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Comparative Analysis of Fibre Reinforced Concrete: A Study on Mechanical and Durability Properties

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***Abstract*— The paper discusses the "fibre-reinforced concrete (FRC) to enhance mechanical strength and crack resistance and durability of the concrete that is brittle in nature and possesses low tensile strength. Polypropylene fibres (FRC) and steel of (1%-0%), (0.75%-0.25%), (0.5%- 0.5%), (0.25%- 0.75%), (0%- 1%) respectively in different proportion were compared-actively analysed to determine the effects on the workability, compressive strength, flexural strength, and split tensile strength at different curing periods and resistance to chemical attack. Discovery has revealed that the character and proportion of the kind of fibre significantly influence the fresh and hardened characteristics of the concrete and steel fibres are superior regarding mechanical strength. Contrast made crack resistance and sustainability in synthetic and natural fibres also better. This paper highlights the reality that FRC can address the structural limitation of the normal concrete. It examined the possibility of using the quarry dust as an alternative to natural river sand in FRC which is eco-friendly considering that quarry dust is a by-product of stone crushing. M40 grade concrete mix was prepared using polypropylene (PP) and steel fibre in 0 to 1 per cent proportions regarding the mass of cement. The project identified the physical and chemical compatibility levels of these fibres with concrete, and identified the workability (slump test), compressive strength, flexural strength, and split tensile strength of such fibres after 14, 28 and 56 days of curing.**

***Keywords*— Fiber Reinforced Concrete (FRC), Steel Fibers, Polypropylene Fibers, Hybrid Fibers, Compressive Strength, Split Tensile Strength, Workability.**

I. INTRODUCTION

Globally, concrete is the most preferred construction material due to its compressive strength and flexibility in addition to relatively low cost. However, blended concrete is linked with several constraints because it lacks tensile strength, ductile, and tends to crack under strain or other circumstances within the environment. These weaknesses reduce its durability and service life in the long term, particularly during the dynamic loading state and under harsh environment and impact conditions.

To contain these weaknesses, fiber-reinforced concrete (FRC) has been put forward. FRC entails a composite construction material in which discrete fiber is evenly dispersed across the cement matrix. The incorporation of fibers helps in controlling the occurrence and dispersion of cracks and therefore improves tensile strength, toughness and impact / shrinkage resistance. The types of fiber that can be used on the concrete are varied and have their own attributes.

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Fiber may be applied to enhance the strength of materials, make them tougher, fibers may be applied to achieve high tensile and improved appearance and synthetic fibers, such as polypropylene or nylon, may be applied to prevent shrinkage and improve ductile behavior, and natural fibers, such as coir or sisal, may be applied using a more sustainable and cost-efficient method and moderate increases in strength. The type, size and volume fraction of the fibers used is as well as a basis of the workability of FRC. Along with mechanical refinements, FRC enhances durability by reducing permeability and increasing freeze-thaw, abrasion, and chemical attack resilience. Nonetheless, the issue of lowered workability and higher cost remains to be the central aspects to be brought up. This paper is an effort to provide a comparative analysis of fiber-reinforced concrete and different types of fiber. The purpose is to evaluate their influences on fresh and hardened properties of concrete which are workability, compressive strength, tensile strength, flexural performance, and durability. The outcomes of this research will provide an idea of the advantages and limitations of the different kinds of fiber and the selection of suitable fiber in diverse structural and construction applications. The most common construction material that is most used in the world is concrete because of its cost efficiency, all round functionality during construction of the building, as well as the massive compressive strength. However, it is brittle in nature and has low tensile strength that leads to premature crack propagation and low ductility, especially when it is subjected to tensile or flex-ural or dynamical body forces.

II. Review of Literature

Sriram M.., et.al. (2021) Hybrid fiber reinforced concrete (HFRC) incorporation of steel and polypropylene fibers is assumed to increase toughness, crack resistance and durability. Steel fibers make it stronger, but poly propylene fibers make it shrink less and augment ductility. The two combined provide greater compressive, flexural and tensile strengths than those of individual fibers and further strengths are obtained using mineral additives. HFRC has a lot of prospects of the pavements, offshore application, and repair, more promising and sustainable with the present construction

K Shyam Prakash et al. (2017) Some studies indicate that partial substitution of natural sand by quarry dust increases the strength of the concrete. Compressive and flexural strengths tend to rise to an optimum after which they start falling. Studies have shown a 25-100 percent improvement (2-4 percent) at a 25-100 percent replacement, and a maximum flexural improvement (17.8 percent) at 50. In another study, 40 per cent replacement was found to be the best level after which the strength starts to diminish.

