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ANALYTICAL STUDY ON DIFFERENT TECHNIQUES OF RETROFITTING OF RCC SHORT COLUMN

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ABSTRACT

The short columns made up of reinforced cement concrete (RCC) have a high possibility of experiencing brittle shear failure under seismic activity due to their low ductility, high stiffness, and reduced effective height. It becomes essential to retrofit these columns for improved performance and durability of the structures. This article presents an analytical review of the techniques used for retrofitting short columns made of reinforced cement concrete (RCC). Reinforced cement concrete (RCC) jacketing, conventional steel jacketing, carbon fibre reinforced polymer (CFRP) wrapping, and glass fibre reinforced polymer (GFRP) wrapping are the methods reviewed in this article. The review highlights the advantages, disadvantages, and structural behaviour of the short columns retrofitted using the aforementioned techniques based on the analytical and experimental findings. The article also provides a brief overview of the use of ETABS for seismic response analysis of the retrofitted columns. The analysis included determining the parameters such as story displacement, inter-story drift, base shear, stiffness, and load capacity. The paper highlights the benefits of each technique used in the retrofitting process. It was found that the use of steel jacketing combined with reinforced concrete provided an improved strength and stiffness of the short *columns retrofitted. Similarly, fibre wrapping was found to have a better strength-to-weight ratio while providing improved corrosion resistance with minimal addition of thickness to the column members. The research recommendations include the need for additional research to identify more effective and economical solution to the problem.*

Keywords: Reinforced Cement Concrete (RCC), Short Column, Retrofitting, RCC Jacketing, Steel Jacketing, Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP).

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1. INTRODUCTION

Reinforced Cement Concrete (RCC) structures are the most common construction used for residential, commercial, industrial, and public buildings due to their high durability, reliability, adaptability, and cost-effectiveness. Columns are the most crucial axial compression structural members carrying the total vertical and horizontal loads from the superstructure to the ground. The strength of a building largely depends on the strength of its columns.[1] In other words, the strength and ductility of columns have a significant impact on the overall response of a structure, especially during earthquakes. Therefore, the strength and seismic behaviour of columns are of great importance in structural engineering. Most of the existing reinforced concrete structures were constructed using the design codes prevailing at the time of their construction, which may not be appropriate for current seismic design practices. In addition, many structures suffer from deterioration of materials, reinforcement corrosion, exposure to environmental forces, insufficient maintenance, poor construction practices, and increased design loads due to changes in use or occupancy. These factors reduce the structural integrity and stability of the structure under seismic loading. Therefore, the retrofitting of such structures has become a necessity, particularly in seismic zones. Among the various column failure mechanisms, the short column effect is one of the most common causes of damage to structures during earthquakes. Short columns are formed when the architectural design or structural design requirements lead to a reduction in the effective height of the column. This could be due to the architectural or structural design features such as partial height masonry infill walls, large window openings, staircases, retaining walls, and intermediate floors. Short columns have a significant impact on the lateral load-carrying capacity of a structure. Since a short column has a smaller height, its stiffness is greater than that of other columns in a building, and it has a tendency to carry a disproportionately high share of lateral load during an earthquake. Short columns are particularly susceptible to shear failure due to induced diagonal cracking during seismic events. Shear failure results in a brittle manner and prevents the column from achieving the required flexural deformation. The short column effect has been reported as the main reason for the damage to several structures during earthquakes.[2] Investigations on the damage to these structures revealed that the absence of adequate transverse reinforcement, poor design details, and improper confinement can cause shear failure of short columns. Since column failure can lead to partial or total collapse of a structure, retrofitting of short columns has become a necessity.[3]

