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Treatment of Bamboo (*Bambusa tulda*) with Clay (Kaolinite) and Chemicals: Evaluation of Dimensional Stability and Termite Resistance

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Three year old common bamboo (*Bambusa tulda*) samples were treated with kaolinite clay suspension followed by kerosene oil. Another sample was treated with kaolinite clay suspension and other chemicals (boric acid, copper acetate and Na-salt of diethyldithiocarbamate in sequence) and dimensional stability and termite resistance of the samples were evaluated. It was observed that compared to untreated and simple kaolinite treated sample, the chemical treated samples showed better dimensional stability in terms of antishrink efficiency, increased bulk coefficient, weight percent gain as well as better termite resistance capacity.

Key Words: *Bambusa tulda*, Dimensional stability, Antishrink efficiency, Weight per cent gain, Termite resistance.

INTRODUCTION

Bamboo is one of the important bio-resources of the tropical and subtropical region. It is one of the oldest construction material used by human kind. Due to stronger physical and mechanical properties, it is used in making temporary bridges, flooring, ceiling, walls, windows, doors, fences, *etc*. It is also a raw material for pulp and paper industry. In spite of its good physical and mechanical properties, dimensional changes with variation of temperature and moisture and biodegradation are the major problems in using bamboo as construction material. Bamboo contains[1,2] hemicellulose (50-70 %), lignin (20-25 %) and pentosans (30 %). The water molecules get bonded to the hydroxyl group of the cellulose of bamboo through hydrogen bonding when atmospheric moisture comes in contact with bamboo, which causes swelling of the cell wall of bamboo. On drying, it shrinks again causing dimensional instability. Bamboo is also susceptible to degradation by termite, bamboo borer and certain types of fungi as they contain cellulose decomposing bacteria in the gut which can digest the cellulose of bamboo and make it unfit as a construction material. It was reported[3] that dimensional instability and biodegradation can be minimized by modifying hydroxyl groups on the cell wall polymers by using anhydrides preservative. Chromium, arsenic, copper, coal-tar, creosote, anhydrides, esters, polymers were used[4] as preservative chemicals for the protection of bamboo from biodegradation and also to prevent the expansion and contraction on further contact with moisture. In traditional method, water submersion, heating and treatment with extracts of various medicinal plants were reported[5]. However, most of the methods have drawbacks in or other form. Recently, Evans *et al*.[6] have reported the potentiality of using nanotechnology for improving performance of lignocellulosic materials. Although, bamboo is a renewable bio-resource, if some easy and eco-friendly method can be formulated, it will not only encourage the use of bamboo more widely but it will also reduce the pressure on our forest.

A new method of preserving lignocellulosic materials by treatment with boric acid, copper acetate, maleic anhydride, sodium salt of diethyldithiocarbamate and polymer was reported[7] from our laboratory. In the present communication, we report the treatment of bamboo (*Bambusa tulda*) with kaolinite clay and other chemicals like boric acid, copper acetate, Na-salt of diethyldithiocarbamate and kerosene and evaluation of their dimensional stability and termite resistance capacity.

EXPERIMENTAL

The internode portions of three year old bamboo (*Bambusa tulda*) were collected from a homestead garden of Dibrugarh, Assam. Rectangular strips with epidermal layer of approximately 10.00 cm^3 × 2.50 × 1.15 cm^3 (length × breath × thickness) were prepared from air-dried bamboo for the treatment as per Bureau of Indian Standards[8]. The samples were extracted separately with each of water, dichloromethane and methanol in sequence at least for 3 h and then the samples were dried in oven at 100 ± 5 ºC in such a way that at least 15-20 % moisture remains inside to facilitate movement of water soluble chemical preservatives. The extraction removes waxes, fats, resins *etc*., which facilitate easy penetration of chemicals. Kaolinite clay used in this work was obtained locally from Dergaon, Assam and purified by reported method[9].

The chemicals used were: (a) boric acid (Rankem, 5 % v/v in water) (b) copper acetate (Rankem, 5 % v/v in water), (c) sodium salt of diethyldithiocarbamate (BDH, 5 % v/v in water).

