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Comparative Seismic Performance and Cost Evaluation of RC Structures in Seismic Zone II: Bare Frame, Shear Wall System, and Diaphragm Modeling using ETABS: A Review

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Abstract: In this thesis, a G+12 (13-storey) RC building located in Seismic Zone II with medium soil conditions is analyzed using ETABS. Three structural models are considered: a bare frame, a frame with shear walls, and a frame with diaphragm action. The seismic response of these models is compared based on key parameters including bending moment, shear force, axial force, torsion, story drift, story displacement, reinforcement quantity, and per floor cost. The inclusion of quantity and cost parameters enables a comprehensive assessment of both structural performance and economic efficiency.
The analysis results indicate that the structure with shear walls and diaphragm action exhibits superior performance by significantly reducing story drift and displacement, while also requiring a lower quantity of reinforcement. Consequently, this model results in the minimum construction cost compared to the diaphragm-only and bare frame systems. This study confirms that the integration of shear walls enhances not only seismic safety but also material efficiency and cost-effectiveness, making it a preferred solution for earthquake-resistant RC building design.
Keywords: Earthquake resistant building, Shear wall diaphragm, cost comparison, Seismic analysis, Structural engineering, ETABS.

I. INTRODUCTION

Powerful natural disasters like earthquakes have the ability to seriously harm structures. Building design that is earthquake-resistant has become essential to construction in order to reduce these risks, particularly in areas that are prone to seismic activity. A fundamental component of this design concept is the application of shear walls. A structure may encounter some of the most severe loading conditions during an earthquake, and if a structure collapses under these conditions, human life will unavoidably be in danger. A frequent site of failure for structures subjected to seismic loading is the junction of a beam and column. A loss of structural integrity and the collapse of floors, if not entire buildings, are possible outcomes of this kind of failure.

II. LITERATURE REVIEW

P. Sai Kumar Reddy et at (2025), In this paper, it is emphasized that the use of advanced structural analysis techniques significantly enhances the seismic performance of buildings in earthquake-prone areas. As the demand for safer and more resilient infrastructure grows, shear walls are recognized as effective lateral load-resisting elements that improve structural stability during seismic events. The study showcases the ETABS software as an essential tool for modeling, analyzing, and optimizing shear wall systems under seismic loads.

The literature indicates that variations in shear wall configuration such as location, cross-sectional dimensions, material properties, and reinforcement detailing have a marked impact on the overall structural response. Comparative evaluations across various building heights and seismic regions demonstrate that optimized shear wall placements lead to reduced lateral displacements and enhanced structural durability, all while maintaining material efficiency. Previous research provides critical insights for structural engineers in developing performance-based, economical, and code-compliant designs using advanced software like ETABS. Overall, the findings advocate for the creation of safer, smarter, and more sustainable urban structures in regions susceptible to seismic activity.

Amit Chauhan et al (2024), In this paper, it was found that a significant number of modern buildings exhibit irregularities in both plan and elevation, which may increase their vulnerability to severe seismic events in the future. Evaluating the seismic performance of such structures is essential for ensuring adequate safety in both newly constructed and existing buildings. In contemporary architectural practice, floor openings have become increasingly common to accommodate functional requirements such as staircases, lighting, and architectural features. However, these openings interrupt diaphragm continuity and introduce stress concentrations at the interfaces with structural elements.

The research indicates that discontinuous diaphragms are often designed without detailed stress evaluation, with the effects of openings frequently underestimated or neglected. This oversight can adversely influence the overall seismic response of buildings during earthquake excitation. Since earthquakes are natural hazards that cause widespread damage primarily through structural failure, it is critical to incorporate seismic-resistant principles during the planning and design stages. Nevertheless, current construction trends often prioritize architectural aesthetics over seismic performance, leading to the development of structures with irregular configurations that may not adequately resist earthquake forces. These findings highlight the need for rigorous seismic assessment and design consideration for buildings with plan and vertical irregularities.

