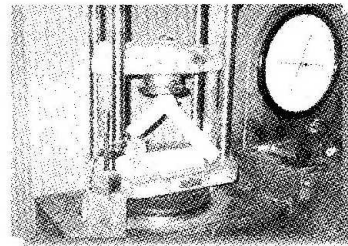
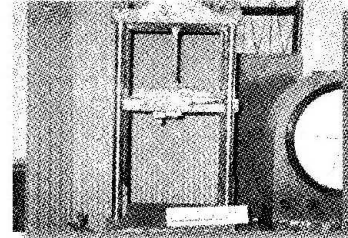
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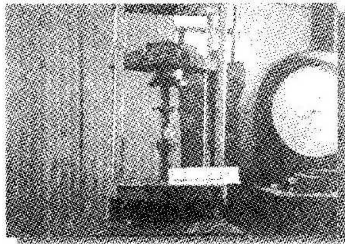
TEST OF BAMBOO CONNECTION



STRAW

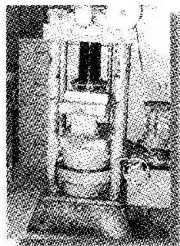
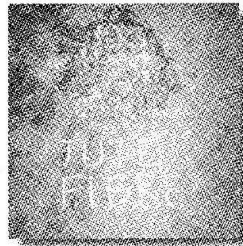
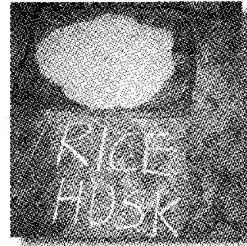


TENSION TEST OF BAMBOO SPECIMEN



COMPRESSION TEST OF BAMBOO SPECIMEN

## BUET'S TEST PROGRAMME

COMPRESSION TEST  
OF MUD CONCRETEMUD  
CONCRETERICE  
HUSK

## PRECAST FERROCEMENT JACKETS FOR BRICK MASONRY COLUMNS

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### Summary

Significant increase in load carrying capacity of brick masonry columns is possible through encasement by ferrocement plaster. This paper presents the test results performed on thirty-two axially loaded brick masonry columns. These columns were divided into four sets. The first set of columns were completely bare, the second set of columns were with plaster, the third set had precast ferrocement jackets divided into two equal halves, around the columns and the fourth set had precast ferrocement jackets divided into three segments, around the columns. All the columns were tested under increasing load until failure. Compared to bare brick masonry columns and plastered columns, precast ferrocement jacketed columns had better cracking resistance and higher ultimate load carrying capacity. They also exhibited more ductile behaviour at failure.

### Introduction

Brick masonry structures are the most common type of structure usually built in Bangladesh. Brick masonry is a combination of burnt clay bricks and mortar made with cement and sand in any practical proportion. The enduring character of masonry structure, the relative simplicity of the processes involved, the pleasing outlines usually obtained, together with the easy availability of the materials and the consequent moderate cost, render masonry construction one of the most important of the civil engineer's activities. A masonry column in a typical multi-storey building is a vertical compression member primarily designed to support a load along its longitudinal axis. Depending upon its location and function, a masonry column may be built as a separate supporting member, or it may be contained entirely within a wall, acting as a flush wall column.

To carry the same amount of load, much larger cross sectional area is required for brick masonry columns than is needed for concrete columns. However, encasement by ferrocement can be a simple way to increase the load carrying capability of brick masonry columns (Ahmed, 1997, Singh et al, 1988), as well as concrete columns (Balaguru, 1989, Sandowiz et al. 1983, Sikder, 1996). This is a new concept of reinforcing a masonry column and hold out a promise for economy. Usually brick columns are plastered. Encasement of the

brick columns can be achieved by applying ferrocement plaster in place of normal plaster ferrocement can be effectively used as a seismic retrofit material for brick masonry wall (Reinhorn et. al, 1985). Ferrocement is considered as a highly versatile form of composite material made of cement mortar and layers of wire mesh or similar small diameter steel mesh closely spaced to create a stiff structural form. This paper deals with the possible use of precast ferrocement jacket to provide confinement for brick masonry columns. Successful use of precast ferrocement jackets will lead to reduction of construction cost and time.

