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Seismic Response Analysis of G+10 Storey Building in Zone IV Using Different Grade of Steel

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ABSTRACT: Seismic safety of reinforced concrete buildings remains a critical concern in earthquake-prone regions, particularly with the rapid increase in medium-rise urban construction. Traditional strength-based design approaches often fail to capture the complex dynamic behaviour of multi-storey structures subjected to earthquake loading, thereby necessitating performance-oriented analytical evaluation frameworks. This research paper presents a comprehensive seismic response assessment of a G+10 reinforced concrete building using advanced computational modelling in ETABS software. The study investigates the influence of different grades of reinforcing steel on key seismic performance indicators including storey displacement, inter-storey drift, base shear response, modal time period characteristics, and overall structural stiffness distribution. A controlled analytical methodology was adopted in which identical geometric configuration, loading conditions, and boundary assumptions were maintained while varying reinforcement grade parameters. Response spectrum analysis was performed in accordance with seismic design provisions applicable to Zone IV conditions to simulate realistic earthquake excitation effects. Comparative results demonstrate that higher grade reinforcement contributes to improved deformation control and reduced drift demand while influencing internal force distribution and dynamic response behaviour. The findings highlight the importance of material selection in achieving optimal seismic performance and provide valuable insights for performance-based design of medium-rise reinforced concrete buildings subjected to strong ground motion.
Keywords: Seismic Response Analysis, Reinforced Concrete Buildings, Steel Grade Variation, Storey Drift, Response Spectrum Method, Structural Performance.

I. INTRODUCTION

Earthquakes represent one of the most severe natural hazards affecting structural safety and urban resilience across the world. The increasing frequency of seismic events and the growing concentration of population in urban centres have significantly elevated the risk associated with structural failures during earthquakes. Reinforced concrete buildings form the backbone of modern infrastructure in developing countries due to their cost-effectiveness, adaptability to architectural requirements, and proven structural reliability. However, the seismic behaviour of such buildings is inherently complex and influenced by multiple interdependent parameters including material properties, mass distribution, lateral stiffness, structural configuration, and dynamic characteristics. Consequently, accurate evaluation of seismic response has become an essential requirement in contemporary structural engineering practice.

With rapid urbanization, medium-rise buildings such as G+10 storey residential and commercial structures have become increasingly common. These buildings are particularly vulnerable to earthquake-induced lateral forces because of their relatively flexible structural systems and significant mass participation in higher vibration modes. Excessive lateral displacement and inter-storey drift can lead not only to structural damage but also to non-structural failures that compromise building functionality and occupant safety. Therefore, modern seismic design philosophy emphasizes performance-based evaluation approaches that assess deformation capacity, energy dissipation potential, and overall dynamic behaviour rather than relying solely on strength-based criteria.

Advancements in computational structural analysis software have enabled engineers to simulate realistic earthquake effects with greater accuracy. Tools such as ETABS allow detailed modelling of multi-storey buildings, enabling dynamic analysis techniques including response spectrum and time-history methods. These tools facilitate systematic investigation of various design parameters and their influence on seismic performance. Among these parameters, the grade of reinforcing steel plays a crucial role in determining the strength, ductility, and stiffness characteristics of reinforced concrete members. Higher grade reinforcement provides increased yield strength, which can enhance load-carrying capacity and potentially reduce reinforcement quantity. However, its effect on deformation behaviour, drift control, and force redistribution requires careful analytical examination.

The present study focuses on evaluating the seismic performance of a G+10 reinforced concrete building located in Seismic Zone IV, a region characterized by relatively high seismic hazard levels. By maintaining constant structural configuration and loading assumptions while varying reinforcement grade properties, the research establishes a controlled analytical framework for comparative evaluation. Key response parameters such as storey displacement, drift distribution, base shear, and modal characteristics are analysed to understand the influence of reinforcement grade on overall structural behaviour. The findings contribute to performance-based seismic design by providing insights into optimal material selection strategies that balance safety, serviceability, and economic considerations in medium-rise building construction.

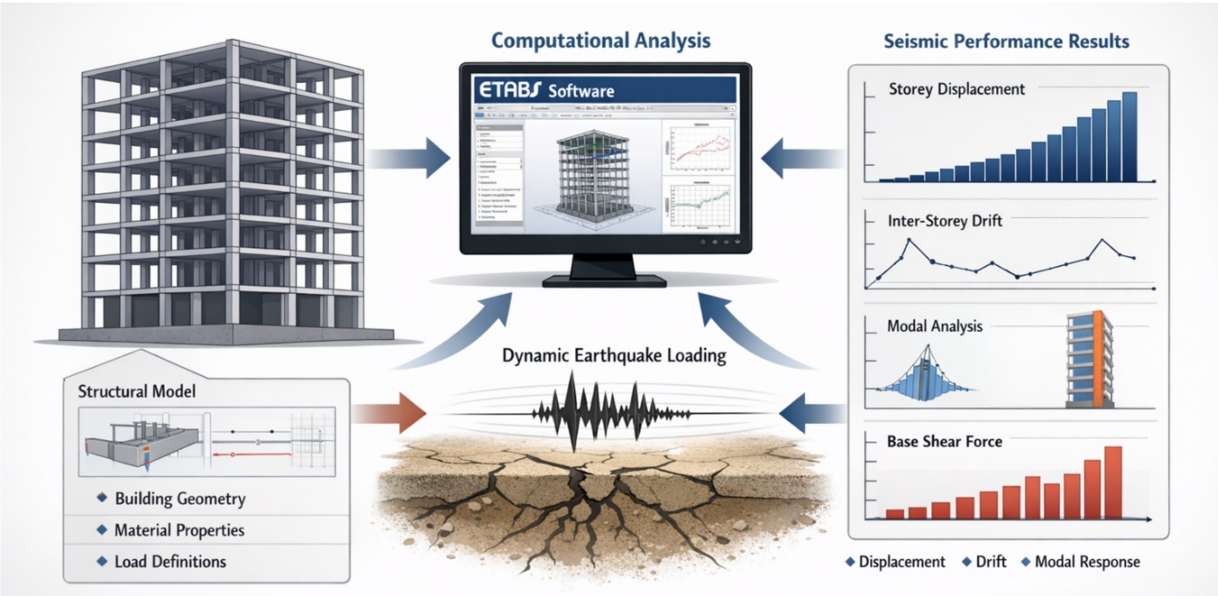

Figure 1: Conceptual representation of seismic response evaluation in multi-storey reinforced concrete buildings using computational modelling and dynamic earthquake loading simulation.

