

Bamboo

A
material for
cost effective and
disaster resistant housing




Building Materials and Technology Promotion Council
Ministry of Urban Development & Poverty Alleviation
Government of India

RATIONALE

Wood has been used for centuries as a common material in construction of buildings and other structures. Similarly, bamboo has also a long and well established tradition for being used as a construction material throughout the tropical and sub-tropical regions of the world. With the rising global concern, bamboo is a critical resource as it is very efficient in sequestering carbon and helps in reduction of Green House gas emissions.

In the modern context when forest cover is fast depleting and availability of wood is increasingly becoming scarce, the research and development undertaken in past few decades have established and amply demonstrated that bamboo could be a viable substitute of wood and several other traditional materials for housing and building construction sector and several infrastructure works. Its use through industrial processing have shown a high potential for production of composite materials and components which are cost-effective and can be successfully utilised for structural and non-structural applications in construction of housing and buildings. Main characteristic features, which make bamboo as a potential building material are its high tensile strength and very good weight to strength ratio. It can withstand upto 3656 Kg/cm² of pressure. It can be easily worked upon by simple tools and machines. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Above all bamboo is renewable raw material resource from agro-forestry and if properly treated and industrially processed, components made by bamboo can have a reasonable life of 30 to 40 years. Though natural durability of bamboo varies according to species and the types of treatments. Varied uses and applications in building construction have established bamboo as an environment-friendly, energy-efficient and cost-effective construction material. With the rising need of housing, buildings and roads the country requires a variety of alternate building materials and construction systems and advancements in bamboo technology offer several cost-effective and environment friendly options.



“There is a need to modernize the bamboo-based industrial sector by bringing in better technology, processing & manufacturing support as well as improved management practices so that our bamboo industry can be globally competitive and the country can secure its due place as a manufacturer and exporter of new generation bamboo products. To achieve these objectives, well coordinated efforts involving Government agencies at the Central and State levels, private, corporate, cooperative and farm sectors & community-based organizations are critically needed.”

K.C.Pant
Deputy Chairman
Planning Commission
Government of India

POTENTIAL IN HOUSING CONSTRUCTION

The Government has declared the goal of ‘Housing for All by 2010’ and it is required that at least 2 million houses are put up every year by the public sector agencies in addition to the ongoing housing construction in the private and informal sectors. Despite the Supply : Demand ratio of 1:3, funds to the tune of Rs.52,000 crores were available from the formal sector for rural and urban housing during the IX Plan (1997-2002).

The National Housing & Habitat Policy recognises housing sector as a medium to generate more employment by strengthening production activities of environment-friendly and cost-effective building materials. As the housing and building construction industry is one of the largest consumers for natural mineral resources and forests, it is increasingly realised that innovative building materials and construction technologies which offer potential for environmental protection, employment generation, economy in construction and energy conservation, need to be encouraged as best options to meet the rising demand of housing in different regions of the country. Nearly 60 percent of the country’s area being prone to natural disasters like earthquakes, cyclones, floods etc. the Policy also lays emphasis on promoting design and construction of disaster resistant technologies for housing. Construction techniques using bamboo as main material have been found very suitable for earthquake resistant housing.

Building materials accounts for nearly 60 to 65% of the cost of house construction. With the constant rise in the cost of traditional building materials and with the poor affordability of large segments of our population the cost of an adequate house is increasingly going beyond the affordable limits of more than 30-35% of our population lying in the lower income segments. This calls for wide spread technology dissemination and availability at decentralised locations of cost-effective building materials and construction techniques.

Roofing and walling are two crucial elements of a house and several R&D institutions have been engaged in developing innovative, alternative roofing and walling materials and construction systems. Considering the need for developing alternate environment-friendly and cost-effective roofing materials for North-Eastern and other earthquake prone and hilly regions the Building Materials and Technology Promotion Council (BMTPC) under the Ministry of Urban Development & Poverty Alleviation and the Indian Plywood Industries Research and Training Institute (IPIRTI) functioning under the Ministry of Environment and Forests, have jointly developed a technology for manufacturing of Bamboo Mat Corrugated Sheets (BMCS). A sandwiched panel system for structural floors using corrugated roofing sheets is also being developed for situations where houses with more than one storey have to be constructed. The IPIRTI, in recent years, has also developed a number of construction techniques and components using bamboo for walls, floors, doors etc. both for structural and non-structural applications in housing and buildings construction. These components have already been tested and evaluated for intended applications. Several of these are also being commercially manufactured and are being utilised in constructions. After evaluating the performance of the BMC sheets produced at pilot scale as well as other bamboo based components, the technology for construction of houses, community buildings using bamboo as main material stands proven. A num-





ber of small and medium sized demonstration structures have already been constructed during past 2/3 years. These have shown very good performance in different climates. The BMC sheets have shown good resistance to water, fire, decay, termites, insects etc. RV-TIFAC Composite Design Centre, Bangalore, is also working on development of a variety of products using bamboo as main material and the CDC has successfully developed several hybrid components for use in building construction.

