** January 2026

DOI: https://doi.org/10.22214/ijraset.2026.77197

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue I Jan 2026- Available at www.ijraset.com

Analysis of High-Rise Buildings with Shear Walls under Dynamic Loads Using STAAD.Pro: A Review

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Abstract: This review examines the evolution, structural behavior, and design principles of shear wall systems in reinforced concrete (RC) tall buildings. The study focuses on a G+6 storey reinforced concrete building located in earthquake zone II on medium soil with a wind speed of 39 m/s. The analysis utilizes STAAD.Pro as the primary computational tool, which provides a suite of tools for structural engineers designing buildings ranging from single-story industrial structures to tall commercial skyscrapers.

The results demonstrate that shear walls are essential components for enhancing the lateral load resistance of high-rise buildings, as evidenced by the significant reduction in lateral displacement and story drift values observed in the analysis results. Furthermore, the equivalent static analysis method employed in STA AD.Pro yielded conservative estimates of seismic forces, confirming that the designed structure meets the safety requirements specified in IS-1893:2002 for buildings located in seismic zones. The findings are intended to support engineers and researchers in developing safer, more efficient, and resilient tall building structures.

Keyword: Reinforced Concrete, Seismic forces, shear wall, lateral displacement, G+6 storey

I. INTRODUCTION

Concrete remains one of the most widely utilized construction materials due to its affordability, durability, fire resistance, and adaptability to diverse structural forms [1]. The availability of raw materials and the simplicity of its production process have contributed to its dominant role in modern infrastructure development. With rapid urbanization and increasing land constraints, the construction of high-rise reinforced concrete (RC) buildings has become a necessity [2]. However, tall buildings present significant engineering challenges, as they must simultaneously satisfy structural safety, serviceability, economic efficiency, and resistance to environmental forces[3].

Modern high-rise buildings are typically more slender than earlier generations, making them increasingly sensitive to lateral loads induced by wind and seismic activity [4]. As building height increases, lateral deflection, dynamic vibration, and overturning effects become critical design considerations. Consequently, the optimization of lateral load-resisting systems has become a central focus in contemporary structural engineering [5]. Among these systems, shear walls have emerged as one of the most effective solutions for enhancing lateral stiffness, reducing drift, and improving overall seismic performance [6][7].

Reinforced Concrete (RC) shear walls are widely adopted in multi-storey buildings to enhance lateral load resistance against seismic and wind forces. These structural elements significantly improve global stiffness, strength, and energy dissipation capacity, thereby reducing storey drift and enhancing overall structural stability. As illustrated in Figure 1, shear walls act as vertical cantilevered members transferring lateral loads efficiently to the foundation. Their strategic placement within the building plan is crucial for optimizing torsional behavior and structural performance. With increasing urbanization and seismic risk in high-rise construction, understanding the behavior, design, and performance of RC shear wall systems remains essential for resilient and code-compliant structural engineering. Their high in-plane stiffness and strength make them particularly suitable for tall and multi-storey RC buildings. Compared to conventional moment-resisting frames, structures incorporating shear walls exhibit reduced lateral displacement, lower demand on beams and columns, and improved energy dissipation under seismic excitation [9][10]. In the absence of shear walls, frame members must be substantially enlarged to control deflection, resulting in increased material consumption and reduced design efficiency[11][12]. Therefore, shear walls are not only structurally beneficial but also economically advantageous.

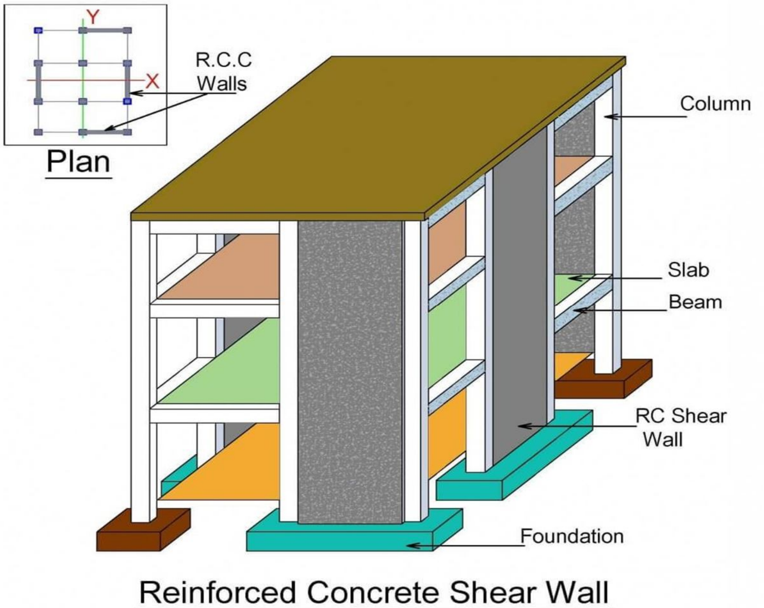

Figure 1 Reinforced Concrete Shear Wall system in a multi-storey RC building showing slabs, beams, columns, shear walls, and foundation

