INTERNATIONAL TROPICAL TIMBER ORGANIZATION

SUBSTITUTE BAMBOO FOR TIMBER IN CHINA

A FINAL REPORT OF PROJECT PD 124/91 REV. 1 (M)

Submitted by Bamboo Information Centre,
Chinese Academy of Forestry

BEIJING, CHINA
March 1994

CONTENTS

INTRODUCTION

PART III. BAMBOO PAPERMAKING

PART IV. BAMBOO WARES

INTRODUCTION

Tropical forest in both hemispheres is decreasing at a rate of 17 million ha a year. Massive tropical forests are being cut by industrialists for obtaining valuable tropical timber, by local authorities for raising funds, and by inhabitants for their living. Most of the problems human facing, such as the loss of biodiversity, the warming of world weather, the hole in ozone layer, are believed to be resulted, directly or indirectly, from forest disappearing. It becomes a worldwide concern to prevent the continuation of this disastrous trend. According to the opinions of experts, one of the options for rescuing tropical forests is to find certain substitutes for tropical timber.

Bamboo is fast-growing, easily cultivated and widely distributed. The extensive bamboo rhizome system and its thick leaf-cover are of great importance in soil and water conservation. The labor-intensive operations of bamboo processing promote employment among local people. Bamboo culms can be used to replace timber in certain fields of processing and utilization. Therefore experts are of the opinion that the development of a bamboo industry may ease the pressure on forests, facilitate the growth of local community and improve the natural environment, and thus protect tropical forests from further destruction.

Environment protection and economic development are two major problems of the world. The development of bamboo plantation and utilization will, to some extent, help people to solve these problems.

China has rich bamboo resources and long history of bamboo cultivation and utilization. The use of bamboo in China can be traced back to thousands of years ago. Bamboo industry, including traditional bamboo products, bamboo-based panels, bamboo paper-making, bamboo food, bamboo fuel, developed quite successfully in certain provinces recently, some one hundred million people make their living on bamboo wholly or partly. Research activities are being carried out in this field actively. More than one hundred research papers on bamboo are published in this country every year.

Since tropical countries in Asia, Africa and South America are suffering from the terrible consequences of forest destruction, a study on Chinese practice in bamboo exploitation may be of some help to officials and professionals in these countries, who are seeking ways to curb forest decrease, to maintain ecological balance and to ensure rural stability.

This research report is compiled by Bamboo Information Centre, Chinese Academy of Forestry, supported by the International Tropical Timber Organization.

PART 1. BAMBOO RESOURCES & THEIR MANAGEMENT

1. Biological characteristics of bamboo plants

Bamboos are classified into clump type bamboo and running bamboo. Generally, bamboo is propagated mainly through vegetative reproduction. The rhizome in soil extends horizontally with buds from nodes of the rhizome growing out of soil and becoming monopodial running bamboos, forming a stand. The horizontally extending rhizome has close nodes and numerous roots forming a large shortened root ball, wherefrom buds grow out of soil and become sympodial extend to far distance. New culms always grow near the old ones. Occasionally, the root stocks may extend and become false rhizomes, and develop into sympodial running bamboos, forming a stand. Some species of bamboos have both sympodial and monopodial rhizomes, forming an amphipodial mixed stand. Despite of the type of bamboos, a stand or a clump with many culms standing above ground have the underground parts closely connected, forming an entity, which may be deemed as a "bamboo tree". Rhizome is the trunk, with the culms to be the ramifications. Culm is connected with rhizome, shoot is connected with culm, and culms contribute to the growth of rhizomes. Bamboo reproduction is completed in such a cycle. Rhizome, culm and shoot are interdependent on each other, producing interaction on each other and influencing each other. Ecologically they are interconnected. Most of bamboo species flower only once. Before flowering, abnormal phenomena often appear in bamboo stands. For example, there are fewer shoots, bamboo leaves turn yellow and wither. Saccharaides in plant body increase, while the N content decreases. Bamboo may flower in any season of the year. In usual case, it begins at the time of leaf change in spring. In the beginning only individual plant or a clump flowers. Then more and more plants flower till the whole stand is in bloom. After flowering and seed setting, the stand dies.

Bamboo plants have wide adaptability, and are distributed in valleys, plains, rolling land and mountains. Except desert, heavy alkali-saline soils and long-time water-logged marshes, they can grow almost on any soil. But vast majority of them prefer warm, wet climate and deep fertile soils. However, their adaptability differs with circumstances. Different terrains and landforms are different economic environments. Their distribution reflects their adaptability to environmental condition. As a general rule, running bamboos are distributed in high altitudes with low temperature and have wide adaptability. Clump type bamboos are mainly distributed in low altitudes with warm, wet weather, and have poor adaptability. Temperature, precipitation and humidity are the chief factors that influence the bamboo growth and distribution. Soil type and good drainage facilities are also important factors that influence the bamboo growth and distribution. For example, moso is somewhat cold tolerant, but it prefers warm, wet climate. The climatic characteristics of its distribution area is warm, more rain and high humidity, especially in spring when it is frequently wet and rainy. The mean annual temperature is 17-18 degrees C, with a frost-free period from mid December to early March next year. The precipitation is 1,500mm, and evenly distributed. The relative humidity is 75-83%. There is no distinct dry and wet season. The major soil type is purple soil generated on sand shale in the mid Jurassic era. The soil is deep, wet, of medium loam, with a high organic matter content, and a pH value of 5.0-5.8. Phyllostachys pubescens is mainly distributed in provinces in the middle and lower reaches of Yangtze River, and areas in Southwest China. Dendrocalamus membranaceus is a thermal type of bamboo. The suitable climate is characterized by a mean annual temperature of 19.8-21.5 degrees C, annual sunshine of 1,860-2,150hr., and an average annual precipitation of 1,200-1,530mm. The salient climatic features are that it is neither hot in summer, nor cold in winter, long summer without winter, spring continuing to autumn with plenty of precipitation. The weather is wet, warm and foggy. Dry season is distinct from wet season. The suitable soil types are laterite and lateritic red loam. In China the yellow bamboo is distributed in low altitudes adjacent to the north border of tropic zone. Fountain bamboo is a cool temperature bamboo, generally grown in mountainous areas at high elevation where the summer is short, in winter there is heaped snow and fog, with high humidity. The elevation above sea level is 2,000-3,800m. The climatic features of its main distribution areas are those of the sub-alpine zone, in agreement with the climate and soil of the distribution area of the subalpine coniferous forests. Other bamboos such as affinity bamboo have wide adaptability. Affinity bamboo prefers cool wet weather. Besides, it is highly cold and drought tolerant. It grows better under shade and in wet localities, and can grow well in areas where there is a distinct dry season on dry solid. According to the traits of sites, bamboo may be classified into cool temperature bamboo, warm temperate bamboo and thermal bamboo.

Bamboos have the same characteristics as those of Gramineae plants. But bamboos have other own particularity in external morphology of vegetative organs, the structure of reproductive organs such as flower and fruit, regularity of growth, external morphology of community, ecological habit, stand composition and geographical distribution, and form a community of evergreen woody perennial plants. The outstanding features of the community are as follows: 1. Evergreens: most of bamboo species do not cast leaf and are green all the year round. 2. Population: a bamboo stand or a clump is an entity, or mixed stand may be formed with other trees. 3. Adaptability: bamboos have high adaptability. It is distributed from tropical zone to temperate zone, from plains to high mountains. Some species may be distributed to cool temperate zone, and in mountains at an elevation of 4,500 m, growing well under all climates. 4. Fast growth: a bamboo stand can be established within 3-5 years. For these reason, in the classification of vegetation, bamboo community is deemed as a special vegetation type, and falls into the vegetation group of hardwood forests. According to site, water and thermal condition, it is classified into three subtypes: cool temperate bamboo forest, warm temperate bamboo forest and thermal bamboo forest.

Apart from natural bamboo stands, bamboos can be cultivated, managed and become an artificial community, because they have a high economic value and multiple use, can grow fast and be easily propagated. The area of moso stands is the largest among artificial plantation in China. In usual case, the artificially managed bamboo stands are pure stands. Under natural conditions, they are mixed with hardwood trees in a forest. Especially in the tropical and subtropical forest communities they form a dominant story in the forest, and play an important or decisive role in the dynamic succession of the community, resulting in a mixed forest. Now in the establishment of mixed forests, researches on the mixture of bamboos with other tree species are conducted. Based on the interspecific relation, the complementary function of biological and ecological characteristics and conditions favoring the promotion of adversity resistance and plant growth, suitable bamboo species are selected for the mixture. However, at present time, priority is set on research on the relation between the species in natural mixed bamboo forests and the state of growth so as to provide scientific data for establishment of the mixed bamboo plantations.

2. Anatimical analyses of native bamboo culms in China

Bamboo plants are characterized by their fast growth, high output and broad usage. The total growing area, storage and annual output of bamboo materials in China are significant. There is a broad future in the development and utilization of bamboo culms. However, due to unfavorable factors of unstable bloom-seed reproductive organs and complicated growth conditions, there exist difficulties in the identification, taxonomy and utilization of bamboo culms. Consequently, there is no comprehensive taxonomic system which could be accepted by bamboo researchers. Therefore, we decided to conduct comprehensive and systematic anatomical analyses on native bamboo culms so as to make comparisons. The results of past anatomical analyses on bamboo culms showed that there was significant difference in vascular bundle structure among different bamboo species or even among different cultivars within the species. For most bamboo species under investigation, the phenotype, size and arrangement pattern of their vascular bundle were relatively stable. If the anatomical taxonomic scheme on the basis of the basic types of vascular bundle is incorporated with the morphological features of the growth organs and other anatomical features, it will be possible to reach a natural taxonomic scheme for bamboo. Therefore, we have undertaken a fairly detailed, comprehensive and systematic analysis research. The concrete method and results will be described in the paper.

2.1. Materials and methodology

The test materials used in this research were taken from Zhejiang, Guangxi, Sichuan, Yunnan and elsewhere during the period of March 1987 to October 1991 and have been identified by bamboo taxonomic experts, so the correctness of their identification is guaranteed. The test materials belong to 71 species of native bamboos which belong to 37 genera (33 genera after merging).

Specimens were taken from the upper-, mid- and lower-sections of the bamboo collected, with mid-section as the main analyses object and the upper- and lower-sections as supplements. The mid-section of a bamboo culm develops most perfectly, with very small changes in histological structure. The surface micro-morphology, cuticle, cortex, subcutis, the types of outer, medium and inner vascular bundle, peripheral tissue of medullary cavity were observed, analyzed and compared, and photographs were taken.

Bamboo culms are fairly hard, it is very difficult to use conventional slicing methods. If steam slicing was adopted, it would be time-consuming as well as slow in speed, and the slice surface was rough. In order to solve this difficult issue, we have developed the carbonizing method for specimen preparation which has been proven fairly ideal after a period of exploration. This method is simple and handy. The actual steps includes the natural drying of the specimen, followed by dry distillation in crucible with controlled temperature at about 250 degrees C. The temperature in crucible varies depending upon the size of the specimen. In general, a specimen has a length of 3 cm and a width of 0.5 cm. If the specimen size is large, the temperature could be increased and the dry distillation time could be extended. In general, the time of keeping the specimen in the crucible is half an hour, and the dry-distilled specimen could be taken out of the crucible when the temperature drops to 150 degrees C. After dry distillation, the specimen gets completely carbonized, with certain extent of strength. It is considered an appropriate dry distillation if the specimen keeps its shape, breaks readily into two pieces when snapped and possesses smooth broken edges. Small specimen was prepared by slicing the smooth edge, stuck on specimen deck by using electric conductive glue, sprayed a layer of 100-200. A thick carbon membrane and another layer of 100-200. A thick gold membrane by spinning method, and finally put on electronic microscope for observation and analyses. During the observation and analyses, the electric voltage should be kept under 20 KV; the angle between specimen surface and electronic beam should be 15 - 20 degrees, and the speed of flow should be 100 graduation (nm).

2.2. Observation and analyses

2.2.1. Bamboo plants can be classified into 3 types on the formation pattern of subterranean stems:

2.2.1.1. Sympodial type.

New bamboos grow from buds at the culm base of mother bamboo. New bamboos grow up in such a way and the subterranean stem system is consisted of culm stalks and culm bases of mother bamboo and new bamboo with no formation of bamboo rhizome. Such bamboo grove, in most cases, becomes dense clump. Of which, there is another type: due to the extension of culm stalk, there is no dense clump between mother bamboo and new bamboo, but forms scattered bamboos. However, from the pattern of the formation of subterranean stem system, it still belongs to sympodial type.

2.2.1.2. Monopodial type.

The buds on the culm base of the mother bamboo can only grow into horizontal subterranean stems, i.e., bamboo rhizome. There are roots and buds in every segment of the bamboo rhizome, these buds can grow into new bamboos. However, the buds on the culm base of the new bamboo can only grow into bamboo rhizomes and cannot grow into new bamboos. Therefore, the bamboo grove formed this way is in monopodial state.

2.2.1.3. Amphipodial type.

The buds at the culm base of the mother bamboo can form bamboo rhizomes as well as new bamboos. Its subterranean stem system seems to be consisted of a combination of monopodial and sympodial types.

Analyzing from the angle of the evolution of subterranean stems, the most primitive is sympodial type which fixes itself in the original place. It adapts itself only to the local climatic environment. The culm stalks of sympodial type bamboo genera have whip-like extensions, such as Melocanna and Pseudostachyum whose culm stalks could extend as lóng as more than 1 meter, form monopodial culms and extend before broom and seeding. Obviously, this is better than sympodial type. But, this culm stalk extended from bamboo rhizomes have no shoot buds. These bamboo rhizomes are called false rhizomes which could not develop. They could become amphipodial type if this kind of false rhizome develop into true bamboo rhizomes with root and buds, the roots can absorb nutrient and water and, the shoot buds grow into new bamboos. In this way the adaptability of bamboos will be obviously strengthened, and can immigrate to places more suitable for their growth. Monopodial bamboo species seem to be more evolved. There are roots but no buds at culm base, and only the buds on the rhizomes can grow into new bamboos. In addition, rhizomes can form their own system. In this way the adaptability to environment is strengthened and this has been proved.

2.2.2. How is the vascular bundle in bamboo culm?

Anatomical analyses of large quantities of bamboo species showed that there were differences in the size and shape of vascular bundle among different bamboo species and even among different segments of the same bamboo culm. In general, there are altogether 4 fiber sheaths in the medium and inner culm wall cross section, i.e., a fiber sheath in both sides, inner and outer layers of the transfusion tissue. Fiber cores are situated in the inner side or both inner and outer sides of the vascular bundle. Most of the bamboo species have no segregated fiber cores. Vascular bundles could be classified into different types on the basis of the presence and absence of these fiber cores and their site in the vascular bundle. Among the bamboo species which have fiber cores, a complete vascular bundle might contain the following two or three parts: i.e.,central vascular bundle, one or two segregated fiber cores. Among bamboo species which have only vascular bundle sheath as supporting the tissue, the vascular bundle contain only one part, i.e., central vascular bundle. According to the shape of vascular bundle, bamboo can be classified into 5 basic types.

2.2.2.1. Double-broken-waist type.

Vascular bundle is segregated into 3 parts by parenchyma, i.e., there is an additional fiber core in the outer and inner central vascular bundle respectively. Bamboo species of this vascular bundle type are all sympodial type and grow into dense clump. Examples are the genera of Thyrsostachys, Gigantochloa, Dinochloa, Dendrocalamopsis and Dendrocalamus as well as some species of Bambusa and Neosinocalamus.

2.2.2.2. Broken-waist type.

Vascular bundle is consisted of 2 parts, i.e.,central vascular bundle and a fiber core. The fiber core is located in the inner the central vascular bundle, while the sheath of the inner vascular bundle between the cells (protoxylem) is usually smaller than other vascular bundle sheath. Bamboo species of this type all belong to sympodial type. Examples are genera of Bambusa, Ampelocalamus, Dendrocalamopsis, Dendrocalamus, Melocalamus, Pseudostachyum, Drepanostachyum, Gigantochloa, as well as some species of Schizostachyum.

2.2.2.3. Tight-waist type:

There is no fiber core in this type, i.e., there is only one central vascular bundle, with the vascular bundle sheath as the supporting tissue. The inner vascular bundle sheath between cells (sheath of inner vascular bundle) is obviously larger than the other 3 vascular bundle sheaths, and extends in a fan-like shape with no stuffings between cells. Bamboo species which possess this type of vascular bundle are also sympodial type. Examples are the genera of Schizostachyum, Melocanna, as well as some individual species of Cephalostachyum.

2.2.2.4. Open type.

The vascular bundle is consisted of only one part, i.e., the central vascular bundle without fiber core. The supporting tissue is vascular bundle sheath. There are stuffings between cells and the four vascular bundle sheaths are of the same size and symmetrically located. Most of the bamboo species which possess this type of vascular bundle sheath are of monopodial or amphipodial types. Examples are the genera of Phyllostachys, Pleioblastus, Shibataea, Bashania, Brachystachyum, Cephalostachyum, Chimonobambusa, Chimonocalamus, Neomicrocalamus, Melocanna, Pseudosasa, Indosasa, Qiongzhuea, Acidosasa, Oligostachyum, and Sinobambusa.

2.2.2.5. Semi-open type.

There is no fiber core, but the lateral and inner vascular bundle sheaths are linked together. Bamboo species which possess this type of vascular bundle include genera of Sasa, Sasamorpha, Yushania, Fargesia, as well as some individual species of Qiongzhuea and Indosasa.

The process of simplification the five typical vascular bundles coincides with the process of bamboo evolution. The process of simplification of vascular bundle is: the outer fiber core of the double-broken-waist type degenerated and became broken-waist type; the inner fiber core of broken-waist type extended outward, linked with vascular bundle sheath and formed tight-waist type; the inner fiber core of tight-waist type shrank and simplified itself into open type; and the left and right vascular bundle sheaths of the open type linked with inner vascular bundle sheath, shrank and simplified into semi-open type. These simplification processes are the indicator of evolution. The degeneration and simplification of fiber core and vascular bundle sheath have shown the enhancement of the functions of transfusion tissues, strengthened the endurance of plants, and become beneficial for the tendency of dwarfism. Although this trend does not meet the benefits of human beings, yet human demands do not always match the evolution of plants. Evolution is the characteristics of biological individuals given by nature. Just like what all the botanists acknowledged: herbaceous bamboo species are more evolved than woody bamboo, and Graminoids, in turn, is more evolved than herbaceous bamboo. From the above-mentioned fact, one could see that the 5 basic types of vascular bundle are arranged in the order of evolution process from clump to monopodial. Double-broken-waist type and broken-waist type are all sympodial bamboos. In sympodial type, broken-waist type is more evolved than double-broken-waist type; tight-waist type is a medium type or transition type. Open type or semi-open type are monopodial bamboo species in most cases.

The structure of the surface micro-morphology of bamboo culm is fairly simple. It is consisted of large microbulges, little microbulges, ceraceous layer, cuticle, stomatic chamber and seta. The shape, size, distribution and arrangement of the microbulges vary from species to species. Most of them are scattered or scattered-aggregate, some are net-shaped, some are scale-shaped, and others are wave-like. Some of the stomatic chambers are situated horizontally, some are sunken and others are protruded. Some of the stomatic chambers have complete and smooth openings while other are blocked by microbulges. The openings of some stomatic chambers have a shape of crevice, some have a shape of spindle, while other have a shape of rings. The morphology of the surface microbulges is different from species to species.

Electronic analyses have been conducted on the basal, medium and top sections of Phyllostachys edulis, Chimonobambusa purpurea, Thyrsostachys siamensis, and Dinochloa puberula. It has proven that the surface grain pattern of the bamboo culm is basically uniform in the top, medium and basal sections. It is suggested that comparison between bamboo species should be made by using medium section. This is because that medium section has the best growth, development and the smallest change in development in terms of the whole culm, while the top and basal sections could be used as supplement reference.

The extent of differentiation of the cuticle, subcutis and cortex of culm varies from species to species and could be classified into obvious, fairly obvious and ambiguous. The details can be found in the book entitled "Microstructure of Bamboo Culms in China". The number of peripheral cell of medullary cavity varies from species to species, and the thickness of peripheral cell wall increases in accordance with the increment of age.

2.3. Result and discussion

The items of systematic anatomical analyses of various bamboo species included the surface micro-morphology of bamboo culm, cuticle, subcutis, cortex as well as the types of epidermis, medium and inner vascular bundle, and peripheral tissue of medullary cavity, etc. The results showed that it is easy and feasible to bring about a natural taxonomic scheme of bamboo classification by combining the anatomical taxonomic system based on the five basic types of vascular bundle with the morphological characteristics of the reproductive and growth organs as well as the anatomical characteristics of the vegetative organs. This method is comparatively scientific and comprehensive, and can provide important reference for the identification, taxonomy and utilization of bamboo culms.

From the external morphological characteristics of bamboo culm, Bambusa and Lingnania, Gigantochloa and Oxytenanthera, Dendrocalamus and Sinocalamus, Oligostachyum and Pleioblastus are very close and sometimes very difficult to distinguish. In addition, the above mentioned 4 pairs of genera are also very similar in internal anatomical structural features of bamboo culm with very little differences.

Therefore, in the opinion of some of the bamboo taxonomic experts, the above mentioned genera were merged into 4 genera in the Bambusoideae part of the newly compiled "Flora of China". All the latter genera are merged into the former.

In most cases, bamboo species with stomatal apparatus of the epidermis encircled by microbulges, or the opening of stomatic chamber blocked by microstructures belong to bushy bamboo species (Sympodial type), while those with few or smooth super microbulges on the surface, or the peripheral area of the opening of stomatic chamber blocked by microbulges belong to monopodial bamboo species (monopodial type or amphipodial type).

Subcutis and cortex: The subcutis of Phyllostachys edulis, Pseudosasa amabilis, Acidosasa edulis, Sinobambusa yixingensis and other monopodial bamboo species is easy to distinguish from the thin cortex cells because of the calcification of cell walls or the regular outline and size of the cell walls. However, the subcutis of Bambusa lapidea, Bambusa pervariabilis, Cephalostachyum pergracile, Dendrocalamopsis oldhami, Neosinocalamus affinis, Oligostachyum sulcatum and other sympodial bamboo species is not easy to distinguish from the cortex cells because the outlines of subcutis cells and cortex cells are very similar, both of them belong to thin cells.

The outline of vascular bundle: In the culm of sympodial bamboo species, the ratio of the thickness of outer fiber and inner fiber of the outer peripheral vascular bundles is less than 50%. However, the ratio could be either "greater than", or "less than" or "equal to" 50% among monopodial bamboo species. In terms of the structural molecules of vascular bundles, there are long shapes of bordered vessel pits on the side wall of most scalariform vessels among the monopodial bamboo species, with a length-and-width ratio of 2-10 times; while in most sympodial bamboo species, the pits on the side wall of vessels are relatively short with a length-and-width ratio of 1-4 times. There are two fairly large xylem molecules between two scalariform vessels in the vascular bundle of nearly all sympodial bamboo species. There are large stuffings of different shapes in the protoxylem-formed empty cavities in monopodial bamboo species, while in sympodial bamboo species, there are only air-filled cavities.

There are very close relationships between the external morphology and internal structure of bamboo culms. For instance, there are significant differences in vascular bundle, subcutis, cortex, pit of scalariform vessel and protoxylem, etc., between monopodial and sympodial bamboo species. The geographical distribution center of sympodial bamboo species is in the high-temperature, rainy Pearl River reaches, while monopodial bamboo species have a wider distribution area. It has been found that these two categories of bamboos which are different in geographic distribution and morphology have notable differences in internal structure. This provides ground for bamboo identification and serves as references in system development, vegetation evolution and genetic breeding in bamboo species.

3. The distribution of bamboo resources

Bambusoideae is subdivided into graminoids (herbaceous bamboos) and bamboos (woody bamboos). The former includes over 180 species of 28 genera, mainly grown in America. In China there is only one species, namely Leptaspis formosana (native to Taiwan province, or may be an introduced species). The latter grows America, Africa and Oceania. There is no wild species of this bamboo in Europe.

As the bamboos are characterized by fast growth, wide adaptability, high economic value and high reproductive capacity with vigorous rhizomes extending steadily to all directions, bamboo plantations are constructed uninterruptedly by people. In recent score of years, although the forest coverage of earth decreases every years, the area of bamboo forests is steadily increasing. Incomplete statistics shows that the total area of bamboo forests over the world is above 14 million ha, mainly distributed in tropical and subtropical areas, a minor part of them distributed in temperate and frigid zones. Among the bamboo forests in the world, those in Asia have the largest area. The area of bamboo forests in Southeast Asia have the largest area. The area of bamboo forests in Southeast Asia is over 10 million ha. Next in descending order of area are America, Africa and Oceania. In Europe there are no natural bamboo forests, with only some bamboo species introduced and cultivated.

Bamboos are distributed in three major regions in the world: Asia and the Pacific Ocean region, America region and Africa region.

Asia and the Pacific Ocean region is the largest one, extending southward to Singapore at 42 degrees S, northward to the middle Kurile Islands at 51 degrees N, eastward to the archipelagoes in the Pacific Ocean and westward to Southwest India. In this vast region, the bamboos are over 900 species of 50 genera. There are clump type bamboos and running bamboos. Those with tall thick culms, high quality and economic value are over 100 species. The Southeast Asia is the center of origin of bamboos in world, and also a modern distribution center of bamboos. In the Asia and Pacific Ocean region, the richest bamboo resources are in China, next in India.

The America region includes north America and South America, extending to South Argentina at 47 degrees S, and to east America at 40 degrees N. In this region there are over 270 species of 18 genera of bamboos and over 100 species of 24 genera of herbaceous bamboos. Except a few species, most of them are of less economic importance. Of the American bamboos, except Bambusa tuldoides sp. to be running bamboo, all other 17 genera are of clump type. In North America except Arundinaria and two other subspecies, no native species exist. Mexico, Quatemala, Honduras, Columbia, Venezuela and Brazil in the Amazon River valley, lying between the Tropic of Cancer and the Tropic of Capricorn are distribution center of bamboos, where species of bamboos are numerous and the land area is extensive. The bamboo species decreases in number when the region extends southward up to Argentina. Bamboos are mainly distributed in east America, and play a less important role in the development of culture, production and human life than those in Asia.

Distribution of bamboos in Africa is limited to a less scope, extending to South Mozambique at 22 degrees S, and to East Sudan at 16 degrees N. There is a tropical rain forest and evergreen deciduous mixed forest belt, stretching slantly from northwest to southeast, namely from South Senegal, Guinea, Liberia, South Ivory Coast, South Ghana, South Nigeria, Cameroon, Gabon, Congo, Zaire, Uganda, Kenya, Tanzania, Mozambique in west coast of Africa to Madagascar off the east coast of Africa. Here is the distribution center of bamboos. But in the main land of Africa bamboo flora are scarce. There are only a few native species, such as Garcinia, Oxytenanthera sp., and Bambusatuldoides sp., forming vast pure forests, or forming the medium or lower stories of mixed forests with other trees. However, in Madagascar there are approximately 40 species of 11 genera of bamboos, far more than those in the main land. The bamboos in Africa total 43 species of 14 genera with an area of 1.5 million ha. bamboos are mainly distributed in the developed countries in Asia, Africa and Latin America. Now most of the bamboo forests in the world lie waste. Being abusively felled and at a low level of management they give a low yield. Bamboos in China and Japan are managed at high level.

4. Bamboo resources in China and its characteristics

4.1. Bamboo resources in China

China is a country in the world, possessing richest bamboo resources, also a distribution centre of bamboos in the world. China has vast expanse of land, with complex terrains stretching over tropical, subtropical, temperate and frigid zones. Of the bountiful bamboo resources, there are sympodial clump type bamboos, growing in tropical zone, monopodial running bamboos growing in subtropical zone, and sympodial clump type bamboos and highly cold tolerant amphipodial mixed bamboos growing in high altitudes, at high elevation above sea level.

The relationship between genus and species in the Bambusoideae is a complicated problem in plant taxonomy. Special taxonomic difficulty arises from the long cycle of flowering of bamboos and the incomplete collection of specimen of reproductive organs collected at different times. But through efforts of majority of bamboo resources, successful study on Bambusoideae is being made, and much progress has been in many aspects of this research. Since 1788 the Swedish scholar

A. J. Retzius published the first scientific name "Bambos", the names of bamboos given by scholars all over the world in more than two centuries have numbered over 1,400 species of more than 120 genera. But great divergence of views exist over some genera and species. Some are wrong taxa, and are merged into one. Some violate the rules of "International Code of Botanical Nomenclature", and are denied. The bamboo plants accepted by majority of scholars are about 1,000 species of 70-80 genera. Those distributed in China are about 400-500 species of 40 genera. Up to now there is not a system of botanical taxonomy generally acknowledged. The major genera in China are: Melocanna Trin., Leptocanna Chia et H. L. Fung, Schizostachyum Nees., Pseudostachyum Munro, Cephalostachyum Munro, Thyrsostachys Gamble, Melocalamus Benth., Dinochloa Buse., Teinostachyum Munro, Bambusa Retz., Dendrocalamopsis (Chia et Fung) Keng f., Neosinocalamus Keng f., Dendrocalamus Nees., Gigantochloa Kurz, Indosasa McClure, Sinobambusa Makino, Brachystachyum Keng, Semiarundinaria Makino, Qiongzhuea Hsuech et Yi, Chimonobambusa Makino, Shibataea Makino, Phyllostachys Sieb et Zucc., Chimonocalamus Hsueh et Yi, Drepanostachyum Keng f., Fargesia Franchet, Yushania Keng f., Thamnocalamus Munro, Monocladus Chia et al, Ampelocalamus Chen et al, Racemobambos Holttum, Acidosasa Chu et Chao, Ligostachyum Wang et Ye. Pleioblastus Nakai, Bashania Keng f. et Yi, Gelidocalamus Wen, Pseudosasa Makino, Sasa Makino et Shibata, Indocalamus Nakai, Ferrocalamus Hsueh et Keng f. In China different views exist, too, over the bamboo taxonomy. For example, in the "Agricultural Encyclopedia: Forestry" 32 genera are recorded. With sci-technical progress and in-depth research, the bamboo taxonomy will be more rational and perfect.

4.2. The geographical distribution of bamboos in China.

Most of them are concentrated in Central China, South China and areas in Southeast China. Areas in Southwest China are noted for natural distribution of bamboos, especially in Yunnan Province. Generally speaking, running bamboos are mainly distributed in the Yangtze River valley, and the tall clump type bamboos are mainly distributed in areas in South and Southwest China. Due to natural geography, climate and geological history, the bamboo species in Yunnan Province not only are numerous, but are of ancient origin, with complexity of flora. Up to now, the bamboos found in Yunnan are over 200 species of 30 genera. Sichuan is one of the distribution centers, with about 200 species of 24 genera, taking a position in the foremost ranks in China. Fujian is also one of the major bamboo producing regions, rich in bamboo resources. There are over 140 species of 16 genera. Zhejiang is in the middle part of the tropical evergreen hardwood forest belt, rich in bamboo resources. There are 99 species of 19 genera, 14 varieties and 13 types. With the introduced bamboos covering 59 species of 5 genera and 8 varieties and 13 types added, there are 158 species of 24 genera, 22 varieties and 26 types. Moreover, in Hunan province, there are over 200 species of 16 genera. In Jiangxi Province the bamboos naturally distributed are 70-80 species of 18 genera with 12 introduced species of 4 genera. In Jiangsu Province there are 56 species of 9 genera, in Henan 23 species of 6 genera, in Guizhou 54 species of 15 genera, in Gansu 16 species of 7 genera and a variety, in Taiwan 56 species of 18 genera (including the introduced ones), in Anhui 39 species of 9 genera, and in Guangxi 92 species of 19 genera (including varieties and types).

Of the 400 species of bamboos distributed in China many species are of economic importance, and many be developed and utilized by people. For example, the moso bamboo is a species most extensively distributed and shares the largest proportion in bamboo resources. It is both important timber bamboo and a shoot bamboo. In China the quality shoot bamboos number over 50. In addition to moso bamboos, those with a large area, higher yield and better quality are early spring shoot bamboo, smooth sheath bamboo, sweet shoot bamboo, red sheath bamboo, Jiangsu glaucous bamboo, stone bamboo, Jinfushan square bamboo, square bamboo, broad flower Dendrocalamus, large bamboo, and giant bamboo. Those used in paper making are Phyllostachys sp., Pleioblastus sp., Bambusa sp., Dendrocalamus sp., Neosinocalamus sp., and Chimonobambusa sp. In addition to these, there is a great lot of other quality bamboos used in ware weaving and horticulture. Bountiful resources create favorable conditions for bamboo development and utilization.

Except Heilongjiang, Jilin provinces, Inner Mongolia and Xinjiang regions, bamboos are distributed in 27 provinces (municipalities and regions) in China, but they are mainly distributed over the vast land south of 40 degrees N. In areas extending from here westward and northward, fewer and fewer species can be found. Due to the differences of climate, soil and landform, and of the biological characteristics, the bamboo distribution has obvious zonal and regional traits. It may be classified into five regions as follows: North running bamboo region. This region includes Southeast Gansu, North Sichuan, South Shaanxi, Henan, Jiangsu, South Shandong and Southwest Hebei. In this region the bamboos are 29 species of 10 genera, 10 varieties and types. The major species are running bamboo such as Bashania sp. and Phyllostachys sp. According to horizontal distribution, the region is subdivided into three natural distribution areas: north subtropical wet climate zone in the Huai River Valley and in the upper reaches of Yangtze River Valley, warm temperate semiwet climate zone in the middle and lower reaches of Yellow River Valley and the warm semiarid climate zone in Gansu and Shaanxi provinces.

Jiangnan mixed bamboo forest region: This region includes Southeast Sichuan, Hunan, Jiangxi, Zhejiang and Northwest Fujian, about at 25-30 degrees N. In this region the running bamboo forests are interspersed with the clump type bamboo forest. The running bamboo species are Phyllostachys sp., Indocalamus sp., Pleioblastus and the clump type species are Neosinocalamus sp. and bambusa sp. In this region the area of bamboo plantations is the largest and they give the highest yield. Especially it is true of moso bamboo. In other words, here is the distribution center of moso bamboo, showing high prosperity of bamboo industry.

Southwest alpine bamboo region: This region includes Southeast Tibet, Northwest and Northeast Yunnan and West and South Sichuan in the Transverse Mountain Range. In this region the major bamboo species are Sinarundinaria sp. and Yushania sp., which are alpine sympodial bamboos. Generally they are distributed in areas at an elevation of 1500-3,800 m, or higher.

South clump type bamboo region: According to stand composition and site quality, it is subdivided into two subregions: South China region and Southwest China region. The South China region includes Taiwan, coastal areas of Fujian and the areas south of the Nanling Mountain in Guangdong Province and Southeast Guangxi in the south subtropical monsoon evergreen hardwood forest belt and tropical monsoon forest and rain forest belt. The major clump type bamboo species are Bambusa sp., Schizostachyum sp. and Monocladus sp., among which there are more species of Bambusa Genus, which form a distribution center. Besides, there is amphipodial mixed bamboos such as Sinobambusa sp. The Southwest China region includes West Guangxi, South Guizhou and most part of Yunnan Province. The major clump type bamboos include Dendrocalamus sp., Gigantochloa sp., Cephalostachyum., and Thyrsostachys sp., among which there are more species of Dendrocalamus genus, which form the distribution center of this genus.

Jiongdian scandent bamboo region: This region includes the central south of Hainan Island, South Yunnan and west border areas of Yunnan and south border areas of Tibet. This region is characterized mainly by the many species of scandent clump bamboos, such as Melocalamus sp., Dinocloa sp., Schizostachyum sp., and Monocladus sp.

Although the warm temperate deciduous hardwood forest belt stretching from areas north of Yellow River in North China to Shandong Province is not the chief distribution area of bamboos, yet in some areas bamboos are cultivated, and there are wild bamboos growing in scattered spots in hills. Only the bamboo species are fewer. There is no endemic species, not speaking of endemic genus. The Pleioblastus chino Makino, a wild species in hills in East Liaoning is the only known bamboo distributed in the extreme north part of China.

In China there is not only significant difference in horizontal distribution of bamboos from north to south, but also in vertical distribution. Generally in areas at a low elevation the major bamboo species are bambusa sp., Dendrocalamus sp., Schizostachyum sp., and some lianoid bamboos. In areas at high altitudes the major species are Fargesia sp., Yushania sp., and Thamnocalamus sp., while the Chimonobambusa sp. and Qiongzhuea sp. frequently grow in areas at medium altitudes in China.

4.3. The area of bamboo forests in China.

China is a country, possessing rich bamboo resources and having long history of bamboo culture, processing and utilization. China ranks among the first ones either in bamboo resources, area of bamboo forests and growing stock, or in bamboo timber and shoot production in the world. Bamboo, it may be said, plays a dominant role in forestry in China.

The statistics of the fourth nationwide forest inventory (1984- 1988) shows that the total area of forests in China is 3.6602 million ha, among which 113,900 ha is in Taiwan Province. The area of bamboo forests is 2.94% of the total forest in China, being more than 10 times the world average total (the total area of bamboo forests is about 26% of the world total of forest areas). This is an evidence that bamboo industry in China plays an important role.

