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Compressive and Tensile Strength of Steel Fiber Reinforced Concrete

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A B S T R A C T

Cement concrete is probably the most extensively used construction material in the world. Concrete consumption is around 10 billion tons per year, which is equivalent to 1 ton per every living person. Production of cement and steel has environmental hazards due to emission of CO_2 and dust particles in the atmosphere. Hence prudent use of cement and steel has distinct economic and environmental impacts. Under impact and dynamic loading plain concrete exhibits extensive cracking and undergoes brittle failure. The concrete is weak in tension and hence to overcome this problem cement concrete is reinforced using steel bars and thus called as reinforced cement concrete (R.C.C.). In this modern age, civil engineering constructions have their own structural and durability requirements.Fiber Reinforced Concrete (FRC) is a composite material made primarily from hydraulic cements, aggregates and discrete reinforcing fibers. Fiber incorporation in concrete, mortar and cement paste enhances many of the engineering properties of these materials such as fracture toughness, flexural strength, resistance to fatigue, impact and thermal shock. Fiber reinforced concrete started to come to its modern industrial use during the 1960's.In this paper, compressive and splitting tensile strength of FRC is carried out.

Keywords:Fiber reinforced concrete, Compressive Strength, Split Tensile Strength

1. Introduction

Concrete is one of the most common materials used in the construction industry. In the past few years, many research and modification has been done to produce concrete which has the desired characteristics. Cementations materials known as pozzolana are used as concrete constituents, in addition to Portland cement. There is always a search for concrete with higher strength and durability. In this matter, blended cement concrete with the incorporation of fibers has been introduced to suit the current requirements. Plain concrete has good compressive strength but has low tensile strength, low ductility and low fire resistance. To circumvent these shortcomings, extensive research by concrete technologist has led them to find a very promising concrete material called as fiber reinforced concrete. A lot of research work has been done and is going on the use of various types of steel fibers in enhancing various properties of concrete. Research work done by various researchers is discussed here in brief.

Kamal *et. al.* [1] carried out experimental test on ultra-high performance concrete (UHPC). This paper aimed to evaluate the behavior of ultra high strength concrete beams. This paper also aimed to determine the effect of adding fibers and explore their effect upon the behavior and strength of the reinforced concrete beams. The main variables taken into consideration in this research were the type of fibers and the percentage of longitudinal reinforcement as well as the existence or absence of the web reinforcement. Two types of fibers were used including steel and polypropylene fibers. Soyle and Ozturan [2] studied steel, polypropylene and glass fiber concretes at low volume fractions, which have been successfully used for crack control in many structural application. These were tested for various properties including water absorption, electrical resistivity, depth of chloride penetration, chloride penetration, compressive strength, splitting tensile strength, flexural strength and fracture toughness were also determined. Khaloo*et. al.* [3] studied self compacting concrete (SCC) is a highly workable concrete that without any vibration or impact and under its own weight fills the formwork and its also passes easily through small spaces between rebar. In this paper, the effect of steel fibers on rheological properties, compressive strength, splitting tensile strength, flexural strength and flexural toughness of SCC specimens using four various steel fiber volume fraction (0.5%, 1%, 1.5% and 2%) were investigated. Pajak and Ponikiewski[4] presented work to investigate the flexural behavior of self compacting concrete reinforced with straight and hooked end steel fibers at levels of 0.5%, 1% and 1.5% and compare it to normally vibrated concrete (NVC). Mohmoud and Afroughsabet [5] this study investigated the impact resistance and mechanical properties of steel fiber reinforced concrete with water cement ratios of 0.46 and 0.36 with and without the addition of silica fume. Hooked steel fibers with 60mm length and aspect ratio of 80, with three volume fraction of 0%, 0.5% and 1% were used. Cadoni*et. al.* [6] presented the experimental results on two types of concrete reinforced with steel and polyvinyl alcohol PVA fibers subjected to

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dynamic tensile loading. The tests were carried out by using a modified hopkinson bar apparatus on fiber reinforced concrete notched specimens under three various strain-rates 50, 100 and 200 etc. In specimens with PVA fibers, an enhancement of the tensile strength was also observed and a significant reduction of fracture energy and ultimate deformation occurred.

