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# EVALUATION OF THE STRENGTH PROPERTIES OF STEEL FIBRE REINFORCED CONCRETE PRODUCED WITH FLY ASH AS PARTIAL CEMENT REPLACEMENT

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**Abstract**

This paper examined how the strength properties of plain concrete performance can be improved by the introduction of hooked-ends steel fibres by volume fraction and fly ash as replacement for cement into concrete batch with the objective of bridging the inherent brittle nature and dramatic disadvantages such as poor deformability and weak crack resistance of plain concrete in practical usage. Compressive and flexural strengths of concrete cubes and prisms produced with fly ash as partial replacement for cement at 0, 10, 20, 30 and 40%, with incorporation of steel fibres at 0%, 0.50%, 0.75% and 1.00% by volume fraction of concrete were determined.

Seventy five (75) concrete cubes of size 150x150x150 mm were cast. Compressive strength of concrete cube specimens was evaluated 7, 14, 21, 28 and 56 days. Compressive strength results indicated that 10% fly ash replacement out-performed all other percentage replacements including the control mix replacement of 0% fly ash. The strength development of concrete cubes at 56 days fly ash replacement of 20%, 30% and 40% indicated faster rate of strength development than those of 0% and 10% fly ash replacement.

Sixty (60) concrete prisms of size 100x100x400 mm were produced with steel fibres incorporation at 0%, 0.50%, 0.75% and 1.00% by volume fraction of concrete and fly ash partial replacement for cement at 10%, 20% and 30%. The flexural strength of concrete prisms was evaluated. Addition of hooked-ends steel fibres 0.55mm diameter and 33mm length to concrete cylinders and prisms slightly improved both split tensile and flexural strength of concrete. The results at 28 and 56 days indicated that concrete prism specimens reinforced with steel fibres have their strengths slightly greater than that of concrete cylinder and prism specimens with no steel fibre added.

***Keywords (steel fibre reinforced concrete, fly ash, flexural strength, compressive strength)***

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## 1.0 Introduction

Steel fibre reinforced concrete is a composite material having fibres as the additional ingredients, dispersed uniformly at random in small percentages, i.e. between 0.3% and 2.5% by volume in plain concrete. SFRC products are manufactured by adding steel fibres to the ingredients of concrete in the mixer and by transferring the green concrete into moulds. Steel fibres are added to concrete to improve the structural properties, particularly tensile and flexural strength. The extent of improvement in the mechanical properties achieved with SFRC over those of plain concrete depends on several factors, such as shape, size, volume, percentage and distribution of fibres.

Compared to other building materials such as metals and polymers, concrete is significantly more brittle and exhibits a poor tensile strength. Based on fracture toughness values, steel is at least 100 times more resistant to crack growth than concrete. Concrete in service thus cracks easily, and this cracking creates easy access routes for deleterious agents resulting in early saturations, freeze-thaw damage, scaling, discoloration and steel corrosion. The concern with the inferior fracture toughness of concrete are alleviated to a large extent by reinforcing it with fibres of various materials. The weak matrix in concrete, when reinforced with steel fibres, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. The randomly-oriented steel fibres assist in controlling the propagation of micro-cracks present in the matrix, first by improving the overall cracking resistance of matrix itself, and later by bridging across even smaller cracks formed after the application of load on the member, thereby preventing their widening into major cracks

The resulting material with a random distribution of short, discontinuous fibre is termed fibre reinforced concrete (FRC) and is slowly becoming a well-accepted mainstream construction material. Significant progress has been made in the last 30years toward understanding the short and long-term performances of fibre reinforced cementitious materials, and this has resulted in a number of novel and innovative applications (Weiss and Shah, 1997).

In the hardened state, when fibres are properly bonded, they interact with the matrix at the level of micro-cracks and effectively bridge these cracks thereby providing stress transfer media that delays their coalescence and unstable growth. If the fibre volume fraction is sufficiently high, this may result in an increase in the tensile strength of the matrix. Indeed, for some high volume fibre composite (Banthia and Sheng, 1996), a notable increase in the tensile/flexural strength over and above the plain matrix has been reported.

## 2.0 Materials and Methods

**Sample Preparation**

The fly ash used was collected from Surulere and Akinyele Local Government areas of Oyo state, Nigeria. Flexural and split tensile strengths of prism and cylinder fibre reinforced concrete specimens were also carried out.

