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Flexural Strength Characteristics of Beams Reinforced with Fan Palm under Various Exposure Conditions

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Abstract
The relative high cost of man-made imported fibres like, glass, steel and plastics used in cement based composites as reinforcement calls for investigation into the use of locally available natural fibre as a substitute. Fan palm is locally available and has been studied as a suitable alternative to steel reinforcement. The need for durability of the fan palm under varying exposure conditions is the concern of this study. The ultimate flexural strength of beams reinforced with fan palm under diverse exposure conditions was determined to evaluate its possible usage, both on short and long term basis. Fan palm specimens were cut, shaped to desired flexural reinforcements sizes and coated with water repellants (epoxy, sulphur and bitumen) and blocking agents (hydroxylamine, sodium sulphate magnesium sulphate) for 24 hours. They were then used as reinforcements for concrete beams (75 x 100 x 500 mm) of 1:2:4 mix ratio and cured in alkaline media (0.1N sodium hydroxide solution). Two sets of uncoated fan palm reinforced beams (in alkaline solution and in water) were used as control experiments. Flexural strength test was carried out on the specimen beams at ages 7, 14, 28, 56, 90, 180, 270, and 365 days. The results were subjected to ANOVA analysis using STATA soft ware. The results at 365 days indicated that out of the beams reinforced with water repellant agents, those reinforced with bitumen retained the ultimate flexural stress of 36.98N/mm^2. For the beams reinforced with fan palm coated with blocking agents, those reinforced with hydroxylamine recorded the ultimate flexural stress of 25.59N/mm^2. The ultimate flexural stress of beams reinforced with uncoated fan palm is 4.69N/mm^2 and 18.07N/mm^2 in alkaline and water media respectively. It was concluded that coating fan palm reinforcements with bitumen (a water repellant agent) improved the durability of fan palm reinforced concrete beams in alkaline media.
Keywords: Fan palm, Flexural strength, Exposure conditions, Water repellant agents, Blocking agents.

1. Introduction

The relatively high cost of man-made fibres, (glass, plastics) used is fibre reinforced cement based composite make it desirable to evaluate locally available materials such as natural fibres that have similar properties to the man made fibres. Steel have longtime been used as the conventional reinforcement in concrete elements such as slab, beams/lintel, columns and structural walls. Steel is durable if not exposed to rain and atmosphere conditions. Hence a natural, locally suitable substitute material to be used in place of steel should posses or made to possess similar characteristic to make it acceptable as a suitable substitute material intentionally.

Intensive research work has been carried out in the field of fibre reinforced concrete. Knowledge of fibre manufacturing has increased substantially, fibre handling, fibre concrete production, mechanism of mechanical behavior of concrete members reinforced with fibre have been studied to a great extent and is still ongoing so as to get the globally acceptable natural fibre and the most economical way of making it durable in concrete environment.

In relation to building in developing countries, the idea of using fibre to improve strength and ductility of brittle materials have been adopted with the use of straw, horse-hair in brick and other product. Jorillo and Shimezu (1992), Marikunte and Soroushian (1994), Pama et.al 1976. Anderson and Gram (1983), Gram and Nimityoungskul (1987) have equally studied the characteristic and durability studied on concrete elements reinforced with natural fibres. They have all suggested that to improve durability of natural fibre in cements environment, it is necessary to stop completely or slow down the embrittled processes of the natural fibre in the concrete. Gram and Nimityonskul (1987), Shafiq et. al (1988) proposed the use of blocking agents such as sodium sulphate, sodium silicate, iron and magnesium compounds or hydroxylamine, Sivaraja and Kandasmy, (2007) and Gram (1983) proposed the used of water repellant agents such epoxy, sulphur, bitumen, cashew oil, sealed matrix so as to delay the decomposition processes of natural fibres in alkaline environments. Shafig *et al.* (1988), Suvanispan (1988), Sivaraja *et al.*, (2010), also suggested the use of partial replacements of ordinary Portland cement with various pozzolanas. This was achieved when the calcium hydroxide that is formed in connection with the cement hydration, react in parts with the silica present in the pozzolanas. When the free calcium hydroxide has been completely consumed the carbonate of the matrix is facilitated thereby entailing a mark reduction in the pH value of the pore water (Shafig *et al.,* 1988).

The results of investigations by Anderson and Gram (1983), Gram and Nimityoungskul, (1987), Sera *et al.*, (1990) shows that most of the natural fibers like sisal, coir, are suitable for uses as reinforcements in cement based composite to produce a low cost housing element in thin sheet for short-term duration. But the methods of making it suitable for a long-term uses is still a challenge that needed to be deeply research into. The use of bamboo, a wood fibre, to replace convectional steel reinforcements in reinforced concrete elements has also received great attention in the past two decades.