Due to the ecologic and biological characteristics of bamboos and the traits of landform, terrain and climate, bamboo forests in China are mainly distributed in South China covering Fujian, Jiangxi, Hunan and Zhejiang provinces. The total area of bamboo forests in the four provinces is 2.1514 million ha, being over 60% of the national total of 3.5463 million ha (excluding that of Taiwan). Among them the area of bamboo forests in Fujian Province is 609,200 ha, being 16.7% of the national total, ranking the first in the country. Next is that in Jiangxi Province to be 534,000, being 15.1% of the national total, that in Hunan Province is 522,000 ha, being 14.7% of the national total, and that in Zhejiang Province is 486,200 ha, being 13.7% of the national total. In addition, there are over 100,000 ha of bamboo forest in Sichuan, Guangdong, Anhui, Guangxi, Yunnan and Hubei provinces, respectively. The area of bamboo forests is 6.7, 5.9, 7.4, 2.5, 1.0 and 1.0% of forest area in each of the six provinces. In other provinces and municipality in South China, such as Guizhou, Jiangsu and Shanghai, there are also bamboo forests with a certain area. In North China there are fewer bamboo forests, which are mainly distributed in Shaanxi Province with an area of 38,400 ha. Apart from these, there are also some bamboo forests in Henan, Shanxi and Shandong provinces.

In China Phyllostachys pubescens predominates in the bamboo resources. Its area is 74.2% of the total area of bamboo forests in China. In Fujian, Jiangxi, Hunan and Zhejiang bamboo producing provinces, Phyllostachys pubescens forest is the major forest, and the proportion of such forests in each province is above 90%. The total area of bamboo forests in these four provinces is 81.2% of the national total.

The bamboo industry is different from forestry in ownership. Forests are mainly owned by state, while the bamboo industry is mainly owned by collectives and individuals. The area of bamboo forests owned by collectives and individuals is 3.2744 million ha, being 92.3% of the national total.

In 1980s, with the technological progress and the increasing social demand for bamboo, bamboo plantations were established every year, but the area decreased annually. In 1981, the area of bamboo plantations newly built was 18,267 ha, in 1986 it was 7,200 ha, and at the end of 1980 it was less than these figures. In the early 1980s, more bamboo plantations were established in Hunan, Hubei, Sichuan and Zhejiang provinces. But in late 1980s, Guangdong, Guangxi and Zhejiang become the major provinces where bamboo plantations were constructed.

In 1989, the bamboo growing stock in China totaled 38.639 billion culms, among which the growing stock of moso bamboo was 7.96 billion culms, being 20.6% of the total. The miscellaneous bamboo stands are 79.4%. Although due to small size and light weight, the number of miscellaneous bamboos is greater than that of moso bamboos, yet the actual output is far less than that of the latter. So the growing stock of moso bamboos still occupies a prominent position.

5. The present situation of bamboo resources in China.

5.1. The continuous increase of bamboo area.

The area of bamboo plantation in Chinese mainland is 3.55 million ha, with a stock of some 80 million ton, the total bamboo area is some 7 million ha, including natural bamboo groves (Zhou Fangchun, 1991).

In the beginning of 1950s, the area of bamboo plantation was 2.6 million ha. In forty years from 1950-1990, the annual increase of bamboo area was some 40 thousand ha per year, in last seven years the increase was 49 thousand ha per year.

The reasons for such increase were: 1) The governments of all levels were always supporting the plantation of bamboo. There were 141 counties with natural conditions favorable for bamboo growth, distributed in 12 provinces and autonomous regions. Substantial investment from governments were made into 70 counties, which were regarded as bamboo production base. 2) Bamboo plants were always mixed with tree species, forming mixed forests. After cutting the second growth emerged with bamboo dominating. Therefore the forest area in China was once decreasing, while the bamboo area was increasing by 2% a year (Lou Chong, 1991).

Sichuan Province has 739,000 ha. of bamboo plantation and natural groves. According to the resources statistics of 1984 - 1988, the area of bamboo plantations was 342,000 ha., 1.4 times more than that of 1977-1981 (144,000 ha.). The rapid increase of bamboo plantations in Sichuan was related to establishing bamboo producing bases for paper-making by paper mills, but a more important reason was that the forest was damaged, the mixed forests with bamboo undergrowth became pure bamboos, and were regarded as bamboo plantations (Liu Yun, 1991).

Table 1.1. Changes of Bamboo Plantations in Main Bamboo-producing Provinces in Mainland of China (Unit: 1,000 ha.)

Province	2nd inventory (1984-1988)	1st inventory (1977-1981)	percentage(%) second/first
Fujian	609	580	105
Jiangxi	534	456	117
Hunan	522	493	106
Zhejiang	486	486	100
Sichuan	342	144	237
Guangdong	317	341	93
Anhui	176	143	123
Guangxi	163	173	94
Yunnan	144	158	91
Hubei	124	83	149
Guizhou	50	51	98
Shaanxi	38	38	100
Jiangsu	23	41	56
total	3546.3	3199.6	111

Note: Compoled of the basis of 2 inventories conducted during 1977-1988)

Two inventories of national forest resources indicated that the area of bamboo plantations expanded by 346,700 ha. But according to silviculture statistics, there were 83,000 ha. of new bamboo forests, which indicated that three forth of them were secondary bamboo groves formed after cutting.

5.2. The decline of bamboo resource quality.

Based on the data of national forest resources inventories conducted during 1977-1981 and 1984-1988, the quality of bamboo resources declined. The proportion of Phyllostachys pubescens bamboo stands (e.g.large-diameter bamboo) declined to 71% from 78%, the area of mixed bamboo increased from 22% to 29%. The total stand volume of Phyllostachys pubescens declined from 3,579.57 million culms to 3,383.56 million culms. The amount of stand bamboos decreased from 1,434 culms/ha. to 1,339 culms/ha. on the average.

Table 1.2. Decline of bamboo stand quality (Unit: 1,000 ha.)

year	area of bamboo plantation	Ph. pubescens area	Ph. pubescens culms	other species area
1977-1981	3196.6 (100%)	2496.6 (78.8%)	357.957 (1434/ha)	703.0 (22%)
1984-1988	3546.3 (100%)	2526.4 (71%)	338.356 (1339/ha)	101.99 (29%)

The area of whole nation's bamboo forests expanded by 49%, while the stand volume increased only 29% during 1957-1980. "The Gist of Development Plan of China's Bamboo Industry during 1992-2000" (draft) admitted that: In the past 40 years, the area of bamboo was doubled and the stand volume increased about 50%.

5.3. Low level in bamboo production

The book "The Present Forestry Situation in China" published in 1985 pointed out that bamboo grows rapidly and has high yield. It takes only 5-6 years for moso bamboo to reach the age to be cut and utilized from coming up out of ground, which is 10-20 years shorter than that of fast-growing tree species. The annual yield/ha. of bamboo forest is several times as much as that of coniferous or broad-leaved forests. Under good growth conditions, bamboos yield 22.5-30 t/ha, twice or three fold as much as that of Chinese fir.

Based on inventory, the area of bamboo under intensive management account for only 3-5% of the total area of bamboo forests in China, with an annual yield 7.5-30 t/ha. The areas of bamboo under normal management or extensive management account for 25-30% and 65-70% of the total area of bamboo, and the yields were 1.5-7.5t/ha. and less than 1.5 t/ha. respectively. Since large proportion of bamboo forests are under extensive management, China's bamboo has a low yield per unit area. The mean yield is only 1.5 t/ha. annually. In the outlying area, bamboo groves are left to themselves and seldom harvested and utilized. While in those accessible areas, bamboo groves are overcut and culms are rather thin. The management of most bamboo groves is far from getting onto the track of increasing yields gradually and sustaining management.

5.4. Output of bamboo culms fluctuates seriously.

It was 60-70 million culms per year in 1960s, 90-100 million culms from 1970s to 1984, it dropped sharply in 1985-1986, and raised to the previous level in 1987. In 1991, the output increased dramatically and reached 292 million culms. The rapid development of bamboo processing industry in recent years stimulated bamboo cutting. The bamboo market changed greatly, the supply surplus has changed into demand surplus. Such a market is favorable for developing bamboo plantation. But a latent crisis is that the bamboo resources may be damaged again if previous management system can not be improved once and for all.

5.5. The present situation of bamboo resources is as much satisfying as worrying.

The bamboo production in Zhejiang Province reached 70,570,000 culms in 1991, which equals to the annual yield of the whole country in 1960's and 1970's on the average. The quality of bamboo resources in this province was improved as a result of rapid increase of yield. While the area of bamboo expanded, the stand density per unit area raised to 1,980 culms/ha. from 1,725 culms/ha.

Table 1.3. Bamboo Yield in Mainland of China, 1949 - 1990.(unit: million culms)

year	yield	year	yield	year	yield	year	yield
1949-1952	27.10	1962	60.76	1972	76.29	1982	101.83
1953	26.43	1963	68.53	1973	114.93	1983	96.01
1954	50.21	1964	67.26	1974	99.54	1984	91.17
1955	59.02	1965	70.31	1975	90.73	1985	56.41
1956	124.9	1966	69.91	1976	104.39	1986	77.16
1957	93.48	1967	72.23	1977	107.99	1987	118.55
1958	148.73	1968	66.03	1978	111.81	1988	262.11
1959	155.47	1969	66.19	1979	105.07	1989	152.38
1960	88.69	1970	69.58	1980	96.21	1990	187.14
1961	49.93	1971	75.42	1981	86.56		

Table 1.4. Bamboo Yield Ratio in 1987-1991 by Provinces (unit: million culms)

Province	1991	1987	Ratio 91/87	Province	1991	1987	Ratio 91/87
Zhejiang	70.571	8.66	815	Hubei	7.3669	17.76	41
Guangdong	54.0769	21.39	253	Shaanxi	6.1082	2.13	287
Fujian	49.1669	12.67	388	Anhui	5.9503	4.41	135
Hunan	32.7475	20.88	157	Jiangsu	4.6195	0.39	1184
Jiangxi	29.1120	12.36	236	Guizhou	2.3439	0.83	282
Yunnan	15.4071	8.49	181	Sichuan	2.2471	1.82	123
Guangxi	11.6781	6.67	175	Henan	0.3324	0.09	369
				Total	91.7328	11.855	246

"A review on the development of the bamboo course in China" (1990) written by Center of Bamboo Research and Development under Ministry of Forestry indicated: "The present situation of China's bamboo is rather serious. The management is extensive, and backward, stand volume reduces, yield per unit area declines, the utilization rate is low, bamboo-processing products are in a low grade, poor economic benefits, backwardness of industrial structure and so on". In recent years, the government invested only several hundred thousands RMB yuan into bamboo scientific and technological research annually, which means less than 0.15 yuan/ha. on the average. It should be admitted that the overall situation of bamboo in the mainland of China may cause people rather to worry than to be satisfied. The examples are as follows:

5.5.1.Chongyi County, Jiangxi Province.

The area of bamboo in this county reduced by a quarter (from 35,100 ha. to 26,600 ha.) during 11 years from 1975 to 1986. The stand volume dropped by 41%. The stand density reduced to 1,425 culms/ha. from 1,927 culms/ha. Within the scope of 1.5 km on both sides of highways the range of residuary bamboo forest expanded.

The culms became thinner. Phyllostachys pubescens with periphery exceeding 33 cm at the height of eyebrow are seldom to be seen. In the area hardly accessible, bamboo groves are left to themselves (Shen Shixiang, 1989).

Table 1.5. The Decline of Bamboo Area in Chongyi County (inventory 1975-1986)

year	area (ha.)	amount of stand volume (culms)	density (culms/ha.)
1975	35,100 (100%)	64,132,101 (100%)	1,827 (100%)
1980	29,086 (82.9%)	49,495,464 (77.2%)	1,701 (93.1%)
1986	26,600 (75.8%)	37,908,162 (59.1%)	1,425 (78%)

5.5.2. Jian'ou County, Fujian Province.

This county owns 62,000 ha. of Phyllostachys pubescens. Measuring by county as the unit, the area of bamboo in Jian'ou occupies the first place in China. The amount of stand bamboo is near 100 million culms. The stand density is 1,605 culms/ha. on the average. But the yield is rather low. According to statistics, bamboo forest in this county yields less than 30 culms/ha. of commercial bamboo, 37.5 kg/ha. of dried bamboo shoot annually. The output value per ha. is 450 yuan on the average (Zheng Jinyan, 1992).

5.5.3. Yihuang County, Jiangxi Province.

This county possessed 12,800 ha. of Phyllostachys pubescens and the amount of stand bamboo was 11.38 million culms in 1987. Yihuang County is one of the 70 base counties which replanted a million culms of commercial Phyllostachys pubescens during 1977- 1985; it is also one of the 4 raw material bases selected by Fuzhou Paper Mill of Jiangxi Province. In 1989, Rao Junda, an official of Yihuang County authority, pointed out: "Peasants feel no interest in cultivating bamboo. At the beginning of 1950's, Yihuang County was rich in Phyllostachys pubescens resources. The grove form was compacted, the diameter of culms was large. Although bamboo groves were damaged during 'The Great Leap Forward' and the 'Cultural Revolution', the stand volume was 21.22 million according to the statistics in 1981. The situation of Phyllostachys pubescens resources has been worsening in the recent years. According to the statistics in 1985, 5 townships where Phyllostachys pubescens grew intensively had 8,300 ha. of bamboo producing area, in which the amount of standing bamboo is only 882 culms/ha. some 99% of the bamboo suffer from overcutting, utilizing without tending".

5.5.4. Tongren County, Guizhou Province.

Liulong Mountain in Tongren had 5412.9 ha. of Ph. nidularia cv. smooth-sheath in 1982, and enlarged to 6,218.7ha. in 1989, while the stand volume decreased from 323,199 tons to 129,584 tons, by 59.91%. Stand volume decreased from 59,709 kg/ha. to 27,585 kg/ha. The mean diameter at eyebrow-high and height of stand bamboo reduced year by year. The weight of individual culm declined at the rate of 66.27%. The inevitable result would be that the Ph. nidularia cv smooth-sheath resource disappears at last without improving the management and preventing deforesting (Wang Jianping, 1993).

5.5.5. Fujian Province.

According to the report of Fujian Daily on September 20, 1986, Fujian has the largest area of Phyllostachys pubescens in China. Some 572,000 ha. of bamboo stands had been established up to 1984, which was fourfold as much as that in the beginning of 1950's. But the amount of stand bamboo was only 1,170 culms/ha., while the amount in 1953-1957, 1963, 1978 was 4,035, 1,761 and 1,335 respectively. The government calls for managing bamboo in the same way as managing trees; the bamboo resources should be richer and the quality of bamboo better after rational harvesting and yield should be sustainable. China has a large population and less land resource comparatively. Only by raising productivity of bamboos continuously can it be possible to realize sustainable yield of bamboo groves.

6. Ideas about the improvement of bamboo resources

Transformation of low-yielding groves is the kernel of developing bamboo resource. It was estimated (1993, Xiao Jianghua) that the area of managed bamboo forest reached 4 million ha. in the mainland, 0.4 million ha. more than that investigated in 1988. The national bamboo industry development program of 1992-2000 calls for setting up 1.733 million ha. of bamboo bases by 2000, in which 1.6 million ha. by transforming, and 0.133 million ha. by establishing, account for 92.3%, 7.7% of the total, respectively.

6.1. Transformation of low-yielding bamboo forest.

The area of moso bamboo forest amounts to three forth of the area of bamboo forest. The annual yield per unit area is only about 1.5 t/ha. "The Standard of Phyllostachys pubescens High-yielding Techniques" drawn up by Bamboo Institute of Nanjing Forestry University, Institute of Subtropical Forestry of Chinese Academy of Forestry, Forestry Institute of Jiangxi, Forestry Institute of Sichuan, Forestry Institute of Guangxi, and Liuzhou Forestry Institute of Guangxi, has been extended throughout China. The yield per unit area of high-yielding moso bamboo forest is as high as over 15 t/ha, 10 times as much as that of ordinary one. The well-managed high-yielding bamboo forest has even higher yield. Prof. Chen Rong considered that the best density of bamboo forest is 3,000 - 4,500 culms/ha. based on experiences. The density of high-yielding moso bamboo in Shimen County, Zhejiang Province is just within this limits.

Within the bamboo forests in China, intensively managed forest (first grade), common managed forest (second grade), and worse-managed forest (third grade) accounts for 7%, 30%, 67% and the stand bamboo densities are higher than 3,000 culms/ha., 1,500 -3,000 culms/ha., and less than 1,500 culms/ha., respectively. The Development Programme calls for transforming 666,700 ha. of third grade bamboo forests into second grade. The area is a quarter of the total area of moso bamboo forests in China. The purpose aims at increasing stand volume of bamboo forests, raising yield per unit area and laying a foundation for directive breeding of high-yielding bamboo forests.

6.2. Establishment of high-yielding bamboo timber forest bases.

The main purpose of the programme is to supply quality raw materials for developing bamboo plywood, breed directly bamboo in 166,600 ha. of moso bamboo forest existed, and supply all the raw materials needed by bamboo plywood industry.

6.3. Establishment of high-yielding shoot and culm stand bases.

Based on the bamboo stands available, the main purpose is to establish 400,000 ha. of high-yielding shoot and culm stands by the year 2000, and supply quality raw materials for culm and shoot processing industry. It is required that these bases, which occupy 10% of the total area of bamboo forests, supply with 22% of the culms and shoots needed by the whole country.

6.4. Establishment of high-yielding bamboo pulpwood stand bases.

The programme aims at supply quality raw materials for machine-made paper. The planned area is 246,700 ha., in which transformed moso bamboo forests 133,300 ha., clump type forest 46.700 ha., new-established clump type forest 66,700 ha. Sichuan, Guangxi and Guizhou provinces occupy 50%, 30% and 20% of the new-established bamboo forests, respectively.

Changjiang Paper Mill of Sichuan Province has cultivated 3,300 ha. of bamboo forest in Yibin since 1983, and supplied bamboo chips for paper-making steadily since 1989. 20,000 tons (6 t/ha.) of bamboo chips are supplied annually on the average (He Tianjian, 1992). The mill plans to expand base construction in 10 years and has selected and bred several fine bamboo species for pulp-making such as

Sinobambusa sp.,Dendrocalamus latiflorus Munro, Bambusa distegia (Keng et Keng. f.) Chia et H. L. Fung, Bambusa intermedia Hsuehet Yi, and Bambusa prominens.

6.5. Establishment of high-yielding shoot stand bases.

It is planned to establish 253,300 ha. of high-yielding bamboo shoot bases, in which transformed bamboo forest, newly-established plantations will occupy 186,700 ha. and 66,700 ha. respectively by 2000. The expected yields of culm and shoot should be raised from 8 million and 1.25 million tons to 160 million and 2 million tons respectively. According to the trend of expanding the area of bamboo forest in the past several decades, the area of bamboo forest will increase sharply by 2000. Based on a conservative estimation, by 2000, the area of bamboo forest may reach 4 million ha. which has reached now according to someone's estimation. At that time, even if the goal (16 million tons of bamboo culms, and 2 million tons of bamboo shoot) is achieved, the average yield of bamboo forest reach 4.5t/ha (fresh weight) which equals to 3 t/ha. (dry weight), the output value of biomass per unit area is only the level reached by European countries and Japan long ago, and far from the acknowledged standard by which the annual growth increment is at least 14 cubic meters/ha. for fast-growing and high-yielding stands.

Reviewing the history of developing bamboo resources in the past 40 years in China, it may be considered that the extension of bamboo forest is the result of forest harvest and succession to a large extent. Prof. Zhou Fangchun made a brilliant explanation about this in 1985: Bamboos have a character of growing by rhizomes. Due to the artificial succession law of bamboo - tree mixed forest, the area of bamboo forest extends year by year. The area of bamboo forest in China extended in the annual rate of 2.45% on the average in 15 years from 1965-1980. By this rate, the area of bamboo forest will reach 82.8 million mu (5.52 million ha.) by 2000.

Table 1.6. The Change of Total Bamboo Area (Unit: million ha.)

year	1957	1965	1967	1980	annual increment rate (1965-1980)
	2	2.3655	2.7047	3.4018	2.45

PART II. BAMBOO-BASED PANELS

As the rapid development of wood-based panels industry in China and the shortage of timber supply, bamboo plays more and more important role in the economic construction. With good physical and mechanical properties, low shrinkage and average density of 0.74 g/cm3, bamboo is very suitable for making various kinds of bamboo-based panels.

Bamboo-based panels industry has been developing very fast in China. With 200 mills, the annual production reached 100,000m3 of panels. The major products include bamboo plywood, bamboo laminated lumber, bamboo concrete form, bamboo particleboard, bamboo veneer faced panels, and bamboo fiberboard etc., and the major applications are platform boards for lorry and train, concrete form, and packing, replacing 1 million m3 of industrial timber annually.

It is reported that the annual total output value of bamboo industry is about 5.5 billion RMB yuan, in which bamboo-based products 4 billion RMB yuan, bamboo processing products 1.5 billion RMB yuan, export value 150 million US$.

As a kind of raw materials for panel industry, compared with wood, bamboo possesses some specific features:

-- High mechanical strength and wear resistance; easy to be processed in to thin splits.

-- Easy to be processed in discoloration and dyeing; good to be used as surfacing materials.

-- Different structures and properties of outer layer and inner layer of culm, which cause difficulties in processing and utilization.

-- Special equipments, different from that for wood processing, are needed for bamboo processing.

-- Easy to be attacked by molds and insects because of high starch, protein and sugar contents.

There are many kinds of panel products being produced in China, including bamboo plywood,bamboo laminated lumber,bamboo veneer faced panels,bamboo particleboard and bamboo fiberboard.

1. Bamboo plywood group

1.1. Bamboo plywood

Bamboo plywood is a panel consisting of an assembly of plies of bamboo sheets bonded together with the direction of the grain, in alternate plies at right angles. An adhesive of phenolic resin is used. The bamboo species used for the raw material is Phyllostachys pubescens which averages 9 cm in diameter at the breast height.

The processing procedure is as follows: Bamboo culm is first crosscut into four or so with the desired lengths and the inner and outer surface layers are scraped out on equipment specially designed. The cuts are then split open into two or three pieces. Following a pretreatment by soaking the pieces in a cooking vat for several hours, the pieces are dipped in a vessel with a medium at a temperature far beyond 100xC so as to enhance the temperature of the pieces to a certain degree to soften the wood. This serves to thermoplasticize the lignin and hemicellulose more effectively. The treated pieces are then spread out, flattened, dried and stabilized through a heated press and a breathing drier, specially used for processing bamboo sheets. The pieces are planed smooth and edged straight on both sides. This prepares the material-faces, backs and crossbands--for the manufacturing of bamboo plywood. The forthcoming procedures are just the same as the manufacture of plywood. Bamboo plywood is extremely high in bending strength--modulus of rupture (MOR); modulus of elasticity (MOE) and it probably ranks as the highest among all of the structural boards and even as good as the solid wood of high density commercial timbers. Bamboo coupled with wood is a material of heterogeneity and anisotropy. This property may be evaluated as a disadvantage on the one hand and an advantage on the other. Some may places this property of bamboo at a disadvantage in competition with other products. In fact, many of the disadvantages, real or implied, as decay and insect attack, could be overcome by intelligent use of bamboo, based on a comprehensive knowledge of its characteristics.

It is known that bamboo is exceptionally anisotropic in nature and this character could be overcame by crossbanding to a certain extent as desired. The problem is in developing the resulting characteristics to a much higher degree as we do in oriented strand board (OSB) and also in oriented strand composite plywood (OSCP). Bamboo plywood serves this purpose. As the orientation of fibers in bamboo is nearly perfect along the grain, the bending strength of the product is remarkably superior to those of OSB and OSCP. It is also high in flexible rigidity. In comparison with other structural materials other than wood and wood products, they are mostly isotropic and there is no way to strengthen the bending strength and stiffness as expected.

A tentative comparison of strength properties of a few structural materials is shown in Table 1.

We understand that the nature of the cell wall substance and its distribution as a system of thin-walled tubes makes wood very efficient in flexible rigidity. So does bamboo. This high flexible rigidity is most effective in members as beams in which length is far in excess of depth. In comparison with other structural materials, the weight-strength ratio for bamboo product is very favorable for some applications. This high stiffness-to-weight ratio exhibits a characteristic which is considered to be an important criterion for evaluating the mechanical properties of a material and this form of cellular organization is also a highly efficient means for obtaining the maximum moment of inertia from a minimum amount of material. The moment of inertia of a bending member is vastly increased if a given amount of material is arranged as a tubular structure rather than a solid rod. For this reason, bamboo products have a high index of rigidity in comparison with solid structural materials and is well suited for use in situations that require elastic stability. Compared with wood, bamboo product is at least times as good an energy- absorbing medium as steel. This makes it an excellent material for floors and similar applications where energy absorption is important.

Table 2.1. Comparison of five wood based materials.

Material	Strength MOR (Kg/cm))	Properties MOE (Kg/cm))
Particleboard (random)	235	34,483
OSCP	740	42,200
Plybamboo	1,175	211,000
Oak, Chinese species	1,506	149,000
Oak, American species	1,655	163,448

Bamboo, being similar to wood, is a cellular substance and in the dry state the cell cavities are filled with air, which is one of the poorest conductors known. Because of this fibrous structure and the entrapped air, bamboo has an excellent insulation property. The common building materials used in house construction with the exception of wood are not good insulators. In comparison with wood, the heat loss through common brick is six times and through a glass window eight times as great, whereas concrete and steel are fifteen and three hundred ninety times as conductive as wood respectively. Experiments show that the coefficient of heat conductivity of bamboo product is a little higher than that of wood, but the difference is too small to be taken into account.

Bamboo plywood associated with wood and wood products provides thermal insulation the year round. It is effective not only in winter against cold, but also in the summer against heat. Combined with wood, it is a remarkable structural material for shelter where an effective thermal insulating property is necessary.

Wood structures can withstand an impact load twice as great as that of static loading. It is also true for bamboo products. This exceptional impact strength gives it a considerable mechanical and economic advantage for structures designed to resist earthquakes or for situations where abrupt loads are imposed. Bamboo is susceptible to fungi and insect. Experiments demonstrate that no damage of decay and insect attack has occurred, when phenolic resin is used as the binder of the bamboo plywood. This is also the case in fire resistance. There is no reason why, if properly used, bamboo products should not last indefinitely. Because of the shortage and uneven distribution of forest resources in China, the supply of timber is far below the even-increasing demands of the country. Therefore China's scientists explore all possibilities to use wood efficiently and develop new product replacement for it. The manufacture of bamboo plywood is perhaps one such achievement in this field.

China is lucky in having extensive bamboo resources with more than 300 species. There are 3.401,800ha of bamboo stands of which 2,418,600ha is made up of Ph. pubescens. The growing stock is about 3,759,890,000(3.796 thousand million) bamboo culms. On a hypothetical rotation of six years, the annual harvesting will be about 632,648,300culms. An estimate on the number of culms of bamboo of 9 cm diameter needed for making 1 m3 of bamboo plywood has been made on a pilot plant. The results show that 150 culms would be sufficient to meet the need at the present running level. This means a total of 4,217,650m3 of bamboo plywood which is equivalent to four times the present production of all the wood-based materials, could be made annually.

The technology and equipment for making bamboo plywood were first developed at the Nanjing Forestry University in 1982.

1.1.1 Production process

The bamboo species used for the raw material is Phyllostachys pubescens with average diameter of 9 cm at the breast height. Bamboo culm is first crosscut into desired lengths and the inner and outer surface layers are scraped out on equipment specially designed. The cuts are then split open into three pieces.

Following a pretreatment by soaking the pieces in hot water of 70-80 degree C for three hours, the pieces are softened by steaming at 160 degree C to thermopasticize the lignin and hemicellulose effectively.

The treated pieces are then spread out, flattened, dried and stabilized through a heated press, a pre-drying kiln and a hot platen press dryer, specially used for processing bamboo sheets.

The pieces are planed smooth and edged straight on both sides. This prepares the material- faces, backs and crossbands for the manufacturing of bamboo plywood. The forthcoming procedures are just the same as the manufacture of plywood.

1.1.2. Properties of bamboo plywood

Bamboo plywood is extremely high in bending strength, very good in dimensional stability, durable, wear resistance properties, and as easy as wood to be processed.

Major properties:

density	< 0.9 g/cm3
moisture content	< 12%
bonding strength	> 2.5 N/mm
static bending strength (longitudinal)	
thickness <15mm	>98 N/mm2
>15mm	>90 N/mm2
>25mm	>30 N/mm2

1.1.3. High strength bamboo plywood concrete form

Impregnated paper faced bamboo plywood has been used successfully as concrete forms.

Major properetíes:

density	< 0.95 g/cm3
moisture content	< 10 %
bonding strength	no delamination (3 hrs. boiling test)
value of abrasion	< 0.08g/100r (Taber test)
re-useable life	200 times for both sides

bending strength (MOR) and modules of elasticity (MOE)

thickness (mm)	longitudinal (MOR)	longitudinal (MOE)	cross (MOR)	cross (MOE)
12	>98	>10,000	>68	>7,000
18	>90	> 8,000	>63	>5,000
20-30	>75	> 7,000	>52	>4,900

1.1.4. Applications

With its excellent performance mentioned above, bamboo plywood has been widely used as platform boards for trucks, buses, and railway carriages, and also can be used as springboards in cargo transport, at wharves, and as concrete forms in constructions.

Bamboo plywood has been used as platform boards for 100,000 and 15,000 trucks at the Nanjing Automobile Manufacturing Company and the 1st Automobile Manufacturing Company in Changchun respectively, replacing 52,000 m3 of timber and 1,600 tons of steel, reducing the dead weight of platform by 53 kgs each.

1.2. Bamboo woven plywood

Bamboo woven plywood consists of bamboo mat plywood, bamboo mat corrugated plywood and bamboo curtain plywood.

1.2.1. Bamboo mat plywood

Bamboo culms are cut into long strips which are woven into mats. The mats are dried, glued assembled and hot pressed into bamboo mat plywood. This consists of two kinds of products, standard bamboo mat plywood and decorative bamboo mat plywood. There are 16 bamboo mat plywood factories, with annual capacity of 20,000 m3.

1.2.1.1. Production procedure

Bamboo culm is cut open into thin strips of inner skin in width of 12-15 mm and thickness of 0.6-1 mm with moisture content below 20%. The strips are woven into mats in size od 2,500 mm x 1,300 mm , and then dried to reduce the moisture content to 8-20 %. The mat is spread with UF glue with an amount of 280-320 g/m2. Soybean flower is used as filler in an amount of 5-10% , and 0.5 % NH_4CL is used as curing agent. The glued mats are assembled into blank and then hot pressed into bamboo mat plywood.

1.2.1.2. Applications

Bamboo mat plywood is used for packing, furniture making and interior decorations.

1.2.2. Bamboo mat corrugated plywood

The production procedure is similar to that of bamboo mat plywood. The mat is dried to reduce the moisture content to 12-14 %. PF glue is applied to the mat with an amount of 400 g/m2 (single face). A set of five layer mats is hot pressed between two corrugated caul plates into corrugated plywood. With The high strength, low weight and good insulation properties, the product is suitable to be used as roof material for low cost buildings such as prefabricated houses,etc..

1.2.3. Bamboo curtain plywood

Culms cut into long strips in thickness of 1 mm and width of 10-20 mm which are woven into curtains. After drying to reduce the moisture content to less than 12

%, the curtains are dipped with PF glue and then dried and hot pressed into plywood with working pressure of 3-4 Mpa. The size of the plywood is 4,500x1,300 mm with thickness of 6,12,16,20,30mm.

Table 2.2. Comparison of properties of 5 bamboo panels

	BCP	BP	BLL	BMP	BP
density (g/cm3)	0.85	0.85	1.0-1.1	---	0.83
MOR (Mpa)	121.2	105.5	160	80	21.7
MOE (Mpa)	11,200	9898	---	---	---
impact strength(J/cm2)	13.6	7.95	12.4	---	---

Notes: BCP-bamboo curtain plywood, BP-bamboo plywood, BLL- bamboo laminated lumber, BMP-bamboo mat plywood, BP-bamboo particleboard

It can be seen from the table above,that the properties of bamboo curtain plywood are much better than other bamboo plywoods, except the MOR is slightly lower than that of BLL.

Bamboo curtain plywood has wide rage of applications, the thin panels can be used for packing purposes, the panels in medium thickness can be used for interior decorations, and the thick panels can be used as structural materials. Having large size, it can be used in some special applications such as large size concrete forms and platforms for trucks, etc..

1.2.4. Bamboo curtain plywood laminated with resin impregnated paper

Main materials include bamboo curtain, bamboo mat, primer paper(a kraft paper of 80-120 g/m2, without water repellant additives), water -borne PF adhesive and modified melamine adhesive.

Bamboo curtain is impregnated with PF adhesive and then dried. Prime paper is impregnated with a modified melamine adhesive, which a small amount of diluent, release agent, and catalyst are added, and then dried.

When assembling ,the position and number of longitudinal and cross bamboo curtains must in accordance with the thickness of the panel and the MOE ratio in longitudinal and cross directions. The face and bottom of the panel are faced with one bamboo mat and one to two impregnated papers.

The hot pressing procedure is "cold-hot -cold". After loaded into press, the assembly is preheated to raise the temperature to 50-135 degree C. Hot pressing time of 1.5-2 min/mm panel thickness is needed for curing the resin. Cooling water is then introduced into hot platens to lower the temperature of the panel to 50 degree C.

After trimmed, the edges of the panel are sealed and coated to improve water resistance properties.

Table 2.3. Properties of Several Concrete Form

	BCPLRIP	Domestic Forms Laminated	Non-laminated	WISA-FORM Finland
Density (g/cm3)	0.80	0.78-0.85		
MOE (Mpa)	104.5	60	35	56
MOR (Gpa)	11.1	10	4.5	9.2
Bonding strength (Mpa)	2.73	1.4-1.8	>1.0	
Wear resistance	0.05g/100r	300 times		300 times
Linear expansion				
length	0.66	0.01% per 1% increase in MC		
width	0.136	ditto		

Notes:

-- Bamboo curtain plywood laminated with resin impregnated paper is a kind of medium density panel;

-- The standard of domestically produced laminated plywood concrete form is in accordance with the enterprise standard of "Panda" Brand Form set by Qingdo Hualin Plywood Limited Company;

-- The standard of domestically produced non-laminated plywood concrete form is in accordance with the standard ZB B 7006-88 for plywood for concrete form;

-- The standard of WISA-FORM of Finland is in accordance with testing report of SCHAUMAN Company of Finland. WISA-FORM is a laminated plywood;

-- All the three kinds of plywoods in (b), (c), (d) are made of birch wood.

Bamboo curtain plywood laminated with resin impregnated paper can be used as concrete forms to replace wood plywood concrete forms, and its performance is compete with WISA-FORM made in Finland.

2. Bamboo laminated lumber

Made from long bamboo strips , the product is used as platform for trucks. At present , the products are available in two sizes:
4070x140x30 mm, and 5371x140x30 mm.

Bamboo culms are cut into long strips with dimensions of 2200/2850 x 11-15 1-2 mm,and dried. The strip are dipped with PF resin and dried in temperature below 100 degree C. The strips are formed into oriented mats in even density and thickness, and then hot pressed at 130-140 degree C. The whole pressing circle may need about one hour.

Table 2.4. Properties of Bamboo laminated lumber

Density	g/cm3	0.99
Moisture content	%	9.7
MOR	Mpa	118.1
MOE	Mpa	32.2
Compression strength	Mpa	62
Shear strength	Mpa	43.5
Anti-splitting	Mpa	20.8
Hardness	Mpa	174.4

With good properties in water resistance,durability,dimensional stability, wear resistance and strength properties, this product is very suitable to be used as engineering materials such as platforms for trucks.

3. Bamboo molded products

3.1 Molded weaving shuttle of bamboo threads

The weaving shuttle is one of the important textile appliances and is generally made from high quality wood. Over 12 millions of weaving shuttles are used each year in China , consuming high quality wood more than 60,000 m3.

For molding weaving shuttles, bamboo culms are split into threads, then dried, impregnated with glue, and pressed in a hot press with a specially designed molds.

The molded bamboo weaving shuttle has advantages as follows:

-- better wear resistance , the service life is about twice that of wood;
-- lower friction compared with wood because of hard and smooth surface;
-- can be used in any environment condition without deformation;
-- the iron heads of a shuttle are inserted into the mold before bamboo threads being filled, and combined firmly with the body of shuttle after hot pressing, can hardly be dropped from shuttle body in operation.

3.2. Molded picking stick of laminated bamboo strips

The picking stick , generally made of laminated wood veneer,is also an important textile appliance . Over 50,000 m3 of high quality wood are consumed in making this product every year in China.

In a weaving machine the power is transmitted to the picking stick, and during swing it strikes the shuttle move quickly. It is obvious that the shock strength is more important than the compression and tensile strength for a picking stick.

The bamboo is good in shock strength. Bamboo culm is split into strips, and then dried, glued,and molded into picking sticks. A report from a textile plant, having tested bamboo sticks for long, indicated its practical service life was four times that of wooden ones.

4. Bamboo particleboard

Bamboo particles in sizes of 20-30 x 1-5 x 0.1-0.5 mm are prepared with chippers and/or ring flakers, and the moisture content is about 25-35%. The particle are dried in a rotary drum dryer at 150-180 degree C, to reduce the moisture content to 4-6 %.

After screening, glue spreading, forming ,prepressing and the bamboo particleboard with thickness of 4-6 mm is produced by hot pressing at 155-165 degree C and 1.18-1.14 Mpa, the pressing time is about 0.4 min/mm thickness of board. The density of the board is about 0.7 g/cm3.

This product can be used for furniture making and interior decorations such as ceiling, doors and intersections,etc..

5. Peeled bamboo veneer faced panels

Bamboo culms in length of 120-150 cm are steamed in hot water at 80-100 degree C for eight hours, and then cross cut into sections in length of 30-60 cm and peeled at a veneer lathe. The veneer is dried to reduce the moisture content to 8-12%.

