Can Bamboo Replace Steel as Reinforcement in Concrete, for the key Structural Elements in a Low Cost House, Designed for the Urban Poor?

Chandra. Sabnani, Madhuwanti. Latkar and Utpal. Sharma

Abstract: **—**Housing shortage in Urban India due to the rising unafforability makes it logical to consider alternative technologies for their application**.** The intention of the research is, to evolve a design using bamboo as one of the chief structural materials, for a safe and durable house, affordable by the urban poor. It is targeted at those Urban Poor living close to bamboo growing regions. The design thus evolved shall clearly indicate the cost reduction, of the superstructure where steel reinforced concrete, is replaced by bamboo reinforced concrete, in key structural elements. A higher cost reduction ratio could help in creating affordable housing markets in most growing cities in India. Proven technologies from all over the world have been examined closely to arrive at the one that would minimize the consumption of steel, which constitutes a large share of the cost of a dwelling unit. This Paper shall project some breakthrough findings on which the overall research has based itself.

Keywords**—**Bamboo, Concrete, Reinforcement, Steel, Structural Elements

I. INTRODUCTION

RESEARCH, innovations in alternative materials and building technologies, targeted for the low cost mass housing sector are unable to see the light of day. There could be many reasons why these experiments, though successfully conducted in Laboratories, never reach the field for application. Are these solutions user-friendly? Are they practicable, feasible, efficient and actually time, cost and energy efficient? Are they socially acceptable? Do they integrate basic demands of a modern urban set-up in terms of amenities and facilities? Surely there has to be an equally robust implementing strategy through timely precipitation, dissemination and awareness building for a widespread market penetration.

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This research seeks to consistently, link and tie up innovation with policies, which can support bamboo technology as well as the concept of mass bamboo housing for the Urban Poor. It necessitates examining Bamboo in detail, for its appropriateness, as a structural material for construction of a single Dwelling Unit. Since Cost is an essential consideration while designing dwellings for the poor, the focus through the iterative process, narrowed down to the substitution of the high energy guzzling and unaffordable material i.e. Steel Reinforced Concrete with Bamboo Reinforced Concrete for the key structural elements like slab, walls, columns and beams, of a modest dwelling unit. It is also imperative to minimize costs drastically without compromising on safety, durability, dignity and social acceptance. This process could make housing affordable, and the housing market reachable. The long term effect would be the increase in the willingness to pay among a large number of the urban poor, primarily those who reside close to bamboo growing regions, most of whom belong to the informal sector. This sector does not have the means, an identity, a support system and documents of citizenship nor the tenural rights, thereby excluding it from a substantial and important part of the mainstream, nationwide housing activity. Such exclusion denies it access to favorable policies, financial and target-group schemes, for enjoying routine benefits such as; access to housing loans, insurance, legal ownership rights and housing at subsidized rates.

II. THE RESEARCH OBJECTIVES

A. Why Bamboo

Bamboo has historically been used as a building material due to its inherent properties, being regenerating, biodegradable, with high tensile strength, and light weight. It does not require sophisticated fuel/energy guzzling procedures for processing. However, despite its innumerable qualities one does not get to see bamboo houses. The conventional brick, RCC, framed structures have emerged as the prime solution for mass housing, even though they are not affordable by the majority of the sections in society. The irony is that while on one hand there is acute housing shortage, homelessness, poverty, growth and worsening conditions of slums in urban areas, on the other hand, valuable research on alternative cheaper and easy to construct solutions, do not disseminate to the level of practical application in the field. The Research Objective is to investigate why this is happening.

Even as the study evolved it saw major milestone shifts in the Research focus.

Whole Bamboo ⟹ Engineered Bamboo ⟹ Bamboo Reinforced Concrete ⟹ Only for Structural Elements

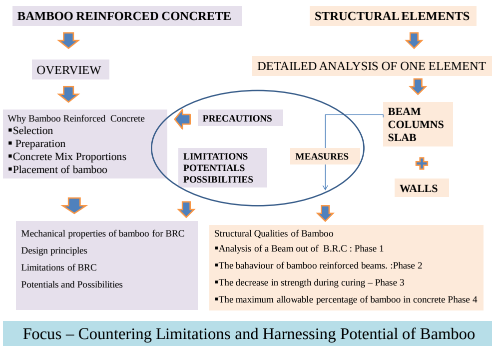

Fig. 1 Research Focus

B. Potential and Possibilities with bamboo

Bamboo is the fastest growing woody plant on the planet belonging to the grass family. Most species produce mature fibre in about three years, much more rapidly than any tree species. Some species grow by up to one metre a day, and the majority of them reach a height of 30 metres or more. Bamboo has exemplary "green" credentials. It is adaptable to most climatic conditions and soil types. It is being used increasingly in land stabilization to check erosion. It can be grown quickly and easily, even on degraded land, and harvested sustainably on three- to five-year rotation. Bamboo is truly a renewable material. Its strength and light-weight makes the buildings resistant to wind and earthquake and can be effectively exploited through careful yet simple design and detailing. Internationally, bamboo has a long history as a building material.

