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STUDY ON BAMBOO COMPOSITES AS COMPONENTS OF HOUSING SYSTEM FOR DISASTER PRONE AREAS

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ABSTRACT

Among destructive and terrifying natural calamities**,** earthquake can causes immense damage to the buildings and structures. As the occurrence of the above natural calamities is unpredictable, there is an ardent need to design and construct the buildings and structures to reduce the damages, thus saving precious human lives. Thus for the development of prefabricated construction technique for disaster prone areas, the selection of the construction materials has a great influence on prefabrication technique. From the comparison of various construction materials conventionally used, bamboo-based composite are one kind of prefabrication materials with great utilization potential. A number of wood substitute have been developed through the efforts of institution like IPIRTI and these are gradually being adopted in the housing and building construction. The article discusses in brief the properties and application of bamboo composite in building and construction which can be constructed quite quickly for immediate and long term rehabilitation for post disaster relief. Moreover these types of demand driven projects on pre-fabricated houses with the involvement of stake holders can go a long way in developing innovative bamboo composites houses meeting quality and wider acceptance by the users thus contributing to the growth of knowledge based business in India.

KEYWORDS: Bamboo Composites Prefabricated, Disaster Prone, Rehabilitation

INTRODUCTION

In recent days, prefabrication, as a modern construction technique, where the whole fabrication is done in a factory unit in some other place and the assembly is done in the site by trained manpower which is attracting a ever-increasing attentions worldwide. In some developed countries, such as China, Japan, Canada, USA, and some European countries, prefabrication is becoming more and more popular. Prefabrication is an efficient construction technique and it dramatically reduces the need for on-site work, lessens time and cost during the construction process, and helps to enhance the construction quality and lower the harm to environment. This technique has a wide range of application during the construction process, from the simple prefabricated houses to advanced fully-finished modular buildings.

The region of Kashmir, the western and central Himalayas, North and Middle Bihar, the North-East Indian region and the Rann of Kutch falls within seismic zone-V which makes it vulnerable to earthquakes.

After a natural disaster like earthquake, the houses get destroyed and therefore the inhabitants become homeless. Now it is responsibility of disaster mitigation team to re-build houses for them as quick as possible so that people can take shelter with their families.

Arun K. Bansal [1] stated that panel composites made from bamboo have great potential due to their better strength, dimensional stability and other characteristics compared to panels made from several fast growing plantation

timbers.

Chen Xuhe [2] in his preliminary study concluded that bamboo mbased panels can be used for making wall / roof components for prefabricated based housing system.

G. E. González [3] had stated that Ply bamboo which has already been brought to the market but mostly as furniture item or for floor finishes with a proven research found that it can also be used for structural walls in housing construction, which is a first step to approach this material into more structural applications. The mechanical properties of ply bamboo are in the same level as those ones of wood-based materials like plywood.

G. E. González [4] concluded that ply bamboo wall panels might be able to withstand high seismic loads with qa second floor on top of them but the gap accommodation effect must be avoided in order to comply with serviceability.

THE COMPARISON OF MAINSTREAM CONSTRUCTION MATERIALS

During the past years in construction industry, different kinds of materials have been used viz. clay brick, steel, concrete, wood/wood composite, and chemical synthetic materials (foam and plastic), etc. All of these materials have exhibited their own advantages in some certain stage in the history of construction. In the view to cater natural disaster which is unpredictable in many cases, people are paying more and more attention to policies of construction after the defects of many materials which have emerged and some kinds of materials also have been replaced.

Conventional Materials

Conventional materials such as steel, concrete and clay brick used for construction of houses are not suitable for modules in fabrication construction since their self weight is so high and also the raw materials of steel, concrete, and clay brick are un-renewable resources, and the process of production of these construction materials will consume large amount of energy resources, such as fossil fuel and electricity. At the same time, it also generates lots of CO_2 which intensify the influence of green-house effect and cause the formation of acid rain.

Wood Based Panels

Wood based panels with good mechanical properties are relatively proper materials can be used in the construction industry. In developed countries, the proportion of wood based panels used as construction materials is between 45% and 65%, especially for wall panels. However, this proportion in India is relatively low, only about 20%, which is still far from developed countries. Nowadays, the trend of construction industry is the standardization of design, prefabricated manufacturing, and assembly construction. And the assembly construction can reveal advantage of wood based panels remarkably. It is a important direction for researchers worldwide to further enlarge the sources of raw materials, enhance the production, and develop various construction panels with multifunction, which will make the plant based panels a promising construction materials in the future.

