Bamboo in modern construction and architecture

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Abstract. The use of bamboo in construction and architecture is considered in the article. The main advantages of bamboo in comparison with modern building materials are considered, some technical characteristics of the material are given. The conclusion about bamboo as a renewable natural material, which in the future may replace the steel and reinforced concrete structures people are used to, was made. The design characteristics of bamboo make it possible to use it in complex architectural forms’ creation.

Introduction
In the modern world of innovative materials and technologies, it is difficult to imagine that somewhere such a plant as bamboo is used as a building material. But in vain. China, Oceania, Latin America, South America, Central and South Africa widely use bamboo as a building material.

Bamboo grows mainly in the humid tropics and subtropics. Not only the frame of the dwelling (walls, columns) is made of it, but also the roof, scaffolding, it can also be used as a finishing material.

Main part
The population in Asian countries is growing every year. More and more people want to live in metropolitan areas, such as Hong Kong, which has a population of over 7.5 million, and population density is over 6500 people / km². A super-modern metropolis, where every seventh inhabitant is a dollar millionaire, has to grow not in breadth, but in height. And bamboo is helpful in this situation.

There are more than 1,500 buildings over 100 meters in height in Hong Kong. The pace of construction is amazing. Builders construct 1 floor per week. The buildings can be said to grow as fast as bamboo. And it will be both literally and figuratively. Because the main building technology in Hong Kong is bamboo scaffolding (Figure 1).

Bamboo woods are used for the construction and reconstruction of any buildings and structures. All nodes are connected with plastic clamps (Figure 2) without a single nail. It is amazing how harmoniously modern skyscrapers and the oldest building technologies in China are combined. So why do engineers in Hong Kong and other countries prefer bamboo?
The beneficial peculiarities of bamboo are as follows:

- Environmentally friendly and renewable. Currently, the destruction of the wood cover of our planet is in progress. The scale of deforestation is amazing. Each year, the planet irrevocably loses 95 million trees. The use of bamboo as a building material can stop this process at least a little. After all, the maximum growth rate of bamboo is 1200 mm per day. In 3-5 years, bamboo becomes fully suitable for construction purposes.
- Low cost.
- Durability. With proper care, bamboo structures can last over 100 years. For example, in the Chinese town of An-Lan, a suspension bamboo bridge across the Ming River was built in the third century AD and is still in operation (Figure 3).
Seismic resistance. Bamboo has high strength and low weight, which increases the building’s resistance to seismic impact. With proper anti-corrosion treatment, the building will not collapse even in the event of a strong earthquake. For example, in 1991, Costa Rica was hit by a 7.7 magnitude earthquake. The buildings in the epicenter of the usual concrete and brick were completely destroyed, and the buildings made of bamboo had only minor damage.

High temperature resistance and low heat transfer coefficient. Thermal conductivity coefficient of bamboo is 0.30 – 0.40 W/(m•°C) (depending on the variety). In order to preserve the thermal insulation effect, the thickness of bamboo should be 1/15 of concrete and 1/400 of steel.

Durability.
The design characteristics of bamboo include:
- tensile strength. Longitudinal fibers of bamboo make it quite strong. For this ability it received the name "vegetable steel".
- tubular section that resists torsional forces.
- Under central compression, no significant deformation occurs. Bamboo retains and restores geometric dimensions even if stability is disturbed.
- Due to the large number of external fibers, bamboo has low shear resistance.

Ways of connecting nodes
The main ways of connecting structural nodes are shown in Figure 4.

Figure 4. Types of nodes’ connection

Contemporary architects
In the modern world, there are engineers and architects who specialize in the design and construction of bamboo structures, for example:
- Simon Velez. On the website of his design office the following slogan "Vegetarian architecture" can be seen. In his work, the architect mainly uses the laguaudia bamboo class, as it is most common in Colombia and Ecuador, and is also highly durable. Also, Simon Velez developed a new type of nodes connection - using bolts and steel plates, which is used for corner joints and overhangs. The assembly consists of axial or longitudinal screws, depending on the work and the plates connecting the bamboo units (Figure 5).

![Figure 5. Node designed by Simon Velez.](image)

Figure 6 shows some examples of Simon Velez’s work. For example, Crosswaters Ecolodge (Figure 6, b), a bridge created in the woods of the Nankun Shan mountain reserve in Guangdong province. This project was the first project of this kind in Asia to use bamboo as a structural element in a house. Simon Velez received the 2006 American Society of Landscape Architects’ Honorary Award for Analysis and Planning.

![a) Contemplation Bamboo Pavilion, Arles, France (2018)](image)
b) Crosswaters Ecolodge, Guangdong (2006).

**Figure 6.** Examples of works performed by architect Simon Veles.

- Markus Heinsdorff, who is one of the activists in this field. In 2008, under his leadership, the company erected 21 unique pavilions (Guangzhou). In these pavilions, a bamboo frame structure was used, and a combination of steel elements, leaf springs and grout was used in the nodal connections (Figure 7).

![Image of Mark Heinsdorff's pavilion](image)

**Figure 7.** Pavilion designed by Markus Heinsdorff (2010).

- Xiao Yang, a professor at Hunan University (China), developed a technology for the production of bamboo plywood, from which a lightweight low-rise residential building was constructed. Structural nodes were carried out using bolted connections, which ensured the speed and convenience of construction.

An important event in the history of bamboo was the holding of the first Biennial of Bamboo Architecture in 2017. Its purpose was as follows: to create such buildings and structures that could serve people, would be integrated into the urban environment precisely for a practical purpose.

The task of the Biennale was completed successfully. The result of the work was such structures as: a bridge, three hotels, cafes and restaurants, museums and workshops for working with wood and ceramics (a strong tradition of work with which is still manifested in the Baoxi settlement).
The interest of the participants in this Biennale gave the organizer inspiration to create more events of this type. Workshops, conferences, practical seminars enable people to work with professionals, join their communities, discuss current issues and create new projects.

Of course, we are talking about the construction of construction projects only in the region where bamboo grows, since its transportation increases the cost and reduces the strength characteristics. In addition, it cannot be used in the countries with cold climates, while in other countries with hot climates there is a “local” alternative to bamboo.

Summary
Taking the above-said into consideration, we can say that bamboo has a future in construction and architecture. Modern computer technology helps to design bamboo nodal connections, based on the classic principles of building reinforced concrete and steel structures. It is possible to make rather cumbersome mathematical calculations to determine the operation of a particular node, integrate it into the project.

Taking into account the scale of deforestation, environmental pollution from the production of traditional materials, as well as the calculated characteristics of bamboo, its cost, we can conclude that it will soon completely replace the usual metal and reinforced concrete structures.

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