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RC BUILDING ANALYSIS OF SEISMIC RETROFITTING

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Abstract-
In present world, many reinforced concrete structures are not designed to withstand earthquakes. The poor performance of these structures during seismic activities has been identified as one of the factors that led to major damage during the past decade. One of the most effective ways to reduce the risk of damaging a structure is by implementing seismic retrofitting. In the past few years, the techniques have improved significantly. This study aims to provide a comprehensive analysis of the various aspects of this process and its applications. This study utilizes a response spectrum analysis method to design a three-dimensional R.C. frame. A reinforced concrete building's performance is evaluated using the dynamics analysis technique and the computer software program STAAD Pro. The various retrofitting techniques used to increase the load bearing capacity of individual structure elements, including the application of fiber reinforced polymer (FRP) composites, steel and concrete jacketing, and shear walls and shear cores, are highlighted. These techniques can also be used to increase the overall stability of buildings. The majority of retrofitting methods lead to an increase in stiffness and a modest increase in mass, which shortens the period as a result. The strength and ductility of the retrofitted structure frequently rise as the period of vibration shortens. Consequently, a proposed retrofit plan is successful if it causes a rise in the structure's strength and ductility capacity that is greater than the demands put on it by earthquakes.

Keywords—
RC Building, Analysis Seismic Retrofitting, Seismic Events, FRP, Jacketing, Stiffness.

INTRODUCTION

The major goal of this project is to improve knowledge and skills in earthquake resistant design and seismic rehabilitation of existing structures as well as educate participants with computer technology modeling and analysis of structures under seismic loads. The following are the main objectives of this study:

- to research how seismic forces affect structures and to conduct an analysis of the literature on earthquake resistant design
- To determine the their viability of seismic evaluation of buildings and the benefits from carrying out the retrofit measures established for strengthening
- to analyze performance-based design and compare many seismic analysis methods
- to emulate a real building with a structural analysis software and analyze the effects of earthquakes with various analysis methods as prescribed in codes and standards and propose proper rehabilitation techniques in terms of performance.

The majority of earthquakes are caused by the abrupt shifting of the earth's crust in fault zones. The abrupt motion releases strain energy and sends seismic waves across the fault's surrounding rock. The primary objective of structural engineering is to resist earthquakes, among many other impacts, and these seismic waves cause the ground to vibrate. The primary data sources for determining the likelihood of ground shaking or earthquakes at a specific area are historical records and geological records of earthquakes. The seismic hazard maps were created by taking into consideration both data sets. To reduce the risk of human death or injury during earthquakes, the main goal of earthquake resistant design is to prevent building collapse. by providing necessary detailing and preventing the development of the undesirable response modes which could lead to building collapse. The likelihood of a severe earthquake occurring over the lifetime of a structure is incredibly low. Traditional structural designs for the majority of loads do not allow stresses and strains to approach the elastic limit. However, structures are allowed to stretch beyond their elastic limit in earthquake design in reaction to ground motion. A costly lateral load resisting system would be needed if a structure was required to withstand such earthquakes elastically. The building must rely on its ductility and ability to dissipate hysteric energy during a strong earthquake to prevent collapse as the structure is likely to experience inelastic deformation. By preventing collapse, modern buildings can be made to remain secure even when there is intense ground shaking. Controlling the building's reactivity is essential for a successful earthquake engineering design. By choosing a desired response mode, adopting inelastic deformations to acceptable zones, and other methods, this can be accomplished. The issue of seismic retrofitting for earthquake-prone buildings is one that has significant political and societal ramifications today. Despite being situated in regions that have long been regarded as having a high seismic threat, the majority of Italian buildings are susceptible to seismic activity. It has been thirty years since Italy has had 5 to 10 year intervals of moderate to severe earthquakes. Such incidents have amply demonstrated both the fragility of the built environment as a whole and the building stock in particular. Due to previous instances of similar occurrences, the seismic hazard in the regions where those earthquakes have occurred has long been known. Therefore, it is reasonable to wonder why earthquake-prone structures exist if individuals and institutions are aware of the risk. Such a circumstance could have resulted from a number of factors. These are linked to historical occurrences, vanishing memory, greed, avarice, poverty, and ignorance. Therefore, if people and institutions were aware of the seismic risk, it is reasonable to wonder why earthquake-prone structures still stand. Such a circumstance can have developed as a result of various factors. These are connected to past events, fading memories, greed, avarice, poverty, and ignorance. Wars, plagues, and natural catastrophes are some historical events that are particularly important because they can significantly reduce a nation's available resources. In such situations, there is a propensity to build using subpar materials, paying little regard to safe construction practices, and leaving plenty of room for error. After the Second World War, a similar situation occurred in Italy and Japan, and it had happened in Italy numerous times before. It is probable that in such a setting the phenomena of fading memory may occur and that old memories would be quickly forgotten.Instead of making the best use of the production elements, Italian businesses frequently make money by using subpar materials and craftsmanship. This framework also encompasses the gloomy scenario of poor quality control and material acceptance, which primarily leads to paperwork with no real value. Sometimes marginal propensity to spend means that even the owner prefers a subpar product to save money for more pressing requirements. Both inadequate awareness of the seismic hazard and design errors caused by inadequate earthquake knowledge may be among the causes of ignorance. The inability to accurately calculate the structural response to the seismic action is another issue.

