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**INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN  
(INBAR)**

**TRANSFER OF TECHNOLOGY MODEL  
(TOTEM)**

**CORRUGATED BAMBOO ROOFING SHEETS**

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## 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 the TOTEM to suit their particular requirements and conditions.

This TOTEM on the production of **corrugated bamboo roofing sheets** has been produced by the Forest Science Institute, Hanoi, Vietnam. It may be used alone, or in conjunction with the TOTEMS on the bamboo splitting and slivering unit and matboard production unit, both of which have been produced by the Indian Plywood Industries Research Institute, Bangalore, India.

The report part of this TOTEM describes the technology for establishing facilities and producing corrugated bamboo roofing sheets for rural development in regions where bamboo is available as



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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 history, its development attributes, its benefits and its applicability. The second part of the report provides detailed information on the technical aspects of producing roofing sheets. **Appendix I** details the method used in China to produce corrugated bamboo roofing sheets. The costs of producing a standard size of roofing sheet are shown in **Appendix II** and the equipment costs are shown in **Appendix III**. A bibliography is given in **Appendix IV**.

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

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**Note 1:** This TOTEM has been edited at INBAR and differs from the form in which it was received from FSI, Hanoi.

**Note 2:** All financial calculations are in Vietnamese Dong. At the time of writing 1 USD = 14, 600 VND.



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## **CORRUGATED BAMBOO ROOFING SHEETS AT-A-GLANCE**

### **What are corrugated bamboo roofing sheets?**

Corrugated bamboo roofing sheets (CBRS) are an excellent alternative to corrugated asbestos, iron, plastic or zinc roofing sheets. They are produced from natural materials and are attractive, durable and resilient to adverse weather conditions and pest attack. They can be produced in a range of standard sizes and can be used to roof dwellings, stores, animal pens and other buildings.

### **How are they produced?**

CBRS are produced by pressing firmly together woven bamboo mats that have been impregnated with an adhesive resin. The corrugations are formed by pressing them between corrugated pressing plates in the pressing machine.

### **What is the market for corrugated bamboo roofing sheets?**

The market for CBRS is somewhat variable in different regions of the world but depends to a large extent on successful marketing strategies. CBRS is popular in rural areas where the low prices are attractive. The potential to increase the use of CBRS in more affluent areas is enormous, and there is considerable export potential in the markets of the more affluent countries where their eco-friendly nature could be a major selling point.

### **What is the role of a corrugated bamboo roofing sheets unit in rural development?**

The unit itself will provide employment to a range of people and there will be extra employment generation in its forward and backward linkages, such as cultivation and harvesting of bamboos, primary processing, mat weaving, marketing and retailing. A unit producing 500, 000 m<sup>2</sup> of sheets per year will require a total workforce of over 200 people. The need for a sustainable supply of raw materials will encourage the proper management of bamboo stands, and the establishment of new plantations, with their associated environmental benefits.

### **How do I establish a corrugated bamboo roofing sheets-making enterprise?**

A corrugated bamboo roofing sheets manufacturing unit requires a regular supply of bamboo mats, electricity, labour and access to markets. An enterprise with a capacity of 500, 000 m<sup>2</sup> per year can be established for approximately USD \$26, 000 in Vietnam but costs will vary in other countries.



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## **PART ONE**

### **INTRODUCTION**

**DEVELOPMENT ATTRIBUTES, TARGET GROUPS and  
BENEFITS of a**

**CORRUGATED BAMBOO ROOFING SHEETS  
MANUFACTURING UNIT**

## **1. Corrugated bamboo roofing sheets**

Corrugated bamboo roofing sheets (CBRS) are produced from woven mats of bamboo that are soaked in adhesive resin and then pressed firmly together. The corrugations are formed by pressing the mats between two corrugated pressing plates. The sheets can be produced in a range of sizes to suit particular requirements and can easily be trimmed for special situations. Bamboos are the only raw material used for the sheets. The sheets are durable and stable and resistant to pest attack, severe weathering and fire.

