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Use of Post Tensioning in Multistoried Buildings: An Observative Review

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Abstract: ***According to recent statistics, India is recognized as one of the most densely populated nations in the world. Due to this density, a severe shortage of land is being faced across urban areas. As a response to this issue, high-rise structures with broad coverage are being preferred by urban planners. To maximize space efficiency, aesthetically attractive buildings are being designed by engineers in increasing numbers. Although these designs are widely favoured by clients, post-tensioning methods are rarely implemented during construction. The benefits of this technique, such as reduced material consumption and enhanced structural integrity, are being largely overlooked in modern high-rise developments. The main challenge is to maintain the stability of architectural buildings when structural instability arises due to their visually attractive designs. In this study, various papers related to the topic have been thoroughly reviewed and critically analysed, revealing that extensive research has already been conducted in this field but not in multi-storeyed buildings. To enhance the stability of these buildings, a comprehensive literature review was carried out. As a result of these findings, clear and focused conclusions were drawn which forms the research objectives of our further technical study.***
Keywords: Multistorey building, Vertical elements, Beams, Shear wall, Post Tensioning.

I. INTRODUCTION

It is being followed as a current trend to follow to financial customs for ensuring cost-effective construction. However, achieving structural stability is often made challenging by this approach, as the use of heavy sections is required, which can result in increased costs. India's evolving construction demands, the need for durable and efficient infrastructure is being addressed through the growing use of post-tensioning. In landmark projects such as the Mumbai Trans Harbour Link, Bandra–Worli Sea Link, and the Coastal Road Project, this method is being applied to strengthen structural performance and reduce build times. Post-tensioning techniques are being adopted by firms like Freyssinet India and NMRD Limited, who are contributing to resource-efficient and faster construction. In congested urban zones, this technology is being favored due to its suitability for limited spaces and accelerated timelines. Especially in multistoried buildings, post-tensioning is being valued for enabling longer spans, thinner slabs, and reduced floor-to-floor heights—features that enhance space utilization and structural efficiency.

A. Post-Tensioning

In concrete construction, post-tensioning is employed to strengthen and reinforce structures. High-strength steel tendons (wires or strands) are placed inside ducts or sleeves within the concrete formwork before the concrete is poured. After the concrete hardens, the tendons are tensioned (stretched) using hydraulic jacks. Once tensioned, the tendons are anchored to the concrete, causing it to compress, which enhances its strength and performance under stress. This technique is widely applied in the construction of beams, slabs, bridges, and multistoried buildings, as thinner, lighter, and more efficient structures are allowed to be created compared to traditional reinforced concrete. Longer spans and improved crack resistance are achieved through post-tensioning, while material usage and construction time are reduced.

