RESEARCH ARTICLE

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Review on The Use of Bamboo as A Construction Material

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ABSTRACT

Bamboo is considered one of the most versatile, sustainable and environment friendly building material. They grow naturally all over the globe but are more abundantly found in the tropical and sub-tropical regions such as Asia, Africa and some parts of America. The social and economic benefits granted by bamboo and its product to the society has been high since time immemorial. On account of this fact, it is widely recognized as one of the most important forest resources. Its compressive strength is higher than that of concrete, brick or wood and its tensile strength is comparable to that of steel. The over consumption of conventional construction material such as steel, bricks has posed serious depletion issues of raw materials. Also, with the global increase in population, it has become a challenge to provide proper housing which is both economical and safe for the common people. In addition, in view of the current tectonic activities around the different parts of the world, Bamboo can serve as an alternative building material to steel reinforcement. This paper studies the results of bamboo reinforced concrete and the performance of housing system where bamboo is used as a chief construction member.

Keywords: Bamboo, Bamboo reinforced concrete, Shock Table, Sustainable construction.

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INTRODUCTION

Bamboos are rapid growing giant grasses belonging to the Bambusoideae sub-family of the perennial evergreen grass of family Poaceae[1]. Due to its rapid growth, it is widely recognized as one of the most important non timber product which has numerous uses for people. It has a world record of being 1.2m in 24 hours in Japan[2].Bamboo is one of the oldest and cost effective housing material used in many forms of construction because of its strength and flexibility .The interest in using bamboo as a construction material renewed during the global shortage of housing materials especially the timber industry in 1980s[3]. With the increase in population, there arise the need to invent new and advanced housing technologies as conventional housing system constructed using the high cost construction material such as cement, brick, steel etc. were not adequate enough to accommodate the inhabitants and the manufacture of these industrialized materials require high energy while also polluting the environment. Also, the gradual depletion of natural resources has posed a crucial need to utilize materials which are sustainable and require less energy for manufacturing. Bamboo is a lightweight, sustainable, easily available, tensile material [4]. Since it is a organic material, it is vulnerable to simple decomposition of its fibers due to water absorption. Hence, with proper treatment bamboo with its structurally favorable characteristics and ecological advantages make it a superior construction material alternative that can contribute to sustainable development. Various civil engineering researchers and architects are researching on the efficiency of the use of bamboo in concrete and as a housing material

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for the last few years. However, the main reason for resistance and less interest in using bamboo in structural construction as compared to the modern building materials may be due to low durability of bamboo and lack of sufficient information regarding procuring the right grade as demanded by housing projects, authentic design data on various species, joining techniques and detailing. Also, as bamboo-based construction system is a colloquial technique, dexterity required to conserve such techniques are also depleting gradually with time.

Figure 1 shows the Dendrocalamus giganteus species of bamboo found abundantly in Manipur.

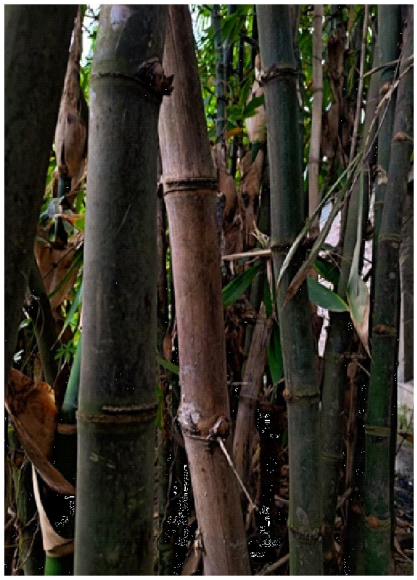

Figure 1: Grove of bamboo trees found locally in Manipur.

