INVESTIGATION OF THE COMPRESSION, SPLIT TENSILE AND FLEXURAL CHARACTERISTICS OF STEEL SCRAP COMPOSITE CONCRETE

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ABSTRACT

The research presents the result of an experimental work conducted to investigate the effect of Lathe waste composite concrete (LWCC) on the compressive, split tensile and the flexural strength. Findings show that there was a slight increase in compressive strength of the composite concrete while the increase on the tensile strength of concrete was clearly much on the high side as a result of the addition of steel scrap from lathe waste. The gain in split tensile strength of lathe waste composite concrete after 7 days was between 45.9% - 122.4% when compared to the control concrete. An increase of 19.3% - 56.6% was recorded on the 14th day as against the same grade of control concrete. Also, a veritable increase, between 44.2% - 93.9%, was observed after 28 days when compared to the same grade of controlled concrete.
It was detected that both the compressive strength and the split tensile strength of the composite concrete peaked at a fibre content of 1.5%. The concrete however experienced a minor bust on further increase in fibre content beyond 1.5%. The flexural strength increased up to 1.5% of fibre and on further increase on fibre content reduced the flexural strength of concrete. Steel scrap from lathe waste was found to be an eco-friendly material that can improve the structural strength of concrete.

Key words: lathe waste, municipal solid waste, steel scrap, steel fibre, composite concrete, Lathe waste composite concrete (LWCC)


1. INTRODUCTION

Currently, Nigeria has taken on a new development to further advance and improve infrastructures such as industrial structures and airport pavements in order to meet the requirements for providing a shift from mono-product to multi product economy [1], [2]. The use of reinforced concrete in the construction industry in Nigeria has therefore become inevitable for the requisite structural stability in most civil engineering structures.

For years, Nigeria has been reliant on orthodox and imported building material which are relatively expensive and outside the affordability of the average income earner. With dwindling oil cost, downward slide of naira to dollar and the economy that grossly depend on importation of raw and finished products, the price of steel is becoming unbearably expensive. Other means of reducing steel reinforcement in concrete is an attractive proposition, one of which is the reuse of steel waste from lathe machine. Steel wastes from lathe machines are stockpiled all over industrial estates in the country, although some are expended in the process of recycling these wastes into steel bars which consumes a lot of money. Thus, using it in its waste form becomes more attractive because the cost of processing it that way is negligible.

Consequently, the current study focuses on the use of lathe waste product to reinforce concrete, and its characteristics in term of compressive, tensile and flexural capacities will be investigated to determine its economic benefits.

In a comprehensive research report on the tensile strength of steel fibre reinforced concrete (SFRC), using steel fibre of varying ratio and fibre content, an increase in tensile strength with short steel fibre - irrespective of the volume fraction - was observed [3]. The study recorded a maximum tensile strength of 33.14N/mm$^2$ at optimum volume fraction of 0.7% and aspect ratio of 80. A more uniform result was obtained from the split tensile strength as compared with the flexural strength test result. In addition, [4] conducted an experiment to investigate the behaviour of steel fibre reinforced concrete slab under loading as well as the impact of volume fraction of the steel fibre on the flexural strength and energy absorption of the fibre reinforced concrete. The findings reveal that energy absorption of fibre reinforced slab can be 12 times higher than the normal slabs without fibre. Results also show that at 1% fibre content, there was a tremendous increase in energy absorption up to 200%. The energy absorption further increased by 150% with a volume fraction of 1.5% steel fibre. The load resistance of concrete after cracking was found to be low in concrete with lower fibre content compared to concrete with higher fibre content. The authors, therefore,
recommend the use of fibre of 0.75-1.75 aspect ratio for maximum concrete strength. Furthermore, [5] lucubrate and purport that an increase in fibre content will result in a decrease in workability and the crack width of concrete. He reported a 28th day crack width reduction from 1.3mm to 0.75mm. The crack width reduction was as a result of bond between the concrete and fibre, thus, proving the toughness of steel fibre. They further carried out a compressive strength test on 150mm³ specimen with fibre of varying volume fraction of between 0% - 5%, applying a gradual increment of 0.5%. They find that maximum compressive strengths of 45.2N/mm² and 70.15N/mm² were attained on the 7th and 28th day respectively at 2% volume fraction. Finally, in [6] study of the compressive and flexural behavior of steel fibre reinforced concrete, an aspect ratio in the order 15, 25, 30, and fibre content of 1.25%, 0.50%, and 0.75% were employed, resulting in the acceleration of the curing of concretes. Consequent upon the foregoing reviews, scholars are of the view that the least aspect ratio of 0.5% volume fraction produce the highest strength in term of both modulus of rupture and compressive strength.