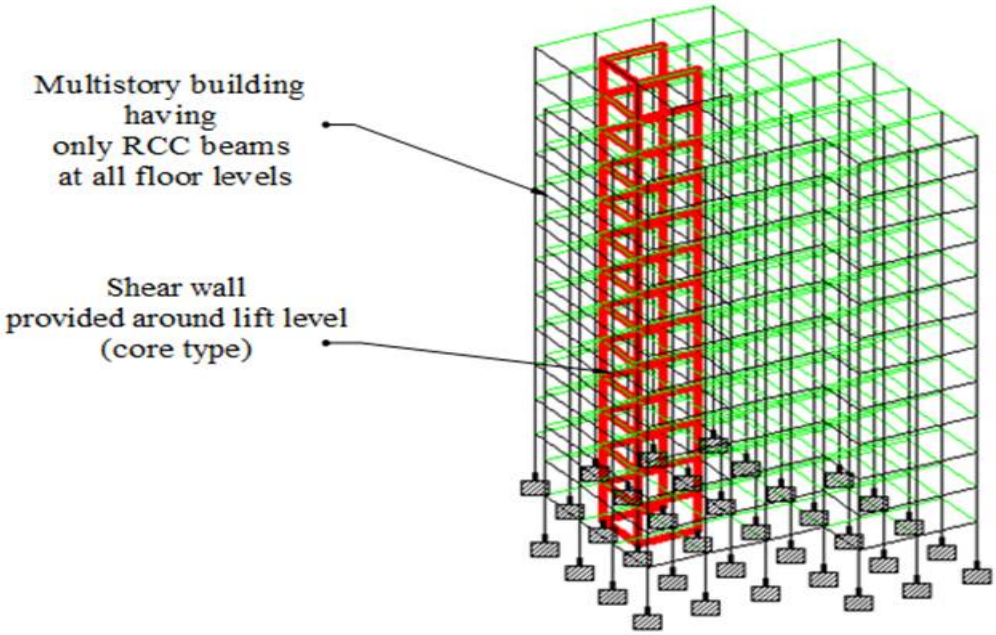

Fig. 1: Structure having RCC beams configuration provided for all floor levels

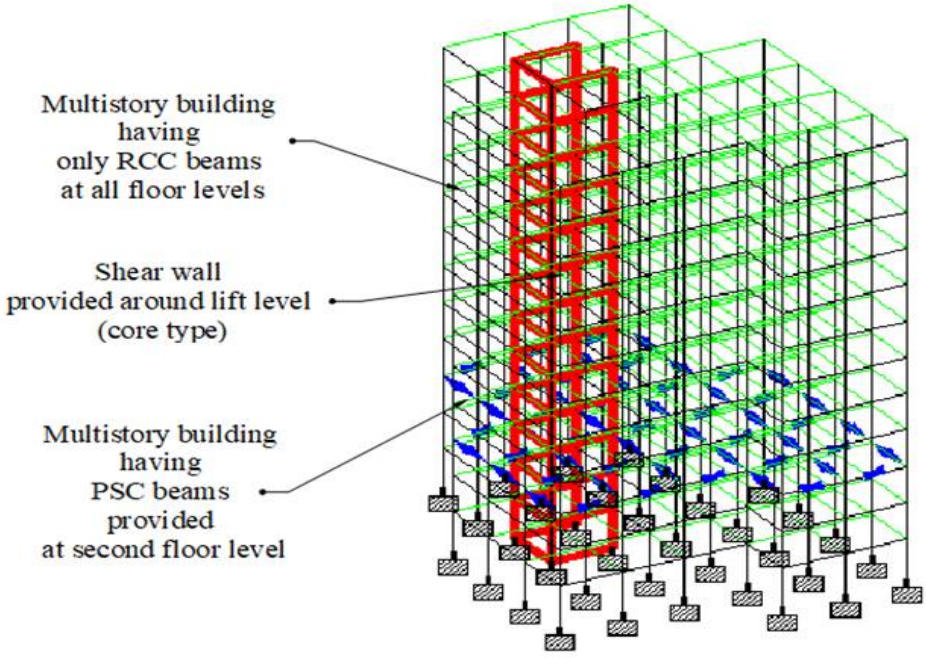

Fig. 2: Structure having PSC beams configuration provided at 2nd floor level and RCC beams provided for all remaining floor levels

II. REVIEW OF LITERATURE

In this paper, the researcher explores the feasibility of pre-stressed precast concrete shell roof structures as an alternative to traditional roofing systems. Various configurations were modeled using STAAD.Pro V8i, with geometric parameters such as shape, slope, length, and reinforcement spacing altered. An increase in thickness (from 0.08 m to 0.1 m) was noted in beam-shell structures under wind loads. Frame-shell structures resisted deformation effectively, while shaft-shell components collapsed due to flexural failure and increased tensile stress. Elastic deformation was induced by the applied strain. Frame-shells demonstrated greater resistance to distortion, whereas shaft-shells failed under stress, were their conclusive outcomes. (Pradeep Nath Mathur et. al. 2015)

In this paper, the researcher investigates the efficiency of precast concrete technology in large-scale construction projects. Using this method, 7 buildings (2B+G+18 floors) were completed in 18 months, achieving a slab cycle of 10-12 days for 7000 sq. ft. slab areas. The use of hollow-core slabs optimized both cost and time, while precast wall panels eliminated the need for brickwork and plaster. Superior quality and finish were attained, with reduced concrete and steel consumption per sq. ft. Automation and mechanization enhanced productivity, while site safety and waste reduction were significantly improved. The ecological footprint was minimized by lowering dust and noise levels, were their conclusive outcomes. (Nirajan Kumar Jha et. al. 2024)

