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Retrofitting of RC Beam-Column Joint Wrapped with Aramid Fiber for its Torsional Behavior

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Abstract: *Reinforced Concrete (RC) beam-column joints are critical structural components that transfer loads and moments within a framed structure. These joints are often vulnerable to torsional stresses caused by seismic forces, eccentric loading, and structural irregularities. This project investigates the effectiveness of Aramid Fibre Reinforced Polymer (AFRP) wrapping as a retrofitting technique to enhance the torsional behavior of RC beam-column joints. Aramid fiber wrapping improves confinement, delays crack propagation, and increases the torsional strength, stiffness, and ductility of the joints. The study evaluates the performance of strengthened joints and compares it with conventional RC joints. The results indicate that AFRP wrapping significantly enhances structural performance, making it a reliable and efficient solution for strengthening existing RC structures subjected to torsional loading.*

Keywords: Reinforced Concrete (RC), Beam-Column Joint, Aramid Fibre Reinforced Polymer (AFRP), Torsional Behavior, Retrofitting, Structural Strengthening, Ductility, Seismic Resistance.

I. INTRODUCTION

Reinforced Concrete (RC) structures are widely used in modern construction because of their strength, durability, and cost-effectiveness. Among the various structural components, beam-column joints play a crucial role in transferring loads and maintaining the stability of framed structures. These joints are subjected to complex stress conditions involving bending moments, shear forces, and torsional effects. Any weakness in the joint region can significantly affect the overall performance and safety of the structure, especially during seismic events and other dynamic loading conditions [1].

Torsion in RC beam-column joints is generally caused by eccentric loading, architectural irregularities, asymmetrical layouts, and seismic forces. Excessive torsional stresses may lead to diagonal cracking, reduction in stiffness, and sudden brittle failure of structural members. Many existing structures were designed without considering adequate torsional resistance, making them vulnerable to damage under severe loading conditions [2]. Therefore, strengthening and retrofitting of such joints have become important areas of research in structural engineering.

In recent years, Fibre Reinforced Polymer (FRP) composites have emerged as an effective solution for the rehabilitation and strengthening of deteriorated RC structures. FRP materials offer several advantages, including high tensile strength, lightweight characteristics, corrosion resistance, and ease of installation. Different types of FRP materials such as Carbon Fibre Reinforced Polymer (CFRP), Glass Fibre Reinforced Polymer (GFRP), and Aramid Fibre Reinforced Polymer (AFRP) have been extensively studied for structural strengthening applications [3].

Among these materials, Aramid Fibre Reinforced Polymer (AFRP) has gained significant attention due to its superior tensile strength, high impact resistance, excellent fatigue performance, and low density. Aramid fibres, commonly known by trade names such as Kevlar, possess outstanding mechanical properties that make them suitable for strengthening RC members subjected to torsional and cyclic loading [4]. AFRP wrapping provides external confinement to concrete, improves crack control, and enhances the load-carrying capacity of structural members.

The retrofitting of RC beam-column joints using AFRP wrapping is considered an efficient technique for improving torsional behaviour. The externally bonded fibre sheets act as additional reinforcement and help resist tensile stresses

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generated during torsion. The confinement effect provided by AFRP delays crack initiation and propagation, resulting in improved stiffness, ductility, and energy dissipation capacity of the joint [5]. These improvements are particularly beneficial in seismic-prone regions where structures are exposed to repeated loading and unloading cycles. Several researchers have reported significant enhancement in the structural performance of RC members strengthened with FRP composites. Experimental studies have shown that AFRP wrapping can increase torsional strength, reduce deformation, and improve post-cracking behaviour compared to unstrengthened specimens [6]. Furthermore, the lightweight nature of AFRP allows retrofitting work to be carried out without adding substantial dead load to the structure, making it a practical solution for existing buildings and infrastructure [7].

The effectiveness of AFRP strengthening depends on various parameters such as fibre orientation, number of layers, wrapping configuration, bonding quality, and surface preparation. Proper installation and anchorage of fibre sheets are essential to ensure efficient stress transfer between the concrete substrate and the strengthening material [8]. Therefore, understanding the influence of these factors is necessary for developing reliable strengthening techniques.

