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Review on Bamboo as Mainstream Construction Material

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Abstract: ***Bamboo is a well-known construction material from long time but only as a secondary and aesthetic material. The review on use of bamboo as a main stream construction material in conventional construction method is done in this paper. The strength properties of bamboo as reinforcement is reviewed and found to be suitable for reinforcement. Some of the new and old bamboo building technologies and properties of bamboo panels are also discussed. The possibility of growing bamboo for construction is also discussed. The overall analysis concludes that bamboo is very potential building material due to its economical, strength and seismic resisting properties.***
Keyword: Bamboo, seismic properties, bamboo reinforcement, bamboo panels.

I. INTRODUCTION

The environmental hazards caused by conventional construction materials have necessitated an alternate construction material which can counteract the environmental problems and show satiable performance. Research were done to invent new materials but couldn't came up with anything as good as concrete. One way to reduce carbon dioxide emission and dumbing of concrete waste is reduce the use of them by other effective material replacement in suitable conditions. Bamboo is a biodegradable material which will not pollute nature and can meet this requirement. Although bamboo had been a construction material in olden days its popularity decreased with introduction of conventional construction method. But research and technology shows that bamboo can be incorporated in modern day construction without affecting the strength and structural properties. They are proved to be safe as reinforcement and replacement for steel in certain conditions. The aesthetic feature of bamboo building is another reason which makes them desirable. The seismic performance of bamboo houses are also analyzed considering the popularity of traditional bamboo houses in earthquake porn areas. The prefabricated panels introduction has made bamboo more suitable for walls and floors. Being a tropical – sub tropical region, India can improve its construction techniques using bamboo as we have the suitable climate for their growth. Cultivating bamboo for construction in rural areas will be highly beneficial due to its low cost housing methods, environmental safety, earthquake resistant properties.

A. Selection And Preparation Of Bamboo[1]

Selection of bamboo should be done with at most care for a durable structure. Bamboo gains its full growth in few months. However it is recommended to select bamboo with longest and large diameter culms showing a pronounced brown colour, gained due to long age of plant. Use of whole culms of green unseasoned bamboo is prohibited. Bamboo should be cut, dried and seasoned for three to four weeks before using when possible. Avoid bamboo cut in spring or early summer reduces the weakness of culms due to increased moisture content. Bamboo has a reinforcement can be bend by applying heat pressure either at wet or dry condition. This property helps use of bamboo as stirrups. Asphalt emulsion, native latex, coal tar, paint, dilute varnish, water glass shall be used as waterproof coating to reduce swelling when in contact with concrete.

B. Cost Analysis Of Bamboo Versus Steel Reinforcement

The design of bamboo reinforcement are done as per US Naval Corps guidelines [1,2]. The cost effectiveness of designed bamboo slab, beam, column and footing as per specification are compared with that of steel in table 2 [2].

Table 1: Cost comparison of bamboo and steel reinforcement

Reinforced structures	Bamboo (Rs)	Steel (Rs)
Slab	9146	20371
Beam	640	5008
Column and footing	530	5110

Studying table 1 it is evident that bamboo reinforced structures are much cheaper than steel reinforced structures. The cost effective technology with bamboo has led to 15 - 40 percent saving over the conventional costs [3]. Especially in tropical rural areas in India where bamboo can be cultivated and made readily available. Another factor which makes bamboo cost effective is its long lasting property when properly harvested and maintained [3]. Requirement of simple tools and no costly machinery for construction also add up to the benefits of bamboo. In case of rigid pavement where bamboo dowels bars are used cost saving is about 89.84% [4].

