Strength Potentials of Rattan Reinforced Concrete Using Concrete Grade C30/35

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ORIGINAL RESEARCH

Abstract- Steel reinforcements have been widely used in concrete work in order to help improve its tensile resistance against applied loads. But steel is susceptible to corrosion due to water ingress through cracks, increased in cost of purchase and dangers associated with maximizing profit due to greed. Rattan fibre is also known to be a suitable structural material both in compression and tension. Hence, this study examines the extent of application of rattan in concrete. Experimental investigation was carried out on conventional concrete (CC), rattan reinforced concrete cubes (RR, RS and SR), control beams (CTBM) and rattan reinforced concrete beams (RRBM, RSBM and SRBM). Compressive and Flexural strength tests were conducted on the samples at 7,14,21 and 28 days. The results revealed great potential of rattan when included in concrete work. The strength obtained is approximately twice that of conventional concrete. The modulus of Rupture (MoR) for all beam samples also revealed similar trend. The study concludes that rattan can partially replace main steel bars by approximately 50% in beams with suitable applications in light load bearing elements like lintel beams, roof beams, and spandrel.

Keywords- concrete, flexural strength, rattan, reinforcement, steel

1 Introduction

Concrete is the most popular construction material around the world. It is a composite material, consists of cement, coarse fine aggregate and water. The mix ratio depends on the expected design strength when harden. They are very effective in compression and low resistance to tensile force. Thus, steel reinforcement is normally used to take up tensile stresses in reinforced concrete sections. Water is added during mixing and this reacts with the cement which hardens and binds the aggregates into the concrete matrix; the concrete matrix sticks or bonds onto the reinforcing bars (Mahzuz, Ahmed, Uddin, Hossain and Saquib, 2013). One of the structural elements of reinforced concrete structures is a beam. Reinforced concrete beams are designed mainly to carry external loads. These load cause bending moment, shear forces or even torsion through the beam span. The bending forces transferred into the material of the beam due to applied loads is called bending moment. Beams support loads from slabs, other beams, walls, and columns but can also be used to carry loads due to an earthquake or wind or in tension to resist rafter thrust as a tie beam or (usually) compression as a collar beam (Ghavami, 1995). Loads which are carried by a beam are transferred to the earth stratum through adjoining members.

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2 Background of Study

Internally, beams suffer stresses such as compressive, tensile and shear stresses due to applied loads. Typically, under loads, the beam span undergo compression at the top and tension at the bottom. The major problem associated with reinforced concrete structures is corrosion of the steel member (Basu and Roshan, 2004). The problem of corrosion in conventional reinforced concrete structures with steel and high cost of steel materials which can bring about dangers of increasing gain at the expense of reinforced concrete (RC) quality, is a situation that poses a major challenge to the structural reliability and durability of buildings and civil infrastructure. Basu *et al* (2004) provoked researchers to start investigating alternative solutions to overcome corrosion challenges in reinforced concrete structures. Akinyele *et al.* (2018) stated that engineers have resorted to the alternative use of plastics in concrete mix due to unrestrained dumping on land.

Many actions have been taken in this area especially, in the use of non-metallic materials which have proved to be good alternative solutions. Adewuyi *et al* (2015), reported that bamboo as a structural material is fit as rebars for lightweight and non-load bearing structures. In this research, a look at a flexural behaviour of concrete beam reinforced with rattans, partially and fully will be undertaken. Rattan is a member of the bamboo family and its use in Portland Cement Concrete has been studied extensively by Clemson Agricultural College. Rattans are prevalent to the mangrove and high timberland vegetation of Southern Nigeria. In any case, they are more amassed in the Niger Delta Area (i.e., Edo, Delta, Bayelsa and River States) and Cross-River State in the South-East of Nigeria flanking the Republic of Cameroon. Rattan fibre has gained interest in many parts of the world due to their roles in limiting tension and compression (Baldaniya and Elizabeth, 2013).

