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FLEXURAL BEHAVIOUR OF FANPALM REINFORCED CONCRETE SLABS

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Abstract: The importance of cracks, crack width and load carrying capacity of reinforced concrete member subjected to flexural load is so vital and is considered as a very important parameter under serviceabity limit state design of concrete elements. The post-crack behavior of a structural member is a measure of its toughness, a vital parameter often used in evaluating the durability of structural element. Steel have been in used as reinforcements in structural members because of its good properties on high tensile stress, ability to improve the toughness of structural members and its durability in concrete environment. However, steel is now very expensive, hence the need for substantive alternative material. Fanpalm is one of the locally available and has been studied as a suitable alternative to steel reinforcements. The study of the cracks and cracks' patterns with the respect to the sustained loads for concrete slabs reinforced with fanpalm is the concern of this study. Fanpalm specimens were cut, shaped to desired flexural reinforcements sizes. Then used as reinforcements for concrete slabs of 1:2:4 mix and cured in water for 28 days. Flexural strength tests were carried out to evaluate the load causing the first visible crack and the load causing full development of yield lines of fanpalm reinforcement concrete slabs were observed. The theoretical yield loads were lower compared with the observed experimental yielding loads. The results reveal that the cracks increase with increased in load. As the load systematically increases there is another sudden change in deflection at yield points. The highest percentage reinforcement 72 %and 65 % on y and x plane respectively occurred on slab SLF2 with corresponding value of 16.20 kN and 29.35 kN at first crack and yield point respectively.
Keywords: Fanpalm, First crack; Flexural stress; Reinforced concrete; Slab; Steel; Yield load

INTRODUCTION

The possibilities of using fanpalm as reinforcement in structural members have developed a grown interest in recent years. Fanpalm is local wood belonging to the family of palmacea commonly found in the tropical countries and widely spread in the middle belt of Nigeria (Jimoh, 2006; Audu, 2015). The physical and mechanical properties as well as its durability condition in alkaline environment make it a potential substitute to steel reinforcements. However, the suitability of a material as reinforcement in structural concrete will depend on its short- term and long- term behavior in term of its strength, bond stress and post- crack behaviors. There is need to investigate and establish the flexural behavior of concrete members reinforced with fanpalm and evaluate its level of suitability as a substitute to steel reinforcements prior to its recommendation for use as reinforcements in concrete members.

Cracks and yield lines play important role in structural failure of reinforced concrete members that are subjected to flexural stress. The failure of well designed reinforced concrete members under flexural loads are often preceded by formation of cracks (Mosley and Bungey, 2000). These cracks increased in numbers and widths as the structures tend to yield point. In all reinforced concrete elements, there is an acceptable limit to the width of crack after which the structure is assumed to have failed (Mosley and Bungey, 2000). Hence, the need to examine the cracks behaviors and yield line formation in concrete members reinforced with natural fibres is inevitable. Concrete is a composite inert material comprising of a binder course (e.g cement), mineral filler (aggregates) and water, Neville, 1989. Aggregates are of two types, fine and coarse. They are usually graded from sand to stone. There are two types of concrete; light weight concrete and dense concrete. The light weight concrete weighed between 1600 to 2000 kg/m^3, while the dense concrete has an average density of 2400 kg/m^3 (Orchard, 1976). Dense concrete is often used for reinforced concrete works. The batching of concrete can either be by weight or by volume. The batching of design mix for high quality jobs is usually by weight. The amount of water to be added to a batch of concrete mix is governed by the workability, strength and the exposure condition. If too much of water is added there is tendency for aggregate segregation during placing and concrete not meeting the target strength after hardened. While, too little of water in a mix, will not make the chemical action of setting of cement to be incomplete. The amount of water to be added to a given batch of concrete mix is guided by specified water cement ratio. For structural concrete that are subjected to flexural stress, is often required that reinforcement introduced at the tensile zone of the member because concrete is very good in compression but weak in tension. Such reinforcements should be of material that has high tensile stress, good bonding with concrete and durable in alkaline media. Section 7 of BS 8110, 1987, specified that concrete reinforcements should comply with BS 4499 and BS 4461 and that different reinforcement may be used in the same structural member. In any case, the reinforcement used in concrete must be durable. Steel reinforcement was found suitable and have long been used as reinforcements in concrete members. But attention is now focusing on natural fibre as a possible reinforcing material that could replace or compliment steel in concrete members to reduce cost. This paper examines the flexural behavior of slabs reinforced with fanpalm subjected to uniformly distributed load. It examines the crack patterns, the first crack loads, the ultimate (yield) loads as compared with theoretical loads.

