PHYSICAL AND MECHANICAL PROPERTIES OF *BAMBUSA ARUNDINACEA, BAMBUSA LONGISPICULATA, BAMBUSA VULGARIS* AND *DENDROCALAMUS GIGANTEUS*

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ABSTRACT

The physical and mechanical properties of *Bambusa arundinacea, B. longispiculata, B. vulgaris* and *Dendrocalamus giganteus* have been studied at three height levels. The moisture content and shrinkage decrease, whereas specific gravity increases as the height of the culm increases. *B. longispiculata* exhibits the highest specific gravity among the four species. The diameter shrinkage is found much lower than the shrinkage in wall thickness. The compressive strength, fibre stress at elastic limit and modulus of elasticity increase with the culm height. Among the four species, *B. arundinacea* shows the highest strength in almost all cases.

সারসংক্ষেপ

তিনটি উচ্চতায় ব্যাম্বুসা অ্যারুনডিনাসিয়া, ব্যাম্বুসা লংগিসপিকুলটা, ব্যাম্বুসা ভালগারিস ও ডেনড্রোক্যালামাস জাইগ্যানটিয়াস বাঁশের ভৌত ও শক্তি সম্বন্ধীয় গুণাবলী পরীক্ষা করা হয়েছে। উচ্চতা বৃদ্ধির সাথে সাথে বাঁশের জলীয় অংশ ও সংকোচন বৃদ্ধি পায় কিন্তু আপেক্ষিক গুরুত্ব হ্রাস পায়। ব্যাস বরাবর সংকোচন, প্রাচীরের সংকোচন অপেক্ষা কম হতে দেখা গেছে। আঁশ বরাবর চাপ শক্তি, স্থিতিস্থাপক সীমায় পীড়ন এবং স্থিতিস্থাপক গুণাংক উচ্চতা বরাবর বৃদ্ধি পায়। এই চারটি প্রজাতির মধ্যে ব্যাম্বুসা অ্যারুনডিনাসিয়া প্রায় সকল ক্ষেত্রে সর্বোচ্চ শক্তি প্রদর্শন করে।

INTRODUCTION

Bamboo is a widely used raw material in Bangladesh. The easy workability, straightness, high strength, comparative cheapness together with easy availability and short growth rotation have made it popular to the people. The different bamboo species are used in different purposes. Thick walled village grown bamboos are generally used for post, beam, bridge and other structural purposes.

The evaluation of the physical and mechanical properties of bamboo is essential for its proper utilization. Many factors, such as the culm height, slope level and climate of its growing, etc. affect the properties of bamboo to a great extent and thus its utilization (Soeprajitno *et al.* 1988, Gnanharan 1991). Previously six bamboo species have been studied in Bangladesh for physical and mechanical properties at different age groups and culm heights (Sattar *et al.* 1990, Kabir *et al.* 1991, Kabir *et al.*

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1993). This study gives the physical and mechanical properties of another important four bamboo species at different culm height levels.

MATERIALS AND METHODS

Four bamboo species, *B. arundinacea*, *B. longispiculata*, *B. vulgaris* and *D. giganteus* were collected from the bambusetum of the Bangladesh Forest Research Institute, Chittagong. The bamboos of three years old were selected because the culms attain maturity at this age (Espiloy 1991, Sattar *et al.* 1990). Three bamboo culms were taken for each species. Each culm was divided into three equal portions - bottom, middle and top which represent three height levels.

The specimens for moisture content, specific gravity and shrinkage in wall thickness were prepared in the form of 2.5 cm wide rings. A total of three rings were taken for each portion. The specimens for diameter shrinkage were the internodes of the culm bounded by the nodes at the extremity. The shrinkage in wall thickness was determined from green to ovendry condition and the diameter shrinkage was taken from green to airdry condition. The specific gravity was determined on the basis of ovendry weight and green and ovendry volumes.

