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Experimental Evaluation of Ferrocement Jacketing for Strengthening Reinforced Concrete Columns

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ABSTRACT

The strengthening and rehabilitation of defective reinforced concrete (RC) columns are becoming more and more significant as original design and construction of structural components are inadequate, construction defects occur in existing structures, various deterioration conditions emerge, and additional service loads are placed upon structures, fire, seismic actions, and building use changes. Ferrocement jacketing is one of the available strengthening techniques that provides a relatively thin, light and economical confinement system that can be fabricated from locally available materials, specifically cement, sand and steel wire mesh. In this study, an experimental study on the strengthening of reinforced concrete columns using ferrocement jacketing with a special focus on the capacity of axial load, the axial deformation and the stress–strain response and ductility is presented. The experimental programme was based on the uploaded research work and comprised four unconfined control columns and twelve ferrocement-jacketed columns. The square RC specimens had a nominal cross-section of 6 in × 6 in and a height of 2 ft, reinforced with four 10 mm longitudinal bars and 6 mm transverse reinforcement at 4 in spacing. Crushed brick aggregate, Portland composite cement, local sand and expanded/square wire meshes were used. The experimental variables included mortar proportion, wire-mesh gauge, mesh type and number of mesh layers. The columns were subjected to monotonically increasing concentric axial compression using a 2000 kN universal testing machine after curing. The results demonstrate a substantial improvement in ultimate axial capacity following ferrocement jacketing. The control columns in Groups A–D achieved ultimate loads of 408, 340, 300 and 360 kN, respectively, whereas the strengthened specimens reached 580–620 kN, 480–540 kN, 420–480 kN and 520–640 kN, respectively. The most pronounced improvement occurred with increasing mesh layers: two, three and four layers increased ultimate capacity by approximately 44.44%, 61.11% and 77.78%, respectively. The corresponding ductility improvements reported for Groups A–D were 21.57%, 20.14%, 6.59% and 31.90%. The findings support the use of ferrocement jacketing as a practical strengthening solution, particularly for lower-strength and brick-aggregate RC columns. Nevertheless, the results are limited to short square columns under concentric compression; therefore, future investigations should include eccentric and cyclic loading, durability, bond behaviour, stone aggregate concrete, numerical modelling and full-scale structural applications.

Keywords: reinforced concrete column; ferrocement jacketing; confinement; axial strength; wire mesh; ductility; retrofitting; brick aggregate concrete; structural rehabilitation

1. Introduction

One of the most important load bearing structural components of buildings is the reinforced concrete column, which carries the weight and in many structural systems, lateral loads to the foundation. Failure or severe deterioration of a column can therefore have consequences substantially more serious than localized damage to many other structural components.