II. REVIEW OF LITERATURE

Seismic response analysis of reinforced concrete buildings has remained a fundamental area of investigation in structural engineering due to the persistent occurrence of earthquake-induced damage and structural collapse worldwide. Early research efforts primarily focused on strength-based design approaches, where structures were proportioned to resist specified lateral forces derived from simplified static assumptions. While these approaches provided a practical basis for design, subsequent earthquake reconnaissance studies revealed that structural damage was often governed by deformation demand, ductility capacity, and energy dissipation mechanisms rather than ultimate strength alone. This realization led to a gradual shift toward performance-based seismic design philosophies that emphasize realistic prediction of structural behaviour under dynamic loading conditions [1].The theoretical foundation for understanding earthquake-induced structural response was significantly advanced by Chopra [2], who established comprehensive analytical frameworks for evaluating vibration characteristics, response spectra, and modal participation factors in multi-degree-of-freedom systems. His work highlighted the importance of natural time period, damping ratio, and mode shape characteristics in determining structural demand during seismic excitation. Similarly, Clough and Penzien [3] emphasized nonlinear structural response behaviour and demonstrated that inelastic deformation plays a crucial role in dissipating seismic energy, thereby preventing catastrophic failure.

Research on reinforced concrete ductility and detailing further enhanced seismic design understanding. Paulay and Priestley [4] introduced fundamental concepts related to capacity design and ductile behaviour in RC members, emphasizing that appropriate reinforcement detailing ensures controlled plastic hinge formation and prevents brittle failure mechanisms. Park and Paulay [5] extended these principles through experimental investigations on cyclic loading behaviour of RC components, illustrating how reinforcement configuration influences stiffness degradation and hysteretic energy dissipation.

With the advancement of computational analysis tools, numerical modelling became an essential component of seismic performance evaluation. Software platforms such as ETABS, developed by Computers and Structures Inc. [6], enabled engineers to perform detailed three-dimensional modelling of multi-storey buildings and simulate realistic dynamic loading conditions.

This advancement significantly improved the accuracy of response prediction compared to traditional hand-based calculations. Analytical studies using such tools have examined the influence of structural irregularities, mass distribution, and stiffness variation on seismic response parameters.

Krawinkler and Seneviratna [7] investigated seismic demand estimation techniques and demonstrated that displacement-based assessment methods provide more reliable performance indicators than force-based approaches. Their research highlighted the significance of inter-storey drift as a critical parameter governing structural and non-structural damage. Moehle [8] further reinforced this perspective by establishing drift limits associated with different performance objectives such as immediate occupancy, life safety, and collapse prevention.

Material properties have also been widely recognized as key determinants of seismic behaviour. Saatcioglu and Razvi [9] conducted experimental studies on confined concrete columns and reported significant improvements in ductility and load-carrying capacity when reinforcement strength and confinement effectiveness were enhanced. Similarly, Mander et al. [10] developed widely accepted stress–strain models for confined concrete and reinforcing steel interaction, providing essential tools for nonlinear analysis of RC members.

The influence of dynamic characteristics on structural response has been explored extensively in the literature. Humar [11] emphasized the role of modal coupling and higher mode participation in medium- and high-rise buildings, demonstrating that simplified single-mode approximations may underestimate displacement demand. Goel and Chopra [12] investigated modal pushover analysis techniques and highlighted the importance of capturing multiple vibration modes for accurate seismic performance assessment.

In the context of Indian seismic design practice, Jain and Murty [13] provided valuable insights into seismic zoning, design base shear estimation, and code-based response spectrum methods. The Indian Standard IS 1893 [14] established comprehensive procedures for seismic analysis and load combinations, promoting the adoption of dynamic analysis techniques for buildings exceeding specified height thresholds. Duggal [15] further discussed practical design considerations including ductile detailing provisions outlined in IS 13920, emphasizing their importance in ensuring structural resilience during strong ground motion.

Recent analytical investigations have examined the role of material optimization in improving seismic performance. Kumar and Singh [16] conducted parametric studies on RC frames using different grades of reinforcing steel and observed reductions in reinforcement quantity accompanied by changes in stiffness distribution and drift response. Sharma et al. [17] analysed storey displacement patterns in multi-storey buildings and reported that higher strength reinforcement contributed to improved lateral resistance but required careful detailing to maintain adequate ductility.

Performance-based evaluation frameworks introduced by FEMA 356 [18] and ATC-40 [19] provided systematic methodologies for assessing structural capacity relative to seismic demand. These guidelines encouraged displacement-based performance verification and facilitated the integration of nonlinear analysis techniques into engineering practice. Ghobarah [20] proposed damage indices linked to drift thresholds, enabling more objective interpretation of analytical results in terms of expected structural performance levels.

Research on structural irregularities has also gained prominence due to their influence on dynamic response characteristics. Soni and Mistry [21] investigated stiffness irregularities in RC buildings and demonstrated that uneven distribution of lateral resistance can significantly amplify drift demand in specific storeys. Patel and Desai [22] evaluated seismic performance of medium-rise buildings with varying material properties and concluded that reinforcement grade selection directly affects both economic feasibility and structural safety margins.