### Objective

There is a lack of information regarding the composite behaviour of precast ferrocement jackets and brick masonry columns. It is important to understand the behaviour of such jacketed columns to make reliable estimates of permissible loading (Ersoy et. al, 1993). The principal objective of the present study was to check the general behaviour (cracking and load bearing capacity) of the jacketed brick columns under uniaxial loading. The behaviour of jacketed columns are compared with bare brick masonry columns and plastered columns.

### Experimental Programme

The experimental programme was designed to obtain the failure load and cracking behaviour of brick masonry columns as well as plastered and jacketed brick columns.

### Materials

The specimens were cast from brick, cement, sand and wire mesh.

### Brick

Specially made bricks were used to cast the specimens. The dimensions of the special bricks were half the dimensions of normal bricks used in Bangladesh. The properties of the bricks are tabulated in Table 1.

**Table 1 : Properties of bricks**

Average size	124.7 mm x59.6mmx34.9mm
Average weight	448.7gm
Average compressive strength	66.2 MPa
Average tensile strength	3.2 MPa
Water absorption	13.6%

### Cement

Ordinary Portland cement was used as a binding material. The average 28 days compressive strength of the cement was 35 MPa.

### Sand

Three different types of sand were used in the investigation. The first one having a fineness modulus (FM) of 2.69 was used to cast the ferrocement jackets and plastering of the columns. Sand with a FM of 2.21 was used to prepare mortar for brick masonry. The FM value of sand used for grouting was 1.14.

### Wire mesh

In this experimental investigation, locally available 18 gauge G. I. woven wire mesh spaced at 10.5mm centre to centre in each direction was used. The diameter of the wire was 1.25 mm and average ultimate strength of the wires was 398 MPa.

### Steel Wire

3.3 mm dia steel wire was used at four corners in the ferrocement jackets. The yield strength of wire was 720 MPa and ultimate strength was 1010 MPa.

### Test Specimens

A total of thirty-two brick columns along with two hollow ferrocement columns were tested. The columns were forty (40) bricks high and two (2) bricks wide. So the columns can be considered to represent a storey high column. The bed joint thickness was 3.3 mm and the vertical joint thickness was 6 mm. The resulting columns had a height of 1525 mm and a cross section of 125mmx125mm.

The brick columns were divided into four sets, each having eight numbers of columns. The first set of columns was bare. The second set had plaster around the columns. The third set had precast ferrocement jackets divided into two equal halves around the columns. The fourth set had jackets divided into three segments, around the columns.

Within each set, columns were built using mortars of different cement-sand and water-cement ratio. The different cement-sand and water-cement ratios used in each set are shown in Table 2.

### Mortar

Mortar used for plastering the columns and casting of ferrocement jackets, had a cement-sand ratio of 1:2 and a water-cement ratio of 0.42. Mortar cubes of 50 mm x 50 mm x 50 mm were taken during construction of specimens. The average compressive strengths of different mortar cubes after 28 days are given in Table 3.

**Grout**

The precast jackets were bonded with the columns with grout. Cement sand ratio was 1:2 and water cement ratio was 1.0 for grout.

**Table 2: Cement sand and water-cement ratios of a set**

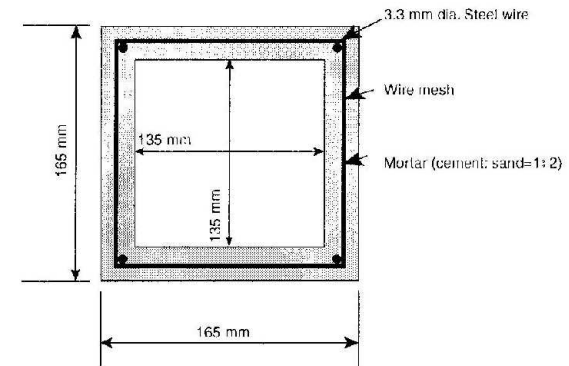
No of columns	Cement-Sand ratio	Water-Cement ratio
2	1:4	0.42
2	1:4	0.70
2	1:6	0.42
2	1:6	0.70

**Table 3: Compressive strength of mortars**

Mortar	Cement Sand ratio	FM of Sand	Water-cement Ratio	Avg. 28 day compressive strength, MPa
For Brickwork	1:4	2.21	0.42	34
	1:4	2.21	0.70	26
	1:6	2.21	0.42	14
	1:6	2.21	0.70	9
For Ferrocement jacket & plaster	1:2	2.69	0.42	59
For grout	1:2	1.14	1.00	20

**Construction of precast ferrocement jackets**

Wooden moulds were used for the construction of ferrocement jackets. At first polythene sheet was placed around the wooden form work and then a single layer wire mesh was wrapped around the mould and fixed. A 3.3 mm dia steel wire was tied with the mesh by wire at each of the four corners. Then cement mortar was applied to make 15mm thick ferrocement jackets. After 24 hours the mould was struck and the ferrocement jacket left for curing. The cross-section of ferrocement jacket is shown in Figure 1.



