ITTO PD 600/11 Rev. 1 (I):
"Model Capacity Building for Efficient and Sustainable Utilization of Bamboo Resources in Indonesia"

Activity 3.4.

Identify Appropriate Bamboo Processing Technologies for a Small-scale Processing Plant

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Bogor, June 2014

Project Number	: ITTO PD 600/11 REV. 1 (I)
Host Government	: Ministry of Forestry, Republic of Indonesia
Executing Agency	: Center for Forest Productivity Research and Development, FORDA, Ministry of Forestry, Republic of Indonesia
Project Coordinator	: Desy Ekawati
Starting Date of the Project	: November 2013 – October 2016
Duration of the Project	: 36 months (3 years)

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SUMMARY

Bamboo is a woody, valuable and strong material. It grows naturally on all continents except Europe and shows potential as a wood substitute given that its physical and mechanical properties are comparable with those of wood. The greatest advantage of bamboo is its growth rate. In general, bamboo matures in 3 – 4 years, compare with those of slower growing wood species to increase annual yield. Bamboo species are of enormous importance to rural people in several regions of Asia. For many centuries bamboo has played an essential role in the daily life of the people of tropical countries. Traditionally it is used for light building materials, scaffolding, ladders, mats, baskets, containers, tool handles, pipes, fencing, handicrafts, toys and musical instruments. In addition to traditional applications, modern processing techniques have considerably extended its usefulness in applications such as ply bamboo, bamboo mat board and laminated bamboo for flooring.

In general, bamboo has a tremendous potential for economic and environmental development as well as international trade, however, bamboo products industries in Indonesia are predominantly of Small and Medium Enterprises (SMEs). The ITTO Project PD 600/11 Rev.1(I), *Model capacity building for efficient and sustainable utilization of bamboo resources in Indonesia* initiate the enhancement capacity among stakeholders to develop and utilize bamboo resources in an efficient and sustainable manner. The expected outputs of the project are promoting investment in bamboo industry development and enhancing institutional framework and increased participation of local communities. The project has been designed as a model of capacity building for bamboo industry development in Bangli Regency, Bali Province that can potentially developed for practitioners and bamboo farmers from other provinces in Indonesia.

Technologies appropriate for SMEs include bamboo furniture, bamboo mats, bamboo chopstick, bamboo slips, incense stick and bamboo pellet. It's not only introducing new technology but also improving existing bamboo industries. Proposed capacity building by training includes training on weaving skills and quality improvement, bamboo basketry and handycraft finishing process improvement, enhancing basketry and handycraft design products, bamboo furniture manufacturing training, bamboo mats manufacturing training, incense stick manufacturing training, bamboo chopsticks manufacturing training, bamboo slips manufacturing training (skewer and toothpicks), bamboo based panels derivative products and bamboo pellet manufacturing trainings. In the context of improving current SMEs capacity, various training topic should be conducted include: online marketing training, cost procing bamboo products, managing Small and Medium Enterprises and how to access on funding for SMEs. On the aim of monitoring and evaluation as well as measuring the impact of the project, a group of local people or such organisation similar with cooperation will benefit to the project.

I. INTRODUCTION

Bamboos are one of the most versatile and widely utilized groups of plants. Bamboo uses ranges from basketry, weaving, mats, traditional implements and furniture to industrial ply-bamboo panels, flooring and construction materials, and from paper-making to bamboo shoots, essential oils and medicines (Ganapathy *et al.,* 1996). In Asia, bamboo is used traditionally and found in almost every part of the country. Bamboo is categorized as cheap and easy to get material and also known as 'timber of the poor' (Rao *et al.,* 1987).

Bamboo has been viewed as an inferior good mainly used by poor people as a substitute for higher quality products. This has meant that bamboo has been frequently labelled as a 'minor forest product' and as such overlooked by official forestry policies and developments projects. Despite of that perception, bamboo plays an active role in the rural economies of Asia. Over the last few decade bamboo products have gained popularity both in developed countries as an attractive material for house decoration and in developing countries for its potential role in rural development. New technologies have resulted in better preservation and expanded uses of bamboo and improved management techniques have allowed for intensification and significant yield increases in raw material production (Fun and Banik, 1996).

China is one of the main bamboo-producing countries in the world, possessing bamboo plants of more than four hundred species of 40 genera. The total area of bamboo resource is 4,210,000 ha, with annual production exceeds eight million ton analogous to eight million cubic meters of wood. In the last twenty years, China and some of modern countries developed modern technology of bamboo products such as ply-bamboo, laminated bamboo, ply-bamboo curtains, bamboo composite board, bamboo chipboard and various bamboo wares for daily use. These products are widely used in vehicle making, construction industries, furniture manufacture, interior decoration and packaging (Qisheng *et al.,* 2002).

Bamboo in Indonesia has also been part of long tradition and culture mostly in classical component of housing, landscape, simple tools and crafts. In cultural and religious region such as Bali, bamboo has play an important role in traditional and religious ceremony and has become part of Balinese culture. In most rural areas, bamboo is a major construction in Indonesia for almost all of houses, including posts, roofs, walls, floors, beams, trusses and fences. People also use bamboo to produce mats, baskets, tools, handles, hats, traditional toys, musical instruments and furniture. In the food sector, bamboo shoots are becoming popular not only for Indonesian traditional cuisine but also finger food such as the famous spring roll from Central Java.

In general, bamboo has a tremendous potential for economic and environmental development as well as international trade, however, bamboo product industries in Indonesia are predominantly by Small and Medium Enterprises (SME), including home scale industries. Kuncoro (2000) stated that there are six weaknesses of general SMEs in Indonesia: limitation on marketing opportunity and possible market expansion, limitation of the capital structure and to obtain the path of capital sources, lack of organization and human resources management, limitation of business networking, unfavorable business climate due to adversarial competition, and less integrated assistancy as well as lack of trust and community care (Kuncoro, 2000). Those six SME's characteristics hinder the SMEs enhancement economically and keep the SMEs undeveloped.

According to Statistic Indonesia (2013), in 2012, there were about 56.5 million SMEs unit in total spreaded all over Indonesia, which employed about 107.6 million people. It was about 2.4 percent enhancement from previous year. SME's products were majority of low tech products, however, SMEs are more resistant to economic turmoil than larger industries. For example, during economic crisis in 1998, more SMEs survive than larger industries and in that ocassion it was good opportunity for SMEs to turn into medium and large industries after economic crisis. Based on the Indonesian Government Law No.9, 1995, SMEs were categorized as business unit that earn less than 1 billion rupiahs annually and net worth exclude land and building less than 200 million rupiahs. Statistic Indonesia divided industries into four based on the human resources employed as follows: home industries (1 – 4 people), small enterprises (5 – 19 people), medium enterprises (20 – 99 people) and large industries (more than 100 people) (BPS, 1999).

As indicated in the activity 3.4. of ITTO Project PD 600/11 Rev.1(I), *Model capacity building for efficient and sustainable utilization of bamboo resources in Indonesia*, the main objective of activity 3.4. is to identify appropriate bamboo processing technologies for a small-scale processing plants. This report discuss the available of bamboo processing technologies that readily implemented for SMEs. The project specific objective includes to initiate the enhancement capacity among stakeholders to develop and utilize bamboo resources in an efficient and sustainable manner. The expected outputs of the project are promoting investment in bamboo industry development and enhancing institutional framework and increased participation of local communities. The project has been designed as a model of capacity building for bamboo industry development in Bangli Regency, Bali Province that can potentially developed for practitioners and bamboo farmers from other provinces in Indonesia.

2. APPLIED METHODOLOGY

Literature review, survey and interviews were carried out in order to gather all data and information on current bamboo processing technologies that appropriate for SMEs. Literature on current bamboo technology was reviewed from research result and scientific journal and mainly from publication by INBAR (International Network for Bamboo and Rattan). INBAR is an intergovernmental organization was established in 1997 with the country member up to 33 countries in 2013. INBAR headquarter is in Beijing, China with the mission of improving the well being of bamboo and rattan producers and users within context of a sustainable resource base by consolidating, coordinating and supporting strategic as well as adaptive research and development. As a center of knowledge, INBAR has published series of working papers, proceeding and technical reports related to bamboo and rattan products, technology, organizations, projects, experts and scientific information, which were very useful for bamboo producers.

The industrial survey and interviews were conducted in Bangli Regency, Bali Province. Bangli Regency is located in between 08°03'30" - 08°31'37" North latitude and 115°13'48" - 115°27'24" East longitude, and lies between 225 to 2,152 m above sea level. The land area of total 521 km^2 or around 9.25% of Bali province, consists of 4 sub-districts and 67 villages.

3. PRESENTATION OF THE DATA

A. Literature review

Bamboo is natural organic matter like wood, both of them are heterogeneous and anisotropic material. However, there are significant differences in morphology, structure and chemical

composition between them, demonstrating specific physico-mechanical properties. In comparison with wood, bamboo has enough strength, great toughness and high rigidity, and it can be processed easily, accordingly this bamboo material is widely used. The specific features of bamboo material are shown below:

a. Easy processing

Bamboo material has straight grain. It can be cleaved into thin splits easily with simple tools. The splits can be used to weave handycrafts of different patterns furniture, agricultural tools and articles of daily use. Fresh bamboo stems can also be made into curved articles of unique shapes through steaming. Bamboo material is of light colour taht can be bleached and coloured easily. Raw bamboo can also be used directly for construction, fishing and other simple equipment.

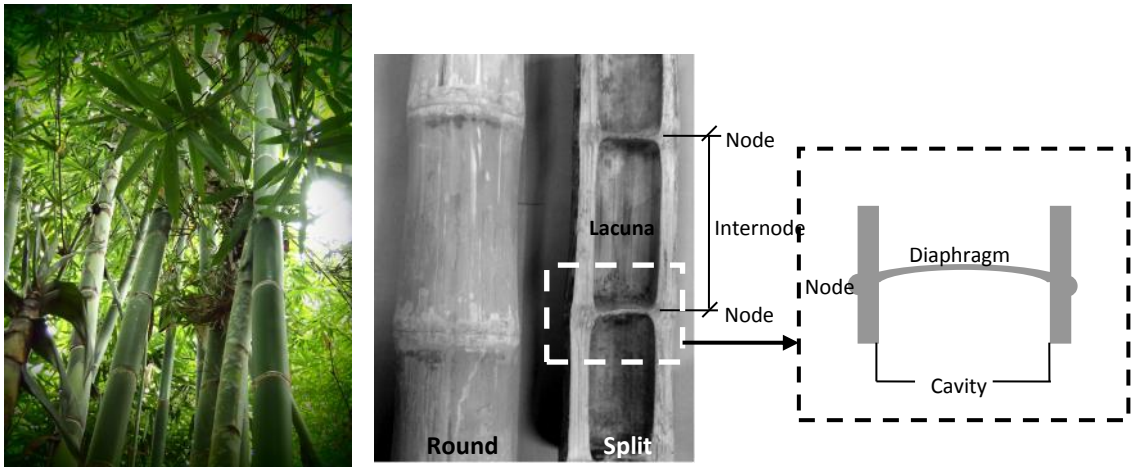

Figure 1. Bamboo stem

b. Small diameter, hollow and taper

Bamboo diameter is smaller than most commercial wood. The diameter of big trees in natural forest reaches 1 – 2 meters, while timber from plantation forest is about 10 – 50 cm. Bamboo stem diameter is about 7 – 12 cm, and may reach 20 cm in certain species and place of growth. Wood is solid, while bamboo stem is hollow, with a thin wall. The bamboo stem diameter and wall tickness decreases from base to the top, with the maximum of wall thickness of base part is about 15 – 20 mm while the top part is about 2 – 3 mm.

c. Uneven structure

Uneven structure can be seen across the bamboo wall thickness from the outer to the inner parts of the stem. The outer part of bamboo stem wall is a compact bark texture, with smooth and shiny bright surfaces as it is covered with wax layer of poor affinity for water and other solutions. The middle part of the stem wall are yellowish woody part that mostly utilized for various products. The inner part is the pith ring that covers the pith cavity. The uneven structure of bamboo wall layer affecting in different density, moisture content, shrinkage coefficient, strength and gluing ability.

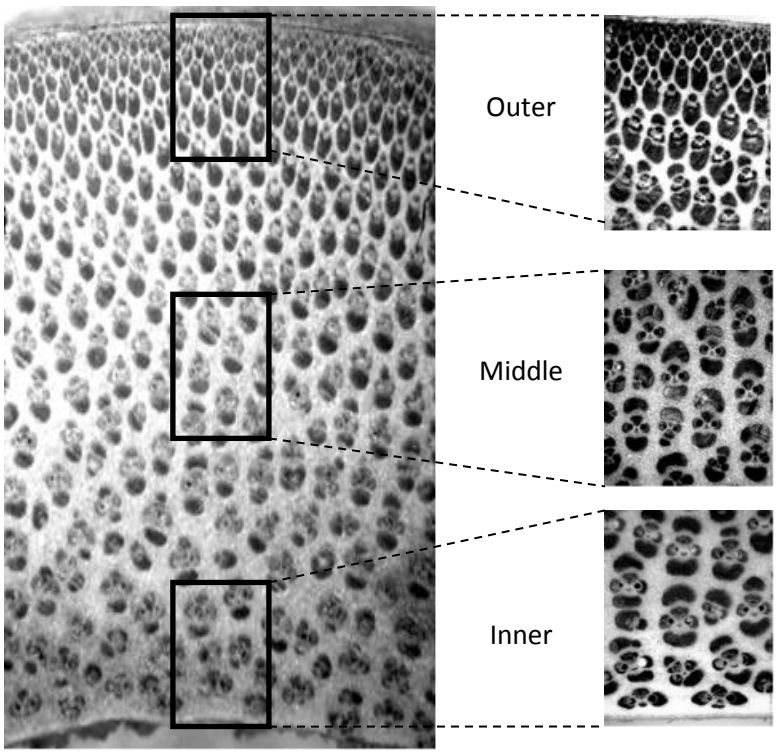

Figure 2. Bamboo wall thickness

d. Anisotropic features

Similar with wood, bamboo stem is anisotropic, which has different properties according to the grain orientation. The vascular bundle of bamboo are arranged in parallel tidy order, the grain is even, without crosswise connection, therefore, bamboo stem is the strongest longitudinally, while less strength in crosswise direction. This fact is also one of the reason for bamboo to be splitted easily.

e. Susceptible to insect and fungus

In comparison to wood, bamboo stem contains more nutrient for bio deterioration agents than wood. Accordingly, bamboo is more suscpetible to insects such as post powder beetle, termite and bamboo wasp as well as rot fungi. Long term used of bamboo products requires preservative treatment to enhance its natural durability.

f. Special care on storage and transporting

As lignocellulosic material bamboo stem is susceptible to insect and fungal attack, outdoor storage and in full contact with soil should be avoided in order to maintain the stem quality. The bamboo cutting season is strictly limited to maintain bamboo regeneration, such as March and April are the prohibited time for bamboo cutting. Consequently, it is difficult to guarantee reliable raw material supply for continuous industrial production. Because of the hollow structure of bamboo, stem transportation requires more space (volume) than weight. It affects the transport loading capacity and long distance transport is extremely unprofitable.

Base on those specific features, almost all the high efficient methods and equipment of woodworking industry can not be applied for bamboo processing directly. For example bamboo

boards with proper thickness can not be produced by means of sawing, while bamboo strips can not be produced by peeling or slicing. For many years raw bamboo is used directly or through simple processing for agriculture, fishery and house construction in primitive manner or for weaving traditional handycrafts.

Inspired by the achievements in woodworking industry, professional have started the research in manufacturing of bamboo-based panels since 1960s. With specific features of natural bamboo material and the uneven properties of bamboo stem, bamboo based panels created with specific features:

- Large dimension, small deformation and dimensionally stable
- Strong, less rigidity and high wear resistance
- Bamboo based panels can meet the standar of wooden panels in term of strength, rigidity, panels structure and dimensions
- More resistance to insect and fungal attacks
- More even properties in term of anisotropic features
- Various finishing and decoration of panel surface to suit with the end products

Bamboo based panels are made from raw bamboo through a series of mechanical and chemical processing. They are manufactured under proper temperature and pressure, with the aid of adhesives and bonding capacity of bamboo material. The thickness of bamboo based panels is 2 ~ 40 mm in general, their dimensions can be decided by the specifications of manufacturing equipment, or by the requirements of users.

Figure 3. Bamboo based panel products

There are many sorts of bamboo based panels, and about twenty of bamboo based panel are efficient to utilise in scale production. They can be classified as follows (Qisheng *et al.*, 2002):

A. Products made of bamboo strips type 1

Cut bamboo stem into plain fragments of certain thickness, make ply bamboo of three or more layers. The strips are made in the ways of pressing-flattening and planning (Figure 4).

a. Pressed and flattened, b. Planed.

Figure 4. Bamboo strips made in different ways

(1) Ply-bamboo (pressed and flattened)

Soften bamboo fragments under high temperature, press and flatten them into strips 60 ~120 mm in thickness. Assemble them in lengthwise and crosswise direction alternately, and make into ply-bamboo by means of hot pressing, using phenol formaldehyde resin as resin. Ply-bamboo is an excellent engineering material of great dimensions, high strength, small deformation and stable form. The thickness of bamboo veneer is 4 ~ 9 mm. Most of the products are of 3 or 5 layers, therefore the adhesive consumption is rather low, about 40 kg per cubic meter. The density is 0.8 ~ 0.85 g/cm^3, similar to hard deciduous wood. The lengthwise MOR// ≥ 90 Mpa, the crosswise MOP_⊥ ≥ 40 Mpa. They are suitable for making bottom board of trucks and buses.

The technology of pressing-flattening under high temperature is simple, and the utilization ratio is high, but there are cracks after flattening on the surface. Such products can not be applied for decoration purposes.

(2) Laminated bamboo board (planed)

Cut bamboo stems into square edged strips of even thickness and width, applying 2 parallel saw blades fixed on one and same axis and planer. The work efficiency and utilization ratio of this method is low. But there are no cracks on the surface of such strips. All these strips are arranged in one and the same direction during assembling, and then pressed. The strips are bleached or carbonized before pressing. The products are multi layered, of great dimension. The surface of laminated bamboo board is fine-grained. They can be used for furniture making and inner decoration like laminated veneer wood or high-grade wood.

(3) Laminated bamboo flooring (planed)

Arrange strips of same thickness and same width in one direction or in crosswise and lengthwise order alternately during assembling. The dimensions of final products are 9 ~ 18 mm in thickness, 90 ~ 150 mm in width and less than 1800 mm in length. The technological standards of laminated bamboo production are very strict. The products are of fine quality and good appearance. The manufacturing process is complicated and difficult. The raw material for making laminated bamboo must be of high quality (great diameter and freshness). This is a new product with higher added value developed in recent years.

B. Products made of bamboo strips type 2

Bamboo material can be split into lengthwise strips 0.5 ~ 30 mm in thickness, 10~ 20 mm in width. These strips can be woven into bamboo mats or bamboo curtains (Figure 5).

(1) Mat ply-bamboo

Weave slivers 0.8 ~ 1.2 mm in thickness into mats. Assemble and press after drying and gluing. The products are of two to five layers. Most of them are thin board. Common mat ply-bamboos are made of thick coarse mats. Woven mat ply-bamboo definition and its properties are

presented in Appendix 1 and glued sliver ply-bamboo is presented in Appendix 2. Thin boards are mainly used as packaging material and covering material of railway wagons. Thick boards are used as concrete forms and bottom boards of trucks.

a. Bamboo mat b. Bamboo curtain

Figure 5. Forms of sliver weaving

The splitting and weaving operations can be done in rural households without complicated equipment. In this way the scattered bamboo of small diameter and stems of miscellaneous species can be exploited successfully, therefore the source of raw material is unlimited. It is feasible to build factories producing mat ply-bamboos in economically less developed areas, where bamboo resources are of small diameter.

(2) Curtain ply-bamboo

In order to simplify weaving process, strips are arranged in parallel order, connected with strings to make them into curtains. After gluing and drying, curtains are to be assembled and pressed into curtain ply-bamboo. If surface curtain is made fine strips accurately, the products after sanding can be of high grade. The thickness of strips can be regulated according to the requirements of final products. Curtain ply-bamboo and mat curtain ply-bamboo details are presented in Appendix 3. Ply-bamboo can be diversified by means of adjusting thickness and width of strips, assemble patterns and processing ways for various uses.

(3) Laminated bamboo of strips

Strips are glued and dried, then assembled and pressed into laminated bamboo of strips. The strips are soaked in phenol formaldehyde resin and arranged in parallel order. Most of the products are thick, used as structural material. As all the strips are soaked, and the unit pressure is high, the density of final product exceeds 1.0. The strips are arranged in parallel order, the lengthwise strength is high, MOR// ≥ 100 MPa, but the crosswise strength is low.

Ply-bamboo of strips is mainly used for making bottom boards of trucks, buses and railway wagons. The strips can be produced in rural households separately. There are no specific requirements concerning the diameter of bamboo stems.

(4) Mat-curtain ply-bamboo

For making mat-curtain ply-bamboo soaked mats are used as surface layers, glued curtains as inner layers. They are arranged in lengthwise and crosswise order alternately, then pressed under high pressure. It is possible to cover the surface mats with paper soaked in melamine resin or phenol formaldehyde resin in case of need. Bamboo chip-strip board coated with impregnated paper is presented in Appendix 4. This product is mainly used to make concrete forms. The curtains and mats used for making mat-curtain ply-bamboo are woven and dried in scattered peasant households. These curtains and mats are purchased by factory workers and transported to the factory. These semi-

finished articles are dried, soaked, assembled, pressed and edged in factory. The equipment for producing mat-curtain ply-bamboo is quite simple, while the products are durable, suitable for making concrete forms.

C. Products made of bamboo chips

Bamboo chipboard

For the sake of improving utilization ratio of bamboo resources the stems of small diameter and of less known species, stem tops and all bamboo processing residue are used to make bamboo chipboard. The manufacturing process is designed following the technology of wood particleboard — rolling, cutting, chipping, re-drying, gluing, spreading and hot-pressing.

The supply of raw material for making bamboo chipboard is abundant. All small bamboo stem of less known species and residue of bamboo cutting on groove land can be used for production. The utilization ratio of raw material for chipboard production is high, From 1.3 ton of raw material 1 m^3 of chipboard can be produced. The technology and equipment for bamboo chipboard production are similar to those of wood particleboard. It is recommended to develop bamboo chipboard for improving the utilization ratio of raw material and the economic performance of enterprise. Figure 6 shows the form of bamboo chip.

