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BAMBOO – A GREEN CONSTRUCTION MATERIAL FOR HOUSING TOWARDS SUSTAINABLE ECONOMIC GROWTH

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ABSTRACT

Any building that is designed, constructed and maintained for the health and well being of the occupants while minimizing the negative impact on the environment falls under the category of green building. Other factors like resource-efficient site design and development practices helps to reduce the environmental impacts and improve the energy performance of newly built house. Bamboo is a positive green option since it qualifies under many of the categories for eco-friendly building material viz low energy consumption, sustainability, fast growing, environmental friendly, high strength to weight ratio and reduction to soil erosion. Moreover bamboo based housing system requires lower operating costs and increases thermal comfort. They have enhanced durability and needs less maintenance. Thus bamboo and bamboo composites have immense potential to serve as a green building material in innovative and aesthetic housing. Armed with a wide gamut of advantages, bamboo composites have a key role to play in the growing market in India. The developmental efforts for finding newer composites for existing and novel applications are an area of top priority. Considerable expertise exists in India in the technological institution and a few manufacturing industries, the usage of composites in all these years has been limited to multiple commercial application and potential for export have also not been tapped even in a limited way. In view of the crucial need for developing indigenous capability in composite technology, institutes like IPIRTI has taken a challenge towards developing bamboo and bamboo composite based houses for dwellings and commercial purposes.

Keywords: Bamboo composites, disaster management, treatment, green building.

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1. BACKGROUND–RELEVANCE TO THE CURRENT REQUIREMENTS

India has a rich diversity of bamboo and they belong to family Poaceae, sub family bambusoideae which comprises both lignified and herbaceous bamboos and bamboo allies. In

India there are 115 species which are from Indian sub-continent whereas 63 species are under 13 genera from present day India and among others 115 species under 20 genera. The North Eastern region of India has more or less than 50% of total bamboo species available in India. There is boom in construction and civil engineering activities due to rapid improvements in procurement of building materials. This has posed many challenges due to few unsustainable pollutant and exhaustive materials. It has also significantly created opportunities for innovative and unconventional resources to emerge. Buildings account for nearly 40 % of the total energy consumption globally. Energy efficient technologies could reduce the consumption approximately to 60 %. In India, the building sector accounts for about 35 % of the nation's total energy consumption and is growing at 8% rate each year. Hence there is a need for energy efficient and economical methods of construction using bamboo as one of the green building material towards sustainable growth.

2. SIGNIFICANCE OF BAMBOO HOUSING TECHNOLOGY

Bamboo based housing system has very high potential for mass housing, housing in disaster prone areas and for earthquake resistant structures and other applications like farm houses, resorts, eco- tourism camps etc. The low mass of the bamboo based building is an advantage under earthquake loading as compared to masonry and concrete buildings. The housing technology developed by IPIRTI is different from conventional bamboo construction practices. The method uses round bamboo as column, rafter, purlin and truss as main load bearing element, split bamboo for grid walls plastered with cement. Bamboo Mat Board is used as gusset in combination with mild steel bolts for load bearing joints in roofing structure and Bamboo Mat Corrugated Sheet for roof cladding. Seismic performance of bamboo housing developed by IPIRTI has proven to withstand a simulated earthquake test carried out using shake table test at CPRI, Bangalore. The prototype bamboo house having mass of 2636 Kg and size 2.7m x 2.7m was tested on shaking table. A seismic simulation of 30 seconds was carried out on the bamboo house for a design spectrum of zone IV and zone V classification as per IS 1893 (Part-1) :2016.

