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Experimental Investigation on Hybrid Fibre Reinforced Concrete

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Abstract – In the past, attempts have been made to impart improvement in inherent tensile strength of concrete members by way of using different type of fibres in concrete. The addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its strength parameters. This type of concrete is known as fibre reinforced concrete. Each type of fibre has its characteristic properties and limitations. However, the use of two or more types of fibres in a suitable combination may potentially improve the overall properties of concrete. This type of concrete can be called as Hybrid Fibre Reinforced Concrete. In this investigation work, 1% of combination of steel fibre and polypropylene fibre added to M30 grade of concrete. Hybridization of steel and polypropylene fibres have been done in various proportions (1%, 0%), (0.8%, 0.2%), (0.6%, 0.4%), (0.4%, 0.6%), (0.2%, 0.8%), and (0%, 1%). Experiments were conducted to study the effect of steel fibre and polypropylene fibre in different proportions in hardened concrete. Compressive strength tests on cubes, split tensile strength tests on cylinders, and flexural strength tests on prisms were carried out to study the properties of hardened concrete.

Index Terms – Hybrid Fibre Reinforced Concrete**,** Compressive strength**,** Split tensile strength**,** Flexural strength**.**

1. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementations materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with ordinary Portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Cement mortar and concrete made with Portland cement is a kind of most commonly used construction material in the world. These materials have inherently brittle nature and have some dramatic disadvantages such as poor deformability and weak crack resistance in the practical usage. Also their tensile strength and flexural strength is relatively low compared to their compressive strength. Fiber Reinforced Concrete is concrete containing fibrous material which increases its structural integrity. The fiber can make the failure mode more ductile by increasing its tensile strength of concrete. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers each of which lend varying properties to the concrete. In addition, the character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. In a hybrid, two or more different types of fibers are rationally combined to produce a composite that derives benefits from each of the individual fibers and exhibits a synergistic response.

Fiber Reinforced Concrete (FRC)

Fiber reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinues, discrete, uniformly dispersed suitable fibers. And fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat the fiber is often described by the parameter aspect ratio which is ratio of fiber length to its diameter. Typical aspect ratio varies from 20 to 150.

Types of Fibre Reinforced Concrete:

1) Steel Fibre Reinforced Concrete.
2) Polypropylene Fibre Reinforced Concrete.
3) Glass Fibre Reinforced Concrete.
4) Carbon Fibre Reinforced Concrete.
5) Nylon Fibre Reinforced Concrete.

Basically fibers can be divided into following two groups

(i) Fibers whose moduli are lower than the cement matrix such as cellulose, nylon, polypropylene etc.

(ii) Fibers with higher moduli than the cement such as asbestos, glass, steel etc.

Fibers having lower modulus of elasticity are expected to enhance strain performance whereas fibers having higher modulus of elasticity are expected to enhance the strength performance. Moreover, the addition of hybrid fibers makes the concrete more homogeneous and isotropic and therefore it is transformed from brittle to more ductile material.

Hybrid Fiber Reinforced Concrete (HFRC)

The usefulness of hybrid fiber reinforced concrete in various Civil Engineering applications is thus indisputable. Hence this study explores the feasibility of hybrid fiber reinforcement with a given grade of concrete. Hybrid Fiber Reinforced Concrete (HFRC) is formed from a combination of different types of fibers, which differ in material properties, remain bonded together when added in concrete and retain their identities and properties. The hybridization of fibers provides improved specific or synergistic characteristics not obtainable by any of the original fiber acting alone.

Hybrid fiber reinforced concrete is use of two or more than two fibers in a single concrete matrix to improve overall properties of concrete. In well-designed hybrid composites, there is positive interaction between the fibers and the resulting hybrid performance exceeds the sum of individual fiber performances.

As a research work on FRC has established that addition of various types of fibers such as metallic (steel) and non- metallic fibers (glass, synthetic, natural and carbon) in plain concrete improves strength, toughness, ductility, post- cracking resistance, etc. For optimal result therefore different types of fibers may be combined and the resulting composite is known as hybrid-fiber reinforced concrete in this experiment steel fiber (Hook end) and polypropylene fiber have been tried.

Application of Hybrid Fibre Reinforced Concrete

HFRC can be used in any kind of construction because of its unique Properties and also as it very easy to obtain high range of strength values.

Some of the pioneering applications are as follows

- Bridges.
- Tunnel linings.
- Building components like column.
- Sandwich structure like steel concrete structure.
- Industrial flooring.
- Machine foundation.