Figure 6. Bamboo chips

Bamboo chipboard manufactured with phenol formaldehyde resin is of comparatively high strength and MOE, low expansion rate of water absorbing. In case of need the products can be strengthened by adding bamboo curtain or bamboo mat to the surface. Such products have broad prospect. Bamboo chipboard manufacturer is presented in Appendix 5.

D. Products of composite materials

In order to improve product quality and decrease production cost, some of the above mentioned bamboo processing residue, strips, boards, particles and fibres, and metal, texture, plastics and soaked paper are selected to make composite boards. As bamboo and wood are cheap and easy to be processed, most of composite boards are made of bamboo, wood and soaked paper at present. Both bamboo and wood have their strong points and shortcomings in processing and utilization. Wood is of larger diameter, it is cheaper than bamboo, and its processing efficiency is high. But the strength and rigidity of fast growing wood are lower than bamboo. Bamboo stem is hollow and of smaller diameter, its price is high and processing efficiency is low. The strength and rigidity of bamboo are higher than wood in general. Its surface quality is also better. The surface material of structural board bears the main load, while the load on intermediate material is smaller. Therefore for both structural and ornamental boards the surface materials are key factors deciding the quality of products. The production technology of bamboo-wood composite board combined the specific features of ply-bamboo and plywood. The production efficiency of composite board is higher than ply-bamboo, and the production cost is lower. The physico-mechanical properties of composite board

are better than plywood. To develop bamboo-wood composite board is a rational way to the successful exploitation of bamboo resources. Main products of composite boards are as follows:

(1) Bamboo-wood sandwich composites

Prepare a list of paper soaked in phenol formaldehyde resin, a bamboo mat and two bamboo curtains as front and rear surface layers, several wood strips as inner layers. Assemble and press them into bamboo-wood sandwich composites 28 mm in thickness. The production cost is lower and production process is simpler. The products are of excellent wear-ability, great strength and high rigidity, with less internal stress. These products are suitable for making bottom board of containers, the density is less than 0.85, MOR≥80 Mpa, MOE≥10000 Mpa. The traditional bottom boards of containers are made of tropical timber *Dipterocarpus* sp. They are of 17 ~ 19 layers of rotary-cut veneer, with phenol formaldehyde resin, 28 mm in thickness. The crosswise and lengthwise strength and modulus of elasticity are high. This is the wood product of highest grade. Bamboo-wood sandwich composites can be made in one step, or make the base plate of wood veneer at first, then assemble is with soaked paper, bamboo mat and bamboo curtain to undergo secondary hot pressing.

(2) Laminated bamboo-wood sandwich composite

This is a kind of thick board, made of curtain ply-bamboo as surface layers and several sawn boards 10 ~ 12 mm in thickness as inner layers. The products possess high strength and wear-ability as bamboo, and enough nail holding power as timber. As the thicker wood boards are selected to substitute for thinner rotary-cut strips, the production cost is much lower. The products can be used to make bottom boards of railway wagons. In the production process first step is to make curtain ply-bamboo and sand the surfaces. Then assemble with wood boards for secondary hot pressing.

(3) Bamboo-wood composite flooring

This is a new type of bamboo-wood flooring with outward appearance of bamboo and properties of wood. It is composed of thin bamboo pieces as front and rear surface layers, wood boards 8 ~ 15 mm in thickness as inner layers. In comparison with pure bamboo flooring, the manufacturing process is simplified and production cost lowered.

(4) Strengthened bamboo chipboard

In order to improve the strength of bamboo chipboard insert a bamboo curtain into chipboard as reinforcing bar, or add one bamboo mat or one to two bamboo curtains as surface layers, then perform secondary hot pressing. Combination of bamboo chip and strip board is presented in Appendix 6.

(5) Overlaid bamboo chipboard

In order to improve the smooth finish and decrease the water absorption of bamboo chipboard to be used as concrete form, it is recommended to cover the board with one or two pieces of paper soaked in phenol formaldehyde resin or melamine resin. This operation can be done simultaneously with chipboard assembling before hot pressing, or cover the chipboard and carry out secondary hot pressing.

(6) Overlaid ply-bamboo

Select sanded and processed ply-bamboo or curtain ply-bamboo as inner layer, a wood veneer and 1 ~ 2 pieces of soaked-paper as surface layers, then assemble and press. The surface of products is covered with a hard adhesive layer, bright and smooth. The overlaid ply-bamboo is widely used as concrete forms on construction sites of great bridges and highways.

Other than bamboo based panels, bamboo utilization has a long history of thousand of years. Bamboo articles of daily use are of most long standing and widely used till now. Main bamboo articles manufactured in various industrial scales are bamboo furniture, bamboo mats, bambo chopsticks and bamboo slips. Furniture is one of basic necessities of human life, it should be both practical and decorative, and in harmony with the indoors environment. The production and use of bamboo furniture has a long history in China and Asian countries. Bamboo furniture is imbued with oriental local colour, in simplified and elegant style, cool and comfortable. Bamboo furniture has been used globally.

Figure 7. Fine bamboo solid furniture

Traditional bamboo furniture is made by means of traditional techniques such as crooking, reinforcing, connecting, holing, tenoning, mortising and board covering. Bamboo furniture includes stools, benches, chairs, tables, cupboards, beds and bookshelves. With the technological innovation and development of bamboo industry, particularly the research and development of bamboo based panels, the structure and modelling of bamboo furniture is being diversified and embellished. Modern bamboo furniture is full of traditional taste on one hand and convenient and comfortable on the other. The manufacturing technology of modern furniture of bamboo based panels is similar to that of wood furniture, therefore, it will not be discussed. Traditional bamboo furniture manufacturing is presented in Appendix 7, while decorative pattern on framework of bamboo furniture is presented in Appendix 8. Traditional way of bamboo furniture manufacturing in China is presented in Appendix 9.

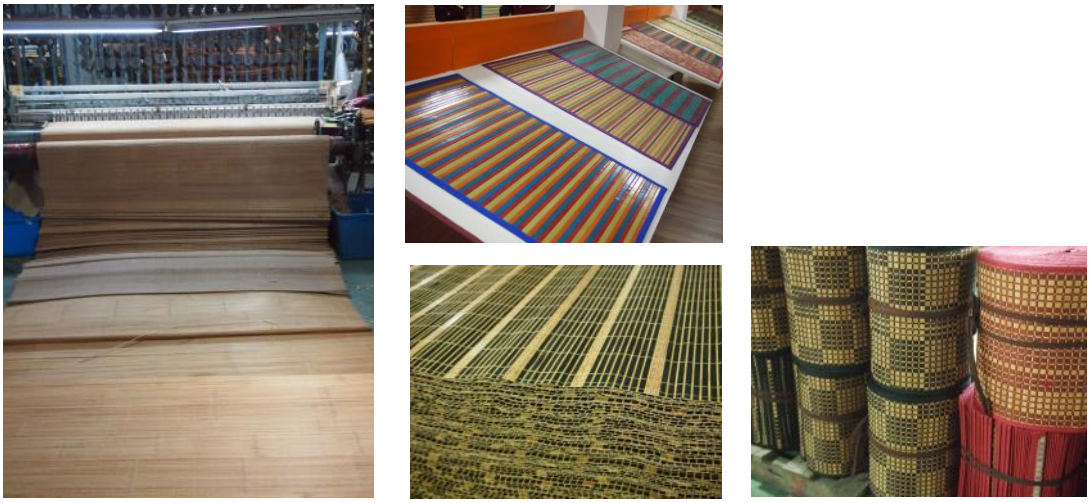

Figure 8. Bamboo mats

Bamboo mats were traditionally manufactured by hand, but in recent years the production of some of the mats are mechanized. Bamboo mats of fine threads are made in the following way: thread making, high temperature boiling, disinfecting and bleaching, mechanical weaving, mounting-gluing, hot pressing and edge processing. According to the quality of raw material, the mats can be divided into categories of "original green", "first green", "second green", "coloured threads", "painted threads" and "spun threads". They can be applied to cover pillows, beds, cushions of easy chairs and auto seats. Bamboo mats manufacturing is presented in Appendix 10.

Figure 9. Bamboo chopsticks

Bamboo chopsticks are in indispensable item of oriental tableware. Bamboo chopsticks are widely used and its demand is high for both in China and abroad. There are three groups of bamboo chopsticks: double sanitary, yuanlu and edge cut chopsticks. Bamboo chopstick is one of the technology that easily implemented in SMEs. Bamboo chopsticks manufaturing detail is presented in Appendix 11.

Similar with bamboo chopsticks, bamboo slips is relatively easy technology to be implemented in SMEs. Products in the bamboo slips include tooth picks, meat skewers and flower stick as well as incense stick. Each product made in similar shape with one or two pointed ends and are in similar way. The bamboo slips manufacturing is presented in Appendix 12.

Bamboo charcoal and active carbon is an item of new product which has been developed in recent years. Being of special microstructure, bamboo material possessed extreme absorbing and other special capacities after carbonization. Their uses in the areas of high and new technology are of importance. There are many kinds of bamboo charcoal. In line with their origin, bamboo charcoal can be divided into two parts: raw bamboo charcoal and charcoal stick of chips. Raw bamboo charcoal is made of small-sized bamboo, old bamboo, bamboo tops, roots, which are not fit for making other bamboo products. Charcoal stick of ships is made of residue from bamboo processing industry. In the process of making bamboo floorboards bamboo mats and other kinds of commodities, there will be vary much residue, they are of different sizes and forms, consequently, they must be broken into chips, dried and pressed into sticks before carbonization.

Figure 10. Bamboo charcoal

Charcoals are of different shapes: cylinders, pieces, chips and powder. In line with the temperature of carbonization charcoals can be divided into three groups: charcoal of high, medium and low temperature. Physical and mechanical properties of charcoals differ due to different temperature of carbonization. Charcoal for regulating humidity is made at temperature of 600ºC, that for absorbing is at 700 ~ 800ºC, and that of high electric conductivity is higher than 1000ºC. According to the their uses charcoals are defined as fuel, for purifying drinking water, for cooking, for bathing, for improving soil for regulating room humidity, for preserving freshness of vegetables, fruits and flowers, for deodorizing, for conducting electricity, etc. Bamboo charcoal and bamboo active carbon is presented in Appendix 13.

B. Current condition in Bangli, Bali

As mentioned before that as part of the activity 3.4. of ITTO Project PD 600/11 Rev.1(I), *Model capacity building for efficient and sustainable utilization of bamboo resources in Indonesia*, the project takes place in Bangli Regency, Bali Province. The project has been designed as a model of capacity building for bamboo industry development not only in Bangli Regency, but also for practitioners and bamboo farmers from other provinces in Indonesia.

Bangli regency is located in the middle of Bali island, Bali Province, Indonesia. It covers about 521 km^2 or about 9.25% of Bali Province. It is located between 8°03'30" - 8°31'37" North latitude and 115°13'48" - 115°27'24" East longitude. The Bangli area contain of hilly mountainuous area 225 – 2,152 m above sea level. It consists of 4 sub-districts and 67 villages. Forest land is about 11,536 Ha of which around 20% is community based forest. Bali figures states that bamboo forest in Bangli is about 6,000 Ha which produces about 4 million culms every year. With the population of 166,000 people in Bangli, the economic sector is presented in Figure 11.

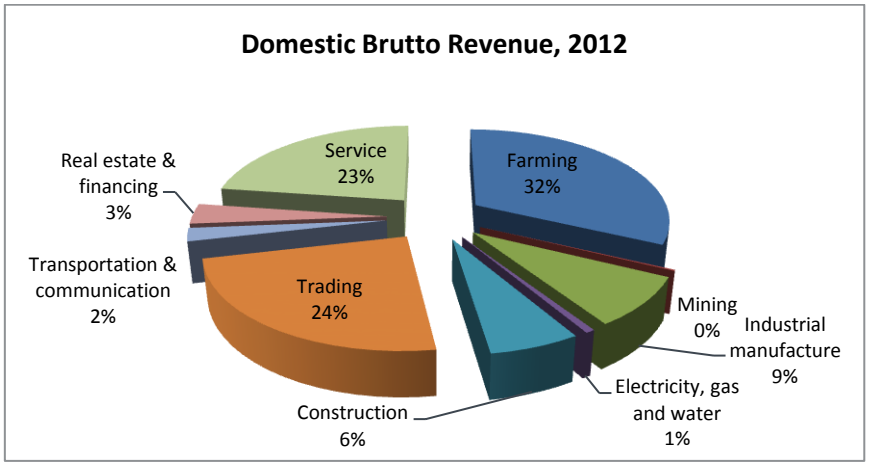

Figure 11. The average of domestic brutto revenue of Bangli Regency

Figure 4 shows that majority of people in Bangli is farmer (32%), trader (24%) and service provider (23%). People working in industrial manufacture is only 9%, while people works in construction is only 6%. It indicates that farming is still the main job for people in Bangli. During survey and interviews, it was found that ladies farmer spent afternoon time weaving bamboo sliver to make boxes or basketry. It shows that hand weaving is ladies side job after working in the paddy field in the morning (Figure 12). In sub-district, about hundreds of group working on handycraft weaving. Bamboo slivers were prepared from bamboo plantation available in their neighborhood and community based forest. The raw weaving boxes and basketry were then collected for finishing

process prior to send it to market. Basketry and bamboo boxes finishing become the bottleneck process, as not every weaving group own the finishing facility.

The skill of bamboo sliver weaving was brought by their ancestor, mainly for flower and praying equipment container. However, the weaving groups is not distributed evenly. Most of the weaving group is in Bangli and Susut sub-districts, but not present in Kintamani and Tembuku sub-districts.

Figure 12. Basket weaving and bamboo basketry products

Groups of bamboo basket weaving in Bangli categorized as small enterprises. Unfinished bamboo basket are collected in larger enterprises who own finishing facility. This medium company were then sell the finished bamboo boxes and basketry into larger company for local and international markets. The bottom part of the chain, the weaving group is less chance to expand bamboo products businesses. With the lack of capital, human resources management and without machinery, this group is in the level of survival to manintain their traditional way of weaving and have less opportunity to expand their business. These bamboo box and basketry are grouped into handycraft and simple technology bamboo utilization.

The other bamboo handycraft found in Bangli is the ornamental statue maker from bamboo rhizome. Bamboo rhizome that left over after harvesting is in various shape of hairy and rough surfaces were then turned into sophisticated mask, pupet or statue of bamboo rhizome. The strong art senses involve in creating this product. Currently new developed bamboo lamina manufacturing is also found in this area. With the support of Industrial and Trade Department Services, this young enterpreneur develops various bamboo lamina products such as chair, table top ciggarete box and handycrafts. Laminated bamboo strips were turned into various furniture products and handycrafts that made by order.

Figure 13. Incense sticks

Local incense stick manufacture is also found in Bangli area. Incense stick is the most popular product in Bali, as a primary needs for everyday praying. In this case, the need of incense stick product is large. Currently, the sticks are coming from Bali and Java as well as imported from Thailand and

Vietnam. Incense stick producton is rarely available in Bangli regency. In general, bamboo business unit in Bangli is shown in Table 1.

Table 1. Bamboo based industries in Bangli Bali

No.	Year	Business Unit	Human Resources (people)	Total production (Unit)	Production Value (Rp.000)	Export value (Rp.000)
1.	2010	2,555	8,682	125,195	890,989.4	259,277.9
2.	2011	2,562	8,692	125,538	910,989.4	273,296.8
3.	2012	2,657	8,700	130,193	911,489.4	301,247.2
4.	2013	2,786	9,076	136,514	933,523.5	308,062.7

Table 1 shows that bamboo business unit increases every year by about 5%. The production value is increasing from 911.5 million rupiahs in 2012 into 933.5 millions rupiahs in 2013. From that production value, it is about 30% going for export in various bamboo products. This percentage is decreasing from 33% in 2012.

According to the Industrial and trade officer, Bangli's problem include: low accessibility on bamboo products marketing (promotion, exhibition etc.), low quality bamboo products because of low skill of manufacturing, poor SMEs management, less original product design, less knowledge on pricing products and low brand mark of Bangli's bamboo product. During the ground survey, waste was found to be general problem in every bamboo utilization unit. Waste in the form of chip, sliver as well as smaller piece of bamboo were found in every industries. Currently, the waste remain unused or in some places were burned for nothing. Making pellet from bamboo waste is one of possible way to improve the use of bamboo waste.

4. ANALYSIS AND INTERPRETATION OF THE DATA AND RESULTS

Based on the literature review on available bamboo processing technologies and ground survey as well as interviews, there are three topics to discuss in enhancing the SMEs bamboo in Bangli Regency and Indonesia in general, include: enhancing current bamboo processing industries, introducing new and simple bamboo processing technology and capacity building of bamboo processing industries.

A. Enhancing current bamboo processing industries

In order to improve the quality of bamboo weaving products from Bangli, training should be conducted on weaving skill and sliver treatment to improve weaving product's quality. Polyethilene glycol bamboo sliver treatment prior to weaving could improve sliver's quality and bamboo basketry and boxes accordingly. The pre-weaving treatment is not only improve products quality but also increasing the bamboo product durability.

As mentioned before that weaving groups are only found in Bangli and Susut sub-districts, therefore the weaving skill can be introduced into two sub-districts Tembuku and Kintamani. As side job, weaving bamboo basketry and boxes can improve the economic of local people in Kintamani and Tembuku. The bamboo weaving product improvement is not only by introducing pre-weaving

treatment and introducing weaving technique to other sub-districts but also enhancing bamboo basketry finishing quality. The improvement can be conducted by bamboo basketry finishing training as well as providing pilot center for finishing process of bamboo basketry.

Incense stick industries are rarely available in Bangli. Most of incense stick product are coming from outer Bali and imported from other country. During interview, some people showed their interest in incense stick hand industry. Incense stick product making should be conducted in Bangli Regency. The technology of incense stick manufacture is relatively simple using bamboo stick for the main holder. Incense stick can also be produced using machine, however hand made incense stick is preferable to be developed in Bangli Regency.

Bamboo based panel industry found in Bangli is under supervision of Trade and Industrial Department Services. The panel industry is relatively new with traditional product furniture design and average of handycraft product. The panel industry can be enhanced by applying proper machining lay out and improving product design skill. The proper machining lay out will keep the good panel quality.

Bamboo based panel industry produces panel product where various product can be derived from it such as furniture, handy craft, household equipment and souvenirs. Other bamboo based panel can also be developed in this facility, such as mat curtain ply-bamboo, bamboo chipboard and combination of wood veneer and bamboo panels. This various panel products require adhesive, resin and hot press which was already available in bamboo based panel industry.

B. Introduction of new bamboo processing technology for SME

The definition of 'new' processing technology refer to the newly introduced bamboo processing technologies. It does not refer to the newly invented technology on bambo processing. As mentioned in the literature review that almost of bamboo panel products requires adhesive and hot press which is hard to obtain in SMEs except the existence bamboo based panel industries. In various bamboo based panel such as mat ply-bamboo and curtain ply-bamboo, the splitting and weaving operations can be done in rural households without complicated equipment. In this way the scattered bamboo of small diameter and stems of miscellaneous species can be exploited successfully, therefore the source of raw material is unlimited. It is feasible to build factories producing mat ply-bamboos in economically less developed areas, where bamboo resources are of small diameter.

In order to simplify weaving process, strips are arranged in parallel order, connected with strings to make them into curtains. After gluing and drying, curtains are to be assembled and pressed into curtain ply-bamboo. If surface curtain is made fine strips accurately, the products after sanding can be of high grade. The thickness of strips can be regulated according to the requirements of final products. Curtain ply-bamboo and mat curtain ply-bamboo details are presented in Appendix 3. Ply-bamboo can be diversified by means of adjusting thickness and width of strips, assemble patterns and processing ways for various uses.

Furniture is one of basic necessities of human life, it should be both practical and decorative, and in harmony with the indoors environment. Bamboo furniture is imbued with oriental local colour, in simplified and elegant style, cool and comfortable. Traditional bamboo furniture is made by means of traditional techniques such as crooking, reinforcing, connecting, holing, tenoning, mortising and board covering. Bamboo furniture includes stools, benches, chairs, tables, cupboards, beds and

bookshelves. With the technological innovation and development of bamboo industry, particularly the research and development of bamboo based panels, the structure and modelling of bamboo furniture is being diversified and embellished. Modern bamboo furniture is full of traditional taste on one hand and convenient and comfortable on the other. The manufacturing technology of modern furniture of bamboo based panels is similar to that of wood furniture.

Traditionally, bamboo mats were manufactured by hand, but in recent years the production of some of the mats are mechanized. Bamboo mats of fine threads are made in the following way: thread making, high temperature boiling, disinfecting and bleaching, mechanical weaving, mounting-gluing, hot pressing and edge processing. According to the quality of raw material, the mats can be divided into categories of "original green", "first green", "second green", "coloured threads", "painted threads" and "spun threads". They can be applied to cover pillows, beds, cushions of easy chairs and auto seats. Bamboo mats manufacturing is presented in Appendix 10.

Bamboo chopsticks are in indispensable item of oriental tableware. Bamboo chopsticks are widely used and its demand is high for both in China and abroad. There are three groups of bamboo chopsticks: double sanitary, yuanlu and edge cut chopsticks. Bamboo chopstick is one of the technology that able to be implemented in SMEs. Bamboo chopsticks manufaturing detail is presented in Appendix 11.

Similar with bamboo chopsticks, bamboo slips is relatively easy technology to be implemented in SMEs. Bamboo slip products include tooth picks, meat skewers and flower stick as well as incense stick. Each product made in similar shape with one or two pointed ends and are in similar way. The bamboo slips manufacturing is presented in Appendix 12.

In order to utilize bamboo waste, bamboo pellet is one possible product from bamboo waste. Bamboo pellet is using bamboo biomass compacted in pellet form for heating purposes. Bamboo pelleting can be developed for home industry scale using small capacity machine and special stove designed to burn the pellet. In the future, bamboo pellet can be used to heat not only stove for cooking but to generate electricity by burning the pellet and replacing the use of fossil based fuel.