Retrofitting is a viable option for upgrading the performance of an existing structure by enhancing its capacity to withstand future loads without the need to dismantle and rebuild the structure. Retrofitting is a cost-effective and sustainable alternative to new construction, as it reduces material waste and energy consumption. The main objective of retrofitting is to improve the structural integrity, stiffness, ductility, and durability of building components while maintaining their aesthetic appeal. The choice of retrofitting technique depends on the severity of the damage, structural considerations, budget constraints, constructability, and service life of the structure. There are several retrofitting techniques available for strengthening reinforced concrete columns. One of the conventional techniques used in retrofitting is reinforced cement concrete jacketing.[1] This technique involves the addition of extra concrete and reinforcement around the existing column to increase its cross-sectional area. The major advantage of RCC jacketing is that it increases the axial load capacity, flexural strength, shear resistance, and stiffness of the column. However, it increases the cross-sectional area and self-weight of the column, which may affect the overall response of the structure under seismic loading. Another conventional technique used in retrofitting is steel jacketing, which involves the use of steel plates or rolled steel sections to strengthen and reinforce the existing column. The steel jacketing technique enhances the axial load capacity, shear resistance, and ductility of the column. In addition, it provides good confinement to the existing concrete column. The steel jacketing technique is preferred when rapid strengthening of a structure is required since it is a fast method. However, it requires regular maintenance and protection against corrosion to ensure its durability. In recent years, fibre-reinforced polymer (FRP) composite materials have been increasingly used in structural retrofitting applications.[4], [5], [6] These materials have proven to be reliable, durable, and economical solutions for strengthening structures.

Carbon fibre-reinforced polymer (CFRP) is a type of FRP material that has a high tensile strength-to-weight ratio, fatigue resistance, and corrosion resistance. CFRP sheets are bonded to the surface of the column using epoxy resin to provide additional confinement. The use of CFRP sheets in retrofitting is ideal for structures that require minimal additional cross-sectional area. In addition, it is suitable for buildings that require maintenance of the existing aesthetic appearance of the column. Glass fibre-reinforced polymer (GFRP) is another FRP composite material that has been used in retrofitting applications. GFRP is a cost-effective alternative to CFRP and has good corrosion resistance, although it has lower tensile strength and stiffness compared to CFRP. GFRP sheets are bonded to the surface of the column using epoxy resin. The GFRP retrofitting technique is suitable for structures that require moderate strengthening. The choice between GFRP and CFRP depends on the structural performance requirements and budget. The use of advanced structural analysis software such as ETABS has improved the accuracy of retrofitting analysis by enabling engineers to evaluate the performance of a building under different retrofitting scenarios.[7] ETABS is a powerful three-dimensional structural analysis software that allows engineers to create a structural model of a building, define material properties, and apply gravity and seismic loads according to design codes. The software can then be used to determine the story displacement, story drift, base shear, lateral stiffness, time period, internal forces, and stresses that develop in a building under different loading conditions. [8]