3. NECESSITY OF BAMBOO HOUSING IN EARTHQUAKE PRONE AREAS IN INDIA (DISASTER MANAGEMENT)

Despite poverty and unprecedented population growth, natural calamity is another important issue to be dealt with. The North and North eastern part of India falls within seismic Zone-IV which makes it vulnerable to earthquake. Every year vast majorities of population suffer from various kinds of natural disasters viz. flood, landslide, earthquake losing their houses, lives and properties resulting to the breaking of social system and leading to an unstable life. These disasters are very difficult to manage especially for rural areas where limited economic and natural resources further deteriorates affected lives. Such reality has also compelled to think about options to re-settle affected populations in a short period of time to provide them immediate relief and re-start their social life. In view of the above, bamboo and bamboo composites based housing system can be thought of. These type of houses can be constructed quite quickly for immediate and long term rehabilitation for post disaster relief.

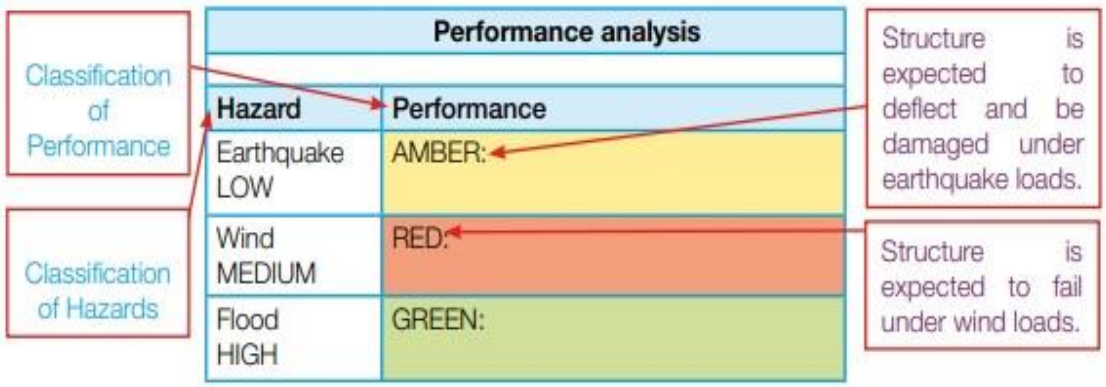

Figure 1 Performance analysis of the bamboo houses with respect to different hazards due to natural disaster

4. AVAILABILITY AND ACCEPTANCE

Bamboo has high compressive strength and low weight which can be the most used building material as substitute for concrete, especially in those locations where it is found in abundance. Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plant in the world and their growth is three times faster than most other plants. They are renewable and extremely versatile resource with multi-purpose usage. Among those, bamboo housing is one of the major areas of application especially in the wake of residential shortages around the globe. A thorough treatment of bamboo is required to protect it against insects and rot before it is put into use. Availability is the measure of how easily accessible the bamboo is in the region and acceptance is the willingness to use the material. An available and accepted resource can minimize transportation costs and also it negate benefits of an alternative material over other local materials.

5. ADVANTAGES OF BAMBOO AS A CONSTRUCTION MATERIAL

The main advantages of Bamboo as a construction material are :

- It has higher tensile strength than steel because its fibers run axially.
- Bamboo culms have a characteristics physical form which gives them high strength weight ratio.
- Bamboo is very elastic. At every joint (node) in the bamboo, there is a cross partition wall on account of which bamboo at their nodes are very hard and do not bend or break easily.
- Bamboo has high load bearing capacity which may be considered as one of the highly endorsed materials for tall structures.
- It is widely preferred in earthquake prone regions due to its elastic features.
- Bamboo can easily be cut into required size and split up into strips using simple tools and ordinary workers.
- Because of lightweight, structures made of bamboo are safe in earthquake prone areas. In case of collapse, house can be re-erected very quickly at very little cost.
- Bamboos are easily displaced or installed making it very easier for transportation and construction.
- Unlike other building materials like cement and asbestos, bamboo poses no danger to health.
- It absorbs carbon dioxide and releases 35% more oxygen into the atmosphere than an equivalent stand of hardwood trees

6. BAMBOO AS A STRUCTURAL MATERIAL

Design Provisions

Structural design has information of equations, detailed guidelines and construction practices. Considering the above, the Bureau of Indian Standards (BIS) has formulated an Indian Standard on the subject namely IS 15912:2012 'Structural design using bamboo - Code of Practice'. The Code has been developed taking into cognizance and advantage of various properties associated with bamboo, for effective structural use of bamboo in the country. The standard covers the general principles involved in the design for structural use of bamboo with regard to mechanical resistance and durability of structures.

