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Use of Outriggers in Tall Structure Building: A Review

Sagar Jain[1], Dr. Savita Maru[2]
[1, 2]Department of Civil Engineering, Ujjain Engineering College, Ujjain, (M.P.), India

Abstract: The rising demand for high-rise and aesthetically captivating structures with vertical and horizontal irregularities, unique architectural themes, and increasing heights has introduced new challenges and necessitated the implementation of advanced safety measures.
To resist earthquakes and the significant impact of wind caused by increasing building height, preventive structural systems need to be adopted, as the stiffness of the structure increases with its tallness. Bracings, shear walls, and outrigger systems are some of the structural mechanisms used for stability.
In this study, the outrigger system is analyzed, as it is considered the most optimal solution for high-rise buildings and skyscrapers. In this system the external columns are connected to main inner or outer core by means of outrigger wall at different floors that resist entire structure against collapse and rotating action of core due to worst horizontal effects seismic and wind forces. In this study various papers allied to this topic are reviewed in which an enormous work is done in this field earlier. With the help of review of research paper we came to know about the conclusive outcome which forms the research objectives of our further study.
***Keywords*: Outrigger system, Wind loading, Gust factor method, Tall structure, Seismic effects.**

I. INTRODUCTION TO TALL STRUCTURE

Tall structures, also known as high-rise or skyscraper buildings, are characterized by their significant height, often exceeding 35 meters or 12 stories. These structures are designed to accommodate large populations or commercial activities in densely populated urban areas. However, their height and complexity make them vulnerable to various challenges, including structural instability, wind loads, seismic forces, and fire hazards. Technological advancements, such as improved materials, innovative structural systems, and performance-based design approaches, have enhanced their safety and resilience. In the current scenario, tall structures are increasingly common in major cities worldwide, driven by urbanization and the demand for vertical expansion. Sustainable building practices, including energy-efficient designs and green building certifications, are also gaining prominence. Despite the benefits, tall structures face vulnerabilities from natural disasters, aging infrastructure, and unforeseen loads. Therefore, continuous research and innovative engineering solutions are essential to ensure their durability and safety.

II. OUTRIGGER SYSTEM IN TALL STRUCTURES: APPLICATIONS AND BENEFITS

The outrigger system is a widely used structural mechanism in tall buildings to enhance their stability and resistance against lateral forces such as wind and seismic loads. It consists of rigid horizontal elements, called outriggers, that connect the central core or spine of the building to the outer perimeter columns.
By creating a coupling effect between the core and the external columns, the outrigger system significantly reduces the overall lateral deflection and enhances the building’s stiffness. This system improves the efficiency of the structural framework by distributing the lateral forces more evenly, thereby reducing the demand on the core. Outriggers can be composed of steel trusses, reinforced concrete, or composite materials, depending on the structural requirements and building height. In modern construction, multiple levels of outrigger floors are often used to maximize stability. Additionally, the use of dampers with outriggers can further reduce vibrations during earthquakes or strong winds, enhancing occupant comfort. The application of outriggers also allows for more flexible architectural designs by minimizing the need for bulky internal columns, resulting in larger, open floor spaces. As urban areas continue to grow vertically, the outrigger system has become a standard solution for supertall skyscrapers. Its adaptability, cost-effectiveness, and efficiency in reducing lateral movements make it an essential technology in contemporary high-rise construction, promoting both safety and structural longevity.

