LABORATORY STUDIES FOR THERMAL TREATMENT ON THREE SPECIES OF BAMBUSOIDEAE

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Abstract: Bamboo (*Bambusoideae*) belongs to a group of perennial plants and grass family. Bamboo as a traditional building material is being used throughout the world's tropical and sub-tropical regions, offering light and easily replaceable forms of shelter & widely used in many forms of the construction, in particular for housing in rural areas. However, it also has certain limitations in the context of shape, durability, fungal & insect attack etc. To overcome these disadvantages, the present study proposes developing a sustainable bamboo by thermal treatment; a non-hazardous process carried out at a high temperature under inert environment for specified duration in an oven. The major focus of the study is hence to confirm if thermally treated bamboo can serve as an alternative sustainable technique that thereby eliminates the conventional use chemical preservatives; all along without compromising on the standard requirements of a bamboo specimens with respect to its physical properties & mechanical properties as per IS 6874:2008 recommendations.

Keywords: Bamboo, Bending, Hazardous, Shrinkage, Thermal.

Introduction: Bamboo (Figure 1) belongs to a group of perennial plants and grass family Bambusoideae. There are about 1200 species growing in Asia, Africa and Latin America. It grows 3 times faster than other species, and approximately 7.5-40 cm/day.

The strongest part of a Bamboo stalk is its node, where branching occurs. It can be harvested in 3 to 4 years when compared to most of the fast growing softwoods and hardwoods [1].

Bamboo is also one of the oldest construction materials, mostly seen in Housing Superstructures (Figure 2) including Roofing etc. as it can be worked with the simplest tools due to its highly silicified outer zone [1]. As a natural fiber, it is strong, highly flexible, environmentally friendly, light-weight, low-cost, and resistant to earthquake damage [1].

Fig. 1 Bamboo

Fig. 2 Bamboo Houses

Although bamboo constructions can be built very quickly, they are easily prone to attack from fungi and insects; and therefore untreated Bamboo structures are temporary with an expected life of not more than 5 years [2].

This situation therefore demands preservation and treatments like Smoking, Drying, Insect infestation, Leaching and most popularly Chemical treatment. However these aforementioned methods are either ineffective or are hazardous for environment especially when while undergoing chemical treatment with chemicals such as Copper Chrome Arsenic, Copper Chrome Boron and Zinc Chrome [1].

Scope of Study: To overcome the limitations of existing treatment techniques, the present study proposes Thermal treatment as a Non-Hazardous technique to increase durability of Bamboo and enhance its potential as a sustainable solution in the constructions of low cost housing; without compromising upon the standard requirements of bamboo specimens in terms of its physical & mechanical properties as per IS 6874:2008 [3].

Methodology: The present research dealt with three species of Bamboo namely *Dendrocalamus strictus* (Figure 3), *Dendrocalamus stocksii* (Figure 4) and *Thyrsostachys ovilveri* (Figure 5).

The sample collection was accomplished with collection of mature specimens from the Forest Department. Before felling, a ring was marked with paint on the culm at a height of 1m from the ground. The culms were felled according to standard harvesting practices [4].

Fig. 3 Dendrocalamus Strictus

Fig. 4 Dendrocalamus Stocksii

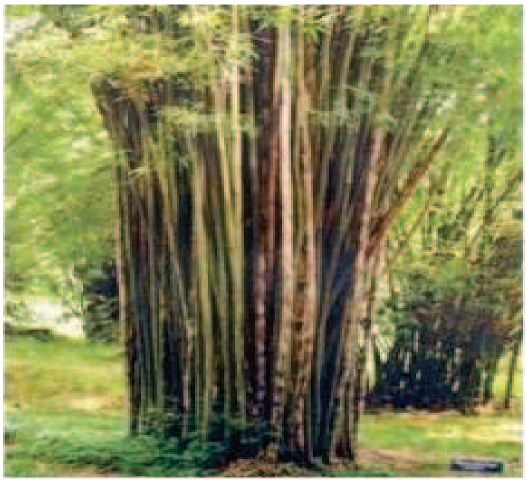

Fig. 5 Thyrsostachys Ovilveri

After felling the culm, the unusable parts from the culm bottom were removed. The remaining culm length was measured, and then each culm was cut into two to three parts. The specimens free from defects like cracks and crookedness were then segregated as 'Untreated' and 'to be Treated' w.r.t. Thermal Modification Process. This was achieved using a vacuum oven at 160°C, 180°C & 200°C under airtight conditions for 36-48 hours.

