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Experimental Investigation on Structural Behaviour of RC Columns & Beams Strengthened by RC Jacketing Technique

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Abstract: ***The growing number of ageing reinforced concrete (RC) buildings in rapidly urbanizing cities such as Pune has increased the need for effective structural rehabilitation. Factors including prolonged service life, excessive loading, aggressive environmental conditions, and inadequate construction practices contribute significantly to the deterioration of RC structural members. Among the available strengthening methods, reinforced concrete jacketing has proven to be a reliable and economical solution for restoring and enhancing the strength, stiffness, and serviceability of existing beams and columns. This research investigates the practical implementation of RC jacketing through an experimental-observational study conducted on rehabilitation projects located within the Pune metropolitan region. Unlike investigations performed under controlled laboratory conditions, the present work evaluates strengthening techniques as they are executed on construction sites. Particular attention is given to reinforcement arrangement, jacketing dimensions, anchorage detailing, workmanship, concrete placement procedures, and curing practices, all of which influence the quality and effectiveness of the rehabilitation process. Three ongoing rehabilitation projects were selected for detailed field assessment. Information was collected through direct site observations, dimensional measurements, photographic records, and documentation of the construction sequence. The observed practices were critically examined and compared with the provisions of relevant Indian Standards and previously reported research to evaluate compliance with recommended procedures and to identify practical challenges encountered during execution. The study provides valuable field-based evidence on the application of RC jacketing under actual construction conditions. The findings contribute to a better understanding of the influence of site practices on strengthening performance, reveal discrepancies between codal recommendations and field implementation, and offer recommendations for improving the durability and structural efficiency of rehabilitation works on ageing reinforced concrete structures.***

Keywords: Reinforced Concrete; RC Jacketing; Structural Strengthening; Field Investigation; Rehabilitation.

1. Introduction

Reinforced Cement Concrete (RCC) has been extensively adopted in infrastructure development due to its favorable mechanical properties, durability, and economic advantages. A large number of existing RCC structures in urban areas have now reached advanced service ages and are subjected to increasing demands due to population growth, functional modifications, and higher operational loads. Continuous exposure to environmental conditions, reinforcement deterioration, inadequate maintenance, construction-related deficiencies, and unexpected loading conditions can adversely affect the structural integrity of these systems. Such deterioration may lead to reduced load-carrying capacity, stiffness degradation, and compromised serviceability, creating the need for effective assessment and rehabilitation strategies.

With the increasing emphasis on sustainable construction practices, strengthening of existing RCC structures has become a preferred alternative to complete demolition and reconstruction. Rehabilitation methods not only reduce material consumption and construction time but also help extend the functional life of existing infrastructure. Among the various strengthening approaches, reinforced concrete (RC) jacketing remains a widely applied technique, particularly for deficient beams and columns, due to its ability to enhance member dimensions, improve confinement, increase load resistance, and restore structural performance.
Although numerous studies have investigated the behavior of RC-jacketed members through laboratory experiments and analytical models, the effectiveness of jacketing in practical applications depends significantly on site-specific factors. Parameters such as reinforcement detailing, surface preparation, bonding between old and new concrete, jacket thickness, anchorage arrangements, concrete quality, workmanship, and curing practices play a crucial role in determining the success of strengthening works. Therefore, evaluation of RC jacketing under actual construction conditions is essential to identify the practical challenges and differences between design recommendations and field execution.

The present study focuses on the practical assessment of RC jacketing applications through field observations and investigations of rehabilitation projects. The research aims to understand the influence of construction practices on the performance of strengthened RCC members and to identify factors affecting the effectiveness and reliability of jacketing as a rehabilitation technique.

