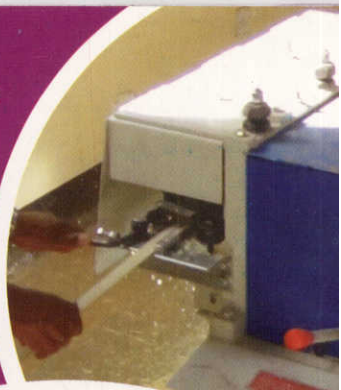
BamCraft – Crafting a Green Future: Bamboo in the curio and souvenir industry of Kenya



## Bamboo Training Manual 5:

# Industrial Products


Funded by:

Government of Japan

Executed by:

United Nations Industrial Development Organization

Implemented by:

Kenya Forestry Research Institute

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This project is being financed by the Government of Japan, executed by United Nations Industrial Development Organization, and Implemented by the Kenya Forestry Research Institute.



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This manual is based on the work of Axumawi Hailemichael Gebremaraim, Mark Dreyer and Victor Brias, UNIDO Consultants under the supervision of UNIDO Project Manager: Frank Hartwich.



This document has not been formally edited.

# CONTENTS:

# Introduction

This booklet is the fifth in a series of training manuals prepared as part of the BamCraft project in Kenya. It deals specifically with processing of bamboo into 2 types of industrial applications:

- Laminated bamboo panels
- Woven bamboo blinds

Making these applications requires the use of advanced machinery like those installed in 2012 as part of BamCraft project at the KEFRI Industrial Bamboo Processing & Training Centre at Karura, which is the latest state-of-the-art training centre of bamboo applications in Eastern Africa.

Kenya has vast bamboo reserves and the potential of developing plantations using indigenous and exotic species has been demonstrated by KEFRI. The development of bamboo industries has to be sustained through the expansion and management of bamboo plantations and forests.

Bamboo is an attractive alternative for wood panels because of its physical similarities to hardwoods. Bamboo laminated panels are strong, durable, resistant to insects and moulding. Woven bamboo shades and curtains are good examples of eco-friendly, attractive and functional products that can be made while combining the natural beauty of bamboo with yarns. Because bamboo is a sustainable resource, such products are also eco-friendly.

It is hoped that the examples and methods explained in this booklet, coupled with on-going practical training at KEFRI, will encourage investment in bamboo plantations and industrial processing, leading to a better environment, job creation and export earnings.

# Selection and Utilization of Raw Materials

It is important to note that the entire bamboo culm can be used for industrial applications.

- The lower portion of the culm is useful for making panels.
- The mid portion is useful for fine splits that can be transformed into woven products such as mats, window blinds, or floor mats.
- The fine upper portion of the culm can be used for horticulture purposes (as temporary props) or can be used for handicrafts,
- The saw dust and waste from processing bamboo can be burned to heat kilns, boilers, etc. or can be processed into briquettes.

Age and size are important factors in determining which bamboo culms should be selected and harvested. When selecting culms to be harvested, always select erect and straight culms. Withered, deformed and mildewed ones should be rejected.

Make sure that the bamboo culms to be cut are mature and at least three years old, with a diameter greater than 80mm and wall thickness greater or equal to 10mm in the lower section of the culm.

Bamboo culms with a diameter of less than 80mm and thickness of less than 10mm cannot be formed into the strips for making the laminated boards.

When cutting bamboo, apply the following rules:

- Cut sections from the base of the culm which have a larger diameter and thicker walls since this can be used most efficiently for producing laminated boards.
- Cut remaining sections according to the dimensions of final product, with a margin of about 50mm for blind weaving products.
- The remaining tips of the culms may be used for some small handicrafts or for energy transformation.

