

**Bamboo: A Viable Alternative Sustainable Material for Affordable & Comfortable
Houses**
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Introduction

Mr. S. Kurz, a former British Forester, while working at the Forest Research Institute, Dehra Dun quoted remarks of Mr. Alf Wallace “*Bamboo is perhaps nature’s best gift to Uncivilized Society*” in his article “On uses of Bamboo” published in Indian Forester in 1878. So is the versatility of bamboo, that it is possible to put it into uses beyond your imagination requiring little technical knowledge. Imagine the usefulness of this material with all the advanced technologies and machinery available to the civilized world.

Bamboo is also called MIRACLE GRASS because of its astonishing growth rate; some species growing 25-40 feet in one month (Venkatraman, 1938; Warnford, 1882). Ueda (1960 & 1963) reported to have observed a growth rate of 121 cm per day in Madake bamboo (*Phyllostachys reticulata*) of 12 cm diameter and 119 cm/day in Moso-chiku (*Phyllostachys heterocycla* var *pubescens*) of 16 cm diameter in 1956-57 in outer skirts of Kyoto, Japan. In addition, bamboo has the shortest maturity period (3-4 years) yielding a woody stem with strength equivalent to the strongest wood obtained from trees having maturity periods of 50+ years. Bamboo is an important woody raw material resource in the entire tropical regions of South East Asia, Africa, China, Japan and Latin America. Bamboo is an integral part of culture in the S. E. Asia region, where it is associated with plethora of uses and nick names; such as “Poor Man’s Timber”, “Green Gold”, “Friend of the People”, “the Cradle of Coffin Timber”, “My mind is Like a Green Bamboo”, etc., reflecting its importance and reverence.

Bamboo is an important primary building material in rural and tribal areas in bamboo producing countries. Its use as a building material is recorded in various publications around the world (Anon.1909, **Philippines**; Edwards, 1938, **Jamaica**; **Marrero, 1944, Latin America**; Anon., 1951, **Ceylon (Sri Lanka)**; Narayananurthi & Bist, 1946, **India**; Vander, 1951, **Indonesia**; McClure, 1953, **different countries**; Hadinoto, 1954, **Indonesia**).

Why Bamboo

According to US Environment Protection Agency, twenty two percent of the current world contribution to global warming comes directly from energy use for industrial production. All the present day building materials like steel, bricks, cement, aluminum, plastics, etc. being highly energy intensive are major contributors to green house gas emissions. Thus using woody raw materials, which consume the least industrial energy for production and

processing, are environment friendly and also help locking up of carbon for longer periods if used judiciously.

Wood, as a material in design, is considered a living, breathing medium that is full of character and nuance. The warmth, color, texture and immediacy of wood are often utilized to enhance the aesthetics of building architecture, interior spaces and furniture. Although bamboo is considered a junior partner, it has shown immense potential even to replace wood especially in structures and furniture. It is considered a less expensive substitute for cane/rattan in furniture manufacturing (Sabaruddin 1987). Bamboo, a fast growing pole like woody stem, offers a good low cost substitute not only for high energy intensive materials but also wood, which is becoming scarce and expensive due to depletion of natural forests, restrictions imposed on felling trees and their movement to processing centers. With growing stock of around 189 million tons inside forests and 17 million tons outside forests (ISFR, 2017), India carries huge potential to harness this nature's gift.

Major issues involved while selecting materials for large scale utilization in buildings as illustrated by Janssen (1985) (making bamboo an ideal choice) are

- (i) **Energy requirement for production:** Bamboo is the least energy intensive material as all the energy for its growth comes free of cost from the Sun God. As compared to wood, which requires energy for logging, transport and sawing, energy requirement for bamboos is limited to harvesting and transport only. Very little energy is required for cutting and shaping. Limited waste production (absence of saw dust) is another plus point for bamboo. Energy required for drying (kiln drying in case of industrial production) and chemical treatment (for durability enhancement), which is very important for long-term use has not been included in these calculations. These costs are, of course, common to wood as well and are not likely to disturb its order of preference. It may be seen from the Table below that bamboo requires the least energy (26) per unit of load bearing capacity. Bamboo scores over even wood for energy utilization per unit stress (Table 1).

