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Enhancement of Axial Capacity of Brick Masonry Column by Ferrocement Jacketing

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Abstract

Due to the increase in population density in rural areas, vertical extension of existing buildings featuring load-bearing masonry columns are essential. As a result, the capacity of these masonry columns will need to be increased. An experimental investigation has been carried out to evaluate the enhancement of axial capacity due to addition of ferrocement jacket on brick masonry columns. Eight categories of specimen have been made, each with a length of 610 mm and the following cross-sections: 230×230 mm^2, 225×225 mm^2, and 114×114 mm^2. The specimens have been strengthened by ferrocement jacketing, leaving one specimen from each category as a control specimen. Ferrocement jacketing involved the use of single, double, triple, and quadruple layers of wire mesh, with the cross-sectional dimensions of the specimens increasing by at least 50mm (25mm on either side). Monotonic loading has been used to investigate axial capacity of both the control and strengthened specimens. The study revealed that the capacity of the brick masonry column was increased by a maximum of 35% when three layers of wire mesh have been used in the ferrocement jacketing. The average increase in axial capacity and ductility has been found to be 26% and 31% respectively.

Keywords: *Strengthening; Axial capacity; Ductility; Ferrocement jacketing; Brick Masonry.*

1 Introduction

Masonry structures have long been favored in the construction sector due to their strength, aesthetic appeal, and cost-effectiveness (Smith, 2015). In low-rise buildings, brick masonry has been extensively used as load-bearing elements. However, many of these structures were designed without considering factors such as seismic and wind loads, inadequate construction techniques, foundation settlements, and deterioration of construction materials (Olsen, 2008). With urbanization accelerating and the demand for vertical expansion increasing, there is a critical need to enhance the axial capacity of brick masonry columns. Various strengthening techniques aim to improve the key parameters of masonry, including compressive, tensile, and shear strength, as well as vulnerability against lateral loads. Traditional methods such as RC jacketing, grouting cracks and voids, stitching with metallic or brick elements, post-tensioning with steel ties, shotcrete jacketing, ferrocement, and center core retrofitting are available for retrofitting existing masonry structures (Saatcioglu & Razvi, 1992). Among these techniques, ferrocement jacketing has emerged as a promising method due to its effectiveness and utility. By applying ferrocement layers, the load-bearing capacity and structural performance of existing masonry columns can be significantly enhanced (Ranjith, et al., 2017). Unreinforced masonry (URM) columns experience transverse expansion when subjected to compressive loads. Due to the varying stiffness of the two materials and the strong bonding behavior between them, the lateral deformation of the mortar is often greater than that of the brick units. This leads to axial compression and bilateral stress on the brick units, resulting in the rapid development and propagation of vertical cracks (Rampello, et al., 2012). To restrict the transverse expansion of masonry and improve its strength and deformability, various reinforcing techniques have been applied to masonry columns.

Due to the unique and special properties of ferrocement, it has been investigated extensively by a number of researchers. Naaman (2000) described the distinctive physical and mechanical properties of ferrocement. Ferrocement has high tensile strength and stiffness due to the confinement with two-dimensional reinforcement of the mesh system and undergo large deformations before cracking or high deflections before collapse. Khan and Monem (2007) studied the composite behavior of brick masonry column encased with ferrocement having one, two and three layers of wire mesh with some bonding agent on the surface. Results indicated a significant strength enhancement of those column. A similar kind of findings were reported by Ahmed and Chowdhury (1998) but in their study no bonding agent was used. Shah (2011) and Kaish et al. (2012) carried out study on ferrocement jacketing of brick masonry columns. An increase of 19% and 21% reported for the first crack load and ultimate load respectively compared to the control specimen (Shah, 2011). Both concentric and eccentric loading were applied on the control and ferrocement jacketed column and, significant strength gain was reported (Kaish et. al., 2012).

In this paper, we present the usage of ferrocement jacketing as an effective method to enhance the structural performance of unreinforced brick masonry columns. The focus lies on improving compressive strength, enhancing ductility, and reducing vulnerability to lateral loads. The findings contribute to the growing body of knowledge on ferrocement jacketing as a viable retrofitting solution for masonry structures.

2 Experimental Program

The experimental program consisted of thirty six clay brick masonry columns tested under axial compression load in which four different categories of bricks were considered. There 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 3.71 after strengthening) and b = 230 mm, h = 230 mm, L = 610 mm (aspect ratio L/b = 2.65 before strengthening and 2.17 after strengthening) as shown in Figure 1. One specimen from each group were considered as control specimen and the rest specimens were strengthened using ferrocement jacketing. The size of the strengthened brick masonry columns are as presented in Table 1.

