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Experimental Study Of The Effect Of Lathe Steel Fiber On The Mechanical Properties Of Concrete

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ABSTRACT

This experimental study presents the mechanical properties of concrete using lathe steel fiber. The utilization of such fibers in concrete work as reinforcing material could be used for the infrastructural development, ultimately solving the problem of waste and its impact on the environment. The experimental tests were conducted using different percentages of fibers (i.e., 0%, 1%, 1.5% and 2%) by total Concrete volume. Compressive and tensile strengths were determined and compared with conventional plain concrete. Twenty-four cubic and 24-cylinder specimens were prepared and cured for 28 days. The addition of lathe steel fibers increased compressive strength up to 1.5%, whereas further addition of fibers reduced the overall compressive strength. The optimum compressive strength was obtained at 1.5% of lathe steel fiber addition and is 27.4 MPa, 14.71% higher than the control specimens. The maximum tensile strength was also observed up to 1.5% steel fiber addition which is 3.30 MPa and is 4.75% more than the results of conventional concrete. The study showed that the compressive and tensile strengths have significantly improved with the increase in lathe steel fiber.

Keywords: Steel Fiber, Concrete, Compressive Strength, Tensile Strength, Experimental, LFRC (Lathe Fiber Reinforced Concrete)

1. INTRODUCTION

Due to the increase in demand for strength and ductility and the infrastructural development in modern-day construction, additional concrete materials are needed to develop economical and sustainable materials. Generally, concrete material is stronger in compression and is weaker in tension which fails suddenly in a brittle manner when subjected to flexure and tensile forces. However, when lathe steel fibers are added to concrete, the material properties are enhanced compared to traditional concrete. There are numerous fibers used in concrete, such as synthetic fibers, steel fibers, and natural fibers, which, when added in suitable proportions, improve the material behavior of Concrete (Shin, 2014). The primary purpose of adding fiber dosage as reinforcement is to improve the tensile strength and control cracking of Concrete (Kamal et al., 2021 Khoso et. al., 2019). Every day about 8 to 10 kilograms of lathe steel fibers waste is generated by each lathe industry (Vijayakumar et. al., 2012). Most of the steel waste generated by industries is dumped on fields, thereby contaminating the soil and groundwater, creating problems to the environment (Khoso et. al., 2017). Hence properly managing and recycling the lathe steel fiber in concrete could be the best possible solution to minimize this waste. In Lathe Fiber Reinforced Concrete (LFRC), the traditional cement concrete is reinforced with randomly dispersed lathe fibers. During Concrete mixing, these fibers are distributed randomly, resulting in a substantial increase in concrete strengths. Fibers help enhance the concrete ductility and improve its tensile strength. The crack formation is controlled and results in less surface cracking ultimately improving the overall material performance (Soltani et. al., 2019 and Khoso et. al., 2016). In other words, such fibers inhibit and control the formation of inherent cracking in concrete, thus guaranteeing durable concrete construction (Qureshi, 2016). Steel fibers improve the overall concrete performance against sudden or impact loads, thus improving the toughness characteristics of hardened Concrete (Haldkar, 2016). Many researchers in the past conducted the experimental study by adding steel fibers to concrete and obtained significant results improving the concrete in flexure and post cracking performance (Ali et al., 2020; Ansari et al., Khoso et al., 2014; Naqash et al., 2014 and Johnston, 1985).

Moreover, adding steel fibers in concrete improved the fatigue effects, flexure strength, and shear strength at a considerable level (Mumtaz et al., 2021; Kumar and Kumar 2017; Khoso et al., 2014). Inclusion of lathe steel fiber as a reinforcing material could reduce the construction cost and cement requirements (Purohit et al., 2020). The workability of concrete with steel fiber has been decreased in most cases (El-Sayed 2019; Abbas 2011). Hence, this research paper sets out to explore the performance of lathe steel fibers and their potential effect on the mechanical properties of concrete, focusing on the reasonable and improved outcome (Afridi, Shahzada, and Naqash 2019; Khoso et al. 2018).

2. PROBLEM STATEMENT

As the world's population increases, there is a dire need for infrastructural development and mass constructions that can accommodate a more significant number of people. In this aspect, economic and durable Concrete is required, which is also sustainable. To enhance the characteristics of concrete material, inclusion of fibrous materials could be introduced and evenly distributed and randomly oriented which improves the compressive strength, tensile strength, shear and crack resistance, hardness, and reduction of concrete shrinkage. By keeping the economy and strength in mind, Lathe steel fibers have been used in the concrete, which is a better solution for utilizing industrial waste and reducing its impact on the environment.

