HYBRID FIBER REINFORCED CONCRETE USING STEEL AND POLYPROPYLENE FIBERS

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Abstract: Concrete is the most widely used construction material because of its specialty of being cast into any desired shape. But it is well known that conventional concrete does not meet many functional requirements such as tensile strength, resistance to cracking, permeability to liquids, chemical attack, etc. These deficiencies have led the researchers to investigate and develop a suitable material which could perform better in areas where the conventional concrete poses several limitations. The recent development in concrete technology has resulted in the arrival of new products such as High Performance Concrete, Fibre Reinforced Concrete, etc. The main requirements of disaster resistant structures are good ductility and energy absorption capacity. Conventional concrete does not fulfill all the requirements of earthquake resistant structures. Fibre reinforced concrete possesses a high flexural and tensile strength, improved ductility, high energy absorption than the conventional concrete against dynamic loads. Because of the advantages of FRC, it can be used in earthquake resistant structures. When the concrete is reinforced with randomly dispersed fibres it prevents micro cracks from widening. The combination of various types of fibres in a mix results in the formation of hybrid fibre composites. One type of fibre improves the properties of fresh concrete and prevents early shrinkage cracks while the other type of fibre contributes to the improvement of strength and ductility of hardened concrete. The scope of the present study is to investigate the influence of different combination of hybrid fibres. The investigation was carried out on two different types of fibres namely round crimped steel fibres and polypropylene fibres. The mechanical properties such as compressive strength and split tensile strength were investigated in the laboratory tests. The reinforced concrete structural elements have been designed with M20 grade concrete.

***Index Terms* –Steel Fibres, Polypropylene Fibres, Hybrid Fibre Reinforced Concrete (HFRC). Compressive strength, Split tensile strength.**

I. INTRODUCTION

Concrete is a ubiquitous widely used man made construction material in the civil engineering field. It has the largest production of all manmade materials. The consumption is of the order of 25-30 billion tons per year in the world, only next to the total consumption of water. Owing to the specialty of being cast in any shape, it has replaced the old construction techniques of stone and brick masonry. However concrete has many deficiencies such as low tensile strength, low post cracking capacity, brittleness, low ductility and low impact strength.

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete In the past, attempts have been made to impart improvement in tensile properties of concrete members by way of using conventional reinforced steel bars and also by apply ingress training techniques. Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Fiber reinforced concrete are of different types and properties with many advantages. Fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fiber is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150. Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers that character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities. Fibre-reinforcement is mainly used in concrete, but can also be used in normal concrete. Fibre reinforced normal concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations etc) either alone or with hand-tied rebar.

A composite can be termed as hybrid, if two or more types of fibres are rationally combined in a common matrix to produce a composite that drives benefits from each of the individual’s fibres and exhibits a synergetic response. Addition of short discontinuous fibres plays an important role in the improvement of mechanical properties of Concrete. It increases elastic modulus; decreases brittleness controls cracks initiation and its subsequent growth and propagation. Deboning and pull out of the fibre require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the materials to the cyclic and dynamic loads. The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibres were used in concrete, there was a need to find a replacement for the asbestos used in the concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass, and synthetic fibres such as polypropylene fibres were used in concrete, and research in to new fibre reinforced concretes continues today.

II. LITERATURE REVIEW

Navilesh J, (June2016) showed that the brittle mode of failure is changed by the addition of steel fibre & coconut fiber into a more ductile one and such fibres were observed to improve the ductility of the concrete, its post-cracking load carrying capacity, and its energy absorption capacity. Josef Novaka and Alena Kohoutkovaa (2016) carried out experimental work on behavior of HFRC under evaluated temperature and mechanical properties of the concrete composite at ambient and evaluated temperature, concluded that the peak compressive strength at 400°C and 600°C represent 60% and 35%, respectively, of the initial strength, the peak tensile strength 60% and 30%, respectively. The fall is mainly caused by the specimen structure damaged by cracks and increased porosity. K.L. Pickeringa et.al., (2016) reviewed the research that has focused on improving strength, stiffness and impact strength including the effect of moisture and weathering on these properties; long and short term performance was addressed. NFCs now compare favorably with GFRPs in terms of stiffness and cost; values of tensile and impact strength are approaching those for GFRFs. Vikrant S et.al. (June 2011) experimentally showed that the increasing the percentage of steel fiber in Hybrid Combination reduces the slump value. G. Suguna B.E and Mrs. S.Parthiban M.E (2016) carried out experimental work on fibers used in FRC may be of different materials like steel, carbon, glass, polypropylene etc. The addition of these fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and impact strength of concrete in the mix proportions of 0.5% of use of M25and M30 grade of concrete.