Aminuddin Jameran et.al (2015). Research on hybrid steel-polypropylene fibre concrete at high temperatures indicates that those mixes with a high proportion of steel do not lose strength post-heating. The 100 percent steel mix retained 47.7 MPa compressive force at 400 C and PP rich mixes lost strength as the fibre melted. The best ratio was a 75:25 ratio of steel to PP, which gave a balance between retaining strength and resistance to cracking. In general, hybrid fibres increase fire resistance, although overly high PP performance reduces at high temperatures.

Tuqa W. Ahmed et.al. (2021) The studies of polypropylene fibre (PPF) reinforced concrete demonstrate enhanced tensile strengths, ductility, resistance to cracks, and wear resistance. The highest content of fibre is approximately 0.3-0.5 percent and the workability becomes low. Although compressive strength values are different, PPF improves flexural and tensile strength, particularly in combination with pozzolanic silica fume. PFP decreases the porosity and compensates material weaknesses in recycled aggregate concrete. The hybrid fibre systems also enhance performance after cracking. All in all, PPF is resistant to corrosion and is affordable and useful in promoting structural integrity in structural workload.

III. Methodology

The research is based on an experimental research design with the purpose of comparing the performance. concrete strengthened with various kinds of fibre. The preparation of concrete is involved in the research. combines with different types and concentrations of fibre, and then tests are conducted to assess new qualities, durability, mechanical strength, and durability.

A. Material Used

- Cement: Ordinary Portland cement of 53 grade was utilized in the study, Ordinary Portland Cement (OPC). It provides high early strength and enhanced durability, which is appropriate to structural concrete. The cement used meets the requirements of the IS 12269:2013, which will allow consistency and strength development.

- Fly Ash: Class fly ash was utilized as a partial substitute of cement to increase the workability, sustainability of the concrete mix, long term strength, and long-term strength. It conforms to IS 3812 (Part 1):2013 and contributes to the reduction of cement usage and also enhances the environmental performance of. concrete.
- Fine Aggregate: Fine Aggregate was taken as fine sand of natural river which was in line with the IS 383:2016. It was fine, well graded and sieved through a 4.75 mm. sieve. The sand has a good workability. and assists in obtaining a thick and bleak mixture that can be used to produce concrete.
- Coarse Aggregate: coarse angular coarse aggregates of 20 mm nominal size were utilized in. accordance with IS 383:2016. These aggregates are stronger and more interlocked. properties, which improves the loading capacity and the performance of the concrete.
- Fibres: The fibrereinforced concrete mixes were prepared using two kinds of fibres, which are steel and polypropylene. Hooked-end steel fibre (3050 mm) enhanced strength and crack. resistance, and polypropylene fibres (12 20 mm) improved ductility and minimised shrinkage. cracks. The fibre contents ranged between 0 and 1 by the weight of cement according to the. experimental design.

B. Mix Design

The concrete mix will be designed for M40 grade as per IS 10262:2019. A control mix (without fibres) will be prepared for comparison. Fibres (PP and SF) will be added in varying proportio TABLE II. COMPRESSION STRENGTH WITH PP, STEEL, FLY ASH (FOR 14, 28,56 DAYS)
ns from 0%, to 1.0%, by volume of cement.

C. Preparation of Specimens

- Mixing: Materials will be mixed in a drum mixer to ensure uniform fibre dispersion.
- Casting: Standard moulds will be used to prepare specimens:
  - Cubes (150 × 150 × 150 mm) for compressive strength.
  - Cylinders (150 mm diameter × 300 mm height) for split tensile strength.
  - Prisms (100 × 100 × 500 mm) for flexural strength.
- Curing: Specimens will be demolded after 24 hours and cured in water for 14,28, and 56 days.

D. Testing Procedures

- Fresh Properties: Slump Test - evaluation of workability
- Mechanical Properties :
  - Compressive Strength Test (IS 516) 14, 28 and 56 days.
  - Split Tensile Strength Examination (IS 5816).
  - Flexural Strength Test (Two point loading method, IS 516).
  - Durability Tests: Water Absorption Test - to test water content

Fig 1: Compressive Strength Test.

