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Bamboo housing: market potential for low-income groups

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Abstract—The world population reached 6 billion in 1999 and at the current growth rate is estimated to reach 7 billion in 2010 with the overwhelming share in developing countries. However, the momentum of poverty alleviation in the developing countries has not kept pace with the population growth. This has serious implications on increased poverty in the regions. One of the visible indicators of the growing poverty is 'lack of shelter'.

Reports reveal that millions of people live in hovel 'life- and health-threatening homes', simply due to their inability to afford the houses. This demands seriously to look for an alternative housing materials that are cheap, widely available and require less technical know-how.

Bamboo has been found being an excellent building material due to its versatile characterises. It is estimated that more than a billion people live in bamboo houses, mostly in developing worlds. Additionally, its ecological and economical characteristics have made it a sustainable building material. In the past, bamboos were only used to build traditional hovel. However, it has gradually received an increased recognition as a building material. Few development organisations have initiated large-scale bamboo building programme to build houses for low to middle income groups. The projects were highly successful in achieving its main objective i.e. to provide shelter to poor families.

This paper mainly deals with the successful stories of three housing projects using comparative assessments of cost and technical aspects. The ultimate objective of the paper is overview the applicability and market potentials of those housing projects for low-income groups in other regions of the world.

Key words: Bamboo; bamboo housing; cost; marketing.

INTRODUCTION

The world population reached 6 billion in 1999 and is estimated to reach 7 billion soon after the year 2010. The overwhelming share of the growth is taking place in developing countries. The population of developing countries has more than doubled in 35 years, growing from 1.89 billion in 1955 to 4.13 billion in 1990 [1].

Growing population has a serious implication to the human settlement followed by housing deficit. At least 600 million urban dwellers in Africa, Asia and Latin

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America live in hovel 'life- and health-threatening homes'. An increasing number of urban poor are also homeless in both developed and developing countries, with the current estimate of the homeless population being over 100 million [1]. The housing deficit affects two million in Central America [2]. In India, it was estimated to be a shortage of 39 million dwelling units [3].

Such an overwhelming shelter problem in the developing countries has resulted in the proliferation of slums and squatter settlements negatively impacting on the management of garbage, sewage and other sanitation problems and affecting to the health condition of dwellers. This is also a prime cause of environmental pollution in developing countries. Not only from the environmental perspective but also from the scenic viewpoint, such scattered temporary settlements make a city ugly and unkempt.

Access to safe and healthy shelter is essential to a person's physical, psychological, social and economic well-being and is a fundamental element of his livelihood. A safe home is a starting point for a family for further socio-economic development through social organization, education and employment, and gives a feeling of security. However, a greater number of the population of the world lives either without or in a very temporary shelter. Poverty and limited access to resources have impelled to look for the low-cost bamboo housing option.

BAMBOO IN HOUSING

Bamboo has a very long history for its use in various purposes, viz., food, shelter, furniture, etc. Bamboo has been serving humanity from cradle to grave in many countries since ages in many different and ingenious ways. It has strength, flexibility and versatility and, therefore, is suitable material for every component of the house when treated and used properly.

Bamboo is one of the oldest materials used for the construction of houses and other structures. As an excellent building materials it is relatively cheap, easy to work with and readily available in most of the countries where bamboo grows. It is estimated that more than 1 billion people in the world live in bamboo houses and in Bangladesh alone more than 70% houses are made up of bamboo [4].

The global shortage of housing materials, especially in the developing countries, is such that it warrants serious consideration. To keep pace with the population growth and to replace old houses, about 75 million units need to be constructed each year in Asia alone [5]. The short supply of timber and other conventional construction materials accompanied by rising costs make it imperative to increasingly use of bamboo for housing.

Why Bamboo Housing?

Economical advantages.

Affordability. Of all the great advantages of bamboo housing is its low cost compared to wood and masonry. The cost of one house built by Viviendas del Hogar de Cristo (VHC) in Ecuador is less than US$ 450, which is affordable to the low- to middle-class people. As a raw material, bamboo is one of the cheapest construction materials. According to calculations done by Janssen [6], the price of 35 pieces of bamboo culm (80 mm outer diameter, thickness 6 mm and length 8 m) is comparable with price of 1 m^3 wood. In the case of the Nepal market the price of 1 bamboo culm (6–8 m) is RS. 75 (approximately US$ 1.00); hence, for 35 pieces it is US$ 35.00, whereas the market price of 1 m^3 of Sal (*Shorea robusta*) wood is almost US$ 80–100. One can easily compare the cost of bamboo and wood.

