INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN
(INBAR)

TRANSFER OF TECHNOLOGY MODEL
(TOTEM)

BAMBOO FLOORING MANUFACTURING UNIT

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CONTENTS

TRANSFER OF TECHNOLOGY MODELS (TOTEMS)

Transfer of Technology Models (TOTEMs) are focussed educational tools providing relevant information and distance training on one specific area of bamboo/rattan management, processing or utilization. They are a means of technology transfer between similar regions throughout the world, with the emphasis on South-South transfer for livelihood development. They enable those involved in the management and use of bamboo and rattan resources to more efficiently and effectively develop and use skills relating to these resources.

TOTEMs are primarily intended as practical information resources and teaching aids for those at the local extension level in their communities, who can utilize them to assist local community development. Each TOTEM consists of a detailed written report of the technology, a PowerPoint presentation, a film, and, where relevant, a set of technical photographs. They also include information on target users, financial analyses of sample set-ups from the partner country preparing the report and information on where to source particular technologies (such as equipment). The TOTEM thus provides all the information required for establishing similar technologies within interested countries and regions.

- The **report** contains all the technical details of the particular processes involved, as well as other relevant information for establishing the technology such as costs of business establishment, running costs and cash flows.

- The **PowerPoint** presentation contains details of the relevant technologies and their applications, and is intended to provide an overview of the potential of the technology for development.

- The **film** provides a visual guide to the processes involved and helps to bring them alive in the minds of the learners.

The different parts of the TOTEM are targeted at slightly different audiences, via the local extension workers. The report and film are intended to be the main means of extension to the individuals and communities who will implement the technology and who will directly benefit from it. The PowerPoint presentation is primarily intended as a tool for the extension worker to sell the technology and its role in development to those who provide the infrastructural, policy and financial support for its implementation, such as government departments, donors and NGOs. There is considerable flexibility, however. Local extension workers will be able to incorporate the TOTEMs in their own work as they wish and adapt and develop them to suit their particular requirements and conditions.

This TOTEM on the **bamboo flooring manufacturing unit** has been produced by Zhang QiSheng and Xu Bin at Nanjing Forestry University, Nanjing, China. The report part of this TOTEM describes the technology for producing and establishing shoot-producing plantations for rural development in regions where bamboo is available as a raw material. It is intended to be used in conjunction with the illustrative film included in this TOTEM package

The first part of the report introduces the technology, discusses its development attributes, its benefits and its applicability. The second part of the report provides detailed information on the

technical aspects of manufacturing laminated bamboo flooring. **Appendix I** gives details of the main features of laminated bamboo flooring, including geometry and quality standards. **Appendix II** gives the initial equipment costs of a unit producing 40, 000 m^2 of flooring per year. **Appendix III** costs consumables and the production cost per square metre.

This TOTEM is one of the first to be produced by INBAR/ NFU and your feedback is most welcome - kindly contact INBAR or NFU with your comments or suggestions.

Note: This TOTEM has been edited at INBAR and differs slightly from the form in which it was received from the authors.

LAMINATED BAMBOO FLOORING AT-A-GLANCE

What is laminated bamboo flooring?

Laminated bamboo flooring is a unique flooring material. The natural grain of the bamboo shows up clearly and is very attractive. The flooring is resistant to moisture, pressure and damage. It is flexible, lasts longer than wood flooring and is cheaper. It also acts as a sound insulator.

How is it produced?

Laminated bamboo flooring is produced by splitting bamboo culms into thick sections or sheets. These are then coated with resin, assembled into units three layers thick and then pressed firmly together in a hot press. After curing the pieces are trimmed to shape and painted or varnished.

What is the market for bamboo flooring?

Bamboo flooring boards are very popular worldwide and markets are developing in Japan, Europe and North America. In China there are over 100 manufacturers producing about 10 million square metres per year (ten square kilometres!).

What is the role of a bamboo flooring manufacturing unit in rural development?

The unit will provide employment for unskilled, semi-skilled and technically trained people in the rural communities in which it is established. The unit will also promote the further use of bamboo resources and the sustainable management of bamboo plantations and natural bamboo stands.