Koksal*et. al.* [7] investigated the changes on some mechanical properties of concrete specimens produced by using silica fume and steel fiber. The main objective of the work was to obtain a more ductile high strength concrete produced by using both silica fume and steel fiber. Two types of steel fibers with aspect ratios (fiber length/fiber diameter) of 65 and 80 were used in the experiments and volume fractions of steel fiber were 0.5% and 1%. Addition of silica fume into the concrete was 0%, 5%, 10% and 15% by weight of cement content. Wang *et. al.* [8] investigated three types of SRFC specimens with 0.0%, 3.0% and 6.0% (percentage by volume) of ultra short steel fibers subjected to impact compression tests conducted on 74 mm diameter split Hopkinson pressure bar (SHPB). Based on the stress–strain curves of various strain-rates, as well as the random statistical distribution hypothesis for SFRC strength, a dynamic damage constitutive model of SFRC composite under compression was proposed. Cucchiara and Mendola [9] carried out experimental tests on simply supported rectangular beams made of hooked steel fiber reinforced concrete with and without stirrups, subjected to two point symmetrically placed vertical loads. The tests, were carried out with controlled displacements, allowing one to record complete load deflection curves by means of which it was possible to deduce information on dissipative capacity and ductile behaviour up to failure.

2. Methodology

In present research work, M-35 Concrete with addition of steel fibers of various types and aspect ratios and keeping volume fraction constant as 2.5% by the weight of cement in the concrete.

Table 1 - Physical Properties of Cement (Confirming to IS 12269 – 1987)

Sr. No.	Description of Test	Results
1	Fineness of cement (residue on IS sieve No. 9)	3%
2	Specific gravity	3.15
3	Standard consistency of cement	29%
4	Setting time of cement a)Initial setting time b) Final setting time	 135 minute 288 minute
5	Soundness test of cement (with Le-Chatelier's mould)	1.3 mm
6	Compressive strength of cement a) 7 days b) 28 days	 57.8 N/mm^2 79.5 N/mm^2

Table 2 - Properties of Super Plasticizers

Sr. No.	Properties	Description
1	Chemical admixture	Master plaster SPL – 9
2	Color	Brown
3	Type	Sulphonated naphthalene formaldehyde polymer
4	Specific gravity	1.27± 0.02 at 30°C
5	pH value	7 to 9
6	Chloride content	Nil
7	Air Entrainment	Nil
8	Nitrate content	Nil
9	Viscosity	Medium viscous

2.1 Types of Fibers Used

Types of fibers and their shapes are shown in Fig. 1, 2, 3 as follows:

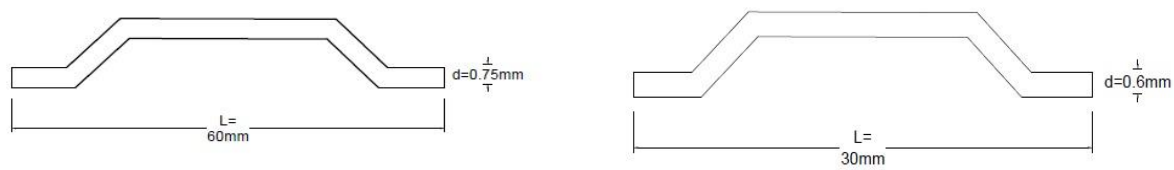

Fig. 1 - (a) Hook ended steel fiber HK-80; (b) Hook ended steel fiber HK-50

Fig. 2 - (a) Crimped steel fiber CR-50; (b) Round steel fiber RD-50

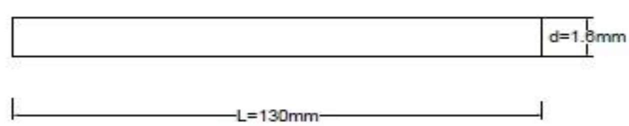

Fig. 3 - (a) Round steel fiber RD-80

Table 3 - Physical Properties of Various Steel Fibers

Sr. No.	Property	Values				
		HK-80	**HK-50**	**CR-50**	**RD-50**	**RD-80**
1	Diameter	0.75 mm	0.6 mm	0.6 mm	1.6 mm	1.6 mm
2	Length of fiber	60 mm	30 mm	30 mm	80mm	130mm
3	Average aspect ratio	80	50	50	50	81.25
4	Tensile strength	1050 MPa	1050 MPa	1025 MPa	1050 MPa	1050 MPa
5	Modulus of elasticity	200 GPa	200 GPa	200 GPa	200 GPa	200 GPa
6	Specific gravity	7.8	7.4	7.5	7.15	7.15
7	Appearance	Bright and clean wire				
8	Deformation	Continuously deformed circular segment				

3. Testing on Hardened Concrete

Compressive strength is carried out on Compression Testing Machine (CTM) of capacity 2000 kN. Cube is tested for 28 days and cylinder for 28 days. Split tensile strength test is conducted on digital universal testing machine (UTM) of 40 tones capacity.

