

# Bamboo Architecture in India and Its Acceptability in Contemporary Times

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**ABSTRACT:** India is the second largest producer of bamboo in the world and has vast traditional knowledge of bamboo, with one of the best bamboo artisan communities in the world. Use of Bamboo for buildings is part of an age-old tradition in India. Because of the distribution of various climatic zones in India, the species of bamboo found in each state are quite different. Hence, India has various bamboo building typologies across the country depending on the climatic zone and the species found in the particular state. This paper will chart the various traditional typologies of bamboo buildings in India and their evolution through time to the present, influenced by the new interest, research, policy framework and development in the material globally. The paper will also discuss the issues that have been hindering the acceptability of bamboo as a preferred material for modern architecture, and our strengths that will enable us to emerge as a major contributor to the bamboo building sector in the future.

**Key words:** Bamboo, Building, Typology, Architecture, Policy, Issues, Materials

## I. INTRODUCTION

With the Global warming issues raging the globe, and the construction sector being a major contributor, scientists across the globe are looking towards low energy, resource efficient building materials and technologies for solving the problem of keeping the pace of development with minimum carbon imprints. A sustainable building should be resilient to the extreme conditions and building material alternatives must be searched without endangering the safety of the built-form.

Tropical and sub tropical regions have the largest housing and infrastructure deficit and are also the sites of major natural disasters. It is in view of these facts, world has started looking for sustainable materials like bamboo as a viable solution for the building sector. Bamboo is now being hailed as the future sustainable material

through research, development and usage across the globe. Majority of the knowledge of bamboo building technologies is based on cultural traditions. India has a rich and diverse tradition of bamboo buildings with various indigenous technologies. In order to develop it as a modern sustainable building material, in both technical and cultural sense, we need to evaluate traditional building techniques technologically and develop them with design and performance assessment to resolve the issues.

India is still far behind the world in adopting the newly developed bamboo building construction technologies for mainstream buildings. Several research institutes are working on bamboo building systems, but the lab to land transfer is very slow. Alternative technologies need to be seriously viewed in the light of global warming and rising inflation. But the question persists - how far do these alternative materials and technologies match up with the conventional ones? What makes people hesitant to build a bamboo house?

This paper tries to find answers to these questions and connect the dots, to explore the reasons for unacceptability, of a material proven for its worthiness, with all its attributes and unique qualities, certified by experts in its multiple applications in the building sector in India, where it is hardly being acknowledged as a strong alternative.

## II. LITERATURE REVIEW

The plant known as bamboo to the entire world has been around and used for centuries. Records dating back more than seven thousand years talk about products made of bamboo such as arrows, paper, building materials, and books. Because of its origins, the current way it is used, and the economic sustainability of the plant, bamboo is an excellent resource.

While bamboo grows everywhere in the world except those places with extremely cold

climates, it is thought to have originated in Southern East Asia, where the first use of bamboo to make every day items was recorded. This tall, hearty plant was used for as many products, as it was a quickly renewable resource.

### 2.1 Characteristics of Bamboo as a Plant

Bamboos are a group of woody perennial evergreen plants in the true grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. (Cronquist,1988) Bamboos can be classified into 47 genera and 1250 species (Ueda 1960), whereas, according to (McClure,1966), there are 63 genera and about 700 species of bamboos in the world. The classification of bamboos is done on the basis of various criteria such as vegetative structures, anatomical characters like epidermal features, arrangement of the vascular bundles, structures of bud sheaths and leaves and the morphology of the culms.

The vascular bundles of bamboos are not arranged in the ring-form along annulus like a tree but irregularly in the cross-section. Although it is classified to the grasses, all bamboos have the material characters of wood in their stems (culms): they are very hard on the surface, grow straight and tall (can reach 35 m with *Phyllostachys pubescens*) and its diameter can reach over 30cm with *Dendrocalamus giganteus*.