Table1. Energy required for production of different materials (Janssen 1985)

Material	Energy for Production MJ/kg	Weight/volume Ratio Kg/m ³	Energy for Production MJ/m ³	Stress when in use N/mm ²	Energy/unit stress Ratio
Concrete	0.8	2,400	1,924	8	240
Steel	30	7,800	234,000	160	1,200
Wood	1	600	600	7.5	80
Bamboo	0.52	600	312	12	26

(ii) **Safety:** Bamboo is a well established material for construction in earthquake/hurricane prone areas. This emerges from two characteristics of the material:

- a) Capacity to absorb or store energy during load bearing. This is calculated from stress-strain curve for different materials. This curve has two components; the elastic under normal load and almost horizontal representing collapse. The ratio between the two represents safety of material, which is given below for the materials referred above, meaning that bamboo stands second only to steel and is superior to wood in terms of safety, while concrete is the most dangerous material:

Concrete	10
Steel	1400
Wood	20
Bamboo	50

- b) Deviation in strength values between different specimens is another factor to be considered. This deviation is small in case of well controlled materials like steel; for materials of biological origin like bamboo the deviation is large; the allowable stress is only 15% of the mean value for better designing.

(iii) **Strength:** Strength and stiffness per unit of material assume more importance in constructional uses. Materials are generally evaluated on the basis of ratios between allowable stresses per unit volume. Given below are specific ratios for the materials discussed in Table 1 above:

Concrete	0.003
Steel	0.020
Wood	0.013
Bamboo	0.017

Stiffness: For stiffness, the ratio between Young's Modulus and mass per unit volumes is used, which again works out in favor of Bamboo as below

Concrete	10
Steel	27
Wood	18
Bamboo	33

(iv) **Simplicity of production:** This aspect is best understood by villagers who have lived with wood/bamboo for centuries proving remarks of Mr. Alf Wallace (Kurz, 1878).

- a) Steel and concrete not being in their culture, they feel more comfortable with wood/bamboo. Where as they have to wait for years to get wood, bamboos are available for harvesting every year.
- b) For harvesting wood, you may have to fell the entire area to allow fresh plantation, where as in a bamboo clump only mature culms are harvested selectively leaving the rest to multiply.
- c) Due to short diameter, hollow shape, harvesting can be done using simple tools. There is no wastage due to bark or sawing (as bamboos are generally split). Foliage is recycled as fertilizer by biological breakdown.

- d) Different species have their own characteristics making it possible to choose the right species for specific end-use.

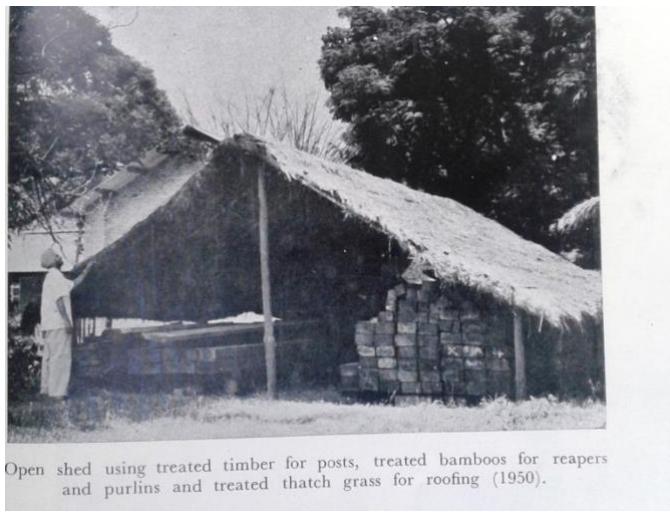
Bamboos for Rural/Tribal Housing: Indian Scenario