2. LITERATURE REVIEW

Vikranth S.(2012) worked on experimental studies on fibre combinations in reinforced concrete which demonstrate the maximum compressive strength and split tensile strength of hardened concrete in which the results shows that both compressive strength and tensile strength are of HFRC is greater than the conventional concrete. He conclude that the study on the effect of hybrid fibres with different proportions can still be a promising work as there is always a need to overcome the problem of brittleness of concrete.

M.D Koli(2013) worked on the flexural behavior of hybrid fibre reinforced concrete beams in which he used combination of polypropylene fibres and steel fibres with different proportions with aspect ratio of 30 and 50, and reinforced concrete beam of M-25 grade concrete were casted and tested under UTM. He concluded that beam having same percentage of fibres shows better results for aspect ratio 30 than aspect ratio 50 and also concluded that the load carrying capacity of beam specimen is increasing at a constant rate for increase in fibre percentage upto 1 percent.

Selina Ruby G., Geethanjali C. (2014) are worked on influence of hybrid fibres on reinforced concrete of grade of M-40 and conducted tests to find the strength parameters of concrete cubes and concluded that HFRC performed good over normal conventional concrete. Different proportions of steel and polypropylene fibres are used and test data of samples are interpretated one over other. They also concluded that the Combination of 75% of steel fibres and 25% of polypropylene are gave maximum compressive strength over other proportions because of high elastic modulus of steel fibres and low elastic modulus of polypropylene fibres.

R.H Mahankar (2016) worked on mechanical performance of hybrid fibre reinforced concrete of grade M-20 with combination of steel and polypropylene fibres in which compressive strength and flexural strengths of concrete cubes are tested and concluded that combination of steel and polypropylene fibres with proportion 1% are gave better results than the other proportions like 0.25%, 0.50%, 0.75%. They also concluded that HFRC results in reduction of secondary reinforcement at some level and make structure economical.

3. MATERIAL PROPERTIES AND MIX DESIGN

Materials used

In this experimental study, Cement, Fly ash, Fine aggregate, Coarse aggregate, Water, Steel fibre, and Polypropylene fibres were used. Various tests on Cement and Aggregates were done as per IS Standards.

Binder (Cement + Fly Ash)

In this experimental study, 30% fly ash is used as replacement by the weight of cement. Therefore mixer of 70 percent of Cement and 30 percent of Fly ash is called as Binder material.

Binder = 70% Cement + 30% Fly ash

Cement: Ordinary Portland cement of 53 grade was used in this experimentation confirming to IS-12269:1987.

Table 1. Physical properties of cement

S. No.	Property	Test method	Test result
1.	Normal consistency	vi-cat apparatus	31%
2.	Initial setting time and final setting time	vi-cat apparatus	32 minutes and 180 minutes
3.	Specific gravity	Sp. Gr. Bottle	3.15
4.	Fineness	Sieve analysis	1.5%
5.	Soundness	Le-chatlier apparatus	2mm
6.	Compressive strength	Compressive test	55.3 N/mm²

Fly Ash: Class-F Fly-Ash is used which has Specific gravity of 2.2 and fineness of 280 m²/Kg.

Fine aggregate

In the present examination fine aggregate is regular sand (Zone-II) from nearby market is utilized.

Table 2. Physical properties of fine aggregate

S. No.	Property	Test method	Test result
1.	Specific gravity	Pycnometer	2.28
2.	Bulking	Bulking of sand test	1.91%
3.	Fineness modulus	Sieve analysis	2.73

Coarse aggregate

The pulverized coarse total of 20 mm greatest size adjusted acquired from the neighborhood squashing plant. Gradation of the aggregates was done confirming to IS 383 (1970).

Table 3. Physical properties of coarse aggregates

S. No.	Property	Test method	Test result
1.	Specific gravity	Pycnometer	2.79
2.	Bulking	Bulking of sand test	4%
3.	Fineness modulus	Sieve analysis	3.61

Chemical admixture

In the present study, super plasticizer (Master glenium) is used as chemical admixture, which permit the reduction of water to extent up to 30 percent without reducing workability in contrast to the possible reduction up to 15 percent in case of plasticizers.

Fibres

In the present study, steel fibre (hook end) and polypropylene fibre are taken in various proportions. 1% of fibres to the total weight of the binder are taken in various proportions.

