Eco-Friendly Preservative Treated Bamboo Culm: Compressive Strength Analysis

Perminder JitKaur, Santosh Satya, K. K. Pant, S. N. Naik

***Abstract*—**Bamboo is extensively used in construction industry. Low durability of bamboo due to fungus infestation and termites attack under storage puts certain constrains for it usage as modern structural material. Looking at many chemical formulations for bamboo treatment leading to severe harmful environment effects, research on eco-friendly preservatives for bamboo treatment has been initiated world-over. In the present studies, eco-friendly preservative for bamboo treatment has been developed. To validate its application for structural purposes, investigation of effect of treatment on compressive strength has been investigated. Neemoil (25%) integrated with copper naphthenate (0.3%) on dilution with kerosene oil impregnated into bamboo culm at 2 bar pressure, has shown weight loss of only 3.15% in soil block analysis method. The results from compressive strength analysis using HEICO Automatic Compression Testing Machine reveal that preservative treatment has not altered the structural properties of bamboo culms. Compressive strength of control (11.72 N/mm^2) and above treated samples (11.71 N/mm^2) was found to be comparable.

***Keywords*—**Compressive strength, *D. strictus* bamboo, Eco-friendly treatment, neem oil.

I. INTRODUCTION

REQUIREMENT of growing population for housing coupled with environmental considerations has necessitated the need to search for suitable alternatives of wood, metals, plastic etc. Bamboo a plenteous forest resource in Asia has emerged as one of such alternatives. Its usage in the manufacture of utility poles, bridges and scaffoldings and in residential complexes as building and flooring material has been increasing. High growth rate and tensile strength combined with cost effectiveness offer great potential as an alternative to wood. Bamboo plant requires low investment cost, low weight to height ratio, high growth rate (7.5 to 40 cm a day), and have ability to sustain in waste lands as well. Recent awareness on this issue leads to development of many aesthetic and engineered bamboo buildings.

In spite of versatile nature of Bamboo material, it is considered as temporary material. Natural resistance of bamboo varies from species to species; yet untreated bamboo culm degrades within 3 years of installation. Degradation by the organisms particularly fungi and insects causes severe loses. This leads to reduction in strength of bamboo and calls for frequent replacements in usage. The commercially available preservatives for wood are also used as such for bamboo. More than 80% of commercial wood is preserved using CCA (Chromated Copper Arsenate) [1]. However, leaching of arsenic, chromium, and copper from CCA-treated products in indoor applications may be hazardous to environmental as well as human health. Restrictions on use of CCA imposed by European countries and Japan have called for the development of environment-benign preservatives [2]. The effect of chemical treatment on strength properties of *Gigantochloa scortechinii* bamboo showed a reduction of 5.0 to 10.7 % for ACQ, 4.4 to 10.3 % for BBA and 4.3 to 9.7 % for CCA treated samples [3].

Plant extractives are reported as potential preservatives to enhance the durability of bamboo [2], [4]. Neem oil, with azadirachtin, as the major components, is known as an assured insect control agent. Neem extracts are found to be effective wood preservatives [5]. Literature reveals that no information is available on efficacy of neem seed extract in post-harvest decay prevention in bamboo. Improvement in effectiveness of neem oil using copper salts on wood durability is reported to be effective. As treated bamboo is extensively used as structural material, the effect of treatment on properties of bamboo are essential. Structural characterization of eco-friendly preservative treated bamboo is lacking in literature.

Compression test is used to examine the change in behavior of treatment bamboo under crushing loads. The control and treated specimen were compressed and deformed at various levels of load and need to be recorded. In the present study, structural characterization of neem oil treated bamboo samples has been investigated. Mechanical properties of treated bamboo culm specimen are determined to validate the usage of treated product for outdoor applications. The study aims at bringing out that substituting timber with bamboo based load bearing structural elements in roofs of rural houses addresses a felt need in areas where supply of timber is a constraint. But, introduction of innovation in rural housing would be acceptable when change is minimal, and only on those aspects where limitations are felt.