Employment generation. The manufacturing of low-cost bamboo houses provides employment to a large number of people, including generation of extra employment in its forward and backward linkages such as cultivation, harvesting, primary processing, transport and marketing of bamboo. In India only, bamboo generates jobs for a total of 60–72 million workdays before primary processing and 120 million workdays for weaving works [7].

Environmental advantages.

Environmental benefits. In recent years this has become a major consideration in the development field. A construction program should emphasize use of local materials, energy efficient designs and materials that do not harm health and the environment and labour intensive technologies that employ more people (UNEP, not dated). Only bamboo can meet most of these criteria. Bamboo requires little energy for the production of normal use of several building materials. It requires only 30 MJ/m^3 per N/mm^2 compared to concrete, steel and timber that require 240, 500 and 80 MJ/m^3 per N/mm^2, respectively [6]. Studies show that processing of bamboo requires only 1/8 of the energy that concrete needs to create a building material of the same capacity. In comparison to steel bamboo needs only 1/50 the amount of energy for processing [8].

Control of deforestation. In the Costa Rican context it has been calculated that only 70 ha of bamboo plantation are sufficient to build 1000 bamboo houses per year. If these houses were built with timber, 600 ha of natural forest would be destroyed each year [7]. Additionally, bamboo can regenerate within 2–3 years, while for timber it could take more than 25 years. It is the fastest growing plant of the world and replacement is easier and faster.

Rural housing in tropical developing counties to a great extent still depends on the availability of product products, i.e. wood, thatch grasses, etc. The depletion of forest resources and checks imposed on their harvesting has led to a severe shortage

of wood raw material and in some countries wood has gone beyond the reach of the poor for building construction. In such a case bamboo could be a viable option or alternative to replace wood [2]. During disasters in developing countries, the obvious tendency is to build temporary shelters in the vicinity of forest using trees, leaving the forest environmentally and economically degraded. Bamboo could make a viable substitute to control indiscriminate cutting of trees and to protect environment.

Social acceptability. As the bamboo has been in use for centuries in our society in one or another way, this is not very new for us. Bamboo housing allows self-help construction with greater flexibility, which develops ownership and intimacy to the people. For example bahareque, which is a traditional bamboo building (wall) system in Latin American countries. There are two types; hollow and solid. In solid type, horizontal bamboo laths are fixed on both sides of culms or timber frame and the space is filled with mud. In hollow type, esterilla (flattened bamboo) is fixed both sides of culm and is plastered with mud or cement mortar. In Latin America, bahareque is not expensive because this can be made by the occupants themselves and the technical aspects are simple [7]. People prefer bamboo houses in the rural tropical areas where temperature is high in summer.

Technological advantages. Construction with bamboo requires minimum technology. Most of the bamboo houses are based on existing local technology, which does not require high-tech. However, its versatility offers multiple technological options from very economic to highly expensive buildings with greater flexibility in designing and construction. One of the important advantages of bamboo housing is that it can be maintained regularly by replacing deteriorated parts.

Durability. With proper treatment bamboo provides a service life of up to 30 years. Durability can be prolonged with careful choice of bamboo species, preservation, use of complementary construction materials and regular replacement of outdated or deteriorated parts.

Earthquake resistance. Due to lightweight and favourable elastic property of bamboo, its quality to resist earthquake pressure is outstanding. Gutierrez [9] reports that 30 houses that were in the epicentre of a 7.6 magnitude earthquake survived without any damage in Costa Rica. Many of the concrete homes and hotels around them had collapsed but all 30 bamboo houses remained intact.

BAMBOO HOUSING: MARKETING PROBLEMS

Despite the overwhelming potential of bamboo housing for various income classes, it has been facing problems for wider acceptability. The problems, however, are mainly associated with ‘people’s perception’. The followings are the main misconceptions.

Perception 1: 'It is a poor man's timber'. Many authors have indicated that the status of bamboo is still low compared to other housing materials. Despite engineering recognition as a strong building material, prejudices of so-called 'poor man's timber' have abated its real value as a construction material and living in a bamboo house can be a stigma on the family [7]. People tend to plaster their houses to make them look like concrete houses. As they think it is an indicator of poverty, as soon as they can afford to, they tend to replace their bamboo buildings with masonry or concrete.

