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The Use of Raffia Palm *(Raffia Hookeri)* Piassava Fibres As Reinforcement Of Concrete

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ABSTRACT
Raffia Hookeri known as "doka" in Akan is abundant in Ghana and its main use is for extraction of local wine. It yields many fibres including piassava fibre which was used as broom and has been abandoned in the advent of plastic brooms. Piassava fibre was used for experimental study as fibre reinforcement in concrete, and reported on workability, density, compressive strength, tensile strength and toughness of the concrete. The study used a basic concrete mix of 1:1.5:3, and 10 separate batches with percentage weight fraction of fibres; 0.00%, 0.25%, 0.50% and 0.75% and three different water/cement ratios of; 0.45, 0.50, and 0.55 at constant aspect ratio of 100mm for both cubes and cylinders. In all, 0.50% Piassava fibre content and 0.50 water cement ratio enhanced the tensile strength and toughness modulus of concrete while best compressive strength of 39.68MPa occurred at 0.25% fibre content with 0.45 water cement ratio

Keywords: *fibre, pissava,, tensile, toughness.*

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I. INTRODUCTION

Raffia plants are generally found in the tropical zones and more precisely in tropical Africa (Musset, 1933). In Ghana, palms especially raffia palm (Raffia hookeri), are basically tapped for the production of palm wine – called odoka or nsafufuo in Akan (Akromah, 1994 as cited in Mintah, Eliason, Barimah, & Oldham, 2011). A typical tall Raffia hookeri gets to a height of 15m (Akpabio, Ekpe, Etuk and Essien, 2001).

Raffia hookeri produces piassava from their leafstalks which are retted and the fibres beaten out. Piassava fibres were exported to Europe for blooms and are used to make brushes for sweeping, rug-washing, climbing ropes, hats and mats. The leaves of *Raffia hookeri*, often split lengthwise (raffia), they are also used to make mats, baskets and other articles. The midribs and petioles of the leaves ('raffia bamboo' or 'bamboo') are used for poles, rafters, ladders, furniture and cross-bearers in canoes. Split lengthwise they are used to make screens (Brink, 2011).

Concrete, an extensively used construction material, is strong in compression but weak in tension. Its weakness is ameliorated by incorporation of steel bars. Steel is however costly, particularly in the developing countries where it is mainly imported (Salau & Sharu, 2004). Addition of fibres to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibres start functioning, arrest crack formation and propagation, and thus improve strength and ductility (Wafa, 1990).

Many works have been carried out on the raffia, among which is the use of the raffia bamboo as main reinforcement in the concrete (Kankam, 1997). Many studies have also been done on the use of natural fibres as for example, coconut fibres (Yalley & Kwan, 2009). But a little is known about the use of Piassava fibres of raffia palm as reinforcement in concrete.

II. EXPERIMENTAL MATERIALS AND METHODS

The main materials used in this study were cement, coarse aggregate, fine aggregate, raffia pissava fibre and water for mixing. The various materials have been discussed in this section.

2.1 Processing of Piassava Fibre

Raffia palm leaf sheaths were taken from the bank of Homonica, (a stream in Akrokerri Adansi in Ashanti region), The matured leaf sheaths were selected, the Piassava obtained from the sides ('wings') of the leaf sheaths of Raffia hookeri was harvested by cutting the leaf sheaths from the trunks (figure 1) and soaked in the Homonica stream for one month until the outer husk begins to break down, and the unwanted part was then combed away by hand (this process is called "retting"). This was done to prevent the influence of retting method on fibre appearance as stated in Brink (2011), that retting period ranges from 2 to 3 mouths and fibre retted in stagnant swamp pool develops a reddish brawn tinge. After retting the fibres were dried in a room to protect it from direct sun shine. The length of the fibres obtained range from 400mm to 1200mm long and the average diameter measured using digital micrometre gauge was 0.70mm.The fibres were cut according to the aspect ratio of (length/diameter) l/d ≤ 100 (figure 1).

