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Assessment of biodeterioration of rubber wood exposed to field conditions

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Abstract

Rubber wood (*Hevea brasiliensis*) can be used commercially for the construction of fishing boats, which are subjected to biodegradation in the water, and on land both with and without soil contact. In order to obtain data on the natural durability of this wood, the extent of biodeterioration was assessed through visual observation, changes in the specific gravity of the wood and loss in the compressive strength of wood panels after 90 and 150 days in field tests. Changes in wood chemistry due to biodeterioration under field conditions were also characterized through Fourier transform infrared (FTIR) spectroscopy. Test samples in soil burial tests (graveyard tests) were more severely damaged than panels exposed to atmospheric weathering or immersed in sea water below the low tide mark. Strength losses in panels exposed to the marine and atmospheric conditions were not commensurate with the weight losses.

Keywords: *Hevea*; Rubber wood; Field studies; Compressive stress; Specific gravity; FTIR spectroscopy

1. Introduction

Hevea brasiliensis (rubber wood), a native of the Amazon valley of South America, was introduced to India in the latter half of the 19th century and is now widely cultivated in the southern states of India for the latex yield. It is estimated by the Rubber Board of India that $1.6 \times 10^6\,m^2$ wood is available annually from the trees that are felled for replanting. The supply of wood is expected to increase with increasing plantation activities in Orissa and the Andaman and Nicobar Islands, as well as the north-eastern states (Shukla and Lal, 1985). Rubber wood is a light-coloured hardwood with a density ranging from 435 to $626\,kg\,m^{-3}$ at 12% moisture content (Rubber Board, 2005). It has physical and mechanical properties comparable with timbers like teak, but is rather susceptible to attack by organisms. The sapwood is not differentiated from the heartwood.

Durability of wood, the natural decay resistance of the heartwood of the timber, can be measured by examining the progressive decay of small wooden stakes buried in the ground, but the natural durability of any wood species cannot be measured in one country and used in another. The natural resistance of rubber wood to decay and its protection have been studied by Hong et al. (1982) and Hong and Liew (1989). The performance of preservative-treated rubber wood in Indian coastal waters (Rao et al., 1993; Edwin and Pillai, 2004) and the mechanical properties of rubber wood (Shukla and Lal, 1985; Gnanaharan and Dhamodaran, 1993; Matan and Kyokong, 2003; Edwin and Pillai, 2004) have also been studied.

The aim of this study was to determine the effect of biological deterioration on the major physical, mechanical and chemical properties of rubber wood. This was done by assessing biodeterioration of untreated wood under marine, atmospheric and soil conditions through visual observations and changes in the specific gravity (SG) and compressive strength of the wood. Attempts were also made to characterize the changes in wood chemistry caused by biodeterioration using Fourier transform infrared (FTIR) spectrometry.

2. Materials and methods

The tree, from which the samples were obtained, had a girth of approximately 25 cm. The planks were air seasoned and seven sets of eight

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Table 1
Hydrographic data during the exposure period

Date	Surface water temp. (°C)	Dissolved oxygen (mg/l)	Salinity (ppt)	pH	Turbidity (NTU)
21.11.00	29.5	5.2	23.86	7.96	12.0
05.12.01	30.0	6.0	19.52	7.86	5.0
12.12.01	27.5	5.6	29.24	8.04	5.5
19.12.00	28.5	5.6	31.98	8.04	23.5
26.12.00	27.5	5.0	26.20	7.90	10.0
02.01.01	27.5	5.0	31.08	8.10	27.0
20.01.01	28.0	5.4	24.76	7.78	24.0
24.01.01	29.0	4.8	27.65	7.86	11.5
30.01.01	28.0	4.8	30.72	8.02	32.0
06.02.01	29.5	6.0	24.76	7.98	7.0
15.02.01	29.0	4.6	24.04	7.64	37.0
20.02.01	30.0	4.6	24.76	7.89	8.0
27.02.01	30.0	3.2	25.12	7.74	31.5
13.03.01	29.5	5.2	25.66	7.66	25.5

samples 50 × 50 × 200 mm were prepared as per IS: 1708-1986 (IS, 1986), for the experiment. Only clear, straight-grained, homogenous samples without defects (knots, cross grains, checks and splits, etc.) were selected for testing. Since it is difficult and costly to simulate service conditions faced by boat building timbers in a laboratory, field tests were used for determining the amount of biodeterioration under different environmental conditions. One set of samples was kept in the laboratory as control panels, and the remaining six sets were used for marine exposure studies, weathering tests and soil burial tests (graveyard tests).