Adetifa (1988), Bystriakova *et al.* (2010) had studied extensively the physical, mechanical properties and the use of bamboo as reinforcements in concrete elements. The materials were found out to be highly susceptible to dimensional changes and lose strength with time in alkaline media. Studies on the physical and mechanical characteristics and the use of fan palm as reinforcement for concrete elements for short-term uses have gained studied in the past decades. However the studies were limited to university of Ilorin-research works. Fan palm, Borassus aethiopum, commonly called African fan palm is a species of Borassus palm from Africa. Physical and mechanical properties of fan palm as reported by Fache (1983), Omotosho (1988), Jimoh (1990) shows that its moisture content is between 10 – 12% if air dried. fresh fanpalm has moisture content as high as 100%. Air dried fan palm could only absorb up to 7% moisture at 7days and hence low absorption characteristic that accounted for very low swelling characteristic and hence stable dimensionally. The tensile strength of fan palm was reported to be between 72 – 134N/mm^2 (Fache, (1983) and Omotosho (1988)). The study on the load carrying capacities were carried on fan palm reinforced concrete beams and slab by Omotosho, (1988), Audu (1989), Ibi (1988). It was reported that fan palm reinforced members could carry 2 to 3 times the ultimate load of an equivalent unreinforced members. Omotosho (1988) further reported that fan palm reinforced members behaves similarly to steel reinforced members provided the load did not exceed 55% of the failure load. In this study, the durability fan palm reinforced concrete beams was investigated. This is to verify the suitability of fanpalm, a local natural wood fibre, as reinforcement in concrete for short and long term uses.

2. Methodology

The test programme consisted of casting 1:2:4 reinforced concrete beams of length 500mm having identical cross section of 75mm x 100mm. The beams were reinforced with four number fan palm in four series, viz;

- Water repellant (epoxy, sulphur and bitumen) coated Fan palm Reinforced Concrete Beams.
- Blocking agents (hydroxylamine, sodium sulphate magnesium sulphate) coated Fan palm Reinforced Concrete Beams.
- Uncoated Fan palm Reinforced Concrete Beams.
- Steel Reinforced Concrete Beams

The coating agents were made by dissolving 20 g of the coating agents (sulphur, epoxy, bitumen, magnesium sulphate, sodium sulphate, and hydroxylamine), in salt form in 50 g of tap water. The alkaline media was made by dissolving 50 g of sodium hydroxide salt in 200 g of water. The coated fan palm reinforcements were air dried in air for 24 hours. Thereafter placed in concrete molds and casting of concrete round the reinforcements. The molds were removed after 24 hours and the concrete beams then soaked in alkaline solution. The flexural strength tests were carried out on the specimen beams at 7, 14, 28, 56, 90, 180, 270, and 365 days in alkaline solution. The flexural tests were carried out thus; the specimen beams were placed on the steel knife edge supports of the Automatic Universal Testing Machine (AUTM). A 12 mm diameter rod of length 20 mm was placed on the beams at the mid-span to provide a line load on them. The load was applied uniformly at the rate of 2 kN/mins through the loading rate knob and the load/release knob of the AUTM. The failure loads were read and recorded.

3. Results and Discussion

Table 1 indicated the results of flexural strength of coated and uncoated fan palm and steel reinforced beams. Figure 1 showed the Flexural stress of beams reinforced with uncoated fan palm while Figure 2 indicated the Flexural stress of beams reinforced with fanpalm specimens coated with water repellants. The Flexural stress of beams reinforced with fanpalm specimens coated blocking agents are presented in Figure 3 while Figure 4 showed the flexural stress beams reinforced with steel.

At 7 days, fan palm coated with epoxy, a water repellant, has the highest ultimate flexural stress of 108.44 N/mm^2 while beams reinforced with fan palm coated with magnesium sulphate retained the highest value of 103.81N/mm^2 for beams reinforced with fan palms coated with blocking agents. Beams reinforced with uncoated fan palm specimens have low values of 91.81N/mm^2 and 99.69N/mm^2 for uncoated fan palm reinforced beam in alkaline and in water respectively. This shows that alkaline environment will affect fan palm reinforced concrete beams but the effect could be reduced by coating the fan palm reinforcements with either blocking agent or water repellant agent. However, water repellant agents will offers better protections to the fan palm reinforcement and consequently improves its durability at this age. Steel reinforced beams failed by shear near the support at flexural stress of 117.19N/mm$^{2.}$.