Mechanical Properties

Mechanical properties of bamboo may vary depending on the analysis. Properties required for structural design and applications include tension, compression, bending strength, shear strength, modulus of elasticity and rupture. These mechanical properties provide the framework for bamboo's implementation in structural design.

6.1. Tension

Tension forces are experienced in a variety of structural member viz. beams, truss-members, tie beams and others. Bamboo has high tensile strength which creates an advantage over other structural materials. The tensile strength of bamboo to be taken into consideration while designing bamboo structures. Many parameters affect the tensile strength, including node placement, age, and moisture content. The tensile strength at the nodes is approximately 80% of the tensile strength at the internodes.

6.2. Compression

The compressive strength of bamboo allows structural engineers to design columns, strud members, and other compression members in bamboo structures. Bamboo compressive strength increases with age, while nodes and moisture content do not affect compressive strength.

6.3. Bending and Shear

Bamboo bending strength is critical to determine the member size and span length. Bending strength of a bamboo member is determined by the span. Shear governs for short members, and pure bending governs for long members, generally depending on load intensity, strength of the species, and span.

6.4. Modulus of Elasticity

The modulus of elasticity of bamboo indicates bamboo's flexibility and behavior. It helps to predict the culms' change in length based on axial loading in tension or compression, and is also used to determine member deflection. Thus, structural engineers should use determined value from testing in design. Maximum tangential strength is determined by bamboo's tangential modulus of elasticity, which is approximately one-eighth of the longitudinal modulus.

6.5. General Properties and Failures

Properties and failures of bamboo in design include the inherent variation of culms and buckling. Culm variation contributes to the difficulty of designing bamboo structures and obtaining accurate quantitative data. Bamboo is weak because of variation in the cross-section, which can substantially impact the bending and axial stiffness of the Culm. Both properties are

avoidable through quality control and design checks throughout the design and construction process.

Table 1 Important strength properties of some bamboo species

Species	Country	Specific Gravity	Moisture Content (%)	MOR (Kg/cm^2)	MOE (Kg/cm^2)	Crushing Strength (Kg/cm^2)
Bambusa bambos	India	0.651	15.5	674	65,000	483
Bambusa bambos	Puerto Rico	0.580	10.0	918	1,20,000	367
Bambusa bambos	Indonesia	-	15.5	905	-	421
Bambusa blumeana	Philippines	0.503	Green	308	86,400	349
Bambusa nutans	India	0.716	16.0	545	85,000	508
Bambusa tuldoides	South America	0.830	11.0	1,547	1,62,000	-
Bambusa vulgaris	Puerto Rico	0.700	10.0	1,224	1,59,000	584
Bambusa vulgaris	Indonesia	-	17.0	860	-	254
Dendrocalamus asper	Indonesia	-	15.0	1,054	-	322
Dendrocalamus strictus	India	0.743	12.0	1,407	1,66,777	619
Dendrocalamus strictus	Puerto Rico	0.620	10.0	1,709	1,77,000	534
Giganto chloaapus	Indonesia	-	14.8	893	-	383
Giganto chloaatter	Indonesia	-	14.5	1,219	-	350
Giganto chloalevis	Philippines	0.539	Green	228	96,960	396
Giganto chloaverticillata	Indonesia	-	14.9	960	-	365
Guadua augustifolia	Puerto Rico	0.820	10.0	1,448	1,76,000	-

Source : INBAR Technical Report No3

7. BAMBOO CONCRETE COMPOSITE CONSTRUCTION

Due to scarcity and high cost of reinforcement material especially steel, there was an ardent need to look up for some alternate material so that it can be used as reinforcement in concrete. The use of bamboo has always been attracting the attention of Engineers, Architects and Builders in exploring its possibility for use as reinforcement in low cost structures. The ultimate tensile strength of some of the species of bamboo is nearly the same as that of steel at its yield point. On an average, it varies from 1400 to 2 800 kg/cm^2. It was for this high value which attracted the attention of investigators for the use of bamboo as reinforcement.