2. Literature Review

M. B. Ishaq [1] Effect of Thickness of Reinforced Concrete Jacketing on Beam Flexural Strength. To study the effect of

reinforced concrete (RC) jacketing thickness on the flexural performance of RC beams. The study focused on rehabilitation and strengthening techniques for damaged or structurally deficient concrete members affected by factors such as overloading, corrosion, earthquakes, environmental deterioration, and aging. Reinforced concrete jacketing is widely used as a strengthening method because it enhances structural capacity and extends the service life of existing structures. The review examined several previous experimental studies involving different jacketing materials, reinforcement details, and strengthening configurations. Materials such as self-compacting concrete (SCC), ultra-high-performance concrete (UHPC), fiber-reinforced concrete, and non-shrink cement grout were analyzed. The study also considered variables such as reinforcement ratio, reinforcement diameter, bonding conditions, and jacketing configurations including U-shaped, T-shaped, and full jacketing systems. The findings revealed that increasing the thickness of reinforced concrete jacketing significantly improves the flexural strength, stiffness, and load-carrying capacity of RC beams. Strengthened beams exhibited load capacities approximately 1.5 to 3 times greater than the original beam specimens. The improvement was mainly due to the increase in cross-sectional area and additional reinforcement provided by the jacket layer. The study also reported stiffness improvements of up to 173%. Among different strengthening methods, full jacketing was found to provide better performance compared to U-shaped and T-shaped jacketing systems. The researchers concluded that full RC jacketing with an effective thickness of around 10 mm is an efficient and economical method for improving beam flexural behavior and overall structural performance.

M. Y. Alkhateeb [2] Strengthening Reinforced Concrete Beams through CFRP bars with new concrete jacketing. To evaluate the effectiveness of combining carbon fiber reinforced polymer (CFRP) bars with concrete jacketing for improving the performance of reinforced concrete (RC) beams. The study aimed to overcome common limitations of conventional strengthening techniques, particularly premature debonding and insufficient load transfer under cyclic loading conditions. A mechanical anchorage system (MAS) was introduced to improve the bonding and performance of CFRP bars attached to existing RC beams. The researchers carried out experimental investigations and finite element simulations considering various parameters such as CFRP bar diameter, number of anchorage systems, and concrete jacket thickness and grade. The strengthening system involved attaching CFRP bars to the tension zone of beams and covering them with a concrete jacket to improve structural interaction and protect the strengthening components. The results showed that the proposed strengthening system significantly improved beam performance. The ultimate load capacity increased from 44 KN to 83 KN, representing an increase of more than 90% compared to the control beam. The strengthened beams also exhibited improved ductility and delayed crack propagation. However, the study found that increasing concrete jacket thickness beyond an optimum level may reduce efficiency because of additional dead load and increased stresses. The researchers concluded that the integrated CFRP-concrete jacketing system is an effective strengthening technique for enhancing the structural performance and load-carrying capacity of RC beams.

A. Singh [3] Field validation of RC jacketing effectiveness in seismic zones (regional studies. Investigate the practical performance of reinforced concrete (RC) jacketing as a seismic retrofitting technique in earthquake-prone regions. The study focused on evaluating the effectiveness of RC jacketing for improving the structural behavior of existing buildings that were originally designed without adequate seismic provisions. Many older structures in moderate and high seismic zones are vulnerable to earthquake-induced damage because of insufficient ductility, inadequate reinforcement detailing, and lower design standards. The research aimed to validate the effectiveness of RC jacketing through regional case studies and field-based assessments. The study analyzed the structural response of retrofitted RC buildings using nonlinear static and pushover analysis techniques under different seismic conditions. Parameters such as base shear capacity, inter-story drift, stiffness, ductility, and damage levels were considered to evaluate performance improvements after retrofitting. The results indicated that RC jacketing significantly improved the seismic resistance of structures by increasing strength, stiffness, and lateral load-carrying capacity. Retrofitted structures achieved lower inter-story drift and delayed plastic hinge formation, leading to improved structural stability and reduced vulnerability to collapse during earthquakes. The study concluded that RC jacketing is an effective and reliable retrofitting technique for enhancing the seismic performance and safety of existing reinforced concrete structures in earthquake-prone regions.