It was observed that at 14 days, beams reinforced with uncoated fan palm conditioned in alkaline media has the lowest mean ultimate flexural stress of value 83.06N/mm^2 compared with beams reinforced with fan palms coated with sulphur, a water repellant and sodium sulphate, a blocking agent that has the flexural strengths of 96.81 N/mm^2 and 92.19 N/mm^2 respectively.This again is an indication that alkaline environment has negative effect on durability of fan palm reinforced concrete. The effect could be minimized by coating the fan palm with either blocking agents or water repellant agents as suggested by Gram (1983). It could be said that coating the fan palm specimens with sulphur, a water repellant agents will give a better protection to fan palm reinforcements and consequently improves its durability in alkaline media at this age.

Table 1. Flexural Stress of Coated and Uncoated Fan palm and Steel Beams

Specimen	FLEXURAL STRESS (F) N/mm2								
	Before	7	14	28	56	90	180	270	365
FU FU1	114.69	90.94	85.94	73.44	69.69	62.19	57.19	44.69	*-7.81
FU2	117.19	94.69	73.44	78.44	65.94	67.19	52.19	45.94	4.69
FU3	118.44	89.69	89.69	74.69	64.69		55.94	48.84	17.19
FU	116.81	**91.81**	**83.06**	**81.81**	**66.81**	**64.69**	**55.06**	**46.31**	**4.69**
FUW UW1	108.44	94.69	87.19	79.69	74.69	64.69	63.44	50.94	*-7.81
FUW2	117.19	97.19	95.94	75.94	70.94	70.94	67.19	52.19	29.69
FUW3	110.94	99.69	93.44	92.19	73.44	70.94	64.69	48.44	32.19
FUW	115.56	**99.69**	**92.19**	**82.56**	**73.06**	**68.81**	**65.06**	**50.56**	**18.07**
FS FS1	118.44	104.69	95.94	93.44	70.94	69.69	69.69	60.94	18.44
FS2	114.69	107.19	89.69	83.44	72.19	70.94	69.69	67.19	23.44
FS3	119.69	99.69	104.69	89.69	72.19	70.94	65.94	64.69	25.94
FS	117.56	**103.81**	**96.81**	**88.81**	**71.81**	**70.56**	**68.44**	**64.31**	**22.61**
FH FH1	115.94	100.94	90.94	87.19	74.69	69.69	60.94	57.19	-*7.81
FH2	118.44	102.19	94.69	85.94	77.19	67.19	57.19	53.44	42.19
FH3	119.69	98.44	89.69	92.19	73.44	63.44	52.19	53.44	42.19
FH	118.81	**100.56**	**91.81**	**88.44**	**75.06**	**66.81**	**56.81**	**54.69**	**25.52**
FE FE1	112.12	108.44	99.69	85.94	88.44	73.44	69.69	64.69	17.19
FE2	113.44	108.44	88.44	*24.69	79.69	75.94	67.19	60.94	29.69
FE3	119.69	108.44	87.19	87.19	77.19	74.69	68.44	599.69	*-3.44
FE	115.06	**108.44**	**91.81**	**86.56**	**81.81**	**69.69**	**68.44**	**61.81**	**14.48**
FMg FMg1	114.63	103.44	89.69	83.44	69.69	64.69	60.94	54.69	4.06
FMg2	118.44	102.19	93.44	87.19	74.69	63.44	55.94	58.44	29.69
FMg3	*39.69	105.94	92.19	77.19	64.69	63.44	58.44	*24.69	10.94
FMg	114.63	**103.81**	**91.81**	**82.56**	**69.69**	**65.94**	**58.44**	**57.19**	**14.9**
FNa FNa1	119.69	98.44	98.44	85.94	94.69	70.94	67.19	55.94	41.56
FNa2	114.69	98.44	92.19	87.19	79.69	72.19	65.94	58.44	8.44
FNa3	118.44	99.69	93.44	90.94	80.94	64.69	62.19	53.44	29.69
FNa	117.61	**98.86**	**92.19**	**88.02**	**85.11**	**69.27**	**65.11**	**55.94**	**25.56**
FB FB1	119.69	99.69	97.19	85.94	79.69	74.69	70.94	64.69	42.19
FB2	114.63	99.69	90.94	84.69	72.19	64.69	67.19	60.94	32.81
FB3	117.19	102.19	92.19	79.69	73.44	67.19	67.19	59.69	35.94
FB	117.19	**100.56**	**93.44**	**83.44**	**75.06**	**68.81**	**68.44**	**69.69**	**36.98**
FSt FSt1	118.44	117.19	115.94	67.19	117.19	115.94	113.44	104.69	85.994
FSt2	117.19	117.19	115.94	118.44	117.19	115.94	117.19	105.94	92.19
FSt3	115.94	118.44	119.69	117.19	113.44	114.69	114.69	108.44	83.44
FSt	117.19	**117.61**	**117.19**	**100.94**	**115.94**	**115.52**	**115.11**	**106.36**	**87.19**