8. SEASONING & PRESERVATION TREATMENT OF BAMBOO

Quality seasoned and treated bamboo are mandatory requirement for structurally safe, economical and long lasting bamboo structures or for construction of bamboo houses. There is a need for setting up treatment plants near bamboo forests for (a) value addition to bamboo and (b) ensuring continued and sufficient supply of bamboo in bamboo depots. Joint Forest Management (JFM)s can set up these units creating large livelihood opportunities to otherwise economically poor and marginalized bamboo communities. Service life of bamboo must be considered before structural use of bamboo commences. Lack of long-term service life negates any benefit or sustainable aspect to using bamboo as a structural material for commercial purposes. The expected service life of bamboo must be extended longer than twenty-five years in order to encourage its use as a structural material. Without this development, the use of bamboo as a structural material is not feasible for commercial use. A thorough treatment of bamboo is required to protect it against insects and rot before it is put into use. Commonly a mixture of Borax and Boric acid or CCB with pressure impregnation is utilized for this purpose. Another procedure generally employed is to boil bottom portion of bamboo for column foundation with creosote oil.

There is very limited use of bamboo as foundation material because when in contact with moisture laden surface they decay fast. However, this issue can be sorted out to quite an extent

though proper treatment. Moisture has a great influence on treatability of bamboo (Ref Fig 2). The various types of foundations constructed with bamboo are:

a) Bamboo which is in direct contact with ground surface.

b) Bamboo fixed to preformed concrete footings

c) Composite bamboo or concrete columns

d) Bamboo piles

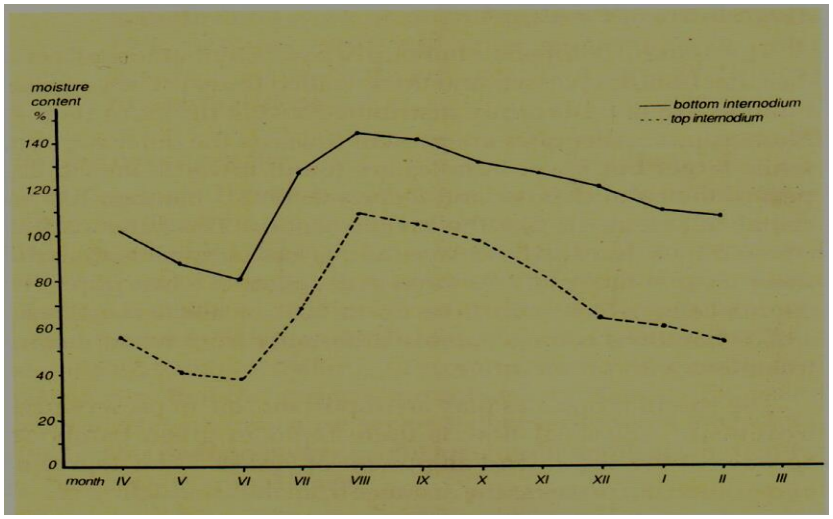

Figure 2 Seasonal Changes of moisture content in bamboo

9. SKILLED MANPOWER DEVELOPMENT

Using bamboo as a structural or building material, there should be capacity building measures at every level of design for (a) Supervision level and (b) Execution level. Institutes like IPIRTI provide vocational education and training programs with emphasis on hands-on experience of construction of energy efficient houses. Skilled manpower for the bamboo construction sector to be tied up with NGOs, grass root level workers, engineers to work in coordination to promote its importance as sustainable building material. There is an ardent need to include bamboo as building material in curriculum for civil engineering & architecture degree courses in India where there can be a source of skilled manpower. Here role of architects is crucial for knowing the properties of bamboo in design of structures.

