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Improving Multistory Building Stability: A Review on Effects of Varied Concrete Grade in Beams at Different Floor Levels

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Abstract: In order to address the issue of decreasing living space and the increasing use of high-rise structures, many countries are pursuing sustainability goals. Multistory buildings, which require less land area, can help transform a city into a metropolitan hub and attract investments. The construction of tall buildings has the only viable option as it maximizes space efficiency. This study extensively reviews various papers related to this topic, with a significant body of work having already been conducted in this field. To ensure that these buildings are cost-effective, safe, and suitable, new ideas and expertise are essential. Stability enhancement techniques are particularly relevant in the field of structural engineering. This literature review provides valuable insights and findings to aid in this pursuit, we came to know the conclusive outcome that aim to provide technical insights and recommendations for future research in this area.
Keywords: Concrete grade, Beam member, Grade change levels, Shear wall, Dual system.

I. INTRODUCTION

The primary need in today's world has to utilize limited land area efficiently, which has led to the construction of tall and high-rise structures. However, the threat of seismic disasters has necessitated the use of a dual structural configuration to provide lateral stability to these buildings.

The construction industry has evolved to incorporate cost-effective practices, but achieving structural stability without compromising on economic efficiency has a challenging task. This is because ensuring stability often requires the use of heavy structural components, which can contradict the economic trend.

Therefore, striking a balance between financial and commercial considerations while ensuring structural stability remains a crucial aspect of modern construction practices.

The primary challenge has to ensure earthquake resistance requires additional costs and supplementary stiffening members. The addition of heavy reinforced concrete (R.C.C.) components increases the overall weight of the structure, which in turn increases the base shear. To address this issue, it has crucial to minimize the weight of the structure as much as possible to achieve the desired level of earthquake resistance.

A. Criteria of Stability Increment Techniques

Structural stability can be improved by altering the configuration of the structure to affect its overall behaviour. Extensive research in this field has demonstrated that stability can be increased both with and without the addition of extra components. Introducing response reduction criteria can reduce the self-weight of the structure while also enhancing its stability.

The stability increment techniques can be achieved by:-

1) By eliminating the structural components.
2) By reducing the weight of the structure.
3) By changing the size of the structural components.
4) By implementing some stability improvement structural components that resist the lateral and vertical loads.
5) By changing the grade of concrete.

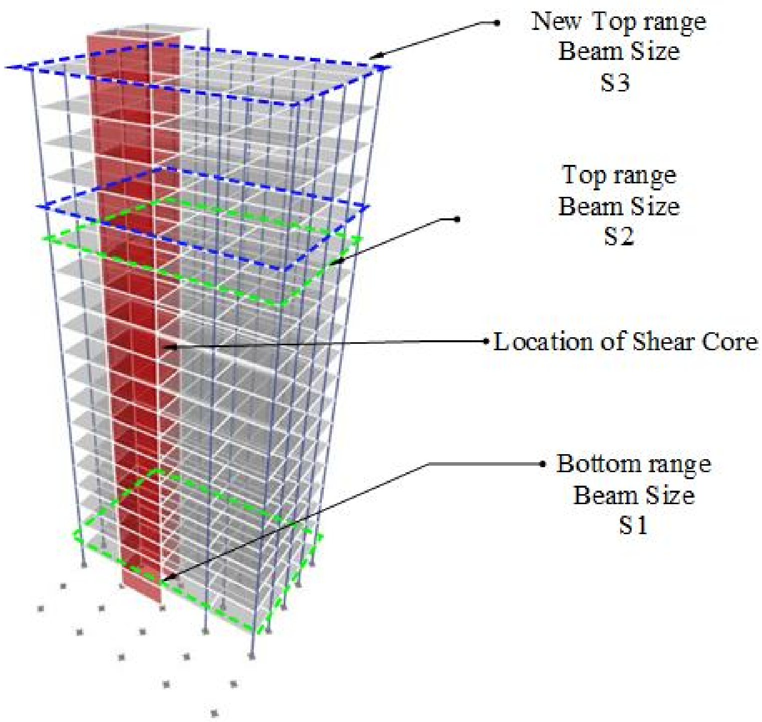

Fig. 1: Structure with Dual Structure Configuration and Stability Increment Techniques

