

# **Bamboo Panel Boards a State-of-the-Art Review**

Technical Report No. 12

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# FOREWORD

In the search for non-timber forest products to substitute for wood, bamboo has emerged as a material par excellence. It is now widely recognized that bamboo in panel form is ideal to replace wood in several applications. Because of this, the Research Advisory Group of the International Network for Bamboo and Rattan accorded high priority for research on bamboo based panels and recommended that a review of existing bamboo panel products and technologies be undertaken as a step to determine future research needs. Bamboo Panel Boards: a State-of-the-Art Review is the result of that recommendation. The Indian Plywood Industries Research and Training Institute was nominated as the lead institution for the study. FORINTEK Canada, the Chinese Academy of Forestry, and the Forest Products Research and Development Institute of the Philippines collaborated in the effort.

The first bamboo-based panel was produced in China in the 1940s. Since then, some 28 panel products have been developed. Among the technologies developed, only a few, like bamboo mat board and bamboo strip board, are the outcome of detailed investigations and industry-scale trials. Others are mostly based on limited laboratory experimentation and industrial testing. Hence, the commercialization of bamboo panels is not commensurate with the variety of products developed. Furthermore, countries in which the panels are produced have not accorded a distinctive status to them, and statistics of their production and trade are incomplete or unreliable. This makes it difficult to assess the potential, but the level of interest provides pointers. For instance, in China, about 100 000 m<sup>3</sup> of panels of various types are produced annually in some 200 mills, whereas in India, industrial-scale production of panels is confined to bamboo mat board with about 2 000 m<sup>3</sup> boards produced by seven mills.

To ensure that all relevant published data are included, a literature review was conducted using advanced search methods and reference to forestry and forest products databases. However, much information on technologies is unpublished and the authors had to depend on personal communications and visits to laboratories.

We hope that all scientists and institutions concerned, in Asia and other parts of the world, will find the information contained in this report useful for their work.

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# 1

## INTRODUCTION

Since research on bamboo is of relatively recent occurrence, the potential of this versatile material has remained largely unexploited. Although wide-ranging research has been carried out on the structure, properties and preservation of bamboo, the results have hardly been applied by engineers and architects.

In the 1980s on account of dwindling wood supplies in the tropics, interest in bamboo as a material intensified. It emerged as the most potentially important non-timber forest product to replace wood in construction and other uses. The realization that bamboo produces woody biomass faster than most fast-growing trees, and that some of its properties rival those of juvenile wood obtained from such species, has evoked keen interest in theoretical and practical research on bamboo as a wood substitute in housing, furniture, packing, transport and other fields.

Bamboo in panel form is well suited to substitute wood and therefore, development/refinement of cost-effective technologies to produce bamboo-based panels is an important area of research. In 1990, the International Development Research Centre of Canada commissioned an evaluation on past research and research needs for bamboo and rattan. The report issued in 1991 indicated the need for further attention on bamboo panels.

Although the environmental and socio-economic implications of bamboo-based panel industries favor their promotion, neither detailed environmental impact assessment nor socio-economic impact assessment of these industries has been carried out. Nonetheless, it is tentatively reckoned that if bamboo mat boards replace plywood to an extent of one-fourth the present production in India, 400 000 m<sup>3</sup> of round wood from natural forests will be saved, thereby preventing disturbance to 30 000 ha of forests per year. It is also estimated that production of mats to manufacture this quantity of mat board will generate 16.7 million workdays of employment per year. In China, approximately 1 million cubic meters of wood are replaced annually by various types of bamboo panels.

When the International Network for Bamboo and Rattan (INBAR) was being formally established, a network meeting was held in June 1993 which endorsed the need for a review of the status of bamboo panels and boards. Accordingly, INBAR commissioned a study and this report is the result. The review involved:

gathering information(Annex 1); preparation of a draft report based on information gathered; circulation of the draft among collaborating scientists for comments; and finalization of the report.

Apart from the contributions of scientists from the collaborating institutes, several others in the panel-producing countries provided valuable insights that have gone into this report. In particular, thanks are due to: Mr. Dao Viet Phu, Dr Haong Van Hien, Dr Hartoyo, Dr Hsiu-Hua Wang, Dr H.N. Jagadeesh, Dr Abd. Latif Mohmod, Dr Sheau-Horng Lin and Mr. Sounthone Ketphanh.

# 2

## BAMBOO PANEL PRODUCTS: AN OVERVIEW

The first recorded production of bamboo-based panels was in China. During World War II, a simple technology was developed in China to manufacture bamboo mat board bonded with casein glue, for use as alternate to plywood in the interiors of aircrafts. At about the same time, research was initiated in India to develop resin-bonded bamboo mat board; technology became available about a decade later. Since then, research has been carried out in several countries and as many as 28 panel products – some of bamboo and others of bamboo in combination with wood and/or inorganic materials – have been developed. While R&D efforts have been mostly confined to Asia (China, India, Indonesia, Laos, Malaysia, the Philippines, Taiwan-China, Thailand and Vietnam), Canada, in collaboration with Costa Rica, has also carried out research on bamboo boards.

China has developed the maximum number of panel products, although many of these are based on commercially uncertain technologies. The growth of bamboo panel board industries in China is related to two factors. First, there were inadequate supplies of raw material. The growth rates and harvesting cycles of temperate bamboo are longer than that of tropical species. Hence, despite the large area under bamboo, availability of culms is low. Moreover, traditional and established uses – such as handicrafts, basketry, chopsticks and poles – compete with use for boards. Second, costs associated with bamboo are steadily increasing, throwing the economics of panel manufacture out of gear.

Although some pioneering work was done and innovative products like plybamboo (bamboo veneer-faced plywood) and lamboo (parallel curved bamboo gluelam) were developed in Taiwan-China, the bamboo board industry in this region is declining since the sharp increase in wages and raw material shortage are causing the manufacturers to emigrate elsewhere.

In India, although several products have been developed, bamboo mat board is the only one that has attracted entrepreneurs and gained user acceptance. In Thailand, bamboo mat board glued with urea-formaldehyde (UF) resin is being manufactured, mainly for export. In countries such as Laos, the Philippines and Vietnam, interest on bamboo board is recent and still experimental or at the level of pilot production.

As bamboo panel products have not been accorded uniformly distinctive categorization in compilation of statistics, reliable production data are not available. Absence of reliable production and market statistics is a severe handicap in evaluating the current status and future prospects of bamboo boards. Projections have, however, pointed out the important role of bamboo boards in view of diminishing wood supplies.

In the absence of standard test methods and generation of standardized information on properties, such as those that exist for wood-based panels, data for individual products are presented in the way in which they were reported. Until test methods are standardized and format of reporting data on properties and performance harmonized, it would be difficult to accurately compare products manufactured in different regions or countries. In this respect, Annex 2 provides data on some products, as a step towards standardization.

## Types of Boards

Based on the culm derivatives used, the boards may be grouped in the following categories:

- . Culms converted into slivers, strips or laths by flattening and/or cutting, and further processed;
- . Culms peeled into veneers and further processed;
- . Culms converted into particles, fibers, wafers or strands and reconstituted; and
- . Combination of one or more of above products among themselves or with other materials and further processed (termed in this report as composites). Such composites include: different bamboo panels; wood or other lignocellulosic materials; and inorganic substances.

### Boards from slivers, strips or laths

Slivers of uniform thickness and width are woven into mats, following traditional or innovative designs and cold or hot-pressed into boards to produce:

|                  |  |
|------------------|--|
| Bamboo mat board | In China, India, the Philippines and Vietnam.  |
| Corrugated sheet | Surface finished or laminated in China, India, the Philippines and Vietnam for use in roofing. |

Strips/slivers assembled in layers and bonded under pressure to produce:

|                                  |                                       |
|----------------------------------|---------------------------------------|
| Parallel gluelam                 | To a limited extent in China.         |
| Parallel curved gluelam (lamboo) | In Taiwan-China region for furniture. |
| Bamboo curtain board             | In China.                             |

**BAMBOO PANEL BOARDS**

|  |  |
|--|--|
| Bamboo strip board/bamboo plywood      | In China, and also to a small extent in Costa Rica, Malaysia, Taiwan-China and Vietnam.  |
| Bamboo lath board/bamboo block board   | In Indonesia on an experimental scale.   |
| Bamboo "semi-fiber" board              | A product simulating "zephyr" wood, in which culms are crushed under pressure and assembled in layers and hot-pressed (experimental scale in Indonesia). |
| Bamboo net board                       | In limited quantity in China.  |
| Bamboo moulded shuttle & picking stick | In restricted quantity in China.   |

**Boards from veneer**

|           |   |
|-----------|---|
| Plybamboo | A highly decorative product, in which rotary-cut bamboo veneers are used as face and wood veneers or blocks as core, is produced at present in small quantities in China. |
|-----------|---|

**Boards from reconstituted particles, strands or fibers**

|   |  |
|---|--|
| Bamboo particleboard                                  | Largely following technology employed for wood particleboard, bamboo particleboard has been developed in Canada (in collaboration with Costa Rica), China, India and Vietnam. Although the product is comparable to wood particleboard in properties and performance, production is limited as the technology is yet to overcome some inherent problems of bamboo. |
| Oriented strand board                                 | Research is reported in Vietnam.   |
| Bamboo fiberboard and medium density fiberboard (MDF) | Research in progress in China and India. A small quantity is produced in China.  |

**Composite boards**

|  |                                       |
|--|---------------------------------------|
| Bamboo mat/bamboo curtain board            | Developed in China.                   |
| Bamboo mat/bamboo particleboard and India. | Produced in small quantities in China |
| Plybamboo                                  | (See information provided earlier).   |

**BAMBOO PANEL BOARDS**

|   |  |
|---|--|
| Bamboo plywood                              | Bamboo mats are used as face and wood veneers as core. A popular product in China and India.                     |
| Bamboo curtain plywood                      | Bamboo curtain board is used as face and wood veneers as core. Small quantity produced in China.                 |
| Bamboo mat and wood particleboard           | Bamboo mat is used as face and wood particleboard as core. Produced in limited quantity in China.                |
| Bamboo mat and rice husk board              | Bamboo mat is used as face and rice husk particleboard as core. Produced in small quantity in India.             |
| Bamboo strip, wood veneer and particleboard | Bamboo strip board forms the face. Wood veneer and particleboard are used as core.                               |
| Bamboo moulded shuttle beating club         | A tough product, in which bamboo sliver and wood veneer are bonded. Made in very small quantity in China.        |
| Gypsum-bonded bamboo particleboard          | Produced on an experimental scale in the Philippines.  |
| Cement-bonded particleboard and wool board  | Produced on an experimental basis in China. The former is produced in Malaysia also.                             |
| Bamboo plaster board                        | An innovative product being developed in China.  |
| Bamboo reinforced plastic                   | A high-tech material under experimentation in India. Bamboo fiber reinforced plastic sheets are being developed. |

Of the above types of boards, only bamboo mat board (a bamboo panel that has shown maximum promise) and bamboo strip board have been exploited on an industrial scale and products marketed for various end-uses. Other technologies are either in various stages of development or only at the initial stages of experimentation. Further research is foreseen in these cases.

## National Standards

National Standards have been formulated in China for bamboo mat plywood (Annex 3) and bamboo strip plywood for automobile carriage base plates (Annex 4), and in India for bamboo mat board for general purposes (Annex 5). A Draft Standard exists in India for bamboo mat-veneer composite for general purposes (Annex 6). Both China and India have standards on test methods for bamboo mat board.

## Commercial Production

The panels for which technology is developed and commercialized or awaiting commercialization are listed in Table 1.

*Table 1: Panels commercialized or ready for commercialization*

| Country           | Panel   |
|-------------------|---|
| China             | Mat board (locally known as bamboo mat plywood)<br>Corrugated roofing sheet<br>Parallel gluelam<br>Curtain board (known as curtain plywood)<br>Strip board (locally known as bamboo strip plywood or bamboo plywood)<br>Lath board (laminated lumber)<br>Plybamboo<br>Particleboard<br>Mat and curtain board<br>Mat and bamboo particleboard<br>Mat and wood particleboard<br>Mat and wood veneer (locally known as bamboo plywood)<br>Bamboo mat/curtain board and wood veneer<br>Plastic overlaid bamboo particleboard<br>Moulded shuttle and picking stick<br>Cement-bonded particleboard and wool board<br>Plasterboard |
| Costa Rica/Canada | Strip board (termed Plybambu)<br>Particleboard (termed Barnboard)   |
| India             | Bamboo mat board<br>Particleboard<br>Mat with wood particleboard<br>Mat with wood veneer<br>Mat with rice husk  |
| Indonesia         | Lath board (Blockboard)<br>Semi-fiber board (Zephyr)<br>Cement-bonded particleboard   |
| Lao PDR           | Mat board   |
| Malaysia          | Curtain board<br>Particleboard<br>Cement-bonded particleboard   |
| The Philippines   | Gypsum-bonded particleboard   |

**BAMBOO PANEL BOARDS**

| Country      | Panel   |
|--------------|---|
| Taiwan-China | Parallel curved gluelam<br>Curtain board<br>Plybamboo                   |
| Thailand     | Mat board   |
| Vietnam      | Mat board<br>Corrugated roofing sheet<br>Curtain board<br>Particleboard |

**Further Information and Contacts**

Most of the above products are manufactured by small-scale enterprises and very few responded to requests for information. Hence, the authors had to resort to existing trade literature, direct personal contacts with manufacturers, and/or indirect contacts with traders or laboratory personnel. More information on products may be obtained from the contacts cited below.

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# 3

## AN APPRAISAL OF BAMBOO PANEL BOARD TECHNOLOGIES

Existing bamboo panel board technologies have resulted from:

1. Research, development and industrial-scale trials carried out in national laboratories either under their own programs or donor assisted projects;
2. Research conducted in national laboratories and passed on to entrepreneurs for trial and adaptation; and
3. Development efforts of entrepreneurs themselves.

While the technologies developed and scaled up in research institutions are mostly documented and/or published, those developed by entrepreneurs are seldom published. Although all available information has been collated in this report, it is scanty in a few cases, especially where individual entrepreneurs have made their own modifications or held back information.

The following appraisal divides technology development into two groups: technologies already developed and technologies still experimental.

### **Technologies Developed**

#### **Bamboo mat board (BMB)**

BMB is the first bamboo-based panel to be produced commercially. Its versatility has been widely recognized and further research is in progress to improve its efficiency, enlarge its application potential and optimize production costs. It is commercially produced in China (under the name bamboo mat plywood), India, Thailand and Vietnam, while laboratory-scale production is reported in the Philippines. The technologies developed are described in the following pages.

#### **CHINA**

##### **Casein glue-bonded BMB**

The earliest boards produced were casein-bonded and their chief use was

for interiors of aircrafts. Only species with long internodes, such as *Bambusa textilis*, were used. The steps involved in the manufacture of boards are:

- Separation of internodal segments;
- Splitting into 5-6 mm wide strips;
- Slitting of strips tangentially into slivers;
- Selection of outer slivers with epidermal layer (for greater strength and stiffness);
- Weaving of slivers into mats, in different patterns;
- Coating of casein to the under surface of slivers;
- Assembly in two layers of mats or three layers, i.e., mat + wood veneer + mat panels;
- Cold-pressing; and
- Trimming.

### **Resin-bonded BMB**

Synthetic resin-bonded BMB was developed in the 1970s in China. Although urea formaldehyde (UF), phenol formaldehyde (PF) and phenol-tannin formaldehyde (PTF) are employed as the bonding resin, UF-bonded BMB is the most common. UF in this case is part of polymerization in three stages (70%, 20%, 10%) instead of two, as in the case of wood adhesives. The optimum gram molecule ratio for formaldehyde and urea is 1 :1 .6. Less commonly, alkali-catalysed PF resin adhesive is used instead of UF. PTF resin, PF resin with phenol replaced to the extent of 60% by tannin from larch bark, is also being successfully employed in some cases. The stages in the manufacture of resin-bonded BMB are:

- Conversion of culms into strips and thereafter slivers of uniform width 12-16 mm and thickness 0.6-1.2 mm, manually or mechanically. Elimination of slivers with outer skin (epidermal layer);
- Weaving of slivers of uniform size manually or mechanically into mats of size 2 500 x 1 300 mm;
- Drying of mats to 8-16% moisture content;
- Coating or impregnation of glue (280-500 g/m<sup>2</sup>). Soybean flour is used as filler to the extent of 510%. Ammonium chloride (NH<sub>4</sub>Cl) of 0.5% concentration is used as curing agent;
- Hot-pressing (temperature: 110-120°C for UF resin, 140-150°C for PF resin; pressing time: 1.5-2 minutes/mm thickness; specific pressure: 4-5 MPa);
- Laying up;
- Curing; and
- Trimming.

In the production of decorative mat boards, the slivers are sanded, bleached and sometimes dyed. Two methods of bleaching are commonly practiced:

1. Soaking of slivers in 1% sodium hydroxide (NaOH) for 2-4 hours, followed by soaking in 25% hydrogen peroxide for 5-10 hours. The slivers are thereafter washed in water and dried to 8-16% moisture content; and
2. Soaking of slivers in a solution of 1% oxalic acid and 0.5% NaOH for 10-16 hours. The slivers are then washed in water and dried.

Dyeing or imparting attractive colors to the slivers using bright and durable synthetic dyes is a common practice. Alternatively, the mat boards are treated with sulphuric or nitric acid and baked immediately in fire to obtain black or brown-red color, respectively. Mat boards are occasionally overlaid with sliced wood veneers to manufacture decorative plywood. The physical and mechanical properties of typical UF-bonded BMB produced in China are given in Table 2.

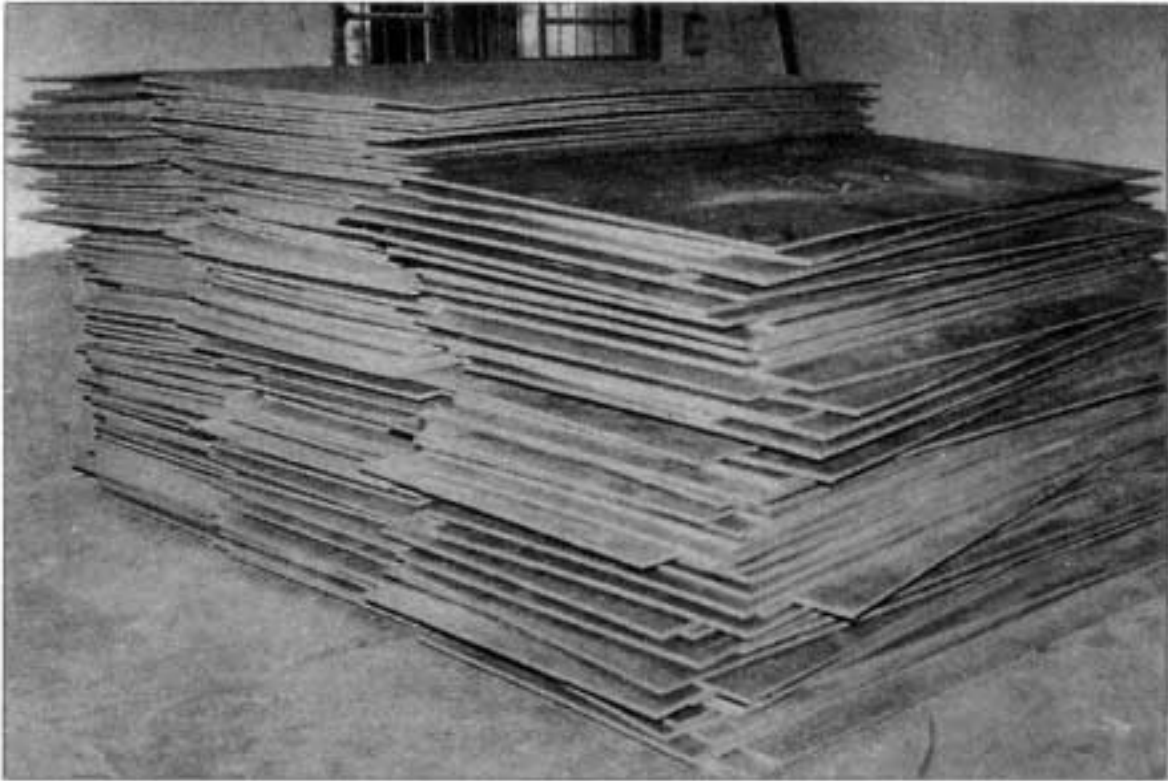
*Table 2: Physical and mechanical properties of bamboo mat board (China)*

| Properties                           | Common BMB | Veneer-overlaid BMB |
|--------------------------------------|------------|---------------------|
| Density (kg/m <sup>3</sup> )         | 850        | 860                 |
| Internal bond strength (MPa)         | 1.57       | 1.37                |
| Modulus of rupture (MPa)             | 93.0       | 119.6               |
| Tensile strength (MPa)               | 72.6       | 64.6                |
| Impact tenacity (J/cm <sup>2</sup> ) | 3.1        | 2.97                |



*Fig. 1: Dried mats being arranged for glue spreading*

BMB (Figs. 1, 2) is used for packing, furniture and interior applications, such as panellings and partitions. There are 16 factories manufacturing this panel and the annual production is about 20 000 m<sup>3</sup> (for standards, see Annex 3).



*Fig. 2: Bamboo mat boards ready for packing and transport*

## **INDIA**

BMB technology development in India has undergone three stages, as described below.

### **Earliest technology**

The first BMB produced in India was PF resin adhesive-bonded. The technology involved:

- Cutting of culms (with or without nodal portions) into pieces of 0.6 m length;
- Splitting culms into strips;
- Immersion of strips in boiling water for 1-2 hours;
- Slitting of strips into slivers of uniform width and thickness (Fig. 3);
- Separating outermost slivers with epidermal layer from innermost slivers, used for other purposes;
- Drying to 10-12% moisture content;
- Weaving into mats of different patterns (Fig. 4);

BAMBOO PANEL BOARDS



*Fig. 3: Slitting of strips into slivers*



*Fig. 4: Manual weaving of mats*

- Soaking in PF resin solution;
- Seasoning to 10-12% moisture content;
- Hot-pressing the assembled mats in 2, 3 or 5 layers for 20-30 minutes at a specific pressure of 2.8-3.5 MPa; and
- \* Trimming (Fig. 5).



*Fig. 5: Trimming of boards*

Although the boards thus produced were attractive and strong, the technology could not be commercialized because the cost of production was higher than that for plywood.

### **Modified technology**

In 1979, efforts were made to modify the technology mainly with the objective of reducing production cost. Important modifications carried out were partial replacement of phenol in PF resin adhesive, method of resin application, and reduction of pressing time and temperature. In the adhesive, phenol was replaced to the extent of 40% by Cardanol (a derivative of cashew nut shell liquid). The Cardanol-phenol formaldehyde (CPF) resin adhesive thus developed was found to give the required bond strength. The process steps were:

- Drying of mats to 6-10% moisture content;
- Spreading of resin adhesive (PF or CPF) on mat, using glue spreader employed in plywood manufacturing;

- Hot-pressing for 6 minutes (for 3-4 mm thick boards) at a temperature of 140-145°C and a specific pressure of 1.6 MPa; and
- Open assembly over a period of 2-24 hours to reduce the moisture content of glue-spread mats to 15%.

The quantity of resin required was 1.3 kg/m<sup>2</sup> of 3-layer board. The strength properties of BMB thus developed are given in Table 3.