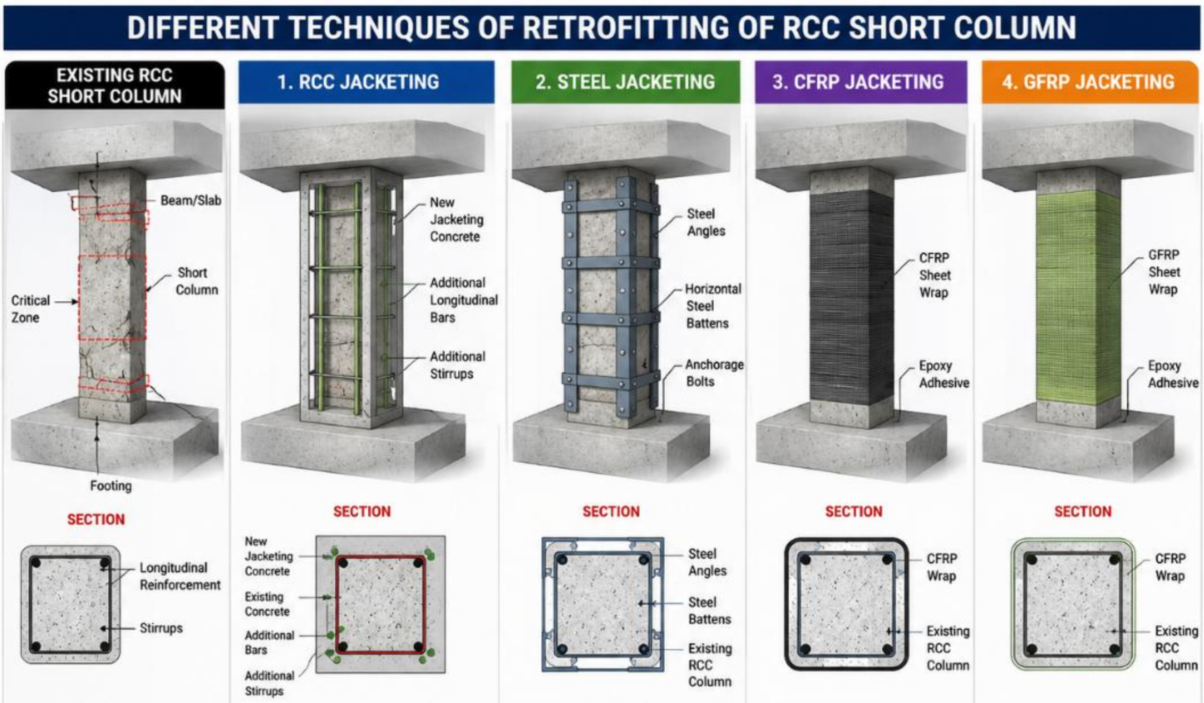

Figure 1 retrofitting technique

By analysing the response of a structure using ETABS, engineers can compare the effectiveness of different retrofitting techniques and make informed decisions when choosing retrofitting techniques. In addition to the conventional methods of retrofitting, performance-based evaluation of retrofitting techniques has become an essential aspect of structural engineering. This approach focuses on the performance of a building or structure under different loading conditions rather than just evaluating the strength of its structural components. For example, storey displacement, story drift, base shear, axial force, bending moment, and shear force are critical performance parameters that are used to evaluate the effectiveness of different retrofitting techniques. The performance of a structure under these parameters can provide valuable insight into the strengths and weaknesses of different retrofitting techniques.[2], [9] By comparing the performance of different retrofitting techniques, engineers can identify the most effective retrofitting technique for a given structure. Based on the review of the literature, it is evident that each retrofitting technique has its advantages and disadvantages. For example, the RCC jacketing technique increases the stiffness and strength of a column but adds weight to the structure. The steel jacketing technique is suitable for rapid strengthening but requires protection against corrosion. The CFRP wrapping technique has a high strength-to-weight ratio and minimal effect on the cross-sectional dimensions of the column but is relatively expensive. The GFRP wrapping technique is a cost-effective retrofitting technique with reasonable structural performance, although it has lower strength compared to CFRP wrapping. The review of the literature also revealed that although several analytical and experimental studies have been conducted on the retrofitting of columns using different techniques, a direct comparison of the performance of various retrofitting techniques is limited. Most of the previous studies focused on a particular retrofitting technique or the structural response of a building under retrofitting. Therefore, future research should focus on comparing the effectiveness of different retrofitting techniques under similar analytical conditions. In addition, future research should focus on exploring other retrofitting techniques that can be used to strengthen existing structures. The present study aimed to review the analytical study on different retrofitting techniques for reinforced concrete short columns. The review focused on the principles of operation, applicability, advantages, limitations, and analytical findings of RCC jacketing, steel jacketing, CFRP wrapping, and GFRP wrapping. The review also aimed to compare the effect of different retrofitting techniques on the performance of a building using ETABS structural analysis software. The review also identified research gaps that could be the focus of future research in the field of retrofitting of existing structures.[10], [11]

2. LITERATURE REVIEW

Pauley & Priestley (1992) discussed the short-column effect as a critical cause of shear-dominant failures in RC structures during earthquakes. Their work highlights that short columns attract higher lateral stiffness, resulting in brittle diagonal shear cracking and limited ductility. The authors further emphasized the disproportionate shear forces in short columns and the need for retrofitting techniques that enhance shear capacity and confinement. Although Pauley & Priestley's Seismic Design of Reinforced Concrete and Masonry Building*s* doesn't specifically call out "short columns" as a dedicated chapter, its fundamental seismic design principles directly apply to understanding *why* short columns behave badly under earthquake loads and how to mitigate that behaviour. The literature on seismic performance consistently identifies short columns as a shear-critical, element low-ductility that requires special attention in design and detailing, aligned with the capacity design philosophy Paulay & Priestley promote.[1]