REVIEW OF LITERATURE

The use of Bamboo, fan palm and some selected woods to replace conventional steel reinforcement in reinforced concrete members. (Slabs, beams, columns) have received attention over the past fifteen years. Mechanical properties of these materials such as; the yield stress, the load-defection characteristics and absorption characteristics of these local fibers as well as the composite behavior have been investigated by; Cassandra (2009), Fache (1986), Ibi (1988), Jimoh (2006), Michelle, 2009 and Law, 2010. In all the research on bamboo, it was discovered that it is not suitable for use as reinforcement because; it is dimensionally unstable, lack durability in water and alkaline media, and often suffers bond failure (Cassandra, 2009; Law, 2010; and Michelle, 2009).

Fache (1986) reported that fanpalm air-dried specimen has the tensile strength within the range 80-120N/mm^2 while the compressive strength within 40-90N/mm^2. Ibi (1988) recorded that air-dried specimen to have average moisture content of 11.66 % and the ultimate tensile strength to be 131.18 N/mm$_2$ while the average ultimate compressive strength were fund to be 71.6 N/mm^2. Ibi (1988) also investigate the variation of ultimate strengths (tensile and compressive) when soaked in water. It was observed that the ultimate strength decreased with increase in moisture content up to 28-32 % after which there is increase in ultimate strength again up to 40 % moisture content. Thereafter, there was decrease in ultimate strength as moisture content increases.

Audu (2015) immerse uncoated fanpalm reinforced beams, beans reinforced with fanpalm coated with, blocking agents and water repellant agents in 0.1NaOH solution over a period of 365 days. The uncoated (untreated) fanpalm beams had sharp decrease in strength with time. While the coated specimens retained higher strength as compared with the corresponding uncoated specimens.

Kankan (1986) investigated the flexible strength and crack behavior or bamboo reinforced composite. He found out that the experimental failure load is about 67 % of the designed load based on concrete section alone.

Concrete in aggressive environment suffers four major types of deterioration; corrosion of the reinforcement, alkali- aggregate reactivity, freeze- thaw deterioration and attack by sulphates (Ozyildirim, 1993). Most structures may be exposed to sulphate and chloride salts and various acids because of environmental pollution. The type of action of these salts on the concrete varies. An investigation of Na+, Cu2+, Mg2+, Ca2+, NH4+ sulphate solutions on truss cements, showed that the most aggressive solution is NH4+ sulphates (Kilinckale, 1974; Chippex and Scivenier, 2012). It has been noted that, concrete exposed to sulphates attack loses compressive strength and this loss increases as a function of sulphate concentration and age of exposure (Kilinckale and Uyan, 1996; Yinusa, 2013). The effect of different sulphates solutions on compressive strength of concrete is not equally severe, the effect of magnesium sulphate is found to be one of the most severe [Kumar and Kameswa, (1994), Collepardi, Marciatis and Turiziani (1982), Afolayan and Alhassan (2010)]. It is also a known fact that the construction industry relies heavily on cement for its operations on the development of shelter and other infrastructural facilities. The provisions of low cost but durable materials are almost universally recognized as one of the major obstacles to improve housing conditions in developing countries. Among the building materials in use today, the ordinary Portland cement (OPC) and steel reinforcement are vital elements in all types of construction. OPC and steel reinforcements are expensive and have limited the construction of housing. It then becomes extremely difficult for majority of the people to own houses and many collapsed structure have been reported in an attempt to reduce cost by not using; designed mix ratio, correct sizes of steel and correct standards of steel reinforcements (Afolayan and Alhassan, 2010). It is believed that the use of low cost local reinforcing materials will be cost effective and evitable eliminate these problems.

EXPERIMENTAL DETAILS

Three set of slabs were casted using the same concrete materials, concrete mix, but varying type and varying percentage of reinforcements. Three samples (a, b and c) of slabs were made for each set. The slabs were subjected to the same curing and testing conditions;

≡ Set I - Fanpalm reinforced concrete slabs (SLF1a,b,c; SLF2a,b,c; and SLF3a,b,c)
≡ Set II - Unreinforced concrete slabs (SLU a,b,c)
≡ Set III - Steel reinforced concrete slab SLS a,b,c (Fy=250N/mm^2).