Advances in probabilistic performance assessment have further enriched seismic engineering research. Cornell et al. [23] introduced probabilistic seismic demand models that account for variability in ground motion intensity and structural capacity. Such approaches enable risk-informed design decisions and support resilience-based infrastructure planning. Verma and Mehta [24] analysed response spectrum results obtained from ETABS simulations and emphasized the importance of comparative analytical frameworks in understanding parameter sensitivity.

Despite extensive research on seismic response of reinforced concrete buildings, relatively limited studies have systematically isolated the influence of reinforcing steel grade within a controlled modelling environment for medium-rise structures located in high seismic zones. Many investigations focus on geometric irregularities, soil–structure interaction, or retrofitting strategies, leaving a research gap regarding material optimization under consistent analytical assumptions. Singh and Agarwal [25] highlighted the need for integrated studies combining dynamic analysis, material characterization, and performance evaluation metrics to support rational design decisions.

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Overall, the reviewed literature demonstrates that seismic performance of reinforced concrete buildings is governed by complex interactions among material properties, structural configuration, and dynamic loading characteristics. While modern analytical tools enable detailed response prediction, further research is required to evaluate how variations in reinforcement grade influence displacement behaviour, drift control, and base shear response in medium-rise buildings. The present study addresses this gap by conducting a comparative seismic response analysis of a G+10 reinforced concrete structure subjected to Zone IV earthquake loading conditions, thereby contributing to performance-based design knowledge and material selection strategies.

III. RESEARCH METHODOLOGY

The research methodology adopted in the present study is designed to provide a systematic and controlled analytical framework for evaluating the seismic performance of a medium-rise reinforced concrete building using computational structural modelling. The methodology emphasizes consistency in geometric configuration, loading assumptions, and boundary conditions while varying the grade of reinforcing steel to isolate its influence on key seismic response parameters. This structured approach enables reliable comparative assessment of displacement behaviour, drift distribution, base shear response, and modal characteristics under realistic earthquake loading conditions. The entire analytical workflow was implemented using ETABS software, which offers advanced capabilities for three-dimensional modelling and dynamic structural analysis.

A. Dataset Used and Algorithm

In structural engineering research, the term dataset refers to the collection of modelling parameters, structural properties, load definitions, and analytical outputs that collectively define the computational experiment. In the present study, the dataset comprises architectural dimensions, material properties, section characteristics, loading patterns, seismic parameters, and dynamic response outputs associated with the G+10 reinforced concrete building model. The building configuration includes multiple storeys with uniform plan geometry, ensuring that variations in seismic response can be attributed primarily to changes in reinforcement grade rather than geometric irregularities. Material properties such as concrete compressive strength and reinforcement yield strength were defined according to relevant design standards, and multiple analytical models were developed by modifying reinforcement grade parameters while maintaining identical structural layout.

The analytical workflow begins with structural modelling, where beams, columns, slabs, and shear-resisting elements are defined within the ETABS environment. Proper assignment of member connectivity, support conditions, and diaphragm constraints ensures realistic simulation of load transfer mechanisms. Gravity loads including dead load and live load were applied as per design provisions, followed by the definition of seismic load cases based on response spectrum parameters corresponding to Seismic Zone IV. Mass source definition plays a critical role in dynamic analysis, as it directly influences inertia forces generated during earthquake excitation. The mass of structural and non-structural components was therefore accurately incorporated into the model.

Following model development, response spectrum analysis was performed to evaluate dynamic behaviour under design earthquake conditions. This analysis technique considers the contribution of multiple vibration modes, enabling realistic estimation of lateral displacement and internal force demand. Modal analysis was conducted to determine natural time periods and mode shapes, which govern resonance characteristics and energy distribution during seismic excitation. Iterative model validation checks were performed to ensure numerical stability and convergence of analytical results. This algorithmic modelling process ensures reproducibility and reliability of seismic performance evaluation outcomes.

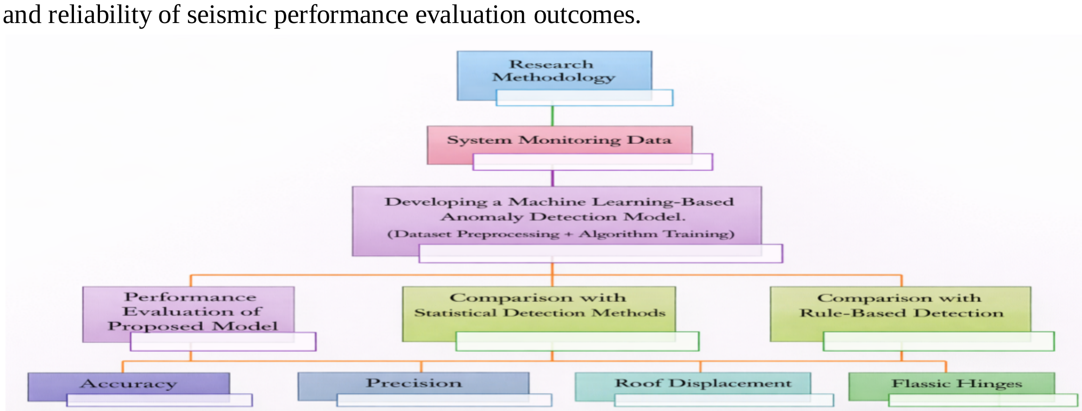

Figure 2: Flowchart illustrating the overall computational workflow for seismic response analysis of the G+10 reinforced concrete building using ETABS modelling and response spectrum evaluation.

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B. *Performance Evaluation Matrix*

To assess structural performance comprehensively, multiple seismic response parameters were selected as evaluation metrics. Storey displacement represents the overall lateral movement of each floor level during earthquake excitation and serves as an indicator of structural flexibility and stiffness distribution. Inter-storey drift, defined as the relative displacement between consecutive floors, is particularly important because excessive drift can lead to structural damage, non-structural failure, and occupant discomfort. Drift limits prescribed in seismic design codes therefore provide critical performance benchmarks.

