Flexural Strength Characteristics of Fly Ash Blended OPC Reinforced Sorrel Fibre Concrete

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ABSTRACT

This research work studied the flexural strength characteristics of Fly Ash blended ordinary Portland cement (OPC) concrete reinforced sorrel fibre. This study considered three mix ratios of concrete specimens and were prepared and cast into 100mm × 100mm × 500mm mould of: (1)1:2:4 mix ratio of plain concrete as control sample (2) concrete sample of 1:2:4 mix ratio, reinforced with 1.5% volume fraction of 50mm average length of sorrel fibre (3) Concrete specimens of 1:2:4 mix ratio with binders containing 90% (OPC) + 10% (FA); 80% (OPC) + 20% (FA) and 70% (OPC) + 30% (FA). The water binder ratio was kept constant at 0.6. All the blended samples were reinforced with 1.5% by volume fraction of heat treated sorrel fibre of 50mm average length. The beams specimens were cast for flexural strength tests. The concrete samples were tested in flexure at 7, 28 and 90 days. With the addition of heat treated sorrel fibre, flexural strength increased from 5.0N/mm^{2,} 6·0 N/mm^{2} and 7.5N/mm^{2} for optimum blend at 7, 28 and 90days respectively. For the blend containing 10% (FA) + 1.5% volume average length of heat treated sorrel fibre recorded the highest flexural strength mentioned above. The properties of sorrel fibre reinforced concrete was improved with the optimum blend of Fly Ash (FA) and Heat Treated Sorrel Fibre (HSF).

Keywords: *Sorrel Fibre, Fly Ash and Blended Concrete, Flexural Strength.*

1. INTODUCTION

Concrete made from Portland cement, is relatively strong in compression, weak in tension and brittle. In conventional concrete, micro-cracks develop before structure is loaded because of drying shrinkage and other causes of volume change. When the structure is loaded, the micro cracks open up and propagate because of development of such micro-cracks, results in inelastic deformation in concrete (Banthia, 2012). Fibre reinforced concrete (FRC) is cementing concrete reinforced mixture with more or less randomly distributed small fibres. In the FRC, a numbers of small fibres are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all directions. The fibers help to transfer load to the internal micro cracks. Fibre reinforced concrete is cement based composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural-tensile strength, resistance to spitting, impact resistance and excellent permeability and frost resistance. It is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar.

The weakness in tension can be overcome by the use of conventional steel bars reinforcement and to some extent by the mixing of a sufficient volume of certain fibers. The use of fibers also recalibrates the behavior of the fiber-matrix composite after it has cracked through improving its toughness (Nataraja and Dhang,1999).

Ordinary Portland cement is virtually the only cementitious product used in the country for construction with high foreign exchange content; it is obvious that any local cement extended will bring great saving in foreign exchange. Fly ash is such a material. This calls for a decisive shift in the selection and application of building materials and technology leading to cost effectiveness and providing durable functional and aesthetic options as against conventional options. In recent times researchers and developers of local building materials have been posed with the challenge of evolving suitable strategies using alternative local materials which are more often left as residues. The subject interest is the use of fly ash (FA) as a partial replacement for ordinary Portland (OPC) and the composite reinforced with sorrel fibre.

Fly ash is solid materials extracted by electrical or mechanical means from the gases of boilers fired with pulverized coal. Fly Ash is one of the artificial Pozzolana which is widely recognized and used as a Pozzolana. The major components being oxides of Aluminum (Al_2O_3), Iron (Fe_2O_3), Silicon (SiO_2) and rarely calcium (CaO), (Rangan and Hardjto, 2005). Fly ash has been used in concrete production for many years as a simple way to improve the workability, durability and sustainability of concrete. (Nwankwo, 2013). Fly ash in this research has been used as a means of for mitigating the performance of concrete when reinforced with sorrel fiber. This is accomplished by replacing a portion of cement with fly ash, however, the cement and the concrete industry together cannot meet the graving demand in construction industry as well as help in reducing the environmental pollution. With the national annual output of several million tonnes of fly ash, the utilization is still below 20% (IOSR M.E. & C.E. Journals, 2013).

Literature reveals the use of natural fibers such as ramie, flax, sorrel, jute and pine needle in graft copolymerization because of their relatively high strength and stiffness for their viability in industries such as automobile, packaging and construction materials as it fulfills the economic and ecological requirements. Various polysaccharides have been modified for their use in metal ion-sorption, drug delivery and water absorption studies and as reinforcement in bio-composites. A lot of research on fiber, polymer and composite materials have yielded fruitful results (Adedayo, 2012).

