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**Evaluation of Sustainable Concrete Production and
Construction Cost Implication in Nigeria**

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Abstract

Sustainable concrete provides a considerable solution to the increasing cost of conventional concrete production in the world. Though, it is generally described as cheap, however it's design and cost implications for low income communities needs to be evaluated. Hence, this paper evaluates the production of sustainable concrete and its cost implication in Nigeria. Experimental design of high strength concrete made with steel fibre and bamboo fibre as reinforcement having a targeted compressive strength of 50 Mpa was considered. The steel and bamboo fibres were

proportioned at 1 % each. From the experimental mix design and cost analysis conducted, it was realized that steel fibre reinforced concrete are most expensive per cubic metre, costing about seven times as much as plain concrete of the same volume, but bamboo is a low cost alternative to steel as a reinforcing material.

Key words: affordable housing, bamboo fibre, concrete, steel fibre, sustainability

Introduction

In the quest for the provision of affordable housing for citizens in peri-urban precincts, the use of sustainable concrete for construction cannot be over stated. Previous and current research findings have revealed different substitute materials for cement, aggregate, and reinforcement bar currently utilized for concrete production (Balaguru and Shah, 1985; Dawood and Ramli, 2009; Dawood and Ramli, 2011; Labana et al., 2009) around the world. Lots of importance are associated with the use of sustainable materials for construction, it helps to reduce the health hazard posed by the environmental degradation as a result of continuous exploration of natural materials (William et al., 2004), or otherwise as a consequence of dumped waste materials in landfill areas (Terry and Kyuho, 2006; Ogbuene et al., 2013). Consequently, the challenges associated with the exploration of natural materials and disposed waste construction materials are overcome by the adoption of environmental friendly sustainable materials, which facilitate green construction. Future concrete constructions are aimed towards the use of sustainable solutions. Naik (2008) described a sustainable concrete structure as that which is constructed in order to ensure that the total environmental impact during its life cycle, including its use, will be minimal.

Some of the advantages of sustainable concrete include that it possess a very low inherent energy requirement, and it is produced with little waste. More so, they are often made of recycled materials which are known to have very high thermal mass, for construction of durable structures. According to Naik, (2008), sustainable constructions have a small impact on the environment, in that it use “green” materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials. Similarly, as a result of high increasing cost of reinforcement bars used in concrete, research are also focused on the investigation of locally available materials for reinforced concrete production.

Previous investigations conducted on bamboo fibre and steel fibre-reinforced concrete (Byung, 1992; Shaaban & Gesund, 1993; Vairagade and Kenelt, 2012; Lucas & Dahunsi, 2004) showcased the viability of their use as substitute for conventional steel reinforcement in concrete production. However, aside the stability of structure, most building owners are more concerned about the cost of concrete production and construction. In the most general sense, cost means the monetary

value of the all goods and services used in order to perform an operation (Hakan & Elçin, 2007). In building construction projects, the direct cost is often emphasized and it is underlined in the cost estimation and cost control studies. Generally, construction done with sustainable materials are regarded as cheap, however this paper is focused on the experimental design of concrete made with steel fibres and bamboo fibres used as substitute reinforcing material. Also their cost implications are considered if they are to be produced in Nigeria.

Methodology

This section presents the experimental design and cost analysis of the high strength concrete produced with steel fibres and bamboo fibres, with a targeted compressive strength of 50 Mpa. Normal concrete mix design was done in accordance with the procedures of Building Research Establishment (BRE) Ltd. The concrete mix design is performed as follows;

Normal concrete

Targeted Concrete Strength at 28 Days	=	50 MPa
Specific Gravity of fine aggregate	=	2.63
Specific gravity of Coarse Aggregate	=	2.72
Fineness modulus of fine aggregate	=	2.67
Assumed Standard Deviation	=	8 MPa
Absorption of C. A.	=	1%