How do I establish a bamboo flooring manufacturing unit?

The machinery for a unit producing 40, 000 m^2 of bamboo floor per year will cost approximately USD $366, 000 and each square metre costs $12.4 to manufacture. In addition to the substantial start-up capital required a sustainable supply of bamboo culms will be required, along with a stable workforce.

PART ONE

INTRODUCTION

DEVELOPMENT ATTRIBUTES, TARGET GROUPS and BENEFITS of a

BAMBOO FLOORING MANUFACTURING UNIT

1. Introduction

Sympodial bamboo flooring is a type of decorative flooring. It is a high quality product that can be used widely and has a large consumer market. It has many advantages, such as its smoothness, stability, resistance to wear, sound insulation, resistance to dampness, pressure resistance, and flexibility. The bamboo floor has a soft and natural lustre, and maintains the natural gloss and grain of the bamboo culm. Bamboo flooring is exceptional and unique and very attractive.

In order to meet increasing demands for wood-based products, many forests have been over-harvested in recent years. Developing non-tree wood alternatives is one means of solving the problem. Sympodial bamboos grow fast, produce a high yield and can become fully rejuvenated within a few years of cutting. Bamboo is a perfect substitute for some wood based products. Bamboo is highly suited to the production of flooring. Bamboo flooring has some excellent advantages over wood flooring, such as its high strength and size stability, and its special decorative effects, so it is popular and has a large market potential in China, Europe, Japan and North America.

2. General development attributes and advantages

The main development attributes of the technology are as follows:

- Provides employment and income generation for rural people
- Increases the use of natural bamboo resources and promotes timber substitution
- Improves living standards of the rural communities in which it is established

The main advantages of the technology are:

- Bamboo flooring is more attractive than wood flooring
- It is cheaper to produce and hence the retail price is cheaper
- Bamboo flooring is more marketable due to its production from renewable bamboo resources.

3. Suitable agro-ecological regions

There are rich sympodial bamboo resources in the tropics and subtropics and the unit may be established anywhere throughout these regions. Once the bamboo forest is mature culms can be harvested every year. The unit is especially suitable for areas where bamboo plantations are desirable for the restoration of degraded forests or wastelands such as abandoned shifting cultivation areas, or where bamboos can be grown to reduce soil erosion, particularly on steep slopes in high rainfall areas. Bamboo can thus play an

important role in raising the productivity of degraded land and in protecting the environment and forest ecology.

4. Target groups

The main target group are the people that will be employed by the unit. The unit will require unskilled, semi-skilled and technically trained personnel and these can all be recruited from the community in which the unit is established. If established as a community cooperative then all members of the community will benefit. Another target group are the local bamboo cultivators who will benefit from the increased area of plantations and demand for bamboo culms that the unit will generate.

5. Requirement for success

The essential requirements for a successful bamboo flooring manufacturing unit are:

- Start-up capital
- Source of raw bamboo materials
- Secure workforce
- Market access

Concluding remarks

The bamboo flooring unit is a commercially and socially effective means of processing bamboo into quality flooring materials. It has significant potential for income and welfare improvement for poor rural people both in the unit itself and in its forward and backward linkages. In addition, by using bamboo as a substitute for wood timber it reduces environmental degradation due to the overharvesting of timber trees. The unit requires considerable start-up capital and may be best established with the guidance of state agencies or NGOs.

