Tensile Strength Characteristics of Fanpalm under Various Exposure Conditions

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Abstract
Fanpalm is a prospective reinforcing material in structural elements. Fanpalm is locally available and has been studied as a suitable alternative to steel reinforcement which is usually imported and expensive. The need for durability of the fanpalm under varying exposure conditions is the concern of this study. The ultimate tensile strength of fanpalm was determined under various exposure conditions to evaluate its possible usage, both on short term and long term basis. Fanpalm specimens were cut, shaped and coated with various protective agents (sodium sulphate, magnesium sulphate, hydroxylamine, epoxy, and sulphur) then cured in alkaline media(0.1N sodium hydroxide solution) for 3, 7, 14, 28 and 56 days. A set of uncoated Fanpalm were subjected to the same curing conditions as the coated specimens to serve as the control. Tensile strength tests were carried out to evaluate the ultimate tensile stress at various ages for each of the exposure conditions. The results showed that epoxy coated fanpalm specimens recorded the highest strength at 56 days of 80.83N/mm^2 while magnesium sulphate coated specimens had the lowest strength of 66.25N/mm^2 during the same period. The uncoated specimens had average strength of 65.00N/mm^2 at 56 days in alkaline media. It could be said that the coating improves the tensile strength of fanpalm in alkaline media. It was concluded that fanpalm coated with epoxy could be used as a reinforcing material in concrete structures for short term usage. Further evaluation of the strength of epoxy coated specimens over longer duration (say one year) should be carried out to determine its usage as reinforcements on long term basis.
Keywords: Fanpalm, tensile strength, reinforcing material, exposure conditions.

1. Introduction

In all engineering works, cost, durability, serviceability and usage have great influence and are normally given due consideration. In the past, steel has played a major role as reinforcements and as a structural member in construction industries. However, the recent high price of steel in most developing countries like Nigeria has called for the urgency in researching into locally available substitute materials for steel. For such material to be globally acceptable, it must possess physical and mechanical properties similar to that of steel. Besides, it must be durable for long term uses. Several attempts have been made on the possible uses of natural vegetable fibres as reinforcements in concrete elements such as roofing sheets as well as slab panels (Sivaraja *et al.*, 2010; Gram, 1983; Gram and Nimityongskul, 1987; Anderson and Gram, 1983). Among the agricultural fibre investigated are: coconut fibre, sugarcane, bagasse, date palm, bamboo and of recent fanpalm as reinforcements in load bearing elements in fibre reinforced concrete and fibre reinforced concrete composites. Results in their investigations support the use of these natural fibres on short term basis and their treatment with water repellant agents, blocking agents and possibly the use pozzolanas in reinforced concrete members or reinforced concrete composite to improve their durability.

Durability of a material, in general is defined as the service life of a material under given environmental condition (Sivaraja and Kandasamy (2007). The above definition holds good for all concrete and cementitous composites (concrete reinforced with artificial fibres like steel, glass and plastic, etc.). However, in the case of natural fibre composite, not only the external environment, but also the internal environment of the matrix (i.e. alkaline medium), play a combined role in determining its durability. Ramakrishna (2005) reported that, durability of natural fiber composites cannot be determined solely on the deterioration characteristics of natural fibres, as fiber-deboning from the cement matrix and reduction of strength of cement matrix in the alkaline medium, and other environments would have cumulatively contributed to the deterioration of the composite and hence may have to be considered for obtaining better insight into the actual deterioration process. Also, post–crack behavior of the cement composite is a measure of ductility and it is an important parameter used to evaluate the durability of fibre composites.

To improve durability, it is necessary to find ways to stop or slow down the embrittlement process of natural fibre concrete. This would be achieved by fibre impregnated with blocking agents. Shafiq *et al*. (1988) proposed impregnating with blocking agents such as sodium sulphate, sodium silicate, Iron and magnesium compounds. The use of water repellant agent (epoxy, sulphur, bitumen, seal matrix and cashew oil etc) was also proposed as another way of delaying decomposition of natural fibres in alkaline environment.

The alkalinity of concrete pore water can be reduced by replacing some of the ordinary Portland cement with various pozzolanas. This was achieved when the calcium hydroxide which is formed in connection with the cement hydration, reacts in parts with the silica present in the pozzolanas. When the free calcium hydroxide has been completely consumed, the carbonate of the matrix is also facilitated, thus entailing a mark reduction in the pH value for the pore water (Shafiq *et al*., 1988).