In this paper, the researcher examines the structural performance of three precast prestressed concrete buildings: Type-1 (office with a central core), Type-2 (office with side cores), and Type-3 (condominium with a central open space). The designs were based on Japan's "Structural Design and Construction Guideline for Precast Prestressed Concrete Structures" using the capacity spectrum method. In the analysis, the capacity spectrum was calculated from the story shear force at the first floor and the horizontal displacement at the centroid. The demand spectrum (with a 5% damping factor) featured a constant acceleration range of 1176 cm/sec² for high frequencies and a constant displacement of 160 cm for low frequencies. The equation $Dh = 1.5 / (1 + 10h)$ was applied for other damping factors. The successful resistance of the buildings in seismic conditions, were their conclusive outcomes. (Satoru FUKAI, 2000)

In this paper, the researcher explores the effectiveness of post-tensioning (PT) in achieving economical and structurally efficient designs for long-span and slender structures. The limitations of RCC in fulfilling architectural demands for extended spans are highlighted, as it becomes costly beyond certain lengths. The use of prestressing is examined not only horizontally but also vertically to resist lateral loads, reducing the need for external scaffolding in high-labor-cost regions. The application of curvilinear forms enabled by prestressing, once deemed impractical, is demonstrated. Enhanced waterproofing capabilities, achieved by keeping the concrete in continuous compression, were their conclusive outcomes. (Vaibhav G Tejani et. Al. 2015)

In this paper, the researcher evaluates the effectiveness of pre-stressed basalt fibre-reinforced polymer (BFRP) composites in enhancing the bending performance of glued laminated timber beams. Using the Near Surface Mounted (NSM) technique, two BFRP bars were glued into the bottom grooves, while a third bar was added to the top groove in the second strengthening method. Experimental testing of 15 full-size beams revealed a 36% increase in load-bearing capacity and a 23% improvement in stiffness compared to unreinforced beams. Tensile stresses were reduced by 11.32% and 25.42%, while compressive stresses decreased by 16.53% and 32.10% with two and three BFRP bars, respectively. Numerical analysis correlated closely with experimental results, showing a variance of 3.63% to 11.45%, were their conclusive outcomes. (Agnieszka Wdowiak-Postulak, 2023)

In this paper, the researcher examines the effectiveness of the Saw-cut method in evaluating initial stress in prestressed concrete structures. It was determined that the method is applicable only to non-pre-cracked structures, necessitating detailed pre-inspection. The study revealed that prestressing force and initial stress values have no influence on the percentage stress change after Saw-cut application. Instead, the saw-cut parameters—specifically a height above 30 mm and an axial distance of 100 mm—were found to be the key factors for effective stress isolation. However, the influence of temperature changes during sawing was not accounted for in the numerical analysis, impacting result reliability. The potential for experimental validation and practical application of this method were their conclusive outcomes. (Jakub KRAĽOVANEC, 2021)

In this paper, the researcher investigates the impact of pre-stressed construction technology on the housing industry amid rapid urbanization. The study highlights that bonding prestressing technology effectively addresses span limitations in concrete structures and enhances load-bearing capacity. Through its application, concrete cross-section sizes are reduced, the use of steel bars is minimized, and space utilization is improved, leading to greater economic benefits. The widespread adoption of this technology, promoted by the Ministry of Construction, demonstrates its increasing importance in modern housing projects. The proven effectiveness in boosting structural efficiency and economic viability were their conclusive outcomes. (Chao LU et. Al. 2022).

In this paper, the researcher examines various methods for assessing prestressed concrete structures, emphasizing their applicability, availability, and affordability. It is noted that Barkhausen noise and Wire-cutting techniques may lead to inaccurate estimations of load capacity and remaining service life due to their focus on individual wires. Conversely, Saw-cut and Structural response methods, which provide residual prestressing force values, are deemed more reliable. The need for further in situ and laboratory studies to evaluate factors affecting accuracy is highlighted. The importance of refining these techniques for practical applications were their conclusive outcomes. (Jakub KRAĽOVANEC, 2022).

In this paper, the researcher investigates the application of the saw-cut method on a precast post-tensioned beam through in situ testing and numerical analysis. It is concluded that the method can be performed with or without external loads, simplifying dead load determination. The 2D finite element analysis reveals a 13.32% difference, highlighting the risk of underestimating prestressing losses due to poor maintenance and corrosion, which may lead to unexpected bridge failures. The real mechanical properties and

average stress changes are identified as key parameters for accurate numerical analysis. The need for future experimental studies on varied specimen dimensions and aging concrete bridges were their conclusive outcomes. (Jakub Kral'ovanec et. Al. 2021)

