# Structural Characteristic of Bamboo and Rattan Cane Reinforced Concrete Struts.

[1]**Akinyele, J. Olawale***, [2]**Aresa, S. Wasiu**

[1 & 2] Department of Civil Engineering,
Federal University of Agriculture,
Abeokuta, Nigeria.

**ABSTRACT**

Corrosion in steel reinforced concrete structures has provoked research for an alternative material to steel that are resistance to corrosion. This paper looked at the use of bamboo and rattan cane as alternative materials to steel in reinforced concrete struts. Fifteen (15) short concrete struts of dimension 150 mm × 150 mm × 300 mm were designed for a 50 KN load. The samples were subjected to axial load, the results after crushing showed that all the struts failed in the same manner with average compressive strength of bamboo and rattan reinforced struts being about 78.18% and 63.48% that of steel reinforced struts respectively. Average crack width generated in bamboo and rattan reinforced struts were about 83.64% and 169.69% that of steel reinforced struts respectively. This paper concluded that bamboo and rattan cane can be effectively used as reinforcement in struts of low load bearing structures.

**Keywords:** Bamboo, Rattan cane, Steel reinforcement, Crack widths, Axial load

***Corresponding author**
E-mail: joakin777@yahoo.com.

## 1. INTRODUCTION

Reinforcement of cementitious materials generated considerable interest in recent years. The high technology of manufacturing conventional reinforced concrete of cement and iron or steel bars coupled with its increasing costs has stimulated the interest on how other materials could be used easily in reinforcing concrete and at a cheaper cost [1]. The use of Fibre Reinforced polymer (FRP) as an emerging technology for concrete structures has been tested and proved successful, this is because of its inherent characteristics such as corrosion resistance, high strength, light weight and anticipated long-term durability. Attention is gradually been focused on the use of bamboo (Bambusa vulgaris) and rattan cane (Calamus deerratus) as alternative reinforcement in concrete after the success recorded in the use of FRP.

Bamboo is used by some American building and construction companies exclusively who prize it as the strongest type of wood for construction as well as being the most durable, resilient and long-lasting. It can be used in conjunction with steel to create mortices and tendon joints, which give a secure locking ability to a wooden frame made entirely of bamboo timbers. Bamboo can withstand heat and humid climates the traditional climates of Asia, and suppliers boast that bamboo houses can withstand hurricane if well constructed. Other uses of bamboo which cannot be disregarded as potential materials are as untreated pipe cover, as ceiling or floor trimmings [2].

The use of bamboo as reinforcement in Portland Cement Concrete has been studied extensively by Clemson Agricultural College [3]. Bamboo has been used as a construction material in certain areas for centuries but its application as reinforcement in concrete had received little attention until the Clemson study [4].

The commonly used canes or “Rattan” have played a significant role in human culture since time immemorial. It is believed that they have been in use since the fifth century BC. Particularly in the making of household articles, furniture, tool handles, lifting heavy items and in bridge construction etc. Rattans have properties that make them very popular as raw materials for furniture, construction, handicraft and other industries – they are durable, elastic, light weight, lustrous and flexible [5].

Rattan has the tenacity and strength that is high enough so that it can be used as a material for the manufacture of reinforced concrete construction. The use of rattan as a material for reinforcing concrete was ever reported in the weekly newspaper in Indonesia.
This finding was demonstrated in the trial manufacture of reinforced concrete construction which was made from rattan for a bridge in Kendari, Southeast Sulawesi Province in early 1985. The experiment was with tohiti rattan that has stronger and higher power after preservation [6].

Akinyele and Olutoge [7], was able to investigate the properties of rattan cane reinforced concrete facade, it was observed that rattan cane reinforced façade and the conventional steel reinforced façade both experienced flexural type of failure, but due to the low modulus of elasticity of rattan cane, its façade exhibited larger strain than those of steel reinforced façade, but the experiment showed that rattan façade has lower crack widths when compared with that of steel which gave it advantaged when exposed to moisture.

## 1.2 Structural properties of Rattan cane and Bamboo.

In order to design any structural component efficiently, it is necessary to know in advance the strength capability of the material to be used. Rattan cane and Bamboo presents a problem in this respect since the quality can not be controlled as they are naturally occurring materials. All the other materials that are used structurally are man made and therefore some form of quality control can be exercised during their productions, this has led to some research work on the structural properties of Rattan cane & bamboo.

