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Enhancement of Axial Capacity of Brick Masonry Column by Reinforced Concrete Jacketing

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Abstract Masonry plays a vital role in construction, serving as either load-bearing or infill material in reinforced concrete or steel-framed buildings. In Bangladesh, brick masonry units are commonly used as load-bearing components, especially in rural areas. While capable of withstanding axial loads, brick masonry is not as strong when it comes to resisting lateral loads. With population density on the rise, there has been a trend of using agricultural lands for new building construction, which could be mitigated by vertically extending existing buildings. In this scenario, the capacity of the masonry columns must be increased. To achieve this, various methods can be employed, such as reinforcing the masonry wall using techniques like reinforced concrete (RC) jacketing. The study aimed to investigate the effectiveness of reinforced concrete (RC) jacketing in enhancing the axial compressive strength and ductility of brick columns. The study involved several types of specimens of similar sizes (114×114 mm^2 before strengthening and 240×240 mm^2 after strengthening) and four different types of bricks, with RC jacketing used for strengthening. The jacketing utilized 0.70% longitudinal reinforcement, and the specimens have been tested under monotonic loading. The study's results revealed that the axial capacity of masonry columns have been enhanced by approximately 150% with RC jacketing. Additionally, the average ductility enhancement has been found to be 38%. These findings indicate the effectiveness of RC jacketing in enhancing the load-carrying capacity and ability to resist deformation.

Keywords Load-bearing wall · Brick column · Strengthening · Axial capacity · Ductility · RC jacketing

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1 Introduction

Due to their strength, aesthetic appeal, and affordability, masonry structures have long been used in the construction sector. Particularly in low-rise buildings, brick masonry has been employed extensively as load-bearing elements. Generally, these types of buildings have been designed (often not designed at all) to only resist gravitational loads and have been realized by rules of common practice [1]. During their existence, many of those structures have suffered from the combined effects of inadequate construction techniques, seismic and wind loads, foundation settlements, and deterioration of construction materials [2]. The necessity to increase the axial capacity of brick masonry columns has become crucial due to the acceleration of urbanization and the rising demand for vertical expansion. The purpose of this study is to determine whether reinforced concrete (RC) jacketing is a practical method for increasing the axial capacity of brick masonry columns.

The main aim of the strengthening techniques is to increase low parameters of masonry such as compressive, tensile, and shear strength as well as vulnerability against lateral loads. Traditional techniques such as: (i) RC jacketing; (ii) filling cracks and voids by grouting; (iii) stitching of large cracks and weak areas with metallic or brick elements; (iv) external or internal post-tensioning with steel ties; (v) shotcrete jacketing; (vi) ferrocement; and (vii) center core are available for retrofitting of existing masonry structures [3, 4]. Reinforced concrete jacketing has emerged as a promising method due to its effectiveness and utility. By adding reinforced concrete layers, the existing masonry columns' load-bearing capacity and structural performance can be significantly improved. Transverse expansion of the masonry takes place when unreinforced masonry (URM) columns are subjected to compressive load. Due to the varying stiffness of the two materials and the strong binding behavior between them, the lateral deformation of mortar is often greater than that of brick units. As a result, the brick units are placed in a state of axial compression and bilateral stress [5, 6], which causes vertical cracks to develop and spread swiftly. As a result, a variety of reinforcing techniques have been applied to masonry columns to increase their strength and deformability by limiting the masonry's transverse expansion. A study by Kog et al. in 2001 [7] examined the behavior of brick masonry columns strengthened with reinforced concrete jacketing. The experimental investigation included axial load tests and the installation of reinforced concrete jackets to brick masonry columns. The results demonstrated a considerable increase in the axial load capacity of the columns, demonstrating the significance of reinforced concrete jacketing as a reinforcing method. Masonry columns' ability to support more weight was significantly increased when they were fortified with stirrups and longitudinal steel-reinforced concrete jackets [7]. A realistic demonstration of RC Jacketing's effectiveness in strengthening unreinforced masonry (URM) walls and columns was performed by Motra and Paudel [8]. They discovered that RC jacketing was the most effective solution for retrofitting masonry structures (80% increase in capacity, 48% decrease in roof displacement). Shear keys and RC columns worked well together to support brick piers since they slightly increased capacity (57%) and decreased roof displacement (26%), compared to URM construction.

