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AXIAL STRENGHENING OF BRICK MASONRY USING PRECAST FERROCEMENT JACKETS: AN EXPERIMENTAL STUDY ON STUB COLUMNS

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ABSTRACT

Unreinforced brick masonry (URM) is widely used in low- to mid-rise buildings in developing regions such as Bangladesh. However, its axial load-carrying capacity often deteriorates over time due to material degradation, aging, and increased service loads. Conventional retrofitting techniques such as reinforced concrete (RC) jacketing and fiber-reinforced polymer (FRP) wrapping are frequently cost-intensive or technically demanding for widespread application in developing regions. This study experimentally investigates the effectiveness of precast ferrocement jacketing as a simple and economical technique for strengthening of brick masonry stub columns. Ten stub-column specimens were tested under concentric axial compression, including one unstrengthened control specimen and nine jacketed specimens with three cement–sand mortar ratios (1:1, 1:2, and 1:2.5 by volume). The specimen geometry was selected as a short masonry compression member in accordance with BNBC 2020 and ACI 530 / TMS 402 provisions, ensuring failure governed by material crushing rather than slenderness or instability. A non-shrink, self-compacting grout was used to achieve composite action between the masonry core and the precast jacket. Test results show that precast ferrocement jacketing significantly improves axial capacity, stiffness retention, and ductility compared with unstrengthened masonry. Strength increases of approximately 118% to 187% were observed, depending on the mortar ratio. Richer mortar mixes produced higher strength enhancement, whereas leaner mixes improved post-peak deformability and energy dissipation. The failure mode transitioned from brittle crushing in control specimens to controlled, more ductile behavior in jacketed stub columns. The findings support precast ferrocement jacketing as a practical and cost-effective strengthening solution for existing masonry structures in developing regions.

Keywords: *Masonry, Stub column, Ferrocement jacketing, Axial compression, Retrofitting.*

1. INTRODUCTION

Masonry construction continues to dominate the built environment of developing nations owing to its low cost, local material availability, and simplicity of workmanship (Almssad et al., 2022; Wang, 2018). In Bangladesh, a large portion of the existing building stock comprises unreinforced brick masonry (URM). However, URM exhibits limited load-bearing capacity and poor deformation characteristics because of the brittle behavior of bricks, weak mortar joints, and negligible tensile resistance (Nežerka et al., 2015; Witzany and Radek Zigler, 2016). These inherent deficiencies are further aggravated by material aging, environmental exposure, construction imperfections, and increased service demands arising from extensions or changes in occupancy (El-Maissi et al., 2022). Consequently, URM shows limited mechanical performance under axial and lateral loads, making it vulnerable to failure under increased service loads, vertical extensions, or seismic excitation (Corradi et al., 2007; El-Maissi et al., 2022).

To enhance the structural performance of existing masonry structures, several strengthening and retrofitting techniques have been proposed, including reinforced concrete (RC) jacketing, steel confinement, and fiber-reinforced polymer (FRP) wrapping. Although these methods can provide substantial strength enhancement, their application in developing regions is often restricted by high material cost, skilled labor requirements, construction complexity, and limited availability of advanced materials (Afroz et al., 2015; Wang, 2018). Therefore, strengthening solutions that are structurally effective, economical, and compatible with local construction practices are needed.

Ferrocement jacketing is a cost-effective option that can provide crack control, confinement, and only a modest increase in member dimensions (Yardim et al., 2018). Previous studies have shown that ferrocement jacketing can enhance the strength and ductility of masonry elements (Khan Shahzada et al., 2012; Mustafaraj et al., 2016). However, in-situ ferrocement jacketing may suffer from practical drawbacks such as prolonged construction time, sensitivity to curing conditions, and workmanship variability, which can affect the consistency and reliability of the strengthening system (Mahmood et al., 2023). In contrast, precast ferrocement jackets can improve quality control and reduce on-site time.

The composition of the jacket, particularly the mortar mix ratio, influences the composite behavior of the retrofitted system. Richer mortars typically increase compressive strength and stiffness, while leaner mixes may improve deformability and ductility at the expense of ultimate capacity (Khan Shahzada et al., 2012; Rajkumar & Sankar, 2020). Although several studies have examined ferrocement confinement of masonry, systematic experimental evidence on precast ferrocement jackets and the influence of mortar ratio on axial response remains limited.