The effectiveness of shear walls depends significantly on their geometry, reinforcement detailing, material properties, and placement within the structural layout. In symmetric buildings, shear walls can be arranged to provide uniform lateral resistance[13][14]. However, in asymmetric configurations, improper placement may induce torsional effects and uneven force distribution. Identifying optimal shear wall locations is therefore essential to maximizing structural performance while minimizing material usage and construction costs. This review examines the evolution, structural behavior, and design principles of shear wall systems in reinforced concrete tall buildings. It emphasizes the role of shear wall configuration in enhancing resistance to wind and earthquake forces, particularly in buildings located in moderate seismic zones. Furthermore, the paper discusses analytical and computational advancements in evaluating shear wall performance, including the use of structural analysis software such as STAAD.Pro for modeling, load application, and response assessment[15].

By synthesizing existing research, this study aims to provide insights into best practices for shear wall design, placement strategies, and performance optimization in both symmetric and asymmetric RC buildings. The findings are intended to support engineers and researchers in developing safer, more efficient, and resilient tall building structures.

II. LITERATURE REVIEW

Several researchers have investigated the seismic performance of multi-story buildings using finite element modeling to understand the behavior of shear walls with openings under seismic load action, particularly in high-risk zones such as Zone V [16]. For instance, studies have modeled structures with specific parameters including a seismic zone factor of 0.36, a response reduction factor of 5, and Type II soil conditions to evaluate the behavior of shear wall systems under dynamic loading [17]. While many prior studies have concentrated on low to mid-rise buildings, this research extends the analysis to high-rise buildings, providing valuable insights applicable to modern urban landscapes [12]. Comparative analyses have demonstrated that the inclusion of shear walls significantly enhances the strength and stiffness of reinforced concrete frames, particularly in G+20 story structures where response spectrum analysis reveals reduced story drift and displacement when shear walls are strategically positioned at the frame and corners [15].

A. Overview and Importance of Shear Walls

The literature review establishes that concrete is considered an ideal construction material due to its cost-effectiveness, versatility, fire resistance, and readily available raw materials. High-rise buildings represent some of the most complex structures to construct as they must meet conflicting requirements and integrate complex systems, making it crucial to address the impact of wind and seismic forces in their design.

Shear walls are identified as critical vertical structural elements within the lateral force-resisting system that are specifically engineered buildings to oppose lateral forces occurring in the plane of the wall due to wind, earthquakes, and other forces

Shear walls are predominantly included in high-rise buildings to prevent the complete collapse of these tall structures during seismic events and are considered essential for economic reasons and to control excessive deflection. When properly designed and constructed, shear walls possess the strength and rigidity needed to counteract lateral forces, resisting both shear forces and uplift forces. These walls function like vertically oriented wide beams that transfer earthquake loads down to the foundation and structures well-designed with shear walls have shown excellent performance during earthquakes. Buildings designed with structural walls are more rigid than those with framed structures, reducing the likelihood of severe deformation and subsequent damage.

B. Analysis Methods and Approaches

1) Equivalent Static Method: The equivalent static investigation characterizes a progression of forces to consider the impact of earthquake ground movement on a building, defined by a seismic design response spectrum. This method assumes the building responds in only one fundamental mode and is most suitable for structures that do not twist and are low-rise. The response is read from a seismic design response spectrum given the natural frequency of the building.
2) Response Spectrum Method: Response spectrum analysis permits multiple modes to be considered in the analysis. This method is required by many building codes for all structures except very complex or very basic ones. The response of a structure is defined as a combination of several different modes (shapes) that correspond to the "sounds" in a vibrating string. For each mode, the design spectrum is used to read the response based on the modal mass and modal frequency, and their combination gives an estimate of the total response of the structure.

The document indicates that the analytical approach has evolved from elastic static analysis to dynamic elastic, then to non-linear static, and ultimately to non-linear dynamic analysis.