C. Limitations

As a material resource, bamboo has not received the mainstream recognition it deserves. The bulk of bamboo is gathered from the wild or rural environment, but in many areas bamboo resources have dwindled due to overexploitation and poor management. Possibly the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. It is susceptible to attack by insects and fungi. Its service life may be as low as one year when in ground contact. Even when issues of durability and strength are resolved, the question of acceptability remains.

III. How to Counter Limitations – Known Practices

The durability of bamboo can be greatly enhanced by appropriate specification and design and by careful use of safe and environmentally friendly preservatives such as boron. A bamboo building need not look "low-cost" or even necessarily look like bamboo! Imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable.

A. Durability

The density of the fibers in the cross section of a bamboo shell varies along its thickness. The thickness decreases from the base to the top of the bamboo shell. Fibre Distribution is more uniform at the base than at the top or the middle part, since bamboo is subjected to maximum bending stress at the base, owing to the wind and its own weight. A mathematical formula, relating thickness (t), to the position of the inter-node (n), is established for all species. The equation for DG is as follows…..T= -0.0003n3 + 0.025n2 – 0.809n + 16.791 The durability of bamboo depends on the Preservative treatment methods. Its chemical composition should not have any effect on the bamboo fibre, and once injected it should not get washed away by rain or humidity. With the help of this equation the designer can choose the required thickness from the range of bamboo species DG. Drying bamboo is critical for its conservation. Bamboo with less moisture is less prone to mould attacks especially if the moisture content is less than 15%.

B. Water Absorption

The capacity to absorb water was found to be the least in the case of species like DG and VS. *(Dendrocalmus Gigantius and Bambusa Vulgaris Schard.)* The Dimensional variation of untreated bamboo, due to water absorption can lead to micro and macro cracks in cured concrete. The dimensional variation of the transversal sections of these species reached up to 6% after 7 days of immersion in water. The main factors that affect this bonding are; adhesive properties of the cement matrix, the compression friction forces appearing on the surface of the reinforcement bar due to shrinkage of the concrete and the shear resistance of concrete due to surface form and roughness of the reinforcement bar. A reinforcement bar in concrete is prevented from slipping either by adhesion or a bond between them. The dimensional changes of bamboo due to moisture and temperature influence all the three bond characteristics severely. During the casting and curing of concrete, reinforcing bamboo absorbs water and expands. itself. The differential thermal expansion of bamboo w.r.to concrete may also lead to cracking of concrete. The swelling and shrinkage of bamboo in concrete creates a serious limitation in the use of bamboo as a substitute for steel. To improve the bond between bamboo segments and concrete, an effective water-repellent treatment is necessary The Impermeability treatment is affected by a) Adhesive properties of the substance applied to bamboo and concrete b) Its water repellent property c) The topography of the bamboo / concrete interface. Application of a thin layer of epoxy to the bamboo surface with a coating of fine sand is an effective treatment.

Others include asphalt paints, tar based paints and specific bituminous materials have good impermeability properties.

C. Bonding strength

The application of a very fine layer of IGOL-T or Negrolin product on bamboo, wrapped with a wire of 1.5mm diameter, has shown to increase shear strength for the interface. The bamboo shear stress = F / L x S. Here F is the applied Pulling load and S is the perimeter of the bamboo and L = 100 mm, is the length of bonded interface. The bonding between bamboo and concrete has been established through pull out tests. To avoid the effects of non-uniform shear stress distribution in conventional tests, only the middle part (100 mm) of the bar is subjected to shear. This treatment has proved to have improved the shearing bond strength of bamboo / concrete interface by up to 90%. Recently a product called Sikadur 32-Gel, which has been developed to prevent the corrosion of reinforcement bars, has been applied on the surface of reinforcing bamboo segments. The results show that this new product has increased the bonding strength of treated bamboo segments, 5.29 times, compared with that of untreated segments of bamboo and steel,

IV. Structure Possibilities

A. Building Components- Beams

Simply supported Bamboo Reinforced Concrete beams, fabricated with normal, light weight and laterite aggregates of 20 mm maximum size have been tested at PUC-Rio and the Federal University of Paraiba (UFPb). A beam, reinforced with steel bars, served as a reference. The Test results showed that the treatment of bamboo prior to use improved the bamboo- concrete bonding by more than 100%. By adopting r (Bamboo reinforcing ratio) = 3% as the ideal value, the ultimate applied load increased by 400% as compared to concrete beams without reinforcement. Ordinary Portland cement CP-32 and natural-washed river sand was used.