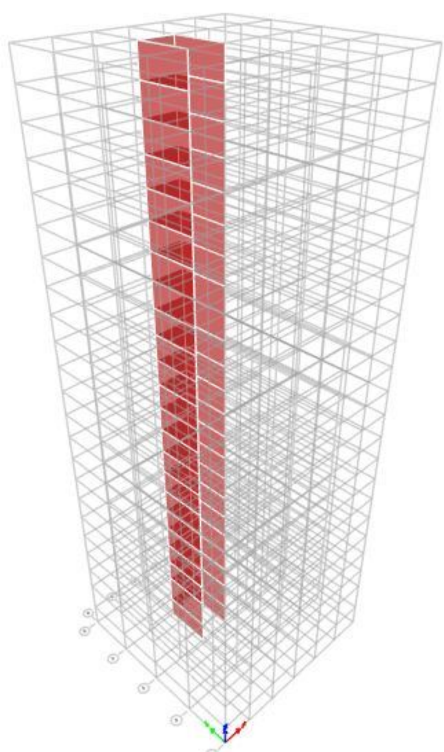

Fig. 2: Structure with shear Wall at Core

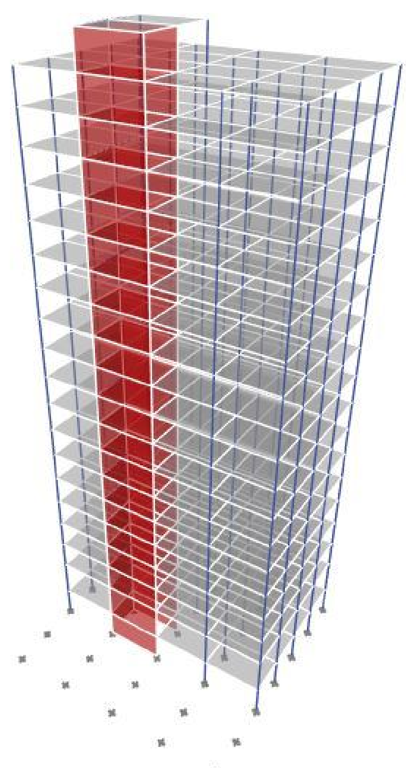

Fig. 3: 3D Sectional View of Structure with basic Base Shear Reduction Techniques

II. REVIEW OF LITERATURE

The research aims to determine the practical limit for rectilinear ties under moderate to high axial load levels and reversed cyclic lateral displacement excursions when using high strength steel as confining reinforcement. The ACI 318-02 building code indicates that the use of high strength steel as confining reinforcement can reduce congestion caused by high concrete strengths. As concrete strength increases, the CAN3-A23.3-M94 and NZS 3101:1995 expressions require a higher volumetric ratio of confining reinforcement, which can result in impractical tie spacings. To address this issue, the NZS 3101:1995 standards allow for the use of high strength steel (up to 800 MPa) as tie reinforcement. (Oguzhan Bayrak et. al.)

In the research paper, a nonlinear dynamic analysis computer program (IDARC-M) was used to conduct an analytical study on High Strength Concrete (HSC) building frames. The study takes into account the HSC beam-column connections as an integral part of the ten-story HSC frame. Unlike conventional investigations, this work examines the inelastic behavior of an interior beam-column connection on the first floor. Results show that the use of HSC enhances the column capacity, increases the rigidity of beam-column joints, reduces the effect of lateral reinforcement distribution in beams and columns, and decreases the fundamental natural period of the frame. Additionally, the type of column support at foundation level was found to have a significant impact on the drift of the building frame. (I. G. Shaaban et. al.)