Further, Standard tests were then subjectively conducted on all specimens to examine variation in their physical and mechanical properties; namely Colour, Density, Equilibrium Moisture Content, Shrinkage/Swelling and Water Absorption (Physical); Static Bending Strength & Compressive Strength (Mechanical); in accordance to IS code 6874:2008 [3]. This assisted in comparative performance evaluation of thermally treated specimens over untreated specimens.

Results and Discussion: Preliminary observations on thermally modified bamboos showed uniform darker brownish surface and Culm wall color. This may also be inferred due to the weight-loss, which was more in 200°C, and comparatively lesser in case of thermally treated bamboos at 180°C and 160°C respectively for all the three species. The weight-loss at higher temperatures is majorly due to the change in the chemical composition. At room temperature the bamboo begins to lose free-water from the moisture in the air deposited in its cell cavities. At a temperature slightly above the boiling point, the water present in the cell cavities is completely driven out thereby making it dry. Beyond 180°C and 200°C, there is more weight-loss as the elevated temperature removes the water that was absorbed by the cell walls. The objective of restricting tests at 200°C was based on the consequence wherein further heating charred it. Thermal treatment was also observed to impact the hygroscopic behavior of bamboos, i.e. Equilibrium Moisture Content, Water Uptake Capacity, and Swelling/Shrinkage of Diameter/Length. Equilibrium Moisture Content (EMC) is achieved when the moisture gained by bamboos upon constant air absorption reaches saturation with the surrounding moisture [4]. This was found to be high in untreated specimens than thermally treated bamboos, since at higher temperatures the chemical composition of the bamboo materials changes which in turn reduces the air-voids that are the potential spaces for water uptake.

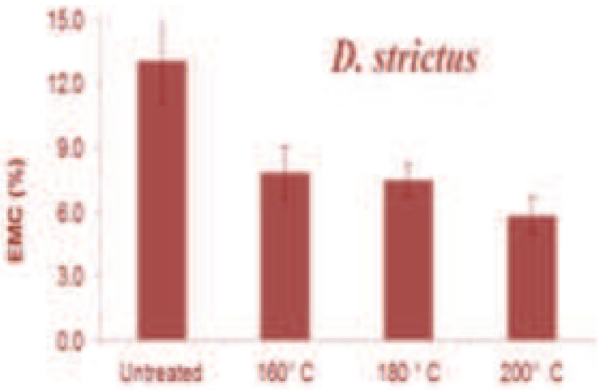

Fig. 6 EMC change in D. strictus

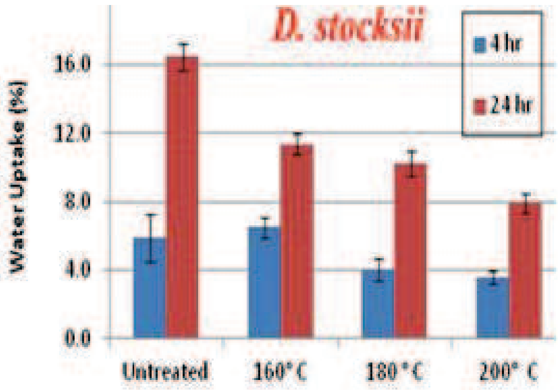

Fig. 7 Water Uptake in *D. stocksii*

This reduction hence leads to lesser water-absorption and moisture content, thereby increasing the longevity and durability. Relatively, this was found to be lowest for specimens treated at 200°C. These randomly may also be graphically confirmed from Figures 6 & 7. In construction industry, this is considered a boon as elevated moisture levels bring in a constant threat of pest attack.

Also, consequently the swelling of diameter (Φ) and length (L) was observed to be highest among untreated specimens, rather than thermally treated bamboos. These may also be graphically confirmed from Figure 8 & 9.

Complimentarily, shrinkage was found to be more in thermally treated specimens than untreated specimens. While diameter shrink was found to be between 10-16%; the wall thickness shrinkage was about 15-17%. The shrinkage (in fresh culms) begins linearly before becoming negative (or almost zero) as moisture content falls between 70-100%; and this continues until fibre saturation point is reached. Below this, shrinkage again follows a linear trend. Both swelling and shrinkage phenomenon were found to steadily increase and dependent on the exposure period before stabilising.