PART TWO

THE BAMBOO FLOORING MANUFACTURING UNIT

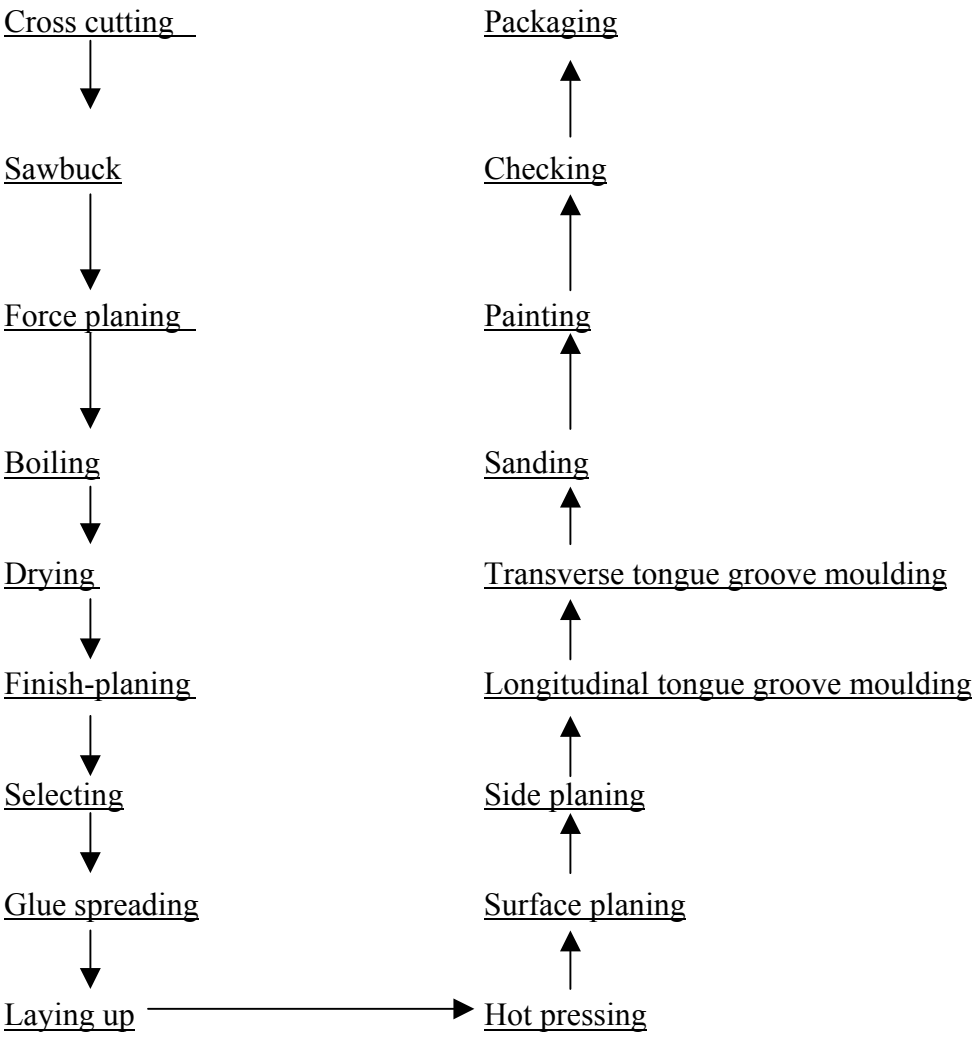
1. Introduction

Laminated bamboo flooring is produced by the following basic steps

- Production of longitudinal bamboo sheets (sections)
- Bleaching sheets
- Drying, sanding and selecting sheets
- Applying glue to sheets and allowing them to dry
- Hot pressing sheets together into floorboards
- Shaping floorboards
- Sanding and painting floorboards

2. Production of bamboo flooring

The detailed process is as follows:



There are two types of floor based on the colour: **naturally-coloured** floor, and **coffee-coloured** floor and two types based on the arrangement of bamboo sheets: **horizontal** and **vertical**.

The processing procedure is as follows:

2.1. Raw materials

Sympodial bamboos with large diameter culms are suitable for manufacturing flooring (e.g. *Dendrocalamus giganteus* Munro. *D. barbatus* Hsueh *et* D.Z. Li and *D. membranaceus* Munro). Culms with a diameter at breast height of over 10 cm should be harvested when four years old. The culms are first crosscut into sections of the desired length (the floor length plus an additional 11-13.5cm) and the sections are then cut into slips of the same width (25 cm, 30 cm or 35 cm). Bamboo sheet is produced after planing the slips to the same width, thickness and length.