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
		H1FS	3	164×164	Strengthened specimen
		H1BL	1	230×230	Control specimen
		H1FL	3	280×280	Strengthened specimen
	2nd class	H2BS	1	114×114	Control specimen
		H2FS	3	164×164	Strengthened specimen
		H2BL	1	230×230	Control specimen
		H2FL	3	280×280	Strengthened specimen
Gas burned	1st class	M1BS*	1	114×114	Control specimen
		M1FS	3	164×164	Strengthened specimen
		M1BL	1	230×230	Control specimen
		M1FL	3	280×280	Strengthened specimen
	2nd class	M2BS	1	114×114	Control specimen
		M2FS	3	164×164	Strengthened specimen
		M2BL	1	230×230	Control specimen
		M2FL	3	280×280	Strengthened specimen

*Effect of multiple layers of wire mesh studied for this particular group.

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 rowel plug). One layer of wire mesh was placed in their designated position and tightened accordingly. A rich mortar having 1:2 mixing ratio made with locally available coarse sand (FM =2.65) and Portland composite cement maintaining a w/c ratio of 0.55 is sprayed around the surface of the column to a thickness of 25mm. In addition to that, effect of multiple layers of wire mesh were studied for one group (M1BS). In this group five specimens were prepared with no wire mesh i.e. control specimen and others with single, double, triple and quadruple layers of wire mesh. After passing 24hrs the specimens were allowed to cure by sprinkling water on its surface for a period of 28 days.

3 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 minutes respectively. Locally available river bed sand was used with a Fineness Modulus (FM) of 1.51 and 2.65 for brick masonry mortar and rich mortar for strengthening respectively. In the brick work 1:4 mortar ratio was used where the compressive strength of mortar was found to be 16.35 MPa. The compressive strength of the rich mortar for ferrocement jacketing was 31.78 MPa.

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

(a) (b) (c)

Figure 1. (a) Brick masonry column, (b) strengthened brick masonry column and (c) experimental setup.

4 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 Figure 1(c). Specimens were loaded under a monotonically increasing vertical load until failure. During testing the cracking load, failure pattern and axial deformation were observed for each specimen and duly recorded.

5 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 using ferrocement jacketing, their average first cracking loads demonstrated a substantial increase compared to the control specimens within their respective groups. The enhancement percentages for single layer ferrocement jacketed full brick columns are about 94%, 88%, 93%, and 90% in series M1FL, M2FL, H1FL and H2FL respectively. For single layer ferrocement jacketed half brick columns are about 174%, 171%, 173%, and 168% in series M1FS, M2FS, H1FS and H2FS respectively. When the strengthening was done with multiple layers of wire mesh in that case the maximum enhancement of cracking load found to be 188% for three layers of wire mesh. The ultimate strength of the columns are also presented in Table 3. As anticipated, the ultimate strength of the strengthened columns were increased significantly. The enhancement percentages for single layer ferrocement jacketed full brick columns are about 25%, 26%, 25%, and 23% in series M1FL, M2FL, H1FL and H2FL respectively. For single layer ferrocement jacketed half brick columns are about 29%, 28%, 28%, and 26% in series M1FS, M2FS, H1FS and H2FS respectively. When the strengthening was done with multiple layers of wire mesh in that case the maximum enhancement of ultimate strength found to be 36% for three layers of wire mesh.

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 (%)
H1BS	53.00	4.08	--	80	--	6.16	--	3.90	--
H1FS	166.00	6.02	47.72	218	172.50	7.89	28.08	5.15	41
H1BL	156	2.95	--	240	--	4.74	--	4.50	--
H1FL	338	4.31	46.19	463	92.92	5.91	24.68	5.89	31
H2BS	44	3.39	--	68	--	5.23	--	4.00	--
H2FS	37	4.97	46.85	182	167.65	6.61	26.32	5.30	33
H2BL	136	2.57	--	216	--	4.08	--	4.40	--
H2FL	291	3.71	44.38	410	89.81	5.01	22.79	5.80	32
M1BS	61	4.69	--	96	--	7.39	--	4.30	--
M1FS	200	7.26	54.63	263	173.96	9.53	28.90	5.46	27
M1BL	188	3.71	--	304	--	6.00	--	4.70	--
M1FL	437	5.78	55.60	590	94.08	7.52	25.40	6.08	29
M2BS	55	4.23	--	84	--	6.46	--	4.55	--
M2FS	176	6.39	50.92	228	171.43	8.27	28.01	5.80	28
M2BL	149	2.94	--	244	--	4.82	--	4.90	--
M2FL	330	4.36	48.26	459	88.11	6.07	25.90	6.60	35

2 shows the effect of multiple layers of wire mesh on the first cracking strength of the column. It is seen that cracking strength increases with the increase of number of layers of wire mesh up to three layers but the trend of strength enhancement changes after that.

