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Experimental Study on Behavior of Self Compacting Concrete Confined with Ferrocement

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Abstract : *This paper researches an experimental study on behavior of ferrocement confined beams concrete specimens. To investigate the effect of reinforcement spacing sizes on the confinement action of ferrocement jacket. There are 5 types of total 30 concrete beams of size 150X150X750 mm with reinforcement. The different reinforcement spacing c/c of 50 mm, 75 mm, 100 mm, and ferrocement jacketing are casted and tested under flexural test. The grade of M45 concrete was used. To increases in the strength and strain of concrete confined with ferrocement shell and lateral tie confinement was found to be linear. Ferrocement specimens are confined with single layer welded wire mesh ferrocement jacket having a 10 mm thickness of the jacket. The experimental results demonstrate the effectiveness of ferrocement confinement in enhancing the flexural strength. The ferrocement confinement action is found more effective in case of different reinforcement spacing specimens. In all failure patterns, the vertical flexural cracks developed within middle third of span. The maximum flexural cracks were observed at ferrocement specimen cured at 28 days. A post-peak descending branch in the load and deflection curve is observed in all the confined specimens. The load and deflection behavior and the failure pattern indicate that single layer mesh ferrocement jacket provide significant confinement. A new analytical model for the strength of ferrocement confined beam concrete specimen is proposed based on the test results of this work and verified with the recent experimental data obtained from the literature.*
Keywords: *Mix design, Flexural strength, Concrete beam, Ferrocement, Reinforcement spacing, Load-Deflection curves.*

I. Introduction

For several years, the problem of the durability of concrete structures was a major topic of interest in India. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Indian construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self compacting concrete (SCC), which can be compacted into every corner of formwork, purely by means of its own weight and without the need for vibrating compaction [7,16]. Though the concrete become more durable but when it is used in High Rise Structures the concrete is subjected to lateral forces such as wind force and earthquake forces [3]. This lateral force tends to produce lateral shear in the structures. To counter act the lateral shear usually more confined lateral reinforcement are provided. Sometimes it happen this confinement may or may not be possible due to construction difficulties. Therefore researchers are trying to develop an alternative technique for confinement laterally. Ferrocement reinforcement may be one of the alternatives. The ferrocement plates are used mainly for water storage tanks and boat construction. Later on many researchers identified a field where in ferrocement can be used for different application such as elevations, repair, and rehabilitation and retrofitting, waterproofing with in-situ application etc. Later on horizontal extension of buildings. Ferrocement plated reinforced cement concrete (RCC) structures with inbuilt formwork with steel reinforcement incorporated used both as permanent formwork and element. But all the application is with convectional ferrocement where the conventional cement mortar is only used.
The aim of the project is Experimental Study on Behavior of Self Compacting Concrete Confined with Ferrocement

To achieve this aims following objectives were set,
1. Procuring the materials.
2. Characterization of materials.
3. Mix design of self compacting concrete.
4. To conduct experimental work to determine the flexural strength of beam of self compacting concrete confined with ferrocement.

II. Mix Design Method

2.1 Material

2.1.1 Cement

The used in all mixture was commercially available Ordinary Portland Cement (OPC) of 53 grade [10]. The specific gravity of cement was 3.15. The Normal Consistency of cement was 33.75 %. The initial and final setting times were found as 120 minutes and 200 minutes respectively.

2.1.2 Fine Aggregate

Locally available natural river sand of size below 4.75 mm [11] used as fine aggregate. Fig. 2.1 shows the particle size distribution of the sand. Laboratory tests were conducted for fine aggregate to determine its physical properties. The specific gravity of the fine aggregate was 2.6. The fineness modulus was 2.5. The bulk density of fine aggregate was 1535.33 kg/m^3 and Moisture content was 0.4%.

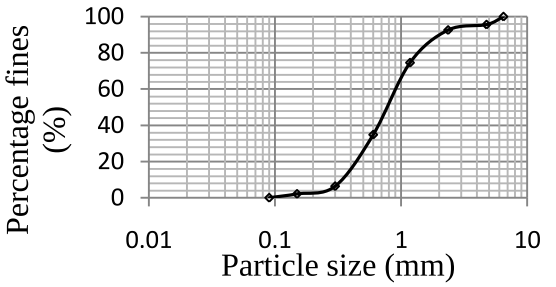


Fig.2.1 Fine aggregate particle size distribution curve

2.1.3 Coarse Aggregate

Coarse aggregate used in this study consist of crushed stone of size 20 mm and below. Fig. 2.2 shows the particle size distribution of the sand. Laboratory tests were conducted on coarse aggregate to determine the different physical properties [11]. The specific gravity of the fine aggregate was 2.8. The fineness modulus was 7.07. The bulk density of fine aggregate was 1729.93 kg/m^3 and moisture content was 1.9%.