Sezen (2004) examined shear deficiencies in older RC columns, concluding that RC jacketing can greatly increase shear strength and delay brittle failure. This foundational study analysed RC jacketing as a reliable retrofit for damaged columns. The authors reported significant increases in load-carrying capacity and ductility after jacketing. The authors investigated steel-angle and plate jacketing and found improved confinement and flexural strength, as well as enhanced plastic rotation capacity. Their experimental analysis demonstrated substantial increases in shear capacity for short RC columns retrofitted with welded steel jackets. This widely cited research introduced FRP composites as an efficient retrofit. The study highlighted improved confinement, ductility, and seismic performance with minimal added weight. Lam and Teng developed a design model that shows how CFRP and GFRP confinement significantly improves strength and ductility—key for retrofitting shear-deficient short columns.The authors provided an overview of FRP confinement benefits, including enhanced shear resistance and improved crack behaviour under cyclic loading[3].

Zahra Amalia(2025) investigated the effectiveness of concrete jacketing as a rehabilitation technique for improving the structural performance of corroded reinforced concrete square columns. The study examined the influence of reinforced concrete jacketing on restoring the load-carrying capacity, stiffness, and durability of columns that had experienced deterioration due to reinforcement corrosion. The proposed jacketing method involved enlarging the column cross-section with additional reinforcement and fresh concrete to provide enhanced confinement and structural integrity. The results indicated that concrete jacketing significantly increased axial load capacity, reduced the adverse effects of corrosion damage, and improved the overall stiffness of the strengthened columns. The authors concluded that reinforced concrete jacketing is a practical and reliable retrofitting solution for extending the service life of deteriorated RC columns, particularly in structures exposed to aggressive environmental conditions. The study also emphasized that proper bonding between the existing and new concrete, along with adequate reinforcement detailing, is essential to achieve effective composite action and long-term structural performance.[12]

Bousias, Spathis & Fardis (2007) Their comparison showed that FRP jackets provide substantial ductility improvements, while RC jackets offer higher strength at lower cost. The author reviewed multiple retrofit techniques and emphasized the importance of selecting methods based on failure mode, cost, and performance needs—particularly significant for short columns' **(Fiber-Reinforced Polymer)** composites—commonly carbon (CFRP), glass (GFRP), or aramid fibres embedded in a polymer matrix—are externally bonded sheets or wraps around the column. When applied as a **jacketing system**, FRP provides **confinement** to the concrete core, increases column strength, and raises deformation capacity (ductility) under cyclic seismic loads. In RC jacketing, a **layer of reinforced concrete** with additional longitudinal and transverse (stirrup) reinforcement is cast around the existing column. This increases not just strength but also **stiffness and ductility**, often more substantially than FRP wraps due to the concrete volume and steel reinforcement continuity. The study examines how these retrofitting approaches improve lateral load capacity, ductility, and energy dissipation of deficient columns under seismic loading.[13]

Sezen & Moehle (2004) Their analytical model remains a foundation in simulation of shear-dominant failure—essential for modelling short columns. The authors' nonlinear modelling approach is frequently applied to simulate retrofitted and non-retrofitted columns. Reinforced concrete (RC) columns under seismic lateral loads don't just bend; they also develop shear forces from combined effects of bending, axial load, and displacement demands. In ductile seismic response, after longitudinal reinforcement yields, the shear strength of a column can degrade rapidly, potentially leading to a brittle failure if not properly accounted for in design or assessment. Sezen & Moehle's work provides a predictive model to estimate the nominal lateral shear strength of rectangular RC columns particularly *lightly reinforced columns* more accurately than earlier code formulas[14]