### 2.2 Characteristics of Bamboo as a material

Material bamboo is the bamboo plant after its “harvest” which is done at different stage of plant growth as per the requirement. As material, bamboo means mostly the Culm, when the material properties of bamboos are discussed, it mostly means the properties of the Culm. The material properties explain how the bamboo plant changes to bamboo material. This study will provide different perspectives, namely chemical, physical, mechanical and processing.

#### 2.2.1 Chemical properties

The chemical properties influence the growth and the mechanical properties of bamboos. Through the chemical analysis more information on the taxonomical identification and propagation can be obtained. The chemical composition of bamboos also has an influence on deciding what kinds of bamboos with which kind of material in combination is suitable for the utilizations.

Bamboo consists mainly of cellulose, lignin and hemicelluloses which are not different to that of trees. The difference lies in the percentages of each component and their micro structures. Some minor chemical components are resins, tannins, waxes and inorganic salts. This chemical composition changes according to the species, the age and the parts of bamboo. The variation of bamboo’s chemical composition has a big influence on the physical and mechanical properties of bamboos and therefore the treatment and utilization of bamboos (Liese,1985).

	Cellulose (%)	Lignin (%)	Hemicellulose (%)
bamboo	55	25	20
softwood	50	25	25

Comparison of chemical compositions of bamboo and softwood. (Janssen, 1981)

#### 2.2.2 Physical properties

- Specific gravity : The specific gravity of bamboo ranges between 0.5 and 0.8 g/cm<sup>3</sup> (oven-dry weight). This value increases from the central parts to the peripheral parts of the Culm and from the bottom to the top (Liese 1985).
- Moisture content: Moisture content influences the utilization of bamboo in a similar way like that of wood. The moisture content of bamboo depends on: 1. Bamboo species: the different species have a different amount of parenchyma cells which correlate to the water holding capacity (Liese & Grover 1961). 2. Culm zones: the base has a higher value than the top. The inner part of the Culm cross section has a

- higher value than the outer part. 3. Nodes or internodes: the nodes have a lower value than internodes (up to 25%). 4. Seasons: at the end of the rainy season it is much higher than at the end of the dry season; 5. Age of the cane: the young Culm has a higher and more uniform moisture content than the mature one (Dunkelberg,1985). After the harvesting the moisture of bamboos can be influenced by the humidity and dryness of the environment.
- Dry shrinkage: Unlike wood bamboo begins to shrink from the beginning of drying. The process is not regular and will stop at about 40% moisture content. After the bamboo is cut, its moisture content decreases and the dry shrinkage begins. The dry shrinkage varies in

different directions. The dry shrinkage also increases from inner to outer parts. The dry shrinkage of the outer part of bamboo in length direction can be neglected, but the crosswise shrinkage is large. (Liese & Grover 1961).

- Resistance against pests : Bamboo has organic nutrients which are favourable to insects and microbes compared to wood. These organic substances are protein (1.5 – 6.0%), carbohydrate (2%), starch (2.0 – 6.0%), fat and wax (2.0 – 4.0%). (Zhang et al 2001). Under proper temperature and humidity bamboo is apt to be attacked by insects and fungi. There are traditional as well as modern methods to deal with this.

### 2.2.3 Mechanical properties

Species	Compression strength $\sigma$ (N/mm <sup>2</sup> )	Bending strength (N/mm <sup>2</sup> )	E Modulus (N/mm <sup>2</sup> )	Shearing strength (N/mm <sup>2</sup> )	Tensile strength $\sigma$ (N/mm <sup>2</sup> )
<i>Phyllostachys pubescens</i>	56	129.1	10500	13.9	196.0
<i>Guadua angustifolia</i>	56	74	19000	9	140

Mechanical properties of bamboo species *Phyllostachys pubescens* and *Guadua angustifolia*. (Steffans 2000 & Zhang 2001)

Compared to other building materials like wood, cement, steel and glass, bamboo has excellent mechanical properties, with which it can be a very good building material. The comparison

The studies on bamboo mechanical properties are commonly based on laboratory tests of the strength of bamboo (tensile strength, bending strength, compression strength, shear strength and modulus of elasticity) (Atrops 1969, Janssen 1981, Dunkelberg 1985). These tests show remarkable differing values when changing species, ages, moisture content, locations, soil and climatic conditions.

