

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

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Abstract

Seismic safety evaluation of reinforced concrete (RC) buildings has become an essential aspect of structural engineering practice, especially in regions categorized under high seismic hazard such as Seismic Zone IV. The reviewed dissertation examines the seismic response behaviour of a G+10 storey reinforced concrete building by investigating the influence of different grades of reinforcing steel on critical structural performance parameters. A three-dimensional analytical model was developed using structural analysis software, and dynamic analysis was carried out through response spectrum analysis and modal analysis in accordance with the provisions of IS 1893 (Part 1): 2016. The analytical results indicate that the use of higher-grade reinforcing steel enhances overall structural stiffness, leading to reduced storey displacement and inter-storey drift. However, increased stiffness also results in higher base shear demand due to greater seismic force attraction. Conversely, lower-grade steel exhibits comparatively higher lateral deformation but provides improved ductility and energy dissipation capacity. All structural models were found to satisfy permissible drift limits prescribed by seismic design codes. The study highlights the importance of balanced material selection strategies to achieve optimal seismic performance in medium-rise RC buildings subjected to dynamic earthquake loading.

Keywords: Seismic analysis, Reinforced concrete buildings, Response spectrum method, Steel grade influence, Storey displacement, Inter-storey drift, Base shear, Modal analysis, IS 1893, ETABS.

1. Introduction

Earthquakes represent one of the most destructive natural hazards affecting the built environment, particularly in densely populated urban regions characterized by rapid infrastructural growth. Unlike gravity loads, seismic forces are dynamic, cyclic, and multidirectional in nature, generating complex stress distributions and deformation patterns within structural systems. Multi-storey reinforced concrete (RC) buildings are especially vulnerable to such loading conditions due to increased mass participation, higher lateral flexibility, and the amplification of seismic demand with elevation. As a result, the assessment of seismic performance has become an essential component of modern structural engineering practice aimed at safeguarding human life and minimizing economic losses. In recent decades, accelerated urbanization and land scarcity have led to a substantial increase in the construction of medium-rise structures, such as G+10 storey buildings, in both metropolitan and developing

cities. These buildings form a significant portion of urban residential and commercial infrastructure and therefore require reliable seismic design strategies. In the Indian seismic zoning framework, regions categorized under Seismic Zone IV are exposed to high seismic hazard, necessitating stringent adherence to codal provisions for earthquake-resistant design. Structures in such zones must be capable of sustaining strong ground motion without experiencing catastrophic failure, thereby ensuring life safety and maintaining post-earthquake serviceability. The reviewed dissertation is centred on evaluating how variations in reinforcing steel grade influence the seismic response behaviour of a G+10 storey reinforced concrete moment-resisting frame building. Reinforcing steel plays a critical role in determining structural stiffness, strength, ductility, and energy dissipation capacity. Commonly used steel grades such as Fe415 and Fe500 exhibit distinct mechanical characteristics, which can significantly affect lateral displacement

response, inter-storey drift distribution, base shear magnitude, and dynamic properties including natural time period and modal participation. Understanding these effects is vital for optimizing material selection and achieving balanced structural performance under earthquake loading. The study adopts a performance-based earthquake engineering perspective, which prioritizes controlled damage mechanisms and collapse prevention during severe seismic events. Rather than designing structures solely for strength, modern seismic design emphasizes deformation capacity, ductile behaviour, and predictable energy absorption. By systematically analysing the impact of steel grade while maintaining constant building geometry, loading conditions, and concrete material properties, the research isolates the contribution of reinforcement characteristics to overall seismic performance. This methodological

approach enhances the reliability of conclusions and provides meaningful insights for structural designers. Furthermore, the research integrates dynamic analysis techniques, including response spectrum analysis and modal analysis, to capture realistic structural behaviour under seismic excitation. Such analytical methods enable the evaluation of lateral force distribution, deformation demand, and structural stability across different storey levels. The findings of the dissertation contribute to improved seismic design decision-making by highlighting the trade-off between increased stiffness and force demand associated with higher-grade steel, as well as the enhanced ductility potential of lower-grade reinforcement. Overall, the study underscores the importance of informed material selection strategies for ensuring safe, economical, and code-compliant construction of medium-rise reinforced concrete buildings in high seismic zones.