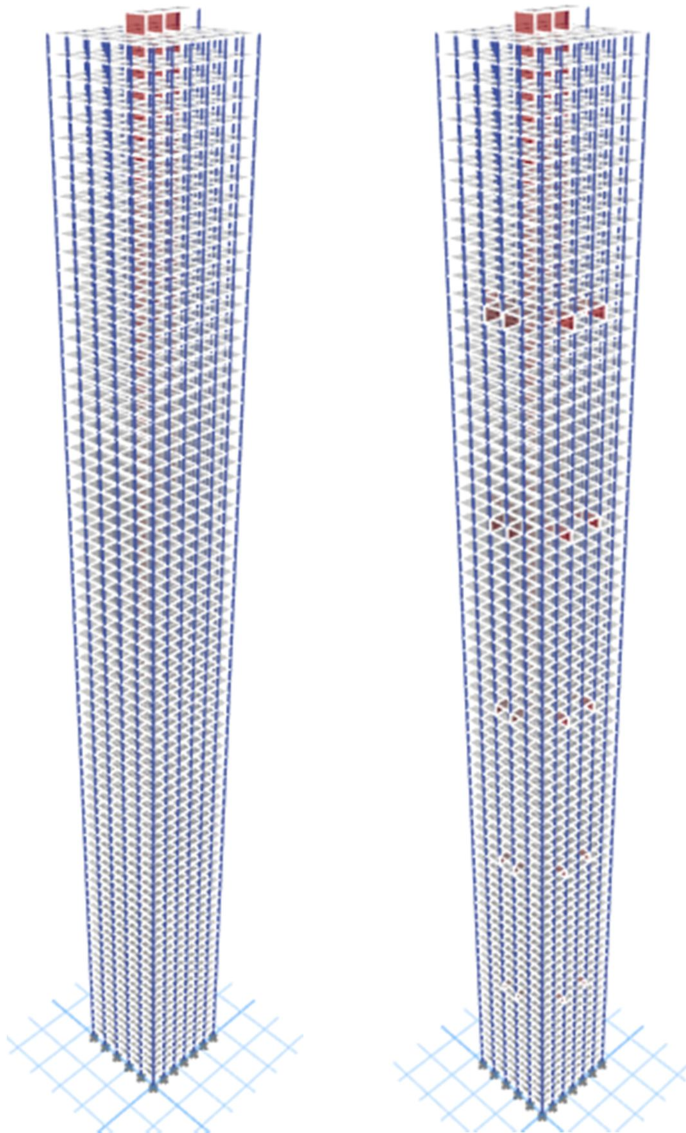

Fig. 1: Tall Structure with and without Outrigger system

III. REVIEW OF LITERATURE

Kiran Kamath et. al. (2012), In this paper, the researcher investigates the behavior of alternative 3D models for reinforced concrete structures using ETABS software. The study focuses on structures with a central core wall, comparing configurations with and without outriggers, while varying the relative flexural rigidity from 0.25 to 2.0 in 0.25 increments. The position of the outrigger is varied along the building's height, with relative heights ranging from 0.975 to 0.4. Parameters such as bending moments, shear force, lateral deflection, peak core acceleration, and inter-storey drifts are analyzed for both static and dynamic conditions. The findings reveal that the outrigger performs most efficiently at a relative height of 0.5 were their conclusive outcomes.

Kwang Rang Chung et. al., (2015), In this paper, the researcher addresses the differential shortening effect during the construction of outrigger systems and the special joints used to resolve these issues. The paper also discusses the characteristics of wind and seismic loads in Korea, which influence the design of tall buildings. The efficiency of outrigger systems in resisting lateral forces is highlighted, as they utilize the perimeter zone, reducing the structural weight. Examples of buildings in Korea using outrigger systems are introduced, and the structural role of these systems is analyzed. The conclusive outcomes of this study emphasize the importance of addressing shortening effects and understanding local load conditions were their research outcomes.

Suraj Nayak U et. al. (2016), In this paper, the researcher investigates the wind-induced responses of irregularly shaped reinforced concrete (RC) structures under static and dynamic wind load cases.

The effects of wind loads at velocities of 33 m/s and 55 m/s are analyzed for various heights and terrain categories (1 to 4). ETABS 15 software is employed to model RC bare frames and evaluate their behavior under these conditions. The study highlights that as the storey height increases, wind-induced displacement also rises; however, wind force decreases with higher terrain category due to increased obstruction. Comparisons are made between gust response factor and non-gust response factor methods to assess wind effects. Findings indicate significant variations in wind responses depending on terrain and height, emphasizing the importance of terrain in wind force prediction. The outcomes aim to assist designers in evaluating wind effects with enhanced assurance were their conclusive outcomes.