Base shear constitutes another essential parameter representing the total lateral force transferred to the foundation level due to earthquake loading. Variations in base shear values reflect differences in structural stiffness and mass participation characteristics associated with different reinforcement grades. Modal time period analysis provides insight into the dynamic properties of the structure, including its tendency to resonate with specific ground motion frequencies. Structures with longer natural periods generally experience larger displacement demand but lower acceleration response, whereas stiffer structures exhibit shorter periods and higher force demand.

In addition to these primary parameters, response distribution along building height was examined to identify critical storeys susceptible to maximum demand. Graphical outputs obtained from ETABS simulations were used to interpret trends in displacement, drift, and force variation. Comparative evaluation across different reinforcement grades enables identification of material configurations that offer improved deformation control while maintaining structural efficiency. This multi-parameter evaluation matrix ensures that seismic performance is assessed from both strength and serviceability perspectives.

The methodological framework adopted in this study emphasizes analytical consistency, parameter sensitivity evaluation, and performance-based interpretation of results. By integrating computational modelling, dynamic analysis, and comparative response assessment, the research provides a robust foundation for understanding how reinforcement grade influences seismic behaviour in medium-rise reinforced concrete buildings located in high seismic hazard regions.

IV. RESULTS AND DISCUSSION

A. *Storey Displacement Analysis (Fe415 Reinforcement)*

The storey displacement response obtained from response spectrum analysis represents the global lateral deformation behaviour of the G+10 reinforced concrete building subjected to seismic loading conditions. The displacement profile exhibits a gradual increase in lateral movement from the base towards the top storey, which is consistent with the fundamental mode-dominated dynamic behaviour typically observed in medium-rise buildings. Lower storeys experience comparatively smaller displacement due to higher stiffness contribution from foundation restraint and cumulative structural mass participation. As height increases, stiffness reduces relative to accumulated inertia effects, resulting in amplified displacement demand at upper levels.

The displacement trend indicates smooth variation without abrupt irregularities, suggesting uniform stiffness distribution and absence of significant structural discontinuities. Such behaviour confirms the adequacy of modelling assumptions and validates the effectiveness of response spectrum analysis in capturing realistic deformation characteristics. Although overall displacement remains within permissible limits prescribed by seismic design provisions, the increasing gradient towards upper floors highlights the importance of drift control strategies in ensuring both structural safety and serviceability performance. This displacement pattern serves as a baseline reference for evaluating the influence of higher reinforcement grades on deformation reduction and stiffness enhancement.

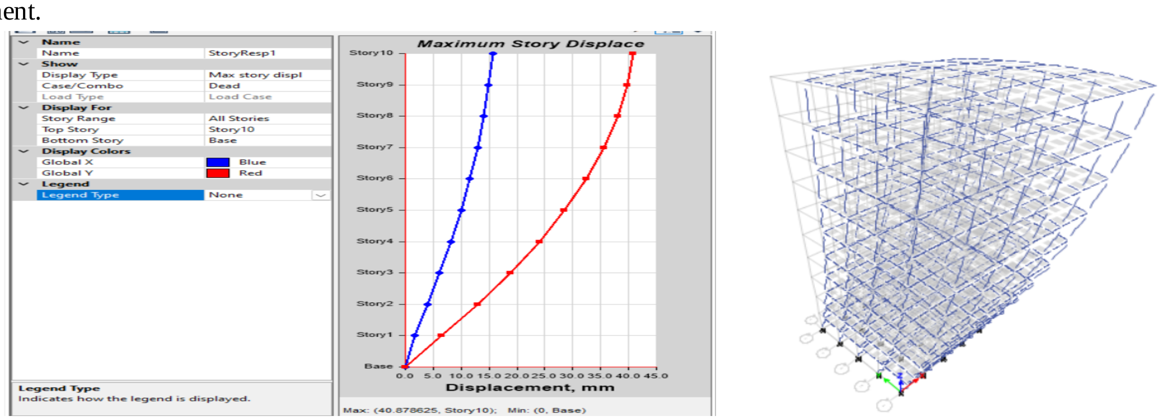

Figure 3: Storey displacement variation along building height for the model with Fe415 reinforcement under response spectrum loading.

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B. Storey Displacement Analysis (Higher Grade Reinforcement)

When higher grade reinforcement is incorporated into the structural model while maintaining identical geometric and loading conditions, a noticeable improvement in lateral displacement control is observed. The enhanced yield strength and stiffness contribution of higher grade steel results in reduced global deformation across all storey levels. The reduction is particularly significant in upper storeys where displacement demand is generally critical due to cumulative dynamic amplification effects. This indicates that reinforcement grade plays an important role in governing the flexibility characteristics of reinforced concrete frames.

The comparative displacement profile demonstrates that while the overall deformation pattern remains similar in shape, the magnitude of displacement decreases consistently across the building height. Such behaviour confirms that increased reinforcement strength contributes to improved lateral load resistance without fundamentally altering vibration mode characteristics. The findings suggest that material optimization strategies focusing on reinforcement grade selection can effectively enhance seismic performance by reducing excessive lateral movement. However, designers must carefully evaluate associated force redistribution effects and ensure that improved stiffness does not lead to undesirable concentration of demand in specific structural components.