To improve the tensile strength of fly ash blended concrete, sorrel fibre was employed. Sorrel is locally called in Hausa Language “Yakuwa” which is mostly grown in Northern Nigeria. It has a sharp taste due to oxalic acid and is apart, from the medicinal use of this plant, its fibre or Terra yarn which was drawn from its stem and used as reinforcement in Composite concrete was due to its high tensile strength. Sorrel stem fiber is rich in cellulose and exists in abundance as waste biomass locally. Its low weight and high tensile strength makes it suitable for use as backbone in graft copolymerization to reinforce physico-chemico-thermo-mechanical resistance in the fiber (Chauhan, 2009).

Most developing countries are rich in agricultural and vegetable fibres. The use of vegetable fibres as reinforcement agent in composite concrete (cement and polymer) is gaining attention across the globe. In this work, sorrel fibre was treated by boiling and washing as a cheap means of removing certain amount of lignin, waxes and oils covering the external surface of the fibre cell wall. Boiling increases the vegetable fibre’s crystallinity of the cellulose, a marginal improvement in the workability of concrete mix and increase the strength and density of the composite (Nwankwo, 2013).

The research explored the use of rare composite concrete with reinforced fibre mixture to synthesize, characterize and evaluate the optimum percentage of reinforcement fly ash (FA) in reinforced sorrel fibre concrete to achieve strength development in later age of the composite concrete. The improved properties of the fibre and the composite as compared with the native form make it an efficient technique for judicious use of renewable resources in scientific, environmental and technological applications.

2. MATERIALS AND METHODS

The ordinary Portland cement (OPC) used in these study include "Dangote 3x" brand grade 42.5R conforming to B.S12 (1996) and ASTM – C -150 (1994). The fine aggregate is river sand was sourced from Miango area in Jos Plateau state Nigeria, while 20mm crushed granite procured from PW yard at Rock Heaven road Jos Plateau State. Fly Ash was obtained from waste dump at thermal power plant in Orji river Enugu state Nigeria. Locally sourced sorrel fibres were cut to an average length of 50mm. The heat treated sorrel fibre; the fibre was simply allowed to boil in clean water for 30mins. It was then allowed to cool, then washed and sun dried for 7 days at ambient temperature, it was cut to 50mm average length.

Preparation of Specimens

The control mix consist of 1:2:4 plain concrete mix, that translate to one part of binder, two parts of fine aggregates to four parts of coarse aggregate. Flexural strength samples were cast in beam moulds measuring 100mm × 100mm × 500mm in accordance with B.S 1881: part 118 1983. An electrically operated machine located in materials concrete testing laboratory of the Department of Building, University of Jos was used to test the flexural strength.

The study employed three different mix ratios. These were identified as (1) plain OPC normal concrete of 1:2:4 mix ratio, referred to as control specimen. (2) Specimen of OPC concrete of 1:2:4 mix ratio mix reinforced with 1.5% volume fraction of 50mm average length sorrel fibres (3) Reinforced concrete specimen with binder containing 10%FA + 1.5%TSF, Reinforced concrete specimen with binder containing 20%FA + 1.5%TSF, Reinforced concrete specimen with binder containing 30%FA + 1.5% TSF. All the specimens were reinforced with 1.5% heat treated sorrel fibre .The specimens were prepared with a constant water binder ratio of 0.6, and the ratio of fine aggregate to coarse aggregate remain 2:4. Table 1 shows the mass of constituent materials per cubic metre of concrete.

Hand mixing was done on a clean, hard non absorbent surface. To avoid balling of fibres and segregation of concrete, the aggregate, cement and fly ash were four times dry mix. The required amount of fibres was uniformly added by hand throughout the mass. Dry mixing continued until homogeneity was attained, followed by the addition of required quantity of water to get a good blend of concrete.

Thus both slump and compacting factor tests were adopted for this research as a measurement of workability of fresh concrete mix. The slump measured in mm is shown in table 2. The compacting factor test resulting (Nevile 1996, Bartos Sorebi and Termimi, 2002), measures the degree of compaction resulting from application of standard work. This was done in accordance with the standards of B.S 1881 part 102 (1993). The results are presented in table 2.

Experimental

The steel beam moulds measuring 100mm × 100mm × 500mm steel moulds were cleaned and oiled with mould oil before they were ready to receive concrete. The wet reinforced concrete was cast into the beam moulds and vibrated on electric vibrated table, until when the slurry overflow the top of the beam. The samples were marked for easy identification and kept in a cool dry place under ambient condition. After 24 hours, the samples were demoulded, weighed and cured by immersion in a large container filled with water for curing ages of 7, 28 and 90 days. The beam samples were tested at the specified curing ages as presented in table 3.