B S Shamana et al (2023), In this paper, it is emphasized that seismic effects are crucial in the structural design of buildings, particularly in earthquake-prone regions. Earthquakes result from the sudden release of energy in the Earth's crust, presenting substantial risks to human life and infrastructure, especially in areas classified as seismically active. The adoption of structural systems designed to withstand horizontal forces and enhance strength, stiffness, and overall stability is essential. The study explores the seismic performance of multi-storey structures that integrate various earthquake-resisting components. Specifically, it examines the use of shear walls and bracing systems within moment-resisting frames to bolster lateral load resistance. A comparative seismic evaluation of high-rise buildings both with and without these structural elements was conducted using ETABS 2019, employing response spectrum analysis to assess key performance parameters: natural frequency, fundamental time period, base shear, storey stiffness, storey displacement, and storey drift. The results indicate that incorporating shear walls and bracings markedly improves seismic behavior, validating their role in enhancing structural performance when subjected to earthquake loads.

Mitali Shelke et.al (2022) The goal of the research paper was to use ETABS to analyze the structure for a G+7 storey with and without elastomeric base isolation and compare the outcomes in terms of storey parameters, displacements, drifts, and base share.

According to the response analysis, the base shear of the base isolated structure is less than that of the fixed base structure, suggesting that the base isolated structure's building response is superior. In contrast to a fixed base structure, a base isolated structure exhibits a small amount of lateral deflection. Building displacement from isolation increases as a result of increased structural flexibility. In contrast to the fixed base building, the base isolation system isolates the building from the earthquake.

Cem Yenidogan (2021), the objective of this paper is to provide an overview of the features of commonly used isolation systems in the industry using mathematical models, sustainable community design criteria, the current state of practice, and the established design requirements of specific, well-known standards, with a focus on the ELF procedure from the standpoint of performance-based design philosophy. Furthermore, the study's content includes two extensive seismic isolation applications from around the globe as benchmark studies for the new construction and upgrading scheme.

High-performance standards and earthquake resilience can be attained during the service life of the design code-compliant structures as a result of the targeted response modification.

In order to achieve cost-effective design with a high margin of safety in the future, it is imperative to increase the number of instrumented SI structures.

Jadhav Nachiket S. et.al (2020), The G+9, G+15, and G+20 storey residential structures' seismic analysis was examined in the research paper using Time History Analysis to determine the overturning moment and storey shear. The PEER Ground Motion Database was used to gather time history data. The effects of cross bracing, base isolation, fluid viscous damper, and shear wall were compared with ordinary moment resisting structures based on the maximum storey shear and storey overturning moment.

The maximum storey shear decreases as storey level increases, according to the results. For G+9, G+15, and G+20 storey structures, the maximum reduction in maximum storey shear happens in structures with base isolation and then with fluid viscous damper, as opposed to ordinary moment resisting structures. The maximum storey shear in the structures with cross bracing and shear walls increased by approximately 41.8% and 76.2%, respectively. When compared to other seismic-resistant components, a structure with base isolation minimizes storey overturning moment by 1.5% to 1.85% and is only appropriate when considering the maximum storey overturning moment. Shear walls placed on structural corners result in an increase in storey overturning moment of between 37.7% and 44.4%, so this placement of the shear wall is not ideal for designing.

Ayuddin (2020), The planned building has one to eight stories, with a concrete quality (f'c) of 33.2 MPa, a steel quality (fy) of 400 MPa, and a shear stress of 240 MPa. SNI 1726: 2012, which provides guidance on building structure and non-building, is one of the rules and regulations that apply in Indonesia. The building is analyzed through 3D structure modeling using the ETABS Version 9.7 program. This building design system is a high-rise structure designed with a portal frame system, where the main components of conventional concrete structures are columns and beams.

Based on the analysis, it can be concluded that the beam, plate, and column structural components are able to withstand various loading combinations with the SRPMK structure, which has very tight detailing, which calculates the risk level of an earthquake that is likely to occur. Besides, the function of the structure of this building is included in the category of earthquake risk in region IV, with the priority factor of the earthquake being Ie = 1.5. For the calculation of vibration time limitation, the structure vibration time that occurs does not exceed the required time. Based on the analysis, it can be said that the structural components of the beam, plate, and column can withstand different combinations of loads when used with the SRPMK structure. This structure has extremely precise detailing that determines the likelihood of an earthquake occurring. Furthermore, the building's structure falls under the category of earthquake risk in region IV, with Ie = 1.5 serving as the earthquake's priority factor. The vibration time of the structure does not surpass the required duration when calculating the vibration time limitation.