The variation of mechanical properties is similar to wood, but even more remarkable. This is one of the reasons why bamboo is difficult to be used in the industry. To show the material mechanical properties two bamboo species, *Phyllostachys pubescens* and *Guadua angustifolia*, which are most commonly used in building construction.

of bamboo to some other typical building materials in mechanical properties can be found in different references (Janssen 1981, Dunkelberg 1985).

Material	Working stress $\sigma$ (N/mm <sup>2</sup> )	E (N/mm <sup>2</sup> ) Modulus of elasticity	Working strain $\epsilon$ (10 <sup>-6</sup> )	Strain energy stored	
				J/m <sup>3</sup>	J/kg
concrete	8	25 000	300	1200	0.5
steel	160	210 000	800	64000	8.2
wood	7.5	11 000	700	2600	4.3
bamboo	10.7	20 000	500	2500	4.2

Material mechanical properties and strain energy stored. (ref. Janssen, 1981)

The research by Janssen (1981) shows that compared to concrete, steel and wood bamboo

has excellent mechanical properties with reference to material efficiency for strength (working stress per volume unit) and stiffness (E modulus per volume unit).

material	$\frac{\text{Working stress}}{\text{Weight by volume}}$	$\frac{E}{\text{Weight by volume}}$
concrete	$8/2400 = 0.003$	$25000/2400 = 10$
steel	$160/7800 = 0.02$	$210000/7800 = 27$
wood	$7.5/600 = 0.013$	$11000/600 = 18$
bamboo	$10/600 = 0.017$	$20000/600 = 33$

Source: Material efficiency for strength and stiffness. (ref. Janssen, 1981)

Some researchers try to analyze and calculate bamboo's mechanical properties by studying its molecule structure. Janssen developed a mathematic model of cells of bamboo Culm to calculate the mechanical properties, whose principle has been used in the research on mechanical properties of cell walls in wood (Janssen 1981). Ye (1995) studied the different mechanical properties in the outer, middle and inner parts of the bamboo Culm by studying the distributions of vascular bundles in these fields. These studies reveal the relationship between the micro structure of bamboo and its properties and help to form a better understanding of the mechanical properties of bamboo (Zhang et al 2001).

### III. TRADITIONAL BAMBOO ARCHITECTURE IN INDIA

In India, tribal communities dependent on bamboo for their livelihood, generally live close to the forests. Due to the climatic diversity across the country, the building materials and species of bamboo found in different climatic zone are quite diverse. Hence, the traditional building systems and typologies developed over several centuries in response to the local climate and available building materials are also quite diverse.

- North Eastern states - Riang houses, Mizo houses and Adi Gallong houses use bamboo as the primary material for construction.
- Bihar, Bengal and Orissa - Houses built with bamboo are found in rural and tribal areas only. Walls are made of mats of splits or flattened bamboo, with mud flooring on a plinth. In these, bamboo was also used as reinforcement in lime surkhi flat slabs in many places.
- In Central India, a traditional dwelling of bamboo has a walls are made of thick bamboo matt covered with mud plaster, thick bamboos are used for vertical support. The attic floor is made of bamboo mating, covered with mud plaster. The roof consists of wooden trusses, rafters and purlins of bamboo and covering of country tile or bamboo thatch. The timber doors and window frames with bamboo shutters, bamboo jail are used for lighting and ventilation.
- In the desert regions of Rajasthan and Gujrat, bamboo is used as reinforcement in walls, boundary walls and also in main roof structures.
- In South India, bamboo was used for walls in a wattle and daub system with composite mud plastering and roof structure in sloped roofs and flat lime surkhi roofs.

