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A Comparative Study of Flexural Strength of Concrete Reinforced With Coir and Raffia-Palm Fibres

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ABSTRACT : *The need to reduce cost of housing construction through the application of local materials and technology is recognised. This study aimed at the comparative analysis of the flexural strength of concrete reinforced with coir and raffia-palm fibres at varying percentages. A total of80 cubes, 20 cylinders and 20 beams were produced and tested. The results show that the introduction of coir and raffia fibres within the range of 0.2 and 0.25 percent by weight resulted in a general increase in the strength of concrete. The coir reinforced mixes yielded greater strength increase than the raffia reinforced mixes for compressive, tensile and flexural strength. The increase in tensile strength for concrete reinforced with coir for 0.5 and 0.55 water/cement ratios constituted 24 and 23 percent above the control mixes. The corresponding values for mixes reinforced with raffia fibres were21 and 21percent above the control mix respectively. The maximum flexural strength occurred at w/c ratio of 0.55for concrete mixes reinforced with 0.25 percent coir and raffia fibre with values averaging7.53 N/mm^2 and 6.53N/mm^{2}respectively.*

KEYWORDS: *Two point method, Deflection estimate, Flexural Strength, Natural Fibres, CFRC, RFRC, Construction Industries*

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I. INTRODUCTION

Affordable and sustainable housing remains one of the major challenges of governments worldwide. According to the communiqué of the Abuja Conference 2016, Nigeria presently has a housing deficit of about 17 million. This is compounded by the dwindling economy, high cost of construction materials and limited foreign exchange for importation of materials and technologies. Concrete is the most vastly employed material with significant impact on cost of construction. One of the approaches to address this problem is in looking inwards to identifying and harnessing alternative local materials for the construction industry. Such local materials are required as beneficial replacement for cement and steel reinforcement which are the cost critical elements of reinforced structural concretes.

In Nigeria, natural fibers are abundant and easy growing in almost all parts of the country. They are used in local practice for strengthening of mortar or concrete, cement paste among others. Technical literature reveals an abundance of useful fibers that can effectively replace steel reinforcement in concrete construction. These include steel fibres, synthetic fibers, carbon fibers, glass fibers, natural fibers among others.

Natural reinforcing materials can be obtained at low cost and low levels of energy requirement, using local manpower and technology. Utilization of natural fibres as a form of reinforcement for concrete is of particular interest in less developed regions where conventional reinforcing materials are not readily available or are too expensive. Sisal-fibre reinforced concrete has been used for making roof tiles, corrugated sheets, pipes, silos and tanks [1]. Specifically, elephant-grass-reinforced mortar has been used for low-cost housing projects; wood-cellulose-fibre reinforced cement for commercial applications in the manufacture of flat and corrugated sheet and non-pressure pipes [2] and coir fibre has been used in concrete to control the development of micro cracks, plastic shrinkage cracking and drying shrinkage cracking in concrete members [3]. The resultant low permeability of concrete and reduced bleeding of water leads to greater resistance to impact, abrasion and shatter [4]. Raffia (rattan) used as reinforcement in concrete beams resulted in increased tensile and flexural strength of the beam specimens, and collapse was mainly due to crushing of the specimens with absence of diagonal cracks in the beams; average loads of about 117 percent of the theoretical values were predicted [5].

The threat to environment, the future of sustainability of natural reserves and the soaring prices of construction materials have forced engineers and developers into the use of natural renewable materials in construction practice. Consequently, the use of natural fibres has received considerable attention in recent studies with huge number of investigations on coir, pineapple leaves, jute, flax, hemp, sisal, bamboo, oil palm, rice husk, straws among others. This is because, these materials are non- pollutant to the environment and do not endanger bio-reserves. They are self –sustaining, promote self-reliance and add value in recycling of polluted waste into usable materials. They are made of locally available materials, utilize local skills, manpower and management systems. They are beneficial to the local economy as income generating ventures. In spite of these overwhelming advantages, a great paucity of research work on raffia-palm fibres is observed compared to coir and other fibres. In addition, researches on natural fibre reinforced concrete have largely been confined to investigation of compressive strength. Consequently, the main objective of this study is to obtain a comparative assessment of the compressive strength, split tensile strength and flexural strength of concrete beams reinforced with coir fibres and raffia palm fibres.

II. EXPERIMENTAL PROGRAM

The structural process of conducting the research was based on sourcing and processing of coir and raffia fibres, concrete constituents and mix design. The batching, casting of test specimens as well as testing of the resulting concrete in the fresh and hardened states are described.

