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

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***Abstract*—Reinforced concrete (RC) structures in urban regions such as Pune are increasingly experiencing deterioration due to ageing, overloading, environmental exposure, and construction deficiencies. Structural strengthening through RC jacketing has emerged as one of the most widely adopted and practical rehabilitation techniques for enhancing the load-carrying capacity and stiffness of existing beams and columns. This study presents an experimental–observational investigation focused on understanding the structural behavior of RC members strengthened using RC jacketing based on real construction sites in the Pune metropolitan area. Unlike laboratory-based studies, this research emphasizes field practices, workmanship quality, reinforcement detailing, jacketing thickness, anchorage provisions, concrete placement, and curing conditions as actually executed on-site.**

Three active rehabilitation sites were surveyed, and detailed measurements, photographic documentation, and execution sequences were recorded. The collected data were analyzed and compared with recommendations from previous research and IS codes to evaluate effectiveness, deviations, and common shortcomings in practical application. The findings of this site-based investigation are expected to contribute to a more realistic under-standing of jacketing performance, highlight practical gaps between theoretical provisions and on-site execution, and provide guidance for improved strengthening strategies for ageing RC structure.

***Index Terms*—Retrofitting, Jacketing, Section Enhancement, Etabs (Analysis).**

I. INTRODUCTION

Reinforced Cement Concrete (RCC) is one of the most widely used construction materials in the world because of its excellent compressive strength, durability, versatility, and economy. RCC structures such as buildings, bridges, flyovers, industrial plants, parking structures, and water tanks are designed to withstand various types of loads during their service life. However, with the passage of time, many reinforced concrete structures experience deterioration and reduction in strength due to several factors such as aging, corrosion of reinforcement, environmental effects, poor construction practices, overloading, seismic activity, design deficiencies, and changes in functional requirements. As a result, the structural members may no longer possess adequate strength, stiffness, and durability to safely resist applied loads. Therefore, strengthening and rehabilitation of existing RCC structures have become important aspects of structural engineering.

In recent years, the rehabilitation of damaged or deficient RCC structures has gained significant importance due to the increasing number of old structures requiring repair and strengthening. Demolition and reconstruction of existing structures are often expensive, time-consuming, and environmentally unfavorable. Hence, retrofitting and strengthening techniques provide a practical and economical solution for improving the structural performance and extending the service life of existing

structures. Among various strengthening techniques available, Reinforced Concrete (RC) jacketing is one of the most effective and widely adopted methods for strengthening RCC columns and beams.

Several experimental and analytical studies conducted by researchers have shown significant improvements in the strength and stiffness of RCC members strengthened by RC jacketing. Experimental investigations indicate that jacketed columns and beams can achieve considerable increases in ultimate load capacity and exhibit more ductile failure behavior compared to strengthened members. The confinement provided by the additional transverse reinforcement in jacketed columns delays concrete crushing and improves post-yield behavior. Similarly, jacketed beams demonstrate better crack control, enhanced flexural resistance, and increased energy absorption.

II. 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-storey 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-storey 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.

M. S. Kim [9] Seismic performance of reinforced concrete columns retrofit-ted by concrete jacketing. evaluate the effectiveness of concrete jacketing as a seismic strengthening technique for reinforced concrete (RC) columns with inadequate seismic detailing. The study focused on improving the behavior of existing columns that are vulnerable to shear failure and poor ductility during earthquake loading. Experimental investigations were conducted on RC column specimens subjected to cyclic loading combined with axial loading to simulate realistic seismic conditions. The study used concrete jacketing systems consisting of additional reinforcement and non-shrink mortar to improve the structural performance of existing columns. Parameters such as load-carrying capacity, stiffness, energy dissipation, and failure patterns were examined. The results showed that jacketed columns exhibited significant improvements in seismic behavior, with retrofitted specimens showing increased strength, enhanced stiffness, and greater energy dissipation capacity. The strengthened columns also transformed brittle failure mechanisms into more ductile behavior. The study concluded that concrete jacketing is an effective retrofitting technique for improving the seismic resistance and overall structural safety of RC columns.

K. Karayiannis et al. [10] Thin reinforced concrete jackets for beam–column joint repair. To assess the effectiveness of thin reinforced concrete (RC) jacketing for repairing and strengthening damaged beam–column joints subjected to seismic loading. The study focused on exterior RC beam–column joints because these regions are highly susceptible to damage during earthquakes due to high shear stresses and inadequate reinforcement detailing in older structures. The primary objective was to develop a retrofitting technique that could improve structural performance without significantly increasing member dimensions or altering the dynamic behavior of the structure. The researchers experimentally tested ten exterior beam–column joint specimens under cyclic loading conditions to simulate earthquake effects. Damaged specimens were then retrofitted using thin RC jackets with a thickness of approximately 20 mm, reinforced with small-diameter steel bars and stirrups. Different reinforcement configurations, including light and dense reinforcement arrangements, were examined to evaluate their effectiveness. The results indicated that thin RC jacketing significantly improved the seismic performance of damaged joints. The retrofitted specimens showed increased load-carrying capacity, enhanced hysteretic energy dissipation, improved stiffness, and delayed crack propagation. In many cases, the repaired joints performed better than the original specimens before damage. The study concluded that thin RC jacketing is an effective and practical retrofitting method for restoring and enhancing the seismic behavior of reinforced concrete beam–column joints while minimizing dimensional changes and construction difficulties.