# PART 1:
# Bamboo Laminated Board

## Raw Material Requirements

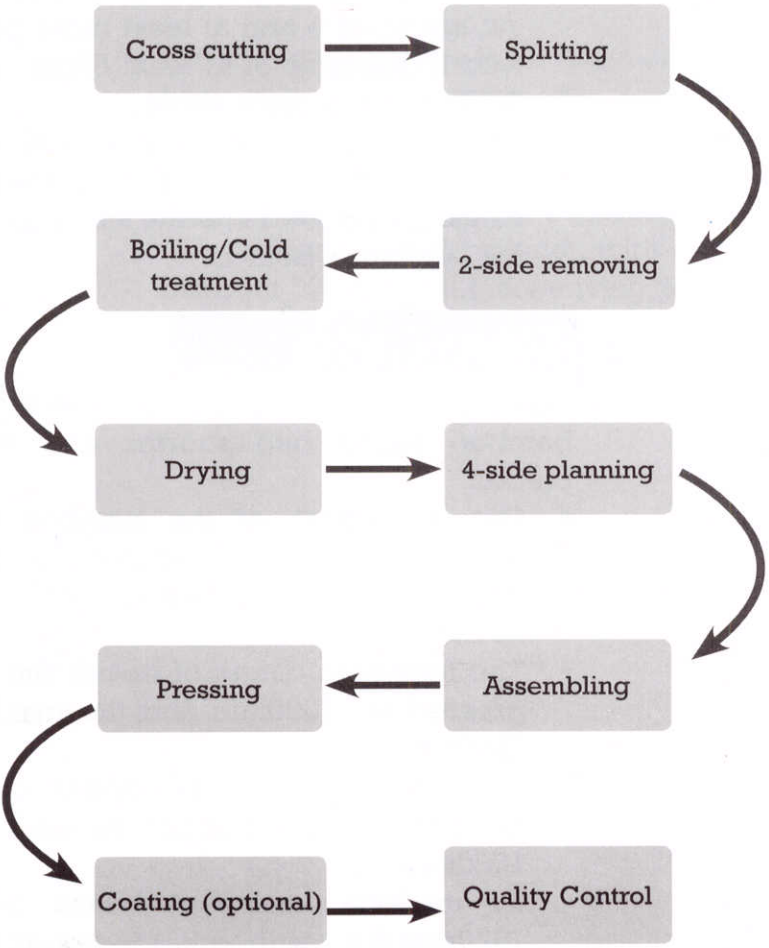
- Make sure that the bamboo culms to be cut are mature and at least three years old, with a diameter of at least 80mm and wall thickness of at least 10mm.
- Bamboo culms with a diameter of less than 80mm and thickness of less than 10mm cannot be formed into the strips for making the laminated boards.

## Cross Cutting

The cross cutting machine is used for cutting bamboo culms into shorter and workable pieces.

- Cut the length of the bamboo sections according to the dimensions of the final product, with an additional margin of about 80 mm.
- The minimum length of board that can be pressed is 1000mm and the maximum is 2000mm.
- To produce laminated board of length 1000mm cut the bamboo to the length of 1080mm.
- To produce laminated board of length 1920mm the bamboo has to be cross-cut to lengths of 2000mm.
- This will ensure that the bamboo segments are sufficiently long and will not be wasted.
- The machine is adjustable to have different lengths of cutting for different purposes.

# Production Process



Cross Cutting Machine

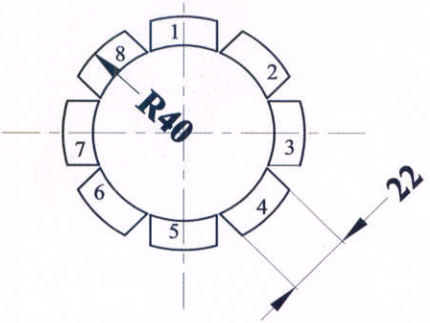
## Splitting

Splitting and Sizing Machine

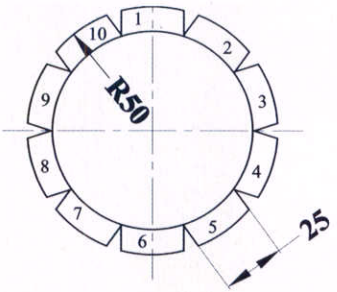


- Splitting is the first stage in the process of converting round bamboo poles into flat strips.
- The splitting and sizing machine with parallel rotary blades is used for this purpose.

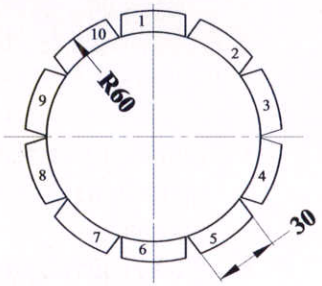
- The hollow poles are longitudinally split into segments that are 22 mm, 25mm or 30mm wide depending upon the diameter and thickness of the bamboo pole.
- If the diameter of the bamboo pole is between 60-80mm split them to a width of 22mm.




- If the diameter of bamboo pole is between 80-100mm split them to a width of 25mm.




- If the diameter of bamboo pole is greater than 100mm split them to a width of 30mm.



## Bamboo strip 2-sides removal

- The bamboo strips need to flattened and pre-shaped before they are boiled and dried.
- Shaping is done using the 2-side removal machine.
- Shaping involves removing the outer skin and inner knot of the strips.
- Care should be taken in removing the outer side of the strips (i.e. the culm epidermis) since this is the strongest part of the bamboo culm and it will be used for making the outer surface of the laminated board. Thicknesses to be maintained in this production process are mentioned in the following table:

Two side removal machine

| Dimensions before 2 side removal | | Dimension after 2 side removal | |
|---|---|---|---|
| Width (mm) | Thickness (mm) | Width (mm) | Thickness (mm) |
| 22 | 10 | 22 | 7 |
| 22 | >10 | 22 | 9 |
| 25 | >10 | 25 | 10 |
| 30 | >10 | 30 | 10 |
| 30 | 10 | 30 | 7 |

## Boiling

The formed sticks must be disinfected and bleached. This is important for protecting bamboo materials and ensuring the quality of products. The formed strips are boiled in a tank for 3 hours to bleach them and protect them against pests in a single process.