#### 3.1 Major Traditional Construction components of Bamboo Buildings of India :-

1. Foundation and Structure	<ul style="list-style-type: none"> <li>• Building on Stilts: Beam and Post system with bamboo in combination with local wood. In this case the flooring is made from bamboo in various ways.</li> <li>• Local stone foundation with mud base with column and beam system with bamboo in combination with local wood. These houses have mud flooring.</li> </ul>
2. Wall	<ul style="list-style-type: none"> <li>• Ekra system- Walls made from woven bamboo</li> </ul>

	<p>mats with either strips or lathened Bamboo. They are either left exposed or plastered with mud or lime depending on the climate conditions. If thermal mass is required, plastering is done. But if ventilation and lighting is required, the wall is left exposed.</p> <ul style="list-style-type: none"> <li>The Assam system. Walls with wattle and daub method with widely spaced frame made of bamboo splits covered with mat, jute or mesh plastered with mud or lime mortar.</li> </ul>
3. Roof	<p>Sloped roof - Almost the whole structure is made from bamboo in combination with local wood. Roofing material generally used is thatch, terracotta tiles and more recently tin or sheets.</p> <p>Flat roofs- Two methods were used. Some places bamboo was used for the under structure in combination with wood with lime surki slab on top. In the second system, bamboo was used as reinforcement in the lime surki slab.</p>
4. Doors and Windows	<p>They are generally made of bamboo in combination with wood, or some places with only bamboo depending on economical and climatic considerations.</p>

The use of bamboo in construction is prevalent across India since ages. The bamboos are already prepared by treatment for preservation and against fungi/insect attack before using. This is followed by cutting and splitting the bamboo into various and required sizes.

#### IV. CONTEMPORARY BAMBOO ARCHITECTURE IN INDIA AND ABROAD - CASE STUDIES

##### 4.1 Bamboo architecture in India

Seeing the global trends, some organizations have engaged in research and development in the field of material science, treatment methods, building components, construction systems and products with bamboo for over few decades. The major organizations and institutes in India working in bamboo sector are:

##### 4.1.1. Institutional Level

- IPIRTI, Indian Plywood Industrial Research and Training Institute, Bangalore- In collaboration with TRADA (Timber Research And Development Association) and BMTPC (Building Material and Technology Promotion Council), they have developed a modified walling system with Bamboo-crete, - an up gradation of Wattle and daub system; and also a construction system for two-story bamboo structure.
- IPIRTI has also developed some treatment methods for bamboo to be used in construction. It has also developed various types of bamboo ply, boards, flooring and

corrugated roofing sheets from woven bamboo. Some of these technologies have been transferred to industries and are under manufacture.

- IWST, Indian Wood Science Institute, Bangalore- IWST has developed treatment method for bamboo and developed a bamboo-wood –plastic composite which can be used in several building applications.
- CGBMT, Centre for Green Building Materials and Technology (with Manasaram Architects), have worked on pre-fabricated bamboocrete wall panels, prefab houses, bamboo construction systems with **BRC**- Bamboo Reinforced Concrete Roof, **BFRC**- Bamboo Fibre Reinforced Concrete, Freeform Bamboo Roofs, Tensegrity and synergetic structures with bamboo, compressed blocks with bamboo and paper waste with mud etc. They have also taken most of the technologies developed by other organizations from lab to land in an innovative and aesthetical manner in their live projects, thereby creating a string of examples and database for other architects and engineers to follow.
- CIBART (Centre for Indian Bamboo Resources and Technology) with KONBAC (Konkan Bamboo and Cane Development Centre) has been working in the furniture sector and has set up some units. They are also developing a construction system with small diameter bamboos.

- Indian Institute of Technology, Delhi is engaged in some works on bamboo buildings and National Institute of Design has been working with bamboo for product design for living spaces etc.

#### 4.1.2. Organizational Level

- Inspirations, an architecture firm has been trying to use bamboo in some of their projects, including their own office building.
- Sangaru Objects Pvt. Ltd. has been developing high-end furniture and products from bamboo thereby trying to elevate the status of bamboo as a material in the field of product design.