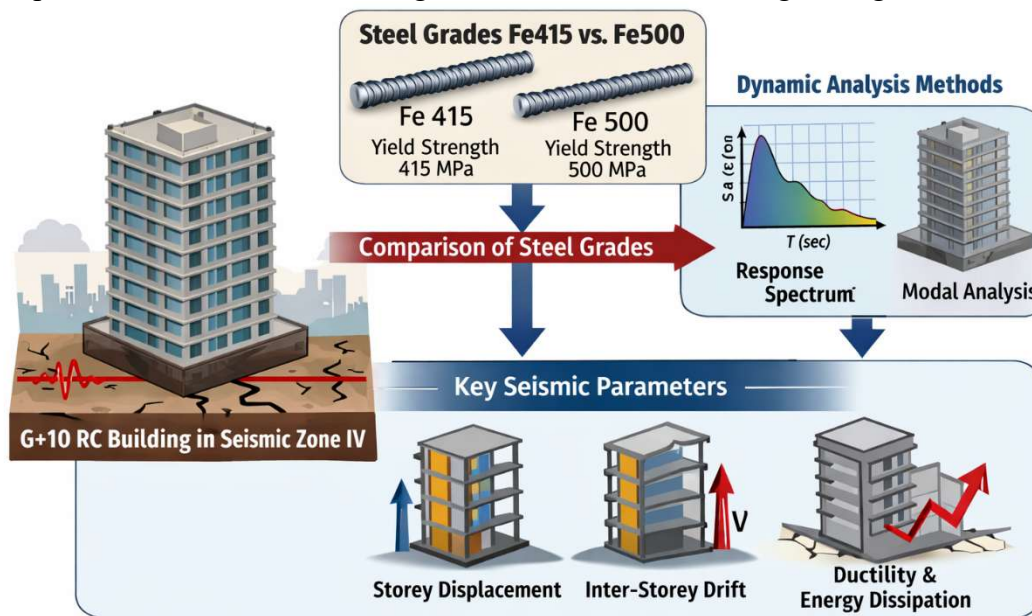


Figure 1: Conceptual overview of seismic response evaluation of a G+10 reinforced concrete building considering the influence of reinforcing steel grade using dynamic analysis methods.

2. Review of Structural Configuration and Seismic Design Considerations

The reviewed dissertation provides a comprehensive description of the structural configuration of a G+10 storey reinforced concrete (RC) building designed as a moment-resisting frame system. The structural framework primarily consists of interconnected beams and columns supporting reinforced concrete slabs that function as horizontal diaphragms for effective distribution

of lateral seismic forces. The diaphragm action of floor slabs ensures that inertial forces generated during earthquake excitation are transferred to vertical lateral load-resisting elements in a coordinated manner. This integrated structural behaviour plays a vital role in maintaining global stability and minimizing differential displacement between structural components. As building height increases, the seismic response becomes increasingly influenced by higher mode

participation and dynamic amplification effects. Medium-rise structures such as G+10 buildings exhibit noticeable lateral flexibility compared to low-rise buildings, which leads to greater displacement demand under earthquake loading. The dissertation highlights that cumulative seismic forces tend to concentrate toward the lower storeys, resulting in higher base shear values and increased deformation demand at foundation and column levels. This phenomenon necessitates careful design of lower storey columns and beam-column joints to prevent structural distress or progressive failure mechanisms.

The research emphasizes the importance of maintaining structural regularity in both plan and elevation to ensure predictable seismic behaviour. Irregularities in mass, stiffness, or geometry can induce torsional effects and localized stress concentrations that significantly increase vulnerability during seismic events. In particular, the formation of soft storey conditions due to abrupt reduction in stiffness or strength at a specific level can lead to disproportionate damage and potential collapse. Therefore, uniform distribution of stiffness and strength along the height of the building is identified as a key design objective. Adequate column strength relative to beam strength is also highlighted as an essential requirement for achieving desirable ductile failure mechanisms. Furthermore, the dissertation underscores the critical role of ductile detailing provisions in enhancing seismic resilience. Compliance with codal requirements such as those specified in IS 13920 ensures improved confinement of concrete, enhanced rotational capacity of plastic hinges, and better energy dissipation during cyclic loading. In high seismic zones, the ability of a structure to undergo controlled inelastic deformation without sudden loss of load-carrying capacity is a fundamental performance requirement. Proper anchorage, lap splicing, transverse reinforcement spacing, and joint detailing contribute significantly to the overall seismic safety of reinforced concrete buildings.