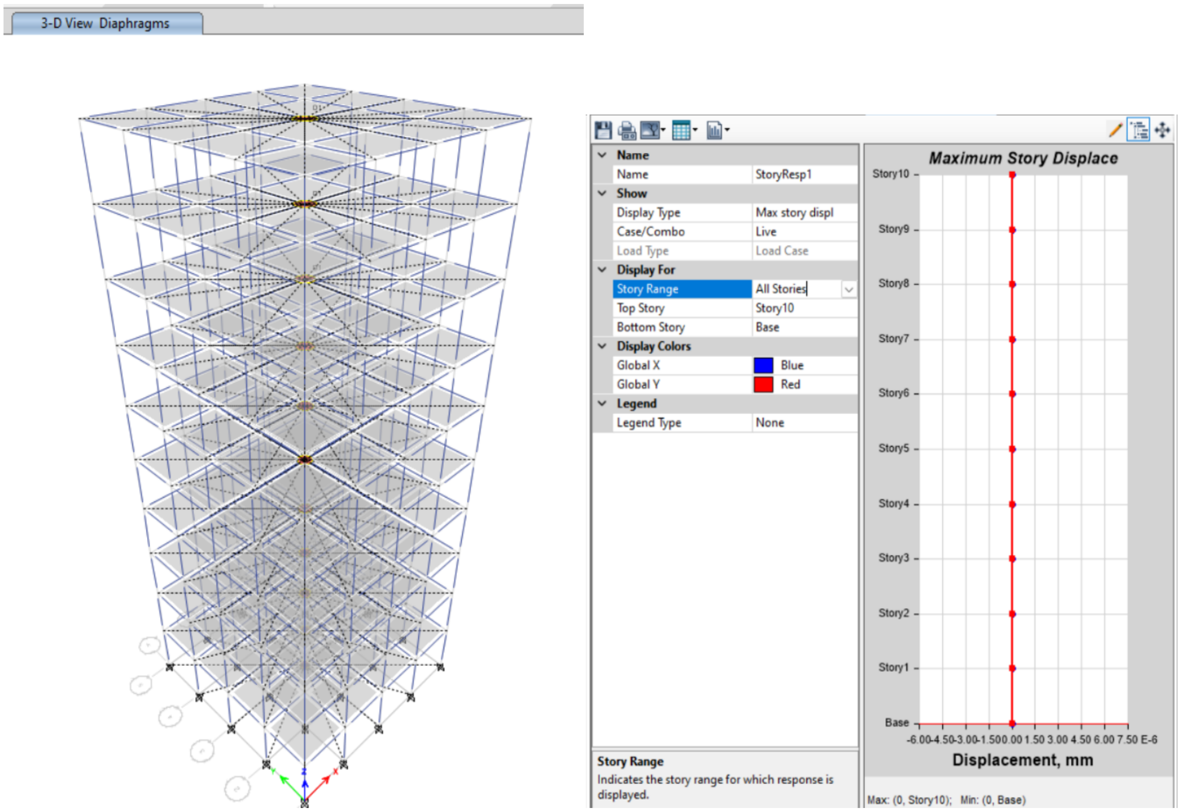

Figure 4: Comparative storey displacement response showing reduced lateral deformation for higher grade reinforcement configuration.

C. Inter-Storey Drift Behaviour

Inter-storey drift represents one of the most critical performance indicators in seismic design because it directly relates to structural damage potential and non-structural component safety. The analytical results reveal that maximum drift demand occurs in intermediate storeys, where the combined influence of modal participation and stiffness variation results in peak relative displacement between consecutive floors. This behaviour aligns with established dynamic response patterns in multi-storey framed structures, where drift concentration often occurs away from both the base and the roof levels.

The introduction of higher grade reinforcement leads to measurable reduction in drift values throughout the building height. Improved stiffness characteristics contribute to enhanced deformation control, thereby reducing the likelihood of cracking, joint distress, and non-structural damage. The drift profile maintains a smooth distribution pattern, indicating stable structural response without abrupt irregularities or soft-storey formation. Maintaining drift within permissible limits is essential for achieving performance objectives such as life safety and immediate occupancy following moderate seismic events. The observed drift reduction demonstrates the practical benefits of reinforcement optimization in improving overall structural resilience.

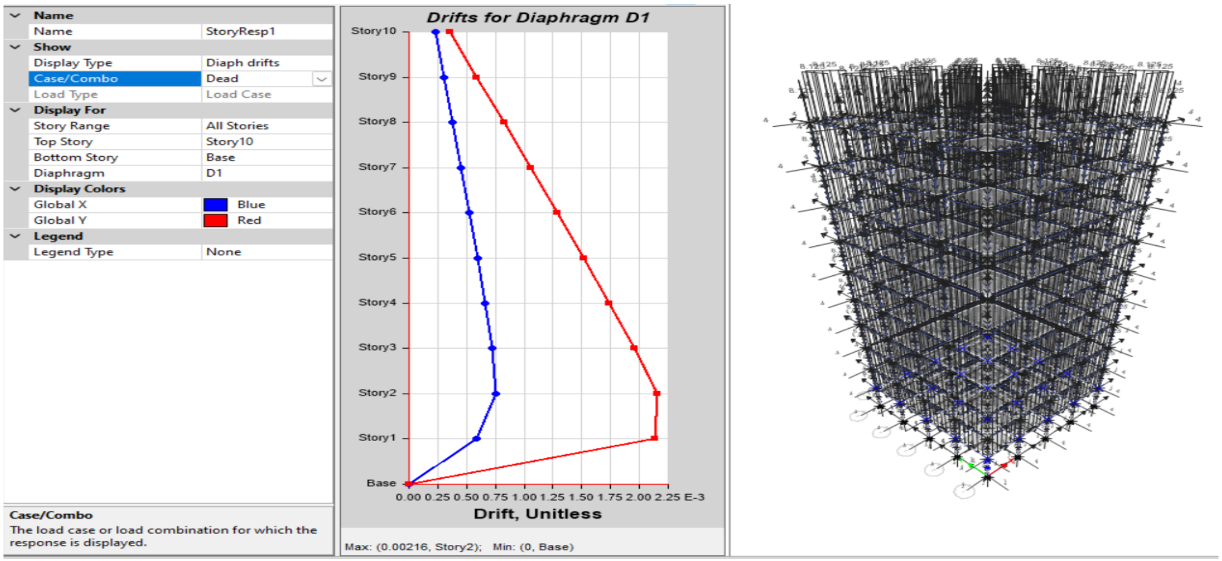

Figure 5: Inter-storey drift distribution along building height highlighting deformation control improvement due to higher grade reinforcement.