Materials

Main component of coir and raffia palm fibre reinforced concrete used in this study include; brown coir fibre, raffia fibre as reinforcement limestone Portland cement as binder material, river sand and granite chippings as aggregates and potable water from the University mains. The coarse aggregate used was well graded with nominal size of 10mm and a specific gravity of 2.7 while the fine aggregate graded within zone 2 of BS 882 and had a specific gravity of 2.38.The nominal length of coir and raffia fibres were 14mm and 12.7mm with aspect ratios of 467 and 318 and specific gravities of0.42 and 0.89. The coconut husks were obtained from Mkpat Enyin Community in Akwa-Ibom State and the raffia stalks from Chokocho Community in Rivers State respectively, all in Nigeria. A pictoral view of the raw fibres are shown in Plate 1.

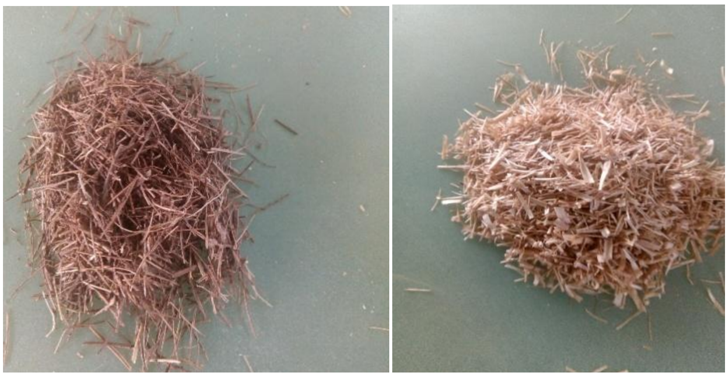

Plate 1. Raw fibres after processing

A proper mix design, batching and casting operations were carried out to produce40cube specimens of size 150mm by 150mmby 150mm, 20cylinder specimens of150mm diameter and 300mm height and 20 beam specimens of dimensions100mm by 100mm by 500mm.An M30 mix design grade was adopted in this study following the American Concrete Institutes (ACI 211.1-91. 1969).The ratio of proportions are 1:1.53:2.3 and 1:1.7:2.6, reinforcement: fine aggregates: coarse aggregates with w/c of 0.5 and 0.55 for 0.2 and 0.25 percent coir and raffia fibre content respectively. The fibre content used was taken as a percentage to the total weight of cement in every mix.

Mixing Proportions

Three types of test specimens were produced for the cube compression test, cylinder splitting tensile and beam flexural strength test of coir and raffia fibre reinforced concrete. Among the five batches each for coir and raffia fibre reinforced concrete mixes, eight cubes, two beams and two cylinders were cast in each batch. Table 1 shows the concrete mix quantities of coir and raffia fibre reinforced concrete mixes for 0.2 and 0.25 percentage fibre content with water cement ratios of 0.5 and 0.55 respectively. Plain concrete specimens (with 0% fibre content) were used as control. The compressive strength was determined after 3, 7, 14 and 28 days duration of wet curing. However, the tensile and flexural strengths were determined after 28 days duration of wet curing.

Table 1. Mix Proportions for Different Specimens

Mix No	Specimens	No of Specimens			Mix Ratio 1:1.53:2.3:0.5					Mix Ratio 1:1.72:2.57:0.55				
		cubes	Cyl	Beams	C (kg)	S (kg)	G(kg)	F(g)	W (lit)	C (kg)	S (kg)	G (kg)	F (g)	W (lit)
M0	0% Fibre Content													
M0	Control	8	2	2	23.9	36.4	54.9	-	11712	21.72	38.55	55.86		11956
M1	0.20% Fibre Content													
M1C	Coir	8	2	2	23.9	36.4	54.9	127	11712	10.86	38.55	55.86	127	11956
M1R	Raffia	8	2	2	23.9	36.4	54.9	127	11712	10.86	38.55	55.86	127	11956
M2	0.25% Fibre Content													
M2C	Coir	8	2	2	23.9	36.4	54.9	158.7	11712	10.86	38.55	55.86	158.7	11956
M2R	Raffia	8	2	2	23.9	36.4	54.9	158.7	11712	10.86	38.55	55.86	158.7	11956

M0 indicates mix with no fibre content – control mix
M1C indicates mix with 0.20% COIR fibre content
M1R indicates mix with 0.20% RAFFIA fibre content
M2C indicates mix with 0.25% COIR fibre content
M2C indicates mix with 0.25% RAFFIA fibre content

Mixing ACI 544, 318

The wet method of concrete mix was adopted. For evenly distribution of fibre orientation, a pan mixer machine was used to get the standard quality of concrete. Firstly, the coarse aggregate was introduced and followed by the fine aggregate and then the cement. The constituents were mixed for two minutes and then water was added and mixed for further one minute. At this point, the mix is already wet and the chopped fibres were added by carefully spraying the fibre as the machine kept rotating and allowed to thoroughly mix for another two minutes. Care was taken while introducing the fibres to ensure no balls were formed which would affect the concrete consistency represented by slump and flow. The concrete mixes were placed in the moulds in two layers and vibrated to compact properly and the top surfaces of moulds were smoothened with a trowel. The specimens were stored in temperature of 25^0c to set. After24 hours, the specimens were demoulded and cured for 3, 7, 14 and 28 days duration in the curing tank under water and thereafter extracted for the relevant tests.