Steel grade selection is identified as an influential parameter affecting multiple aspects of seismic performance, including stiffness, strength, ductility, and force demand. Higher-grade reinforcing steel provides greater yield strength,

which can reduce the required reinforcement area and increase overall structural stiffness. This reduction in flexibility can lead to lower storey displacement and inter-storey drift values, thereby improving serviceability performance. However, increased stiffness may also result in higher seismic force attraction and consequently greater base shear demand, influencing the design of foundations and load-resisting elements. Conversely, lower-grade steel exhibits comparatively higher deformation capacity and ductile behaviour, which can be beneficial for energy absorption during severe seismic events. Although it may require increased reinforcement quantity to meet strength requirements, its enhanced ductility contributes to improved structural robustness. The dissertation therefore highlights the necessity of achieving a balanced approach in material selection, ensuring that both strength and deformation capacity are adequately addressed in the seismic design of medium-rise reinforced concrete buildings.

3. Review of Methodology and Analytical Approach

The reviewed dissertation adopts a systematic analytical research methodology aimed at evaluating the seismic performance of a G+10 storey reinforced concrete (RC) building using advanced dynamic analysis techniques. The study primarily utilizes response spectrum analysis as the principal method for assessing structural response under earthquake excitation. This approach enables the estimation of peak structural responses such as storey displacement, inter-storey drift, and base shear without performing time-consuming nonlinear time-history simulations. By incorporating spectral acceleration values corresponding to different natural periods of vibration, response spectrum analysis provides a practical yet reliable framework for seismic performance evaluation of multi-storey buildings. A comprehensive three-dimensional structural model of the building is developed using ETABS software, which is widely recognized for its capability to perform detailed analysis and design of building systems. The modelling process involves defining structural elements such as beams, columns, slabs, and supports in accordance with reinforced concrete moment-resisting frame

behaviour. Floor slabs are considered to act as rigid diaphragms to ensure appropriate distribution of lateral seismic forces among vertical load-resisting components. Material properties including concrete grade, modulus of elasticity, and reinforcement characteristics are carefully incorporated into the model to simulate realistic structural behaviour.

The building geometry, storey heights, bay dimensions, and loading conditions are defined based on typical design assumptions relevant to medium-rise residential or commercial structures. A key strength of the methodological framework lies in the generation of multiple analytical models by varying only the grade of reinforcing steel while maintaining all other design parameters constant. This controlled modelling strategy allows for an isolated investigation of the influence of steel grade on seismic response characteristics. By ensuring consistency in factors such as building configuration, dead and live load intensities, seismic zone parameters, importance factor, response reduction factor, and soil conditions, the study eliminates confounding variables that could otherwise affect the interpretation of results. Consequently, observed variations in structural performance indicators can be directly attributed to differences in reinforcement yield strength, stiffness contribution, and ductility potential. In addition to response spectrum analysis, modal analysis is conducted to evaluate the dynamic properties of the structure. Modal analysis provides critical information regarding natural time periods, mode shapes, and mass participation factors associated with various vibration modes. For medium-rise buildings, higher mode effects can significantly influence lateral displacement patterns and force distribution along the building height.