Abeena mol N M, et. al., (2016), In this paper, the researcher investigates the performance of outrigger structural systems in a 30-story high-rise core wall building. A regular floor plan of 38.5m x 38.5m is considered for the analysis. Time history analysis and push-over analysis are carried out to determine the maximum storey displacement as the key parameter. The analysis is performed using ETABS software to evaluate the efficiency of various outrigger systems in controlling drift. Different configurations of outrigger systems are studied, and their effects on structural performance are compared. The most effective system for reducing displacement is identified as their conclusive outcomes.

Dattaprasad Patil et. al. (2018), In this paper, the researcher investigates the seismic performance of high-rise buildings in developing countries like India, where urban population growth at an annual rate of 1.2% (as per 2016 data) has intensified the demand for taller structures. Non-linear dynamic analysis is conducted on three structural systems: framed structure, framed tube structure, and tube-in-tube structure. ETABS 2016 is utilized to analyze their response to lateral loads such as wind and earthquakes, which increase exponentially with height. Structural parameters, including maximum lateral displacement, maximum storey drift, base shear, and shear lag, are compared. The findings reveal the effectiveness of advanced framing schemes in mitigating lateral load impacts on tall buildings were their conclusive outcomes.

Pankaj Sharma et. al. (2018), In this paper, the researcher conducts a dynamic analysis of an outrigger system for a 60-storey building with a total height of 180 meters. The performance of single versus multiple outriggers is compared, followed by an analysis of various outrigger configurations, including X, V, Inverted V, and shear wall with and without belts. Outriggers are positioned according to Taranath's theory, with locations at (1/n+1), (2/n+1), etc. The analysis, performed using ETABS software, compares parameters such as maximum story displacement, story drift, and story shears under earthquake (Response Spectrum) and wind (static) loads. Results indicate that the structure's resistance to lateral loads improves with the number of outriggers, with the Inverted V configuration proving most effective. When shear walls are used as outriggers, better results are achieved, especially when combined with belt trusses or shear bands, enhancing the overall system's performance were their conclusive outcomes.

Neeraj Patel et. al. (2019), In this paper, the researcher analyzes the use of the outrigger system in high-rise buildings to address the challenges posed by increasing height and irregularities in vertical and horizontal dimensions. As building height increases, stiffness also increases, requiring structural systems to resist earthquake and wind forces effectively. The outrigger system is chosen for its efficiency in preventing story drift and core rotation under seismic and wind loads. External columns are connected to the core via outrigger beams at various floors. A comprehensive review of existing research highlights the system's effectiveness, forming the basis for the objectives of the current study were their conclusive review outcomes.

Archit Dangi et. al. (2019), In this paper, the researcher analyzes the behavior of lateral load-resisting systems, with a focus on the outrigger structural system, for a G+10 RCC high-rise building under earthquake forces. A 3D computer model is created, and outrigger locations are determined according to the Taranath method. Seven different cases are examined using the Response Spectrum method, including regular, shear core, outrigger, wall belt, and outrigger-truss belt supported systems. Parameters such as base shear, column axial forces, and member shear forces are analyzed. Efficient cases for all parameters are identified and discussed, and these were their conclusive outcomes.

Neeraj Patel et. al., (2019), In this paper, the researcher investigates the effectiveness of shear wall belts in resisting lateral loads in a 25-story high-rise residential building. A standard floor plan with a plinth area of 825 m² is used for analysis. Various cases with shear wall belts positioned at different floors are considered. The response spectrum method with SRSS combinations is employed to determine parameters such as base shear, maximum nodal displacement in both longitudinal and transverse directions, drift values, and load cases causing maximum drift. The study is conducted using Staad Pro software. Recommendations for the optimal location of the shear wall belt are provided, with the most effective position identified as their conclusive outcomes.

Ashitha V Kalam et. al. (2019), In this paper, the researcher presents a vulnerability assessment of bundled tube structures against heavy wind loads using dynamic wind analysis. The study focuses on the efficiency of the bundled tube system, which is highly effective in resisting lateral loads, particularly in super-tall buildings. As building height increases, wind sensitivity also rises, necessitating the design for dynamic wind loads.