Bamboos played a vital role in rural and tribal areas, where modern materials like bricks, steel, and cement were not available or affordable. Such houses started looking like slum houses in 3-4 years and seldom provided a proper shelter beyond 8-10 years. Owners of such hutments could not upgrade to go in for cement-brick houses because limited financial resources. This problem was identified by Late Dr. A. Purushotham, a prominent Scientist at the Forest Research Institute, Dehra Dun and one of the pillars of Wood Preservation Research in India. His travels to the North East India and tribal areas in Andhra and Kerala identified great potential of bamboos, reeds and other grasses in rural housing. He sought the help of FAO and obtained services of Dr. Walter Liese, a German Scientist to identify reasons of degradation so as to improve the durability of this wonderful material. Ironically bamboo was available as forest rights to local dwellers and labor came free from fellow villagers and Dr. A. Purushotham, conceived that Forest Rights may not continue in the future considering constraints on available raw material and increasing country demands from forests. He accepted the challenge and undertook pioneering research on treatment of bamboo for improving its durability and enhancing fire resistance of bamboo and thatch to enable poor villagers and tribes residing in remote areas build durable and comfortable hutments.

Forest Research Institute, Dehra Dun participated in UN regional Seminar on “Housing & Community improvement” held in New Delhi in 1954 and Dr. A Purushotham put up a low cost structure prefabricated at Dehra Dun (Purushotham, 1954). Mud houses are not only economical to build, they also provide a higher comfort level as per conclusions arrived at by Central Building Research Institute, Roorkee (India), undertook observations on exhibited structures and concluded that such buildings behaved well in providing thermal and acoustic insulation. Vermin including spiders keep away from treated thatch, where as untreated thatch is easily infested.

He continued with his efforts to produce low cost structures using local materials and erected several structures using bamboo in different forms with mud and lime during 1950s and 1960s. Majority of these structures performed well with several of these surviving even today without much maintenance. Dr. A Purushotam (1963), who was member of the FAO working group on wood preservation, presented a paper on Low Cost Structures at the 5th FAO Conference on Wood Technology at the Forest Products Laboratory, Madison (Wis,) USA held on September 16-27, 1963. He described three different types of structures useful for Indian villages using Bamboo as the main material. Some of these structures do have future potential relevance in the village scenario.

Structure 1: An open shed for storage purposes with thatched roof providing a covered area of 360 ft². (Approx. 36 m²) costing Rs. 284 at the then prevailing costs of labor and materials in 1950 as shown in plate below.



Structure 2: Treated Bamboo Hut with total covered area of 130 ft² (approx. 13 m²) costing Rs. 690. This structure has become an iconic monument still housing the office of wood preservation plant at F.R.I. Dehra Dun (Fig. 2, Year of erection 1954).



Fig.2. Bamboo Hut (FRI); One of the earliest structure created with CCA treated half-split bamboo (cladding) reinforced mud as walls (Left portion constructed in 1954; Right portion added later) defies the elegance of even brick and mortar structures and still in full service.

Structure 3: Air Seasoning/Storage Shed for wood/other agriculture produce, covered area 527 ft² (Approx. 5m²) and estimated cost with three different roofing materials options as below (based on costs prevailing in 1959; USD was approx equivalent to 7.5 Indian Rupees in 1960's)

Rs. 1586 with preservative treated thatch supported (Rs. 3/ft²; Rs 32/m²)

Rs. 2008 with Galvanized Iron (GI) sheets (Rs. 3.81/ft²; Rs.41/m²)

Rs. 2485 with GI sheets covered with creosoted wooden shingles (Rs.4.72/ft²; Rs. 51/m²).



Fig.3. Air seasoning shed for wood/Storage Shed (FRI) using CCA treated bamboo mats for shutters and split bamboo reinforced mud walls (Year erected 1957; Picture taken in 2006).

These structures used primarily treated bamboo for mud wall reinforcement and treated wood where bamboo was not found suitable. The binding materials were grass ropes (treated with preservatives) and steel wire for binding split bamboo to make bamboo jafri. Earth (mud), bajri, boiler ash and Lime mortar was used for plastering. Only limited quantity of bricks and cement for making foundation and flooring was used for structures 2 and 3.