Obviously, lathe scrap, which is a waste product attained from lathe industries, poses an adverse impact on the environment and the creatures around. The utilization of lathe steel fibers in traditional cement concrete enhances its characteristics and improves the compressive and tensile strengths. Moreover, the inclusion of the Lathe steel fibers in concrete also improves the post cracking behavior and reduces the formation of surface cracks when subjected to flexural load. It has been found that the mechanical properties have significantly improved by increasing the percentage of lathe scrap fibers up to 1.5%. Beyond this limit, the strength has been found to decrease.

3. MATERIALS

The concrete mixture prepared during this research mainly consists of Portland cement, fine aggregate, coarse aggregate, lathe steel fibers waste, and potable water.
A fresh Ordinary Portland Cement (OPC) with the brand name “Elephant Cement” was purchased from the local market and used to prepare all samples. Plain cement is the main ingredient of the concrete in the shape of powder, which helps the concrete get the form of solid once mixed with water. Being very fine, Cement fills the small openings left due to fine and coarse aggregates.
Fine aggregate is one of the essential components of concrete naturally available in a granular form. In general, fine aggregates are natural sand particles obtained from the through the process of mining. This material is one of the most used sand due to its high resistance to weathering actions. The natural sand used as fine aggregates consists of stone particles that are 0.25 inches in size or smaller. In this study, hill sand passing from a 4.75 mm sieve was used in fabricating all specimens and is shown in **Figure 1**. Fine aggregate provides resistance against shrinking and cracking, and it fills voids between aggregates, resulting in the formation of solid material.

Figure 1: Hill Sand used as Fine Aggregate in this Study

Coarse aggregate obtained from crushed particles passing from a 12 mm sieve and retained on 4.75 mm was used in this experimental study used, as shown in **Figure 2**. The specific gravity of the coarse aggregates was found to be 2.87. Coarse aggregate is the main component of cement concrete, which provides enough volume and binder material, and fine aggregate is one of the essential components of concrete. Coarse Aggregates provides volume to the concrete, which acts as a filler material resulting in homogenous concrete mass. Generally, the coarse aggregates used in the concrete mixture have a size greater than 4.75 mm (Firdous and Bajaj, 2017; Khoso et al., 2015)

Figure 2: Coarse Aggregate used in this research study

Considering concrete's economy and producing good quality concrete, the inclusion of late steel fibers could remarkably impact the overall concrete strength. Using such steel fibers could also produce sustainable concrete posing a more negligible effect on the environment due to reducing waste material dumped to open fields. Due to its availability in abundance, the steel fibers are used in this research investigation. These steel fibers are used as reinforcing material in concrete to improve the mechanical properties of concrete and make it resistant to impact loads. It also enhances various properties of concrete.

4. RESEARCH METHODOLOGY

In total 24-cylinder specimens (100 mm diameter by 200 mm height) were cast using a water to cement ratio of 0.5 for the curing period of 28 days. The samples were cast for all different groups i.e., control and with different steel fiber percentages of 0.5%, 1% and 1.5% addition They were tested for compressive and tensile strengths. Three standard-sized cylinder specimens were prepared for each fibre-reinforced mixture to determine the average compressive and tensile strengths and compare them with traditional concrete's strengths. Different percentages of lathe steel fiber were randomly dispersed in the mix while preparing and were poured into cylinder specimens for testing purposes.

A mix design of plain concrete and fiber reinforced concrete mixtures with a water to cement ratio (w/c) of 0.50 were prepared. Lathe steel fibers were used in cement concrete by weight of cement. One mixture of the controlled group with plain concrete and three mixtures of different percentages of steel fiber in the ranges of 1%, 1.5% and 2% were fabricated. The details of mixture proportions of concrete used in this study are given in Table 1. All the mixtures of concrete were prepared following ASTM-C192-18, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory."

Table 1: Mixture Proportions used in this Research Study

Mixture Type (%)	Cement by weight (%)	Lathe Steel Fiber by weight (%)	Coarse Aggregate (Kg)	Fine Aggregate by weight (%)	W/C
PC (0)	100	0	kg138	100	0.5
FC (1)	100	1%	138kg	100	0.5
FC (1.5)	100	1.50%	138kg	100	0.5
FC (2)	100	2%	138kg	100	0.5

A detailed methodology of various concrete mixtures, fabrication of specimens, and the curing period of the samples made for different tests carried out in this research, are explained below.

