International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 06, June-2022

# Effect of Fly Ash and Steel Fibres on The Strength and Durability Properties of Concrete

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***Abstract*:- This study presented the effect of fly ash and steel fibers on the strength properties and durability properties of concrete. This paper presented the properties of compressive strength, split tensile strength and flexural strength. Whereas the durability properties, i.e., water absorption and porosity were studied. The strength properties increased with the variation of steel fibres but decreased by including fly ash. The values of durability decreased due to dense concrete structure but were within the limits.**

***Keywords : Fly ash , Steel fibres, Compressive strength , Water absorption***

## 1. INTRODUCTION

Pozzolanic materials such as fly ash (FA) and cementitious materials such as ground granulated blast furnace slag (GGBFS) are by-products of industry [1,2]. Pozzolanic materials possess self-cementitious properties but cannot undergo hydration reaction, thus are used as a replacement for cement by weight or by volume at defined proportions, keeping the batch's efficiency in terms of strength and durability [2–4].

Two major factors influence fly ash concrete's properties - its intrinsic variation in chemical and mineralogical composition and the philosophy of mix proportioning adopted to produce the concrete incorporating fly ash. As per the previous research, it has been summarized that cement can be replaced with fly ash between 20% to 30% by weight, maintaining the efficiency of the concrete mix and participating in making an eco-friendly environment without compromising the strength and durability properties of concrete [5,6].

Concrete is an important building material in the industry, but it has drawbacks regarding brittleness, low tensile strength, and poor resistance to crack growth [7]. Therefore, optimizing and improving concrete structures to meet the various engineering requirements is vital. In order to improve the performance of concrete structures, steel fibres are added to the concrete. As per the previous findings, fibres are beneficial for concrete structures because they help influence concrete's mechanical and durability properties. Over the last few decades, different fibres (e.g., steel, polypropylene, glass, and basalt fiber) have been used as concrete reinforcements. The mechanical properties of steel fiber reinforced concrete (SFRC) under different loading configurations, i.e., compression and tension, have been widely researched, where the main variables included fiber surface shapes, fiber volume fraction, fiber length, fiber orientation, concrete aggregate size, concrete matrix strength, etc [7].

Hasim et al. [8] studied the mechanical properties of concrete, comprised of high-volume coal bottom ash with fly ash. The study evaluated the workability test, compression test, flexural test and modulus of elasticity. The results showed that the concrete batch with 100% CBA as coarse and fine aggregate replacement produced better compressive strength than the control mixture. Flexural strength reduction was experienced with the increment in coal bottom ash proportion. Kumar et al. [9] investigated the behavior of HVFAC made with fine aggregate replaced by steel slag. In this study, a steel slab was incorporated in the mix as a replacement with fine aggregate by varying replacement levels from 0% to 60% in M30 grade of concrete. It was observed from the results that 50% replacement of steel slag showed better results when HVFAC was prepared with 40% fly ash, other increments resulted in a reduction in strength. Shi et al. [10] investigated two types of SFRC (straight and hooked steel fibres) with various fiber volume fractions under uniaxial compression. Through their experimental results, adding fibres did not significantly change compressive strength, but it improved the concrete post-peak behaviors in achieving higher ductility, residual strength, and toughness. Zhang et al. [11] analyzed the effect of fiber surface shapes on the mechanical properties of concrete. They found that corrugated steel fibres had a better reinforcing effect on compressive strength and splitting tensile strength of SFRC than the straight fibers. Similar conclusions could be observed in the study on specimens using closed steel fibers proposed by Iqbal et al. [12]. Han et al. [13] assessed the effects of steel fiber length and coarse aggregate maximum size on the compressive properties of SFRC. They found that the compressive strength of SFRC was only slightly influenced by the coarse aggregate maximum size, while it was barely influenced by steel fiber length. Zhu et al. [14] conducted an experimental study on the tensile properties of SFRC using hooked and corrugated fibers. They confirmed that the splitting tensile strength was improved more obviously by hooked steel fibers compared to corrugated fibers. Wu et al. [15]investigated the effect of fiber surface shapes on the mechanical properties of ultra-high-performance concrete. It was reported that the strength and toughness of concrete followed the order of hooked fibers > corrugated fibers > straight fibers. Yoo et al. [16]characterized the tensile properties of ultra-high-performance SFRC, and concluded that the best tensile performance was achieved by incorporating straight fibers instead of deformed fibers. Plague et al. [17]analyzed the effect of fiber orientation on the cracking of high-performance concrete reinforced with hooked steel fibers under tensile loading. Based on the results, as fiber orientation becomes less favorable (from 39° to 54°), the tensile strength of specimens is reduced by up to 33%. In addition to straight and hooked fibers investigated by these previous works, steel fibers with other surface shapes, such as corrugated fibers, have been successfully used to enhance concrete properties recently. Tran et al. [18]conducted direct tension tests for high-performance concrete reinforced with twisted and hooked steel