2. MATERIALS AND METHODOLOGY
Lathe waste composite concrete is a mixture of water, Portland cement, aggregate and lathe waste as by-product from process of lathe machine. Engineers are able to regulate the ratio of materials in the composite concrete to obtain their desired properties.

Portland Cement
Cement binds together the concrete matrix. Locally made elephant Portland cement of grade 32.5 was used for the purpose of this experiment. The cement used was tested as per [7] BS EN 197-1.

Water
Water free from salt with an estimated pH of 7.0 was used for mixing and curing the concrete.

Coarse Aggregate
Gravels retained on sieve no. 4 (4.75mm) that conform to [8] BS 1377 part 1 was collected and used as coarse aggregate.

Fine Aggregate
Fine sand collected from deposits of transported sand in front of Lamo hostel, Osogbo was used. The fineness modulus of sand is 2.75 with specific gravity of 2.64. The gradation test result is as presented in Fig. 1

Scrap Steel
Lathe waste was collected from Osun State University mechanical laboratory dumpsite and the properties of lathe waste were investigated. The wastes were collected at zero cost and the cost of transportation was relatively low enabling the production of cost-effective composite concrete. The properties of scrap steel fibre from lathe waste is as shown in table 1.

<table>
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<th>Table 1 Properties of steel scrap from lathe waste</th>
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Casting of cubes, cylinders and beams were done. The adopted concrete grade was M20 concrete with varying percentages of lathe waste ranging from 0% to 2.5%

**Compressive Strength Test**

150mm³ concrete cubes were cast for the purpose of carrying out the compressive strength of concrete. The cubes contain varying volume fraction of lathe waste from 0% to 2.5%. A total of 18 samples of cubes were cast for 7th, 14th and 28th day respectively. The concretes cubes were tested after 7, 14 and 28 days of curing.

Failure loads were recorded and compressive strength of concrete was calculated as follows (equation 1):

\[
\text{Compressive strength} = \frac{\text{Failure load}}{\text{Cross-sectional Area} \ (\text{MPa})}
\]

**Split Tensile Strength Test**

A total number of 18 cylinders were cast for 7th, 14th and 28th day split tensile strength test. Cylinder specimens of 150x300mm were cast for the purpose of this experiment. A control specimen with 0% volume fraction of lathe waste was also included to make a comparison with other volume fraction of lathe waste. The specimens were tested under the universal testing machine (Plate 1) and failure loads were noted.

The split tensile strength of concrete was calculated as follows (equation 2):

\[
\text{Split tensile strength of concrete} = \frac{2F}{\pi D h}
\]

Where \( F \) = Failure Load, \( D \) = Diameter of cylinder and \( H \) = Height of cylinder

**Plate 1** Cylindrical specimens being tested under Universal Testing Machine

**Flexural Strength Test**

Flexural beams of 150x150x150mm were cast and cured in a curing tank for 28 days. The beams were brought out of the curing tank after 28 days and subjected to a two-point loading. The beam was set on the flexural testing machine to have an effective span of 650mm with end bearing of 25mm on both sides. The loads corresponding to the failure loads were noted and recorded for all 18 samples tested.

