EXPERIMENTAL INVESTIGATIONS ON MECHANICAL PROPERTIES OF SELF COMPACTING CONCRETE USING POLYPROPYLENE AND STEEL FIBERS WITH PULVERIZED SYNTHETIC RUBBER

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Abstract: This research paper shows that the use of steel fibers, polypropylene fibers and rubber powder as a replacement for fine aggregate adds to strength up to fixed percentage, hence promotes their use in SSC. In this study, workability test was performed to check the change in behavior of workability of SSC concrete by addition of steel fibers and rubber powder and polypropylene. With the increasing percentage of fiber workability decreases because more fiber will need more water to lubricate it. The increasing fiber content decreases movement of fibers hence increases workability. Compressive strength test was done for 7 days and 28 days of curing to check the strength of sample cubes in compression and pictures the quality and performance of concrete with compressive strengths. Flexural Strength Test and Split Tensile Strength test were also performed that measures the strength of concrete indirectly at 28 days. Finally, impact test was done and Results of this study depicts that with addition of fibers in SSC rubberized concrete has so many beneficial effects. Apart from that some aspects of concrete are having negative impact. Therefore, it becomes important to decide the usage of these concrete keeping negative properties in limit by other procedures.
Index Terms- Steel fibers, Polypropylene fibers, Rubber powder, Fine aggregate, SSC, Workability, Compressive strengths, Flexural Strength Test, Split Tensile Strength test, impact test.

1. Introduction

Self-Compacting Concrete as its name depicts is that concrete which flows and settles under the impact of its own weight and reaches every corner of form work, no matter how congested reinforcement is present there. SSC is a high performance concrete which flows through complicated sections without bleeding and segregation under its own weight. Fiber-reinforced SSC concrete (FRSCC) is produced from cement, which includes various sizes of aggregates, accompanied with fibers. FRSCC as concrete comprising uniformly directed, distributed fibers. The SCC has a porous appearance, just like any other cement-based stuff. Various kinds of fibers are added to boost the mechanical characteristics and also actions under the effect.

Fibers are added to the concrete in order to manipulate various types of shrinkages cracks in concrete. Moreover, progressive work uncovers that alternative steel fibers builds flexural toughness and power absorption ability to greater extent in concrete, and also ductile conduct previous to the closing failure decreased cracking and progressed sturdiness.

Steel fibre concrete is prepared by adding closely placed and evenly distributed fibers in concrete at different percentage in concrete. Mostly in field application which are tried till date, the fibers in range scale of 0.25-1mm in diameter and from 12 mm and 60 mm in length, and the fiber content ranges from 0.3 to 5 percentages by extent. As explained above, blending metallic fibers improves concrete strength, particularly flexural strength and tensile strength, cracking strength and ductility, impedance to fatigue, sapling and put on and tear of SFRC are higher than a case of traditional reinforced concrete.

The benefits of rubber can be achieved in a Self-compacting concrete by adding it in required proportions in SSC either by replacing it with coarse aggregate of fine aggregate. Since SSC promotes the application of concrete by filling tight voids between the reinforcement and the workforce needed in the process. Polypropylene fibers are new generation chemical fibers. The various types of polypropylene fibers add to mechanical performance of concrete results of which is called fiber reinforced self-compacting concrete. Improvements in performance are attributed to fiber reinforced concrete are tensile, flexural and dynamic strength, ductility etc. The material forms of mostly used fibers are glass, steel, polymer, carbon, asbestos etc.

The efficient exchange of stress between fibers and SSC concrete mix depends on lots of elements. Lots of these factors depend on each other and exercising a deep however complicated effect on the concretes of the composite. By adding steel fibers, decreases its workability. This drastically impacts the condensation of clean blend. Even vibrators do not help to compact concrete.

2. Literature Review

Understanding of the applicability of Self compacting concrete having fibers, it is important to review the experimental data base from previous studies and documentation. Not only the FRSCRC but also the FRSCC and SCRC are used for literature data used for creating the data base. Since little research is done on FRSCRC.