Maryam B. Ishaq [4] Critical review on jacket thickness effect and design practice recommendations examine the influence of reinforced concrete (RC) jacket thickness on the strengthening efficiency and structural behavior of reinforced concrete members. The study focused on identifying how variations in jacket thickness affect the flexural strength, stiffness, ductility, and load-carrying capacity of rehabilitated structural elements. The review highlighted the growing need for effective strengthening methods because many existing structures experience deterioration due to aging, overloading, corrosion, seismic effects, and changing functional requirements. The research analyzed several previous experimental and analytical studies involving different strengthening materials, reinforcement details, and jacketing configurations. Parameters such as concrete grade, reinforcement ratio, bonding conditions, and jacket geometry were considered to understand their influence on structural performance. The study indicated that increasing jacket thickness generally enhances structural strength because of the increase in cross-sectional area and additional reinforcement contribution. However, excessive thickness may lead to increased dead load and reduced economic efficiency. The review recommended that jacket thickness should be selected based on structural requirements rather than using a uniform design approach. Proper surface preparation, adequate bonding between existing and new concrete, and optimized reinforcement detailing were identified as important factors for effective strengthening. The study concluded that optimized RC jacket thickness improves strength, stiffness, and serviceability while maintaining cost effectiveness and structural safety.

A. Singh [5] Capacity ratio and parametric modelling of RC column jacketing. To study the structural performance of reinforced concrete (RC) columns strengthened through RC jacketing and to develop an efficient predictive model for assessing their behavior. The study focused on seismically deficient structures where columns designed primarily for gravity loads may become vulnerable under earthquake loading. The research aimed to understand the influence of various design parameters on the demand-to-capacity ratio (DCR) and reduce the complexity associated with conventional finite element modelling methods. The study adopted a parametric modelling approach integrated with machine learning techniques for predicting the structural response of jacketed columns. Several parameters including jacket thickness, concrete compressive strength, cross-sectional dimensions, reinforcement ratio, retrofit location, transverse reinforcement area, and slenderness ratio were considered in the analysis. Finite element simulations were performed to generate structural datasets, which were then used to train predictive models for evaluating column performance under seismic loading conditions. The results showed that RC jacketing significantly improves the load-carrying capacity and seismic resistance of existing columns. The developed model successfully predicted demand-to-capacity ratio values with less than 7% variation compared to finite element results, demonstrating high accuracy and reduced computational effort. The study concluded that parametric modelling combined with data-driven approaches can effectively support the design and optimization of RC column jacketing systems for seismic retrofitting applications.
M. Hadzima-Nyarko [6] High-performance concrete jacketing experimental evaluation. To assess the effectiveness of high-performance concrete (HPC) jacketing in improving the behavior of reinforced concrete (RC) structures. The study focused on strengthening deficient RC members, particularly columns in existing buildings with poor seismic resistance. Older structures often suffer from inadequate transverse reinforcement, low-strength concrete, and insufficient cover thickness, which reduce structural capacity and increase vulnerability under seismic loading. The research aimed to evaluate whether HPC jacketing could enhance the overall performance and safety of such structures. The study involved analytical and experimental evaluation of RC members strengthened using high-performance concrete jackets. Parameters such as shear strength, confinement effect, stiffness, and load-carrying capacity were investigated. A jacketing thickness of approximately 100 mm was adopted, and high-strength concrete materials were used to examine their influence on structural behavior. The performance of jacketed members was compared with conventional concrete-strengthened systems. The results indicated that HPC jacketing significantly improved the seismic and structural performance of RC elements. The strengthened members showed considerable enhancement in shear resistance, stiffness, and confinement efficiency. The study observed that columns strengthened with high-performance concrete eliminated shear-capacity deficiencies in critical regions and reduced structural damage under loading conditions. The researchers concluded that HPC jacketing is an effective strengthening technique for increasing structural capacity, improving ductility, and enhancing the overall safety and durability of reinforced concrete structures.