Instrumentation and Testing

The prepared cubes and cylinders were tested using the Universal Compression Testing Machine ELE Model and the maximum crushing load measured. The compressive strength was calculated in accordance with BS EN 201-1 (2002) using the equation $f_{cu}=P/A$ where f_{cu} is the compressive strength, P is the maximum crushing load resisted by the specimens before failure (N), A is the cross sectional area of the cube (in mm^2). The test progress photographs presented in Plate 2.

Plate 2. Progress Photograph for Cube Compression Test

A splitting tensile test was carried out in accordance with BS EN 12390-3, 7-9 (2009). The prepared cylinders were instrumented and failure loads measured. The splitting tensile strength was calculated using the expression $f_{ct} = 2F \times 1000/ \pi l d^2$. Where F is the maximum load, l is the length of specimens, d is the specimen diameter. To determine the material property in shear, flexural strength test was carried out in accordance with BS EN 12390-5 (1990). Figure 3 shows the setup of beams for direct shear. The test set ups are shown in Plate 3

Plate 3 Progress photographs of Split Tensile and Flexural Strength Test

III. RESULTS AND DISCUSSION

The results obtained from the various laboratory tests are presented and discussed under the relevant subheads that follow. These include the physical properties of fibres, aggregates and engineering properties of the concrete mixes in their fresh and hardened states.

Physical Properties of Coir and Raffia Fibres

The results of tests on the physical properties of coir and raffia fibres are presented in Table 2.

Table 2: Physical Properties of Coir and Raffia Fibres

Properties	Coir Fibre	Raffia Fibre
Specific Gravity	0.42	0.89
Air Entrainment	Air content not significantly increased	Air content not significantly increased
Fibre Thickness	40microns	30microns
Fibre Chopped Length	14mm	13.7mm
Aspect Ratio	350mm	457mm

From the Table, it can be seen that the fibres testes satisfy the requirements of ACI 544-1R-57 and therefore are adequate for use as reinforcement in concrete.

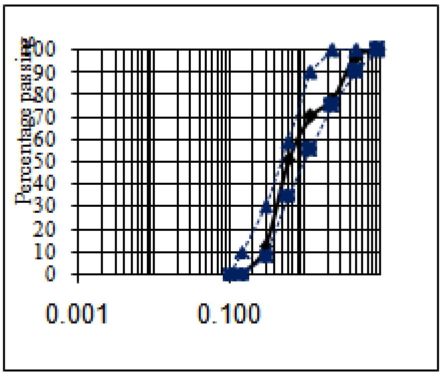

Fig. 1. Particle Size Distribution for Fine Aggregates

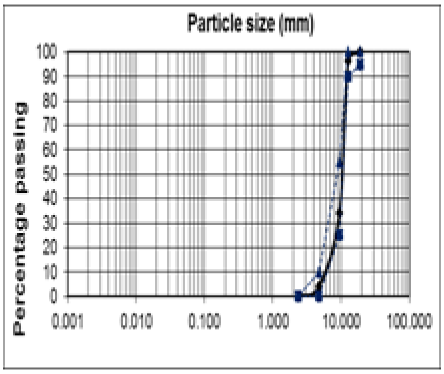

Fig. 2. Particle Size Distribution for Coarse Aggregates

The graphs consist of 10% coarse sand, 40% gravel and 50% medium gravel and fit into sieve 12.5 – 4.75 mm nominal size bracket according to BS 882(1992). The coefficient of uniformity of the aggregates are 5.71 and 8.18 for coarse and fine respectively. The corresponding values of coefficient of curvature Cc here are 3.21 and 1.67 while the grading modulus for fine aggregates was 2.66. These results meet the requirements of BS882 (1992) and therefore confirm the adequacy of the aggregates for application in structural concrete production.