Perception 2: 'It is not durable'. In general, the natural durability of bamboo is low and varies from 1–7 years, depending upon its use and exposure [6, 10]. As the general people lack knowledge on life-prolonging treatments of bamboo, the general perception among the local people is that the bamboo housing is a temporary solution, as it does not last long.

Perception 3: 'We do not have the technology'. Although bamboo has been used traditionally for centuries for housing and does not generally require high-tech, there seems to be a feeling of a technological gap among the people to use bamboo in improved engineering designs. The general tendency is that people sought to have a proven technology and do not want to take risk involved in own innovation.

Knowledge transfer. Additionally, bamboo building projects often involve a North–South transfer of knowledge, since much of the building research works take place in industrialized nations while the need for housing is mostly in developing countries [7].

Perception 4: 'We do not have good bamboo'. It can be heard most often that there is not good quality bamboo as in other countries. The reality is that they have not tested their own bamboo and sought to have new species, which have been used in other countries. This perception has also hindered the local marketing of bamboo for housing purposes.

BAMBOO HOUSING PROJECTS: SUCCESS STORIES

Despite misperceptions regarding bamboo housing, there are few housing projects, which have proven bamboo as an excellent building material. The projects are briefly described in Tables 1–6 below.

MARKET POTENTIAL

The experiences from these housing projects have clearly indicated the market potential of bamboo as a building material for low- to middle-income-class people. The following paragraphs summarize the main points.

Wider target groups

One of the most obvious advantages of bamboo housing is that it offers ranges of building options from very low cost to expensive. So, it does not only attract

Table 1.
General description of the projects

Project	Description
Viviendas del Hoger de Cristo (VHC), Ecuador	Viviendas del Hogar de Cristo (VHC) is a non-governmental organization, which started its work in Guayaquil in 1971. It is a non profit organization that aims to give shelter to the homeless, strengthen the family unit and promote human and spiritual value at home. As a first step towards a better life, VHC offers migrants and other homeless people a temporary, affordable and low cost house made of bamboo. In general a VHC house with all its components of bamboo and wood is fabricated in about 2.5 h, resulting in a daily production of 50–80 houses at the VHC production plant. A house can be assembled in a single day with minimal instruction and the help of friends. Clients are offered credits of US$ 450.00 which can be paid back over three years. During 30 years, VHC provided houses for more than 61 000 families. In the early years averages of 160 houses were built per year and went up 843 per year in 1984. Presently they produce 80 houses a day [11].
The National Bamboo Project (PNB), Costa Rica	The National Bamboo Project (PNB) was officially endorsed by the Costa Rican Government through the Ministry of Housing and Human Settlements, the ministry of planning and the ministry of foreign affairs. The original grant was US$ 5.7 million from the government of The Netherlands and the UNDP. The administration was carried out through UNCHS habitat and UNDP. The project was started in 1986 as a new technological approach to prevent deforestation in Costa Rica. The project has achieved the construction of 703 houses in rural areas, among them the indigenous communities of Terraba, Rey Curre and Boruca. During the first phase of the project 300 hectares of bamboo were cultivated. A general process of the project was that groups of five to six people from the community were formed and each group built five to seven houses. Each group built its houses simultaneously so that all five to seven houses were at the same stage of construction at any time [2].
Indian Plywood Industries Training and Research Institute (IPITRI), India	TRADA International, with the funding from DFID, has supported IPITRI (Bangalore, India) to develop and demonstrate affordable bamboo housing and to increase the access of the poor to safe, durable and affordable shelter. The bamboo building system is sustainable and cost-effective. It is also simple to erect, strong and durable. As such, it incorporates all the essential requirements for affordable shelter. Moreover, the basic system can be enhanced through improved use of shape, space and colour at little or no extra cost. For example, a shaded porch provides a useful external space for working or relaxing. Large roof overhangs look attractive, and also provide protection from the sun and rain. Louvered openings and large windows increase light and airflow, providing a comfortable internal environment [12]. Overall, the system effectively demonstrates that desirability and quality are fully compatible with affordability. This has led to growing interest in bamboo as a building material, and the potential solution it offers to the shortage of affordable shelter in many developing countries [12].