K. Surender Kumar et al (2020), the goal of this paper is to identify more effective analyses for load case creation, load combinations, support reactions, column and beam reinforcement, etc. Afterwards, reviewing (whether the column or beam failed or passed the loads). This comprehensive design analysis is a case study of a building project that is currently under construction in Hyderabad, and the building analysis is conducted using standard code books (IS 456: 2000, SP 16).

The same structure was designed for the results in STAAD and ETABS. professional software. Both software's calculations yield nearly identical results. The eight-story building's ETABS and STAAD floors are comparable. Pro is the ideal program that can be used for analysis. Application of STAAD and ETABS. Expert software reduces the amount of time needed for design and analysis.

Raja Gowhar et al (2019), the current study, "Earthquake Resistant Design of Multistory Building," by ETABS, aims to define strategies for maintaining structural stability by using regular geometry, appropriate column and beam cross sections, and other design elements. It also develops specifications and support conditions, types of loads, and load combinations. This study uses ETABS to analyze a G+25 storey high rise structure for seismic load combinations. A comparison is made by substituting a column for a shear wall. It was determined that the frame in Zone IV was suitably designed for seismic loads. The structure is designed in accordance with IS 1893(Part 1):2016. Comparing the variations in steel percentage, maximum shear force, maximum bending moment, and maximum deflection in seismic zone IV is the primary goal of this paper.

According to the findings, the maximum storey drift is.0306, which is less than the IS 1893-2016 permissible drift of 0.312. Seismic zone IV considers the building to be safe. Different seismic zones yield different results. Storey drift is a major factor contributing to seismic activity collapse in open frame structures. Without a shear wall, the storey forces and BM are higher; on the other hand, a shear wall lessens base shear and drift. In a frame structure, reinforcement entails more than just switching out columns for shear walls. Properties such as drift, shear force, moment, and displacement are insufficient because of the floating column.

AKASH KUMAR et al (2019), the author is currently employed in a multi-story, G+21 earthquake-resistant reinforced cement concrete building. In India, different earthquake zones have different requirements for building design. However, I've selected earthquake zone III (LUCKNOW), which is classified as a moderately risky area. ETABS software was used to design the structure. These projects categorize seismic analysis based on lateral forces and earthquake effect. The importance of designing and building an earthquake-resistant structure cannot be overstated worldwide.

According to the conclusion, the author's design is currently being implemented in a multi-story reinforced cement concrete building that is earthquake resistant and has 21 stories. In India, different earthquake zones have different requirements for building design. However, I've selected earthquake zone III (LUCKNOW), which is classified as a moderately risky area. ETABS software was used to design the structure. These projects categorize seismic analysis based on lateral forces and earthquake effect. The importance of designing and building an earthquake-resistant structure cannot be overstated worldwide of the structure was discovered to be stable, and etabs was discovered to be a better piece of software for designing structures. The building will be a safe zone once I have thoroughly examined and measured all of the joints in the beams and columns. In an earthquake, the width of the beams and columns should be equal, allowing for very economical bonding between them.

Kavita Verma et al (2018), This paper uses STAAD Pro to analyze and design G+6 buildings in various seismic zones of India. The earthquake force analysis is done in accordance with IS 1893(part1):2002. Varying from Zone II to Zone V increases variances.

Steel percentage, maximum shear force, maximum bending moment, maximum deflections, and other variations are examples of variations.

Zone II to Zone V exhibits greater variations in the results. The percentage of steel in an external column can range from 0.9 to 1.6 and 2.5. In the case of edge columns, the steel percentage ranges from 0.9 to 1.6 and 2.5. The percentage of steel in interior columns ranges from 1.13 to 2.01 and 2.

Taruna R Kamble et al (2018), This project's goal is to use STAAD.Pro and ETABS to analyze a high-rise (G +20 story) building in 3-D frame. The project's dynamic analysis of an RC building with a shear wall aims to understand the structure's seismic behavior. The project also includes a Response Spectrum Analysis to verify the building system's response with a long column in the key plan. Modern user interfaces, visualization tools, and robust analysis and design engines with sophisticated finite element and dynamic analysis capabilities are all features of STAAD.Pro and ETABS. STAAD.Pro and ETABS are the professionals' choice for everything from modal generation, analysis, and design to result verification and visualization.