Existing RC columns may require strengthening because of inadequate original design, construction deficiencies, deterioration, corrosion, increased imposed loads, vertical extension of buildings, seismic damage, fire exposure or changes in building occupancy. The source study specifically identifies increased structural loading, inadequate concrete strength or reinforcement, construction deficiencies, excessive inclination, earthquake and fire as important reasons for strengthening existing columns. The rehabilitation of existing structures has gained importance because demolition and reconstruction can require large quantities of materials, labour, time and energy. In the current structural engineering era, greater focus is placed on maximizing the useful life of existing structures instead of discarding and replacing inadequate structures (Raza et al., 2019). Strengthening can also help minimize building disruption and save embodied resources. In recent years, the main emphasis has been placed on RC column rehabilitation methods including conventional RC jacketing, steel jacketing, FRP systems, FRCM systems, ECC-based and hybrid system, depending on the strength, ductility, constructability, durability and cost (Raza et al., 2019; Alghannam, Abdulqader and Al-Fakih, 2026). Ferrocement is a special type of strengthening material of interest to developing countries. It is basically a thin cementitious composite, with a close spacing of wire reinforcement. It is also a relatively high reinforcement surface area crack-control material and has the capability to form thin jackets making it attractive for repair and confinement applications (ACI Committee 549, 2018; Kaish et al., 2018). According to the study uploaded, ferrocement is thin reinforced cement mortar system where hydraulic cement mortar is reinforced by the steel wire system which is laid in continuous layers with close spacing. It also specifies “low weight”, “relatively low material cost”, “ease of construction” and “availability of raw materials” as important advantages. The key to the structural mechanism is the confinement. Due to the Poisson effect and internal cracking, when a concrete column is loaded axially, this column tends to expand laterally. This lateral restraint causes an advantageous triaxial stress state in the concrete core and is provided by an external jacket. Classical confined-concrete studies have shown that the lateral confinement can enhance a concrete's compressive strength and ultimate strain (Richart, Brandtzaeg and Brown, 1928 and Mander, Priestley and Park, 1988). Ferrocement jackets give confinement by means of the tensile confinement of the surrounding mesh-mortar composite. Therefore, the jacket is able to postpone concrete spalling, control crack propagation, restrain lateral expansion and enhance the post peak deformation capacity. There is good evidence from earlier experiments for this mechanism. The authors of Abdullah and Takiguchi (2003) concluded that the ferrocement jackets significantly increased the ductility of RC columns under both axial and cyclic lateral loading applied. Kazemi and Morshed (2005) have shown that the shear deficient RC columns could be strengthened by use of expanded steel mesh ferrocement jackets. Mourad and Shannag (2012) found that the ferrocement jackets applied to the square RC columns contributed significantly to the axial strength and stiffness of the columns. Kaish et al. (2012, 2013) then explored more efficient jacketing arrangements for square columns and discussed the significance of the behaviour of the corners and stress concentration. The present experimental study is based on the above findings. The significance of this research is of special importance in Bangladesh and other areas that may already have structures containing crushed brick aggregate concrete, and may need cost-effective rehabilitation methods. The research uploaded clearly points out the need to study about Ferrocement strengthening of Brick Aggregate RC column.

2. Literature Review

Ferrocement is different from traditional reinforced concrete primarily in terms of the distribution and shape of the reinforcement. Ferrocement is made with a thin layer of cement mortar containing a large number of small diameter reinforcing wires or small diameter mesh, which are placed closely together and extend throughout the thickness of the mortar. The high reinforcement surface area provides better crack distribution and provides tensile stresses after cracking (ACI Committee 549, 2018; Kaish et al., 2018). The study uploaded shows that the sand to cement ratios are in the range of 1.5-2.5 and the water to cement ratios are in the range of 0.35-0.50 and it also highlights the importance of using clean water and well graded fine aggregate for ferrocement mortar. These ranges are in line with the basic requirement of ferrocement mortar that it should be sufficiently workable to penetrate and completely cover the mesh, yet be strong enough and durable enough to withstand the forces applied to it. A major advantage of ferrocement for strengthening columns is that it can be used as a relatively thin layer on the outside of the column, which does not significantly increase the cross-sectional dimensions of the column as compared to conventional concrete jacketing. This technique can then be used to maintain the architectural space and enhance the structural performance. The main drawbacks are that it can be prone to corrosion if the mesh is not embedded properly, it is sensitive to construction quality, labour requirements and it can be difficult to achieve uniform confinement around sharp corners. The strengthening mechanism can be explained based on the principles of confined concrete. When subjected to axial compression, an unconfined concrete core will show nearly linear-elastic behaviour before it cracks, crushes and loses load carrying capacity. Lateral dilation causes tensile stresses in the confining material when lateral restraint is provided. In simplified form, the confinement pressure can be thought of as:fl≈2tjftjDf_l \approx \frac{2t_j f_{tj}}{D}Where fl is an equivalent lateral confining pressure, tj is the effective jacket thickness, ftjf_{tj} is the effective tensile capacity of the jacket reinforcement system and DD is a representative core dimension.The actual mechanism for a ferrocement jacket is more complex as confinement relies on the orientation of the mesh, mesh area, strength of the mortar, bond, geometry of the corners, thickness of the ferrocement jacket, overlap, and interaction between the cracking of the mortar and yielding of the mesh. However, the basic concept is that more lateral restraint will delay lateral expansion and concrete deterioration. Mander, Priestley and Park (1988) found that confinement affects both the peak compressive stress and the ultimate strain. It is interesting to note that the following work was done many years ago by Richart, Brandtzaeg and Brown (1928) who showed that concrete under lateral pressure can withstand much higher compressive stresses than unconfined concrete. These classical models were developed for the conventional transverse reinforcement and not for the ferrocement jackets, but are useful for interpretation of the experimental results. Nedwell and coworkers examined the ferrocement repair of short square columns and found that the apparent stiffness and ultimate load capacity were increased. This literature review has been uploaded and is identified as an early example of the effectiveness of ferrocement repair under axial loading. Abdullah and Takiguchi (2003) did a more systematic experimental study of RC columns strengthened with square and circular ferrocement jackets. They had different variables such as axial-load ratio, jacketing configuration and wire-mesh layers. They stated that they achieved significant ductility improvement by external confinement. Kazemi and Morshed (2005) studied the shear deficient short RC columns strengthened with ferrocement jackets with expanded steel mesh. They were able to strengthen their specimens so that they reached the nominal flexural capacity and they also reported that the ductility capacity factors were significantly enhanced, reaching about 5.5.Kondraivendhan and Pradhan (2009) studied the ferrocement confinement of concrete of varying concrete strengths. They found that lower-strength concrete can benefit most from confinement. The uploaded source reports an increase of approximately 78% for M25 concrete compared with approximately 45.3% for M55 concrete. Mourad and Shannag (2012) tested one-third-scale square RC columns that were preloaded to different fractions of their ultimate capacity and subsequently strengthened using ferrocement jackets containing two layers of welded wire mesh. Their results indicated approximately 33% improvement in axial capacity and 26% improvement in axial stiffness for strengthened columns, while repaired columns substantially recovered their original performance. Kaish et al. (2012) identified an important limitation of conventional square ferrocement jacketing: stress concentration at corners. They had 41 scaled specimens in their experimental programme and explored rounded corners, shear keys and extra corner mesh.