C. Software Tools and Analysis Parameters

The literature review documents the use of various computational software for analyzing high-rise buildings with shear walls, including ETABS (versions 9.5, 9.7, and V16.2), SAP2000 V14.1, and STAAD.Pro V8i 1oads applied on structures are based on Indian Standards including IS:875 (dead, live, and wind loads) and IS:1893-2002 (earthquake load).

Key parameters selected for comparative analysis include:

1) Lateral displacement
2) Story drift
3) Base shear
4) Story shear
5) Bending moment
6) Torsion
7) Time period
8) Deflection .

D. Comparative Studies and Research Findings: as shown in Table 1

Table 1 Comparative Studies and Research Findings

Author & Year	Objective / Focus	Methodology / Software	Key Parameters Analyzed	Major Findings
Huo et al. (2022) [8]	Modeling challenges and nonlinear RCC behavior with shear wall systems	ETABS (Continuum + 1D FEM), static & dynamic analysis	Lateral displacement, lateral forces	Accurate nonlinear modeling improves prediction of lateral response
Chayaboot et al. (2024) [9]	Behavior evaluation of RC frames using pushover	Nonlinear pushover analysis	Base shear, displacement, performance point	Displacement-controlled pushover effectively captures inelastic behavior

Lu et al. (2018) [10]	Optimization of shear wall area in multi-storey buildings	ETABS, zone II–V seismic analysis	Storey drift, displacement, cost	Dual structural systems reduce drift and improve seismic efficiency
Borkar et al. (2021) [11]	Performance evaluation of shear walls in high-rise buildings	ETABS, linear static & dynamic	Story drift, story shear, displacement	Central solid core wall reduces drift and improves stability
Armaly et al. (2019) [12]	Effect of shear wall placement on seismic performance	ETABS 9.5, SAP2000, pushover	Storey drift, deflection, reinforcement demand	Proper wall positioning significantly enhances lateral resistance
Saeed et al. (2022) [13]	Optimal shear wall location in asymmetric buildings	ETABS	Lateral displacement, torsion, stability	Strategic wall placement improves torsional control
Lai et al. (2022) [14]	Seismic analysis of hospital building (G+5)	ETABS, IS 875, IS 1893, IS 456	Base shear, design forces, structural safety	Structural design met Indian seismic safety standards
Ozturkoglu et al. (2017) [15]	Optimal shear wall positioning in multi-storey buildings	ETABS, pushover analysis	Base shear, displacement	Proper wall location minimizes lateral displacement
Varsha R. Harne (2015)	Best shear wall placement in 6-storey RCC	STAAD Pro, IS 1893	Seismic forces, displacement	Shear walls are critical for resisting lateral loads
Chithambar Ganesh A. (2016)	Optimal shear wall placement using nonlinear ETABS	Nonlinear analysis	Lateral displacement, drift, forces	Shear walls significantly reduce drift and lateral forces
S. Natarajan (2016)	Seismic behavior of irregular RCC buildings	ETABS, Response Spectrum	Lateral load, drift, torsion	Shear walls improve irregular building stability
Raad Dheyab Khalaf (2016)	Effect of plan irregularity and shear wall placement	ETABS v15, Response Spectrum	Displacement, drift, stiffness	Shear walls improve stiffness and drift control
Md. Maksudul Haque et al. (2018)	Effect of shear wall openings	ETABS	Deflection, shear force, bending moment	Triangular openings increase deflection; rectangular openings increase shear
Wesam Al-Agha et al. (2020)	Seismic performance of irregular buildings	ETABS V16.2	Base shear, bending moment	Response Spectrum Method outperforms Equivalent Static Method
Mahammadasfak Memon et al. (2021) [21]	Comparison of RCC, steel plate & composite shear walls	Response Spectrum Analysis	Displacement, ductility	Composite shear walls provide superior resistance & ductility
Xin Nie et al. (2022) [22]	Experimental shear resistance of RC shear walls	Lab testing under axial load	Drift ratio, shear strength	Increased axial load reduces shear strength
Hurmet Kucukgoncu et al. (2023) [23]	Experimental strengthening using external RC shear walls	Reverse cyclic loading tests	Strength, stiffness, energy dissipation	Strengthening effectiveness depends on frame-wall interaction

Key Outcomes of Literature Review

The literature review identifies several critical outcomes based on previous research :

- Frame with shear wall results in less lateral force distribution in beams and columns
- Tall structures show more lateral displacement as their storey heights increase
- Shear wall in tall structures reduces the effect of lateral displacement and storey drift

