**Sustainable Design Using Bamboo:**

**Case Study of Bamboo Research and Training Centre**

**At Chandrapur Maharashtra**

|  |
| --- |
| Er. Mohd Mueez Khan, Er. Tobin Nainan and Er.(Dr.) Abhay Gupta |
| (GM-Design) (Design Engineer) (Director) |
| *(Skeleton Consultants Pvt Ltd, NOIDA)* |
| *(A-75, Sector-5, second floor, NOIDA,UP )* |
| {Corresponding author’s email: abhay.gupta@skeleton.in} |

**Abstract - Based on the Sustainable, Bio remediation, eco-friendly, Low cement landscape, and creating local jobs the project, Bamboo Research and Training Centre was awarded to the Shift studio, New Delhi for Architectural planning led by Ar. Sanjay Prakash and designed by Skeleton Consultants Pvt Ltd. NOIDA. The project consists of Academic block and Canteen block. The buildings are located in Chandrapur, Maharashtra. Geometrical configuration of the buildings is of different type like inclined, curve and circular roof. The material used for these structures are Bamboo, RCC, Steel and Rammed earth. The modelling, analysis and design of the structure were done using STAAD Pro software and properties of the bamboo were manually calculated and were input in STAAD. Out of different species of bamboo available, 50mm diameter bamboo was chosen due to the ease of bending as per architectural view and 100 mm diameter bamboo was selected for straight members. The total built-up area is (144076 Sq. ft) 13385 Sq. m.**

**Keywords – Bamboo; Sustainable construction; Eco-friendly; Rammed Earth walls; B.bambos (Balcooa); D.strictus (Stocksii).**

Introduction

With the change in construction techniques, and the promotion of more sustainable construction and the use of ecofriendly materials in the advancement of civil and structural engineering construction techniques, Bamboo is no more seen as a poor man Timber. Nor it is considered as inferior and fit for only temporary construction. In its natural form, bamboo as a construction material is traditionally associated with cultures of South Asia, East Asia and South Pacific. Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three times faster than most of her species of plants. They are renewable and extremely versatile resource with multi-purpose usage.

Some of the latest bamboo constructions all over the world include: Bamboo Research & Training Center – Chandrapur; India Pavilion Expo in Shanghai; Green School, Bali; Kontum Indochine Café, Guadua; Bamboo Car Park, Amsterdam; Sesa Goa Pavallion.

Bamboo has certain advantages and limitations over other construction materials:

*Advantages:*

1. Bamboo is a versatile resource possessing high strength-to-weight ratio and cost ratio and offers considerable ease in working with simpler tools.
2. Resilience (elasticity) coupled with light weight makes bamboo an ideal material for housing in disaster prone/earthquake prone area.
3. The bamboo culm has a tubular structure consisting of nodes and inter-nodes. In the internodes the cells are axially oriented while the nodes provide the transverse interconnections.
4. With good physical and mechanical properties, low shrinkage and good average density, bamboo is well suited to replace wood in several applications
5. Bamboo is highly flexible. During its growth, it can be trained to grow in unconventional shapes. Thus after harvest it can be bent and utilized in archways and other curved areas.
6. In each of its nodes, bamboo has a dividing or transverse wall that maintains strength and allows bending thus preventing rupturing when bent. Because of this fantastic characteristic a bamboo construction offers superior earthquake-resistance.
7. Bamboo is also extremely lightweight thus it requires simpler tools for construction and construction is also faster.
8. Bamboo is non-polluting and does not have crusts or parts that can be considered waste. Instead of adding to the problems of polluting land-fills like conventional building waste, any part of the bamboo that is not used is recycled back into the earth as fertilizer or can be processed as bamboo charcoal.

*Limitations:*

1. Bamboo has a high starch content thus in areas of high humidity it is susceptible to attacks from Insects, fungus, rot etc.
2. Matured bamboo of at least four years of age shall be used. The bamboo shall be used after at least six weeks of felling period. Thus it requires extra cost for storage and maintenance.
3. Since there is little regulation of bamboo thus quality of bamboo varies largely from region to region.
4. Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
5. It is often difficult to find trained skill manpower in the domestic market for construction of engineered bamboo housing.
6. Lack of design guidance and codes.