3.8.1 Compressive strength and Split Tensile Strength test

Cube compression strength and split tensile strength were performed on standard cubes and cylinder of plain and SFC after 28 days of immersion in water for curing. The compressive strength and split tensile strength of specimens areshown in Fig. 4 and calculated by the following formula

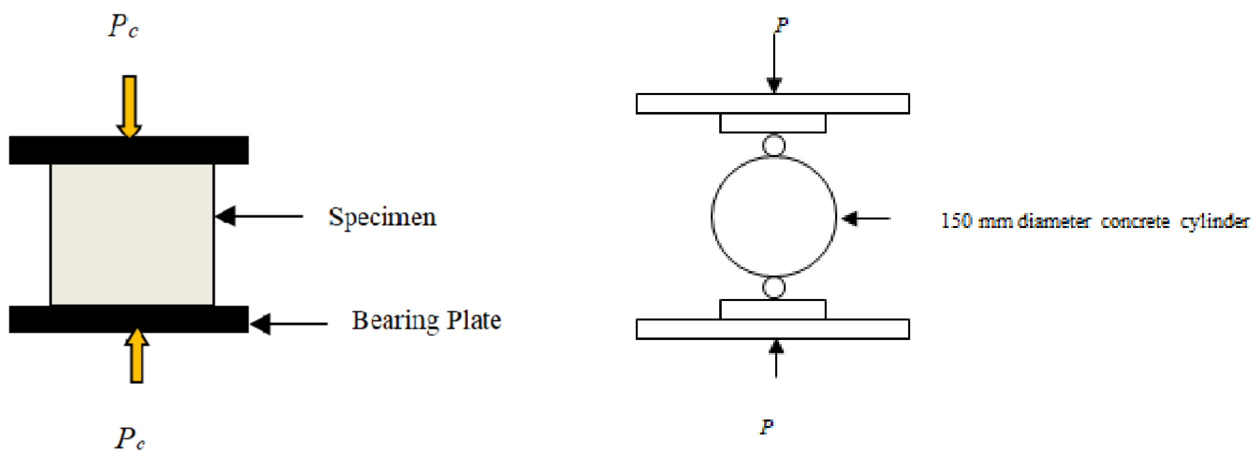

Fig. 4 - (a) Compression Test Set-up; (b) Split Tensile Test Set-up

Compression Strength Test Formula

$$f_{cu} = \frac{P_c}{A}$$

where,

f_{cu}= Compressive Strength, MPa

P_c= Failure load in compression, kN
A = Loaded area of cube, mm^2

Split Tensile Strength Test Formula

$$f_t = \frac{2P}{\pi LD}$$

where,
f_t = Tensile strength, MPa
P = Load at failure, N
L = Length of cylinder, mm,
D = Diameter of cylinder, mm

3. Results and Discussions

3.1. Compressive Strength and Split Tensile Strength

In the present study, cube compression test and split tensile teston plain and various types of steel fiber concrete (SFC) are carried out. The experimental results and discussion for these tests are described below:

Table 4-Comparative statement of compressive strength for various fibers at constant rate of 2.5% for 28 days

Sr.No.	Type of steel fiber	Compressive Strength (MPa)	% Increase in strength for 28 Days
1	PCC	44.21	1.105
2	HK-80	54.95	1.373
3	HK-50	53.63	1.342
4	RD 80	50.59	1.264
5	RD-50	50.59	1.264
6	CR-50	46.62	1.165

Table 5- Comparative statement of splitting strength for various fibers at constant rate 2.5% for 28 days

Sr.No.	Type of steel fiber	Splitting Tensile Strength in MPa	% Increase in 28 Days
1	PCC	5.73	0.1432
2	HK-80	7.42	0.1855
3	HK-50	6.79	0.1697
4	RD-80	6.58	0.1645
5	RD-50	6.07	0.1517
6	CR-50	4.57	0.1142

1. In general, the significant improvement in compressive and tensile strengths is observed with the inclusion of hooked end steel fibres in the plain concrete as compared to crimped and straight types of steel fiber.
2. From comparative statement of same aspect ratio
   a. Compressive strength addition of steel fiber irrespective of type and aspect ratio improves the compressive strength of concrete. Strength comparison between same aspect ratio HK-80 and RD-80 is 54.95 MPa and 50.59 MPa respectively and HK-50, RD-50 and CR-50 is 53.63 MPa, 50.59 MPa and 46.62 MPa respectively.
   b. Split tensile strength it is observed that the tensile strength between same type's aspect ratio HK-80 and RD-80 is 7.42 MPa and 6.58 MPa respectively and HK-50, RD-50 and CR-50 is 6.79 MPa, 6.07 MPa and 4.57 MPa respectively.

4. Conclusions

1. The mechanical properties of concrete are enhanced with the addition of Steel fibers. The properties of concrete like compressive strength and split tensile strength is increased.
2. From the results and discussion it shows that for 2.5% addition of steel fibers, concrete showing overall improvement.
3. In general, the significant improvement in compressive and tensile strength are observed with the inclusion of Hooked end steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content.

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