- Wonder Grass Initiatives, Nagpur is involved in developing standardized prefab bamboo panels for walling and has also done some construction projects.
- Used for eco-tourism projects, such as, Cherai Beach Resort- Kochi by Architecture BRIO.

Slowly but steadily, bamboo is again in the reckoning. Internationally, books on bamboo are increasing and the one by Gernot Minke proves the value of the material so simply and directly. Vaibhav Kale, Sanjay Prakash, Neelam Manjunath, Uravu group, Sanjeev Karpe, Saajan and many more have been promoting it in their own ways. Bamboo has a future again.



#### 4.2 Various initiatives from institutes and organizations globally

- **Green School** is a holistic learning community that emphasizes the usage of bamboo as a sustainable resource both in construction and in daily life.
- **Dasso-xtr** is an exclusive enterprise under the Dasso group of companies that works on bamboo based construction products such as exterior bamboo cladding, floor panels etc.
- **Bamcore** is a bamboo composite based walling system in USA.

- **EcoPlanet Bamboo** is leading the industrialization of bamboo as a viable and environmentally attractive alternative fibre. They majorly exercise in bamboo moulded pulp alternative of Styrofoam and production of plybamboo etc.
- Many dedicated industries are working on bamboo products for construction industry such as, **Doocity, Resource Fiber, Moso BP, Damyang Korea** etc.
- Many countries now have specific organizations and research labs focusing on development of bamboo treatment techniques for more efficient use in construction industry.



#### 4.3 Case studies

##### 4.3.1. Case Study 1 - Bamboo Symphony - Manasaram Architects, Bangalore.

Bamboo Symphony is the office of Manasaram Architects. Hence the basic requirement of the Project was to embody all their Design and other Philosophies in the building along with other requirements of Space and Services.

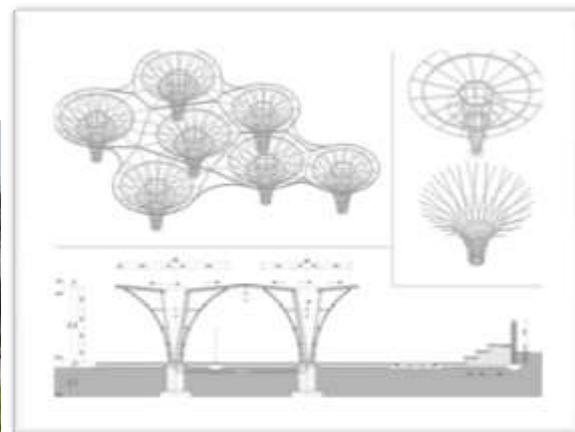
Bamboo was used as the main material in this building. Bamboo Reinforced Concrete, with bamboo fibers, (BFRC) – bamboo splits as reinforcement, and bamboo fibers added to concrete to reduce weight, improve bonding (thus preventing shrinkage cracks) and thermal insulation.



#### 4.3.2 Case Study 2 - The Bamboo Garden – Atelier Rep

- Location – Chengdu, China (2015)  
 Structural consultant – Keliang Han

- The “Bamboo garden” is considered to be an area to experiment with different types of bamboo structure to find some new methods to explore contemporary hand-making construction based on traditional methods of bamboo techniques.



### V. INDUSTRIALIZATION OF BAMBOO

The traditional working process of bamboo functions on a very restricted scale which does not match the productivity of bamboo in nature as well as its booming industrial demands. Bamboo stands facing industrialization. For its function as a material, bamboo should be standardized like all the other industrial material, so that it can be worked by machines, and the components made of bamboo can be assembled with other components made of other materials to become an end product. Through the industrialization some of traditional bamboo’s utilizations turn to be more efficient by the processing with industrial machines, and also overcome the geographic restriction.

