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An Experimental Study on the Effect of Steel Fibres in S-Sand Concrete

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Abstract:
Sand is a prime material used for preparation of mortar and concrete and which plays a major role in mix design. In this study, one of the ingredients of concrete is sand partially replaced by S-Sand and its nature is studied. Extensive laboratory investigations have been undertaken to study the effect of varying S-Sand on mechanical properties such as compressive strength, split tensile strength and flexural strength. The same study is made by adding 2% of steel fiber by weight of cement to the S-Sand concrete. Steel fiber increases the mechanical properties of concrete. It prevents crack formation and provides reinforcement to the concrete structure. S-Sand concrete and steel fiber reinforced S-Sand concrete specimens were cast, cured and tested for mechanical properties. In this experiment the results of S-Sand concrete, steel fiber with S-Sand concrete and plain concrete are discussed for M30 grade of concrete.
Keywords: *Concrete, S-Sand, fine aggregates, steel fibers, compressive strength*

INTRODUCTION

Construction sector has considered concrete as a versatile material, being adoptive for non- structural and structural parameters. Concrete is a homogeneous mixture of cement, fine and coarse aggregates along with water [1,2]. Cement is the binding material, which is the costliest ingredient in concrete. Aggregates act as the filler material in the cement composites and it constitutes about 70-80% in concrete volume. Due to the increased construction activities, demand for aggregates has increased which in turn increases the cost of material [3][4]. Meanwhile, the cost of conventional construction materials upsurges frequently due to an increase in demand and thus inflating the cost of construction. Many research activities claim that recycled products can be adopted as building material with minimal processing, which makes the concrete sustainable [1].

To reduce the ecological imbalance, pollution and cost of material, it is essential to identify and use the alternative for aggregates [3]. With the improvement in technology and production mechanism, it is possible to reuse or recycle the material for various purposes in which concrete is found to be most feasible and economical product to imbibe industrial solid waste material [5]. Recycling is a process of convalescing useful materials from waste and utilizing them in the manufacturing process of some other useful product [30,31]. For the civil engineering sector, recycling refers to chemical modification, mechanical processing, thermal treatment, fillers [6]. Recycled resin aggregate exhibit negligible water absorption and hence, slump of concrete mix increases with increase in replacement levels [7].

In this study, an attempt has been made to use S-Sand as partial replacement to fine aggregate with the addition of steel fiber. Strength properties of this concrete are carried out. The construction sector has long regarded concrete as a versatile material, adaptable for both structural and non-structural applications [15][20]. Concrete is a composite material composed of cement, fine and coarse aggregates, and water. Among these, cement acts as the primary binding agent and is the most expensive ingredient in the mix [18]. Aggregates serve as filler materials and typically constitute about 70–80% of the total concrete volume [24]. Due to increasing construction activities, the demand for natural aggregates has surged, leading to a corresponding rise in material costs [27][29].

Simultaneously, the cost of conventional construction materials continues to escalate with rising demand, thereby inflating the overall cost of construction [16][22]. Numerous studies have suggested that recycled materials can be adopted as building components with minimal processing, thereby promoting sustainability in concrete production [21][28]. To address issues of ecological imbalance, environmental pollution, and material scarcity, it becomes crucial to explore and utilize alternative aggregate sources [19][30].

With advancements in technology and production techniques, it is now feasible to reuse or recycle various industrial waste materials, especially in concrete—one of the most suitable and economically viable options for such reuse [23][31]. Recycling, in this context, involves the recovery of useful materials from industrial or construction waste and employing them in the production of other value-added construction materials. In civil engineering, recycling may include processes such as mechanical grinding, chemical treatment, thermal processing, or use as mineral fillers [17][25].

Recycled resin aggregates, for instance, show negligible water absorption, and thus, the slump of concrete tends to increase with higher replacement levels [26,34]. In the present study, an effort has been made to use S-Sand as a partial replacement for natural fine aggregates in combination with steel fibers [32,33]. The mechanical properties of this composite concrete mix have been experimentally evaluated to assess its suitability as a sustainable construction material [14][13].

MATERIALS AND METHODOLOGY

Materials:

Cement: 53 grade cement was considered for this study, and the characteristics of cement were examined as per IS: 269 – 2015[8] and IS 4031- 1996[9]and represented in Table 1.

