RESEARCH REPORT

Current status and prospects of new house construction materials from bamboo

Wang Zheng Guo Wenjing

Research Institute of Wood Industry, CAF, Beijing 100091

This work was carried out with the collaboration and assistance of the International Network for Bamboo and Rattan

Current status and prospects of new house construction materials from bamboo

Wang Zheng Guo Wenjing
(Research Institute of Wood Industry, CAF, Beijing 100091)

Bamboo is widely recognized as one of the most important non-timber forest resources because of the high socio-economic benefits from bamboo based products. It is estimated that there are over 1200 species growing in about 14.5 million hectares areas. Most of them grow in Asia, Africa and Latin America. For example, bamboo can be found in almost every area in China except for Xinjiang, Inner-Mongolia, Jilin and Hei longjiang provinces.

Bamboo based products are widely used in housing, furniture, packing, transport and other fields. Houses were made of bamboo in China even as early as 2000 years ago. Many building materials from bamboo are used in the bamboo-rich rural areas of South China, Eastern-South Asia and Latin America.

With the development of advanced processing technologies, the utilization of bamboo-based construction materials has tended to replace the initially simple methods by cost-effective technologies using composites, high strength, high performance and high accessory values. As a result, various kinds of new building materials from bamboo have been involved in our construction and decorating fields. In this review, the current status and future prospects of bamboo products in construction is evaluated in the paper.

1. Current application of bamboo materials in construction field

In the construction field, bamboo-based materials can mainly be utilized for following three areas: scaffolds, concrete formwork and housing materials.

Straight culms of thick-walled species such as *Phyllostachys pubescens* are employed for scaffolds. It is easy to find such scaffolds in China, India, Thailand and other Asia areas. The bending resistance against the wind of bamboo-based scaffolds is superior to steel ones. However, its disadvantages of dimensional variability and, hence, inconvenience for assembly and disassembly limit its common utilization.

The technology for bamboo-based construction concrete formwork has been improved over the last 3 decades. Bamboo mats or curtains are used as the raw materials. The board is manufactured as the process of laminated plybamboo which involves resin impregnation, drying, assembly and hot-pressing steps. The laminated bamboo plywood is used in concrete formwork and has gained wide acceptance as compared with steel formworks, because it is: lighter, cheaper, easier and quicker to assemble, more heat-resistant and ideal to get smooth formwork surface. These advantages have earned it official endorsement, and steel-framed bamboo plywood has been declared as the ideal formwork material.

Bamboo has been used to build house for a long time. Even now, bamboo houses are common in the countryside of South China, Eastern-South Asia and Latin America. Usually, the house is built with bamboo culms. The thicker culms or strands made up of several culms are employed for load-bearing materials such as the girder, purlin, post and rafter. The walls are covered with bamboo strips. In order to improve sound insulation and heat-protection, the strips sides are covered with plaster or cement. The bamboo houses are cheap cost and easy treatment. However, it is only suitable for simple, lightly loaded and low-grade house buildings because of its variety in dimension. For top-grade buildings such as villas, the above technology can’t meet the strict demands. So, new kinds of materials must be developed to build top-grade houses. Based on bamboo materials, techniques of composite and reforming can be introduced to prepare new construction materials. The physical and mechanical properties of such products are suitable for top grade buildings. For example, the composites can be made into girder, purlin, post, rafter, ceiling, roof, walls, doors, windows and panelling etc.

2. Development and application of new technologies for bamboo based housing material

With the prosperity of our economy and the improvement of our living conditions, people are asking for better living environment. Many kinds of top grade wooden houses, villas have emerged and developed quickly in the tour sites and economy-developed areas. Hence, the development of bamboo-based products to substitute

wood could be a trend in top grade houses building, which will give the depressed area a new income opportunity.

Bamboo can be manufactured into kinds of top-grade housing materials to meet different performances by introducing the advanced combination, restructuring technologies. The progresses will be illustrated in detail as followed.