## **2. History of the development of corrugated bamboo roofing sheets in Vietnam**

The Centre of Experiment and Transfer of Techniques of the Forestry Industry, part of the Centre of Forest Industries at the Forest Science Institute of Vietnam, has been producing and developing corrugated bamboo roofing sheets on an industrial scale since 1992. Bamboo mats have been produced here since 1982, and the technology for producing both mats and roofing sheets has been transferred to many processing enterprises, where they have been widely used. Many regions (communes, districts) have been established in Vietnam to specially supply raw bamboos for the units. Many of the units do not just produce roofing sheets. The technology for producing roofing sheets is almost the same as that for producing mats, and the equipment required is very similar, so most of the units produce roofing sheets, matboard and bamboo flooring concurrently.

In the earlier days of the first “Doi Moi” period in Vietnam when the service sector was developing strongly there was very high demand for the roofing sheets and matboard for the construction of temporary bars and restaurants. At the same time, CBRS have been used in many public locations and the demand for their use in the construction of temporary houses for workers was also very high. There is now considerable competition from corrugated plastic, metal and cement roofing sheets in the cities, but in the countryside, especially in the poorer, mountainous areas, CBRS are still widely used especially because they are competitively priced.

The technology was first developed in China, from where much of it was transferred to Vietnam. The Indian Plywood Industries Research and Training Institute in Bangalore has also developed roofing sheets technology.

## **3. General development attributes and advantages**

The main development attributes of the technology are as follows:

- Increase in area of bamboo plantations will benefit the environment and protect precious forest resource through substitution of bamboo wood for timber.



- Rehabilitation of degraded forests and other waste lands.
- Creation of employment opportunities in bamboo cultivation, splitting, mat weaving and the CBRS unit itself.
- Opportunities for family members, particularly women, to spend their free time weaving bamboo mats at or near their homes.
- The CBRS unit is not a capital-intensive project but is labour-oriented and develops the small-scale industry in rural and mountainous regions.

The main advantages of the technology are:

- CBRS are an environmentally friendly and safe alternative to asbestos, zinc or corrugated iron roofing panels.
- The sheets are also quieter in the rain than metal roofing panels.
- The sheets are durable and strong with excellent internal bond strengths and high resistance to weathering and biological agencies such as insect attack.
- They have a natural appearance.

#### **4. Suitable agro-ecological regions**

The CBRS technology is suitable for bamboo growing regions that can supply the raw material for their production. Regions of natural bamboo forest are suitable, but CBRS could also be produced in areas where bamboo is grown on plantations or in homesteads. Management of plantations and natural stands is highly desirable, both to guarantee a standard level of supply to the unit and to maximise the benefits of the plantation to the owner and cultivators. The technology 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.

#### **5. Target groups**

There are three main target groups of the CBRS unit. The first are those who will be employed by the unit itself. Unskilled, semi-skilled and technically trained personnel will all be required. The second group are those who weave the mats from which the sheets are made. Many of these people are women who will be able to weave at home in their spare time and who will benefit from the regular income. The final group are those who will cultivate and harvest the bamboos. This group includes ethnic minorities in mountainous regions, homestead owners who may cultivate a few bamboos on their plots and plantation workers. If the unit is established as a cooperative venture within the community it will also benefit the community as a whole and lead to increased prosperity. Finally there will be increased opportunities for transporters, wholesalers and retailers.

## 6. Benefits

The environmental benefits of the unit are considerable. The use of large quantities of bamboo in the production of mats promotes the sustainable management and increased area of plantations of bamboos. The cultivation of bamboo is also beneficial for soil conservation and afforestation activities and plantations are often encouraged as part of social forestry programmes.

