EXPERIMENTAL STUDY ON COMPRESSIVE STRENGTH OF CONCRETE WITH STEEL-POLYPROPYLENE HYBRID FIBER

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ABSTRACT- The use of reinforcement material is to provide excellent bonding characteristic, connection properties, high tensile strength, good thermal efficiency, toughness and flexibility for brittle cemented matrices. The mechanical properties of concrete can be made better by the inclusion of a single type of fiber, but it is not so effective. The incorporating hybrid fiber of two fiber into concrete can lead to improvements and representation of their benefits.

For this investigation 9 mixes, one plain concrete mix each for compressive and tensile strength, one for the hybrid reinforced fiber and 6 other reinforced concrete mixes were prepared for all the three fibers used. Various volume percentages of fibers are added i.e. steel (0.5%, 0.6%, 0.7%, 0.8%, 0.9%, 1.0%) and polypropylene (0.1%, 0.2%, 0.3%, 0.4%, 0.5%). From the investigation, it was found that steel and polypropylene (0.8% & 0.2%) gave the best result for all the three fibers used and out of the hooked-end and crimped-end steel fiber, hooked-end gave more compressive as well as tensile strength and it was also effective, so hooked-end steel fiber was used for hybrid reinforced fiber content.

For the hybrid reinforced fiber content, different volume percentages were prepared for hooked steel and polypropylene (0.5%-0.5%), (0.6%-0.4%), (0.7%-0.3%), (0.8%-0.2%), (0.9%-0.1%), (1.0%-0.0%). Here, also the (0.8%-0.2%) of steel-polypropylene gave the highest compressive strength from all the volume percentages which is 59.55MPa.

Keywords: Concrete, Steel Fiber, Polypropylene Fiber, Hybrid Fibers, Fiber Reinforced Concrete, Compressive strength, Tensile strength

Introduction

Concrete is a composite construction material which is mainly made of aggregate, cement and water. Concrete is hard and strong like stone, it is due to a chemical reaction between water and cement. The benefit of concrete is its most multipurpose use in the construction field. Concrete is the material that can be molded in some shapes and well-formed regular rectangular or circular structures such as dome or hemisphere. There are some special features of concrete made from Portland cement. Concrete is relatively strong in compression but weak in tension and becomes brittle. These two weaknesses have limited their use. Another basic weakness of concrete is that the cracks begin to form as soon as the concrete is placed before it is properly rigid. These cracks weaken the concrete, which is a major cause, especially in large onsite applications where there is a general lack of fracture, failure and stability. Use of traditional rod reinforcement and some quantity of fiber in adequate quantity can reduce the weakness of stress in some areas.There is hardly any type of fiber that can improve all the desirable qualities of fresh and hardened concrete. In order to improve all the properties of concrete, a combination of two or more types of fiber is required and it is known as "hybrid fiber reinforced concrete". The basic purpose of using hybrid fiber is to increase the properties of concrete by mixing the benefits of concrete and controlling the crack at different size levels in different areas of concrete, which can provide each type of fiber. In this project, an experimental study will be conducted on the compressive and tensile behavior of hybrid-reinforced concrete using two fibers steel and polypropylene.

1. EXPERIMENTAL STUDY ON COMPRESSIVE STRENGTH OF CONCRETE WITH STEEL-POLYPROPYLENE HYBRID FIBER -

1.1 Overview of the Project

In this project steel and polypropylene fibers are used. Detailed information regarding these fibers is as follows:

Steel fiber- cross-section. Steel fiber is especially used to improve the properties of mechanical concrete, such as post-cracking tensile resistance. In addition, it has recently been used in short-term concrete slabs as an alternative engineering material rather than steel bars/steel strips. The construction of steel fiber is more economical than conventional construction. Besides the cost reduction, the SFRC has other beneficial properties such as high hardness, high flexibility, lightweight, low repair costs, and better post-cracking.

Steel fiber is used in steel-fiber reinforced applications, including highway pavement, airport runway, construction of industrial floors, refractory concrete, bridge deck, overlays, spillways, dams, slope stabilizations, and shotcrete tunnel lining by spraying fiber-reinforced concrete. Its potential improvement is to reduce the breakdown due to temperature, increase the hardness, resist effectiveness, friction, destroy and reduce fatigue In addition, steel fiber significantly reduces the strength of reinforced concrete fracture and spalling.