Figure 1 Processing of Piassava Fibre (Before and after powdering)

2.2 Water
Portable water was used to prepare the concrete specimens

2.3 Preparation of Specimen
The study used a total of hundred specimens of a basic concrete mixes of.1:1.5:3 (cement: fine aggregate: coarse aggregate).They were divided into 10 separate mixes in accordance with percentage weight fraction of fibres; 0.00%, 0.25%, 0.50% and 0.75% with three different water/cement ratios of; 0.45, 0.50, and 0.55 with constant aspect ratio of 100mm for both cube and cylinders. The concrete was mixed by hand, compacted on compacted table and cured for twenty eight days. Table 1 shows details of materials for the cube and cylinder specimens.

Table 1 Details of Material Mix for Cubes and Cylinders

Specimens	Cement Content in Kg	Fine Aggregate content in Kg	Coarse Aggregate content in Kg	Water Content in Kg	Fibre Content in Kg
A00%/ 0.50	23.74	35.60	71.22	10.68	00
B0.25%/0.45	23.74	35.60	71.22	10.68	0.0594
B0.25%/0.50	23.74	35.60	71.22	11.88	0.0594
B0.25%/0.55	23.74	35.60	71.22	13.06	0.0594
B0.50%/0.45	23.74	35.60	71.22	10.68	0.1186
B0.50%/0.50	23.74	35.60	71.22	11.88	0.1186
B0.50%/0.55	23.74	35.60	71.22	13.06	0.1186
B0.75%0.45	23.74	35.60	71.22	10.68	0.1780
B0.75%/0.50	23.74	35.60	71.22	11.88	0.1780
B0.75%/0.55	23.74	35.60	71.22	13.06	0.1780
TOTAL	237.4	356	712.2	117.54	1.068

The dry cement and aggregates were mixed for two minutes by hand on smooth cemented platform till uniform colour was obtained, 80% of weighed water was added. The mixing continued after one minute and thirty 30seconds, then fibres were spread over the concrete and mixing continued for additional two minutes. Finally, the remaining 20% weighed water was added and the mixing continued for an additional two minutes. The timing was done to ensure consistency for all mixes and to ensure a complete distribution of fibres throughout the concrete mix. For each mix, a total of twenty specimens were cast comprising ten cubes of side 150mm for compressive test and ten cylinders of 100mm x 200mm for splitting tensile strength. The specimens were labelled A for control and Bx/y for specimen with X% of fibre and Y water cement ratio.

2.4 Testing of Fresh Concrete
The slump test was used to test the workability of the concrete. A slump cone mould of diameters 200mm and 100mm, and height 300mm was filled with concrete in three layers of equal volume. Each layer was compacted with 25 strokes of a tamping rod. The slump cone mould was lifted vertically and the change in height of concrete was measured to the nearest millimetre of 1mm.

2.5 Casting and Compaction of Concrete

The oiled plastic moulds, free from any foreign material were arranged close to the platform. The concrete was simultaneously filled in the moulds approximately 50mm thick and each layer was compacted on compacted table using tamping rod. The surplus on the mould was stripped off and leveled by hand trowel. The specimens were packed neatly to maintain proper hydration of the cement.

2.6 Curing

The specimens were demoulded after 24 hours and immersed in water in a water tank for 28 days figure 2. This was done in accordance with BS 1881: part 111, 1983.

Figure 2 Specimens in water tank for curing

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Several initial trial mixes were made to ascertain a concrete mix that would produce a concrete for targeted cube strength of 40N/mm^2. The specimens were prepared using three different mixes with three different water cement ratios and tested at the age of 28days for compressive strength. Table 2 shows mix proportions of trial mixes.

Table 2: Material and Mix Proportion of Try Mix

Specimen	Mix ratio	Water cement ratio	Number_of cubes
A1	1:1.5:3	0.45	5
A2	1:1.5:3	0.50	5
A3	1:1.5:3	0.55	5
B1	1:1.8:2.8	0.45	5
B2	1:1.8:2.8	0.50	5
B3	1:1.8:2.8	0.55	5
C1	1:1.5:3.1	0.45	5
C2	1:1.5:3.1	0.50	5
C3	1:1.5:3.1	0.55	5

Compressive Strength of Concrete with Piassava Fibre

The compressive strength test results of the research carried in accordance with BS1888-part 116, 1983, are presented in Table 3.