To prove his point further Dr. Purushotham designed a 2BHK house was also constructed as per layout given in Fig. 4. This house had two bed rooms, with store, bathroom and servant quarter. The wooden trusses were as per FPL Madison (Wis.) design. Cow dung slurry was used to provide sealing of mud wall both in the interior as well as exterior sides. Mud plaster was blended with 3-5% lime to provide better adhesion to subsequent lime or cement plaster. Several alternatives for roofing were described; the cost of basic structure with wood bamboo and thatch was Rs. 3,590 for covered area of 1024 ft² (32' X 32').

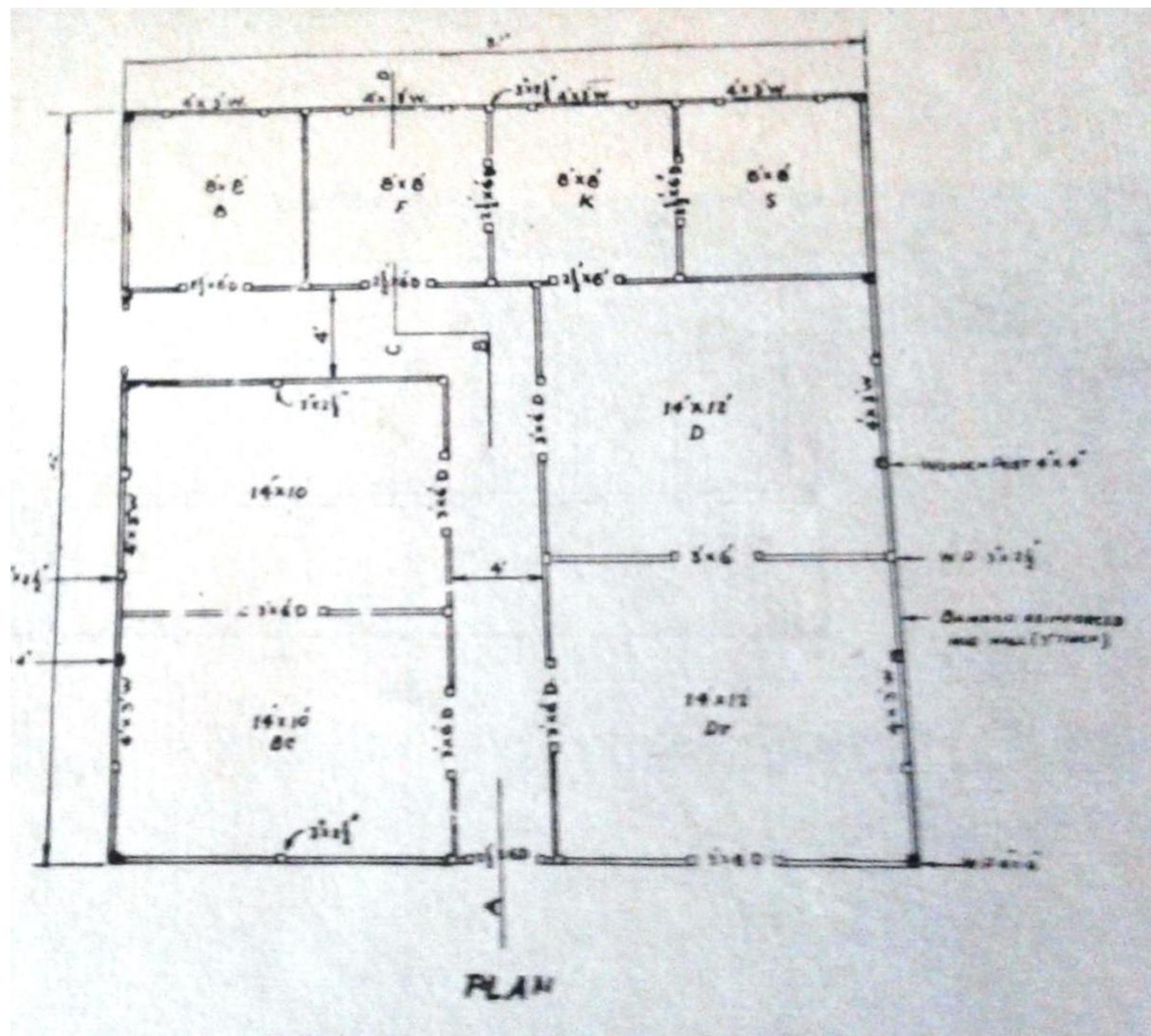


Fig.4. Layout of 2-BHK house.

