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 132 N/mm² was obtained for bamboo splints of size 10x10mm (square section). The design was based on two failure 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 (Mₘₖ = 0.156bd²fₚ). 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% Mₘₖ. 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 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 implemented by the government to meet the needs of the new residents of a town. Concrete comprises cement, sand and coarse aggregate or gravel combined together in a definite proportion with water depending on the required strength. Concrete structures are often subjected to stress strains before their elements are often reinforced against the stresses. The reinforcement is provided in the form of steel, synthetic and glass fibers. The use of bamboo as a fiber 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 McGraw (1966) that there were 1560 species of bamboo worldwide.

In Nigeria, over the years, the use of steel reinforcement increased progressively to the extent that many people now prefer bamboo (which is an alternative material) to buildings with multiple floors. исследования by Alkam and Babalo (1997) revealed that one of the species of bamboo (Bambusa Vulgaris) in Nigeria could be used as substitute for steel in some structural elements. The choice of bamboo is attributed to its reasonably high tensile strength, good availability, its renewable nature, negligible cost and the non-susceptibility to corrosion being a non-metallic reinforcement. The principal problems associated with the use of bamboo as reinforcement are: Volume changes, strength susceptibility, pet food and acidity. 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 cement have been recommended for use in rectangular beams. Cox and Claymayer (1950) recommended an optimum reinforcement ratio of 5 - 45% while Babalo and Asaori (1993) recommended a minimum bamboo content of 50%. The difference in these results may be attributed to the fact that concrete is a composite material with steel reinforcement, while bamboo structure was required to form bamboo reinforcement to form members of beam. According to their results, bamboo reinforcement was found to be 60% stronger than the corresponding steel reinforced member.

Kankam et al. (1988) performed laboratory tests on the behavior of simply supported one-way bamboo reinforced concrete slabs subjected to concentrated line loads and the bamboo reinforced concrete two-way slabs with simply supported boundaries subjected to concentrated line loading. In the one-way slab, Kankam et al. (1988) reported that three different modes of failure were observed, primarily due to the excessive reinforcement, but both shear failure as well as plain concrete in compression and the bamboo failure mode. For the two-way slabs, they used the yield line theory, by (1990) reported that bamboo reinforcement consider increased the load capacity of the beams until it reaches an optimum value compared to an inclusion member. The load increased to about 4.5 times more than that of plain concrete at equal dispersion. Mason et al. (1977) indicated that the load capacity of bamboo reinforced concrete increased by using bamboo piles, due to their diagonal tension reinforcement along the length of the beams where the vertical shear was generally. Therefore, it is essential to define the reinforcement amount to be incorporated in the concrete to maximize use in structural elements.

The objectives of these studies are to assess the performance of bamboo under imposed uniformly distributed load and determine the extent to which

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2.6 EXPERIMENTAL PROCEDURE

The particles of the fine aggregate (sand) used for the compressive strengths were those passing sieve with aperture 0.75mm and retained on sieve with aperture 0.063mm. The mortar is Ordinary Portland cement whose properties conformed to British standard BS1610 (1972). The mix proportion of 1:2:4 (cement: sand: granite chippings) with water cement ratio 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 slump of the mix was determined on an O'Brien Avery-Davis Universal Testing machine using a loading rate of 200 KN/min.

2.1 STRUCTURAL DESIGN

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

2.1.1 Ultimate limit state

The ultimate limit state examines the strength of concrete beams.

1) Bending

24 simply supported beams were designed over varying effective spans of 3.0, 3.3, 4.0 and 4.5 metres. The beams were subjected to 25% 40%, 60%, 80% and 100% of the ultimate moment of resistance of the section. They have uniform cross-sectional area of 225 mm² made by 425 mm deep. Fig. 1 shows the loading arrangement on each beam.

\[ M_u = 0.1250 h^4 \]  
\[ M_{r} = 0.850 h^4 \]

where:
\[ M_u \] = Ultimate moment of resistance
\[ M_r \] = Moment of resistance

\[ h \] = Width of the beam (mm)

\[ d \] = Effective depth

\[ f_{ck} \] = Characteristic compressive strength of concrete at 28-day curing age.

The lever arm factor was evaluated from equation:

\[ f = \frac{M_{r}}{0.850 h^4} \]

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where:
\[ f \] = Lever arm factor

The mixed reinforcement was calculated from equation:

\[ A_{s} = 0.54 f_{ck} d \]

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where:
\[ M_u \] = Ultimate moment of resistance
\[ A_{s} \] = Area of Bamboo splices
\[ f_{ck} \] = Stress in Bamboo splices
\[ d \] = Effective depth

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

\[ (\text{E}: \text{S}) \]

\[ \text{S} \] - area at longitudinal tension reinforcement

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

- The bamboo splices were obtained from bamboo culms.
- The splices were water treated with 2 coats of naphthenic paint and cured for 28 days at the site.
- The studs were gluing with naphthenic and for effective bond, water was used.

The moment of resistance of the beam was computed from equation:

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6) 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:

\[ V = \frac{wL}{2} \] .......................... (14)

where:
\( V \) = shear force,
\( w \) = uniformly distributed load
\( L \) = effective span.

The shear stress for each loading was determined from the equation:

\[ \tau = \frac{V}{bd} \] .......................... (15)

where:
\( \tau \) = shear stress, \( b \) = width of the beam
\( d \) = effective depth of the beam, \( 0.7D-C + \frac{D}{2} \)
\( D \) = overall depth.