*Table 3: Typical strength values of BMB bonded with PF and CPF resin adhesives (India)*

| Resin type | Average strength values (MPa) |          |                  |          |
|------------|-------------------------------|----------|------------------|----------|
|            | Internal bond strength        |          | Surface strength |          |
|            | Dry                           | Boil/Dry | Dry              | Boil/Dry |
| PF         | 1.05                          | 0.73     | 5.36             | 4.44     |
| CPF        | 1.10                          | 0.60     | 5.95             | 4.54     |

A factory in Kerala State started manufacturing BMB in 1984 using the modified technology. This factory is still producing BMB, with slight modifications of the process, and marketing it for use in furniture, housing and shuttering. Entrepreneurial interest in the product, however, did not grow because of the following problems:

- High quantity of resin requirement (1.3 kg/m<sup>2</sup> for 3-layer board) as compared with plywood (0.30-0.33 kg/m<sup>2</sup> for 3-ply plywood);
- Non-uniform bonding owing to glue starvation where slivers overlapped;
- Blotches on faces of board caused by resin pushed to the surface during hot-pressing;
- Difficulty in separating panels from hot press; and
- Low durability.

### **Improved technology**

To overcome the above-mentioned problems, renewed efforts were made under a project sponsored by the International Development Research Centre (IDRC) of Canada. As a result, a much improved and cost-effective board was developed. The technology has been standardized after pilot and factory-scale trials. As testimony of maturity of the technology, seven units took up production after the improved technology was released. Several more small-scale enterprises are in various stages of establishment. An international team of experts mobilized by IDRC expressed the view that the technology was suitable for adoption by other countries. A training workshop was therefore organized with INBAR support in which technologists from Bangladesh, Canada, China, India, Lao PDR, Malaysia,

Nepal, the Philippines and Thailand participated. In this workshop, the technology was demonstrated and transferred. The improvements effected in the process are:

- Reduction of PF resin quantity from 1.3 kg/m<sup>2</sup> to about 0.3 kg/m<sup>2</sup>;
- Better resin application method to ensure uniform bonding and surface appearance;
- Smooth release of panels from metal cauls; and
- Increased durability imparted by incorporating a preservative in the glue.

The strength properties of BMB manufactured using the improved technology are given in Table 4.

*Table 4: Strength properties of BMB bonded with PF resin (India)*

| Properties                              | No. of mats used for making board |       |       |       |
|---|-----------------------------------|-------|-------|-------|
|   | 2                                 | 3     | 5     | 7     |
| Density (kg/m <sup>3</sup> )            | 751                               | 766   | 771   | 790   |
| Internal bond strength (MPa)            |                                   |       |       |       |
| - Dry state                             | 2.23                              | 2.18  | 2.42  | 1.97  |
| - Wet state                             | 1.79                              | 1.98  | 2.14  | 1.73  |
| Surface strength by torque wrench (MPa) |                                   |       |       |       |
| - Dry state                             | 12.14                             | 11.42 | 11.23 | 9.47  |
| - Wet state                             | 11.01                             | 11.42 | 10.47 | 9.10  |
| Tensile strength (MPa)                  |                                   | 22.69 | 26.59 | 29.54 |
| Compressive strength (MPa)              |                                   | 16.77 | 30.35 | 35.30 |
| Modulus of rupture (MPa)                |                                   | 50.74 | 56.31 | 59.35 |
| Modulus of elasticity (MPa)             |                                   | 3 678 | 3 220 | 3114  |
| Modulus of rigidity (MPa)               | 5 401                             | 5 881 | 6 050 | 6 066 |

Another notable feature in the improved technology is the replacement of phenol to the extent of 30-40% by lignin obtained from pulp mill effluent (black liquor). The properties of BMB manufactured using phenol-lignin-formaldehyde (PLF) resin adhesive are given in Table 5.

The improved manufacturing process involves the following steps:

- Dipping the mats in PLF resin in which a preservative is incorporated. Mole ratio of phenol, formaldehyde and sodium hydroxide is 1:2.2:0.18. The resin spread is 0.11 kg PLF of 48% solids/m<sup>2</sup>, while dilution of resin with water is in the ratio 1:2;
- Drawing of excess resin;
- Drying to 8-12% moisture content;
- Hot-pressing for 6 minutes (3-layered board) at a temperature of 140-1 45°C and a pressure of 1.6 MPa; and
- Trimming.

**BAMBOO PANEL BOARDS***Table 5: Strength properties of BMB bonded with PLF resin (India)*

| Properties                              | No. of mats used for making board |       |       |       |
|---|-----------------------------------|-------|-------|-------|
|   | 2                                 | 3     | 5     | 7     |
| Density ( kg/m <sup>3</sup> )           | 782                               | 826   | 775   | 847   |
| internal bond strength (MPa)            |                                   |       |       |       |
| - Dry state                             | 1.06                              | 1.19  | 1.07  | 1.25  |
| - Wet state                             | 1.47                              | 1.11  | 0.97  | 1.03  |
| Surface strength by torque wrench (MPa) |                                   |       |       |       |
| - Dry state                             | 7.20                              | 7.27  | 6.64  | 8.33  |
| - Wet state                             | 7.00                              | 5.88  | 5.93  | 6.17  |
| Tensile strength (MPa)                  | 10.80                             | 17.43 | 21.18 | 26.18 |
| Compressive strength (MPa)              | 19.85                             | 23.38 | 25.00 | 34.31 |
| Modulus of rupture (MPa)                | 40.09                             | 43.97 | 4250  | 50.74 |
| Modulus of elasticity (MPa)             | 3 119                             | 3 087 | 2 679 | 3 095 |
| Nail withdrawal strength (face) (N)     | 350                               | 1 005 | 1 660 | 1 750 |
| Screw withdrawal strength (face) (N)    | 2 300                             | 2 535 | 3 025 | 3 325 |

At present, seven factories are manufacturing this product and the estimated annual production is 2 000 m<sup>3</sup>. Standards are given in Annexes 5 and 6.

Some of the end-uses for which this panel is found suitable, in conformity to relevant national standards, are:

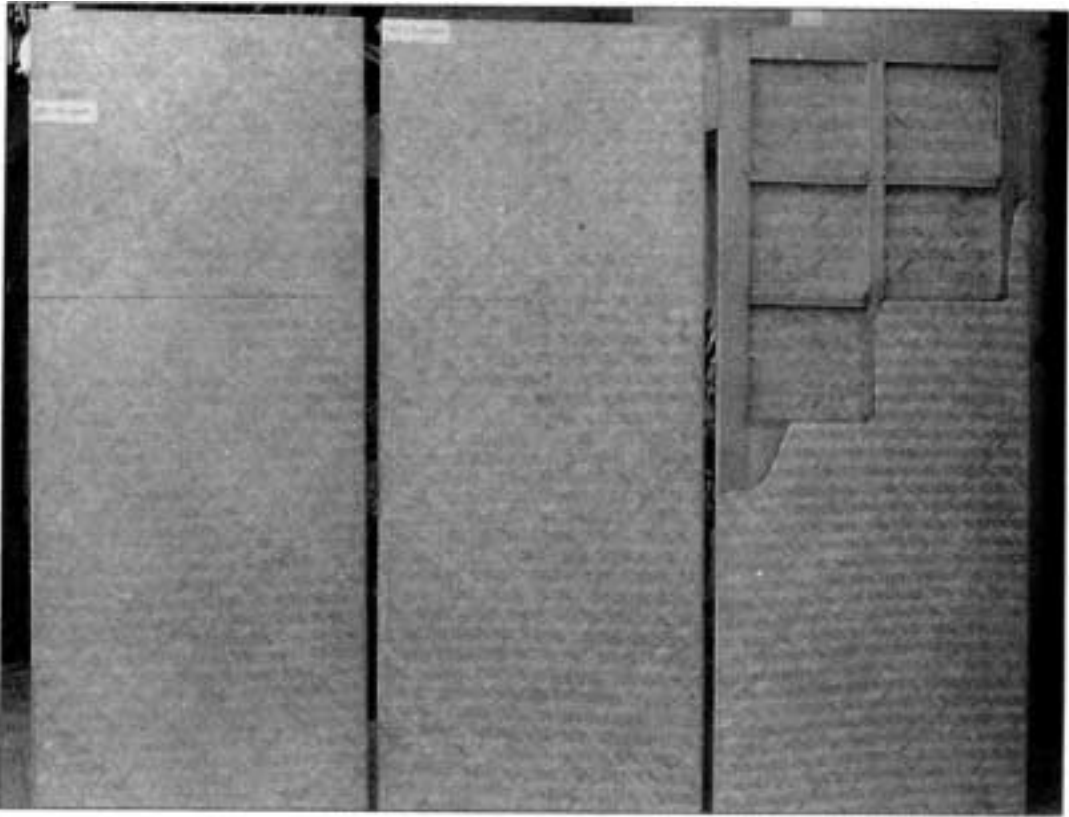
- Housing - doors (Figs. 6, 7), partitions, panelling, furniture, cladding;
- Packaging - fruit packing cases (Fig. 8), ammunition boxes;
- Storage - grain storage bins (both internal and external) (Fig. 9); and
- Transport - bullock carts (Fig. 10), horse/mule drawn carriages.

**THAILAND**

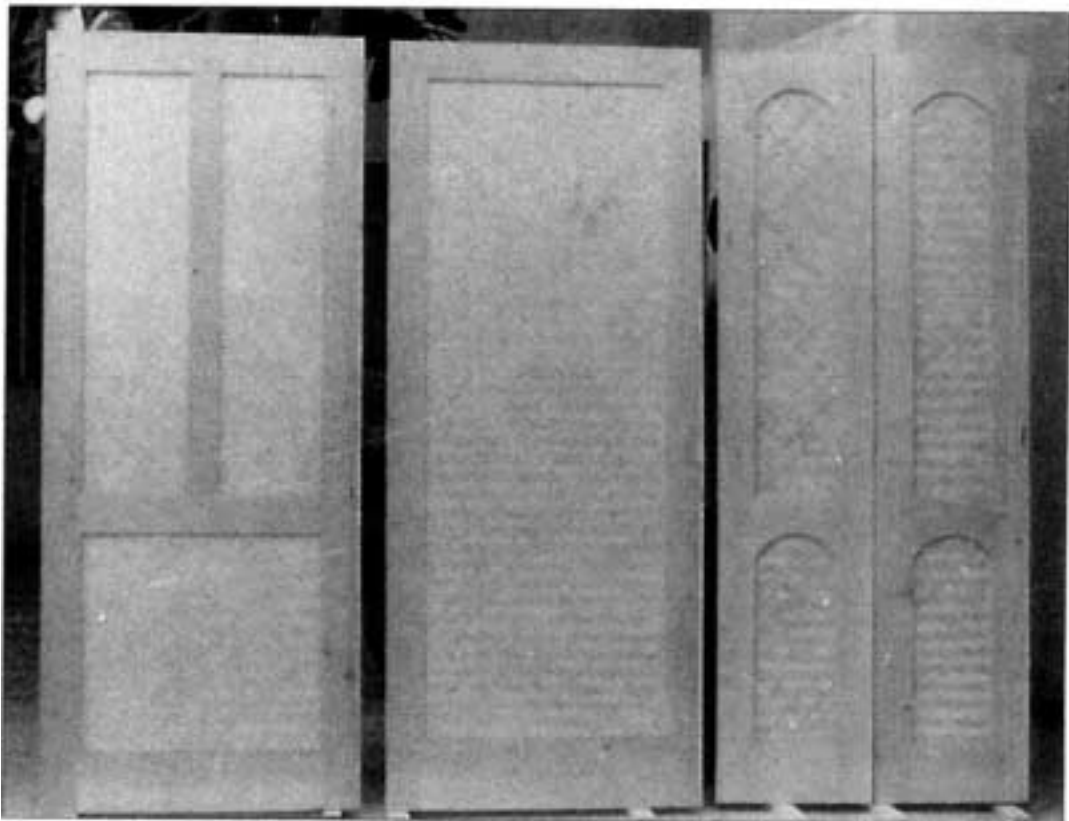
BMB is being produced since 1985, mostly for export to European countries. UF resin is used to bond mat board of 1-10 mm thickness. At present, two factories are producing the boards and each is following technology developed in-house. Vital information is neither published nor readily disclosed. The boards are attractive, but uses are limited on account of the resin employed. The process is as follows:

- Conversion of culms into strips and thereafter slivers, mechanically;
- Weaving of slivers into mats (both manually and mechanically) of various attractive patterns;
- Coating UF resin;
- Hot-pressing;

BAMBOO PANEL BOARDS

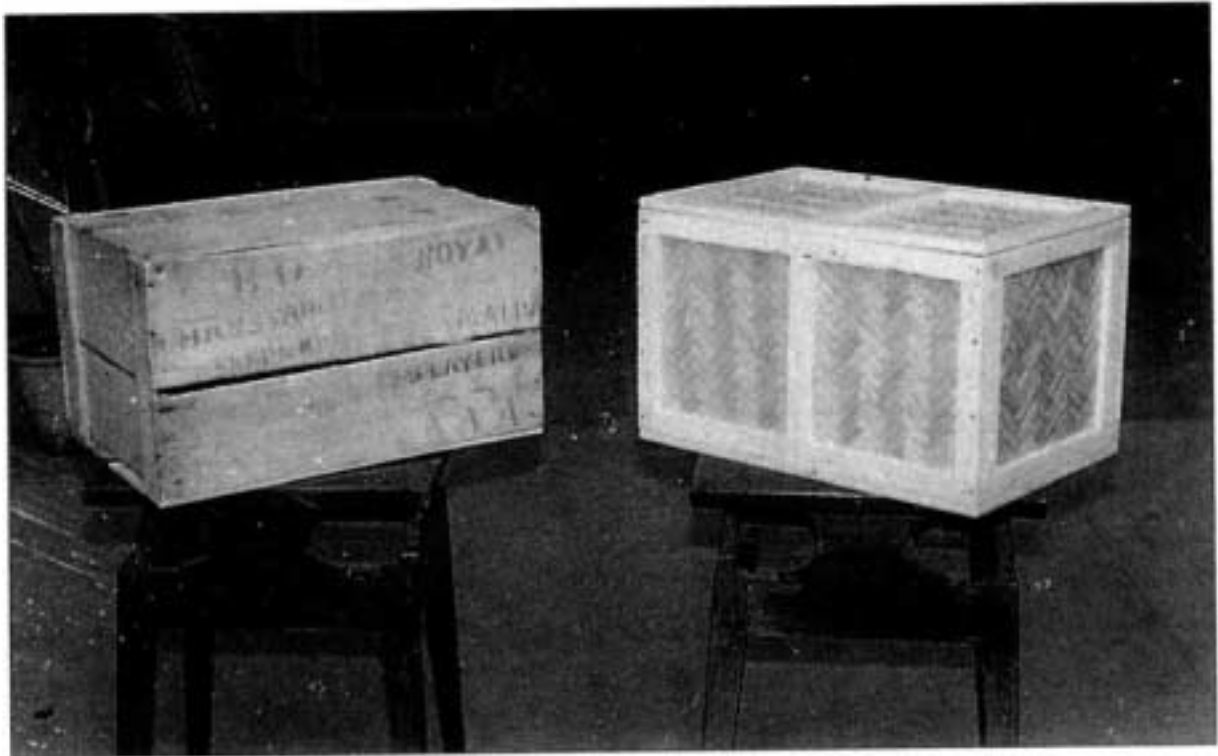


*Fig. 6: Hollow-core flushdoor shutters*



*Fig. 7: Panel doors*

BAMBOO PANEL BOARDS



*Fig. 8: Apple packing case (compared with conventtional case)*



*Fig. 9: Grain storage bins*

**BAMBOO PANIL BOARDS**

*Fig. 10: BMB roof for bullock cart*

- Finishing (sanding); and
- Trimming.

The aesthetic appearance of the board is the main attraction. Thickness is determined according to the end-use as follows:

- 1 mm - for panelling;
- 3-4 mm - for ceiling and partitions;
- 6 mm - for doors, windows and furniture; and
- 8-10 mm - for concrete form work.

The physical and mechanical properties of the product are presented in Table 6.

**VIETNAM**

Two-layered BMB is manufactured, with PF resin and PF resin modified with lignosulphate effluent from paper mills employed for bonding. Because of the dark color imparted, consumers do not favor boards bonded with the latter adhesive. The end-uses are:

- Housing - for ceiling, partition, shelving;
- Storage - for rice bins; and
- Packaging - for concrete form work.

**BAMBOO PANEL BOARDS**

The strength properties of MBM made in Vietnam are given in Table 7.

*Table 6: Properties of UF-bonded BMB made (Thailand)*

| Properties                    | Values                  |
|-------------------------------|-------------------------|
| Density                       | 659 kg/m <sup>3</sup>   |
| Moisture content              | 11.6%                   |
| Absorption                    |                         |
| - in 2 hours                  | 9.1%                    |
| - in 24 hours                 | 21.8%                   |
| Swelling in 2 hours           |                         |
| - Width                       | 0.4%                    |
| - Length                      | 0.8%                    |
| - Thickness                   | 4.9%                    |
| Surface absorption in 2 hours | 6.6%                    |
| Modulus of rupture            | 6.75 kg/mm <sup>2</sup> |
| Internal bond strength        | 0.14 kg/mm <sup>2</sup> |

*Table 7: Physical and mechanical properties of BMB (Vietnam)*

| Properties            | Values                    |
|-----------------------|---------------------------|
| Density               | 700-750 kg/m <sup>3</sup> |
| Tensile strength      | 30-32 MPa                 |
| Modulus of elasticity | 35-45 MPa                 |

## Corrugated roofing sheet

Bamboo mat corrugated roofing sheets are produced in China (known as bamboo mat corrugated plywood) and, to a limited extent, in Vietnam. Exploratory studies have recently been initiated in India and the Philippines.

### CHINA

Four layers of mat bonded with UF resin adhesive are used. The top layer is overlaid with UF resin-impregnated, reprocessed paper. On top of this, PF resin is impregnated by hot-pressing. The production process is as follows:

- Drying of mats to 8-12% moisture content;
- Application of UF resin;
- Overlaying UF resin-impregnated, reprocessed paper;
- Pressing between two corrugated cauls in a specially designed press;

## BAMBOO PANEL BOARDS

- Laying up;
- Overlaying PF-resin impregnated film;
- Hot-pressing (in a specially designed press); and
- Trimming.

Another process employed is to dry the mats to 12-14% moisture content; apply PF resin adhesive (400 g/m<sup>2</sup>) and press 5-layer boards between corrugated cauls in a specially designed hot press.

The physical and mechanical properties of corrugated roofing sheets with and without overlays are shown in Table 8.

*Table 8: important physical and mechanical properties of bamboo corrugated roofing sheet (China)*

| Properties                           | Types of corrugated boards |                       |                       |
|--------------------------------------|----------------------------|-----------------------|-----------------------|
|                                      | Non-overlaid board         |                       | Overlaid board        |
|                                      | Wide<br>corrugation        | Medium<br>corrugation | Medium<br>corrugation |
| Density (kg/m <sup>3</sup> )         | 860                        | 760                   | 870                   |
| Crest modulus of rupture (MPa)       | 37.63                      | 32.54                 | 57.53                 |
| Moisture content (%)                 | 13.4                       | 13.2                  | 7.9                   |
| Water absorptivity (%)               | 41.8                       | 46.9                  | 11.0                  |
| Boiling/drying test (No. of cycles*) | 20                         | 20                    | 100                   |

• *Water boiling/drying circulation period: the sample for test is immersed in boiling water for 1 h, taken out and the surface is wiped. Then it is put into an oven (100.3°C for 1 hour for drying. The whole process forms one cycle.*

### VIETNAM

Corrugated roofing sheets are produced to a limited extent. The technology of China is adopted.

Exploratory studies are in progress in India and the Philippines. Efforts in India are to develop corrugated sheets in single pressing cycle employing PF resin.

### Parallelgluelam

This specialty panel is produced in China as bamboo sliver laminated board. There are two types: single structural panel and non-single structural panel. In the former, all slivers are placed parallel to each other, while in the latter a few are placed criss-cross. The technology is as follows:

- Conversion of culms into slivers. 15-20 mm wide and 0.8-1.2 mm thick;

## BAMBOO PANEL BOARDS

- Removal of slivers with epidermal layer;
- Drying to less than 15% moisture content;
- Application of PF resin adhesive (dipping);
- Laying up;
- Hot pressing for 1½ to 2 hours (for 30-32 mm thick panels) at a temperature of 110-160°C and a specific pressure of 4-6 MPa (increasing gradually in steps); and
- Trimming.

The important physical and mechanical properties are summarized in Table 9.

*Table 9: Important physical and mechanical properties of bamboo parallel gluelam (China)*

| Properties                   | Variety of product     |                            |
|------------------------------|------------------------|----------------------------|
|                              | Single direction panel | Non-single direction panel |
| Density (kg/m <sup>3</sup> ) | 850-1 050              | 840-1 050                  |
| Moisture content (%)         | 3.6-8.7                | 4.0-9.3                    |
| MOR longitudinal (MPa)       | 167-201                | 128-223                    |
| MOR traverse (MPa)           | 10.3-13.8              | 30.4-72.0                  |
| MOE longitudinal (x 10 MPa)  | 11.5-14.8              | 10.1-15.9                  |
| MOE traverse (x 10 MPa)      | 3.0-4.4                | 2.3-4.1                    |

The main applications for this panel are for truck floors, gang planks and, less commonly, in building construction. While it is a material of great strength, its weight is a disadvantage. Moreover, it requires large quantity of resin, thereby pushing up the cost and pressing time.

### Parallel curved gluelam

This specialty panel (locally known as 'lamboo') is produced in Taiwan-China and used in furniture making. The aesthetically designed curvature and attractive color imparted by dyeing produce highly valued panels for manufacturing furniture. Moso bamboo (*Phyllostachys pubescens*) and Ma bamboo (*Dendrocalamus latiflorus*) of 8 cm diameter at the bottom end and 2.5 cm at the top were found to be the most suited. The technology is as follows:

- Conversion of culms into slivers;
- Dipping in acidic dye solution at 80°C temperature and under 10 kg/m<sup>2</sup> pressure to impart attractive color;
- Preservative treatment with sodium pentachlorophenate (NaPCP) or Tenalith C (former is found to be better);

- Drying;
- Application of glue – a mixture of urea formaldehyde (UF), melamine formaldehyde (MF) and polyvinyl acetate (PVA) in the ratio of 55:12:33 – at the rate of 100-150 g/m<sup>2</sup> on dry basis, including on the sides of slivers to make wider panels; and
- Bending narrower panels into desired shapes, after subjecting to steam treatment.

## Bamboo curtain board

This is a relatively new panel produced in China and Taiwan-China. Culms are cut into thin slivers and formed into “curtains”, with slivers placed side by side and parallel to each other. The board is assembled by placing layers of curtains with slivers of one layer at right angles to the other, followed by glue application and pressing. The panel, thus, resembles plywood in construction.

The three-layered boards generally manufactured are locally known as bamboo curtain plywood. It is found that several species of bamboo are suitable for this, and the process of making curtains is simpler and less time-consuming than weaving mats. In view of the simple processing technology and high quality of the product, this panel has high potential. The technology is outlined below:

- Large thick strips of flattened culms are converted into slivers of uniform width (between 10 and 20 mm) and thickness 1 mm (conversion manually or mechanically);
- Drying to 10-12% moisture content;
- Weaving slivers into curtains;
- Adhesive application (generally by dipping in PF glue);
- Hot-pressing for 2-2½ minute/mm thickness at a temperature of 140-150°C and a specific pressure of 3-4 MPa; and
- Trimming to 4500 x 1300 mm size (6, 12, 16, 20 or 30 mm thickness) and end-sealing.

Paper-laminated bamboo curtain plywood is produced more commonly. The paper normally used is resin-impregnated Kraft paper. PF (at 80-120 g/m<sup>2</sup>) or modified melamine is used as resin adhesive. Impregnation of resin is accomplished by dipping. Before dipping, small amounts of a diluent and release agent are added to the resin. After resin impregnation, the paper is dried. One or two layers of dried paper are placed on either faces of a layer of bamboo curtain board, and hot-pressed into shape by pre-heating (50-135°C), curing and shaping (1½ to 2 minutes/mm thickness), and cooling to 50°C. The properties of the panel are furnished in Table 10.

