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DESIGN OF HIGH STRENGTH CONCRETE BY USING STEEL FIBER REINFORCEMENT

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ABSTRACT- Although it is commonly known that concrete has a high compressive strength, when it is subjected to impact and dynamic stresses, its brittle mode of failure is seen as a disadvantage. This may be avoided by increasing the flexural strength of a brittle matrix by adding fibres, which is a well-known technique. Additionally, the interaction between the fibres and the matrix determines how well the reinforcements work. This study's goal is to figure out how strong fibre reinforced concrete (FRC), which contains variable concentrations of steel fibres, is mechanically. According to the testing technique specified by the Indian Standard, samples of plain and fiber-reinforced concrete that had been curing for 28 days each were used for the compressive strength, split tensile strength, and flexural strength tests. Concrete was mixed with crimped steel fibre in a range of concentrations, including 0%, 1.0%, 1.5%, 2%, 2.5% and 3% with a water-to-cement ratio of 0.42 and an aspect ratio of 50. According to the test results, the (FRC) was efficient under impact loads, increasing impact resistance.

1. **Introduction-** Normal concrete is used extensively due to its benefits, including its low cost and wide availability; however, these benefits are outweighed by its drawbacks, which include low strain capacity, brittleness of concrete. Concrete failure happens after crack development and is influenced by it; for instance, temperature and moisture variations cause tiny cracks to form on the surface of the aggregate, which subsequently spread throughout the body of the concrete through continual loading. As structural engineering has advanced recently, there has been an increase in demand for new concrete kinds with improved qualities. High-strength concrete improves the amount of usable space in storeys and prevents excessively massive columns in lower stories in high-rise buildings. Researchers have been seeking for ways to strengthen high-strength concretes and enhance their behaviour since they are more brittle than regular concrete. Fibres may be classified as typically being made of synthetic, glass, steel and natural materials. Depending on the features

of the kind used, steel fibres may or may not improve the compressive strength, sometimes by as much as 25%. Steel fibre-reinforced concrete (SFRC) are frequently adopted in highway pavements, tunnels, hydraulic structures, airports, bridges and other civil and industrial constructions. Also used in the renovation of old structures is high-strength concrete reinforced with steel fibres. Typically, steel fibres are constructed of stainless steel, which is employed in constructions that call for corrosion-resistant fibres. Tensile strengths can range from 200 to 2600 MPa, while ultimate elongations can range from 5% to 20%. Strong fibres may reduce the efficiency of reinforcing, even if their tensile strength must be substantially greater than that of the matrix.

2. **Literature review**- **Susan Bernal (2010)** explored on the permeability and mechanical characteristics of steel fiber-reinforced alkali activated slag concrete (AASC). When steel fibre was added to AASC, the compressive strength was lower than it would have been with regular concrete. The split tensile strength, flexural behaviour, and rupture modulus of composite concrete were all enhanced. With an increase in fibre volume, significant improvements in load capacity and flexural toughness were made. Fibre inclusion increased durability characteristics including water absorption and permeability. **Erhan Guneyisi (2013)** explored on the impact of steel fibres and their aspect ratio on the binding strength of concrete and steel fibre and concrete became more adherent when the fly ash component of concrete was reduced from 60% to 45%. For cold bonded fly ash concrete, a water-cement ratio of 0.4 and a 400 kg cement content were specified. Steel fibres with hooked ends and various aspect ratios (55, 65, and 80) were used. Steel fibre was used, which increased the binding strength. Bond strength rose with an increase in steel fibre volume fraction (0.30%, 0.70%, 1.0%, and 1.5%). Maximum compressive strength was attained with volume fraction of one percent steel fibre having aspect ratio 65 and fly ash aggregate content of 45%, and maximum split tensile strength at 1.5% volume of steel fibre. The maximum bond strength was produced by steel fibres having aspect ratio of 80. In comparison to steel fibre aspect ratio and fly ash aggregate content, steel fibre volume fraction was an effective metric for bond strength. **Luccioni et.al. (2017)** discussed the steel fibre impact on static and blast tests in heavy construction. A 60 mm long steel fibre with a hooked end was added to 114 MPa concrete. Under static stresses, fibre enhanced toughness and residual loading capacity. Due to the large volume of fibre material (1% in volume), many cracks formed. From the main fracture in a slab, secondary cracks were spreading out. The use of steel fibre considerably improved blast behaviour. The diameters of the spalling zone, the flexural crack width, the erosion zone, and the permanent deflection were all decreased.