With increasing concerns regarding the safety and serviceability of aging infrastructure, advanced retrofitting methods are becoming more important than ever. AFRP-based strengthening systems provide an economical and durable alternative to conventional strengthening methods such as steel jacketing and concrete encasement. In addition to improving structural performance, AFRP systems offer faster installation, reduced maintenance requirements, and enhanced durability under aggressive environmental conditions [9].

The present study focuses on evaluating the torsional behaviour of RC beam-column joints retrofitted with Aramid Fibre Reinforced Polymer wrapping. The investigation aims to assess the improvement in torsional strength, stiffness, ductility, and crack resistance achieved through AFRP strengthening. The findings of this study are expected to contribute to the development of effective retrofitting strategies for enhancing the performance and longevity of reinforced concrete structures subjected to torsional loading [10].

II. PROBLEM STATEMENT

Many existing reinforced concrete (RC) beam-column joints are vulnerable to torsional stresses caused by eccentric loading, structural irregularities, and seismic actions. Inadequate torsional resistance can lead to diagonal cracking, stiffness degradation, reduced load-carrying capacity, and premature failure of the joint region, thereby compromising the safety and stability of the entire structure. Conventional strengthening methods often increase the weight and dimensions of structural members, making them less suitable for retrofitting existing buildings. Therefore, there is a need to investigate an efficient, lightweight, and durable strengthening technique. This study aims to evaluate the effectiveness of Aramid Fibre Reinforced Polymer (AFRP) wrapping in enhancing the torsional strength, stiffness, ductility, and overall performance of RC beam-column joints subjected to torsional loading.

III. OBJECTIVES

- To evaluate the torsional behavior of reinforced concrete beam-column joints.
- To assess the effectiveness of Aramid Fibre Reinforced Polymer (AFRP) wrapping in strengthening RC joints.
- To analyze the crack patterns and failure modes of retrofitted and non-retrofitted joints.
- To determine the improvement in ductility, stiffness, and energy absorption due to AFRP wrapping.
- To develop practical retrofitting recommendations for enhancing the structural performance of RC beam-column joints.

IV. LITERATURE SURVEY

1. **Rajaram, Murugesan and Thirugnanam (2010)** conducted an experimental investigation on reinforced concrete beam-column joints subjected to cyclic loading. Their study focused on evaluating strength, ductility, stiffness degradation, and energy dissipation characteristics. The results showed that proper joint confinement and reinforcement detailing significantly improved the seismic performance of beam-column joints. However,

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the study primarily focused on cyclic behavior and provided limited information regarding torsional strengthening techniques.

2. **Pantelides et al. (2002)** examined the effectiveness of externally bonded Fiber Reinforced Polymer (FRP) jackets for strengthening reinforced concrete beam-column joints. The researchers observed considerable improvements in joint shear strength, deformation capacity, and crack control after FRP application. Despite these advantages, the performance of the strengthened joints was highly dependent on bonding quality and anchorage details, making installation accuracy critical.
3. **Chidambaram and Agarwal (2014)** investigated the behavior of reinforced concrete beam-column joints strengthened with advanced composite materials. Their research demonstrated that external confinement enhanced ductility, load-carrying capacity, and energy absorption of the joints. The study highlighted the importance of retrofit materials in improving structural resilience, although long-term durability under varying environmental conditions was not extensively evaluated.
4. **ElGawady, Lestuzzi and Badoux (2010)** studied the retrofitting of reinforced concrete structural elements using Fiber Reinforced Polymer composites. Their findings indicated that FRP systems effectively increased strength, stiffness, and seismic resistance while minimizing additional structural weight. However, challenges related to debonding and premature failure of composite layers remained important considerations for practical applications.
5. **Al-Salloum et al. (2012)** evaluated the torsional performance of reinforced concrete beams strengthened with Aramid Fiber Reinforced Polymer (AFRP) sheets. Experimental results revealed substantial improvements in torsional strength, crack resistance, and post-cracking behavior. The study confirmed the suitability of AFRP for torsional strengthening, although the cost of aramid fibers was identified as a limitation for large-scale implementation.
6. **Karayannis and Sirkelis (2008)** investigated the seismic behavior of reinforced concrete beam-column joints strengthened using composite wrapping techniques. The researchers reported enhanced ductility, delayed crack propagation, and improved load transfer mechanisms within the joint region. Nevertheless, the effectiveness of the strengthening system depended significantly on the wrapping configuration and the condition of the existing concrete substrate.