Peeled bamboo veneer is good decorative material for furniture making and the bamboo veneer faced panels are being used for interior decorations.

6. Bamboo fiberboard

The process for making bamboo fiberboard is almost the same as that for wood fiberboard.

Chips are prepared in sizes of 20 x 5 mm, and immersed in water to increase the moisture content to 40-50 %. The chips are then steamed at 170 degree C and pressure of 8 kg/cm2 for 15 min. After defiberation and refining additives including PF resin and wax are added in the pulp, the PH of the pulp is adjusted to 5. After forming, prepressing and hot pressing, bamboo hardboard or MDF is made. For making 4mm thick, density of 1.0 g/cm3 hardboard, 1% PF resin and 1.0% wax are used, and the pressing time is 7 min at 210 degree C, 60 kg/cm2. For making MDF in thickness of 10 mm with density of 0.7 g/cm3, 5% PF and 1% wax are used and pressing time is about 16 min at 200 degree C , 35 kg/cm2.

For the manufacture of bamboo fiberboard, the Chinese made fiberboard production equipment is available , and only very little modifications are needed.

7. Bamboo wool-cement board

For making 1 m3 bamboo wool-cement board,150kg bamboo wool, 220 kg cement and 8 kg $CaCl_2$ are needed.

Bamboo wools are immersed in water at room temperature for 3-5 minutes. The moisture content of the soaked wool should not exceed 25% to facilitate the bonding between bamboo wool and cement. Bamboo wool are treated with 5% $CaCl_2$ and then mixed with cement. The ratio of bamboo wool and cement in weight is 1:1.8-2.2.For making bamboo-magnesite board, the ratio of bamboo wool and magnesite in weight is 1:1.7-1.8.

After forming, the mats are pressed into final thickness with working pressure 2-3 kg/cm2 (0.8-1.0kg/cm2 is used for bamboo wool-magnesite board). The package of pressed mats is dried and cured in panels at 30-40 degree C for 24-48 hours. The panels need conditioned and ventilation at room temperature for 1-2 weeks to reduce the moisture content to less than 20%, and then trimmed into final products.

Like low density fiberboard, bamboo wool cement board is very good in insulating, water repellent, fire retardant properties and is suitable for building applications such as ceiling, partitions, etc..

8. Bamboo parquet for flooring

This product was developed by Import and Export Corporation in Hunan Province in 1986. It is a single layer bamboo parquet in width of 10 cm made by radial jointing bamboo strips. This a good parquet product and now is in mass production and for export.

9. Considerations

Because of gradual reduction of forest resources and the shortage of wood supply, bamboo , with its characteristics of fast growth , short rotation, and strong regeneration, is an ideal material to replace wood. In the past 10 years, bamboo based panel industry has been developed rapidly, and bamboo is becoming more and more important rescouses in China.

For further develop bamboo based industries, some R&D work still need to be done, including:

-- development of new products such as bamboo scrimber, and value-added products;

-- development of bamboo processing equipment to improve the quality of products and production efficiency.

10. Examples for using bamboo-based panels

10.1. Bamboo plywood used as platform board of lorry

The Jiefang type medium lorry manufactured in 1956 by the First Automobile Factory at Changchun had wood platform. Wood consumption per lorry was 1.258 m3. In 1981, experiment was made to use steel in combination with wood. Of the new structure, the caul plates under longitudinal and cross beams and 10 central platform boards were made of wood, the longitudinal and cross beams, front, rear and side boards were all made of steel. In comparison two thirds of wood were saved. Wood consumption per lorry was 0.523 m3, but its dead weight increased by 200 kg. If a whole steel structure was adopted, the dead weight would increase by 350 kg. This was against the specification limit in weight of whole lorry. In 1958 the Nanjing Motors adopted a design of its own to construct the Yuejin type light lorry. The lorry platform and side boards were made entirely of wood. Wood consumption per lorry was 0.699 m3. In 1980, a new design was adopted. Front, rear and side boards, longitudinal and cross beams were made of steel. Only the caul plates under beams and platform boards were made of wood. Wood consumption per lorry was 0.412 m3. Supposing the annual output of lorries by Nanjing Motors be 40,000 and that by Changchun First Motors be 60,000, the annual consumption of high quality wood by both factories would be 60,000 m3 (85,000 m3 of log). In order to use less wood or not to use wood at all, both factories cooperated with concerned units in developing hard polyethylene platform boards instead of wooden ones. The lorries so made were examined in trial driving in Hainan Island, Beijing and Inner Mongolia, with some good results obtained. However, as the cost of plastic platform boards was 60% higher than that of wooden ones, it is not easy to be adopted by all factories.

10.2. Technical parameters of bamboo plywood as platform boards

The application of bamboo plywood to manufacturing platform boards in both types of lorries will meet with harsh terms. The lorries must drive or park with full load or excessive load on rough road in the extreme cold weather, in hottest summer, under direct sunshine or in steady rain. Therefore the platform boards of box must have enough strength, rigidity and an endurance life, with a greater factor of safety. For a low production cost and a lighter dead weight of lorry body, the design of platform boards demands a bamboo plywood structure as light as possible. Technical parameters based on adequate scientific data are necessary in designing the rational structure of platform boards of lorry box.

10.2.1. Choose proper kind of bamboo plywood

The test materials for platform boards include bamboo plywood supplied by Nanjing Forest University. The key technical point in this plywood processing is " bamboo materials softened at a high temperature and then flattened". The bamboo laminated plywood as test material supplied by the Laminated Wood Factory at Youlong county in Zhejiang province is made from bamboo strips which are impregnated with glue, unidirectional compressed and glued together. For correct choice of materials it is necessary for the test materials supplied and the wood originally used to stand a physico- mechanical test. Choice is made after comparison of their performance. The physico- mechanical properties are listed in Table 1-5.

Table 2.5. Physico-mechanical properties of tested materials

property	density	SBS of material (MPa)		SBS of joints (MPa)		BoS (MPa)		RD
material	g/cm3	MV	SV	MV	SV	MV	SV	1/cm3
PB 15 mm 3 layers	0.78	113.3	>,= 98			3.68	>,= 2.5	8.7
5 layers	0.85	105.5	>,= 98			3.52	>,= 2.5	9.1
PB 22 mm 5 layers 7 layers	0.85	126.1	>,= 98	75	>,= 68	3.50	>,= 2.5	9.1 12.4
LB 20 mm	1.03	120	>,= 98	41	>,= 68	to be degumed easily in boiling water		
WB (spruce) 33 mm	0.45	82.6						4.44

Note: 1. PB - Plybamboo. LB - Laminated bamboo. WB - Wood board. SBS - Static bending strength. BoS - Bonding strength. MV - Measured value. SV - Standard value.
2. measured value of bonding strength of plywood is obtained after 3 hr. of boiling water test.

Table 2.6. Aging resistance of bamboo plywood

stages \ property	BoS (MPa)	SBS (MPa)	test requirements
prior to aging	3.68	111.6	According to test criteria of accelerated aging set by ASTMD 1037 in USA, soaked in water 49°C for 1 hr -- vapor jet steaming 93°C for 3 hrs -- freezing at -12° for 20 hrs -- blast heating at 99°C for 3 hrs -- vapor jet steaming at 93°C for 3 hrs -- blast heating 99°C for 18 hrs. This is a cycle. It takes 288 hrs to complete 6 cycles.
post aging	3.03	52.8	
decreasing %	17.7	52.7	

Table 2.7. Acid corrosion resistance

stages \ property	SBS of PB (MPa)	central platform (cold-rolled steel)	test requirements
pre acid corrosion	105.2	no rust on surface	Plybamboo sample 22 x 200 x 300 mm soaked in solution pH 4 for 1 hr and air-dried. 10 days after drying, SBS pre and post testing were measured. Central steel platform waw treated same way.
post acid corrosion	102.8	thick yellow rust	
decerasing %	2.3		

Table 2.8. Desiccation of the materials

material \ property	desiccation percent.		
	length	width	thickness
PB	0.016	0.017	0.202
LB	0.015	0.181	0.127

Note: The desiccation percentage is a disiccation coefficient of moisture content (within 30% minus 1% of moisture). There is an assembly relation between the directions of length and width while the direction of thickness is of free dimension. The desiccation percentage of the width of LB is 12 times that of PB. The total desiccation of LB with a width of 1,000 mm is 18.1 mm, while that of PB is only 1.7 mm.

Table 2.9. The friction coefficient of 4 kinds of materials

property \ material	wood board platform	steel-wood platform	steel platform	PB platform	PB coated with resin
coefficient	0.52	0.31	0.28	0.42	0.47

From an integrated study of the properties listed in above 5 tables, a conclusion may be drawn: both the bamboo plywood and bamboo laminated plywood have high strength and acid resistance. Yet owing to the unevenness of assembly, similar grain direction, weak bonding strength, less strength in width, and a high desiccation percentage the laminated plywood is not suitable to be converted into large size boards, and therefore cannot meet the technical requirements of large size platform boards. The bamboo plywood is made of bamboo strips, each lying perpendicularly to the other in assembly, so it has high bonding strength, a long endurance life, acid resistance, lower desiccation percentage, less strength difference in longitudinal and transverse directions, and a high friction coefficient. All these properties are superior to those of wood. Based on scientific, economic and safety considerations, a decision is finally made to use bamboo plywood 15 mm thick instead of the pine wood 25 mm thick produced in Northeast China to make platform boards of box in the NJ type light lorry. The platform boards of box in CA 1091 type medium lorry are also made from the plywood 22 mm thick instead of the pine wood boards 33 mm thick. On each cross beam of the truss is fastened a slat of plywood 11 mm thick so that the platform boards of plywood, when installed on truss, reach a height of 33 mm equal to that of iron or wooden platform boards.

10.2.2. Structure of platform boards made of bamboo plywood

Nanjing Motors and Changchun First Motors propose a structure design of platform boards according to the particular features of chassis of their lorries.

10.2.2.1. Structure of platform boards of NJ type light lorry

Mode of fixation: Special steel nails with its surface carburized and hardened and with longitudinal and transverse fine grain on it are used to fix the platform boards of bamboo plywood on the 2mm thick steel cross beams of the truss. The holding power of the steel nails is about 5 times that of common iron nails.

10.2.2.2. Structure of platform boards of box of CA 1091 type medium lorry

Mode of fixation: Platform boards of plywood are fixed on the steel cross beams of the truss with 38 screws to prevent the box from deformation owing to torsion, and to avoid the relative displacement of the platform boards that may cause shear fracture of the nails. Experiment shows that the fixation of platform boards of bamboo plywood with bolts is firmer than that with steel nails, with the firmness increasing by 6-10%.

Up to now three structures of platform boards have ever been adopted. After examining the practical installation of the platform boards on truss and the operation of lorry at three experimental sites, the conclusions drawn are as follows: 1). The adoption of three-board structure demands high-low grooves on both sides of the boards. An advanced technique of processing is necessary for this job. Moreover, the resultant joints are not even and neat. 2). The strength of two-board structure is higher than that of the former one. 3). In the three-board structure, the narrow one of them is easy to suffer from damage. 4). Adoption of the structure of two long platform boards of plywood with a central iron platform board between them may increase the rigidity of the whole truss. Besides, the platform board of bamboo plywood may be as narrow as 1062 mm, and can be made by all factories with existing equipment. In such structure it is unnecessary to have grooves on both sides of the boards. With these advantages considered, a decision is made to adopt it as the standard structure for production by factories.

10.2.2.3.Mode of bamboo plywood joining for length increase

To meet the requirement of definite length of platform boards, it is necessary for the bamboo plywood boards to be joined. Repeated experiments show that both ends of the bamboo plywood should be beveled with an angle ratio 1:5. With bevels coated with phenolic adhesive, the bamboo plywood boards are joined by hot pressing, with the strength of joints being 70% higher than that of the board itself. For purpose of safety, the joints of platform boards are kept in contact with the cross beams. The boards are fixed on the cross beams with steel nails or bolts. In order to guarantee the strength of joints, they should be even and neat so that they may not be damaged during loading and unloading.

10.3. The development and utilization of bamboo concrete form

The construction industry has made rapid progress due to continous economic development. The technology of casting reinforced concrete is playing an important role in this progress. In Beijing, 90 per cent of the buildings were of reinforced concrete construction. The cost of the formwork is one third of the total engineering expense, and the amount of labor used is more than one third. All these show the importance of the formwork in casting reinforced concrete construction. The engineers in many countries are trying to find a new kind of formwork material for saving labor and time.

10.3.1.The status of formwork development

The development of the formwork structure trends to generate serial and system of formwork products, each having its characteristics and all being specially produced. Engineers are looking for the materials for producing more economic concrete form. Steel frame compositive formwork is regarded as the formwork by developed countries, because it has overcome the demerits of steel formwork and wood formwork and has many merits. Its weight is one third lighter than that of steel formwork, the amount of steel used are one half less than before, and one square metre of plywood has the same function as that of 5 square metres of logs. For this kind of plywood is made of steel as the skeleton and the plywood as appearance, it can save steel and wood. It is light, low- price and durable and could be used in a large scope.

During 1950s and 1960s, planks and finalized formwork are used in engineering. After the government encouraged to use steel formwork in 1970s, steel formwork was used in most constructive engineering. According to the statistical data in 1987, the amount of steel formwork China possessed were 25,000,000 square metres. But in broad engineering, there are many demerits in using steel formwork (its area is limited and it needs large amount of labor to assemble it). In this formwork, steel is the main material, its heavy weight brings the problem for carrying, and the price of thin steel plate is high in our country which costs 160 RMB yuan for one square metre. It is difficult for enterprises to afford.

After investigating the third generation of plywood technology in foreign countries, China Constructive Technology Development Centre and Qingdao Hualin Plywood Ltd. Co. imported advanced technology to produce phenolic compound plywood in 1987. Its annual output is 1,760,000 square metres. The plywood has merits of smooth appearance, durability and waterproofing, etc.. Each formwork can be used repeatedly for more than 50 times and it has been used in many big constructive engineerings in more than 20 provinces in China.

In China, the resources of wood and steel are short, so we have to develop new formwork. As each region has its own resources, after researching for many years we have developed 8 kinds of formworks which are:

-- Plastics formwork.

-- Casting aluminium alloy formwork.

-- Cylinder glass fibre reinforced plastics formwork.

-- Medium density fibreboard formwork.

-- Casting sand and wood formwork.

-- Compound hemp scrape formwork.

-- Plywood formwork.

-- Bamboo plywood formwork.

Each kind of formwork has its special merits. But here I would like only to deal with the bamboo plywood formwork in details because in China it is one of the fittest formwork to develop. It has many advantages which are as follows:

Firstly, there are more than 3,400,000 ha. of bamboo in China which is one of the richest countries in the world in terms of bamboo resources. China has an annual bamboo output of 60,000,000 to 70,000,000 tons. Owing to the rapid growth of bamboo, we can get the resources continuously.

Secondly, as the bamboo plywood formwork is woven by strips of bamboo and hot pressing, its properties are better than that made of other materials. It has high elastic modulus. Its contraction and the rate of water absorption are lower than that of wood formwork. It is shock wave-resisting. Its intensity and hardness are higher than that of wood formwork. It is lighter and can be produced conveniently.

Thirdly, plywood formwork is cheap, with only 40 to 50 per cent of the price of wood plywood formwork. Although it has many merits, its application is at the beginning stage. There exist some problems which should be settled down to get more rapid development.

10.3.2. Bamboo plywood formwork and steel frame bamboo plywood formwork

10.3.2.1. Bamboo plywood formwork

After weaving the strips of inner bamboo to blanket and curtain (or only using scatter strips of bamboo), drying, painting glue, assembling the base and hot pressing, we can get bamboo plywood. This kind of plywood is made of woven bamboo mat as the appearance (2 sides), painting coating or fire-resisting coating on its surface.

Processing technology of bamboo plywood:

bamboo --> cuting --> weaving into mat or curtain --> drying --> painting glue --> assembling the base --> hot pressing --> cuting out --> examining --> being laid up

The maximum size of this kind of plywood is 1,200 X 2,400 mm.

The adhesive is made from phenolic resin. How to blend it is vital to the adhesive and the rate of temperature, time and pressure are also the crux.

10.3.2.2. Steel frame bamboo plywood formwork

This kind of formwork was developed after learning foreign advanced technology. It is suitable to the condition in China because it has gathered the main merits of assembling steel formwork and plywood formwork. There are enough bamboo to make it, so the investment is not large. In addition, its machine size is suitable to that which produces assembling steel formwork and we can use it to produce steel frame bamboo plywood formwork. So, in China, the manufacturer can accept it easily. Now we have developed 15 different sizes with the maximum of 1,200 mm wide multiple 3,000 mm long and the weight of 70.6 kg, and the minimum of 0.72 square metres and the weight of 18 kg. The formwork can meet the building projects, especially the large-scale building projects. It has many advantages which are as follows:

-- Its area is large. The work efficiency to assemble it is 3-5 times more than before. It is suitable especially to high buildings.

-- Its weight is lighter, with one square metre being 19.61 kg which is 40 per cent less than assembling steel formwork.

-- Compared with assembling steel formwork, it saves 15.4 kg steel per square metre and its thickness is only 1/3 of that of wood formwork.

-- Its cost is low. One square metre can save 6.18 RMB yuan compared with assembling steel formwork. It takes only 60 per cent of time of assembling steel formwork. Each formwork can be used for 50 times and it can be easily mended up if damaged.

-- It can be widely used. It can meet the requirements of different shape buildings, round, arch, cone or ladder-shaped.

-- It can save the amount of work to assemble.

-- It does not need more investment than before.

-- It has a good property of temperature protection.

Taking all above into account, in China, the steel frame bamboo plywood formwork is the ideal formwork. It has been declared officially for extension. Perhaps, it will be the third generation of formwork in China.

Table 2.10. Different sizes of large formwork at home and abroad

Manufacture	length grade cm			width grade cm		maximum weight kg.	minimum area m^2	weight (kg/m^2)
Symons (USA)	90 150 240	120 210	30	60		34.8	1.44	24
Univers (USA)	60 120 180 240	90 150 210	30	30 45 60	15		1.44	
Bur (USA)	60 150 240	120 180	60	30 60 90 120	30	124	2.88	43
Mill (UK)	90 150 240	120 180	30	30 45 60	15	36	1.44	25
Uni-form (France)	90 150	120 180	30	30 65	15 45	33	1.08	30.5
Passchai (Ger)	62.5 100 150 275	75 125 250	25	10-100	5	110	2.75	40
Sanlian* (China)	122 244	183	61	30.5 61 91.5 122	30.5		3.0	
Wugong** (China)	120 180 300	150 240	30	60 90 120	30	70.6	3.6	19.6

Notes: * China Sanlian Concrete form Corporation.
** Wuhan Engineering Machinary Building Factory under the Ministry of Railways.

10.3.2.3.Tests on strength of structure with bamboo platform

-- Bending strength test

Bending strength test on the platform boards of 5 layer bamboo plywood (22 x 1,000 x 1.200 mm) and wooden platform boards under uniform load and concentrated load in transverse simulation was conducted by Changchun Automobile Research Institute. The results are tabulated in Table 6.

Table 2.11. Bending strength of the bamboo and wooden platform boards

load	BS	max. deflect./max. carrying capacity prior to breakage: fixed with 4 M10 screws	fixed with 10 M10 screws
CL	BB	44 mm / 27.5 KN	42 mm / 30 KN
	WB	35 mm / 7.5 KN	
UL	BB	51 mm / 30 KN	57 mm / 30 KN
	WB		29 mm / 28 KN

Note: BS - bending strength. CL - concentrated loading. UL - uniform loading. BB - bamboo board. WB - wood board.

Conclusions: 1. Nature of breakage of wood platform board is fracture. The carrying capacity after breakage was 1/5 or 1/4 of that of narrow board. 2. Nature of breakage of plybamboo platform board was tensile failure. The carrying capacity after breakage was 1/3 or 2/3 of that of the normal load, 3. Under the same load the strength of plybamboo platform board was superior to that of wood platform board. 4. Under concentrated load the strength of plybamboo platform board was about 2 times that of wood platform board.

-- Torsional fatigue test

Fatigue test on both kinds of platform boards are conducted by the Research Institutes of Changchun Motors and Nanjing Motors. The test results are tabulated in Table 7.

Table 2.12. Fatigue test on structure with bamboo boards and wood boards

TF material	TF till cross beam damaged	inspection after 500,000 torsions	No of tests set by standard
structure with BB light lorry NJ type	No damage of cross beam after 100,000 torsions		120,000
structure with BB medium lorry CA 1091 type	136,000	BB remain intact	120,000
structure with steel-wood medium lorry CA 1091	83,000	Disjunction at most welting points boards and beams	120,000

Note: TF - frequency of torsion

Test requirements: 1. Frequency of torsions 7/min. 2. With the truss with a max. torque, the difference in height between front and rear wheels was 312 mm, with the lorry at an axial angle 3.65 degrees. 3. A uniform load of 5 t. sand bags at the platform, a uniform load of 51 kg sand bags on the cabin floor and a uniform load of 144 kg sand bags on seats.

-- Drop hammer ram test

-- Drop hammer ram test

Drop hammer ram test on the two kinds of platform boards of box was conducted by the Research Institute of Nanjing Motors. The test results are tabulated in Table 8.

Table 2.13. Drop hammer ram test on platform boards

material / conditions	hammer 40 kg drop from 1.8 m high	hammer 40 kg drop from 1.5 m high
BB light lorry NJ type	Partial breakage in back of platform, but the structure could be used further	Breakage as deep as 1/3 of thickness of board, but the structure could be used further
WB light lorry NJ type	complete breakage	

It was concluded that the ram resistance of platform boards of BB was superior to that of WB.

The three tests mentioned above show that the bending strength, torsion resistance and ram resistance of bamboo plywood platform boards of lorry box are superior to those of either wooden platform boards or iron and wood platform boards. The plywood is indeed an ideal structural material for a lorry box. It is reported that 11 CA 1091 type lorries were examiner for their carrying capacity and operation at three experimental sites designated by Hainan Motor Transport Corporation, Huadian City Motor Transport Corporation in Jilin province, and Xingan Meng Transportation Corporation in Inner Mongolia. One lorry of hainan Motor transport Corporation has been used over three years traveling over 80,000km. During the same period the iron and wood platform boards of lorry box have become heavily rusty, incapable of further service, whereas the platform boards of plywood remain intact and can be used continually. The boxes with bamboo plywood as platform boards in other experimental lorries operating about two years and traveling over 40,000 km all remain intact without any damage. A general response by users is that platform boards of plywood are friction resistant, and the box has a longer service life, easy for cleaning. When the boards are damaged, repair and replacement with new ones are also easier than the iron and wood platform boards.

In July, 1987, the project "Research on the use of plywood as platform boards of box in NJ type light lorry" was approved by a technical appraisal committee under the auspices of Jiangsu Science Commission. In July, 1991, the project "Research on use of plywood as platform boards of box of CA 1091 type medium lorry" was approved by a technical appraisal committee under the auspices of the Group of Companies under the First Motors. Experts in the two appraisal committees gave full assent to the researches and made a high estimate of them. Up to now, the cumulative total of lorries assembled by Nanjing Motors is 100,000. 42,000 m3 of wood is saved and the decreased production cost is over 1.5 million yuan. The cumulative total of lorries assembled by Changchun First Motors is about 15,000. The decreased production cost is over 3 million yuan. More than 10,000 m3 of wood and more than 1,600 ton of steel are saved. Moreover, the dead weight of lorry box decreased by 52 kg. Thus more economic and social benefits are secured. At present the two factories may use either wood or bamboo plywood as platform boards to construct boxes. This facilities the organization of production in a factory. Since 1988, the second Motors also conducted experiment on using large size plywood as platform boards to construct boxes. The lorries assembled by it in 1990 amounted to 1,000, and 5,000 in 1991. Several tens of automobile factories and railway carriage factories such as Zhejiang Refrigeration Van Factory, Fujian Omnibus Factory, Guangzhou Motors, Changsha Omnibus Factory, Jiangxi Omnibus Factory, Hefei Omnibus Factory in Anhui, Nanjing Public Communication Repair Factory are also using bamboo plywood as platform boards to construct boxes or carriages. It is a deep belief of ours that more and more plywood will be used in the future by the automobile industry in China. A wide extension is expected.

10.4. Bamboo curtain plywood laminated with resin impregnated paper

Concrete form is widely applied as the rapid development of casting reinforced concrete in construction. Concrete form is the main consumable material for concrete formation. China consumes 20 million cubic meters of concrete form, accounting for one third of the total cost of concrete engineering. The properties of concrete form affect the surface quality of concrete greatly. All the wood concrete form, plywood concrete form, steel concrete form and steel frame plywood concrete form now widely applied are made of either wood or steel. In China, both wood and steel are deficient materials which need to be imported to meet the demand of domestic construction. Therefore, it is an important research task to seek and use more suitable concrete form materials.

Although China is not rich in forest resources, it abounds in bamboo resources, with a total stock of 5-6 billion culms of main economic bamboo speices and an annual output of commercial bamboo of 6.5 million tons. Thus "substituting bamboo for wood" is a strategic policy of forest resources utilization in China. The effective way of "substituting bamboo for wood" is to produce bamboo-based panel using bamboo as the raw material, while bamboo curtain plywood laminated with resin impregnated paper is a new product of bamboo-based panels. The South Central Forestry College in 1991 developed this product successfully and in the same year put it into batch production and on the market. The product is mainly used as concrete form which is now applied both at home and abroad.

10.4.1. Processing technology

Bamboo curtain plywood laminated with resin impregnated paper is an engineering structural material which is made with bamboo as the main raw material, with woven bamboo curtain as the basic component unit, and by adhesive spreading, drying, assembling, direct laminating and hot pressing.

10.4.1.1. Main materials

-- Bamboo curtain: Bamboo culms with the diameter of 6 centimeters and above are selected, cut into thin strips in accordance with a certain length, and woven into bamboo curtain. Bamboo culms can be woven artificially into large curtains. They can also be woven mechanically into stripe bamboo curtain by using curtain weaving machine of thin bamboo strip developed by South Central Forestry College. After being spread with adhesive and dried, stripe bamboo curtain is cut into bamboo curtain with certain sizes. Bamboo curtain is a basic component unit of bamboo-based panel.

-- Bamboo mat: Thin bamboo strips with a certain length and section size are woven crisscrossly into bamboo mat with a certain specifications.

-- Primer paper: Primer paper is the craft paper of waterproof with fixed quantity of 80-120 g/m2.

-- Adhesives: There are two kinds of adhesives which are water-borne phenolic adhesive and modified melamine resin adhesive.

10.4.2.Spreading adhesive and drying

10.4.2.1.Adhesive dipping and drying of bamboo curtain and bamboo mat

Before they are dipped with adhesive, bamboo curtain and bamboo mat should be dried to control the moist content below 12 per cent. After being dried, they are dipped with water-borne phenolic adhesive at the special dipping device. Dipping shou'd be well-distributed with a certain quantity at all surfaces of bamboo curtain and bamboo mat. And then they are dried with low temperature to make the water brought when dipping all evaporate so as to guarantee the quality.

10.4.2.2.Adhesive dipping and drying of primer paper

Modified melamine resin adhesive is used for dipping primer paper. Before dipping, a small amount of diluent, release agent and airing agent should be added in the adhesive to reach a certain amount of dipping quantity and to break film. After being dipped with adhesive and dried to evaporate most solvent, primer paper becomes an adhesive film paper with a certain resin content and resin condensation degree. The process of adhesive dipping and drying of primer paper is undertaken for adhesive dipping and drying machine.

10.4.2.3.Assembling

Since bamboo is an anisotropic material, it must be assembled in accordance with the thickness of the panel and the ratio of vertical strength to horizontal strength. The number of layers of the panel, the position and the number of the vertical bamboo curtain and horizontal bamboo curtain in the panel must be reasonably determined. One layer of bamboo mat and one to two layers of film adhesive are placed in the two surfaces of bamboo curtain panel. Bamboo mat is used to increase smooth finish of the planking, while film adhesive in the surface is used to enhance wear-resisting and waterproof ability. Attention to symmetry should be paid when assembling so as to guarantee concrete form stability of the panel.

10.4.2.4.Hot pressing

Hot pressing is an important process of guaranteeing panel quality. The hot pressing of bamboo curtain plywood laminated with resin impregnated paper has two characteristics: hot pressing of direct laminating and hot pressing of "cold-hot-cold".

For the former, the hot pressing of base panel and the hot pressing of laminating with resin impregnated paper are undertaken simultaneously. So the process is simple. The latter aims to guarantee gluing quality.

The procedure of hot pressing of "cold-hot-cold" is divided into three stages: stage for preheating, stage for curing and shaping and stage for cooling.

The hot pressing cycle includes the time of these three stages and the time for loading and unloading of the panel. The time for preheating is in accordance with the temperature rising from 50 to 135 degrees centigrade, the time for curing and shaping is calculated in accordance with 1.5 to 2 minutes per millimeter of the final product of the panel, while the time for cooling is in accordance with the temperature dropping to 50 degrees centigrade. The hot pressing cycle is determined mainly according to the panel thickness. Generally, the duration of the hot pressing with 12 millimeters of the panel is about 45 minutes.

Bamboo is a thermoplastic material with many holes. Under the action of heat and pressure, as the panel thickness decreases and panel density increases, the more the time of hot pressing, the more the condensation. Therefore, under the premise of guaranteeing panel strength, the technical parameters of temperature, pressure and time should be reasonably determined to enhance output ratio and reduce hot pressing cycle.

The hot pressing technique of direct laminating, compared with normal technique of two times of hot pressing, reduces the process of polishing, adhesive spreading, and hot pressing of laminating with resin impregnated paper of the base panel, but the thickness deviation of the panel is large. Thus, when direct laminating is undertaken, thickness gauge must be used to guarantee the thickness tolerance of the panel within the limits allowed.

10.4.2.5.Side sealing

After the panel is pressed with heat and sawn, its sides should be coated and sealed so as to enhance the waterproof property of the panel.

10.4.3.Properties and characteristics

10.4.3.1.Properties

According to the measurement report of China "National Centre for Quality Supervision and Examination of Wood-based Panel", bamboo curtain plywood laminating with resin impregnated paper has advantages of high strength, good rigidity, small linear dilatation and ware-resistance and corrosion-resistance of the panel surfaces. Its mechanical strength is not only higher than other bamboo-based panels, but also much higher than birch plywood. So, it is a new type of concrete form engineering material. The physical and mechanical properties of bamboo curtain plywood laminated with resin impregnated paper are as Table 1 and Table 2, respectively.

Table 2.14. Physical properties

Item		Unit	Medium Density Panel	High Density panel	Standard
Density		g/cm3	0.82	0.92	GB4899-85
Moist Content		%	3.0	2.4	GB4900-85
Linear Dilatation	Length	%	0.066	0.067	ASTM
	Width	%	0.136	0.135	ASTM
Wear-resistance		g/100 revolutions	0.053	0.049	GB7911-87
Retarding Combustibility		oxygen index	29.0	29.0	GB7911-87
Pollution-resistance			little corrosion under the action of sodium carbonate solution with 10 % of solvent		GB7911-87

Table 2.15. Mechanical properties

Item	Unit	Medium Density Panel	High Density panel	Standard
Bending Strength	MPA	104.5	127.4	ZB B70006-88
Elastic Modulus	MPA	11,100	13,500	ZB B70006-88
Impact Toughness	J/CM2	6.35	5.5	GB 1940-80
Gluing Strength	MPA	2.73	4.81	GB 9846-80
Soak Peel of First Category	MM	0 millimeter at any layer		Bulletin No. 1373 of J/\S of the Ministry of Agriculture and Forestry

Table 2.16. Comparison with famous brand concrete forms

Type of Forms / Properties		BCPLRIP	Domestic Forms		WISA-FORM of Finland
			Laminated	Non-laminated	
Density (g/cm3)		0.80	0.78-0.85		
Bending Strength (MPA)		104.5	60.0	35.0	56.0
Elastic Modulus (MPA)		11,100	10,000	4,500	9,200
Gluing Strength (MPA)		2.73	1.4-1.8	>=1.0	
Ware-resistance of the Surfaces		0.05g/100 revolutions	300 times		300 times
Linear Dilatation	Length	0.066	Both Increase 0.01% as Moist Content Increases to 1%		
	Width	0.136			

Notes:

-- Bamboo curtain plywood laminated with resin impregnated paper is a kind of medium density panel;

-- The standard of domestically produced laminated concrete form is in accordance with the enterprise standard of "Panda" Brand Form set by Qingdao Hualin Plywood Limited Company;

-- The standard of domestically produced non-laminated concrete form is in accordance with the standard ZB B7006-88 for plywood as the concrete form;

-- The standard of WISA-FORM of Finland is in accordance with measurement report of SCHAUMAN Company of Finland. WISA-FORM is a kind of laminating plywood;

-- The famous brand forms listed in Table 3 are all birch plywood which is of best properties in all kinds of plywood.

Bamboo curtain plywood laminated with resin impregnated paper is used mainly as concrete form. Its property comparison with famous brand forms at home and abroad is as follows:

According to Table 3, when the densities are nearly close, the mechanical strength of bamboo curtain plywood laminated with resin impregnated paper is much higher than famous brand forms at home and abroad. e.g.,the bending strength and elastic modulus are 3 times and 2.5 times, respectively, as much as those of plywood as concrete form with ZB B7006-88, and 1.9 times and 1.2 times, respectively, as much as those of WISA-FORM of Finland. The practice proves that the high elastic modulus is of important significance to form deformation and rigidity and the enhancement of applied characteristics of the concrete form.

10.4.3.2. Applied characteristics as concrete form

-- After the concrete is away from form, the surface of the form is smooth, bright and clean. It can be directly coated on the surface and does not need to be whitewashed inside.

-- Due to high strength and good rigidity and two ware-resistant surfaces both of which can be used, the form can be used repeatedly for many times, so the construction cost can be reduced.

-- Since phenolic adhesive and modified melamine resin adhesive with good water-tolerance, water-resistance, ageing-resistance are used as the adhesives for the form, it can tolerate climate change.

-- Low linear dilatation, stable sizes and good form stability.

-- It can easily be mechanically processed.

-- Its surfaces are smooth, bright and clean and easily delaminated and cleared up.

Qingdao Ruida Concrete form Company thinks that bamboo curtain plywood laminated with resin impregnated paper can be used repeatedly for about 100 times when it is used as concrete form and its surfaces are chemically treated.

If bamboo curtain plywood laminated with resin impregnated paper is combined with special steel, its rigidity will be increased, it can be easily operated, and it can be used repeatedly for more times. Since this combined concrete form was not put into application until early 1992, its real applied repetition is not available. According to concerned materials, wood concrete form can be used just for 3-5 times, laminated birch plywood can be used for 20-30 times, and WISA-FORM can be used for less 50 times. That is why SCHAUMAN Company of Finland which is famous for producing WISA-FORM and covers half of European concrete form market still imports from China the bamboo curtain plywood laminated with resin impregnated paper and sell it in European concrete form market.

10.4.4. Conclusion

10.4.4.1. Bamboo curtain plywood laminated with resin impregnated paper as the concrete form can certainly replace wood concrete form and plywood concrete form. In terms of properties, it is a new type of concrete form which can rival world famous WISA-FORM of Finland.

10.4.4.2.Bamboo curtain plywood laminated with resin impregnated paper as the concrete form not only has elite applied properties, but also can be used repeatedly for more times than other forms. So, the constructive cost of concrete can be reduced, which can bring certain economic benefit. In addition, its initial cost is low with only about 43 per cent of investment of the concrete form made of steel. This kind of concrete form is easy to extend, and is conducive to the renewal of form materials and the promotion of the development of China's building industry.

10.4.4.3Bamboo curtain plywood laminated with resin impregnated paper is an elite wood substitute, which is made by using China's rich resources of bamboo as the main raw material and bamboo curtain as the basic component unit, by adhesive spreading, drying, assembling, direct laminated and hot pressing, which follows further China's policy of "substituting bamboo for wood". The manufacturing and utilization of bamboo curtain plywood laminated with resin impregnated paper can not only partially alleviate China's wood shortage, but the high quality concrete form can be applied to construction. Thus a way of industrial utilization of bamboo resources is opened up.

10.5. The development of molding bamboo-based products

It is well know, China is not abundant in wood resources, but it is very rich in bamboo resources. Developing the industrial utilization of bamboo, partly substituting for ordinary wood, is of great importance in China. Besides some traditional methods of using bamboo, such as manufacturing, using as a construction material, making article and furniture, recently some kinds of bamboo-based products have been developed in China, such as bamboo plywood, bamboo mat plywood, particle board, medium fiber- board, and molded products.

10.5.1.Basis for development of molded bamboo products

The wood-based molded products have been developed for years, and the methods mainly include wood veneer molding, wood fibre molding, and wood particle molding. Of course, the molded bamboo products could be manufactured in the same way, however, some advantages of bamboo can not be utilized as full as possible.

The length of bamboo fiber is much greater than the width. Table 1 shows the lengths and widths, and the ratio between length and width of some species of bamboo.

Table 2.17. Fiber of different species

species	fiber length	fiber width	ratio l:w
Ph. pubescens	1.987 mm	11.43 um	178.8
Ph. arcana	1.997	13.10	152.4
Pl. amarus	2.129	14.35	148.4
Ch. quadrangularis	1.544	12.65	122.1
Ph. nigra	2.203	12.34	178.9
Ph. viridis	1.614	11.89	131.7

One of the outstanding characteristics of its mechanical property is that the tensile strength and compressive strength in longitudinal direction are much greater than that in transverse direction. For example, the compressive strength of moso bamboo in longitudinal direction is up to 5.76 x 105 N/mm2; the tensile strength of Ph. arcana in longitudinal direction, tested with bamboo strips, is up to 7.34 x 105 N/mm2. However, the strengths in transverse direction are generally only a tenth of that in longitudinal direction. Such a mechanical property of bamboo is a little different from that of wood.

