Water repellent treatments for catamaran grade *Bombax ceiba* Linn. (Spermatophyta/Dicotyledoneae) wood


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Received 9 October 2002, revised 24 July 2003

Water repellency effectiveness (WRE) of four chemical formulations, namely polymeric methylene diisocyanate (PMDI), cashew nut shell oil (CSNL), varnish and chromium trioxide, was assessed on Cooper-Chrome-Arsenic (CCA) treated *Bombax ceiba* wood. Fifteen cycles of repeated wetting and drying were performed on water repellent coated and untreated wood. Water repellency was very high in the first cycle and then declined in all the coating system in subsequent cycles. After 10th cycle WRE became constant for all the systems. PMDI exhibited highest water repellency followed by chromium trioxide, CSNL and varnish. With the application of water repellent formulations, water uptake can be reduced considerably, which will maintain buoyancy of wood. The water repellents apart from reducing water holding capacity also reduces leaching of preservatives from the structures, which resulted in enhancing the durability of wood.

**Key words**: *Bombax ceiba*, catamaran, water absorption, water repellent

Wood, being a porous material, absorbs water through capillary action. Presence of water in wood in combination with temperature and humidity makes it an ideal material for fungal attack. Application of water repellents over the wood surface is a common practice to prevent liquid water uptake and fungal attack in wood. The effectiveness of water repellents depends on several parameters like nature of bond between wood surface and water repellent, treatment technique, physical characteristics of wood etc.² The mechanism of water movement in wood and its prevention using water repellents have been studied extensively².³ However, study on water repellent in marine structures especially on catamarans (marine fishing craft) has not been carried out so far in Indian conditions.

Catamarans are the most extensively used fishing craft in India and the livelihood of millions of fishermen depends mainly on the ready availability of traditional tree species like *Albizia chinensis* (siris) and *Paraserianthus falcata* (Albizia falcata) for catamaran fabrication. Due to non-availability of these species, a potential alternative species viz. *Bombax ceiba* has been suggested for fabrication of fishing craft after suitable chemical treatment⁴. The problem associated with alternative species is the increase in weight, when put in service condition, due to highly porous nature. Swelling, surface cracks and splits appear on the logs due to high water holding capacity of the timber species. Therefore, to avoid these defects, there is a need to apply suitable water repellents to copper chrome arsenic (CCA) treated catamarans. In the present study, water repellency effectiveness (WRE) of four different formulations was studied on wood of *Bombax ceiba* Linn. (semul wood) (Spermatophyta/Dicotyledoneae).

From the normal wood of *Bombax ceiba*, 100 sample pieces (of 1.9 cm*1.9 cm in cross section and 30 cm in length) were prepared. All the samples were air dried and subsequently weighed. About 80 air-dried test samples were treated with 8% aqueous solution of CCA wood preservative using vacuum-pressure impregnation to obtain around 16 kg/m³ loading of chemical. Immediately after treatment, excess solution was wiped from the samples and weighed to calculate the loading of chemical. The treated samples were open stacked for 15 days for air drying and proper fixation of CCA. Twenty untreated samples were kept separately to use as control specimens for water repellency test.

Four formulations namely polymeric methylene diisocyanate (PMDI), cashew nut shell oil (CSNL), commercial grade varnish and 5% aqueous solution of chromium trioxide were assessed for their effectiveness in imparting water repellency to the wood. All the chemicals were of commercial grade
while chromium trioxide was laboratory grade chemical.

Out of 80 CCA treated samples, 50 samples having CCA loading of around 16 kg/m³ were selected and divided into five groups each containing 10 specimens. These 50 CCA treated and 10 untreated samples were end-coated with a thick layer of paraffin wax to prevent water absorption from the ends during the water soaking test. The four groups out of five were treated (brush coating) with individual water repellent formulations. The fifth group of 10 samples was without any coating in order to assess the water repellency induced by CCA treatment only. After coating with formulations, samples were air-dried for a week for proper fixation of water repellents on the wood surfaces and weighed.

Water repellency effectiveness (WRE) of the coating systems was assessed by measuring water uptake by the samples after immersing them in fresh water for a fixed period. Each group of water repellent and untreated control samples were completely immersed in water in separate containers for 8 hours. After the immersion period, samples were weighed to know the water absorption and were kept open stacked overnight (16 hours) for air-drying. This process of 8 hour soaking and 16 hour air-drying (one cycle) was repeated for 15 days. WRE was evaluated using the following equation:

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\text{WRE} \% = \left( \frac{W_u - W_t}{W_u} \right) \times 100
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where \(W_u\) (mean value of 10 control samples) and \(W_t\) (mean value of 10 treated samples) are water uptake by untreated and treated sample respectively. The experiment was carried out in fresh water and it was presumed that the behaviour of different water repellents in seawater and fresh water will not differ with a great magnitude. To confirm this, a small experiment on the effect of water absorption in seawater and fresh water in untreated samples of Bombax ceiba wood was performed in laboratory condition. Results indicated that the water absorption in seawater was 3% less than that of fresh water. This confirms that the water absorption with seawater and fresh water is almost same.

