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Innovative Retrofitting Method for Structural Performance Enhancement

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Abstract: *The increasing age of existing infrastructure, changing loading requirements, and vulnerability to seismic activities have highlighted the need for effective structural retrofitting techniques. Retrofitting is the process of strengthening and upgrading existing structures to improve their load-carrying capacity, durability, stability, and overall performance without complete reconstruction. This project presents an innovative retrofitting method for structural performance enhancement using concrete jacketing techniques for reinforced concrete (RC) beams and columns. The results indicate a significant reduction in lateral displacement and considerable improvement in the strength and stability of the structure*

Keywords: Structural Retrofitting, Structural Performance Enhancement, Concrete Jacketing, Seismic Retrofitting, ETABS Analysis, Reinforced Concrete Structures, Earthquake Resistance, Load-Bearing Capacity, Structural Strengthening, Building Rehabilitation

I. INTRODUCTION

The rapid growth of urbanization and industrialization has led to the construction of a large number of reinforced concrete (RC) structures worldwide. Many of these structures have exceeded their intended service life and are currently exposed to deterioration caused by environmental effects, corrosion, excessive loading, design deficiencies, and natural disasters. As a result, the structural integrity and safety of existing buildings are often compromised, creating a need for effective strengthening and rehabilitation measures. Structural retrofitting has emerged as a practical and economical solution for improving the performance of aging infrastructure without requiring complete demolition and reconstruction [1].

Retrofitting refers to the process of modifying and strengthening existing structures to enhance their load-carrying capacity, stiffness, ductility, and durability. In seismic-prone regions, retrofitting plays a crucial role in reducing the vulnerability of buildings to earthquake-induced forces. Traditional design methods may not satisfy the current seismic code requirements, making many existing structures susceptible to structural damage or collapse during earthquakes. Various retrofitting techniques such as concrete jacketing, steel jacketing, fiber reinforced polymer (FRP) wrapping, steel bracing, and shear wall addition have been successfully adopted to improve the seismic resistance and overall performance of structures [2].

Among the available strengthening methods, concrete jacketing is one of the most widely used techniques due to its simplicity, cost-effectiveness, and compatibility with existing reinforced concrete members. This method involves increasing the cross-sectional dimensions of beams and columns by adding reinforced concrete layers and additional reinforcement. The enhanced structural members exhibit improved axial, flexural, and shear capacities, resulting in greater stability and resistance against external loads. Furthermore, concrete jacketing provides additional confinement to structural elements, thereby improving their ductility and energy dissipation capacity during seismic events [3].

In this study, an innovative retrofitting approach based on concrete jacketing is proposed for enhancing the structural performance of an existing multi-storey reinforced concrete building. The building is modeled and analyzed using ETABS software under gravity, wind, and earthquake loading conditions. The structural response before and after

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retrofitting is compared in terms of displacement, shear force, bending moment, and load-bearing capacity. The results demonstrate that the retrofitting technique significantly improves structural strength and reduces lateral displacement, thereby increasing the safety, reliability, and service life of the building. The proposed methodology offers an effective solution for the rehabilitation of deficient structures and contributes to sustainable infrastructure development [4].

II. PROBLEM STATEMENT

Many existing reinforced concrete buildings suffer from structural deficiencies due to aging, material deterioration, increased loading demands, poor maintenance, and non-compliance with current seismic design standards. These deficiencies reduce the strength, stiffness, ductility, and load-carrying capacity of structural members, making buildings vulnerable to excessive deformation, damage, or collapse during earthquakes and other extreme loading conditions. Demolition and reconstruction of such structures are often costly and impractical; therefore, an effective and economical strengthening solution is required. This study addresses the problem of enhancing the structural performance and seismic resistance of existing buildings through innovative retrofitting techniques, particularly concrete jacketing of beams and columns, to improve safety, stability, durability, and overall structural reliability.