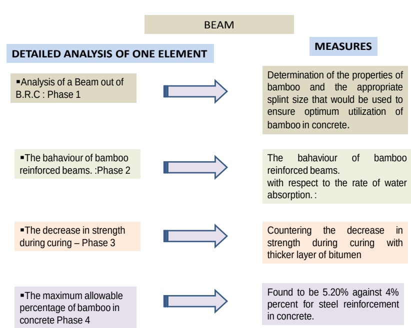

Fig.2 Measures to counter limitations for the design of BRC beams

The normal concrete was 1: 1.4::2.4 by weight with a water cement ratio of 0.45 and the proportion for light weight concrete were 1:3.22:0.78 of cement, fine and course aggregate, with a water cement ratio of 0.55 respectively. The compressive strength was established on 15 diameter and 30 cm high cylinders. The ultimate compressive strength fa and modulus of elasticity in compression, Ec varied between 20 to 40 MPa and 12- 34 Gpa, respectively. The split culms were of 30 mm wide rectangular sections. The smooth surface of the bamboo splints was cleaned and slightly roughened before being coated with a thin layer of the impermeable product with fine sand. The pieces are then wrapped with 1.5 mm wire at 10 mm distance and once more coated with the same product. Immediately after that, fine sand was manually pressed into the surface and splints were allowed to dry for 24 hrs before being fixed inside the formwork. The bamboo reinforcement ratio, r, varied between 0.75% and 5%

B. Possibilities for replacing steel – Columns

Recently tested structural component is a bamboo reinforced column. The main reinforcement of a 300mm diameter column is made entirely of treated 300mm wide DG bamboo segments. The bamboo was treated with a new product, Sikadur 32-Gel, to improve bonding. In this, apart from the bamboo reinforcement, the concrete form is also entirely made of bamboo. Finishing costs of concrete are thus economized. In Brazil the steel reinforcement consists of square sections for a 200x200 mm column. An experiment was conducted to substitute the steel with treated bamboo segments. 3 years old DG was split and cut into rectangular sections of 30mm width and was used as reinforcement of the column. The surface of the column was then cleaned and slightly roughened. The bamboo reinforcement was treated with Sikadur 32-Gel. The form made from plywood of 15 mm thickness stiffened with 20 x 80 mm timber ribs at 400 mm spacing, improved the rigidity against the side deflection. A comparison was made between a steel reinforced column (having the same mix proportions and curing of 28 days, with wet saw dust), and the bamboo reinforced column for the strains, lateral deflection, crack initiation and propagation of concrete. It was observed that when axial; load was incrementally applied, the crack which could be seen with a magnifying glass of x5, was considered to be the first crack. All the columns failed at almost the same load due to crashing of concrete at the extreme end including the conventional steel reinforced concrete. *The main conclusion of this research was that 3% of the bamboo reinforcement treated with Sikadur 32-Gel would be as good as the conventional steel reinforcement for normal concrete recommended by Brazilian Norm*.

V. Analysis of BRC Elements Subjected to Bending

Based on the research results of bamboo studies in Brazilian universities, and other institutes around the world the first norms for bamboo were created, determining the physical and mechanical properties of bamboo. These norms have been evaluated by ICBO and will be included in the ISO norms. The results of the investigations show that bamboo can substitute steel satisfactorily. The structural elements developed and studied could be used in construction, and efforts are being made to investigate and establish the durability of bamboo reinforcement, besides improving the bonding of bamboo reinforcing bars.

VI. Precautions for using BRC- Beams Columns Slabs

A. Selection

The following factors should be considered in the selection of bamboo culms (whole plants) for use as reinforcement in concrete structures: Use only bamboo showing a pronounced brown color. This will ensure that the plant is at least three years old. Select the longest large diameter culms available. Do not use whole culms of green, unseasoned bamboo. Avoid bamboo cut in spring or early summer. These culms are generally weaker due to increased fiber moisture content.

