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Rattan Cane Reinforced Concrete Slab as a Component for Agricultural Structures

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Abstract

The potentials of Rattan Cane as a reinforcement material in concrete slabs were investigated. The principal objective was to determine the flexural strength of rattan cane reinforced concrete slabs. The use of steel reinforced concrete façade is gradually becoming unpopular due to the susceptible nature of mild steel to corrosion. This study investigated experimentally the flexural strength of *Eremospatha macrocarpa* canes reinforced concrete slab in terms of the maximum load the slabs could withstand under axial loading. The research investigated the feasibility of constructing lightweight slabs using rattan cane reinforcements as a replacement for corrosion-prone steel in lightweight construction. Ten slabs of 0.125 m^2 and concrete over of 20 mm were constructed for rattan cane and steel reinforcements using the ratio 1:2:4:0.5 for cement, fine aggregate, coarse aggregate and water respectively. The slabs were subjected to incremental third point loading until failure occurred. Deflection and crack width were measured simultaneously at the instance of the first crack and at the point of failure. The results for both types of reinforcements were compared and it showed that the rattan cane reinforced panels failed at 6.53kN load while steel reinforced slabs failed at 12.15 kN. It was observed that steel reinforced slabs had a deflection and crack width of 1.75mm and 0.063 mm respectively while rattan cane reinforced slabs recorded a deflection and crack width of 0.94 mm and 0.002 mm respectively. The flexural strength of 15 N/mm^2 and 9.75 N/mm was recorded for steel and rattan reinforced slabs, respectively. The ultimate load and flexural strength of rattan cane were lower than the steel reinforcement, as a result, rattan reinforced slabs can be used in the construction of silo, piggery and cattle barn floors.

Keywords: Rattan canes, steel, deflection, reinforcement, corrosion, flexural, crack width, point load

Introduction

Rattans are the second most important forest products after timber. They are climbing solid core vine palms with long tough slender stems of the family *Palmae* and sub-family *lepidocaryoideae* found mostly in the tropical rainforest. There are about six hundred (600) different species, belonging to thirteen (13) genera. Only three (*Eremospatha macrocarpa, Calamus deerratus* and *Lacosperma secundiflorum*) out of the 13 genera are present in different locations in Nigeria. Rattan, a versatile climbing palm, is available in many forests in southern Nigeria and can be considered as a material with high potential in the construction industry. Being an important forest product rattan cane is extensively used for various activities such as furniture, utensils, ropes, decorative items, agricultural implements and housing (Olorunshola, 2007; Adefisan, 2011).

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Important properties of rattans are flexibility, workability (easy to shape and form), noncorrosive, non-conductor of heat, durability, elasticity, lightweight and lustrous. (Olorunnisola *et al.*, 2005; Olorunnisola Adefisan, 2007; Olorunnisola, 2008).

The difficulty in the workability of steel bars coupled with its increasing costs has stimulated research interest in finding alternative reinforcing materials (Lucas and Dahunsi, 2004). Sivagamasundari and Kumara, (2008) and Lucas and Dahunsi, (2004) reported that concrete slabs reinforced with glass fibre reinforced polymer (GFRP) experienced better performance and longer fatigue under load than steel reinforced concrete slabs. (Hegger *et al.*, 2005) also reported that textile and fibre reinforced polymer (FRP) reinforced concrete structures have been tested and proved successful in the construction of pedestrian bridges and other light weight structures in terms of inherent characteristics such as high strength, light weight, long-term durability and corrosion resistance. Akinyele and Olutoge, (2011) investigated the properties of *Lacosperma secundiflorum*, a species of rattan cane, reinforced concrete façade subjected to axial loading and reported that at the ultimate load of 4.60 kN the slabs crushed followed by the rupture of the rattan cane. Akinyele and Olutoge, (2011) reported also that due to the low modulus of elasticity, rattan cane reinforced slabs exhibited larger strains than those reinforced with steel reinforcement.