2.2. Manufacturing bamboo sheets

Because bamboo can not be cut in some seasons (eg. spring), the factory should store some dried bamboo sheets according to its manufacturing capability. Boiling is a key procedure in the manufacturing of floors. It removes some water-soluble extracts and at the same time can add insecticides and preservatives if these are included in the boiling mixture. Bamboos are usually boiled for about 3-4 hours.

After being boiled all the bamboo sheets are piled up in the drying kiln (80^0C) for 4-5 days. If the sheets have been carbonised, they are removed when the moisture content reaches 14-25%. The moisture content of other dried sheets is reduced to 5-8%.

At present, there are the two main ways for color treatment: bleaching and light carbonisation. In bleaching, the bleaching agent solution can be brushed onto the surface of the bamboo sheets, and the bleaching agent, such as H_2O_2, can be added to the water during boiling. In carbonization, high temperature and moisture are required to treat bamboo sheets in a closed container. Steam at 0.3 MPa is passed into the container for 40-120 minutes. Then the sheets are taken out and piled up to dry to 5-8% moisture content. After finishing the sheets are planed to a thickness variation allowance of ■ 0.2mm.

Sheets are then selected to weed out faulty sheets and to reduce the colour differences among the sheets, so that finished floor has an even colour.

2.3. Laying up and hot pressing

Urea-formaldehyde (UF) adhesive is usually used to bond bamboo sheets. The solid content of UF adhesive is above 60%, the viscosity is 30-50 Pa.S and the free

formaldehyde content is below 0.5%. Modifiers can be added to UF adhesive to improve its properties, or an alternative adhesive can be used.

Usually floors are made of 3 layers. There are two kinds of flooring: one in which the three layers are parallel to each other, and the other in which the outer layer and the central layer are vertically orientated. The two edges of the bamboo sheet and both surfaces of the central sheet should be spread with liquid adhesive at about 150g/m^2 per surface. Sheets of the same color should be placed on the upper face and those of different colours may be used for the lower and central layers. String is used to tie the sheets after laying up. UF adhesive should be spread on both surfaces of each sheet for a vertical floor at a similar rate. The inner and outer surface layers of adjoining sheets should face one-another. Two pieces of string should be used to tie up the two sides after laying-up to the desired width.

The hot pressing method is used to seal the sheets together as floorboards. A two-dimensional single open hot press is required with heat provided by steam or high frequency heating. Place the laid-up sheets in the hot press, add a few press stops between each lay-up and then apply the heated pressure. If the heat source is steam a steam pressure of 1.0MPa is required. The pressure of the hot press should be 1.5-2.0MPa, the temperature of the hot press plates should be 105-110^{0}C, and the pressing time required is 1.1-1.2 minutes per millimeter of thickness of lay-up. If high-frequency heating is used, 5-minutes is sufficient.

2.4. Planing, moulding and sanding process

The following procedures are the same as for the manufacture of wood floors. The back and one side of the blank of bamboo floor should be manufactured to be the datums plane from which all measurements will be taken. Then the longitudinal tongue-groove and the back slots should be moulded. The next process is manufacturing the transverse tongue-groove.

Initial sanding is done with an 80 grit belt sander. Final sanding is with a 180 or 240 grit belt sander so the blank surface is smooth and level. All these procedures are in preparation for painting.

2.5. Painting

UV-cured paint is usually used for painting. Several undercoats are painted on the upper face of the floor with one final topcoat. The sides and the rear receive only one coat.

APPENDICES

Appendix I

PART III

Main Features of Sympodial Bamboo Floors.