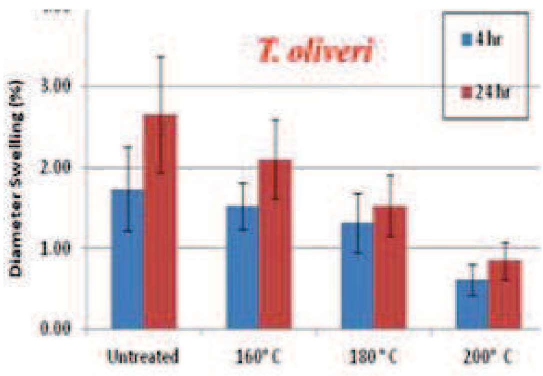

Fig. 8 Φ Swelling in *T. ovilveri*

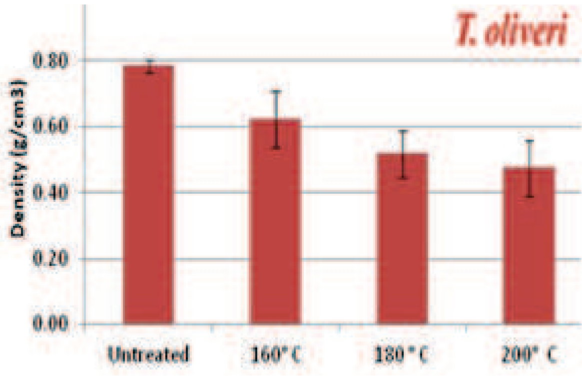

Fig. 9 'L' Swelling in *D. strictus*

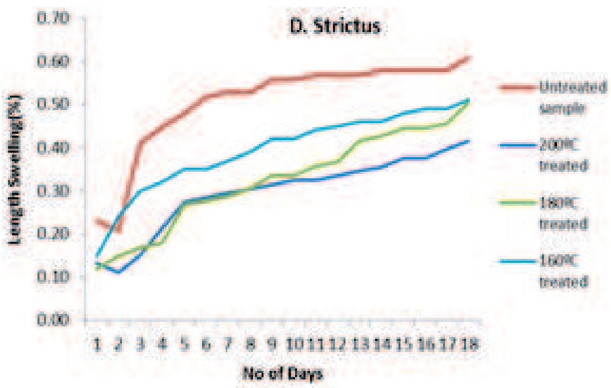

Fig. 10 Density Change in *T. Ovilveri*

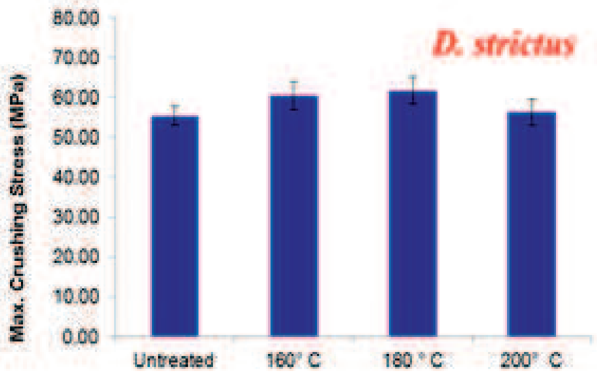

Fig. 11 Compressive str. of *D. strictus*

Figures 10 depict the variation in Density for the thermally treated bamboo species. In any Bamboo species, the highest density is usually observed in the outer portion of the culm wall due to the presence of higher number of vascular bundles and higher proportion of fibrous tissues. These gradually decrease to the inner region of the culm wall.

In the current study, as temperature was risen during thermal treatment, it may be generally observed that there was no significant change in density values for D. strictus and D. stocksi; however there was a slight but distinct decrease in bamboo density of T. ovilveri.

The results of tests for Mechanical properties in accordance to IS code 6874:2008 are discussed herewith. Bamboo has a compressive strength twice than that of concrete due to the presence of fibres. Bamboo possesses only a small proportion of lignin & its main component is silicic acid, which gives the shoot its durability and hardness. The tissues contribute to astonishing strength and flexibility [5]. In the current study, it was found that Maximum Crushing Stress remained high in untreated specimens, while it had declined only beyond the thermal application of 180°C. The graphical plot for results of Compressive Strength is showcased in Figure 11.

Modulus of Rupture, which is the ultimate bending strength of a material, and describes the load required to cause a beam to fail; was found to be high in untreated specimens of present research. However it had reduced by 8-10% in case of thermally treated specimen's up to 180°C. The rate of reduction was rapid up to 15-20% for specimens treated beyond 180°C and correlated well with weight-loss. In the case of Bamboo, each of its nodes has a dividing or transverse wall which maintains strength and allows bending, thus preventing rupturing when bent. Modulus of Elasticity (stiffness) was also found to be almost unaffected up to 200°C and reduced thereafter by 8-12% with increasing temperature.

Conclusion: Although Thermal Modification (Heat Treatment) process may be viewed as an eco-friendly alternative to chemical preservatives. The recommended heat treatment for bamboo is at 180°C. The results of the present study would certainly be useful in recommending the protocols for heat treatments of bamboo in construction industries.

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