By examining modal characteristics, the study gains deeper insights into how reinforcing steel grade may alter overall structural stiffness and vibration behaviour. Increased stiffness associated with higher-grade steel typically leads to reduced fundamental time periods, which in turn affects spectral force demand and base shear values. The analytical procedure is performed in accordance with codal provisions specified in IS 1893 (Part 1): 2016, ensuring that the adopted seismic parameters and design assumptions align with

nationally recognized standards. Parameters such as design horizontal seismic coefficient, zone factor, damping ratio, and response spectrum shape are incorporated into the analysis framework to enhance practical relevance. This compliance with codal requirements strengthens the applicability of the research findings to real-world structural design scenarios, particularly in high seismic zones. Overall, the methodological approach adopted in the dissertation demonstrates a well-structured balance between analytical rigor and practical feasibility. The integration of three-dimensional modelling, controlled parameter variation, and dynamic analysis techniques enables a comprehensive assessment of seismic performance. By focusing on the isolated impact of reinforcing steel grade, the study provides valuable insights into material optimization strategies that can contribute to improved safety, serviceability, and economy in the design of reinforced concrete multi-storey buildings subjected to earthquake loading.

4. Review of Results and Key Findings

The analytical investigation presented in the reviewed dissertation clearly demonstrates that the grade of reinforcing steel plays a significant role in influencing the seismic response characteristics of the G+10 reinforced concrete building. By comparing multiple analytical models developed under identical geometric and loading conditions, the study establishes a direct relationship between reinforcement yield strength and key structural performance indicators such as storey displacement, inter-storey drift, base shear, and overall dynamic behaviour. These findings provide meaningful insights into how material selection decisions can affect both serviceability and safety performance during earthquake excitation. The results indicate that models incorporating higher-grade reinforcing steel exhibit increased global stiffness due to the enhanced strength and rigidity of reinforcement elements. This increased stiffness contributes to reduced lateral displacement across all storey levels, thereby improving deformation control and minimizing the likelihood of excessive structural and non-structural damage during moderate seismic events. Lower inter-storey drift values further suggest improved performance in terms of structural integrity, occupant comfort, and

protection of architectural components such as partitions, cladding, and façade systems. From a serviceability perspective, the use of higher-grade steel can therefore contribute to enhanced overall building performance under dynamic loading conditions.

However, the research also identifies an important consequence of increased stiffness in the form of higher base shear demand. As structural stiffness increases, the natural time period of the building tends to decrease, leading to greater spectral acceleration values and consequently higher seismic force attraction. This increase in force demand necessitates careful consideration in the design of primary load-resisting components, including columns, beam-column joints, shear walls, and foundation systems. Inadequate design of these elements may result in stress concentration or overstressing, potentially compromising structural safety. Thus, while higher-grade steel improves deformation characteristics, it also introduces challenges related to force redistribution and structural capacity requirements. In contrast, models utilizing lower-grade reinforcing steel display comparatively higher lateral deformation due to reduced stiffness. Although this may lead to increased displacement and drift values, the study highlights that such configurations exhibit improved ductility and energy dissipation capacity. These characteristics are particularly advantageous during severe seismic events, where the ability of a structure to undergo controlled inelastic deformation without collapse becomes critical.

Enhanced ductility allows the building to absorb and dissipate seismic energy through plastic hinge formation and redistribution of internal forces, thereby reducing the risk of sudden brittle failure. Importantly, the analytical results confirm that all investigated structural configurations satisfy the permissible inter-storey drift limits prescribed by seismic design codes. This observation indicates that both higher-grade and lower-grade steel options can be considered safe from a code compliance perspective when appropriately designed. The study ultimately concludes that reinforcement grade selection should not be driven solely by strength considerations but must involve a balanced evaluation of stiffness, ductility,

seismic force demand, and overall structural performance. Such a holistic approach supports the development of resilient and economical reinforced concrete buildings capable of withstanding earthquake-induced stresses while maintaining functional safety.