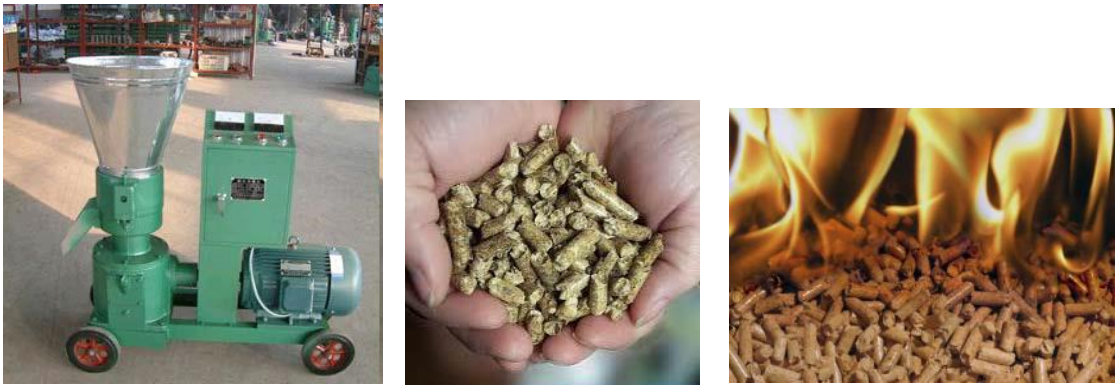

Figure 14. Small pelleting machine and wood pellet

C. Capacity building of bamboo processing industries

In order to improve the SMEs capacity, trainings must be conducted to enhance SMEs skills in developing the bamboo product technologies, include:

- Training on weaving skills and quality improvement
- Bamboo basketry and handycraft finishing process improvement
- Enhancing basketry and handycraft design products
- Bamboo mats manufacturing training
- Incense stick manufacturing training
- Bamboo furniture manufacturing training
- Bamboo chopsticks manufacturing training
- Bamboo slips manufacturing training (skewer and toothpicks)
- Bamboo based panels derivative products
- Bamboo pellet manufacturing training

In the context of improving current SMEs capacity, various training topic should be conducted include:

- Online marketing training
- Cost procing bamboo products
- Managing Small and Medium Enterprises
- How to get access on funding for SMEs

D. Modern bamboo handycraft in China

Bamboo handycraft in China has been moved from home industry to small and medium industry. Chinese local government has supported the handycraft home industries for business expansion. Hand carving is now replaced by laser carving that open the possibility of the handycraft business development. This handycraft development can also be copied into Indonesian SMEs. Full support from government assistance from expert is necessary.

A B

Figure 15. Handycarft products engraved by laser (A) and preservative treatment (B)

Creative design bamboo products play a significant role in SMEs bamboo products development. Nowadays product design such as keyboard, memory stick, I-pad and I-phone casing and computer mouse are branded as creative products from China. Design products should be developed in accordance to current market.

Figure 16. Creative design of bamboo products

Bamboo clothing has also been developed in China for various clothing products such as socks, towel and bed sheets. Bamboo fibres were mixed with cotton to have better water absorbance and antibacterial cloth.

Figure 17. Bamboo cloth products

5. CONCLUSION

1. To conclude the appropriate bamboo processing technologies for SMEs include bamboo furniture, bamboo mats, bamboo chopstick, bamboo slips, incense stick and bamboo pellet.
2. In order to enhance current bamboo processing technologies for SMEs, proposed supporting activities include training on: improving the weaving skills, enhancing bamboo basketry finishing quality and designing bamboo based panel products.
3. Series of capacity building through training are important way to build bamboo producers knowledge.

6. RECOMMENDATION

In order to improve the SMEs capacity, trainings must be conducted to enhance SMEs skills in developing the bamboo product technologies, include:

- Training on weaving skills and quality improvement
- Bamboo basketry and handycraft finishing process improvement
- Enhancing basketry and handycraft design products
- Bamboo furniture manufacturing training

- Bamboo mats manufacturing training
- Incense stick manufacturing training
- Bamboo chopsticks manufacturing training
- Bamboo slips manufacturing training (skewer and toothpicks)
- Bamboo based panels derivative products
- Bamboo pellet manufacturing training

In the context of improving current SMEs capacity, various training topic should be conducted include:

- Online marketing training
- Cost procing bamboo products
- Managing Small and Medium Enterprises
- How to get access on funding for SMEs

On the aim of monitoring and evaluation as well as measuring the impact of the project, a group of local people or such organisation similar with cooperation will benefit to the project.

7. IMPLICATIONS FOR PRACTICE

As mentioned in the objective of ITTO Project 600/11 Rev.1(I) *Model capacity building for efficient and sustainable utilization of bamboo resources in Indonesia,* to initiate the enhancement capacity among stakeholders to develop and utilize bamboo resources in an efficient and sustainable manner. The expected outputs of the project are promoting investment in bamboo industry development and enhancing institutional framework and increased participation of local communities. Bamboo industries developed in Bangli, Bali: bamboo furniture, bamboo mats, bamboo chopstick, bamboo slips, incense stick and bamboo pellet will give bamboo products development directions.

It is not only intorducing new technology, but also enhancing current bamboo processing technologies for SMEs by various activities include training on: improving the weaving skills, enhancing bamboo basketry finishing quality and designing bamboo based panel products. The series of capacity building through training are important way to build bamboo producers knowledge. The project has been designed as a model of capacity building for bamboo industry development in Bangli Regency, Bali Province that can potentially developed for practitioners and bamboo farmers from other provinces in Indonesia.

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Appendices

Appendix 1. Woven-mat ply-bamboo

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

Woven-mat ply-bamboo appeared in 1940s to 1950s. The technology of its production is rather simple and the investment for building a factory is insignificant. The supply of raw material for making such products is abundant, the utilization ratio is high and the production cost is low. Woven-mat ply-bamboo has high mechanical properties, and it is widely used in packaging, furniture making, construction and vehicle making.

1. Definition and classification

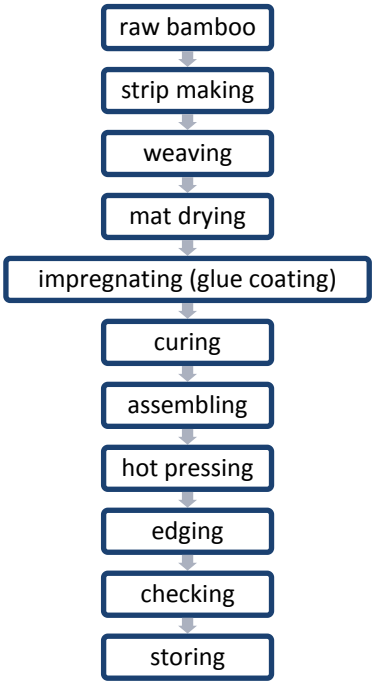
The woven-mat ply-bamboo is manufactured by means of strip-making, weaving, adhesive coating (impregnating), hot pressing. The appearance of woven-mat ply-bamboo is shown in Figure 1.

Figure 1. Woven-mat ply-bamboo

Woven-mat ply-bamboo is classified according to its uses: package board, top board of railway wagon, furniture board, construction forms, bottom board of vehicles.

2. Processing technology

The processing technology of woven-mat ply-bamboo is as follows:



Woven-mat ply-bamboo for furniture making and decoration must meet higher requirements. The strips must undergo sanding, bleaching or colouring operations before weaving. The processing

technology depends on the uses of final products. Package boards and boards for vehicles are made of rough mats. Such mats can be woven in peasant families, and purchased by manufacturers for the further processing. If the products are to be used for making furniture and decoration, the strips must be processed, bleached or colored. Therefore, the strip-making and weaving operations of these products should be carried out in factories for effective quality controlling.

3. Preparation of raw material

Raw bamboo species must be suitable for making strips and have larger inter-joint length. These species are *Phyllostachys heterocycla, Dendrocalamus latiflorus* Munro, *Neosinocalamus affinis* (Rendle) Keng f. *Phyllostachys glauca* McClure, *Phyllostachys heteroclada* Oliver and *Dendrocalamus membranaceus* Munro. For making fine slivers it is better to choose *Phyllostachys heteroclada, Phyllostachys glauca* and *Neosinocalamus affinis*. While *Phyllostachys heterocycla* and *Dendrocalamus latiflorus* can be used for producing rough slivers. The suitability of bamboo material for making slivers reduces with aging of bamboo. Bamboo 3 ~ 4 years old can be used for making slivers easily, but the strength is lower, these slivers can be used to weave fine mats for decoration. The slivers of bamboo 5 ~ 8 years old have higher and stable mechanical properties, they are fit for making ordinary woven-mat ply-bamboo.

Sliver making is easy when the water content of bamboo material is high, consequently, it is better to choose fresh bamboo with higher water content.

4. Making slivers

This operation consists of the following steps: cross cutting, joint removing, splitting, sliver making and sorting.

(1) Cross cutting

Cut bamboo culm into sections according to the dimensions of product with a margin of about 15 mm. The incisions must be plane and smooth, and be arranged 3 ~ 5 cm from joints.

(2) Remove joints and split sections

Remove outer joints of section, split the sections into slivers 1.5 cm in width. At the same time remove the inner joints from the yellow face. This operation can be done manually or on a splitting machine.

(3) Making slivers

When make slivers, the incisions must be parallel with the chord of bamboo culm. Remove the yellow layer at first, then split one sliver into two, two into four and further. Slivers from green surface are called green slivers, all the others are called yellow slivers. Those near green surface can be very thin and more slivers can be made in this part. The texture near yellow face is loose and the slivers must be thicker. Green slivers are used to weave and make handicrafts, not to make bamboo-based panels. The thickness of yellow slivers for weaving mats is 0.5 ~ 1.2 mm. Sorting and storing. Slivers are sorted into piles of green, second yellow, third yellow, fourth yellow and so on. Sorted slivers are bundled up, dried by airing, and then stored.

5. Weaving

Slivers are used to weave mats of pre-determined dimensions. At present bamboo mats are woven only by hand. Mats for making bamboo-based panels are woven by passing slivers crosswise over and under lengthwise ones. Crosswise slivers are called warps and lengthwise wefts. For weaving rough mats, warps pass over three wefts first and then under three wefts, for making fine mats, warps pass over and under only one weft. The mats must be even and smooth, and rectangle.

6. Drying

Bamboo mats are woven separately. Due to the difference of raw material, the water content of mats is not even. In order to achieve the evenness of water content for further processing, the woven or purchased mats should be dried immediately. The water content of mats must be kept in

the range of 6 ~ 12%. It can be higher for urea-formaldehyde resin and lower for phenol resin. Mats can be dried naturally or artificially. The effect of artificial drying is better, and great batches can be dried in this way for industrial production. Artificial drying can be implemented in kiln dryers or on drying machines. It is acceptable to use ordinary wood-kiln dryer for bamboo mats, the heat energy may be steam or stove gas. Drying machine of single tier or double tier for plywood can be applied to dry bamboo mats, the drying time is 10 ~ 15 min, and temperature is 140 ~ 160ºC. If there are no possibilities of artificial drying, bamboo mats can be dried naturally, by airing. But this method depends on the weather, the effect is not stable and can not be done in great batches.

7. Adhesive coating (impregnating)

Mats are coated or impregnated with adhesive for hot pressing. Urea-formaldehyde resin (solids content 48 ~ 65%) is used for coating. The coating amount is 200 ~ 275 g/m^2 for single surface and 400 ~ 550 g/m^2 for double surface. The adhesive coat must be thin and even. Phenol resin is used for impregnating. Impregnate bamboo mats with resin pool for a certain period of time, fetch them out and extrude surplus resin from them with upper and lower rollers. When the solids content of resin is 28%□}2%, and the water content of mats is 4 ~ 6%, the impregnating time can be kept in the range of 2 ~ 2.5 min, when the water content is 10 ~ 12%, the impregnating time can be 2.5 ~ 3.5 min. Under these conditions the impregnating rate achieves 6 ~ 7%. If other kinds of adhesives are applied, the impregnating time must be determined by tests. The impregnating rate is a ratio between solid matter of resin absorbed by mat and the weight of the mat itself. It is an important factor for evaluating impregnating quality. Generally speaking, if the adhering effect is achieved, the lower impregnating rate is the better. The quality of panels improves with the raise of impregnating rate, but if the impregnating rate exceeds 10%, the effect is not evident. Therefore the impregnating rate should be kept in the range of 6 ~ 7%.

8. Maturing or drying

The coated mats must be laid for a certain period of time in order that the resin permeates the surface of slivers and weaving crosses, and the moisture evaporates by airing. This process is called maturing. The length of maturing time depends on the viscosity of adhesive and the room temperature. Maturing time must be longer if the viscosity is higher and the room temperature is lower, it can be shorter under opposite conditions. The impregnated mats can be laid for several hours (not longer than 24 hours) for natural drying. For the sake of high quality and batch production, the mats can be dried artificially, the temperature of drying medium should not exceed 80ºC, the final water content kept in the range 15 ~ 18%.

9. Assembling

Mats are woven of wefts and warps, their crosswise and lengthwise mechanical properties are quite similar. Therefore they can be assembled not only in odd number, but also in even number. Both surfaces of assembled sets should be covered with a metal plate respectively to avoid the possible pollution of platens and the mat surface. If metal plates stick to mat surfaces upon unloading, it is recommended to smear ungluing agent on the plates.

10. Hot pressing

The hot pressing indexes of woven-mat plybamboo are shown in Table 1.

Table 1. The hot pressing indexes of woven-mat ply-bamboo

Type of adhesives.	Temperature. (ºC)	Unit pressure. (MPa)	Hot pressing time (min) double-l	triple-l	quadruple-l	penta-l
phenol resin	140 ~ 150	2.5 ~ 4.0	3 ~ 4	5 ~ 7	8 ~ 12	10 ~ 15
urea formaldehyde	110 ~ 120	2.5 ~ 4.0	3 ~ 4	4 ~ 5	5 ~ 7	6 ~ 7

For the sake of further solidification of adhesive inside the pressed panels, they should be piled tidily right after the unloading from pressing machine, this also helps to eliminate the inner stress of panels and reduce their deformation.

11. Edging and checking

Hot pressed panels are piled tidily right after unloading from pressing machine. After 12 ~24 hours of hot piling. They are cut in crosswise and lengthwise directions according to the product standards or the requirements of customers. The dimensions and tolerances, appearance, physico-mechanical properties of panels are checked after cutting. Then they are packaged and stored.

12. **Physico-mechanical properties**

Physico-mechanical properties depend on the type of adhesive, hot pressing conditions, number of layers, thickness of panel, etc. The MOR of thinner panels can be over 90 MPa. The MOR of thicker panels is lower than that of thinner ones of same sort and same adhesive. Samples of woven-mat plybamboo can hardly be gripped firmly, their adhering strength can not be tested as usual plywood. To solve this problem, the samples of products are treated in the way of "boiling (impregnating) – freezing - drying", then their MOR is tested.

Appendix 2. Glued sliver ply-bamboo

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

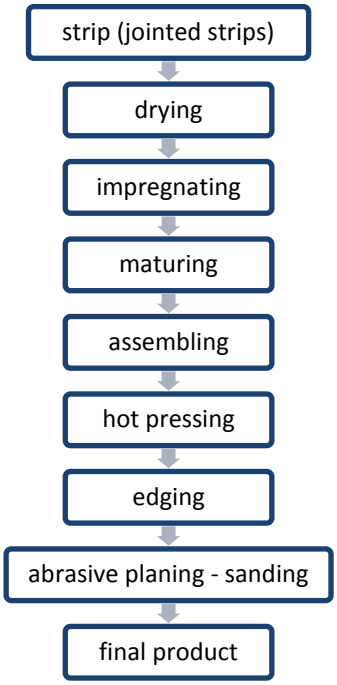
1. Definition and uses

Glued sliver ply-bamboo is formed of bamboo slivers or livers joined together as a whole piece. After drying, impregnating and maturing, the strips and strip pieces are assembled all in lengthwise direction and hot pressed. The lengthwise strength and rigidity of glued sliver ply-bamboo are high, it is a good material for engineering construction, mainly used for making bottom boards of railway wagons and trucks. The appearance of glued sliver ply-bamboo is shown in Figure 1.

Figure 1. Glued sliver ply-bamboo

2. Production technology

The production technology of glued sliver ply-bamboo is simple in comparison with that of ply-bamboo of weaving and mat-curtain ply-bamboo.



3. Raw material

Ply-bamboo is made of slivers 0.8 ~ 1.4 mm in thickness. If strips are too thick, the adhering effects will be affected. Thick strips have higher rigidity, they can hardly be deformed to fill up the blank space between strips even under high pressure. The MOR and adhering strength of ply-bamboo of thicker strips are lower. It is suggested to apply thinner strips. The width of strips is 15 ~ 20 mm generally. The length should be the length of final product plus the margin of processing. It is permitted to use some short strips, the ratio between long strips and short ones is 1 : 0.2 ~ 0.3. Short strips should not be shorter than 30 mm. Strips are produced in peasant families separately and purchased by manufacturers.

To improve the product quality, it is proposed to join the strips together to make a whole piece for mechanized and continuous processing, to weave the strips into a curtain with threads-warps. Curtains can be woven manually or on weaving machines. The quality requirements for such curtains are similar to those for mat-curtain ply-bamboo.

4. Drying and impregnating

The water content of strips after drying must be kept within the range 10 ~ 12%. Strips can be dried naturally or in kiln dryers. The impregnating rate is the ratio between the weight of solid adhesive and the absolute weight of strips. It is an important factor that influences the adhering quality. A low rate leads to poor adhering strength and peeling of layers. Too high rate causes the waste of adhesive. In general, the impregnating rate is fixed at 6 ~ 7%, and water-soluble phenol resin can be applied for impregnating.

The impregnating rate is determined by means of weight calculating. To measure the water content of curtain W0 and its weight G0 at first, then calculate the absolute weight of strips G1,
G1 = G0 (1- W0); lift the impregnated strips, measure their weight after dripping and artificial drying G2. The impregnating rate will be $[(G_2 – G_1)/G_1] \times 100\%$.

Strips are bundled with wire ropes before impregnating. Let the bundles down into an adhesive pool to impregnate by means of an electric hoist. Lift them up after 1 ~ 2 min of impregnating and let down again to impregnate for 2 min. After that hang them above a dripping tank.

5. Drying after impregnating

Impregnated strips are hung for dripping and drying. The final water content of dried strips should be fixed at 10 ~ 12%. The impregnated strips are dried naturally or in kiln dryers. The temperature of kiln must be at □}65ºC, higher temperature may lead to the solidification of adhesive. The drying time should last 4 ~5 hours. Measure the weight of impregnated strips after drying as G1, measure the absolute weight as G0, the water content will be $[(G_1 – G_0)/G_0] \times 100\%$.

6. Assembling

Glued sliver ply-bamboo is assembled on a worktable manually. Separated strips are assembled in a frame after weighing, while jointed strips can be assembled on the plate. Long strips are used for surface layers and short ones for core layers. Compared with separated strips, joined strips are assembled more effectively, with even thickness and density. The amount of strips for assembling depends on the density, thickness and dimensions of products.

If the dimensions of products are 2440mm x 1220mm x 30mm, the margin of cutting is 100 mm, the margin of thickness processing is 2mm, the dimensions of assembled set will be 2540mm x 1320mm x 32mm. If the pre-determined volume weight of products is 1.1 g/cm^3 and the impregnating rate is 7%, the strips to be used for assembling will be:
G_1 = l x b x d x r = 254 x 132 x 3.2 x 1.1 = 118018.56 g = 118.02 kg.
G_1: weight of bamboo strip board;
l: length of board;
b: width of board;
d: thickness of board;
r: volume weight of board.

The absolute weight of strips used for making a bamboo strip board
$G_2 = [G_1/(1+W_2+P)] = [118.02/(1+0.1+0.07)] = 100.8$ kg
G_2: absolute weight of strips needed.
W_2: water content of product, 10%.
P: impregnating rate.

Weight of adhesive used for every bamboo strip board:

G_3 = P x G_2 = 0.07 x 100.8 = 7.07 kg
G_3: adhesive needed

If the water content of impregnated strips after drying W_3 is 14%, the weight of impregnated and dried strips needed for making a bamboo strip board G_4 will be:
$G_4 = (1 + W_3) \times (G_2 + G_3) = (1 + 0.14) \times (100.87 + 7.06) = 123.04$ kg, or
$G_4 = (1 + W_3) \times (1 + P)\ G_3 = (1 + 0.14) \times (1 + 0.07) \times 100.87 = 123.04$ kg.

7. Hot pressing

The hot pressing conditions are: temperature: 140 ~ 150ºC; unit pressure: 4.5 ~ 6.0 MPa; pressing time: 1.3 min/mm of thickness of final products. The process of hot pressing is "cold loading and cold unloading", as used for making mat-curtain ply-bamboo. The pressure is raised gradually or in stages.

8. Further processing

The semi-finished product after hot pressing must be processed further on pressing plane or sanding machine to adjust its thickness, then cut or milled according to the dimensions of bottom board of truck or railway wagon.

9. Physico-mechanical properties

In general, the density of ply-bamboo board of glued strips is over 1.0. The lengthwise MOR of glued sliver ply-bamboo board 30 mm in thickness exceeds 100 MPa, and the MOE exceeds 8000 MPa. As all the strips of the glued sliver ply-bamboo are assembled in one and the same direction, its lengthwise strength is great, while the crosswise strength poor.

Appendix 3. Curtain ply-bamboo and mat-curtain ply-bamboo

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

1. Definition, classification and uses

Curtain ply-bamboo is formed of bamboo curtains, curtain ply-bamboo and mats are formed of bamboo curtains and bamboo mats. Impregnated with adhesive (generally phenol resin), the curtains and mats are hot-pressed into bamboo-based panels according to their uses. Curtain ply-bamboo is mainly used as the base to be covered with a surface of high strength for making concrete forms. Mat-curtain ply-bamboo is used as ordinary concrete forms.

Mat-curtain ply-bamboo is made of mats as surface layers and curtains as core layer. This kind of panel can be divided into "thick-curtain" and "thin-curtain" according to the thickness of curtains. In comparison with traditional materials for making concrete form, such as steel, wood and plywood, mat-curtain ply-bamboo has larger dimensions, higher rigidity and strength. It is widely used on construction sites of high buildings, engineering constructions and industrial buildings, where many cement components are made on the spot and finalized with cement mortar. The appearance of mat-curtain ply-bamboo is shown in Figure 1.