3. Methodology- detailed discussion of method adopted for this dissertation was explained. Selection of materials and properties of aggregates were discussed according to Indian Standard code IS: 2386 – 1967 and IS: 383-1970.

a) Fine Aggregates

Aggregates were collected from the local market. Fine sand was in saturated surface dry condition, collected from local market. Different test was performed according to IS: 383 and IS: 2386 on sand and results were tabulated below in Table 3.1.

S.No	*Particulars of test*	*Result*	*Reference*
1	Zone	3	IS:383-1970
2	Specific gravity	*2.63*	IS:2386(Part 3)-1963
3	Water absorption (%)	1	IS:2386(Part 3)-1963

Table.1: Properties of fine aggregate (fine Sand)

b) Coarse Aggregates

Coarse aggregate of 20 mm passing and 10 mm passing crushed granite type aggregates were collected from local market. Different Properties of coarse aggregate were compared with standard value of Indian Standard code and tabulated.

c) Cement

Cement acts as binder in concrete and plays major role towards strength of concrete and its durability. Any type of cement can be used but due to availability, OPC-43 has been used in this study project.

d) Steel fibre

Steel fibre is widely accepted and used in construction industry. Different types of steel fibre having various aspect ratios are used. The Crimped steel fibre with zinc coated was selected for this study and shown in Figure 1.

Fiber type	**Diameter (d_f) mm**	**Length (l_f) mm**	**Aspect ratio (l_f/d_f)**	**Tensile strength (MPa)**
Crimped	0.5	25	50	2670

Figure 1. Steel fiber specification

e) Super plasticizer

Plasticizer is mostly used admixture in infrastructure industry. Different types of super plasticizer with different chemical composition were used. Polycarboxylate ether is used as admixture which is high range water reducing superplasticiser. Polycarboxylate ether was the only super plasticizer that didn't separate or leak as easily as other super plasticizers. The amount of superplastizer in the cement ranged from 0.3% to 1.0%.

f) Gradation of aggregate

Concrete is made from aggregates, which come in a range of sizes. This distinction between coarse aggregate and fine sand particle sizes is known as "gradation." This particle size distribution was established using the sieve analysis. A sample of aggregates must have every standard fraction of aggregate in the necessary proportion for the sample to contain the fewest voids, and proper gradation ensures this.