S. G. Hong [7] Strengthening shear-dominant RC members via hybrid jackets. To evaluate the effectiveness of hybrid jacketing systems for improving the structural behavior of shear-deficient reinforced concrete (RC) members. The study focused on RC beams where shear failure governs structural performance. Shear-dominant failures are generally sudden and brittle in nature, leading to rapid strength loss and limited warning before collapse. Therefore, the study aimed to enhance load-carrying capacity, ductility, and stiffness using advanced hybrid jacketing materials. Experimental investigations considered strengthening methods involving high-performance concrete and composite jacket systems. The researchers tested full-scale beam specimens under loading conditions and examined parameters such as jacket thickness, strengthening configuration, and material properties. Side strengthening and U-shaped jacketing systems were evaluated to determine their effectiveness in improving structural response. The study also analyzed failure modes, crack development, and energy dissipation behavior. The results showed that hybrid jacket systems significantly improved the behavior of shear-deficient beams. The load resistance of strengthened beams increased by approximately 35% to 88%, while ductility improved by 21% to 61% and stiffness increased by 9% to 77%. The strengthened members exhibited delayed crack propagation and transformed brittle shear failure into more ductile flexural behavior. The study concluded that hybrid jacketing techniques are effective solutions for retrofitting shear-dominant RC members and improving structural safety and performance.

M. Del Zoppo [8] Light FRCC jacketing: field trials and durability assessment. Evaluate the performance of light Fiber Reinforced Cementitious Composite (FRCC) jacketing as an innovative strengthening and repair technique for existing reinforced concrete (RC) structures. The study focused on improving both durability and seismic performance of deteriorated RC members without significantly increasing the member dimensions. Traditional RC jacketing methods generally increase cross-sectional size and self-weight, whereas light FRCC jacketing uses a thin high-performance layer to provide strengthening with minimal geometric changes. The researchers carried out experimental investigations on full-scale RC column specimens subjected to cyclic loading conditions. Both flexural-critical and shear-critical columns were considered to evaluate structural response under seismic actions. Digital Image Correlation (DIC) techniques were used to monitor strain distribution, crack development, and damage patterns in the FRCC jacketed members. The study also examined the influence of pre-existing damage and the interaction between the original concrete and the FRCC jacket. The results indicated that light FRCC jacketing effectively enhanced the structural behavior and durability of RC columns. Significant reductions in crack propagation and damage concentration were observed. The technique was particularly effective for shear-critical members by improving ductility and delaying brittle failure mechanisms. The researchers concluded that FRCC light jacketing is a promising retrofitting method due to its durability benefits, improved seismic performance, and minimal increase in member dimensions.

3. Methodology

3.1 Research Methodology

The study begins with the selection of buildings undergoing retrofitting or rehabilitation using RC jacketing. Preliminary information such as the building age, structural system, type of distress, and purpose of strengthening is collected. Detailed field inspections are conducted to document defects, measure structural dimensions before and after jacketing, and assess reinforcement detailing, concrete quality, and workmanship. Where jacketing work is in progress, construction procedures including surface preparation, corrosion treatment, bonding methods, reinforcement placement, concreting, and curing practices are observed.

The collected data are analysed by comparing the condition of structural members before and after strengthening and by evaluating compliance with relevant Indian Standards, including IS 456:2000 and SP 34. Discussions with structural engineers, contractors, and site personnel provide practical insights into execution challenges and project outcomes. Finally, detailed case studies are prepared to summarize the strengthening techniques adopted, observed improvements, and key findings regarding the performance of RC jacketing in existing structures.

3.2 Problem Statement

Ageing, environmental exposure, overloading, and construction deficiencies have led to the deterioration of many existing RCC structures, creating a need for effective strengthening techniques. RC jacketing is widely used to enhance the strength and stiffness of deficient beams and columns; however, its performance under actual site conditions depends on several factors such as reinforcement detailing, interface bonding, workmanship, concrete quality, jacketing thickness, and curing practices. Most existing studies are based on controlled laboratory experiments and may not represent practical construction conditions. Therefore, field-based investigation is required to evaluate the effectiveness, challenges, and practical limitations of RC jacketing in real rehabilitation projects.