Treatment of samples: Following treatments were carried out to evaluate the dimensional stability and termite resistance: (a) oven dried bamboo samples were submerged into 1 % clay suspension for 7 days, after which they were taken out from the solution and then first air-dried and then oven-dried at 100 ± 5 ºC. (b) Another set of oven-dried samples were first submerged in 1 % clay suspension for 7 days and then oven-dried. Then the samples were again submerged in 5 % of boric acid solution (BA), copper acetate (CA) and sodium salt of diethyldithiocarbamate (DEDTC) in sequence and every treatment were carried out for 7 days and after each treatment, samples were first air-dried and then oven-dried. After the completion of the treatment, samples were treated with kerosene for 1 day.

Evaluation of properties of treated and untreated samples: The properties of treated and untreated bamboo samples were determined[10] by using the following relations. The dimensions of treated and untreated samples were monitored with vernier calipers.

The antishrink efficiency (ASE) were calculated from the following relationship:

$$ASE = (S_u - S_t) \times 100/Su$$

where S_u and S_t are the volumetric swelling coefficient of oven dried untreated and treated samples.

Bulk-coefficient (BC) were calculated by the following relation:

$$BC = (V_t - V_u) \times 100/V_u$$

where V_t and V_u are the oven-dried volumes of treated and untreated samples.

The weight per cent gain (WPG) or chemical retention was determined by the following relationship:

$$WPG = (W_t - W_u) \times 100/W_u$$

where W_t and W_u are the oven-dried weight of treated and untreated samples, respectively.

Thermal studies: Thermal analyses were carried out using Perkin Elmer Pyris Dimond TG/DTA instrument at a heating rate 20 ºC min^{-1} in static atmosphere using α-alumina as a reference material.

Penetration test: The test for chemical penetration inside bamboo was done by reported method[11].

SEM studies: SEM patterns were taken at IIT Guwahati, on a LEO 1430 VP scanning electron microscope.

Graveyard test[12]: The treated samples along with the untreated one were buried vertically on exposed ground containing termite colony, with at least 1 cm exposed to air, for 1 year. After 1 year, the samples were dug out, the adhering mud were brushed away and attack by termites was assessed visually.

RESULTS AND DISCUSSION

From dimensional characteristics (Table-1), it was observed that the bamboo samples treated with clay followed by boric acid, copper acetate and sodium salt of diethyldithiocarbamate showed higher antishrink efficiency with increase in bulk-coefficient compared to only clay treated sample. The added chemicals were absorbed by the remaining pores of the cell wall in bamboo after the impregnation of clay particles. In presence of clay and chemicals, the cell wall of bamboo showed less shrinkage in contact with moisture than the untreated sample. Treatment of bamboo with clay followed by boric acid, copper acetate, sodium salt of diethyldithio-carbamate and kerosene showed higher weight per cent gain (WPG) value than only clay treated sample. Increase of weight per cent gain indicates the presence added substance in bamboo.

Variation of weight loss and decomposition temperatures of treated and untreated bamboo samples are shown in Table-2. From TG curves, it was observed that due to loss of water molecules, initial weight loss occurred upto 100 ºC. The major weight loss started from 215.5 ºC for untreated (Fig. 1), 236 ºC for only clay treated (Fig. 2) and 240 ºC for clay followed by boric acid, copper acetate and DEDTC treated bamboo samples (Fig. 3). The active decomposition temperatures that caused

TABLE-1
DIMENSIONAL CHARACTERISTICS AND WEIGHT PER CENT GAIN OF UNTREATED AND TREATED BAMBOO SAMPLES

Chemicals used	Su (%)	St (%)	ASE (%)	BC (%)	WPG (%)
Untreated	0	0	0	0	0
Clay + kerosene	9.49	5.20	45.21	4.08	14.82
Clay + BA + CA + DEDTC + kerosene	10.93	5.22	52.24	5.43	19.37

TABLE-2
THERMAL DATA OF UNTREATED AND TREATED BAMBOO SAMPLES

Chemicals used	2nd decomp temp. (°C)	Weight loss (%)	Active decomp. temp. (°C)
Untreated	215.5-503.19	86.405	327.50
Clay + kerosene	236.0-505.67	85.804	330.41
Clay + BA + CA + DEDTC + kerosene	240.0-502.46	82.883	344.31

the major weight loss were 327.50 °C for untreated, 330.41 °C for only clay treated and 344.31 °C for clay followed by boric acid, copper acetate and DEDTC treated bamboo samples (Figs. 1-3). These results indicate that treated samples were thermally more stable than untreated samples.

