PROSIDING

SEMINAR KEBANGSAAN

SAINS, TEKNOLOGI & SAINS SOSIAL

27 ~ 28 MEI 2002
HOTEL VISTANA, KUANTAN, PAHANG

Anjuran :

Universiti Teknologi MARA
Cawangan Pahang

Dengan Kerjasama

Kerajaan
Negeri Pahang Darul Makmur

JILID 1

LAMINATED BAMBOO: ALTERNATIVE MATERIAL OF THE FUTURE

RAZAK WAHAB, HASHIM W.SAMSI, MOHD. TAMIZI MUSTAFA AND NUROL HISHAM HAMID

Forest Product Technology Division, Forest Research Institute Malaysia (FRIM), Kepong, 52109 Kuala Lumpur, Malaysia.

ABSTRACT

Gigantochloa scortechinii *bamboo species were used to manufacture three-layers laminates and composite consisting of single-layer bamboo and two layers of wood veneers. Polyvinyl Acetate (PVAc) and Phenol Resorcinol Formaldehyde (PRF) were used as the binder for the process. Both, panels and a single strip were tested for its physical and mechanical properties in accordance of ASTM's and BS 373 with some modification. This paper will discuss on these properties of both panels and strips. Comparisons were also made to some common wood species. Results obtained were compared between glue types and laminates configuration.*

Keywords: *Bamboo, lamination, gluing and strength*

INTRODUCTION

Predictions for the next century are that the demand for timber by the various wood-based industries in Asia and elsewhere will exceed the existing timber supply. With the objective of addressing this anticipated shortage, various panel products are being used to replace many solid wood applications. Region-wide, the plywood industry is no longer expanding, reflecting diminishing supplies of large diameter hardwood peeler logs.

In the search for non-timber forest products (NTFPs) to substitute for wood, bamboo has emerged as a material par excellence. Bamboo is closer to medium-density hardwood and possesses higher strength values than juvenile hard wood obtained from a fast-growing species. With good physical and mechanical properties, low shrinkage and average density of 0.7 g/cm3 (Anon. 1999), bamboo is well suited to replace wood in several applications, especially in panel form.

In order for the bamboo industry to have the competitive edge in the international market, there need a shift - from the production of low end to high value added products. Bamboo is somewhat similar in properties to a certain timbers. Hence, such advantages should be exploited to make it into an ideal form of resource supplement for manufacturing and construction sectors.

Efforts to promote its utilization into furniture and structural uses have not received favorable responses due to the low product quality and low market returns. Lack of research on product development also contributed to the lack of interest of public towards this material. Recent effort to rejuvenate interest on modified bamboo through lamination for furniture received overwhelming responses from the public.

There is no bamboo products currently produced in the country of the same nature and quality as envisioned in this paper. FRIM has succeeded in developing laminated bamboo board and its products since 1996. Among the products were: a) floor strips (Razak *et al.* 1997), b) furniture and component (Razak *et al.* 1998) and bent furniture components (Razak *et al.* 1999). During the process, several problems were encountered, among which were: a) drying related problems, b) laborious and uneconomical manufacturing methods and c) lack of design. This paper present and discuss properties of laminated bamboo encountered in a series of studies.

MATERIALS AND METHODS

The bamboo species used for making the three-layer laminated and composite bamboo ply for this study was *Gigantochloa scortechinii*. It had been identified as one of the most important and extensively used species in the bamboo industry and is the most widely distributed in Peninsular Malaysia. All bamboo culms used in this study were taken from the Forest Research Institute of Malaysia's (FRIM) research trial plot in Nami, Kedah in Malaysia. Selected culms of young and matured age (2 and 4 year-old) were harvested, split into smaller sizes, treated with preservative and kiln dried. After reaching about 9 % moisture content, all strips were than manufactured into three-layer bamboo strips and a mixture of bamboo-wood consisting of one-layer of bamboo and two-layers of wood strip. Types of adhesive used were phenol resorcinol formaldehyde and polyvinyl acetate (PVAc) with moisture resistance capability. This adhesive was chosen since it is commonly used by the furniture industry in Malaysia and easily obtained in the market. The manufacturing was carried out manually with hand-held roller and clamping.