3.3 Structural Modeling

ETABS was used for structural modelling and analysis due to its efficient interface and capability to define, modify, and evaluate structural systems. The modelling process began with the creation of grid lines and the generation of the three-dimensional building model by specifying plan dimensions, story height, and structural configuration. Material properties, including concrete and reinforcement characteristics, were defined, followed by the assignment of sectional properties for beams, columns, and slab elements.

Structural members were then created using frame elements, and the corresponding properties were assigned to each component. Support conditions were applied at the column bases by providing fixed restraints to represent the foundation condition. After completing the structural model, different loading conditions were defined and assigned according to relevant Indian Standard codes.

Dead loads, including self-weight, wall loads, and floor finishes, were applied as per IS 875 (Part 1):1987. Live loads were assigned according to IS 875 (Part 2):1987, while wind loads were considered based on IS 875 (Part 3):1987. Seismic loads were applied according to IS 1893 (Part 1):2002. The developed ETABS model was then analysed to assess the structural behaviour under various loading conditions and to obtain the required design parameters.

3.4 Analysis And Design

After completing the structural modelling and load assignment, the ETABS model was analyzed to verify accuracy and evaluate structural responses. Shear force and bending moment diagrams were generated to determine internal forces in structural members. Concrete design was then performed according to IS 456:2000 by selecting appropriate load combinations and executing the concrete frame design check. ETABS evaluated each structural element and provided design results such as reinforcement requirements, shear reinforcement, and rebar percentages. The analysis outputs, including displacement patterns, force diagrams, and maximum story displacement, were used to assess the overall structural performance and design adequacy.

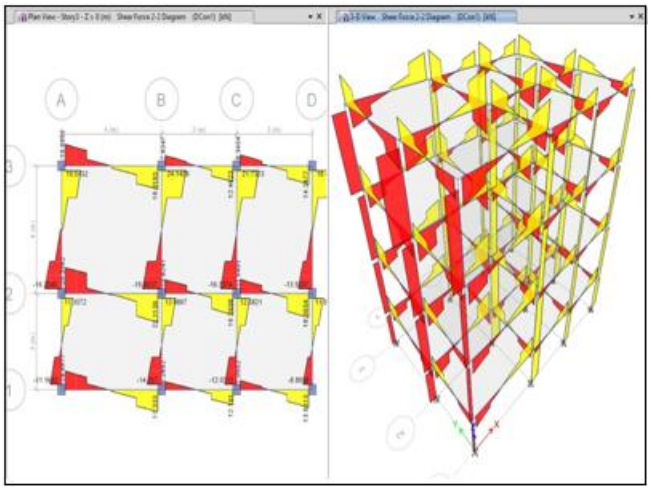

Figure 1: Shera force diagram of Existing Structure

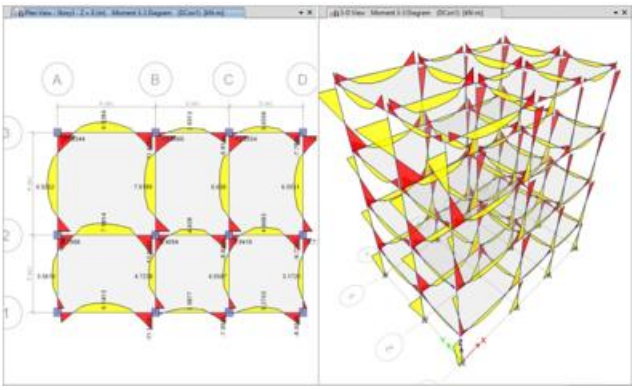

Figure 2: Bending Momenrt diagram of Existing Structure

3.5 Strengthening by Concrete Jacketing

Concrete jacketing is one of retrofitting structures used to the columns and beams of the building. The demand for using concrete jackets to strengthen or repair reinforced concrete has been increasing in the past few decades. Reinforced concrete jacketing is a common method for retrofitting existing columns with poor structural performance. Jacketing implemented by enlarging the column and beam section by increase the amount of reinforcement