Tap water, ordinary portland cement, washed erosion sand, local gravel of 20mm maximum size and sliced fanpalm were used. Concrete mix of 0.65: 1: 2: 4 that is the ratio of water to cement to fine aggregate to coarse aggregate which gave an average compressive strength of 20 N/mm^2 was used for the production of the three sets of slabs from the nine numbers wooden molds of 880 x 880 x 70 mm that were made. The wooden molds were cleaned oiled and placed on the flat and smoothened concrete base. Fanpalm logs were sliced trimmed and smoothened to 10 x 10 mm and 12 x 12 mm reinforcements' sections using hack saw and smoothening machine. Figure 1 showed samples of the sliced and smoothened fanpalm ready for used as reinforcement in the slabs.

Concrete biscuit of 15 mm thickness were made and cured for 7 days. The concrete biscuits were placed in the moulds, and then the reinforcements were placed on concrete biscuit in the molds. Concrete of mix ratio of 1: 2: 4 to meet the designed target strength of 20 N/mm^2 was made. The batching was by weight, while the mixings were done using concrete mixer. The concrete was poured to fill the molds containing the reinforcements. The fresh concrete then compacted gently with vibrating poker for 5 minutes. The molds were removed after 24 hours and the concrete slabs then soaked in water for 28 days. The slabs were removed and air dried for 2 hours before subjected to flexural strength test in compliance with ASTM C 348 standards.

Figure 1: Samples of fanpalm reinforcement

The flexural strength tests were carried out on the fanpalm reinforced slab specimens thus; the specimens were placed on the steel knife edge supports of the Automatic Universal Testing Machine (AUTM). A fabricated steel plate 4mm thick that covered the entire surface of the slabs was placed on slabs a under the universal testing machine. The load was applied uniformly at the rate of 1 kN/mins through the loading rate knob and the load/release knob of the Automatic Universal Testing Machine, AUTM. The loads at first cracks and loads at yield point and the corresponding type (shape or pattern) of the cracks were read and recorded. The crack patterns at ruptured of the slabs were also observed and recorded.

RESULT AND DISCUSSION

The results of the experimental investigation are presented in Tables 1, 2 and 3 below: Table I presents the three sets of slabs and their corresponding dimensions.

Table 1: Concrete properties of the slabs

Slab No	Dimension (mm) of Slabs	Age at test (days)	Average 28 days cube strength (N/mm2)
SLF1(a,b,c)	880X880X70	28	21.50
SLF2(a,b,c)	880X880X70	28	22.00
SLF3(a,b,c)	880X880X70	28	21.70
SLU(a,b,c)	880X880X70	28	21.60
SLS(a,b,c)	880X880X70	28	21.80

SLF1-Fanpalm reinforced concrete slabs Type1; SLF2-Fanpalm reinforced concrete slabs Type 2; SLF3-Fanpalm reinforced concrete slabs Type 3; SLU-Unreinforced concrete Slabs; SLS-Steel reinforced concrete slab.

Table 2 showed the slabs, the type of reinforcement and the corresponding percentages of these reinforcements in the slabs. Table 3 presents the experimental and theoretical loads at first crack and at yield point. It also presents the shapes of the cracks as observed at yield point.

Table 2: Percentage of reinforcement of the slabs

Slab No.		Spacing		Area		Percentage of reinforcement	
	Size (mm)	Sx (mm)	Sy (mm)	AFx (mm^2)	AFy (mm^2)	100 (AFx/bh)	100 (AFy/bh)
SLF1(a,b,c)	10x10	410	410	300	300	0.43	0.43
SLF2(a,b,c)	12x12	405	405	432	504	0.65	0.72
SLF3(a,b,c)	12x11	405	405	396	396	0.57	0.57
SLU(a,b,c)	0	0	0	0	0	0.00	0.00
SLS(a,b,c)	Φ12mm	410	410	339.3	226.7	0.59	0.52