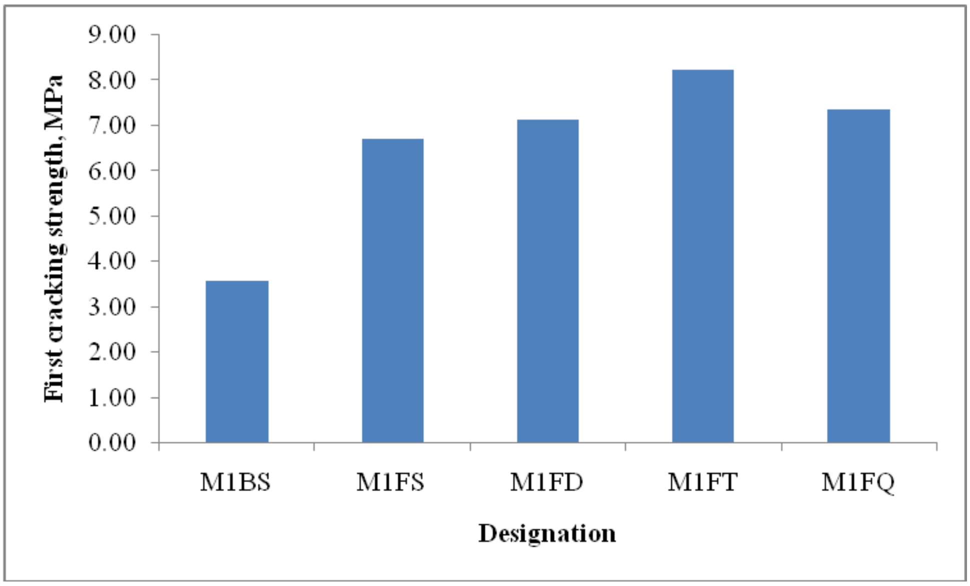

Figure 2. Effect of multiple layers of wire mesh on the cracking strength

Figure 3 shows the effect of multiple layers of wire mesh on the displacement of the columns. It is seen that columns undergoes large deformation with the increase of number of layers of wire mesh up to three layers but the trend changes after that as in the case of strength enhancement.

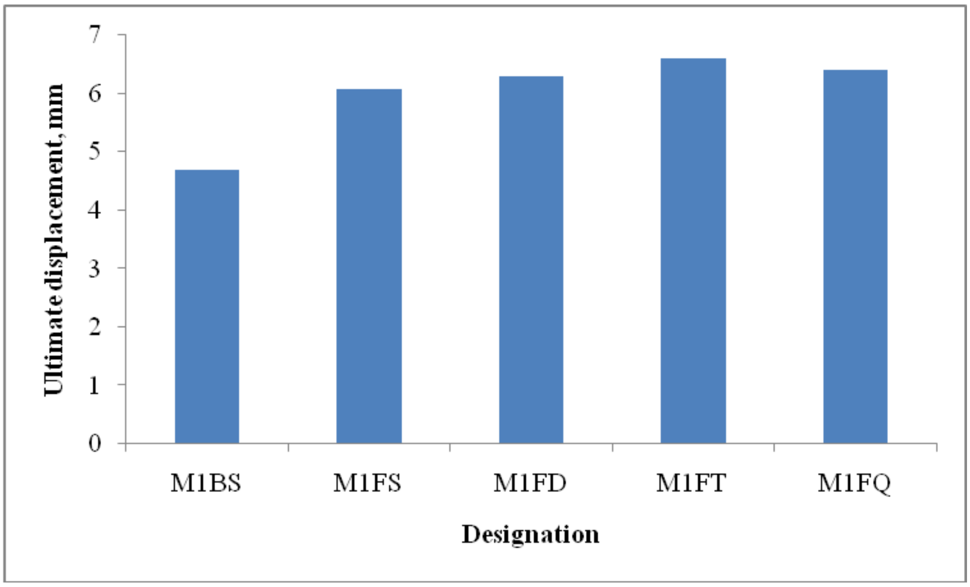

Figure 3. Effect of multiple layers of wire mesh on the displacement.

This similarity implies a dependable reaction to the employed strengthening approach. The enhanced load carrying capacity observed in the Table 3 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, Figure 3 depicts 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.

6 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 ferrocement jacketing.
- It was found that the average improvement in first cracking strength was 49%.
- The average increase in ultimate strength over the control specimen was found to be 27%.
- Furthermore, as compared to the control specimen, the average increase in ductility was found to be 32%.

References

Al-Salloum, Y., Alsayed, S., & Almusallam, T. (2013). Ferrocement Jacketing for the Strengthening of Unreinforced Masonry Columns. Journal of Materials in Civil Engineering, 25(11), 1643-1650.

Kaur, N., Sharma, A., & Agrawal, R. (2019). Ferrocement: A Review on Material and Structural Performance. Journal of Constructional Steel Research, 153, 406-419.

Olsen, M. (2008). Masonry Structures: Between Mechanics and Architecture. Springer Science & Business Media.

Rampello, S., Cosenza, E., D'Amore, E., & Manfredi, G. (2012). In-Plane Behavior of Reinforced Masonry Panels Strengthened with Ferrocement Laminates. Journal of Composites for Construction, 16(5), 570-580.

Ranjith, B., Zhang, L., & Viete, D. (2017). Recent Developments in the Use of Ferrocement for Strengthening of Concrete Structures: A Review. Engineering Structures, 132, 622-636.

Saatcioglu, M., & Razvi, S. R. (1992). Retrofitting of Masonry Walls with Ferrocement. ACI Structural Journal, 89(3), 262-271.

Smith, M. (2015). Masonry Design and Detailing for Architects, Engineers and Builders. McGraw-Hill Education.