Laminated bamboo curtain plywood is used in concrete formwork, and has gained wide acceptance as compared with steel and plywood formworks, because it is: lighter; cheaper; easier and quicker to assemble; more heat-resistant; and ideal to get smooth

formwork surface. These advantages have earned it official endorsement, and steel frame bamboo curtain plywood has been declared as the ideal formwork material.

Table 10: Physical and mechanical properties of bamboo curtain board (China)

| Properties                            | Curtain | Laminated curtain |
|---------------------------------------|---------|-------------------|
| Density (kg/m <sup>3</sup> )          | 850     | 780-850           |
| Modulus of rupture, parallel (MPa)    | 121.2   | 130.0             |
| Modulus of elasticity, parallel (MPa) | 12 500  | 14000             |
| impact strength (J/m <sup>2</sup> )   | 136 000 | 136 000           |

## Bamboo strip board

A panel of high strength, stiffness and rigidity, the board is also called bamboo strip plywood and bamboo plywood. Resistance to deformation, abrasion and weathering characterizes it. Its bending strength, torsion and impact resistance are superior to wood panel and therefore its application potential – particularly as platform boards, vehicle platforms, rail carriages, ship floors, etc. – is very high. It is produced in China, and to a small extent in Costa Rica, Malaysia and Vietnam.

### CHINA

Next to bamboo mat board, this is the most popular bamboo-based panel and is used in vehicle bodies. A national standard was formulated for the panel in 1991 (Annex 4). The species commonly used is *Phyllostachys pubescens* with a culm diameter of about 9 cm. The technology involves:

- Cross cutting of culms to desired strength;
- Scraping and removal of nodes (outer surface), and removal of epidermal layer using a specially designed tool;
- Softening, steaming at about 160°C and flattening;
- Scraping of nodes (inner surface);
- Drying to 8% moisture content;
- Planing edges and surfaces;
- Application of PF resin adhesive at the rate of 350-400 g/m<sup>2</sup>;
- Assembly;
- Hot-pressing for 1 minute/mm thickness at a temperature of 140-150°C and a specific pressure of 3 MPa; and
- Trimming.

The major uses are for:

- Concrete formwork (paper-laminated bamboo strip board is used) - It is found that reuse is as many as 200 times and superior in one or more respects to formwork of plywood, MDF, steel, plastic, GRP, aluminium, etc.

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- Platforms for trucks, buses, rail coaches, spring boards - Estimated to be in use in over 115 000 carriages, replacing about 52 000 m<sup>3</sup> timber and 1 600 t of steel, and reducing dead weight in each coach by 53 kg.

The physical and mechanical properties of the board-are given in Table 11.

*Table 11: Physical and mechanical properties of bamboo strip board (China)*

| Property                                 | Thickness (15 mm) |         | Thickness (22 mm) |          |
|--|-------------------|---------|-------------------|----------|
|  | 3-layer           | B-layer | 5-layer           | 7- layer |
| Density (kg/m <sup>3</sup> )             | 780               | 850     | 850               | -        |
| Modulus of rupture (MPa) - Board         | 113.3             | 105.5   | 126.1             | -        |
| Internal bond (MPa) <sup>1</sup>         | 3.68              | 3.52    | 3.50              | -        |
| Shock tenacity (J/m <sup>2</sup> )       | 87 000            | 91 000  | 91 000            | 124 000  |
| Ageing resistance*                       |                   |         |                   |          |
| Bonding strength (MPa)                   |                   |         |                   |          |
| - before ageing                          | 3.68              | -       |                   |          |
| - after ageing                           | 3.03              | -       |                   |          |
| Modulus of rupture (MPa)                 |                   |         |                   |          |
| - before ageing                          | 111.6             | -       |                   |          |
| - after ageing                           | 52.3              | -       |                   |          |
| Corrosion resistance <sup>3</sup>        |                   |         |                   |          |
| Modulus of rupture (MPa)                 |                   |         |                   |          |
| - before acid corrosion                  | 105.2             | -       |                   |          |
| - after acid corrosion                   | 102.8             | -       |                   |          |
| Dry shrinkage rate <sup>4</sup> (%)      |                   |         |                   |          |
| - Length                                 | 0.160             | -       |                   |          |
| - Width                                  | 0.017             | -       |                   |          |
| - Thickness                              | 0.202             | -       |                   |          |
| Static friction coefficient <sup>5</sup> | 0.47              | -       |                   |          |

1 Determined after the sample is boiled in water for 3 hours.

2 Determined through the treatment of 6 cycles (totally 288 hours) with reference to ASTM 1037.

3 The sample is soaked in acid solution (pH = 4) for 12 hours and dried naturally.

4 Dry shrinkage rate when the moisture content is reduced by 7%.

5 Of the base board of truck, made of bamboo strip plywood coated with PF resin adhesive layer on the surface.

## COSTA RICA

The Costa Rica Building Research Center (CIVCO), with the cooperation of the Queen's University of Canada, has developed a bamboo strip board called 'plybambu'. It is still in the experimental stage and a small quantity is produced on a laboratory scale. *Guadua* spp. is employed and PVA is used as binder. This product is expected

## BAMBOO PANEL BOARDS

to find interior applications like doors, windows, partitions, ceilings, etc. Further work is in progress to achieve consistent physical and mechanical properties.

### MALAYSIA

A small quantity is produced using manually split culms bonded with PVA. Prior to drying and application of adhesive, the strips are dipped in 2% solution of borax and 2% solution of NaPCP for protection against insects and fungi. Typical applications are as parquet, flooring boards, built-in wardrobes, cabinets, etc. Physical and mechanical properties of these boards are given in Table 12.

*Table 12: Physical and mechanical properties of bamboo strip board (Malaysia)*

| Properties            | Values                |
|-----------------------|-----------------------|
| Density               | 650 kg/m <sup>3</sup> |
| Modulus of rupture    | 733 MPa               |
| Tensile strength      | 3 450 MPa             |
| Modulus of elasticity | 5 440 MPa             |

### TAIWAN-CHINA

More or less the same manufacturing process followed in China is used here. The product, because of its high strength and durability, finds wide-ranging applications, especially in truck bodies and railway carriages.

### VIETNAM

Bamboo strip board is a recent development in the country and is gaining popularity. The technology involves:

- Cross-cutting of culms;
- Splitting;
- Scraping of nodes on both outer and inner surfaces;
- Preservative treatment (dipping in mixture of NaPCP and sodium fluoride)
- Drying to 8-12% moisture content:
- Application of resin (melamine urea formaldehyde at the rate of 140-160 g/m<sup>2</sup>);
- Hot-pressing for 9 minutes (for 16 mm thick panel) at a temperature of 120-140°C and a normal pressure of 1.2-1.6 MPa; and
- Finishing by paint or varnish.

The board is used in interior applications like ceiling, parquet flooring, etc. The physical and mechanical properties are given in Table 13.

*Table 13: Physical and mechanical properties of bamboo strip board (Vietnam)*

| Properties            | Values                |
|-----------------------|-----------------------|
| Density               | 815 kg/m <sup>3</sup> |
| Thickness swelling    | 1 %                   |
| Modulus of rupture    | 123.57 MPa            |
| Modulus of elasticity | 9 600 MPa             |

Although the board is strong and application potential is wide, its manufacture has not expanded on account of problems such as high energy requirement for flattening, suitability of only species with thick-walled culms, and requirement of sophisticated machinery.

## Bamboo lath board

### CHINA

This innovative panel is produced in a limited quantity, under the name 'bamboo laminated lumber'. Long strips are used in boards of sizes 4 070 x 140 x 30 mm and 5 370 x 140 x 30 mm. The procedure is as follows:

- Cutting of culms into long strips 2 200/2 850 mm in length, 11-15 mm in width and 1-2 mm in thickness;
- Drying to 8-10% moisture content;
- Dipping in PF resin adhesive in specially made tanks;
- Assembly in layers with laths oriented in the same direction or at right angles (Figs. 11, 12); and
- Hot-pressing for about 60 minutes at a temperature of 130-140°C

### INDONESIA

This relatively new product developed in Indonesia is sometimes referred to as 'bamboo blockboard'. It is similar to strip board except that the strips are much larger in size. Although the technology is still undergoing refinement, a small quantity has been produced and strength values – particularly MOE and MOR – have been found to exceed those of wood-based panels. The technology, is as follows:

- Conversion of culms into laths of uniform width and thickness;
- Drying to 10-16% moisture content;
- Adhesive (PVA) application;
- Assembly in layers (laths of each layer at right angles to the other);
- Hot-pressing; and
- Trimming.

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*Fig. 11: Laying up strips, with each layer parallel to the other*



*Fig. 12: Laying up strips, wrth alternate layers at rright angles*

The potential of the product as an alternative building material is very high, and it is presently being tried for flooring, tiles and partitions. Important properties of this panel are given in Table 14.

*Table 14: Properties of laminated lumber made in Indonesia*

| Properties            | Values                |
|-----------------------|-----------------------|
| Density               | 970 kg/m <sup>3</sup> |
| Modulus of rupture    | 118.1 MPa             |
| Modulus of elasticity | 3220 MPa              |
| Compression strength  | 62 MPa                |
| Shear strength        | 43.5 MPa              |
| Hardness              | 174.4 MPa             |

Laminated lumber has excellent water resistance, durability, dimensional stability and strength properties, and is used in building construction and carriage platforms. However, its production is limited at present.

### **Bamboo “zephyr” board**

This bamboo counterpart of “zephyr” wood has been developed in Indonesia and is locally called ‘semi-fiber bamboo board’. It is also a variant of strip board, but here the culm is crushed into strands of fiber. A small quantity of this board has been produced and the technology is undergoing further trials. The process is as follows:

- Splitting of fresh culms;
- Crushing of split culms under pressure;
- Drying to 10-12% moisture content;
- Soaking in resin (both UF and PF resin have been employed);
- Assembly (culm fibers of one layer at right angles to fibers in the other layer);
- Hot-pressing (at 120°C for UF and 160% for PF); and
- Trimming.

The product tested according to the Japanese Standard JIS A-5908 has shown that it is not inferior to zephyr wood.

### **Bamboo net board**

This product, analogous to honeycomb plywood, has recently been developed in China and a small quantity produced. In this panel called ‘bamboo net board’, thin, narrow slivers of varied sizes are used as core and bamboo strips or resin-impregnated paper as face and back layers. Various decorative designs have been

developed for the face and back. The board has a density of 338 kg/m<sup>3</sup>, an MOR of 10-15 MPa and a compressive strength of 5.5 MPa. At present, it is being tried out in furniture and packaging, and also as insulation board in housing.

## Bamboo moulded products

Moulded wood products based on veneers, particles, fibers, etc., have been in use for a long time. Moulding is economical only when solid wood is plasticized or broken into fibers. In the case of bamboo, moulding does not require so much energy as wood and it is not necessary to break it into particles or fibers. It is enough if bamboo is split into strips or slivers and hot-pressed after impregnation of glue. Thus, bamboo is finding increasing acceptance for manufacturing moulded shuttles in textile mills, which are generally made of high-class wood.

In China, over 12 million weaving shuttles are required annually for which 60 000 m<sup>3</sup> of wood are needed. The wood employed is oak or maple, which are in short supply. Moulded bamboo shuttles have been found to be highly suitable and over 100 000 are already in use. Bamboo shuttles have following advantages over wood:

- Availability of raw material is not restricted;
- Production cost is less;
- Wear and tear is less and hence, service life is twice as long; and
- Friction is lower and hence, power consumption is reduced by 10%.

The manufacturing process involves:

- Mechanical crushing of culms;
- Cooking of crushed culms;
- Separating strands from culms;
- Drying;
- Resin impregnation;
- Drying;
- Layer forming;
- Loading in mould hot-press;
- Hot-pressing;
- Machining; and
- Polishing.

The physical and mechanical properties of the product are given in Table 15.

The moulded picking stick is another product required in the textile industry. It is generally made of laminated wood veneer. Over 50 000 m<sup>3</sup> of high-quality wood is used annually for this purpose. Bamboo is found to be a better material for picking sticks because of the following advantages:

## BAMBOO PANEL BOARDS

- . About four times more service life than wood because of higher shock absorption property;
- . Wear and tear is less; and
- . Production costs are lower.

The manufacturing process involves the following steps:

- . Slivers are made from culm strips (outermost layer is avoided);
- . Slivers are edge-cut to uniform size;
- . Dipped in PF resin adhesive;
- . Assembled and hot-pressed;
- . Dried, sanded and sized; and
- . Bamboo pickings overlaid with wood veneer/bamboo veneer/paper.

*Table 15: Properties of moulded shuttles*

| Properties           | Values                                    |
|----------------------|---|
| Density              | 1 165 kg/m <sup>3</sup>                   |
| Compressive strength |   |
| - along the grain    | 86.1 MPa                                  |
| - across the grain   | 72.2 MPa                                  |
| Modulus of Rupture   | 79.4 MPa                                  |
| Impact strength      | 0.52 x 10 <sup>2</sup> N-M/m <sup>2</sup> |
| Hardness             | 2.06 x 10 <sup>5</sup> N/m <sup>2</sup>   |
| Cracking strength    | 706 N/cm <sup>2</sup>                     |

## Plybamboo

Plybamboo is a high-class product developed in China. It is being manufactured also in Taiwan-China, where it was the most important bamboo board product until recently. Straight culms of a thick-walled species, such as *Phyllostachys pubescens*, are peeled into veneers and employed in overlaying. The production process adopted is as follows:

- . Cross-cutting selected culms into pieces 120-150 cm long;
- . Cooking the pieces for 8 hours at 100°C in water containing 10% NaOH;
- . Cross-cutting into pieces 30-60 cm long;
- . Rotary-cutting (60 rpm) as per the following parameters;
  - . rear angle - 1 5°
  - . grinding angle - 20°
  - . cutting angle - 21.5°
  - . thickness of veneer - 0.3-0.4 mm, max. 0.6 mm

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- Drying to 8-12% moisture content;
- Clipping;
- Bleaching;
- Drying; and
- Coloring.

Bamboo veneers are used for overlaying on various kinds of panel substrates and employed in furniture, walling, and handicraft items such as moulded plates, fans, bookmarks and screens. As only selected culms can be peeled and skilled operators are required, adoption on a commercial scale is limited.

**Particleboard**

This is the only reconstituted bamboo panel in which some amount of success has been achieved. Although it is produced in China, and to some extent in Costa Rica, India, Malaysia, the Philippines and Vietnam, commercialization of the technology has not attracted much entrepreneurial interest as optimization is required in some critical areas of manufacture. Recent studies carried out at the Queen's University in Canada have clearly indicated that it is feasible to economically produce high-quality, durable bamboo particleboards by using environmentally friendly resins and latest pressing technologies. Boards thus manufactured have been found to surpass wood particleboards in properties like MOR, MOE and IB, when tested according to ASTM Standard. The emergence of bamboo particleboard as an alternative to wood particleboard and structural panels like wafer board for use in construction, furniture, packaging, etc. is therefore very much possible.

**CHINA**

Generally, lops, tops and felling residues are used in the manufacture of particleboards. Residues of BMB and other bamboo-based panel industries are also used. The manufacturing process is as follows:

- Mixing of bamboo residues;
- Roll-pressing;
- Cutting;
- Milling to (needle or flake-shaped) particles of size 20-30 x 1.5 x 0.1-0.5 mm;
- Screening;
- Drying to 3-6% moisture content in a rotary drum drier at a temperature of 150- 180°C;
- Spraying of 8-12% (on dry weight basis) synthetic resin adhesive;
- Mat forming (moisture content of furnish 10-13%);
- Pre-pressing;

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- Hot-pressing for 0.4 minute/mm at a temperature of 150-160°C and a specific pressure of 1.4-1.18 MPa; and
- Trimming.

Length of particle is a critical factor and should not exceed 30 mm. Other critical aspects are to maintain the proportion of fresh to dry bamboo at 60:40, and to ensure that the moisture content of particles and furnish does not exceed 6% and 13%, respectively. The physical and mechanical properties of the product are given in Table 16.

*Table 16: Properties of bamboo particleboard (China)*

| Property               | Value                     |
|------------------------|---------------------------|
| Density                | 730-800 kg/m <sup>3</sup> |
| Moisture content       | 6.9 %                     |
| Thickness swelling     | 1.6 %                     |
| Internal bond strength | 0.64 MPa                  |
| Modulus of rupture     | 24.24 MPa                 |
| Modulus of elasticity  | 2 480 MPa                 |

### CANADA/COSTA RICA

Researchers at Queen's University (Canada) have developed an economical bamboo particleboard, known as 'bamboard', with the cooperation of the Costa Rican Building Research Center (CIVCO) and Forintek Canada Corporation. The product is intended to offer an alternative to plywood in several applications such as packaging containers, furniture and sheathing. The manufacturing process involves the following steps:

- Bamboo is refined using a hammer mill;
- The particles are sieved into coarse and fine material;
- Sieved particles are blended with PF resin (4% by mass) and wax (1%) in a rotary blender;
- Mats are formed in three layers, with the product mass being divided 40:60 between the faces and core, respectively;
- 16-mm panels are pressed for 3 minutes using steam injection at a temperature of 215°C; and
- Pressed panels are cured for 3 minutes.

The product was tested according to the Canadian Standards CAN/CSA 0437.1. Results are given in Table 17.

*Table 17: Test results obtained for bamboard (Canada)*

| Properties                            | Values                |
|---------------------------------------|-----------------------|
| Density                               | 750 kg/m <sup>3</sup> |
| Modulus of elasticity (longitudinal)  | 3 100 MPa             |
| Modulus of rupture (longitudinal)     | 17.2 MPa              |
| Internal bond strength                | 345 kPa               |
| Water absorption (after 24 h soaking) | 57%                   |
| Thickness swelling                    | 14%                   |

## INDIA

Only a small quantity of bamboo particleboard (about 1 500 t/y) is produced and entrepreneurial interest has not shown any signs of growth. As a common national standard exists for particleboard produced from all lignocellulosic materials, bamboo particleboard requires to conform to IS:3087-1 985 (Standard Specification for Medium Density Wood Particleboard for General Purposes). The technology employed is as follows:

- Breaking culms into needle-shaped particles in a hammer mill;
- Screening;
- Drying to 3-4% moisture content;
- Application (10-12% of weight on solid basis) of adhesive containing 1-1.5% wax emulsion;
- Mat forming (moisture content of furnish 12-14%); and
- Hot-pressing for 0.9 to 1.0 minute/mm at a temperature of 140-150°C (specific pressure depends on the density required).

## MALAYSIA

Particleboard that conforms to British Standard BS:5906-1989 is produced in Malaysia, although in very small quantities. The main manufacturing steps are:

- Beating of culm into particles;
- Drying;
- Spraying UF resin adhesive;
- Mat forming; and
- Hot-pressing for 6 minute at 160°C.

The physical and mechanical properties are shown in Table 18.

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Table 18: Properties of bamboo (*Bambusa vulgaris*) particleboard (Malaysia)

| Resin (%)       | Density (kg/m <sup>3</sup> ) | Modulus of rupture (MPa) | Internal bond strength (MPa) | Screw withdrawal (N) | Thickness swelling (%) |
|-----------------|------------------------------|--------------------------|------------------------------|----------------------|------------------------|
| 6               | 550                          | 12.7                     | 0.15                         | 489                  | 7.6                    |
| 6               | 610                          | 17.6                     | 0.27                         | 671                  | 9.3                    |
| 6               | 710                          | 27.9                     | 0.36                         | 777                  | 9.5                    |
| 8               | 840                          | 11.8                     | 0.31                         | 418                  | 4.0                    |
| 8               | 610                          | 16.9                     | 0.49                         | 528                  | 5.2                    |
| 8               | 690                          | 21.3                     | 0.74                         | 697                  | 4.4                    |
| 10              | 610                          | 20.7                     | 0.52                         | 650                  | 5.7                    |
| 10              | 660                          | 27.3                     | 0.62                         | 670                  | 6.3                    |
| 10              | 720                          | 27.4                     | 0.85                         | 881                  | 7.6                    |
| B.S. for Type 1 |                              | Min. 13.8                | Min. 0.34                    | Min. 360             | cl 2.0                 |

## VIETNAM

Culms as well as residues of mat manufacture are used in Vietnam to manufacture particleboards. The manufacturing process is as follows:

- Conversion into particles;
- Drying to 7-10%;
- Adhesive application (UF resin adhesive 9-1 1% of weight on dry basis);
- Mat formation; and
- Hot-pressing (12 minute for 18-mm board) at a temperature of 120-140°C and a specific pressure of 2.2-2.4 MPa.

The properties of boards are summarized in Table 19.

Table 19: Properties of bamboo particleboard (Vietnam)

| Properties                                       | Values                    |
|--|---------------------------|
| Density  | 650-720 kg/m <sup>3</sup> |
| Thickness swelling (after 24 h soaking in water) | 3.519%                    |
| Water absorption (after 24 h soaking in water)   | 40.91%                    |
| Modulus of rupture                               | 16.5-1 7.53 MPa           |
| Modulus of elasticity                            | 4 150 MPa                 |
| Internal bond strength                           | 1.05-1 50 MPa             |

Various composites of different bamboo panels are made in different countries. Some of these are mentioned below.

### Bamboo mat and bamboo curtain board

This board is produced in China. Bamboo mat is used as face and back layers, and multi-layered bamboo curtain board as core. PF resin is used for bonding. The face layer is sometimes overlaid with PF resin-impregnated Kraft paper. This panel is used in concrete formwork.

### Bamboo mat and bamboo particleboard

This panel also is manufactured in China. Here, bamboo mats form the face and back layers and particleboard the core. The panel is produced in a single operation in which mats and particles in mat form are pressed at the same time - both at the pre-pressing and hot-pressing stages as in the manufacture of particleboard. These boards are used in rail coaches. The properties of the board are shown in Table 20.

*Table 20: Properties of bamboo mat-bamboo particle composite board (China)*

| Properties tested                            | Set values        | Tested values          |
|--|-------------------|------------------------|
| Density (kg/m <sup>3</sup> )                 | 750-950           | 920                    |
| Moisture content (%)                         | 2-9               | 5.7                    |
| Absorptivity (%)                             | <10               | 4.8                    |
| Thickness swelling (%)                       | <4                | 3.5                    |
| Modulus of rupture (MPa)                     | >35               | 50.06                  |
| Modulus of elasticity (MPa)                  | >3 000            | 5 330                  |
| Internal bond strength (MPa)                 | >0.6              | 0.87                   |
| Nail holding ability (N)                     | >2 300            | 2 828                  |
| Linear swelling (%)                          | co.20             | 0.10                   |
| Impact strength (J/m <sup>2</sup> )          | >9 000            | 13 000                 |
| Cold brittleness (-50°C) (J/m <sup>2</sup> ) | >4 000            | 14 000                 |
| Compressive strength (MPa)                   | >20               | 9.5                    |
| Oxygen index                                 | >28               | 32                     |
| Combustibility (bevel)                       | Difficult to burn | Very difficult to burn |

There are also bamboo panel composites with wood or other lignocellulosic materials, the most important one being plywood overlaid with bamboo veneer (popularly known as plybamboo, and described earlier). Others are described here.

**Bamboo mat wood veneer board**

This composite panel is produced both in China (where it is known as bamboo plywood) and India (where it is called bamboo-wood veneer composite board) by enterprises manufacturing bamboo mat boards. Bamboo mat is used as face and back layers and wood veneers as core. Uses are similar to those of bamboo mat board.

**Bamboo mat/curtain with wood veneer**

A composite board in which bamboo mats form the face and back layers, while wood veneer and bamboo curtain layers form the core. It is manufactured in a simple process employing PF resin adhesive. Limited quantities are made in China for use mainly in rail coaches.

**Bamboo mat overlaid particleboard**

In India, panels are produced to a very limited extent in which wood particleboard forms the core, while bamboo mats make up the face and back layers. The manufacture is in a single operation.

