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Bamboo: Eco-Friendly Building Material in Indian Context

Engineering

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ABSTRACT

The diminishing wood resource and reduction in natural forests, particularly in the tropics, have focused world attention on the need to identify a substitute building material that should be renewable, environment friendly and widely available. In view of its rapid growth, a ready adaptability to most climatic conditions and properties, superior to most new fast growing wood, bamboo emerges as a very suitable alternative. This paper deals with some of the main properties and the major uses of bamboo and its culms. It also recommends on the various preservation techniques to be adopted in order to enhance the durability and various Indian Standard codes (IS codes) for bamboo and bamboo products.

INTRODUCTION

Bamboo has a long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. It is widely used for many forms of construction, in particular for housing in rural areas. Bamboo is a renewable and versatile resource, characterized by high strength and low weight, and is easily worked using simple tools. It is widely recognized as one of the most important non-timber forest resources due to the high socio-economic benefits from bamboo based products. It is estimated that there are 1200 species growing in about 14.5 million hectares area. Most of them grow in Asia, Africa and Latin America.

Bamboo is the world's fastest growing woody plant. It grows approximately 7.5 to 40cm a day, with world record being 1.2m in 24 hours in Japan. Bamboo grows three times faster than most other species. Commercially important species of bamboo usually mature in four or five years in time, after which multiple harvests are possible every second year, for up to 120 years in some species and indefinitely in others. Bamboo also excels in biomass production, giving 40 tons or more per hectare annually in managed stands. It accounts for around one-quarter of biomass produced in tropical regions and one-fifth in subtropical regions.

It has been used successfully to rehabilitate soil ravage by brick making in India, and abandoned tin-mine sites in Malaysia. It shelters top soil from the onslaught of tropical downpours, preserves many exposed areas, providing micro-climate for forest regeneration and watershed protection it is often introduced into the banks or streams or in other vulnerable areas, for rapid control of soil erosion; one bamboo plants closely matted roots can bind up to six cubic meters of soil.

SCENARIO OF BAMBOO IN INDIA

TABLE: - 1
FOREST COVER IN INDIA

DESCRIPTION	FOREST COVER IN INDIA
Land area	329 m hectares
Notified as forest	63.34 m hectares- 19.15%
Dense forest	11%
Open forest	8%
Mangrove	0.15%

Therefore, there is a need to save forest timber.

BAMBOO RESOURCES IN INDIA

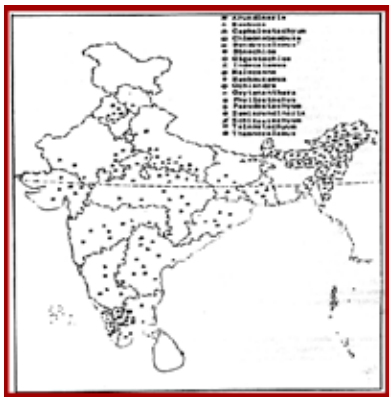

Figure: 1 Regions showing bamboo production
Source: www.bmtpc.org

The Land area 329 mha, forest area 63.3 mha, bamboo area 8.96mha, 67% clump forming and 33% non-clump forming. India is home to almost 45 % of world's bamboo forests 4.5 m tons annually produced from 8.96 m ha.

MAJOR BAMBOO GROWING REGIONS / STATES

TABLE: 2
MAJOR BAMBOOS GROWING REGIONS / STATES

STATE	AREA (%)	GROSS SHARE
North East	28.0	66
Madhya Pradesh	20.3	12
Maharashtra	9.9	5
Orissa	8.7	7
Andhra Pradesh	7.4	2
Karnataka	5.5	3
Other States	20.2	5

Source: - Madhab Jayanta (2003)
(http://agricoop.nic.in/AgriMinConf/National_hort_Mission.ppt.)