(*) Denote values not used

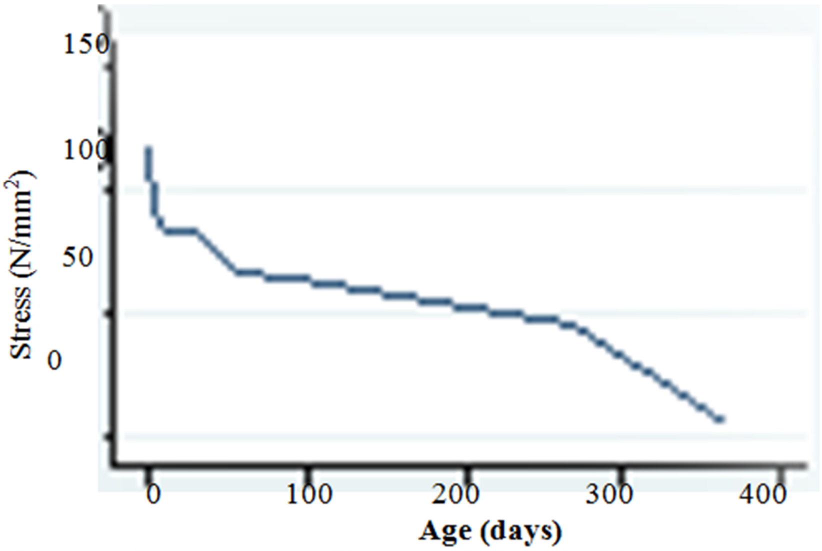
F_u = Flexural Stress of Beams Reinforced with Uncoated Fan palm in Alkaline: F_{WU} = Flexural Stress Beams Reinforced with Uncoated Fan palm in Water

F_E = Flexural Stress of Beams Reinforced with Fan palm Coated with Epoxy: F_s = Flexural Stress of Beams Reinforced with Fan palm Coated with Sulphur

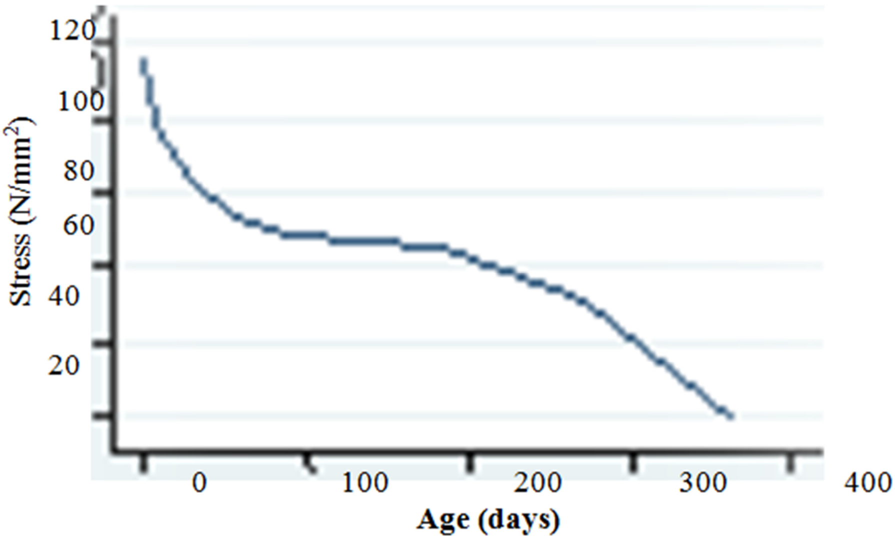
F_B = Flexural Stress of Beams Reinforced with Fan palm Coated with Bitumen: F_{Mg} = Flexural Stress of Beams Reinforced with Fan palm Coated with Magnesium

F_{Na} = Flexural Stress of Beams Reinforced with Fan palm Coated with Sodium Sulphate F_H = Flexural Stress of Beams Reinforced with Fan palm Coated with Hydroxylamine