5. Critical Discussion

From a research standpoint, the reviewed dissertation makes a meaningful contribution to the understanding of how reinforcing steel grade influences seismic performance parameters in medium-rise reinforced concrete (RC) buildings. By adopting a controlled analytical framework in which reinforcement grade is varied while other design variables are maintained constant, the study successfully isolates the impact of material strength and stiffness characteristics on overall structural response. This methodological clarity enhances the credibility and interpretability of the results, allowing for more reliable conclusions regarding the relationship between reinforcement properties and seismic behaviour. The use of dynamic analysis techniques, particularly response spectrum and modal analysis, further strengthens the study by providing a more realistic representation of earthquake-induced structural response compared to conventional equivalent static methods. The research also contributes to the broader seismic design literature by highlighting the inherent trade-off between deformation control and seismic force demand. Increased structural stiffness resulting from higher-grade reinforcing steel improves displacement performance and reduces inter-storey drift, thereby enhancing serviceability and limiting non-structural damage. However, this same increase in stiffness can lead to higher base shear and internal force demand, which must be accommodated through adequate design of load-resisting components and foundations. This dual effect underscores a fundamental principle of performance-based structural engineering: optimizing structural performance requires balancing multiple response parameters rather than maximizing a single design objective.

Furthermore, the dissertation's emphasis on ductility and energy dissipation capacity aligns well with modern earthquake-resistant design philosophy. Contemporary seismic design

approaches prioritize the ability of structures to undergo controlled inelastic deformation without collapse, ensuring life safety even in the presence of significant structural damage. By demonstrating that lower-grade reinforcing steel can contribute to enhanced ductile behaviour, the study reinforces the importance of considering deformation capacity alongside strength and stiffness in material selection decisions. This perspective supports the development of resilient structural systems capable of sustaining severe seismic loading through predictable and stable failure mechanisms. Despite these strengths, the research scope could be expanded to provide deeper insights into actual seismic performance. The inclusion of nonlinear time-history analysis would enable the investigation of structural response under realistic ground motion records, capturing complex phenomena such as stiffness degradation, strength deterioration, and cyclic loading effects. Additionally, consideration of soil-structure interaction could improve the accuracy of response prediction by accounting for foundation flexibility and site-specific ground conditions. Incorporating cost optimization and lifecycle performance evaluation would also enhance the practical applicability of the findings, enabling designers to make informed decisions that balance safety, performance, and economic feasibility. Overall, while the dissertation offers valuable analytical insights, further research integrating advanced modelling techniques and multidisciplinary considerations could strengthen its contribution to performance-based seismic design practice.

6. Conclusion

The reviewed dissertation presents a detailed analytical investigation into the seismic performance of a G+10 storey reinforced concrete building situated in Seismic Zone IV, with particular emphasis on evaluating the influence of different grades of reinforcing steel. Through the application of dynamic analysis techniques, including response spectrum analysis and modal analysis, the study successfully examines how variations in reinforcement yield strength affect key seismic response parameters such as storey displacement, inter-storey drift, base shear, and overall structural stiffness. The research highlights the significance of reinforcement characteristics in

determining the dynamic behaviour and stability of medium-rise reinforced concrete moment-resisting frame systems subjected to earthquake loading. The findings clearly demonstrate that the use of higher-grade reinforcing steel contributes to increased structural stiffness, resulting in reduced lateral displacement and improved control of inter-storey drift.

These performance improvements are particularly beneficial in enhancing serviceability and minimizing non-structural damage during moderate seismic events. However, the study also identifies that increased stiffness can lead to greater seismic force attraction and consequently higher base shear demand, which must be carefully considered in the design of foundations, columns, and beam-column joints. This observation underscores the need for balanced structural design approaches that account for both strength and force distribution. Conversely, the research indicates that lower-grade reinforcing steel provides comparatively higher deformation capacity and improved ductility, enabling the structure to dissipate seismic energy more effectively during severe earthquake excitation. Enhanced ductile behaviour plays a crucial role in preventing sudden brittle failure and ensuring controlled inelastic response mechanisms, which are fundamental objectives of modern performance-based earthquake engineering. Although the use of lower-grade steel may require increased reinforcement quantity to satisfy strength requirements, its contribution to structural robustness and resilience remains significant.

Overall, the dissertation reinforces the understanding that reinforcing steel grade is not merely a material selection parameter but a critical design variable influencing global seismic performance. The insights derived from this analytical study offer valuable guidance for structural engineers involved in the design and evaluation of medium-rise buildings in high seismic zones. By promoting informed decision-making in material optimization, the research contributes to the development of safe, economical, and code-compliant reinforced concrete structures capable of sustaining earthquake-induced demands while maintaining structural integrity and life safety.

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