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fibers. Their research showed that the twisted fibers produced a better reinforcing effect on post-cracking strength, strain capacity, and energy absorption capacity of concrete than hooked fibers.

From the literature, it was observed that fly ash incorporation in concrete is limited to 20% to 30%. Still, limited research has been carried out on the effect on the properties of concrete when fly ash at a high volume is added to the mix. Moreover, the study on steel fibers to arrest the cracks in fly ash concrete was discussed briefly. Hence in this current work, the focus is to provide an eco-friendly environment and influential strength, not only by adding fly ash but also by adding steel fibers which impart tensile properties to the concrete mix. Moreover, steel fibers added to the concrete will also help provide elastic properties to the concrete.

## 2. MATERIALS AND METHODS

### *2.1.1 Cementitious Materials*

The present study used Ordinary Portland Cement (OPC) of 43 grade as per BIS 8112 [19]. The physical properties of cement are shown in Table 1. Fly ash was collected from the Rajpura in Punjab and belonged to Class F fly ash according to BIS 3812: (Part 1) [19]

Table 1: Physical properties of cement

| **Property** | **OPC** |
|---|---|
| Specific gravity | 3.10 |
| Initial Setting Time (minutes) | 80 |
| Final Setting Time (minutes) | 250 |
| Standard Consistency (%) | 30 |
| Soundness (mm) | 1 |

### 2.1.2 Coarse Aggregates

The maximum size of coarse aggregates of 20 mm was used in this study to prepare the design concrete mix. The physical properties of coarse aggregates are shown in Table 2.

Table 2: Physical Characteristics of coarse aggregates

| **Property** | **Coarse aggregates** | |
|---|---|---|
| | **10 mm** | **20 mm** |
| Fineness Modulus (FM) | 6.25 | 6.70 |
| Water Absorption (%) | 0.98 | 0.99 |
| Specific Gravity | 2.70 | 2.70 |

### 2.1.3 Design Mix Proportions

The mix proportion will be prepared as per BIS-10262 [20], considering the fly ash content corresponding to the M30 grade of concrete. The water to binder ratio is decided to be kept as 0.35. For maintaining the workability of the mix, a water-reducing admixture with polypropylene base will be used at a prescribed ratio to avoid bleeding and segregation of the mixtures. In this study, the replacement of fly ash with cement was fixed and the percentage of steel fibers was varied. The different concrete batches are shown in Table 3.

Table 3: Different Concrete Batches

| S.no. | Nomenclature | Description |
|---|---|---|
| 1 | CM (SF0FA0) | Conventional Mix |
| 2 | SF1.5FA0 | Steel Fibre 1.5% and FA 0% |
| 3 | SF2.5FA0 | Steel Fibre 2.5% and FA 0% |
| 4 | SF0FA40 | Steel Fibre 0% and FA 40% |
| 5 | SF1.5FA40 | Steel Fibre 1.5% and FA 40% |
| 6 | SF2.5FA40 | Steel Fibre 2.5% and FA 40% |

### 2.2 Methodology

### 2.2.1 Compressive Strength

The compressive strength of the prepared mixes was determined as per BIS 516 [21]. The cubes of 150 mm size were prepared and tested in Compression Testing Machine on different days of curing.

### 2.2.2 Split Tensile Strength

The split tensile strength was determined as per BIS 5816 [22] on cylindrical specimens of 300 mm length and 150 mm diameter in the compression testing machine.

### 2.2.3 Flexural Strength

Flexural strength of the beam specimens prepared with different mixes was determined using 100 mm x 100 mm x 500 mm sized prisms and tested as per BIS 516 [21] in the Universal Testing Machine. The load is applied equally divided between the two loading rollers.

