Vol. 3 No . 1 - 2, December, 2006

JOURNAL OF CONSTRUCTION AND MATERIALS TECHNOLOGY

Published By The Nigerian Building And Road Research Institute (NBRRI)

Journal of Construction and Materials Technology. Vol. 3, No 1 2. pp. 96-104 December, 2006.(c) 2006.
Published by Nigerian Building and Road Research Institute. ISBN: 1595-6318

SCOPE OF BAMBOO REINFORCEMENT IN CONCRETE BEAMS FOR LOW-COST HOUSING

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Abstract

This paper investigates the extent to which bamboo reinforcement can be used in concrete beams for low-cost housing. Beams of uniform cross sectional area (225x450mm) were designed to BS 8110. They were simply supported over varying effective spans of 3.0, 3.5, 4.0 and 4.5 metres. The results of the laboratory tests showed that the average 28-day characteristic strength of concrete was 25N/mm² while an average tensile strength of 133.50N/mm² was obtained for bamboo splints of size 10x10mm (square section). The design was based on two limit states: ultimate and serviceability (deflection). The beams were subjected to 20%, 40%, 60%, 80% and 100% of the ultimate moment of resistance of the section ($M_u = 0.156bd^2f_{cu}$). The corresponding uniformly distributed load was computed from the well-known relationship between maximum moment and uniformly distributed load (udl) on beam and its effective span. The udl was imposed on each beam at different percentages of ultimate moment of resistance.

All the beams were singly reinforced. The lever arm curve that permits the area of reinforcement to be calculated for singly reinforced beams was used. The corresponding deflection at each level of loading was calculated for each span. The well-established equations of deflection were used with some modifications that reflect the characteristics of the bamboo splints.

The shear stress at each level of loading was calculated and compared with both allowable and ultimate values. The computed deflection for each loading case showed that the deflection of bamboo-reinforced beams increased with increase in value of applied moment and span but reduced with increase in the quantity of bamboo reinforcement in the beams.

The results show that the optimum span for bamboo reinforcement in reinforced concrete beams based on cross-sectional dimensions of 225x450mm is 4000mm at optimum load of 60% M_u. Within this limit, the requirements of ultimate and serviceability limit states were achieved.

1.0 INTRODUCTION

In Nigeria, the problem of low-cost housing cannot be overemphasized. Many attempts have been made both by the government and private sector to alleviate the problem by providing affordable housing scheme to all categories of the population but such efforts have not been too successful.

Usually a housing project initially conceived as low-cost ends up being high cost housing scheme because of high cost of construction materials. Concrete comprises cement, sand and crushed rock aggregate or gravel combined together in a definite proportion with water depending on the required strength. Concrete structures are often subjected to tensile stresses, hence, their elements are often reinforced against the stresses. The reinforcement is provided in the form of steel, synthetic and glass fibres. The use of bamboo as tensile reinforcement for beams has been extensively studied and found to be adequate for some structural applications. However the strength characteristics vary from species to species and locality of growth. It was reported by McClure (1966) that there were 1250 species of bamboo worldwide. In Nigeria, over the years, the unit cost of steel reinforcement increased progressively to the extent that many people now prefer bungalows (where the use of reinforcement is minimal) to buildings with multiple floors. Investigation by Akeju and Falade (1997) revealed that one of the species of bamboo (Bambusa Vulgaris) in Nigeria could be used as substitute for steel in minor structural elements. The choice of bamboo is attributed to its reasonably high tensile strength, good availability, its replenishable nature, its negligible cost and its non-susceptibility to corrosion being a non-metallic reinforcement. The principal problems associated with the use of bamboo as reinforcement are: Volume changes, moisture susceptibility, poor bond and decadency. Bamboo reinforcement absorbs moisture from fresh concrete and swells, causing severe cracking of concrete before any load is applied. Subsequently, as moisture content decreases, the bamboo shrinks causing separation of bamboo from the matrix.

