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Strength Evaluation of *Cocos nucifera* Fibre Reinforced Concrete

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Abstract: Agro-waste can be used as raw materials for manufacturing various products after recycling. Different researches have investigated the usefulness of coconut fibers (coir) as a micro-reinforcement in concrete this research is aimed at determining properties of fresh and hardened concrete from Ordinary Portland Cement (OPC) reinforced with coconut fiber (coir) and super plasticizer admixture in the form of liquid soap. The flexural and compressive strength of the Coconut Fiber Reinforced Concrete (CRFC) were evaluated at varying percentages (0.1, 0.3 and 0.5% by weight of cement) of fiber. The optimal percentage of fiber for both compressive and flexural strength was determined. It is observed that, there is an increment in the various properties and strength of concrete by the addition of fiber as reinforcement, up to an optimum percentage where the strength starts to drop. The flexural strength was seen to increase considerably by about 17.6% while the compressive strength improved by 23%.

Key words: Agro-waste, coconut fiber, coir, concrete, waste, Civil Engineering

INTRODUCTION

The recent increase in the rate of industrialization in our countries is having a great impact in the environment both positively and negatively as much as it brings development to the environment, it also, adds to the volume of waste being produced. Wastes produced both industrially and agriculturally which comes from extractive, manufacturing and construction processes upsets the environment and immediate community. A major way out of the menace posed by waste is the recycling of the wastes for various products, various industrial and agricultural wastes have been recycled for different purposes (Sadiq and Atoyebi, 2015; Odeyemi *et al.*, 2017; Atoyebi and Sadiq, 2018; Atoyebi *et al.*, 2018a; Modupe *et al.*, 2018, 2019; Atoyebi *et al.*, 2019) and one of such materials is fibers from shells and fruits (Atoyebi *et al.*, 2018b).

The use of natural fibers in reinforcing concrete can be dated as far back as thousands of years ago with the use of straw to make bricks, poles and mud. Various types of fibers fall into two categories namely man-made fibers and natural fibers (Fordos, 1989; Satyanarayana *et al.*, 1990; Ali, 2011; Verma *et al.*, 2013). Numerous researchers in lots of countries have investigated the replacement of

reinforcement in concrete (cement-sand matrix) with natural fibers, the development of new stronger fibers and better fiber reinforced composites with new substitutes (Satyanarayana *et al.*, 1990; Filho *et al.*, 2003; Agopyan *et al.*, 2005; Yalley and Kwan, 2009; Ali, 2011; At Naw *et al.*, 2011; Ali and Chouh, 2013; Verma *et al.*, 2013; Zakikhani *et al.*, 2014; Ede *et al.*, 2014; Anifowoshe and Nwaiwu, 2016). Natural fibers are readily available, cheap, strong, eco-friendly, light weight, biodegradable and renewable, all these qualities make it a choice for use providing adequate mechanical properties like stiffness and strength at an affordable cost. They come from plants and contain lignocellulosic in nature. Natural fibers despite their wide use in building, construction, packaging and automobile, it is relatively high in moisture absorption and therefore, subjected to chemical treatments to enhance the fiber surface properties.

Coconut (*C. nucifera*) belongs to the family of the Arecaceae (Palmae), the subfamily Cocoideae. Coconut parts are the core, husk, shell, coconut meat and the coconut water (Fig. 1). A mature coconut consists of 28 wt.% of coconut meat, 12 wt.% of coconut shell and 35 wt.% of coconut husk (Ali, 2010; Shreeshail *et al.*, 2014). Coconut fruit is a drupe, not a truenut and it

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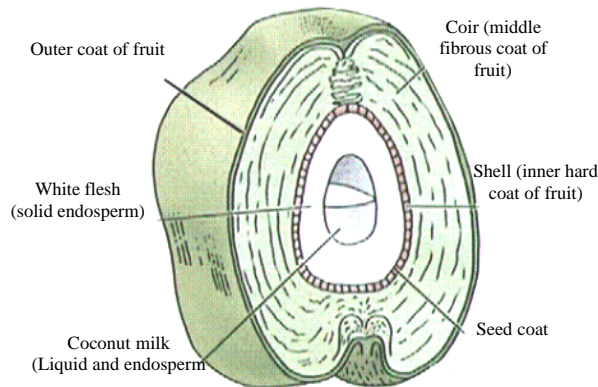


Fig. 1: Parts of a coconut (coconut palm)

comprises of three layers namely the exocarp (outer layer), the mesocarp (middle layer) and the endocarp (inner layer). The exocarp and mesocarp make up the “husk” of the coconut.