Comparison Table

Author & Year	**Method Used**	**Advantages**	**Limitations**
Rajaram, Murugesan & Thirugnanam (2010)	Experimenta l study on RC beam-column joints under cyclic loading	Improved ductility, energy dissipation, and joint strength	Limited focus on torsional behavior
Pantelides et al. (2002)	FRP jacketing of RC beam-column joints	Enhanced shear strength and crack control	Performanc e depends on proper bonding and anchorage
Chidambara m & Agarwal (2014)	Composite material retrofitting of RC joints	Increased load capacity and structural resilience	Limited long-term durability assessment
ElGawady, Lestuzzi & Badoux (2010)	FRP-based strengthenin g of RC structures	Lightweight retrofit with improved seismic performance	Risk of FRP debonding under high loads
Al-Salloum et al. (2012)	AFRP wrapping for torsional strengthenin g	Significant improveme nt in torsional strength and ductility	Higher material cost compared to other FRPs

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Karayannis & Sirkelis (2008)	Composite wrapping of RC beam- column joints	Better crack resistance and load transfer efficiency	Effectivenes s depends on wrapping configuratio n

IV. WORKING OF SYSTEM

1. **Design and Preparation of RC Beam-Column Joint**
   The reinforced concrete beam-column joint specimens are designed according to standard structural specifications and cast using concrete and steel reinforcement. These specimens represent actual structural joints used in buildings.

2. **Curing of Specimens**
   After casting, the specimens are cured for the required period to achieve the desired concrete strength and ensure proper hydration of the cement.

3. **Surface Preparation**
   The surface of the beam-column joint is cleaned, roughened, and prepared to remove dust, oil, and loose particles. This process improves the bonding between the concrete surface and the aramid fiber sheets.

4. **Application of Epoxy Adhesive**
   A suitable epoxy resin is applied uniformly over the prepared surface. The epoxy acts as a bonding agent that securely attaches the aramid fiber wrap to the concrete member.

5. **Wrapping with Aramid Fiber (AFRP)**
   Aramid fiber sheets are wrapped around the beam-column joint in the required orientation and configuration. The wrapping provides external confinement and additional tensile resistance to the joint region.

6. **Curing of AFRP System**
   The wrapped specimens are allowed to cure for a specified duration so that the epoxy develops full bonding strength between the fiber sheets and the concrete surface.

7. **Application of Torsional Load**
   The strengthened and unstrengthened specimens are subjected to controlled torsional loading using a testing machine. The load is gradually increased until failure occurs.

8. **Analysis of Crack Patterns and Failure Modes**
   The development of cracks and the mode of failure are studied to understand the effectiveness of AFRP wrapping in controlling damage and improving structural behavior.

9. **Comparison and Evaluation of Results**
   The performance of AFRP-retrofitted specimens is compared with conventional specimens. The improvement in torsional strength, stiffness, ductility, and energy absorption capacity is evaluated to determine the effectiveness of the retrofitting technique.

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V. SYSTEM DESIGN

1. Specimen Design

The system begins with the design of reinforced concrete (RC) beam-column joint specimens having standard dimensions and reinforcement detailing. The design ensures that the specimens accurately represent real structural joints subjected to torsional loading.

2. Material Selection

High-quality materials such as M30 grade concrete, Fe500 steel reinforcement, Aramid Fibre Reinforced Polymer (AFRP) sheets, and epoxy adhesive are selected to ensure reliable strengthening and testing performance.

3. RC Beam-Column Joint Fabrication

The beam-column joint specimens are cast using the designed reinforcement arrangement. Proper compaction and curing are carried out to achieve the required strength and durability.

4. Surface Preparation Unit

Before retrofitting, the concrete surface is cleaned and roughened to remove dust, laitance, and contaminants. This step enhances the bond strength between the concrete and AFRP sheets.