Table 1: Properties of cement

Sl. No.	Properties	Value obtained
1	Fineness (90micron sieve test)	4% residue
2	Soundness (Le-Chatelier test)	2mm expansion
3	Initial setting time	50 minutes
4	Final Setting time	350 minutes
5	Standard consistency	31%
6	Specific gravity	3.1
7	28 days compressive strength	56 MPa

Fine aggregates: Manufactured – Sand [M-sand] was procured from local quarry for fine aggregate. The characteristics of M-sand and S-Sand were examined as per IS: 383- 2016 [10] and IS: 2386- 1963 [11]. Properties of fine aggregate are represented in Table 2.

Table 2: Properties of M-sand and S-Sand

Particulars	M-Sand	S-Sand.
Zoning	Zone II	Zone II
Fineness Modulus	2.65	2.85
Silt Content (%)	5.3%	3.21%
Loose density (Kg/m^3)	1521	1268
Compacted density (Kg/m^3)	1767	1376

Specific Gravity	2.60	2.67

Coarse aggregates: Conventional coarse aggregates were procured from local quarry. The properties of coarse aggregates were examined according to IS: 383-2016 [10] and listed in Table 3.

Table 3: Properties of coarse aggregates

Properties	Coarse Aggregate	
Specific Gravity	2.63	
Water Absorption (%)	0.10	
Bulk Density (kg/m^3)	1581	

Water: Portable water abiding by IS-456:2000 [12] was used for casting and curing concrete.

Steel fibers: Commercially available Steel fibers named "DRAMIX RC – 80/60 BN" is used in the present Study. The fiber is 6mm long with 0.75mm diameter. The aspect ratio was 80, with a specific gravity of 7.25. Steel fibers with cranked ends are used in the study.

METHODOLOGY:

M30 grade concrete was designed in accordance with IS: 10262–2009 [13][25], resulting in a mix proportion of 1:1.57:2.63 with a water-to-cement (w/c) ratio of 0.45. This proportioning was used for the preparation of concrete specimens throughout the study [21]. Natural fine aggregates were partially replaced by S-Sand at varying replacement levels of 0%, 10%, 20%, 30%, and 40% by weight, while maintaining a constant steel fiber dosage across all mixes [17][27].

Based on previous studies, it was observed that 2% steel fiber dosage by weight of cement yielded optimal mechanical properties; therefore, this percentage was adopted for the current experimental program [20][28]. The concrete specimens were tested for compressive strength, split tensile strength, and flexural strength at both 7 and 28 days of curing, in accordance with IS: 516–1959 [15][30].

RESULTS AND DISCUSSION:

Mechanical properties of concrete are determined by conducting tests on compression strength, split tensile strength and flexural strength.

Compressive Strength:

Table 4: Variation of compressive strength of concrete with replacement of fine aggregates by S-Sand along with steel fibers

Concrete Mix	% of Industrial wastes	28 days Compressive Strength (N/mm^2)	
		With S-Sand	S-Sand + steel fiber
1	0	44.59	50.04
2	10	40.44	47.90
3	20	39.99	42.80
4	30	39.25	40.10
5	40	37.62	36.42

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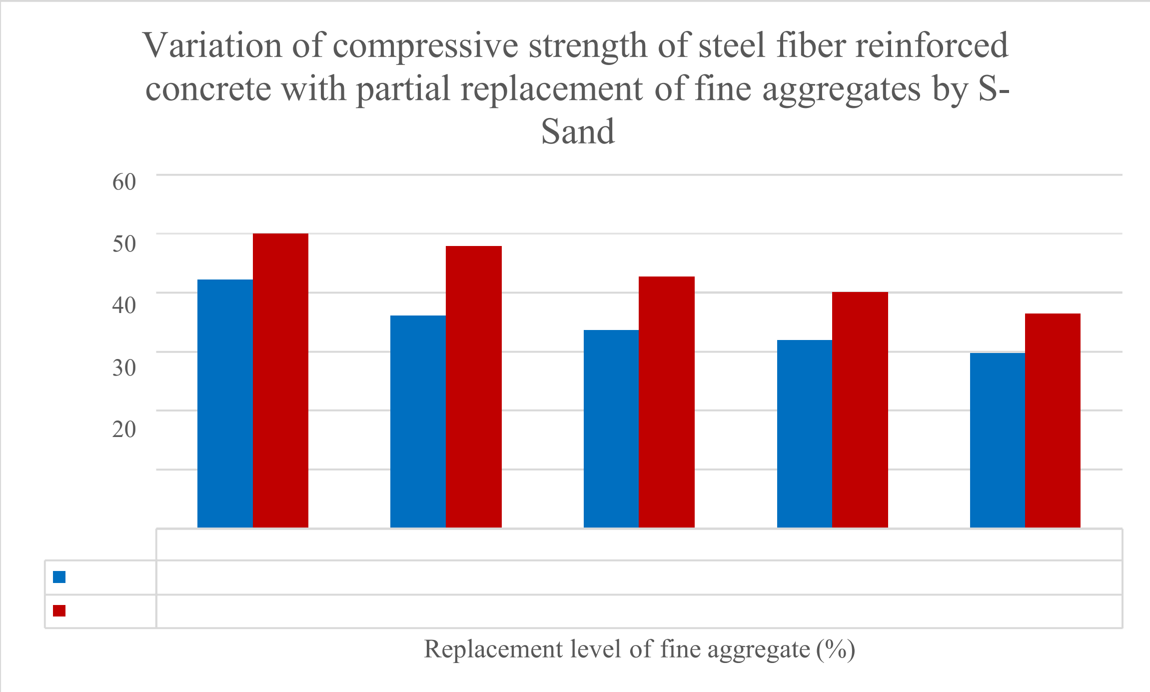


