

Bamboo Wall Structure: A Step towards Sustainable Construction Paper

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Abstract— Bamboo is a very old traditional natural building material which can be used in various engineering applications. Especially in wall, use of bamboo in different pattern is widely diversified across the globe. In wall, use of bamboo along with mud has been used since ancient times, but it is ignored due to its regular maintenance and regarded as poor man's tag. Bamboo concrete panel (Ekra wall) is a significant innovation for sustainable construction compared to conventional masonry and RCC wall. Different types of bamboo walls used and its improvement with age are discussed in this paper. This paper also illustrates the use and characteristics of different types of bamboo walls and a 40 years old bamboo concrete wall house in Guwahati, Assam. The properties of wall panels of this house were studied. This demonstrates that bamboo can survive without problem for a long time as long as it is properly plastered. Bamboo concrete wall is beneficial for use as non-load bearing wall compared to other types of modern wall system. It is eco-friendly and respond well to earthquakes. Bamcrete wall can therefore ensures a sustainable construction.

Keywords— Bamcrete wall panel, Chitra wall, Cracks, Ekra wall, Spalling.

I. Introduction

In the era of industrialization, construction is the key point in developing countries after agriculture. Making construction sustainable seems to be difficult, as modern construction is using mostly the non-renewable and non-green materials like sand, cement, steel, aggregate etc. leading to heavy production of greenhouse gases with great environmental impact. Research are going on in utilization of industrial wastes products. There is still no education or research concerning the traditional and locally available materials. Steps are needed to implement and perform research on eco-friendly materials. [1]. In this context use of 'Bamboo' is an good natural engineering material can replace bricks, concrete, steel and wood depending on the application [2]. Very less effort is being done in utilization of bamboo as a part of structural element. Use of bamboo in wall is a good measure to eradicate the enormous use of non-green masonry bricks. The objective of this paper to focus on utilization of bamboo in wall structure.

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II. Bamboo Distribution and Its Usage

Bamboo is considered as giant grass taxonomically and belongs to the family Graminea [3]. It is abundantly available in equatorial region or in places where heavy rainfall occurs (Fig. 1). According to the Indian Census data of 2012, around 22 million households or 9% of the population live in grass, thatch or bamboo walled houses [4].

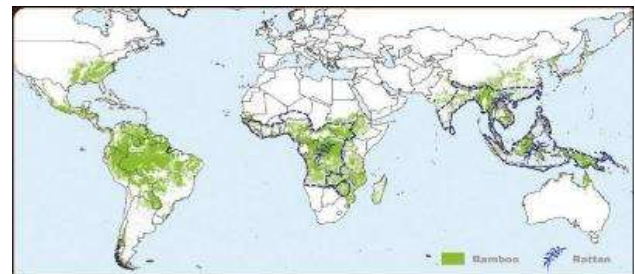


Figure 1. Bamboo and Rattan Distribution (Jiang 2007)

III. Bamboo Walls

Bamboo is pliable, hollow and lightweight which makes it relatively easy to strip into long horizontal pieces. It can made into strips using sharp knife like machete or khurkuri (local name). In thin wall round bamboo, crushing strength under transverse load is pretty weak. When transverse compressive load is applied the geometry of the material is destroyed, but the actual failure does not happen [5]. In other words, the strips do not easily fail. Strips can withstand considerable tensile and compressive load across the grain. Therefore strips have been used for their strength for since ancient times. The modern laminated bamboo sheets are made by gluing many



Figure 2. Exposed Bamboo wall design variety



Figure 3. Use of Chitra Wall

strips of bamboo. Woven wall did not take vertical compressive load, but they are expensive both in terms of cost and labour. In India, north eastern states like Arunachal and Assam, 64.4 and 66.4 percent of the population live in bamboo walled houses. In these regions bamboo are appropriated either into walls, or sometimes into columns and beams. The bamboo walls are sometimes left exposed or plastered with mud, lime or cement [4]. When bamboo are cut into tiny strips and woven, it enhances its tensile strength. Not all bamboo have thick skin, and do not provide good stiffness or shear strength and thus they are not very widely used for columns and beams, which can be used for walls making in a better way without any confusion [4]. Different type of weaving techniques are adopted for the making of bamboo wall and some works are illustrated in Fig. 2 done in IIT, Delhi. Some of the important bamboo walls are cited based on different weaving pattern and construction practices, both with and without plaster on wall based on locality like; Lepcha houses, Ekra walls system, Barahaque wall system (flattened bamboo), Tanti Walls of Nepal, House of Rene, Chitra wall etc. Out of all Ekra wall system has got better response with due variation with time. A field visit and studied were conducted to study the prevailed different types of bamboo wall panels. It was found that the mostly prevailed Chitra pattern of bamboo walls are mostly used unplaster and some time it is plastered (Fig. 3).