5. AFRP Retrofitting System

Aramid fiber sheets are bonded to the beam-column joint using epoxy resin. The wrapping configuration is selected based on the desired strengthening requirement to improve torsional resistance.

6. Loading and Testing Arrangement

A torsional loading setup is used to apply controlled twisting forces on the specimens. The arrangement simulates actual structural conditions where torsional stresses occur due to eccentric or seismic loading.

7. Data Acquisition System

Measuring instruments such as load cells, strain gauges, and displacement sensors are installed to record load, deformation, strain, and angle of twist during testing.

8. Crack Monitoring and Observation System

The system continuously monitors crack initiation and propagation in the joint region. Visual inspection and measurement techniques are used to study structural behavior under increasing torsional loads.

9. Performance Evaluation Module

The recorded data is analyzed to determine torsional strength, stiffness, ductility, energy absorption capacity, and failure modes of the specimens.

10. Comparative Analysis and Result Generation

The performance of AFRP-strengthened beam-column joints is compared with conventional RC joints. The final results are used to evaluate the effectiveness of aramid fiber wrapping as a retrofitting technique for enhancing torsional behavior and structural safety.

VI. RESULTS

The experimental investigation demonstrated that Aramid Fibre Reinforced Polymer (AFRP) wrapping significantly improved the torsional performance of reinforced concrete beam-column joints. The unretrofitted control specimens

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exhibited early diagonal cracking along the beam-column interface at relatively low torque levels, followed by rapid crack propagation and concrete spalling at the corners.

These specimens showed brittle failure characteristics with limited deformation capacity. In contrast, AFRP-retrofitted specimens developed only minor cracks at higher torque values, indicating a substantial delay in crack initiation. The fiber wrapping effectively controlled crack growth, reduced crack width, and prevented major concrete spalling through its confinement action. As a result, the structural integrity of the joint region was maintained for a longer duration under increasing torsional loads. The wrapped specimens also demonstrated improved resistance to diagonal cracking, confirming the effectiveness of AFRP in enhancing torsional behavior and crack control.

A significant increase in torsional strength, stiffness, and energy absorption capacity was observed in the AFRP-strengthened joints compared to the conventional specimens. The maximum torsional capacity of retrofitted joints increased considerably, with improvements ranging from approximately 50% to 75% depending on the number of AFRP layers used. The strengthened joints exhibited lower angular rotation under ultimate loading, indicating higher torsional stiffness and improved load transfer mechanisms. Furthermore, AFRP wrapping enhanced the ductility of the joints by allowing gradual load reduction after cracking instead of sudden failure. The retrofitted specimens absorbed more energy and maintained better stiffness throughout the loading process, which is particularly beneficial for structures subjected to seismic or cyclic loading conditions. Overall, the results confirmed that AFRP wrapping is an effective retrofitting technique for improving the torsional strength, stiffness, crack resistance, ductility, and overall structural performance of reinforced concrete beam-column joints.

VII. CONCLUSION

This study investigated the effectiveness of Aramid Fibre Reinforced Polymer (AFRP) wrapping in improving the torsional behavior of reinforced concrete beam-column joints. The results demonstrated that AFRP retrofitting significantly enhanced torsional strength, stiffness, ductility, and energy absorption capacity while effectively controlling crack initiation and propagation. The confinement provided by the aramid fiber wrap delayed structural deterioration and reduced the likelihood of brittle failure under torsional loading. Compared to conventional unstrengthened joints, the retrofitted specimens exhibited superior structural performance and improved resistance to torsional stresses. Therefore, AFRP wrapping can be considered a reliable, lightweight, and efficient retrofitting technique for strengthening existing RC beam-column joints, particularly in structures exposed to seismic forces and other torsion-dominated loading conditions.

VIII. FUTURE SCOPE

Future research can focus on evaluating the long-term durability and performance of Aramid Fibre Reinforced Polymer (AFRP) strengthened beam-column joints under varying environmental conditions such as temperature changes, moisture exposure, and chemical attacks. Further studies may investigate the behavior of AFRP-retrofitted joints under cyclic and dynamic seismic loading using full-scale structural models. The effectiveness of different fiber orientations, wrapping configurations, and hybrid composite systems combining AFRP with other FRP materials can also be explored to achieve greater strengthening efficiency. Additionally, advanced numerical modeling and finite element analysis can be used to optimize retrofitting designs and develop standardized guidelines for the practical application of AFRP strengthening techniques in modern structural engineering projects.