The paper presents a study on the use of self-consolidating concrete (SCC) mix with Alccofine-1203, superplasticizer, viscosity modification agent, and crimped steel fiber in reinforced-concrete (RC) beam column joints. The study involves eight RC column joints with M25 grade concrete, where two serve as Alccofine, two as Alccofine-5%, two as Alccofine-10%, and two as Alccofine-15%. All specimens are tested until failure under compression in a 2000 kN capacity loading frame. Results indicate that the Alccofine-10% mix has a higher loading capacity compared to Alccofine-5% and Alccofine-15%. Nonlinear finite element analysis (FEA) through ANSYS software was used to model and analyze the beam column joint. The results obtained through ANSYS modeling show good agreement with the experimental results, with a predicted detection ductility of 1.59 in the Alccofine-10% mix. The study validates the use of ANSYS software for predicting the parameters of self-consolidating concrete in beam column joints. (G. Vimal Arokiaraj et. al.)

The objective of the study was to investigate the behavior of concrete columns reinforced with newly developed high-strength steel under eccentric loading, with a focus on reducing steel bar congestion and construction costs. Ten reinforced concrete columns were constructed and subjected to various test variables, including transverse reinforcement amount and yield strength, eccentricity, and longitudinal reinforcement yield strength. The failure patterns were compression and tensile failure, depending on the level of eccentricity. The use of high-strength transverse reinforcements in columns with small eccentricity resulted in the same level of post-peak deformability and ductility with lower amounts of transverse reinforcement. Additionally, the use of high-strength longitudinal reinforcement improved the bearing capacity and post-peak deformability of the concrete columns. The study also discusses three different equivalent rectangular stress block (ERSB) parameters for predicting the bearing capacity of columns with high-strength steel. The findings suggest that the China Code GB 50010-2010 overestimates the bearing capacity of such columns, while the American Code ACI 318-14 and Canada Code CSA A23.3-04 are in good agreement with the test results. (Yonghui Hou et. al.)

The paper presents experimental data on the use of high-strength steel as longitudinal reinforcement in concrete frame members for earthquake-resistant construction. The study involved six concrete specimens subjected to displacement reversals, with two specimens reinforced longitudinally with steel bars Grade 410, two with Grade 670, and two with Grade 830. The study also varied axial load and volume fraction of hooked steel fibers. The loading protocol consisted of repeated cycles of increasing lateral displacement reversals followed by a monotonic lateral push to failure. The test data showed that replacing conventional Grade-410 longitudinal reinforcement with reduced amounts of Grade-670 or Grade-830 steel bars did not cause a decrease in usable deformation capacity or flexural strength. The study concludes that the use of advanced high-strength steel as longitudinal reinforcement in frame members was a viable option for earthquake-resistant construction. (Andres Lepage et. al.)

This study aimed to investigate the seismic behavior of columns in Ordinary Moment Resisting Concrete Frames (OMRCF) and Intermediate Moment Resisting Concrete Frames (IMRCF). Two three-story OMRCF and IMRCF structures were designed according to the minimum requirements specified in ACI 318-02. The buildings were assumed to be located in seismic zone 1, as classified by UBC. ACI 318-02 specifies less stringent reinforcement detailing requirements for OMRCF compared to IMRCF or SMRCF (Special Moment Resisting Concrete Frames). 2/3 scale model columns were used to evaluate the seismic behaviors of OMRCF and IMRCF columns through quasi-static reversed cyclic loading with constant or varying axial forces. The test variables included the type of axial force, the existence of lap splices, and the type of moment resisting concrete frame.

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The results showed that all OMRCF and IMRCF column specimens had strengths greater than required by ACI 318, and drift capacities greater than 3.0% and 4.5%, respectively. However, the drift capacity of specimens varied based on the existence of lap splices and the spacing of lateral reinforcement at column ends. (Sang Whan Han et. al.)

