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AFFECTATION OF RCC COLUMN CONFINED WITH FERROCEMENT

[1]Avinash Arjun More

[1]Associate Professor
[1]Department of Civil Engineering
[1]Rizvi College of Engineering, Mumbai, India

Abstract: The repair of unstrengthen and damaged reinforced concrete members by external bonding such as ferrocement laminate is increasing, which demands the need for investigations into the behavior of ferrocement confinements. Many studies are been carried out on the confinement of columns with ferrocement laminates considering changes in parameters such as types of meshes, different sizes, concrete grades, slenderness ratio, etc. Retrofitting of the existing structures has become a large part of the construction activity. Ferrocement confinement is one of the oldest, most efficient, and cost-effective techniques of re-strengthening of deteriorated and weak columns. Ferrocement is a thin wall reinforced using wire mesh and high-strength mortar. Small diameter of wires used as reinforcement, leads to a higher specific surface, providing homogeneity to the ferrocement. Closely spaced wires and uniformly distributed reinforcement provide more ductility and energy absorption capacity to the otherwise brittle concrete. The parameters such as cement mortar thickness, gauge-wire spacing, and bond at the interface of ferrocement and brick columns have effects on overall behavior. New applications have been developed in recent years, such as low-cost dwelling buildings and the strengthening of a wide variety of structural elements. However, these applications are still in their first stages.
***IndexTerms* – *Concrete columns, ferrocement, Glass fibers mixed in cement mortar, and Compressive strength*.**

I. INTRODUCTION

Ferrocement of Ferro-Cement (Also called thin shell concrete or Ferro Concrete) is a system of reinforced mortar or plaster applied over a layer of metal mesh, woven expanded-metal or metal fibers, and closely spaced thin steel rods such as rebar, metal commonly used is iron or some type of steel. It is used to construct relatively thin, hard, strong surfaces and structures in many shapes such as hulls for boats, shell roofs, and water tanks. Ferrocement originated in the 1840s in France and is the origin of reinforced concrete. It has a wide range of other uses including sculpture and prefabricated building components. The term 'Ferrocement' has been applied by extension to other composite materials includingsome containing no cement and no ferrous material.

Ferrocement is a type of thin reinforced wall commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh (ACI Committee 549-R97, 1997). In-situ casting of ferrocement structures consists of high cement content, a low water-cement ratio of around 0.4, wire mesh layers, light structural steel, admixtures like silica fume, superplasticizers, and non-metallic fibers. This makes ferrocement structures high strength-to-weight ratio. Therefore, the self-weight of ferrocement structure is much less as compared to RCC. In its role as a thin reinforced concrete product and as a laminated cement-based composite, ferrocement has found itself in numerous applications both in the construction of new structures and the repair/rehabilitation of existing structures. Compared with conventional reinforced concrete, ferrocement is reinforced in two directions; therefore, it has homogenous isotropic properties in two directions. Due to these properties, ferrocement shows high tensile strength and high modulus of rupture. Ferrocement is highly waterproof, crack formation resistant, energy absorbing material. During earthquakes, the forces at nodal points of ferrocement structures are less accordingly thereby decreasing the damage and devastation. Structural members confined with ferrocement such as beams, columns develop the first crack at a high value of force reasonably above the elastic point. In addition, because the specific surface of ferrocement reinforcement is higher than that of reinforced concrete, larger bond forces develop with the matrix resulting in average crack spacing and crack width of smaller magnitude than that of conventional reinforced concrete. Other unique features of ferrocement include ease of fabrication and low cost in maintenance and repair. Based on these advantages, ferrocement can be effectively utilized for strengthening or retrofitting such as water tanks, boats, housingwall panels, roofs, and formwork.