Concrete cubes, cylinders and prisms were cast by using the percentage order of 0%, 10%, 20%, 30%, and 40% by weight replacement of cement with fly ash. Three (3) samples were cast for each percentage . The 0% replacement served as the control.In this experimental study, Cement, Sand, Coarse aggregate, Water, Fly ash and Steel fibres were used.

**Cement:** Ordinary Portland cement of grade 43 was used in this experimentation conforming to IS-8112-1989.

**Sand:** Locally available sand specific gravity of 2.45, water absorption 2% and fineness modulus 2.92, conforming to IS-383-1970 was adopted in this study.

**Water:** Portable water was used for the experimentation.

**Steel Fibre:** Hooked end steel fibres were used.

**Fly Ash:** The fly ash was obtained locally from combustion of coal, the fly ash complies with ASTM 6 618 for mineral admixtures in Portland cement concrete. Because if it production method, it is considered to be class C fly ash.

**Mixing:** The measured coarse aggregates were spread on a hard clean and non-porous base, followed by the fine aggregates and then spread over the aggregates (sand) with the necessary proportion, cement and fly ash was then added, thematerials were thenmixed by turning over fromone end to the otheruntil it appears uniform.Water was then added using water-cement ratio of 0.6 and the mixing was continued until a workable mix was achieved, the measured steel fibres of 0.5%, 0.75% and 1.00% by volume of concrete for cylinder and prism specimens were later spread and mixed with concrete**.** The samples were demoulded after 24hrs and placed in water to cure until the appropriate testing day.

Table 1 shows the summary mix design for this study; while Table 2 shows the summary of all the concrete mix design for all the mixes.

Table 1: Summary of Concrete Mix Design

| Quantities | Cement (Kg) | Water (Kg) | Fine Aggregate (Kg) | Coarse Aggregate (Kg) |
|---|---|---|---|---|
| Per $m^3$ | 425 | 170 | 722 | 1083 |
| Mix Ratio | 1 | 0.4 | 1.7 | 2.6 |

Table 2: Summary Concrete Mix Design for allMixes

| mix no. | mix id. | | water (kg) | cement (kg) | fly ash (kg) | c.a (kg) | f.a (kg) |
|---|---|---|---|---|---|---|---|
| 1 | A | Per $m^3$ | 170 | 425 | - | 1083 | 722 |
| | | Per 0.0633 $m^3$ | 10.76 | 26.90 | - | 68.55 | 45.70 |
| 2 | B | Per $m^3$ | 170 | 425 | - | 1083 | 722 |
| | | Per 0.0633 $m^3$ | 10.76 | 24.21 | 2.69 | 68.55 | 45.70 |
| 3 | C | Per $m^3$ | 170 | 425 | - | 1083 | 722 |
| | | Per 0.0633 $m^3$ | 10.76 | 21.52 | 5.38 | 68.55 | 45.70 |
| 4 | D | Per $m^3$ | 170 | 425 | - | 1083 | 722 |
| | | Per 0.0633 $m^3$ | 10.76 | 18.83 | 8.07 | 68.55 | 45.70 |
| 5 | E | Per $m^3$ | 170 | 425 | - | 1083 | 722 |
| | | Per 0.0633 $m^3$ | 10.76 | 16.14 | 10.76 | 68.55 | 45.70 |

**Figure 1**: Steel Fibre used




**Figure 2**: Fly Ash used **Figure 3**:Mixed concrete **Figure 4**:Cube specimen **Figure 5**:Prism and cylinder Constituentsspecimen

### 3.0 Results and Discussion.

Figure 3 shows the compressive strength development of concrete cubes containing 0%, 10%, 20%, 30% and 40% of F.A replacement by weight of cement. The 10% F.A replacement outperformed all other percentage fly ash replacement. The increase in strength at 7 to 56 days testifies to the fact that the strength of the blended fly ash mixture is proportional to their reactive silica content from 7 days. The fly ash replacement lowered the strength of 20%, 30% and 40% replacement which is an indication of the slow evaluation of the pozzolanic action, which mainly determines the strength development of the system containing fly ash. However, during the same period especially at 56 days of concrete hydration, fly ash replacements of 20%, 30% and 40% by weight of cement were developing strength at a faster rate than the control mix and 10% F.A replacement.