### Hydrogen Peroxide ($H_2O_2$) for Bleaching:

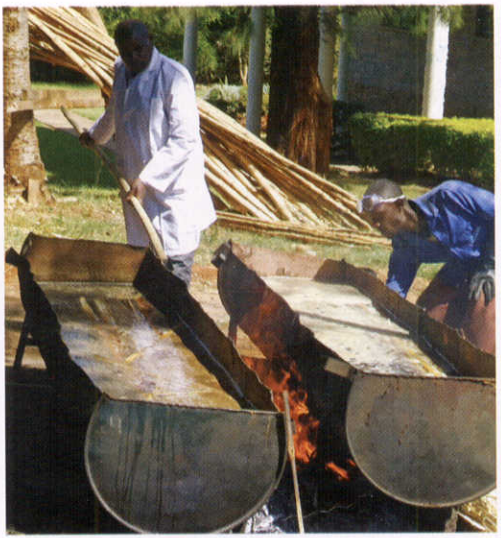
Bleaching is achieved by boiling the strips for three hours in a hydrogen peroxide solution. $H_2O_2$ solution is a strong oxidizer in both acid and alkaline media, and also functions as a reducing agent that extracts starch, protein and other nutrients thereby bleaching the surface of bamboo.

- Use hydrogen peroxide with a concentration of 80%
- Mix the hydrogen peroxide with water using a proportion of 5/1000 or (1 litre of $H_2O_2$ for every 200 litres of water)

### Borax Preservation Treatment:

The preservative agent is a mixture of boric acid and borax oxide which results in the

Boiling Tank



Low cost troughs

formation of disodium octaborate. Boron salts are effective against borers, termites and fungi (except soft rot fungi). These boron salts are dissolved in water. After treatment, the water evaporates leaving the salts inside the bamboo. This method of preservation will however only be effective if the bamboo materials are still fresh and moist, i.e., recently harvested. The method is recognized to be environmentally acceptable and safe for the mammals.

For the preservation of bamboo strips, an alkaline Borax solution is required.



- Make a 1% Borax solution by using 8kg of borax oxide and 2kg of boric acid per 1000 litres of water.
- Bamboo strips can be impregnated by boiling for three hours.

# Note:

It is important to keep in mind that the treatment method recommended for bamboo strips to be used for making laminated panels is significantly different from the method used for treating whole bamboo culms.

- For the preservation of bamboo strips, an alkaline solution with lower concentrations of borax is effective and economical.
- For treatment of raw bamboo culms, a higher concentration is needed in order to permeate the culm walls. When treating bamboo culms, it advisable to use a pH neutral solution mixing 2.5% boric acid + 2.5% borax oxide in water (i.e. 5 kg borax per 100 L of water.

Bleaching and preserving strips is achieved in a single process by using the following mixture:

| Chemical Composition for Preservation and Bleaching of Bamboo Strips | | |
|---|---|---|
| Chemical Agent | % in solution | Quantity per 1000 L of water |
| Hydrogen peroxide (80%) | 0.5 | 5 L |
| Borax oxide | 0.8 | 8 Kg |
| Boric acid | 0.2 | 2 Kg |



## Safety considerations

Gloves or polythene bag covers should be worn to protect hands from chemicals during the treatment process.

## Drying

- Place the bamboo strips in a kiln.
  Recommended drying time is as follows:
  - First phase 80C$^0$ for 8hrs
  - Second phase 60C$^0$ for 8hrs
  - Third phase 80C$^0$ for 8hrs
  - Fourth phase 60C$^0$ for 8hrs

- Check the moisture content and leave the strips inside the kiln until the moisture content is reduced to 6%.

Kiln at KEFRI Karura

Bundles of kiln-dried bamboo strips



## 4 side planning

- Size and moisture content of bamboo is very important at this stage. Double check that the moisture content is 6%.
- In order to produce stable laminated boards,

the strips must be rectangular and flat on each side.