II. RESEARCH METHODOLOGY

Ferrocement also called thin-shell concrete or ferroconcrete is a system of reinforced mortar applied over a layer of metal mesh, woven expanded-metal or metal fibers, and closely spaced thin steel rods such as rebar, a metal commonly used is iron or some type ofsteel. The working principle involved in the project is confining the reinforced concrete column with a layer of galvanized iron wire mesh. Ferrocement shows a high tensile strength and high modulus of rupture. It acts as a highly waterproof, crack formation-resistant, energy-absorbing material. The confinement of the column leads to an increase in strength and enhances the performance of the same against axial as well as lateral loads. The reinforcing steel wire mesh has openings large enough for adequate bonding; the closer distribution and uniform dispersion of reinforcement, transform the otherwise brittle mortar into a high-performance material distinct from reinforced concrete. The addition of a thin layer of ferrocement to a concrete column enhances its ductility and cracking strength. To make the whole cross-section effective, all the corners are re-strengthened by providing an extra layer of meshat the corners thus reducing the stress concentration at the corners. Also, the mortar used for plastering is mixed with discontinuous fibers which increases the shear capacity of the matrixand also reduces the decrease in average crack spacing and width.

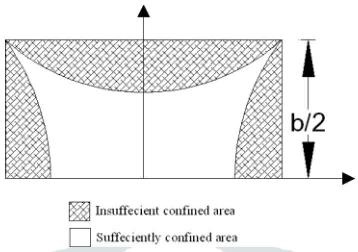

Figure 1 *effectively confined concrete in a square column*

2. Experimental Setup:

2.1 Objective: The major parameter affecting the behavior of concrete columns confined externally with ferrocement is considered as the orientation of mesh, concrete grade. For this experimental program, the effect of orientation of meshes varying from 30°, 45°, 60°, 75°, and 90° is studied concerning compressive strength of ferrocement confined column. The research is to evaluate the effectiveness of wire mesh confinement in strength-deficient columns. This is achieved by comparing the behavior of ferrocement confined columns with that of the reinforced unconfined columns.

2.2 Materials Used:

2.2.1) Cement: Ordinary Portland cement (OPC) 53 grade (fineness=225m^2/kg) is used for preparing M20 grade concrete and cement mortar (1:4). The cement was checked for its basic properties.

2.2.2) Sand: Locally available natural river sand owing to its rounded shape was used in this work, as it ensures better packing characteristics than the crushed sand. Dry sand was used in preparing the concrete and cement mortar.

2.2.3) Coarse aggregate: The crushed graded aggregate of quartzite origin having a maximum size of 20mm was used as coarse aggregate. Coarse aggregate had negligible water absorption. Aggregates that are clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

2.2.4) Water: Potable, clean, and freshwater of pH $\geq$ 7 free from organic matter, silt, oil, sugar, chloride, and acidic material as per Indian Standards is used for mixing the mortar matrix and concrete constituents.

2.2.5) Steel wire mesh: Small diameter steel wire/ welded mesh as reinforcement with a high volume fraction (2 to 8%) and the specific surface of reinforcement is considerably higher for ferrocement than for RCC.

2.2.6) Concrete Mix: Concrete mix is designed as per Indian Standards using the properties of materials. The proportions of the concrete design mix are 1: 1.5 : 3 by weight. The water-cement ratio was kept at 0.45. The cement concrete cubes 150mm x 150mm x 150mm were cast and compressive strength after 28 days was recorded N/mm2.

2.2.7) Mortar Mix: In ferrocement application cement sand mortar of ratio 1:4 is used. The water-cement ratio of 0.6 is used.

Wire mesh	Galvanized iron mesh
Opening size	Square opening (15mm X 15mm)
Wire diameter	(0.9mm – 1mm)

Table 2.1 *Properties of wire mesh*

2.2.8) Fiber: Glass fiber is mixed in the mortar used for plastering the outer surface of the column inproportion to 1% by weight of cement.

Figure 2.2 *Glass fibers mixed in cement mortar.*

2.3 Casting of Columns: Experimental investigation has to investigate the influence of the orientation of meshes on the compressive strength of ferrocement confined column. For this investigation, a total of seven columns are cast. Two columns are kept as control specimens and the remaining five specimens are confined using ferrocement with different orientations of wire mesh **(30°, 45°,60°,75°, and 90°)**. The cross-section of the column is kept as **(100mm X 100mm)** with an overall height of **500mm**. The reinforcement used in the column consists of four longitudinal bars of diameter **8mm** of grade **Fe500**. The main bars are bent at a right angle to prevent the direct punching of reinforcement into concrete during loading conditions. Stirrups of diameter **5mm** with center-to-center spacing of **100mm** are used as ties. A spacing of **300mm** is maintained for the end stirrups. Stirrups are tied to the main reinforcement at uniform spacing using binding wires. A total of five stirrups are required at the complete height of the column.