Different percentages of bamboo content have been recommended for use in rectangular beams. Cox and Geymayer (1970) recommended an optimum reinforcement ratio of 3 – 4% while Falade and Akeju (20.. recommended an optimum bamboo content of up to ... The difference in these results may be attributed to ... in the bamboo species that was investigated. The te... strength of seasoned bamboo indicates its suitability as reinforcement; however, its low moduli of elasticity ... and flexure will require an area of bamboo reinforcement for flexural members of about ten times that of corresponding steel reinforced member.

Kankam et al. (1986) performed laboratory tests on simply supported one-way bamboo reinforced concrete slabs subjected to concentrated line loads and also bamboo reinforced concrete two-way slabs with simply supported boundaries subjected to concentrated ... loading. In the one-way slab, Kankam et al. (1986) reported that three different modes of failure were observed: ... of concrete in compression, which is symptomatic of ... reinforcement, (ii) both shear failure as well as failure of concrete in compression and (iii) bamboo failure ... For the two-way slabs, they used the yield line theory. ... (1980) reported that bamboo reinforcement considerably increased the load capacity of the beams at ... up to an optimum value compared to an unreinforced member. The load increased to about 4-5 times ... than that of plain concrete of equal dimension. Mason ... (1977) indicated that the load capacity of bamboo reinforced concrete increased by using bamboo split dowels as diagonal tension reinforcement along the ... of the beams where the vertical shear was generally ... There is therefore the need to define the limit to ... bamboo can be incorporated in concrete to maximize ... use in structural elements.

The objectives of these studies are to: (i) Assess the ... performance of bamboo under imposed uniformly distributed load, and (ii) Determine the extent to ...

bamboo can be safely used as reinforcement in beams using different intensities of loading and spans.

2.0 EXPERIMENTAL PROCEDURE

The particles of the fine aggregate (sharp sand) used for the compressive strength test were those passing sieve with aperture 4.75mm and retained on sieve with aperture 0.063mm, the cement is Ordinary Portland cement whose properties conform to British standard BS12 (1971). The mix proportion of 1:2:4 (cement: sand: granite chips) with water cement ratios of 0.55 was used. 100x100x100mm concrete cubes were cast, cured and tested. The preparation and curing of the specimens were in accordance with BS1881 (1978). The strength of each cube was determined on a 600kN Avery Denison Universal Testing machine using a loading rate of 120KN/min.

2.1 STRUCTURAL DESIGN

Generally, the design of structural elements is based on the ultimate and serviceability limit states.

2.1.1 Ultimate limit state

The ultimate limit state examines the strength of concrete beams.

(i) Bending

24 simply supported beams were designed over varying effective spans of 3.0, 3.5, 4.0 and 4.5 metres. The beams were subjected to 20% 40%, 60%, 80% and 100% of the ultimate moment of resistance of the section. They have uniform cross sectional area of 225mm wide by 450mm deep. Fig 1 shows the loading arrangement on each beam.

Fig 1. Simply supported beam with imposed uniformly distributed load.

A_s – area of longitudinal tension reinforcement

The following assumptions were made during the design of the beams.

(i) The bamboo splints were obtained from matured culms.

(ii) The splints were water proofed with 2 coats of bituminous paint and therefore the durability of the splints was ensured.

(iii) The bamboo splints were dusted with sharp sand for effective bond with concrete matrix.

The moment of resistance of the beam was computed from equation

$M_u = 0.156bd^2f_{cu}$ ……………… (BS 8110, 1985)

where

M_u = Ultimate moment of resistance

b = Width of the beam

d = Effective depth

f_{cu} = characteristic compressive strength of concrete at 28-day curing age

The lever arm factor was evaluated from equation:

$$\frac{M_u}{bd^2f_{cu}} = 0.89(1 - l_a)l_a \quad \text{……………… (1)}$$

Mosely and Bungey (1985)

where:

l_a = lever arm factor

The area of reinforcement was calculated from equation

$$A_{sb} = \frac{M_u}{0.54 f_{sb} l_a d} \quad \text{……………… (2)}$$

Falade and Akeju (2003b).

where:

M_u = Ultimate moment of resistance

A_{sb} = Area of Bamboo splints

F_{sb} = Stress in Bamboo splints

d = Effective depth

The appropriate quantity of bamboo splints whose area equals or higher than the area computed in the equation was selected.