From the above literature survey work it can be seen that no work is carried out on the behavior of concrete with hybridization of fibers using steel and polypropylene fibers. Hence the present experimental program is planned to conduct the study on behavior of hybrid fibers in concrete at different dosages.

III. OBJECTIVES OF THE EXPERIMENTAL WORK

3.1 OBJECTIVES

The following are the objectives of the present experimental work:

1. To study the behavior of steel and polypropylene fibers in fresh state by conducting slump and compaction factor tests.
2. To evaluate the compressive strength of FRC and HFRC with steel and polypropylene fibers in different dosages (0.5% and 1.5% by volume) cured at 28 days.
3. To evaluate the split tensile strength of FRC and HFRC with steel and polypropylene fibers in different dosages (0.5% and 1.5% by volume) cured at 28 days.
4. To decide the optimum dosage of steel and polypropylene fibers in FRC.
5. To decide the optimum dosage of steel and polypropylene fibers in HFRC.

3.2 EXPERIMENTAL PROGRAM

To achieve the specified objectives of the present work, an experimental program was planned and the same is presented in Table 3.1. In the experimental program total 7 mixes are prepared with steel fiber and polypropylene fiber. The mix design for all mixes is taken as M20 grade concrete. The research program as planned two strength of compressive and split tensile strengths. For compressive strength test cubes and for other test cylinder specimens are cast. Numbers of samples for the tests are stated in Table 3.1.

Table 3.1: Experimental program

Mix designation	Polypropylene fiber in(%) by volume of mould	Steel Fiber In(%) by volume of mould	Cubes casted to evaluate the compressive strength (150x150x150 mm)	Cylinders casted to evaluate the split tensile strength (150mm dia and 300 height)
			28 days	28 days
M0	0	0	3	3
M1	0.5%	0	3	3
M2	0	0.5%	3	3
M3	1.5%	0	3	3
M4	0	1.5%	3	3
M5	0.25%	0.25%	3	3
M6	0.75%	0.75%	3	3

3.3 MIX DESIGNATION

3.3.1 WITHOUT FIBER

1. *M0:* Where M0 refers to control concrete without addition of polypropylene fibers and steel fibre.
2. *M1:* Where M1 refers to addition of 0.5% of polypropylene fiber.
3. *M2:* Where M2 refers addition of 0.5% of steel fiber.
4. *M3:* Where M3 refers to addition of 1.5% of polypropylene fiber.
5. *M4:* Where M4 refers to addition of 1.5% of steel fiber.
6. *M5:* Where M5 refers to addition of 0.25% of polypropylene fibers and 0.25 of steel fibre.
7. *M6:* Where M6 refers to addition of 0.75% of polypropylene fibers and 0.75% of steel fibre.

IV. MATERIALS AND METHODOLOGY

4.1 MATERIALS

The following materials are used in the present work:

Cement: 43 grade ordinary Portland cement (OPC) was used in this experimentation program with specific gravity 3.01 and conforming to IS: 8112-1989.

Fine aggregate: Locally available river sand was used in this experimentation program with specific gravity 2.8 and belongs to zone II of IS: 383-1970.

Coarse Aggregate: Crushed angular aggregates of specific gravity 2.7 was used. The water absorption was 0.6%.

Water: Water which is free from acids, oils, alkalis and other impurities was used.

Steel fibres: In the present work flat crimped steel fibres of length 50mm were used. The aspect ratio of fibres is 50. Steel fibres were obtained from Ryan International Pune.

Polypropylene fibres: In the present work, macro polypropylene fibres of length 50mm were used. The aspect ratio of fibres is 50. Steel fibres were obtained from S K Marketing, Dharwad.