Shapes- Typically the diameter of the steel fibers (based on the cross-sectional area) is from 0.15 mm to 2 mm and length from 7 to 75 mm. The fibers were round and smooth and the wires were cut in the required length. Depending on the geometry, steel fibers are produced for the deformed ending flats and increased end size. Now the ends of rough surface fibers are eliminated or crumble through their length or they are crumbled. Steel fibers are produced by modern commercially available steel wire, slit sheet steel or melt-extraction process, which produce a crescent-cross-section fiber.

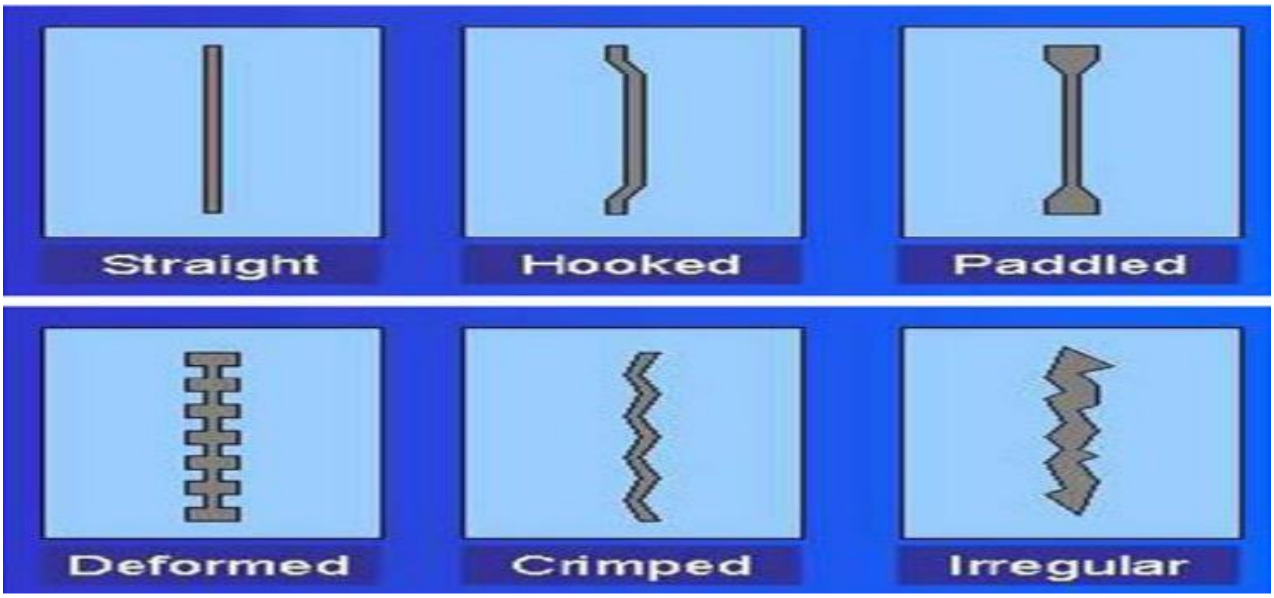

Fig. 1.1: Steel Fiber Shapes.

1.2 Objective and scope of work

In the past, many experimental works have been done on fiber-reinforced concrete, which have different types of fibers. These fibers study their superior engineering properties in compressive strength, tensile strength, flexural strength, etc. Fiber is able to prevent surface cracking through the leading action for the impact of the concrete action resistance effect. Certain properties of concrete can be improved by the use of one type of fiber, for example, steel fibers can improve structural strength, flexibility, impact resistance, and abrasion resistance, reducing the need for steel reinforcement, crack width and synthetic fiber mix can improve mix cohesion, freeze-thaw resistance, impact resistance and resistance to plastic shrinkage. In recent years, a special combination of metal and non-metal fibers has been very useful in fiber hybridization. For optimal behavior, various types of metals and non-metal fibers have been mixed. The mechanical properties such as compressive strength, flexural strength and flexural toughness etc. of Hybrid Fiber Reinforced Concrete (HFRC) have been investigated by different investigators.