D. Base Shear Response

Base shear represents the cumulative lateral force transmitted to the foundation level during earthquake excitation and serves as an indicator of overall structural stiffness and mass participation characteristics. Analytical results show that variation in reinforcement grade influences base shear magnitude due to changes in lateral rigidity and dynamic response behaviour. Structures with higher stiffness tend to attract greater seismic forces, resulting in marginally increased base shear demand compared to more flexible configurations.

The comparative analysis indicates that while higher grade reinforcement improves displacement and drift control, it may also lead to increased force demand in primary structural elements. This observation reflects the fundamental trade-off between stiffness and force response in seismic engineering. Designers must therefore ensure that enhanced strength capacity is accompanied by adequate detailing and load redistribution mechanisms to prevent localized overstressing. The base shear variation remains within acceptable design limits, confirming the structural adequacy of the analysed configurations.

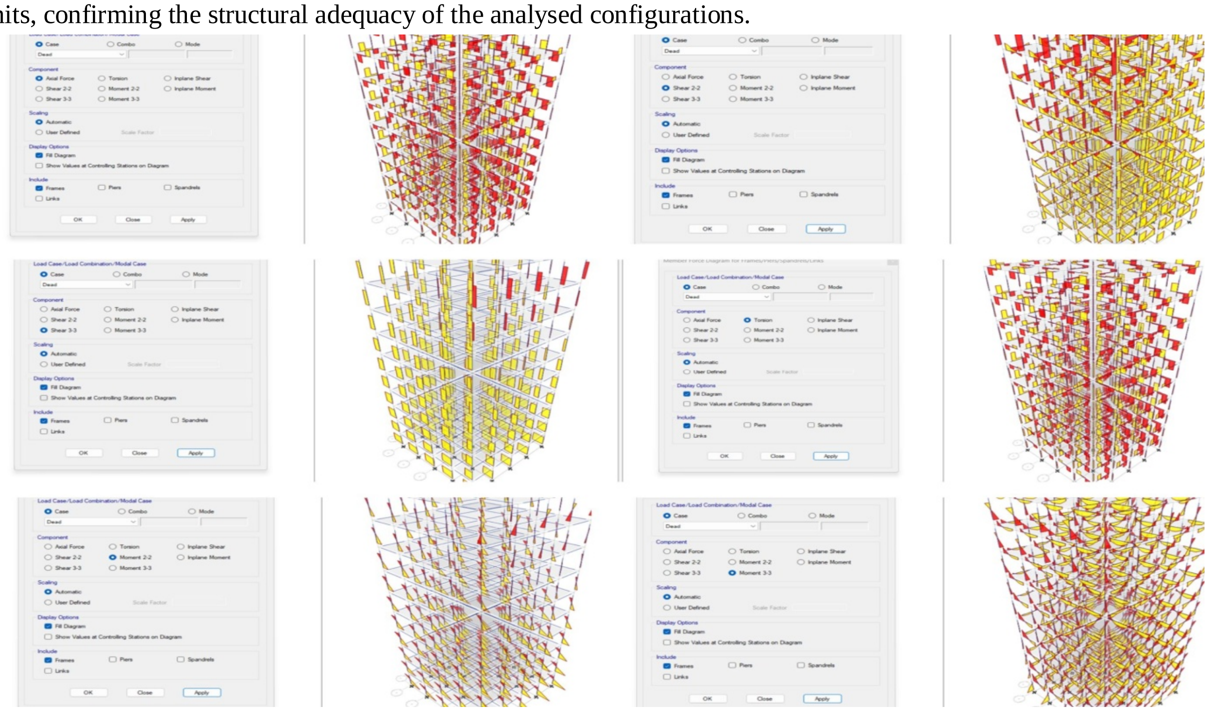

Figure 6: Base shear comparison for different reinforcement grade configurations obtained from response spectrum analysis.

E. Modal Time Period Characteristics

Modal analysis results provide valuable insight into the dynamic properties of the structure, particularly its natural time period and vibration mode shapes. The fundamental mode dominates lateral response behaviour, with higher modes contributing progressively smaller participation factors. Introduction of higher grade reinforcement results in a slight reduction in natural time period due to increased structural stiffness. This shift indicates reduced flexibility and altered resonance characteristics relative to design response spectrum demands.

The modal shape distribution confirms that deformation primarily occurs in translational modes with minimal torsional coupling, suggesting symmetric structural configuration and balanced stiffness distribution. Accurate estimation of modal properties is essential for reliable response spectrum analysis, as these parameters directly influence seismic demand prediction.

The observed variation in time period highlights the importance of considering material properties during dynamic modelling to ensure realistic representation of structural behaviour.

