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Effect of Aluminium and Steel Fibers on Flexural Performance of Reinforced Concrete Beam

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Abstract:

Introduction: Fibers are widely used in concrete to reduce water absorption, surface permeability, curling, shrinkage cracks, and improve durability and strength. Steel and aluminium fibers can be easily extracted from scraped materials and affordable compare to other fibers. In this study, the combined steel and aluminium fibers are mixed in concrete with percentage varies from 0.5 to 2.5. The fifteen fibrous reinforced concrete beam were prepared to analyses the impact of steel and aluminium fibers on the flexural behavior of the reinforced concrete beam. The test results of steel and aluminium fiber RC beam specimens are compared to concrete beam samples. In contrast to typical concrete beam specimens, the failure patterns seen in steel and aluminium fiber reinforced concrete specimens are different. When fibers are used, RC beams can support higher loads than regular reinforced concrete beams. The flexural strength of the beam specimens was improved by addition of the fibrous material in reinforced concrete beam. The study finds that adding steel and aluminium fibers to reinforced concrete improves its flexural strength as well ductility. It is also found that use of steel and aluminium fiber in concrete a good substitute to improve performance of flexural member.

Keywords: RC beam, Steel fiber, Aluminum fiber, Flexural strength, Ductility.

1. Introduction

Fibers from natural sources or constructed of steel, glass, and polymer are commonly utilized in cement-based composites. By incorporating randomly distributed steel fibers into the concrete mixture, inelastic damage of the concrete under tension can be prevented or postponed. Steel fiber reinforced concrete has several advantages compare to conventional reinforced concrete, according to experimental studies directed in the last few eras. These benefits include higher shear as well as tensile strength, upgraded cyclic performance, enriched post-cracking activities, and greater spalling resistance. The fibers are closer together than traditional reinforcing steel bars and they can better handle cracks. In the context of modern concrete technology, steel bars and fibers have distinct purposes, while both types of steel bars and fibers can be used in a multitude of ways. Steel fiber is the utmost widely utilized category of fiber in concrete reinforcement. Steel fibers were first adopted in concrete to avoid and manage plastic shrinkage also drying. Subsequent investigation and development revealed that addition of Steel fibers to concrete increases its durability, ductility before to ultimate failure, energy absorption capacity, and resistance to cracking. This article looks at the influence of adding Steel fiber to concrete, in addition to the mechanical characteristics and applications of Steel fiber reinforced concrete (SFRC).

The qualities of steel fibers that make them appropriate for use in a variety of applications were established by earlier research on steel fiber in concrete as reinforcement. (Wijatmiko et al., Citation 2019) It has been determined that adding 15% of aluminium fibers as a volume fraction to lightweight concrete is the ideal amount. In addition to reference concrete, concrete containing 1% and 2% aluminium fibers from soft drink cans was evaluated for flexural and compressive strength. (Dhanapal and Jeyaprakash, Citation 2020) For experiments, two different fiber sizes were used: macro fibers measuring 38 mm in length as well as micro fibers assessing 15 mm. When compared to lengthy fibers, they discovered that micro steel fibers increased the compressive strength. (Birincioglu et al., Citation 2021) It has been proposed to rise the shear strength of concrete constructions by means of adding steel fibers. It can be utilized as a substitute for completely replacing the structure's minimum shear reinforcement requirement. (Sabapathy et al., Citation 2019) Three concrete grades and five distinct fiber volume sections 0, 0.5, 1, 1.5, and 2 percent were combined. Laboratory tests were adopted to measure the concrete specimens' split tensile and compressive strength after a 28-day curing period. To predict the strength of fiber-reinforced concrete, a regression analysis was carried out using statistical modeling based on the experimental results.

(Afroughsabet et al., Citation 2016) The flexural properties of RC beams reinforced by means of high-strength steel fibers has been explored. It looked into things like ductility, crack management, and load-carrying ability and gave information regarding how well steel fibers work to improve the structural performance of RC beams. (Kishore et al., Citation 2019) In order to prepare concrete specimens, steel fibers in the form of waste such as empty tin, soft drink bottle caps, and lathe waste are distorted into the required shape and adopted in proportions of 0%, 0.50%, 0.75%, 1.0%, and 1.5%. Samples were tested for compressive strength and split tensile strength for 7, 14, and 28 days.

The researchers (Aziz et al., Citation 2020; Yoo et al., Citation 2018; Ramezanianpour et al., Citation 2013; Narule et al., Citation 2022; Ulape et al., Citation 2015; and Shendge et al., Citation 2017) have worked on using steel fiber, soft drink can fibers, or aluminium waste fibers to develop some of the factors and features of concrete, such as workability, post-crack performance, workability, fatigue strength, density, and energy-absorbing capability. The current experiment aims to investigate the effects of varying fiber percentages in concrete reinforcement on specimens composed of RC beams' flexural strength and deformation.

2. Experimentation work

The reinforced concrete conventional beams and beam with addition of variable quantity of steel and aluminium fibres were prepared to assess the flexural performance of beam.