The use of bamboo, fanpalm and wood to replace the conventional steel reinforcements in reinforced concrete beams, columns and slabs have received attention over the past fifteen years (Adetifa, 1988; Bystriakova *et al.,* 2003; Michelle, 2009; Pakotiprapha, 1976; Youssef, 1976; Suvanispan, 1988; Sivaraja *et al.,* 2010). Mechanical properties of these materials such as stress-strain characteristics, load-deflection characteristics, absorption characteristics and behavior of the composite elements have been investigated. Most of these materials, as reported by (Mojola and Omotoyosi, 1976; Youssef, 1976; Fache, 1983 and Ibi, 1988) were found to be highly susceptible to dimensional changes and loss of strength with time.

Results of the investigations by Anderson and Gram, 1983; Gram and Nimityoungskul, 1987 and Sera *et al.*, 1990 on the possibility of using natural fibre as reinforcements in building have shown that most of the natural vegetable fibres are suitable as reinforcement in cement-based composites to produce low cost housing elements in thin sheets for short term duration. These materials are cheaply sourced and are available in large quantities and can be grown extensively within the locality.

Fanpalm, *Borassus aethiopum,* is a species of Borassus palm from Africa. In English it is variously referred to as African fan palm, African palmyra palm, and deleb palm amongst others (Wikipedia, 2012). It also has names in African languages; it is called 'igi agbon' in Yoruba, Nigeria.

Studies by Fache (1983), Omotosho (1988) and Jimoh (1990), on physical characteristics of air dried fanpalm indicated that they have moisture content varying between 10-12%. While the moisture content of fresh fanpalm was reported to be as high as 100% of its dried weight. Soaking fanpalm in water, Fache (1983), reported that only about 19% of moisture was absorbed in 7 days. This accounted for the low swelling and shrinking characteristics of fanpalm specimens. Mechanical strength of air dry fanpalm in tension was reported to vary between 72-134N/mm^2. The flexural strength (modulus of rupture) was found to range between 70-95N/mm^2. The compressive strength of fanpalm was found to be between 40-105N/mm^2 while bond was as high as 1.68N/mm^2 (Fache, 1983). Omotosho (1988) and Jimoh (1990) reported that the load carrying capacities of fanpalm reinforced concrete beams and slabs increased with increase in percentage of reinforcements. Adetifa (1988), found that fanpalm reinforced members could carry 2 to 3 times the ultimate load of an equivalent unreinforced member. Omotosho (1988), in his investigation on the long-term behavior of fanpalm reinforced slabs subjected to sustained constant loading, found that the slabs behaved similarly to steel reinforced beams/slabs if the load did not exceed 55% of the failure load. He further reported that fanpalm reinforced concrete beams and slabs, as well as steel reinforced concrete beams and slabs behaved alike.

In this study, the durability of Fanpalm under various exposure conditions was investigated. This is with a view to determine the short and long term utilization of the material.

2. Methodology

Fanpalm logs of 100mm x100mm x3200mm that have been seasoned by air for 4 weeks were sliced to 12mm x 25mm x 320mm using band saw machine. Fanpalm tensile specimens measuring 10mm x 25mm x 310mm were prepared as tensile specimens from the sliced bunches by trimming and smoothening using planner and smoothener (see figure1). The tensile Fanpalm specimens were prepared in set of threes for the coated fanpalm specimens with:

- water repellant agents (sulphur, and epoxy),
- blocking agents (sodium sulphate, hydroxylamine and magnesium sulphate); and
- the uncoatted specimens,

The coating agents were made by dissolving 20g of the coating agent (sulphur/epoxy/sodium sulphate/hydroxylamine/magnesium sulphate) in 50g of tap water. 50g of sodium hydroxide was dissolved in 200g of tap water to obtained 0.1N of NaOH solution used as the alkaline media. The alkaline media represents the condition the specimens will be subjected to when embedded in concrete as reinforcing material.

The coated fanpalm specimens were left for 24 hours after coating to air dried. The specimens were then conditioned in alkaline environment (0.1N NaOH solution) for 7, 14, 28, and 56days. Tensile strength tests were carried out by holding the tensile specimens in the grips at the tensile zone of the Automatic Universal Testing Machine (Avery Denison type, Model 7133 CCJ/DCJ, 600KN Maximum Capacity). With the speed adjusted to the loading rate of 2KN/min, the load was then applied and the load at failure read and recorded.