**Bamboo mat overlaid rice husk board**

This composite board is produced as follows:

- Rice husk is blended with PF resin in which phenol is partially replaced by Cardanol (CPF);
- Resin-coated husk is dried to 8-10% moisture content;
- Bamboo mat soaked in PF resin is dried to 10-12% moisture content;
- Assembling of components in the following manner;
  - metal support caul
  - bamboo mat treated with resin
  - rice husk formed into mat
  - bamboo mat treated with resin
  - metal support caul
- Hot-pressing for 60 s/mm thickness at a temperature of 150-160°C and a specific pressure of 152.0 MPa; and
- Conditioning and trimming.

Sometimes, bamboo slivers are employed as reinforcement in rice husk boards. Such reinforcement is known to increase bending strength by 80-120%, depending on sliver thickness.

## Bamboo strip and wood veneer

A newly developed product in China, this panel has bamboo strips and wood veneer bonded with PF resin. Thickness of bamboo strip is 2.5-6.5 mm and its moisture content 8-10%, while thickness of veneer (chiefly of *Pinus massoniana*) is 1.6 mm and its moisture content 6-8%. Hot-pressing is done at 130-140°C, using a specific pressure of 2.5-3.0 MPa. Pressing time varies from 30 to 40 minutes. The panel surface is coated with PF resin. It is used as the base of containers. The physical and mechanical properties are given in Table 21.

Table 21: Properties of bamboo-wood composite board (China)

| Properties  | Standard           | Bamboo-wood composite | Limit   |
|---|--------------------|-----------------------|---------|
| Moisture content (%)                                | GB9846.1 I-88      | 10.3                  | <1 2.0  |
| Density ( kg/m <sup>3</sup> )                       | GB4899-85          | 820                   | <850    |
| Modulus of rupture (MPa)                            | JIS Z2113-63       |                       |         |
| - Parallel  |                    | 116.9                 | >75.0   |
| - Perpendicular                                     |                    | 56.9                  | 30.0    |
| Modulus of elasticity (MPa)                         | JIS Z2113-63       |                       |         |
| - Parallel  |                    | 10 028                | >10 000 |
| - Perpendicular                                     |                    | 3 074                 | > 3 000 |
| Bond durability after six cycles of treatment (MPa) |                    |                       |         |
| Modulus of rupture                                  | ASTM D1039-78      |                       |         |
| - Parallel  |                    | 70.3                  |         |
| - Perpendicular                                     |                    | 30.5                  |         |
| Modulus of elasticity                               | ASTM D1037-78      |                       |         |
| - Parallel  |                    | 9933                  |         |
| - Perpendicular                                     |                    | 2474                  |         |
| Partial compression strength (MPa)                  | JIS Z2117-63       |                       |         |
| - Parallel  |                    | 1175                  |         |
| Impact strength (J/m <sup>2</sup> )                 | GB13123-91         |                       |         |
| - Parallel  |                    | 89760                 |         |
| Linear expansion (over dry to 15%) (%)              | JIS Z2103-57       |                       |         |
| - Parallel  |                    | 0.024                 |         |
| - Perpendicular                                     |                    | 0.082                 |         |
| Thickness loss in wear (mm)                         | GB7911.7-88        | 0.09                  |         |
| Internal bond strength (MPa)                        | JAS type I plywood | 1.72                  | >0.70   |

## **Bamboo strip, bamboo particle and wood veneer**

This panel is manufactured in China, using wood veneers as faces, and bamboo strip and bamboo particle as core. PF resin is employed for bonding by thorough spreading. Wood veneer of 1.2 mm thickness is placed adjacent to bamboo chips of 3.5 mm thickness assembled in layer form. Inside core is formed by particles.

This board has a symmetrical structure with flat and smooth surface, and is used for concrete formwork and side-board of trucks.

## **Veneer overlaid bamboo slivers moulded beating club**

This is a highly specialized product manufactured in China in very limited quantity. PF resin-impregnated slivers are used as core and wood veneer is overlaid through spreading and bonding. The manufacturing process involves the following main steps:

- Bamboo slivers dried to 6-8% moisture content;
- PF resin impregnation;
- Drying;
- Wood veneer hot-pressed; and
- Machining.

Some inorganic materials, such as cement and gypsum, have also been tried in the manufacture of bamboo panel composites, as described below.

## **Cement-bonded bamboo particleboard**

Analogous to cement-bonded wood particleboard, this composite board has been developed in China. Malaysia too has carried out studies on this product and produced a small quantity. It is reported that Indonesia is beginning to produce cement-bonded particleboard following a technology developed in Japan, but further information is not available.

### **CHINA**

The panel is made from needle-shaped bamboo particles and silicate cement (No. 525) mixed with calcium chloride as solidifying agent. Using good grades of cement, boards with improved strength, water absorption and thickness swelling properties can be made. Water absorption rate is not significantly affected by the ratio between cement and bamboo particles. The technology is similar to the one adopted for cement-bonded wood particleboard, except that bamboo particles require to be pre-treated with boiling water for about one hour.

A panel material similar to wood wool-cement board is also produced in China. To manufacture 1 m<sup>3</sup> of bamboo wool board, about 150 kg of bamboo wool, 220 kg

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of cement and 8 kg of calcium chloride are required. Lops and tops, as well as residues from other bamboo panel mills, are used in the manufacture. The process is as follows:

- Culm pieces are finely shredded;
- Immersed in water at room temperature for 3-5 minutes (moisture content not to exceed 25%);
- Treated with 5% calcium chloride;
- Mixed with cement (ratio of bamboo wool and cement by weight 1 :1.8 to 2.2);
- Mat forming;
- Hot-pressing;
- Drying to 20% moisture content at 30-40°C and curing for 24-48 hours; and
- Trimming.

The panels thus made are used in housing applications, such as insulation board, ceiling and partition.

### MALAYSIA

Studies have confirmed that before fresh bamboo particles can be used in panel manufacture, they require to be pre-treated to reduce sugar content. Cement mixed with aluminium sulphate, or aluminium sulphate and sodium silicate, to the extent of 2% of total weight is used for bonding. The optimum ratio between bamboo particles and cement mixed with sulphate is 1:2.75 by weight. The product conforms to the Malaysian Standard MS:934 for cement-bonded particleboard. Important properties of the board are given in Table 22.

*Table 22: Properties of cement-bonded bamboo (B. vulgaris) particleboard (Malaysia)*

| Wood to Cement Ratio | Additives and their percentage on cement | Modulus of rupture (MPa) | Internal bond strength (MPa) | Water absorption (%) | Thickness swelling (%) |
|----------------------|--|--------------------------|------------------------------|----------------------|------------------------|
| 1:2.75               | Nil                                      | 3.64                     | 0.10                         | 26.10                | 1.16                   |
| 1:2.75               | Aluminium sulphate/ sod. silicate        | 9.10                     | 0.70                         | 13.27                | 1.03                   |
| MS. 934 provision    | -  | 9.00                     | 0.50                         |                      | <2.00                  |

### Gypsum-bonded particleboard

This panel has been developed in the Philippines and a small quantity

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produced. Gypsum mixed with cement is used as the binder. Some of the important properties reported are given in Table 23.

*Table 23: Properties of gypsum-bonded particleboard*

| Properties                      | Values                |
|---------------------------------|-----------------------|
| Density                         | 350 kg/m <sup>3</sup> |
| Thickness swelling              | 2.4 %                 |
| Water absorption (24 h soaking) | 34.5 %                |
| Modulus of rupture              | 4.6 MPa               |

### **Bamboo particle plaster board**

This panel, produced in China in very small quantities, is generally made with residues of *Phyllostachys pubescens* utilized for other purposes and small-sized culms. The main process parameters established are:

- . Coarse, medium and fine bamboo particles in the ratio 5:3:2;
- . Bamboo and plaster in the ratio 1 :0.18;
- . Water and plaster in the ratio 1 :0.18;
- . Pressing under pressure for 60 minutes; and
- . Adhesive quantity 0.55%.

The properties of the board compare favorably with those of wood particle plaster boards (Table 24).

*Table 24: Comparison of properties of wood and bamboo-based plaster particleboard*

| Properties                    | Wood-based plaster particleboard | Bamboo-based plaster particleboard |
|-------------------------------|----------------------------------|------------------------------------|
| Density (kg/m <sup>3</sup> )  | 1 100-1 200                      | 1 430                              |
| Modulus of rupture (MPa)      | 6-10                             | 7.83                               |
| Internal bond strength (MPa)  | 0.3-0.6                          | 0.64                               |
| Thickness swelling in 2 h (%) | 3                                | 0.29                               |

### **Technologies Being Experimented**

Considerable interest is seen in the development of bamboo-based fiberboard and medium density fiberboard (MDF) and studies are in progress in several countries. In India, research was initiated as far back as 1961. No commercial technology has emerged so far, although technical feasibility has been established. Some progress has been reported in China, where process modifications in line with

those adopted for wood-based fiberboard and MDF have been suggested. Chips are prepared in 20 x 5 mm size and immersed in water to increase the moisture content to 40-50%. They are then steamed at 170°C under pressure for 15 minutes. After defibering and refining, PF resin and wax are added. The pH of the furnish is adjusted to 5. Mat is formed, pre-pressed and hot-pressed. For manufacturing a 4-mm board of 1 000 kg/m<sup>3</sup> density, 1 % PF resin and 1% wax are used.

The technological parameters worked out on the basis of research completed so far are given in Tables 25-27.

*Table 25: Technological parameters for bamboo fiberboard and MDF (China)*

| Board                   | Thickness (mm) | Density (kg/m <sup>3</sup> ) | Freeness (s) | Temperature (°C) | Pressure (MPa) | Time (Min) | Adhesive (%) | Wax (%) |
|-------------------------|----------------|------------------------------|--------------|------------------|----------------|------------|--------------|---------|
| Hardboard (wet process) | 4              | 1 000                        | 18-20        | 210              | 6.0            | 7          | 1.0          | 1.0     |
| MDF                     |                |                              |              |                  |                |            |              |         |
| Wet process)            | 10             | 700                          | 18-20        | 200              | 3.5            | 16         | 5.0          | 1.0     |
| Dry process             | 9              | 750                          | 15-17        | 180              | 3.5            | 8          | 11.0         | 1.0     |

*Table 26: Properties of bamboo (p pubescens) hardboard (wet process)*

| Properties                   | Determined values China Standard GB 12626-90 |                  |
|------------------------------|--|------------------|
| Density (kg/m <sup>3</sup> ) | 980  | >80              |
| Modulus of rupture (MPa)     | 5.3  | 3-10             |
| Moisture content (%)         | 4.6  | 39 (first grade) |
| Moisture absorption (%)      | 18.9   | <20(first grade) |

*Table 27: Properties of bamboo (P pubescens) MDF of dry and wet processes*

| Properties                       | MDF (wet process) | MDF (dry process) | China Standard BG1718-89 |
|----------------------------------|-------------------|-------------------|--------------------------|
| Density (kg/m <sup>3</sup> )     | 710               | 760               | 700 ±70                  |
| Modulus of rupture (MPa)         | 30.2              | 26.8              | >19.6 (special grade)    |
| Modulus of elasticity (MPa)      | 2 350             | 2 960             | >1 850 (special grade)   |
| Internal bond strength (MPa)     | 0.48              | 0.80              | >0.44 (first grade)      |
| Surface nail holding ability (N) | 1 370             | 1 520             | >1 250 (special grade)   |
| Thickness swelling (%)           | 6.86              | 5.42              | <12                      |
| Moisture content (%)             | 5.66              | 6.20              | 4-13                     |
| Free formaldehyde (mg/l 00g)     |                   | 15                | <70                      |

The equipment used is the one employed for the manufacture of wood fiberboard, with-some minor modifications.

## Bamboo oriented strand board

In Vietnam, exploratory studies have been undertaken to develop bamboo oriented strand board. Very thin slivers of *Dendrocalamus* spp. are used after excluding those with epidermal layer. Thin slivers are dipped in NaPCP for preservative treatment, dried and sprayed with UF resin adhesive. The slivers are oriented in one direction and the furnish is hot-pressed. Important properties of the product are given in Table 28.

*Table 28: Properties of bamboo oriented strand board (Vietnam)*

| Properties                        | Values                    |
|-----------------------------------|---------------------------|
| Density                           | 650-729 kg/m <sup>3</sup> |
| Thickness swelling (24 h soaking) | 3.519%                    |
| Water absorption (24 h soaking)   | 40.91%                    |
| Modulus of rupture                | 23-45 MPa                 |
| Modulus of elasticity             | 4150 MPa                  |
| Internal bond strength            | 1.05-1.5 MPa              |

## Arc-shaped decorative board

This highly specialized product under development in China employs the inner culm portion of selected species of bamboo as the main raw material. The board has a characteristic appearance and pronounced stereoscopic property.

## Bamboo fiber reinforced plastic

A bamboo-based substitute for glassfiber reinforced plastic (GRP) is being developed in India. It is much lighter than GRP and stronger than other natural fiber (jute, coir, banana stem) reinforced plastic (FRP). The product is reported to have a density of about 500 kg/m<sup>3</sup> and a tensile strength of 264 by 386 MPa, depending on the stacking sequence.

# 4

## CONCLUSION

Some 28 bamboo-based panels have emerged as a result of research carried out during the last three decades, mostly in Asia. Their production, however, has not kept pace with the diversity in variety. In China, where most have been developed, production is reported as stagnant at about 100 000 m<sup>3</sup> per year. In India, the annual production is estimated to be only 2 000 m<sup>3</sup>. The reasons for this slow growth can be attributed to:

1. Non-commercialization of technologies;
2. Inadequate supplies of bamboo at stable prices, resulting in entrepreneurial hesitation; and
3. Non-recognition of the much articulated environmental and socio-economic benefits of substituting wood with bamboo, as they have not been analysed and quantified.

Consequently, important sector-related issues – such as identification of raw material resource and appropriation of the same to the manufacture of bamboo-based panels, formulation of product as well as performance standards, and documentation of statistics relating to production, trade and consumption – have largely been ignored.

Wood from natural forests is becoming increasingly scarce, while the potential of bamboo, particularly in panel form, to replace wood is being increasingly acknowledged. Hence, it is important to address the issues mentioned above to fully exploit the versatility of bamboo in construction and other major applications in the next century.

As mentioned earlier, a large variety of bamboo-based panels has been developed. However, in the absence of scaled-up technologies and standardized methods to test product properties and performance, it will be premature to promote their production. It is therefore necessary to:

1. Focus on mature technologies and scale them up for industrial production, „ Bamboo mat board and bamboo strip board technologies in China, as well as bamboo particleboard technologies in China, Costa Rica/Canada and India are some such technologies that can be considered for the purpose. An excellent example of how a small investment can kick-start entrepreneurial interest in technologies is the bamboo mat board project funded by IDFC/INBAR in India.

Commercial exploitation of this two-decade-old technology was rendered possible when, under the project, it was scaled-up after addressing floor level problems, and seven small-scale enterprises started manufacturing the panel.

2. Select promising technologies tested in laboratories and scale them up to pilot production to establish their suitability for industrial-scale production. Bamboo plywood, gluelam, laminated curtain board for concrete formwork, particleboards based on inorganic binders (cement, slag cement, gypsum, etc.), dimensionally stable fiberboard, etc. are examples.

There is confusion about product names and the terms for culm derivatives used in the production of panels. For example, "plywood" is used for veneer-based panels as well as those produced from strips. Similarly, "plybamboo", "plybambu", "strand board", "blockboard", etc. are used for panels produced from the same culm derivatives. The nomenclature of derivatives is also confused. For instance, the terms "sliver", "strip", "strand" and "lath" are applied loosely to the same or similar derivatives. Standardization of terms and the production of a glossary of terms used in bamboo panel manufacture are therefore urgently needed.

In the absence of standardized methods for testing properties, products in different countries cannot be compared and assessments made for their application. Standardization of testing methods therefore requires urgent attention.

As bamboo has not been included in building codes and its design considerations (particularly with regard to application in panel form) not given adequate attention, its use in building and construction (despite the known advantages) is much hampered. A high priority needs to be given to the formulation of building codes and the generation of a framework for design of buildings in which bamboo/bamboo panels are used. INBAR, which had included this in its program, has made considerable progress in this direction.

Inputs required to facilitate international trade in bamboo panels are totally lacking. Even national statistics on raw material used, production, demand, supply, pricing, etc. are inadequate. A nodal agency (preferably under INBAR) to collect, compile and disseminate such data would help in promoting the marketing and utilization of bamboo-based panels.

At present, policy intervention to ensure sustained supply of bamboo to panel enterprises at stable prices is lacking. To ensure further growth in panel production, such an intervention is essential. This will be possible only when reliable data on environmental and socio-economic implications of using bamboo in construction and other large-scale applications are studied and disseminated. It is therefore vital that case studies evaluate the implications of using bamboo in place of wood.

Once this report is widely distributed and studied, it is expected that action will be taken to organize case studies, formulate standards and mobilize small grants to upgrade technologies. This will require continuing partnerships with and among national programs, with INBAR acting as the focal point.

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# ANNEX1

## Proforma used for gathering information on bamboo panel/composite products

### Part I

Name of the country:

---

1. The category to which the product belongs to which the product belongs  
(Please tick as appropriate)\*

- |                                     |   |                               |   |                                 |
|-------------------------------------|---|-------------------------------|---|---------------------------------|
| 1) Particle<br>chipboard            | 2) Cement/gypsum<br>bonded particle-<br>board | 3) OSB                        | 4) Fibre<br>board                                 | 5) MDF                          |
| 6) Plybamboo<br>(bamboo<br>plywood) | 7) Bamboo mat<br>board                        | 8) Bamboo<br>curtain<br>board | 9) Laminated<br>bamboo<br>(straight<br>or curved) | 10) Overlaid<br>bamboo<br>board |

11) Any other (Please specify)

---

2. Form in which bamboo is employed (Please tick as appropriate)

- |                    |                  |                |                      |            |           |
|--------------------|------------------|----------------|----------------------|------------|-----------|
| 1) Chips/particles | 2) Fibres        | 3) Dust        | 4) Strips            | 5) Slivers | 6) Veneer |
| 7) Woven mat       | 8) Crushed culms | 9) Split culms | 10) Others (specify) |            |           |
- 

3. Quantity produced per annum in tonne/m<sup>3</sup>  
and price in US\$ per tonne/m<sup>3</sup>

---

4. Species employed and quantity in tonnes (per annum)

---

5. Type of adhesive (binder) used for making the panel (Please tick as  
appropriate)

- |                      |                                  |                           |               |
|----------------------|----------------------------------|---------------------------|---------------|
| 1) Urea formaldehyde | 2) Urea melamine<br>formaldehyde | 3) Phenol<br>formaldehyde | 4) Isocyanate |
| 5) Gypsum cement     | 6) Any other (Please specify)    |                           |               |
- 

\* Please use separate proforma for each category of product

## BAMBOO PANEL BOARDS

## 6. Important physical properties

Density ..... kg/m<sup>3</sup>                      Thickness swelling ..... %  
 Water absorption after 24 h soaking ..... %  
 Thermal conductivity ..... W/moK      Sound absorption ..... Hz

## 7. Important mechanical properties

Modulus of rupture ..... N/mm<sup>2</sup>                      Tensile strength ..... N/mm<sup>2</sup>  
 Modulus of elasticity ..... N/mm<sup>2</sup>                      Internal bond strength ..... N/mm<sup>2</sup>  
 Glue shear strength ..... N/mm<sup>2</sup>                      Screw/nail holding strength ..... kg

## 8. Major uses, category-wise (Please tick as appropriate)

| Sector                            | Applications           |  |                   |                                   |                             |
|-----------------------------------|------------------------|--|-------------------|-----------------------------------|-----------------------------|
| Housing                           | Doors<br>Windows       | Partitions<br>Screens                        | Ceiling           | Shelving<br>Storage               | Flooring<br>Parquette       |
| Furniture                         | Chairs<br>Sofas        | Tables<br>Benches                            | cots              | Built-in<br>furniture<br>Cabinets | Outdoor<br>furniture        |
| Construction/<br>structural       | Concrete<br>shuttering | Wall/roof<br>sheathing                       | Built-up<br>beams | Floor<br>underlay                 | Prefab                      |
| Transport/<br>vehicle<br>building | Coach/<br>truck body   | Rail carri-<br>age coach<br>flooring         |                   | Animal-<br>drawn<br>vehicle       | Vehicle<br>interiors        |
| Industrial                        | Pallets                | Shelving<br>& bins                           | Ducts             | Cold<br>storage                   | Liquid<br>chemical<br>tanks |
| Packaging                         | Batten<br>Cases        | Non-returnable<br>fruit/vegetable<br>package |                   | Drums                             | Shipping<br>containers      |

Any other (Please specify)

## 9. Brief particulars of preservative treatment against insects, decay &amp; weathering

---

 10. Chemical used for preservative treatment
 

---

| Causative factor | Chemicals used and method of treatment |
|------------------|--|
|------------------|--|

---

|         |  |
|---------|--|
| Insects |  |
|---------|--|

---

|               |  |
|---------------|--|
| Fungi & other |  |
|---------------|--|

---

|           |  |
|-----------|--|
| Pathogens |  |
|-----------|--|

---

|                         |  |
|-------------------------|--|
| Moisture/<br>weathering |  |
|-------------------------|--|

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 11. Brief particulars of fire retardant treatment
 

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 12. Environment in which used (Please tick as appropriate)
 

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|             |                  |             |
|-------------|------------------|-------------|
| 1) Exterior | 2) Semi-exterior | 3) Interior |
|-------------|------------------|-------------|

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 13. National standards formulated
 

---

| Title | Year of introduction |
|-------|----------------------|
|-------|----------------------|

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 14. Limitations/deficiencies of the product
 

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15. Difficulties encountered in manufacture of the product

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16. Aspects requiring further research & development (R&D)

17. Any other information

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## **Part II**

Role of bamboo panel products in:

1. Employment generation
2. Energy conservation
3. Replacement of wood from natural forest
4. Others (if any)

# ANNEX2

## Profiles of selected bamboo panels

### I. Product Name : Bamboo Mat Plywood Country of Origin : China

#### Product summary

|                              |   |
|------------------------------|---|
| Type of product              | Bamboo Mat Board                                |
| Form of bamboo               | Slivers   |
| Type of refinement of bamboo | Machine used for sliver production              |
| Pre-treatment of bamboo      | Slivers bleached or dyed or chemically treated* |
| Type of binder               | Urea-formaldehyde (UF)                          |
| Applications of product      | Interior applications                           |

#### Testina results

|   | Product A                   | Product B**             |
|---|-----------------------------|-------------------------|
| Final product thickness (mm)                  | NA                          | NA                      |
| Resin/binder type                             | UF                          | UF                      |
| Resin/binder amount (% bv mass)               | NA                          | NA                      |
| Temperature of press(°C)                      | 110-120                     | 110-120                 |
| Press pressure (MPa)                          | 4-5                         | 4-5                     |
| Time to cure (minutes)                        | 1.5-2.0 per mm<br>thickness | 1.5-2.0 mm<br>thickness |
| Testing standard used for following results : | GB 1312-91                  | GB13123-91              |
| Density (kg/m <sup>3</sup> )                  | 850                         | 860                     |
| Modulus of elasticity (MPa) (longitudinal)    |                             |                         |
| Modulus of rupture (MPa) (longitudinal)       | 93                          | 119                     |
| Modulus of elasticity (MPa) (transverse)      | NA                          | NA                      |
| Modulus of rupture (MPa) (transverse)         | NA                          | NA                      |
| Internal bond (kPa)                           | NA                          | NA                      |
| Water absorption (%)                          | NA                          | NA                      |
| Thickness swelling (%)                        | NA                          | NA                      |
| Screw withdrawal strength (N)                 | NA                          | NA                      |
| Impact strength (J/m <sup>*</sup> )           | NA                          | NA                      |
| Tensile strength (MPa)                        | 72.6                        | 64.6                    |
| Impact strength (J/m <sup>*</sup> )           | 31 000                      | 29 000                  |

\* In the production of decorative boards. . \* Bamboo mat composite with veneer overlay