C. Bamboo As Replacement To Steel

Cost effectiveness of bamboo alone cannot be considered for its replacement with steel. Strength property of bamboo is one major consideration to take while using it has reinforcement. Bamboo showed a favorable result for various tests such as tensile, double shear and flexural tests. However compared to steel, tensile and double shear results were low for bamboo (almost 50%) which might be because of the low density of bamboo [5]. Bamboo reinforced concrete has attained flexural strength almost near to steel reinforced concrete [5]. Table 1 shows the comparison of strength properties of spruce wood, steel and bamboo [6,7] and it is indicate that strength properties of bamboo is less than that of steel but greater than spruce wood. But the bending strength of bamboo is much higher even than that of steel. Still values of strength properties prove bamboo as a qualified construction material.

Table 2 : Comparison of strength properties of spruce wood, steel and bamboo [6,7]

Properties	Spruce wood	Bamboo	Steel
Compressive srrength (N/mm^2)	43	62-93	140
Tensile strength (N/mm^2)	89	233	410
Elastic modulus (N/mm^2)	11000	20000	21000
Bending strength (N/mm^2)	68	76-276	140
Shearing strength (N/mm^2)	7	20	92

Instead of traditional steel reinforcement, bamboo can be used as dowel bars in rigid pavements. When 20mm steel dowel bar was replaced with 20mm bamboo dowel bar, its spacing was increased about 12 to 10 mm [4].

D. Bamboo Panels For Walls And Flooring

The prefabricated bamboo panels are preferably constructed as sandwiched structures for walls and roofs with sound and heat insulation in between the interior and exterior panel. Mostly bamboo oriented strand broad (OSB) are provided for the interior panel while veneer composite material for the exterior panel due to its low density, aesthetic features, good durability and dimensional stability. The bamboo is split into strips then made to bundle fibers using mechanical rollers. These bamboo bamboo bundles are woven using rubber thread and the veneer is coated on exterior or both sides by a rubberizing machine and glues. Later it is dried and hot pressed at temperature of 150 – 155 degree Celsius with pressure of 4 Mpa and pressing time 1mm/min to form the bamboo bundle veneer laminated composite [8]. The walls, roofs and floors of the building can be connected with different type of steel connections. Engineered bamboo are natural bamboo that has been cut into thin strips and glued back together to form wide panels to use for bamboo flooring and walls[9]. This engineered bamboo is durable, resilient and harder than many hardwoods. Bamboo scrimber is a type of engineered bamboo which has continuously researched and manufactured due to its excellent mechanical characteristics and design. These scrimber materials have similar look and smoothness of wood and manufacturer can utilize the wood processing equipment and technology to process the bamboo scrimber [10].

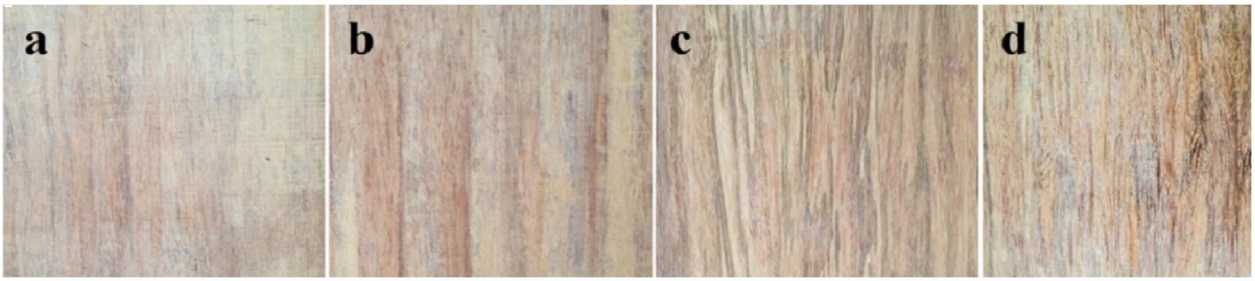

Fig 1: The surface of bamboo scrimber with different textures (**a** wood grain; **b** strip shaped; **c** mountain shaped; **d** pattern of vortexes)[10]