Nahhab et al. (2020) presented investigations on fresh properties like slump flow, density, V- funnel, $T_{50\ cm}$ and L- box height ratio in which hardened properties like compression, oven dry density, flexural strength, drying shrinkage, weight loss and water absorptivity were checked.

Arifa et al. (2019) in this research Self compacting concrete with fibers is presented. Due to addition of fly ash impact on properties of SSC was investigated. In this work 50% of fly ash by weight of cement was replaced and water binder ratio as maintained at 0.38. the properties studied were workability, compressive strength, tensile strength and modulus of elasticity.

Bhaskar et al. (2018) this research presented that self-compacting concrete has ability to flow under its own weight without any type of mechanical vibrations. Four mixes are produced with water cement ratio of 0.45. addition of fibers in ratio of 0.3,0.6,0.9 and 1.2 % with size of 5mm. for fresh state properties L-Box, U-Box, V-Funnel and J-Ring tests were performed on both river sand made samples and manufactured sand made samples.

Gupta et al. (2017) this paper represents comparative analysis of mechanical properties of glass fiber reinforced self-compacting concrete at various contents. The fresh properties of FRSSC and mechanical properties, fracture energy, toughness were studied. Microstructure of various mixes was studied for hydrated structures and development of bond between fiber and mixes was studied using electron microscope.

Fard et al. (2016) presented the impact of combined glass fiber and polypropylene fiber on mechanical and rheological behavior of FRSSC are studied. The results of this research revealed that that combined polypropylene and glass fiber can increase tensile and bending strength. In addition, these additives increase toughness of concrete.

Shukla et al. (2015) Self compacting concrete being a high performance concrete has ability to flow under its own weight through the complicated sections and fills the formwork completely without segregation and does not need any vibrators for consolidation. Three mixes are prepared; control mix, SSC with viscosity modifying admixtures (VMA) and SSC with VMA and glass fibers with water powder ratio of 0.35.

Ragab et al. (2014) presented experiment to select effective content of fiber for SSC. Volume fractions of three hooked steel fibers are taken for study. The volume fractions of these fibers were taken in the fractions of 0%, 0.75% and 1.5 %. To study the effects on tension and bending moments a total of seven beams are casted and test is performed on them and classified in three groups.

Yakhlaf et al. (2010) This research was carried out to investigate the effect of pitch based carbon fibers on fresh properties of self-compacting concrete. Ten mixes of carbon fiber self-compacting concrete (CFSSC) are produced with two different water binder ratios (0.35 & 0.4) & 0, 0.25, 0.5, 0.75 and 1% of carbon fibre as per concrete volume.

3. Methodology

Portland cement with 53 grade is used for production of SSC. Also the addition of steel Fibers PP fibers and rubber powder is done in SSC concrete. Rubber powder is replaced with fine aggregate. Steel fibers and PP fibers are additives in SSC but not a replacement material.

Ultra tech Cement 53 Grade was used in this work. Aggregates of size 10-20 mm are utilized in this study with specific gravity of 2.74. Locally available coarse aggregate is also in use. The Flakey shapes should be avoided. It should be as per IS code 2838. Coarse aggregates for all concrete mixes are used as per IS 456:2000. The gradation of the coarse aggregates was done as specification that Coarse aggregates of 20 mm and 12 mm sizes were used in 60:40 ratios.

The fine aggregate was mostly available locally which was used in this work and passing ability through 4.75 mm sieve. T specific gravity of sand is 2.258. Fines modulus of 2.50-3.50 of sand was found. Silit content below 4% was adjusted and selected. Material gradation analysis was done in laboratory under standard conditions.

To select various mixes confined number of trial mixes was prepared. All of the prepared trial mix design behavior containing fibers and rubber powder were studied thoroughly. Finally, five mixes were selected and studied for further experiments. The names of the finalized mixes are kept CCSF0PF0RP0, SF0.5PF0.4RP5, SF1.0PF0.8RP10, SF1.5PF1.2RP15, and SF2PF1.5RP20 includes conventional mix too. Mix design is made for

M30 grade concrete according Indian standard code 10262-2009. For preparing all the mixes steel fiber, rubber powder and polypropylene fiber was used.