LITERATURE REVIEW

Researchers and engineers fully developed three fundamental ideas for seismic design. First, the inertial loads produced by earthquake ground motions change quickly over time. As a result, calculations frequently involve a term that is designated by a measurement of time (typically seconds), and these phrases include frequency, acceleration, and velocity. There is no usage of a time unit in numerous additional structural engineering issues, such as computations of gravity loads. Second, since there is a lot of uncertainty around the equation of forces and structural reactions. It is impossible to anticipate with accuracy the earthquake's occurrence time, magnitude, rupture surface characteristics, or the structure's dynamic response behavior. These unpredictability factors and their implications on the structural effectiveness of evaluation and design must be taken into account using probability and statistical methods. The ability of the earthquake loading to be so severe that materials frequently need to be engineered to react elastically is the third key earthquake engineering idea that sets this discipline apart. Stress corresponds to strain within the purview of Hooke's Law, but beyond that, behavior becomes complex. The majority of the mathematical and experimental research into inelastic behavior started in the 1960s, about. The literature review for the analysis of seismic retrofitting on RC buildings aims to provide a comprehensive overview of existing research, studies, and technical literature related to seismic retrofitting techniques for RC structures. This review explores various aspects, including the effectiveness of retrofitting methods, case studies on retrofitted buildings, performance evaluation criteria, and advancements in retrofitting technologies.

1. Overview of Seismic Retrofitting Techniques:
- Review studies that provide an introduction to seismic retrofitting, highlighting the importance and benefits of retrofitting techniques for RC buildings.
- Examine the different types of retrofitting methods, such as concrete jacketing, steel plate bonding, fiber-reinforced polymers (FRPs), base isolation, energy dissipation devices, and other strengthening techniques.
- Explore the advantages, limitations, and applicability of each retrofitting technique in improving the seismic performance of RC structures.
2. Performance Evaluation and Assessment:
- Investigate performance evaluation criteria and assessment methodologies used to evaluate the effectiveness of seismic retrofitting.
- Examine performance indicators, such as displacement, inter-story drift, base shear, and structural capacity, for comparing the pre-retrofit and post-retrofit conditions of RC buildings.
- Analyze case studies and experimental studies that provide insights into the performance assessment of retrofitted buildings.