The buildings located at the Bamboo Research and Training Centre, Chandrapur consists of Academic block have ground and mezzanine floor. The Academic building is equipped with fire safety system, and designed for 25 minute fire rating, which is a major concern in bamboo construction, by installation of sprinkler system. Canteen block is a ground floor building. All buildings are analysed using STAAD-Pro software. The section properties were manually calculated and in the STAAD software for analysis and design.

Material and methodology

*Material Specification for Bamboo:*

Following are the properties of Bamboo adopted from IS 15912:2012. These values are provided for air dry condition of bamboo.

*B.bambos (syn.B.arundinacea)*

Modulus of Elasticity (E) – 8.96 x10^3 N/mm².

Density of Bamboo – 663 kg/m³.

Max. Compressive strength – 53.4 N/mm².

Design life of bamboo structure – 30 years

Modulus of Rupture (E) – 80.1 N/mm².

*D.strictus*

Modulus of Elasticity (E) – 15.00 x10^3 N/mm².

Density of Bamboo – 728 kg/m³.

Max. Compressive strength – 69.1 N/mm².

Design life of bamboo structure – 30 years

Modulus of Rupture (E) – 119.1 N/mm².

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TABLE 1: Calculation of safe working stress | | | | | | |
| IN DRY CONDITION | Ultimate strength  N/mm2 | PERMISSIBLE STRESS  N/mm2 | AFTER APPLYING modification FACTOR (N/mm2) | FYLD USE IN STAAD  ( N/mm2) |  | kN/m2 |
| **B.bambos  (syn.B.arundinacea)** | | | | | | |
| modulus of rapture -(N/mm2) | 80.1 | 20.03 | 30.04 | 1.51x 30.04 = | 45.52 | 45520 |
| max compressive stength (N/mm2) | 53.4 | 15.26 | 22.89 | 1.5 x 22.89 = | 34.34 | 34335 |
| **D.strictus** | | | | | | |
| modulus of rapture -(N/mm2) | 119.1 | 29.775 | 44.67 | 1.51x44.67 = | 67.67 | 67670 |
| max compressive stength (N/mm2) | 69.1 | 19.74 | 29.61 | 1.5 x 29.61 = | 44.415 | 44415 |

The strength factor for deriving safe working stresses of bamboo shall be as under: *Cl. 6.1.1- IS 15912:2012*

Extreme fibre stress in beams : 4

Max compressive stress Parallel to grain/ fibres : 3.5

For change in duration of load other than continuous (long term), the permissible stresses shall be multiplied by the following modification factor *Cl. 6.3- IS 15912: 2012*

For short- term loading

(Permanent + temporary load + wind load) : 1.5

Table 1 gives the calculated material strength values for safe working stress for B.bambos (Balcoa) and D.strictus (Stocksii).

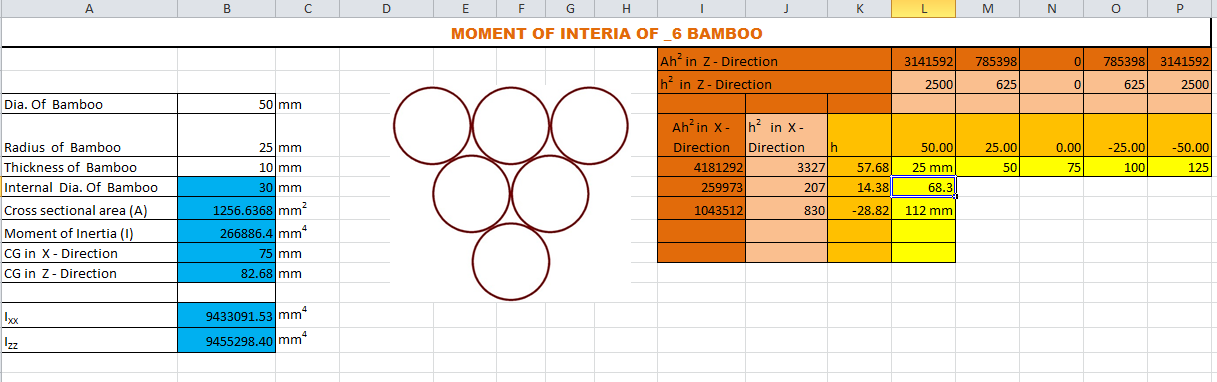
There are certain values adopted from other source and literature for the purpose of designing.

