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Effect of ferrocement confinement on behavior of concrete

B. Kondraivendhan [a], Bulu Pradhan [b,*]

[a] Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi 110016, India
[b] Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781 039, India

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ABSTRACT

In this study, the use of ferrocement as an external confinement to concrete specimens is investigated. The effectiveness of confinement is achieved by comparing the behavior of retrofitted specimens with that of conventional specimens. The primary test variable considered in this study is the concrete compressive strength. All the other parameters, such as size, shape, number of layers of wire mesh, and L/d ratio of the specimens, were kept constant. The sections chosen are circular cylinders with a size of 150 mm $\times$ 300 mm and L/d ratio of 6:1. The test results showed that the confined concrete specimens can enhance the ultimate concrete compressive strengths and failure strains.

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1. Introduction

The traditional construction materials such as steel and concrete have exhibited signs of deterioration over the years in their long-term performance, which can be attributed to either the inherent nature of the materials or the weak resistance offered by these materials to adverse environmental conditions and natural disasters such as fires and earth quakes. In addition, retrofitting or rejuvenation of structures composed of such materials requires the use of skilled labors, heavy equipments, excessive energy and time which results in the escalation of the overall cost. Strengthening the reinforced concrete columns may become necessary for a number of reasons, such as substandard detailing of the steel reinforcement and deterioration of the concrete under severe environmental conditions [1]. Recent evaluation of the civil engineering infrastructure has demonstrated that most of it will need major repairs in the near future. Other needs for strengthening arise because either the design codes have changed that make these structures substandard or larger loads are permitted on the components of the infrastructure where extensive retrofitting is required [2]. This justifies the development of innovative rehabilitation and strengthening methods for concrete structures.

The development of innovative rehabilitation and strengthening technique is required to extend the life expectancy of many concrete structures. The above mentioned factors have contributed to motivate researchers to unleash the potential of using composite materials to retrofit and strengthen the structures. Procedures that are technically sound and economically feasible are needed to upgrade the deficient structures [3]. One such strengthening technique currently being studied is the confinement of concrete columns.

There are a lot of confinement materials that are used for strengthening the concrete structures. Ferrocement, glass fiber, aramid fiber, carbon fiber, etc. are some of the few materials that are used in the confinement of concrete columns. The use of ferrocement as an external confinement to concrete column is investigated in this study. Ferrocement is a special form of reinforced concrete, which exhibits a behavior differing much from conventional reinforced concrete in strength performance and potential application. Therefore, the uniform dispersion of reinforcement in the matrix offers in achieving improvement in many of the engineering properties of the material, such as tensile and flexural strength, toughness, fracture, crack control, fatigue resistance and an impact resistance and in addition it also provides advantages in fabrication [4]. In developing countries, the raw materials for ferrocement construction are easily available, and also it could be constructed in any complicated shape. The skill required is of low level and it has superior strength properties as compared to conventional reinforced concrete [5–10]. These are the reasons for which the ferrocement is considered to be an appropriate confinement material in developing countries such as India.

In this study, first, the plain cement concrete specimens were cast, and then the specimens were wrapped with ferrocement laminates. The compressive strength of confined and controlled specimens was determined, and the same was predicted by an adopted analytical model with reasonable accuracy.

* Corresponding author. Tel.: +91 361 258 2425; fax: +91 361 258 2440.
E-mail addresses: bulu@iitg.ernet.in, bulu_pradhan@rediffmail.com (B. Pradhan).

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2. Experimental investigation

The main purpose of this investigation is to evaluate the effectiveness of confinement in strengthening the concrete specimens. The experimental factors and their levels have been chosen accordingly.

2.1. Materials

2.1.1. Cement

To investigate the response of compressive strength, one type of cement, i.e., ordinary Portland cement (OPC) 43 grade conforming to IS 8112: 1989 [11] and ASTM Type 1 specifications, was used.

2.1.2. Sand

Natural river sand owing to its rounded shape was used in this work, as it ensures better packing characteristics than the crushed sand. Locally available river sand having the fineness modulus value of 2.66 and specific gravity of 2.65 was used. The grading of the sand satisfies the Indian standards IS: 383-1970 [12].

2.1.3. Coarse aggregate

Crushed graded aggregate of quartzite origin having a maximum size of 20 mm was used as coarse aggregate. Coarse aggregate had negligible water absorption and a specific gravity of 2.62. The overall grading requirement of coarse aggregate satisfies ASTM C 33-92a [13] and Indian standards IS: 383-1970 [12].

