Experimental Study on Steel Fiber Reinforced Concrete

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Abstract— As a sort of important engineering material, steel fiber reinforced concrete was used widely in engineering. Up to now, steel fiber reinforced concrete was usually produced by the normal mixing method. For the reason of uniform distribution of fiber, the reinforcement of mechanical properties of concrete was inadequately performed. In this paper, C50 steel fiber reinforced concrete and C60 steel fiber reinforced concrete were manufactured by traditional mixing and vibratory mixing methods, respectively, and then, the cube compression test, flexural test, splitting tensile test, and therefore the bending test were administered. The reinforcement effects of mechanical properties were analyzed by comparing the normal mixing and vibratory mixing methods. The results show that vibratory mixing can effectively improve the distribution of steel fibers in concrete and can increase the density of steel fiber concrete, and therefore, it effectively improves the mechanical properties of steel fiber reinforced concrete when compared to the traditional mixing method.

Keywords: fiber Reinforced Concrete, Compressive Strength, Steel, Concrete, Tensile Test

I. Introduction

Nature paid attention on the difference of improvement effect by various stirring technologies. As a kind of new stirring technology, compared to traditional stirring technology, vibratory mixing technology could effectively improve the distribution of fibers in concrete, further increase the density of steel fiber concrete, and finally improve the mechanical properties of steel fiber reinforced concrete But, at the present , vibratory mixing technology has not been wide a crucial artifact , concrete has been widely utilized in engineering applications like bridges and roads engineering, and therefore the related experimental study of the mechanical properties of concrete was also fruitful . With the vigorous development of engineering construction, high-performance concretes such as fiber reinforced concrete was applied gradually in important engineering structures. Among these high-performance concretes, for the advantages of low cost, easy fabrication, and performance improvements, obviously, steel fiber-reinforced concrete was used widely in the current engineering field. However, the study showed that uneven incorporation of steel fiber would affect the fluidity and uniformity of concrete mixing and even end in fiber bonding, which eventually affects the reinforcement effect of mechanical properties. Up to now, most research paid attention on the development effect of different sorts of fiber or optimum fiber content, but little literely utilized in engineering, and research on its improvement of concrete mechanical properties is insufficient reception and abroad. For such reasons, in this paper, different steel fiber incorporation volume concrete test specimens of various mix proportions were prepared, which were made by different stirring technologies. And then, compression test, flexural test, splitting tensile test, and bending test were conducted; finally, the differences of workability and me- chemical properties of steel fiber concrete made by vibratory mixing and the traditional mixing technologies, respectively, were compared and analyzed.

II. Literature survey

A. History of Fiber Reinforced Concrete

Use of fibers in construction isn't a recent breakthrough. Egyptians and Babylonians used straw as reinforcement in adobe bricks (ACI Committee 544, 1996). In 1874, metallic waste was added to concrete as reinforcement (Minelli, 2005) and asbestos strips were used in concrete in the 1900s. However, fiber reinforced concrete (FRC) did not become a focus of the research community until the 1950s. By the 1960s, FRC with glass, synthetic, and steel fibers had been tested. In that decade, straight steel fiber was first used to reinforce mortar and plain concrete (Balaguru & Shah, 1992). In the last half of the 1970s, the ECU market started producing steel fiber ferroconcrete (SFRC), but there have been no recommendations or standards for his or her use by engineers. Partially thanks to the shortage of standards, adoption of SFRC by the market has been slow (Ross, 2008). Figure 2.1 illustrates the timeline of design and test methods that have been adopted for FRC (Ross, 2008).

B. Development of Self Consolidating Fiber Reinforced Concrete

New generations of additives such as super plasticizers (SPs), which improve concrete plasticity, and viscosity modifying agents (VMAs), which adjust concrete viscosity and prevent segregation, have been developed and added successfully to SCFRCs. Those new additives make achieving high strength concrete possible without any reduction in concrete workability. Fine cementations materials such as fly ash, blast furnace slag, silica fumes, and limestone fines have also been developed that improve SCFRCs. For example, addition of fine cementitious materials reduces voids, which tends to enhance the fiber-matrix bond (Barnes, 2007).