## II. Product Name : Bamboo Mat Plywood Country of Origin : India

### Product summary

|                              |  |
|------------------------------|--|
| Type of product              | Bamboo Mat Board (BMB)   |
| Form of bamboo               | Slivers woven into mat   |
| Type of refinement of bamboo | None   |
| Pre-treatment of bamboo      | None   |
| Type of binder               | Phenol-formaldehyde (PF)   |
| Applications of product      | To replace thin plywood panels in interior and exterior applications |

### Testing results

|   | Product A     | Product B     |
|---|---------------|---------------|
| Final product thickness (mm)                | <b>3</b>      | <b>7</b>      |
| Resin/binder type                           | <b>PF</b>     | <b>PF</b>     |
| Resin/binder amount (% by mass)             | 7.5-10        | 7.5-10        |
| Temperature of press (°C)                   | 140-145       | 140-145       |
| Press pressure (MPa)                        | 1.6           | 1.6           |
| Time to cure (minutes)                      | 6             | 6             |
| Testing standard used for following results | IS:13598-1994 | IS:13958-1994 |
| Density (kg/m <sup>3</sup> )                | 766           | 790           |
| Modulus of elasticity (MPa) (longitudinal)  | 3678          | 3114          |
| Modulus of rupture (MPa) (longitudinal)     | 5074          | 59.35         |
| Modulus of elasticity (MPa) (transverse)    | 3678          | 3114          |
| Modulus of rupture (MPa) (transverse)       | 5074          | 59.35         |
| Internal bond (MPa)                         | 2.18          | 1.97          |
| Internal bond, boil dry (MPa)               | <b>1.98</b>   | <b>1.83</b>   |
| Surface strength, dry (MPa)                 | 11.92         | 9.47          |
| Surface strength, boil dry (MPa)            | 11.42         | 9.10          |
| Tensile strength (J/m <sup>2</sup> )        | 22.69         | 29.54         |
| Compressive strength (MPa)                  | 16.77         | 35.30         |
| Modulus of rigidity (MPa)                   | <b>5881</b>   | <b>6066</b>   |

**III. Product Name : Bamboo Silver Laminated Board (Lambo)**  
**Country of Origin : China**

**Product summary**

|                              |                                    |
|------------------------------|------------------------------------|
| Type of product              | Parallel gluelam                   |
| Form of bamboo               | Slivers                            |
| Type of refinement of bamboo | Machine used for sliver production |
| Pre-treatment of bamboo      | None                               |
| Type of binder               | Phenol-formaldehyde (PF)           |
| Applications of product      | Truck flooring, structural panels  |

**Testing results**

|   | Product A*  | Product B** |
|---|-------------|-------------|
| Final product thickness (mm)                | 31-32       | 30-32       |
| Resin/binder type                           | PF          | PF          |
| Resin/binder amount (% by mass)             | NA          | NA          |
| Temperature of press (°C)                   | 110-160     | 110-160     |
| Press pressure (MPa)                        | 4-6         | 4-6         |
| Time to cure (minutes)                      | 90-120      | 90-120      |
| Testing standard used for following results | LY 1055-91  | LY 1055-91  |
| Density ( kg/m <sup>3</sup> )               | 850-1050    | 840-1050    |
| Modulus of elasticity (MPa) (longitudinal)  | 11500-14800 | 10100-15900 |
| Modulus of rupture (MPa) (longitudinal)     | 167-201     | 128-223     |
| Modulus of elasticity (MPa) (transverse)    | 3000-4400   | 2300-4100   |
| Modulus of rupture (MPa) (transverse)       | 10.3-13.8   | 30.0-72.0   |

\* All slivers in parallel direction

\*\* Slivers in parallel as well as a few in cross direction

#### IV. Product Name : Bamboo Curtain Plywood Country of Origin : China

##### Product summary

|                              |   |
|------------------------------|---|
| Type of product              | Curtain Board/Laminated Curtain Board                     |
| Form of bamboo               | Slivers   |
| Type of refinement of bamboo | Machine used for sliver production of slivers and curtain |
| Pre-treatment of bamboo      | None  |
| Type of binder               | Phenol-formaldehyde (PF)                                  |
| Applications of product      | Concrete form work  |

##### Testing results

|   | Curtain Board<br>Product A | Laminated<br>Curtain Board<br>Product B |
|---|----------------------------|---|
| Final product thickness (mm)                | 6-30                       | 6-30                                    |
| Resin/binder type                           | PF                         | PF                                      |
| Resin/binder amount (% by mass)             | NA                         | NA                                      |
| Temperature of press (°C)                   | 140-1 50                   | 140-1 50                                |
| Press pressure (MPa)                        | 3-4                        | 3-4                                     |
| Time to cure (minutes)                      | 2-2.30 min/mm              | 2-2.30 min/mm                           |
| Testing standard used for following results | LY 1055-91                 | LY 10005-91                             |
| Density ( kg/m <sup>3</sup> )               | <b>850</b>                 | 78-850                                  |
| Modulus of elasticity (MPa) (longitudinal)  | 12 500                     | 14000                                   |
| Modulus of rupture (MPa) (longitudinal)     | 121.2                      | 130                                     |
| Impact strenath (J/m*)                      | 136 000                    | 136 000                                 |

**V. Product Name : Bamboo Strip Plywood/Bamboo Plywood**  
**Country of Origin : China**

**Product summary**

|                         |  |
|-------------------------|--|
| True of product         | Bamboo Strip Board   |
| Form of bamboo          | Strips of about 5 mm thickness                             |
| Type of refinement used | Outer & Inner layers are scraped off                       |
| Pre-treatment of bamboo | Flattering under pressure and temperature                  |
| Type of binder          | Phenol-formaldehyde (PF)                                   |
| Applications of product | Platform body in transport vehicles;<br>concrete form work |

**Testing results**

|   | Product A  | Product B |
|---|------------|-----------|
| Final product thickness (mm)                | 15-35      |           |
| Resin/binder type                           | PF         |           |
| Resin/binder amount (% by mass)             | NA         |           |
| Temperature of press (°C)                   | 140-150    |           |
| Press pressure (MPa)                        | 3          |           |
| Time to cure (minutes)                      | 1 min/mm   |           |
| Testing standard used for following results | LY 1055-91 |           |
| Density ( kg/m <sup>3</sup> )               | 780        |           |
| Modulus of elasticity (MPa) (longitudinal)  | NA         |           |
| Modulus of rupture (MPa) (longitudinal)     | 111.6      |           |
| Modulus of elasticity (MPa) (transverse)    | NA         |           |
| Modulus of rupture (MPa) (transverse)       | NA         |           |
| Internal bond (MPa)                         | 3.68       |           |
| Water absorption (%)                        | NA         |           |
| Thickness swelling (%)                      | NA         |           |
| Screw withdrawal strength (N)               | NA         |           |
| Impact strength (J/m <sup>2</sup> )         | 87 000     |           |

**VI. Product Name : Bamboo Strip Board**  
**Country of Origin : Vietnam**

**Product summary**

|                         |   |
|-------------------------|---|
| Type of product         | Bamboo Strip Board                                |
| Form of bamboo          | Bamboo strip                                      |
| Type of refinement used | Outer & inner layers are scraped off              |
| Pre-treatment of bamboo | Preservative treatment with NaCO and NaF          |
| Type of binder          | Melamine-Urea-formaldehyde (MUF)                  |
| Applications of product | Interior uses like ceiling, parquet flooring etc. |

**Testing results**

|   | Product A   | Product B |
|---|-------------|-----------|
| Final product thickness (mm)                  | 16          |           |
| Resin/binder type                             | MUF         |           |
| Resin/binder amount (% by mass)               | NA          |           |
| Temperature of press (°C)                     | 120-140     |           |
| Press pressure (MPa)                          | 1.2-1.6     |           |
| Time to cure (minutes)                        | 9           |           |
| Testing standard used for following results : | GOST - 1970 |           |
| Density ( kg/m <sup>3</sup> )                 | 815         |           |
| Modulus of elasticity (MPa)                   | 916         |           |
| Modulus of rupture (MPa)                      | 127.57      |           |
| Thickness swelling (%)                        | 1           |           |
| Screw withdrawal strength (N)                 | NA          |           |
| Impact strength (J/m <sup>2</sup> )           | NA          |           |
| Tensile strength (MPa)                        | NA          |           |
| Impact strength (J/m <sup>2</sup> )           | NA          |           |

**VII. Product Name : Bamboo Particleboard**  
**Country of Origin : China**

**Product summary**

|                         |   |
|-------------------------|---|
| Type of product         | Particleboard                               |
| Form of bamboo          | Particles                                   |
| Type of refinement used | Milling and screening                       |
| Pre-treatment of bamboo | -   |
| Type of binder          | Synthetic resin                             |
| Applications of product | In construction. furniture. packaaina. etc. |

**Testing results**

|   | Product A       | Product B*      |
|---|-----------------|-----------------|
| Final product thickness (mm)                  | NA              |                 |
| Resin/binder type                             | Synthetic resin | Synthetic resin |
| Resin/binder amount (% by mass)               | 8-12            | NA              |
| Temperature of press (°C)                     | 150-1160        | NA              |
| Press pressure (MPa)                          | 1.14-1.18       | NA              |
| Time to cure (minutes)                        | 0.4 min/mm      | NA              |
| Testing standard used for following results : | LY 1055-91      | LY 1055-91      |
| Density (kg/m <sup>3</sup> )                  | 730-800         | 920             |
| Modulus of elasticity (MPa) (longitudinal)    | 2 480           | 5 330           |
| Modulus of rupture (MPa) (longitudinal)       | 24.24           | 50.06           |
| Internal bond (MPa)                           | 0.64            | 0.87            |
| Water absorption (%)                          | NA              | 4.8             |
| Thickness swelling (%)                        | 1.6             | 3.5             |
| Nail holding ability (N)                      | NA              | 2 828           |
| Impact strength (J/m*)                        | NA              | 13000           |

\* Mat overlaid particleboard

**VIII. Product Name : Bamboard****Country of Origin : Canada/Costa Rica****Product summary**

|                         |  |
|-------------------------|--|
| Type of product         | Particleboard  |
| Form of bamboo          | Particles, random orientation                            |
| Type of refinement used | Hammer mill  |
| Pre-treatment of bamboo | None   |
| Type of binder          | Phenol-formaldehyde (PF)                                 |
| Applications of product | Structural panels, sheathing, furniture, packaging, etc. |

**Testing results**

|   | Product A         | Product B |
|---|-------------------|-----------|
| Final product thickness (mm)                | 16                |           |
| Resin/binder type                           | PF resin          |           |
| Resin/binder amount (% by mass)             | 4                 |           |
| Temperature of press (°C)                   | 215               |           |
| Press pressure (MPa)                        | Press blocks used |           |
| Time to cure (minutes)                      | 3.0               |           |
| Testing standard used for following results | CAN/CSA 0 437.1   |           |
| Density (kg/m <sup>3</sup> )                | 750               |           |
| Modulus of elasticity (MPa) (longitudinal)  | 3 100             |           |
| Modulus of rupture (MPa) (longitudinal)     | 17.2              |           |
| Modulus of elasticity (MPa) (transverse)    | NA                |           |
| Modulus of rupture (MPa) (transverse)       | NA                |           |
| Internal bond (MPa)                         | 0.345             |           |
| Water absorption (%)                        | 60                |           |
| Thickness swelling (%)                      | 14                |           |
| Screw withdrawal strength (N)               | NA                |           |
| Impact strength (J/m <sup>*</sup> )         | NA                |           |
| Tensile strength (MPa)                      | NA                |           |
| Impact strength (J/m <sup>2</sup> )         | NA                |           |

# ANNEX3

The State Standard of the People's Republic  
of China : GB 13123-91

## Bamboo-Mat Plywood

Issued in July 16th, 1991

Enforced in April, 1992

Issued by the State Technology Supervision Bureau

### 1. Subject content and scope of application

This Standard stipulates the definition, classification, technical requirements, test method, test rule, product marking, packing, transportation and storing of bamboo-mat plywood.

This Standard is applicable for bamboo-mat plywood made through processing of the bamboo silvers into mats by applying adhesive, hot pressing and trimming.

### 2. The quoted standards

GB 13 124 Methods of testing bamboo-mat plywood.

BG 9 846.3 Plywood technical conditions of dimensions and tolerance for ordinary plywood.

### 3. Definitions

#### 3.1 Blister

Partial separation between mats in the adjacent layer caused by losing efficacy of bonding.

#### 3.2 Delamination

Separation caused by lack of glue or poor bonding in the adjacent two mat layers.

### **3.3 Decay rot**

After the mat is eroded by decay fungus, the timber turns to be loose and soft, lower strength and breakable.

### **3.4 Defects at the edges of the panel.**

Defects at the edge caused by sawing or striking.

### **3.5 Adhesive delamination of silvers**

Separation of silvers from the panel caused by lack of glue or poor bonding, of which the "sporadic adhesive delamination of silvers" refers to the area of adhesive delamination at one place being less than 0.001 m; the "concentrated adhesive delamination of silvers" refers to the area of adhesive delamination at one place being less than 0.002 m.

### **3.6 Surface polluted**

On the surface of the bamboo-mat plywood, some pollution may occur, caused by greasy dirt and other matter, of which "slight" refers to the total polluted area within 1 m<sup>2</sup> at anywhere being no more than 0.005 m<sup>2</sup> "allowable" refers to the total polluted area within 1 m<sup>2</sup> at anywhere being no more than 0.01 m<sup>2</sup>

### **3.7 Imprint**

The partial hollow and partial protruding mark on the surface of the bamboo-mat plywood.

### **3.8 Remaining strength**

Modulus of rupture (MOR) determined by high and low temperatures and humid treatments alternatively for bamboo-mat plywood.

## **4. Classification and grading**

4.1 .1 Bamboo-mat plywood of category I is resistant to weather and boiling water.

4.1.2 Bamboo-mat plywood of category II is resistant to cold water but not to boiling water.

4.1.3 The nominal thickness of the thin type of bamboo-mat plywood is 2-6 mm.

4.1.4 The nominal thickness of the thick type of bamboo-mat plywood is 2 7 mm.

## **4.2 Grading**

The bamboo-mat plywood is classified into 3 grades, i.e. Grade 1, Grade 2 and Grade 3.

## 5. Technical requirements

### 5.1 Dimension and deviation

5.1 .1 For dimension and deviation of panel, see Table 1.

Table 1 (in mm)

| Length | Deviation | Width | Deviation |
|--------|-----------|-------|-----------|
| 1 830  |           | 915   |           |
| 2 000  |           | 1 000 |           |
| 2 135  | 5         | 915   | 5         |
| 2 440  |           | 1 220 |           |
| 3 000  |           | 1 500 |           |

Notes : 1. Only positive deviation is allowable, but not negative deviation for length and width.

2. For bamboo-mat plywood with special requirements the dimension of panel may be restricted by Table 1, through agreement.

5.1.2 for the deviation of the two diagonal lines, see Table 2.

Table 2 (in mm)

| Nominal length | Difference of two diaaonal lines |
|----------------|----------------------------------|
| 1830 - 2135    | ≤6                               |
| 2 440 - 3000   | ≤7                               |

5.1.3 Thickness and deviation

5.1.3.1 Thickness: The thickness of bamboo-mat plywood: 2, 3, 4, 5 and 6 mm, and starting from 7 mm, the size is increased progressively with 2 mm.

5.1.3.2 For thickness and deviation, see Table 3.

Table 3 (in mm)

| Nominal thickness | Deviation of thickness | Maximum allowable deviation of thickness in each sheet of plywood |
|-------------------|------------------------|---|
| 2-6               | + 0.5<br>- 0.6         | 0.9   |
| 7-11              | + 0.8<br>- 1.0         | 1.2   |
| 12-9              | + 1.2<br>- 1.5         | 1.5   |
| 20                | ± 1.5                  | 1.6   |

5.1.3.3 For the corresponding relationship between layer and thickness, see Appendix A (Supplementary document).

5.2 For the technical requirement on quality of the outward appearance, see Table 4.

Table 4 (mm)

| Type of defect                   | Item tested                            | Unit                 | Grade 1            |      | Grade 2 |      | Grade 3 |          |
|----------------------------------|--|----------------------|--------------------|------|---------|------|---------|----------|
|                                  |  |                      | Surface            | Back | Surface | Back | Surface | Back     |
| Decay, Mildew, Spot              |  |                      | Not allowable (NA) |      |         |      |         |          |
| Defect at the edges of the panel | Within nominal dimension No. more than | mm                   | Not allowable (NA) |      | <5      |      | <10     |          |
| Blister, delamination            |  |                      | Not allowable (NA) |      |         |      |         |          |
| Adhesive delamination of sliver  | Sporadic adhesive delamination         | piece/m <sup>2</sup> | NA                 |      | NA      |      | 1       | 3        |
|                                  | Concentrated adhesive delamination     |                      | NA                 |      | NA      |      | 2       |          |
| Surface polluted                 | Slight                                 | piece/m <sup>2</sup> | NA                 |      | NA      | 2    | 4       | No limit |
|                                  | Allowable                              |                      | NA                 |      | NA      | 1    | 2       | No limit |
| Imprint                          | Individual max. area mm <sup>2</sup>   |                      | NA                 | 50   | 400     |      | 3 000   |          |
|                                  | Piece on each .m <sup>2</sup>          |                      | NA                 | 2    | 4       | 8    | 4       | No limit |

### 5.3 Surface warping of bamboo-mat plywood

For thick type bamboo-mat plywood, warping of Grade 1 is no more than 0.5%, Grade 2 no more than 1 .0% and Grade 3 no more than 2.0%.

5.4 For property index, see Table 5.

Table 5

| Type       | Item   | Category and Grade   |                      |                      |                      |                      |                      |
|------------|--|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|            |  | Category I           |                      |                      | Category II          |                      |                      |
|            |  | Gr. 1                | Gr. 2                | Gr. 3                | Gr. 1                | Gr. 2                | Gr. 3                |
| Thin type  | Moisture content (%)   | ≤12                  | ≤15                  |                      | ≤12                  | ≤15                  |                      |
|            | MOR MPa  | ≥90.0                | ≥80.0                | ≥60.0                | ≥80.0                | ≥70.0                | ≥50.0                |
|            | Remaining strength through boiling water Soaking-Freezing - Drying (MPa) | ≥60.0                | ≥50.0                | ≥40.0                | ≥50.0                | ≥40.0                | ≥30.0                |
|            | Formaldehyde releasing (mg/100g)   | -                    |                      |                      | ≤50.0                |                      |                      |
| Thick type | Moisture content (%)   | ≤12                  | ≤15                  |                      | ≤12                  | ≤15                  |                      |
|            | MOR (MPa)  | ≥90.0                | ≥80.0                | ≥70.0                | ≥90.0                | ≥70.0                | ≥60.0                |
|            | MOE (MPa)  | ≥6.0x10 <sup>3</sup> | ≥5.0x10 <sup>3</sup> | ≥4.0x10 <sup>3</sup> | ≥6.0x10 <sup>3</sup> | ≥5.0x10 <sup>3</sup> | ≥4.0x10 <sup>3</sup> |
|            | Remaining strength through boiling water Soaking-Freezing - Drying (MPa) | ≥70.0                | ≥60.0                | ≥50.0                | ≥60.0                | ≥50.0                | ≥40.0                |
|            | Impact strength (kJ/m <sup>2</sup> )                                     | ≥60.0                | ≥50.0                | ≥40.0                | ≥60.0                | ≥50.0                | ≥40.0                |
|            | Formaldehyde releasing (mg/100g)   |                      |                      |                      | ≤80.0                |                      |                      |

## 6. Test method

6.1 The appearance test for grading is made according to the stipulation in Table 4 of this Standard. The grade is determined by eye-estimation or through measurement with steel straightedge for allowable defects on the surface of the panel.

6.2 The test of dimension and warping is made according to the stipulation of items 5.1 and 5.3 of this Standard, and conducted with the methods of measurement of Appendix A in GB 9846.3.

6.3 The test for the property indexes of bamboo-mat plywood is made according to GB 13124.

## 7. Test rules

### 7.1 Classification of test

The Test for bamboo-mat plywood is divided into the ex-factory test and model test.

### 7.1 .I Ex-factory test

Before the bamboo-mat plywood leaves the factory, the appearance quality, dimensions and mechanical property indexes of the products should be tested.

#### 7.1.2 Model test

7.1.2.1 The model test should be performed if one or more of the following cases occur in the production of bamboo-mat plywood:

- a. Trial production and type fixation appraisals are made when the new or old product production is transferred to another factory.
- b. After the factory is officially put into operation, there is a big change such as structure, materials, technological process, which may impair the properties of the products;
- c. The production is resumed after it has been stopped for over one year;
- d. There are some big differences in the ex-factory test result from that of the model test of last time;
- e. The model test is to be made as required by the State Quality Supervision Department.

#### 7.1.2.2 Contents of model test

Complete test on appearance quality, dimensions and all the property indexes of the products is conducted.

### 7.2.1 Sampling plan

7.2.1 A one-time sampling plan is adopted for the test of appearance grade. Its inspecting level is I and the qualified quality level is 4.0. See Table 6.

Table 6

| Range of batch | Number of sample | Qualified number judged | Non-qualified number judged | Number of qualified sample |
|----------------|------------------|-------------------------|-----------------------------|----------------------------|
| 50-90          | 13               | 1                       | 2                           | 12                         |
| 91-150         | 20               | 2                       | 3                           | 18                         |
| 151-280        | 32               | 3                       | 4                           | 29                         |
| 281-500        | 50               | 5                       | 6                           | 45                         |
| 501-I 200      | 80               | 7                       | 8                           | 73                         |
| 1 201-3 200    | 125              | 10                      | 11                          | 115                        |
| 3 201-10 000   | 200              | 14                      | 15                          | 186                        |
| 10 001-35 000  | 315              | 21                      | 22                          | 294                        |

7.2.2 A one-time sampling plan is adopted for the test of dimensions. Its inspecting level is S-4 and the qualified quality level is 6.5. See Table 7.

Table 7

| Range of batch | Number of sample | Qualified number judged | Non-qualified number judged | Number of qualified sample |
|----------------|------------------|-------------------------|-----------------------------|----------------------------|
| 51-150         | 8                | 1                       | 2                           | 7                          |
| 151-500        | 13               | 2                       | 3                           | 11                         |
| 501-1 200      | 20               | 3                       | 4                           | 17                         |
| 1201-10000     | 32               | 5                       | 6                           | 27                         |
| 10001-35000    | 50               | 7                       | 8                           | 43                         |

7.2.3 The property indexes for the test are drawn within the range of samples. See Table 8.

Table 8

| Range of batch                 | No. of sheets sampled for 1st time | No. of sheets sampled for 2nd time |
|--------------------------------|------------------------------------|------------------------------------|
| Less than 1 000 Sheets         | 1                                  | 2                                  |
| 1 000 - less than 5 000 Sheets | 2                                  | 4                                  |
| Over 5 000 Sheets              | 3                                  | 6                                  |

### 7.3 Result judgement

When the three indexes, i.e. the appearance quality, dimensions and all the properties of the product are up to standard through the test, that batch of the product is judged as "up to standard". If the first-time sampling result shows that the appearance quality and dimensions are not up to standard, they should be repaired and arranged piece by piece and then re-tested. If they pass the re-testing, they will be judged as "up to standard". If the mechanical property index is not up to standard, it should be re-tested according to the second-time sampling plan. If it does not pass the re-testing, the batch of product is judged as "not up to standard".

## 8. Marking, packing, transportation and storing

### 8.1 Marking

On the product, factory name, standard-number, category, dimension, grade, date of production, code-name of tester, and test date are marked with fadeless printing ink.

### 8.2 Packing

When bamboo-mat plywood products leave the factory, they are packed respectively with different categories, dimensions and grades. For those products

with special requirements, they can be packed according to the supply and demand agreement.

### 8.3 Transportation and storing

In the course of storing and transportation, the products should be protected from rain, moisture and sun, and protected from artificial and mechanical damage during transportation.