Table 2.
Bamboo species used in the projects

Project	Bamboo species	General characteristics of the species
VHC PNB	*Gauda augustifolia* *Gauda augustifolia*	Thicker-sized bamboo, diameter varies from 80–140 mm; mostly available in Latin American countries.
IPITRI	*Bambusa nutuns*, *Dendrocalamus strictus*	*Babusa nutans* is a thicker-sized bamboo (80–120 mm diameter and 8–14 mm wall thickness); mostly found in the south Asian region. *Dendrocalamus strictus* is a medium-size bamboo, diameter 40–60 mm. However, because of bigger wall thickness, it is relatively stronger.

Table 3.
Bamboo treatments

Project	Preservation methods
VHC	VHC did not apply any treatment to bamboo. Instead, they considered appropriate time of harvesting and maturity of bamboo to ensure durability of bamboo.
PNB	Two preservation methods were used in PNB for bamboo treatment, Boucherie and dip diffusion. Boucherie treatment is the process of sap displacement using boron (boric acid and borax) chemicals. The chemical is intruded into bamboo culm by pressure. The internal bamboo sap drips out of the other end of the culm when the preservative (boron) displaces it [2]. The dip diffusion method uses the same preservation but to treat tablillas (split-dried bamboo lath). These laths are then immersed in boron solution for some time.
IPITRI	The base of the columns was treated using the hot and cold method. The bamboo is submerged in a tank of preservative (creosote oil), which is heated directly by a fire. After a period at a constant temperature, the tank is allowed to cool. During the cooling process, the preservative is drawn into the bamboo. Above ground, the columns were treated by internodal injection using tar oil. Holes are drilled between each node, and a small quantity of tar oil is injected. The holes are sealed with wax, and the columns are rolled at intervals to distribute the preservative. Another water based method — dip-diffusion — involves soaking the bamboo in a tank of preservative solution (boron) for a period of several days. The effectiveness of the treatment can be increased by drilling holes in the bamboo. As with the tar oil methods, complete penetration is possible [12].

the poor group, but also the higher-income sumptuous class. A company, namely Bamboo Technologies, produces elegant bamboo houses. The houses are prefabricated in Vietnam and are exported and assembled in Hawaii, USA, as per demand [14]. The house in shown in Fig. 5 is one of the examples, which is 430 square feet and costs US$ 33 300.00.

Table 4.
Designs

Project	Design and construction
VHC (Fig. 1)	There are a number of different designs of houses and these are evolved gradually over the years. Houses are designed to fit in three sizes: small (3.3 m × 6.4 m), medium (4 m × 6.4 m) and large (6.5 m × 6.4 m). The houses are not made entirely of bamboo, but consist of prefabricated wooden frames with bamboo panels attached [13]. The main division is between ground-level houses and houses raised on stilts. The raised foundation is for better air circulation in the base and for storage. The VHC houses are rectangular in shape with the surface area varying from 20.5 m^2 to 41 m^2. They have both one and two sides slope gable roof [4]. These houses lack basic facilitates such as toilet, kitchen, etc. As the bamboo and wood used are not treated, the estimated durability of these houses is not much longer than 5 years. However, life could be extended by preservation of bamboo and improvements with additional materials, such as stones and clay [11].
PNB (Fig. 2)	PNB adapted the use of bamboo to a modern housing design. It applied the timber-frame single-layer bahareque system to the houses [9]. There are basically 3 sizes of houses: 31.3 m^2, 37.7 m^2 and 46 m^2, with a total of 20 different layouts [2]. The house has one room that serves as living and dining room, a kitchen, a bathroom and some bedrooms. Each house has at least two bedrooms and maximum of four. All types of houses have a rectangular shape. They are single story and not elevated from ground. The roof is two sloped. Durability of the building is estimated to be similar to that of cement concrete building.
IPITRI (Figs 3 and 4)	The IPITRI bamboo-housing system is based on the principle of modular systems in which bamboo columns spaced at 1.2-m centre to centre acts as main load-bearing elements for transmission of roof dead loads. The columns are tied at the top with wooden plates and bottom is embedded in foundation concrete. The wall is made up of grid of bamboo lath and chickens mesh and plastered with cement mortar and bamboo lath, and steel dowels hold spaces between columns. The roof consists of bamboo trusses, bamboo purlins and bamboo-corrugated mats. Flooring is generally done by using broken brickbats and is plastered with cement mortar. The finished building may look like a masonry structure, but it derives its strength from an integrated, resilient bamboo skeleton. Bamboo columns, set in individual concrete footings, support bamboo grid infill panels. The grid components are wired to each other, and also to steel dowels passing through the columns [12]. Durability of the building is estimated to be similar to that of normal cement concrete building.