4.2 METHODOLOGY

The mix design procedure adopted in the present work to obtain M20 grade concrete is accordance with IS: 10262-2009. The obtained mix proportion was 1:2.36:2.89. The w/c ratio was 0.55. The dry components are blend and water added slowly unless the concrete is achievable. The mix should not be to sloppy are too stiff. It is difficult to type good test specimen, if it is too stiff. Whether if it is too sloppy, water may just break from the mixture. For casting, all the mould had been cleaned and oiled correctly. They have been securely tightened to proper dimension earlier than casting. Consideration was taken that there is no gaps left, where there is any probability of spillage of slurry, cautions strategy was embraced in the mixing, casting and batching operation. The FA and CA were weighed first. The concrete combination used by hand mixing. FA and cement are mixed thoroughly absolutely except uniform colour is obtained, to this mixture CA was introduced and mixed absolutely. Water is added precisely making definite no water is lost while 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. Mould can be clean first and oiled mould for each and every category used mould is placed on the vibrating machine and stuffed in different 3 layers. These specimens were permitted to stay in the metal mould for the essential for twenty four hours at encompassing circumstance. After that these were demould with consideration all together that no edges were harmed and had been set in the tank at the surrounding temperature for curing is required.

The cubes of inner dimensions (150X150X150) mm were cast to find out the compression strength of mixes. To evaluate the split tensile strength, cylinders of 150mm diameter with 300mm height were cast. Cement, CA & FA were taken in mix proportions 1:2.36:2.89 which relate to grade concrete is M20. Later the fibres are uniformly mixed as per the weights and mixed thoroughly.

V. TESTS ON CONCRETE

5.1 TESTS ON FRESH CONCRETE

5.1.1 SLUMP TEST

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. Slump cone test basically comprises of a steel mould in sort of frustum of a cone having the interior top dia 10cm, base dia 20cm and 30cm as shown in Fig. 5.1.

5.1.2 COMPACTION FACTOR TEST

Compaction factor test can also be utilized to examine the workability of fresh concrete. Compacting factor experiment is gives a more accurate workability occurs in fresh concrete than slump cone test. Compaction factor test is also known as "drop test".

Compaction factor test is the ratio of the load partly compacted concrete to the burden of fully compacted concrete. The apparatus can be viewed in Fig. 5.1.

5.2 TESTS ON HARDENED CONCRETE

5.2.1 COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material or constitution withstand axial masses tend to reduce the scale. It is measured using of compression testing machine [CTM]. Concrete can be made excessive compressive strength. Both conventional and fiber in concrete specimen were tested at varying percentage of fiber. Compression testing machine as shown in Fig. 5.1.

Compressive force for evaluating, mould dimension (150x150x150)mm. compression testing machine is capacity 3000KN as per Indian standard 516-1959.

5.2.2 SPLIT TENSILE STRENGTH TEST

For conducting the split tensile strength, cylinder specimen of dia 150mm and height 300mm were cast. The spilt tensile test was carried out in 3000KN capacity compression testing machine (Fig. 5.1) as per Indian Standard 5816-1999. The load applied at the uniform rate of 140kg/cm^2 and the failure load is noted.

			
Slump Test	Compaction Factor Test	Compressive Strength Test	Split Tensile Strength Test

Fig 5.1: Tests on Concrete

VI. EXPERIMENTAL RESULTS

6.1 SLUMP AND COMPACTION FACTOR TEST

The slump and compaction factor test results are presented in the Table 6.1. The test results show that as the fibre content and recycled aggregate in the concrete mix increases, the slump and compaction factor values decreases.

TABLE 6.1: SLUMP AND COMPACTION FACTOR VALUES

Sl. No	Mix designation	Slump in mm	Compaction Factor
1	M0	100	0.90
2	M1	95	0.88
3	M2	93	0.86
4	M3	93	0.82
5	M4	90	0.84
6	M5	94	0.84
7	M6	92	0.82

6.2 COMPRESSIVE STRENGTH TEST

The compressive test is conducted on cubes of dimensions 150mm the values of compressive strength for different mixes for 28 days curing is represented in the Table 6.2 and Fig.6.2.

TABLE 6.2: COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

Sl. No	Mix designation	Compressive strength (N/mm^2)
1	M0	27.85
2	M1	28.60
3	M2	28.3
4	M3	28.29
5	M4	28.00
6	M5	29.48
7	M6	30.37