Poission’s Ratio – 0.1

Critical Damping – 0.05

Shear Modulus (G) – 4.072 x103 N/mm².

Crushing & Shearing Strength of Bamboo is considered to be negligible.



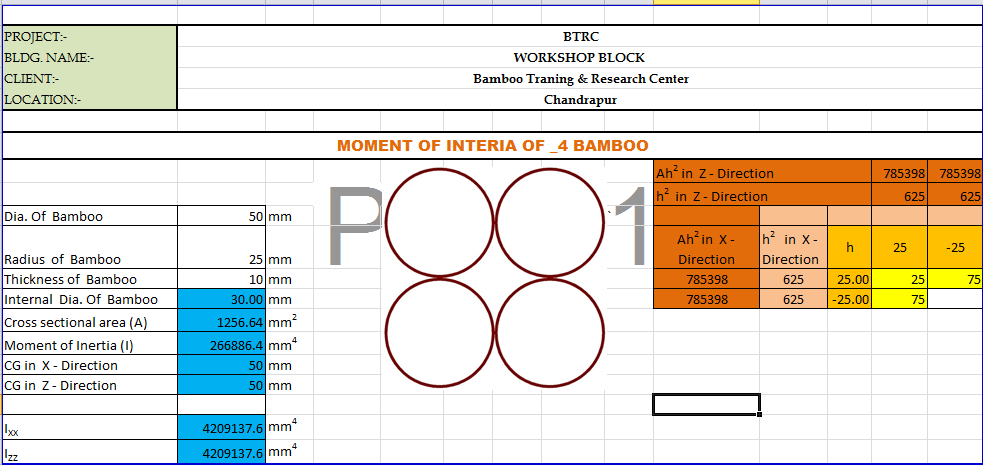
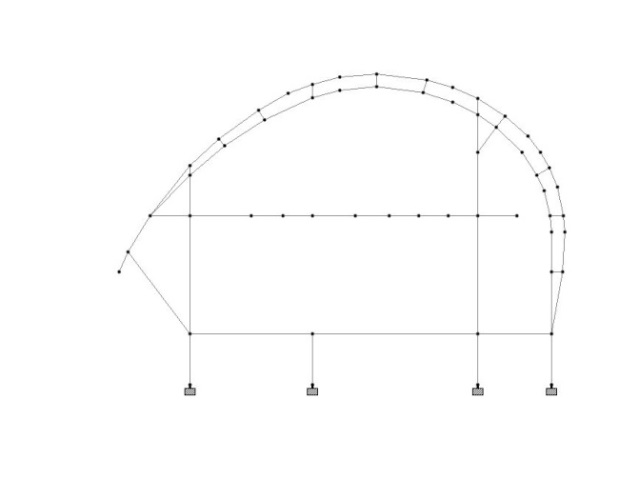


Figure 1 Moment of Inertia Calculation for Bamboo

*Methodology*

The irregular shape of the structure made it challenging to analyse and design. Geometry of the structure was modelled using pre-defined tubular sections and the material properties of bamboo such as modulus of elasticity, density, compressive stress, modulus of rupture, shear modulus and moment of inertia were calculated and replaced in place of existing steel section properties for the analysis and design of the structure using STAAD Pro software. Supports for bamboo supported on pedestal were hinged/pinned and fixed at bottom of pedestal. The building was designed as a RC-Bamboo hybrid structure. Superstructure is designed using Bamboo and rammed earth to give it a unique identity, whereas RCC is used in the substructure. A Bamboo column consists of three or more number of culms of 50mm and 100mm diameter with minimum 10mm thickness acting as an integrated unit. The columns are cast in various shapes i.e. in rectangular, square, circular and irregular shape. Roof of the structure are considered as non-structural member but load of the roof sheeting was considered during the analysis and design.