0	0	10	20	30	40
7 Days	42.2	36.12	33.64	31.97	29.72
28 Days	50.04	47.9	42.8	40.1	36.42

Figure 1: Variation of compressive strength of concrete with replacement of fine aggregates by S-Sand and along with steel fibers

From **Figure 1**, it can be observed that up to 30% replacement of natural fine aggregates with S-Sand in steel fiber reinforced concrete (SFRC) can be achieved without compromising the target mean compressive strength [19][27]. The strength results at both 7 days and 28 days exhibit a consistent trend, indicating uniform strength development over time [14][30]. Hence, it can be inferred that the incorporation of S-Sand as a partial replacement for natural fine aggregates leads to a gradual reduction in the compressive strength of SFRC as the replacement level increases [21][28]. However, up to a 30% replacement level, the reduction is within acceptable limits and meets the performance requirements [16][25].

Split Tensile Strength:

Table 5: Comparison of 28 days Split Tensile strength of various concrete mixes

Concrete Mix	% of S-Sand	28 days Split Tensile Strength (N/mm^2)	
		With S-Sand	S-Sand + steel fiber
1	0	3.41	4.21
2	10	2.80	3.96
3	20	2.78	3.83
4	30	2.76	3.79
5	40	2.75	3.66

The variation of split tensile strength of steel fiber reinforced concrete with S-Sand concrete are represented in figure 2.

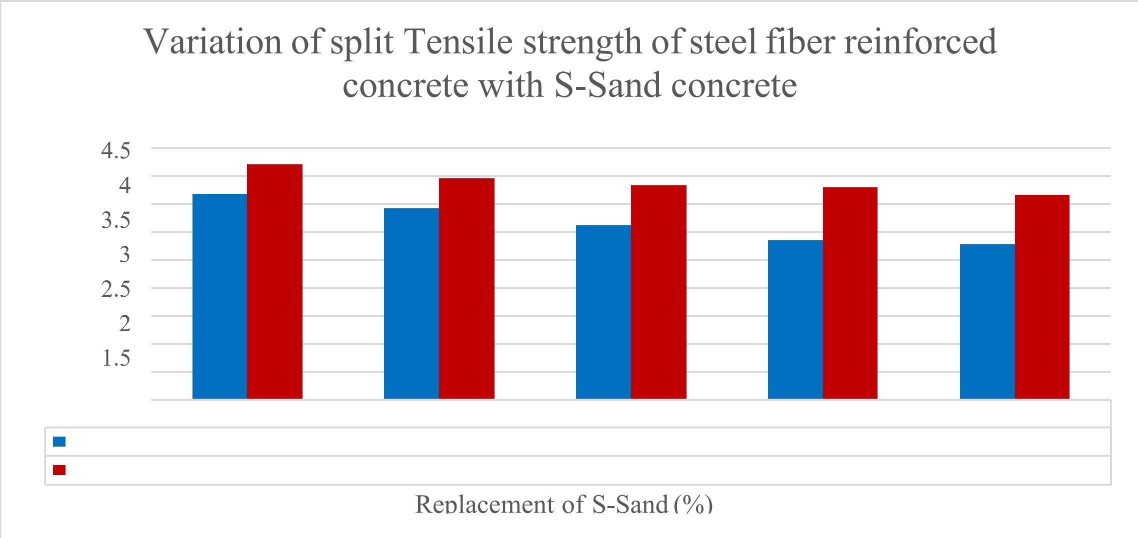


Figure 2. Split tensile strength of steel fiber reinforced concrete for variousreplacement levels of fine aggregates by S-Sand