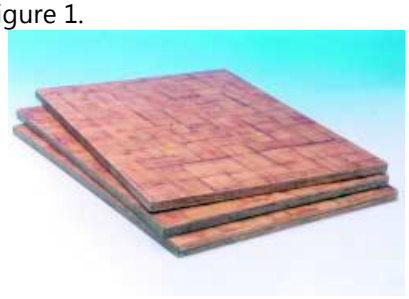
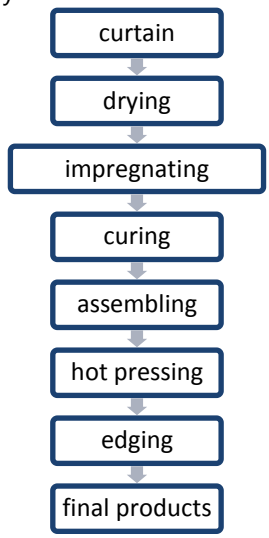


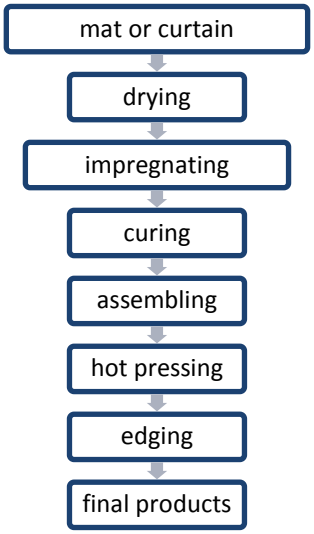
Figure 1. The appearance of mat-curtain ply-bamboo

2. Production technology

The production technology of curtain ply-bamboo is as follows:



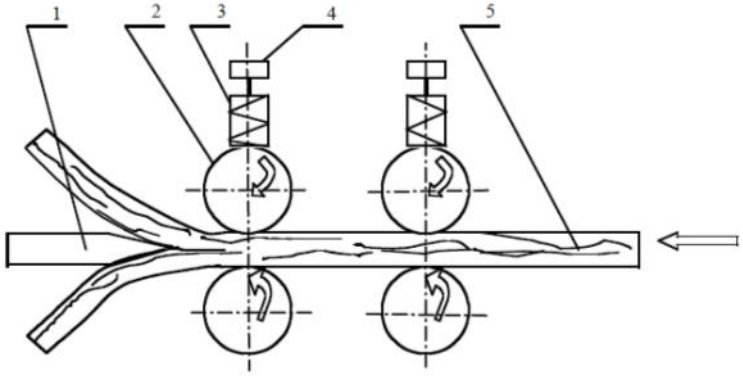
The production technology of mat-curtain plybamboo is as follows:



3. Raw material

The curtains for making ply-bamboo are about 1 mm thick, the sliver making and weaving are carried out on machines. The trips of curtain are arranged very closely, the thickness of curtain is uniform. The mats used for making mat-curtain ply-bamboo are the same as those used for making woven-mat ply-bamboo. Thin curtains are made of slivers 1 mm in thickness, with warp threads of polyester fiber, the space between two adjacent warps is 300 mm. The thick curtains are made of slivers 2 ~ 3 mm in thickness.

Most of the curtains used for making mat-curtain plybamboo are woven and dried in scattered peasant families. These curtains are purchased and processed further by factories of ply-bamboo. Curtains for making curtain plybamboo have to meet higher thickness and evenness requirements. The sliver making and weaving operations are carried out on machines in factories. Slivers are made on a bamboo splitting machine of single cutter as shown in Figure 2.



1.Cutter. 2. Feeding roller. 3. Pressing spring. 4. Adjusting bolt. 5. Bamboo strip

Figure 2. Bamboo splitting machine of single cutter

4. Drying

Bamboo mats and curtains must be dried to reduce their water content to less than 12% before impregnating. They are dried as those for making ply-bamboo of weaving.

5. Impregnating

The adhesive consumption is significant if it is applied to coat curtains, because there are many pores and chinks in them. The curtains and mats are loaded vertically in steel cages. Let the cages down into an adhesive pool to impregnate by means of an electric hoist. Lift them up after 2 ~

4 min of impregnating and hang them above a dripping tank. The impregnated curtains and mats are to be dried or matured as those used for making woven-mat ply-bamboo, because they are also moisturized by adhesive in the process of impregnating.

6. Assembling

Bamboo mats are applied as surface layers, while curtains as core layers. The number of layers and the arrangements of crosswise and lengthwise curtains are decided in accordance with the uses of products and strength requirements. The structure must be symmetrical for the stability of dimensions. The structure of mat-curtain ply-bamboo is shown in Figure 3. Along with the structure shown in Fig. 2-32, where one crosswise curtain is piled on one lengthwise curtain alternately. It is also permitted to pile several crosswise curtains on several lengthwise ones alternately. In such cases several crosswise curtains or several lengthwise curtains are regarded as one layer.

1.Bamboo mat. 2. Lengthwise curtain. 3. Crosswise curtain

Figure 3. The structure of mat-curtain plybamboo

7. Hot pressing

The hot-pressing conditions are similar to those for manufacturing ply-bamboo. But because of the high water content of thin curtains and the high unit pressure, the pressing process is "cold loading and cold unloading". It means the process consists of 3 steps:

1. Pre-heating: load the assembled sets into pressing machine and raise the temperature and pressure to the pre-determined extent.
2. Setting up and forming: operate according to the pre-determined conditions.
3. Cooling: inject cold water into hot platens to cool them, keeping proper pressure. Release the pressure when the temperature declines to 50 ~ 80ºC and unload the pressed sets then.

This process of "cold loading and cold unloading lasts longer than usual, consumes a great deal of water and more energy. But it makes the dimensions stable and surfaces even, and prevents the peeling of layers.

8. Edging and edge banding

The crosswise and lengthwise edges of pressed sets must be cut to achieve the predetermined dimensions and tolerances. In order to improve the water resistance and outward appearance of products their edges can be coated with waterproof agent.

9. Main quality indexes

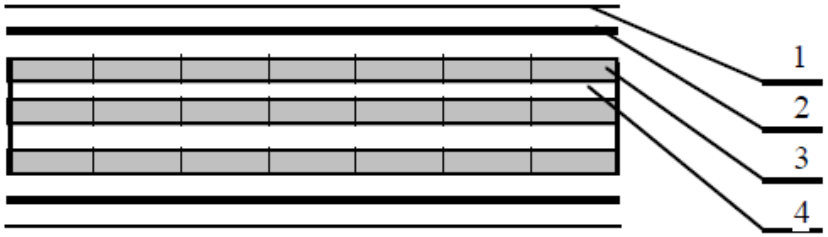
Mat-curtain ply-bamboo of "thin curtain" type has higher quality indexes. Its MOR reaches 100 MPa, MOE reaches 10000 MPa, density approaches to 1.0, and its adhesive consumption is also higher. The adhesive consumption of "thick curtain" type is lower, the density is 0.75 ~ 0.80, quality indexes are inferior to those of "thin curtain" type. But they meet the quality requirements on construction sites.

10. About mat-curtain ply-bamboo covered with impregnated paper

Mat-curtain ply-bamboo of "thin curtain" type can be covered with impregnated paper for making "clean water" concrete forms. The technological process of such products is similar to that of ordinary mat-curtain plybamboo. The only difference is to cover the upper and lower surfaces with a

piece of impregnated paper in assembling respectively. Before hot pressing a stainless steel plate is placed on the assembled set and another one under the set. In this way a film can be formed on the surfaces of products, which makes the unloading easy.

The paper can be impregnated with melamine resin or phenol resin, or melamine-phenol mixed resin. The structure of mat-curtain ply-bamboo covered with impregnated paper is shown in Figure 4. The physico-mechanical properties of mat-curtain ply-bamboo covered with impregnated paper are shown in Table 1.



1.Impregnated paper. 2. Bamboo mat.3. Lengthwise curtain 4. Crosswise curtain

Figure 4. Structure of mat-curtain ply-bamboo covered with impregnated paper

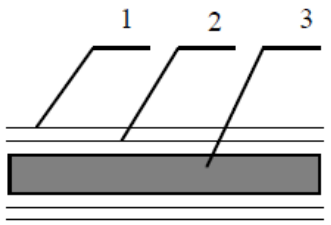
Table 1. Physico-mechanical properties of mat-curtain ply-bamboo covered with impregnated paper

Property	Index
Density (g/m^3)	0.80
MOR (Mpa)	104.5
MOE (Mpa)	11100
Adhering strength (Mpa)	≥ 2.5
Attrition resistance of surface	0.05g/100r

Appendix 4. Bamboo chip-strip board coated with impregnated paper

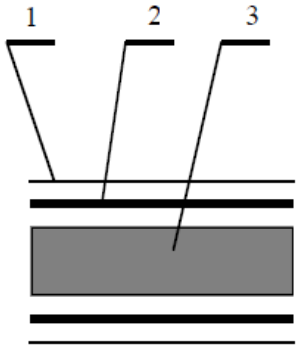
1. Classification and uses

Strip-covered board coated with impregnated paper is mainly used for making concrete forms. Cement components produced by such concrete forms have fine surface, and there is no need to mend them with cement mortar. These coated boards can be divided into three types in accordance with their structure: concrete forms of bamboo chipboard coated with impregnated paper; concrete forms of bamboo mat chipboard coated with impregnated paper; concrete form of bamboo-curtain chipboard coated with impregnated paper. The structures of these boards are shown in Figure 1, 2 and 3.



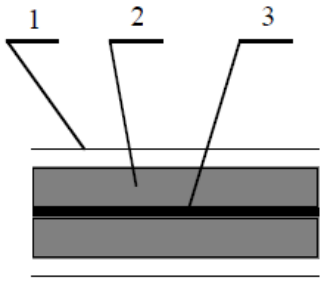
1.Surface paper impregnated with melamine or phenol resin. 2. Sub-surface paper impregnated with phenol

Figure 1. Sturcture of bamboo chipboard coated with impregnated paper



1.Surface paper impregnated with melamine. 2. Impregnated mat. 3. Bamboo chipboard.

Figure 2. Sturcture of bamboo-mat chipboard coated with impregnated paper



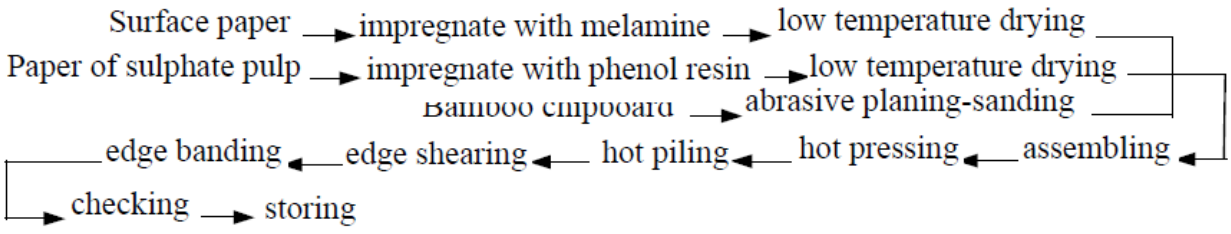
1.Surface paper impregnated with melamine or phenol resin. 2. Bamboo chipboard. 3. Impregnated bamboo curtain

Figure 3. Sturcture of bamboo-curtain chipboard coated with impregnated paper

1. Main points of production

Bamboo chipboard coated with impregnated paper and bamboo curtain chipboard are manufactured by means of two-step molding. It means that the bamboo chipboard and bamboo curtain chipboard are produced, processed on shaving and abrasive machines at first, then to be coated with impregnated paper. In this way the thickness tolerance can be controlled. Bamboo mat chipboard is manufactured by one-step molding, because the surface mats can not be processed on abrasive machine.

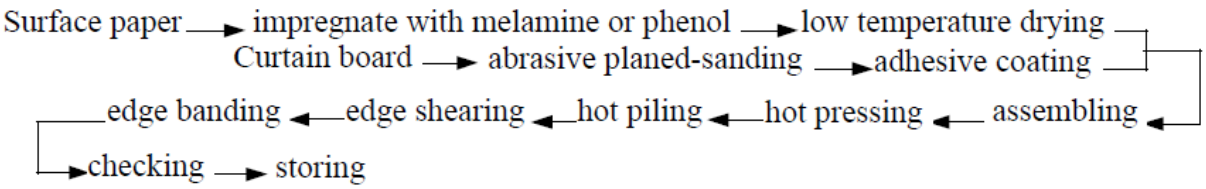
(1) Production technology of bamboo chipboard coated with impregnated paper



(2) Production technology of bamboo mat chipboard coated with impregnated paper

The production technology is the same as that of mat-covered board, the only difference is that the mats should be laid together with impregnated paper before and after forming shavings.

(3) Production technology of bamboo curtain chipboard coated with impregnated paper



2. Raw material and main points of production

(1) Impregnated paper

Titanium white paper is selected as surface paper, and sulphate pulp paper as sub-surface paper, about 100g/m2. If the supply of titanium white paper is short, it is permitted to use sulphate pulp paper as surface paper for reducing production cost. The resin content of impregnating is 80 ~ 120%, the content of volatile matter after drying should be 10 ~ 15%. To increase the alkali, acid and attrition resistance of the surface, the surface paper should be impregnated with melamine resin.

(2) The base-plate of bamboo chipboard and curtain chipboard

The base-plate must be of desired mechanical properties and fine appearance. It is preferable to smear phenol resin on the base-plate after abrasion if it is to be coated with only surface paper

(3) Hot pressing

Bamboo mat chipboard coated with impregnated paper is manufactured by one-step molding. The pressure temperature is 135 ~ 145℃, and the pressure is 4.0 ~ 4.5 MPa. To make the surface smooth and bright, the hot pressing should be implemented in the way of "cold loading and cold unloading". Bamboo chipboard coated with impregnated paper and bamboo curtain chipboard coated with impregnated paper are manufactured by means of two step molding. The pressure is 1.5 ~ 1.8 MPa and the pressing time is 10 ~ 12 min.

(4) Edge banding

After shearing, the four edges are to be banded with phenol resin or other kind of waterproof paint, which may improve its water vapor resistance and external appearance.

Appendix 5. Bamboo chipboard

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

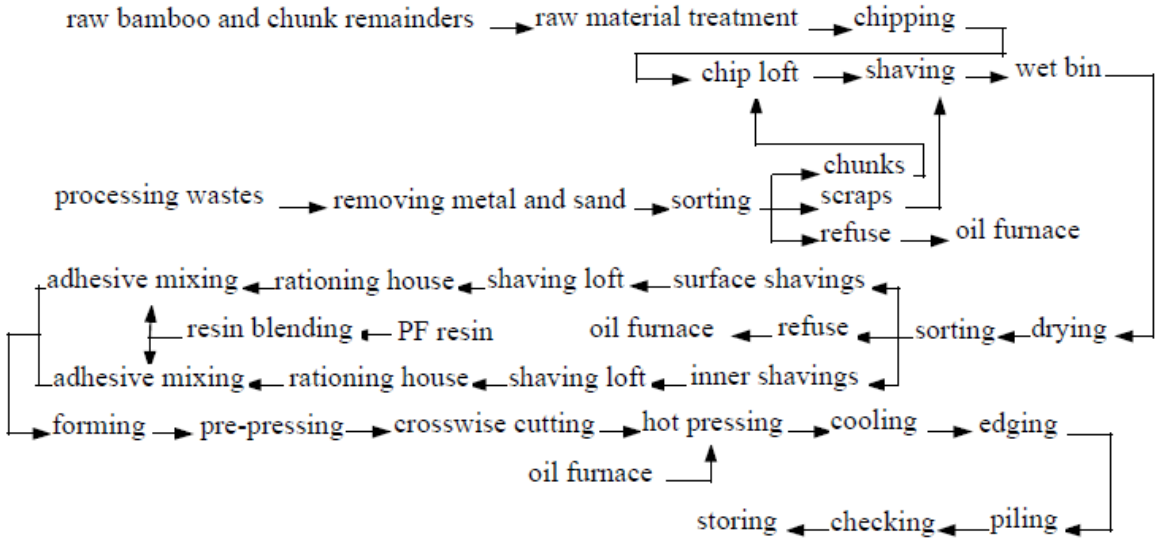
1. Definition and uses

Bamboo chipboard is formed of bamboo shavings as elementary units, which are dried, mixed with certain amount of adhesive and waterproof agent, spread, shaped and hot-pressed at a proper temperature with proper pressure. Shavings are made of small-sized bamboo culm and bamboo wastes. As negative effects of green and yellow matter on adhesion are weakened after shaving, the adhering quality of bamboo chipboard is high. The supply of raw material for making bamboo chipboard is abundant and its production is an effective way to raise utilization ratio of bamboo resources.

Bamboo chipboard is produced using water-soluble phenol resin, such a product has higher water tolerance, higher modulus of rupture and modulus of elasticity, and lower moisture expansion in thickness (compared with wood chipboard). Bamboo chipboard can be used as a kind of material for engineering construction. At present, it is mainly used for making ordinary concrete forms.

2. Production technology

Bamboo chipboard is made of three layers with high density. Its production technology is similar to that of wood chipboard. The production technology with hot oil as heating medium is as follows:



3. Raw material and its treatment

Raw material for making bamboo chipboard includes raw bamboo and processing wastes. Raw bamboo means bamboo culm of different diameter, processing waste can be divided into chunks and scraps. Chunks are bamboo culm tops, joints and nodes; scraps are bamboo chips, threads and broken bits. Chunks are to be made into special shavings, while scraps are sorted and regarded as factory shavings. The amount of factory shavings should not exceed 4/10, otherwise the strength of bamboo chipboard may be reduced.

The optimum water content of bamboo material for processing is 40 ~ 60%. Low content leads to the increase of broken bits, which may affect the quality of products. High content prolongs the drying time and energy consumption. If the water content is less than 40%, the material is suggested to be soaked in warm water of 50ºC in winter, and in tap water in other seasons. The impregnating time depends on the water content, it is about 2 hours in general.

If the content is higher than 60%, the piling time must be longer, the material can be

processed when its water content decreases to less than 60%. To guarantee continuous production the storage of raw material must be enough for 15 ~30 days' use. Raw material can be stored in an economy house. For keeping the freshness of raw material and avoiding moulds, the principle "first come, first used" should be observed.

4. The preparation of shavings

The lengthwise pulling strength of bamboo material is great while the crosswise is poor. The width of shavings is always larger than their thickness. Raw bamboo and chunks are made into pieces 30 mm in length. These pieces are converted further into special shavings 0.3 ~ 0.8 mm in thickness and 1.2 ~ 2.0 mm in width. The production practice has proved that cutter cylinder chipper and ring-type shaving machine are suitable for making shavings. The shape of shavings made on such machines is fit for producing bamboo chipboard, and broken bits are less in comparison with other machines.

Scraps from which metal and sand have been removed and sorted are transported into wet bin simultaneously with special shavings for proper mixing. The amount of scraps should not exceed 10% of the total weight.

5. Drying and sorting

Shavings are to be dried on a rotary dryer, the water content of dried shavings should be maintained at 2 ~ 6%. The dried shavings are sorted. Chunks are transported to shaving machine to be shaved further. Proper shavings are conveyed pneumatically to shaving lofts for surface and core layers respectively. Wastes are conveyed to oil furnace as fuel.

6. Mixing adhesive

For bamboo chipboard production water soluble phenol resin with higher primary viscidity is applied. The primary viscidity is extremely important when continuous prepressing is practiced on roll pressing machines and the hot pressing is implemented without metal plates. The quality indexes of adhesive used on a certain factory:

Solid content: 47% $\pm$ 2%.

Viscosity (20°C): 0.26 ~ 0.3 Pa.S; pH: 10 ~ 12; Free formaldehyde: ≤ 0.6%

Storage period: 2 months;

The recipe of waterproof agent (wax emulsion) by weight.

Wax: 100; Synthetic fatty acid: 5 ~ 2 (acid value ≥200)

Water: 150 ~ 200

Ammonia solution: 4.5 ~ 5.5

The quality indexes of wax emulsion:

pH: 7.0 ~ 8.5

Volume weight: 0.9 ~ 0.94g/cm^3

Wax density: 20 ~ 40%

Granularity: more than 90% of granules are ≤ 1 μ

Storage period: 3 days, not layered and not condensed.

Mix phenol resin with emulsion wax according to the recipe. The rate of wax utilization (the ratio between weight of solid wax and the absolute weight of shavings) depends on the quality of the product, it is usually 0.3 ~ 1.0%. The rate of resin utilization (the ratio between solid weight of adhesive and the absolute weight of shavings) is 9 ~ 12%. The rate should be lower if the shavings of core layer are larger; it should be higher if the shavings of surface layer are smaller. The amount of adhesive is calculated in accordance with the weight of shavings and the utilization rate; it is controlled with an adhesive pump.

The water content of shavings mixed with adhesive must be maintained at 9 ~ 16%. The water content of shavings in core layer should be a little lower than that of surface layer. The mixed shavings should not stored more than 2 days.

7. Forming and pre-pressing

Shavings are spread by means of airflow or on forming machine, which guarantee the evenness of density and smoothness of surface. Manual forming may cause the unevenness of density and deformation of products. The feeding and measuring system should be adjusted according to the density, thickness and structure of final products.

If the shavings are hot-pressed without metal plates, the pre-pressing can be implemented on a continuous rolling machine, connected with forming machine. If shavings are hot-pressed with metal plates, the pre-pressing can be implemented on a pressing machine of single tier (or to be hot-pressed without pre-pressing). The pre-pressed sets are more grain closed, of certain strength, which may prevent the crack and rupture in transportation. During pre-pressing the air is extruded from shaving sets and the thickness of sets is reduced, which decreases the space between hot-platens. The indexes of pre-pressing are:

Linear pressure of rolling machine: 1000 ~ 2000 N/cm

Unit pressure of pressing machine of single tier: 1.0 ~ 1.6 MPa

Compression rate of sets: 30 ~ 50%

Reversion rate of sets: 15 ~ 25%

Compression rate = $[(h_1 - h_2)/h_1] \times 100\%$

Reversion rate = $[(h_2 - h_3)/h_1] \times 100\%$

h_1 – thickness of spread sets

h_2 – thickness of sets after reversion

h_3 – minimum thickness of sets during pre-pressing

8. Hot pressing

Hot pressing is one of the key links in bamboo chipboard production, which influences the efficiency of production and quality of products directly. Hot-press can be of great size and single- or multiple-tier. At present pressing machines of multiple-tier are widely used. As the density of bamboo is higher than that of wood, higher pressure must be exerted to join the shavings together closely. In the process of hot pressing, three factors: pressure, temperature and time are influencing one another. If raise the temperature of hot pressing, the temperature gradient will be increased, the thermal transmission fastened and the heating time shortened. But too high temperature solidifies the adhesive over the surface shavings before the closing of platens and pressing operation. This leads to the loosening and shedding of surface shavings. The hot pressing indexes in bamboo chipboard production are as follows:

Pressing temperature: T = 160 ~ 180ºC

Pressing time: t = 0.4 ~ 0.7 min/mm of thickness of final product. In general it is fixed at 0.5 ~ 0.55 min/mm of thickness of final product

Unit pressure: P = 4.0 ~ 4.5 MPa

The final thickness of bamboo chipboard is controlled with a steel gauge.

9. Physico-mechanical properties

The density and strength of bamboo material are higher than those of wood, consequently, the density and mechanical properties of bamboo chipboard are also higher than those of ordinary chipboard. The physico-mechanical properties of bamboo chipboard are shown in Table 1.

