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ENHANCING STRUCTURAL RESILIENCE: FERROCEMENT JACKET RETROFITTING OF REINFORCED CONCRETE BEAM-COLUMN JOINTS

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Abstract
In this paper, we investigated the effectiveness of ferrocement jackets in retrofitting beam-column joints to enhance the structural performance and resilience of reinforced concrete (RC) structures. Twenty-seven exterior RC beam-column joint specimens were cast, with nine specimens for each stress level: ultimate load, 85% of ultimate load, and 50% of ultimate load. The retrofitting process involved surface preparation, including chipping grooves and cleaning, to ensure proper adhesion between the existing concrete surface and the ferrocement jacket. A wire mesh was then wrapped around the cleaned surface, and a cement slurry was applied as a bonding agent. The ferrocement jacketing process involved careful positioning of the wire mesh cage, secured in place with mild steel wire, and application of a cement-sand mortar mix to reinforce the structure. Different retrofitting configurations were tested, allowing for the investigation of their effectiveness in enhancing the structural performance of RC beam-column joints under various stress levels.

Introduction
The resilience of structures against various environmental and load-induced challenges is a top priority in civil engineering. One of the critical areas of concern is the reinforced concrete beam-column joints, which are essential components in structural frameworks. As structures age or face increased stresses, these joints often develop deficiencies, jeopardizing the overall stability and safety of the building[1].

To address this issue, engineers and researchers have been exploring innovative retrofitting techniques to strengthen these vulnerable junctures. One such method gaining popularity in recent years is the use of ferrocement jackets for retrofitting reinforced concrete beam-column joints.[2]

Ferrocement is well-known for its exceptional durability, ductility, and versatility, making it a promising solution for enhancing the structural resilience of these critical points. By encasing the joint with a layer of ferrocement, engineers aim to increase its load-bearing capacity, reduce cracking, and enhance overall structural performance, particularly under seismic events, cyclic loading, and other external pressures[3-5].

Retrofitting of buildings

Retrofitting an existing building can often be a more cost-effective option than constructing a new facility. Since buildings consume a significant amount of energy, particularly for heating, cooling, and lighting, it's crucial to initiate energy conservation retrofits to reduce energy consumption and operational costs[6]. Additionally, existing buildings make up the largest segment of the built environment, so focusing on retrofitting is essential for sustainable development.

However, energy conservation isn't the only reason for retrofitting existing buildings. The goal should be to create high-performance buildings by applying an integrated, whole-building design process during the planning phase[7]. This approach ensures that all key design objectives are met. For instance, the integrated project team may discover a single design strategy that fulfills multiple objectives.

By retrofitting, the building becomes less costly to operate, increases in value, and contributes to a better, healthier, and more comfortable environment for occupants. Improving indoor environmental quality, decreasing moisture penetration, and reducing mold all lead to improved occupant health and productivity[8]. Moreover, retrofitting for accessibility, safety, and security should also be considered simultaneously.

When retrofitting historic buildings, unique aspects must be given special consideration. Designing major renovations and retrofits for existing buildings to include sustainability initiatives not only reduces operational costs and environmental impacts but also increases building adaptability, durability, and resiliency.

The basic concept of retrofitting aims at upgrading the lateral strength, increasing the ductility, and enhancing the overall strength and ductility of the structure. This not only ensures safety but also extends the lifespan of the building, making it a more sustainable and cost-effective option in the long run.

Material and Methods

The investigation of beam-column joints retrofitted using ferrocement jackets serves a crucial purpose in enhancing the structural performance and resilience of reinforced concrete (RC) structures. In this study, twenty-seven exterior RC beam-column joint specimens were cast, with nine specimens for each stress level: ultimate load, 85% of ultimate load, and 50% of ultimate load.

The retrofitting process involved several steps. Initially, the stressed beam-column joints were prepared by chipping grooves and cleaning the surface thoroughly with a metallic brush and potable water. This preparation ensured proper adhesion between the existing concrete surface and the ferrocement jacket.

Next, a wire mesh was wrapped around the cleaned surface, and a cement slurry was applied as a bonding agent. This slurry acted as an interface between the old concrete and the new ferrocement layer, facilitating better adhesion and structural integrity. It's notable that the application of the cement slurry was done without repairing the initial cracks, suggesting an approach focused on enhancing the overall strength and load-bearing capacity rather than simply cosmetic repairs.

