

Bamboo as an Emerging Source of Raw Material for Household and Building Products

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Bamboo is a category of fast-growing and widely distributed perennials having unique physical and mechanical properties. The mechanical properties of bamboo are often higher (typically by two to three times) than those of conventional timbers, and it has become a very important raw material for the household/ building industries. Bamboo has been commercially used for the production of indoor and outdoor floors, furniture, and structural timber for building. Some performance defects/drawbacks of bamboo have been effectively remedied, due to the new technologies, such as bamboo scrimber, which facilitates the market penetration/ acceptance of bamboo-based household and building products.

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Bamboo (subfamily Bambusoideae) products have played an increasing role in the forest products industry in recent years. There are 115 genera and more than 1,400 species of bamboo plants, and among them 100 types of economic bamboo plants are known. Globally, bamboo is mainly distributed in the Asia-Pacific region (65%), followed by the Americas region (28%), and the African region (7%). In China there are more than 40 genera and more than 500 species, with about 6.01 million hm² bamboo forest, which accounts for about 1/3 of the total bamboo forest area in the world.

Performance Advantages of Bamboo

Bamboo is a renewable biomass material that has a high annual output of biomass per area of land. The internode cells of bamboo are arranged strictly in the longitudinal direction, with no radially oriented cells such as ray cells. These unique microstructural features have a significant impact on the durability and strength of bamboo and the manufacture process of bamboo products, such as low density, high strength, and stiffness. The tensile strength of bamboo fiber (650 MPa) is close to that of steel (500 to 1000 MPa) and about twice that of wood. In addition, the flexibility of bamboo fiber is much higher than that of steel. The compressive strength of bamboo is in the range of 40 to 80 N/mm², which is two to four times higher than that of most timber species. In general, bamboo is a lightweight and high-strength biomass material (Scurlock *et al.* 2000).

Bamboo, growing in different regions/ conditions, can be grouped into two major categories: cluster bamboo and loose bamboo. There are differences in morphology and performance between different types of bamboo. Most Asian bamboo, with strong, light, and flexible stems, has been used as building materials. Moso bamboo (*Phyllostachys edulis*), is the most important one for this purpose with larger than 0.64

g/cm³ of the basic density at the age of two years, 138 MPa of the average static bending strength, and 10.44 GPa of the average flexural modulus.

Application Developments of Bamboo

There are about 100 bamboo species that are economically important. In the 1980s the total revenue of bamboo and its products reached 4.5 billion US dollars. In 2005 the global bamboo product market was about 7 billion US dollars. By 2015 the number had grown to an astonishing 60 billion US dollars.

China is rich in bamboo resources and has a global leading level in the research and utilization of bamboo. In 2017 its industrial output value of bamboo was 35 billion US dollars, ranking first in the world, and it increased 11.2% compared with that in 2016 (Dai *et al.* 2017). More and more attention has been paid to the economic benefits and social value of bamboo, and the development prospects of bamboo products are expected.

Bamboo-based Household and Construction Products

Bamboo fibers have been used in many industries, for example the garment/textile, automotive, pulp and paper industries. Due to its excellent durability, fire safety, environmental impact, user safety, energy efficiency, and so on, bamboo is one of the ideal raw materials for the production of sustainable household/ building products. In fact, the household/ construction sector accounts for 30 to 40% of the annual bamboo consumption in the world.

Due to the intensive research and development activities related to the materials science, chemistry, and environmental ecology of bamboo, in recent years many new bamboo products have emerged targeting household and construction applications. Examples of these products include particleboard, medium density fiberboard (MDF), oriented strand board (OSB), mat board, corrugated roofing sheets, lumber, beams, flooring, glulam, and strand woven bamboo (SWB). In 2017, the global bamboo and rattan products reached 60 billion US dollars, of which China accounted for 35 billion US dollars. It should be noted that bamboo as raw materials for household/ construction products is not as well known in Europe/ North America as that in China, partly because construction grade timber bamboos primarily grow in tropical countries. Moreover, China is a leader in the development of bamboo-based household/ construction products in the world and has established a set of national standards for low-rise buildings for the construction industry, such as CECS 434-2016 (technical specification for round bamboo-structure building).

There are still several technical challenges for bamboo household/ construction products, for example, bamboo construction materials for high-rise buildings. Another issue is under-utilization for some bamboo species: 1) large-diameter bamboo such as moso bamboo (*Phyllostachys heterocycla* Carr.), only 20 to 50% of which has been utilized; 2) small-diameter bamboo, which accounts for more than 50% of bamboo resources, hasn't been widely used.

Strength and durability are two key parameters for household and building products. Bamboo-based fiber composites, such as bamboo scrimber, have been developed in recent years. Bamboo scrimber, a new generation of bamboo products with high strength, which is formed by changing the bamboo cell structure under the dual actions of high pressure and resin, has emerged as another noticeable bamboo product. China is an international leader in the area, which covers overall production processes,

development of new adhesives, and equipment/ installments (Gong *et al.* 2018). In China, the total annual output was 1.52 billion US dollars in 2017. Bamboo scrimber has become one of the mainstream products of the Chinese bamboo industry, which has been used in indoor and outdoor floors, furniture, container floors, building beams and columns, wind power blades and so on.

Without doubt, with more innovations and investments, more novel household/ building bamboo products will be expected. Fast-growing bamboo has emerged as a natural alternative to meet the high demand from the booming construction/ household market.

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