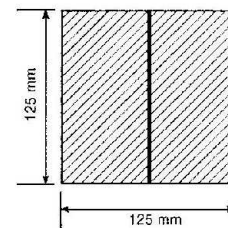
**Fig. 1 : Cross-section of precast ferrocement jackets**

**Construction of columns.**

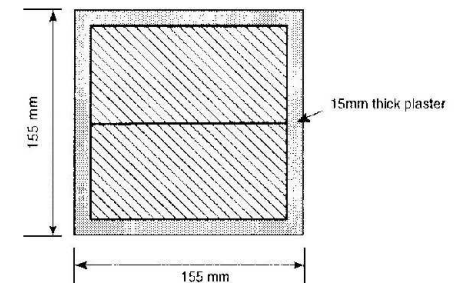
A professional bricklayer constructed the columns in conventional manner. Each set of columns was cast in four batches, with each batch consisting of two columns.

There were eight columns with 15 mm thick plaster. Plaster was applied after 7 days of casting the columns.

Typically, the ferrocement jacket and the brick column around which it would be put, were cast on the same day. After 7 days the jacket was put on around the column.



**Fig. 2 : Cross-section of bare brick column**



**Fig. 3 : Cross-section of plastered column**

For columns having jackets divided into two halves, at first the bottom half was put on around the column. Then grout was poured in the gap between jacket and column. The gap was completely filled with grout flowing under gravity. After 24 hours the top half was put on and connected with the bottom half through wire mesh protruding from the jackets. Then the joint was plastered. The joint width was 25 mm. After 24 hours the gap between the top half of the jacket and the column was filled with grout.

For columns with jackets divided into three segments, the segments were put on, one after another, around the brick column. Then the gap between column and jacket was completely filled with grout in one go. Each of the top and bottom segments of the jacket was 457.5mm high and the middle segment was 610mm high. The cross-section of a typical jacketed column is shown in Fig 4.

#### Instrumentation and procedure

All the specimens were loaded under a monotonically increasing vertical load until failure. The specimens were tested using Universal testing machine of capacity 1780 kN. The vertical load was applied through a rigid steel bearing plate located on the top of the specimen. Loads were recorded using machine dial gauge. Deformations at mid-height of the columns were measured by a Demec gauge. The gauge length was 200 mm.

At the start of each test, a small load (12kN) was applied and then released. The zero reading of the Demec gauge was then recorded. The load was applied in increments until the final failure occurred. At each increment, the deflection was recorded. The cracking load, failure load, failure pattern and stress-strain characteristics have been observed for every specimens during testing.

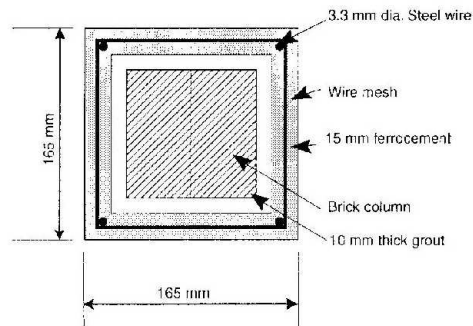


Fig. 4 : Cross-section of jacketed column

#### Test results and Analysis

The test results are summarised in Table 4. The cracking load, cracking stress, failure load and failure stress for the axially loaded columns represent the average load and stress of two test samples. As expected failure load was minimum for bare masonry columns and maximum for columns having precast ferrocement jackets.

It is observed from Table 4 that the failure stresses of columns with precast ferrocement jackets divided into two halves are 60% to 85% higher than those of the bare masonry columns and 50% to 70% higher than those of the columns with plaster. The stress increment is higher for columns having weaker mortar. The use of rich mortar plaster for brick columns does not increase the load carrying capacity appreciably. The increase in strength varies from 8% to 10%.