Lucas and Dahunsi (2004) found that the interfacial bond qualities of rattan-cement were in the range 0.082 - 0.598 N/mm² relying upon the species, solid review and other characteristic conditions. The test after effects of 0.34 - 0.38 N/mm² acquired by Cox and Gyemayer (1969) fall inside the range. Besides, Youssef (1976) gave a range of 0.56 - 0.68 N/mm² for some bamboo species reinforced with cement. Every one of the discoveries fall in the vicinity of 3.94 and 28.86% of steel solid bond quality of 2.07 N/mm² of similar solid review. Neville and Brook (1987). It was found that the moduli of versatility for three types of Rattan were 3396, 516 and 11,106 N/mm² for *C. deerratus, E. macrocarpa and L. secundiflorum* individually (Lucas and Dahunsi 2004).

Akinyele and Olutoge (2011) were able to investigate the properties of rattan cane reinforced façade. They observed that rattan cane reinforced façade and the conventional 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. However, the research showed that the rattan façade had lower crack widths when compared with that of steel which gave it an advantage when exposed to moisture. Akinyele and Aresa (2013) carried out research on the use of bamboo and rattan canes as alternative materials to steel in reinforced struts. Their results revealed failure of struts with average compressive strength of bamboo and reinforced struts being about 78.18% and 63.48% that of steel struts respectively. Rattan reinforced concrete has been suggested herein for singly reinforced concrete beams of grade C30/35, in order to lower the cost of structural concrete for building infrastructures.

3 Materials and Method

3.1 Materials

3.1.1 Rattan

The bamboo family cane, rattan, which is locally available in Nigeria, was collected from Ijebu-Ode, a town, which is located at the south west part of Nigeria, and it is shown in Figure 1. This is the basic material of this work.

Fig. 1: Rattan cane or sticks used as Reinforcement

3.1.2 Steel

The steel used is 10mm diameter high yield reinforcing bars of 460N/mm² tensile strength. The shear link is mild steel R10 bar (250N/mm²) as shown in Figure 2.

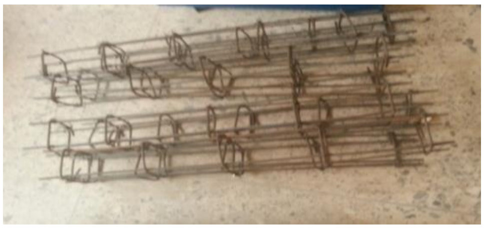

Fig. 2: Steel reinforcement with links in beams

3.1.3 Cement

The cement used was Ordinary Portland Cement, Grade 42.5. It was sourced from a cement store in Ado-Ekiti, a town in south west Nigeria, and it conformed to the requirements of BS EN 197-1 (2011). It is the most common type of Portland cement in general use for construction purposes, and it is one of the ingredients of the concrete employed.

3.1.4 Aggregates

(A) Fine aggregate

Clean and dry river sand available locally was used for casting all the specimens. The sand was kept in close doors at room temperature, to prevent it from trapping any unsuitable moisture that could cause bulking of the aggregates.

(B) Coarse aggregate

Locally available crushed granite stones conforming to the requirements BS 882 (2000) as coarse aggregates of nominal size 20 mm were used as obtained from a quarry site.

3.1.5 Water

The University borehole water was used during this research for the mixing of concretes, washing of used items, curing of the concrete cubes and beams. This water before use was tested to ensure that the water is potable and which conformed to the requirements of BS EN 17075:2018.

3.2 Method

The laboratory experimental method was conducted in phases as follows, namely;

3.2.1 Determination of Physical Properties of Materials

The physical properties of cement, fine and coarse aggregates used were determined in the laboratory and in line with relevant specifications. Tables 1,2 and 3 shows comparison with standard code of practice.

