COMPARATIVE STUDY ON THE BEHAVIOR OF MODIFIED FERROCEMENT WRAPPED COLUMNS AND CFRP WRAPPED COLUMNS

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ABSTRACT

Ferro cement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials. The fineness of the mortar matrix and its composition should be compatible with the mesh and armature systems it is meant to encapsulate. The matrix may contain discontinuous fibers. The results of an experimental study on the increase in the load carrying capacity of modified ferro cement wrapped columns and Carbon Fiber Reinforced Polymer sheet wrapped columns. The modified ferro cement wrapping reinforced with 2 layers of welded steel meshes is used. Six short RCC square columns including four strengthened columns (Two with modified ferro cement and two with 2 layers of CFRP) were tested. The specimens were subjected to axial compressive load till failure. The results indicated that the increase in load carrying capacity of Column wrapped with modified ferrocement is about 89.80% over control specimen and that of column wrapped with CFRP sheet is about 74.28% over control

specimen. Hence it is concluded that modified ferro cement jackets can be effectively used for strengthening of columns.

Keywords: Ferrocement, Wrapped Columns, CFRP Wrapped Columns.

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1. INTRODUCTION

Concrete is a common material used for construction of Buildings and other civil Engineering structures all over the world. It is likely for deterioration due to various factors such as earth quake, floods, over loading etc. Moreover most of the existing structures were designed according to old code provisions and design procedures. Column is the most important structural element which is designed to support mainly the compressive loads (Hasan, *et.al.*, 2011). Failure of building columns lead to failure of a building, as only through that element, vertical loads are transferred to the ground (Kaish and Hasan, 2008). Hence it is important to develop an effective technique to strengthen and retrofit the deteriorated columns. The method is to be structurally effective and cost effective. Jacketing/wrapping of concrete columns with a suitable material for strengthening can be a better option. Reinforced Concrete, steel plates, fiber reinforced polymers, FRP composites are the commonly used strengthening techniques. Each technique has some advantages and disadvantages. There may be some limitation in all the above techniques for field applications. Reinforced concrete columns can be effectively strengthened using ferrocement wrapping because of its adaptability, high strength to weight ratio, good cracking characteristics, and good bond with existing concrete when compared to other strengthening materials.

Fiber Reinforced Polymers is extensively used nowadays for strengthening of concrete members. But FRP is very expensive and its installation also requires skilled labors. Providing FRP installation in hot and humid climate is very difficult and requires special arrangement. Ferro cement, on the other hand is cost effective. The raw materials used for ferrocement is easily available locally in developing countries. In its role as thin reinforced concrete product and as laminated cement based composite, ferrocement can be used in numerous applications, including new structures and the repair and rehabilitation of existing structures. Although ferro cement is an old technology, it is widely used as a construction material with modern technology in developed and developing countries. It is one of the cost effective materials for strengthening of concrete columns due to its improved structural properties.

Many researchers have recommended ferrocement as the wrapping material for strengthening of concrete columns. Sandwich and Grabowski, (1981) have studied both axial and eccentric load behavior of circular composite columns made of ferro cement pipes filled concrete column and reported a ductile behavior of such columns. Singh and Kaushik, (1988) studied the effectiveness of ferrocement confinement for repairing both circular and square short columns and achieved an enhanced strength and ductility of the jacketed specimens. Mourad, (1992) investigated the behavior of externally confined plain concrete with welded wire mesh ferro cement. He studied the effect of different attaching methods of wire mesh around the concrete specimen. Kondraivendhan and Pradhan, (2009) have investigated the behavior of ferro cement confined cylindrical concrete specimens of different grades and observed that the strength enhancement varies with grade of concrete. Xiong *et al.*, (2011)

investigated the strength and ductility of plain concrete encased with ferrocement including skeletal steel bars and compared with FRP confined concrete. They concluded that the ferrocement confined concrete is more ductile under axial load than that of FRP confined concrete. Kaish *et al.*, (2013) proposed some improved square ferrocement jacketing to strengthen square RC columns. The performance of those improved square ferrocement jacketed square RC columns under concentric compressive load was verified later by Kaish *et al* (2013) have also investigated the behavior of ferro cement encased square RC columns under eccentric load . Ho *et al.* (2013) have proposed a strengthening method of circular RC columns using high performance ferro cement composites. The use of fiber reinforced materials for structural repair and strengthening has increased in recent years due to several advantages of these composites compared to conventional materials like steel. The major disadvantage of using steel jackets are low resistance to corrosion, high cost and heavy weight. (Olivova and Bilecik, (2009).