Types of Fibers:-

Depending on the original material, fiber can be mainly classified as:

1. Mineral fiber (such as asbestos, glass, carbon)
2. Metallic fiber (e.g. gold, silver, stainless steel, galvanized iron, aluminum)
3. Synthetic fibers (polyester, nylon, polypropylene, polythene)
4. Natural fibers (cotton, silk, bamboo, cashmere, hemp, coir, jute, sisal, wood, sugarcane)

Asbestos Fiber Reinforced Concrete (AFRC): Asbestos fibers reinforced concrete are quite cheap. They provide cement with chemical, thermal and mechanical resistance, although they show low impact strength.

Carbon Fiber Reinforced Concrete (CFRC): These fibers have recently been used due to the high modulus of their flexibility. Characteristics such as strength and hardness are superior to steel fibers, although they are more sensitive to damage.

Natural Fiber Reinforced Concrete (NFRC): NFRC contains cellulose fibers that are processed by pine trees. This category is also giving good results. Recycled carpet waste has been successfully used for solid reinforcement using waste carpet fiber.

Reinforced Concrete (RC): Concrete in which the steel is amalgamated, works together in two-face-faced forces.

2. Materials for Hybrid Fiber Reinforced Concrete

2.1 Cement: Cement is a material used for construction works. It works as a binder, which simultaneously establishes other materials and hard materials. Cement is used to connect sand and gravel (aggregate) together. If the cement is added with sand only then it makes mortar which is used for masonry works and if it is mixed both sand and gravel then it makes concrete used for RCC works. Cement is of different types but mostly used cement is OPC which is known as Ordinary Portland cement. It has three grades: 33, 43 and 53 grade. Ordinary Portland Cement of grade 53 initiated from IS-269:1989, IS-8112: 1989, IS-12269: 1987 is used with an initial setting time of 30 minutes and the final setting time of 600 minutes.

Figure 2.1 Cement

Some physical characteristics of cements are given in table 2.1

IS Code	Fineness (sq.m/kg) min	Soundness by		Setting time	
		Le-chatlier (mm) max	Autoclave Max (%)	Initial (minutes) min	Final (minutes) max
(IS 269-	225	10	0.8	30	600

Table 2.1 Physical characteristics of cement

2.2 Test-Soundness of cement- This test is performed to ascertain the soundness or unsoundness of cement which affects durability of the structure. The soundness of cement depends on its ingredients. Excess of lime and/or magnesium oxide present in the cement cause unsoundness .The test is designed to accelerate the expansion in the cement paste by application of heat. As per IS 269-1987, the expansion of cement should not be more than 10mm.

2.3 Aggregates: Aggregates used in concrete matrix increase the soundness and impact of the properties of concrete. Aggregates with the same nominal size and grading give the satisfactory workability with the concrete. Aggregates are mainly of two types: Fine and coarse aggregates. The fine set used in M-sand passing 4.75 mm sieve and the coarse set is used for greater than 4.75mm.


Figure 2.1.1 Fine Aggregate **Figure 2.1.2 Coarse Aggregate**

3. EXPERIMENTAL INVESTIGATIONS

3.1 Tests on Cement:

The cement is tested as per IS:431 (part-4)-1988 and properties are listed below

Property	Values
Specific gravity	3.15
Standard Consistency	26%
Setting time Initial final	 30 min 600 min

Table 3.1 Properties of cement

3.2 Tests on Aggregates:

Aggregates in the concrete matrix increase the soundness and impact absorbing properties of the concrete. Aggregates with the same nominal size and grading induce the concrete with satisfactory workability. The fine aggregate used is the M-sand passing 4.75 mm sieve is taken for the mix. Fine aggregate is passing through 4.75mm sieve is tested as per IS: 2386 part-3. The properties of aggregates are listed below:

Properties	Fine Aggregate	Coarse Aggregate
Specific gravity	2.56	2.75
Fineness modulus	3.16	4.29

Table 3.2 Properties of aggregates

3.3 Calculation of Aggregate:

Required Data:

Characteristics compressive strength (Fck) = 40 Mpa
Maximum cement content = 450kg/m
Degree of workability = 0.8 compacting factor
Grade of cement = OPC 53
Specific gravity of cement = 3.15
Specific gravity of sand = 2.6
Specific gravity of aggregate = 2.6
Maximum size of aggregate = 20mm

1. Target mean strength for mix design

The mean compressive strength at 28 days is given by Fck = Fck+ts

= 40+1.65*5 (t= 1.65 and s = 5) from IS 10262:2009

= 48.25 N/mm²

2. Selection of water content

For 20mm aggregate = 450X0.4=180 Kg< 186 kg (IS: 10262)

Hence o.k.

3. Estimation of entrapped air

Entrapped air = 2% for 20mm aggregate (from IS 10262:1982)

4. Determination of coarse and fine aggregate: As per IS:10262 , Cl. No. 3.5.1

Assume F.A. by % of volume of total aggregate = 36.5 %

$$V = \left[W + \frac{C}{Sc} + \frac{1}{P}\frac{fa}{Sfa}\right]\frac{1}{1000}$$

$$0.98 = \left[180 + \frac{450}{3.15} + \frac{1}{0.365} * \frac{fa}{2.6}\right]\frac{1}{1000}$$

$$\frac{fa}{0.365 * 2.6} = 980 - \left[180 + \frac{450}{3.15}\right]$$

fa = 623.63 kg/m^3

$$ca = \frac{1 - 0.365}{0.365} * 623.63 * \frac{2.6}{2.6}$$

ca= 1084.95 kg/m^3

- **Design Mix:**

According to the Indian Standard Code, the M40 concrete grade target for mix design is 48.25 N / mm² of average strength. Mix proportion of the study is **Water: cement: C.A. : F.A. = 0.4: 1: 2.42:1.38**

- **Concrete:**

It is a mixture of sand, cement, water, coarse and fine aggregate. We have some values as follows. Admixture is used as per the suitability of conditions.

Water	Cement	Sand	Coarse aggregate
0.4 Liter	1 Kg	1.38 Kg	2.42 Kg

Table 3.3 Concrete mix design

3.4 Fibers used in project and their properties:-

The project work is focused on hybrid fiber reinforced system using steel and polypropylene fibers. Steel fibers are used to increase the flexural strain capacity and to improve the ductility of concrete. While polypropylene fiber is used to improve the toughness properties in post cracking zones. The details of the fibers used in the project are as follows-

Fiber Type	Shape	Length(mm)	Equivalent Dia. (mm)	Tensile Strength (MPa)	Density (Kg/m3)
Steel Fibers	Crimped	30	0.75	1100	7850
Polypropylene	Flat Fibrillated	12	0.6	550	910

Table 3.4 Hybrid Fiber Reinforced

4. Fabrication Methodology

Procedure

The whole process is distinguished into two parts viz. procedure of casting and procedure of testing.

Procedure of casting

1. Transfer the scoop around the upper portion of the mould and fill the concrete in the mould at a depth of approximately 50 mm so that the symmetrical distribution of concrete is ensured within the mould.

2. If the compaction is done by hand tamps, the concrete is tamped with the standard rod, the number of strokes uniformly distributed over the cross-section of the mold should not be less than for 35 per layer for 15 mm cube and 25 per layer for 10 cm cubes. For cylindrical specimens, the number of strokes will not be less than 30 per layer. Turn the voids off by folding the edges of the mould which was left by the tamping bars.

3. If compaction is done by vibration, then each layer is compacted by a suitable vibrator or vibration hammer. Mode of laboratory sampling and quantum vibration will be similar in adoption in actual operation.

4. If vibration is done by vibration, then each layer is compressed by a suitable vibrator or vibration table, the vibration hammer. Mode of laboratory sampling and quantum vibration will be similar in adoption in actual operation.

5. After moulding operations, cylindrical specimens are usually covered with a thick layer of clean cement for 2 to 3 hours. Caps will be manufactured by a glass plate or metal plate. Reduce the plate on the mould until its lower surface is fixed on the top of the mould. For capping, the cement should be mixed in a stiff plate for approximately 2 hours, so that it can be used to prevent the tendency to shrink the cap.