III. OBJECTIVES

1. To assess the structural performance of the existing reinforced concrete building under gravity, wind, and seismic loading conditions using ETABS software.
2. To identify structural deficiencies and vulnerable members that require strengthening to meet current safety and performance requirements.
3. To implement concrete jacketing as a retrofitting technique for beams and columns to enhance their strength, stiffness, and load-carrying capacity.
4. To evaluate and compare the behavior of the structure before and after retrofitting in terms of displacement, shear force, bending moment, and overall stability.
5. To improve the seismic resistance, safety, and service life of the building through a cost-effective and sustainable structural retrofitting approach.

IV. LITERATURE SURVEY

Paper 1
Title: Seismic Assessment and Retrofitting of RC Building Using Concrete Jacketing and CFRP: A Finite Element Modelling Study
Authors: B. Talahmeh, B. Almassri, and H. Ayyad
Year: 2025
This study investigated the seismic performance of an existing multi-storey reinforced concrete building using ETABS and SAP2000 software. The researchers evaluated two retrofitting techniques: reinforced concrete (RC) jacketing and Carbon Fiber Reinforced Polymer (CFRP) wrapping. The results showed that both methods significantly improved structural strength and seismic resistance. RC jacketing increased the load-carrying capacity of columns, while CFRP provided higher stiffness and ductility. The study concluded that retrofitting effectively eliminated plastic hinge formation and enhanced the overall structural performance of the building.
Paper 2
Title: Advancements in Fiber-Reinforced Polymer (FRP) Retrofitting Techniques for Reinforced Concrete Structures
Authors: N. Kabashi et al.
Year: 2025
This paper reviewed recent developments in FRP-based retrofitting techniques for reinforced concrete structures. The authors focused on beam-column joints, which are critical components during earthquake loading. The study highlighted the advantages of FRP materials, including high strength-to-weight ratio, corrosion resistance, ease of

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installation, and improved seismic performance. The findings indicated that FRP retrofitting substantially increases structural ductility and energy dissipation capacity while requiring minimal changes to the existing structure.

Paper 3

Title: Dynamic Performance of Concrete Columns Retrofitted with FRP Using Segment Pressure Technique

Authors: Shikhar Anand Singh and Daljeet Pal Singh

Year: 2025

This research introduced an innovative FRP retrofitting method known as the Segment Pressure Technique for strengthening reinforced concrete columns. Experimental investigations were conducted on retrofitted column specimens subjected to dynamic and impact loading conditions. The results demonstrated significant improvements in stiffness, damping characteristics, impact resistance, and durability. The proposed technique achieved better bonding between FRP layers and concrete surfaces compared to conventional wrapping methods, resulting in enhanced structural performance.

Paper 4

Title: Experimental Study on Square RC Short Columns Strengthened with Corrugated Steel Jacket under Axial Compression

Authors: Yang Fan, Yang Ligui, Wang Yuyin, Fang Yong,
Jin Shuangshuang, Chen Yunwen, and Xia Qilong

Year: 2025

This study proposed a novel strengthening method using corrugated steel jackets for deteriorated reinforced concrete columns. Experimental testing revealed that the retrofitted columns exhibited an increase in ultimate load-bearing capacity ranging from 34% to 67% compared to conventional columns. The corrugated steel jackets improved confinement, ductility, and failure resistance of the structural members. The researchers concluded that the proposed method provides an effective and economical solution for strengthening existing RC structures.

Paper 5

Title: Retrofitting and Strengthening Techniques in Structural Engineering: A Review

Authors: Various Researchers

Year: 2025

This review paper analyzed modern retrofitting techniques such as concrete jacketing, steel jacketing, FRP wrapping, steel bracing, and shear wall systems. The study compared the effectiveness of various strengthening methods in terms of strength enhancement, seismic performance, cost, and sustainability. The authors concluded that concrete jacketing and FRP wrapping are among the most efficient techniques for improving the load-carrying capacity and seismic resistance of reinforced concrete structures while extending their service life.