As already noted, the employment opportunities for a range of people in rural areas are considerable. A unit producing half a million square metres of roofing sheet per year will create employment for 200 people, most of whom will be required for the production of bamboo mats. More economic activities will be created in the region, particularly in the marketing and selling of the sheets, and the social and cultural conditions of the communities involved should improve as a result. Opportunities for export should also be explored to earn foreign exchange.

## 7. Scope for small enterprise development

There is considerable scope for the development of small CBRS-producing enterprises. Corrugated bamboo roofing sheets are particularly popular in poorer, rural, mountainous regions due to their inaccessibility, the proximity of natural raw materials and the low cost of the sheets. Given some effective marketing the sheets could easily be popularised in more affluent areas and in affluent countries, where eco-friendly products are very popular. In this case the establishment of a vigorous sales department within the unit, or at a local or community level to pool resources from a number of units and act on their behalf would be beneficial.

The establishment of a corrugated bamboo roofing sheets unit requires an estimated capital investment of approximately USD \$25, 500 in Vietnam (**Appendix III**), although costs would vary depending on the country, and the region. It may be possible to apply for incentives/benefits offered by the government for the establishment of small-scale enterprises - check with your local government office or business advisory centre for details.

## 8. Requirements for success

The essential requirements for a successful corrugated bamboo roofing sheets unit are:

- Start-up capital
- Land
- Regular supply of raw bamboos for weaving into mats



- Access to appropriate machines and equipment for the production of mats and sheets and some technically trained personnel to install, manage and maintain the unit.

## **9. Potential improvements and research needs**

Many aspects of the production of CBRS still require improvements. Some of the most pressing are:

- Improved harvesting and management of bamboo stands.
- Improved equipment for splitting bamboos and further research on its mechanization
- Improvements in the methods of drying bamboo mats.
- Mechanization of synthesizing and gluing.
- Improved training, dissemination and transfer of the technology to interested countries and region around the world
- Investigations of new, practical applications of CBRS.
- New designs of housing in rural and mountainous regions using bamboo roofing sheets.
- Proper marketing approaches to bring the benefits of the sheets to the attentions of a wide range of potential consumers.

## **Concluding remarks**

The production of corrugated bamboo roofing sheets is a commercially viable and socially effective means of utilising bamboo resources to produce value added items for the benefit of consumers and producers alike. The development of bamboo roofing sheets enterprises offer considerable income generating opportunities for different categories of resource-poor people. The technology has strong forward and backward linkages and its implementation will benefit a wide range of rural people involved in all stages of CBRS production. The technology is ideally initially implemented in a new location with the support of state agencies, NGO's or private enterprises to ensure the linkages are properly in place.



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## **PART TWO**

# **MANUFACTURING OF CORRUGATED BAMBOO ROOFING SHEETS**

## 1. Introduction to CBRS manufacturing

There are two methods of producing corrugated bamboo roofing sheets. The method described here involves one pressing cycle and involves the following steps.<sup>1</sup>

1. Splitting of bamboo culms into thin slivers
2. Weaving of slivers into mats
3. Application of adhesive/binder to mats
4. Assembling of mats in preparation for hot-pressing
5. Hot pressing
6. Cutting to size
7. Finishing

The process of producing corrugated bamboo roofing sheets is illustrated in figure 1 on page 14. The stages of the manufacturing process of CBRS are described below.

## 2. Production of CBRS

The equipment required for the processing of bamboo culms into corrugated bamboo roofing sheets are: cross cutting equipment, splitting and slivering equipment, glue synthesizing equipment, loading-unloading instrument, gluing instrument, drying equipment, hot press and trimming equipment (**Appendix III**).

### 2.1. Preparation of raw materials<sup>2</sup>

#### 2.1.1. Cross-cutting and splitting of culms

Bamboo culms are sectioned and the nodes discarded. Only internodes with a minimum length of 0.4 m are selected for splitting. Internodes are split into splits 20 mm wide and then soaked in water. They are removed from the water 1-2 hours before slivering.