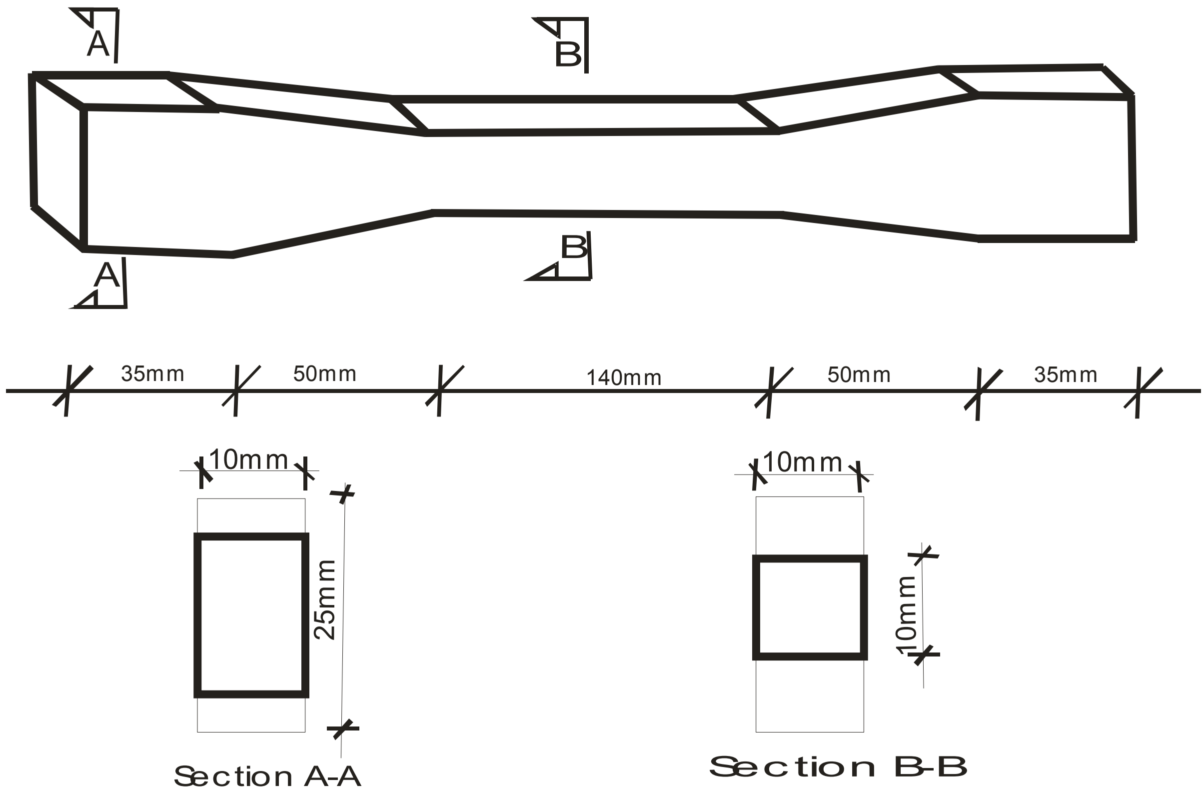

Figure 1 Fanpalm Tensile Specimen

3. Results and Discussion

Table 1 presents the experimental results of fanpalm specimens at 7, 14, 28, and 56days of soaking in alkaline media. It was observed that all the coating agents improve the durability of fanpalm in alkaline media. Among the agents, epoxy retains the highest strengths at all ages.

At 7days, the uncoated specimens have average tensile strength of 85.00 N/mm^2 while sulphur, hydroxylamine, epoxy, magnesium sulphate, sodium sulphate have strengths of 91.37 N/mm^2, 91.39 N/mm^2, 98.08 N/mm^2, 89.47 N/mm^2, 90.41 N/mm^2 respectively. While at 56days, the tensile strength of uncoated fanpalm reduces to 65.00 N/mm^2, while the tensile strength of sulphur, hydroxylamine, epoxy, magnesium sulphate, sodium sulphate is about 7.95%, 3.85%, 24.36%, 1.92%, and 4.62% higher than the equivalent uncoated specimens. It could be seen also from figure 2 that the rate of decrease in strength of uncoated specimens decreases with time in alkaline media. At 7days, the percentage of decrease in strength is about 14.95% for sulphur coated specimens, 14.85% for hydroxylamine, 8.63% for epoxy, 16.62% for magnesium sulphate and 15.77% sodium sulphate. But between 28days and 56days, the percentage of decrease is about 12.37% for sulphur, 0.52% for epoxy, 13.82% for hydroxylamine, 16.73% for sodium sulphate and 14.51% for magnesium sulphate. These values are generally lower than those obtained at 7 days. This showed that the durability of coated specimens improves with age.