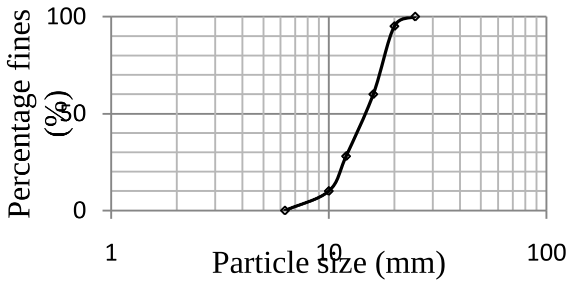


Fig.2.2 Coarse aggregate particle size distribution curve

2.1.4 Silica fume

Silica fume is a by-product of electric arc furnace used for the production of silicon metal or alloy, having bulk density typically being in the range of 150-350 kg/m^3 [12]. It was added in concrete to increase the strength.

2.1.5 Superplasticizer

Polycarboxylate Ether as a super plasticizer complying with ASTM C-494 type F used. Superplasticizer appearance to Clear white to reddish brown liquid. The specific gravity was 1.06. Chloride ion content was < 0.2% and pH value was >6.

2.1.6 Reinforcement

High yield strength mild steel bars of 6 mm and galvanized iron wire bars of 3 mm diameter were used for the study. 6 mm bars were used as longitudinal reinforcement and 3 mm were used for lateral ties.

2.1.7 Wire mesh

Wire mesh of 0.5 mm diameter was used for the study. The wire mesh would be used to configure the ferrocement skeleton.

2.2 Mix Design

2.2.1 Concrete mix

The self compacting concrete mix design is done on trial basis. The initial mix values were taken from [5]. Thereafter, standard 150 mm cubes were casted and tested in compression testing machine after accelerated curing [14]. The figure 2.3 shows the photograph of accelerated curing. The table 2.2 shows the strength of 150 mm cube strength with different trial mix and curing conditions.

Fig 2.3 Accelerated curing & testing

Table 2.1 Trial Mixes

Designation	Cement content, kg per cu.m	Fine aggregate kg per cu.m	Coarse aggregate kg per cu.m	Silica fume kg per cu.m	Super plasticizer Lit. per cu.m	Water Lit. per cu.m
Mix Proportion (By Weight)	1	1.50	1.53	0.139	0.0098	0.490
Mix A	465	700.4	715	65	4.6	227.92

Table 2.2 Results of Trial Mixes

Designation	Strength after accelerated curing for regression equation (R_{28}=8.09+1.64*R_a) (IS: 9013-1978)	Strength after 28 days pond curing	Flowability
Mix A	37.61 MPa	45.0 MPa	Good

2.2.2 Ferrocement mortar

The mix proportion of ferrocement mortar was 1:2 by weight of cement and sand, respectively. The water to cement ratio was 0.5 [15]. The compressive strength of mortar was achieved 32.66 MPa at 28 days of pond curing.

Fig. 2.4 casting and testing of mortar cube

2.3 Preparation of test specimens

2.3.1 Preparation of concrete beams

The material quantities were calculated in accordance to Mix A proportion. All the ingredients of SCC are mixed in dry state first except water and super plasticizer which are in liquid state. After mixing the 75% water of total is added initial period of mix and 25% is later added in final stage. The superplasticizer is added in between. The total time taken for mixing is 10 minutes after the water is added to the dry mix. The design of concrete mix for SCC concrete with a proportion of 1:1.50:1.53 by weight to achieve a grade of concrete. The maximum size of coarse aggregate used as 20 mm. The water cement ratio is fixed at 0.49 shown in table 2.1.

After preparing the mix, required beam were casted and left for 24 hours from the time of mixing the water. Reinforcement cage consist of lateral ties and longitudinal bars and ferrocement mesh. Longitudinal bars of 3 mm Galvanized Iron Wire are used in order to form skeleton in longitudinal direction. The prepared cage of reinforcement was kept in the moulds and spacing bars of 10 mm are placed to obtain uniform cover of 10 mm. First, reinforcement cage was entering in the mould and then core concrete filled in the mould. Specimens were demoulded 24 hours after casting and then after covering of ferrocement jacketing. All total 30 beams were casted. After 24 hours specimen were removed from the mould and immersed in water filled tank for curing. Figures show the casting of the beams specimen.