According to BNBC 2020, masonry structures in Bangladesh are designed following internationally recognized masonry standards, including ACI 530 / TMS 402 / ASCE 5. Under these provisions, short masonry compression members are governed primarily by material crushing rather than slenderness or instability. In this context, the present study experimentally investigates axial strengthening of brick masonry stub columns using precast ferrocement jackets with three mortar ratios (1:1, 1:2, and 1:2.5). The effectiveness of the proposed technique is evaluated in terms of axial capacity, stiffness retention, ductility, and failure mode, aiming to support an economical retrofitting solution suitable for developing regions.

2. METHODOLOGY

This study experimentally evaluated the effectiveness of precast ferrocement jacketing in enhancing the axial load-carrying capacity of unreinforced brick masonry stub columns. The methodological framework included material characterization, preparation of control and jacketed specimens, fabrication and installation of ferrocement jackets, and axial compression testing. The overall experimental layout is shown in Fig. 1.

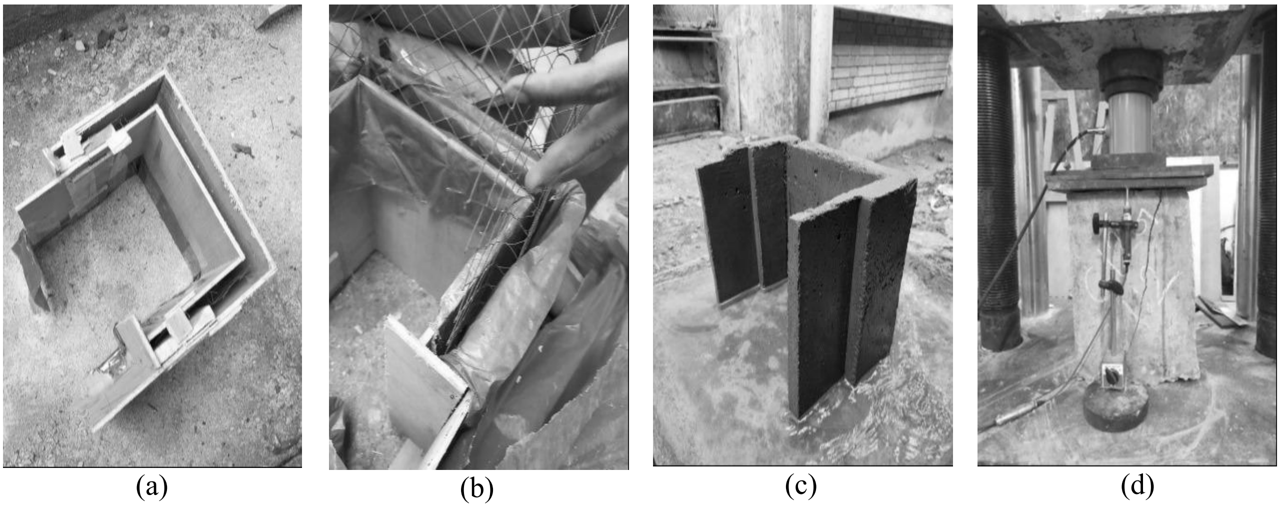

(a) (b) (c) (d)

Figure 1: Experimental layout: (a) Formwork; (b) Mesh placement; (c) Pre-cast jacket; (d) Test setup

2.1 Experimental Program

Ten brick masonry stub-column specimens were fabricated and grouped as one control specimen and three jacketed groups with varying mortar ratios using SWG No. 14 expanded galvanized wire mesh. This classification enabled a systematic investigation of mortar ratio effects on confinement efficiency. The experimental matrix is provided in Table 1.

Table 1: Experimental matrix of specimens

Specimen Designation	Jacket Type	Mortar Ratio	Wire Mesh (SWG)	No. of specimens
CS	Unjacketed control	–	–	1
C-MR 1:1	Pre-cast ferrocement jacket	1:1	14	3
C-MR 1:2	Pre-cast ferrocement jacket	1:2	14	3
C-MR 1:2.5	Pre-cast ferrocement jacket	1:2.5	14	3

2.2 Materials

Locally available first-class coal-burnt bricks were used. Ordinary Portland cement (OPC) conforming to ASTM C150 was utilized. Natural sand was used as fine aggregate for masonry mortar and Sylhet sand for jacket mortar; sand grading was verified following ASTM C136. Expanded galvanized wire mesh (SWG No. 14) was used for confinement. Sika Grout-214 was used as the bonding medium between the masonry core and the jacket due to its flowability, self-compacting behavior, and non-shrink characteristics.