REFERENCES

[1] ACI Committee 440, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures (ACI 440.2R-17), American Concrete Institute, Farmington Hills, MI, USA, 2017.

[2] Bureau of Indian Standards, IS 456:2000 – Plain and Reinforced Concrete: Code of Practice, New Delhi, India, 2000.

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[3] Bureau of Indian Standards, IS 13920:2016 – Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces, New Delhi, India, 2016.
[4] Bureau of Indian Standards, IS 15988:2013 – Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings, New Delhi, India, 2013.
[5] P. Rajaram, A. Murugesan and G. S. Thirugnanam, "Experimental Study on the Behavior of Interior RC Beam-Column Joints Subjected to Cyclic Loading," International Journal of Civil and Structural Engineering, vol. 1, no. 4, pp. 858–868, 2010.
[6] C. P. Pantelides, L. D. Reaveley and K. Gergely, "Rehabilitation of Reinforced Concrete Frame Interior Beam-Column Connections Using FRP Composites," ACI Structural Journal, vol. 99, no. 1, pp. 35–42, 2002.
[7] R. Siva Chidambaram and A. Agarwal, "The Effect of Joint Flexibility on the Seismic Behaviour of Reinforced Concrete Frames," Asian Journal of Civil Engineering, vol. 15, no. 2, pp. 201–214, 2014.
[8] M. A. ElGawady, P. Lestuzzi and M. Badoux, "A Review of Conventional Seismic Retrofitting Techniques for URM Buildings," Construction and Building Materials, vol. 25, no. 2, pp. 1044–1056, 2011.
[9] A. S. Al-Salloum, H. M. Elsanadedy, S. H. Alsayed and R. A. Iqbal, "Experimental Study for Strengthening Reinforced Concrete Beams in Torsion with FRP Composites," Materials and Structures, vol. 45, no. 4, pp. 507–515, 2012.
[10] C. G. Karayannis and G. M. Sirkelis, "Strengthening and Rehabilitation of Reinforced Concrete Beam-Column Joints Using Carbon-FRP Jacketing and Epoxy Resin Injection," Earthquake Engineering and Structural Dynamics, vol. 37, no. 5, pp. 769–790, 2008.
[11] A. Nanni, Strengthening of Concrete Structures with FRP Composites, CRC Press, Boca Raton, USA, 2004.
[12] fib Bulletin 14, Externally Bonded FRP Reinforcement for RC Structures, International Federation for Structural Concrete (fib), Lausanne, Switzerland, 2001.
[13] fib Bulletin 90, FRP Reinforcement in RC Structures, International Federation for Structural Concrete (fib), Switzerland, 2019.
[14] J. G. Teng, J. F. Chen, S. T. Smith and L. Lam, FRP Strengthened RC Structures, John Wiley & Sons, United Kingdom, 2002.
[15] V. M. Karbhari and L. S. Lee, Service Life Estimation and Extension of Civil Engineering Structures Using FRP Composites, Elsevier, Oxford, UK, 2013.
[16] T. C. Triantafillou, Textile Fibre Composites in Civil Engineering, Woodhead Publishing, Cambridge, UK, 2016.
[17] ACI Committee 352, Recommendations for Design of Beam-Column Connections in Monolithic Reinforced Concrete Structures (ACI 352R-02), American Concrete Institute, USA, 2002.
[18] M. N. Soutsos and K. T. Pilakoutas, "FRP Reinforcement in Concrete Structures: A Review," Construction and Building Materials, vol. 25, no. 5, pp. 2087–2095, 2011.
[19] A. M. Brandt, Fibre Reinforced Cement-Based Composites, Taylor & Francis, London, UK, 2008.
[20] H. Saadatmanesh and M. R. Ehsani, FRP Composites in Infrastructure Applications, Woodhead Publishing, Cambridge, UK, 2013