BENDING AND COMPRESSION STRENGTHS OF PRESERVATIVES TREATED BAMBOO *Gigantochloa scortechinii* GAMBLE

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ABSTRACT. The strength properties, particularly the bending and the compression, of preservative treated 2- and 4-year-old *Gigantochloa scortechinii* Gamble were evaluated. The preservatives used in the study were the ammoniacal-copper-quarterary (ACQ), copper-chrome-arsenic (CCA) and borax-boric acid (BBA). These preservatives were applied to the bamboo at solution strengths of 2 and 4 % through vacuum impregnation process. The initial vacuum at 600 mm were applied for 30 minutes, followed pressure at 12 kg/cm^2 for 2 hours and final vacuum at 600 mm Hg for another 30 minutes to remove excess preservatives from the treated bamboo. After conditioned to 12 % moisture content, the samples were tested for evaluation of their strength. The results indicated that there were an overall reduction in strengths of the bamboo. The strength reduction ranged from 5.0 to 10.7 % for ACQ, 4.4 to 10.3 % for BBA and 4.3 to 9.7 % for CCA treated bamboo. Reductions in the strengths were found to be dependent on the type of preservative applied, solution strengths used and their retention in the treated bamboo.

KEYWORDS. Bamboo treatment, preservative application, preservative retention, vacuum impregnation process and strength properties.

Introduction

Bamboo 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 (Anon., 2004; Espiloy, 1994 and Janssen, 1981).

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 (Janssen, 1985; Kabir *et al*., 1991 and Lavers, 1952).

Compressive strength of the bamboo were found to increase with height. While at the same time the bending strength showed a decrease value (Janssen, 1985; Kabir et al., 1991; Lavers, 1969 and Sattar *et al*., 1990)). 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. Studies on bamboo strength

properties in natural condition have been conducted by several researchers. However, the study on the strength properties of bamboo after preservative treatment is still lacking.

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

Materials and methods

All bamboo culm (*G. scortechinii)* used in this study were taken from Nami Forest Reserve area in Kedah, Malaysia. 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 according to Razak (1998) 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 were as follows: -

Initial vacuum	-	600 mm Hg for 30 minutes (to take the air out of bamboo)
Applying Pressure	-	12 kg/cm^2 for 2 hours
Final vacuum	-	600 mm Hg for 30 minutes (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. They were then placed under controlled condition chamber at 65% relative humidity and temperature at 20°C for at least 3 weeks prior to testing. This was done in order to attain the final moisture content of 12% for each bamboo samples. The strength properties evaluated were the static bending and the compression parallel to grain. All tests were carried out in accordance to the ISO 22157 (Anon, 2004) using the Shimadzu Computer Controlled Universal Testing Machine located at the Structural Laboratory in Forest Research Institute Malaysia.

Results and Discussions

The results on the strength properties of natural untreated culms of *G. scortechinii* are presented in Table 1. 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. 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 (Limaye, 1952 and 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 Janssen (1981), Limaye (1952) and Latif (1991).

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

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

* based on 2 year-old value;

The preservative retentions of the 2 and 4 year-old treated *G. scortechinii* are tabulated in Table 2. The preservatives retention were higher in CCA treated bamboo 2 and 4-year old culms followed by the ACQ treated and BBA treated culms respectively.

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

Mean of 5 replicates

The results of the strength tests after preservatives treatment are presented Table 3 and Table 4. The analysis of variances for both tests is shown in Tables 5. There is a significantly higher amount of preservative retention on 2 year-old *G. scortechinii* compared to 4 year-old. The significance differences at $P<0.01$ were also observed in both the bending and compression strengths of the treated bamboo culms at different age, type of preservative, level of preservative concentrations applied and at different bamboo culm portion.

Table 3 : Bending strength (MOR) and strength reduction of treated bamboo samples.

Chemical	Portion	Bending strength (MOR) of 2 year-old	Strength* decrease (%)	Bending strength (MOR) of 4 year-old	Strength** decrease (%)
ACQ (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
ACQ (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
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***	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
CCA (4%)		1328	5.2	1388	5.1
	Bottom				
	Middle	1288	8.1	1339	4.8
	Top	1251	6.2	1325	4.3
	Mean	1289	6.5	1351	4.7
		1297	7.4	1379	5.7

Table 4 : Compression strength and strength reduction of treated bamboo samples.

Chemical	Portion	Compression strength of 2 year-old	Strength* decrease (%)	Compression strength of 4 year-old	Strength** decrease (%)
ACQ (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
ACQ (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
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***	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

CCA (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

* 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 & compression strength for preservative treated blocks

Type of test	Source of variation	Sum of square	d.f.	Mean square	F-ratio
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 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 5.0 to 10.7% for the ACQ, 4.4 to 10.3% for the BBA and 4.3 to 9.7% 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

1. Treating *G. scortechinii* culms with preservatives (ACQ, BBA and CCA) resulted in a slight decreased in the bamboo strength properties. The reduction in the strength properties are however dependent on the type of preservatives, the age of the culms used and the preservatives retention during treatment process.

2. The CCA treated bamboo experienced the highest strength reduction followed closely by ACQ and BBA treated bamboo culms. On the average the used of preservatives reduced the strength of the bamboo by 5 to 11% from their original strength in natural form at 12% moisture content.

3. The bending strength of CCA treated bamboo were reduced between 5.2 to 9.7% for the 2 year-old and 4.3 to 6.4% for the 4 year-old bamboo. The bending strength of ACQ treated bamboo were reduced between 5.4 to 10.7% for the 2 year-old and 5.0 to 6.7% for the 4 year-old bamboo. While the bending strength of BBA treated bamboo were reduced between 5.5 to 10.3% for the 2 year-old and 4.4 to 5.8% for the 4 year-old bamboo.

4. The compression strength of CCA treated bamboo were reduced between 5.5 to 8.9% for the 2 year-old and 6.1 to 7.6% for the 4 year-old bamboo. The compression strength of ACQ treated bamboo were reduced between 5.2 to 7.5% for the 2 year-old and 5.3 to 6.6% for the 4 year-old bamboo. While the compression strength of BBA treated bamboo were reduced between 5.0 to 6.5% for the 2 year-old and 4.5 to 5.5% for the 4 year-old bamboo.

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