2.2.1 Material characterization included

The physical and mechanical properties of masonry constituents were determined prior to specimen preparation. Standard procedures were followed to evaluate brick compressive and flexural strength, water absorption, mortar compressive strength for different mix ratios, grout strength, and sand grading (ASTM C136 and relevant BDS specifications). Table 2 summarizes the measured properties used to interpret the test results.

Table 2: Material Properties

Property	Value/ Test detail
Brick compressive strength	14.3 MPa (average)
Brick flexural strength	2.75 MPa
Brick water absorption	12.46%
Mortar compressive strength (1:1, 1:2, 1:2.5)	Tested on 75 × 150 mm cylinders
Grout compressive strength	Tested on 50 × 50 × 50 mm cubes
Sand grading	Verified by sieve analysis (ASTM C136)

2.3 Preparation of Control Brick Masonry Columns

Ten brick masonry stub columns were constructed with a cross-section of 230 mm × 230 mm and a height of 408 mm, resulting in a height-to-thickness ratio of approximately 1.77. According to BNBC 2020 and ACI 530 / TMS 402 / ASCE 5, such members are classified as short masonry compression members. The selected geometry ensured that axial failure was governed by compressive crushing rather than buckling or slenderness effects. Bricks were soaked in water for 24 hours and kept in saturated surface-dry (SSD) condition prior to laying. Units were bonded using 1:4 cement–sand mortar. After construction, specimens were cured under wet gunny bags for 28 days.

(a) (b)

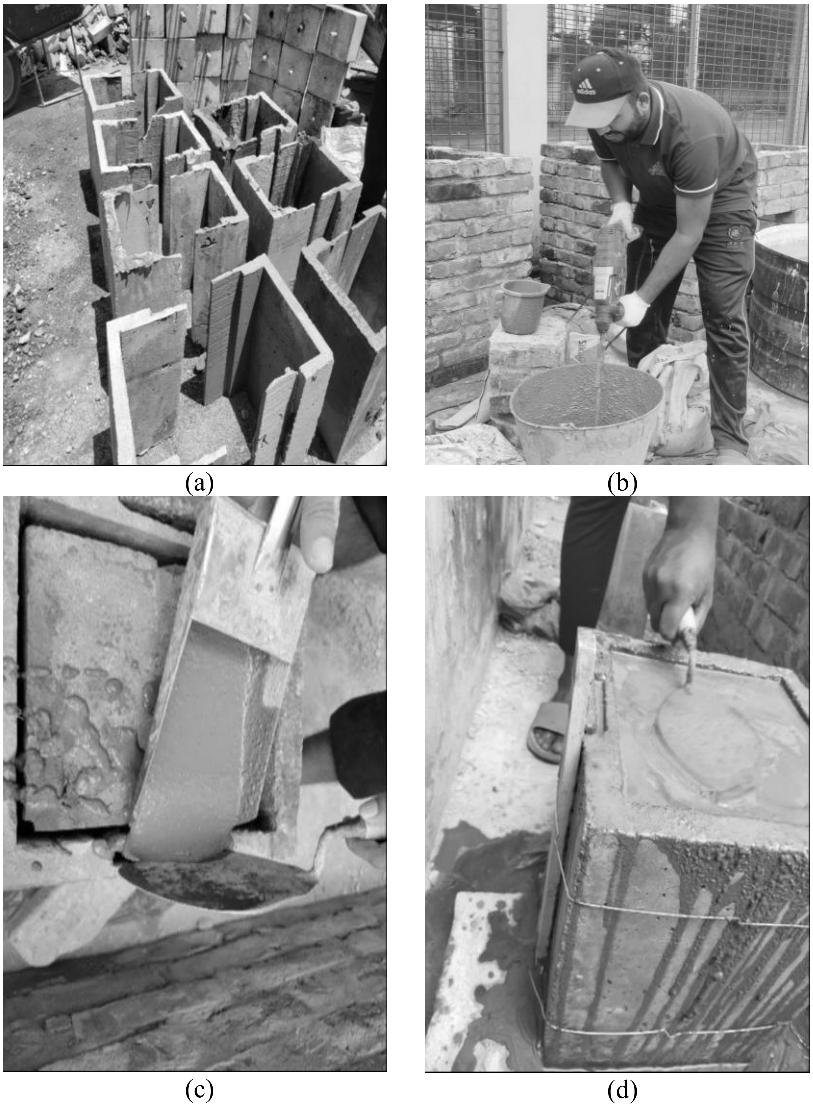
Figure 2: Brick masonry column: (a) Water-tight curing; (b) Wet gunny bag curing.