2.1 Bearing materials for top-grade house from bamboo

The bearing structures of a house include girder, purlin, post and rafter. The hollow culms can not meet all the requirements for the structure material, so they need to be converted into board or square bamboo materials. . There are many ways this can be achieved. It is perfectly feasible to make laminated bamboo lumber. The bamboo commonly used is from thick-walled culms with wide diameter. The processes include cutting, softening, flattening, drying, resin application, assembly and hot-pressing. Fig.1 shows the procedure.

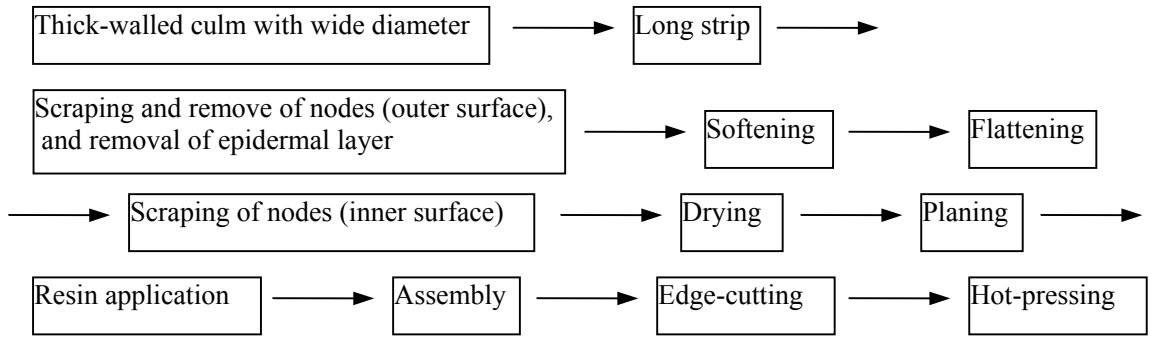

Fig. 1 Technological process of laminated bamboo board

In the process, the culms are cross cut to desired strength, then scraped and nodes removed (outer surface), and epidermal layer removed, after softening and steaming, the strips are flattened and dried to 8 % moisture content, edges and surfaces are then planed and resin is applied. For laminated lumber, phenolic resin with high weather resistance properties is recommended, other resins are resorcinol formaldehyde adhesive and isocyanate resins. After drying, the strips are assembled parallel to each other as the laminated board requires. The board is then hot pressed for 1minute/mm thickness at a temperature of 140-150□ and a specific pressure of 3 Mpa. The final stage is that the strips are finally trimmed to laminated board

The bamboo laminated board made from this technology showed high mechanical properties along with good weather-resistance because of phenolic and isocyanate adhesives employed. They have been successfully applied to prepare cement moulding plates and carriage platforms. If used for building construction materials, it has to be noticed that:

1. There is a need for different thicknesses of lamination. Up to now the thickest laminations are still less than 30 mm thick. . In order to make thicker ones, a press machine with bigger opening is needed. One good possibility is to use a cold press, but the products must be glued with resorcinol formaldehyde adhesive or isocyanate resins that are good at cold cure performance.

2. Standardization of testing methods requires urgent attention for testing their properties. In order to guarantee performance in the application, methods to test

resistance properties to abrasion, weathering and creeping along with normal physical mechanics performances must be standardized.

For lower-bearing building materials, bamboo mat board technology as illustrated in fig. 2 can be used. For bamboo mat, there is no particular restriction as to the species that can be used: culms with narrow diameter and thin-wall are also possible as raw materials:

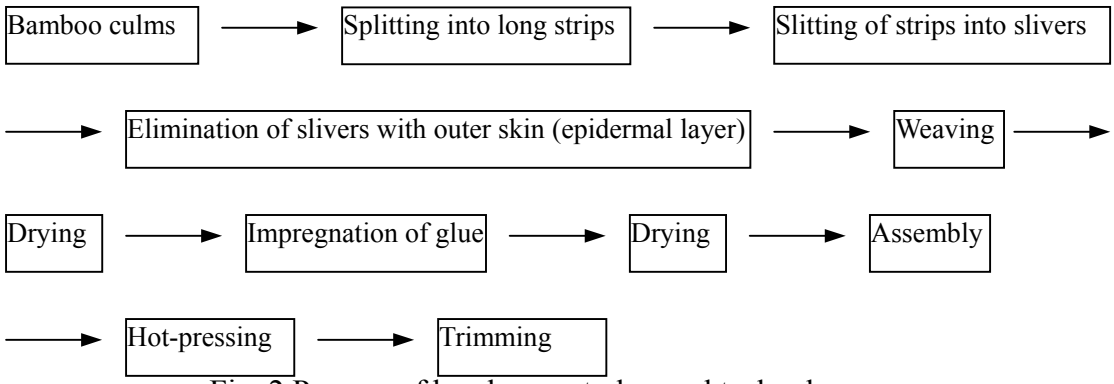

Fig. 2 Process of bamboo mat plywood technology

In the process described above, the culms are firstly converted into strips and slivers of uniform width 5-6 mm or 10-15 mm and thickness 0.6-1.2 mm. The slivers of epidermal layer are removed. The slivers are then woven into mats of different size according to the size of the available hot-press plates and the users' demands. After drying the mats to 6-10 % moisture content, sufficient glue is applied to ensure enough glue into the overlapped areas. In construction bamboo mat boards, phenolic resins are employed. The resins are diluted with water in the ratio 1:2 to ensure uniform bonding and reduce resin consumption. After drying with steam or oven to 10-12% moisture content, the mats are assembled in the same way employed in plywood manufacturing. The layers are determined according to the thickness for end-use. The assembled mats are hot-pressed at 140-145□, 1.6 MPa for 2 min/mm. finally, cut the edges and the mat board is manufactured.

The mat boards have been widely used as cement moulding panels in China. In the construction use, thicker board can be cut into purlins, rafters etc. The middle thick ones are suitable for ceilings and partitions. The thin panels are suitable for paneling and claddings.

In order to avoid non-uniform bonding owing to glue starvation where the slivers are overlapped, a relative new processing technology making laminated boards or curtain boards has been developed. The process is similar to but less time-consuming than weaving mats. The process is outlined below: convert flattened culms into slivers of uniform width 15-20 mm and thickness 0.8-1.2 mm, then weave slivers into parallel curtains with thread. The layers can be assembled in two ways: one is all slivers placed parallel to each other and the other is placing one layer at right angles to the other. Usually, the faces of a layer of bamboo curtain board are overlaid with resin-impregnated kraft paper or woven mats, which give a smooth and flat appearance.

2.2 ceilings and wall materials from bamboo

In building constructions, modified bamboo boards can be used in ceilings and wall. Such boards can be manufactured by different technologies. The above-mentioned mat boards, curtain boards and co-mat-curtain boards have been commonly used. Now, new technologies are being developed in this field. For example, bamboo particleboard, fiberboard, cement-bonded particleboard, gypsum-bonded particleboard and other composites.

The technology for making bamboo particleboard is similar to that of wood particleboard. The main process includes milling, screening, drying, spraying adhesives, mat forming, hot-pressing and trimming. Compared with plybamboo, the requirements for the raw materials for particleboard are few. Generally, lops, tops and felling residues are used in the manufacturing of particleboard. Residues from BMB (bamboo mat board) and other bamboo-based panel industries are also used. The manufacturing process has several stages: firstly, cutting by ring flaker the mixture of different bamboo residues into needle type flakes of size 20-30 × 1.5 ×0.1-0.5 mm, then screening and drying the particles to 3-6% moisture content, next, blending them with resin in a rotary blender (UF resin is avoided in order to reduce free formaldehyde emission and improve weather resistance property). Then, the mixture is formed into three layers, with the product mass being divided 40:60 between the faces and core, respectively. After pre-pressing, hot-pressing and edge-cutting, the bamboo particleboard is produced. The product can be used in construction for several applications (after over-laying with coatings) such as ceiling, roof-board and various kinds of light partitions, door shutters, paneling and decorating board etc.