This study investigated experimentally the flexural strength of *E. macrocarpa* canes reinforced concrete slab in terms of the maximum load the slabs could withstand under axial loading.

Strength Properties of Rattan Cane as a Structural Material

According to Akinyele and Olutoge, (2011) the rattans-concrete bond strength ranges between 0.0816 and 0.598 N/mm^2 depending on the species and natural conditions, as compared to 2.07 N/mm^2 obtained for steel-concrete bond and the moduli of elasticity for *Calamus deerratus*, *E. macrocarpa* and *Lacosperma secundiflorum* the three species of rattan cane are 3396 N/mm^2, 516 N/mm^2 and 11106 N/mm^2, respectively.

Table 1: Properties of Reinforcement

S/N	Reinforcement type	***F*** ***N/mm²***	E_s ***N/mm²***	D_f ***(mm)***	***Strain*** **E**
1.	Rattan cane (*Calamus deerratus)*	204	3396	6	0.0184
2.	Steel rod	250	200,000	6	0.0013

(**Source:** Akinyele *et al.*, 2011)

Methodology

Preparation of Specimen

The concrete was made using the Ordinary Portland Cement, gravel (as coarse aggregates) and sharp sand (as fine aggregates) and water in the ratio 1:2:4:0.5 as this is the ratio recommended by BS 8500-1 for reinforced concrete slab construction. Aggregates were free from impurities (dust, clay particles and organic matter). Sand and gravel were mixed first and then cement was added and mixed in the dry condition until a well dispersed and uniform cement coating on the aggregate was obtained. Water was then added gradually until a homogenous concrete paste was obtained in accordance with ASTM C192 / C192M-16a

(2016). The network of reinforcement was made from 6 mm diameter rattan canes and steel rods. The casting was done using 500 by 250 mm wooden form. Fifteen castings were made; five castings each for rattan cane reinforcement, steel rod reinforcement and the control. After each casting, concrete was manually compacted in order to expel air pockets, using rubber mallets to vibrate the concrete. The forms were removed after 24 hours and the specimens were cured in a curing tank for 14, 21 and 28 days.

Plates 1, 2, 3 and 4 show reinforcement, formwork, samples and sample testing on Testometric, respectively.

Plate 1: Reinforcement

Plate 2: Formwork

Plate 3: Samples

Plate 4: Testometric (Model M500-100 AT)

Results and Discussion

Weight of Slabs

The average weight of the slabs is presented Table 2. It can be seen from the average values that the steel rods and rattan cane reinforced slabs had average weights of 14.93 kg and 14.25 kg, respectively while the un-reinforced concrete had the least average weight of 13.89 kg. This difference in weight was due to the fact steel rods are denser than rattan canes. However, the difference in weight between the steel rod and rattan cane reinforced slab is not significant.

Table 2: Average Weight of the Slabs

S/No.	Sample A, (kg)	Sample B, (kg)	Sample , (kg)
1	14.27	14.48	14.20
2	14.13	14.99	13.52
3	14.23	15.23	13.67
4	14.18	14.76	14.17
5	14.43	15.18	13.89
Average	**14.25**	**14.93**	**13.89**

Ultimate Yield Load Capacity

The ultimate yield load result is presented in figure 1. The two-way rattan canes reinforced slabs recorded higher ultimate yield load and ductility in comparison with the control specimen. The average ultimate yield load of steel reinforced slabs was 12.51 kN with a deflection of 1.75 mm while rattan cane reinforced specimens recorded 6.53 kN with 0.94 mm deflection. The important difference between the steel rods reinforced slabs and rattan canes reinforced specimens is stiffness. The steel rods reinforced specimen had superior quality over rattan canes reinforced slabs in terms of both stiffness and ultimate yield load. This implies that RCRS are suitable only in lightweight constructions.