Workability of Fresh Coir and Raffia Fibre Reinforced Concrete Mixes

A total of 10 mixes were tested for slump and compacting factor in accordance with BS 1881-102-1983 to check the consistency of the coir and raffia fibre reinforced concrete and the control mix. The laboratory test results are shown in Table 3**.**

Table 3: Average Experimental Values for Slump and Compacting Factor of Coir and Raffia Fibre Reinforced Concrete

w/c	Control Mix	Mix with 0.20% Fibre		Mix with 0.25% Fibre	
		C0.2	R0.2	C0.25	R0.25
		Slump Values			
0.5	117	81	87	67	25
0.55	118	85	90	72	77
		Compacting Factor Values			
0.5	0.94	0.957	0.956	0.949	0.945
0.55	0.91	0.929	0.948	0.933	0.898

The results show that addition of fibre reduced the slump value of fresh concrete. This is attributed to the fact that the fibres absorbed some of the water in the concrete mix. Raffia fibre reinforced mix with 0.25 percent fibre content yielded the lowest compaction factor of 0.90at 0.55 w/c whereas the highest compacting factor of 0.96 was observed for the coir fibre reinforced concrete (CFRC for the same fibre content but at 0.50 w/c.. Thus, it can be suggested that a 0.5 w/c, corresponding to 80-100mm slump value for a 10mm maximum aggregate size is the most suitable to achieve a uniform compaction factor across the mix. The observation is in agreement with those indicated in [6] in which an increase in fibre content from 0 – 2% decreased slump value from 30 mm to 20correspondingly.

The compacting factor test is used to quantitatively determine the degree of compaction achieved by a standard amount of work done. On the fresh concrete on the other hand, the slump test is a qualitative test that measures the consistency of a cone of fresh concrete. Depending on the profile of slumped concrete, the slump may be termed as true slump, shear slump or collapses slump.

Density of Coir and Raffia Fibre Reinforced Concrete

The results from density tests conducted on the coir and raffia fibre reinforced mixes are presented in Table 4 and represented in the bar graph of Figure as a function of water/cement ratios and fibre contents.

Table 4: Average Experimental Values for Density of Coir and Raffia Fibre Reinforced Concrete

W/C	28 Days Density Results				
	0% Fibre	0.20% Fibre		0.25% Fibre	
		C0.2	R0.2	C0.25C	R0.25
0.5	2459	2230	2330	2107	2200
0.55	2578	2289	2359	2167	2289

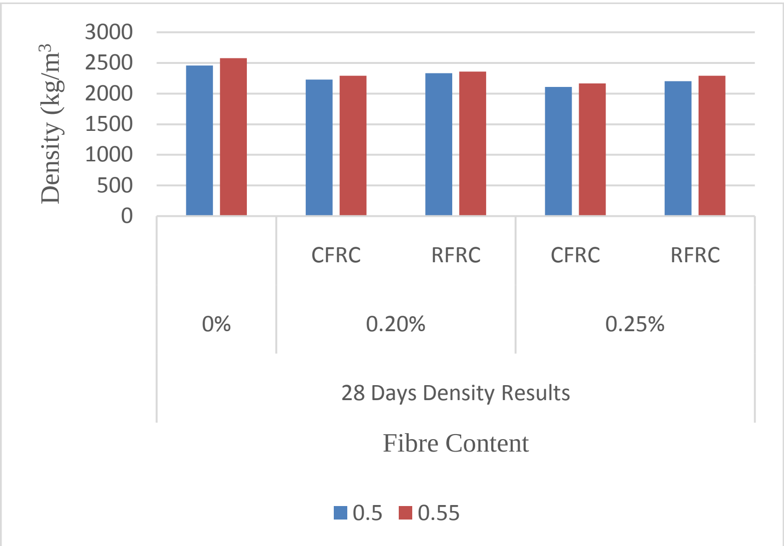

Fig. 3. Density of CFRC and RFRC at Varying W/C Ratios and Fibre Contents

The results show a general decrease in density with increasing fibre content and water cement ratios. The mixes reinforced with coir fibres decreased in density compared to mixes reinforced with raffia fibres (Figure 3). The average density values yielded were 2371kg/m^3, 2272kg/m^3 and 2160kg/m^3 for 0.15%, 0.20% and 0.25% coir fibre reinforced concrete (CFRC) with average percent of 1.136, 1.067 and 1.116. Whereas, the corresponding raffia fibre reinforced concrete (RFRC) mixes yielded average density values of 2396 kg/m^3, 2355 kg/m^3 and 2263 kg/m^3 with average percent of 1.126, 1.058 and 1.108 for 28 days duration of wet curing with varying water cement ratios.

It was further observed that the coir fibre reinforced concrete mix with 0.25 percent fibre content and 0.5 water cement ratio yielded a lesser density value of 2107kg/m^3 compared to the control mixes values of2578 kg/m^3 and 2578 kg/m^{3}at water/cement ratios of 0.55 and 0.6respectively.. This density behaviour conforms to the results of the investigations carried out by [7] CSI 2010, BS 877:1997.

Average Compressive Strength Test Results for Coir and Raffia Fibre Reinforced Concrete

Compressive strength of concrete is the governing mechanical property of concrete as it controls the flexural and tensile strength. Here, the compressive strength is discussed in terms of fibre content, w/c ratio, fibre type and duration of wet curing. The average compressive strength test results are presented in Table 5and charts of Figure 3(a&b).