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Table 1. Properties of Ordinary Portland Cement (OPC) used

S/N	Physical test	Experimental values	References: BS 12
1	Fineness (retained on 90µm sieve) (%)	6.90	≤ 10
2	Specific gravity	3.15	-
3	Density (Kg/m^3)	1450	-
4	Vicat Setting time (minutes)	Initial setting time = 92 Final setting time = 266	≥ 45 ≤ 375

Table 2. Physical properties of fine aggregate

S/N	Physical test	Experimental values	Reference: Wasiu and Baba
1	Fineness modulus	2.85	2.3 – 3.0
2	Specific gravity	2.65	2.63 – 2.67
3	Apparent specific gravity	2.68	-
4	Water absorption (%)	0.55	-
5	Coefficient of uniformity (Cu)	2.18	≤ 4
6	Coefficient of curvature (Cc)	1.14	1 – 4

Table 3. Physical properties of coarse aggregate

S/N	Physical test	Experimental values	Reference: Wasiu and Baba
1	Aggregate impact value (AIV) (%)	14.3%	≤ 25%
2	Specific gravity	2.75	2.5 – 3.0
3	Apparent specific gravity	2.69	-
4	Water absorption (%)	0.61	-
5	Coefficient of uniformity (Cu)	1.57	≤ 4
6	Coefficient of curvature (Cc)	1.05	1– 4

Fig. 3: Casting, de-molding and curing of concrete cubes

3.2.2 Determination of Mechanical Properties of Specimens

(A) Determination of compressive strength

A total of 64 cube were cast for different specimen. The specimens included; control cube (CC), rattan reinforced cube (RR), rattan-steel reinforced cube (RS) and steel reinforced cube (SR) with 16 Nos. in each category. The Department of Environment Design (DOE) method was used for the design mix and mix ratio obtained as 1:1.5:3.9 with characteristic strength of 30N/mm^2. The compressive strength test was carried out on cubes with size 150mm x 150mm x 150mm in accordance with BS EN 12390-3 specification. A Compression Testing Machine with capacity of 2000kN was used to determine the strength at the curing age of 7, 14, 21 and 28 respectively. Figure 3 shows the casting and curing of cube samples.

(B) Determination of flexural strength

The beam mould (1000mm x 150mm x 150mm) was cleaned and lubricated. 16 Nos. of beams each for control beam (CC), rattan reinforced beam (RRBM), rattan-steel beam (RSBM) and steel reinforced beam (SRBM) were cast. Figures 4 and 5 show beam details, section and demoulding of beam specimen. Flexural strength test was carried out in accordance with ASTM C 293 (centre-point loading) using a digital 100 kN electronic universal testing machine as shown in Figure 6. The digital display unit records the peak load, deflection and bending moment generated at failure.

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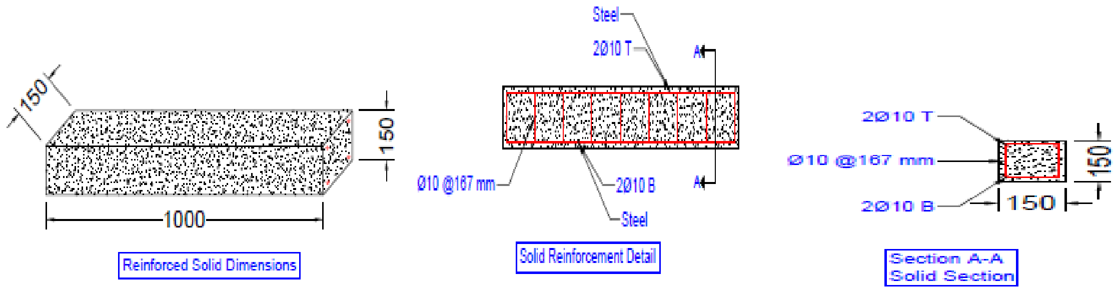

Fig. 4: Control beam, reinforced beam and section

Fig. 5: Casting and demolding of beam specimens

Fig. 6: ASTM C293 test

4 Results and Discussion

4.1 Results

Physical properties of all aggregates used are within specification as presented in Tables 1, 2 and 3 respectively. The compressive strength for the different concrete cube samples generally increases with increase in curing days as shown in Table 4. The highest compressive strength was recorded with steel-reinforced cube (SR) at 28 days curing. The rattan-reinforced (RR) cube has a great significant increase in strength over control concrete (CC) cubes. The compressive strength of steel-reinforced (SR) cube is higher than that of rattan-steel (RS) reinforced cube. There is a significant improvement in strength with the use of rattan as reinforcement in concrete as shown in Figure 7.