Table 3: Result of Compressive Strength of Concrete with Piassava Fibre

Specimen	Compressive Strength (MPa)	Difference in %
A0.00/0.50	39.29	
B0.25/0.55	35.87	9.517
B0.50/0.55	36.03	9.037
B0.75/0.55	34.72	13.014
B0.25/0.50	37.72	4.152
B0.50/0.50	38.60	1.777
B0.75/0.50	29.49	33.218
B0.25/0.45	39.68	-1003
B0.50/0.45	36.85	6.611
B0.75/0.45	31.99	22.807

From Table 3 the compressive strength obtained from a mix with 0.25% of piassava fibre by weight of cement and 0.45 water/cement ratio was 1.003% higher than that obtained from the plain concrete (control) value of 39.29MPa with 0.50 water cement ratio. Conversely, other batches with various contents of piassava fibre by weight of cement and different water/cement ratio recorded lower compressive strength ranging from 31.99 to 38.60 correspond to percentage decrease ranging from 1.8% to 22.8% respectively from the control specimen.
At a constant fibre content specimen with water/cement ratio of 0.50 recorded the highest compressive strength among the specimen with fibre addition. Again it was observed that specimen with water cement ratio of 0.55 recoded the lowest compressive strength when the fibre content is held constant. At all levels of water/cement ratios compressive strength decreased as fibre weight fraction of cement increases.

Density of Concrete with Piassava Fibre
The density of concrete with piassava fibre was computed by finding the mean values of densities obtained from the cylinder and cube specimens as described in Table 4.

Table 4: Results on Density of Concrete with Piassava Fibre

Specimens	Density of Cube(kg/m^3)	Density of cylinder(kg/m^3)	Mean Density(kg/m^3)	Diff. in %
A0.0/0.50	2412.2	2977.2	2694.7	
B0.25/0.55	2408.8	2903.1	2660.3	1.30
B0.50/0.55	2384.8	2900.7	2642.7	1.97
B0.75/0.55	2348.7	2872.4	2610.5	3.23
B0.25/0.50	2409.3	2918.5	2663.9	1.16
B0.50/0.50	2392.9	2888.5	2640.7	2.05
B0.75/0.50	2387.8	2853.6	2620.7	2.82
B0.25/0.45	2373.3	2759.2	2566.2	5.01
B0.50/0.45	2344.5	2703.9	2524.2	6.76
B0.75/0.45	2285.5	2780.3	2532.9	6.48

For the density of concrete, the control specimen value was 2694.7kg/m^3. Increase in the percentage weight fraction of fibres caused the density of the concrete to decrease. The percentage decrease of density lower than control specimen, ranges from about 1.16% for concrete with 0.25% piassava fibre to about 7% for specimen with 0.75% piassava fibre addition. It was also observed that (Table 4.) at the same piassava fibre content the density decreased with decreased water/cement ratio.

Splitting Tensile Strength of Concrete with Piassava Fibre
The tensile strength test results presented in Tables 5 for twenty eight days matured concrete cylinders.

Table 5: Result of splitting tensile Strength of Concrete with Piassava Fibre

Specimen	Splitting tensile strength (MPa)	Diff in %
A0.0/0.50	3.34	
B0.25/0.55	3.35	-5.38
B0.50/0.55	3.118	7.38
B0.75/0.55	3.080	8.70
B0.25/0.50	3.438	-2.61
B0.50/0.50	3.992	-16.13
B0.75/0.50	3.556	-5.85
B0.25/0.45	3.530	-5.156
B0.50/0.45	3.114	7.514
B0.75/0.45	3.082	8.61

The tensile strengths of concrete with the various percentage fractions of fibre content and different water cement ratios compared to plain concrete with 0.50 water/cement ratio were determined by the splitting tensile test. From Table 5, the tensile strength values were greater than the control specimen value of 3.34MPa ranges and from the increase ranged 2.6% for concrete with 0.25% piassava fibre to about 16.1% for specimen with 0.50% addition of piassava fibre. It was observed that 0.25% of piassava fibre content had an increase over the control at all levels of water/cement ratio. Again it is observed that the tensile strength had increased at all percentage weight fractions of piassava fibre for specimen with 0.50 water/cement ratio. However, the tensile strength decrease from the control specimen value of 3.34MPa ranged from about 7.3% for concrete with 0.50% fibre content to about 8.7% for specimen with 0.75% fibre content at the same water cement ratio of 0.55.