Many materials could be used for over-laying such as bamboo mats, resin-impregnated kraft paper, wood veneer, rotary-cutting bamboo veneer, decorative papers and panels. For bamboo mat overlaid particleboard, the panel is produced in a single operation in which the resin-blended particles are laid between the glued mats. The mats and particles are pressed together—both at the pre-pressing and hot-pressing stages. This process cancels surface sanding and separated overlaying steps, which simplifies the procedure, reduces sand dust diffusion, and then decreases production cost.

In order to reduce the damage of free formaldehyde emission in housing materials, bamboo-plastic composite technology has been developed. Based on bamboo particles and plastic (or waste plastic), treated by breaking, drying, blending, laying up, pre-pressing, hot-pressing and trimming, bamboo-plastic particleboard composite is made. Compared with common bamboo particleboard, the composite is better for water-resistance, durability and dimensional stability properties, and no formaldehyde-based resin is employed (which overcomes the free formaldehyde emission problem). Some inorganic materials such as cement, gypsum and even fine coal ash, have also been potential in the manufacture of bamboo panel composites as cement-bonded particleboard, gypsum-bonded particleboard and bamboo particle plaster board.

For cement-bonded bamboo particleboard, the panel is made from needle-shaped bamboo particles and good grades of cement mixed with calcium chloride as solidifying agent. To manufacture a panel, culm pieces are finely shattered, immersed with hot water to reduce sugar content, treated with 5% calcium chloride, mixed with cement with a weight ratio1: 1.8 to 2.2, after mat formed and hot-pressed, dried to 2% moisture content at 30-40□ and cured for 24-48 hours, then at last, trimmed.

The technology to make gypsum-bonded particleboard or bamboo particle plaster board is almost the same as the one adopted for gypsum-bonded wood particleboard. The main process is cutting culms into particles, mixing particles, gypsum and water,

lying up and cold-pressing.

Those panels thus made as mentioned above are used in housing applications, such as insulation board, ceiling and partition. Owing to their advantages like fire-resistance and no free formaldehyde emission, these bamboo panel composites have been recommended as the ideal architecture materials.

2.3 Doors and windows materials from bamboo

Various products from different bamboo panel manufacture technologies could be applied for doors and windows. The main materials are bamboo square boards in different sizes or panels in different thickness. The squares for door or window frame made from laminated technology should have the sizes of 40×60 mm, 50×100-mm etc. For the thinner ones, bamboo mats and curtains are employed. Meanwhile, the panels are also made from plybamboo, particleboard and bamboo-based medium density fiberboard (MDF) process. These highly specialized products under development employ the bamboo-fiber moulding technology.

Bamboo strips, as well as residues from other bamboo panel mills are the main raw materials. After softening, crushing into fiber, then followed wet fiberboard or MDF technologies to form layers, next loaded into mould hot-press to get the molding panel which has a characteristic appearance and pronounced stereoscopic properties with various shapes and patterns.

The fiber molding panel technology includes two ways: one-step and two-steps. In the one-step case, bamboo fiber is sprayed with resin, dried and formed into mats. Then the mats are put into the mould hot-press machine directly to make the molded products. About the two-steps procedure, the resin-impregnated fibers are pressed and formed special panels. The panels are then hot-pressed to the molded products with high strength. The former is suitable for commercial production and the latter is feasible for the renewal of products and reform of old technologies.

In two-step procedure, there are also two processes: hardboard process by wet method and MDF process by dry method. The first one has a lower production cost but creates difficulties in waste water treatment, while the second one has a higher production cost due to higher quantity of resin requirement.

The molding panels by wood fiber molding technology applied to decorative doors have been popular in the world, but using bamboo as the raw material is in the research phase.