B. Preparation

1. Sizing

Splints (split culms) are generally more desirable than whole culms as reinforcement. Larger culms should be split into splints approximately ¾ inch wide. Whole culms less than ¾ inches in diameter can be used without splitting. Splitting the bamboo can he done by separating the base with a sharp knife and then pulling a dulled blade through the culm. The dull blade will force the stem to split open; this is more desirable than cutting the bamboo since splitting will result in continuous fibers and a nearly straight section TABLE I shows the approximate net area provided by whole culms and by ¾-inch-wide splints, as well as the cross-sectional properties of standard deformed steel bars and wire mesh.

TABLE I

NET AREA PROVIDED BY WHOLE CULMS AND BY ¾-INCH-WIDE SPLINTS

Whole Culms		3/4 Inch Wide Splints	
Diameter (in.)	Area (sq. in.)	Thickness (in.)	Area (sq. in.)
3/8	0.008	1/8	0.094
1/2	0.136	1/4	0.188
5/8	0.239	3/8	0.282
3/4	0.322	1/2	0.375
1	0.548	5/8	0.469
2	1.92	3/4	0.563

2. Seasoning

When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using. The culms must be supported at regular spacing to reduce warping.

3. Bending

Bamboo can be permanently bent if heat, either dry or wet, is applied while applying pressure. This procedure can be used for forming splints into C-shaped stirrups and for putting hooks on reinforcement for additional anchorage**.**

4. Water-proof Coatings

When seasoned bamboo, either split or whole, is used as reinforcement, it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged, especially if more than 4 percent bamboo is used. The type of coating will depend on the materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native latex, coal tar, paint, dilute varnish, and water-glass (sodium silicate) are other suitable coatings. In any case, only a thin coating should be applied; a thick coating will lubricate the surface and weaken the bond with the concrete.

VII. Construction Principles - Beams Columns Slabs

In general, techniques used in conventional reinforced concrete construction need not be changed when bamboo is to be used for reinforcement.

A. Concrete Mix Proportions

The same mix designs can be used as would normally be used with steel reinforced concrete. Concrete slump should be as low as workability will allow. Excess water causes swelling of the bamboo. High early-strength cement is preferred to minimize cracks caused by swelling of bamboo when seasoned bamboo cannot be waterproofed.

B. Placement of bamboo

Bamboo reinforcement should not be placed less than 1½ inches from the face of the concrete surface. When using whole culms, the top and bottom of the stems should be alternated in every row and the nodes or collars, should be staggered. This will ensure a fairly uniform cross section of the bamboo throughout the length of the member, and the wedging effect obtained at the nodes will materially increase the bond between concrete and bamboo. The clear spacing between bamboo rods or splints should not be less than the maximum size aggregate plus ¼ inch. Reinforcement should be evenly spaced and lashed together on short sticks placed at right angles to the main reinforcement. When more than one layer is required, the layers should also be tied together. Ties should preferably be made with wire in important members. For secondary members, ties can be made with vegetation strips. Bamboo must be securely tied down before placing the concrete. It should be fixed at regular intervals of 3 to 4 feet to prevent it from floating up in the concrete during placement and vibration. In flexural members continuous, one-half to two-thirds of the bottom longitudinal reinforcement should be bent up near the supports. This is especially recommended in members continuous over several supports. Additional diagonal tension reinforcement in the form of stirrups must be used near the supports. The vertical stirrups can be made from wire or packing case straps when available; they can also be improvised from split sections of bamboo bent into U-shape, and tied securely to both bottom longitudinal reinforcement and bent-up reinforcement. Spacing of the stirrups should not exceed 6 inches.

C. Anchorage and Splicing of Reinforcements

Dowels in the footings for column and wall reinforcement should be embedded in the concrete to such a depth that the bond between bamboo and concrete will resist the allowable tensile force in the dowel. This embedded depth is approximately 10 times the diameter of whole culms or 25 times the thickness of ¾ inch wide splints.

TABLE II
MECHANICAL PROPERTIES OF BAMBOO

Mechanical Property	Symbol	Value (psi)Value (psi)
Ultimate compressive strength	---	8,000
Allowable compressive stress	s	4,000
Ultimate tensile strength	---	18,000
Allowable tensile stress	s	4,000
Allowable bond stress	u	50
Modulus of elasticity	E	$2.5x10^6$

In many cases the footings will not be this deep; therefore, the dowels will have to be bent into an L-shape. These dowels should be either hooked around the footing reinforcement or tied securely to the reinforcement to insure complete anchorage. The dowels should extend above the footings and be cut so that not more than 30 percent of the splices will occur at the same height. All such splices should be overlapped at least 25 inches and be well tied. Splicing reinforcement in any member should be overlapped at least 25 inches. Splices should never occur in highly stressed areas and in no case should more than 30 percent of the reinforcement be spliced in any one location.