#### 2.1.2. Slivermaking

Slivers 0.5-1 mm thick and between 15-20 mm wide are produced, either by hand slivering or in a slivermaking machine. They are then allowed to dry to 18-20% moisture content and may be bleached or preserved by smoking or sulphur treatment.

#### 2.1.3 Mat weaving.

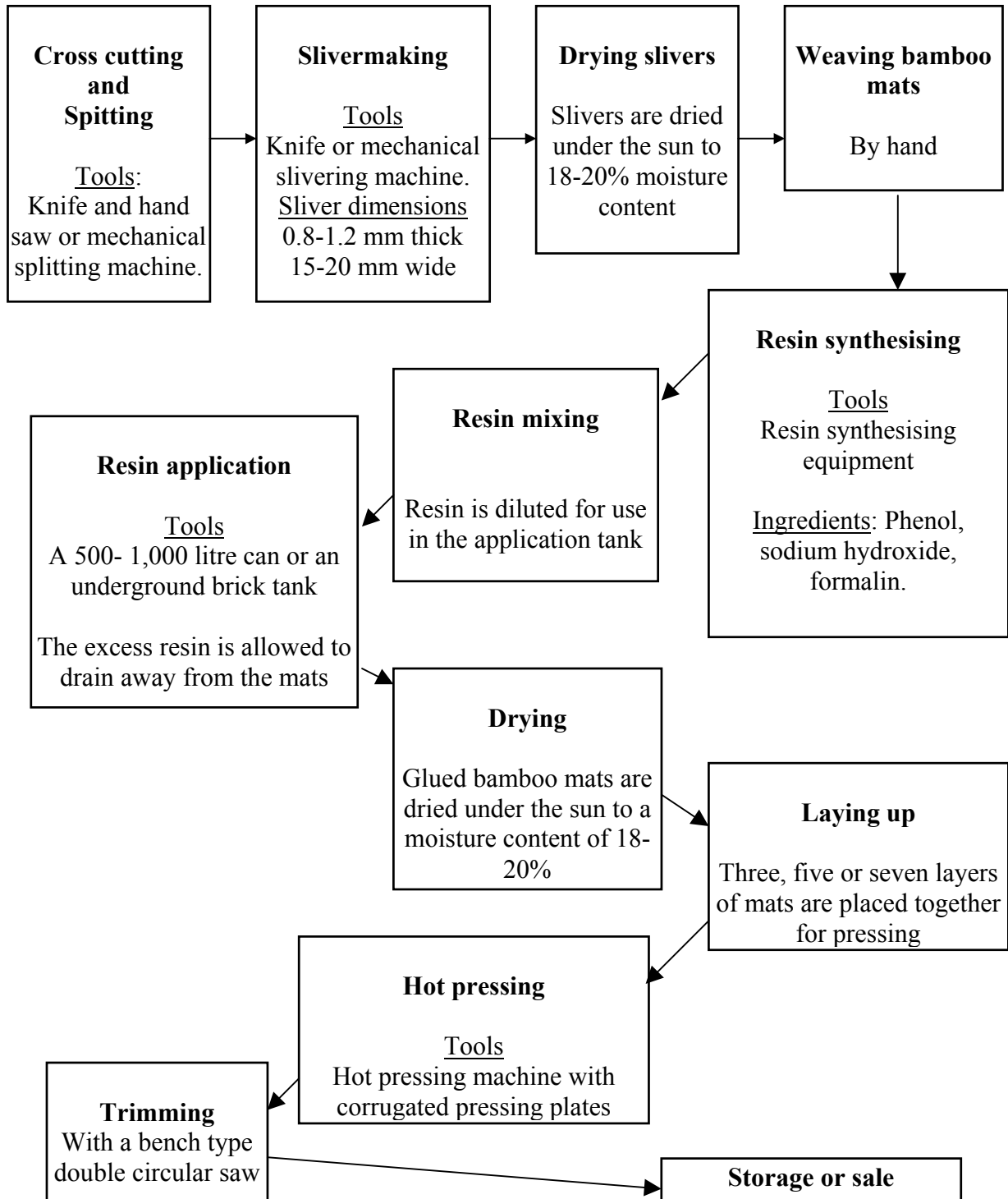
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<sup>1</sup> Another method is used in China that involves a more complex process but that produces stronger boards with lower moisture content. Brief details of this method are given in **Appendix I**.