Table 1. The physico-mechanical properties of bamboo chipboard

Properties	Unit	Index
Density	G/cm^3	0.85 ~ 0.95
MOR	Mpa	27~ 40
MOE	Mpa	3000 ~ 4000
Plane pulling strength	Mpa	0.7 ~ 0.8
Swelling rate of thickness	%	≤ 8

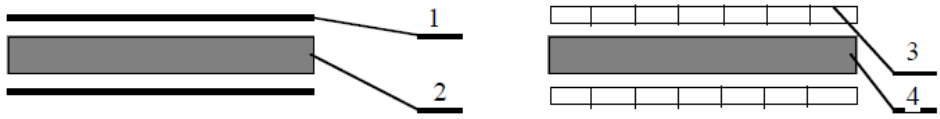
Appendix 6. Bamboo chip-strip board

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

The utilization ratio of raw material in bamboo chipboard production is high, and its production process is also highly mechanized. But its mechanical strength is low, volume weight is great and dimension stability is poor. In addition, it can be easily covered with mould. To eliminate these shortcomings, bamboo chip-strip board is developed.

1. Definition, classification and uses

Bamboo chip-strip board is formed of bamboo fibers as main elementary units, its core layer is made of shavings, while the surface layers are of bamboo strips or bamboo mats. Before hot pressing, shavings are mixed with, strips are coated with, and mats are impregnated with adhesive. There are two types of bamboo chip-strip board; mat-covered board and strip covered board. Mat-covered board is used to make concrete forms, strip-covered board is used as floorboard and bottom of trucks and buses. The structure of bamboo chip-strip boards is shown in Figure 1.

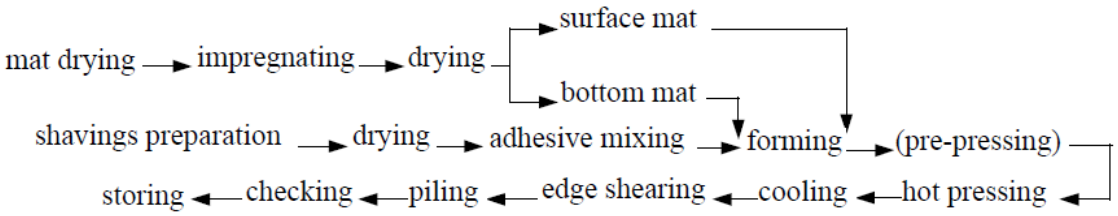


1. Bamboo mat, 2. Shaving layer, 3. Bamboo strips, 4. Bamboo chipboard
Figure 1. Structure of mat covered board (A) and strip-covered board (B)

2. Production technology

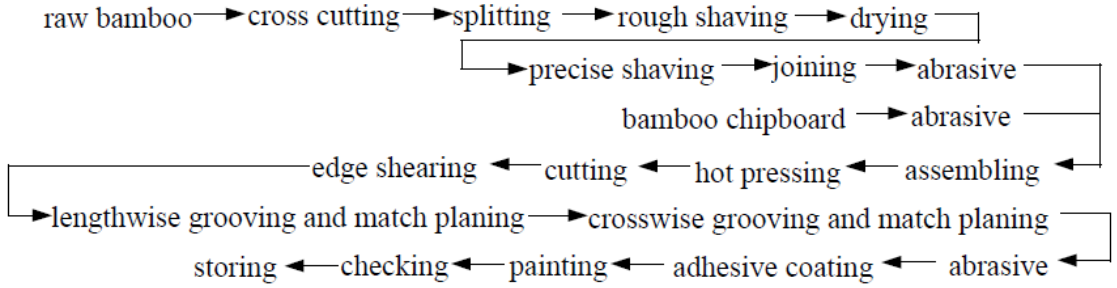
(1) Production technology of mat-covered board

The first step is to lay a impregnated and dried mat for forming shavings. Spread shavings on the mat and cover the shavings with another impregnated and dried mat for hot pressing and further processing. The flow scheme is as follows:



(2) Production technology of strip-covered boards

The production technology of strip-covered boards depends on their uses. The flow scheme of product to be used as floorboard is as follows:



3. Main points of mat-covered board production

As the surface layers are made of bamboo mats, the shavings can be spread not so precisely. In general machines with two forming heads are used. The assembled sets are hot pressed with

protecting plates. Before moving into forming machine the base plate must be covered with one or two impregnated and dried mats. Move the base plate with mats into forming machine. Spread bamboo shavings and cover them with other one or two mats. It is also suggested to lay a bamboo curtain when the shavings are spread to half of the predetermined thickness. This improves the shock resistance of products. The shock resistance is one of the most important parameters for judging the quality of concrete form.

4. Main points of strip-covered board production

For making strip-covered board the strips can be joined together with adhesive to form a whole layer, then to be assembled in the way as that of mat-covered board. It is also possible to produce bamboo chipboard first, sand and coat it with adhesive, then assemble it with coated lengthwise strip layers. The production process of strip layers is the same as that of bamboo strip of single layer. If the product is to be used as floorboard, attention should be paid to the color of strips. They can be bleached or carbonized in case of need.

5. Physico-mechanical properties

The indexes of physico-mechanical properties of bamboo chipboard and bamboo chipstrip board are listed in Table 1.

Table 1. Physico-mechanical properties of bamboo chipboard and bamboo chip-strip board

Properties	Density (g/cm^3)	Moisture expansion rate (%)	MOR (MPa)	MOE (MPa)	Plane pulling strength (MPa)
Product					
Mat-covered	0.85 ~ 0.96	≤ 8	40 ~ 65		
Strip-covered	0.96	2 ~ 3	70 ~ 90	7000 ~ 8000	2.0 ~ 3.0

Notes: 1. The MOR and MOE of strip-covered board are measured in lengthwise direction. 2. The thickness of strips is 4.5 mm, the thickness of strip-covered board is 18 mm.

This table demonstrates better mechanical properties of bamboo chip-strip boards as a result of strengthened surface layers. The lengthwise strength of strip-covered board is especially improved because of the strips of proper thickness arranged in one and the same direction. This kind of board is suitable for making floorboard and bottom of vehicles. Mat covered board is fit for making concrete forms due to its uniform strength.

Appendix 7. Bamboo furniture

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

Furniture is one of basic necessities of human life, it should be both practical and decorative, and in harmony with the indoors environment. The production and use of bamboo furniture has a long history in China. Bamboo furniture is imbued with oriental local colour, in simplified and elegant style, cool and comfortable. It is widely used in China and abroad.

Traditional bamboo furniture is made by means of traditional techniques such as crooking, reinforcing, connecting, holing, tenoning, mortising and board covering. Bamboo furniture includes stools, benches, chairs, tables, cupboards, beds and bookshelves. With the technological innovation and development of bamboo industry, particularly the research and development of bamboo based panels, the structure and modelling of bamboo furniture is being diversified and embellished. Modern bamboo furniture is full of traditional taste on one hand and convenient and comfortable on the other. The manufacturing technology of modern furniture of bamboo based panels is similar to that of wood furniture, therefore, it will not be discussed.

Bamboo grows rapidly, it is noticed for its high strength, toughness and rigidity. But it has some shortcomings, which can hardly be overcome, such as small diameter, hollow culm and numerous joints. Therefore, bamboo material can not be made into plain boards for furniture making as wood. Bamboo poles are to be crooked, reinforced and connected to make frames of furniture, then the frames to be covered with bamboo planks. To toast poles over fire and crook them, to make frames by means of tenon and mortise, to reinforce the frame with additional poles, to arrange bamboo planks on the frame and to embellish the furniture with curved pieces. All these operations are traditional techniques for making bamboo furniture.

I. Techniques and tools for making traditional bamboo furniture

Traditional bamboo furniture items are made of *Phyllostachys pubescens* Mazel ex H. de Lehaie, *Pseudosasa amabilis* (McClure) Keng f., *Phyllostachys heteroclada* Oliver, *Bambusa textilis* McClure, *Neosinocalamus affinis* (Rendle) Keng f. or *Phyllostachys sulphurea* cv. Viridis according to their specific features. Traditional bamboo furniture items have a rich diversity, they are of different forms, but of similar structure. All of them are made of frames and planks. Frames embody the form of furniture and bear the load of furniture. Therefore the design of frame defines the quality of furniture directly.

1. Tools for making traditional bamboo furniture

"A workman must first sharpen his tools if he is to do his work well." Traditional bamboo furniture is made with special tools. In order to make such furniture, it is necessary to know the special tools. The techniques for making traditional bamboo furniture are a category of handicraft art. Although there are some special machines developed in this field, such furniture is made mainly manually. As the area of bamboo furniture making is widespread, the tools are also highly varied.

A. Knife for cutting thin strips

This is an important tool for bamboo furniture making. Culm cutting and slicing are carried out by means of such knives. The knife blade is 26 cm in length and the handle is 12 cm. The end of blade is hook-shaped, which is applied to remove bamboo joints. The back of knife blade is quite thick, about 1.5 cm, which improves the efficiency of operation (Figure 1).

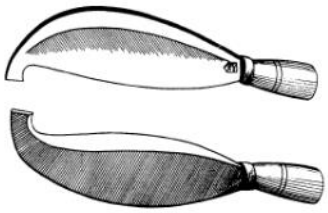


Figure 1. Knife for cutting and making slivers

B. Pointed knife

Pointed knife is a tool frequently used for hole opening, peeling, sharpening, frame making, assembling and clearing. Pointed knives are small and easy to use. The blade must be sharp (Figure 2).

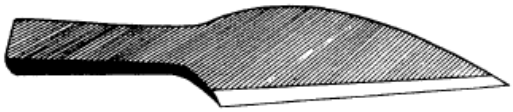


Figure 2. Pointed knife

C. Scraper

Scraper is a specialized tool for removing wax cover of bamboo. The blade is of arc shape, with two wood handles for operation (Figure 3).

Figure 3. Scraper

D. Gouging tool

Gouging tool is specially applied tool to scoop out mortise fro assembling (Figure 4).

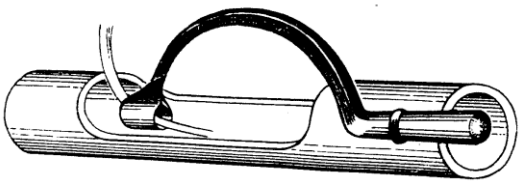


Figure 4. Gouging tool for scooping out mortise

E. Plane for removing bamboo joints

This is a specialized tool for removing flange of bamboo joints (Figure 5).

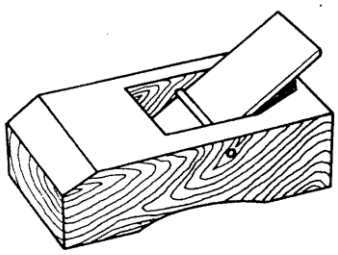


Figure 5. Plane for removing bamboo joints

F. Line plane

This is a tool similar to planes used in woodworking, but it is comparatively light and handy (Figure 6).

Figure 6. Line plane

G. Splitter an chisel

Splitter and chisel are used for splitting bamboo culm into strips of required width. The splitters is 12 cm in length and 3 cm in width. The width of splitter blade is about 0.5 cm. The blade with an iron handle does not need to be very sharp. The chisel is similar to that used in woodworking, but light and handy (Figure 7).

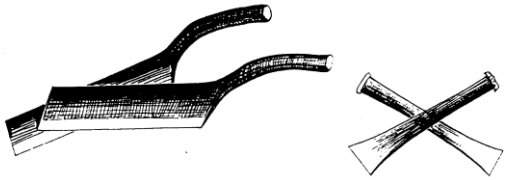


Figure 7. Splitter and bamboo chisel

H. Round chisel and squire chisel

Both the chisels are used for makiing round and square holes on bamboo material for assembling bamboo furniture. The size of square holes can be 3, 6, 10 mm and more (Figure 8).

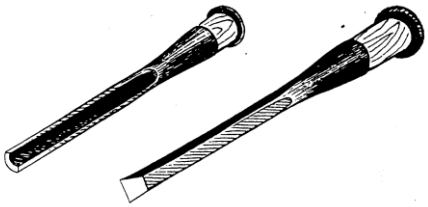


Figure 8. Gouge and square chisel

I. Hand saw

Hand saw is applied to cut bamboo culm and bamboo pieces, or to slit bamboo material according to the requirements of furniture design. The saw blade must be thin and saw-teeth be fine (Figure 9).

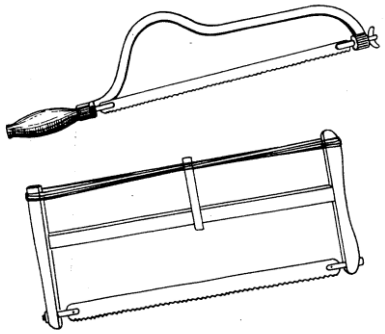


Figure 9. Hand saw

J. Slitting saw

Slitting saw is applied to slit the surface of furniture parts for connection (Figure 10).

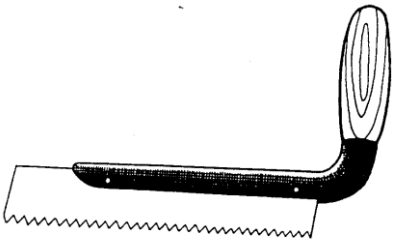


Figure 10. Surface saw

K. Hand drill

Hand drill is applied to drill holes on bamboo material. Before pushing bamboo nails into bamboo strips or tubes it is necessary to make holes for them. Therefore hand drill is a kind of tools most in use. As bamboo culm wall is thin and can be broken easily, the bit must be very sharp amd of different sizes (Figure 11).

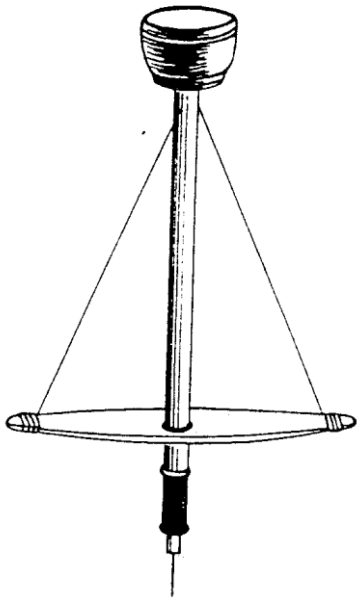


Figure 11. Hand drill

L. Hammer

Hammer is applied to drive nails into furniture parts, it must be light and handy in comparison with that used in woodworking.

M. Bending column

Bending column is a kind of auxiliary tool for bending bamboo tubes. A wooden column is made in T shape, the width of column is about 13 cm and the length is about 250 cm. Several holes are made on the height of 120 ~ 140 cm. The diameter of holes is 3 ~ 5 cm. Bamboo tubes to be bend are inserted into holes and heated with fire for bending (Figure 12).

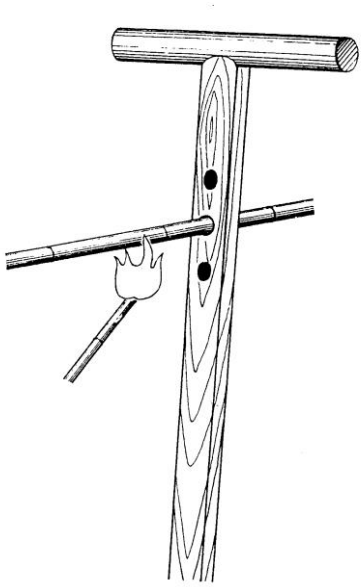


Figure 12. Bending column

2. Bending bamboo tubes

Bamboo tubes can be bent by menas of heating or making groove.

A. To bend bamboo tubes by heating

Bamboo material is of certain plasticity. Its plasticity can be improved by raising temperature with enough water content. In this way the natural color of bamboo and its physical strength will not be seriously affected. Consequently, most parts of bamboo furniture are bent by means of heating. This method is particularly fit to bamboo tubes of smaller diameter.

There are several ways to bend bamboo tubes. The most popular one is fire heating. Put bamboo tubes over fire to raise its temperature, then bend them when warm. They will keep bent when cooled. Tubes to be bent should be of small or medium diameter. Their length is decided according to the furniture design with certain surplus. The green surface and wax cover are removed after bending. The fuel applied for heating must not cause black smoke, therefore the tubes will not be blackened by heating fume. Heat a selected part of bamboo tube over flame to soften it. When bright oil drops appear on its inner surface, bend it slowly to form the required curve. Soak the bent tube in cold water for 1 ~ 3 min to decrease its temperature rapidly and recover its physical strength. It should be mentioned that the tube over flame during heating must be moved back and forth to make the heating evenly. The heating time should not be too long, in order to avoid the charring of tube, which may affect the strength of tube and the service life of the final product (Figure 13).

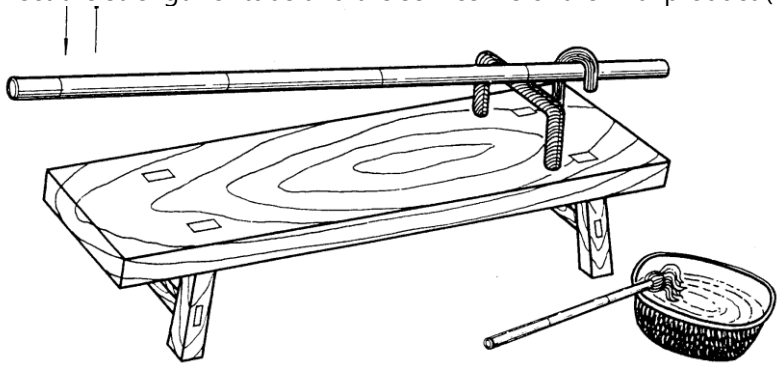


Figure 13. Bamboo straigthening stand with fire

The heated tubes may be put in setting moulds for cooling in industrial massive production. Bamboo tube can also be heated and bent with steam. Insert bamboo tubes into mechanical moulds in heat vessel, bring in steam and bend the tubes under high temperature to form the predetermined curve. To avoid the breaking and deformation of tubes resulted from the change of stress, it is recommended to remove the inner partitions of bamboo culm and input hod sand for bending.

B. To bend bamboo tubes by making groove

This method is applied for bending tubes of larger diameter. The process is rather complicated and it may affect the strength of bamboo parts. The size of grooves is calculated in accordance with the predetermined curve. There are several ways for bending:

(1) Broken line bending
This way of bending is shown in Figure 14.

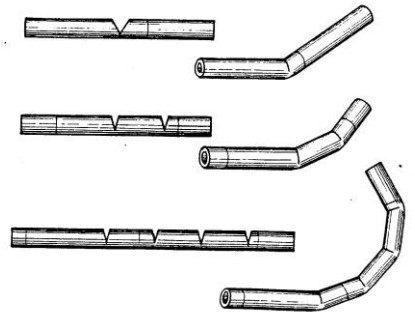


Figure 14. Broken line bending

$D \geq r\ 4/3$

D – diameter of bent part
r – radius of breaking angle
n – number and breaking angles

Depth of groove: $D/2 \leq h \leq 3D/4$
Radius of groove: $R = r = h$
Length of groove: $L = 2 \pi r + 2 (n -1) r – 2R$
Regular breaking bending

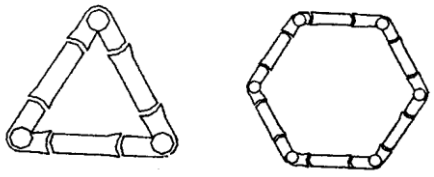


Figure 15. Regular breaking bending (3 angles, 6 angles)

In this way tubes can be bent into several angles, three or six or more. The angle is expressed as α (Figure 15)
Length of groove: $L = 2 \pi r – \alpha \pi r/180^o$
Radius of groove: $R = r$
Depth of groove: $h \leq r + r \sin (\alpha /2)$
Breaking angle: $\beta = 90^o + \alpha /2$
In general, the form of 3, 4, 5, 6, 8, 12, 18 angles are most frequently applied. The data for such bending are shown in Table 1.

Table 1. Data for regular breaking bending

Number of angles	Angle α °	Length *L*	Angle β °	Height *h*
3	60	5.23 *r*	120	1.50 *r*
4	90	4.71 *r*	135	1.71 *r*
5	108	4.39 *r*	144	1.81 *r*
6	120	4.17 *r*	150	1.87 *r*
8	135	3.92 *r*	157.5	1.92 *r*
12	150	3.66 *r*	165	1.97 *r*
18	160	3.49 *r*	170	1.98 *r*

(3) Triangle bending

In the inner part of bending cut even triangle groves, bend the part after heating over fire, then cool for recovering the strength. This method is also applied for processing tubes of larger diameter. The shortcomings of this method are as follows: the strength of tube may be affected and the process is quite complicated. The triangle bending can be carried out in round form and angle round form.

a. Round form

Turn the tube into round form after bending (Figure 16). The bamboo tubes of this form are made ad part of round table, chair or stool. In general these pats are wrapped round with a belt. The number of grooves is n.

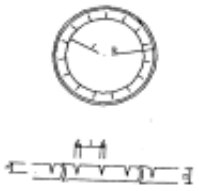


Figure 16. Round bending

Length of wrapping belt: $L = 2\pi R$ + length of joint
Net length of wrapping belt: $L\ R\ n = 2\pi$
Depth of groove: $D/2 \leq h \leq 3D/4$
Width of groove: $d = 2\pi h/n$
Space between groove: $I = 2\pi r/n$

b. Angle round form

Turn the tube into an angle for making handrail of armchair or corner of side table (Figure 17).

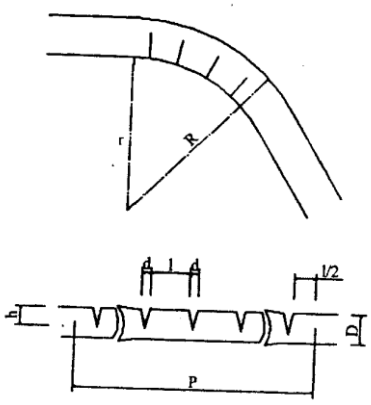


Figure 17. Angle round bending

The data for bending are calculated as follows:
n - number of grooves
Length of bent part: $P = \_\pi R/180^{o}$
Depth of grooves: $D/2 \leq h \leq 3D/4$
Width of grooves: $d = \_Jlh/180^{o}n$
Space between grooves: $I = \_Jlh/180^{o}n$

Determine the length at first, then the number of grooves and the space between grooves. If the some grooves are made too large, it is necessary to fill in the gaps with bamboo pieces or glue.

3. The reinforcement of bamboo framework

It is difficult to make framework from single bamboo tubes for furniture. In order to improve the strength of bamboo furniture, the framework must be reinforcement by parallel connection of bamboo tubes. The parallel connection of bamboo tubes improves the load capacity of furniture and makes it good looking and comfortable. To carry out parallel connection, the first step is to cut the surface of bamboo tubes for connecting and arrange them in parallel order, then bore holes through tube wall with hand drill and insert bamboo nails to connect them (Figure 18).

