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Effect of Freezing and Thawing on the Strength Characteristics of Slurry Infiltrated Fibrous Ferrocement using Steel Fibers

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Abstract- The concrete composites play an important role in the field of concrete. The addition of fibers to concrete enhances the strength properties and ductility characteristics. Ferrocement is light weight and versatile material having high cracking, ductility and fatigue resistance and is additionally impermeable to make it far superior than reinforced concrete. It is used for prefabricated residential units, marine and industrial structures. Slurry infiltrated fiber concrete (SIFCON) could be considered as a special type of fiber concrete with high fiber content. The matrix consists of cement slurry or flowing cement mortar. This composite material withstands blast loading and can be used for pre-stressed concrete beams and safe vaults. Slurry infiltrated fibrous ferrocement (SIFF) is a combination of SIFCON and ferrocement and can overcome the limitations of latter. SIFF can be used for the structures like runways in aerodromes, industrial floors etc.

This paper deals with an experimental investigation on the strength characteristics of SIFF using 1% by volume of steel fibers of aspect ratio 25 when subjected to 90 cycles of freezing and thawing (1cycle of freezing and thawing means 24 hours of immersion of specimens in freezer at a temperature of -14°C and then keeping the specimens in open atmosphere for 24 hours). The results indicated that with the addition of 0.8% steel fibers yield higher compressive strength, flexural strength, toughness indices and impact strength.

Keywords: ferrocement, fibers, fiber reinforced concrete; slurry infiltrated fibrous ferrocement (SIFF), welded mesh, chicken mesh, compressive strength, flexural strength, impact strength.

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I. Introduction

Today, concrete fiber composite is the most promising and cost effective material used in the construction. Many researchers have shown that the addition of small closely spaced and uniformly dispersed fiber to concrete transforms the brittle cement composite into a more isotropic and ductile material called fiber reinforced concrete (FRC).

FRC can be used in the preparation of various precast building units such as cladding sheets, window frames, roofing units, floor tiles, manhole covers and advanced applications in highway pavements, air field, machine foundations, industrial floorings, bridge deck overlays, sewer pipes, earthquake resistant structures and explosive resistant structures (like MX missile silos etc).

Similar to FRC, the ferrocement has also many advantages and its applications are rapidly increasing in the precast construction industry. Ferrocement make use of different types of steel meshes for its construction. Ferrocement also suffer from limitations. It cannot be employed where high impacts, vibrations, wear and tear are expected. The strength of the ferrocement increases with the increase in steel content. But when the reinforcement is more, the mortar cannot be easily forced inside without forming voids. Thus strength of ferrocement reduces.

The fibrous ferrocement, which is a combination of fibrous concrete and ferrocement, can overcome all the above said limitations to some extent and can be employed with assurance where high impacts, vibrations, wear and tear are expected. In this new material the advantage of both ferrocement and fiber reinforced concrete are combined. The fibrous cement is becoming a promising material for bridge overlays and industrial floorings where high impacts, high vibrations and high wear and tear are expected. The reinforcements used in fibrous ferrocement are of three kinds. The first type reinforcement is welded mesh where smaller diameter bars (approx. 12 G) are kept closely in both directions and are spot welded. This mesh gives stability and shape to the structure. The second type reinforcement is chicken mesh. This is mesh of similar wires (approx 20G) which are interwoven to different openings. The spacing between the wires of chicken mesh is small. This mesh mainly distributes the stresses evenly and the cracks will be minimized. The third type of reinforcement is fiber. The fibers may be of steel, carbon, glass, polypropylene, GI etc. These fibers act as crack arresters and are randomly distributed in the concrete.

Depending upon the shape required, the cage is prepared out of welded mesh and chicken mesh. The cage can be prepared by tying the chicken mesh over the welded mesh at regular intervals by using binding wires. The calculated quantities of fibers are placed in the mould. The mortar is then infiltrated into the mould to form SIFF.

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II. Materials and Method

Main objective of this experimentation is to study the strength characteristics of slurry infiltrated fibrous ferrocement with steel fiber of aspect ratio 25. Different strength parameters considered for study are compressive strength, flexural strength and impact strength.

Ordinary Portland cement of 43 grade and locally available sand (passing 1.18 mm and retained on 150 micron IS sieve) with specific gravity 2.64 was used in the experimentation. To impart additional workability a super plasticizer (Conplast SP 430), 1% by weight of cement was used. The welded mesh (WM) used in the experimentation was square opening of 25 mm x 25 mm. The chicken mesh (CM) used was having a hexagonal opening with 0.5 mm diameter. The cement mortar with a proportion of 1:1 was used with a water cement ratio of 0.45.