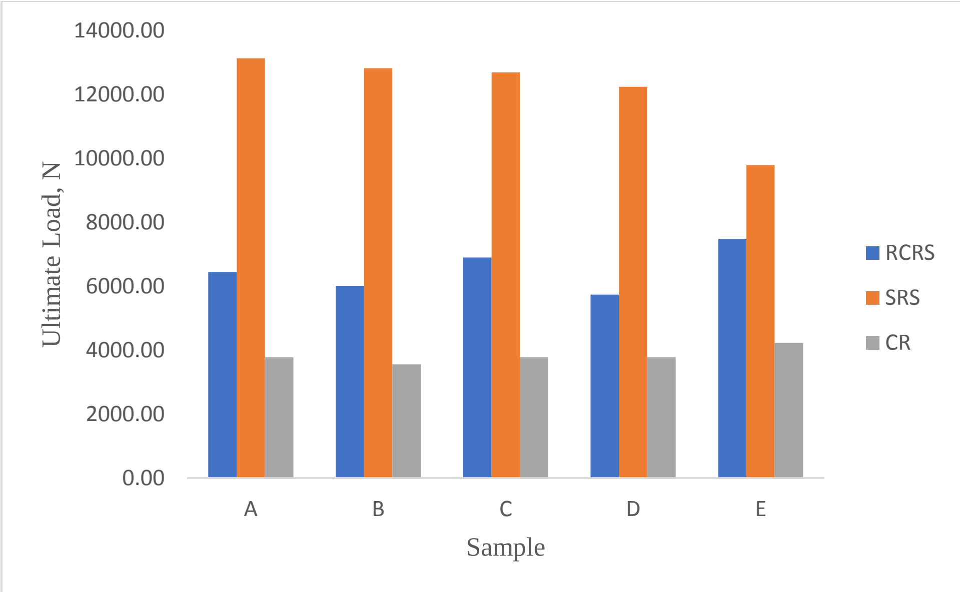

Figure 1: Ultimate Yield Load, N

Load – Deflection Relation

Flexural test was carried out on ten slabs of dimension 500 mm x 250 mm in order to determine the flexural strength and the capacity of the structure to withstand deflection after the curing ages of 14, 21 and 28 days using a Universal Testing Machine (Testometric, Model M500-100 AT) in accordance with ASTM C78 / C78M-16 (2016) and the result is presented in table 3. At each measurement, the load was applied gradually at a speed of 25 mm/sec until the sample failed.

Presented in figure 2 are the responses of the specimen to load. The effect of the self-weight of the test slabs was not included in the calculation of the test loads as it had a negligible effect on the results (Lindley & Whitaker, 1996). Maximum deflection of steel reinforced slabs occurred at a load of 12.15 kN, which coincided with flexural failure. However, in *Eremospatha macrocarpa* reinforced slabs flexural failure occurred at 6.53 kN load, which was recorded as the maximum load the slabs could withstand. While the control specimen failed at 3.83 kN without any form of deflection rather split into pieces. At failure, the rattan canes ruptured due to their low modulus of rupture.