The strength tests for shear, compression parallel to grain and static bending were conducted using the Shimadzu Computer Controlled Universal Testing Machine on split bamboo. These tests were conducted in the Structural and Mechanical Laboratory in Forest Research Institute Malaysia (FRIM). The preparation of the test blocks and methods were made according to the guidelines prepared by Gnanaharan, *et al*. (1994), ASTM D 143-52 (Anon. 1974), BS 373 (Anon. 1957) with some modifications. Ten (10) replication were used for each test.

RESULTS AND DISCUSSION

The results of a series of studies conducted on laminated bamboo boards are tabulated in Tables 1, 2 and 3.

Table 1: Means comparative strength on single bamboo strip (with skin) of the 2 and 4-years old culms.

		Compression Strength (N/mm^2)	Bending Strength (N/mm^2)
Culm age	Young (2-year old)	55	160
	Mature (4-year old)	60	171

Table 2: Means comparative strength of 3-layers bamboo board manufactured from 2 and 4-years old culms.

			Compression Strength (N/mm^2)	Bending Strength (N/mm^2)
Type of glue used	PRF	2-year	59	113
		4-year	65	125
	PVAc	2-year	58	110
		4-year	63	118

Note: PRF is phenol resorcinol formaldehyde
PVAc is polyvinyl acetate (moisture resistance type)

The strength of bamboo boards from matured bamboo culm show slightly higher values than the younger culm. These were expected as matured culm posses thicker cells wall materials.

Whilst, strength properties of laminated bamboo boards applied with different type of adhesives indicate that the PRF treated board shows slightly higher values in the compression and bending strengths when compared to the PVAc (Table 2).

Table 3. Means physical and mechanical properties of single strips, laminated 3-layers and composite bamboo boards of 4-years old bamboo.

	Properties	Bamboo strip (single)	3-layer bamboo strip (parallel laminate)	Composite bamboo ply (parallel laminate)
1.	Moisture Content	10 to 12 %	10 to 12 %	10 to 12 %
2.	Density (kg/m^3)	670	780	590
3.	Compression Strength			
	Longitudinal (N/mm^2)	60	63	54
	Transverse (N/mm^2)	44	38	26
4.	Bending Strength			
	MOR (N/mm^2)	171	118	98
	MOE (N/mm^2)	15,515	16,210	15,830
5.	Shear Strength (N/mm^2)	4.5	9.4	7.2
6.	Tensile Strength (N/mm^2)	154	125	101
7.	Swelling in 2 hours			
	Width	0.3%	0.4%	0.7%
	Length	0.6%	0.8%	1.2%
	Thickness	3.4%	4.9%	6.2%
8.	Surface absorption in 2 hours	4.1%	6.6%	7.8%