SEISMIC ACTIVITY

Although not an absolute term, seismic vulnerability is closely tied to the event under consideration. The same construction may not be vulnerable to one class of earthquakes and yet be vulnerable to another. Therefore, before attempting a seismic vulnerability evaluation of a given construction, the seismic action that will affect that construction must be fully specified. All seismic codes specify the seismic action by means of one or more design spectra. These are a synthetic and quantitative representation of the seismic action which, besides depending on the characteristics of the ground motion, depends on some intrinsic characteristics of the structure such as the fundamental mode of vibration and its energy dissipation capacity. The elastic design spectrum depends on the vibration periods of the structure and on the available damping. In **Figure 1** the elastic spectrum of Eurocode 8 (CEN, 1998) is drawn for three different values of damping. A new draft of Eurocode 8 (CEN, 2003) became available in 2003, but is not being used here because some of the Eurocode 8 material relevant to the present work is still questionable and not generally accepted. The value of the spectral pseudo-acceleration, corresponding to a vanishing small period, corresponds to the peak ground acceleration (PGA). In fact, for T = 0 the structure is rigid and, therefore, subject to the same acceleration as the ground. This acceleration, called the maximum effective ground acceleration or PGA, depends directly on the seismic hazard at the construction site and acts as the anchoring acceleration of the spectrum. This value is generally prescribed by seismic codes as a function of the seismic hazard at the construction site. Furthermore, four regions may be identified for the elastic spectrum, each defined by a lower and upper period. In the first region, (0) ≤ ≤ T TB , the spectral ordinates increase linearly with the period; in the second ( ) T TT B C ≤ ≤ , these are independent of the period; in the third ( ) T TT C D ≤ ≤ , the spectral ordinates decrease rapidly with the period, that is with the reciprocal of the period T according to Eurocode 8; and finally in the fourth region ( ) T T ≥ D , they decrease even more rapidly, with the reciprocal of the period squared according to Eurocode 8. More details on the elastic design spectrum may be found in the seismic codes (CEN, 1998), in specialized publications and in the treatises on dynamics of structures and seismic engineering (Chopra, 2001; Clough and Penzien, 1993). The separation periods , , TTT BCD depend on seismological factors and on local site conditions. For instance Eurocode 8 specifies them as a function of three subsoil classes: A (firm soil), B (medium soil), C (soft soil). In traditional seismic design the energy dissipation capacity of the structure deriving from plastic deformations is generally considered. Including the inelastic resources of a structure allows for a considerable reduction of the spectral ordinates in the design spectrum. This reduction generally depends on the available ductility and on the vibration period. Eurocode 8 considers that this reduction is mainly dependent on a factor related to ductility and it is described as structure behaviour factor or simply structure factor. Typical values of the structure factor q may fall in the range 1 to 5 for reinforced concrete structures (CEN, 1998).

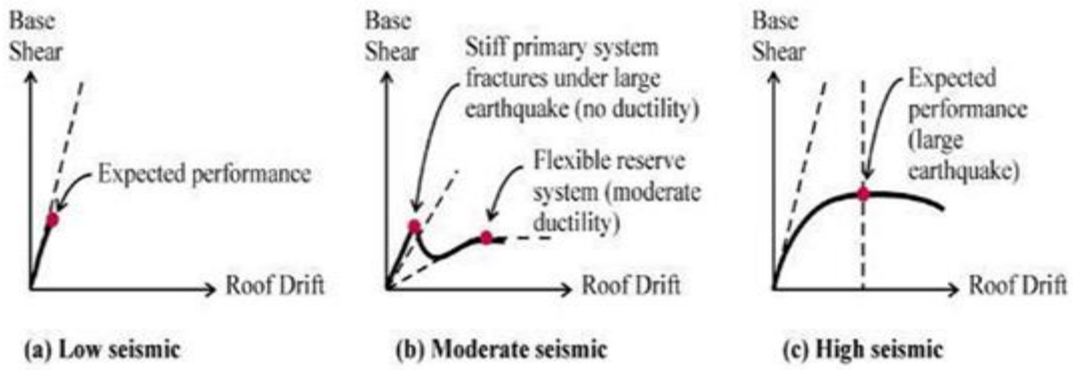

Figure 1- Schematic system behavior for low, moderate and high seismic demands

As may be seen from **Figure 2**, the use of the inelastic resources of a structure allows for a considerable reduction in the spectral ordinates and therefore in the design strength. In addition, the earth consists of three layers; the first one is the crust layer which is the surface of the earth, the second one is the mantle layer which is the second inner part of the earth, and last one the core layer which is the most inner part of the earth.

Figure 2- Additional shear wall

When the surface of the earth creates a sudden movement, this in turns creates an earthquake, and strain energy is released causing the seismic waves through the crust. The earthquakes are largely concentrated to limited seismogenic zone, which Sweden does not lay close to that zone. Although the Swedish territory can be classified as a very low seismicity, an earthquake magnitude of 5 Richter in Sweden would be expected about once per 100 years, due to the fact that geodetic and paleoseimologic data which according to some researchers indicates continues active uplift and deformation of