TABLE: 3
STATUS OF BAMBOO RESOURCES IN - NORTH-EASTERN REGION

STATE	BAMBOO GROWING AREA (SQ.KM.)	BAMBOO STOCK (MT)
Mizoram	9210	10.89
Assam	8213	13.41
Arunachal Pradesh	4590	9.84
Manipur	3692	11.47
Meghalaya	3102	4.41
Tripura	939	0.86
Nagaland	758	3.66
Total	30504	54.53

Source: - www.bmtpc.org

DISTRIBUTION OF SOME IMPORTANT BAMBOO SPECIES IN INDIA
TABLE: 4
DISTRIBUTION OF SOME IMPORTANT BAMBOO SPECIES IN INDIA

SPECIES	AVAILABILITY (%)	STATES
D. Strictus	45	Meghalaya, Manipur, Nagaland, Orissa
M. Baccifera	20	Assam, Manipur, Meghalaya, Mizoram,
B. Arundinacia	13	Nagaland, Karnataka, Orissa
D. Hamiltonii	7	Arunchal Pradesh, Assam, Nagaland
B. Tulda	5	Arunachal Pradesh, Nagaland, Tripura
B. Pallid	4	Arunachal Pradesh, Nagaland, Tripura

Source: - www.bmtpc.org

MAJOR USES OF BAMBOO
TABLE: 5
MAJOR USES OF BAMBOO

USE	PERCENT CONSUMPTION
Paper Pulp	35.0
Housing	20.0
Non-Residential	5.0
Rural uses	20.0
Fuel	8.5
Packing, including baskets	5.0
Transport	1.5
Furniture	1.0
Other wood industries	1.0
Others, including ladders etc.	3.0

Source: - Tewari, D.N. (1992)

PROPERTIES OF BAMBOO

Tensile Strength

Bamboo is able to resist more tension than compression. The fibres of bamboo run axial. In the outer zone are highly elastic vascular bundles that have a high tensile strength. The tensile strength of these fibres is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicate outer skin, axial parallel elastically fibers with a tensile strength up to 400 N/mm2 can be found. As a comparison, extremely strong wood fibers can resist a tension up to 50 N / mm2.

Compressive Strength

Compared to the bigger tubes, slimmer ones have got, in relation to their cross-section, a higher compressive strength value. The slimmer tubes possess better material properties due to the fact that bigger tubes have got a minor part of the outer skin, which is very resistant in tension. The portion of lignin inside the culms affects compressive strength, whereas the high portion of cellulose influences the buckling and the tensile strength as it represents the building substance of the bamboo fibers.

Elastic Modulus

The accumulation of highly strong fibers in the outer parts of the tube wall also work positive in connection with the elastic modulus like it does for the tension, shear and bending strength. The higher the elastic modulus, the higher is the quality of the bamboo. Enormous elasticity makes it a very useful building material in areas with very high risks of earthquakes.

Anisotropic Properties

Bamboo is an anisotropic material. Properties in the longitudinal direction are completely different from those in the transversal direction. There are cellulose fibers in the longitudinal direction, which is strong and stiff and in the transverse direction there is lignin, which is soft and brittle.

Shrinkage

Bamboo shrinks more than wood when it loses water. The canes can tear apart at the nodes. Bamboo shrinks in a cross section of 10-16 % and a wall thickness of 15-17 %. Therefore it is necessary to take necessary measures to prevent water loss when used as a building material.

Fire Resistance

The fire resistance is very good because of the high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside.

Bamboo's Extreme Strength

Bamboo is heartier than oak and stronger than steel, yet grows out of the ground like a weed. It's flexible and lightweight, but stronger than most hardwoods. Bamboo's strength is often compared to maple wood, one of the strongest hardwoods available. Though bamboo is naturally water-resistant, its treatment process further increases its water resistance, so you don't have to worry about warping.

Affordability

Because it is so sustainable and easy to grow, bamboo is more affordable than most wood. It can be easily grown and harvested, so it is one of the cheapest construction materials around.

Exotic Look

Bamboo looks wonderful, adding a natural tone to anything you use it for. It makes great outdoor decoration and can be used as quality fencing for privacy and security. Bamboo adds an island look to your home that's natural and exotic.

Versatility

The uses of bamboo are extremely versatile. It can be used as a construction substitute for any sort of wood, and has been fashioned into skateboards, bicycles and bike helmets because of its light weight and durability. Its many uses make bamboo perfect for fencing, flooring, building posts and house walls.