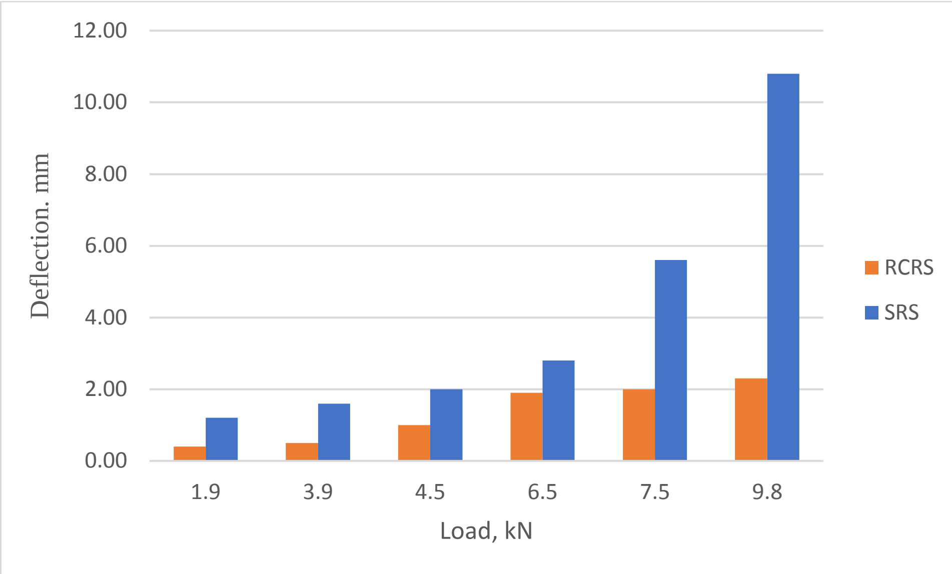

Figure 2: Load – Deflection Relationship

Table 3: Average Mechanical Properties of Slabs

Reinforcement Material	Rattan Cane Reinforced	Steel rod Reinforced	Control Reinforced
Weight, Kg	14.25	14.93	13.89
Load at First Crack, kN	5.20	8.00	3.12
Maximum Load, kN	6.53	12.15	3.83
Tensile Strength, N/mm^2	204	250	185
Modulus of Rupture (kN/mm^2)	9.8	18.23	5.745
Deflection at First Crack, mm	1.04	0.42	0
Maximum Deflection, mm	1.75	0.94	0
Crack width, mm	0.002	0.063	Split into pieces
Flexural Strength, N/mm^2	9.75	15	0
Strain (E)	0.0184	0.0013	0.0005
Density, kg/m^3	285	298.6	267.8

Crack Width and Flexural Strength

For all specimens, flexural cracks started in slabs tension side at the point of loading and propagated diagonally to the edges of the slabs. Each slab was simply supported over an effective span of 500 mm. The slabs were tested in flexure under third point loading and the load was applied at a distance of 250 mm from each support. The third load was applied on the slabs until the first crack was noticed and the corresponding deflection was recorded until the final collapse of the slab was reached. For cane reinforced slabs the first crack was observed at 5.20 kN while the final collapse was observed at 6.53 kN while for the steel rods reinforcement the first crack was observed at 8 kN and final collapse observed at 12.15 kN.

Table 3 shows that the crack width at failure in rattan reinforced slab was smaller than the corresponding steel reinforced slabs, however, steel rods reinforced slabs had higher flexural strength than rattan reinforced slabs. As a result, rattan cane-reinforced slabs are most applicable and limited to lightweight agricultural structures such as silo and animal housing flooring.

Conclusion

Flexural tests were carried out on fifteen numbers of two-way slabs reinforced with *Eremospatha macrocarpa* canes and steel rods. It was also recorded that all slabs experienced flexural failure at ultimate yield load. However, rattan cane reinforced slabs crushed under load followed by the rupture of the rattan cane whereas the steel did not rupture but lost its elasticity. Rattan cane reinforced slabs exhibited lower but moderate flexural strength than steel reinforcement. As a result, rattan cane reinforcement can be used as an alternative to steel in light and low cost construction.

The experimental results also showed that rattan cane reinforced slab had lower crack width. This is advantageous because the ingress of moisture will be lower in rattan reinforcement than in steel reinforcement, which could lead to rapid penetration of corrosive factors such as high humidity, repeated saturation, vapour, salt-water, and chemicals. As a result, rattan cane reinforcement is preferred to steel rod reinforcement, where such a structure is most likely to be exposed to moisture continuously.

Recommendation

It is recommended that the size of the rattan canes be varied in order to determine the optimum size that will withstand the maximum applied load. The concrete cover thickness of the slabs be varied also in order to determine the concrete cover thickness that will give the best result in terms of strength.

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