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Strength Properties of Preservative Treated *Gigantochloa scortechinii* after Vacuum Impregnation Process

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Abstract: Strength properties of preservative treated two-year-old and four-year-old *Gigantochloa scortechinii* Gamble were evaluated. The preservatives used in the study were Ammonium Copper-Quaternary (ACQ), Copper Chrome Arsenic (CCA) and Borax Boric Acid (BBA) at 2 and 4% concentrations using vacuum pressure impregnation process. It was found that there was an overall strength reduction in the treated bamboo immediately after treatment. The strength reduction ranged from 4.9 to 7.6% for ACQ, 5.0 to 7.2% for BBA and 5.9 to 7.9% for CCA treated bamboo. The reduction in strength was found to be dependent on the type of preservatives applied, concentration used and their retention in the bamboo.

Key words: Bamboo treatment, preservative application, preservative retention, vacuum impregnation, strength properties

Introduction

The strength properties of bamboo have been investigated by a number of researchers. It possesses excellent strength properties that are as good as other building materials like steel, concrete and timber (Janssen, 1985). The strength of bamboos are associated with their anatomical structure and composition particularly the fibres and parenchyma. It relies to a large extend on the quantity and quality of fibres. However, the strength of bamboo varies with respect to species, age, moisture content and position along the culm (Limaye, 1952; Lavers, 1969; Janssen, 1981; Liese, 1987).

An optimum strength occurs when bamboo attained its maturity age of around 3-4 years. For this reason bamboo are harvested at this age especially for structural or other heavy-duty uses (Liese, 1986; Sattar *et al*., 1990; Kabir *et al*., 1993; Espiloy, 1994).

Compressive strength was found to increase with height while the bending strength showed a decrease in bending strength (Kabir *et al*., 1991, 1993; Sattar *et al*., 1990; Liese, 1986; Abd. Latif, 1991; Espiloy, 1985; Janssen, 1985; Limaye, 1952). The compressive and the bending strength also increased from the inner part to the periphery of the culm wall.

Treating bamboo with preservative is intended to increase the life span service of the bamboo and their products. However, questions arise on whether the treatments process will affect the strength properties of the bamboo. Although several studies on strength properties have been conducted, information on the bamboo strength properties after treatment is not available somehow.

The aim of this study was to investigate the effect of treatment using various preservative on strength properties of bamboo with emphasis on the strength reduction. The strength reduction being investigated is static bending (MOR) and compression parallel to the grain.

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Materials and Methods

All bamboo culm (*G. scortechinii)* used in this study were taken from Nami Forest Reserve area in Kedah, Malaysia from Jan. 2004 to July 2005. Each culm was equally crosscut into three length portion. Each sample has a length of 80 cm and with diameter ranging between 8 to 12 cm. Treatment were done on round bamboo with combination of Borax and Boric Acid (BBA) at ratio 1.54 : 1, Copper Chrome Arsenate (CCA) and Ammoniacal Copper-Quaternary (ACQ) at 2% and 4% by vacuum impregnation processes. Culm samples were placed in the treatment cylinder and treated under vacuum pressure condition. The treatment cycle protocol adopted was as follows: -

Initial vacuum	-	600 mm Hg for 30 min (to take the air out of bamboo)
Applying Pressure	-	12 kg cm^{-2} for 2 hr
Final vacuum	-	600 mm Hg for 30 min (to remove the excess preservative from the bamboo)

After treatments all samples were sliced into strips of 2 cm x thickness x 80 cm length. Strength properties evaluated were static bending and compression parallel to grain and carried out in accordance to the ISO 22157 with some modification using the Shimadzu Computer Controlled Universal Testing Machine (ISO, 2004). All testing blocks were conditioned to 12% moisture content prior to testing. This was done by placing the test blocks in a conditioning chamber and controlled relative humidity, temperature and air-circulation for a week until the required equilibrium moisture contents were obtained. All testing on the mechanical properties of the bamboo were conducted at the UMS laboratory.