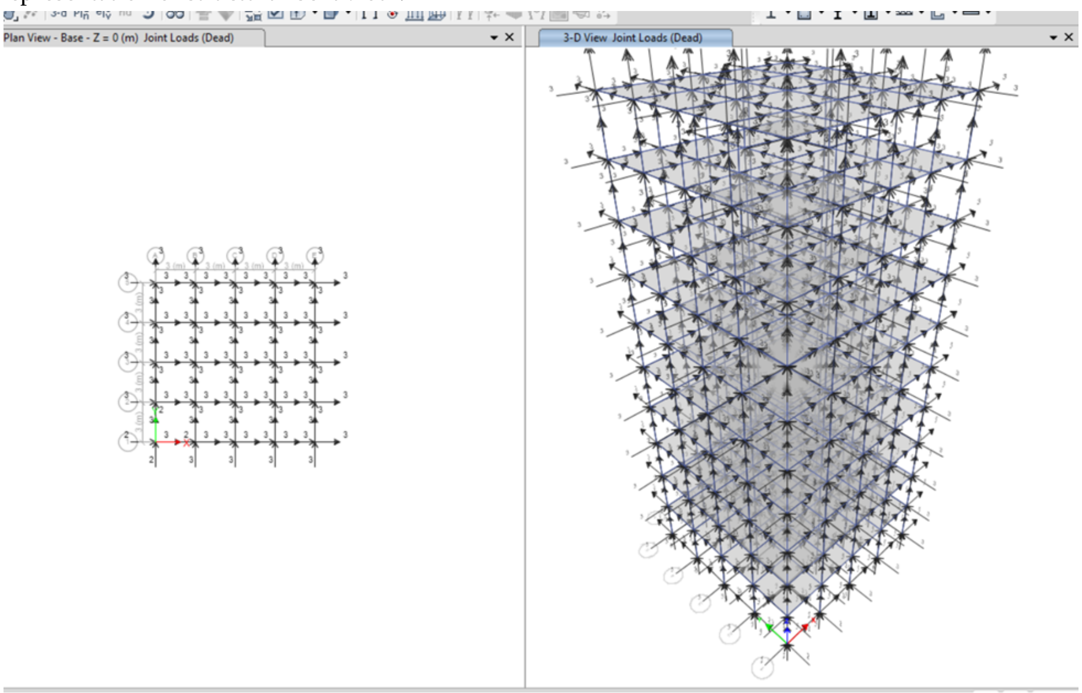

Figure 7: Fundamental mode shape and time period characteristics of the analysed G+10 reinforced concrete building model.

Table 1: Comparative Performance Table

Parameter	Conventional Reinforcement	Higher Grade Reinforcement	Performance Observation
Storey Displacement	Higher	Reduced	Improved deformation control
Inter-Storey Drift	Moderate	Lower	Enhanced serviceability performance
Base Shear	Lower	Slightly Higher	Increased stiffness effect
Time Period	Longer	Shorter	Reduced structural flexibility

Table Interpretation:

The comparative performance table provides a consolidated overview of seismic response characteristics observed in analytical models developed using different grades of reinforcing steel. The results clearly indicate that reinforcement grade significantly influences deformation behaviour, dynamic properties, and force distribution within the structural system. Storey displacement values show a consistent reduction when higher grade reinforcement is used, demonstrating improved lateral stiffness and enhanced resistance to earthquake-induced deformation. This reduction is particularly beneficial for maintaining structural integrity and minimizing damage to architectural and non-structural components.

Inter-storey drift values also exhibit noticeable improvement with increased reinforcement strength. Since drift is directly associated with potential structural damage and occupant safety concerns, its reduction represents a key performance advantage. Improved drift control contributes to better post-earthquake functionality and reduces the likelihood of progressive damage mechanisms. However, the analysis also reveals that increased stiffness results in marginally higher base shear demand. This behaviour is consistent with fundamental seismic response theory, where stiffer structures attract greater inertia forces due to reduced natural time period.

The variation in modal time period further confirms that reinforcement grade influences dynamic characteristics of the building. A shorter time period indicates increased rigidity and altered resonance interaction with ground motion frequency content. While this change improves deformation performance, it may necessitate careful design consideration to ensure adequate ductility and energy dissipation capacity. Overall, the comparative results highlight the need for balanced design strategies that integrate strength enhancement with performance-based evaluation to achieve optimal seismic resilience.

F. Discussion

The analytical findings obtained in this study provide meaningful insights into the relationship between reinforcement grade and seismic performance of medium-rise reinforced concrete buildings. The results confirm that material properties play a crucial role in governing deformation characteristics, dynamic behaviour, and force response under earthquake excitation. Higher grade reinforcement contributes to improved stiffness distribution, leading to reduced lateral displacement and inter-storey drift demand. These improvements enhance both structural safety and serviceability performance, particularly in high seismic hazard regions where deformation control is a primary design objective.

However, the observed increase in base shear demand highlights the inherent trade-off associated with stiffness enhancement. While reduced flexibility limits excessive deformation, it simultaneously increases seismic force attraction. This necessitates careful detailing and capacity design considerations to ensure that structural components possess sufficient strength and ductility to accommodate increased demand. The findings reinforce the importance of performance-based design approaches that evaluate multiple response parameters rather than relying solely on displacement or force criteria.

The modal analysis results further demonstrate that reinforcement grade influences natural vibration characteristics, which in turn affect seismic demand prediction. Accurate representation of material properties during computational modelling is therefore essential for obtaining realistic response estimates. The controlled analytical framework adopted in this study enables clear interpretation of parameter sensitivity and supports rational material optimization strategies. Overall, the results indicate that appropriate selection of reinforcement grade can significantly enhance seismic resilience of medium-rise buildings when integrated with holistic structural design considerations.

V. CONCLUSION

This research paper presented a comprehensive analytical investigation into the seismic performance of a G+10 reinforced concrete building considering the influence of different grades of reinforcing steel under response spectrum loading conditions corresponding to Seismic Zone IV. The primary objective of the study was to evaluate how variations in reinforcement material properties affect key structural response parameters such as storey displacement, inter-storey drift, base shear demand, and modal time period characteristics. By adopting a controlled computational modelling framework in which geometric configuration, loading conditions, and boundary assumptions were maintained constant, the research successfully isolated the role of reinforcement grade in governing dynamic structural behaviour.

The analytical results demonstrate that higher grade reinforcement contributes significantly to improved deformation control in medium-rise reinforced concrete buildings. Reduction in global storey displacement and inter-storey drift values indicates enhanced lateral stiffness and increased resistance to earthquake-induced deformation. Such improvements are particularly important in seismic performance evaluation because excessive deformation is closely associated with both structural damage and non-structural component failure.

The observed drift reduction suggests that reinforcement optimization can play an effective role in achieving performance objectives such as life safety and operational continuity following moderate seismic events.