Later Efforts to Promote Bamboo Structures

1966. Efforts were continued to demonstrate utility and versatility of bamboo. A room with semi circular arched roof was constructed in Wood Preservation branch for purpose of a lecture room and museum (Purushotham, 1966).

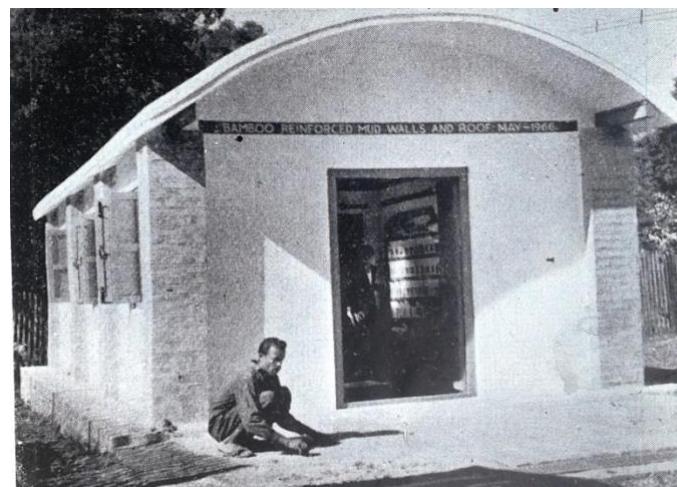


Fig.5a Completed structure with semi-circular arched roof

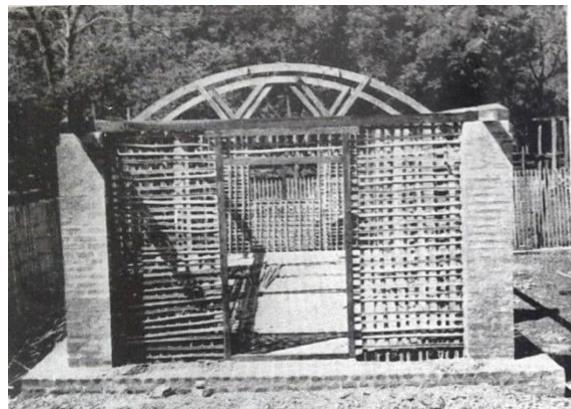


Fig. 5b Wall system in place



Fig.5c Roofing in progress

The structure was put up on 4 brick pillars using bamboo reinforced mud walls and roof (Fig. 4a, 4b and 4c). After filling in mud, the walls were plastered with treated grass cuttings reinforced mud followed by lime plaster. The roof was further coated with cement slurry containing water proofing formulations. Cost of this structure was Rs. 2188 or Rs. 4/ft².

1970. It was observed that where as these walls performed very well, mud roof developed had seepage problem during heavy monsoon rains. This problem does exist in normal flat roofs built from cement concrete as well in heavy rainfall areas. Even cement concrete flat roofs need frequent asphalting or grouting with cement/waterproofing emulsions. A mixture containing boiler ash, lime, and shingles (bajri) was developed for roofing. A structure (8.2m in length and 3.7 meter wide was constructed using the proven technology for walls and improved formulation for roofing (Chandra and Purushotham 1970). The roof was further given a light cement plaster (Fig. 5). The cost of this structure worked out to be (overall dimensions 10m X 5.5m) Rs. 4940 @ Rs. 89.50 /m².