Toughness of concrete with piassava fibre

Energy absorption capacity of the concrete with piassava fibre which is toughness was calculated as the area under the stress-strain curve under compression to a length of 1.5 mm. Table 6, and Figure 3, provide the summary the test result.

Table 6: Toughness of Concrete with Piassava Fibre

Specimen	Toughness	Difference (%)
A0.0/0.50	15.09	
B0.25/0.55	23.25	-35.1
B0.50/0.55	17.79	-15.2
B0.75/0.55	15.11	-0.13
B0.25/0.50	19.88	-24.1
B0.50/0.50	19.30	-21.8
B0.75/0.50	14.38	4.9
B0.25/0.45	21.25	-29
B0.50/0.45	20.54	-26.5
B0.75/0.45	14.61	3.3

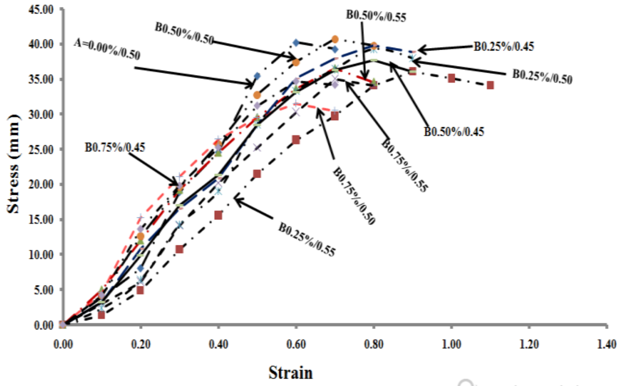

Figure 3: Toughness of Concrete with Piassava Fibre Compared to Plain Concrete

Table 6 and Figure 3 show results of the use of Raffia palm *(raffia hookeri)* piassava fibres as reinforcement to concrete compared with plain concrete the result indicated that all batches of 0.55 water cement ratio at all level of fibre weight fraction by weight of cement increases in toughness. The percentage increases of toughness over the control specimen of 15.09MPa range from about 0.13% for concrete with 0.75 fibre content to about 35% for specimen 0.25% fibre content at the same water cement ratio of 0.55. However it was observed that at water cement ratio of 0.45 and 0.50 toughness decreases when 0.75% of fibre was added.

In general the result of toughness of concrete with piassava fibre shows that the fibre increases the ductility properties of concrete, however the increase depends on the fibre content and the amount of water used in the mix.

IV. CONCLUSION

On workability, at constant water cement ratio slump height decreased as fibre content increased maximum decrease of 65mm lower than the control value of 129mm occurred in specimen with 0.75 fibre content and 0.45 water cement ratio. Again control specimen of density had a value of 2694.7kg/m^3, increase in the percentage weight fraction of fibres caused density of the concrete to decrease at all levels of water cement ratio. The optimum density of 2663.9kg/m^3 which was 1.2% lower than the control was attained by the specimen with 0.25 fibre content and 0.50 water/cement ratios. Also compressive strength experienced marginal reduction with increases of fibre content within the range of 1.8% to 33.21%, lower than control specimen with a value 39.29MPa. The optimum compressive strength of 39.68 occurred when 0.25 fibre content and 0.45water/cement ratio were used.

However fibre addition increased the tensile strength, with a maximum value of 3.99 MPa for concrete with 0.50 fibre content and 0.50 water/cement ratio being 16% over the control value of 3.35MPa. Tensile strength increased at all levels of fibre content when 0.50 water cement ratio was used. Once more Toughness had maximum increase of 23.25MPa which was 35.3% over the control specimen value of 15.09MPa for 0.25 fibre content and 0.55 water cement ratio. All batches of 0.55 water cement ratio had increase over the control. Further studies are recommended to be conducted on the bond between the fibre surface and the cement matrix.

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