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Exposure to high temperature led to decrease in mechanical property of bamboo scrimber and colour change was observed in the inner and external area of the sample [10]. Above 150 degree Celsius colour changes become prominent and 170 degree Celsius was found to be the turning point for physical, mechanical and chemical properties of bamboo scrimber under heat treatment condition [11]. Horizontal, vertical and strand woven bamboo are the three main type of bamboo flooring. Layers of bamboo are stuck collectively horizontal to make horizontal bamboo flooring while they are stuck collectively vertical to make vertical bamboo flooring. Bamboo grains is less visible and transparent on ceiling of the platform in vertical bamboo flooring while bamboo grains are more visible as it looks full on exterior of the platform. Bamboo strands are collectively made and pressed under intense heat and weight to make the board of flooring of strand woven bamboo. Strand woven bamboo is stronger than any wood floor and bamboo grains are irregular in them. Study was conducted on Bamboo Composite Lumbrt (BCL) with four different core layer materials, viz, bamboo strips vertically glued, jabon wood plank, manii wood plank and sengon wood plank manufactured using horizontally glued Andong bamboo strips as the outer layers and all BCLs produced are concluded to be suitable for solid wood substitute [12].

E. Bamboo As An Effective Roofing Material

Bamboo is a light weight material and its chances of falling are very less due to its flexibility make it suitable for roofing skeleton in earthquake prone areas. Even if it falls it can be re-erected easily with less human and property loss with least efforts and minimum cost [13]. When weight of the roof covering increases a stronger support is need to be provided [14]. The bamboo trusses has strength comparable to Teak and Sal and hence roofing frames can be made using bamboo rafters, purlins etc. for fixing the roof [13]. A study was conducted to find the displacement value in eight different truss shapes: Double Howe, Modified Fan, Modified Queen, Pratt, Fan, Double W, M shape and W shape by using standard load (Dead Load, Live Load, and Wind Load) to calculate axial force in each truss shape member [15]. As per the result of eight type displacement values, the minimum displacement is Modified Fan truss shape and the minimum weight of the trusses structure in greenhouse is Double Howe truss shape [15]. The best shape for this study was concluded to be Double Howe because it has minimum weight and the deflection is in the limit. Certain types of roof coverings require special type of construction and extra care has to be taken at joints. Traditional techniques of bamboo joint in roof typically require the use of ropes or ties with buckles, or the mortgage by simple snap and it can obtain simple knots but not efficient from structural point of view [16]. The strategy of “weak pins” at bamboo roof joints allows quick and easy to repair of the nodes, avoiding collapses in the bamboo canes or in the plywood plates [16].

F. Future Of Bamboo In Indian Construction

Public work department (PWD) has included bamboo as one among the 12 new items in the state schedule rates (SSR) 2020-21, a guideline and manual on the use of materials in PWD projects. This is expected to increase the use of bamboo as mainstream material in construction of buildings and complexes apart from its limited use as furniture and sheds. Even though bamboo had been a well-known construction material in India before 20-30 years ago the conditions has changed due to popularity of conventional building techniques. But considering its sustainable and environmental features and incorporation of new technologies and prefabrication methods bamboo has great future in Indian construction. The bamboo research and training institute (BRTC) in Chandrapur, Maharashtra is one of Asia’s largest training and research centre built in bamboo. SSR took a cue from BRTC in allowing bamboo as mainstream construction material. BRTC aims at developing high yield and fast growing bamboo species by using the latest cutting edge technologies. BRTC is also planning various programs to create awareness in farmers to promote bamboo sector. The engineering application of bamboo in housing is demonstrated by IPIRTI, Bangalore in collaboration with TRADA, U.K and they differ from conventional bamboo use practices. IPIRTI suggest uses of round bamboo as columns, rafters and tresses as main load bearing elements. They suggest bamboo mat board (BMB) as gussets in combination with mild steel bolts for load bearing joints in roofing structures and bamboo mat corrugated sheet (BMCS) as roof claddings. Various preservative treatment are recommended by IPIRTI for bamboo.