6. Storing the samples for 24 + 0.5 hours till its ingredients dry. Remove the specimen from the mould and keep it immediately clean, dipped in fresh water and keep them for testing.

Figure 3.5 Mixing and Casted specimens

5. Procedure of testing

1. Age of the test: Usually the test is done after 7 and 28 days. The days are measured from the time when water is mixed in dry material. Test at least 3 samples at a time.

2. Test the sample immediately or remove it from the water, while they are still in wet conditions. Wipe off the surface water. If samples are dry, keep them in water for 24 hours before testing.

3. Note down the nearest dimension to 0.2 mm and also the mass.

4. Place the specimen in such a manner that the load should be applied to opposite sides of the cube cast.

5. Apply load gradually at the rate of 14 N/mm^2. Unless the cube breaks.

6. Note the maximum load and presence of the concrete failure i.e. whether aggregates have broken or cement paste separates from the aggregates etc.

6. RESULTS AND DISCUSSION: Test Results:

6.1 Compressive Strength Test Results

Sr. No.	DAYS	Plain concrete	
		Obtained Value	Minimum Value
1.	7 days	37.30	27.00
2.	28 days	48.50	40.00

Table 4.1 Effect of Concrete on Compressive Strength

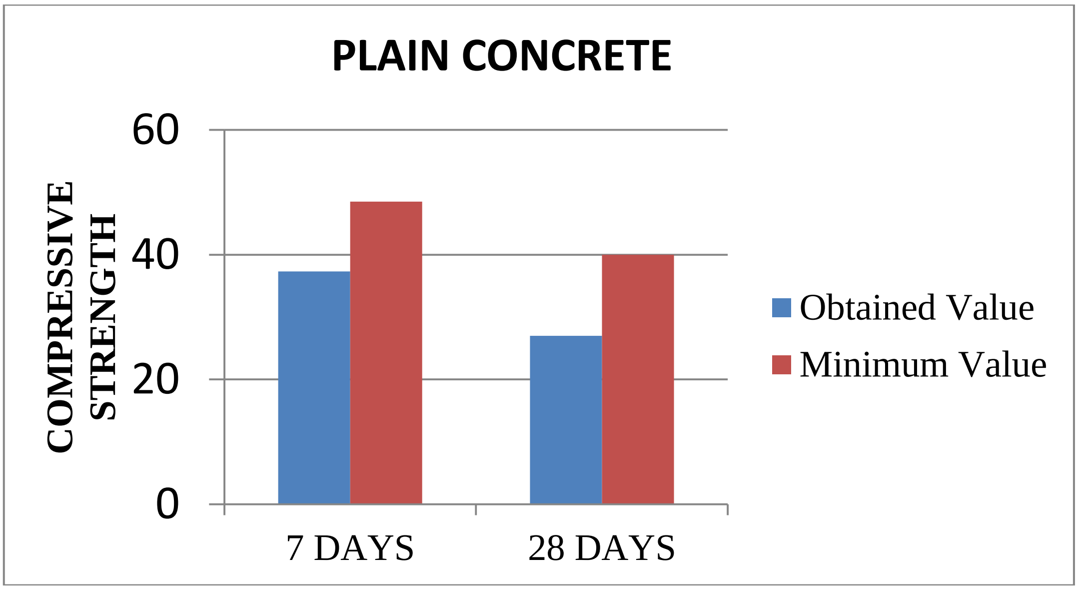

Figure 4.1: Compressive strength of Plain concrete

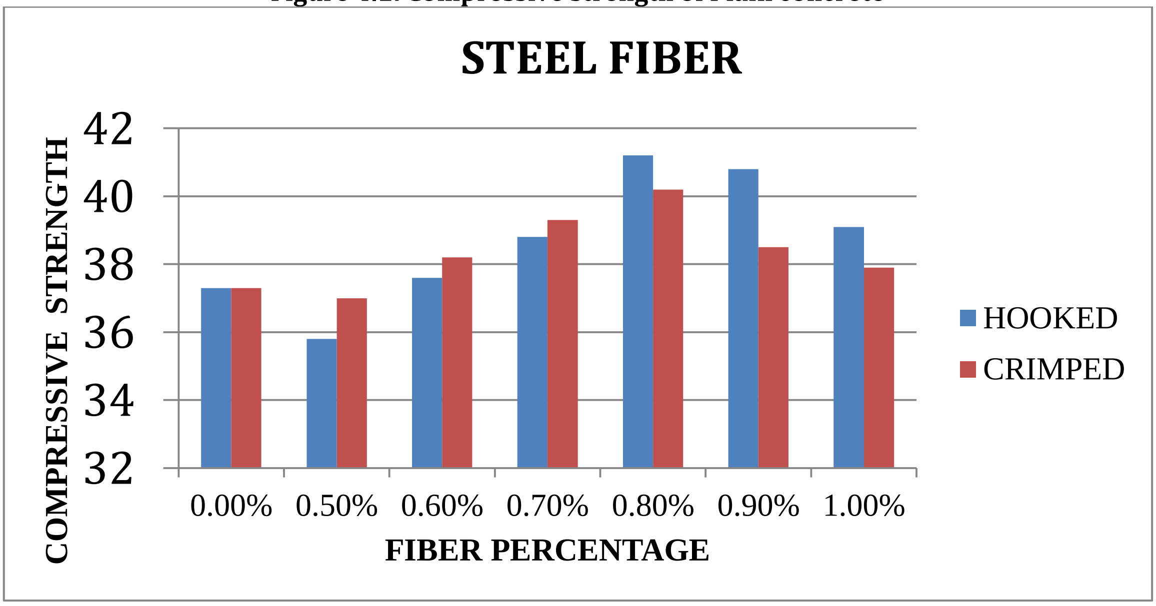

Figure 4.2: Compressive strength of steel

6.2 Compressive strength result for Polypropylene

From the same study, it was concluded that by adding a volumetric ratio of polypropylene fiber up to 0.20% can increase concrete compressive strength by 2.5%. Nevertheless, 0.30% to 0.50% volumetric ratio will decrease the compressive strength by 1.5% and 13% respectively.