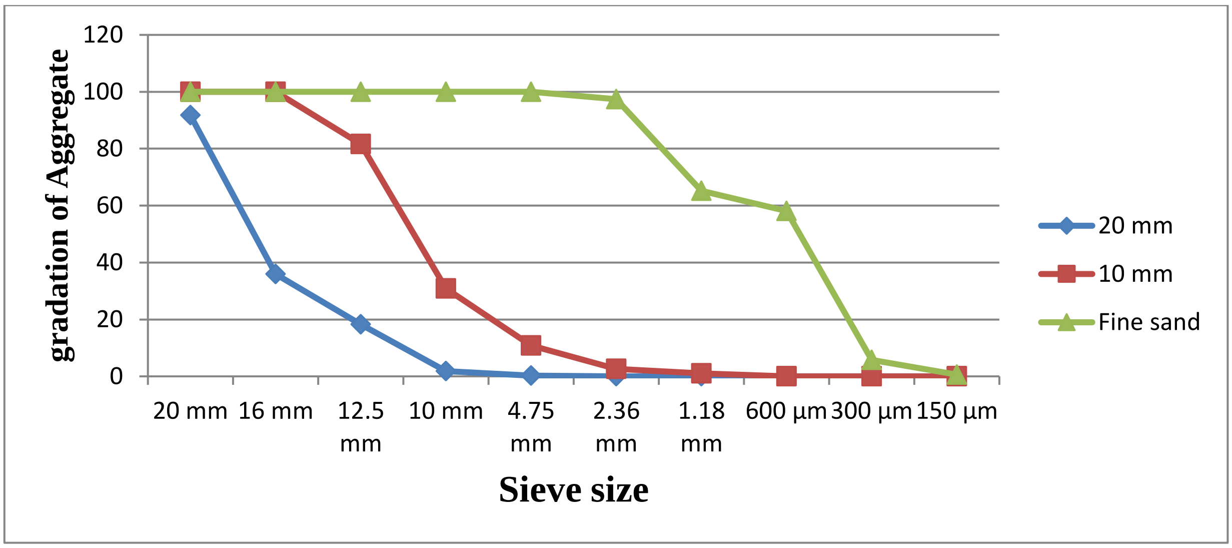

Figure 2. - Aggregate gradation

4. Laboratory Investigations

a) Compressive strength test

After the specimen had been cured, testing was done on it. A compressive strength test is carried out to determine the compressive value. Utilising 2000 KN capacity AIMIL hydraulic testing equipment, the compressive strength test was performed in accordance with the relevant Indian standard code (IS: 516-1959). Three 15 cm x 15 cm x 15 cm cubes were analysed using Indian Standard code. Cube was put to the test using the compressive strength testing equipment. The specimen was loaded without applying any shock, and the load was axially raised steadily at a rate of 140 kg/cm/min until the specimen's capacity to tolerate the increasing stress failed and no further load could be supported. The specimen's maximum load was recorded. Any peculiar characteristics in the type of fracture and specimen's appearance were documented. In N/mm^2 (MPa), the compressive strength value was computed.

Compressive strength value is calculated by formula:

$$\sigma = \frac{f}{A}$$

Where,

σ = Stress of the specimen (N / mm^2)

F = Applied load (in N)

A = Area of specimen (in mm^2)

For each batch 15 cm x 15 cm cube specimens are used to cast. At least three cubes are tested for compressive strength at an interval of 21 days and 28 days. The average results are tabulated in Table 4.2. After 21 days of plain concrete, the compressive strength of casted specimens SF@1%, SF@1.5%, SF@2%, SF@ 2.5% and SF@3%, were 39.16 MPa, 41.95 MPa, 40.9 MPa, 40.2 MPa, and 39.5 MPa (Table 4.2). Similarly, after 28 days of casting, test specimens had strengths of 41.62 MPa, 44.59 MPa, 43.48 MPa, 42.73 MPa, and 41.99 MPa. The third sample achieves maximum strength of 44.59 MPa and 41.95 MPa after 28 and 21 days of casting, respectively.

b) Indirect tensile strength test

An indirect tensile strength test was run on a cylindrical specimen. A hydraulic testing equipment with a 2000 KN capacity was used to perform the indirect tensile strength test in line with Indian Standard code IS: 5816 - 1999.

The hydraulic testing equipment was used to test three cylinders. The diameter of the cylinder could not be less than four times the maximum aggregate size and could not be less than 150 mm, while the length of the specimen could not be greater than twice the diameter and could not be less than the diameter. As a result, a cylinder with dimensions of 150 mm by 300 mm had its splitting tensile strength measured. The specimen was positioned in the machine's centre (see Figure 3). Then, a load was supplied to the test subject without shock, and it was gradually raised over time at a nominal rate between 1.2 and 2.4 N/mm/min. A record was made of the highest load at which the specimen failed.

Figure 3: Testing of a cube on hydraulic testing machine

Results-

a) Compressive strength

According to the experimental results depicted in figure 5.1, the strength varies with varying volumes of steel fibre. stronger fibre volume % yields stronger compressive strength with minor increases. In actuality, 1.5% volume of steel fibre, further addition of fibre causes decrease in compressive strength.