Table 3: First cracks and yield loads of the slabs

Slab No	Experimental		Theoretical				
	Yield Load P^*_y (kN)	First Crack Load P^*_x (kN)	Yield Load P_y (kN)	First Crack Load P_x (kN)	$\frac{P^*_y}{P_y}$	$\frac{P^*_x}{P_x}$	Crack Pattern
SLF1a	20.35	17.90	20.98	8.44	0.97	2.12	**Y**
SLF1b	22.00	18,20	20.98	8.44	1.05	2.16	**Y**
SLF1c	21.10	17.90	20.98	8.44	1.01	2.12	**Y**
SLFI	**21.15**	**17.98**	**20.98**	**8.44**	**1.01**	**2.13**	**Y**
SLF2a	29.20	14.90	29.48	15.02	0.99	0.99	Y
SLF2b	29.25	15.35	29.48	15.02	0.99	1.02	Y
SLFb	29.35	16.20	29.48	15.02	0.99	1.07	Y
SLF2	**29.24**	**15.50**	**29.48**	**1502**	**0.53**	**1.03**	**Y**
SLF3a	22.95	9.50	23.40	11.76	0.98	0.98	Y
SLF3b	23.00	9.60	23.40	11.76	0.99	0.99	Y
SLF3c	23.70	9.15	23.40	11.76	1.01	1.01	Y
SLF3	**23.55**	**9.42**	**23.40**	**11.76**	**1.01**	**1.00**	**Y**
SLUa	0.30	0.25	0.28	0.27	1.07	0.93	Y
SLUb	0.25	0.20	0.28	0.27	0.93	0.74	Y
SLUc	0.35	0.30	0.28	0.27	1.25	1.11	Y
SLU	**0.28**	**0.27**	**0.28**	**0.27**	**1.00**	**1.00**	**Y**
SLCa	68.55	22.60	45.98	44.21	1.45	0.51	Y
SLCb	68.40	21.90	45.98	44.21	1.49	0.50	L
SLCc	68.60	22.50	45.98	44.21	1.49	0.51	Y
SLC	**68.45**	**22.59**	**45.98**	**45.95**	**1,49**	**0.50**	**Y,L**

Y = y – shaped cracks on the slabs; L = l – shaped cracks on the slabs

It was observed during the experiment that the cracks widths increased with increased of the load on the slabs. As the load systematically increases there is a sudden change in deflection at yield points. The highest first crack and yield loads occurred on slabs with the highest percentage of reinforcements, 72% and 65% on y and x plane respectively occurred on slab SLF2c with corresponding value of 16.20 kN and 29.35 kN respectively.

It was observed that after the first crack formation, the increased in applied load on the slabs resulted in multiplication of cracks and increases of cracks width, and then followed the full development of yield lines, and rupture of the slabs. It was observed that the unreinforced slabs, SLU a,b,c failed just after the appearance of the first crack with just little incremental loads. Table 3 showed that the theoretical yield load comparatively equals the experimental yield load for the fanpalm reinforced slabs but for the steel reinforced slabs, the experimental failure loads is averagely 49.9 % higher than theoretical failure loads. This could be attributed to the factor of safety often adopted in the design for the applied load and the materials. The design was based on Ultimate Limit State design method using BS 8110, 1987. All the slabs except one of the steel reinforced slab, SLCb, had Y - shaped crack patterns but SLCb had L-shaped crack pattern. The theoretical first crack loads were lower than the experimental first crack loads except for the steel sections. This could be attributed to the fact that prior to the point of cracking, concrete in practical terms also bears some percentage of tensile load as against the theoretical assumption that only the reinforcements in the tensile sections for flexural members bears the tensile stress even at loads below the first cracks.

CONCLUSION

Fanpalm reinforcement composite behaves in like manner as steel reinforcement composite when subjected to flexural stresses. The experimental failure load is always higher than the theoretical failure load. The loads at first cracks and at yields increased with the increased in percentage of reinforcements (steel and fan palm). Before the point of first crack, concrete also sustained some percentage of loads at the tensile zone. Fanpalm could be used as reinforcement for structural elements that carries light loads. Also, since BS 8110, 1987 allow different reinforcements to be used in the same structural member; fan palm can be introduced at sections where the tensile/flexural stress is not high while steel is used at sections where the tensile/flexural stress is high in a given member. Fan palm could be use as distribution reinforcements also. It is recommended that further studies be carried out to know the maximum percentage of fan palm reinforcements to be used in a given section.