Victor C. Li(2003) introduced Engineered Cementitious Composite (ECC) as an advanced cement-based material capable of exhibiting strain-hardening behaviour and multiple fine cracking under loading. ECC was shown to possess superior ductility, crack control, and energy dissipation characteristics compared with conventional concrete. Experimental investigations demonstrated that ECC significantly improves the seismic performance and resilience of reinforced concrete members subjected to cyclic loading. These characteristics make ECC a promising material for retrofitting RCC short columns, where enhanced deformation capacity and crack resistance are essential for preventing brittle failure during earthquakes.[7]

3. LITERATURE SUMMARY

Table 1: Summary of literature

Author(s) & Year	***Retrofitting Technique / Focus***	***Major Findings***	***Research Contribution***
Paulay & Priestley (1992)	Seismic behaviour of RC short columns	Explained that short columns experience high lateral stiffness, resulting in increased shear forces, diagonal cracking, and brittle failure during earthquakes. Emphasized the importance of adequate confinement and ductile detailing.	Established the theoretical basis for understanding the short-column effect and highlighted the need for effective seismic retrofitting strategies.
Sezen (2004)	RC jacketing and shear strengthening	Demonstrated that reinforced concrete jacketing significantly enhances shear strength, stiffness, and ductility of deficient columns while delaying brittle shear failure.	Confirmed RC jacketing as a practical and reliable strengthening technique for improving the seismic performance of existing RC columns.
Lam & Teng (2003)	CFRP/GFRP confinement	Investigated FRP confinement and reported considerable improvements in axial strength, ductility, and crack control with minimal increase in structural weight.	Developed confinement models that form the basis for the design of FRP-jacketed reinforced concrete columns.
Sezen & Moehle (2004)	Shear strength modelling of RC columns	Proposed a nonlinear analytical model for predicting shear strength and failure of reinforced concrete columns under seismic loading.	Provided a widely adopted analytical model for evaluating shear-deficient columns and assessing retrofit effectiveness.
Bousias, Spathis & Fardis (2007)	Comparison of RC and FRP jacketing	Compared RC and FRP jacketing techniques and found that RC jacketing offers greater strength enhancement, whereas FRP jacketing provides superior ductility and easier installation.	Demonstrated the advantages and limitations of different jacketing techniques for seismic strengthening of RC columns.
Victor C. Li (2003)	Engineered Cementitious Composite (ECC)	Introduced ECC as a high-ductility cementitious material exhibiting strain-hardening and multiple micro-cracking, resulting in improved energy dissipation and crack resistance.	Established ECC as an advanced material suitable for seismic retrofitting and rehabilitation of reinforced concrete members.
Zahra Amalia et al. (2025)	Concrete jacketing of corroded square RC columns	Evaluated concrete jacketing for restoring the strength of corrosion-damaged square columns. The study reported significant improvements in axial load capacity, stiffness, confinement, and structural durability.	Demonstrated that concrete jacketing is an effective rehabilitation method for extending the service life of deteriorated RC columns in aggressive environments.

The reviewed articles highlight the fact that the failure of reinforced concrete short columns was mainly attributed to inadequate shear strength, confinement, and brittle behaviour. In this regard, conventional reinforced concrete jacketing proves to be one of the best retrofitting interventions for increasing the shear capacity, stiffness, and ductility of such structures. On the other hand, fibre-reinforced polymer jacketing is highlighted as a promising retrofitting technique with superior confinement capabilities, improved corrosion resistance, and reduced dead load addition compared to conventional reinforcement methods. Engineered Cementitious Composite (ECC) is highlighted as an innovative material with remarkable ductility and crack control capability for repairing deteriorated concrete structures. Recent studies also demonstrate the potential of using concrete jacketing for restoring the load-carrying capacity of corroded columns with improved durability. Altogether, the reviewed articles provide sufficient evidence for the efficacy of various jacketing techniques, including reinforced concrete, CFRP, and GFRP, for retrofitting reinforced concrete short columns subjected to seismic loading using ETABS analysis software.[1], [3], [4]

4. COMPARATIVE ANALYSIS OF RETROFITTING TECHNIQUES FOR RCC SHORT COLUMNS

Different retrofitting techniques have been developed to improve the seismic performance of RCC short columns. Each method offers distinct advantages in terms of strength, stiffness, ductility, durability, cost, and ease of construction. The selection of an appropriate strengthening technique depends on the structural condition of the existing column, the required performance level, construction constraints, and economic considerations. A comparative evaluation of the commonly adopted retrofitting methods is presented in Table