Bamboo being a highly versatile resource and widely available needs to be adopted as an engineering material for construction of houses and other buildings. In order to propagate these for wider application, awareness and confidence building amongst professionals and householders is required. This calls for organised action on prototyping, demonstration, standardisation aimed at improving acceptance levels and promoting appropriate construction practices. One of the key objectives of the proposed National Mission on Bamboo is to promote value added products which are being commercially and industrially produced. Demonstration projects based on bamboo applications will help in creating high visibility for use of bamboo as a material for housing construction. Once the demand is built up, investment from entrepreneurs will automatically flow to enhance availability of bamboo based materials and components. The technology for manufacturing of Bamboo Mat Corrugated Sheets and for several other items has already been transferred to private entrepreneur who has set up a production unit, M/s Timpack Pvt. Ltd. at Byrnihat, Meghalaya with production capacity of 3000-4000 BMC sheets per month. The commercialisation of Bamboo Mat Corrugated Sheet technology has been possible within the framework of a project funded by Ministry of Environment & Forests. It is estimated that this unit alone will generate livelihood for nearly 7000 women/men (through mat weaving) in rural regions where bamboo is abundantly grown.



PRESENT STATUS OF BAMBOO BASED COMPOSITES AND THEIR UTILISATION IN INDIA

In India, although several products have been developed, bamboo mat board (BMB), Bamboo Mat Veneer Composites (BMVC) and Bamboo Mat Corrugated Sheets (BMCS) developed at IPIRTI have already attracted entrepreneurs and gained user acceptance as alternate to wood, plywood and corrugated ACC and GI Sheets. The BMB technology has been recognised to be as an exemplary item in implementation of Agenda 21 by the International Selection Panel and as such was recognised as a World Project at the Expo-2000.

R&D efforts at IPIRTI in collaboration with BMTPC for the development of bamboo mat corrugated sheets (BMCS) have established the technical feasibility and these are being commercially produced and marketed. The sheets developed are superior in strength properties compared to ACC sheets.

In collaboration with TRADA Technology of UK and funding by DFID, IPIRTI has developed a building system using round and split bamboo, BMB for walling, door and window shutters and BMCS roofing. The system is based on 1.2m module with bamboo posts and bamboo sliver reinforced cement mortar wall panels of 5 cms thick only. The experience on the development of housing system has shown that the systems developed are cost effective, attractive and are expected to withstand normal weather and wind conditions. Being light it can be suitably utilised by adopting appropriate design for earthquake prone regions. The system developed and study of prototypes already constructed have shown high potential for wider propagation particularly in North-Eastern and other bamboo growing regions where traditional building practices already exist but need to be improved for longevity of buildings.

Several manufacturing units are already engaged in production and marketing of bamboo based building materials (boards, panels, composites, laminates, roofing sheets) Variety of industrially produced products and elements are being used in building construction besides hundreds of traditional systems and types where bamboo is predominantly used for house/building construction.





Photographs of Traditional Houses

Photographs of Modern Structures





POTENTIAL FOR SUBSTITUTING TRADITIONAL TIMBER & ROOFING COMPONENTS BY BAMBOO BASED MATERIALS

Continuing dependence on traditional building materials like burnt clay bricks, cement, steel and primary timbers from natural forests is neither possible nor desirable without detriment to environment. A large number of alternative materials and wood substitutes have been developed in past 2 to 3 decades by our research & development organisations in the country. Though their application in field has yet to achieve the desired level, however, it is amply demonstrated that by their increasing application it is possible to conserve non-renewable materials, reduce pollution and achieve substantial savings in energy consumption. Bamboo as a versatile material and its various composites alongwith other building materials offer a very appropriate option to partially replace materials like steel, aluminium and hard forest wood for housing applications. Use of bamboo and plantation timbers is gradually opening new avenues for meeting demand from the housing construction sector.