- Later, when the strips are formed into laminated boards, the rectangular strips will bond firmly into solid boards.
- The four sides of each strip must be shaped into a fixed width and thickness. The width and thickness of strips can vary for different arrangements of strips that give the laminated board a distinct look.
- Some possible dimensions of strips are listed below:

| | Strip size before 4 side planning | Strips (ready for gluing) after 4 side planning |
|---|---|---|
| 1. | 22mm x 7mm | 17mm x 5mm |
| 2. | 22mm x 7mm | 18mm x 5mm |
| 3. | 22mm x 9mm | 18mm x 6.5mm |
| 4. | 25mm x 7mm | 20.4mm x 5mm |
| 5. | 25mm x 10mm | 20.4mm x 6.5mm |
| 6. | 30mm x 7mm | 25mm x 5mm |
| 7. | 30mm x 10mm | 25mm x 6.5mm |

4 Side Moulding Machine

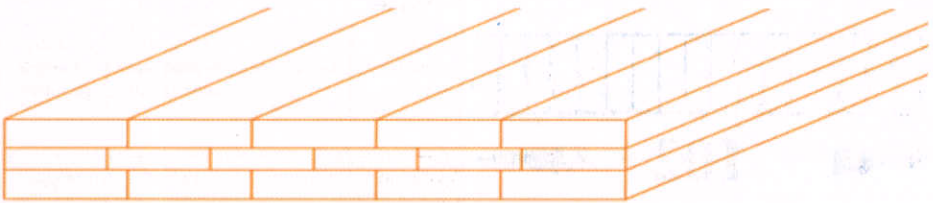
## Assembling

- The first step in this process is sorting the bamboo strips into groups of the same colour. Because bamboo is a natural product, colour variations occur. The bamboo strips are sorted so that each board is made with strips of a similar shade.

- After the strips have been sorted for colour, they are sorted for hardness. The hardest strips are marked for use as the top or outer layer of the boards. Softer strips are marked for use on the middle of the boards . After sorting, the bamboo is assembled into planks. For solid boards, the strips are glue-coated and hand assembled in either vertical or horizontal configurations.

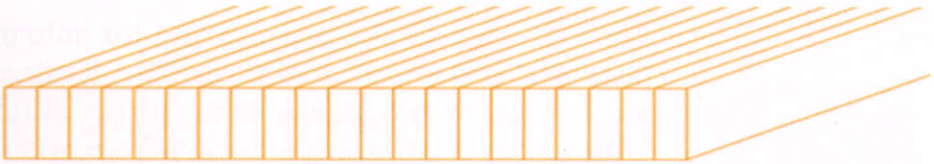
Horizontally oriented laminated boards are made of 3 staggered layers of bamboo strips. The strips are positioned such that the outer layer of the bamboo culm forms the surface of the board. Horizontal bamboo laminated board highlights the peculiar quality of bamboo, particularly the nodes that separate the segments of the bamboo culm.





Horizontal Arrangement

Vertical oriented laminated board is laminated from a single layer of strips. Each strip is positioned vertically on its narrowest edge, such that the internal grain of the culm wall forms the surface of the laminated board. The vertical orientation gives a lined and uniform look to the surface of the board.



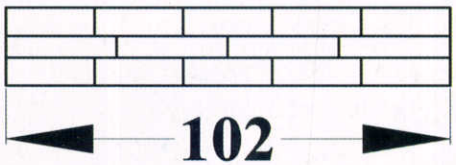
Vertical Arrangement

Some possible horizontal and vertical arrangements of strips for the production of laminated boards are detailed in the following tables:

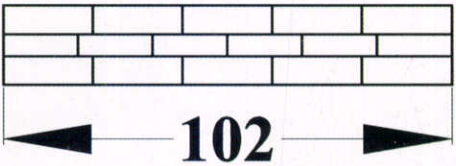

| Type | Vertical | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 18mm | 5mm | 105mm | 21pcs |




| Type | Vertical | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 18mm | 6mm | 102mm | 17pcs |




| Type | Horizontal | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 20.4mm | 6.5mm | 102mm | 10pcs |
| 25.5mm | 5mm | 102mm | 4pcs |

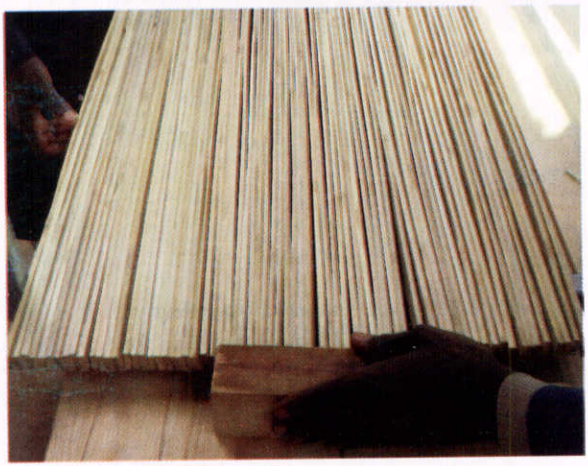



| Type | Horizontal | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 20.4mm | 6.5mm | 102mm | 10pcs |
| 17mm | 5mm | 102mm | 6pcs |


| Type | Vertical | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 17mm | 5mm | 900mm | 180pcs |


| Type | Vertical | | |
|---|---|---|---|
| Strip width | Strip thickness | Over all laminated board width | Number of strips required |
| 18mm | 6mm | 900mm | 150pcs |