According to Lucas and Dahunsi [8], The rattan cane 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 [9]. These values represent between 3.94 and 28.86 percent of the bend strength of steel with concrete. They fall within the range obtained by Nindyawati *et al* [10], that is 0.33 – 0.48 N/mm$^2$ although, Harish et al [11] obtained between 0.90 - 1.95 N/mm$^2$ for some bamboo species bonded with concrete. In a research carried out by Mesquita *et al* [12] on plain bars (Smooth steel) and bamboo in concrete, it was observed that bond strength of bamboo was 70% of smooth steel in 35 N/mm$^2$ concrete and 90% bond strength of smooth steel in 15 N/mm$^2$ concrete.

The average tensile strength for this bamboo family was determined to be between 204 N/mm$^2$ and 250 N/mm$^2$ [1], this result is comparable to mild steel. Tensile strength is also influenced by the diameter of the reinforcement; similar effects do not exist in the case of conventional steel reinforcement. It was found that the moduli of elasticity for three species of Rattan cane were 3396, 516 and 11106 N/mm$^2$ for *C. deerratus, E. macrocarpa* and *L. secundiflorum* respectively [13].

The average compressive test for different bamboo family have bee investigated by various researchers, and the results depends on the bamboo species, but on the average, Harish et al [11], obtained 108.9 N/mm$^2$, Chung and Yu [14] obtained 103 N/mm$^2$, while Baldaniya et al [15] got 109.5 N/mm$^2$ as the average compressive strength of bamboo.

### 1.2.1 Swelling of bamboo

Olutoge *et al*, [1], Ghavami [16], Francis and Paul [4], Mentioned in their works hat the ability of the bamboo family to absorb water easily will lead to the swelling and shrinkage of this material when in contact with wet concrete, and to prevent this phenomenon, water repellants like coal tar, creosote, native latex, paints dilute varnish, are suitable for coating, and only a thin coat should be applied, as a thick coating will lubricate the surface and weaken the bond with the concrete.

### 1.2.2 Accelerated ageing test

The ageing of bamboo was investigated by Olutoge *et al* [1], the research was to ascertain the level of physical-mechanical depreciation the bamboo will go through when it is taken through some cycles in line with the American Society of Testing and Measurement (ASTM) code [17]. Two types of specimens were used, unseasoned green bamboo and seasoned creosote coated bamboo. The specimens were subjected to six complete cycles of accelerated ageing, which were: immersion in water at ($49 \pm 2^oC$) for 1 hour, Expose to steam and water vapor at ($93 \pm 30^oC$) for 3 hours, store at ($-12 \pm 3^oC$) for 20 hours, heat at ($99 \pm 2^oC$) in dry air for 3 hours, Expose to steam and water vapor again at ($93 \pm 30^oC$) for 3 hours and finally heat in dry air at ($99 \pm 2^oC$) for 18 hours. The research concluded that the physical-mechanical properties of bamboo are stable over a long period of time.

## 1.3 Buckling and Compression of Struts

When load is applied to the centroid of cross section of a column (i.e axial load) uniform compressive stresses are developed. Failure occurs when the actual direct stress exceeds the crushing stress of the material (i.e $F_a \geq F_y$). The crushing load is given by

$$P_y = AF_y \quad \ldots\ldots\ldots\ldots 1$$

Where $P_y$ is the crushing load, A is the cross sectional area of the column and $F_y$ is the yield or crushing stress of the material.

In 1757, Euler derived a formula for the maximum load a column can carry without buckling called critical load and it is given by

$$P_{cr} = \pi^2 EI/L^2 \quad \ldots\ldots\ldots\ldots 2$$

Where $P_{cr}$ is the critical load, E is the modulus of elasticity, I is the area moment of inertia and L is the effective length of the column depending on support condition.