Figure 1. 1 VHC house.

Figure 2. PNB house.

Figure 3. IPITRI house.

Figure 4. IPITRI house.

Figure 5. Hawaii house.

Table 5.
Cost

SN	Project	Cost per m^2 (US$)	Remarks
1	VHC	15–25.00, depending upon roofing type	The cost of a 4.8 × 4.8 m house is US$ 450 and includes transportation and labour costs. It is 7-times cheaper than the social homes of the government [13].
2	IPITRI	55–65.00	The built house was US$ 60.0 per m^2. However, basic house is said to be US$ 45.0 per m^2. It is said that the house is 30–50% cheaper than the traditional house in Bangalore.
3	PNB	80.00	PNB houses are 20% cheaper than traditional masonry buildings [7].

Table 6.
Target groups

Project	Target group
VHC	The main target groups of the VHC house are the poor, homeless migrants living in shantytowns on the outskirts of many of Ecuador's large cities. These houses would be suitable for poor, disadvantaged families, displaced homeless family due to natural and socio-economic reasons.
IPITRI	The target group of the building is middle-class people.
PNB	The target group of these houses are from low-income to middle-class people who can afford relatively expensive houses.

Resource abundance

Bamboo grows in a wider range of climate throughout the world, as high as 4000 m, although it is are mostly confined to tropical and sub-tropical regions. Fortunately, it grows in most of the African and Asian countries, where there is a need for the cheapest materials for housing, so as to address current housing problems. Additional experiences so far show that suitable species of bamboo for construction are available in almost all the countries where it grows naturally. There are 65 species of bamboo which are used for construction purposes [10]. *Guadua angustifolia is* normally popular in Latin America countries. Similarly, *Bambusa nutans, Dendrocalamus strictus, Dendrocalamus hamiltonii, Bambusa balcooa, Bambusa vulgaris*, and *Phyllostachys bambusoides* are widely used in Asian countries. *Bambusa arundinaceae* and *Bambusa vulgaris* are found to be very suitable species for construction in Africa [15].

Popularity

Bamboo is gradually getting popularity among the high-income class because of two reasons: (1) it is decorative and (2) it is known as a green product. The European market is highly sensitive to uncertified forest products. Bamboo has a reputation of a sustainable natural plant because of its reproductive capacity and short rotation cycle compared to wood. This popularity makes it easily marketable as a sustainable building resource.

Housing in seismic areas

Bamboo housing has a great potential in seismic-prone areas. Due to its low weight and favourable elastic properties, its quality to resist earthquake pressure is very good. 30 bamboo houses that were in the epicentre of a 7.6 magnitude scale earthquake were reported to be survived without any damage in Costa Rica. Many of the concrete homes and hotels around them had collapsed.

Bamboo Mat Corrugated Sheet (BMCS)

This is a recent development in bamboo housing sector. Bamboo can be used as corrugated roofing sheet (Fig. 6). The BMCS sheets are light and tough. As such they are easy to handle, and resistant to breakage. They can be readily cut to size, and fixed using standard methods. Tests show that material is strong, fire and weather resistant with low thermal conductivity [12]. The resulting roof is,