VIII. DESIGN PRINCIPLES- FOR BEAMS COLUMNS AND SLABS

A. Similarity with Steel Reinforced Concrete

Bamboo reinforced concrete design is similar to steel reinforcing design. Bamboo reinforcement can be assumed to have the mechanical properties. When design handbooks are available for steel reinforced concrete, the equations and design procedures can be used to design bamboo reinforced concrete if the above mechanical properties are substituted for the reinforcement. Due to the low modulus of elasticity of bamboo, flexural members will nearly always develop some cracking under normal service loads. If cracking cannot be tolerated, steel reinforced designs or designs based on unreinforced sections are required. Experience has shown that split bamboo performs better than whole culms when used as reinforcing. Better bond develops between bamboo and concrete when the reinforcement is-split in addition to providing more compact reinforcement layers. Large-diameter culms split into ¾-inch-wide splints are recommended. Design principles for the more common structural members are presented in the following sections. Examples of the use of these principles for each member discussed are included.

B. Beams and Girders

Flexural members reinforced with bamboo can be designed with the use of Fig.5

Bamboo longitudinal reinforcement should be between 3 and 4 percent of the concrete cross section. Fig. 6 can be used to convert existing designs for steel reinforced beams to equivalent bamboo reinforced designs. The curve provides the cross-sectional dimensions of a bamboo reinforced beam that will have the same bending moment resistance coefficient as a balanced steel reinforced beam, singly reinforced.

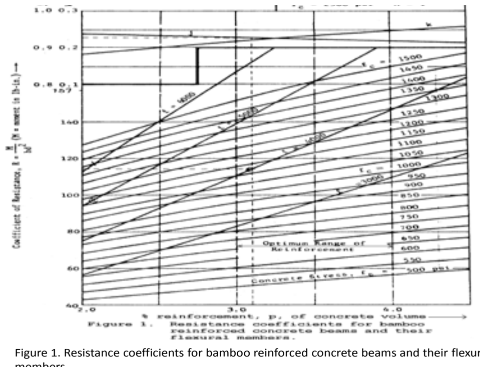

Fig. 5 Design of Flexural Members Reinforced with Bamboo

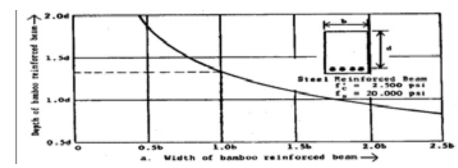

Fig. 6 Bamboo Steel Equivalence for Reinforcement

Economy of concrete increases going to the left on the curve; therefore, deeper, narrower replacement beams are recommended. The number and size of bamboo reinforcing rods (culms or splints) can be selected from Fig.7.

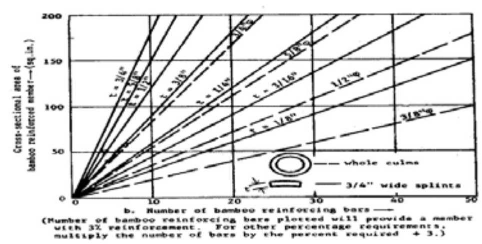

Fig. 7 The number and size of bamboo reinforcing rods

These curves are drawn for 3 percent of the concrete cross section as bamboo reinforcement which is in the optimum range for flexural members. Other reinforcement percentages can be used as noted on the figure. A minimum number of rods should be used to provide adequate spacing. The bamboo stirrup area should always be about 4 times the steel stirrup area.

C. Columns

Bamboo reinforcement in columns serves to resist a compression load equal to that taken by the concrete it displaces; it also will resist shear and tensile stresses. Of the full cross section of concrete, only 80 percent is considered effective in rectangular tied, columns. Allowable concrete stress should not exceed 0.225 f'c where f'c is the ultimate compressive strength of the concrete. Vertical reinforcement should be approximately 4 percent of the column cross section for rectangular columns. When bamboo is used as lateral tie reinforcement, the ties should be spaced not over 16 times the least dimension of the vertical reinforcement nor farther apart than the least dimension of the column. Enough ties should be provided so that every vertical bar is held firmly in its designed position and has lateral support equivalent to that provided by a 90-degree corner of a tie. A common rule for determining the size of a tie is that its cross-sectional area is 2% of the area of all the vertical reinforcement confined by it. The concrete cross-sectional area of bamboo reinforced rectangular columns conservatively should be 2.25 times the concrete area of steel reinforced rectangular columns, indicating a 50-percent increase in face dimensions.