At the same time, the study highlights the fundamental trade-off between stiffness enhancement and seismic force demand. Increased structural rigidity associated with higher grade reinforcement results in marginally higher base shear values, reflecting greater inertia force attraction. This behaviour reinforces the importance of adopting balanced design strategies that integrate strength, stiffness, and ductility considerations rather than focusing exclusively on deformation control. Adequate detailing and capacity design provisions remain essential to ensure that increased force demand does not lead to premature failure mechanisms.

Modal analysis results further confirm that reinforcement grade influences dynamic characteristics by reducing the fundamental natural time period of the structure. This change modifies resonance interaction with ground motion frequency content and contributes to overall variation in seismic demand distribution. Accurate representation of such material-dependent dynamic properties is therefore critical in computational structural analysis. The study demonstrates that advanced modelling tools such as ETABS provide valuable capabilities for evaluating parameter sensitivity and supporting performance-based design decisions.

From a practical engineering perspective, the findings of this research provide useful guidance for material selection in medium-rise building construction located in high seismic hazard regions. Reinforcement grade optimization can improve structural resilience, reduce damage potential, and enhance long-term serviceability performance. However, designers must ensure that stiffness enhancement is accompanied by sufficient ductility capacity and energy dissipation mechanisms to maintain overall seismic safety. The research therefore contributes to the broader objective of developing rational, performance-oriented structural design approaches that balance safety, economy, and constructability considerations.

Despite its contributions, the study acknowledges certain limitations that offer opportunities for future research. The analytical framework focused on a regular G+10 building configuration and response spectrum analysis methodology. Future investigations may extend this work by examining taller buildings, structural irregularities, soil–structure interaction effects, and nonlinear time-history analysis for more detailed performance evaluation. Experimental validation of analytical findings and integration of seismic retrofitting strategies such as bracing systems or supplemental damping devices may further enhance the reliability and applicability of results.

In conclusion, the research demonstrates that reinforcement grade selection is a critical parameter influencing seismic performance of reinforced concrete buildings. Through systematic computational analysis and comparative response assessment, the study provides meaningful insights that support performance-based structural design and contribute to improving earthquake resilience in urban built environments.

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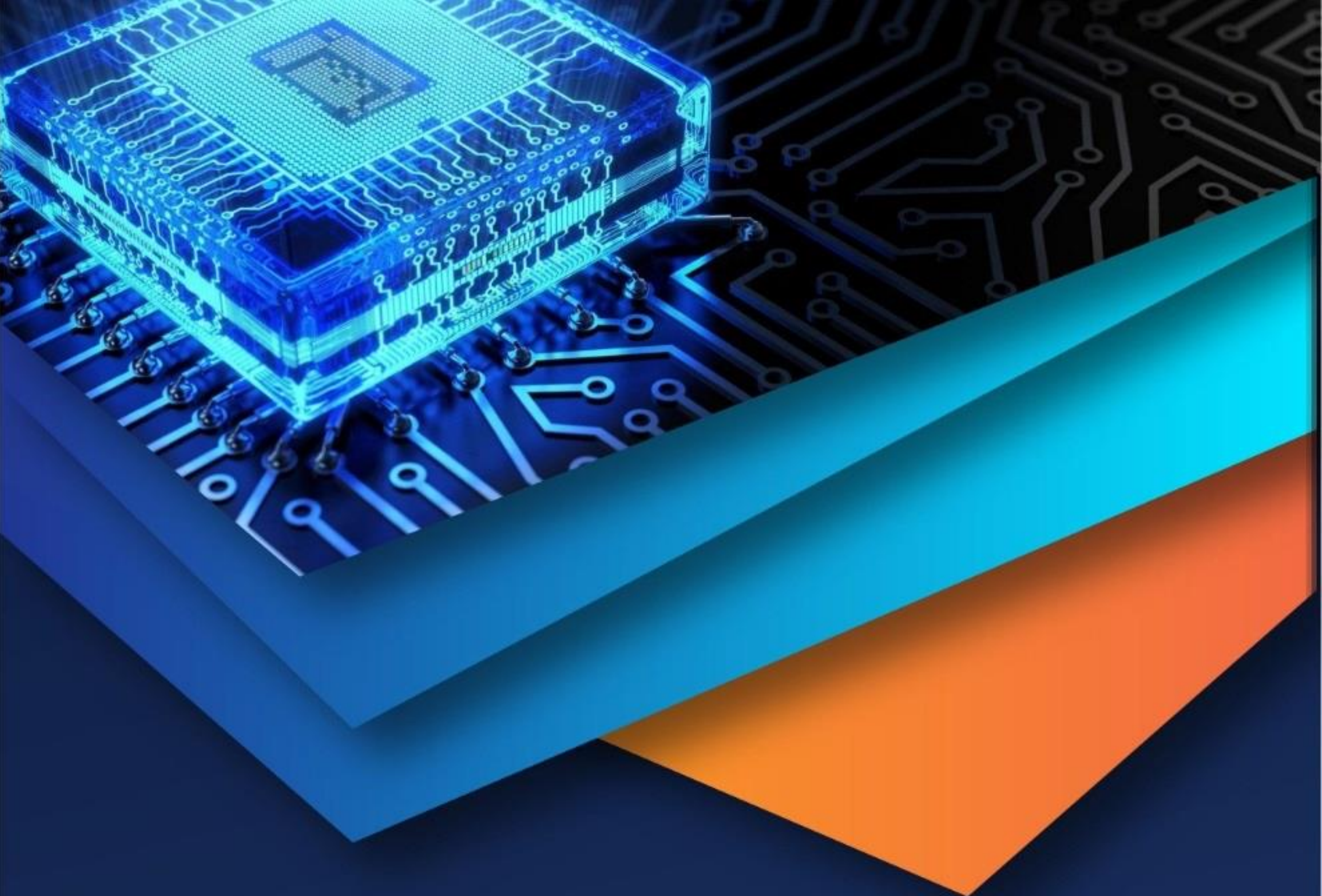

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