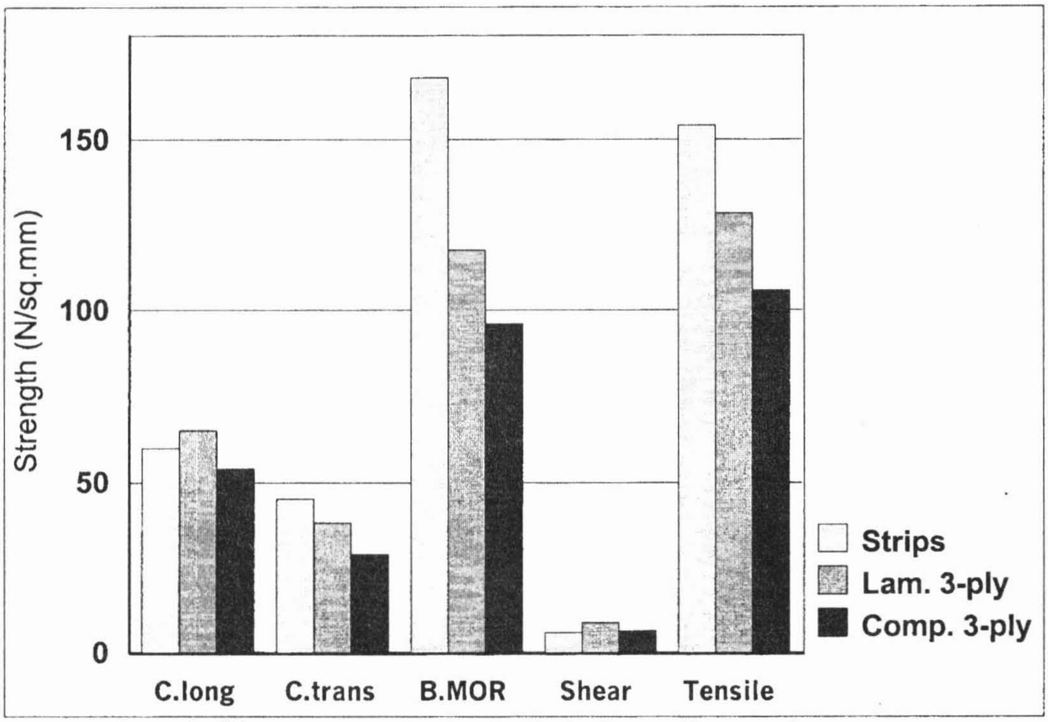
Table 4. Means comparative strength of laminated bamboo (4 years old) and some common tropical timber species (Razak, *et al.* 2000).

	MoR (N/mm^2)	MoE (N/mm^2)
Teak	98	12,839
Shorea species	101	12,545
Bamboo strip (single)	171	15,515
Laminated bamboo 3-layer	118	16,210
Laminated bamboo 4-layer	109	15,940
Composite bamboo ply 3-layer	98	15,070

The 3-layer bamboo strip (TLS) exhibited highest basic density as compared to the single strip and bamboo composite board (CBP). The CBP however, showed a lower value of their basic density compared to single-layer. The basic density of single-layer strip, TLS and CBP were 670, 780 and 590 kg/m^3 respectively. A lower basic density of CBP was probably due to the usage of LRM, a low density species.

In general, laminated bamboo boards, regardless of its matrix arrangement or mixture of species, were found to possess equivalent or higher strength properties than some of the commercial hardwood species (see Table 3). This observation is in agreement with other findings such as Zoolagud and Rangaraju (1991) and Anon (1999).

In comparison to strength properties, a single bamboo strip possesses higher bending strength than TLS and CBP. However, data run under statistical analysis indicated that there were no significant different on MOE between all samples tested. This confirms earlier studies that MOE is not influence by the number of layers, as its is a function of stiffness.