10. TECHNO–ECONOMIC VIABILITY

The conventional construction technology along with spiraling cost of traditional building material makes building unaffordable and may be a distant dream for an average income salaried person. Whereas, bamboo houses are energy efficient and saves up-to 60% of cost of masonry construction. Moreover, if fly ash is being used as partial replacement of cement, it saves the construction cost and minimize the carbon emission from masonry and concrete in the tune of 30%. Use of treated bamboo and bamboo composite products makes the building much more sustainable and affordable. Tremendous reduction of concrete material consumption and lesser demand of timber will contribute so much to the preservation of environmental resources of lesser quarrying required and utilization of forest product is substantially reduced.

Figure 3 Different types of Bamboo Houses

11. COMMERCIAL OPPORTUNITIES

Bamboo houses built with bamboo as structural members and bamboo composite material can be used for pre fabricated housing systems. This technology will be highly useful particularly for relief agencies for disaster management. Besides the benefits of a quick supply of bamboo houses or shelters in large quantities, the design of a bamboo based modular housing production chain will also directly benefit the bamboo growers, harvesters and employees of the building industries by generating direct and indirect employment and linking them with industries in pre-processing and processing of panel components. This will lead to the development of long term rural-urban market linkages. These types of prefabricated houses can be used highway workers and urban infrastructure. Bamboo housing and related industries can provide direct employment opportunities to the local communities through cultivation, management, pre-possessing and processing stages. In order to promote sustainable use of Bamboo in Construction and related activities, the Bureau of Indian Standards (BIS) has a series of standards on bamboo preservation, testing, products and structural design of buildings using bamboo. It may particularly be noted that the standard on structural use of bamboo has since been revised and updated in National Building Code 2016.

12. CHALLENGES

12.1. Poor quality of bamboo supplied

Aggregator who collect bamboo harvested by cultivators perform a crucial function of grading and sorting bamboo but for their lack of knowledge and expertise the end users still receive unsorted bamboo poles of varying quality,

12.2. Lack of availability of trained labour

Bamboo processing is a technical activity which requires a certain degree of technical proficiency and thus they are insufficient to cope up with the requirements of an industrial process, including efficiency and speed

12.3. Low levels of quality assessment and absence of standardization

The absence of quality standardization in bamboo products, as well as for bamboo poles has created a significant problem for exports in India

12.4. Treatment at site

There is minimal facility to built up treatment process for bamboos at site, the cost for treating the bamboo increases the total expenditure. Though bamboos are available in various parts of India but due to lack of treatment facilities, the end users are being compelled to buy bamboo at high price with added transportation cost.

12.5. Limitation of use

There is very limited use of bamboo as foundation material because when it comes in contact with moisture laden surface they decay fast.

12.6. Shrinkage

Bamboo shrinks at a much higher rate than any type construction material especially when it looses water.

12.7. Jointing

Despite prevalence of various techniques of jointing methods, structural reliability of bamboo is questionable.

13. CONCLUSION

Resilience coupled with light weight of bamboo makes an ideal building material for housing in disaster and earthquake prone areas. It has the capacity to withstand repetitive loadings and absorb more energy and show larger deflections before collapse and thus it is safer under earth tremors. As the design guidelines were inadequate, the application of bamboo as an engineering material was largely based on practical and engineering experience as an engineering material. The usage of natural fiber based composites from bamboo in post disaster management of rehabilitation and re-building would become cost effective to other building materials. The main aim was to promote local industries producing bamboo based pre-fabricated modular houses, which would benefit the environment, local building enterprises and families, particularly poor rural people, slum dwellers and homeless disaster victims who can't afford expensive houses. Moreover bamboo houses developed by institute like IPIRTI consumed 7.1 times less energy than that of a conventional house of similar dimensions. Low cost bamboo houses are cheap and safe alternative to the shelters of plastic, wood and stone that are currently being used by many homeless people.

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