The Gust factor method is employed for calculating wind loads and response. The analysis and modeling of the structure are carried out using ETABS software. This research addresses the structural engineering challenges posed by tall buildings subjected to high wind forces were their conclusive outcomes.

Archit Dangi et. al. (2019), In this paper, the researcher examines the stability of a G+10 multistory residential building located in seismic zone IV using a shear core outrigger and belt-supported system. Comparisons are conducted between wall belt and truss belt systems, with optimal locations determined by the Taranath method. Seven cases are analyzed using the Response Spectrum Method to evaluate parameters such as nodal displacement, story drift, time period, mass participation, and beam stress. Findings reveal significant variations in structural performance based on belt system configurations. It is shown that structural stability decreases with increasing height under combined seismic and gravity loads. The most efficient case is identified, offering insights for improved stability under critical loading conditions were their conclusive outcomes.

Sakshi Goyal, et. al. (2020), In this paper, the researcher addresses the challenges posed by reduced living land in urban areas due to population growth, emphasizing the adoption of high-rise structures as a sustainable solution. Multistoried buildings, requiring minimal land area, are examined as key components for metropolitan transformation and investment generation. A detailed review of research articles is conducted, focusing on advancements in structural engineering to enhance safety, affordability, and functionality. Stability improvement techniques using Outrigger Wall systems are highlighted as essential in modern high-rise construction. Findings from previous studies on the placement and efficiency of Outrigger systems in multistoried buildings are analyzed. The outcomes provide clarity on prior research and establish the basis for future technical objectives to optimize high-rise building designs were their conclusive review outcomes.

Mohammad Bilal Rasheed et. al., (2020), In this paper, the researcher analyzes the impact of different concrete grades on multistory buildings equipped with outrigger and wall belt support systems using analytical methods and design software. The effects of earthquake and non-earthquake actions on such systems are examined, highlighting their relevance for both low and high seismic zones. A comprehensive review of previous studies is conducted to evaluate the performance of these systems under varying concrete grades. Software-based analysis is employed to validate the findings and assess structural behavior. The comparative results of the research trends are summarized, leading to conclusions that establish objectives for future investigations in this field were their conclusive review outcomes.

Mustafa Hussaini, et. al. (2020), In this paper, the researcher evaluates the seismic performance of a 24-storey building using bracing, diagrid, and outrigger systems, modeled and analyzed in ETABS 2017. The bracing system, known for transferring lateral loads through members in tension and compression, is compared to the diagrid system, where lateral loads are resisted by inclined structural elements. The outrigger system, incorporating belt trusses and a core shear wall, is analyzed for its effectiveness in resisting lateral forces. Optimization of bracing types, along with the number and placement of outriggers, is emphasized. Findings from the analysis highlight the efficiency of each system in improving stability and reducing deformations under seismic loads were their conclusive outcomes.

Rasheed Altouhami et. al. (2020), In this paper, the researcher investigates the impact of shear wall placement on the structural performance of multistory buildings under wind and seismic forces using ETABS software. Shear walls are analyzed at various locations, with their effects compared between buildings without walls and those with walls placed near the core or periphery. Results reveal that periphery-placed walls exhibit 5.85% and 1.54% higher displacement than core walls in square and rectangular buildings, respectively. Additionally, external shear walls demonstrate the highest base shear in both shapes. Stress levels in rectangular buildings with core walls are found to be 3.23% higher compared to square ones. The study emphasizes the importance of precise shear wall configuration to enhance overall stability under extreme loading conditions were their conclusive outcomes.

Mohammad Bilal Rasheed et. al., (2020), In this paper, the researcher examines stability improvement techniques for multistoried semi-commercial apartment buildings with various configurations, including horizontal and vertical irregularities. As the demand for vertical living increases, new safety measures are necessary to counteract seismic forces. To enhance structural stiffness, systems like shear walls, bracings, wall belt systems, and outrigger systems are implemented. The outrigger and wall belt system is analyzed, with external columns connected to the central shear core to resist lateral effects. Eight cases (OTB1 to OTB8) are considered, situated in seismic zone III on medium soil. After analyzing various load combinations, cases OTB7 and OTB8 were found to be the most efficient and should be recommended for adoption in earthquake zone III, as these were their conclusive outcomes.