But some of the industrial uses have also brought problems, because large percentages of the industrial bamboo utilizations are based on the technology of wood industry. The bamboo and wood are similar in many ways but equally different in their structural form. This difference

has led to inefficient usage of bamboo as a material.

Also, bamboo’s industrialization takes bamboos just as a link of the industrial processing chain where bamboo’s own structure has to be destructed and even the botanical or physical features are changed. Finished industrial bamboo products have not so many features to let it be recognized as bamboo products. Till date, bamboo is utilized for economic reasons rather than, for its viability as a sustainable solution. This opens a great possibility of research in techniques to optimally utilize the bamboo.

Major industrialized bamboo products for construction industry are bamboo-ply, bamboo laminates, bamboo chipboard and particle boards, bamboo composite panels, bamboo reinforced concrete etc.

## VI. ACCEPTABILITY OF BAMBOO ARCHITECTURE-- IDENTIFYING MAJOR ISSUES

Despite being available for centuries and having hands on knowledge evolved over centuries of local innovation, bamboo has not grown as a material to be used in rapid pace construction industry of modern times. This could be attributed to several factors listed as below :-

### 6.1 Material limitations :

Steps need to elevate bamboo technically to a level for it to qualify as a sufficiently durable and structurally safe material for construction for the building sector and for bamboo buildings to become bankable assets.

- a) Fire Rating: Susceptibility to fire is a major limiting factor in the use of whole bamboo culms in buildings. Engineered bamboo is a solution to this problem, but it is unaffordable to the majority of clients. Hence fire rating of round bamboo and fire retarding treatment material and methodologies need to be developed for bamboo to be used in large-scale projects.
- b) Jointing Systems: Owing to the round shape, jointing is very difficult and cumbersome in bamboo. The reduction of diameter along the length is another limiting factor. Various types of engineered and tested jointing systems with appropriate materials need to be developed for effective structural load distribution and transfer. Not many studies have been done relating suitability of joints and their mechanical behaviour. Researchers need to include connection types with complete structural systems.
- c) Conical form of bamboo: Bamboo reduces in diameter and weight along its length. With an approximately hollow circular transverse section with varying density in both directions, bamboo is a unique and difficult material to design with. Digital Image Analysis (DIA) is a reliable tool to derive appropriate equations to map fiber distribution in sections of bamboo. This can help an architect or engineer to calculate the modulus of elasticity of bamboo with fair degree of accuracy.
- d) Splitting Behaviour of bamboo: Most common failure is splitting in longitudinal direction. These failures are usually due to tension, compression and flexure loads in bolted connections and also from drying. It is a technical and practical necessity and needs to be fully addressed. There is a need to formulate simple mathematical equations

involving fundamental properties of bamboo which can be used for designing complex structures with bamboo with the same confidence as for other materials.

- e) Hygroscopic nature of bamboo: The main deterrent for bamboo to be used as reinforcement in place of steel is its water absorbing capacity. The swelling and then shrinking of bamboo in concrete results in micro and macro cracks. To avoid this, effective water-repellent treatments for bamboo splits with suitable modification of concrete is necessary.
- f) Small spans of bamboo buildings: Large spans difficult with bamboo as it is difficult to get splits of uniform cross-section for reinforcement for very long lengths owing to its tapering structure.

### 6.2 Academics, research and development issues:

- a) Integration in Academic curriculum: Bamboo is not included as a mainstream material for building construction in the curriculum of architecture, civil and interior design disciplines. Hence most of the designers remain unaware of this wonderful sustainable material. Awareness needs to be built through workshops, seminars and lectures etc by experts in the universities and institutes.
- b) Architectural Solutions: Most of the bamboo buildings in India today have been done by govt agencies as part of some testing and research with minimum attention to aesthetics and finish. These in reality never have been able to attract the public for their own usage. Construction of aesthetically designed prototypes in prominent locations, for active promotions and display, to attract those willing to experiment with construction of bamboo buildings, has to be taken up on to make bamboo a desirable material
- c) Non-availability of data and Research results in usable format: Research and innovations in alternative materials and building technologies hardly see the light of day. There could be many reasons for these experiments, though successfully conducted in laboratories, to never reach the field of applications. One major reason is the cumbersome and elaborate precautions that have to be taken for design and also during construction of the structural elements. This makes them non user-friendly. Most of the time they are not practically possible, are time consuming and very expensive