Fig 2: IPIRTI type housing [17]

G. Growing Bamboo On Commercial Scale For Construction: Factors To Consider

There are 75 genera with 1250 bamboo species worldwide and their physical property, mechanical property and anatomical structure are significantly different [18]. All these different species of bamboo but all are not suitable to use for construction and adaptable to cultivate in India. Two species of running bamboo viz, Moso bamboo (Phyllostachys edulis) and rubro bamboo (Phyllostachys rubromarginata) and a clumping bamboo (Dendrocalamus asper) are more suitable for subtropical climate [19]. Running bamboo are more tolerant of cold than clumping bamboo and are generally better suited for temperature climates [19]. Bamboo cultivation does not require much area as it grows densely. Due to its dense growth it does not support much wild life. However, when grown at wider spacing, bamboo planting can be desirable for some bird species [19,20]. But in bamboo invaded areas bamboo leaf litter can also significantly influence stream chemistry and dynamics leading to impacts on aquatic species [21]. Proper irrigation system should be installed mainly at initial stage of cultivation. Proper measures should be taken to prevent fire hazards. Bamboo growth is strongly influenced by environmental factors and is highly variable from year to year [22]. Some species of bamboo may take decades to grow, and farmer does not get profit until it is harvested [19]. Table 3 shows average tensile and compressive strength of different species of bamboo.

Table 3: Average tensile and compressive strength of different species of bamboo [6].

Species	Average tensile strength (N/mm^2)	Average compressive strength (N/mm^2)
Gigantochloa Scortechinii	169.6	58.14
Schizostachyum Grande	188.57	28.6
Bambusa Vulgaris	232	67.62
Dendracalamus Asper	221.95	63.2

As per table 3 tensile strength and compressive strength is higher for Bambusa Vulgaris and Dendracalamus Asper and both these bamboos are widely grown in India. The densely tufted culms of Bambusa Vulgaris grow 10–20 m high and 4–10 cm thick. Dendracalamus Asper grows 15–20 m tall, and 8–12 cm in diameter and is commonly known as giant bamboo or dragon bamboo.

H. Bamboo Housing System And Seismic Performance Of Bamboo

Compared to an equivalent wooden panel, bamboo panels are superior in terms of their physical and mechanical properties as well as their seismic performance [23]. The high bending or flexible property and light weight make bamboo suitable for seismic conditions. Traditional houses in Sikkim are made of bamboo which is also known as Assam type housing or Ikra have resistance to earth quake[24]. A weed called Ikra is used extensively in the walls and roofand the roof are generally light weight sheets supported by bamboo trusses which are laterally conneceted to the parallel walls. In bamboo housing system the stresses are higher than modern housing system and in Ikra bamboo housing system seismic force is 12.97% and 11.72% of reinforced brick masonry and confined brick masonry systems respectively [25].

Fig 3: Ikra type housing [24]

The prefabricated bamboo bahareque walls have some ductility under cyclic loading [26]. Research shows that bamboo bahareque house resists earthquake shaking without slightest damage [27,28].

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II. CONCLUSION

Bamboo is highly recommended in modern day construction due to its cost effective and sustainable properties. Replacing bamboo with conventional building materials have advantages like reduced carbon dioxide emission [29]. According to studies conducted in China, bamboo may sequester carbon dioxide at higher rates than conifer or hardwood forest [30]. Thus cultivating bamboo for construction purpose can also benefit environment, apart from how its replacement to cement and steel benefits environment. Bamboo is much preferred as reinforcement in members taking less loaded structures like public toilet, parking area, sunshade since bamboo as a reinforcement deflects more due to low density; but it attains flexural strength almost equivalent to steel reinforced concrete [5]. The light weight and flexural property of bamboo make it suitable for seismic condition. Improved technology helps to use bamboo more effectively as floors, wall and roofing materials and bamboo have great role in present and future construction industry.