Figure 8 shows the relationship between the peak load and curing days. The peak load increases with days of curing for all beam specimen. Rattan-steel reinforced concrete beam shows a positive strength improvement judging from their peak load at 28 days curing. The force-deflection and modulus of rupture (MoR) curves for control beam (CTBM), rattan-reinforced concrete beam (RRBM), rattan-steel beam (RSBM) and steel-reinforced beam (SRBM) increases with increase in curing days. The force-deflection and modulus rupture graphs are shown in Figure 9 and 10 respectively.

Table 4. Compressive strength values by percentage replacement

Days	Specimen/ compressive strength (N/mm^2)			
Rattan content	CC (0%)	RR (100%)	RS (50%)	SR (0%)
7	27.7	34.8	41.6	39.8
14	29.6	37.0	45.3	51.8
21	31.3	40.7	49.9	56.4
28	40.6	44.4	53.6	67.9

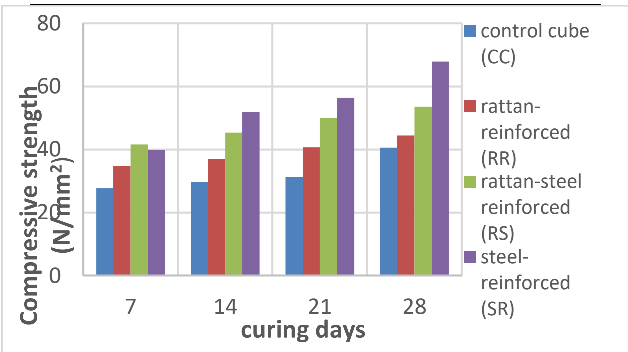

Fig. 7: Compressive strength against curing days

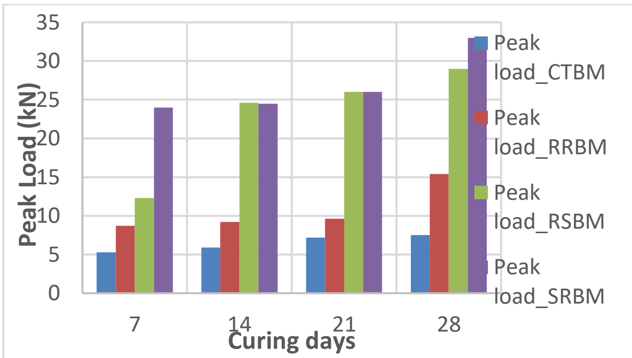

Fig. 8: Relationship of Peak load to curing days

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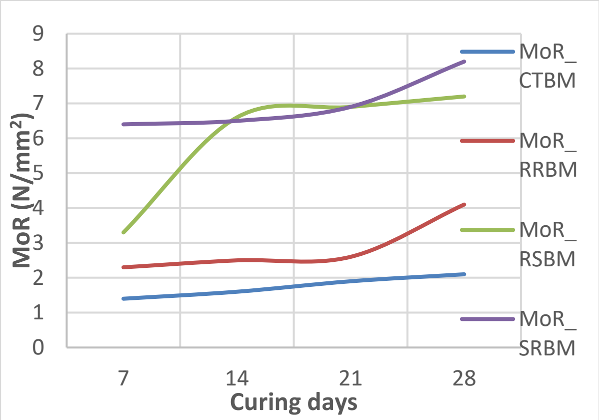