THE POTENTIAL OF BAMBOO BASED PANELS AS CONTRUCTION MATERIALS

In recent scenario, the cost of wood is increasing so much and declining availability of wood resources has made people to use some other alternative material. Similar to wood, bamboo is one of the material which is strong, lightweight, renewable, and with a strong adaptability to the environment. The growth rate of bamboo far exceeds that of most natural growing trees and its yield is high. Its properties are superior to most of the juvenile fast growing wood. When compared to

wood, bamboo has a higher strength/ weight ratio, better abrasive resistance, and a lower swelling rate after absorbing moisture. So, in the view of making eco-friendly material, bamboo is the best choice where on a large scale bamboo-based composite panels with different structures can be designed and functions according to the properties of bamboo.

The reinforcing slivers are the primary load carriers of composite materials with the matrix component transferring the load from sliver to slivers. Selection of optimal thickness of the materials is dependent on the property requirements of the finished part. It has been observed that a weight saving of over 20% is attainable in most of the structures. These are due to lower density of composites and in addition to their inherent properties provide performance benefits over other conventional materials.

The use of composite structures has become an increasingly important factor in engineering design. Composites of high performance fibres' and a range of polymeric matrices have enabled many engineering achievements. Composite products meet stringent requirements such as satisfactory performance even at high temperature, pressure, corrosive environment or high stress.

ADVANTAGES OF BAMBOO COMPOSITE MATERIAL OVER CONVENTIONAL MATERIAL

- Improved shear modulus and impact strength properties
- Composites exhibit excellent corrosion resistant and fire retardancy
- Composites have higher fatigue endurance limit.
- Composite materials are 30-40% lighter than aluminum structures designed to the same functional requirements
- Composites are less noisy while in operation and provide lower vibration transmission than metals
- Composites are more versatile than metals and can be tailored to meet performance needs and complex design requirements.
- Composites enjoy reduced life cycle cost compared to metals.
- Improved appearance with smooth surface and readily incorporable integral decorative melamine are other characteristics of composites.

DEVELOPMENT OF BAMBOO COMPOSITES

The cost effective technologies have been developed for the manufacture of Bamboo mat boards (BMB), Bamboo Mat Corrugated Sheets (BMCS) and Bamboo Mat Ridge Caps required for construction of housing. All the bamboo mat composites are water resistant, resistant to decay, termite/insects and fire. They also posses' excellent physical and mechanical properties. All the bamboo composites are environment friendly, energy efficient and will certainly revolutionize house construction activity, particularly in disaster prone areas through pre-fab houses.

All the bamboo composites were tested for their physical and mechanical properties before using the same in prefabricated houses. The properties of BMB and BMCS are given Table 1 & Table 2

Table 1: Physical and Mechanical Properties of BMB

Sl. No.	Property	Results of Bamboo Mat Board	
		6mm	16mm
1.	Density, Kg/m^3	0.678	0.694
2	Tensile Strength, N/mm^2	9.907	19.86
3	Compressive Strength, N/mm^2	19.60	31.34
4.	Modulus of rupture, N/mm^2	57.98	44.93
5.	Modulus of Elasticity, N/mm^2	3077.0	2336.0
6.	Screw Withdrawal strength, N	2230.0	3120.0
7.	Nail Withdrawal strength, N	830.0	1770.0
8.	Panel Shear Strength, N/mm^2	14.33	12.21
9.	Modulus of Rigidity, N/mm^2	5050.0	4402.0
10.	Flammability, minutes	46.0	8.0
11.	Flame penetration, minutes	6.0	13.0
12.	Rate of burning, minutes	6.0	19.0

Table 2: Physical and Mechanical Properties of BMCS

Sl. No.	Tests	Results
1.	Load Bearing capacity N/mm^2 (a) Dry State (b) Wet State (after 24 hr immersion in water)	 4.26 3.31
2.	Falling hard body impact, visual observation	No sign of rupture, crack or tear
3.	Impermeability, visual observation	No droplets of water
4.	Water Absorption %	12.59
5.	Flame penetration, minutes	13.67
6.	Rate of burning, minutes	24.78
7.	Surface spread of flame, mm^2	3045.67
8.	Thermal Conductivity, k.cal/m^0C	0.1928
9.	Thermal resistance (1/k)	5.19

PROPERTIES OF BAMBOO BASED PANELS

The materials used in the construction should be of sufficient mechanical resistance, to be able to bear the stresses resulting from self-weight, structural loads, snow, wind, and walking-on if they are used as roofs. Bamboo based panels can bear more load and have higher value of MoR than wood and common concrete. Hence, it is more suitable to be used as construction material than wood and concrete. In addition, with the increase of world population and the ever-increasing requirement of space utilization efficiency, the effective utilization of construction space is becoming one of the major concerns of developers. Bamboo based panels, with the characteristic of high strength/ weight ratio, may be more suitable to be used in multi-storey buildings, and it can also enhance the resistance of lateral load, which can decrease the possibility of collapse of the buildings in many natural disasters, like seismic activity or high winds due to hurricanes or tornadoes.