2.4 Fabrication of Pre-cast Ferrocement Jackets

Precast ferrocement jackets were prepared separately to improve dimensional control and ease of installation. Wooden molds were fabricated to produce external jacket dimensions of 300 mm × 330 mm, providing a 30 mm annular clearance around the masonry core. A single layer of expanded wire mesh (SWG No. 14) was placed at mid-thickness. Mortar ratios of 1:1, 1:2, and 1:2.5 (cement:sand by weight) were used. Mortar was applied in two layers to fully embed the mesh. Jackets were demolded after 48 hours and water-cured for 28 days.

2.5 Installation of Jackets Using Non-shrink Grout

Before installation, the masonry surfaces were wire-brushed and roughened to enhance bond. Precast jackets were aligned concentrically using temporary steel straps. The annular gap was filled with Sika Grout-214 to ensure full contact and composite behavior. Grouting was performed from one side to minimize air entrapment, and jacketed specimens were cured for 7 days before testing.



(a) (b) (c) (d)

Figure 3: Installation of Jacket: (a) Precast jacket; (b) Grout mixing; (c) Grout filling; (d) Jacketed specimen.

2.6 Test Setup and Loading Procedure

All specimens were tested under monotonic concentric axial compression using a universal testing machine (UTM) with 1000–2000 kN capacity. Rubber pads were placed between specimen ends and steel platens to reduce stress concentration. Axial deformation was recorded using an LVDT, and failure patterns were visually documented. The following parameters were obtained: first cracking load, ultimate load, stiffness degradation, ductility, and failure mode.

3. RESULTS AND DISCUSSION

3.1 Control Specimen (CS)

The control stub column was tested under concentric axial compression to establish baseline behavior. The load–deformation response remained approximately linear up to a cracking load of about 138 kN, followed by nonlinear response associated with micro-cracking and progressive stiffness reduction. The specimen reached an ultimate load of 283.38 kN, after which a sharp post-peak load drop occurred, indicating brittle crushing typical of unconfined masonry. Failure was characterized by prominent vertical cracking along mortar joints, localized brick crushing and surface spalling.

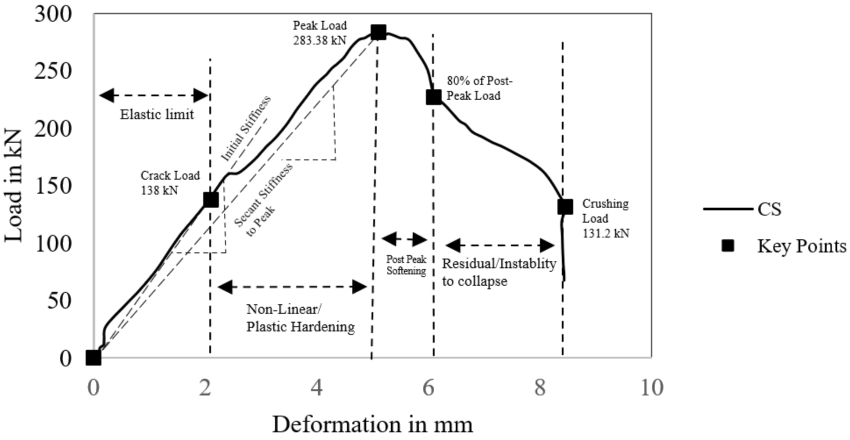


Figure 5: Load-deformation curve for control specimen (CS)

3.2 Jacketed Specimen with Mortar Ratio 1:1 (C-MR 1:1)

The C-MR 1:1 specimen exhibited the highest strength enhancement. First cracking occurred at 372.3 kN, indicating effective stress transfer and confinement by the jacket. The specimen attained an ultimate load of 812.38 kN, corresponding to a 186.7% increase relative to CS. Post-peak softening was gradual, demonstrating improved stability and ductility compared with the control specimen. Failure involved distributed cracking, controlled masonry crushing, and delayed debonding.