Energy Requirement of Construction Materials

Materials	Energy for production MJ/Kg	Weight per volume Kg/m ³	Energy for production Kg/m ³	Stress when in use	Energy per unit stress
Concrete	0.8	2400	1920	8	240
Steel	30	7800	234000	160	1500
Wood	1	600	600	7.5	80
Bamboo	0.5	600	300	10	30

Source: Prof.J.A.Janssen, Eindhoven University, The Netherlands

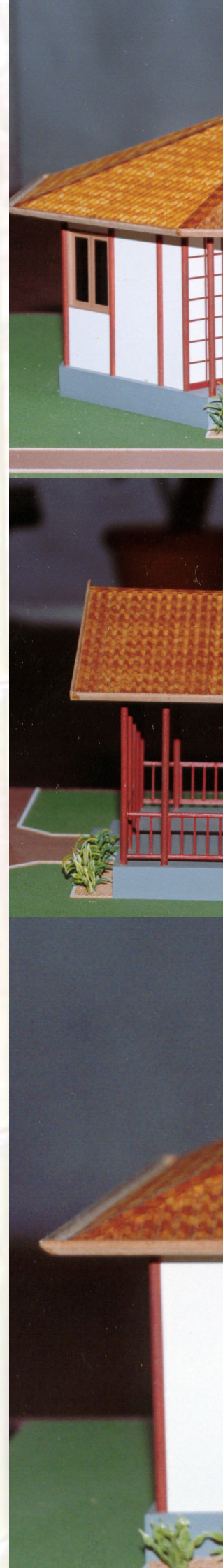
The Government of India has envisaged 'Housing for All by 2010', that means 3,30,00,000 houses to be built in next 10 years. Of the 3,30,00,000 houses 1,67,00,000 would be constructed in urban areas and 1,62,00,000 in rural areas. During next 10 years estimated investment in housing is likely to be 6,46,000 crores. The Rural Development Ministry has the mandate to construct 25 lakh houses every year and Urban Development Ministry has to construct 11 lakh houses every year. This comes to the target of constructing 36 lakhs houses every year to achieve the target of

3,30,00,000 houses by 2010. For growth of housing building materials and technology is a crucial component besides land and finance.

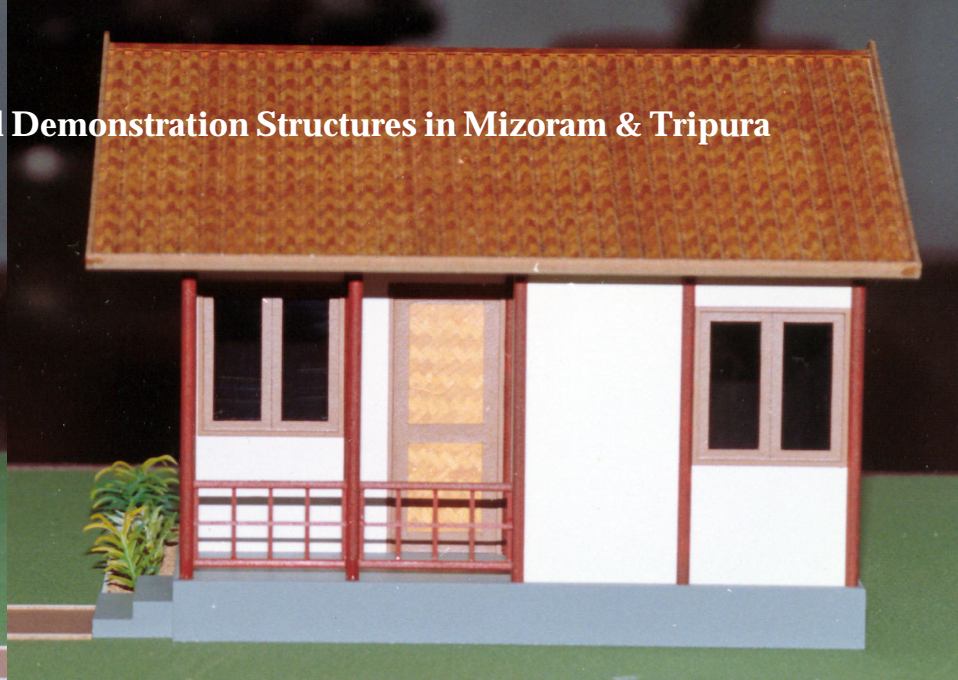
Assuming that an urban house will have an average area of 800 sq.ft. and cost of construction as Rs.450 sq.ft., the total investment on housing in urban areas on 11 lakhs houses will be of the order of Rs.39,600 crores. Similarly for a rural house, assuming an average area of 400 sq.ft. and the cost of construction at Rs.250 sq.ft. (since part labour is expected to be contributed by the family), the total investment per year in rural housing on 25 lakhs houses will be of the order of Rs.25,000 crores. The material and labour break up in the cost of construction of a house generally indicates that cost of timber items (excluding roof) used is 6 to 8%. Accordingly, the cost of timber used in urban housing and rural housing per year will be Rs.2320 crores for urban and Rs.2032 crores for rural. If we assume that 10% of the timber items can be substituted by bamboo based products then the investment of Rs.435 crores per year (Rs.232 crores on urban housing and Rs.203 crores on rural housing) can be expected thereby indicating that in housing alone bamboo products will have a share of Rs.435 crores per year at the current price level (see Table-1). Similarly the other types of buildings for community centres, schools, health care, tourism, etc. would also offer a large share for bamboo products having structural and non-structural applications.