The enhanced configurations minimized the negative effect of corner stress concentration. Kaish et al. (2013) also studied the effect of square ferrocement jacketing under concentric compression and found that strengthening the corners is an effective way of enhancing the confinement. Kaish et al. (2018) found that the distributed reinforcement and crack-control properties of ferrocement composites offer great potential for strengthening concrete columns, and that there is no fully developed standardized design methodology for ferrocement column jacketing. Recent studies have shown that ferrocement is still relevant even in the face of the development of strengthening technology. Tabassum and Noor-E-Yeasmin (2025) for instance studied the ferrocement jacketing of fire damaged RC columns and concluded that jacketing could significantly restore the strength of RC columns at lower levels of fire damage and enhance the deformation capacity at higher levels of fire damage. A 2026 review also includes ferrocement with RC, steel, FRP, FRCM, ECC and hybrid jacketing systems, noting that the current research is increasingly considering strengthening systems based on more than just ultimate strength (Alghannam, Abdulqader and Al-Fakih, 2026). The results of the previous studies show the effectiveness of ferrocement jacketing, however, there are several research gaps. First, the large number of published studies are on conventional stone-aggregate concrete, and the performance of ferrocement confinement on crushed brick aggregate concrete needs more experimental evidence. This is particularly true for Bangladesh and the neighbouring areas. Second, the square columns are more complicated than the circular columns due to the non-uniform confinement. Stress concentration can occur in the corner regions which can lead to early cracking of the jacket (Kaish et al., 2012, 2015). So, the effect of the type of mesh, thickness and number of layers must be studied. Third, while ferrocement has proven to enhance the axial strength, the design of ferrocement-jacketed RC columns is less developed than that of conventional steel and FRP confinement (Kaish et al., 2018). Fourth, a large portion of the experimental data available is from small scale specimens. Further investigations are needed to determine the transferability of these results to full scale columns, deteriorated field structures, eccentric loading and seismic loading. The present study adds to this knowledge base by systematically changing the mortar ratio, wire-mesh gauge, and type of wire-mesh and number of wire-mesh layers in short square RC columns and measuring their axial load capacity, deformation and ductility.

3. Research Objectives

The principal objectives were:

1. To study the effect of ferrocement jacketing on the axial load carrying capacity of RC column.
2. To evaluate the influence of ferrocement jacketing on axial deformation and ductility.
3. To examine the effects of mortar proportion.
4. To investigate the influence of wire-mesh gauge.
5. To compare different mesh configurations.
6. To determine the effect of increasing the number of mesh layers.