The study aimed to develop a new preparation scheme for lightweight foamed concrete using recycled concrete aggregate (RCA) from old city reconstruction waste. The researchers conducted single-factor tests to investigate the effects of RCA gradation, RCA volume ratio, water-cement ratio, and foam content on the preparation process and performance of RCA foamed concrete (RCAFC). The results showed that the grading of RCA had a significant influence on the performance of RCAFC. Grading level III was found to be the most effective, reducing water absorption by 4.6%, increasing compressive strength by 6.0%, and making sample preparation less difficult compared to natural grading. Increasing the volume fraction of RCA was directly proportional to compressive strength and inversely proportional to water absorption. As the water-cement ratio increased, the fluidity of the foamed concrete paste increased linearly, while dry density decreased, water absorption decreased first and then increased, and compressive strength increased first and then decreased. Increasing foam content was found to be inversely proportional to fluidity, dry density, and compressive strength, and directly proportional to water absorption. Overall, RCA grading had the greatest impact on the early strength of the sample, while foam content had the smallest impact among the four factors investigated. (Shangyu Han et. al.)

It ahs important to consider the seismic performance of buildings during the design process. One way to improve this performance was by using specially shaped columns instead of regular ones. Specially shaped columns can help to avoid prominent corners in a room, which can increase the usable floor area and potentially improve the building's seismic performance. There has been previous research done on the effect of different column shapes on the seismic performance of buildings, and this paper presents a review of that research. By understanding the impact of column shape on seismic performance, designers can make more informed decisions about the construction practices they use. Overall, it has important to consider modified construction practices in order to improve the seismic performance of buildings and ensure their safety during earthquakes. (Shruti S. Ladvikar. al.)

In the study, the effectiveness of two-layer reinforced concrete beams with varying grades of concrete was investigated. To accomplish the research objective, twelve reinforced concrete beams measuring 1200mm x 100mm x 150mm (with two 10mm diameter rebars in the tension zone, two 8mm diameter rebars as hanger bars, and 6mm diameter rebars spaced at 200mm as shear bars) were constructed according to BS 1881-109:1983 specifications. Three of the beams were control reinforced concrete beams made entirely of higher-grade concrete (1:2:4 mix ratio). The remaining nine beams were divided into different groups, including Type-P with beams and cubes made entirely of higher-grade concrete (1:2:4 mix ratio), Type-E1 with a higher-grade (1:2:4 mix ratio) compression layer (half the depth) and a lower-grade (1:3:6 mix ratio) tension layer (half the depth), Type-E2 with a lower-grade (1:3:6 mix ratio) compression layer (half the depth) and a higher-grade (1:2:4 mix ratio) tension layer (half the depth), Type-E3 with a higher-grade (1:2:4 mix ratio) compression layer (two-thirds the depth) and a lower-grade (1:3:6 mix ratio) tension layer (one-third the depth), and Type-E4 with beams and cubes made entirely of lower-grade concrete (1:3:6 mix ratio). All the reinforced concrete beams were flexurally tested after 28 days of curing over a 1100mm span at two points of load application. Dial gauge was placed at the midpoint beneath the beam, and the load was incrementally applied at 3.66kN intervals using a hydraulic jack. Deflection was recorded at each 3.66kN increment using the dial gauge. The test results showed that the two-layer beam achieved nearly the same bending resistance as the control reinforced concrete beam made entirely of higher-grade concrete. However, the control reinforced concrete beam made entirely of higher-grade concrete performed about 3.4%, 8.7%, and 0.2% better than Type-E1, Type-E2, and Type-E3, respectively. (John A. Trust God et. al.)

To investigate the behavior of column shapes, a comparative analytical study was conducted. The study focused on two column shapes: circular and rectangular, with the height and cross-sectional area being kept constant, and the study utilized the OMRF (Ordinary Moment Resisting Frame) approach. Seismic forces were taken into account to determine the realistic behavior of the structures. The analytical approach involved two models, with the dimensions of the columns and beams being determined according to construction practice requirements. The study's conclusion was based on the analysis of floor-wise shear forces, and equations for these forces were developed. (Gourav Sachdeva et. al.)

The study compares the performance of conventional and high-strength concrete using stress-strain response as a tool. Two sets of mix compositions, M40 and M80 grade concrete, were designed and checked for target strength using load-controlled tests on 28-day cured cube specimens. M40 grade concrete consisted of cement and water as binding material, and fine and coarse aggregates as filler, while M80 grade concrete was designed with cement, mineral admixture, and water as binding material, and fine and coarse aggregates as filler. Superplasticizer was added in required proportion to ensure adequate workability of the high-strength concrete. Displacement control tests were performed on 28-day cured cube specimens, with controlled strain rate.