Fig. 2.5 Photograph of SCC mix

Fig. 2.6 Reinforcement cage filled in moulds

Fig. 2.7 Casting of beam moulds

Fig. 2.8 covering of ferrocement jacketing on beam specimen

2.4 Test Procedure

2.4.1 Flexural test procedure

The IS 516: 1959 code of practice was followed for flexural testing. The tools for the test were fabricated. Figure 4.16 shows the fabricated tools. The base support is 150 mm wide and 900 mm long, mounted with metal block. The center to center distance between metal blocks is adjusted to keep 700 mm respectively. This is the effective length for the specimen under test. The upper support is made to give two (four) point flexural load on the specimen and accordingly to IS 516: 1959 code. Take out the test specimen from curing tank, kept in open for air drying. After air drying, brush out the loose particles if any, from specimen surface. Measure and record the specimen dimension and weight. Adjust the load frame to accommodate the specimen properly. All the specimens were tested in a 2040 KN capacity Universal Testing Machine. The specimen was placed horizontal on the floor of the machine and tested under monotonically increasing flexural load. The test was carried out under displacement controlled load of 400 kg/min. Initialized the load value on display unit to zero. A load cell and Linear Variable Differential Transducer (LVDT) were used to measure the flexural load and vertical displacement of the specimen respectively. Load cell and LVDT were connected to a data logger and both are calibrated before use. The load cell is attached to the dead plate and gives corresponding load value in load display unit. The readings were taken to note down, till the maximum load is taken by the specimen. Figure 2.9 shows the load frame and test setup for flexural test.

Fig. 2.9 Load frame and test setup for flexural test

Fig. 2.10 Fabricated two point load tool

III. Result and Discussion

3.1 Flexural test specimens

3.1.1 Failure pattern on flexural specimens

The entire beam specimen is tested under four point bending test. The cracks developed within middle third of span. Before, developing vertical flexural cracks in specimen, the cracks develop at bottom of the specimen as shown in fig. 5.6. Brittle failure was observed in unreinforced specimen and ductile failure was observed in reinforcement and ferrocement specimen.

The maximum failure load is obtained from load and deflection diagram. Table 3.1 gives the flexural strength of various specimens. The flexural strength varies from 50.60 to 132.74 MPa.

Table 3.1 Flexural strength for beam specimens

Specimens	Flexural strength (MPa)		
	7 Days	14 Days	28 Days
Unreinforced	50.60	62.22	91.25
50 mm R/F	84.62	106.19	130.25
75 mm R/F	69.27	101.21	124.44
100 mm R/F	58.07	92.91	100.38
Ferrocement	91.67	116.14	132.74

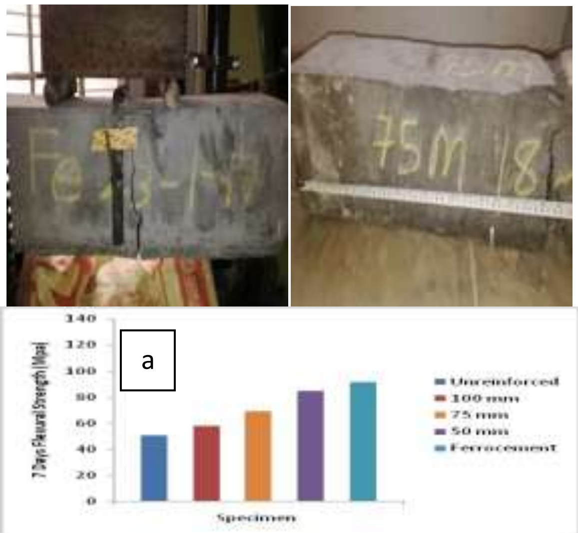


Fig. 3.1 Failure pattern of specimens under flexural

3.1.2 Flexural strength (Modulus of rupture)

The flexural strength of the beam is obtained by using formula given in IS 516: 1959 is used to calculate the flexural strength expressed as.