Water repellency effectiveness (WRE) of different coating systems with respect to each cycle (8 hours soaking and 16 hours air drying) is shown in Fig. 1. It is evident that PMDI, cashew nut shell oil and varnish coating exhibited very high water repellency in the first cycle (about 75%) but decreased sharply in the second cycle. In subsequent cycles of wetting and drying, a gradual decrease in WRE was observed in all the treatments except for chromium trioxide. However after ten cycles, WRE became almost constant for all the coating systems examined although its magnitude was different for each system. A very high WRE in the first cycle in all treatments is due to absorption of large quantities of water by the untreated controls as compared to the water repellent coated samples. Therefore, it does not depict the true water repellency effectiveness on coating systems. Water repellency has to be evaluated for repeated cycles of soaking and drying in order to assess the effectiveness and permanency of water repellents. The amount of water absorption by untreated samples dropped sharply in the second cycle as the wood started to get saturated with water and absorption became almost constant after the 5th cycle. In contrast, the absorption of water by treated samples dropped slightly every day. Therefore WRE decreased gradually in the first ten cycles of wetting. After ten cycles the water absorption by treated as well as untreated samples became almost constant resulting in constant WRE with different magnitude.

Amongst all of the formulations, polymeric methylene diisocyanate (PMDI) coating exhibited highest water repellency and after 15 cycles of wetting and drying it was around 55%. High water repellency by PMDI coating can be attributed to the nature of its chemical reaction with the wood constituents. PMDI reacts quickly with the hydroxyl groups of wood to form urethanes, which subsequently react with additional isocyanate to form
a polyurethane network making the wood surface hydrophobic in nature. Cashewnut shell oil (CSNL) coating also exhibited a consistent WRE of nearly 50% after 4 cycles of wetting and drying. However, with the application of CSNL, wood became very heavy (16%) and also sticky in nature, which is undesirable for catamaran timbers as buoyancy and low density are important criteria. The coatings with PMDI, varnish and chromic acid gives weight gain of 6%, 9% and 5% respectively after treatment. These weight gains are in water in addition to the weight gain in preservatives. WRE of commercial grade varnish coating decreased almost linearly (from 75% to 35%) till the 10th cycle and then became constant afterwards. Water repellency by cooper chrome arsenic (CCA) treatment decreased quite rapidly in each cycle and was only 4-5% after 4-5 cycles of repeated wetting and drying.

Application of 5% aqueous solution of chromic trioxide resulted in consistent WRE of nearly 50% from the first cycle. The water repellency due to chromium trioxide is attributed to the increase in lignin cross-linking by formation of water repellent chromium (VI)-guaiacyl unit complexes. Application of aqueous solution of chromium trioxide solution has been reported to improve surface finish, water repellency and prevent surface degradation due to weathering of rubber wood (Hevea brasiliensis), mango wood (Mangifera indica) and Acacia auriculaeformis wood. Chromium trioxide could prove to be an excellent water repellent system for catamaran grade timber; however, large quantity of chromium trioxide could result in oxidation of the wood surface and could also raise some environmental concerns as it has been considered as a hazardous chemical. It has been tested in field by applying chromium trioxide treatment to CCA treated catamaran made of Bombax ceiba. Trial on this catamaran is going on at Krishnapatnam harbour of Andhra Pradesh. It is observed that this catamaran is performing well as water absorption is less than that of only CCA treated catamarans. However, a detailed study is in progress.

Cumulative weight gain in the treated and untreated samples after each cycle of wetting is shown in Fig. 2. The water absorption in treated samples was quite low as compared to untreated samples. After 15 cycles, untreated wood became almost 70% heavier than initial air-dried weight. With the increased absorption of water, buoyancy of wood decreases which in turn affects the efficiency of catamarans. Water repellent coated wood (except CCA treated wood) absorbed much less water and became heavier only by 15-20% with respect to initial air-dried condition. A small weight gain by water repellent coated samples indicates their effectiveness in restricting water movement in the wood.

It was thought necessary to know the water retention by samples treated with different water repellents while air-drying for 16 hours. Weight gain (%) was calculated after each drying cycle with respect to initial air dried weight (weight before water repellency tests were started) as it was obvious that sample can not regain the same initial air dried weight.
after immersion in water for 8 hours and airdrying for only 16 hours. Figure 3 shows the weight gain (%) by samples after 16 hours drying in each cycle with respect to initial air-dry weight. In the case of untreated control wood, water retention was very high and samples continued to accumulate water, indicating a high rate of water absorption during the 8 hours of soaking, and a slow rate of drying. In the later stages (after 10 cycles) as the wood started saturating with water, the difference between the amount of water absorbed during soaking and the amount of water desorbed during drying became minimal. This resulted in an almost identical air-dried weight in consecutive cycles. Air-dried weight of the samples increased slowly in all the water repellent treatments except chromium trioxide. In case of chromium trioxide treated wood, samples regained almost the initial weight. Chromium trioxide dries at much faster rate as it does not form any layer over wood surface like other water repellents.

It can be concluded that with the application of water repellent formulations, water uptake can be reduced considerably which will maintain buoyancy of wood. This could be of immense importance for catamarans, as they are in water for almost 8-10 hours every day and kept outside for nearly 14-16 hours. Since PMDI and chromium trioxide both chemically react with the wood constituents and form stable bonds, they were found to be most effective in inducing considerable water repellency without adding much weight to wood unlike cashewnut shell oil.

The work is a part of World Bank sponsored project “Forestry Research Education and Extension (FREE)” and the same is acknowledged. Thanks are due to Mr. K.T. Chandashekar, Mrs Shalini P. Rao and Mr. K. Kamalnathan of IWST Bangalore for their technical support in carrying out the experiment.

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