(ii) Shear

The maximum shear force on the beam was computed by applying the equation for determining the value of the shear force on a beam subjected to uniformly distributed load:

$$V = \frac{wL}{2} \quad \text{.......................(3)}$$

where:
V = Shear force
w = uniformly distributed load
L = Effective span

The shear stress for each loading was determined from equation:

$$v = \frac{V}{bd} \quad \text{.......................(4)}$$

where:
v = shear stress, b = width of the beam

d = effective depth of the beam, ($d = D - C - \frac{\phi}{2}$)

D = overall depth, C = Concrete cover, ϕ = Depth of bamboo splint

D = Depth of bamboo splint

2.1.2 Serviceability limit state.

The deflection of each beam due to the applied load was computed using the equation of deflection for uniformly distributed load

$$\delta = \frac{5wL^4}{384EI} \quad \text{.......................(5)}$$

where:

δ = Deflection of beam
w = Intensity of uniformly distribution load
L = Effective span of the beam
E = Modulus of Elasticity ($1.5833 \times 10^4 N/mm^2$)
I = Moment of inertia ($1.7085 \times 10^8 mm^4$)

'w' was obtained from:

$$M_{max} = \frac{wl^2}{8} \quad \text{.......................(6)}$$

$$w = \frac{8M_{max}}{l^2} \quad \text{.......................(6.1)}$$

The values of deflection obtained for each loading was compared with allowable deflection stipulated in BS 8110 with some modifications that took cognisance of the characteristics of bamboo.

$$\delta = \frac{L}{350} \quad \text{.......................(7)}$$

The basic ratios given are for a uniformly distributed lo[ad] and for limiting deflection to $\frac{span}{250}$ (2002a)

In the earlier study by Falade and Akeju (2002a), it [was] reported that within the limit of proportionality the defle[ction] of bamboo reinforced beams was three times that of [the] steel reinforced beams thus the above equation for bamb[oo] reinforced beam was factored by 1.43 to obtain $\frac{L}{1050}$ [and] $\frac{L}{750}$ for the allowable deflection and the basic ratio[s for] limiting deflection respectively. The latter was used to eval[uate] deflection in this study

3.0. RESULTS AND DISCUSSIONS

(i) Preliminary test results

The results of the laboratory tests showed that 28-d[ay] characteristic strength of concrete is $25N/mm^2$ while t[he] average tensile strength of bamboo is $137.50N/mm^2$ fo[r a] splint of 10x10mm cross sectional area.

(ii) Behaviour of beam under uniformly distribut[ed] load

Table 1: Calculated values of intensity of loading

Moment Capacity (%)	Span (m), udl (kN/m)			
	3.00	3.50	4.0	4.50
20	25.6	18.81	14.4	11.38
40	51.2	37.62	28.80	22.76
60	76.8	56.42	43.20	34.14
80	102.40	75.23	57.6	45.52
100	128.00	94.04	72	56.89

Table 1 shows that for a given value of moment capacity, with increase in span the allowable value of udl, which the beam can support decreases. Furthermore, the relationship between the udl and moment capacity of each beam reflects a linear function. At 20% loading, the value of udl, which can be supported by beams of span 3.0m is 124% more than the value of udl which can be supported by 4.5m span. Also, at 100% M_u loading, it was observed that the 3.0m span beam will take udl of 124% more than M_u load of the 4.5m span beam. This is an indication that the load bearing capacity of the beams relative to their respective spans reflects a near perfect linear relationship.

(iii) Shear stress in beams

Figure 2 shows the values of the shear stress for different intensities of loading on beams. The values increased with increase in the intensity of loading. For example, at 20% loading, the value is 0.41N/mm² for 3.0m span. For the same span, the stress values are 0.82, 1.23, 1.64 and 2.06N/mm² for 40%, 60%, 80% and 100% loading respectively. The same trend was observed for the other spans. Shear stress decreased when the span increased under a constant load. For 3.0m span at 40% load the stress is 0.82N/mm². At the same loading arrangement, the stress values are 0.71, 0.61 and 0.55N/mm² for 3.5m, 4.0m and 4.5m span respectively.