A system that effectively resists lateral loads is obtained by presenting test results that include base shear and story drift. provides the modal mass participation value as well as the design outcomes for the column and beam with the shear wall. The investigation of the structures' seismic response to an earthquake is done in this study using member forces and joint displacement as indicators. The response for G+20 building structures is examined through the use of ETABS and STAAD Pro design software.

Rajat Srivastava et al (2018), this study uses joint displacement and member forces as indicators to investigate the seismic response of the structures to an earthquake. ETABS and STAAD Pro design software are used to analyze the response for G+20 building structures.

The research paper makes it possible to compile knowledge about structural analysis and design during seismic events. Given that the project building is situated in the Delhi (Zone 2) region, we have prioritized the earthquake load over other factors. The building is examined more thoroughly using the Staad.Pro program, which is currently a useful tool for analyzing frames under various loading conditions.

Test results including base shear and story drift are presented in order to create a system that effectively resists lateral loads. supplies the design results for the column and beam with the shear wall along with the modal mass participation value. In the paper, values were entered into required fields in the software and the design and detailing of every necessary building element were calculated manually.

A. Ravi Kumar et al (2017), the goal of this study was to identify the optimal location for the shear wall in a multi-story building by analyzing its elastic and elasto-plastic behaviors. It is necessary to compute and apply the earthquake load to a multi-story building with a plan size of 26 m by 26 m and 10 (G+9) floors that are 40 m high. The model's effective shear wall location is determined by calculating and analyzing the results. The design above is verified for this same structure using extended three dimensional analysis of buildings (ETABS) software. There is a comparison of the outcomes. The sophisticated program ETABS is used to analyze any type of building structure. It is capable of accurately and swiftly analyzing structures up to forty stories high.

With this software, shear wall design is completed independently using various load combinations. Any building structure with predefined load conditions and load combinations for shear walls in accordance with IS codes can be analyzed by ETABS. Therefore, if we use ETABS software to design a building's shear wall structure, it will analyze the building easily and provide quick results with accurate data. Due to the rapid population growth in India, the majority of people suffer from homelessness. We can add more floors and more people to a building in a small space by using this shear wall design. Because of this, shear wall construction is regarded as the foundation of the building industry in developing countries like India.

M.Gopinath et.al (2016), STAAD was used to create a building model for the research paper.Pro software was used to create the model shear wall and bracings. Storey drift and displacement were computed using a static method based on seismic analysis.

There was a lot of lateral displacement in the soft storey frame. In the building where a shear wall is inserted in both the X and Z directions, the minimum displacement for the corner column is noted. The extra strength in an RC frame that is braced comes from both the brace system's added strength and the RC frame's increased strength from the connections' stiffening effects. The number of braced bay connections taken into account as a stiffness ratio is recognized as the significant parameter affecting the capacity interaction. Structures with bracing have a higher ductility value than those without a bracing system.

V. ABHINAV et al (2016), In this instance, an eleven-story RCC building exposed to seismic loading in Zone-V is taken into consideration. Using IS 1893(PART-I):2002, the seismic coefficient method is used to calculate an earthquake load. The three separate shear wall position installments for the eleven-story building are subsequently analyzed. The results of the four analyses mentioned above will be compared, and the shear wall frame structure will be optimized and suggested for the building under consideration. This analysis can help you stay flexible from the frame structure while also achieving safety against earthquakes.

In order to withstand lateral forces, it has been determined that the inclusion of shear walls in multi-story buildings is becoming necessary. In Zone-V, the type II shear wall that this analysis suggests is more effective and can achieve the highest level of safety against earthquakes.

Piyush Tiwari et al (2015), The writers of this work looked into the earthquake resistance of an open ground floor building. Using commercial Etabs software, three different models of an existing RC-framed building with an open ground floor located in Seismic Zone V are taken into consideration for the study. A diagonal strung method was used to model infill stiffness with openings. For these models, both linear and nonlinear analysis is done, and the outcomes are compared.

The presence of an infill wall in the upper stories results in an increase in column forces at the ground floor, according to linear (static/dynamic) analysis. It was discovered that the design force Multiplication factor was significantly less than 2.5. Base shear is underestimated as a result of seismic analysis of the bare frame structure. Underestimating base shear causes a structure to collapse when an earthquake is occurring. As a result, it's crucial to take the infill walls into account when doing a structural seismic analysis. The Multiplication factor for (G+4) varies 41.2 % (Column) and 42.8 % (Beam) less than what is required by IS Code of 2.5 Value, according to the ESA and RSA results. Comparably, it is 36% and 40% for (G+7) and 32.4 and 40% less for (G+12) than what the IS Code of 2.5 indicates.