Concrete of grade **M20** is used to cast the columns. The proportion for this grade of concrete is **1:1.5:3**. Initially, sand, cement, and aggregate are mixed in a dry state in the required proportions. Sand used is in a dry state, as the use of wet sand results in bulking of sand. Bulking of sand leads to a proportion of the mix. The water-cement ratio adopted for concrete mix is **0.45**. Water is then added to the dry cement, sand, and aggregate mix. Mixing of concrete is done manually with a spade.

Steel mold of size **(100mm X 100mm X500mm)** is used for casting the column. The mold is oiled properly on all the faces so that the concrete does not stick to the mold. The reinforcement skeleton is placed into the mould maintaining a clear cover of **20mm** at the top and bottom. The side cover is also kept at **20mm**. Cover blocks are used to maintain the required amount of cover to prevent the steel from corrosion. Concrete is then poured into the mold containing the reinforcement in equal layers. A tamping rod is used to tamp the concrete to remove air voids. The mold is also placed on the vibrator to remove any air voids remaining in the mold.

After placing the concrete, the molds are kept in a cool place for 24 hours for drying. The mold is demolded after 24 hours of drying. The specimen is kept submerged in clear fresh water until taken out before the test for 28 days.

Fig2.3 *Column before ferrocement Jacketing*

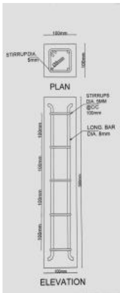

Fig2.4 *Column after ferrocement Jacketing*

Fig 2.5 *Column after plastering with cement mortar*

Fig2.6 *Column specimen hand chiseled to make the surface rough*

2.4 Ferrocement Jacketing

After the column specimens are cured for 28 days, the ferrocement jacketing is done. Welded steel wire mesh is used for ferrocement jacketing. The openings of the wire mesh are square with openings of 15mm.

To accomplish the ferrocement jacketing, five-column specimens are plastered using cement mortar. To prepare the mortar, cement, and sand are mixed in a dry state in the proportion of 1:4. Glass fibers are added to the dry mix with a proportion of 1% of cement as it gives maximum compressive strength. The addition of fibers to mortar helps to develop a proper bond between the two coats of plaster. Water is added to the dry mix with a w/c ratio of 0.6.

Before the plastering work is started, the surfaces of all five specimens are made rough so that a proper bond is established between concrete and mortar. The work of plaster is then started. Initially, the specimens are plastered with a coat of 10mm thick. The second coat of plastering is done after a time interval of 30 minutes. Before the second coat of plaster is applied, the wire mesh is bent in the shape of the column with sides of 120mm. Extra layers of mesh are provided in two layers in all the corners of the folded mesh, one layer inside and the other one outside. The cage of wire mesh, along with extra mesh in corners is tied together with binding wires. The wire mesh in the first column is inclined at 30°. The extra mesh provided in corners is also in the same orientation as that of the main mesh so that the mortar enters easily through the openings. The second coat of plaster of thickness 10mm is then applied after the mesh is covering the first coat of plaster. The cross-sectional area of the column thus increased to 140mmX140mm due to plastering of 20mm on all the faces. The same procedure is adopted for the column specimens with mesh orientations of 45°, 60°, 75° and 90°.

The specimens are then allowed to dry for 24 hours in a cool place. Curing of all five plastered specimens is done for the next seven days by sprinkling water on the plastered surface. The specimens are then tested in the universal testing machine for their ultimate load-carrying capacity.

2.5 Tests on Concrete:

2.5.1) Compressive Strength Test;

The compressive strength test is used to check whether the concrete mix prepared during the casting of columns has gained the required amount of strength after the completion of 28 days.