Table 1 Mass of Constituent Materials Cubic Metre of Concrete (kg)

Material	Mix Ratio 1:2:4
Cement (control mix)	286
Cement (with 1.5% fibre)	281
Fine Aggregate	743
Coarse Aggregate	1486
Sorrel fibre (1.5% V_f)	26
Water (litres)	226
10FA + 1.5TSF	74 + 668
20FA + 1.5TSF	148 + 668
30FA + 1.5 TSF	223 + 520

Table 2 Results of Slump and Compaction Factor Tests

Mix Ratio	Sorrel Fibre	Blending % OPC : FA	Sorrel Fibre % (V_f)	Slump (mm)	Compaction Factor	Degree of Workability
Control	None	None	None	140	0.98	High
	None	None	1.5	65	0.92	Medium
1:2:4	TSF	90:10	1.5	55	0.93	Medium
	TSF	80 : 20	1.5	65	0.95	Medium
	TSF	70 : 30	1.5	75	0.94	Medium

Table 3 Program of Flexural Strength Tests

Type of test	Curing Age (days) 7	28	90	Sorrel Fibre %(Vf)	Percentage replacement FA	Temperature (^{0}C)
Flexural strength test on 100 × 100 × 500mm Beams	3	3	3	None	None	Ambient
	3	3	3	1.5	None	Ambient
	3	3	3	1.5	10	Ambient
	3	3	3	1.5	20	Ambient
	3	3	3	1.5	30	Ambient

Table 4 Flexural Strength Results for 1:2:4 Mix Ratio

Identification	Average Failure Load (kN) Curing age (days)			Flexural Strength (N/mm^2) Curing (days)		
	7	28	90	7	28	90
P	2.0	4.0	4.0	1.0	2.0	2.0
RC	7.0	6.0	6.5	3.5	3.0	3.25
RC10	10.0	12.0	15.0	5.0	6.0	7.50
RC20	5.5	7.0	6.0	2.75	3.50	3.0
RC30	6.5	4.0	5.0	3.25	2.0	2.50

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3. RESULTS AND DISCUSSION

Flexural load is the maximum load the sample can bear before rupture during flexure test. During the flexural Strength tests, it was noticed that all the samples failed within the e third span of the beam. Therefore the flexural strength of the samples was obtained from the conventional plain concrete method (ASTM, 200M), which states that:

$$f_b = PL/bd^2 \quad \text{.......} \quad (1)$$

Where by: P = maximum total load of the beam (N)
L = length of the beam (mm)
b = width of the beam (mm)
d = depth of the beam (mm)

Equation 1 was used in the computation of the modulus of rupture in this experiment. The Blend of 10 (FA), reinforced with 1.5% volume of heat treated sorrel fibre, an optimum flexural strength of 5.0 N/mm^2 was recorded at 7 days of curing as shown on figure 1. It was observed that the increase in the quantity of Fly Ash in the composite led to a decrease in flexural strength of 2.75 N/mm^2 and 3.25 N/mm^2 for 20(FA) and 30(FA) respectively. This could be due to the decrease in quantity of Portland cement. It was also observed that when failure occurs, the cracks in the weak zone for fibre reinforced samples were less than that of plain concrete, which is an indication of stiffness and hence a delay in collapse.

Table 4 and figure 2, shows the flexural strength results of OPC/FA fibre reinforced concrete cured at 28 days. From the results there is a consistency in flexural strength development, of the blend with 10(FA), reinforced with 1.5% heat treated sorrel fibre. The sample recorded the highest flexural strength of 6.0N/mm^2, in comparison with reinforced sorrel fibre blends of 20 (FA) and 30 (FA), which recorded 3.5N/mm^2 and 3.0 N/mm^2 respectively.

From table 4, figure 3, shows a sharp increase in flexural strength of 7.5 N/mm^2 at 90 days of curing age in comparison with 20(FA) and 30(FA) that recorded 3.0N/mm^2 and 3.5N/mm^2 respectively. There is a consistency increase in flexural strength for sample containing 10 (FA), reinforced with 1.5% volume of heat treated sorrel fibre at all the curing ages. This is due to the bonding of the cementatious materials in the composite and the filler effect of the pozzolana. The resulting composite is suitable for resisting high bending stresses because the strength recorded at 90 days of curing for the sample is higher than control sample that recorded as indicated on the table4 and chart 3.

In this study, the inclusion of pozzolan to blend Ordinary Portland Cement, reinforced with sorrel fibre, leads to the improvement in workability.