Concrete jacketing is a popular method of retrofit as it follows the same design and con- striction procedures of RC columns. The jacket can provide protection from both environ- mental effects and fire. The jacket can increase the axial and flexural strength by increasing confinement and providing additional steel reinforcement. Modeling columns and beams that jacketed on ETABS is done by enlarging the cross-sectional dimensions and adding reinforcement according to the amount planned for columns and reinforcing beams.

Figure 3: Jacketing of Beam on site

3.6 Result After Jacketing

The use of concrete jacketing was indirect effect to the building displacement. The lateral displacement has been calculated for both X and Y-directions, for effects of the earthquake in both directions. The displacement on x-direction and y-direction has reduced in the range of 60% to 65%.

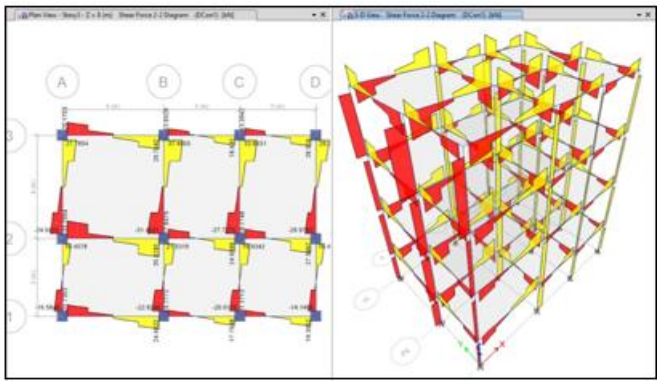

Figure 3: Shera force diagram After Jacketing of Structure.

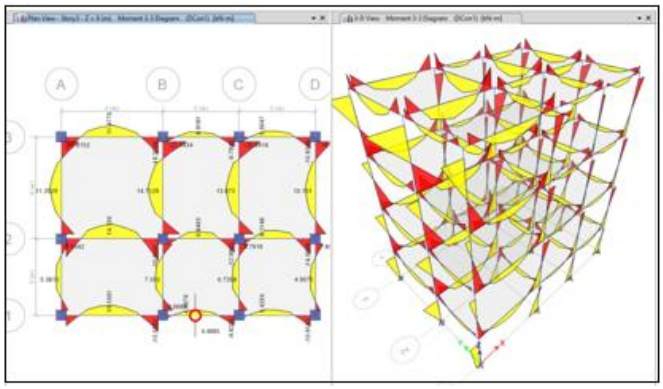

Figure 4: Bending Momenrt diagram After Jacketing of Structure.

4. Conclusion

The present study highlights the practical application and effectiveness of RC jacketing as a strengthening technique for deteriorated RCC beams and columns under actual construction conditions. Through field-based observations, the study identifies the major factors influencing the performance of jacketed members, including workmanship quality, material properties, reinforcement detailing, surface preparation, concrete placement, and curing practices. The investigation reveals that proper execution plays a significant role in achieving the desired improvement in strength, stiffness, and durability of strengthened structural members.

The study also identifies common site-related challenges and construction deficiencies that may affect the long-term performance of RC jacketing, such as inadequate bonding, improper reinforcement placement, insufficient compaction, and poor curing practices. Based on the observations, practical recommendations are suggested to improve the quality and reliability of jacketing works, particularly for construction conditions in the Pune region.

The field-oriented methodology adopted in this research provides a realistic understanding of RC jacketing performance by focusing on actual rehabilitation practices rather than controlled laboratory conditions. The findings can assist engineers, contractors, and stakeholders in adopting improved strengthening strategies and achieving safer, more durable, and cost-effective rehabilitation of existing RCC structures.

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