## Appendix A

The corresponding relationship between layer and thickness of bamboo-mat plywood (Supplementary document)

Table : A1 Corresponding relationship between layer and thickness of bamboo-mat plywood

| No. of layers | Range of thickness (mm) | No. of layers | Range of thickness (mm) |
|---------------|-------------------------|---------------|-------------------------|
| 2             | 1.4-2.5                 | 13            | 9.0-i 0.8               |
| 3             | 2.4-3.5                 | 14            | 11.0-11.8               |
| 4             | 3.4-5.0                 | 15            | 11.8-12.5               |
| 5             | 4.5-5.0                 | 16            | 12.5-13.0               |
| 6             | 5.0-5.5                 | 17            | 13.0-14.0               |
| 7             | 5.5-6.0                 | 18            | 14.0-14.5               |
| 8             | 6.0-6.5                 | 19            | 14.5-15.3               |
| 9             | 6.5-7.5                 | 20            | 15.5-16.2               |
| 10            | 7.5-8.2                 | 21            | 16.5-17.2               |
| 11            | 8.2-9.0                 | 22            | 17.5-18.0               |
| 12            | 9.0-9.8                 | 23            | 18.0-l 9.5              |
|               |                         | 24            | 19.5-20.0               |

# ANNEX4

The Forestry Trade Standard of the  
People's Republic of China : LY 1055-91

## **Bamboo strip plywood for automobile carriage base plates**

Issued on 13 August, 1991

Enforced on March 1,1992

Issued by the Ministry of Forestry of the People's Republic of China

### **1. Main subject content and scope of application**

This standard covers the definitions, classifications, technical requirements, test methods, test rules, marking, packing, shipping and storage of bamboo strip plywood for automobile carriage base plates.

This standard is applicable to bamboo strip plywood made through processing, softening, spreading and hot pressing and used for automobile carriage base plates.

### **2. The cited standard**

GB1 0111-88 Methods for random sampling by utilizing dices of random number.

### **3. Terminology and definitions**

#### **3.1 Outer part of bamboo**

The outer part of the bamboo wall, with tight structure, hard and tough properties, a smooth surface; green in colour.

#### **3.2 Inner part of bamboo**

The inner part of the bamboo wall in the direction of thickness, with a looser structure and weaker properties; light yellow in colour.

### **3.3 Residual outer part of bamboo, residual inner part of bamboo**

After being processed, the residual outer part of the bamboo or the residual inner part remain on the inner or outer surfaces of the bamboo strips.

### **3.4 Split of spreading out**

The splits are caused by processing of spread out bamboo strips.

### **3.5 Defects at face and back**

The dimensions in length and/or width of some parts of the face and/or back are smaller than that of the nominal core.

### **3.6 Defects at the crossband**

The dimensions in length and/or width of some part of the crossband are smaller than that of the nominal face and back.

### **3.7 Surface contamination**

The surface of the panel is polluted by oil-stains, mould, spots or other types of artificial contamination.

### **3.8 Length-wise jointed bamboo strip plywood**

Two or more than two sheets of bamboo strip plywood being scarf-jointed with glue bond to increase the length.

### **3.9 Bamboo failure rate**

The rate of the area of residual bamboo fibres after sheer failure against the area of sheer surface.

## **4. Classification**

### **4.1 Types of Products**

4.1.1 Type A. The bamboo strip plywood is covered with phenol formaldehyde resin on its outer surfaces.

4.1.2 Type B. The bamboo strip plywood is not covered by resin on its outer surfaces.

## 4.2 Layer number and surface size

### 4.2.1 Layer number 3,5,7,9, etc.

### 4.2.2 Surface size

4.2.2.1 Surface size is specified as shown in Table 1

Table 1: Surface size of bamboo strip plywood (in mm)

| Width |  | Lengths |      |      |      |      | Thicknesses                |
|-------|--|---------|------|------|------|------|----------------------------|
| 915   |  | 1220    | 1830 | 2000 | 2135 | 2440 |                            |
| 1 000 |  | 1220    | 1830 | 2000 | 2135 | 2440 | 10,12,15,18,20,22,25,28,30 |
| 1 220 |  | 1220    | 1830 | 2000 | 2135 | 2440 |                            |

Note : The automobile works can put forward the dimensions specially for their products.

4.2.2 The dimensions of the plywood surface can extend beyond the limitations specified in table 1, provided that the supply and demand sides are in agreement.

## 5. Technical requirements

5.1 The bamboo selected as material shall be of over four years in age without insect attack or rot etc.

5.2 The adhesive used shall be water soluble PF resin or any other with corresponding properties.

5.3 The bamboo strip plywood shall obey the symmetry principle; the strips for face and back of plywood shall be laid with their outer part of bamboo outward.

5.4 The butt joint between the ends of bamboo strips is not allowed for any layers of the bamboo strip plywood.

5.5 For bonded bamboo strips, the remaining outer parts of the bamboo and the inner parts of the bamboo shall not exceed 5 mm and 7 mm respectively.

5.6 The surface layer of PF resin painted on the Type A bamboo strip plywood shall be uniform, firm and without skips of glue. The surfaces of the Type B shall be clean.

5.7 The strips shall be over 3.5 mm in thickness as used for the surface of the bamboo strips plywood of a nominal thickness < 15 mm; and over 4.5 mm for that of a nominal thickness > 15 mm. The sum of the thickness of the layers whose strips are oriented in the same direction as that for the surface layers shall be within the range of 55% – 70% of the total thickness of the plywood.

5.8 The defect near the edges of the plywood resulting from the splits of spreading out shall not exceed 5 mm in width and 300 mm in length and shall not occur more than twice for one sheet panel.

5.9 The gap between strips within 3-5 mm in width on the face of the plywood shall be mended, and more than 5 mm gaps are not allowable.

5.10 The physical and mechanical properties of the bamboo strip plywood shall be in accordance with the specified values shown in Table 2.

5.11 The static bending strength at the joint of the bamboo strip joint shall not be lower than 70% of the specified value in Table 2.

Table 2: The specified values of physical and mechanical properties for bamboo strip plywood

| Item                               | Plywood thickness | Specified value |
|------------------------------------|-------------------|-----------------|
| Absolute moisture content, %       | All               | < 10            |
| Bonding strength, MPa              | All               | > 2.5           |
| Static bending strength (MOR), MPa | ≤ 15 mm           | < 98            |
|                                    | > 15 mm           | > 90            |

5.12 The allowable defects in appearance of bamboo strip plywood are listed in Table 3.

5.13 The tolerances of the length and width are both 3 mm for the bamboo strip plywood whose size conforms to the specifications in Table 1. Only negative tolerance is allowed for the base plates of truck carriage.

Note: Tolerance for plywood with special requirements cannot be restricted, through special agreement.

5.14 Tolerance of bamboo plywood thickness shall conform to the specifications in Table 4.

Table: 4 Tolerance of bamboo strip plywood thickness 9 mm)

| Normal thickness | Tolerance      |
|------------------|----------------|
| ≤ 15             | ± 1.0          |
| 15               | + 2.0<br>- 1.0 |

5.15 The difference between the two diagonal lines of a panel shall not exceed 5 mm.

5.16 The difference between diagonal lines of the end jointed bamboo strip plywood can be specified by the supply and demand sides themselves.

5.17 The edges of the bamboo strip shall be straight and tidy.

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Table: 3 The allowable defects in appearance of bamboo strip plywood

| Defect type                                 | Examined item for face  | Allowable value | Examined item for back   | Allowable value           |
|---|---|-----------------|--|---------------------------|
| (1) Residual outer part of bamboo           | Width 55 mm, accumulative length.   | No limitation   | Width 8 mm   | No limitation             |
|   | Width 5-10 mm, accumulative length  | 3 000 mm        | Allowable number of per strip (width 8-15 mm)  | 1 piece                   |
| (2) Gap caused by splicing                  | Width $\leq 2$ mm   | No limitation   |  |                           |
|   | No. of strips within width 2-3 mm for one sheet of plywood.<br>Within width 2-3 mm, the % of max. length of a single one is length of plywood | 1 piece<br>50%  | Width $\leq 3$ mm<br>Within width 3-4 mm, accumulative length                                | No limitation<br>2 000 mm |
| (3) Splits caused by spreading out          | Maximum width for single one  | 5 mm            | Maximum width at the end (need mending).<br>Maximum width for a single one (without mending) | 12 mm<br>8 mm             |
|   | Maximum width of a single over-lap  | 3 mm            | Maximum width of a single over-lap   | 3 mm                      |
| (4) Overlapped cores                        | Maximum width of a single over-lap  | 3 mm            | Maximum width of a single over-lap   | 3 mm                      |
|   | Maximum width of a single one   | 3 mm            | Maximum width of a single one  | 3 mm                      |
| (6) Shortage & damage of dimension on cores | Maximum width of a single one.  | Not allowed     | Maximum width of a single one  | 2 mm                      |
|   | No. for one sheet of plywood  | Not allowed     | No. for one sheet of plywood   | 1                         |
| (7) Shortage & damage in dimension on cores | Maximum width of a single one.  |                 | 2 mm   |                           |
|   | No. for one sheet of plywood  |                 | 2 mm   |                           |
| (8) Blister and delamination                |   | Not allowed     |  | Not allowed               |
| (9) Surface contamination                   | Percentage of the accumulated area vs. that of olwood   | $\leq 1\%$      | Percentage of the accumulated area vs. that of olwood  | $\leq 5\%$                |

## 6. Test methods

### 6.1 Specimens cutting

#### 6.1 .1 Sampling methods

6.1 .1.1 Random sampling shall be carried out for each batch of the products by the examination department in the plant.

6.1 .1.2 Three groups of specimens shall be cut from half of a selected panel as shown in Fig. 1. The arrangement of the specimens is shown in Fig. 2.

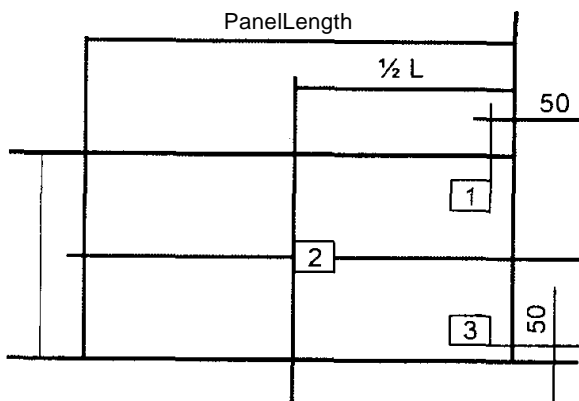


Fig. 1: Distribution of the three groups (1, 2, 3) of specimens

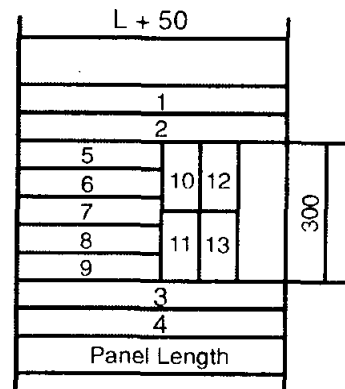


Fig. 2: Arrangement of the specimens in each group

Note: L - Span between the supports; (Fig. 2) 1, 2, 3, 4 Specimens for MOR; 5, 6, 7, 8, 9 Specimens for bonding strength; 10, 11, 12, 13 Specimens for moisture content

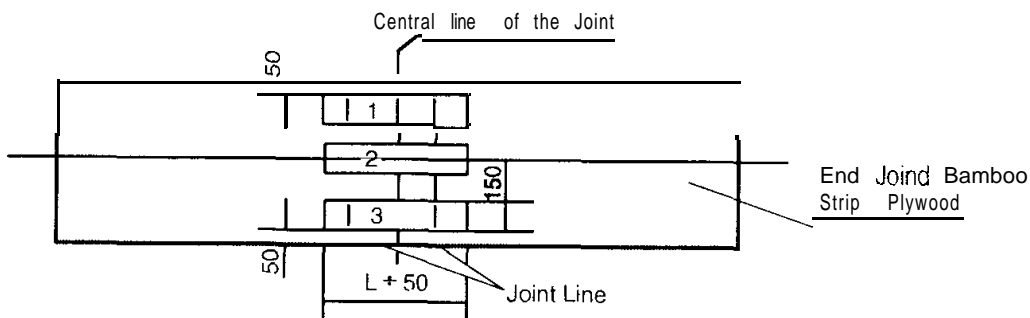


Fig. 3: Distribution of the three group of specimens for static bending strength

Note: L - the span between two supports; 1, 2, 3 - Group nos.

6.1 .1.3 Three groups of specimens shall be cut for determining static bending strength (MOR) at the joint lines of the plywood. The specimens shall be arranged as shown in Fig. 3.

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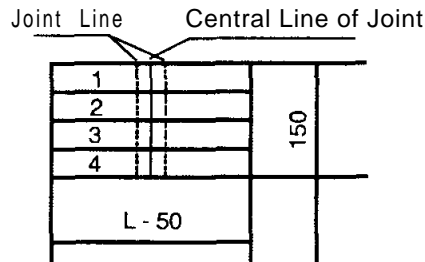


Fig. 4: Arrangement of the specimens in each group

Note: L – span between the supports; 1, 2, 3,4 – Specimens for the static bending strength (MOR) at the joint.

6.1 .1.4 The sample number for static bending strength (MOR) of the jointed bamboo plywood shall be no less than six if difficulty caused by the nails is encountered.

6.1 .1.5 The span L shall be 240 mm as the panel thickness  $\leq 15$  mm and 300 mm as that  $> 15$  mm.

6.1.1.6 The specified numbers of the specimens from each panel are listed in Table 5.

Table 5: Number of specimens from each panel (pieces)

| Test items                           | Numbers of layers |    |    |    |    |
|--------------------------------------|-------------------|----|----|----|----|
|                                      | 3                 | 5  | 7  | 9  | 11 |
| Moisture content                     | 12                | 12 | 12 | 12 | 12 |
| Bonding strength                     | 12                | 12 | 18 | 24 | 36 |
| Static bending strength              | 12                | 12 | 12 | 12 | 12 |
| Static bending strength at the joint | 12                | 12 | 12 | 12 | 12 |

6.1 .1.7 The edges of the specimens from the selected panels should be straight, with two adjacent ones perpendicular to each other, and the burr sanded off.

## 6.2 Specimen preparation

### 6.2.1 Specimens for moisture content

Dimensions of the content specimens are shown in Fig. 5. The tolerances for length and width are both  $\pm 1$  mm.

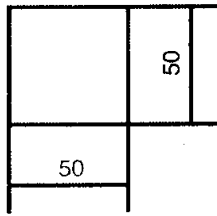


Fig. 5: Shape and dimensions of the specimens for moisture content

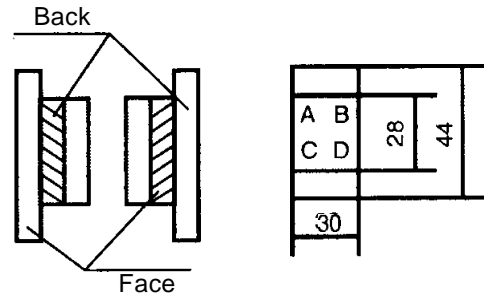


Fig. 6: Shape and dimensions of the specimens for bonding strength

## 6.2.2 Specimens for bonding strength and requirements

6.2.2.1 Dimensions of the bonding strength specimens are shown in Fig. 6. The tolerances for the length and width of the shear plane are both  $\pm 1$  mm. The length shall be measured on sides AD and BC, and the width on sides AB and CD to the nearest 0.1 mm. Their averages will be taken.

6.2.2.2 Different glue lines should be involved in the determination of bonding strength; the faces and backs respectively account for half of the total.

6.2.2.3 The edges of the specimen should be straight and smooth with the top and base surfaces parallel to each other.

6.2.2.4 The shape and dimension of the specimens from multi-layer (> 3) plywood are shown in Fig. 7. The number of specimens shall make various glue lines of the each group included, The number of the specimens containing the centre layer shall not be less than 1/3 of the total.

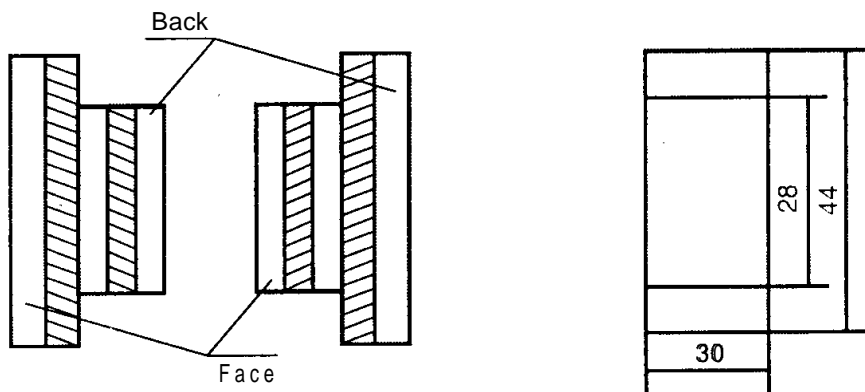


Fig. 7: The shape and dimensions of bond strength specimens for multi-layer plywood

6.2.2.5 It is permissible to plane off the other layers of the multi-layer plywood with only three layers remaining for bonding strength determination.

### 6.2.3 Specimens of static bending strength (MOR)

The shape and dimensions of the specimens are shown in Fig. 8.

The tolerances for length and width are both  $\pm 1$  mm. The width of specimens shall be measured at the center of the length to the nearest 0.1 mm and the thickness measured at one point for each side 10 mm to the edge on the central line of the length to the nearest 0.01 mm. Data from the two points shall be averaged to the nearest 0.01 mm.

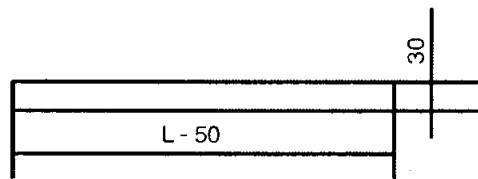


Fig. 8: The shape and dimensions of the specimens for static bending strength

## 6.3 Test procedure

The tests for moisture content, bonding strength, static bending strength (MOR) and related calculations are specified. The calculations are conducted in accordance with the State Standard of the People's Republic of China GB 8170-87, Rules for Rounding off of Numerical Values.

### 6.3.1 Determination of moisture content.

#### 6.3.1.1 Instruments

- a. balance, to an accuracy of 0.01 g.
- b. A drier with air convection in which the temperature can be kept at  $103 \pm 2^\circ\text{C}$ .
- c. A desiccator, with the air controlled at the condition of absolute dried one by means of a desiccating agent.

#### 6.3.1.2 Program

##### 6.3.1.2.1 Weighing the specimens to the nearest 0.01 g.

6.3.1.2.2 The specimens shall be dried at  $103 \pm 2^\circ\text{C}$  to be constant in mass. The drier shall not be full of specimens. No more specimens shall be put into the drier as the specimens inside are close to the final weighing conditions. The constant mass is considered to have reached the difference between to measurements with an interval of as 2h decreases to be not more than 0.01 g.

6.3.1.2.3 The specimens shall be rapidly weighed to the nearest 0.01 g. after cooling in the desiccator. An increase in weight of more than 0.1% because of the postponed measurement shall be avoided.

6.3.1.2.4 The moisture content shall be expressed by percentage of absolute moisture calculated from the formula (1) to the nearest 0.1%.

$$H = \frac{M_H - M_0}{M_0} \times 100 \quad (1)$$

where H - absolute moisture of content, %,

$M_H$  - mass of specimens sampling, g.

$M_0$  - mass of specimens after drying, g.

6.3.1.2.5 The averaged value from the specimen to the nearest 0.1% shall be regarded as the moisture content of the bamboo strip plywood.

### 6.3.2 Determination of bonding strength

#### 6.3.2.1 Instruments

- a. A vernier calliper, to an accuracy 0.1 mm.
- b. A constant-temperature water bath with temperature controlled from 30 to 100°C.
- c. A universal material test machine to an accuracy in loading of 9.8N.
- d. A drier with air convection on in which the temperature can be kept at  $63 \pm 3^\circ\text{C}$ .
- e. A stop watch.

#### 6.3.2.2 Program

6.3.2.2.1 Measuring the length and width of the shear plane.

6.3.2.2.2 The specimens shall be boiled in water for 4 hours, dried in the drier for 20 hours, boiled in water for another 4 hours, and then taken out and cooled at room temperature for 10 minutes. When boiled, specimens shall be fully soaked in water with the boiler covered.

Note: It is allowed in production sites to use rapid examination with boiling lasting for 3 hours, while the results shall be timed 0.9 as the bonding strength of products.

As the average bamboo failure rate exceeds 50%, the index value shall be minus 0.2 MPa.

6.3.2.2.3 If any layer of a specimen is delaminated during boiling, zero shall be recorded as the bonding strength of this specimen.

6.3.2.2.4 The test set-up is shown in Fig. 9. The knife shall not extent pressure on the specimen; the shearing direction shall be parallel to the grain directions of the face and back.

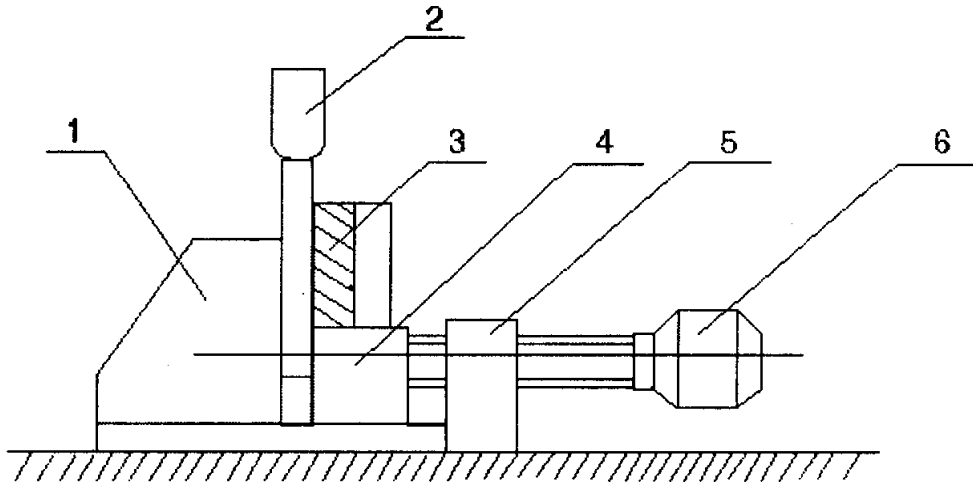


Fig. 9: Schematic drawing of test set-up for bonding strength test

Note: 1 - Base; 2 - Loading head; 3 - Specimen; 4 - Knife; 5 - Nut; 6 - Screw

6.3.2.2.5 The specimens shall be loaded moderately and uniformly at a speed of 3 500 N/min  $\pm 20\%$ , with the maximum load at failure to the nearest 9.8N.

6.3.2.2.6 The bonding strength shall be calculated from formula (2) to the nearest 0.1 MPa.

$$r = \frac{P}{A \times B} \times 100 \quad (2)$$

where r - bonding strength, MPa;

P - the maximum load, N;

A - width of the shear plane, mm;

B - length of the shear plane, mm.

6.3.2.2.7 If the specimens whose bonding strength are below the index value account for more than 30% of the total, that batch of bamboo strip plywood shall be regarded as failing to be up to standard; if less than 30%, the arithmetic mean value to the nearest 0.1 MPa from the total specimens shall be recorded as the bonding strength of the batch.

### 6.3.3 Determination of static bending strength (MOR)

#### 6.3.3.1 Instruments

- a. A universal materials test machine, to an accuracy in loading 9.8N;
- b. A micrometer, to an accuracy of 0.01 mm;
- c. A stop watch.