- Concrete was mixed as per ASTM C192-18, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory."

- For every mixture, three cylindrical specimens of 100 mm diameter and a height of 200 mm were fabricated for the compressive strength test and three cylinders for the tensile strength test at 28 days of age.
- After carrying out mixing of concrete, molds were filled with concrete in three equal layers, and compaction was performed using vibrating table shown in **Figure 3**.

Figure 3: Vibrating table used for compaction of concrete

5. EXPERIMENTAL ACTIVITY

Compressive strength cylinder specimens for all mixtures were determined following ASTM C39/ C39M-16, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." Cylinders specimens from every mix were tested after the curing period of 28 days. This testing process was carried out for all mixture groups with 1%, 1.5% and 2% proportions of lathe steel fibers. The testing setup of compressive strength is shown in **Figure 4**.

Figure 4: Compressive Strength Test Setup

The tensile strength of concrete measures its ability to resist the applied forces. Unlike steel, concrete is stronger only under compression forces and weak in tension. The tensile strength of concrete has measured nearly equal to ten percent of the compressive strength, which is not considered for the design purposes of concrete structures. The primary purpose of adding lathe steel fibers in concrete is to increase its tensile strength. The split tensile test was carried out for all specimens, also known as the Brazilian test. The samples were placed horizontally between the plates of a compression-testing machine, as shown in **Figure 5**.

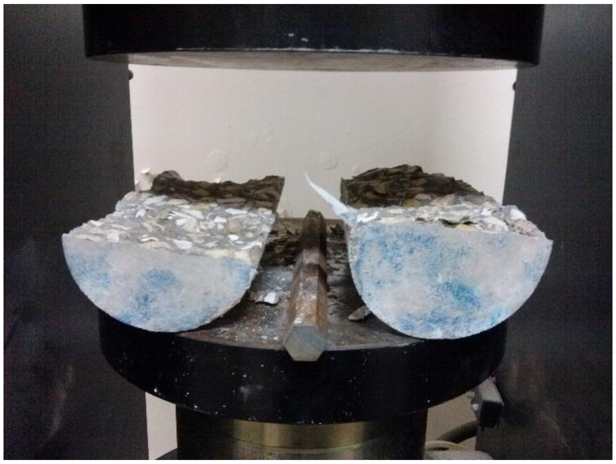

Figure 5: Split Tensile Strength Test Setup

The load was gradually applied until the cylinders failed in their vertical diameter. The Brazilian tensile strength test is easy to perform which reveals consistent results compared to other tensile tests. This test was performed to find the changes occurring in strengths with the increasing percentage of lathe steel fiber in the concrete. The test procedure was carried out following ASTM-C-496-18, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens”. Once the ultimate load was determined, the tensile strength of concrete was calculated using the formula given by Equation 1.

$$f'tc = \frac{2Px1000}{\pi LD} \qquad \text{Eq (1)}$$

Where:

$f'tc$= Tensile strength of Concrete (MPa).

P = Maximum applied load to the samples in KN.

L = Specimen length in mm.

D = Specimen diameter in mm

6. RESULTS AND DISCUSSIONS

The result of compressive strength of concrete mixtures with different percentages of lathe scrap steel fibers is shown in **Figure 6**. It has been found that the inclusion of lathe scape fiber has increased compressive strength up to the limit of 1.5%. In contrast, further addition resulted in the decrease of compressive strength. The maximum compressive strength observed at 1.5% is 27.4 MPa which is 14.71% more than the control mixture group.