Figure 18. Parallel connection

It is important that the bamboo nails must be driven in different directions to raise the connecting strength. After connection use a hand saw to mend the ends of nails and edges of connected parts, then sand their surface.

4. The combination of bamboo parts of framework

Bent parts are to be combined with other bamboo tubes or pieces to form a framework of furniture in the way of end combination, T combination, parallel combination, inlay combination, cross combination, L combination. End combination is applied to prolong the tubes of same diameter or to close the framework. The ends of tubes to be combined must be cut evenly, then select a piece of bamboo tube with diameter similar to or smaller than the internal diameter of combined tubes. Glue the selected tube and insert it into the end holes of bamboo parts to be combined. Combine the two

parts closely, drill holes in different directions and insert bamboo nails, cut the projecting ends of nails (Figure 19).

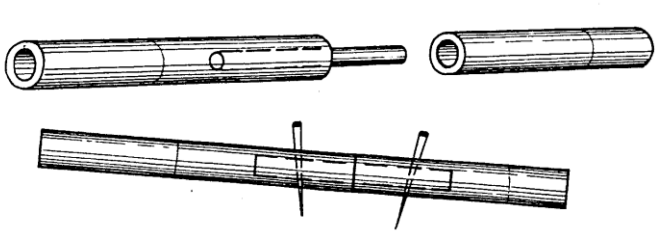


Figure 19. Ends connection with straight

If combined tubes are bent, the insert tube should be in the same bent form (Figure 20).

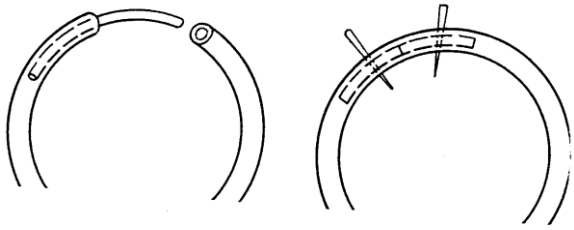


Figure 20. Ends connection with bent

If combined tubes are of different diameter, select a piece of bamboo according to the internal diameter of thicker one. Insert one end into the thicker tube, then cut the other end to fit the thinner one. The end of thicker tube must be mended to make it similar to the thinner one.

If the diameter of tubes to be combined differs greatly, the method of combination will be introduced in the next section. Bamboo nails applied for combination are made of thick wall of dried bamboo culm. The nails are about 10 mm in length (Figure 21).

Figure 21. Bamboo nails

Appendix 8. Decorative pattern on framework of bamboo furniture

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

The frameworks of bamboo furniture are to be reinforced and decorated after completion. Decorative pattern of small bamboo pieces is a frequently used variant. Select the branch and top of thin bamboo culm to fill the gaps of frameworks. By means of decorative patterns, there will be small-sized frames within larger frames. This embodies the oriental artistic style. There are a great variety of decorative patterns, most popular ones are "*" form pattern, "long life" pattern, "double foot" pattern, plum pattern. In general they are used for making furniture of high and middle grades (Figure 1).

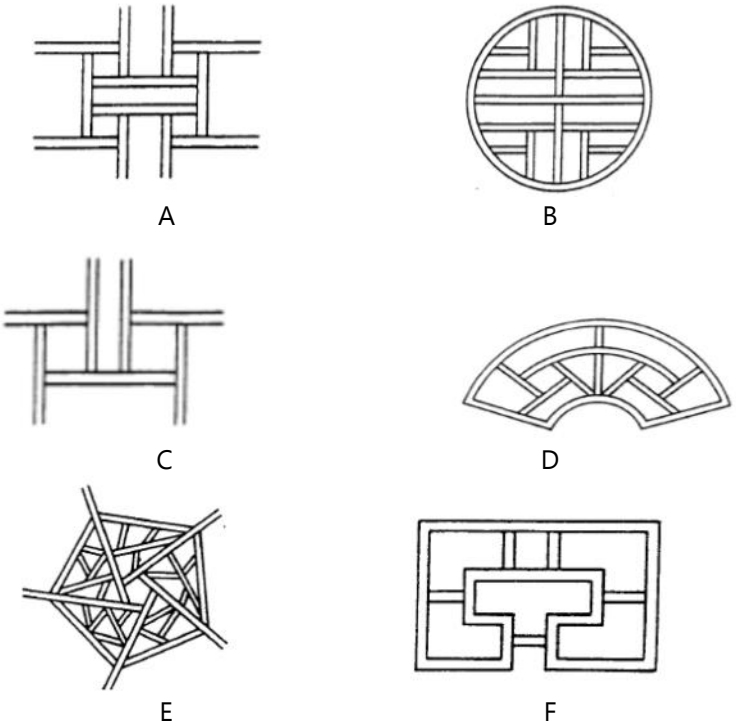


Figure 1. Double foot (A), long life (B), tied (C), fan (D), iced plum (E), satisfactory (F) patterns

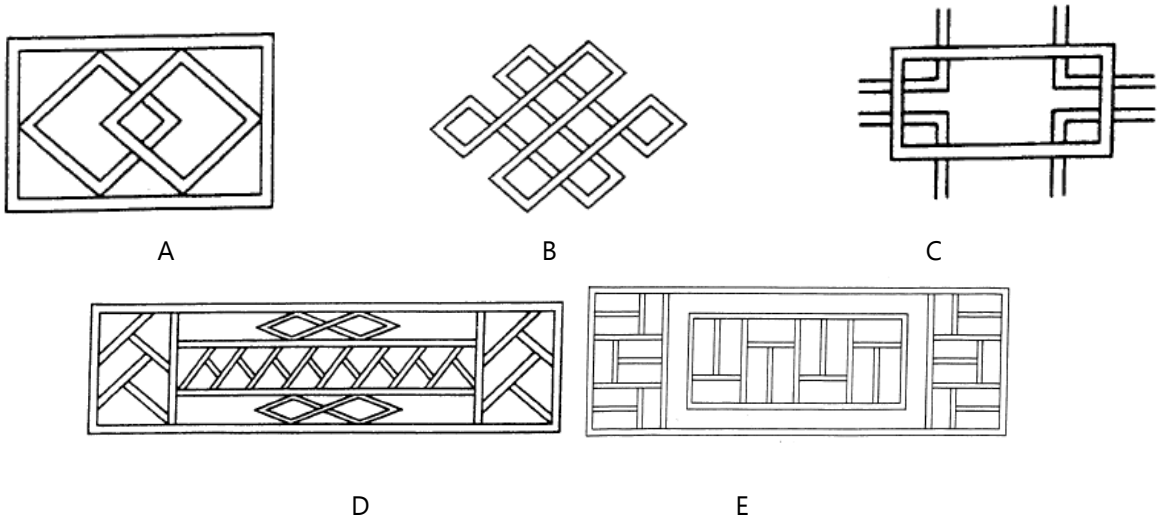


Figure 2. Double diamond (A), winding paths (B), connected rectangle (C), diamond and λ form (D), rectangular road and bridge (E) patterns

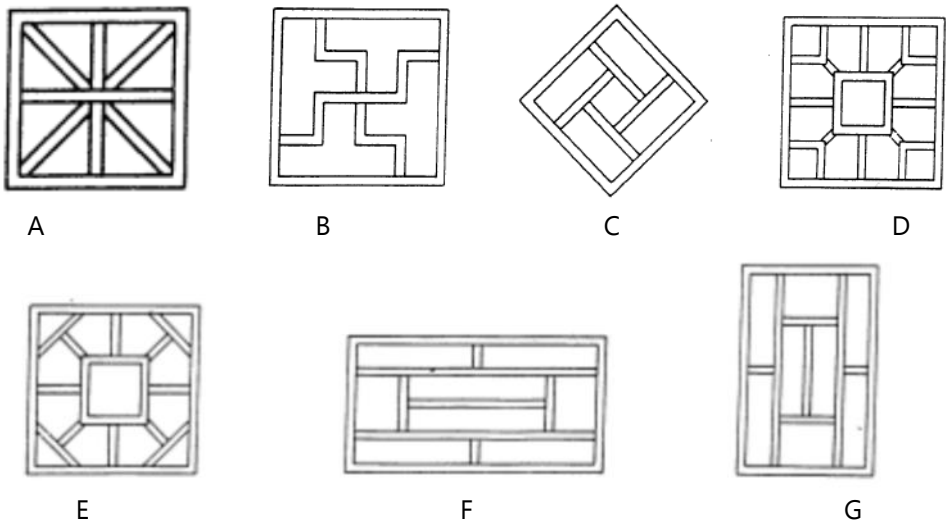


Figure 3. Star (A), ten thousand (B), oblique (C), tortoiseshell 1 (D), tortoise shell 2 (E), horizontal road and bridge (F) and vertical road and bridge (G) patterns

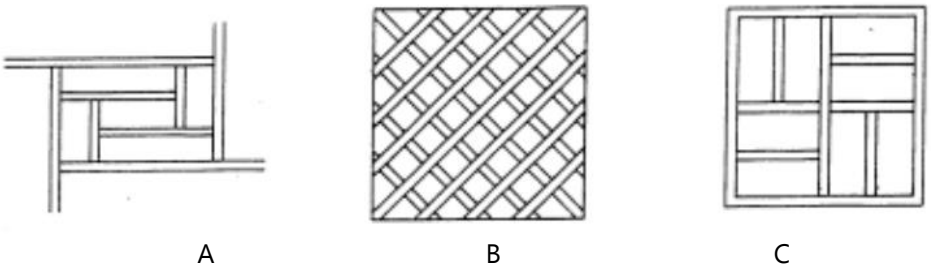


Figure 4. connected rectangle (A), inclined square (B), square road and bridge (C) patterns

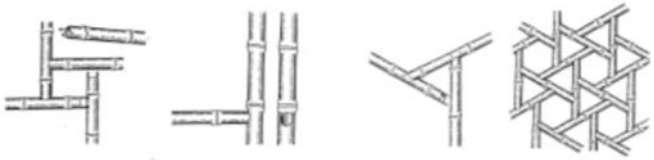


Figure 5. Tube's dowel ad joint 1 (A), tube's dowel and joint 2 (B)

Techniques for making decorative patterns are comparatively complicated, the process for making different patterns are similar in some aspects, but different in others. They should be made in accordance with the furniture design. Material for making decorative patterns is selected carefully. Branches for making one and the same pattern must be of same thickness, and cut and arranged in the light of design. Decorative patterns are generally assembled by means of dowel and mortise joint. Before shaping the dowel, it is recommended to consider the direction of pattern and turn the better part of branch outside. Determine the position of dowel and mark signs with ink. Then make the dowel. If both the ends of a piece are to be made into dowel, they should be made at the same time.

Mortise holes should be made accurately, strictly according to the size of dowels. Check every part of decorative pattern when they are put together, change or mend the unsuited ones. Some of the parts can not be connected by dowel and mortise joint, they can be connected with glue joint. The bevel faces of pattern parts are jointed with glue and a bamboo nail as a rule. The last step is the installation, it is to insert the decorative pattern into the framework of furniture. It is necessary to have a trial insert to make sure that the pattern is fit. Then mark signs of mortise holes on framework and drill the holes, separate the pattern into parts, install the pattern into the framework part by part reinforce the joints with nails.

Appendix 9. The making process of traditional bamboo furniture from China

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

This section is explaining the making process of traditional bamboo furniture from China.

1. Bamboo stool

Bamboo stool is an item of bamboo furniture of simple structure. One of it is shown in Figure 1. Its framework, including legs are of single tube, without any sustaining tubes, thus saves labor and raw material. It is necessary to choose bamboo of larger diameter to make stools. The stool shown in Figure 1 is 30 cm in length, 22 cm in width and 30 cm in height.

Figure 1. Bamboo stool

The first step is to make the scat of stool.

- Select two bamboo tubes 30 cm in length and 4 cm in diameter. Drill three mortise-holes 2~3 cm in diameter on each of them. One mortise-hole is in the center of tube and other ones are 6 cm from both ends.
- Select three tubes 21 cm in length, their diameter must fit the above-mentioned mortise holes.
- Insert the ends of these tubes into the mortise-holes. It is necessary to make mortise-slit on every side tube for forming seat plate. As the seat is of small size, it is recommended to select bamboo strips between joint-knots to avoid the knots appeared on seat plate.

The second step is to make legs of stool.

- Select two main tubes 80 cm in length and 4 cm in diameter. Cut out two grooves on each of them for making bent mortise. Bend the main tubes and fit the ends of seat tubes into the bent mortises. The length of stool leg is 26 cm, from bent mortise joint to the end of main tube. Tie the legs of stool with a rope to avoid falling to piece until a rectangular collective bent mortise is made (Figure 2). The third step is to make rectangular collective bent mortise.

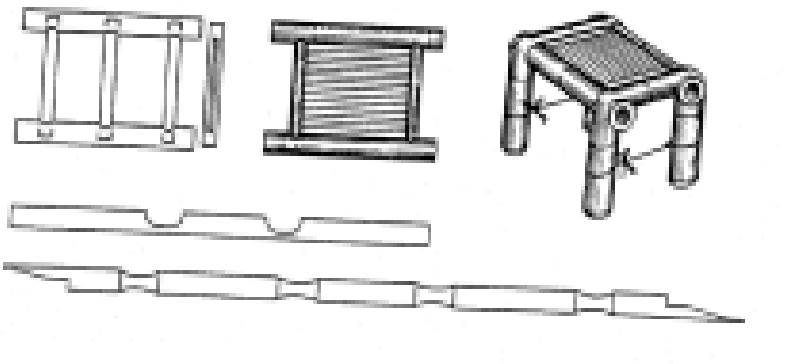


Figure 2. The making process of bamboo stool

- Select a tube 100 cm in length and 4 cm in diameter to make rectangular collective bent mortise, joint the legs on the height 5 cm from the earth (Figure 2).

2. Bamboo chair

Bamboo chairs can be made easily. Light, sturdy and highly diversified, they are well receives by consumers, and are a most popular item of bamboo furniture. An armchair is shown in Figure 3. It is of simple structure and plain shape, imbued with local color. Such a chair consists of two parts, the lower part is a square stool, the upper one is a back with armrest.

Figure 3. Bamboo armchair

The first step is to make a square stool.
The square stool is made in the way mentioned above, its size is 50 cm in length, 45 cm in width and 40 cm in height. The legs should be slightly inclined outward to make the chair stable (Figure 4).

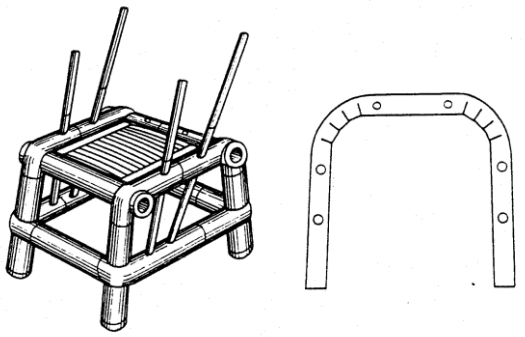


Figure 4. The making process of bamboo armchair

The second is to make the back with handrail

- Select a bamboo tube 5 cm in diameter, bend it into the form as shown in Figure 4 with four saw kerves of acute angle on each bent part. This tube is used for armrest and to connect the back of chair.
- Select 4 tubes 2 ~ 3 cm in diameter, install them on two sides of square stool reciprocally in the way as shown in Figure 4.
- Cut out mortise holes on the tube for armrest and connect it with 4 tubes by means of mortise joint.

The last step is to make the back of chair according to Figure 3.

- Select 2 tubes, stand them upright on the rear edge of seat and connect them with the tube for armrest.
- Insert 2 parallel tubes between upright tubes horizontally. Make one slit on each of the parallel tubes, insert bamboo strips of proper length, form a facial plate for back (Figure 3).
- Thus the chair is completed.

Figure 5 shows a traditional bamboo chair from China. The length of seat is 38 cm, width is 32 cm, the height is 36 cm. The height of chair back is 38 cm. Such a chair is made in the same way as making above-mentioned chair.

Figure 5. Traditional bamboo armchair

3. Square bamboo table

Square bamboo table is of comparatively simple structure. The top of table is on the height of 70 ~ 80 cm. The diameter of frame tube should be 3 ~ 4 cm.

The first step is to form the framework.

- Select four straight bamboo tubes of same thickness to be used as legs, 70 ~ 80 cm in length.
- Select three tubes with the same thickness as that of legs. They are used to provide upper, middle and lower closed bent mortises. Cut out 4 grooves on them for making bent mortise. The position of mortises is decided in accordance with the size of table.

The tube of upper closed bent mortises is to support the top of table. Therefore the ends of this tube is to be connected with bamboo plug to guarantee the evenness of top. The legs must have knot joint on their upper part near the end, otherwise they may be damaged by bent mortise. If the upper part of leg does have knot joint, fill in a wood or bamboo plug to prevent the possible damage. For making framework of table, connect the upper tube of closed bent mortise with four legs by means of bent mortise joint. Number the mortise grooves and bent them in order to joint them with legs. The tube of closed bent mortise should be perpendicular to legs. After the completion of bent mortises drive in bamboo nails for stable connection.

Connect middle and lower tubes of closed mortise in the same way as that for the upper one. The middle tube should be positioned closely to the upper tube. These two tubes are to be treated together for supporting the top of table. The lower tube of closed bent mortise is to be put 15 cm under the middle (Figure 6). The lower tube of closed bent mortise is to be put 15 cm under the middle (Figure 6).

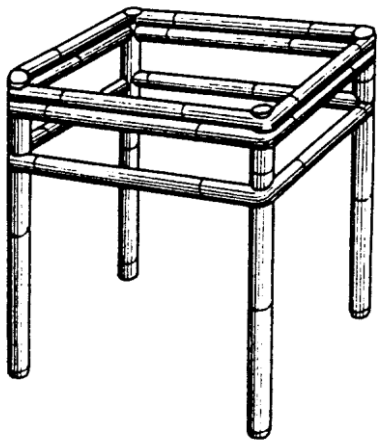


Figure 6. Framework of square bamboo table

The second step is to reinforce the framework.
Three measures are to be taken:

A. The upper tube of closed bent mortise is for supporting the top of table. It should be reinforced with slightly thinner lining tubes. Two of them are positioned closely to the upper tube, other two of them are in the central part to support strips of top (Figure 7).
B. Insert vertical short tubes between upper and middle tubes of closed bent mortise by means of single dowel joint on one end and without mortise joint on the other (Figure 6).
C. Select four long tubes to support the framework, fix each of them closely to one leg and the lower tube and then to the opposite leg, forming a "doorframe" (Figure 7).

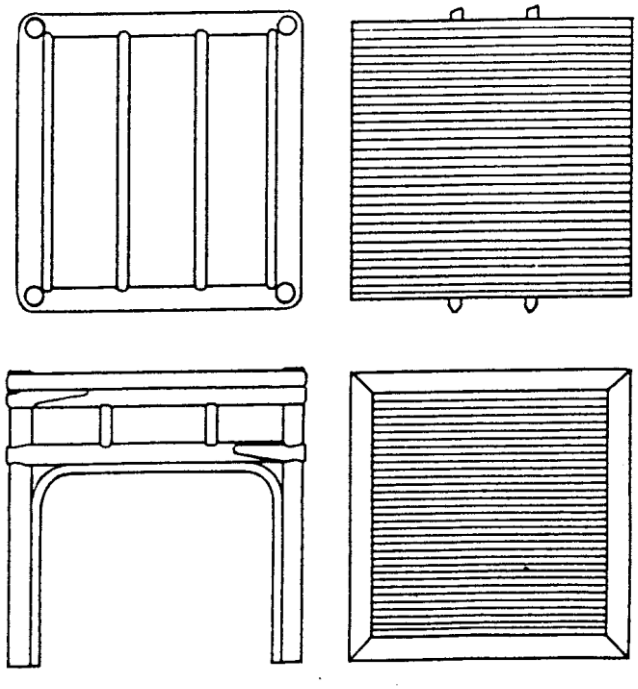


Figure 7. Making process of square bamboo table

The third step is to make the top of table

The strips for making facial plate as the top of table are cut from bamboo culm of larger diameter. The area of facial plate is slightly smaller than the inner area within the upper tube of closed bent mortise. The direction of strips is perpendicular to that of lining tubes. The edges of facial plate should arranged closely to the inner face of upper tube. Prepare four bamboo strips 4.5 cm in width, their length is equal to that of the edge of table. The ends of strips are cut into 45°, fix them to the upper tube with bamboo nails (Figure 7). The square bamboo table is made in this way (Figure 8).

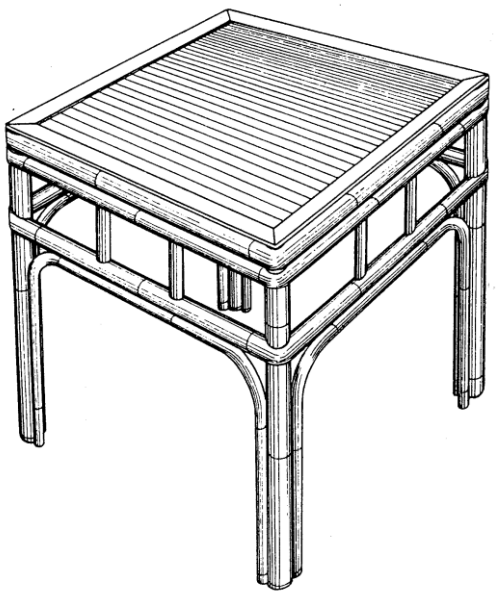


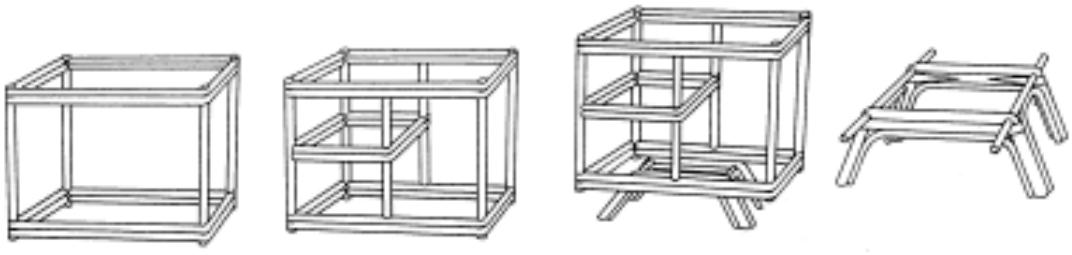
Figure 8. Square bamboo table

4. Bamboo cupboard

As bamboo culum is a hallow tube, its strength is lower than that of wood, therefore the cupboard of bamboo can not be of large size. Figure 9 shows the making process of a popular bamboo cupboard, it is made in three steps.