This expression predicts that when a column becomes indefinitely long, the load required causing the member to buckle approaches zero and when the length of the column begins to approach zero, the load required to cause it to buckle becomes indefinitely large. What actually happens is that as the member becomes short, the failure mode changes to that of crushing [18]. From the above, since short struts are under consideration in this work, test for compression or crushing was carried out. The use of rattan reinforcement in lieu of conventional steel reinforcements requires better understanding under axial loading and performance conditions. This paper presents the behavior of reinforced short struts with rattan cane, Bamboo and the conventional steel reinforcements under axial loading. The experiment has been carried out on Fifteen (15) short concrete struts.

## 2. MATERIALS AND METHODS

### 2.1 Detail of experimental study

The study considered fifteen (15) short struts of dimension 150 mm × 150 mm × 300 mm were designed for a 50 KN load and cast with five (5) each reinforced with bamboo, rattan and steel (being control)., out of which five were reinforced with Rattan cane. The average age of the bamboo and Rattan cane used in this study was less than 40 days after harvesting.

### 2.2 Experimental Procedures

The formula used for steel reinforced struts according to BS 8110 is:

$N = 0.4\ F_{cu}bh + A_{sc}\ (0.8F_y - 0.4\ F_{cu})$ [19]

Where: N is the design axial load, $F_{cu}$ is the characteristic strength of concrete, $F_y$ is the characteristic strength of Steel, b and h are the width and length of the column cross section respectively and $A_{sc}$ is the area of steel provided.

Bamboo and rattan cane reinforced column design formula, developed by the U.S. Naval civil engineering laboratory is:

$P = 0.8\ Ag\ (0.225\ F_{cu})$ [4]

Where P is the design axial load, and $F_{cu}$ is the characteristic strength of concrete.

All the reinforcing materials (i.e. bamboo, rattan and steel) were cut to the length of 260 mm to allow for 20 mm cover each at the top and bottom of the struts.

Bamboo culm was cut transversely with the aid of hacksaw and split longitudinally to width of 18.75 mm (3/4 inch) as specified by the design. Rattan was also cut transversely with the aid of hacksaw. Both bamboo and rattan where seasoned with a thin layer of coal tar with the aid of brush and allowed to dry for two days, this coating is to serve as water repellent, in order to reducing swelling of the bamboo and rattan cane reinforcement when in contact with wet concrete (Figure1). The structural properties of the reinforcement used are shown in Table1.

The low yield steel was cut to the lengths of 260 mm as others with the aid of hacksaw.

The mild steel was cut and bent as designed for to serve as links for all the reinforcements with the aid of binding wire. The prepared reinforcements are shown in the figure 1.

Table 1: Properties of reinforcement

| No | Reinforcement type | $f$ (N/mm$^2$) | $E_s$ (N/mm$^2$) | $D_f$ *(mm)* | Strain, ε | No. of reinforcements |
|---|---|---|---|---|---|---|
| 1 | Rattan cane | 204 | 11,106 | 12 | 0.0184 | 4 |
| 2 | Bamboo | 231 | 25,000 | 18.75 | 0.00924 | 4 |
| 3 | Steel rod | 250 | 200, 000 | 12 | 0.00125 | 4 |

$f$ = Tensile strength of reinforcement, $E_s$ = Modulus of elasticity of Reinforcement, $D_f$ = size of reinforcement, ε = Strain of reinforcement at ultimate load.

Figure1: Prepared Reinforcements.

The fifteen formworks were greased with engine oil for easy removal after the concrete is set. The already prepared reinforcements were placed into the formworks considering the cover to the reinforcements. Batching by mass was done in the mix ratio of 1:2: 4 (i.e. one part of cement with two parts of fine aggregate and four parts of coarse aggregate) and the water – cement ratio of 0.65 for easy workability. Concrete was then placed immediately after the batching and adequate tamping done to prevent voids within the concrete.

The struts were allowed to set for 24 hours after which the formworks were removed. The struts were cured for 28 days by wetting them everyday after which they were tested for crushing (compression). The crack widths observed after crushing of the struts were measured using Vernier caliper. Table 2: showed the detail mix ratio of the concrete materials used in this experiment.

Table 2: Concrete mix ratio

| **Properties** | **Test Results** |
|---|---|
| 28 days compressive strength ($N/mm^2$) | 21 |
| Cement (kg) | 320 |
| Fine aggregate (kg) | 660 |
| Coarse aggregate (kg) | 1400 |
| Water/cement ratio | 0.65 |
| Density of concrete ($kg/m^3$) | 25.7 |
| Mix ratio | 1:2:4 |

Fig.2 Strut under test.