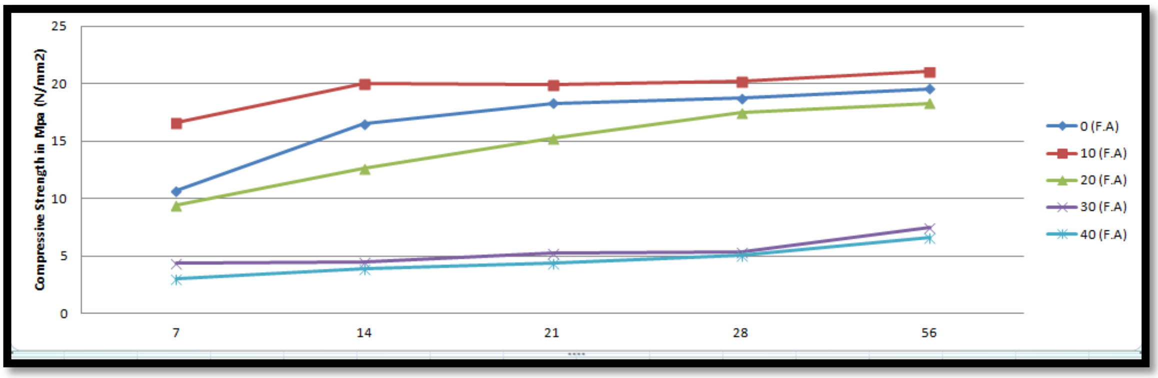
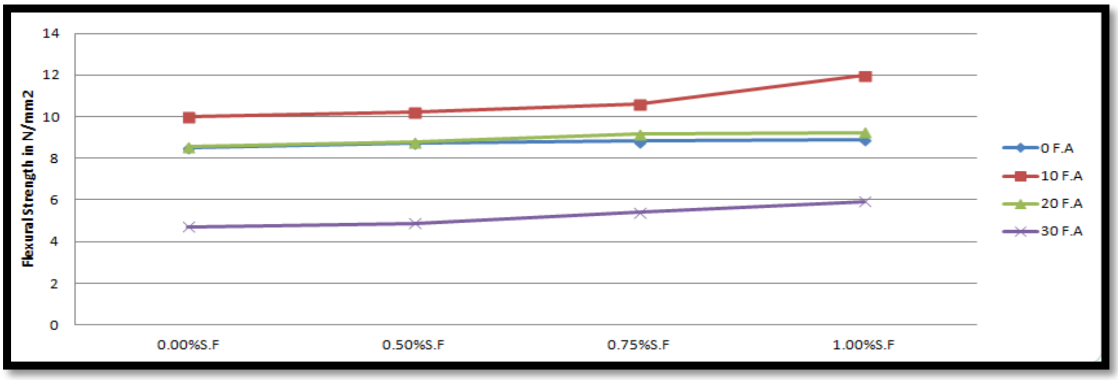