Adding fibers to cementitious composites reduces the matrices workability, especially if the cementitious composites contain coarse aggregates. Ritchie and Rahman (1973), and Luke et al. (1973) examined the impact that adding steel fiber had on concrete workability. They found that concrete workability decreased steadily with the increase of steel fiber content. They found that a 3% fiber volume fraction of steel fibers decreased the slump by 12%, while 8% volume fraction of steel fiber reduces the slump by 70%. Liao et al (2006) investigated the effect of adding 1.2 inch long hooked end steel fibers in volume fractions ranging between 1.5% to 2% to SCCs of compression strengths ranging between 5 ksi to 9.5 ksi. They developed a mix design for a tensile-strain hardening self-consolidating FRC that was used as a basis for the mixture designs utilized in this study.

III. MATERIALS AND METHODS

A. Materials

1) Steel Fiber: The physicochemical parameter of steel fiber should meet the requirements of JGT 472-2015. The length of steel fiber should be 20 mm,60 mm and diameter or equivalent diameter should be 0.3 mm,1.2 mm; length to diameter ratio was 30-65.
2) Cement: P.O 42.5 ordinary Portland cement was used in this paper, and each performance index of cement and its strength of 3 days and 28 days were checked according to the performance index of "General Portland Cement" (GB175- 2007).
3) Fine Aggregate: Good quality graded sand was selected, and fineness modulus should be controlled in 2.3 to 3.0; fine aggregate performance was checked according to GB14684-2011.
4) Coarse Aggregate: Test selection of hard texture, graded continuous gravel, and aggregate shape with a more uniform edge polyhedron was made as well, with a particle size of 5 mm~20 mm and clay content <1%. The "standard test method for building pebbles, gravel" (GB/T14685-2011) was used as test performance indicators of the coarse aggregate.
5) Admixture: Polycarboxylate super plasticizer was used as admixture, with water reduction rate not less than 25%. The amount of admixture was 0.5%~1% of cement content.
6) Mineral Admixture: Addition of fly ash should be consistent with the provisions of GB/T1596.
7) Mixture Proportion Design: The purpose of this experiment is to study the improvement of mechanical properties of different types of steel fiber-reinforced concrete (SFRC) which was made by ordinary stirring and vibratory mixing, respectively. In the field of engineering, steel fiber-reinforced concrete was always used as high-strength concrete, so in this paper, two kinds of high-strength concrete C50 and C60 were studied in this paper, and the amounts of steel fiber admixture were 0.5%, 1%, 1.5%, and 2%, respectively.

IV. MECHANICAL PROPERTIES OF FRC

The following section offers a brief description of the most important mechanical properties of FRC. Characteristics such as strength, stress-strain behavior, modulus of elasticity, and toughness, as well as a brief discussion of some results found in the literature are reported. In general, there is no significant improvement in the elastic region (before cracking) from addition of fibers to cement-based materials. In addition, small fiber volume fractions have a negligible effect on the compression strength and the modulus of elasticity (Barnes, 2007). Introducing fibers to concrete can, however, result in significantly improved post-cracking behavior.

A. Compression Strength

In plain concrete and FRC with fiber volume fractions less than 1% the stress-strain relationship can be represented by a line up to approximately 30% of the compression strength, followed by a period of gradual softening up to the concrete compression strength. Beyond the compression strength, the stress-strain relationship exhibits strain softening until failure occurs (Williamson, 1974; Wafa & Ashour, 1992). Adding steel fibers tends to reduce the post-peak slope of the stress-strain relationship, resulting in a response to compression like that of well confined concrete, as illustrated in Figure 2.13 (LÖFGREN, 2005).

B. Tensile Strength

As defined previously, HPFRC is a class of FRC materials that exhibit tensile strain hardening, or increased tensile strength after cracking. In contrast, plain concrete and conventional FRC exhibit the greatest strength at first cracking, and therefore they exhibit strain-softening, as shown in Figure1.