Table 2.18. Strength of shuttle

compressive strength (N/m3)			tensile strength (N/m3)		
longitudinal	transvers	ratio	longitudinal	transvers	ratio
6.28x106	6.28x108	1/10	(1.49-1.91)x108	(6.57-8.93)x106	1/16-1/29

On the other hand, bamboo is plastic and can be deformed easily at higher temperature, and it wiil be stiffened and keep the deformation after proper cooling. Such as property has been known and used for many years.

Naturally, it will be better if the bamboo is divided, based on the need of practical product, into threads, matchstick or strips, instead of particles, fibers or chips, when we mold bamboo products.

10.5.2.Molded weaving shuttle of bamboo threads

The weaving shuttle is one of the important textile appliances and it is generally made of high quality wood. Over twelve millions of weaving shuttle are required every year in China, consuming high quality wood more than 60,000 m3.

For molding weaving shuttles, bamboo culms are split into treads, then dried, impregnated with glue, and pressed in a hot pressing machine with a specially-designed mold.

To illustrate the characteristics of a bamboo shuttle, some mechanical properties have been rested, the results shown in Table 3, in which the mechanical properties of some species of wood used in normal wooden shuttle are listed, too.

Table 2.19. Mechanical properties of molded bamboo shuttle

items	unit	bamboo shuttle body	oak	maple
density	g/cm3	1.165	0.892	0.880
comp. streng.	l.N.m2	86.1 x106	64.0x106	52.0x106
comp. streng.	t.N.m2	72.2x106	17.5x106	14.3x106
bend. streng.	t.N.m2	79.4x106	145.2x106	131.2x106
shock streng.	N.m.m2	0.527x105	1.112x105	1.118x105
hardness	N.m2	2.06x108	1.11x108	1.06x108
split force	N/cm	706	402	275

Up to now, over a tenth of million of molded weaving shuttles of bamboo shreads have been used in texitile plants. The result shows the following advantages of the bamboo shuttle.

10.5.2.1.The wear-and-tear of bamboo shuttle is less than that of the wooden one, and the service life in normal condition is about twice that of wood.

10.5.2.2. Because the bamboo shuttle is quite smooth and has lower friction compared with wooden shuttle, the power consumption of a weaving machine can be reduced by 10%.

10.5.2.3.Bamboo shuttles can be used in any climate conditions without deformation. As to wooden ones, products made in the south can not be used in the north, and vice versa.

10.5.2.4.The iron heads of a shuttle are inserted into the mold before bamboo threads being filled, and combined firmly with the body of shuutle after hot pressing, so that they can hardly be removed from shuttle body in operation.

10.5.2.5.Almost all species of smaller bamboo, growing everywhere in the south of China, can be cut into threads and molded into threads and molded into bamboo shuttle or similar products. The utilization rate of bamboo is higher than 90%.

10.5.3.Molded piching stick of laminated bamboo strips

The picking stick is also an important textile appliance and generally made of laminated wood veneer lumber. Over fufty thousands cubic meters of high quality woood are consumed to manufacture textile picking sticks every year in China.

In a weaving machine the power is transmitted to the picking stick, and during swing it strikes the shuttle to make the shuttle move quickly. It is obvious that the shock strength is more important than the compressive and tensile strength for a picking stick.

The bamboo is good in shock strength. Considering such a property, the bamboo material is split into strips when molding picking sticks.

About 10 thousand of molded picking sticks of laminated bamboo strips have been in some textile plants. The result shows following advantages of bamboo sticks.

10.5.3.1.Due to the great shock strength, bamboo picking sticks has a service life much longer than that of wooden ones. A report from a textile plant, having tested bamboo sticks for long, indicated its practical service life was four times that of wooden ones.

10.5.3.2.The picking stick is formed with different thickness in both ends when being molded, so the further processing of the semifinished products can be simplified greatly, and the raw material can be more effectively.

10.5.3.3.The bamboo picking sticks are covered with wood veneer on its surface and pressed together during molding. Thay seem to textile workers be the same as traditional wood one, therefore, they will be accepted by workers easily.

10.5.4. Bamboo veneer as overlay in molding particle PRODUCTS

Normally, paper cloth and wood veneer are used as the overlay material in molding particle products. The bamboo veneer can also be used as an overlay material.

In laboratory, a test was carried out to use bamboo veneer as surface layer of a molded particle stool. The bamboo veneer was made with a veneer lathe, about 0.5 mm in thickness. The process of molding is similar to that of molding particle products.

The result showed the bamboo veneer could be softened. The products overlaid with bamboo veneer seemed to be made from bamboo wholly, and well-worn.

PART III. BAMBOO PAPERMAKING

1. General situation of bamboo papermaking

1.1. A brief history of papermaking

Paper is one of the four inventions in ancient China. Cai Lun in the Later Han Dynasty developed the technique of papermaking in 105 A. D. In the "Biography of Cai Lun in the History of Later Han Dynasty", it was recorded: "In ancient time, writing was carved in bamboo slips bound together, or characters were written on silk or fine silk, which was called 'paper'". Silk was expensive, while bamboo slips were heavy. They were inconvenient to handle. Cai Lun had a new idea to make paper with tree barks, waste jute, rags and broken fishing nets. He achieved success. In the first year of reign of Yuanxing, he made a report to the Emperor about his invention, and he was praised by the Emperor for his ability. Since that time paper was extensively used. It gained a popular name "Marquis Cai's paper". In other ancient documents, the process of papermaking by Cai Lun was recorded. Its basic principle and the main production technology are still used in modern world. The development and spread of his technology both at home and abroad made great contribution to the development of human civilization and industrial production.

The key point of Cai's technology was to make paper with the phloem of tree, waste jute, rags and plant fibers, instead of silk and bamboo slips, facilitating hand writing. It was welcome by people and was quickly popularized. With the increasing demand for paper, material supply ran short, because collection of large quantity of materials met with difficulty. A good idea came to the mind of some ingenious people, who though bamboo could be made into cord, which was inferior to the cord made of jute, but it might be feasible to make paper with bamboo. Satisfactory result was obtained by tentative use of bamboo to make paper. Since then there was record about using bamboo for papermaking. "Tongtian Qinglu Ji (Record of Valuables in Caves)" stated: "most of the hand writing by the two Wangs was on vertically grained bamboo paper made in Kuaiji". The two Wangs referred to the famous calligraphers Wang Xizhi the father and Wang Xianzhi the son in Jin Dynasty. In recent years, the evidences given by some experts show that the original inventor of bamboo paper was a native to Kuaiji, named Zhang Mao in East Jin Dynasty. According to the researches conducted by Japanese Scholar Dr. Sawasinobi in the Liang Dynasty (502-555) the paper on which Buddhist scripture was written contained bamboo fibers. This shows that the bamboo paper has a long history. In China the Tang Dynasty was the peak period of feudalism, noted for political stability, cultural progress and economic prosperity. In frequent contacts with foreign countries, paper requirement increased rapidly. The raw materials of bamboo were collected locally. In the "Manual of Paper", written by Su Yijian, it was said that the natives in Sichuan, Fujian, Shanzhou and Zhejiang used jute, fresh bamboo, liana and wheat straw or rice straw to make paper, respectively. Since Tang Dynasty, the variety of paper multiplied, such as Yuban paper, Gongchuan paper, Shujian paper, Jingxiao paper, Biaoguang paper and Guangdu paper, etc. All these papers were made of plant fiber, with bamboo fiber as the main, next being grass and tree barks. Rags and waste jute were rarely used.

In Song Dynasty, Bi Sheng invented the art of printing with wooden types. The development of printing industry affiliated with character-carving sped up the development of papermaking. In provinces such as Zhejiang and Fujian in South China great quantity of bamboo paper had been produced, with paper quality improved. The bamboo paper made in Yuezhou in Zhejiang province became a popular product. Statesmen and men of letter such as Wang Anshi and Su Dongpo all preferred using bamboo paper to write. They though bamboo paper absorbed ink well and could show clearly the vigorous strokes. All the time many scholars followed their examples. The famous calligrapher and artist Mi Fei wrote in the "History of Calligraphy": "With a hammer I often beat the Yuezhou bamboo paper which appears like a metal plate....". Now in the Beijing Historical Museum valuable copybooks of Mi Fei's handwriting were kept, paper of which was made of bamboo and jute fibers. In south Song Dynasty, the capital was Hangzhou, where crowded celebrities and famous scholars who had removed there from North China. Hangzhou was one of five major printing centers in the country. The other four were Jiangyang in Fujian, Meizhou in Sichuan, Kaifeng in Henan and Pingyang in Shanxi. The developing printing industry required large quantity of paper. The bamboo paper became increasingly refined, and enjoyed great popularity. It was said that "only bamboo paper wings the greatest reputation." in Tang Dynasty the hand-made paper industry and prospered in Sichuan. The jute paper made in Yizhou was quite popular. In Song Dynasty bamboo paper began to be produced. Bamboo was less expensive than jute, because the bamboo resources were rich. Since Yuan and Ming Dynasties, the bamboo paper industry in Sichuan was further developed. In Qing Dynasty less jute paper was produced. Instead more and more bamboo paper was produced, and was circulated throughout Sichuan. In Ming Dynasty the production technology of bamboo paper was perfected. Song Yingxing gave details of the technology in his book "Tiangong Kaiwu" (Development of Agricultural and Industrial Production): Removal of Green Skin" with illustrations of equipment and operation. The key points were material sorting and soaking, full boiling, pounding (beating) and bleaching, picking up with bamboo screen, web pressing, sunning and drying. It was the earliest work recording the detailed production technology of bamboo paper in China. It had been translated into English, French and Japanese, and introduced into Europe and Japan. The book contained such a statement: "Bamboo paper was produced in South China, and the industry is particularly prosperous in Fujian province." A certain literature shows that in Song, Yuan and Qing Dynasties, bamboo paper was constantly produced in Fujian province. From Qing Dynasty to modern time, bamboo paper was made in all areas where was source of bamboo, water, lime and technical workers. More paper mills were distributed in Zhejiang, Fujian, Jiangxi and Sichian. The paper making became one of the important industries in these provinces. The paper products were marketed both at home and abroad. In shared a large proportion in the township by-product lines in mountain areas. For example, in the Jiajiang county in Sichuan province, in the peak period of papermaking the paper making households numbered 2,000, having paper tanks of 4,000, with employees reaching 30,000. But due to the low level of economy and technology, the hand made paper industry suffered from many differed from many difficulties and showed great fluctuation in production.

Since the founding of the new republic, at the time when great effort was made in developing the mechanical paper, some attention was also paid to the construction and development of hand made paper industry. In 1949, the annual production of hand made paper was only 120,000 t. Since 1953, the output remained about 200,000 t (in 1954 the highest output was 300,000 t). After 1979 the reform and open policy reached the rural and mountain areas. As a result of liberal policy and economic reinvigoration, the production of hand made paper rose again. Up to 1985, the annual production was kept at 260,000 t (in Sichuan the paper mills and workshops registered at the Industrial and Commercial Control Office was 364. In 1985, the production was 28,400 t). There was no statistic data concerning the ratio of bamboo paper to the hand made paper. A rough estimate shew that it was over 50%, which was a significant figure. The production of writing paper and drawing paper developed to a far more extent. In 1986, a Hand Made Paper Museum was built and opened in Jiajiang county which was the first paper museum in China. The museum with rich historical data makes a systematic display of the technology of paper making with the bamboo paper as the main, inherited from Cai Lun and being further developed. It also shows the cultural contribution to the fatherland.

1.2. The production technology of papermaking

The production technology of hand made paper is basically a traditional technology that has been practiced hundreds of years. It has a complete set of procedures. The specific procedure differs little despite of materials used. The paper quality is dependent on the choice of materials, water quality, dose of chemical egest, carefulness of operation and the expertise of master workers. In the "Study Series: A Talk on Paper" it says: "the key link is the materials used." In "Tiangong Kaiwu" it says: "As to bamboo felling, attention should be paid to the depth of the deeps and the bamboo about to put forth twigs and leaves after shoot production. The bamboo at this growth stage is the best material." In hand made paper production, fresh bamboo was used as material. The bamboo for pulping was divided into raw material and boiled material. A brief description of the key points of manufacturing process is given as follows:

1.2.1. Soaking (removing the green skin of bamboo). Fresh bamboos are cut into 2 m long segments, and are put into ponds for soaking 1-3 months according to local particular conditions. Now time of soaking is shortened by adding lime. Then wooden hammer was used to remove the green skin by repeated pounding. Bamboo joints and diaphragms were gotten rid of with part of soluble trash removed.

1.2.2. Boiling. Caldrons with a capacity of 5,000 kg were used boiling. In the past the boiling was made through two stages: boiling with lime and boiling with soda ash. Materials were boiled about 5-10 days under normal air pressure. With lignin removed, the fibers were dispersed into stock. In recent years, the procedure has been improved. Bamboos are cut into short segments and are first put in the lime water or soda ash solution. Or after caustification, the boiled materials were put in the clear solution, covered and water sealed. Only one day is needed for boiling. Raw material is not boiled with soda ash.

1.2.3. Washing. Black liquor was dripped off from the boiled materials, which were washed with warm water twice or thrice. Then they were put in ponds for soaking till they were macerated. The alternative was to pour bean drink or rice water in them to be fermented for 5-7 days. Then they were soaked and washed.

1.2.4. Bleaching (sunning). In ancient time in making white paper, the stock was spread on the southern slopes of hills to be sunned and weathered for 3-4 months. During this period they were turned twice or thrice. This was the natural oxide bleaching. During the time of Republic of China, most of the hand made paper in Sichuan was bleached with bleaching powder. The paper thus bleached was called "powdery white".

1.2.5. Pounding (beating). Coarse matter and trash were removed before they were washed and pounded. As to material pounding in most localities in Sichuan, water-moved stone hammer or treadled stone hammer was used in pounding. Fibers were fibrillated and dispersed into stock with a high concentration. As the fibers were well interwoven, the paper had better strength.

1.2.6. Preparing the stock. Stock was put in the tank containing clean water with dispersing agent added with fibers suspended evenly in the water, facilitating web picking up. The area of tank should be larger than the bamboo screen.

1.2.7. Picking up. The wet web in which fibers were evenly distributed and well interwoven was left on the bamboo screen. Then they were shifted to a wooden press. This is the critical link in papermaking. The picking up was often done by the technical superintendent.

1.2.8. Pressing When the number of webs was over one thousand, a flat board was put on them. A part of water was pressed out of them by a level. A soft brush was used to paste them on the walls of bakery.

1.2.9. Baking there were cold baking and hot baking. The brick wall of bakery was plastered with lime water to have a smooth surface. Hot baking meant the inner layer of wall was heated. Cold baking meant drying by natural ventilation.

1.2.10. Packing The oven-dried or air dried sheets were sorted and counted. In usual case, each one hundred sheets were a dao. Sometimes two hundred sheets were a dao. 40 daos made a bale. 200 daos was a bundle. They were bound with bamboo strips, being ready to be marketed.

The production process was simple or complex, depending on the quality and variety of paper. But all work was done manually. It was characterized by high intensity of labor, simple equipment and long cycle of production. Long ago, effort had been spent by the workers in improving the equipment, tools and method of operation. Now in some mills chemical pulping is adopted, but picking up is still done manually. In workshops using the traditional production technology and manual operation, the stock is mainly churned tanks. The traditional technology of hand made paper has its own strong points, which the modern mechanized paper making should learn from. For example, the choice of bamboo materials, joint and diaphragm removal, green skin removal, oxide bleaching, pulp beating at high concentration were its advantages. Some of these have been applied in modern paper industry and are mechanized. In a word, the hand made paper industry should adopt the modern pulping and papermaking technology to give up the low efficient methods of production.

1.3. Variety of paper and the traditional famous papers

In China the hand made paper has a long history and is noted for numerousness in variety. But as the name, specification, color and variety were diversified, it is difficult to make distinction between some of them. Based on relevant data, the paper was estimated to be over 200 varieties. Papers made of bamboo pulp were than 100 varieties. According to uses, they are roughly grouped into three major types:

1.3.1. Cultural papers. These include quill pen writing paper, paper for rural book-keeping, letter paper, fan paper, copybook, paper for printing Chinese classics, paper for bound Chinese book, high grade drawing paper and paper for calligraphy.

1.3.2. Toilet papers. These include papers used in the countryside. Great quantity of them is required, being about half of the total demand. The bamboo pulp was mixed with some rice straw or wheat straw pulp. The toilet paper made of mixed pulp is poor in quality, and is named "native straw paper".

1.3.3. Religious papers. This type of paper was to meet the special demand that the paper, when burning, will curl and twist, with grayish white flakes of ashes fluttering in the air. Some variety is stained yellow, and is given a vernacular name "Huangbiao paper".

1.4. New types of paper

In view of development of national economy, the raised living standard of people and the future market demand, different production policies should be adopted towards to three types of papers. The hand made toilet papers are poor in quality and sold at a low price. Concerning this type of paper, high health index and transportation are all problems not well resolved. Moreover each ton of toilet paper will consume 5-6 t of fresh bamboo, being detrimental to bamboo growth. In recent years, mechanical toilet paper develops rapidly, and penetrates all corners of rural community. For rational utilization of bamboo resources, and to increase the economic returns of processing, a recommendation is made on controlling the production and development of hand made toilet paper made of bamboo pulp. With the promulgation of religious policy and opening to the outer world, the religious papers have shared the domestic market. In the markets in Southeast Asia, Taiwan province, Hongkong and Macao the demand for religious papers is daily increasing. Suitable variety for suitable market should be stressed. Effort should be made to export the religious papers, with quality improved and variety increased.

At present time, the production of cultural papers is not high. Quality differs widely between the varieties. But in view of the particular traits and uses, this type of paper has a bright future. For example, now in the society there arises a trend for calligraphy and drawing, in which either the pupils of primary schools or retired cadres and workers all take interest. They may number about one hundred million. The demand for this type of paper is increasing. Mechanical paper cannot substitute for it. Especially some traditional famous hand made bamboo papers are best sellers over hundreds of years in domestic and foreign markets. They are much appreciated by the customers. Some of them are briefly described as follows:

1.4.1. Imitation Xuan paper.

This is a high grade writing and drawing paper, a result from the achievement of the production technology of Anhui Xuan paper, with the process modified.

The Liancheng Xuan paper in Fujian Province is made of fresh bamboo pulp, in which there were phloem fibers to increase the tenacity of paper. It is made by traditional process, and naturally bleached. It is said that "it will not decolored in one hundred years, and does not turn yellow hundreds of years". For example, the Mianlian paper 802 was successfully produced first in February 1980. It is a high grade writing and drawing paper, being white, transparent, soft, tough and never wrinkled. It absorbs ink well, providing a smooth surface for writing. It is better in quality than the ordinary Xuan paper. Yuban paper was soft, tough and durable. It is used by archeological units, file keeping units, and fine art associations in refined printing, in replicating and tracing writings and drawings, copying ancient works, frescoes and writings on stone tablets or imitating other valuables of fine art. Liancheng Xuan paper as well as Anhui Xuan paper were welcome by the Japanese calligraphers, painters, artists and social celebrities, and often used as precious gifts. For example, after successful tentative production, 250 bales of Mainlian paper 802 were bought by the Japanese merchants. Next year an order of 200 ton was made. This kind of paper is exported even to the countries in Southeast Asia.

In Sichuan, Jiajiang writing and drawing paper was a modified Lianshi paper. In the early period of Qing Dynasty (1683), it was designated as a tribute paper.. It was used as exam papers in the imperial examination in the royal court. In the period of Anti Japanese War, the famous artist Zhang Daqian twice came to the paper making county Jiajiang to conduct a research on improving the production technology in cooperation with the paper making peasants. The bamboo pulp mixed jute fibers was made into high grade writing and drawing paper with water colored clouds and flowers. It was named Jiajiang imitation Xuan paper. The comments given by the artist circles on the paper were:" the paper is of fine texture, with high tenacity, and bear heavy touches of brushes. It absorbs ink well, and is moisture tolerant. The ink in it was not decolored, never turned grey. The drawing on it appeared more distinct and beautiful. Now it is renamed "Zhang Daqian writing and drawing paper".

1.4.2. Yuanshu paper It was made of pure bamboo pulp which was not bleached. The paper was thin and appeared yellowish. It was used as writing paper, and paper of copybook. In Zhejiang, the Fuyang Yuanshu paper was made by refined process. before pulping all old green skins and piths in inner walls were removed. The paper is of fine texture, and sold well in both domestic and world markets.

1.4.3. Maobian paper It was made of fresh bamboo pulp. The paper was not trimmed, used in printing ancient classics, and for writing with quill pen. This paper was produced in all provinces in South China. Great quantity was produced every year. It was thin, sold at a low price and was very popular among the masses of people. The "Bailian Maobian paper produced in Jiangle in Fujian Province was ever used in printing classical poems in bound Chinese book.

1.4.4. Yukou paper The normal Yukou paper produced in Changding county in Fujian province was favorably named "spring and white snow". The paper was of fine texture, soft, fresh and glossy. It absorbed ink well, and was borer proof. It was used in printing ancient classics, or as papers of books, which could be kept for a long time.

1.4.5. Lianshi paper It was white, fine and durable. The thick Lainshi paper was named "Haiyue paper", used as stone tablet copy, fan paper, letter paper and newsprint. It was produced in Zhejiang, Fujian, Jiangxi and Sichuan provinces.

1.4.6. Gongchuan paper It was made of fresh bamboo pulp. Materials were fermented, and the pulp was bleached. The paper was thin, used as writing paper or for lithography.

There are other varieties of the traditional famous papers. In the past they sold well in domestic market. But, the quality of hand made papers for special uses should be improved. It is necessary to diversify the products. Special kinds of hand made papers, such as fine paper for brush writing and drawing, for gift wrapping should be developed to increase the value added, and to export for earning foreign exchange. Production in small batches of diversified specific papers can bring about great benefits, giving full play to the particular function of the technology.

1.5. Development of mechanical paper

In 1930s, the Fuzhou Paper Mill (its was called the Fujian Co. Ltd.) began to produce mechanical bamboo paper. The founder was Mr. Chen Xiqing who studied in early years in Europe and USA. When back home, he managed to set up a mechanical paper mill. The 1929 report of the company described the origin of the mill, saying: "Bamboo, I think, is a specialty in China. The provinces in South China are rich in bamboo resources. The old method of bamboo paper production is to use fresh shoots as materials. But shoots can be collected only in a short period. Its production is, of course. limited. Moreover, the collection of fresh shoots is detrimental to the growth of bamboo stands. If a new method can be found to use culms instead of shoots to produce pulp, the raw material will be plentiful, and more economic returns can be achieved. So I determined to go abroad across oceans to Europe and America to learn the new method of paper making with machines. Attention was paid to pulping with bamboo culms. Over more than a decade, with repeated experiments, the efforts succeeded. Not only the traditional kinds of paper can be mechanically produced from bamboo pulp, but also the imported papers......".

The said paper mill was built in May 1932 and was put into operation. Bamboo materials were boiled in a globe with sulfite method. Paper was made, using machines including cylinders and multiple driers, with a daily capacity of 3 t. The papers include white newsprint (relief paper), drawing paper (off set printing paper), manifold tissue, Haiyue paper, kraft , etc. These papers have better quality, were used in Tianjin, Shanghai, Hangzhou, Guangzhou and Chaozhou, and were exported to Phillipines, Thailand, Indonesia and Malaysia. They contributed to the development of national industry and the production of mechanical bamboo paper.

The paper industry in Sichuan was the industry early to produce mechanical bamboo paper. Now the pulp yield in Sichuan ranks first in the country. In 1940s, the Jianguo Paper Mill in Chengdu and Zhongyuan Paper Mill in Yibin (Now Changjiang Paper Mill) had used deskinned bamboos, bamboo threads and sulfite method for pulping and produce drawing paper, manifold tissue and cigarette paper. In 1950s, great quantity of bamboos were consumed for paper production. As the Chongqing, Yibin and Changjiang Paper Mills were expanded, the bamboo requirement also increased. In the entire province, the ratio of bamboo pulp for mechanical paper making increased by 30% from 1953 to 1959. In 1957, the ratio of bamboo pulp in Chongqing Paper Mill rose to 98%, producing more than 10 varieties of newsprint and high grade writing papers. The Yibin Paper Mill produced newsprint with bleached bamboo pulp. The Changjiang Paper Mill used unbleached bamboo pulp to produce 6-7 varieties of papers such as kraft and bag papers. For rational utilization of bamboo resources, culm pulp was gradually substituted for that of fresh shoot. But from 1966 onwards, due to many causes, the ratio of bamboo pulp dropped drastically, to only 5-6%. In 1980s, the provinces and regions in South China adopted a policy to strengthen the development and utilization of bamboos as materials in papermaking. By remodeling the old mills, the bamboo pulp yield increased year by year. In China about 105 paper mills produced bamboo pulp. In Sichuan the average annual increase rate of bamboo pulp was 15%. In 1991, the production of bamboo pulp rose to 98,000 t. In Guangxi the bamboo pulp consumed in Liuzhou Paper Mill rose from several thousand tons of few years ago to 20,000 t now. In Hunan province, the Yueyang Paper Mill taking advantage of the rich bamboo resources in West Hunan built a new three stage bleaching workshop, with a capacity of 10,000 t. It was completed in 1991 and was put into operation. At the same time 5 new pulping and papermaking mills were constructed, with a capacity of 3-50,000 t. Advanced technology and equipment were introduced from other countries. The construction of paper Board Mill in Wuzhou in Jiangxi province, and the Paper Mill in Puyi in Hubei province have been completed and are carrying out pilot production. All these are new advances in the development of paper industry with the bamboo requirement largely expanded.

2. Production technique of mechanical papermaking

2.1. Bamboo fiber character

There are several hundred bamboo species in China, 30 species are often used for mechanical papermaking. They are roughly divided into two types, the first type is of medium and small size, with thin-wall type, 2-8 mm in thickness, diameter 2-6 cm, such as Sinocalamus affinis, Dendrocalamus membranaceus, Phyllostachys heteroclada, Phyllostachys nidularia, Pleioblastus amarus, Bambusa textilis, Phyllostachys bissetii, Bambusa portentosa and Monocladus amplexicaulis, etc. they are mostly used for papermaking recently. The second one is of large size, with thick-wall, 10-20 mm in wall thickness, diameter 8-20 cm, the main species of this type is Phyllostachys pubescens, which occupies 70% area of bamboo forest in China, covering more than 0.54 million ha in Fujian Province, 0.54 million ha. in Hunan Province, 0.46 million ha. in Jiangxi Province and some 0.46 million ha. in Zhejiang Province. In the past, it was mainly used as construction material, in agricultural production and for daily uses, the amount of Phyllostachys pubescens used in the above-mentioned fields was reduced recently, it is to be used for establishing large bamboo paper mills, the newly-established Shaowu Paper Mill and Wuzhou Paper Board Factory, as well as Puqi Paper Mill are operating with the utilization of Phyllostachys pubescens. Technical tests demonstrated that, Dendrocalamus latiflorus and Sinocalamus sp. possess good strength for papermaking, they also belong to the type of thick wall and large diameter.

Bamboo fiber is thin and long, the average length is 1.4-2 mm, slightly shorter than that of coniferous tree species; and it is longer than that of broad-leaved trees, and that of most species from Gramineae, it belongs to the category of medium or long fiber. The average of width is only 0.01-0.015 mm. Large ratio between length and width is suitable for crosswise connection in papermaking. The cellulose content of bamboo is as much as that of wood, the ash content is higher than that of wood, but lower than that of grass. Consequently, bamboo is a kind of excellent material for papermaking. But its texture is tense, the density of culm wall is high, cell membrane is thick and cell space is small, proper measures are needed in production to solve the problems caused. The fiber form, chemical composition and culm structure of different species and age, growing in different areas differ greatly. Bamboo should be effectively used for pulping, therefore it is very important to study the behavior of bamboo material in pulping and papermaking process. The quality of chemical pulp depends on the parameter structure of fiber, especially the fiber form, and the character of thin fiber structure. Due to the increase of bamboo species use for papermaking since 1980s, related institutions of scientific research and higher learning, as well as major paper mills have carried out many experimental tests for improving the technology and economic effect of papermaking. The indices obtained are shown in table 3-1 and 3-2.

Table 3-1 Fiber form of some paper raw materials

Material	length mm mean	length mm in general	width mm	membrane thickness	cavity u	ratio u	cell %	%	thin %
S. affinis	2.05	1.2-3.4	0.014	2.54	0.89	0.89	18.65	42.5	
D. membranaus	2.0	1.2-3	0.012	2.45	5.7	1.17	18.20	37.7	
P. bissetii	1.66		0.013						
S. latiflorus	2.75	1.7-4.8	0.018	4.9	5.95	2.3	17.06	28.19	
Ph. pubescens	1.5	0.8-2.2	0.013	6.1	3.2	30.0			
S.beecheyana	1.88		0.013			25.0			
masson pine	3.61	2.2-5	0.05	3.8	33.1	0.23	1.5		
eucalyptus	0.88	0.7-1.0	0.015	3.7	7.2	0.9	17.6		
wheat grass	1.32	1 -1.6	0.014			37.9			
weed	1.12	0.6-1.6	0.01	3.0	3.4	1.77	35.5		

Table 3-2 Chemical composition of main species

species	area	ash	extration phenol	extration 1% NaOH	polyose	lignin	fiber	remarks
S. affinis	Sichuan	2.4	3.63	17.94	24.3	27.27	55.05	
S. affinis	Sichuan	2.94	2.8	24.7	19.1	25.3	74.7	synthesis
D.membranaceus	Suchuan	1.74	1.8	22.65	19.06	25.1	76.13	"
D.membranaceus	Guangxi	1.82	3.1	27.75	20.6	21.8	47.12	
Ph. pubescens	Jiangxi	0.54	3.35	25.88	22.6	22.22	43.5	4-year
Ph. pubescens	Fujian	1.21	1.02	28.26	22.31	31.8	45.53	4-year
Ph. pubescens	Hunan	0.9	6.43	26.76	20.54	29.6	50.66	7-year
B. textilis	Guangdong	2.39	2.28	29.08	20.7	25.47	42.3	
Ph.niduloria	Guizhou	1.37	2.1	21.53	21.9	27.02	46.29	
Ph.heteroclada	Yunnan	1.39	3.09	23.94	18.18	25.12	44.52	

2.2. Bamboo storage and material preparation

2.2.1. Storage

The quality of bamboo culm depends on the time of cutting greatly. One of the record says: "Bamboo wares made of culm cut in winter will not be damaged by moth." Generally speaking, bamboo cutting should be done from the Beginning of Winter to the Beginning of Spring the next year. In this period of time the physiological action is lowered by the low temperature, which reduces the nutrient and ash content of the culm, and, as a result, the strength of culm is improved. The products made of winter-cut bamboo are hardly attached by fungus and borer. Bamboo culms are is cut from the end of October to February next year in Sichuan Province for papermaking.

For ensuring the continuous operation of a paper mill with an annual output of twenty thousand ton of bamboo pulp, it is necessary to keep 30-40 thousand ton of fresh bamboo for 5-6 months in storage. As bamboo culms contain moisture, starch and carbohydrate, they may be damaged by mould or boring easily if stored under improper conditions, which results in the reduced quantity of pulp obtained. Experiments demonstrated that the yield of coarse pulp from damaged bamboo culms decreases by 5-10%, and the strength by 20-35% in comparison with that from undamaged ones. It is essential to pay great attention to the purchase and storage of bamboo. Some paper mills regard bamboo storage as the first link of production process and strengthened its management. The main measures are:

2.2.1.1. Strengthen the quality check when bamboo culms come into mill. Culms damaged by mould or insect pests should not be accepted. The moisture content of healthy culms should be checked strictly.

2.2.1.2. Keep good drainage of the storage site. The ground should be flat. The base of bamboo stacks should be 300-500 mm higher than ground surface, with stones underlaid, which prevents water stock.

2.2.1.3. Keep good ventilation of the bamboo stack, arranging ventilating channels and transport passages among them. The stack size should be properly arranged according to the production scale and the area of material storage. It is desirable that they were 30 m long, 10-12 m wide, 5-6 m high, with a ridged top, and covered with waterproof material during the rainy season.

2.2.1.4. Carry out strict fire control measures, prepare enough fire extinguishing facilities. Forbid smoking and using fire near the bamboo stacks. Appoint specialized fire control officers in accordance with the site conditions.

2.2.1.5. Use bamboo culms in a reasonable order. The name of bamboo species, weight, date of acceptance and the name of store man should be mentioned on a brass plate on every stack, the rule of "first come, first used" should be observed.

2.2.1.6. Check bamboo stacks on time. The stacks should be checked frequently, at regular intervals. The check should be strengthened during rainy season, insecticide and fungicide should be applied when damage by insect or mould is found. The slightly damaged culms should be used immediately.

Fuzhou Paper Mill based in Jiangxi Province has conducted a one-year experiment of bamboo storage. They stated that the newly cut Phyllostachys pubescens culms were stored in stacks underlaid with stones on a storage site, the culms were chipped when their moisture content decreased to 20%. The chip was piled in a storage shed. Both the storage site and shed had good ventilation and drainage. No insect damage was found after one-year storage.

2.2.2. Chipping and material preparation

Chipping is the beginning of pulping. The quality of chips is closely connected with the economic benefit of pulp and paper production. The long-term production experience has indicated that the ideal chip size is 20 +-2 mm long. The actual size of chips in production was kept in the range of 15-30 mm, the rate of qualified chips exceeded 90%. The chips of improper size affected pulping:

-- The chips of greater size will prop against each other in container and distributor, causing the insufficient utilization of container space and the increase of chemical consumption; normal production can not be continuous cook.

-- Uneven chip size will cause uneven permeability of chemical liquid, increase uncooked cellulose in coarse pulp.

-- The chips of smaller size will reduce the yield and strength of coarse pulp, particularly the tearing strength.

The size of chips is very important, it affects the cooking quality and the amount of chemical consumption. In order to produce chips of proper size, the following measure were suggested:

2.2.2.1. Select proper chipping and screen machines in accordance with the papermaking scale and chip demand, so as to guarantee an even feeding and continuous chipping.

2.2.2.2. Retain the sharpness of chipping knife blades, appoint special grinders to grind them regularly. Equip all the shift teams with their own knife blades. Observe closely the wearness of blades and change them timely. The clearance between rolling knife and fixed knife should not be too large. The clearance should be 0.5-1 mm for disc chipper, and 0.05 mm for roll chipper.

2.2.2.3. Pay close attention to the removal of dust and screening of chips in the process of chipping. Remove metal scraps, sand and stones from bamboo bundles, bamboo waste and long pieces should be removed. Check the quality of chips every shift.

The material preparation process in existing paper mills is quite simple: bamboo culm --> chipper --> belt conveyer--> chip sieve --> belt conveyer --> digester

The medium-sized and large paper mills are equipped with intermediate silo for a continuous production. The technical data of existing chippers are as follows:

ZCQ 3-blade roll chipper, production capacity: 2-3 t/h, 5-7 t/h (absolute dried), 45 KW, 75 KW, connected with a double deck sieve.

ZMX 5-blade disc chipper, diameter 2500, production capacity: 7-10 t/h, 115 KW, connected with a three-deck rocking sieve.

The above-mentioned technological process and its key equipments require less investment, less working space, causing little loss in material preparation, consuming less energy. The size of chips fits the demand of sulphate pulping. A roll chipper ZCO 22 was set up in Changning Paper Mill, Sichuan Province for processing Sinocalamus affinis, the actual output exceeded the designed capacity of 7 t/h, chip length was 19-22 mm, the rate of up-to-standard was 90-95%, the loss of raw material during preparation was 3-4.5%, the energy consumption was 18 KWH per ton of chips. Considering the present situation of bamboo pulp production in China, the above process is reasonable on economically, and reliable technically, it can be applied for a long time by medium and small mills.

Advanced technical equipments for bamboo chip preparation were introduced from abroad into several new mills in recent years, the major equipments of them were:

-- Technology of PEADCO Corporation, based in the US. The process is: raw material --> chipping machine --> belt conveyer --> tearing machine --> belt conveyer --> feeder --> semi-wet depithing --> needle type meter --> washing machine --> wet depithing --> continuous cooking

The main features of this process are: the chips are torn to shreds, the dust and soluble matter are removed through double wet depithing, the SiO_2 content is reduced by 30%, the shredded chips are fed to the continuous digester with double educt crosswise pipe, which ensures the even permeability of alkali liquid, and decrease the consumption of steam and alkali, and improves the yield and strength of coarse pulp. According to an investigation, this kind of technology has been adopted by ITAPAGA Mill in Brazil, the consumption of NaOH was 16.5%, the hardness of coarse pulp was Kappa 45, yield exceeded 46%, the steam consumption was 2.2 ton per one ton of pulp. It is concluded that the process is technically reasonable.

The main problems of this process are: the loss of raw material in preparation reaches 15%, about 30-50% of the loss are good fibre; the energy consumption is three times that of the traditional process. These costs can not be born by mills. Some measures are being implemented to reuse screening comprehensively for making paper board and other products in China. But, evidently, new problems will happen in future production.