Once the surface was prepared and the wire mesh was in place, the ferrocement jacketing process began. The wire mesh cage was carefully positioned to ensure a tight fit, and mild steel wire was used to secure it in place. Additionally, a cement-sand mortar mix with a specified water-cement ratio was applied to further reinforce the structure. The process shown in figure 1 illustrates the meticulous steps involved in ferrocement jacketing, emphasizing the importance of proper surface preparation, adequate bonding agents, and precise application techniques.

Figure 1. Application of Ferrocement Jacket

For each stress level, nine beam-column joint specimens were retrofitted using ferrocement jackets with varying configurations: three with two layers, three with four layers, and three with six layers reinforced with woven wire mesh. This approach allowed for the investigation of different retrofitting strategies and their effectiveness in enhancing the structural performance of the RC beam-column joints under different stress levels.

Retrofitting Using Ferro cement Jackets

The four beam-column joints were initially stressed to the ultimate load, and two types of retrofitting schemes, designated as Type-A and Type-B, were employed for wrapping the GI wire mesh.

In Type-A retrofitting, two L-shaped wire mesh pieces were cut and wrapped on the lower and upper faces of the beam at the joint, with a 25mm thick cement mortar (1:2) layer, as illustrated in Figure 2.

On the other hand, Type-B retrofitting involved the same process as Type-A, with the addition of extra mesh diagonally at a 45-degree angle to the joint. This extra mesh was also secured with a 25mm thick cement mortar (1:2) layer, as depicted in Figure 3.

The retrofitted specimens are visually represented in Figure 4, showcasing the different retrofitting approaches employed in the study.