Sr. No.	Name of the Concrete	No. of days		Name
		7 days	28 days	
1.	Minimum Reinforcement	27	40	B1-MS
2.	Hooked Steel	41.20	-	B2-HS
3.	Crimped Steel	40.20	-	B3-CS
4.	Crimped Polypropylene	37.43	49.76	B4-CPP
5.	No Reinforcement	37.30	48.50	B5-NS

Table 4.3 Higher Compressive strength values of different concrete

6.3 Tensile Strength Test Results

Sr. No.	DAYS	Plain concrete
1.	7 days	3.18
2.	28 days	5.41

Table 4.4 Effect of Concrete on Tensile Strength

7. CONCLUSIONS

Based on the experimental investigation carried out, the following conclusions are made:

1. Maximum compressive strength of SFRC at Hooked steel is 41.20Mpa achieved at 0.8% adding of concrete by steel fibers (M40 grade) at 7 days. When compared to normal standard concrete 27Mpa, it increases by 52%

2. Maximum compressive strength of PPRC is 49.76Mpa achieved at 0.20% adding of concrete by polypropylene fibers (M40 grade) at 28 days. When compared to normal standard concrete 40Mpa, it increases by 24.4%

3. Maximum tensile strength of SFRC at Hooked steel is 5.42Mpa achieved at 0.8% adding of concrete by steel fibers (M40 grade) at 7 days. When compared to normal standard concrete 3.18Mpa, it increases by 70%

4. Maximum tensile strength of PPRC is 8.35Mpa achieved at 0.20% adding of concrete by polypropylene fibers (M40 grade) at 28 days. When compared to normal standard concrete 5.41Mpa, it increases by 54%

5. Compressive strength of HFRC is 59.65Mpa is achieved at (0.8%Steel & 0.2% Polypropylene) adding of concrete (M40 grade) when compared to normal concrete it increases by 49%. when compared to SFRC it increases by 45% at 7 days when compared to PPRC it increases by 20%

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