-- Technology of PALLMANM Corporation based in Germany. A PHT drum chipper, connected with a chip washing device, is used. the process is: bamboo bundle --> chipper --> belt conveyer --> chip screen --> washing machine --> dewatering screen --> belt conveyer --> material bin --> belt conveyer --> cook pot

PHT drum chipper made by PALLMANN has a wide scope of application, the raw material is chipped when it is clipped by clipping rolls. Various raw materials, such as log, twig, top and slipping bamboo can be chipped. Unqualified chips resulted from vibration of short raw material during chipping can be reduced by means of PHT drum chipper. The chips are sieved with an arc sieve, the larger slices will be rechipped. The average length is 22 mm, the actual length is kept in the range 17-25 mm. Mud, sand and bamboo dust are washed away from chips. The moisture content of chips after washing is 30%, which benefits the permeability of alkali liquid. The productive capacity exceeds 30t/h, the power of main transmission engine is 375 KW. The chipper should be fed evenly with enough good bamboo material to guarantee the chip quality and control the energy consumption.

The new technology and new equipments described above should be checked in practice, and be improved in accordance with the local conditions.

2.3. Sulphate cooking

According to the characteristics of bamboo fiber, alkali pulping is most suitable, especially sulphate method. The strength of pulp made with acid sulphite is low. Sulphate method is adopted by most of the mills. The production process is shown in figure 3-1. Rotary spherical digester of batch charging and cooker are mainly used for cooking. Digesters of continuous operation have been introduced into Liujiang and Yibin Paper Mills. The technology of sulphate cooking for the production of bamboo pulp is quite mature as a result of rich experiences in recent years. Taking into consideration the characteristics of bamboo fiber, the conclusions of cooking tests and new equipments are discussed, and the examples of production technique are described in this report.

2.3.1. Reaction course of delignification

The lignin content of bamboo is higher than that of straw, and similar to that of coniferous timber, the composition of bamboo lignin is different from that of timber, therefore, the delignification course of bamboo chips is also different from that of timber. Pulping study on the mechanism of delignification of Pseudosasa amabilis chips was carried out in South China University of Science and Engineering. The course of sulphate cooking was divided into three stages. Table 3-3

2.3.1.1. Initial stage. Delignification rate was 46.33% when temperature raised to 100 degrees C, it showed the speed of initial delignification was fast.

2.3.1.2. Mid stage. The temperature raised from 100 degrees C to the highest point, 160 degrees C, the delignification rate increased to 87.71%, a part of bamboo chips was decomposed into coarse pulp, mid delignification speed was also fast.

2.3.1.3. Final stage. The highest temperature of 160 degrees C was maintained for one hour, the delignification rate reached 92.91%, chips completely decomposed. Evidently, it is necessary to maintain the highest temperature for a certain period of time in the course of bamboo sulphate cooking.

Table 3-3 Course of sulphate cooking of Phyllostachys amabilis

delign. stage	temperature (C)	time	act. alkali consumption%	pulp yield %	delign. rate %	appearance
initial	100	0:47	40.23	76.96	46.33	chip
mid	140	1:46	59.53	60.24	74.11	bundlelike
	160	2:16	66.28	53.33	87.71	partial pulplike
	160	2:18	71.35	51.03	91.68	pulplike
final	160	3.18	73.55	49.85	92.91	pulp
	160	3.48	75.95	49.41	93.29	pulp

note: alkali consume (NaOH) 16%, sulphidity 25% liquid ratio 1:4

In recent years, a method of straw delignification developed by Prof. Chen Jiaxiang from South Mechanical University, was adopted in Nanchuan Paper Mill in Sichuan Province. The result was hopeful. The temperature for mass delignification was 134 degrees C, the temperature for final delignification was 153 degrees C. The hardness of coarse pulp was KmnO4 10-13, the alkali consumption reduced by 1.5%. The whole course of cooking reduced by one hour and twenty minutes. The yield of coarse pulp increased.

Table 3-4 The results of cooking experiment

	alkali consum. NaOH %	alkalinity %	temp. raise time	300/134	500/148	550/153	600/	cook	uncreen
former skill	22.5	16.5	0:30	0:30	1:30	-	1:30	5:10	53.85
later skill	21	16.5	0:30	0:30	-	1:25	-	3:50	58.78

The above mentioned experiments and practice demonstrated that satisfactory results can be obtained if proper technological process is worked out in accordance with the specific features of bamboo chips. Due to the different structure of fiber of different bamboo species, proper technological process should be worked out individually for every species. The cell membrane of Phyllostachys pubescens is very thick, it causes more difficulties in cooking than species with thin cell membrane. The experiments showed that the alkali consumption of Phyllostachys amabilis chips in cooking was comparatively low. Every mill should work out proper technological process in combination with local conditions.

2.3.2. Liquor osmosis when cooking

As it is well-known to us all that in sulphate cooking, the liquor evenly infuses into the bamboo strips, that is an indispensable requirement for the guarantee of obtaining high yield pulp with well-distributed quality and less screening.

Since the structure of bamboo is dense with a high specific gravity, its fiber cell membrane is thick, the cooking solution can not infuse into the inside of the fibers easily to get rid of the lignin distributed in cell membrane. After the air-dry of culm's capillaries, which does not like those of the wood that can still remain in a state of vertically running through the stem and which either does not like those of the rice straw, that become flat and shortened, and form an irregular closed state and the air, which is closed in the capillary, is difficult to be got rid of. Thus, the bamboo strips will float on the cooking liquor, which will affect the osmosis till all of the air in the capillary is repelled. Then the cooking liquor can infuse into the cell tissue thoroughly. This is the main factor to cause the unevenness of bamboo liquor cooking. To enhance the osmosis of bamboo liquor, common measures are adopted: raise the cooking temperature to over 85 degrees C, prolong the raising-temperature time and carry out the act of sending out the air for 2 times during the heating, or under mid-pressure to have heat preservation 1:30. In some mills, strengthening instrument is installed to strengthen the liquor osmosis with high speed airflow. The PEADCO technique for material preparation has already been introduced into China. The pitch is removed for two times after the bamboo strips are torn to shreds and make the liquor infuse into the fiber quickly and evenly. But the loss of more prepared material and high electric consumption make the extension of this technique difficult to be done in most of the mills. According to the investigation, the test of natural color pulp cooking of bamboo strips after pressing has been conducted by the Guizhou Light Industry Institute, the main data is as follows (table 3-5).

Table 3-5 The comparison test on the pulp of Ph. nidularia cooking after pressing.

alkali consumption (NaOH) %	13		14	
sulphidity %	20		20	
material preparation (strip)	pressed	unpressed	pressed	unpressed
unscreenings yield rate %	51.8	50.1	51.6	50.9
screening rate %	0.5	1.7	1.1	2.0
screened yield rate %	51.3	48.4	50.5	48.9
unscreened hardness KmnO4 value	37.3	37.2	36.8	36.9
virgin beating degree SxQ	15	14	14	13
beating time mm	15	15	15	15
pulp beating degree xSQ	28	28	28	30
pulp fiber wet weight g	14.7	9.8	14	11.2

Note: cooking time temperature increasing 2:30, temperature preservation (b 37 kpa) 2.00

The fibers split warpingly after the chips are pressed and the structure of internal layer is exposed. The area of alkali osmosis enlarged, at the some condition of cooking skill and same case of pulp hardness control, the amount of screening can be reduced, the pulp yield increased, the wet weight of fiber raised after beating, average length of the medium fiber is longer than that of unpressed and this is favorable to increase the paper strength.

Recently, the test on osmosis characters of Phyllostachys pubescens chips provided by the Shaowu Pulp Mill of Fujian Province shows that chip thickness had the greatest influence on osmosis and the increases of osmosis amount and area of bamboo chips are kept at the same level. In the range of chips length of the mill, the crosswise contact area plays an important role on osmosis but not the vertical one. The above test shows that osmosis function of the alkali liquor can be improved after the chips are pressed, and this is very important for the prepared material of thick-wall Phyllostachys pubescens. It is suggested that the related equipment manufacturing factory would take an active part in the exploitation of new press for Phyllostachys pubescens chips or chipping machine with pressing function.

2.3.3. Practical examples of cooking

The main technical requirements for pulp interval cooking.

-- Bamboo strip size: 15-30 mm long, up to standard rate 85%.

-- Alkali consumption (NaOH): The amount of alkali used vary with species, age and producing area, it is old bamboo of thin-wall type is taken as raw material, soft pulp (bleaching pulp) 19-22%, hard pulp (original-color) 14-16%, 22-24% is needed for soft pulp of thick-wall type moso.

-- Sulphidity: 20-25% is usually controlled and not lower than 15%.

-- Liquid ratio: direct heating for spherical digester is low (1:2.3-2.5), indirect heating for boiling pot is a little bit higher (1:2.8-3.0).

-- Boiling temperature (pressing) and time: in order to match with osmosis and action speed, it is often divided into two stages of low temperature osmosis and high temperature evaporation, the temperature is controlled at 2:30, the boiling pressure of high temperature mostly at 637 kpa, the time of heat preservation for hard pulp at 0:30-1:00, soft pulp is a little longer 1:30-2:30.

Table 3-6 Example of sulphate boiling

	Jiangxi Pl.simoni	Hunan Ph.pubescens	Guangdong B.textilis	Sichuan S.affinis	D.membranaceus	
digester type	rsd	rsd	rsd	rsd	rsd	charge
digester capacity M3	25	25	25	40	40	75
absolute feeding wt. (kg/m3)	180	180	180	190	180	200-220
alkali consumption (%)	19-21	18-20	17-18	21-22	14-16	19-21
sulphidity (%)	20	20	18	25	25	20
liquid ratio	1:2.4	1:2.5	1:2.5	1:2.3	1:2.4	1:2.8
cooking pressure (Kpa)	637	637	686	637	686	637
cooking temp. C	163+-2	163+-2	168+-2	163+-2	168+-2	163+-2
cooking time:						
digester feeding	0:15	0:15	0:15	0:20	0:20	0:30
heating up time	3:00	2:30	2:30	2:30	3:00	2:30
high temp. kept	1:30	2:00	1:00	2:00	0:40	2:00
decharging	0:15	0:15	0:15	0:20	0:20	0:30
whole process	5:00	5:00	4:30	5:10	4:20	5:30
unscreened hardness KmnO4	13:15	13:16	14-18	9-12	28-32	16-21
unscreened yield (%) 77'(44-48	43-46 42-46 50-52	43-47 45-48				
cooking dissolving rate %				> 97	> 96	> 97
pulp usage	bp	bp	bp	bp	pp	bp

Note: rsd -- rotary spherical digester. bp -- bleached pulp. pp -- pure pulp.

2.3.4. Progress of cooking skill

2.3.4.1. Introduction of transverse pipe continuous digester

A set of Pandia four pipe continuous digester (50 t/day) manufactured by Tampella Company, Finland was introduced to Liuzhou Paper Mill of Guangxi Province. In comparison with batch digester, it has the characters of smaller liquor ratio, shortened cooking time, steam saving, less area for equipment, easy operation and high productivity. It was put into production in 1974, which was used for bamboo cooking and unbleached soft pulp of crop stalks. Through the test in recent 20 years, the production capacity per day reached 60 ton, 20 thousand ton of output per year is reached, culms of Dendrocalamus membranaceus was used as raw material. The current technical requirements are:

-- Amount of feeding material: 100-160 kg/min

-- Alkali consumption (NaOH): 20-22%

-- Sulphidity: 14-18%

-- Temperature of alkali liquor: 80-90 degrees C

-- Liquor ratio: 1:3

-- Cooking pressure: 0.7-0.8 Mpa

-- Cooking temperature: 155-165 degrees C

-- Cooking time: 45 min

-- Unscreened hardness: 14-18 KmnO4 value

2.3.4.2. Introduction of Kamyr continuous digester

In the technical innovation project of Yibin Paper Mill, Kamyr-Asthmyr continuous digester with high-heat washing was introduced, 110 ton bamboo pulp can be produced per day, 200 kg strips can be held per square meter of the digester volume the total height of the digester is 20 m, cooking area of digester is O/ 3m, diffusing area for high temperature is o/ 3.3 m, cooling area o/ 3.5 m, outer shell is welded by compound stainless steel board. The technological process is controlled by a set of control instruments, the process is summarized as follows:

-- Pre-steaming: bamboo strips preheated with normal pressure in storehouse, pre-steaming is done by 98 Kpa in steaming house, alkali liquor needed is pumped into steam house by a pump at the same time.

-- Feeding material: High pressure is used to send the bamboo strips and alkali liquor to digester with the pressure of 686-785 Kpa, high pressure feeder is adopted under the pressure of 98 Kpa.

-- Cooking: reaction time is decided according to the variety of materials.

-- Washing: high heating washing is often conducted for 3-4 hrs, after 4 hrs washing, its equivalent to 3 sets of series drum washing machine at the least.

-- Pulp sending: washing liquor is added to the bottom pulp, and which is cooled to 90 degrees C for spouting to maintain the strength.

The main technical requirements for cooking:

-- Alkali consumption (NaOH): 183 kg/ BDT bamboo

-- Cooking temperature and time: 165 C/120 min

-- Unscreened yield: 50%

-- Rate of pulp dregs: 0.9%

-- Hardness (Kappa value): 26

The complete set of the equipment is established, now it is put into trial operation stage.

2.4. Sulphite amine cooking

Sulphite amine process is adopted for pulp cooking, which followed the experience of imide process for straw pulp by Dujiang Paper Mill in Sichuan in 1983, combining with the bamboo fiber character for the extension of kraft paper production, the specialized standard index of IBY 32014-88 kraft paper can be reached for the production quality, see the Table 3-7.

Table 3-7. Strength of bamboo pulp kraft paper by imide process

	ration g/m2		tearing resistance Kpa		chord tearness mN	
	80	60	80	60	80	60
specialized standard A	80+-4	60+-3	>265	>185	>765	>540
100% imide	80		284		853	
" "		62		206		584
" "	84		282		944	

The kraft paper board production line with an annual production of 10 thousand ton board was established by Laishan paper board factory in 1987, GB 13024-91 box paper board standard with class B index was also reached for the quality. Since the imide pulp color is light, dyestuff is used for coloration on surface pulp, the package decoration can be improved, the products have been used for outer packing of household appliances, high-grade cigarettes and instruments etc are used. In recent years, the test of imide process is also carried out for Fujian moso. According to the preliminary statistic, imide process is used by 8- 10 mills.

Table 3-8 Example of imide pulp cooking

	unit	Sichuan S.affinis Ph.heteroclada	Sichuan D.membranaceus 90% straw 10%	Fujian Ph.pubescens
imide	%	16-18	16	25
buffer	%	4 (NH3)	3 (NaOH)	3.5(NH4HCO3)
liquor ratio		1:2.5	1:2.1	1:3
max. pressure	Kpa	>10	>10	680
max. temperature	C	175	175	170
duration of increasing temp.	hour	1	1	1.5
duration of max. temperature	hour	4	3	4.5
initial cooking liquor	pH	10.5	10	10
end cooking liquor	pH	7.5	7	7
unscreened hardness	KMnO4	29-32	28-32	15-18
unscreened yield	%	55-60	55	48-50
pulp usage		kraft paper and box board		semi-bleached

The specific features of imide process

2.4.1. Comparatively high yield

The degradation of fiber bundles and semi-fiber during imide cooking is not so serious as that of alkali process, yield of pulp making is increased by 5-10% than that of the sulphate process, and, as a result, 8-10% production cost can be reduced. The shortcoming is that the bleaching is more difficult, some colored mass of fiber is produced at high pressure and temperature by ammonia or amino ion, because the unscreened hardness and yield is high, it also has the effect on bleaching if the cooking conditions are not suitable. Sometimes, even its strength is reduced and it becomes fragile. Imide process pulp is suitable for producing kraft package paper or paper board.

2.4.2. Comparatively high cooking temperature

The major reaction of imide cooking delignification is lignin sulphonating reaction, which resulted in the formation of lignin sulphonate, which is soluble in water and can be removed from the water. Lignin sulfonic acid is dissociated into ions in water. Along with the condition of sulphonating, the amount of lignin sulfonic acid is increased, cooking liquor pH value gradually reduced. For the reduction of corrosion of the equipment, pH value of cooking liquor should be strictly controlled to keep it at a slight alkalinity. Due to the slow reaction of sulphite acid radical the raising of cooking temperature and prolongation of cooking time at maximum temperature can quicken the speed of sulphonation and improve the solubility of the sulphonated lignin.

2.4.3. More serious corrosion

Imide process is a kind of acid pulping method, which will do serious corrosive on carbon steel cook equipment. If there is no necessary control measure adopted, the thickness of corrosion for the rotary spherical digester steel board is 1 mm per year. Buffer must be used for ensuring the cook under alkaline condition and that is a very important measure for reducing corrosion. The buffers commonly used are: ammonia water ($NH3$), sodium hydroxide ($NaOH$), hydro acid ammonium ($NH4HCO3$), urea ($(COCNH2)2$ etc. Strictly control the pH value of cooking liquid at over than 10 at the initial and guarantee it no less than 7 in the end of the cooking. According to the latest information, using 4% magnesium oxide (MgO) as buffer, we can achieve high unscreened yield, less screen dregs, light color and good water filtering property. There are cheap and rich resources of Mgo in China and it's transportation and utilization are easy and convenient. There is magnesium alkali existing in waste liquor, which is needed for the plants.

2.4.4. Regular checking of the thickness of equipments

The cooking equipment is strictly forbidden to be used for imide method cooking or alkali method cooking alternatively, otherwise the corrosion speed will be quickened for two times. The parts, such as evaporating-ball steel plate, bend of spray pipe etc. must be examined at regular intervals and some resolute measures must be adopted in time.

2.4.5. Strict waste control

When imide method is adopted, the main elements dissolved in the waste liquid is organic matters, such as sulfonated lignin and other organic matters containing nitrogen as well as the imide residue. The waste liquid can be used as fertilizer because of its content of organic and inorganic matters. It is used for the growth of agricultural crops, especially for crops on saline soil. As for wheat, rape and other crops, the use of it can increase the yield better than that of sulphuric ammonium or manure. But it should be applied at suitable places and time with rational amount. The problem existed is that paper mills are in production all year round, while the application of fertilizers is a seasonal work. Since the concentration of nutritional matters in waste liquid is low and its quantity is large, if we drain it away without any treatment, it will pollute the environment. This is the main adverse effect which affects the development of pulping with imide method.

2.5. Washing and sieving method

2.5.1. The washing of bamboo coarse pulp

It is comparatively easy to wash bamboo pulp, because its filtering property is high, just second to that of wood pulp. Now large and medium sized paper mills which are equipped with alkali recovering workshops mostly adopted common vacuum washing machine used for washing wood pulp. After cooking, get rid of nodes from bamboo pulp, then use three or four vacuum pulp washing machines to wash it reversely to get black liquid, then take it to alkali recovering evaporation workshop section. Generally, according to the equipment capacity selected, each square meter washes 3.5-4 tons of bamboo pulp daily, the black liquor rate will be 90% or so. One wood pulp mill did a lot of experiments and through production practice, it turned the technological process of traditional practice, it turned the technological process of traditional method "remove nodes before washing" into "remove nodes after washing" or "remove nodes in washing". It has the feature of good separation between pulp and liquid, foam is basically got rid of, black liquor rate increased by 3%. If the method of removing nodes in washing is adopted, material should be fully mixed, and put into node removing machine, and then spray it with hot water 60 degrees C, and by potential, put it into the fourth pulp washing machine, it enlarges the washing condition and time, so it is good for pulp and liquor to separate completely and does not produce foam. Besides those, each ton of pulp can reduce to the 3 kg remnant alkali away.

Washing equipment is quite simple for small mills which have no recovering workshop. Recently, relevant equipment manufacturing factories studied the advantages of dehydrated equipment made both in China and abroad, and manufactured a series of pressing and filtering machine. It's said that the main property indices of these machines were superior to those of old type. The equipment of less investment, smaller operating space, less water and consumption and lower chlorine consumption etc. They are suitable for small paper mills.

Liujiang Paper mill in Guangxi is the earliest mill which has imported the Finland PW pulp washing press to wash bamboo pulp. Its working principle the same as that of vacuum pulp washing machine. Its special feature is that the pulp on washing drum's of the washing press is affected by the press filtering function produced by hot air of the blower. The wind pressure is very great, so it achieved good washing result. And it's washing area is larger than that of vacuum pulp washing machine. Each washing gum can do two sequences of washing, to raise the efficiency. The pulp washing press is in operation with pressure under the condition that the whole pulp material and air systems are air-tighten. In this way, when washing pulp with sulphate cook, it does not produce foam, heat and offensive smell are not easy to spread, the operating environment condition is good, heat loss is small. The mill uses two presses which are linked in series in production. Black liquor rate is 92%.

Recently, Yibin Paper Mill has imported from Kamyr-Asthma Corporation a set of high temperature washing machine for successive cook of bamboo pulp and a matching set of PFW type pulp washing press. It has the washing system of modern level. It is introduced that bamboo pulp in the washing area of the cooker is washed at high temperature for 4 hrs. It is equivalent to three in series linked vacuum pulp washing machines. So the washing procedure only needs one PFW pulp washing press. On the basis of the traditional vacuum pulp washing machine and FW pulp washing press, PFW is the newly exploited type of pulp washing press with high efficiency. The production capacity is big, washing efficiency is high, pulp concentration has been increased from 1 - 1.5% to 3-4%, filtering area capacity has been almost doubled. It is estimated that the black liquor rate can be increased to over 95%. The projects of Ya'an Paper Mill in construction is to purchase Canada"s Hi-Q type node removing press and P24-6 type of vacuum pulp washing machine. It is introduced that dilution factor is 2.5. The washing loss of each ton of air-dried pulp is not over 10 kg alkali (Na_2SO_4). Black liquor rate can be up to around 95%. The structure of water distribution value should be used for reference worthily in China.

2.5.2. Sieving and purification

Sieving and purification of bamboo are the same as those of other pulp materials. Usually we adopt the two-grade ZSL type centrifugal screen and 3-sequence dreg-removing equipment to take off the compounds which can not meet the need of quality requirements in paper pulp, for example, some impurities such as rough fiber bundle, sand etc. In this way, it can reduce the dust. Producing bamboo pulp with its original color generally only adopt sieving equipment. It is suitable for the requirement of making kraft package paper and cardboard.

ZSL type centrifugal screen is made based on the CX type centrifugal screen and improved and produced in drawing some features of B type centrifugal screen. It has so many advantages, such as great production capacity, high screen efficiency, low power consumption, compact structure, small area used and convenient disassembling and washing as well as convenient to be examined and repaired. Now there are four types of ZSL 1-4 series of equipments for providing different production capacities, fig. 3-9 is an example of one paper mill in adopting two grade screen in production.

Table 3-9 An example of two-grade screening

	area	diameter	consistency	pressure	speed	capacity
	m2	mm	%	Kpa	r.p.m	t/d
1st grade	1.6	1.8	1.2-1.8	176	485	40-60
2nd grade	0.9	2.6	0.6-0.8	-	576	20-30

This mill has not been equipped with centricleaner for purification. It uses sand trap instead. Dust rate in fine pulp is 0.5-2.0 mm in length, 3.8 g absolute dry pulp is no more than 3, bigger than 2 mm is not allowed. It is suitable for the fixed requirement of no bleaching pulp of the bleaching workshop section. It also saves power.

Press sieve is developed from type A screen. Pipe line is air tighten and the pulp is pumped to get in with pressure. In the recent ten years of development, there have been many kinds of it. In our country, we still use single gum external flowing type mainly. The blade section is almost like the wings of aeroplane, so it is also called whirling screen, mainly used for pulp material selection before producing paper. In countries, for automatic control, press sieve is commonly used to replace centrifugal screen and vibrator screen. In recent years, for the important construction projects inside China, we imported UNi press screen from Sweden, node removing press, press screen and three sequence contrifugal dregs removing system made from the Ingersoll-Rand Corporation of Canada. They are in construction at the moment.

As for the purification of bamboo pulp without bleaching, 606 type high pressure-difference and low concentration, centricleaner is usually adopted. According to the introduction of some experience that entering pulp pressure is 300 Kpa or so, pulp-out pressure is 30 Kpa or so. The concentration is controlled at 0.5% the best. The consistency is low, although the purification has high efficiency, the output is low while it consumes a lot of power. So the efficiency will be reduced when the concentration is up to 7%.

The thin-wall cells of bamboo (It's commonly called miscellaneous), after it is cooked for delignification, it scatters into single ones in paper pulp. Because it is easy to be damaged while the thin wall of bamboo is being beaten, it will affect the process of papermaking, due to the dehydration of netted part is difficult. It will makes paper combination imcompact and easy for the surface of paper to have powder peeling down, and it has disadvantages to paper strength also. So paper mills which produce high-grade printing paper and paper bags, during the operation, they pay close attention to pulp washing, screening and purification, and remove the miscellaneous in paper pulp as much as possible.

2.6. Bamboo pulp bleaching

Bamboo pulp is suitable for producing printing and writing papers. It must be bleached and get rid of the coloring material such as lignin residue etc after cooking. It's necessary not to damage the fiber strength and make the bamboo pulp white enough. In this way, we can enlarge the application range and raise the product's quality.

It is difficult for bamboo pulp to be bleached in non-wood fiber raw materials. For instance, the hardness of bamboo without bleaching is higher, it contains more lignin. It will consume a large quantity of efficient chlorine if we use routine hypochlorite to bleach, and the whiteness is not high. Because the fiber's morphological structure of bamboo pulp is different from that of the wood pulp and straw pulp, bleaching agent can only be scattered inside through centrifugal point of the cell cavity. It made it difficult to remove lignin, and meanwhile, in cells of unbleached pulp there are 25% of condensed lignin of the total lignin, when bleached, semicellulose expands, it makes cell cavity narrow, so it's difficult for bleaching agent to infuse. In recent years, with the progress of bleaching technique, oxygen alkali treatment is adopted to delignify, enlarge the usages of chlorine dioxide, hydrogen peroxide is used for additional bleaching. Pulp can be bleached to 90xGE brightness. It also can reduce the damage to the fiber and pollutant load of the waste water. The newly-built and enlarged bamboo pulp mills have imported this kind of new technological equipments.

2.6.1. Hypochlorite bleaching

The pulp bleaching, in our paper mills at present, mainly adopt hypochlorite oxidizing bleaching agent (it is also called bleaching liquor), the bleaching methods are: single stage bleaching (H), two-stage bleaching (HH), three-stage bleaching (CEH) and four-stage bleaching (CEHH).

2.6.1.1. Hypochlorite single stage bleaching

The whole process of single bleaching is done inside machine. Add the required amount of bleaching liquor for once according to its quantity. The equipment is simple, less investment and easy to handle. It has been used by many small paper mills in China. But it consumes quite a lot of chlorine, especially it's reaction is intense at the beginning of the bleaching. The fiber strength suffers some damage, so the hardness of unbleached pulp is generally controlled at 10-12 KmnO4 value.

-- Chlorine consumption. It is very important to use right quantity of chloride. Adding too much or too little will affect its quality or cause waste. Some paper mills adopted the method of adding more bleaching liquor for strong bleaching, while this damage the fiber and its strength, and after bleaching, it turned yellow. So this method can not be adopted. Most paper mills according to the bleaching sulphate pulp's, hardness is between 9 and 12, and make use of the formula of chlorine consumption.

$$X = \frac{K + 1.28}{2.8} (\%)$$

In formula: X = chlorine consumption
K = hardness of unbleached pulp

-- Bleaching pH value. It is very important to control the pH value for bleaching effect and quality of paper pulp. Bleaching under alkaline, the oxidizing ability of the main component of the bleaching liquor, CIO is weak. Although the fiber expands vigorously, the damage is small. Usually, 11-12 pH value of bleaching liquor is added at the beginning of bleaching, while at the end of bleaching, it keeps 8-9 pH value. It makes whiteness stable, and the damage to cellulose and hemicellulose.

-- Bleaching temperature. The bleaching temperature is generally controlled at 35-40 degrees C. The raising of its temperature can quicken the chemical reaction's speed and shorten the time. But if the temperature is too high, it will resulted in fiber degradation by oxidation. recently it was reported that an experiment of hypochlorite bleaching was made at high temperature. The temperature was raised to 50-60 degrees C, and used NH2SO3H as protective agent, those filling amount is 2-6% of the chlorine consumption to reduce the influence of low pH value to the cellulose. This can shorten its time and reduce the chlorine consumption. According to the tests and practice made by Yibin Paper Mill, it had some good result for reducing bleaching pulp yellowing if 3% NH2SO3H is added without the regulation of pH value, and the bleaching temperature is at 40 degrees C, but if its temperature is 50 degrees C, it will be different. But it also can reduce 1.5-2% of the chlorine consumption. Because NH2SO3H agent is very expensive, it is difficult to be used in production. The main point of rapid bleaching at high temperature is to control pH value at 9-10 at the end of the bleaching.

-- Bleaching concentration. If the concentration is high, its reaction speed will be quick, time will be shortened and chlorine consumption reduced. But the normal concentration in bleaching machine is 5-7%, and bleaching reaction time is longer.

-- Rational control the bleaching process. If the efficient chlorine is basically used up, the bleaching time should not be prolonged any more, otherwise it will be difficult to raise its whiteness and it will be easy to be yellowing after the pulp is bleached, when whiteness is up to its requirement, chlorine reside should be at 0.2-0.3 g/e, and the dissolvable organic matter produced in the bleaching process should be thoroughly washed off.

2.6.1.2. Hypochlorite two sequence bleaching (HH).

As bamboo pulp is difficult to be bleached, small and medium- sized plants, which are short of equipments for multistage bleaching, often HH to increase paper pulp brightness and reduce fibre damage. The HH process is mainly like this: the bleaching liquor is put in separately for the times. The amount for the first time is 60-70% of the chlorine consumption fixed in advance. After bleaching, it should be washed and its dissolved substance should be taken away. It can reduce the pulp yellowing after bleaching. And then add the remaining part of bleaching liquor for the second sequence bleaching. if the bleaching is quite moderate, the strength of paper pulp is also quite good. For instance, the hardness of unbleached pulp is at 10-12 K value, after bleaching, the brightness can reach 75-78%. It saves 20% of the chlorine consumption as compared with single stage. But its operating process is longer, and the water consumption and drainage amount are raised. Now, it has been the method for small and medium sized plants to produce high brightness pulp.

2.6.1.3. Multistage bleaching

In 1964, in order to help a paper mill in Burma, China set up a CEH 3 sequence bleaching workshop, mainly using bamboo pulp combined with the original bleaching machine to carry out 4 sequence bleaching. Medium brightness can be reached. In the early 1970s, Liujiang Paper Mill built a 3 stage workshop using bamboo and crop stalk pulp. Now some medium sized paper mills have set up CEH

3 sequence bleaching workshops. The raw materials are bamboo, wood and straw.

Stage C is for chlorination. We mainly make use of the character of chlorine element which has selecting function for lignin. To form the chlorine which are soluble in alkali and the fiber will not be damaged seriously. It makes lignin residue in pulp turn into chlorine lignin to affinity, and dissolve out. It can take away 50% chlorinated lignin or so, and plays a role of purifying paper pulp. Although its brightness doesn't increase, after chlorination, it can reduce the chlorine consumption and the fiber damage during the bleaching stage, and can increase pulp bleaching yield and intensity. For multistage bleaching, the chlorine consumption of sequence C and sequence H generally is 60:40. After chlorination, pH value can affect the viscosity of bleaching pulp. According to the experimental result, pH value is at 1.4 or so and the viscosity of paper pulp is the highest.

Stage E alkali treatment. It's possible not to increase cellulose degradation, to get chlorine lignin to reduce its bleaching liquor consumption for the next working procedure to make paper pulp gain quite high brightness, with a reduction of copper value and an increase of its viscosity. Consumption of NaOH used for alkali treatment is generally controlled at 2%. If the hardness of bamboo pulp is high, NaOH capacity consumption will be increased appropriately.

Stage H, that is hypochlorite bleaching, is mainly to supplement bleaching function, and to oxidize the lignin residue and coloring matter, because of its less chlorine consumption, concentration increases by 10-12%, bleaching condition is quite moderate. Compared with single stage bleaching and two-stage bleaching, the brightness of multistage bleaching is stable and its strength is also nice.

Table 3-10 Technical process of sulphate pulp bleaching.

hardness KMnO4	process	stage	consump. %	concen. %	temp. C	time	end pH	whiteness
10-13	H	H	8-9	6	38	2:00	8	70-75
10-13	HH	H1	6-7	6	38	1:30	8	75-78
		H2	3	6	38	2:00	8	
		C	5	3	normal	1:00	1.5	
13-16	CEH	E	2	10	60	1:00	8.5	70-75
		H	3	10	38	3:00	8.5	
		C	6	3	normal	0:45	1.5	
13-16	CEHH	E	2	10	60	1:00	8.5	78-80
		H1	3	10	38	2:00	8.5	
		H2	1.5	6	38	4:00	8.5	
		C	5.67	6	normal	0:50	1.59	
16	CEHH	E	3.5	10	60	1:00	10.6	
		H1	3	10	50	1:30	9.4	70
high temperature bleaching		H2	2	6	50	2:30	9.3	80

Note: stage E - NaOH consumption, time for single and 2 stage bleaching does not include washing.

2.6.2. Study and application of new technology for bleaching

In recent years, papermaking circle in China takes the development of bleaching technology seriously and is very much interested in it. According to the characteristics of pulping, experiments and studies were carried out, and in the main construction projects of some paper mills, the foreign advanced technical equipments were introduced.

2.6.2.1 Use CIO2 as the main multistage bleaching

CIO2 is a selective bleaching agent which has strong oxidation. And it takes off lignin and nonferrous coloring matter effectively, and it has less degradation to cellulose and hemicellulose, Pulp bleaching whiteness is high and is not easy to be yellowing. The loss of fiber strength is less. CIO2 can reduce pollution load in waste water and poisonous matter compared with hypochlorite bleaching. Projects in the newly-built and enlarged Ya'an, Guangning, Shaowu etc. paper mills mainly used bamboo as raw material. In China, the scientific research units have carried out many CIO2 pulp bleaching experiments early or late. For example, papermaking institute of Sichuan chose C/D -E-D-E-D 5 stage bleaching for Ya'an Paper Mill, brightness can reach over 90x GE after bleaching. The yellowing rate is low and polymerization degree is high, see table 3-11.

Table 3-11 Multistage bleaching test using chlorine dioxide mainly

raw material	Ph. bissetii	Ph. heteroclada	Masson pine	Eucalyptus globulus
hardness K value	13.3	14.6	20.9	16.8
lignin %	1.93	2.4	3.64	1.6
polymerizing DP	1628	1752	1340	2056
brightness %	35	32.5	24.5	24.8
total bleaching %	8.18	7.2	14.57	8.95
bleaching process		C/D -- E -- D -- E -- D		
pulp yield %	82	83	97	93.4
pulp brightness GE	92.1	91.2	91.7	92.9
bright reversion GE	88.9	88.3	86.3	88.3
yellowing value PC	0.35	0.56	0.71	0.5
polymerization DP	1275	1172	1002	1182

According to the result, in the design made together with Canada, oxygen delignify is used, and adopted the new technology of C/D- Eo-D short 3 stage bleaching. After oxygen delignification, Kappa value of coarse pulp hardness reduced from 34.6 to 19.9, lignin removing rate is 42.5%. Replacing ratio of chlorine CIO2 is C80D2o in, CIO2 consumption is 0.49%, D stage consumption is 1.48%. The total is 1.97%. The brightness can be bleached to 90% ISO.

2.6.2.2. Oxygen and alkali treatment and hydrogen peroxide bleaching

It is well known that ClO_2 bleaching can get fine and high brightness pulp. But at present, ClO_2 bleaching technology is difficult to be commonly popularized and applied because the conditions of investment, equipment and available supplies etc. are limited. In recent years, considering the actual situation, the relevant scientific research institutes and enterprises have adopted EO treatment in bamboo bleaching process and H_2O_2 to make up for bleaching. They have conducted many experiments and researches. Because of filling in oxygen in alkali treatment, it can strengthen the function of delignify. It can make chlorine lignin out at the maximum under the condition of not increasing degradation of cellulose. And it can save more bleaching agent for the next working procedure. Oxygen price is lower than liquid chlorine, so it is reasonable economically. H_2O_2 is also a kind of fine oxygen bleaching agent. Its bleaching mechanism is not to dissolve and take lignin and pigment off, but to change the structure of coloring matter and make it turn into nonferrous colorless matter. In the last sequence, H_2O_2 bleaching is adopted, it can raise the bleached yield gained and raise whiteness as well as its stability. It does not easy to be yellowing. Compared with bleaching with hypochlorite, both the new bleaching technique and ClO_2 bleaching mentioned above can reduce organic pollution load in waste water. Quite satisfied results have been achieved through experiments.

-- Adopting C-Eo-H-P new technology to bleach pulp, oxygen consumption is 0.5%, H_2O_2 consumption in sequence P is 0.6%, brightness after bleaching is 88.7%, yellowing value is 1.04, polymerization degree is 820, its reducing rate is not great.

-- Stage Eo treatment can remarkably improve pulp bleaching effect. Compared with normal sequence E, brightness after bleaching the brightness increases by 4.4%, 0.6% of the bleaching agent is reduced. Polymerization degree does not change.

-- After CEH stage 3 bleaching, brightness is up to 75-78%, and in the last stage, H_2O_2 is used to supplement the bleaching, its brightness can be increased by 5-6%, it can significantly prevent pulp from yellowing and PC reduction is 64-73%.

Since oxygen's price is low, so it is quite economical to adopt Eo treatment. Adopting C-Eo-H technology, Yibin Paper Mill has set up workshops to finish 100 tons of bamboo pulp bleaching daily.