E. Present Study Details

The current study focuses on a G+6 storey reinforced concrete building situated in earthquake zone II on medium soil with a wind speed of 39 m/s. The study compares 2D and 3D buildings with both regular and irregular high-rise structures using STAAD.Pro V8i software Linea static analysis is conducted with each storey having a height of 3.15 m, making the total building height 22.05 m, which qualifies it as a high-rise structure. The specific objectives include assessing the impact of dynamic forces, conducting comparative analysis of 2D and 3D buildings, and determining the effect of shear walls under dynamic loading on high-rise buildings. The modeling and analysis of the G+6 storey high-rise building frame have been conducted using STAAD.Pro V8i software to assess the impact of dynamic forces, such as seismic and wind loads, on a tall building according to Indian Standards.

III. METHODOLOGY

The methodology follows a structured flow chart process for analysis and design using STAAD.Pro software in accordance with IS-1893:2002 and IS-875-III. The analysis consists of six sequential steps:

1) Step 1: Modeling of Building Frames

The methodology models RCC structures as assemblies of beams, columns, slabs, and foundations interconnected as a single unit, where load transfer follows the path from slab to beam, beam to column, and finally column to foundation before transfer to soil The study adopts both unsymmetrical and symmetrical building shapes, modeled as both 2-dimensional and 3-dimensional structures using STAAD.Pro software, considering dynamic loading from seismic and wind forces. Specifically:

- Model-1 & 2: 3-dimensional and 2-dimensional boys hostel project model with dynamic loading
- Model-3 & 4: 3-dimensional and 2-dimensional frame with symmetrical shape and same loading/geometry

2) Step 2: Application of Load

All load conditions are applied to the structure using design load values determined according to IS-875 Parts I, II, III and IS-1893 Part I

- Dead loads: Calculated based on unit weights of materials specified in IS 875
- Imposed load: Varied load assumptions in line with IS 875

3) Step 3: Selection of Seismic and Wind Parameters

The methodology defines specific environmental and structural parameters:

- Earthquake Zone: Zone II with wind speed of 39 m/s considered for lateral load resistant structure design
- Soil condition: Medium soil conditions selected for structural analysis
- Wind pressure: Calculated using formula Pz = 0.6 \times Vz, where Pz is design wind pressure
- Earthquake parameters: Various parameters including Zone Factor (Z), Importance Factor (I), Response reduction factor (R), soil condition, damping ratio, and eccentricity ratio are defined for different load cases using STAAD.Pro analysis software

4) Step 4: Application of Equivalent Static Analysis

After defining seismic parameters, static analysis is performed using STAAD.Pro software by applying Equivalent static analysis in accordance with IS-1893: 2002 methodology calculates:

- Building time period: Using formulas T = 0.075 × h^0.75 for bare frame and T = 0.09h/√d for infilled frame (where h = height, d = base dimension)
    - X-direction: Ta = 0.09h $\sqrt{d}$= 0.85 sec
    - Y-direction: Ta = 0.09h $A = \pi r^2 \sqrt{d}$= 0.94 sec
- Lateral loads: Computed and distributed along building height according to IS-1893: 2002
- Seismic weight: Computed by adding full dead load to 50% of live load

5) Step 5: Formation of Load Combinations

The methodology accounts for nine load combinations for analysis and limit state design of reinforced concrete structures, following IS-1893: 2002 and wind combinations as per IS-875 Part-III (Sec. 6.3.1.2). Examples include:

- Load Combination 1: Dead Load (1.5) + Live Load (1.5)

- Load Combination 2: Dead Load (1.5) + Earthquake Load (1.5) + wind-X (1.5)
- Load Combination 3: Dead Load (1.5) + Earthquake Load (-1.5) + wind-X (-1.5)

6) Step 6: Design of RCC Structure

The final step involves designing the RCC structure using STAAD.Pro software according to IS-456:2000.