- d) Need for Standards and testing methods: Standardization of bamboo as a construction material through research and development, testing and redevelopment and experiences, will serve both technical and social purposes. This will give a more reliable understanding of the material's properties which can lead to refinement and confidence in design values, leading to acceptance of the material in the design community.
- e) Field Testing: The testing procedures for bamboo building components are complex, expensive and inaccurate and unavailable most of the time. This makes it very uneconomical and difficult to adhere to standards and timelines. The field test methods must be standardized to produce a useful data that can (1) directly determine design values; (2) get correlated to values obtained in a laboratory test; or (3) be accurately used to compare different batches of materials. Standardization of bamboo test methods is critical if material is to gain greater engineering acceptance. Methods that capture fundamental material properties permit comparison of the behaviour and performance of different bamboo species, their geometry, weathering patterns and the treatment methods required. Also testing of bamboo is quite difficult due to many varieties of bamboo and many variations within the same variety itself.

### 6.3 Legal, financial and policy issues:

Need for Policy frameworks for promotion of bamboo usage : Government Departments must re-look at the housing strategies, the necessity for evolving policy frameworks, in order to incorporate alternative materials for building construction. A large potential segment of buildings are considered as being valueless due to usage of materials like bamboo. This is majorly due to the definition of a "pucca house" as per the census. The other factors are the criteria listed for housing finance by funding agencies, the National policies, the building byelaws, the development control regulations and finally the psyche of the inhabitants for whom a house can only mean a pucca house only if it is made of steel, cement, bricks, and concrete.

- a) Redefining a 'Pucca house -It is immediately required to change the census definition of a pucca house with inclusion of alternative buildings, to make these building also a financial asset for the house owners throughout its life span.

- b) Inclusion in SSR and National Building Code – Bamboo needs to be included in the Standard Schedule of Rates and National Building Code published by the government for all civil and infrastructure works in the country. Formulation of a set of standards for using bamboo, with treatment and testing methods etc included into the National building Code will make it convenient for architects and civil engineers to include bamboo in material specifications of their projects easier without risking the clients financing options. This will also facilitate software based designing of complex bamboo structures.
- c) Special Policies for bamboo buildings: A national level program can be proposed to streamline the financial / administrative/local level machinery, so that special bylaws can be framed for bamboo buildings. These could extend specially for seismic zones which generally have bamboo readily available. Special relaxations in criteria for housing finance for bamboo houses meant for the rural and urban poor, cross subsidy and house insurance etc. could be a great booster. Special provision can be made for smooth and fast clearance of applications for buildings with alternate materials like bamboo with an incentive package.
- d) Finance for bamboo buildings: Techno-financial environment has to be created to encourage the use of bamboo for construction purposes, and attempts have to be made to elevate a bamboo building to the status of a capital asset having an appreciating property value. Currently, funding is now being available for bamboo buildings only from the Ministry of Rural Development and National Wasteland Development Board.

### 6.4 Social issues

- a) Affordability vs. Priorities - Affordability is perhaps the prime reason for people to opt for a more permanent solution. A substandard house can be very demanding in terms of time, energy and money for its maintenance. Bamboo being one of the cheaper materials can play an important role in providing an economic alternative in combination with other materials for a durable and safe house.
- b) Social acceptability: Experts from the industry indicate that whole bamboo has failed to live up to the social urban image. This can be dealt with by modern bamboo construction and aesthetical architectural design using global innovations and best practices. Cost reduction by using prefabricated components, increasing

the speed of construction, availability of finance and insurance facilities will go a long way in social acceptance of bamboo buildings.