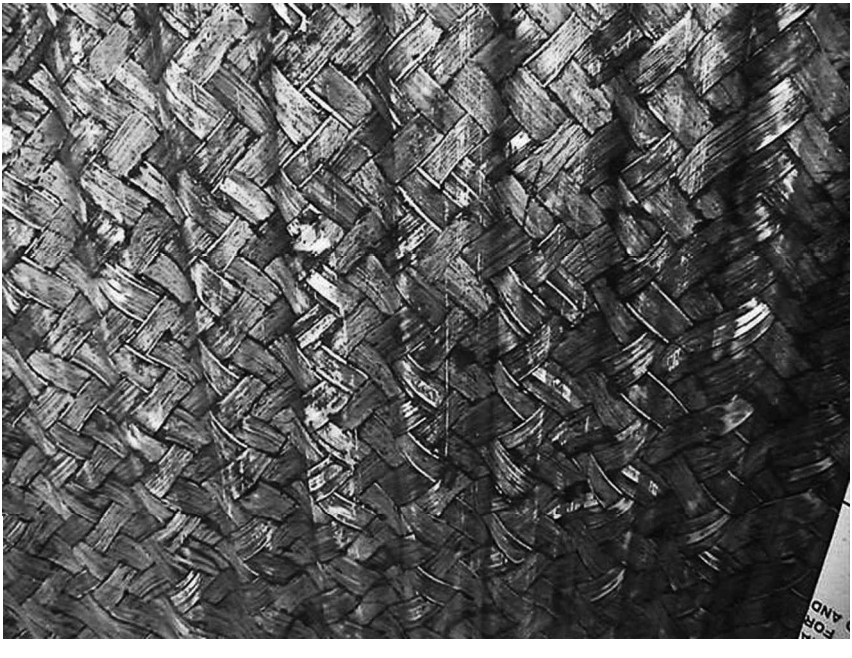

Figure 6. Bamboo mat corrugated sheet.

Figure 7. Bamboo windy house.

therefore, durable and attractive with good insulating properties. It transmits much less heat to the inside of the building compared to iron sheets due to high thermal resistance. Additionally, it does not amplify the sound of heavy rain like iron sheet [16]. Although it is higher quality and environmental friendly compared to iron corrugated roof, cost is comparable and affordable to lower income group.

Other kinds of housing potential

Not only for dwelling purpose, bamboo could be a potential option for making other kinds of houses as well. Flat-pack or prefabricated horse stable, poultry houses, windy houses, etc., are very popular in Europe. Such products could be easily made from bamboo mat board in a flat-pack form, which would be lightweight, cheaper and durable than wooden one and would be a lucrative business in the European market. (Figs. 7 and 8)

DISCUSSION

Bamboo has been found to be a perfect building material in terms of technical, economical, social and environmental perspectives. However, there are few misperceptions regarding its wider applicability for building purpose.

PNB housing and other expensive designs by Simon Velez (Columbia) have proved that bamboo is not only poor man's timber but also for higher income class.

Figure 8. Bamboo windy house.

Regarding durability of bamboo, most of the traditional bamboo users, from where the knowledge emerged, are not aware of treatment of bamboo, which could prolong the life of bamboo. Various methods of bamboo preservations have been developed. One has to make a careful choice of methods and preservatives, considering economical and environmental factors. Proper use is another consideration. There is a report from Das (NE India) [17] that untreated bamboo strips last for 60 years. In his own words: 'When it is fact that myself have witnessed 60 years old untreated bamboo strip in mud plastered wall . . .'.

Knowledge that is developed in the North is not likely to be easily transferred to the south where the demand of low cost bamboo housing is high. Hence, the transfer of knowledge should be south to south so as to ensure cost effectiveness, technological adaptability and sustainability. A suitable bamboo species is not a problem. In fact, most bamboo species are suitable for construction if they meet the required dimensions, provided they are treated and used properly.

VHC houses are quite cheap but less durable. In fact, only the less durable part is bamboo esterilla, which is not treated. The durability could easily be prolonged by proper treatment and plastering. The PNB house is far too expensive for the low-income target group, as it is obviously designed for a somewhat higher income group. However, it has clearly been demonstrated that the bamboo can be used to construct a higher quality expensive building and has an ample opportunity to consider this green material to build houses for sumptuous target group. The IPITRI housing system seems to be a compromise of PNB and VHC for the middle income group.

The housing systems differ between the various locations and projects. A combination of systems may allow greater flexibility according to local situations, so as to compromise between cost and appearances. A study in India shows that dwellers of bamboo houses prefer tiled bamboo houses because of its superiority to thatched houses. Economic feasibility and viability tests also show that the cost of maintenance of this type of house is less and benefits accrued are higher compared to thatched bamboo house [18]. The thatched house costs Rs 167–229 and tiled house costs Rs 331–360 per square meter (45 Rs = 1 USD) [18]. Roofing types and materials can make huge difference in the total cost of the house.

CONCLUSIONS

Bamboo offers varieties of building options from very low cost to highly expensive one and, therefore, has a wider range of target groups. However, there are still few misperceptions regarding bamboo housing, which could easily be explained with proper extension education. Demonstration houses built by various development organizations will be models for future to explain people reality about the bamboo in construction. Because of its reputation as a sustainable product and growing prospects as a building material, bamboo has a huge market potentiality, especially in the low to middle income family classes.

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