<sup>2</sup> A more detailed description of crosscutting, splitting and slivermaking is given in the INBAR-IPRTI TOTEM on the splitting and slivering unit.

Bamboo Mats are woven by traditional hand weaving techniques: Mats are usually woven in sizes of 1x2, 1x3, or 1x4 m and are 1-2 mm thick. The size is chosen depending upon the dimensions of the pressing plate.

**Figure 1: Main stages in the process of producing corrugated bamboo roofing sheets**



### 2.1.4. Preservation of Bamboo Mats.

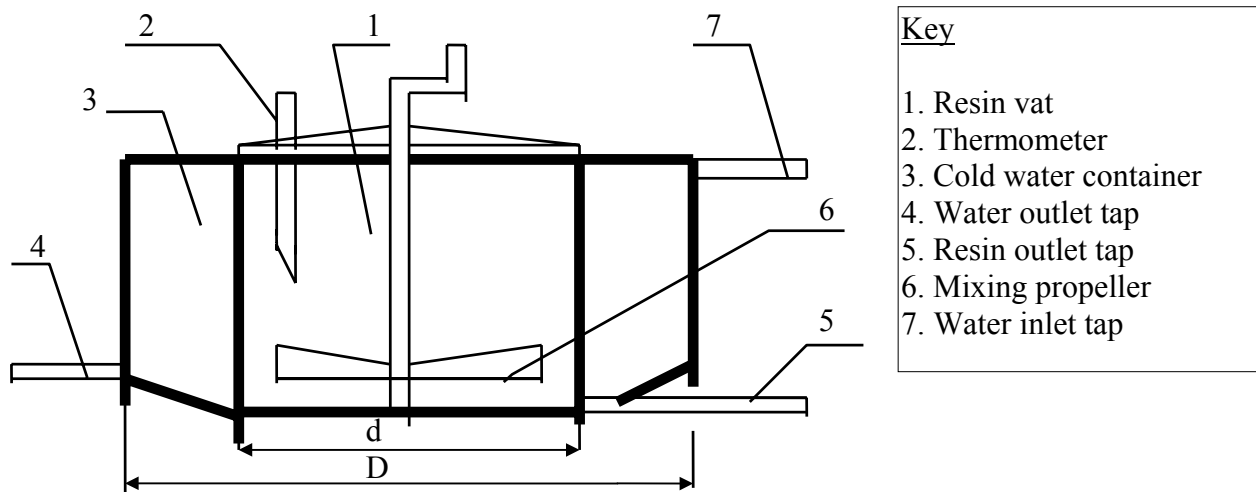
Bamboo mats are rolled up in groups of 10 mats (1x4 m mats), 15 mats (1x3 m mats) or 20 mats (1x2 m mats) and stored in a dry-aerated store. If the mats are to be stored for over about three weeks they should be treated with preservative chemicals, such as a 1% solution of a mixture of boric acid and borax in a 1:1 ratio. Mats should be checked regularly for signs of fungal or insect attack and retreated at intervals of about 3 months.

## 2.2 Resin manufacturing

### 2.2.1 Resin synthesizing equipment

The resin synthesizing equipment used at FSI is made by inox, and is double layered - the resin container is surrounded by an outer jacket containing cooling water.

**Figure 2. Glue synthesizing equipment**



Usually the resin synthesizing equipment is produced with capacities of 50, 75, 100 and 150 litres. The energy used may be supplied by firewood, coal or electricity.

### 2.2.2 Raw materials

The raw materials required for phenolformaldehyde resin are phenol, formalin and sodium hydroxide.