Research Gap

Although recent studies have demonstrated the effectiveness of concrete jacketing, FRP wrapping, and steel jacketing techniques, limited research has focused on the comparative performance evaluation of retrofitted RC buildings using ETABS-based seismic analysis under current design codes. Furthermore, there is a need for cost-effective retrofitting solutions that can significantly reduce structural displacement while improving load-bearing capacity. Therefore, this project investigates the effectiveness of concrete jacketing as an innovative retrofitting technique for enhancing the structural performance and seismic resistance of existing reinforced concrete buildings.

IV. WORKING OF SYSTEM

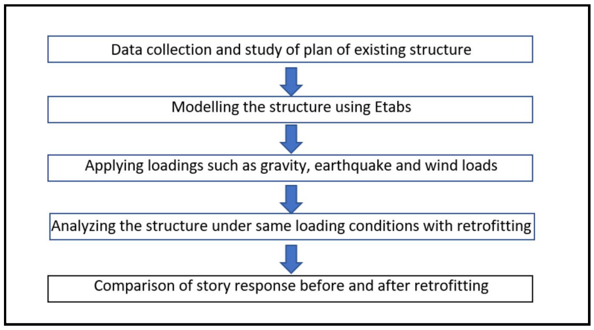

Fig 1: Flowchart

A. Data Collection and Study of Existing Structure

The first step involves collecting all necessary information related to the existing building, including architectural drawings, structural plans, dimensions of beams, columns, slabs, material properties, and loading details. A detailed assessment of the structure is carried out to identify deficiencies, deterioration, and vulnerable structural members. This information forms the basis for structural modeling and performance evaluation.

B. Structural Modeling Using ETABS

After collecting the required data, a three-dimensional model of the existing building is developed using ETABS software. Structural components such as beams, columns, slabs, and supports are modeled according to actual dimensions and material specifications. The software enables accurate representation of the building behavior under various loading conditions and provides a platform for detailed structural analysis.

C. Load Application and Structural Analysis

The modeled structure is subjected to different types of loads, including dead loads, live loads, wind loads, and earthquake loads as per relevant design codes. ETABS performs structural analysis to determine parameters such as lateral displacement, storey drift, shear force, bending moment, and load distribution. The results help identify critical structural members that require strengthening through retrofitting techniques.

D. Retrofitting and Performance Evaluation

Concrete jacketing is applied to the deficient beams and columns by increasing their cross-sectional dimensions and reinforcement. The retrofitted structure is then analyzed under the same loading conditions used for the existing structure. Finally, a comparative study is performed to evaluate the structural performance before and after retrofitting. The comparison of displacement, shear force, bending moment, and load-carrying capacity demonstrates the effectiveness of the retrofitting method in enhancing the overall strength, stability, and seismic resistance of the building.

V. SYSTEM DESIGN

A. Overview of System Design

The proposed system is designed to evaluate and enhance the structural performance of an existing reinforced concrete building through retrofitting techniques. The system utilizes ETABS software to model, analyze, and compare the behavior of the structure before and after retrofitting. Concrete jacketing is adopted as the strengthening method for beams and columns to improve load-carrying capacity, stiffness, and seismic resistance.

B. Input Module

This module collects all necessary data related to the existing structure, including:

- Architectural and structural drawings
- Beam, column, and slab dimensions

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- Material properties of concrete and steel
- Dead load, live load, wind load, and earthquake load details
- Existing reinforcement details

The collected data serves as input for structural modeling and analysis.

C. Structural Analysis Module

The existing building is modeled in ETABS based on the collected structural data. The software performs analysis under different loading conditions such as:

- Dead Load (DL)
- Live Load (LL)
- Wind Load (WL)
- Earthquake Load (EQ)

The analysis generates results including displacement, storey drift, shear force, bending moment, and member forces, which are used to identify structurally deficient components.