Target mean strength

Assume 5% of results fall below specified strength

$$\begin{aligned} \text{Target Mean strength } f_m &= f_{\min} + k_s \\ &= 50 + (8 \times 1.96) = 15.68 \text{ MPa} \\ &= 50 + 15.68 = 65.68 \text{ MPa} \end{aligned}$$

Water/cement ratio for 65.68 MPa concrete (G50 concrete)

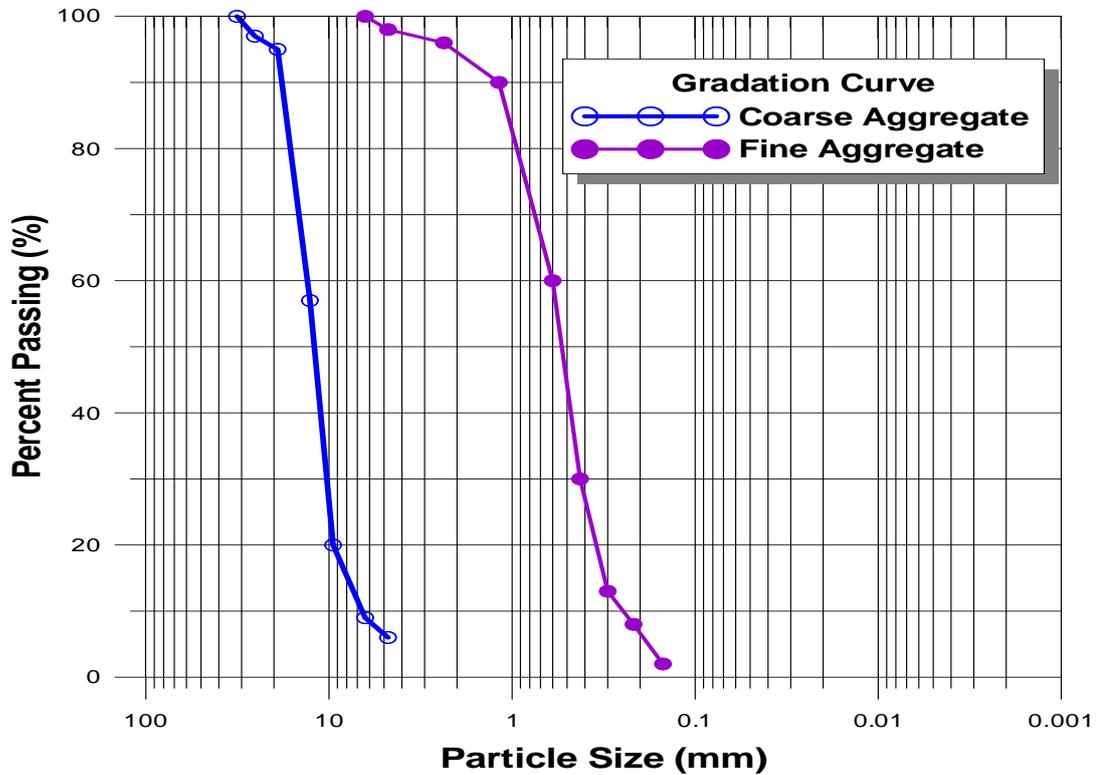
From a preliminary test conducted (fig.1) on fine and coarse aggregates, for OPC, crushed aggregate, and w/c ratio of 0.5, compressive strength at 28 days is 49 MPa. The W/C ratio for the target mean strength 65.68Mpa:

Water-cement ratio = 0.4

Taking durability into consideration, the water cement ratio recommended = 0.45

Thus adopt W/C ratio of 0.40 (the smaller of the two values)

Fig. 1- Gradation curves for fine and coarse aggregate



Water-content for required workability (i.e. slump or vebe time)

The water content for a slump of 60mm (assumed) using a naturally occurring fine aggregate and crushed 20mm (max. size) coarse aggregate.