Fig 2: Split Tensile Strength

Fig 3: Slump Cone Test Fig 4. Casted Beam of Mixer Mixing as well as Hand mixing

IV. Result and Discussion

A. Compression Strength with Fly Ash and PP (FOR 14, 28 , 56 Days)

The findings strongly show that the incorporation of fibres has a great bearing on the compressive. strength of concrete. The mix of steel fibre-dominant (M7) had the maximum compressive strength. over the entire curing intervals -39.66 N/mm2 at 14 days, 51.73 N/mm2 at 28 days, and 54.67 N/mm2 at 56 days- the better crack-bridging and transfer of the load by fibres of steel. The compressive strength went in direct proportion to the addition of the steel fibre, and polypropylene fibres helped to control crack and ductility. The two mixes illustrated were hybrid. synergistic effects, which are a combination of the benefits of both types of fibre. Therefore, concrete with high amounts of steel fibres. The mix (M6 and M7) has the highest mechanical performance and life than all investigated mixes.

TABLE I: COMPRESSION STRENGTH WITH PP, STEEL, FLY ASH (FOR 14, 28,56 DAYS)

Sr No	Mix ID	Description	Compressive Strength (N/mm²)		
			14 Days	28 Days	56 Days
1	M1	Conventional Concrete	30.06 N/mm²	40.5 N/mm²	43.7 N/mm²
2	M2	Fly Ash Mix (25%)	21.16 N/mm²	35.2 N/mm²	42.8 N/mm²
3	M3	PP 1% – Steel 0%	22.8 N/mm²	35.3 N/mm²	43.2 N/mm²
4	M4	PP 0.75% – Steel 0.25%	23.5 N/mm²	36.7 N/mm²	44.5 N/mm²
5	M5	PP 0.5% – Steel 0.5%	25.4 N/mm²	39.2 N/mm²	50.3 N/mm²
6	M6	PP 0.25% – Steel 0.75%	26.19 N/mm²	39.96 N/mm²	48.6 N/mm²
7	M7	PP 0% – Steel 1%	39.66 N/mm²	51.73 N/mm²	54.67 N/mm²

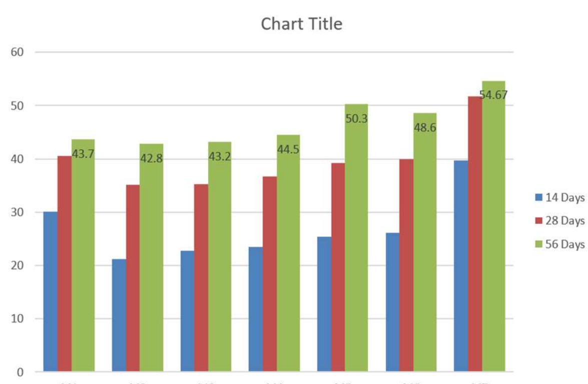

Figure 5. Compressive Strength of various FRC Mixes.

B. Compression Strength with Fly Ash and PP (For 28 Days)

The findings indicate that fibre content and the split tensile strength of are directly related. concrete. The steel fibre dominating mix (M7) had the maximum tensile strength of 4.85 N/ mm 2. proving the excellence of crack-bridging and bonding ability of steel fibres. Moreover, mixes greener steel fibre content (M5 0M7) had smaller values of water absorption (approximately 4.7 4.8%), which is better at preventing water entering the product and making it more durable. The findings prove that the inclusion. the tensile strength and the tensile strength decree of fibres, more particularly, of steel and encumbrances of steel and other fibres, are promoted by the combination of fibre. concrete strength of concrete, which can give such mixes a more appropriate high-performance structural applications.

TABLE II: SPLIT TENSILE STRENGTH PP, STEEL, FLY ASH (FOR 28 DAYS)

Sr. No.	Mix ID	Description	28 Days
1	M1	Conventional Concrete	3.65
2	M2	Fly Ash Mix (25%)	3.26
3	M3	PP 1% – Steel 0%	3.45
4	M4	PP 0.75% – Steel 0.25%	3.63
5	M5	PP 0.5% – Steel 0.5%	4.14
6	M6	PP 0.25% – Steel 0.75%	4.06
7	M7	PP 0% – Steel 1%	4.85