**Phenol:** Phenol is a white crystalline solid with a melting point of 43<sup>0</sup>C.

**Formalin:** Formalin is the liquid form of the gas, formaldehyde. It contains 37% formaldehyde by weight with methyl alcohol as a stabiliser.

**Sodium hydroxide:** Sodium hydroxide is available in white pellets and flakes.

The following proportions are used:

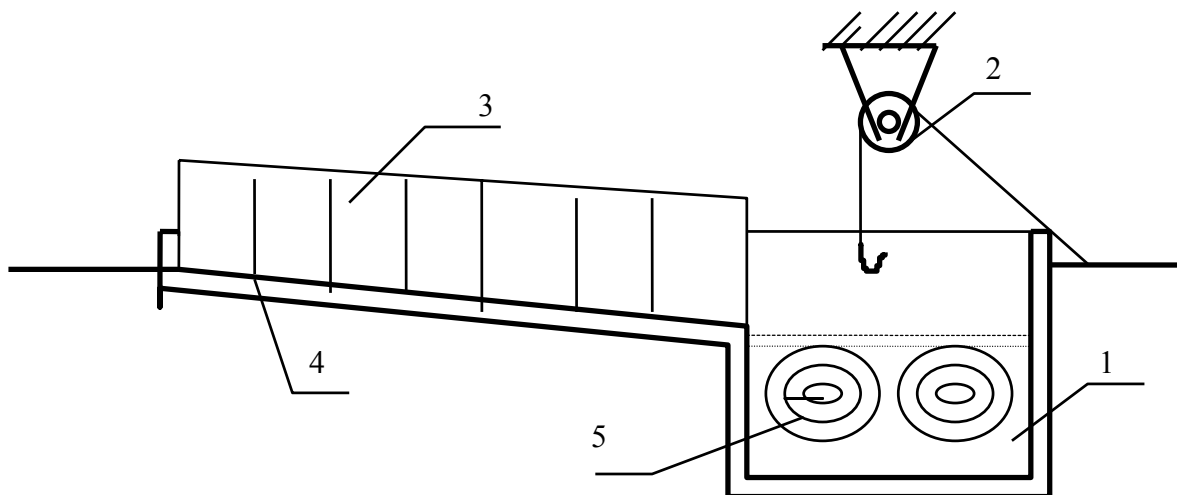
	Proportion by weight
- Phenol (98%)	100
- Formalin (37%)	200
- Sodium hydroxide (98%)	25-28
- Water	72-75

**2.2.3 Resin manufacturing:** Molten phenol is first placed in the manufacturing vat. The formalin is then added and the mixture stirred continuously. Sodium hydroxide dissolved in the required quantity of water is then added and stirring continued. The temperature of the mixture then rises as the reaction takes place. Once the temperature has stabilised the mixture is heated to 60°C. After this the temperature is maintained at 85-88°C. The reaction should take about one hour and then the mixture can be cooled by circulating cold water around the mixture.

## 2.3 Resin application

### 2.3.1 The resin applicator.

The resin applicator should be made of a 200-300 litre can or an underground brick tank as shown below (figure 3).



1. Resin application tank
2. Loading and unloading pulley
3. Draining rolls of bamboo mats
4. Gutter (allows resin draining from treated mats to flow back into the treatment tank)
5. Rolls of bamboo mats being treated



### 2.3.2 Procedure

The resin is poured into the resin applicator and diluted with water in the ratio **1 part resin: 0.5-1.2 parts water**. The bamboo mat rolls are dipped into the resin for about 2-3 minutes. They are then removed and the excess resin is allowed to drain away for about 30 - 45 minutes.

Mats are then dried to moisture content of 18-20% either under the sun or in a drying machine such as a band drier. If using a machine-dryer keep the temperature around 55°C.

## 2.4 Pressing.

### 2.4.1 Laying up.

To produce corrugated bamboo roofing sheets, each sheet is usually laid up with 3, 5 or 7 layers.