## 3. RESULTS AND DISCUSSIONS

It was observed that after crushing the struts, all of them failed in similar patterns with cracks emanating from their bases and extending up to more than two - third of their heights from the base and crack widths were also larger at the base as shown in figures 3-5 . The crack width formed are different from each other, rattan cane had larger crack width, followed by steel reinforced column, although the difference between the crack widths of bamboo and steel struts were very small, the implication is that mode of failure is independent of the type of reinforcing material used, the crack pattern has showed that the reinforcement is not involved in forming the pattern, hence the cracks run parallel to the reinforcement, although the stirrup used was made of low yield steel materials, but it has little to contribute to the crack patterns. Only the intensity of the failure load in terms of crack width generated is of significance because, the ability of the reinforced column to resist axial force depends on the yield strength of the individual material used as reinforcement, and this will determine the amount of load to be resisted and eventually the crack widths. The higher the ability to resist load, the lower the crack width that will be formed on the concrete column, the reason for this is because if the stress due to load on the reinforcement is more than what the reinforcement can withstand the excess stress is then transferred to the concrete which has a lower strength: hence cracks are formed on the concrete before it will eventually failed by crushing. Although, the actual unit stress on the concrete or the actual unit stress on the reinforcement of a concrete column under sustained actual loading cannot be precisely measured. If the materials were really elastic, it would be possible to equate the unit deformation of the two materials and obtain the ration of the reinforcement stress to concrete stress.

A load applied for only a short time causes very little creep, especially when the concrete is well cured; a long time loading may not necessary give the same results as that of the short term test carried out in this study.

It is evident from Table3 that all the struts performed efficiently with respect to the design load of 50 KN but the average ultimate load that caused compression or crushing of bamboo reinforced concrete struts and rattan reinforced struts were about 78.18% and 63.48% that of steel reinforced struts respectively. Since all the struts are of the same cross sectional area, the average compressive or crushing strength which can be calculated from equation 1 are also of the same proportions as the average ultimate loads. Although, Khare ( Khare L, University of Texas, USA, Unpublished) reported that the ultimate load capacity of bamboo was about 35% of the equivalent reinforced steel concrete beams, also Junior *et al* [20] mentioned just 25% bamboo load capacity when compared to equivalent reinforced steel concrete beams, this may be acceptable for beams, since the beam elements were subjected to flexural test, where the possibility of the structure to deflect and fail in flexure is very high, unlike in this research where the specimens were subjected to compressive test, hence the results obtained from Table 3.

Furthermore from the Table 3, the average crack width generated after the failure of the struts was the lowest in bamboo reinforced column (83.64% that of steel) and highest in rattan reinforced struts (169.69% that of steel). Since cracking is an undesirable property in reinforced concrete, it follows that in terms of cracking, bamboo performed more efficiently than steel and rattan cane was the least efficient.

**Table3: Values of the test results**

| Reinforcing Materials | Average ultimate load (KN) | Average crack width (mm) |
|---|---|---|
| Rattan | 94.82 | 2.80 |
| Bamboo | 116.78 | 1.38 |
| Steel | 149.38 | 1.65 |

Figure 3. Failure mode in Rattan cane reinforced Strut

Fig.4 Failure mode in Bamboo Reinforced Strut

Fig.5. Failure mode in Steel Reinforced Strut

## 4. CONCLUSION

From this study, it can be inferred that all the concrete struts reinforced with the three different materials performed efficiently with respect to the design load. The compressive strength of steel reinforced concrete struts was the highest followed by bamboo reinforced concrete struts and that of rattan reinforced concrete struts was the least. In terms of cracking, struts reinforced with bamboo performed more efficiently than those reinforced with steel and those reinforced with rattan were the least efficient.

Bamboo and rattan cane can be used as alternative to steel in light construction at low cost for areas where steel reinforcement may be prohibitive, since both of them performed less efficiently than steel.

Research and design engineers should work on classification of the various bamboo and rattan species, preservative and bond strength enhancing conditions. Characteristic strength for each class should also be established from which unified codes and specifications for design can be provided. Possibility of forming bamboo and rattan cane into stirrups or links should also be investigated so that the reinforcements will be uniform.