Table 5 Average Compressive Strength Test Results for Coir and Raffia Reinforced Concrete

	3days		7days		14days		28days	
Specimen ID	Water/Cement Ratio		Water/Cement Ratio		Water/Cement Ratio		Water/Cement Ratio	
	0.5	0.55	0.5	0.55	0.5	0.55	0.5	0.55
C0R0	18.67	18.22	26.04	25.2	33.33	32.44	39.36	39.11
C0.20	21.78	22.22	28	28.67	36.89	37.8	41.33	42.67
R0.20	21.33	21.56	27.56	28	36.44	36.89	40.44	41.33
C0.25	22.2	23.33	28.44	29.33	38.67	39.76	42.22	43.56
R0.25	21.78	22.2	28	28.44	38.22	39.11	41.78	42.22

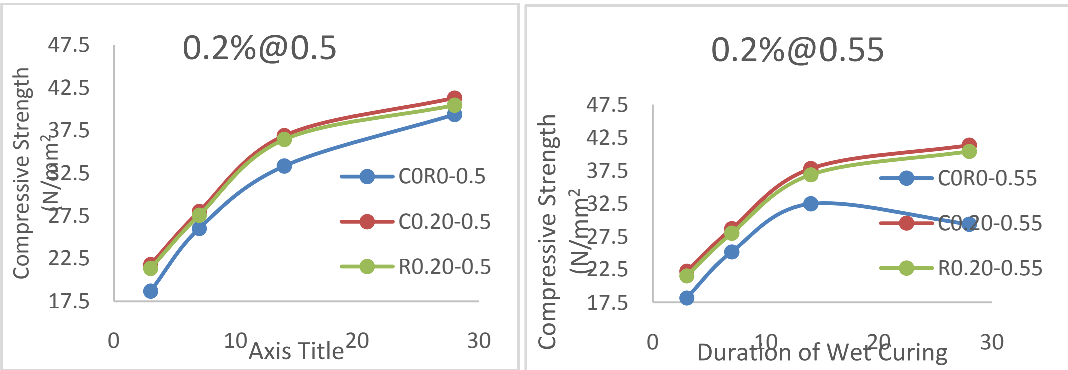

Fig. 3a. Variation of Compressive Strength with Duration of Wet Curing for Concrete Reinforced with 0.20% Coir and Raffia Fibre at Water/Cement ratio of 0.5 and 0.55

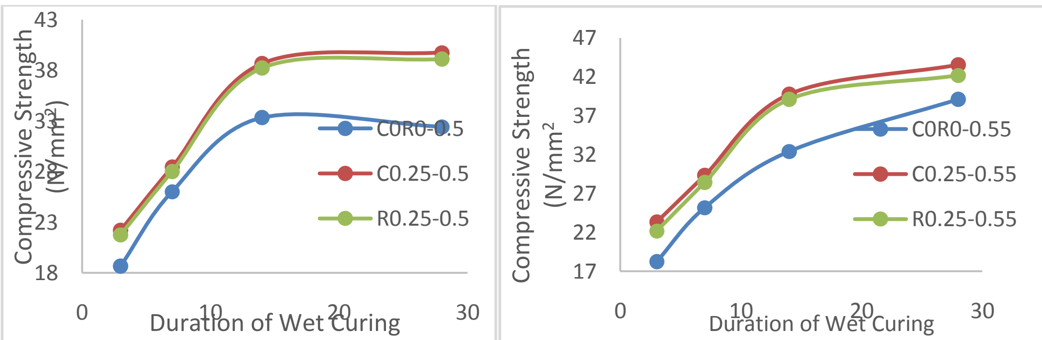

Fig. 3b. Variation of Compressive Strength with Duration of Wet Curing for Concrete Reinforced with 0.25% Coir and Raffia Fibre at Water/Cement ratio of 0.5 and 0.55

From the results, it can be seen that the control mix exhibited a general decrease in compressive strength with increase in w/c ratio, averaging about 9percent in the w/c range of 0.5 and 0.55 considered. The introduction of natural fibres resulted in a general increase in compressive strength over the control mixes.