AGE	COMPRESSIVE STRENGTH (%)
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

Table 2.2 *Strength of concrete*

Specimen	Cube 1	Cube 2
Size of the cube (mm)	**(150 X 150 X 150)**	**(150 X 150 X 150)**
Cross-sectional area (mm^2)	22500	22500
Load (KN)	452.67	476.23
Compressive strength (N/mm^2)	20.11	21.16
Average compressive strength(N/mm^2)	20.635	

Table 2.3 *Compressive Strength Test Results*

2.5.2) Slump Cone Test:

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.

Slump (mm)	78
Degree of workability	Medium
Type of slump	True Slump

Table 2.4 *Slump Cone Test Results*

2.5.3) Aggregates Test:

Sr. No.	Sieve Size (mm)	Mass Retained	Percentage Retained	Cumulative Percentage Retained	Percentage passing
1	40	0	0	0	100
2	20	0	0	0	100
3	10	4846	48.46	38.46	51.54
4	4.75	3879	38.79	87.25	12.75
5	Pan	1275	12.75		
				∑= 135.75	

Table No. 2.5 *Sieve Analysis of coarse aggregates*

Fineness modulus of **20mm** coarse aggregates= **(135.75+500)/100 = 6.3575**

2.5.4) Testing of Column Specimen:

The column specimens are confined with ferrocement and also the control specimens are tested in the computerized universal testing machine (UTM) after 7 days of ferrocement jacketing. The specimens are then loaded in between the transducer and the top plate. The specimens are subjected to a uniformly increasing concentric load. The plane surfaces at the top and bottom help to achieve this requirement of concentric loading. All the specimens are loaded till cracks appear on the outer surface of the plaster. The ultimate load-carrying capacities of the seven-column specimen are noted. Also, the deflection of the columns is noted till the ultimate load. The cracking pattern of the specimen is studied.

Fig 2.7 *Testing of specimen in UTM*

III. RESULTS AND DISCUSSION

After conducting a successful test following results were obtained.

Sr. No.	Column ID	Age Days	Column Weight (kg)	Crushing Load (kN)	Compressive Strength (kN/m2)
1	**Control Specimen 1**	39	18.53	278.2	27.82
2	**Control Specimen 2**	39	19.05	271.3	27.13
				Average	**27.48**

Table 2.6 *Testing Results of Control Specimens*

Sr No.	Column ID	Age Days	Column Weight (kg)	Crushing Load (kN)	Compressive Strength (kN/m2)
1	**Column (90˚)**	39	23.78	552.4	28.18
2	**Column (75˚)**	39	22.17	588.5	30.03
3	**Column (60˚)**	39	23.15	622.2	31.76
4	**Column (45˚)**	39	22.87	652.2	33.28
5	**Column (30˚)**	39	23.52	630.4	32.16

Table 2.7 *Testing Results of Ferrocement Jacketed Columns*

This experimental study is carried out to analyze the affectation of RCC columns with different of slenderness ratios and ferrocement confinement on the strength of the columns. Based on the test results, the following conclusions are obtained:

- Ferrocement jacketing improves the ultimate load-carrying capacity.
- Both approaches [a) strengthening all the corners, & b) reducing stress concentration at corners] are effective in overcoming the stress concentration problems of square jacketing.
- Ferrocement laminates can be used as a good strengthening material, or they can be used for retrofitting techniques as confined specimens give more strength than unconfined specimens.
- There is an increase in strength with a change in orientation of mesh from 90˚ to 45˚ and further, it decreases for 30˚.
- Column retrofitted with wire mesh oriented at zero degrees is found to be efficient concerning cost-to-strength ratio.

3.1 Future Scope of Studies:

However, further studies on this project can be carried out to advance more research. Several factors depend on which studies can be executed. The factors that can influence the study are changing the mesh size, material, grade of concrete, fiber material, water-cement ratio, etc.

Further studies on ferrocement confinement can boost new methods to improve the properties of reinforced columns. The effect of engineering properties of different materials on concrete behavior can also be studied and analyzed. Since the current research does not include the use of admixtures in concrete, this can be a good alternative to study its effect. Also, the effect of ferrocement confinement can be studied on different structural elements of a building like beams, slabs, footings, etc. Thus, a study depending on the above shortcomings can be a very effective source to better results in improving the properties of concrete.

IV ACKNOWLEDGMENT

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