For Compressive strength check 30 cubes of standard size 150x150x150 are prepared. Also 15 beams of size 100x100x500mm are prepared for flexural strength check. For tensile strength check 15 number of 150 mm diameter and 300mm height cylinders are prepared. Also for impact resistance check 15 specimens were selected.

4. Result and Discussions

4.1 Workability Test

Figure 4.1 below shows that with increase in steel fibers, polypropylene fibers and rubber powder, workability of decreases. With the increasing percentage of fiber workability decreases because more fiber will need more water to lubricate it. The increasing fiber content decreases movement of fibers hence increases workability.

Due to addition of rubber powder workability decreases because of the air voids left by rubber in concrete. The rubber particles show surface adsorption of air molecules with is present in fresh concrete. Specific surface area of fine rubber is higher than coarse rubber hence absorbs more air molecules than coarse powdered rubber. The surface of the rubber particles can catch molecules of water too. Also, the fine rubber surface catches more water molecules and decreases the workability to much greater extent.

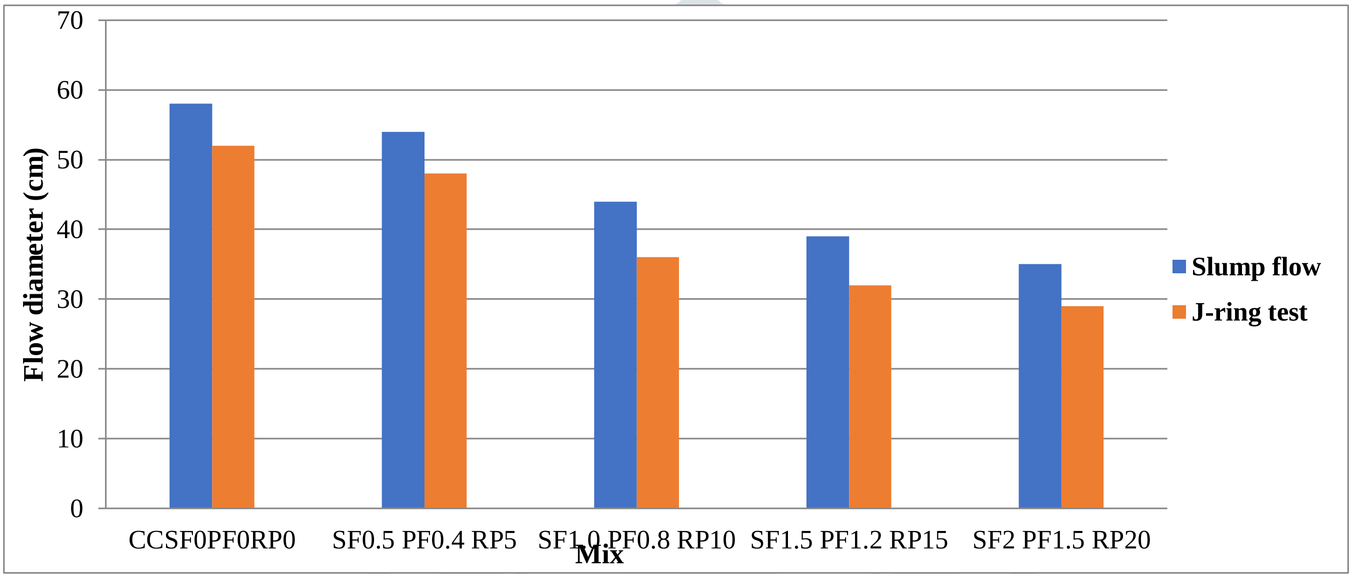

Fig. 4.1: Relationship between Flow Diameter and other Mixes of Fiber Self-Compacted Concrete

4.2 Compressive Strength Test

This test checks the strength of sample cubes in compression and pictures the quality and performance of concrete with compressive strengths. This test is performed in laboratory on compression test machine.

4.2.1 For 7 Days of Curing

It is observed with increasing percentage of steel fibers, polypropylene fibers and rubber powder compressive strength shows increases. With the addition of steel fiber results in increase of compressive strength by fascinating progression of cracks due to established bonding of cement paste and steel fibers. And peak strength value was recorded at 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is 23.53 MPa. Hence 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is the maximum percentage that can be used for achieving maximum strength.