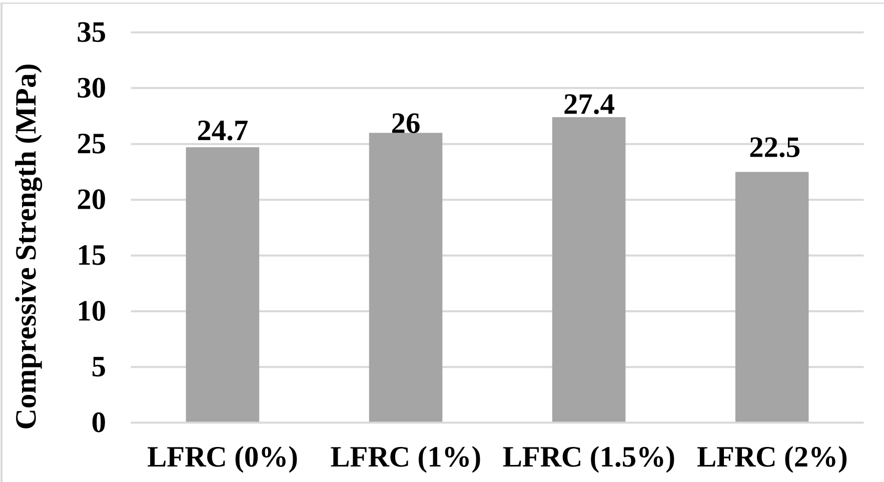

Figure 6: Compressive Strength Test Results of all mixture groups

The tensile strength results of different percentages of lathe steel fiber reinforced concrete are shown in **Figure 7**. With the inclusion of lathe steel fibers in concrete, the tensile strength is increased up to the fiber percentage of 1.5. Whereas beyond this limit, the tensile strength decreased drastically. The maximum tensile strength observed at 1.5% of fiber addition is 3.30 MPa which is 4.75% more than the control mixture group. Based on conducted parameters, 1.5% of the addition of lathe fiber results are optimum.

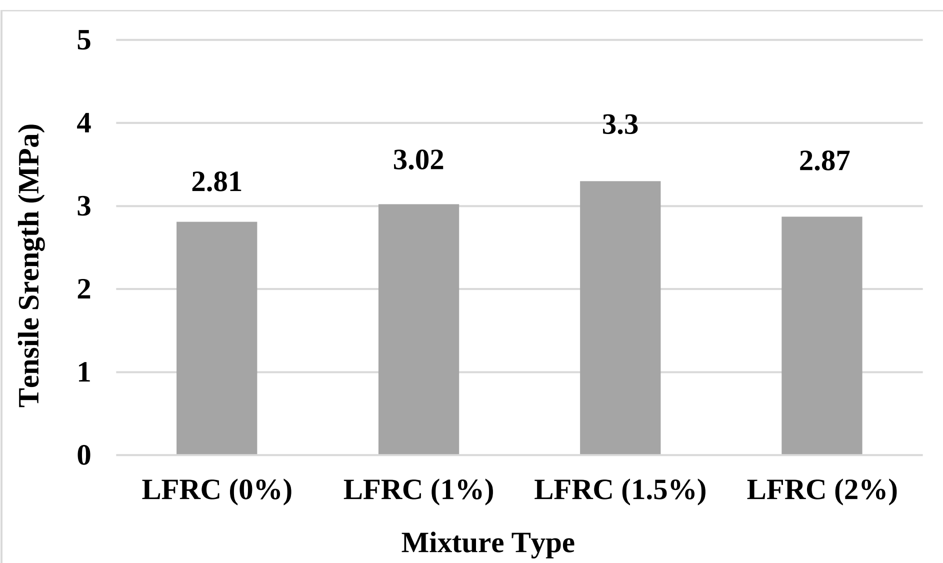

Figure 7: Tensile Strength Test Results of all mixture groups

7. CONCLUSIONS

This research work utilizes the Lathe steel scrap fiber in concrete as a reinforcing material and reduces its impact on the environment. It is usually dumped in open spaces and fields. Some interesting findings were obtained while conducting this experimental investigation, which is given as under.

1. It was observed that with the addition of lathe steel fibers in concrete, the compressive strength gradually increased with fiber proportion in concrete. The maximum results for compressive strength were obtained at 1.5% fiber content and decreased when fiber percentage was 2.0. The highest value obtained was 27.4 MPa which is 14.71% more than traditional cement concrete.
2. The same was observed when the concrete was tested under the split tensile test, and the maximum results were obtained at 1.5% fiber content in concrete. The obtained result was 3.30 MPa which is 4.75% higher than the plain cement concrete.

Based on this experimental work and the outcomes, it could be concluded that the most suitable proportion of lathe steel scrap fibers could be used up to 1.5% in concrete, which has been shown to improve concrete's mechanical properties significantly. This could make the concrete economical, but it would also benefit the environment and the surroundings as the waste is being utilized and its impact is being decreased.

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