Parameter	RCC Jacketing	Steel Jacketing	CFRP Jacketing	GFRP Jacketing
Strength Improvement	Excellent	Excellent	Very High	High
Shear Capacity	Excellent	Excellent	Very High	High
Ductility	High	Very High	Excellent	High
Stiffness	Very High	High	Moderate	Moderate
Energy Dissipation	High	Very High	High	Moderate
Increase in Member Size	Significant	Moderate	Negligible	Negligible
Additional Dead Load	High	Moderate	Very Low	Very Low
Corrosion Resistance	Good	Low (requires protection)	Excellent	Excellent
Fire Resistance	Excellent	Good	Moderate	Moderate
Ease of Installation	Moderate	Moderate	Easy	Easy
Construction Time	Longer	Moderate	Short	Short
Maintenance Requirement	Low	High	Very Low	Very Low
Initial Cost	Moderate	High	Very High	Moderate
Long-Term Durability	High	Moderate	Excellent	Very Good
Suitability for Space-Constrained Buildings	Low	Moderate	Excellent	Excellent
Overall Seismic Performance	Excellent	Excellent	Excellent	Very Good

4.1 Comparative Discussion

RCC jacketing has proven to be one of the most reliable methods of strengthening due to the substantial increase in axial load capacity, shear strength, and stiffness. The additional amount of concrete and reinforcement provides exceptionally good confinement, which improves the overall seismic response. However, increased dimensions and dead load may prove to be a disadvantage in case of architectural limitations. Steel jacketing allows for a rapid improvement of the column's properties and provides exceptional confinement, resulting in outstanding ductility, with good energy dissipation characteristics. Being one of the most cost-effective methods, steel requires corrosion protection and regular maintenance. Despite being a great option for strengthening structures subjected to seismic forces, it has a significant drawback of being corrosive's jacketing is one of the most recent methods of structural strengthening. It has proven to be amazingly effective with regard to increasing the ductility, shear capacity, and confinement. Moreover, CFRP does not add significant weight to the structure, which allows using it for retrofitting structural members with limited space for reinforcements. The main disadvantage of CFRP is its high premerger jacketing is very similar to its carbon fibre counterpart, but its mechanical properties are slightly lower, which means that it is less effective in terms of improving the shear capacity and stiffness. At the same time, GFRP is much more affordable than CFRP. Its other characteristics, including crack control and seismic performance are satisfactory for retrofitting Workses jacketing has gained increasing interest in recent years due to its remarkable ductility and strain-hardening characteristics. It demonstrates excellent ability to control cracks, which allows improve the energy dissipation properties of a structural member, as well as reducing the width of cracks.**[5], [15]** Despite promising results, there is a need for further studies regarding its application in practice. In particular, its economic feasibility requires further analysis. In general, it is hard to say which method is best applicable for a certain type of structure since there are different degrees of damage and various requirements under which a reinforced concrete structure should operate. For instance, in cases when a heavily damaged column fails to meet the requirements of increased axial load capacity and stiffness, the first three methods of jacketing could be applicable. On the other hand, in cases when there is a need to retrofit a structure without increasing its weight and dimensions, especially under highly corrosive environment, ECC would be a great option. GFRP could be chosen over CFRP, if there is no need for exceptionally high mechanical properties**.[12], [16]**