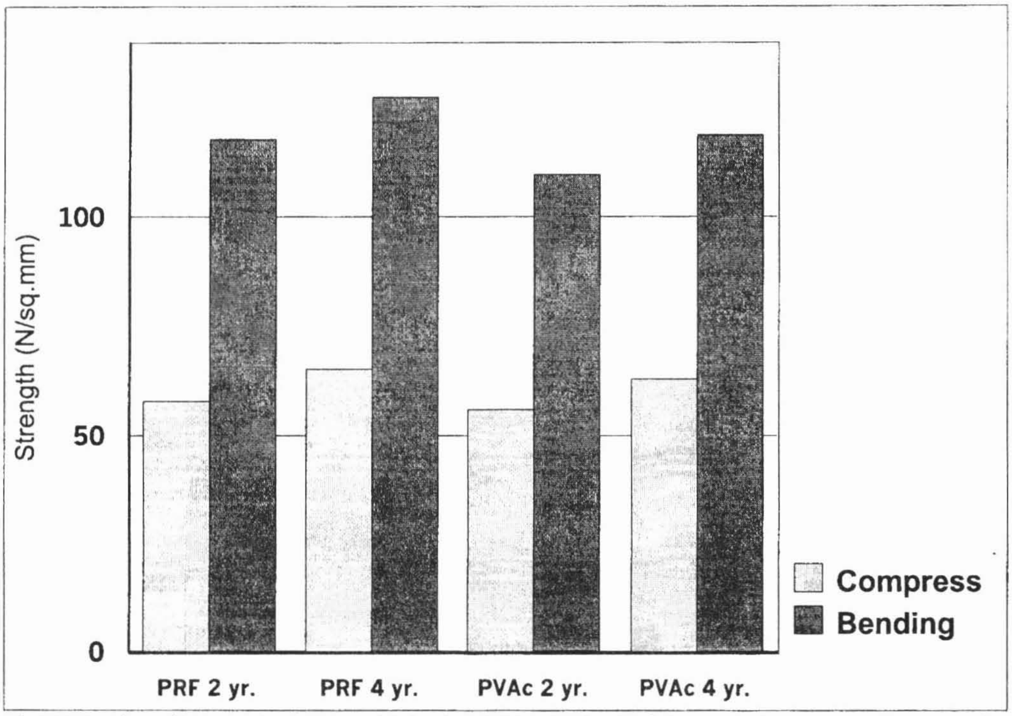
Legend: C.long=compression longitudinal, C.trans=Compression transverse
B.MOR=Bending MOR, Lam.=Laminates bamboo, Comp=Composite ply

Figure 3: Comparative mechanical properties between bamboo strips, laminated 3-ply and composite 3-ply of 4 years old culms.

Laminated bamboo possesses excellent mechanical properties especially with regards to tensile strength. Sekhar, *et al*, (1960) also made similar finding in his studies on the strength properties of bamboo. Tensile strength and compressive strength of laminated bamboo in the longitudinal direction were also found to be higher than those of wood. However, it has low parallel to grain shear strength and low resistance to splitting compared to wood (Janssen, 1980). Therefore, this property has been advantageously utilized in splitting the bamboo into strips for laminated boards.

Laminated bamboo boards with higher ply layers have greater strength value compared to the boards of lesser ply layers (Table 3 and Figure 3). This property can be of advantage when used in making construction and building materials when strength is the most crucial factor.

In dimensional stability aspects, the change of moisture content was significantly less than compare to most common tropical hardwoods (Anon, 1999). This makes bamboo laminated boards most suitable for used as flooring and paneling materials.



Legend: PRF=Phenol Resorcinol Formaldehyde, PVAc=Polyvinyl Acetate, Compress=Compression test, Bending=Bending test

Figure 4: Strength of laminated bamboo 3-ply with PRF and PVAc

Studies on the strength properties of laminated bamboo boards applied with different types of glue indicated that the PRF treated samples possess slightly higher values in the compression and bending strength when compared to the PVAc (Table 2 and Figure 4).

CONCLUSION

Laminated bamboo boards provide higher strength properties and usage, as well as having better dimensional stability than bamboo composite boards and some solid wood. These boards are expected to be more important in the future furniture and construction industry. They have high strength properties in term of MOR and MOE values. However, composite bamboo that has strength of slightly lower can also be used as substitute to laminate bamboo in order to cut cost especially in panel products.

PVAc adhesive with moisture resistance, proof to be slightly better than the PRF. This type of glue would be recommended for used by the bamboo-based industry as they are cheaper to the PRF and are more available commercially in the local market.

With the sourcing of wood from natural forest is becoming increasingly scarce, the used of laminated bamboo and composite boards for future substitute to the wood industry is expected to receive good respond by the public. The potential of bamboo, particularly in laminated form, to replace wood is being increasingly acknowledged. Hence, it is important to address the issues mentioned earlier to fully exploit the versatility of bamboo not only in furniture but also in construction and other major applications.

Some technologies of the manufacturing laminated bamboo boards have been generated during the duration of these studies. However, despite these accomplishment, a lot of R & D effort still needs to improve processing techniques especially in turning bamboo to laminated boards and furniture. These include the development of a new products and design.

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