Table - 1

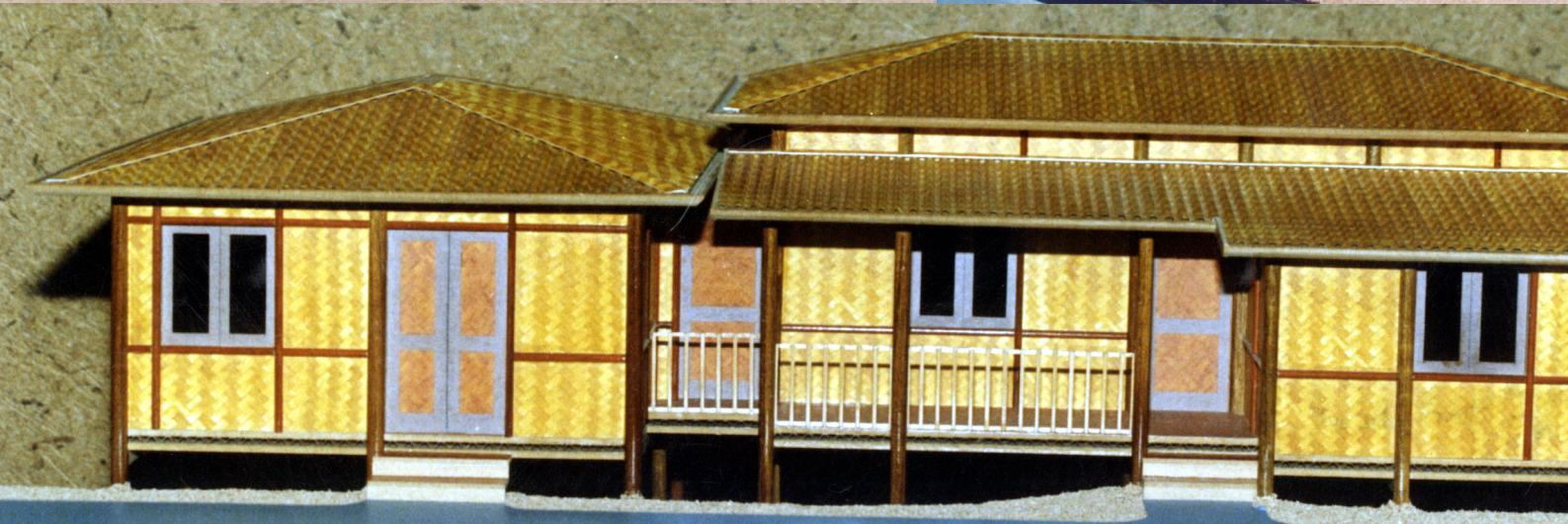
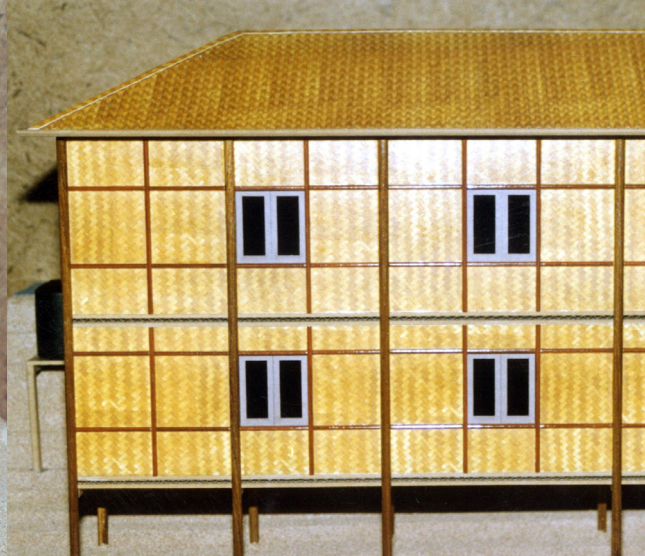
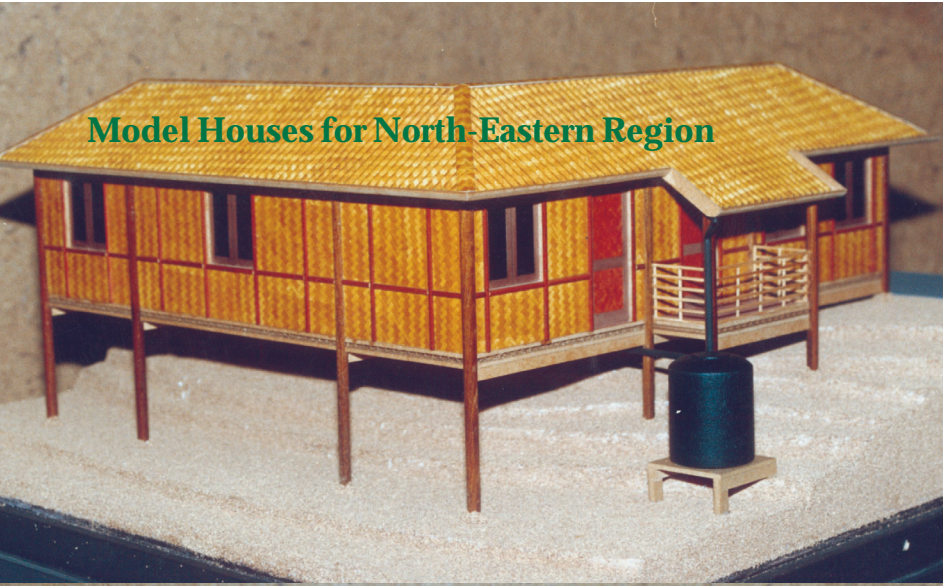
	Urban housing	Rural housing
No. of houses to be constructed per year	11 lakhs	25 lakhs
Average Area per house	800 sq.ft.	400 sq.ft
Plinth area cost of construction	Rs.450 per sq.ft.	Rs.250 per sq.ft.
Estimated Investment per year	Rs.39,600 crores	Rs.25,000 crores
Estimated cost of timber elements per house (6-8%) per year	Rs.2320 crores	Rs. 2032 crores
Assumed Share of bamboo application per year	10%	10%
Share of construction cost for bamboo application per year	Rs.232 crores	Rs.203 crores
Estimated share of bamboo in total investment for housing per year	Rs.435 crores	