Table 3: Comparison of Properties among Some Construction Materials

Types of Materials		Properties	
		MoR (MPa)	MoE (MPa)
Bamboo Based Panels	6mm	58.0	3077.0
	16mm	45.0	2336.0
Common Timber		13-17	10000
Concrete (M25 Grade)		11.9	28000

Acoustic Properties viz. sound absorption co-efficient and transmission loss was evaluated using B & K acoustic pulse tester and is given in Table 4 and Figure 1 and Table 5 and Figure 2 respectively.

Table 4: Absorption Co-efficient

Frequency	Absorption Coefficient	
	BMB (6mm thick)	Sandwich Sample
0	0	0
125	0.02	0.005
250	0.04	0.0175
500	0.04	0.0163
1000	0.03	0.029
1500	0.06	0.036

Table 5: Thermal Loss

Frequency	Transmission Loss	
	BMB (6mm thick)	Sandwich Sample
0	0	0
125	14.74	10.39
250	6.4	16.86
500	23.8	10.62
1000	3.02	36.76
1500	25.33	13.7

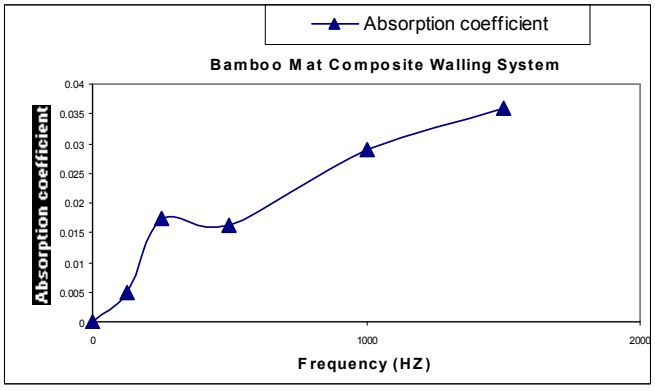


Figure 1: Sound Absorption Co-Efficient

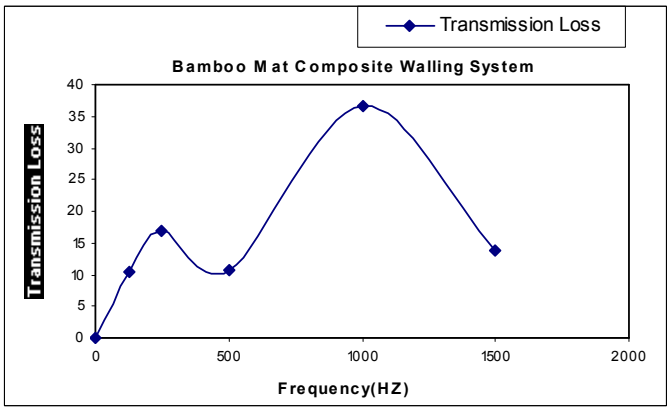
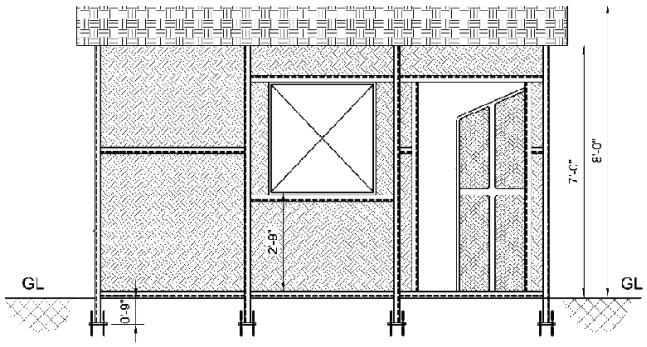