II. MATERIAL AND METHODS

A. Sample Preparation

D. strictus bamboo species were obtained from Forest Research Institute (FRI), Dehradun. Defect free bamboo was selected for experimental work. The samples were air-dried and conditioned in control atmosphere before treatment. The specimen was prepared as per specifications of soil block analysis (1.9x1.9x1.9cm). *Polyporus versicolor* white-rot

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fungus (commonly found in almost all tropical countries) was obtained from Indian Agricultural Research Institute (IARI), New Delhi. It was grown on Potato Dextrose Agar (PDA) medium and the grown culture was maintained at 4+1^{o}C. Compressive strength was analyzed using bamboo samples of12 - 15 cm size.

B. Bamboo Culm Treatment

Neemseed oil was obtained from Arora chemicals, New Delhi. Various combinations of neem seed oil, copper naphthanate and kerosene oil were investigated. For preservative preparation neem oil was mixed with copper naphthenate by constant stirring and was 5 times diluted with kerosene. Neem oil alone (NO), Copper naphthenate added neem oil (CNO) were investigated. Dip treatment was performed using vacuum impregnation method. Modified Broucherie equipment, equipped with cylinder of 20 Liter capacity, fitted with a pressure gauge to maintain pressure was used for pressure treatment of bamboo.

C. Decay Resistance

Decay resistance of bamboo as per ASTM D 1413. To prepare the cultured bottles, sand was washed with water until the wash was clear. The sand weighed 175 g/ 100 ml, a pH of 5.98 and 25% water-holding capacity. Glass jars (300 ml capacity) were filled with 100 ml sand. The surface of the sand was then covered with a filter paper to serve as fungal feeder strip. The cultured bottles were sterilized, inoculation and incubation. The steam-sterilized samples of bamboo were transferred into culture sterilized bottles of fungus. Additionally untreated samples were also used in the process to determine the efficacy of treatment. After 12 weeks of fungal attack at 30°C and 70% Relative Humidity, the specimens were harvested. The adhering mycelium was scraped off. The specimens were oven dried, weighted till constant weight.

D. Compression Strength Analysis

Compression test is used to examine the change in mechanical behavior of treated bamboo under crushing loads. The control and treated specimen were compressed and deformed at various levels of load and were recorded using HEICO Automatic Compression Testing Machine. Seven control and CPNO treated bamboo samples were prepared for the analysis. All the specimens used for compression test were cut out from between the nodes of bamboo. The diameter and length of specimens were carefully recorded. The uniform stress distribution was achieved by applying electronic cutter at ends. The constant rate of loading was maintained at 0.02 mm/sec.

III. Results And Discussions

A. Decay Resistance Analysis

Studies on decay resistance analysis of bamboo are scanty. Like wood untreated bamboo culms are highly susceptible to fungi attack. White-rot fungi are generally more destructive in nature than brown rot fungi causing more weight loss to biomass samples [3], [6]. In the present studies, exposure of bamboo to *Polyporus versicolor* fungi has resulted in severe destruction of species (weight loss: 65.12 %). The weight of untreated bamboo was comparable to rubber wood [3]. Difference of basic structure of wood and bamboo causes absorption of preservative to be different. Reference [3] reported that neem oil was found to be effective preservative for wood species, bamboo samples dip treated with Neem oil alone for 96 hours are susceptible to white rot attack (weight loss: 32.22%). Addition of copper naphthenate to the neem oil was resulted in significant improvement in decay resistance properties of bamboo samples. The bamboo samples dip treated for 72 hours with copper naphthenate (0.3 %), neem oil 25% in kerosene oil solution were found to perform the best. Further addition of copper naphthenate and increase of dipping duration has no effect on decay resistance properties of treated samples.