MAIN PROPERTIES OF BAMBOO

Tensile Strength

The tensile strength of bamboo is quite high which is roughly 28000 per square inch versus steel's 23,000. In tensile load application test, the results obtained have shown that bamboo can be an alternative for steel because the tensile strength to specific weight ratio of bamboo is six times greater than that of steel. But it is not possible to construct connections that can transfer this tensile strength.[5]

Compressive Strength

Bamboo with slimmer tubes have higher compressive strength value compared to bigger tubes. Slimmer bamboo tubes possess better material properties reason being that bigger tubes have got a minor part of the outer skin which is quite resistant in tension The lignin portion affects the compressive strength, whereas the high portion of cellulose influences the tensile strength and buckling.[6]

Elastic Modulus

The extensive elasticity of bamboo makes it the best building material to build earthquake resistant buildings in earthquake prone areas.The accretion of distinctly sturdy fibers in the exterior parts of the cannular wall is responsible for the high elastic strength. The higher the elastic modulus, the higher is the quality of the bamboo [6]

Shrinkage

Bamboo shrinks more compared to wood when it loses water. It shrinks in a cross section of 10-16%. Hence, it necessary to take proper caution to prevent moisture by applying suitable sealants on its surface before using it as a reinforcement.[6]

Anisotropic Properties

Bamboo is a highly anisotropic material unlike steel which demonstrates isotropic behavior. The properties of bamboo in the transverse directions contrast with that of longitudinal directions reason being that in the transverse direction there is lignin which is brittle and soft while there are cellulose fibers in the longitudinal directions, which is strong and stiff. [6]

Fire Resistance

Bamboo poles can resist the fire and temperature only up to 400°C. Engineered bamboo products needs to be laminated with resins to makeit fire resistant.So, fire safety is an issue to be addressed in bamboo housing as it can catch fire easily and fire-retardant treatment of bamboo is not an option as it is costly. [6,7]

Natural Durability

The short durability of bamboo is a main concern for actual or potential bamboo and bamboo product users. One of the problems that compounds the low durability of bamboo is the hollowness of the bamboo culm, compared to the end-to-end massive cross-section of wood. Culms harvested during the dry seasons have better durability than those harvested in the rainy season.[7]

APPLICATION OF BAMBOO

Bamboo is a versatile material and can used in different approaches such as bamboo trusses, bamboo walling or ceiling, bamboo doors and windows, scaffolding, bamboo reinforcing concrete,bamboo formwork, soil reinforcement and as bamboo flooring:

Bamboo trusses: The strength of bamboo is comparable to that of Teak and Sal. A frame is made using bamboo rafters, purlins etc. for fixing the roof [6]

Walling or Ceiling: The high strength to weight ratio of bamboo makes it an ideal building material for earthquake prone areas compared to concrete structures. It can be easily erected again with least efforts and minimum cost even if it collapses. Bamboo walls can be constructed in different ways like whole stem halved or strips of bamboo nailed to one more side of bamboo frames, cement or lime plastering can be done on the mud covering for better hygiene and appearance [6].

Windows and doors: Bamboo frames can be an alternative for timber frames appropriate to function. Bamboo mat shutters fixed to bamboo, or a panel of bamboo board fixed to the frame which is hinged to the wall can be used as doors or windows.[6]

Scaffolding : Bamboo poles lashed together have been used as scaffolding in high rise structures due to their resilience and strength. The timber planks can be replaced with bamboo culms, and these can be lashed to the vertical columns [7]

Bamboo reinforcing in concrete : This application of bamboo has some advantage,but disadvantages are more and more rigorous technical studies are still needed to find out the efficiency of bamboo when it is used as reinforcement in concrete. Bamboo in the form of splints and culm after proper treatment is used as reinforcement. The main advantages of using bamboo in concrete are high tensile strength and low cost.[7]

Bamboo formwork : Bamboo formwork is a good application of saving much concrete and the need for reinforcement since much of the dead weight of concrete is avoided. It is a promising application that merits a discussion in the near future [7]

Soil reinforcement : As in concrete, bamboo can be used as reinforcement in soil, mostly to stabilize slopes, riverbanks or to support roads. Use of bamboo culms which are put vertically in the soil to act as a kind of dowels thereby keeping the soil together preventing landslides.[7]