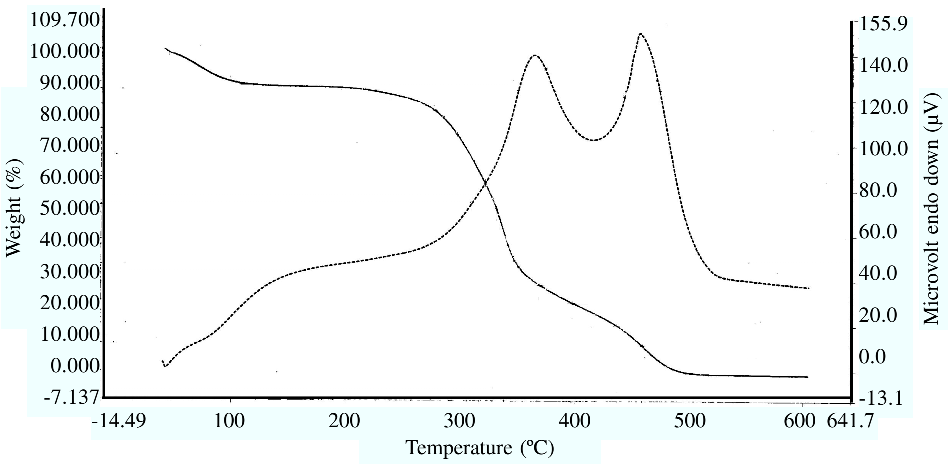

Fig. 1. Thermogram of untreated bamboo sample

The SEM pattern of untreated bamboo sample is shown in Fig. 4. Penetration of chemicals was observed from the SEM patterns. The patches which were observed in Fig. 5 indicate the presence of added substance. Fig. 6 shows bamboo samples after the field test. From the field test, it was observed that untreated sample was heavily damaged due to termite attack but the extent of damage was minimal when samples were treated with clay and other chemicals.