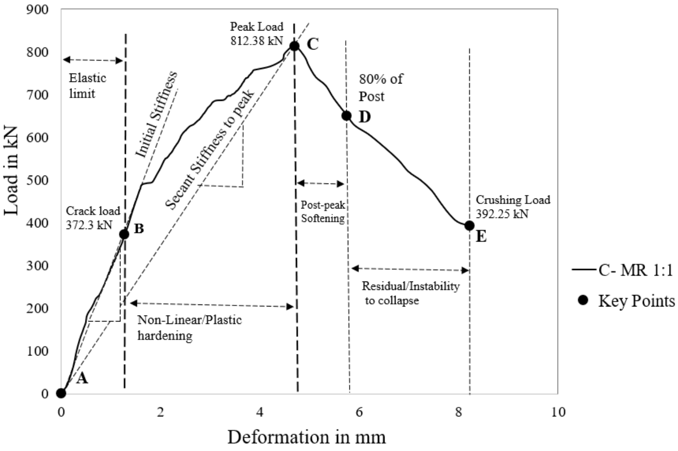


Figure 6: Load-deformation curve for C- MR 1:1

3.3 Jacketed Specimen with Mortar Ratio 1:2 (C-MR 1:2)

The C-MR 1:2 specimen provided a balanced combination of strength and deformability. First cracking occurred at 332 kN and the peak load reached 718.28 kN (153.5% increase relative to CS). The post-peak response showed stable softening with increased deformation capacity compared to CS, reflecting effective confinement and energy dissipation.

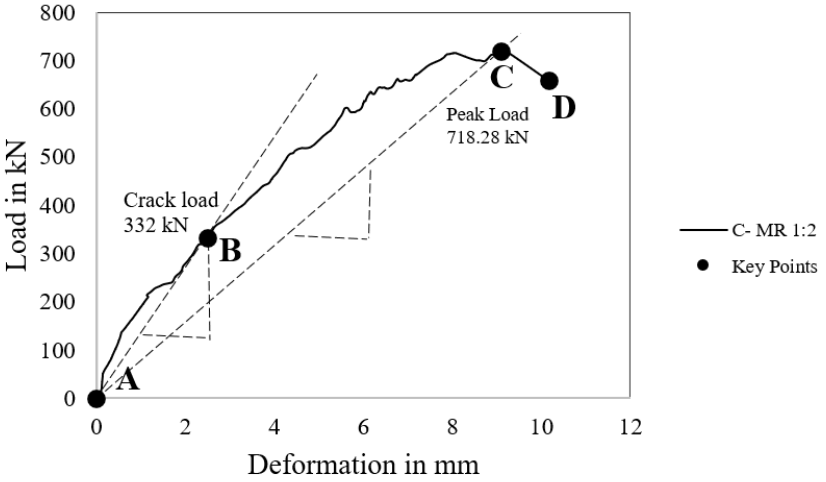


Figure 7: Load-deformation curve for C- MR 1:2

3.4 Jacketed specimen with Mortar Ratio 1:2.5 (C-MR 1:2.5)

The C-MR 1:2.5 specimen exhibited lower peak load but higher post-peak deformability. First cracking occurred at 319.4 kN, and the peak load reached 618.03 kN (118.2% increase relative to CS). The extended nonlinear region and gradual load decay indicate improved ductility and residual capacity.