Flooring : Bamboo based mats possess superior resistance, resilience and greater wear and tear properties. Hence, it is suitable to be used as floor covers. Whole culms act as a framework and the floor covering is done using split bamboo, bamboo boards, mats etc. by means of wire lashing these to the frame [8]

FINDINGS OF VARIOUS RESEARCHERS

Dinesh Bhonde et.al.[9] studied the bending stress in bamboo reinforced concrete by casting 3 beams of size 750mmX200mmX200mm. Splints of length 16-20 mm of species *Dendrocalmus Strictus* were selected as the reinforcement. Characteristic Tensile Strength of bamboo reinforcement was 95.81 MPa. Asphalt coating was applied on the reinforcement to reduce the absorptionof water by the reinforcement and increase its bond strength. Final beams were tested under computerized UTM. The experimental and analytical bending moment were found to be 10.576586 KN-m and 10.48352 KN-m with 0.88% percentage variation.

Atul Aggarwal and Damodar Maity [10], studied axial compression and bending test on a total of 12 columns (150X150X1000)mm which were casted using design mix (M20) as per IS code . The 12 columns included 3 plain concrete columns, 3 untreated bamboo reinforced columns,3 steel reinforced columns and 3 treated bamboo reinforced columns with reinforcements varying at 3,5 and 8% respectively. Failure of columns mostly occurred in shear under compressive loading. The nonlinearity nature of the load deformation curve indicates the energy absorbing capability of bamboo.

Ghavami et.al.[11], studied the bonding strength of bamboo in light weight concrete mixture by performing pull out test. The bond strength between the concrete mixture and reinforcement is influenced by various elements such as unevenness of the reinforcement, adhesive characteristics of the cement slurry on the reinforcement and the compressive force developed on the surface of the reinforcement. Bond stress of treated bamboo was 0.97 N/mm^2 and that of untreated bamboo was 0.52 N/mm^2

Humberto C. Lima et.al.[12], studied the durability aspect of using bamboo as reinforcement in cement concrete mixtures on the basis of tensile test obtained before and after being exposed to 6 months of ageing. The experimental test was done by using *Dendrocalamus giganteus* species as reinforcement. The study showed that the bamboo tensile strength is comparable with the best woods used in constructions and even steel.

Dewi[13], has used bamboo concrete composite for roof frame structure. The loading test of the frame showed that the failure occurs in the joints of the truss and cracks of concrete in tension bars.

Jagadish Vengala et.al.[14], studied the seismic efficiency of bamboo housing on the standard IPIRTI-

TRADA bamboo house model by utilizing a shock table. The IPIRTI-TRADA (Indian Plywood Industries Research and Training Institute- Timber Research and Development Association) model househaving a dimensions of 2.44 mX2.44m was mounted on the shock table and was exposed to a sequence of controlled shocks for contrasting angle of motion introduced from 5° to 50° with an interval of 5°with the help of a pendulum impacting instrument. Altogether 15 shocks were administered to the shock table during the experimental program.

Kaushik et.al.[15], in the Ikra housing system, the wall is made of stone masonry plastered with cement or mud mortar where the height of the wall is nearly equal to 1m and is above the plinth. The roof standardly consists of light-weight construction materials such as thatch roof or GI (Galvanized Iron) sheets, supported by wooden or bamboo trusses which are then connected sideways towards the parallel walls. It was observed that Ikra type of housing performed best in plain areas and are vulnerable to collapse during earthquakes. However, an observation made during the 2011 September tremor in Sikkim showed no major damage in the two storeyed Ikra housings.

Ashish Kumar Dash et.al.[16], analyzed the application of bamboo in Bamboo reinforced concrete wall. The observations made from the study which included a technical visit and a site evaluation of a 40-year-old building constructed using bamboo reinforced concrete showed that bamboo reinforced concrete walls were unaffectedby the earthquake and did not undergo any major damage except for a few slight cracks which were visible on the brick walls.