To study the effect of steel fibers on the strength properties of SIFF, the compressive strength specimens, flexural strength specimens and impact strength specimens were casted. For compressive strength test, specimens of dimensions 150 x 150 x 150 mm were cast. For flexural strength test, specimens of dimensions 100 x 100 x 500 mm were cast. Flexural strength specimens were tested under two point loading over an effective span of 400 mm. The impact strength test specimens were of 152.4 mm in diameter and 63.5 mm thick. An ASTM D 1557 drop hammer was used (drop hammer weighs 4.5 Kg and falls at 457 mm per blow, each blow represents 20.2 N-m of energy). The number of blows required to cause the first crack and final failure were noted.

Initially, the cages of size 130 x 130 x 130 mm, 480 x 80 mm and 140 mm diameter were prepared by welded mesh, upon which chicken mesh was tied by using binding wire for cube, flexure and impact specimens respectively and is as shown in the figure The cement – sand slurry was prepared with a mix proportion of 1:1 with a w /c ratio of 0.45, and a super plasticizer dosage of 1% (by weight of cement). Initially a small quantity of the slurry was poured into the mould as cover and then the cage is placed into the mould. Then the fibers were placed in different percentages such as 0%, 0.2%, 0.4%, 0,6%, 0.8%, 1.0%, 1.2% and 1.4% into the mould. Now the slurry was infiltrated into the mould upto brim level and was compacted through table vibrator. Then the moulds were covered with wet gunny bags for 12 hours. After 12 hours, the specimens were demoulded and kept in water for 28 days curing. After 28 days of curing, the specimens were subjected to freezing and thawing for 90 cycles (1cycle of freezing and thawing means 24 hours of immersion of specimens in freezer at a temperature of -14°C and then keeping the specimens in open atmosphere for 24 hours). After 90 cycles, the specimens were tested for their respective strengths.

For compressive strength, cubes of dimension 150 x 150 x150 mm were cast and tested as per IS 516: 1959. For flexural strength, the specimens of dimensions 100 x 100 x 50 mm were cast and tested with two point loading as per IS 516: 1959. Impact strength test specimens were of dimension 152 mm diameter and 63.5 mm height. Impact strength test was carried out according to the procedure recommended by Ernest K. Schrader.

a) Test Results

Test results of compressive strength, flexural strength and impact strength for varying percentages of fibers are tabulated in Table 1 and Table 2.The variation in the compressive strength, flexural strength and impact strength for varying percentages of fibers are represented graphically in Figure 1, 2 and 3.

Table 1 : Compressive and flexural strength test results of slurry infiltrated fibrous ferrocement when subjected to freezing and thawing

Percentage addition of fiber	SIFF with steel fiber					
	Compressive strength (MPa)	Percentage increase or decrease of compressive strength w.r.t ref mix	Flexural strength (MPa)	Percentage increase or decrease of flexural strength w.r.t ref mix	Toughness Indices	
					I_5	I_{10}
0 (Ref, mix)	29.33	-	5.84	-	4.74	10.15
0.2	33.63	15	7.09	21	5.26	10.48
0.4	34.81	19	8.08	38	5.45	10.94
0.6	35.26	20	8.24	41	5.87	11.35
0.8	36.15	23	8.27	42	6.14	11.87
1.0	34.22	17	8.37	43	6.51	12.61
1.2	31.56	8	8.48	45	6.74	13.19
1.4	27.11	-8	8.80	51	6.97	14.09

Table 2 : Impact strength test results of slurry infiltrated fibrous ferrocement when subjected to freezing and thawing

Percentage addition of fiber	SIFF with steel fiber			
	Impact strength required to cause (N-m)		Percentage increase or decrease of impact strength w.r.t ref mix	
	First crack	Final failure	First crack	Final failure
0(Ref.mix)	6080.20	6881.47	-	-
0.2	10820.47	14961.47	78	117
0.4	14476.67	19620.93	138	185
0.6	18806.20	21405.27	209	236
0.8	20832.93	23142.47	243	236
1.0	19641.13	22933.73	223	233
1.2	16961.27	20247.13	179	194
1.4	15163.47	18617.67	149	171