Coconut fiber, extracted from the husk is cheap and locally available in many tropical and semitropical countries, this has encouraged many researchers to look into the using of it to enhance the effectiveness of cementitious materials in recent years. Its various uses cut across boards, concrete building (Ali, 2011; Ali and Chouw, 2013) and low-cost roofing materials where coconut fiber was used as reinforcement for cementitious composites and cast under 1-2 MPa of pressure. It has been discovered in researches that the retentive and strong water absorptive nature of coconut fibre influences its reinforced cementitious mixtures to decrease in workability (Savastano *et al.*, 1999) to improve this defect in coconut fibers some techniques employed are washing and boiling in water, alkali treatment and immersion in slurred silica fume. This study looks into the effect of using coconut fibre as an additive on concrete behavior.

MATERIALS AND METHODS

The experimental program focused on investigating the properties of fresh and hardened concretes containing locally available coir fibers. A total of (90) 150 mm cubes and (60) 100×400 mm beams were cast to measure the density, flexural strength and compressive strength.

The materials used in this research include *Cocos nucifera* (coconut) fiber, Ordinary Portland Cement (OPC), coarse and fine aggregate. Coconut fiber was sourced from badagry area (6.4316° N, 2.8876°E) in Lagos State, Nigeria and every other material sourced locally

Table 1: Specimen constituents and identification

Specimen constituents	Specimen ID
Concrete with no fiber	S0
Concrete with 0.1% fiber	S0.1
Concrete with 0.3% fiber	S0.3
Concrete with 0.5% fiber	S0.5%
Concrete with 0.1% fiber+1% admixture	A1S0.1%
Concrete with 0.1% fiber+2% admixture	A2S0.1%
Concrete with 0.3% fiber+1% admixture	A1S0.3%
Concrete with 0.3% fiber+2% admixture	A2S0.3%
Concrete with 0.5% fiber+1% admixture	A1S0.5%
Concrete with 0.5% fiber+2% admixture	A2S0.5%

from Omuaran area in Kwara State (8.1402°N, 5.096°E), Nigeria. Ratio 1:2:4 was used as the concrete mix ratio and the water-cement ratio is 0.6. The cement properties were in conformity to the requirement of ASTM Type I (ASTM., 2018). Coconut fibers were extracted from the coconut husk which consists of fiber with various diameters, cutting and hand picking operations on the sheath was used too btaina fiber of 40 mm length and added at proportions (0.1, 0.3 and 0.5%, respectively) by mass of total cement used (Table 1).

Experimental tests

Slump test: Slump test was carried out on each batch of concrete to determine its work ability and consistency and was done as specified in ASTM C-143 (ASTM., 2015). The apparatus for executing the slump test basically consists of a metallic mould in the form of a frustum of a cone known as slump cone having the internal dimensions of bottom diameter 20 cm, top diameter 10 cm and a height of 30 cm.

Compressive strength test: This testis carried out to determine the strength or the resistance of the concrete to direct (axial) loading. The test was carried out on the 150×150×150 mm cubes at the concrete laboratory according to BS 1881-part 116 (Anonymous, 1983). The specimens were tested by compression testing machine after 7, 14 and 28 days of curing. They were removed from the water and excess water wiped off and then placed on the bearing surface of the compression machine with the smooth surface facing the front. The load was applied on the specimen gradually to failure point at a rate of 25 kPa per sec.

Flexural strength test: Flexural test also known as Modulus of Rupture (MOR) was carried out on the beams samples to determine their flexural strength resistance to bending. The third-point load test was used for this experiment. Flexural strength of concrete is considered as an index of tensile strength of concrete. Tensile stresses

are likely to develop in concrete due to rusting of steel reinforcement, drying shrinkage, temperature gradients and many other reasons. In beam flexural tests, theoretical maximum tensile strength is obtained at the bottom of the beam and is called modulus of rupture which depends on the dimension of beam and position of loading.

RESULTS AND DISCUSSION

Test on fresh concrete: Slump conetest was carried out on the fresh concrete mix to determine the work ability of normal concrete along with CFRC mix. Figure 2 shows that there was a drop in height of slump as the fiber content increase show ever the addition of the admixture produced arise in the height of this lump. The highest value of slump was 148 mm for 2% admixture for the control. The slump for the 0% fibre content increased by 13.64 for 1% admixture and 34.5 for 2% admixture.