2.4 Architecture decorative materials from bamboo

With the development of our economy and the improvement of our living conditions, the demands for building, fitting up and decorating are increasing. Among kinds of decorative materials, the products based on bamboo such as panelling, screen, stairs handrails and crossbandings are becoming more attractive.

The thin plybamboo, particleboard and fiber panel can be made into all kinds of fitting-up and decorative panels if designed with thin strips or strip overlaid. With the fiber moulding technology, stereoscopic relief boards are produced, and the high strength fiber moulding technology is suitable for moulded stairs handrails and crossbandings. Another recommended technology is milling thick MDF board and face decoration. Now, the corresponding product has emerged in commercial market.

The technology of decorative veneer based on bamboo has been promoted in China, which is mainly rotary-cutting manufactured. The process is as followed:

Cross-cut selected culms into pieces 120-150 cm long, cook the pieces for 8 hours at 100□ in water containing 10 % NaOH, further cross-cut into pieced 30-60 cm long, then rotary-cut into veneer. Dry to 8-12 % moisture content, clip, blench, dry and dye to get the decorative veneer.

Bamboo veneers are used for overlaying on various kinds of panel substrates and employed in future, walling, and handicraft items such as moulded plates, fans, bookmarks and screens.

2.5 Floorings from bamboo fiber

Floorings from solid bamboo have emerged in the market and are gaining popularity. However, no research has been focused on bamboo fiber reinforced composite floorings until now. Anyway, considering the bamboo fiber property, it is feasible to introduce the processing technology of wood fiber reinforced composites flooring as well as modify the fiber-milling, resin-impregnation and overlaying steps.

Among popular wood fiber reinforced composites, the formaldehyde-based resins are still employed to bond the substrates. A new idea is bamboo-plastic composite technology: bamboo fiber is the raw material and compounded with plastic as the core material of the reinforced flooring. Such composite floorings have higher water-resistance and dimensional stability properties than those of normal floorings impregnated with formaldehyde-based adhesive. The process involves the following steps: softening lops, tops, grove species and the residues of other bamboo-based industries, milling the residues into fibers, drying to needed moisture content, mixing with fine or flake-shapes plastic, forming, hot-pressing and trimming to make the base-material. The base-material is overlaid with face-paper, edge-cut, and tenoned, the reinforced flooring is manufactured. In the process, something need to be noticed:

1) The ratio of plastics should be over 30 % for higher water-resistance and dimensional stability.
2) The recommended plastic material is polypropylene, the others must be co-blended and co-polymerized before using.
3) Recycled plastic is ideal to reduce production cost.
4) The density of the substrate should be higher than 1 g/cm^3 (1.0-1.10 g/cm^3) to ensure the mechanical properties.

The most advantage of bamboo-plastic composite flooring is solving the free formaldehyde emission problem, and thereby creates something which is green and environment friendly. Another advantage of the bamboo-plastic composite flooring is that it prevents the flooring from swelling and cracking contributing to high water-resistance and dimensional stability properties. Usually, the swelling and cracking due to moisture variation is the disadvantage of common solid or fiber-reinforced wood floorings.

3. conclusion

As mentioned above, a large variety of bamboo-based panels have been developed. Accordingly, it is feasible to apply bamboo materials for boards, blocks, and laminations via advanced processing technologies. On account of the enforcement of our natural forest protection project, wood is becoming increasingly scare. The realization that bamboo is the most potentially important non-timber resource and fast-growing woody biomass, has evoked keen interest in the processing and

utilization of bamboo for high performances and high valued product. It is important to exploit the versatility of bamboo in middling and top-grade building construction, architecture decorating, and other major applications. Its high valued utilization not only promotes the economic development in bamboo areas where people are in low-income, but also saves forest resources to protect our ecological environment as a wood substitute.

4. Acknowledgement

This research work was carried out with the collaboration and assistance of the International Network For Bamboo and Rattan.