### 2.2.4 Water Absorption

Water absorption is an indicator of the perviousness of the material and was performed in concrete mixes in accordance to ASTM C642 [23]. This test was conducted based on oven-dry mass and saturated mass.

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Vol. 11 Issue 06, June-2022

### 2.2.5 Porosity

Porosity influences the functional properties of concrete mix. The test was performed as per ASTM C1754 [24]. The specimens of size 100 mm in diameter and 200 mm in height. The specimens were kept submerged in water, and the submerged weight was calculated.

## 3. RESULTS AND DISCUSSION

### 3.1 Compressive Strength

The compressive strength results of different mixes containing fly ash and steel fibres at 7, 28, and 90 days are shown in Fig. 1. It was observed that with different percentage variations of steel fibres, the compressive strength values increased at all curing ages, but with cement replacement with fly ash, the values decreased with respect to the control mix. The increase in compressive strength with steel fibres was due to the bonding of fibres into the concrete, which resists the development of cracks [13]. However, the strength decreased with the replacement of fly ash because of the slow pozzolanic reaction compared to cement [2]. But at later ages, the strength increased with the variation of steel fibres and replacement of cement with fly ash which is comparable to the control mix.

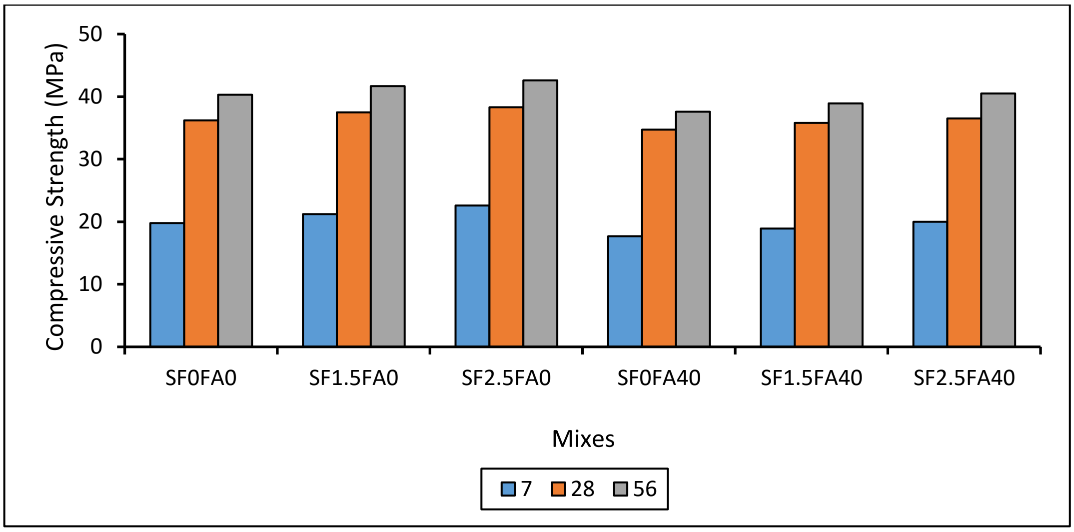


Fig. 1: Compressive strength of different mixes

### 3.2 Split Tensile Strength

The split tensile strength results of different mixes containing fly ash and steel fibres at 7, 28, and 90 days are presented in Fig. 2. It has been found that with different percentage variations of steel fibres, the split tensile strength values increased at all curing ages but with the replacement of cement with fly ash, the values decreased with respect to control mix. The increase in compressive strength with steel fibres was due to the propagation of cracks resisted by the bonding of fibres in concrete [13]. However, the strength decreased with the replacement of fly ash because of delayed pozzolanic reaction compared to cement [2].