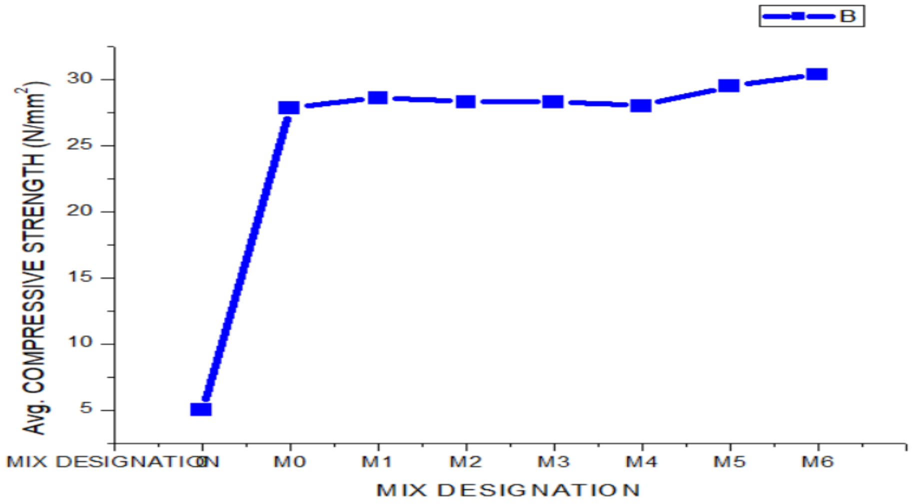

FIG. 6.2: COMPRESSIVE STRENGTH OF CONCRETE FOR 28 DAYS

6.3 SPLIT TENSILE STRENGTH TEST

The split tensile test is conducted on cylinders of dimensions 150mm dia and 300mm height. The values of split tensile strength for different mixes for 28 days curing is represented in the Table 6.3 and Fig 6.3.

TABLE 6.3: SPLIT TENSILE STRENGTH OF CONCRETE FOR 28 DAYS

Sl. No	Mix designation	Split tensile strength (N/mm^2)
1	M0	2.50
2	M1	3.34
3	M2	3.16
4	M3	3.07
5	M4	2.78
6	M5	3.63
7	M6	3.35

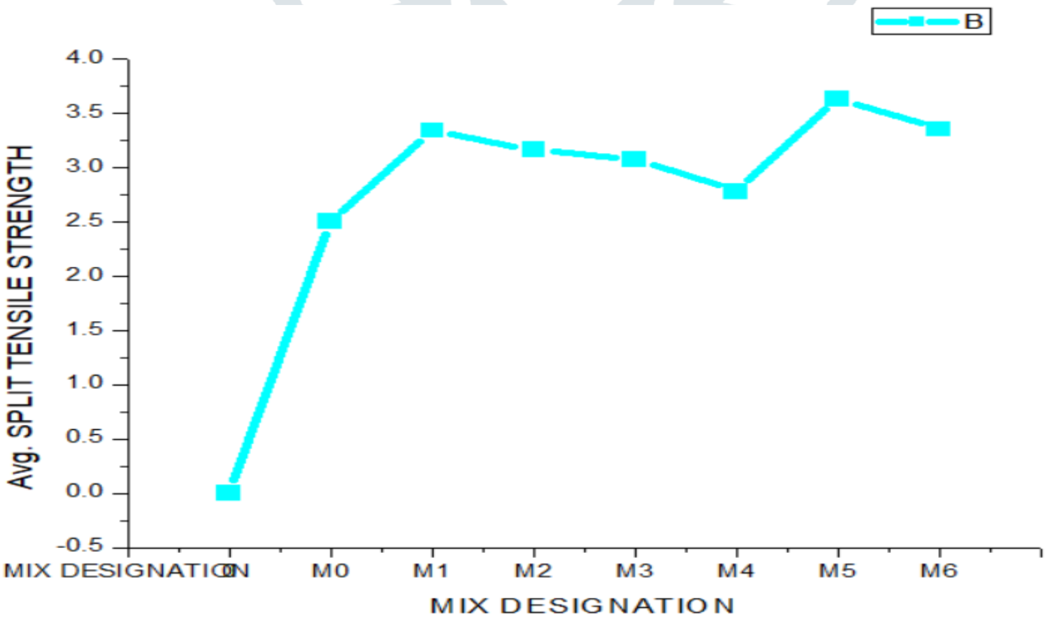

FIG. 6.3: SPLIT TENSILE STRENGTH OF CONCRETE FOR 28 DAYS

VII. OBSERVATIONS AND DISCUSSIONS

In the present work, the effect of fibers in fresh and harden state of concrete is investigated. The following observations were made from the experimental work.