Results and Discussion

In general the strength properties conducted on the untreated 2 and 4 year old *G. scortechinii* varied with age and culm heights. Four-year-old bamboo possess better strength with an average increased about 4.2% for MOR and 10.3% for compression strength, as compared to two-year-old bamboo (Table 1). The increase may be associated with the basic densities, which were found to increase from 2 to 4 year-old culms and from the bottom to the top portion of the culms (Razak, 1998; Sulaiman, 1993). The age is considered to be an important factor influencing the strength properties of bamboo. These results are in agreement with the finding of Limaye (1952), Janssen (1981) and Abd. Latif (1991).

Table 1: Means strength properties of untreated 2 and 4 year-old *G. scortechinii*

		Age		
	Portion	2 Years	4 Years	Increase in strength of* 4 years-old culms (%)
Bending strength (MOR)	Bottom	1401	1462	4.3
(kg cm^{-2})	Middle	1356	1406	3.7
	Top	1334	1385	4.5
	Mean	1364	1418	4.2
Compression strength	Bottom	493	529	7.3
parallel to the grain	Middle	536	607	13.2
(kg cm^{-2})	Top	627	692	10.4
	Mean	552	609	10.3

* based on 2 year-old value;

Table 2: Preservative retention (km/m^{-3}) of 2 and 4 year-old *G. scortechinii* bamboo treated by vacuum pressure impregnation process.

Chemical	Portion	2 year-old	4 year-old
ACQ (2%)	Bottom	4.95	4.32
	Middle	6.45	4.54
	Top	7.21	5.96
	Mean	6.20	4.94
ACQ (4%)	Bottom	9.15	7.75
	Middle	9.93	7.89
	Top	10.73	9.07
	Mean	9.94	8.24
BBA (2%)	Bottom	4.50	4.21
	Middle	6.30	4.41
	Top	6.89	5.12
	Mean	5.90	4.58
BBA (4%)	Bottom	8.84	7.15
	Middle	9.36	7.65
	Top	10.57	8.22
	Mean	9.59	7.67
CCA (2%)	Bottom	5.63	4.86
	Middle	7.74	4.93
	Top	8.65	5.92
	Mean	7.34	5.24
CCA (4%)	Bottom	10.54	7.20
	Middle	12.15	8.46
	Top	14.53	10.80
	Mean	12.41	8.82

Table 3: Bending strength (MOR) and strength decreased of treated samples after vacuum pressure treatment (kg cm^{-2})

Chemical	Portion	Bending strength (MOR) of 2 year-old	Strength* decrease (%)	Bending strength (MOR) of 4 year-old	Strength** decrease (%)
ACQ (2%)	Bottom	1297	7.4	1379	5.7
	Middle	1265	9.7	1316	6.4
	Top	1240	7.0	1308	5.6
	Mean	1267	8.0	1334	5.9
ACQ (4%)	Bottom	1328	5.2	1388	5.1
	Middle	1288	8.1	1339	4.8
	Top	1251	6.2	1325	4.3
	Mean	1289	6.5	1351	4.7
BBA (2%)	Bottom	1309	6.6	1383	5.4
	Middle	1257	10.3	1325	5.8
	Top	1249	6.4	1315	5.1
	Mean	1272	7.8	1341	5.4
BBA (4%)	Bottom	1321	5.7	1397	4.4
	Middle	1285	8.3	1334	5.1
	Top	1260	5.5	1321	4.6
	Mean	1289	6.5	1351	4.7
CCA (2%)	Bottom	1302	7.1	1364	6.7
	Middle	1251	10.7	1322	6.0
	Top	1240	7.0	1301	6.1
	Mean	1264	8.3	1329	6.3
CCA (4%)	Bottom	1325	5.4	1372	6.2
	Middle	1275	9.0	1335	5.0
	Top	1253	6.1	1308	5.6
	Mean	1286	6.8	1338	5.6

* Calculated based on 2 year-old value of untreated *G. scortechinii* culms

** Calculated based on 4 year-old values of untreated *G. scortechinii* culms

Table 4: Compression strength and decreased of treated samples after vacuum pressure treatment (kg cm^{-2}).