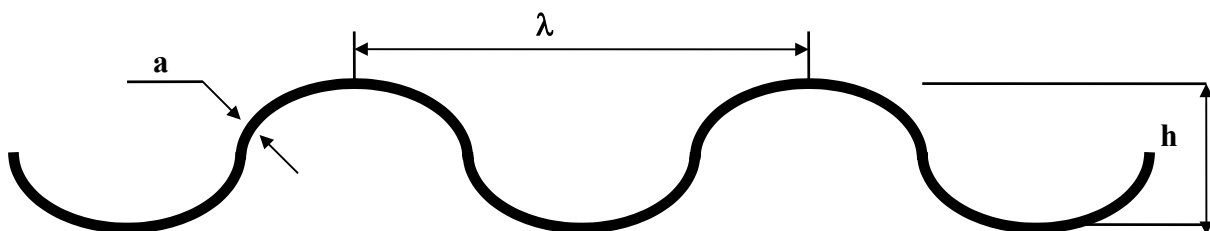
### 2.4.2 Equipment

A suitable hot press has been designed and produced by the experimental factory, Centre of Forest Industry, FSI with the following parameters:

- Dimension of pressing plate (m)	<b>1.1x1.1</b>	<b>1.1x1.5</b>	<b>1.1x2.1</b>
- Pressure (tonnes)	200	300	500
- Number of pressing floors	1-2	1-2	1-2
- Number of pistons	2	4	6
- Pressing pressure (kg/cm <sup>2</sup> )	25-30	25-30	25-30

The dimensions of the corrugated plates are based on a theoretical relationship between thickness (a), wavelength ( $\lambda$ ) and height (h) in order to ensure the quality of the surface and gluing force are optimum (Figure 4).

**Figure 4: The corrugated characteristic of corrugated Bamboo roofing sheets**



In Vietnam corrugated Bamboo roofing sheets are produced with the following dimensions 800 x 2000 x 5/7 mm and with a corrugation characteristics of

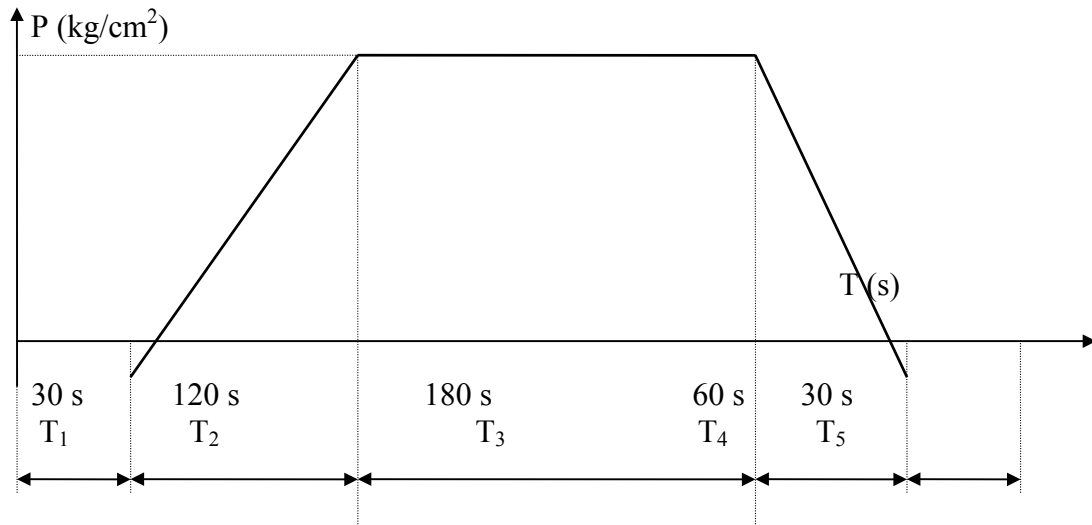
$$a = 5/7 \text{ mm, } h = 20 \text{ mm, } \lambda = 80 \text{ mm}$$

The corrugations are achieved by using corrugated pressing plates montaged onto the standard plates used for matboard.