TABLE: 6
SPECIFIC PROPERTIES OF BAMBOO

PROPERTY	VALUE
Specific gravity	0.575 to 0.655
Bond stress	5.6kg/cm2
Safe working stress in shear	115 to 180kg/cm2
Safe working stress in tension	160 to 350kg/cm2
Safe working stress in compression	105kg/cm2
Ultimate compressive stress	794 to 864kg/cm2
Modulus of Elasticity	1.5 to 2.0 x105kg/cm2

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Modulus of rupture	610 to 1600kg/cm2
Average weight	0.625kg/m

Source: - www.bmtpc.org

USES OF BAMBOO IN CONSTRUCTION INDUSTRY

Through research it has been found that some species of bamboo have ultimate tensile strength same as that of mild steel at yield point and this coupled with other merits boosts the usage of bamboo as construction material. Bamboo is a versatile material because of its high strength-to-weight ratio, easy workability and availability. Bamboo needs to be chemically treated due to their low natural durability. It can be used in different ways for roof structure as purlins, rafters and reapers, for flooring, doors and windows, walling, ceiling, man-hole covers etc.

Bamboo Trusses

The bamboo has strength comparable to that of teak and SAL. An experiment with the construction and testing of a 4m span truss made of round bamboo and different jointing techniques for web-chord connections gave results that were matching with the strength of timber.

Bamboo Roofs Skeleton

It consists of bamboo truss or rafters over which solid bamboo purlins are laid and lashed to the rafter by means of G.I.wire. A mesh of halved bamboo is made and is lashed to the purlins to cover the roof.

Bamboo walling/ceiling

As the bamboo material is light in weight it is more advantageous in earthquake prone areas as its chances of falling are very less and even if it falls it can be re-erected easily with less human and property loss with least efforts and minimum cost. Bamboo walls can be constructed in different modes like Whole stem, halved or strips of bamboo can nailed to one or both the sides of the bamboo frame Split bamboo mats can be fastened to the bamboo posts or mats can be woven, mud can also be applied to both sides of such mats Bamboo strips nailed to bamboo frame or posts for interior walling Cement or lime plastering can be done on the mud covering for better appearance and hygiene. It has been found that the bamboo in the vertical position is more durable than in horizontal direction. For partition walls only single layer of bamboo strips are used.

Bamboo Doors and Windows

Bamboo frames can replace timber frames appropriate to function. Bamboo mat shutters fixed to bamboo frame or a panel of bamboo board fixed to the frame which is hinged to the wall can be used as door. Small framed openings hinged to the top in the wall can serve as windows.

Bamboo Flooring

Bamboo can be used as flooring material due to its better wear and tear resistance and its resilience properties. Whole culms act as frame work and the floor covering is done using split bamboo, bamboo boards, mats etc by means of wire lashing these to the frame.

Reed Boards

Reed boards are made by flat pressing the reed at high temperatures. These reed boards are used in elements like flooring, walls, ceiling and roofing. They can also be used for partitions, doors, windows etc.

Scaffolding

Bamboo poles lashed together have been used as scaffolding in high rise structures due to their strength and resilience. The timber planks can be replaced with bamboo culms and these can be lashed to the vertical culms.

Bamboo Based Panels

China started producing bamboo panels in the early 19th century. At present more than 20 different types of panels are produced in Asia. Bamboo fibre is longer than wood fibre, which gives bamboo some technological advantages. The panels are widely used in modern construction as structural elements or as forms for concrete mouldings. They are also used for flooring, roofing, partitions, doors and window frames. Bamboo panels have some advantages over wooden board due to their rigidity and durability. Various types of bamboo veneers, panels and boards can be broadly classified as follows: veneers, strip boards, mat boards, fibreboards, particle boards, medium density boards, combinations of these, and combinations of these with wood and other ligno-cellulose materials and inorganic substances. Composites of bamboo and jute are also possible to make panels.

Bamboo Flooring

Bamboo flooring is a quality product that can be used widely and has a large, global consumer market. It has certain advantages over wooden floors due to its smoothness, brightness, stability, high resistance, insulation qualities and flexibility. Bamboo flooring has a soft natural luster and maintains the natural gloss and elegance of bamboo fibre. This flooring is attractive to the demanding markets in Europe, Japan and North America. The estimated annual production of bamboo flooring in China was 17.5 million square meters in 2004, with about 65% being exported (Customs General Administration of China, 2004).

Bamboo Sticks for Blinds and Incense Industry

The art of making screens and blinds from bamboo is not new to India. For centuries, people have woven elegant screens from bamboo that have provided privacy, protection from the sun and added aesthetic appeal to living spaces. Mechanized blind making units can be economically viable enterprises. Again, bamboo sticks making units can substitute the wood that is used in the incense stick, and that industry in India is estimated to be worth US$400 million. It can also be used in match sticks.