Cement content

$$\begin{aligned} \text{Water content required} &= 210 \text{ kg/m}^3 \\ \text{Required cement content} &= \frac{210}{0.4} = 525 \text{ kg/m}^3 \end{aligned}$$

Determination of density of wet concrete

$$\text{Wet Density of Fresh Concrete} = 2,410 \text{ Kg/m}^3$$

Total aggregate content

20mm crushed aggregate of specific gravity 2.70

$$\text{Wet density of concrete} = 2410\text{kg/m}^3$$

$$\begin{aligned} \text{Weight of total aggregate} &= 2410 - (525+210) = 1675\text{kg/m}^3 \\ \text{Weight of Fine Aggregate} &= 1675 \times \frac{38}{100} = 636.5\text{kg/m}^3 \\ \text{Weight of Coarse Aggregate} &= 1675 - 636.5 = 1038.5 \text{ kg/m}^3 \end{aligned}$$

Mix Proportions

Cement :	F.A.	:	C.A.	:	Water
525 kg	637kg		1039kg		210 kg
1	1.21	:	2.00	:	0.40

The summary of the experimental concrete mix design is presented in table 1.

Table 1: Summary of Design Mix Proportions

Quantities	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (Kg)
Per m ³ of concrete	525	637	1039	210
Per 0.005m ³ of concrete (trial mix)	2.63	3.19	5.20	1.05

Based on trial mixes the design mix was adjusted to obtain an optimum mix.

The final optimum mix used is as presented in Table 2.

Table 2: Summary of Final Mix Proportions

Quantities	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (Kg)
Per m ³ of concrete	425	722	1083	170

Thus, the total volume of concrete for each mix was calculated based on the number of specimens to be cast per mix and are presented as follows:

Cubes (0.1m x 0.1m x 0.1m)

Vol. of cube = 0.1m x 0.1m x 0.1m = 0.001m³

No. of specimens = 9

Total vol. of cubes per mix = 9 x 0.001 = 0.009 m³

Cylinders (0.1m dia. x 0.15m long)

Vol. of cylinder = $\frac{\pi(0.1^2) \times 0.15}{4} = 0.00118\text{m}^3 = 0.00118\text{m}^3$

No. of specimens = 2

Total vol. of cylinders per mix = 2 x 0.00118 = 0.00236 m³

Beams (0.1m x 0.1m x 0.5m)

Vol. of beam = 0.1m x 0.1m x 0.5m = 0.005 m³

No. of specimens = 2

Total vol. of beams per mix = 2 x 0.005 = 0.010 m³

Total = 0.009 + 0.00236 + 0.010 m³ = 0.02136 m³

Add 30% for slump test and waste = 0.00641 m³

Total volume of concrete per mix = 0.02136 + 0.00641 m³
= 0.0278 m³

Cost analysis

The cost analysis performed on each of the mixes is presented in this section. The cost of preparing 1m³ each of plain concrete, concrete with 1.0% steel fibre and 1.0% bamboo fibre is compared as a way of assessing the relative cost effectiveness. The summary of cost analyses for plain concrete, 1% steel fibre reinforced concrete and 1% bamboo fibre reinforced concrete are presented in Tables 3, 4 and 5 respectively.

Table 3: Cost breakdown for 1m³ of plain concrete

DESCRIPTION	QTY	UNIT	RATE (N)	AMOUNT(N)
	RQD			
Cement	425	kg	37.00	15,725.00
FA	722	kg	1.80	1,299.60
CA	1063	kg	2.73	2901.99
SP	0.124	L	150	18.60
Water	170	L	1.00	170.00
Workmanship	-	Sum	-	6,000
Overhead	-	Sum	-	4,000
Total				30,115.19

Table 4: Cost breakdown for 1m³ of concrete with 1.0% steel fibre

DESCRIPTION	QTY RQD	UNIT	RATE (N)	AMOUNT(N)
Cement	425	kg	37.00	15,725.00
FA	722	kg	1.80	1,299.60
CA	1063	kg	2.73	2901.99
SF	60	kg	3,000.00	180,000.00
SP	0.124	L	150	18.60
Water	170	L	1.00	170.00
Workmanship	-	Sum	-	6,000
Overhead	-	Sum	-	4,000
Total				210,115.19