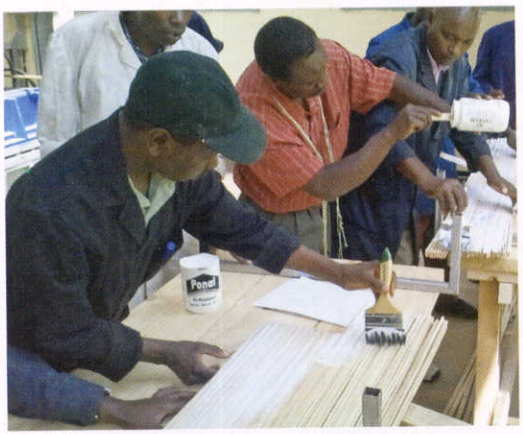
The images to the right show the assembly of strips for making horizontally oriented boards.



## Gluing

It is recommended to use a top-quality, environmentally friendly adhesives that conforms with E1 standards.
Use of this adhesive is specifically designed for parquet and bamboo laminated board applications for indoor use.
The recommended glue for laminated board is:

1. Melamine M-3, Urea Formaldehyde or any similar glue for hot pressing.
2. PVAC or white glue for cold pressing.

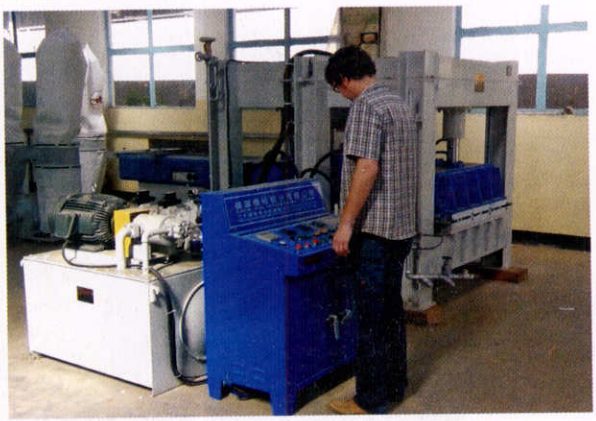



## Pressing

The assembled strips are bound together and placed in a press. They are then subjected to heat and high pressure. This activates the glue and strongly bonds the strips together into a single board. The assembled strips are pressed at 200 tons top pressure and 100 tons side pressure.

Pressing time will be 2 hours in a cold press and 10-15 minute in hot press with temperature of 100-140°C

Laminated Boards



Pressing Machine

Inserting the pieces into the pressing machine

Pieces inside the pressing machine

Pieces being pulled out of the pressing machine

## Sanding

The laminated boards are passed through a joiner, planer, and sander to shape them into the desired thickness, width and surface finish. Make sure that pneumatic pressure is connected to the machine with pressure of 3 bar.

Use sanding paper of different grit size for different finishes:

- Use grit size of 40, 60, and 80 for thickness sanding
- Use grit size of 120, 180, and 240 for surface sanding

Surface Sander

## Spray painting (coating)

This step is optional. It is only necessary for products such as floor boards and decorative wall panels. Many other laminated products are not immediately coated. Coatings are only applied after the panels are cut and assembled into other products (e.g. tables and chairs).

As spray finish is built up in thin layers, small scratches and blemishes are not so obvious and significantly easier to remedy. A finish can be sprayed on a multitude of shapes and sizes much faster than ever could be done with a brush or rag. In addition, as the finish material has been broken into small particles by a stream of air (atomisation), it dries very quickly. Varnishes, lacquers and water based products dry in minutes and can be sanded and recoated in as little as an hour. Applying several coats of finish in one day makes this process very efficient. Also due to the rapid drying time, dust particles have very little time to settle which reduces the need for sanding between coats.

Use sanding paper of grit size 240 and 320 to achieve smooth surface finishes.



## Quality finishes

For industrial (high-scale) production, investing in a spraying/finishing production line system will provide a quality finish on a consistent basis.

## SAFETY CONSIDERATIONS

During finishing and high pressure spraying, paint is atomized and released into the air. It is vital that due consideration is directed to personal safety. The following safety guidelines are advised:

- Wear protective clothing
- Wear a standard facemask or air fed mask.
- Work in a clean and dust free environment
- Use an exhaust system to ensure good ventilation
- Never spray in poorly ventilated areas. For example, closed rooms or basements need to have a very good fan system.

Many problems associated with a hand finish such as drips, sags and trapped air bubbles will be vastly reduced or eliminated.