2.7. Bamboo pulp beating

Bamboo pulp beating plays an important role in papermaking by composition furnish. Pulp beating can increase the combination of fibre, reduce the average length of fiber, raise the resistance intensity and tearing resistance, meanwhile, it can increase compactness, smoothness; but tear resistance must be lowered, and increase transparency and shrinkage of paper. Transparency is no good for producing printing and writing paper, but it is good for producing copy paper and tracing paper. So we should make a good use of applying and controlling the function of beating, try our best to avoid bad effects to paper and cardboard products on the basis of pulp property and product requirements.

Bamboo pulp fiber is thin and it's ratio of length: width is large, cell wall is thick and cell cavity is small, secondary wall has a structure of multiple layers, the fiber is straight and solid, so it is called "pulp being able to stand beating". Through experiment and studies, it shows that when beating pulp or fine grinding, fiber softness is small. The raising of strength is mainly making use of mechanical function of pulp beating equipment and the fibers rub each other fibers to take the newly nascent wall off and expose both the inside and outside secondary wall. It causes fibers to suck water and expand, and then turns into thin fiber. It makes fiber surface fibrillate and increase hydrogen bond between fibers. The higher the degree of fibrillation of fiber, the more the microfibril fiber. The combination force of forming hydrogen bond is great and the paper strength is fine. According to the experiments and testing results for the property of papermaking with bamboo made by a Burma scholar, bamboo fiber tissue contains quite thick wall fiber, and also contains a lot of microfiber. The property of pulp strength is between needle-leaved wood pulp and broad-leaved wood pulp. If the bamboo pulp contains a large quantity of thin- wall fiber, its strength is almost the same as that of needle- leaved wood pulp. " Fine bamboo species selection for expand paper-bag and pulping technological test" made by Sichuan Paper Institute points out: the average fiber length of Sinocalamus affinis and Dendrocalamus membranaceus is 2 mm more or less, belt-shaped thin-wall fiber is quite many. (Sin. affinis is 42.5%, Den. membranaceus is 37.7%), wall cavity ratio is all at one or so (Sin. affinis is 0.89, Den. membranaceus is 1.7). For cell-wall thickness, Sin. affinis is 2.54 mm, while Den. membranaceus 2.45 mm." After Sin. affinis and Den. membranaceus pulp are beaten, during pulp beating, the morphological changes of thick wall fiber is not obvious, while thin-wall cell has commonly thread grading, from the superficial phenomenon, it is microfibril. Especially the pulp for paper bag which needs slight beating, the quantity of thin-wall cell is the important factor for forming paper strength, it is also the main mark for evaluating whether a kind of bamboo belongs to fine bamboo or not." But in pulping, of the pulp contains more impure cells, it will effect both paper strength and papermaking process. So, correspondent methods should be taken in technology of papermaking.

2.7.1. The selection of pulp beating equipment

Bamboo pulp beating is the same as the wood and straw pulp beating, it also undergoes the developing stages of tub beater, conical refiner, cylinder refiner and disc refiner. Through quite a long time of production practice, double disc refiner, among present pulp beating equipments, is a continuously beating equipment. It has advantages of high productive capacity, low energy consumption and fine quality of pulp. In pulp beating, we take press damp expanding for the main point. Cutting function is not important. It is suitable widely, and it can be combined with other pulp beating equipment in series in use. Table 3-12 is the main feature and specifications of the double refiner made in China at present.

Table 3-12 Main character and specifications of the double refiner

type	ZDP12A	ZDP11	ZDP13
disc diameter mm	350 or 360	450	550
rotating speed rpm	960	980	980
pulp passing rate t/d	4-20	8-40	15-110
pulp entering concentration %	2.5-5	2.5-5	2.5-5
pulp entering pressure kpa	148-196	148-196	148-294
main motor power Kw	55	110	215

Single disc refiner is also used for pulp beating in small paper mills.

2.7.2. The experiments on the change of fiber after bleaching and disc treatment.

Sichuan Ruled Paper Mill uses single disc refiner to treat bleached bamboo pulp. Its concentration was 3.7%, pulp passing capacity is 21 m3/h. During the initial beating up period, the middle part or the end of the fiber begins to expand, then turns reticulate. After the reticulate structure increases gradually, fiber begins to broom. There is no such kind of phenomenon in the beating process of wood and straw pulps. After the fiber bends, brooming begins.

Pulp beating control and practical example of disc refiner.

2.7.2.1. Concentration of ground pulp

The interstice of disc refiner is very small, when the refiner is working, so enough concentration must be ensured. If the concentration is low, fiber will be easily affected by its cutting- off function. Since the function between gears reduces, high concentration plays an important role in fiber threading brooming. It is generally controlled at 3.5-4.5%, not lower than 3%.

2.7.2.2. Refine electric current and refiner interstice.

The among of electric current used at grinding indirectly reflects the relation of beating specific pressure and refiner interstice. In order to fully develop working efficiency of the equipments, through production practice, according to the power capacity of the electric motor, not over the rated load of the electric current, adjust the passing amount of grinding pulp and pressure, to find out a fine, high output, low consumption index and changeable range. Common refiner electric current should not be lower than 70% of the rated current. In refiner operation, the interstice between the two disc refiner reflects the specific pressure in beating. It is the an important controlling factor, and generally should be 3-4 times of fiber diameter.

2.7.2.3. Beating mode.

As for bamboo papermaking, according to their different mixing ratio, usually two or three kinds of pulping ar adopted. According to the investigation, there are two opinions, one is stressing the mode of mixing up and another one is the mode of beating separately. Since different kinds of pulp have different specific properties, there are some differences both in technique of pulping treatment and equipment conditions, so paper mill should select economical and reasonable beating mode according to their own reality and through experiments and production practice. In this way, they can ensure to bring the properties of the pulp into full play, and produce fine quality of paper and reduce power consumption.

Table 3-13 Production practice of disc refiner beating

papers	composit. %	equipment	concent. %	degree SR in	degree SR out	pulp passing	fiber length
typing	bamboo 70 straw 30	three 360 double connected with cylindric refiner	3.8-4	22	60-62	380-400	0.9-1
enamel	bamboo 40 wood 25 straw 35	four 450 double refiners connect with conical disc	3.5-4	20	38-42	800-1000	0.9-1
kraft bag	bamboo 30 wood 70	four 450 double disc connected	3-3.5	14-15	25-28	1000-1200	1.8-2
kraft board	bamboo	three groups of 45 double disc linked	4-4.5	18-20	28-32	700-800	1.2-1.5

2.8. Papermaking

It has a history of over a half century adopting bamboo pulp in producing machine-made paper and cardboard. Quite rich experiences have been accumulated. Now quite a lot of kinds of paper and cardboard are partly or wholly made by bamboo pulp instead of needle-leaved wood pulp, and produced paper products to meet the needs of quality standard or meet the needs of the customers. Varieties of products increased day by day. In this article, only a few cases of papermaking with bamboo pulp are mentioned.

2.8.1. Reasonable composition ratio

Adopting bamboo pulp only for papermaking, the production process, technical equipment and operating control are all quite simplified. But bamboo pulp fiber has both advantageous property and disadvantageous factors. So quite a few paper mills, according to the paper pulp property and technical equipment conditions, adopt two or more kinds of paper-pulp composition ratio to improve product quality and meet the needs of users. It has achieved better results than using bamboo pulp alone in papermaking. For example, Chongqing Paper Mill now uses old bamboo pulp, Chinese alpine rush pulp with small quantity of wood pulp to produce offset printing paper. It is even better than the paper which was produced with pulp of fine green-removed tender bamboo pulp in the 1950s and 1960s. It is mainly to bring the various properties of fibers of different paper pulps into full play. Bamboo pulp is quite soft. You will feel it elastic, fine and smooth by hand, its wet strength is a little bit poor. The dry and wet strength of Chinese alpine rush is good. It is quite hard and difficult to be out of shape, while dry and wet strength and opacity of wood pulp are both good. So high grade offset printing paper produced by the mill has the advantages of neat, fine and smooth, fine elasticity, high strength and correct set printing. It is praised by paper printing circles both at home and abroad. In 1981, It won the state silver medal. The paper mills, which produce typing paper wholly with bamboo, in order to meet the needs of the market, also mix wood or straw pulp up to produce many kinds and grades of typing paper. Fuzhou Cardboard Mill of Guangxi Province, which went into production recently, produces 34 thousand tons of kraft liner board annually. It uses wood pulp to coat surface and quite high yield as base core pulp. It has produced strong kraft liner board. From the above, it shows that reasonable composition ratio is also an important thing to raise the quality for papermaking with non-wood fiber paper pulp. According to the investigations, quite a few of small paper mills are now using completely bamboo pulp in producing kraft paper, so great attention should be paid to it. To improve kraft liner board made with bamboo pulp of imide method, its specialties should be kept on the basis of improving its quality and raising its grades.

2.8.2. The process and equipment of printing and writing paper

At present, mills are using bamboo to make paper mainly producing two kinds of products, that is, printing and writing paper, kraft paper and paper board. Now the technological process and technical equipment of printing and writing paper are introduced as follows.

2.8.2.1. Technical process

The main points of the technical process of daily production of 20-30 tons of 60-100 g/m2 printing and writing paper are:

-- In order to raise the exterior quality, use carefully selected purified pulp material by three stage screening and screw sieve.

-- Adopt surface sizing to improve the property of printing and writing paper.

-- Play attention to the reusing of white water and condensation water to save power, reduce consumption and lighten pollution.

-- Beating and mixing the three kinds of bamboo, wood and straw pulp with disc refiner without before this sequence.

-- Dry damaged paper is broken up with hydraulic breaking machine, and directly sent to the pulp beating room and ground mixedly.

If the two production process mentioned above is carried out normally, and the product quality is not affected. It can simplify the operation and save power. It also avoid to have blocks of unloosening damaged paper. But the big and medium sized paper mills should pay attention to being equipped with refiner and high frequency dissolver for treatment.

2.9.2.2. Main technical equipments

-- Adopt square conical pipe for flow box to let pulp flow through and use porous plate pulp-spreading machine, or biconical multi pipes of flow box. Horizontal fixed quantitative difference is controlled within 1-1.5 g/m2.

-- At present copper net has been gradually replaced by polyester forming net, and equipped with flow roll (dandy roll). It is used for improving the evenness rate of paper and reducing losses.

-- Machine for pressing part is at the speed of below 200 m/min. Press 1 adopts grooved press and needled felt. Paper dryness when entering the cylinder is up to 40% so as to reduce deformation.

-- Machine for drying part, apart from a group of baking cylinder which adopted dry felt, the rest all uses polyester cylinder. It ensures the paper's flatness and reduce power consumption.

-- Give priority to the selection of state-produced microcomputer for the control of fixed quantity of water.

According to the investigations, at present some small paper mills still use cylinder machine or simple fourdrinier machine in production. The equipment level is generally low.

2.8.2.3. The application of advanced technical equipment for papermaking machine

-- 3940 mm long strainer papermaking machine was introduced by Liujiang Paper mill in 1950s. Its original design was to produce 100 tons of newsprint paper per day. But since it was put into production, using bamboo pulp and crop stem pulp with a part of wood pulp to produce topographic printing paper, owing to different kind of factors, the output has been only about 80% of its design. In order to further raise the output and quality, the technical equipment imported from Beloit Corporation in America was transformed. The main points are as follows:

a. Low pulse pulp fan pump, pressurized sieve and pulse attenuator are adopted for upper roll system. As for flow box, narrow poly shape plate is selected in use. It does good for improving paper formation, and evenness, and reducing horizontal rationing waving.

b. Bel-Form folding refiner forming is adopted for the net part. It reduces the two surface difference.

c. Compound press completely blocked up of roll 5 press nip 3 is used for the press part to lead paper. Quite high pressure can make paper moisture reduce, and the wet strength is good. It also reduces the two surface difference of smoothness. Paper breaking is less while it's convenient to operate.

d. The calender is reformed into 4 roll calender which can control both up and down medium and high rolls. Line pressure is quite high and even so as to ensure paper horizontal and compactness, ensure the same thickness and smoothness.

e. Adopt çomputer control for moisture, fixed capacity and thickness.

The formed machine offers output of 140 ton/day of 52 g/m2 offset book and periodical paper. The highest output is up to 160 tons/day. The speed of the machine is at over 560 m/min. Bamboo pulp composition ratio of the paper is 60% or so. The quality is completely up to the ministry standard. Products can not meet the needs of the market and are well welcomed by users.

-- Recently, Changjiang Paper Mill imported a second hand production line from Sweden with of 3100 mm to produce cardboard. Its annual production capacity is 34 thousand ton. It is planned to produce high strength craft cardboard using wood pulp for coating and bamboo pulp for core base pulp. The machine was made in 1950. It has achieved certain characters after transformation for three times from 1971 to 1989.

a. Wet part is formed by cylinder mold with five mould, which is equipped with UMW press forming and a set of vacuum couch press to raise paper dryness.

b. The first part of the press is the double felt vacuum press. The secondary is the chief press. It reduced two presses less than it is designed.

c. The dry part has many kinds of function.

The front dry part is behind the twenty-fourth o/1500 mm dryer, o/4500 mm Yankee dryer and moisture measuring device are installed.

There are 11 dryers at the back dry part. In the middle, a surface sizing press, a scrape stick coating machine, a pre-coating pliability roll, gas cutting coating machine and a infra-red drying device are installed.
The dry parts adopt polyester dry cylinder and ventilation device, it is equipped with dry controller. Power consumption is low.

Calender part is equipped with a five roll calender and a brush calender. Among the rolling machines, a computer control system for moisture fixed thickness is installed.

From the above equipment level, the cardboard machine can be used to produce high coating cardboard. It can be used for reference for the technical transformation of existing cardboard machine in the mills, which have no cardboard machine.

2.9. Alkali recovery from black liquor

Ash content in the bamboo chemical composition and silicon amount in black liquor during pulp making are higher than those of the wood. The effect of getting alkali recovery is a problem which the papermaking circle is pay great attention to. At present, China hasn't got any paper mill which are gets overall alkali recovery from bamboo pulp black liquor. We reclaim these which mixed with black liquor of wood and straw pulp. According to the statistics in recent years, the reclaiming of alkali from bamboo pulp black liquor mixed with wood pulp black liquor was done by Yibin Paper Mill and Changjiang Paper Mill, the recovery rate is 68-78%. The black liquor alkali recovery rate which recovered from bamboo pulp and crop stem pulp by Liujiang Paper Mill is up to over 75%, usually 40-60%. As a whole, alkali recovery level is not high, this involves many factors, such as production scale, equipment level as well as technical management. In this article, we will not discuss the production technique of alkali recovery in all its aspects, mainly introduce the specific property of bamboo pulp black liquor, the measures adopted to lighten silicon interference and the cases of renovation and important of equipment at present.

2.9.1. Characteristics of black liquor

2.9.1.1. Black liquor viscosity

Higher viscosity has great influence on evaporation. When the evaporation concentration is high, black liquor flows poorly, the coefficient of heat conduction and evaporating efficience reduce, its difficult to go on raising black liquor viscosity. According to some relevant information, bamboo pulp black liquor viscosity in papermaking industry of China is not high, so it won't have bad influence on evaporating. But the influence will be great if mixed with other straw pulp black liquor. Usually adopt the methods of increasing heating surface with evaporator and raising black liquor's temperature.

Table 3-14 Black liquor viscosity

	30xC	60xC	90xC
wood pulp	< 50	< 20	<10
bamboo pulp	100	30	15
crop stem pulp	1100	200	50
bagasse pulp	1600	500	102
Chinese alpine rush	4000	750	30

Note: All kinds of pulp, 30x Be'(20xC), black liquor viscosity (unit: gram).

2.9.1.2. Silicon content in black liquor.

High silicon content will make evaporation, burning and causticization difficult. For instance, stain will be remained heavily in evaporated pipe so that evaporating result will be reduced greatly, and even affects salt cake reduction rate and white liquor clarification degree. A lot of work has been done for pulp making alkali recovery from some main raw material since 1960s. From the research for black liquor characteristics, according to 1960s' analysis data, black liquor SiO2 of Sinocalamus affinis pulp contains 0.52% of the total solid contents, which is 0.2-0.3% higher than that of the wood pulp, and 2.3-6.5% SiO2 content lower than other straw pulp black liquor. Again according to the recent years's data, bamboo pulp black liquor SiO2 content is all under 1%. Ph. pubescens pulp black liquor in Jiangxi, Yichun Paper Mill is only 0.3%. The main contents of black liquor from bamboo pulp, wood pulp in some relevant mills are shown as Table 3-16. But if mixing bamboo pulp with straw pulp, SiO2 contents will be over 2%, it will cause silicon interference to alkali recovery. So great attention should be paid to and correspondent method should be adopted too.

Table 3-15. The main contents of black liquor from bamboo and wood pulps (%).

	Yibin Paper Mill			Ya'an Paper Mill	
	bamboo pulp	wood pulp	mixed pulp	bamboo pulp	wood pulp
SiO2				0.77	0.49
C	32.44	36.94	34.88	33	33.66
H	2.7	3.38	2.94	3.89	3.36
S	2.14	2.43	2.37	5.09	4.54
Na	17.17	18.57	18.32	19.1	18.4
Si	0.6	0.3	0.49	0.36	0.23
N	0.21	0.21	0.21	0.31	0.12
O	44.56	37.94	39.99	38.05	39.55

2.9.2. Measures for lightening interference of silicon in black liquor.

Silicon content in black liquor is from impurities coming with raw materials and during the processing, so attention should be paid at the beginning of using raw materials which are delivered into mills. This part is not restated since it has been introduced in bamboo preparation part. Now, let's say something about several problems to which attention should be paid in alkali recovery process of black liquor of bamboo pulp.

2.9.2.1. Strengthen purification process of thin black liquor before sending for evaporation.

This is a useful measure to reduce the dirt formed on evaporator. Now wood pulp mills are also paying attention to alkali recovery from black liquor. For example, Qingzhou Paper Mill adopts two turning drum of black liquor filters connected with wood pulp black liquor filter. In this way, impurities as fines and so on can be removed effectively. It is one of the reasons that this mill has achieved good efficiency in evaporation and the power consumption is low. Its alkali recovery rate, for a long time, keeps at the advanced level of over 90%. So, the purification of black liquor from bamboo pulp should be strengthened before evaporation.

2.9.2.2. Strictly carry out the regular washing system

It can remove the water-soluble and alkaline-soluble dust formed in time. We should not use mechanical brushing to get rid of dusting in case rough surface will be formed on the inside of the pipe wall. I and II are stainless steel pipes. Every year, use acid to remove the dust in pipes once during repair and overhaul for alkali boiler is carried out.

2.9.2.3. As for the black liquor, whose silicon content (SIO_2 1-2 g/e) is not high, alkali is added before evaporation to make SiO_2 in black liquor be in free state completely, the ratio of oxygen sodium and oxygen silicon is within the range of 2-2.5.

2.9.2.4. Attach great importance to the quality of salt cake and ash used as well as the components of liner materials. Making a good use of them is the basic requirement for reducing the dirts of sulphate, carbonate and silicate on the pipe.

2.9.2.5. Reduce the chance of black liquor being in touch with air during the production process. Try one's best to shorten the storage time of black liquor in each container and get rid of mud formed by the black, white liquor's cleaning must be well ensured.

2.9.2.6. If a new kind of bamboo is adopted for pulp making, analysis of black liquor should be made to grasp its characteristics.

Table 3-16 Results of waste water treatment in Chengdu Pulp Mill.

	pH	chromaticity (dilution ratio)	SS (mg/1)	CODcr (mg/1)	BOD5 (mg/1)
first checks times of checking	34	35	19	51	21
waste water					
max. value	10.13	333	1808	3232	901.27
minim. value	8.02	166	172	852.12	334.4
mean value	8.82	252	566	1388	539
treated water					
max. value	7.64	25	63.5	425.6	228.75
minim. value	6.11	14	5.3	124.08	61.49
mean value	6.87	17	18	297	140
second checks times of checking	20	25	20	24	20
waste water					
max. value	8.74	500	1178	1954.53	995.4
minim. value	6.84	250	203	602.81	249.8
mean value	7.64	446	576	1096	478
treated water					
max. value	7.14	33	48	370	159.3
minim. value	6.44	17	4	79.95	30.30
mean value	6.87	25	18	241.95	118
international standard GB8978-88	6-9	50	200	350	150

Table 3-17. Experimental treatment result of wood and bamboo pulp waste water

	national standard GB 8978-88	waste water	treated water	purifying ratio
pH	6-9	9.6	7.2	
chromaticity (dilution ratio)	50	250	8	96.8
SS (mg/L)	200	1380	14	98.98
CODcr (mg/L)	350	1764	292	83.45
BOD5 (mg/L)	150	342	88	74.27

2.9.3. Progress in equipment updating and technological innovation

From the investigation on soda recovery workshops which are newly enlarged and soda recovery technique has been innovated, it is found that advanced foreign equipments have been used selectively.

2.9.3.1. Liujiang Paper Mill introduced plate-type falling-film evaporator produced by Ahlstrom Company and connected it with five-efficiency evaporator formerly used. This kind of equipment has a high heat efficiency. The effective efficiency of heating area is up to 100%. The black liquor consistency is 65%. The evaporator has also some other advantages such as low power consumption, high velocity of black liquor flow so that the formation of dirt is weakened, low stink emission etc. It affords us experiences in reforming present evaporating stations. Ya'an Paper Mill and other newly-built projects introduced pipe-type raising-falling-film evaporating station from Uniteç Company. It is said the consistency after evaporating could reach as high as 55%, heating efficiency is 4.38 kg(water)/kg(vapor) when the efficient black liquor consistency is 15% TS. If black liquor has a high velocity of flow, the formation of dirt could be weakened.

2.9.3.2. On the basis of drawing foreign technique, domestic evaporator ZHZ series which the separator is installed on the upper part were developed. Practice proved that both the heat efficiency and evaporating intensity increase by 25-30% compared with the old type evaporator and the effluent black liquor consistency could reach as high as 50-55%. If a plate-type falling-film evaporator was fixed as densifying device, the consistency of black liquor will raised to over 65%. This equipment leads soda boiler to the direction of deodorant. The 100 cubic meters x 3 plate-type artesian fall-film evaporator and 550 cubic meters falling-film evaporator have been developed in China. They are suitable for treating bamboo and straw pulp black liquor and have good effects.

2.9.3.3. Domestic soda recovery boilers have been improved. According to the properties of bamboo pulp black liquor, soda recovery boilers which have the daily capacity of treating 120 tons, 220 tons of solid material have been developed. This kinds of boilers accompanied with electric duster whose efficiency is over 90% and telescopic type dust blower which is driven by new type double gear rack have been used in large- and medium-scale bamboo pulp mills. Since traditional soda recovery equipments need large funds and are unsuitable for small paper mills whose annual pulp output is less than 10,000 tons, recently, some scientific research and designing institutions, cooperated with paper mills, develop small-size simplified soda recovery equipments using bamboo pulp and straw pulp as raw material mainly and some progress have been made.

2.10. Prevention and control of waste water pollution

2.10.1. Waste water treatment inside mills

Pollution caused by pulping, especially water pollution, have been paid great attention by papermaking industry. China attaches great importance to the prevention and control of pulping waste water and lists it as a key field of environment protection. The Government issued "the stipulation on prevention and control of water pollution in papermaking". It laid down some principles and policies such as: The pulping waste water of existing enterprises should be brought under control combining with technical reform. For newly built enterprises, the control measures and facilities must be designed and constructed simultaneously with those of principal part of project. The production scale of pulping mills should be controlled. The construction of small mills whose production capacity is less than 10,000 tons of chemical pulp should be strictly restricted. In the near future, prevention and control are mainly carried out inside mills with comprehensive planning, integrated control both inside and outside mills.

The main pollution sources in the course of bamboo pulping are: (1) waste liquor in pulping after boiling; (2) waste water from washing, sieving and bleaching and condensed sewage after soda recovery; (3) white water in the course of papermaking. The methods adopted for treating waste water inside mills at present are as follows:

2.10.1.1. Soda recovery workshops have been set up in bamboo pulp paper mills whose annual output is over 10,000 tons using soda method. The method of static electric dust removing has been used so as to lighten environment pollution. Now some research institutions cooperated with paper mills are co-developing black liquor soda recovery equipment which can treat 15-25 tons of bamboo and straw pulps. Some initial achievements have been made.

2.10.1.2. Large-scale bamboo pulp mills which are under construction now adopt the new technology of using 3-stage (O-C/D-Eo-D) bleaching relying mainly on oxygen delignify and dioxide chlorine. Experiments of increasing hydrogen peroxide during the course of routine bleaching were made and the result indicated that this method plays a positive role in lightening pollution.

2.10.1.3. The recovery and use of white water in paper making
The air-float method and multi-disc fibre recovery equipment are adopted. The recovery rate of fibre and filler is 80-90%. The pollution can be lightened by 70-80%. The economic benefit is obvious. Recently, micropore filter are developed which is a kind of new type solid-liquid separator. It has the advantages of high recovery rate, low energy consumption, little investment (about 20% of that of the air-float method) and is suitable for medium- and small-scale mills.

2.10.1.4. Economizing on water

Clean and dirty water in production flows along separate routes. The reasonable seal circulation is adopted. The water can be used repeatedly.

2.10.1.5. Strengthening environment management in working site

Preventing from running, giving off, leaking and unexpected flowing, combining power saving, consumption reducing and civilized production with environment protection management, monitoring, examining pollution resource regularly, putting the environment protection target into post economic responsibility system and reward system.

At present, the basic situation of pollution control is: those mills whose annual outputs are over 10,000 tons of wood, bamboo pulp have installed recovery equipment for soda and white water recovery. Pollution has been lightened, but pollution in small mills is still very serious because small mills are large in number and distributed everywhere.

2.10.2. Waste water treatment outside mills

According to the investigation, there are more than 20 mills which have adopted the method of treating waste water outside mills, most of them adopts biochemical two-grade treatment method ("biochemical method" in short) such as bio-membrane method, active sludge process, air oxidation pond process, which have been used for 20 years. Good results have be reached for removing SS and BoD in waste water. But COD removing rate is quite low. The COD content in waste water goes beyond the drainage standard and the color cannot be cleared away. The main reason is that the waste water treatment with biochemical method can only remove soluble organic matters which can be degraded by microbe, and the removing rate of BOD is some 80%. But for lignin which is not easy to be oxidized, the efficiency of this method is poor. DOD represents all the organic and inorganic matters which can be oxidized by chemical agent, including that can be oxidized or decomposed by microbe. The COD removing rate, with the biochemical method used domestically is 40-50%. At present, the experience of pollution control in Amlai Branch of Indian East Paper Mill (annual output of bamboo pulp is 80,000 tons) shows that "3 kinds of waste water and brown dark dirt water can not be biologically degraded, which include:

-- Washing water from pulp making workshop.

-- Coarse pulp washing waste water.

-- Black liquor drooping, leaking and overflowing from boiling workshop.

-- Washing water in bleaching soda extracting section.

Three-stage treatment is adopted. Decoloring method is to add hypochlorous calcium into waste water. In China, biochemical method together with physico-chemical method are also adopted to treat middle section waste water. COD content and color reach the standard of waste water drainage. But it is difficult for enterprises to bear because of heavy investment and high cost.

In recent years, domestic research institutions test various methods to treat waste water of middle section and reach some breakthrough. For instance, Mr. Li Kaichun, chief engineer from Sichuan Yatai Water Treatment Technical Engineering & Designing Research Institute developed a physico-chemical method and applied it in a project of middle section waste water industrialized treatment of Chengdu Paper Mill. The conclusion of examination meeting organized by Science Committee of Sichuan, Light Industrial General Office, Environmental Protection Bureau and so on is: (1) The result of pulping waste water treatment equipment using physico-chemical coagulating method in Chengdu Paper Mill indicated that the compound concrete agent PPA, flocculator PPM are non-poisonous, high efficiency, low price, easily accessible, without second pollution and good decoloring effect. All the technological and economic indexes reached the desired target. (2) The design and type selection of technology, equipments, electric appliances, computerized automatic control system are reasonable. The process of waste water treatment is simple and advanced. It is easy to operate and the operation is safe and reliable. (3) Treating middle section waste water with physico- chemical coagulating method has the advantages of small area, less investment, low operating cost. Based on the datum from the checking and accepting report, it is suitable for large- and medium-scale paper mills. A brief introduction is as follows:

2.10.2.1. Treatment effect

A continuous monitoring and sampling was organized by Sichuan Province Environmental Protection Science Research Monitoring Institute at working site three time a day in early, middle and late shift respectively. The test data is shown in table 3-17.

In June, 1992, some institutions concerned made an experiment with bleaching sulphate wood and bamboo pulp waste water in middle section in Yibin Paper Mill. The result is shown in table 3-18.

2.10.2.2. Operation features

-- Stirring PPA/PPM compound coagulant with waste water in pipe in high speed, the reaction of sediment and separation is perfect. The removing rate of SS, COD and BOD pollutants in waste water is rather high, and the decoloration effect is obvious. The waste water come to the national drainage standard. Compared with second-grade biochemical treatment method commonly used in China, the need of funds and area can save by 50-60%, the operating cost and operators can reduce by 30-40%, and 50-80% of the treated waste water can be used repeatedly.

-- The treatment effect isn't affected by the sharp change of temperature, flow rate of waste water, SS, COD and BOD. The difference between the maximum and minimum value shown in fig. 3-17 varying from 3-10 times, the ratio of BOD/COD is 0.25-0.38on the average, but good result can be achieved in any case. The operating site is clean and has no foam or bad odor.

-- Operations are controlled by micro-computer and are easy to manage. The equipment was frequently turned on and off, but after one or two hours' adjusting, it can operate normally and the treated waste water can reach the drainage standard. It is very difficult for biochemical method or other methods to suit this.

-- It is introduced that the method is suitable for treating waste water of printing and dyeing, beer producing, water used in urban living and dirty water.

The physico-chemical method for treating waste water in paper making won the Gold Medal of New Technology given by State Science and Technology Committee and the People's Government of Sichuan Province. The physico-chemical coagulating method have been decided to be used in the paper mill construction projects of Yibin, Ya'an, Pengshui, Fujiang. The Yibin Paper Mill is being constructed now. The mill can be put into use within 1993.

3. The situation of bamboo papermaking

3.1. Bamboo pulp output and main products

In early 1950s, bamboo pulp took a large proportion, as high as 8%, in the structure of raw material for machine-made paper in China, in which 33% were come from Sichuan province. Because of various reasons, the percentage had decreased year by year hereafter. In 1970s, the percentage decreased to lower than 2%. Under the guidance of reforming and opening to the outside, the output of bamboo pulp has increased since 1980s. The outputs of bamboo pulp in 1980, 1985, 1988, and 1990 are 85,900 tons, 108,000 tons, 15.2,000tons, over 200,000 tons respectively. Now the output has reached 250,000 tons. Sichuan province takes the largest proportion, about 45% of the total output in China, followed by Hunan, Jiangxi, Guangxi, Guangdong provinces. According to an investigation on 105 bamboo papermaking mills in 8 provinces (regions) in south China, the variety of paper and paperboard products using bamboo pulp only or mixed with wood pulp and straw pulp is about 50. The main products and pulp mixture components are listed in table 3-18.

Table 3-18 Paper made of bamboo and the percentage of bamboo pulp

No.	kinds of paper	fields of use	bamboo pulp %
1	offset printing	scientific publications, illustrations etc.	30-50
2	M G. offset	color pictures, cigarette cases etc.	30-50
3	offset text	textbooks, periodicals etc.	40-50
4	typographic printing	typographic board, books etc.	30-50
5	enamel ground	coated printing	30-40
6	thin typographic printing	academic publications	30-40
7	copy printing	photocopying	30-40
8	cover	covers of publications	30-50
9	map	map printing	30-40
10	writing	forms, accountbook, exercisebook	40-50
11	manifold	typing, carbon and letter papers	40-80
12	glazed	writing, office working and exercises	30-50
13	copying	copying and typing	30-50
14	Chinese classical	brush writing and drawing	70-80
15	kraft	wrapping	30-40
16	glossy kraft	wrapping	80-100
17	laid kraft	wrapping paper for high grade goods	30-50
18	kraft cardboard	cards and bags	30-40
19	bag	bags for cement and fertilizer	20
20	extensible bag	elastic paper bag for cement	40-50
21	neutral wrapping	for goods of acid, soda or chloride	20
22	crepe cable	wrapping paper for outer protecting cover	20
23	explosive rolling	for mining and road-building explosives	40-50
24	bottom layer	bottom layer for making plastic compress	30-40
25	cigarette	for cigarette rolling	20-30
26	paraffin	for liner of cigarette, food wrapping	30-40
27	candy wrapping	for candy	60-80
28	sanitary paper	for toilet	40-50
29	yellow paper	for religions superstition use	80-100
30	blue print	for blue print	30-40
31	kraft cardboard	box packing for shipment goods	50-80

32	ordinary cardboard	for packing general merchandise	30-40
33	high strength corrugated	liner for carton	30-40
34	one-side cardboard	for packaging after color printing	30-40
35	neutral packing cardboard	for wrapping metal goods	80-100
36	fine pile pulp	sanitary towel for women	70-80

3.2. The way of developing bamboo papermaking in Sichuan province

According to the statistic data of early 1980s, the area of bamboo forest in 20 provinces (regions) was 3.308 million ha (49.62 million mu), which in Sichuan was 160.5 thousand ha (2.408 million mu), ranking the sixth place in China. The output of machine-made bamboo pulp in Sichuan in 1985, 1988 are 46.7 thousand tons (43.08% of the total), 77.8 thousand tons (51.02% of the total) respectively. and reached to over 100 thousand tons in 1992. In the period of "Eighth Five-Year Plan", the output of bamboo pulp raised to 180 thousand tons. From 1985-1991, the output increased at a average rate of 9%. It is planned that the output of bamboo pulp will be nearly re-doubled on the basis of 1985. In papermaking industry in Sichuan, not only the output of bamboo pulp increases rapidly, but also the quality of products produced partly with bamboo pulp and the technical equipment level increase.

Investigation indicated that 22 paper mills once produced 48 varieties of products using bamboo pulp only or mixed with wood pulp or straw pulp. The quality of products improved. For example, Changjiang Paper Mill trial-produced elastic bag paper (90g/square meter) with 50% of bamboo pulp mixed with wood pulp successfully. This kind of paper is used to produce 3-layer paper bag for cement package. Compared with 4-layer bags made from ordinary bag paper, it can reduce damage rate and save paper for 15.6%. This products won the second class medal of scientific and technological achievements of Sichuan Province. Using 40% of bamboo pulp mixed with wood pulp and Eulaliopsis binata pulp as raw materials, Chongqing Paper Mill produced offset print paper, which won national silver medal. The kraft paper produced with Bamboo pulp and wood pulp by Yibin Paper Mill won the Light Industry Ministry Export Bronze Medal.

While developing production, the technical equipments have be improved. In the technological innovation project during the "Seventh Five-Year Plan" period, Yibin Paper Mill imported Kamyr 114 t/d bamboo pulp continuous cooking equipment from Sweden, PFW new-type press pulp washing machine from Finland. Filling up oxygen of 3 stages bleach soda treatment. The C-EO-H process was adopted. On the basis of adding machines which can produce 20 thousand tons of elastic paper annually, Yibin Paper Mill imported from Sweden a second hand papermaking production line which can coat and brush 34,000 tons of paperboard annually. The key equipment part reaches the level of 1970s or 1980s in the world.

It is planned to use it to produce strong kraft paperboard for carton with bamboo pulp mainly and 25% of wood pulp on the outside face. This product is a substitute for imported one. Ya'an Pulping Mill, which is in construction, has a annual pulp production capacity of 55,000 tons, in which bamboo pulp 38,000 tons. The short 3-stage bleaching technical equipment with oxygen delignify, and chlorate dioxide as the main agents has been imported. This O-C/D-EO-D technological process has the level of 1980s in the world. With this production line, it is planned to produce 88-90 degree GE high whiteness commodity bamboo pulp and wood pulp.

Sichuan Province has made great progress in developing bamboo pulp papermaking. The main way is as follows:

3.2.1. Investigating bamboo resources and making a overall plan

From 1950s to 1980s, the working group organized by papermaking- concerned institutions at all levels and enterprises investigated for 8 times on bamboo resources used as the raw material of papermaking in 50 counties and townships. In 1953, a bamboo forest investigating team investigated the key bamboo-producing area along Minjiang River, Qingyijiang River and Changning River, Yongning River Chishui River. While investigating the bamboo resources, distribution, characteristics and environmental conditions of bamboo were studied. The key area of developing bamboo forest was determined. After 3 resource investigations, a basis was provided for decision-making of planning raw material structure, production plan, production scale of Yibin, Zhongyuan (now Changjiang Paper Mill) and Chongqing paper mills. The use of bamboo was expanded. In 1957, the ratio of bamboo pulp in the structure of raw materials for papermaking is as high as 33.3%. Meeting the need of reforming and opening to the outside, on Dec. 7, 1985, Jiang Minkuan, governor of Sichuan province held a discussion meeting on developing and utilizing bamboo resources in Yibin area and all Sichuan. The Scientific and Technological Committee of Sichuan Province promptly organized to work out "Research on the future and way for developing and utilizing bamboo resources in Sichuan". Up to 1985, it was found out that the area of economic bamboo forest was 340 thousand ha (5.1 million mu) in Sichuan, the stock volume and annual increment were 144.3 thousand tons and 3.75 million tons respectively.