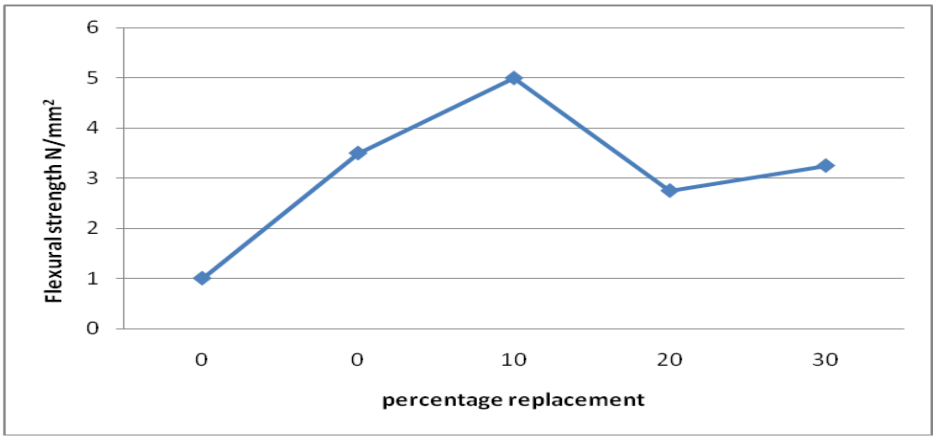

Fig.1. Flexural Strength of 7 Days Curing Age of Blended OPC/FA Reinforced Sorrel Fibre Concrete

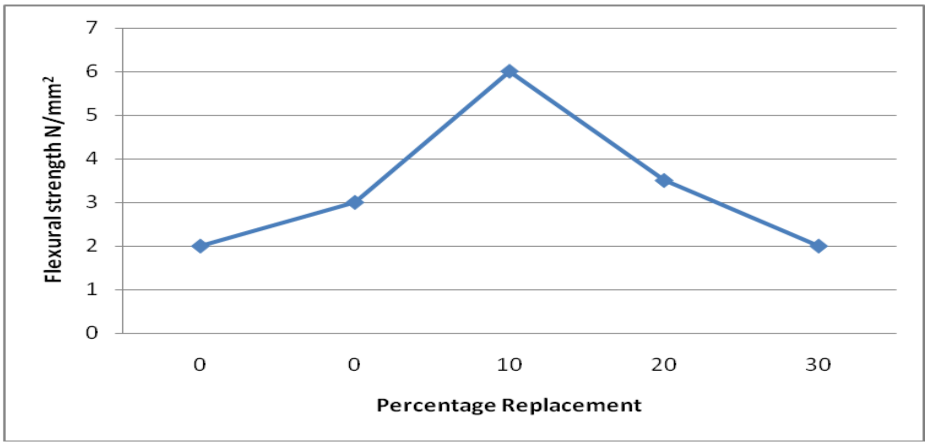

Fig.2. Flexural Strength of 28 Days Curing Age of Blended OPC/FA Reinforced Sorrel Fibre Concrete

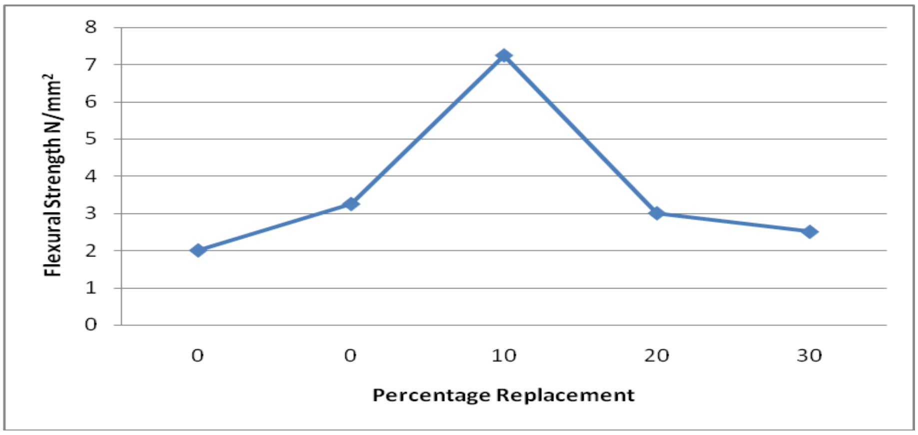

Fig.3. Flexural Strength of 90 Days Curing Age of Blended OPC/FA Reinforced Sorrel Fibre Concrete

4. CONCLUSION

The incorporation of 1.5% volume fraction of 50mm average length of sorrel fibre causes a sharp increase in flexural strength of the optimum sample from 5.0N/mm^2, 6.0N/mm^2 and 7.5N/mm^2 at7,28 and 90 days of curing ages. The optimum blend containing 10% fly Ash gave the aforementioned optimum result for flexural strength. This is due to the increased in pozzolanic activity of fly ash that activated the cementatious materials leading to a sharp increase in bonding and hence increase in flexural strength.

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