The coir fibre reinforced mixes yielded an average of about 4 percent increase over raffia fibre reinforced mixes within the fibre content of 0.2% and 0.25%, w/c ratio range of 0.5 and 0.55 w/c ratio and duration of wet curing range of 3 days to 28 days. Mixes reinforced with 0.2% coir fibres increased in compressive strength and exhibited a drop in strength at 0.55w/c ratio with average values of21.78, 28.00,36.89 and 41.33 N/mm^{2}for 3 days to 28 days duration of wet curing respectively. However, for mixes reinforced with0.25% fibre, a steady increase in the compressive strength was observed within the range of water cement ratio and curing duration considered with average values of 22.2, 28.44, 38.67 and 39.76 N/mm^{2}respectivelyThe corresponding values for raffia reinforced mixes constituted about 21,33, 27.56, 36.44, 40.44 N/mm^2 and21.78, 28,38.22, 39.11N/mm^{2}respectively.For coir fibre reinforced concrete mixes, the rate of increase of compressive strength with fibre content constituted about 7.72 and 7.85 percent within the fibre range of 0.20% and 0.25%. The corresponding rate values for raffia reinforced mixes constituted about 6.15 and 6.37 percent respectively. However, the coir reinforced mixes gave an average of 19 percent increment over raffia reinforced mixes. The increase in average compressive strength above the control for coir fibre reinforced mixes constituted 5 and 9 percent for w/c ratios of 0.5 and 0.55 The corresponding increase in average compressive strength for raffia fibre reinforced mixes were about 3 and 4 percent. Hence, introduction of coir fibre or raffia palm fibres to normal strength concrete gave an average above 30 percent strength gain.

Tensile Strength of Concrete Reinforced with Coir and Raffia Natural Fibres

The tensile strength results of concrete reinforced with coir and raffia fibres as recorded during test and the percentage changes for all mix batches relative to control batch are presented in Table 6 and Figure 4.

Table 6: Average Values of Tensile Strength of Concrete Reinforced with Coir and Raffia Natural Fibres after 28 Days Wet Curing

Fibre Content	Tensile Strength of Coir Fibre Reinforced Concrete for Water/Cement Ratios of				Tensile Strength of Raffia Fibre Reinforced Concrete for Water/Cement Ratios of				%Coir over Raffia
	0.5	0.55	0.6	Average	0.5	0.55	0.6	Average	
Control	2.83	2.55	1.98	2.45	2.83	2.55	1.98	2.45	—
0.20%	3.11	3.4	2.67	3.16	2.97	3.11	2.83	2.97	6.4
0.25%	3.4	3.91	3.4	3.51	2.97	3.11	2.90	3.0	17

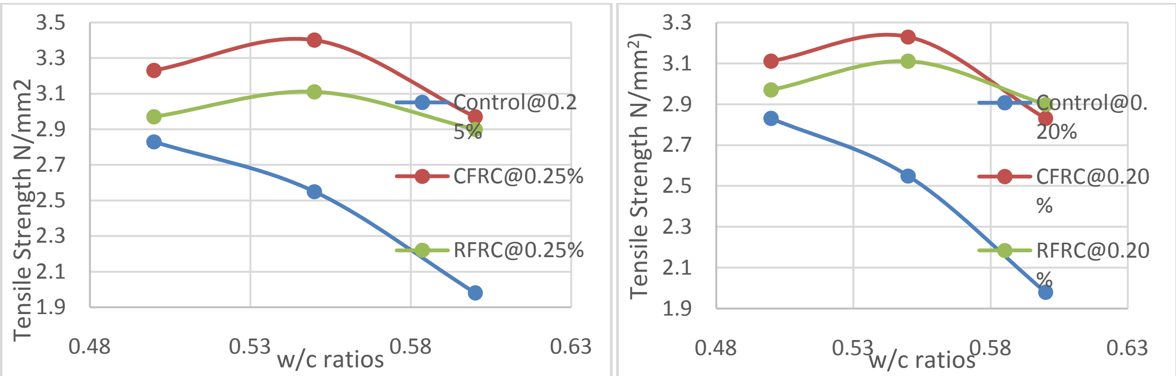

Fig. 4. Variation of Twenty Eight Days Tensile Strength of Concrete Reinforced with Coir Fibre Content with W/C Ratio

Generally, the 28 days tensile strength increased with increase in fibre content and decreased with increase in water cement ratios over the values for the control mixes. The introduction of 0.20% coir fibre with 0.5 water cement ratio yielded greater tensile strength values of about 6 percent greater than for the raffia reinforced mix.

The maximum tensile strength for a given w/c ratio occurred in mixes reinforced with 0.25% fibre content for both coir and raffia fibre reinforced concrete. However, coir fibre reinforced concrete mixes showed a higher tensile strength across fibre content for a given w/c ratio. It was observed that coir fibre reinforced mixes within the fibre range of 0.20% and 0.25% considered, constituted an average tensile strength of about 29 and 43 percent over control mixes across the w/c ratios of 0.5, 0.55 and 0.6. The corresponding increase in average tensile strength for raffia fibre reinforced mixes constituted about 21 and 22 percent over control mixes. Thus, the strength growth was higher in concrete reinforced with coir fibres than that reinforced with raffia fibres.

Flexural Strength of Concrete Reinforced with Coir and Raffia Natural Fibres

Flexural strength is a measure of unreinforced concrete beam or slab to resist failure in bending. It is measured by loading concrete beams with a span length at least three times the depth. The flexural strength is measured as Modulus of rupture in psi (MPa). The beams were tested using the hydraulic jack frame. The flexural strength test results are presented in Table 7and Figure 5.