According to a instruction given by the State Planning Committee about the comprehensive developing and utilizing of bamboo resources in the lower reaches of Jinshajiang River, an investigation on bamboo resources of 23 counties, cities in south Sichuan and east Yunnan was made from 1988-1989. The result indicated that the area of bamboo forest there is 82,500 ha, the stock volume is 4.525 million tons. It is planned that 70,000 ha of bamboo forest will be planted by 2000, which can lay a solid foundation for making bamboo pulp paper in Yibin area.

3.2.2. Giving priority to science and technology and strengthening test and research of bamboo pulp.

From 1950s on, especially from 1980s, research institutions concerned and some large- and medium-scale paper mills have made many researches and tests on bamboo pulping and papermaking. Systematic test and analysis were made on ingredients, fibre structure, mechanisms and technologies of cooking, bleaching, beating and papermaking for bamboos different in variety and age. Experiences are summed up and accumulated. Some results are: "The basic characters of major bamboo species, bamboo ages in Sichuan and their pulping property" , "Bamboo culm structure and its pulping technology", "Selection of bamboo fine species for elastic bag paper making and pulping technological test" published by Sichuan Research Institute of Papermaking. Besides, some reports were put forward for to producing high whiteness bamboo pulp in newly built and enlarged Ya'an Pulp Mill and Yuzhou Pulp Mill; Some 20 foreign technical papers were translated, a "Selected Translations about bamboo pulping" was published. Many academic thesis and experiences were introduced in "Sichuan Papermaking". Recently, Changjiang Paper Mill cooperated with Sichuan Research Institute of Forestry, Sichuan Research Institute of Papermaking have made some experiments on breeding and pulping of fast- growing and high-yielding bamboo species. The initial achievement has been made.

3.2.3. Formulating policies and countermeasures, bring every positive factor into play

In recent year, based on forest law, local authorities concerned and forestry department formulated some local policies and countermeasures in the light of local conditions.

3.2.3.1. Who develops and funds, who manage and benefit from it.

Based on the principle of maintaining the existing system, keeping channels in order, being cooperated closely, all-round developing, mutual benefiting and each in his proper place, mobilizing state owned forest farms, enterprises, collectives and individuals to plant bamboos.

3.2.3.2. Further stabilizing family contract system and forestry policies, adopting elastic and various contract management systems, bring farmers' positive factors into play, allowing and encouraging farmers to afforest bamboo forest on unoccupied land, supporting them with funds, combining afforestation with improving ecological environment. Now bamboo forest are standing along Changning River and Yuexi River beaches.

3.2.3.3. Supporting bamboo consumers to establish their own bamboo bases

In 1984, State and provincial authorities concerned made a decision that both Yibin Paper Mill and Changjiang Paper Mill could draw 12 yuan (18 yuan now) of cultivating forest fund from every ton of air-dried bamboo strip consumed. Up to now, 10,000 ha of bamboo forest have been established by the two paper mills as their own bamboo bases. These bases will be expanded to 20,000 ha by 2000. On the basis of 6,667 ha of bamboo forests, Qionglai Paper Company established 13 bamboo base townships. Both the base and seller share cultivating funds. In recent years, 2,333 ha of bamboo forest has been newly established and low-yielding bamboo forest was improved. In the past, farmers sold 3,000-5,000tons of bamboo each year, but now, they sold 50,000 tons of bamboo each year. The farmers' income from selling bamboo increased to 6 million yuan. The annual output of paper and paperboard are over 20,000 tons and it is planned to raise it to 40,000 tons in the near future.

2.3. Economic benefit and social benefit

Bamboo is a kind of raw materials with middle length fibre. There are many ripe experiences in using it for papermaking. In those countries which is rich in bamboo resources but poor in wood resources, a feasible way to remedy wood shortage is to make use of bamboo in paper making. India, with 100% of bamboo pulp, has produced kraft paper, elastic multi-layer bag paper, high-quality writing and printing paper successfully. It is obvious that bamboo papermaking has economic and social benefits.

3.3.1. Saving wood and reducing production cost

Based on statistic data, 2.8 tons of air-dried bamboo will be consumed in producing 1 ton of leached sulphate bamboo pulp, while 5.5 cubic meters of Pinus massoniana will be consumed in producing 1 ton of bleached wood pulp. The current price of air- dried bamboo is about 350 yuan/ton which nearly equals to that of 1 cubic meters of Pinus massoniana. Estimated from the datum, it can seen that producing 1 ton of bamboo pulp can save 5 cubic meters of wood and reduce some 800 yuan of raw material cost.

Adopting new technology, some products will have even better technical and economic benefits. For instance, using 3-layer 90 g/square meter paper bag made of elastic bag paper produced by 50% bamboo pulp and wood pulp to package cement will reduce damage rate by half or two third compared with that using 4-layer 80 g/square meter ordinary bag paper. By increasing bamboo pulp ratio, producing 1 ton of paper can save 2.2 cubic meters of wood and reduce cost 350 yuan of cost. The reduce of paper layers can cut down paper consumption by 15.6%. The economic benefit is perfectly good.

3.3.2. Increasing the value of processed bamboo

The price of raw bamboo is rather low in producing area. One ton of air-dried bamboo is about 240 yuan only. Using it in papermaking, the value can increase by 3-5 times. Now the annual output of bamboo pulp is 250,000 tons. Counting at the price of 2,800 yuan/ton, the total output value is 700 million yuan. The value of 700,000 tons of bamboo strips worth 168 million yuan. The value increases by over 4 times. If it is made into middle- or high-grade paper or paperboard, the output value will be even higher.

3.3.3. Increasing farmer's income

40% of the bamboo mentioned above belongs to the state, the rest belongs to farmers. So the annual income of bamboo farmers can be increased by 100 million yuan.

3.3.4. Providing forest funds and revenue tax for China

The annual consumption of air-dried bamboo strips is 700,000 tons. According to the statistic of purchasing data in Yibin, Sichuan province, these products can provide 30.8 thousand yuan for cultivating funds and regeneration and stand improvement funds (12% of the raw bamboo price) and can provide 20 million yuan for forest special product tax and product tax (8.5% of the raw bamboo price). Bamboo pulp processed into paper or paperboard, value-increase tax (12%) should be paid. Together with this, the total amount of tax is 84 million yuan/year.

3.3.5. Eco-environmental benefit

Pulping and papermaking with bamboo as raw material have good economic benefit and social benefit, and may promote enterprises, collectives and individuals to develop bamboo forest. In recent years, 3,500 ha of bamboo forest is newly afforested annually in Yibin, Sichuan province. Bamboo grows fast and could be put into use within 3-5 years. We should cut the old one and remain the new one, harvest volume will never exceed the increment. The bamboo forest can be sustainablly utilized and the soil erosion can be avoided from.

3.4. Product selling and market prospect

A small part of bamboo pulp is used for making all-bamboo pulp kraft paper and carton paperboard, while most of bamboo pulp is mixed with wood pulp and straw pulp to produce various paper and paperboard. Based on a initial estimation, there is about 1 million ton of paper and paperboard which uses bamboo pulp as raw material. It makes up only 5.8% of the total output of paper and paperboard. The bamboo pulp fibre is better in quality than straw pulp and lower in production cost than wood pulp. Reducing straw pulp ratio and increase bamboo pulp ratio, the quality of writing paper and printing paper can be improved. Using bamboo pulp as the substitute for part of wood pulp, the production cost of packaging paper and paperboard can be reduced and they will be more competitive in market. Liujiang Paper Mill produces 140 tons of offset printing paper each day, the bamboo pulp ratio has been raised to 50-60%. The products are of good quality and sells well in market. Even the substandard products were sold out. According to statistics on paper enterprises in southwest China, the production and marketing of several main products which use bamboo pulp as part of raw material, such as offset printing paper and enamel paper made in Chongqing Paper Mill, offset printing paper made in Mianzhu Paper Mill, printing paper made in Wanyuan Paper Mill, kraft carton paperboard made in Liangping Paper Mill and Laishan Paper Mill, are equivalent basically. The demand for some products even exceeds the supply.

Paper and paperboard have many uses. Their production is closely related to culture, education, commodity circulation, information transmitting, industries, technology and daily life. The consumption of paper will increase along with the development of national economy, raise of people' living standard and increase of population. From 1979 on, China has been the fourth place in paper production, followed after U.S.A., Japan and Canada. The annual outputs of paper and paperboard in 1991 and 1992 are 14.78 million tons and 17.25 million tons respectively. But since China has a large population, the consumption per capita is only one third of the world mean level which is 44.6 kg per capita. In the recent years, a large amount of paper and paperboard has been imported continuously to meet domestic demand. It is said that 710 thousand ton of high-strength kraft paper and paperboard, 430 thousand ton of high-grade coating paper and paperboard were imported in 1992.

An important feature of rapid development of paper industry in developed countries is that the products structure tends to high quality, i.e. turning from high energy consumption, high material consumption to low energy consumption and low material consumption, raising product additional value and leading products to the directions of deep processing, high technology, high quality and high grade.

The above shows that the middle- and high-grade printing and writing paper, high-strength kraft paper, carton paperboard, high-quality coating paper and white paperboard, which are produced partly with bamboo pulp, have a swimming market. High- quality and low price are needed in competition. In the light of characteristics of bamboo pulp fiber, the mixture ratio should be rationalized, products structure be adjusted and optimized, products grade be raised. It is not adaptable to produce low-quality complete bamboo pulp kraft paper any longer.

4. Prospect of development

4.1. Favorable conditions for developing bamboo papermaking

4.1.1. Rich bamboo resources

China is rich in bamboo resources. A large area, ranging from 92 degree to 122 degree E longitude and from 18 degree to 35 degree N latitude, is suitable for bamboo growth. Based on the latest statistic data, the total area of bamboo forest in China is 3.6667 million ha (55 million mu), the stock volume is 75 million tons (fresh bamboo), in which 5 million tons of bamboo can be provided for papermaking. Now the consumption amount of bamboo for papermaking is about 1 million tons. So there is rich resources for increasing papermaking production.

4.1.2. Great developmental potential

At present, India ranks the first place in using bamboo as the raw material for papermaking. The proportion of bamboo in the raw materials is as high as 32%. So in those countries, which is rich in bamboo resources but poor in forest, using bamboo to remedy the shortage of woody raw material is feasible. China has as much bamboo forest, stock volume and increment as India, but has a long way to go in increasing bamboo pulp production capacity. This shows that China has great potentialities of using bamboo in papermaking. Table 3-20 shows the pulp production capacity of main countries and their proportions in total production capacity in the world.

Table 3-19 Production of some countries and the percentage of the world total

country	1985		1987		1990	
	capacity 0.01 M.T.	percentage %	capacity 0.01 M.T.	percentage %	capacity 0.01 M.T.	percentage %
India	120.0	76.3	130.0	73.2	130.0	71.5
China	17.5	11.1	21.0	11.8	25.2	13.9
Brazil	5.5	3.5	5.5	3.1	5.5	3.0
Pakistan	3.5	2.2	9.5	5.3	9.5	5.2
Viet-Nam	4.7	2.3	5.3	3.0	5.3	2.9
Bengal	3.0	1.9	3.3	1.9	3.1	1.8
Burma	1.8	1.1	1.8	1.0	1.8	1.0
Indonesia	1.1	0.7	1.1	0.6	1.1	0.5
Total	157.1	100	177.5	100	181.5	100

Note: From "Collected thesis of American TAPPI Public Lecture." International Paper Industrial Exhibition in Shanghai.

4.1.3. Fast growing and short rotation

Bamboo is a kind of fast-growing plant fiber resources. Bamboo grows quickly and the growth period is short and needn't to be transplanted. 3-5 years after planting, some bamboo species, such as Sin. affinis and Den. membranaceus, can grow into useful bamboo timber. Bamboos are good in regrowth ability. Cutting the old one and remaining the new one, they can be sustainablly used. It is said that fine bamboo species can produce fiber raw material five times more than that of coniferous trees per unit area. Afforesting bamboo forest in the area of 1 square km, it needs only 6 years to obtain raw material for 4,000 tons of pulp. If planting coniferous species or fast-growing poplar, 20 years or 10 years are needed. Taking developing cultivation into account, to use bamboo in papermaking industry has quite a superior significance.

4.1.4. Good technological basis

In the respect of using bamboo in papermaking, there is large numbers of specialists engaged in education, scientific and technological research, production and management in China. From 1950s to 1970s, China helped tow paper mills in Vietnam and Myanma to undertake all the survey, design, installation, technical training and trial-production. Recently, in accordance with the development of bamboo pulping and papermaking, foreign equipments for bamboo raw material preparation, cooking, bleaching were imported which laid a foundation for producing high- quality and high whiteness bamboo pulp.

4.2. Attentions have been paid to developing papermaking with bamboo

On a national symposium on moso bamboo held in Sichuan province on Nov. 11, 1983, specialists suggested: "devoting major efforts to develop middle- and long-fiber raw materials, taking bamboo as substitute for wood so as to remedy the shortage of woody raw materials in papermaking industry". The suggestion was adopted by the authorities concerned. Hereafter, the development and utilization of bamboo was strengthened. Bamboo was widely used as raw material for papermaking in many paper mills. According to incomplete statistics, from 1990-1995, the construction projects of pulp mills, whose annual pulp production capacities are over 30,000 tons, are Yibin Paper Mill, Changjiang Paper Mill, and Ya'an Paper Mills in Sichuan province, Puxin Paper Mills in Hubei province, Fuzhou Paperboard Mills in Jiangxi province, Guangning Paper Mills in Guangdong province, Shaowu Pulp Mills in Fujian province. Those projects in preparatory stage are: Yuzhou Paper Mill in Sichuan province and Yichun Paper Mill in Jiangxi province. Other medium- and small-scale paper mills increased output of bamboo pulp in line with local conditions. It is estimated that the production capacity of bamboo pulping and papermaking will increase remarkably.

4.3. Suggestions

Although China is rich in bamboo resources, it is necessary to exploit them reasonably and increase production benefits from the viewpoint of long-term development. It is suggested that:

4.3.1. Improving low-yield bamboo forests and strengthening the construction of raw material bases.

The production capacity of various bamboo stands differs greatly due to different site conditions and different management measures.

The main reasons are over-exploitation and unreasonable cutting, and that the old stumps have not been removed for a long time. Close attention should be paid to the remaking of low-yield bamboo forests, because it involves little investment while returns a brisk profit. Meanwhile the big- and medium-sized paper mills must attach great importance to the construction of source of raw materials, to meet the demand in bamboo reliably. As an example, Shaowu Bamboo Pulp Mill has planned to plant 36 thousand ha of bamboo stands in the period 1990 - 1994.

4.3.2. Selecting fine bamboo species.

According to materials from Taiwan Province, seven bamboo species were used for pulping experiment, some species provided fibre of greater length, the coarse pulp of high strength and the tearing rate exceeded that of imported pulp from coniferous tree species. The data are showed in table 3-22, 3-21.

Table 3-20 Fibre features of 3 bamboo species

bamboo species	length avr.	width avr.	ash	lignin	cellulose
D. latiflorus	3.088 mm.	37	2.82%	24.16%	50.94%
B. dolichoclada	3.112 mm.	30	1.19%	22.03%	49.66%
Ph. glauca	2.94 mm.	27	1.82%	21.36%	45.52%

Table 3-21 Features of different kinds of pulp

kind of pulp	hardness K	quantity g	tear. length Km	break. rate	tear strength
D. latiflorus	17.57	58.58	7.49	66.94	188.73
B. dolichoclada	19.54	59.15	8.13	74.95	190.31
Ph. glauca	19.05	57.22	7.9	73.18	311.92
Canadian wood pulp		59.12	8.58	78.75	141.11

Notes: steaming conditions: Alkali rate: Na2 0.19%. Sulphidity: 25%. Hyperthermal process: 2:00. Temperature maintained: 160 degrees C. Percentage of coarse pulp: 44 - 48%.

It is reported that the mean fiber length of some Philippines' bamboo species is 3.78 mm. After cooking, the tear factor of 65 g/square meter kraft paper is between 185-217, better than those of 80 g/square meter bag paper produced with coniferous pulp. It is suggested that authorities concerned should introduce these fine bamboo species and cultivate them in line with the local condition. At the same time, great attention should be paid to develop local fine bamboo species and enlarge cultivation area.

4.3.3. Paying attention to developing papermaking from eucalypt

Although bamboo is a kind of good raw materials for papermaking, the characteristics of fiber and structure will influence expanding species use and raising technical and economic benefits to some extent. For this reason, accompanied with developing bamboo papermaking, the southern provinces and regions should take the experiences of Brazil, Australia and Spain in developing papermaking industry as reference, pay great attention to using eucalypt which is fast-growing and can be put into use within 7-10 years. Although the fiber of eucalypt is short, but it is even and contains low ash and disorder cell content. The lignin in it is lower than that in coniferous trees and bamboo. Bleached eucalypt sulfate pulp has the characteristics of soft thickness and high opacity, and is suitable for producing various kinds of high-grade printing paper, writing paper and other papers used in daily life. The strength of pulp is good. It can replace part of pine pulp in producing kraft paper and high-strength paperboard. Eucalypt pulp is also suitable for high yield pulping such as NSSC (Neutral Sodium Sulphite Process) and CTMP (Chemi- Thermo-Mechanical Pulping). It is reported that the BSCP eucalypt pulp bleached with hydrogen peroxide was developed. The yield rate is 80-82%, and the whiteness is as high as 80% ISO. These characters are incomparable with other raw materials such as bamboo, reed or wheat straw. The fast-growing eucalypt species have been planted in south China. To develop eucalypt pulp and mix it with bamboo pulp in a reasonable ratio, the use of new eucalypt species can be expanded and developed. Better technical and economic benefits can be achieved.

Table 3-22. Quality property of printing paper by eucalyptus CTMP abroad.

index list	unbleached pulp	bleaching pulp
freeness mlCSF	84	86
density kg/m3	442	522
tensile index Nm/g	47.1	50.7
tear index mN.m2/g	4.5	6.1
scattering system m2/kg	45	42
brightness % ISO	53	80.5
opacity %	95.0	79.5

4.3.4. Strengthening the research on technical equipments introduced

In recent years, China has imported some advanced technological equipments for bamboo raw material preparing, cooking, bleaching and papermaking. It is suggested that the department concerned should pay attention to assimilation of these new technologies and equipments, sum up experiences, make these equipments into full use and stop acting blindly in importing technology and equipment. Meanwhile, advanced technology and equipment series in line with China's condition should be developed.

PART IV. BAMBOO WARES

Bamboo wares are extremely rich and colorful in China.

The making of bamboo wares can be traced back to thousands of years ago. As a result of diversification during such a long period of time, bamboo wares can be roughly divided into three groups: bamboo weaving, bamboo carving and bamboo articles of every day use.

1. Bamboo weaving

Bamboo woven products are made of bamboo threads and strips.

The art and craft reflect the features and thinking of the age, and also directly express the life style of society. The bamboo weaving art is early originated, it dates from the New Stone Age, some 5 or 6 thousand years ago. On the pottery of Banpo and Miaodigou relics, most of the weaving mat veins engraved, were bamboo weaving, willow and straw weavings. The woven articles in ancient times were used in every day life, they they were created much earlier than pottery. However, due to obvious reasons it was difficult to preserve them. In recent years, in Qianshandang of Zhejiang ruins (5300-4200 years) a lot of bamboo weaving relics were unearthed, among two hundred and more peices of weaving relics their were bamboo baskets, grain baskets, dustpan, mats as well as tools for silkworm breeding and fishing.

In Shang Dynasty (1600-1028 D. C.), the patterns of bamboo and rattan weaving were even more diversified. On the surface of pottery, corrugation, circle vein, metric vein and square veins as well as variety of patterns were found. In pace with the development of history, the scope of bamboo utilization was gradually expanding. When it came to Warring States (475-221 D. C.) people recorded history on bamboo splits, and they took bow and arrow made of bamboo as important weapon. Bamboo weaving was gradually improved. At that time, the weaving technique of Chu country (Zhu Dynasty) reached quite high level. In Warring States, people began to make iron wares, which played an important role in further improvement of weaving technology. In Jianglingwang Hill of Hubei, a weaving box lid in No. 1 tomb was found, the split was 0.1 cm wide, 0.01 cm thick and covered with red and black lacquer, the red paint was as background, the black split was woven into rectangle pattern, it looked like today's brocade pattern. A short stick bamboo fan was unearthed from No. 1 tomb of Jiangling Ma Hill in Hubei, it was covered with red and black color, the weaving was also of rectangle vein, the fan face was ladder-shaped, no rectangle holes near the side of stick, wide and thick bamboo strips were clipped along the sides, the grain was very tidy. In Qin and Han Dynasties (221-220 D. C.), the weaving craft was developed on the base of Chu

Country during the Warring States, the skill was similar to that of the Warring State.

In the beginning of Song Dynasty, weaving lantern were very popular in Lantern Festival, the weaving crafts were very fine in Fujian, Zhejiang, Jiangsu, Sichuan and Guangdong provinces. According to the record of Song Dynasty, Yangzhou Wan mat, Suzhong mat, Changzhou dragon and phoenix thin mat, Fuzhou Diao mat, Wenshou shred lantern and Yuanzhou shoes enjoyed high reputation.

When it came to Ming and Qing dynasties, bamboo weaving craft of south China was widely developed. The folk weaving artists continuously increased. The type of bamboo wares diversified, and weaving skill improved greatly, from stitching weaving to monofilament cross. Kinds of calligraphy and patterns can also be weaved. Some 120 shreds could be cut out from one bamboo culm. On the surface of bamboo woven articles propitious pictures could be drawn with gold lacquer and single lines.

Weaving process: material selection -- raw material treatment -- weaving -- assemble and decoration -- package -- storage

The main points of weaving technique are as follows:

1.1. Material selection: Bamboo material is tough, flexible, straight, pressure-resistant, tension-resistant and corrosion-resistant. However, culms of different bamboo species, or of the same species of different age, or under different site conditions have different mechanical strength. So, proper material for certain bamboo woven products should be selected in accordance with the design requirement. In recent years, the main bamboo species used for bamboo weaving are:

1.1.1. Sinocalamus affinis (Rendle Keng f.): Tissue dense, durface fine and smooth, fragmented easily, bright yellow, suitable for producing thin strips and making high quality goods.

1.1.2. Phyllostachys heterocycla (Carr. Mitf. var. pubescens (Mazel) ohwi): Tissue tough and tensile, grain straight, elastic, shrinkage insignificant, fragmented easily, culms with flat nodes and thin wall used for weaving.

1.1.3. Phyllostachys congesta Rendle: Culm wall thin, tough and tensile, soft and wearproof, with fine veins and flat nodes, suitable for making middle grade goods.

1.1.4. Bambusa distegie: Internodes long, nodes flat, tissue tough, shrinkage insignificant, suitable for producing fine strips and making fine goods.

1.1.5. Phyllostachys henonis Mitf: Culm straight, tissue not very tough, fragile and breaks easily, mostly used for making middle and low grade goods or articles for every day use.

1.1.6. Phyllostachys praecox c. P. Chuet c. s. Chao: Internodes long, culm wall slightly thin, grains straight, fragmented easily, suitable for producing extra fine shreads and making woven handicraft.

Ideal site conditions for growing bamboo plants for making bamboo wares: sunny hill slope, soil of comparative poor fertility.

Proper age for cutting: 2-4 years for Phyllostachys pubescens, 1-2 years for Sinocalamus affinis, Phyllostachys congesta, Bambusa distegie, Phyllostachys henonis and Phyllostachys praecox.

Culms should be straight, free of mechanical damage, · insect damage and diesease, be cut in cloudy days in summer, strong sun shine should be avoided. The cullm skin should not be damaged while cutting and transporting.

1.2. Raw material treatment: A very important process which affects the quality of final goods. The operations of treatment are as follows:

1.2.1. Remove waxy epidermis and nodal flange: The waxy epidermis and nodal flange should removed from culm surface timely, preferable in the same day of cutting, which guarantees the brightness and smoothness of culms. At first remove the nodal flange, and then fix culms on a frame, remove waxy epidermis with a sharp knife quickly, slightly and evenly, without any damage to the surface appearance.

1.1.2. Dissect bamboo culms: This operation can be carried out manually or on a machine. The culms should be vertically splited into two equal parts, close attention should be paid mainly to the smooth pass of nodes through the edge of knife.

1.2.3. Drying: Dissected bamboo parts should be put on frames in open air to be dried under the sun with skin side upward. The air-drying process continues until the bamboo skin turns slight yellow or yellowish white. The bamboo parts should not be exposed to the rain for retaining the natural beauty of bamboo surface.

1.2.4. Produce bamboo strips and threads: Split bamboo parts vertically along the radius of the cross section into bamboo bars. Split bamboo bars vertically along the chord of cross section into bamboo strips. Cut bamboo strips into bamboo threads according to the requirements of the final products. All the bamboo strips should be of same width and same thickness.

1.3. Weaving: Bamboo weven goods are made of bamboo strips or threads by interlacing them in different directions. while bamboo mats, curtains are made of bamboo strips.

1.3.1. Bamboo thread weaving method is mostly used for making such articles as baskets, boxes, bottles, jars, dolls. All these goods are being woven from their bottom part, after the bottom is finished, the weaving goes on spirally.

1.3.2. Bamboo strip weaving is used for making bamboo mats and curtains. This kind of goods is usually woven from the middle to borders and corners.

1.3.3. Lock stich. This is a very important operation in weaving. All kinds of woven goods can not be finished without locking stich.

1.3.4. Assemble and finish. This is the last operation of bamboo weaving. All the woven parts are assembled together and painted.

2. Bamboo carving

Bamboo carving art was first developed in Han Dynasty (before 206-220 D. C.), however, from lack of historical records, the carving art at that time could not be fully understood. The earliest bamboo craft which we have seen is a piece of colored lacquer bamboo spoon stick with dragon vein unearthed from No. 1 Han tomb, in Mawangdui, Changsha, Hunan Province, it demonstrated that bamboo carving art had achieved quite high level at that time. Later, the special making of carving art was graduly accumulated, according to legend in Jin Dynasty (265-420 D. C.), calligrapher Wang X. Z had a very exquisite Phyllostachys bambusoides pen container, he named it as "Qiuzhong". In the Six Dynastries, Qi G. Z. presented a shoot sheath crown made of bamboo root to Ming Z. S., it is thus evident that root carving art already appeared at that time.

When it came to Tang and Song dynasties (618-1279 D. C.) the carving art became more mature and fine. According to Guo R. X. of Song Dynasty, a high ranking official's family kept a writing brush, on its bamboo tube were carved lineal drawings with a poem, all the persons and horses were expressed very clearly and vividly. At that time, "green retained carving" skill also appeared. According to Tai Zongyi of Yuan Dynasty recorded, bamboo bridge carving by Zhancheng of Song Dynasty was warmly praised, grand palaces, high mountains and great river, flowers and birds were all carved on a single bamboo strip.

Ming Dynasty (1368-1644 D. C.) was a golden age for the development of bamboo carving, most of the bamboo carving masters were mainly concentrated at that time in south bamboo producing areas, such as Suzhou, Shanghai, Zhejiang, Sichuan, Hunan and Fujian. When it cane to mid of Ming dynasty, carving became a special craft. Due to the different art style, variety of schools have been formed in different areas, artistic distinction coming forth in large numbers, and was flourishing at an unprecedented level. The most famous work were from Jiading school and Jinling shool. The founder of Jiading school, Zhu Songling, his son Zhu Xiaosong, grandson Zhu Sansong, created so many excellent carving pieces in their life, that they were called "Jianding three Zhu." The masters of the same style were Zou Yijue and Shen Dasheng. They were all of Jiading school. Being good at deep and full carving, Zhu Songling was also good at poem and drawing with high artistically accomplishment. His relief sculpture "Chinese flower crab apple" on a pen container is kept in Beijing Palace Museum. Another of his masterpiece, a box with carving "Pine Crane" is kept in Jiangsu Museum. Zhu 's outstanding skill is fully expressed in these works. He is famous for his figures of Buddha carving, his bamboo carving box is kept in Beijing Palace Museum, and it is made of natural bamboo root. The works of bamboo carving by Zhu family were regarded as valuable as those made of jowels and jades at that time.

The master was Pu Zhongqian of Jinling school, he is good at bamboo carving with water mill, such as ribs of fan and pen container. His pine kettle of bamboo root carving is kept in Palace Museum.

In the beginning of Qing Dynasty, the first high skilled master was Wu Zhifan. His contribution to bamboo carving art is praised by the artists up to now. His works "Old Man under the Pine" on a piece of bamboo is kept in Shanghai Museum. In Qing Dynasty, there were several producing areas, such as Shaoyang of Hunan Province, Hangyan of Zhejing Province, Jiangan of Sichuan Province. The material for bamboo carving was very strictly selected, the workmanship was raised to a new level, the figures were thin and vivid, the color and brightness were as fine as ivory.

Bamboo carving can be divided into two groups: one is of ornamental arts, the other is carved articles of every use, such as carved container, carved fan and writing brush.

2.1. The operations are as follows: design --> raw material selection --> treatment --> modelling --> carving --> finishing --> package --> storage

2.2. Carving methods.

2.2.1. Line carving. It is carried out on flat surface of articles, such as pen-holders, boxes and screens, expressing Chinese characters, figures, birds, flowers and landscapes.

2.2.2. Relief sculpture. This is a kind of carving in which the image stands out from the surface of bamboo articles, in accordance with the approximation of image to the objects depicted the relief sculpture can be divided into low relief, mid relief and high relief sculpture.

2.2.3. Hollow out. Certain parts of carved images are hollowed out, which makes the carving more vivid.

2.2.4. Entirety carving. A whole piece of bamboo material is carved for making certain articles, such as a doll, a miniature animal. It is most important to select bamboo material of proper shape for entirety carving. The natural shape of bamboo material helps artists to create great sculpture.

2.2.5. Cuticle removing. Drawings are expressed on the flat surface of bamboo articles by means of removing cutilce from certain parts of the drawings.

2.2.6. Carving on bamboo surface layer of certain articles. Inner part of bamboo culms is segmented, softened, flatened, smoothed and glued to certain articles as a surface layer, and the carving is carried out on this bamboo surface layer.

2.3. Main points of carving process

2.3.1. Material selection. Excellent Phyllostachys pubescens culms should be selected as raw material for carving. Culm quality affects the quality of final goods directly. While selecting material close attention should be paid to the age, size and shape of culms, the selected culms should be free of damages and be cut in the period from November to January. The moisture content of culms cut in this period is low, which benefits their storage. It is desirable that the culms for carving be taken from sunny slopes with comparatively poor soil. They should be 6-7 years old, which guarantees high quality of final goods.

2.3.2. Raw material treatment.

2.3.2.1. Drying and antiseptic treatment

The physico-mechanical properties of bamboo material and the quality of final goods are directly affected by the water content of raw material. The water content of fresh bamboo culm is some 60%. The culms should be cut into pieces of size according to the size of final products. Put the bamboo pieces vertically in ventilative shade, avoiding direct sunshine. Remove the bamboo green cuticle from the surface, then treat with chamicals to prevent the damage of fungus and borer.

2.3.2.2. Green color conservation

Bamboo culm possesses a very attractive green skin, people are fascinated by this outstanding characteristics. In addition, due to the excellent flexibility and machining properties of bamboo, it is widely used as materials for construction, furniture, art and crafts. However, after harvesting the green colored skin of bamboo turns to yellow, grey or other colors and beset by insect pests or decays which reduce its uses and permanence.

Development of appropriate methods to achieve conservation of the green colored skin of bamboo is expected to encourage bamboo industry to explore its potential utilization and increase the economic value of bamboo products. Prof. Chang Shangtzen studied the methods for conserving the original green of Phyllostachys pubescens and at the same time enhance its durability.

In order to achieve the green color conservation of bamboo skin, three types of inorganic salts including chromates (acid copper chromate and Boliden K-33), nickel salts (nickel nitrate, nickel sulfate and nickel acetate) and copper salts (copper sulfate and copper acetate) were employed as protectors. The concentration of each chemical preparation was 0.5%, 1%, 2% and 4%. Before the treatment with inorganic salts, bamboo specimens were pretrated with appropriate alkali solution in irder to remove the wax layer of its outer skin. The conclustion of his study is as follows:

-- Alkali pretreatment was a prerequisite to achieve green color conservation of Phyllostachys pubescens before treating with inorganic salts.

-- The green color conservation of Phyllostachys pubescens obtained by treating with inorganic salts was better with increasing solution concentration or longer treatment time.

-- Among the inorganic salts examined, nickel nitrate, Boliden K -33 and copper sulfate offered better green color conservation of Phyllostachys pubescens skin.

-- The brightness and chroma of Phyllostachys pubescens skin could be improved by consecutively treating with nickel nitrate (or copper sulfate) and then with Boliden K -33. The best green color conservation is obtained by treating with a mixed solution of nickel nitrate and copper sulfate.

-- Phyllostachys pubescens treated with Boliden K-33 possessed the best green color fastness and durability against weathering.

2.3.3. The bamboo carving knife is very important. Carbon tool steel t8A and t7A are usually used for the knife, the hardness should be HRCbo- 64 or 65-62; high-carbon steel and alloy also can be used.

2.3.4. Carving:

2.3.4.1. Pattern printing: Polish the surface of bamboo, reprint the carving pattern on the surface with a peice of duplicating paper. Use a pencil 2H to draw the pattern clearly.

2.3.4.2. Carving: After the pattern drawn well on the surface, use a sharp knife to make the contour of the pattern, then use a carving knife to express the relief of carving.

3. Bamboo wares for every day use

Bamboo wares of every day use are very important in the life of reral people in regions where bamboo grows. They can be divided into furniture, articles of daiy use and farm tools. A few typical furnitures and processing expenses are as follows:

3.1. Furniture. Bamboo furniture is an important part of bamboo wares, bamboo furniture is light-weighted, handy unique and beautiful.

3.1.1. Bending bamboo furniture

Split the culms of 5-7-year-old Phyllostachys pubescens into 5 cm wide strips of same thickness, remove the outer cuticle and inner skin, polish the surface. Carry out antiseptic treatment. Dry, apply glue, bend according to the shape of furniture and assemble.

3.1.2. Folding furniture

Take the lower part (1.5 m) of culm as frames of furniture, use the middle part as the surface board, and assemble them with iron and screw spores. Chairs, tables and benches can be made in this way. Such furniture can be folded when not used.

3.2. Articles of every day use

Bamboo wares such as chopstick, large wicker basket, steamer, rice basket, mat and curtain, are closely related to people's life.

3.2.1. Bamboo mat, including summer sleeping mat, mat for heatable brich bed, mat for air drying and mat for storage. Summer sleeping mat is soft and smooth, used not only for a comfortable sleeping, but also for ornamental prupose. Phyllostachys heteroclada and Sinocalamus affinis are the main material for making mats. The culm can be cut into very thin strip, the surface is flat, smooth, absorbing sweat. The mats made of these species can be folded or rolled up easily.

3.2.2. Bamboo curtain: Used at doors and windows, which has two types, one is woven from strips, the other from beads. Species such as Phyllostachys heteroclada, Sinocalamus affinis, Phyllostachys pubescens and Dendrocalamus membranaceus are mainly used as raw material.

3.2.3. Bamboo basket: The making of bamboo baskets has a history of hundreds of years, they are highly popular, exquisite, light, durable and beautiful. The culm of 2-year-old Sinocalamus affinis is commonly used as raw material.

3.3. Farm tools:

In recent years, farm tools are produced in bamboo growing areas in south China, they are used widely in agricultural production.

4. Marketing trend

The market of bamboo products is quite extensive. The market investigation showed an upward trend. The products will be upgraded gradually.

4.1. Domestic market

Chinese people are very fond of bamboo. Various bamboo articles are used extensively in daily life. With deepened reform and opening to the outside world, the living standard of Chinese people will be steadily improved. Changes have taken place in the sense of consumption and beauty. More and more people changed their attitude toward articles of daily use. They want the articles be useful and cost-effective, as well as beautiful and decorative, which enrich their life materially and mentally. Making a comprehensive survey on urban and rural makets of bamboo wares, we noticed that tremendous changes have taken place in consumer psychology, they are seeking new and unusual products, seeking new furniture for their new houses, they are in favor of all articles made of natural materials such as bamboo, rattan, willow and grass. as raw materials have taken place trememdous changes. For example, on the National Daily Article Interflow Meeting held in the first ten days of September, 1985 and the National Local Product Interflow Meeting held in the last ten days of September, 1985, in Zhengzhou City, Henan Province, the total value of bamboo wares sold were 390 million and 413 million RMB yuan respectively, which were 1.1 times and 1.3 times higher than those of the same meetings held in 1979. The orders for bamboo mats on the two meetings in 1985 was more than 5 million sheets, and the demand of bamboo furniture exceeded the supply greatly. The volumes of business for bambooware on the two meetings in 1992 were 37% and 58% higher than those on the same meetings in 1985 respectively. The order volume for bamboo furniture, such as the deck chair, easy chair, children chair and middle or high-grade furniture was more than 2.7 million pieces, which was 15.2 times higher than that in 1979. The high-grade bamboo daily handicrafts have been preferred by consumers. It is evident that the market of bamboo handicrafts and bamboo wares have great potentialities in China. The trend of domestic market in the future will be: the demand in bamboo wares favored by consumers will be doubled. These bamboo wares include the appreciated goods and ornaments in family, the daily handcraft articles, the treasures of study, such as bamboo pen container, flower vase, flower basket, flower socket, hanging screen, fresco, simulated animal, mat, door curtain, bed, childen's article, gift, ornaments in bedroom, and compact bamboo furniture of multiple use, and folding ones.