The first step is to make the framework of cupboard.

- Select four bamboo tubes of same thickness to be used as uprights, number them in a numerical order for connecting with a tube of closed bent mortise properly and firmly.
- Select four tubes of the same thickness as that of upright tube, they are to be used to make closed bent mortises, the length of these tubes are decided according to the size of cupboard.
- Two tubes of closed bent mortise are positioned on the top of framework close to each other, and the other two tubes are on the bottom of framework, also close to each other (Figure 9A).



A B C D

Figure 9. The making process of bamboo cupboard

Install one vertical tube in the center of the front frame and one in the rear frame. Select two tubes to connect the center of these vertical tubes by means of bent mortise, the ends of the tubes of bent mortise are to be inserted into the mortise holes on upright tubes of one side of the framework. Select two short tubes to connect the two upright tubes on the mortise holes. These tubes are used to support facial plates (Figure 9B).

The second step is to make the base of cupboard.

- Install two crosswise lining tubes in the lower tubes of closed bent mortise. Two grooves are cut out on each of two thick base tubes to form pentagon bent mortise. The length of groove is of the perimeter of crosswise lining tubes. The ends of base tubes stretch outward to

support the cupboard firmly. In order to reinforce the base tubes with bent mortise, two lining tubes are used to support them, and arrange lining tube between every two opposite legs. Tie theses parts with rattan if possible (Figure 9C and 9D).

The third step is to make facial plates.

- Prepare lining strips for facial plates on top, bottom, back, sides and partition, the length of lining strips equals to the lengthwise side of every rectangle form.
- There are seven facial plates on this cupboard. The ends of strips are to be inserted into the shorter side tube.
- The strips must be arranged correctly and closely. The ends of strips should be fixed in the slit or holes of side tubes.

As a rule, bamboo cupboards are not equipped with doors, because bamboo material is not fit for making a door. Instead of doors textile curtains are hung (Figure 10).

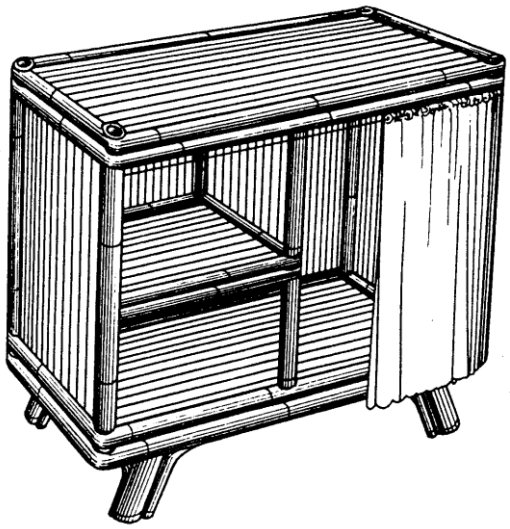


Figure 10. Bamboo cupboard

5. Bamboo bed

Beds made of bamboo are cool, they are very popular in southern parts of China in summer. Most bamboo beds are single because of their heavy load. Figure 11 shows a single bamboo bed. It is made in three steps.

The first step is to make the framework of bed.

- Select four bamboo tubes of same length, 5 ~ 6 cm in diameter to be used as legs of bed.
- Number them in numerical order.
- Select six bamboo tubes of same length, 4 ~ 5 cm in diameter. Put three tubes together to make bent mortises for jointing two legs. The ends of every three tubes are connected to form rectangle closed mortise and fix them with bamboo nails (Figure 11).

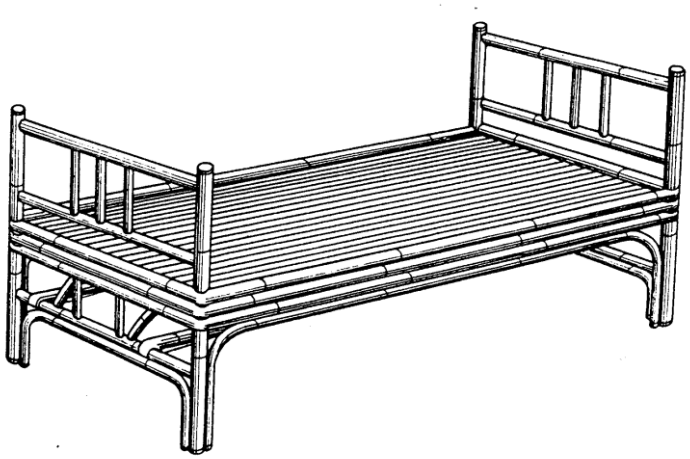


Figure 11. Single bamboo bed

The second step is to reinforce the framework.

- Select bamboo tubes of thick wall, 4 cm in diameter, use them as crosswise lining material on both short sides.
- Select tubes of thick wall to connect every two opposite legs with tube of bent mortise in the form of doorframe on four sides (Figure 12).
- Make 8 semicircular strips for inserting into the rectangular frame of bed as lining material (Figure 12).
- Select two tibes to reinforce the framework in bent form, they are used to support the crosswise semicircular stris, connected with the strips and other parts of framework by means of mortise joints.

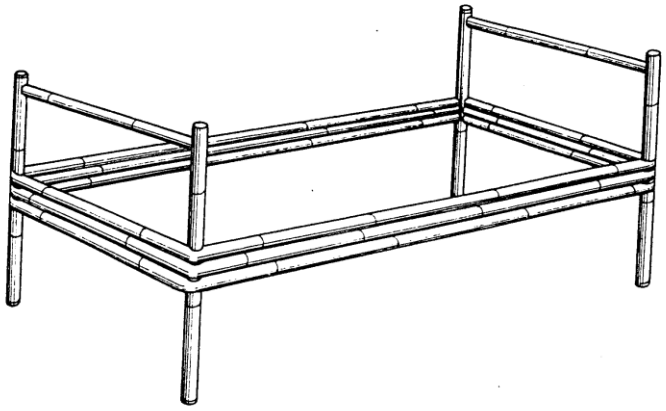


Figure 12. Framework of the bamboo bed

The third step is to make the base of bed.

The area of base is quite great, therefore it is necessary to select bamboo of larger diameter to cut strips. The strips are to be connected with a string through drilled holes to form the base plate, this plate is to be fixed on the crosswise semicircular strips and connected with the upper tube of bent mortise (Figure 11).

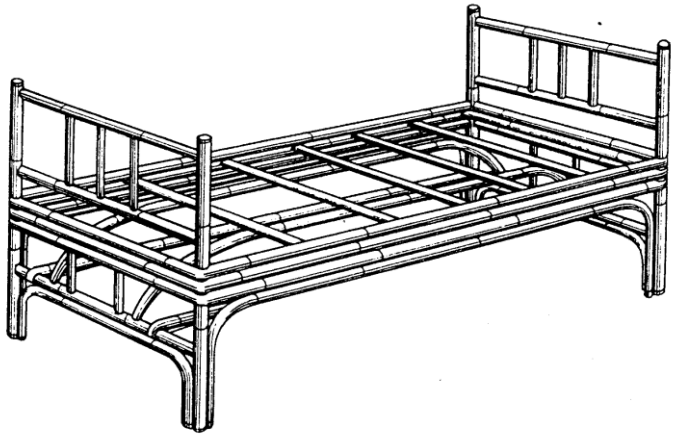


Figure 13. Reinforce the framework

Figure 14 shows a simple bed, which is common in Zhejiang, China. It is 190 cm in length, 72 cm in width and 46 cm in height. The framework is composed of single bamboo tubes, they should be thick, 6 ~ 7.5 cm in diameter, the diameter of lining tubes should be 3 ~4 cm. Make such beds are quite easy:

- Select two bamboo tubes 190 cm in length, 6 ~ 7 cm in diameter. Cut out 7 ~ 8 semicircular on each of the tubes, insert 7 ~ 8 semicircular lining strips 70 cm in length into the holes of these two tubes to form a frame of the base.
- Select two tubes 164 cm in length, 6 ~ 7 cm in diameter, cut two grooves for making bent mortise on each of these tubes. The length from bent mortise to the end is the leg of bed.
- Meanwhile make mortise holes on legs for jointing with lining tubes. The joints should be strengthened with bamboo nails.
- Make base plate of bed according to the inner length and inner width of frame. Fix the plate on the frame with bamboo nails (Figure 14).

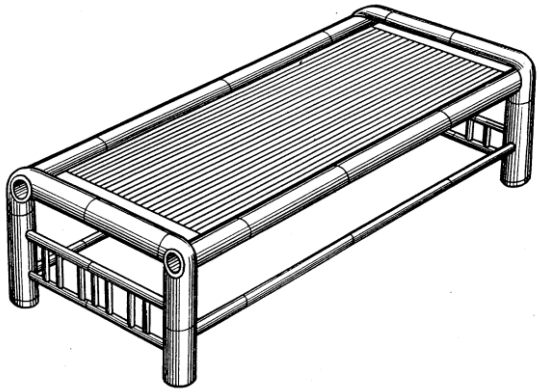


Figure 14. Simple bamboo bed

6. Bookcase and mini-landscape stand

Bookcases and mini-landscape stands embody the beauty of bamboo. By means of bending and connecting bamboo bookcases and mini-landscape stands can be made in diversified forms. They are well received by users. Figure 15 shows a common bookcase of four shelves. It is made in three steps.

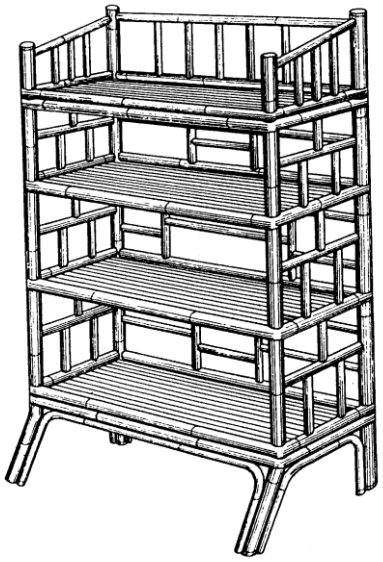


Figure 15. Four-shelved bookcase

The first step is to make the framework of bookcase.

- Select four tubes to be used as columns of the bookcase. The foot of two front columns must be bent forward to improve the stability of bookcase. Two rear columns are fixed vertically. Bookcase is to be put close to a wall to avoid falling backward. The space between shelves is decided according to the height of books, in general, it should be 3 cm higher than the book. The first and fourth shelves are equipped with two tubes of bent mortise, the others with one (Figure 16).

The second step is to reinforce the framework.

- Four tubes are used as lining tubes to connect every two opposite legs with the lower tube of closed bent mortise. Many short tubes are to form decorative patterns.

The third step is to make facial plates of close strips.
Figure 16 shows a mini-landscape of high grade. The structure and method are similar to those of bookcase.

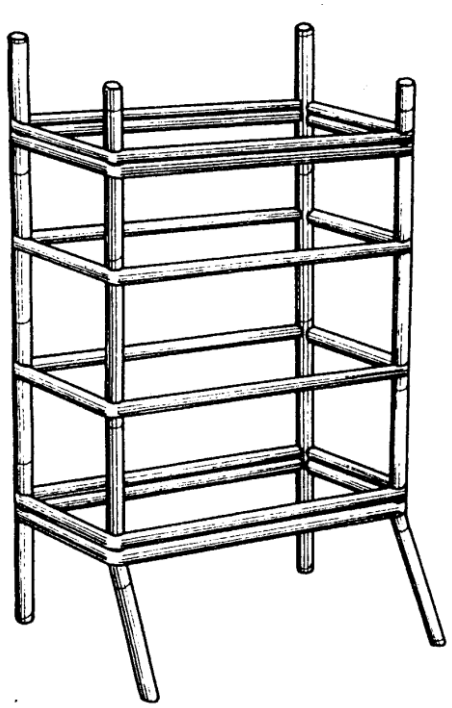


Figure 16. Framework of 4-shelved bookcase

The height of min-landscape is more than 2 m in general. As a mini-landscape is put on its top, the upper part is heavy while the lower is light, the stability of stand is very important keep the mini-landscape on top. The tubes must be bent symmetrically. As a rule, ordinary stands are equipped with tubes of closed bent mortise in upper and middle parts, those of high grade are with tubes of closed bent mortise in upper, middle and lower parts, of excellent workmanship. The upper tube of closed bent mortise should be fixed with a facial plate to support the mini-landscape. The decoration patterns are put between middle and upper tubes of closed bent mortise, because the line of sight of consumers is concentrated on this part (Figure 16).

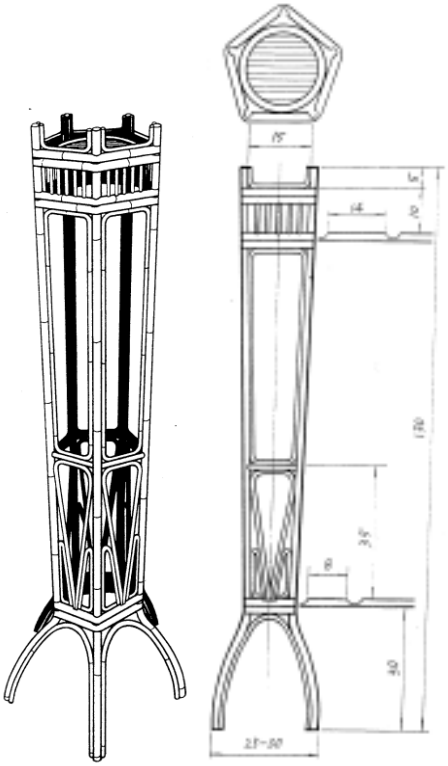


Figure 17. Mini-landscapes stand

Appendix 11. Bamboo chopsticks

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

Chopsticks are in indispensable item of oriental tableware. Bamboo chopsticks are widely used. The demand for bamboo chopsticks is high both in China and abroad.

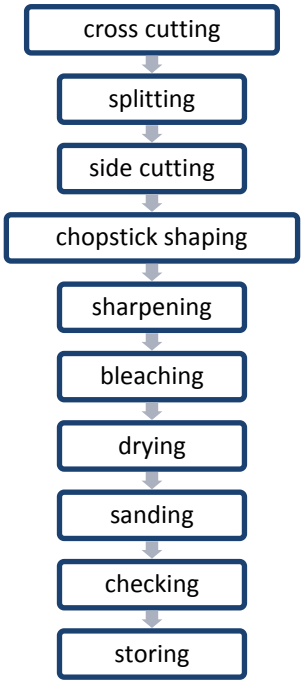
1. Double sanitary chopsticks

Double sanitary chopsticks are the most popular ones at present.

A. Size

The cross section of the upper part of double sanitary chopsticks is oval. The length of ordinary chopsticks is 21 cm and 24 cm. that for children is 18 cm. The size of upper part is 14 mm x 7 mm. The lower end is 35 mm x Φ3 mm.

B. Manufacturing process



(1) Cross cutting

Double sanitary chopsticks must be made of bamboo material without knots, and the thickness of culm wall about 10 mm. Therefore the raw bamboo should be cut into bamboo sections according to these requirements.

(2) Splitting

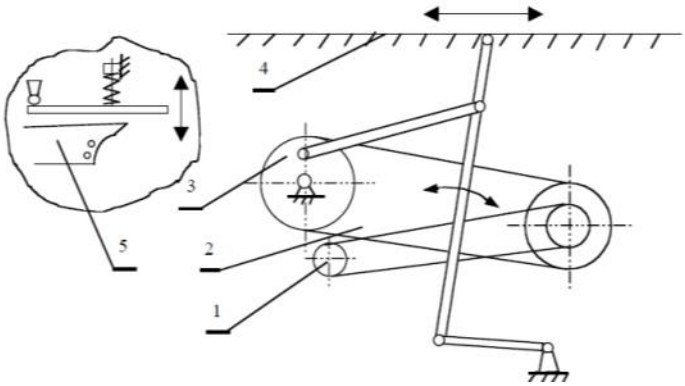
Bamboo sections are to be split into two semicircular fragments. It is suggested to split the section from the end where the culm wall is thinner, thus the split operation will be easier. While the length between knots is larger than the required length, it is better to take the upper part to avoid the groove-like defects.

(3) Side-cutting

Bamboo fragments are to be cut, on a special side-cutting machine, into pieces with green and yellow matter removed, 14 mm in width and 7 mm in thickness.

(4) Chopstick shaping

This operation is carried out on a special shaping machine. The work principle of shaping machine is shown in fig. 3-9a, and its appearance is in fig. 3-9b. Bamboo pieces are shaped by means of semicircular knives on shaping machine.



1. Electrical machine, 2. Transmission belt, 3. Crank ad rocker mechansim, 4. Sliding block, 5. Knife with adjusting device

Figure 1. Work principle of shaping machine

Figure 2. Chopstick shaping machine

(5) Sharpening

Chopsticks are sharpened on special sharpening machine of continuous operation, the sharpness can be regulated on the machine. It is shown in Figure 3.

Figure 3. Chopstick sharpening machine

(6) Bleaching

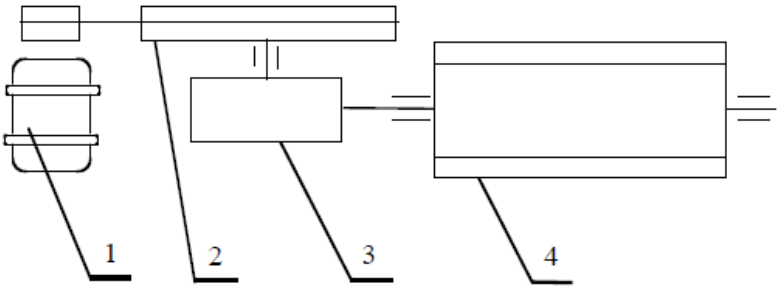
Chopsticks are bleached using hydrogen peroxide solution of density 9%, or using natrium sulfite solution of density 8 ~ 14%, treated for 48 h under normal atmospheric temperature. As a result of bleaching the color of chopsticks is harmonized, and the insect and fungus damages prevented.

(7) Drying

In order to prevent mould damage occurring in the process of storage and transport, the water content of chopsticks should be reduced to 10 ~ 12%. They could be dried in drying kilns, at the beginning the temperature of drying media could be higher, then lowered gradually and fixed at 80° C for 12 h.

(8) Sanding

Dried chopsticks are to be sanded in a sanding cylinder by means of mutual friction between chopsticks to remove burrs. The work principle of sanding is shown in fig. 3-11. For improving the sanding effect talcum powder can be added in the process of operation. The sanding time is more than 1 h. Sanded chopsticks are to be sorted, packaged and stored.



1. Electrical machine, 2. Transmission belt, 3. Retarder, 4. Cylinder

Figure 4. Work principle of sanding cylinder

2. Yuanlu chopsticks

Yuanlu are of higher grade than ordinary double sanitary chopsticks. The cross section of their upper part is rectangular 8 mm x 5 mm. The length of yuanlu chopsticks is 240 mm and 210 mm. Yuanlu chopsticks are shaped on special machine. The processing requirements are higher.

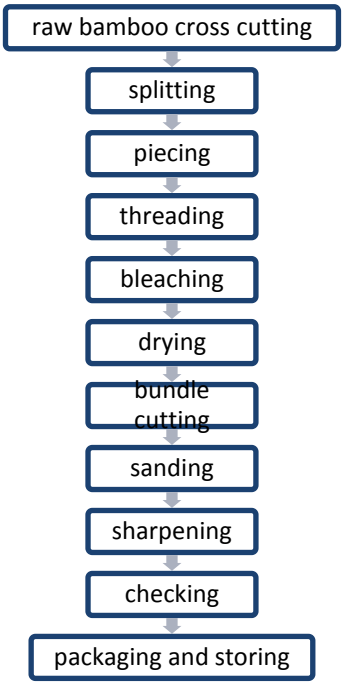
3. Edge-cut chopsticks

Edge-cut chopsticks are made in the same way as that of yuanlu, the only difference is the upper end is cut slantingly in an angle of 45º to form a sharp edge, which helps the user to blend mustard when eating sashimi. The edge is cut on a special machine with a knife-disc rotating on high speed. The half of upper end of chopsticks can be cut rapidly. There are many kinds of chopsticks, some of them are in novel style, or of brilliant colour, and be used as ornamental articles.

Appendix 12. Bamboo slips

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

Toothpicks, meat skewers and flower are of different uses, but they are of similar shape, with one or two pointed ends, and are made in similar way. The process of making toothpick is an example.



1. Raw bamboo cross cutting

There are no special requirements concerning the diameter of raw bamboo and the thickness of bamboo culm wall for making toothpicks. In general, tip of *Phyllostachys pubescens* is used for this purpose. For the convenient further processing tips are cut into pieces 140 mm in length. Material with knots is acceptable.

2. Splitting

There are no special requirements concerning the width of bamboo pieces for making toothpicks, but they should be smooth and leveled. The width of pieces depends on the number of threads from them for making toothpicks. As the diameter of toothpicks is insignificant, bamboo pieces should not be too wide.

3. Piecing

The thickness of bamboo pieces for making toothpicks is about 2.8 ~ 3 mm, the number of pieces depends on the thickness of bamboo culm wall. In general green pieces are cut at first, they can be threaded directly. If yellow pieces are too thick, they can be cut into two before threading.

4. Threading

Bamboo pieces are to be threaded into needles 1.8 mm in diameter. During threading the location of upper and bottom knives must be adjusted strictly, without any dislocation or gap. The number of needles depends on the form of knife set, 6 ~ 10 in general.

5. Bleaching

Needles are to be bleached to prevent mould or insect pest. Before bleaching they should be kept in clean water for avoiding color-change. As a rule needles are socked in hydrogen peroxide solution 9 ~ 13% of density. The solution can be heated or not heated. But the soaking time under normal air temperature must be longer, about 30 hours.

6. Drying

As the needles are very thin, they can be dried naturally when the air temperature is comparatively high. The water content of needles should be kept at 10 ~ 12%.

7. Bundle cutting and sanding

Needles are to be bundled and cut into 420 mm in length. They are to be sanded in a vibrating sanding machine by means of mutual friction for about 3 ~ 4 hours. Sanded needles are to be cut into 65 mm in length for making toothpicks.

The appearance of sanding machine is shown in Figure 1.

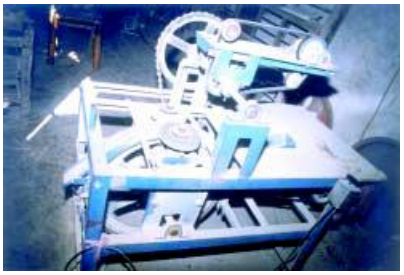


Figure 1. Sanding machine

8. Sharpening

Semi-products are to be sharpened to form one or two pointed ends, and remove burrs. The sharpening machine is shown in Figure 2.