RESULTS AND DISCUSSIONS

The experimental results of Ultimate Moment of Resistance and the Analytical results according to design method envisaged in IS 456 were found to be almost equal. Hence the design parameters used in IS 456 can fairly be used to design the bamboo reinforced concrete. However, it was observed that the tensile strength of bamboo reinforcement varies on various factors such as type of specie, land type of cultivation and environmental conditions. Hence, it is recommended to test the bamboo samples for tensile strength before using it as a reinforcement in concrete. Also, proper care should be taken to apply coatings on the bamboo reinforcement with appropriate sealant such as asphalt to prevent high water absorption by the bamboo which degrades the bond strength [9]

It was observed that failure of columns predominantly occurred in shear under compressive loading.Columns with no reinforcementsand the columns with untreated bamboo reinforcement displayed observable frangible nature where little cracks became visible at column surfaces at about 80% of maximum axial force. After being subjected to the highest load, the load capacity of the columns decreased and failed all of a sudden in few secondswithout any warnings of imminent failure. On the other handin columns with bamboo and steel reinforcement more ductile behavior were observed where in tiny cracks became visible on the column surface initially at 80-90% of thehighest axial force. The results obtained from the experiment exhibited that the load carrying capacity of steel reinforced (minimum reinforcement, 0.8%) column is nearly equivalent to that of treated bamboo (8% reinforcement) reinforced column (owing to the strength of bamboo samples) [10].

It was observed that the values obtained from the test of compression and shear are dependent on the types of bamboo used. The experimental data of compressive strength was higher than the tensile strength.*Bambusa vulgaris* schrad possessed the highest value of tensile strength varying from 120 to 140MPa.Treated bamboo was more effective than the untreated bamboo with up to 90% improved bond stress[11].

The tensile stress vs. strain curve of bamboo was observed to be linear up to failure. The tensile strength of bamboo specimens with node is 100 MPa and 275 MPa forspecimens without node. Also, the test exhibited that 60 cycles of wetting and drying in solution of calcium hydroxide and tap water did not decrease the bamboo tensile strength neither the Young's Modulus.[12]

Extra pegs reinforcement increased the effective stress varying from 45MPa to 90 MPa. It was also concluded that the use of bamboo for environment friendly construction were more easy,quickto implement and more sustainable.[13]

It was observed that at the end of the three shocks corresponding to 40°, minor fissures were noticed not only on the outside walls but also in the inside portion of the walls. However, the fissures were more distinctly evident on the external wall of the house model. Right after the experimental analysis, the model house was found to resist the different series of vibration and displayed no indication of collapse. Hence, it was concluded that the model has met the

objective of resisting major to moderate level of dynamic forces with minimal damage levels[14].

It was reported that Ikra types of houses constructed on slopes are vulnerable to slope failure and can be risky during ground agitation due to strong earthquake as unequal lengths of the posts lead to unsymmetrical shaking. It was concluded that Ikra housing system is unsuitableto be used for higher storeys construction asthere is a high risk of probable increase in intensity of earthquake along with increase in height of the house. Also wall maintenance were required during summer and rainy season [15].

It was concluded that bamboo reinforced concrete wall panels did not show any major damage during earthquakes and did not show any huge cracks or required any significant repair works in its life span except normal whitewashing once in a while [16]

CONCLUSION

In response to global warming issues and the need for sustainable development, the manufacturing of environment friendly construction materials has been a recent trend. Bamboo as a fast-growing renewable material with simple production process and broad distribution of growth is expected to be a sustainable alternative compared to conventional building materials such as steel, concrete, wood, etc. According to years of studies by bamboo practitioners, bamboo when treated and used properly, it can be a sound engineering material due to its flexibility, strength and versatility. Also, results obtained from the investigations done by the various researchers showed that it can substitute steel quite satisfactorily. However, it possesses few drawbacks such as it is weak in shear, bond stress and node section and thus is unsuitable to be used for shear reinforcement in RCC structure.Moreover, there are no sufficient guidance and codal provisions for the use of bamboo in construction. The use of bamboo as reinforcement in concrete and as a housing material needs more rigorous statistical analysis on its characteristic strength. Inclusion of courses on bamboo technologyin technical institute will play a beneficial role in the field of sustainable construction in the future.

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