Fennoscandia. However, in 2008 a moderately strong earthquake recorded in southern Sweden 5 km south-west of the town with the magnitude Throughout the years, investigations have been made regarding the capacity of the buildings against seismic effects; which demonstrated that damages occur to buildings that do not fulfil the requirements of sustainable structures regarding seismic resistant design. Therefore, regulations and standards have been developed to improve the behaviour of buildings regarding ductility and stiffness, to resist seismic actions. Therefore, the seismic design has been applied to design and construction of buildings and civil engineering works in seismic regions in Europe through Eurocode 8 Part1 (EC8:1) where the regulations and method of analysis for seismic design are included. Moreover, the development of existing structures can be completed through Eurocode 8 Part 3 (EC8:3). EC8:3 provides assessment and retrofitting of buildings, where the performance of the building can be improved to fulfil the requirements of seismic design reducing the seismic vulnerability of buildings with no significant additional costs. Since the majority of buildings were constructed in the past using various rules specific to each country, retrofitting is now required. Given the advancement of technology, the traditional approaches to earthquake-resistant building design may not be as effective as they once were; Along with the emergence of new structural kinds and applications, laws are also being revised. Additionally, as the climate and ground morphology are changing over time, this may have an impact on the frequency of earthquakes.

EARTHQUAKE RESISTANT DESIGN

The ground surface shakes as a result of the seismic waves, which is of utmost importance to structural engineers. They can build new structures that can withstand earthquakes by employing these data. However, the primary sources of information used to calculate the seismic intensity or ground tremor at a particular area come from earlier geological and historical records. When load values are taken into account, the primary distinction between the structural and earthquakes responses is that the former is static and the latter is dynamic.Today, most of the buildings in Europe are designed in order to be resisted against earthquakes; where the designer controls the building response by using engineering software programs based on Eurocode 8. This is an advantage; since engineers can modify and control the structure in a proper way in order to obtain the proper design. The earthquake response in the structure is considered above ground level, and the forces are generated by the inertia of buildings when they respond to earthquake induced ground shaking. Moreover, in designing, the structure's response against earthquake is predicted from a design spectrum; which is specified in EC8:1 and the first step of creating a design response spectrum is to determine the maximum response of the structure to a specific ground motion. Normally, this first step is prepared from the seismologists and geotechnical engineers where they are presenting a response spectrum such as displacement, acceleration or velocity against the response period. The role of earthquake resistant design is to prevent buildings from collapse during an earthquake event, and minimizing the injuries to people. The seismicity differs from place to place due to the morphology of ground; thus, low seismicity has less effect on injuries and collapse of structures. Furthermore, in earthquake design the structure is permitted to undergo beyond the elastic limit which is called inelastic; this is mostly common for severe earthquakes which can cause inelastic deformations and it relies on the ductility and energy dissipation capacity of the structure in order to avoid the collapse.
The fundamental principles of earthquake-resistant design include:

1. Understanding Seismic Forces: Earthquakes generate various types of forces, including vertical and horizontal ground motion, as well as inertial and impulsive forces. Designers must analyze and consider these forces to determine the structural response and develop appropriate design measures.

2. Site Evaluation and Soil Analysis: The characteristics of the site and the soil play a critical role in the seismic performance of a structure. Geotechnical investigations are conducted to assess soil conditions, liquefaction potential, and ground amplification effects to inform the design process.
3. Structural Integrity and Redundancy: Designers employ structural systems that ensure the integrity and redundancy of the building. This includes designing load paths that efficiently transfer forces to the foundation, using reinforced concrete or steel members, and employing appropriate connection details to enhance ductility.
4. Damping and Energy Dissipation: Incorporating damping mechanisms and energy dissipation devices can help dissipate seismic energy and reduce the forces transmitted to the structure. Examples include tuned mass dampers, viscoelastic dampers, and friction pendulum systems.
5. Base Isolation: Base isolation involves placing flexible bearings or isolators between the structure and its foundation to decouple the building from the ground motion. This technique reduces the transfer of seismic forces to the superstructure, minimizing structural damage.
6. Strengthening and Retrofitting: Existing buildings can be retrofitted to enhance their seismic resilience. Techniques such as concrete jacketing, fiber-reinforced polymers (FRPs), and steel bracing can be employed to strengthen critical structural elements and improve overall performance.
7. Building Codes and Regulations: Building codes and regulations establish the minimum requirements for earthquake-resistant design. They ensure that structures are designed and constructed to withstand the anticipated seismic forces in a particular region.

BUILDING MODELING

The RC building utilized in this study is an eight-story (G+7) building with the identical floor plan as shown in **Figure 3**, but with 4 bays spaced 4 meters apart in the longitudinal direction and 3 bays separated 4 meters apart in the transverse direction

(i) Load combinations- Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.