Bamboo Furniture

Traditional bamboo furniture uses natural round or split bamboo. A new type of 'pack-flat,' 'knockdown' furniture uses glue-laminated bamboo panels. Unlike the traditional design, this furniture may be shipped in compact flat packs, to be assembled on the spot. The new design overcomes many of the problems of traditional bamboo furniture, such as high labour and transportation costs, low productivity, instability, varying quality and susceptibility to insects and fungi. At the same time, it retains the distinct physical, mechanical, chemical, environmental and aesthetic features of bamboo. Export of laminated bamboo furniture is growing rapidly. However, trade statistics currently do not capture the value, owing to the absence of a special code for bamboo furniture. It is usually classified as wooden furniture.

INDIAN SPECIFICATIONS (IS CODE) FOR BAMBOO & BAMBOO PRODUCTS

TABLE: 7
INDIAN SPECIFICATIONS (IS CODE) FOR BAMBOO & BAMBOO PRODUCTS

IS CODE	SPECIFICATIONS FOR BAMBOO & BAMBOO PRODUCTS
IS 14588: 1999	Specification for Bamboo Mat Veneer Composite for General Purposes
IS 13958: 1994	Specification for Bamboo Mat Board for General Purposes
IS 1902: 1993	Code of Practice for Preservation of Bamboo and Cane for non-structural purposes
IS 10145: 1982	Specification for Bamboo Supports for Camouflaging Equipment
IS 9096: 1979	Code of Practice for Preservation of Bamboo and Cane for Structural purposes
IS 8242:1976	Method of Tests for Split Bamboo
IS 8295:1976	Specification for Bamboo Chicks ; Part 1 Fine, Part 2 Coarse
IS 7344: 1974	Specification for Bamboo Tent Pole
IS 6874: 1973	Method of Tests for Round Bamboo
IS 15476: 2004	Specification for Bamboo Mat Corrugated Sheets

PREVENTION OF BAMBOO

Bamboo is subject to attack by microorganisms and insects in almost any construction applications. The decay and biodegradation of bamboo culms during outdoor storage can be checked to a great extent by adopting a good storage yard practices. Culms should be stacked horizontally over raised wall to facilitate water drainage and air circulation. For reed bamboos, vertical stacking results in a small gain in pulp yield over horizontal stacking because the former suffers less fungal damage. The service life of bamboo is therefore, mainly determined by the rate of attack. A variety of methods to improve the durability of bamboo have however, been developed. Basically, there are two methods for increasing the durability of bamboo.

NON CHEMICAL METHODS OR TRADITIONAL METHOD

Non-chemical methods are otherwise known as traditional methods of preservation are widely used by villagers and are usually done on bamboos used for structural purposes. However, the treatment cost is almost nothing and thus can be carried out at village level without special equipment. This method includes curing, smoking, whitewashing and soaking.

a) Smoking

Traditionally, bamboo culms are placed above fireplaces inside the house so that the smoke and heat rises up and both dries and blackens the culms. It is possible that the process produces some toxic agents that provide a degree of protection. Alternatively, the heat generated by the fire could possibly destroy or reduce the starch content of the parenchyma cells by pyrolysis. This is considered an effective treatment against insects and fungi.

b) White washing

Bamboo culms and bamboo mats for housing construction are often painted with slaked lime. This is carried out mainly to enhance the appearance, but there is also an expectation that the process will prolong the life of the bamboo structure by preventing moisture entering the culms. It is possible that the water or moisture absorption is delayed or in some cases prevented which will provide a higher resistance to fungal attack. In Indonesia, bamboo mats are tarred and later sprinkled with a layer of sand. When this is dry, upto 4 coats of whitewash are applied. Plastering is also a common practice using cow dung mixed with either lime or mortar.

c) Curing

Bamboo culms are treated during or immediately after extraction and before stacking in the storage yard. Curing involves harvested culms, with branches and leaves intact, in open air. The leaves continue to transpire causing the starch content of the culms to fail.

d) Soaking

The culms are submerged in either stagnant or running water or mud for several weeks. This is one of the best methods to preserve bamboo against the attack of microorganisms and insects.