Compared to the plain SCC (CCSF0PF0RP0), the compressive strength at 7 days of SCC reinforced concrete with steel fibers, polypropylene fibers and rubber powder increased by 13.94%.

Table 4.1: Compressive Strength at 7 days

Sample	Compressive Strength, (MPa)
CCSF0PF0RP0	20.65
SF0.5 PF0.4 RP5	22.42
SF1.0 PF0.8 RP10	23.53
SF1.5 PF1.2 RP15	23.36
SF2 PF1.5 RP20	22.18

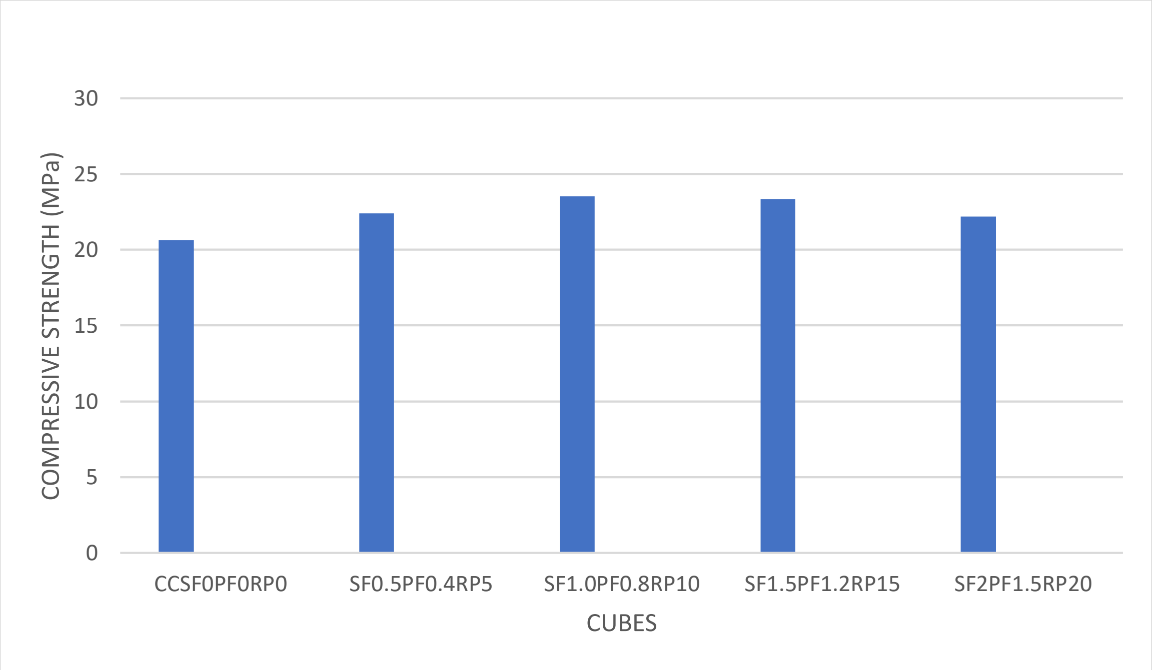

Fig.4.2 Compressive Strength of cubes at 7 days of curing

4.2.3 For 28 Days of Curing

It is observed that with increased percentage of steel fibers, polypropylene fibers and rubber powder compressive strength shows increase. With the addition of steel fiber results in increase of compressive strength by fascinating progression of cracks due to established bond of steel fibers and cement paste. The peak value was measured at 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is 40.83 MPa. Hence 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is the maximum percentage that can be used for achieving maximum strength.

Compared to the plain SCC (CCSF0PF0RP0), the compressive strength of (SF1.0PF0.8RP10) at 28 days of SCC reinforced with steel fibers, polypropylene fibers and rubber powder increased by 25.55%.