2.1 Assembling test samples using the following supplies:

The river bed sand as per IS: 383-1970 code standards of zone III were adopted as fine aggregate in the concrete mix. Coarse aggregates from crushed stone aggregate from a nearby quarry of size 20mm were collected for the concrete. The cement used is common Portland cement of 53 grade, which complies with IS:12269-1987 code requirements. Throughout the experiment, turbidity, organic content, and salt content-free potable water were used for mixing and curing. Test samples were made from 60 mm-long steel fibres with a grey-metallic tone as shown in Fig.1. Also, 60mm-long silvery-colored aluminium fibres extracted from an aluminium cold drink can, as indicated in Table 1. The mix design for conventional concrete was structured using the IS:10262-2009 specification. It was intended to be used with M25 grade concrete.

Figure 1 a) Steel Fiber, b) Aluminum Fiber.

Table.1 Properties of Steel and Aluminium fibers

Fiber Type	Steel Fiber	Aluminum Fiber
Colour	Grey metallic	silvery-coloured
Specific Gravity	7.85	2.7
Water Absorption	3.25	2.65
Tensile Strength	1000-1200 Mpa	1500-2000 MPa

2.2 Preparation of specimens

The formworks were constructed using wooden planks of required size to cast the beam samples. Oilments were applied to internal surfaces of mould before casting beam specimens so as to make it easier to remove the specimen after setting.

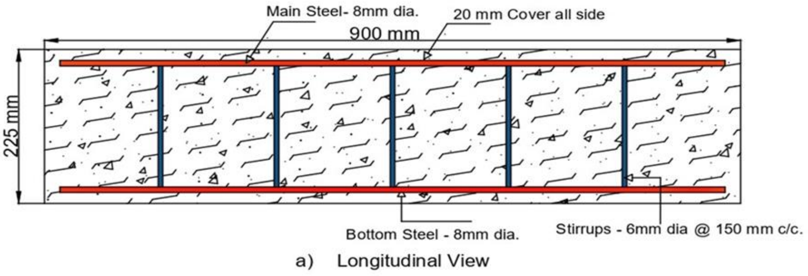

Figure 2 Reinforcement details of RC beam

Figure 2 shows that the RC beams were cast with dimensions of 900 X 150 X 225 mm. The RC beams were prepared utilizing the M25 grade concrete with variation in quantity of steel and aluminium fibre. As shown in table. 2, specified fiber doses of steel and aluminium were mixed into the concrete during the weigh-batching process for fibrous concrete. RC beam specimens were prepared for flexural testing after 28 days curing as shown in Fig.3.

Figure 3 Reinforced concrete beams after 28days curing

Table.2 Experimental work's test matrix

Beam samples	Abbreviated beam sample name	Number of Sample	% of Fibers in concrete
Beam Specimen & Size- 150 X 225 X 900 mm	CB S-0%, A-0%	3	Steel-0%, Aluminum-0%
	B S-0.5%, A-0.5%	3	Steel-0.5%, Aluminum -0.5%
	B S-1.0%, A1.0%	3	Steel -1.0%, Aluminum -1.0%
	B S-1.5%, A-1.5%	3	Steel -1.5%, Aluminum -1.5%
	B S-2.0%, A-2.0%	3	Steel -2.0%, Aluminum -2.0%
	B S-2.5%, A-2.5%	3	Steel -2.5%, Aluminum -2.5%

2.3. Testing of specimens

Each beam test sample was given a 28-day curing period in a curing tank before being taken out for soaking. Beam specimens were subjected to flexural load testing utilising a 400 kN universal testing apparatus. The beam specimens were positioned in a one point loading configuration between two jaws as shown in Fig. 4. The specimen was placed in a one-point loading system and subjected to a loading ratio of 2 kN/m2 until it damaged. An incremental flexural loading were applied until the test specimens failed completely. Beam specimens measuring 900 mm x 150 mm x 225 mm were examined on Universal Testing machine to verify the ultimate load and corresponding deflection of an RC beam. The maximum flexural load at failure of each test specimen was noted with the intention of determine the flexural strengths of beam specimen. The following formula was adopted to evaluate the flexural capability of rectangular beam samples that were exposed to single point loading. Flexural Stress = PL/bd^2.

Figure 4 Testing arrangement of RC beam specimen.