Houssam *et al.*, (2007) studied the behavior of large-scale rectangular columns. It was found that the higher aspect ratio resulted in a reduction in the confinement pressure and the compressive strength of a confined column increased as the corner radius increased. The behavior of FRP wrapped concrete cylinders with different wrapping materials and bonding dimensions has been studied by Lau and Zhou, (2001) using the finite element method (FEM) and other analytical methods. It was found that the load-carrying capacity of the wrapped concrete structure is governed by mechanical properties such as tensile elasticity modulus and Poisson's ratio of the wrapping sheet. Manuel and Carios, (2006) have conducted tests on models of circular cylindrical columns of concrete with GFRP jackets subjected to axial loading for different heights of cylinders and it was found that the increase in number of layers led to an increase in the maximum load. Riad, (2008) conducted tests on square prismatic concrete column, strengthened with external glass fibre composite. It was found that the stiffness of the applied FRP jacket was the key parameter in the design of external jacket retrofits. Shamim *et al.*, (2002) have investigated the seismic behavior of concrete columns confined with steel and FRP. It was concluded that the use of FRP significantly enhances strength, ductility, and energy absorption capacity of columns. Richard Iacobucci *et al* (2003) investigated the retrofit of square concrete columns with Carbon Fibre Reinforced Polymer (CFRP) for seismic resistance. It was found that added confinement with CFRP at critical locations enhanced ductility, energy dissipation capacity and strength of all substandard members. Zhao and Feng (2003), investigated experimentally the seismic strengthening of RC columns with wrapped CFRP sheets. The ductility enhancement with the confinement of CFRP sheets was studied by the strain development and distribution in the CFRP sheets. Based on the experimental results, a confinement factor of CFRP and an equivalent transversal reinforcement index were suggested. In spite of the extensive work on reinforced concrete columns, very few researchers have worked on reinforced concrete columns strengthened using FRP subjected to reversed cyclic loading.

From the above ferrocement is considered as an effective material for strengthening of axially loaded columns due to the following:

- Ferrocement is homogeneous and isotropic in two directions.
- Ferrocement has good tensile strength and high specific surface area of reinforcement
- Ferrocement has better extensibility, smaller crack width, higher durability to environmental exposure etc.
- Cost effective
- Local labours can be employed for ferrocement construction

- Very high quality control
- Light in weight
- Environmental friendly
- Easy production

The repair and strengthening of reinforced concrete (RC) columns through FRP composites includes external FRP wrapping, FRP encasement, and FRP spraying. Columns can be strengthened to increase the axial, shear, and flexural capacities for a variety of reasons such as lack of confinement, eccentric loading, seismic loading, accidental impacts, and corrosion. This study is intended to compare the additional load carrying capacity of the reinforced concrete columns strengthened with modified ferrocement wrapping and CFRP wrapping.

2. EXPERIMENTAL PROGRAM

The experimental study was carried out on 6 concrete columns. The size of specimen was 150x150x700mm. The columns were provided with four 12mm dia rods as reinforcement and 8mm dia lateral ties at 100mm centre to centre spacing. Out of these 6 columns, two specimens were control specimen. Two columns were wrapped with modified ferrocement and the remaining two were wrapped with 2 layers of CFRP sheet. The ferrocement wrapping consisting of two layers of welded wire mesh. The thickness of ferrocement wrap was kept at 25mm for the wrapped specimens of both the types.

3. MATERIALS

CEMENT: Ordinary Portland cement 53 grade conforming to Indian standards (IS-12269, 1987) is used throughout. The standard consistency is 29% and its initial and final setting time is 50 min and 250 min respectively. The specific gravity of cement is 3.14 and its compressive strength after 28 days of curing is 54 N/Sqmm.

COARSE AGGREGATE: Crushed hard granite stone aggregate of maximum size 20mm is used for concrete. The bulk density of aggregate is 16.90 KN/Cum and its specific gravity is 2.64.

FINE AGGREGATE:

Fine aggregate used is river sand conforming to Zone-II of IS: 383, 1970. The fineness modulus is 2.61. Its specific gravity is 2.69 and its dry density is 16.05KN/Cum.

WATER: Potable water is used for casting as well as curing as per IS: 456/2000.

SUPER PLASTICIZER: To achieve strength and workable mortar, super plasticizer CONPLAST SP-337 of FOSROC is used.

WIRE MESHES: Galvanised steel welded wire meshes are used. The diameter of wire mesh is 0.6mm and size of mesh is 12mm x 12mm and its yield strength is 250 N/Sqmm.

REINFORCEMENT:

8mm, 12mm diameter TMT bars are used in columns. Steel grade = 415N/Sqmm. The fly ash of following mass composition was used for this investigation.

- SiO₂ – 53.39%
- Al₂O₃ -26.45%
- Fe₂O₃- 11.19%
- CaO – 1.39%

Comparative Study on the Behavior of Modified Ferrocement Wrapped Columns and CFRP Wrapped Columns

- Na₂O – 0.35%
 - K₂O – 0.93%
 - TiO₂ – 1.46%
 - P₂O₅ – 1.47%
 - SO₃ – 1.77%
- a) Silica fume: Silicafume a by-product of producing silicon metal.
- a) Silicon Dioxide >85%
- b) CaO <1
- c) Sp surface area = 22000Sqm/kg
- d) Sp Gravity =2.2
- e) Particle size = one micrometer

3.1. CFRP SHEET

2.3 The Concrete mix comprised cement 400 Kg/Cum, water 200 Ltr/Cum , sand 640 kg/Cum and Stone aggregate 1200 kg/cum. The average compressive strength of 150x150x150mm standard concrete cubes after 28 days of curing was 22.05 N/Sqmm.