Mr. S.Mahesh et al (2014), In this paper, ETABS and STAAS PRO V8i are used to study the seismic and wind loads of a residential G+11 multistory building.Analyses are conducted, assuming that the material property is linear in both static and dynamic terms. These analyses take into account various seismic zones, and the behavior of each zone is evaluated using three distinct soil types: hard, medium, and soft.Plotting of various responses, such as base shear, story drift, and displacement, is done for various zones and soil types.

According to the findings, zone 5 and the soft soil with an irregular configuration had higher base shear values. Moreover, zone 5 and the soft soil in a regular configuration have higher base shear values. The regular configuration has a higher base shear value when compared to the irregular configuration. Due to the more symmetrical dimensions of the structure. The story drift value is higher in the regular configuration when compared to the irregular configuration. due to the fact that the structure is larger. In the end, the STAAD PROV8i software is more valuable than the other one. The steel makes up 5–10% of the area.

Sean Wilkinsona et al (2005), In order to strengthen earthquake-resistant structures, a novel moment-resisting detail is suggested in this paper. In order to dissipate the energy that would otherwise yield the connection, a plastic hinge is induced away from the column face in a novel design known as the wedge detail tested in this project. By reducing the depth of the web and reforming the flange to the new beam profile, the plastic capacity of the beam is locally reduced. This increases the section's plasticity and lessens the buckling issue that other reduced section joints experience.

According to laboratory testing, the joint can achieve plastic rotations greater than 0.05 rad without experiencing a significant loss in energy dissipation capability. This is significantly more than what the latest standards for joints based on post-Northridge data require. The connection needs to be strong enough to allow the beam's entire plastic moment to develop. To meet the presumption that it is a fully rigid connection, the connection needs to be sufficiently stiff. Large post-yield deformation capacity without appreciable strength loss is required for the connection.

Shunsuke Otani (2003), This study provides an overview of the evolution of building design that is earthquake resistant. The 1930s saw the beginning of ground acceleration measurement, and the 1940s saw the development of response calculation technology. The late 1950s and early 1960s saw the formulation of design response spectra. The 1960s saw the introduction of non-linear response in seismic design, and the 1970s saw the widespread introduction of the capacity design idea for collapse safety.

As per the results it is important to highlight the importance of performance-based engineering; a building should meet the intended structural performances for a given set of loading conditions. In the future, damage control and keeping buildings functional after an earthquake will become crucial issues. New building materials, structures, and technologies should be applied for this purpose.

Durgesh C. Rai (2000), the writers of this paper talked about the trends that will affect earthquake resistance construction in the future. The design of structures that withstand earthquakes has developed into a genuinely multidisciplinary field of engineering, with many exciting advancements anticipated in the near future. The most noteworthy of these are new structural systems and devices using non-traditional civil engineering materials and techniques; performance-based design codes; a comprehensive probabilistic analysis and design approach; multiple annual probability hazard maps for response spectral accelerations and peak ground accelerations with improved characterization of site soils, topography, and near-field effects; and new refined analytical tools for reliable prediction of structural response, including nonlinearity, strength and stiffness degradation due to cyclic loads, geometry effects, and most importantly effects of soil–structure interaction.

This paper discusses some important developments that we will see in the next years.

Along with the growth of non-traditional civil engineering materials and techniques, new structural systems and devices for base-isolation, passive energy dissipation, and active control systems will continue to be developed. New devices and materials will be regularly added to analytical tools for accurate structural response prediction, which are crucial tools in performance-based design processes. These tools will keep getting better.

R. I. Skinner et al (1974), In this paper, an earthquake-resistant building was constructed using hysteretic dampers. Many structures can have their earthquake resistance increased by adding unique parts that function as hysteretic dampers. These dampers function as stiff members that lessen structural deformations during earthquakes of a moderate severity. In earthquakes of a very severe nature, however, the dampers serve as energy absorbers that restrict the quasi-resonant accumulation of forces and structural deformations.