Sakshi Goyal et. al. (2020), In this paper, the researcher investigates the use of outrigger systems, implemented with outrigger walls below the plinth level, to enhance structural stability. Previous studies have focused on outrigger systems placed at specific heights, but no research has explored this approach.

The study aims to identify the optimum grade of concrete for such a configuration. A total of 8 cases were selected, analyzed, and compared to determine the most efficient solution. The building case OT8 was found to be the most effective and is recommended for improving structural stability in high-rise buildings with irregularities were their conclusive outcomes.

Palak Joshi et. al., (2021), In this paper, the researcher examines four structural configurations for tall buildings: Framed Tube, Tube in Tube, Bundled Tube, and Moment Resisting Frame with Shear Wall Core. The analysis is performed on 60-storey buildings located in Seismic Zone IV with medium soil conditions, using the Response Spectrum method for seismic loads and the Gust Factor method for wind loads. The dynamic response is assessed in terms of storey displacement, storey drift, base shear, and fundamental time period. The results reveal that certain configurations outperform others in terms of structural stability were their conclusive outcomes.

Mohammed Sanaullah Shareef, et. al. (2022), In this paper, the researcher analyzes the performance of high-rise structures equipped with outrigger shear walls under lateral loads in seismic zone V using ETABS 2018. Two buildings of 36 and 50 storeys, each with a constant area of 900 sqm (30m x 30m) and a typical storey height of 3m, are examined. Eight models are studied by varying the positions of outriggers along the height of the structures. Response spectrum analysis is conducted to evaluate earthquake loads, and the Gust Factor method is employed for wind load analysis. Parameters such as modal mass participation, base shear, storey displacement, drift, time periods, and accelerations are compared. Findings reveal that for the 36-storey model, outriggers placed at extreme ends provide superior performance, while in the 50-storey model, outriggers positioned at regular intervals are most effective. The results highlight the importance of optimizing outrigger placement to enhance stiffness and damping under severe conditions were their conclusive outcomes.

Mohammed Mudabbir Ahmed et. al. (2022), In this paper, the researcher investigates the performance of a 30-storey high-rise building under seismic conditions in Zone V, focusing on three structural systems: Special Moment Resisting Frame with Shear Wall, Outrigger Core Belt Truss System, and Braced Frame System. Using ETABS 2018, all models are analyzed under identical loading conditions, geometrical dimensions, and a typical storey height. Parameters such as modal mass participation, base shear, storey shear, time period, lateral displacement, storey drift, storey stiffness, and performance points are evaluated. Dynamic analysis through Response Spectrum Analysis and Non-Linear Static Analysis reveals that the Outrigger Core Belt Truss System provides superior performance. The results demonstrate its effectiveness in minimizing lateral deformations and enhancing stability compared to other systems were their conclusive outcomes.

IV. CONCLUSIONS AND OUTLINE OF PROPOSED WORK

It seems that there is a research gap in the literature regarding the different analysis and design work done previously on seismic method of analysis, Gust factor method of wind analysis and analysis of Tall structure building. Based on the literature review, we have reached a conclusion that highlights the key findings of the research and lists the necessary outcomes:

1) It is essential to compare the Gust factor of wind analysis with response method of seismic analysis.
2) Conducting a study on comparison over Tall structure with Outrigger system.
3) It is important to use recommend the recommendations followed by IS 1896:2016 for seismic analysis and IS 875 part III for wind analysis of the structure over medium soil conditions.
4) To ensure accuracy in the analysis, it is recommended to use outrigger for increasing stability with different cases and its usage over different floor levels.
5) Different parameters such as Displacements, Base shear, Axial Forces, Bending moments and Shear forces since these parameters should be necessary to determine the behavior of a building structure.