Table 4.2: Compressive Strength at 28 days

Sample	Compressive Strength, (MPa)
CCSF0PF0RP0	32.52
SF0.5PF0.4RP5	34.01
SF1.0PF0.8RP10	40.83
SF1.5PF1.2RP15	39.10
SF2PF1.5RP20	32.50

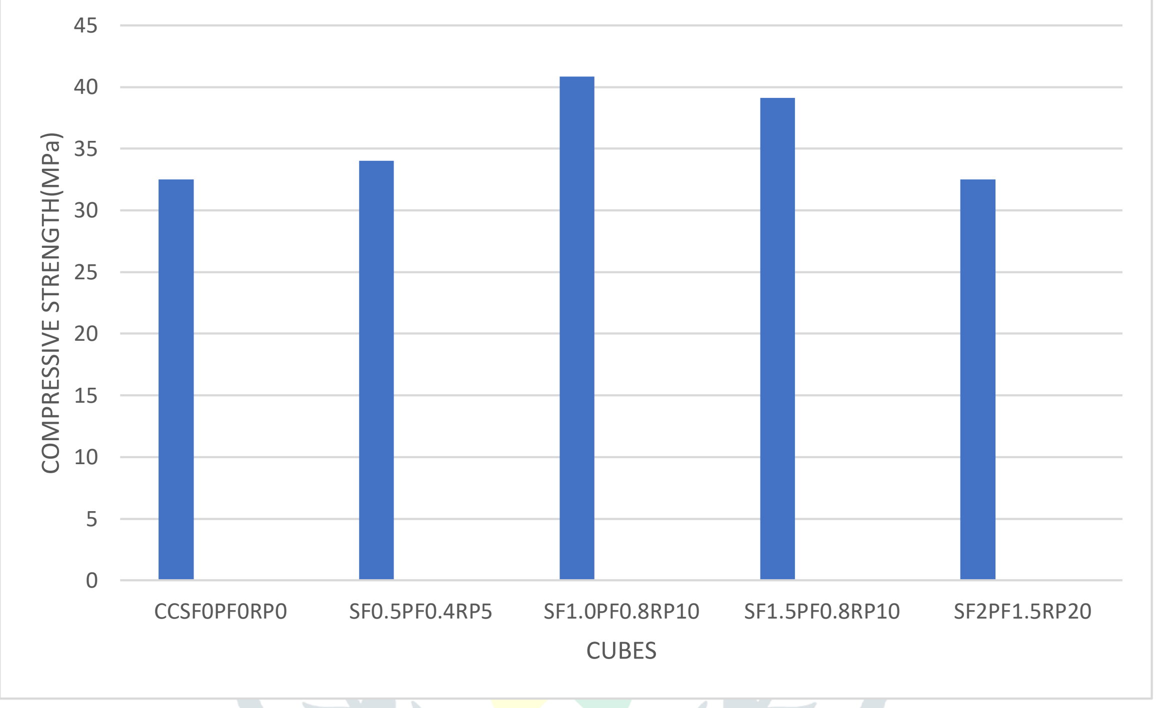

Fig1.3 Compressive strength of cubes at 28 days of curing

4.3 Flexural Strength Test

Results in flexural strength for 28 days are tabulated as under; the flexural strength shows increase as the percentage addition of steel fibers, polypropylene fibers and rubber powder is increased in 28 days testing.

Compared with the plain SCC, the enhanced percentage of the split tensile strength of SCC reinforced with 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder (SF1.0PF0.8RP10) at 7 days was 65.26%.
Peak reading of flexure was measured with 1% of steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is 8.23 MPa. 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is the maximum percentage of that can be used.

Table 4.3: Flexural Strength at 28 days

Sample	Flexural Strength, (MPa)
CCSF0PF0RP0	4.98
SF0.5 PF0.4 RP5	5.25
SF1.0 PF0.8 RP10	8.23
SF1.5 PF1.2 RP15	6.08
SF2 PF1.5 RP20	5.43