D.Example - Square Bamboo Reinforced Column Design

Determine the cross section and bamboo reinforcement of a column required to carry an axial load of 70,000 lb. Ultimate compression strength of the concrete, f'c, is 2500 psi. 1. For an unreinforced rectangular column the safe axial load, P, is given by:

P = 0.8Ag (0.225 f'c) where Ag is the cross-sectional area of the concrete column.

2. The column should have a cross-sectional area of:

$$A_g = \frac{70{,}000}{0.8\,(0.225)\,(2500)} = 155.5 \text{ sq. in.}$$

3. If a square column is chosen, it will have face dimensions

$b = (155.5)^{1/2} = 12.47$ in., say 12.5 in.

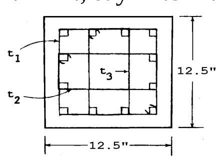

Fig. 8 Bamboo Reinforcement in a Square Column

The amount of vertical reinforcement should be 4 percent of the concrete area and can be obtained from Figure 7. Try 3/4-inch-thick splints. The number required is 8.8 for an area of (12.5) (12.5) = 156 sq in. However, Figure 7 provides only 3-percent reinforcement; thus 8.8 should be multiplied by (4/3) to get 11.7. Thus, 12 splints should be used; these should be spaced evenly around the perimeter with 1-1/2 in. of cover. Lateral ties should be arranged as shown in the following figure to provide each vertical splint with a 90-degree corner (or smaller)

IX. Conclusion

Having understood from extensive research through literature available on the use of bamboo as reinforcement in concrete it is established that bamboo can replace steel for modest housing for the urban poor who live close to bamboo growing regions.

The reason why it is not a favorable proposition arises not due to the material's inherent limitations, but the procedural methods required for its treatment before it is actually used as a structural material, The reason for its non popularity can be attributed to the Precautions that have to be used during the design and construction of the structural elements. The research so far leads to further analysis on how to simplify its treatment and eliminate operational problems in making bamboo one of the key structural materials. The research focus now shifts to examining whether bamboo reinforcement actually works out to be cheaper than steel reinforcement given the labour costs, the wastages, the skills required, and the need for on-the-job-training for its use in the long term.

X. Acknowledgment

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XI. References

[1] Publications of the Brazilian Association of the sciences of Non-Conventional Material Technologies
[2] Professor Funso Alphonsus Falade, Head of Civil & Environmental Engineering, and University of Lagos.
[3] T. A. I. Akeju and F. Falade (2001), 'Utilization of Bamboo as Reinforcement in Concrete for Low-cost Housing', Proceedings, International Conference on Structural Engineering, Mechanics and Computation, Cape Town, South Africa, 2-4 April 2001, pp 1463-1470.
[4] F. Falade and T. A. I. Akeju (1997). 'The Potential of Bamboo as Construction Material' Fourth Int. Congress on Structural Engineering Analysis and Modeling (SEAM 4) – Ghana 9-11 September, 1997, pp. 447-460.
[5] F. Falade and T. A. I. Akeju (2002). 'Structural Design and Economy of Bamboo Reinforced Concrete Beams', Proc. Fifth International Conference on Structural Engineering Analysis and Modeling, (SEAM Engineers' Centre, Accra, Ghana, Marchz
[6] F. Falade and T. A. I. Akeju (2002). 'Structural Design and Economy of Bamboo Reinforced Concrete Beams', Proc. Fifth International Conference on Structural Engineering Analysis and Modelling, (SEAM Engineers' Centre, Accra, Ghana, March, 2002, pp 215-228.

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She is currently a researcher and this is an interim paper, as part of an on-going research, on Bamboo Architecture and Technology, leading to a PhD. The Title of the paper: Can bamboo replace steel as reinforcement in concrete, for the key structural elements in a low cost house, designed for the Urban Poor?

The Title of the Thesis is: Investigating the Prevalence, Relevance and Appropriateness of Bamboo Technology for Housing in India. The Study is currently at the stage of structural analysis. However, being a qualitative research, few of the findings even as the research is in progress, are of great relevance to the Profession.