## Quality control

Quality inspections are needed throughout the entire production process to ensure that bamboo laminated boards are strong and have a good appearance. Fine makers inspect the bamboo carefully before beginning any work, and are able to observe it throughout the manufacturing process. The maker picks the bamboo for a pleasing colour and grain, and strives to bring out these characteristics in the shaping and finishing.

# PART 2:
# Woven Bamboo Blinds and Similar Products

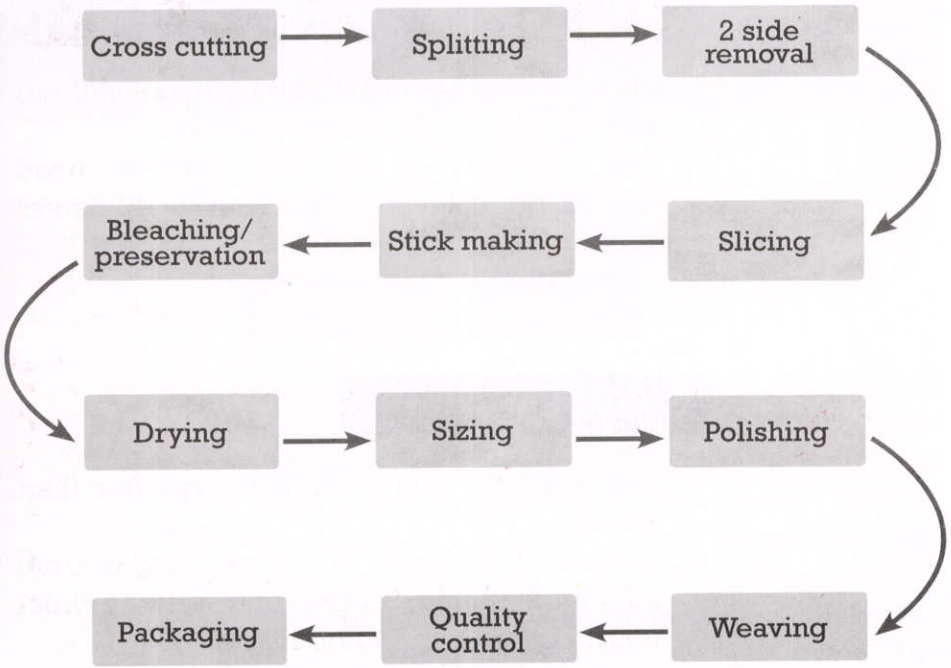
## Raw Material Requirements

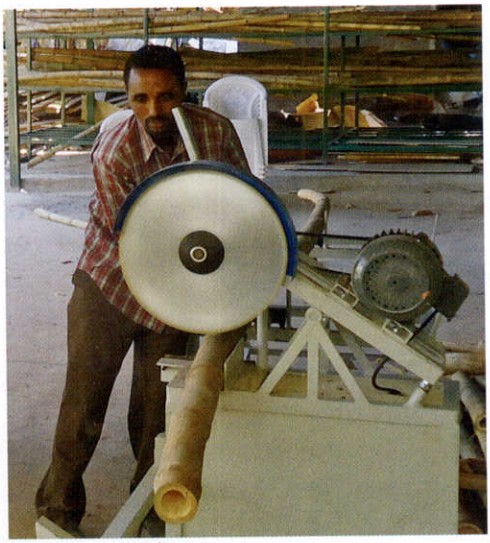
- Make sure that the bamboo culms used are mature and at least three years old
- The diameter of the culm sections used should be at least 30mm with a thickness greater or equal 10mm.

## Cross Cutting

- Use bamboo with a diameter greater than 30mm
- Length of bamboo to be cut ranges from 600mm-2000mm, depending on the final length of the blind to be made.

# Production Process





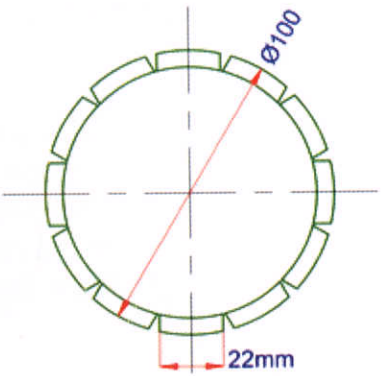
Cross-cutting Machine

## Splitting

Splitting is the first stage in the process of converting round bamboo poles into flat sticks that are needed for making blinds.

Bamboo sections are split into fragments of certain width in the direction of bamboo fibre, this operation can be implemented manually or mechanically from the small end.