It was discovered from the conclusion that torsional-beam dampers or flexural-beam dampers could be used to construct buildings with a base isolation system in a convenient manner. Research is being done on composite base-isolating devices, which include laminated rubber bearings and flexural-beam dampers. These composite isolators may have parts that prevent the structure's base from being raised. It should be feasible to offer extremely dependable protection against both structural and non-structural damage with base-isolated structures.

III. CONCLUSION

"In this paper, we reviewed several research studies related to our topic.Various software tools and analytical methods were examined. The review helped us understand existing approaches and findings in this area".

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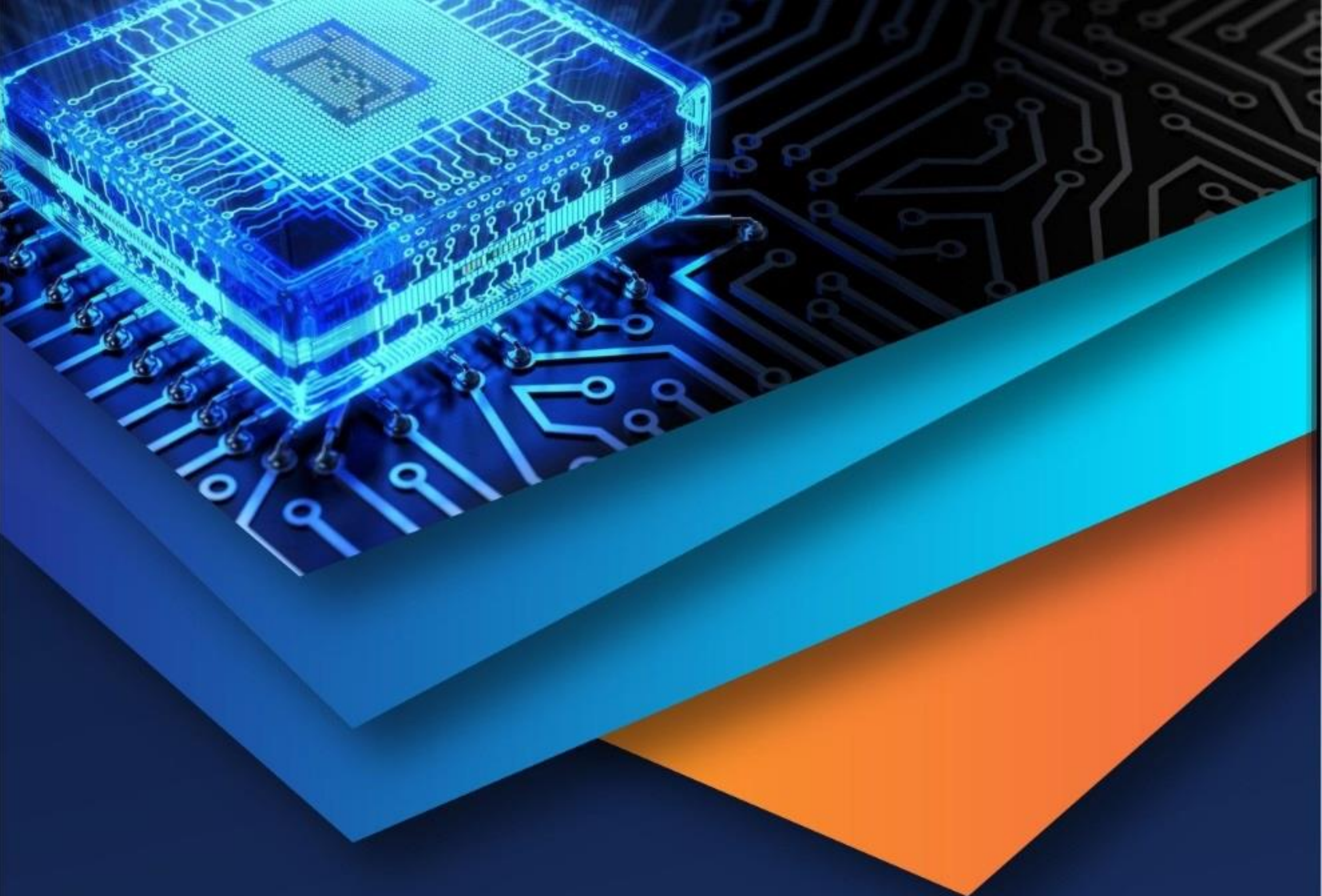

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