Earlier studies (Rao et al., 1993; Edwin and Pillai, 2004) showed that maximum deterioration occurred in about 6 months, it was decided to retrieve one set of the panels after 90 days and another after 150 days from all three types of exposure. For marine exposure, the specimens were tied by polyethylene ropes onto iron racks and then immersed below the low tide mark at the Institute test site. Hydrographical parameters, including salinity, surface water temperature, pH, dissolved oxygen (DO) and turbidity were monitored at the test site throughout the period of the study (Table 1). The rating scheme was patterned as per ASTM D-2481-81 (ASTM, 1982). The graveyard test was conducted on the Institute site where such tests had been carried out earlier. In this test, two-thirds of each test specimen was buried in the ground with the remaining one-third above ground. The specimens were placed in four rows of four specimens each. Vegetation was removed manually as and when required. At the time of inspection, specimens were removed from the ground, scraped clean, visually examined, probed with a sharp instrument and rated numerically for both decay and termite attack as per ASTM D1758-74 (ASTM, 1980). The weathering test panels were tied to iron racks and exposed on the Institute terrace. The racks were placed at an angle of 45° to the vertical to achieve maximum exposure for decay. The panels were rated at the end of the prescribed periods as described by Highley (1995).

Since SG is an index of the amount of wood substance in a piece of wood, the changes in SG of the samples were measured on the basis of oven-dry weight and volume at 12% moisture content in order to estimate percentage weight loss due to exposure.

The panels were subjected to mechanical strength testing to assess the compression parallel to grain stress of unexposed and exposed specimens, using a 200 kN ZWICK Universal Testing Machine 1484. The test results for mechanical strength only were analysed using multivariate analysis of variance. The dependent variables were compressive stress and compression, and the treatment factors were period and type of exposure. The level of probability at which the significance was tested was 1%.

Finely powdered wood samples were pelleted after mixing with KBr and the spectra of the good and deteriorated samples were recorded using a Nicolet Avatar 360 Esp FTIR Spectrometer (Dent, 2005). Fifty parallel scans were taken in the mid-infrared region (400–4000 cm^{-1}).

3. Results and discussion

3.1. Visual observations

Inspection was conducted after 90 and 150 days at the time of retrieval from the marine environment. The weekly monitoring of hydrographic parameters showed that salinity ranged between 19.52 and 31.98 ppt during the period of exposure (Table 1). The average surface water temperature during this period was 28.8 °C. DO and turbidity values also showed conditions favourable for the growth of fouling and boring organisms. The panels exhibited moderate attack at the end of 90 days and moderate to heavy attack at the end of 150 days. They were given ratings of 7 and 4, respectively. There were up to five borer holes at the end of 150 days, and the volume of the borer holes ranged from 0.05 to 0.22 cm^3. The borers were identified as *Martesia* sp. and *Sphaeroma* sp. When marine exposure studies of small, preservative-treated wood panels were made by Johnson and Gutzmer (1984), they found that untreated panels could be badly damaged by marine borers in 6–18 months. Studies on the natural resistance of rubber wood to marine borers by Rao et al. (1993) showed that rubber wood in untreated state is highly perishable; their samples were completely destroyed by marine borers in 4–6 months. Similar studies conducted by Edwin and Pillai (2004) also showed that, while preservative-treated rubber wood panels performed well under marine conditions, the control panels were completely destroyed at the end of 6–7 months.

After 90 days, the panels exposed to atmospheric conditions showed grayish discolouration and slight splitting and cracking. The staining deepened after 150 days, and splits and cracks became more prominent. When Beesley et al. (1983) studied exposed painted timbers, they showed that the decay hazard can be expected to be high in humid, tropical climates, and that permeable species of wood with very low natural durability are likely to show extreme effects due to fungal decay within 2–3 years.