The primary objective of this study is to determine the further research needed to investigate the comparative effect of gust factor method and seismic analysis that justify the impact of use of outrigger on tall structure building to see the behavior of the structural performance that has going to be a major study for upcoming proposed work.

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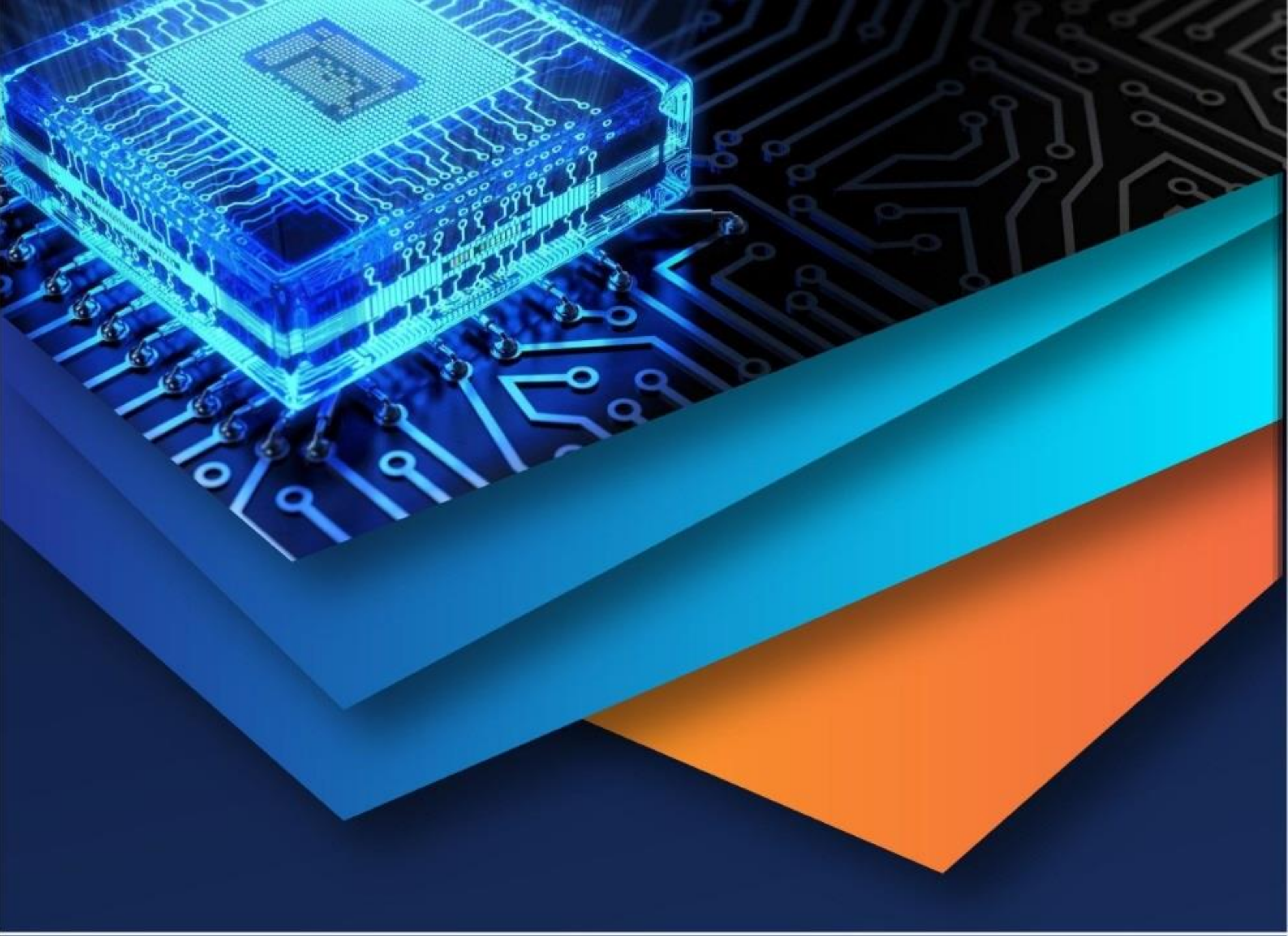

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