Table 5: Cost breakdown for 1m³ of concrete with 1.0% bamboo fibre

DESCRIPTION	QTY RQD	UNIT	RATE (N)	AMOUNT(N)
Cement	425	kg	37.00	15,725.00
FA	722	kg	1.80	1,299.60
CA	1063	kg	2.73	2901.99
SF	60	kg	2,000.00	120,000.00
SP	0.124	L	150	18.60
Water	170	L	1.00	170.00
Workmanship	-	Sum	-	6,000
Overhead	-	Sum	-	4,000
Total				150,115.19

The rates used are considered, being the present attainable rate in Nigeria:

Cement = N1, 850/50kg = ₦ 37/kg

1 no. 30-ton truck of coarse aggregate (CA) = N 82,000.00

= N 2,733.00/ton

= N 2.73/kg

1 no. 10-ton truck of fine aggregate (FA) = N 18,000.00

= N 1,800.00/ton

= N 1.80/kg

Super plasticizer (SP) = ₦ 1,000.00/L

= ₦ 1,000.00/1.2 kg (Density = 1.2kg/L)

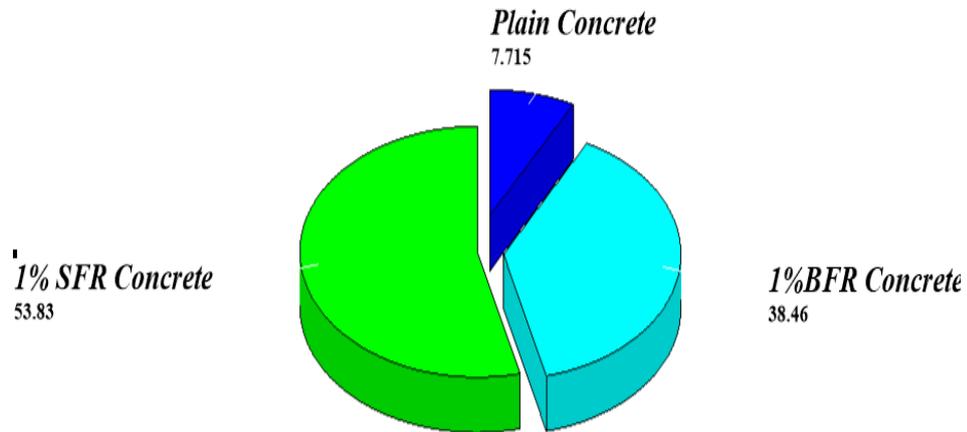
= ₦ 833.33/kg

Steel Fibre (SF) = ₦ 75,000.00/25kg
 = ₦ 3,000.00/kg
 Bamboo Fibre (RF) = ₦ 10,000.00/5kg
 = ₦ 2,000.00/kg
 Water = ₦ 1.00/L

Result and discussion

The cost analysis shows steel fibre reinforced concrete to be the most expensive per cubic metre, costing about seven times as much as plain concrete of the same volume. Concrete reinforced with bamboo fibre, on the other hand, is cheaper, costing only five times as much plain concrete of the same volume. Fig. 2 depicts the cost comparison for the 1m³ of concrete types. The high cost of steel fibre reinforced concrete could be attributed to high cost of its importation into the country.

Fig. 2- Cost comparison for 1 m³ of each concrete type



Conclusion

The results of investigations conducted by research on steel fibre and bamboo fibre reinforced concretes have confirm that the fibres are good for reinforcing concrete subjected to tensile loading, as it plays an important role in limiting the propagation of cracks in the concrete and delaying the ultimate failure of the concrete. Hence, considering the economic situation of some low income countries around the world; the evaluation of sustainable concrete coupled with their cost implication is

necessary. From the investigation, it was realized that steel fibre reinforced concrete are most expensive per cubic metre, costing about seven times as much as plain concrete of the same volume, however, the cost analysis proves that bamboo is a low cost alternative to steel as a reinforcing material.

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