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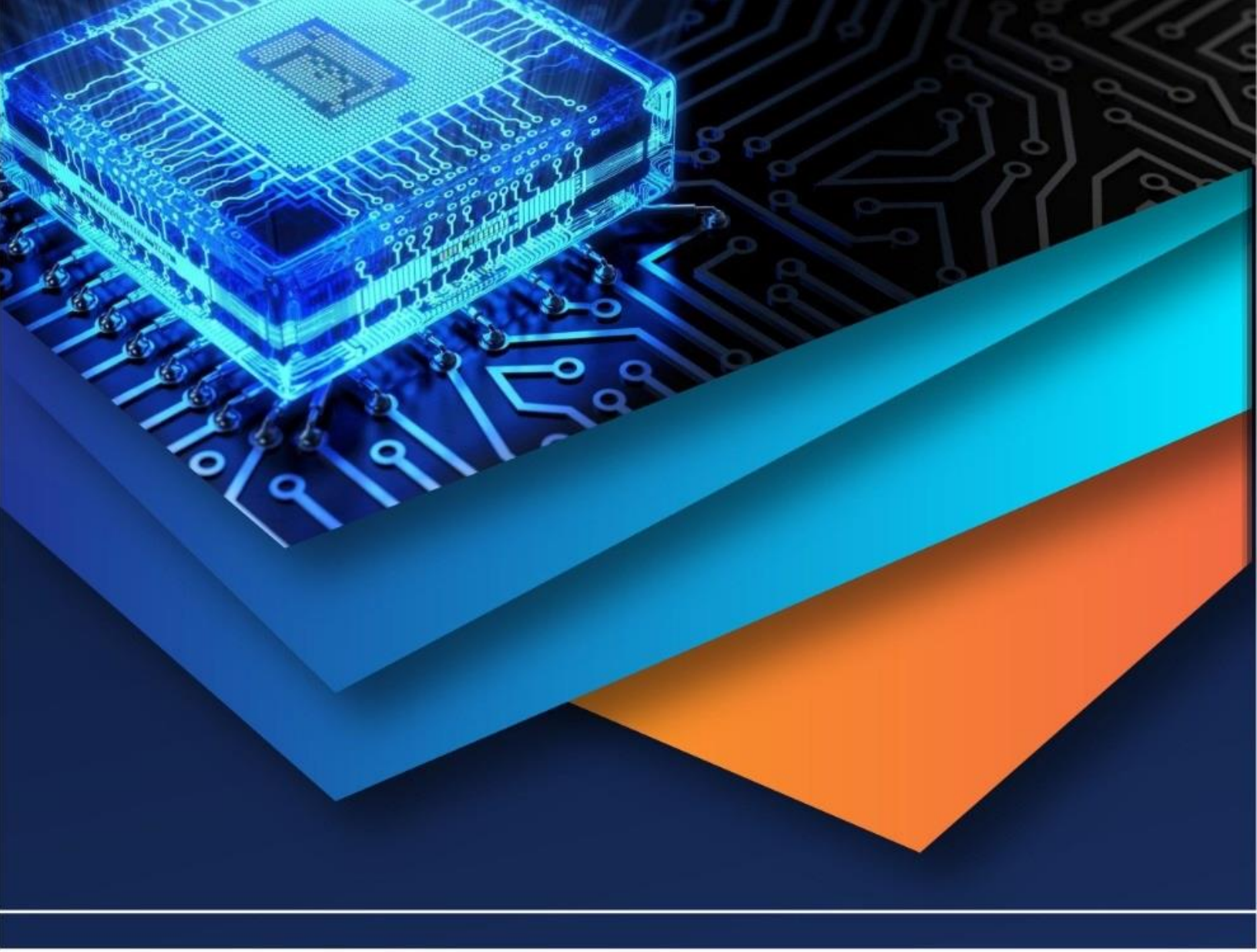

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