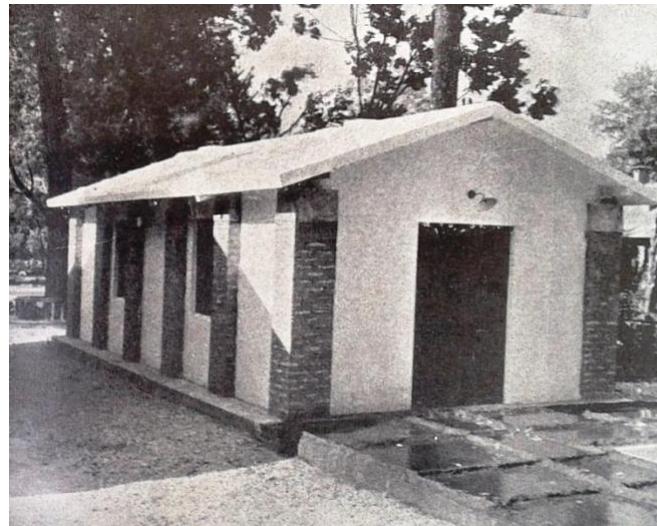


Fig.6. Low cost structure with improved roof.

1983. A mud hut (20.36 m^2 over all covered area including kitchen 2.18 m^2) was constructed in June 1983 in a village on Dehra Dun- Delhi highway as a demonstration structure to promote bamboo houses and create confidence in public as well as engineers and architects (Kumar *et al.* 1989). This cottage was built on private land and was handed over to the land owner who started living in the same. This hut used 10 meter long bamboos (50) for walls, timber (0.5 m^3) for trusses, purlins, doors and windows, Pine posts (10) as supports and Bamboo mat (20 m^2) for ceiling cost just Rs. 2,820 at prevailing market rates. Treatment cost with wood preservatives was Rs. 385.

Brick work was raised 30cm above ground to act as moisture barrier (1000 bricks) for supporting bamboo reinforced mud walls. The total material cost including grass, cement, mud and lime was Rs. 4,295. The total cost for this 2.45 m high structure worked out as Rs. 6,875 (Rs. $340/\text{m}^2$) including labor (Rs. 2,180) and hardware (Rs. 400).



Fig.7. Treated bamboo reinforced Mud hut (constructed 1983) after 24 years service (Picture taken 2007).

The current cost of such a structure will be around Rs. 60,000 or Rs.3000/m². If thatch roof is replaced by bamboo corrugated sheets, the costs will escalate to about Rs. 1,00,000 compared to approximately Rs.2,00,000 for a brickwork house with Galvanized Iron (GI) corrugated roofing sheets with a false ceiling and Rs. 3,00,000 with cement concrete roof. (one USD = Rs. 67 approx

These results were highlighted during several presentations in seminars/ workshops organized under Indra Awaas Yojna of the Govt. of India (A national program for providing durable houses to poor) during 1980s but found no response (Kumar 1988, Kumar 1989, 1990, Kumar & Shukla 1988;). Despite the fact that this was the only available technology which could fit into the budget of this mass housing scheme in rural and tribal areas, Architects and Engineers engaged in the program having no knowledge and little confidence in Bamboo failed to appreciate this wonderful material. Bamboo is still mentioned for temporary structures in various national standards and building codes produced by these highly qualified urban oriented Technocrats.

No lessons learnt in earthquake-prone North-East

Manipur, a state in the North-East India was hit by an earthquake of intensity 6.7 on January 4, 2016, causing devastation in the state capital, Imphal and adjoining areas. Scientists from three Indian Institutes of Technology (IITs) – Kanpur, Guwahati and Patna-- undertook a reconnaissance survey of the earthquake affected regions immediately after the quake. Their findings were not at all surprising. The finding reported varying degrees of damage to reinforced cement (RC) buildings, while traditional houses of bamboo and wood - known as Shing-Khim - reported no damage. According to Dr Durgesh C Rai, a professor of civil engineering at IIT Kanpur, who led the study, concluded that despite considerable awareness among the public about earthquakes and associated risks, both the public and administrators, chose to ignore the threat and continued to build structures that were not earthquake-resistant, Many publicly-funded buildings like Inter State Bus Terminal (ISBT), Government Polytechnic and Central Agriculture University (CAU) suffered severe damages under shaking intensity of VI–VII.

The newly constructed concrete buildings of the world famous Ima Keithel or Mothers' Market too suffered damage. The market earlier operated from bamboo structures, which were functional but were in poor condition due to lack of maintenance. Lessons from the Manipur quake are applicable to the entire North-East region.