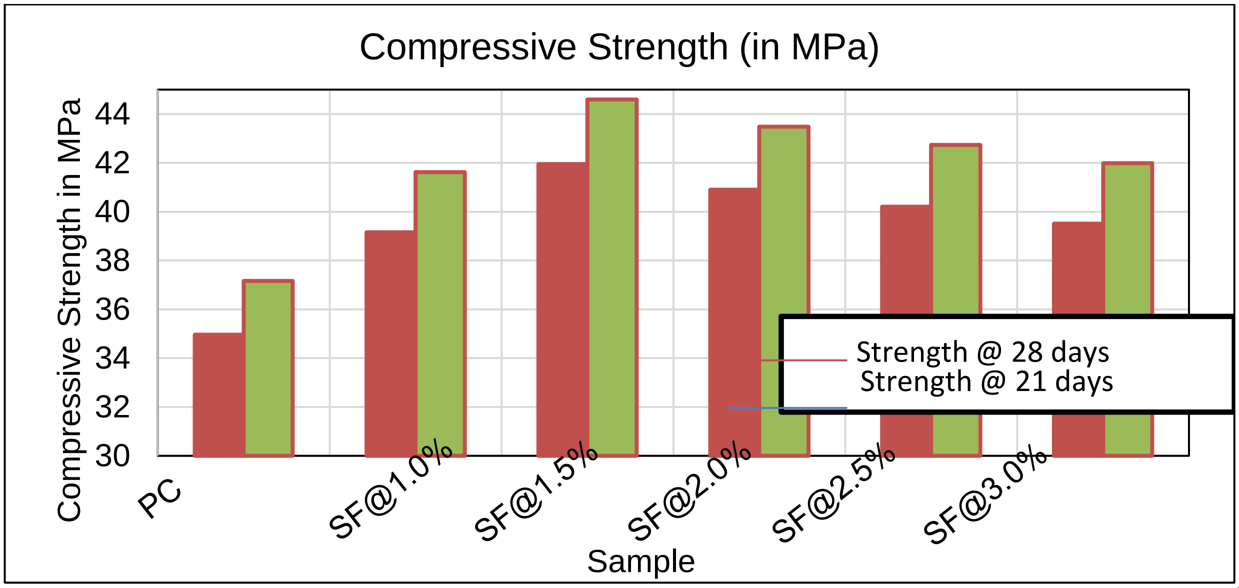

Figure 4: Compressive strength @ 21 days and @28 days

In comparison to 0% fibre content during a 28-day interval, compressive strength is 44.59% greater at 1.5% volume of fibre. Strength initially increases as fibre volume increases, but after 1.5% fibre, strength decreases. When discussing individual fibre strength, the pattern for the increase in compressive strength with steel fibre is comparable.

b) Split tensile strength

The strength figures show that the concrete's indirect split tensile strength is rising in a similar manner to its compressive strength. The strength increases from 0% to 1% has been more noticeable. In terms of strength, the conduct of 1.0% and 1.5% is more comparable. On the other side, it matters how the fibres impact the specimens' failure. The test specimens' splitting tensile strength increased by around 57%, according to the results, as steel fibre content increased from 0% to 3%. On additional addition of steel fibre, the indirect tensile strength value of test specimens decreases (as illustrated in Figure 5). A test specimen that is analysed 21 days after casting shows a similar pattern.

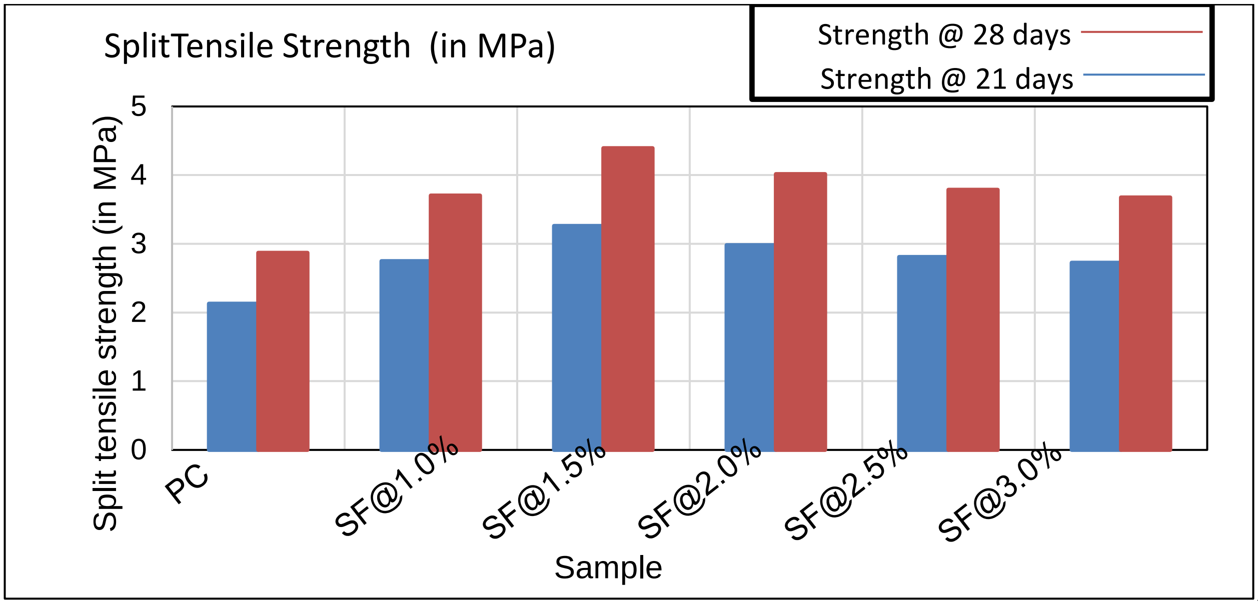

Figure 5: Split Tensile strength @ 21 days and @28 days

c) Flexural strength

The results of the Average Stress clearly show that the test's flexural strength increases in direct proportion to the addition of steel fibre. Steel fibres were added to concrete in volume fractions 1.0%, 1.5%, 2.0%, 2.5% and 3.0% increasing its flexural strength by 9.5%, 29%, and 48%, respectively. After the addition of 1.5% steel fibre, negative results have been observed. According to the literature, employing 1.5% fibres will increase flexural strength in comparison to utilising plain concrete by 1.5–3 times. The use of 1.5% fibres boosted flexural strength by 1.5, according to this study's findings. When the beam is loaded, the bottom fibre is stressed. With increased tensile strength, the beam will function better, especially after cracking.