1.5(DL + LL)
1.2(DL + LL + EQ – X)
1.2(DL + LL + EQ –Y)
1.5(DL + EQ –X)
1.5(DL + EQ –Y)
0.9DL + 1.5EQ – X
0.9DL + 1.5EQ - Y

(ii) Structural Details - The floor to floor height is 3m for all the stories.

The live load = 3KN/m2 for all floors.
The gravity load = 12KN/m2 for all floors.
Thickness of shear wall = 200mm
The unit weight of concrete = 20KN/m3
The compressive strength of concrete = 20N/mm2
Yield strength of steel = 415 N/mm2
The modulus of elasticity of concrete = 25000 N/mm2
The modulus of elasticity of steel = 2×105 N/mm2
The steel bracing used is ISA 110 ×110 ×10
Located in seismic region V sub-soil type 2 (medium)
Importance factor = 1
Response Modification Coefficient = 5

Seismic analysis is carried out on building models using the software Staad pro V8i.

The load cases considered in the seismic analysis are as per IS 1893 – 2002 and IS 456 – 2000

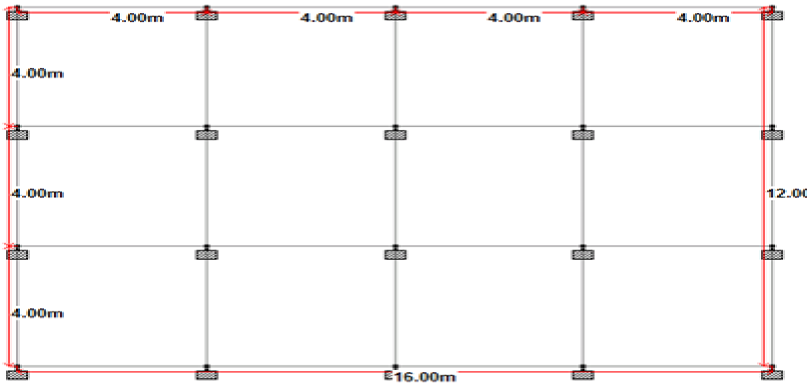

Figure 3- Building plan

RESULTS

The results of an analysis of seismic retrofitting on RC buildings can vary depending on the specific objectives, methods, and data utilized in the study. Some potential results and findings that may arise from such an analysis could include:

1. Effectiveness of Retrofitting Techniques: The analysis may reveal the effectiveness of different retrofitting techniques in improving the seismic performance of RC buildings. This could include reductions in displacement, inter-story drift, and base shear, indicating enhanced structural resilience.
2. Comparative Performance Evaluation: By comparing the pre-retrofit and post-retrofit conditions, the analysis may demonstrate the extent to which the retrofitting measures have improved the structural behavior of the buildings. This could be observed through quantitative indicators such as increased structural capacity and improved response under simulated seismic loads.

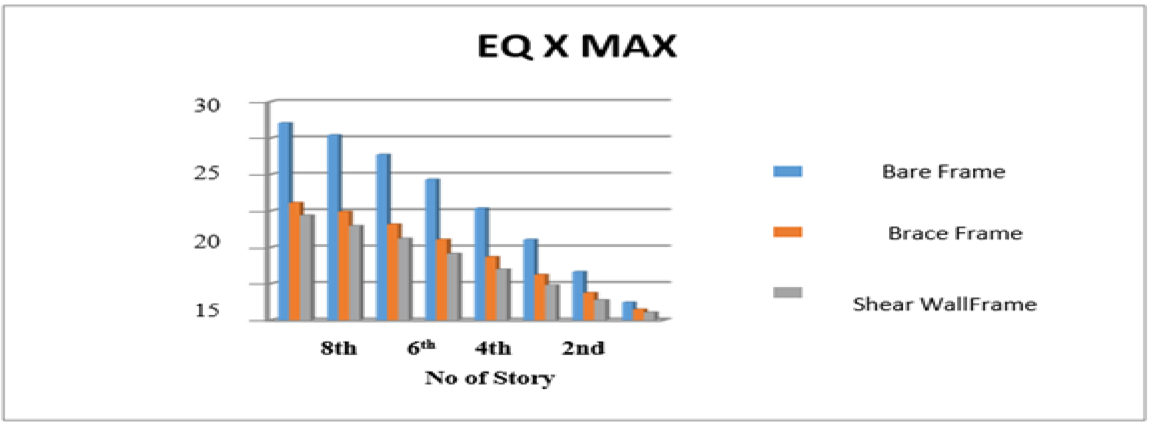

Figure 4- Graph of Maximum Lateral Displacement (mm) in X Direction

3. Retrofitting Recommendations: The analysis may provide insights into the most suitable retrofitting techniques for specific types of RC buildings. It could offer recommendations regarding the selection and implementation of retrofitting strategies based on the performance evaluation and cost-effectiveness considerations.
4. Case Study Analysis: If case studies were conducted, the results may highlight the performance of retrofitted RC buildings during actual seismic events. This could include observations of reduced damage, improved occupant safety, and minimized repair and recovery costs compared to similar non-retrofitted buildings.