The mechanical properties, such as compressive strength and static bending were carried out according to the Indian Standard (Anon 1973). The compressive strength parallel to grain was determined from the internode of the culm on full diameter and the length was ten times of the average wall thickness of the culms. The length of the specimens for the static bending test was 75 cm. These were bounded by two nodes. The paired specimens were prepared for both compressive and static bending test from each portion, one for test in the green condition and the other for test in the airdry condition. All the tests were conducted with a universal testing machine.

RESULTS

The physical properties, moisture content, specific gravity and shrinkage of *B. arundinacea*, *B. longispiculata*, *B. vulgaris* and *D. giganteus* at different height levels are presented in Table 1. The mechanical properties, viz., compressive strength, fibre stress at elastic limit, modulus of elasticity and modulus of rupture of these four bamboo species are given in Table 2. The average values of each bamboo species at the bottom, middle and top positions are expressed as per cent relative to teak (*Tectona grandis*) wood and are presented in Table 3. Data of the physical and mechanical properties were statistically analysed to find the effect of height and the results are shown in Table 4.

DISCUSSION

Physical properties

The moisture content decreases as the height of the culm increases for all the four species (Table 1). The variation is, however, found statistically insignificant (Table 3). The highest moisture content is found in *B. vulgaris*, while the lowest value is noticed in *B. arundinacea*. In all the species, the lowest moisture content is found at the top of the culm. It may be associated with a decrease in percentage of parenchyma cell which acts as the site of water storage (Liese 1987, Latif and Jusoh 1992). The similar trend was also noted for other Bangladeshi bamboo species (Sattar *et al.* 1990, 1992 and Kabir *et al.* 1991). The moisture content fluctuates from 100 to 173 relative to teak.

The specific gravity of these four bamboo species increases from the bottom to the top (Table 1). The top is found to exhibit the highest specific gravity. The variation of specific gravity is found significant only in the ovendry condition for *B. arundinacea*, *B. longispiculata* and *D. giganteus* (Table 3). The higher specific gravity at the top portion of the culm is attributed to the decreasing wall thickness which results in the gradual decrease in the actual number and size of the vascular bundles towards the top (Grosser and Liese 1971, Janssen 1981, Liese 1980). Like wood, the ovendry specific gravity is higher than the green value. The species *B. vulgaris* shows the lowest specific gravity among the four species. The specific gravity values of these bamboo species are found 100 to 128 relative to teak wood.

Table 1. Physical properties of four bamboo species of Bangladesh

Species	Height Position	Moisture content (%)	Specific gravity based on ovendry weight and		Shrinkage (%)	
			green volume	ovendry volume	in wall thickness	in diameter
B. arundinacea						
	bottom	83	0.60	0.71	21.94	5.16
	middle	70	0.69	0.79	17.76	3.76
	top	66	0.71	0.83	10.37	2.49
B. longispiculata						
	bottom	92	0.61	0.89	21.38	7.32
	middle	82	0.65	0.91	18.77	6.64
	top	79	0.66	0.95	12.80	5.09
B. vulgaris						
	bottom	107	0.54	0.75	25.74	7.70
	middle	94	0.58	0.79	22.45	4.94
	top	85	0.62	0.81	19.73	3.08
B. giganteus						
	bottom	104	0.55	0.63	15.52	4.31
	middle	79	0.62	0.73	7.87	2.98
	top	65	0.68	0.80	5.15	2.36

Table 2. Mechanical properties of four bamboo species

Species	Height position	Compressive strength kg/cm^2		Fibre stress at elastic limit kg/cm^2		Modulus of elasticity 1000 kg/cm^2		Modulus of rupture kg/cm^2	
		green	airdry	green	airdry	green	airdry	green	airdry
B. arundinacea									
	bottom	371	426	430	533	107	154	979	1125
	middle	426	481	539	600	136	178	802	930
	top	528	534	702	768	153	216	622	778
B. longispiculata									
	bottom	406	550	242	305	74	92	920	920
	middle	449	557	280	343	81	103	414	506
	top	483	614	338	668	178	173	361	447
B. vulgaris									
	bottom	297	425	377	496	78	106	744	851
	middle	366	478	483	555	114	120	635	773
	top	425	472	525	592	149	213	452	661
D. giganteus									
	bottom	208	348	71	94	6	76	200	660
	middle	314	504	115	123	15	98	153	518
	top	355	551	139	195	20	222	103	427