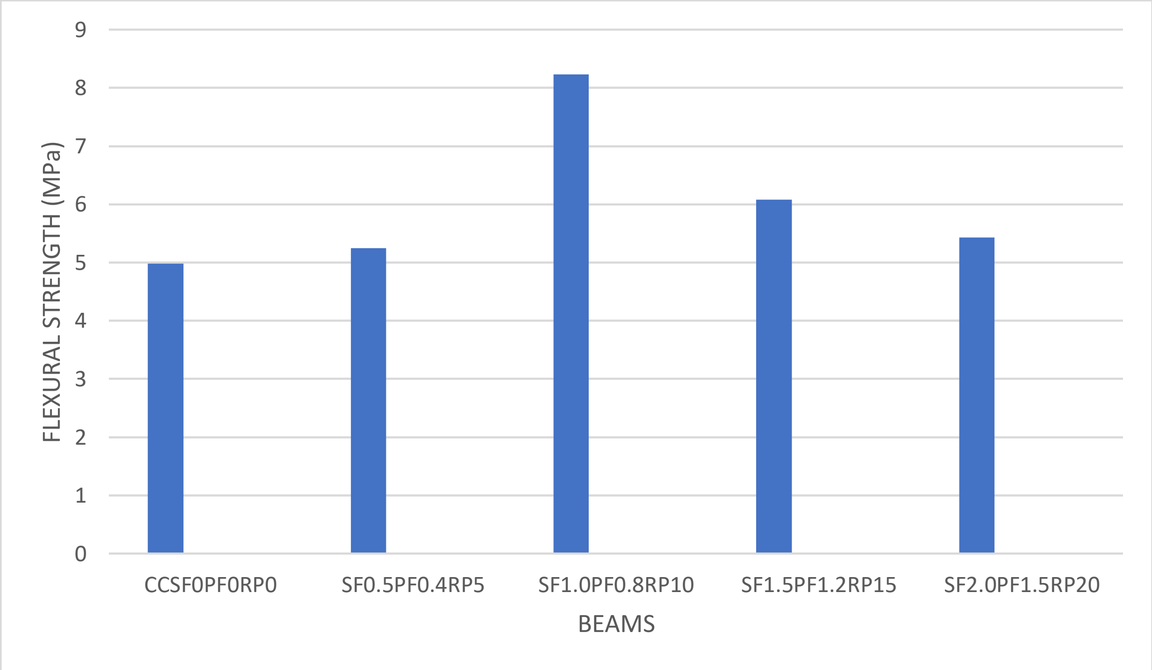

Fig1.4 Flexural strength of Beams at 28 days of curing

4.4 Test for Split Tensile Strength

This test measures the strength of concrete indirectly. Various percentages of steel fiber, polypropylene fibers and rubber powder were used in casting 150mm diameter and 300mm high cylinder. The result of test shows increase in strength at 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder beyond this percentage it shows decrease and observations show strength increase at 28 days' test after proper curing.

The maximum value of split tensile strength at 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is 8.31 MPa. 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is the maximum percentage of that can be used.

Comparing results with the conventional SCC, the increased percentage of the split tensile strength of SCC reinforced with 1% steel fiber, 0.8% polypropylene fibers and 10 % rubber powder (SF1.0PF0.8RP10) at 7 days was 9.77%.

Table 4.4: Split Tensile Strength at 28 days

Sample	Split Tensile Strength, (MPa)
CCSF0PF0RP0	7.57
SF0.5 PF0.4 RP5	7.82
SF1.0 PF0.8 RP10	8.31
SF1.5 PF1.2 RP15	8.26
SF2 PF1.5 RP20	7.76