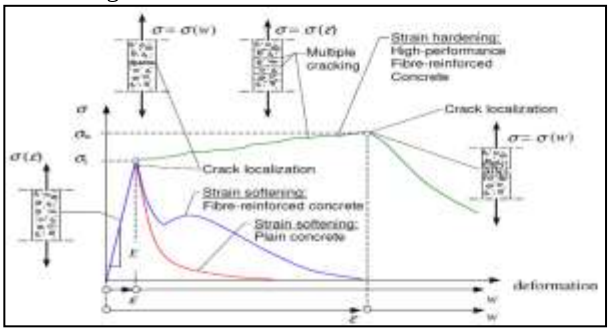

Fig. 1: Classification of FRCs based on their behavior under tensile.

V. EXPERIMENTAL METHODOLOGY

A. Compressive Strength Test:

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M40 grade of concrete. Super plasticized (0.6% to 0.8% by weight of cement) was added to this. The moulds were filled with 0%, 1% 2% and 3% fibres. Vibration was given to the moulds using table vibrator. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 28 days. After 28 days curing, these cubes were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each category three cubes were tested and their average value is reported. The compressive strength was calculated as follows.

Compressive strength (MPa) = Failure load / cross sectional area.

Fig. 2: "Testing Of Compressive Strength Test Specimen"

B. Flexural strength test:

For flexural strength test beam specimens of dimension 100x100x500 mm were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 400 mm on Flexural testing machine. Load and corresponding deflections were noted up to failure. In each category three beams were tested and their average value is reported. The flexural strength was calculated as follows.

Flexural strength (MPa) = (P x L) / (b x d2),

Where, P = Failure load, L = Centre to centre distance between the support = 400 mm, b = width of specimen=100 mm, d = depth of specimen= 100 mm.

Fig. 3: "Testing of flexural strength test specimen"

C. Split Tensile strength test:

For Split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested under compression testing machine. In each category three cylinders were tested and their average value is reported. Split Tensile strength was calculated as follows as split tensile strength:

Split Tensile strength (MPa) = 2P / π DL, Where, P = failure load, D = diameter of cylinder, L = length of cylinder

Fig. 3: "Testing of Split tensile strength test specimen"

VI. EXPERIMENTAL RESULT

Following graphs give compressive strength, flexural strength and Split Tensile strength result for M-40 grade of concrete with 0%, 1%, 2% and 3% steel fibres for aspect ratio 50, 60 and 67.

Compressive strength (MPa)	Average Compressive strength (MPa)
48.89 42.22 44.44	45.19

Table 1: Compressive Strength of SFRC with 0% fibres M40 grade

Different aspect ratios of fibres	For SFRC with 1% fibres		For SFRC with 2% fibres		For SFRC with 3% fibres	
	Comp. strength (MPa)					
		Avg.		Avg.		Avg.
	52.00		53.33		55.56	
50	51.56	52.00	54.67	53.33	56.44	56.30
	52.44		52.00		56.89	
60	53.33 48.89 48.89	50.37	53.33 52.89 51.56	52.59	53.33 53.78 55.11	54.07
67	50.67 51.56 48.44	50.22	53.33 51.56 49.33	51.41	51.56 52.44 55.11	53.04

Table 2: Compressive Strength of SFRC With 1%, 2% And 3% Fibres

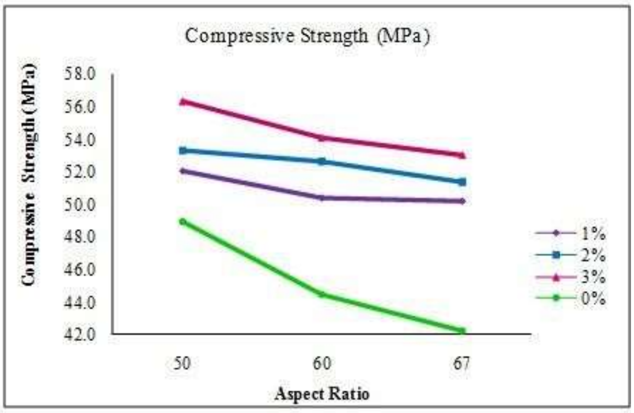

Fig. 4: % increase in 28 days compressive strength for m-40 grade concrete.