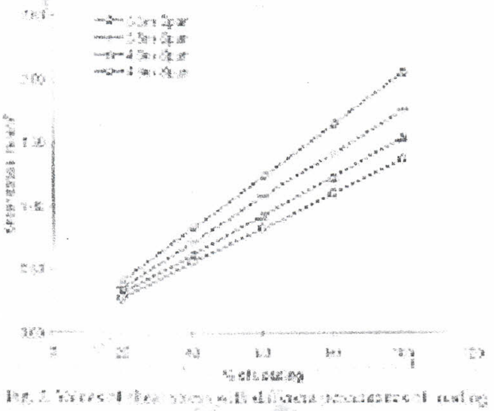

Fig. 2: Values of shear stress with different percentage of loading

Generally, the stress values are lower than the ultimate value of 3.75N/mm² specified for 25N/mm² concrete.

(iv) Deflection of beams

Figure 3 indicates the values of deflection for each load case. The analysis carried out on the twenty four simply supported bamboo reinforced concrete beams that were subjected to uniformly distributed load showed that the beams deflected more under the same intensity of load when the span is increased.

The values of deflection are 1.0, 1.36, 1.77 and 2.24mm for the spans of 3.0, 3.5, 4.0 and 4.50m respectively. For a load of 25kN/m (20% of M_u); whereas at 51.2 KN/m (40% of M_u) the results are 1.90, 2.72, 3.55 and 4.49mm for 3.0, 3.5, 4.0, and 4.5m respectively.

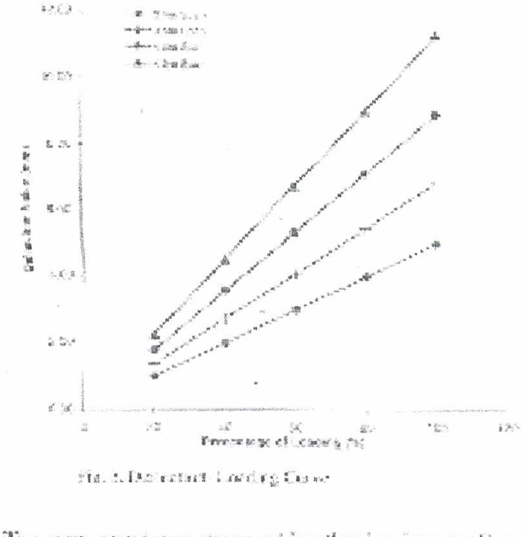

Fig. 3: Deflection - Loading Curve

The same trend was observed in other load cases (Figure 3). This is an indication of the relative stability of the beams from the serviceability point of view. While the deflection-load curve of each beam shows linear relationship, it was observed that with increase in span and notwithstanding, decrease in absolute value of udl, the deflections of the beams become more pronounced. The allowable deflection values are 4.0mm for 3.0m span, 4.6mm for 3.5m while for 4.0 and 4.5m the values are 5.33mm 6.0mm respectively.

Figure 4 presents the variation of deflections with different spans at different levels of loading. The figure shows that there exist a span for beams reinforced with bamboo that satisfies the requirements of both ultimate and serviceability limit state designs.

Figure 4 shows that for 3.0m span the beam could sustain 102.40kN/m (80% of the moment capacity). For 3.5m span, the permissible imposed load is 75.23 kN/m (80% of the moment capacity), while for 4.0m the allowable load is 43.20kN/m (60% of the moment of resistance of the section). In addition to these, for 4.50m the allowable load is 22.50kN/m (about 30% of moment resistance of the section.