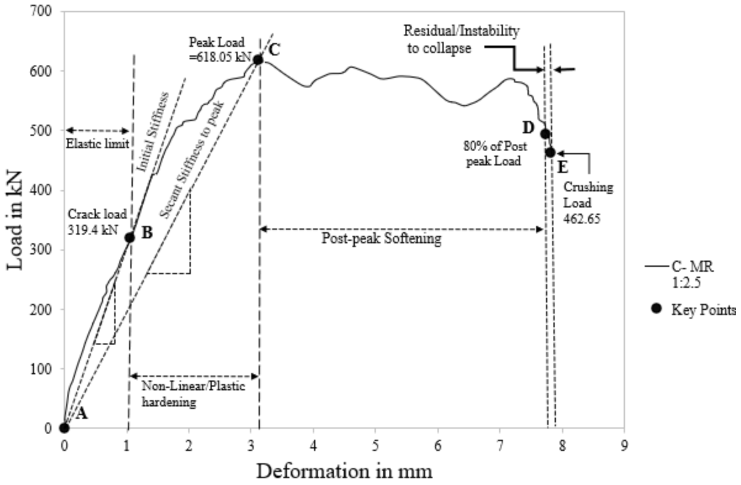


Figure 8: Load-deformation curve for C- MR 1:2.5

3.5 Comparative Performance

Among jacketed specimens, C-MR 1:1 achieved the highest ultimate capacity and stiffness, while C-MR 1:2.5 exhibited the greatest post-peak deformability. C-MR 1:2 provided a balanced response.

Overall, precast ferrocement jacketing improved axial capacity, stiffness retention, and ductility relative to the control stub column.

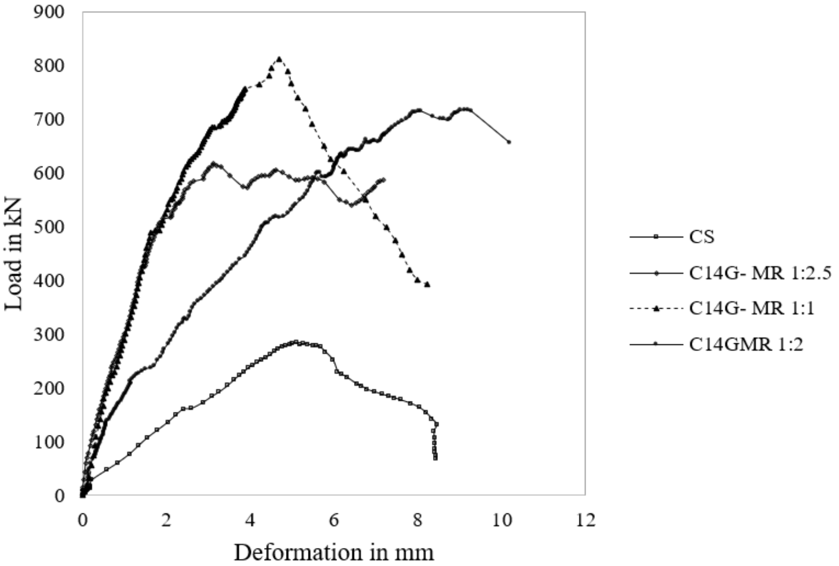


Figure 9: Comparative load-deformation curves

Table 3: Axial performance summary

Specimen	Cracking Load (kN)	Ultimate Load (kN)	% increases vs. CS
CS	138.00	283.38	---
C-MR 1:1	372.30	812.38	186.7%
C-MR 1:2	332.00	718.28	153.5%
C-MR 1:2.5	319.40	618.03	118.2%

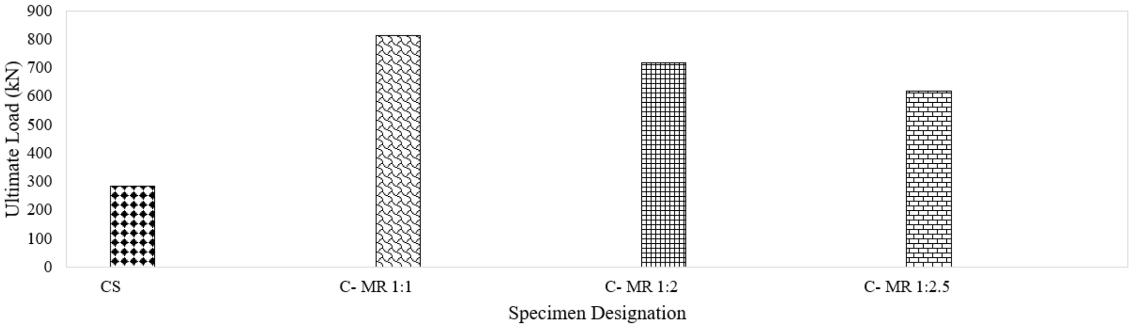


Figure 10: Ultimate load comparison (bar chart)