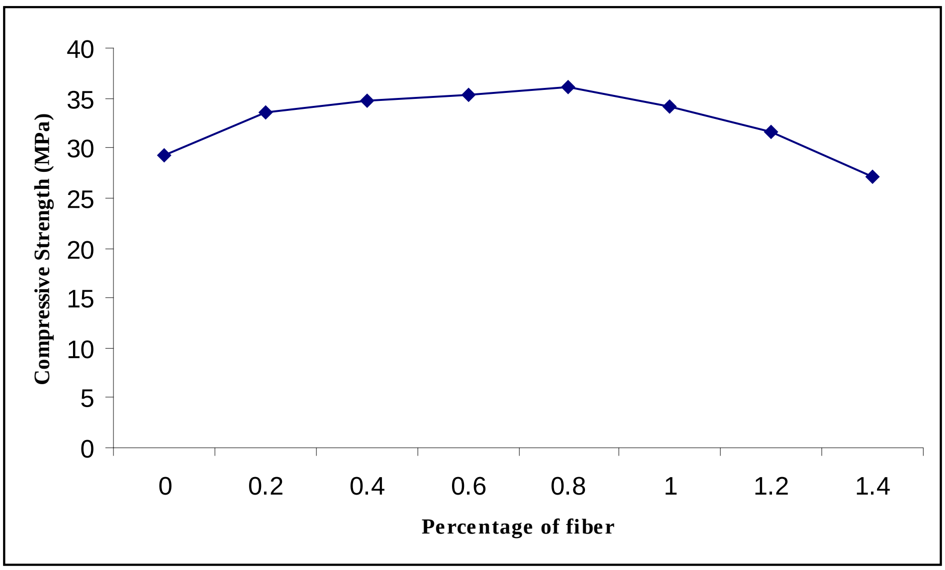

Figure 1 : Variation of compressive strength of SIFF

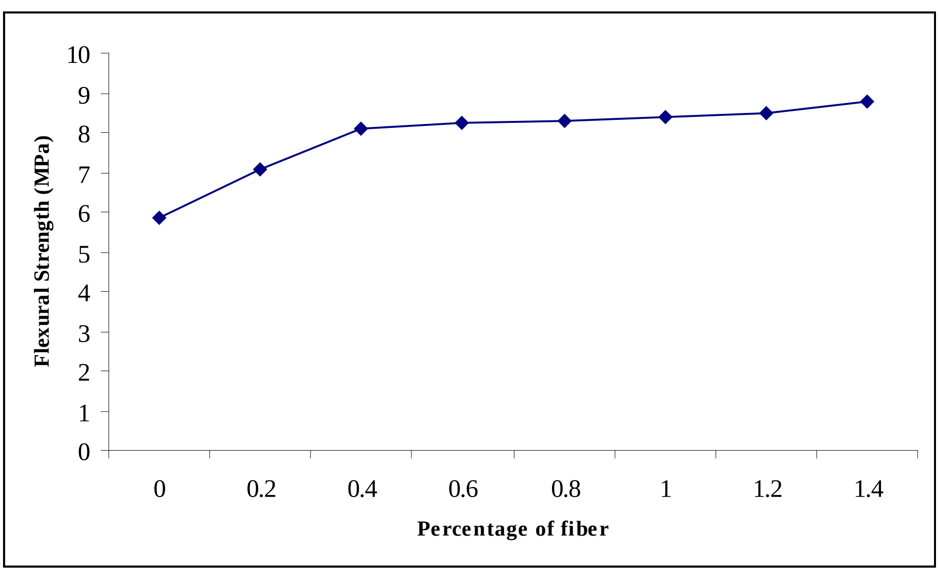

Figure 2 : Variation of flexural strength

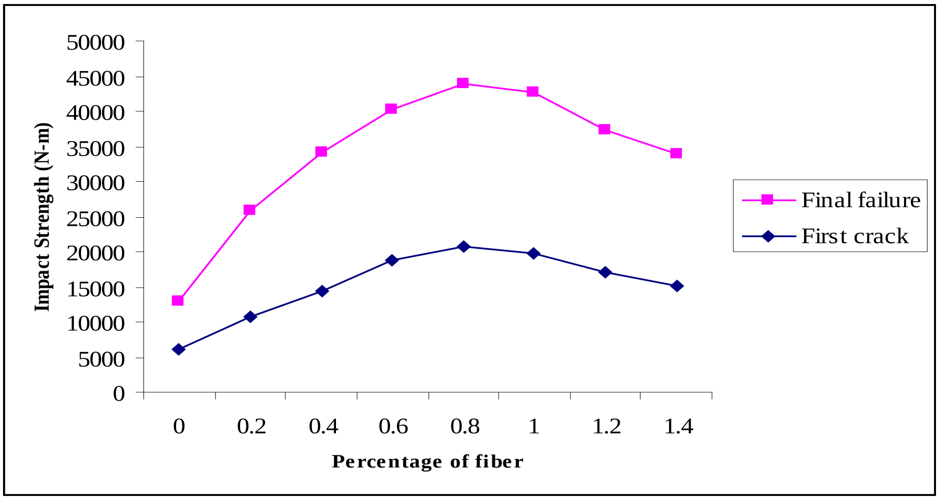

Figure 3 : Variation of impact strength of SIFF

III. Conclusions

Following conclusions can be drawn based on the study conducted on effect of freezing and thawing on the strength characteristics of slurry infiltrated fibrous ferrocement.

a) Addition of 0.8% of steel fibers into slurry infiltrated fibrous ferrocement can result in higher compressive strength when subjected to 90 cycles of freezing and thawing.
b) Addition of 1.4% of steel fibers into slurry infiltrated fibrous ferrocement can result in higher flexural strength and higher toughness indices when subjected to 90 cycles of freezing and thawing.
c) Addition of 0.8% of steel fibers into slurry infiltrated fibrous ferrocement can result in higher impact strength when subjected to 90 cycles of freezing and thawing.

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