2.1.4. Mix proportions and experimental factors

In this investigation, concrete mixes had been chosen over a wide range of grades of concrete, namely M25, M30, M35, M40, M45, M50 and M55. The M25, M30, M35, M40, M45, M50 and M55 have a characteristic compressive strength (f_{ck}) of 25 N/mm^2, 30 N/mm^2, 35 N/mm^2, 40 N/mm^2, 45 N/mm^2, 50 N/mm^2 and 55 N/mm^2, respectively. The mix design for M25–M40 are according to IS 10262-1982 [14] and SP 23-1982 [15] and for M45–M55 is according to Erntroy Shack Lock's empirical graph method [16]. The mix proportions of the concrete used in this investigation are given in Table 1.

2.1.5. Casting

For this investigation, plain cement concrete (PCC) specimens with different compressive strengths were prepared. A total of 42 cylindrical specimens (21 each for controlled and confined specimens) with a diameter of 150 mm and a height of 900 mm, three replicates for each grade of concrete, were cast. The test specimens were cast on a steel mould, and oil was applied on the inner side of the mould for easy removal of the specimens. The concrete was mixed by using concrete mixer. First, cement and fine aggregate were mixed in a dry form until uniformity was achieved and lastly coarse aggregate was added. Then, water was sprinkled and mixed thoroughly until a uniform mix was obtained. The concrete was then placed as suitable layers of equal thickness, and each layer was compacted on a needle vibrator. The specimens were demoulded after 24 h, and the specimens were kept for curing in a water tank till the age of the test (28 days).

2.1.6. Confinement of plain cement concrete

For the preparation of confined specimens, the plain cement concrete specimens were wrapped with ferrocement laminates. The specimens were taken out after curing (28 d), and then the surface of the specimen was roughened. A rich mortar of 1:1 (cement mortar) was applied on the roughened surface of the specimens, and then Chicken mesh of a constant (single layer) thickness was wrapped around the specimen. Finally, the specimens were plastered with 1:2 mix mortars with a water:cement ratio of 0.4 and a confinement thickness of 15 mm. Thus, the diameters of the confined specimens were 180 mm, i.e. the diameter of plain concrete, 150 mm, plus ferrocement confinement thickness equal to 15 mm around the specimen. As the diameter to length ratio increases, the axial compressive strength as well as the enhancement of confining pressure increases. In addition, the stiffness and energy absorption capacity also increase due to the larger diameter. The reason for maintaining a larger diameter for confined specimens is that if one adopts the same diameter for both confined (including thickness of confinement) and reference specimens, then the net surface area of the concrete available for confinement will be less in case of confined specimens, and hence there may not be a significant increase in load carrying capacity in the case of confined specimens. Therefore, the diameter of plain cement concrete portion should be the same in both confined and reference specimens to observe the effect of external ferrocement confinement on load carrying capacity. Control specimens were also cast simultaneously along with the confined specimens. The confined concrete specimens were further cured for 7 days, and their strength was determined as discussed in the following section. The dimensional detail of the confined concrete specimen is shown in Fig. 1.

Table 1
Mix proportions of concrete (by mass)

Mix designation	Cement	Fine aggregate	Coarse aggregate	*W/C* ratio
M25	1	1.42	2.56	0.43
M30	1	1.18	2.13	0.37
M35	1	1.02	1.84	0.33
M40	1	0.9	1.62	0.3
M45	1	0.88	2.63	0.38
M50	1	0.78	2.33	0.36
M55	1	0.65	1.95	0.32

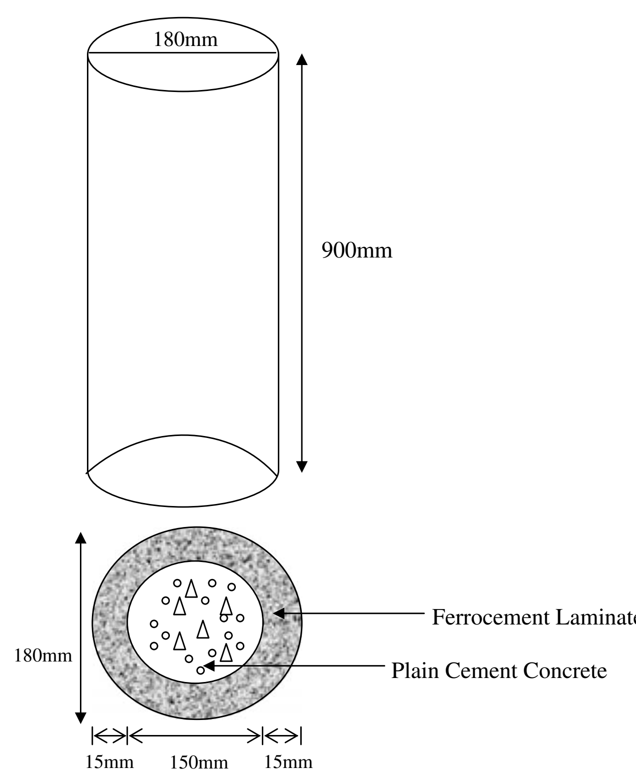

Fig. 1. Dimensions of confined concrete specimen.

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