Chemical	Portion	Bending strength (MOR) of 2 year-old	Strength* decrease (%)	Bending strength (MOR) of 4 year-old	Strength** decrease (%)
ACQ (2%)	Bottom	451	8.5	491	7.2
	Middle	500	6.7	561	7.6
	Top	571	8.9	650	6.1
	Mean	507	8.0	567	7.0
ACQ (4%)	Bottom	466	5.5	494	6.6
	Middle	502	6.3	563	7.2
	Top	579	7.7	643	7.1
	Mean	516	6.5	566	7.0
BBA (2%)	Bottom	461	6.5	501	5.3
	Middle	501	6.5	577	4.9
	Top	588	6.2	654	5.5
	Mean	517	6.4	577	5.2
BBA (4%)	Bottom	470	4.7	505	4.5
	Middle	509	5.0	580	4.4
	Top	589	6.1	656	5.2
	Mean	523	5.3	580	4.7
CCA (2%)	Bottom	456	7.5%	497	6.0
	Middle	502	6.3%	568	6.4
	Top	581	7.3%	646	6.6
	Mean	513	7.0%	570	6.3
CCA (4%)	Bottom	463	6.1%	501	5.3
	Middle	508	5.2%	573	5.6
	Top	592	5.6%	653	5.6
	Mean	521	5.6%	576	5.5

* Calculated based on 2 year-old value of untreated *G. scortechinii* culms

** Calculated based on 4 year-old values of untreated *G. scortechinii* culms

Table 5: Summary Analysis of Variance for bending and compression strength for preservative treated blocks

Type of test	Source of variation	Sum of square	d.f.	Mean square	F-ratio
Static bending strength	Age	215082.67	1	215082.67	6644.83 *
	Preservative	3077.00	2	1538.67	47.54 *
	Concentration	13254.00	1	13254.00	409.47 *
	Height	167934.33	2	83967	2594.11 *
Compression strength	Age	174762.67	1	174762.67	2880.02 *
	Preservative	3627.00	2	1813.50	29.89 *
	Concentration	1350.00	1	1350.00	22.25 *
	Height	683404.00	2	341702.00	5631.12 *

* : Significant at $p<0.01$

The preservative retentions of the 2 and 4 year-old treated *G. scortechinii* are tabulated in Table 2 and the results of the strength tests are presented Table 3 and 4. The analysis of variances for both tests is shown in Table 5. There is a significantly higher amount of preservative retention on 2 year-old *G. scortechinii* compared to 4 year-old.

The presence of preservatives in *G. scortechinii* after the treatment process slightly decreased the strength properties of the bamboo. It was observed that there is a variation in the decrease of the strength properties that are dependent on the type of preservative and the age of the bamboo used. The overall results indicate a strength reduction of 4.9 to 7.6% for the ACQ, 5.0 to 7.2 for the BBA and 5.9 to 7.9% for the CCA. Bamboo samples treated with ACQ and CCA were found to reduce the bamboo strength properties slightly more than BBA. The 2 year-old culms show slightly higher reduction in strength properties than the 4 year-old culms.

Certain preservative are known to fix in the cell walls of the bamboo during the treatment process. This is especially true for CCA and ACQ. The fixing of this chemical might interfere with

the chemical structure of the cell wall. As the results of this, some cellulose chain are broken down that might reduce the strength. BBA on the other hand is known to have no fixing ability and thus the effect on the treatment is reduce significantly compare to CCA and ACQ.

Conclusions

- The MOR of the bending strength decreased from bottom to top portion of the bamboo culms. The 4 years bamboo has higher values between 3.7 to 4.5% then those of the 2 years old culms.
- The compression strength increased from bottom to the top portion of the bamboo culms. The strength values of the 4 years bamboo have higher values between 7.3 to 13.2% compared to the 2 years bamboo culms.
- Treating *G. scortechinii* culms with preservatives (ACQ, BBA and CCA) resulted in a slight decreased in the bamboo strength properties.
- The rate of the strength decrease depend on the type of preservatives, the age of the culms used and chemical retention during treatment process in the bamboo culms.

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