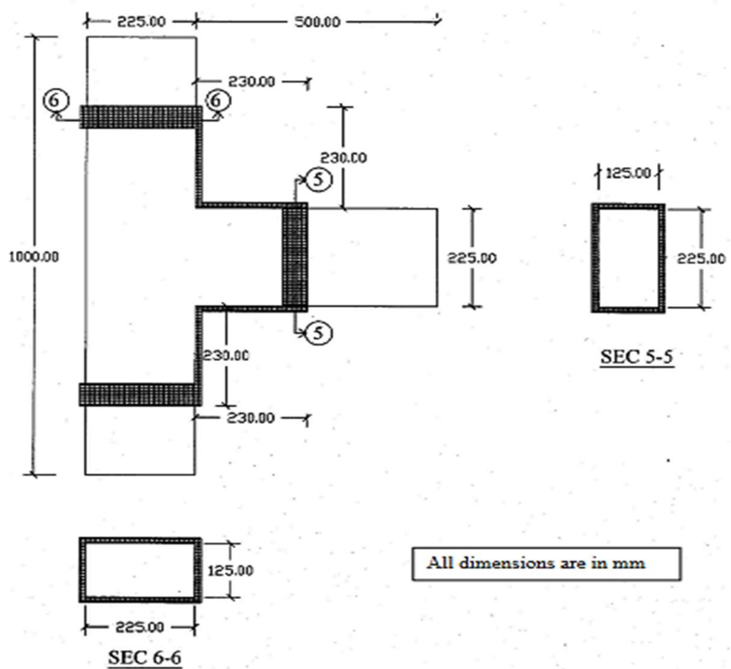

Figure 2. Type-A L-Shaped Wire Mesh Wrapping Method

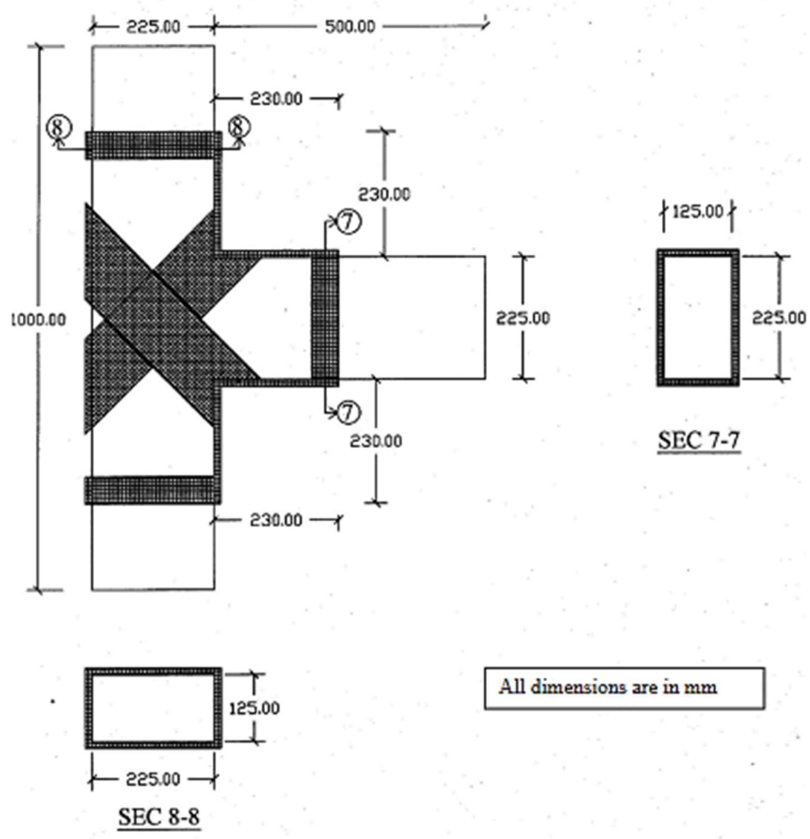

Figure 3. Enhanced Wire Mesh Wrapping Technique: Type-B Retrofitting

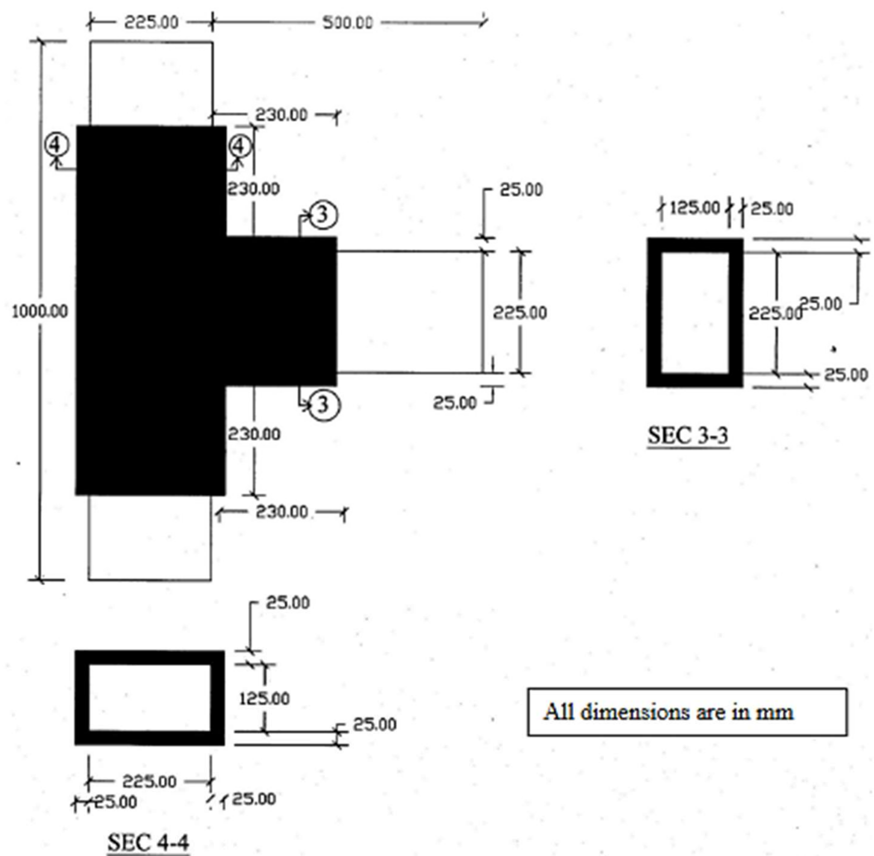

Figure 4. Enhanced Beam-Column Joint Design: A Detailed Retrofit Solution

Result and Discussion

The experimental data and corresponding graphs for Type-A retrofitted specimens (R1 and R2) show a consistent trend of marginal increases in ultimate load carrying capacity compared to control specimens. For instance, in R1, the load capacity increased from 22.7kN to 24.6kN, with a corresponding decrease in deflection from 23.3mm to 20.5mm. Similarly, in R2, there was an increase from 22.7kN to 23.8kN with a decrease in deflection. Overall, Type-A retrofitted specimens exhibited an average 6.7 percent increase in load capacity and a 15.7 percent decrease in deflection compared to controls.