4. Experimental Programme

4.1 Specimen geometry and reinforcement

The experimental study used short square RC columns with nominal dimensions of approximately 6 in × 6 in × 2 ft. Each column contained four 10 mm longitudinal reinforcing bars and 6 mm transverse reinforcement at 4 in spacing. The experimental programme consisted of four control specimens and twelve strengthened specimens. The uploaded study therefore evaluated 16 columns in total and tested those following 28 days of curing.

4.2 Experimental variables

The specimens were organized into four groups.

Group A: Mortar ratio

The control concrete had a 1:1.5:3 proportions. The jacketed specimens used G-22 expanded wire mesh with one layer while changing the cement-to-sand mortar ratio to 1:1.5, 1:1 and 1:2.

Group B: Mesh gauge

The concrete proportion was 1:2:4 and the mortar ratio were maintained at 1:1.5. G-22, G-18 and G-20 expanded wire meshes were used.

Group C: Mesh type

A 1:3:6 concrete mixtures were used with a 1:2 mortar ratio. Expanded G-22, square G-22 and square G-18 meshes were compared.

Group D: Number of layers

The 1:2:4 concrete and 1:1.5 mortar were kept constant while the number of G-22 expanded mesh layers was increased from two to four.

4.3 Materials

Portland composite cement was used for both the concrete and ferrocement mortar. Locally available sand with a reported fineness modulus of approximately 2.5 was used as fine aggregate; while 19 mm downgraded crushed brick aggregate was used as coarse aggregate. Tap water was used for mixing. Expanded steel wire mesh with a diamond-shaped pattern was used as the principal external reinforcement. The use of crushed brick aggregate is particularly significant because it represents construction materials commonly found in Bangladesh and parts of South Asia. The relatively lower strength of brick aggregate concrete also provides an appropriate material system for assessing whether external confinement can compensate for deficiencies in the original concrete.

4.4 Ferrocement jacketing procedure

After 28 days of curing, the surfaces of the columns were roughened to facilitate a good mechanical interlock and bond between the original concrete and the new layer of ferrocement. The wire mesh was cut to the desired size and wrapped around the column. 100 mm overlap was given in the lateral direction. The mesh was then filled with cement mortar and the jacketed specimens were then cured in water for another 28 days. The surface preparation is of special significance since the composite action relies on the transfer of loads between the existing concrete and the jacket. If the surfaces are not prepared properly, the debonding or relative slip can occur prematurely, which may decrease the theoretical confinement efficiency.

4.5 Testing procedure

The specimens were tested under monotonically increasing concentric axial compression using a 2000 kN universal testing machine. Both control and strengthened columns were loaded until failure. Axial load and vertical deformation were recorded, allowing load–deflection and stress–strain responses to be developed. The experimental approach therefore represents a controlled evaluation of the pure axial-strengthening effect of ferrocement confinement. It should not be interpreted as a complete simulation of an in-service column, where axial load is frequently combined with bending, shear, cyclic displacement and environmental deterioration.

5. Results and Discussion

5.1 General response

The experimental results clearly demonstrate that ferrocement jacketing increased the ultimate axial capacity of all investigated groups. The control columns failed at substantially lower loads than their corresponding strengthened specimens. This is consistent with the established confinement mechanism whereby the jacket restrains lateral expansion and delays concrete crushing.The source study reports ultimate loads of 408, 340, 300 and 360 kN for control specimens A–D, respectively. The corresponding jacketed specimens reached 580–620 kN in Group A, 480–540 kN in Group B, 420–480 kN in Group C and 520–640 kN in Group D.

5.2 Effect of mortar ratio

For Group A, the control column achieved an ultimate load of 408 kN. Specimens A-1, A-2 and A-3 reached 580, 600 and 620 kN, respectively.
The corresponding strength enhancements were:

- A-1: 42.16%
- A-2: 47.06%
- A-3: 51.96%

So, even one ferrocement layer resulted in a significant improvement. The maximum enhancement was achieved for A-3, which is about 52% above the control. The source data also show that the ultimate deformation increases from 10.15 mm (control) to 10.30, 11.70 and 12.34 mm (A-1, A-2 and A-3). The trend shows that the properties of the jackets are not only dependent on the number of meshes. The quality of the mortar and the interaction of the mortar and mesh have an impact on the stiffness and tensile resistance of the jacket. However, the experimental results presented here should not be extended to other mortar formulations as only a small number of mortar formulations were tested.