The failure stresses of columns with precast ferrocement jackets divided into three segments are 13% to 10% lower than those of the columns with jackets divided into two halves. This is due to the fact that in case of columns with jackets divided into three segments, the segments are not connected with one another through wires, whereas in case of columns with jackets divided into two halves the two halves are connected with one another through wires. However, the failure stresses of these columns are 44% to 66% higher than those of the bare masonry columns and 34% to 52% higher than those of columns with plaster.



Fig. 5 : Mode of failure and crack pattern of columns with precast ferrocement jackets divided into two halves



Fig. 6 : Mode of failure and crack pattern of columns with precast ferrocement jackets divided into three segments

**Table 4 : Cracking and failure load**

Type of Column	Cross-sectional area (cm <sup>2</sup> )	Cement-Sand Ratio	Water-Cement Ratio	Cracking load (kN)	Cracking Stress (MPa)	Failure Load (kN)	Failure Stress (MPa)
Bare column	156.3	1:4	0.42	71	4.54	107	6.85
		1:4	0.70	71	4.54	93	5.95
		1:6	0.42	60	3.84	85	5.44
		1:6	0.70	53	3.39	78	4.99
Plastered column	240.3	1:4	0.42	128	5.33	177	7.37
		1:4	0.70	113	4.70	156	6.49
		1:6	0.42	105	4.37	144	5.99
		1:6	0.70	86	3.58	131	5.45
Column with precast jacket in 2 halves	272.3	1:4	0.42	209	7.68	300	11.02
		1:4	0.70	188	6.91	274	10.06
		1:6	0.42	178	6.54	264	9.70
		1:6	0.70	169	6.21	251	9.22
Column with precast jacket in 3 parts	272.3	1:4	0.42	191	7.02	269	9.88
		1:4	0.70	180	6.61	248	9.11
		1:6	0.42	165	6.06	232	8.52
		1:6	0.70	152	5.58	226	8.30

There are substantial increase in cracking stresses, due to the application of ferrocement jackets. In case of columns with precast ferrocement jackets divided into two halves the cracking stresses are 70% to 83% higher than those of the bare masonry columns and about 50% higher than those of the columns with plaster. For columns with precast ferrocement jackets divided into three segments the cracking stresses are 55% to 65% higher than those of the bare masonry column and 32% to 56% higher than those of the columns with plaster.

The failure modes are different for bare masonry columns and plastered columns from that of the columns with ferrocement jackets. The failure of columns with ferrocement jackets occurred slowly, whereas failure of the bare column coated with plaster took place suddenly. In case of bare masonry columns, cracks were initiated in the vertical joints in the region near mid height of the columns. In case of jacketed columns cracks were initiated in the joints of the jackets and propagated vertically through the jackets.

#### Cost Analysis

The construction cost of a single bare brick-masonry column (1.5m high, with 1:4 mortar) is Tk. 400. The cost of the same column with plaster (1:6) is

Tk. 525 and with precast ferrocement jacket is Tk. 705. The cross sectional area of column with precast ferrocement jacket is 74% higher than that of the bare masonry column and 13% higher than that of the plastered columns. The construction cost of jacketed column is 76% higher than that of bare brick masonry column and 34% higher than that of column with plaster. However, in case of commercial production, the construction cost of ferrocement jacket can be reduced substantially. The use of precast ferrocement jackets is estimated to reduce the construction time by about two weeks.

#### Conclusions

Based on compression tests carried out on 125mm x125mm brick masonry columns encased with 15mm thick precast ferrocement jackets and 15mm thick cement-sand plaster, the following conclusions can be drawn.

1. The cracking and failure stresses of columns with precast ferrocement jackets are substantially higher than those in the bare masonry and plastered columns.
2. The nominal stresses at ultimate and cracking load for columns with precast ferrocement jackets divided into two halves (connected through wires) are slightly higher (about 10%) than those of the columns with precast ferrocement jackets divided into three segments (not connected through wires).
3. Even the application of rich mortar (1:2) plaster over a bare masonry column is found to increase the nominal stress at failure by only about 10%.
4. The failure of bare masonry column and column coated with plaster is sudden and crack width increases very rapidly after their formation, leading to brittle failure for the system. On the contrary the failure of columns with ferrocement jackets occurred slowly, exhibiting much ductile response.

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