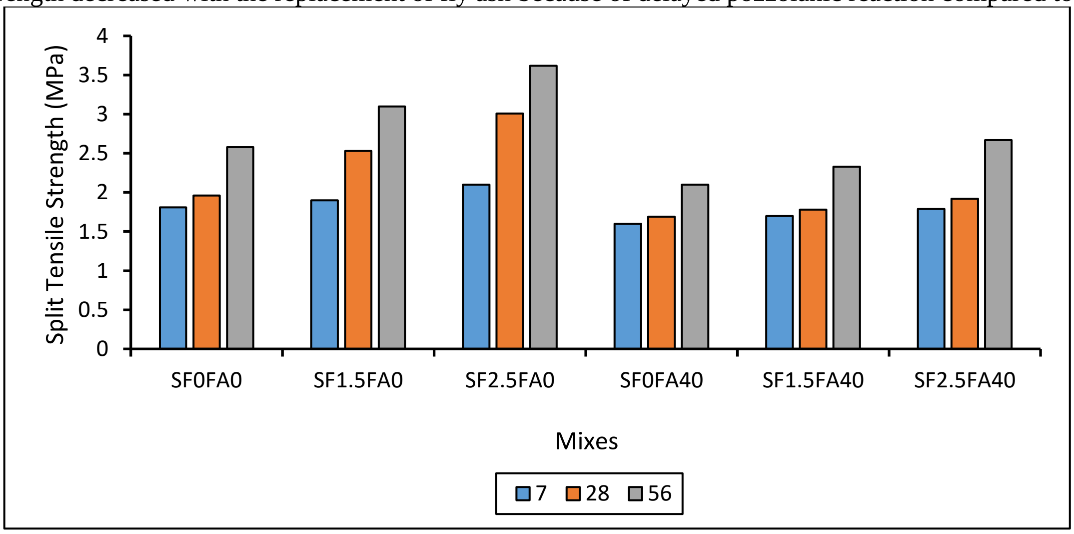


Fig. 2: Split tensile strength of different mixes

### 3.3 Flexural Strength

The flexural strength results of different mixes containing fly ash and steel fibres at 7, 28, and 90 days are presented in Fig. 3. It has been found that with different percentage variations of steel fibres, the split tensile strength values increased at all curing ages, but with the replacement of cement with fly ash, the values decreased with respect to the control mix. A similar trend of flexural strength was observed to compressive strength and split tensile strength.

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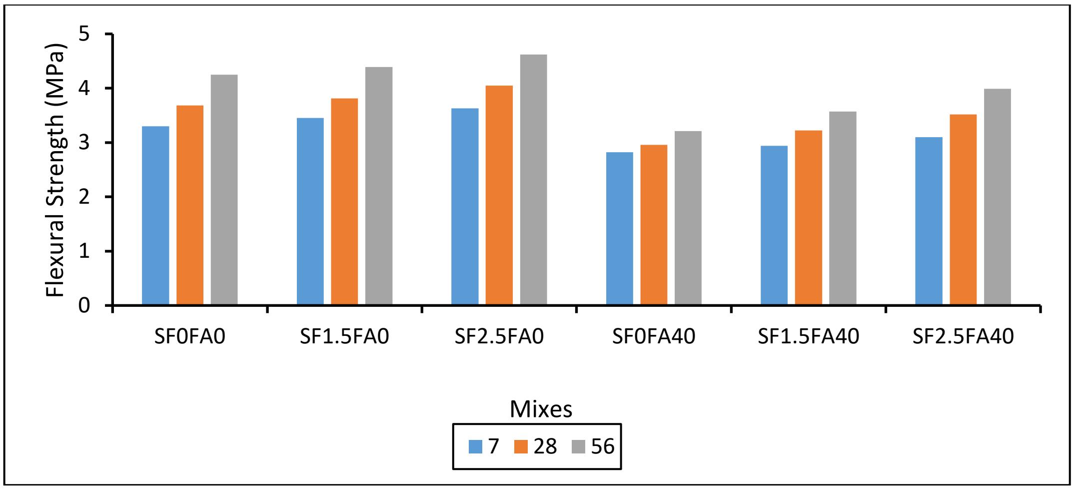


Fig. 3: Flexural strength of different mixes

### 3.4 Water Absorption

The water absorption results of different mixes containing fly ash and steel fibres at 7, 28, and 90 days are exhibited in Fig. 4. From the graphs, it was seen that the water absorption values linearly decreased at all curing ages. The decreased water absorption values were due to denseness of concrete mix and slow reactivity during hydration of cement which caused a decrease in water absorption values.