$$f = \frac{P.L}{b.d^2}$$

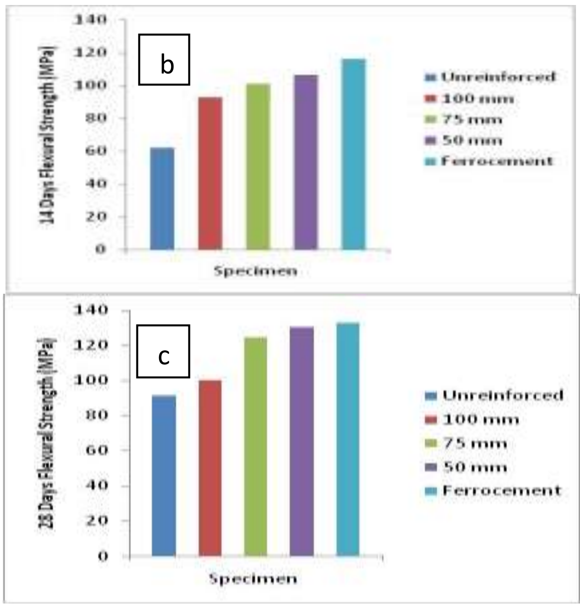
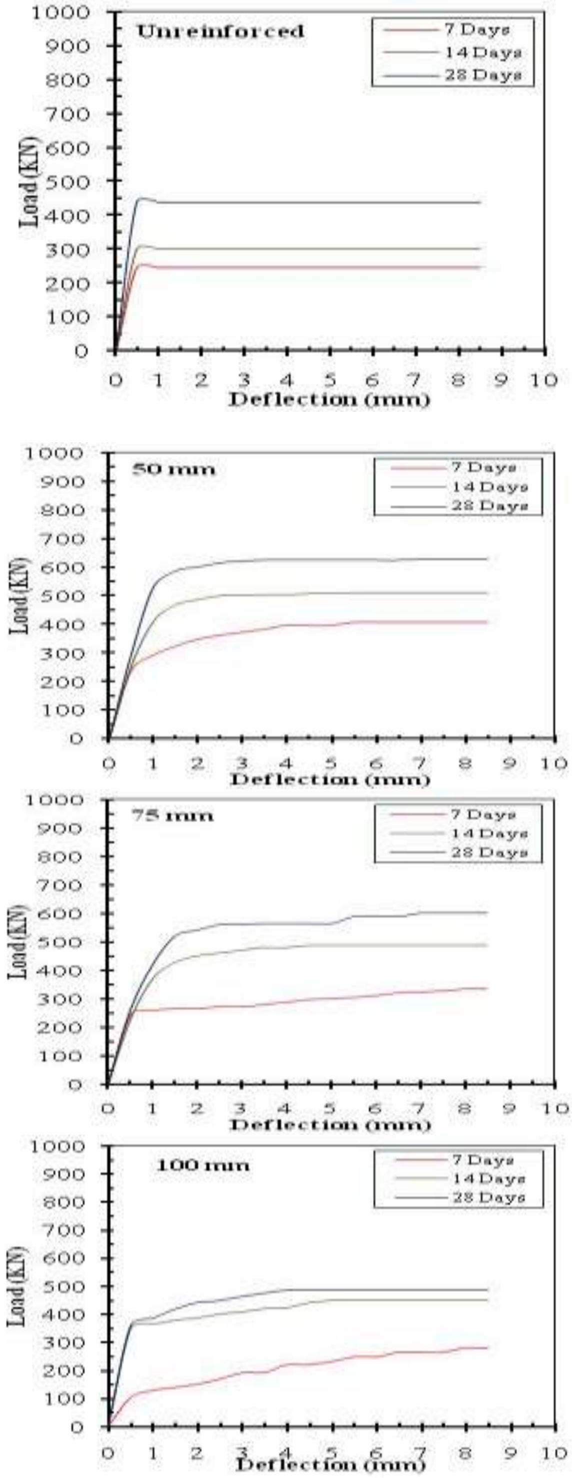


Fig. 3.2 Variation of flexural strength of different specimen (a) for 7 days (b) 14 days (c) 28 days

3.1.3 Load and deflection curve

The load vs. deflection curves gives the stiffness of material against flexure. A non linear relation was obtained between load and deflection in present study. The stiffness of specimen found to increase with the flexural strength. The entire specimen found to fail at deflection range 0.5 to 8.5 mm. The load varies linearly with deflection up to failure point than deflection propagates at very slow rate. The maximum load and deflection curve observed in ferrocement specimen. Fig. 3.3 shows the load and deflection curve for 7 days, 14 days, and 28 days curing period.



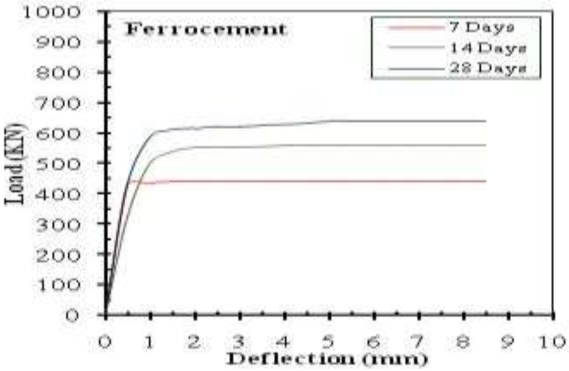


Fig. 3.3 Load and deflection curve for different specimens (a) unreinforced (b) 50 mm (c) 75 mm (d) 100 mm (e) Ferrocement

IV. Observation

From the experimental study following are the finding.

1. The flexural strength of SCC specimen increases with decrease in spacing of confinement.
2. The flexural strength of SCC specimen confined laterally with ferrocement gave higher result.
3. The flexural strength found to increase with curing period.
4. The load varies linearly with deflection up to failure point than deflection propagates at very slow rate. The entire specimen found to fail under a deflection range of 0.5 to 8.5 mm.

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