IV. Ekra Wall and its variation

Ekra wall houses are good example of how bamboo wood composite can become mainstream material. The walls mostly constructed without mud plaster comes under chitra pattern. They are economical, well ventilated, and quickly constructed. But these wall are not well durable because of weathering and termite issue. Even if it plaster with mortar, the concrete begins to spall and gradually detached from walls (Fig. 3). This is due to there is no interconnection of mortars from both side of walls together with bamboo. On contrary in case of Ekra wall bamboo slits are covered well inside the plaster and become more durable. Ekra is such system where long strips

are woven into walls as in-fills for timber framed house. The infill were plastered with mud on either side and the outside was washed with lime. The reason being, when it is plastered



(a) Wall in Construction



(b) Panel plastered with mud and lime

Figure 4. Traditional Ekra wall

with mud, the moisture content in bamboo/timber is reduced from 15% to 10% which makes it difficult for the termites to survive [6]. After Assam earthquake, the system was modified in order to meet the contemporary need, developed a new ekra system, where the walls were plastered with cement instead of mud and became very popular. So technically it can be regarded as bamboo concrete wall or 'bamcrete' wall. According to a report on earthquake of 2011 [7] explained the good response of bamboo walling compared to stone masonry load-bearing walls. It was derived from the tradition and can be integrated well in modern system. But due to scarcity of wood and government law to 'preserve wood' it unfortunately is seeing a decline.

This system of wall can consume large amount of bamboo and can replace bricks. The mostly used burnt clay bricks is well known for its negative factors like land degradation [8] by using top fertile soil and uses high amount of energy in manufacturing with heavy production of greenhouse gases.

v. A Field visit to Bamboo-concrete house

The modern concrete, gave an illusion of durability, but it ignores many aspects like thermal comfort. Many people who live in concrete house, invariable agree that the thermal comfort in bamboo houses are much better. In order to facilitate the use of revamped Ekra wall in present day construction practices, a field visit was conducted at Guwahati, India. The constructional detailing and properties of bamboo concrete wall of 40 years old house (Fig. 5) built in the year 1973 were studied.



(a) Front View of the House



(b) Internal View of the Bamcrete Walls



(c) Bamboo strips in vertical direction



(d) Extended strips in horizontal direction



(e) Panels with thin skinned strip



(f) Width of Bamcrete Panel

Figure 5. Constructional detailing of 40 years old bamboo-concrete house

A. Construction Detailing

The partition posts and frames used were of timber, which were the main load bearing members and the house had the brick work below the window level, shown in Fig. 5a. Different dimension of panels were used as shown in Fig. 5b. The walls above the window sill level were of bamboo concrete composite or bamcrete panels. Bamcrete wall panels in this house were placed both as an external walls and separation walls. They are not expected to carry any load. Since they are thin, they are susceptible to buckling. Hence they have to build in segments. The walls are wattle built with strips of bamboo, placed in grooves of wooden frames (Fig. 5c and Fig. 5d). Wooden frames cannot be a solution to modern buildings as wood cutting itself might not be ethical. Hence, detailing of joints is an issue which will be addressed in future. In vertical direction the strips of the panel were inserted inside the grooves of wooden frames and in horizontal direction the partition strips were extended maintaining a gap of 0.22-0.27 m depending on size of panel to place the panel rigidly in its position. The width of the bamcrete panels were 0.052-0.054m (Fig. 5e). The bamboo used in bamcrete wall panels were untreated thin skinned stripped cut transversely (Fig. 5f). This house has experienced various levels of small and medium earthquakes as they are very common in this area. Such

Such earthquakes regularly induce cracks in RCC buildings. Its lighter weight compared to conventional wall panels would also decrease the load on the structure. These structures have withstood several earthquakes because of the walls are light in weight and more ductile because of bamboo. It shows bamcrete walls are highly resistant to earthquake. Surprisingly, these panels have not apparently undergone any damage and not even shown any cracks or required any significant repair works in its life span except normal white washing. But few small cracks were observed at certain places only on the bricks wall. The cracks are only restricted to bricks wall only. Not a single crack was marked on any of the bamboo wall panel structure of the house shown in Fig. 6.