The variability in pre-peak and post-peak stress-strain response was analyzed for both conventional and high-strength concrete, and an average response over at least four samples was computed for both M40 and M80 grade concrete. The characteristic response was normalized with respect to peak strength to obtain a common reference basis for comparison. The change in pre-peak response and post-peak ductility was then summarized for both types of concrete, enabling the quantification of relative performance changes between M40 and M80 grade concrete. These results are significant for benchmarking the performance of high-strength concrete structures against conventional concrete structures. (V. Bhonde et. al.)

The objective of the research was to examine the influence of carbon steel grade on corrosion resistance in a synthetic concrete pore (SCP) solution. Two grades of carbon steel, GR-60 (420 MPa) and GR-80 (550 MPa), as specified by ASTM A615-16, were selected for investigation. The open circuit potential (OCP) and Tafel polarization plots were utilized in this study and were conducted at a temperature of 24 °C. Additionally, metallographic inspection was also performed on both grades. The electrochemical corrosion behavior of the two steel grades was evaluated in the same SCP solution. Results showed that the open circuit potential of GR-80 (-375 mV) was nobler than that of GR-60 (-385 mV), indicating that the passive layer of GR-80 had better quality. Moreover, the cathodic slopes of the Tafel plot for both grades were approximately equal, with 0.111 V/decade for GR-80 and 0.107 V/decade for GR-60. However, the anodic slope of GR-60 (0.257 V/decade) was relatively higher than that of GR-80 (0.222 V/decade), indicating a higher dissolution of iron (F++) ions for GR-60. Consequently, the findings obtained through the mixed potential theory and Faraday's law showed that the corrosion resistance of GR-80 (0.305 μm/y) in the same environment was greater than that of GR-60 (0.353 μm/y) due to chemical changes and variations in the steel's matrix microstructural characteristics that affect the protective oxide layer formed on the steel surface. (Ahmed Kareem Abdulameer et. al.)

The recent earthquakes around the world have brought attention to the poor performance of beam-column joints in reinforced concrete moment resisting frame structures. As a result, extensive research has been conducted to understand the complex mechanisms and ensure safe behavior of these joints, leading to code recommendations. This paper provides a critical review of the design and detailing aspects of beam-column joints recommended by well-established codes, namely ACI 318M-02, NZS 3101: Part 1:1995, and Eurocode 8 of EN 1998-1:2003. All three codes aim to fulfill the bond and shear requirements within the joint. However, ACI 318M-02 requires a smaller column depth compared to the other two codes, based on the anchorage conditions. While NZS 3101:1995 and EN 1998-1:2003 consider the shear stress level to obtain the required stirrup reinforcement, ACI 318M-02 provides stirrup reinforcement to maintain the axial load capacity of the column by confinement. The paper identifies the significant factors influencing the design of beam-column joints and compares the effect of their variations on design parameters. The three codes show substantial variations in the requirements for shear reinforcement, which is an important consideration for the design of beam-column joints. (S. R. Uma et. al.)

III. CONCLUSIONS AND OUTLINE OF PROPOSED WORK

After analyzing the literature reviews and the overall theme of this study, we have come to the realization that no previous research has discussed the new approach proposed in this study for mitigating the worst effects on the structure.

Specifically, no one has given adequate importance to stability improvement criteria under various conditions, especially through the alteration of beam members. Considering the seismic effects on structures, it has crucial to pay attention to stability-improving components. We have also examined IS codes that outline various fixed criteria related to this field and are relevant to the current study.

The conclusive outcomes drawn from this study are enlisted below:

1) Prior to commencing any proposed work, the seismic zone should be checked to determine the final dual structural configurations.
2) Earthquake parameters should be analyzed and validated as per Indian Standards and within the acceptable limits.
3) Checking the lateral effects in the form of displacements is always necessary.
4) To calculate lateral effects, it is necessary to conduct a study for both directions for many reasons.
5) Soil type should also be checked in accordance with Indian Standardization IS 1893-2016.