D. Retrofitting Module

After identifying critical structural members, concrete jacketing is applied to beams and columns. The retrofitting process includes:

- Increasing beam dimensions from 250 mm × 250 mm to 300 mm × 300 mm
- Increasing column dimensions from 350 mm × 350 mm to 400 mm × 400 mm
- Providing additional reinforcement
- Enhancing strength, stiffness, and ductility

The retrofitted model is updated in ETABS for further analysis.

E. Performance Evaluation Module

The retrofitted structure is analyzed under the same loading conditions as the existing structure. The results obtained are compared with those of the original structure to evaluate:

- Reduction in lateral displacement
- Increase in shear capacity
- Increase in bending moment capacity
- Improvement in seismic performance
- Enhancement in overall structural stability

VI. RESULTS

A. Site Inspection and Damage Assessment

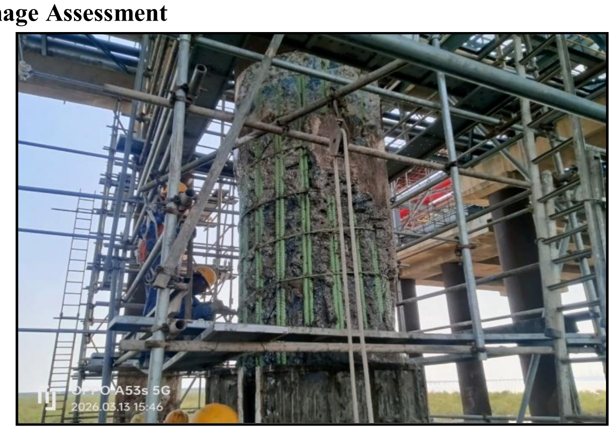

Fig 2: Damaged Bridge Pier Before Retrofitting

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A detailed site inspection was conducted on the bridge pier structure to identify signs of deterioration and structural distress. The inspection revealed surface damage, concrete degradation, and exposure of reinforcement in certain portions of the pier. The observed deterioration indicated a reduction in durability and load-carrying capacity, necessitating immediate rehabilitation and retrofitting measures. The damaged regions were carefully marked and evaluated before initiating the strengthening process.

B. Surface Preparation and Structural Rehabilitation

Fig 3: Retrofitted Bridge Pier After FRP Wrapping

The deteriorated concrete was removed using suitable mechanical methods until sound concrete was exposed. The damaged surface was cleaned thoroughly to eliminate dust, loose particles, rust, and contaminants. Repair mortar was then applied to restore the original geometry of the pier. Proper surface preparation ensured strong bonding between the existing concrete and the retrofitting material, thereby improving the effectiveness of the strengthening system.

C. Application of FRP Wrapping System

Fig 4: Application of FRP Wrapping on Bridge Pier

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Fiber Reinforced Polymer (FRP) wrapping was adopted as the primary retrofitting technique for enhancing the structural performance of the bridge pier. After surface preparation, an epoxy bonding agent (STRUCT GUARD–NOVOCOAT) was applied to the concrete surface. The epoxy used in the project is a two-component epoxy resin system with a mix ratio of 3:1 and a curing period of 24 hours. Carbon/Glass FRP sheets were then wrapped around the circular pier in multiple layers to provide confinement and increase strength. The wrapping process was carried out carefully to avoid air voids and ensure uniform bonding throughout the surface.