1. The slump of reference mix M0 is 100mm. for FRC and HFRC slump value decrease when composed to reference mix. As the volume of fiber increase, slump value decrease.
2. The compaction factor for reference mix M0 is 0.9 for FRC and HFRC compaction factor decreased when compared to reference mix. As the volume of fiber content increase, compaction factor decrease.
3. For 28 days of curing it is observed that compressive strength without fibers is 27.85 N/mm^2, the compressive strength increased for 0.5% volume of polypropylene fiber and 0.5% volume of steel fiber by 2.7% and 1.62% respectively.
4. For 28 days of curing it is observed that compressive strength without fiber is 27.85 N/mm^2. The compressive strength increased for 1.5% volume of polypropylene fiber and 1.5% volume of steel fiber by 1.6% and 0.54% respectively.
5. For 28 days of curing it is observed that compressive strength without fibers is 27.85 N/mm^2. The compressive strength increased for HFRC with 0.25% volume of polypropylene fiber and 0.25% volume of steel fiber by 9.05%. The compressive strength increased for HFRC with 0.75% volume of polypropylene and 0.75% volume of steel fiber by 5.85%.
6. For 28 days of curing it is observed that split tensile strength of concrete without fibers (reference mix M0) is 2.5 N/mm^2. The split tensile strength increased for 0.5% volume of polypropylene fibers and 0.5% volume of steel fiber by 33.6% and 26.4% respectively.
7. For 28 days of curing it is observed that split tensile strength of concrete without fibers (reference mix M0) is 2.5 N/mm^2. The split tensile strength increase of 1.5% volume of polypropylene fiber and 1.5% steel fiber by 22.8% and 11.2% respectively.
8. For 28 days of curing it is observed the split tensile strength of concrete without fibers (reference mix M0) is 2.5 N/mm^2. The split tensile strength of HFRC mix having 0.25% volume of polypropylene fiber and 0.25% volume of steel fiber is increased by 45.2%.
9. For 28 days of curing it is observed the split tensile strength of concrete without fibers (reference mix M0) is 2.5 N/mm^2. The split tensile strength of HFRC mix having 0.75% volume of polypropylene fiber and 0.75% volume of steel fiber is increased by 34%.
10. The increase in strength may be due to presence of glass fiber and polypropylene fiber in the interfacial transition zone. The steel fiber and polypropylene fibers produced good bond in the matrix of the during applications of loads the stress transfer may takes place in the matrix through fibers also fiber have good adhesive nature so that the concrete do not bond easily, taking more energy to fail.
11. From the thorough inspection of the tested specimen it can be seen that concrete cylinder with fibers do not split into two pieces after attaining the failure load this may be due to the glass and polypropylene fibers may act as bridge between the two fractions.

VIII. CONCLUSIONS

Based on the fresh concrete properties and limited strength tests, the following conclusion can be drawn.

1. The slump value decrease as the % of fiber increase.
2. The compaction factor decrease as the % of fiber increase.
3. In compressive strength increase as the % of glass fiber and polypropylene fiber are added upto 0.5% by volume of mould in the FRC.
4. As the fiber content in the FRC mix is increased beyond 0.5% by volume of mould, the compressive strength decrease but it is more than the reference mix.
5. In HFRC mixes, the increment in compressive strength is more than that of FRC mixes. For higher volume fractions (>0.5% by volume of mould) the compressive strength again decrease.
6. In split tensile strength increase as the % of glass fiber and polypropylene fiber are added upto 0.5% by volume of mould in the FRC.
7. As the fiber content in the FRC mix is increased beyond 0.5% by volume of mould, the split tensile strength decrease but it is more than the reference mix.
8. In HFRC mixes, the increment in compressive strength is more than that of FRC mixes. For higher volume fractions (>0.5% by volume of mould) the split tensile strength again decrease.
9. Hence the optimum dosage of fiber for FRC and HFRC is 0.5% by volume of mould.