4.1.1. Markets of Bamboo Handicraft Article in Coastal and Inland provinces

Most of coastal provinces in China are the producing areas of bamboo wares, such as Guangxi, Guangdong, Fujian, Zhejiang, Hainan provinces and Shanghai Municipality. The articles and daily uses produced in these areas are exported to USA, UK, Germany, Russia, Japan, the Netherlands and the countries in South-East Asia. The industrial output value and export earnings of bamboo wares in Zhejiang Province in 1988 were about 400 million RMB yuan and 38 million USD respectively. The export earnings of bamboo wares in the province in 1990 was more than 40 million USD, which was more than the value of sales in the domestic market. The export earnings in Fujian Province in 1990 was more than 45 million USD which was also more than the value of sales in the domestic market. The bamboo wares produced in Guangdong and Guangxi Provinces are basically exported to markets of Hong Kong, Europe, America, Japan and Southeast countries. The inland areas, Sichuan, Yunnan and Guizhou provinces being a long way from coastal ports and ill-informed, have not got efficient access to markets outside, so that only some famous, excellent and new bamboo products such as the Gong fan of Zigong city, the bamboo curtain paintings of Liangping, the bamboo weaving of Chengdu city, the bamboo flute of Guizhou Province and daily-used handicraft articles, bamboo furniture are exported. Most of daily-used bamboo wares and production tools such as sleeping mat, bamboo mat, straw mat, curtain, chopsticks, food steamer and bamboo furniture are sold mainly in domestic market. The output value of bamboo wares in Sichuan Province annually is about 500 million RMB yuan, of which the rate of external trade is less than 10%.

4.1.2. Markets of Bamboo Wares in South and North

In the South of China, the economy of coastal cities is developing fast, achieving a higher living standard and consumer level. This is the major market of handicraft article in China. From urban areas to countrysides, almost every family has a few of bamboo handicrafts and daily used bamboo wares. There are about 30 million pieces of bamboo wares has to be added for residents in southern part of the country every year. The major market of willow and straw handicrafts is in the north part of China. But in recent years, bamboo wares have entered into the northern market, and most of them are daily used articles and produtive tools such as bamboo mat and folding furnitures. With the progress of science and technology, the defects bambo wares such as rifting, deforming, mildewing and moth-eaten have been solved, and northerners meet bamboo wares warmly. The northern market will be a great potential.

4.2. International market

The bamboo handicrafts and daily-used bamboo wares have a broad prospects on international market. With the rapid increase of sales volume on domestic market, the demands from Europe, America and Japan are too big. According to statistics of customs, in recent years the import of the products made of bamboo, rattan, willow and strawto to the United States was increasing. It was US$ 0.164 billion in 1979, 0.245 billion in 1981, 0.35 billion in 1983, 0.45 billion in 1988, from which some 25% were of bamboo wares. Most of the products in the US market were from Thailand, India and China. The proportion of bamboo handicrafts from China on the market of the United States was less than 20 percent. In addition, handicrafts, furniture, toys, chopsticks, toothpick have been exported to Germany, the Netherlands, the United Kindom, Russia, Japan, Bulgaria and Southeast Asia. The export earnings of the bamboo products in Guangdong Province is more than US$ 3000 every year, and the situation is tending to expansion.

At present, the handicrafts and daily-used bamboowares which are most fasionable and welcom on international market include: bamboo handicrafts for family ornament, for gardening and for daily-use such as baskets, flowerpots, flower-racks, curtain, lamp-lanterns, pen containers, flower vases. The bamboo wares which sell well on foreign markets are also including a string of baskets and birdcages, lampshades, animal utensils, bamboo domestic bowls and birds, hanging baskets, fence, hand-bags, bamboo slippers, carpets and curtains for beautifying the living environment. Many kinds of bamboo handicrafts have been exported to the United States, Japan and some countries in Europe. The handicrafts and bamboo wares with more varieties, in small qualities and of higher value are more needed and the natural color or coffee colour are in favor. The raw materials of bamboo products are tending to combine rigid material with soft material such as the bamboo combining straw, hemp and cotton. The shape, style and pattern of handicrafts are tending towards seriation and whole set, in natural.

4.3. Market propects

The business of bamboo handicrafts, bamboo wares and bamboo material for ornament is tending to brisk in 3 to 5 years. The bamboo products for house decoration and gardening will be in grear demand on demestic market. It is estimated that the market of family ornament will be prosperous and the daily-used bambooware will be doubled. There are about 40-50 million households in the cities of whole country and about 1100 hotels which need bamboo products. In the past few years, the area fitted up with bamboo was 2000-2500 square meters annually, and it is estionated the area will be increased to 10,000-15,000 squar meters every year. People are paying more and more attention to beautifying the life and environment. The daily-used bamboo wares in demand will amount to 10-15 million pieces in demestic market.

It is estimated that the market of Chinese bamboo handicrafts and daily-used bamboo wares in Europe will be increased sharply in 3 or 5 years, with the development of foreign economic trade, the export of bamboo handicrafts and bamboo wares will increase steadily.

5. Benefit analysis

Bamboo can be used for making various handicrafts and bamboowares along with papermaking and manufacturing various bamboo-based panels. The precise processing and comprehensive utilization of bamboo bring about obvious benefits, increasing the income of local people, facilitating the development of local economy, promoting the prosperity of local community. In 1990, the output value, the tax revenues and the exchange earnings from bamboo handicrafts and bamboo wares in Fujian Province were RMB yuan 0.41 billion, 38 million and US$ 36 million respectively; those in Zhejiang Province were RMB yuan 0.45 billion, 42 million and US$ 40 million; and those in Hunan Province were RMB yuan 0.13 billion, 13 million and US$ 5 million. The output value and the tax revenues from bamboo canned food were RMB yuan 0.12 billion and 16.8 million respectively. The following investigation materials indicate further that better economic benefits from the precise processing of bamboo meterial.

The total output value of Chinese bamboo industry in 1992 was about 3,000 million RMB yuan, 5-6 times that in 1979.

5.1. A significant increment in revenue can be earned through diversification of products

Every part of bamboo is useful, bamboo leaf, culm, branch sheath, rhizome, stump and root are all useful. Bamboo has great potentialities in making various products. The revenue from Phylloctachys pubescens, Bambusa omeiensis, Bambusa textilis, Phyllostachys nigra, Phyllostachys makinoi and Phyllostachys heteroclada through manufacturing different products is 2-10 times, even 20 times that of the price of raw bamboo culms. The profits made by five bamboo handicraft factories through comprehensive utilization are shown in the following tahle.

Table 4.1 Output Value and Tax Revenue of Eight Counties in 1990

regions	Annual Output Value million RMB yuan	Percentage in Gross Output Value of Industry & Agriculture (%)	Tax million RMB	Export Value million US$
Longyou Zhejiang	33	10	3.465	3.5
Tonggu Jiangxi	28.65	20	2.850	/
Muchuan Sichuan	40	13.99	2.673	/
Boai Henan	65	7.2	6.825	/
Linan Zhejiang	46	/	4.830	/
Anji Zhejiang	150	/	/	/
Guangning Guangdong	65.5	17	6.878	6
Xinyi Guangdong	140	/	/	7

Table 4.2 Economic benefits of Bamboo Wares made of Ph. pubescens (1000 yuan)

Unit	Annual consump. (1000 culms)	Annual Output Value Total	Per capita	Per culm	Tax Total	% of value
Jiangan	13.7	1,660	9	1,210	200	12.04
Yifeng	150	3,300	20.3	220	660	20.00
Rongshui	260	3,510	9.7	130	165.2	4.7
Xiaofeng	288	2,520	37.6	87.5	170	6.7
Chonggan	58	1,050	13.1	181	120	11.42

It is clear from the above table, that all the five factories are using Phyllostachys pubescens as raw material, having a good assortment of products with different grades and gaining a profit from the production and selling.

The table also shows some differences among the five factories. It is quite interesting to have a close look at them. First of all, we noticed that the consumption of raw bamboo material in Jiangan Bamboo Handicraft Factory is lower than all other factories, but the per piece value after processing is highest. The consumption of raw material in Xiaofeng Bambooware Factory is higher than all others, but the per piece value after processing is lower than all the other factories. Besides the management factors, we can see from the table that the former produces bamboo products in a great variety, pay attention to making high-grade, high value-added products, to achieving high rate of comprehensive utilization, while the latter produces just single bamboo product, of lower grade, with lower rate of comprehensive utilization. The technological process of the factory and the quality of workers are also important for the bysiness management. The per capita value in Jiangan Factory is 9 thousand RMB yuan, which is only 25% of the per capita value in Xiaofeng Factory. So the better economic profits can be earned from the precision work of products with more varieties and higher grades, and from the comprehensive utilization. It is also important to rely on the science and technology, the training of technical workers, the improvement of workers' quality, the scientific management of enterprise.

5.2. Abundant profit can be gained from the precise processing and comprehensive utilization.

The income from selling raw bamboo of Phyllostachys pubescens is just 90 thousand RMB yuan per 10 thousand culms of raw bamboo. If the culms were processed for making different kinds of end products, the profits will be increased greatly.

5.2.1. From 10 thousand culms of Phyllostachys pubescens, 110 thousand square meters of bamboo skin which is 0.45 mm in thickness can be whirled from the lower part of culms for 2 meters high. According to the current selling price in Chinese domestic market, one square meter is about 6 RMB yuan and the total earning from selling will be 660 thousand RMB yuan. From middle part of the culm 260 thousand pairs of chopsticks can be procuced, the income from selling will be 182 thousand RMB yuan. The daily-used bamboo wares produced from upper part of the culm will be 30 thousand RMB yuan. From all these products, the income will reach 872 thousand RMB yuan, 9.17 times that of price of raw bamboos.

5.2.2. If the 110 thousand square meters of bamboo skins whirled from lower part of culm is processed into 550 thousand of bamboo fans, the selling price will be 1.65 million RMB yuan. If the middle part of culm is used to produce handicrafts such as bamboo boxes, vases and gifts, the income will reach 520 thousand yuan. The earning from selling bamboo wares for children produced from upper part of culm will reach 50 thousand yuan. The total income from selling all the products will be 2.22 million RMB yuan, which is 23.36 times more than that from selling raw bamboo culms.

5.2.3. If 10 thousand culms of Phyllostachys pubescens are used to make 8000 folding chairs the income will be 256 thousand RMB yuan, which will be 2.69 times that of culm price. If the culms of Phyllostachys pubescens are used to produce 3,000 sets of easy chair, the income will be 1.68 million yuan which be 17.68 times that of culm price. If the culms are used to make 1,400 sets of furniture of ancient style, the income will be 3.5 million yuan, which is 29.6 times more than the price of raw bamboo culms.

5.2.4. As mentioned above the income from industrial processing of 10 thousand bamboo culms is about 160 thousand RMB yuan, much more than the price of raw bamboo culms. While the income from artistic processing of bamboo is even higher.

5.2.4.1. Bamboo skin can be used to make 60 thousand containers, 15.4 cm in height, the selling price will be 240 thousand RMB yuan.

5.2.4.2. Seventy thousand pen containers with a relief sculpture on the surface, 18 cm in height, can be sold at the price of 980 thousand RMB yuan.

5.2.4.3. Forty five thousand pen containers with a relief sculpture on the surface, 20 cm in height, can be sold at the price of 1.26 million RMB yuan.

5.2.4.4. Forty thousand pen containers with a relief sculpture on the surface, 30 cm in height, can be sold at the price of 6 million yuan.

The total income from the above products will be 8.48 million RMB yuan, which is 53 times that of raw bamboo price.

5.2.4.5. The income from selling one ton of Bambusa omeiensis is 250 RMB yuan. But the income from selling woven vases, flower baskets and food containers produced from the same amount of Bambusa omeiensis will be 1300 RMB yuan, which is 615 times that of selling raw bamboo. The income from selling farm tools produced with the bamboos will be 480 yuan, which is 1.97 times that of selling raw bamboo. The earning from selling packing boxes for well-known wine with the bamboos will be 3,500 yuan, which is 14 times that of selling raw bamboo.

5.3. Social benefit

The production of bamboo handicraft and bambooware has extensive social benefit.

-- Abundant bamboo handicrafts enrich people's life materially and mentally.

-- Bamboo industry provides goods for foreign trade, gain foreign exchange for national economic construction.

-- Bamboo processing offers local people employment opportunities and improves the stability of local community.

-- Bamboo utilization helps to mitigate the contradiction between wood supply and demand, helps to recuperate and multiply the wood resources.

-- Great benefit from bamboo utilization makes bamboo peasants to realize the importance of resources and encouraging them to protect and develop bamboo resourcers.

6. Prospects

The bamboo handicrafts and daily-used bamboo wares in China are rich and varied, the new products emerge in an endless stream, the bamboo weaving screens, the big paintings on bamboo curtains, and the bamboo household utensils.

To sum up, bamboo handicraft and bambooware played a tremendous role in the course of economic and cultural development in China. Its merits and achievements can not be obliterated. We believe that bamboo handicraft and bamboo wares will play an important role and make a greater contribution to the social development in the future.

PART V. IDEAS ON THE DEVELOPMENT OF BAMBOO INDUSTRY

I. Economic benefits should be the basis of decision making in bamboo industry

Bamboo resources are concentrated in comparatively poor areas. More than one hundred millioin people make their living in connection with bamboo cultivation and processing wholly or partially. Therefore the successful exploitation of bamboo resources is one of the useful ways for the economic development of poor rural areas.

In recent years the area of bamboo was increasing continuously, while the output was not increasing simultanuously. This means the bamboo industry in China as a whole became less effective and less profitable. It is essential to conduct detailed investigation and carry out scientific research for the better exploitation of existing bamboo resources. Various development alternatives should be worked out for decision-making.

It is a truth widely accepted that poverty is the basic reason for forest depletion. If the cultivation and exploitation of bamboo resorces can make some contribution to wiping out the abject poverty, it must be a great help to the conservaton and restoration of forest resources.

Forest resources are of great social, environmental and ecological importance, but without an industry based on their exploitation, forests themselves can not bring about financial revenue, and without financial revenue it is impossible to stimulate people to protect forests, to protect the source of their income.

The history of forestry development of Nordic countries such as Sweden and Finland demonstrated that the formation and development of timber processing industry, which played an important role in their national economy, was the basis for the sustainable management and continuous growth of the forest resources.

The situation of new successful forest plantations are also based on a high efficient timber processing industry. The timber output of Portugal was 6.1 million cubic meters in 1966, and the export value of forest products (not including rosin and cork) was only US$ 18.977 million. After the establishment of new plantation of 400 thousand ha. in recent 20-30 years, a pulping industry was developed, the timber output reached 10.44 million cubic meters, while the export value raised to US$ 1.25 billion.

The experience of world forestry showed convincingly that it is impossible to have a prosperous forestry without a developed timber processing industry. And, similarly, without effective bamboo utilization industry, it is also impossible to have a healthy bamboo industry.

The total global revenue from bamboo and its procucts was estimated approximately at US$ 4.5 billion (W. Liese 1988), while the annual output value from bamboo industry in Mainland China was just RMB yuan 5.5 billion (1 US$ = 5.7 RMB). Generally speaking, the output from bamboo industry in Mainland China does not match the title "bamboo kingdom" of China.

In 1989, the bamboo yield was 733 million culms, being 1.41 times that of 1980s. Incomplete statistics shows that the actual output value of bamboo products in China totals RMB yuan 4 billion.

China is also a shoot producing country. Shoot is the traditional food of Chinese people. When the fresh shoot is converted into dried shoot at a rate of 10:1, the dried shoot output in 1989 was 72,821 t.

Now bamboo has been beyond the field of traditional utilization, and has been widely applied to architecture, paper making, light industry, food industry, furniture making, packing and transport and horticulture. Bamboo is one of important materials to the industry and handicrafts in South China. The varieties of bamboo products are diverse and have multiple use. Due to inperfect statistic system, the statistic figures may not reflect the true complete situation, though they have a certain value of reference. The statistics of Ministry of Light Industry shows that the output and output value of bamboo products in 1989 were as follows:

The bamboo pulp yield was 132,200 t, most of which was produced in Sichuan province. Its yield was over 50% of the national total. Next was Jiangxi, Hunan and Guangdong. Farm implements made of bamboo were 81.24 million, most of which were made in Guangdong, Sichuan, Fujian and Hunan provinces. The amount of the four provinces was over 70% of the national total. The output value of bamboo carving and sculpture was 1.29 million yuan. Hunan shared the largest proportion, next were Zhejiang and Jiangxi provinces. The output value of bamboo products was 85.95 million yuan, and Guangdong, Zhejiang and Fujian provinces gave the highest output. The output value of the three provinces was over 3/4 of the national total. The output value of woven art articles was 90.88 million yuan. Zhejiang, Fujian and Guangdong provinces gave the highest output. The output value of these three provinces was over 60% of the national total. The output value of bamboo and rattan products was 255 million yuan. Hunan, Guangdong, Fujian and Hubei provinces gave the highest output. The output value of these four provinces was 60-65% of the national total.

2. Bamboo industry in Zhejiang and Guangdong provinces

2.1. Zhejiang Province is comparatively advanced in bamboo cultivation and processing. It is said that the bamboo area, stock vulume and revenue were increased during the period from 1978 to 1991 in this province. The bamboo area increased from 423 thousand ha. to 541 thousand ha. The stock volume increased by 41.8%, from 670 million culms to 950 million culms. The density of bamboo forest increased by 14.8%, from 1725 culm/ha. to 1980 culm/ha. This growth was achieved through the following measures:

-- To regulate the structure of bamboo production, forming the rational production of bamboo culm, bamboo shoot, bamboo pulp and other kinds of products.

-- To enlarge the production units of bamboo production, forming great specialized bamboo plantations.

-- To intensify the cultivatioin of bamboo, forming intensively-cultivated bamboo areas.

2.2. Bamboo industry in Guangdong Province.

There are 318 thousand ha of bamboo stands in Guangdong Province, The total annual output of bamboo values about 300 million yuan and $30 million comes from exporting bamboo products. The production of dried bamboo shoots in 1991 was 2,700 ton. The province has 10 bamboo pulp and paper mills with an annual production capacity of 9,000 ton, 20 bamboo shoot processing factors with an annual production capacity of 15 thousand ton, and 180 bamboo handicrafts and processing factories.

2.2.1. Bamboo industry in Guangning county plays a decisive role in its economy. Guangning county had for a long time a name of "the county of bamboo". Its bamboo products sell well in Europe, America and Southeast Asian countries with "Zhengjiang bamboo strips" world- famous. The county has 54 bamboo species and 70 thousand ha of bamboo stands which takes up one third of the total forest area, of which 63 thousand ha are Bambusa textilis, covering 90 per cent of the total bamboo areas. Over 2,000 years ago, the county began to cultivate and utilize bamboo. The annual output value of bamboo industry in Guangning county is about 60 million yuan, which takes up 17 per cent of gross industrial and agricultural output value of the county. Of 60 million yuan of output value, bamboo shoots take up 21 million yuan with an annual production of 2.03 million kilograms, bamboo paper takes up 15 million yuan, sticker, toothpick and chopsticks take up 2.2 million yuan, farm tools of large bamboo, basket and others take up 1 million yuan, bamboo handicrafts take up 3.5 million yuan with over 300 varieties and an export value of 2 million yuan, bamboo incense boxes take up 8.7 million yuan with an annual production of 4,000 tons and an export value of 3 million yuan, thin bamboo strips take up 8.4 million yuan with an annual production of 3 miilion pieces and an export value of 1 million yuan, and bamboo (P. amabilis) timber takes up 1.69 million yuan with an export value of 200,000 yuan.

This county has nearly 100 bamboo processing factories. Therefore, bamboo industry proves decisive in the county and is the important pillar of its economy.

2.2.2. Huaiji County has 20 thousand ha of bamboo stands, of which P. amabilis takes up 15 thousand ha. This county is the main growing area of P. amabilis with an annual output of P. amabilis of 50 thousand tons and an annual output value of 20 million yuan. In 1990, the county exported 13,282 tons of P. amabilis with an export value of 1.5 million yuan. It has 6 " Shabai bamboo" processing factories with an annual output value of over 6 million yuan. Foreign enterpreneurs have high enthusiasm to set up bamboo processing enterprises in county.

Aozai Township in the county has a population of 32,000, 7,000 ha of Ph. amabilis with an annual production of 25,000 ton and an annual income of 15 million yuan only from bamboo timber, averaging 468 yuan for each person. Now, the annual production of bamboo timber per ha is only 35,000 ton. If these stands were managed more effectively and utilized more intensively, it would be possible to increase the production and income greatly. At the same time, with value-added processing developed, Ph. amabilis will play a decisive role for the economy of the township.

2.2.3. Shaba Township of Yingde County is a famous "countryside of bamboo" in Guangdong Province. It has a total population of 9,102, hilly area of 6,400 ha. and cultivated land of 342 ha (of which 240 ha of irrigated field). In 1981, it had 133 ha of bamboo (mainly Dendrocalamus latiflorus) shoot stands. In 1984 and 1985, the twonship administration established a demonstrated area of bamboo shoot production and affected peasants to cultivate bamboo shoots, thus promoting the development of bamboo shoot.

Year	Bamboo shoot area	Per capita income
1981	133	128
1985	533	284
1990	2,000	1,028
1991	2,400	1,500

In 1991, this township had 1,866 ha of bamboo shoots which were cultivated and utilized. If all the 2,400 ha of bamboo shoots were cultivated and utilized, the annual income per capita from bamboo shoots could reach 2,000 yuan.

2.3. Problems

2.2.1. Unstable policy and orderless system are not conducive to the development of bamboo industry in bamboo growing areas. The policy of bamboo industry in Guangdong province is unstable and the administrative system is orderless. Bamboo industry was supervised by forestry department of government before 1975, by local products corporation administration from 1976 to 1985. After 1986, the bamboo industry is supervised by forestry department in some counties, by local products corporation administration in others, and in certain counties neither by forestry department nor by local products corporation administration. This is very harmful to the centralized management of bamboo industry of the whole province and is also not conducive to its development in bamboo growing areas.

2.3.2. Due to orderless exploitation, there are serious wastes of bamboo resources as a result of unreasonable processing, distribution, and many products of low added value, thus the economic and social potential of bamboo can not be full exploited.

3. The development targets of bamboo industry set up for the year of 2000 are as follows:

-- The total output value be increased to RMB yuan 11 billion.

-- The output value per ha. be increased to RMB yuan 3101.8 from 1550.9.

-- The total export revenue be increased to US$ 300 milliom from 150 million.

-- The export revenue per ha. be increased to US$ 84.6 from 42.3

Frankly speaking, even these targets be achieved by 2000, the bamboo industry in Mainland China still will be backward as an individual industry. Malaysia started oil palm plantation some one hundred years ago, 2,080 thousand ha. of oil palm plantation were developed in recent tens of years, the export revenue from palm oil reached US$ 5.8 billion. It means the export revenue per ha. of palm plantation was some US$ 2,700, much higher than the export revenue target of bamboo plantation set for 2000.

The output value from bamboo industry in some advanced counties in China has exceeded the target for 2000 already, but as a whole the bamboo industry in Mainland China is far hehind Japan and Taiwan Province. The culm production of Japanese bamboo plantation approached 2.5 ton (air dried) in 1950-60s, the same as the target for 2000 in Mainland China. The area of bamboo shoot shands of Zhejiang Province in 1990 was as much as that of Taiwan in 1982 (approximately 23,000 ha.), the shoot output exceeded 240 thousand ton in Taiwan, while that of Zhejiang was just 150 thousand.

Output per unit area decides the economic benefits and income of bamboo peasants. China is scarce of land resources, therefore the development of bamboo industry, which is besed on the effective utilization of land, should pursue a great output value per unit area. Otherwise, the development of bamboo resources should be impossible.

Japan, Taiwan and India used to have developed bamboo industries, but the bamboo instries in these countries and area have passed their peak years. Mainland China is entering a period of bamboo development. Therefore, it is desirable to have a look at the experiences of Japan and Taiwan.

4. Bamboo industry in Taiwan

Taiwan had only 75,275 ha. of bamboo at the beginning of 1960s, the area increased to 175,638 ha. in 1971 in order to meet the needs in raw meterial of rapidly developing cellulose industry and the needs in scaffolding for construction. But as a result of high price of bamboo culms, construction engineers turned to aluminum and steel pipes, and the cellulose industry did not grow as predicted. Under these unfavourable conditions the area of bamboo decreased to 133,000 ha. in 1978. The present bamboo area in Taiwan is some 150,000 ha. The bamboo area in Taiwan is just 4.2% of that in Mainland China, but the export revenue of bamboo products from Taiwan is as much as that from Mainland China. The export revenue of bamboo products from Mainland was some US$ 150 million (People's Deily, March 1, 1993), which was equal to that from Taiwan in 1985 (W. Liese, 1985). The export of bamboo articles (indluding bamboo weaving, bamboo swords, fishing rods, bamboo petitioins and plybamboo etc.) from Taiwan amounted to US$ 97,774 thousand, while that of bamboo shoot products was 97,097 thousand, the total value was US$ 195 million. These results were achieved through the following measures:

-- To upgrade the quality of export products. The export bamboo products from from Taiwan was always upgrading, the weight of export bamboo products decreased from 74,706 ton in 1982 to 46,703 ton in 1987, while the export value raised from US$ 700,65 to 977,74 during the same period. These figures means that the price of export products improved greatly, it was US$ 937.88 per ton in 1982, and 2,093.53 in 1987.

-- To organize specialized bamboo shoot zones. It was defined in a document "Measures for facilitating reral development" that the specialized zones for agricultural production should be organized, including bamboo shoot zones. Based on similar natural conditions and expected market demands the peasant families were organized into cooperatives with enlarged scale of management, scientific processing and unified marketing. Bamboo shoot area was 1,888 ha. in 1964, the output averaged 7,231 kg. per ha. The area increased to 19,487 ha. in 1978, and 27,192 ha. in 1987, the average output of shoot exceeded ten tons per ha. The export revenue was US$ 2,186 - 3578 per ha. in the period 1978 - 1987. The shoot output from specialized zone was much higher than that from non-specialized area, which was just 0.22 - 1 ton per ha.

-- To organize specialized bamboo processing zones. There are 831 bamboo processing enterprises of seven groups, consuming 230-240 thousand ton of raw material, 76.9% are used for making household effects, 10.9% for sporting goods, 4.3% for construction material, 4.2% for furniture, 3.7% for ornamental goods. Specialized processing zones have been formed. Zhushan Township is specialized on making bamboo mats, chopsticks and sporting goods. Lugang is famous for bamboo curtains. Meishan is good at bamboo sheath processing. Tucheng Township of Taipei is known for bamboo furniture and Guanmiao Township of Tainan is for bamboo weaving.

5. Bamboo industry in Japan

Bamboo industry was decling sharply in recent 10-20 years. The Europeanization of housing has lost bamboo its importance in house construction. Many kinds of bamboo wares are being replaced by products made of plastic or other materials. The cheap imported bamboo shoots occupys two thirds of the domestic market. The depressive market and lack of labor force affected the interest of peasants and businessmen in bamboo greatly.

5.1. Bamboo area

In a period of forty one year (1915-1956) the area of bamboo experinced two sharp increases. The first one took place before World War II, when Japanese government encouraged bamboo plantation to meet the market demands by means of state subsidy. The second one happened after the War, when economic restoration required more raw material, the demand in bamboo was enlarged, which caused the increase of bamboo area. The bamboo area reached its peak in 1957, accounting for 176 thousand ha.

Bamboo consumption decreased from year to year at the end of 1960s. In a period of thirty years (1960-1990), the consumption of bamboo decreased from 389.2 thousand ton to 225.2 thousand ton, the decrease rate was 42%. The output of raw bamboo was 13,470 thousnd bundles in 1960, which equaled to 404 thousand ton, while the output was just 6820 bundles in 1990, which equaled to 204.7 thousand ton, decreased by 50%. Due to the decrease of bamboo consumption and processing, the area of bamboo also shrinked to 88 thousand ha. about half of the highest figure.

Japan used to be a bamboo exporting country before 1965. The export of bamboo in 1960 was 14,800 ton while no import was recorded. The export decreased to 100 ton in 1990, while the export reached to 20,600 ton. In the period 1957-1961, the annual export of bamboo material was 0.6-0.7 billion Japanese yen, the total export value of bamboo industry was 3 billion Japanese yen, including all the bamboo products. It is clear that bamboo industry was quite important at that time.

5.2. The reorientation of bamboo industry

With the shrinking of bamboo area and the decrease of bamboo production, the annual yield of raw bamboo per ha. is always kept in the range 70-80 bundles, without sharp fluctuation. It means the bamboo output per ha. is some 2,250 kg. per ha.

Bamboo material was mainly used in construction, agriculture, forestry, fishery, the production of articles of daily use and handicrafts before 1965. Now the use of bamboo is mainly for the improvement of environment and cultural life, flower and tea ceremony, gardening, special building, artistic processing.

Bamboo used to be a kind of wide-spread resources in Japanese rural areas. The increment of bamboo plantation is high, and the bamboo possesses several specific features in terms of physiology and ecology, therefore foresters are of the opinion that bamboo resources should be exploited effectively. They suggested two ways of exploitation. The first one is to develop the products of massive production, such as fodder, bamboo pulp, active carbon, organized fertilizer, special fuel, etc. The other is utilize bamboo as raw material for making new kinds of products, this should be achieved through the cooperation of various industries.

5.3. The development of shoot stands

Bamboo shoot is regarded as a kind of healthy, nutritious natural food. The demand is increasing continuously. The consumption was 54,200 ton in 1951, 140,636 ton in 1971, 235,249 in 1980. Up to the begining of 1960 the bamboo shoot export was 1,400-1,500ton per year, since 1966 the import has exceeded export. During the period 1971-1980 the shoot output increased from 101,613 ton to 172,793 ton. Consequently, being depressed in bamboo culm production, the total output value of bamboo industry still shown a little increase.

Impacted by cheap shoot flow from China and Thailand, Japanese shoot production decreased drastically in recent 10 years. It decreased to 138 thousand ton in 1990, and 113 thousand ton in 1992. In the period 1971-1980 the degree of self-sufficiency maintained above 70%, but some two thirds of bamboo market was occupied by imported shoot in 1990. The price of shoot for making canned goods was 110 Japanese yen per kg. in 1984, it dropped to more than 40 Japanese yen in 1990. The interest of Japanese peasants in producing shoot was hurt seriously.

Accorging to the statistics of the Department of Foodstuff Circulation, the Ministry of Agriculture and Forestry of Japan, shoot output was 9.92 ton per ha. in 1988, 8.51 ton in 1990. According to the statistics of the Department of Forestry, the Ministry of Agriculture and Forestry, the area of specialized shoot producing stands was 40-50 thousand ha. in 1980, 53 thousand ha. in 1990.

5.4. Bamboo industry in Fukuoka

Fukuoka County is the most important shoot producing county in Japan, it owned 6,533 ha of specialized shoot producing stands in 1990, with an annual shoot output of 32,716 ton, 5 ton per ha. in average. An expert from the county forest research farm suggested that three categories of shoot producing stands should be formed in accordance with the conditions of stands (topograph, climate, soil etc.):

-- High-yield shoot stands, with an annual output of 15-20 ton per ha. which are located in areas comparatively far from the market, with a continental climate and abundant rainfall, the shooting period should start late.

-- High-quality shoot stands, with proper soil for bamboo growth.

-- Early-shooting stands, there are certain parts of the bamboo growing area with micro relief and micro climate which are favorable for early shooting. The production of early shoot will bring about more income to peasants.

5.5. Bamboo industry in Kagoshima

Kagoshima is a county owning the biggest bamboo area in Japan. When the national bamboo area was decreasing, bamboo area in Kagoshima had an increase, it was 14,084 ha. in 1980, and 15,692 in 1990. Kagoshima produces both bamboo culm and bamboo shoot. The output of bamboo culm of Kagoshima ranked first in Japan, and that of shoot second. Therefore the bamboo industry of Kagoshima reflects the situation of national bamboo industry of Japan.

According to the investigation of Japanese Department of Forestry, the total sales of bamboo industry of Kagoshima (not including shoot) was 3.728 billion Japanese yen, it means 237.6 thousand Japanese yen per ha. equals to some US$ 2,000 per ha. An investigation report suggested that being impacted by bamboo products imported from Chinese Mainland and Taiwan, bamboo processing should turn to producing original goods of high grade. In comparison with those in 1975 and 1983, (the total sales were 2.186 billion and 2.330 billion Japanese yen respectively), bamboo industry of Kagoshima was still developing.

Kagoshima produced bamboo culm 2,019 thousand bundles, shoot 18,455 ton in 1980, culm 2,245 thousand bundles and shoot 20,982 ton in 1990. The output per unit area kept almost unchanged.

Kagoshima bamboo industry did not pursue simply the high yield of shoot, they maintained a stable yield and pay attention to early shooting. Shoot period began in the first ten days of October, fresh shoots are transported to Tokyo, Osaka, Nagoya and other cities by air, the selling price reached 2,000-3,000Japanese yen per kg. when shoots appeared on markets massively, the price dropped to some 800 per kg. Obviously, to shift bamboo shoot period to an early date is extremely effective for increasing the income from selling shoot. The shoot output in 1989 was almost the same as in 1984, while the total sales increased by 90%.

6. Proper orientation of bamboo industry

Pulping and papermaking were an important way of bamboo culm utilization, which once promoted the development of bamboo resources. But as a result of the import of foreign machine-made paper, the traditional paper hand-made of bamboo declined. The output of traditional paper was 363 thousand ton in 1932, it dropped to some 100 thousand ton in 1940s. The value of imported paper was 70 million yuan in 1931, the national output value of traditional paper was just 19 million in 1937.

Bamboo was widely used in scafolding in recent 20-30 years. Bamboo accounted for some 66.25% of scafolding material in 1974, the percentage dropped to 29.65% in 1984.

As the bamboo material is being pushed out of its traditional fields of utilization, it is necessary to seek a new, effective way of utilization. Facing the stagnation of bamboo culm market, the enlargement of bamboo shoot production is the first alternative for the development of bamboo resources. Fujian Province used to produce much dried bamboo shoots, it was due to the difficult transportation for bamboo culms. The difficult transportation of bamboo culms in Jiangxi Province in mid 80s resulted in the increase of bamboo shoot production, shoot sales in 1984 was 2.3 times those in 1974.

How to use bamboo resources more effectively and profitably, this is the question people have to answer.

The following ideas are for the development of bamboo indusstry.

-- To carry out scientific research on more bamboo species, there are more than 500 bamboo species in China, but only a few are utilized in industry, the most important one is Phyllostachys pubescens, all the others are regarded as not very useful ones. Officials and peasants were alway developing Phyllostachys pubescens and excluding other species. It is hardly wise to expand Phyllostachys pubescens to all bamboo growing area, because every bamboo species chooses its optimal habitat. Sometimes Phyllostachys pubescens can not grow well where the other bamboo species grow vigorously, and people can not expect a high yield of Phyllostachys pubescens on these sites. With the rapid progress of sciences, with the continuous improvement of processing technology, it should be possible to exploit the other bamboo species more successfully, to find more effective uses for lesser known bamboo species, and thus exploit our natural bamboo resources more rationally, maintaining biological diversity of bamboo family.

-- Bamboo culm processing is a more laborous operation than wood processing, this affects the cost of final bamboo products negatively. In order to avoid such an unfavorable factor, it is important to diversify the products, to make products with high value-added. According to the bamboo-based panels manufacturers, the production cost of bamboo plywood used as wall board and parquet flooring is as much as that of high grade plywood made of expensive hardwood. As the beautiful natural grain of bamboo makes the surface of plybamboo extremely attractive, and the great hardness also makes the floor more durable, plybamboo can be competitive against plywood of hardwood. With the existing plybamboo technology, it is possible to manufacture the products of high quality, but in order to produce plybamboo comparatively cheap, more scientific research is needed.

-- To invest more in bamboo papermaking research. At present, a great part of commercial wood is consumed for pulping and papermaking. Papermaking was an important form of traditional utilization in China. Due to the impact of imported machine-made paper, bamboo papermaking in China shrinked drastically. Chinese papermaking experts are using bamboo fibre for pulping on modern paper mills. The high content of various organic matters in bamboo biomass cause some problems in storage and pulping, and the different quality of fibre between its nodes and internodal parts also makes the pulping process more complicated and less profitable. Some of these problems are being solved. But further research is needed to work out more efficient pulping technology.

-- To develop comprehensive use of bamboo culm and bamboo shoot. Bamboo culm processing is a kind of labor-intensive industry, in certain developing countries where the wage level is low, timber shortage is serious and the price of forest products is high, the manufacturing of bamboo products may be quite profitable, but with the improvement of living standard and the raising of wage level, bamboo processing industry may be less profitable. Therefore to form a bamboo industry based on both culm processing and shoot production is desirable. At present, shoot production is an effective way for exploiting bamboo resources. The income from shoot selling always exceeds that from culm selling. Actually bamboo shoot is a kind of orienta food, accepted mainly by Asian people and by Chinese communities in other parts of the world. But as people are becoming more and more aware of keeping fit, bamboo shoot as a kind of healthy, nutritious food will have broader market.

-- To combine the industrial processing of bamboo culms with the production of artistic handicrafts. In general, some parts of bamboo culms are not suitable for industrtial processing, they are of odd shape, their fibre are twisted, which can not be peeled into veneer, nor to be processed mechanically. From the viewpoint of industrial processing they are wastes, but they are of great value for artistic processing. Valuable handicraft can be made of a small piece of such waste. Sometimes the price of a piece of bamboo handicraft exceeds that of tons of bamboo pulp. Therefore the comprehensive utilization of bamboo culm and root will increase the profit greatly.

-- To extend the knowledge and technology of bamboo cultivation and processing to local peasants, as a great part of bamboo groves are managed by peasants in separate form, it is necessary to organize expert teams to carry out the extension work.