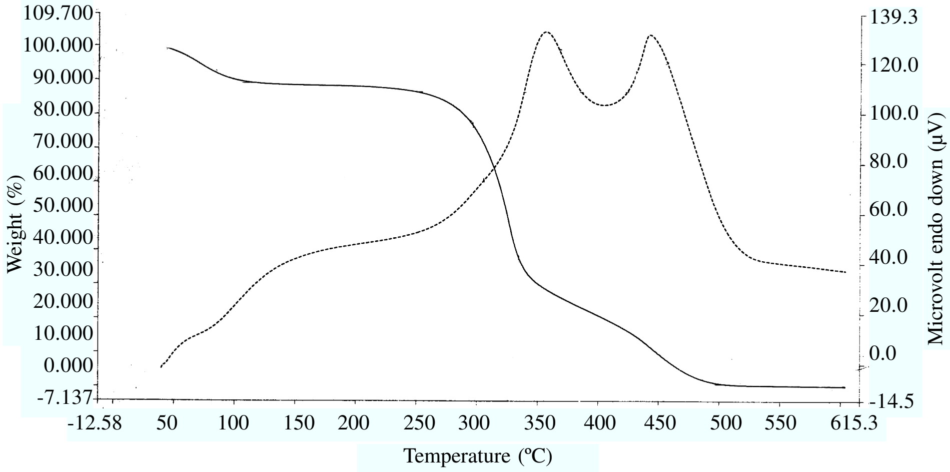

Fig. 2. Thermogram of clay + kerosene treated bamboo sample

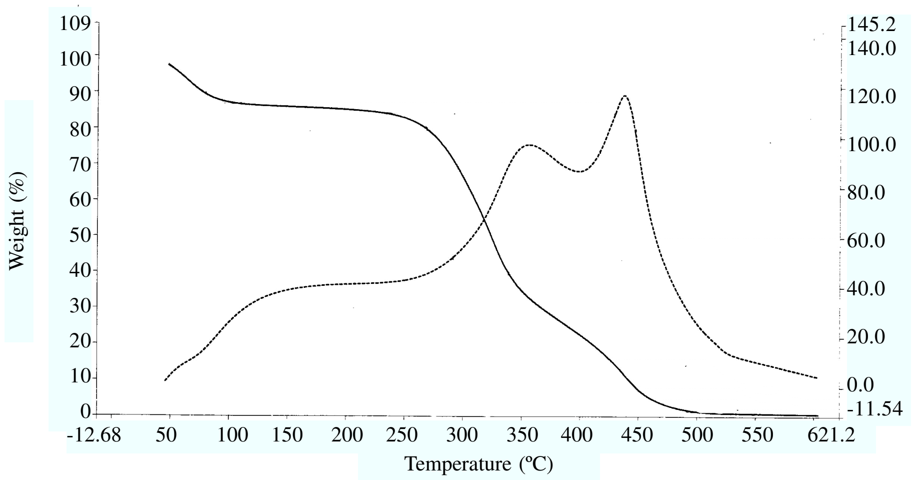

Fig. 3. Thermogram of clay + BA + CA + DEDTC + kerosene treated bamboo sample

The use of dithio compounds, particularly, dithiocarbamates as antibacterial and antifungal agent are well known[13,14]. Both Cu^{2+} and DEDTC probably forms strong covalent bonds with the nucleic acids and metalloenzymes of bacteria and make them dysfunctional. Similarly, boric acid has been reported[15,16] as a stomach poison for termite and acts as a good deterrent. The penetration of clay nanoparticles inside the pores, created after extraction with various solvents, gave good weight per cent gain and dimensional stability. Treatment with kerosene makes the bamboo surface hydrophobic and moisture cannot go inside, which help to retain dimensional stability and also repulse fungal and insect attack.

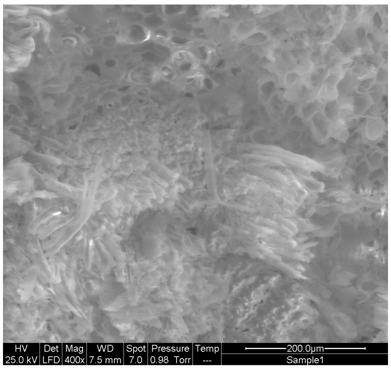

Fig. 4. SEM pattern of untreated bamboo sample

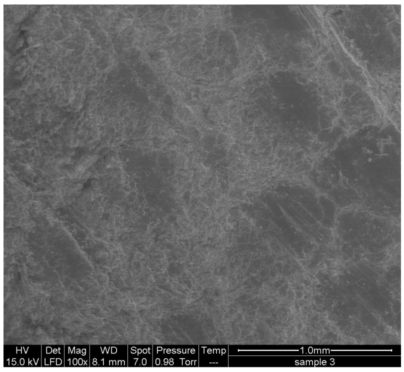

Fig. 5. SEM pattern of clay + BA + CA + DEDTC + kerosene treated sample

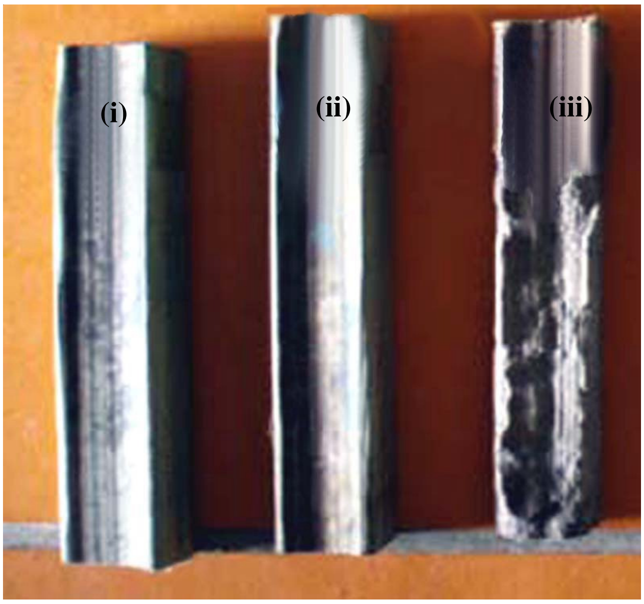

Fig. 6. Bamboo samples after graveyard test for one year (i) clay + BA + CA + DEDTC + kerosene treated (ii) clay + kerosene treated (iii) untreated

Conclusion

From analysis of thermal and dimensional parameters, it may be concluded that impregnation of clay and chemicals into bamboo gives good dimensional and thermal stability. Results of field tests over 1 year showed that there was no damage by termites on the surface of treated bamboo. Therefore, clay and chemicals like boric acid, copper acetate and sodium salt of diethyldithiocarbamate have good potential to resist termite and fungal attack as well as to retain dimensional stability of bamboo.

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