Table 7: Flexural Strength of Concrete Reinforced with Coir and Raffia Natural Fibres

	0.5	0.55	0.60	Average
CORO	5.02	4.52	3.52	4.35
C0.20%	6.78	7.03	5.52	6.44
C0.25%	6.02	7.53	5.52	6.36
R0.20%	5.52	6.02	4.52	5.35
R0.25%	6.02	6.53	5.52	6.02

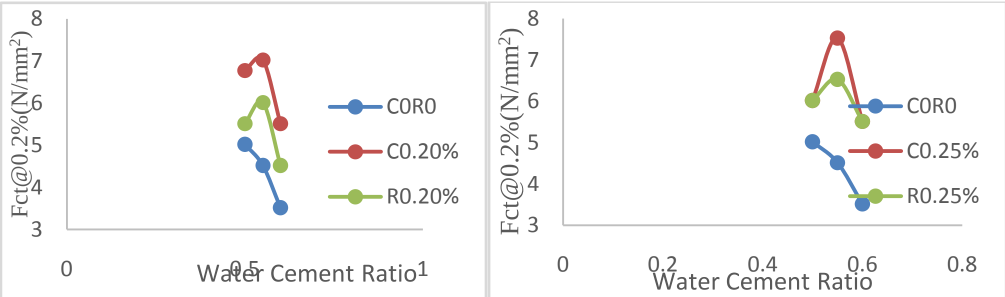

Fig. 5. Variation of Tensile Strength of Concrete Reinforced with Coir Fibre Content with Varying W/C Ratio

Generally, the flexural strength increased the properties of concrete with about 38.6 and 23.7 percent in coir and raffia fibre reinforced concrete mixes with a peak value of 0.55 water. Whereas, further increase in w/c ratio caused a reduction.

The flexural strength test result showed that 0.25% coir fibre reinforced concrete (CFRC) mix with 0.55 w/c with specimen identification C0.25-0.55 yielded higher increase with 66.59% increment over the control mix with an ultimate load of 18.83KN. However, specimen R0.20-0.5 gave the lowest flexural strength of 5.52N/mm yielding a flexural strength increment of 4.98%.

The CFRC increased with 48.5 and 46 percent over control mix and the corresponding RFRC constituted23 and 38 percent.

Comparison of CFRC and RFRC for Flexural Strength

The comparison of flexural strength between CFRC and RFRC mixes is expressed in Table 7and the graphs plotted in Figure 6. The variation between the coir and raffia fibre reinforced concrete mixes showed that both systems increased in flexural strength of concrete beam reinforced with 0.2 and 0.25 percent fibre content with a peak value of 0.55 w/c ratio. In spite of the increase in both systems, the coir fibre reinforced concrete mixes yielded greater increase than the raffia fibre reinforced concrete mixes.

The optimum fibre content with which the bending stress reached its maximum strength occurred in mixes reinforced with 0.25% coir and raffia fibre content with each system showing some differences in values of average flexural strength about 5.02, 8.45 and 4.12 percent for 0.5, 0.55 and 0.6 w/c ratio, respectively.

Overall, the average flexural strength within the water cement ratio of 0.5 to 0.6 was approximately 7.53N/mm^{2}within the coir fibre content range of 0.2% and 0.25%. The corresponding average flexural strength for raffia fibre content was 6.53/mm^2. The maximum flexural strength occurred at w/c ratio of 0.55 for concrete mixes reinforced with 0.25 percent coir and raffia fibre with values averaging 7.53 N/mm^2 and 53 N/mm^2 respectively.

Failure Mechanism

The collapse pattern of the concrete beams tested for flexure on plain concrete mixes were observed to have broken in two pieces once the peak load was reached with very little energy absorption. Whereas, the coir and raffia fibre reinforced concrete mixes exhibited a pseudo-ductile behaviour and fibres bridging mechanism. The energy absorption during flexural failure was significantly higher than the unreinforced concrete mixes. The crack pattern was observed to be angular for the fibre reinforced concrete beam specimens. Table 8 shows test results and Plate 4 shows progress photographs.