Splitting machine

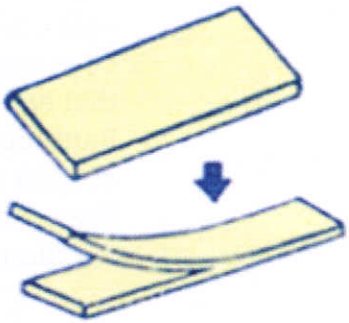


Hollow poles are longitudinally split into segments that are 22 mm
The number of pie segment will differ with different diameters of bamboo.

## Slicing

- The knots on bamboo splits should be removed.
- The splits are then sliced into strips of the required thickness.
- The number of strips that can be sliced from a split is determined by the thickness of the

Slicing Machine





culm wall. If the culm wall is 10mm thick, it may be possible to obtain 2 slivers of 4mm thickness that can be used for making sticks in the next process.

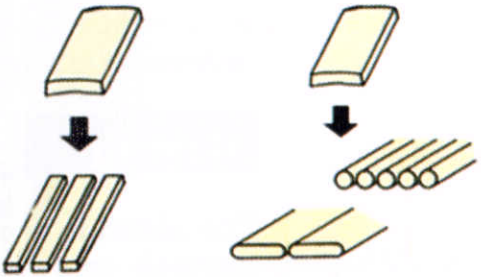
- Slice the strips into slivers of 4mm thickness

## Stick making

The slivers are formed into either circular or rectangular shapes (as required) to make it ready for the next process.

- The width of the rectangular stick is 5 mm, and the thickness is 2 mm.
- Diameter of the round stick is 2.5mm.

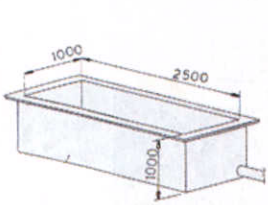
Stick making machine

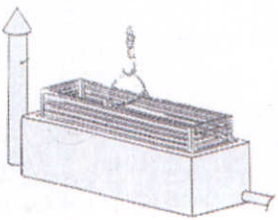


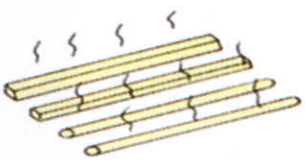
## Boiling

The formed strips are boiled in a tank for 3 hours with bleaching and preservation agents to bring out their pure natural colour and also to disinfect the materials. The method to be applied is the same one used for materials





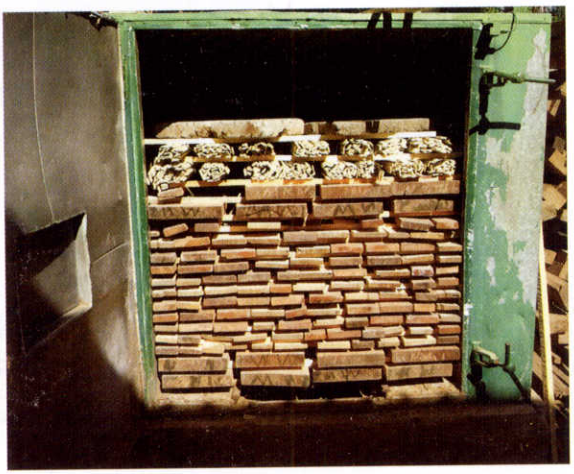





needed in making laminated boards. The only difference is the size of the materials.

## Drying

The moisture content of disinfected-bleached bamboo sticks is quite high and should be reduced to 10 ~ 12% by means of drying,which is usually done in kilns. In order to economize on energy resources or shorten the time of drying, it is possible to combine the kiln drying with air-drying.



Drying kiln

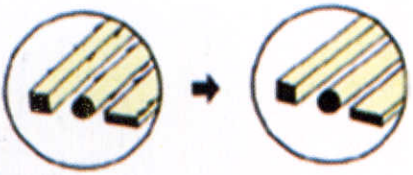
## Sizing

The circular/rectangular formed strips should be cut to the final length of woven blind (with a maximum length of 2 meters).