A. Software Platform

The analysis utilizes STAAD.Pro as the primary computational tool, which provides a suite of tools for structural engineers designing buildings ranging from single-story industrial structures to tall commercial skyscrapers. The software is described as highly capable yet user-friendly, providing engineers with advanced yet intuitive tools to maximize productivity.Figure 1 shows flow of STAAD.Pro software

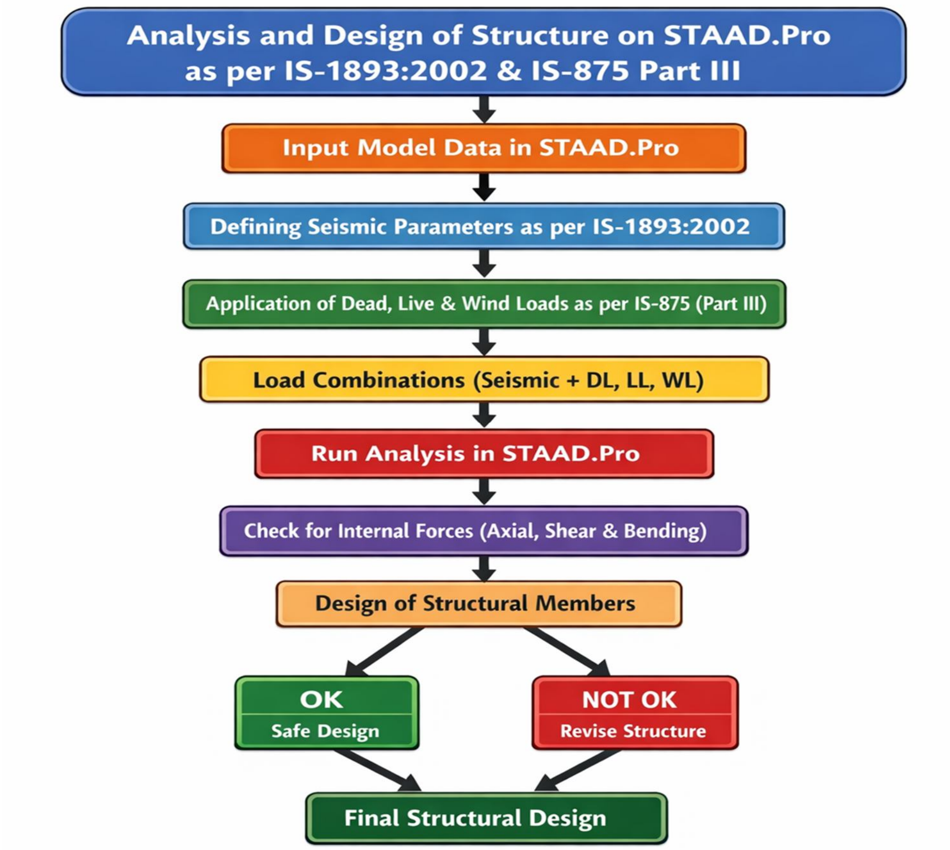

Figure 2 Flow of STAAD.Pro

IV. RESULTS

The structural analysis yielded critical data regarding the building's response to lateral loads, including storey-wise displacement, shear force, bending moment, and node displacement values for both 2D and 3D models[18].

Based on the provided context, the document content you shared does not contain information for a completed "Results" section. The text includes an Introduction, Literature Review, Methodology, and headers for Results, Discussion, and Conclusion, but the sections following the "Results" header are currently empty.

The provided content details the analysis steps, such as modeling a G+6 storey building in Zone II using STAAD.Pro and defining parameters like time periods (Ta = 0.85$ sec in the X-direction and Ta = 0.94$ sec in the Y-direction) and load combinations. However, these are classified under the Methodology section. The specific outcomes of this analysis, such as the final displacement, story drift, and shear force values for the models, are not included in the provided text.

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V. DISCUSSION

The analysis results demonstrate that the inclusion of shear walls significantly reduces lateral displacement and story drift compared to bare frame structures, while the equivalent static analysis method provides a conservative estimate of seismic forces that aligns with the design parameters established in IS-1893:2002 [19], [20]. This reduction in lateral movement is attributed to the high stiffness of shear walls, which effectively resist seismic and wind forces, thereby enhancing the overall stability and safety of the high-rise building [21], [22]. The findings further indicate that the placement of shear walls, particularly at the core or outer periphery, plays a crucial role in mitigating tension cracking and improving the structural integrity of tall buildings under dynamic loading conditions [3], [23]. The comparative evaluation of 2D and 3D models confirms that symmetrical configurations exhibit more uniform stress distribution than unsymmetrical arrangements, validating the effectiveness of STAAD.Pro in simulating complex dynamic behavior for seismic-resistant design [24]. The study concludes that shear walls are essential components for enhancing the lateral load resistance of high-rise buildings, as evidenced by the significant reduction in displacement and drift values observed in the STAAD.Pro analysis results.