In this paper, the researcher evaluates the stress state in tendons of a prestressed concrete structure through experimental and numerical analysis. The monitored tendon stress was recorded at 760 MPa, aligning with the 776 MPa obtained from numerical simulations, confirming their consistency. The deflection at midspan, measured at −84.80 mm, also corresponded with the numerical predictions. The saw-cut method (SCM) effectively released almost 100% of normal stress with 120 mm axial distance and 30 mm depth, indicating its efficacy. The 80% stress change in the post-tensioned member did not compromise structural integrity. The methods proved reliable even under permanent loads, making them practical for rapid in situ applications were their conclusive outcomes. (Jakub Kralovanec et. Al 2022)

In this paper, the researcher investigates the corrosion behavior of prestressing steel bars of CKT type (grade Y 1050, 1050 MPa) under different stress levels. The copper cathode distance significantly influenced the corrosion uniformity, with horizontal placement proving more effective. No morphological differences were observed at varying stress levels for the same corrosion duration. An electric current of 0.25 A was found optimal, preventing pitting corrosion. The prestressing level directly affected the corrosion degree, with 90% of tensile stress increasing corrosion by 7.3%. Corrosion caused a decrease in prestressing force due to the reduced steel surface area. The results' accuracy depended on the coating quality and chemical composition. The need for further tests with diverse steel types, diameters, and concrete compositions were their conclusive outcomes.(Michal Zahuranec, 2023)

In this paper, the researcher compares the standard values of prestress losses with the experimentally determined actual prestressing state in precast pre-tensioned sleepers. The saw-cut method, used without applying an external load, demonstrated that prestress losses ranged from 10% to 20%, aligning with Eurocodes (14.8%).

Saw-cuts of 10 mm and 30 mm showed good conformity with numerical analysis, while 20 mm cuts displayed discrepancies due to unstable strain readings. 30 mm deep saw-cuts with 120 mm axial distance caused approximately 70% stress relief without compromising the structure's integrity. The findings suggest that small interventions can effectively measure residual prestressing force, aiding in the accurate assessment of load-carrying capacity. (Jakub Kral'ovanec, 2021)

In this paper, the researcher conducted a numerical and experimental analysis of a four-span continuous bridge on Slovak Highway D1, section Hricovske Podhradie – Lietavska Lucka, with a total length of 129.4 m. The superstructure, composed of eight post-tensioned precast I-beams, was assessed through a proof-load test. The predicted structural response was verified, and any unusual behavior was identified. The recorded data was compiled into a detailed report. This report was distributed to all subcontractors and the bridge owner. The study aimed to contribute to future bridge management programs. The verified structural performance and the reliable assessment of potential issues were their conclusive outcomes. (Petra BUJNAKOVA, 2022)

In this paper, the researcher assessed the application of prestressed concrete in Nigeria's construction sector as a means to enhance infrastructural development. The frequent collapse of buildings and bridges has severely impacted the construction industry, resulting in loss of lives and properties, and labeling the nation as underdeveloped. Countries like Malaysia, India, and the UAE, despite facing similar setbacks, have continued to develop. The study emphasized that Nigeria can achieve world-class prestressed concrete structures if both the government and individuals collaborate. The promotion of structural stability and the potential for national economic growth were their conclusive outcomes. (Dr. Engr Gana et al. 2015)

In this paper, the researcher reviewed bridge design methodologies by comparing various national design codes and analyzing structures using different software tools. The distribution of loads was examined using load combinations and girder sections, with CSi Bridge software applied to assess circumstantial loading. Manual design methods were also discussed, and their results were compared with software-generated values. It was found that manual results were consistently lower than those obtained through software analysis. The accuracy and precision of CSi Bridge in modeling structures under diverse loads were their conclusive outcomes. (Ravindra Balawane 2022)

In this paper, the researcher concluded that major failures in bridge construction, particularly overturning and toppling of girders, are primarily caused by negligence, unauthorized support removal, poor supervision, and non-compliance with method statements. It was observed that while the initial phases of construction are monitored by experienced engineers, later stages often lack proper supervision. Secondary failures, such as staging collapse, stressing issues due to cavitation, honeycombs in end blocks, and inadequate concrete strength, were identified. These issues can be prevented through qualified teams, strict quality control, and precise execution of girder casting, stressing, and erection, which were their conclusive outcomes. (Abhijit Mangaraj 2023)