In this paper, the usage of RC-jacketing technique is presented as an effective method to improve structural performance, i.e., compressive strength and ductility enhancement of unreinforced brick masonry columns.

2 Methodology

2.1 Specimen Description and Preparation

The experimental program consisted of sixteen clay brick masonry columns tested under axial compression load in which four different categories of bricks were considered. The authors considered coal burned and gas burned clay brick with two different class, i.e., first-class and second-class brick. The nominal dimensions of the control specimens were b = 114 mm h = 114 mm, L = 610 mm (aspect ratio L/b = 5.35 before strengthening and 2.54 after strengthening) as shown in Fig. 1. One specimen from each group were considered as control specimen and the rest specimens were strengthened using RC jacketing where 4–10 mm diameter bar as longitudinal reinforcement were utilized with a 6 mm diameter bar as lateral reinforcement 75 mm on center. The size of the strengthened brick masonry columns is as presented in Table 1.

In doing so, the brick masonry columns were pre-wetted prior to the surface preparation (removal of dust, foreign particles, etc. and then chipping of the surface to make it rough and, insertion of shear key). The longitudinal and lateral reinforcement were placed in their designated position and then typical wooden form is inserted

(a) (b) (c)

Fig. 1 **a** Brick masonry column encased in reinforcement before casting, **b** strengthened brick masonry column, and **c** experimental setup

Table 1 Description of specimens

Types of brick	Class	Column designation	Number of specimen	Cross section (mm^2)	Remarks
Coal burned	1st class	H1BS	1	114 × 114	Control specimen
		H1R	3	240 × 240	
	2nd class	H2BS	1	114 × 114	Control specimen
		H2R	3	240 × 240	
Gas burned	1st class	M1BS	1	114 × 114	Control specimen
		M1R	3	240 × 240	
	2nd class	M2BS	1	114 × 114	Control specimen
		M2R	3	240 × 240	

using 19 mm cover maintaining block. A concrete, having 1:1.5:3 mixing ratio, was made with stone chips, locally available river bed sand, and Portland composite cement maintaining a w/c ratio of 0.55 and poured in the inserted form. After passing 24 h the forms were removed and specimens were allowed to cure by sprinkling water on its surface for a period of 28 days.

2.2 Properties of the Materials Used

The properties of the bricks used in this study are shown in Table 2.Portland composite cement was used with an initial setting and final setting time of 90 and 350 min, respectively. Locally available river bed sand was used with a fineness modulus (FM) of 1.51 and 2.65 for brick masonry mortar and concrete for strengthening, respectively. Crushed stone chips with FM of 6.35 was used in the strengthening concrete. In the brick work 1:4 mortar ratio was used where the compressive strength of mortar was found to be 16.35 MPa. Three cylindrical specimens were made to know the compressive strength of RC jacketing concrete and the result was 31.78 MPa. The yield strength of the longitudinal reinforcement and lateral reinforcement were 500 and 395 MPa, respectively.

2.3 Experimental Setup

The specimens were tested using a universal testing machine (UTM) with a capacity of 2000 kN. The specimens were inserted in the UTM by using two rubber pads one at the top and other at the bottom end of the specimen in a manner so that the load can be transferred through the centroid of the specimen and there will be no eccentricity. The experimental setup is shown in Fig. 1. Specimens were loaded under a monotonically

Table 2 Properties of bricks

Types of brick	Class	Size (mm)	Weight (gm)	Absorption (%)	Compressive strength (MPa)	Tensile strength (MPa)
Coal burned	1st class	230 × 110 × 65	2923	14.23	11.80	1.19
	2nd class	230 × 110 × 65	2702	17.36	8.83	0.97
Gas burned	1st class	225 × 110 × 65	3380	9.56	23.89	2.63
	2nd class	225 × 110 × 65	3275	15.20	18.43	1.78

increasing vertical load until failure. During testing the cracking load, failure pattern and axial deformation were observed for each specimen and duly recorded.

3 Results and Discussion

The first cracking loads of different columns are presented in Table 3. As anticipated, the average first cracking loads were lower for each type of control brick masonry column. However, when the columns were strengthened through RC jacketing, their average first cracking loads demonstrated a substantial increase compared to the control specimens within their respective groups. The enhancement percentages for M1R, M2R, H1R, and H2R were found to be 199, 183, 172, and 143%, respectively.