D. Performance Enhancement After Retrofitting

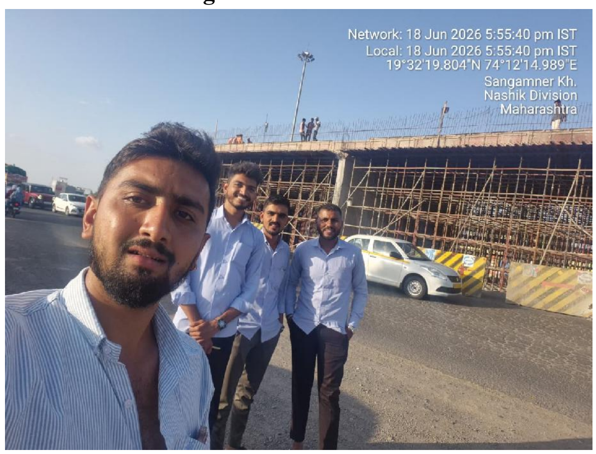

Fig 5: Site Visit During Retrofitting Work

The retrofitted pier exhibited significant improvement in structural integrity and durability. The FRP wrapping provided additional confinement to the concrete core, resulting in increased compressive strength, stiffness, and ductility. The strengthened pier showed enhanced resistance against cracking, corrosion, environmental degradation, and seismic forces. Visual inspection after retrofitting confirmed a smooth and continuous FRP jacket around the pier, indicating successful installation. The retrofitting technique effectively restored the structural capacity of the damaged pier and extended its service life while minimizing maintenance requirements.

Summary of Results

Parameter	Before Retrofitting	After Retrofitting
Surface Condition	Damaged and deteriorated	Smooth and protected
Structural Strength	Reduced due to deterioration	Significantly enhanced
Crack Resistance	Low	High
Durability	Moderate	Improved
Corrosion Protection	Limited	Excellent
Seismic Performance	Vulnerable	Enhanced
Service Life	Reduced	Extended

Overall Result

The implementation of the FRP wrapping retrofitting technique successfully enhanced the structural performance of the bridge pier. The rehabilitation process restored the damaged concrete surface, improved confinement, increased load-carrying capacity, and provided long-term protection against environmental deterioration. The strengthened structure is expected to perform more efficiently under service and seismic loading conditions, demonstrating the effectiveness of innovative retrofitting methods for structural performance enhancement.

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VII. CONCLUSION

The present study demonstrates the effectiveness of innovative retrofitting techniques in enhancing the structural performance of deteriorated reinforced concrete bridge piers. Through detailed site inspection, structural assessment, surface rehabilitation, and the application of Fiber Reinforced Polymer (FRP) wrapping, the damaged structural member was successfully strengthened and protected against further deterioration.

The use of FRP wrapping proved to be an efficient, lightweight, and economical strengthening solution that required minimal alteration to the existing structure. The application of epoxy bonding materials ensured proper adhesion between the concrete surface and FRP layers, resulting in an effective confinement system. Visual observations after retrofitting confirmed the successful restoration of the structural member and the achievement of a uniform protective jacket around the pier.

Overall, the retrofitting methodology significantly enhanced the structural reliability and service life of the bridge pier. The study concludes that FRP-based retrofitting is a practical and sustainable solution for the rehabilitation of aging infrastructure and can be effectively adopted for similar bridge and civil engineering structures requiring performance enhancement and long-term durability.

VIII. FUTURE SCOPE

1. **Implementation of Advanced Composite Materials:** Future studies can investigate the use of advanced composite materials such as Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), and Basalt Fiber Reinforced Polymer (BFRP) to achieve higher strength, durability, and corrosion resistance.
2. **Integration with Structural Health Monitoring Systems:** Sensors and Internet of Things (IoT)-based monitoring systems can be integrated with retrofitted structures to continuously monitor strain, displacement, vibration, and crack development for real-time structural assessment.
3. **Seismic Performance Optimization:** Further research can focus on evaluating the behavior of retrofitted structures under different seismic zones and earthquake intensities using advanced nonlinear dynamic analysis techniques.
4. **Application to Large Infrastructure Projects:** The proposed retrofitting methodology can be extended to bridges, flyovers, industrial structures, marine structures, and high-rise buildings requiring rehabilitation and strengthening.
5. **Development of Sustainable Retrofitting Techniques:** Future work can emphasize eco-friendly and sustainable strengthening materials that reduce construction waste, maintenance costs, and environmental impact while enhancing structural performance.

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