Proposed Demonstration Structures in Mizoram & Tripura



Model Houses for North-Eastern Region





APPLICATION AREAS

Door Shutters

Assuming that each house would need atleast 4 door shutters in urban areas and 2 door shutters in rural areas that means 94,00,000 doors would be required annually. If bamboo based shutters are used even in 20% of houses then 18,80,000 doors based on bamboo would be required every year. The market size for 18,80,000 door shutters based on bamboo will be around Rs.197.40 crores only for housing.

Flooring

Bamboo flooring and bamboo board are newly developed interior designing material developed by using modern scientific methods from superior quality bamboo. Bamboo flooring is an attractive alternative to wood or laminate flooring.

Total area of the flooring for 11 lakhs houses in urban area and 25 lakhs houses in rural areas per year will be 6070 lakh sq.ft. Assuming that bamboo flooring is able to penetrate 10% of the market per year then the demand for bamboo flooring will be 607 lakh sq.ft. The market size for bamboo flooring in monetary terms will be around Rs.303.50 crores per year (see Table-2).

Table-2

	Total no. of houses	Area of flooring available (lakh sq.ft.)	Assuming 10% of flooring to be replaced by bamboo flooring (lakh sq.ft.)	Cost of bamboo flooring per sq.ft. (Rs.)	Cost of flooring using bamboo (Rs.in lakhs)
Urban	11 lakh	3520	352	50	17600
Rural	25 lakh	2550	255	50	12750
Total	36 lakh	6070	607		30350

Shuttering and Scaffolding

Of 13.47 million tons of bamboo, currently being consumed in the country, 3.4 million tons is used for scaffolding alone.

If 10% of the centring, shuttering and scaffolding is to be replaced by

bamboo shuttering and scaffolding in urban areas and 50% of the shuttering and scaffolding in rural areas then market potential in urban areas for centring, shuttering and scaffolding will be Rs.21.46 crore per annum and Rs.44.84 crore per annum in rural areas. Thus the total potential will be around Rs.66.30 crores (see Table-3).

Table-3

(Potential per annum)

	Centring shuttering (Rs. in crores)	Scaffolding (Rs. in crores)	Total (Rs. in crores)
Urban	8.19	13.27	21.46
Rural	9.84	35.00	44.84
Total	18.03	48.27	66.30

Roofing Sheets

Similarly, if 5% of 11 lakhs houses in urban areas and 15% of 25 lakh houses in rural areas are constructed every year using Bamboo mat Corrugated Sheets as roofing material then the 277.6 million sq.ft. of bamboo sheets would be required. One manufacturing unit with capacity of 72000 sheets (4'x8') per annum in 2 shifts would produce roofing material measuring 2.30 million sq.ft. that means nearly 120 manufacturing units would be required to produce required number of sheets per year (see Table-4A). Or if one manufacturing unit with production capacity of 50% units at 6000 per month in 2 shifts and 50% units of 16000 per month in 2 shifts will produce 4.22 million sq.ft. that means 66 manufacturing units would be required to produce required number of sheets per year (see Table-

4B). Or if one manufacturing unit with production capacity of 1,92,000 sheets per annum in 2 shifts will produce 6.14 million sq.ft. then 45 manufacturing units would be required to produce required number of sheets per year (see Table-4C).