## Polishing

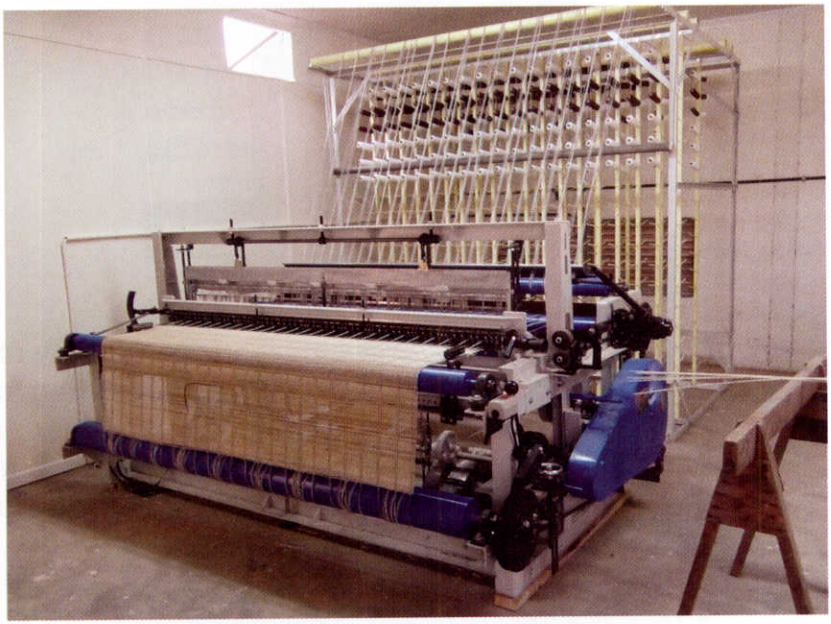
In order to have a good surface quality, the dried sticks should pass through a polishing machine. The polished sticks should be sorted, and the finest ones should be used for weaving so that they don't splinter in the hands of the user and so that they render an attractive finish.

Stick Polishing Machine

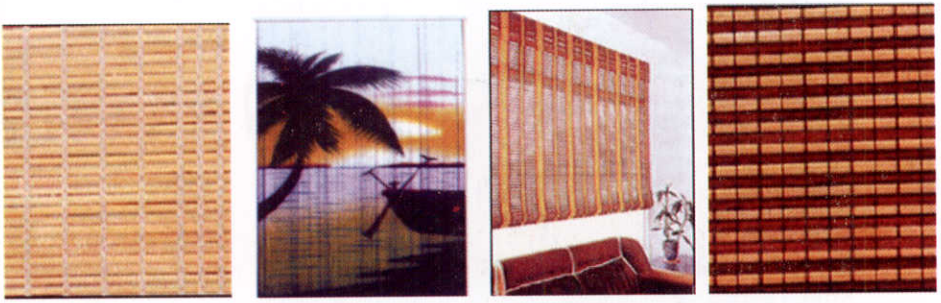


# Weaving

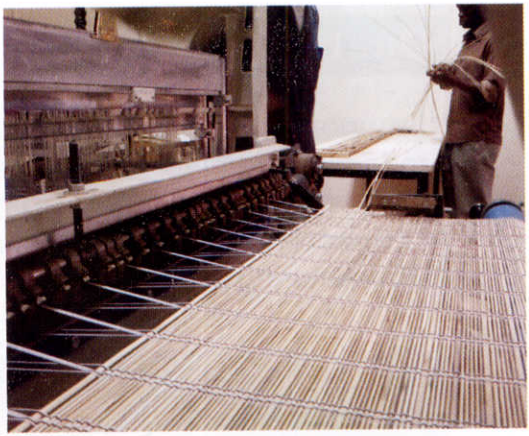
The weaving operation is carried out on special weaving machine. For weaving a bamboo blind, the sorted bamboo sticks are used as wefts and nylon or cotton strings as warps. The nylon or cotton strings are prepared for weaving on special reels by means of bobbin winders.

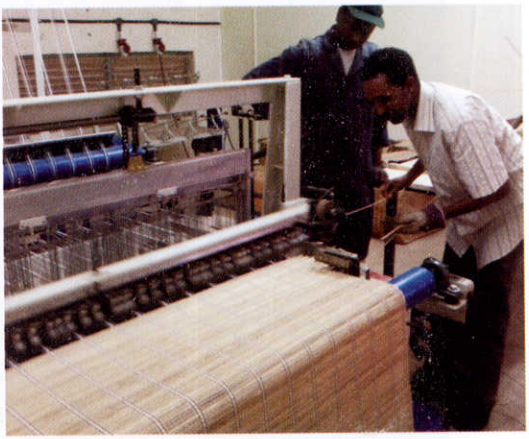


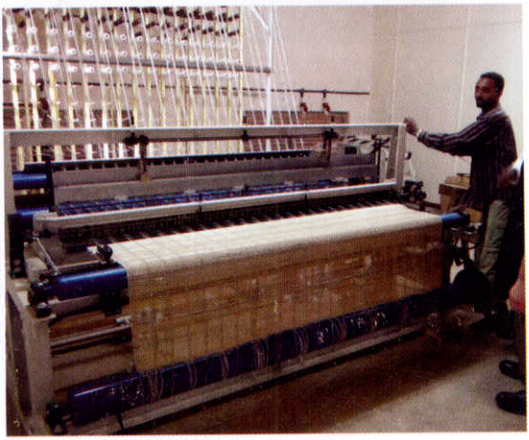
Weaving Machine



Different design of Weaved Products







## Quality control

It is important to inspect the woven blinds for any production defects. Quality control is needed at all steps of production, from the selection of raw material, the shaping of sticks, and so on up to the weaving process.