Table 4: Summary of observed trends by mortar ratio

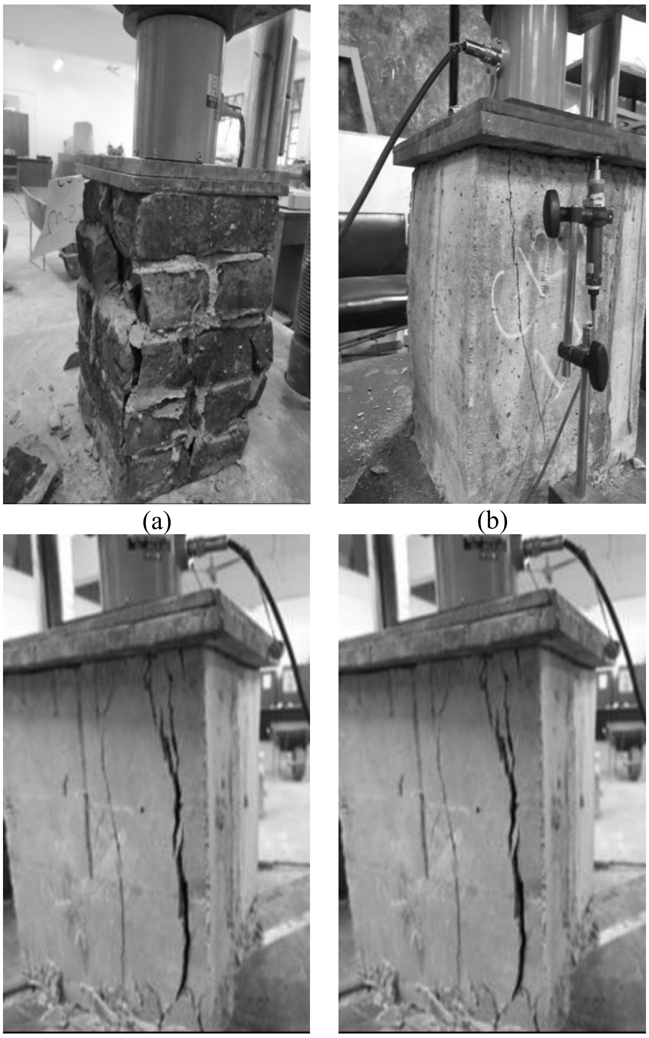
Mortar Ratio	Strength gain	Ductility	Suitability
1:1	Highest	Moderate	High-strength retrofitting
1:2	High	Balanced	Most practical
1:2.5	Moderate	Good	Economic retrofitting

Table 5: Ductility ratio based on load-deformation response

Specimen	Deformation at cracking (mm)	Deformation at peak (mm)	Ductility Ratio
CS	2.103	5.098	2.424
C- MR 1:1	1.283	5.754	4.485
C- MR 1:2	1.571	7.891	5.023
C- MR 1:2.5	1.080	7.042	6.520

3.6 Failure Mode

The control stub column failed abruptly with vertical cracking and crushing along mortar joints, reflecting brittle behavior of unconfined masonry. In contrast, jacketed specimens exhibited distributed cracking and delayed crushing, indicating effective confinement. The 1:1 jacket produced higher strength with relatively limited post-peak deformation, whereas leaner mortar ratios provided increased deformability and more gradual load decay.



(a) (b)

(c) (d)

Figure 11: Failure patterns: (a) CS; (b) C-MR 1:1; (c) C- MR 1:2; (d) C- MR 1:2.5

4. CONCLUSIONS

Based on the experimental investigation of brick masonry stub columns strengthened using precast ferrocement jackets, the following conclusions are drawn:

(1) Precast ferrocement jacketing substantially improved the axial performance of URM stub columns, increasing ultimate capacity by approximately 118% to 187% compared with the control specimen.
(2) Richer mortar in the jacket (1:1) provided the highest strength enhancement and stiffness retention, whereas leaner mixes improved post-peak deformability and energy dissipation.
(3) Jacketing transformed brittle crushing of unconfined masonry into a more controlled and ductile failure mode with distributed cracking and delayed crushing.
(4) Precast ferrocement jacketing offers a practical and economical strengthening option for existing masonry structures in developing regions, particularly where rapid execution and quality control are important.

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‘Declaration of Use of AI’

The authors declare that no AI tools has been used for research design, data collection, processing, analysis, and interpretation of results but for grammatical corrections.

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