B. Fire Resistance and Durability Issues of The house

The fire and termite resistance of bamboo is always a question. The house had also stood 40 years even the kitchen had constructed in similar material. Neither fire nor termite had ever posed any problem as the bamboo is completely covered concrete providing an excellent protection against both the problems. There was a huge colony of 20 thatched

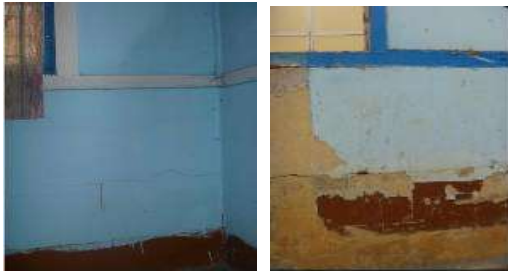


Figure 6. Cracks at different interior and exterior side of the brick wall

house behind this house. It was barely 10 m away with a 2 m high brick boundary wall between them. In 1992, a devastating fire burnt down the full colony within 2 hours' time. This house only had black marks, shattered windows. To protect the house, a group of three to 4 people kept pouring water on this house. The heat was still unbearable. Surprisingly nothing absolutely happened to the walls of this house.

VI. Conclusion

- The strips were in good condition even after 40 years of construction without suffering from any termite attack, even though non-treated bamboo is used in construction.
- New framing technique is needed to promote the utilization of bamcrete wall panel. Use of timber frame is not a good option as to government law for the preservation of wood.
- The Ekra walls not only acts as bracing for two columns but provides ductility by absorbing the frequent seismic vibrations. This shows the flexibility of bamcrete panel, which sustain nicely in dynamic loading condition.
- The bamboo concrete wall panel can be integrated well in modern system with proper scientific validation on grading of partition wall.
- Plaster not only creates the thermal barrier but also protects the bamboo from termite or beetle attack.
- The use of bamboo-concrete wall panel in modern construction is a good step to gradually mitigate the extensive use of non-green bricks in wall structure.
- Use of bamcrete wall in modern day concrete framed structure not only make construction sustainable but also it can boost the local economy.

References

- [1] K. Ghavami, "Bamboo: Low Cost and Energy Saving Construction Materials", Modern Bamboo Structures, ICBS, Changsha, China, pp. 5-21, Oct 2007.
- [2] R. Tjerk, 'The Role of Bamboo in Green Building Design', <http://www.academia.edu/3295582/The_Role_of_Bamboo_in_Green_Building_Design> [accessed 20 May 2014].
- [3] <http://bambus.rwth-aachen.de/eng/PDF-Files/Bamboo%20as%20a%20building%20material.pdf> [accessed 20 May 2014].
- [4] S. Gupta, C. Korde, P. Sudhakar, R. Babu, N. Adhikary, "Study of Structure Using Bamboo" in: Bamboo as a Green Engineering Material in Rural Housing and Agricultural Structures for Sustainable Economic Growth, NAIP (Component 4), pp. 22-60.
- [5] J. J. A. Jansen, "Designing and Building with Bamboo", International Network for Bamboo and Rattan, Technical University of Eindhoven, The Netherlands, pp. 63-77, 2000.
- [6] G. Minke, "Building with Earth Design and Technology of a Sustainable Architecture", Birkhauser, Berlin, pp.80-82, 2006.
- [7] S. Tambe, M. L. Arrawatia, and A. K. Ganeriwala, "Managing Rural Development in the Mountain State of Sikkim, India", International Mountain Society, pp. 246.
- [8] 'Greening Red Earth', INBAR Proceedings, Jor Bag, New Delhi, 2003.