## AUTHORS' CONTRIBUTIONS

'Author B' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript, managed the literature searches. 'Author A' Supervise and managed the analyses of the study, read and approved the final manuscript."

## REFERENCES


1. Alade, G.A, Olutoge, F.A and Alade, A.A, "The Durability and Mechanical Strength Properties of Bamboo in Reinforced Concrete". Journal of Applied Science, Engineering and Technology, Vol.4, No.1, pp 35-40. 2004
2. James, M.W. "Sustainable Buildings using Bamboo Construction", http//www.sustainablebuild.co.uk. Accessed, Nov 2011.
3. Glenn, H.E., "Bamboo Reinforcement in Portland concrete", Engineering Experiment Station Clemson, Agricultural College, Clemson, South Carolina, Bulletin No.4. 1950
4. Francis, E.B. and Paul, J.R., "Bamboo Reinforced concrete Construction". U.S. Naval,Civil Engineering Laboratory, Port Hueneme, California. 1966.
5. Wikieducator,"Bamboo and Rattan/rattan/course-2-unit-7-wikieducator.com. 2011 www.wikipedia.com. Accessed Nov. 2011.
6. Nurul A., "Rattan and its Direct Benefits", www.rattan-wicker-globent.com. 2011, Accessed Nov. 2011
7. Akinyele, J.O. and Olutoge, F.A.,"Properties of Rattan Cane Reinforced Concrete Façade Subjected to Axial loading". Journal of Civil Engineering and Architecture, Volume 5, No.11, Pp 1048-1052, 2011
8. Lucas E.B., and B.I.O., Dahunsi. "Bond strength in concrete of canes from three rattans species". Journal of Applied Science, Engineering and Technology.Vol.4.No.1 pg 1-5. 2004
9. Neville A.M., Brook K.M. Concrete technology. Longman group London. 1987.
10. Nindyawati, Sri M.D, and Agoes S. "The Comparison Between Pull-Out Test And Beam Bending Test To The Bond Strength Of Bamboo Reinforcement In Light Weight Concrete" IJERA, Vol.3. No.1. 2013 www.ijera.com Acceesed May 9, 2013

11. Harish.S, Vamsi Krishna .N.V, Ramana Reddy, I.V. " Investigation on properties of Bamboo as Reinforcing material in concrete" IJERA, Vol.2. No.1. 2012 www.ijera.com Acceesed May 9, 2013.
12. Mesquita L, Czarnieski C, Filho A, Willrich F, Junior H, Barbosa N (2006). "Adhesion strength between bamboo and concrete". R Bras Eng Agr Ambient 10: 505-516.
13. Lucas E.B., and B.I.O., Dahunsi, "Characteristics of three western Nigerian rattan species in relation to their utilization as construction material". Journal of Bamboo and Rattan, Vol. 3, No. 1, pp. 45-56(12). 2004.
14. Chung K.F, Yu W.K. "Mechanical properties of structural bamboo for bamboo scaffoldings" Engineering structures, 24, 2002. Pp 429-442. www.elsevier.com Accessed 9 May 2013.
15. Baldaniya B.H, Elizabeth G, Patel S.B. "Test of Bamboo materials for structural purpose" Indian Journal of Research, Vol. 2. Issue 4. 2013.
16. Ghavami K. "Bamboo as reinforcement in structural concrete elements. Cement and Concrete Composite, 27 (6), pp. 637-649.
17. American society for Testing and Measurement. ASTM D3345-74 "Laboratory Evolution of Wood and other Cellulosic Material for Resistance to termite" 1974
18. Daniel, L.S., "Structures", fourth edition, New-Delhi, Asoke K. Ghosh, Prentice-Hall of India Private Limited, pg 299-304. 2001
19. BS 8110-1: British Standards Institution, Structural use of concrete – Code of Practice for design and construction. 1997.
20. Junior H, Mesquita L, Fabro G, Willrich F, Czarnieski C. " Concrete beams reinforced with bamboo Dendrocalamus giganteus. Experimental analysis. R. Bras Eng Agr. Ambient 9: 642-651. 2005