F_{St} = Flexural Stress of Beams Reinforced with Steel

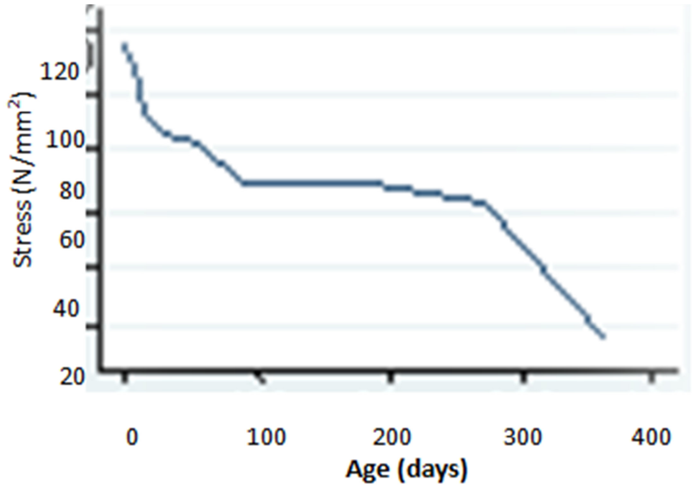


(a) F_U: Flexural stress of beams reinforced with uncoated fan palm in alkaline solution

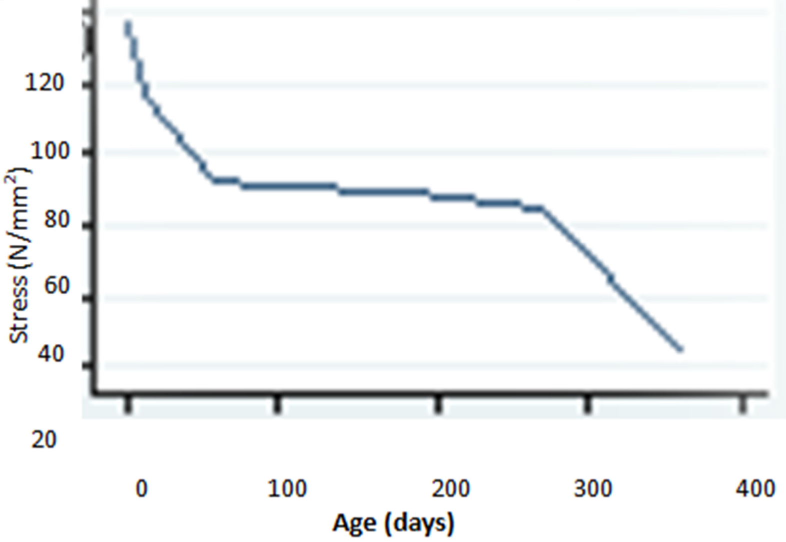


(b) F_{UW}: Flexural stress of beams reinforced with uncoated fan palm soaked in water

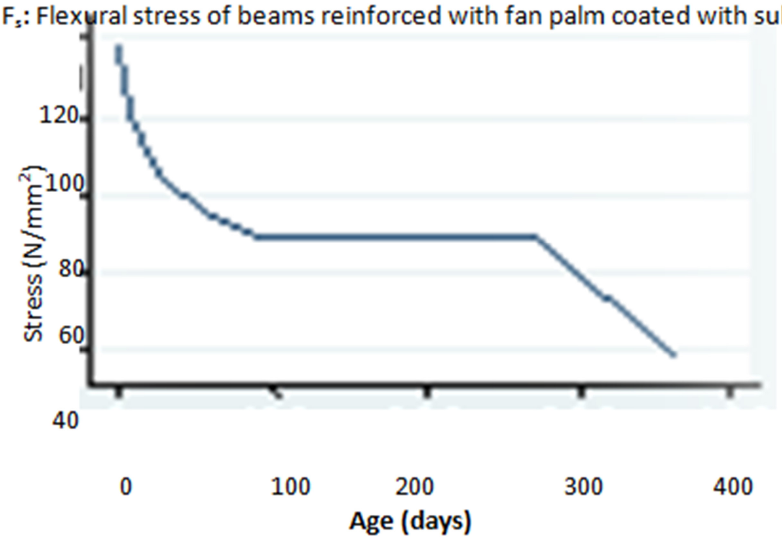
Figure 1: Flexural stress of beams reinforced with uncoated fan palm **SPECIMENS**