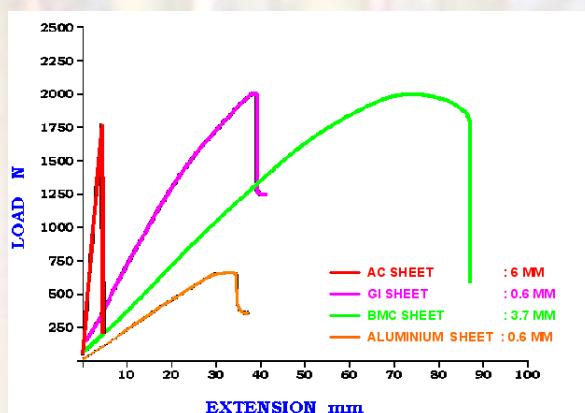


Table - 4A:
Comparative Strengths of various Corrugated Roofing Sheets

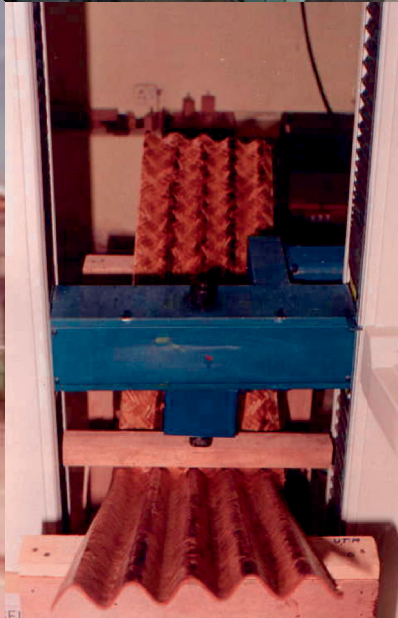


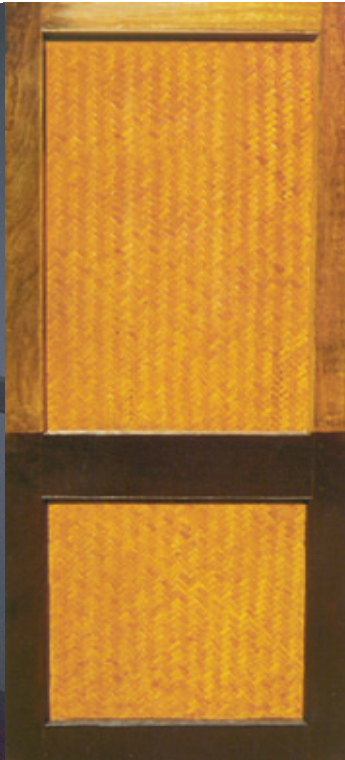
Some Important Properties of BMCS

Size	1.05m X 1.8 m X 3.5 mm
Weight	6.5 – 7.90 kg/sheet (app. half that of ACCS)
Load Bearing Capacity	4.8 N/mm width
Deflection at Breaking Point	85 mm
Thermal Conductivity	0.1928 k cal/m °c (app. half that of ACCS)
Fire Resistance	Conforms to flammability test
Energy Requirement	Highly Energy Efficient

Comparison of properties of BMCS with other alternatives

	Thickness mm	Width mm	Maximum Load N	Load bearing Capacity N/mm	Weight of sheet (1.05 m x 1.8 m) Kgs.
BMCS (4-layers)	3.7	400	1907	4.77	7.2
G.I.Sheet	0.6	400	1937	4.84	7.7
Aluminium Sheet	0.6	405	669	1.67	2.9
ACCS	6	330	1800	5.45	15.85





PRODUCTION CAPACITY 72000 SHEETS (2.30 MILLION SQ.FT.) PER ANNUM (2 SHIFTS PER DAY)

Type of Houses	No. of Houses to be constructed per annum	% of houses constructed with BMCS per annum	No. of houses constructed with BMCS per annum	No. of BMCS Sheets required per house	BMCS Sheets required	No. of Units required
Urban	11,00,000	5	55,000	35	19,25,000	120 Units
Rural	25,00,000	15	3,75,000	18	67,50,000	
					86,75,000	

Table - 4B:

PRODUCTION CAPACITY OF 50% UNITS AT 3000 PER MONTH PER SHIFT OR 6000 PER MONTH 2-SHIFTS AND 50% UNITS OF 8000 PER MONTH PER SHIFT OR 16000 PER MONTH 2-SHIFT i.e. 1,32,000 SHEETS (4.22 MILLION SQ.FT.)