5.3 Effect of wire-mesh gauge

The mesh gauge assessment is provided by Group B. The control specimen achieved 340 kN, whereas B-1, B-2 and B-3 reached 480, 520 and 540 kN.

The calculated increases were:

- B-1: 41.18%
- B-2: 52.94%
- B-3: 58.82%

The source study also indicates 58.82% as the highest percentage of increase in this population group. The ultimate deformation rose from 9.73 mm in the control to 9.93, 10.69 and 11.00 mm. This implies that the mesh reinforcement can be stronger or more effective, which means that it can also offer increased resistance and increased deformation capacity before failure. The physical interpretation is in line with the mechanics of ferrocement: the mesh has to take up tensile stresses due to lateral expansion and cracking. The better the mesh, the more it will be able to provide restraint and crack bridging. The performance is not just a function of gauge, however, it is also dependent on the geometry of the mesh, anchorage, penetration of the bond and the penetration of the mortar.

5.4 Effect of mesh type

The expanded and square mesh configurations were studied by group C. The control column reached 300 kN, while C-1, C-2 and C-3 reached 420, 460 and 480 kN.

The resulting strength enhancements were:

- C-1: 40.00%
- C-2: 53.33%
- C-3: 60.00%

The experimental source indicates that for various mesh types, the maximum improvement was about 60% in the lower-strength concrete group. The result indicates that the confinement efficiency can be affected by the geometry of the mesh. The reinforcement distribution and interaction with the mortar can vary from one mesh to another, for example, between square mesh and smaller gauge mesh. However, it is important to note that only three configurations were tested, so additional testing would be required before determining a general ranking of mesh types.

6. Effect of Number of Ferrocement Mesh Layers

The most pronounced trend occurred in Group D, where the number of G-22 mesh layers was systematically increased.The control column reached 360 kN. D-1, D-2 and D-3 achieved 520, 580 and 640 kN, respectively.

Therefore:

Strength enhancement=P_j-P_c×100\text{Strength enhancement}= \frac{P_j-P_c}{P_c}\times100

Where P_j is the ultimate load of the jacketed column and P_c is the control load.
The resulting enhancements were:

Specimen	**Mesh layers**	**Ultimate load (kN)**	**Increase**
Control D	0	360	—
D-1	2	520	44.44%
D-2	3	580	61.11%
D-3	4	640	77.78%

The trend is supported by good experimental data that more layers of mesh leads to better confinement. But the relationship should not be taken for granted as being linear for all time. With the increase in mesh density, the confinement mechanism can change from lack of confinement to failure of the bond, cracking of the mortar, local instability, or corner distress or crushing of the original core. Thus, extra layers can be useful only during the period when the load transfer mechanism is still in operation. The enhancement of ductility also is supported by the increase in ultimate deformation. The ductility improvement for Group D was 31.90%, which is significantly higher than the increments in Groups A – C.

7. Stress and Strain Behaviour

The stress–strain response shows that the confinement in the ferrocement alters the deformation behaviour of the columns as well as the peak load. The stronger specimens tended to have higher stresses and greater ultimate strains than the unconfined specimens. The source study reports stress increases of approximately 11.64%, 16.68%, 17.55% and 30.61% for Groups A, B, C and D, respectively. Ductility enhancements were reported as 21.57%, 20.14%, 6.59% and 31.90%.The enhanced deformation capacity is structurally important. Strength alone is insufficient to characterize a strengthening technique because brittle failure can still be dangerous even when ultimate capacity is high. Ferrocement confinement may cause the cracking to be redistributed and prevent sudden disintegration of the concrete, enabling the member to deform more before it loses capacity. This observation is consistent with the previous cyclic loading studies in which it was found that ferrocement confinement can enhance the ductility and energy dissipation characteristics of structures and can change the failure mode from brittle shear to ductile (Abdullah and Takiguchi, 2003; Kazemi and Morshed, 2005).