The highest average first cracking strength was observed in the case of a first-class gas burned clay brick masonry RC jacketed column, measuring 14.03 MPa. Conversely, the lowest average first cracking strength was recorded for a coal burned second-class brick column, measuring 8.23 MPa, which aligns with the expected outcome.

As seen in Table 3, the ultimate load-carrying capacity or strength is also enhanced.

significantly for each type of column. The average ultimate strength enhancement were found to be 162, 155, 161, and 135% for M1R, M2R, H1R, and H2R, respectively. The increase in ductility was found to be 35, 38, 41, and 37% for M1R, M2R, H1R, and H2R, respectively. Figures 2, 3, 4 and 5 show the load vs. deformation curve for each of type of specimen considered in the study.

The study's conclusions are visually supported by the (Figs. 2, 4, 5). The data shows that the strengthened column's load-carrying capability was significantly higher than its non-strengthened counterpart. The strengthened column's deformation capacity was also greatly improved. The figures, for instance M1R-1, M1R-2, and M1R-3, show an intriguing link between comparable specimens. In terms of load-carrying capability and deformation properties, these specimens behaved in a strikingly comparable manner. This similarity implies a dependable reaction to the

Table 3 Summary of test results

Designation	Avg. first cracking load (kN)	Avg. first cracking strength (MPa)	Avg. first cracking strength enhancement (%)	Avg. failure load (kN)	Avg. failure load enhancement (%)	Avg. ultimate strength (MPa)	Avg. ultimate strength enhancement (%)	Avg. deformation (mm)	Ductility enhancement (%)
M1BS	61.00	4.69	–	96	–	7.39	–	4.30	–
M1R	808.00	14.03	199	1138	1085	19.75	162	5.80	35
M2BS	55.00	4.23	–	84	–	6.46	–	4.55	–
M2R	691.00	12.00	183	960	1043	16.46	155	6.30	38
H1BS	53.00	4.08	–	80	–	6.16	–	3.90	–
H1R	640.00	11.11	172	927	1059	16.09	161	5.50	41
H2BS	44.00	3.39	–	68	–	5.23	–	4.00	–
H2R	474.00	8.23	143	707	940	12.27	135	5.46	37

Fig. 2 Load versus deformation curve of M1R type specimens

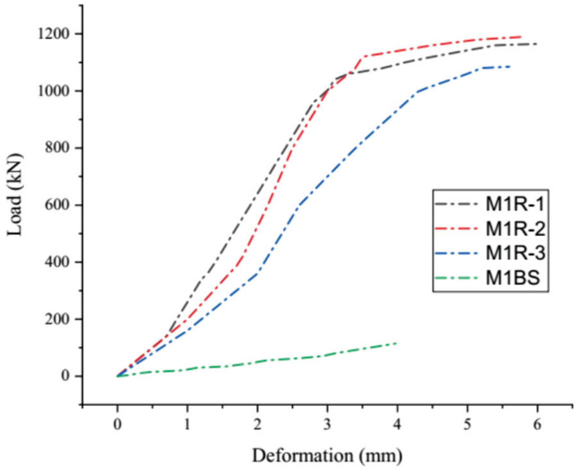
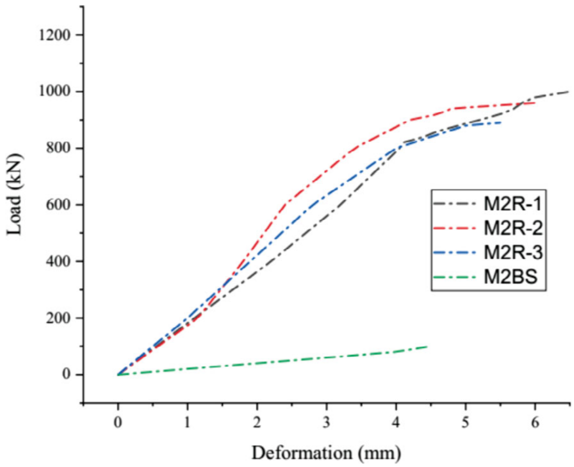


Fig. 3 Load versus deformation curve of M2R type specimens



employed strengthening approach. The enhanced load-carrying capacity observed in the figures indicates that the strengthened columns possessed an increased ability to withstand applied loads. This improvement in axial capacity is a positive outcome, as it signifies the effectiveness of the strengthening method in enhancing the structural performance of the columns. Furthermore, the figures depict a substantial increase in the deformation ability of the strengthened columns compared to their non-strengthened counterparts. This elevated ductility is a desirable attribute as it allows the columns to undergo larger deformations while maintaining structural integrity.