3.2. High Strength Ferrocement (MODIFIED)

The ferrocement of fresh matrix was cast with cement to sand ratio was 1:2 with silica fume 10% by weight of cement ; 10% by weight of fly ash and the water cement ratio 0.40. 3% super plasticizer by weight of cement was also added. (Shannag and Mourad,2012).

3.3. Preparation of specimens

The Column specimens were prepared according to the following procedure.

3.4. Reinforcement

Four vertical bars of 12mm diameter were used as vertical reinforcement. 8mm diameter lateral ties were provided at 150mm centre to centre. The clear cover provided was 25mm.

3.5. Timber formwork

Timber form work of size 150x150x700mm were designed and fabricated to cast the columns in vertical position. The formwork can be easily assembled and separated to parts. The form work was made of 150x20mm wooden pieces. Three sides were assembled in horizontal position, the fabricated reinforcement cage was carefully placed in the formwork and the fourth side was fixed in position and then stiffeners were added and the fourth side was turned in vertical position.

3.6. Mixing and casting of concrete Columns

The concrete was mixed manually with the specified ratios given in section 2.2. The fresh concrete was transferred to the formwork in position and was poured vertically. Concrete was consolidated by vibrator to provide concrete without voids or honeycomb. All the column specimens were demoulded after 24 hours of casting and were cured under moist sacking for 28 days.

3.7. Reinforced Columns Strengthened with Ferrocement Jacketing

After 28 days of curing four reinforced columns were strengthened using ferrocement wrapping, two with conventional ferrocement and other two with modified ferrocement. The Concrete columns were painted with bonding agent. This was to fill the micro cracks on the concrete surface and to act as a bonding agent between the concrete and ferrocement. The modified ferrocement of fresh matrix was cast with cement to sand ratio was 1:2 with silica fume 10% by weight of cement ; 10% by weight of fly ash and the water cement ratio 0.40. 3% super plasticizer by weight of cement was also added. After completion of 30 minutes of painting of columns, two layers of the welded wire mesh wrapped over the columns. Concrete spacers of 12mm thick were used to maintain the cover. Then a steel trowel was used and force applied to ensure full penetration of matrix of conventional ferrocement in to the mesh. The final dimensions of the finished columns were 200x200mm. A steel float was used to make the surface flat. The strengthened Columns were cured for 28 days . After 28 days of curing the remaining two columns were wrapped with 2 layers of CFRP sheets using polymer based adhesives.

3.8. Testing of Columns

After 28 days of curing, all the columns were tested under monotonically increasing concentrated load applied at the top with a hydraulic compression testing machine of 2000 KN capacity. Both the reference columns, ferrocement wrapped columns and CFRP wrapped columns were tested to failure. Axial deflection and lateral buckling of columns were measured using dial gauges.

Figure 1. Typical failure pattern of tested columns

4. RESULTS AND DISCUSSION

Experimental results of the test specimen are discussed in this section. The results are tabulated in Table-1. All the four ferrocement wrapped columns show higher ultimate load carrying capacity than the reference/control columns. The column specimen wrapped with modified ferrocement show an average of 87.51% increase in ultimate load carrying capacity

over reference columns. Columns wrapped with 2 layers of CFRP sheet show an average of 72.18% increase in ultimate load carrying capacity over reference columns. Typical failure pattern of tested columns are shown in Fig.1. The Control columns failed by crushing of concrete at the point of application of load. The ferrocement wrapped columns failed from ferrocement jacket.

Table-1. Experimental results of the test specimen

SI No	Specimen Type	Ultimate Load (KN)	% ge increase in Ultimate Load
A	Control specimen		
1	CS1	452	0.00
2	CS2	461	0.00
	Average	456.50	
	Average	817	78.97
B	Ferrocement wrapped Column (Modified High Strength Ferrocement)		
1	MFCC1	852	86.64
2	MFCC2	860	88.39
	Average	856	87.51
C	CFRP wrapped Columns		
	C1	792	73.49
	C2	780	70.87
	Average	786	72.18

5. CONCLUSION

From the findings of this experimental investigation, the following conclusions are drawn:

- Ferrocement wrapping/jacketing (with normal ferrocement) increases the ultimate load carrying capacity to about 78.97% over the control columns.
- Modified ferrocement wrapping/jacketing (with high strength ferrocement) increases the ultimate load carrying capacity to about 87.51% over the control columns.
- Modified ferrocement wrapping can be used for strengthening and rehabilitation of structures effectively.

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