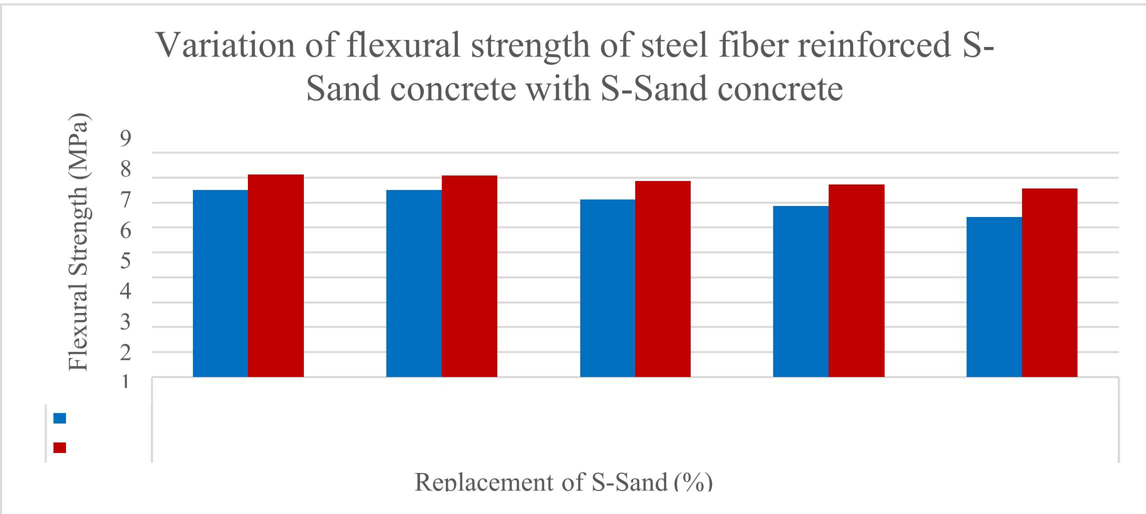
From figure2, it can be noticed that split tensile strength of steel fiber reinforced concrete will decrease with increase in S-Sand. It is also observed that split tensile strength is almost same for 10, 20, 30% replacement levels.

Flexural Strength:

Table 6: Comparison of Flexural strength of various concrete mix

Concrete Mix	% of S-Sand	28 days Flexural Strength (N/mm^2)	
		With S-Sand	S-Sand + steel fiber
1	0	7.33	8.12
2	10	7.91	8.09
3	20	7.58	7.87
4	30	7.17	7.72
5	40	6.25	7.56

The variation of flexural strength of steel fiber reinforced concrete with partial replacement of fine aggregates by S-Sand is represented in figure 3.



	0	10	20	30	40
7 Days	7.51	7.5	7.12	6.86	6.42
28 days	8.12	8.09	7.87	7.72	7.56

Figure 3. Flexural strength of steel fiber reinforced S-Sand concrete with S-Sand concrete

From figure 3, it can be observed that, the flexural strength achieved was almost same as that of normal concrete. With increment in fine aggregate replacement levels beyond 10% will decrease the flexural strength. It is also observed that initial flexural strength of concrete (at 7 days) followed the same trend.

Observations:

1. A small amount of reduction in slump is seen with the addition of S-Sand.
2. Steel fiber reinforced concrete gives less workable concrete as compared to concrete with S-Sand.
3. The compressive strength decreases marginally by 10.3% with the replacement of sand by S-Sand up to 20% replacement level.
4. Compressive strength increased by about 7% with the addition of 2% of steel fiber in concrete with 20% replacement level of S-Sand.
5. The split tensile strength in steel fiber reinforced concrete with S-Sand concrete decreased by about 18.47% when compared to conventional concrete but it shows 9% reduction in strength as that of conventional concrete when 2% of steel fiber is added to 20% replacement level of S-Sand.
6. In steel fiber reinforced concrete with S-Sand concrete, the flexural strength decreases by 3.07% when compared to conventional concrete.

CONCLUSIONS:

Based on the experiment conducted the following conclusions are obtained

1. Compressive strength of concrete decreases gradually with an increase in replacement levels of fine aggregates by S-Sand up to 20% replacement level and increases with the 2% addition of steel fiber.
2. Compressive strength of both the types of concrete is marginally decreased up to 20% replacement of sand by S-Sand.
3. Split Tensile strength of steel fiber reinforced S-Sand concrete is increased compared to concrete with S-Sand concrete.
4. Flexural strength of steel fiber reinforced S-Sand concrete is increased compared to concrete with S-Sand concrete.
5. Compressive strength, Split Tensile strength and flexural strength are improved by adding 2% of steel fiber in concrete with S-Sand concrete.

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