Figure 2. Toothpick sharpening machine

9. Checking and packaging

Finished toothpicks are to be straightened out on vibrating plates, then packaged on packaging machines. These operations can also be done manually.

Appendix 13. Bamboo charcoal and bamboo active carbon

Source: Zhang Qisheng, Jiang Shenxue and Tang Yongyu (2002). Industrial Utilization on Bamboo. INBAR Technical Report No.26. www.inbar.int

Bamboo charcoal and active carbon is an item of new product developed in recent years. Being of special microstructure, bamboo material possessed extreme absorbing and other special capacities after carbonization. Their uses in the areas of high and new technology are of importance.

1. The variety of bamboo charcoal

There are many kinds of bamboo charcoal. In line with their origin, bamboo charcoal can be divided into two parts: raw bamboo charcoal and charcoal stick of chips. Raw bamboo charcoal is made of small-sized bamboo, old bamboo, bamboo tops, roots, which are not fit for making other bamboo products. Charcoal stick of ships is made of residue from bamboo processing industry. In the process of making bamboo floorboards bamboo mats and other kinds of commodities, there will be vary much residue, they are of different sizes and forms, consequently, they must be broken into chips, dried and pressed into sticks before carbonization.

Charcoals are of different shapes: cylinders, pieces, chips and powder. In line with the temperature of carbonization charcoals can be divided into three groups: charcoal of high, medium and low temperature. Physical and mechanical properties of charcoals differ due to different temperature of carbonization. Charcoal for regulating humidity is made at temperature of 600ºC, that for absorbing is at 700 ~ 800ºC, and that of high electric conductivity is higher than 1000ºC. According to the their uses charcoals are defined as fuel, for purifying drinking water, for cooking, for bathing, for improving soil for regulating room humidity, for preserving freshness of vegetables, fruits and flowers, for deodorizing, for conducting electricity, etc.

2. The making process of bamboo charcoal

Bamboo material is organic matter of high polymer, composed of cells of different shapes and properties. In the period of growth, chlorophyll in bamboo leaves absorbs dioxide carbon from atmosphere, the root absorbs water, minerals and nutrients from soil. By means of photosynthesis, carbon, hydrogen, oxygen, nitrogen and other chemical elements combine bamboo material, which contains the following matters:

Polysaccharide - cellulose and semi - cellulose.

Lignin(aromatic compound).

Extractable matter - soluble fat and protein.

Ash content

Lignin, cellulose and semi – cellulose compose cell wall of bamboo. The content of cellulose in ordinary bamboo material is about 40~60%. It decreases with the growth of bamboo. For example, the cellulose content of young *Phyllostachys pubescens* is 75%, that of one year old is 66%, 3 years old is 58%. The cellulose content of young *Phyllostachys heteroclada* is 63.42%, that of one year old is 59.96%, 3years old is 59.26%. The simple molecular formula is (C6H10O5)n, the simple chemical formula is C6H10O5. It means the cellulose is a kind of carbohydrate composed of carbon 44.44%, hydrogen 5.17%, and oxygen 43.39%.

Semi-cellulose means the carbohydrate in polysaccharide matter. The content of semicellulose in bamboo material is about 14 ~ 25 %. It differs in different bamboo species, 23.68% in *Phyllostachys glauca*, 22.73% in *Phyllostachys pubescens*, 22.37% in *Phyllostachys sulphurea* and 18.51% in *Neosinocalamus affinis*. It also changes in connection with the growth of bamboo. The content of semi-cellulose in bamboo material of 1 ~ 2 years old is higher, that in 3 years old is lower, for example, the content of semi-cellulose in *Phyllostachys pubescens* 2 years old is 24.9%, that of 4 years old is 23.65%.

Lignin is a kind of natural high-molecular compound, it does not exist separately in natural environment. It exists together with cellulose and semi-cellulose in cell wall of wood and bamboo. The lignin content in bamboo material is 16 ~ 34 %. It is differs in different bamboo species. The lignin

content in *Phyllostachys glauca* is 33.4%, in *Phyllostachys pubescens* is 26.41%, in *Bambusa pervariabilis* As a rule, the content of lignin in older bamboo culm is higher than that in youngers.

Along with cellulose, semi-cellulose and lignin, there are other matters, such as protein, starch, fat and gum. The change of these matter influences the color, smell, taste, pest resistance and durability of bamboo material, and its evenness as well. From bamboo material, the lixivium by cold water is 2.5 ~ 5.0%, that by hot water is 5.0 ~ 12.5%, by ether and alcohol is 3.5 ~ 9.0%, by sodium hydroxide of 1% is 21 ~ 31%. The quantity of lixivium decreases with the growth of bamboo. It is more from younger bamboo than that from older one. The making process of bamboo charcoal is the process of heating and resolution, this process can divided into four stages according to the change of temperature:

A. Drying stage

The temperature in this stage is lower than 120º ~ 150ºC, the resolution is very slow, the water content is evaporating continuously by the heat from outside, but the chemical composition remains unchanged.

B. Pre-carbonizing stage

The temperature in this stage raises to 150º ~ 275ºC, the hot resolution of bamboo material becomes evident, the chemical composition begins change and the unstable part of semi-cellulose begin resolve.

C. Carbonizing stage

The temperature in this stage raises to 275º ~ 450ºC, the heat resolution develops rapidly, resulting in many disintegrant, the liquid of them are bamboo tar, bamboo acetic acid, the gas are flammable methane, ethylene. This is a stage of heat-release reaction. A great deal of heat is released.

D. Calcining stage

The temperature in this stage raises to 450º ~ 500ºC, by heat from outside bamboo material is calcined, residual volatile matter is released, and the content of carbon is increased. In this stage, jar and other liquids are decreased to the minimum. In the process ofheat resolution lignin resolves at the temperature of 225º ~ 235ºC, cellulose at 240º ~ 400ºC, lignin at 280º ~ 550ºC. Different temperature of carbonization influences the quantity and compound of charcoal.

3. Methods of charcoal making

There are two methods for charcoal making: dry distillation – pyrogenic decomposition, direct kiln burning. The main equipment for dry distillation – pyrogenic decomposition is a cauldron for distillation. Bamboo material should be pre-dried to decrease the water content to 20% before loading into the cauldron for pyrogenic decomposition. The mixed steam-gas is to be processed in jar-separator and in condenser for retrieving bamboo vinegar liquid and bamboo tar. In this process the oxidation of bamboo material is lower, and the rate of production is higher, it reaches 25%.

In the process of direct kiln burning, the heat resulted from fuel burning curls up to the top of kiln and spreads in the kiln. Most of the heat moves about in the upper part of kiln, the rest of it radiates on all sides, step by step goes down to dry and pre-carbonize bamboo material. In the process of carbonization a small part of bamboo material is being oxidized and burnt, raising the temperature in the kiln and removing volatile matter. The smoke and steam move in circles, and regulating the temperature in kiln. Thus complete the carbonization and refining process, producing charcoal fine and close in texture. In this process bamboo material undergoes stages of pre-drying, drying, pre-carbonizing, carbonizing, refining and natural cooling. The temperature differs in different stages. It is 60º ~ 100ºC for pre-drying, 100º ~ 150ºC for drying, 150º ~ 270ºC for pre-carbonizing, 270º ~ 450ºC for carbonizing and 450º ~ 1000ºC for refining. The temperature of refining stage influences the density and electric conductivity of charcoal greatly. The rate of production of this method is low, and the quality of charcoal is not stable.

4. Matters resulted from pyrogenic decomposition and their properties.

The matters resulted from pyrogenic decomposition are in solid, liquid and gaseous states.

A. Solid matter

The solid matter produced in pyrogenic decomposition is bamboo charcoal. Bamboo charcoal is made in the form of cylinders, chips or powder, depending on the shape of raw material. The resistivity of bamboo charcoal can be high, middle or low. The electric conductivity of charcoal depends on its density, moisture content, ash content, refinement and other factors. Bamboo charcoal of higher density, better refinement, less ash content and low resistivity possesses higher electric conductivity.

There are many elements in the ash of bamboo material, among them are phosphorus, potassium, silicon, calcium, aluminium, magnesium, iron, sodium, barium, copper, strontium, nickel, etc. The content of silicon, aluminium, sodium and iron is comparatively high in outer part of bamboo culm wall, while the content of phosphorus, potassium and magnesium is higher in the yellow matter in inside part. SiO2 mainly exists in silicon cells of surface part of bamboo material. These elements influence the electric conductivity of bamboo charcoal.

The production of bamboo charcoal is still in its beginning stages at present. Their quality standards haven't been worked out yet. The main physical and chemical properties are shown in Table 1.

B. Liquid matter

Table 1. Main physical and chemical properties of bamboo charcoal

	Raw bamboo charcoal		Charcoal stick of chips	
Items	1st grade	2nd grade	1st grade	2nd grade
Moisture content %	<7	<7	<8	<8
Ash content %	<2.5	<3.0	<3.0	<4.0
Carbon content %	>88	>85	>86	>82
Volatile matter %	<6	<8	<8	<8
Calorie value of dried charcoal KJ/kg	>33000	>31300	>31800	>30100
Value of PH	8	8	9	9

The mixture of steam and gas emerges in the process of carbonization is condensed and separated to produce crude vinegar liquid. The liquid is divided into two layers after sediment. The upper layer is clean bamboo vinegar liquid, the lower layer is sediment bamboo tar.

The clean bamboo vinegar liquid is smells smoky, contains acetic acid, methyl alcohol and other chemical compounds. The sediment bamboo tar is a kind of black oily glutinous liquid, it contains a great deal of phenol matter, including organic matters. Its composition is very complicated and the techniques of its utilization are to be studied.

C. Gaseous matter

Carbon monoxide, methane, ethylene and other gaseous matters emerge in the process of bamboo pyrogenation. The composition and quantity of gaseous matters relate to the temperature of carbonization, speed of heating and other factors.

5. Methods for determining the physical and chemical properties of bamboo charcoal

A. Determine the moisture content

Key points; Moisture content means the total water contained in the samples when they are taken. Weigh the sample of certain quantity and dry it at the temperature 102~105ºC to reach the constant weight. The moisture content is the lost weight divided by the primary weight expressed in percentage.

Apparatus

Drying chamber: with automatic temperature-regulating device and air-blower or ventilator.

Desiccator: with drying agent (undeliquescent calcium chloride cubes or silica gel)

Glass-faced dish: 190 mm in diameter Industrial scales: precision up to 0.1 g.
Specific measures:
Homogenize the sample rapidly, the granule size must be less than 10 mm. Take 100 g (precision up to 0.1 g) of sample, put it into the glass-faced dish, (the weight is known). Put load the dish with sample into the drying chamber of temperature 102~105ºC. Unload it after 2~3 hours of drying, and cover it closely. Put it into a desiccater to cool the sample to room temperature and weigh.

Dry the sample for 30 minutes and weigh it again, repeat these steps until the decrease of weight is less than 0.1 g, or the weight does not increase. In the latter case the weight measured before the increase is to be applied for calculation.

Calculation:
The moisture content W (%) is calculated according to the following formula;
W=(G1/G) x 100%
Where: G1 – the decrease amount of weight (g)
G – the weight of sample (g)
Allowable error

The allowable error of calculated moisture content ≤0.4%
B. Analyze the sample

(1) Sample treatment: rind the charcoal to be used as sample until it is completely sieved through pores of 0.3 mm. Dry it to constant weight at 102~105ºC. The weight of sample must not be less than 50 g.
(2) Determine ash content: put the sample of proper weight into a electric furnace of high temperature to incinerate it at 815 □} 10ºC, weigh it after cooking, the weight of residual part is to be used to calculate the ash content.

Apparatus:
Electric furnace: with a temperature-regulating device maintaining 815 U± 10ºC,with a thermocouple and thermometer of high temperature.
Ash container: 45 mm in length, 22 mm in width and 14 mm in height.
Desiccator: as that for determining moisture content.
Specific measures:
Take 1 g of charcoal from the sample treated in B (1), the precision of weight is up to 0.0002 g. put the sample into a porcelain crucible with cover, load the crucible with sample the electric furnace, open the crucible and raise the temperature to 500ºC. Keep the temperature for 30 minutes, raise the temperature further to 815 ± 10ºC, incinerate it at 815 ± 10ºC for 1 hour. Take out the crucible, cover it and cool it in open air for 5 minutes, put into desiccator to cool to room temperature and weigh.
Incinerate the sample at 815ºC for 30 minutes and weigh, repeat these steps until the decrease of weight is less than 0.001 g, or the weight does not increase. In the latter case the weight measured before the increase is to be applied for calculation.
Calculation:
The ash content A (%0 is calculated according to the following formula:
A = (G1/G) _ 100%
Where: G1 – the weight of residual part after incineration
G – the weight of sample
Allowable error:
The allowable error in one and the same laboratory is 0.2%, in different laboratories is 0.3%.

(3) determine the volatile matter: key points: take a sample of certain weight, put it into a porcelain crucible. Heat it at 900□} 10ºC without air for 7 minutes. Calculate the lost weight as the content of volatile matter. The operation must be repeated anew if sparks are observed.

Apparatus:
Porcelain crucible: 40 cm in height, the inner diameter of upper rim is 30 cm, outer diameter of base of 18cm, the out diameter of cover is 35 cm.
Electric furnace: the same as that for determining ash content.
Crucible rack: the rack is made of chrome-nickel steel, the base of crucible put on this rack must be 10~15 mm over the base of furnace. Stopwatch or timer.
Analytical scales: the same as that for determining ash content.
Desiccator: the same as that for determining moisture content.

Specific measures:
Take 1 g of charcoal from the sample mentioned in B (1), the precision should be up to 0.0002 g. cover the crucible with a lid, wave it slightly to make the sample distributed evenly in crucible. Put it on the rack and load rack with crucible rapidly onto the electric furnace, of volatile matter is calculated according to the following formula:
V= (G1/G) x 100%, where: G1-the decrease of weight after test
G – weight of sample (g)
Allowable error:
The allowable error in one and the same laboratory is 0.3%, in different laboratories is 0.5%.

(4) Determine the content of carbon:
The content of carbon C (%) is calculated according to the following formula:
C = 100 – (A + V)
Where: A – ash content of the sample (%)
V – volatile matter content of the sample (%)
(5) Determine the caloric value of dried charcoal:
Specific measures: take a sample of certain weight and put it into an oxygen container of calorimeter, burn it completely, record the raise the temperature accurately. Thereby calculate the caloric value.
The unit for calculation is J or KJ.

Apparatus:
The calorimeters usually used are of constant temperature or of heat insulation.
Main parts of calorimeter;
- Oxygen container: made from heat and corrosion resisting alloy steel of chrome-nickel or chrome-nickel-molybdenum.
- Inner cylinder: made of corrosion resisting metal, the inner and outer surface must be electroplated and polished.
- Outer cylinder; a double-walled metal container.
- Mixer; a propeller mixer, rotational speed 400~600 r.p.m.
- Thermometer for measuring heat: minimum scale value 0.01ºC
- Ordinary thermometer, minimum scale value 0.2 ºC, working range 0~50 ºC.
Attached parts:
- Magnifying lens for reading thermometer with head lamp, magnifying five times.
- Vibrator, vibrating thermometer before reading.
Analytical scales, the same as that for determining ash content.
Industrial scales, the same as that for determining moisture content.
- Reagents and materials: Oxygen, Benzoic acid.
Acid pickling asbestos, to be burnt at 850 ~ 900ºC for half an hour before using.
Port-fire wire of chrome-nickel, 1400 J/g.
Method for determination:
Apply Bunte formula for cooling and correcting to calculate the heat energy.
- Take 1 ~ 1.2 g from container for burning as analytical sample.
- Take a piece of port-fire wire, the weight of which is known.

- Add 10 ml of water into oxygen container, cover it with a lid carefully and tightly.
- Regulate the temperature of water in inner cylinder, make the temperature in inner cylinder higher that in outer cylinder by 0.5 ~ 1ºC at the end of test. The temperature of water in outer cylinder should approach to room temperature, the difference should not exceed 1ºC.
- Weigh the water in cylinder after temperature regulation on industrial scales, the precision up to 1 g.
- Load the oxygen container into inner cylinder with water.
- Connect the oxygen container with port-fire electrode, with mixer and heat measuring thermometer, cover with the lid of outer cylinder.
- Connect with the mains and start the mixer.
- Apply Bunte formula to cool and correct, record the temperature at the beginning, main and ending stages.

Observe the temperature every minute after 5 minutes of mixing, until the difference between two close observations is less than 0.003ºC. At the moment starts the beginning stage. Record the temperature, then record it once every minute, altogether 6 records in 5 minutes. Turn on the electricity to heat the sample, entering the main stage.

In the main stage, record the temperature every half a minute, until it begin to decline.

The first record of declining temperature is regarded as the end of the main stage (tn).

In the ending stage record the temperature every minute, altogether 6 records in 5 minutes.

- Stop mixing and unload the oxygen from inner cylinder.
- Open the air-flow valve.
- Open the oxygen container, check the body of oxygen container and container for burning, if any residual carbon black, the test is invalid.

6. The utilization of bamboo charcoal

The development of bamboo charcoal production is in its initial stage at present, the techniques of its production and utilization are to be researched. Bamboo charcoal is utilized in the following areas:

A. Purifying water

Thanks to its micro-porous structure, bamboo material possesses excellent absorbing capability after carbonization. Bamboo charcoal can be used to treat drinking water for eliminating organic impurities and offensive smells. This method is better than using chlorine or bleaching powder. Because, added with chlorine, hydrocarbon chlorides are formed in treated water, which are harmful to human health. It is better to combine the treating matters, at first disinfect water with chlorine, then eliminate the residual chlorine and chloride with bamboo charcoal. Bamboo charcoal can be used not only for treating drinking water, but also for sewage and industrial water treatment.

B. Purifying air

Main pollution source of air is phosphorus dioxide, carbon monoxide, hydrogen sulphide released from chimneys and offensive smells formed in living environment. Proper amount of bamboo charcoal can absorb these offensive smells and harmful gases, and regulate air temperature, put down the multiplication of moulds and microorganisms. Bamboo charcoal in refrigerator eliminates strange smells, it is propitious for preserving the freshness of foods. It also functions as dehumidizer, anti-mould agent and deodoriser in shop-windows or cupboards. When cooking rice, bamboo charcoal helps to eliminate the residual pesticides and improve the quality of rice. Bamboo charcoal positioned by computers, televisions and microwave ovens shelters users from the radiation of electromagnetic wave.

C. Absorbing unpleasant odors

Bamboo charcoal helps to eliminate the unpleasant odors of food in refrigerators, keeps rice fresh and dry.

D. Health-care capacity of bamboo charcoal.

Bamboo charcoal releases natural fragrance and radiates far infrared rays. The far infrared rays stimulate the network of passages of human body, along which acupuncture points are distributed. Therefore it protects human health. Bamboo charcoal pillows and mattress are good for health.
Bamboo charcoal performs some other specific functions, it may improve women's look, improve soil, promote the growth of root system of plants.

7. Bamboo vinegar liquid and its utilization.

A. The main content of bamboo vinegar

Bamboo vinegar liquid is a kind of by-product of bamboo carbonization. It contains many organic compounds. The quantity depends on the species and quality of bamboo material, and carbonization conditions. The content of liquid varies with the methods of its collection and storage.
Along with a great deal of water content, the liquid contains a lot of chemical compounds, such as acetic acid, formic acid, butyric acid, phenol, aldehyde, saturated alcohol and unsaturated alcohol. Its pH value id 2.20 ~ 3.01, and the specific gravity is about 1.02.

B. The separation and refinement of vinegar liquid

Laid aside for a certain period of time, bamboo vinegar liquid decomposed into two layers, the upper one is clean vinegar liquid and the lower one is bamboo tar. The clean vinegar liquid contains 10 ~ 20% of organic matter. Acetic acid, butyric acid, methyl alcohol and other organic solutions can be obtained by processing this liquid. The sediment bamboo tar contains a great deal of phenol matter, which can also be obtained by processing the tar.

The development of bamboo charcoal and bamboo vinegar liquid is a newly born industry of certain scale. But their production and utilization technology is to be studied further. The superior absorbing capability of bamboo active opens a vast range of prospects for environment protection. The consumption of active carbon for water and gas treatment is very high in developed countries. In the United States the annual consumption exceeds 70 thousand ton, while in Japan more than 50 thousand ton is used for environment protection annually. The problem of environment pollution is quite serious in China, the water in Huaihe River, Taihu Lake and Pearl River is being polluted seriously, therefore the production and utilization of active bamboo carbon will benefit the health of local people. Bamboo active carbon can be used to refine coarse sugar. The annual consumption of sugar exceeds 6 million ton in China, while the production is 4 ~ 5 million ton. As the coarse sugar in decolorized by using phosphorus, the refined sugar gets dump and agglomerated easily, furthermore, the residual phosphorus in sugar may cause cancer. With the improvement of living standards and awareness of self-protection in China, phosphorus will not be used for sugar refinement, and active carbon will be in great demands. The sugar industry needs about 20 ~ 40 thousand ton of active carbon. Active carbon decolorizes the sugar, and removes pigments, moulds and ash contents from coarse sugar, promotes the speed of its crystallization. Bamboo active carbon can be used for refining wines of high grade and edible oil. In pharmaceutical industry bamboo active carbon can be used to refine antibiotics, vitamins and sulfanilamide, and remove pigments and impurities. Bamboo active carbon is widely used in civil and military industries for filling gas masks, for purifying discharged steam or gas, preventing environment pollution and recovering useful matters. It is also used as deodorant in refrigerators, bathrooms and pools. The function of cigarette filter tip can be improved by adding bamboo active carbon. Bamboo active carbon in filter tips not only absorbs air-soluble glue particles, but also removes methyl benzene, methyl alcohol, acrylic aldehyde and other harmful matters. This is the function which ordinary filter tips can not perform.

Bamboo active carbon can be used in many other ways. It can be used as filter of emergency ventilation system of atomic reactor, to absorb radiating xenon and krypton, to prevent the pollution by discharged gas. It can be used in cosmetic communication to absorb interfering gas for guaranteeing correct communication. It can be used in agriculture to promote the nitrogen fixation, to speed up the formation of ammonia and nitrate from organic nitrogen, to regulate the soil structure, raise soil temperature, absorb the harmful matters in soil. It can also be used as electrode material in microelectronic technology, as compound catalytic agent, for the storage of energy matter. It is

evident that bamboo active carbon will be used widely in the area of high-tech as a kind of newly developed material.