The flexural strength of concrete was then calculated using equation 3:
Investigation of the Compressive, Split Tensile and Flexural Characteristics of Steel Scrap Composite Concrete

Flexural strength $= \frac{FL}{bd^2}$  \hspace{1cm} (3)

Where $F =$ Failure load $L =$ effective span (650mm) of beam $b =$ corresponding width of beam (150mm) and $d =$ depth of beam (150mm)

3. RESULTS AND DISCUSSION

Results from the experimental tests are hereby presented in the charts below. compressive strength, split tensile and flexural strength result for M-20 grade of concrete with varying volume fraction of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% lathe waste.

Gradation test conducted on fine aggregate is as shown in Fig. 1 below

![Sieve Analysis Curve](image1.png)

**Figure 1** Particle size distribution test of fine aggregate.

The sieve analysis result as shown above reveals that fine aggregate is well graded and the fineness modulus is given as 2.75

![Compressive strength of LWCC (N/mm²)](image2.png)

**Figure 2** Increase in compressive strength
The compressive strength test results are illustrated in Fig 2 and Fig. 3. The increase in compressive strength of steel scrap composite concrete after 7 days was between 7.3% - 29.5% when compared to the controlled concrete. An increase of 8.0% - 24.8% was recorded at 14 days old compared to the same grade of controlled concrete. The compressive strength also varies at 28 days old, between 2.8% - 46.9% when compared to the same grade of controlled concrete. The ultimate strengths were taken at the peak load which was considered to represent the material strength of steel scrap composite concrete. The compressive strength increased up to 1.5% steel scrap content after which it reduced.

The split tensile test results are as shown in Fig 4 and Fig. 5. The increase in strength of steel scrap composite concrete at the age of 7 days was between 45.9% - 122.4% compared to the controlled concrete. An increase of 19.3% - 56.6% was recorded at 14 days compared to the same grade of controlled concrete. It also varies after 28 days, between 44.2% - 93.9% when compared to the same grade of controlled concrete. The ultimate strengths were taken at the peak load which was considered to represent the material strength of steel scrap composite concrete. The compressive strength increased up to 1.5% steel scrap content after which it reduced.
All beam specimens were tested under third point loading. The effective span of beam was 650mm with an end bearing of 25mm. Flexural strength of concretes were determined on the 28th day. Figure 4.5 shows that flexural strength increased up to 1.5% of fibre and on further increase of fibre content, reduced the flexural strength of concrete. There was an increase from 25.3% up to 58.1% compared to the control specimen.

4. CONCLUSIONS

In conclusion, the study validates the claim that lathe scraps have the potential to improve the characteristic, in term of compressive, split tensile and the flexural strength of concrete. The above results show that steel scraps from lathe waste in concrete improve its strength characteristics and made it suitable for civil engineering applications. It was noticed that the compressive, split tensile and flexural characteristic strength of concrete all peaked at 1.5% addition of fibre and a minor burst in strength was noticed on further application of fibre to the concrete.

The compressive strength of the concrete increased with addition in the volume fraction of lathe scrap from 0.5% to 1.5%, while a reduction in compressive strength was recorded, from 1.5% to 2.5%. An increase in strength up to 29.5%, 24.8% and 46.9% were obtained for the
7th, 14th and 28th day strength respectively with an optimum fibre content of 1.5% when compared to the control concrete.

The split tensile strength of lathe waste composite concrete also increases with increasing fibre content from 0.5% to 1.5%, but reduced on further addition of lathe waste. A consequential increase in tensile strength was observe compared to the compressive strength. The split tensile strength was increased up to 122.4%, 56.6% and 93.9% for the 7th, 14th, and 28th days strength of steel scrap composite concrete.

The flexural strength like the compressive and split tensile strength increased with increasing fibre content from 0.5% to 1.5%. There is a slight reduction in flexural strength on further increase in fibre. There was an increase from 25.3% up to 58.1% when compared with the control specimen.

5. RECOMMENDATION

For future development in this project, the following recommendations are proffered:

- As the volume fraction increases so does the concrete tend to clump together while mixing. Thus, the water cement ratio should increase as the fibre content increases.
- Optimum fibre content of 1.5% should not be exceeded for desirable strength of concrete so as to avoid any decrease in the strength of concrete.
- Further research should be carried out to investigate the reaction of Lathe waste composite concrete under loading and impact.

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