Fig. 9: Relationship of MoR to days of curing

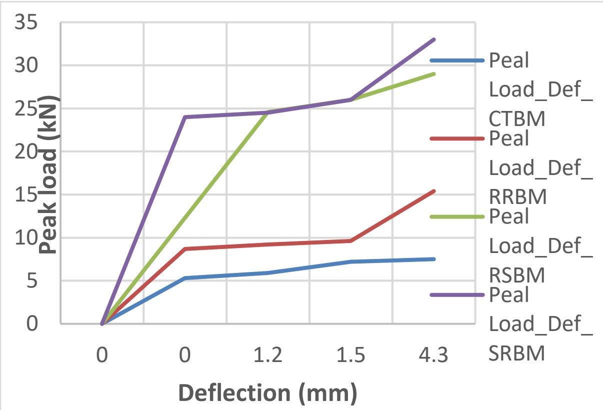

Fig. 10: Relationship of Peak load to deflection

4.2 Discussion

The ordinary Portland cement used have fineness modulus of 6.9% retained on the 90μm sieve. The initial and final setting time are 92 and 266 seconds respectively. These values conform to the requirements of BS12.

The physical properties of the fine aggregate such as fineness modulus, specific gravity, coefficient of uniformity and coefficient of curvature are 2.85, 2.65, 2.18 and 1.14 respectively. For the coarse aggregates, the values are 2.75, 2.69, 1.57 and 1.05 respectively for specific gravity, apparent specific gravity, coefficient of uniformity and coefficient of curvature.

The compressive strength for normal concrete cubes (0% rattan, 0% steel) increases with the days of curing. The strength value is 27.7 N/mm² at 7 days curing and 40.6 N/mm² at 28 days curing. Fully reinforced concrete cube with rattan (100% rattan, 0% steel) attained a strength of 34.8 N/mm² and 44.4 N/mm² at 7 and 28 days of curing. This is a remarkable increase in strength by 9.3% compared normal concrete cubes. On the other hand, concrete cubes reinforced with rattan and steel (50% rattan, 50% steel) revealed a strength range of 41.6-53.6 N/mm² at the end of 7-28 days of curing while concrete cubes fully reinforced with steel bars (0% rattan, 100% steel) gave a maximum strength of 67.9 N/mm² at the 28 days curing. Generally, concrete cubes fully reinforced with steel bars have higher compressive strength values than other concrete cube specimens. Concrete cubes with 50% rattan and 50% steel have strength which is 21% lower than concrete cubes fully reinforced with steel bars.

The modulus of rupture (MoR) of all tested beam specimens namely; control beams (CTBM), rattan reinforced beams (RRBM), rattan-steel reinforced beams (RSBM) and steel reinforced beams (SRBM) increases with increase in the applied load. Their MoR are 2.1, 4.1, 7.2 and 8.2 N/mm² respectively. These results revealed that RRBM have twice the strength capacity of CTBM while SRBM have 3.9 times the strength of CTBM. Similarly, The RSBM have strength of about 12.2% lower than that of the SRBM. This is a positive improvement on strength of beams with 50% rattan and 50% steel as reinforcement. The peak load follows similar trends with experimental failure loads of 7.5, 15.4, 29 and 33kN respectively. The maximum deflection is higher with RSBM specimen at 28days curing compared with other beam specimens.

5 Conclusion and Recommendation

5.1 Conclusion

The following conclusion were drawn from this work:

(a) Judging from the compressive strength of various specimens produced, the strength difference between rattan-reinforced (RR) cube and steel-reinforced (SR) cube is about 34.6% of compressive the strength of SR cube.

(b) For lightweight application, rattan can replace steel up to a maximum of 52.9% by weight of steel bars judging from the difference in the maximum strength attained at 28 days curing.

(c) The Modulus of Rupture (MoR) recorded for RSBM is 13.8% lower than that of SRBM. This is an indication of the positive potential of rattan as replacement for steel (partially or wholly).

(d) Rattan which is a locally available material, will reduce the cost of construction and increase the rate of infrastructural development as its cost per meter is considerably lower than that of steel and it is sustainable.

(e) Rattan plantations should be encouraged to grow and maintained for sustainability in the area of infrastructure provisions or development.

5.2 Recommendation

This research concludes that rattan as an alternative to steel should be applied to lightweight structures such as lintel beams, roof beams and spandrel.

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