VI. CONCLUSION

The study demonstrates that shear wall systems provide superior strength and stiffness for high-rise structures, with results indicating that lateral displacement and story drift are significantly minimized compared to bare frame configurations [23]. Furthermore, the equivalent static analysis method employed in STAAD.Pro yielded conservative estimates of seismic forces, confirming that the designed structure meets the safety requirements specified in IS-1893:2002 for buildings located in seismic zones [1], [12]. Specifically, the incorporation of shear walls was found to reduce lateral displacement by approximately 67% in the X-direction and 58% in the Y-direction, while also decreasing base shear and bending moments to ensure structural stability under dynamic loading conditions [25], [26].

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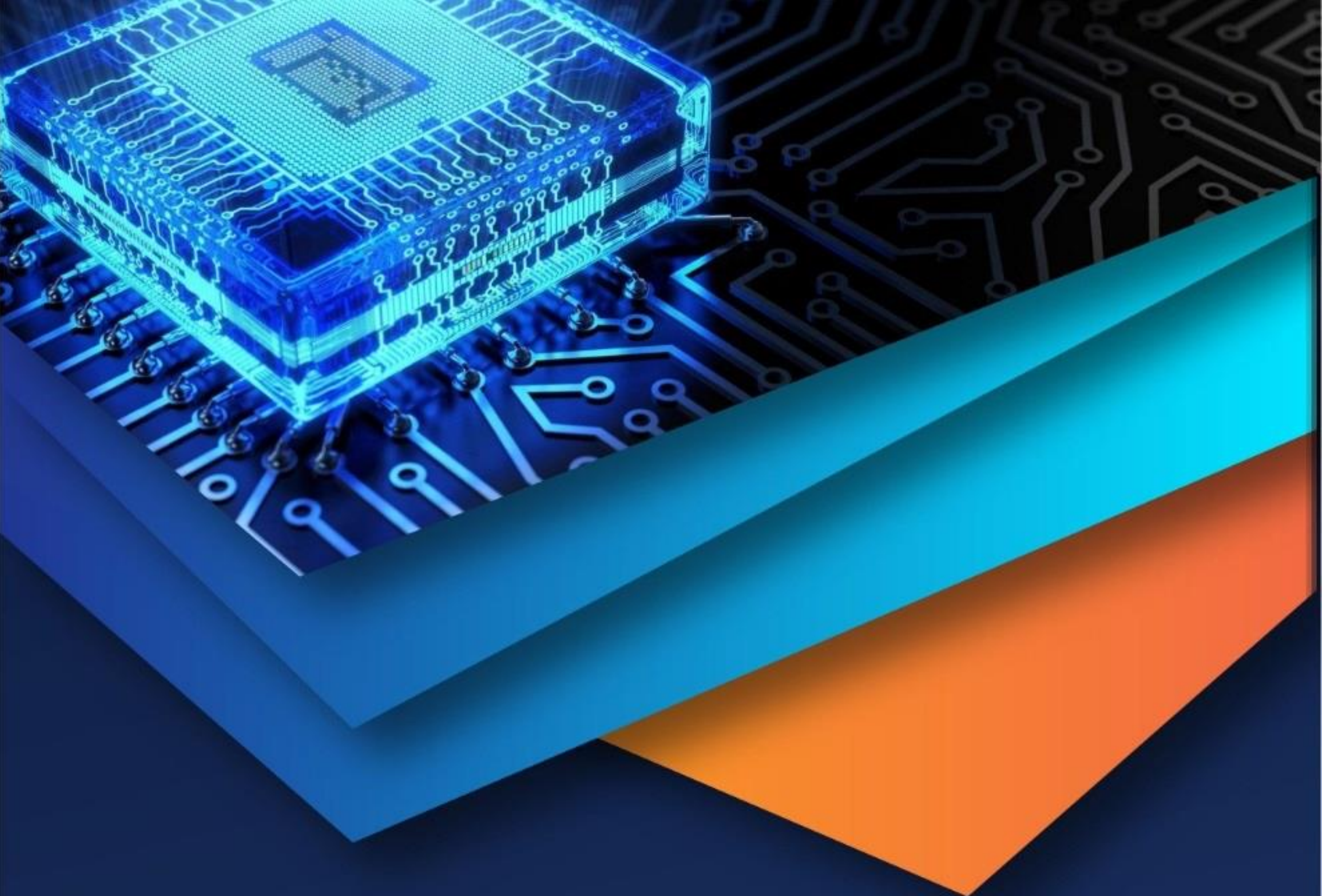

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