#### 6.5 Execution issues

- a) Material availability: Availability of good quality and quantity bamboo of suitable species for building sector is a major issue hindering the usage of this material. If treated and standardized graded bamboo is made available readily, use of bamboo in building sector will increase manifold within no time.
- b) Skill development: Bamboo working is a tough task and demands special set of skills. Capacity building measures at every level of design, supervision and execution on large scale must precede the actual construction boom in order to cater to the demands of bamboo building sector.
- c) Pre fabrication- Building components, partially replaced with bamboo and bamboo composites etc. if made available to create permutations and combinations, for creating a variety of architectural designs, will provide choices for selection for design and budget, and also enhance the speed of construction on site thereby making it economical. Engineered bamboo can provide more options for increasing speed of construction.
- d) Treatment of bamboo- Elaborate procedures of treatment also is a major issue in usage for bamboo by contractors. Quality treated bamboo is a mandatory requirement for structurally safe, economical and long lasting bamboo buildings. Governments need to set up treatment plants near forests and other areas for value addition to bamboo from the forest areas and ensure continued and sufficient supply of bamboo in bamboo depots.
- e) Raising the standards of implementation: In India, bamboo had been a well-established building material. But this has drastically changed recently because of bamboo buildings being generally very poorly implemented most of the time. We need to form superior guidelines and frameworks for building bamboo structure
- f) Backward linkages unavailable – In order to be able to substitute the energy intensive materials on a large scale, parallel activities involving plantation, drying, seasoning and chemical treatment have to be promoted and up scaled as parallel industries. The product would thus be “especially and exclusively treated and graded bamboo for the purpose of building and mass housing for the urban and rural areas,

following the customized design specifications and construction details.

#### VII. CONCLUSION

Systemic approach is the only road ahead

If bamboo building technology is made convenient to apply and is promoted along with standards, codes and bylaws, tied up with the legal and the financial framework, then entirely put together, it could go a long way in creating a gateway for bamboo and all other alternative materials and technologies.

A. Create a Parallel Construction Industry - A new segment of alternative building sector needs to be initiated. The need for a fresh approach at the age-old materials and technologies, repackaged to blend with the current social and cultural environment, and the demands of the time, is inevitable.

Measures need to be evolved to formulate technical as well as financial models or system mechanisms which should operationally be able to transform an architecturally designed bamboo house into an easily accessible commodity which can be treated as an asset or an investment. This would encourage investments in bamboo buildings. In this context it would be beneficial to review global best practices for alternative technologies, where the policies have led to an increase in the efficiency in construction and distribution, for the bamboo-building sector.

B. Selection and Looping- In order to arrive at a standard package, several looped packages linking limitations, potentials and possibilities, measures, policies and the legislative-techno-financial models are expected to be generated, through experiences, developments, innovative break-through and traditional practices. All of these are inter-dependent factors and only by connecting all these factors appropriately, a reasonably workable package with a comprehensive strategy can be evolved.

C. Use of engineered bamboo, bamboo composites and prefabrication - Though whole bamboo has been and can be used in construction for many types of buildings, for bamboo to be established in the building sector as a mainstream material, we need to use it as composite construction with other materials and an large scale usage of engineered and prefabricated bamboo based components. Many of the traditional construction techniques will have to be either improved or substituted for mass usage of engineered bamboo especially for multi-storied buildings.

Extensive study is therefore required in the field of processed bamboo construction materials and methods.

D. Once these problems are countered, bamboo will become a highly appropriate building material for India. All these technological advancements will help bamboo to get its rightful place in the building sector and result in tremendous economic and environmental advantage.

Bamboo is an excellent material with great potential in fulfilling the ever increasing demands of the construction industry in the most sustainable way. With adequate efforts and technological advancements bamboo can certainly replace traditional construction materials.

But, Unless the policies are carefully drafted and brought into actions with promotion of such projects, Bamboo building technology, would forever remain a part of ambitious policies.

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