5. RESEARCH GAP

An extensive review of the literature reveals that tremendous developments have taken place in retrofitting techniques for reinforced cement concrete (RCC) columns. Various traditional techniques like RCC and steel jacketing and modern approaches like Carbon Fibre Reinforced Polymer (CFRP), Glass Fibre Reinforced Polymer (GFRP) and Engineered Cementitious Composite (ECC) have been found to be efficient in enhancing the strength, stiffness, ductility and seismic response of columns. However, there are various research gaps in the field of retrofitting of RCC short columns. Most of the researchers have investigated the retrofitting techniques one or two and compared their effectiveness.[2], [17] The analytical comparison of RCC jacketing, steel jacketing, CFRP jacketing and GFRP jacketing using same building model, material properties, loading conditions, seismic parameters etc. have not been done yet. Most of the researchers have conducted experimental investigations on isolated column members. Though the behaviour of individual column member retrofitted by various techniques has been studied, the effect of retrofitted short column on the overall seismic response of a building frame has not been studied extensively. The parameters like storey displacement, inter-storey drift, base shear, stiffness, time period etc. of the building model with retrofitted short column need to be investigated using three dimensional analytical models. Most of the researchers have investigated the strengthening techniques for columns with uniform geometrical dimensions and same loading conditions. However, there is a need to investigate the effectiveness of various retrofitting techniques for short columns formed due to partial masonry infill, window opening, staircases, irregular plan etc. which are more prone to shear failure. The durability, maintenance and life cycle cost of various retrofitting techniques have not been studied in detail. The selection of retrofitting technique should be based on various factors like ease of construction, economy, service life, maintenance and repair. The effectiveness of advanced composite materials and hybrid retrofitting systems for strengthening of short columns need to be investigated. The comparative effectiveness of hybrid systems using combination of traditional and advanced composite materials for retrofitting of short columns subjected to nonlinear seismic loading has not been studied yet. Based on the literature review, the present study has been planned to investigate the effectiveness of various retrofitting techniques like RCC jacketing, steel jacketing, CFRP jacketing and GFRP jacketing for strengthening of RCC short columns using ETABS software.[9] The effectiveness of different retrofitting techniques has been compared by considering same building model, material properties, loading conditions and seismic parameters. The various parameters like storey displacement, inter-storey drift, base shear and stiffness have been investigated. The results obtained from this study will be helpful in selection of appropriate retrofitting technique for strengthening of existing RCC building frame against earthquakes.[1], [8]

6. CONCLUSION

The literature reviewed in this study shows that retrofitting can be done to enhance the seismic performance of reinforced cement concrete (RCC) short columns. Short columns have a smaller effective height and are, therefore, vulnerable to greater lateral forces that lead to shear failure compared to ordinary columns. Strengthening of short columns is critical, especially in seismically active regions.The conventional retrofitting techniques like reinforced cement concrete jacketing and steel jacketing have been widely used due to their ability to improve the shear strength, stiffness, and load-carrying capacity of existing structures. While RCC jacketing has good confinement and stability properties, it is associated with increased size and weight of a structure. On the other hand, steel jackets offer better workability and a higher ductility factor than other materials. However, steel jacketing requires regular maintenance due to the effects of corrosion.Carbon fibre reinforced polymer (CFRP) and glass fibre reinforced polymer (GFRP) retrofitting techniques have excellent mechanical properties and can be used to enhance the seismic performance of structures and infrastructures. The CFRP jacketing is preferred in retrofitting applications where there are size limitations due to its lightness and ability to provide good confinement. It also resists corrosion and decreases the cross-section of a column. The GFRP jacketing has lower stiffness and strength than the CFRP counterpart but can be used as an alternative to conventional materials because of its cost-effectiveness.The literature reviewed indicates that ETABS analysis can be used to evaluate the performance of retrofitted buildings subjected to seismic activities. The storey displacement, storey drift, base shear, stiffness, and time period of vibration were used to make a comparative assessment of different retrofitting interventions. A numerical comparison provides a basis for selecting the most appropriate retrofitting technique when given the same lateral load, story mass, and lateral displacement. While the current study highlights the benefits of retrofitting, more research is needed to compare the performance of different retrofitting interventions using ETABS. Further studies should focus on hybrid strengthening concepts, durability, life-cycle assessment, and nonlinear seismic responses of retrofitted buildings. From the discussions, it is evident that there is no universal retrofitting intervention that can be used in all buildings. Some retrofitting techniques may be more appropriate depending on the severity of the problem in the building or structure. As a result, this study makes analytical comparisons among the four retrofitting techniques in order to identify the most appropriate ones for improving the seismic performance of RCC short columns.

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