## 6.3.3.2 Program

6.3.3.2.1 Measuring the length, width, and thickness of the specimens.

6.3.3.2.2 The test set-up for MOR is shown in Fig. 10.

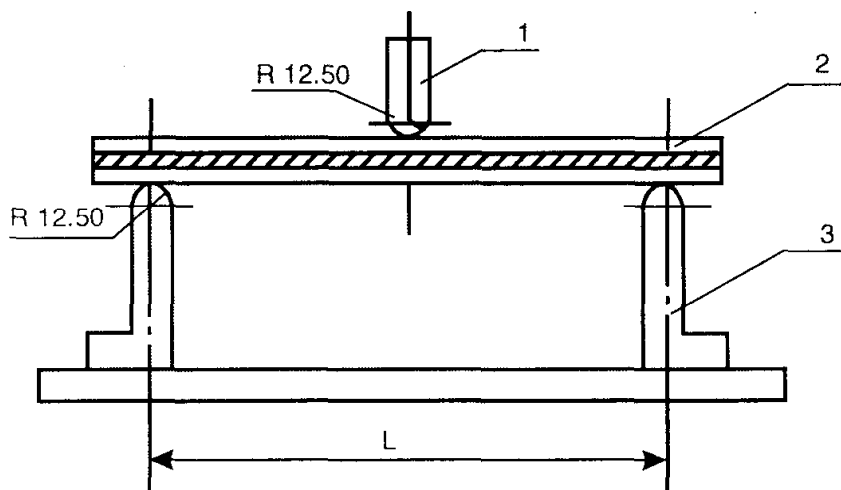


Fig. 10: Schematic drawing of test set-up for bending.

Note: 1 - Loading head; 2 - Specimen; 3 - Support; L - Span between supports

6.3.3.2.3 The span shall be 240 mm, as the specimen thickness  $\leq 15$  mm, and 300 mm, as that  $> 115$  mm.6.3.3.2.4 The specimens shall be loaded moderately and uniformly at a speed of  $3\ 500\ \text{N/min} \leq 20\%$  with the maximum load at failure to the nearest 9.8N.

6.3.3.2.5 The static bending strength shall be calculated from formula (3) to the nearest 0.1 MPa.

$$a = \frac{3PL}{2bh^2} \times 100 \quad (3)$$

where a - static bending strength, MPa;

P - the maximum load, N;

L - span between supports, mm;

b - width of the specimen, mm;

h - thickness of the specimen, mm.

6.3.3.2.6 If the specimens whose static bending strength are below the index value account for more than 30% of the total, that batch of bamboo strip plywood shall be regarded as failing to be up to standard; if less than 30%, the arithmetic mean value from the total specimens shall be recorded as the bending strength of the batch.

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6.3.3.2.7 The test set-up for the static bending strength of scarf-jointed bamboo strip plywood is shown in Fig. 11. The center of the loading head shall coincide with that of the joint.

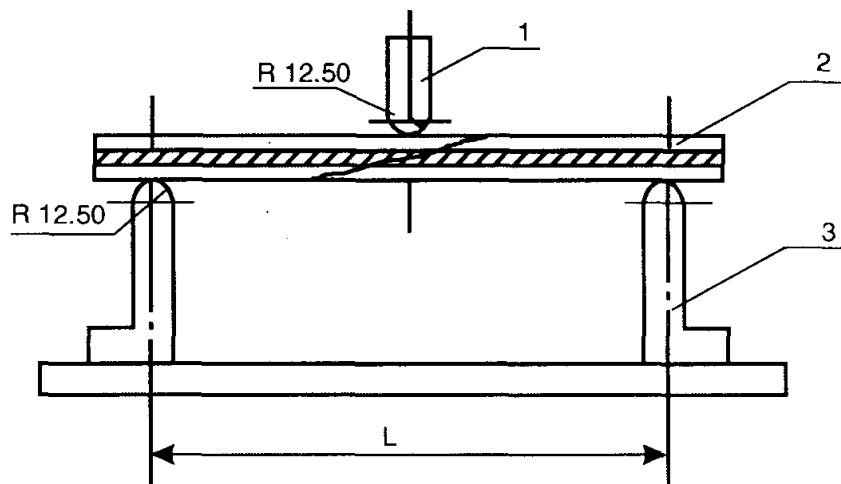


Fig. 11: Schematic drawing of test set-up for the static bending of the scarf-jointed bamboo strip plywood

Note: 1 - Loading head; 2 - Specimen; 3 - Support; L - Span between supports

## 6.4 Records and report

For the test records and report see Appendix A (Supplementary document).

## 7. Specified dimensions and their measurements

The stipulations here are the measurements of the length, width, thickness and diagonal lines of bamboo strip plywood.

### 7.1 Measuring tools

- a. Steel tape, to an accuracy of 1 mm;
- b. Vernier calliper, to an accuracy of 0.1 mm.

### 7.2 Sampling

Randomly sampled in accordance with the stipulations in Table 6, for the end products in batches.

### 7.3 Thickness

The panel thickness shall be measured at the three equally divided points. The points near the ends shall keep a distance more than 10 mm to the nearest 0.1 mm to the adjacent. The vernier calliper shall come into contact with the panel moderately without too high a pressure.

The average value from all the measurements shall be recorded as the measured panel.

#### **7.4 Length and width**

Length and width shall be measured twice respectively for each panel and 10 mm near the edges to the nearest 1 mm. The average value of the length or width, respectively from two measurements in the same direction shall be recorded as respectively the length or width of the measured panel.

#### **7.5 Diagonal lines**

The two diagonal lines shall be measured to the nearest 1 mm. The difference between the results shall be recorded as the difference of diagonal lines.

### **8. Examination regulation**

8.1 The plants shall guarantee their products to be up to standard. The appearance and specified dimensions shall be examined sheet by sheet.

#### **8.2 Classification examination**

##### **8.2.1 Model examination**

8.2.1.1. Model examination; shall be carried out under any one of the cases in the production of bamboo strip plywood as follows:

- a. Trial production and type fixation appraisal and made when new products or some old ones are transferred to other plants.
- b. Changes in structure, material and technology after the production begins, which may affect the properties of the products.
- c. The production is resumed after it has been stopped for over one year.
- d. Large differences occur between the results of examination for end products and that of the last model examination.
- e. Requirements are put forward by the state quality supervision agency.

8.2.1.2 Items of the model examination:

- a. Specified dimensions;
- b. Appearance quality;
- c. Physical and mechanical properties.

##### **8.2.2 Examination for end products**

The content of examination for end products is physical and mechanical properties.

### 8.3 Sampling and batching

The following shall be conformed to as the batches of bamboo strip plywood are examined.

8.3.1 One-time sampling plan is adopted for the examination of specified dimensions in accordance with GB 10111 and Table 6, at the level of examination S-4 and the level of qualification 6.5.

Table 6: Sampling for the examination of specified dimensions

| Batch size   | Number of sample | Qualified number | Unqualified number | Number of qualified samples |
|--------------|------------------|------------------|--------------------|-----------------------------|
| 51-90        | 5                | 1                | 2                  | 4                           |
| 91-150       | 8                | 1                | 2                  | 7                           |
| 151-280      | 13               | 2                | 3                  | 11                          |
| 281-500      | 13               | 2                | 2                  | 11                          |
| 501-1 200    | 20               | 3                | 4                  | 17                          |
| 1 201-3 200  | 32               | 5                | 6                  | 27                          |
| 3 201-10 000 | 32               | 5                | 6                  | 27                          |

8.3.2 Two-time sampling plan is adopted for the examination of appearance in accordance with GB 10111 and Table 7, with the level of examination S-4, and the level of qualification 6.5.

8.3.3 For the examinations of moisture content, bonding strength and static bending strength the total panels shall be divided into batches. Each one shall contain 500 panels (if the remaining panels are less than 500 and shall be regarded as a batch). Sampling one panel from each batch randomly shall be examined.

8.3.4 The bamboo strip plywood shall be calculated in the unit of  $m^3$  the tolerance shall not be involved; for a single panel, to the nearest  $0.00001 m^3$  for a batch of panels,  $0.001 m^3$ .

### 8.4 Regulation for judgement

8.4.1 If the test results for moisture content, bonding strength and static bending strength fail to be up to standard, it is allowed to double the sample size and re-examined.

8.4.2 A batch of plywood shall be judged as qualified, as the results from the examination of dimensions, appearance, and physical and mechanical properties reach the specified values; otherwise it shall be judged as unqualified.

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Table 7: Sampling for the examination of specified dimensions

| <b>Batch size</b> | <b>Sampling time</b> | <b>Sample size</b> | <b>Qualified number judged</b> | <b>Unqualified number judged</b> | <b>Number of qualified sample</b> |
|-------------------|----------------------|--------------------|--------------------------------|----------------------------------|-----------------------------------|
| 51-90             | First                | 3                  | 0                              | 2                                | 3                                 |
|                   | Second               | 3                  | 1                              | 2                                | 5                                 |
| 91-150            | First                | 5                  | 0                              | 2                                | 5                                 |
|                   | Second               | 5                  | 1                              | 2                                | 9                                 |
| 151-280           | First                | 8                  | 0                              | 3                                | 8                                 |
|                   | Second               | 8                  | 3                              | 4                                | 13                                |
| 281-500           | First                | 8                  | 0                              | 3                                | 8                                 |
|                   | Second               | 8                  | 3                              | 4                                | 13                                |
| 501-I 200         | First                | 13                 | 1                              | 3                                | 12                                |
|                   | Second               | 13                 | 4                              | 5                                | 22                                |
| 1 201-3 200       | First                | 20                 | 2                              | 5                                | 18                                |
|                   | Second               | 20                 | 6                              | 7                                | 34                                |
| 3201-10000        | First                | 20                 | 2                              | 5                                | 18                                |
|                   | Second               | 20                 | 6                              | 7                                | 34                                |

8.4.3 The products unqualified in the dimensions or appearance shall be re-examined one by one by the producer and are permitted to be handed over again after being repaired.

## **9. Making, packing, shipping and storing**

9.1 The products leaving the plant shall have the quality examination report showing the specifications and the physical examination in the plant.

9.2 The producer's name, the examiner code, the dates of production and examination should be marked or sealed with fadeless ink on the right-below corner of the panel back.

9.3 Products of different types, dimensions or specifications shall be separately shall be made through the agreement between the supply and demand sides.

9.4. Each package shall be of label in company, noting the name of the producer and the commodity, trade mark, standard code, specification, type, quantity, batch no., etc.

9.5 The bamboo strip plywood shall be sheltered during transportation, and also protected from artificial and mechanical damage.

9.6 The stacks of bamboo strip plywood shall be sheltered during storing.

## BAMBOO PANEL BOARDS

## Appendix A

### Record and Report Tables (Supplementary Document)

AI .Table AI is the record of physical and mechanical properties for bamboo strip plywood

Table AI : Record of physical and mechanical properties for bamboo strip plywood

Producer \_\_\_\_\_ Test No. \_\_\_\_\_ Date of production \_\_\_\_\_

Number of layers \_\_\_\_\_ Type \_\_\_\_\_ Specification \_\_\_\_\_

Thickness \_\_\_\_\_ Thickness of the surface layers

Thickness of the core layers with their grain parallel to that of surface layer

Number panels of tested \_\_\_\_\_ Dates of tests \_\_\_\_\_

| Test Item               | No. of specimens                 | Specimen's massg                 |            | Moisture content, %                  |                              | Note                   |      |
|-------------------------|----------------------------------|----------------------------------|------------|--------------------------------------|------------------------------|------------------------|------|
|                         |                                  | Original                         | Over-dried | Specimen                             | Average                      |                        |      |
| Moisture content        | 2                                |                                  |            |                                      |                              |                        |      |
|                         | 3                                |                                  |            |                                      |                              |                        |      |
|                         | 4                                |                                  |            |                                      |                              |                        |      |
|                         |                                  |                                  |            |                                      |                              |                        |      |
| Test Item               | No. of specimens                 | Shear plane, mm                  |            | Maximum load, N                      | Bonding strength, MPa        | Bamboo failure rate, % | Note |
|                         |                                  | Width                            | Thickness  |                                      |                              |                        |      |
| Bonding strength        | 1                                |                                  |            |                                      |                              |                        |      |
|                         | 2                                |                                  |            |                                      |                              |                        |      |
|                         | 3                                |                                  |            |                                      |                              |                        |      |
|                         | 4                                |                                  |            |                                      |                              |                        |      |
|                         | Total number of specimens        |                                  |            | Number of qualified specimens        |                              | Average MPa            |      |
| Test item               | No. of specimens                 | Dimension Of failure section, mm |            | Maximum Load, N                      | Static bending strength, MPa | Note                   |      |
|                         |                                  | Width                            | Thickness  |                                      |                              |                        |      |
| Static bending strength | 1                                |                                  |            |                                      |                              |                        |      |
|                         | 2                                |                                  |            |                                      |                              |                        |      |
|                         | 3                                |                                  |            |                                      |                              |                        |      |
|                         | 4                                |                                  |            |                                      |                              |                        |      |
|                         | Total number of specimens, piece |                                  |            | Number of qualified specimens, piece |                              | Average MPa            |      |

Examiner \_\_\_\_\_

A2. Table A2 is the report table for the tests of physical and mechanical properties of bamboo strip plywood.

Table A2: Report on the physical and mechanical properties of bamboo strip plywood

Producer \_\_\_\_\_ Test No. \_\_\_\_\_ Specification \_\_\_\_\_

Number of layers \_\_\_\_\_ Type \_\_\_\_\_ Number of tested panels

Thickness \_\_\_\_ Thickness of the surface layer Date of examination \_\_\_\_\_

| Test item               | Unit | Result | Note |
|-------------------------|------|--------|------|
| Moisture content        | %    |        |      |
| Bonding strength        | MPa  |        |      |
| Static bending strength | MPa  |        |      |
| Comment on the results  |      |        |      |
|                         |      |        |      |

Examiner \_\_\_\_\_

Examination unit \_\_\_\_\_

# ANNEX5

**IS: 13658: 1984**

**Indian Standard**

## **Bamboo Mat Board for General Purposes – Specification : UDC 677545419**

**Bureau of Indian Standards**

April 1994

### **Foreword**

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Wood Products Sectional Committee had been approved by the Civil Engineering Division Council.

Bamboo mat board is made of two or more bamboo mats bonded with an adhesive. The mat used is made by weaving thin, uniform strips of bamboo. In the present scenario, where availability of conventional timber has been reduced to considerable extent, the bamboo mat board is expected to find extensive use in future. The product is now being produced and marketed in India. This standard has therefore, been formulated to guide the manufacturers and users of bamboo mat boards.

In this preparation of this standard, considerable assistance has been rendered by Indian Plywood Industries Research and Training Institute, Bangalore.

The composition of the technical committee responsible for the formulation of this standards is given at Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2:1960 "Rules for rounding off numerical values (revised)". The number of significant places retained in the rounded off value should be the same as that of the specified value in this standards.

## **1. Scope**

This standard covers the method of manufacture and the requirements of bamboo mat board used for general purposes.

## **2. References**

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

## **3. Terminology**

3.1 For the purpose of this standard, the definitions given in IS 707:1976 and IS 6874:1973, and the following shall apply.

### **3.1 .1 Bamboo**

Bamboos are tall perennial grasses found in tropical and sub-tropical regions. They belong to the family Poaceae and subfamily Bambusoideae.

### **3.1.2 Sliver**

Slivers are thin uniform strips of bamboo processed from bamboo culm.

### **3.1.3 Mat**

Mat is a woven sheet using thin slivers.

### **3.1.4 Interslivers**

The overlapping area of the slivers in the mat.

### **3.1.5 Bamboo mat board**

A board made of two or more bamboo mats bonded with an adhesive.

### **3.1.6 Discolouration (Sound)**

A change from the normal colour of the bamboo which does not impair the strength of bamboo mat board.

### **3.1.7 Discolouration (Unsound)**

A change from the normal colour of the bamboo which may have some effect on the strength of bamboo mat board.

### **3.1.8 Delamination**

Separation of mats through failure of glue.

## **4. Materials**

### **4.1 Bamboo**

Any suitable species of bamboo may be used for making bamboo mat board.

### **4.2 Adhesive**

Adhesive for bonding bamboo mat board shall be of phenolic type conforming to BWR type specified in IS:848-1974.

## **5. Manufacture**

### **5.1 Bamboo mats**

Bamboo mats required for the manufacture of bamboo mat board shall be woven from slivers of uniform thickness and width. Thickness of slivers shall not be less than 0.5 mm and width shall be in the range of 5 mm to 15 mm. Care shall be taken to exclude the slivers with epidermal layer.

#### **5.1 .1 Prophylactic treatment**

If transport or storage time of one month or more is inevitable, mats shall be given prophylactic treatment as per Group 9 in Table 2 of IS:401:1982.

### **5.2 Application of adhesive**

Bamboo mats shall be applied with the adhesive either by soaking or by spreading using mechanical spreader.

### **5.3 Conditioning of adhesive coated bamboo mats**

Adhesive coated mats shall be allowed sufficient length of open assembly time and/or passed through a band drier at elevated temperature in the range of 80°C to 90°C to bring down the moisture content of adhesive coated mats to 8 to 12 percent.

### **5.4 Assembly**

Adhesive coated and conditioned mats shall be assembled between two aluminium caul plates whose surfaces are coated with releasing agent.

### **5.5 Hot pressing**

Assembly of the adhesive coated mat shall be hot pressed at not less than 140°C at a specific pressure of 1.5 N/mm<sup>2</sup> to 2.0 N/mm<sup>2</sup>. Hot pressing time shall depend on the thickness of the board.

## 5.6 Moisture content of bamboo mat board

After hot pressing the finished bamboo mat board shall be conditioned to a moisture content not less than 5 percent and no more than 15 percent.

## 5.7 Preservative treatment

57.1 For bamboo mat board manufactured by applying the resin by soaking method, preservative treatment shall be done by incorporating the preservatives like boron (octaborate or tetraborate) into the resin before soaking the mats. The preservative becomes non-leachable during hot pressing.

5.7.2 For bamboo mat board manufactured by applying the resin by passing the mats through mechanical glue spreader, the manufactured boards shall be treated with non-leachable type preservatives such as Copper-Chrome-Arsenic (CCA), Copper-Chrome-Boron (CCB), or Acid-Copper-Chrome (ACC) as per 5.2.2.3 of IS:5539:1969.

## 6. Dimensions and tolerances

6.1 The dimensions of bamboo mat board shall be quoted in the following order. The first dimension shall represent the length; the second dimension, the width; and the third dimension, the thickness.

6.2 The dimensions of bamboo mat board shall be as given for plywood in IS:1 2049-I 987.

(Note: Any other dimension as agreed to between the manufacturer and the purchaser may be used.)

6.3 Thickness of bamboo mat board shall be specified depending upon the number of plies. The thickness shall be measured up to one decimal place of millimetre.

**6.4 Tolerances.** The following tolerances on the nominal sizes of finished boards shall be permissible.

| Dimension            | Tolerance    |
|----------------------|--------------|
| a) Length            | +6mm<br>-0mm |
| b) Width             | +3mm<br>-0mm |
| c) Thickness         |              |
| less than 6 mm       | ± 10 percent |
| 6 mm and above       | ± 5 percent  |
| d) Squareness        | 0.2 percent  |
| e) Edge straightness | 0.2 percent  |

## 7. Workmanship and finish

7.1 The bamboo mat boards shall be of uniform thickness within the tolerance limit specified in 6.4.

7.2 The faces of bamboo mat boards shall be reasonably smooth and uniform in colour.

## 8. Sampling

8.1 The method of drawing representative samples and the criteria for conformity shall be as prescribed in IS:7368-1986 for BWR grade plywood for general purposes (IS:303).

## 9. Tests

### 9.1 Test of specimen

9.1 .1 Specimens of size 50 mm x 50 mm in full thickness shall be cut from different positions of the board selected as per 8.1.

9.2 Specimens cut from boards shall be subjected to the test for bond strength. Bond strength shall be deemed satisfactory if the requirement specified either in 9.3 or 9.4 is complied.

### 9.3 Internal Bond Strength Test

#### 9.3.1 Internal bond in dry state

Six test specimens prepared as per 9.1.1 when tested in accordance with the methods described in IS:2380 (Part 5)-1977, shall give an average and minimum individual value of 0.7 N/mm<sup>2</sup> and 0.5 N/mm<sup>2</sup> respectively.

#### 9.3.2 Internal bond strength in wet state

Six test specimens prepared as per 9.1.1 shall be subjected to boiling in water for a period of 3 hours. Afterwards they shall be dried in ambient conditions till they attain a moisture content of 1 0-1 2 percent. The dried specimens when tested in accordance with the method described in IS:2380 (Part 5)-1977 shall give an average and a minimum individual value of 0.5 N/mm<sup>2</sup> and 0.3 N/mm<sup>\*</sup>.

#### 9.3.3 Mycological Test

Six test specimens prepared as per 9.1.1 shall be subjected to attack by micro-organisms as per the method described in Annex B and tested as per IS:2380 (Part 5)-1977, shall give an average and a minimum individual value of 0.5 N/mm<sup>2</sup> and 0.3 N/mm<sup>2</sup> respectively.

## 9.4 Surface Strength Test (Alternative Test)

### 9.4.1 Surface Strength Test in dry state

Six test specimens prepared as per 9.1.1 when tested in accordance with the method described in IS:2380 (Part 22)-1981 shall give an average and a minimum individual value of  $4.5 \text{ N/mm}^2$  and  $3.0 \text{ N/mm}^2$  respectively.

### 9.4.2 Surface Strength Test in wet state

Six test specimens prepared as per 9.1.1 shall be subjected to boiling in water for three hours. Afterwards they shall be dried in ambient conditions till they attain a moisture content of 10 to 12 percent. The dried specimens when tested in accordance with the method described in IS:2380 (Part 22)-1981 shall give an average and a minimum individual value of  $3.1 \text{ N/mm}^2$  and  $2.0 \text{ N/mm}^2$ , respectively.

### 9.4.3 Mycological Test

Six test specimens prepared as per 9.1.1 shall be subjected to attack by micro-organisms as per the method described in Annex B and then tested as per IS:2380 (Part 22)-1981 shall give an average and a minimum individual value of  $3.0 \text{ N/mm}^2$  and  $2.0 \text{ N/mm}^2$  respectively.

## 10. Marking

10.1 Each bamboo mat board shall be legibly and indelibly marked or stamped with the following:

- a) Indication of the source of manufacture,
- b) Year of manufacture, and
- c) Batch No.

### 10.2 BIS certification marking

The Bamboo mat board may also be marked with Standard Mark.

10.2.1 The use of the Standard Mark is governed by the provisions of Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

10.2.3 All markings shall be done on the face of the board near one corner.

## Annex A (Clause 2)

### List of Referred Indian Standards

| IS No.                  | <i>Title</i>   |
|-------------------------|--|
| 401 : 1982              | Code of practice for preservation of timber (third revision)   |
| 707 : 1976              | Glossary of terms relating to timber technology and utilization (second revision)  |
| 848 : 1974              | Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) ( <i>first revision</i> )  |
| 2380 (part 5) :<br>1977 | Methods of test for wood particle boards and boards from other lignocellulosic materials : Part 5 Determination of tensile strength perpendicular to surface ( <i>first revision</i> ) |
| 2380 (Part 22)<br>1981  | Method of test for wood particle boards and boards from other lignocellulosic materials : Part 22 Determination of surface glueability test ( <i>first revision</i> )                  |
| 5539 : 1969             | Specification for preservative treated plywood   |
| 6874 : 1973             | Method of tests for round bamboos  |
| 7368 : 1986             | Methods of sampling for plywood, fibre hardboards, insulation boards and particle boards ( <i>first revision</i> )   |
| 12049 : 1987            | Dimensions and tolerances relating to wood based panel materials.  |

## Annex B (Clauses 9.3.3 and 9.4.3)

### Mycological Test

#### **B-1 Object**

B-1 .1 This test is intended to evaluate the resistance of glue line to attack by micro-organisms in addition to the durability of bamboo from which the board is manufactured.