CHEMICAL METHODS

Methods that use preservative chemicals are generally more effective than non-chemical methods in the protection of bamboo under storage, but they are not always economical or feasible. The penetration of liquids into the culms takes place through the vessels in the actual direction from end to end. The vessels account for only 5-10% the bamboo cross-section. Thus even when the vessels are filled to saturated point, the bamboo can still be vulnerable to fungal insect attack if the preservative does not diffuse sufficiently into the main tissue of the culms. The chemical treatment techniques are as follows:

a) Butt treatment

The butt ends of the freshly cut culms with the branches and leaves intact are placed in a drum containing the preservative. The continued transpiration of the leaves draws the chemical solution into the vessels of the culms. This process is very slow and often the vessels do not take up enough of the liquid to preserve by diffusion, the surrounding fibers and parenchyma cells. The preservative in the barrel must be replenished regularly in order to maintain the desired level. When the treatment has been completed, care should be taken in the disposal of the contaminated foliage. Butt treatment is usually adapted to bamboo posts.

b) Open tank method for cold soaking

This method is economical simple and provides good effective protection for bamboo. Culms, which have been prepared to size, are submerged in a solution of water-soluble preservative for a period of several days. The solution enters the culms through the ends and sides by means of diffusion.

c) Boucherie method

This method requires the culms to be in green condition. Best results are obtained when the bamboo is used during or shortly after the rainy season. The water transporting part of the culm can be penetrated completely and the treatment itself is applied by an inexpensive installation. Preservative is fed by gravity from a container placed at a higher level than the culms through pipes into the base ends. The treatment is terminated when the solution at the dripping end shows a sufficiently high concentration of chemicals. Allowing the bamboo to dry slowly in the shade for a period of at least two weeks after treatment ensures that the solution diffuses into all of the tissues surrounding the vessels.

d) Pressure treatment

Pressure treatment, using either creosote or water borne preservatives offers the best method of preservation for bamboo culms. The applied pressure ranges from around 0.5-1.5N/mm2 and as such requires special plants and equipment. Costs are high, but a service life upto 15 years can be expected from adequately treated bamboo when used in the open and in contact with the ground.

e) Hot and cold bath process

The bamboo is submerged in a tank of preservative, which is then heated, either directly over a fire or indirectly by means of steel coils in the tank. The bath temperature is raised to 90o C and maintained as such for 30 minutes and then allowed to cool. The bamboo should be allowed to dry slowly to provide further diffusion of the preservative to take place.

f) Glue line treatment

This is specific to bamboo mat board and involves adding preservatives to the glue during manufacture. Additives that have been shown to provide effective preservation treatment without impairing the bond strength of the mat include 1% chlordane or 1% sodium octaborate tetra hydrate with a 1:2 diluted pH solution containing 17% solid content.

ADVANTAGES OF BAMBOO

- The various advantages of bamboo are mentioned below.
- Light, strong and versatile.
- Light, strong, versatile.
- Environment friendly.
- Accessible to the poor.
- Self renewing resource
- Fast growing.
- Highly productive.

DISADVANTAGES OF BAMBOO

The major disadvantages of bamboo are as follows:

- Requires preservation
- Shaped by nature
- Durability- bamboo is subjected to attack by fungi, insects; for this reason, untreated bamboo structures are viewed as temporary with an expected life of not more than 5 years.
- Jointing- although many jointing techniques exist, their structural efficiency is low.
- Lack of design guidance and codes.
- Prone to catch fire very fast by the friction among the culms during wind, and is seen to cause forest fires.

CONCLUSION

Since time immemorial, bamboo has played an important role in the development of mankind. It is used for a wide range of

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day-to-day purposes, both as a woody material and as food. It has been the backbone of much of the world's rural life and will remain so as the population increases. Bamboo will continue to play an important part in the development of enterprises and the transformation of rural environments, in all regions of the developing world where it grows.

On account of the enforcement of our natural forest protection project, wood is becoming increasingly scarce. The realization that bamboo is the most potentially important non-timber resource and fast-growing woody biomass, has evoked keen interest in the processing, preservation, utilization and the promotion of bamboo as an alternative to wood. The properties as top grade building material and increased availability of bamboo in our country makes it possible to use, bamboo in the field of construction extensively. Its high valued utilization not only promotes the economic development, but also saves forest resources to protect our ecological environment as a wood substitute.

As an economic building material, bamboo's rate of productivity and cycle of annual harvest outstrips any other naturally growing resource, if today you plant three or four structural bamboo plants, then in four or five years later you will have mature clumps, and in eight years you will have enough mature material to build a comfortable, low cost house.

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