In this paper, the researcher examined static and dynamic behavior of bridges, focusing on T-beam girder, rectangular, and trapezoidal box girder structures. Pre-stressed concrete bridges were found to offer excellent riding characteristics, reduce traffic

vibrations, and exhibit torsional rigidity, making them less prone to early cracking. Their natural vibration frequency rarely aligns with vehicle frequency, making them ideal for freeways, flyovers, and metro train systems. To ensure life safety under earthquakes, bridges must withstand both static and dynamic stresses, especially earthquake-induced loads, which were their conclusive outcomes. (Arpit Shrivastava, 2023)

In this paper, the researcher conducted a dynamic analysis of prestressed concrete (PSC) precast I-girder and box girder bridges for various parametric variations and span ranges. The Response Spectrum Analysis (RSA) was performed using FEM-based software, evaluating parameters such as geometric dimensions, span range, bending moment, shear force, displacement, base shear, base moment, time period, and natural frequency. It was found that PSC bridges offer superior resistance to traffic vibrations, torsional rigidity, and reduced cracking potential, making them ideal for freeways, highways, and metro systems. The study confirmed that both static and dynamic loads, particularly earthquake-induced forces, must be considered to ensure life safety, which were their conclusive outcomes. (Narendra Singh et. al. 2023)

In this paper, the researcher investigates the structural performance of bridge superstructure girders on NH-16 near Benz Circle, Vijayawada, constructed with precast and post-tensioned concrete. The girders were analyzed for IRC Class 70R and Class A vehicular loads using STAAD Pro with a grillage girder-slab model. The bending moments and shear forces were calculated for each load configuration, and the governing envelope forces were identified. The maximum flexural and shear demands on the bridge girders were presented. The efficiency and limitations of grillage analysis were highlighted, with recommendations for more precise modeling techniques. The accurate force estimations and optimal load-bearing capacity of the bridge girders were their conclusive outcomes. (Phani Ram Gollapudi, 2024)

In this paper, the researcher examines the seismic performance of prestressed concrete frame structures by comparing three building codes: ACI 318-14, Eurocode 2004-2, and Chinese GB50010-2010. A 10-story prestressed concrete frame system was analyzed under gravity and seismic loading, with the strong-column weak-beam mechanism achieved to meet the latest design standards. The nonlinear static pushover analysis was applied to capture the seismic response, while finite element modeling (FEM) using CSI SAP2000 was utilized to simulate structural behavior. The increased strength and stiffness, along with fewer cracks and longer spans, demonstrated the advantages of prestressed concrete over reinforced concrete. The cost-effectiveness and ease of site erection of this system were highlighted. The superior seismic resilience and code-compliant performance of the prestressed concrete frame structures were their conclusive outcomes. (Ratanak Mony 2024)

In this paper the researcher has explored the seismic behavior of flat slab buildings integrated with Post Tensioned (PT) tendons, where span-to-thickness ratios ranging from 35 to 45 were achieved—exceeding the 30 typically observed in conventional RC systems. Greater control of deflection and cracking, along with reduced floor-to-floor heights and lighter structural weights, were provided by PT systems. Compared to pre-stressing, reduced losses and flexible tendon shaping were enabled through post tensioning. Construction efficiency, sustainability, and long-term durability were additionally enhanced. However, the seismic performance under lateral forces in high seismic zones was critically examined. Nonlinear static analysis, considered a partial yet effective method for evaluating structural capacity under ground motion, was implemented. The behavior of PT flat slab buildings both with and without Lateral Force Resisting Systems was assessed. Enhanced resistance to seismic forces and superior structural efficiency were their conclusive outcomes. (Yogesh Poptani, 2019)

III. CONCLUSIONS AND OUTLINE OF PROPOSED WORK

Based on the reviewed literature, enhanced ease and stability in building analysis or other structure analysis/experimental work have been conducted until date, allowing both simple and complex architectural structures to be examined effectively through the application of PSC. Through the conducted literature survey, it has observed that the impact of PSC (Pre/Post stressed) usage in multistorey buildings under seismic loading conditions has not been adequately addressed.

From the collective findings of past studies, a conclusion regarding the usage and performance of PSC has reached, and the key outcomes derived from this research outlined below:

1) There should be a research based on the usage of LRPC in multistoried building structure.
2) There should be a research based on the comparative analysis on PSC strand based and RCC rebar based concrete beam that which one is better.
3) There should be a research based on the guidelines followed by IS 456:2000 with IS 1343-2012, should be performed with necessary checks.
4) There should be a research based on the seismic analysis by taking a seismic zone as per IS 1893:2016 considering the PSC.