The final work in this field after the conduction of literature review is that there should be an approach to increase the stability by changing grade of concrete at different floor levels in beam component and that has going to be a major study for upcoming proposed work.

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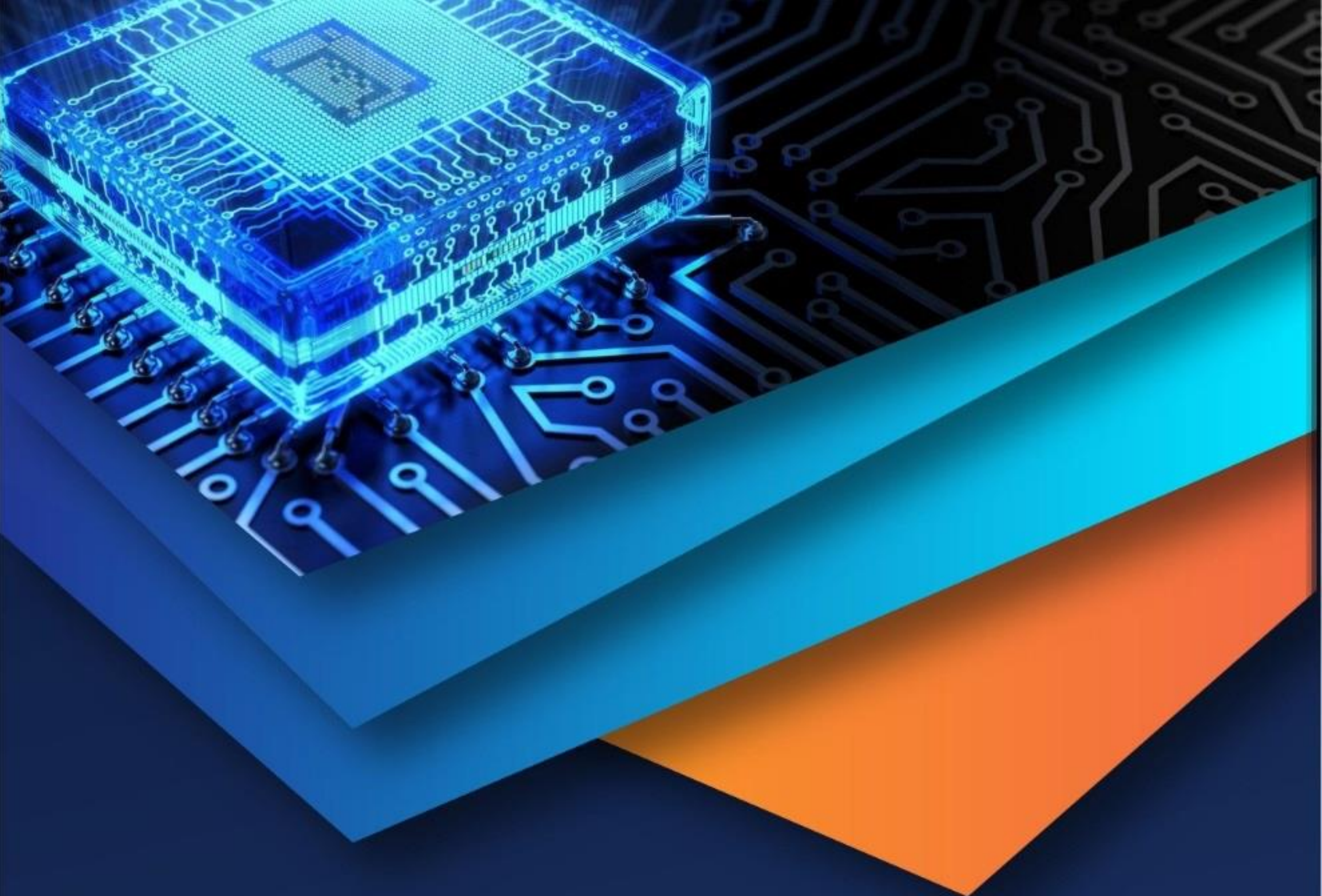

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