(a) F_E: Flexural stress of beams reinforced with Fan palm Coated with epoxy

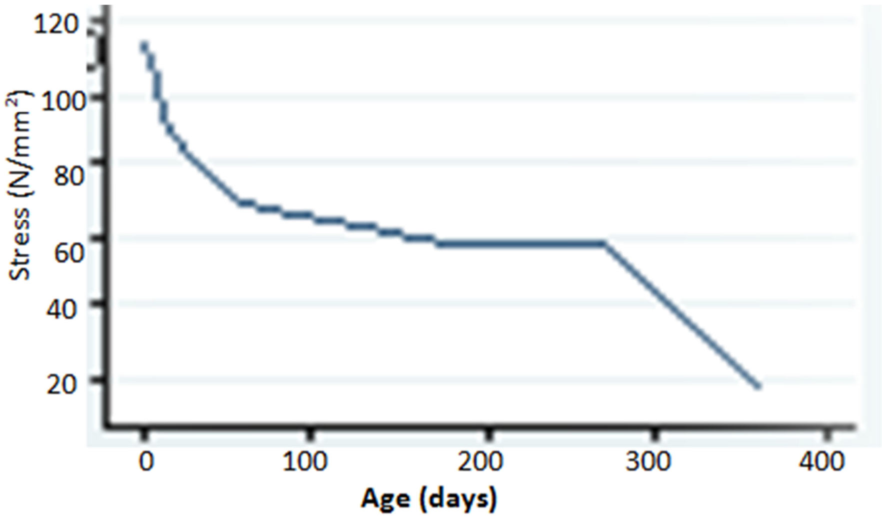


(b) F_s: Flexural stress of beams reinforced with fan palm coated with sulphur

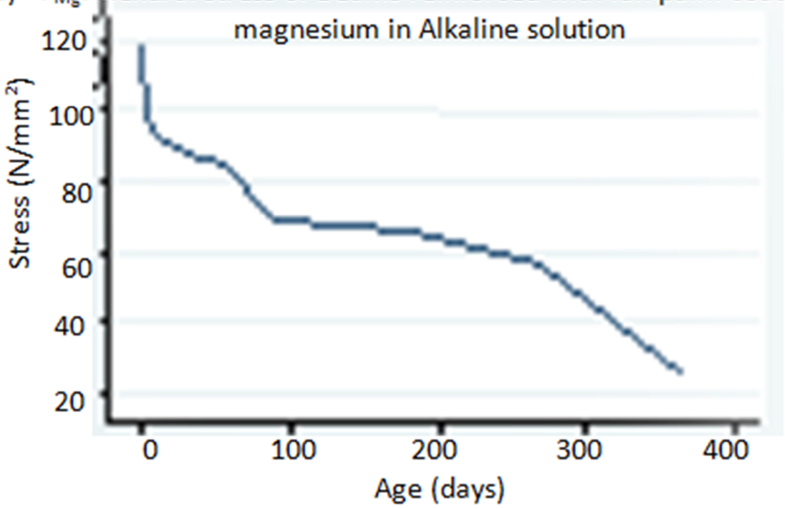


(c) f_b: Flexural stress of beams reinforced with fan palm coated with bitumen

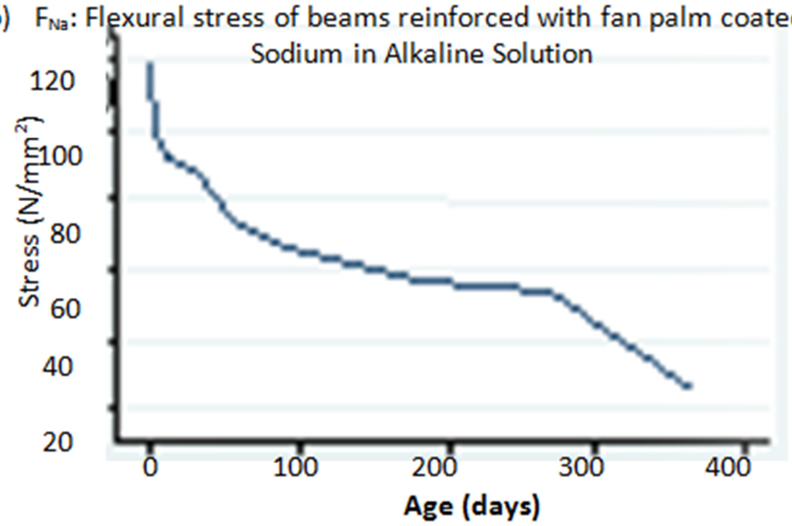
Figure 2: Flexural stress of beams reinforced with fanpalm specimens coated