Table 8 Deflection and Ultimate Loads Test Results

S/No	Specimens Identification	Fibre Content (%)	Weight	First crack Load	Failure Load (KN)	Flexure(N/Mm2)	Yield Deflection (δy)	Ultimate Deflection (δu)	Deflection Ductility (δu/δy)
1	C0R0-0.50	-	13.6	10.5	12.55	5.02	2.0	2.2	1.10
2	C0R0-0.55	-	13.6	10.5	11.3	4.52	2.0	2.1	1.05
3	C0R0-0.60	-	13.8	7.53	8.79	3.52	1.6	1.8	1.15
4	C0.15-0.50	0.15	13.6	13.81	15.06	6.02	2.0	2.2	1.10
5	C0.15-0.55	0.15	13.8	11.3	13.18	5.27	2.1	2.2	1.05
6	C0.15-0.60	0.15	12.8	8.79	10.04	4.02	1.9	2.1	1.11
7	C0.20-0.50	0.2	13.2	15.06	16.94	6.78	2.1	2.2	1.05
8	C0.20-0.55	0.2	13	15.06	17.57	7.03	1.9	2.0	1.05
9	C0.20-0.60	0.2	13.4	12.55	13.81	5.52	2.0	2.2	1.10
10	C0.25-0.50	0.25	14	13.81	15.06	6.02	2.1	2.2	1.05
11	C0.25-0.55	0.25	13.4	16.32	18.83	7.53	1.9	2	1.05
12	C0.25-0.60	0.25	13.6	12.55	13.81	5.52	1.8	2	1.11
13	R0.15-0.50	0.15	12.6	12.55	13.18	5.27	1.9	2.2	1.16
14	R0.15-0.55	0.15	13.5	11.3	12.55	5.02	1.8	2.0	1.11
15	R0.15-0.60	0.15	12.4	8.79	10.04	4.02	1.8	2.0	1.11
16	R0.20-0.50	0.2	13	11.33	13.81	5.52	1.8	2.0	1.11
17	R0.20-0.55	0.2	13.6	15.06	16.32	6.02	2.0	2.1	1.05
18	R0.20-0.60	0.2	13.3	10.04	11.3	4.52	1.7	1.8	1.06
19	R0.25-0.5	0.25	12.8	13.81	15.06	6.02	2.0	2.2	1.10
20	R0.25-0.55	0.25	13	13.81	16.32	6.53	1.8	2.0	1.11
21	R0.25-0.60	0.25	13.7	11.3	13.81	5.52	2.1	2.2	1.05

Test results have indicated that in the range of up to 0.2 percent coir and raffia fibre reinforced mixes by volume of concrete, the beam deformation increased.

In the case involving the control mixes, for the various w/c ratios ranging from 0.5 to 0.6, the shear cracks began to appear around at 12.55KN, 11.3 KN and 8.79KN of shear strength. A shear stress appear along the line connecting the load point and the support point when the relative errors reached 2.2, 2.1 and 1.8 and a drastic decrease of strength was observed which was typically shear failure. However, in the case of coir fibre reinforced concrete mixes of 0.2 and 0.25 percent, shear cracks began to appear from support point on the right side of the beam within the range of 16.94KN, 17.57 KN and 13.81KN, and 15.06KN, 18.83KN and 13.81KN of loading, and the strength gradually increased and reached a maximum at 2.2 and 2.4rad of the relative errors. For the corresponding raffia fibre reinforced mixes, cracks reached a maximum strength before 16.32KN of load from support point of right side of beam like the coir fibre reinforced mixes and then the strength reduction occurred as the w/c ratio tends to increase to 0.6 constituting 13.81KN, 16.32 KN,11.3KNand 1505KN, 16.32KN, 13.81KN for 0.5 to 0.6 water cement ratio with 0.2% and 0.25% fibre content.

IV. CONCLUSION

1. The introduction of 0.2% and 0.25% coir and raffia fibres by weight of cement resulted in a general increase in the strength of concrete, averaging about 9, percent above the strength of the control mixes.
2 The increase in compressive strength for concrete reinforced with coir fibre for water/cement ratios 0.5, 0.55 and 0.6 constituted 5.39, 7.72 and 8.11percent above the control mixes. The corresponding values for mixes reinforced with raffia fibres constituted 3, 4.37 and 7.43 percent respectively
3. The increase in split tensile strength above that for the control concrete mix averaged 25, 29 and 43 percent for coir reinforced mixes and 13, 21 and 22 percent for raffia reinforced mixes. The increase in tensile strength of coir reinforced mixes was about 9 percent higher than for raffia reinforced concrete mixes with peak value water/cement ratio of 0.55.
4 The maximum flexural strength occurred in concrete mixes reinforced with 0.2 and 0.25 percent coir and raffia fibre reinforced concrete; the maximum values occurred at a water/cement ratio of 0.55 and averaged 7,53 N/mm^2 and 6.53N/mm^2respectively. The corresponding increases in flexural strength were 19, 67and 57percent for coir and the corresponding raffia reinforced mixes constituted 19, 44 and 57 percent over control.
5. The addition of coir and raffia fibres improved the shear strength of concrete significantly. Shear failure in plain concrete beams containing no fibre was totally brittle, in each of the plain concrete beams once the peak load was reached, the beams failed and a post peak load capacity was none existent as opposed to those with coir and raffia fibre reinforced beams. This indicates that the fibre reinforced concrete beams possess greater cracking resistance compared to the unreinforced beams.

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