Urban	11,00,000	5	55,000	35	19,25,000	66 Units
Rural	25,00,000	15	3,75,000	18	67,50,000	
					86,75,000	

Table - 4C:

PRODUCTION CAPACITY 1,92,000 SHEETS (6.14 MILLION SQ.FT.) PER ANNUM (2 SHIFTS PER DAY)

Urban	11,00,000	5	55,000	35	19,25,000	45 Units
Rural	25,00,000	15	3,75,000	18	67,50,000	
					86,75,000	

Substituting ACC/GP/GI Sheets by BMCS

Total annual production of ACC and GP/GI sheets in India is 170.56 crore sqm. If 1% of this is replaced with Bamboo Mat Corrugated Roofing Sheets (BMCS) then area covered with BMCS will be 1.7 crore sqm. To cover this area 57.35 lakhs bamboo sheets would be required. If a plant with a production capacity of 72000 sheets per annum in 2 shifts is installed then 80 units will be required. Or if a plant with production capacity of 1,32,000 sheets per annum in 2 shifts is installed the requirement of units will be 43. Or if a plant with production capacity of 1,92,000 sheets per annum in 2 shifts is installed then 30 units will be required (see Table-5).

Table-5

Annual Production in India (sqm.)	Percentage replacement with BMCS	Area covered by BMCS per annum (sqm)	No. of sheets required per annum	No. of units required			
				Production capacity 72000 sheets per annum (2 shifts per day)	Production capacity of 50% units at 6000 per month per 2 shifts and 50% units of 16000 per month per 2 shift i.e. 1,32,000 sheets per annum	Production capacity 1,92,000 sheets per annum (2 shifts per day)	
Type of Sheets							
ACC sheets	GP/GI sheets	1	1,70,56,203	57,35,148	80	43	30
1386529412	319090909						
Total	1705620321						

EMPLOYMENT GENERATION THROUGH ESTABLISHMENT OF BAMBOO MAT PRODUCTION CENTRES AS FEEDER UNITS FOR BAMBOO MAT BASED COMPONENT MANUFACTURING UNITS

Bamboo mats are the main raw material for manufacture of Bamboo Mat Corrugated Sheets (BMCS). As bamboo mats are woven mainly by rural women in bamboo producing regions, the activity provide gainful employment to them throughout the year. Virtually they can weave money at home as part of the process for production of mat. The splitting and slivering can be partly mechanized, resulting in increased production and promotion of entrepreneurial culture in rural areas and enhanced market potential for bamboo mats. The total employment potential for 30 BMCS manufacturing units is estimated to be 16 million man days during one year in mat weaving alone.

Considering the demand being generated by the market potential of the BMCS, there is need to establish Bamboo Mat Production Centres as Feeder Units for bamboo mat based component manufacturing units to enhance the productivity with improvement in quality of mats in different sizes. The Feeder Unit will provide right quality mats to the BMCS units. BMTPC proposes to establish these Feeder Units in the States of Mizoram, Tripura, Meghalaya and Assam. A proposal for the same is under consideration of Department of Development of North Eastern Region (DONER).

Activities Planned

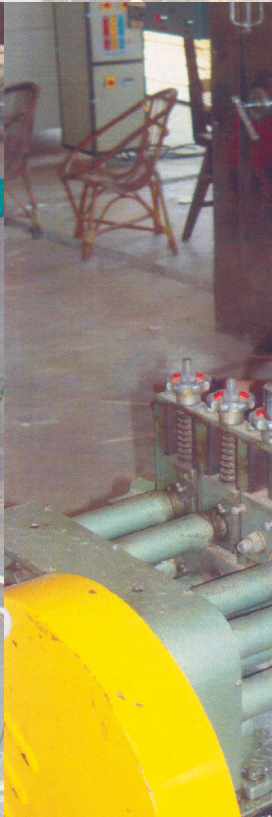
1. Setting up of Bamboo Splitting and Slivering Units and linking them with manufacturing units of bamboo based building materials;
2. Providing entrepreneurs information on technologies, machinery & equipment for setting up manufacturing units on commercial scale;
3. Promotion of establishment of Building Material Centres/Banks/Marts and help in providing appropriate customised infrastructure support;
4. Development and design of new products/components suitable for application in building construction and providing focussed support to promote entrepreneurship for taking up production at commercial level;
5. Development of training manuals in local languages for wider dissemination of the bamboo technology.