The following pressing regime is used

- Pressing regime	Temperature (°C)	Pressure (kg/cm <sup>2</sup> )	Pressing time (s)
	<b>130-150</b>	<b>25-30</b>	<b>420</b>

- Pressing diagram (figure 5)



- The total time for one pressing cycle is  $T = 420$  seconds

$$T = \sum T_i = T_1 + T_2 + T_3 + T_4 + T_5$$

$$T_1 = 30\text{s, mat loading}$$

$$T_2 = 120\text{s, pressure raising}$$

$$T_3 = 180\text{s, pressure maintenance}$$

$$T_4 = 60\text{s, pressure lowering}$$

$$T_5 = 30\text{s, Roofing sheet unloading}$$

## 2.5 Trimming

The pressed roofing sheets are finally trimmed to size on a circular bench saw.

### **3. Comprehensive input requirements**

The following is a very brief summary of the costs of establishing and running a CBRS unit, and the profits to be made from it.

#### **3.1 Capital costs**

The capital cost of establishing a CBRS unit producing 500, 000 m<sup>2</sup> of roofing per year is 375 million VN Dong (USD\$25, 600). The costs of producing a single, 5-layered corrugated bamboo roofing sheet, 0.8 x 2.0 m in size, is shown in **Appendix II**.

#### **3.2 Tools and Machinery**

The tools and machinery costs in Vietnam are shown in **Appendix III**. They are generally the same as those for the bamboo mat board manufacturing unit. The INBAR-IPIRTI TOTEM on the bamboo mat board unit contains a more detailed analysis.

## APPENDICES

## Appendix I

### Method of producing CBRS used in China (taken from Ganapathy *et al.*,1996).

Four layers of urea formaldehyde (UF) bonded mats are used. The top layer is overlaid with UF resin-impregnated, reprocessed paper. On top of this, phenol formaldehyde (PF) resin is impregnated by hot-pressing. The production process is:

- 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
- Laying up
- Overlaying PF resin-impregnated film
- Hot pressing in a specially designed press
- Trimming

Sheets produced by this method are significantly stronger and more durable than by the method presented in this TOTEM. The crest modulus of rupture is about 57 MPa, compared to 32-38 MPa for sheets produced by the simpler method. It is, however, more involved, and the extra strength and durability may not, in fact, be required for the particular uses to which it will be put.

## Appendix II

**Cost of producing one, 5-layer corrugated bamboo roofing sheet, 0.8 x 2 m, in a unit producing 500,000m<sup>2</sup> per year in Vietnam**

N <sup>o</sup>	Item	Unit	Unit price VND	Quantity	Amount VND
1	Raw Bamboo mat	mat	4,500	2.5	11,250
2	Glue	kg	7,500	1	7,500
3	Surface covering	-	10,000	0.5	5,000
4	Energy	KW	750	3	2,150
5	Employment	sheet-	2,000	1	2,000
6	Subsidiary material	-	500	1	500
7	Organization Expenses	-	500	1	500
8	Precautions	-	500	1	500
9	Equipment and construction Subtraction		2,000	1	2,000
	<b>Total</b>	-	-	-	<b>28,600</b>

In Vietnam the selling price for such a sheet is **32,000** Dong, which give a pre-tax profit of 3,400 Dong per sheet, or **11.8%** of the production costs.

## Appendix III

### Equipment costs

N <sup>o</sup>	Name of the equipment	Unit price mill. VND	Quantity	Amount Mill VND
1	Hot press	120	1	120
2	Corrugated plates	25	2	50
3	Glue synthesizing equipment	15	1	15
4	Gluing instrument	5	1	5
5	Loading-unloading instrument	10	1	10
6	Trimming equipment	25	2	50
	<b>Total</b>			<b>250</b>

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