To make bamboo suitable for building and construction industry, sufficient impregnation of preservative inside the bamboo culm is very important. Above prepared solutions were impregnated inside the bamboo culm at pressure of 2 bar using Broucherie equipment. The samples were allowed to stay in same condition for different duration of time. Soil block analysis of treated blocks has been performed and weight loss of samples before and after treatment has been investigated. Solution containing copper naphthenate (0.3 %), neem oil 25% in kerosene oil solution was able to provide the desirable protection to bamboo species (weight loss: 3.27%). The optimum pressure of dipping was 72 hours.

B. Compressive Strength Analysis

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some material fracture at their compressive strength limit; others deform irreversibly. A given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

HEICO Automatic Compression Testing Machine was used to investigate the effect of treatment on strength properties of bamboo samples (Fig. 1). Various loads were applied at sample. The analysis of compressive strength is performed using constant rate of loading 0.02 mm/sec. The variation of load and displacement is recorded. The specimen seems to be fairly linear up to 51 KN and decreases progressively. The compressive strength of control specimen is in accordance with [7]. The treated specimens are found to have intact strength properties. The CPNO treated bamboo is found to have the similar compressive strength as control specimen. The typical stress strain is shown in Fig. 2. The mode of failure of the beam is dependent on the compressive strength, the type of material and the ratios of main and web reinforcements and the shear span-effective depth ratio (av/d) of the beams [8].

Fig. 1 HEICO Automatic compression testing machine

Different modes of failure were observed in both control and eco-friendly treated bamboo samples. There was no particular mode of failure observed for both type of samples.

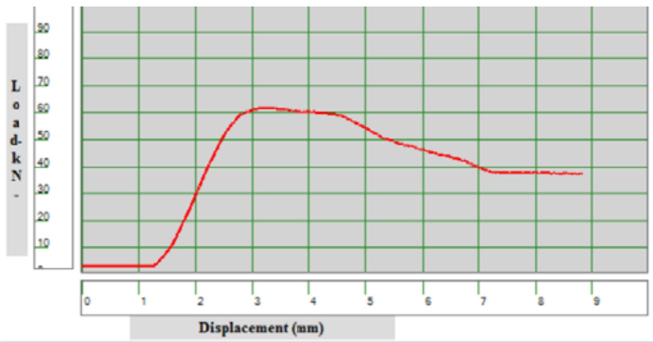

Fig. 2 variation of on increasing loading

The peak load and thus peak stress is recorded for a series of investigations. The ultimate stress at which sample broke was recorded. The ultimate load bearing capacity of treated and control samples were found to be similar. Thus treatment has not found to affect the load bearing capacity of bamboo. The application of increasing load resulted in splitting and cracking of bamboo species. The specimens were found to either crack or crushed. Figs. 3 and 4 show failure modes shown by the investigated specimen. No particular pattern of mode of failure was observed in control and treated samples.

Reference [9] describes the use of bamboo as modern construction material. Results obtained from above analysis indicate that if treated bamboo is used for housing, and construction industry usage value of bamboo will improve.

From structural engineering point of view, treated bamboo culm possesses competitive strength characteristics, comparable to concrete and steel.

Fig. 3 Cracking and splitting mode of failure

Fig. 4 Mixed modes of failure observed in samples

IV. Conclusion

Bamboo seems to be the best choice as material of construction material for future. It is expected that application role of bamboo in construction industry will be helpful for creation of environment benign aesthetically appealing buildings and structures. Neem oil was found to possess antifungal properties, inhibiting the growth of bamboo-destroying fungus *P. versicolor*. The weight of neem oil treated samples was found to be better than control. The observed synergy between copper naphtheanate and neem oil has resulted in desirable level of protection in bamboo species. The pressure treated copperised (0.3%) neem oil (25%) in kerosene is able to provide “A-Class” protection to bamboo sample (weight loss: 3.25%). In the present treatment similarity in compressive strength of eco-friendly treated bamboo and control specimens, makes is the treated product righteous choice as building material with intact strength and improved durability. The use of the comprised neem oil based preservatives could be exploited at commercial level to develop new environment benign preservatives.

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