(a) F_{Mg}: Flexural stress of Beams reinforced with fan palm coated with magnesium in Alkaline solution

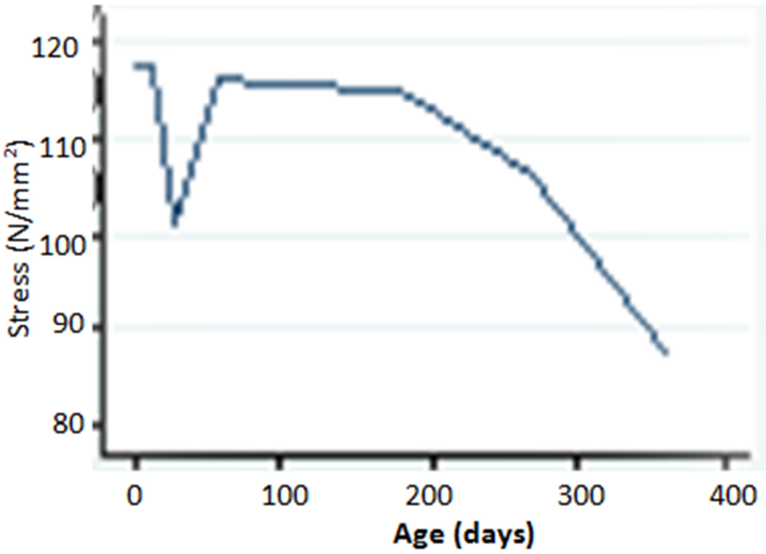


(b) F_{Na}: Flexural stress of beams reinforced with fan palm coated with Sodium in Alkaline Solution



(c) F_H: Flexural stress of beams reinforce with fan palm coated with hydroxylamine in alkaline solution

Figure 3: flexural stress of beams reinforced with fan palm specim with blocking agents



F_{St}: Flexural stress of beams reinforced with steel

Figure 4: Flexural stress of beam reinforced with steel

At 28 days beams reinforced with fan palm coated sulphur, a water repellant agent retained the highest modulus of rupture with mean value of 88.81N/mm^2. But of beams reinforced with fan palm coated with water repellant, those reinforced with fan palm coated with hydroxylamine retained the highest mean ultimate flexural stress of 88.44N/mm^2.

The results at 56days indicated that out of the beams reinforced with water repellant agents, beams reinforced with fan palm coated with epoxy gave better protection with mean values of ultimate flexural stress of 81.81N/mm^2. While for beams reinforced with fan palm coated with blocking agents, those coated with sodium sulphate gave the best protection and retain highest mean ultimate flexural strength of value 85.11N/mm^2. As expected beams reinforced with uncoated fan palm specimens conditioned in alkaline environment recorded the lowest retained mean ultimate flexural strength of value 66.81N/mm^2. This as explained by Gram and Nimitiyonngskul (1987) is as a result of continuous attack of the hemicelluloses of the fan palm reinforcements by the hydroxyl ions of the alkaline media. The steel reinforced beams failed by shearing near the supports at the flexural stress of 115..94N/mm^2.

At 90 days beams reinforced with fan palm coated with sulphur retained the highest flexural stress of mean value of 70.56N/mm^2.. While for the fan palm coated with beams reinforced with fan palm coated with blocking agents, the beams reinforced with fan palm coated with sodium sulphate gave the best protection with mean value of ultimate flexural stress of 69.27N/mm^2. All the beams reinforced with uncoated fan palm retained lower mean ultimate flexural stress compared to the mean flexural stress of beams reinforced with water repellant agents. It could be said then that blocking agents and water repellant agents aids durability of fan palm reinforced concrete beams in alkaline media. Again, all the steel reinforced beams failed by ends shear at the mean flexural stress of 115.52N/mm^2.

At 180 days, the ultimate failure stress of beams reinforced with fan palm coated with water repellant agents. It could be observed that all the water repellant agent retained the mean ultimate flexural stress of values 68.44N/mm^2. On the other hand, beams reinforced with fan palm coated with sodium sulphate retained the highest ultimate flexural stress of 65.11N/mm^2 for beams reinforced with fan palm coated with blocking agents. Again, beams reinforced with uncoated fan palm specimens conditioned in alkaline have the lowest value of ultimate flexural stress of 55.06N/mm^2. Also all the steel reinforced concrete beams failed by shear failure near the ends and could not attained the ultimate flexural failure loads before failure.