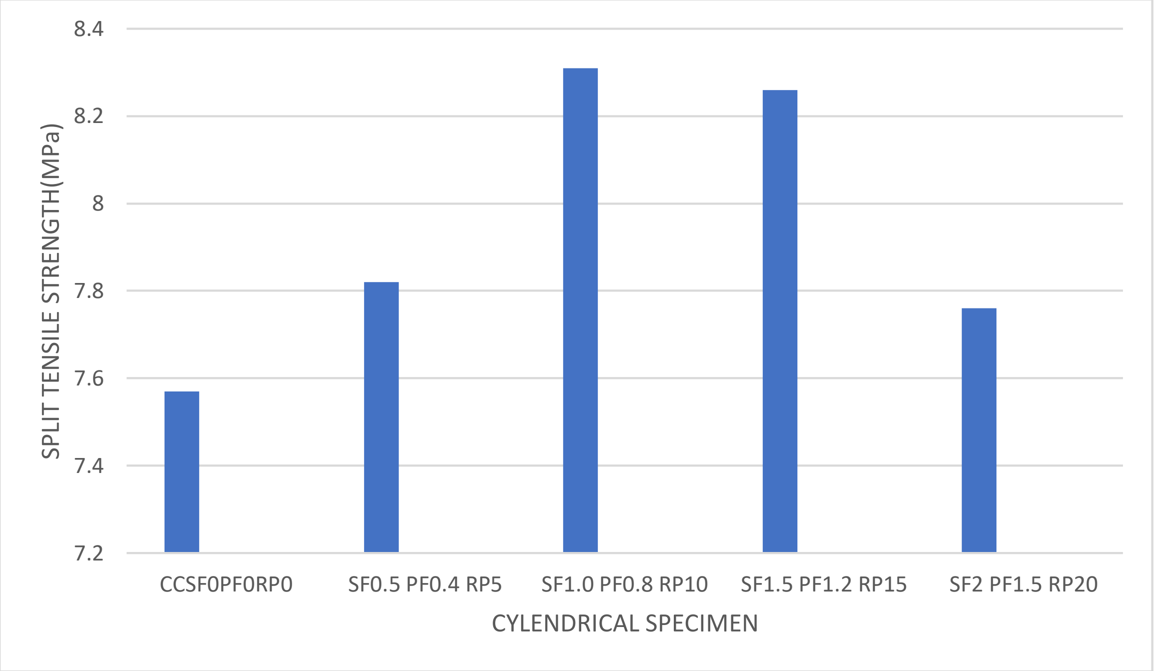

Fig 1.5 Split Tensile Strength of cylindrical specimen at 28 days of curing

4.5 Impact Test

The substitution of fine aggregate with rubber powder shows increase in cracking under the drop load test. Rubber concrete shows quick failure under drop load test. Hence minute rubber particles have little resistance for delaying cracking’s in rubberized fibre reinforced self-compacting concrete. Under the impact all specimens are broken into parts with impact force. Crack visibility was not evident in specimen prior to partition and no displaced rubber was seen in any specimen surface fracture. This could be the attribution of good bonding between fibre and concrete. The crack path develops along fibres but not along surface of particles. The impact strength and number of blows are shown below in table 4.6.

Table 4.5: Impact test results with drop 2m

Sample	No. of blows for first crack	Energy (KN-m)
CCSF0PF0RP0	18	2.1168
SF0.5 PF0.4 RP5	23	2.7048
SF1.0 PF0.8 RP10	29	3.4104
SF1.5 PF1.2 RP15	36	4.2336
SF2 PF1.5 RP20	59	6.9384

5. Conclusion

All the experimental results obtained in above experiments gives us following conclusions.

1. Both steel fibers and polypropylene reduces workability of FRPRSSC but this can be curbed by adding admixtures (SP). The addition of admixtures can surpass the reduced rheological properties of FRPRSSC concrete.
2. All of these fibers have shown positive effect on split tensile strength of this concrete. Addition of steel fibers increases split tensile strength continuously with breaks at higher volumes. Also polypropylene increases the split strength when compared with mixes having no polypropylene up to fixed percentage of PP of 1% and drastically decreases at higher percentages.
3. As depicted from compressive strength both fibers increase this strength than mixes with no fibers up to 1% of fiber content. From that on compressive strength decreases with increasing fibers.
4. 1 % steel fiber, 0.8% polypropylene fibers and 10 % rubber powder is the maximum percentage of that can be used.
5. Resistance to impact to cause fracture of specimen in terms of number of drops shows increase by percentage of 22% and 67% when fibers of steel and polypropylene are used.
6. Results of this study depicts that with addition of fibers in SSC rubberized concrete has so many beneficial effects. Apart from that some aspects of concrete are having negative impact. Therefore, it becomes important to decide the usage of these concrete keeping negative properties in limit by other procedures.

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