Table 4. physical properties of steel and polypropylene fibres

Specification	Steel fibres	Polypropylene fibres
Length in mm	30	40
Diameter in mm	0.5	0.1
Aspect ratio	60	400

Specific gravity	6.5	0.9

Water

This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete , should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

Concrete Mix Proportions

Concrete for M30 grade were prepared as per IS 10262:2009 with W/B ratio 0.47. Mix proportion for M30 grade of concrete for tested materials as fallows

4. EXPERIMENTAL

INVESTIGATON Mixing of

Concrete

The coarse aggregate and fine aggregate were weighed and the concrete mixture was prepared by mechanical mixing. Cement and fine aggregates are mixed thoroughly until a uniform colour is obtained, to this mixture coarse aggregate was added and mixed thoroughly. Then water and super plasticizer is added carefully making sure no water is lost during mixing. While adding water care should be taken to add it in stages so as to prevent bleeding which may affect the strength formation of concrete rising of water required for hydration to the surface. While mixing the concrete, fibres should be added to the concrete. Fibres are taken in various proportions should be weighed carefully.

In pylene fibres had done in various proportions and they named as fallows

HFRC(P1 SO), HFRC(P0.8 S0.2), HFRC(P0.6 S0.4), HFRC(P0.4 S0.6), HFRC(P0.2 S0.8), and HFRC(P0 S1).

For this various proportions of fibres concrete mixing should be done.

Casting of Specimens

In the present study, M30 grade of concrete specimens are casted with help of pre oiled standard iron moulds of different shapes like cubes, cylinders, and prisms. List of number of specimens casted are given below.

Curing of Specimens

The solid samples were restored utilizing until when their compressive qualities were resolved at ages 3,7 and 28 days.

Testing of Specimens

Compressive Strength Test

Compressive strength is the capacity of a material or structure to withstand axial loads tending to reduce the size. It is measured using the Universal Testing machine. Concrete can be made to have high compressive strength, e.g. many concrete structures have compressive strengths in excess of 50 MPa. Here the compressive strength of concrete cubes for the plain concrete and fiber reinforced concrete are found out using Compression testing machine. Three cubes were cast for each percentage of fibers and the average of the three compressive strength values was taken.

Split Tensile Strength test

Tensile strength is the capacity of a material or structure to withstand tension. It is measured on concrete cylinders of standard dimensions using a Universal Testing machine. Both conventional and fiber reinforced specimens were tested at varying percentages of fiber and the average value was obtained.

Flexural Strength test

Flexural strength of concrete is considered as an index of tensile strength of concrete. Tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Beam tests are conducted to determine flexural strength of concrete. In flexural tests on beam theoretical maximum tensile strength is obtained at bottom of beam and is called modulus of rupture, which depends on dimension of beam and position of loading.

5. DISCUSSION OF TEST RESULTS

Table 6. Compressive Strength of Concrete in N/mm^2

Mix Id	3 Days	7 Days	28 Days
Conventional	18.67	25.34	37
(S0 P1)	18.33	27.16	39.16
(S0.2 P0.8)	20.66	29.17	41.5
(S0.4 P0.6)	19.16	29.33	42.17
(S0.6 P0.4)	21.16	31.34	45.17

(S0.8 P0.2)	25.34	35	49.66
(S1 P0)	19.50	29.34	42.16

Split Tensile strength of concrete in N/mm^2

Mix Id	3 Days	7 Days	28 Days
Conventional	1.80	2.38	3.40
(S0 P1)	2.99	3.64	4.39
(S0.2 P0.8)	3.18	3.78	4.50
(S0.4 P0.6)	3.66	4.06	4.96
(S0.6 P0.4)	3.92	4.23	5.84
(S0.8 P0.2)	4.32	5.15	6.16

6. CONCLUSION

The study on the effect of hybrid fibers with different proportions can still be a promising work as there is always a need to overcome the problem of brittleness of concrete.

Compressive strength, tensile strength, and flexural strength values of the HFRC are higher than the normal conventional concrete.

Compressive strength of Mix S0.8 P0.2 is having higher value (49.66 N/mm^2) than the other HFRC mixes and conventional mix.

Tensile strength of Mix S0.8 P0.2 is having higher value (6.16 N/mm^2) than he other HFRC mixes and conventional mix.

Flexural strength of Mix S0.8 P0.2 is having higher value (4.85 N/mm2) than the other HFRC mixes and conventional mix.

Compressive strength, tensile strength and flexural strengths are optimum at Mix S0.8 P0.2.

All Strength parameters are gradually increasing from Mix S0 P1 to Mix S0.8 P0.2 and then it is decreasing at Mix S1 P0

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