REFERENCES

1. C G Konapure and P T Kalyankar, "Experimental study on Effect of Basalt Fiber and Polypropylene Fiber on Hybrid Fiber Reinforced Concrete", (IJCET), Vol. 5, Year 2015, pp. 2787-2790.
2. C Selin Ravikumar and T S Thandavamoorthy,"Glass Fibre Concrete: Investigation on Strength and Fire Resistant Properties", Vol. 9, Issue 3, Sep.-Oct. 2013, pp. 21-25.
3. G. Suguna B E and Mrs. S Parthiban M E, "Experimental and Investigation of Hybrid Fiber Reinforced Concrete", (IJISET), Vol. 3, Issue 5, Year May 2016, pp. 409-414.
4. Geethu Asoka and Dr. SunilaGeorge, "Experimental study on Hybrid Concrete Using Steel and Polypropylene Fiber", Vol. 2, Issue 5, Year 2016, pp. 61-64.
5. H S Jadhav1 and M D Koli, "Flexural behaviour of hybrid fiber reinforced concrete beams", (IJSER), Year
6. Josef Novaka and Alena Kohoutkovaa, "Experimental study on the Fire response of hybrid fiber reinforced concrete to high temperature", Year 2016, pp. 784-790.
7. K Murahari and Rama mohan Rao p, "Effects of Polypropylene fibres on the strength properties of fly ash based concrete", (IJESI), Vol. 2, Issue 5, May-2013, PP.13-19.
8. Kannan s, "Study on strength properties of hybrid fiber reinforced concrete", (IJSER), Vol. 7, Issue 4, April-2016, pp. 61-68.
9. M S Shetty "Text book concrete technology theory and practice".
10. Mr. B BanuBalakrishnaBharath and B Joshna, "Experimental study on strength and durability properties of hybrid fibre reinforced concrete for M25 grade concrete", (IJRER), pp. 231-239.

11. N Banthia and R Gupta, “Hybrid fiber reinforced concrete (HyFRC): fiber synergy in high strength matrices”, Vol. 37, December 2004, pp. 707-716.

12. Navilesh J, Rahul B K, Shankar B K, Shiva Kumar Patil, Vivekananda A and Gutteder, “Experimental study on A Study on Hybrid Fiber Reinforced Concrete”, (IRJET), Vol.4, Issue 6, June 2017, pp. 1647-1656.

13. Prof. S.K.Kulkarni, Mr.Kekade G A and Dr. S A Halkude, “Experimental study on Hybrid Fiber Reinforced Concrete Deep Beams”, (IJCE), Vol. 4, Issue 2, Year February 2017, pp. 33-39.

14. R T Annavahini and Dr. S Christian Johnson, “Experimental Investigation on Hybrid Fibre Reinforced Concrete”, (IJIRS), Vol. 6, Issue 6, June 2017, pp. 12043-12054.

15. R Bhoopathi, M Ramesh and Deepa B, “Experimental study on fabrication and property evaluation of Banana-Hemp-Glass fiber reinforced composites”, (GCMM), Year 2014, pp. 2032-2041.

16. S Taner yildirima, Cevdet E ekincib and Fehim Findikc, “Experimental study on properties of HFRC under repeated impact loads”, (RJNT), Vol. 46, Issue 7, Year 2010, pp. 82-92.

17. SmitModi, Akshil Shah, Disha Parmar and Urvi Rathod, “Compressive Strength of Hybrid Fiber Reinforced Concrete”, (IJIERE), Vol. 3, Issue 5, Year 2016, pp. 92-94.

18. Surinder pal singh, “Experimental study on Fatigue Strength of Hybrid Steel-Polypropylene Fibrous Concrete Beams in Flexure”, Vol. 14, Year 2011, pp. 2446-2452.

19. T V Chandrasekhar, G. Senthil Kumar and S. Manivel, “Study on shear behaviour of steel and polypropylene fiber reinforced concrete beam”, (IJPAM), Vol. 119, Issue 4, Year 2018, pp. 285-290.

20. Vikrant S and Kavita S Kene, “Experimental study on Experimental Investigation on Hybrid Fiber Reinforced Concrete”, (IRJET), Vol. 2, Issue 3, May-Jun 2012, pp.1037-1041.

21. Vineetha V and Arya Aravind, “Mechanical Properties of Hybrid Fibre Reinforced Concrete using Recycled Aggregate”, (IJASRE), Vol. 03, Issue 5, June -2017, pp. 47-56.

22. Xiaofei Guana,Xian Liub, Xin Jiad, Yong Yuanc, Junzhi Cuie, Herbert A and Mangb d, “A stochastic multiscale model for predicting mechanical properties of fiber reinforced concrete”,Vol.56, Year 2015, pp.280–289.

IS CODES USED:

IS-516:1959 - “Method of tests for strength of concrete”.
IS-383:2016 - “Specification for coarse and fine aggregate”.
IS-5816:1999 - “Specification for split tensile test”.
IS-10262:2019- “Mix design”.
IS-456:2000 “Plain and reinforced concrete”
IS-2386 (Part 3):1963- “Methods of test for aggregates for concrete, specific gravity, voids, absorption and buckling”.