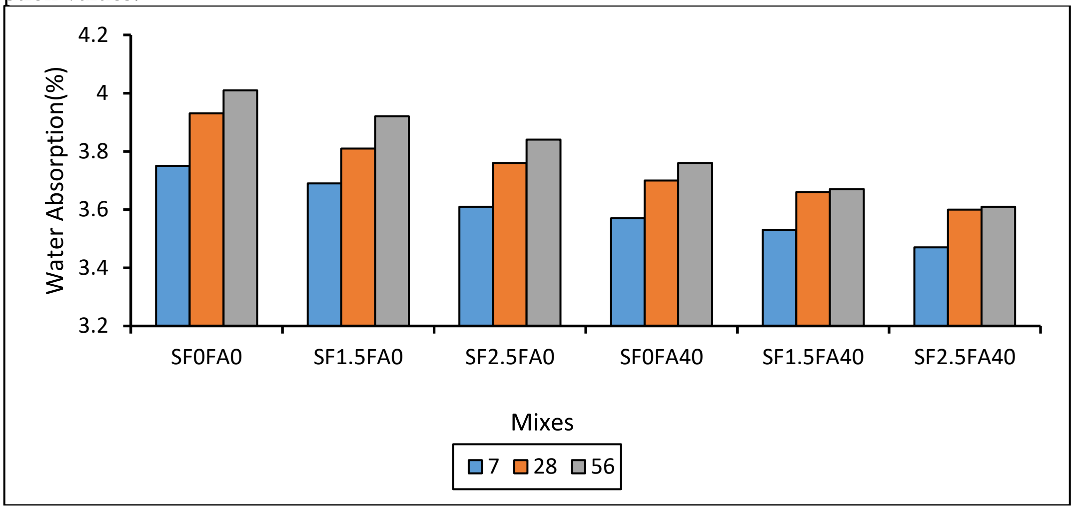


Fig. 4: Water absorption of different mixes

### 3.5 Porosity

The porosity results of different mixes containing fly ash and steel fibres at 7, 28, and 90 days are demonstrated in Fig. 5. From the graphs, it was seen that the water absorption values linearly decreased at all curing ages. A similar trend was observed to that of water absorption.

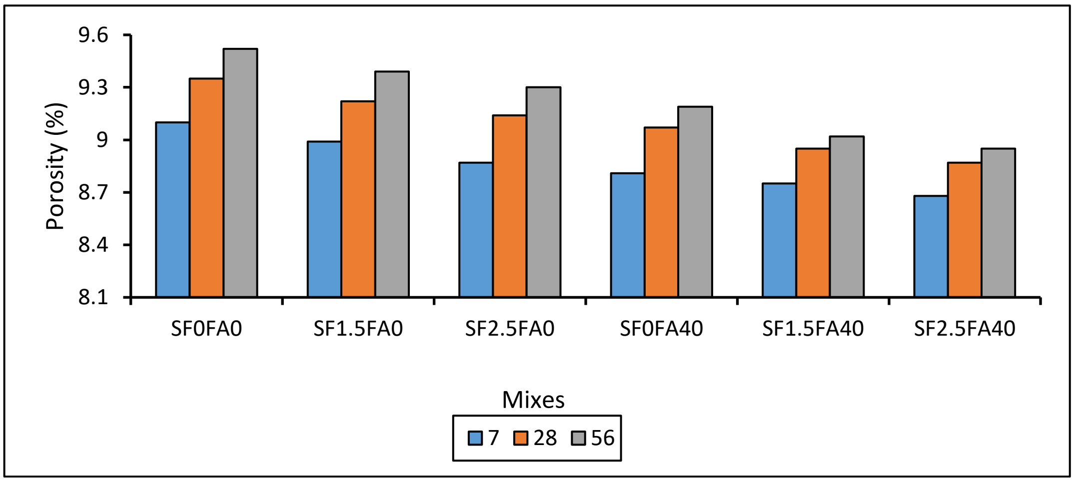


Fig. 5: Porosity of different mixes

## 4. CONCLUSIONS

Based on test results, the conclusions are drawn that with the variation of steel fibres the strength properties such as compressive strength, split tensile strength, and flexural strength increased at all curing ages. But with the inclusion of fly ash, the strength values decreased and showed a similar trend. The values of durability properties such as water absorption and porosity decreased due to the denseness of the concrete mix.

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