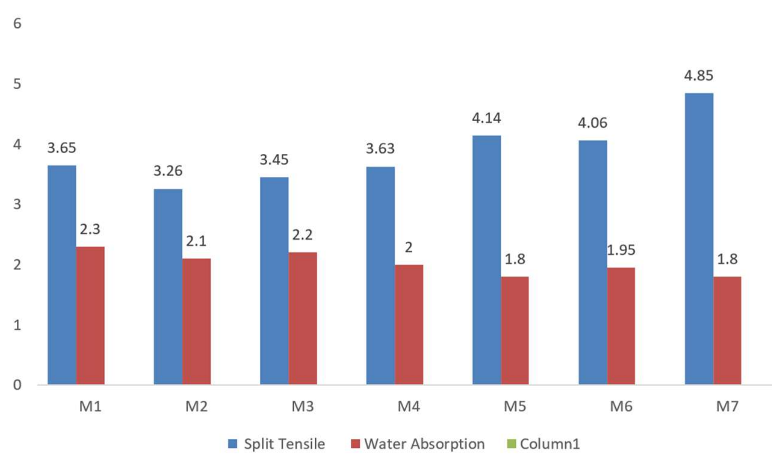

Figure 6: Split Tensile Strength of various FRC Mixes.

C. Slump Cone Test and Water Absorption

TABLE III. SLUMP AND WATER ABSORPTION (28 DAYS)

Sr. No.	Mix ID	Slump (mm)	Water Absorption (%) (28 Days)
1	M1	85	2.35
2	M2	77	2.10
3	M3	80	2.25
4	M4	76	2.00
5	M5	75	1.80
6	M6	72	1.95
7	M7	69	1.88

V. FINDINGS

The results of compressive strength given in Table 01 indicate that an average compressive strength of 28 days of conventional mix (M1) was. 40.5 N/mm 2. The Fly Ash Mix (M2) was weaker at an early age (21.16 N/mm2 14 days) because the reaction of the pozzolans was slower but was 42.8 N/mm2 at 56 days. The mixes of PP fibers mixes (M3) did not significantly impact strength, and the increase in hybrid fiber mixes (M4 -M6) had a positive correlation with the content of steel fibers. M5 (PP 0.5% - Steel 0.5%) was providing a balanced result in 50.3 N/mm2 at 56 days and was giving the best result among all the ages due to the superlative carrying ability and EPS. The same trends can be observed in the findings of the split tensile strength data that is presented in Table 02. Tensile strength of M1 was 3.65 N/mm 2 which was marginally low in M2 (3.26 N/mm 2), PP fiber mixes (M3M4) improved tensile strength to 3.45-3.63 N/mm 2 but hybrid mixes (M5-M6) further improved tensile strength to 4.06 -4.10 N/mm 2. The predominant mix that was 4.85 N/mm 2 was predominantly made of steel fiber (M7) and the slump value in decreses as the % of fibers increses and the value is 69 MM . The absorption of water was also reduced (1.65-1.88%), and it increased through increasing the content of steel, which increased impermeability. Strength and durability are enhanced by the addition of fibers especially steel and hybrid fibers. Mechanical performance, and crack and water penetration resistance of concrete with high steel fiber content have been increased, which makes fiber steel-laden concrete mixes most applicable in the high-strength and durable structural loading.

VI. CONCLUSION

According to the experimental study of fiber-reinforced concrete, the utilization of fiber in reinforcing traditional concrete improves the concrete significantly. Based on the experimental study, it can be concluded that they can be significantly impacted by the addition of fibers to them in terms of their mechanical and durability. M1 provided a reference point of 40.5 N/mm 2 compressive strength at 28 days and 43.7 N/mm 2 compressive strength 56 days. Only mixture polypropylene fibers (M3, M4, M5, M6) was lower in the first age (14 days) but with slow progress that resulted later in ages to the extent of approaching the. Performance of traditional concrete is enhanced by 56 days. These mixes were, however, observed to contain some more water. reduced impermeability otherwise known as absorption. Blending with polypropylene blended with steel fibers (M5 and M6) produced balanced results, compression was high at 56 days (around 50 N/mm2) and the splitting tensile strength was high and water absorption was low in comparison to the pure polypropylene blends. Optimal outcomes were achieved using the predominant mix of steel fiber (M7) that achieved compressive strengths of 51.73 N/mm 2 at 28 days and 54.67 N/mm 2 at 56 days." The maximum split tensile strength of acceptable absorption of water is 4.85 N/mm2 also the workability decreses as the fiber Qty increses and the value comes to 69mm. This disadvantage was compensated by the improvements in workability (particularly in hybrid and steel-rich blends), the increase in strengths, cracks, and life resistance. Typically, the study confirms the fact that concrete that includes steel fiber as a significant constituent offers. high quality of performance and the material can best be applied in high strength and durable constructions.

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