Table1. Tensile Strength of Coated and Uncoated Fanpalm Specimens in Alkaline Media

Specimen	**Tensile Stress (N/mm^2) at**				
	0 days	7 days	14 days	28 days	56 days
T_{u1}	107.50	83.80	80.00	73.00	-
T_{u2}	107.40	85.20	70.00	70.00	65.00
T_{u3}	107.60	86.00	95.00	70.00	65.00
T_u	**107.50**	**85.00**	**81.67**	**71.67**	**65.00**
T_{s1}	107.40	92.00	77.50	75.00	67.50
T_{s2}	107.48	91.00	85.00	87.50	70.00
T_{s3}	107.40	91.11	95.00	80.00	70.00
T_s	**107.43**	**91.37**	**85.83**	**80.83**	**69.17**
T_{H1}	107.50	91.02	75.00	70.00	67.50
T_{H2}	107.00	92.10	87.50	80.00	67.50
T_{H3}	107.46	91.05	85.00	85.00	32.50
T_H	**107.32**	**91.39**	**83.33**	**78.33**	**67.50**
T_{E1}	107.00	98.42	80.00	80.00	75.00
T_{E2}	107.58	98.81	91.40	-	82.50
T_{E3}	107.44	97.00	95.00	82.50	85.00
T_E	**107.34**	**98.08**	**88.80**	**81.25**	**80.83**
T_{Mg1}	107.60	90.00	82.50	20.00	66.25
T_{Mg2}	107.00	89.80	82.50	72.50	65.00
T_{Mg3}	107.33	88.60	70.00	82.50	67.50
T_{Mg}	**107.31**	**89.47**	**78.33**	**77.50**	**66.25**
T_{Na1}	106.99	90.11	90.00	80.00	67.50
T_{Na2}	107.60	90.51	80.50	82.50	71.00
T_{Na3}	107.43	90.61	80.50	82.50	65.50
T_{Na}	**107.34**	**90.41**	**83.67**	**81.67**	**68.00**

Bold values represent the average tensile stress
T_u = Tensile strength of uncoated specimen
T_s = Tensile strength of sulphur coated specimen
T_H = Tensile strength of hydroxylamine coated specimen
T_E = Tensile strength of epoxy coated specimen
T_{Mg} = Tensile strength of magnesium coated specimen
T_{Na} = Tensile strength of sodium sulphate coated specimen

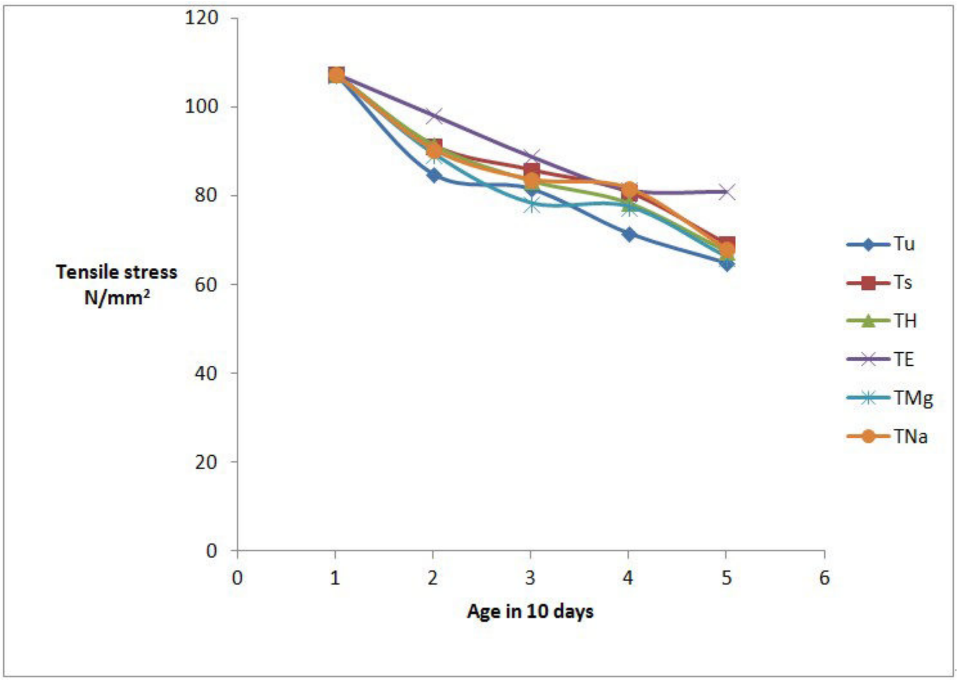

Figure 2: Tensile Stress of Fanpalm Specimens (coated and uncoated) against Duration in Alkaline Media

4. Conclusion and Recommendation

It could be concluded that epoxy provides the best coating option out of the experimented coating conditions. Durability of fanpalm could be improved by coating it with epoxy and epoxy coated fanpalm could be used as structural reinforcements for lintels and beams that span up to 3m.

It is recommended that coated fanpalm specimens be subjected to a longer period of up to 1 year and possibly accelerated ageing conditions to examine its suitability for long term uses. It is also recommended that the use of pozzolanas as partial replacement for cement to reduce alkalinity of the concrete media should be investigated.

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