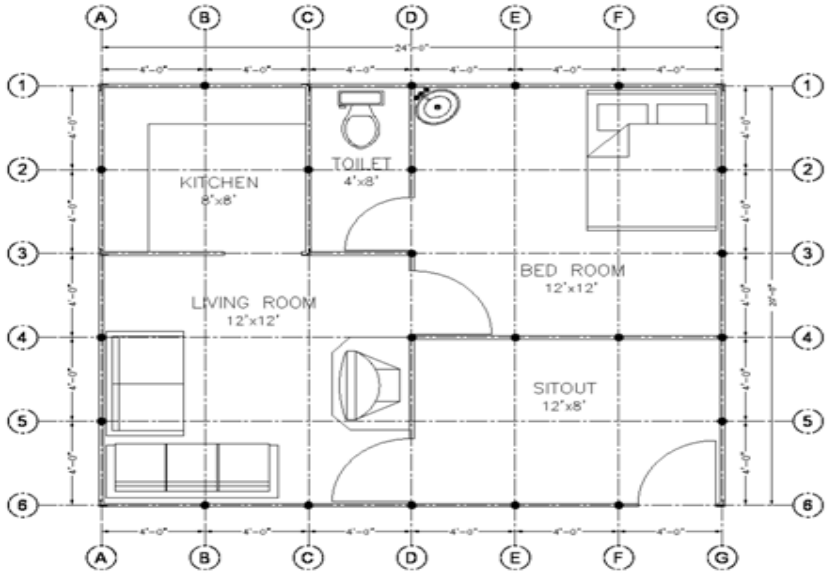
Figure 2: Sound Transmission Loss

PRE-FABRICATED MODULAR HOUSE

Single Walled Modular House



Double Walled Modular House



PROPOSED PLAN

The material of construction to be used in disaster prone areas should be such that they absorb and reduce seismic energy and are able to withstand wind forces. Conventional heavy and brittle building materials such as stones, bricks, mortar, granite etc. do not absorb shock waves but they amplify them, causing more destruction. In contrast, lightweight bamboo mat boards fixed on steel frames with bolts and nuts are more flexible allowing lateral movements of the structures. They also absorb and reduce seismic energy.

CONCLUSIONS

From the point of view of wood substitution, natural fiber composites would enjoy wider acceptance. India enjoys a niche for the manufactures of natural fiber composites (viz. bamboo), as the country is endowed with large varieties of natural fiber. Thus the usage of natural fiber based composites from bamboo in post disaster management of rehabilitation and re-building would become cost competitive to other building materials.

International building and construction technology trends establish the fact that the composites occupy a prominent position as the building material dislodging many conventional houses. Bamboo composites are having attractive proposition considering the embedded energy (energy required to manufacture) especially aluminum, steel and other metals. Other properties such as impact resistance, corrosion resistance, thermal resistance and acoustic insulation all contribute favorably to bamboo composites claiming its position as an ideal building material.

REFERENCES

1. Arun K. Bansal and S.S Zoolagud, “Bamboo composites: material of Future” J. bamboo and Rattan, Vol 1. No 2. pp 119-130 (2002)
2. Chen X., Wang Z., Maxim L., Chang X. and Gao L, “Preliminary study on the manufacture of bamboo panel components for prefabricated house”, Research Institute of Wood Industry, Chinese Academy of Forestry, INBAR. P 1-5
3. G.E. Gonzalez, “Ply bamboo wall panels for housing”, University of Technology, Eindhoven, The Netherlands, 2003, pp 210
4. G.E. Gonzalez, “lateral resistances of ply bamboo wall panels”, Heron, Vol 48, No 2. (2003).
5. Mikołaj M. and Czesław M., “The Wood-Framed With Sheathing Buildings – Alternative For Housing Construction”, Journal Of Civil Engineering And Management, 2006, Vol XII, No 2, 143–151.
6. Eric D., William G., Habib J. and Douglas J. G., “Performance of Wood Shear Walls Sheathed with FRP-Reinforced OSB Panels”, J. Struct. Engrg, 2006, Volume 132, Issue 1, pp. 153-163.
7. Schwab, Sara C., Bender, Donald A., Carradine, David M., Frank E., “Tensile strength of oriented strand board as affected by specimen width”, Forest Product Journal, 2007.
8. G.E. Gonzalez, “Structural Behavior of ply bamboo –wood wall panels”, University of Technology, Eindhoven. The Netherlands, 2002, Report C0-02-22 pp 96 .
9. “Pre-feasibility profile for Bamboo Mat Corrugated sheet”, BMTPC Report, Aug-2002

10. IS: 1734-1983, “Methods of test for plywood”, Bureau of Indian Standards, New Delhi.
11. IS: 5509-2000: “Fire retardant plywood – Specification”, Bureau of Indian Standards, New Delhi
12. IS: 15476-2004: “Bamboo Mat Sheets – Specifications”, Bureau of Indian Standards, New Delhi
13. IS: 3346-1980: “Method for the determination of thermal conductivity of thermal insulation materials (Two slab, Guarded hot plate method)”, Bureau of Indian Standards, New Delhi
14. IS: 13958- 1994: “Specification for bamboo mat board for general purposes”, Bureau of Indian Standards, New Delhi
15. ASTM Standard: C 177 -1963, “Test for thermal conductivity of materials by means of guarded hot plate”.