It was observed that at 270 days, beams reinforced with fan palm coated with bitumen, a water repellant agent, gave the highest flexural stress of 69.69N/mm^2. While for the beams reinforced with blocking agents, beams coated with magnesium sulphate offer the highest mean ultimate flexural stress of value, 57.19N/mm^2. However one of the beams reinforced with magnesium sulphate (F_{mg3}) failed by shear failure. Also all the beams reinforced with uncoated beams recorded lower mean ultimate flexural stress. This again could be explain as the fan palm reinforcements of the flexural beams are exposed to direct attack of the hydroxyl ions of sodium hydroxyl solution as explained by gram (1983), and Gram et al. (1987). For steel reinforced beams as shown in figure 4.41. It was observed that all the beams failed by shear failure near the support with mean flexural failure stress of 106.36N/mm^2.

The result of flexural stress tests on the nine levels of the beams at 365 days showed that of the beams reinforced with, water repellant agents, beams reinforced with bitumen retained the highest ultimate flexural stress of value 36.98N/mm^2. While for the beams reinforced with fan palm coated with blocking agents, beams reinforced with hydroxylamine recorded the highest mean ultimate flexural stress with mean value of 25.59N/mm^2. The average ultimate flexural stress of beams reinforced with uncoated fan palm is 4.69N/mm^2 and 18.07N/mm^2 in alkaline and in water respectively. Beams with reinforced fan palm coated with bitumen are more durable than other set of beams at one year. Beams reinforced with uncoated fan palm specimens soaked in alkaline media over the period of 365 recorded the highest lost in strength. However, for the steel reinforced beams the failure mode was predominantly shear failure near the support.

The ANOVA analysis was also carried out on the flexural stress data to compare the level of closeness of the flexural stresses of the various treatments applied on the reinforcements of the beams. The result is as shown in Table 2. From the table, the values f = 32.34 and prob > f = 0.0000 i.e 0.00% were obtained over nine observations of each treatment. Statistically, it could be said that this is 0% level of significance which is to say that the data is highly significant, and implies that the observed mean flexural stress varies drastically with the treatments over the specified periods of the experiments (0 – 365 days). All the specimens suffers decline in flexural strengths with time in both alkaline and in water. However, as discussed above, beams reinforced with uncoated fan palm specimens in alkaline environment recorded remarkably higher declination in flexural strength as compared to beams reinforced with fan palm coated with blocking agents and water repellant agents over the period of one year that they were embeded in alkaline solution.

Table 2: Anova of flexural stress

Treatment	Mean	Std. Dev	Freq.
F_B	79.29	23.005461	9
F_E	77.566666	29.65259	9
F_H	76.501111	27.313186	9
F_{Mg}	77.1	29.888059	9
F_{Na}	77.518888	27.002962	9
F_S	78.302221	27.707244	9
F_{St}	110.39	10.403528	9
F_U	67.894444	31.672502	9
F_{UW}	73.945555	28.684207	9
Total	79.834321	27.864492	81

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	10283.5956	8	1285.44944	1.79	0.0940
Within groups	51830.7954	72	719.872158		
Total	62114.391	80	776.429887		

Bartlett's test for equal variances: chi2(8) = 9.2385 Prob>chi2 = 0.323

4.0 Conclusion and Recommendations

4.1 Conclusions

Almost all the beams reinforced with fanpalm attain full ultimate flexural stress before failure but no steel reinforced beams attained full ultimate load before failure. They all failed by shear failure near the end.

Beams reinforced with uncoated fanpalm specimens suffer most decline in Modulus of Rupture, MOR, (Ultimate Flexural Stress) with time in alkaline media. Beams reinforced with fan palm coated with water repellants; bitumen, sulphur and epoxy retained the highest flexural stress at failure when compared with others.

Fan palm will be a good substitute to steel but should be treated with bitumen or sulphur before been used as reinforcement in concrete.

4.2 Recommendations

From the findings and discussion of result in this study, the following recommendations are suggested.

The study was conducted for the period of 365 days, further study should be conducted using the same specimens same coating condition but with a longer period (between 2 – 3 years).

Also, other treatment measures like partial replacement of alkaline with pozzolanas, combination of water repellant and blocking agents, etc. should be examined to establish the most effective way of preserving the strength of the fan palm.

It was very difficult to slice, machine to shapes, grind to smoothen the surfaces of the fan palm specimens and to grind fan palm specimens to powder for chemical analysis. Hence effective Mechanical Methods should be devised to machine (conversion, slicing, grinding and shaping) of the fan palm to get the desired shapes and sizes required without much stress.

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