#### **B-2 Procedure**

B-2.1 A flat rectangular dish of enamelled iron, glass or porcelain (such as a photographic developing dish) of a minimum depth of 50 mm, shall be filled to a depth of about 25 mm with a layer of sawdust obtained from the sapwood of a perishable timber, like semul (*Bombax ceiba*) in its natural condition. The sawdust shall have previously been moistened with water containing 15 g of sucrose

(normally sugar may be used; but if not available, 30 g of commercial malt extract may be substituted) to a litre of water so that it is saturated with moisture, but not so wet that free water is squeezed out of it by hand pressure. To attain this condition with dry sawdust, it is usually necessary to add three times its mass of water.

B-2.2 The sawdust shall then be charged with the spores of commonly occurring wood destroying fungi and loosely compacted. The test specimens shall be pressed down into it so that their upper surfaces are level with the top of the sawdust layer.

B-2.3 The dish shall then be covered with a sheet of glass and the edges of the dish sealed against the glass with modelling clay or a similar suitable material so that the atmosphere round the test specimens shall remain saturated with water vapour.

B-2.4 The dish and the contents shall be maintained at a temperature of  $27^{\circ} \pm 2^{\circ}\text{C}$  for a period of three weeks, after which the test pieces shall be removed, washed in water and allowed to dry to a moisture content of 10 to 12 percent in ambient conditions.

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# ANNEX6

## Preliminary Draft Indian Standard for Bamboo Mat-Wood Veneer Composite for General Purposes

### **1. Scope**

This standard covers the method of manufacture and the requirements of bamboo mat-veneer composites for general purposes.

### **2. References**

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

### **3. Terminology**

3.1 For the purposes of this standard, the definitions given in IS:707-1976, IS:6874-1973 and IS:1 3958-1994 and the following shall apply.

#### **3.2 Bamboo-veneer composite**

Panel manufactured with a combination of bamboo mat and veneer. Bamboo mat can be either as outer skins or as core/crossbands. However, the composite panel should be a balanced construction on either side of central ply.

### **4. Materials**

#### **4.1 Bamboo**

Any suitable species of bamboo may be used for making bamboo mat-veneer composite.

#### **4.2 Adhesive**

Adhesive for bonding bamboo mat-veneer shall be of phenolic type conforming to BWR type specified in IS:848-1974.

### **4.3 Veneer**

Any species of timber may be used for the manufacture of veneers. However, a list of species is given in Annex B for guidance.

## **5. Manufacture**

### **5.1 Bamboo mats**

Bamboo mats required for the manufacture of bamboo mat-veneer composite shall be woven from slivers of uniform thickness and width. Thickness of slivers shall not be less than 0.5 mm and width shall be in the range of 5 mm to 15 mm. Care shall be taken to exclude the slivers with epidermal layer.

### **5.2 Prophylactic treatment**

If transport or storage time of one month or more is inevitable, mats shall be given prophylactic treatment as per Group 9 in Table 2 of IS:401-1982.

### **5.3 Veneer**

Veneer shall be either rotary cut or sliced. The veneers shall be sufficiently smooth to permit an even spread of adhesive. The quality requirement of veneers shall conform to the requirements given in Table 1 of IS:303-1989. However, the maximum number of categories of defects permitted on the surface of the veneer used for faces shall be restricted to the requirements laid down in Table 2 of IS:303-1989. Treatment as specified below shall be given at the veneer stage.

#### **5.3.1 Treatment**

Veneers of non-durable species and sapwood of all species shall be soaked in 1.25 percent solution of boric acid or 1 .0 percent solution of borax at a temperature of 85-90°C for a period of 10-40 minutes depending upon the thickness of the veneers or the veneers may be dipped in 2 percent solution of boric acid or 3 percent borax solution for 2 minutes and block stacked at least for two hours. Alternatively, the veneers may be soaked at an ambient temperature in a mixture of 0.5 percent solution of sodium pentachlorophenate and 1.5 percent of borax in water for a period of 2 minutes and then soaked for at least half an hour before drying.

### **5.4 Thickness**

The thickness of all veneers shall be uniform within a tolerance of 5 percent.

### **5.5 Joints in veneers**

Veneers that require to be joined to from a ply shall be spliced before assembly.

**BAMBOO PANEL BOARDS**

All joints shall be cut square. In assembly, joints in veneer running in the same direction, shall be staggered.

**5.6 Permissible defects**

5.6.1 Gaps in cores and crossbands may be permitted except for 3 ply provided the width of the gap does not exceed 2 mm in case of 5 ply or more and provided such gaps, if more than one, shall be spaced not less than 80 mm away from each other and are staggered not less than 50 mm away as between ply, the next ply having the same grain direction.

5.6.2 Splits in cores and crossbands may be permitted to an extent of 2 per core or crossband.

5.6.3 Overlap shall not be permitted.

**5.7 Application of adhesive**

Bamboo of adhesive shall be applied with the adhesive either by soaking or by spreading using mechanical spreader. However, veneers are coated with the adhesive using mechanical spreader.

**5.8 Conditioning of adhesive coated bamboo mats/veneers**

Adhesive coated mats/veneers shall be allowed sufficient length of open assembly time and/or passed through a band drier at a temperature ranging between 60°C and 90°C to bring down the moisture content of adhesive coated mats/veneer to 6 to 12 percent.

**5.9 Assembly**

Adhesive coated and conditioned mats shall be assembled between two aluminium caul plates whose surfaces are coated with releasing agent. Care shall be taken to see a) on either side of the central ply same material and same thickness is used to get balanced construction, b) the grain direction of the outermost veneer from the centre ply shall be along the larger dimension of the panel and c) when two veneers are used adjacent to each other the grain direction of the veneers shall be at right angles to each other.

**5.10 Hot pressing**

Assembly of the adhesive coated mats/veneers shall be hot pressed at not less than 140°C at a specific pressure of 1.5 N/mm<sup>2</sup>. Hot pressing time shall depend on the thickness of the board.

**5.11 Preservative treatment**

5.11 .1 For bamboo mat-veneer composite, preservative treatment shall be done

by incorporating the preservatives like boron (octaborate or tetraborate) into the resin before soaking/spreading bamboo mats/veneers with adhesive as the case may be. The preservative becomes non-leachable during hot pressing.

5.11.2 Alternatively, the manufactured composite boards shall be treated with non-leachable type preservative such as CCA, CCB or ACC as per IS:1 2120-I 987.

## 6. Dimensions and tolerances

6.1 The dimensions of bamboo mat-veneer composite shall be quoted in the following order. The first dimension shall represent the length, the second dimension the width and the third dimension the thickness.

6.2 The dimensions of bamboo mat veneer composite shall be as given for plywood in IS:1 2049-I 987.

**Note: Any other dimension as agreed to between the manufacturer and the purchaser may be used.**

6.3 Thickness of bamboo veneer composites shall be 3 mm, 4 mm, 5 mm, 6 mm, 8mm,9mm,12mm,15mm,16mm,22mm and 25mm.

### 6.4 Tolerances

The following tolerances on the nominal sizes of finished composite boards shall be permissible.

| Dimension            | Tolerance    |
|----------------------|--------------|
| a) Length            | +6mm<br>-0mm |
| b) Width             | +3mm<br>-0mm |
| c) Thickness         |              |
| Less than 6 mm       | ± 10 percent |
| 6 mm and above       | ± 5 percent  |
| d) Squareness        | 0.2 percent  |
| e) Edge straightness | 0.2 percent  |

## 7. Workmanship and finish

7.1 The bamboo mat veneer composite boards shall be of uniform thickness within the tolerance limit specified in 6.4.

7.2 When bamboo mats are used for faces of the composite, the surface shall be reasonably smooth and uniform in colour.

## **8. Sampling**

8.1 The method of drawing representative samples and the criteria for conformity shall be as prescribed in IS:7368-I 986 for EWR grade plywood for general purpose (IS:303).

## **9. Tests**

### **9.1 Test specimen**

9.1 .1 Specimens in full thickness shall be cut from different positions of the board selected as per 8.1 as follows.

From boards with bamboo mats as faces, specimens shall be prepared in accordance with IS:1734 (Part 4)-1983.

From boards other than those cited above, 50 mm x 50 mm in full thickness shall be cut from different positions.

9.2 Specimens cut from boards shall be subjected to the tests for bond strength. Bond strength of boards with bamboo mats as faces shall be deemed satisfactory if the requirements specified in either in 9.4 or 9.5 are complied.

### **9.3 Glue Shear Strength Test**

#### **9.3.1 Glue Shear Strength Test in dry state**

Six test specimens prepared and tested in accordance with IS:1734 (Part 4)-1983 shall give an average and minimum individual glue shear strength not less than 1 350 N and 1 100 N respectively.

#### **9.3.2 Water Resistance Test**

Six test specimens prepared in accordance with IS:1 734 (Part 4)-I 983 shall be subjected to boiling in water for a period of 8 hours and tested in wet condition in accordance with IS:1 734 (Part 4)-1983. The average and minimum individual glue shear strength shall not be less than 1 000 N and 800 N respectively.

#### **9.3.3 Mycological Test**

Six test specimens prepared in accordance with IS:1734 (Part 4)-1983 shall be subjected to attack by microorganisms as per Annex C. Such specimens shall be tested in accordance with IS:1734 (Part 4)-I 983. The average and minimum individual glue shear strength shall not be less than 1 000 N and 800 N respectively.

## 9.4 Internal Bond Strength Test

### 9.4.1 Internal bond strength in dry state

Six test specimens prepared as per 9.1.1 when tested in accordance with the method described in IS:2380 (Part 5)-1977 shall give an average and a minimum individual value of 1.5 N/mm<sup>2</sup> and 1.2 N/mm<sup>2</sup>, respectively. Failing loads of specimens with material failure only, shall be taken for the purposes of averaging.

### 9.4.2 internal bond strength in wet state

Six test specimens prepared as per 9.1.1 shall be subjected to boiling in water for a period of 8 hours. Afterwards they shall be dried in ambient conditions till they attain a moisture content of 10 to 12 percent. The dried specimens when tested in accordance with the method described in IS:2380 (Part 5)-1977 shall give an average and minimum individual value of 1.2 N/mm<sup>2</sup> and 0.9 N/mm<sup>2</sup>, respectively. Failing loads of specimens with material failure only, shall be taken for the purposes of averaging.

### 9.4.3 Mycological Test

Six test specimens prepared as per 9.1.1 shall be subjected to attack by micro-organisms as per the method described in Annex C and then tested as per IS:2380 (Part 5)-1977, and shall give an average and minimum individual value of 1.2 N/mm<sup>2</sup> and 0.9 N/mm<sup>2</sup> respectively. Failing loads of specimens with material failure only, shall be taken for the purpose of averaging.

## 9.5 Surface Strength Test (Alternative Test)

9.5.1 Six test specimens prepared as per 9.1.1 when tested in accordance with the method described in IS:2308 (Part 22)-1981 shall give an average and minimum individual value of 9.0 N/mm<sup>2</sup> and 7.0 N/mm<sup>2</sup>, respectively. Failing load of specimens with material failure only, shall be taken for the purposes of averaging.

### 9.5.2 Surface Strength Test in wet state

Six test specimens prepared as per 9.1.1 shall be subjected to boiling in water for a period of 8 hours. Afterwards they shall be dried in ambient conditions till they attain a moisture content of 10 to 12 percent. The dried specimens when tested in accordance with the method described in IS:2380 (Part 22)-1981 shall give an average and minimum individual value of 7.0 N/mm<sup>2</sup> and 5.0 N/mm<sup>2</sup>, respectively. Failing load of specimens with material failure only, shall be taken for the purposes of averaging.

### 9.5.3 Mycological Test

Six test specimens prepared as per 9.1.1 shall be subjected to attack by micro-

organisms as per the method described in Annex C and then tested as per IS:2380 (Part 22)-1 981, and shall give an average and minimum individual value of 7.0 N/mm<sup>2</sup> and 5.0 N/mm<sup>2</sup> respectively. Failing load of specimens with material failure only, shall be taken for the purposes of averaging.

## 10. Marking

10.1 Each bamboo mat-veneer composite board shall be legibly and indelibly marked or stamped with the following:

- a) Indication of the source of manufacture
- b) Year of manufacture
- c) Batch No.

10.2 The bamboo mat-veneer composite may also be marked with Standard Mark.

## Annex A (Clause 2)

### List of referred Indian Standards

| <i>IS Nos.</i>      | <i>Title</i>   |
|---------------------|--|
| 303-I 989           | Plywood for general purposes ( <i>Third revision</i> ).  |
| 401-I 976           | Code of practice for preservation of timber ( <i>Third revision</i> ).   |
| 707-I 976           | Glossary of terms relating to timber technology and utilization ( <i>Second revision</i> ).  |
| 848-I 974           | Synthetic resin adhesives for plywood (phenolic and aminoplastic) ( <i>First revision</i> ).   |
| 1734 (Part 4)-I 983 | Methods of test for plywood; Part 4 Determination of glue shear strength ( <i>Second revision</i> ).   |
| 2380 (Part 5)-1977  | Methods of test for wood particle boards and boards from other lignocellulosic materials: Part 5 Determination of tensile strength perpendicular to surface ( <i>First revision</i> ). |
| 2380 (Part 22)-1977 | Methods of test for wood particle boards and boards from other lignocellulosic materials: Part 22 Determination of surface glueability test ( <i>First revision</i> ).                 |

|             |  |
|-------------|--|
| 6874- 1973  | Methods of test for round bamboos.   |
| 7368-I 986  | Methods of sampling for plywood, fibre and hardboards, insulation boards and particle boards (First <i>revision</i> ). |
| 12049- 1987 | Dimensions and tolerances relating to wood based panel materials.  |
| 12120-1987  | Code of practice for preservation of plywood and other panel products.   |
| 13958-I 994 | Bamboo Mat Board for general purposes.   |

## Annex B ( Clause 4.3)

### Timber species for plywood

[Note: Species of timber to be treated (5.3.1) are indicated by dagger mark (†)].

| Sl. No. | Trade Name | Botanical Name   | Abbreviation |
|---------|------------|--|--------------|
| 1.      | Aini       | <i>Artocarpus hirsutus</i>                                       | AIN          |
| 2.      | Alder †    | <i>Alnus nitida</i>  | ALD          |
| 3.      | Alder †    | <i>Alnus</i> spp.  | ALD          |
| 4.      | Amari      | <i>Amoora</i> spp.   | AMA          |
| 5.      | Amra †     | <i>Spondias</i> spp.   | AMR          |
| 6.      | Arjun      | <i>Terminalia arjuna</i>   | ARJ          |
| 7.      | Bahera †   | <i>Terminalia ballerica</i>                                      | BAH          |
| 8.      | Banati †   | <i>Lophopetalum wightianum</i>                                   | BAN          |
| 9.      | Birch †    | <i>Betula</i> spp.   | BIR          |
| 10.     | Bonsum     | <i>Pheobe</i> spp.   | BON          |
| 11.     | Carallia † | <i>Carallia brachiata</i><br>(Syn. <i>Carallia integerrima</i> ) | CAR          |
| 12.     | Champ      | <i>Michelia</i> spp.   | CHM          |
| 13.     | Chaplash   | <i>Artocarpus chaplasha</i>                                      | CHP          |
| 14.     | Chatian †  | <i>Alstonia scholaris</i>  | CHT          |
| 15.     | Chikrassy  | <i>Chukrasia tabularis</i>                                       | CHI          |
| 16.     | Chilauni † | <i>Schima wallichii</i>  | CHL          |
| 17.     | Cinnamon   | <i>Cinnamomum cecicodaphne</i>                                   | CIN          |
| 18.     | Debdaru †  | <i>Polyalthia</i> spp.   | DEB          |
| 19.     | Dhup †     | <i>Canarium</i> spp.   | DHU          |
| 20.     | Didu †     | <i>Salmalia insignis</i>   | DID          |
| 21.     | Dillenia † | <i>Dillenia</i> spp.   | DIL          |

| Sl. No. | Trade Name | Botanical Name  | Abbreviation |
|---------|------------|---|--------------|
| 22.     | Ebony      | <i>Diospyros</i> spp.   | EBO          |
| 23.     | Elm        | <i>Ulmus wallichiana</i>                                      | ELM          |
| 24.     | Gamari     | <i>Gmelina arborea</i>  | GAM          |
| 25.     | Garuga †   | <i>Garuga pinna ta</i>  | GAU          |
| 26.     | Gokul †    | <i>Ailantbus grandis</i>                                      | GOK          |
| 27.     | Gurjan     | <i>Dipterocarpus</i> spp.                                     | GUR          |
| 28.     | Gutel †    | <i>Trewia nudiflora</i>                                       | GUT          |
| 29.     | Haldu      | <i>Adina cordifolia</i>                                       | HAL          |
| 30.     | Hathipaila | <i>Pterospermum acerifolium</i>                               | HAT          |
| 31.     | Hollock †  | <i>Terminalia myriocarpa</i>                                  | HOL          |
| 32.     | Hollong    | <i>Dipterocarpus macrocarpus</i>                              | HON          |
| 33.     | Indian Oak | <i>Quercus semecarpifolia</i>                                 | IOA          |
| 34.     | Indian Oak | <i>Quercus dila ta ta</i>                                     | IOA          |
| 35.     | Indian Oak | <i>Quercus serrata</i>  | IOA          |
| 36.     | Jaman      | <i>Syzygium</i> spp.  | JAM          |
| 37.     | Jhingan †  | <i>Lannea coromandelica</i><br>(Syn: <i>Lannea grandis</i> )  | JHI          |
| 38.     | Jutili     | <i>Altingia excelsa</i>                                       | JUT          |
| 39.     | Kadam †    | <i>Anthocephalus cadamba</i>                                  | KAD          |
| 40.     | Kanju †    | <i>Holoptelea integrifolia</i>                                | KAN          |
| 41.     | Karani †   | <i>Cullenia rosayroona</i><br>(Syn. <i>Cullenia excelsa</i> ) | KAR          |
| 42.     | Kathal     | <i>Artocarpus heterophyllus</i>                               | KAT          |
| 43.     | Kindal     | <i>Terminalia paniculata</i>                                  | KIN          |
| 44.     | Kokko      | <i>Albizia lebeck</i>   | KOK          |
| 45.     | Lampati †  | <i>Duabanga grandiflora</i>                                   | LAP          |
| 46.     | Laurel     | <i>Terminalia tomentosa</i>                                   | LAU          |
| 47.     | Litsa †    | <i>Liteasa polyantha</i>                                      | LIT          |
| 48.     | Machilus † | <i>Machilus</i> spp.  | MAC          |
| 49.     | Mahogany   | <i>Swietenia</i> spp.   | MAG          |
| 50.     | Maina †    | <i>Teterameles nudiflora</i>                                  | MAI          |
| 51.     | Makai      | <i>Shorea assamica</i>  | MAK          |
| 52.     | Mango †    | <i>Mangifera indica</i>                                       | MAN          |
| 53.     | Maple      | <i>Acer</i> spp.  | MAP          |
| 54.     | Menudito   | <i>Enterolobium</i> spp.<br>(Exotic)                          | MEN<br>ENT   |
| 55.     | Mullilam   | <i>Fagara budrunga</i><br>(Syn. <i>Zanthoxylum rhetsa</i> )   | MUI          |
| 56.     | Mundani †  | <i>Acrocarpus fraxinifolious</i>                              | MUN          |
| 57.     | Narikel †  | <i>Pterygo ta ala ta</i>                                      | NAR          |
| 58.     | Neem       | <i>Azadirachta indica</i>                                     | NEE          |

## BAMBOO PANEL BOARDS

| Sl. No. | Trade Name                | Botanical Name  | Abbreviation |
|---------|---------------------------|---|--------------|
| 59.     | Nodunari                  | <i>Mansonia</i> spp.  | NED          |
| 60.     | Pali                      | <i>Paiaquium ellipticum</i>   | PAL          |
| 61.     | Persian Lilach            | <i>Melia azadarach</i>  | PLI          |
| 62.     | Piney †                   | <i>Kingiodendron pinna turn</i><br>(Syn. <i>Hardwickia pinna ta</i> ) | PIN          |
| 63.     | Pitraj                    | <i>Aphanamixis polystachya</i>  | PIT          |
| 64.     | Poon                      | <i>Colopyllum</i> spp.  | POO          |
| 65.     | Poplar                    | <i>Populus cilia ta</i>   | POP          |
| 66.     | Poplar                    | <i>Populus deltoides</i>  | POP          |
| 67.     | Pula †                    | <i>Kydia calycina</i>   | PUL          |
| 68.     | Pussur                    | <i>Xylocarpus molluccensis</i>  | PUS          |
| 69.     | Pyinma                    | <i>Lagerstroemia hypoleuca</i>  | PYI          |
| 70.     | Red Bombwe                | <i>Planchonia valida</i><br>(Syn. <i>Planchonia andamanica</i> )      | RBO          |
| 71.     | Red Dhup †                | <i>Parishia insignis</i>  | RDH          |
| 72.     | Rose wood                 | <i>Dalbergia la tifolia</i>   | ROS          |
| 73.     | Salai †                   | <i>Boswellia serra ta</i>   | SAA          |
| 74.     | Satinwood                 | <i>Chloroxylon swietenia</i>  | SAT          |
| 75.     | Seleng                    | <i>Sapium bacca turn</i>  | SEL          |
| 76.     | Semul †                   | <i>Salimolia malabarica</i>   | SEM          |
| 77.     | Silver Oak †              | <i>Grevillea robusta</i>  | SOA          |
| 78.     | Sissoo                    | <i>Dalbergia sissoo</i>   | SIS          |
| 79.     | Teak                      | <i>Tectona grandis</i>  | TEA          |
| 80.     | Toon                      | <i>Cedrela</i> spp.   | TOO          |
| 81.     | Udal †                    | <i>Firmiana villosa</i><br>(Syn. <i>Sterculia villosa</i> )           | UDA          |
| 82.     | Uriam                     | <i>Bischofia javanica</i>   | URI          |
| 83.     | Vellapine †               | <i>Valeria indica</i>   | VEL          |
| 84.     | Walnut †                  | <i>Juglans</i> spp.   | WAL          |
| 85.     | White Bombwe †<br>(badam) | <i>Terminalia procera</i>   | WBO          |
| 86.     | White Cedar               | <i>Dysoxylum malabricum</i>   | WCE          |
| 87.     | White Chuglam †           | <i>Terminalia biala ta</i><br>(Sapwood)                               | WCH          |

## **Annex C**

*(Clauses 9.3.3, 9.4.3 and 9.5.3)*

### **Mycological Test**

#### **C-1. Object**

C-1 .1 This test is intended to evaluate the resistance of glue line to attack by micro-organisms in addition to the durability of bamboo mat and veneer used in the manufacture of composite board.

#### **C-2. Procedure**

C-2.1 A flat rectangular dish of enamelled iron, glass or porcelain (such as a photographic developing dish) of a minimum depth of 50 mm, shall be filled to a depth of about 25 mm with a layer of sawdust obtained from sapwood of perishable timber like Semul (*Bombax ceiba*) in its natural condition. The sawdust shall have previously been moistened with water containing 15 g of sucrose (normally sugar may be used; but if not available 30 g of commercial malt extract may be substituted) to a litre of water so that it is saturated with moisture, but not so wet that free water is squeezed out of it by hand pressure. To obtain this condition with dry sawdust, it is usually necessary to add three times its mass of water.

C-2.2 The sawdust shall then be charged with spores of commonly occurring wood destroying fungi and loosely compacted. The test specimens shall be pressed down into it so that their upper surfaces are level with the top of the sawdust layer.

C-2.3 The dish shall then be covered with a sheet of glass and the edges of the dish sealed against the glass with modelling clay or a similar suitable material so that the atmosphere around the test specimen shall remain saturated with water vapour.

C-2.4 The dish and the contents shall be maintained at a temperature of  $27^{\circ} \pm 2^{\circ}\text{C}$  for a period of three weeks, after which the test pieces shall be removed, washed in water and allowed to dry to a moisture content of 10 to 12 percent in ambient conditions.