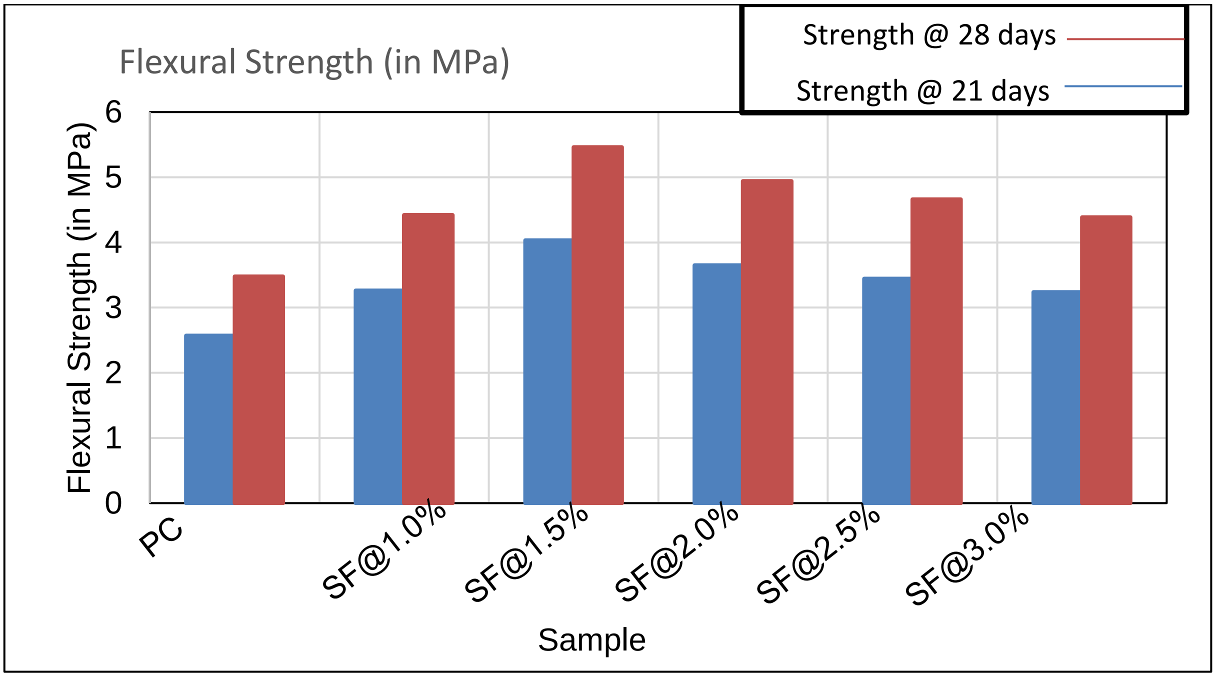

Figure 6: Flexural strength @ 21 days and @28 days

5. Conclusions

Structural engineering applications. The creation of steel fibre reinforced concrete is proof that new materials may perform effectively as structural elements. The static performance of members has been the focus of the majority of SFRC research to date; however, there has been little investigation into how these materials affect the impact behaviour of slabs with various concrete characteristics.

The findings of this study are as follows:

1. Steel fibre is added to the mix design, the workability of fresh concrete reduces.
2. Steel fibre has a compressive strength that is 20% higher than that of plain concrete at 1.5% volume.
3. Compared to ordinary concrete, indirect tensile strength is 53% higher at 1.5% volume of steel fibre.
4. SFRC exhibits a maximum flexural strength of 1.5% by volume, which is 57% higher than that of concrete without fibre.

7. Recommendation

The ingredients of concrete for 1 m^3 are coarse aggregate 1044 Kg, fine sand (zone 3) 696 Kg, cement 375 Kg and 167 Lit water.

The above ingredients give 44.59 MPa compressive strength that is equivalent to M40 cement concrete, 4.39 MPa indirect tensile strength and 5.46 MPa flexural strength when cured for 28 days. As a result, rigid pavement made of M40 cement can use steel fibre reinforced concrete.

6.3 Future scope of work

With the inclusion of hybrid fibre, concrete's mechanical strength can be increased. It is possible to investigate the behaviour of adding micro and macro fibre to concrete. Use of ABAQUS should be used to create the material model.

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