1. Geometry standard of bamboo floor (Table-1)

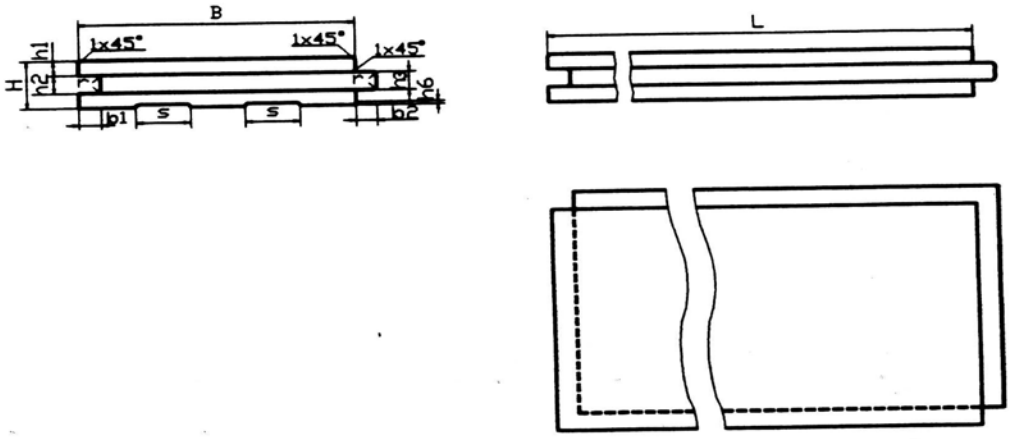


Table 1. The geometry standard of bamboo floor.

Name	Sign	Dimension (mm)	Allowance
Floor board length	L	450, 610, 760, 915	+0.5 0
Floor board width	B	76, 91, 100	0 - 0.3
Floor board thickness	H	9, 12, 15, 18	±.2
Face layer thickness	h_1	4, 4.5, 5, 6	±.1
Groove width	h_2	3, 4, 5, 6	+ 0.2 0
Groove height	b_1	6	+ 0.3 0
Tongue width	h_3	3, 4, 5, 6	.0 - 0.2
Tongue height	b_2	5	+0.3 0
Black slot width	s	15±25	±
Black slot height	h_6	1	±0.5
Tongue and groove corner radius	r	0.5±1	±0.2
Tongue back low depressed height	f	1	±0.2
Tongue surface corner angle	(	3	30’

2. Surface qualities standard (Table 2[redacted]3)

Table 2 Quality standards for bamboo floor faces

Name	Degree			Note
	Grade A	Grade B	Grade C	
Decay	Prohibited			
Color difference	Allow little	Allow chromatism		
Splits	Prohibited	Less than one width <0.2mm length <10% 0f floor	Less than one width <0.5mm length <20% 0f floor	
Worm holes	Prohibited			
Wavy grain	Prohibited	Allow little		
Floor's wane	Prohibited			
Open joint	Prohibited		Less than one Width < 0.5mm Length < 30% of floor	
Discoloration	Prohibited		Area <5% of floor	
Blisters	Prohibited	Allow little	Less than 10 per floor Diameter <1mm	Painted floor
Pinholes	Prohibited	Allow little	Less than 10 per floor Diameter <1mm	Painted floor
Wrinkling	Prohibited		Area < 5% of floor	Painted floor
	Prohibited		Area <5% of floor	Painted floor
Other defects	Prohibited			

Table 3. Quality standards for floor backs and sides

Name	Degree			Note
	Grade A	Grade B	Grade C	
Decay	Prohibited			
Color difference	Allow chromatism			
Split	Width < 1mm		Width < 2mm	
Worm holes	Prohibited	Diameter < 2mm		
Wavy grain	Allow			
Floor's wane	Length < 20% of floor Width < 10% of floor Depth < 1mm	Length < 30% of floor Width < 20% of floor Depth < 1.5mm	Length < 40% of floor Width < 30% of floor Depth < 2mm	
Open joint	Prohibited	Less than one Width < 1mm	Less than 2 every floor width < 1mm	
Blisters	Prohibited		Less than 10 every floor diameter < 2mm	Painted floor
Pinholes	Allow little		Less than 10 every floor diameter < 2mm	Painted floor
Wrinkling	Area < 5% of floor		Area < 10% of floor	Painted floor
No paint	Area < 5% of floor		Area < 10% of floor	Painted floor