8. First-Crack Behaviour

The first-cracking load also increased following jacketing. Control cracking loads of 348, 250, 195 and 234 kN have been recorded in the source study for Groups A–D. The first crack loads for the jacketed columns increased, in general, from between 310 kN to 483 kN, depending on the group and configuration. This behaviour suggests that the ferrocement jacket will resist cracking of the original concrete core until the cracks can be seen, as it offers tensile resistance around the core. The distributed mesh is especially helpful in controlling crack width and crack spacing as it offers reinforcement over a much larger surface area than traditional longitudinal bars. However, first crack load should not be confused with ultimate capacity. A jacket can slow down the cracking that is visible, but there has been a significant amount of micro cracking in the concrete. Thus, further experimental studies would benefit from instrumentation like strain gauges, digital image correlation, and acoustic emission or detailed crack-width monitoring.

9. Failure Mechanism

The experimental behaviour can be explained as a progressive deterioration of the concrete and external confinement. In the unconfined specimens, as the axial compression increases, internal micro cracking occurs, followed by visible cracking and lateral dilation, localised crushing, and loss of load capacity. As the concrete cover starts to spall, the cross-sectional area of the member is reduced and the longitudinal reinforcement is exposed to greater instability. The jacketed specimens prevent lateral expansion by the ferrocement layer. The tensile forces in the wire mesh arise as the core tries to expand. These forces are passed from the concrete surface to the mesh, creating an externally confined composite system. But in the case of square columns, confinement is a non-uniform problem. The corners are under higher stress concentration, which is why Kaish et al. (2012, 2015) highlighted the need for rounded corners and extra reinforcement around the corners as a possible modification to the traditional square jacketing. This is one of the most significant implications of the present research; the effectiveness of ferrocement jacketing is not only due to the addition of material but also to the ability to create an efficient confinement configuration.

10. Comparison with Previous Research

The results of the experiments are generally in agreement with the literature. The results of the present study indicated that the two-layer welded wire mesh configuration gave an increase in axial capacity of more than 33%, while several single-layer configurations yielded increases greater than 40% and four layers yielded increases greater than 78%, compared to the control. Mourad and Shannag (2012) reported about 33% increase in axial capacity with two layers of welded wire mesh, while the present study showed increases greater than 40% for several single-layer configurations and more than 78% for four layers compared to the control. Such differences are reasonable as they depend on column dimensions, concrete strength, and reinforcement ratio, properties of the mortar, mesh characteristics, surface preparation and loading history. Kondraivendhan and Pradhan (2009) noted that the relative benefits were higher for lower strength concrete, which is also seen in the present study.

Abdullah and Takiguchi (2003) pointed out that external confinement plays an important role on ductility. The present study also shows that the ultimate deformation and ductility increase. Kaish et al. (2012, 2013, 2015) have shown that the conventional jackets can be inefficient due to the effects of square-column corners. The present results should therefore be taken with special care in regard to corner geometry and the continuity of the mesh. The wider RC strengthening literature also suggests that ferrocement should not be considered as a universal solution as compared to FRP, steel, ECC or other sophisticated systems. Instead, it has the main benefits of low material cost, relatively simple construction and compatibility with locally available materials (Raza et al., 2019; Kaish et al., 2018).

11. Engineering Significance

The experimental results have a number of practical implications. First, the ferrocement jacketing can offer a significant boost in the axial capacity without the large dimensional increase that is needed for the conventional RC jacketing. Second, the technique is particularly appealing for low and medium strength concrete where confinement can yield relatively high percentage gains. Third, the more layers of mesh the better the capacity and ductility. The 77.78% improvement in Group D with four layers is the best improvement in the current experimental programme. Fourth, the technique is especially applicable when cement, sand and steel mesh is easily available, but advanced FRP materials are costly or hard to come by. Fifth, the ferrocement jacketing may be able to increase the service life of existing structures by delaying cracking and protecting the existing reinforcement, but long-term durability needs to be tested. Recent research on fire damaged columns also indicates that ferrocement can be used in post-fire rehabilitation, but with a high degree of dependency on the level of thermal damage and cooling regime (Tabassum and Noor-E-Yeasmin, 2025).