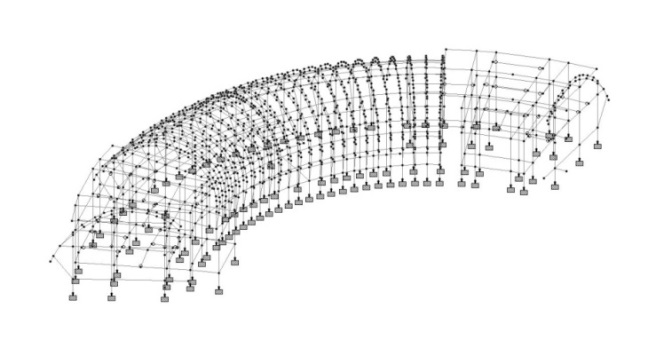


Figure 2 STAAD view

Foundation of these buildings are isolated, combined and strip footing with pedestals. The various key points of design and construction in this project give sharp view of the structure as well as the productivity of design. For mezzanine flooring, 50mm thickness IPS flooring is considered along with, 50mm thickness Bamboo board facia and 50mm thickness cement concrete is also considered in mezzanine flooring. Rammed earth wall of thickness 350mm were used as external walls on ground floor level of the bamboo structures.

STAAD model was prepared and analysed for this configuration with loadings of 40kg/m2, taking into account the weight due to rainy season moisture on roof.



Figure 3 Truss configuration

CHALLENGES

1. Among the different types of species of bamboo available, bamboos with diameter of 100mm were primarily used, due to the difficulty in bending of 100mm diameter bamboo, 50mm diameter was alternatively proposed, maintaining architectural aesthetic.
2. Geometry of the bamboo is not uniform throughout the length and tapered at the end and hence a conservative design approach is considered.
3. Length of bamboo is only 4.5 m which is insufficient from structural point of view and hence splicing is required.
4. Properties of bamboo are not readily available in STAAD pro. An in house spread sheet was developed for calculating the section properties of bunch of bamboo as per requirement and same has been replaced in STAAD for analysis and design purpose.
5. Density, elasticity and strength values of Bamboo vary with species.
6. Connections between bamboos are challenging. In order to have uniform behavior of bunch of bamboo, steel plate was inserted between bamboo and then were bolted together to act as a single unit.
7. During construction the bamboo were crushing and tearing, to prevent this number of bolts was increased and diameter of bolt was reduced.



Figure 4 View as on site

test on bamboo

Both B Bambos balcooa and D stocksii were tested and compared for the following properties in dry condition and green condition:

1. Compressive strength
2. Tensile Strength
3. Modulus of rupture
4. Modulus of elasticity
5. Shear strength

treatment

1. Fire coating
2. Anti-termite
3. Made the bamboo sugar free by treatment with borax

SALIENT FEATURES

1. Inclined, Curve and Circular shape of buildings.
2. Bamboo as a design & construction material
3. Two types of Bamboo are used 50mm and 100mm diameter with 10mm thickness with different properties.
4. Zone 3 , Response Reduction Factor 4 for Bamboo structure and Damping ratio 5%
5. Rammed earth walls



Figure 5 3D rendered view of Academic Block

Acknowledgment

Special thanks to Tata trust, PWD Maharashtra, Ar. Studio Shift New Delhi, M/s Jans Bamboo-NKKC (JV) for taking the initiative in construction of Sustainable and Ecofriendly building model.

References

1. IS15912-2012 Structural Design using Bamboo-Code of Practice
2. IS875-P1-P3- Design code for loads
3. IS883-1994 Design of Structural Timber-Code of Practice
4. IS6874-2008 Method of Tests for Bamboos
5. IS8242-1976 Method of Tests for Split Bamboos
6. IS9096-2006 Preservation of Bamboo for Structural Purpose
7. IS1902-2006 Preservation of Bamboo for Non-Structural Purpose
8. IS13958-1994 Manufacture and requirement of Bamboo mat boards.
9. A Review of Rammed Earth Construction, Maniatidis and Walker, 2003.