A. Zaiter et al. [11] Experimental study of jacket height and reinforcement effects on RC square columns. Investigate the influence of jacket height and reinforcement arrangement on the structural performance of reinforced concrete (RC) square columns strengthened through concrete jacketing. The study focused on understanding how variations in retrofit dimensions and reinforcement details affect the load-carrying capacity, ductility, and failure behavior of existing columns. Many older RC structures possess insufficient reinforcement detailing and reduced confinement, making them vulnerable to failure under seismic and service loads. The researchers carried out experimental tests on square RC column specimens strengthened with different jacket heights and reinforcement configurations. Parameters such as jacket thickness, longitudinal reinforcement ratio, transverse reinforcement spacing, and confinement effects were considered. The columns were subjected to axial and cyclic loading conditions to evaluate structural response. Crack

patterns, load–displacement behavior, and failure mechanisms were also examined to assess strengthening efficiency. The results indicated that increasing jacket height and providing adequate reinforcement significantly improved column behavior. Columns with larger jacket heights exhibited greater load-carrying capacity and improved confinement characteristics. Enhanced reinforcement detailing increased ductility and delayed crack propagation, resulting in a more controlled and stable failure pattern. The study concluded that proper optimization of jacket dimensions and reinforcement arrangements plays a critical role in improving the strength, stiffness, and seismic performance of reinforced concrete.

S. G. Hong et al. [12] Seismic strengthening of concrete columns by ultrahigh-performance materials and jacketing. To evaluate the use of ultra-high-performance materials (UHPM) in retrofitting reinforced concrete (RC) columns subjected to seismic loading. The study focused on improving strength, ductility, and energy dissipation capacity of deficient columns. Experimental investigations were conducted on jacketed column specimens under cyclic loading conditions. The results showed that UHPM jacketing significantly enhanced load-carrying capacity, stiffness, and crack resistance while reducing damage progression. The study concluded that ultra-high-performance material jacketing is an effective method for improving seismic resistance and overall structural performance of reinforced concrete columns.

III. OBJECTIVES

- To study failure modes, crack patterns, and ultimate load-carrying capacity.
- To experimentally investigate the structural behavior of RC beams strengthened using RC jacketing.
- To compare the performance of control (unstrengthen) and strengthened.
- To evaluate load–deflection response, stiffness improvement, and ductility enhancement.
- To assess the effectiveness of surface preparation and bonding in RC jacketing.
- To provide recommendations for practical implementation of RC jacketing.

IV. METHODOLOGY

The research adopts a qualitative, field-based methodology to evaluate the effectiveness of RC jacketing for strengthening reinforced concrete columns and beams in existing buildings in Pune, Maharashtra. Since laboratory testing is beyond the scope of this study, the methodology focuses on site inspections, visual observations, measurements, photographic documentation, and interaction with project personnel.

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.

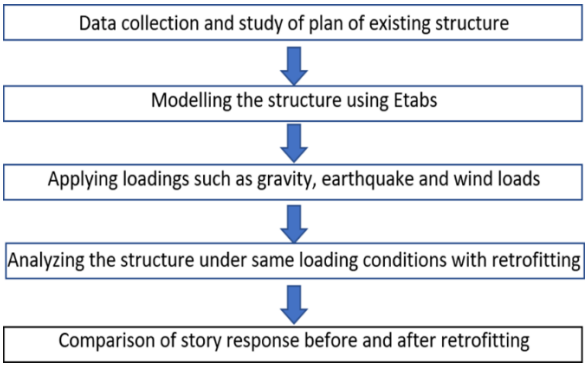

Figure1: Methodology Procedure

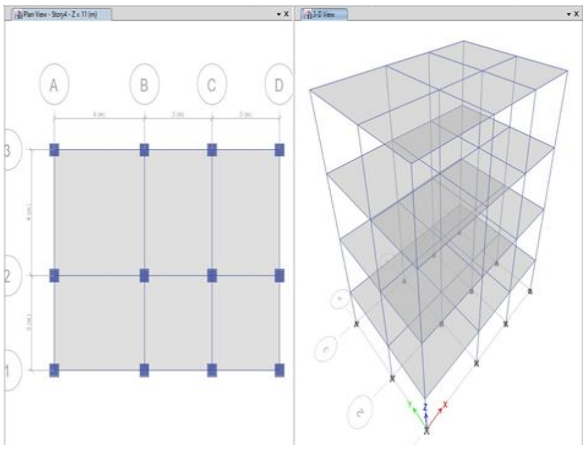

Figure 2: Plane View and 3D View of Structure

V. RESULT AND DISCUSSION

This study evaluates the effectiveness of reinforced concrete (RC) jacketing as a strengthening and retrofitting technique for existing reinforced concrete buildings. The results demonstrate that RC jacketing significantly enhances the structural performance of deteriorated columns and beams by increasing their strength, stiffness, and overall load-carrying capacity. The analysis indicates that lateral displacement in both the X- and Y-directions is reduced by approximately **60–65%**, reflecting improved seismic performance and greater resistance to lateral loads.

Furthermore, the retrofitted structural members show an increase of approximately **6–12%** in shear force and bending moment capacities compared to the existing structure. The highest improvement is observed at the bottom of the columns, where the increase reaches about **11.5%**, indicating better confinement and enhanced structural behavior. The strengthened members are capable of safely resisting the applied working loads while improving the stability and durability of the building. Overall, the findings confirm that RC jacketing is a reliable, economical, and practical retrofitting technique for extending the service life of aging reinforced concrete structures.

It effectively restores structural capacity, improves seismic resistance, and enhances the safety and performance of buildings requiring rehabilitation, making it a suitable solution for strengthening existing infrastructure in earthquake-prone regions.

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