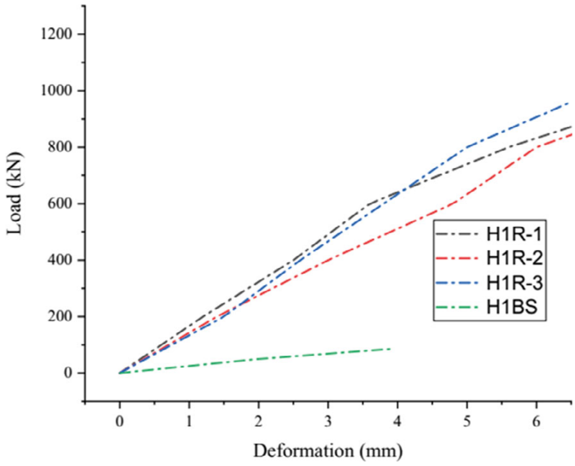


Fig. 4 Load versus deformation curve of H1R-type specimens

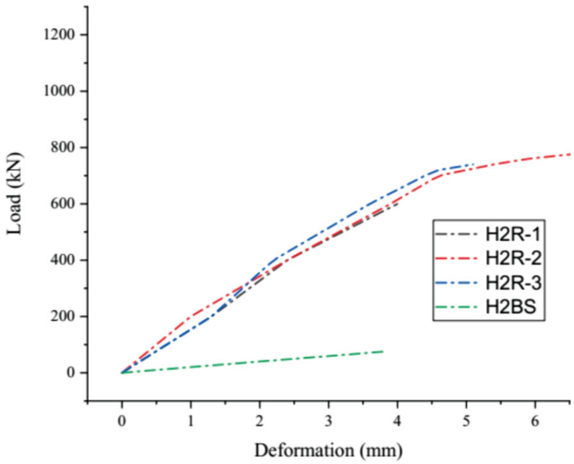


Fig. 5 Load versus deformation curve of H2R-type specimens

4 Conclusions

The following conclusions have been reached based on the findings of the current study:

- Different types of brick masonry columns can be strengthened with great success using RC jacketing.
- It was found that the average improvement in first cracking strength was 174%.
- The average increase in ultimate strength over the control specimen was found to be 153%.
- Furthermore, as compared to the control specimen, the average increase in ductility was found to be 38%.

References

1. Mustafaraj E, Yardim Y (2016) Usage of ferrocement jacketing for strengthening of damaged unreinforced masonry (URM) walls. In: Proceeding of 3rd international Balkans conference on challenges of civil engineering, 3-BCCCE, 19–21 May 2016, Epoka University, Tirana, Albania
2. Lourenço PB (1996) Computational strategies for masonry structures. Delft University of Technology, Delft, Netherlands
3. Kalali A, Kabir MZ (2012) Experimental response of double-wy the masonry panels strengthened with glass fiber reinforced polymers subjected to diagonal compression tests. Eng Struct 39:24–37.https://doi.org/10.1016/j.engstruct.2012.01.018
4. Triantafillou TC (1998) Strengthening of masonry structures using epoxy-bonded FRP laminates. ASCE J Comp Constr 2:96–104. https://doi.org/10.1061/(ASCE)1090-0268(1998)2:2(96)
5. McNary WS, Abrams DP (1985) Mechanics of masonry in compression. J Struct Eng 111(4):857–870. https://doi.org/10.1061/(ASCE)0733-9445(1985)111:4(857)
6. Kaushik HB, Rai DC, Jain SK (2007) Stress-strain characteristics of clay brick masonry under uniaxial compression. J Mater Civil Eng 19(9):728. https://doi.org/10.1061/(ASCE)0899-1561(2007)19:9(728)
7. Kog YC, Ong K, Yu CH, Sreekanth APV (2001) Reinforced concrete jacketing for masonry columns with axial loads. ACI Mater J 98:105–115. https://doi.org/10.14359/10194
8. Motra GB, Paudel S (2021) Performance evaluation of strengthening options for institutional brick masonry buildings: a case study of Pulchowk Campus. Progr Disast Sci 10:100173. https://doi.org/10.1016/j.pdisas.2021.100173