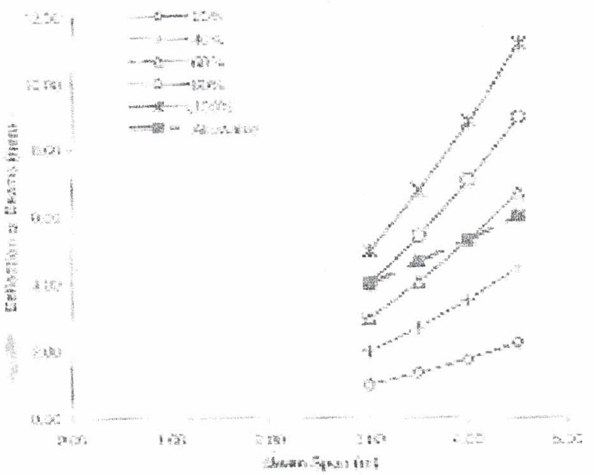

Fig. 4: Variation of Deflection with Span for different percentages of loading

It was observed that the value of deflection for 4.0m span was higher than the value for 3.0m span by 124% at a load level of 20% of moment of resistance (M_r). At 100% of M_r loading, for the 3.0m beam, deflection recorded was 4.98mm while for the 4.5m span beam deflection 11.22mm, an indication of 127% increase in defl[illegible]

4.0 CONCLUSIONS

From this study, the following conclusions are made

1. Bamboo reinforcement can be used in concrete structures where the applied load [illegible] 80% of moment of resistance (M_r) of the [illegible] and span not exceeding 4.0m as both the ult[illegible] and serviceability requirements are satisfied.
2. In bamboo-reinforced beams of same [illegible] sectional areas, the allowable value of [illegible] the beams can support, decreased with incre[illegible] span.
3. In bamboo reinforced beams, value of defl[illegible] increased under the same intensity of load wh[illegible] span is increased.

REFERENCES

Akeju T.A.I and Falade F. (1997), 'Utilization of Bam[illegible] as Reinforcement in Concrete for Low-cost Housing' Proceedings, International Conference on Structural Engineering Mechanics and Computation, Cape Town So[illegible] Africa, 2-4 April 2001, pp1463-1470.

British Standard BS 12 (1971), 'Portland Cement (Ordin[illegible] and Rapid hardening) part 2, British Standard In[illegible]

British Standard BS 1881 (1970), 'Methods of Testing Concrete' part 2, British Standard Institution

British Standard BS 8110 (1985), 'The Structural Us[illegible] Concrete', part 1, Design Material and Workmanship. Br[illegible] Standard Institution London.

Cox F.B. and Geymayer H.G. (1970), 'Bamboo Reinf[illegible]

Concrete' Misc paper C-7 – 2 U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi. 15pp.

Falade F. and Akeju T.A. I. (2002a), 'Structural Design and Economy of Bamboo Reinforced Concrete Beams', Proc. Fifth International Conference on Structural Engineering Analysis and Modelling (SEAM5), Engineers Centre Accra Ghana, March 2002 pp 215–228.

Falade F. and I. Akeju F. (2002b), 'The Behaviour and Analysis of Bamboo Reinforced Concrete Beams under Flexural Loading. Proceedings, 5th International Conference on Structural Engineering Analysis and Modelling (SEAM 5), Engineers' Centre, Accra, Ghana, March 2002, pp 277–288.

Glenn H.E. (1950), 'Bamboo Reinforcement in Portland Cement' Clemson Agricultural College, South Carolina. 171pp.

Kankam J.A., Perry S.H. and Ben George M. (1986), 'Bamboo Reinforced Concrete one-way slab subjected to line loading', Int. cement comp. and lightweight concrete 8, 1–9.

Kankam J.A., Ben George M. and Perry S.H. (1988), Bamboo Reinforced Concrete one-way slab subjected to concentrated loading', Structural Engineer 64B 85–92.

Masani N.J., Dhamani B.C. and Singh B. (1977), 'Studies on Bamboo Concrete Composite Construction, Controller.

McClure F.A. (1966), 'The Bamboos', Harvard University Press, Cambridge, Mass., U.S.A.

Mosley W.H. and Bungey J. H. (1982), 'Reinforced Concrete Design' 2nd Edition, The Macmillan Press Limited London.