Moving to Type-B retrofitted specimens (R3 and R4), the trend continues with marginal increases in ultimate load capacity compared to controls. For example, in R3, the load capacity increased from 22.7kN to 27.6kN, with a decrease in deflection from 23.3mm to 14.7mm. In R4, there was a similar increase in load capacity with a decrease in deflection. On average, Type-B retrofitted specimens showed a 22.6 percent increase in load capacity and a 46.3 percent decrease in deflection compared to controls.

These findings suggest that both Type-A and Type-B retrofitting methods contribute to improved load-bearing capabilities and reduced deflection in beam-column joint specimens.

However, Type-B retrofitting appears to offer greater improvements in both load capacity and deflection reduction compared to Type-A retrofitting.

When comparing the different wrapping techniques used in the beam-column joints, it was evident from Figure 5 that they exhibited varying behaviors. Specifically, specimens with Type-B retrofitting showed the most significant improvement in ultimate load carrying capacity compared to those with Type-A retrofitting. However, it's important to note that while Type-B retrofitting demonstrated superior load-carrying capacity, the ductility ratio and energy absorption were not detailed in the discussion. These aspects are crucial for evaluating the overall performance and effectiveness of the retrofitting techniques. Therefore, a comprehensive analysis considering not only load capacity but also ductility ratio and energy absorption would provide a more thorough understanding of the retrofitting schemes' effectiveness.

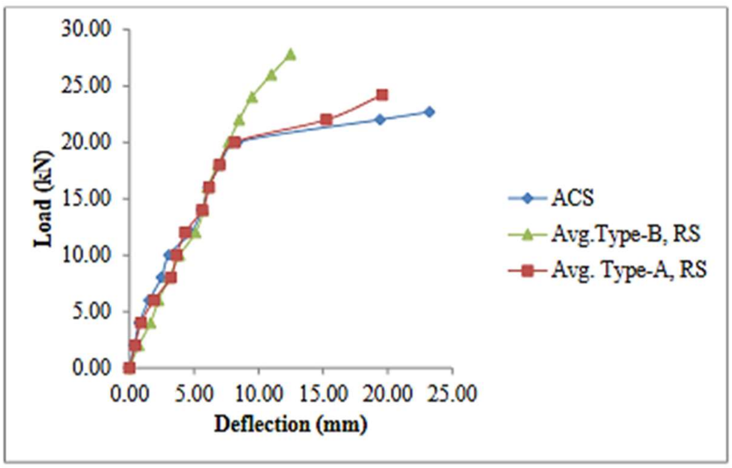

Figure 5. Comparative Analysis of Load-Deflection Curves for Various Ferrocement Retrofitting Techniques

Avg. Type-A, RS= Type-A retrofitted beam -column joints Avg. ACS = Control / un-retrofitted beam -column joints, Type-B, RS = Type-B retrofitted beam -column joints

Conclusion

The experimental results indicate that both Type-A and Type-B retrofitting methods using ferrocement jackets contribute to improved load-bearing capabilities and reduced deflection in beam-column joint specimens.

Type-B retrofitting, which involved an enhanced wire mesh wrapping technique, showed a more significant improvement in ultimate load carrying capacity compared to Type-A retrofitting. On average, Type-B retrofitted specimens demonstrated a 22.6 percent increase in load capacity and a 46.3 percent decrease in deflection compared to control specimens.

However, while Type-B retrofitting demonstrated superior load-carrying capacity, further analysis of ductility ratio and energy absorption is necessary for a comprehensive evaluation of retrofitting effectiveness. Nonetheless, this study underscores the potential of ferrocement jacketing as an effective retrofitting technique for enhancing the structural performance and resilience of RC beam-column joints.

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