References

[1.] Afolayan, J.O. and Alhassan, A. Y. (2010): Durability of concrete containing fly ash (fa) in Aggressive Environment. Journal of Engineering and Applied Sciences Volume 2, September 2010

[2.] American Society for Testing Materials (2013), Standard Test Method for Compressive Strength of Hydraulic Cement Mortar, ASTM C 345, ASTM International, West Conshohocken, PA, www.ASTM.org.

[3.] American Society for Testing Materials (2013), Standard Test Method for Flexural Strength of Hydraulic Cement Mortar, ASTM C 348, ASTM International, West Conshohocken, PA, www.ASTM.org

[4.] Audu, M. T. (2015): Durability Study of Fan Palm (Borassus Aethiopum) As a Reinforcing Material in Concrete. PhD. Thesis Submitted to the Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo state, Nigeria.

[5.] Cassandra, A. (2009), Bamboo Architecture and Construction with Osca Hidalgo. http://www.networkhert.org/naturalbuilding/bamboo.com.

[6.] Chappex, T.; Scrivener K. (2012), Alkali fixation of C-S-H in blended cement pastes and its relation to alkali silica reaction. Cement and Concrete Research 42: 1049–1054

[7.] Collepardi, M, Marciatis, A. and Turiziani, R. (1982), Penetration of Chloride Ions in Cement Paste and in Concrete. J. Am. Ceram . Soc, 55 (10) 534- 535.

[8.] Fache, J. O. (1983): Mechanical Properties and Pysical Characteristic of Fanpalm B. Eng. Project Report submitted to Department of Civil Engineering, University of Ilorin.

[9.] Ibi, T. M. (1988): The Behaviour of Fanpalm Reinforced Concrete Beams and Slabs Subjected to short term loading. B. Eng. Project Report submitted to Department of Civil Engineering, University of Ilorin.

[10.] Jimoh, A. A., (2006), Conversion and Properties of Fan palm (Borassus Aethiopum) for Structural Uses. PhD Thesis. Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.

[11.] Kankan, T. A. (1986): Bamb00 Reinforced Concrete Slabs subjected to concentrated Loading. MPil. Thesis, University of Science and Technology, Kumasi, Ghana.

[12.] Kilinckale, F. M (1997), "The Effect of MgSO4 and HCL Solution on the Strength and Durability of Pozzolana Cement Mortars." Cement and Concrete Research, Vol. 27, No. 12, pp. 1911-1918.

[13.] Kilinckale, F. M and Uyan, M; (1996), Turkish Chamber of Civil Engineers Technical journal 7, 1231.

[14.] Kumar, S. and Kameswa C.V.S, (1994), Effect of Sulfates on the Setting Time of Cement and Strength of Concrete", Cement and Concrete Research, Vol 24, No7, pp 1237-1244.

[15.] Laws, B. (2010), Bamboo, Fifty Plants that Changes the Course of History. New York: Firefly Bonks (U.S) incorporation.

[16.] Michelle, N. (2009), Bamboo Boom: Is This Material for You? Scientific American Earth 3.0 Special. http://www.scientificamerican.com/article. Retrieved August, 2009.

[17.] Mosley, W. H. and Bungey, R. H. (2000), Reinforced Concrete Design. Fifth edition, Published by Macmilland Publishers ltd, USA.

[18.] Neville, A.M. (1989), Properties of Concrete, Fifth edition, Longman Scientific and Technology, London.

[19.] Orchard, D. F. (1976), Properties of Materials. Concrete Technology Vol. 1, Third Edition, Published by Applied Science Publisher Ltd. London.

[20.] Ozyildirim, C. (1993), Durability of Concrete Bridges in Virginia. ASCE Structures Congress XI Proceedings; Structural engineering in natural hazards mitigation. New York: American Society of Civil Engineers, pp.996-1001.

[21.] Sivaraja M., Kadasamy, S., Velman, N. and Sudhakaram, N. P. (2010), Study on Durability of Natural Fibre Concrete Composite using Mechanical Strength and Microstructural Properties, Vol. 5, No. 6, pp. 45 - 50.

[22.] Yunusa, A. and Danladi, E. (2013), Properties of Concrete made with Ordinary Portland Cement partly replaced with Rice Husk Ash and Pulverished-Fuel Ash. Journal of Engineering and Applied Science, Vol. 5, No .2, pp. 27 - 32.

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