Table 3. Physical and mechanical properties of bamboos relative to teak

Species	Moisture content	Specific gravity		Static bending						Compression parallel to grain	
		green	OD	FS at El		MOE		MOR			
				green	airdry	green	airdry	green	airdry	green	airdry
Tectona grandis	100	100	100	100	100	100	100	100	100	100	100
B. arundinacea	133	116	128	108	101	109	140	92	94	115	94
B. longispiculata	153	110	151	56	70	92	94	65	62	116	112
B. vulgaris	173	100	128	90	87	94	111	70	76	95	89
D. giganteus	151	113	118	21	22	12	101	18	53	76	91

Table 4. Summary of the results of analysis of variance of the physical and mechanical properties of four bamboo species

Species	Effect of height on												
	Moisture content (%)	Specific gravity		Shrinkage in wall thickness green to ovendry	Shrinkage in diameter gr. to 12% mc	Compression parallel to grain		FS at El		Modulus of elasticity		Modulus of rupture	
		gr. vol	OD. vol			green	airdry	green	airdry	green	airdry	green	airdry
B. arundinacea	ns	ns	*	*	*	ns	*	*	*	*	*	**	ns
B. longispiculata	ns	ns	*	*	ns	*	ns	ns	**	**	*	ns	**
B. vulgaris	ns	ns	ns	ns	*	ns	ns	**	ns	ns	*	*	ns
D. giganteus	ns	ns	*	*	**	*	**	*	**	**	*	**	**

ns not significant
* significant at 5% level of probability
** significant at 1% level of probability

Unlike wood, bamboo starts shrinking both in wall thickness and diameter from the beginning of the drying (Rehman and Ishaq 1947). The shrinkages in wall thickness and in diameter are observed to decrease from the bottom to the top appreciably (Table 1). This decreasing trend is found significant for *B. arundinacea*, *B. longispiculata* and *D. giganteus* and diameter shrinkage for *B. arundinacea*, *B. vulgaris* and *D. giganteus* (Table 3). The bottom portion shrinks more probably due to the presence of the higher initial moisture content (Rehman and Ishaq 1947). It is however reported that the correlation between the initial moisture content and shrinkage is very low (Jai Kishen *et al.* 1956, Gnanaharan 1991).

Mechanical Properties

The compressive strength parallel to grain from the bottom toward the top is observed to increase although the variation is not found significant for all species (Tables 2 & 3). The species *B. giganteus* is found to be the weakest in compressive strength among the species in green condition. Similar to wood, the airdry bamboos are stronger in respect of compressive strength. The increase of compressive strength from the bottom to the top may be associated with the higher specific gravity. The fibre stress at elastic limit and modulus of elasticity increase both in green and airdry conditions as the height of the culm increases (Table 2). It is evident from Table 3 that the variation of most of the properties is found statistically significant. This result also supports the findings of Limaye (1952), Janssen (1981) and Widjaja (1985). The height has a significant effect on the modulus of rupture. It is observed that the bottom portion is stronger in modulus of rupture than the middle and top of the culm (Table 2). A similar observation is also found by some other workers (Espiloy 1987, Janssen 1981 and Limaye 1952). It is obvious from Table 4 that the modulus of rupture of these bamboo species is less than of teak wood which varies from 18 to 94 relative to teak.

CONCLUSION

The moisture content, shrinkage in wall thickness, shrinkage in diameter and bending strength decrease from the bottom towards the top. The specific gravity, compressive strength, fibre stress at elastic limit and modulus of elasticity increase along the culm height in all these species. Regarding strength properties, *B. arundinacea* exhibits the highest value in most cases, while *B. giganteus* shows the lowest value among the four species. The relative values of physical properties vary from 100 to 173% and 12 to 140% for mechanical properties compared to teak wood.

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