(Concrete cover, \( C = \))

Depth of bamboo splint

\( d = \sqrt{\frac{S}{0.65}} \) 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

\[ \delta = \frac{5wL^4}{384EI} \] .......................... (5)

where:
\( \delta \) = Deflection of beam
\( w \) = Intensity of uniformly distributed load
\( L \) = Effective span of the beam
\( E \) = Modulus of Elasticity (1.58 x 10^6 N/m²)
\( I \) = Moment of inertia (1.39 x 10^8 mm^4)

The values of deflection obtained for each loading was compared with allowable deflection stipulated in BS 5410 with some modifications that took cognizance of the characteristics of bamboo.

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The basic ratios given are for a uniformly distributed load and for limiting deflection.

In the earlier study by Bakari and Adeja (2009a), it was reported that within the limit of proportionality the deflection of bamboo-reinforced beams was three times that of steel-reinforced beams thus the above equation for bending moment of beam was factored by 1.75 to obtain (180).

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for the allowable deflection and the basic ratio of limiting deflection respectively. The latter was used in this study.

3.0 RESULT AND DISCUSSIONS

3.1 Preliminary test results

The results of the laboratory tests on bamboo characteristic strength of concrete is 2885 N/mm² while the average tensile strength of bamboo is 141.50 N/mm² for bamboo splint of 10x10mm cross sectional area.

(b) Behaviour of beam under uniformly distributed load

Table 1: Calculated values of intensity of loading:

<table>
<thead>
<tr>
<th>Moment (kNm)</th>
<th>Span (m)</th>
<th>Intensity (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.50</td>
<td>3.50</td>
<td>4.01</td>
</tr>
<tr>
<td>2.0</td>
<td>28.5</td>
<td>18.81</td>
</tr>
<tr>
<td>10</td>
<td>51.2</td>
<td>57.62</td>
</tr>
<tr>
<td>60</td>
<td>78.8</td>
<td>56.42</td>
</tr>
<tr>
<td>50</td>
<td>102.40</td>
<td>72.24</td>
</tr>
<tr>
<td>100</td>
<td>128.00</td>
<td>94.04</td>
</tr>
</tbody>
</table>
Table 1 shows that for a given value of moment capacity, with increase in span the allowable value of load, which the beam can support decreases. Furthermore, the relation between the load and moment capacity of each beam follows a linear function. At 20% loading, the value of load, which can be supported by beams of spans 3.5m, 5.5m and 7.5m is 1.34, 1.1 and 0.89 times the value of load which can be supported by a 3m span. Also, at 100% M<sub>c</sub> loading, it was observed that the 3m span beam will allow 1.39% more than M<sub>c</sub> load at the 4.5m span beam. This is an indication that the load bearing capacity of the beams relative to their respective spans reflect a near perfect linear relationship.

Shear stress in beams

Figure 2 shows the values of the shear stress for different spans of beam at loading in beams. The values increased with increase in the intensity of loading. For example, at 20% loading, the values are 0.41, 0.50, 0.59 and 0.68 N/mm<sup>2</sup> for 3.5m, 5.5m, 7.5m and 5.5m beam respectively. The same trend was observed for the other spans. Where shear stress increased when the span decreased under a constant load. For 5.5m span at 40% load the shear stress is 0.82 N/mm<sup>2</sup>. At the same loading arrangement, the shear stress are 0.70, 0.66 and 0.55 N/mm<sup>2</sup> for 5.5m, 4.5m and 3.5m span respectively.

Generally, the stress values are lower than the ultimate value of 3.75 N/mm<sup>2</sup> specified for 25N/mm<sup>2</sup> concrete.

(iii) Deflection of beams

Figure 3 indicates the values of deflection for each loading case.

The analysis and experimental tests on beams of reinforced concrete beams that were subjected to uniformly distributed load showed that the beam deflection varies under the same intensity of load when the span is increased.

The values of deflection are 1.39, 1.36, 1.37 and 2.24 mm for the span of 3.5m, 5.5m, 7.5m and 4.5m respectively. For a load of 25kN/m (20% of M<sub>c</sub>) whereas at 51.2 kN/m (40% of M<sub>c</sub>) the results are 1.99, 2.72, 3.55 and 4.49 mm for 7.5m, 5.5m, 4.5m and 3.5m span respectively.

![Deflection Graph](image)

The same trend was observed in other loading cases (Figure 4). 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 a linear relationship, it was observed that with increase in span and corresponding increase in absolute value of load, the deflections of the beam...
It was observed that the value of deflection for 4.0m span was higher than the value for 3.0m span by 0.4% at load level of 20% of moment of resistance (M), i.e. 1996 kNm, leading to the 3.0m beam. Deflection recorded was

4.9% while for the 4.0m span beam deflection was 11.25mm, an indication of 123% increase in deflection.

4.0 CONCLUSIONS

From this study, the following conclusions are made:

1. Bamboo reinforcement can be used in concrete structures where the applied load is 60% of moment of resistance. Majority of small structures exceeding 4.0m in both thickness and serviceability requirements are satisfied.

2. In bamboo-reinforced beams of same sectional areas, the allowable value of load that the beam can support, decreases with increase in span.

3. In bamboo-reinforced beams, value of safety increased under the same intensity of load with span increase.

REFERENCES


Cox F.B. and Heynery E.G. (1970), "Bamboo Reinforcement of Concrete".

[Diagram]

[Graph]