It was a good opportunity for scientists to understand the risks posed to buildings and the state of construction practices in the region and reinvent the wheel. It is ironical that Engineers and architects passing out of these very Institutes fail to implement what they studied for earning their coveted degrees and ignored practices followed by our not-so-well-qualified ancestors who ably used local materials like bamboo, wood and thatch to build residential home and other structures. This report has been published in Current Science" an Indian Science Magazine and has been abridged from "India Science Wire" report flashed on my Linkedin Account.

Some Recent and Modern Structures using Bamboo



Shed in Nagpur (supposed to be constructed with treated bamboo and bamboo products)



Restaurant in Kohima, Nagaland Capital,



Guru Nanak Dhaba (Local low cost Restaurant) on Hardwar- Sitarganj Highway, Uttrakhand (Low cost solution for High End Use at low cost)



Inner View of the dome Structure



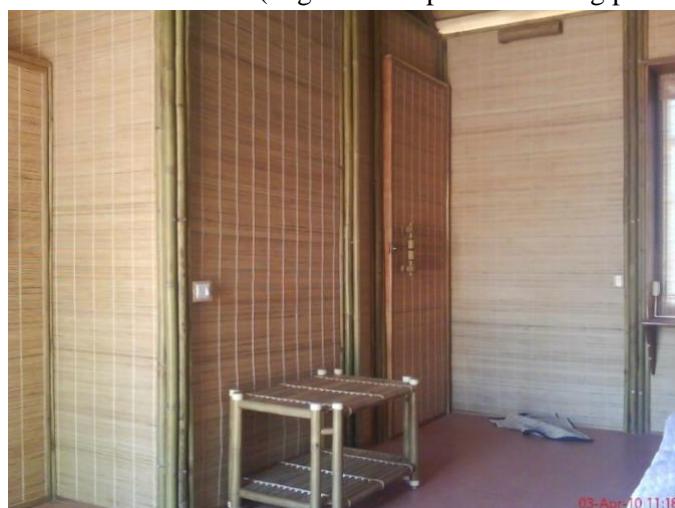
Bamboo and thatch used to make passenger shed on Konkon Railway



External View of Freshly Constructed Bamboo Resort (Dima Pur, Nagaland, India 2005) shows potential of Bamboo in high end products.



Model Bamboo Hut at Kudal 2010 (KONBAC) erected with CCB treated bamboo (A good example of realizing potential of bamboo)



Bamboo Interiors of Bamboo Hut at Kudal (KONBAC)



Bamboo Resort at Kodiyal, Uttrakhand, India



Inside view of the guest room (Kodiyal Resort)

Some Imposing Structure Making Bamboo a Material for Privileged Section of the Society are reproduced below.

Constructed by Organo Builders in Hyderabad for Infosys, a famous IT company of India, the club complex has covered area 10750 ft², Total Cost Rs.1.7 Crores (Rs.1581/ft²). This lavish construction compares well to an ordinary brick cement construction for middle class @ Rs 1500/ft². Photographs Courtesy Sanjeev Karpe (KONBAC), who carried out the entire interior work using bamboo, bamboo strip board for flooring, furniture, window blinds, wall cladding to false ceiling.





Caution

All the demonstration structures (Figs 1-7) used bamboo/thatch treated with Copper-Chrome-Arsenic (CCA, known as ASCU in India) wood preservative. Use of this preservative has been restricted in some countries due to perceived environmental risks. This preservative has however, demonstrated unbeaten performance the world over. Other structures cited in the paper were photographed when erected. Structures raised by Organo Builders are reported to use bamboos treated with Copper Chrome Boric (CCB) an alternative to CCA. Several alternatives to this formulation have been suggested but none has matched the performance of CCA.. More details of the preservatives and treatment methods for bamboo in different forms have been explained in “Bamboo Preservation Compendium” published by CIBART/ABS/INBAR (Liese and Kumar 2003), Unfortunately most of the recent preservatives have not been tested adequately for treating bamboo and being more expensive will require special efforts for adoption for an inexpensive material like bamboo..

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