Compressive strength test: From Table 2 Specimen S0.1% gives the highest compressive strength value for 28 days.

Flexural test: This test was designed and carried out to determine the MOR for each specimen. Table 3 gives a summary of these results. From Table 4 above Specimen S0.3% gives the highest MOR value for 28 days (Fig. 3).

Density determination test: The mass for each cube specimen was taken and recorded and the average determined as the ratio of their respective mass to

volume. The average values for the samples ranged from 2283.3-2554.7 kg/m³ which is very similar to the value of density for concrete (2400 kg/m³). The variation may be due to improper compaction of

Table 2: Mean compressive strength for 7, 14 and 28 days

Specimen (%)	7 days (N/mm ²)	14 days (N/mm ²)	28 days (N/mm ²)
S0	19.34	21.22	25.53
S0.1	20.41	26.01	31.37
S0.3	17.48	19.74	23.22
S0.5	18.31	22.37	28.08
A1S0.1	18.57	21.14	27.23
A2S0.1	20.55	17.59	30.42
A1S0.3	20.67	24.05	30.00
A2S0.3	21.70	23.60	28.08
A1S0.5	21.10	25.79	28.97
A2S0.5	20.20	27.05	29.99

Table 3: Summary of flexural test carried out on specimen

Specimen (%)	7 days (N/mm ²)	14 days (N/mm ²)	28 days (N/mm ²)
S0	4.79	7.19	6.83
S0.1	5.97	7.49	7.52
S0.3	5.63	6.06	8.03
S0.5	5.19	6.59	7.34
A1S0.1	7.04	6.53	7.25
A2S0.1	5.69	6.44	7.59
A1S0.3	5.67	6.32	7.02
A2S0.3	5.19	6.59	7.34
A1S0.5	4.68	6.21	6.86
A2S0.5	5.31	6.21	7.19

Table 4: Summary of average density values for each specimen

Specimen (%)	Volume (cm ³)	Average density (kg/m ³)
S0	3375	2464.7
S0.1	3375	2554.7
S0.3	3375	2490.1
S0.5	3375	2470.6
A1S0.1	3375	2283.3
A2S0.1	3375	2428.2
A1S0.3	3375	2416.0
A2S0.3	3375	2474.6
A1S0.5	3375	2490.1
A2S0.5	3375	2508.1