5) There should be a research that shows the limiting values by applying the checks.
6) There should be a research based on taking different output parameters, as it will be necessary to judge the behavior of structure.
7) There should be a research based on taking the different cases for analytical analysis.

The main focus of this study is to check whether the PSC beams are feasible or not when applied to the multistorey building under seismic effects and need to find out the optimised dimensions achieved in the replacement of RCC at an efficient floor level that has going to be a major study for upcoming proposed work.

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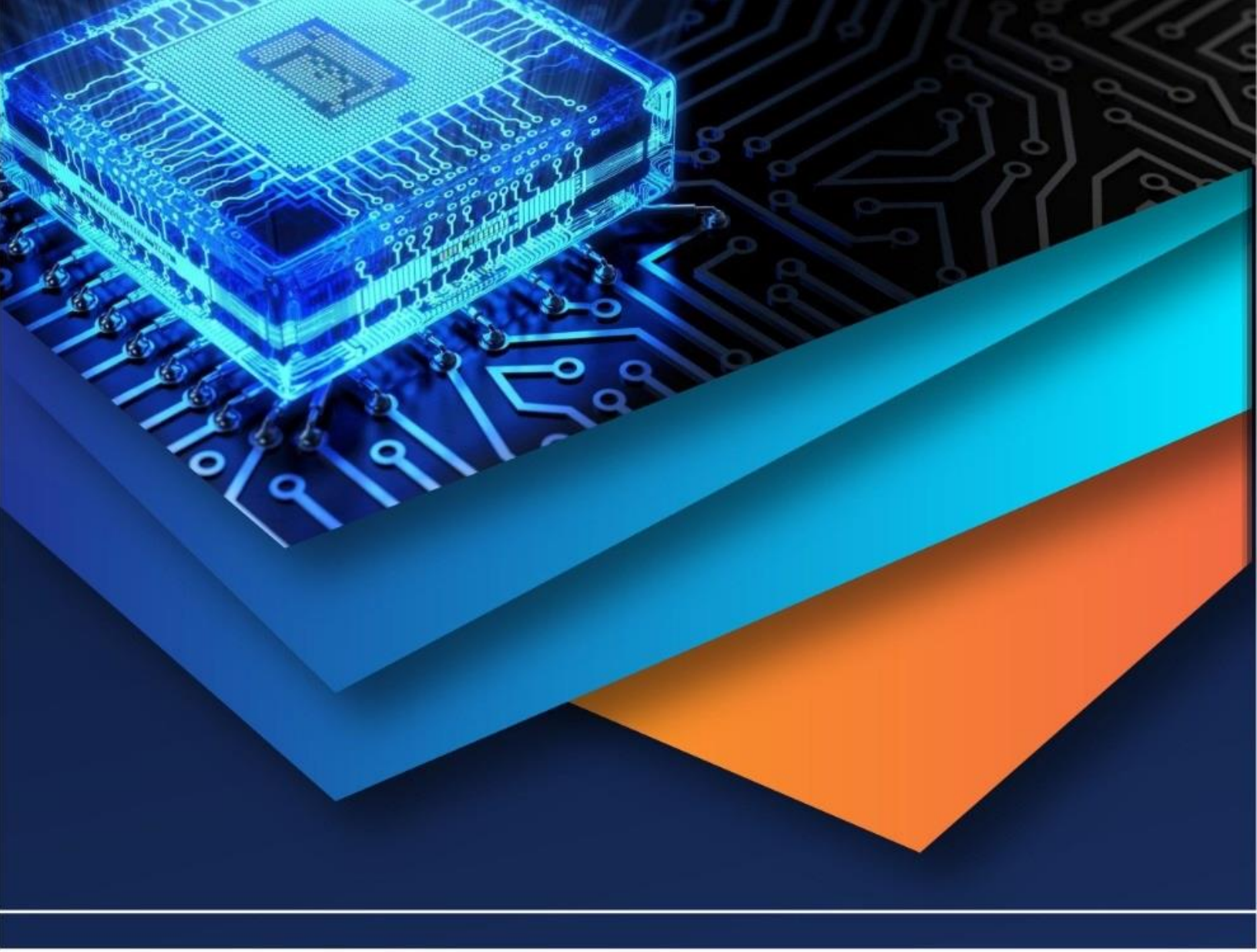

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