**Figure 3: Summary of Compressive Strength from 7 Days to 56 Days**

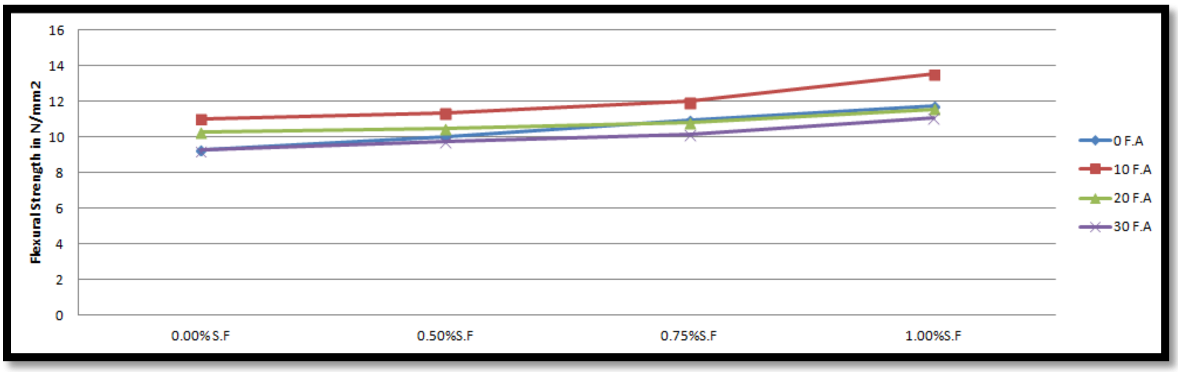
**Flexural strength result**

Tables 4 and 5 presents the summary of flexural strength at 28 and 56 days. At 10% F.A replacement by weight of cement indicated higher flexural strength compared to the control and other F.A percentage replacement. Also, steel fibre introduction to concrete specimen by volume fraction and partial replacement of fly ash by weight of cement at 10% and 20% reflected an effective and economical way to covert cementitious material into a tough and ductile product. Addition of steel fibres enhanced flexural strength of concrete in comparison with control mix. The increase in flexural strength of high performance steel fibre concrete was attributed to the capacity of steel fibre to delay the unstable development of micro cracks and as well as to limit the propagation of these micro cracks and the composite effect for concrete and steel fibres under load.

| `Sample No | Sample ID In (%) | Flexural Strength in N/mm$^2$ at 56 days | | | | |
|---|---|---|---|---|---|---|
| | | Steel Fibre (%) | 0% | 0.5% | 0.75% | 1.00% |
| 1 | 0 F.A | Flexural Strength in N/mm$^2$ at 56 days | 9.31 | 10.02 | 10.95 | 11.86 |
| 2 | 10 F.A | | 11.04 | 11.35 | 12.00 | 13.54 |
| 3 | 20 F.A | | 10.27 | 10.49 | 10.81 | 11.58 |
| 4 | 30 F.A | | 9.25 | 9.75 | 10.17 | 11.07 |




Flexural Strength Development at 28 Days




Flexural Strength Development at 56 Days

Table 5: Summary of Flexural Strength of Prism at 28 Days

| `Sampl e No | Sample ID In (%) | Flexural Strength in N/mm$^2$ at 28 days | | | | |
|---|---|---|---|---|---|---|
| | | Steel Fibre (%) | 0.00% | 0.50% | 0.75% | 1.00% |
| 1 | 0 F.A | Flexural Strength in N/mm$^2$ at 28 days | 8.51 | 8.74 | 8.82 | 8.88 |
| 2 | 10 F.A | | 10.00 | 10.23 | 10.63 | 11.98 |
| 3 | 20 F.A | | 8.54 | 8.78 | 9.16 | 9.25 |
| 4 | 30 F.A | | 4.72 | 4.89 | 5.42 | 5.94 |

**4.0 Conclusion**

The strength properties of steel fibre reinforced concrete produced with fly ash as partial replacement with cement was investigated in this study and the following conclusions are drawn:

1. The addition of fly ash as partial replacement by weight of cement in concrete production, especially at 10% F.A replacement was suitable. The 10% F.A replacement showed good and higher strength development compared to all other percentage replacements.

2. The Steel fibres increased the flexural strength of concrete specimens, although the difference is not that significant. The higher the percentage volume fraction of steel fibre to concrete mix, the higher the strength but with no uniform pattern. 0.75% and 1.00% of steel fibres with 10% F.A replacement by weight of cement indicated maximum flexural strength over concrete specimen with 0.5% and control mix.

3. The compressive strength was higher at 56 days; fly ash replacements of 20%, 30% and 40% by weight of cement were developing strength at a faster rate than the control mix and 10% F.A replacement.

4. Steel fibre was observed to be appropriate in controlling cracks which occurs in the hardened concrete and provides post–crack performance of concrete.

## RECOMMENDATIONS

Steel fibres incorporation to concrete with fly ash partial replacement for cement enhanced the strength properties of concrete and from this the following recommendations are made;

i. Steel fibres are recommended as a good material to convert cementitious system to structural material with desirable physical and mechanical properties.
ii. Steel fibres are seen to be very appropriate material to improve the brittleness nature of plain unreinforced concrete.
iii. Addition of steel fibres to concrete matrix is recommended for use as this shows significant effect in resisting the crack propagation associated with plain concrete.
iv. Fly ash at 10% and 20% replacement by weight of cement is recommended for use in concrete construction work, because of it higher strength indication compared with control mix that contain no fly ash.
v. The application of steel fibres is identified to be an effective and economical way to convert cementitious material into a tough and ductile product.

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