Machines Required for establishing BMCS Feeder Units

1. Bamboo cross cutting machine
2. Bamboo splitting machine
3. Bamboo knot removing, width sizing and planning machine
4. Bamboo slicing and inside knot removing machine
5. Bamboo sliver making machine
6. Manual bamboo splitting tools
7. Grinding machine for sharpening the cutters
8. Trolleys
9. Measuring instruments

Training

BMTPC jointly with IPIRTI have provided training to tribal members of a Society in Karnataka, in selection of right type of bamboo, improving the same for splitting and making slivers of desired size. So far 75 members have been trained. The training programme was designed in such a way that trainees can acquire knowledge about the operation of the machinery used for bamboo processing and its application. The trainees showed





lot of enthusiasm and started operating the machines themselves without the help of training staff. The trainees opined that, use of machineries for bamboo processing not only relieves of their durgery but also improves their income generation and that instead of weaving 1-2 mats in a day, they can weave 4-6 mats per day, if the machines made slivers are made available to them. They also opined that the quality of the mats will also improve using machineries made slivers.

List of Indian Standards related to Bamboo as Construction Material

IS 13958:1994 Specification for Bamboo Mat Board for general purposes.

IS 14588:1999 Specification for Bamboo Mat Veneer Composite for general purposes.

Indian Standards on Specification for Bamboo Mat Corrugated Sheet has been finalised under CED 20 - yet to be printed.

FOCUS AREAS OF ACTIVITY OF BMTPC

- * Commercial viability of manufacturing technologies of composite building materials from local resources
- * Working models of simple machinery and equipment developed in India for production of building materials and components for housing
- * Potential for utilisation of agro-industrial wastes and natural fibres in the production of building materials
- * Cost-effective and innovative planning, design and construction methods of housing for different income groups.
- * Technology options for rural and urban housing
- * Disaster resistant construction technologies for regions prone to earthquakes, cyclones, wind storms and floods.
- * To mobilise cooperation & partnerships with R&D, financial & construction agencies and with design, planning & development professionals and entrepreneurs.
- * To promote environment friendly and energy efficient manufacturing technologies through certification and validation services.

The Bamboo is an important resource in the Indian socio-economic-cultural-ecological-climatic-functional context with 1500 recorded uses. It is a fast growing, wide spread, renewable, versatile, low-or-no cost, environment-enhancing resource with potential to improve livelihood security in the years to come, in both rural and urban areas. Apart from its traditional uses bamboo has various new applications as an alternative to rapidly depleting wood resources and as an option to more expensive materials.

Recognizing the potential of bamboo and the fact that it has been subjected to neglect, and thus remain disorganised with poor market linkage and sub optimal level technology application for manufacture of value added products in the industrial and artisanal sector, the National Mission on Bamboo Technology & Trade Development has formulated an Action Plan to upgrade the bamboo economy by according bamboo development a strategic role in rural development, poverty alleviation and bamboo based handicrafts & industrial development. This is to be achieved under an integrated programme of expansion of plantation, of bamboo species on selective basis, with a view to reaching the markets and utilization centres, scientific management with the involvement of JFM committees, Self Help Groups (SHGs), and assisting the industry to access & apply modern technology for producing globally competitive new generation bamboo products.

As the market for environment friendly “green” products is growing, India must try to secure her due share in the world bamboo market which is expected to grow from the present size of US\$10 Billion to over US\$20 Billion by 2015, if we could expand the bamboo economy steadily to the level of Rs.26,000 crore by the 2015, from the level of about Rs.2000 crore.

I am confident that the Mission will realize the full potential of bamboo to benefit the socio-economic development and environmental sustainability of the country.

Dr.D.N.Tiwari
Member, Planning Commission
Government of India

For starting commercial production of bamboo based products, the prospective entrepreneurs may contact the Adviser, National Mission on Bamboo Applications, TIFAC, Deptt. of Science & Technology, D-3, Qutub Hotel, New Mehrauli Road, New Delhi.

The **Building Materials and Technology Promotion Council (BMTPC)** was setup in 1990 as an inter-ministerial apex organisation to develop and operationalise a comprehensive and integrated approach for technology development, transfer and investment promotion to encourage application of environment-friendly & energy-efficient innovative materials, manufacturing technologies and disaster resistant construction practices for housing and buildings in urban and rural areas.

The Council with its multi-disciplinary character is structured to promote investment and technology transfer nationally and internationally by networking its activities with institutions, centres of excellence and expert groups engaged in R&D, standardisation, housing finance, industrial promotion. The Council supports strengthening of SMEs in the building materials sector through development and promotion of eco-friendly and energy-efficient products, manufacturing technologies and appropriate support service to entrepreneurs.

BMTPC and IPIRTI, Bangalore have jointly developed a technology for manufacturing of Bamboo Mat Corrugated Sheets (BMCS) considering the need for developing alternate environment-friendly and cost effective roofing materials for bamboo growing areas in the country.



**Building Materials and
Technology Promotion Council**

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