12. Limitations of the Present Study

Although the results of the experiments were encouraging, there are some limitations which should be recognized in the present study. The investigation was carried out using small scale laboratory column specimens and the columns were mainly tested under concentric axial compression. Therefore, the effect of load eccentricity and cyclic lateral loading was not fully studied. Furthermore, only a few proportions of ferrocement mortar were taken into consideration, and the use of crushed brick aggregate restricts the comparison of the ferrocement columns with the RC columns made with conventional stone aggregate. The study also did not consider the long term durability and corrosion resistance of the existing concrete core and the ferrocement jacket, nor the detailed bond-slip behaviour. In addition, there was limited replication on single configurations in the experimental matrix which limited the assessment of statistical variability and uncertainty. Lastly, the findings show significant enhancement in the axial strength and ductility, but the study does not offer a general design equation for ferrocement-jacketed RC columns. The limitations suggest that more experimental and analytical studies of full-scale specimens under eccentric and cyclic loading, using various types of aggregate, exposure to durability, interface behaviour and numerical modelling are necessary before the technique can be generalized for wide structural design applications.

13. Recommendations for Future Research

Future studies should extend the concentric axial compression and create a more comprehensive performance-based framework for ferrocement jacketed reinforced concrete columns to explore the effects of eccentric axial compression, constant axial compression and cyclic lateral displacement and various ratios of axial loading. Additional testing should be performed on columns of varying aspect ratios and cross section shapes such as circular, square and rectangular, and how rounded and specifically strengthened corners affect the confinement efficiency. The use of various types of wire-mesh, various wire-mesh gauges and various orientations should also be explored in combination with high and low strength ferrocement mortars, corrosion resistant wire-mesh and mortars containing natural or synthetic fibres. Comparative studies between brick, conventional stone and recycled aggregate concrete would give a wider understanding of the compatibility and strengthening efficiency of the materials. Further studies are required to rehabilitate fire damaged and corrosion damaged columns and advanced numerical modelling using finite element analysis (FEA) and the development of analytical models of confinement could be used to predict strength, deformation and failure behaviour. Particular attention should be given to bond and interface-fracture mechanisms between the existing concrete and ferrocement jacket, as well as long-term durability under wet–dry cycles, chloride exposure and other aggressive environmental conditions. Finally, the economic, environmental and practical feasibility of ferrocement jacketing should be assessed with life-cycle cost analysis and embodied-carbon assessment and full-scale field trials should be conducted to ensure reliable application of ferrocement jacketing in real structural rehabilitation projects. Special attention should be paid to confinement modelling, oriented towards design. Confined-concrete models that have already been developed for existing confined concrete, such as the Mander, Priestley and Park model (1988), serve as a conceptual basis, and models for confined concrete with FRP jackets show how to include the stiffness of the jacket, the effectiveness of the confinement, and the ultimate strain in the concrete into the model (Lam and Teng, 2003).

14. Conclusions

From the experimental evidence presented in the uploaded study it can be concluded that ferrocement jacketing is a good technique to improve the axial performance of short reinforced concrete columns. The ultimate load-carrying capacity of all the jacketed specimens were higher than the ultimate load-carrying capacity of their corresponding control columns, which is in agreement with the beneficial effect of external confinement. The maximum loads of the control specimens in Groups A–D were 408, 340, 300 and 360 kN, respectively, while those of the strengthened specimens were 620, 540, 480 and 640 kN, respectively. The maximum improvement was achieved with the addition of more layers of G-22 wire-mesh; two, three and four layers gave an increase in axial capacity of about 44.44%, 61.11% and 77.78% respectively. The changes in mortar ratio, mesh gauge and mesh type also resulted in significant strength gains, with the highest gains of around 51.96%, 58.82% and 60.00%, respectively. The enhanced columns also had higher ultimate deformation and better ductility, and reported increases of 21.57%, 20.14%, 6.59% and 31.90% for Groups A–D. The results show that the ferrocement jacketing process can enhance both the strength and deformation capacity of the column at the same time, which is very useful for the columns with strength deficiency and deterioration. The technique has great potential for application in developing countries like Bangladesh as it can be built with relatively simple materials and techniques. The results, however, should be interpreted within the limits of the experimental conditions of the study. In particular, the square-column corner effects, interface bond, eccentric loading, cyclic seismic response, durability and full-scale behaviour need to be further investigated. In general, the study findings indicate that ferrocement jacketing is technically feasible and economical strengthening method for existing RC columns, especially for low to medium strength brick-aggregate concrete structures, and can be considered as a sustainable strengthening method.

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