4. Physical and chemical properties of bamboo floors (Table 4).

Item		Unit of measurement	Degree
Moisture content		90	6.0-14.0
Strength MOR	Thickness <15mm	MPa	98.0
	Thickness > 15mm		90.0
Immersion test adhesive bond		mm	Every adhesive open length = 25
Hardness		MPa	55.0
Paint resistance To abrasion	Circle	r	400
	Surface information		Left 50% of face
	Lost weight	g/100r	0.08
Paint stain			NO stain
Paint adherence			Allow intersect of knifecut paint scars to leave; allow paint scar left by a knifecut to leave a little
Paint gloss		%	85
Formaldehyde emission from floor		mg/100g	50

Appendix II. Equipment required for the bamboo flooring unit (yearly output: 40, 000M^2) (Table 5)

Number	Type, name and specification of machine	Price (US dollar)	Quantity of machine (Table/set)	Power of machine (kw/Table)	Sub-total power (kw)	Operators (person/Table)	Sub-total operators	Sub-total cost (US dollar)
1.	Trim saw for bamboo	130	2	2.2	4.4	1	2	260
2	Ripsaw for bamboo tube (single operator L=1350mm)	400	2	2.2	4.4	1	2	800
3.	Ripsaw for bamboo tube (double operators L=1350mm)	680	1	4.4	8.8	2	2	680
4.	Ripsaw for bamboo tube (single operators L=2250mm)	680	4	4.4	17.6	2	8	2720
5.	Force planer for bamboo slip	4300	5	10.4	52	1	5	21500
6.	Boiler. (2T)	14500	1			2	2	14500
7.	Single stringer crane (2T) (span: 9—12m)	1200	1			1	1	1200
8.	hot—water vats	2400	2			1	1	4800
9.	Drying room (20M^3/single kiln) eight overhead fan vapor dryer kilns (not including ground works)	16300	4	15	60	1	4	65200
10.	Finishing planer of bamboo	4700	5	12	60	1	5	23500
11.	Two—dimensional single open press	31300	1	9.5	9.5	1	1	31300
12.	Auto—feed platform bamboo slip	2400	1	1.5	1.5	2	2	2400
13.	Two—dimensional sing open press	50600	1	13	13	1	1	50600
14.	Auto—feed platform for bamboo slip	4800	1	1.5	1.5	2	2	4800
15.	Slashing saw for bamboo board	7200	1	15	15	1	1	7200
16.	Single head trimmer	100	2	3	6	1	2	200
17.	Planer saw bamboo board	4400	2	10.7	21.4	1	2	8800
18.	Scraping machine for bamboo sheet	4650	2	10.7	21.4	1	2	9300
19.	**T**ransverse slot mortiser for bamboo sheet 1 (**200—600**)	6800	1	8.95	8.95	1	1	6800
20.	Transverse slot mortiser for bamboo sheet 2 (**200—1200**)	7200	1	8.95	8.95	1	1	7200
21.	Longitudinal slot mortiser for bamboo sheet	6000	2	9.6	19.2	1	2	7200
22.	Ultraviolet infrared film and curing apparatus	15700	1			2	2	15700
23.	Three heads wide belt sander	7900	2	12.5	25	1	2555	15800
24.	Universal wood working grinding machine	3000	1	0.41	0.41	1	2	300
25.	Center gathering collector	21700	2	27.5	55			43400
26.	Carbonization container	14400	1					14400
27.	Sanding belt; knife tool and other tools	6000						6000
Total					414		55	366560

Note: the above information has been collected from an anonymous manufacturer in South China.

Appendix III

Quantity of Raw Material Consumed (Table 6)

Material	Quantity required annually (tonnes)
Bamboo	5000
UF adhesive	12
Polyvinyl acetate emulsion adhesive	0.5
Ammonium chloride (NH_4Cl)	0.12
Paint	8
Other chemical materials	0.4

Note: about 50% of the bamboo will be wasted and may be used for other uses.

Cost of per Square Meter of Manufactured floor (Table 7)

Item	Cost (US dollar)
Bamboo materials	6.5
Chemicals	2.5
Water and power	0.7
Wages	1.4
Manufacturing costs	0.8
Other materials	0.5
Total	12.4

Note: the above data are from an anonymous manufacturer in South China.