5. Challenges and Limitations: The analysis may identify challenges and limitations associated with certain retrofitting techniques, such as construction complexities, cost implications, or specific constraints that may affect their implementation.

CONCLUSION

- Shear wall elements are highly effective in reducing the lateral displacement of the frame because they cause significantly less drift and horizontal deflection than braced or planar frames do.
- The position of shear-wall-3 is advantageous as they are effective in minimizing actions caused in frame with less horizontal deflection and drift. The location of shear-wall-3 has considerable effect on the seismic response than the plane frame.
- The idea of using steel bracing is one of the advantageous concepts that can be used to strengthen or retrofit the existing buildings. Shear wall construction will provide considerable stiffness to the building by limiting the damage to the structure.
- Since the total weight on the current building won't change considerably, steel bracings are a viable alternative to other strengthening or retrofitting procedures.
- Steel bracings distribute lateral loads through an axial load mechanism while reducing the flexure and shear demands on beams and columns.
- The employment of bracing systems of the X type helps to limit the lateral displacements of the building under study.
- When compared to other types of bracing systems, building frames with the X bracing system will experience the least amount of bending moments.
- The weight of the current structure as a whole won't change much with the use of steel bracings.
- Shear walls minimize the maximum displacement because they reduce the lateral displacement of the building by 46.81% and by 40.56%, respectively, when compared to the bare frame.

The analysis of seismic retrofitting on RC buildings is a critical area of research and practice aimed at enhancing the structural resilience of existing structures in earthquake-prone regions. Through a comprehensive literature review and examination of related works, several key conclusions can be drawn:

1. Importance of Seismic Retrofitting: Seismic retrofitting plays a crucial role in mitigating the risks associated with earthquakes by improving the structural performance of RC buildings. It offers an effective means of enhancing the resilience and safety of existing structures.
2. Retrofitting Techniques: Various retrofitting techniques, such as concrete jacketing, steel bracing, fiber-reinforced polymers (FRPs), base isolation, and energy dissipation devices, have been widely investigated and employed for improving the seismic performance of RC buildings. Each technique has its advantages, limitations, and applicability depending on the specific structural characteristics and performance objectives.
3. Performance Evaluation: Performance evaluation criteria and assessment methodologies are essential for evaluating the effectiveness of seismic retrofitting measures. Parameters such as displacement, inter-story drift, base shear, and structural capacity are commonly used to assess the performance of retrofitted RC buildings. Experimental testing, numerical modeling, and case studies are valuable tools for evaluating retrofitting effectiveness.
4. Case Studies: Case studies of retrofitted RC buildings provide valuable insights into the real-world application and performance of retrofitting techniques. These studies demonstrate the effectiveness of retrofitting measures in improving the structural behavior and seismic performance of existing buildings.
5. Advancements in Retrofitting Technologies: Advancements in retrofitting technologies, such as innovative materials, advanced monitoring and sensing techniques, and intelligent structural control systems, offer new opportunities for enhancing the seismic resilience of retrofitted RC

buildings. Ongoing research and development in these areas contribute to the continuous improvement of retrofitting practices.

6. Cost-Effectiveness and Practical Considerations: Retrofitting strategies should consider cost-effectiveness, feasibility, and compatibility with existing building systems. Evaluating the economic benefits and practical aspects of retrofitting measures is crucial for widespread adoption and implementation.

In conclusion, the analysis of seismic retrofitting on RC buildings provides valuable insights into the effectiveness, limitations, and advancements in retrofitting techniques. Through a comprehensive understanding of retrofitting strategies, performance evaluation methodologies, and case studies, engineers and researchers can make informed decisions in selecting and implementing the most appropriate retrofitting measures to enhance the seismic resilience of existing RC structures. Ultimately, the goal is to create safer communities, protect lives and property, and minimize the impact of earthquakes on built environments.

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