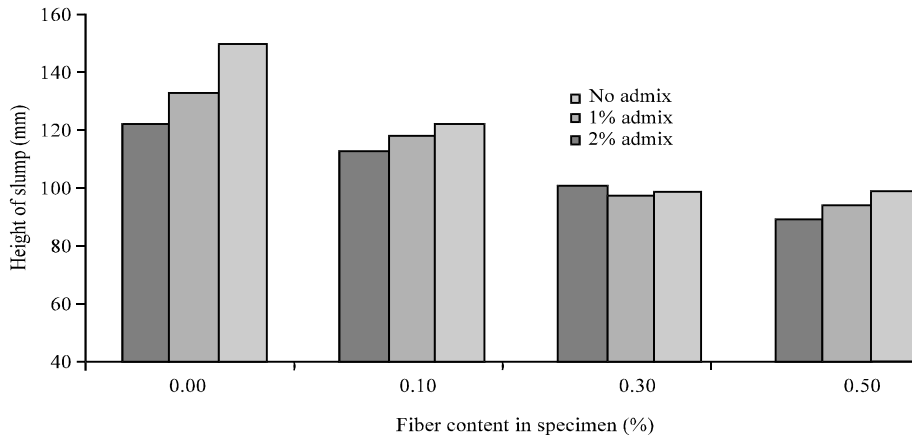


Fig. 2: Slump comparison chart



Fig. 3: Beam showing crack after failure due to bending

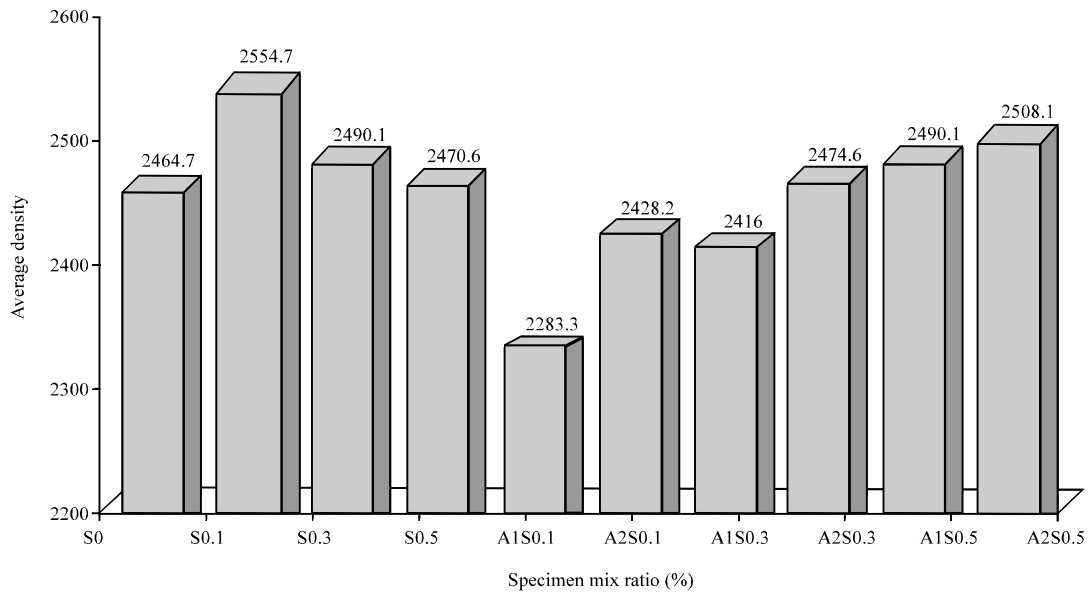


Fig. 4: Comparison of specimen densities

concrete in the mould due to the difference in workability of the concrete as indicated in the slump test which was carried out. The workability determines how well the concrete will flow and become compacted. Generally, higher workability points to easier flow and compaction (Fig. 4).

CONCLUSION

Coconut fiber is obtainable in great quantity at the test site which makes it quite viable as a reinforcement material in concrete. It also acts as a source of income for the producer of coconut who gets the benefits of the new demand made by the construction industry. In addition to this, it is an efficient method for the disposal of coir

mattress waste which will reduce the demand for additional waste disposal infrastructure and decrease the load on existing landfills, dump sites and incinerators. Coconut fibers being natural in origin are ecologically sustainable and can bring down the global carbon footprint quite effectively. After the completion of testing and analysis, the following conclusions can be deduced.

The presence of fibers in concrete generally causes a decrease in the workability of concrete. This is due to the absorption of water when the fibers are added to the concrete mix. This is deduced from the reduction in workability of the concrete mixes. However, the addition of the admixture improved the workability of the various mixes. Flexural strength of the concrete was also

increased by the addition of fiber into the concrete mix with as high as 17.6% in the case of 0.3% coconut fiber content as at 28 days of curing. It had the highest flexural strength of 8.03 N/mm². There is an optimum fiber content for every type of mix, at which the concrete attains the highest strength and beyond which the mechanical strength of concrete mass begins to decrease consistently. This optimum was realized at 0.1% fiber content for compressive strength. The compressive strength is increased by an average 23% of coir fiber at 0.1% having the highest strength (31.37 N/mm²) as at 28 days of curing.

For samples without admixture, the fiber percentage that generated the highest density was 0.1% with 2554.7 kg/m³ while the lowest 0.50% fiber batch yielded 2470.6 kg/m³. For specimen with admixture, the density increased steadily probably as a result of the use of a concrete mixer to give an even homogeneous mix. Higher density values were realized resulting from improved workability of the mix. Generally, the density of the concrete increased with an increase in the fiber content just up to the optimum fiber percentage after which the density then decreases due to the increase in the volume of voids.

RECOMMENDATIONS

This research while corroborating the proposition of the positive impact of fibers on concrete focused on the strength and workability of concrete. However, other criteria should be evaluated and looked into: the durability of natural fiber reinforced concrete should be investigated. In addition, impact and abrasive resistance and chemical resistance test could be carried out, so as to obtain an array of optimum series of the composite to be used in civil construction. Standard extraction of fiber, pre-treatment and transformation into usable products should be considered. Techniques could be developed and the resulting procedure for natural fiber reinforced concrete design standardized.

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