3. Experimental outcomes along with discussions

Table 3 Experimental results after testing

Types of Specimen	1st Crack Load (kN)	Ultimate load (kN)	Deformation (mm)	Flexural stress (N/mm^2)	Strain in Concrete (Micron)
CB S-0%, A- 0%	57.3	71.3	7.9	8.4	2363.7
B S-0.5%, A- 0.5%	60.6	75.0	8.3	9.0	2423.3
B S-1.0%, A1.0%	62.3	78.3	8.5	9.4	2752.7
B S-1.5%, A- 1.5%	64.7	83.0	11.1	9.8	2625.0
B S-2.0%, A- 2.0%	65.3	85.0	11.3	10.1	2925.0
B S-2.5%, A- 2.5%	67.0	87.0	11.5	10.3	2959.0

The flexural performance of RC beams by means of concrete additives ranging from 0% to 1.5% steel and aluminium fiber is presented in Table No. 3. The value of all parameters highlighted in table such as load at first cracking, ultimate load, deformation and flexural stress improved significantly with fiber additives in range 0.5% to 1.5% while casting RC fiber reinforced beams compared to the control beam without fiber. As the proportion of fiber increased between 0.5% and 2.5%, the average first crack loading for incremental flexural loading on RC beam specimen increased from 57.3 kN to 67 kN, respectively. Also, the ultimate loading capacity of RC fiber reinforced beam increased from 71.3 kN to 87 kN respectively with the increasing quantity of aluminium and steel fiber in concrete as compared to control beam as shown in Fig.5.

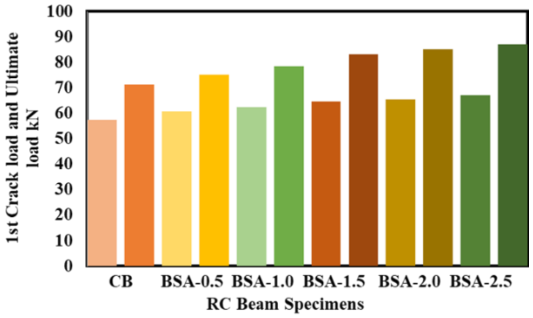

Figure 5 1st crack load and ultimate load of beam specimen

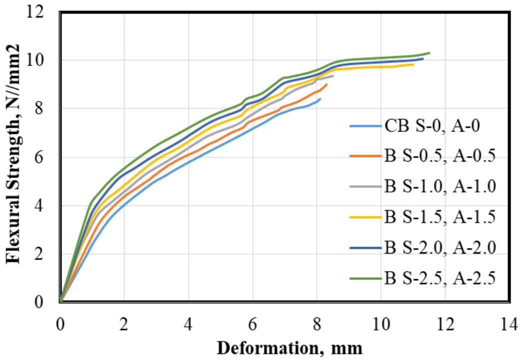

Figure 6 Flexural stress -deformation

As increasing fiber content in concrete, flexural testing results revealed that there was improvement in deformation capacity as well as corresponding ductility of beams as shown in Fig.6. The crack creation of the control beam, which contains 0% fibre, exceeds that of the 2.5% fibre beams as shown in Fig.7. As increase in percentage of fibers in concrete from 0.5% to 2.5%, there is crack resisting capacity of RC beam. The assessment of outcomes of testing also explored that the flexural strength of RC beam specimen improved drastically with increasing the share of additives fibers in concrete while casting respective RC beam specimens. According to the test results, it was observed that local strain in concrete was also upsurged with addition of fibers in concrete.

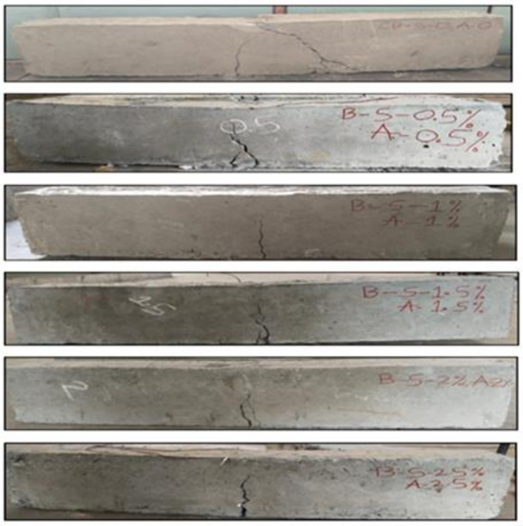

Figure 7 Cracking behavior of RC beam

4. Conclusions

The purpose of the experimental investigation was to analyse how the performance of RC beams was affected by varying amounts of steel and aluminium fiber added to concrete. A flexural capacity and ductility comparison was assessed for regular RC beam and fibrous RC beam with addition of steel and aluminium fibres at different fibre dosages. Following specific outcomes has been observed through study as listed below:

1. Increasing the steel and aluminium fiber doses in concrete from 0.5% to 2.5% enhances the flexural strength by 7.2% to 22.61% with respect to control beam.

2. Concrete with steel and aluminium fibers at a dose of roughly 1.5% would be an appropriate amount of fibers for boosting concrete strength.

3. Adding steel and aluminium fibers to concrete improves its effectiveness over conventional concrete.

4. Using steel and aluminium fibers in a concrete mixture helps to minimize cracking.

5. Aluminium fibers have excellent corrosion resistance when compared to steel fibers, which can be useful in contexts where corrosion is a problem, such as marine or industrial settings.

6. The test findings showed that, in comparison to the fiber-free control beam, the addition of steel and aluminium fibre with 2.5% for the beam section greatly increased load capacity by 22% and 1st cracking capacity by 17%.

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