Flexural strength (MPa)	Average Flexural strength (MPa)
7.6 7.2 7.6	7.47

Table 3 – Flexural Strength of SFRC With 0% Fibres M40 Grade

Different aspect ratios of fibres	For SFRC with 1% fibres		For SFRC with 2% fibres		For SFRC with 3% fibres	
	Flexural strength (MPa)					
		Avg.		Avg.		Avg.
50	8.8 9.2 8.4	8.8	8.8 9.6 10	9.47	10.4 10 10.8	10.40
60	8.4 8.8 8	8.40	8.8 9.2 9.6	9.20	9.6 10 10.4	10.00
67	8 8 8.8	8.27	8 9 10	9.00	8.8 10.4 10	9.73

Table 4: Flexural Strength of SFRC With 1%, 2% And 3% Fibres

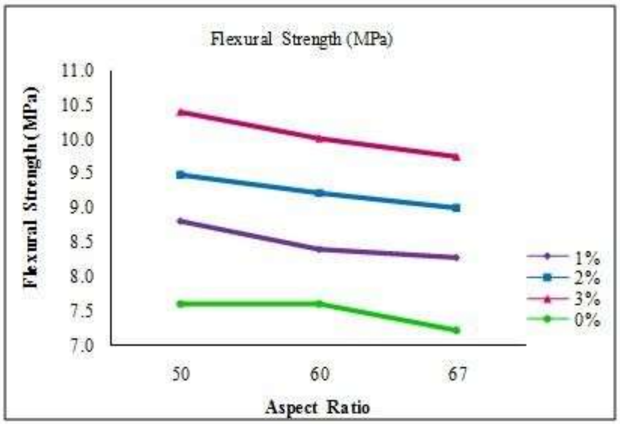

Fig. 5: Percentage Increase in 28 Days Flexural Strength for M-40 Grade Concrete

Split Tensile Strength (MPa)	Average Split Tensile strength (MPa)
2.83 3.11 3.26	3.07

Table 5: Split Tensile Strength of SFRC With 0% Fibres M40 Grade

Different aspect ratios of fibres	For SFRC with 1% fibres		For SFRC with 3% fibres		For SFRC with 3% fibres	
	Tensile strength (MPa)					
		Avg.		Avg.		Avg.
	3.11		3.82		4.39	
50	3.54	3.30	3.82	3.92	4.25	4.34
	3.26		4.10		4.39	
	2.97		3.96		4.25	
60	3.40	3.21	3.54	3.68	4.10	4.25
	3.26		3.54		4.39	
	2.83		3.54		3.82	
67	3.26	3.16	3.96	3.63	4.25	4.20
	3.40		3.40		4.53	

Table 6 – Split Tensile Strength of SFRC With 1%, 2% And 3% Fibres

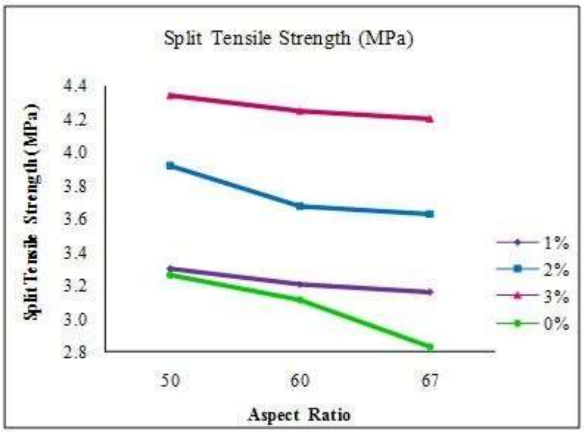

Fig. 6: Percentage Increase in 28 Days Split Tensile Strength for M-40 Grade Concrete

VII. CONCLUSION

The following conclusions could be drawn from the present investigation.

1) It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibres as compared to that produced from 0%, 1% and 2% fibres.
2) All the strength properties are observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 and 67.
3) It is observed that compressive strength increases from 11 to 24% with addition of steel fibres.
4) It is observed that flexural strength increases from 12 to 49% with addition of steel fibres.
5) It is observed that split tensile strength increases from 3 to 41% with addition of steel fibres.

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